

Professional Edition

Version 1.1

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GREEN HIPPO
INNOVATIONS

User Manual

Version 1.1

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ACKNOWLEDGEMENT

GHI HydroSuite has been developed as an integrated engineering software platform for hydrological, hydraulic and hydropower analysis. Its development draws upon established engineering methods, published research, nationally recognised design guidance, and publicly available software and datasets.

Full acknowledgement and credit are given to the organisations, researchers and developers responsible for the following key references and resources, which have informed the methodologies implemented within GHI HydroSuite and have been referenced, where applicable, in the software and supporting documentation.

SANRAL Drainage Manual
Drainage Manual, 6th Edition (2013)
South African National Roads Agency SOC Ltd (SANRAL)
Website: https://www.nra.co.za/downloads?region_id=national#manuals-and-policies

The SANRAL Drainage Manual provides comprehensive guidance on hydrological and hydraulic analysis and the design of drainage infrastructure in South Africa. Methods and design guidance contained in the manual have been referenced in the development of the flood estimation and culvert analysis components of GHI HydroSuite.

South African Design Rainfall
South African Design Rainfall and Flood Estimation
Smithers, J.C. and Schulze, R.E.
Water Research Commission Project K5/1060 (2002)
Website: http://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/1060%20web1.pdf

The South African Design Rainfall research and associated databases developed by Smithers and Schulze provide an important foundation for the estimation of design rainfall in South Africa. GHI HydroSuite makes use of methodologies and design rainfall information derived from this work in its hydrological and flood estimation analyses.

Full acknowledgement is given to the Water Research Commission (WRC) and the researchers responsible for the development of these nationally important design rainfall resources.

A best practice guideline for design flood estimation in municipal areas in South Africa
CJ Brooker, C.J., du Plessis, J.A., Dunsmore, S.J., James, C.S. & Gericke, O.J.
WRC Report No. TT 921/23 (2023)
Website:
http://wrcwebsite.azurewebsites.net/wp-content/uploads/mdocs/TT%20921%20final%20web.pdf

This guideline provides current South African best-practice guidance for the estimation of design floods, with particular emphasis on municipal and urban catchments. It provides guidance on the selection and application of appropriate flood estimation methods, including probabilistic, deterministic event-based and empirical approaches, together with the associated rainfall, catchment and hydrological data requirements. The guideline has been referenced in the development and implementation of the flood estimation functionality incorporated into GHI HydroSuite, particularly with respect to the selection, application and comparison of design flood estimation methods.

Full acknowledgement is given to the Water Research Commission (WRC), the Institute of Municipal Engineering of Southern Africa (IMESA), the Urban Flood Estimation Working Group, and the authors and contributors responsible for the development of this important South African best-practice resource.

HY-8 Culvert Hydraulic Analysis
HY-8 Culvert Hydraulic Analysis Program (2026)
Federal Highway Administration (FHWA), United States Department of Transportation
Website: www.fhwa.dot.gov/engineering/hydraulics/software/hy8/

HY-8 is a publicly available culvert hydraulic analysis program developed and maintained for the Federal Highway Administration. The program and its associated technical documentation provide established procedures for analysing culvert hydraulics, including inlet and outlet control conditions and a range of culvert inlet configurations.

The HY-8 methodology and documentation have been referenced in the development and verification of the culvert analysis functionality incorporated into GHI HydroSuite.

GHI sincerely acknowledges SANRAL, the Water Research Commission, the Federal Highway Administration, and the many researchers, engineers and organisations whose published work, technical guidance, datasets and publicly available software have contributed to the engineering knowledge upon which GHI HydroSuite has been developed.

Their contributions to making reliable engineering methods and resources accessible to practitioners, researchers and students are gratefully acknowledged.

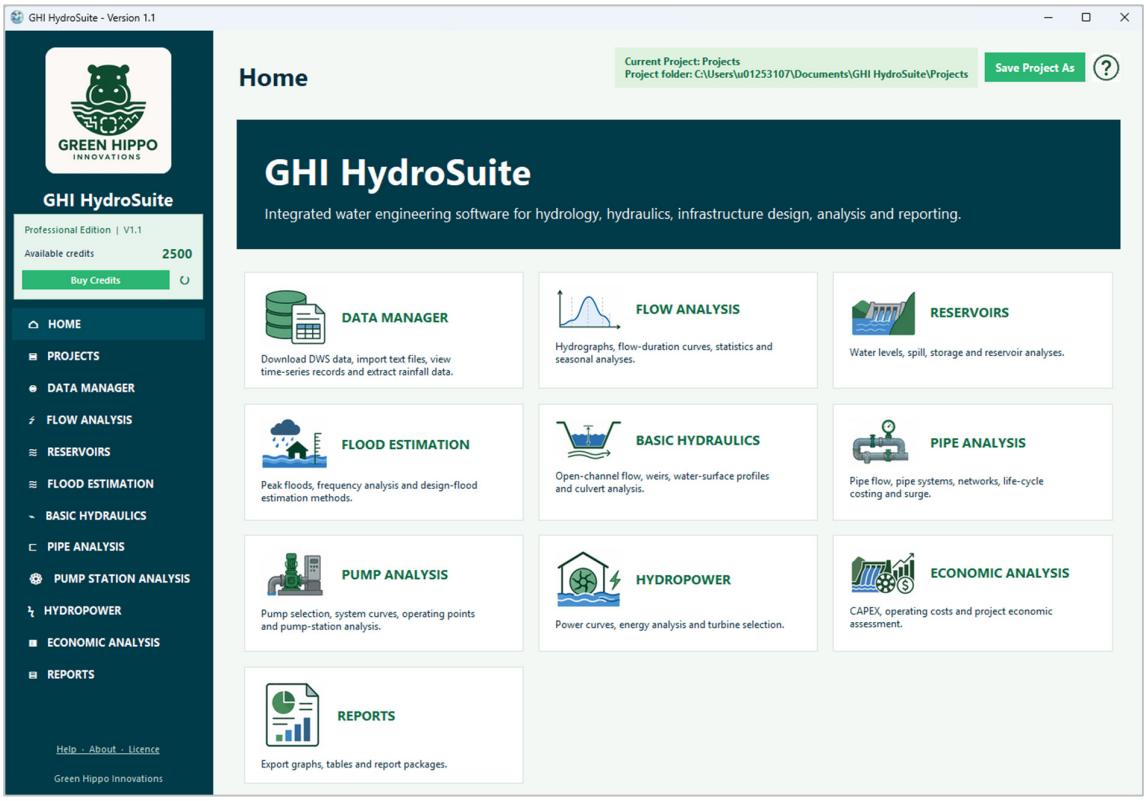
1 ABOUT GHI HYDROSUITE

GHI HydroSuite is an integrated water engineering software platform developed to assist engineers, researchers, planners, students, and water-sector professionals with the analysis, assessment, design, and evaluation of water infrastructure and water-resource projects.

The software brings together a range of commonly required hydrological, hydraulic, hydropower, flood estimation, reservoir, and economic analysis tools within a single, user-friendly environment. Rather than relying on a collection of separate spreadsheets, scripts, calculation packages, and plotting applications, GHI HydroSuite provides a structured workflow in which project information, input data, engineering calculations, results, graphs, and reports can be managed within one application.

GHI HydroSuite has been developed specifically with practical engineering applications in mind. The software combines established engineering methods with automated calculations, graphical presentation of results, data-management functionality, and project-based workflows. It is intended to support both preliminary assessments and more detailed engineering investigations, while maintaining transparency in the methods, assumptions, and input parameters used.

The software is organised into dedicated modules covering the principal stages of water engineering analysis, including project management, data management, flow analysis, reservoir analysis, hydropower assessment, flood analysis, pipeline assessment, pump station analysis, basic hydraulics, economic analysis, and reporting. The modular structure allows users to make use of individual tools independently or combine them as part of a broader project assessment.



Some of the key features of **GHI HydroSuite** include:

1.1 Integrated water engineering analysis

GHI HydroSuite combines a wide range of engineering tools within a single software environment.

1.2 Flow-duration curve development and interpretation

- Reservoir and storage-related assessments
- Hydropower resource and project assessment
- Flood estimation using recognised engineering methods
- Design rainfall analysis and catchment rainfall estimation
- Basic pipe, channel, and weir hydraulic calculations
- Economic and financial evaluation of infrastructure projects

The integrated approach reduces the need to transfer information manually between multiple independent programs and spreadsheets and provides a consistent environment for completing engineering assessments.

1.3 Intuitive graphical user interface (GUI)

GHI HydroSuite has been developed primarily for engineers, researchers and water-sector practitioners. A consistent graphical user interface provides structured access to the various engineering modules and analysis methods.

- Clearly defined engineering modules and workflows
- Logical grouping of inputs, calculations, results, and graphs
- Tab-based analysis screens for more complex assessments
- Consistent presentation of engineering units and parameters
- Graphical presentation of calculated results
- Results viewers for reviewing important outputs
- Context-specific controls that guide users through individual analyses

The interface is intended to reduce the learning curve associated with specialised engineering software while retaining access to the underlying engineering parameters required by experienced users.

1.4 Integrated data management

Water engineering studies frequently require data from numerous sources and in different formats. **GHI HydroSuite** provides dedicated data-management functionality for preparing, processing and managing information required by the various analysis modules.

Depending on the analysis being undertaken, this may include:

- Daily and monthly streamflow records
- Hydrological time-series data
- Design rainfall information
- Rainfall station and spatial rainfall data
- Catchment characteristics and location information
- Reservoir information
- Project-specific engineering data
- Imported and calculated datasets

Information processed within the Data Manager can be transferred to the relevant analysis modules, reducing repetitive data entry and improving consistency between different stages of an assessment.

1.5 Flow and hydrological analysis

GHI HydroSuite includes tools for analysing observed and generated flow information and converting hydrological datasets into information that can be used for engineering decision-making. Available functionality includes:

- Flow-duration curve analysis
- Standard, annual, seasonal, and monthly flow-duration curves
- Flow exceedance statistics
- Stochastic flow generation
- Statistical analysis of hydrological datasets
- Graphical representation of hydrological datasets
- Export of calculated results for further analysis and reporting

These tools allow users to investigate the magnitude, frequency, and variability of available flows and provide important input information for water-resource and hydropower assessments.

1.6 Reservoir and storage analysis

GHI HydroSuite provides functionality for evaluating reservoirs and water-storage systems and their interaction with available inflows and downstream water requirements. Depending on the assessment, the reservoir functionality can be used for:

- Reservoir level and storage analysis
- Processing reservoir-related datasets
- Assessment of inflow and storage behaviour
- Evaluation of reservoir operating conditions
- Integration of reservoir levels with hydropower assessments
- Graphical representation of reservoir behaviour

The reservoir tools provide an important link between hydrological analysis, available hydraulic head and subsequent water-resource or hydropower assessment.

1.7 Flood estimation and design rainfall

GHI HydroSuite provides an integrated environment for flood estimation, including tools for obtaining and processing the rainfall information required by different flood-estimation procedures.
The flood-analysis functionality is being structured around recognised South African engineering methods and provides workflows for:

- Design rainfall extraction
- Point rainfall analysis
- Catchment-average rainfall
- Area-weighted rainfall
- Rainfall station and Thiessen polygon approaches
- Rational Method flood estimation
- Selection and management of return periods
- Transfer of rainfall results directly to the applicable flood-estimation method
- Graphical and tabulated presentation of results

By linking design rainfall and flood estimation within the same application, HydroSuite reduces manual transfer of rainfall information and provides a more consistent calculation workflow.

1.8 Basic Hydraulics analysis

GHI HydroSuite incorporates a range of commonly required hydraulic calculations to support routine engineering assessment and a section on culvert-analysis for evaluating the hydraulic performance of road and drainage culverts. The module provides functionality for:

- Hydraulic losses
- Open-channel and weir flow
- Weir flow
- Culvert hydraulics
- Inlet- and outlet control analysis
- Determination of the governing headwater condition
- Roadway overtopping assessment
- Hydraulic cross-section visualisation
- Comparison of hydraulic conditions against selected design criteria

The basic hydraulics and culvert functionality incorporates established approaches used in SANRAL and FHWA HY-8 methodologies, providing engineers with an integrated environment for assessing culvert capacity and hydraulic performance.

1.9 Pipe analysis

GHI HydroSuite incorporates commonly required hydraulic calculations so that users can undertake routine engineering assessments. It includes a dedicated thrust block design module for determining hydraulic thrust forces and the required bearing area for common pipe fittings and changes in pipeline geometry. These tools include calculations associated with:

- Pressurised pipes
- Thrust block design for bends, t- or y-pieces and end caps.
- Hydraulic losses and related engineering parameters

The Basic Hydraulics module is intended to provide access to frequently used calculations during preliminary design and engineering assessment.

1.10 Hydropower assessment

Hydropower assessment is one of the principal engineering applications incorporated into **GHI HydroSuite**. The software provides tools for evaluating the relationship between available flow, hydraulic head, energy generation, and project economics. Hydropower functionality can be used to assist with:

- Preliminary hydropower resource assessment
- Flow-duration based energy calculations
- Assessment of alternative design flows
- Turbine and scheme parameter evaluation
- Annual and monthly energy estimates
- Technical comparison of development alternatives
- Preliminary project costing
- Economic and financial evaluation

This allows the technical and economic components of a hydropower assessment to be evaluated within the same project environment.

1.11 Economic and financial evaluation

Engineering feasibility cannot be assessed solely on technical performance. GHI HydroSuite therefore incorporates economic analysis tools that allow the financial implications of infrastructure projects to be evaluated together with their technical performance. The economic analysis functionality includes assessment of parameters such as:

- Capital expenditure (CAPEX)
- Operating expenditure (OPEX)
- Energy production and revenue
- Financing assumptions
- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Payback period
- Levelised Cost of Energy (LCOE)
- Cash flow
- Loan balance and debt-service indicators
- Sensitivity analysis

Graphical dashboards and sensitivity tools assist users in understanding the variables that have the greatest influence on project feasibility.

1.12 Graphical results and reporting

Engineering results are most useful when they can be interpreted and communicated clearly. GHI HydroSuite therefore places significant emphasis on the graphical and tabulated presentation of results. Depending on the analysis, users can:

- View calculated results in dedicated results panels
- Generate engineering graphs
- Compare alternative scenarios
- Copy selected graphs for use in other documents
- Export data for further analysis
- Produce analysis-specific PDF reports
- Produce project outputs suitable for engineering reports
- Review key technical and economic indicators through summary dashboards

This allows calculated information to move efficiently from engineering analysis to project documentation and decision-making.

1.13 Project-based workflow

GHI HydroSuite is designed around individual engineering projects. Project information and analysis inputs can be managed as part of a structured project rather than as unrelated calculations. This approach allows users to progressively develop an assessment as additional information becomes available. A project may, for example, begin with hydrological data analysis, progress to hydropower or flood assessment, and subsequently incorporate hydraulic calculations and economic evaluation.

The project-based approach also assists with maintaining consistency between the assumptions, datasets, and calculations used throughout an engineering study.

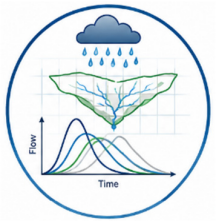
GHI HydroSuite is intended to support, rather than replace, professional engineering judgement. The software provides engineers with an integrated implementation of established analytical procedures, engineering relationships and published methodologies. Users remain responsible for selecting appropriate methods, verifying input information, assessing the reasonableness of calculated results and applying the relevant standards, guidelines and professional judgement to each engineering application.

GHI HydroSuite has been developed according to a user-centred engineering philosophy. The intention is not to replace engineering judgement, but to provide engineers with an efficient and transparent environment in which established engineering calculations can be performed, reviewed, compared and documented. Input parameters, assumptions and intermediate information remain accessible to the user, allowing the engineer to understand how results have been derived and to assess their suitability for the particular application.



All-in-one water engineering platform

Bring hydrology, flood estimation, hydraulics, reservoirs, hydropower and economic analysis together in one integrated engineering environment.



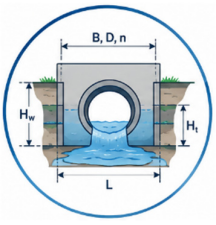
Multi-method flood estimation

Apply and compare recognised South African flood-estimation methods, including Rational Methods, SDF, SCS-SA, Unit Hydrograph, empirical methods and Flood Frequency Analysis.



Integrated design rainfall

Determine point or catchment design rainfall and transfer the results directly into applicable flood-estimation workflows, reducing repetitive data entry and transcription errors.



Advanced hydraulic design tools

Analyse pipes, channels, weirs and culverts, including inlet and outlet control, tailwater, roadway overtopping and thrust block design, within the same engineering platform.



Hydropower from flow to feasibility

Progress from flow-duration analysis and available head through energy assessment, project costing and detailed economic evaluation, all within the same project.



Engineering-ready reporting

Convert analyses into structured PDF reports containing engineering inputs, assumptions, methodology, tables, graphs and calculated results ready for project documentation.

2 SYSTEM REQUIREMENTS

The following system requirements apply to the installation and operation of **GHI HydroSuite**.

Operating System

GHI HydroSuite is designed for use on Microsoft Windows computers.

- Windows 10 or later, 64-bit
- Windows 11 recommended

macOS and Linux are not currently supported as native operating systems. Operation through virtualisation or emulation may be possible but is not officially supported.

Hardware requirements

Component	Minimum requirement	Recommended requirement
Processor	Dual-core 2.0 GHz	Quad-core 3.0 GHz or higher
RAM	4 GB	8–16 GB
Storage	500 MB available space plus space for project files	SSD with at least 2 GB available space
Graphics	Integrated graphics	Dedicated graphics for large datasets and complex visualisations
Display	1280×768 resolution	1920×1080 or higher

Actual storage requirements may increase depending on the number and size of projects, downloaded datasets, generated reports, graphs and other project outputs.

Software and Additional Requirements

- Administrator rights may be required for installation.
- An internet connection is required for initial software activation and may periodically be required for licence verification.
- An internet connection is also required for functions that access online data sources or other internet-based services.
- QGIS is optional and may be used for viewing and further processing of GIS information exported from **GHI HydroSuite**.

All components required for normal operation of **GHI HydroSuite** are supplied with, or installed as part of, the official software distribution unless otherwise indicated.

Licensing and activation

GHI HydroSuite is licensed software and requires a valid software licence to access the functionality associated with the applicable edition.

Software licences are electronically activated and issued by Green Hippo Innovations (Pty) Ltd. Depending on the licence purchased, conditions may apply to the number of authorised computers, concurrent users, licence duration and available software functionality.

GHI HydroSuite currently supports the following principal licensing arrangements:

- **Trial Licence** - provides access to the software for a limited evaluation period. Trial licences expire automatically at the end of the applicable trial period, after which a commercial licence is required for continued use.
- **Individual Licence** - issued to an individual user and permits activation on the number of computers specified by the applicable licence conditions. Where permitted, a licence may be deactivated on one computer and subsequently activated on another, allowing a user to replace or change computers without purchasing a new licence.
- **Floating Licence** - intended for organisations requiring access from multiple computers. The software may be installed on an authorised number of computers, while the number of users able to use GHI HydroSuite simultaneously is controlled by the number of concurrent licences purchased. Floating licences require access to the organisation's designated GHI HydroSuite Floating Licence Server while the software is in use.
- **Academic Licence** - licensing arrangements may be provided to qualifying academic institutions for teaching, research and educational use. The applicable installation and concurrent-user limits are determined by the licence purchased.

An internet connection is normally required for the initial activation of an Individual or Trial Licence. The software may subsequently operate without a continuous internet connection; however, periodic online licence verification may be required to confirm that the licence remains valid.

Where online activation is not possible, offline activation or verification may be available for supported licence types. Users requiring offline activation should contact Green Hippo Innovations for assistance.

Licence information and available licensing functions can be accessed from *Help-About-License* within **GHI HydroSuite**. Depending on the licence type and current licence status, this interface may be used to activate, verify or deactivate a licence.

The licence status displayed by **GHI HydroSuite** indicates whether the installation is operating under a valid Trial, Professional or other authorised licence. If a licence expires, becomes invalid or cannot be verified when required, access to some software functionality may be restricted until a valid licence is restored. The use of **GHI HydroSuite** is subject to the applicable Software Licence Agreement and the terms and conditions associated with the licence purchased. Licence keys and activation credentials should be retained securely and should not be distributed to unauthorised users.

3 INSTALLING THE PROGRAM

Step 1: Obtain the installation package

- Download the latest authorised version of the GHI HydroSuite installer from the official Green Hippo Innovations website or obtain it directly from an authorised software provider.
- Only install GHI HydroSuite from a trusted source. Do not use installation packages obtained from unauthorised third-party websites or file-sharing services.

Step 2: System preparation

Before installing the software:

- Confirm that the computer meets the minimum system requirements described in Section 2.
- Close any previous instance of GHI HydroSuite.
- Ensure that sufficient disk space is available.
- Ensure that you have the necessary Windows permissions to install software.
- Ensure that an internet connection is available if an Individual or Trial Licence is to be activated immediately after installation.
- For a Floating Licence, ensure that the computer can communicate with the organisation's GHI HydroSuite Floating Licence Server.

Step 3: Run the installer

- Double-click the GHI_HydroSuite_Setup.exe installation file.
- If Windows displays a security or User Account Control prompt, confirm that you wish to run the installer.
- Review and accept the Software Licence Agreement.
- Select the installation location, if this option is provided.
- Select any additional installation options presented by the installer.
- Click Install and allow the installation process to complete.
- Once installation has been completed, launch GHI HydroSuite from the Windows Start menu or desktop shortcut, where applicable.

Step 4: Activate the software

GHI HydroSuite must be activated or connected to an authorised licence before the licensed functionality can be used. The activation procedure depends on the type of licence issued.

Individual and Trial Licences

When **GHI HydroSuite** is started on a computer that has not yet been activated, the licence interface will indicate that no valid licence is currently available.

- Open *Help-About-Licence*, to access the licence management interface.
- Enter the licence information provided by Green Hippo Innovations and select Activate (see **Figure 3-1**).
- An internet connection is normally required for initial online activation.
- Once the licence has been successfully validated, **GHI HydroSuite** will display the applicable licence status and enable the corresponding software functionality.

- Where the licence conditions permit activation on more than one computer, the licence may be activated on additional computers up to the permitted activation limit.
- If a computer is replaced or an activation is no longer required, the licence should first be deactivated on that computer before being activated on another computer.

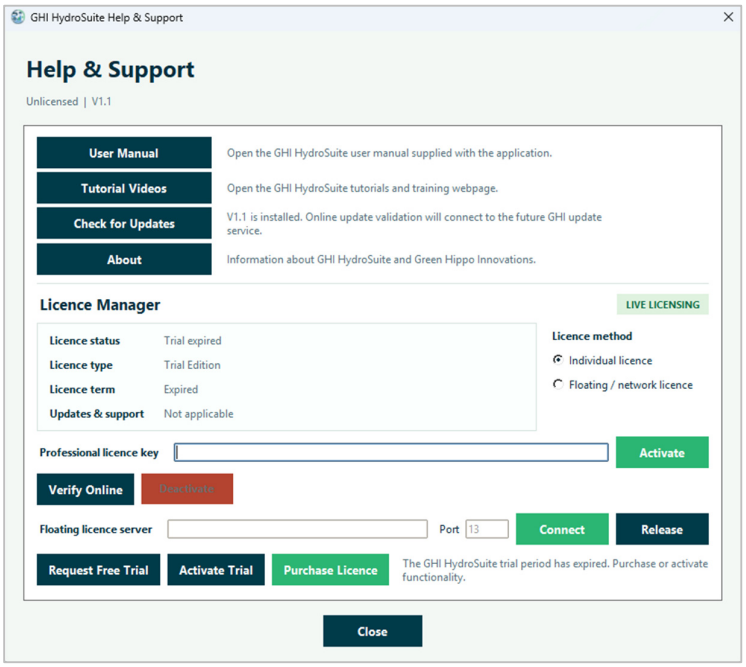


Figure 3-1: License activation

Floating Licences

Floating Licences operate differently from Individual Licences. The licence is activated on a designated **GHI HydroSuite Floating Licence Server**, rather than separately on each user computer.

The Floating Licence Server must first be installed and activated by the organisation's administrator. Once configured, authorised computers running GHI HydroSuite connect to the licence server through the organisation's network.

- Install GHI HydroSuite normally on each authorised user computer.
- Configure the software to connect to the designated Floating Licence Server, where required.
- The user computer must be able to communicate with the Floating Licence Server when obtaining a licence.
- When **GHI HydroSuite** starts, an available licence is obtained from the server.
- The number of users who may use GHI HydroSuite simultaneously is limited by the number of concurrent licences purchased.
- Closing GHI HydroSuite releases the floating licence so that it becomes available to another authorised user.

Installation and activation of the Floating Licence Server should normally be undertaken by the organisation's system administrator or IT personnel. Separate instructions are provided for configuring and activating the server.

Trial Licences

Where a Trial Licence has been issued, GHI HydroSuite may be used for the specified evaluation period.

The Trial Licence provides access in accordance with the applicable trial conditions and expires automatically at the end of the trial period. Continued use thereafter requires a valid commercial licence.

Where supported, a Trial Licence may be replaced by a commercial licence without reinstalling GHI HydroSuite. The commercial licence can be activated through the License interface.

Activation and Licence Problems

Individual licence problems

If activation is unsuccessful:

- Confirm that the computer has an active internet connection.
- Confirm that the licence information has been entered correctly.
- Check that the permitted number of computer activations has not been exceeded.
- Restart GHI HydroSuite and attempt activation again.

Floating licence connection problems

If a workstation cannot obtain a floating licence:

- Confirm that the GHI HydroSuite Floating Licence Server computer is switched on and accessible over the organisation's network.
- Confirm that the Floating Licence Server service is running. If necessary, restart the service or server computer.
- Confirm that the correct server computer name or IP address has been entered.
- Confirm that the workstation and server are using the same TCP port (default: 13).
- Confirm that the selected TCP port is permitted through Windows Firewall and any corporate firewall or network security system.
- Confirm that a floating licence is currently available. If all concurrent licences are in use, another user must close GHI HydroSuite or release their licence before another workstation can obtain one.
- For users working remotely, confirm that the workstation has access to the organisation's network or VPN and can reach the Floating Licence Server.
- If the server itself cannot be activated or reverified, confirm that the server has internet access and that any corporate proxy, firewall or security software is not preventing the Floating Licence Server from accessing the online licensing service.

If activation or licence verification remains unsuccessful, contact Green Hippo Innovations for licensing assistance.

Step 5: Verify installation

After installation and activation:

- Start GHI HydroSuite.

- Confirm that the program opens without displaying an installation or licensing error.
- Confirm that the correct licence status is displayed.
- Create a new project or open an example project supplied with the software.
- Confirm that the modules included with your licensed edition are available.
- Perform a simple analysis and confirm that results can be generated.
- Where applicable, confirm that graphs, reports and project files can be generated and saved successfully.

The installation is complete once GHI HydroSuite starts successfully, recognises the applicable licence and provides access to the functionality included with the licensed edition.

4 PURCHASING THE SOFTWARE

GHI HydroSuite is available as a fully functional Trial Version and through a range of Professional and Academic licence options. The appropriate licence depends on whether the software will be used by an individual, by multiple users within an organisation, or within an academic environment.

Current licence options, pricing and order forms are available from Green Hippo Innovations.

4.1 Trial Version

The GHI HydroSuite Trial Version provides prospective users with an opportunity to evaluate the software before purchasing a licence.

The Trial Version provides access to the full functionality of **GHI HydroSuite** for a limited evaluation period (7-days). This allows users to explore the integrated water engineering environment, open or create projects, and evaluate the available engineering analysis and design functionality.

The Trial Version is intended for software evaluation. On expiry of the trial period, a Professional or Academic Licence is required for continued licensed use of the software.

Trial activation is managed electronically through the Licence Manager, available under Help-About-Licence.

4.2 Professional Individual Licence

The Professional Individual Licence is intended for an individual professional user requiring full access to GHI HydroSuite. It provides:

- Full access to the available **GHI HydroSuite** engineering analysis and design modules.
- Project creation, saving, reporting and export functionality.
- An initial allocation of analysis credits.
- Software updates and standard technical support for the first 12 months.
- Electronic licence activation on one computer.

The Professional Edition incorporates the integrated engineering functionality available within GHI HydroSuite, including data management, flow analysis, reservoir analysis, hydropower assessment and design, flood estimation, design rainfall, basic hydraulics, pipe analysis and economic analysis.

4.3 Professional Floating Licence

The Professional Floating Licence is intended for companies and organisations that require **GHI HydroSuite** to be available on multiple computers.

HydroSuite may be installed on an agreed number of company computers, while the number of users able to use the software simultaneously is controlled by the number of concurrent licences purchased.

For example, an organisation may install HydroSuite on several authorised computers while purchasing only the number of concurrent seats required for its normal engineering workload. When a user opens HydroSuite, a licence is obtained from the organisation's GHI licence server. When HydroSuite is closed, the licence is returned to the pool and becomes available to another authorised user.

Different Floating Licence configurations are available to accommodate organisations of different sizes. These range from small installations with a single concurrent user through to larger team and enterprise configurations. The appropriate option is determined by both:

- the maximum number of computers on which **GHI HydroSuite** will be installed; and
- the maximum number of users requiring simultaneous access.

Floating licences include an allocation of analysis credits appropriate to the selected licence package, together with software updates and standard technical support for the first 12 months.

4.4 Academic Licence

The Academic Licence is intended for universities and recognised educational institutions using GHI HydroSuite for teaching and academic purposes.

Floating/concurrent licensing can be configured to accommodate computer laboratories, lecturers and students. The licence configuration is therefore based on the required number of installations and the number of users who need simultaneous access.

Academic licences are intended for non-commercial educational use. Where HydroSuite is to be used for commercial research, consulting or other professional engineering activities, a Professional Licence may be required.

Academic licence requirements are assessed individually, and institutions should contact Green Hippo Innovations to determine an appropriate configuration.

4.5 Annual Renewal

Professional licences include access to software updates and standard technical support for the initial 12-month period. Thereafter, an Annual Renewal may be purchased to provide a further 12 months of:

- Software updates and improvements.
- New features and functionality introduced into the applicable edition.
- Standard technical support.
- An additional allocation of analysis credits.
- Access to user-requested enhancements incorporated into subsequent releases, where applicable.

Each annual renewal includes 50% of the analysis credits originally supplied with the applicable licence package. The number of renewal credits therefore depends on the Professional Licence selected.

The underlying Professional Licence remains valid if the Annual Renewal is not purchased. However, access to subsequent software updates, support and renewal credits will cease. A renewal therefore maintains the software support and update service rather than requiring the Professional Licence itself to be purchased again.

4.6 Analysis Credits

GHI HydroSuite uses an analysis-credit system for applicable analyses.

Analysis credits provide a simple usage-based mechanism for selected engineering analyses. Where an analysis is credit-controlled, the required credit is deducted when the applicable analysis is successfully performed.

Professional licence packages include an initial allocation of credits. Annual renewals provide a further allocation equal to 50% of the credits originally included with the applicable licence package.

Additional analysis credits may be purchased separately at any time and do not affect the underlying software licence. This allows users and organisations to increase their available analysis capacity according to their requirements.

4.7 Ordering and Licence Activation

The current Pricing Schedule and Software Order Form should be consulted when selecting a licence.

For a Professional Individual Licence, the user selects the Individual Licence option. For a Professional Floating Licence, the organisation should specify the required number of installations and number of simultaneous users so that the appropriate floating licence configuration can be determined. Academic users should similarly provide their anticipated installation and concurrent-user requirements.

Following completion of the order and receipt of the required payment, the software is made available for download and/or the applicable electronic licence key is issued. No physical licensing device is required.

Licence activation and management are undertaken from the Licence Manager (see **Figure 3-1**).

The Licence Manager allows the user to select the applicable Individual licence or Floating/network licence method and configure the licence accordingly.

For current licence options, pricing, ordering information or assistance in selecting an appropriate licence configuration, contact:

Green Hippo Innovations (Pty) Ltd
GHI HydroSuite Sales
Email: mailto: sales@greenhippo.co.za
GHI HydroSuite – Green Hippo Innovations

Licence options, credit allocations and commercial conditions may be amended from time to time. Users should therefore refer to the current Pricing Schedule and Order Form or contact Green Hippo Innovations for the latest information.

5 DISCLAIMER

This software has been developed as a tool to assist users and is provided for convenience only. The GHI HydroSuite software is provided "as is" without any expressed or implied warranties, including but not limited to warranties of merchantability, fitness for a particular purpose or non-infringement. While every reasonable effort has been made to ensure the accuracy and reliability of the calculations and outputs, Green Hippo Innovations makes no warranties, express or implied, regarding the results produced. Users are responsible for independently verifying all results and interpretations. Green Hippo Innovations accepts no liability for any loss, damage, or consequences arising from the use of this software or reliance on its outputs. Use of this software is entirely at the user's own risk.

Users are solely responsible for verifying the accuracy, adequacy, and applicability of the results for their specific needs. Any reliance placed on the software outputs is strictly at the user's own risk.

By installing or using the software, the user agrees to these terms and acknowledges that they have read and understood this disclaimer.

Warning

This computer program is protected by copyright law and international treaties. Unauthorized reproduction or distribution of this program, or any portion of it, may result in severe civil and criminal penalties and will be prosecuted to the maximum extent possible under law.

6 GETTING STARTED

Welcome to GHI HydroSuite – an integrated water engineering software platform developed to assist engineers, researchers, planners, students and water-sector professionals with the analysis, assessment, design and evaluation of water infrastructure and water-resource projects.

This chapter provides a brief introduction to starting GHI HydroSuite, navigating the main workspace and creating or opening a project. Detailed descriptions of the individual analysis modules and their functionality are provided in the subsequent chapters of this manual.



6.1 Starting GHI HydroSuite

GHI HydroSuite can be started by double-clicking the GHI HydroSuite program icon on the Windows desktop or by selecting the application from the Windows Start menu.

When the program starts, the Home screen is displayed, as shown in **Figure 6-1**.

The Home screen provides the main point of access to the different HydroSuite modules. The available modules are displayed in the main navigation area and can be selected according to the type of analysis being undertaken.

The modules available to the user may depend on the installed software version and applicable licence.

6.2 The GHI HydroSuite Workspace

GHI HydroSuite uses a common workspace throughout the software. Although the information displayed in the central working area changes according to the selected module, the principal navigation and project controls remain consistent.

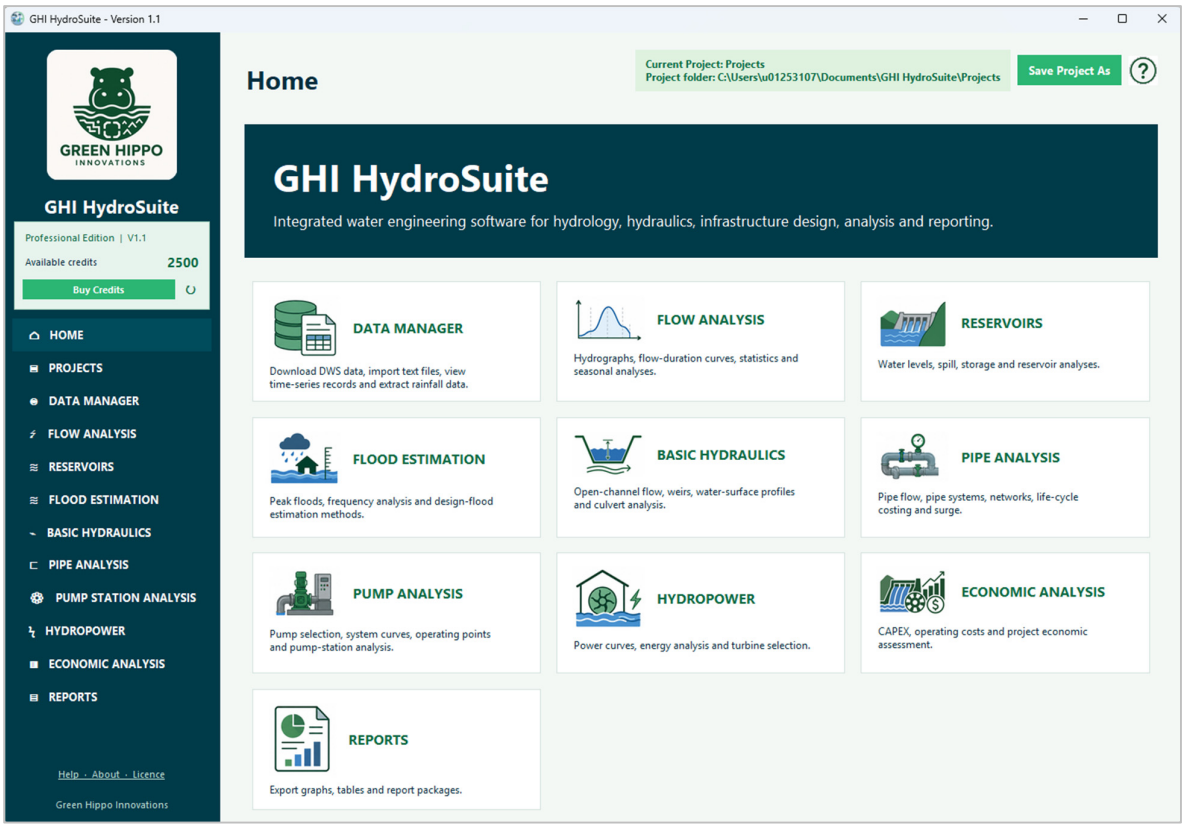


Figure 6-1: GHI HydroSuite home screen

Workspace area	Description
Main navigation	Provides access to the principal HydroSuite modules, including Data, Flow Analysis, Reservoirs, Hydropower, Flood Analysis, Basic Hydraulics, Pipe Analysis, Economic Analysis and Reports.
Working area	Displays the inputs, results, graphs and other controls associated with the selected module.
Current Project	Displays the name and working folder of the currently active project.
Save Project	Provides quick access to saving the current project while working in any module.
Help	Provides access to assistance and supporting information where available.

Detailed descriptions of the HydroSuite workspace and the controls available within individual modules are provided in the relevant chapters of this manual.

6.3 Starting a Project

Most work in GHI HydroSuite should be undertaken within a defined project. A project provides a common location for storing project information and the applicable inputs and results generated by the different HydroSuite modules.

The user can either create a new project or open an existing HydroSuite project.

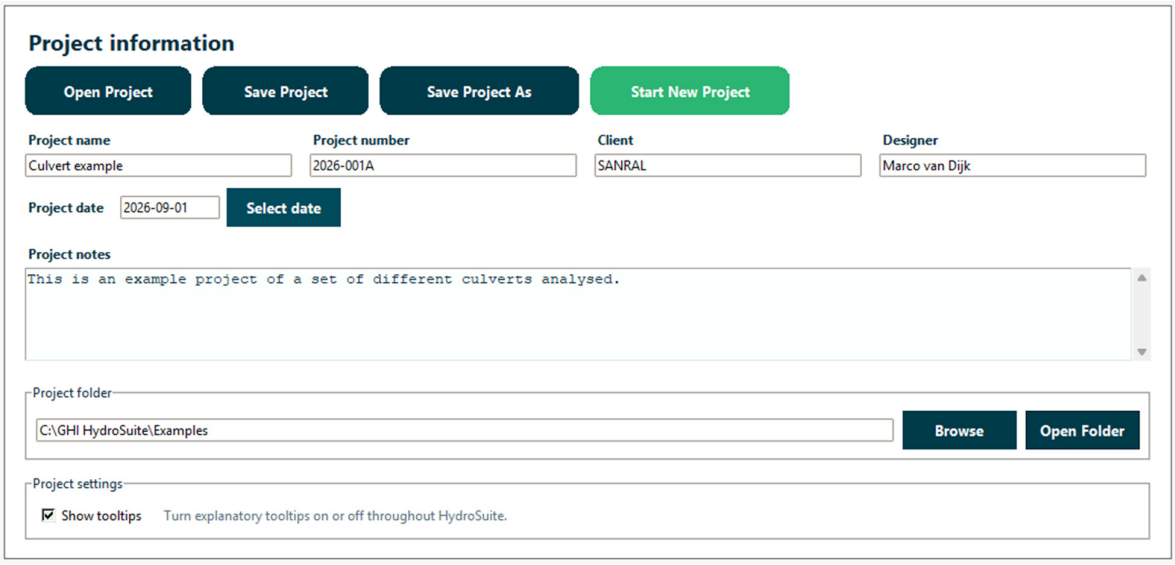


Figure 6-2: Creating and managing a GHI HydroSuite project

Creating a new project

To create a new project:

- Open the Projects screen.
- Select *Start New Project* button.
- Enter the *project name* and other relevant project information.
- Select the required *Project folder*.
- Select *Save Project As* and specify the project filename and location.
- Proceed to the required HydroSuite module.

The project information includes the Project name, Project number, Client, Designer, Project date and optional Project notes. The project folder defines the working location associated with the project.

A complete description of the Projects screen is provided in Chapter 8.

Opening an existing project

To continue working on an existing project, select *Open Project* and browse to the required GHI HydroSuite project file. The saved project information and applicable analysis data will be restored.

The name and folder of the active project are displayed in the Current Project panel at the top of the workspace.

6.4 Typical HydroSuite Workflow

A typical GHI HydroSuite workflow consists of the following, **Figure 6-3**:

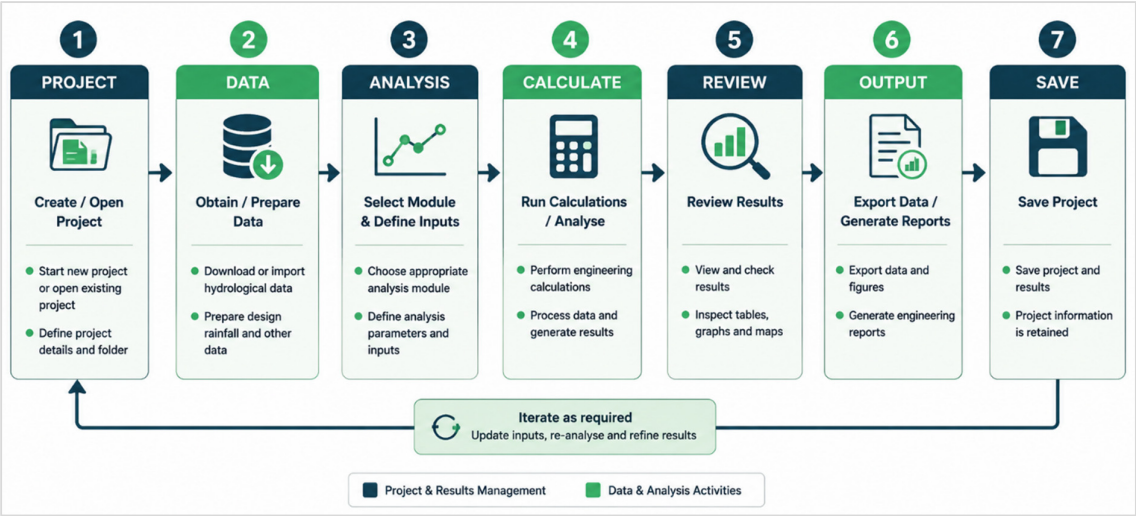


Figure 6-3: Typical HydroSuite Workflow

GHI HydroSuite is designed as an integrated platform, and information generated or prepared in one module may be used by subsequent analyses where applicable. For example, hydrological data prepared using the Data Manager can be used for flow analysis, while design rainfall information can be used in applicable flood-estimation procedures.

6.5 Where to Go Next

After creating or opening a project, proceed to the chapter corresponding to the required analysis:

- Data Manager – obtaining, importing and managing hydrological and design rainfall data.
- Flow Analysis – analysis of hydrological flow records and flow-duration characteristics.
- Reservoirs – reservoir-related analyses.
- Hydropower – hydropower assessment and design.
- Flood Analysis – design flood estimation using the available hydrological methods.
- Basic Hydraulics – hydraulic calculations and analysis of hydraulic structures.
- Pipe Analysis – pipe-system and associated engineering analyses.
- Economic Analysis – economic and financial evaluation of engineering projects.
- Reports – accessing and managing applicable project outputs and reports.

7 GHI HYDROSUITE WORKSPACE

The GHI HydroSuite workspace provides a central interface from which users can create and manage projects, access the different engineering analysis modules, monitor the current project and software status, and save their work. The interface has been designed so that the principal functions remain accessible from a consistent location regardless of the analysis being undertaken.

The main components of the GHI HydroSuite Home workspace are illustrated in **Figure 7-1** and described below.

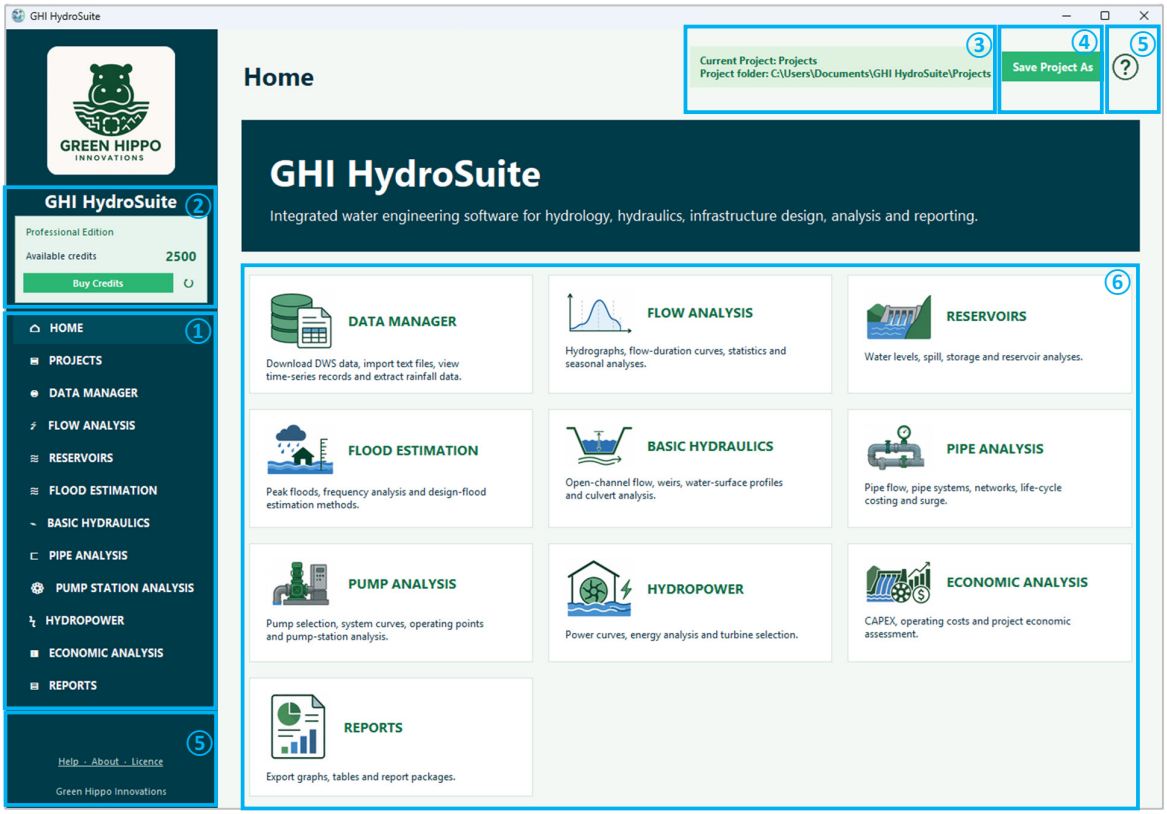


Figure 7-1: GHI HydroSuite Home workspace

① Main navigation panel

The main navigation panel, located on the left-hand side of the workspace, provides permanent access to the principal HydroSuite functions. The currently selected section is highlighted to assist the user in identifying their location within the software.

The navigation panel provides access to:

- **Home** – returns the user to the main HydroSuite workspace.
- **Projects** – provides access to project creation, selection and management.
- **Data Manager** – manages hydrological, rainfall and other datasets used by the analysis modules.

- **Flow Analysis** – provides hydrological flow analysis, flow-duration curves, statistics and associated analyses.
- **Reservoirs** – provides access to reservoir, water-level, spill, storage and related analyses.
- **Flood Estimation** – provides access to the design rainfall and flood-estimation methods incorporated into HydroSuite.
- **Basic Hydraulics** – provides commonly required open-channel, weir, water-surface profile, culvert and related hydraulic calculations.
- **Pipe Analysis** – provides access to pipe-flow, pipe-system and associated pipeline design analyses.
- **Pump Station Analysis** – provides tools for pump selection, system curves, operating-point and pump-station assessment.
- **Hydropower** – provides access to hydropower energy, turbine and related scheme-assessment functionality.
- **Economic Analysis** – provides project costing, financial and economic assessment functionality.
- **Reports** – provides access to available project reports and reporting outputs.

The navigation panel remains in a consistent position throughout the application, allowing users to move between related engineering analyses without returning to the *Home* screen.

② Software and licence information

The upper portion of the left-hand panel identifies the software as GHI HydroSuite and displays the applicable edition of the software.

The licence information panel immediately below the logo displays information associated with the current software licence, including the number of available analysis credits. Where applicable, the Buy Credits button provides access to the facility for obtaining additional analysis credits.

This area allows the user to confirm the software edition and credit status directly from the main workspace.

③ Current project information

The Current Project panel is displayed near the top-right of the workspace. This panel identifies the project currently open in HydroSuite and displays its associated project folder.

When no project has been selected, this is clearly indicated in the panel. Once a project is opened or created, the information is updated to identify the active project.

Users should confirm the current project before entering or modifying project-specific information, particularly when working with several HydroSuite projects.

④ Save Project As / Save Project

The *Save Project As* button is located adjacent to the Current Project panel and allows the current HydroSuite project to be saved under a new project name or location.

The button changes to a *Save Project* button once a project name has been entered.

Project information should be saved regularly while working in HydroSuite.

⑤ Help and information

The *Help (?)* button in the upper-right corner provides access to help and supporting information associated with HydroSuite.

Additional *Help* and *About* links are provided at the bottom of the main navigation panel. These provide access to supporting information relating to the software and its use.

⑥ Home dashboard

The central portion of the **Home** workspace contains the **Home** dashboard. This provides graphical shortcuts to the principal engineering modules and presents the major capabilities of HydroSuite at a glance.

Each module is represented by an identifiable engineering icon, module name and brief description. Selecting a module tile opens the corresponding analysis environment.

The Home dashboard currently provides direct access to:

- Data Manager
- Flow Analysis
- Reservoirs
- Flood Estimation
- Basic Hydraulics
- Pipe Analysis
- Pump Analysis
- Hydropower
- Economic Analysis
- Reports

The module tiles provide an alternative to the left-hand navigation panel. Users may therefore access the principal modules using whichever navigation method is most convenient.

Module workspace

When an engineering module is selected, the central **Home** dashboard is replaced by the applicable module workspace. Depending on the type and complexity of the analysis, a module workspace may contain:

- project or analysis-case selectors;
- input panels;
- tabbed analysis screens;
- engineering parameter fields;
- calculation and analysis controls;
- graphical displays and engineering schematics;
- results tables and results viewers; and
- report-generation or export controls.

Although individual modules contain different engineering inputs and functionality, a consistent interface philosophy is maintained throughout HydroSuite. This allows users who become familiar with one part of the software to navigate other modules more easily.

Typical workspace workflow

A typical HydroSuite workflow begins by creating or opening a project and confirming that the correct project is shown in the Current Project panel. The required engineering module can then be selected from either the left-hand navigation panel or the **Home** dashboard.

Depending on the assessment, information may subsequently be transferred between related modules. For example, hydrological data may be processed in the Data Manager, analysed under Flow Analysis, and subsequently used for a Hydropower assessment. Similarly, design rainfall information can be used by the applicable Flood Estimation methods, with calculated flood discharges subsequently available for hydraulic assessment.

Users are encouraged to save the project regularly as an assessment develops. The project-based structure allows the relevant inputs, analysis cases and results to be retained together as part of the engineering study.

8 PROJECTS

The Projects screen is used to create, open, save and manage GHI HydroSuite project files. It also contains the general project information that is used throughout the software and, where applicable, included in generated reports.

A HydroSuite project provides a common working environment for the different analysis modules. Project information and applicable analysis inputs and results are stored with the project, allowing an existing project to be reopened and continued at a later stage.

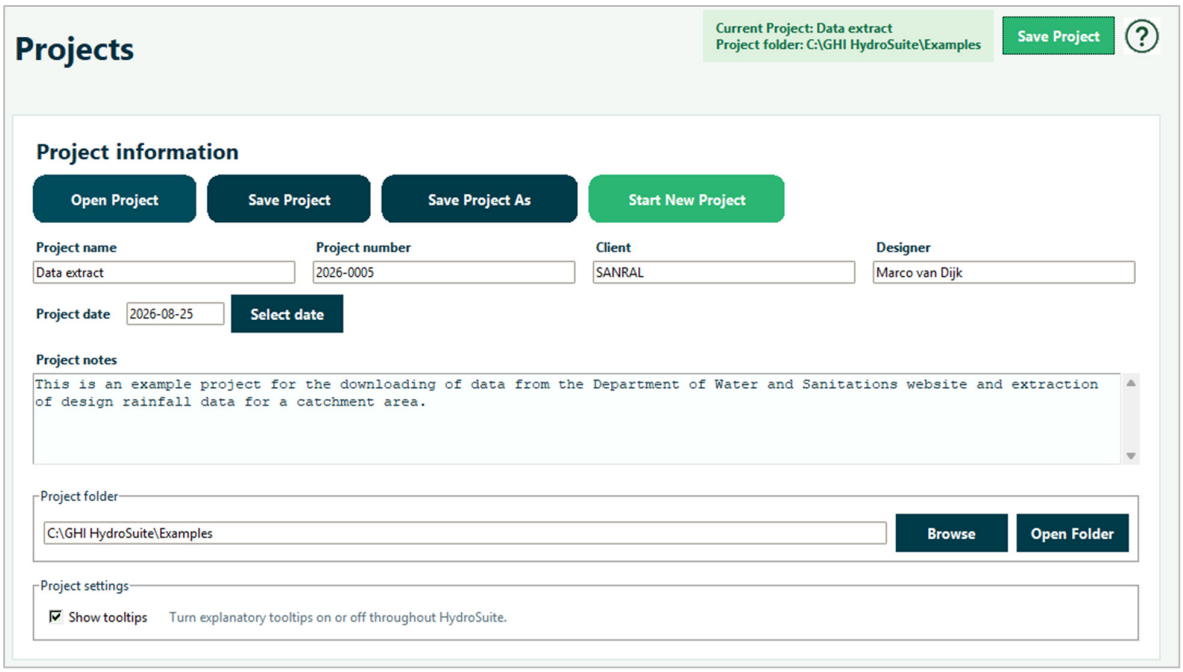


Figure 8-1: GHI HydroSuite Projects screen

8.1 Project information

The Project information section contains the general identification and administrative information associated with the project. The available fields and controls are described in **Table 8-1**.

Table 8-1: Project information settings

Option	Description
Open Project	Opens an existing GHI HydroSuite project. The user is prompted to select a previously saved HydroSuite project file. The project information and saved data associated with the project are restored.
Save Project	Saves the current project and its associated information. Where the project has already been saved, the existing project file is updated.
Save Project As	Saves the current project under a new file name or at a different location. This is useful for creating a copy of an existing project or developing alternative analysis scenarios while retaining the original project.

Option	Description
Start New Project	Creates a new HydroSuite project. Existing project information and applicable analysis selections and results are cleared so that a new project can be defined.
Project name	Descriptive name assigned to the project. The project name is used to identify the project within HydroSuite and may also be included in generated reports.
Project number	User-defined project, contract or reference number. This field may be used to associate the HydroSuite project with the organisation's internal project numbering system.
Client	Name of the client, organisation or authority for whom the analysis is being undertaken.
Designer	Name of the engineer, designer or analyst responsible for the HydroSuite project.
Project date	Date associated with the project. The date can be entered directly or selected using the Select date button.
Select date	Opens the date-selection facility and allows the project date to be selected rather than entered manually.
Project notes	Free-text field for recording a description of the project or other relevant information. This may include the purpose of the analysis, assumptions, project background, data sources or other notes that should remain associated with the project.

The current software implementation also stores the principal project information when a HydroSuite project is saved and restores it when the project is subsequently opened.

8.2 Project folder

The Project folder identifies the working directory associated with the current HydroSuite project. This directory provides the location in which project-related files and outputs generated by the various HydroSuite modules are organised. The available fields and controls are described in **Table 8-2**.

Table 8-2: Project folder settings

Option	Description
Project folder	Displays the directory associated with the current project. Project data and generated output files are organised relative to this working directory.
Browse	Allows the user to browse the computer and select the required project folder.
Open Folder	Opens the current project folder in Windows File Explorer, providing direct access to files and output generated for the project.

The selected project directory forms an important part of the HydroSuite project structure. When an existing project is opened, its saved project directory is restored.

8.3 Project settings

The Project settings section contains settings controlling the general behaviour of HydroSuite for the current working environment.

Show tooltips will enable or disable explanatory tooltips throughout GHI HydroSuite. When enabled, positioning the mouse pointer over supported controls displays a short explanation of the function or input. Tooltips are particularly useful for new users becoming familiar with the software.

8.4 Current project information

The upper-right corner of the HydroSuite workspace provides a permanent indication of the project currently being used.

The Current Project panel displays the current project name and its associated project folder. This provides a quick visual confirmation of the active project when moving between the different HydroSuite modules.

The *Save Project* button in the upper-right corner provides convenient access to the project-saving function without requiring the user to return to the Projects screen. This is particularly useful when working through several analysis modules.

The *Help ?* button provides access to the applicable HydroSuite help facilities.

8.5 Recommended project workflow

When commencing a new HydroSuite analysis, the recommended procedure is:

1. Select *Start New Project*.
2. Enter the *Project name*, *Project number*, *Client* and *Designer*.
3. Select the appropriate *Project date*.
4. Enter any relevant information under *Project notes*.
5. Confirm or select the required *Project folder*.
6. Select *Save Project* or *Save Project As* and create the HydroSuite project file.
7. Proceed to the design/analysis module.
8. Use *Save Projec*t regularly while working to retain the latest project information and analysis data.

9 DATA MANAGER

The Data Manager provides facilities for obtaining, importing, viewing and managing hydrological and rainfall data used by the different analysis modules within GHI HydroSuite.

The Data Manager brings the principal data-management functions into a single workspace. Users can download hydrological data directly from the Department of Water and Sanitation (DWS), import existing data files, inspect time-series data, browse the available hydrological station catalogue and extract design rainfall information from the South African design rainfall database.

The Data Manager contains the following tabs:

- Download DWS Data
- Import Files
- Data Viewer
- Station Catalogue
- Design Rainfall

The Show Engineering Reference Library option at the top of the screen provides access to the Engineering Reference Library while working within the Data Manager.

9.1 Download DWS Data

The ***Download DWS Data*** tab allows hydrological records to be obtained directly from the Department of Water and Sanitation data service. The user selects the required monitoring station, period of record and datasets to be downloaded.

Station and period selection

The upper section of the screen, **Figure 9-1** is used to identify the required DWS station and define the period for which data are required, see **Table 9-1**.

Table 9-1: Station and period selection

Option	Description
Search station	Enter a DWS station number, or part thereof, to locate the required monitoring station.
Search button	Searches the available station information using the entered station number.
Station selection	Displays matching stations and allows the required station to be selected.
Selected station	Confirms the station currently selected for downloading. The station number and station name are displayed.
Site type	Identifies the type of hydrological monitoring site. Available station types may include river, reservoir, canal, conduit or other station categories contained in the DWS database.
Default start / Default end	Displays the available period of record identified for the selected station.

Option	Description
Start date	Defines the first date for which records are to be downloaded.
End date	Defines the final date for which records are to be downloaded.

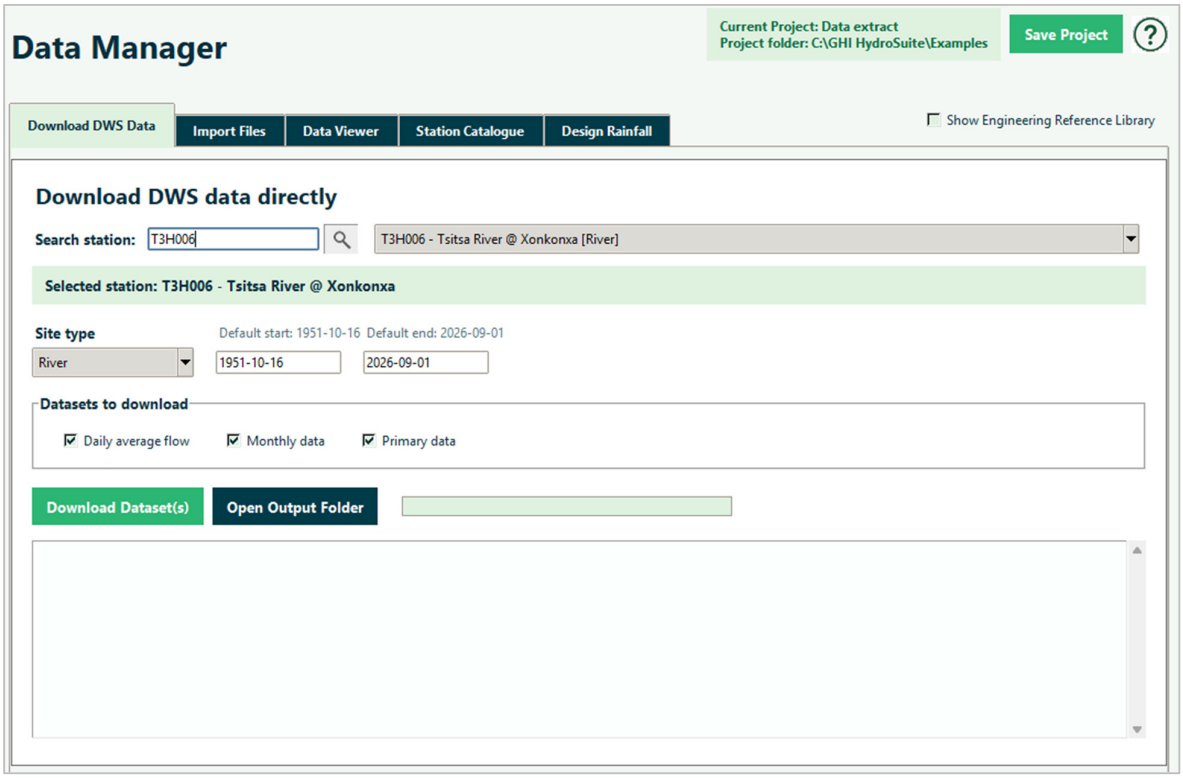


Figure 9-1: Data Manager – Download DWS Data

Datasets to download

The Datasets to download panel allows one or more available datasets to be selected, as listed in **Table 9-2**.

Table 9-2: Datasets to download

Option	Description
Daily average flow	Downloads the available daily average flow records for the selected station and period.
Monthly data	Downloads the available monthly data.
Primary data	Downloads the available primary hydrological data associated with the selected station.

The availability of particular datasets depends on the selected DWS monitoring station and the information available from the source database.

Download controls

The download controls are listed in **Table 9-3**.

Table 9-3: Download controls

Option	Description
Download Dataset(s)	Initiates the download of all selected datasets for the specified station and period.
Open Output Folder	Opens the folder containing the downloaded data files in Windows File Explorer.
Progress indicator	Displays the progress of the data download operation.
Information panel	Displays information, messages and the status of the download process, example shown in **Figure 9-2**).

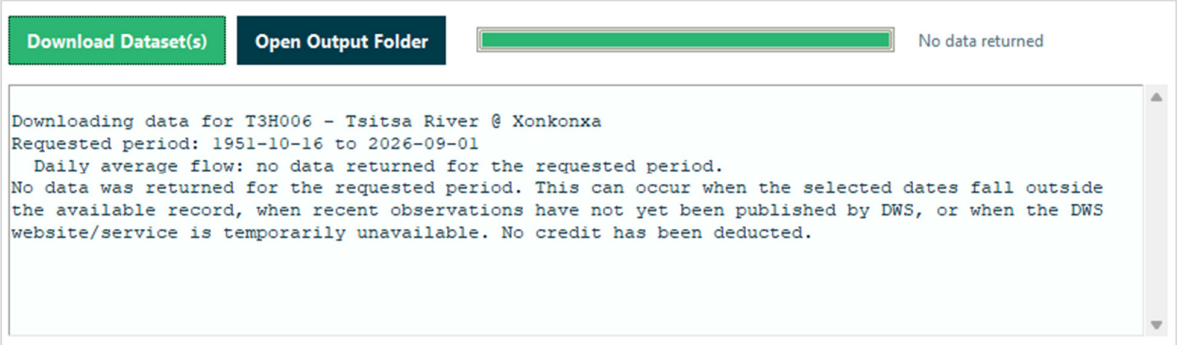


Figure 9-2: Information panel

9.2 Import Files

The ***Import Files*** tab provides a facility for importing hydrological data that have already been downloaded or otherwise obtained as a compatible text file, see **Figure 9-3**.

It is particularly useful for converting DWS-format text data into a CSV format that can subsequently be used within HydroSuite and other applications.

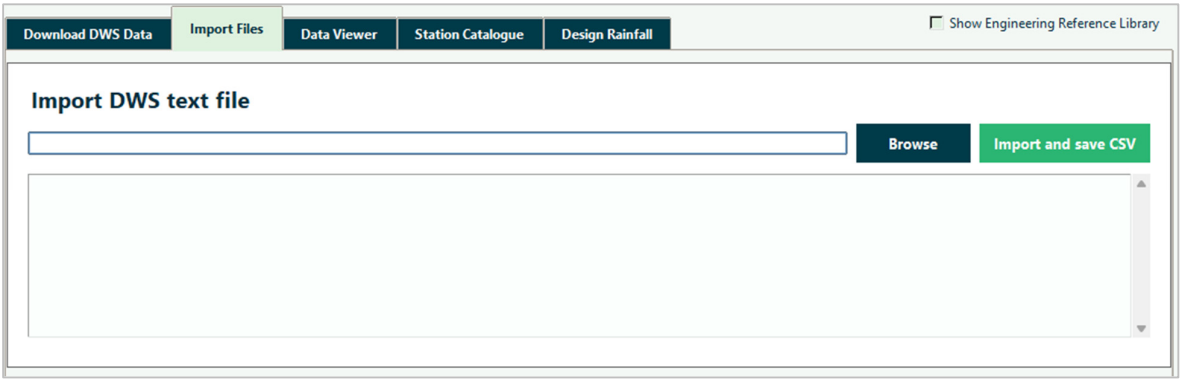


Figure 9-3: Data Manager – Import Files

The Import file options are listed in **Table 9-4**.

Table 9-4: Import file options

Option	Description
File selection field	Displays the path and filename of the text file selected for import.
Browse	Opens a file-selection dialogue from which the required text file can be selected.
Import and save CSV	Imports the selected text file, processes the available data and saves the resulting dataset in CSV format.
Information panel	Displays information relating to the imported file, processing operation and resulting output.

The imported CSV data can subsequently be inspected using the Data Viewer (see **Figure 9-4**).

9.3 Data Viewer

The ***Data Viewer*** tab, **Figure 9-4**, allows time-series data to be loaded and inspected directly within HydroSuite. It provides a convenient means of checking the contents, period of record, data values and associated quality information before the dataset is used in an analysis.

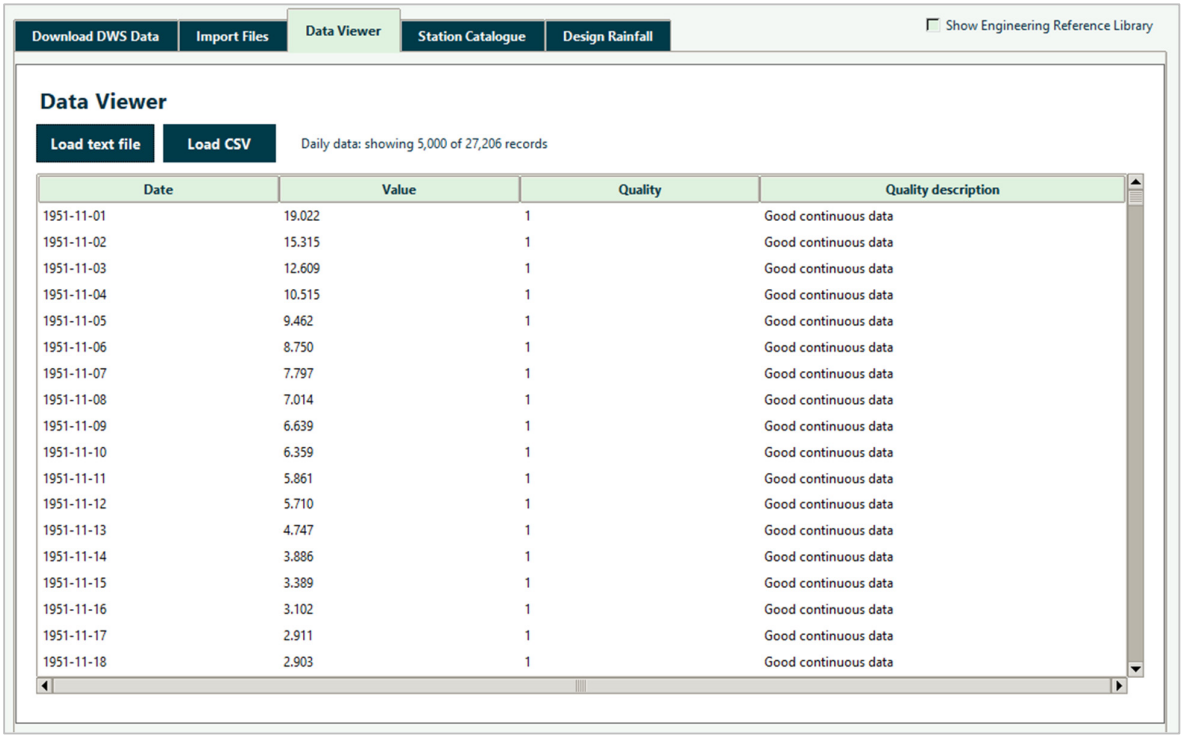


Figure 9-4: Data Manager – Data Viewer

The Data Viewer Loading data options are listed in **Table 9-5**.

Table 9-5: Data Viewer Loading data

Option	Description
Load text file	Loads a supported text-format dataset into the Data Viewer.
Load CSV	Loads a previously created or compatible CSV dataset into the Data Viewer.
Data information	Displays information about the loaded dataset, including the type of data and the number of records currently displayed relative to the total number of records.

For large datasets, only a portion of the complete dataset may initially be displayed in the table to maintain responsive operation. The loaded records are presented in tabular form (**Figure 9-4** and Table 9-6).

Table 9-6: Data table

Column	Description
Date	Date associated with the individual data record.
Value	Recorded hydrological value for the corresponding date.
Quality	Numerical quality code associated with the record.
Quality description	Description of the applicable data-quality classification.

The horizontal and vertical scroll bars can be used to navigate through the displayed dataset.

The *Data Viewer* is useful for identifying the available period of record and examining data quality before undertaking subsequent flow or hydrological analyses.

9.4 Station Catalogue

The ***Station Catalogue*** tab provides access to the hydrological monitoring-station information available within HydroSuite. It can be used to identify suitable stations and inspect their location, status and available period of record.

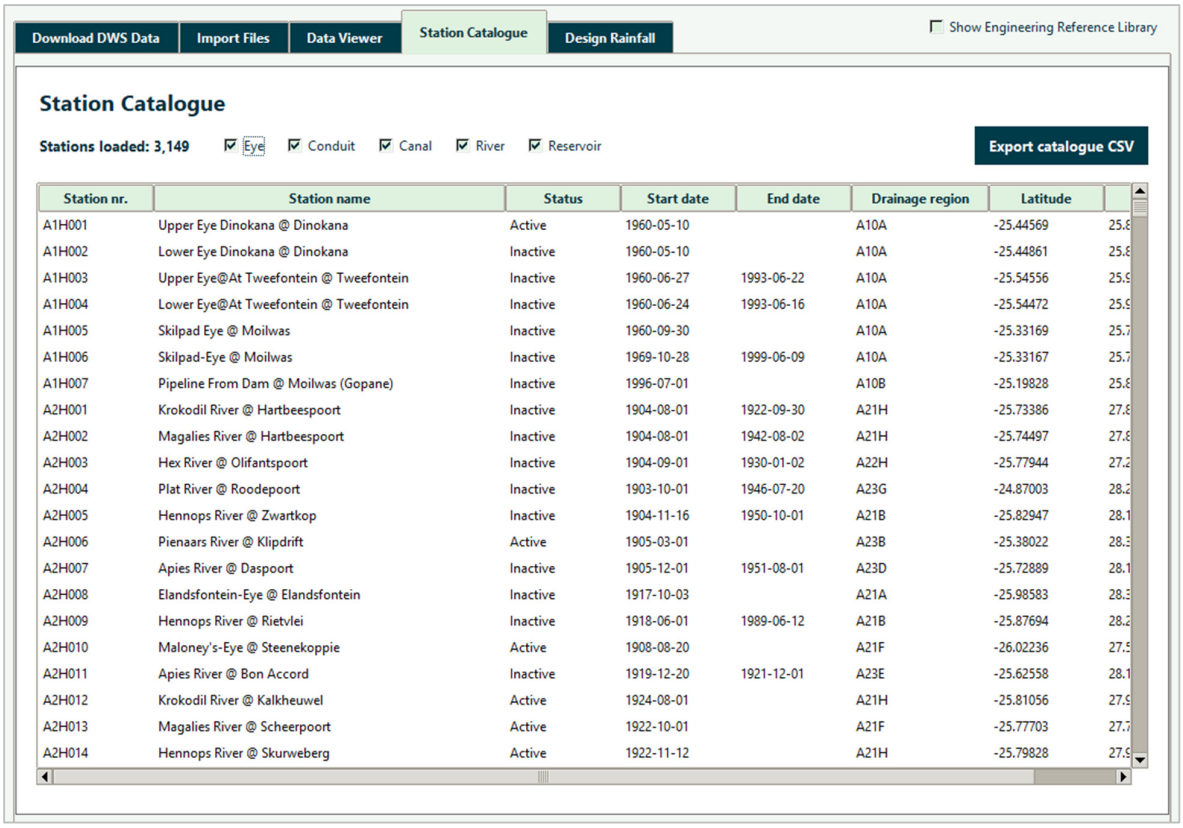
The number of stations currently available in the catalogue is displayed at the top of the screen, **Figure 9-5**.

Station type filters

The check boxes can be used to control which station types are included in the catalogue, see **Figure 9-5** and **Table 9-7**. More than one station type can be displayed simultaneously.

Table 9-7: Station type filters

Option	Description
Eye	Displays monitoring stations classified as eyes or springs.
Conduit	Displays stations associated with conduits.
Canal	Displays canal monitoring stations.
River	Displays river monitoring stations.
Reservoir	Displays reservoir monitoring stations.



Station nr.	Station name	Status	Start date	End date	Drainage region	Latitude	
A1H001	Upper Eye Dinokana @ Dinokana	Active	1960-05-10		A10A	-25.44569	25.8
A1H002	Lower Eye Dinokana @ Dinokana	Inactive	1960-05-10		A10A	-25.44861	25.8
A1H003	Upper Eye@At Tweefontein @ Tweefontein	Inactive	1960-06-27	1993-06-22	A10A	-25.54556	25.9
A1H004	Lower Eye@At Tweefontein @ Tweefontein	Inactive	1960-06-24	1993-06-16	A10A	-25.54472	25.9
A1H005	Skilpad Eye @ Moilwas	Inactive	1960-09-30		A10A	-25.33169	25.7
A1H006	Skilpad-Eye @ Moilwas	Inactive	1969-10-28	1999-06-09	A10A	-25.33167	25.7
A1H007	Pipeline From Dam @ Moilwas (Gopane)	Inactive	1996-07-01		A10B	-25.19828	25.8
A2H001	Krokodil River @ Hartbeespoort	Inactive	1904-08-01	1922-09-30	A21H	-25.73386	27.8
A2H002	Magalies River @ Hartbeespoort	Inactive	1904-08-01	1942-08-02	A21H	-25.74497	27.8
A2H003	Hex River @ Olifantspoort	Inactive	1904-09-01	1930-01-02	A22H	-25.77944	27.2
A2H004	Plat River @ Roodepoort	Inactive	1903-10-01	1946-07-20	A23G	-24.87003	28.2
A2H005	Hennops River @ Zwartkop	Inactive	1904-11-16	1950-10-01	A21B	-25.82947	28.1
A2H006	Pienaars River @ Klipdrift	Active	1905-03-01		A23B	-25.38022	28.3
A2H007	Apies River @ Daspoort	Inactive	1905-12-01	1951-08-01	A23D	-25.72889	28.1
A2H008	Elandsfontein-Eye @ Elandsfontein	Inactive	1917-10-03		A21A	-25.98583	28.3
A2H009	Hennops River @ Rietvlei	Inactive	1918-06-01	1989-06-12	A21B	-25.87694	28.2
A2H010	Maloney's-Eye @ Steenekoppie	Active	1908-08-20		A21F	-26.02236	27.5
A2H011	Apies River @ Bon Accord	Inactive	1919-12-20	1921-12-01	A23E	-25.62558	28.1
A2H012	Krokodil River @ Kalkheuwel	Active	1924-08-01		A21H	-25.81056	27.9
A2H013	Magalies River @ Scheerpoort	Active	1922-10-01		A21F	-25.77703	27.7
A2H014	Hennops River @ Skurweberg	Active	1922-11-12		A21H	-25.79828	27.9

Figure 9-5: Data Manager – Station Catalogue

Station information

The catalogue provides information for each available monitoring station, including:

Table 9-8: Station information

Column	Description
Station nr.	Unique DWS identification number assigned to the monitoring station.
Station name	Name and/or location of the monitoring station.
Status	Indicates whether the monitoring station is recorded as active or inactive.
Start date	Date from which records are available or the station commenced operation.
End date	End date of the available record where applicable. An active station may not have an end date.
Drainage region	Drainage-region designation associated with the station.
Latitude	Geographic latitude of the monitoring station.
Longitude	Geographic longitude of the monitoring station.

The table, **Figure 9-5**, can be scrolled horizontally and vertically to inspect all available station information.

Export catalogue

The *Export catalogue CSV* button exports the station catalogue to a CSV file. This allows the station information to be viewed or processed in spreadsheet, GIS or other compatible software.

9.5 Design Rainfall

The ***Design Rainfall*** tab provides access to the South African design rainfall database and allows design rainfall depths to be extracted for use in hydrological and flood-estimation analyses.

Rainfall information can be obtained using different spatial extraction methods. The required storm durations and return periods can be selected, and the location of interest can be identified using coordinates, a rainfall station, a catchment centroid, catchment area or other options applicable to the selected extraction method.

The Design Rainfall Spatial Viewer provides a graphical representation of the rainfall stations, catchment boundary, rainfall grid cells or Thiessen polygons used in the extraction.

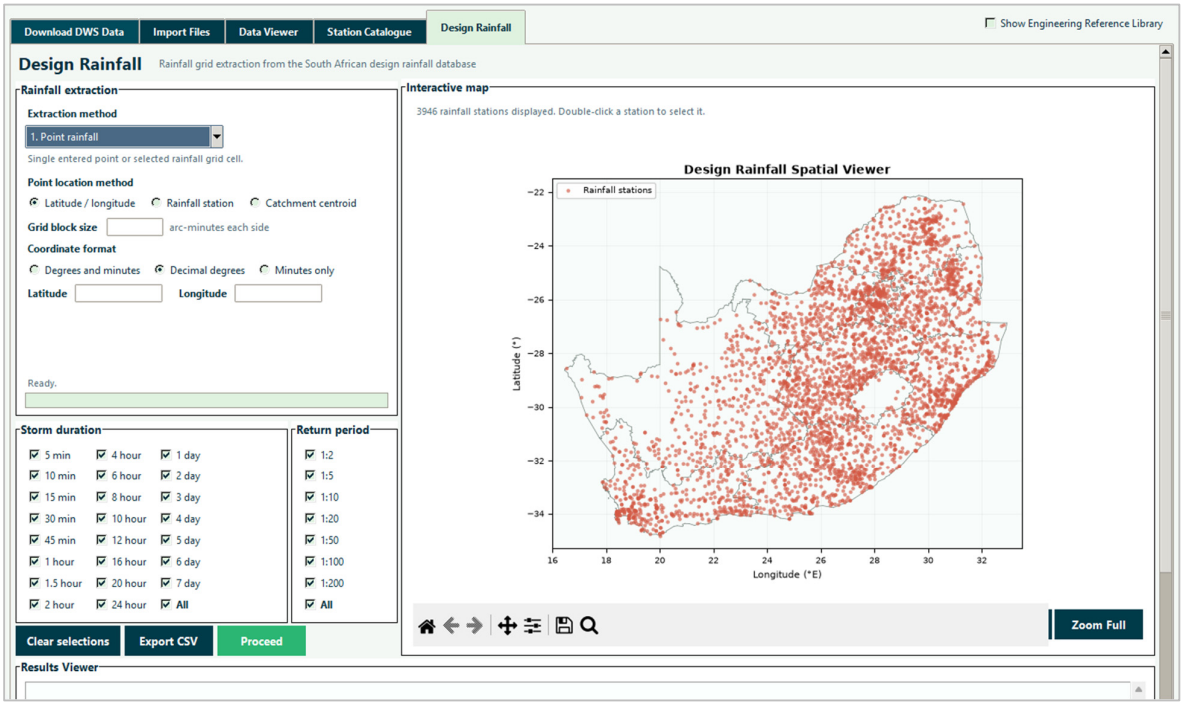


Figure 9-6: Data Manager – Design Rainfall

The user selects an appropriate spatial extraction method, identifies the required location or catchment, selects the required storm durations and return periods, and proceeds with the rainfall extraction.

Four rainfall extraction methods are available:

- Point rainfall
- Catchment average grid rainfall
- Area-weighted grid rainfall
- Thiessen polygon rainfall

The appropriate method depends on whether rainfall is required for a specific location or as a representative rainfall estimate over an entire catchment.

9.5.1 Point Rainfall

The Point rainfall method extracts design rainfall information for a single specified location or selected rainfall grid cell.

Three methods are available for identifying the point:

- Latitude / longitude
- Rainfall station
- Catchment centroid

The Grid block size can be specified in arc-minutes where applicable to define the rainfall grid area associated with the selected point.

9.5.1.1 Latitude / Longitude

The Latitude / longitude option allows the user to specify the required rainfall extraction point directly using geographic coordinates, **Figure 9-7**.

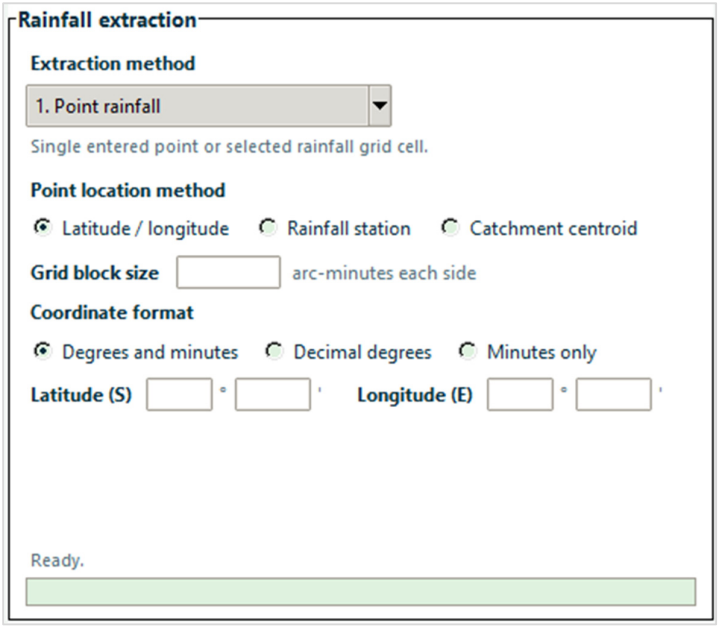


Figure 9-7: Point rainfall extraction using latitude and longitude

The available inputs are described below, **Table 9-9**.

After defining the location, the required storm durations and return periods are selected in the main Design Rainfall screen before proceeding with the extraction.

Table 9-9: Point rainfall extraction using latitude and longitude

Option	Description
Extraction method	Select 1. Point rainfall.
Point location method	Select Latitude / longitude to define the extraction location using geographic coordinates.
Grid block size	Defines the rainfall grid block associated with the selected location, expressed in arc-minutes on each side.
Coordinate format	Specifies the format in which coordinates are entered. Available formats include Degrees and minutes, Decimal degrees and Minutes only.
Degrees and minutes	Coordinates are entered as separate degree and minute values.
Decimal degrees	Coordinates are entered directly in decimal-degree format.
Minutes only	Allows coordinates to be specified using the applicable minutes-only format.
Latitude (S)	Specifies the latitude of the required point.
Longitude (E)	Specifies the longitude of the required point.
Status indicator	Displays the current status of the rainfall extraction process.

9.5.1.2 Rainfall Station

The Rainfall station option allows a rainfall station contained in the design rainfall database to be used to define the point of interest, **Figure 9-8**.

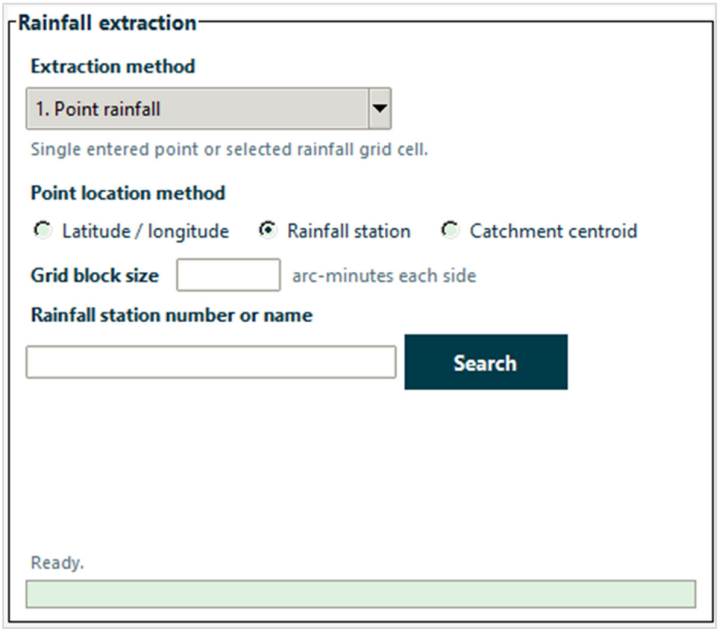


Figure 9-8: Point rainfall extraction using a rainfall station

The available inputs are described below, **Table 9-10**.

Table 9-10: Point rainfall extraction using a rainfall station

Option	Description
Point location method	Select Rainfall station.
Grid block size	Defines the rainfall grid block associated with the selected station where applicable.
Rainfall station number or name	Allows the user to enter a complete or partial rainfall station number or station name.
Search	Searches the rainfall station database for the specified station information.

Rainfall stations can also be investigated spatially using the Design Rainfall Spatial Viewer, **Figure 9-9**. The map displays the available rainfall stations across South Africa.

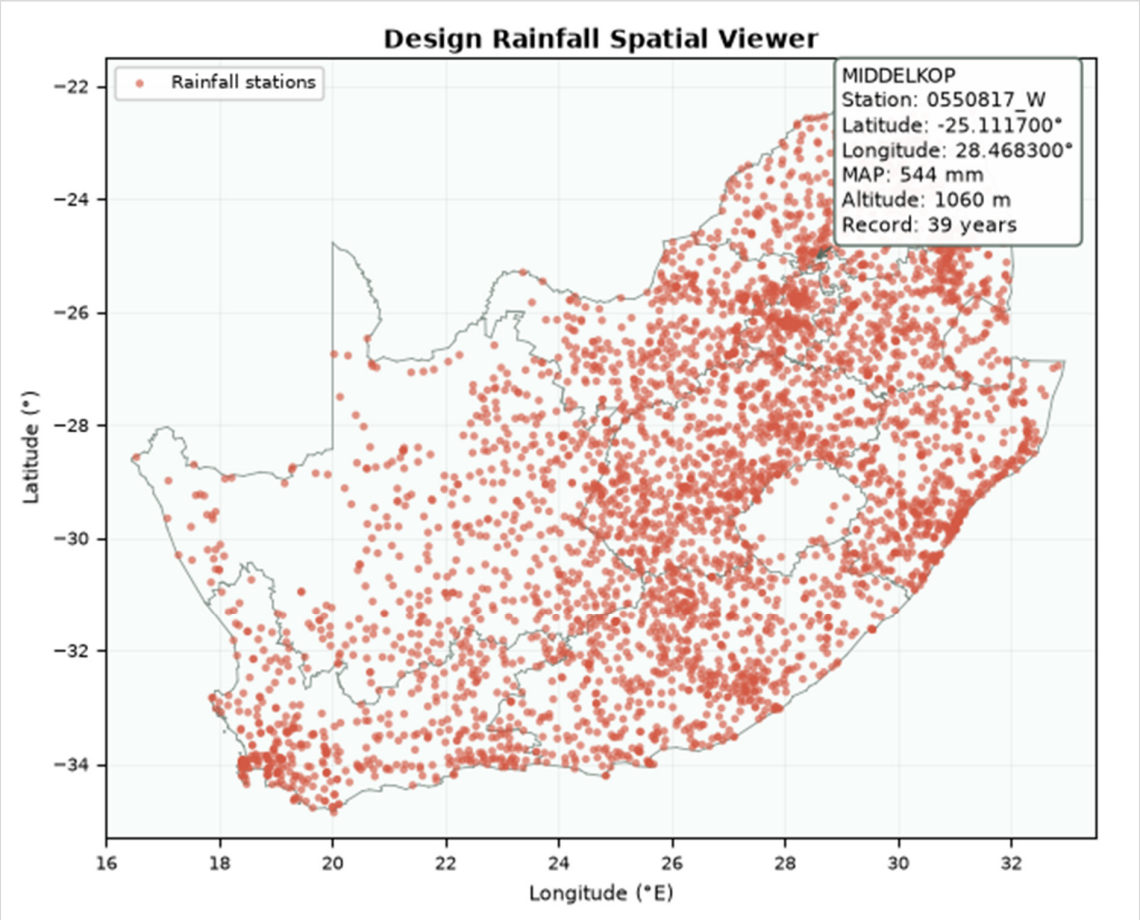


Figure 9-9: Design Rainfall Spatial Viewer showing rainfall stations

Individual rainfall stations are represented by points on the map. When a station is interrogated, information associated with the station is displayed. As illustrated in **Figure 9-9**, this may include:

- rainfall station name;
- station number;
- latitude;

- longitude;
- Mean Annual Precipitation (MAP);
- altitude; and
- available record length.

This facility assists the user in evaluating the location and characteristics of available rainfall stations before selecting a station for rainfall extraction.

9.5.1.3 Catchment Centroid

The Catchment centroid option determines the point rainfall location from the geometric centroid of a user-supplied catchment polygon, **Figure 9-10**. The available inputs are described below, **Table 9-11**.

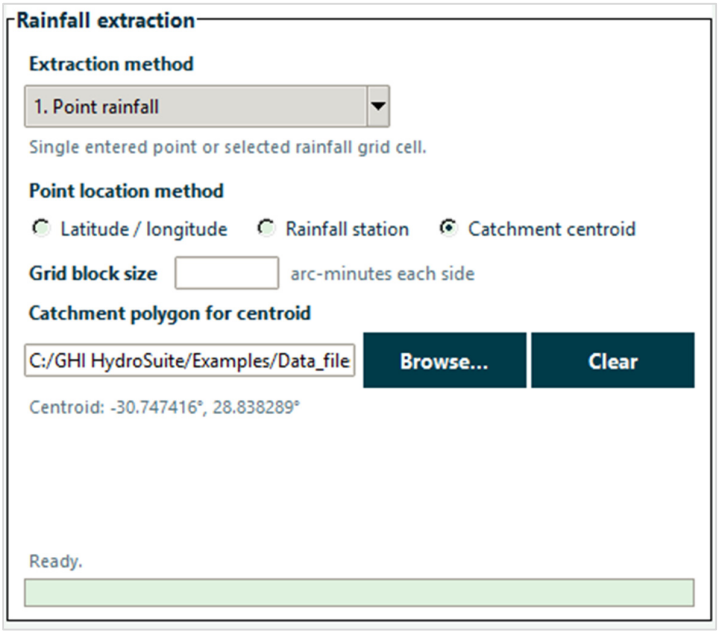


Figure 9-10: Point rainfall extraction using a catchment centroid

Table 9-11: Point rainfall extraction using a catchment centroid input requirement

Option	Description
Point location method	Select Catchment centroid.
Grid block size	Defines the rainfall grid block associated with the calculated centroid where applicable.
Catchment polygon for centroid	Displays the selected catchment polygon file. The format of the polygon that can be loaded could be a Shapefile (*.shp) or GeoPackage (*.gpkg).
Browse	Opens a file-selection dialogue from which the required catchment polygon can be selected.
Clear	Removes the currently selected catchment polygon.
Centroid	Displays the calculated latitude and longitude of the catchment centroid after a valid polygon has been loaded.

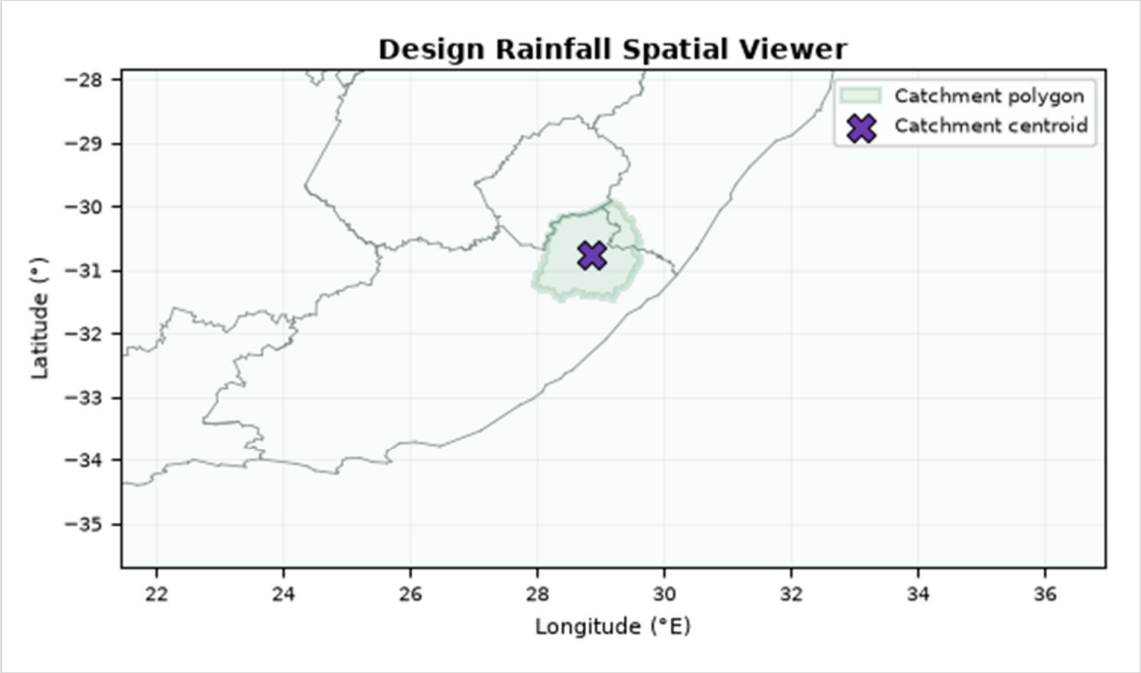


Figure 9-11: Spatial viewer showing catchment polygon and calculated centroid

Once the catchment polygon is loaded, HydroSuite calculates its centroid and uses this location as the point for the design rainfall extraction, as depicted in **Figure 9-11**. The Design Rainfall Spatial Viewer displays the catchment polygon together with the calculated catchment centroid. This provides a visual check of the catchment geometry and the point being used for the rainfall extraction.

This method is particularly useful where a representative point rainfall is required for a catchment and the user wishes to use the catchment centroid rather than manually determining coordinates.

9.5.2 Catchment Average Grid Rainfall

The Catchment average grid rainfall method calculates representative catchment rainfall by applying equal weighting to all rainfall grid cells within the catchment, **Figure 9-12**. A catchment polygon is required to define the spatial extent over which the rainfall information is extracted, **Figure 9-13**. The available inputs are described below, **Table 9-12**.

Table 9-12: Catchment Average Grid Rainfall input requirements

Option	Description
Extraction method	Select 2. Catchment average grid rainfall.
Catchment polygon	Displays the polygon file defining the catchment boundary.
Browse	Allows the user to select the required catchment polygon file.
Clear	Removes the selected catchment polygon and allows another catchment to be selected.
Status indicator	Displays the status of the selected extraction method and subsequent rainfall processing.

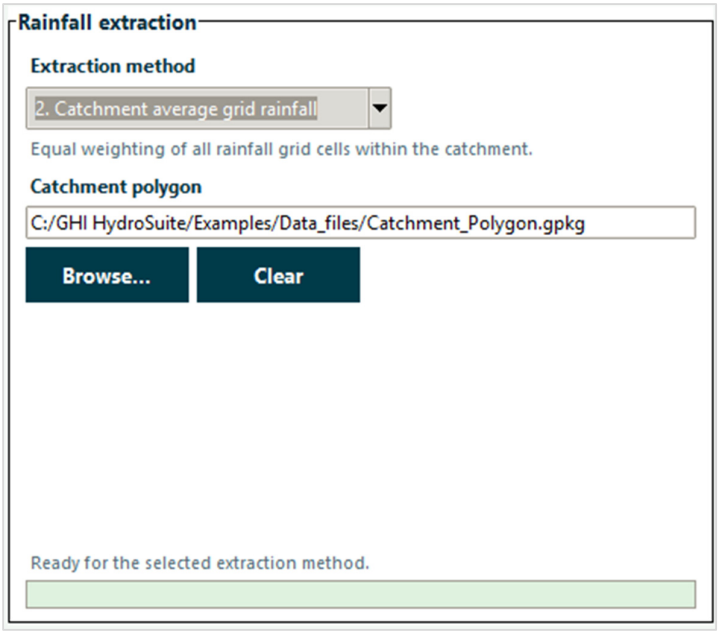


Figure 9-12: Catchment average grid rainfall input

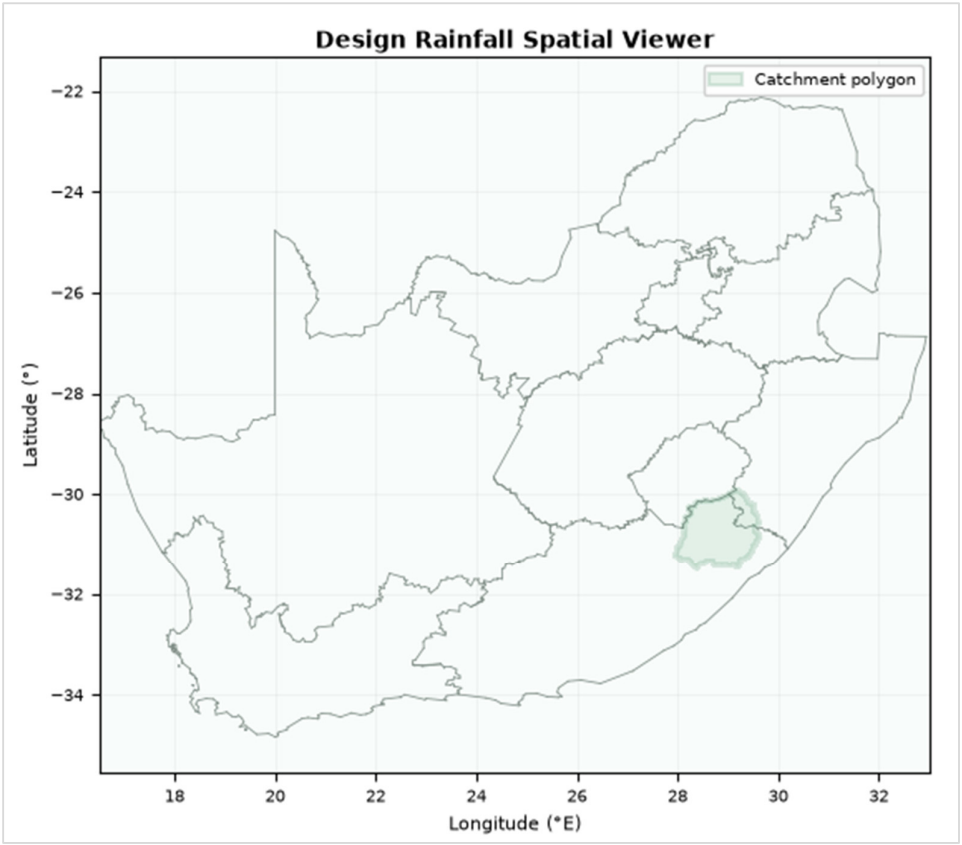


Figure 9-13: Spatial viewer for catchment average grid rainfall

Under this method, the rainfall grid cells contained within the catchment are treated equally when determining the representative catchment rainfall.

The Spatial Viewer displays the selected catchment polygon in its geographic position. This allows the user to confirm that the correct catchment has been loaded before proceeding with the rainfall extraction.

This method differs from the area-weighted approach described in Section 9.5.3 because each contributing rainfall grid cell receives equal weighting rather than being weighted according to the proportion of its area falling within the catchment.

9.5.3 Area-Weighted Grid Rainfall

The Area-weighted grid rainfall method determines representative catchment rainfall using the rainfall grid cells intersecting the catchment boundary, **Figure 9-14**. Each grid cell is weighted according to the proportion of the cell that falls within the catchment.

This provides a spatially weighted estimate of rainfall over the catchment and accounts for partially intersecting cells along the catchment boundary, see **Figure 9-15**. The available inputs are described below, **Table 9-13**.

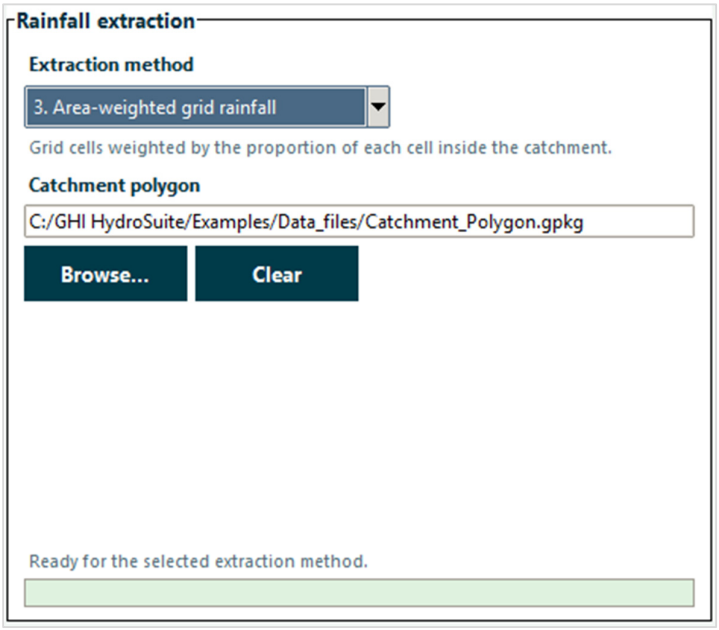


Figure 9-14: Area-weighted grid rainfall input

Table 9-13: Area-weighted grid rainfall input requirements

Option	Description
Extraction method	Select 3. Area-weighted grid rainfall.
Catchment polygon	Displays the polygon file defining the catchment boundary.
Browse	Allows the required catchment polygon to be selected.
Clear	Removes the currently selected catchment polygon.
Status indicator	Displays the status of the rainfall extraction procedure.

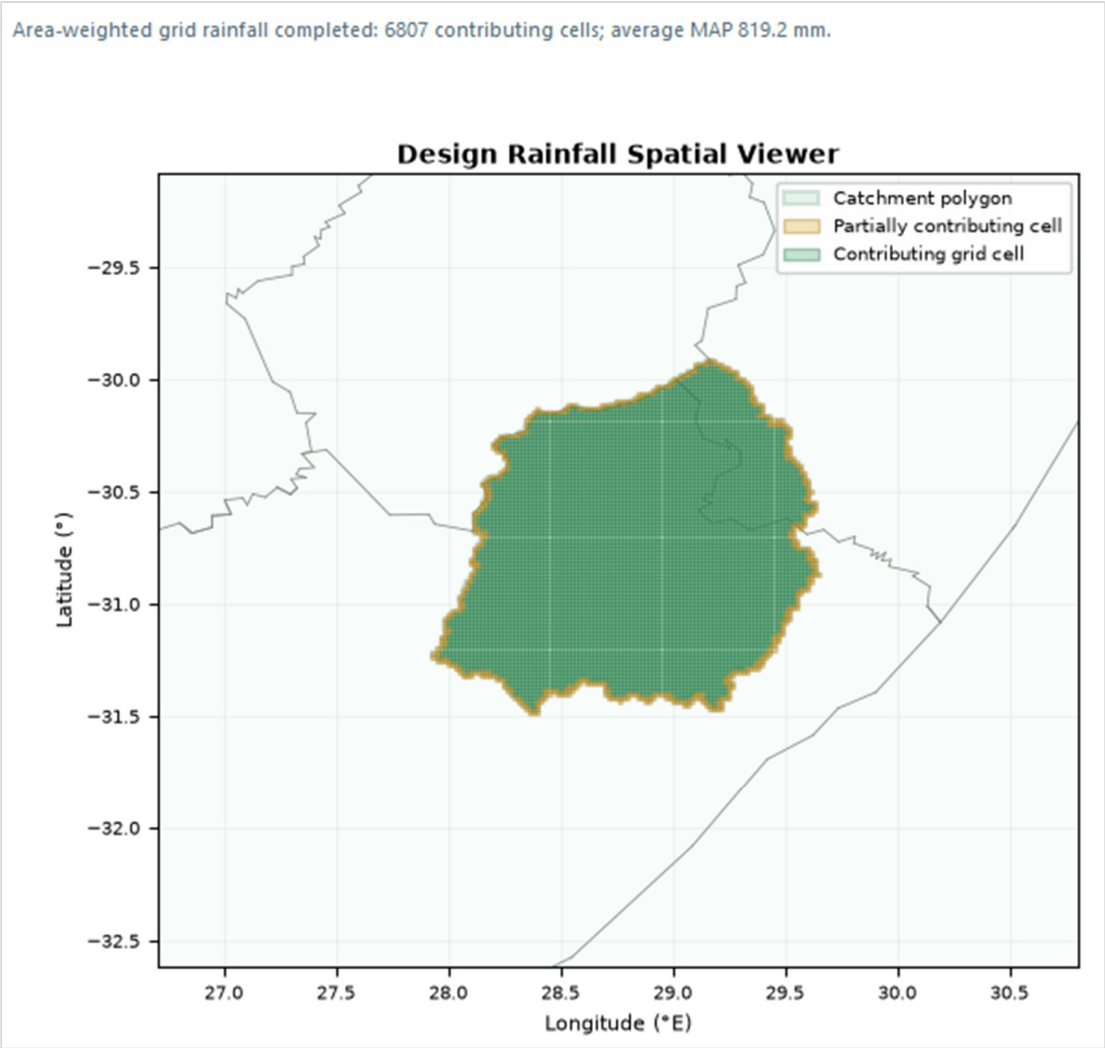


Figure 9-15: Spatial viewer showing contributing cells for area-weighted grid rainfall

The map distinguishes between:

- the catchment polygon;
- contributing grid cells; and
- partially contributing grid cells along the catchment boundary.

Cells lying completely within the catchment contribute their full area, whereas cells intersected by the catchment boundary contribute according to the proportion of their area located inside the catchment.

The results information displayed above the Spatial Viewer also provides a useful check on the extraction. In the example shown, HydroSuite reports the number of contributing cells and the calculated average MAP for the catchment.

This visualisation provides an important means of checking that the rainfall grid has been correctly intersected with the selected catchment.

9.5.4 Thiessen Polygon Rainfall

The Thiessen polygon rainfall method determines representative catchment rainfall from surrounding rainfall stations using Thiessen polygon area weighting, **Figure 9-16**.

Each rainfall station is associated with a Thiessen polygon representing the area considered to be most representative of that station. The polygons are intersected with the catchment, and the contribution from each rainfall station is weighted according to the area of its Thiessen polygon falling within the catchment.

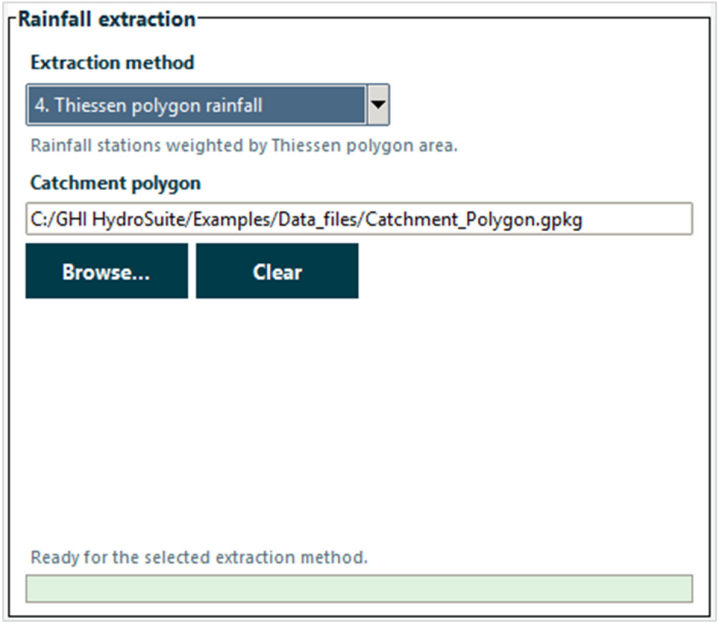


Figure 9-16: Thiessen polygon rainfall input

The available inputs are described below, **Table 9-14**.

Table 9-14: Thiessen polygon rainfall input requirements

Option	Description
Extraction method	Select 4. Thiessen polygon rainfall.
Catchment polygon	Displays the polygon file defining the catchment boundary.
Browse	Allows the user to select the required catchment polygon.
Clear	Removes the selected catchment polygon.
Status indicator	Displays the status of the Thiessen polygon rainfall calculation.

Following processing, HydroSuite identifies the rainfall stations contributing to the catchment and constructs the applicable Thiessen polygons.

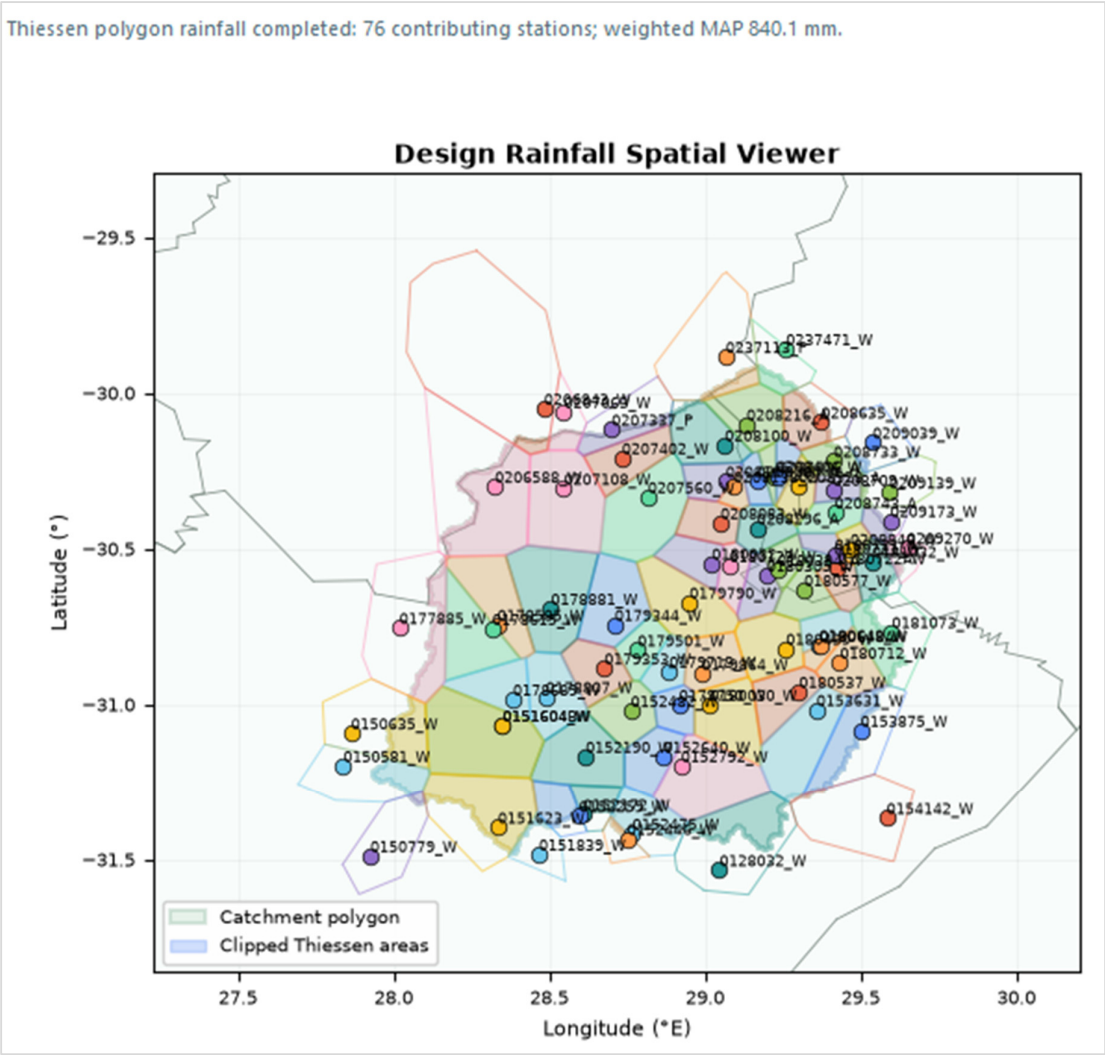


Figure 9-17: Spatial viewer showing rainfall stations and clipped Thiessen polygons

The Spatial Viewer shows:

- the catchment polygon;
- the rainfall stations considered in the analysis;
- the spatial distribution of the Thiessen polygons; and
- the clipped Thiessen areas contributing to the selected catchment.

Each contributing rainfall station is represented spatially together with the area over which its rainfall information is applied.

The results information displayed above the map reports the number of contributing rainfall stations and the resulting weighted MAP. In the example shown, 76 rainfall stations contribute to the calculation.

The Thiessen method is useful where the spatial distribution of observed rainfall stations is to form the basis of the representative catchment rainfall rather than rainfall-grid cells.

9.5.5 Storm Durations and Return Periods

The Storm duration and Return period panels define the rainfall information to be extracted.

Storm duration
The user can select one or more storm durations. Available durations extend from short-duration events to multi-day rainfall events and include:

5, 10, 15, 30 and 45 minutes; 1, 1.5, 2, 4, 6, 8, 10, 12, 16, 20 and 24 hours; and 1 to 7 days.

The *All* option selects all available storm durations.

Return period
One or more design return periods may be selected:

1:2, 1:5, 1:10, 1:20, 1:50, 1:100 and 1:200 years.

The *All* option selects all available return periods.

Selecting only the durations and return periods required for a particular analysis reduces unnecessary output and makes the resulting rainfall tables easier to review.

9.5.6 Rainfall Results and Export

Once the location or catchment has been defined and the required storm durations and return periods selected, the *Proceed* button initiates the rainfall extraction, **Table 9-16**.

Table 9-15: Rainfall extraction controls

Option	Description
Clear selections	Clears the current rainfall extraction selections and allows a new analysis to be defined.
Export CSV	Exports the available rainfall results to a CSV file.
Proceed	Performs or advances the rainfall extraction using the selected location, durations, return periods and extraction method.
Zoom Full	Restores the interactive map to its full extent.
Results Viewer	Displays the design rainfall information obtained from the selected extraction method.

The resulting design rainfall information is displayed in the *Results Viewer* at the bottom of the Design Rainfall tab.

Where the design rainfall information is required by one of the HydroSuite flood-estimation methods, the extracted information can subsequently be used as part of the applicable hydrological analysis.
Spatial Viewer Controls

The toolbar located below the Design Rainfall Spatial Viewer provides standard controls for navigating, adjusting and exporting the displayed map, **Table 9-16**.

Table 9-16: Spatial Viewer Navigating Controls

Control		Description
Home		Restores the Spatial Viewer to its original or default map extent.
Back		Returns to the previous map view or extent. This is useful after zooming or panning to another location.
Forward		Returns to the next map view after the Back function has been used.
Pan		Allows the map to be moved horizontally or vertically. Select the tool and drag the map to reposition the displayed area.
Configure subplots		Opens the plot-layout adjustment controls. This is primarily a standard plotting function and will generally not be required during normal HydroSuite operation.
Save		Saves the current Spatial Viewer display as an image file.
Zoom		Allows a selected portion of the map to be enlarged. Select the tool and define the area of interest on the map.

Note: The Spatial Viewer toolbar provides standard graphical navigation functions. The separate Zoom Full button provided by GHI HydroSuite restores the viewer to the full spatial extent relevant to the current rainfall analysis.

10 FLOW ANALYSIS

10.1 Overview of the Flow Analysis module

The Flow Analysis module provides a set of tools for the assessment and analysis of historical flow records. It allows flow data to be evaluated, processed and analysed within a single environment, with results presented through tables, graphs and reports.

The main Flow Analysis screen is shown in **Figure 10-2**. The module includes separate analysis tabs for:

- Data quality - assessment of gaps, consistency, outliers and other potential data-quality concerns;
- Statistics - calculation of statistical characteristics of the selected flow record;
- Time series - evaluation and visualisation of flows over time;
- Flow duration curve - assessment of the relationship between flow magnitude and exceedance probability;
- Volume analysis – assessment of the relationship between volume magnitude and exceedance probability as well as volume frequency analysis;
- Low/High Flow Analysis - analysis of low- and high-flow characteristics;
- Flood frequency analysis - frequency analysis of flood events and estimation of flows associated with selected return periods;
- Seasonality analysis - assessment of the seasonal distribution and variability of flows;
- Stochastic flow generation – generation and assessment of synthetic flow sequences; and
- Report generation - compilation of the Flow Analysis results into a report.

The different analyses operate on a common selected flow record and analysis period. This allows the user to move between the individual analysis tabs without repeatedly selecting the underlying flow dataset.

The general Flow Analysis workflow is, **Figure 10-1**:

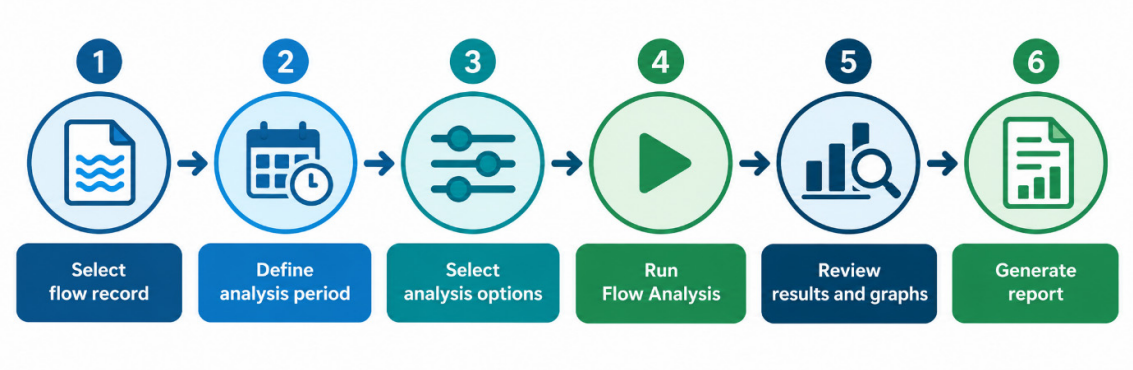


Figure 10-1: Flow Analysis workflow

The available inputs and analysis options depend on the selected tab and are described in the following sections.

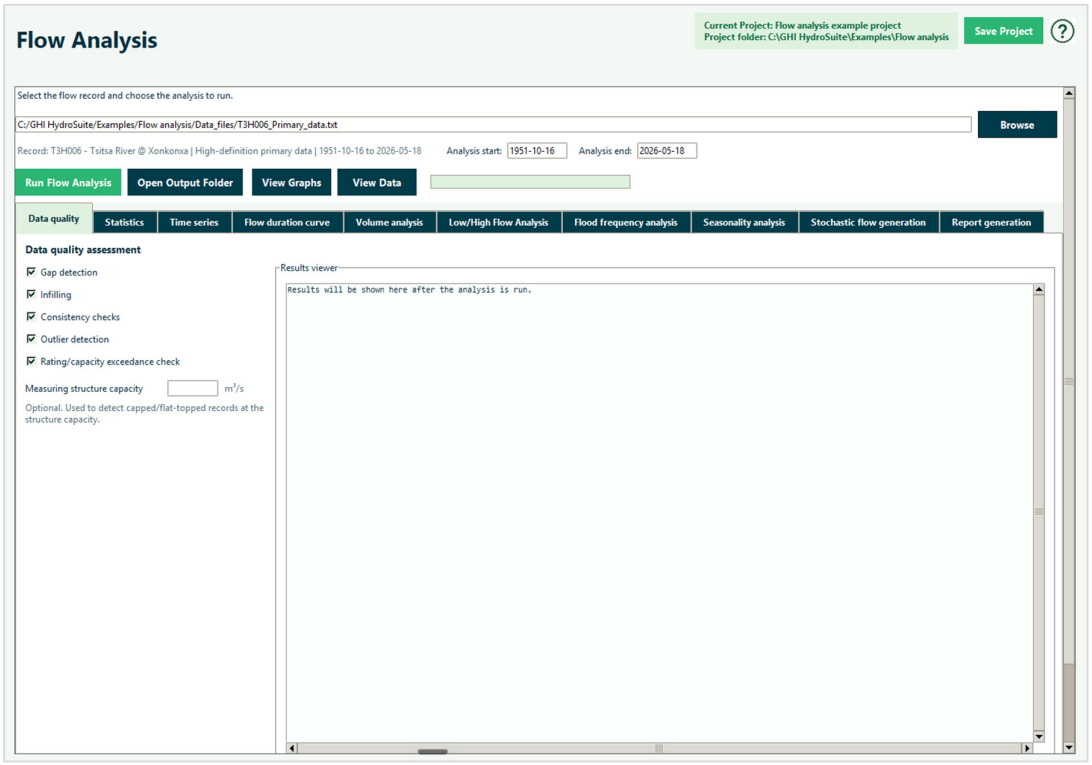


Figure 10-2: Flow Analysis screen

10.2 Flow record selection and analysis period

The upper section of the Flow Analysis screen provides the controls used to select the flow record and define the period to be analysed, as shown in **Figure 10-2**. These settings provide the common basis for the analyses undertaken within the different Flow Analysis tabs.

The currently selected flow-data file is displayed in the file-path field near the top of the screen. The Browse button can be used to locate and select a different flow record.

Once a valid flow record has been selected, information describing the record is displayed immediately below the file path. This includes the record/station identifier and name, the type of flow record and the full period for which flow data are available.

The *Analysis start* and *Analysis end* fields allow the user to specify the portion of the available flow record that is to be included in the analysis. By default, these may correspond to the beginning and end of the available record, but the dates can be adjusted where only a particular period is to be considered.

It is important to distinguish between the two periods displayed on the screen:

- The available record period represents the full period covered by the selected flow dataset.
- The analysis period represents the user-selected portion of that record that will be used for the current analysis.

Changing the *Analysis start* or *Analysis end* date therefore does not modify the original flow record. It limits the data considered by the Flow Analysis calculations to the specified period. This allows, for example, a particular historical period to be assessed without having to create a separate flow-data file.

The selected analysis period should be checked before running an analysis, particularly where the results are sensitive to record length or the period of record used.

10.3 Main Flow Analysis controls

A number of controls are provided near the top of the Flow Analysis screen and are common to the different analysis tabs (**Figure 10-2**), see **Table 10-1**.

Table 10-1: Main Flow Analysis controls

Option	Description
Run Flow Analysis	executes the analysis using the selected flow record, analysis period and options specified within the relevant analysis tabs. The results generated depend on the analyses and options selected by the user.
Open Output Folder	Opens the folder in which Flow Analysis outputs are stored. This provides direct access to generated files without requiring the user to navigate manually to the project directory.
View Graphs	Provides access to graphical outputs generated during the analysis.
View Data	Provides access to the user to inspect the underlying or processed flow data associated with the analysis.
Progress/status bar	An indicator is provided alongside the main controls to indicate progress while an analysis is being performed.
Results viewer	This is displayed within the individual analysis tabs, presents the principal numerical and text-based results associated with the selected analysis. The information displayed in the Results viewer changes according to the active tab and the analysis performed.

Together, these common controls provide a consistent workflow across the Flow Analysis module as depicted in **Figure 10-1**.

10.4 Data Quality

The ***Data quality*** tab provides tools for assessing the quality and completeness of the selected flow record before undertaking the subsequent flow analyses. The assessment can be used to identify missing data, potential inconsistencies, unusual values and possible limitations associated with the measuring structure.

The available data-quality assessment options are shown in **Figure 10-3**. Individual checks can be enabled or disabled using the corresponding selection boxes, allowing the user to determine which assessments are performed when the flow analysis is run.

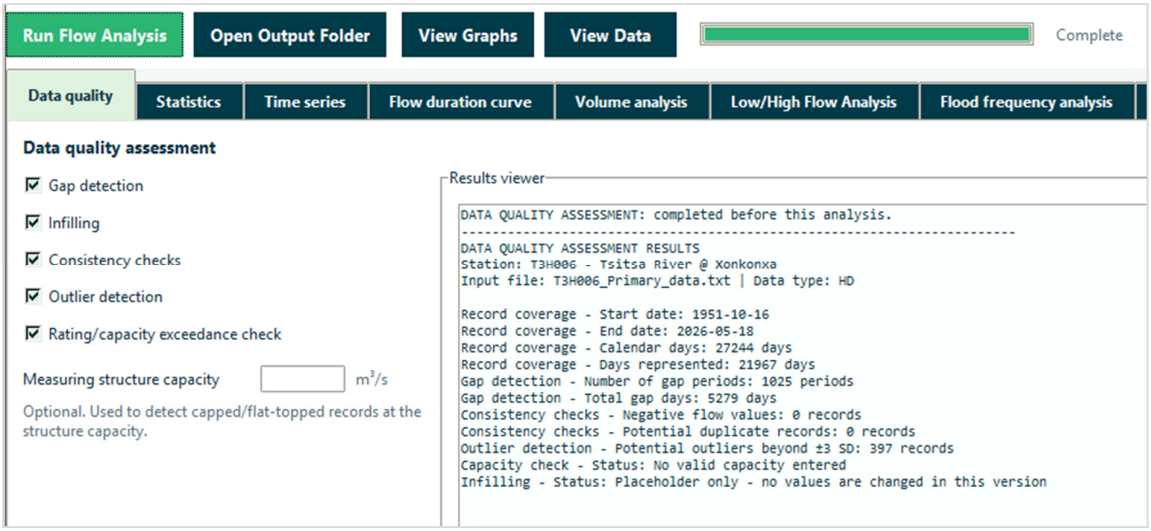


Figure 10-3: Flow Analysis - Data quality assessment

Five data-quality assessment options are available:

- Gap detection
- Infilling
- Consistency checks
- Outlier detection
- Rating/capacity exceedance check

The required checks are selected before running the Flow Analysis. Where applicable, additional information such as the Measuring structure capacity can be entered. The findings from the selected assessments are displayed in the *Results viewer* after the analysis has been completed. The available options are described in **Table 10-2**.

Table 10-2: Data quality assessment options

Option	Description
Gap detection	Checks the selected flow record for periods where flow data are missing and identifies gaps in the time series.
Infilling	Enables the infilling of missing values in the flow record where the applicable infilling procedure can be applied. This provides a more complete time series for subsequent analyses.
Consistency checks	Performs checks on the flow record to identify potential inconsistencies in the data or time series.
Outlier detection	Identifies flow values that differ substantially from the general characteristics of the record and may warrant further investigation. An identified outlier is not necessarily an incorrect value and should be considered in the context of the flow record.
Rating/capacity exceedance check	Checks for flow values that may be affected by the capacity of the measuring structure. This can assist in identifying potentially capped or flat-topped high-flow records.

Option	Description
Measuring structure capacity	Specifies the estimated maximum capacity of the measuring structure in m^3/s. The value is optional and is used with the rating/capacity exceedance check to identify records that may be capped or flat-topped at the structure capacity.
Results viewer	Displays the results of the selected data-quality assessments after the Flow Analysis has been run.

The data-quality assessment should preferably be undertaken before interpreting the statistical, flow-duration, flood-frequency or other analyses derived from the flow record. Identified data-quality concerns do not necessarily mean that the record is unsuitable for analysis; rather, they provide information that should be considered when evaluating and interpreting the subsequent results.

10.5 Statistics

The ***Statistics*** tab provides a summary of the principal statistical characteristics of the selected flow record over the defined analysis period. The analysis provides a quantitative overview of the magnitude, variability and distribution of flows and calculates selected runoff-volume and trend statistics.

The available statistical analyses are shown in **Figure 10-3**. Individual analyses can be enabled or disabled using the corresponding selection boxes.

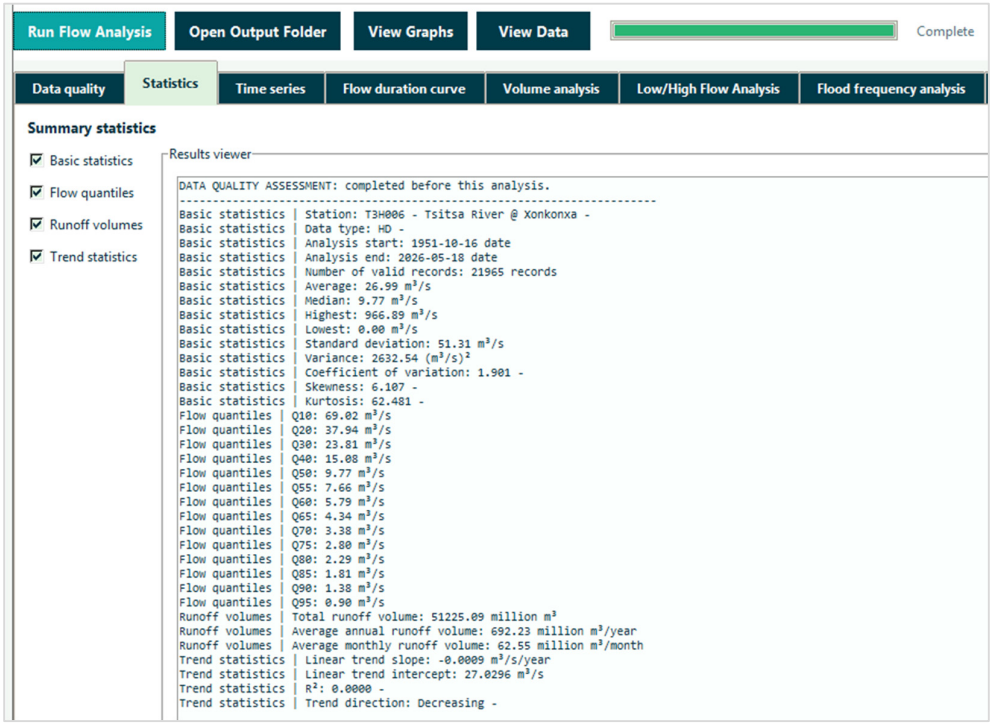


Figure 10-4: Flow Analysis - Statistics

Four groups of statistical analyses are available:

- Basic statistics
- Flow quantiles
- Runoff volumes
- Trend statistics

The required analyses are selected before running the Flow Analysis. Results are displayed in the *Results viewer* and are also available for use in subsequent graphical outputs and reporting. The available options are described in **Table 10-3**.

Table 10-3: Statistical analysis options

Option	Description
Basic statistics	Calculates the principal descriptive statistics for the valid flow records within the selected analysis period. These include the number of valid records, average, median, highest and lowest flow, standard deviation, variance, coefficient of variation, skewness and kurtosis.
Flow quantiles	Calculates selected flow quantiles expressed as exceedance flows. The results include flows from Q10 to Q95, where the Q-value represents the percentage of time that the corresponding flow is equalled or exceeded.
Runoff volumes	Converts the analysed flow record into volumetric runoff statistics, including the total runoff volume, average annual runoff volume and average monthly runoff volume.
Trend statistics	Evaluates the long-term linear trend in the flow record. The results include the linear trend slope, intercept, R^2 value and an indication of whether the calculated trend is increasing or decreasing.
Results viewer	Displays the calculated statistical results for the selected flow record and analysis period.

The statistical results provide useful context for the subsequent analyses. For example, the flow quantiles provide characteristic exceedance flows that can be compared with the Flow Duration Curve, while the runoff-volume statistics provide an indication of the overall water resource represented by the flow record.

Trend statistics should be interpreted with appropriate consideration of the length and completeness of the record. A calculated increasing or decreasing linear trend describes the fitted trend over the selected analysis period and does not, on its own, establish the cause or statistical significance of changes in the flow regime.

10.6 Time Series

The ***Time series*** tab provides tools for examining how flow varies with time and for evaluating temporal patterns within the selected flow record. The analysis converts the underlying flow data into a series of hydrographs and temporal summaries that can be used to investigate short-term variability, long-term changes and seasonal flow behaviour.

The available Time Series options are shown in **Figure 10-5**.

Five time-series analyses are available:

- Daily hydrograph
- Monthly hydrograph
- Annual hydrograph
- Moving averages
- Periodicity analysis

The required outputs are selected before running the Flow Analysis. Where Moving averages is selected, the *Moving average window (days)* specifies the period over which the moving-average flow is calculated.

After completion of the analysis, the *Results viewer* provides a summary of the principal results. The associated hydrographs can be accessed using *View Graphs*.

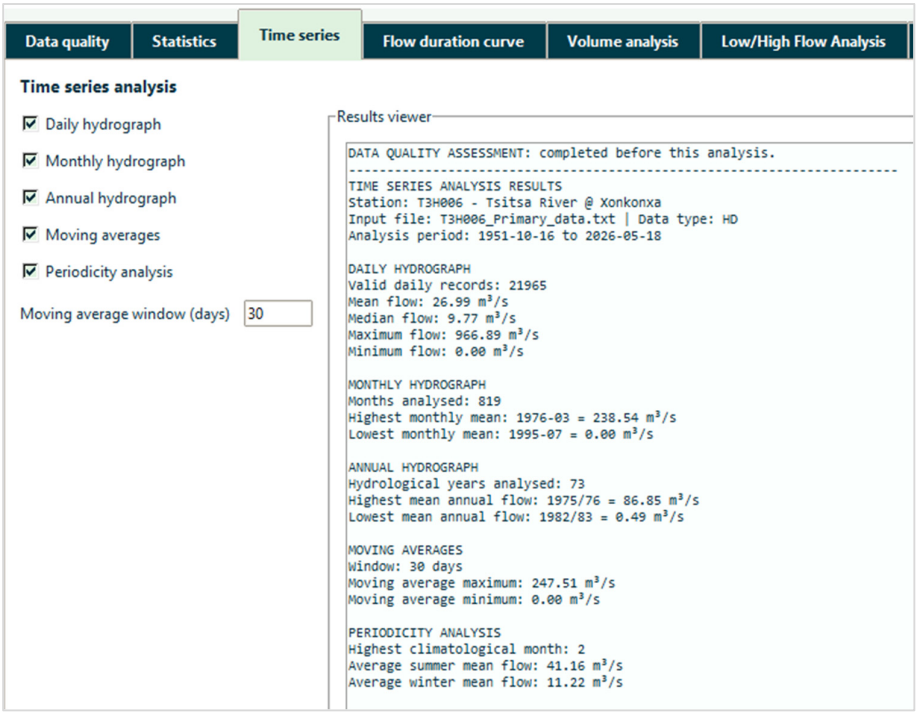


Figure 10-5: Flow Analysis - Time series analysis

The available options are described in **Table 10-4**.

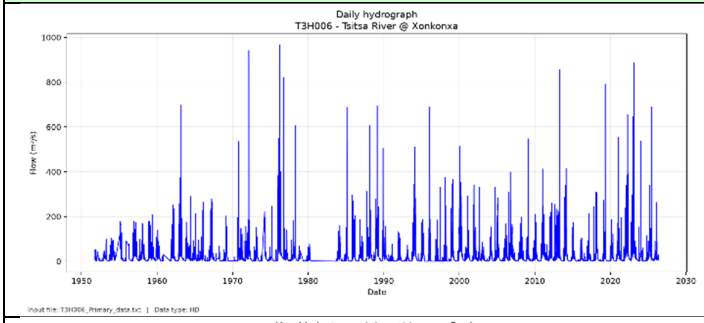
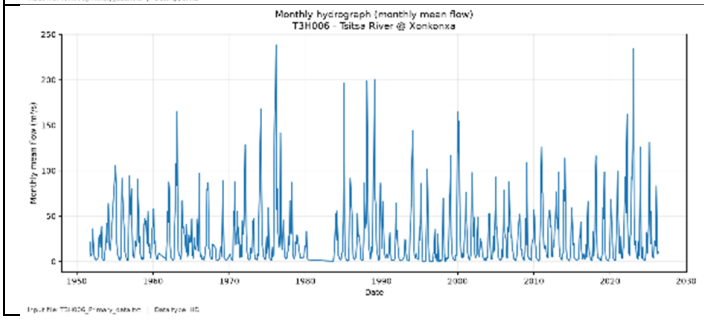
Table 10-4: Time-series analysis options

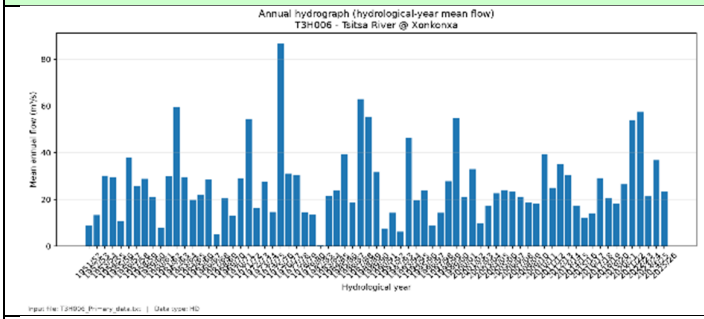
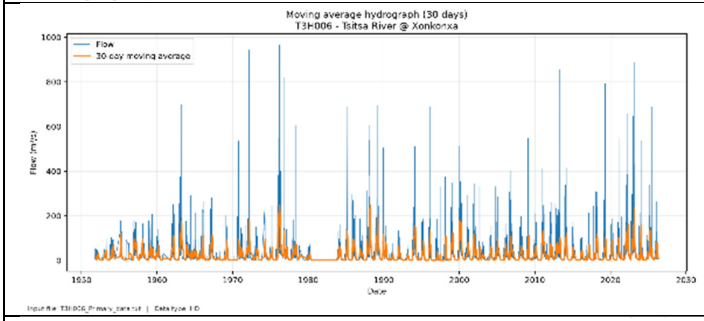
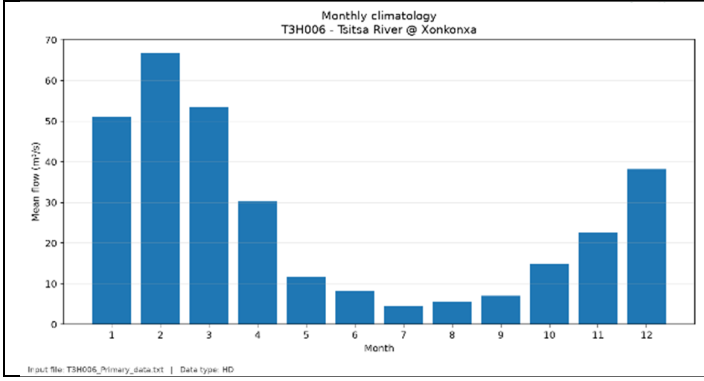
Option	Description
Daily hydrograph	Plots the available daily flow values over the selected analysis period. The graph provides the highest temporal resolution of the flow record and is useful for identifying individual high-flow events, low-flow periods, gaps and longer-term changes in flow behaviour.

Option	Description
Monthly hydrograph	Aggregates the flow record to monthly mean flows and plots their variation through time. This reduces short-term daily variability and provides a clearer indication of medium- and long-term changes in the flow regime.
Annual hydrograph	Calculates and plots mean annual flows for each hydrological year represented within the selected analysis period. The graph provides an overview of inter-annual variability and highlights relatively wet and dry hydrological years.
Moving averages	Calculates a moving average through the daily flow record using the user-defined averaging window. The moving-average series is plotted together with the underlying flow record to smooth short-term variability and make broader flow patterns easier to identify.
Moving average window (days)	Defines the number of consecutive days used to calculate the moving average. For example, a value of 30 days generates a 30-day moving-average hydrograph.
Periodicity analysis	Evaluates the recurring seasonal characteristics of the flow record. Monthly climatological mean flows are calculated to illustrate the typical distribution of flow through the year and to identify the months associated with higher and lower flows.
Results viewer	Summarises the principal results of the selected time-series analyses, including record statistics and selected temporal characteristics.

The Time Series analysis produces a range of graphical outputs that provide different views of the same underlying flow record. Examples of these outputs are presented in **Table 10-5**.

Table 10-5: Time-series graphical outputs

Graphical output	Description
	**Daily hydrograph** Displays the daily flow record over the selected analysis period. This provides a detailed representation of flow variability and individual high- and low-flow periods.
	**Monthly hydrograph** Displays the monthly mean flow through time, reducing short-term variability and providing a clearer representation of longer-term flow behaviour.

Graphical output	Description
	**Annual hydrograph** Displays the mean flow for each hydrological year, allowing year-to-year variability and relatively wet or dry years to be readily identified.
	**Moving-average hydrograph** Displays the original flow series together with the calculated moving average. The averaging window is defined by the user and provides a smoothed representation of the flow record.
	**Monthly climatology** Displays the long-term mean flow for each calendar month. This illustrates the typical seasonal flow regime and identifies the months during which higher and lower flows generally occur.

10.7 Flow Duration Curve

The ***Flow duration curve*** tab provides tools for analysing the relationship between flow magnitude and the percentage of time that a particular flow is equalled or exceeded. A Flow Duration Curve (FDC) provides a compact representation of the overall flow regime and is useful for evaluating flow availability, variability and the persistence of different flow conditions.

The available Flow Duration Curve analyses are shown in **Figure 10-6**.

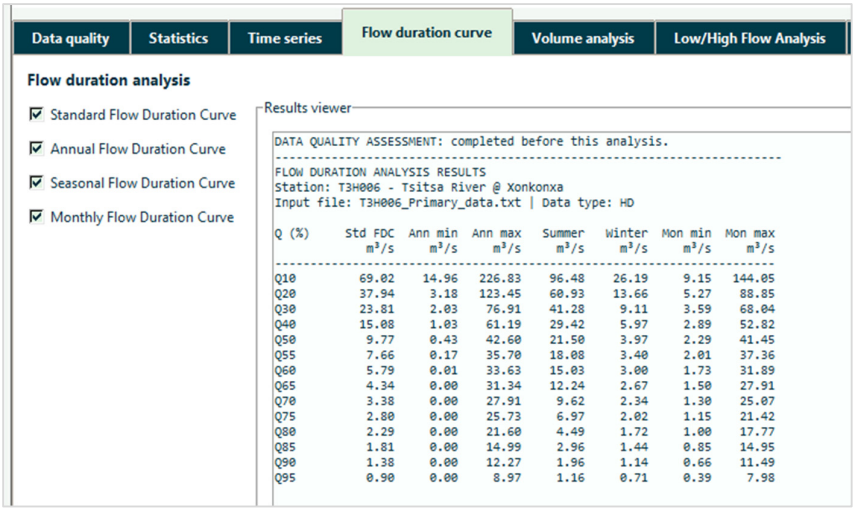


Figure 10-6: Flow Analysis - Flow duration curve

Four Flow Duration Curve analyses are available:

- Standard Flow Duration Curve
- Annual Flow Duration Curve
- Seasonal Flow Duration Curve
- Monthly Flow Duration Curve

The required analyses are selected before running the Flow Analysis. The resulting characteristic flows are displayed in the *Results viewer*, while the associated curves can be accessed using *View Graphs*.

Flow Duration Curves are presented with exceedance probability (%) on the horizontal axis and flow (m^3/s) on the vertical axis. Exceedance probability represents the percentage of time that a specified flow is equalled or exceeded. For example, Q10 represents a relatively high flow that is equalled or exceeded 10% of the time, whereas Q90 represents a lower flow that is equalled or exceeded 90% of the time.

The available analyses are described in **Table 10-6**.

Table 10-6: Flow Duration Curve analysis options

Option	Description
Standard Flow Duration Curve	Generates a single Flow Duration Curve using all valid flow values within the selected analysis period. The curve provides an overall representation of the frequency and persistence of flows within the complete record.
Annual Flow Duration Curve	Generates separate Flow Duration Curves for the individual years represented within the selected record. This allows the variability in flow-duration characteristics between years to be assessed and provides an indication of relatively wet and dry years.
Seasonal Flow Duration Curve	Separates the flow record into seasonal periods and generates an FDC for each season. This allows differences in flow availability between the principal seasonal periods to be evaluated.

Option	Description
Monthly Flow Duration Curve	Generates separate Flow Duration Curves for each calendar month using the corresponding flows from the complete analysis period. This provides a detailed representation of how flow availability and exceedance characteristics vary throughout the year.
Results viewer	Displays characteristic exceedance flows calculated from the selected FDC analyses. The results allow the different standard, annual, seasonal and monthly flow characteristics to be compared numerically.

For the Seasonal Flow Duration Curve, the graphical output shown in the current implementation separates the record into Summer (October–March) and Winter (April–September). This seasonal definition should therefore be stated explicitly in the manual.

The Results viewer summarises selected exceedance flows, including Q10, Q20, Q30, Q40, Q50, Q55, Q60, Q65, Q70, Q75, Q80, Q85, Q90 and Q95. Depending on the selected analyses, these values are reported for the standard FDC and comparative annual, seasonal and monthly conditions.

10.7.1 Interpretation of Flow Duration Curves

The position and shape of an FDC provide information on the characteristics of the flow regime. The left-hand portion of the curve represents relatively high flows with low exceedance probabilities, while the right-hand portion represents lower, more frequently available flows.

A relatively flat curve indicates that flows remain comparatively consistent over a broad range of exceedance probabilities, whereas a steep curve indicates greater variability between high- and low-flow conditions.

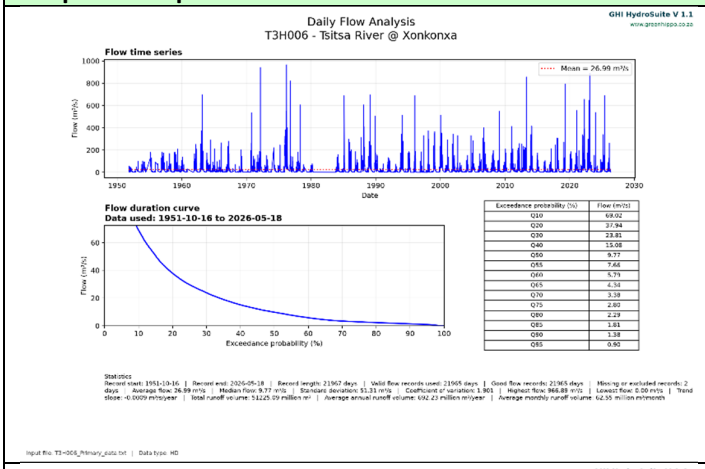
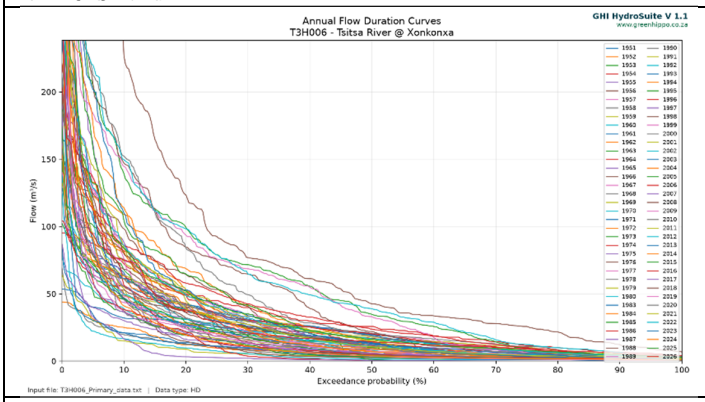
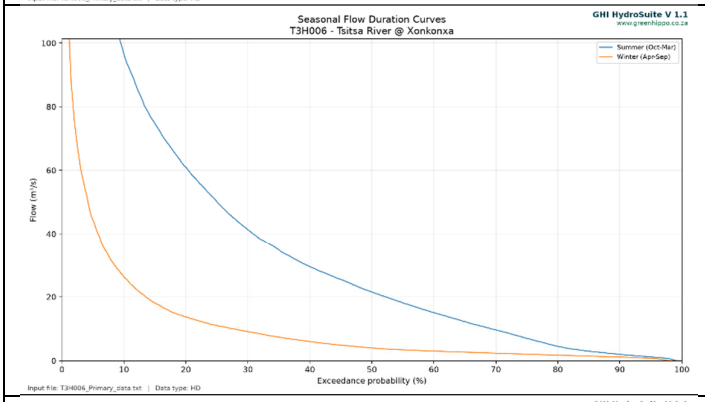
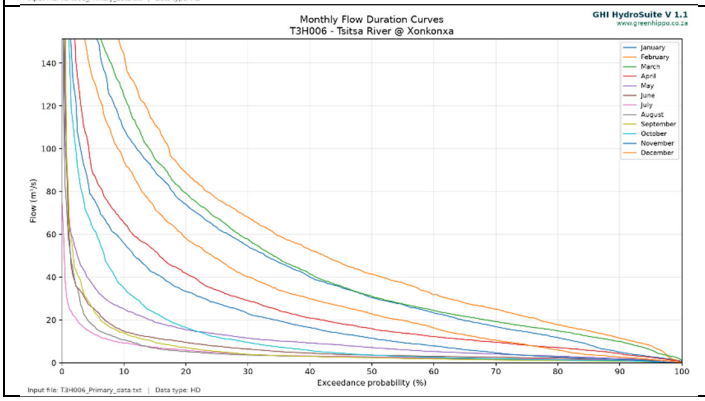
The comparative annual, seasonal and monthly curves extend this interpretation by showing how the flow-duration characteristics vary with time. For example, the seasonal curves can identify substantial differences between summer and winter flow availability, while the monthly curves provide a more detailed indication of the months during which particular flow rates are most likely to be available.

Flow Duration Curves are particularly useful when evaluating the reliability or availability of a particular flow rate. They can therefore provide important input to subsequent water-resource, abstraction, environmental-flow and hydropower assessments.

10.7.2 Flow Duration Curve graphical outputs

The Flow Duration Curve analysis generates a number of graphical outputs depending on the options selected. Examples are presented in **Table 10-7**.

Table 10-7: Flow Duration Curve graphical outputs

Graphical output	Description
	**Standard Flow Duration Curve** Displays the relationship between flow and exceedance probability for all valid flow values within the selected analysis period. Characteristic flows such as Q10, Q50 and Q90 can be used to describe high, median-duration and more persistent flow conditions.
	**Annual Flow Duration Curves** Displays separate Flow Duration Curves for the individual years within the analysed record. The spread between the curves illustrates inter-annual variability and allows years with distinctly different flow-duration characteristics to be identified.
	**Seasonal Flow Duration Curves** Compares the FDCs for Summer (October–March) and Winter (April–September). The graph illustrates seasonal differences in both the magnitude and persistence of available flows.
	**Monthly Flow Duration Curves** Displays separate FDCs for each of the twelve calendar months. The graph provides the most detailed representation of recurring within-year changes in flow availability and allows the flow-duration characteristics of individual months to be compared.

10.8 Volume Analysis

The ***Volume analysis*** tab provides tools for assessing the volume of water passing the gauging station over specified durations. Whereas the Flow Duration Curve considers the magnitude and exceedance of flow rates, the Volume Analysis integrates flow over a selected duration and expresses the result as a water volume.

The available Volume Analysis options are shown in **Figure 10-7**.

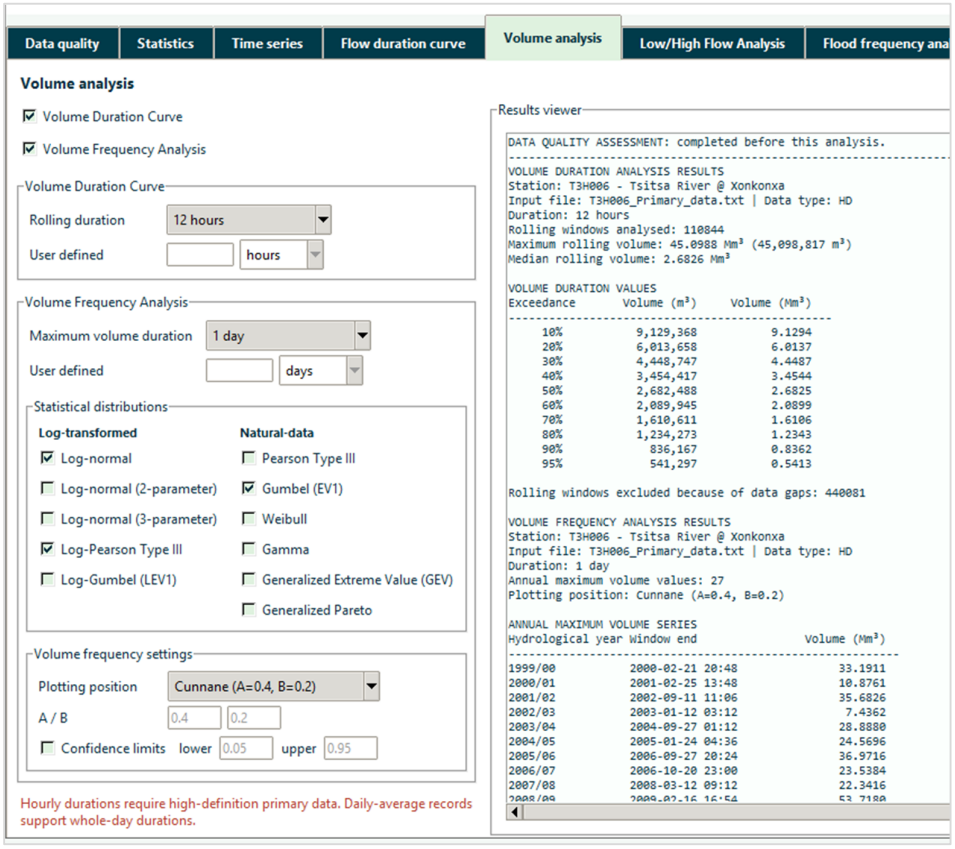


Figure 10-7: Flow Analysis - Volume analysis

Two forms of volume analysis are available:

- Volume Duration Curve
- Volume Frequency Analysis

The *Volume Duration Curve* evaluates the distribution and exceedance characteristics of rolling water volumes calculated over a selected duration. The *Volume Frequency Analysis* identifies the maximum volume occurring within each hydrological year for a selected duration and applies statistical frequency distributions to estimate volumes associated with different return periods.

The required analyses are selected using the corresponding selection boxes. The duration and, where applicable, the statistical distribution and plotting-position parameters are then specified before running the Flow Analysis. The principal options are described in **Table 10-8**.

Table 10-8: Volume Analysis options

Option	Description
Volume Duration Curve	Generates a duration curve of rolling water volumes calculated over the selected duration. The resulting curve relates accumulated volume to percentage exceedance.
Rolling duration	Specifies the time period over which successive flow volumes are accumulated. The user selects one of the available predefined durations.
User defined	Allows a custom rolling duration to be specified together with the applicable time unit.
Volume Frequency Analysis	Performs a frequency analysis on the maximum rolling volume occurring within each hydrological year for the selected duration.
Maximum volume duration	Specifies the duration over which the maximum water volume is determined for each hydrological year.
User defined	Allows a custom duration to be specified for the Volume Frequency Analysis.
Statistical distributions	Allows one or more probability distributions to be selected and fitted to the annual maximum-volume series.
Plotting position	Specifies the plotting-position method used to assign empirical return periods to the observed annual maximum volumes. Options available are: Weibull, Median Hazen, Cunnane, Hirsch/Stedinger or Other
A / B	Displays the coefficients associated with the selected plotting-position method. In case Plotting position was selected as Other the A/B parameters can be specified.
Confidence limits	Where selected, enables lower and upper confidence limits to be specified for the frequency analysis.
Results viewer	Displays the calculated Volume Duration and Volume Frequency results, including characteristic volumes, annual maximum-volume values and information associated with the selected analyses.

10.8.1 Volume Duration Curve

The Volume Duration Curve (VDC) is generated by moving a time window of the selected duration through the flow record and calculating the total water volume occurring within each valid window.

The calculated volumes are ranked and expressed in terms of percentage exceedance, in a similar manner to a conventional Flow Duration Curve. The resulting curve therefore indicates the volume that is equalled or exceeded for a specified percentage of the analysed rolling periods. For example, a 12-hour rolling duration calculates the volume passing the gauging station during successive 12-hour windows. Longer durations can be selected where the user is interested in sustained water availability over periods of several days rather than short-duration flow conditions.

The *Results viewer* reports the number of valid rolling windows analysed, the maximum and median rolling volumes, and characteristic volumes at selected exceedance percentages. Rolling windows that cannot be evaluated because of gaps in the underlying flow record are excluded from the analysis and reported separately.

The availability of short-duration analyses depends on the temporal resolution of the underlying data. Hourly durations require high-definition primary data, while daily-average flow records support whole-day durations.

10.8.2 Volume Frequency Analysis

The *Volume Frequency Analysis* evaluates the frequency of large accumulated water volumes occurring over a specified duration.

For each hydrological year, GHI HydroSuite identifies the maximum rolling volume occurring over the selected duration. These annual maximum volumes form the series used for the frequency analysis.

One or more statistical probability distributions can then be fitted to the annual maximum-volume series. The distributions available on the Volume Analysis screen include:

Log-normal, Log-normal (2-parameter), Log-normal (3-parameter), Log-Pearson Type III, Log-Gumbel (EV1), Pearson Type III, Gumbel (EV1), Weibull, Gamma, Generalized Extreme Value (GEV) and Generalized Pareto.

The user can select the required distribution or distributions to allow alternative statistical models to be compared.

A plotting-position method is also selected for the observed annual maximum-volume data. The associated A and B coefficients are displayed for the selected method. In the example shown in **Figure 10-7**, the Cunnane (A=0.4, B=0.2) plotting position is selected.

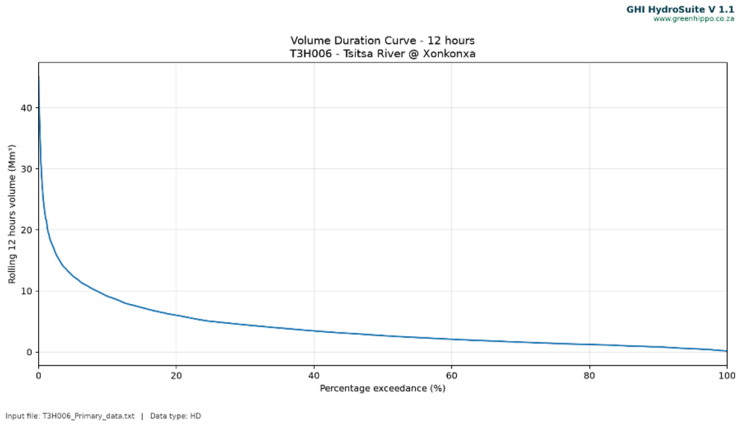
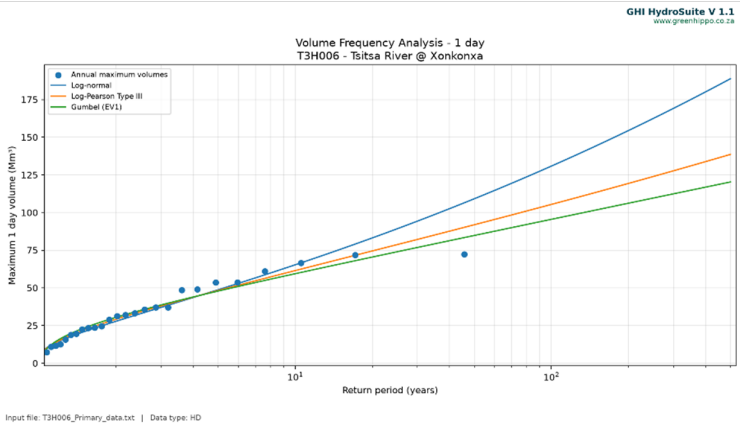
The *Results viewer* lists the annual maximum-volume series together with the corresponding hydrological year and the end of the rolling window associated with each maximum. The fitted probability distributions can then be compared graphically against the observed annual maximum volumes.

The Volume Frequency Analysis therefore provides an estimate of the magnitude of accumulated water volumes associated with selected return periods, rather than estimating instantaneous peak discharge.

10.8.3 Volume Analysis graphical outputs

The Volume Analysis generates graphical outputs for both duration and frequency analyses. Examples are presented in **Table 10-9**.

Table 10-9: Volume Analysis graphical outputs

Graphical output	Description
	**Volume Duration Curve** Displays rolling water volume against percentage exceedance for the selected duration. It indicates the accumulated volume that is equaled or exceeded for a specified percentage of the valid rolling periods. The selected rolling duration is identified in the graph title and the volume is reported in Mm^3**.**
	**Volume Frequency Analysis** Displays the observed annual maximum volumes together with the selected fitted probability distributions against return period (years)**.** The graph allows the fitted distributions to be compared with the observed annual maximum-volume series and with one another.

10.9 Low/High Flow Analysis

The ***Low/High Flow Analysis*** tab provides tools for evaluating both low-flow and high-flow characteristics of the selected flow record. The analyses can be used to assess minimum-flow conditions, drought characteristics, zero-flow occurrence, baseflow behaviour, annual and seasonal peak flows, threshold exceedances and high-flow volumes.

The available analyses and user-defined thresholds are shown in **Figure 10-8**.

The required analyses are selected using the corresponding selection boxes before running the Flow Analysis. Where applicable, the user can specify *a Low-flow threshold* and *High-flow threshold*. If these fields are left blank, the default values indicated on the screen are used.

The tab includes analyses based on the daily flow record as well as analyses that make use of the available high-definition primary flow data. High-resolution data are required for analyses that depend on the timing and magnitude of individual high-flow events.

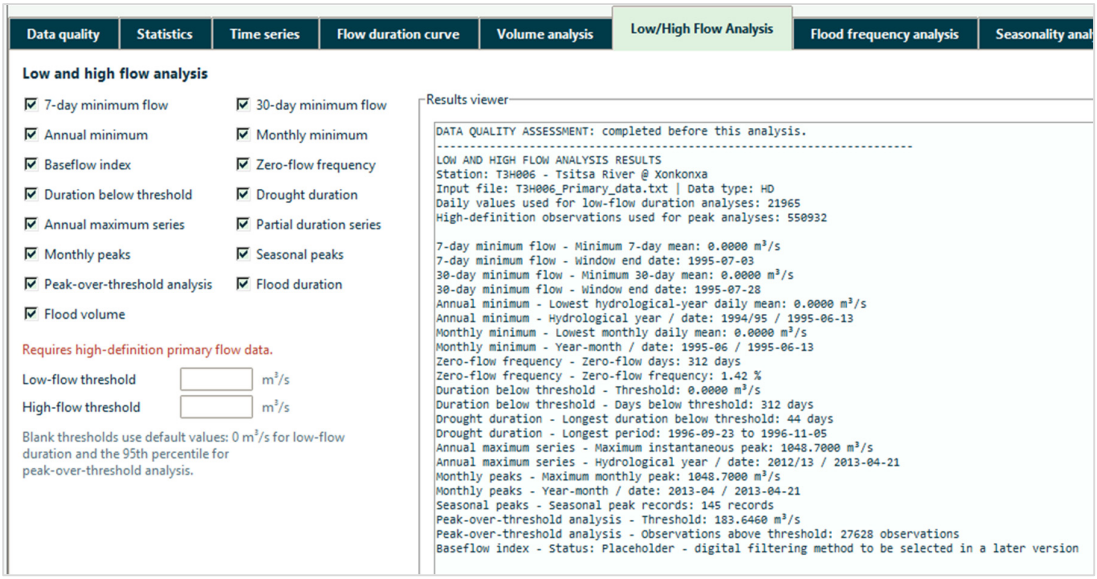


Figure 10-8: Flow Analysis - Low/High Flow Analysis

The available analyses are described in **Table 10-10**.

Table 10-10: Low/High Flow Analysis options

Option	Description
7-day minimum flow	Determines the minimum 7-day mean flow within the selected record and identifies the end date of the corresponding 7-day period.
30-day minimum flow	Determines the minimum 30-day mean flow and identifies the corresponding period within the flow record.
Annual minimum	Determines the minimum daily mean flow for each hydrological year and identifies the lowest annual minimum within the analysed record.
Monthly minimum	Determines minimum-flow conditions on a monthly basis and identifies the lowest monthly daily mean flow and its corresponding year and month.
Baseflow index	Provides an assessment of the contribution of baseflow to the overall flow record. The current implementation identifies the analysis status, with the digital-filtering method to be selected in a later version.
Zero-flow frequency	Determines the number of zero-flow observations and expresses their occurrence as a percentage of the valid flow record.
Duration below threshold	Determines the number of days for which flow is below the specified Low-flow threshold.
Drought duration	Identifies continuous periods during which flows remain below the applicable low-flow threshold and determines the longest drought period.
Annual maximum series	Extracts the maximum instantaneous peak flow associated with each hydrological year to form an annual maximum series.
Partial duration series	Extracts qualifying high-flow events for use in a partial-duration or peaks-over-threshold series.
Monthly peaks	Identifies maximum instantaneous peak flows on a monthly basis and reports the maximum monthly peak and its date.

Option	Description
Seasonal peaks	Extracts and evaluates peak-flow events according to the applicable seasonal grouping.
Peak-over-threshold analysis	Identifies high-flow observations exceeding the specified High-flow threshold.
Flood duration	Evaluates the duration of high-flow or flood events associated with the applicable high-flow threshold.
Flood volume	Evaluates the volume of water associated with qualifying high-flow or flood events.
Low-flow threshold	Specifies the flow threshold in m^3/s used for the applicable low-flow duration and drought analyses. If left blank, the default value indicated by the software is applied.
High-flow threshold	Specifies the flow threshold in m^3/s used for the applicable peak-over-threshold analysis. If left blank, the software applies the default threshold indicated on the screen.
Results viewer	Displays the calculated low- and high-flow results for the selected flow record and analysis period.

10.9.1 Low-flow analysis

The low-flow analyses provide information on the magnitude, frequency and persistence of reduced-flow conditions within the selected analysis period.

The *7-day and 30-day minimum-flow* analyses use moving periods to identify sustained low-flow conditions rather than relying only on an individual minimum daily value. These measures are useful for distinguishing prolonged low-flow conditions from isolated low daily observations.

The *Annual minimum* and *Monthly minimum* analyses provide additional information on the temporal occurrence of minimum flows. Annual minima allow low-flow conditions between hydrological years to be compared, while monthly minima provide a finer temporal indication of when the lowest flows occur.

The *Zero-flow frequency* analysis identifies the number and percentage of valid observations for which zero flow is recorded. This can be particularly useful for intermittent or highly seasonal rivers.

The *Duration below threshold* and *Drought duration* analyses make use of the specified *Low-flow threshold*. Duration below threshold reports the total number of days below the threshold, while drought duration considers the persistence of continuous below-threshold conditions and identifies the longest such period.

The *Baseflow index* is included as an analysis option; however, as indicated in the current *Results viewer*, the digital-filtering method is to be selected in a later version.

10.9.2 High-flow analysis

The high-flow analyses provide tools for identifying and characterising individual peak-flow events and periods of sustained high flow.

The *Annual maximum series* extracts the maximum instantaneous peak associated with each hydrological year. This provides the annual peak series commonly required for subsequent flood-frequency assessment.

The *Partial duration series* provides an alternative representation of high-flow events by allowing multiple qualifying events to be extracted rather than restricting the series to a single maximum for each hydrological year.

The *Monthly peaks* and *Seasonal peaks* analyses provide information on the timing and seasonal distribution of high-flow events. These analyses can assist in identifying periods of the year during which large flows occur most frequently.

The *Peak-over-threshold analysis* identifies observations exceeding the specified *High-flow threshold*. This allows the occurrence of high-flow conditions to be assessed relative to a user-defined flow magnitude.

The *Flood duration* and *Flood volume* analyses extend the assessment beyond peak magnitude by considering the persistence and accumulated volume associated with qualifying high-flow events.

Where instantaneous peak characteristics or high-resolution event behaviour are required, high-definition primary flow data are necessary. The software indicates this requirement directly on the Low/High Flow Analysis screen.

10.9.3 Interpretation of low- and high-flow results

The *Results viewer* provides a consolidated summary of the selected analyses, see **Figure 10-8**. Depending on the options selected, this includes minimum-flow magnitudes and dates, annual and monthly minima, zero-flow frequency, days below the low-flow threshold, longest drought duration, annual and monthly peak flows, seasonal peak information and the number of observations exceeding the high-flow threshold.

The low- and high-flow analyses should be interpreted in conjunction with the Data Quality assessment, particularly where missing records, zero values or limitations in the available high-flow measurements may influence the results.

10.10 Flood Frequency Analysis

The ***Flood frequency analysis*** tab provides tools for statistically analysing observed flood peaks and estimating flood magnitudes associated with specified return periods. The analysis uses flood peaks extracted from the selected flow record and fits one or more probability distributions to the resulting flood series.

The available probability distributions and frequency-analysis settings are shown in **Figure 10-9**.

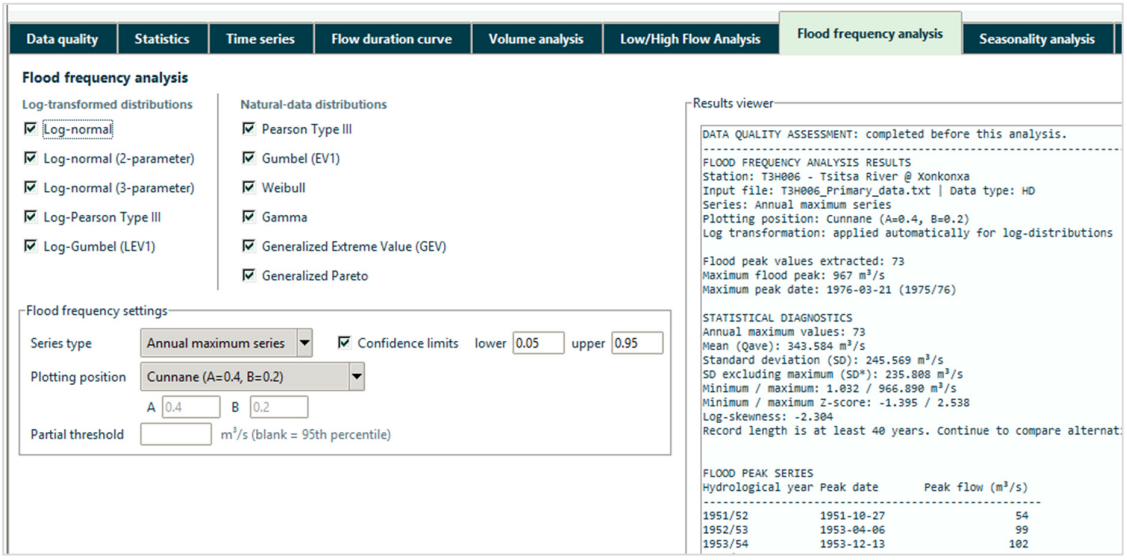


Figure 10-9: Flow Analysis - Flood frequency analysis

The analysis allows the user to select the flood series to be analysed, the plotting-position method applied to the observed flood peaks, the statistical probability distributions to be fitted and, where required, confidence limits.

Multiple probability distributions can be selected simultaneously. This allows the fitted distributions to be compared and assists the user in evaluating the sensitivity of estimated flood magnitudes to the selected statistical model. The available inputs and settings are described in **Table 10-11**.

Table 10-11: Flood Frequency Analysis options

Option	Description
Log-normal	Fits a Log-normal probability distribution to the flood series. The logarithmic transformation is applied automatically.
Log-normal (2-parameter)	Fits the two-parameter form of the Log-normal distribution to the selected flood series.
Log-normal (3-parameter)	Fits the three-parameter form of the Log-normal distribution.
Log-Pearson Type III	Fits a Pearson Type III distribution to logarithmically transformed flood values.
Log-Gumbel (EV1)	Fits the Gumbel Extreme Value Type I distribution using logarithmically transformed flood values.

Option	Description
Pearson Type III	Fits the Pearson Type III distribution directly to the natural flood data.
Gumbel (EV1)	Fits the Gumbel Extreme Value Type I distribution to the natural flood data.
Weibull	Fits a Weibull probability distribution to the selected flood series.
Gamma	Fits a Gamma probability distribution to the selected flood series.
Generalized Extreme Value (GEV)	Fits a Generalized Extreme Value distribution to the flood series.
Generalized Pareto	Fits a Generalized Pareto distribution to the selected flood series.
Series type	Specifies the flood series to be used in the frequency analysis. The selected series determines how flood peaks are extracted from the underlying record. Annual maximum series or Partial series can be selected from the drop-down list.
Plotting position	Specifies the empirical plotting-position formula used to assign exceedance probabilities or return periods to the observed flood peaks. Options available are: Weibull, Median Hazen, Cunnane, Hirsch/Stedinger or Other
A / B	Displays the coefficients associated with the selected plotting-position method. In case Plotting position was selected as Other the A/B parameters can be specified.
Partial threshold	Specifies the flow threshold used when a partial-duration series is selected. If left blank, the default threshold indicated by the software is used.
Confidence limits	Enables confidence limits for the fitted frequency distributions.
Lower / Upper	Specifies the lower and upper probability limits used when confidence limits are selected.
Results viewer	Displays information on the extracted flood series, statistical diagnostics, flood-peak values and results of the selected frequency analyses.

10.10.1 Flood series selection

The Series type determines which flood events are included in the frequency analysis.

For an *Annual maximum series*, the maximum flood peak occurring within each hydrological year is extracted. The resulting series therefore contains a maximum of one flood peak for each hydrological year represented by the analysed record.

The *Results viewer* identifies the hydrological year, date and corresponding peak flow for the extracted annual maximum series. It also reports the number of flood peaks extracted and the maximum observed flood peak and its date.

Where a *Partial duration series* is selected, qualifying flood events are identified relative to a specified Partial threshold. This approach allows more than one qualifying flood event to be included from a particular year. If the Partial threshold field is left blank, the software applies the default threshold indicated on the screen.

10.10.2 Plotting positions

Observed flood peaks are assigned empirical probabilities using the selected Plotting position method. The plotting position determines where the observed flood peaks are displayed relative to return period on the frequency graph.

The corresponding A and B coefficients are displayed automatically for the selected plotting-position method. In the example shown in **Figure 10-9**, the Cunnane plotting position (A = 0.4, B = 0.2) is selected.

The plotting positions represent the observed flood data and provide a basis for visually comparing the observed series with the fitted statistical distributions.

10.10.3 Statistical probability distributions

GHI HydroSuite allows several statistical probability distributions to be fitted to the selected flood series. The distributions are divided on the screen into Log-transformed distributions and Natural-data distributions.

For log-transformed distributions, the required logarithmic transformation is performed automatically by GHI HydroSuite. Natural-data distributions are fitted directly to the extracted flood values.

More than one distribution can be selected for a single analysis. The fitted curves and estimated flood magnitudes can therefore be compared to assess differences between the alternative statistical models.

The selection of an appropriate probability distribution should not be based solely on the estimated flood associated with a particular return period. The fitted distribution should also be considered in relation to the observed flood series, record length and the statistical characteristics of the data.

10.10.4 Statistical diagnostics

Before presenting the fitted frequency results, GHI HydroSuite calculates statistical characteristics of the extracted flood series. As shown in the Results viewer in **Figure 10-9**, these may include the:

- mean flood peak;
- standard deviation;
- standard deviation excluding the maximum flood;
- minimum and maximum values;
- minimum and maximum Z-scores;

- log-skewness; and
- length of the available flood record.

These diagnostics provide additional information on the characteristics of the flood series and can assist the user when comparing alternative frequency distributions.

The *Results viewer* may also provide diagnostic comments relating to the available record and the suitability of comparing alternative frequency distributions. These should be considered together with the graphical and numerical frequency-analysis results.

10.10.5 Confidence limits

Where Confidence limits are selected, lower and upper probability limits can be specified for the frequency analysis. These provide an indication of the uncertainty associated with the fitted frequency relationship. The required lower and upper limits are entered in the corresponding fields. In the example shown in **Figure 10-9**, values of 0.05 and 0.95 are specified.

The uncertainty associated with estimated floods generally becomes increasingly important when extrapolating to return periods substantially longer than the available observed record. Design-flood estimates at long return periods should therefore be interpreted with appropriate consideration of the available record length, observed flood behaviour and differences between fitted distributions.

10.10.6 Flood Frequency Analysis results

The *Results viewer* provides a summary of the flood-frequency analysis, including the selected flood series, plotting-position method, statistical characteristics of the extracted flood peaks and the flood-frequency results obtained from the selected probability distributions.

For the selected flood series, the viewer presents the extracted flood peaks together with their hydrological years and dates. *Statistical diagnostics* and the results associated with the selected probability distributions are also provided.

The graphical frequency-analysis outputs allow the observed flood peaks and fitted probability distributions to be compared over a range of return periods, as depicted in **Figure 10-10**. Where several distributions are selected, the divergence between the fitted curves provides a useful indication of the sensitivity of the estimated design floods to the selected statistical model.

The observed flood peaks are plotted according to the selected plotting-position method, with return period (years) shown on the lower horizontal axis and the corresponding exceedance probability (%) on the upper horizontal axis. Flood-peak magnitude is shown in m^3/s on the vertical axis.

Each selected probability distribution is fitted independently to the flood series and displayed on the same graph. This allows the user to visually compare how the alternative distributions represent the observed flood data and how their estimates diverge when extrapolated for longer return periods.

Particular attention should be given to the upper end of the frequency curves. Differences between fitted distributions generally become more pronounced at return periods extending beyond the observed record, illustrating the uncertainty associated with extrapolating extreme flood magnitudes. The fitted curves should therefore be considered together with the observed flood series, statistical diagnostics and available record length rather than selecting a distribution solely on the basis of a particular design-flood estimate.

The graph also identifies the input data type, selected series and plotting-position method, providing a record of the principal settings used to generate the analysis.

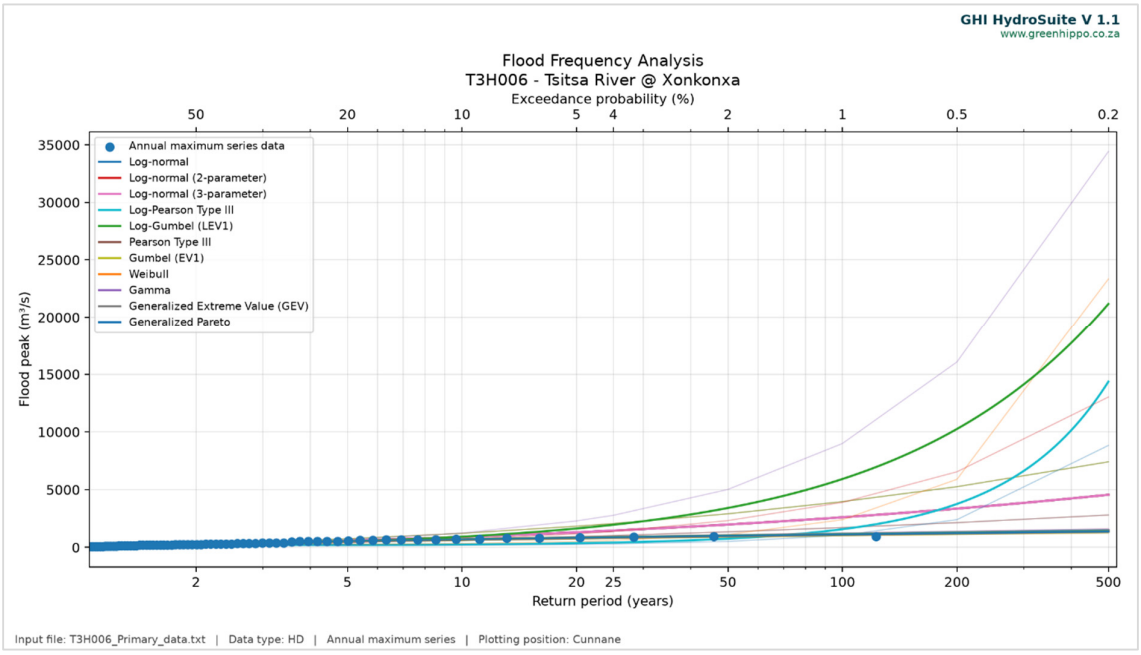


Figure 10-10: Flood Frequency Analysis – comparison of observed flood peaks and fitted probability distributions

Note: Additional flood-frequency analysis and output options are available in the Flood Estimation module described in **Chapter 12**. These include additional methods such as IPZA analysis, together with further graphical and frequency-analysis options, including control over the exceedance-probability scale used for displaying frequency results.

10.11 Seasonality Analysis

The ***Seasonality analysis*** tab provides tools for examining how river flow characteristics vary throughout the year. The analysis assists in identifying wet- and dry-season behaviour, monthly flow patterns and the variability of flows between months and seasons. Seasonality analysis is particularly useful where the timing of water availability is important, as average annual flow alone does not indicate how flow is distributed throughout the year. The available analyses are shown in **Figure 10-11**.

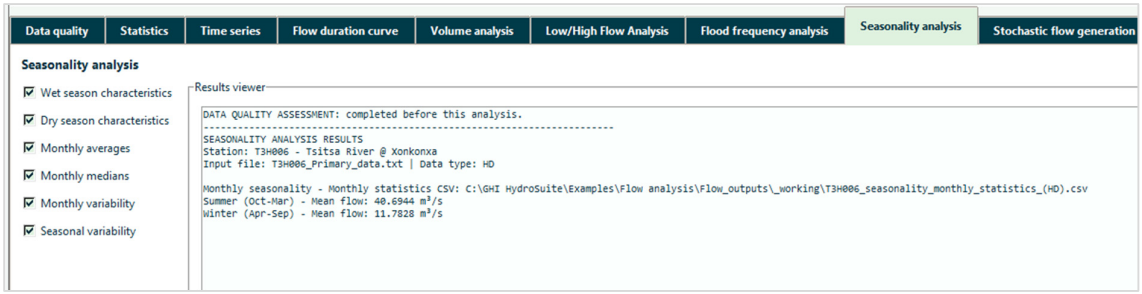


Figure 10-11: Flow Analysis - Seasonality analysis

The required analyses are selected using the corresponding selection boxes before running the Flow Analysis. The Results viewer provides a summary of the calculated seasonal characteristics and identifies the output files generated during the analysis.

The available options are described in **Table 10-12**.

Table 10-12: Seasonality Analysis options

Option	Description
Wet season characteristics	Calculates representative flow characteristics for the defined wet season.
Dry season characteristics	Calculates representative flow characteristics for the defined dry season.
Monthly averages	Calculates the mean flow for each calendar month using the available flow record.
Monthly medians	Calculates the median flow for each calendar month, providing an indication of typical monthly conditions that is less influenced by individual extreme-flow events than the monthly mean.
Monthly variability	Evaluates the variability of flows for each calendar month over the analysed record.
Seasonal variability	Evaluates differences and variability between the defined wet and dry seasons.
Results viewer	Displays a summary of the seasonality results for the selected flow record and analysis period and identifies the associated output data where applicable.

10.11.1 Wet- and dry-season characteristics

The *Wet season* characteristics and *Dry season* characteristics provide a broad comparison of flow conditions during the principal seasonal periods.

For the South African seasonal definition applied in the analysis shown in **Figure 10-11**, the periods are:

- Summer / wet season: October to March
- Winter / dry season: April to September

The *Results viewer* reports representative mean flows for the two periods. These values provide a convenient indication of the magnitude of seasonal differences within the flow record.

For example, the record shown in **Figure 10-11** has a substantially higher summer mean flow than winter mean flow, indicating a pronounced seasonal flow regime.

10.11.2 Monthly flow characteristics

The *Monthly averages* analysis groups the available flow observations according to calendar month and calculates the long-term mean flow for each month. The resulting monthly pattern provides a simple representation of the typical annual flow cycle.

The *Monthly medians* provide a complementary measure of typical monthly conditions. Because the median is less affected by occasional extreme high-flow events, comparison between monthly mean and median flows can be useful for identifying months in which relatively infrequent flood events have a strong influence on the long-term average.

The *Monthly variability* analysis provides additional information on the degree to which flows for a particular month vary between years.

Together, these analyses allow the user to distinguish between the typical magnitude of flow and the variability of that flow throughout the year.

10.11.3 Seasonal variability

The *Seasonal variability* analysis extends the monthly assessment by considering differences in flow behaviour between the wet and dry seasons.

This is useful where the hydrological behaviour of a river is strongly seasonal and can assist in identifying the extent to which water availability is concentrated within a particular part of the year. Seasonality results should be interpreted together with the Time series, Flow duration curve and other Flow Analysis outputs where a more complete assessment of temporal water availability is required.

10.11.4 Seasonality Analysis graphical output

The Seasonality Analysis generates a graphical representation of the monthly flow pattern, as illustrated in **Figure 10-12**.

The *Monthly average flow seasonality* graph displays the long-term mean flow for each calendar month. Month is shown on the horizontal axis and mean flow in m^3/s on the vertical axis. The graph provides a direct visual indication of the annual flow cycle and allows the principal high- and low-flow periods to be readily identified. In the example shown, mean flows increase strongly during the summer months, reach their highest monthly value in February and decline through autumn towards the lowest-flow period during winter. Flows subsequently increase again towards the end of the year.

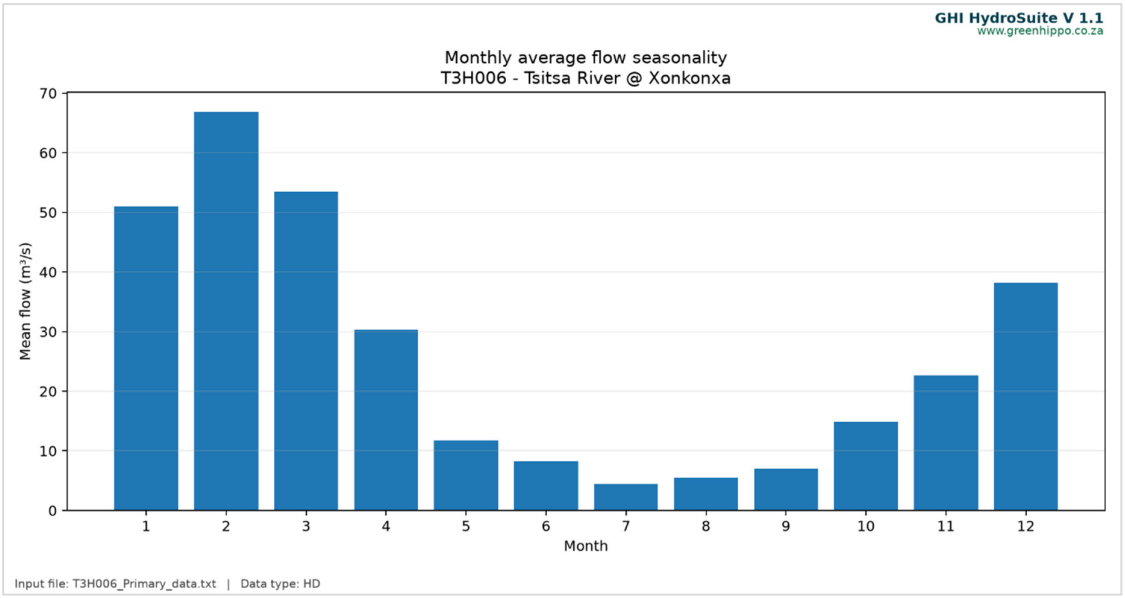


Figure 10-12: Monthly average flow seasonality

The graph is particularly useful for identifying the timing and magnitude of seasonal water availability and provides a concise visual complement to the numerical wet-season, dry-season and monthly statistics presented in the *Results viewer*.

10.12 Stochastic Flow Generation

The ***Stochastic flow generation*** tab provides tools for generating multiple synthetic flow sequences based on the statistical and temporal characteristics of the observed flow record. Synthetic sequences can be used to investigate a range of plausible flow conditions beyond the single historical sequence available at a gauging station.

This is particularly useful for analyses where the variability and sequencing of flows may influence the results, such as reservoir behaviour, water availability and hydropower assessment.

Two stochastic generation methods are currently available:

- Simple Random Resampling (Bootstrap)
- Monthly Statistics Generator

The selected method determines the additional input parameters displayed on the screen and the manner in which the synthetic sequences are generated.

10.12.1 Simple Random Resampling (Bootstrap)

The Simple Random Resampling (Bootstrap) method generates synthetic flow sequences by resampling values from the observed flow record. The method therefore uses the historical observations themselves as the basis for generating alternative sequences.

The Bootstrap generation options are shown in **Figure 10-13**.

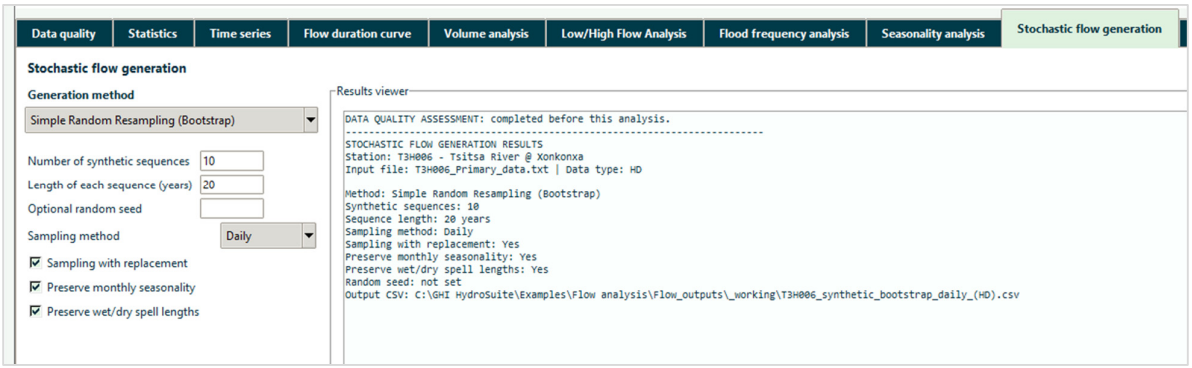


Figure 10-13: Stochastic Flow Generation – Simple Random Resampling (Bootstrap)

The available inputs are described in **Table 10-13**.

Table 10-13: Stochastic Flow Generation options

Option	Description
Generation method	Selects the stochastic flow-generation method. Select Simple Random Resampling (Bootstrap) for the Bootstrap method.
Number of synthetic sequences	Specifies the number of independent synthetic flow sequences to be generated.
Length of each sequence (years)	Specifies the required duration, in years, of each generated synthetic sequence.
Optional random seed	Allows a random seed to be specified. A defined seed can be used where repeatability of the stochastic generation process is required. If left blank, no fixed random seed is applied.
Sampling method	Specifies the temporal basis used for resampling. Options that can be selected are Daily, Monthly or Annual sampling.
Sampling with replacement	Allows observations to be selected more than once during the generation process, thereby enabling sequences of the required length to be assembled from the historical record.
Preserve monthly seasonality	Maintains the seasonal characteristics of the observed record by accounting for the month from which values are sampled.
Preserve wet/dry spell lengths	Provides additional preservation of the persistence characteristics of wet and dry periods within the generated sequences.
Results viewer	Summarises the selected generation method, number and length of sequences, sampling settings, preservation options and location of the generated output data.

When *Preserve monthly seasonality* is selected, the generation process retains the seasonal dependence of the flow regime rather than treating observations from all months as interchangeable.

This is particularly important for rivers exhibiting strong seasonal differences in flow.

The *Preserve wet/dry spell lengths* option provides additional control over temporal persistence so that the generated sequences better represent the occurrence of sustained wet and dry periods evident in the historical record.

10.12.2 Monthly Statistics Generator

The *Monthly Statistics Generator* provides an alternative stochastic-generation approach based on the statistical characteristics of flows for individual calendar months.

The available settings are shown in **Figure 10-14**.

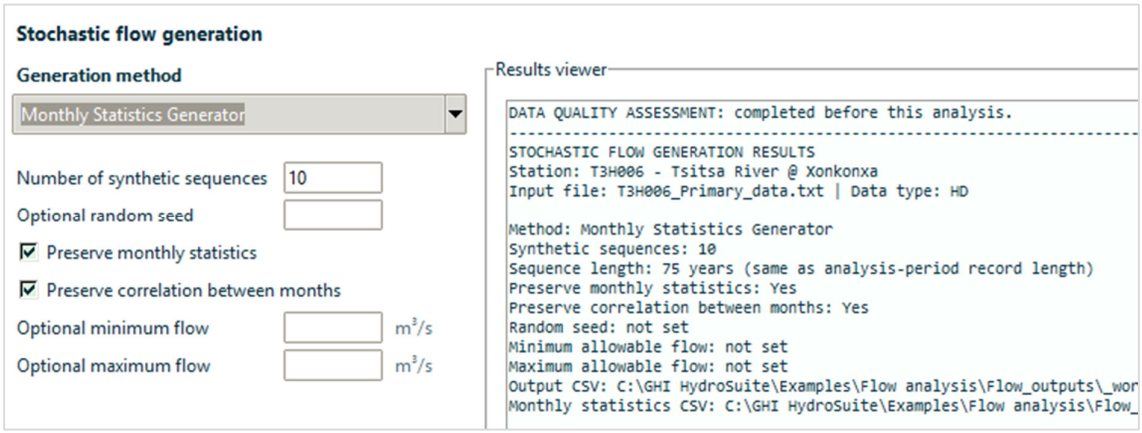


Figure 10-14: Stochastic Flow Generation - Monthly Statistics Generator

The principal inputs are described in **Table 10-14**.

Table 10-14: Monthly Statistics Generator

Option	Description
Generation method	Select Monthly Statistics Generator to generate synthetic sequences using monthly flow statistics.
Number of synthetic sequences	Specifies the number of synthetic flow sequences to be generated.
Optional random seed	Allows a fixed random seed to be specified where reproducibility of the generated sequences is required.
Preserve monthly statistics	Generates the synthetic sequence while preserving the statistical characteristics associated with the individual calendar months.
Preserve correlation between months	Preserves correlation between successive monthly flow conditions to provide greater temporal continuity between months.
Optional minimum flow	Allows a minimum allowable generated flow, in m^3/s, to be specified. If left blank, no user-defined minimum limit is applied.
Optional maximum flow	Allows a maximum allowable generated flow, in m^3/s, to be specified. If left blank, no user-defined maximum limit is applied.

Option	Description
Results viewer	Summarises the generation settings and identifies the output files containing the generated synthetic sequences and associated monthly statistics.

For this method, the sequence length corresponds to the length of the selected analysis-period record, as indicated in the *Results viewer*.

The *Preserve monthly statistics* option is intended to retain the characteristic differences between individual months, while *Preserve correlation between months* maintains dependence between consecutive monthly conditions. Together, these options provide synthetic sequences that reproduce the broad seasonal and temporal structure represented by the historical record.

The *Optional minimum flow* and *Optional maximum flow* can be used to constrain the generated values where appropriate.

10.12.3 Selection of generation method

The two methods provide different approaches to generating alternative flow sequences.

Simple Random Resampling (Bootstrap) is based directly on resampling the historical observations and is therefore suited to applications where alternative arrangements of historically observed flow behaviour are required. The user can specify the required number and length of synthetic sequences and can preserve monthly seasonality and wet/dry spell characteristics.

The *Monthly Statistics Generator* generates sequences from the monthly statistical characteristics of the observed record and can preserve both monthly statistics and correlation between months. It is therefore more focused on reproducing the statistical structure of the monthly flow regime.

In both cases, the synthetic sequences represent plausible alternative realisations based on the characteristics of the historical record. They should not be interpreted as forecasts of the actual future sequence of river flows.

10.12.4 Stochastic Flow Generation graphical output

The generated stochastic sequences can be viewed graphically to compare their behaviour with the historical flow record, as illustrated in **Figure 10-15**.

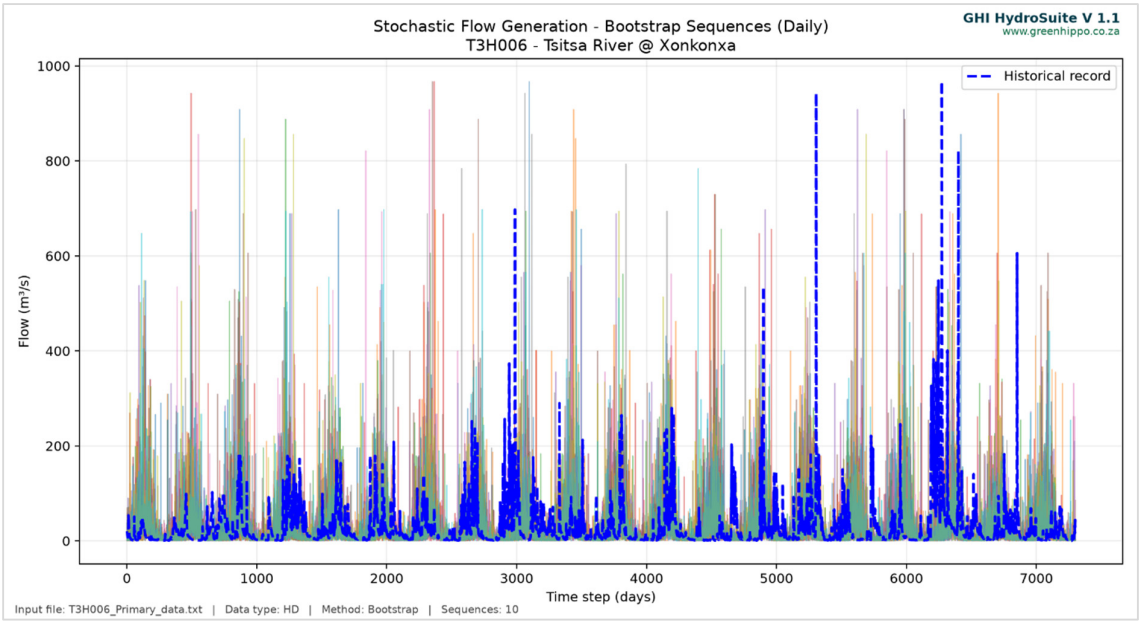


Figure 10-15: Stochastic Flow Generation – Bootstrap sequences

The graph displays the generated synthetic sequences over the selected sequence length, with flow (m^3/s) on the vertical axis and the generated time step on the horizontal axis. The individual synthetic sequences are plotted together, while the historical flow record is superimposed as a reference.

This graphical comparison allows the user to assess whether the generated sequences reproduce the general range, variability, occurrence of high-flow events and temporal behaviour represented by the historical record.

Where multiple synthetic sequences are generated, the spread between the sequences illustrates the range of alternative flow realisations produced by the selected stochastic-generation method and settings.

10.13 Report Generation and Outputs

The ***Report generation*** tab allows the results from completed Flow Analysis procedures to be combined into a single PDF report. The user can select which completed analyses are to be included, allowing the report to be tailored to the purpose of the particular assessment.

Only analyses that have been completed during the current flow-analysis process are available for inclusion. The available report sections correspond to the principal analysis tabs described in the preceding sections.

The Report generation screen is shown in **Figure 10-16** whilst the available report options are described in **Table 10-15**.

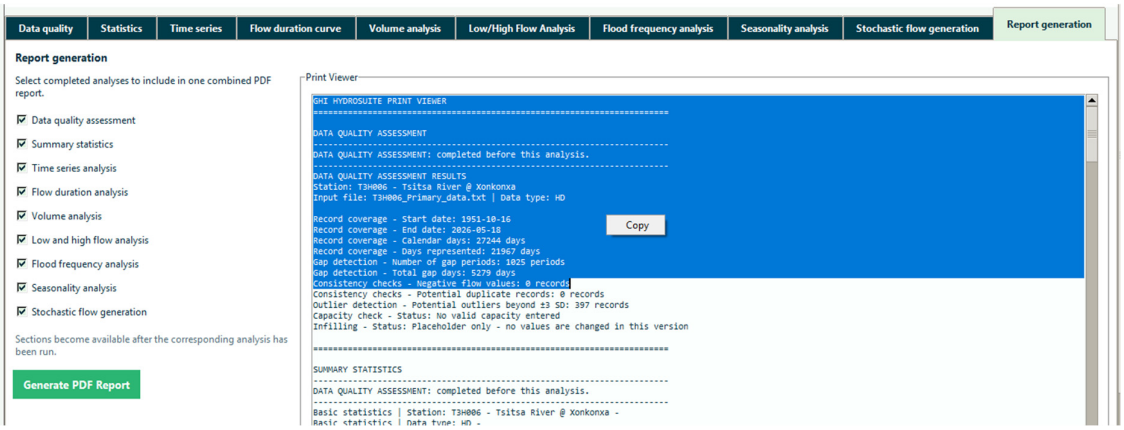


Figure 10-16: Flow Analysis - Report generation

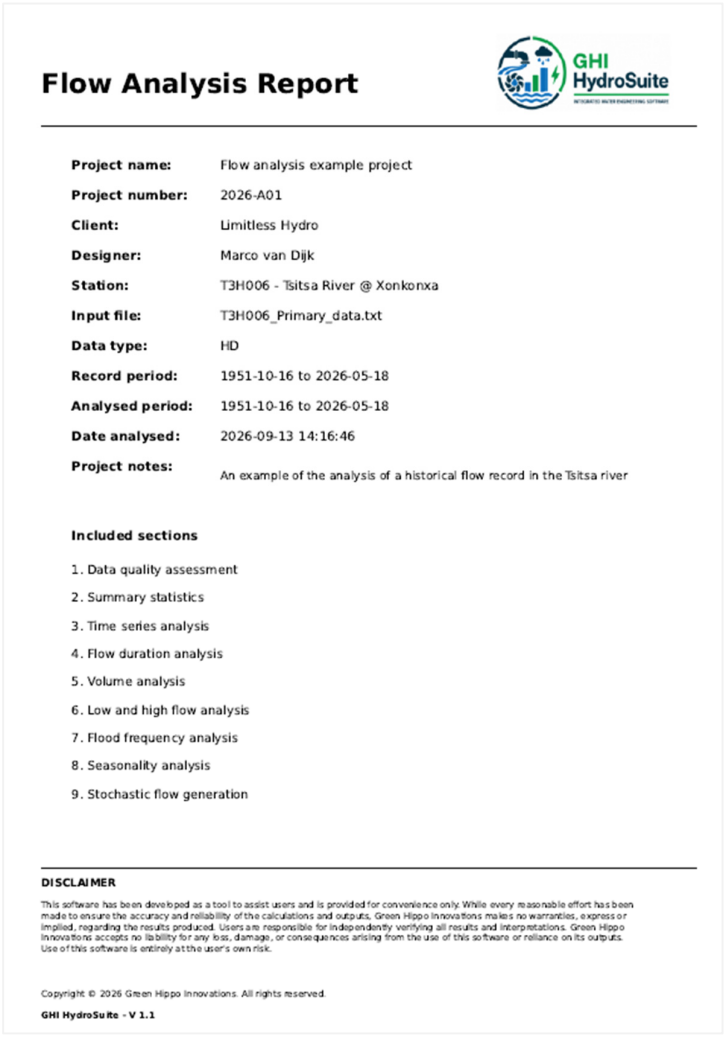
Table 10-15: Report generation options

Option	Description
Data quality assessment	Includes the results of the data-quality assessment.
Summary statistics	Includes the calculated flow statistics, quantiles, runoff volumes and trend statistics.
Time series analysis	Includes the selected time-series analysis results.
Flow duration analysis	Includes the flow-duration analysis results.
Volume analysis	Includes the Volume Duration and Volume Frequency Analysis results, where applicable.
Low and high flow analysis	Includes the calculated low-flow, high-flow and associated threshold-analysis results.
Flood frequency analysis	Includes the flood-frequency analysis results.
Seasonality analysis	Includes the seasonal flow-analysis results.
Stochastic flow generation	Includes information relating to the selected stochastic flow-generation analysis.
Print Viewer	Displays the information that will be incorporated into the report and allows the displayed text to be reviewed before the PDF is generated.
Copy	Copies selected information from the Print Viewer to the clipboard for use in other documents or applications. Right click as shown in **Figure 10-16.**
Generate PDF Report	Click the Generate PDF Report button to creates a PDF report containing the selected analysis sections and associated outputs.

10.13.1 PDF report

The *Generate PDF Report* function compiles the selected analyses into a structured Flow Analysis report. The report includes a cover page containing the applicable project and flow-record information, followed by the selected analysis sections and their associated results and graphical outputs.

An example report cover page is shown in **Figure 10-17**.



Flow Analysis Report

Project name:	Flow analysis example project
Project number:	2026-A01
Client:	Limitless Hydro
Designer:	Marco van Dijk
Station:	T3H006 - Tsitsa River @ Xonkonxa
Input file:	T3H006_Primary_data.txt
Data type:	HD
Record period:	1951-10-16 to 2026-05-18
Analysed period:	1951-10-16 to 2026-05-18
Date analysed:	2026-09-13 14:16:46
Project notes:	An example of the analysis of a historical flow record in the Tsitsa river

Included sections

1. Data quality assessment
2. Summary statistics
3. Time series analysis
4. Flow duration analysis
5. Volume analysis
6. Low and high flow analysis
7. Flood frequency analysis
8. Seasonality analysis
9. Stochastic flow generation

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GHI HydroSuite - V 1.1

Figure 10-17: Example Flow Analysis PDF report cover page

The report cover page identifies the project, project number, client, designer, flow station, input file, data type, available record period and analysed period. Project notes are also included where these have been defined for the project.

The Included sections list provides a record of the analyses incorporated into the generated report. This is particularly useful where only a subset of the available Flow Analysis procedures has been selected.

10.13.2 Copying results

Results do not have to be exported through the PDF report. Information displayed in the Results Viewer and Print Viewer can also be selected and copied directly for use in calculations, technical notes, spreadsheets or other reports.

The Copy function is activated by selecting the text and right-clicking on the selected text and provides a convenient means of transferring the displayed information to the clipboard without first generating a complete report.

10.13.3 Graphical outputs

Graphs generated during the Flow Analysis are also saved separately in PNG format in the applicable Graphs folder.

These files provide access to the individual high-resolution graphical outputs independently of the PDF report and can therefore be incorporated directly into other reports, presentations and supporting documentation.

The *View Graphs* function described earlier in this chapter provides direct access to the generated graphical outputs.

10.13.4 CSV data outputs

Numerical output data and generated sequences are provided separately in CSV format in the applicable CSV folder.

The CSV outputs provide access to the underlying calculated or generated data for subsequent processing, checking or further analysis in spreadsheet, statistical or other engineering software. This is particularly useful for analyses that generate extensive datasets, including stochastic flow sequences and other derived flow-series outputs.

10.13.5 Flow Analysis output structure

The Flow Analysis module therefore provides results at three complementary levels:

- PDF report - provides a consolidated and formatted record of the selected analyses suitable for reporting and project documentation.
- PNG graphical outputs - provide the individual graphs in image format for direct use in other documents and presentations.
- CSV data outputs - provide the underlying numerical results and generated sequences for further analysis and processing.

Together with the ability to copy information directly from the *Results Viewer* and *Print Viewer*, these output formats allow the user to either generate a complete Flow Analysis report or use individual results and outputs in a broader engineering assessment.

11 RESERVOIRS

11.1 Overview of the Reservoirs Module

The Reservoirs module provides tools for the assessment and analysis of historical reservoir water-level records. The module allows reservoir records to be checked for data quality, statistically analysed and evaluated over a user-defined analysis period.

The analyses are organised into a series of tabs, allowing the user to progress from verification of the source data through statistical and time-series assessment to water-level duration analysis and flood-routing applications. Results can be reviewed directly within the program, displayed graphically and incorporated into a combined PDF report. The main Reservoirs screen is shown in **Figure 11-1**.

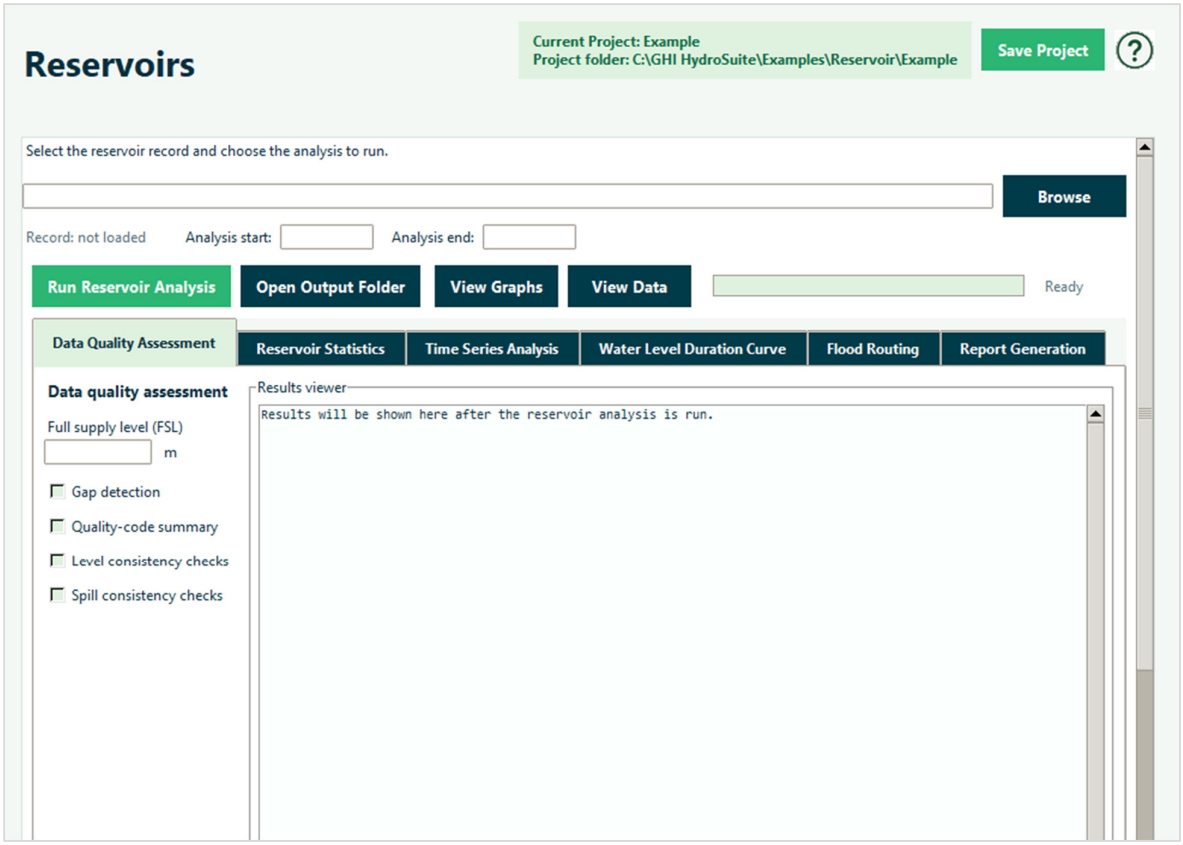


Figure 11-1: Reservoirs analysis screen

The following principal analysis options are available, **Table 11-1**:

Table 11-1: Reservoirs options

Analysis	Description
Data Quality Assessment	Assesses the completeness and consistency of the reservoir record, including gaps, quality codes, water-level consistency and possible spill-related inconsistencies.

Analysis	Description
Reservoir Statistics	Calculates statistical characteristics of the reservoir record over the selected analysis period.
Time Series Analysis	Evaluates changes in reservoir water levels through time and provides graphical representations of the historical record.
Water Level Duration Curve	Determines the percentage of time that specified reservoir water levels are equalled or exceeded.
Flood Routing	Provides tools for assessing the routing of flood hydrographs through a reservoir.
Report Generation	Combines selected completed analyses and associated results into a PDF report.

A typical Reservoir Analysis workflow is therefore, **Figure 11-2**:

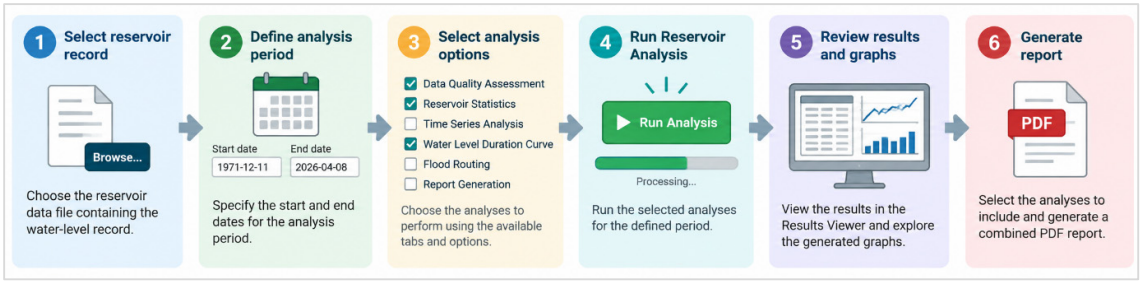


Figure 11-2: Reservoir Analysis workflow

11.2 Reservoir Record Selection and Analysis Period

The controls at the top of the Reservoirs screen are common to the different analysis tabs and are used to select the reservoir dataset and define the period over which the analyses are performed.

The *Browse* button is used to select the required reservoir data file. Once a valid record has been loaded, information describing the record is displayed immediately below the selected file path, as illustrated in **Figure 11-3**.

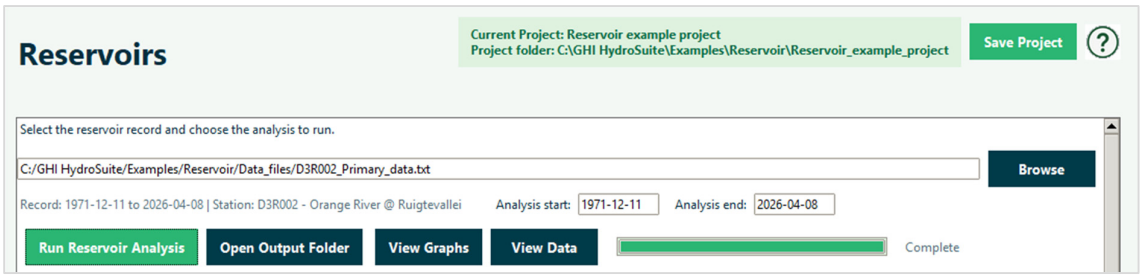


Figure 11-3: Reservoir record selection, analysis period and main analysis controls

For the example shown, the software identifies the available record period together with the reservoir station number and station name.

The principal controls are described below **Table 11-2**.

Table 11-2: Record selection options

Option	Description
Reservoir data file	Displays the path and filename of the currently selected reservoir record.
Browse	Opens the file-selection interface to select the required reservoir data file.
Record	Displays the full period represented by the selected reservoir dataset.
Station	Displays the station number and reservoir/station name obtained from the selected record.
Analysis start	Defines the first date to be included in the analysis.
Analysis end	Defines the final date to be included in the analysis.

The record period represents the full period for which information is available in the selected data file, whereas the analysis period represents the portion of that record that the user wishes to analyse. This distinction allows a shorter period to be investigated without modifying the original reservoir dataset.

Unless otherwise indicated for a particular analysis, subsequent Reservoirs analyses are performed using the selected analysis period.

11.3 Main Reservoir Analysis Controls

A common set of controls is provided above the analysis tabs, as shown in **Figure 11-3**. These controls, listed in **Table 11-3**, are used to execute the selected analyses and access the resulting outputs.

Table 11-3: Main control analysis options

Control	Description
Run Reservoir Analysis	Performs the analyses selected within the applicable Reservoirs tabs using the specified analysis period.
Open Output Folder	Opens the folder containing the generated Reservoirs output files.
View Graphs	Provides access to graphical outputs generated by the completed analyses.
View Data	Provides access to the reservoir data associated with the selected analysis.
Progress indicator	Displays the progress of the analysis while calculations are being performed.
Status	Indicates the current state of the analysis, such as *Ready* or *Complete*.
Results Viewer	Displays the numerical results, summaries, diagnostics and other information generated by the selected analysis.

The *Results Viewer* is used throughout the Reservoirs module and allows results to be reviewed directly without first generating a report.

11.4 Data Quality Assessment

The ***Data Quality Assessment*** tab provides an initial assessment of the selected reservoir record before subsequent reservoir analyses are performed. The purpose of this assessment is to identify potential gaps, questionable observations and inconsistencies that could affect the interpretation of the reservoir data. The *Data Quality Assessment* screen is shown in **Figure 11-4**.

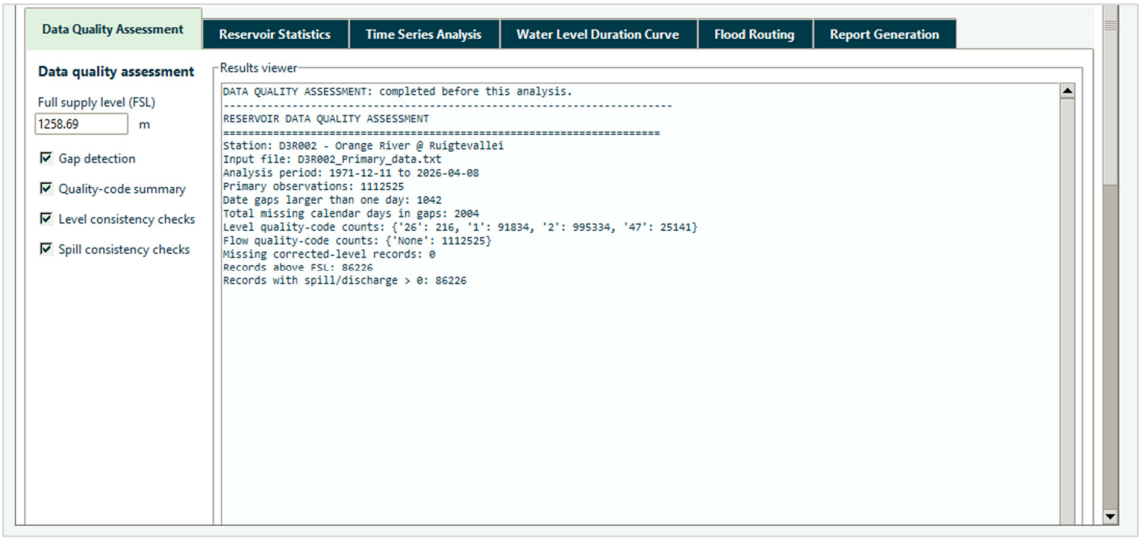


Figure 11-4: Reservoirs - Data Quality Assessment

The *Full supply level (FSL)* can be specified for the reservoir and is used where applicable to assist with water-level and spill-related consistency checks. The available data-quality assessments may be selected individually.

Table 11-4: Data Quality Assessment options

Option	Description
Full supply level (FSL)	Specifies the reservoir full supply level in metres. The value provides a reference level for applicable reservoir-level and spill consistency assessments.
Gap detection	Identifies periods for which observations are missing from the reservoir record and reports the number and extent of detected gaps.
Quality-code summary	Summarises the quality codes associated with the reservoir observations, allowing the user to identify records carrying particular data-quality classifications.
Level consistency checks	Checks the reservoir-level record for values or behaviour that may indicate inconsistencies in the recorded water-level data.
Spill consistency checks	Assesses the reservoir record for potential inconsistencies associated with water levels and spill conditions, using the specified FSL where applicable.
Results Viewer	Displays the results of the selected data-quality checks, including record information and identified data-quality observations.

The assessment also provides a summary of the reservoir dataset, including the station information, analysis period, number of primary observations and the number of records used in the analysis.

For example, where Gap detection is selected, the *Results Viewer* identifies the number of missing calendar days within the selected analysis period. The quality-code assessment provides a summary of the quality classifications present in the source record, while the consistency checks identify observations requiring further consideration.

The data-quality assessment should be reviewed before interpreting the results of subsequent reservoir analyses. The identification of a gap or consistency issue does not necessarily mean that the reservoir record is unsuitable for analysis; rather, it provides the user with information needed to assess the completeness and reliability of the available data.

11.5 Reservoir Statistics

The ***Reservoir Statistics*** tab provides a statistical summary of the reservoir water-level and spill/discharge record over the selected analysis period, as shown in **Figure 11-5**. The analysis allows the user to characterise typical and extreme reservoir levels, quantify spill or discharge conditions, examine the seasonal distribution of spill events and determine water levels associated with specified exceedance probabilities.

The Full supply level (FSL) is specified as a reference level for the reservoir and is used in the interpretation of reservoir levels and spill conditions.

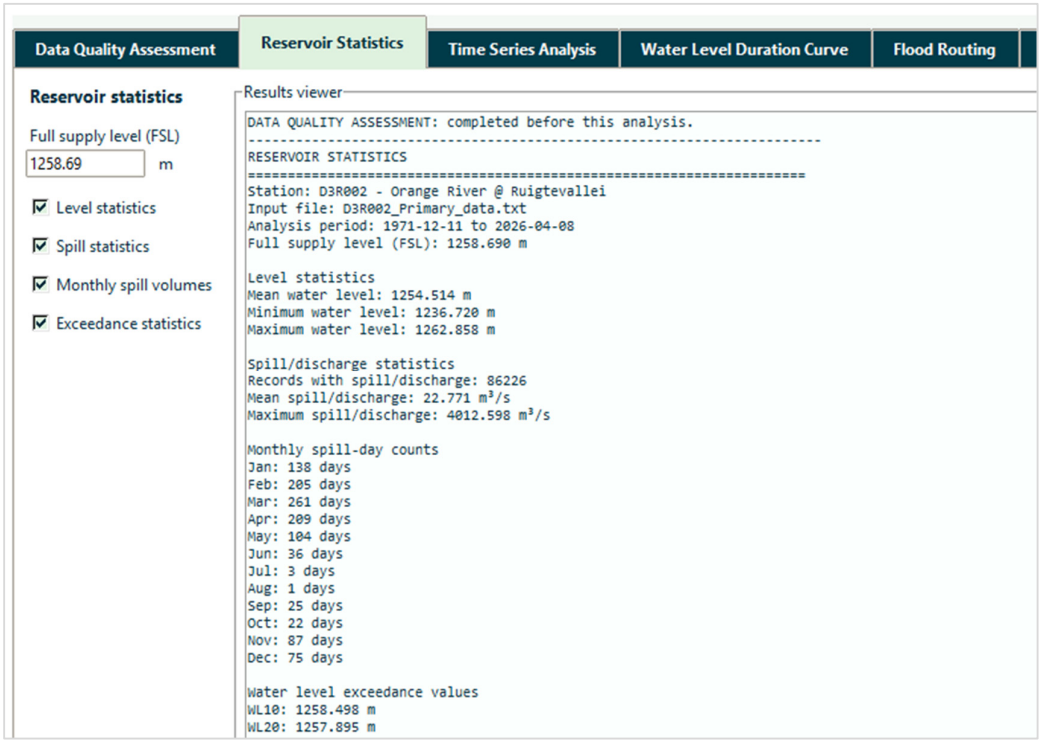


Figure 11-5: Reservoirs - Reservoir Statistics

The user can select the individual statistical analyses to be performed as described in **Table 11-5**.

Table 11-5: Reservoir statistics options

Option	Description
Full supply level (FSL)	Specifies the reservoir full supply level in metres and provides the reference level used for the reservoir statistics.
Level statistics	Calculates summary statistics for the reservoir water-level record, including the mean, minimum and maximum recorded water levels over the selected analysis period.
Spill statistics	Calculates statistics associated with spill or discharge observations, including the number of records with spill/discharge, mean spill/discharge and maximum spill/discharge.
Monthly spill volumes	Evaluates the occurrence and volume of spill/discharge on a monthly basis, allowing the seasonal distribution of reservoir spilling to be assessed.
Exceedance statistics	Determines reservoir water levels associated with selected exceedance probabilities, indicating the proportion of the analysed period for which particular water levels are equaled or exceeded.
Results Viewer	Displays the calculated reservoir statistics together with the station, input file, analysis period and FSL used in the assessment.

The *Level statistics* option provides a concise summary of the reservoir water-level record. The calculated statistics include the mean water level, minimum water level and maximum water level for the selected analysis period. These values provide an initial indication of the general operating range of the reservoir and allow the observed water levels to be considered relative to the specified FSL.

The *Spill statistics* option summarises the spill/discharge observations contained in the reservoir record. The Results Viewer reports the number of records for which spill or discharge occurred, together with the mean spill/discharge and maximum spill/discharge. These statistics provide an indication of the frequency and magnitude of recorded releases or spill conditions over the selected analysis period.

The *Monthly spill volumes* analysis evaluates spill/discharge according to calendar month. The results allow the seasonal occurrence of spilling to be assessed and can assist in identifying the months during which spill conditions occur most frequently or contribute the greatest volumes. Where applicable, the *Results Viewer* also reports the number of spill days associated with each month.

The *Exceedance statistics* option evaluates the distribution of observed reservoir water levels and determines the water levels corresponding to selected exceedance probabilities. An exceedance value represents the water level that is equalled or exceeded for a specified percentage of the analysed record.

These statistics provide a useful numerical summary of reservoir operating levels and complement the graphical Water Level Duration Curve described later in this chapter. The selected analyses are performed when *Run Reservoir Analysis* is selected.

11.6 Time Series Analysis

The ***Time Series Analysis*** tab provides graphical analyses of reservoir water levels and spill/discharge behaviour over the selected analysis period as depicted in **Figure 11-6**. These analyses are useful for examining long-term reservoir operating behaviour, identifying periods of drawdown and recovery, assessing the occurrence and magnitude of spilling, and identifying longer-term trends in reservoir water levels.

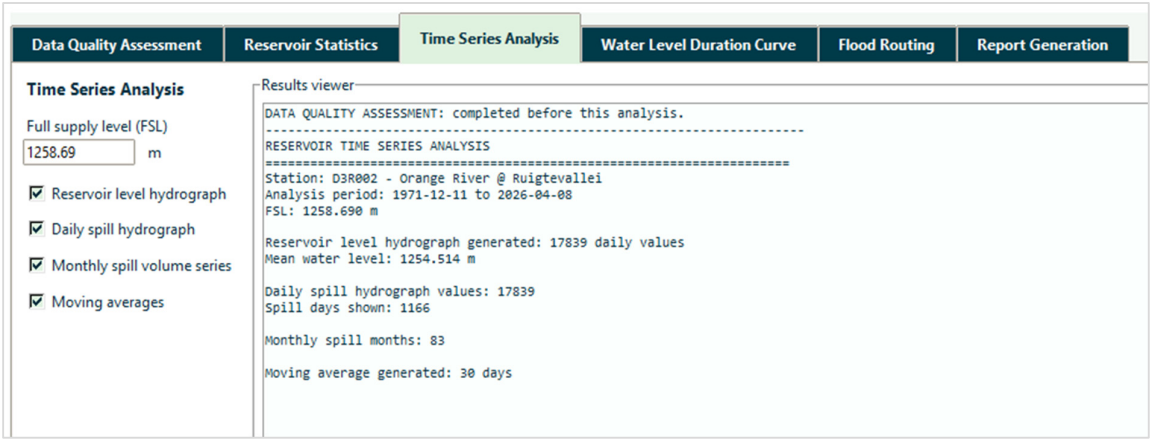


Figure 11-6: Reservoirs - Time Series Analysis

The *Full supply level (FSL)* specified for the reservoir is used as a reference level in the applicable graphical outputs. The *Results viewer* provides a summary of the analyses completed, including the number of reservoir-level observations used, the number of spill days or months identified and the moving-average period applied.

The available time-series analyses that can be selected are described below in **Table 11-6**.

Table 11-6: Time Series options

Analysis option	Description
Reservoir level hydrograph	Generates a continuous hydrograph of the daily mean reservoir water-surface elevation over the selected analysis period. The FSL and mean reservoir water level are included as reference lines, allowing periods of reservoir drawdown, recovery and operation near or above FSL to be readily identified.
Daily spill hydrograph	Displays the daily spill/discharge record for periods during which spilling occurred. This provides an indication of the timing, duration and magnitude of individual spill events and allows significant historical spill periods to be identified.
Monthly spill volume series	Summarises spill occurrence on a monthly basis, providing a longer-term representation of the timing and persistence of reservoir spilling. This is useful for identifying periods and years associated with frequent spill conditions.
Moving averages	Applies a moving average to the reservoir water-level record to reduce short-term fluctuations and highlight longer-term variations in reservoir storage behaviour. A 30-day moving average is generated in the current analysis.

11.6.1 Reservoir level hydrograph

The *Reservoir Level Hydrograph* plots, see **Table 11-7**, the daily mean water-surface elevation against time for the complete selected analysis period. The FSL is shown together with the mean water level calculated from the analysed record.

This graph provides a direct representation of how the reservoir has historically operated. Periods during which the water level remains close to FSL indicate relatively full reservoir conditions, whereas sustained reductions in level indicate reservoir drawdown. The magnitude and duration of these drawdowns can provide useful information regarding historical reservoir operation, drought periods and storage availability. For the example shown, the long historical record also makes it possible to compare reservoir behaviour between different periods and to identify significant historical drawdown events.

11.6.2 Spill/discharge time series

The *Daily Spill Hydrograph,* see **Table 11-7**, displays the magnitude and timing of spill/discharge events over the analysis period. Only periods associated with spilling are of primary interest in this output, making it easier to identify significant events that may otherwise be difficult to distinguish within the complete reservoir record.

The *Monthly Spill Hydrograph*, see **Table 11-7**, provides a complementary representation of spill occurrence at a monthly scale. Together, the daily and monthly analyses provide information on both the magnitude of individual spill events and the frequency or persistence of spilling over time.

These outputs can be particularly useful when assessing opportunities that depend on releases or surplus flows, including hydropower applications, downstream flow availability and reservoir operational studies.

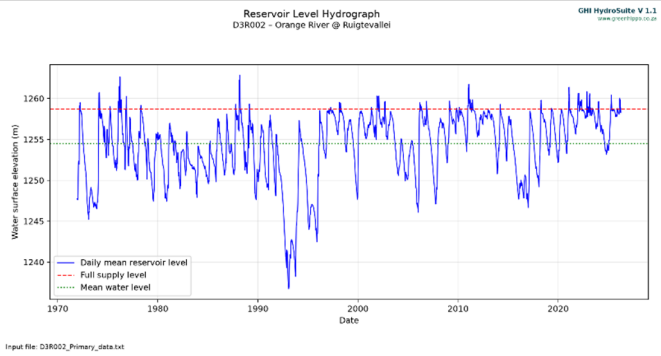
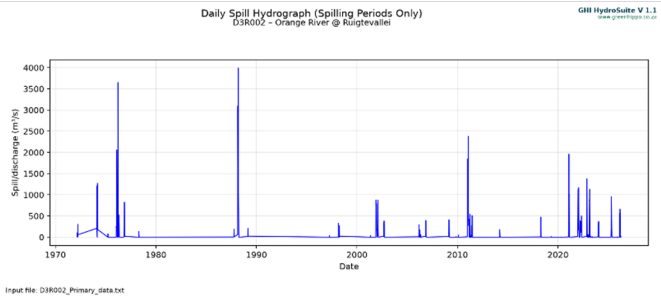
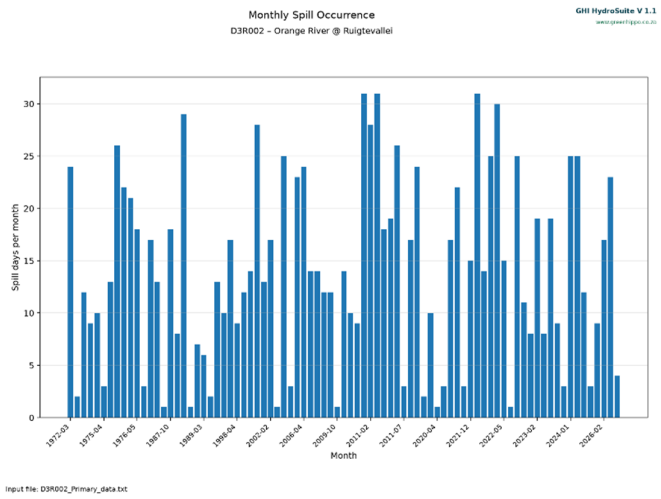
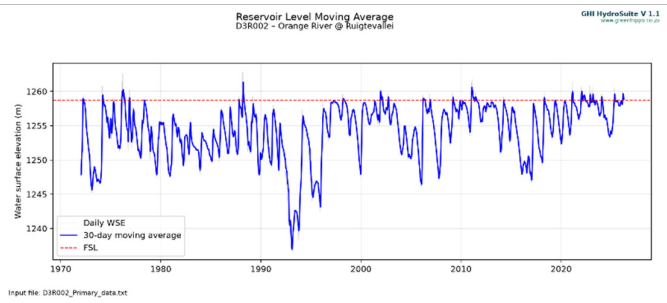
11.6.3 Reservoir level moving average

The *Reservoir Level Moving Average*, see **Table 11-7**, smooths the daily reservoir-level record over a specified period. The current analysis uses a 30-day moving average, which reduces the influence of short-duration fluctuations while retaining the principal seasonal and longer-term variations in reservoir level.

The daily water-surface elevations remain visible in the background, while the moving-average series provides a clearer representation of the underlying trend. The FSL is included as a reference line.

The moving-average graph is particularly useful for identifying sustained drawdown and recovery periods and for distinguishing these longer-term changes from short-duration fluctuations in the daily reservoir record.

Table 11-7: Reservoir Time Series Analysis graphical outputs

Graphical output	Description
	**Reservoir level hydrograph** Displays the daily mean reservoir water-surface elevation over the analysis period, together with the full supply level (FSL) and mean water level for reference.
	**Daily spill hydrograph** Displays the timing and magnitude of daily spill/ discharge events, allowing significant historical spill periods and peak discharges to be identified.
	**Monthly spill volume series** Summarises reservoir spilling on a monthly basis, illustrating the occurrence and persistence of spill conditions throughout the historical record.
	**Moving averages** Displays the daily reservoir water levels together with a moving-average series to reduce short-term fluctuations and highlight longer-term variations in reservoir level.

11.7 Water Level Duration Curve

The ***Water Level Duration Curve (WLDC)*** tab, describes the percentage of time that particular reservoir water levels are equalled or exceeded. It provides a compact representation of the complete reservoir-level record and is useful for assessing the persistence and reliability of particular operating levels. The Water Level Duration Curve (WLDC) tab is shown in **Figure 11-7**.

The analysis is conceptually similar to a Flow Duration Curve, but reservoir water-surface elevation is used instead of flow. Water levels are ranked from highest to lowest and plotted against their corresponding exceedance probability (%).

A point at an exceedance probability of 20%, for example, represents the reservoir level that was equalled or exceeded for approximately 20% of the analysed observations.

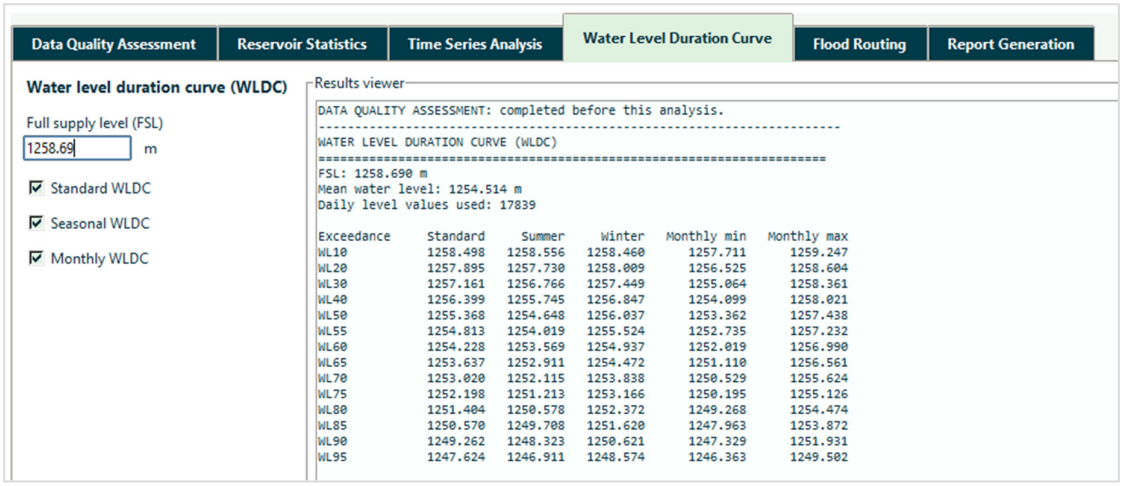


Figure 11-7: Reservoirs - Water Level Duration Curve

Three WLDC analyses are available as listed in **Table 11-8**:

Table 11-8: WLDC selection options

Analysis option	Description
Standard WLDC	Generates a single duration curve using all valid daily reservoir-level observations within the selected analysis period.
Seasonal WLDC	Separates the reservoir-level record into summer and winter periods and generates separate duration curves, allowing seasonal differences in reservoir operation to be evaluated.
Monthly WLDC	Generates separate duration curves for each calendar month, providing a more detailed representation of seasonal variations in reservoir water levels.

The *Results viewer* reports selected exceedance levels for the standard, seasonal and monthly analyses. These include WL10, WL20, WL30 and subsequent exceedance levels through to WL95. The results can therefore be used both graphically and numerically.

11.7.1 Standard Water Level Duration Curve

The Standard Water Level Duration Curve represents the distribution of all valid daily reservoir levels within the selected analysis period, as depicted in **Figure 11-8**.

The horizontal axis represents exceedance probability (%), while the vertical axis represents water-surface elevation (m). High reservoir levels occur towards the left-hand side of the curve and progressively lower, more frequently exceeded levels occur towards the right.

The Full Supply Level (FSL) and mean reservoir water level are included as reference lines. Their positions relative to the duration curve provide additional information regarding historical reservoir operation.

A relatively flat portion of the WLDC indicates that the reservoir frequently operates within a comparatively narrow range of levels. A steep portion indicates that a relatively large change in reservoir level occurs over a comparatively small range of exceedance probabilities.

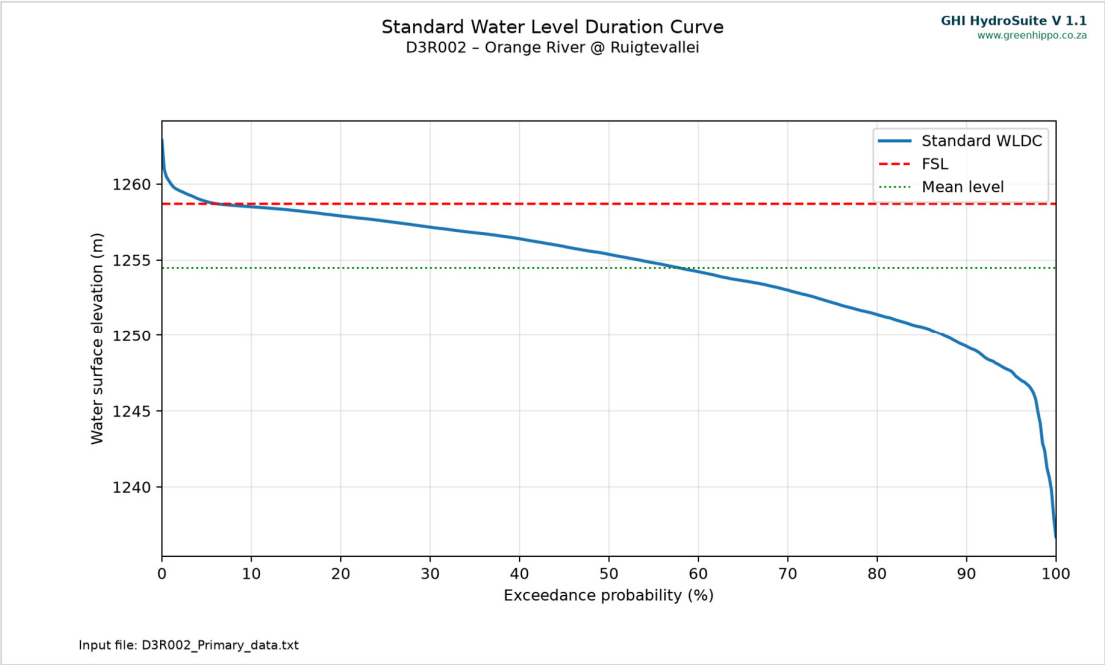


Figure 11-8: Standard Water Level Duration Curve

11.7.2 Seasonal Water Level Duration Curves

The Seasonal WLDC, **Figure 11-9,**divides the reservoir record into:

- Summer: October to March
- Winter: April to September

Separate duration curves are generated for the two periods. This allows differences in reservoir behaviour between the summer and winter seasons to be identified directly.

The relative position of the two curves indicates whether particular reservoir levels are more persistent during one season than another. Seasonal WLDCs are therefore useful where reservoir levels are influenced by seasonal inflows, water demands, releases, evaporation or operating practices.

The FSL is again included as a reference level.

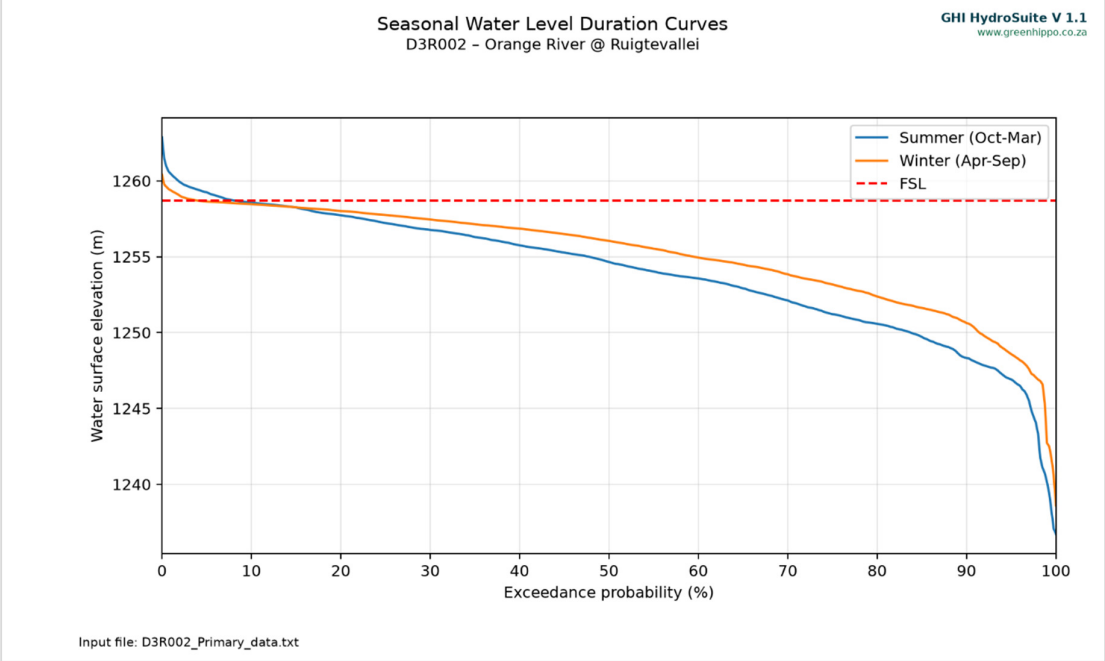


Figure 11-9: Seasonal Water Level Duration Curve

11.7.3 Monthly Water Level Duration Curves

The Monthly WLDC, see **Figure 11-10**, provides the most detailed temporal comparison by generating a separate duration curve for each calendar month.

All observations for a particular month within the analysis period are grouped together to generate the corresponding monthly curve. The resulting twelve curves allow the seasonal evolution of reservoir levels to be examined throughout the year rather than using only the broader summer and winter classifications.

This output is useful for identifying months during which high reservoir levels are most likely, periods associated with systematic reservoir drawdown, and months during which lower operating levels occur more frequently.

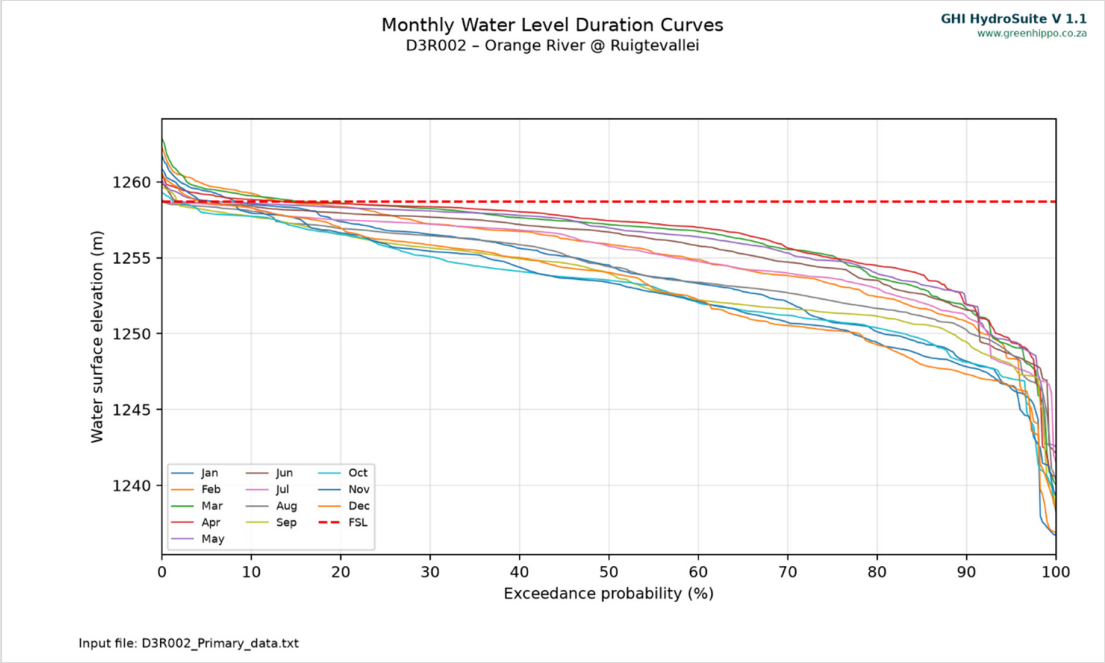


Figure 11-10: Monthly Water Level Duration Curve

11.7.4 Interpretation and application of Water Level Duration Curves

Water Level Duration Curves provide a useful means of assessing the availability and persistence of reservoir head. Unlike a conventional time-series graph, which shows when particular reservoir levels occurred, the WLDC shows how frequently particular levels were available.

The standard, seasonal and monthly WLDCs therefore provide progressively greater detail. The standard curve describes the overall historical distribution, the seasonal curves highlight broad summer–winter differences, and the monthly curves reveal variations throughout the year.

This information can be particularly valuable for reservoir operation and hydropower assessments, where available hydraulic head may vary with reservoir water level. Combining the WLDC with downstream water levels and flow-duration information can provide an indication of the range and persistence of gross head available for energy generation.

11.8 Flood Routing

The ***Flood Routing*** tab, **Figure 11-11**, is currently under development and is included in GHI HydroSuite as a preview of the planned reservoir flood-routing functionality. The module will provide facilities for defining reservoir characteristics, inflow hydrographs, initial reservoir conditions, elevation–storage and elevation–area relationships, spillway characteristics and outlet works.

No flood-routing calculations are performed in the current version of the software. Once development and validation of the flood-routing functionality have been completed, a detailed description of the required inputs, calculation procedures, results and graphical outputs will be incorporated into this User Manual.

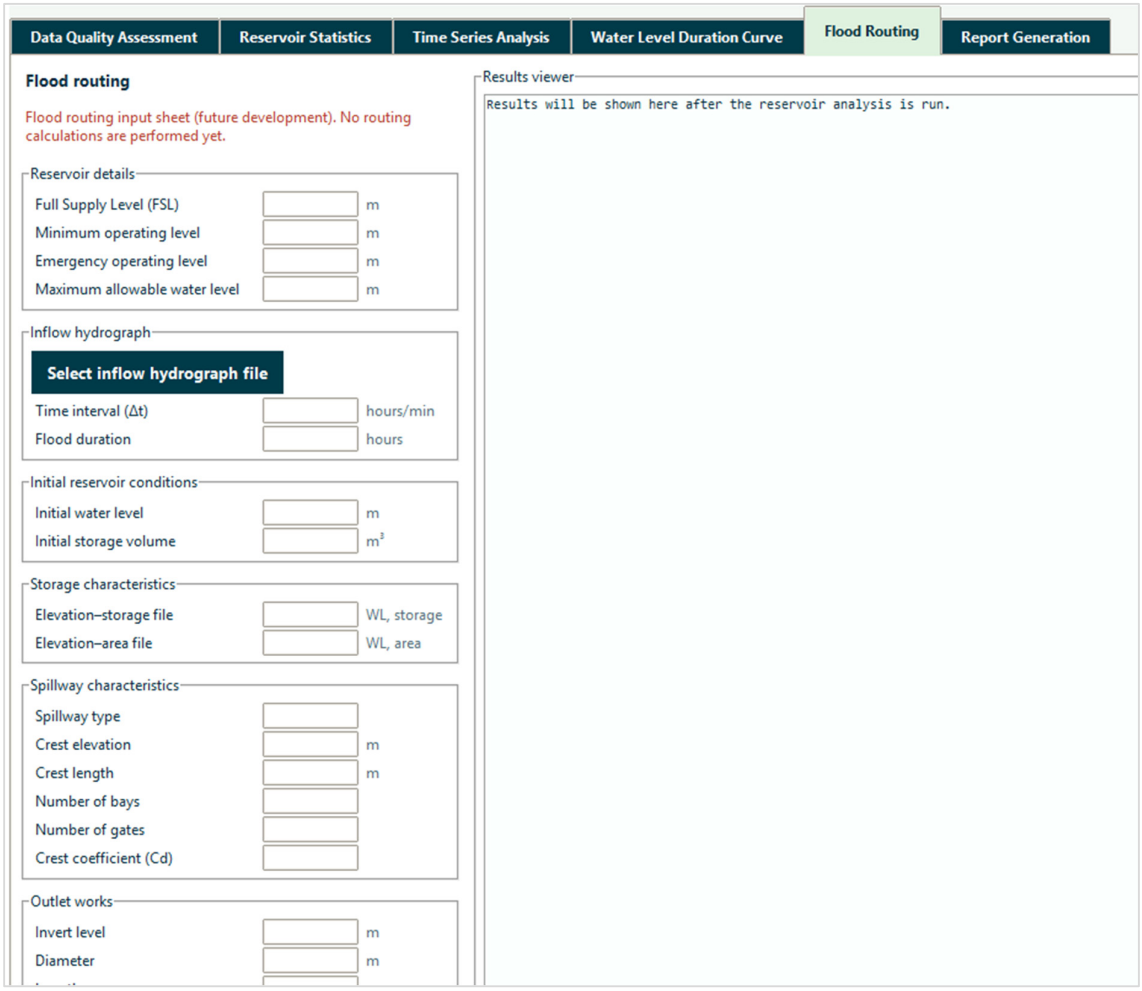


Figure 11-11: Reservoirs - Flood Routing

11.9 Report Generation

The ***Report Generation*** tab, **Figure 11-12**, allows the results of the completed reservoir analyses to be combined into a single PDF report. Only analyses that have been completed are made available for selection, allowing the user to determine which results are included in the final report.

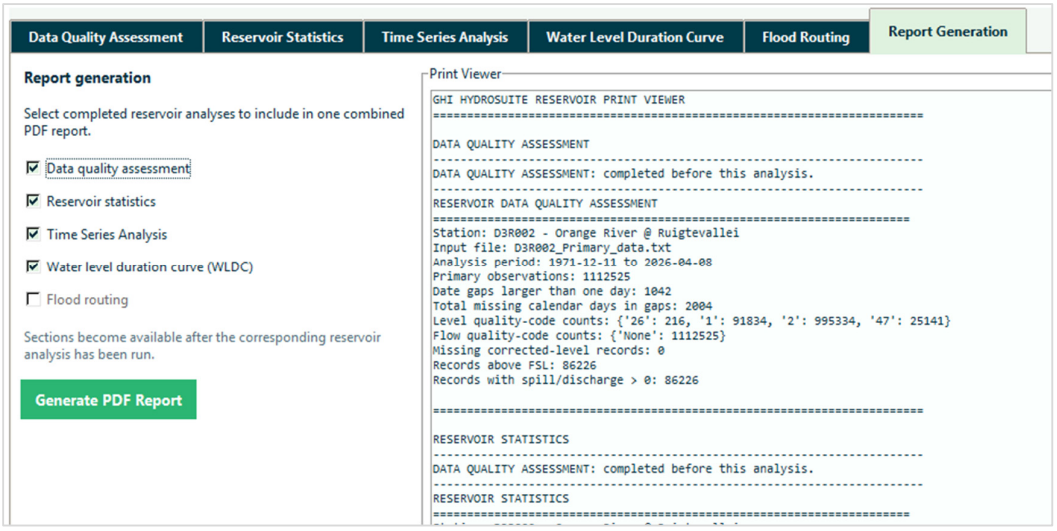


Figure 11-12: Reservoirs - Report generating

The available report sections correspond to the principal reservoir analyses described in this chapter, including:

- Data quality assessment
- Reservoir statistics
- Time series analysis
- Water Level Duration Curve (WLDC)
- Flood routing, once this functionality becomes available

The *Print Viewer* provides a preview of the selected analysis results before the report is generated. This allows the user to review the information and confirm that the required analyses have been completed and selected.

Once the required sections have been selected, click *Generate PDF Report* to create the combined reservoir analysis report. The report includes the relevant project and reservoir information, analysis results and associated graphical outputs.

Information displayed in the Print Viewer can also be selected and copied for use in other documents or calculations. In addition to the PDF report, the individual graphical outputs generated during the reservoir analysis are available as PNG image files, while applicable numerical and time-series results are provided as CSV files in the corresponding output folders. This allows results to be incorporated into external reports, spreadsheets or further engineering analyses as required.

The reporting functionality therefore provides both a consolidated PDF record of the reservoir assessment and access to the underlying outputs for further use.

12 FLOOD ESTIMATION

12.1 Overview of the Flood Estimation Module

The Flood Estimation module provides an integrated environment for estimating design flood peaks using a range of deterministic, empirical and statistical methods. The module allows alternative flood-estimation techniques to be applied within a single project so that results can be compared and an appropriate design flood can be selected for the hydraulic structure or application being investigated.

The module combines project and catchment information with design rainfall, catchment characteristics, runoff parameters and historical flood information. Depending on the selected method, calculations can make use of information obtained from the Data Manager, including design rainfall results and other project data generated elsewhere in GHI HydroSuite.

The Flood Estimation module includes three Rational Method approaches, the Standard Design Flood method, SCS-SA Method, Unit Hydrograph analysis, empirical flood-estimation methods and statistical flood-frequency analysis, see **Figure 12-1**. The different approaches provide complementary estimates and allow the engineer to assess the sensitivity of the calculated design flood to the selected methodology and assumptions.

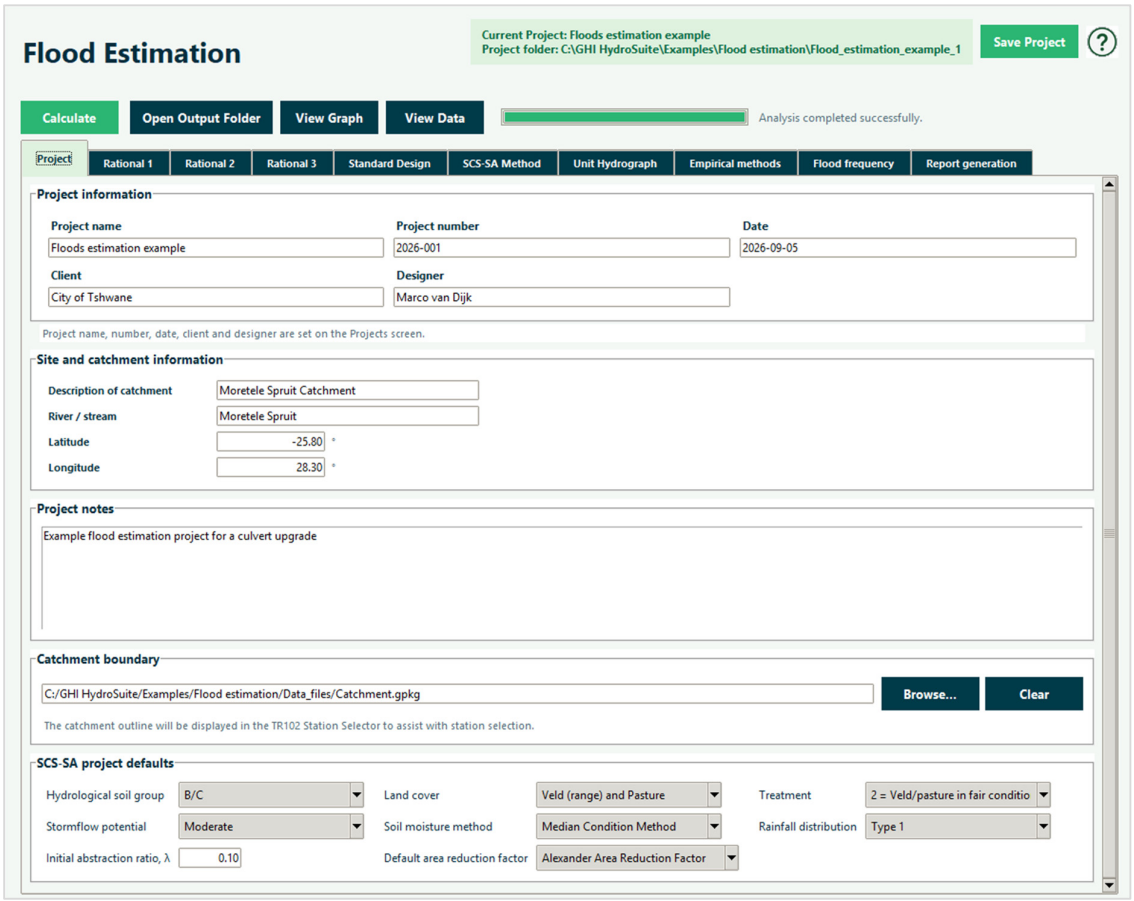


Figure 12-1: Flood Estimation screen

The principal analysis tabs are, **Table 12-1**:

Table 12-1: Flood Estimation tabs

Tab	Purpose
Project	Defines the project, site and catchment information, catchment boundary and project-level defaults used by the applicable flood-estimation methods.
Rational 1	Provides the first Rational Method flood-estimation approach using the applicable catchment, rainfall and runoff parameters.
Rational 2	Provides an alternative Rational Method calculation and associated input parameters.
Rational 3	Provides an integrated Rational Method analysis linked to the Design Rainfall results generated within the Data Manager.
Standard Design	Provides flood estimation using the Standard Design Flood methodology.
SCS-SA Method	Provides flood estimation using the SCS-SA methodology and associated soil, land-cover, antecedent-moisture and rainfall parameters.
Unit Hydrograph	Provides flood estimation using the Unit Hydrograph approach.
Empirical methods	Provides alternative empirical flood-estimation methods for comparison with the other design-flood estimates.
Flood frequency	Provides statistical frequency analysis of observed flood records using alternative probability distributions and flood-series options.
Report Generation	Combines selected flood-estimation calculations, results and graphical outputs into a project PDF report.

The individual methods and their required inputs are described in the sections that follow.

A typical flood-estimation assessment in **GHI HydroSuite** follows the sequence as depicted in **Figure 12-2**.

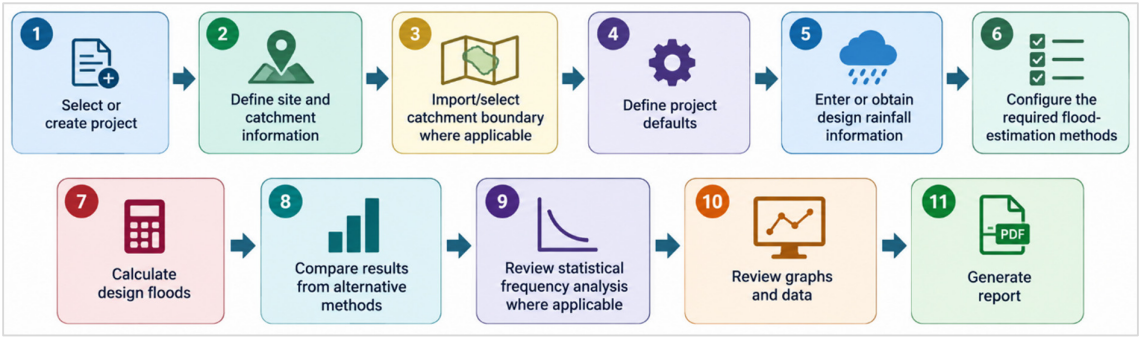


Figure 12-2: Typical flood estimation workflow

The workflow is deliberately structured to allow several flood-estimation methods to be applied to the same catchment. The results should not necessarily be expected to be identical, as the methods are based on different assumptions, input parameters and hydrological approaches. Comparison of the alternative estimates forms an important part of the engineering assessment.

Where historical flood records are available, the Flood frequency analysis provides an additional basis for comparison with the deterministic and empirical methods. More advanced frequency-analysis options, including IPZA analysis, alternative graphical outputs and configurable exceedance-probability scales, are available within this part of the Flood Estimation module and are discussed later in this chapter.

The final Report Generation tab allows the relevant calculations and results to be assembled into a consolidated flood-estimation report.

12.2 General Flood Estimation Controls

A common set of controls is provided at the top of the Flood Estimation screen, **Figure 12-3**, and remains available while moving between the individual analysis tabs.

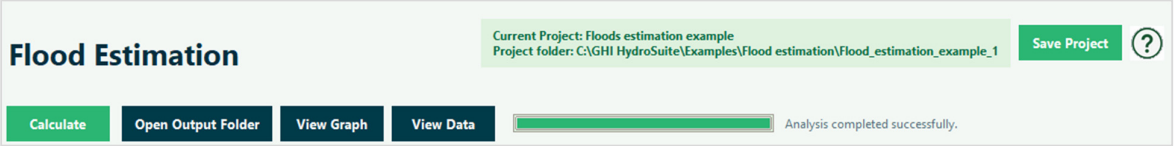


Figure 12-3: Flood Estimation main controls

These controls, listed in **Table 12-2**, are used to execute the selected analyses and access the resulting outputs.

Table 12-2: Main control analysis options

Control	Description
Calculate	Calculate performs the selected flood-estimation calculations using the current project inputs and analysis settings. The progress bar and status message indicate the progress and successful completion of the analysis.
Open Output Folder	Open Output Folder opens the project output location containing the files generated by the flood-estimation analyses.
View Graphs	Provides access to graphical outputs generated by the completed analyses.
View Data	View Data provides access to the corresponding numerical results and output data to be reviewed.
Progress indicator	Displays the progress of the analysis while calculations are being performed.
Status	Indicates the current state of the analysis, such as *Ready* or *Complete*.

The *Results Viewer* is used throughout the Flood Estimation module and allows results to be reviewed directly without first generating a report.

The Current Project panel identifies the active GHI HydroSuite project and its project folder. The Save Project button saves the current project information and analysis settings.

12.3 Project Tab

The ***Project*** tab, as shown in **Figure 12-1**, contains information applicable to the overall flood-estimation assessment and provides the common project and catchment information used by the different calculation methods.

The Project information section displays the project name, project number, date, client and designer. These fields are populated from the information defined on the main **Projects screen**, thereby maintaining consistent project information throughout GHI HydroSuite.

The *Site and catchment information* section allows the user to define a description of the *Catchment*, the associated *River or stream* and the *latitude* and *longitude* of the site.

A *Project notes* field is provided for recording information relevant to the flood-estimation assessment, such as the purpose of the study, assumptions, design requirements or other project-specific comments.

12.3.1 Catchment boundary

A catchment boundary file can be associated with the flood-estimation project using the *Browse* button. The selected catchment outline can subsequently be displayed in the relevant station-selection interface to assist with the spatial selection of rainfall or other hydrological information.

The *Clear* button removes the currently selected catchment boundary from the project.

12.3.2 SCS-SA project defaults

The ***Project*** tab also provides project-level defaults for the SCS-SA Method as shown in **Figure 12-4**. These settings allow commonly used catchment parameters to be defined once and subsequently applied within the SCS-SA analysis.

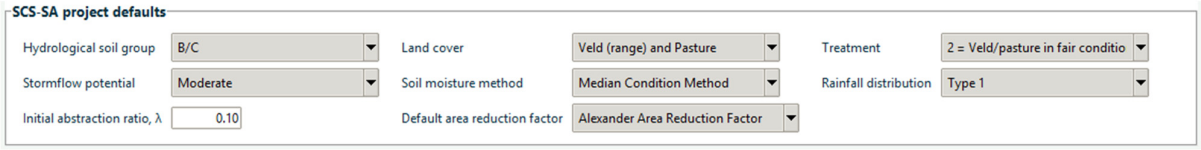


Figure 12-4: Flood Estimation - SCS-SA project defaults

The available defaults include the:

- Hydrological soil group
- Stormflow potential
- Land cover, Treatment
- Soil moisture method
- Rainfall distribution
- Initial abstraction ratio (λ)
- Default area reduction factor method

These values should be selected to represent the characteristics of the catchment being analysed. They provide the initial project settings for the SCS-SA calculations and can be reviewed as part of the detailed analysis.

12.4 Rational Method 1

The ***Rational 1*** tab shown in **Figure 12-5**, provides a detailed implementation of the Rational Method for estimating peak design flood discharges for selected return periods. The method combines catchment characteristics, design rainfall, area distribution and runoff characteristics to determine the design peak flow.

The tab allows the catchment to be represented as a combination of rural, urban and lake areas. Rural and urban runoff coefficients are determined from the characteristics specified by the user, while a separate coefficient is provided for lake areas. This allows the overall runoff coefficient to reflect the different runoff responses occurring within a mixed catchment.

Multiple return periods can be analysed simultaneously. The resulting peak flows are presented in a summary table and graph, with detailed calculation information provided in the *Results Viewer*.

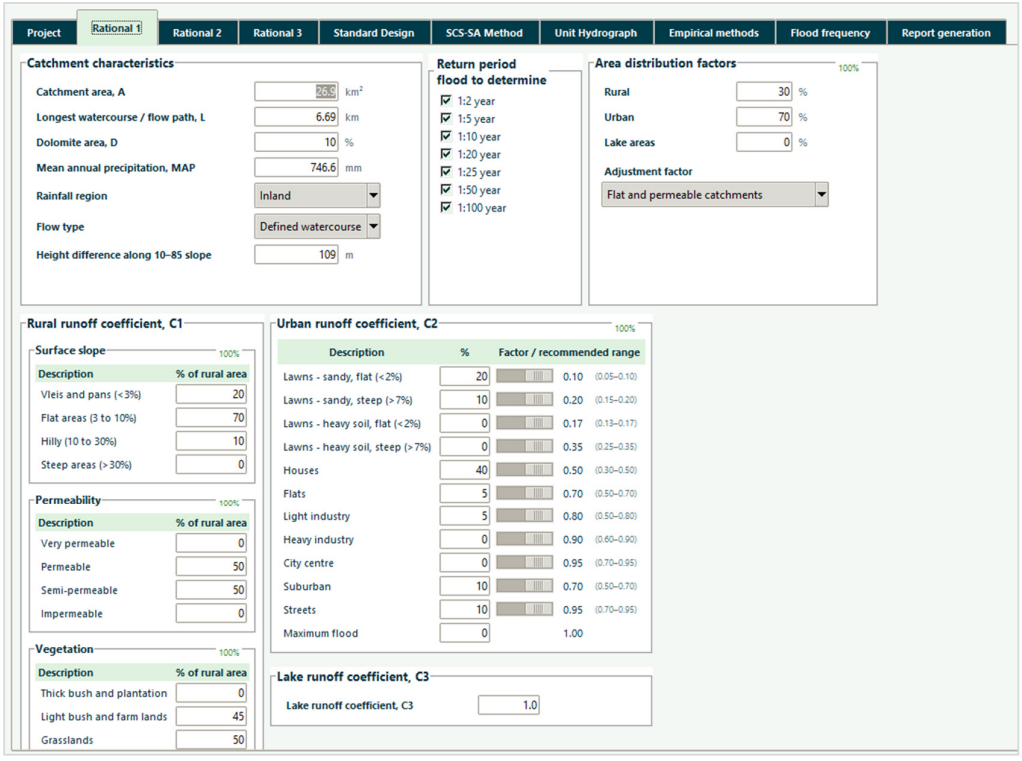


Figure 12-5: Flood Estimation - Rational method 1 tab

12.4.1 Catchment characteristics

The Catchment characteristics section defines the principal physical and hydrological properties required for the Rational Method 1 calculation.

Table 12-3: Catchment characteristics data input RM1

Input	Description
Catchment area, A	Total contributing catchment area in km².
Longest watercourse / flow path, L	Length of the longest principal drainage path through the catchment, expressed in km.
Dolomite area, D	Percentage of the catchment underlain by dolomitic conditions.
Mean annual precipitation, MAP	Mean annual precipitation for the catchment, expressed in mm.
Rainfall region	Specifies the applicable rainfall region used in the calculation. This could be set as *Inland* or *Coastal.*
Flow type	Defines the nature of the principal drainage path. Select *Defined watercourse* or *Overland flow*
Height difference along 10–85 slope	Elevation difference along the 10–85% portion of the principal flow path, used in determining the catchment response and time of concentration in meters.

The user should enter values representative of the catchment being assessed. Particular care should be taken when determining the longest flow path and associated elevation difference, as these parameters influence the calculated time of concentration and consequently the rainfall intensity applied in the flood calculation.

12.4.2 Return periods

The Return period flood to determine section, see **Figure 12-5**, allows one or more design return periods to be selected for simultaneous calculation.

The available standard return periods shown are 1*:2, 1:5, 1:10, 1:20, 1:25, 1:50* and *1:100* years. Only the selected return periods are included in the calculation and reported in the results.

Selecting several return periods is useful for developing a design-flood relationship across a range of recurrence intervals and for comparing flood magnitudes required for different levels of infrastructure design.

12.4.3 Area distribution factors

The catchment is divided between three principal land-area categories:

Rural represents the proportion of the catchment treated using the rural runoff coefficient, *Urban* represents the proportion treated using the urban runoff coefficient, and *Lake areas* represents open-water areas treated using the lake runoff coefficient.

The percentages should collectively represent 100% of the catchment area. The percentage indicator displayed above the input fields (top right corner) provides a convenient check of the entered area distribution.

An *Adjustment factor* can also be selected to account for the applicable catchment condition. The user can select between *Steep and impermeable catchments* or *Flat and permeable catchments* from the drop-down list.

12.4.4 Rural runoff coefficient, C1

The *Rural runoff coefficient (C1)* is determined from the characteristics of the rural portion of the catchment as shown in **Figure 12-6**. The user describes the rural catchment using three groups of characteristics: surface slope, permeability and vegetation.

For each group, the percentage distribution should total 100% of the rural area.

For *Surface slope*, the available classifications are:

- Vleis and pans (<3%)
- Flat areas (3 to 10%)
- Hilly (10 to 30%)
- Steep areas (>30%)

For *Permeability*, the rural area is divided between:

- Very permeable
- Permeable
- Semi-permeable
- Impermeable

For *Vegetation*, the available classifications include:

- Thick bush and plantation
- Light bush and farm lands
- Grasslands
- No vegetation

The percentage distributions entered for these characteristics are used by **GHI HydroSuite** in determining the representative rural runoff response.

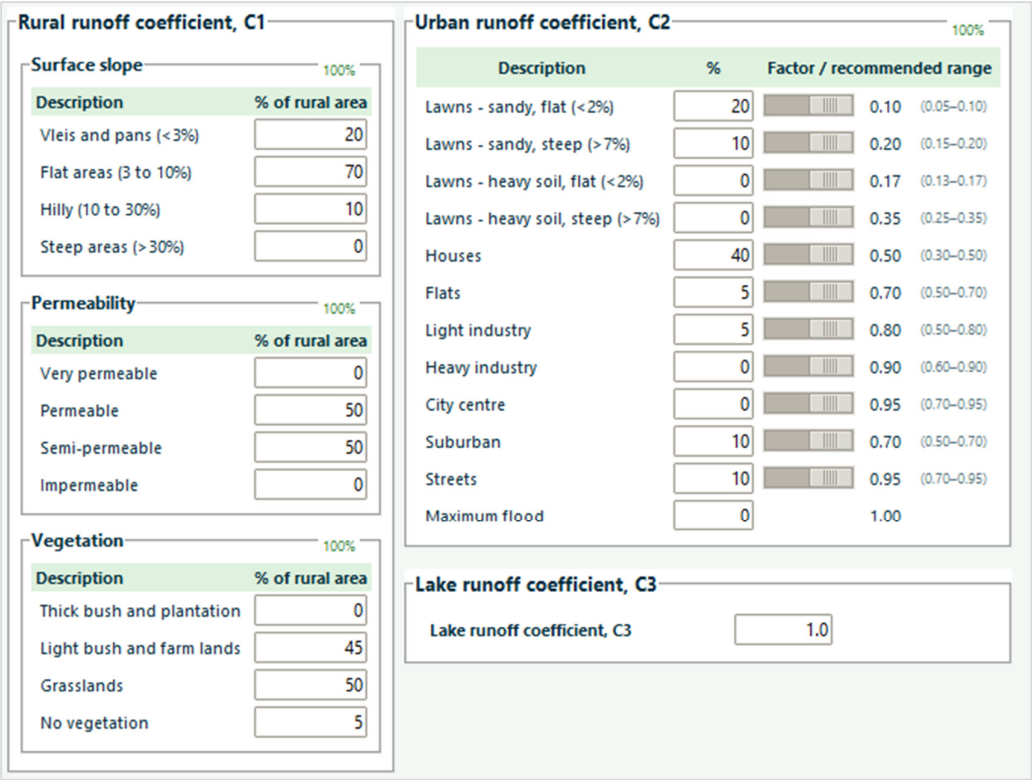


Figure 12-6: Runoff coefficients RM1

12.4.5 Urban runoff coefficient, C2

The *Urban runoff coefficient (C2)* represents runoff from the urbanised portion of the catchment. The user specifies the percentage of the urban area associated with the different surface and development types, as shown in **Figure 12-6**.

Available classifications include lawns with different soil and slope conditions, houses, flats, light and heavy industry, city centre, suburban areas, streets and maximum-flood conditions.

Each classification is associated with a runoff factor and a displayed recommended range. The factor can be adjusted within the interface to represent the particular characteristics of the catchment by moving the horizontal bar.

The percentage allocations should collectively represent 100% of the urban area. The resulting urban coefficient is determined from the combination of the selected land-use proportions and runoff factors.

12.4.6 Lake runoff coefficient, C3

The *Lake runoff coefficient (C3)* is applied to the portion of the catchment classified as lake or open-water area. A separate coefficient can be specified directly by the user, as shown in **Figure 12-6**.

Where the catchment contains no lake area, the area allocation to this category is set to zero and consequently does not contribute to the combined catchment runoff coefficient.

12.4.7 Rational Method 1 results

After the flood-estimation analysis has been calculated, by clicking on the *Calculate* button, the Rational Method 1 summary presents the principal calculation results for each selected return period, as shown in **Figure 12-7**.

The results table includes the following results (**Table 12-4**):

Table 12-4: Rational method 1 results table

Result	Description
Return period	Recurrence interval for the calculated design flood.
Time of concentration	Calculated catchment response time used to determine the applicable design rainfall.
Point rainfall	Design point rainfall corresponding to the return period and applicable storm duration. This is determined from the Depth-Duration-Frequency diagram for point rainfall (HRU Report 2/78, A *Depth-Duration-Frequency Diagram for Point Rainfall in Southern Africa* (1978), which is an update from a similar diagram published in HRU Report 1/72, *Design Flood Determination in South Africa* in 1972)
ARF	Area Reduction Factor applied to convert point rainfall to a rainfall value representative of the catchment area.
Average intensity	Average rainfall intensity corresponding to the applicable rainfall depth and duration.
Factor Ft	Return-period-related factor applied within the Rational Method 1 calculation.
Runoff coefficient	Calculated representative runoff coefficient for the catchment.
Peak flow	Estimated design peak discharge for the selected return period, expressed in m^3/s.

The summary allows the user to trace how the rainfall and catchment parameters change with return period rather than presenting only the final peak-flow estimate.

The *Peak flood by return period* graph provides a graphical summary of the calculated design flood peaks. Each selected return period is shown on the horizontal axis, with the corresponding peak discharge in m^3/s on the vertical axis.

The graph provides a convenient visual comparison of the increase in estimated design flood magnitude with increasing return period and can be used together with the numerical summary when reviewing the Rational Method 1 results.

The *Results Viewer* provides a detailed text-based record of the Rational Method 1 analysis. It includes

the relevant project and catchment information together with the calculation inputs and results generated during the analysis. The *Results Viewer* complements the summary table and graph by providing a more detailed record that can be reviewed, copied and incorporated into supporting calculations or engineering documentation.

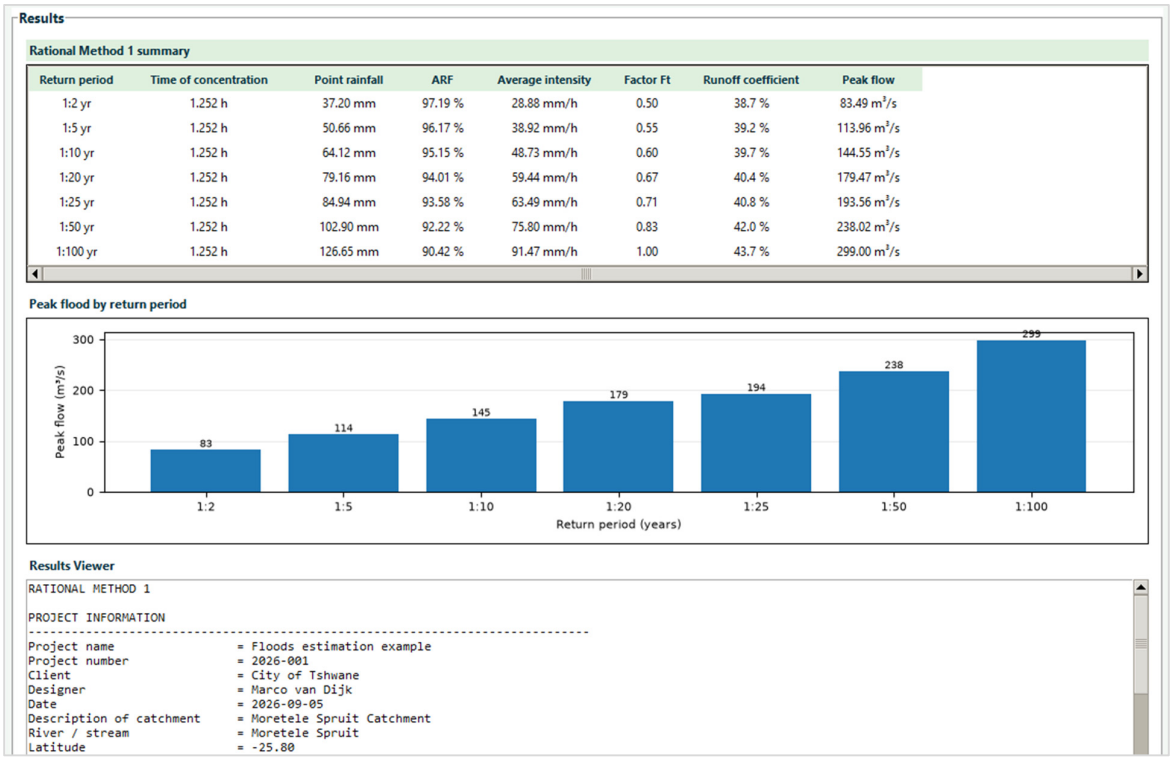


Figure 12-7: Rational method 1 results table, graphical output and results viewer

12.5 Rational Method 2

The ***Rational 2*** tab shown in **Figure 12-8**, provides a detailed implementation of the Rational Method for estimating peak design flood discharges for selected return periods. The method combines catchment characteristics, design rainfall, area distribution and runoff characteristics to determine the design peak flow.

The tab allows the catchment to be represented as a combination of rural, urban and lake areas. Rural and urban runoff coefficients are determined from the characteristics specified by the user, while a separate coefficient is provided for lake areas. This allows the overall runoff coefficient to reflect the different runoff responses occurring within a mixed catchment.

Multiple return periods can be analysed simultaneously. The resulting peak flows are presented in a summary table and graph, with detailed calculation information provided in the *Results Viewer*.

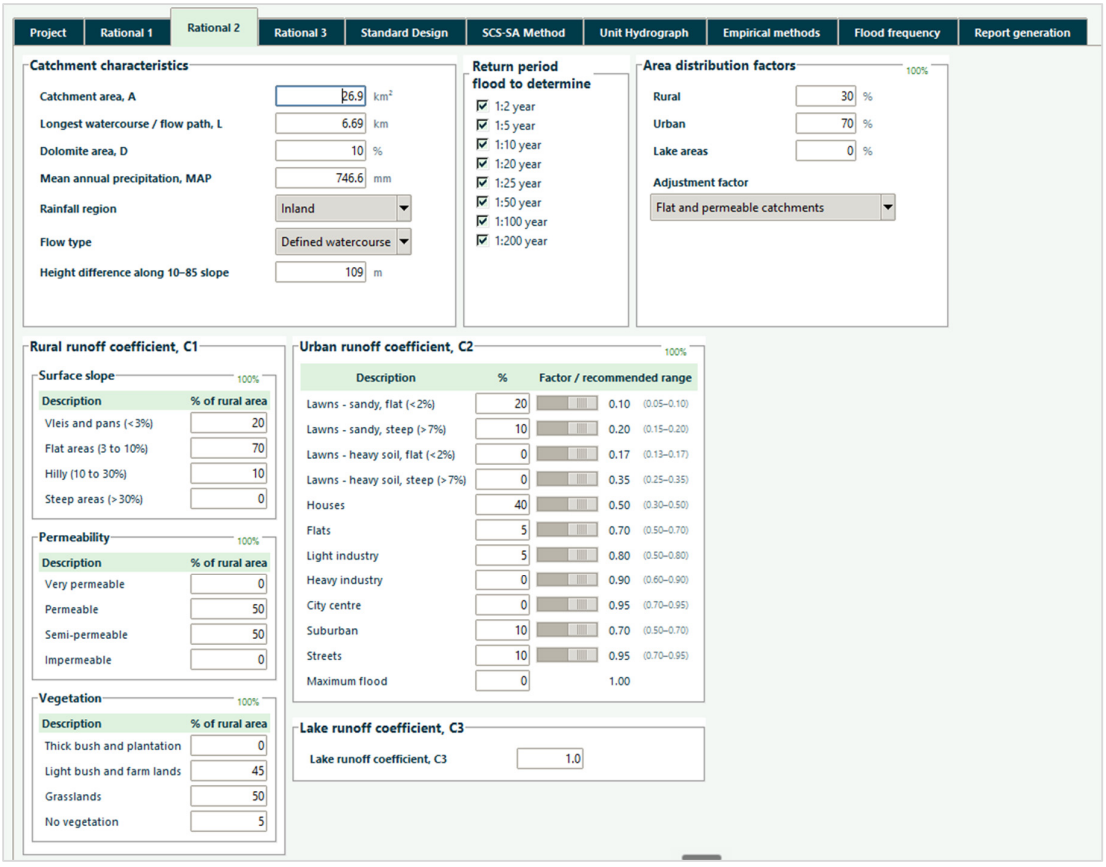


Figure 12-8: Flood Estimation - Rational method 2 tab

12.5.1 Catchment characteristics

The Catchment characteristics section, **Table 12-5**, defines the principal physical and hydrological properties required for the Rational Method 2 calculation.

Table 12-5: Catchment characteristics data input – RM2

Input	Description
Catchment area, A	Total contributing catchment area in km².
Longest watercourse / flow path, L	Length of the longest principal drainage path through the catchment, expressed in km.
Dolomite area, D	Percentage of the catchment underlain by dolomitic conditions.
Mean annual precipitation, MAP	Mean annual precipitation for the catchment, expressed in mm.
Rainfall region	Specifies the applicable rainfall region used in the calculation. This could be set as *Inland* or *Coastal.*
Flow type	Defines the nature of the principal drainage path. Select *Defined watercourse* or *Overland flow*
Height difference along 10–85 slope	Elevation difference along the 10–85% portion of the principal flow path, used in determining the catchment response and time of concentration in meters.

The user should enter values representative of the catchment being assessed. Particular care should be taken when determining the longest flow path and associated elevation difference, as these parameters influence the calculated time of concentration and consequently the rainfall intensity applied in the flood calculation.

12.5.2 Return periods

The Return period flood to determine section, see **Figure 12-8**, allows one or more design return periods to be selected for simultaneous calculation.

The available standard return periods shown are 1*:2, 1:5, 1:10, 1:20, 1:25, 1:50, 1:100* and *1:200* years. Only the selected return periods are included in the calculation and reported in the results.

Selecting several return periods is useful for developing a design-flood relationship across a range of recurrence intervals and for comparing flood magnitudes required for different levels of infrastructure design.

12.5.3 Area distribution factors

The catchment is divided between three principal land-area categories:

Rural represents the proportion of the catchment treated using the rural runoff coefficient, *Urban* represents the proportion treated using the urban runoff coefficient, and *Lake areas* represents open-water areas treated using the lake runoff coefficient.

The percentages should collectively represent 100% of the catchment area. The percentage indicator displayed above the input fields (top right corner) provides a convenient check of the entered area distribution.

An *Adjustment factor* can also be selected to account for the applicable catchment condition. The user can select between *Steep and impermeable catchments* or *Flat and permeable catchments* from the drop-down list.

12.5.4 Rural runoff coefficient, C1

The *Rural runoff coefficient (C1)* is determined from the characteristics of the rural portion of the catchment as shown in **Figure 12-9**. The user describes the rural catchment using three groups of characteristics: surface slope, permeability and vegetation.

For each group, the percentage distribution should total 100% of the rural area.

For *Surface slope*, the available classifications are:

- Vleis and pans (<3%)
- Flat areas (3 to 10%)

- Hilly (10 to 30%)
- Steep areas (>30%)

For *Permeability*, the rural area is divided between:

- Very permeable
- Permeable
- Semi-permeable
- Impermeable

For *Vegetation*, the available classifications include:

- Thick bush and plantation
- Light bush and farm lands
- Grasslands
- No vegetation

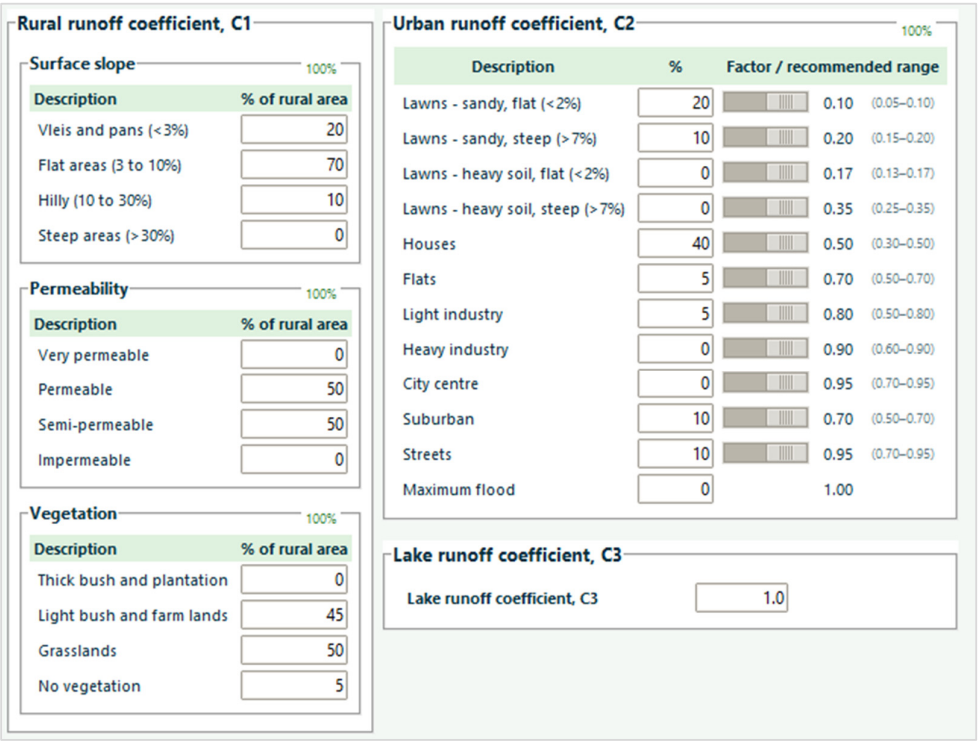


Figure 12-9: Runoff coefficients RM2

The percentage distributions entered for these characteristics are used by **GHI HydroSuite** in determining the representative rural runoff response.

12.5.5 Urban runoff coefficient, C2

The *Urban runoff coefficient (C2)* represents runoff from the urbanised portion of the catchment. The user specifies the percentage of the urban area associated with the different surface and development types, as shown in **Figure 12-9**.

Available classifications include lawns with different soil and slope conditions, houses, flats, light and heavy industry, city centre, suburban areas, streets and maximum-flood conditions.

Each classification is associated with a runoff factor and a displayed recommended range. The factor can be adjusted within the interface to represent the particular characteristics of the catchment by moving the horizontal bar.

The percentage allocations should collectively represent 100% of the urban area. The resulting urban coefficient is determined from the combination of the selected land-use proportions and runoff factors.

12.5.6 Lake runoff coefficient, C3

The *Lake runoff coefficient (C3)* is applied to the portion of the catchment classified as lake or open-water area. A separate coefficient can be specified directly by the user, as shown in **Figure 12-9**.

Where the catchment contains no lake area, the area allocation to this category is set to zero and consequently does not contribute to the combined catchment runoff coefficient.

12.5.7 Rainfall information

A distinguishing feature of Rational Method 2 is the use of TR102 rainfall station data (Adamson, 1972). Rainfall information can either be entered manually or obtained from the rainfall-station database using the integrated Station Selector.

The *Rainfall information* section contains the rainfall parameters required for the Rational Method 2 calculation. The information may be entered manually or automatically populated by selecting a rainfall station using the Station Selector.

The rainfall information includes the station identification and location, mean annual precipitation, thunder-day information and rainfall depths for a range of storm durations and return periods, see **Figure 12-10** and **Table 12-6**.

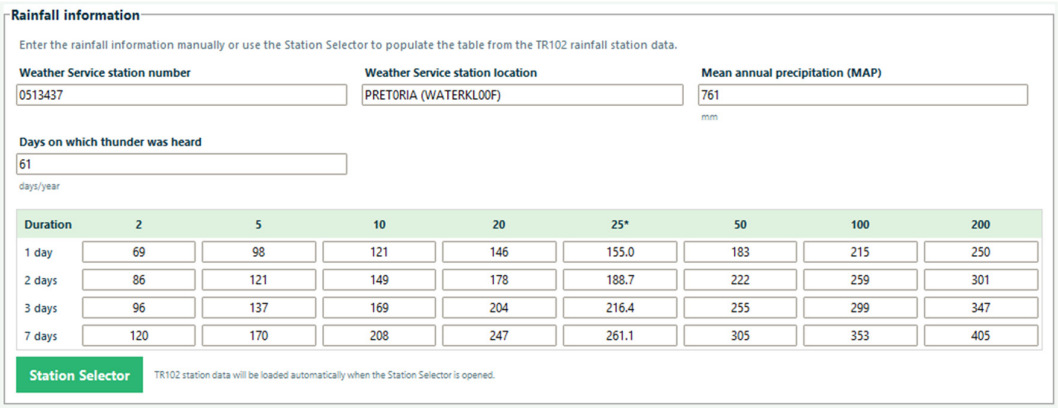


Figure 12-10: Rainfall information RM2

Table 12-6: Rainfall information input – RM2

Input	Description
Weather Station number	Identification number of the selected TR102 rainfall station.
Weather Service station location	Name or location associated with the rainfall station.
Mean annual precipitation (MAP)	Mean annual precipitation associated with the selected station, expressed in mm.
Days on which thunder was heard	Average number of thunder days per year associated with the rainfall station.
Duration	Storm duration associated with each row of rainfall data.
Rainfall values	Rainfall depth in mm for the respective storm duration and return period.
Station Selector	Click Station Selector button to open the TR102 Rainfall Station Data screen from which a rainfall station can be searched for and selected.

The rainfall table contains design rainfall depths for 1-, 2-, 3- and 7-day durations and the available return periods. These rainfall depths form the rainfall information are used by the Rational Method 2 calculation.

The 1:25-year rainfall values are identified separately because these values are interpolated within the rainfall dataset.

TR102 Rainfall Station Selector

Selecting *Station Selector* opens the TR102 Rainfall Station Data screen, see **Figure 12-11**. This interface provides access to the rainfall-station database and allows an appropriate station to be identified using its station number or name, geographic coordinates, the station list or the interactive map.

The currently selected station is highlighted in the station list and on the map. Detailed rainfall information for the selected station is displayed on the right-hand side of the screen before the station is transferred to the Rational Method 2 analysis.

The Station Selector therefore provides both a search facility and a spatial means of reviewing the location of available rainfall stations relative to the catchment being analysed.

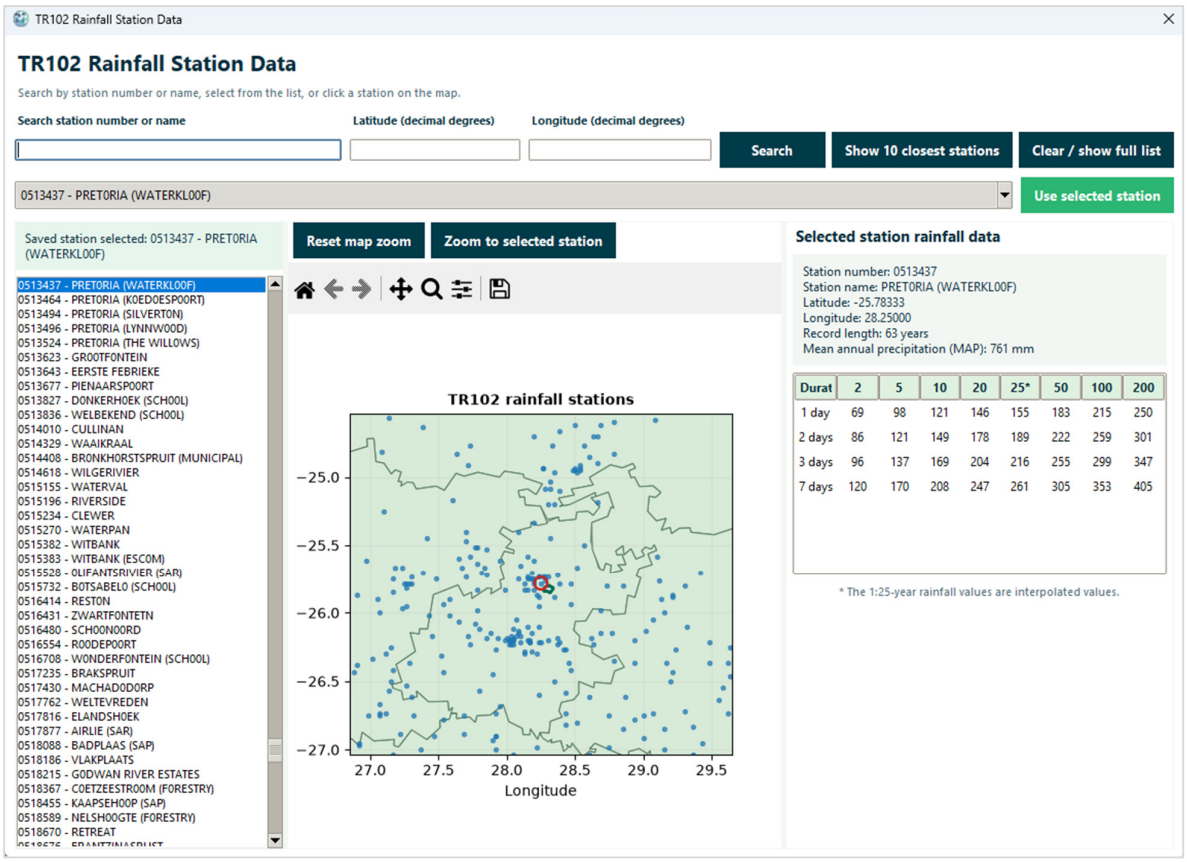


Figure 12-11: TR102 Rainfall station data screen

Searching for a rainfall station

Several methods are available for identifying a suitable rainfall station.

- The user can enter a station number or station name (or part thereof) in the search field and select *Search*, see example of the search results in **Figure 12-12**. Alternatively, *latitude* and *longitude* coordinates can be entered to assist with identifying stations close to a particular location.
- The *Show 10 closest stations* function identifies the ten rainfall stations closest to the entered coordinates. This can be particularly useful when the catchment coordinates are known but the most appropriate TR102 station has not yet been identified.
- The station can also be selected directly from the station list or spatially from the map.

The principal controls are summarised below in **Table 12-7**.

Table 12-7: Controls on TR102 Rainfall Station Data screen

Control	Function
Search station number or name	Searches the station database using a station number or station name.
Latitude / Longitude	Specifies geographic coordinates that can be used when searching for nearby rainfall stations.

Control	Function
Search	Performs the station search using the entered search information.
Show 10 closest stations	Displays the ten stations closest to the specified geographic coordinates.
Clear / show full list	Clears the current search and restores the complete station list.
Station list	Displays available TR102 stations and allows a station to be selected directly.
Map	Displays the spatial distribution of rainfall stations and allows stations to be reviewed geographically. In addition, it also shows the catchment area boundary if that was set on the Flood Estimation – Project tab.
Reset map zoom	Returns the map to its default viewing extent.
Zoom to selected station	Centres and enlarges the map around the currently selected station.
Use selected station	Transfers the selected station and its associated rainfall information to the Rational Method 2 input screen.

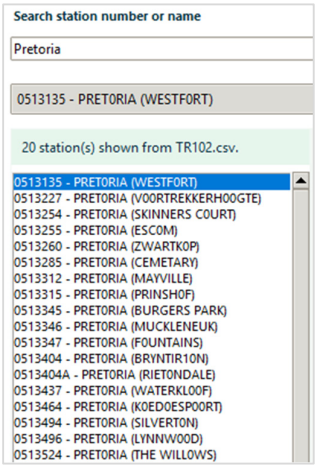


Figure 12-12: Search on station name

Interactive rainfall-station map

The map provides a geographic representation of the available TR102 rainfall stations. Individual stations are represented spatially, allowing their positions relative to the site or catchment to be assessed.

The standard map controls allow the user to pan, zoom and navigate within the map. When a station is selected, its location is identified on the map and its associated information is displayed in the Selected station rainfall data panel.

Where a catchment location is known, the map and closest-station search can be used together to assist in identifying rainfall stations located near the study area. The selection of the most appropriate rainfall station nevertheless remains an engineering decision and should consider the representativeness of the station for the catchment rather than distance alone.

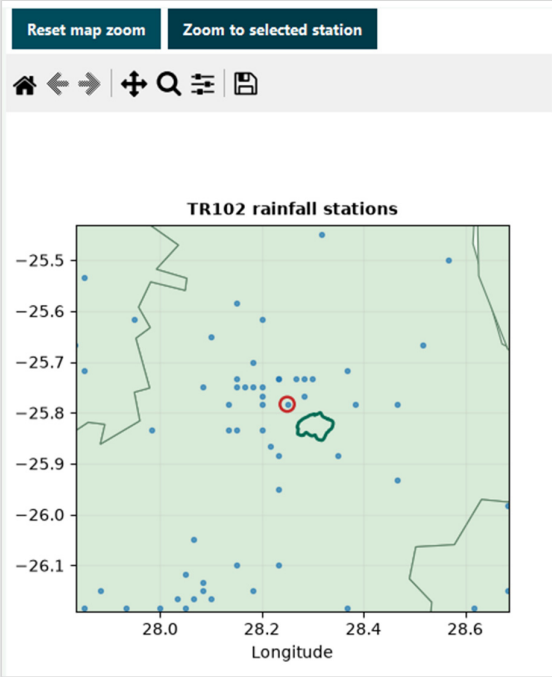


Figure 12-13: Station selector map

Spatial Viewer Controls

The toolbar located above the TR102 Rainfall Stations Spatial Viewer provides standard controls for navigating, adjusting and exporting the displayed map, Table 9 16.

Table 12-8: TR102 Rainfall Stations Spatial Viewer Navigating Controls

Control		Description
Home		Restores the Spatial Viewer to its original or default map extent.
Back		Returns to the previous map view or extent. This is useful after zooming or panning to another location.
Forward		Returns to the next map view after the Back function has been used.
Pan		Allows the map to be moved horizontally or vertically. Select the tool and drag the map to reposition the displayed area.
Configure subplots		Opens the plot-layout adjustment controls. This is primarily a standard plotting function and will generally not be required during normal HydroSuite operation.
Save		Saves the current Spatial Viewer display as an image file.
Zoom		Allows a selected portion of the map to be enlarged. Select the tool and define the area of interest on the map.

The Spatial Viewer toolbar provides standard graphical navigation functions. The separate *Reset Map* button provided by GHI HydroSuite restores the viewer to the full spatial extent relevant to the current rainfall analysis. The *Zoom to selected station* button enlarges that portion of the map.

Selected station rainfall data

The Selected station rainfall data panel, shown in **Figure 12-14**, provides a summary of the currently selected rainfall station before it is transferred to the Rational Method 2 calculation.

The displayed information includes:

- station number and station name;
- latitude and longitude;
- available record length;
- mean annual precipitation (MAP); and
- design rainfall depths for the available durations and return periods.

This allows the user to inspect the station information before selecting *Use selected station*.

Once the station is accepted, its applicable information is automatically transferred to the Rainfall information section of the Rational Method 2 tab. The user can therefore verify the populated values before performing the flood calculation.

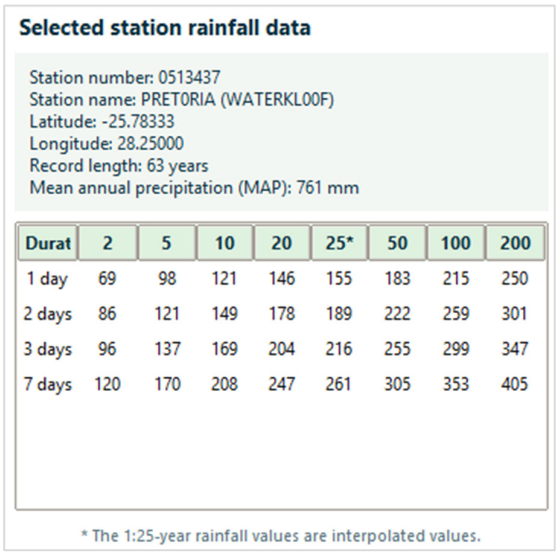


Figure 12-14: Selected station rainfall data

Manual rainfall data entry

The *Station Selector* is provided for convenience, but the rainfall information can also be entered manually. This allows Rational Method 2 to be applied where rainfall information has been obtained independently or where the user wishes to apply alternative rainfall values.

When rainfall data are entered manually, the user should ensure that the station information, MAP, thunder-day information and rainfall depths are appropriate for the catchment and are entered using the required units.

12.5.8 Rational Method 2 results

After the flood-estimation analysis has been calculated, by clicking on the *Calculate* button, the Rational Method 2 summary presents the principal calculation results for each selected return period, as shown in **Figure 12-15**Figure 12-15.

The calculated results are presented for each selected return period and provide the intermediate rainfall and catchment parameters together with the resulting design peak discharge. This enables the user to review the basis of the calculation rather than relying only on the final flood estimate.

As with Rational Method 1, the calculated peak floods can be compared across the selected return periods and against the results obtained using the other flood-estimation methods available in GHI HydroSuite.

The results table includes the following results (**Table 12-9**):

Table 12-9: Rational method 2 results table

Result	Description
Return period	Recurrence interval for the calculated design flood.
Time of concentration	Calculated catchment response time used to determine the applicable design rainfall.
Point rainfall	Design point rainfall corresponding to the selected return period and applicable storm duration, determined from the TR102 rainfall data or, where applicable, using the Modified Hershfield method.
ARF	Area Reduction Factor applied to convert point rainfall to a rainfall value representative of the catchment area.
Average intensity	Average rainfall intensity corresponding to the applicable rainfall depth and duration.
Factor Ft	Return-period-related factor applied within the Rational Method 2 calculation.
Runoff coefficient	Calculated representative runoff coefficient for the catchment.
Peak flow	Estimated design peak discharge for the selected return period, expressed in m^3/s.

The summary allows the user to trace how the rainfall and catchment parameters change with return period rather than presenting only the final peak-flow estimate.

The *Peak flood by return period* graph provides a graphical summary of the calculated design flood peaks. Each selected return period is shown on the horizontal axis, with the corresponding peak discharge in m^3/s on the vertical axis.

The graph provides a convenient visual comparison of the increase in estimated design flood magnitude with increasing return period and can be used together with the numerical summary when reviewing the Rational Method 2 results.

The *Results Viewer* provides a detailed text-based record of the Rational Method 2 analysis. It includes the relevant project and catchment information together with the calculation inputs and results generated during the analysis. The *Results Viewer* complements the summary table and graph by providing a more detailed record that can be reviewed, copied and incorporated into supporting calculations or engineering documentation.

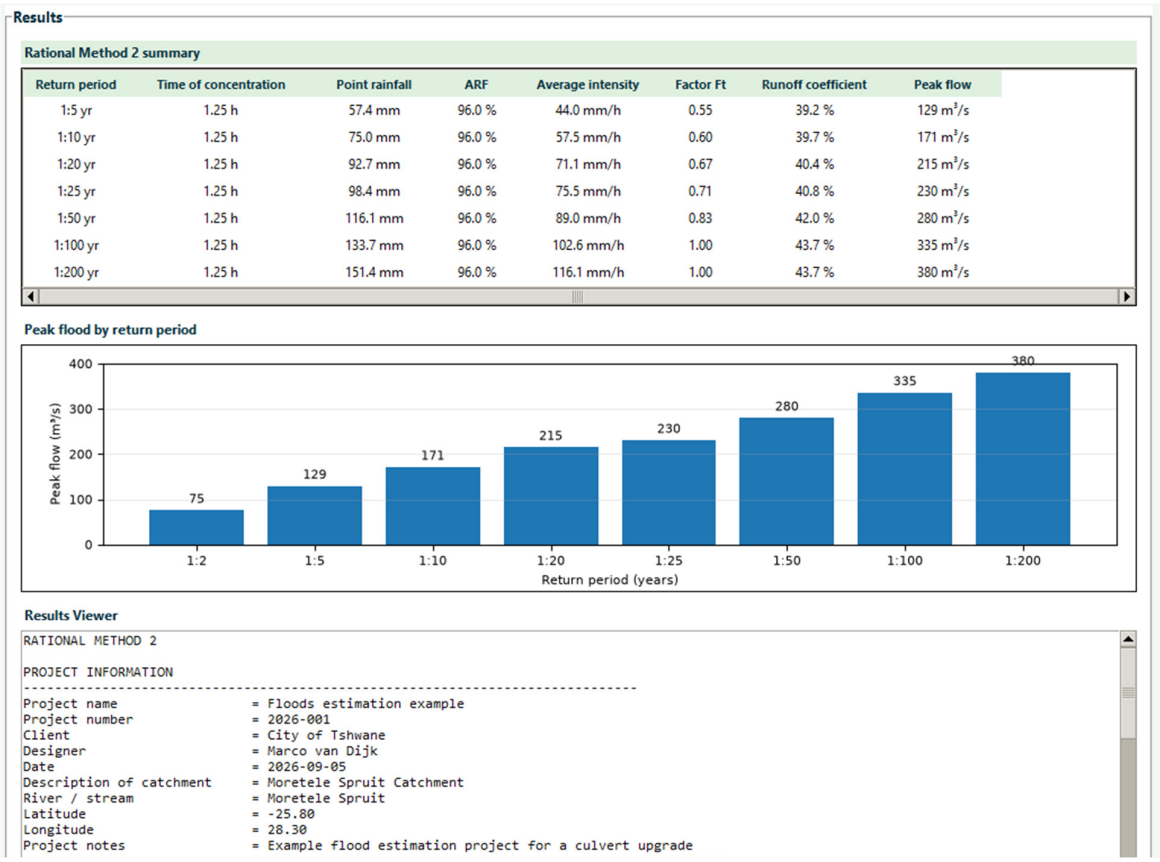


Figure 12-15: Rational method 2 results table, graphical output and results viewer

12.6 Rational Method 3

The ***Rational 3*** tab shown in **Figure 12-16**, provides a detailed implementation of the Rational Method for estimating peak design flood discharges for selected return periods. The method combines catchment characteristics, design rainfall, area distribution and runoff characteristics to determine the design peak flow.

The tab allows the catchment to be represented as a combination of rural, urban and lake areas. Rural and urban runoff coefficients are determined from the characteristics specified by the user, while a separate coefficient is provided for lake areas. This allows the overall runoff coefficient to reflect the different runoff responses occurring within a mixed catchment.

Multiple return periods can be analysed simultaneously. The resulting peak flows are presented in a summary table and graph, with detailed calculation information provided in the *Results Viewer*.

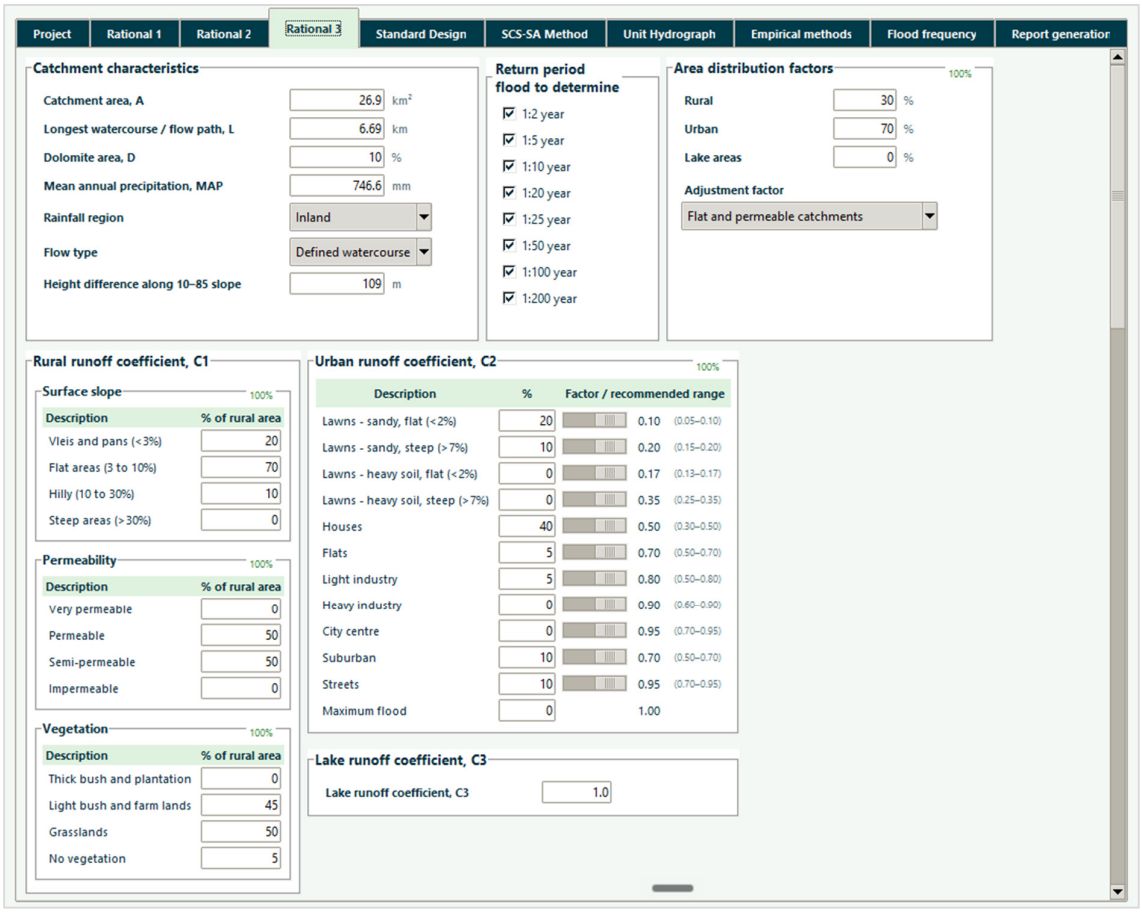


Figure 12-16: Flood Estimation - Rational method 3 tab

12.6.1 Catchment characteristics

The Catchment characteristics section defines the principal physical and hydrological properties required for the Rational Method 3 calculation.

Table 12-10: Catchment characteristics data input RM3

Input	Description
Catchment area, A	Total contributing catchment area in km².
Longest watercourse / flow path, L	Length of the longest principal drainage path through the catchment, expressed in km.
Dolomite area, D	Percentage of the catchment underlain by dolomitic conditions.
Mean annual precipitation, MAP	Mean annual precipitation for the catchment, expressed in mm.
Rainfall region	Specifies the applicable rainfall region used in the calculation. This could be set as *Inland* or *Coastal.*

Input	Description
Flow type	Defines the nature of the principal drainage path. Select *Defined watercourse* or *Overland flow*
Height difference along 10–85 slope	Elevation difference along the 10–85% portion of the principal flow path, used in determining the catchment response and time of concentration in meters.

The user should enter values representative of the catchment being assessed. Particular care should be taken when determining the longest flow path and associated elevation difference, as these parameters influence the calculated time of concentration and consequently the rainfall intensity applied in the flood calculation.

12.6.2 Return periods

The Return period flood to determine section, see **Figure 12-16**, allows one or more design return periods to be selected for simultaneous calculation.

The available standard return periods shown are 1*:2, 1:5, 1:10, 1:20, 1:25, 1:50, 1:100* and *1:200* years. Only the selected return periods are included in the calculation and reported in the results.

Selecting several return periods is useful for developing a design-flood relationship across a range of recurrence intervals and for comparing flood magnitudes required for different levels of infrastructure design.

12.6.3 Area distribution factors

The catchment is divided between three principal land-area categories:

Rural represents the proportion of the catchment treated using the rural runoff coefficient, *Urban* represents the proportion treated using the urban runoff coefficient, and *Lake areas* represents open-water areas treated using the lake runoff coefficient as shown in **Figure 12-16**.

The percentages should collectively represent 100% of the catchment area. The percentage indicator displayed above the input fields (top right corner) provides a convenient check of the entered area distribution.

An *Adjustment factor* can also be selected to account for the applicable catchment condition. The user can select between *Steep and impermeable catchments* or *Flat and permeable catchments* from the drop-down list.

12.6.4 Rural runoff coefficient, C1

The *Rural runoff coefficient (C1)* is determined from the characteristics of the rural portion of the catchment as shown in **Figure 12-17**.

The user describes the rural catchment using three groups of characteristics: surface slope, permeability and vegetation.

For each group, the percentage distribution should total 100% of the rural area.

For *Surface slope*, the available classifications are:

- Vleis and pans (<3%)
- Flat areas (3 to 10%)
- Hilly (10 to 30%)
- Steep areas (>30%)

For *Permeability*, the rural area is divided between:

- Very permeable
- Permeable
- Semi-permeable
- Impermeable

For *Vegetation*, the available classifications include:

- Thick bush and plantation
- Light bush and farm lands
- Grasslands
- No vegetation

The percentage distributions entered for these characteristics are used by **GHI HydroSuite** in determining the representative rural runoff response.

12.6.5 Urban runoff coefficient, C2

The *Urban runoff coefficient (C2)* represents runoff from the urbanised portion of the catchment. The user specifies the percentage of the urban area associated with the different surface and development types, as shown in **Figure 12-17**.

Available classifications include lawns with different soil and slope conditions, houses, flats, light and heavy industry, city centre, suburban areas, streets and maximum-flood conditions.

Each classification is associated with a runoff factor and a displayed recommended range. The factor can be adjusted within the interface to represent the particular characteristics of the catchment by moving the horizontal bar.

The percentage allocations should collectively represent 100% of the urban area. The resulting urban coefficient is determined from the combination of the selected land-use proportions and runoff factors.

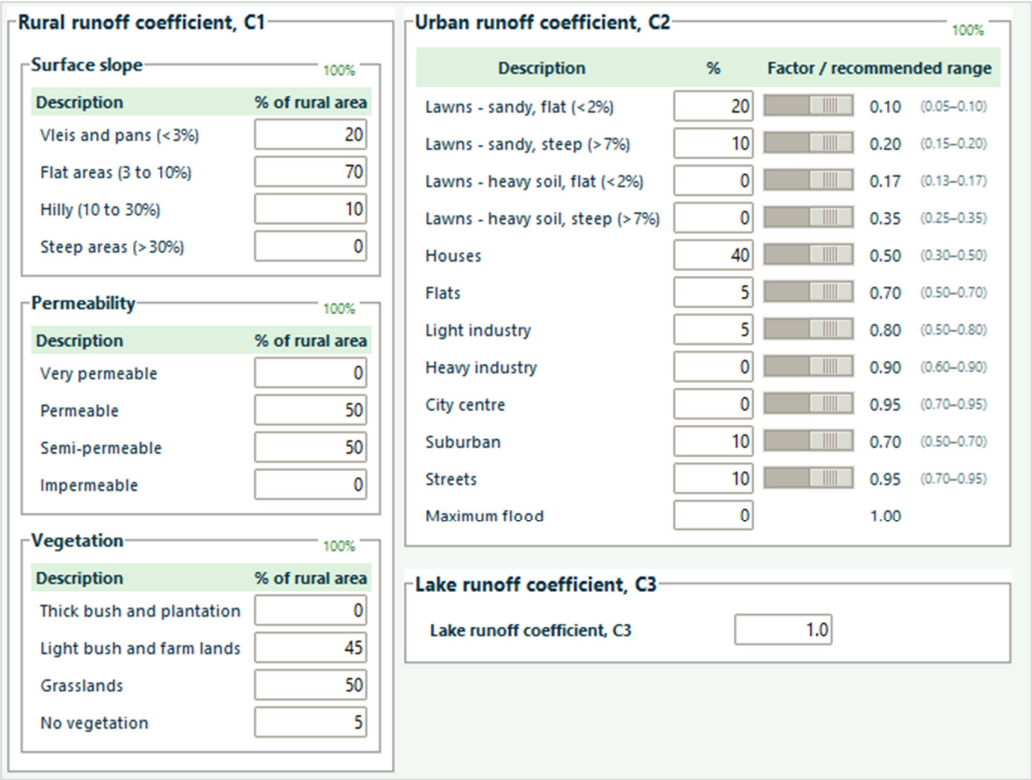


Figure 12-17: Runoff coefficients RM3

12.6.6 Lake runoff coefficient, C3

The *Lake runoff coefficient (C3)* is applied to the portion of the catchment classified as lake or open-water area. A separate coefficient can be specified directly by the user, as shown in **Figure 12-17**.

Where the catchment contains no lake area, the area allocation to this category is set to zero and consequently does not contribute to the combined catchment runoff coefficient.

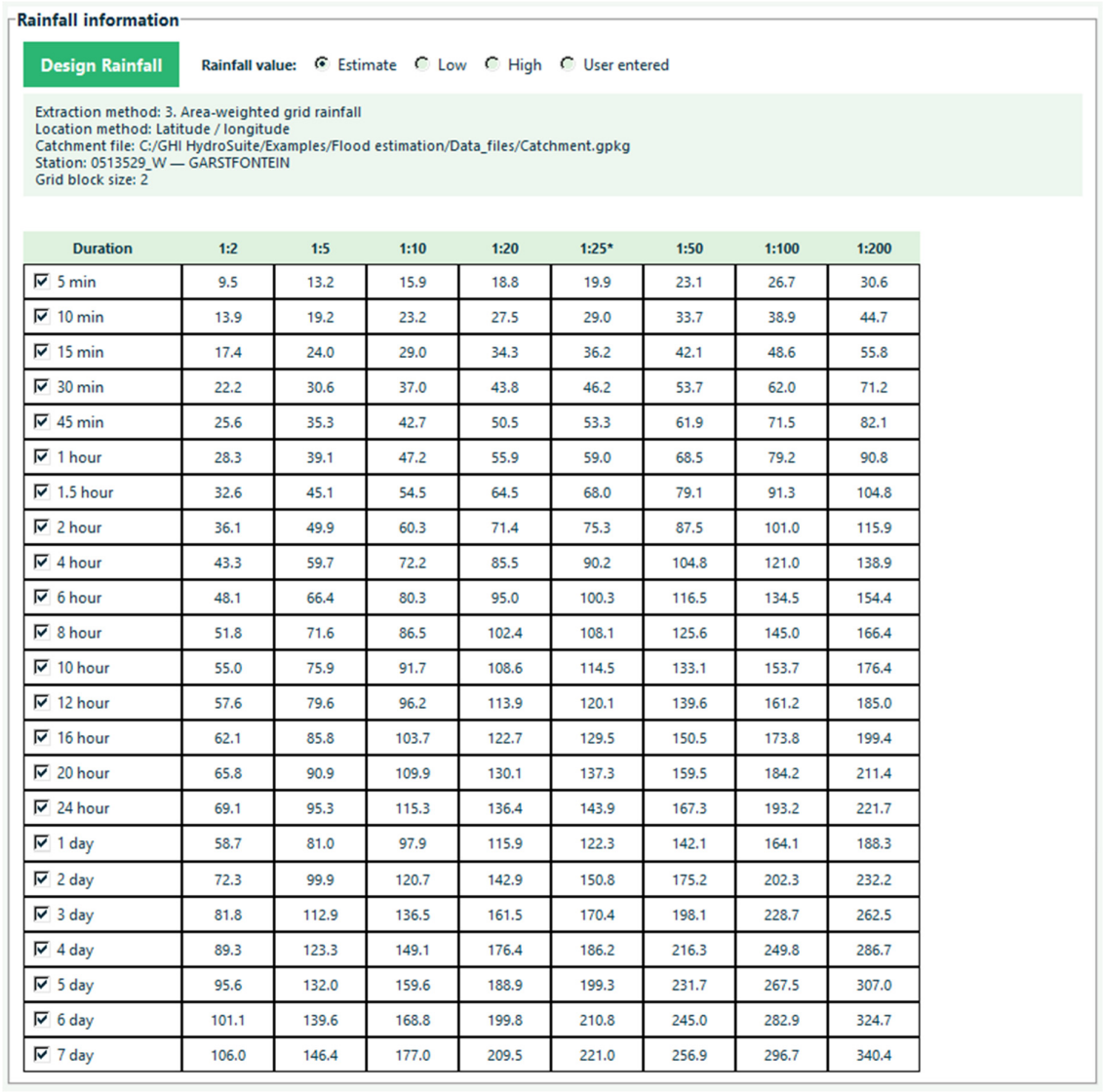
12.6.7 Rainfall information

Rational Method 3 uses design rainfall depths obtained from the Design Rainfall functionality in **GHI HydroSuite**. The rainfall information is provided for a range of storm durations and return periods and is used to determine the rainfall intensity corresponding to the calculated time of concentration of the catchment.

The user can select *Design Rainfall* button, as shown in **Figure 12-18**, to obtain or update the rainfall information. The rainfall dataset displayed in Rational Method 3 reflects the most recently completed Design Rainfall analysis and includes information on the extraction method, location or catchment used, rainfall station where applicable, and grid characteristics associated with the analysis.

A detailed description of the Design Rainfall extraction procedure is described in **Section 9.5**.

When a user has navigated from the *Rational Method 3 Flood Estimation* screen a *Return to Flood Estimation* button will be visible on the ***Design Rainfall*** tab that will navigate the user back to the Flood Estimation screen.



Rainfall information

Design Rainfall | Rainfall value: (•) Estimate ( ) Low ( ) High ( ) User entered

Extraction method: 3. Area-weighted grid rainfall
Location method: Latitude / longitude
Catchment file: C:/GHI HydroSuite/Examples/Flood estimation/Data_files/Catchment.gpkg
Station: 0513529_W — GARSTFONTEIN
Grid block size: 2

Duration	1:2	1:5	1:10	1:20	1:25*	1:50	1:100	1:200
☑ 5 min	9.5	13.2	15.9	18.8	19.9	23.1	26.7	30.6
☑ 10 min	13.9	19.2	23.2	27.5	29.0	33.7	38.9	44.7
☑ 15 min	17.4	24.0	29.0	34.3	36.2	42.1	48.6	55.8
☑ 30 min	22.2	30.6	37.0	43.8	46.2	53.7	62.0	71.2
☑ 45 min	25.6	35.3	42.7	50.5	53.3	61.9	71.5	82.1
☑ 1 hour	28.3	39.1	47.2	55.9	59.0	68.5	79.2	90.8
☑ 1.5 hour	32.6	45.1	54.5	64.5	68.0	79.1	91.3	104.8
☑ 2 hour	36.1	49.9	60.3	71.4	75.3	87.5	101.0	115.9
☑ 4 hour	43.3	59.7	72.2	85.5	90.2	104.8	121.0	138.9
☑ 6 hour	48.1	66.4	80.3	95.0	100.3	116.5	134.5	154.4
☑ 8 hour	51.8	71.6	86.5	102.4	108.1	125.6	145.0	166.4
☑ 10 hour	55.0	75.9	91.7	108.6	114.5	133.1	153.7	176.4
☑ 12 hour	57.6	79.6	96.2	113.9	120.1	139.6	161.2	185.0
☑ 16 hour	62.1	85.8	103.7	122.7	129.5	150.5	173.8	199.4
☑ 20 hour	65.8	90.9	109.9	130.1	137.3	159.5	184.2	211.4
☑ 24 hour	69.1	95.3	115.3	136.4	143.9	167.3	193.2	221.7
☑ 1 day	58.7	81.0	97.9	115.9	122.3	142.1	164.1	188.3
☑ 2 day	72.3	99.9	120.7	142.9	150.8	175.2	202.3	232.2
☑ 3 day	81.8	112.9	136.5	161.5	170.4	198.1	228.7	262.5
☑ 4 day	89.3	123.3	149.1	176.4	186.2	216.3	249.8	286.7
☑ 5 day	95.6	132.0	159.6	188.9	199.3	231.7	267.5	307.0
☑ 6 day	101.1	139.6	168.8	199.8	210.8	245.0	282.9	324.7
☑ 7 day	106.0	146.4	177.0	209.5	221.0	256.9	296.7	340.4

Figure 12-18: Rainfall information RM3

Depending on the selected *Design Rainfall* method, rainfall may be determined for a single point or spatially across a catchment. The available approaches include Point Rainfall, Catchment Average Grid Rainfall, Area-Weighted Grid Rainfall and Thiessen Polygon Rainfall. Where a catchment-based method is used, the selected catchment boundary is used in determining the representative design rainfall.

The rainfall table displays design rainfall depths in millimetres for storm durations ranging from short-duration events in minutes and hours to multi-day events. Values are provided for the available return periods, allowing the appropriate rainfall depth to be selected for each design flood calculation.

Rainfall value

Where uncertainty limits are available in the Design Rainfall dataset, the user can select which rainfall estimate is to be applied, see **Table 12-11**:

Table 12-11: Rainfall value options

Option	Description
Estimate	Uses the central or best-estimate design rainfall values. This is the normal selection for design calculations.
Low	Uses the lower rainfall estimate associated with the selected Design Rainfall analysis.
High	Uses the upper rainfall estimate associated with the selected Design Rainfall analysis.
User entered	Allows the user to specify or modify the rainfall values manually for the Rational Method 3 calculation. Simply enter the values in each of the input boxes.

The *Low* and *High* options provide a convenient means of investigating the sensitivity of calculated peak flows to uncertainty in the design rainfall estimates.

Design rainfall information

A summary above the rainfall table identifies the source of the currently loaded rainfall information, as shown in **Figure 12-19**. Depending on the method used, this may include the extraction method, location method, catchment file, rainfall station and grid block size. This information provides traceability between the rainfall dataset used in the Rational Method calculation and the Design Rainfall analysis from which it was obtained.



Figure 12-19: Summary of rainfall information

In the example shown, the rainfall was determined using the Area-Weighted Grid Rainfall method for the selected catchment boundary.

Storm durations and return periods

The rainfall table, **Figure 12-19** presents the available design rainfall depths according to storm duration and return period. Individual storm durations can be selected or deselected using the check boxes alongside the table.

The available rainfall durations extend from 5 minutes to 7 days, while the table provides rainfall depths for return periods from 1:2 years to 1:200 years, including the interpolated 1:25-year rainfall values.

For the Rational Method calculation, HydroSuite uses the rainfall information corresponding to the required return period and the storm duration associated with the catchment response. The resulting rainfall depth is subsequently converted to an appropriate rainfall intensity for calculation of the design peak flow.

Note: The Design Rainfall functionality and the different methods available for obtaining point and catchment rainfall are described in detail in **Section 9.5 - Design Rainfall**. This section therefore focuses on the use of these rainfall results within Rational Method 3 rather than repeating the rainfall extraction procedures.

12.6.8 Rational Method 3 results

After the flood-estimation analysis has been calculated, by clicking on the *Calculate* button, the Rational Method 3 summary presents the principal calculation results for each selected return period, as shown in **Figure 12-20**.

The results table includes the following results (**Table 12-12**):

Table 12-12: Rational method 3 results table

Result	Description
Return period	Recurrence interval for the calculated design flood.
Time of concentration	Calculated catchment response time used to determine the applicable design rainfall.
Point rainfall	Design rainfall (in mm) corresponding to the selected return period and applicable storm duration, obtained from the South African Design Rainfall database, (Lynch, 2004) using the selected Design Rainfall extraction method. The Estimate, Low or High rainfall value is applied according to the option selected by the user.
ARF	Area Reduction Factor applied to convert point rainfall to a rainfall value representative of the catchment area.
Average intensity	Average rainfall intensity corresponding to the applicable rainfall depth and duration (mm/h).
Factor Ft	Return-period-related factor applied within the Rational Method 3 calculation.
Runoff coefficient	Calculated representative runoff coefficient for the catchment (%).
Peak flow	Estimated design peak discharge for the selected return period, expressed in m^3/s.

The summary allows the user to trace how the rainfall and catchment parameters change with return period rather than presenting only the final peak-flow estimate.

The *Peak flood by return period* graph provides a graphical summary of the calculated design flood peaks. Each selected return period is shown on the horizontal axis, with the corresponding peak discharge in m^3/s on the vertical axis.

The graph provides a convenient visual comparison of the increase in estimated design flood magnitude with increasing return period and can be used together with the numerical summary when reviewing the Rational Method 3 results.

The *Results Viewer* provides a detailed text-based record of the Rational Method 3 analysis. It includes the relevant project and catchment information together with the calculation inputs and results generated during the analysis. The *Results Viewer* complements the summary table and graph by providing a more detailed record that can be reviewed, copied and incorporated into supporting calculations or engineering documentation.

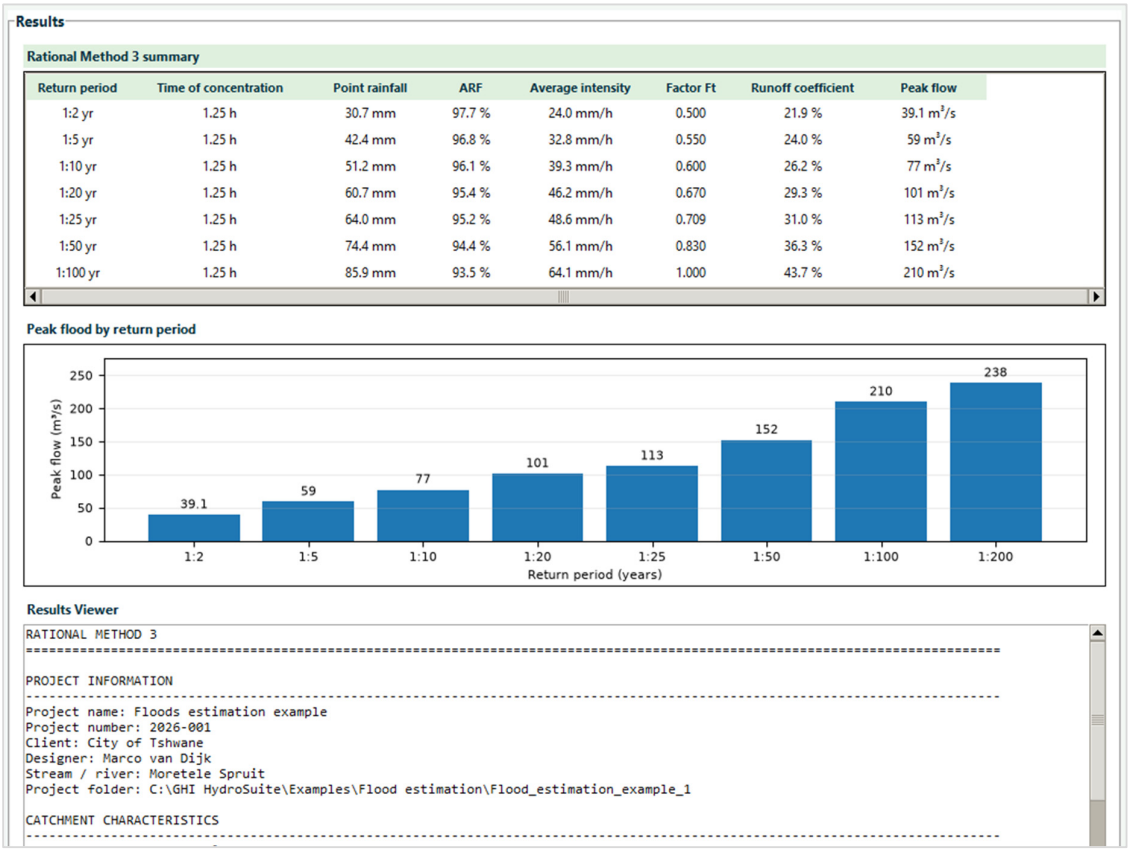


Figure 12-20: Rational method 3 results table, graphical output and results viewer

12.7 Standard Design Flood method

The Standard Design Flood (SDF) Method provides an alternative deterministic approach for estimating design peak discharges for a range of return periods. Within **GHI HydroSuite**, the method uses the principal physical characteristics of the catchment together with the applicable SDF basin number and design rainfall information to calculate the design flood peaks.

The method is particularly useful for comparing design flood estimates obtained using the Rational Methods and other flood-estimation procedures available in **GHI HydroSuite**. Results are calculated for the return periods selected by the user and are presented in both tabular and graphical form.

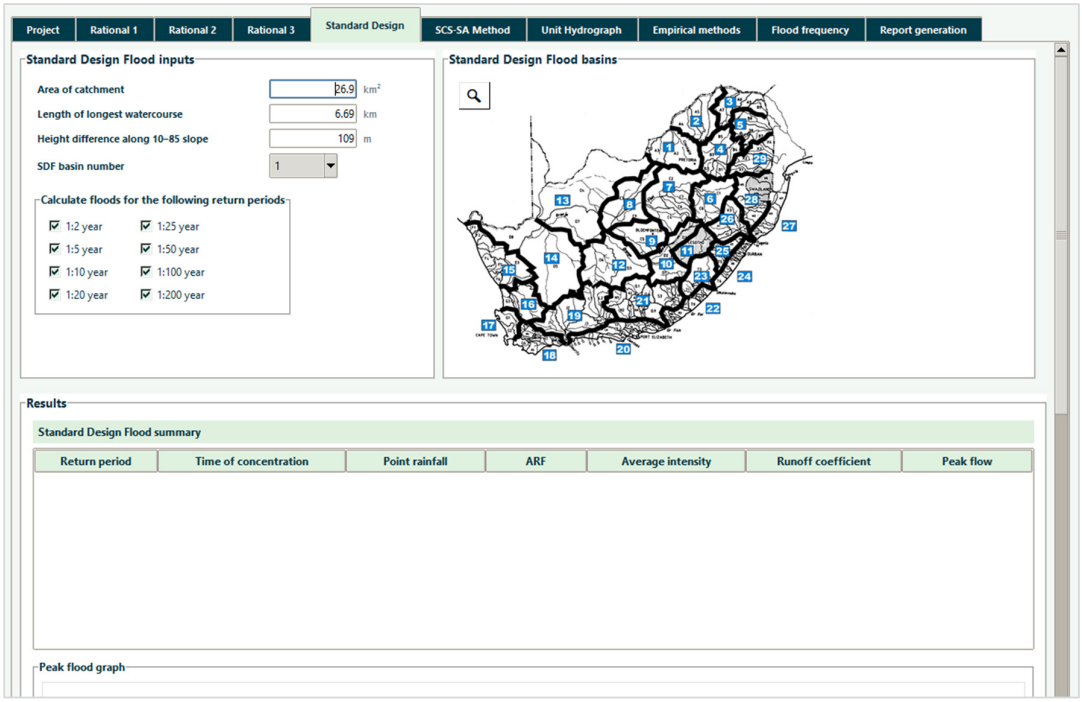


Figure 12-21: Flood Estimation – Standard Design Flood method tab

12.7.1 Standard Design Flood inputs

The ***Standard Design Flood*** tab is divided into an input panel, a Standard Design Flood basins map, and a Results section.

The principal input parameters are summarised below in **Table 12-13**.

Table 12-13: Standard Design Flood input parameters

Input	Description
Area of catchment	Specifies the contributing catchment area, A, in km².
Length of longest watercourse	Specifies the length of the longest watercourse or principal flow path, L, in km.
Height difference along 10–85 slope	Specifies the elevation difference along the 10–85% portion of the principal watercourse and is used in determining the catchment response characteristics in meters.
SDF basin number	Identifies the Standard Design Flood basin applicable to the catchment. The basin number is selected from the drop-down list with reference to the SDF basin map displayed alongside the input panel (1 – 29).
Return periods	Specifies the return periods for which design floods are to be calculated. Individual return periods can be selected or deselected as required.

The *Standard Design Flood basin map* displayed on the right-hand side of the tab provides a geographical reference for selecting the appropriate SDF basin. The map can be enlarged using the magnification control to assist with identifying the basin applicable to the project location.

12.7.2 Design rainfall

The Standard Design Flood calculation incorporates design rainfall corresponding to the selected return periods and the applicable storm duration. The calculated rainfall information is reported in the *Results Viewer* together with the other intermediate parameters used in the analysis.

The design rainfall output includes rainfall depths for the relevant durations and return periods, allowing the rainfall information used by the method to be reviewed as part of the calculation record.

12.7.3 Standard Design Flood results

Following calculation, the Standard Design Flood summary presents the principal calculation results for each selected return period, **Table 12-14**.

Table 12-14: Standard Design Flood method results table

Result	Description
Return period	Recurrence interval of the design flood event, expressed in years.
Time of concentration	Calculated catchment time of concentration used to establish the applicable design storm duration (hours).
Point rainfall	Design point rainfall (in mm) corresponding to the selected return period and calculated time of concentration. Short-duration rainfall is determined using the Modified Hershfield method, with interpolation between available rainfall durations where required.
ARF	Area Reduction Factor applied to the design point rainfall to account for the spatial reduction in average rainfall over the catchment. The factor is determined from the catchment area and applicable storm duration and is used to convert point rainfall to an equivalent catchment-average rainfall (%).
Average intensity	Average catchment rainfall intensity after application of the applicable rainfall depth, storm duration and area reduction (mm/h).
Factor Ft	Return-period-related factor applied within the SDF calculation.
Runoff coefficient	Return-period-dependent runoff coefficient used in the Standard Design Flood calculation (%).
Peak flow	Calculated design peak discharge, Q, in m^3/s for the specified return period.

The summary table enables the progression from the selected return period and rainfall information through to the resulting design peak flow to be readily reviewed.

A *Peak flood* graph is automatically generated below the results table. The graph presents the calculated peak discharge against return period, providing a quick visual indication of the increase in design flood magnitude with increasing recurrence interval.

The graphical output is useful for comparing the relative magnitude of the design events and identifying the overall trend in the calculated flood estimates. As with the other graphical outputs in GHI HydroSuite, the graph can subsequently be included in the project reporting outputs.

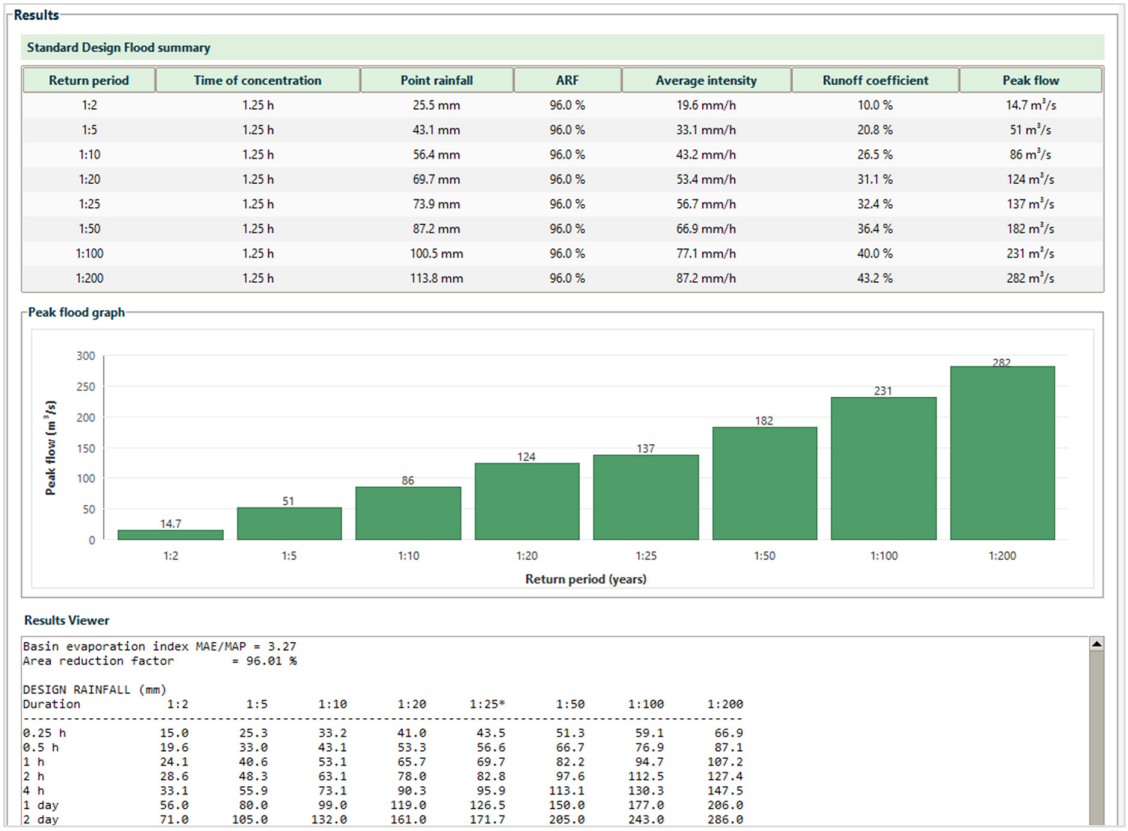


Figure 12-22: SDF method results table, graphical output and results viewer

The *Results Viewer* provides a more detailed text-based record of the Standard Design Flood calculation. It includes the relevant project and catchment information, design rainfall data, intermediate calculation parameters and calculated flood results.

This information supplements the summary table and provides a transparent record of the values used in the analysis. The information displayed in the Results Viewer can also be copied for use in other engineering documentation.

The *Standard Design Flood* results should be considered together with estimates obtained from the other applicable flood-estimation methods. Differences between methods are expected because the procedures represent catchment characteristics, rainfall and runoff response differently.

Where several methods are applicable, comparison of the calculated design floods provides an important basis for engineering judgement when selecting an appropriate design discharge. Particular attention should be given to the reliability of the catchment parameters, selection of the appropriate SDF basin, design rainfall information and the suitability of the method for the catchment being analysed.

12.8 SCS-SA method

The SCS-SA Method provides an event-based rainfall-runoff procedure for estimating stormflow volumes, peak discharges and design flood hydrographs. The method represents the catchment using one or more Hydrological Response Units (HRUs), allowing different combinations of soil group, land cover, treatment and stormflow potential to be represented within the same catchment.

The analysis combines the selected design rainfall with catchment response characteristics and the Curve Number (CN) approach. HydroSuite calculates the stormflow contribution from each HRU, combines these on an area-weighted basis and determines the resulting runoff volume and peak discharge for each selected return period. The ***SCS-SA Method*** tab is shown in **Figure 12-23**.

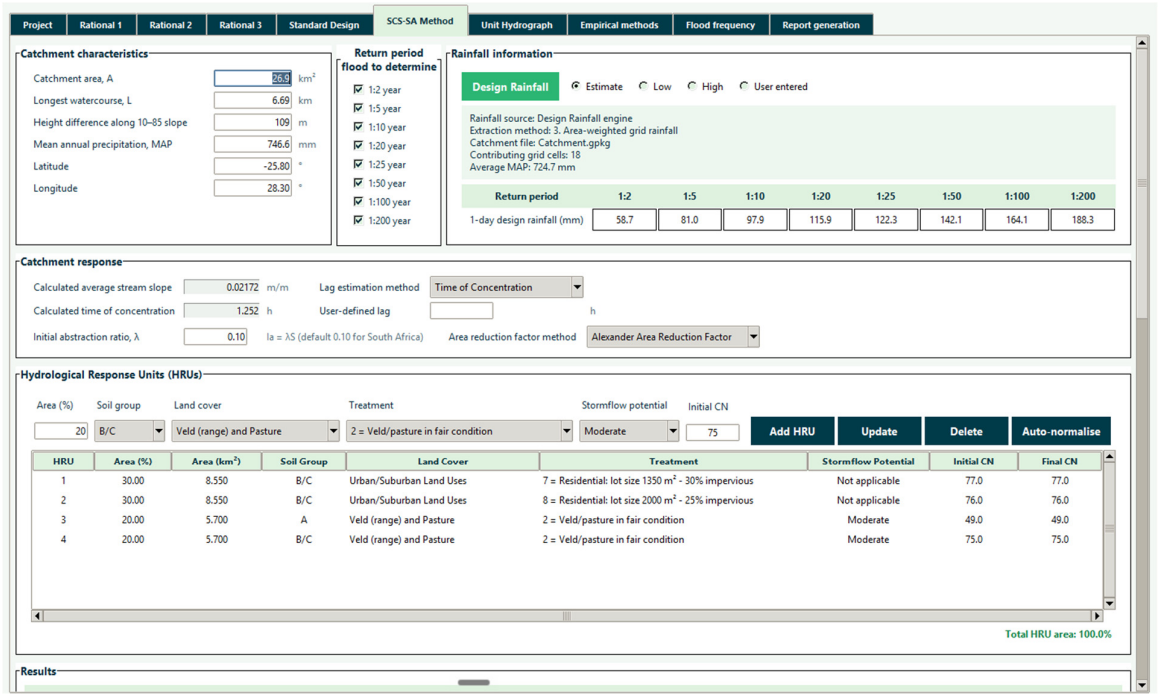


Figure 12-23: Flood Estimation - SCS-SA Method tab

12.8.1 Catchment characteristics

The Catchment characteristics section defines the basic physical and rainfall characteristics required for the SCS-SA analysis and are listed in **Table 12-15**. These parameters are also used in determining the catchment response time.

Table 12-15: SCS-SA Method catchment characteristic

Input	Description
Catchment area, A	Total contributing catchment area in km².
Longest watercourse, L	Length of the longest principal flow path through the catchment, in km.
Height difference along 10–85 slope	Difference in elevation difference between the 10% and 85% points along the longest watercourse. This is used together with the watercourse length to determine the representative stream slope, in meters.
Mean annual precipitation, MAP	Mean annual precipitation for the catchment, in mm.
Latitude / Longitude	Geographic coordinates representing the catchment location.

12.8.2 Return periods

The *Return period flood to determine* section allows one or more design return periods to be selected for simultaneous calculation.

The available standard return periods shown are 1:2, 1:5, 1:10, 1:20, 1:25, 1:50, 1:100 and 1:200 years. Only the selected return periods are included in the SCS-SA calculations, results tables, graphical outputs and generated report.

Selecting several return periods is useful for developing a design-flood relationship across a range of recurrence intervals and for comparing flood magnitudes required for different levels of infrastructure design.

12.8.3 Rainfall information

Design rainfall may be obtained directly from the integrated Design Rainfall functionality or entered manually. Where Design Rainfall results are available, the panel identifies the rainfall source, extraction method, catchment file, contributing grid cells and average MAP, as shown in .

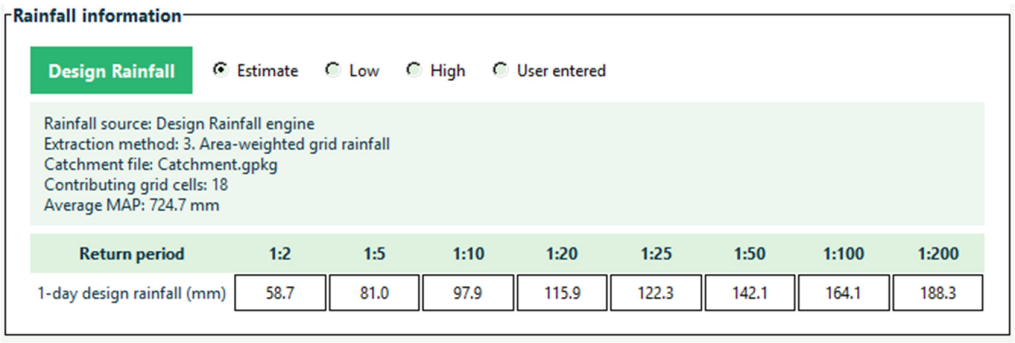


Figure 12-24: SCS-SA Method rainfall information

A detailed description of the Design Rainfall extraction procedure is described in **Section 9.5**.

When a user has navigated from the *SCS-SA Method Flood Estimation* screen a *Return to Flood Estimation* button will be visible on the ***Design Rainfall*** tab that will navigate the user back to the Flood Estimation screen.

For the SCS-SA Method, the rainfall table displays the 1-day design rainfall for each selected return period. The user can select the Estimate, Low or High rainfall estimate, or select User entered to specify rainfall values manually.

The point rainfall is subsequently converted to catchment-average rainfall by applying the selected Area Reduction Factor (ARF) method.

12.8.4 Catchment response

The Catchment response section controls the timing and initial abstraction assumptions used in the rainfall-runoff calculation, **Table 12-16**.

Table 12-16: SCS-SA Method Catchment response parameters

Input	Description
Calculated average stream slope	Representative slope of the principal watercourse calculated from the catchment characteristics, expressed in m/m.
Calculated time of concentration	Estimated time required for runoff from the hydraulically most remote part of the catchment to reach the catchment outlet.
Lag estimation method	Specifies how catchment lag is determined. The drop-down lists provide four lag estimation options: Time of Concentration, SCS Lag Equation, Schmidt-Schulze Equation or a User defined time. These differences are described in **Table 12-17** below.
User-defined lag	Allows a catchment lag to be entered directly when a user-defined lag approach is selected.
Initial abstraction ratio, λ	Defines the relationship between initial abstraction and potential maximum retention, Ia=λS. The interface identifies 0.10 as the default value for South Africa.
Area reduction factor method	Specifies the method used to convert point design rainfall to catchment-average rainfall. The drop-down lists provide four ARF estimation options: No Area Reduction Factor, SANRAL Area Reduction Factor, Alexander Area Reduction Factor or the Pietersen Area Reduction Factor. These different types are described in **Table 12-18** below.

<u>Lag estimation method</u>

The Lag estimation method specifies how the catchment lag used to construct the SCS-SA design flood hydrograph is determined. HydroSuite provides four options:

Table 12-17: Lag estimation methods

Lag estimation method	Description
Time of Concentration	Determines the catchment lag from the calculated time of concentration. This provides a convenient approach where the time of concentration has already been established from the catchment length and slope characteristics.
SCS Lag Equation	Estimates catchment lag using the SCS lag relationship, which relates lag to catchment characteristics and the runoff-retention characteristics represented by the Curve Number. This allows the lag to respond to both catchment geometry and the hydrological characteristics of the catchment.
Schmidt-Schulze Equation	Estimates catchment lag using the Schmidt-Schulze relationship developed for application to South African catchments. The calculated lag is based on the applicable catchment characteristics required by the relationship.
User defined	Allows the user to specify the catchment lag directly in hours. This option is useful where a lag value has been determined independently, calibrated from observed events, or specified as part of a particular design study.

The selected method and resulting catchment lag are reported in the Results Viewer so that the timing assumption used in the analysis is retained with the calculation results.

Area Reduction Factor method

Point design rainfall represents rainfall at a specific location and may overestimate the average rainfall occurring simultaneously over a larger catchment. An Area Reduction Factor (ARF) can therefore be applied to convert the point rainfall to an equivalent catchment-average rainfall depth.

HydroSuite provides the following ARF options, **Table 12-18**:

Table 12-18: Area Reduction Factor estimation options

ARF method	Description
No Area Reduction Factor	No spatial reduction is applied. The point design rainfall is used directly as the catchment rainfall, equivalent to an ARF of 100%.
SANRAL Area Reduction Factor	Applies the area-reduction procedure associated with the SANRAL drainage design methodology to determine an ARF appropriate to the catchment and design event.
Alexander Area Reduction Factor	Applies the Alexander area-reduction relationship to convert point design rainfall to catchment-average rainfall. The calculated ARF is applied to the point rainfall for each return period.
Pietersen Area Reduction Factor	Applies the Pietersen area-reduction relationship for estimating catchment-average design rainfall from point rainfall.

The selected ARF method is applied automatically during the analysis. The resulting ARF (%) and catchment rainfall (mm) are displayed in the SCS-SA results table, allowing the user to see the effect of the spatial rainfall adjustment directly.

12.8.5 Hydrological Response Units (HRUs)

The Hydrological Response Units (HRUs) section allows a heterogeneous catchment to be represented as a combination of areas having different hydrological characteristics, **Figure 12-25**. Each HRU is assigned a percentage of the total catchment and its own soil and land-use characteristics.

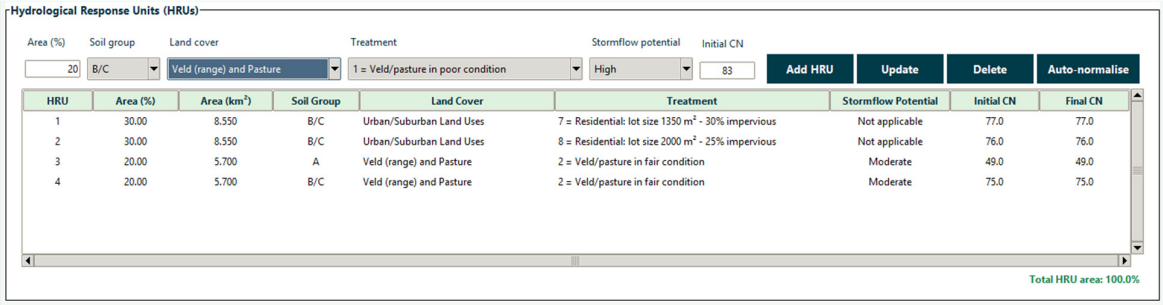


Figure 12-25: Hydrological Response Units (HRUs)

Each HRU is defined by selecting a land-cover class, an associated treatment/practice, the applicable stormflow potential, and a hydrological soil group, see **Table 12-19**. HydroSuite then obtains the corresponding Initial Curve Number (CN) from the Engineering Reference Library. The available CN values are based on the SCS-SA initial Curve Number.

Table 12-19: HRU description options

Land-cover class	Available treatments / practices	Stormflow potential
Fallow	Straight row; Straight row + conservation tillage	High / Low where applicable
Row Crops	Straight row; Straight row + conservation tillage; Planted on contour; Planted on contour + conservation tillage; Conservation structures; Conservation structures + conservation tillage	High / Low
Garden Crops	Straight row	Low / High
Small Grain	Straight row; Straight row + conservation tillage; Planted on contour; Planted on contour + conservation tillage; Planted on contour – winter rainfall region; Conservation structures; Conservation structures + conservation tillage	High / Low as applicable
Close Seeded Legumes or Rotational Meadow	Straight row; Planted on contour; Conservation structures	High / Low
Sugarcane	Straight row: trash burnt; trash mulch; limited cover; partial cover; complete cover; Conservation structures: limited cover; partial cover; complete cover	Not separately specified
Veld (range) and Pasture	Veld/pasture in poor condition; fair condition; good condition; Pasture planted on contour	High / Moderate / Low

Land-cover class	Available treatments / practices	Stormflow potential
Irrigated Pasture	Irrigated pasture	Low
Meadow	Meadow	Low
Woods and Scrub	Woods; Brush – winter rainfall region	High / Moderate / Low as applicable
Orchards	Winter rainfall region, understory of crop cover	Not separately specified
Forests & Plantations	Humus depths of 25, 50, 100 and 150 mm, each with compact, moderate or loose/friable soil conditions	Not separately specified
Urban/Suburban Land Uses	Open spaces, parks and cemeteries; Commercial/business areas; Industrial districts; Residential areas of different lot sizes and imperviousness; Paved parking lots and roofs; Tarred, gravel, dirt and dirt-hard-surface streets/roads	Not applicable

The full table provides a separate Initial CN for each of the following soil groups:
A - A/B - B - B/C - C - C/D - D
with increasing runoff potential generally reflected by increasing CN values.

Initial CN - Initial Curve Number automatically obtained from the HydroSuite Engineering Reference Library for the selected combination of land cover, treatment/practice, stormflow potential and hydrological soil group.
Final CN - Curve Number ultimately adopted by HydroSuite for the HRU and used in the SCS-SA runoff calculation after any applicable Curve Number adjustment. Where no adjustment is required, the Final CN is equal to the Initial CN.

The HRU table summarises the resulting configuration, including the corresponding physical area in km². The total HRU area should represent 100% of the catchment. A stepped procedure is followed to Add, Update or Delete an HRU (**Figure 12-26**).

The Add HRU, Update and Delete controls are used to construct and edit the HRU representation, while *Auto-normalise* can be used to adjust the HRU percentages so that their total equals 100%.

This approach allows, for example, urban/suburban portions of a catchment to be represented separately from veld, pasture or other rural land uses rather than applying a single Curve Number to the entire catchment.

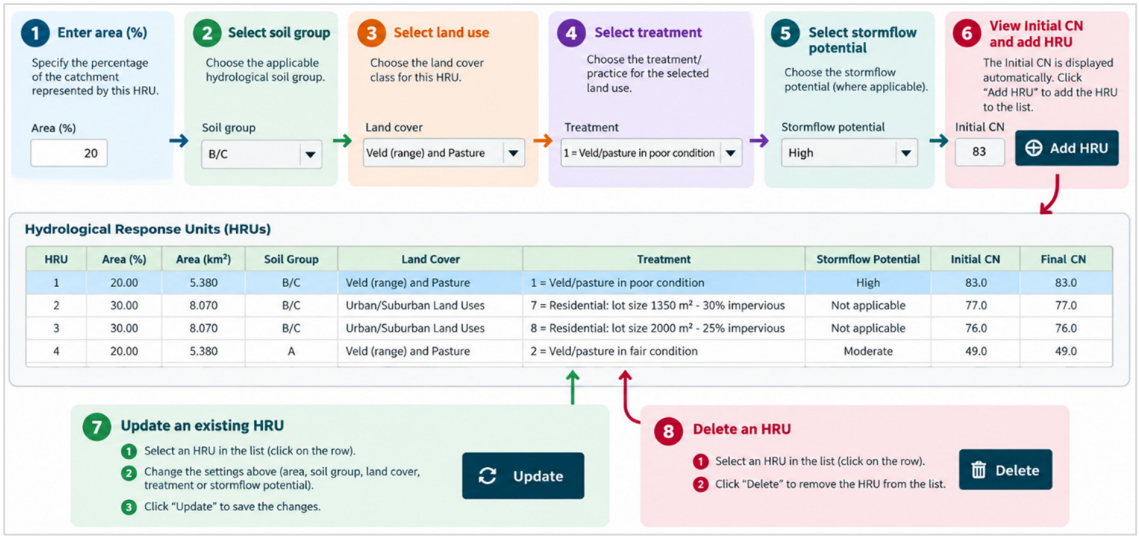


Figure 12-26: Add, Update or Delete an HRU

12.8.6 SCS-SA results

After the analysis is calculated, the SCS-SA Results table provides the principal rainfall, stormflow and flood characteristics for every selected return period, see **Figure 12-27**.

Table 12-20: SCS-SA results table

Result	Description
Return period	Recurrence interval of the design rainfall and associated design flood.
Point rainfall	1-day design rainfall depth corresponding to the selected return period before application of the area reduction factor, in mm.
ARF	Area Reduction Factor used to convert point rainfall to an equivalent catchment-average rainfall depth (%).
Catchment rainfall	Design rainfall depth averaged over the catchment after application of the ARF, in mm.
Weighted stormflow	Area-weighted stormflow depth calculated by combining the runoff response of the individual HRUs.
Runoff volume	Total stormflow volume generated over the catchment for the selected return period, expressed in m^3.
Lag	Catchment lag used in developing the design flood hydrograph, in hours.
Peak discharge	Maximum discharge of the calculated design flood hydrograph, expressed in m^3/s.

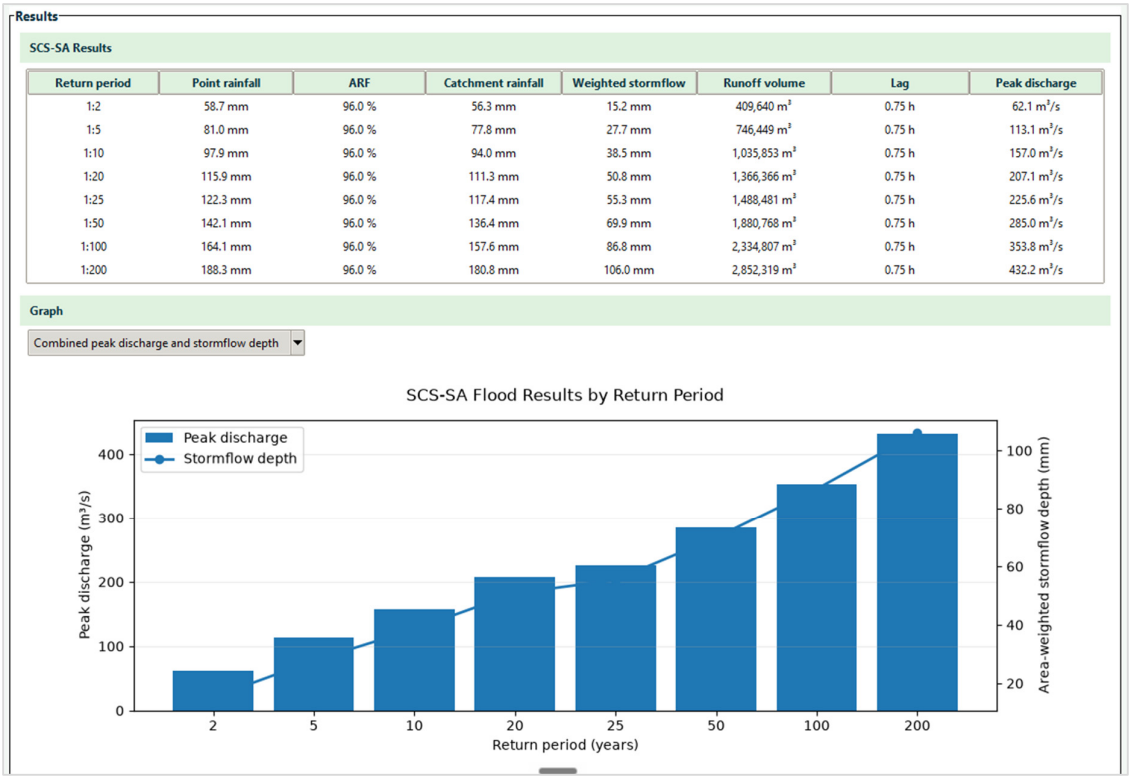


Figure 12-27: SCS-SA results table and graph

The results therefore provide both the design peak discharge required for conventional flood estimation and the associated stormflow depth, runoff volume and hydrograph, allowing the temporal and volumetric characteristics of the design event to be assessed.

The Graph drop-down list, shown in **Figure 12-28**, provides several alternative presentations of the calculated SCS-SA results as listed in **Table 12-21**. The selected graph is displayed directly below the results table.

Table 12-21: SCS-SA graphical outputs

Graphical output	Description
Peak discharge	Displays calculated peak discharge against return period, allowing the increase in design flood magnitude with recurrence interval to be assessed.
Stormflow depth	Displays the area-weighted stormflow depth calculated for each return period.
Runoff volume	Displays the total calculated runoff volume for each selected return period.
Combined peak discharge and stormflow depth	Presents peak discharge and area-weighted stormflow depth together, using separate axes, to compare the magnitude of the flood peak with the corresponding stormflow depth.
Flood hydrographs	Displays the complete calculated design flood hydrographs for the selected return periods, showing discharge as a function of time and allowing the peak magnitude, timing and recession of the events to be compared.

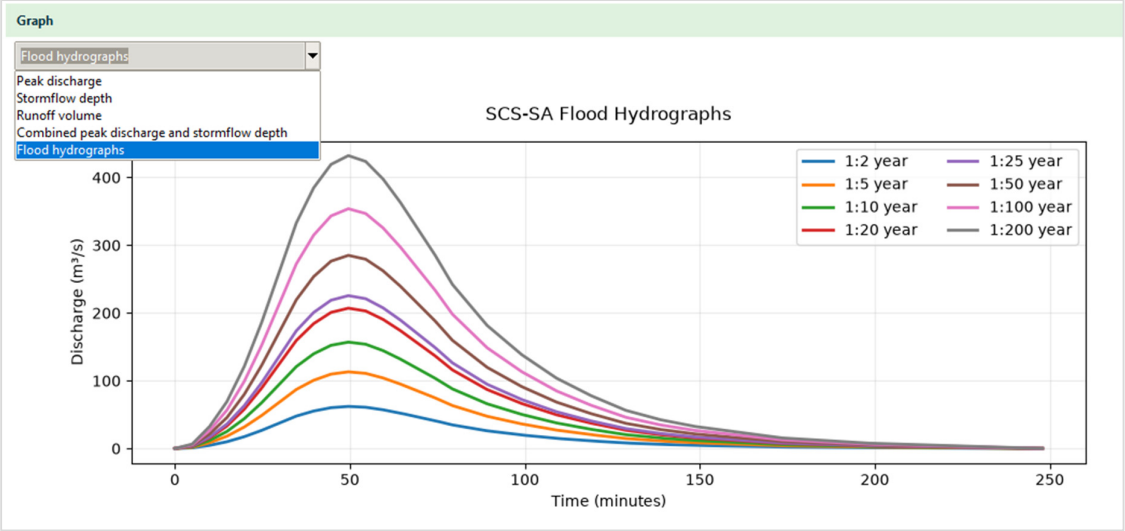


Figure 12-28: Selection of different graph options

The *Results Viewer,* as shown in **Figure 12-29***,* provides a detailed text summary of the SCS-SA calculation. It records the catchment characteristics and response parameters, including calculated stream slope, time of concentration, lag estimation method, catchment lag, initial abstraction ratio and selected ARF method.

The viewer also records the parameters assigned to each HRU, including its area, soil group, land cover, treatment, stormflow potential, Curve Number and associated retention/initial-abstraction information. The rainfall and calculated runoff results are subsequently reported for the selected return periods.

This detailed output provides a record of the assumptions and intermediate parameters used in the SCS-SA calculation and complements the summary results table and graphical outputs.

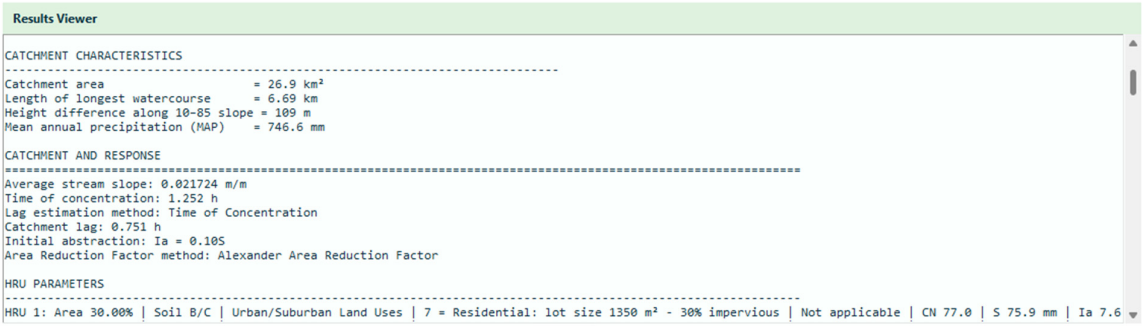
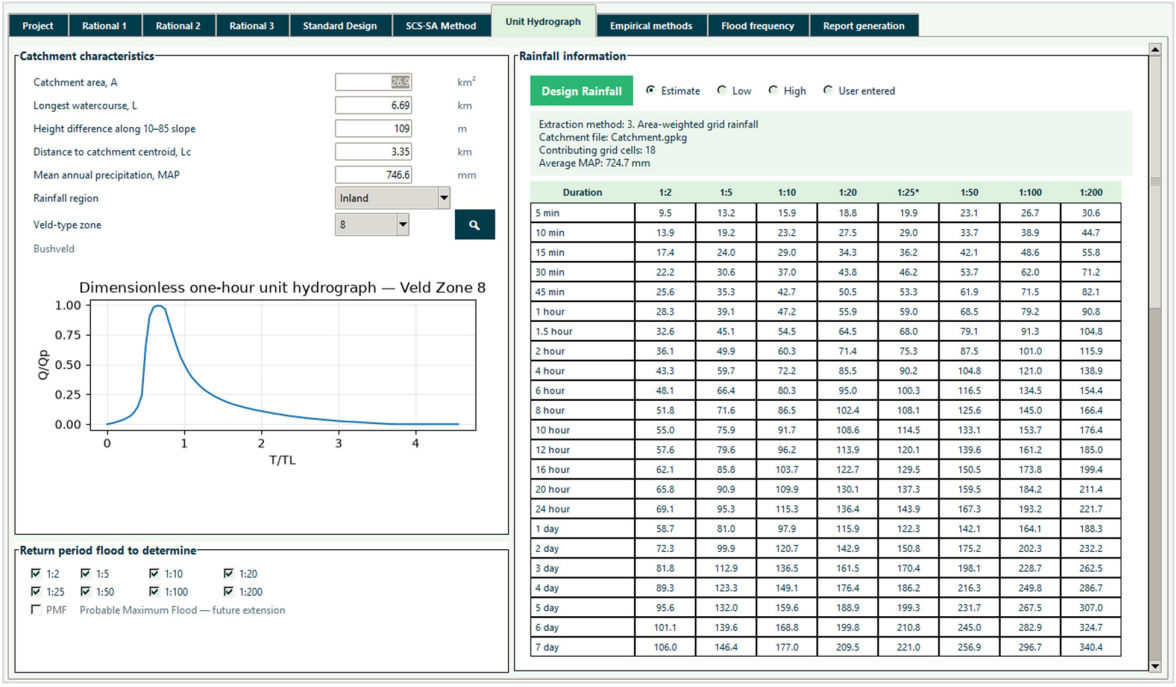


Figure 12-29: SCS-SA Results viewer

12.9 Unit Hydrograph method

The ***Unit Hydrograph*** tab, **Figure 12-30**, provides a method for estimating design flood hydrographs and peak discharges from catchment characteristics and design rainfall. Unlike methods that provide only an estimate of the peak flood discharge, the Unit Hydrograph Method represents the variation in discharge with time, allowing both the magnitude and temporal distribution of a design flood event to be assessed.

GHI HydroSuite applies the selected veld-type zone unit hydrograph together with catchment characteristics and design rainfall information to derive the design flood hydrograph for the selected return periods. The dimensionless one-hour unit hydrograph associated with the selected veld-type zone is displayed graphically to assist the user in reviewing the adopted hydrograph shape.



Duration	1:2	1:5	1:10	1:20	1:25*	1:50	1:100	1:200
5 min	9.5	13.2	15.9	18.8	19.9	23.1	26.7	30.6
10 min	13.9	19.2	23.2	27.5	29.0	33.7	38.9	44.7
15 min	17.4	24.0	29.0	34.3	36.2	42.1	48.6	55.8
30 min	22.2	30.6	37.0	43.8	46.2	53.7	62.0	71.2
45 min	25.6	35.3	42.7	50.5	53.3	61.9	71.5	82.1
1 hour	28.3	39.1	47.2	55.9	59.0	68.5	79.2	90.8
1.5 hour	32.6	45.1	54.5	64.5	68.0	79.1	91.3	104.8
2 hour	36.1	49.9	60.3	71.4	75.3	87.5	101.0	115.9
4 hour	43.3	59.7	72.2	85.5	90.2	104.8	121.0	138.9
6 hour	48.1	66.4	80.3	95.0	100.3	116.5	134.5	154.4
8 hour	51.8	71.6	86.5	102.4	108.1	125.6	145.0	166.4
10 hour	55.0	75.9	91.7	108.6	114.5	133.1	153.7	176.4
12 hour	57.6	79.6	96.2	113.9	120.1	139.6	161.2	185.0
16 hour	62.1	85.8	103.7	122.7	129.5	150.5	173.8	199.4
20 hour	65.8	90.9	109.9	130.1	137.3	159.5	184.2	211.4
24 hour	69.1	95.3	115.3	136.4	143.9	167.3	193.2	221.7
1 day	58.7	81.0	97.9	115.9	122.3	142.1	164.1	188.3
2 day	72.3	99.9	120.7	142.9	150.8	175.2	202.3	232.2
3 day	81.8	112.9	136.5	161.5	170.4	198.1	228.7	262.5
4 day	89.3	123.3	149.1	176.4	186.2	216.3	249.8	286.7
5 day	95.6	132.0	159.6	188.9	199.3	231.7	267.5	307.0
6 day	101.1	139.6	168.8	199.8	210.8	245.0	282.9	324.7
7 day	106.0	146.4	177.0	209.5	221.0	256.9	296.7	340.4

Figure 12-30: Flood Estimation - Unit Hydrograph method tab

12.9.1 Catchment characteristics

The catchment characteristics required for the Unit Hydrograph Method are entered on the left-hand side of the tab. Some values may be carried across from information already defined elsewhere in the Flood Estimation project. The input required for this section is listed in **Table 12-22** below.

Table 12-22: Unit hydrograph method catchment characteristics

Input	Description
Catchment area, A	Total contributing catchment area, expressed in km².
Longest watercourse, L	Length of the longest principal watercourse or flow path through the catchment, expressed in km.

Input	Description
Height difference along 10–85 slope	Difference in elevation between the 10% and 85% points along the longest watercourse, used to characterise the longitudinal catchment slope in meters.
Distance to catchment centroid, Lc	Distance measured along the principal watercourse from the catchment outlet to the point nearest the centroid of the catchment, expressed in km.
Mean annual precipitation, MAP	Mean annual precipitation for the catchment, expressed in mm.
Rainfall region	Specifies the applicable regional rainfall classification, such as Inland.
Veld-type zone	Specifies the applicable veld-type zone, shown in **Figure 12-32** and descriptions listed in **Table 12-23**, used to select the regional dimensionless one-hour unit hydrograph.

The Veld-type zone defines the characteristic shape of the unit hydrograph used in the analysis. Once a zone has been selected, **GHI HydroSuite** displays the corresponding dimensionless one-hour unit hydrograph, **Figure 12-31**.

The graph expresses discharge as the dimensionless ratio Q/Qp and time as T/TL, thereby describing the relative shape and timing of the hydrograph independently of the final flood magnitude. This provides the user with a visual indication of the hydrograph that will be used in the subsequent design flood calculations.

The *Search/selection* button adjacent to the veld-type zone field can be used to assist with identification or selection of the applicable zone, **Figure 12-32**.

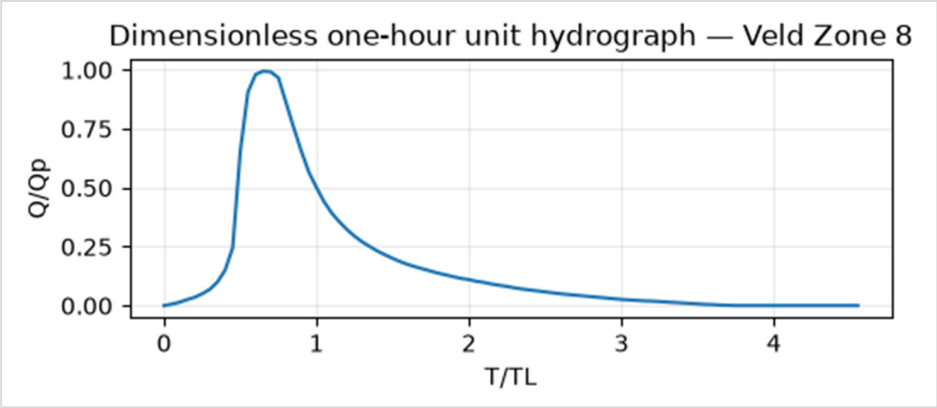


Figure 12-31: Dimensionless one-hour unit hydrograph for veld zone

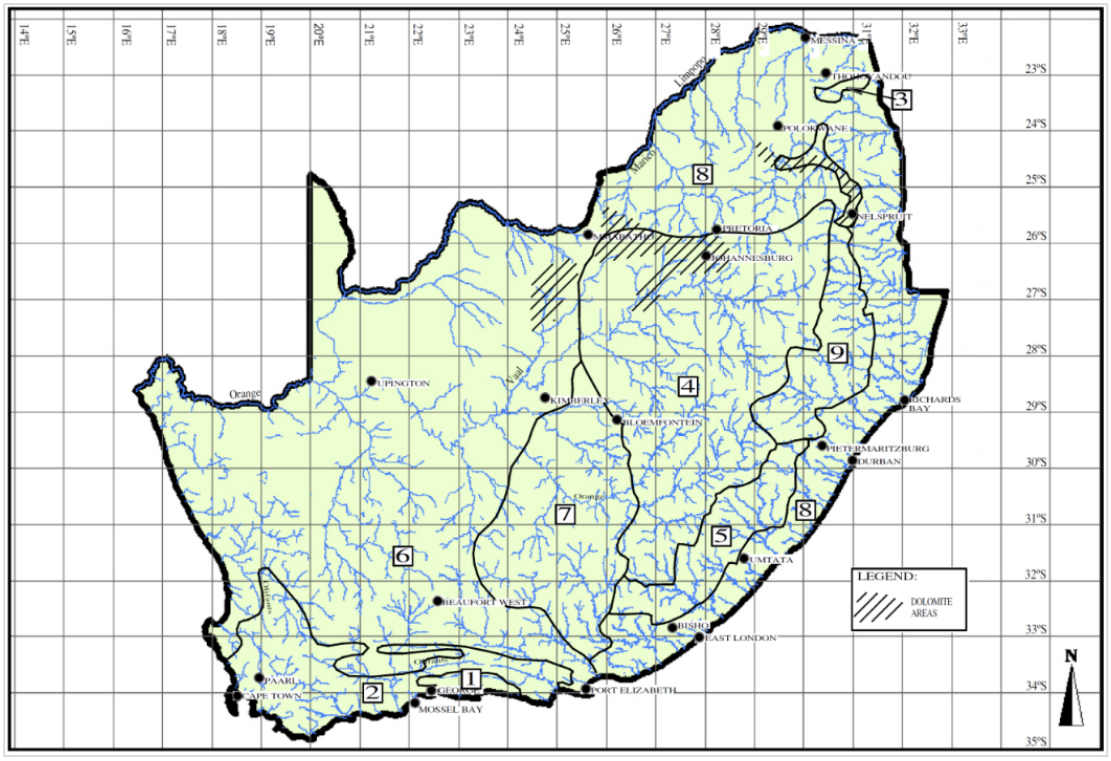


Figure 12-32: Veld-type zones (SANRAL, 2013)

Table 12-23: Generalised veld types

Regional number	Generalised veld type	Factor K_u
1	Coastal tropical forest	0.261
2	Schlerophyllous bush	0.306
3	Mountain sourveld	0.277
4	Grasslands of interior plateau	0.386
5	Highland sourveld and Dohne sourveld	0.351
5a	As for Zone 5 – but soils weakly developed	0.488
6	Karoo	0.265
7	False Karoo	0.315
8	Bushveld	0.367
9	Tall sourveld	0.321

12.9.2 Return periods

The Return period flood to determine section allows the user to select the design floods to be calculated. One or more of the following return periods may be selected:

1:2, 1:5, 1:10, 1:20, 1:25, 1:50, 1:100 and 1:200 years.

The interface also provides for a Probable Maximum Flood (PMF) option. This functionality is identified as a future extension and is not currently included in the calculation.

12.9.3 Rainfall information

Design rainfall information is obtained through the integrated *Design Rainfall* functionality. The rainfall table provides rainfall depths for durations ranging from 5 minutes to 7 days and for the available return periods. The rainfall information panel identifies the source and extraction method used. Where a catchment boundary has been defined, rainfall may, for example, be obtained using the area-weighted grid rainfall extraction method, with the contributing grid cells and average MAP reported for traceability.

The user can select *Design Rainfall* button, as shown in **Figure 12-30**, to obtain or update the rainfall information. The rainfall dataset displayed in the Unit Hydrograph Method reflects the most recently completed Design Rainfall analysis and includes information on the extraction method, location or catchment used, rainfall station where applicable, and grid characteristics associated with the analysis.

A detailed description of the Design Rainfall extraction procedure is described in **Section 9.5**. When a user has navigated from the *Unit Hydrograph Method Flood Estimation* screen a *Return to Flood Estimation* button will be visible on the ***Design Rainfall*** tab that will navigate the user back to the Flood Estimation screen.

Rainfall information

Design Rainfall | Estimate | Low | High | User entered

Extraction method: 3. Area-weighted grid rainfall
Catchment file: Catchment.gpkg
Contributing grid cells: 18
Average MAP: 724.7 mm

Duration	1:2	1:5	1:10	1:20	1:25*	1:50	1:100	1:200
5 min	9.5	13.2	15.9	18.8	19.9	23.1	26.7	30.6
10 min	13.9	19.2	23.2	27.5	29.0	33.7	38.9	44.7
15 min	17.4	24.0	29.0	34.3	36.2	42.1	48.6	55.8
30 min	22.2	30.6	37.0	43.8	46.2	53.7	62.0	71.2
45 min	25.6	35.3	42.7	50.5	53.3	61.9	71.5	82.1
1 hour	28.3	39.1	47.2	55.9	59.0	68.5	79.2	90.8
1.5 hour	32.6	45.1	54.5	64.5	68.0	79.1	91.3	104.8
2 hour	36.1	49.9	60.3	71.4	75.3	87.5	101.0	115.9
4 hour	43.3	59.7	72.2	85.5	90.2	104.8	121.0	138.9
6 hour	48.1	66.4	80.3	95.0	100.3	116.5	134.5	154.4
8 hour	51.8	71.6	86.5	102.4	108.1	125.6	145.0	166.4
10 hour	55.0	75.9	91.7	108.6	114.5	133.1	153.7	176.4
12 hour	57.6	79.6	96.2	113.9	120.1	139.6	161.2	185.0
16 hour	62.1	85.8	103.7	122.7	129.5	150.5	173.8	199.4
20 hour	65.8	90.9	109.9	130.1	137.3	159.5	184.2	211.4
24 hour	69.1	95.3	115.3	136.4	143.9	167.3	193.2	221.7
1 day	58.7	81.0	97.9	115.9	122.3	142.1	164.1	188.3
2 day	72.3	99.9	120.7	142.9	150.8	175.2	202.3	232.2
3 day	81.8	112.9	136.5	161.5	170.4	198.1	228.7	262.5
4 day	89.3	123.3	149.1	176.4	186.2	216.3	249.8	286.7
5 day	95.6	132.0	159.6	188.9	199.3	231.7	267.5	307.0
6 day	101.1	139.6	168.8	199.8	210.8	245.0	282.9	324.7
7 day	106.0	146.4	177.0	209.5	221.0	256.9	296.7	340.4

Figure 12-33: Rainfall information Unit Hydrograph method

Depending on the selected *Design Rainfall* method, rainfall may be determined for a single point or spatially across a catchment. The available approaches include Point Rainfall, Catchment Average Grid Rainfall, Area-Weighted Grid Rainfall and Thiessen Polygon Rainfall. Where a catchment-based method is used, the selected catchment boundary is used in determining the representative design rainfall.

The rainfall table displays design rainfall depths in millimetres for storm durations ranging from short-duration events in minutes and hours to multi-day events. Values are provided for the available return periods, allowing the appropriate rainfall depth to be selected for each design flood calculation.

Rainfall value

Where uncertainty limits are available in the Design Rainfall dataset, the user can select which rainfall estimate is to be applied, see **Table 12-24**:

Table 12-24: Rainfall value options

Option	Description
Estimate	Uses the central or best-estimate design rainfall values. This is the normal selection for design calculations.
Low	Uses the lower rainfall estimate associated with the selected Design Rainfall analysis.
High	Uses the upper rainfall estimate associated with the selected Design Rainfall analysis.
User entered	Allows the user to specify or modify the rainfall values manually for the Rational Method 3 calculation. Simply enter the values in each of the input boxes.

The *Low* and *High* options provide a convenient means of investigating the sensitivity of calculated peak flows to uncertainty in the design rainfall estimates.

Design rainfall information

A summary above the rainfall table identifies the source of the currently loaded rainfall information, as shown in **Figure 12-40**. Depending on the method used, this may include the extraction method, location method, catchment file, rainfall station and grid block size. This information provides traceability between the rainfall dataset used in the Unit Hydrograph method calculation and the *Design Rainfall* analysis from which it was obtained.

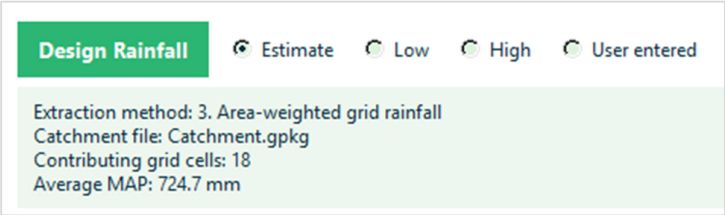


Figure 12-34: Summary of rainfall information

Storm durations and return periods

The rainfall table, **Figure 12-33**, presents the available design rainfall depths according to storm duration and return period. Individual storm durations can be selected or deselected using the check boxes alongside the table.

The available rainfall durations extend from 5 minutes to 7 days, while the table provides rainfall depths for return periods from 1:2 years to 1:200 years, including the interpolated 1:25-year rainfall values.

Note: The Design Rainfall functionality and the different methods available for obtaining point and catchment rainfall are described in detail in **Section 9.5 - Design Rainfall**. This section therefore focuses on the use of these rainfall results within Rational Method 3 rather than repeating the rainfall extraction procedures.

12.9.4 Unit Hydrograph Results

Once the Unit Hydrograph analysis has been completed (clicking on the *Calculate* button above the tabs), the Results section summarises the calculated design flood characteristics for each selected return period. The results combine the selected design rainfall, area reduction, runoff characteristics and duration-adjusted unit hydrograph to determine the resulting design peak discharge.

The summary table allows the user to compare how the critical storm duration, effective rainfall and resulting peak discharge vary with return period, descriptions provided in **Table 12-25**.

Table 12-25: Unit hydrograph method results table

Result	Description
Return period	Design flood return period for which the results have been calculated.
Critical duration (min)	Storm duration producing the controlling or maximum design peak discharge for the selected return period.
Point rainfall (mm)	Design point rainfall depth corresponding to the critical storm duration and return period, obtained from the selected Design Rainfall dataset.
Point intensity (mm/h)	Average rainfall intensity calculated from the point rainfall depth and corresponding storm duration.
ARF (%)	Area Reduction Factor applied to convert point rainfall to an equivalent rainfall representative of the catchment area.
Runoff factor (%)	Proportion of the catchment rainfall contributing to effective rainfall and direct runoff for the applicable return period.
Effective rainfall (mm)	Rainfall depth contributing to direct runoff after application of the relevant rainfall and runoff adjustments.
UH peak ($m^3/s/mm$)	Peak discharge of the duration-adjusted unit hydrograph per millimetre of effective rainfall.
Peak discharge (m^3/s)	Calculated maximum design flood discharge obtained from the effective rainfall and applicable unit hydrograph.

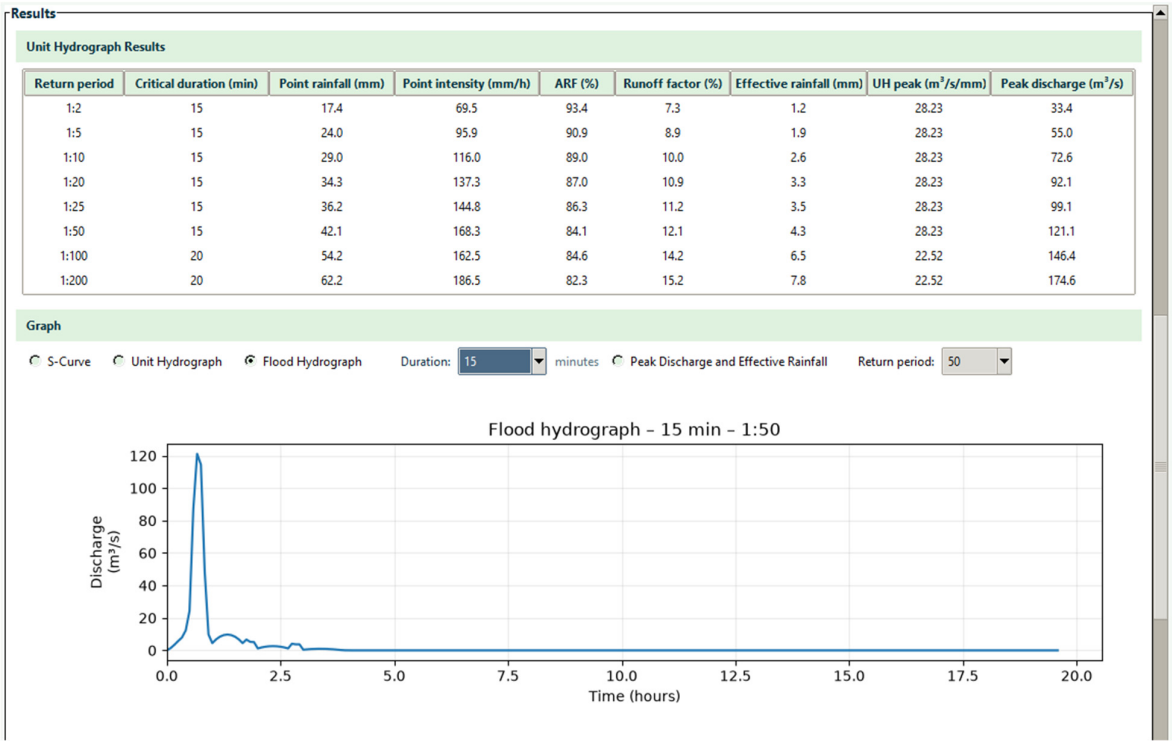
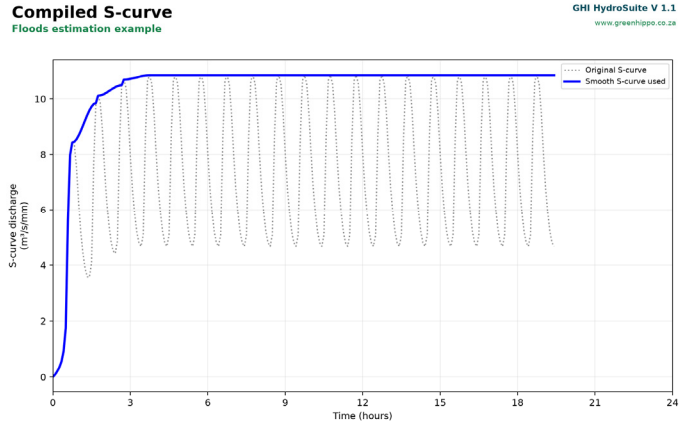


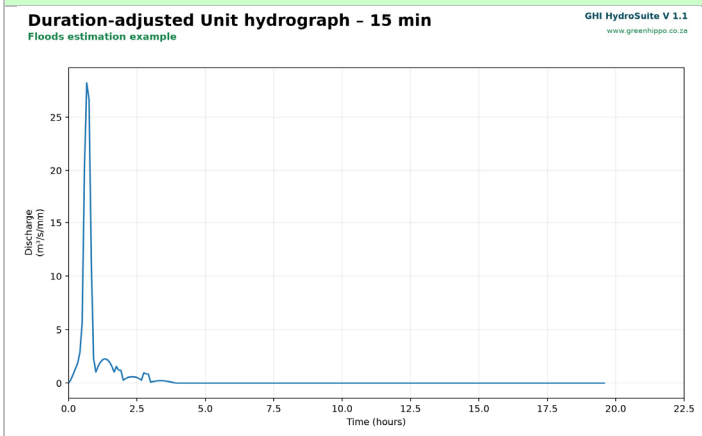
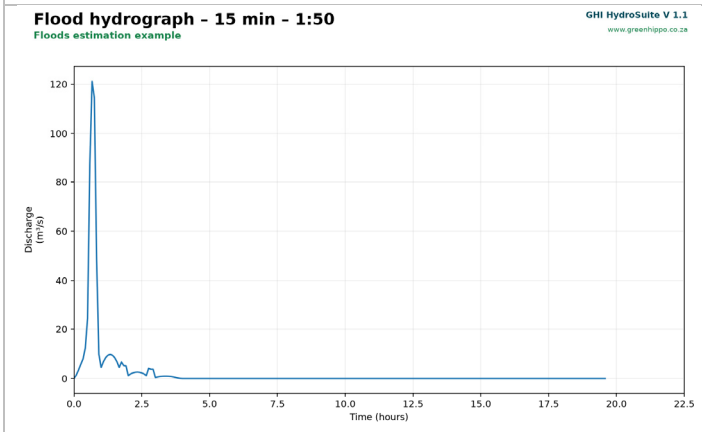
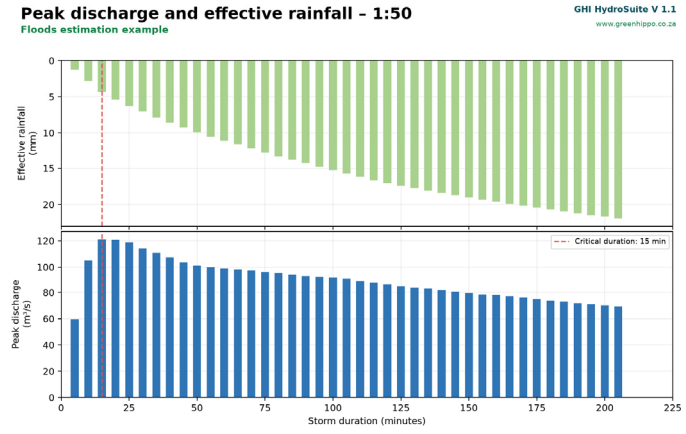
Figure 12-35: Unit hydrograph method results table and graph

The Graph section provides several graphical representations of the Unit Hydrograph calculations. The required graph is selected using the radio buttons above the graph. Where applicable, the *Duration* and *Return period* controls allow the user to investigate the results for different combinations of storm duration and return period.

The available graphical outputs include, **Table 12-26**:

Table 12-26: Unit hydrograph method graphical outputs

Graphical output	Description
	**S-Curve** Displays the compiled S-curve derived from the unit hydrograph. Both the original compiled S-curve and the smoothed S-curve adopted by the calculation are shown, allowing the user to review the transformation used in developing duration-adjusted unit hydrographs.

Graphical output	Description
	**Unit Hydrograph** Displays the duration-adjusted unit hydrograph for the selected storm duration. The graph shows discharge per unit depth of effective rainfall against time and illustrates how the adopted unit hydrograph is transformed for the selected duration.
	**Flood Hydrograph** Displays the calculated design flood hydrograph for the selected storm duration and return period. The graph shows the variation in discharge with time and allows the peak discharge, timing and overall hydrograph shape to be assessed.
	**Peak Discharge and Effective Rainfall** Provides a comparative graphical representation of the calculated peak discharge and corresponding effective rainfall for the design return periods.

A particular advantage of the graphical viewer is that the user is not restricted to viewing only the critical-duration result reported in the summary table. The *Duration* drop-down list can be used to select different storm durations, while the *Return* period drop-down list allows the corresponding design return period to be selected.

The graphs are updated for the selected combination. This enables the user to investigate how the unit hydrograph and resulting flood hydrograph change with storm duration and return period, and to examine the calculations leading to the critical design flood.

For example, selecting Flood Hydrograph, a duration of 15 minutes, and a return period of 1:50 years displays the complete 15-minute, 1:50-year design flood hydrograph. Similarly, selecting Unit Hydrograph allows the duration-adjusted unit hydrograph for that storm duration to be inspected independently of the design rainfall magnitude.

12.9.5 Interpretation of the results

The critical duration should be noted when interpreting the Unit Hydrograph results. Hydrographs are evaluated for the applicable storm durations, and the duration producing the controlling peak discharge is reported for each return period. Consequently, the critical duration does not necessarily remain constant between return periods.

The graphical outputs provide additional information beyond the peak-discharge value alone. They allow the user to assess the shape of the flood hydrograph, time to peak, recession of the hydrograph and sensitivity of the calculated flood to storm duration. This can be particularly useful where the complete flood hydrograph, rather than only the peak discharge, is required for subsequent hydraulic or flood-routing analyses.

12.10 Empirical methods

The ***Empirical methods*** tab provides additional approaches for estimating design flood magnitudes from regional empirical relationships. These methods are particularly useful for providing an independent comparison with the deterministic and statistical flood-estimation methods available elsewhere in **GHI HydroSuite**.

The tab, shown in **Figure 12-36**, currently provides the Midgley-Pitman empirical method and the Regional Maximum Flood (RMF) method. Both methods use catchment characteristics together with regional parameters derived from the applicable empirical methodology.

12.10.1 Catchment characteristics

The upper section of the tab contains the catchment parameters required by the empirical methods, listed in **Table 12-27**. Where the same information has already been entered for other flood estimation methods, it is linked automatically and does not need to be entered again. The user is required to provide the additional outlet-to-centroid distance where applicable and mean catchment slope.

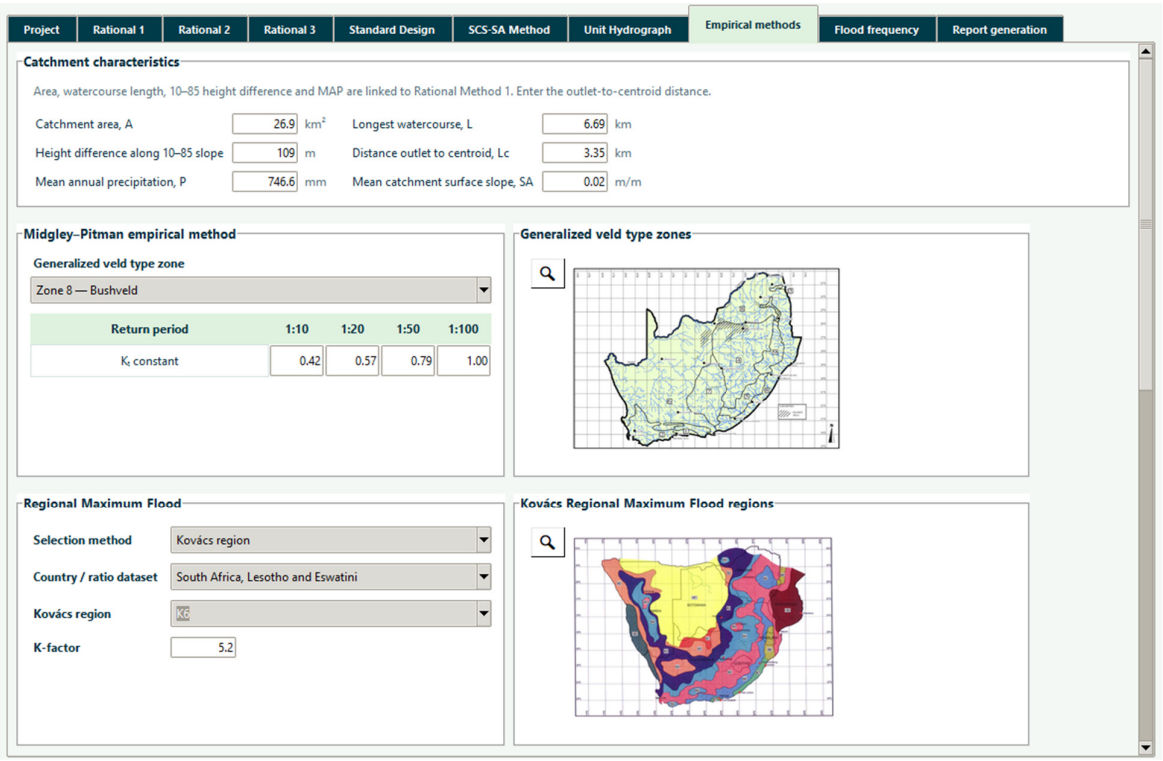


Figure 12-36: Flood Estimation - Empirical methods

Table 12-27: Empirical methods catchment characteristics

Input	Description
Catchment area, A	Total contributing catchment area, expressed in km².
Longest watercourse, L	Length of the longest principal watercourse through the catchment, expressed in km.
Height difference along 10-85 slope, $\Delta H_{10\text{-}85}$	Elevation difference between the 10% and 85% points along the longest watercourse, expressed in metres.
Distance outlet to centroid, Lc	Distance along the principal watercourse from the catchment outlet to the point nearest the catchment centroid, expressed in km.
Mean annual precipitation, P	Mean annual precipitation applicable to the catchment, expressed in mm.
Mean catchment surface slope, SA	Mean surface slope of the catchment, expressed in m/m.

12.10.2 Midgley-Pitman empirical method

The Midgley-Pitman (MIPI) empirical method provides estimates of design flood magnitude using catchment characteristics and regional coefficients associated with the applicable generalized veld-type zone (**Table 12-28**).

The user selects the generalized veld-type zone applicable to the catchment from the drop-down list. **GHI HydroSuite** then displays the corresponding K_t constants for the supported return periods.

For example, the screen shown above has Zone 8 - Bushveld selected, with separate K_t constants provided for the 1:10, 1:20, 1:50 and 1:100-year return periods.

Table 12-28: Generalised veld types

Regional number	Generalised veld type
1	Coastal tropical forest
2	Schlerophyllous bush
3	Mountain sourveld
4	Grasslands of interior plateau
5	Highland sourveld and Dohne sourveld
5a	As for Zone 5 – but soils weakly developed
6	Karoo
7	False Karoo
8	Bushveld
9	Tall sourveld

A reference map of the Generalized veld-type zones is provided alongside the input controls to assist the user in identifying the appropriate zone. The *magnifying-glass* button, **Figure 12-36**, can be used to open or enlarge the reference map where closer inspection is required.

The selected zone should be representative of the catchment being analysed. The regional classification is important because the empirical constants used in the calculation vary between veld-type zones.

Table 12-29: MIPI information

Input	Description
Generalized veld-type zone	Specifies the regional veld-type zone applicable to the catchment and used by the Midgley-Pitman empirical method.
K_t constant	Regional empirical coefficient corresponding to the selected generalized veld-type zone and return period. The applicable values are populated automatically by **GHI HydroSuite**.

12.10.3 Regional Maximum Flood

The *Regional Maximum Flood* section provides an estimate of the potential maximum flood magnitude using a regional empirical relationship. It is intended primarily as an indication of the magnitude of extreme floods that may reasonably be associated with a catchment rather than as a replacement for return-period design flood methods.

GHI HydroSuite provides controls for selecting the applicable regional methodology and dataset.

Table 12-30: RMF information

Input	Description
Selection method	Specifies the method used to determine the regional parameter. The displayed implementation allows selection according to the Kovács region. There is also a *User defined* option from the drop-down list which would require the user to enter the *K-factor*.
Country / ratio dataset	Specifies the geographical dataset applicable to the analysis. For South African applications, the available dataset includes *South Africa, Lesotho and Eswatini*. The two other country options available from the drop-down list is *Namibia* and *Zimbabwe*.
Kovács region	Specifies the Regional Maximum Flood region applicable to the catchment.
K-factor	Regional coefficient associated with the selected Kovács region (*K1 to K8*) and used in the Regional Maximum Flood calculation.

A reference map showing the *Kovács Regional Maximum Flood regions* is displayed alongside the input fields. This map assists the user in determining the region within which the catchment is located. Once the appropriate region has been selected, the corresponding K-factor is populated for use in the calculation.

The *Magnifying-glass* button, **Figure 12-36**, can be used to inspect the regional map in greater detail, **Figure 12-37**.

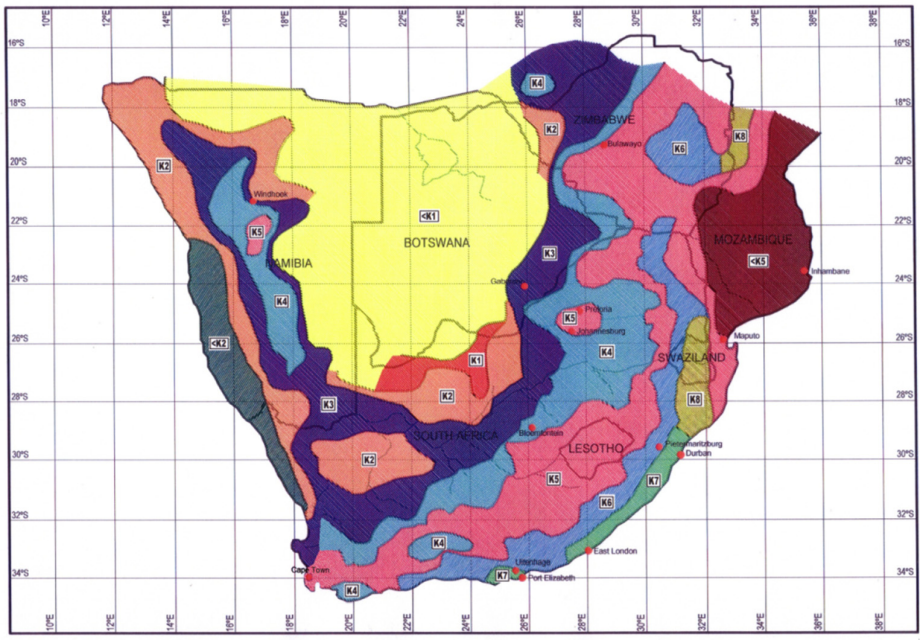


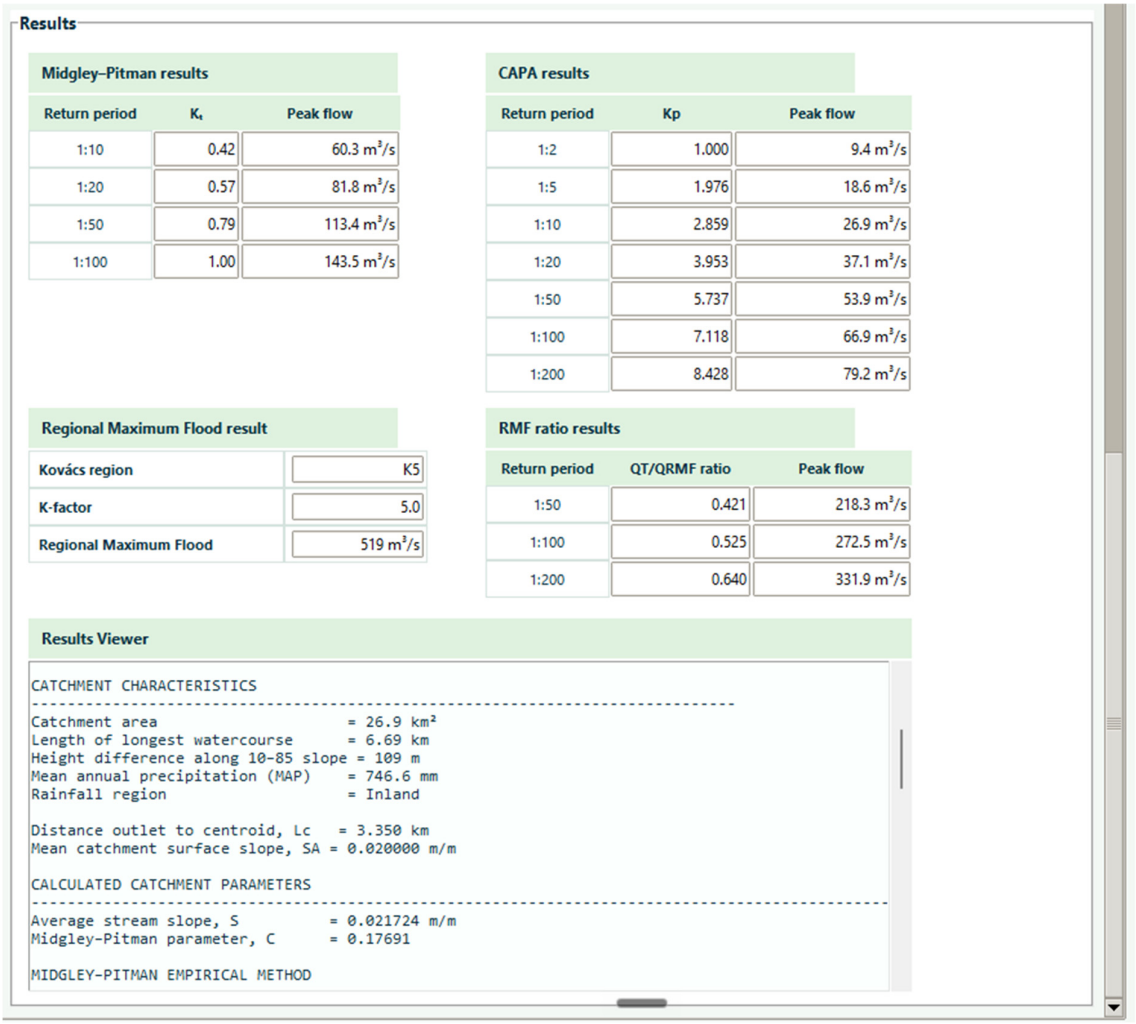
Figure 12-37: Regional maximum flood Kovács regions (SANRAL, 2013)

Because these methods are based on regional empirical relationships, the selection of the appropriate regional classification is an important part of the analysis. The maps provided in GHI HydroSuite should therefore be used together with the catchment location and the engineering judgement of the user when selecting the applicable zone or region.

12.10.4 Empirical Methods Results

Following calculation, the Results section presents the design flood estimates obtained from the different empirical approaches. The results are grouped according to the Midgley-Pitman method, CAPA method, Regional Maximum Flood (RMF) and RMF ratio method, allowing the different estimates to be reviewed together.

The *Results Viewer* and the summary tables below, **Figure 12-38**, provide a more detailed record of the input catchment characteristics, calculated catchment parameters, selected regional parameters and calculated flood estimates.



Results

Midgley–Pitman results

Return period	K_t	Peak flow
1:10	0.42	60.3 m³/s
1:20	0.57	81.8 m³/s
1:50	0.79	113.4 m³/s
1:100	1.00	143.5 m³/s

CAPA results

Return period	Kp	Peak flow
1:2	1.000	9.4 m³/s
1:5	1.976	18.6 m³/s
1:10	2.859	26.9 m³/s
1:20	3.953	37.1 m³/s
1:50	5.737	53.9 m³/s
1:100	7.118	66.9 m³/s
1:200	8.428	79.2 m³/s

Regional Maximum Flood result

Kovács region	K5
K-factor	5.0
Regional Maximum Flood	519 m³/s

RMF ratio results

Return period	QT/QRMF ratio	Peak flow
1:50	0.421	218.3 m³/s
1:100	0.525	272.5 m³/s
1:200	0.640	331.9 m³/s

Results Viewer

```
CATCHMENT CHARACTERISTICS
-------------------------------------------------------------------------------
Catchment area                    = 26.9 km²
Length of longest watercourse     = 6.69 km
Height difference along 10-85 slope = 109 m
Mean annual precipitation (MAP)   = 746.6 mm
Rainfall region                   = Inland

Distance outlet to centroid, Lc   = 3.350 km
Mean catchment surface slope, SA = 0.020000 m/m

CALCULATED CATCHMENT PARAMETERS
-------------------------------------------------------------------------------------------------
Average stream slope, S          = 0.021724 m/m
Midgley-Pitman parameter, C      = 0.17691

MIDGLEY-PITMAN EMPIRICAL METHOD
```

Figure 12-38: Empirical methods results table

Midgley-Pitman results

The Midgley-Pitman results provide peak flood estimates for the supported return periods using the applicable empirical coefficient for the selected generalized veld-type zone, **Table 12-31**.

Table 12-31: MIPI results table

Result	Description
Return period	Return period associated with the calculated design flood.
K_t	Empirical return-period coefficient associated with the selected generalized veld-type zone.
Peak flow	Calculated Midgley–Pitman design peak discharge, expressed in m^3/s.

The method provides results for the 1:10, 1:20, 1:50 and 1:100-year return periods.

CAPA results

The CAPA results, **Table 12-32**, provide an additional set of empirical design flood estimates for a broader range of return periods.

Table 12-32: CAPA results table

Result	Description
Return period	Return period associated with the calculated design flood.
Kp	Return-period coefficient used by the CAPA empirical relationship.
Peak flow	Calculated design peak discharge corresponding to the applicable Kp value, expressed in m^3/s.

Results are provided for the 1:2, 1:5, 1:10, 1:20, 1:50, 1:100 and 1:200-year return periods.

Regional Maximum Flood result

The Regional Maximum Flood result provides an estimate of the Regional Maximum Flood based on the selected Kovács region and its associated regional K-factor, **Table 12-33**.

Table 12-33: RMF results table

Result	Description
Kovács region	Regional Maximum Flood region applied to the catchment.
K-factor	Regional coefficient corresponding to the selected Kovács region.
Regional Maximum Flood	Calculated Regional Maximum Flood, expressed in m^3/s.

The RMF represents an estimate of an extreme regional flood magnitude and is therefore presented separately from the return-period flood estimates.

RMF ratio results

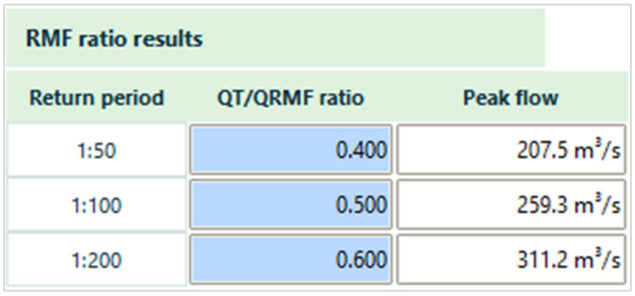
The RMF ratio results derive selected return-period flood estimates relative to the calculated Regional Maximum Flood, **Table 12-34**.

Table 12-34: Q_T/Q_{RMF} ration results table

Result	Description
Return period	Return period for which the peak flood is estimated.
QT/QRMF ratio	Ratio of the return-period flood, Q_T, to the calculated Regional Maximum Flood, Q_{RMF}.
Peak flow	Resulting return-period peak discharge, expressed in m^3/s.

The software reports RMF-ratio estimates for the 1:50, 1:100 and 1:200-year return periods.

If a different ration wants to be used the Q_T/Q_{RMF} ratio can be changed by the user and the floods recalculated, i.e., then it does not use the published ratios.



RMF ratio results

Return period	QT/QRMF ratio	Peak flow
1:50	0.400	207.5 m^3/s
1:100	0.500	259.3 m^3/s
1:200	0.600	311.2 m^3/s

Figure 12-39: User entered Q_T/Q_{RMF} ratios

Results Viewer

The *Results Viewer* provides the detailed calculation output supporting the summary tables. It includes the principal catchment characteristics, calculated parameters such as average stream slope and the Midgley-Pitman parameter, and the parameters and results associated with each empirical method.

The *Results Viewer* is useful for checking the assumptions and intermediate values used in the analysis and provides a more complete calculation record than the summary tables alone.

Interpretation and comparison

The empirical methods provide several independent estimates of flood magnitude based on different regional relationships. The results should therefore be considered alongside the other flood-estimation methods available in GHI HydroSuite, rather than interpreted as interchangeable estimates. Differences between the methods can provide useful information on the range of plausible design flood magnitudes and should be considered together with the applicability of each method to the catchment being analysed.

12.11 Flood frequency analysis

The ***Flood frequency*** tab, see **Figure 12-40**, provides statistical frequency analysis of observed historical flood peaks. The frequency-analysis procedures are similar to those described for the *Flow Analysis – Flood Frequency Analysis* section; however, within the Flood Estimation module an additional *Data Quality Review* is provided before the frequency analysis is undertaken.

This review allows the user to examine the historical record on a hydrological-year basis, identify incomplete or potentially unreliable flood peaks, consider the capacity of the measuring structure, and, where justified, replace an observed annual peak with an independently reviewed value before it is included in the frequency analysis.

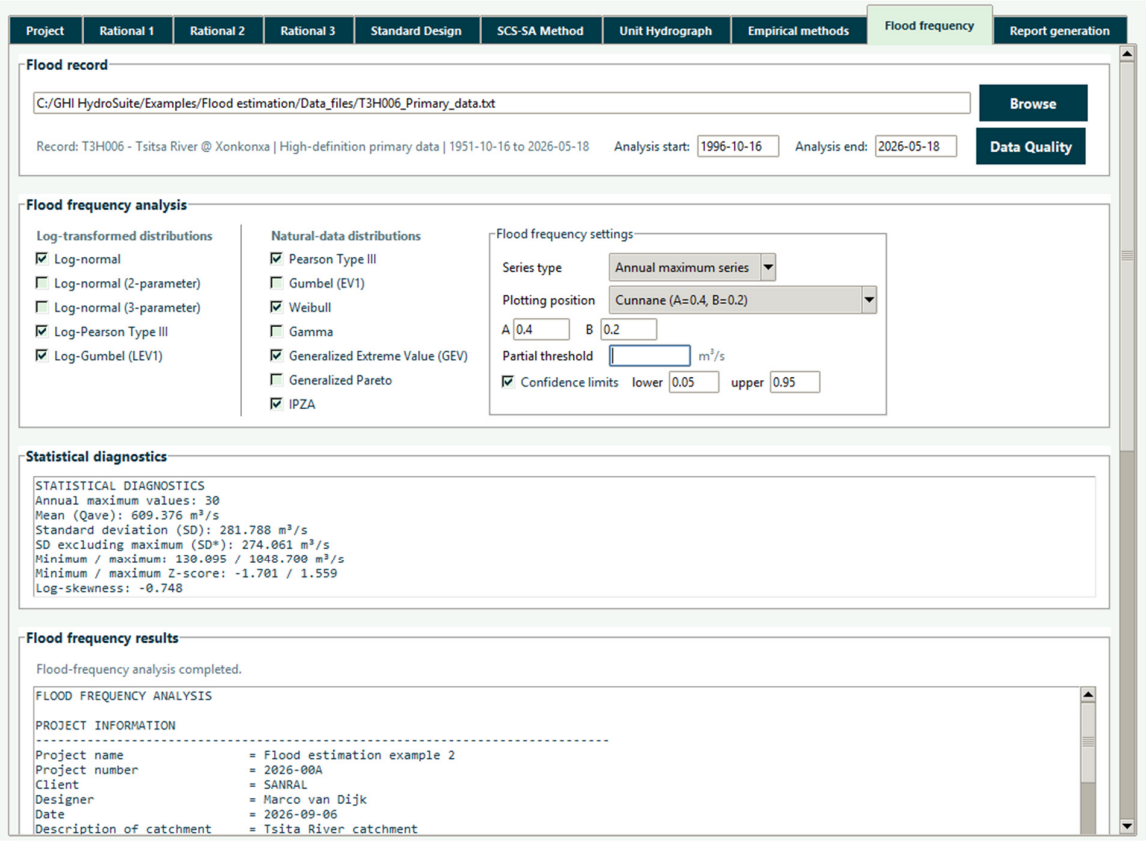


Figure 12-40: Flood Estimation - Flood frequency analysis

12.11.1 Selecting the historical flood record

The historical flow record to be analysed is selected at the top of the ***Flood frequency*** tab.

The user should:

- Click *Browse* and select the required historical flow record.
- Confirm that the correct station and data record have been loaded.
- Specify the required *Analysis start* and *Analysis end* dates.

These allow the frequency analysis to be restricted to an appropriate portion of the available historical record.

- Click *Data Quality* to extract the annual flood information and open the Flood Frequency Data Quality Review screen.
- Review and, where necessary, edit the flood-peak information before clicking *Accept* to return the reviewed dataset to the Flood Frequency Analysis.

The selected analysis period should contain a sufficiently representative historical record for the intended frequency analysis.

12.11.2 Flood Frequency Data Quality Review

The *Flood Frequency Data Quality Review,* **Figure 12-41**, screen presents the extracted historical record by hydrological year. The monthly peak flows are displayed for each year together with the annual peak selected for use in the frequency analysis.



2005/06	20.5	136.4	35.7	207.6	186.5	88.4	94.3	124.2	7.8	4.5	587.4	813.2	813.2	
2006/07	370.3	450.4	215.0	62.2	82.6	38.4	74.8	5.8	6.7	3.9	1.9	1.0	450.4	
2007/08	16.8	45.3	93.2	196.0	675.9	360.4	130.4	35.7	65.4	9.5	6.0	2.7	675.9	
2008/09	2.1	61.5	166.1	53.1	855.4	66.3	10.8	14.3	3.9	3.4	15.2	1.8	855.4	
2009/10	80.7	78.8	148.8	233.1	281.9	68.8	33.4	6.7	7.7	2.6	1.6	0.8	281.9	Missing data days: Sep(1)
2010/11	14.1	135.3	213.8	515.6	270.4	317.9	88.0	41.9	45.3	84.1	45.1	11.3	515.6	
2011/12	28.2	16.8	217.4	448.5	178.0	327.5	282.4	10.7	13.6	23.0	367.0	43.2	448.5	
2012/13	295.2	209.2	593.4	433.6	345.8	446.6	1048.7	33.7	8.8	5.3	3.0	2.4	1048.7	Missing data days: Jun(1), Jul(1), Aug(1) | Scrut
2013/14	136.4	48.4	324.5	529.5	502.0	168.5	38.9	11.9	3.4	2.4	3.6	1.1	529.5	Missing data days: Oct(1), Jun(1), Jul(1), Sep(1)
2014/15	7.7	26.1	133.0	421.4	79.0	55.7	60.3	6.7	2.7	4.9	3.2	9.1	421.4	Missing data days: May(3), Jun(4), Jul(1), Aug(
2015/16	6.4	5.4	4.9	104.9	89.1	130.1	51.4	15.1	4.0	41.0	26.8	5.4	130.1	Missing data days: Nov(1)
2016/17	6.0	90.2	17.4	100.9	292.3	74.6	42.4	28.9	4.3	3.0	7.6	1.1	400	Replaced with a know peak value
2017/18	588.2	15.2	38.5	341.6	407.0	342.1	80.5	14.1	6.6	5.1	8.3	9.4	588.2	
2018/19	2.9	1.6	22.3	42.9	580.7	149.4	978.7	47.7	9.4	3.7	2.1	1.6	978.7	
2019/20	1.2	4.6	29.5	109.4	196.7	451.0	153.5	96.0	6.4	3.2	2.1	2.7	451.0	
2020/21	14.2	82.8	206.9	657.2	226.6	103.1	21.8	34.4	282.4	5.9	5.3	9.5	657.2	Missing data days: Jul(3)
2021/22	76.6	58.4	275.5	975.6	270.4	470.9	1048.7	151.3	23.0	11.7	10.5	209.2	1048.7	Missing data days: Jul(1) | Scrutinize the stage
2022/23	130.1	357.7	357.7	887.2	1048.7	130.4	31.7	78.0	43.6	10.4	5.6	3.5	1048.7	Missing data days: Apr(1), May(1), Sep(1) | Scr
2023/24	241.1	20.3	382.7	1048.7	56.1	9.7	76.6	4.6	4.0	2.2	2.3	16.8	1048.7	Scrutinize the stage level reached during the fl
2024/25	157.0	103.6	30.4	133.5	370.9	482.0	214.6	49.2	1048.7	17.0	9.9	6.2	1048.7	Missing data days: Sep(6) | Scrutinize the stage
2025/26	14.7	135.0	47.3	51.8	393.0	40.9	15.4	35.1					393.0	

Figure 12-41: Flood Frequency Data Quality Review screen

Colour coding is used to draw attention to the condition of the underlying data. The options and descriptions for the Data Quality Review is listed and described in **Table 12-35**.

Table 12-35: Data quality review options

Option / indication	Description
Complete / good	Indicates data considered complete and suitable for use without an identified data-quality concern.
Missing or poor-quality data	Highlights periods containing missing or potentially poor-quality observations. These periods should be considered when assessing whether the annual peak is representative.

Option / indication	Description
At/above structure capacity	Identifies values at or above the specified measuring-structure capacity. Such flood peaks may require additional scrutiny because the reliability of the recorded discharge may be affected by the capacity of the gauging structure or rating relationship.
User override	Identifies an annual peak that has been replaced manually by the user with a reviewed value.
Measuring structure capacity	Allows the user to specify the estimated maximum capacity of the measuring structure in m^3/s. Clicking the *Apply* button uses this value to identify observations at or above the specified capacity.
Monthly peak values	Displays the extracted maximum flow for each month of the hydrological year, allowing the user to inspect the observations from which the annual maximum is selected.
Peak used	Displays the flood peak that will be used for the particular hydrological year in the frequency analysis. By default, this is the maximum observed flood peak for that year.
Include / exclude	The check box associated with each hydrological year allows the user to determine whether that year's flood peak should be included in the subsequent frequency analysis.
Comments / warnings	Provides information on identified data-quality concerns, such as missing data days, together with prompts where particular flood events may warrant further scrutiny.
User replacement value	The annual peak may be edited where an independently reviewed replacement peak is available. The replacement is identified as a user override so that it can be distinguished from the originally extracted value.
Accept	Accepts the reviewed flood-peak series and returns it to the ***Flood Frequency Analysis*** tab for subsequent statistical analysis.
Cancel	Closes the review without accepting the changes.

The Peak used value defaults to the maximum observed flood peak within each hydrological year. A value should only be replaced where an independently reviewed replacement peak is available. The *Data Quality Review* is therefore intended primarily as a quality-control and screening procedure rather than a mechanism for arbitrarily modifying the historical record.

12.11.3 Completing the frequency analysis

Once the reviewed flood series has been accepted, the user can proceed with the statistical frequency analysis. The required series type, plotting position, probability distributions and confidence limits can then be selected on the main ***Flood Frequency*** tab. Statistical diagnostics and fitted frequency results are displayed below the analysis controls.

The additional functionality within the Flood Estimation module is principally the Flood Frequency Data Quality Review, which allows the historical flood series to be assessed and refined before the statistical analysis is performed.

The available probability distributions and frequency-analysis settings are shown in **Figure 12-40**.

Multiple probability distributions can be selected simultaneously. This allows the fitted distributions to be compared and assists the user in evaluating the sensitivity of estimated flood magnitudes to the selected statistical model. The available inputs and settings are described in **Table 12-36**.

Table 12-36: Flood Frequency Analysis options

Option	Description
Log-normal	Fits a Log-normal probability distribution to the flood series. The logarithmic transformation is applied automatically.
Log-normal (2-parameter)	Fits the two-parameter form of the Log-normal distribution to the selected flood series.
Log-normal (3-parameter)	Fits the three-parameter form of the Log-normal distribution.
Log-Pearson Type III	Fits a Pearson Type III distribution to logarithmically transformed flood values.
Log-Gumbel (EV1)	Fits the Gumbel Extreme Value Type I distribution using logarithmically transformed flood values.
Pearson Type III	Fits the Pearson Type III distribution directly to the natural flood data.
Gumbel (EV1)	Fits the Gumbel Extreme Value Type I distribution to the natural flood data.
Weibull	Fits a Weibull probability distribution to the selected flood series.
Gamma	Fits a Gamma probability distribution to the selected flood series.
Generalized Extreme Value (GEV)	Fits a Generalized Extreme Value distribution to the flood series.
Generalized Pareto	Fits a Generalized Pareto distribution to the selected flood series.
IPZA	Applies the Improved Probability-Zero Adjustment (IPZA) flood-frequency method to the selected flood series. It provides an alternative approach for estimating design flood magnitudes, particularly where the observed flood record exhibits characteristics that are not adequately represented by conventional probability distributions. IPZA results can be displayed together with the fitted statistical distributions for comparison (Van der Spuy & Du Plessis, 2022a; Van der Spuy & Du Plessis, 2022b).
Series type	Specifies the flood series to be used in the frequency analysis. The selected series determines how flood peaks are extracted from the underlying record. Annual maximum series or Partial series can be selected from the drop-down list.
Plotting position	Specifies the empirical plotting-position formula used to assign exceedance probabilities or return periods to the observed flood peaks. Options available are: Weibull, Median Hazen, Cunnane, Hirsch/Stedinger, Z-set (Van der Spuy & Du Plessis, 2024) or Other
A / B	Displays the coefficients associated with the selected plotting-position method. In case Plotting position was selected as Other the A/B parameters can be specified.

Option	Description
Partial threshold	Specifies the flow threshold used when a partial-duration series is selected. If left blank, the default threshold indicated by the software is used.
Confidence limits	Enables confidence limits for the fitted frequency distributions.
Lower / Upper	Specifies the lower and upper probability limits used when confidence limits are selected.
Results viewer	Displays information on the extracted flood series, statistical diagnostics, flood-peak values and results of the selected frequency analyses.

12.11.4 Flood series selection

The Series type determines which flood events are included in the frequency analysis.

For an *Annual maximum series*, the maximum flood peak occurring within each hydrological year is extracted. The resulting series therefore contains a maximum of one flood peak for each hydrological year represented by the analysed record.

The *Results viewer* identifies the hydrological year, date and corresponding peak flow for the extracted annual maximum series. It also reports the number of flood peaks extracted and the maximum observed flood peak and its date.

Where a *Partial duration series* is selected, qualifying flood events are identified relative to a specified Partial threshold. This approach allows more than one qualifying flood event to be included from a particular year.
If the Partial threshold field is left blank, the software applies the default threshold indicated on the screen.

12.11.5 Plotting positions

Observed flood peaks are assigned empirical probabilities using the selected Plotting position method. The plotting position determines where the observed flood peaks are displayed relative to return period on the frequency graph.

The corresponding A and B coefficients are displayed automatically for the selected plotting-position method. In the example shown in **Figure 12-40**, the Cunnane plotting position (A = 0.4, B = 0.2) is selected.

The plotting positions represent the observed flood data and provide a basis for visually comparing the observed series with the fitted statistical distributions.

12.11.6 Statistical probability distributions

GHI HydroSuite allows several statistical probability distributions to be fitted to the selected flood series. The distributions are divided on the screen into Log-transformed distributions and Natural-data distributions.

For log-transformed distributions, the required logarithmic transformation is performed automatically by GHI HydroSuite. Natural-data distributions are fitted directly to the extracted flood values.

More than one distribution can be selected for a single analysis. The fitted curves and estimated flood magnitudes can therefore be compared to assess differences between the alternative statistical models.

The selection of an appropriate probability distribution should not be based solely on the estimated flood associated with a particular return period. The fitted distribution should also be considered in relation to the observed flood series, record length and the statistical characteristics of the data.

12.11.7 Statistical diagnostics

Before presenting the fitted frequency results, **GHI HydroSuite** calculates statistical characteristics of the extracted flood series. As shown in the in **Figure 12-42**, these may include the:

- mean flood peak;
- standard deviation;
- standard deviation excluding the maximum flood;
- minimum and maximum values;
- minimum and maximum Z-scores;
- log-skewness; and
- length of the available flood record.

These diagnostics provide additional information on the characteristics of the flood series and can assist the user when comparing alternative frequency distributions.

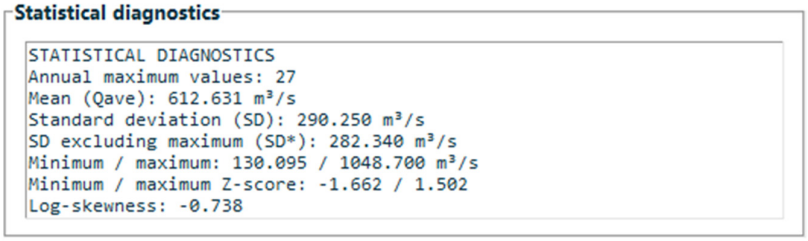


Figure 12-42: Statistical diagnostics

The *Results viewer* may also provide diagnostic comments relating to the available record and the suitability of comparing alternative frequency distributions. These should be considered together with the graphical and numerical frequency-analysis results.

12.11.8 Confidence limits

Where *Confidence limits* are selected, lower and upper probability limits can be specified for the frequency analysis. These provide an indication of the uncertainty associated with the fitted frequency relationship.

The required lower and upper limits are entered in the corresponding fields. In the example shown in **Figure 12-40**, values of 0.05 and 0.95 are specified (5% and 95 confidence limits).

The uncertainty associated with estimated floods generally becomes increasingly important when extrapolating to return periods substantially longer than the available observed record. Design-flood estimates at long return periods should therefore be interpreted with appropriate consideration of the available record length, observed flood behaviour and differences between fitted distributions.

12.11.9 Flood Frequency Analysis results

The *Flood Frequency Distribution Graphs* section provides a graphical comparison of the observed flood record, the selected fitted probability distributions and the IPZA frequency relationship. The graph is updated according to the distributions and display options selected by the user as depicted in **Figure 12-43**.

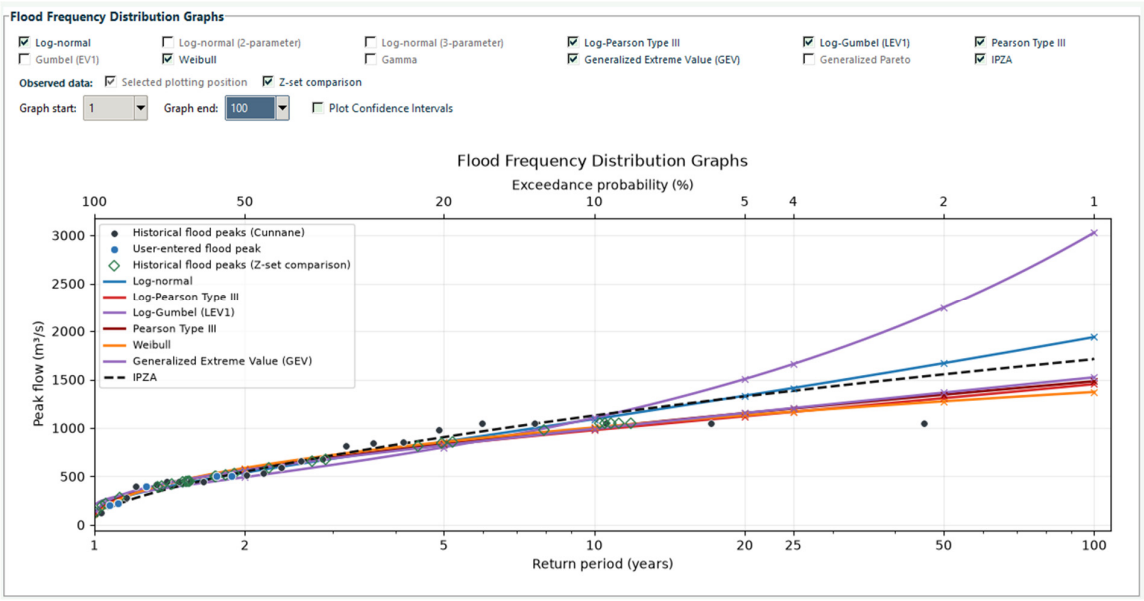


Figure 12-43: Flood Frequency Distribution Graphs

The lower horizontal axis represents return period (years), while the upper horizontal axis provides the corresponding exceedance probability (%). Peak flow is plotted on the vertical axis in m^3/s. This dual-axis presentation allows the frequency results to be interpreted in either return-period or exceedance-probability terms.

The check boxes above the graph allow individual probability distributions to be displayed or removed without changing the underlying analysis. Multiple distributions may therefore be shown simultaneously to assess how alternative statistical models represent the historical flood record and how their estimates diverge at longer return periods.

The *IPZA* result may also be displayed on the graph together with the conventional fitted distributions. This provides an additional flood-frequency estimate against which the statistical distributions and observed flood behaviour can be compared.

Observed historical flood peaks, black dots, are plotted using the selected plotting-position method. Where a user-entered flood peak has been specified, it is displayed using a separate marker (blue dot) so that it can be distinguished from the historical flood peaks.

The *Selected plotting position option* controls the display of the observed historical flood peaks based on the plotting-position method selected for the analysis.

Where *Z-set comparison* is selected, an additional set of historical flood-peak plotting positions is shown using the Z-set method of Van der Spuy and Du Plessis. These points are displayed using a separate marker (green diamond shape) and provide a direct graphical comparison between the selected plotting-position method and the Z-set plotting positions. Selecting this option does not replace the selected plotting position; it overlays the Z-set positions for comparison.

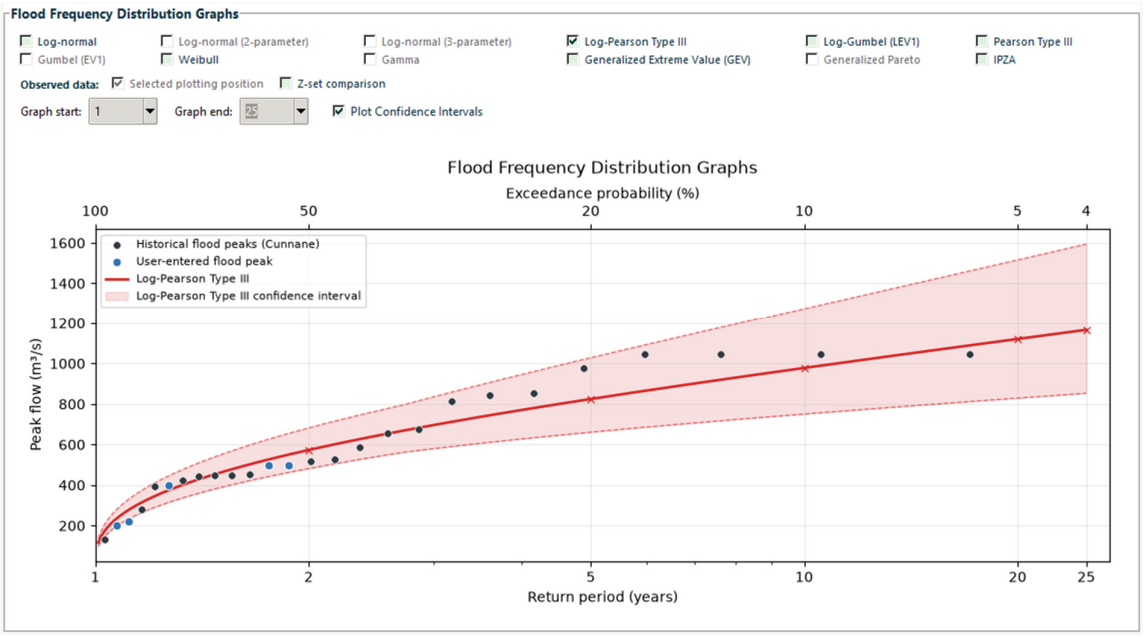


Figure 12-44: Flood Frequency Distribution Graphs - Period & Confidence limits

As depicted in **Figure 12-44** the *Graph start* and *Graph end* controls define the return-period range displayed on the graph. These controls allow the user to focus on a particular portion of the frequency relationship or extend the graph to the longer return periods required for the analysis.

The *Plot Confidence Intervals* option displays the calculated uncertainty bounds associated with the selected fitted probability distributions. When enabled, the confidence intervals are shown as shaded bands around the corresponding frequency curves.

The probability levels used to calculate the intervals are defined by the Lower and Upper confidence-limit settings described in paragraph 12.11.8. For example, lower and upper values of *0.05* and *0.95* define the corresponding lower and upper probability limits.

Confidence intervals generally widen as the frequency curves are extrapolated towards longer return periods. This provides a useful visual indication of the increasing uncertainty associated with estimating extreme floods beyond the range well represented by the historical record.

Where several distributions are plotted simultaneously, their confidence intervals may overlap. The confidence intervals should therefore be interpreted together with the fitted curves, observed flood peaks, statistical diagnostics and available record length rather than as a basis for selecting a particular distribution on their own.

12.11.10 Interacting with and exporting the frequency graph

The *Flood Frequency Distribution Graph* is interactive and can be configured using the controls immediately above the graph. The user can select which fitted distributions are displayed, show or hide the observed plotting positions and Z-set comparison, specify the displayed return-period range, and enable or disable confidence intervals.

The graph can also be *right-clicked* to copy the current graphical output to the Windows clipboard, see **Figure 12-45**. The copied image reflects the graph as currently configured, including the selected probability distributions, IPZA relationship, observed flood peaks, Z-set comparison where selected, user-entered flood peaks and confidence intervals where enabled. The copied graph can then be pasted directly into reports, documents or other applications.

The graphical comparison provides an important means of evaluating the flood-frequency analysis. A fitted distribution should not be selected solely because it produces a particular design-flood magnitude. Consideration should also be given to how well the fitted relationship represents the observed flood peaks, the statistical characteristics and length of the available record, the behaviour of alternative distributions, the IPZA estimate and, where applicable, the Z-set comparison and confidence intervals.

Particular caution is required when extrapolating to return periods substantially longer than the historical record. Differences between the alternative frequency relationships and the widening of confidence intervals at longer return periods provide an indication of the uncertainty associated with such extrapolation.

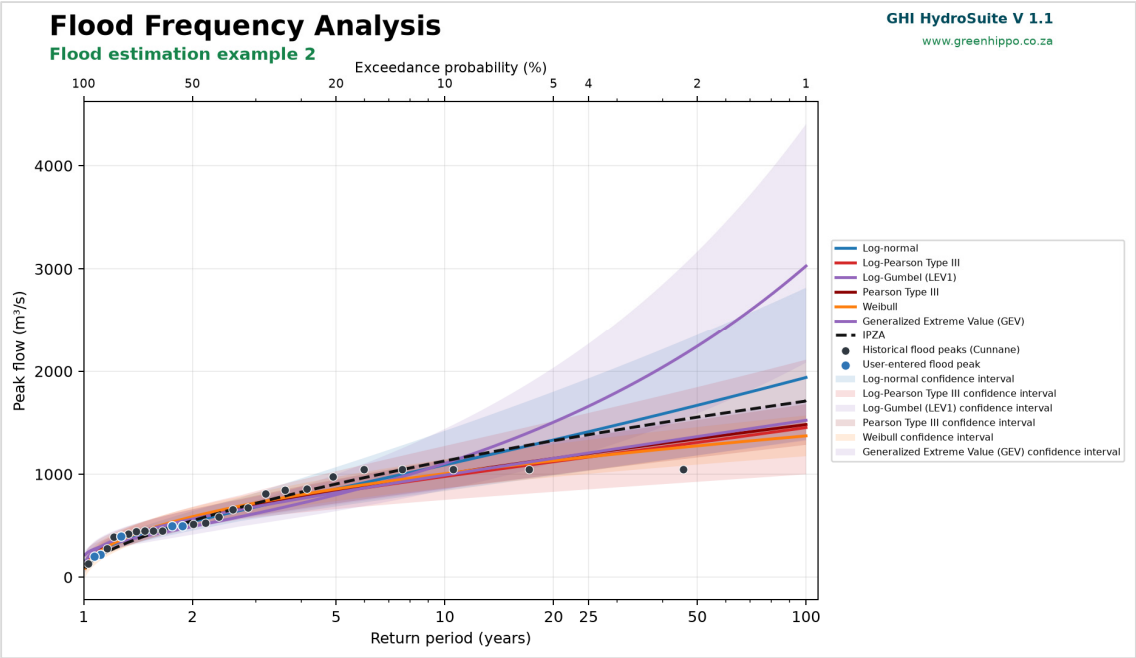


Figure 12-45: Flood Frequency Distribution Graph - Copied to clipboard

The *Results viewer* provides a summary of the flood-frequency analysis, including the selected flood series (shown in **Figure 12-46**), plotting-position method, statistical characteristics of the extracted flood peaks and the flood-frequency results obtained from the selected probability distributions.

Flood frequency results

Flood-frequency analysis completed.

FLOOD PEAK SERIES

Hydrological year	Peak date	Peak flow (m³/s)	Comment
1999/00	2000-03-16	844.0	
2000/01	2001-02-14	200.0	user entered value
2001/02	2002-09-10	220.0	user entered value
2002/03	2003-01-11	500.0	user entered value
2003/04	2004-09-26	443.5	
2004/05	2005-01-23	500.0	user entered value
2005/06	2006-09-27	813.2	
2006/07	2006-11-27	450.4	
2007/08	2008-02-24	675.9	

Figure 12-46: Flood frequency results viewer

12.12 Report Generation

The ***Report generation*** tab provides the final step in the Flood Estimation workflow and enables the results from the completed analyses to be compiled into a single, professionally formatted PDF report, shown in **Figure 12-47**. The reporting system is designed to consolidate the project information, catchment characteristics, calculation inputs, intermediate parameters and final design flood results into a consistent format suitable for engineering documentation, review and record keeping.

The Report generation screen consists of two main components: the analysis selection panel and the *Print Viewer*.

Analysis selection panel - The left-hand panel lists the flood-estimation analyses that are available for inclusion in the report. These include Rational Method 1, Rational Method 2, Rational Method 3, Standard Design Flood, SCS-SA Method, Unit Hydrograph Method, Empirical Methods and Flood Frequency Analysis. Each completed analysis can be selected or deselected independently using the corresponding checkbox. Sections only become available once the associated analysis has been completed, thereby preventing incomplete analyses from inadvertently being included in the final report.

Print Viewer - The right-hand panel provides a text-based preview of the information that will be incorporated into the report. This allows the user to review project information, catchment characteristics and calculated results before generating the final document. The preview is particularly useful for identifying missing or incorrect project information before the report is finalised.

Once the required analyses have been selected, the *Generate PDF Report* button compiles the selected sections into a single PDF document.

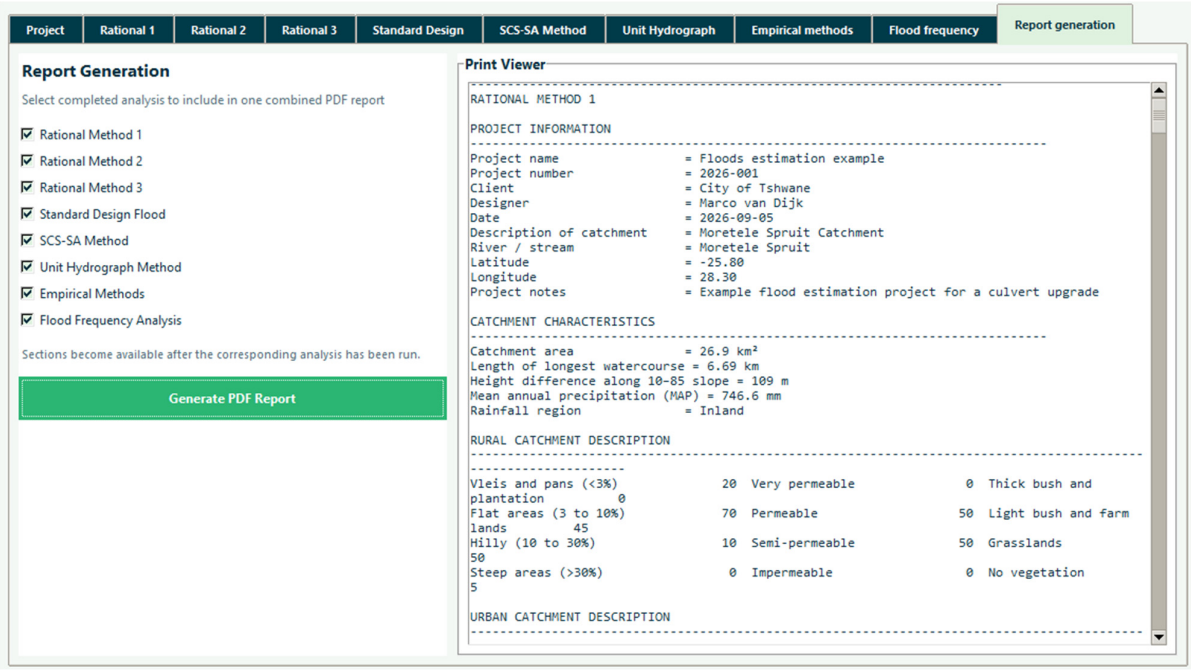


Figure 12-47: Flood Estimation - Report generation

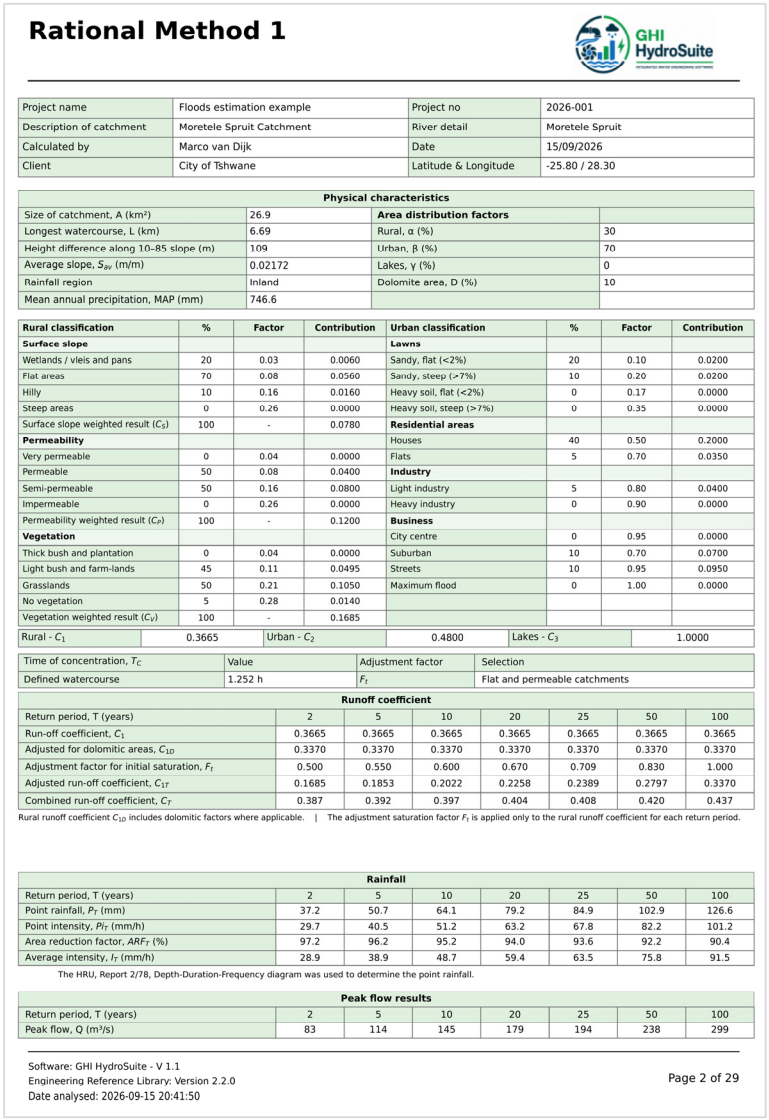
The generated report presents the analyses in a standardised engineering-report format. Each selected flood-estimation method is presented as a dedicated report section containing the relevant information for that method. Depending on the analysis, the report may include:

- project and catchment information;
- physical catchment characteristics and classification;
- calculation parameters and selected coefficients;
- time of concentration and applicable adjustment factors;
- design rainfall depths and intensities for the relevant return periods;
- intermediate calculation results;

- calculated peak flood discharges for the selected return periods;
- flood-frequency tables and graphical outputs, where applicable; and
- calculation notes, software version information and analysis date.

The tables are arranged to allow the principal inputs, assumptions and results to be readily reviewed. Where results are calculated for several return periods, these are presented consistently across the report to facilitate comparison.

The generated PDF uses a consistent **GHI HydroSuite** report template, incorporating clearly defined section headings, structured tables, units, explanatory notes, page numbering and GHI HydroSuite branding. The example below in **Figure 12-48**, illustrates the output generated for Rational Method 1, where the project information is followed by the physical catchment characteristics, runoff-coefficient calculations, rainfall information and resulting peak design flows.



Rational Method 1

Project name	Floods estimation example	Project no	2026-001
Description of catchment	Moretele Spruit Catchment	River detail	Moretele Spruit
Calculated by	Marco van Dijk	Date	15/09/2026
Client	City of Tshwane	Latitude & Longitude	-25.80 / 28.30

Physical characteristics

Size of catchment, A (km²)	26.9	**Area distribution factors**	
Longest watercourse, L (km)	6.69	Rural, α (%)	30
Height difference along 10–85 slope (m)	109	Urban, β (%)	70
Average slope, S_{av} (m/m)	0.02172	Lakes, γ (%)	0
Rainfall region	Inland	Dolomite area, D (%)	10
Mean annual precipitation, MAP (mm)	746.6		

Rural classification	%	Factor	Contribution	Urban classification	%	Factor	Contribution
Surface slope				**Lawns**			
Wetlands / vleis and pans	20	0.03	0.0060	Sandy, flat (<2%)	20	0.10	0.0200
Flat areas	70	0.08	0.0560	Sandy, steep (>7%)	10	0.20	0.0200
Hilly	10	0.16	0.0160	Heavy soil, flat (<2%)	0	0.17	0.0000
Steep areas	0	0.26	0.0000	Heavy soil, steep (>7%)	0	0.35	0.0000
Surface slope weighted result (C_S)	100	-	0.0780	**Residential areas**			
Permeability				Houses	40	0.50	0.2000
Very permeable	0	0.04	0.0000	Flats	5	0.70	0.0350
Permeable	50	0.08	0.0400	**Industry**			
Semi-permeable	50	0.16	0.0800	Light industry	5	0.80	0.0400
Impermeable	0	0.26	0.0000	Heavy industry	0	0.90	0.0000
Permeability weighted result (C_P)	100	-	0.1200	**Business**			
Vegetation				City centre	0	0.95	0.0000
Thick bush and plantation	0	0.04	0.0000	Suburban	10	0.70	0.0700
Light bush and farm-lands	45	0.11	0.0495	Streets	10	0.95	0.0950
Grasslands	50	0.21	0.1050	Maximum flood	0	1.00	0.0000
No vegetation	5	0.28	0.0140				
Vegetation weighted result (C_V)	100	-	0.1685				

Rural - C_1	0.3665	Urban - C_2	0.4800	Lakes - C_3	1.0000

Time of concentration, T_C	Value	Adjustment factor	Selection
Defined watercourse	1.252 h	F_t	Flat and permeable catchments

Runoff coefficient

Return period, T (years)	2	5	10	20	25	50	100
Run-off coefficient, C_1	0.3665	0.3665	0.3665	0.3665	0.3665	0.3665	0.3665
Adjusted for dolomitic areas, C_{1D}	0.3370	0.3370	0.3370	0.3370	0.3370	0.3370	0.3370
Adjustment factor for initial saturation, F_t	0.500	0.550	0.600	0.670	0.709	0.830	1.000
Adjusted run-off coefficient, C_{1T}	0.1685	0.1853	0.2022	0.2258	0.2389	0.2797	0.3370
Combined run-off coefficient, C_T	0.387	0.392	0.397	0.404	0.408	0.420	0.437

Rural runoff coefficient C_{1D} includes dolomitic factors where applicable. | The adjustment saturation factor F_t is applied only to the rural runoff coefficient for each return period.

Rainfall

Return period, T (years)	2	5	10	20	25	50	100
Point rainfall, P_T (mm)	37.2	50.7	64.1	79.2	84.9	102.9	126.6
Point intensity, PI_T (mm/h)	29.7	40.5	51.2	63.2	67.8	82.2	101.2
Area reduction factor, ARF_T (%)	97.2	96.2	95.2	94.0	93.6	92.2	90.4
Average intensity, I_T (mm/h)	28.9	38.9	48.7	59.4	63.5	75.8	91.5

The HRU, Report 2/78, Depth-Duration-Frequency diagram was used to determine the point rainfall.

Peak flow results

Return period, T (years)	2	5	10	20	25	50	100
Peak flow, Q (m³/s)	83	114	145	179	194	238	299

Software: GHI HydroSuite - V 1.1
Engineering Reference Library: Version 2.2.0
Date analysed: 2026-09-15 20:41:50

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Figure 12-48: Example of the PDF output generated by the Flood Estimation Report generation module

13 BASIC HYDRAULICS

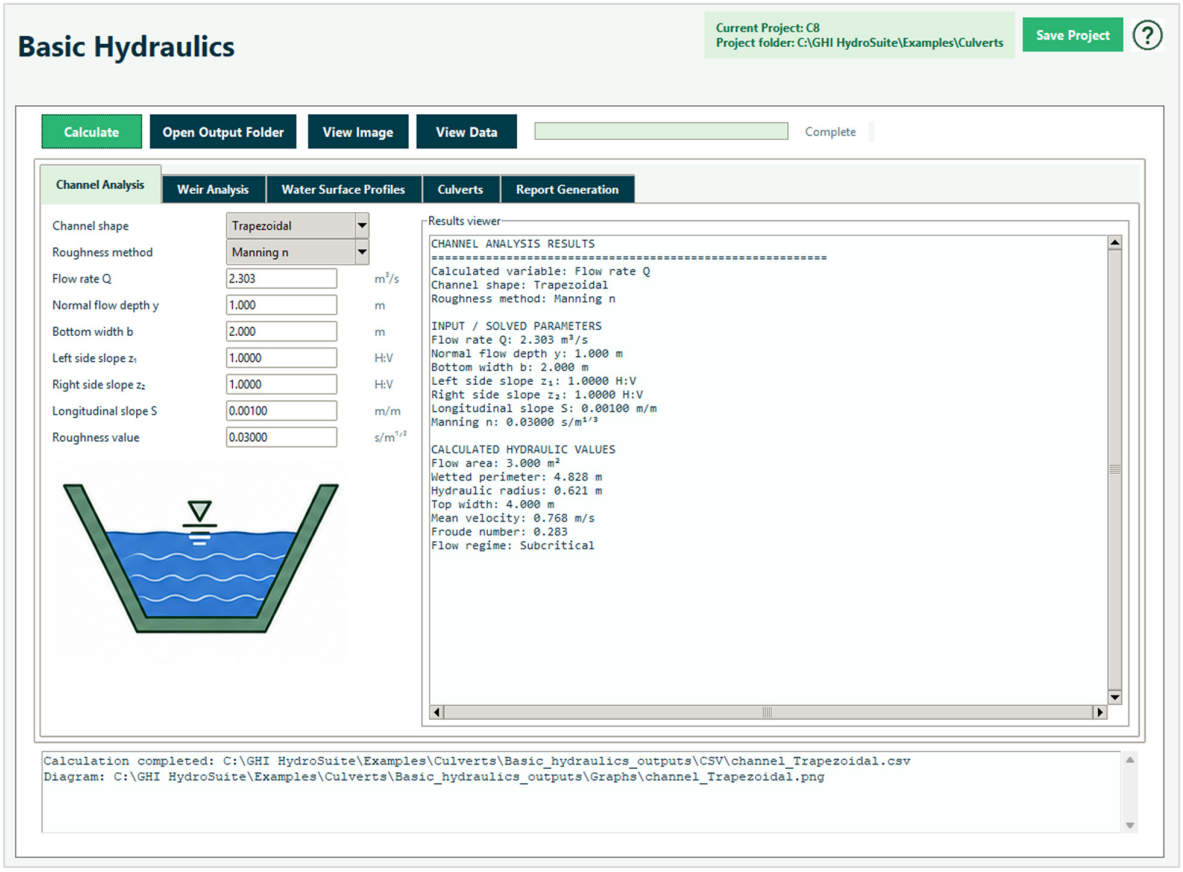


Figure 13-1: Basic Hydraulics screen

To be completed

14 PIPE ANALYSIS

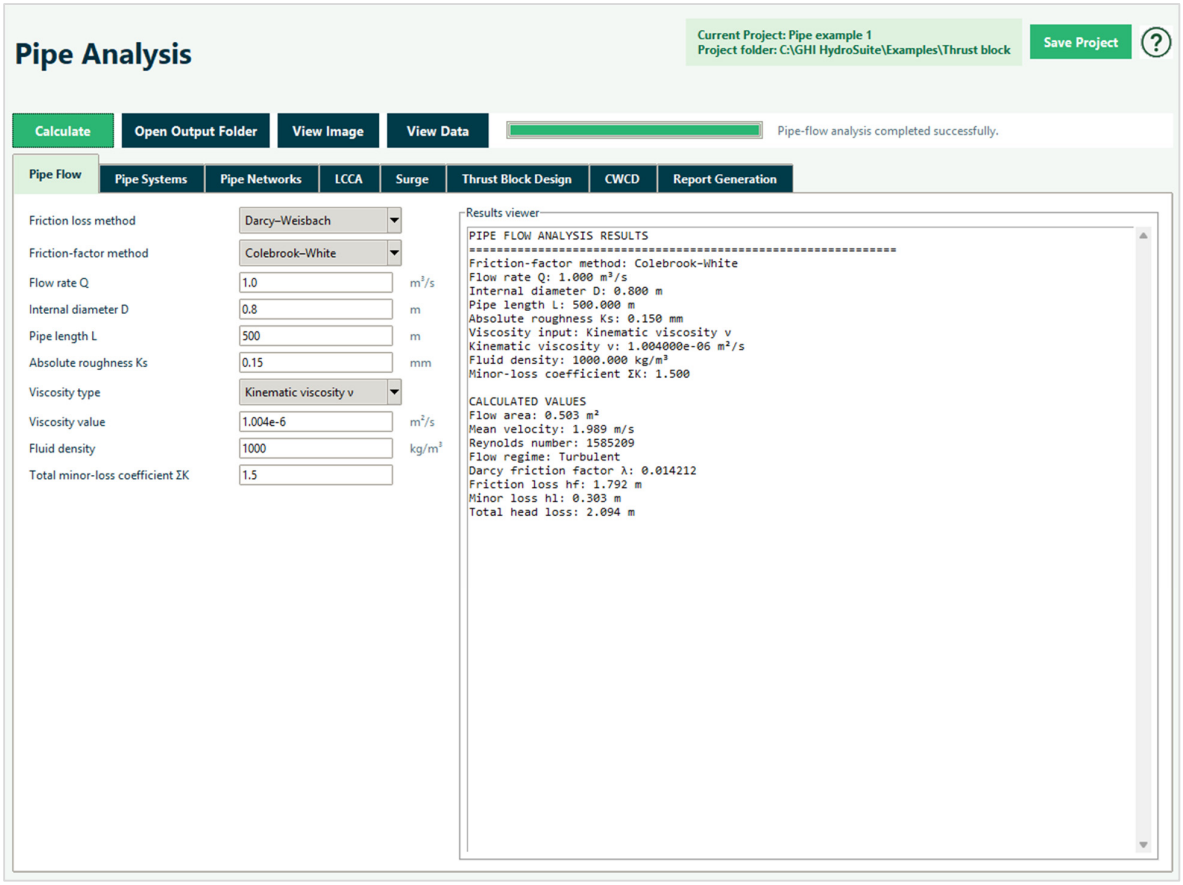


Figure 14-1: Pipe Analysis screen

To be completed

15 PUMP STATION ANALYSIS

This will be a future section in the GHI HydroSuite software.

16 HYDROPOWER

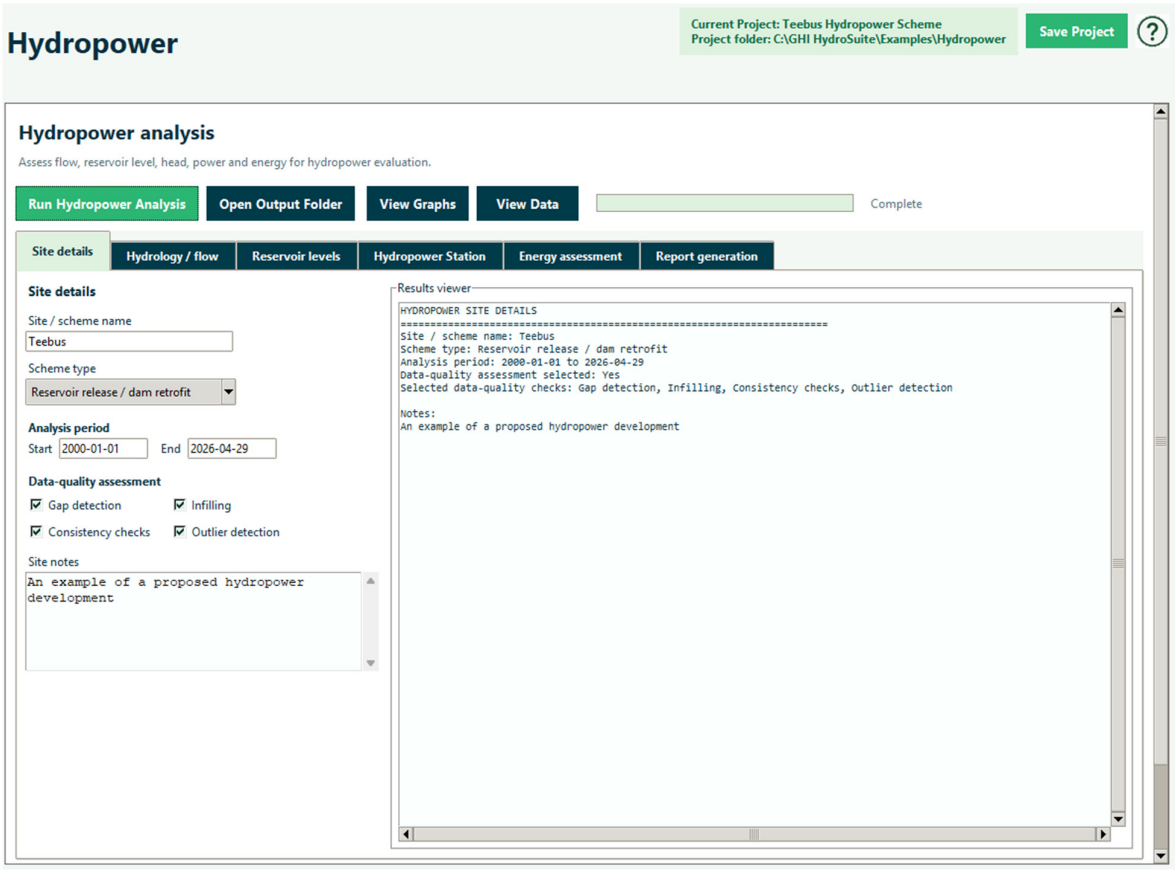


Figure 16-1: Hydropower analysis screen

To be completed

17 ECONOMIC ANALYSIS

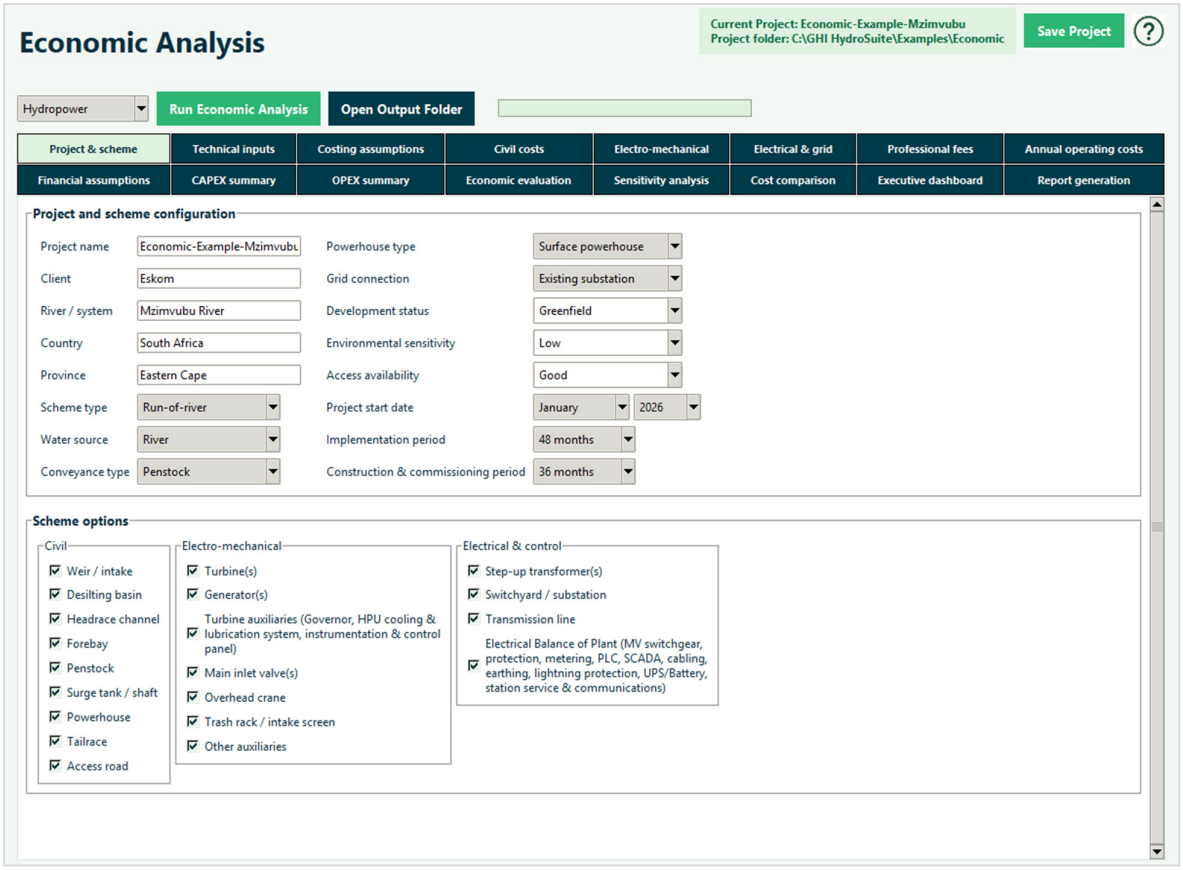


Figure 17-1: Economic Analysis screen

To be completed

18 REPORTS

The Reports screen, **Figure 18-1**, provides a central location for accessing the output generated by the different analysis modules in **GHI HydroSuite**. Rather than navigating back to an individual analysis screen to locate previously generated results, the Reports and output browser allows the user to browse the graphs, data files and PDF reports associated with the current project.

Only outputs that have already been generated by the respective analysis modules are displayed. The files remain stored within the relevant output folders of the current **GHI HydroSuite** project.

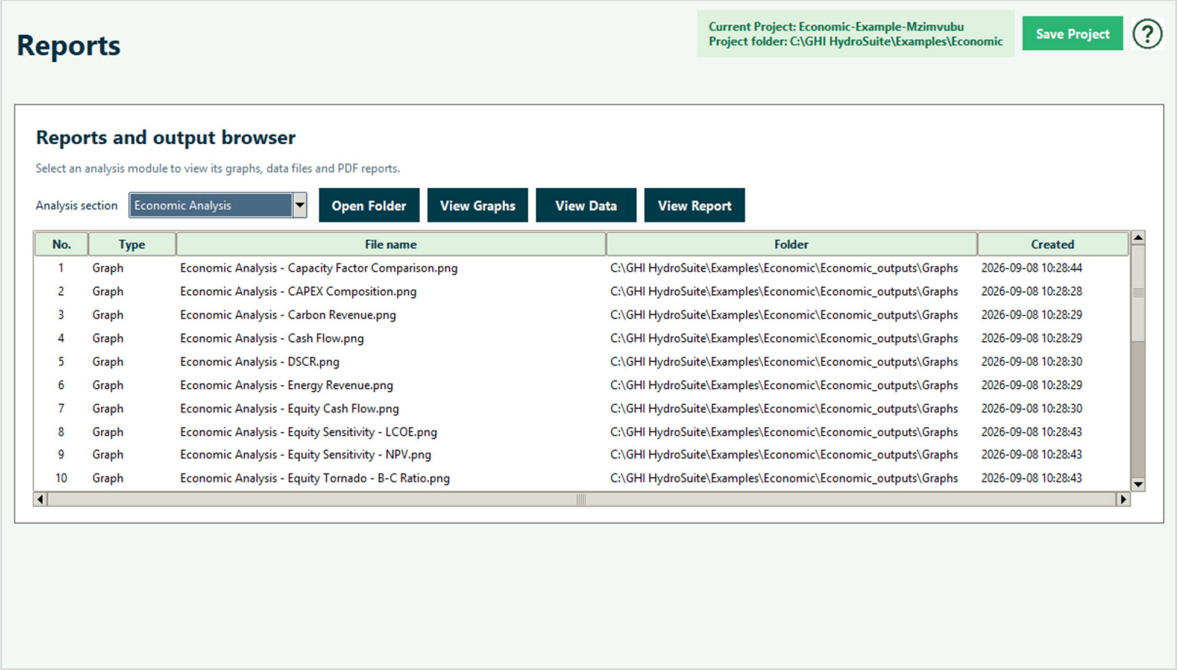


Figure 18-1: Reports screen

18.1 Reports and output browser

The *Analysis section* drop-down list is used to select the analysis module for which outputs are to be viewed which includes:

- Flow analysis
- Reservoir Analysis
- Hydropower analysis
- Flood Analysis
- Economic Analysis
- Basic hydraulics
- Pipe Analysis

Once a module is selected, the output browser automatically displays the available files associated with that analysis.

The output table provides the following information, **Table 18-1**:

Table 18-1: Output table

Item	Description
No.	Sequential number assigned to the displayed output file.
Type	Identifies the type of output, such as a graph, data file or report.
File name	Name of the generated output file. The file name normally identifies the analysis and the particular result represented.
Folder	Location within the current project where the output file is stored.
Created	Date and time at which the output file was generated.

This arrangement allows the user to identify individual outputs and confirm when they were created.

18.2 Viewing outputs

Four buttons are provided above the output browser for accessing the generated files, **Figure 18-1**.

Function	Description
Open Folder	Opens the output folder for the selected analysis module in Windows File Explorer, providing direct access to all generated files.
View Graphs	Displays or provides access to the graphical outputs generated for the selected analysis.
View Data	Provides access to the data files generated by the selected analysis, where applicable.
View Report	Opens the generated PDF report associated with the selected analysis, where available.

The available outputs depend on the selected analysis module and on the analyses that have already been completed. For example, an analysis may produce several individual graphical outputs in addition to supporting data files and a consolidated PDF report.

18.3 Output organisation

GHI HydroSuite automatically organises generated outputs within the current project folder. Separate output folders are maintained for the applicable analysis modules and output types. This ensures that graphs, data and reports remain associated with the project from which they were generated and provides a structured record of the completed analyses.

The Reports screen therefore acts primarily as an output browser and access point; calculations and report generation are undertaken within the respective analysis modules.

Note: If an expected graph, data file or report is not listed, first confirm that the corresponding analysis has been completed and that the required output has been generated within that module.

19 CONTACT US

Green Hippo Innovations is committed to providing support to users of GHI HydroSuite. Should you require assistance with software installation, licensing, operation, technical issues or general enquiries, please contact us using the details below.

We also welcome user feedback and suggestions for improvements or additional functionality. Such feedback assists with the continued development and enhancement of GHI HydroSuite.

General enquiries and technical support
E-mail: mailto:info@greenhippo.co.za

Software sales and licensing
E-mail: mailto:sales@greenhippo.co.za

Website
www.greenhippo.co.za

When requesting technical assistance, users are encouraged to provide the GHI HydroSuite version number, a brief description of the problem and, where appropriate, relevant screenshots or project information.

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