

Tasmania's Next Iconic Walk

Hydrological modelling

20 September 2024

Prepared by Hydro-Electric Corporation ABN48 072 377 158

t/a Entura, 4 Elizabeth Street, Hobart TAS 7000, Australia



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Client organisation	EPA Planning and Environment
Client contact	Monica Cameron
Project manager	Stewart Franks
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Reviewed by	Prafulla Pokhrel	<i>Prafulla</i>	20/9/2024
Approved by	Prafulla Pokhrel	<i>Prafulla</i>	20/9/2024
	(name)	(signature)	(date)
Distributed to	Monica Cameron	EPA Planning and Environment	
	(name)	(organisation)	(date)

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1. Introduction

As part of the proposed Next Iconic Walk (NIW) project, Tasmanian Parks and Wildlife Service (PWS) are proposing two new huts at Lake Mary and Lake Huntley. These huts are intended for overnight stays as a base for bushwalking in the area. Figure 1.1 shows the intended locations of the Huts – Lake Huntley (Hut Night 1) and Lake Mary (Hut Night 2).

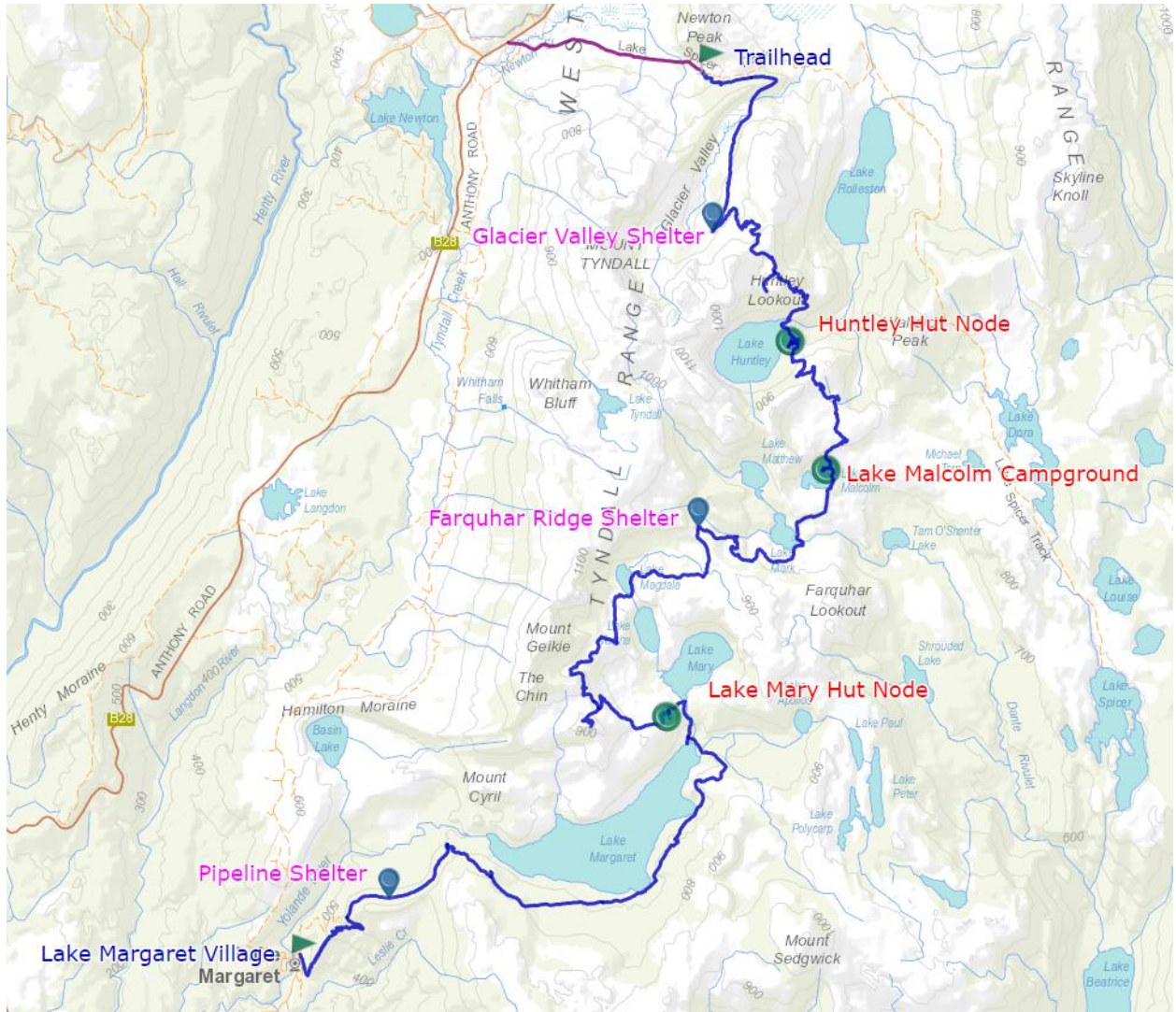


Figure 1.1: Intended location of the huts

A key feature of these huts is that they are intended to be primarily powered by micro-hydro schemes, similar to that already in existence at Lake Tahune near Frenchman's Cap. The power supply will primarily be for hut heating and cooking, but electricity would also be used for drying, communications, lighting, ventilation recharging back-up batteries and miscellaneous services. It is noted that some additional power is to be sourced through solar panels to augment the micro-hydro schemes.

As part of the design process, Island Renewables require a hydrological assessment of the viability of micro-hydro at these two sites and to provide a hydrological baseline for Entura's aquatic ecology assessment. This report documents the hydrological assessment provided for energy modelling and the aquatic impact assessment. Operational modelling will be completed by Island Renewable which will be used by Entura to inform the potential ecological impacts on the lakes and their outlet streams.

2. Methodology

After an analysis of energy requirements, Island Renewables have determined that a minimum of 50 kWh/d (or approx. 2kWh) would be required at both huts. This equates to a flowrate of approximately 10 litres per second. This hydrological assessment is provided to assess the reliability of sufficient flow to meet this flowrate.

To assess the availability of flows for the micro-hydro schemes, estimated flows have been generated with the use of a dynamic rainfall-runoff model – GR4J. This model has been employed to represent the non-linear transformation of rainfall to runoff. GR4J is a daily, lumped conceptual hydrological model which has seen extensive application. Details of the GR4J model structure are provided in Appendix A.

A dynamic hydrological model is required to capture the wetting/drying non-linearities of runoff production. That is, as the catchment dries, less runoff is generated per unit rainfall, and this is considered important as low flow periods impact reliability.

No rainfall or runoff data is available for either sites. To estimate flows, a catchment rainfall-runoff model was utilised. Given the lack of in situ data, a nearby catchment, the Tyndall Raceline (Site ID 100014), was identified as being similar in terms of the terrain, land cover and hydrological function.

The hydrological model GR4J was calibrated to the available Tyndall Raceline to achieve parameters representative of the study locations. GR4J model was then adjusted for the Lake Mary and Lake Huntley micro-hydro sites but with the calibrated parameter transposed to these catchments.

Long-term daily rainfall is available from the Lake Margaret site maintained by Hydro Tasmania, located just south of Lake Mary (TSM Site ID 370). This was chosen due to it being the nearest long-term rainfalls site to the project sites.

Reliability of flow has been determined in two approaches:

- **Approach 1** - Estimated runoff assuming no catchment storage (ie. lakes): estimating flows assuming no storage provides a highly conservative approach to estimating the sufficiency of flows. The catchment is treated as if no storage exists and consequently flows available to the micro-hydro schemes are based purely on catchment runoff generation processes.
- **Approach 2** - Estimated streamflow from catchment storages: estimating streamflow from the catchment storages provides a more realistic (compared to approach 1) simulation of water available for the micro-hydro schemes as well as estimating consequent flows downstream of the hydro intakes and catchment storages.

Results from both approaches for both proposed micro-hydro sites are presented as flow duration curves to assess the probabilities of periods of insufficient water supply.

3. GR4J calibration to Tyndall Raceline

GR4J was coded and configured for the Tyndall Raceline catchment (Figure 3.1). The Tyndall Raceline catchment area has been derived as 6.07 km². Daily rainfall and runoff were available for the period 22/5/2015 to 21/3/2023. The configured model was then calibrated using a simplex-based optimisation routine.

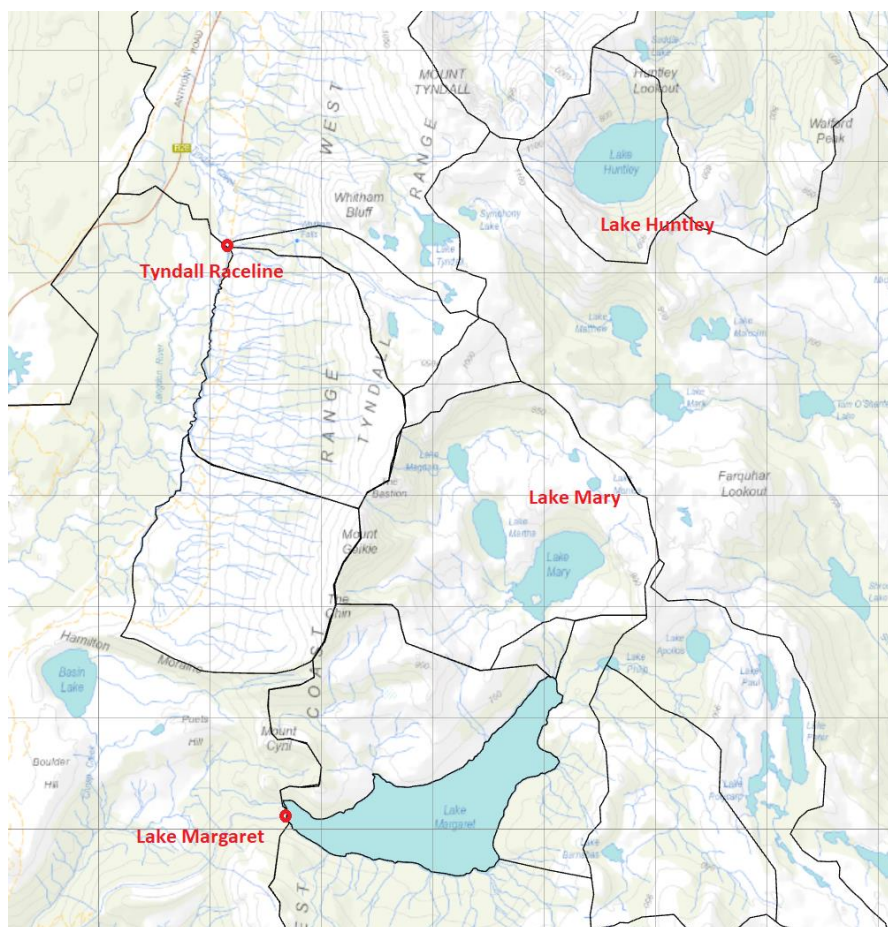


Figure 3.1: Location map indicating Tyndall Raceline in relation to Lake Huntley and Lake Mary and Lake Margaret rainfall collection point.

The calibration of the model was based on the maximisation of the Nash-Sutcliffe efficiency measure which calculates the proportion of observed data variance explained by the model simulation. As this study is concerned with the low flow catchment behaviour, the modelling objective to optimise in this case was selected as the logarithm of the simulated/observed flows. This ensures that the model is optimised with a focus on the low flow recession behaviour of the catchment and puts less weight on the peak, flood events.

The model calibration results and parameters are presented in Table 3.1. Figure 3.2 shows the entire sequence of calibration whilst Figure 3.3 shows a selected portion of the simulation focussed on the low flow, recession within the time series.

As demonstrated in Table 3.1, the calibration to log-transformed flow achieves model efficiency of 0.86 representing 86% of the observed variance of the log flows explained by the model simulations. This represents a good calibration indicating that the model is capable of simulating the observed streamflow. Figure 3.2 and Figure 3.3 demonstrate the comparison between simulated and observed in terms of the low flow characteristics of the catchment. Consequently, the results of the calibration indicate that the model is fit-for-purpose in providing realistic simulations of the observed flows.

Table 3.1: Calibrated parameters and performance – GR4J

Model parameters and efficiencies	Optimised value
Model Parameters	
x1: Capacity of production store (mm)	13.5198
x2: Water exchange coefficient (mm)	-0.2657
x3: Capacity of routing store (mm)	32.1563
x4: UH time base (days)	0.501
Model Efficiencies	
Nash-Sutcliffe E – flow, Q	0.79
Nash-Sutcliffe – root square transformed Q	0.85
Nash-Sutcliffe – log transformed Q	0.86
Bias (Simulated flow/ observed flow)	0.98
R ²	0.84

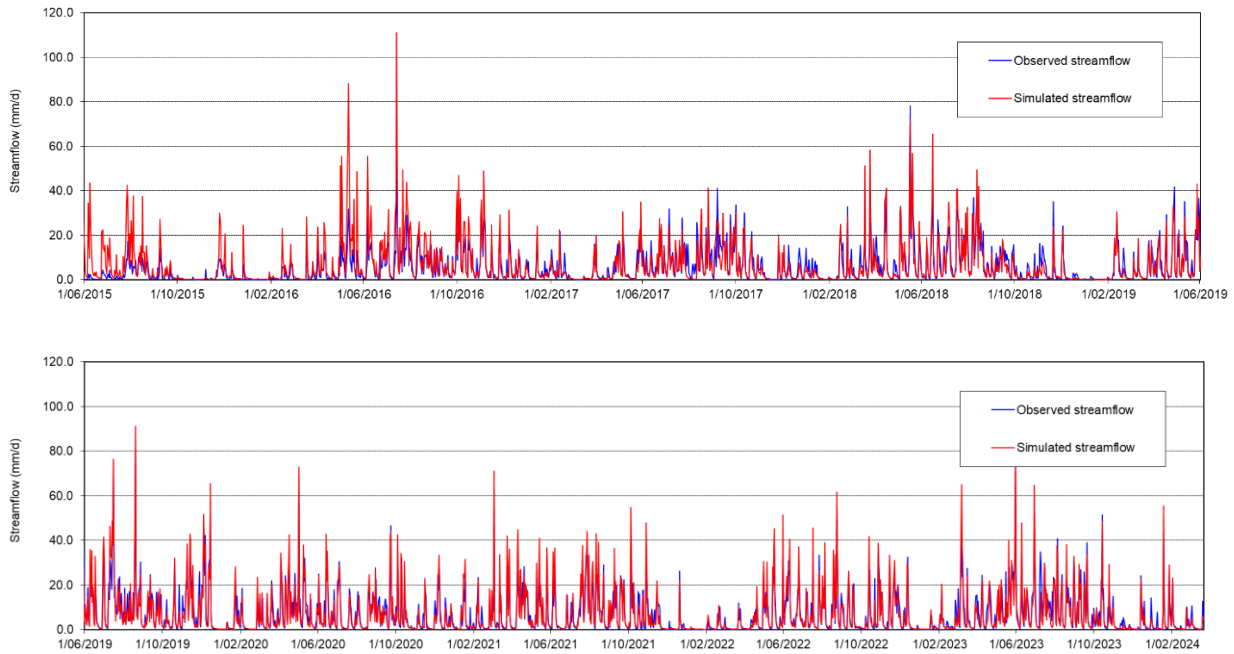


Figure 3.2: Simulated (red) and observed (blue) catchment discharge, Tyndall Raceline ($E[\log Q] = 0.86$)

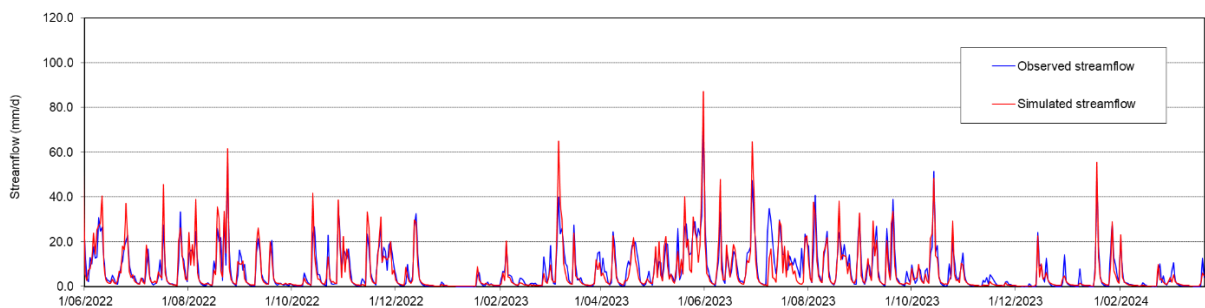


Figure 3.3: Simulated (red) and observed (blue) catchment discharge - 1/6/2022 – 1/4/2024

To assess the suitability of utilising the long-term Lake Margaret (Site ID 370) rainfall series for simulating Tyndall runoff, the calibrated model was then re-run utilising Lake Margaret rainfall, coincident with the Tyndall range data. This provides a check on whether the transposition of rainfall results in a comparable simulation of Tyndall Raceline flows. The simulation utilising the Lake Margaret rainfall resulted in a modelling efficiency of 0.80 for Log flows and 0.67 for absolute flows. These results are comparable with the calibrated efficiencies, indicating that the use of long-term rainfall from Lake Margaret is appropriate.

4. Lake Mary simulation results

The calibrated GR4J hydrological model was re-configured for the Lake Mary site and catchment. Figure 4.1 shows the catchment area contributing to outflows at the proposed Lake Mary micro-hydro site.

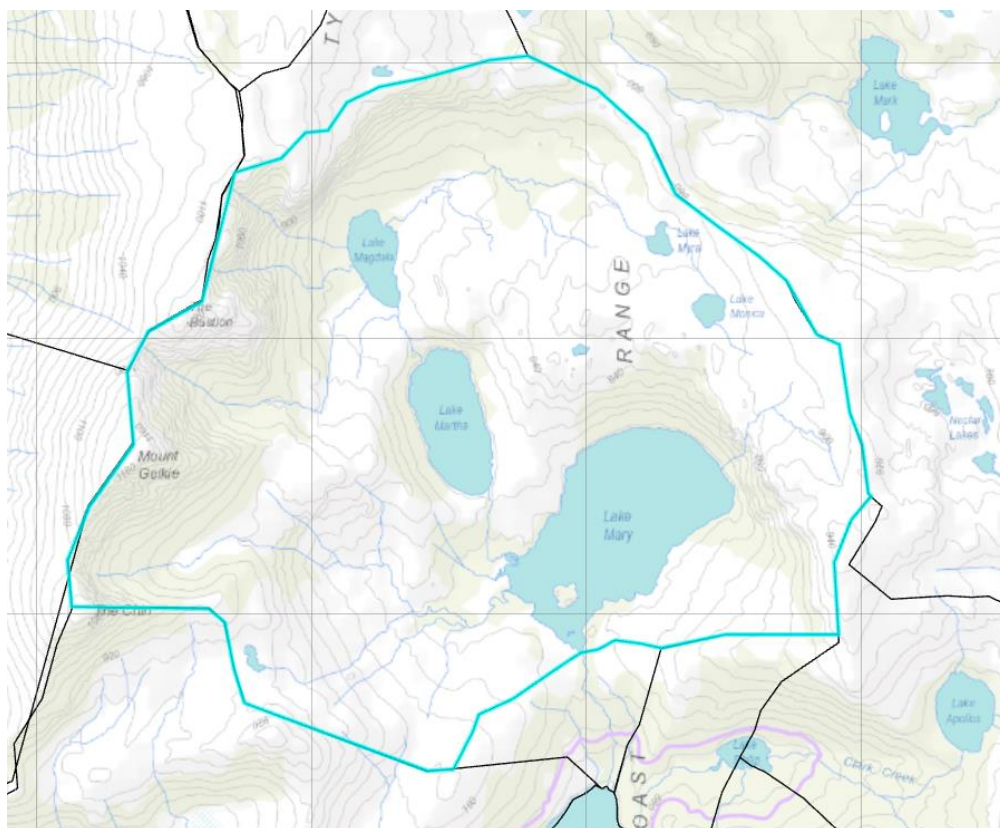


Figure 4.1: Location and catchment area of Lake Mary – 4.64 km²

4.1 Approach 1 – catchment outflows without storages

The model was configured as if the catchment did not contain any of the storages so as to simulate the ongoing flow contributions at the micro-hydro site. This is an inherently conservative approach to assessing the reliability of flows as the assessment does not rely on storage capacities to maintain flows.

The model was run with historic daily rainfall data available from the nearby Lake Margaret monitoring site (Site ID 370.1) spanning the period 1/8/1924-31/12/1990. This data set was selected due to its proximity to the study sites. The period is limited to 1924 to 1990 due to limitations in data availability as this gauge was discontinued in 1990. The 65-year period contains significant periods of drought and hence is deemed representative of the dynamic range of behaviour expected within the catchments. Figure 4.2 shows representative timeseries of rainfall and the simulated streamflow simulations.

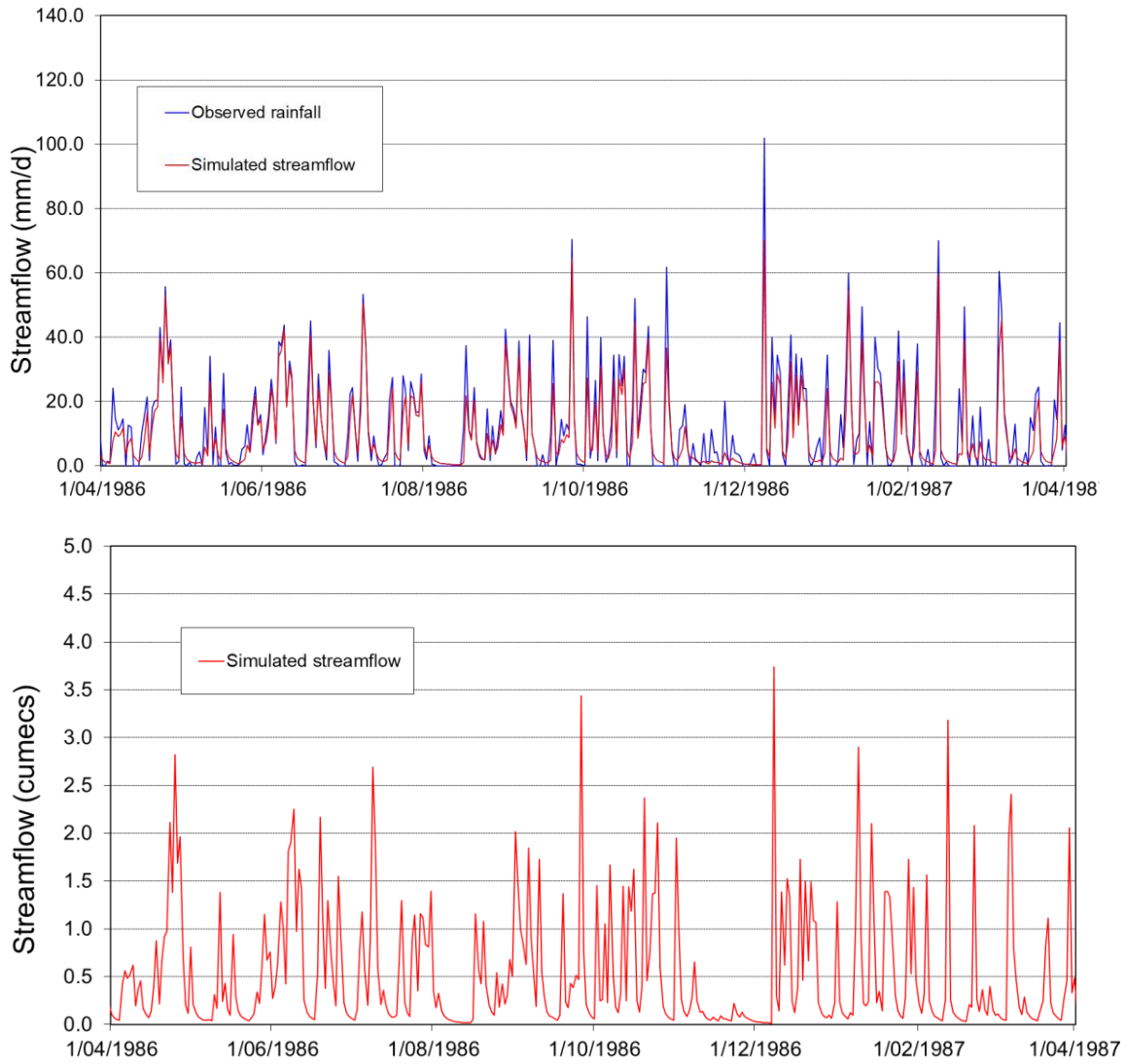


Figure 4.2: Sample timeseries of observed rainfall and simulated streamflow (upper panel) and simulated streamflow in cumecs (lower panel). Simulation is between 1/4/1986 and 1/4/1987. Note flashy nature of response to significant rainfall events.

To assess the reliability of inflows with this approach, the resultant flow duration curve was derived, representing the probabilities of different flow rates (Figure 4.3 and Figure 4.4). Also indicated in Figure 4.3 and Figure 4.4 are nominal thresholds of 10 and 20 litres per second.

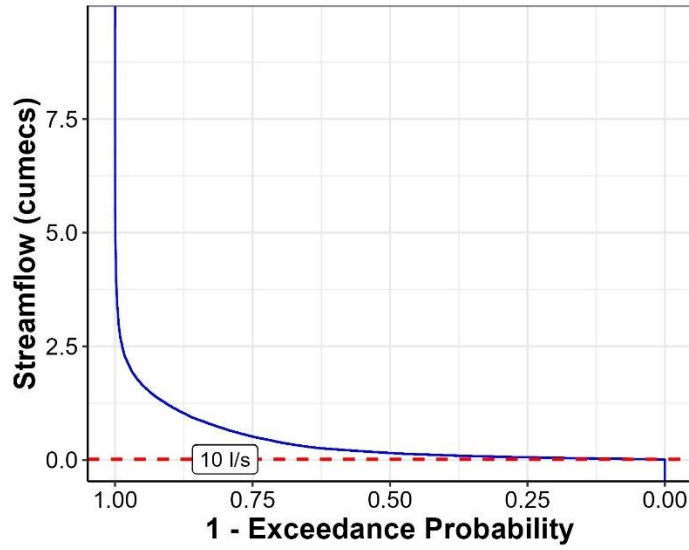


Figure 4.3: Flow duration curve for the simulated streamflow

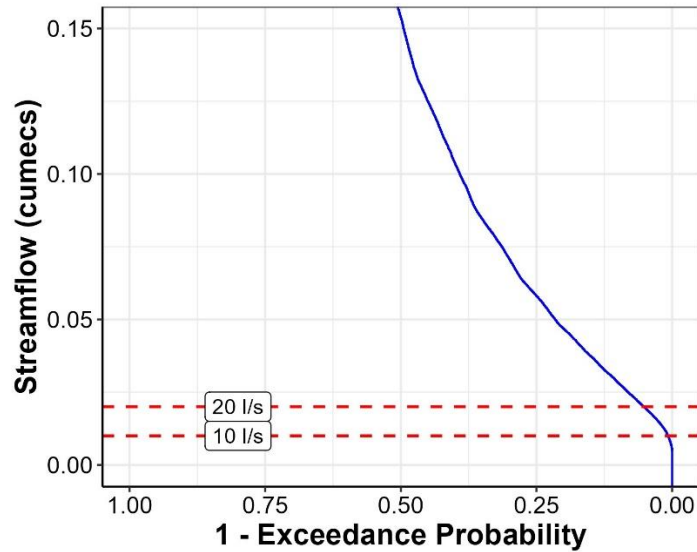


Figure 4.4: Flow duration curve for the simulated streamflow (focus)

From Figure 4.4, it can be derived that the probability of failure to supply at 10 l/s is 0.77%, whilst this probability for flows below 20 l/s is 5.24%. These probabilities represent the percentage proportion of time that the required inflows are not achieved.

4.2 Approach 2 – catchment inflows with storage

A more realistic approach is to incorporate the storage capacity present in Lake Mary. This storage covers an area of approximately 0.35 km². Rainfall on the open water storage is not subject to rainfall-runoff transformation and directly contributes in full to the water stored. The storage itself has the effect of moderating the outflows from the catchment.

To include the Lake Mary storage and its effect on the outflows from the catchment, a number of assumptions need to be made regarding the geometry/bathymetry of the storage itself as well as a stage-discharge rating curve for the storage outlet. The simplest assumption for the storage is to assume a rectangular geometry with the surface area as 0.35 km².

To simulate outflows from Lake Mary, a simple rectangular weir is assumed with a 2m crest, a standard coefficient of 1.45 and an exponent of 1.45. This is selected as an exemplar rather than as a definitive representation of the actual lake storage-discharge relationship. In the absence of actual ratings at the lake outlet, the weir is intended to capture a general draining dynamic and hence provide more realism.

The model is run for the non-storage area of the catchment. In this case, a constant drawdown on the storage of 10l/s is taken. This drawdown is to simulate the effect of withdrawing the maximum water required for the micro-hydro site assuming constant maximum power requirement.

The model is also run without the withdrawal (drawdown) of flows from the storage to simulate 'natural' conditions ie. without micro-hydro scheme.

The two simulations can then be compared to evaluate the possible effect of maximum micro-hydro withdrawals on the resultant flow duration curves of the flow at the outlet of Lake Mary.

Figure 4.5 shows a representative timeseries of simulated streamflow with and without drawdown from Lake Mary. As can be seen, two periods of low flows can be observed in this period (1/4/1986-87). Intuitively, the greatest proportional impact of the hydro abstraction is apparent when the flows are the lowest.

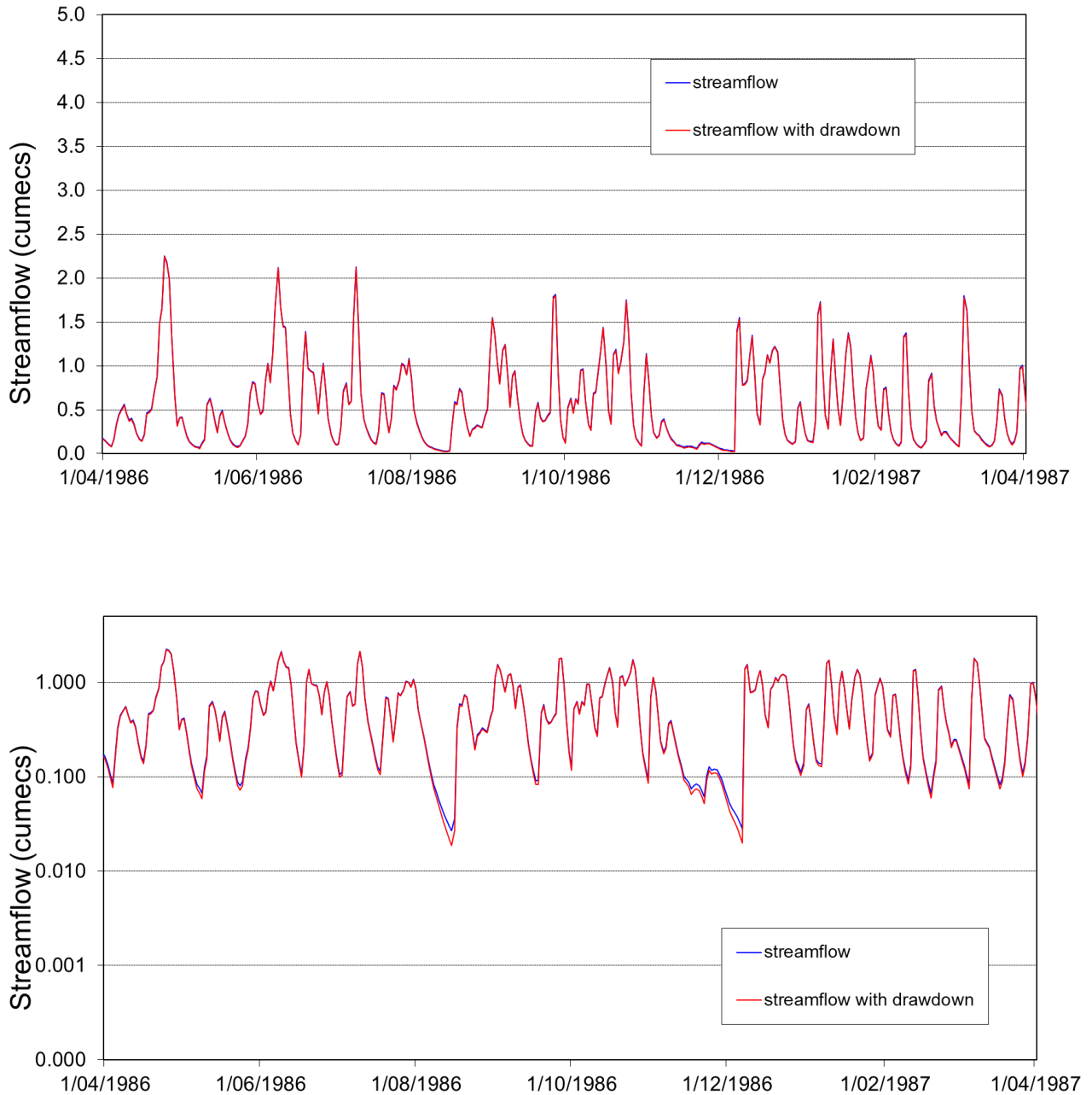


Figure 4.5: Representative timeseries of simulated streamflow with and without drawdown from Lake Mary. Note logarithmic scale on lower panel.

Figure 4.6 shows the timeseries of streamflow simulations over the period containing the lowest flows (1/4/1937-8). As can be seen, during this critical period, the effect of the hydro intake is essentially to hasten the reduction of streamflow as the storage drains.

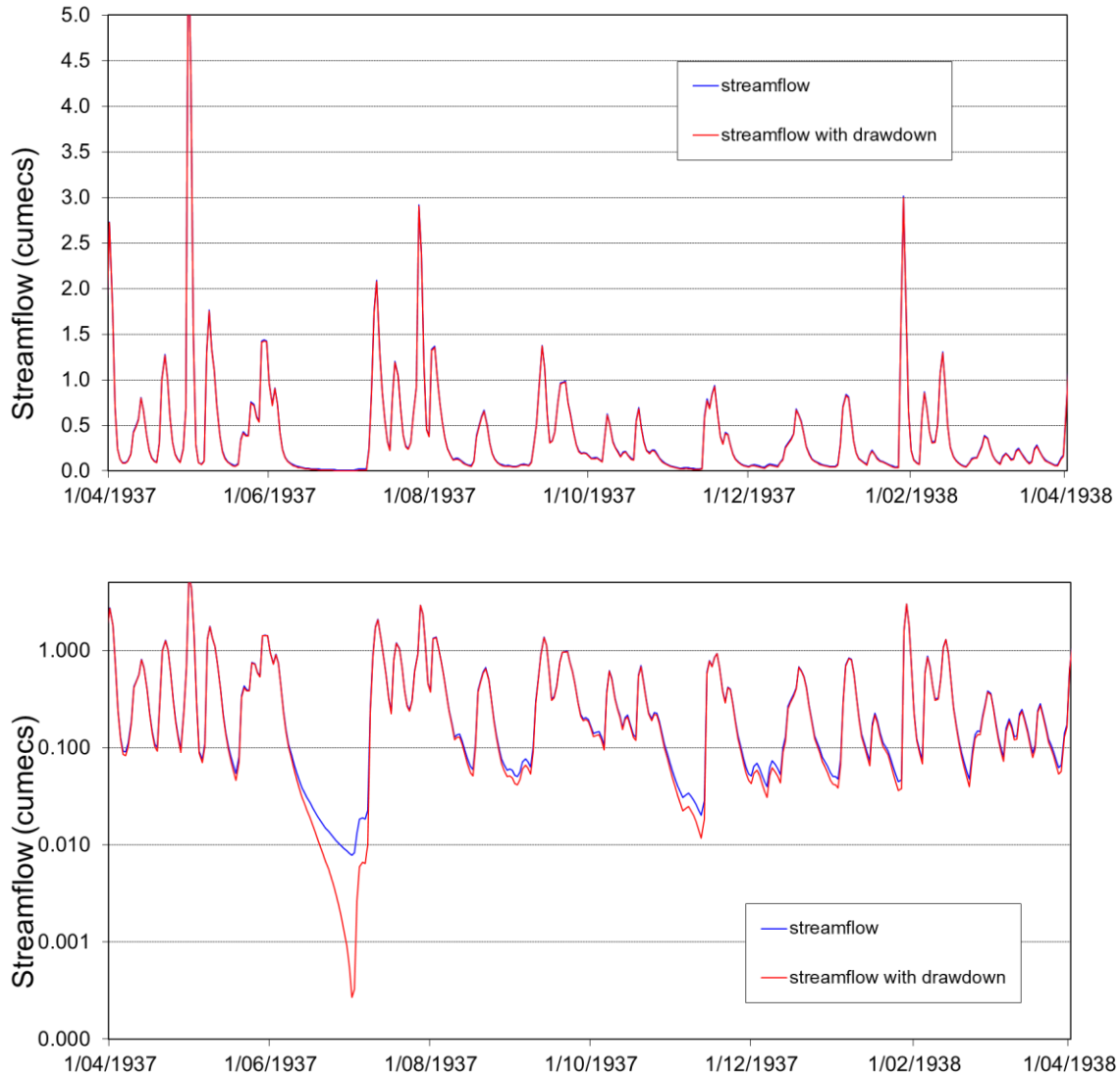


Figure 4.6: Timeseries of simulated streamflow with and without drawdown from Lake Mary corresponding to the period of lowest streamflow. Note log scale on lower panel.

Figure 4.7 shows the resultant flow duration curves for 'natural' (blue) and with micro-hydro abstractions from the storage (green). Thresholds of 10 and 20 litre per second are also indicated in Figure 4.8. In this case, these thresholds can be taken as reference levels for low flows downstream of Lake Mary. The duration curves show little difference in higher flows.

Figure 4.8 focusses on the tail of the probability distribution. From this it can be seen that, for this scenario, the natural flows are below the 10 l/s threshold for 0.07% of the time, whilst accommodating maximum inflow to the proposed hydro scheme raises this to 0.97% of the simulated time.

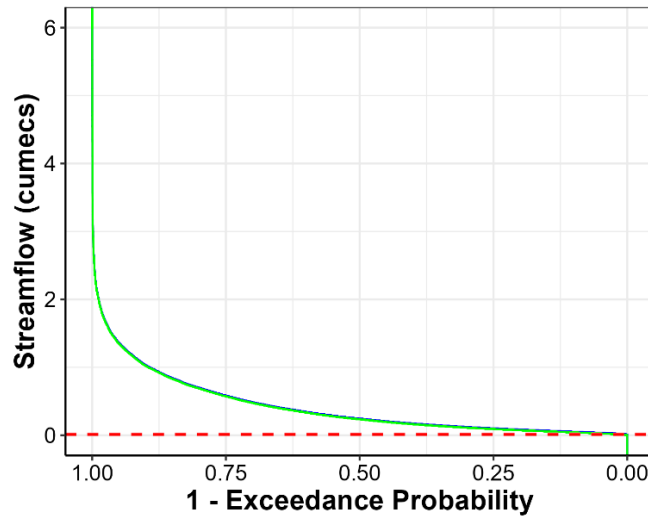


Figure 4.7: Flow duration curve. With (green) and without hydro (blue). Red dashed line shows the thresholds of 10 and 20 litres per second.

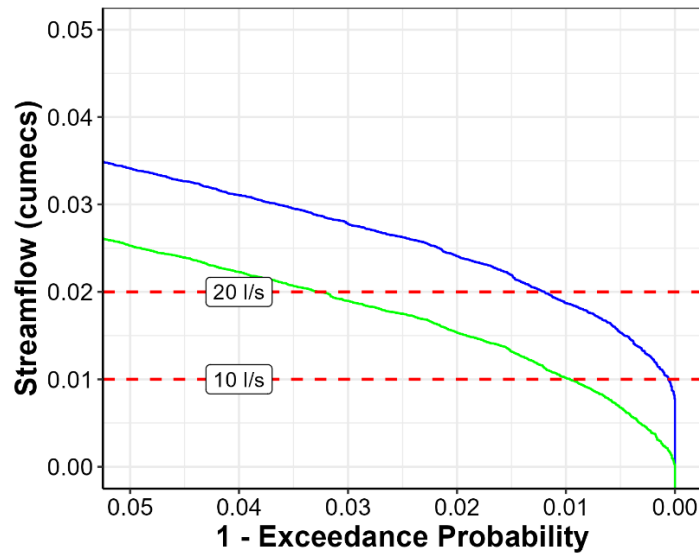


Figure 4.8: Flow duration curve – focus 0 - 5%

5. Lake Huntley simulation results

The calibrated GR4J hydrological model was re-configured for the Lake Huntley site and catchment. Figure 5.1 shows the catchment area contributing to outflows at the proposed Lake Huntley micro-hydro site.



Figure 5.1: Location and catchment area of Lake Huntley – Area = 1.80 km²

5.1 Approach 1 – catchment outflows without storages

The model was re-configured as if the catchment did not contain any of the storages so as to simulate the ongoing flow contributions at the micro-hydro site. This is an inherently conservative approach to assessing the reliability of flows as the assessment does not rely on storage capacities to maintain flows. This is particularly the case for Lake Huntley as the lake itself covers approximately 25% of the total catchment area.

The model was run with historic daily rainfall data available from the nearby Lake Margaret monitoring site (Site ID 370) spanning the period 1/8/1924-31/12-1990. Figure 5.2 shows representative timeseries of rainfall and the simulated streamflow simulations.

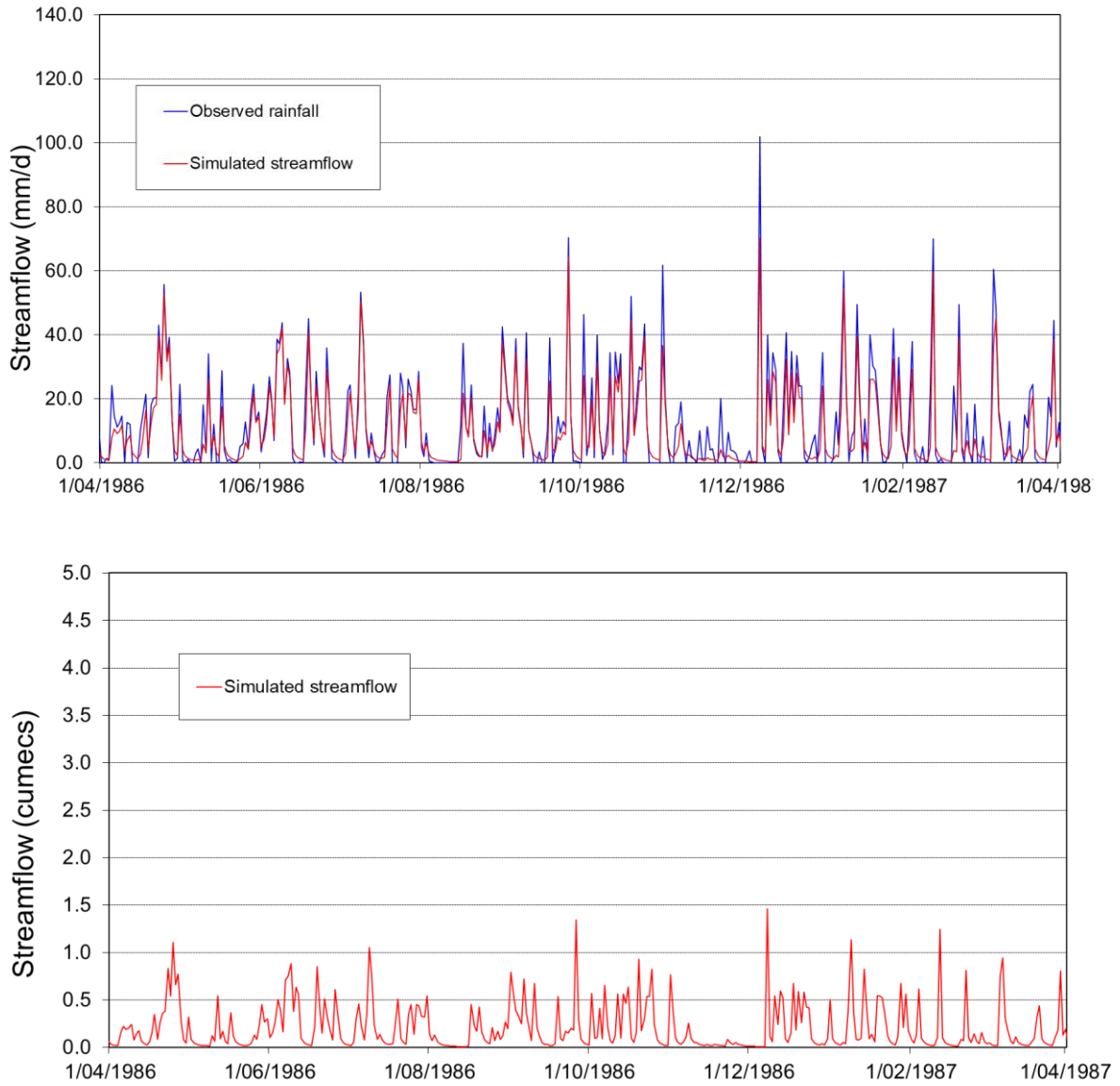


Figure 5.2: Sample timeseries of observed rainfall and simulated streamflow (upper panel) and simulated streamflow in cumecs (lower panel). Simulation is between 1/4/1986 and 1/4/1987. Note significantly lower streamflow volumes in comparison with Lake Mary (see Figure 4.2).

To assess the reliability of inflows with this approach, the resultant flow duration curve has been derived, representing the probabilities of different flow rates (Figure 5.4). Also indicated in Figure 5.4 are nominal thresholds of 10 and 20 litres per second.

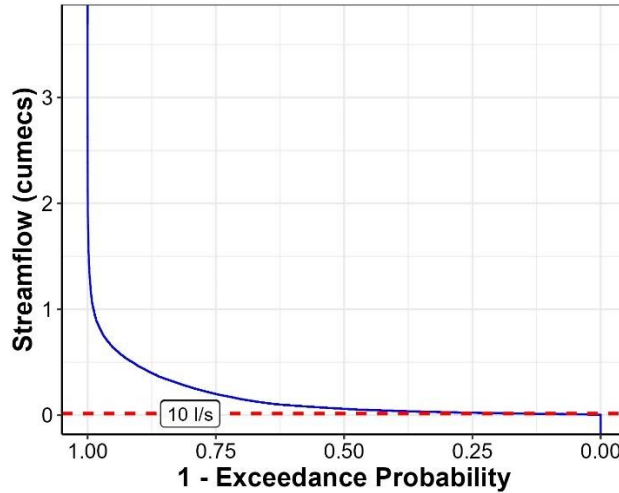


Figure 5.3: F Flow duration curve for the simulated streamflow – Lake Huntley site. Red dashed line shows the thresholds of 10 and 20 litres per second.

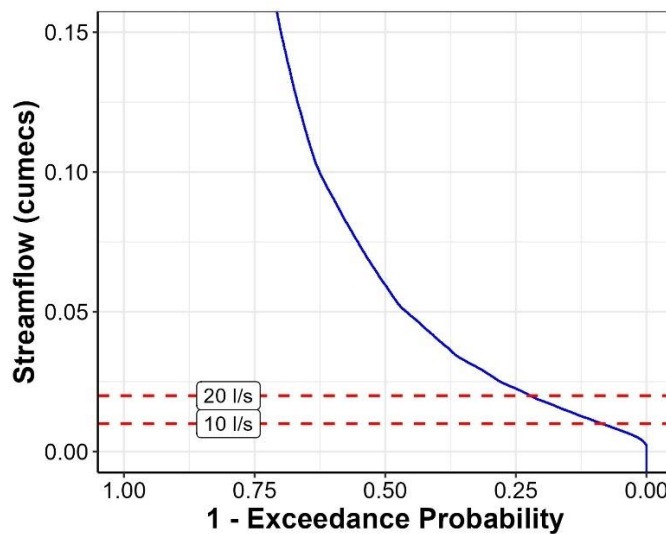


Figure 5.4: Flow duration curve for the simulated streamflow – focus

From Figure 5.4, it can be seen that the probability of failure to supply at 10 l/s is 8.50%, whilst this probability below 20 l/s is 22.24%. These probabilities represent the proportion of time that the required inflows are not achieved. These results indicate a relatively low level of reliability.

5.2 Approach 2 – catchment inflows with storage

Again, a more realistic approach is to incorporate the storage capacity present in Lake Huntley. As this lake represents approximately 25% of the total catchment area, it represents a substantial storage which acts to moderate outflows.

This storage covers an area of approximately 0.45 km². Rainfall on the open water storage is not subject to rainfall-runoff transformation and is directly contributes in full to the water stored. The storage itself has the effect of moderating the outflows from the catchment.

To include the Lake Huntley storage and its effect on the outflows from the catchment, again a number of assumptions need to be made regarding the geometry/bathymetry of the storage itself as well as a stage-discharge rating curve for the storage outlet. In this case, we assume the same rectangular geometry with the surface area as 0.45 km².

To simulate outflows from Lake Huntley, the same simple rectangular weir used for Lake Mary is assumed (2m crest, a standard coefficient of 1.45 and an exponent of 1.45).

The model is run for the non-storage area of the catchment. This provides the inflow to the storage in addition to direct rainfall over its area.

The model is then run with and without a constant drawdown on the storage of 10l/s. This drawdown is to simulate the effect of withdrawing the maximum water required for the micro-hydro site assuming constant maximum power requirement.

The model run without the withdrawal (drawdown) of flows from the storage represents the 'natural' conditions ie. without micro-hydro scheme. The two simulations can therefore be compared to evaluate the possible effect of maximum micro-hydro withdrawals on the resultant flow duration curves of the flow at the outlet of Lake Mary.

Figure 5.5 shows a representative timeseries of simulated streamflow with and without drawdown from Lake Huntley. As can be seen, two periods of low flows can be observed in this period (1/4/1986-87). Again, the greatest proportional impact of the hydro abstraction is apparent when the flows are the lowest.

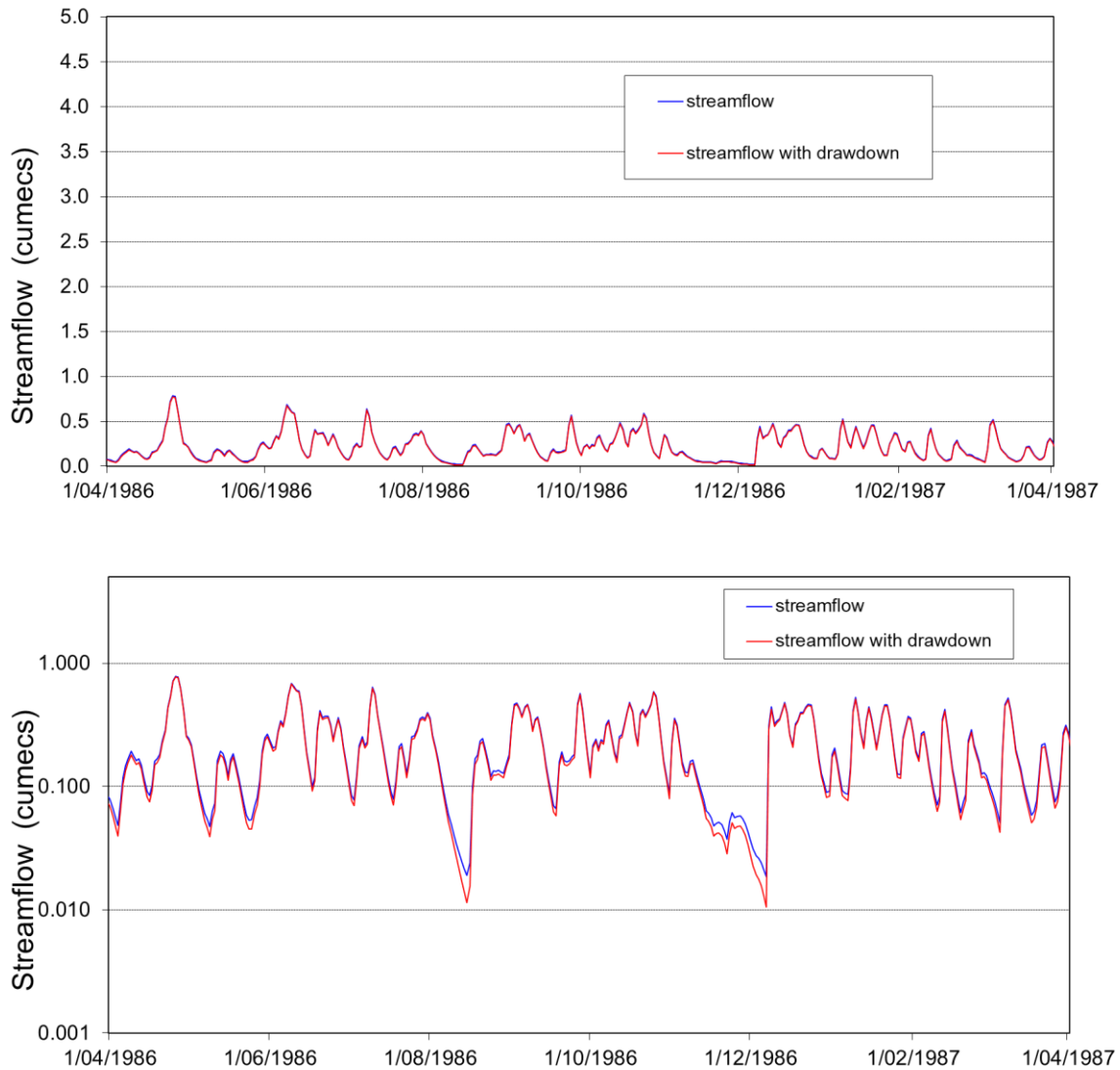


Figure 5.5: Representative timeseries of simulated streamflow with and without drawdown from Lake Huntley. Note logarithmic scale on lower panel.

Figure 5.6 shows the timeseries of streamflow simulations over the period containing the lowest flows (1/4/1937-8). As can be seen, during this critical period, the effect of the hydro intake is markedly greater than that of the Lake Mary design. This is due to the much lower catchment area contributing to inflows, relative to the volume/rate of water abstracted.

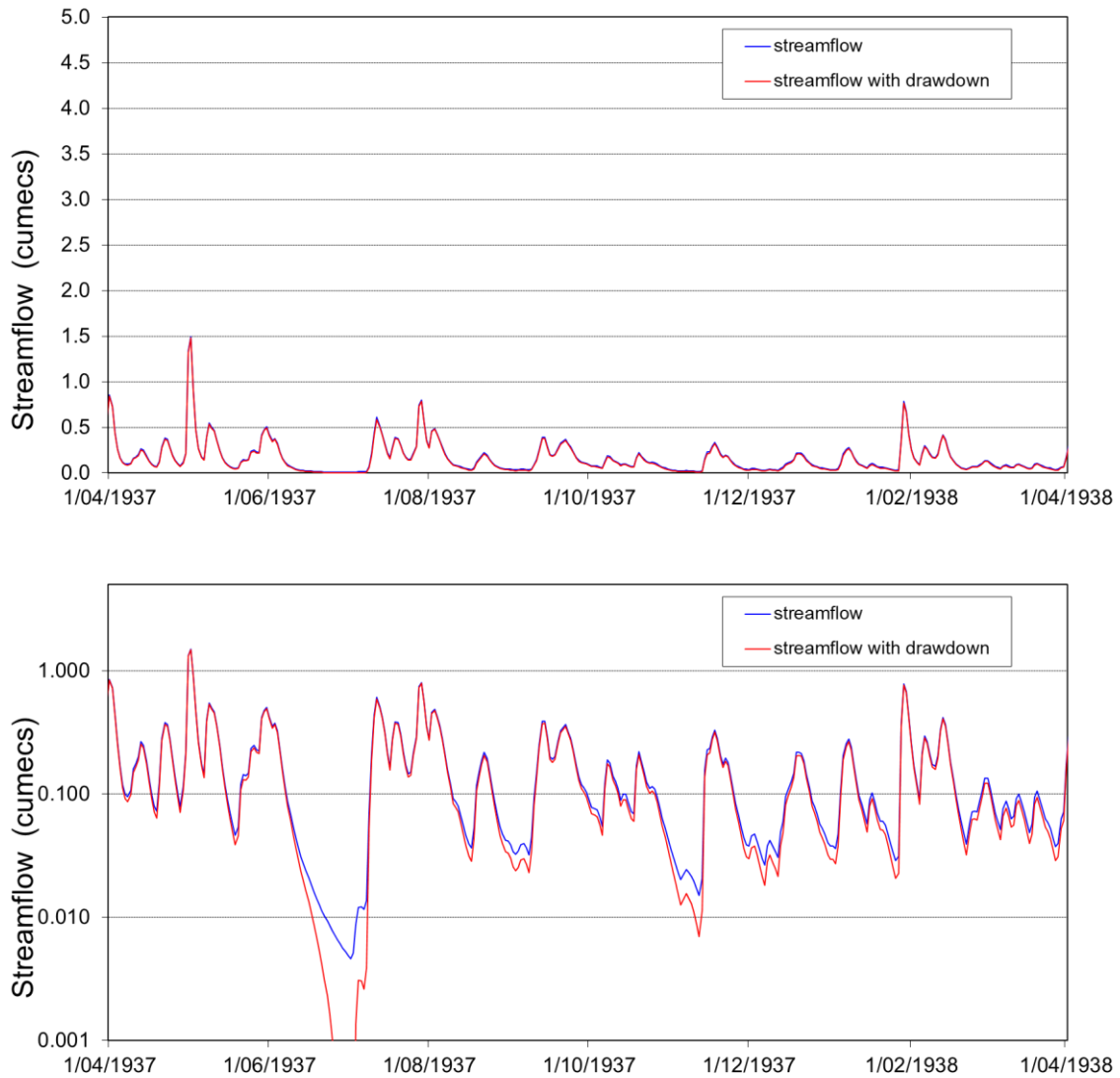


Figure 5.6: Timeseries of simulated streamflow with and without drawdown from Lake Huntley corresponding to the period of lowest streamflow. Note log scale on lower panel.

Figure 5.7 shows the resultant flow duration curves for 'natural' (blue) and with micro-hydro abstractions from the storage (green). Thresholds of 10 and 20 litre per second are also indicated. In this case, these thresholds can be taken as reference levels for low flows downstream of Lake Huntley. The duration curves show little difference in higher flows.

Figure 5.8 focusses on the tail of the probability distribution. From this it can be seen that, for this scenario, the natural flows are below the 10 l/s threshold for 0.39% of the time, whilst accommodating maximum inflow to the proposed hydro scheme raises this to 2.72% of the simulated time.

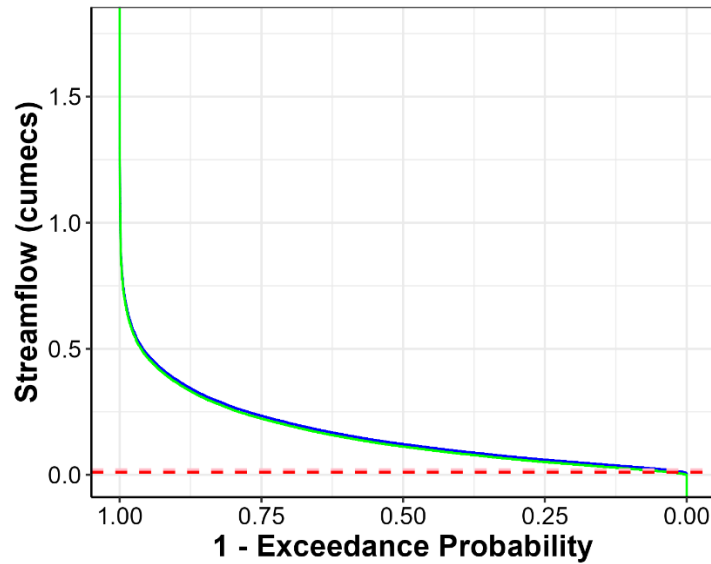


Figure 5.7: Flow duration curve. With and without hydro

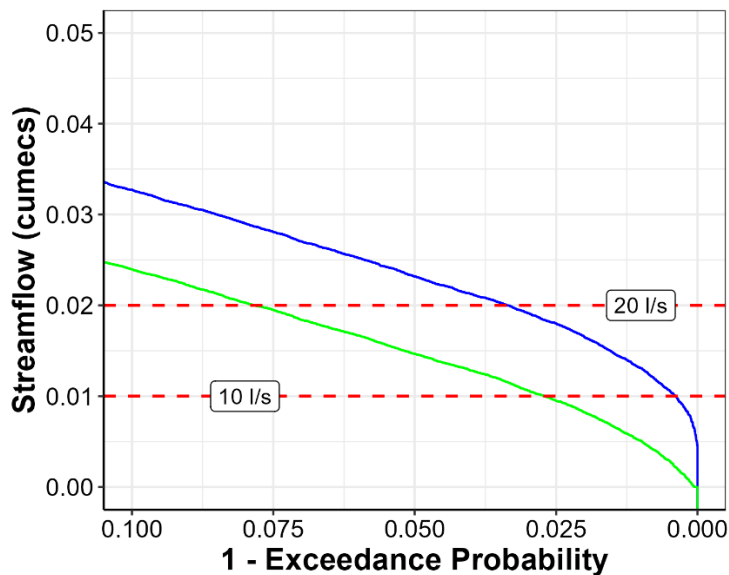


Figure 5.8: Flow duration curve – focus 0 - 10%

6. Summary, conclusions and limitations

Streamflow simulations have been developed representing inflows and catchment storage. From these, streamflow duration curves have been derived, both with and without maximum hydro utilisation. The results are presented as flow reliability in Table 6.1. The flow exceedance curves are provided in Appendix B. Within the limitations of the modelling (Section 6.1) the modelled flows indicate that water reliability appears very high for operation under 10 l/s and high for operation under 20 l/s.

The reliability results presented here are conservative because they do not consider supplementation with solar operation which would reduce the use of the hydro-turbines, particularly over summer when solar operation would be highest and when flows are likely to be at their lowest. Operation under solar operation is discussed in a separate report (Island Renewables 2024). The operational flow regime that is assessed in the aquatic ecology report has solar operation included (Entura 2024).

Table 6.1: Summary results

Streamflow	10 l/s		20 l/s	
	Natural flow	With max hydro utilisation	Natural flow	With max hydro utilisation
Lake Mary	99.93%	99.03%	98.80%	96.73%
Lake Huntley	99.61%	97.28%	96.63%	92.16%

6.1 Limitations of the study

It should be noted that the work presented here has required a number of assumptions regarding the storage and discharge characteristics of both Lake Mary and Lake Huntley.

- Detailed storage information is not available, therefore both Lake Mary and Huntley storages have been assumed as fixed areal extent as estimated from geographic information. Additionally, lack of storage-level curve (or bathymetry) meant that a rectangular storage was assumed.
- Most significantly, flow data is not available, therefore assumptions regarding the storage-discharge relationship are required. This has been achieved by assuming a simple weir rating curve, applied to both lakes.
 - This relationship is important as it essentially governs the rate at which the lakes drain and hence controls the availability of water both for the micro-hydro projects and the downstream creeks.

Given the limitations of this study, the results presented here are indicative rather than definitive. The limitations of this study should be taken into consideration when using this data for energy modelling or any other engineering applications.

6.2 Recommendations

As discussed above (Section 6.1), no rating curves were available for the weirs at the outlet of each lake. Development of rating curves via survey and gauging could be undertaken to improve the confidence of this hydrology assessment. Such an assessment may also aid the refinement of the location of the hydropower intakes and the potential or need for any modifications to the lake outlets.

7. References

Island Renewables (2024). Tyndalls Next Iconic Walk Energy Supply: Draft Concept Design and Modelling Report for PWS, September, 2024

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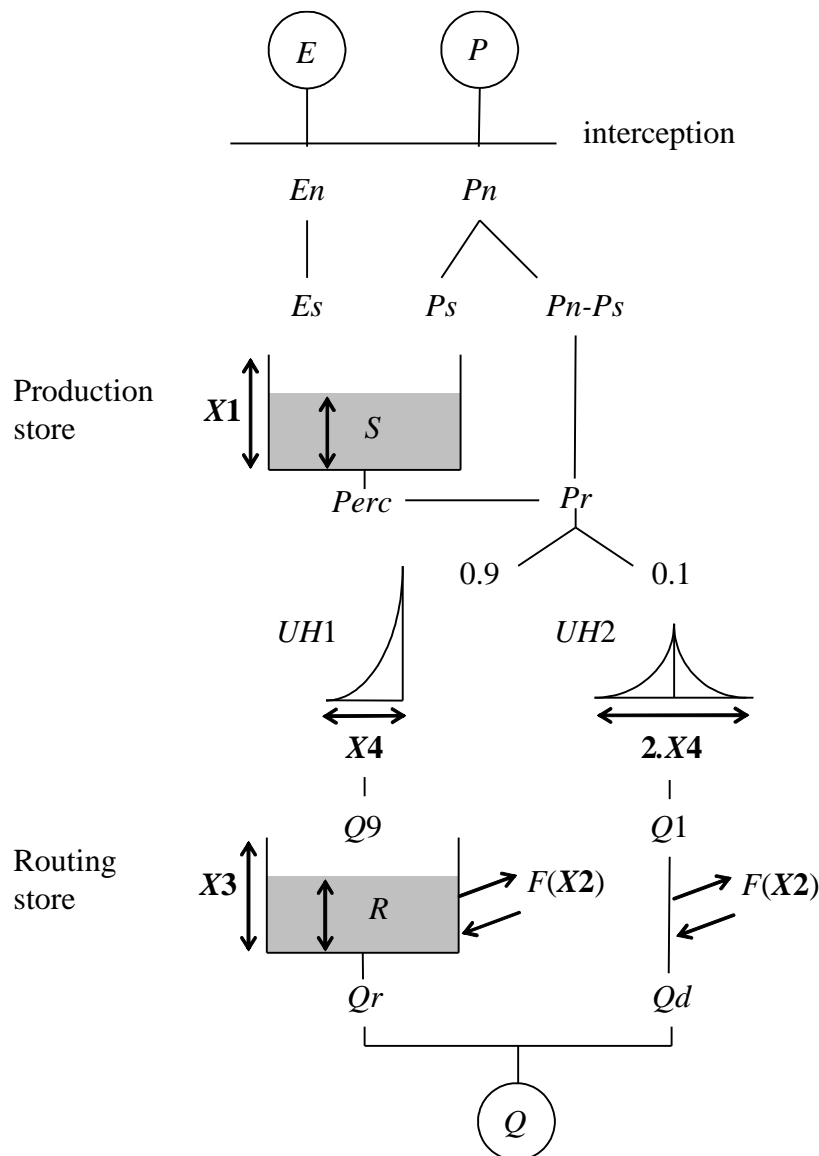
Perrin, C. (2002). Vers une amélioration d'un modèle global pluie-débit au travers d'une approche comparative. *La Houille Blanche*, n°6/7, 84-91.

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Appendices

A Hydrological simulation model – GR4J

GR4J is a daily, lumped conceptual hydrological model which has seen extensive application and is documented by Perrin (2002) and Perrin et al. (2003). Please refer to these documents for more details about the model.



B Simulated exceedance data

B.1 Lake Mary outflow exceedance curve data

P(exceedance)	Outflows (m ³ /s)		
	Approach 1 No storage	Approach 2 Storage incl.	Approach 2 Storage with max hydro offtake
0	9.438	5.982	5.982
0.1	1.179	1.021	1.021
0.2	0.675	0.687	0.687
0.3	0.385	0.475	0.475
0.4	0.232	0.333	0.333
0.5	0.152	0.234	0.234
0.6	0.103	0.162	0.162
0.7	0.070	0.110	0.110
0.8	0.046	0.073	0.073
0.9	0.028	0.041	0.041
0.95	0.019	0.025	0.025
0.99	0.011	0.010	0.010
0.999	0.006	0.002	0.002
1	0.005	0.000	0.000

B.2 Lake Huntley outflow exceedance curve data

P(exceedance)	Outflow (m ³ /s)		
	Approach 1 No storage	Approach 2 Storage incl.	Approach 2 Storage with max hydro offtake
0.000	3.693	1.767	1.754
0.100	0.461	0.378	0.367
0.200	0.264	0.269	0.258
0.300	0.151	0.205	0.194
0.400	0.091	0.157	0.147
0.500	0.060	0.122	0.112
0.600	0.040	0.094	0.084
0.700	0.027	0.070	0.061
0.800	0.018	0.051	0.042
0.900	0.011	0.033	0.024
0.950	0.008	0.023	0.015
0.990	0.004	0.013	0.005
0.999	0.002	0.007	0.000
1.000	0.002	0.005	0.000

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