AMURI IRRIGATION CO

MEMORANDUM

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Reviewer	Matthew Morgan
To	Jeanine Topelen (Environment Canterbury)
Date	25 September 2017
Subject	Hydrological change from implementing HWRRP minimum flows
Status	FINAL

Overview

This memorandum describes a hydrological model of the Hurunui and Waiau Rivers that was set up to assess how main stem flows will change when Hurunui Waiau River Regional Plan (HWRRP) minimum flows are implemented on all water take permits. Results are summarised in Table 1. Since the change only affects A-Block water, only lower flows are affected. The change has no impact on median or fresher flows. Results consider only the minimum flow change impact, and not the impact of Amuri Irrigation's piping project. Piping impacts are considered separately. Scenarios 1 and 2 provide an upper and lower estimate. Scenario 1 assumes water is only taken when there is a demand for irrigation, while Scenario 2 assumes water is taken when available, regardless of the demand.

Table 1: Change in Hurunui River at SH1 from implementing HWRRP minimum flows

Parameter	Current	With change		% change	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2
Mean flow (m^3/s)	68.72	68.83	68.89	0.2%	0.2%
Median flow (m^3/s)	52.05	52.06	52.06	0.0%	0.0%
5%ile	22.40	23.93	24.35	6.9%	8.7%
7DMALF (m^3/s)	21.83	22.87	23.15	4.7%	6.0%
FRE3 (mean #/y)	6.9	6.9	6.9	0.0%	0.0%

Table 2: Change in Waiau River at Mouth from implementing HWRRP minimum flows

Key parameters	Current	With change		% change	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2
Mean flow	103.40	103.63	103.69	0.2%	0.3%
Median flow	79.99	79.99	79.99	0.0%	0.0%
5%ile	25.80	27.68	27.98	7.3%	8.4%
MALF	24.96	27.47	27.79	10.1%	11.4%
FRE3 (mean #/y)	9.1	9.1	9.1	0.0%	0.0%

Time series extension

Four sites were used in modelling – two upstream sites where flows are largely naturalised (Hurunui US Mandamus and Waiau at Marble Point), and two downstream sites that are altered by irrigation takes (Hurunui at SH1 and Waiau at Mouth). For each of these locations a timeseries of average daily flow was generated for the period June 1960 to August 2017. The timeseries were extended to provide a greater length of record for the main catchment model. Any errors in timeseries extension have only a minor impact on the main catchment model, which estimates the *change* to the status quo.

Flow records for the Hurunui upstream of the Mandamus confluence extend back before 1960. We used data from June 1960 to present. Only minor gap filling was required. Waiau at Marble point has flow data from 1967. The record was extended back to 1960 using correlation with Hurunui US Mandamus.

For the Hurunui at SH1, flow data from 2005 was used, and extended back to 1960 using correlation with the upstream recorder. This date range was used to reflect the 'status quo', where A-Block water has been fully developed, and most borderdyke irrigation has converted to spray irrigation. Flows at SH1 are impacted by irrigation practises, including the inter-catchment transfer from the Waiau River via the Amuri Irrigation Scheme. From 1960 to 2005 model flows represent what flows would have been like given current irrigation infrastructure and practises, not actual historic flows, which would have been different prior to large scale irrigation. That is, the historic modelled timeseries is a modified flow that includes the impacts of all irrigation takes in use at the time the HWRRP became operative.

Continuous flow data has been available in the Waiau River at the Mouth (upstream of the reach of tidal influence) since 2010. This was extended back to 1960 using correlation with the upstream recorder. Like the Hurunui at SH1, modelled flows for the period 1960 to 2010 is a modified flow that includes the impact of current irrigation practises. The modelled flow is not an estimate of actual historic flows, that would have been different prior to large scale irrigation development in the 1980's.

In the Hurunui, there is a net gain in the mainstem from the Mandamus confluence to SH1 (refer Table 4). That is, tributary and bywash gains exceed irrigation abstraction losses. Consequently, reliability for lower Hurunui irrigators is significantly better than for irrigators who abstract water above SH1. In contrast, in the Waiau River at times there is a net loss from Marble Point to the Mouth, reflecting the impact of a larger irrigation take and less irrigation return flow. The impact is greatest from January to March at lower flows. 7DMALF at the Mouth is 6-7 m^3/s lower than at Marble Point.

Further details are provided in Appendix A.

Table 3: Time series extension

Name	Site No.	Data availability	Gap filling and timeseries extension
Hurunui US Mandamus	65104	1960-2017	Correlation with 64602(1)
Waiau at Marble Point	64602	1967-2017	Correlation with 65104
Hurunui at SH1	65101	2005-2017(2)	Correlation with 65104
Waiau at Mouth	64609	2010-2017	Correlation with 65602

1. Minor gap filling only.
2. Data is available, but was not used for the period prior to 1/1/2005.

Table 4: Net gain in flow between Hurunui Mandamus recorder and SH1 at HWRRP minimum flows

Month	Flow (m^3)		
	US Mandamus	SH1* (average)	Gain (average)
Sep	15	20.3	5.3
Oct	15	20.1	5.1
Nov	15	18.0	3.0
Dec	15	18.3	3.3
Jan	15	17.7	2.7
Feb	15	19.2	4.2
Mar	15	21.3	6.3
Apr	15	23.4	8.4

*Estimated from correlation relationship with 65101. Refer Appendix A.

Minimum flow change

The model considers how main stem flows at the two lower sites (SH1 and Mouth) will change when HWRRP minimum flows are implemented on all water take permits. Modelling considers only the impact of consented minimum flow conditions, and assumes all other aspects (irrigated area and type, distribution losses) are the same as when the HWRRP became operative.

Some A-Block consents already have HWRRP minimum flows or comparable reliability. A preliminary summary of consents by reliability is provided below. Environment Canterbury is currently undertaking a more extensive analysis of consents. Only water permits that have supply reliability that is more favourable than the HWRRP will impact of river flows. A few A-Block consents have reliability that is less favourable than the HWRRP.

Table 5: Mainstem Hurunui and Waiau A-Block consent reliability

Reliability	Approx. A-Block allocation (m^3/s)	
	Hurunui Mandamus to SH1	Waiau below Marble Point*
Better than HWRRP	5.1	14.5
Comparable to HWRRP	1.0	3.3
HWRRP	0.4	

*Estimate provided by Environment Canterbury on 3 August

For the Hurunui, we have assumed that 6.0 m^3/s of A-Block irrigation water between Mandamus to SH1 currently has better reliability than HWRRP minimum flows. This includes a 0.9 m^3/s allowance for tributary water permits.

Not all water taken for irrigation is consumptively used (i.e. net water use is less than gross abstraction). Conveyance water from schemes (e.g. Amuri Irrigation) is returned to the mainstem within about 24 hours of the water being taken. For both the Hurunui and Waiau we have allowed for 1.0 m^3/s of losses, most of which will be conveyance water.

Net consumption = Gross take – losses

Net consumption depends both on the demand, and whether the water is available. Scenario 1 considers both irrigation demand and water availability. That is, water is only removed from the system if it is available *and* there is irrigation demand. Irrigation demand is calculated from a soil water balance model. Scenario 2 is more conservative and considers only water availability (i.e. if the water is available it is taken and consumed).

For current restrictions, we modelled Amuri Irrigation's consent reliability (CRC951304 for Waiau, and CRC951326.1 for Hurunui), since these water permits account for most of the A-Block allocation that is not yet on HWRRP minimum flows.

The change in flow is given by:

$(HWRRP_{\%\ available} - Current_{\%\ available}) \times Net\ consumption$

and

Scenario 1: *Net consumption = block size/maximum net consumption*
Scenario 2: *Net consumption = MINIMUM(block size, irrigation demand)*

For example, the change in flow in the Hurunui at SH1 on 10 March 2017 is:

Scenario 1: MINIMUM[(28% - 96%) ×5.0m^3/s, 2.33[1] m^3/s] = 2.33 m^3/s

Scenario 2: (6% - 68%) ×5.0m3/s = 3.1m^3/s

Further details are provided in the associated spreadsheet.

[1] Net irrigation demand on this day from soil water balance modelling was 2.33m^3/s

Results

Results are presented below. The change to minimum flows only affects the river when flows are low. It has no impact on fresher frequency, and virtually no impact on mid-range flows. The change will result in a 5-6% increase in 7DMALF[2] for the Hurunui at SH1, and a 10-11% increase in 7DMALF for the Waiau River at the Mouth.

Table 6: Change in Hurunui River at SH1 from implementing HWRRP minimum flows (1960-2017)

Parameter	Current	With change		% change	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2
Mean flow (m^3/s)	68.72	68.83	68.89	0.2%	0.2%
Median flow (m^3/s)	52.05	52.06	52.06	0.0%	0.0%
5%ile	22.40	23.93	24.35	6.9%	8.7%
7DMALF (m^3/s)	21.83	22.87	23.15	4.7%	6.0%
FRE3 (mean #/y)	6.9	6.9	6.9	0.0%	0.0%

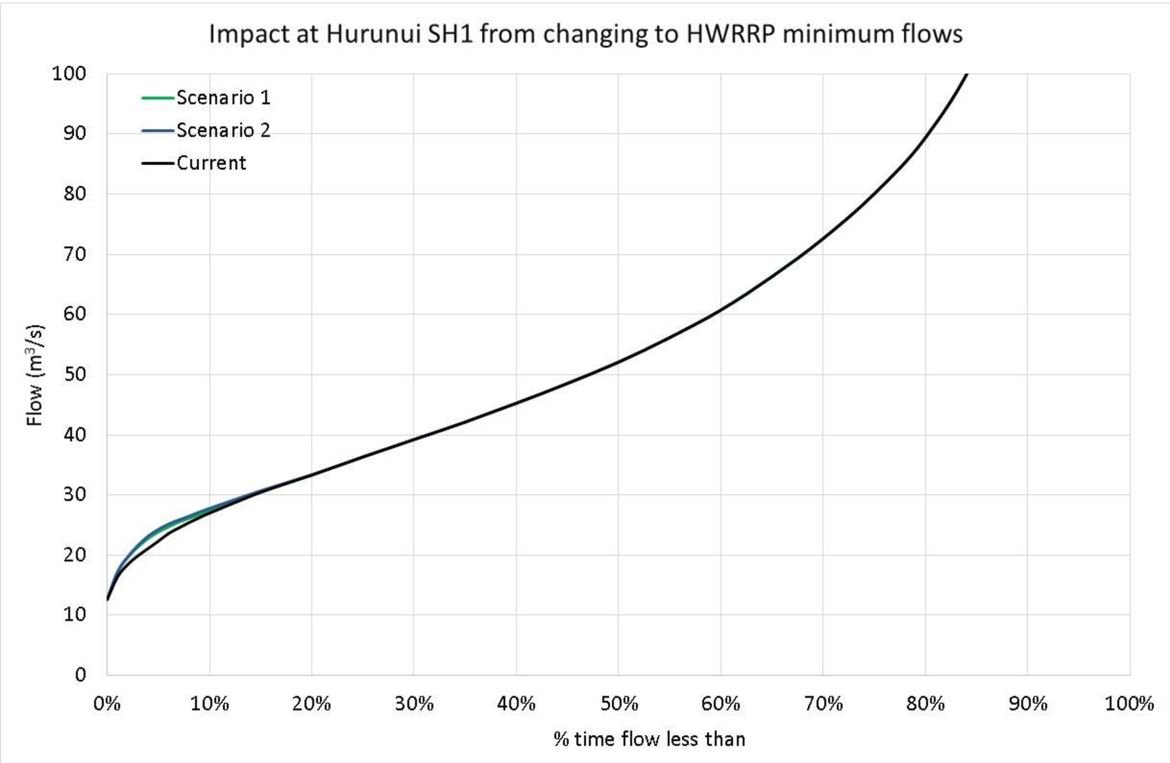


Figure 1: Hurunui at SH1 with minimum flow change. Flow duration curve (0-100m^3/s)

[2] 7 day mean annual low flow

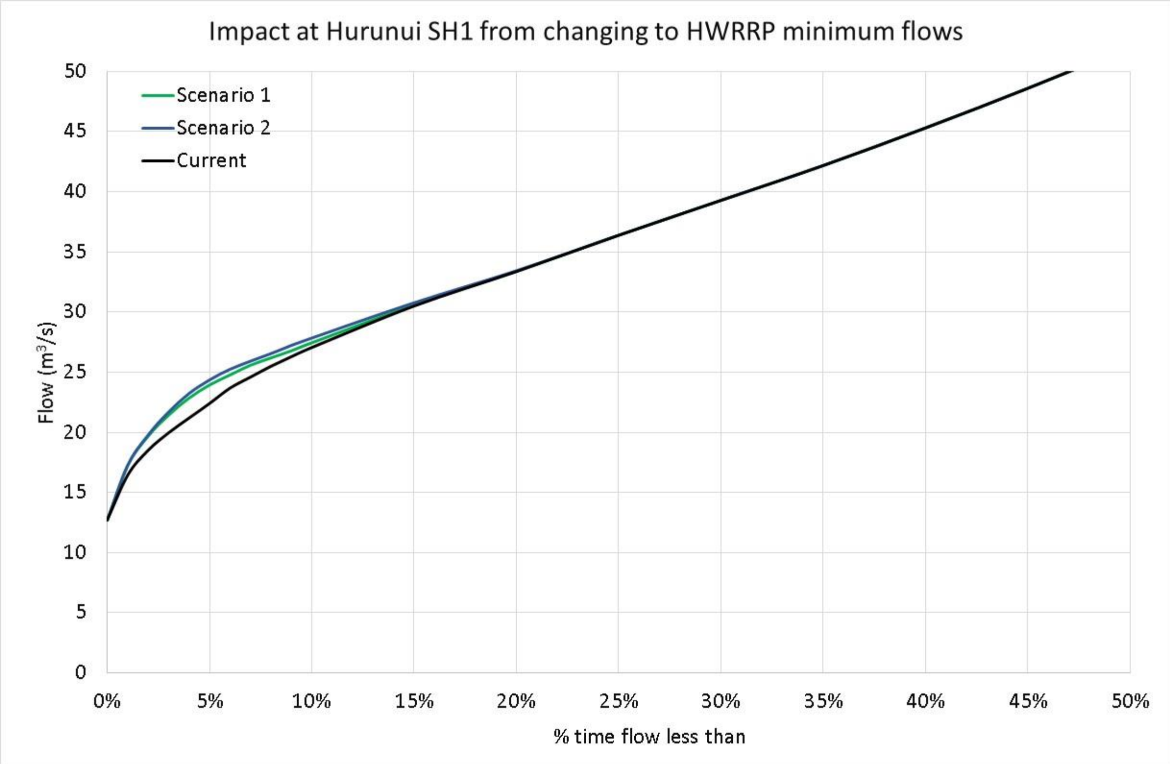


Figure 2: Hurunui at SH1 with minimum flow change. Flow duration curve (0-50m^3/s)

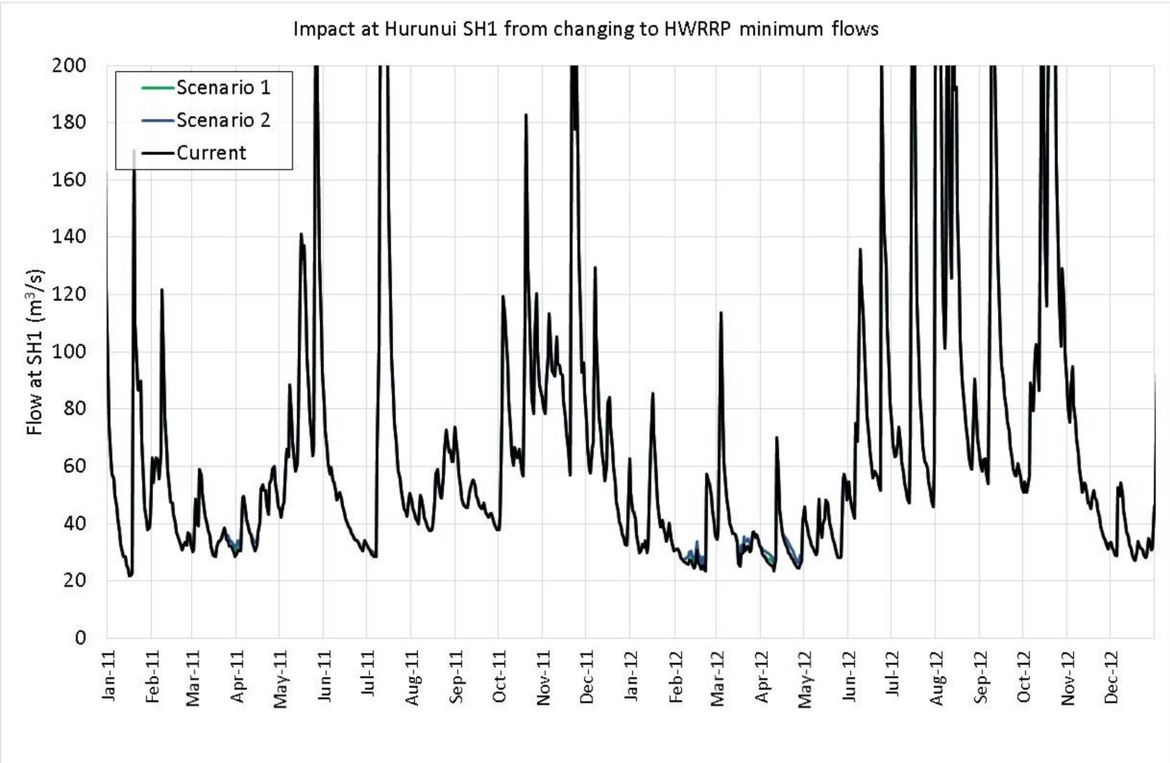


Figure 3: Hurunui at SH1 with minimum flow change. 2011-12

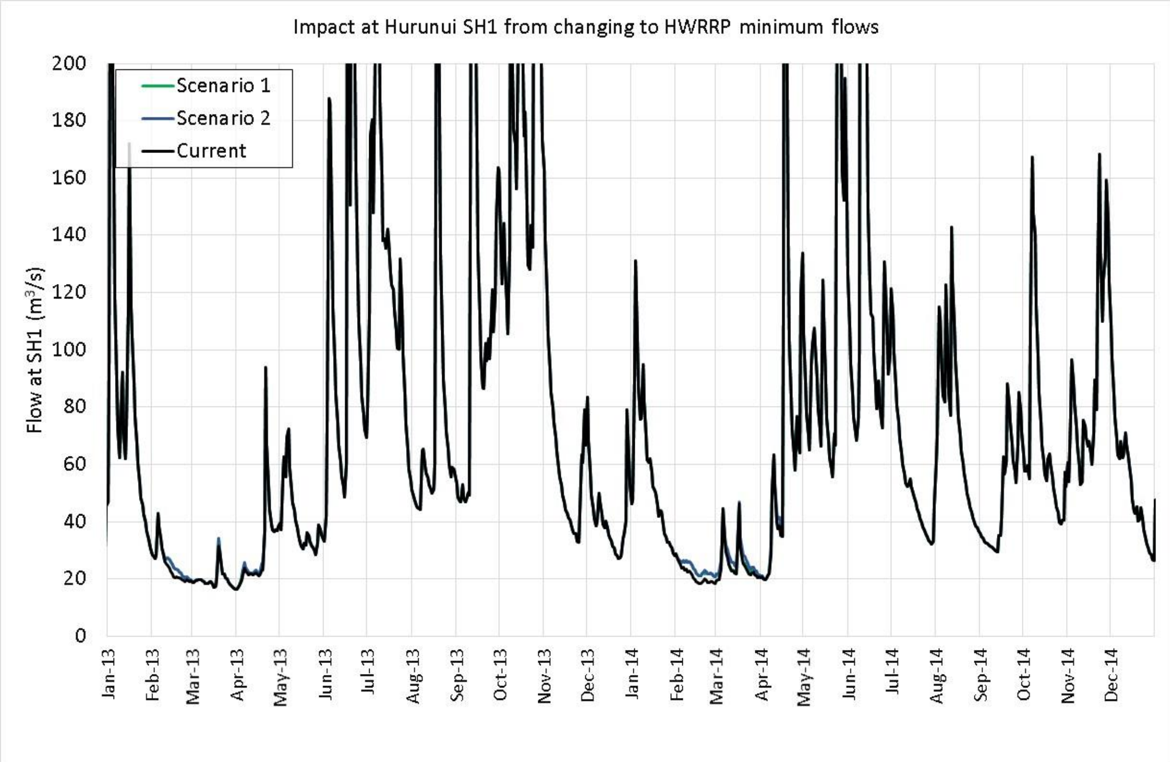


Figure 4: Hurunui at SH1 with minimum flow change. 2013-14

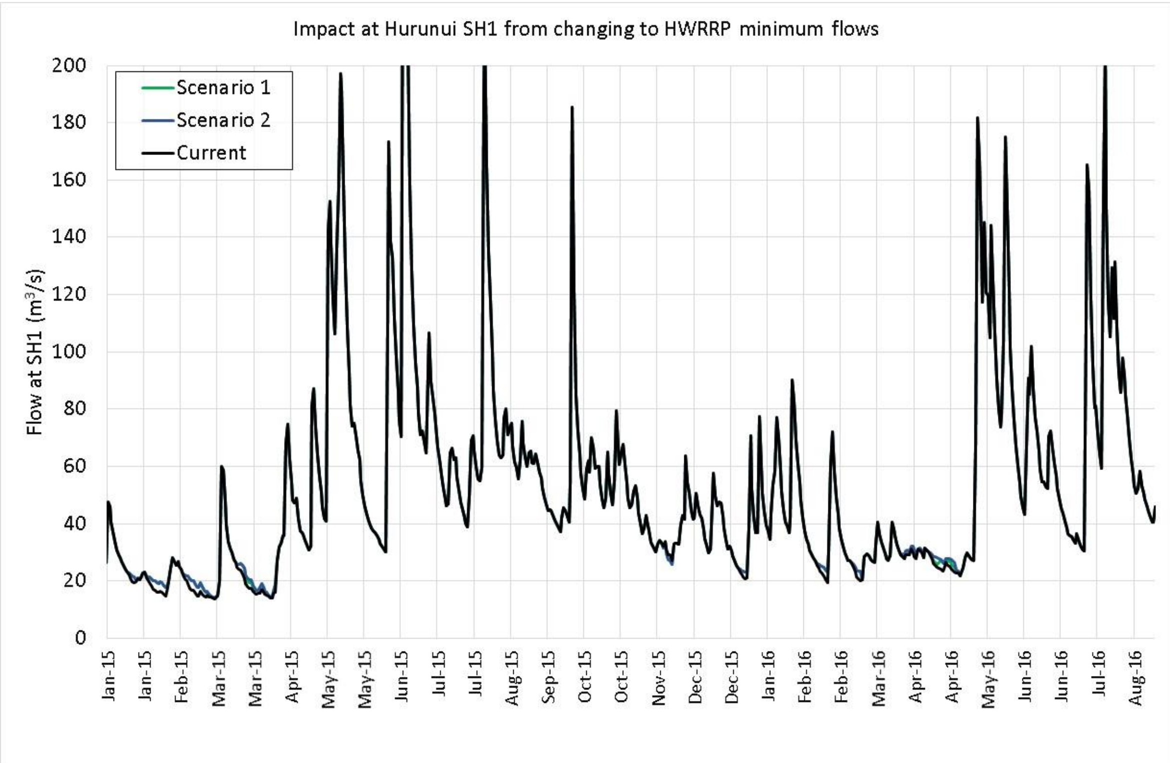


Figure 5: Hurunui at SH1 with minimum flow change. 2015-16

Table 7: Change in Waiau River at Mouth from implementing HWRRP minimum flows (1960-2017)

Key parameters	Current	With change		% change	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2
Mean flow	103.40	103.63	103.69	0.2%	0.3%
Median flow	79.99	79.99	79.99	0.0%	0.0%
5%ile	25.80	27.68	27.98	7.3%	8.4%
MALF	24.96	27.47	27.79	10.1%	11.4%
FRE3 (mean #/y)	9.1	9.1	9.1	0.0%	0.0%

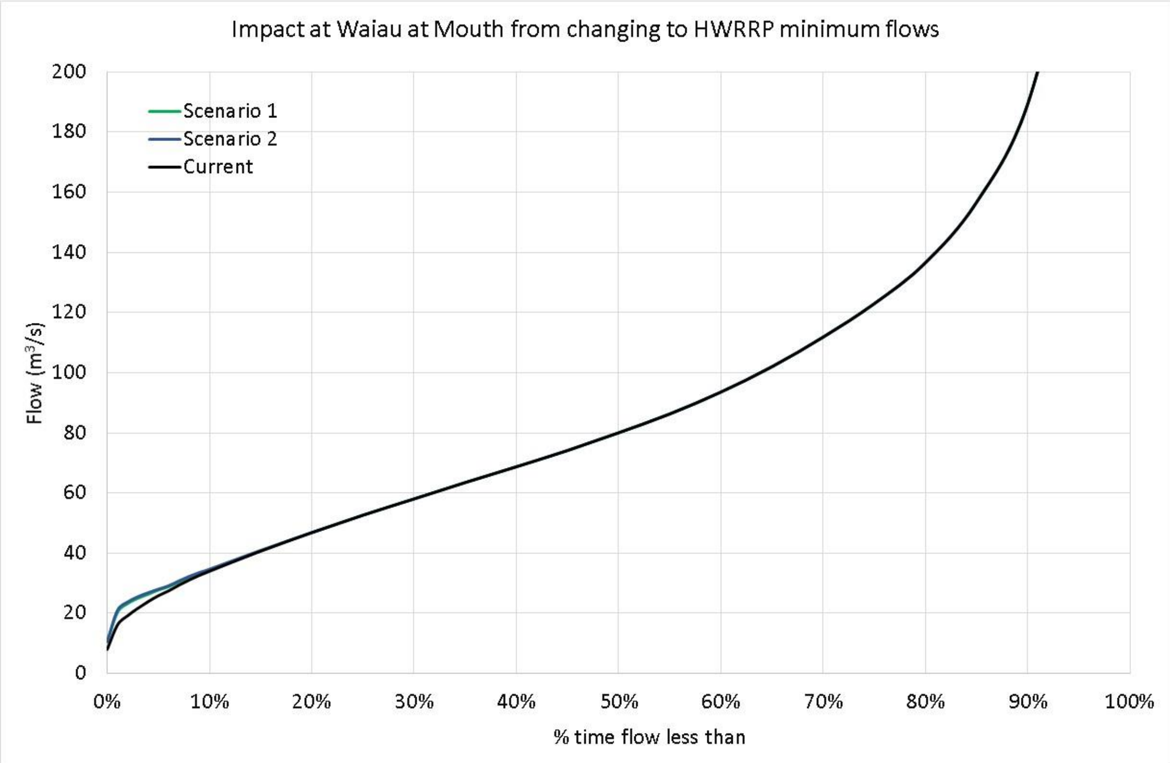


Figure 6: Waiau at Mouth with minimum flow change. Flow duration curve (0-200m^3/s)

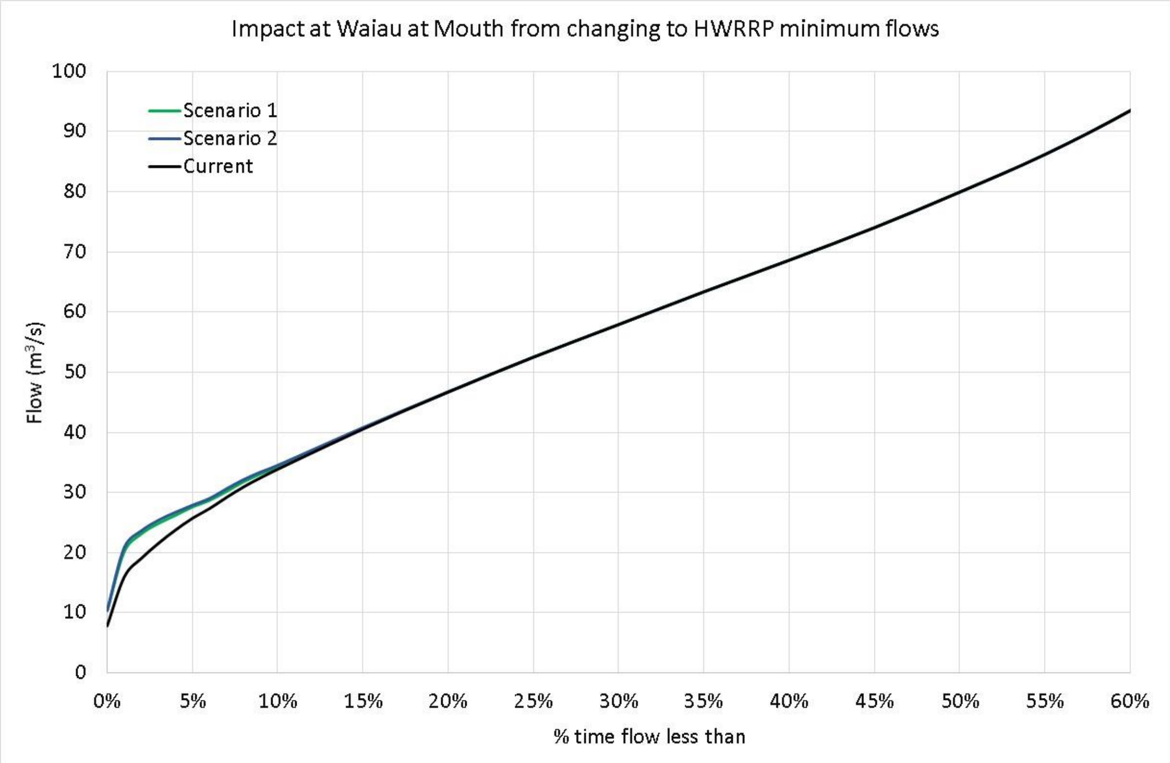


Figure 7: Waiau at Mouth with minimum flow change. Flow duration curve (0-100m^3/s)

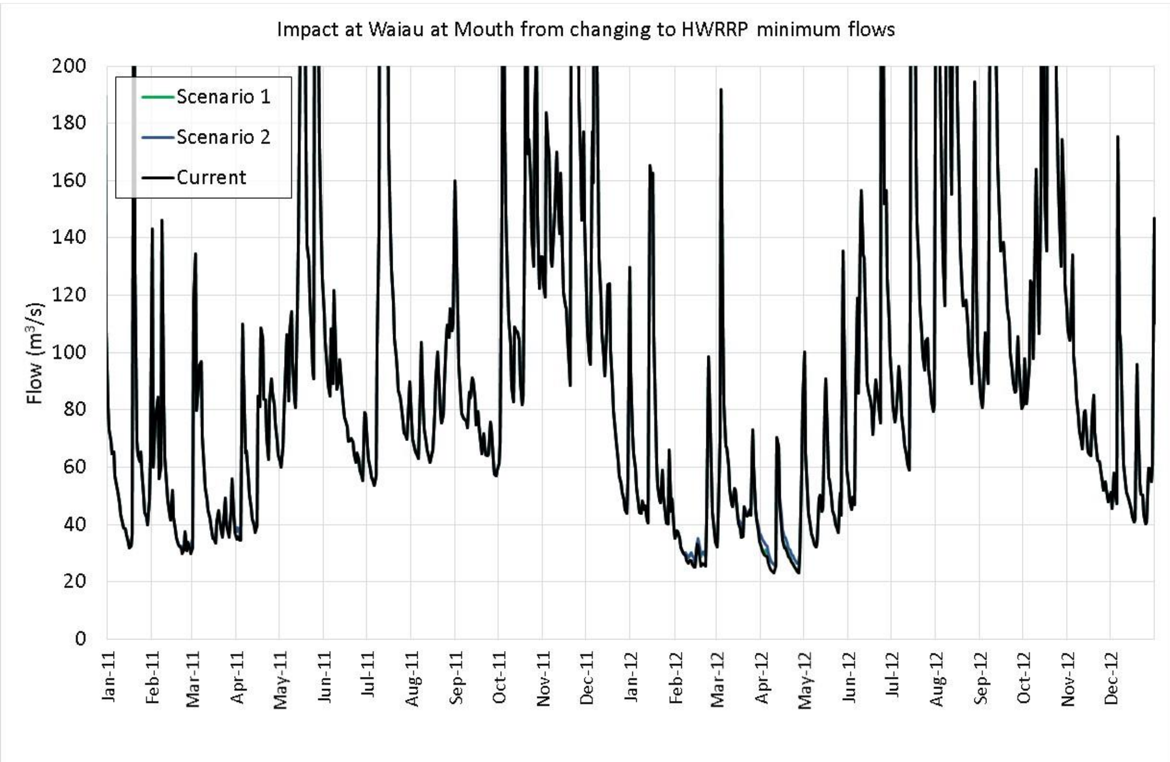


Figure 8: Waiau at Mouth with minimum flow change. 2011-12

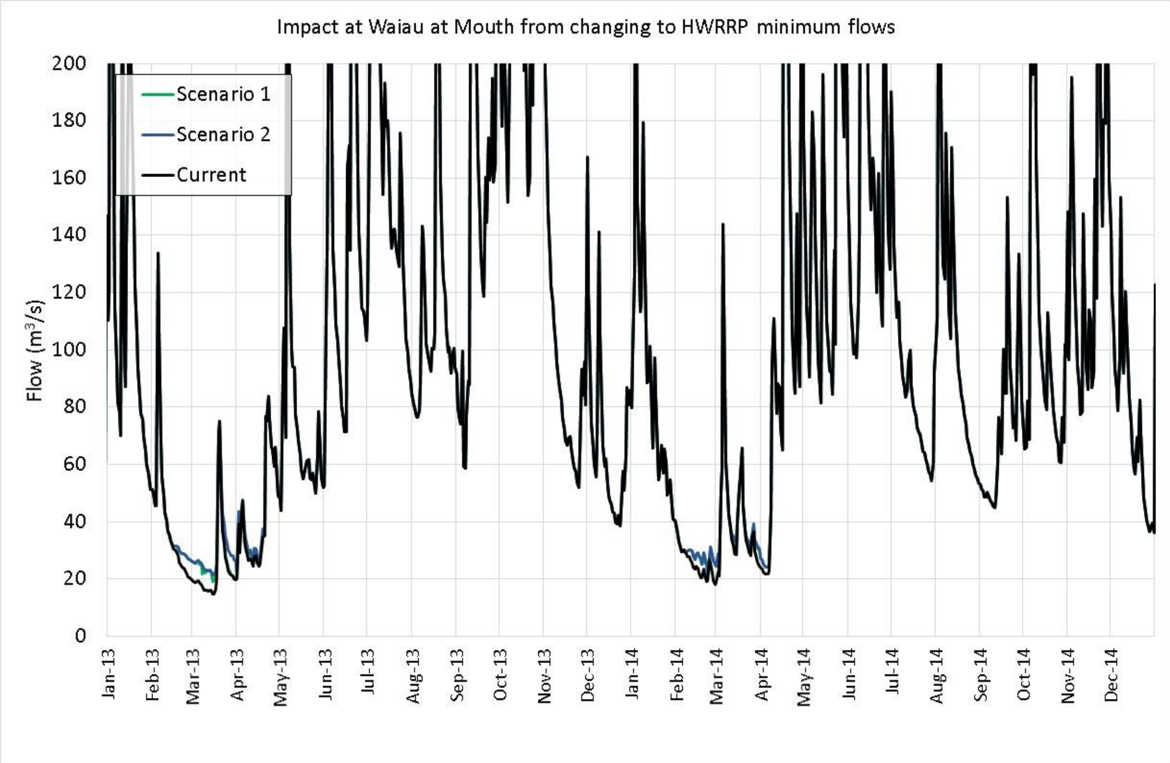


Figure 9: Waiau at Mouth with minimum flow change. 2013-14

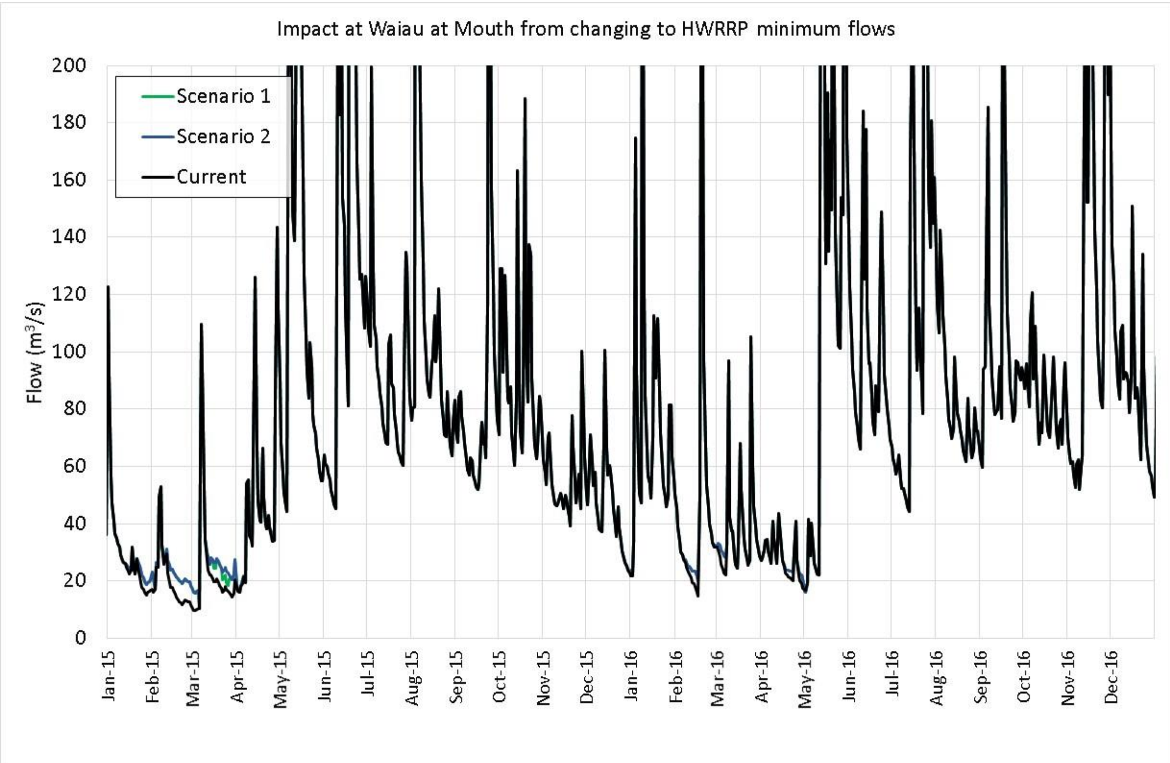


Figure 10: Waiau at Mouth with minimum flow change. 2015-16

Appendix A: Time series extension

Hurunui River upstream of Mandamus Confluence

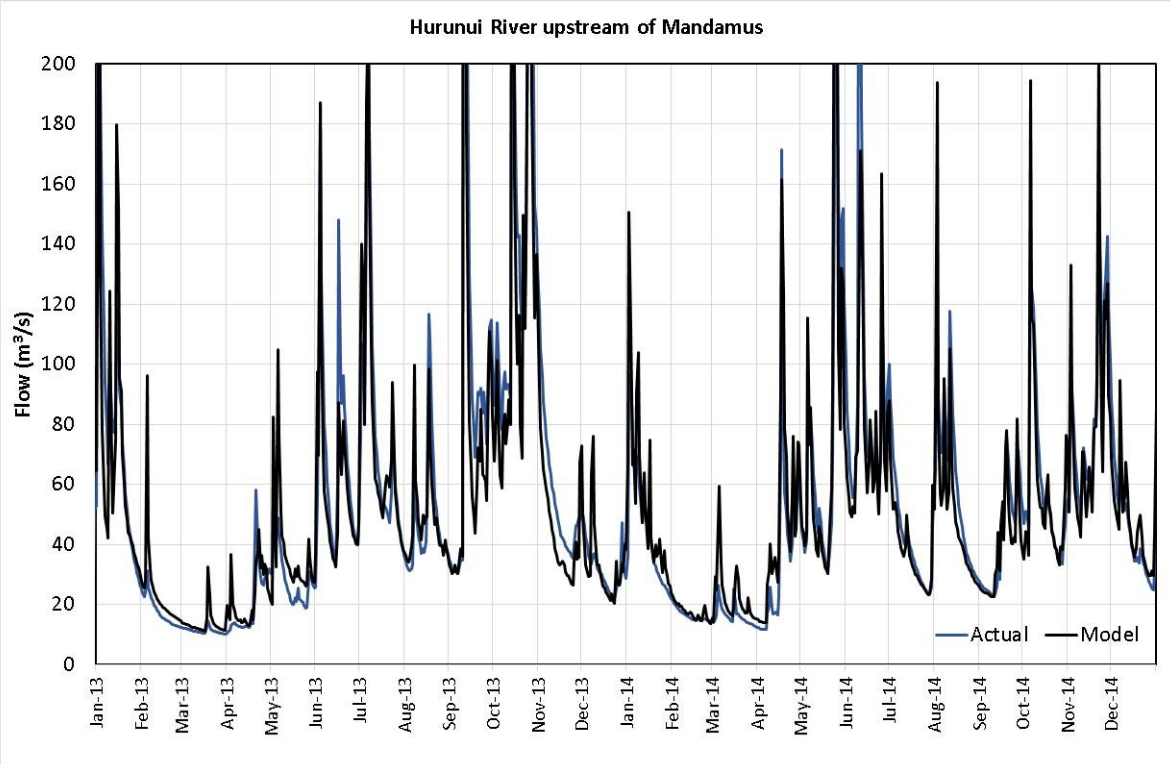
Parameter setting for the relationship with Waiau at Marble Point was optimised to minimise errors at low flows, up to 2 times MALF. However, the model is not an accurate predictor of peak flood flows, since Lake Sumner means peak flood flows in the Hurunui are more attenuated than in the Waiau. Lake Sumner has a lesser impact on low flow recessions. Only 0.1% gap filling was required, so any errors in synthetic flows have a negligible impact on catchment modelling.

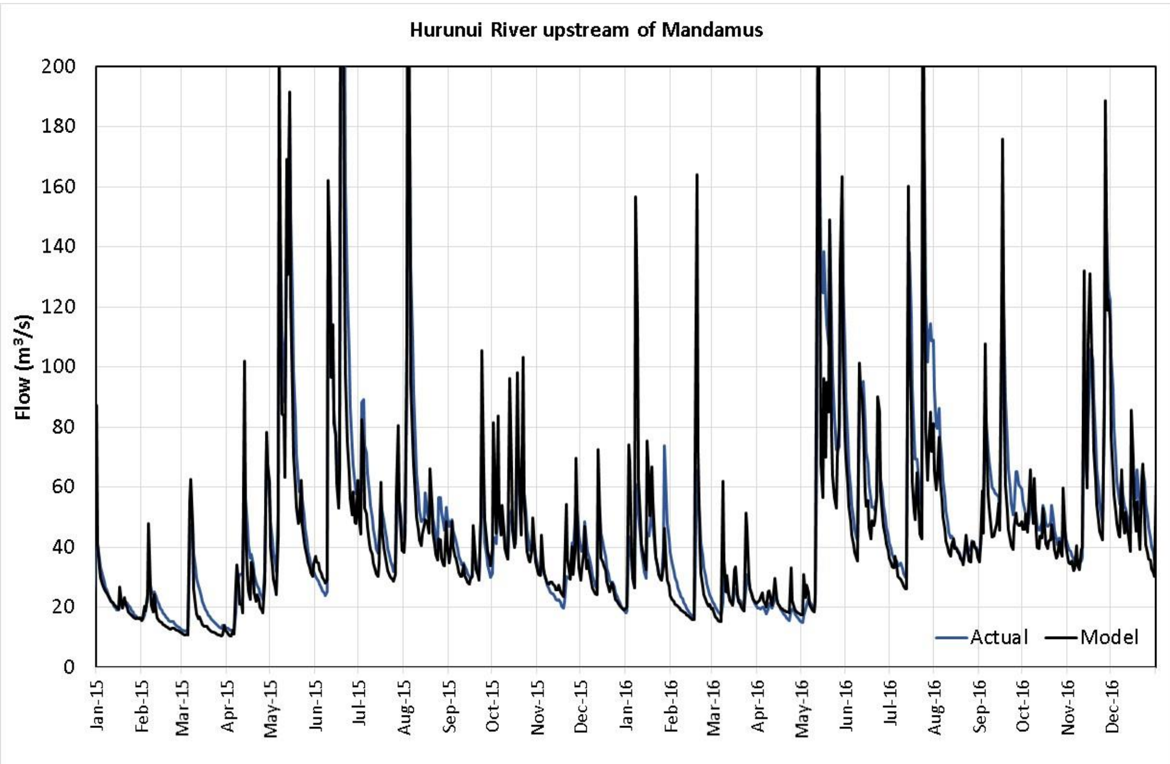
Parameter	Value
Data availability	1960-2017
% gap filling	0.1%
Correlation with	64602

$Flow_1 = A \times Flow_1 + B$

Month	A	B
Jan	0.586	-0.75
Feb	0.551	-0.75
Mar	0.545	-0.75
Apr	0.563	-0.75
May	0.552	-0.75
Jun	0.581	-0.75
Jul	0.564	-0.75
Aug	0.584	-0.75
Sep	0.571	-0.75
Oct	0.566	-0.75
Nov	0.557	-0.75
Dec	0.551	-0.75

Parameter	Actual	Modelled	% error
Mean flow (m^3/s)	52.41	52.41	0.0%
Median flow (m3/s)	39.58	39.99	-1.0%
5%ile (m^3/s)	16.86	16.76	0.6%
7DMALF (m3/s)	16.03	16.29	-1.6%
FRE3 (mean #/y)	7.1	8.8	-25.1%


Hurunui River upstream of Mandamus
Flow (m³/s)
0
20
40
60
80
100
120
140
160
180
200
Actual
Model
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
Nov-14
Dec-14


Hurunui River upstream of Mandamus
Flow (m³/s)
0
20
40
60
80
100
120
140
160
180
200
Actual
Model
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
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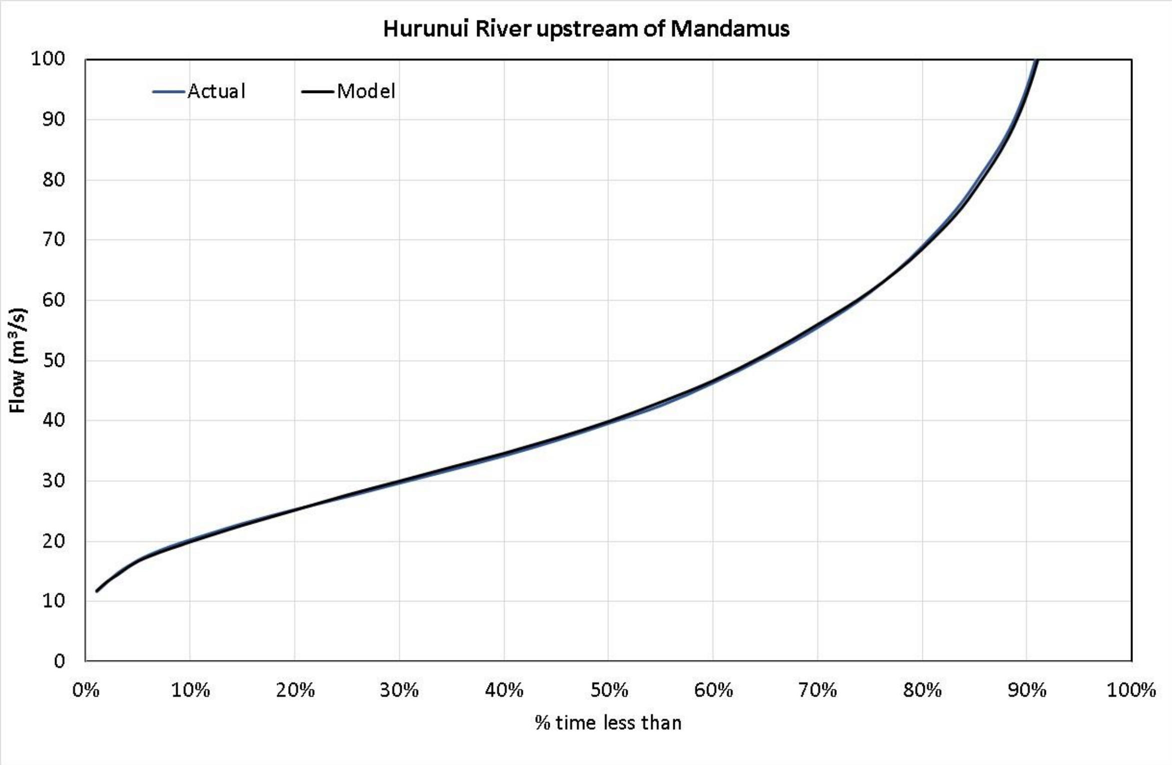
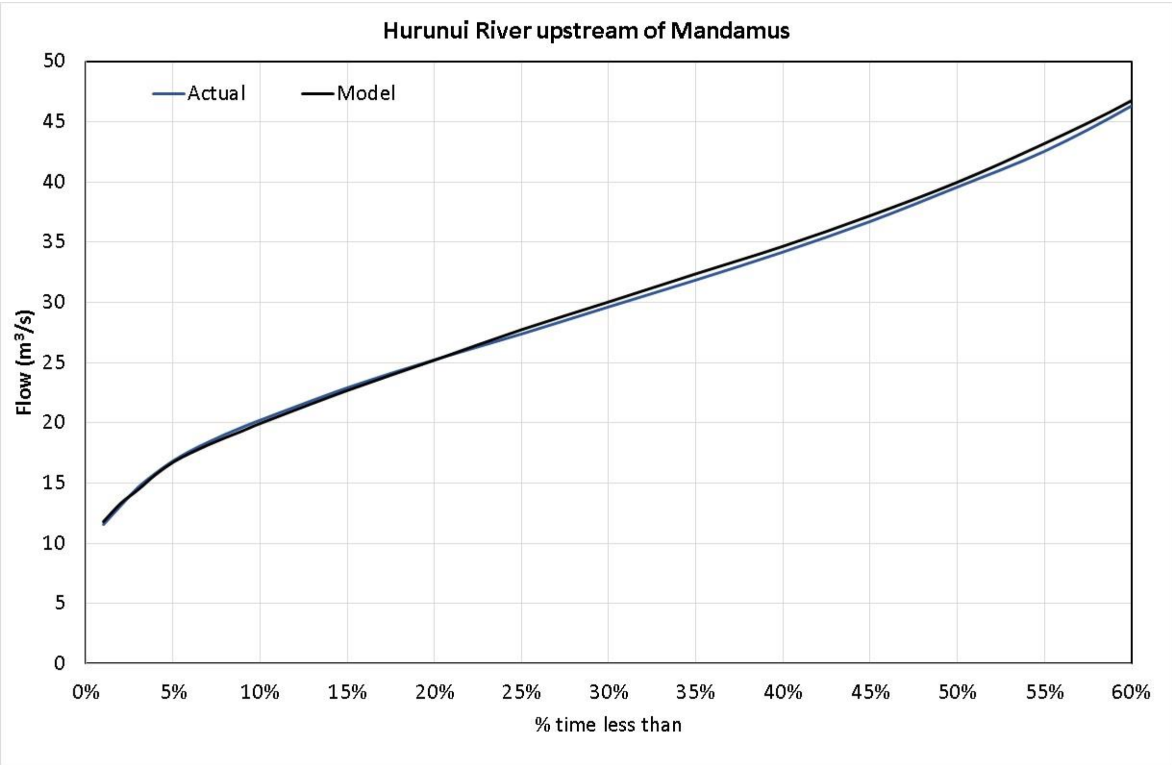
Sep-16
Oct-16
Nov-16
Dec-16


Hurunui River upstream of Mandamus
Actual
Model
Flow (m3/s)
100
90
80
70
60
50
40
30
20
10
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% time less than


Hurunui River upstream of Mandamus
Actual
Model
Flow (m3/s)
50
45
40
35
30
25
20
15
10
5
0
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
% time less than

Waiau River at Marble Point

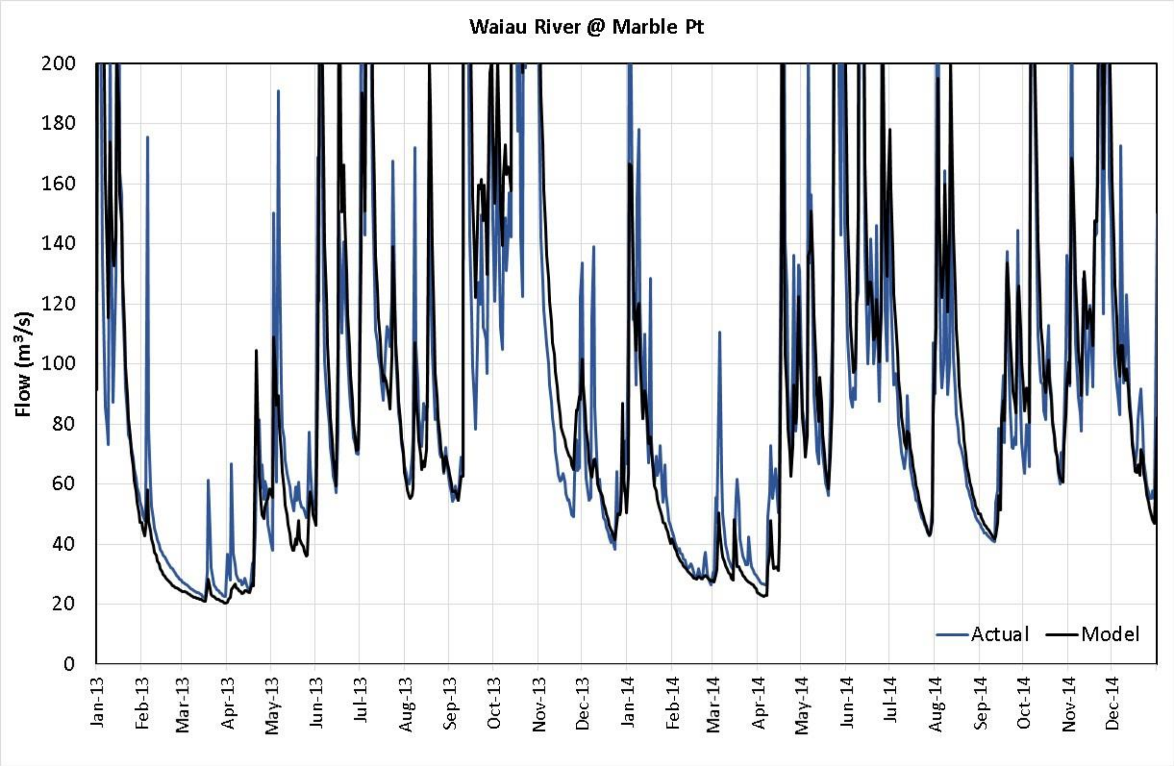
Parameter setting for the relationship with Hurunui US of Mandamus was optimised to minimise errors at low flows, up to 2 times MALF. However, the model is not an accurate predictor of peak flood flows. After October 1967 only 1% gap filling was required, so any errors in synthetic flows have a negligible impact on catchment modelling. Prior to 1967 the model is a good predictor of flows less than 2 times the median flow, but underestimates flood peaks.

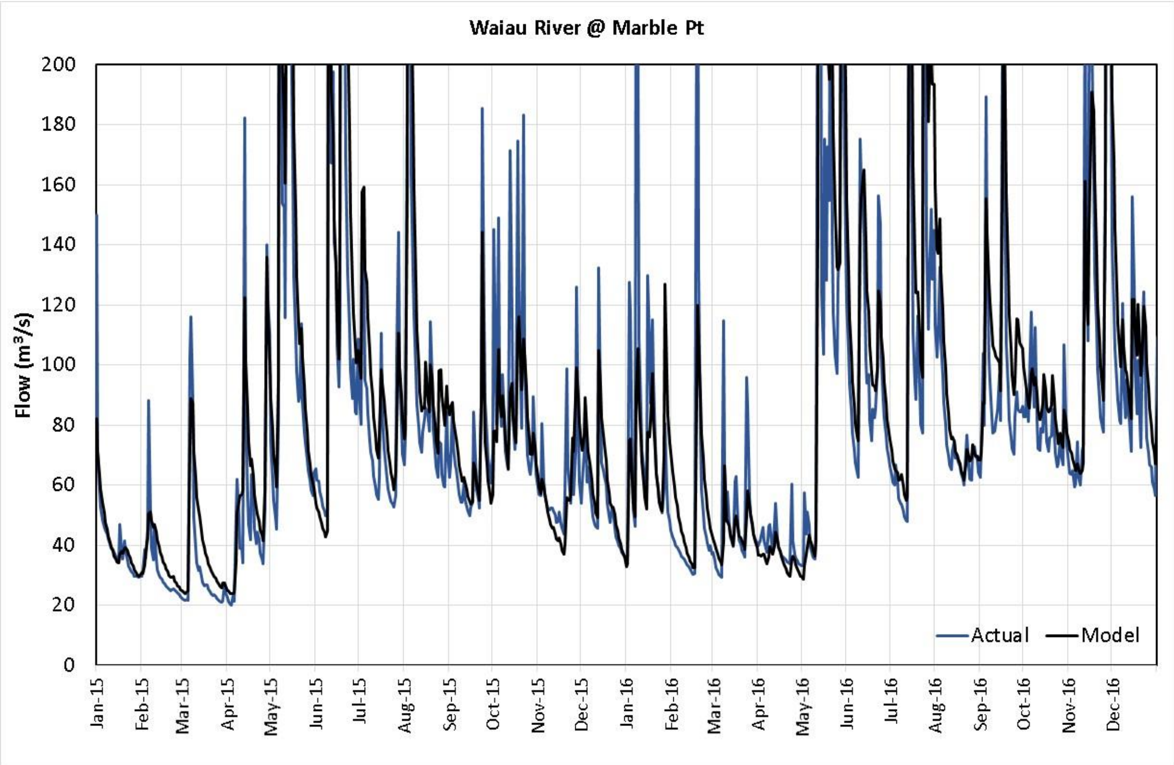
Parameter	Value
Data availability	October 1967-2017
% gap filling	1%
Correlation with	65104

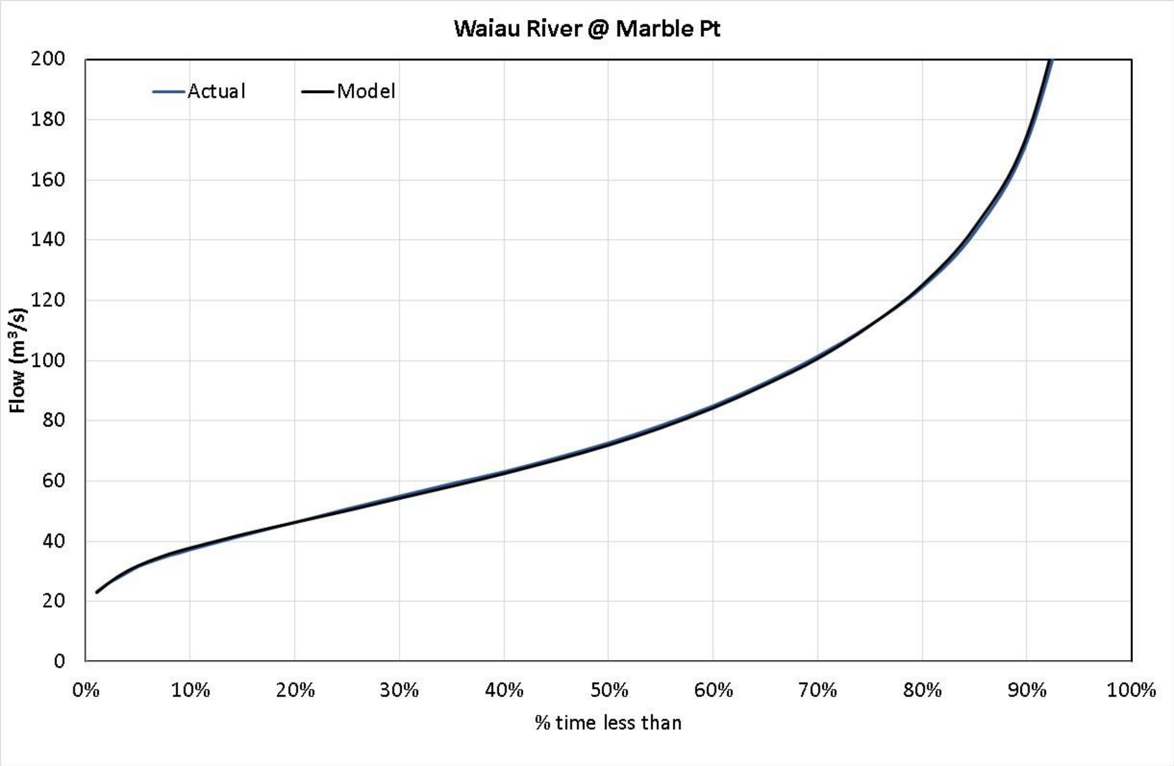
$$Flow_1 = A \times Flow_1 + B$$

Month	A	B
Jan	1.694	2.0
Feb	1.801	2.0
Mar	1.821	2.0
Apr	1.764	2.0
May	1.797	2.0
Jun	1.709	2.0
Jul	1.760	2.0
Aug	1.700	2.0
Sep	1.737	2.0
Oct	1.755	2.0
Nov	1.781	2.0
Dec	1.800	2.0

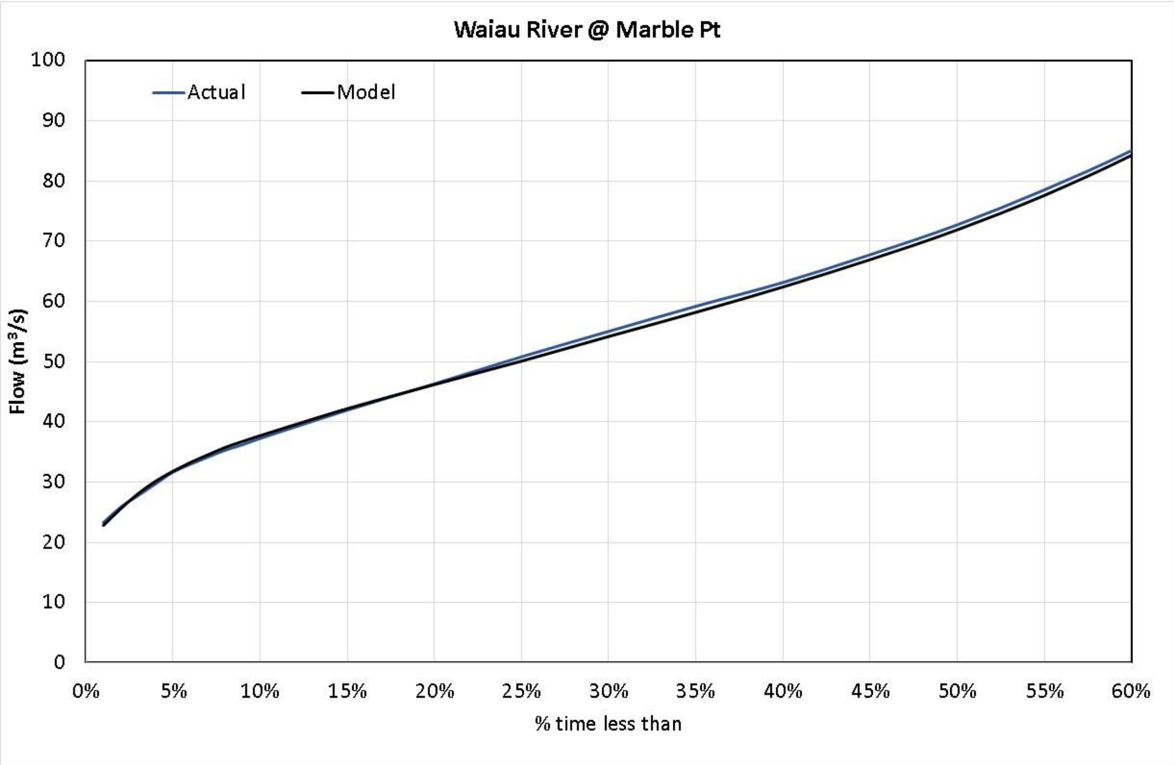
Parameter	Actual	Modelled	% error
Mean flow (m^3/s)	94.04	94.04	0.0%
Median flow (m^3/s)	72.78	71.89	1.2%
5%ile (m^3/s)	31.74	31.85	-0.3%
7DMALF (m^3/s)	31.27	30.57	2.2%
FRE3 (mean #/y)	9.3	7.1	23.7%


Waiau River @ Marble Pt
Flow (m³/s)
200
180
160
140
120
100
80
60
40
20
0
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
Nov-14
Dec-14
Actual
Model


Waiau River @ Marble Pt
Flow (m³/s)
200
180
160
140
120
100
80
60
40
20
0
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Actual
Model



Waiau River @ Marble Pt
Actual
Model
Flow (m³/s)
0
20
40
60
80
100
120
140
160
180
200
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% time less than



Waiau River @ Marble Pt
Actual
Model
Flow (m³/s)
0
10
20
30
40
50
60
70
80
90
100
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
% time less than

Hurunui River at SH1

For the Hurunui at SH1, flow data from 2005 was used, and extended back to 1960 using correlation with the upstream recorder. This date range was used to reflect the 'status quo'. From 1960 to 2005 model flows represent what flows would have been like given current irrigation infrastructure and practises, not actual historic flows, which would have been different prior to large scale irrigation.

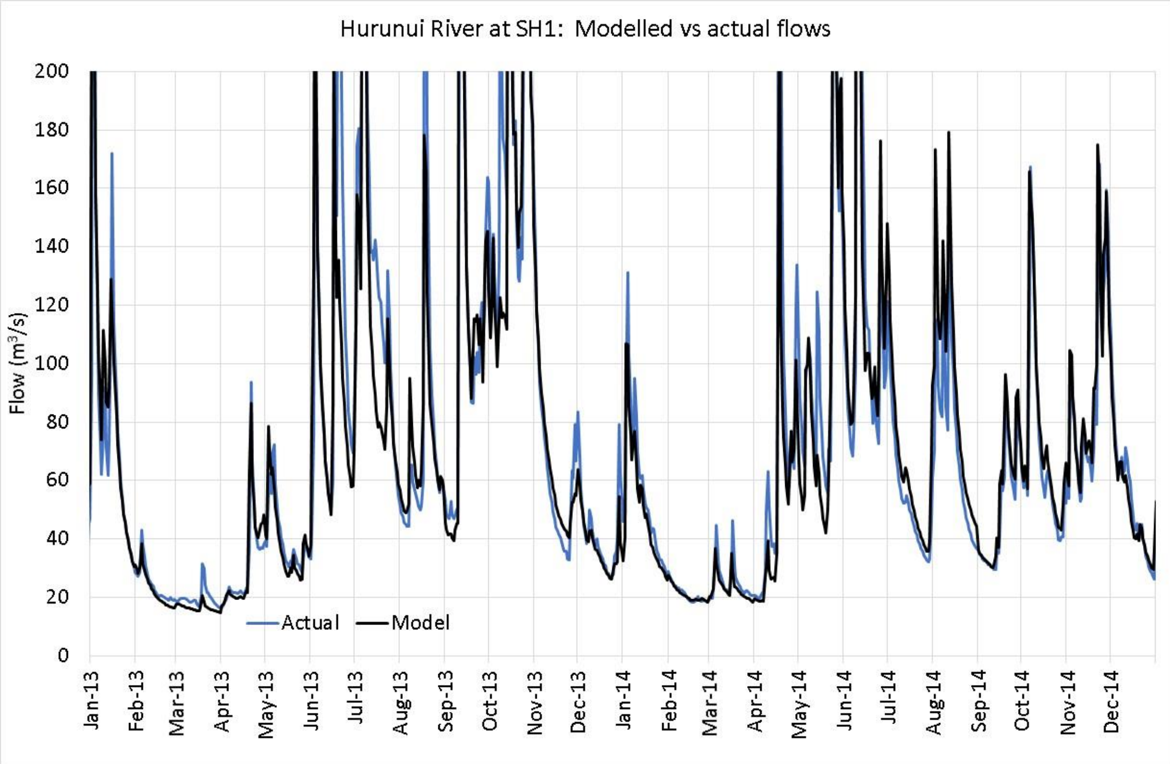
This relatively simple model provides reasonable predictions. The model replicates key flow statistics, and provides a long record that captures the range of climate extremes. A more detailed model that made use of longer term tributary flow monitoring sites (Mandamus, Waitohi) might be able to provide slightly improved accuracy, but would be limited by the shorter duration of these tributary records. The model could also be improved by better accounting for year to year variations in the consumptive irrigation use and the transfer of water to the Hurunui catchment.

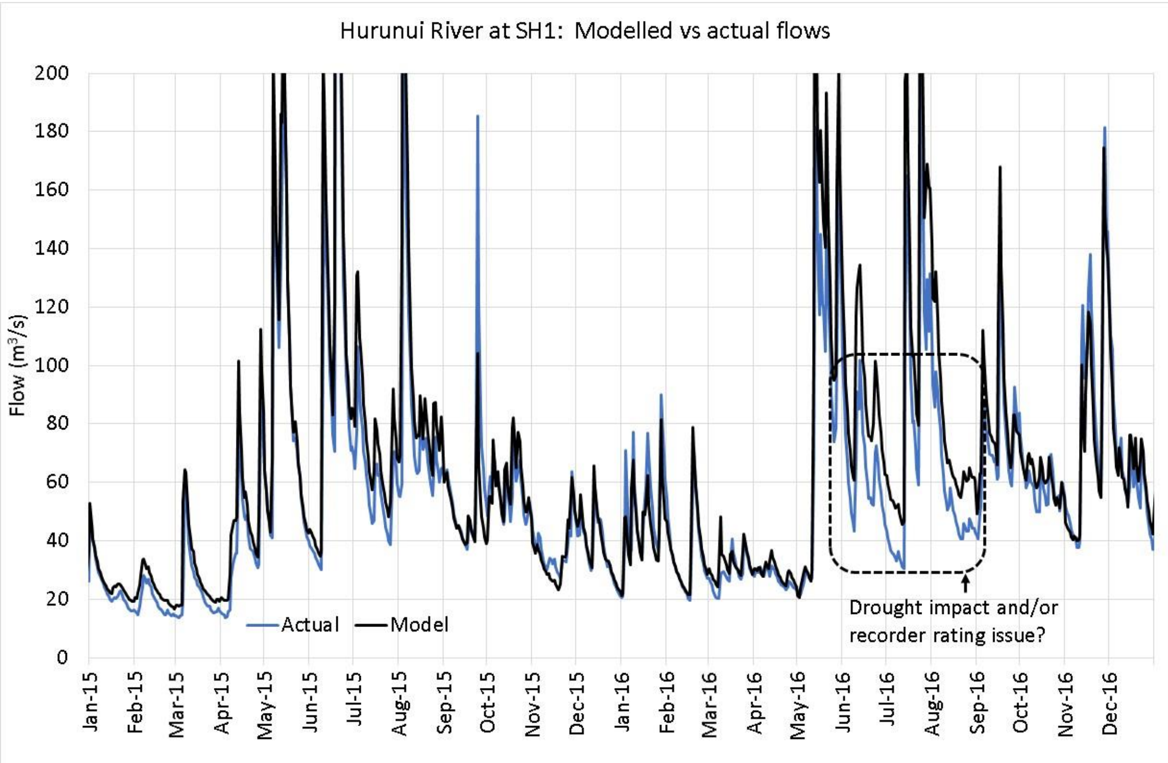
Parameter	Value
Data availability	2005-2017
Correlation with	65104

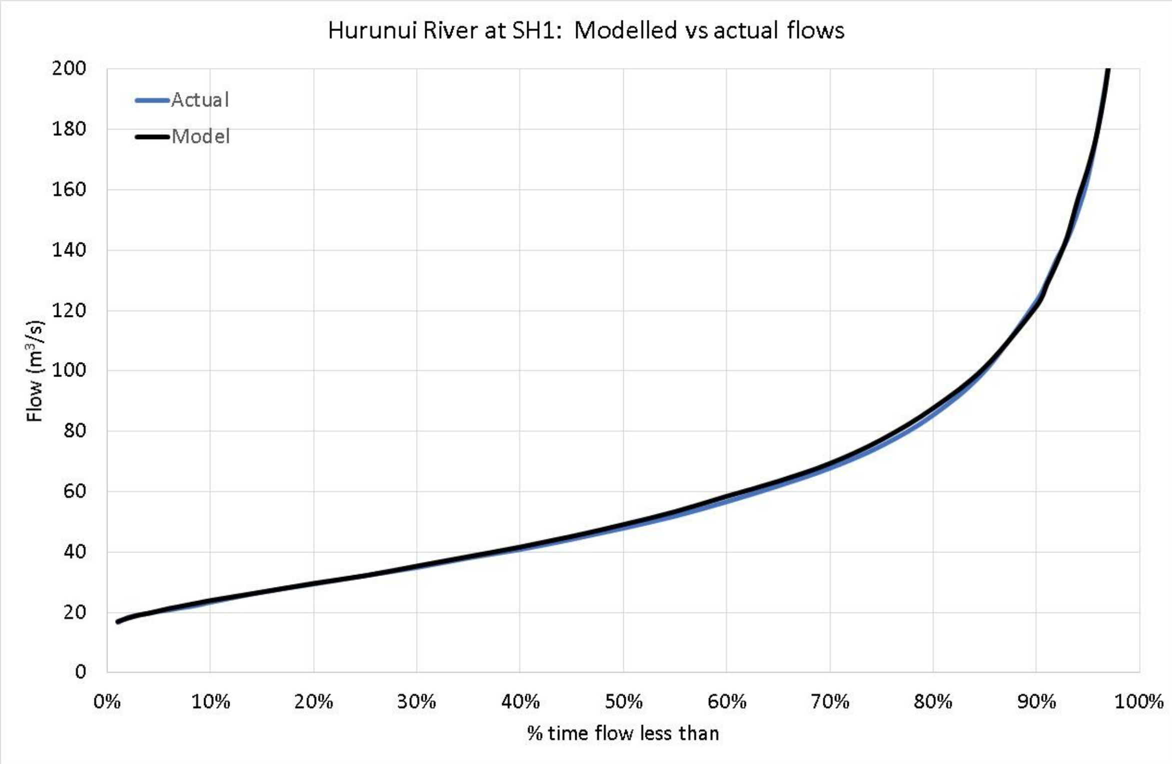
$$\text{Flow}_1 = \text{A}\times\text{Flow}_1+\text{B}$$

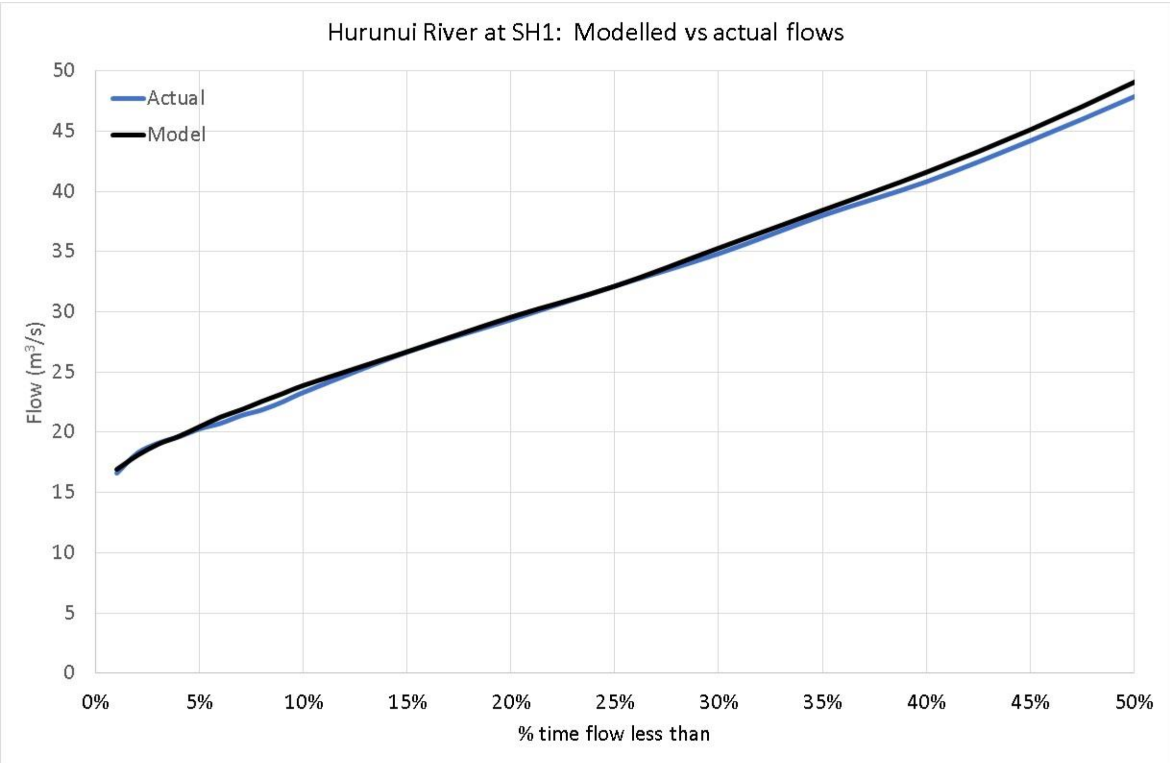
Month	A	B
Jan	1.083	1.5
Feb	1.183	1.5
Mar	1.323	1.5
Apr	1.463	1.5
May	1.293	1.5
Jun	1.393	1.5
Jul	1.463	1.5
Aug	1.513	1.5
Sep	1.253	1.5
Oct	1.243	1.5
Nov	1.103	1.5
Dec	1.123	1.5

Parameter	Actual	Model	% error
Mean flow (m^3/s)	65.2	65.2	0.0%
Median flow (m^3/s)	47.9	49.0	-2.4%
5%ile (m^3/s)	20.3	20.4	-0.7%
7DMALF (m^3/s)	19.5	18.5	5.3%
FRE3 (mean #/y)	8.1	7.9	2.1%


Hurunui River at SH1: Modelled vs actual flows
Flow (m3/s)
200
180
160
140
120
100
80
60
40
20
0
Actual
Model
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
Nov-14
Dec-14


Hurunui River at SH1: Modelled vs actual flows
Flow (m3/s)
200
180
160
140
120
100
80
60
40
20
0
Actual
Model
Drought impact and/or
recorder rating issue?
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16


Hurunui River at SH1: Modelled vs actual flows
Actual
Model
Flow (m3/s)
% time flow less than
0
20
40
60
80
100
120
140
160
180
200
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Hurunui River at SH1: Modelled vs actual flows
Actual
Model
Flow (m3/s)
% time flow less than
0
5
10
15
20
25
30
35
40
45
50
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%

Waiau at Mouth

Continuous flow data has been available in the Waiau River at the Mouth (upstream of the reach of tidal influence) since 2010. This was extended back to 1960 using correlation with the upstream recorder. Flows for the period 1960 to 2010 represent current irrigation practises, not actual historic flows. Amuri Irrigation provides a significant cross-catchment water transfer to the Hurunui River, during the irrigation season. At times there is a net loss from Marble Point to the Mouth, reflecting the impact of a larger irrigation take and less irrigation return flow. The impact is greatest from January to March at lower flows. 7DMALF at the Mouth is 6-7 m^3/s lower than at Marble Point.

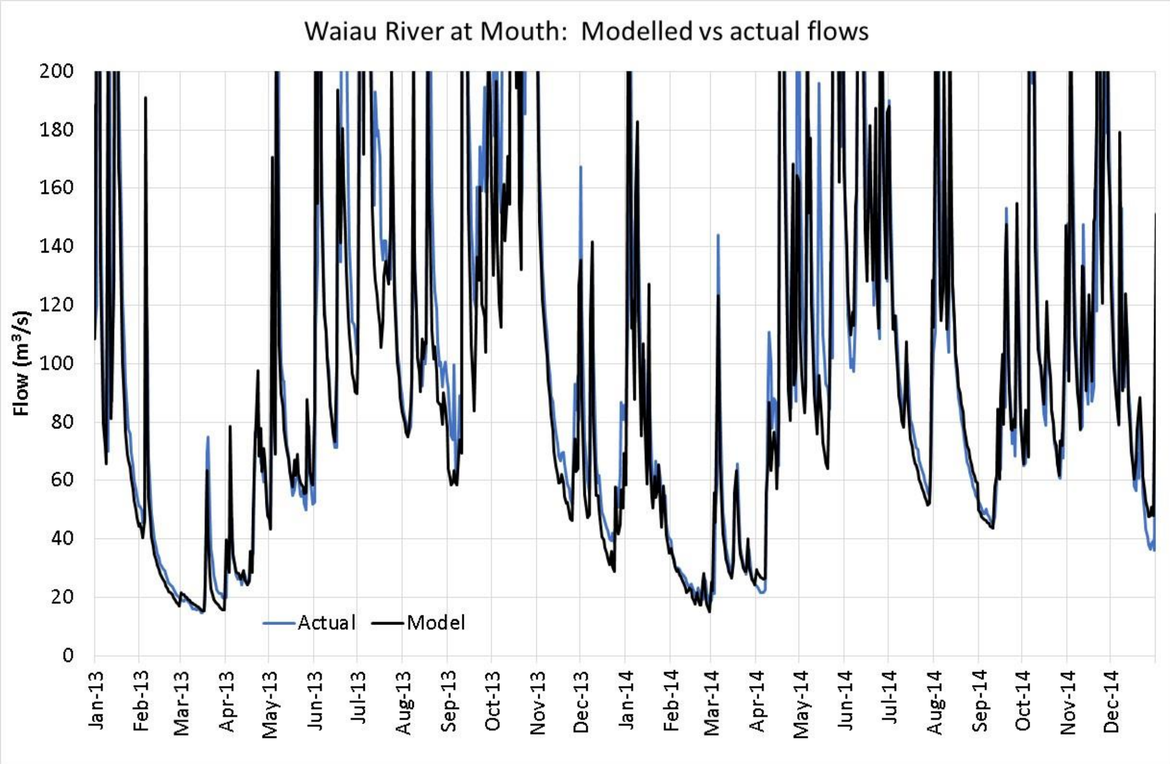
This relatively simple model provides reasonable predictions. The model replicates key flow statistics, and provides a long record that captures the range of climate extremes. A more detailed model that made use of longer term tributary flow monitoring sites (Mason and Stanton) might be able to provide slightly improved accuracy, but would be limited by the shorter duration of these tributary records. The model could also be improved by better accounting for the year to year variations in the consumptive irrigation use and the transfer of water to the Hurunui catchment.

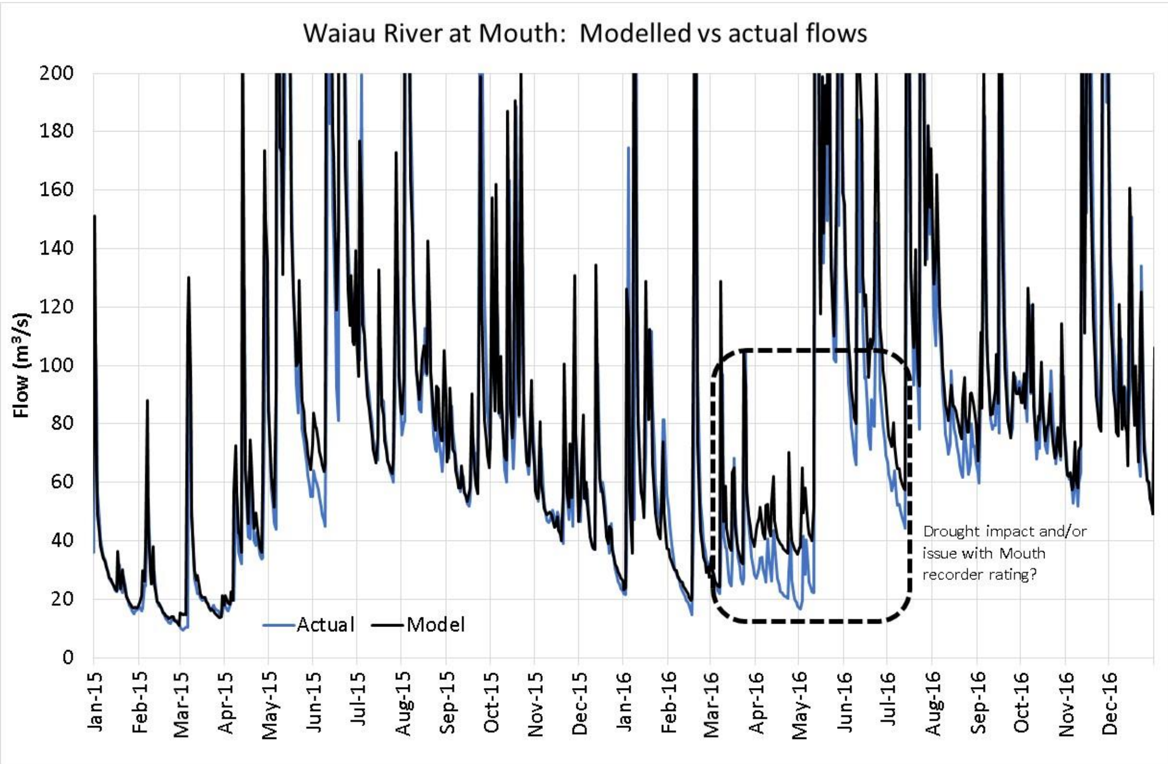
Parameter	Value
Data availability	2010-2017
Correlation with	65602

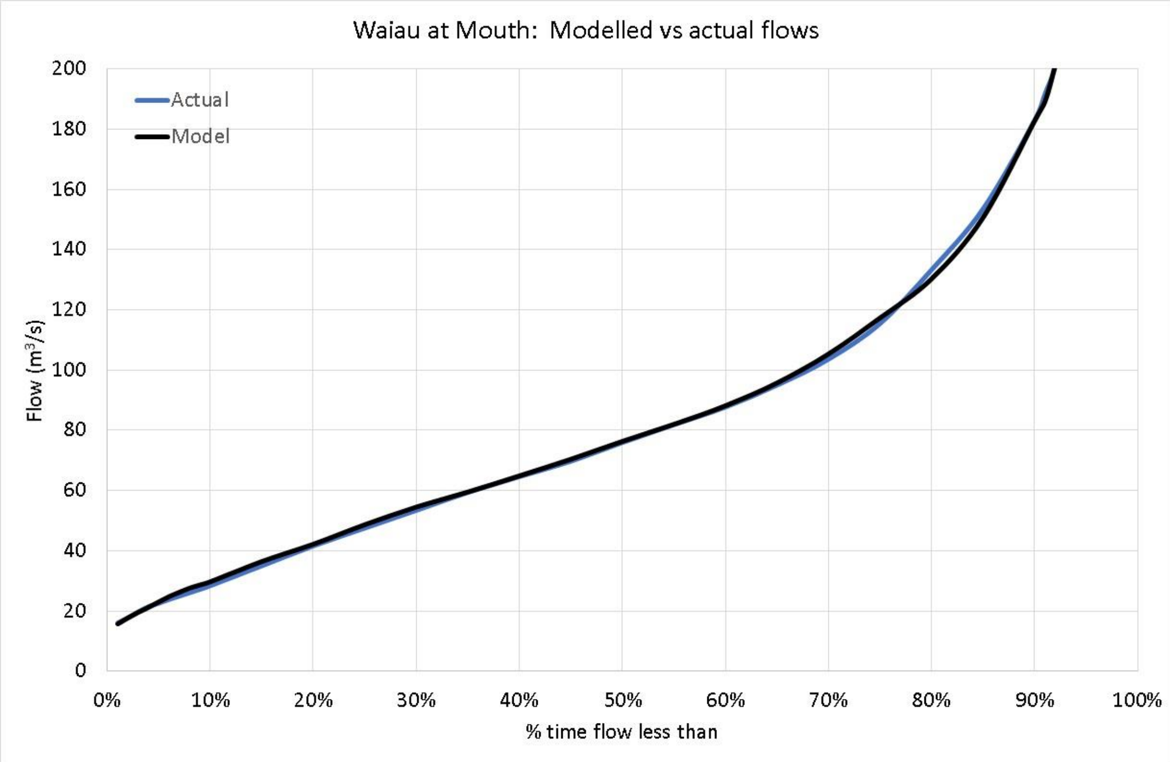
$$Flow_1 = A \times Flow_1 - B$$

Month	A	B
Jan	1.116	16
Feb	1.180	16
Mar	1.250	12
Apr	1.332	8
May	1.144	0
Jun	1.282	0
Jul	1.201	0
Aug	1.247	0
Sep	1.072	0
Oct	1.127	6
Nov	1.102	8
Dec	1.120	14

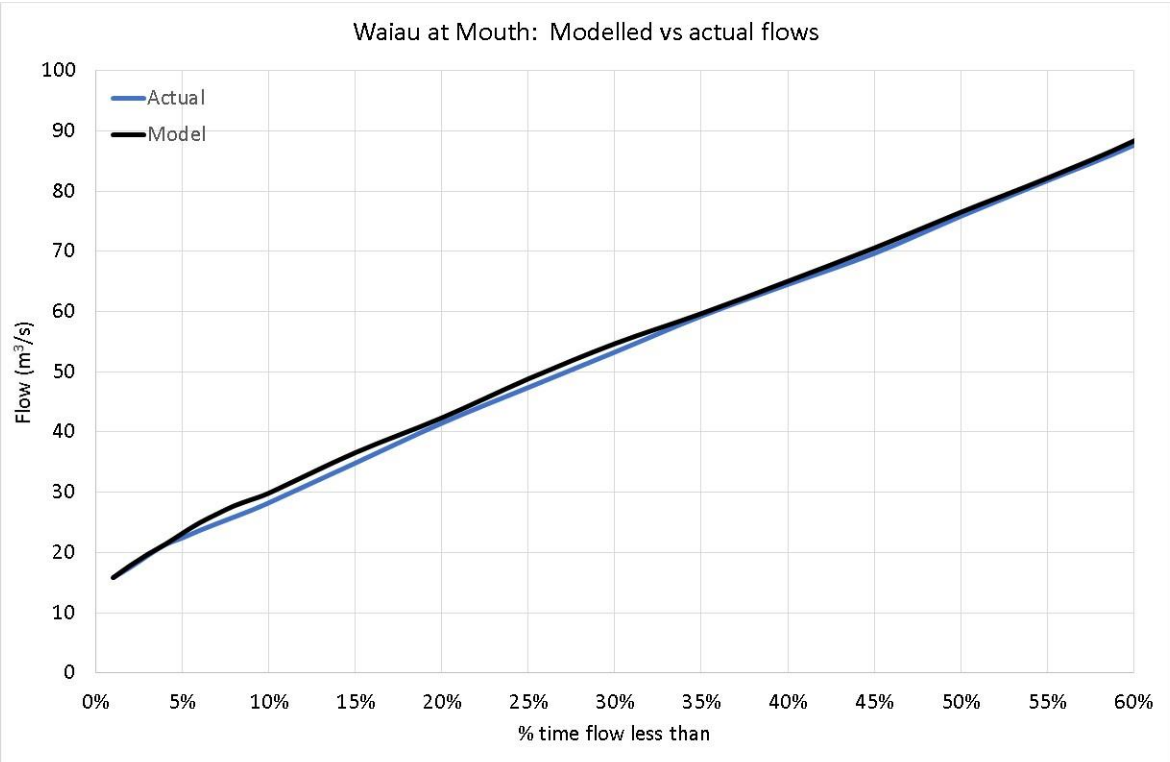
Parameter	Actual	Model	% error
Mean flow (m^3/s)	98.39	98.38	0.0%
Median flow (m^3/s)	75.89	76.60	-0.9%
5%ile (m^3/s)	23.26	23.33	-0.3%
7DMALF (m^3/s)	22.87	22.64	1.0%
FRE3 (mean #/y)	10.1	10.0	1.4%


Waiau River at Mouth: Modelled vs actual flows
Flow (m³/s)
Actual
Model
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Feb-14
Mar-14
Apr-14
May-14
Jun-14
Jul-14
Aug-14
Sep-14
Oct-14
Nov-14
Dec-14


Waiau River at Mouth: Modelled vs actual flows
Flow (m³/s)
Actual
Model
Drought impact and/or issue with Mouth recorder rating?
Jan-15
Feb-15
Mar-15
Apr-15
May-15
Jun-15
Jul-15
Aug-15
Sep-15
Oct-15
Nov-15
Dec-15
Jan-16
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16



Waiau at Mouth: Modelled vs actual flows
Actual
Model
Flow (m³/s)
200
180
160
140
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
% time flow less than



Waiau at Mouth: Modelled vs actual flows
Actual
Model
Flow (m³/s)
100
90
80
70
60
50
40
30
20
10
0
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
% time flow less than