Wharekirauponga Hydrology (WAI-985-000-REP-LC-0063)

Modelling Report

Oceana Gold Ltd

27 January 2025

→ **The Power of Commitment**

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GHD Limited [626860]
Contact: Emily Diack, Environmental Scientist | GHD
27 Napier Street, GHD Centre Level 3
Freemans Bay, Auckland 1010, New Zealand
T +64 9 370 8000 | **F** +64 9 370 8001 | **E** aklmail@ghd.com | **ghd.com**

The Power of Commitment

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1. Introduction

Oceana Gold New Zealand Ltd. (OceanaGold) has requested GHD New Zealand Ltd. (GHD) provide hydrology advice associated with the potential surface water impacts in the Wharekirauponga catchment associated with the proposed Wharekirauponga Underground Mine (WUG Mine).

It is understood that if the WUG Mine was to impact the hydrology of the Wharekirauponga catchment, the effect would most likely be evident in a reduction in flow of the headwater springs which could reduce stream baseflows. To provide advice associated with potential surface water impacts GHD has developed a water balance model (WBM) that captures the current continuous flow monitoring locations and assesses flows at locations within the Wharekirauponga catchment, as well as providing an assessment of the projected effects (from the development of the WUG Mine) on the low flow statistics.

1.1 Purpose of this report

The development of the Water Balance Model (WBM) has been an on-going process, incorporating monitoring data as it becomes available. This phase of work has involved incorporating the recent monitoring data and performing scenario simulations to inform the ecological assessment. The purpose of this report is therefore to:

– Describe the construction and current configuration of the WBM.
– Describe the input data and pre-processing of data prior to application in the model.
– Provide an overview of the current WBM calibration, at five key existing monitoring locations.
– Outline the current predictive simulation results, which will inform the ecological assessment, and present the summary statistics for the scenarios.
– Provide recommendations for improvements to monitoring data and locations.

1.2 Limitations

This report: has been prepared by GHD for Oceana Gold Ltd and may only be used and relied on by Oceana Gold Ltd for the purpose agreed between GHD and Oceana Gold Ltd as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Oceana Gold Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Oceana Gold Ltd and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

GHD has prepared the GoldSim Model ("Model") for, and for the benefit and sole use of, Oceana Gold Ltd to support hydrological characterisation and must not be used for any other purpose or by any other person.

The Model is a representation only and does not reflect reality in every aspect. The Model contains simplified assumptions to derive a modelled outcome. The actual variables will inevitably be different to those used to prepare the Model. Accordingly, the outputs of the Model cannot be relied upon to represent actual conditions without due consideration of the inherent and expected inaccuracies. Such considerations are beyond GHD's scope.

The information, data and assumptions ("Inputs") used as inputs into the Model are from publicly available sources or provided by or on behalf of Oceana Gold Ltd, (including possibly through stakeholder engagements). GHD has not independently verified or checked Inputs beyond its agreed scope of work. GHD's scope of work does not include review or update of the Model as further Inputs becomes available.

The Model is limited by the mathematical rules and assumptions that are set out in the Report or included in the Model and by the software environment in which the Model is developed.

The Model is a customised model and not intended to be amended in any form or extracted to other software for amending. Any change made to the Model, other than by GHD, is undertaken on the express understanding that GHD is not responsible, and has no liability, for the changed Model including any outputs.

GHD has not been involved in the preparation of the preparation of the Assessment of Environmental Effects (AEE), prepared by Mitchell Daysh, and has had no contribution to, or review of the AEE] other than in this technical report for water management. GHD shall not be liable to any person for any error in, omission from, or false or misleading statement in, any other part of the AEE. The GHD document containing the disclaimer is to be included in any other document, the entirety of GHD's report must be used (including the disclaimers contained herein), as opposed to reproductions or inclusions solely of sections of GHD's report.

2. Water Balance Model

GHD has developed a WBM that captures key surface water monitoring points within the Wharekirauponga catchment. The WBM has been developed in GoldSim using the Australian Water Balance Model (AWBM) (Figure 2.1). GoldSim is a dynamic, probabilistic simulation software, and the AWBM is a rainfall-runoff model which can be used within GoldSim to simulate rainfall runoff in a watershed.

The WBM has been configured with available data obtained from monitoring in and near the Wharekirauponga catchment, which allows for calibration of the model. The WBM has been utilised as a predictive tool by the inclusion of additional rainfall data (available outside the catchment) to allow for stochastic modelling and prediction of flow rates over a long-term period, enabling the development of likely natural flows based on actual data, historic rainfall variability, and future climate conditions.

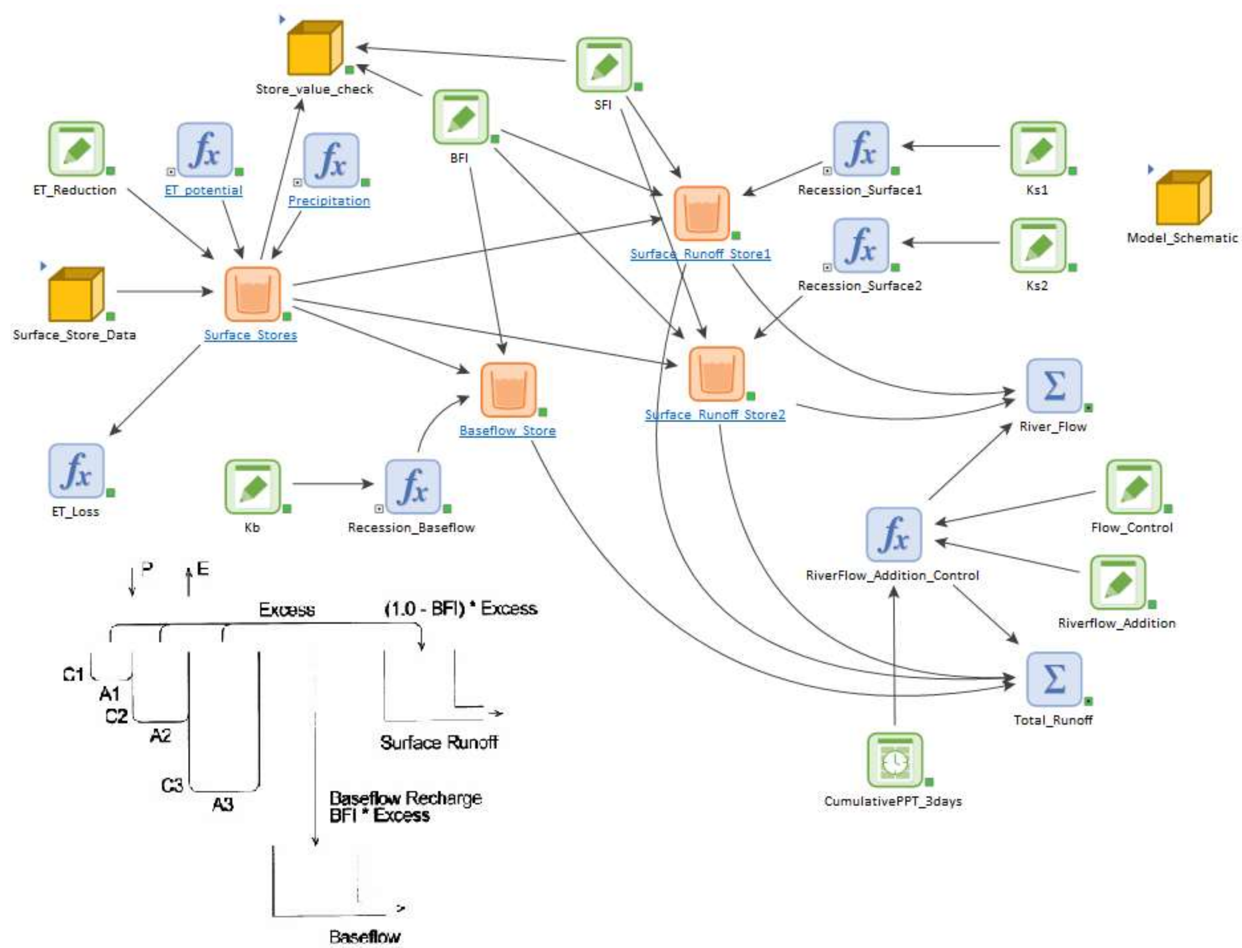

Figure 2.1 Overview of the AWBM component of the WBM for the T Stream West sub-catchment.

2.1 Input data

The WBM has been developed using the following input data. Please note this is not an exhaustive list of inputs in the WBM but captures data that has been provided by other parties, has been modified prior to application in the WBM or is utilised as a calibration variable.

2.1.1 Rainfall

2.1.1.1 Wharekirauponga Rainfall

Actual and derived rainfall data has been applied to the model. For calibration purposes actual (measured) rainfall data from the Wharekirauponga rainfall gauge has been used.

Following investigations by Waihi Gold Company Limited (Waihi Gold) and Golder Associates (NZ) Limited (Golder), a weather station and rainfall gauging equipment was installed in the Wharekirauponga catchment to collect baseline climate data. The weather station and rainfall gauges were installed at different locations due to limitations at the weather station location for rainfall collection, and limitations at the rainfall monitoring site with regards to monitoring wind. The location of the rainfall gauges (R1) and weather station (W1) is shown in Figure 2.2.

The rainfall gauges have been installed at the site of the constructed drill pad number two, on the north side of the Wharekirauponga catchment. Two rain gauges have been installed, 1.6 metres apart, in the centre of the built wooden platform. One gauge is a graduated cylinder, and the other gauge is a tipping bucket intensity gauge. The intensity gauge is also comprised of a data logger and battery.

Drill pad number two is a flat structure situated at an altitude of 270 metres above sea level. The structure itself is a cleared area so there is no immediate obstruction of the rain gauges, however the trees surrounding the platform are relatively tall, providing some shelter to the platform and therefore gauges. It is assumed the shelter provided by the trees does not significantly obstruct rain catch.

Both rain gauges were assembled, tested, and programmed by EnvCo (an environmental equipment supply company), and installed by Waihi Gold on 01 March 2019. Additional information regarding the equipment specifics is provided in the relevant Golder Report[1].

The Wharekirauponga rainfall data, collected from the rainfall gauges described above, is currently available from 1 March 2019 through to 16 March 2024 (with some data gaps). The application of this data in the WBM is described further in Section 2.1.1.3.

2.1.1.2 Waihi rainfall data

For stochastic modelling and prediction of flow rates over a long-term period a rainfall record for the Waihi region has been derived from rainfall data sourced from local rain gauges between 1917 and 2023.

Measurements are taken from:

– Cliflo agent 1550 (station B75381), located in the Waihi township, for the period of 1/1/1917 to 1/1/1990.
– Newmont data for 1990 to 2010 infilled with Cliflo VCS (station P198205) data,
– Waihi met station, located near the pit of Martha mine, for 2011 to the end of 2017. This data is in-filled with Mill gauge data where necessary, and
– Mill gauge rainfall data from 2018 onward. Mill gauge is operated by OceanaGold and located near the processing plant for the mine.

A monthly comparison of the Waihi and Wharekirauponga data was produced, for the days where overlapping data was available (Figure 2.3). The comparison confirmed the rainfall at Wharekirauponga is consistently higher than the rainfall received at Waihi. This was expected given the higher elevation of the Wharekirauponga catchment, and therefore rain gauges.

To predict likely variability in flow rates in the Wharekirauponga catchment over a long-term period, the long-term Waihi rainfall record has been scaled up to reflect the likely rainfall in the Wharekirauponga catchment. The method used to scale up the long-term Waihi rainfall record is as follows:

1. Only using days where rainfall data was available for both locations, the data from each site was plotted against each other.

[1] Golder Associates (NZ) Limited, Documentation of Installation of Water Level Monitoring Stations and a Weather Station for Baseline Monitoring in the Wharekirauponga catchment, dated May 2019. Herein referenced in the report as Golders (2019).

2. The plot indicated two possible relationships; one when rainfall was less than 10mm per day at Waihi, and another when rainfall was greater than 10mm per day at Waihi. Filtering the Waihi data for rainfall greater than, and less than or equal to 10 mm, two relationships were created (refer to Figure 2.4 and Figure 2.5).
3. Using the plots and associated linear relationships, it was determined:
   a. When rainfall at Waihi was greater than 10mm a day, a factor of 1.19 was required to mimic rainfall in the Wharekirauponga catchment.
   b. When rainfall at Waihi was equal to or less than 10 mm a day, a larger factor of 1.58 was required to mimic rainfall in the Wharekirauponga catchment.
4. The Wharekirauponga rainfall data gaps were then infilled using the Waihi rainfall data adjusted to the two relationships (scaling factors) depending on the daily volume of rain, to create a continuous rainfall record from 1 March 2019 – 16 March 2024.

The scaled Waihi rainfall data set has been applied in the WBM for long term predictive simulations of flow.

2.1.1.3 Derived Wharekirauponga rainfall

As described in Section 2.1.1.1, the Wharekirauponga rainfall data is currently available from 1 March 2019 through to 16 March 2024. However, there are considerable gaps in this data set, including a 300-day gap from July 2021 to May 2022 and a 78-day gap from October 2022 to Jan 2023.

Considering the gaps, the Wharekirauponga actual rainfall data set has been infilled with data from the Waihi rainfall monitoring station to produce a continuous rainfall data set for the Wharekirauponga catchment. The Waihi rainfall data used to fill the gaps was scaled up to mimic Wharekirauponga, as described in Section 2.1.1.2. A comparison of the Wharekirauponga actual rainfall data and the infilled data set is shown in Figure 2.6 . The infilled Wharekirauponga rainfall data set has been applied in the WBM for calibration purposes.

An analysis of the Wharekirauponga rainfall indicated rainfall in 2020 was low, particularly around the summer period (January – March). A detailed analysis of the rainfall from January to March, each year, of the derived long term WKP rainfall data set was undertaken (Figure 2.7). The results indicated January to March of 2020 was one of the lowest rainfall periods to occur when considering the long-term data set. The long-term record suggests similar conditions occurred in 2013, and 1950. However, when the total rainfall from the proceeding November and December is also considered, the period of November to March 2020 stands out as an exceptionally dry period in comparison to the rest of the record (Figure 2.8).

Given the focus on low flow periods it is advantageous the Wharekirauponga rainfall (from 1 March 2019 onward) is utilised for calibration purposes, as this period of actual rainfall data captures the driest period recorded since 1917.

2.1.1.4 Climate Change

The MfE produces climate projections based on historical base periods with results published by region at **https://map.climatedata.environment.govt.nz/**. In terms of variables, the predicted change in total rainfall holds the most relevance in determining effects on flow within the Wharekirauponga catchment, with the projections providing seasonal percentage change estimates on rainfall. The projections explore three different climate change scenarios: 'Sustainability' scenario (SSP1-2.6); 'Middle of the road' scenario (SSP2-4.5) and 'Regional rivalry' scenario (SSP3-7.0), and are dependent on region, the comparative base period and projected timeframe (in the future).

The projections are summarised in Table 2.1 for two locations (the open Martha Pit at Waihi and the junction of the Teawaotemutu Stream / Edwards Stream and Wharekirauponga Stream) as the projections vary on a relatively small scale. Two projection periods are also provided that encompass the Life of Mine (LOM).

Table 2.1 Percentage Change in Rainfall Climate Change Projections

Martha Open Pit					Wharekirauponga Stream				
Period : 2021 - 2040 - Waihi					Period : 2021 - 2040				
	Spring	Summer	Autumn	Winter		Spring	Summer	Autumn	Winter
SSP1-2.6	-1.8	10.4	-4.1	-4.4	SSP1-2.6	-3.1	8.2	-4.9	-5
SSP2-4.5	-4.5	6.4	6.6	1.7	SSP2-4.5	-6.1	5.2	-7.6	-2.6
SSP3-7.0	-3.3	9.8	-0.4	0.1	SSP3-7.0	-4.5	6.7	-1.5	-1.9
Period : 2041 - 2060					Period : 2041 - 2060				
	Spring	Summer	Autumn	Winter		Spring	Summer	Autumn	Winter
SSP1-2.6	-7.4	3.9	-4.2	0	SSP1-2.6	-8.9	3.4	-4.2	-1.2
SSP2-4.5	-9	6.1	2.4	-4.2	SSP2-4.5	-11.9	5.7	1	-5.8
SSP3-7.0	-12.2	2.1	2.6	-2.9	SSP3-7.0	-12.6	0.7	3.1	-4.6

*% projected change in seasonal rainfall (source: **https://map.climatedata.environment.govt.nz/**).

In terms of assessing the potential cumulative effects on the low flow statistics within the Wharekirauponga catchment (inclusive of drawdown effects from the WUG Mine development and effects driven by climate change), a projected reduction in rainfall during the late summer / early autumn period is deemed the most relevant as this period typically sees the lowest recorded flows. As the projections vary widely between scenario and season, the most conservative scenario (in terms of projected rainfall reduction) during the summer / autumn period has been selected to assess the potential effects (on flow) from climate change. The SSP2-4.5 scenario covering the period 2021-2040 includes a predicted 7.6 % reduction in rainfall within the Wharekirauponga Stream during the autumn period and thus is deemed the most conservative estimate of rainfall reduction applicable to the low flow period. This climate change projection (SSP2-4.5) has therefore been applied to the Wharekirauponga WBM (mining scenario) to assess the potential cumulative effects (on flow).

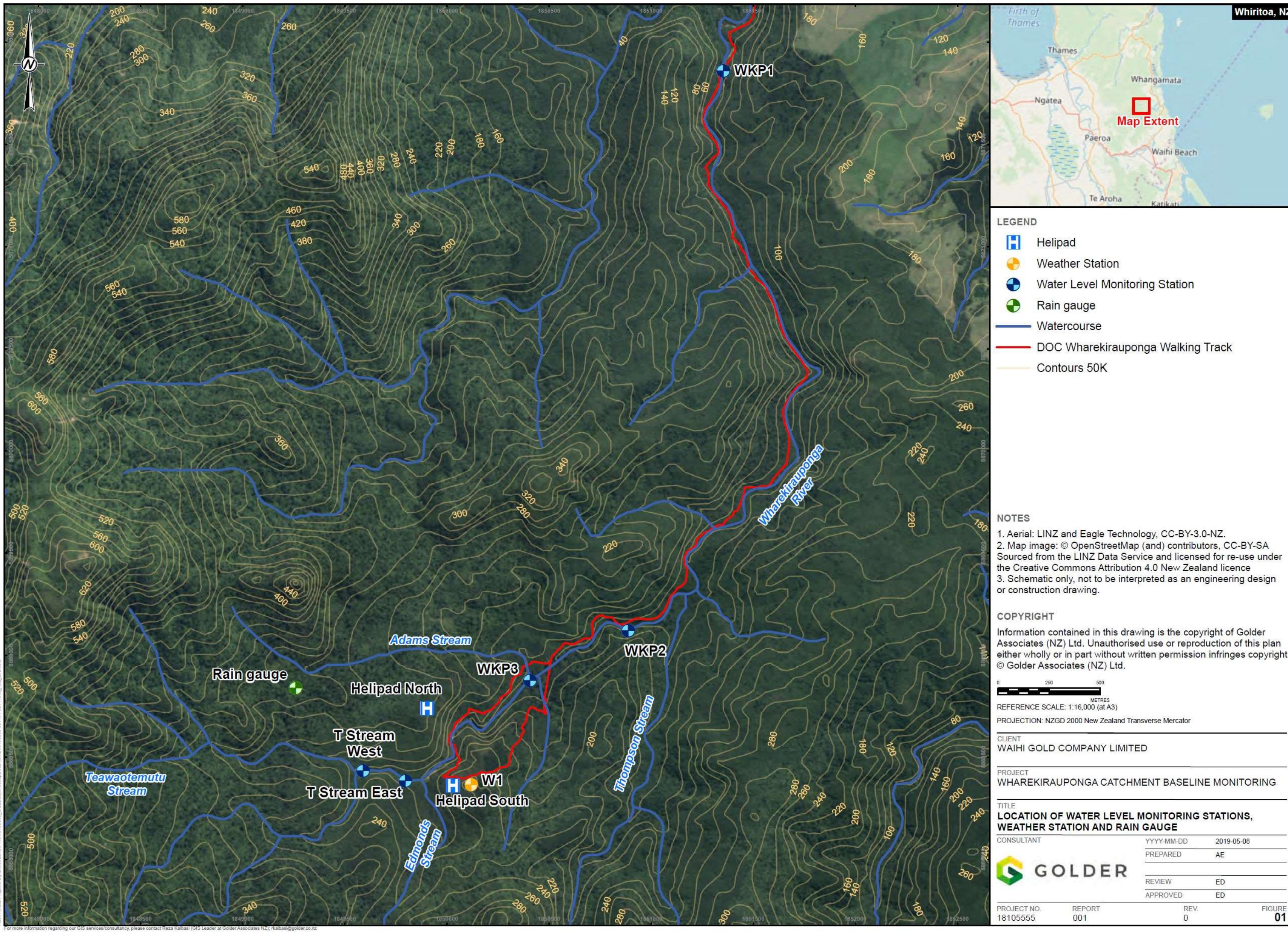

Figure 2.2 *Climate and continuous level monitoring locations (calibration locations) in the Wharekirauponga catchment. (Figure taken from Golder Associates (NZ) Limited, Documentation of Installation of Water Level Monitoring Stations and a Weather Station for Baseline Monitoring in the Wharekirauponga catchment, dated May 2019)*

Figure 2.3 ***Waihi and Wharekirauponga daily average rainfall per month for overlapping days of data (from March 2019 – March 2024).***

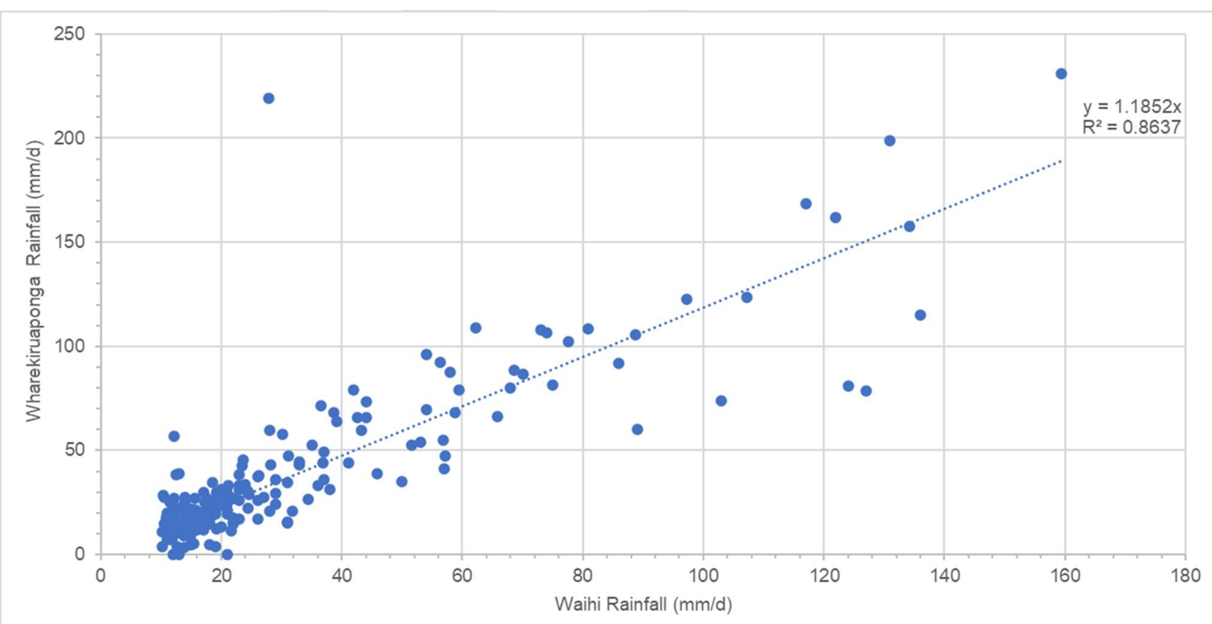

Figure 2.4 ***Relationship between Waihi and Wharekirauponga rainfall when Waihi rainfall is greater than 10 mm/day.***

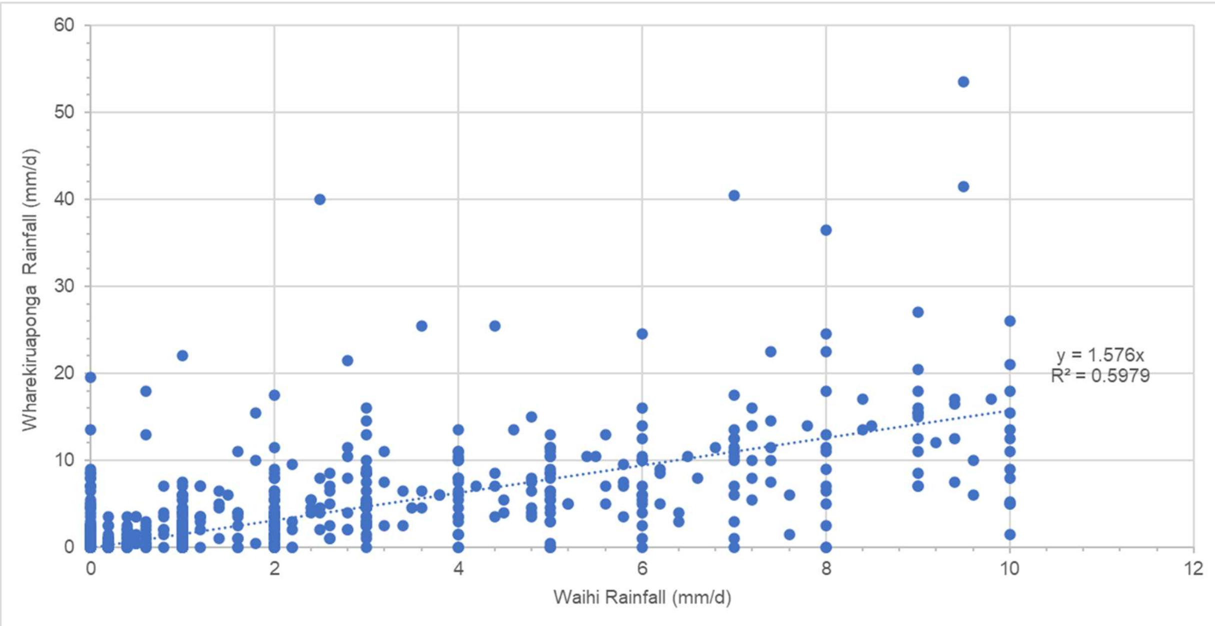

Figure 2.5 ***Relationship between Waihi and Wharekirauponga rainfall when Waihi rainfall is less than or equal to 10 mm/day.***

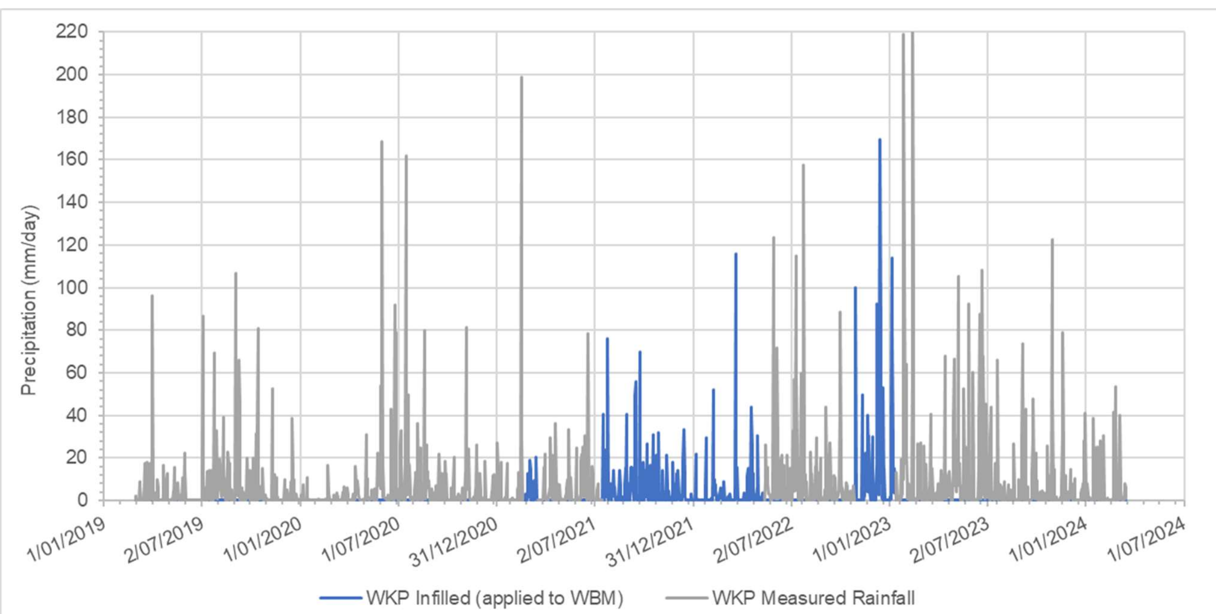

Figure 2.6 ***Wharekirauponga (WKP) actual rainfall data and the Wharekirauponga (WKP) infilled applied in the WBM. Note where there is overlap the actual and infilled data is identical.***

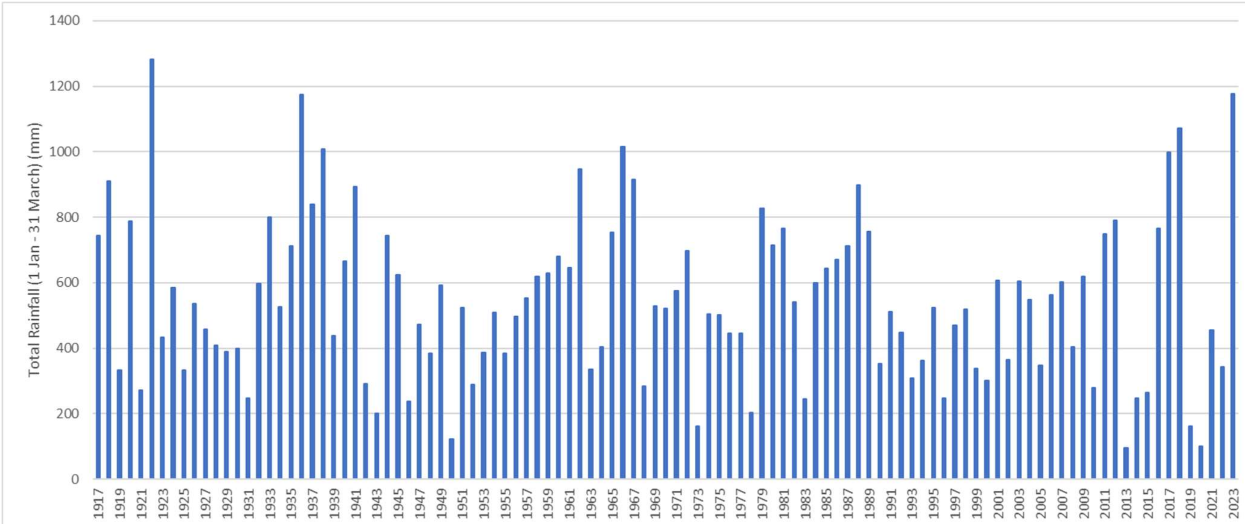

Figure 2.7 Total rainfall from January to March, each year, from the derived WKP long-term rainfall record.

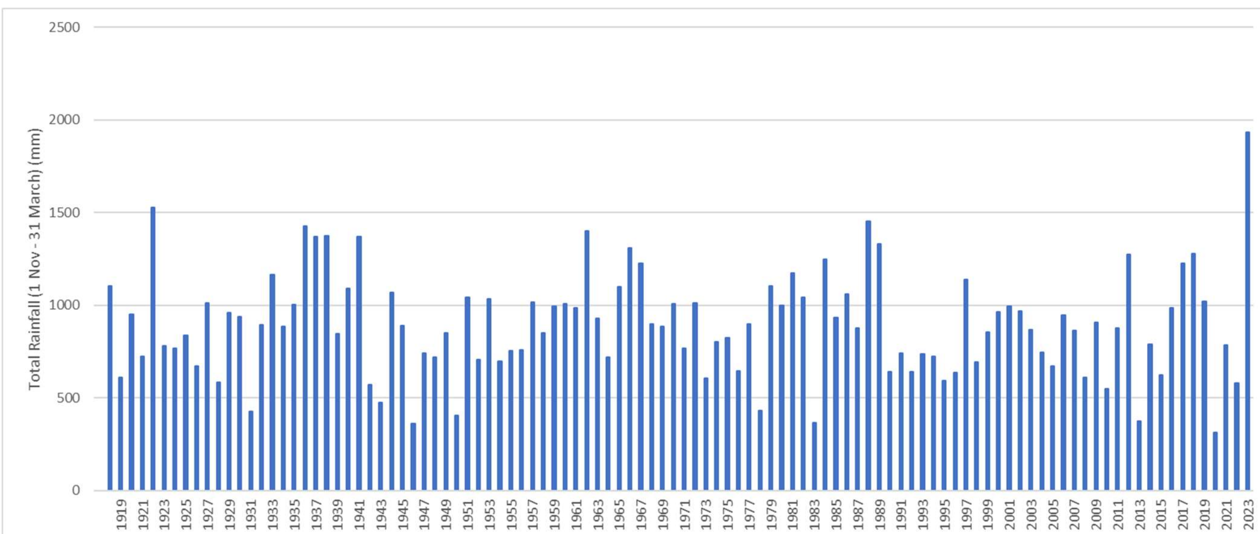

Figure 2.8 Total rainfall from November to March, each year, from the derived WKP long-term rainfall record.

2.1.2 Evaporation data

The evaporation data applied in the WBM is derived from Cliflo Station B75381, located in the Waihi township. Penman open-water evaporation data was available from this station from 26 April 1971 to 30 July 2001. To generate a long-term record, to match the rainfall data set period, the average monthly penman open-water evaporation was calculated from the available station data. This data was then applied daily in the WBM for predictive and calibration simulations.

2.1.3 Flow data

The Wharekirauponga river is fed by four main streams: Teawaotemutu Stream (T Stream), Edmond's Stream, Thompson Stream, and Adam's stream. The Wharekirauponga river originates downstream of the junction with Edmonds Stream and flows north to where it discharges, approximately 6.6 km downstream, into the Otahu River.

The Wharekirauponga catchment is characterised by steep topography and dense vegetation in the headwaters and upper part of the catchment. In the headwaters the river is generally fast flowing with riffle sections and chutes separated by the occasional pools. The topography reduces in steepness and becomes flatter in the lower catchment, which is also densely vegetated by native bush. The gradient of the river in the lower catchment is characterised as smooth, compared to the upper catchment, with a wider channel and a series of deep, slow flowing reaches (Golder, 2019). The river level is continuously monitored at five locations throughout the Wharekirauponga catchment, as shown in Figure 2.2:

- T Stream West
- T Stream East
- WKP3
- WKP2
- WKP1

These locations were selected following investigations by Waihi Gold and Golders. The general set up at each monitoring locations is comprised of a pressure transducer with an internal datalogger (level logger) which continuously measures absolute pressure. The level loggers are placed in a perforated PVC pipe stilling well, which is fixed on a waratah secured in the riverbed. Majority of the level loggers are programmed to record level every 10 minutes. Atmospheric pressure (barometric pressure) is also recorded at WKP01, using an internal datalogger, to allow for compensation of the level logger data to atmospheric pressure. Additional information on the configuration of each monitoring location is provided in the associated Golders Report (Golders, 2019).

In addition to continuous level monitoring, manual flow gauging is carried out at these locations approximately 4 times a year.

Before utilising the data for calibration purposes, the data has undergone a series of modifications:

1. The raw data is assessed for gaps, jumps in level, or incorrect data values (i.e., when the logger is removed from in situ). Erroneous data is then removed from the data set.
2. The barometric data is converted from pressure to level.
3. The water level data is compensated for changes in barometric pressure by subtracting the changes in barometric level from the recorded water level.
4. The compensated data is collated into a singular time series for each flow monitoring location. Note, data gaps are not infilled.
5. The data for each location is then corrected, through a two-point calculation process, to the manual gauging data from the relevant location.
6. The corrected data is plotted against manual gauging data and the data is assessed a final time for any outliers.

The corrected data plots for each site, at the time of writing, are provided in Appendix A. It is anticipated as more data is collected (automatically and manually) the flow data record will be updated to include all available data.

Due to monitoring equipment failure, maintenance, and in some instances equipment replacement, the level logger data is not always continuous. Gaps in the level logger data subsequently leads to gaps in the final flow data sets. In addition, because the data is corrected to manual gauging events, the duration of the flow data set is limited to the last available manual gauging data. Table 2.2 therefore summarises the period of data utilised for calibration purposes in the WBM at each monitoring location. Further gaps exist where there is no data from the Wharekirauponga Rainfall gauge for the corresponding period. The period between July 2021 – January 2023 is also excluded from the calibration due to limited rainfall data over this period (refer Section 2.1.1.1).

Table 2.2 Summary of corrected flow data utilised for calibration.

Location	Start date	End date	Notes regarding gaps in the original river level data sets.
T Stream West	20/06/2019	16/11/2023	Minor gaps in level data set
T Stream East	20/06/2019	16/11/2023	Minor gaps in level data set
WKP03	20/06/2019	16/11/2023	Gap in level data set from 19/08/2020 – 09/09/2020 and 1/12/2022 – 16/11/2023*
WKP02	21/05/2020	16/11/2023	Gap in level data set from 20/06/2019 – 20/05/2020 and 01/03/2023 – 1/08/2023 Shortest data set.
WKP01	30/01/2020	16/11/2023	Gap in level data set from 17/02/2020 – 13/03/2020 and 04/03/2022 – 25/03/2022.

*Waratah knocked over during January 2023 floods effecting level logger readings

2.1.4 Groundwater 3D model inputs

FloSolutions has developed a 3D groundwater model for the Wharekirauponga catchment (FloSolutions, 2024) which evaluates potential interactions between the proposed WUG project and shallow groundwater and surface water within the Wharekirauponga Stream and adjacent catchments.

From the groundwater model the following aspects (in relation to surface waters flows) are calculated for defined zones, with the zone predictions providing the following data:

- River leakage to groundwater
- Baseflow projections
- Baseflow transient model projections and
- The mass balance results (river in, river out, river balance, drain out and baseflow) from each zone in the model.

In order to assess the uncertainty within the groundwater model, uncertainty analysis of the groundwater model predictions has been undertaken by Intera Geosciences Pty Ltd. (Intera, 2024). The uncertainty analysis includes model parametrisation utilising pilot points that consider the spatial variability of the hydrogeological parameters and a series of stochastic model runs to develop a range of possible predictions. The model predictions in relation to surface water flows (both continuous flow gauging sites and other key surface water locations) are provided within hydrostratigraphic (HSU) zones as depicted in Figure 2.9.

In addition, WWLA (2024) report an additional baseflow loss during mining in the lower reaches of the Wharekirauponga catchment between WKP02 and WKP01. This loss models the indicative drainage boundary running and predicted reduction in drainage during mining where there is a modelled loss of 5 L/sec due to the predicted drawdown of the water table. This affect has been applied to HSU_32 in the mining scenario only, and thus effects the flow results and statistics in this hydrostratigraphic unit and at the monitoring location WKP01.

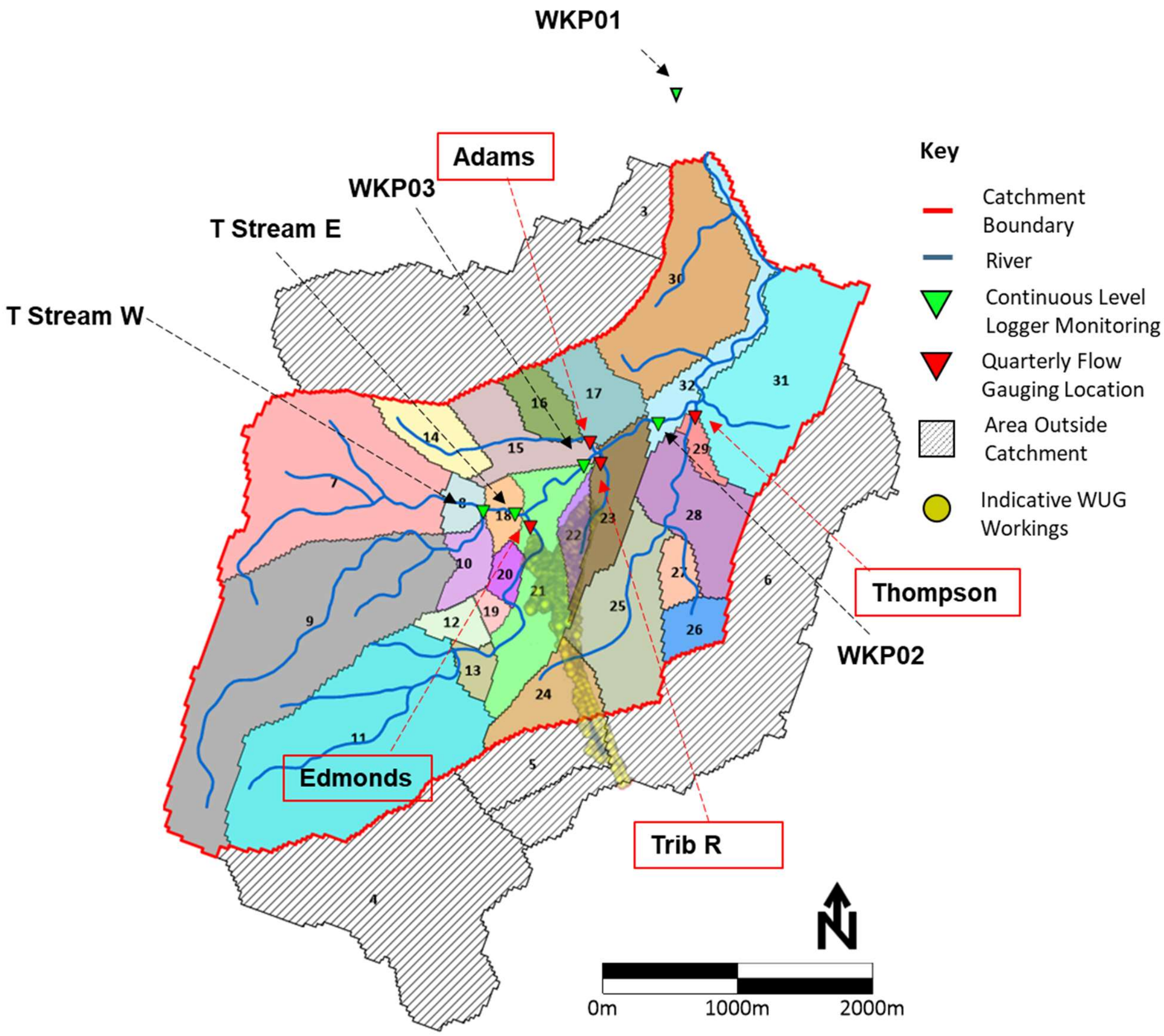

Figure 2.9 Hydrostratigraphic (HSU) zones in relation to the Wharekirauponga River Surface Water catchments within the WBM.

The river leakage to groundwater and baseflow projection data provided by Intera is applied in the WBM and utilised in calibrating the WBM predictions to the corrected flow data. For the purposes of assessing the potential impact (on surface water flows) due to mining, predictions from 2035 (the peak mining period and period of greatest potential reduction in baseflows) are utilised in the WBM to conservatively assess the impact on the hydrology. The baseflow is the sum of the river balance less any volume lost to WUG Mine within the groundwater model. The change in baseflow over the groundwater simulation period relates to the change in baseflow from pre-mining conditions (regular baseflow) to predicted mining conditions. The pre-mining river leakage and effect on baseflow are applied to the respective zones within the WBM over 100 model runs (realisations) which take into account the variability of the long term rainfall record (pre and during mining predictions) and the full range of the Intera's stochastic model drawdown predictions (during peak mining).

The cumulative change (at each catchment monitoring location, eg. WKP01, WKP03 etc.) was calculated by adding the change in baseflow of the various HSUs upstream of each respective monitoring location.

The change in baseflow (from mining) for each HSU and catchment monitoring location is illustrated utilising the baseline scenario as outlined in Table 2.3. The range of baseflow reductions for the stochastic mining model run by each HSU unit is illustrated in Appendix B.

Table 2.3 Basecase scenario baseflow loss by HSU / catchment area (data provided by Interna (2024)).

HSU	2018 Predictions. Baseflow Loss	2035 Predictions. Baseflow Loss	Calculated Effect on Baseflow (by HSU)	Calculated Effect on Baseflow (by Monitoring Location) - Discrete	Calculated Effect on Baseflow (by Monitoring Location) - Cumulative
T Stream West					
5_7	-7.92953	-7.90592	-0.02361	-0.31	-0.31
5_8	0.11933	0.20692	-0.08759		
5_9	-16.80461	-16.77703	-0.02758		
5_10	-0.92542	-0.75225	-0.17316		
T Stream East					
6_18	-1.50266	-0.92395	-0.57871	-0.58	-0.89
Edmonds					
7_11	-7.47718	-7.40849	-0.06869	-0.70	-0.70
7_12	-0.37111	-0.34265	-0.02846		
7_13	-1.17988	-1.09275	-0.08713		
7_19	-0.66689	-0.46862	-0.19826		
7_20	-1.20651	-0.88439	-0.32213		
WKP03					
7_21	-3.22275	-1.59247	-1.63028	-1.63	-3.23
WKP02					
9_14	-0.50902	-0.48510	-0.02392	-0.88	-4.10
9_15	-6.46021	-6.21552	-0.24468		
9_16	-0.64973	-0.56571	-0.08402		
9_17	-0.02290	0.04305	-0.06594		
9_22	0.79474	1.05756	-0.26282		
9_23	-0.95570	-0.76103	-0.19466		
Thompson					
8_24	0.00000	0.00000	0.00000	-2.25	-2.25
8_25	-3.44550	-1.41828	-2.02722		
8_26	0.09600	0.09600	0.00000		
8_27	-0.45740	-0.34900	-0.10840		
8_28	-1.93971	-1.83798	-0.10173		
10_29	-0.72234	-0.70781	-0.01452		
WKP01#					
10_30	0.00000	0.00000	0.00000	-0.22	-6.57
10_31	-0.57344	-0.56717	-0.00627		
10_32	-11.89648	-11.68680	-0.20968		

**All values are L/sec*

 # An additional 5 L/sec loss is applied to the HSU 32 during mining (year 2035) as per WWLA (2024)

The change in baseflow per catchment (due to mining) is applied as a fixed loss from the river flow rate in the mining scenario simulation of the WBM with the rate of loss randomly selected (based on the respective

HSU probability distribution) at the start of each model realisation. It is important to note the baseflow change applied to each model realisation in the WBM is independent of stream flow and therefore generates a conservative results for the worst-case (2035) scenario and does not vary with flow.

The sensitivity of the groundwater model predictions are incorporated within the stochastic model run where the reduction in baseflow is randomly selected for each model realisation based on the calculated probability distributions (refer Appendix B).

2.1.5 Other parameters

The WBM is set up with several other parameters and data variables. Many of these are fixed values or pre-defined variables included as part of the AWBM standard configuration. This section briefly touches on the other key parameters that have been defined, and in some instances adjusted, in the WBM. Given each of the flow monitoring locations (calibration points) have been built into the model as sub-catchments, these parameters are applied in each sub-catchment:

– *Catchment area:* The sub-catchment area. The sub-catchment areas were calculated using the available digital elevation model for the wider region, the location of the flow data monitoring loggers, and a watershed delineation tool in ArcGIS.
– *Evaporation reduction:* The evaporation reduction factor applied to the evaporation data. The evaporation data utilised in the model is from Waihi township, which is much lower in elevation than the Wharekirauponga catchment and is subject to significantly less vegetation cover. The evaporation reduction is therefore utilised in the AWBM to reduce the likely evaporation to reflect conditions in the Wharekirauponga catchment.
– *Surface store area proportions and depth capacities:* The AWBM predefines the surface store data. The premise of these factors in the WBM relates to the relationship of runoff to rainfall with variability in surface storage. The surface store areas are therefore the partial area proportions represented by the three defined surface store components. The depth capacities are the depth capacities of the three associated surface store components. It is important to note these stores and capacities do not represent individual catchments, but rather make up the soil store composition of a single catchment and are therefore replicated in each sub-catchment configuration in the WBM.
– *Baseflow index factor*: The fraction of runoff that is proportioned to baseflow storage in the AWBM.
– *Surface store index factor*: The fraction of runoff that is proportioned to each surface store in the AWBM portion of the WMB.
– *Baseflow recession constant (Kb)*: The baseflow recession constant used to help define the recession rate of baseflow.
– *Surface runoff recession constant (Ks1 and Ks2)*: The recession rate for the surface runoff store. Two surface water stores are configured in the model and a recession rate for each store is applied (recession rate for store 1 = Ks1, recession rate for store 2 = Ks2).
– *River flow addition:* The addition of a water into the simulated river flow in each catchment. This is applied as a constant value (mm/day) and is factored into the model to reflect the addition of flow into the rivers from springs.
– *River flow addition control:* The limiting factor that controls the proportion of river flow addition added to the river during periods of low rainfall. This parameter is developed as a formula referencing the volume of cumulative rain received over the preceding days. If cumulative rainfall over the preceding three days is less than 1mm per day, the river flow addition control factor is applied to the river flow addition, reducing the amount of water added. This parameter is designed to reflect the reduction in spring flow anticipated when dry conditions occur.

The values assigned to these parameters in each sub-catchment of the WBM, to achieve calibration are detailed in Appendix C.

2.2 Calibration

The WBM has been calibrated, at the time of writing, to the flow data at the five flow monitoring locations where continuous monitoring data is available (T Stream West, T Stream East, WKP03, WKP02 and WKP01). The calibration process has focused on achieving the best possible calibration at the low flow periods, given this is the flow range of focus for the project. It is worth noting that the manual gauging events have generally focussed on low - median flow events. It is also important to note, it is expected that the quality of the measured data will improve with continuation of the project and the introduction of vented water level transducers in the future. Furthermore, a prolonged dataset coupled with increasing manual measurements during low flow events will enable better calibration and more reliable predictions in the future. The current calibration should be updated when more data is available, and prior to the commencement of mining.

The WBM runs on a daily timestep. The calibration period used is 1 March 2019 to 15 November 2023 and utilises corresponding continuous logger data (benchmarked by actual flow measurements) and daily Wharekirauponga rainfall data.

The calibrated daily modelled (simulated) data versus the measured flow data (as described in Section 2.1.3) is presented for each location. For each monitoring location a timeseries graph, flow duration curve (plotted on a log scale), and regression plot of simulated and measured flow is provided.

Calibration at T Stream West shows the measured and simulated daily flow are generally following the same pattern, with over and under estimations throughout different periods of the hydrograph. The simulated flow is closely predicting low flow periods, until the 96th percentile when the model begins to over simulate low flows by between 0.003 and 0.001 m^3/s. The measured data shows a higher degree of variability compared to the simulated data, highlighting the potential influence of the daily timestep in the WBM and localised climatic variability on measured flow. This observation is consistent for all calibration locations.

T Stream East is a small catchment and predominately controlled in the WBM by the configuration of the upstream T Stream West catchment. The calibration at T Stream East shows a greater variability between measured and simulated daily flow. High flows are generally over predicted by the WBM, with flows then under predicted as the flow rates get below 0.1 m^3/s. At extreme low flow conditions the WBM begins to overpredict flows. This is evident from around the 88th percentile mark.

WKP03 receives flows from the upstream T Stream West and East catchment. The calibration at WKP03, consistent with the upstream sites, shows an overprediction of flow at high flow periods. Calibration at low flows is considerably better with the model generally simulating flows consistent with measured data when flow is below 0.04 m^3/s. This is clearly reflected in the flow duration curve (Figure 2.17) from the 95th percentile onward.

WKP02 has the poorest calibration, this is a direct reflection of the limited data available at this site. Measured flow data is only available at WKP02 from 21 May 2020, limiting the calibration at this site to a calibration period from end of May 2020 through until July 2021 (just over a year). The limited data period therefore only captures one year of flows, which may not be an accurate reflection of the long-term flow regime at WKP02. As such, adjustments in the WBM parameters to achieve calibration (outside of the realm of values used for calibration at all other locations) is unjustified. It is recommended WKP02 is not used as a key calibration site, until a more robust / longer term data set is available for calibration.

The WKP01 catchment, captures all the above sub-catchments and additional sub-catchments (such as Edmonds and Thompson). The calibration at WKP01 is strongest at low flows with measured and simulated flows from the 96th to 100th percentile generally being within 0.005 m^3/s of each other (Figure 2.23). However, as evident in the timeseries, flow duration curve and regression plots, the WBM over predicts the higher end of the flow regime at this location.

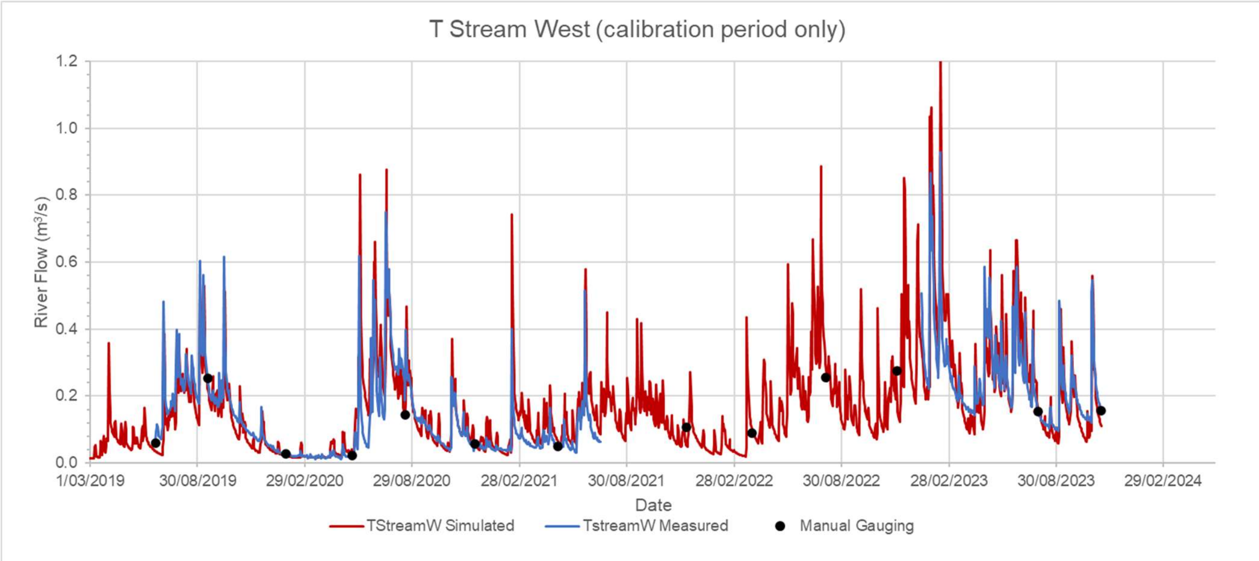

Figure 2.10 ***Timeseries plot of average daily measured flow, daily modelled (simulated) flow and manual gauging of flow at T Stream West during the calibration period.***

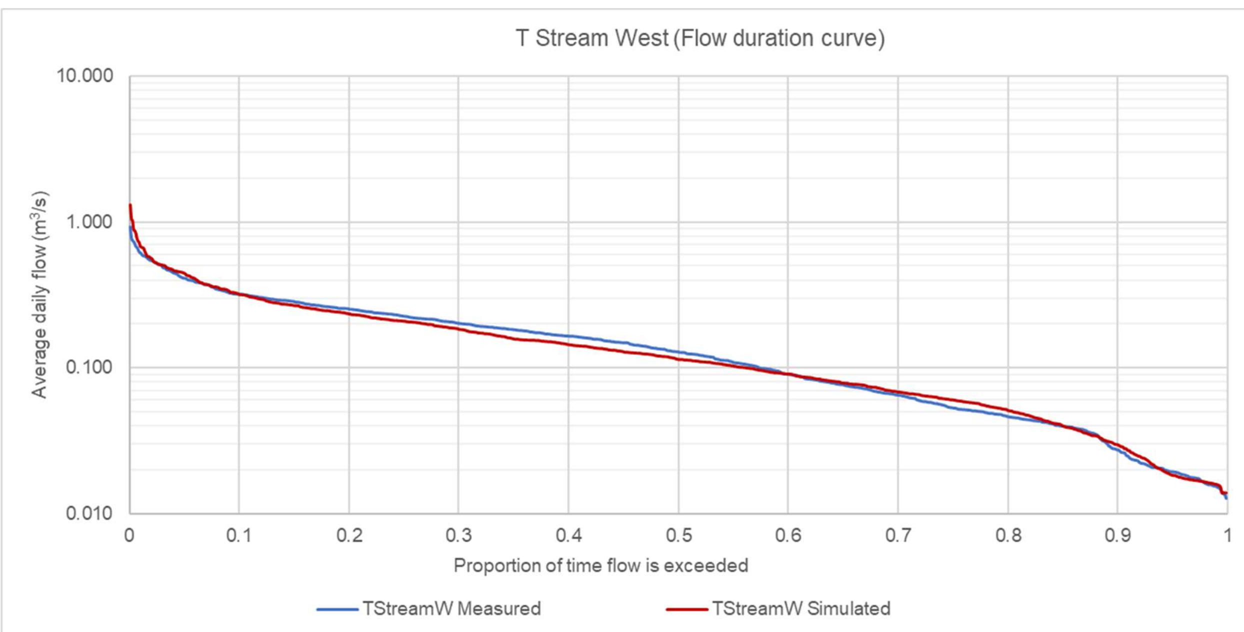

Figure 2.11 ***Flow duration curve indicating the proportion of time flow exceeds a certain rate, over the calibration period, for measured and simulated flow at T Stream West.***

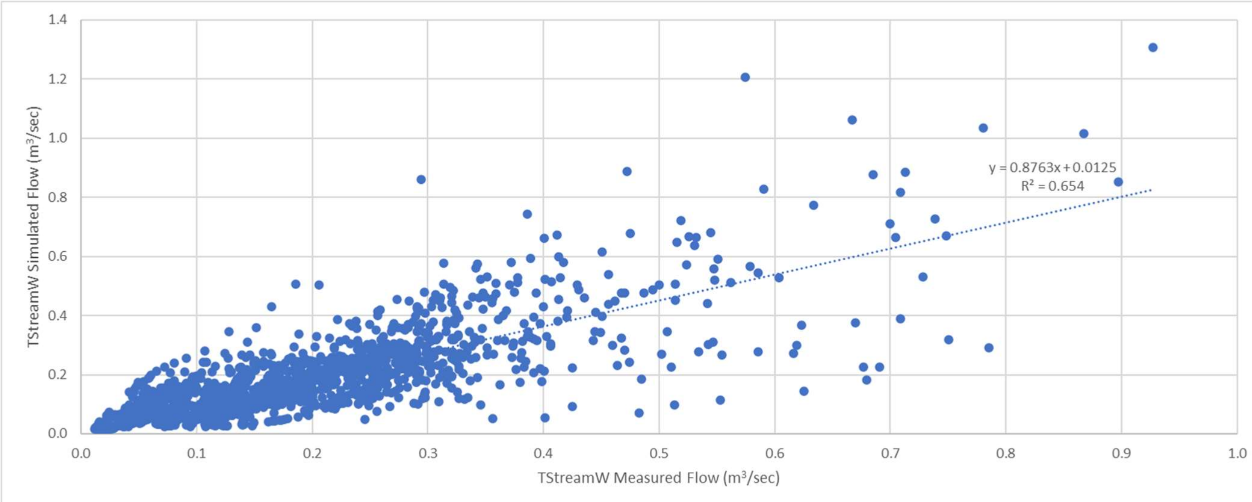

Figure 2.12 ***Regression plot of measured and simulated flow at T Stream West for the calibration period.***

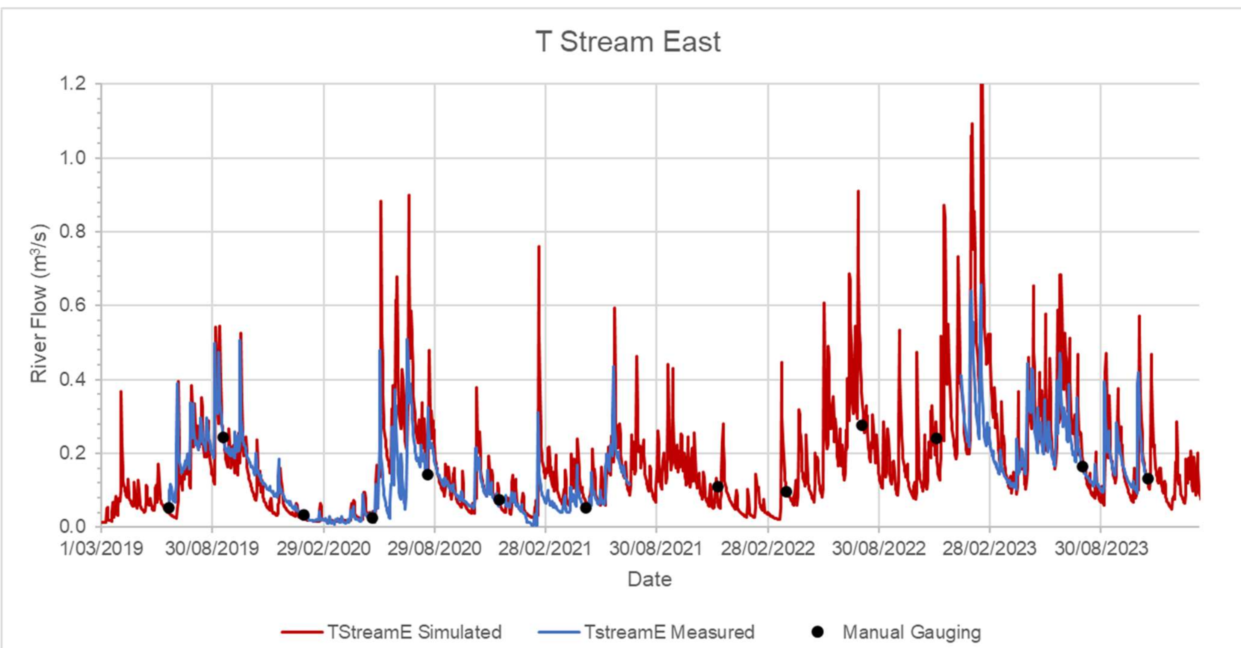

Figure 2.13 ***Timeseries plot of average daily measured flow, daily modelled (simulated) flow and manual gauging of flow at T Stream East during the calibration period.***

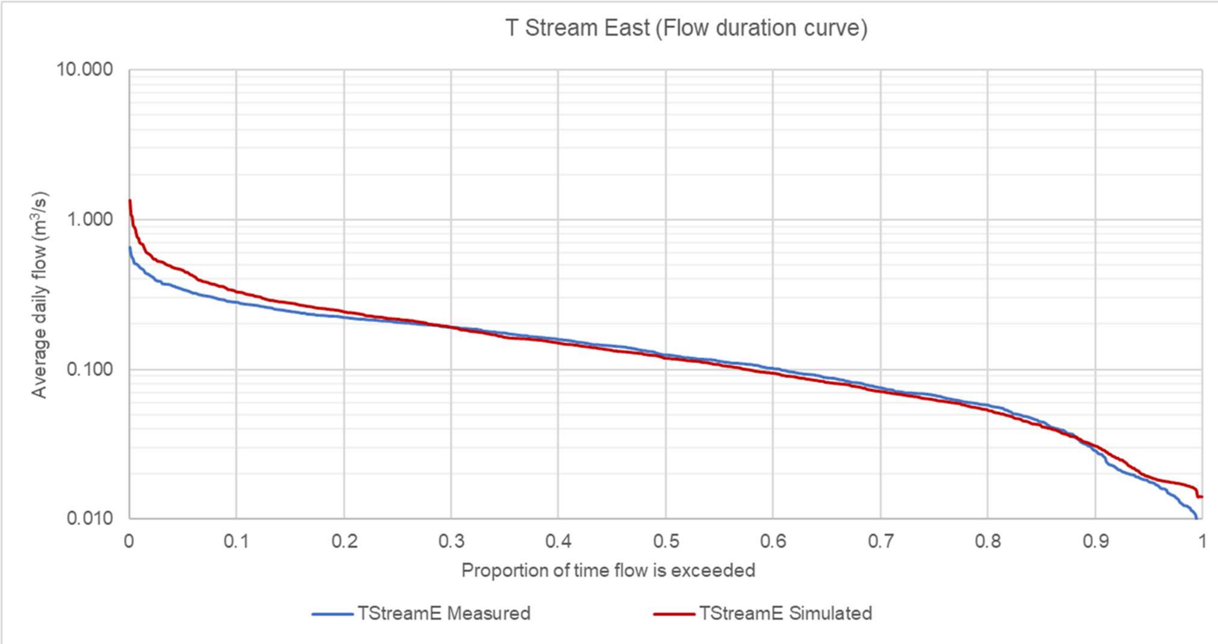

Figure 2.14 ***Flow duration curve indicating the proportion of time flow exceeds a certain rate, over the calibration period, for measured and simulated flow at T Stream East.***

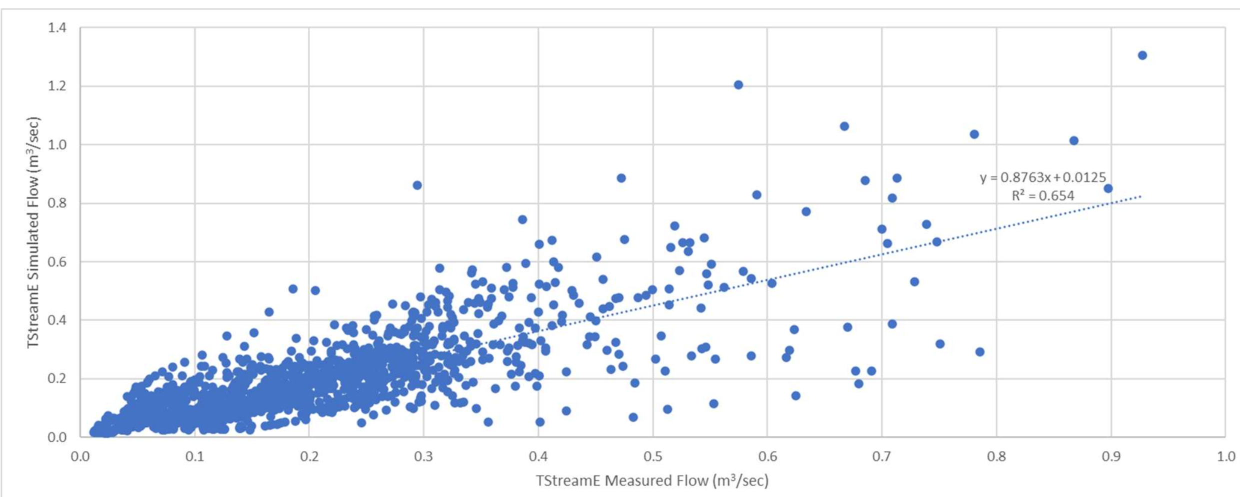

Figure 2.15 ***Regression plot of measured and simulated flow at T Stream East for the calibration period.***

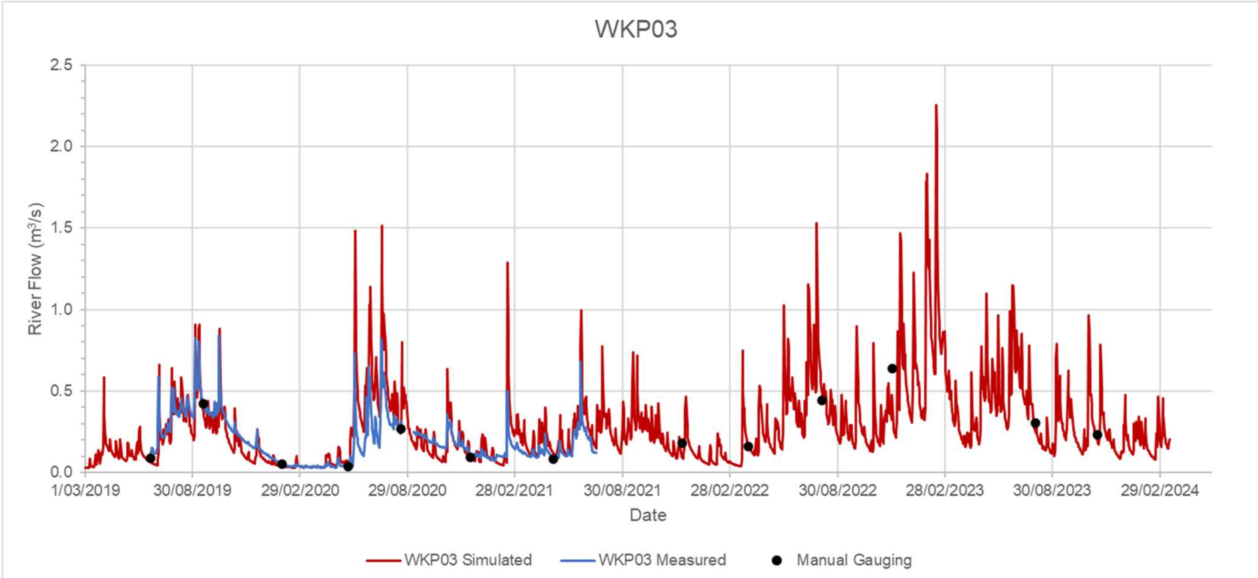

Figure 2.16 ***Timeseries plot of average daily measured flow, daily modelled (simulated) flow and manual gauging of flow at WKP03 during the calibration period.***

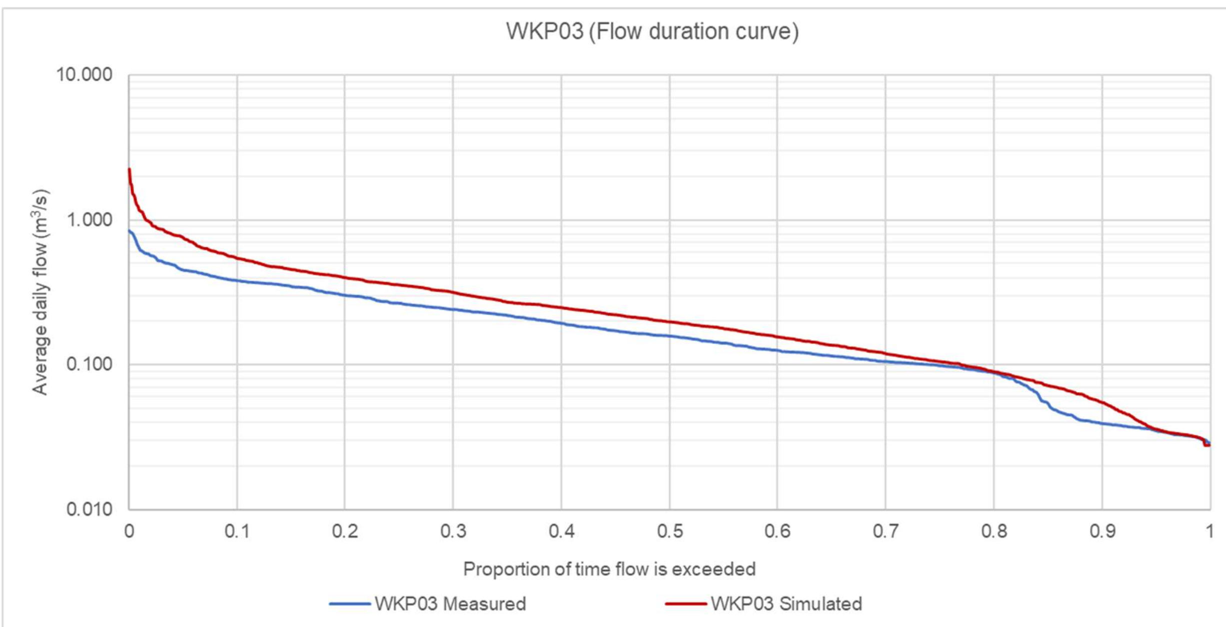

Figure 2.17 ***Flow duration curve indicating the proportion of time flow exceeds a certain rate, over the calibration period, for measured and simulated flow at WKP03.***

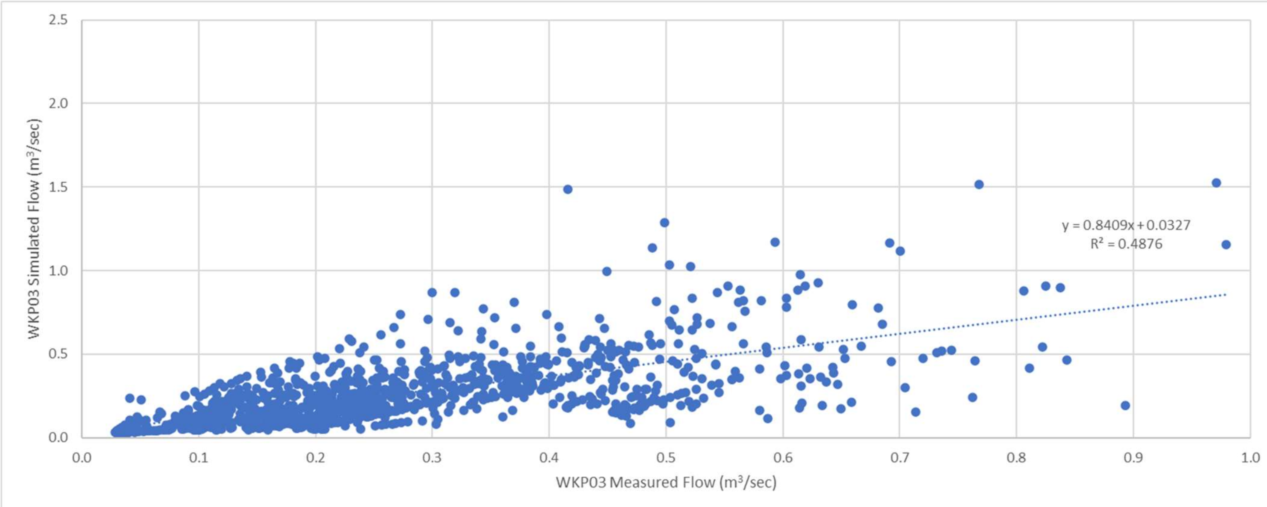

Figure 2.18 *Regression plot of measured and simulated flow at WKP03 for the calibration period.*

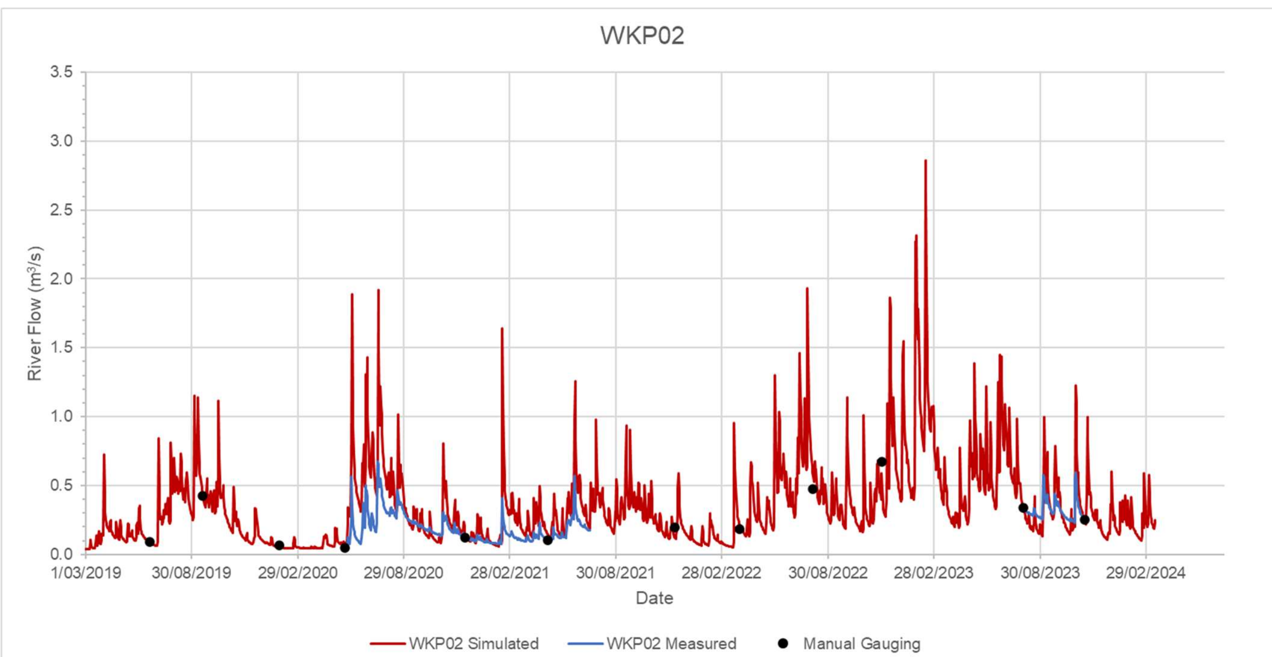

Figure 2.19 *Timeseries plot of average daily measured flow, daily modelled (simulated) flow and manual gauging of flow at WKP02 during the calibration period.*

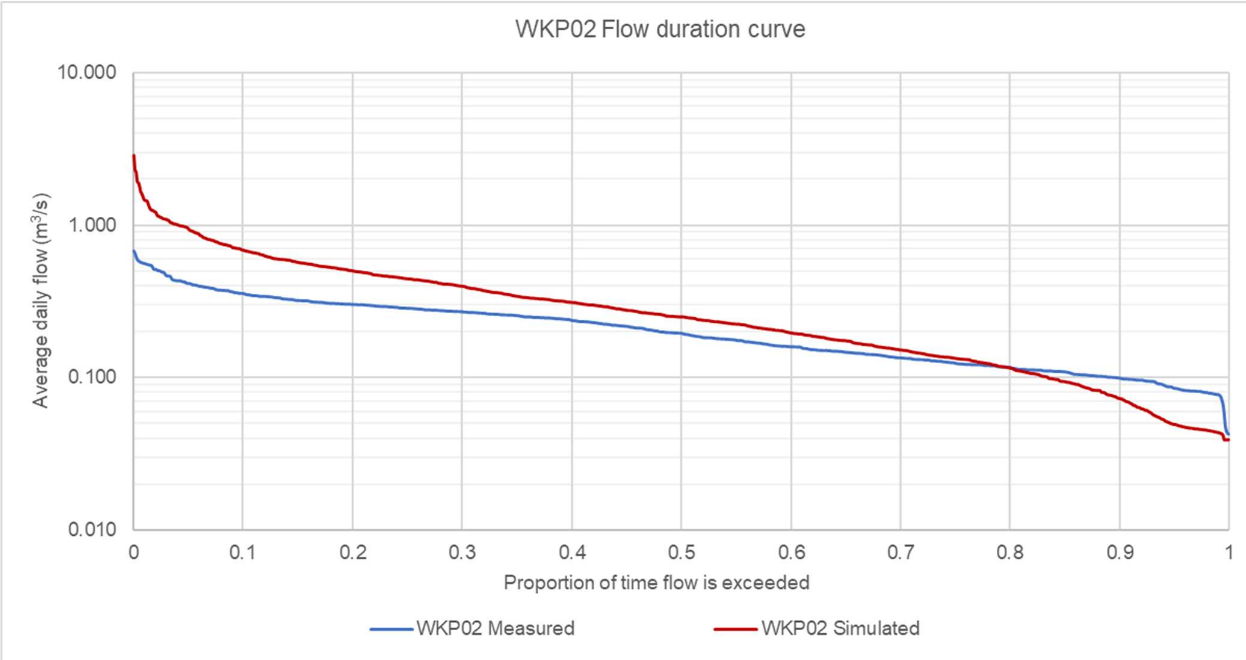

Figure 2.20 ***Flow duration curve indicating the proportion of time flow exceeds a certain rate, over the calibration period, for measured and simulated flow at WKP02.***

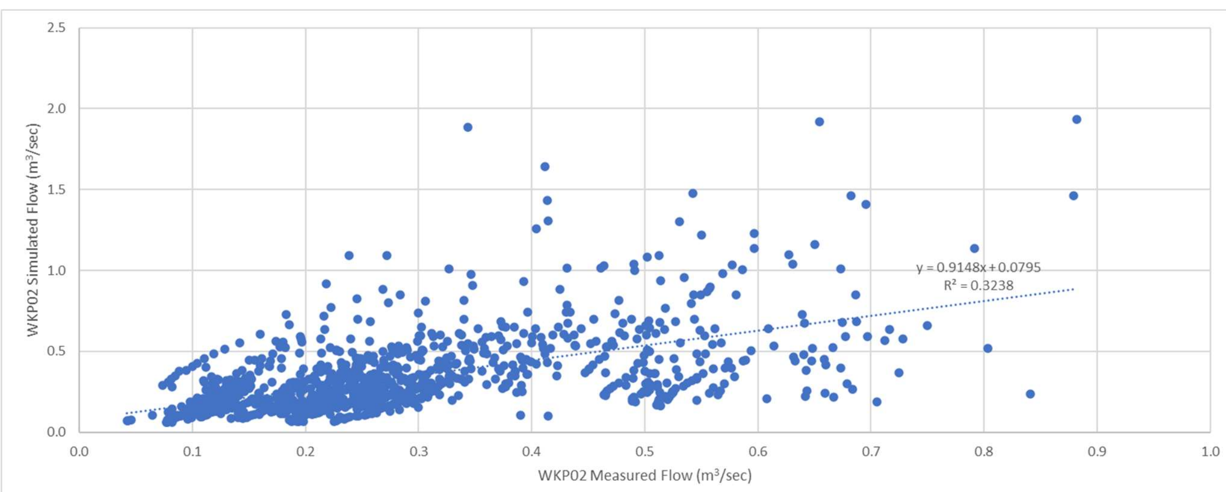

Figure 2.21 ***Regression plot of measured and simulated flow at WKP02 over the calibration period.***

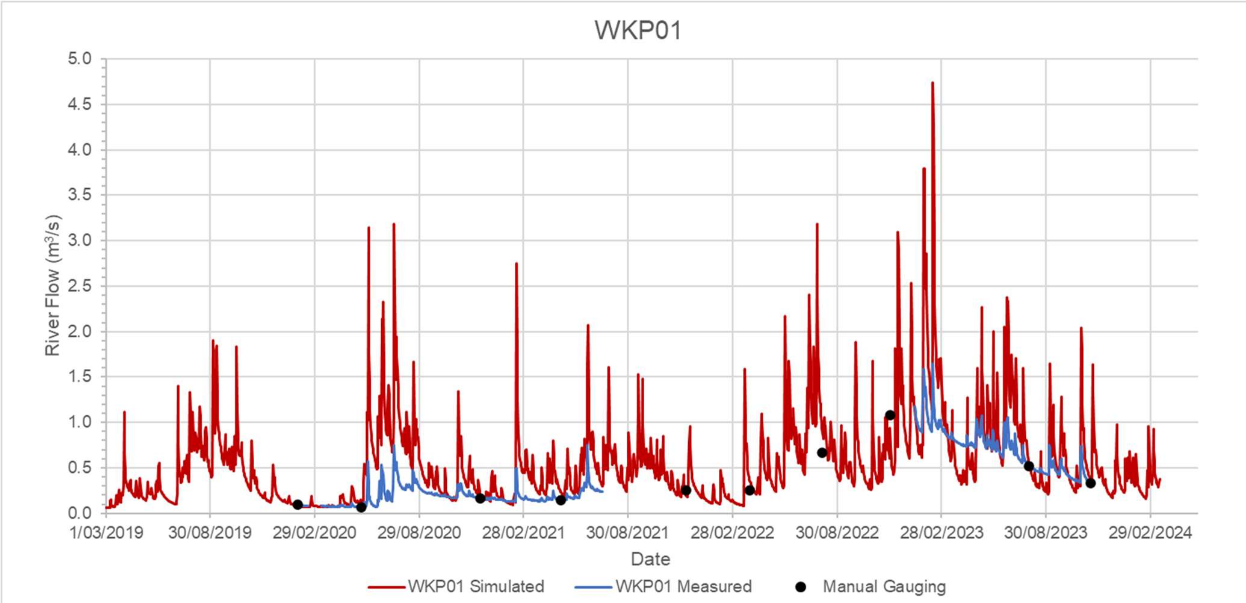

Figure 2.22 ***Timeseries plot of average daily measured flow, daily modelled (simulated) flow and manual gauging of flow at WKP01 during the calibration period.***

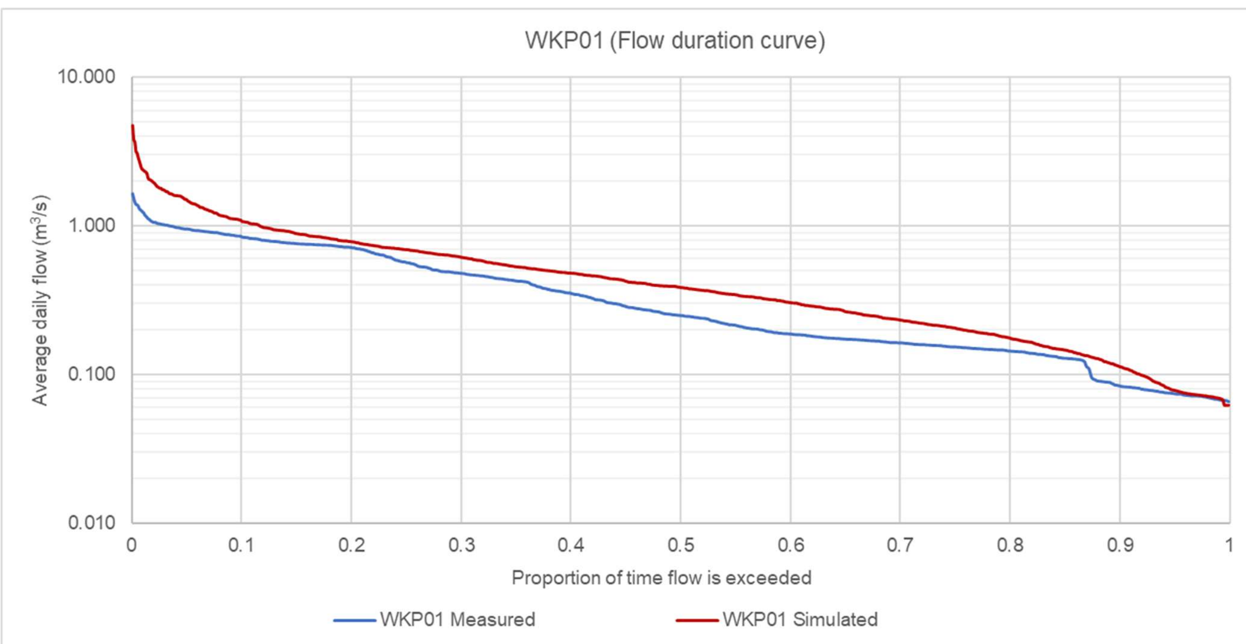

Figure 2.23 ***Flow duration curve indicating the proportion of time flow exceeds a certain rate, over the calibration period, for measured and simulated flow at WKP01.***

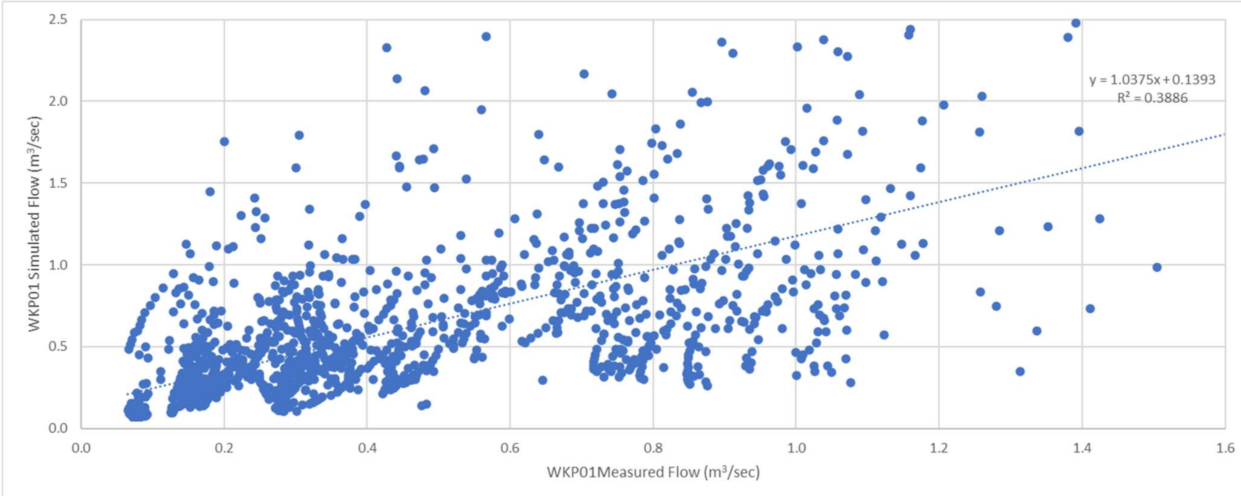

Figure 2.24 Regression plot of measured and simulated flow at WKP01 for the calibration period.

2.3 Model limitations

The current WBM calibration is subject to limitations which effect the predictive accuracy of the model. These limitations include:

- The rainfall data utilised for calibration of the model has been infilled in places, which limits the reliability of the input data.
  - This limitation is the driver for the shorter calibration period utilised (1 March 2019 – 16 July 2021 and January 2023 to November 2023), described in Section 2.2
- The available actual (measured) data sets are considered short for calibration purposes. It is envisaged that this WBM will be updated with additional monitoring data (prior to mining) to improve the current calibration and predictive accuracy.
- Predictions for Thomsons, Edmonds and Adams are based on a pro-rated assessment from WKP01 and WKP03 flow data (based on the sum of the proportional catchment areas located upstream of these locations).
- Predictions for Trib R are based on a developed relationship between manual gauging events at Trib R and WKP03 (Figure 2.25).
- The WBM works on a daily timestep. The natural response of hydrological systems can be rapid and therefore the changes to the hydrological regime within a day can vary. As such the WBM cannot reflect the true, sub-daily, hydrological responses times of the natural rainfall runoff water balance in the Wharekirauponga catchment.

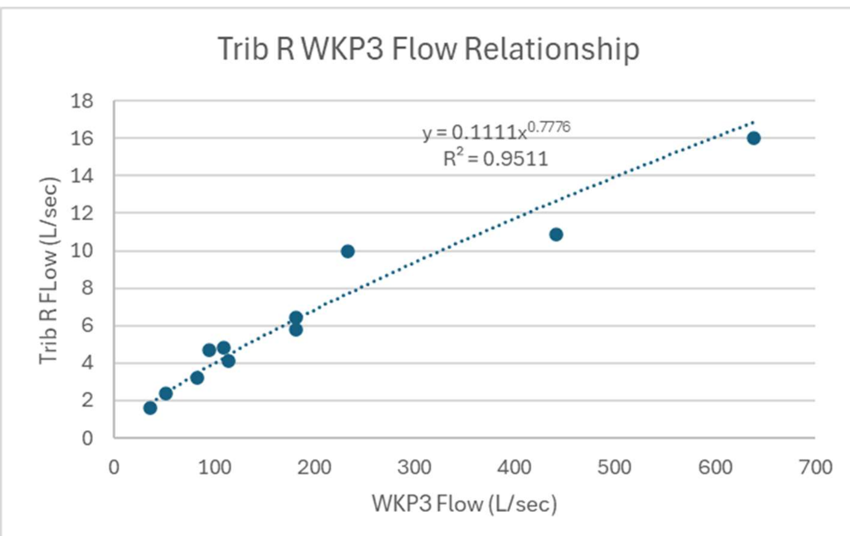

Figure 2.25 Flow relationship Trib R – WKP03

3. Stream Wetted Width Estimation

The wetted width of a stream/river is defined as the distance between the sides of the channel at the point where substrates are no longer surrounded by surface water. The wetted width is an important measurement in understanding the physical and ecological habitat and can influence the range and density of periphyton, macroinvertebrate and fish species present.

The wetted width of a particular reach of surface water (and its variability) is highly influenced by a number of factors. These factors include the topography, geology, catchment size, sediment characteristics and flow. Booker (2010) has developed coefficient relationships between discharge and wetted width over a wide range of gauging stations (numbering 326 different locations) throughout New Zealand utilising existing data, site geometry and climate variables. These relationships are applied to the publicly available NIWA New Zealand River Maps online database (**https://niwa.co.nz/freshwater/new-zealand-river-maps**) (Whitehead & Booker, 2020) that allows for estimation of wetted width at set locations based on estimated flow.

Flow / wetted width relationships have been downloaded from the NIWA New Zealand River Maps online database at locations that coincide with monitoring locations and HSU units as listed in Table 2.3. The corresponding locations highlighting the respective Monitoring location / HSU Unit against the respective location on the NIWA New Zealand River Maps online database are provided in Figure 3.1. The relationships utilised to predict the wetted width (based on the predicted flow) are provided in Appendix D.

The calculated wetted width (from the WBM) at each location is provided on a relative basis. I.e. the wetted width within any stream reach can vary considerably. This is illustrated in NIWA (2024) where habitat surveys (included wetted width measurement) were carried out at locations within the Wharekirauponga catchment. The modelled calculated wetted width (utilising the coefficients and the WBM generated flows) were found to be in general, a reasonable match with the surveyed data in that the modelled median / average wetted widths were generally similar to the surveyed wetted width reach averages for the various locations. Modelled Trib R and Adams wetted widths showed the poorest fit to survey data with modelled median / average wetted widths approximately half the width of the surveyed data.

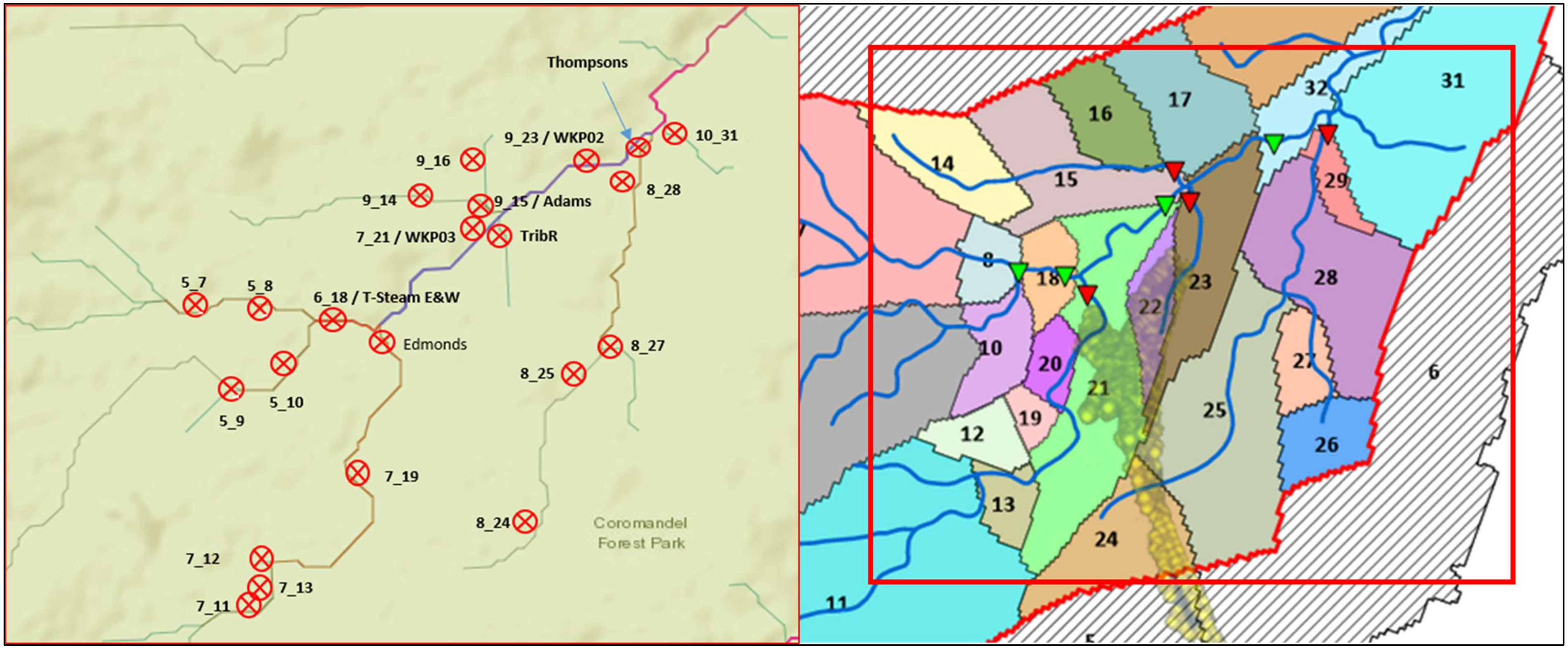

Figure 3.1 NIWA River Map Wetted Width and Flow Data locations corresponding to Groundwater HSU and Wharekiraupонga Monitoring Locations

4. Predictive simulations - Flow

Using the calibrated WBM, a base case (current state / pre-mining) simulation and a base flow reduction (mining) simulation have been run over a long-term predictive period of 104 years. Both simulations were modelled stochastically over 100 model realisations (with rainfall and baseflow loss the stochastic modelled elements). In addition, a separate climate change simulation (as per Section 2.1.1.4) has been run.

Summary statistics from both scenarios (pre-mining and mining) are presented in Table 4.1 and Table 4.2. The 5th percentile and average (mean) results are provided as they are deemed to conservatively reflect the likely range in flow statistics based on pre-mining and mining (including the predicted range of baseflow loss) WBM predictions taking into account the long-term rainfall record.

The 5th percentile and mean statistics are calculated as follows:

- For each model realisation, the annual hydrological statistics are calculated (for each 104 years of the model run).
- For each model realisation, the collective hydrological statistics (utilising the annual hydrological statistics) covering the model run period are calculated.
- The 5th percentile and the mean values for all the model realisations are calculated utilising the collective hydrological statistics from each realisation.

The statistics calculated include a range of hydrological statistics commonly calculated when considering low flow conditions and the effect of the flow regime on ecological conditions. The statistics include:

- Mean annual low flow (MALF), where the lowest flow for each (hydrological) year is averaged over the data record available. This metric is often used during low flow and ecological analysis.
- Seven-day mean annual low flow (7-day MALF), where using a 7-day rolling average the lowest flow for each (hydrological) year is averaged over the data record available. Again, this metric is often used for low flow and ecological analysis.
- Three times the median (FRE3), where the median of the data is multiplied by three. This metric is used to indicate stream bed movements during high flow events.
- The 5th quartile (or 20th percentile) of flow (Q5).

Additional estimations of average, median, Q5 and MALF for T Stream East, T Stream West, Edmonds, TribR, Adams, WKP02, Thompson and WKP01 are also provided alongside the modelled predictions for comparison. These estimates are from the National Institute of Water and Atmospheric Research (NIWA) online River Maps tool (https://shiny.niwa.co.nz/nzrivermaps/ accessed 12/09/2023) which utilises a physical and empirical based approach to estimate hydrological statistics (Booker & Woods 2014; Booker & Woods 2012).

The MALF, 7-day MALF, and Q5 statistics are calculated using hydrological (water) years, from 1 July through to 30 June. When compared to the NIWA derived estimates, the calculated statistics are comparable, particularly for the low flow statistics (MALF and Q5).

To quantify the potential effect of mining a percentage reduction between the pre-mining scenario and the mining scenario has been calculated (Table 4.3).

The percentage reduction shows the MALF and 7-day MALF is reduced during mining at each location. The percentage reduction is predicted to be the smallest at T Stream West (between 1.6% and 1.8% for the MALF, and 1.4% for the 7-day MALF) and greatest at Thompson, (between 12.4% and 13.3% for MALF, and 11.5% and 12.4% for the 7-day MALF). The Q5 is reduced at all sites with the reduction ranging between 1.9 – 15.5%. Similarly, the FRE3 threshold is also reduced at all sites, with the reduction ranging between 0.4 – 3.8%. The average and median flows are affected, however this effect is small (<3.8%) compared to the predicted reductions on the low flow statistics.

The statistics indicate the mining scenario will influence the flow regime to some degree, with low flow conditions reducing at all sites. Climate change is expected to have a negligible effect on the low flow statistics with the modelled 7-day MALF statistic very similar for all locations in the mining scenario (Table 4.3).

Results and predictions at an HSU level are provided in Appendix E. These are considered less reliable (when compared to the results at the defined monitoring locations) due to a lack of model calibration data and/or uncertainty in how the rainfall / runoff / storage relationship function on both a smaller scale and/or within the head water catchments.

Figure 4.1 and Figure 4.2 illustrate the modelled pre-mining MALF (5^{th} percentile and mean modelled predictions) versus the predicted change in 7-day MALF during mining (as a percentage of the pre-mining 7-day MALF) in heat maps illustrating the relative difference between the various HSU units. The maps show that flows are significantly greater in the HSUs that coincide with the main Wharekirauponga Stream channel, however the predicted effects are greatest in the smaller headwater catchments (i.e., HSU 22) in which there is no (or limited) flow gauging data to calibrate the WBM estimates. These model units both have a very low calculated 7-day MALF (<= 1 L/sec) and are significantly removed from the main gauging / calibration locations, and it is possible that they run dry during prolonged dry periods. The calculated percentage reduction (based on a reduction in baseflow (from the groundwater model calibration period) during peak mining coinciding with a prolonged dry period) is therefore considered conservative.

Table 4.1 Summary statistics of the long term predictive current state (pre-mining) conditions scenario at each location.

Statistic (L/s)	T Stream West		T Stream East		Edmonds		Trib R		Adams		WKP03		WKP02		Thompson		WKP01	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	144.4	148.1	148.0	151.8	104.1	106.7	4.8	4.8	33.6	34.3	252.1	258.5	318.6	326.6	75.3	77.1	510.1	522.9
Average flow (Booker & Woods, 2014)	140.72				88.91		11.58		40.73		252.53		322.05		75.67		575.70	
Median flow	117.3	121.0	120.0	123.9	84.7	87.3	4.2	4.3	27.9	28.6	204.6	211.2	258.5	266.5	59.9	61.6	410.0	422.4
Median flow (Booker & Woods, 2014)	86.16				48.30		6.95		24.42		155.76		191.43		38.97		347.84	
MALF	26.6	27.7	26.8	28.0	22.1	22.9	1.4	1.4	10.3	10.5	48.9	50.9	65.0	67.4	17.4	17.9	104.3	108.1
MALF (Booker & Woods, 2014)	30.93				16.37		2.35		8.27		50.58		54.38		14.66		103.09	
70% MALF	18.6	19.4	18.8	19.6	15.5	16.0	1.0	1.0	7.2	7.3	34.3	35.6	45.5	47.2	12.2	12.5	73.0	75.6
50% MALF	13.3	13.8	13.4	14.0	11.1	11.4	0.7	0.7	5.1	5.2	24.5	25.4	32.5	33.7	8.7	8.9	52.1	54.0
7day-MALF	29.4	30.8	29.7	31.2	24.0	25.0	1.5	1.5	10.8	11.1	53.7	56.2	70.9	73.9	18.6	19.2	113.7	118.4
70% 7day-MALF	20.6	21.6	20.8	21.8	16.8	17.5	1.0	1.1	7.6	7.7	37.6	39.3	49.6	51.8	13.0	13.4	79.6	82.9
50% 7day-MALF	14.7	15.4	14.9	15.6	12.0	12.5	0.7	0.8	5.4	5.5	26.9	28.1	35.5	37.0	9.3	9.6	56.9	59.2
FRE3	351.9	363.1	360.0	371.6	254.1	261.9	12.6	12.9	83.7	85.9	613.9	633.5	775.5	799.6	179.7	184.8	1,230	1,267
Q5	21.2	22.4	21.3	22.6	18.5	19.4	1.2	1.2	9.2	9.5	39.9	41.9	53.8	56.3	15.2	15.7	86.5	90.5
Q5 (Booker & Woods, 2014)	21.93				12.43		1.79		6.30		34.19		39.78		10.99		75.82	
5% of MALF	16.5	17.3	16.5	17.3	15.6	16.1	1.0	1.0	8.4	8.5	32.1	33.4	44.2	45.8	13.4	13.7	71.1	73.7
10% of MALF	17.3	18.7	17.3	18.7	16.1	16.9	1.0	1.1	8.5	8.8	33.4	35.6	45.7	48.5	13.7	14.2	74.1	78.1
30% of MALF	21.3	22.3	21.4	22.4	18.6	19.3	1.2	1.2	9.2	9.4	40.0	41.7	53.9	56.0	15.2	15.6	86.7	90.1
50% of MALF	24.5	26.0	24.7	26.2	20.8	21.7	1.3	1.4	9.9	10.1	45.6	47.9	60.8	63.7	16.6	17.1	97.8	102.3

*Unshaded cells indicate WBM estimates, Shaded cells indicate physical and empirical based estimates (Booker & Woods 2014; Booker & Woods 2012).

Table 4.2 Summary statistics of the long term predictive state (mining) conditions scenario at each location.

Statistic (L/s)	T Stream West		T Stream East		Edmonds		Trib R		Adams		WKP03		WKP02		Thompson		WKP01	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	144.0	147.7	146.9	150.8	101.3	104.0	4.7	4.8	33.1	33.9	248.4	254.7	313.7	321.7	72.9	74.9	497.4	510.4
Median flow	116.8	120.6	119.0	122.8	82.0	84.6	4.2	4.3	27.5	28.2	201.0	207.4	253.7	261.6	57.6	59.4	397.4	409.9
MALF	26.1	27.3	25.6	26.9	19.3	20.2	1.3	1.3	9.8	10.0	44.9	47.1	59.7	62.4	15.1	15.7	91.4	95.6
70% MALF	18.3	19.1	17.9	18.9	13.5	14.1	0.9	0.9	6.8	7.0	31.4	33.0	41.8	43.7	10.6	11.0	64.0	66.9
50% MALF	13.0	13.6	12.8	13.5	9.7	10.1	0.6	0.7	4.9	5.0	22.5	23.6	29.8	31.2	7.5	7.8	45.7	47.8
7day-MALF	29.0	30.4	28.6	30.2	21.2	22.3	1.4	1.4	10.3	10.6	49.9	52.4	65.9	69.0	16.3	17.0	100.9	105.9
7day-MALF*	28.8	30.3	28.4	30.1	21.2	22.2	1.4	1.4	10.3	10.6	49.6	52.3	65.5	68.8	16.3	17.0	100.3	105.7
70% 7day-MALF	20.3	21.3	20.0	21.1	14.9	15.6	1.0	1.0	7.2	7.4	34.9	36.7	46.1	48.3	11.4	11.9	70.7	74.1
50% 7day-MALF	14.5	15.2	14.3	15.1	10.6	11.1	0.7	0.7	5.2	5.3	24.9	26.2	32.9	34.5	8.1	8.5	50.5	53.0
FRE3	350.4	361.8	357.0	368.5	246.0	253.8	12.5	12.8	82.4	84.5	603.0	622.3	761.2	784.7	172.8	178.1	1,192.1	1,229.6
Q5	20.7	22.0	20.3	21.5	15.7	16.7	1.1	1.1	8.7	9.0	35.9	38.2	48.6	51.3	12.9	13.5	73.9	78.0
5% of MALF	16.1	16.9	15.5	16.3	12.7	13.4	0.9	0.9	7.9	8.0	28.4	29.7	39.2	40.8	11.0	11.5	58.4	61.2
10% of MALF	16.9	18.2	16.3	17.7	13.3	14.2	0.9	1.0	8.0	8.3	29.6	31.9	40.8	43.5	11.3	12.0	61.3	65.6
30% of MALF	20.9	21.9	20.3	21.4	15.8	16.6	1.1	1.1	8.8	9.0	36.2	38.0	48.9	51.0	12.9	13.4	74.2	77.6
50% of MALF	24.1	25.6	23.7	25.2	17.9	19.0	1.2	1.3	9.4	9.7	41.7	44.2	55.7	58.7	14.3	14.9	84.9	89.9

Climate Change Scenario Model Run

Table 4.3 Percentage reduction (flow) between pre-mining and mining - long term predictive scenario.

% Reduction	T Stream West		T Stream East		Edmonds		Trib R		Adams		WKP03		WKP02		Thompson		WKP01	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	0.3	0.3	0.7	0.7	2.7	2.5	1.4	1.3	1.4	1.4	1.5	1.4	1.5	1.5	3.3	2.9	2.5	2.4
Median flow	0.4	0.4	0.8	0.8	3.2	3.1	1.4	1.4	1.6	1.6	1.8	1.8	1.9	1.9	3.8	3.6	3.1	3.0
MALF	1.8	1.6	4.4	3.7	12.7	11.8	6.5	5.9	4.9	4.5	8.2	7.4	8.1	7.4	13.3	12.4	12.3	11.6
70% MALF	1.8	1.6	4.4	3.7	12.7	11.8	6.5	5.9	4.9	4.5	8.2	7.4	8.1	7.4	13.3	12.4	12.3	11.6
50% MALF	1.8	1.6	4.4	3.7	12.7	11.8	6.5	5.9	4.9	4.5	8.2	7.4	8.1	7.4	13.3	12.4	12.3	11.6
7day-MALF	1.4	1.4	3.7	3.3	11.5	10.8	5.8	5.3	4.6	4.2	7.2	6.7	7.1	6.7	12.4	11.5	11.2	10.5
7day-MALF*	2.0	1.7	4.4	3.5	11.7	11.1	5.8	5.3	4.7	4.2	7.7	6.9	7.6	7.0	12.3	11.4	11.8	10.7
70% 7day-MALF	1.4	1.4	3.7	3.3	11.5	10.8	5.8	5.3	4.6	4.2	7.2	6.7	7.1	6.7	12.4	11.5	11.2	10.5
50% 7day-MALF	1.4	1.4	3.7	3.3	11.5	10.8	5.8	5.3	4.6	4.2	7.2	6.7	7.1	6.7	12.4	11.5	11.2	10.5
FRE3	0.4	0.4	0.8	0.8	3.2	3.1	1.4	1.4	1.6	1.6	1.8	1.8	1.9	1.9	3.8	3.6	3.1	3.0
Q5	2.6	1.9	5.0	4.6	15.5	14.0	8.0	7.0	5.4	5.0	10.1	8.9	9.6	8.8	14.9	14.0	14.7	13.8
5% of MALF	2.7	2.5	6.5	6.0	18.3	16.9	9.3	8.8	5.9	5.5	11.7	11.2	11.3	10.9	18.0	16.1	17.8	16.9
10% of MALF	2.5	2.3	6.1	5.5	17.4	16.0	8.9	8.3	5.6	5.4	11.4	10.5	10.8	10.3	17.5	15.5	17.2	16.0
30% of MALF	2.0	1.9	5.1	4.6	15.3	14.1	7.4	7.1	5.3	5.0	9.4	9.0	9.2	8.9	15.4	14.1	14.4	13.9
50% of MALF	1.8	1.7	4.4	4.0	14.2	12.5	6.7	6.1	5.1	4.6	8.5	7.8	8.4	7.8	14.0	12.9	13.2	12.2

Climate Change Scenario Model Run

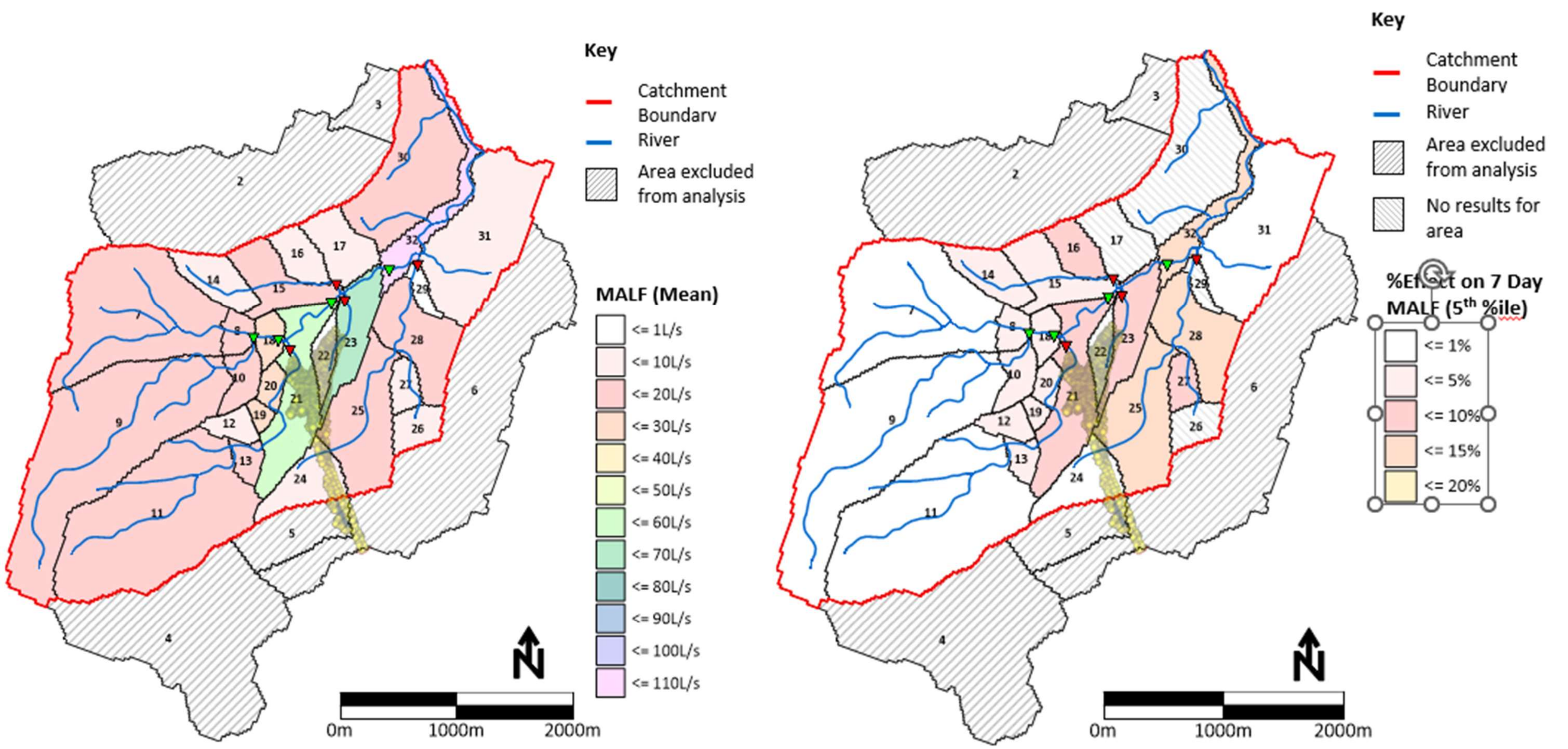

Figure 4.1 Heat Maps showing: LEFT: Pre-mining / current MALF (5th %ile) ; RIGHT: Mining / 2035 (% effect on 7-day MALF – 5th %ile result)

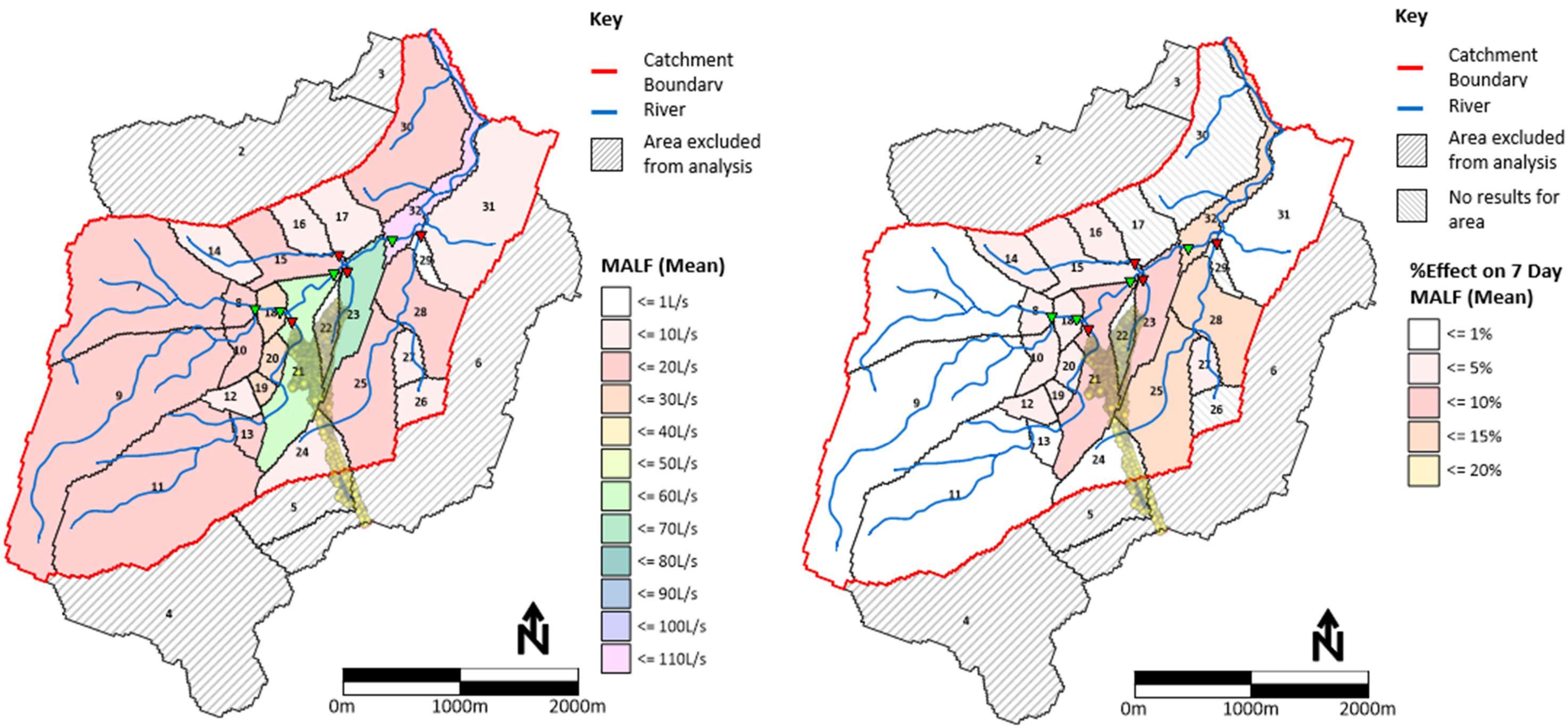

Figure 4.2 Heat Maps showing: LEFT: Pre-mining / current MALF (mean) ; RIGHT: Mining / 2035 (% effect on 7-day MALF – mean result)

4.1 Annual Low Flow Comparison

The modelled 7-day MALF for the pre-mining and mining scenarios are illustrated against the modelled annual low flow (ALF) for each hydrological year (July to June) of the extended rainfall record to illustrate how the projected changes in 7-day MALF (as a result of the mining and modelled reduction in baseflow) compares to the current natural ALF variation (Figure 4.3 to Figure 4.9). The results show that in general, the modelled reductions in MALF do not significantly depart from the current calculated 7-day MALF and are unlikely to significantly affect the flow variability currently observed from year to year – which exhibits significant variation in ALF. The exception to this is within the Thompsons tributary (Figure 4.8) and to a lesser extent Edmonds (Figure 4.5) where the modelled reductions in 7-day MALF (as a result of the WUG mine development) approach the lower end of the estimated ALF variability.

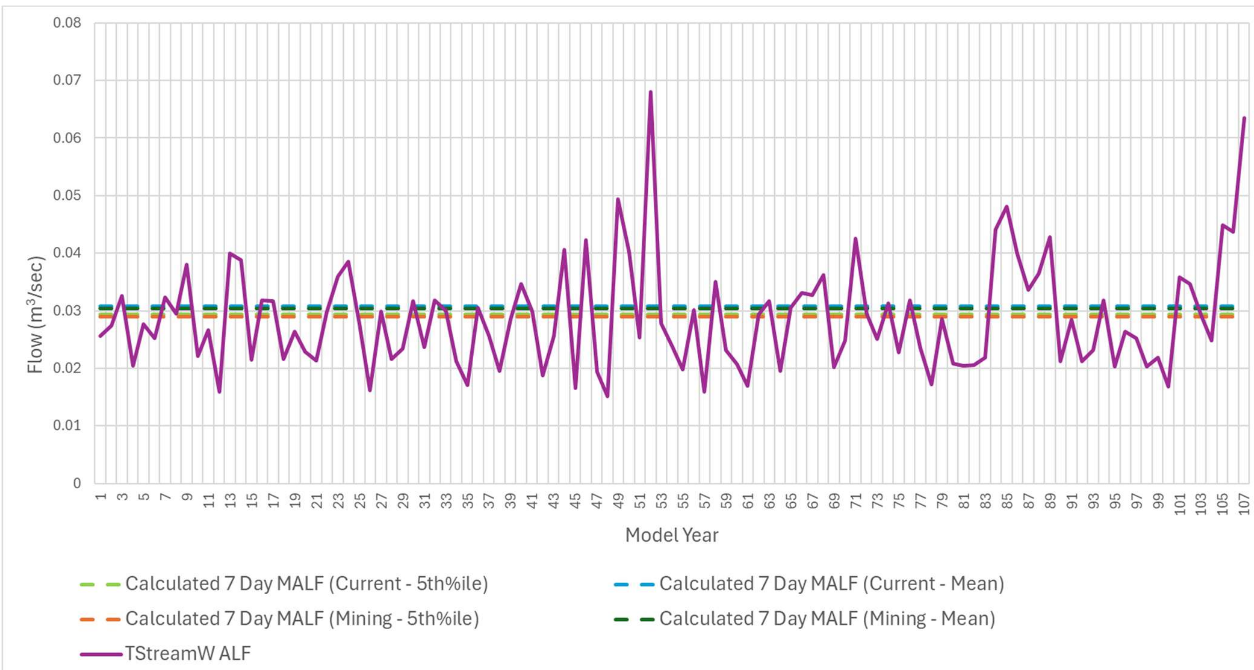

Figure 4.3 T Stream West - Modelled Annual Low Flow versus calculated 7-day MALF (Baseline versus Mining)

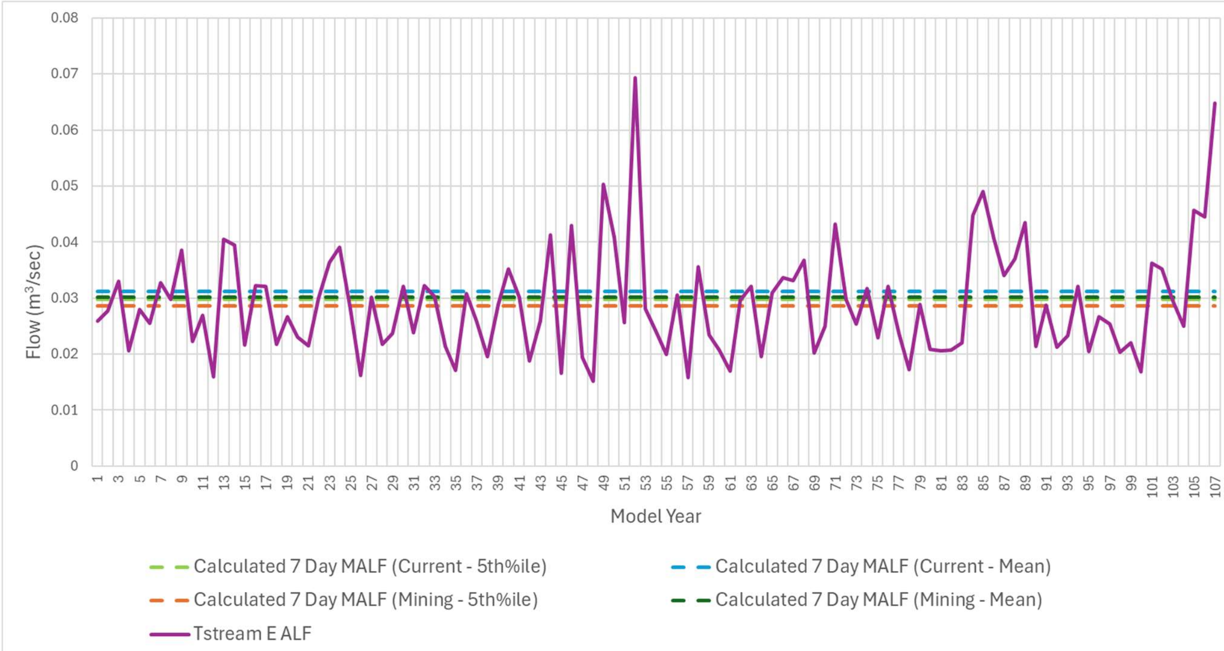

Figure 4.4 T Stream East - Modelled Annual Low Flow versus calculated 7-day MALF (Baseline versus Mining)

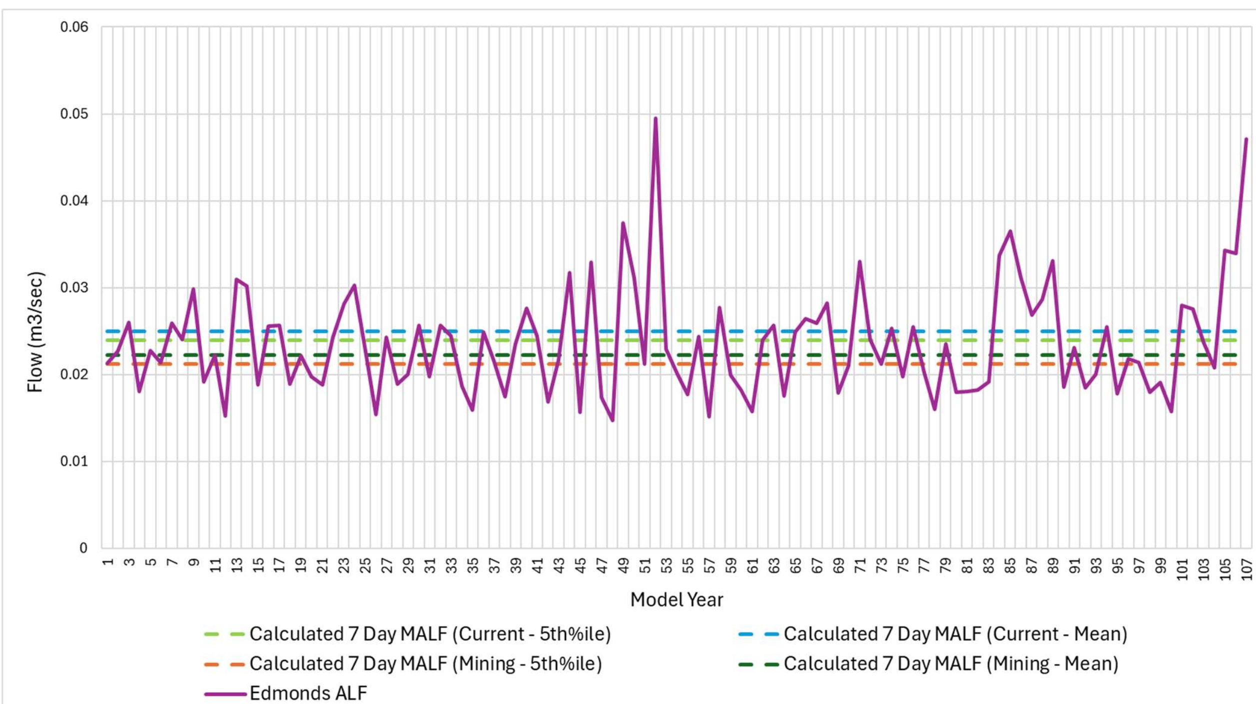

Figure 4.5 Edmonds - Modelled Annual Low Flow versus calculated 7-day MALF (Baseline versus Mining)

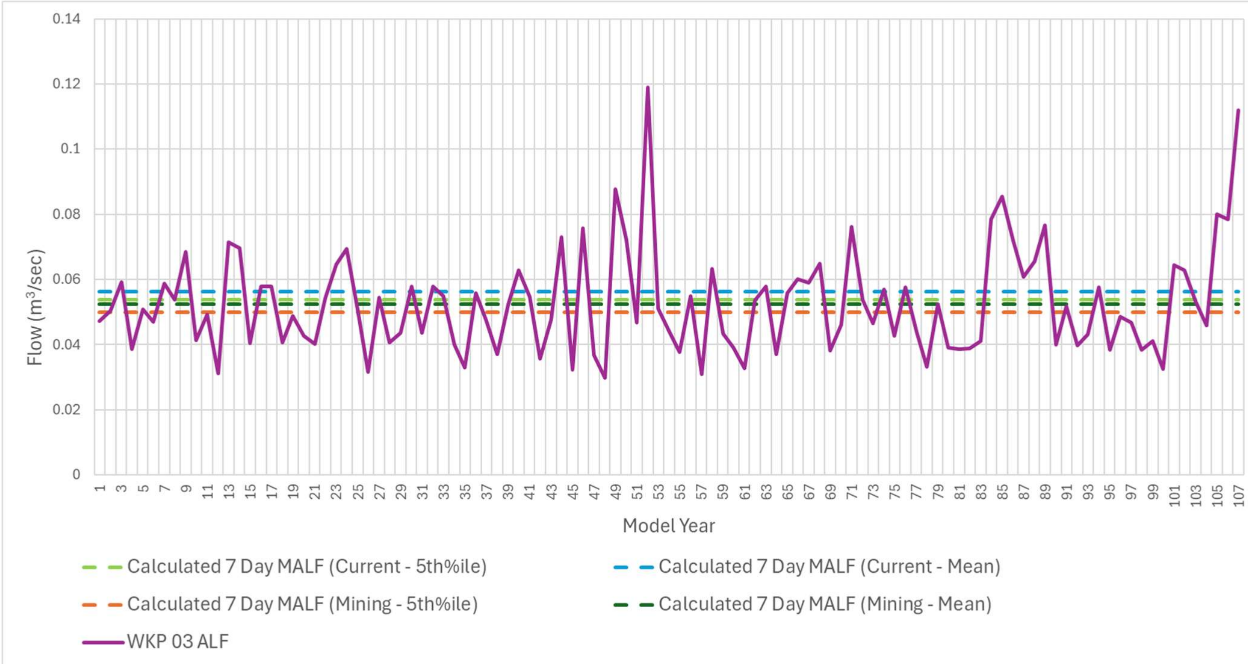

Figure 4.6 WKP03 - Modelled Annual Low Flow versus calculated 7-day MALF (Baseline versus Mining)

Figure 4.7 WKP02 - Modelled Annual Low Flow versus calculated 7-day MALF (Baseline versus Mining)

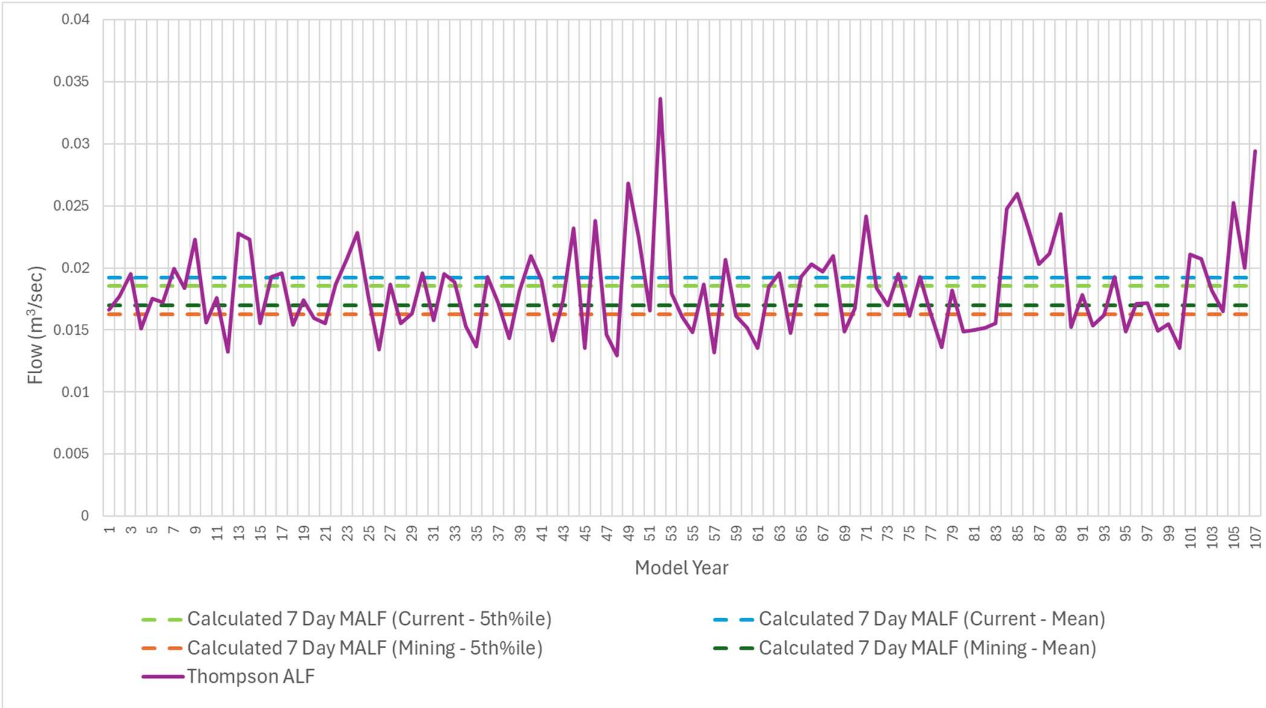

Figure 4.8 Thompsons - Modelled Annual Low Flow versus calculated 7-day MALF (Baseline versus Mining)

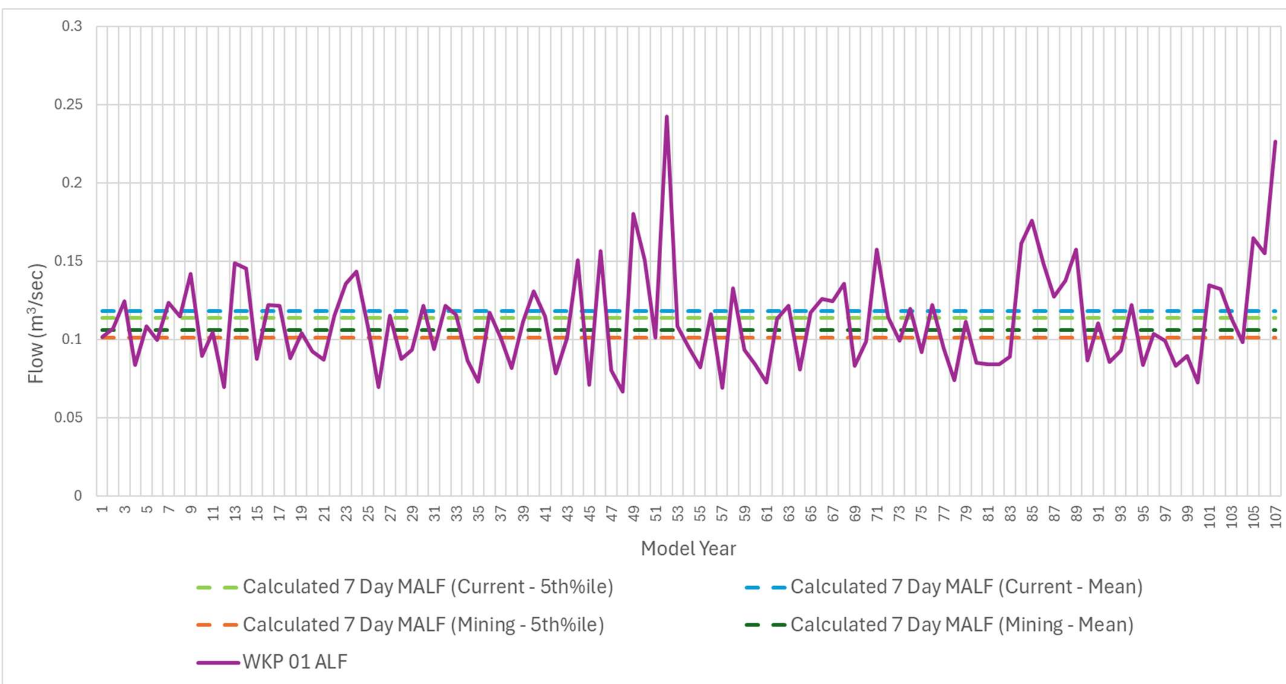

Figure 4.9 WKP01 - Modelled Annual Low Flow versus calculated 7-day MALF (Baseline versus Mining)

5. Predictive simulations – Wetted Width

The calculated wetted width (based on the flow / width relationship - refer Section 3) at each catchment location for each corresponding flow statistic is provided in Table 5.1 for the pre-mining scenario and Table 5.2 for the mining scenario.

The predicted percentage difference between the pre-mining and mining scenario is given in Table 5.3 for each corresponding flow statistic.

Results and predictions at an HSU level are provided in Appendix E.

Figure 5.1 and Figure 5.2 illustrate the modelled pre-mining MALF (5th percentile and mean modelled predictions) versus the predicted change in wetted width during mining (as a percentage of the pre-mining wetted width) in heat maps illustrating the relative difference between the various HSU units. Wetted width is not calculated for HSUs 17, 22, 24, 26, 29 and 30 within the Wharekirauponga catchment area as there are no corresponding data available on NIWA New Zealand River Maps online database (**https://niwa.co.nz/freshwater/new-zealand-river-maps**) (Whitehead & Booker, 2020).

The maps show that wetted width is predicted to be impacted the greatest within the Thompsons Stream and in the lower Wharekirauponga catchment (<=5%). It should be noted that the modelled percentage reductions in wetted width are considerably lower than the modelled percentage reduction in flows. As per the modelled reductions in flows, the calculated percentage reduction in wetted width are considered conservative.

Table 5.1 Summary statistics of wetted width (pre-mining) based on the long term modelled flow statistic.

Statistic (m)	T Stream West		T Stream East		Edmonds		Trib R		Adams		WKP03		WKP02		Thompson		WKP01	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	3.57	3.60	3.60	3.62	2.60	2.61	0.61	0.61	0.74	0.74	4.83	4.86	5.47	5.51	2.55	2.56	7.02	7.06
Median flow	3.39	3.42	3.41	3.44	2.46	2.48	0.59	0.59	0.70	0.71	4.59	4.62	5.20	5.24	2.40	2.42	6.66	6.71
MALF	2.34	2.36	2.34	2.37	1.75	1.76	0.43	0.44	0.53	0.54	3.23	3.26	3.71	3.75	1.75	1.76	4.80	4.84
70% MALF	2.14	2.16	2.14	2.16	1.59	1.61	0.39	0.40	0.48	0.49	2.96	2.98	3.40	3.43	1.60	1.61	4.40	4.44
50% MALF	1.96	1.98	1.97	1.99	1.46	1.47	0.36	0.36	0.44	0.44	2.72	2.75	3.13	3.16	1.47	1.48	4.06	4.10
7day-MALF	2.40	2.42	2.40	2.43	1.78	1.80	0.44	0.45	0.54	0.55	3.30	3.34	3.79	3.83	1.78	1.80	4.90	4.94
70% 7day-MALF	2.19	2.22	2.20	2.22	1.63	1.64	0.40	0.41	0.49	0.49	3.02	3.06	3.48	3.51	1.62	1.64	4.50	4.54
50% 7day-MALF	2.01	2.04	2.02	2.04	1.49	1.51	0.36	0.37	0.45	0.45	2.78	2.81	3.20	3.23	1.49	1.50	4.15	4.19
FRE3	4.47	4.50	4.49	4.53	3.26	3.29	0.80	0.80	0.95	0.96	6.01	6.06	6.80	6.85	3.19	3.21	8.67	8.73
Q5	2.21	2.24	2.21	2.24	1.67	1.69	0.42	0.42	0.52	0.52	3.07	3.11	3.55	3.58	1.69	1.71	4.59	4.64
5% of MALF	2.07	2.10	2.07	2.10	1.60	1.61	0.40	0.40	0.51	0.51	2.91	2.94	3.38	3.41	1.64	1.65	4.38	4.41
10% of MALF	2.10	2.14	2.10	2.14	1.61	1.63	0.40	0.41	0.51	0.51	2.94	2.98	3.41	3.46	1.65	1.66	4.42	4.47
30% of MALF	2.21	2.23	2.21	2.24	1.67	1.68	0.42	0.42	0.52	0.52	3.07	3.10	3.55	3.58	1.69	1.70	4.59	4.63
50% of MALF	2.29	2.32	2.29	2.33	1.72	1.74	0.43	0.43	0.53	0.53	3.17	3.21	3.65	3.69	1.73	1.74	4.72	4.77

Table 5.2 Summary statistics of the wetted width (mining) based on the long term modelled flow statistic.

Statistic (m)	T Stream West		T Stream East		Edmonds		Trib R		Adams		WKP03		WKP02		Thompson		WKP01	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	3.57	3.59	3.59	3.61	2.58	2.59	0.61	0.61	0.74	0.74	4.81	4.84	5.45	5.49	2.53	2.55	6.98	7.02
Median flow	3.39	3.42	3.40	3.43	2.44	2.46	0.59	0.59	0.70	0.70	4.57	4.60	5.18	5.22	2.38	2.40	6.61	6.66
MALF	2.32	2.35	2.32	2.34	1.69	1.70	0.43	0.43	0.53	0.53	3.16	3.20	3.64	3.68	1.69	1.70	4.65	4.70
70% MALF	2.13	2.15	2.12	2.14	1.54	1.56	0.39	0.39	0.48	0.48	2.89	2.93	3.33	3.37	1.54	1.55	4.27	4.31
50% MALF	1.95	1.98	1.95	1.97	1.41	1.43	0.35	0.36	0.44	0.44	2.66	2.70	3.07	3.10	1.41	1.43	3.93	3.98
7day-MALF	2.39	2.42	2.38	2.41	1.73	1.75	0.44	0.44	0.53	0.54	3.24	3.28	3.73	3.77	1.72	1.74	4.76	4.81
70% 7day-MALF	2.18	2.21	2.18	2.20	1.58	1.60	0.40	0.40	0.49	0.49	2.97	3.01	3.41	3.45	1.57	1.59	4.37	4.42
50% 7day-MALF	2.01	2.03	2.00	2.03	1.45	1.46	0.36	0.36	0.44	0.45	2.73	2.77	3.14	3.18	1.44	1.46	4.03	4.08
FRE3	4.46	4.50	4.49	4.52	3.23	3.26	0.80	0.80	0.95	0.95	5.99	6.03	6.77	6.82	3.15	3.18	8.61	8.67
Q5	2.19	2.23	2.18	2.22	1.60	1.62	0.41	0.41	0.51	0.52	2.99	3.04	3.46	3.50	1.62	1.64	4.42	4.47
5% of MALF	2.06	2.08	2.04	2.07	1.52	1.53	0.39	0.39	0.50	0.50	2.82	2.85	3.28	3.31	1.56	1.57	4.17	4.22
10% of MALF	2.08	2.12	2.07	2.11	1.53	1.56	0.39	0.40	0.50	0.50	2.85	2.90	3.31	3.37	1.57	1.59	4.22	4.29
30% of MALF	2.20	2.22	2.18	2.21	1.60	1.62	0.41	0.41	0.51	0.51	3.00	3.03	3.46	3.50	1.62	1.64	4.42	4.47
50% of MALF	2.28	2.31	2.27	2.30	1.65	1.68	0.42	0.43	0.52	0.53	3.10	3.15	3.58	3.62	1.66	1.68	4.57	4.63

Table 5.3 Percentage reduction of predictive wetted width (pre-mining versus mining).

% Reduction	T Stream West		T Stream East		Edmonds		Trib R		Adams		WKP03		WKP02		Thompson		WKP01	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	0.1	0.1	0.2	0.2	0.7	0.7	0.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.9	0.7	0.6	0.6
Median flow	0.1	0.1	0.2	0.2	0.8	0.8	0.3	0.4	0.4	0.5	0.4	0.4	0.5	0.5	1.0	0.9	0.8	0.7
MALF	0.5	0.4	1.1	0.9	3.4	3.2	1.3	1.6	1.4	1.3	2.1	1.9	2.1	1.9	3.6	3.3	3.1	2.9
70% MALF	0.5	0.4	1.1	0.9	3.4	3.2	1.3	1.6	1.4	1.3	2.1	1.9	2.1	1.9	3.6	3.3	3.1	2.9
50% MALF	0.5	0.4	1.1	0.9	3.4	3.2	1.3	1.6	1.4	1.3	2.1	1.9	2.1	1.9	3.6	3.3	3.1	2.9
7day-MALF	0.4	0.4	1.0	0.8	3.1	2.9	1.1	1.5	1.3	1.2	1.8	1.7	1.8	1.7	3.3	3.1	2.8	2.6
70% 7day-MALF	0.4	0.4	1.0	0.8	3.1	2.9	1.1	1.5	1.3	1.2	1.8	1.7	1.8	1.7	3.3	3.1	2.8	2.6
50% 7day-MALF	0.4	0.4	1.0	0.8	3.1	2.9	1.1	1.5	1.3	1.2	1.8	1.7	1.8	1.7	3.3	3.1	2.8	2.6
FRE3	0.1	0.1	0.2	0.2	0.8	0.8	0.3	0.4	0.4	0.5	0.4	0.4	0.5	0.5	1.0	0.9	0.8	0.7
Q5	0.7	0.5	1.3	1.2	4.2	3.8	1.9	2.1	1.5	1.4	2.6	2.3	2.4	2.2	4.1	3.8	3.7	3.5
5% of MALF	0.7	0.6	1.7	1.5	5.0	4.6	2.4	2.3	1.6	1.5	3.0	2.9	2.9	2.8	5.0	4.4	4.6	4.4
10% of MALF	0.6	0.6	1.6	1.4	4.8	4.4	2.2	2.4	1.6	1.5	2.9	2.7	2.8	2.6	4.8	4.2	4.4	4.1
30% of MALF	0.5	0.5	1.3	1.2	4.2	3.8	1.6	1.9	1.5	1.4	2.4	2.3	2.3	2.2	4.2	3.8	3.7	3.5
50% of MALF	0.4	0.4	1.1	1.0	3.8	3.4	1.3	1.7	1.4	1.3	2.2	2.0	2.1	2.0	3.8	3.5	3.3	3.1

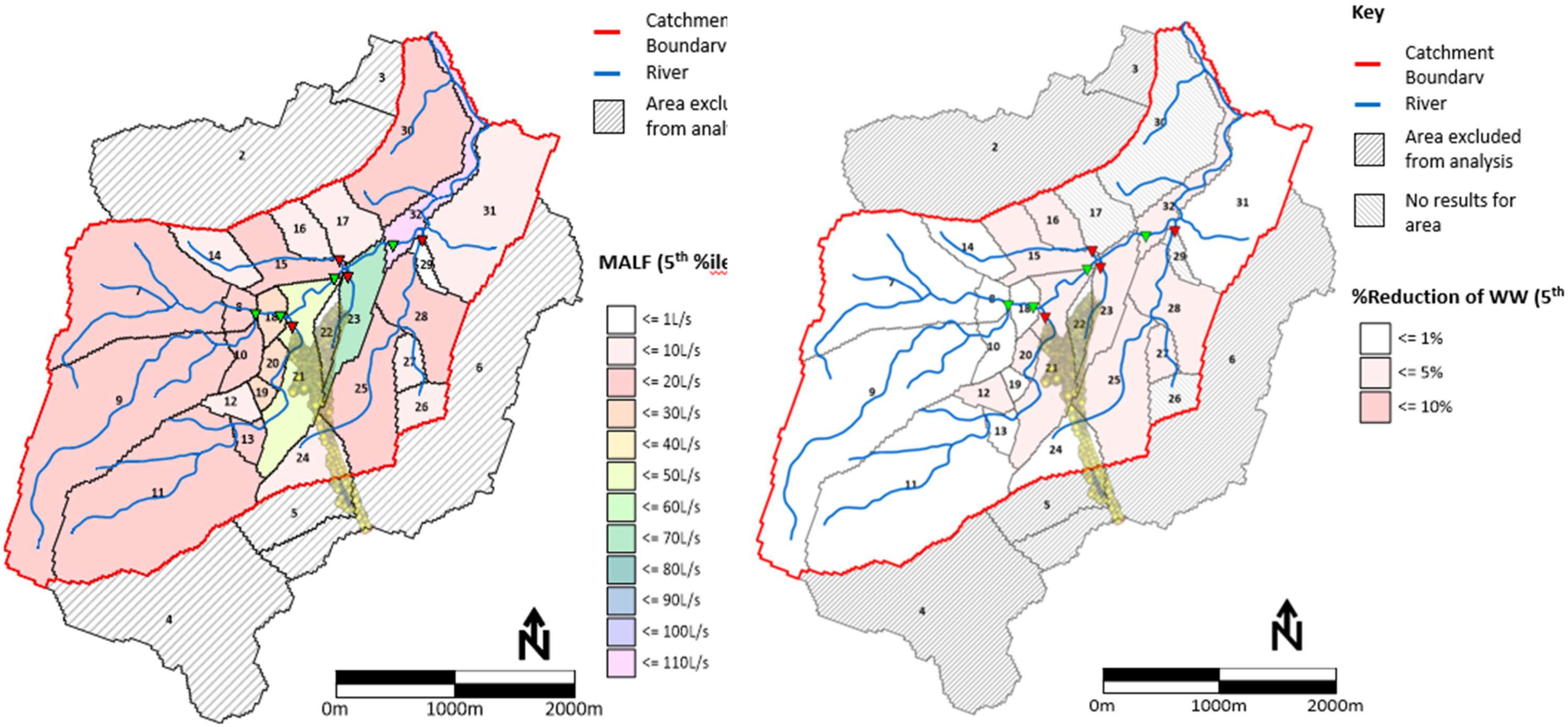

Figure 5.1 Heat Maps showing: LEFT: Pre-mining / current MALF (5th %ile); RIGHT: Mining / 2035 (% effect on Wetted Width @ 7-day MALF – 5th %ile result)

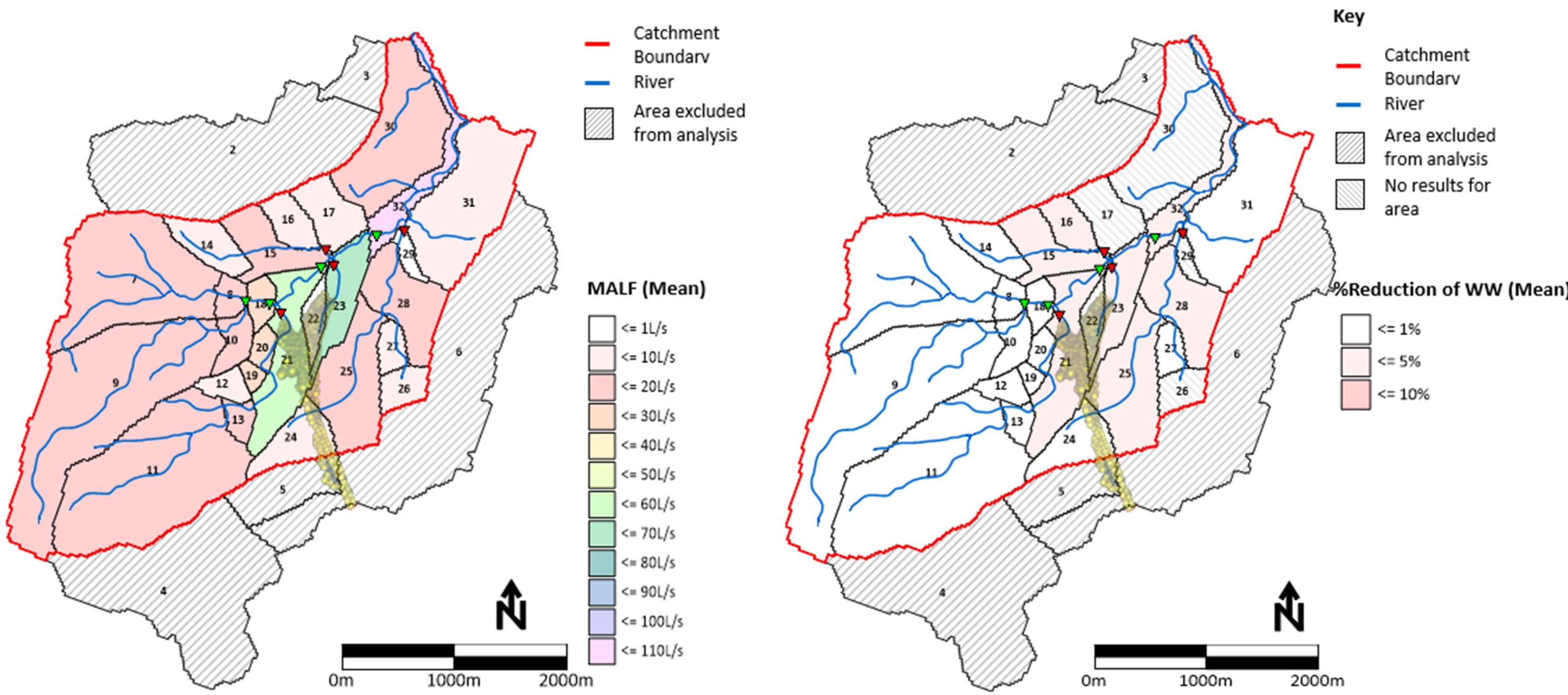

Figure 5.2 Heat Maps showing: LEFT: Pre-mining / current MALF (mean); RIGHT: Mining / 2035 (% effect on Wetted Width @ 7-day MALF – mean result)

6. Derivation of Trigger Levels

Effects on stream flow during mining (if any) are expected to be small and only measurable / realised during low flow periods within the Wharekirauponga catchment. As the actual flow is highly variable and influenced by climate (particularly the preceding rainfall events falling within the catchment), recommended consent trigger flow values need to take into account the expected variability in flow (at specific locations), within the catchment, based on climatic variables in the preceding days.

Utilising the WBM and the long-term derived rainfall record, calculated ALF variability and the influence of the preceding rainfall events has been explored. It has been found that the average rainfall in the preceding 30 days leading up to the ALF event (defined as the 7-day ALF) shows a good correlation with the calculated 7-day ALF (R-sq 60-63%). This relationship together with the minimum expected corresponding flow associated with the preceding 30 day average rainfall is shown in Figure 6.1 for the key monitoring locations within the Wharekirauponga Stream.

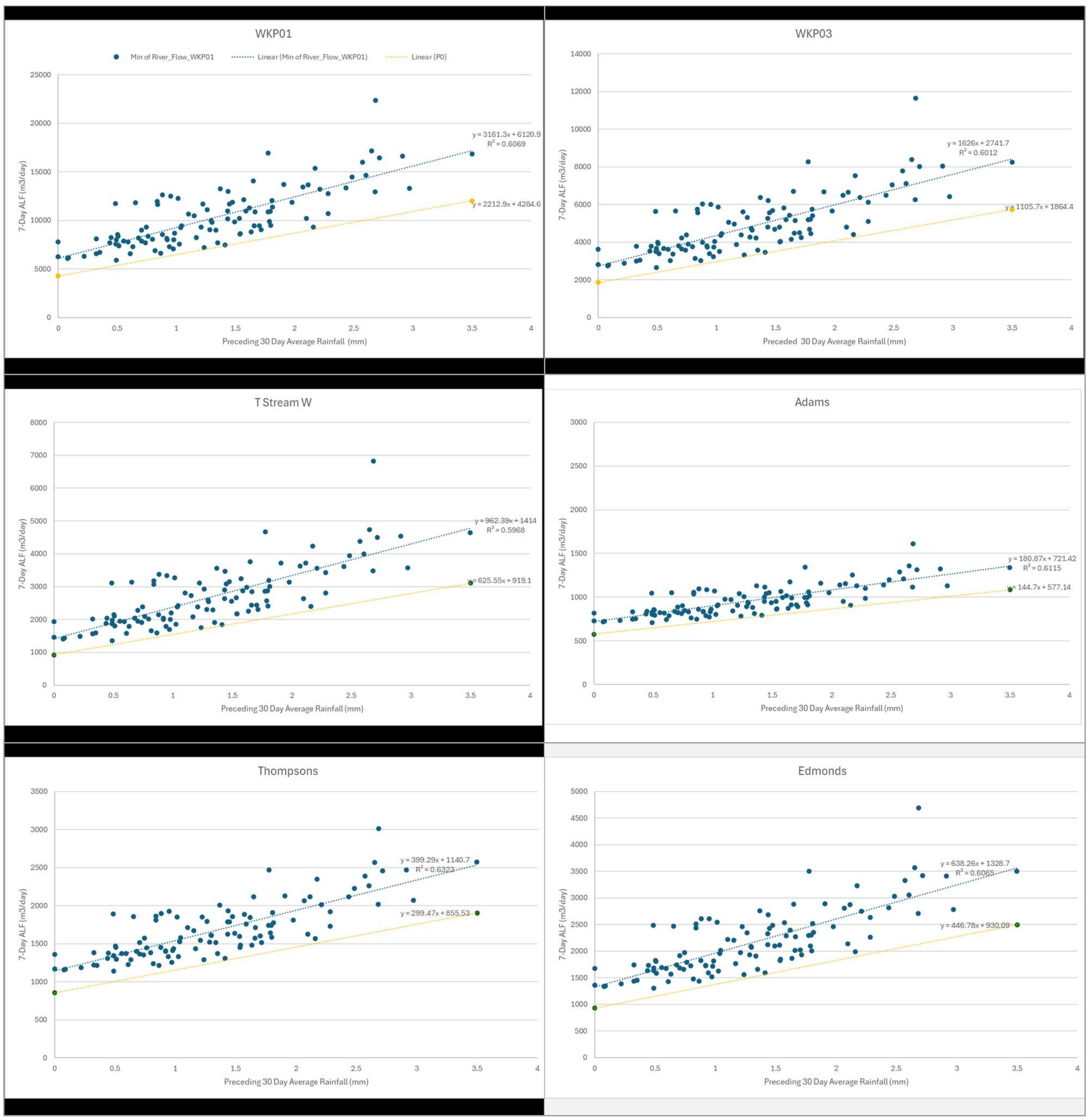

Figure 6.1 Developed Flow / Rainfall Relationships

Based on the pretext that effects are likely to only be realised during low flow periods and during these periods the developed flow / rainfall relationships (for each site) can be utilised to inform the expected minimum flow, a dual alert system is proposed where the alert trigger value indicates low flow conditions are present and the respond trigger levels defines if the actual flow is lower than expected (based on the preceding 30 days rainfall). The recommended dual trigger values are explained as follows:

Alert Trigger Level

The trigger level is based on the calculated 7-day MALF for specific locations within the Wharekirauponga catchment. The trigger value signifies a defined low flow period. Effects from mining (if any) are not likely to be measurable/realised at flows above low flow events.

Respond Trigger Level

Flows lower than expected flows (as defined by the respond trigger level relationship) signify a potential departure from known trends and trigger the need for additional investigation.

The respond trigger levels have been developed utilising the extended climate dataset. This dataset has been used to plot the relationship between flow and rainfall at specific locations within the Wharekirauponga catchment. For each hydrological year (July – June), the period of lowest flow (defined as the lowest average 7-day flow) is compared to the preceding 30 days rainfall. This is done for every hydrological year to explore the spread of the relationship (between rainfall and flow) and to provide a baseline with which to assess actual flows from preceding rainfall events. The lowest expected flow (for concomitant 30 day proceeding rainfall) is then calculated based on this relationship. If the actual measured flow (defined as the 7 day rolling average flow) is lower than the expected flow (based on the minimum expected flow relationship), this triggers the need for further investigation.

Flow will fall below the minimum expected flow relationship naturally (estimated to be approximately once every two years) as the trigger basis works on data that is annualised, whereas compliance is expected to be monitored daily (the relationship on a daily basis is more variable).

The summarised alert and respond trigger values are outlined in Table 6.1.

Table 6.1 Summarised Alert and Respond Trigger Levels.

Flow Gauge	Alert Trigger Level, m^3/day	Respond Trigger Level, m^3/day
WKP01	10,200	2213 x $R_{30'}$ + 4285
WKP03	4,800	1106 x $R_{30'}$ + 1864
T-Stream West	2,700	626 x $R_{30'}$ + 919
Edmonds	2,200	447 x $R_{30'}$ + 930
Thompson	1,600	299 x $R_{30'}$ + 856
Adams	1,000	145 x $R_{30'}$ + 577

where $R_{30'}$ is the average rainfall (in mm) that falls over the preceding 30 days

7. Conclusions and Recommendations

This report outlines the build of the WBM, including the primary input data, the current calibration and predicted flow reductions based on baseflow loss estimates as a result of the development of the WUG Mine. The model is developed using actual (measured) and derived rainfall data and measured barometric and water level data which has been transformed to flow and corrected against manual gauging data.

Using the most reliable period of rainfall and flow data, the WBM has been calibrated to low flow periods, at the five monitoring sites throughout the Wharekirauponga catchment. The calibration period utilised is 1 March 2019 until the 15 November 2023. The calibration to low flow periods is acceptable at majority of the sites, excluding WKP02. The WKP02 calibration is limited to a shorter calibration period due to additional data limitations, and therefore is not recommended for use as a calibration location until more data is available.

The WBM construction and calibration to date is limited by the accuracy and availability of input data, which can affect the predictive accuracy of the model. The flow gauging reports provided by Riley and WSP provide a measurement of uncertainty (of the Acoustic Doppler Velocity measurement instrument) of generally between 2% and 3% for the locations modelled in this assessment. There are many other areas of uncertainty that must be considered when using the modelled flow estimates such as sub-daily flow variation not captured within the model, transducer and barometric measurement accuracy, changing stage / volume relationships at certain locations throughout time, etc. It is difficult to quantify the total uncertainty within the current data set. However, the current calibration provides some context, as does the comparison of the calculated long term flow statistics with the generated physical and empirical based estimates. Based on these comparisons it is surmised that at lower flows the model provides a reasonable estimate of rainfall storage / runoff and groundwater dependent flow, and at locations with a continuous flow record this uncertainty is probably in order of 10-20 % of the actual values. Outside of these flow ranges and the continuously monitored locations, the uncertainty is likely to increase.

Using the calibration configuration and the long-term derived data, a pre-mining simulation and a mining simulation (representing the sensitivity of the baseflow loss projections from the groundwater modelling undertaken) have been run over a long-term period. Using the results from both simulations a comparison of the long-term flow regime can be compared between two scenarios to predict the effect of mining on low flow conditions. The results suggest that at established flow monitoring locations a small decrease in flow (relative to baseflow) is expected and that large decreases in flow (relative to existing and predicted low flow events) are unlikely. Potential changes to seasonal rainfall patterns (as a result of climate change) are not expected to exacerbate the modelled effects. The results indicate the 7-day MALF could be reduced at current monitoring locations within the catchment between 2 to 13% because of base flow reduction as a result of mining. All other flow metrics calculated also indicate a reduction between the pre-mining and mining scenarios. Larger modelled reductions are calculated within the Edmonds and Thomsons catchments which are smaller tributaries located above the proposed WUG Mine area. In terms of comparing the predicted effects to the long-term low flow variability, the modelled effects appear most noticeable in Edmonds and Thompsons where the modelled reductions in 7-day MALF approach the lower end of the current estimated ALF variability.

The predicted reductions in wetted width are proportionally (in terms of percentage) smaller when compared to the percentage reduction in flows and range from 0% to 5%. The smaller predicted reductions in wetted width (compared to flows) are related to the flow / wetted width relationships (characterised by an exponential line of best fit) which only sees significant reductions in wetted width (for reduction in flow) as the flow approaches zero. The wetted width estimates provided should be considered on a relative change basis only (i.e., although calculated wetted widths are in general agreement with field wetted width measurements at median / average flows, wetted width can be highly variable over a stream reach).

The mining predictions provided (and the relative decrease in flow / wetted width statistic predictions as a result of mining) are considered conservative based on:

– Baseflow loss is applied as a constant not a variable rate (relative loss is likely to be less during drier periods);
– There is limited flow data available from the headwater HSUs and therefore estimates provided for these areas have a higher degree of uncertainty;
– Predictions utilise peak baseflow loss estimates only (from 2035) and apply them to the whole mining model run; and
– The reported 5^{th}%ile predictions in the mining scenario include the lower end of the stochastic rainfall estimates combined with the higher end of the stochastic drawdown effects (from mining).

Additional rainfall and stream flow data (both continuous and spot sampling) in conjunction with upgrades to some of the monitoring equipment and additional manual gauging events during low flow conditions, will ensure that calibration of the WBM improves with time.

8. References

Booker, DJ. 2010. Predicting wetted width in any river at any discharge. Earth Surface Processes and Landforms. 35: 828-841.

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NIWA. 2024. Instream Habitat of the Wharekirauponga Stream and Tributaries.

Whitehead, A.L., Booker, D.J. (2020). NZ River Maps: An interactive online tool for mapping predicted freshwater variables across New Zealand. NIWA, Christchurch. https://shiny.niwa.co.nz/nzrivermaps/

WWLA. 2024 WKP Groundwater Effects Assessment.

Appendices

Appendix A

Corrected flow data

Figure A.1 to Figure A.5 below provide an overview of the flow data at each monitoring location in comparison with the manual flow gauging data. The method used to calculate the flow data is described in Section 2.1.3. Table A.1 summarises the manual gauging data.

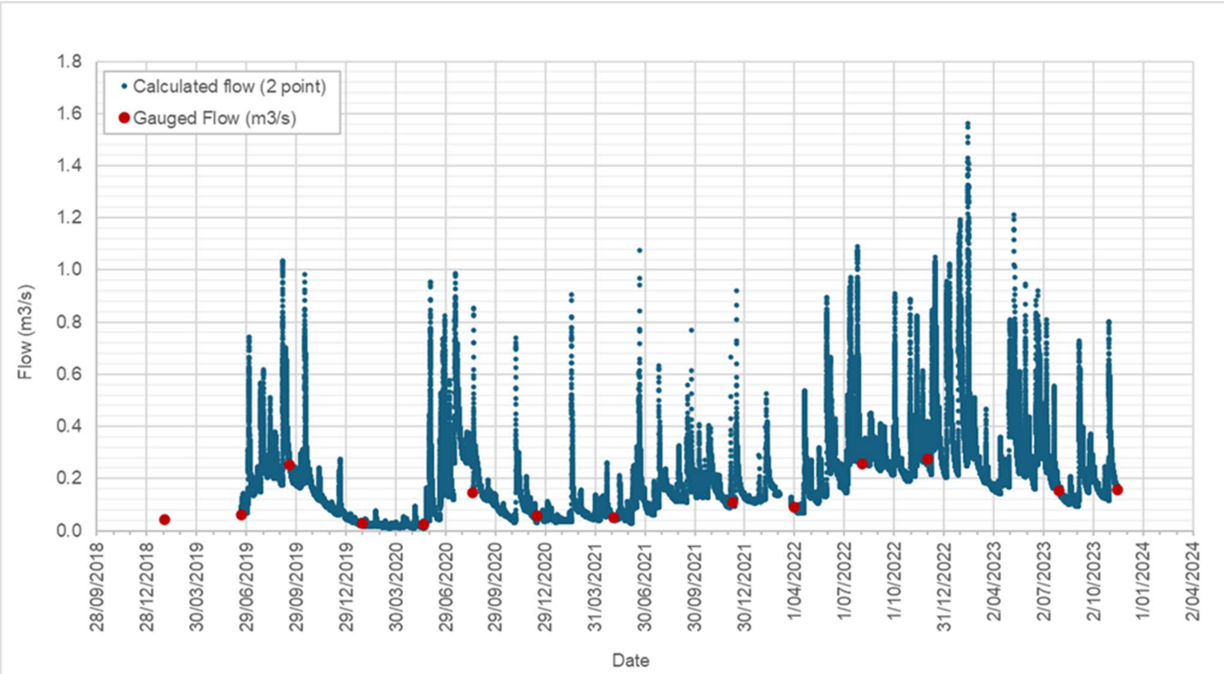


Figure A.1 *Calculated and manual gauging flow data for T Stream West.*

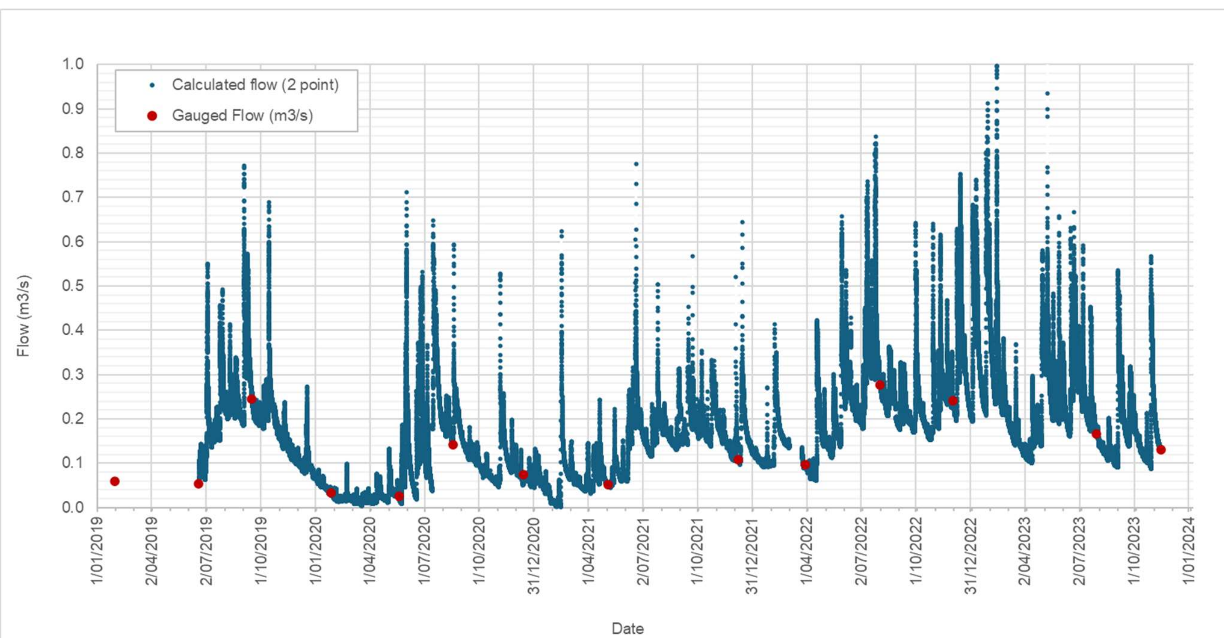


Figure A.2 *Calculated and manual gauging flow data for T Stream East.*

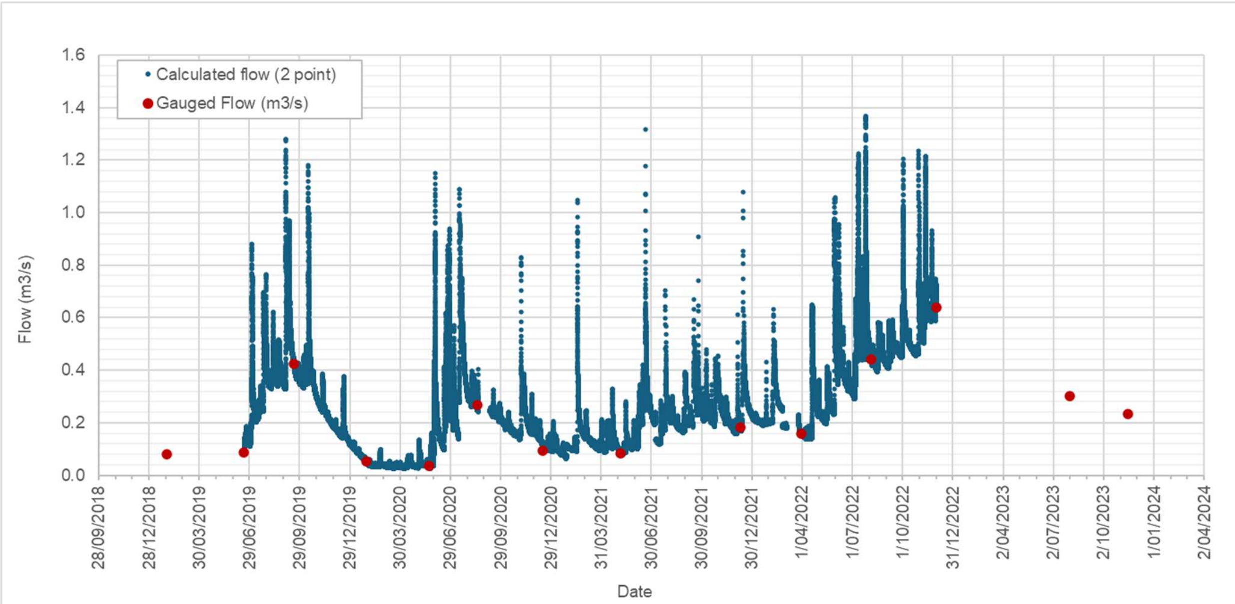


Figure A.3 *Calculated and manual gauging flow data for WKP03.*

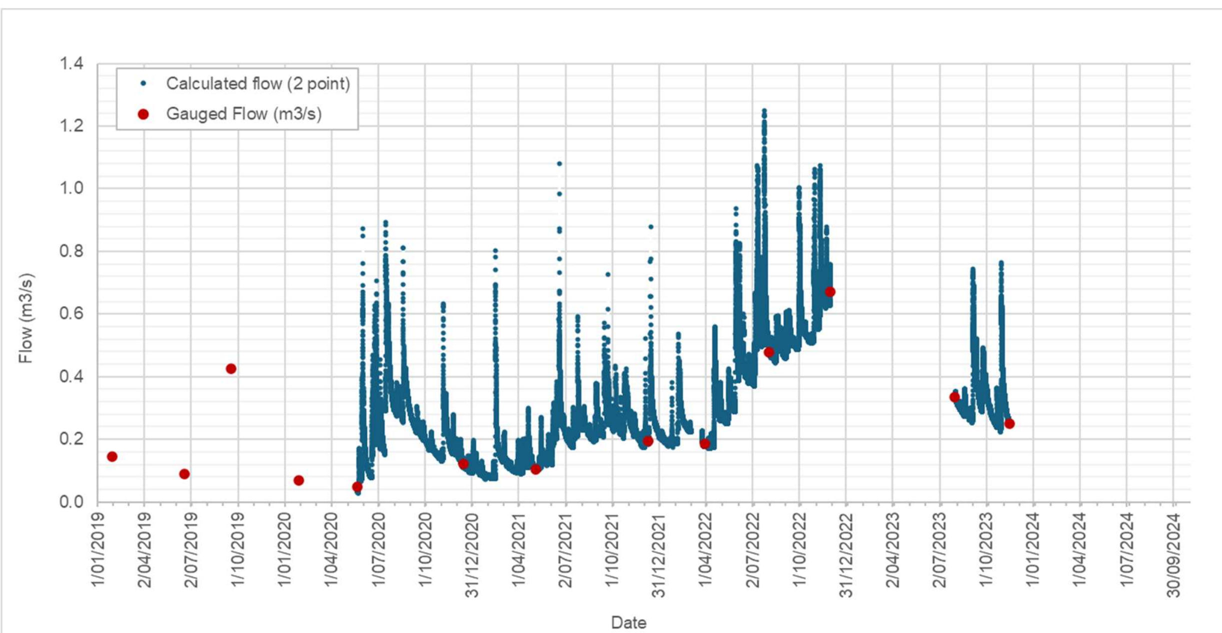


Figure A.4 *Calculated and manual gauging flow data for WKP02.*

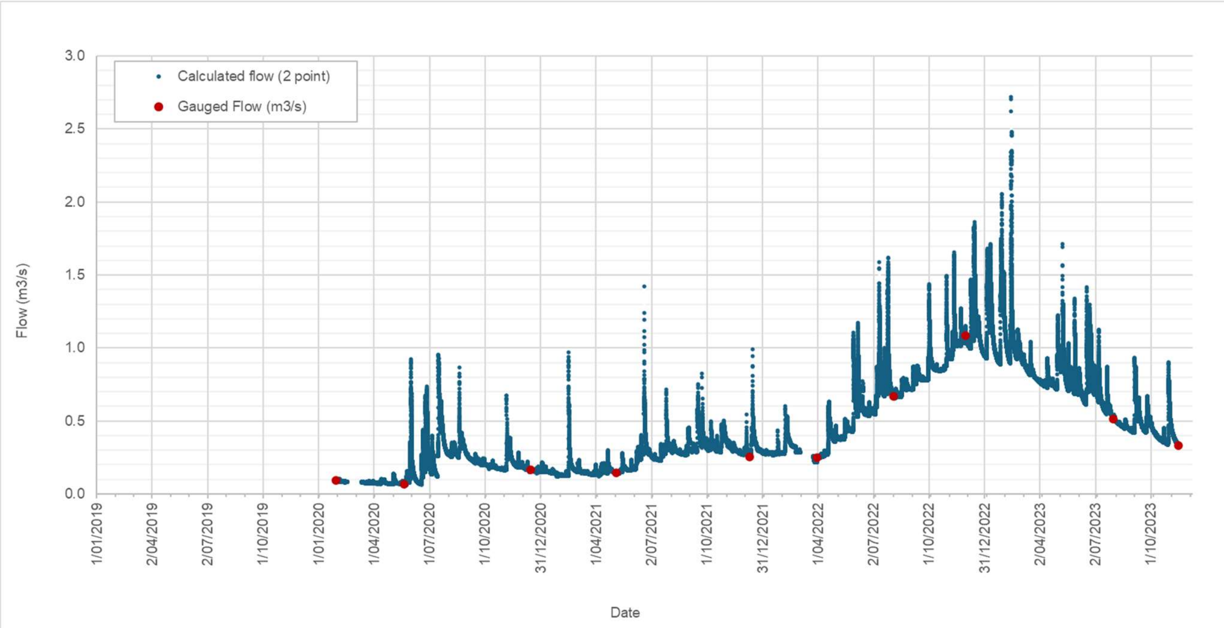


Figure A.5 Calculated and manual gauging flow data for WKP01.

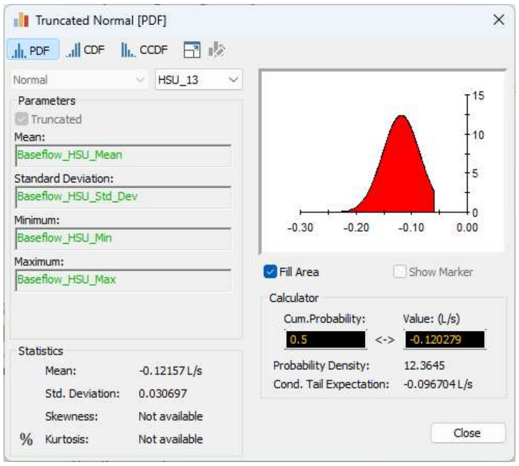
Table A.1 Manual gauging flow (L/s) data for each of the five key monitoring sites

Date	Time	WKP1	Date	Time	WKP2	Date	Time	WKP3	Date	Time	T Stream East	Date	Time	T Stream West
30-Jan-19			30-Jan-19		145.9	30-Jan-19		79.6	30-Jan-19		59.6	30-Jan-19		44.3
20-Jun-19			20-Jun-19	15:00	90.5	20-Jun-19	13:25	85.8	20-Jun-19	11:30	53	20-Jun-19	10:15	60.8
17-Sep-19			18-Sep-19	13:00	426.2	18-Sep-19	10:25	424.5	17-Sep-19	13:30	244.5	17-Sep-19	11:40	252.9
30-Jan-20	9:00	90.8	29-Jan-20	13:55	69.7	29-Jan-20	11:35	52.5	28-Jan-20	13:45	33.3	28-Jan-20	12:15	28.8
21-May-20	15:40	68.2	21-May-20	12:35	48.6	21-May-20	10:55	36.9	20-May-20	14:00	26.3	20-May-20	12:35	23.6
19-Aug-20			19-Aug-20		-	18-Aug-20	13:35	267	18-Aug-20	11:40	142	18-Aug-20	10:05	144
15-Dec-20	9:45	164	14-Dec-20	10:40	120.9	14-Dec-20	9:00	95.2	14-Dec-20	7:20	74.2	14-Dec-20	9:15	56.4
5-May-21	14:50	143.2	5-May-21	12:50	104.7	5-May-21	11:00	83.5	5-May-21	8:30	52.1	4-May-21	13:35	50.5
10-Dec-21	15:15	254.7	10-Dec-21	11:25	196	9-Dec-21	12:07	181.3	9-Dec-21	9:55	109	9-Dec-21	8:30	107.6
31-Mar-22	16:30	248.3	31-Mar-22	14:15	185.3	31-Mar-22	12:00	158.3	31-Mar-22	10:15	96.7	31-Mar-22	8:30	90.1
4-Aug-22	16:00	669	4-Aug-22	12:30	477	4-Aug-22	10:00	442	3-Aug-22	14:40	276	3-Aug-22	13:15	255
1-Dec-22	10:00	1083	1-Dec-22	12:40	671	1-Dec-22	14:50	639	2-Dec-22	12:20	242	2-Dec-22	10:50	276
1-Aug-23	15:40	516	1-Aug-23	12:50	336	1-Aug-23	9:20	303	31-Jul-23	13:20	166	31-Jul-23	11:50	153
16-Nov-23	8:40	331	16-Nov-23	10:10	251	15-Nov-23	12:20	233.9	15-Nov-23	14:00	131.1	15-Nov-23	12:20	156

Appendix B

Intera Baseflow Reduction Data

Figure B.1 ***Stochastic baseflow loss results (2018 – 2035) by HSU*** Values calculated from Intera (2024)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Kurtosis: Not available
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Show Marker
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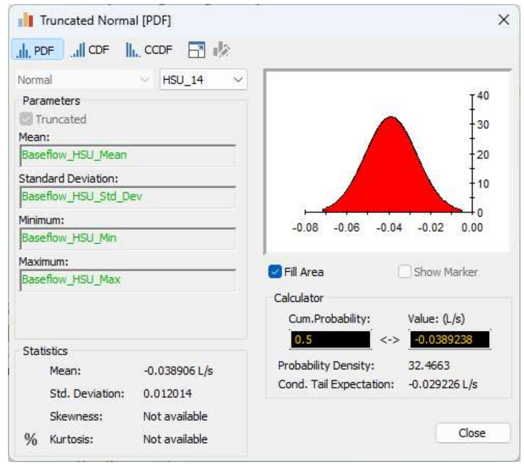
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Baseflow_HSU_Max
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Mean: -0.038906 L/s
Std. Deviation: 0.012014
Skewness: Not available
Kurtosis: Not available
Fill Area
Show Marker
Calculator
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Value: (L/s) -0.0389238
Probability Density: 32.4663
Cond. Tail Expectation: -0.029226 L/s
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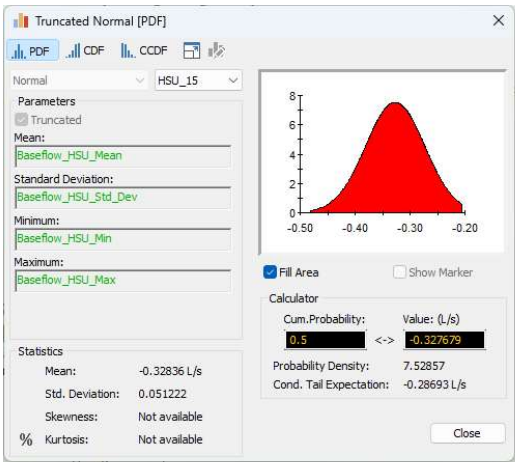
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Mean: -0.32836 L/s
Std. Deviation: 0.051222
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Kurtosis: Not available
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Show Marker
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Value: (L/s) -0.327679
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Cond. Tail Expectation: -0.28693 L/s
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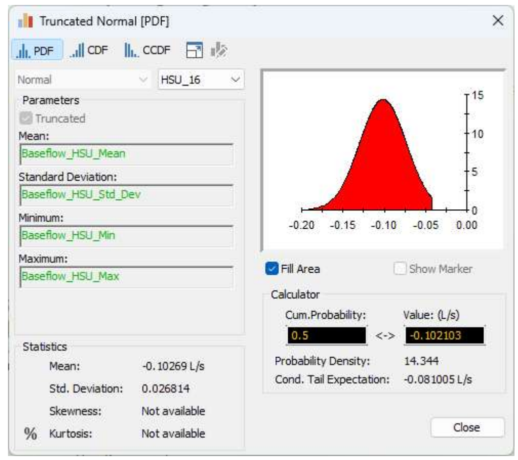
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Mean: -0.10269 L/s
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Kurtosis: Not available
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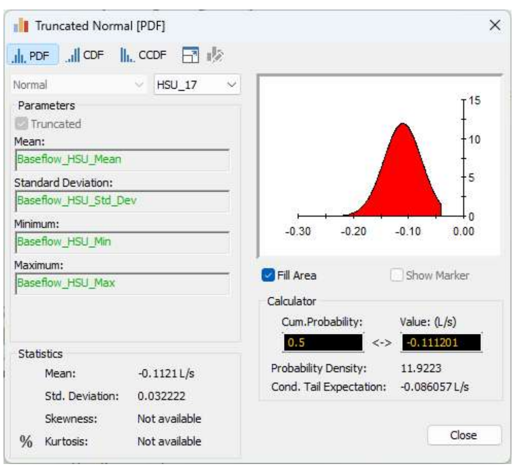
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Kurtosis: Not available
Fill Area
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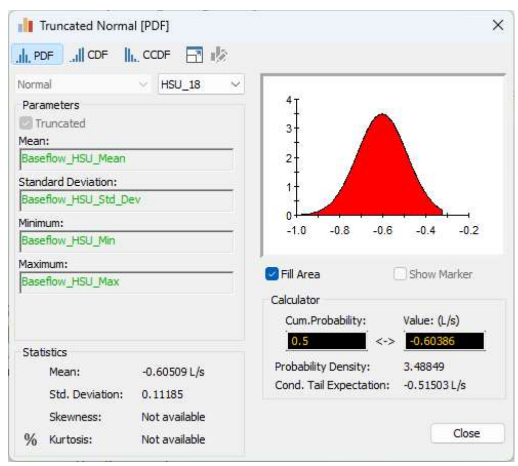
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Mean: -0.60509 L/s
Std. Deviation: 0.11185
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Kurtosis: Not available
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Show Marker
Calculator
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Cond. Tail Expectation: -0.51503 L/s
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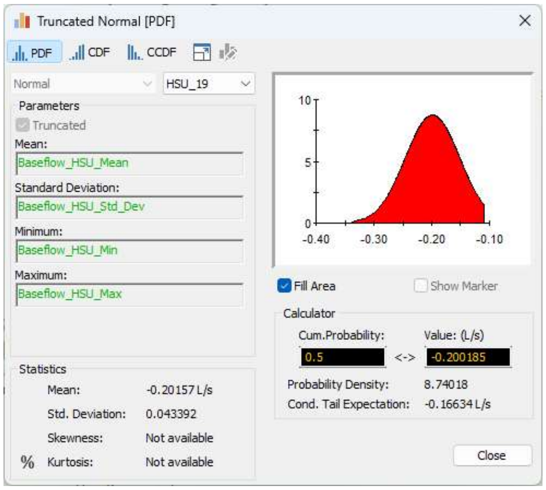
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-0.40
-0.30
-0.20
-0.10
Fill Area
Show Marker
Calculator
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Value: (L/s)
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<->
-0.200185
Probability Density:
8.74018
Cond. Tail Expectation:
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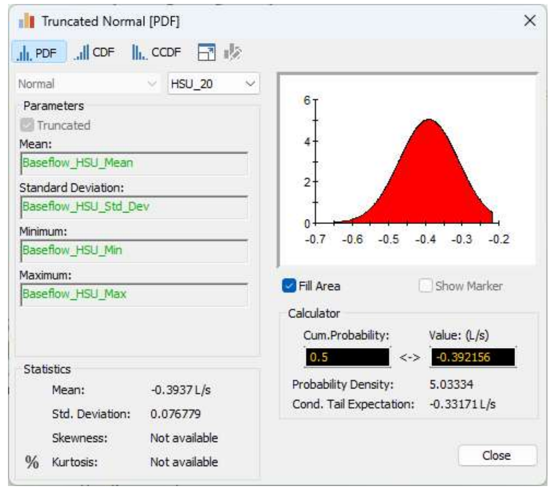
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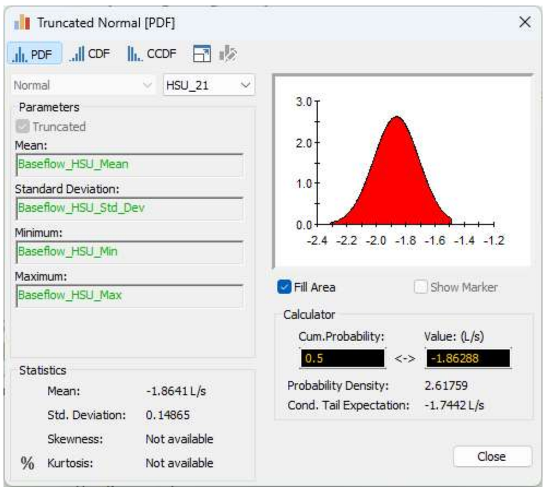
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0.0
-2.4
-2.2
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-1.2
Fill Area
Show Marker
Calculator
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Value: (L/s)
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<->
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Probability Density:
2.61759
Cond. Tail Expectation:
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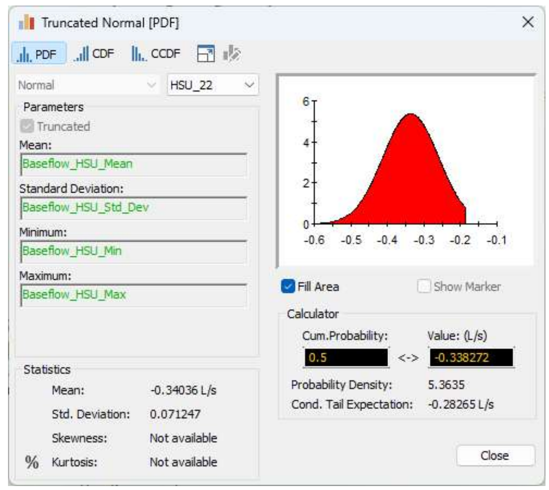
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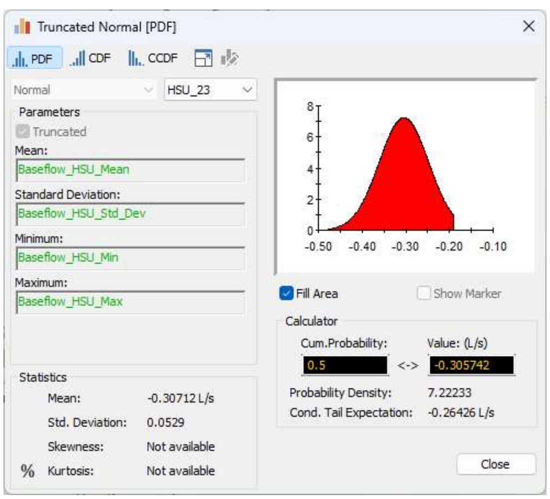
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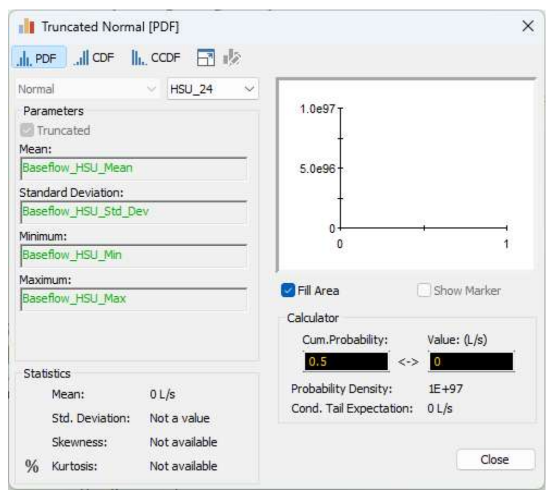
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<->
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Probability Density:
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Cond. Tail Expectation:
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Std. Deviation:
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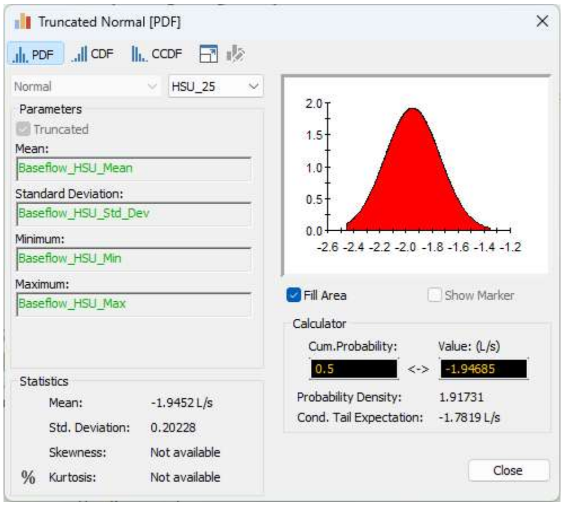
Kurtosis:
Not available
Close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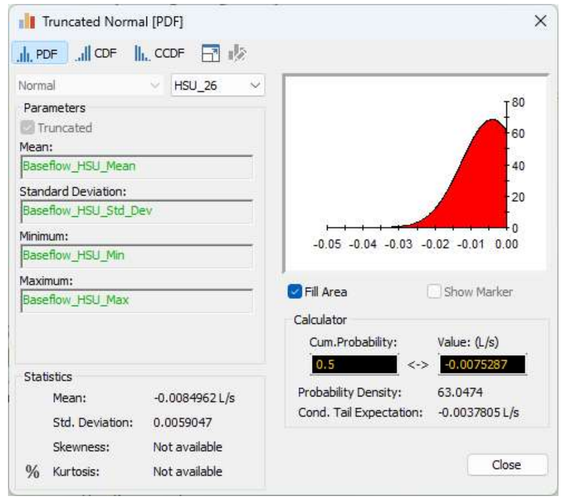
PDF CDF CCDF
Normal
HSU_25
Parameters
Truncated
Mean:
Baseflow_HSU_Mean
Standard Deviation:
Baseflow_HSU_Std_Dev
Minimum:
Baseflow_HSU_Min
Maximum:
Baseflow_HSU_Max
2.0
1.5
1.0
0.5
0.0
-2.6 -2.4 -2.2 -2.0 -1.8 -1.6 -1.4 -1.2
Fill Area
Show Marker
Calculator
Cum.Probability:
Value: (L/s)
0.5
<->
-1.94685
Probability Density: 1.91731
Cond. Tail Expectation: -1.7819 L/s
Statistics
Mean: -1.9452 L/s
Std. Deviation: 0.20228
Skewness: Not available
Kurtosis: Not available
Close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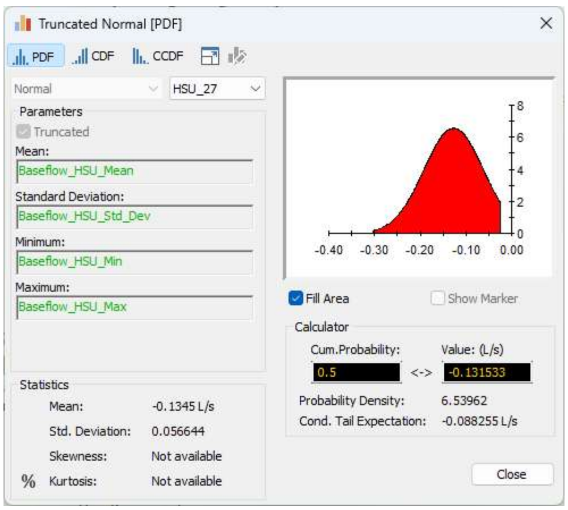
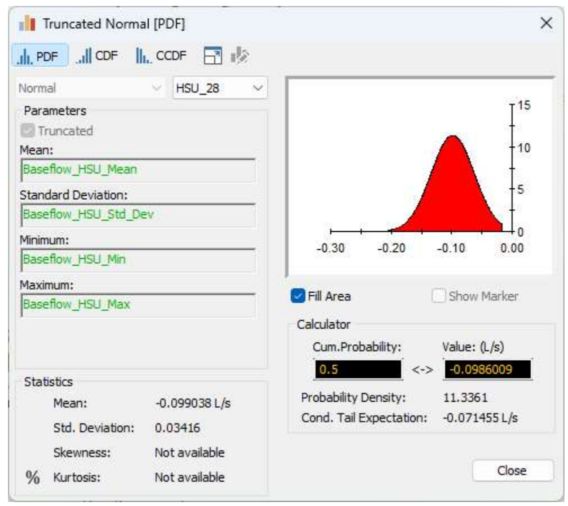
PDF CDF CCDF
Normal
HSU_26
Parameters
Truncated
Mean:
Baseflow_HSU_Mean
Standard Deviation:
Baseflow_HSU_Std_Dev
Minimum:
Baseflow_HSU_Min
Maximum:
Baseflow_HSU_Max
80
60
40
20
0
-0.05 -0.04 -0.03 -0.02 -0.01 0.00
Fill Area
Show Marker
Calculator
Cum.Probability:
Value: (L/s)
0.5
<->
-0.0075287
Probability Density: 63.0474
Cond. Tail Expectation: -0.0037805 L/s
Statistics
Mean: -0.0084962 L/s
Std. Deviation: 0.0059047
Skewness: Not available
Kurtosis: Not available
Close


Truncated Normal [PDF]
PDF CDF CCDF
Normal
HSU_27
Parameters
Truncated
Mean:
Baseflow_HSU_Mean
Standard Deviation:
Baseflow_HSU_Std_Dev
Minimum:
Baseflow_HSU_Min
Maximum:
Baseflow_HSU_Max
8
6
4
2
0
-0.40 -0.30 -0.20 -0.10 0.00
Fill Area
Show Marker
Calculator
Cum.Probability:
Value: (L/s)
0.5
<->
-0.131533
Probability Density: 6.53962
Cond. Tail Expectation: -0.088255 L/s
Statistics
Mean: -0.1345 L/s
Std. Deviation: 0.056644
Skewness: Not available
Kurtosis: Not available
Close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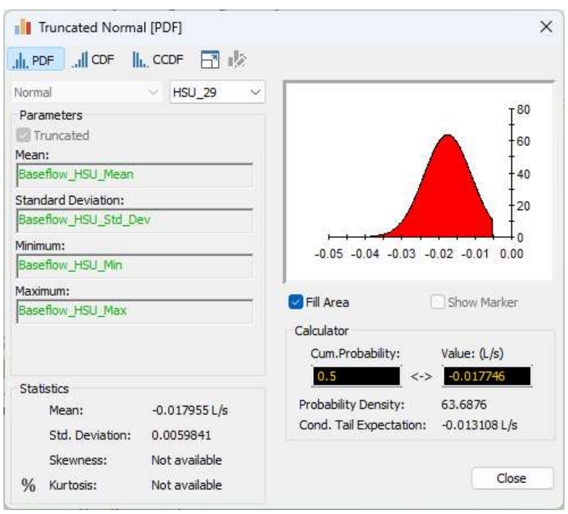
PDF CDF CCDF
Normal
HSU_28
Parameters
Truncated
Mean:
Baseflow_HSU_Mean
Standard Deviation:
Baseflow_HSU_Std_Dev
Minimum:
Baseflow_HSU_Min
Maximum:
Baseflow_HSU_Max
15
10
5
0
-0.30 -0.20 -0.10 0.00
Fill Area
Show Marker
Calculator
Cum.Probability:
Value: (L/s)
0.5
<->
-0.0986009
Probability Density: 11.3361
Cond. Tail Expectation: -0.071455 L/s
Statistics
Mean: -0.099038 L/s
Std. Deviation: 0.03416
Skewness: Not available
Kurtosis: Not available
Close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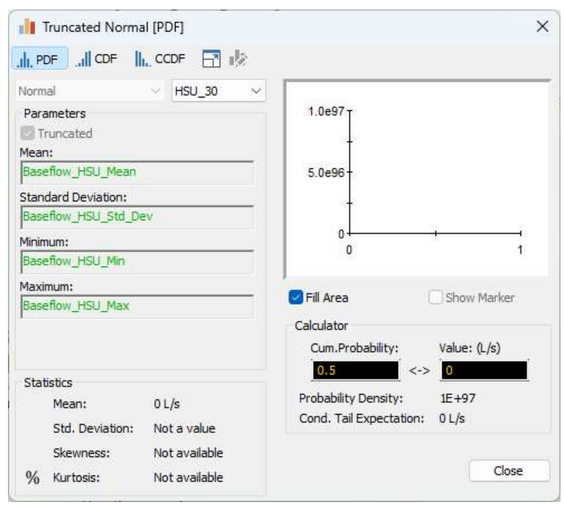
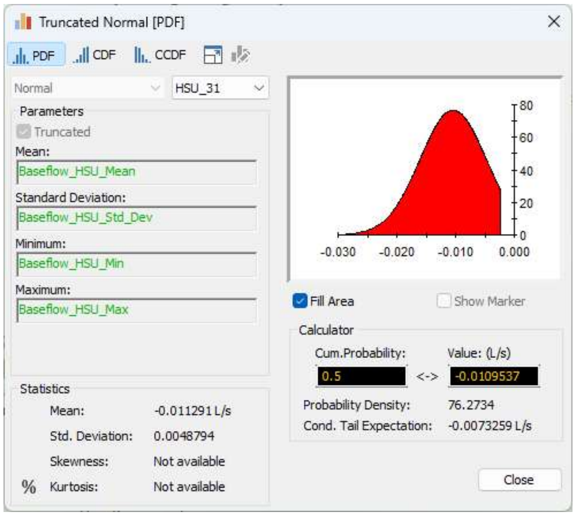
PDF CDF CCDF
Normal
HSU_29
Parameters
Truncated
Mean:
Baseflow_HSU_Mean
Standard Deviation:
Baseflow_HSU_Std_Dev
Minimum:
Baseflow_HSU_Min
Maximum:
Baseflow_HSU_Max
80
60
40
20
0
-0.05 -0.04 -0.03 -0.02 -0.01 0.00
Fill Area
Show Marker
Calculator
Cum.Probability:
Value: (L/s)
0.5
<->
-0.017746
Probability Density: 63.6876
Cond. Tail Expectation: -0.013108 L/s
Statistics
Mean: -0.017955 L/s
Std. Deviation: 0.0059841
Skewness: Not available
Kurtosis: Not available
Close


Truncated Normal [PDF]
PDF CDF CCDF
Normal
HSU_30
Parameters
Truncated
Mean:
Baseflow_HSU_Mean
Standard Deviation:
Baseflow_HSU_Std_Dev
Minimum:
Baseflow_HSU_Min
Maximum:
Baseflow_HSU_Max
1.0e97
5.0e96
0
0 1
Fill Area
Show Marker
Calculator
Cum.Probability:
Value: (L/s)
0.5
<->
0
Probability Density: 1E+97
Cond. Tail Expectation: 0 L/s
Statistics
Mean: 0 L/s
Std. Deviation: Not a value
Skewness: Not available
Kurtosis: Not available
Close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PDF
CDF
CCDF
Normal
HSU_31
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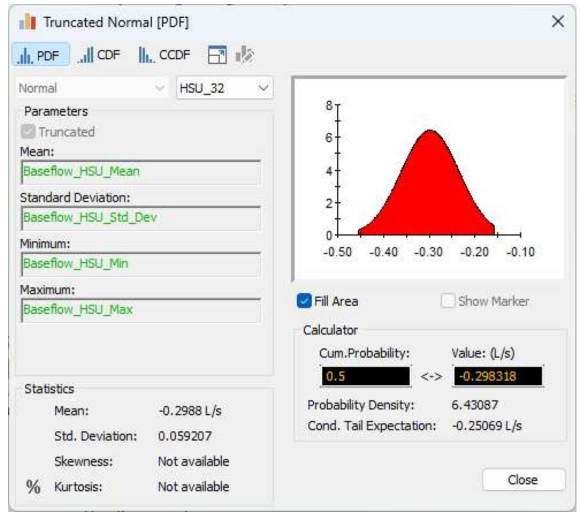
Truncated
Mean:
Baseflow_HSU_Mean
Standard Deviation:
Baseflow_HSU_Std_Dev
Minimum:
Baseflow_HSU_Min
Maximum:
Baseflow_HSU_Max
Statistics
Mean: -0.011291 L/s
Std. Deviation: 0.0048794
Skewness: Not available
Kurtosis: Not available
80
60
40
20
0
-0.030 -0.020 -0.010 0.000
Fill Area
Show Marker
Calculator
Cum.Probability:
Value: (L/s)
0.5 <-> -0.0109537
Probability Density: 76.2734
Cond. Tail Expectation: -0.0073259 L/s
Close


Truncated Normal [PDF]
PDF
CDF
CCDF
Normal
HSU_32
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Truncated
Mean:
Baseflow_HSU_Mean
Standard Deviation:
Baseflow_HSU_Std_Dev
Minimum:
Baseflow_HSU_Min
Maximum:
Baseflow_HSU_Max
Statistics
Mean: -0.2988 L/s
Std. Deviation: 0.059207
Skewness: Not available
Kurtosis: Not available
8
6
4
2
0
-0.50 -0.40 -0.30 -0.20 -0.10
Fill Area
Show Marker
Calculator
Cum.Probability:
Value: (L/s)
0.5 <-> -0.298318
Probability Density: 6.43087
Cond. Tail Expectation: -0.25069 L/s
Close

Appendix C

Water Balance Model Catchment Parameters

Table C.1 Values assigned to the various parameters in each sub-catchment of the WBM – Head Water Tributaries (Upper).

Parameter	T Stream West	T Stream East	Edmonds	WKP03	WKP02	Thompson	WKP01
Area (km^2)	3.88	0.00	2.33	0.00	1.40	1.53	1.12
Evaporation reduction (-)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Surface store area proportions: A1 A2 A3	 0.433 0.134 0.433	 0.433 0.134 0.433	 0.433 0.134 0.433	 0.433 0.134 0.433	 0.433 0.134 0.433	 0.433 0.134 0.433	 0.433 0.134 0.433
Depth capacities: C1 (mm) C2 (mm) C3 (mm)	 1.5 80 100	 1 45 120	 2 80 120	 1 45 95	 2 95 120	 2 95 120	 2 95 120
Baseflow index factor (-)	0.55500	0.49296	0.60000	0.60000	0.60000	0.60000	0.60000
Baseflow recession constant (-)	0.99348	0.99348	0.99348	0.99348	0.99348	0.99348	0.99348
Surface store index factor (-)	0.20	0.13	0.20	0.20	0.20	0.20	0.20
Surface runoff recession constant (-) Ks1 Ks2	 0.35 0.94	 0.35 0.93	 0.35 0.94	 0.35 0.93	 0.35 0.94	 0.35 0.93	 0.35 0.94
River flow addition (mm/d)	0.9507	0.9507	0.9507	0.9507	0.9507	0.9507	0.9507
River flow addition factor (-)	0.395	0.600	0.600	0.650	0.900	0.935	0.935

Table C.2 Values assigned to the various parameters in each sub-catchment of the WBM – Non-Head Water Tributaries (Lower).

Parameter	T Stream West	T Stream East	Edmonds	WKP03	WKP02	Thompson	WKP01
Area (km^2)	0.30	0.13	0.17	0.71	0.39	0.57	1.62
Evaporation reduction (-)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Surface store area proportions: A1 A2 A3	 0.433 0.134 0.433	 0.433 0.134 0.433	 0.433 0.134 0.433	 0.433 0.134 0.433	 0.433 0.134 0.433	 0.433 0.134 0.433	 0.433 0.134 0.433
Depth capacities: C1 (mm) C2 (mm) C3 (mm)	 3 120 160	 2 120 180	 3 120 160	 2 125 210	 2 100 210	 2 120 210	 2 120 180
Baseflow index factor (-)	0.59000	0.59000	0.59000	0.60000	0.40000	0.50000	0.35000
Baseflow recession constant (-)	0.99348	0.99348	0.99348	0.99348	0.99348	0.99348	0.99348
Surface store index factor (-)	0.26	0.24	0.23	0.23	0.29	0.30	0.30
Surface runoff recession constant (-) Ks1 Ks2	0.34 0.94	0.35 0.94	0.35 0.94	0.35 0.93	0.35 0.94	0.35 0.94	0.35 0.95
River flow addition (mm/d)	0	0	0	0	0	0	0
River flow addition factor (-)	0	0	0	0	0	0	0

Table C.3 HSU Catchment Areas and allocated sub-catchment

HSU	Sub-catchment	Catchment Type (Upper / Lower)	Area (Km^2)
7	T Stream West	Upper	1.587263
8	T Stream West	Lower	0.121219
9	T Stream West	Upper	2.290275
10	T Stream West	Lower	0.182869
11	Edmonds	Upper	2.098181
12	Edmonds	Upper	0.132075
13	Edmonds	Lower	0.110644
14	WKP02	Upper	0.293287
15	WKP02	Upper	0.405338
16	WKP02	Upper	0.218025
17	WKP02	Upper	0.345994
18	T Stream East	Lower	0.127575
19	Edmonds	Lower	0.055800
20	Edmonds	Upper	0.096075
21	WKP03	Lower	0.711731
22	WKP02	Upper	0.138150
23	WKP02	Lower	0.385762
24	Thompson	Upper	0.351225
25	Thompson	Upper	0.770006
26	Thompson	Upper	0.184950
27	Thompson	Upper	0.136350
28	Thompson	Lower	0.567900
29	Thompson	Upper	0.084600
30	WKP01	Upper	1.118025
31	WKP01	Lower	1.205100
32	WKP01	Lower	0.411188

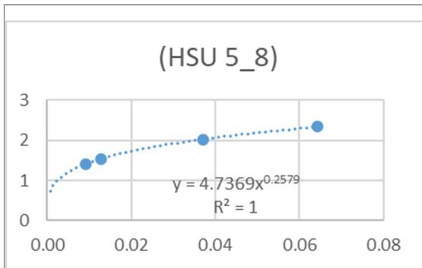
Appendix D

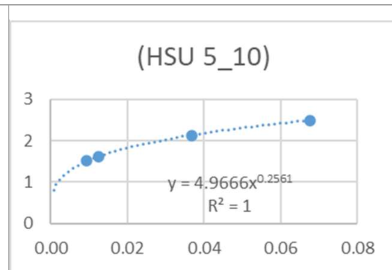
Wetted Width Flow Relationships

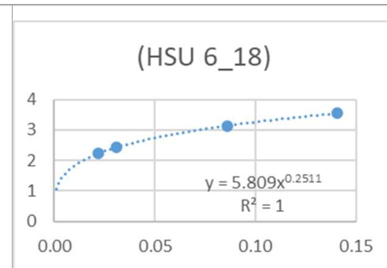
Table D.1 Wetted Width Flow Calculations (from NIWA River Database)

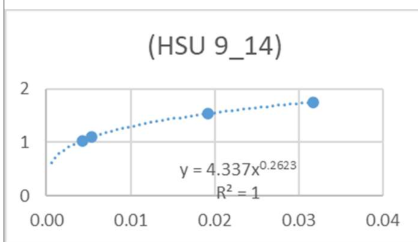
*Relationships developed from MALF, Mean, Median and 1 in 5 year low flows at corresponding locations from (**https://niwa.co.nz/freshwater/new-zealand-river-maps**).*

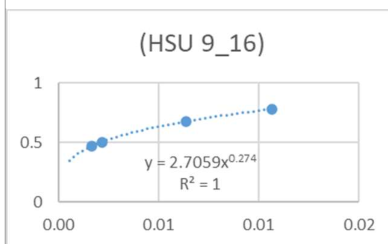
X axis – Flow (m^3/sec), Y axis Wetted width (m)

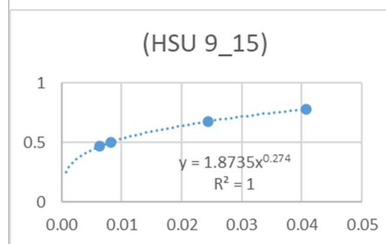


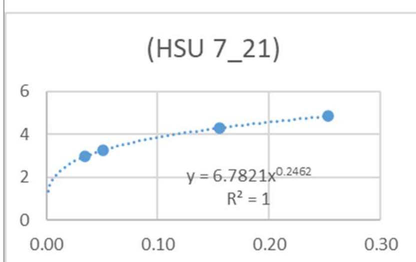


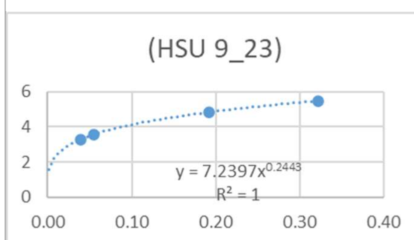


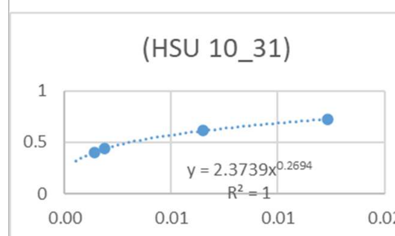


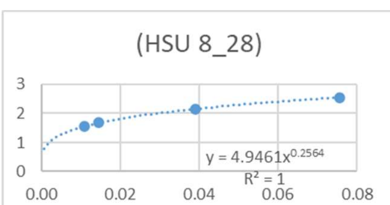


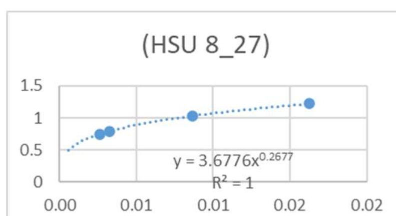


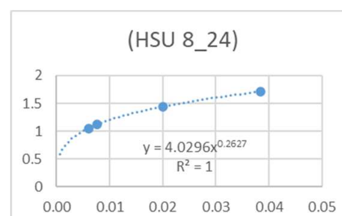


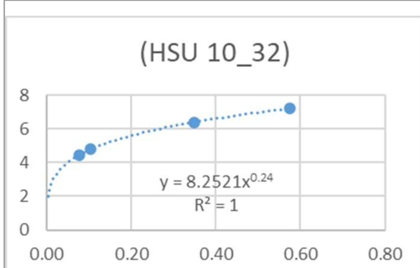


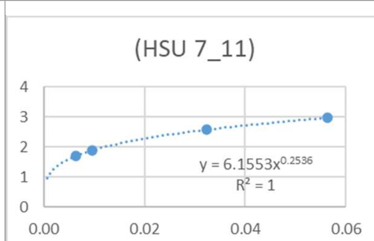


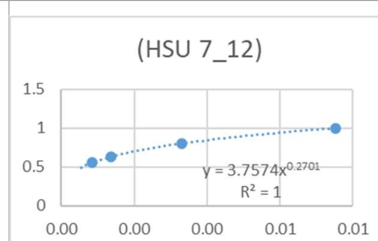


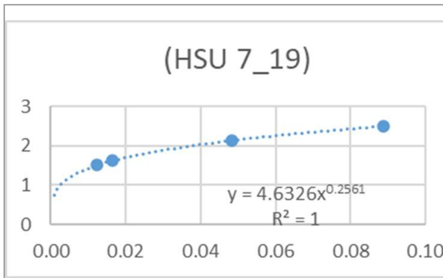


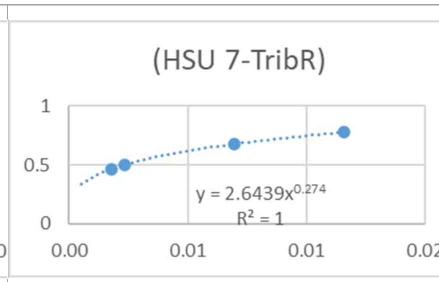









(HSU 7_19)
3
2
1
0
y = 4.6326x0.2561
R² = 1
0.00
0.02
0.04
0.06
0.08
0.10


(HSU 7-TribR)
1
0.5
0
y = 2.6439x0.274
R² = 1
0.00
0.01
0.01
0.02

Appendix E

HSU Flow and Wetted Width Modelled Results

Hydrology

Table E.1 HSU 7-19 summary statistics of the long term predictive current state (pre-mining) conditions scenario at each location.

Statistic (L/s)	5_7		5_8		5_9		5_10		7_11		7_12		7_13		9_14		9_15		9_16		9_17		6_18		7_19	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	56.1	57.5	58.4	59.9	81.2	83.2	86.0	88.2	72.6	74.3	4.5	4.7	75.7	77.5	11.1	11.3	33.6	34.3	8.0	8.1	12.8	13.1	148.0	151.8	81.7	83.7
Median flow	45.9	47.3	47.3	48.8	66.4	68.5	70.0	72.2	60.5	62.1	3.8	3.9	62.8	64.6	9.3	9.5	27.9	28.6	6.6	6.8	10.7	10.9	120.0	123.9	67.7	69.7
MALF	11.1	11.6	10.2	10.7	16.3	16.9	16.3	17.0	19.3	19.8	1.2	1.2	19.5	20.0	3.6	3.7	10.3	10.5	2.4	2.5	4.0	4.1	26.8	28.0	20.7	21.3
70% MALF	7.8	8.1	7.2	7.5	11.4	11.8	11.4	11.9	13.5	13.9	0.8	0.9	13.6	14.0	2.5	2.6	7.2	7.3	1.7	1.7	2.8	2.9	18.8	19.6	14.5	14.9
50% MALF	5.6	5.8	5.1	5.3	8.1	8.5	8.2	8.5	9.6	9.9	0.6	0.6	9.7	10.0	1.8	1.8	5.1	5.2	1.2	1.2	2.0	2.0	13.4	14.0	10.4	10.6
7day-MALF	12.2	12.8	11.4	12.0	17.8	18.7	18.0	18.9	20.6	21.2	1.3	1.3	20.8	21.5	3.8	3.9	10.8	11.1	2.6	2.6	4.2	4.3	29.7	31.2	22.2	22.9
70% 7day-MALF	8.5	8.9	8.0	8.4	12.5	13.1	12.6	13.2	14.4	14.9	0.9	0.9	14.6	15.0	2.6	2.7	7.6	7.7	1.8	1.8	2.9	3.0	20.8	21.8	15.5	16.0
50% 7day-MALF	6.1	6.4	5.7	6.0	8.9	9.3	9.0	9.4	10.3	10.6	0.6	0.7	10.4	10.7	1.9	1.9	5.4	5.5	1.3	1.3	2.1	2.2	14.9	15.6	11.1	11.4
FRE3	137.6	141.8	141.9	146.5	199.2	205.4	210.0	216.6	181.4	186.4	11.3	11.7	188.3	193.7	27.8	28.4	83.7	85.9	19.9	20.4	32.0	32.8	360.0	371.6	203.1	209.0
Q5	9.1	9.5	8.0	8.5	13.3	14.0	13.2	13.9	16.9	17.4	1.0	1.1	16.9	17.5	3.3	3.4	9.2	9.5	2.2	2.2	3.6	3.7	21.3	22.6	17.9	18.6
5% of MALF	7.3	7.6	6.1	6.4	10.7	11.2	10.4	10.9	14.8	15.1	0.9	0.9	14.7	15.1	3.0	3.0	8.4	8.5	2.0	2.0	3.3	3.3	16.5	17.3	15.6	16.0
10% of MALF	7.6	8.1	6.4	7.0	11.1	11.9	10.9	11.7	15.2	15.7	0.9	1.0	15.1	15.7	3.1	3.1	8.5	8.8	2.0	2.1	3.4	3.4	17.3	18.7	16.0	16.6
30% of MALF	9.1	9.5	8.1	8.5	13.4	13.9	13.2	13.8	16.9	17.4	1.0	1.1	16.9	17.4	3.3	3.3	9.2	9.4	2.2	2.2	3.6	3.7	21.4	22.4	18.0	18.5
50% of MALF	10.3	10.9	9.4	10.0	15.2	16.0	15.2	16.0	18.4	19.0	1.1	1.2	18.5	19.2	3.5	3.6	9.9	10.1	2.3	2.4	3.9	4.0	24.7	26.2	19.7	20.4

Table E.2 HSU 20-32 summary statistics of the long term predictive current state (pre-mining) conditions scenario at each location.

Statistic (L/s)	7_20		7_21		9_22		9_23		8_24		8_25		8_26		8_27		8_28		10_29		10_30		10_31		10_32	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	85.0	87.0	252.1	258.5	4.4	4.5	318.6	326.6	13.5	13.8	52.6	53.8	7.0	7.1	12.0	12.3	72.3	74.0	3.0	3.1	42.9	43.8	54.9	56.5	510.1	522.9
Median flow	70.4	72.4	204.6	211.2	3.5	3.6	258.5	266.5	11.1	11.4	42.8	44.0	5.7	5.9	9.8	10.1	57.5	59.1	2.5	2.5	35.9	36.8	41.7	43.1	410.0	422.4
MALF	21.5	22.2	48.9	50.9	0.9	0.9	65.0	67.4	4.3	4.4	15.1	15.4	2.2	2.2	3.7	3.7	16.6	17.0	0.8	0.9	14.4	14.7	5.8	6.4	104.3	108.1
70% MALF	15.1	15.5	34.3	35.6	0.6	0.6	45.5	47.2	3.0	3.1	10.6	10.8	1.5	1.6	2.6	2.6	11.6	11.9	0.6	0.6	10.1	10.3	4.1	4.5	73.0	75.6
50% MALF	10.8	11.1	24.5	25.4	0.4	0.4	32.5	33.7	2.2	2.2	7.5	7.7	1.1	1.1	1.8	1.9	8.3	8.5	0.4	0.4	7.2	7.3	2.9	3.2	52.1	54.0
7day-MALF	23.0	23.8	53.7	56.2	0.9	1.0	70.9	73.9	4.5	4.6	15.9	16.3	2.3	2.3	3.8	3.9	17.7	18.3	0.9	0.9	15.1	15.4	7.0	7.6	113.7	118.4
70% 7day-MALF	16.1	16.7	37.6	39.3	0.7	0.7	49.6	51.8	3.2	3.2	11.1	11.4	1.6	1.6	2.7	2.8	12.4	12.8	0.6	0.6	10.5	10.8	4.9	5.3	79.6	82.9
50% 7day-MALF	11.5	11.9	26.9	28.1	0.5	0.5	35.5	37.0	2.3	2.3	7.9	8.1	1.1	1.2	1.9	2.0	8.9	9.1	0.4	0.5	7.5	7.7	3.5	3.8	56.9	59.2
FRE3	211.3	217.3	613.9	633.5	10.6	10.9	775.5	799.6	33.3	34.1	128.5	132.0	17.2	17.7	29.5	30.3	172.4	177.2	7.4	7.6	107.7	110.3	125.1	129.3	1,230.1	1,267.1
Q5	18.6	19.3	39.9	41.9	0.7	0.7	53.8	56.3	4.0	4.1	13.7	14.0	2.0	2.1	3.4	3.4	14.4	14.9	0.8	0.8	13.1	13.4	3.5	4.0	86.5	90.5
5% of MALF	16.2	16.6	32.1	33.4	0.6	0.6	44.2	45.8	3.7	3.8	12.6	12.8	1.9	1.9	3.1	3.2	12.7	13.0	0.7	0.7	12.1	12.3	1.3	1.8	71.1	73.7
10% of MALF	16.7	17.3	33.4	35.6	0.6	0.6	45.7	48.5	3.8	3.9	12.8	13.1	1.9	1.9	3.2	3.2	13.0	13.5	0.7	0.7	12.3	12.6	1.8	2.4	74.1	78.1
30% of MALF	18.7	19.2	40.0	41.7	0.7	0.7	53.9	56.0	4.0	4.1	13.7	14.0	2.0	2.0	3.4	3.4	14.4	14.9	0.8	0.8	13.2	13.4	3.5	4.0	86.7	90.1
50% of MALF	20.4	21.2	45.6	47.9	0.8	0.8	60.8	63.7	4.2	4.3	14.6	14.9	2.1	2.2	3.5	3.6	15.8	16.3	0.8	0.8	13.9	14.3	5.0	5.7	97.8	102.3

Table E.3 HSU 7-19 Summary statistics of the long term predictive base flow reduction (mining) conditions scenario at each location.

Statistic (L/s)	5_7		5_8		5_9		5_10		7_11		7_12		7_13		9_14		9_15		9_16		9_17		6_18		7_19	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	56.1	57.5	58.2	59.7	81.2	83.2	85.7	87.9	72.5	74.2	4.5	4.6	75.5	77.2	11.0	11.3	33.1	33.9	7.8	8.0	12.7	13.0	146.9	150.8	81.3	83.2
Median flow	45.8	47.2	47.1	48.7	66.4	68.4	69.7	71.9	60.3	62.0	3.7	3.9	62.6	64.3	9.2	9.4	27.5	28.2	6.5	6.7	10.5	10.8	119.0	122.8	67.3	69.2
MALF	11.1	11.5	10.0	10.5	16.2	16.9	16.0	16.7	19.2	19.7	1.1	1.2	19.2	19.8	3.6	3.6	9.8	10.0	2.3	2.4	3.9	4.0	25.6	26.9	20.2	20.9
70% MALF	7.8	8.1	7.0	7.4	11.4	11.8	11.2	11.7	13.4	13.8	0.8	0.8	13.4	13.9	2.5	2.5	6.8	7.0	1.6	1.7	2.7	2.8	17.9	18.9	14.2	14.6
50% MALF	5.5	5.8	5.0	5.3	8.1	8.4	8.0	8.4	9.6	9.9	0.6	0.6	9.6	9.9	1.8	1.8	4.9	5.0	1.1	1.2	1.9	2.0	12.8	13.5	10.1	10.4
7day-MALF	12.2	12.7	11.2	11.8	17.8	18.6	17.7	18.6	20.4	21.1	1.2	1.3	20.6	21.3	3.7	3.8	10.3	10.6	2.4	2.5	4.1	4.2	28.6	30.2	21.7	22.4
70% 7day-MALF	8.5	8.9	7.9	8.3	12.5	13.0	12.4	13.0	14.3	14.8	0.9	0.9	14.4	14.9	2.6	2.7	7.2	7.4	1.7	1.8	2.9	2.9	20.0	21.1	15.2	15.7
50% 7day-MALF	6.1	6.4	5.6	5.9	8.9	9.3	8.8	9.3	10.2	10.6	0.6	0.6	10.3	10.6	1.9	1.9	5.2	5.3	1.2	1.3	2.0	2.1	14.3	15.1	10.8	11.2
FRE3	137.5	141.7	141.4	146.0	199.1	205.2	209.1	215.8	181.0	186.1	11.2	11.6	187.8	193.0	27.7	28.3	82.4	84.5	19.5	20.1	31.6	32.5	357.0	368.5	201.9	207.6
Q5	9.0	9.5	7.9	8.4	13.3	13.9	12.8	13.6	16.7	17.3	1.0	1.0	16.7	17.3	3.2	3.3	8.7	9.0	2.1	2.1	3.5	3.6	20.3	21.5	17.5	18.1
5% of MALF	7.2	7.5	5.9	6.3	10.7	11.1	10.1	10.6	14.7	15.1	0.9	0.9	14.5	14.9	3.0	3.0	7.9	8.0	1.9	1.9	3.2	3.2	15.5	16.3	15.1	15.5
10% of MALF	7.5	8.0	6.3	6.8	11.1	11.9	10.6	11.4	15.1	15.6	0.9	0.9	14.9	15.5	3.0	3.1	8.0	8.3	1.9	2.0	3.2	3.3	16.3	17.7	15.6	16.2
30% of MALF	9.1	9.4	7.9	8.3	13.3	13.9	13.0	13.5	16.8	17.3	1.0	1.0	16.7	17.2	3.2	3.3	8.8	9.0	2.1	2.1	3.5	3.6	20.3	21.4	17.5	18.1
50% of MALF	10.3	10.9	9.2	9.8	15.1	15.9	14.9	15.7	18.2	18.9	1.1	1.1	18.2	18.9	3.4	3.5	9.4	9.7	2.2	2.3	3.7	3.9	23.7	25.2	19.2	19.9

Table E.4 HSU 20-32 Summary statistics of the long term predictive base flow reduction (mining) conditions scenario at each location.

Statistic (L/s)	7_20		7_21		9_22		9_23		8_24		8_25		8_26		8_27		8_28		10_29		10_30		10_31		10_32	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	84.2	86.2	248.4	254.7	4.0	4.2	313.7	321.7	13.5	13.8	50.3	51.7	7.0	7.1	11.9	12.1	69.9	71.9	3.0	3.1	42.9	43.8	54.9	56.5	497.4	510.4
Median flow	69.6	71.6	201.0	207.4	3.1	3.3	253.7	261.6	11.1	11.4	40.8	41.9	5.7	5.9	9.7	10.0	55.2	56.9	2.4	2.5	35.9	36.8	41.7	43.1	397.4	409.9
MALF	20.6	21.3	44.9	47.1	0.4	0.6	59.7	62.4	4.3	4.4	12.9	13.3	2.2	2.2	3.5	3.6	14.3	14.8	0.8	0.8	14.4	14.7	5.8	6.3	91.4	95.6
70% MALF	14.4	14.9	31.4	33.0	0.3	0.4	41.8	43.7	3.0	3.1	9.0	9.3	1.5	1.6	2.4	2.5	10.0	10.4	0.6	0.6	10.1	10.3	4.1	4.4	64.0	66.9
50% MALF	10.3	10.7	22.5	23.6	0.2	0.3	29.8	31.2	2.2	2.2	6.4	6.7	1.1	1.1	1.7	1.8	7.1	7.4	0.4	0.4	7.2	7.3	2.9	3.2	45.7	47.8
7day-MALF	22.2	23.0	49.9	52.4	0.5	0.6	65.9	69.0	4.5	4.6	13.6	14.2	2.3	2.3	3.6	3.8	15.4	16.1	0.9	0.9	15.1	15.4	7.0	7.6	100.9	105.9
70% 7day-MALF	15.5	16.1	34.9	36.7	0.4	0.5	46.1	48.3	3.2	3.2	9.6	9.9	1.6	1.6	2.6	2.7	10.8	11.3	0.6	0.6	10.5	10.8	4.9	5.3	70.7	74.1
50% 7day-MALF	11.1	11.5	24.9	26.2	0.3	0.3	32.9	34.5	2.3	2.3	6.8	7.1	1.1	1.2	1.8	1.9	7.7	8.1	0.4	0.4	7.5	7.7	3.5	3.8	50.5	53.0
FRE3	208.8	214.8	603.0	622.3	9.4	9.9	761.2	784.7	33.3	34.1	122.4	125.7	17.2	17.7	29.1	29.9	165.5	170.6	7.3	7.5	107.7	110.3	125.1	129.3	1,192	1,229
Q5	17.8	18.5	35.9	38.2	0.3	0.4	48.6	51.3	4.0	4.1	11.5	12.0	2.0	2.0	3.2	3.3	12.2	12.8	0.7	0.8	13.1	13.4	3.5	4.0	73.9	78.0
5% of MALF	15.3	15.8	28.4	29.7	0.1	0.3	39.2	40.8	3.7	3.8	10.3	10.7	1.9	1.9	2.9	3.0	10.4	10.8	0.7	0.7	12.1	12.3	1.3	1.8	58.4	61.3
10% of MALF	15.8	16.5	29.6	31.9	0.2	0.3	40.8	43.5	3.8	3.9	10.5	11.0	1.9	1.9	2.9	3.1	10.6	11.3	0.7	0.7	12.3	12.6	1.8	2.4	61.3	65.6
30% of MALF	17.9	18.4	36.2	38.0	0.3	0.4	48.9	51.0	4.0	4.1	11.4	11.9	2.0	2.0	3.2	3.3	12.1	12.7	0.7	0.8	13.2	13.4	3.5	4.0	74.2	77.6
50% of MALF	19.5	20.4	41.7	44.2	0.4	0.5	55.7	58.7	4.2	4.3	12.4	12.8	2.1	2.2	3.4	3.5	13.5	14.1	0.8	0.8	13.9	14.3	5.0	5.7	84.9	89.9

Table E.5 HSU 7-19 Percentage reduction between the current state (pre-mining) and base flow reduction (mining) long term predictive scenario

Statistic (%)	5_7		5_8		5_9		5_10		7_11		7_12		7_13		9_14		9_15		9_16		9_17		6_18		7_19	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	0.1	0.1	0.3	0.3	0.0	0.1	0.3	0.3	0.2	0.1	0.7	0.8	0.3	0.3	0.4	0.3	1.4	1.4	1.6	1.3	1.1	0.9	0.7	0.7	0.5	0.5
Median flow	0.1	0.1	0.3	0.3	0.1	0.1	0.4	0.4	0.2	0.1	0.8	0.9	0.3	0.3	0.4	0.4	1.6	1.6	1.7	1.5	1.2	1.0	0.8	0.8	0.6	0.6
MALF	0.3	0.3	1.9	1.4	0.3	0.3	2.2	1.7	0.5	0.5	4.0	2.9	1.2	1.1	1.4	1.1	4.9	4.5	5.3	4.2	2.9	2.7	4.4	3.7	2.2	2.1
70% MALF	0.3	0.3	1.9	1.4	0.3	0.3	2.2	1.7	0.5	0.5	4.0	2.9	1.2	1.1	1.4	1.1	4.9	4.5	5.3	4.2	2.9	2.7	4.4	3.7	2.2	2.1
50% MALF	0.3	0.3	1.9	1.4	0.3	0.3	2.2	1.7	0.5	0.5	4.0	2.9	1.2	1.1	1.4	1.1	4.9	4.5	5.3	4.2	2.9	2.7	4.4	3.7	2.2	2.1
7day-MALF	0.2	0.2	1.3	1.3	0.3	0.2	1.8	1.5	0.6	0.4	3.9	2.7	1.1	1.0	1.4	1.0	4.6	4.2	5.0	3.9	3.0	2.6	3.7	3.3	2.2	2.0
70% 7day-MALF	0.2	0.2	1.3	1.3	0.3	0.2	1.8	1.5	0.6	0.4	3.9	2.7	1.1	1.0	1.4	1.0	4.6	4.2	5.0	3.9	3.0	2.6	3.7	3.3	2.2	2.0
50% 7day-MALF	0.2	0.2	1.3	1.3	0.3	0.2	1.8	1.5	0.6	0.4	3.9	2.7	1.1	1.0	1.4	1.0	4.6	4.2	5.0	3.9	3.0	2.6	3.7	3.3	2.2	2.0
FRE3	0.1	0.1	0.3	0.3	0.1	0.1	0.4	0.4	0.2	0.1	0.8	0.9	0.3	0.3	0.4	0.4	1.6	1.6	1.7	1.5	1.2	1.0	0.8	0.8	0.6	0.6
Q5	0.3	0.3	2.1	1.8	0.3	0.3	2.6	2.0	0.6	0.5	3.8	3.3	1.1	1.2	1.2	1.2	5.4	5.0	5.3	4.6	3.4	3.0	5.0	4.6	2.4	2.4
5% of MALF	0.4	0.4	2.9	2.3	0.4	0.4	2.6	2.6	0.7	0.6	4.5	3.8	1.5	1.4	1.4	1.3	5.9	5.5	6.0	5.1	4.4	3.3	6.5	6.0	2.9	2.8
10% of MALF	0.4	0.4	2.4	2.2	0.4	0.4	2.6	2.4	0.6	0.6	4.2	3.7	1.4	1.4	1.6	1.2	5.6	5.4	6.0	5.0	4.3	3.3	6.1	5.5	2.6	2.7
30% of MALF	0.3	0.3	2.5	1.8	0.4	0.3	1.8	2.0	0.5	0.5	3.6	3.3	1.1	1.2	1.2	1.2	5.3	5.0	5.3	4.6	3.6	3.0	5.1	4.6	2.3	2.4
50% of MALF	0.3	0.3	1.7	1.5	0.3	0.3	1.8	1.8	0.7	0.5	3.4	3.0	1.5	1.1	1.4	1.1	5.1	4.6	5.3	4.3	3.4	2.8	4.4	4.0	2.3	2.2

Table E.6 HSU 20-32 Percentage reduction between the current state (pre-mining) and base flow reduction (mining) long term predictive scenario

Statistic (%)	7_20		7_21		9_22		9_23		8_24		8_25		8_26		8_27		8_28		10_29		10_30		10_31		10_32	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	1.0	1.0	1.5	1.4	8.9	7.6	1.5	1.5	0.0	0.0	4.4	3.9	0.1	0.1	1.3	1.2	3.4	3.0	0.8	0.6	0.0	0.0	0.0	0.0	2.5	2.4
Median flow	1.2	1.2	1.8	1.8	11.0	9.4	1.9	1.9	0.0	0.0	4.8	4.7	0.3	0.1	1.5	1.4	4.0	3.7	0.7	0.7	0.0	0.0	0.0	0.0	3.1	3.0
MALF	4.2	3.8	8.2	7.4	49.8	38.0	8.1	7.4	0.0	0.0	14.8	13.6	0.6	0.4	5.4	3.8	13.9	12.9	2.9	2.1	0.0	0.0	0.3	0.2	12.3	11.6
70% MALF	4.2	3.8	8.2	7.4	49.8	38.0	8.1	7.4	0.0	0.0	14.8	13.6	0.6	0.4	5.4	3.8	13.9	12.9	2.9	2.1	0.0	0.0	0.3	0.2	12.3	11.6
50% MALF	4.2	3.8	8.2	7.4	49.8	38.0	8.1	7.4	0.0	0.0	14.8	13.6	0.6	0.4	5.4	3.8	13.9	12.9	2.9	2.1	0.0	0.0	0.3	0.2	12.3	11.6
7day-MALF	3.9	3.5	7.2	6.7	44.9	34.6	7.1	6.7	0.0	0.0	13.9	12.8	0.6	0.4	5.1	3.6	12.9	12.0	2.6	2.0	0.0	0.0	0.1	0.1	11.2	10.5
70% 7day-MALF	3.9	3.5	7.2	6.7	44.9	34.6	7.1	6.7	0.0	0.0	13.9	12.8	0.6	0.4	5.1	3.6	12.9	12.0	2.6	2.0	0.0	0.0	0.1	0.1	11.2	10.5
50% 7day-MALF	3.9	3.5	7.2	6.7	44.9	34.6	7.1	6.7	0.0	0.0	13.9	12.8	0.6	0.4	5.1	3.6	12.9	12.0	2.6	2.0	0.0	0.0	0.1	0.1	11.2	10.5
FRE3	1.2	1.2	1.8	1.8	11.0	9.4	1.9	1.9	0.0	0.0	4.8	4.7	0.3	0.1	1.5	1.4	4.0	3.7	0.7	0.7	0.0	0.0	0.0	0.0	3.1	3.0
Q5	4.5	4.4	10.1	8.9	61.7	45.8	9.6	8.8	0.0	0.0	15.8	14.9	0.6	0.4	5.7	4.2	15.5	14.6	2.8	2.3	0.0	0.0	0.2	0.3	14.7	13.8
5% of MALF	5.6	5.1	11.7	11.2	77.8	56.8	11.3	10.9	0.0	0.0	18.4	16.3	0.7	0.5	7.0	4.5	18.8	16.8	3.0	2.6	0.0	0.0	0.8	0.6	17.8	16.9
10% of MALF	5.3	4.9	11.4	10.5	72.7	53.5	10.8	10.3	0.0	0.0	18.0	15.9	0.7	0.4	7.0	4.4	18.4	16.2	3.3	2.5	0.0	0.0	0.9	0.5	17.2	16.0
30% of MALF	4.2	4.4	9.4	9.0	63.0	46.0	9.2	8.9	0.0	0.0	16.8	14.9	0.5	0.4	6.1	4.2	16.0	14.7	2.9	2.3	0.0	0.0	0.5	0.3	14.4	13.9
50% of MALF	4.6	4.0	8.5	7.8	53.2	40.3	8.4	7.8	0.0	0.0	15.0	14.0	0.2	0.4	5.3	3.9	14.6	13.4	2.6	2.2	0.0	0.0	0.1	0.2	13.2	12.2

Wetted Width

Table E.7 HSU 7-19 summary statistics of wetted width (pre-mining) based on the long term modelled flow statistic

Statistic (m)	5_7		5_8		5_9		5_10		7_11		7_12		7_13		9_14		9_15		9_16		9_17		6_18		7_19	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	2.25	2.27	2.28	2.29	2.48	2.50	2.65	2.67	3.17	3.18	0.88	0.88	3.20	3.22	1.33	1.34	0.74	0.74	0.72	0.72	N/A	N/A	3.60	3.62	2.44	2.45
Median flow	2.14	2.16	2.16	2.17	2.35	2.37	2.51	2.53	3.02	3.04	0.83	0.84	3.05	3.07	1.27	1.28	0.70	0.71	0.68	0.69	N/A	N/A	3.41	3.44	2.32	2.34
MALF	1.48	1.50	1.45	1.47	1.64	1.65	1.73	1.75	2.26	2.28	0.61	0.61	2.27	2.28	0.99	1.00	0.53	0.54	0.52	0.52	N/A	N/A	2.34	2.37	1.72	1.73
70% MALF	1.35	1.37	1.32	1.34	1.49	1.51	1.58	1.60	2.07	2.08	0.55	0.56	2.07	2.08	0.90	0.91	0.48	0.49	0.47	0.47	N/A	N/A	2.14	2.16	1.57	1.58
50% MALF	1.24	1.25	1.21	1.23	1.37	1.38	1.45	1.46	1.90	1.91	0.51	0.51	1.90	1.91	0.83	0.83	0.44	0.44	0.43	0.43	N/A	N/A	1.97	1.99	1.44	1.45
7day-MALF	1.52	1.54	1.49	1.51	1.68	1.70	1.78	1.80	2.30	2.32	0.62	0.63	2.31	2.32	1.00	1.01	0.54	0.55	0.53	0.53	N/A	N/A	2.40	2.43	1.75	1.76
70% 7day-MALF	1.39	1.40	1.36	1.38	1.53	1.55	1.62	1.64	2.10	2.12	0.56	0.57	2.11	2.12	0.91	0.92	0.49	0.49	0.48	0.48	N/A	N/A	2.20	2.22	1.59	1.61
50% 7day-MALF	1.27	1.29	1.25	1.27	1.40	1.42	1.49	1.50	1.93	1.94	0.51	0.52	1.93	1.95	0.84	0.84	0.45	0.45	0.44	0.44	N/A	N/A	2.02	2.04	1.46	1.47
FRE3	2.84	2.86	2.86	2.89	3.12	3.15	3.33	3.36	3.99	4.02	1.12	1.13	4.03	4.06	1.69	1.70	0.95	0.96	0.92	0.93	N/A	N/A	4.49	4.53	3.08	3.10
Q5	1.41	1.43	1.37	1.39	1.56	1.58	1.64	1.66	2.19	2.20	0.59	0.59	2.19	2.21	0.97	0.97	0.52	0.52	0.50	0.51	N/A	N/A	2.21	2.24	1.65	1.67
5% of MALF	1.33	1.34	1.27	1.29	1.47	1.49	1.54	1.56	2.11	2.13	0.57	0.57	2.11	2.13	0.95	0.95	0.51	0.51	0.49	0.49	N/A	N/A	2.07	2.10	1.60	1.61
10% of MALF	1.34	1.37	1.29	1.32	1.49	1.51	1.56	1.59	2.13	2.15	0.57	0.58	2.13	2.15	0.95	0.96	0.51	0.51	0.49	0.50	N/A	N/A	2.10	2.14	1.61	1.62
30% of MALF	1.41	1.42	1.37	1.38	1.56	1.57	1.64	1.66	2.19	2.20	0.59	0.59	2.19	2.20	0.97	0.97	0.52	0.52	0.50	0.51	N/A	N/A	2.21	2.24	1.65	1.67
50% of MALF	1.46	1.48	1.42	1.44	1.61	1.63	1.70	1.72	2.23	2.25	0.60	0.61	2.24	2.26	0.98	0.99	0.53	0.53	0.51	0.52	N/A	N/A	2.29	2.33	1.69	1.71

Table E.8 HSU 20-32 summary statistics of wetted width (pre-mining) based on the long term modelled flow statistic

Statistic (m)	7_20		7_21		9_22		9_23		8_24		8_25		8_26		8_27		8_28		10_29		10_30		10_31		10_32	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	2.46	2.48	4.83	4.86	N/A	N/A	5.47	5.51	1.30	1.31	1.86	1.87	N/A	N/A	1.13	1.13	2.52	2.54	N/A	N/A	N/A	N/A	1.09	1.09	7.02	7.06
Median flow	2.35	2.37	4.59	4.62	N/A	N/A	5.20	5.24	1.24	1.24	1.76	1.77	N/A	N/A	1.07	1.07	2.38	2.39	N/A	N/A	N/A	N/A	1.01	1.02	6.66	6.71
MALF	1.73	1.75	3.23	3.26	N/A	N/A	3.71	3.75	0.96	0.97	1.34	1.35	N/A	N/A	0.82	0.82	1.73	1.74	N/A	N/A	N/A	N/A	0.59	0.61	4.80	4.84
70% MALF	1.58	1.59	2.96	2.98	N/A	N/A	3.40	3.43	0.88	0.88	1.22	1.23	N/A	N/A	0.74	0.75	1.58	1.59	N/A	N/A	N/A	N/A	0.54	0.55	4.40	4.44
50% MALF	1.45	1.46	2.72	2.75	N/A	N/A	3.13	3.16	0.80	0.81	1.12	1.12	N/A	N/A	0.68	0.68	1.45	1.46	N/A	N/A	N/A	N/A	0.49	0.50	4.06	4.10
7day-MALF	1.76	1.78	3.30	3.34	N/A	N/A	3.79	3.83	0.98	0.98	1.36	1.37	N/A	N/A	0.83	0.83	1.76	1.77	N/A	N/A	N/A	N/A	0.62	0.64	4.90	4.94
70% 7day-MALF	1.61	1.62	3.02	3.06	N/A	N/A	3.48	3.51	0.89	0.89	1.24	1.24	N/A	N/A	0.75	0.76	1.60	1.62	N/A	N/A	N/A	N/A	0.57	0.58	4.50	4.54
50% 7day-MALF	1.48	1.49	2.78	2.81	N/A	N/A	3.20	3.23	0.81	0.82	1.13	1.14	N/A	N/A	0.69	0.69	1.47	1.48	N/A	N/A	N/A	N/A	0.52	0.53	4.15	4.19
FRE3	3.11	3.13	6.01	6.06	N/A	N/A	6.80	6.85	1.65	1.66	2.35	2.37	N/A	N/A	1.43	1.44	3.15	3.17	N/A	N/A	N/A	N/A	1.36	1.37	8.67	8.73
Q5	1.67	1.69	3.07	3.11	N/A	N/A	3.55	3.58	0.94	0.95	1.31	1.31	N/A	N/A	0.80	0.81	1.67	1.68	N/A	N/A	N/A	N/A	0.52	0.54	4.59	4.64
5% of MALF	1.61	1.62	2.91	2.94	N/A	N/A	3.38	3.41	0.93	0.93	1.28	1.28	N/A	N/A	0.79	0.79	1.62	1.63	N/A	N/A	N/A	N/A	0.40	0.43	4.38	4.41
10% of MALF	1.62	1.64	2.94	2.98	N/A	N/A	3.41	3.46	0.93	0.94	1.28	1.29	N/A	N/A	0.79	0.79	1.63	1.64	N/A	N/A	N/A	N/A	0.43	0.47	4.42	4.47
30% of MALF	1.67	1.68	3.07	3.10	N/A	N/A	3.55	3.58	0.94	0.95	1.31	1.31	N/A	N/A	0.80	0.80	1.67	1.68	N/A	N/A	N/A	N/A	0.52	0.54	4.59	4.63
50% of MALF	1.71	1.73	3.17	3.21	N/A	N/A	3.65	3.69	0.96	0.96	1.33	1.34	N/A	N/A	0.81	0.82	1.71	1.72	N/A	N/A	N/A	N/A	0.57	0.59	4.72	4.77

Table E.9 ***HSU 7-19 Summary statistics of the predicted wetted width (mining) based on the long term modelled flow statistic.***

Statistic (m)	5_7		5_8		5_9		5_10		7_11		7_12		7_13		9_14		9_15		9_16		9_17		6_18		7_19	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	2.25	2.27	2.28	2.29	2.48	2.50	2.65	2.66	3.16	3.18	0.87	0.88	3.20	3.22	1.33	1.34	0.74	0.74	0.72	0.72	N/A	N/A	3.59	3.61	2.44	2.45
Median flow	2.14	2.16	2.15	2.17	2.35	2.37	2.51	2.53	3.02	3.04	0.83	0.84	3.05	3.07	1.27	1.28	0.70	0.70	0.68	0.69	N/A	N/A	3.40	3.43	2.32	2.34
MALF	1.48	1.50	1.45	1.46	1.64	1.65	1.72	1.74	2.26	2.27	0.60	0.61	2.26	2.28	0.99	0.99	0.53	0.53	0.51	0.52	N/A	N/A	2.32	2.34	1.71	1.72
70% MALF	1.35	1.37	1.32	1.34	1.49	1.51	1.57	1.59	2.06	2.08	0.55	0.55	2.06	2.08	0.90	0.91	0.48	0.48	0.46	0.47	N/A	N/A	2.12	2.14	1.56	1.57
50% MALF	1.24	1.25	1.21	1.22	1.37	1.38	1.44	1.46	1.89	1.91	0.50	0.51	1.90	1.91	0.82	0.83	0.44	0.44	0.42	0.43	N/A	N/A	1.95	1.97	1.43	1.44
7day-MALF	1.52	1.54	1.49	1.51	1.68	1.70	1.77	1.79	2.30	2.31	0.61	0.62	2.30	2.32	1.00	1.01	0.53	0.54	0.52	0.52	N/A	N/A	2.38	2.41	1.74	1.75
70% 7day-MALF	1.39	1.40	1.36	1.38	1.53	1.55	1.61	1.63	2.10	2.11	0.56	0.56	2.10	2.12	0.91	0.92	0.49	0.49	0.47	0.48	N/A	N/A	2.18	2.20	1.59	1.60
50% 7day-MALF	1.27	1.29	1.24	1.26	1.40	1.42	1.48	1.50	1.93	1.94	0.51	0.52	1.93	1.94	0.83	0.84	0.44	0.45	0.43	0.43	N/A	N/A	2.00	2.03	1.45	1.47
FRE3	2.84	2.86	2.86	2.88	3.12	3.15	3.33	3.35	3.99	4.02	1.12	1.13	4.03	4.06	1.69	1.70	0.95	0.95	0.92	0.93	N/A	N/A	4.49	4.52	3.08	3.10
Q5	1.41	1.43	1.36	1.38	1.55	1.57	1.63	1.65	2.18	2.20	0.58	0.59	2.18	2.20	0.96	0.97	0.51	0.52	0.50	0.50	N/A	N/A	2.18	2.22	1.64	1.66
5% of MALF	1.33	1.34	1.26	1.28	1.47	1.49	1.53	1.55	2.11	2.12	0.56	0.56	2.10	2.12	0.94	0.95	0.50	0.50	0.48	0.49	N/A	N/A	2.04	2.07	1.58	1.59
10% of MALF	1.34	1.37	1.28	1.31	1.48	1.51	1.55	1.58	2.12	2.14	0.56	0.57	2.12	2.14	0.95	0.95	0.50	0.50	0.49	0.49	N/A	N/A	2.07	2.11	1.60	1.61
30% of MALF	1.41	1.42	1.36	1.38	1.56	1.57	1.63	1.65	2.18	2.20	0.58	0.59	2.18	2.20	0.96	0.97	0.51	0.51	0.50	0.50	N/A	N/A	2.18	2.21	1.65	1.66
50% of MALF	1.46	1.48	1.42	1.44	1.61	1.63	1.69	1.71	2.23	2.25	0.60	0.60	2.23	2.25	0.98	0.99	0.52	0.53	0.51	0.51	N/A	N/A	2.27	2.30	1.68	1.70

Table E.10 ***HSU 20-32 summary statistics of the predicted wetted width (mining) based on the long term modelled flow statistic***

Statistic (m)	7_20		7_21		9_22		9_23		8_24		8_25		8_26		8_27		8_28		10_29		10_30		10_31		10_32	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	2.46	2.47	4.81	4.84	N/A	N/A	5.45	5.49	N/A	N/A	1.84	1.85	N/A	N/A	1.12	1.13	2.50	2.52	N/A	N/A	N/A	N/A	1.09	1.09	6.979	7.022
Median flow	2.34	2.36	4.57	4.60	N/A	N/A	5.18	5.22	N/A	N/A	1.74	1.75	N/A	N/A	1.06	1.07	2.35	2.37	N/A	N/A	N/A	N/A	1.01	1.02	6.613	6.662
MALF	1.71	1.73	3.16	3.20	N/A	N/A	3.64	3.68	N/A	N/A	1.28	1.30	N/A	N/A	0.81	0.82	1.66	1.68	N/A	N/A	N/A	N/A	0.59	0.61	4.647	4.697
70% MALF	1.56	1.58	2.89	2.93	N/A	N/A	3.33	3.37	N/A	N/A	1.17	1.18	N/A	N/A	0.73	0.74	1.52	1.53	N/A	N/A	N/A	N/A	0.54	0.55	4.266	4.312
50% MALF	1.44	1.45	2.66	2.70	N/A	N/A	3.07	3.10	N/A	N/A	1.07	1.08	N/A	N/A	0.67	0.68	1.39	1.41	N/A	N/A	N/A	N/A	0.49	0.50	3.935	3.977
7day-MALF	1.75	1.76	3.24	3.28	N/A	N/A	3.73	3.77	N/A	N/A	1.30	1.32	N/A	N/A	0.82	0.83	1.70	1.72	N/A	N/A	N/A	N/A	0.62	0.64	4.759	4.814
70% 7day-MALF	1.59	1.61	2.97	3.01	N/A	N/A	3.41	3.45	N/A	N/A	1.19	1.20	N/A	N/A	0.74	0.75	1.55	1.57	N/A	N/A	N/A	N/A	0.57	0.58	4.369	4.419
50% 7day-MALF	1.46	1.48	2.73	2.77	N/A	N/A	3.14	3.18	N/A	N/A	1.09	1.10	N/A	N/A	0.68	0.69	1.42	1.44	N/A	N/A	N/A	N/A	0.52	0.53	4.030	4.076
FRE3	3.10	3.12	5.99	6.03	N/A	N/A	6.77	6.82	N/A	N/A	2.32	2.34	N/A	N/A	1.43	1.44	3.12	3.14	N/A	N/A	N/A	N/A	1.36	1.37	8.607	8.672
Q5	1.65	1.67	2.99	3.04	N/A	N/A	3.46	3.50	N/A	N/A	1.25	1.26	N/A	N/A	0.79	0.80	1.60	1.62	N/A	N/A	N/A	N/A	0.52	0.53	4.415	4.473
5% of MALF	1.59	1.60	2.82	2.85	N/A	N/A	3.28	3.31	N/A	N/A	1.21	1.22	N/A	N/A	0.77	0.78	1.53	1.55	N/A	N/A	N/A	N/A	0.39	0.43	4.174	4.221
10% of MALF	1.60	1.62	2.85	2.90	N/A	N/A	3.31	3.37	N/A	N/A	1.22	1.23	N/A	N/A	0.77	0.78	1.54	1.57	N/A	N/A	N/A	N/A	0.43	0.47	4.223	4.291
30% of MALF	1.65	1.66	3.00	3.03	N/A	N/A	3.46	3.50	N/A	N/A	1.24	1.26	N/A	N/A	0.79	0.80	1.60	1.61	N/A	N/A	N/A	N/A	0.52	0.54	4.420	4.468
50% of MALF	1.69	1.71	3.10	3.15	N/A	N/A	3.58	3.62	N/A	N/A	1.27	1.28	N/A	N/A	0.80	0.81	1.64	1.66	N/A	N/A	N/A	N/A	0.57	0.59	4.566	4.628

Table E.11 HSU 7-19 Percentage reduction of predictive wetted width (pre-mining versus mining).

% Reduction	5_7		5_8		5_9		5_10		7_11		7_12		7_13		9_14		9_15		9_16		9_17		6_18		7_19	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.2	0.1	0.1	0.1	0.1	0.4	0.4	0.4	0.3	N/A	N/A	0.2	0.2	0.1	0.1
Median flow	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.2	0.1	0.1	0.1	0.1	0.4	0.5	0.5	0.4	N/A	N/A	0.2	0.2	0.2	0.2
MALF	0.1	0.1	0.5	0.4	0.1	0.1	0.6	0.4	0.1	0.1	1.1	0.8	0.3	0.3	0.4	0.3	1.4	1.3	1.5	1.2	N/A	N/A	1.1	0.9	0.6	0.5
70% MALF	0.1	0.1	0.5	0.4	0.1	0.1	0.6	0.4	0.1	0.1	1.1	0.8	0.3	0.3	0.4	0.3	1.4	1.3	1.5	1.2	N/A	N/A	1.1	0.9	0.6	0.5
50% MALF	0.1	0.1	0.5	0.4	0.1	0.1	0.6	0.4	0.1	0.1	1.1	0.8	0.3	0.3	0.4	0.3	1.4	1.3	1.5	1.2	N/A	N/A	1.1	0.9	0.6	0.5
7day-MALF	0.1	0.1	0.3	0.3	0.1	0.1	0.5	0.4	0.2	0.1	1.1	0.7	0.3	0.3	0.4	0.3	1.3	1.2	1.4	1.1	N/A	N/A	1.0	0.8	0.6	0.5
70% 7day-MALF	0.1	0.1	0.3	0.3	0.1	0.1	0.5	0.4	0.2	0.1	1.1	0.7	0.3	0.3	0.4	0.3	1.3	1.2	1.4	1.1	N/A	N/A	1.0	0.8	0.6	0.5
50% 7day-MALF	0.1	0.1	0.3	0.3	0.1	0.1	0.5	0.4	0.2	0.1	1.1	0.7	0.3	0.3	0.4	0.3	1.3	1.2	1.4	1.1	N/A	N/A	1.0	0.8	0.6	0.5
FRE3	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.2	0.1	0.1	0.1	0.1	0.4	0.5	0.5	0.4	N/A	N/A	0.2	0.2	0.2	0.2
Q5	0.1	0.1	0.6	0.5	0.1	0.1	0.7	0.5	0.2	0.1	1.0	0.9	0.3	0.3	0.3	0.3	1.5	1.4	1.5	1.3	N/A	N/A	1.3	1.2	0.6	0.6
5% of MALF	0.1	0.1	0.8	0.6	0.1	0.1	0.7	0.7	0.2	0.2	1.2	1.0	0.4	0.4	0.4	0.3	1.6	1.5	1.7	1.4	N/A	N/A	1.7	1.5	0.8	0.7
10% of MALF	0.1	0.1	0.6	0.6	0.1	0.1	0.7	0.6	0.2	0.1	1.1	1.0	0.4	0.3	0.4	0.3	1.6	1.5	1.7	1.4	N/A	N/A	1.6	1.4	0.7	0.7
30% of MALF	0.1	0.1	0.7	0.5	0.1	0.1	0.5	0.5	0.1	0.1	1.0	0.9	0.3	0.3	0.3	0.3	1.5	1.4	1.5	1.3	N/A	N/A	1.3	1.2	0.6	0.6
50% of MALF	0.1	0.1	0.4	0.4	0.1	0.1	0.5	0.5	0.2	0.1	0.9	0.8	0.4	0.3	0.4	0.3	1.4	1.3	1.5	1.2	N/A	N/A	1.1	1.0	0.6	0.6

Table E.12 HSU 20-32 Percentage reduction of predictive wetted width (pre-mining versus mining).

% Reduction	7_20		7_21		9_22		9_23		8_24		8_25		8_26		8_27		8_28		10_29		10_30		10_31		10_32	
	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean	5%ile	Mean
Average flow	0.2	0.2	0.4	0.4	N/A	N/A	0.4	0.4	N/A	N/A	1.2	1.0	N/A	N/A	0.3	0.3	0.9	0.8	N/A	N/A	N/A	N/A	0.0	0.0	0.6	0.6
Median flow	0.3	0.3	0.4	0.4	N/A	N/A	0.5	0.5	N/A	N/A	1.3	1.3	N/A	N/A	0.4	0.4	1.0	1.0	N/A	N/A	N/A	N/A	0.0	0.0	0.8	0.7
MALF	1.1	1.0	2.1	1.9	N/A	N/A	2.1	1.9	N/A	N/A	4.1	3.8	N/A	N/A	1.5	1.0	3.8	3.5	N/A	N/A	N/A	N/A	0.1	0.0	3.1	2.9
70% MALF	1.1	1.0	2.1	1.9	N/A	N/A	2.1	1.9	N/A	N/A	4.1	3.8	N/A	N/A	1.5	1.0	3.8	3.5	N/A	N/A	N/A	N/A	0.1	0.0	3.1	2.9
50% MALF	1.1	1.0	2.1	1.9	N/A	N/A	2.1	1.9	N/A	N/A	4.1	3.8	N/A	N/A	1.5	1.0	3.8	3.5	N/A	N/A	N/A	N/A	0.1	0.0	3.1	2.9
7day-MALF	1.0	0.9	1.8	1.7	N/A	N/A	1.8	1.7	N/A	N/A	3.9	3.6	N/A	N/A	1.4	1.0	3.5	3.2	N/A	N/A	N/A	N/A	0.0	0.0	2.8	2.6
70% 7day-MALF	1.0	0.9	1.8	1.7	N/A	N/A	1.8	1.7	N/A	N/A	3.9	3.6	N/A	N/A	1.4	1.0	3.5	3.2	N/A	N/A	N/A	N/A	0.0	0.0	2.8	2.6
50% 7day-MALF	1.0	0.9	1.8	1.7	N/A	N/A	1.8	1.7	N/A	N/A	3.9	3.6	N/A	N/A	1.4	1.0	3.5	3.2	N/A	N/A	N/A	N/A	0.0	0.0	2.8	2.6
FRE3	0.3	0.3	0.4	0.4	N/A	N/A	0.5	0.5	N/A	N/A	1.3	1.3	N/A	N/A	0.4	0.4	1.0	1.0	N/A	N/A	N/A	N/A	0.0	0.0	0.8	0.7
Q5	1.2	1.1	2.6	2.3	N/A	N/A	2.4	2.2	N/A	N/A	4.4	4.1	N/A	N/A	1.6	1.1	4.2	4.0	N/A	N/A	N/A	N/A	0.1	0.1	3.7	3.5
5% of MALF	1.5	1.3	3.0	2.9	N/A	N/A	2.9	2.8	N/A	N/A	5.2	4.6	N/A	N/A	1.9	1.2	5.2	4.6	N/A	N/A	N/A	N/A	0.2	0.2	4.6	4.4
10% of MALF	1.4	1.3	2.9	2.7	N/A	N/A	2.8	2.6	N/A	N/A	5.1	4.5	N/A	N/A	1.9	1.2	5.1	4.4	N/A	N/A	N/A	N/A	0.2	0.1	4.4	4.1
30% of MALF	1.1	1.1	2.4	2.3	N/A	N/A	2.3	2.2	N/A	N/A	4.7	4.2	N/A	N/A	1.7	1.1	4.4	4.0	N/A	N/A	N/A	N/A	0.1	0.1	3.7	3.5
50% of MALF	1.2	1.0	2.2	2.0	N/A	N/A	2.1	2.0	N/A	N/A	4.2	3.9	N/A	N/A	1.4	1.1	4.0	3.6	N/A	N/A	N/A	N/A	0.0	0.1	3.3	3.1

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