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Manuherikia Flow Regime and Water Quality impacts

Prepared for the Manuherikia Catchment Water Strategy Group

Report C12119/7

December 2012

CENTRAL OTAGO DISTRICT COUNCIL

Ministry for Primary Industries
Manatū Ahu Matua

Otago Regional Council

AQUALINC RESEARCH LIMITED

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Raising Falls Dam gives significant flexibility for achieving a flow regime that provides for both irrigation and environmental needs. Falls Dam allows for a 'designer flow regime', with the flow regime dependent on dam release rules. We have made a 'first cut' at what we see as a possible dam management regime that would provide both security of supply for irrigators and an enhanced flow regime from an environmental perspective. Other flow regimes are possible, and it would be up to the community to come up with a solution that works for both farmers and other stake holders. The final outcome should pool on the knowledge from different groups and should include factors such as iwi values, trout habitat, minimising algae build-up, and swimming conditions.

Low flows are the most important aspect of the flow regime for protecting in-stream values. Long periods of low flows in summer and autumn are a natural occurrence due to the semi-arid climate, although the low flow level is significantly below natural levels in the Lower Manuherikia River due to irrigation abstraction. Increasing Falls Dam storage allows excess winter and spring water to be released in summer. Given the 60 m high dam and 15,000 ha of new Upper Valley irrigation (Scenario 4), flows in the Lower River could be increased 3-4 fold above current levels.

Flow variability, and in particular fresh flows and floods, help to clear out water ways. The Manuherikia River naturally has long periods (up to 11 months) between fresh flows. Raising Falls Dam and increasing the irrigated area has the potential to further reduce the period between fresh flows. One possible mitigation approach is to allow for additional disturbance or rejuvenating flows to be provided from storage. Further work is required to understand the role high flows have in removing algae, and to determine the amount of flow that is necessary to effectively disturb the river.

Manuherikia tributary flows

Raising Falls Dam and increasing the irrigated area would not have a direct impact on tributary flows. For most of the Dunstan Range tributaries (other than Dunstan Creek) virtually all the head-water flow is diverted into irrigation races near the base of the ranges. Irrigation drainage water re-enters these streams but is generally abstracted further down at other irrigation intakes. Ultimately only a residual flow reaches the Manuherikia River during the irrigation season. The amount of water in these streams is ultimately determined by the residual flow left below irrigation intakes, which is a separate consenting issue independent of any increase in irrigated area. ORC have set residual flows to protect native fish habitat, and to minimise the risk to native fish of predatory trout.

Dunstan Creek differs from other tributaries since this creek provides a significant proportion of the flow to the Manuherikia River year round. All options modelled, except Scenario 5 (18,000 ha new Upper Valley irrigation) had no impact on Dunstan Creek flows. Scenario 5 would raise minimum flows but increase the maximum take during the irrigation season to 2 m^3/s, up from 1 m^3/s.

Water quality

Water quality in the Manuherikia Catchment is generally good. This is partly due to the lower agricultural intensity and partly due to the catchment’s natural hydrology and geology.

Land use intensification can pose a risk to water quality. The most important risks are EColi, sediment, and ammonia contamination. These point source contaminates can be minimised through good effluent and riparian management, and preventing irrigation run-off. Converting surface to spray irrigation will help to reduce EColi and sediment contamination, since current water quality is compromised by irrigation runoff water entering streams.

Another concern with land use intensification is more algae growth as a result of increased nitrogen and phosphorus. Managing these diffuse source contaminates can be more challenging. There is however some factors that mean the Manuherikia River is at less risk of nutrient problems compared with some other catchments in Otago. These factors include the dry climate, the lack of groundwater, the irrigation command area being relatively flat, and the free draining soils. Furthermore, we expect converting existing surface irrigation to spray irrigation will reduce both phosphorus and nitrogen losses during the irrigation season. Other factors that mitigate the nutrient risk are higher minimum flows and potentially artificial fresh flows.

The dry climate and lack of groundwater means with efficient irrigation most nitrogen losses from land will probably enter water ways during periods of high river flows, at a time when nutrients do not cause any problems. In the Manuherikia, efficient irrigation is probably the single most important factor in minimising nutrient losses during the critical summer and early autumn period. Nitrogen is only lost when soil drainage occurs, so if soil drainage is well controlled during the irrigation season losses will be low. With good irrigation management irrigation can even reduce nitrogen losses, by increasing plant uptake.

Current nutrient levels are one to two orders of magnitude less than concentrations that are even remotely toxic to fish, or the Drinking Water Standard limits, consequently risks from irrigation development on these values are negligible.

We recommend further monitoring and data analysis be done to understand periphyton (i.e. algae) growth and removal dynamics. Until this work is done it is not possible to say for sure how periphyton cover may be affected by land use intensification and/or land use change.

Early indications are that it will be possible to fully irrigate the Manuherikia Valley and to farm effectively, while at the same time maintaining good water quality, provided land use remains predominately sheep farming. Good irrigation management and farming practices will be necessary. What is less clear is whether the catchment could also accommodate a large scale shift in land use to higher risk activities such as cropping and dairying, without compromising water quality.

We expect Plan Change 6a nutrient limits will be significantly revised before the plan is finalised. Until the final version of the plan is known, we cannot say how well irrigation development scenarios align with the plan.

Monitoring

A critical limitation in current data is the lack of periphyton cover measurements. To better understand the periphyton growth and removal dynamics we recommend periphyton cover estimates be made as part of regular water quality sampling at Ophir and Galloway. We recommend that the sampling frequency be increased to monthly, up from two monthly, for a period of 12 months.

We recommend a macro-invertebrate survey in late summer, following a long period of low flows. This information will help with understanding periphyton removal dynamics, and would complement the survey undertaken in the wet summer of 2010/11.

We recommend monthly water quality sampling in Falls Dam, Upper Manor Burn and Pool Burn reservoirs, for a period of 12 months. This data is needed to assess whether or not more storage at Falls Dam will increase nitrogen concentrations below the dam in summer.

1 Introduction

The Manuherikia Catchment Water Strategy Group (MCWSG) was set up to develop and oversee the implementation of a water strategy for the catchment. The MCWSG envisages that the project will provide information to help the community make informed decisions, leading to a comprehensive Manuherikia Catchment water strategy. Figure 1 provides an overview of the study.

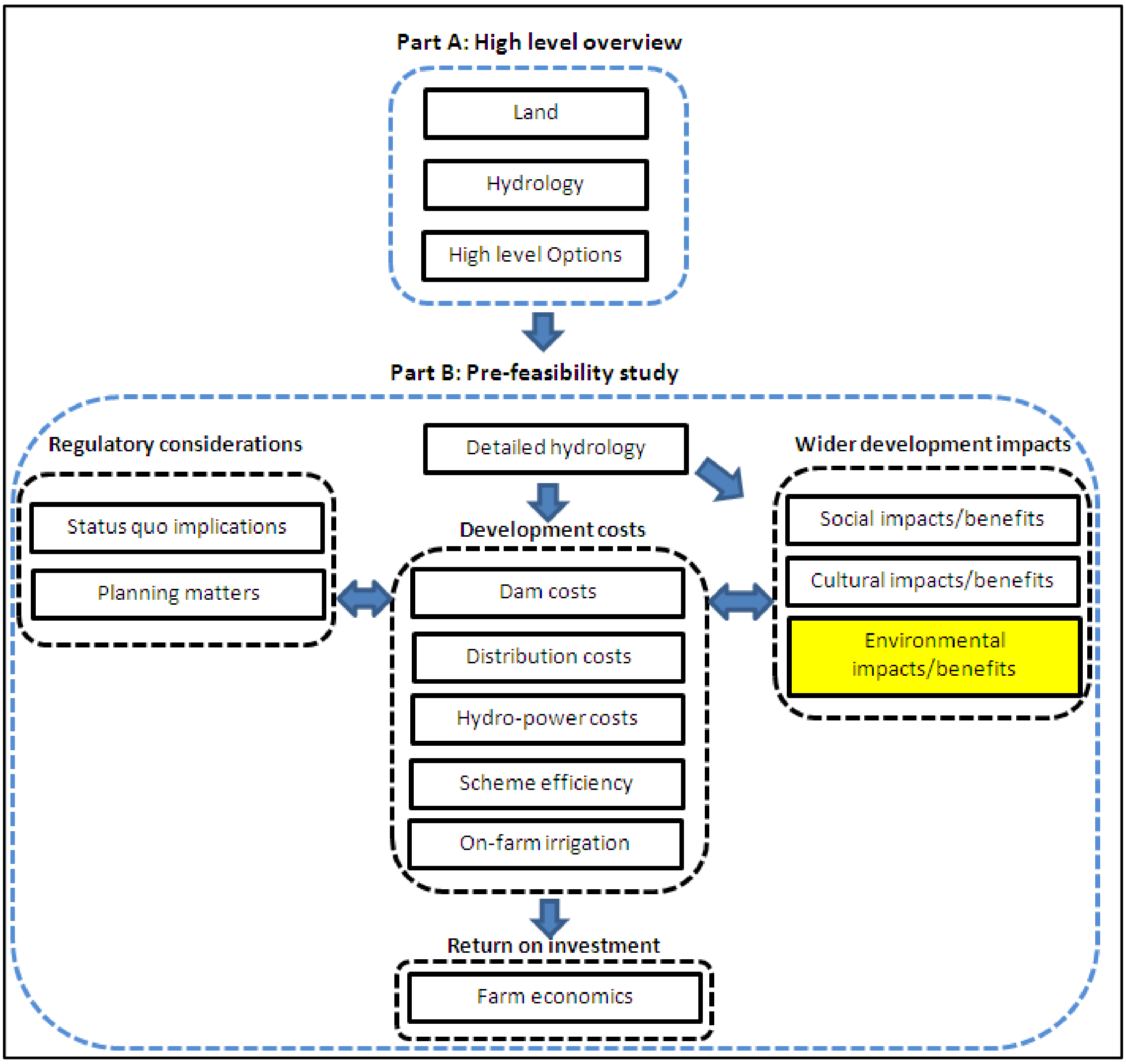


Figure 1: Manuherikia Catchment Study overview

This report covers Manuherikia Valley flow regime and water quality impacts of the Falls Dam proposals described in the Upper Manuherikia Valley Distribution report (Aqualinc 2012b). A separate report addresses wider environmental and recreational values and impacts.

This report builds on the Manuherikia Valley detailed hydrology report (Aqualinc 2012a), where raising minimum flows was identified as an affordable method to counter the impacts of land use intensification.

This report should be read in conjunction with the Land, Hydrology and Upper and Lower Valley distribution reports.

This study has been made possible by the generosity of the following who have contributed by way of direct funding or by in-kind contributions. MCWSG are grateful for this support and wish to thank the following:

- Ministry of Primary Industries with funding via the Irrigation Acceleration Fund.
- The Otago Regional Council (ORC).
- The Central Otago District Council (CODC).
- The Manuherikia Community.

2 Flow regime impacts

Raising Falls Dam and increasing the irrigated area in the Upper Manuherikia Valley would significantly alter flows in the Manuherikia Main Stem. We modelled flows at six different locations down the River, as described in Table 1 and Figure 2.

Table 1: Manuherikia main stem locations where flow was modelled

Location	Comments
D/S of Falls Dam	Summer flows higher because the river is used for conveyance
D/S of Omakau Intake	Lowest Upper Valley flows are between the Omakau intake and the SH85 bridge, at the Dunstan Creek confluence.
D/S SH85 bridge	Flows and flow variability increases below Dunstan confluence
Ophir	Long term flow monitoring site
Below MIS intake	Lowest Lower Valley flows are below the Manuherikia Irrigation Scheme intake
Campground	ORC proposed minimum flow site

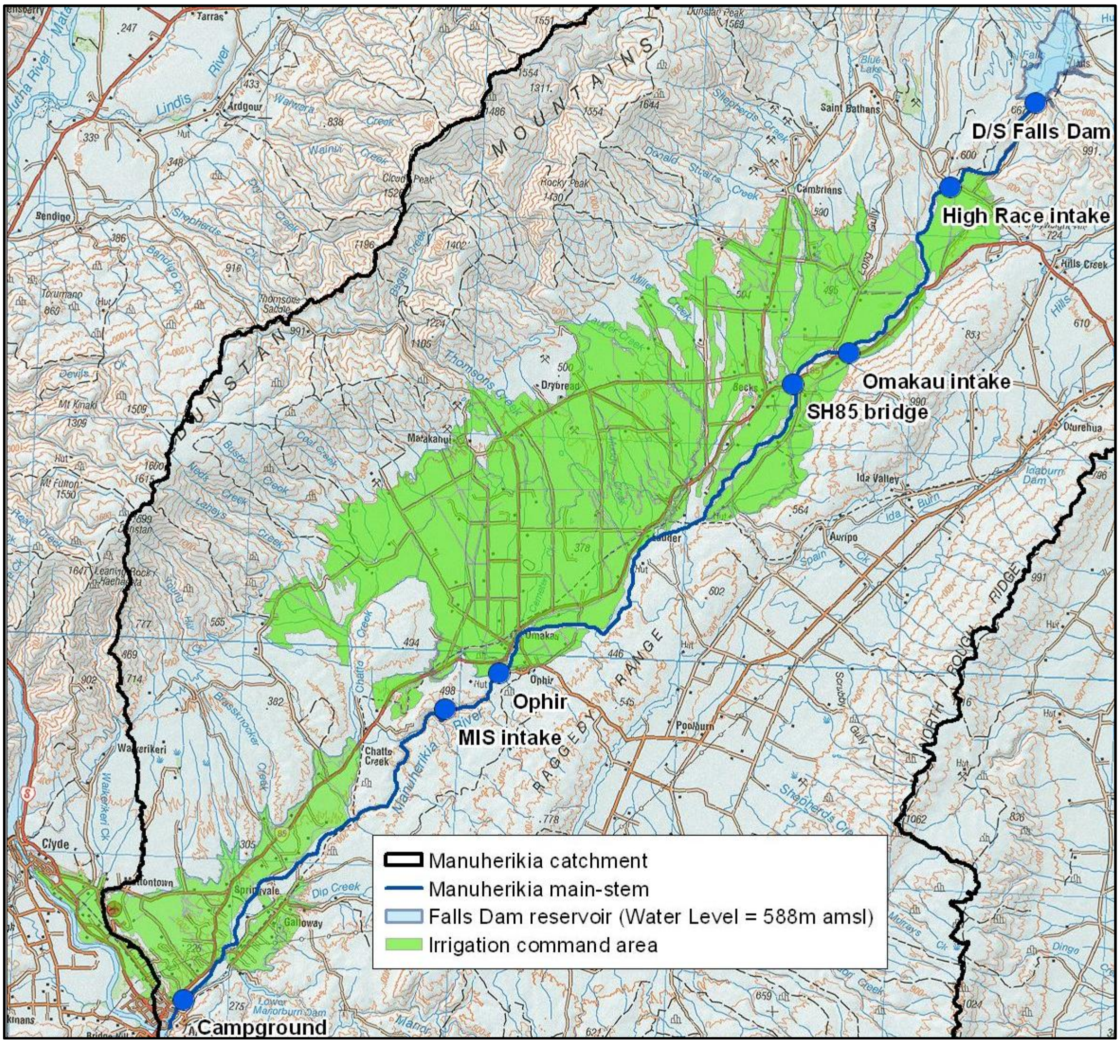


Figure 2: Manuherikia main stem locations where flow was modelled

We modelled seven different scenarios. These are summarised in Table 2. Full modelling results are provided in Appendices A-H.

Table 2: Irrigation development scenarios

Scenario	Area fully irrigated (ha)(1)	Falls Dam storage (Mm^3)	Comment
Status quo	6,500	10	
Scenario 1	6,500	19	Refer Upper Valley Distribution report (Aqualinc 2012e)
Scenario 2	12,000	50	
Scenario 3	18,000	80	
Scenario 4	21,000	100	
Scenario 5	24,000	100	Maximum possible Upper Valley irrigated area from a hydrological perspective.
No irrigation	0	0	No Manuherikia Valley irrigation, but status quo Mt Ida Race and Ida Valley water use
(1) Upper Valley only. Lower Valley irrigated areas are additional.			

The “no irrigation” scenario was modelled to provide a comparison with natural Manuherikia Valley flows. However there is no intention to reduce the irrigated area below current levels.

Scenario 5 is also only included for comparison. We recommend the maximum Falls Dam design supply area be 21,000 ha (Scenario 4), rather than 24,000 ha, since this allows for a hydrological design safety margin. If Scenario 4 were constructed, with time the system may prove it is possible to irrigate a greater area than the initial design of 21,000 ha.

Raising Falls Dam gives significant flexibility for achieving a flow regime that provides for both irrigation and environmental needs. Falls Dam allows for a ‘designer flow regime’, with the flow regime dependent on dam release rules. We have made a ‘first cut’ at what we see as a possible dam management regime that would provide both security of supply for irrigators and an enhanced flow regime from an environmental perspective. Other flow regimes are possible, and it would be up to the community to come up with a solution that works for both farmers and other stake holders. The final outcome should pool on the knowledge from different groups and should include factors such as iwi values, trout habitat, minimising algae build-up, and swimming conditions.

Low flows are the most important aspect of the flow regime for protecting in-stream values. Long periods of low flows in summer and autumn are a natural occurrence due to the semi-arid climate, although the low flow level is significantly below natural levels in the Lower Manuherikia River due to irrigation abstraction. Increasing Falls Dam storage would allow for the increased capture of winter and spring water, for use in summer for both irrigation and raising minimum flows. Under all development scenarios we allowed for increased minimum flows along the entire length of river from Falls Dam to the Clutha Confluence. Low flows are summarised in Table 3.

Table 3: Manuherikia main-stem low flows under difference scenarios

Scenario	Low flow (m^3/s)(1)					
	D/S Falls Dam	D/S Omakau intake	SH 85 bridge	Ophir	D/S MIS intake	Camp ground
Status quo	0.50	0.79	1.08	2.15	0.23	0.66
Scenario 1	0.50	0.75	1.26	2.55	0.57	1.00
Scenario 2	0.60	0.92	1.27	2.84	1.06	1.50
Scenario 3	0.70	1.01	1.34	3.17	1.60	2.02
Scenario 4	0.80	1.05	1.36	3.30	1.83	2.24
Scenario 5	0.80	1.04	1.59	3.43	2.17	2.58
No irrigation	1.21	1.48	2.51	3.27	3.27	3.51
(1) Flow less than or equal to this value on average 18 days per year (i.e. 5%ile)						

The largest increase in low flows, given development scenarios 2-5, would be in the lower catchment. Under Scenario 4 flows would be over 3 times higher at Campground compared with the status quo. This is 50-60% of natural low flows.

Flow variability, and in particular fresh flows and floods, help to clear out water ways. The Manuherikia River naturally has long periods (on average 5 months, but up to 11 months) between fresh flows. Raising Falls Dam and increasing the irrigated area has the potential to further reduce the period between fresh flows, particularly for development Scenarios 4 and 5. One possible mitigation approach is to allow for additional disturbance flows to be provided from storage, to help remove algae. Fresh flow releases would occur during a natural rain event. Falls Dam release flows would be ramped up and down to mimic a natural flow curve. In modelling we have assumed under development Scenarios 4 and 5 that 15-25 m^3/s would be release from Falls Dam for 24-48 hours, during a natural fresh flow, if there had not been a fresh flow with a flow of twice the median flow at Campground in the previous 30 days. This would require larger release gates at Falls Dam than would be required if disturbance flows were not provided. Whether such a release flow regime would be effective in disturbing the river would require further investigation. Fresh flow frequencies for each of the scenarios are summarized in Table 4 and Table 5.

Opuha Dam is an example of where a dam has reduced fresh flow frequency, and has contributed to nuisance algae growth and algae blooms downstream of the dam. Since the dam was built, downstream of the dam before the confluence with the Opihi River, there has been a dramatic reduction in fresh flows and floods. The lack of fresh flows means algae build up to undesirable levels. Unfortunately at Opuha Dam the release gates are not big enough to provide a flow great enough to scour the river (Lessard et al. 2012). An important conclusion from the Opuha Dam experience is to assess these potential changes before raising Falls Dam, and if fresh flows are required to size the gates on the dam accordingly.

Table 4: Manuherikia main-stem Fre2 frequency under difference scenarios

Scenario	Max. days per year between Fre2 events(1)					
	D/S Falls Dam	D/S Omakau intake	SH 85 bridge	Ophir	D/S MIS intake	Camp ground
Status quo	167	165	164	161	162	169
Scenario 1	170	169	168	161	163	169
Scenario 2	210	206	189	177	176	176
Scenario 3	162	272	212	185	183	186
Scenario 4(2)	117	184	172	168	167	167
Scenario 5(2)	118	188	174	168	168	168
No irrigation	147	144	147	154	145	151

(1) Average of the [maximum days of accrual between Fre2 events (flow greater than 2×median flow) for each hydrological season (1 July – 30 June)].
(2) Given a Falls Dam fresh release flow of 15 m^3/s.

Table 5: Manuherikia main-stem Fre3 frequency under difference scenarios

Scenario	Max. days per year between Fre3 events(1)					
	D/S Falls Dam	D/S Omakau intake	SH 85 bridge	Ophir	D/S MIS intake	Camp ground
Status quo	238	231	227	218	209	207
Scenario 1	243	235	227	223	214	212
Scenario 2	274	282	239	233	220	225
Scenario 3	341	337	283	264	252	249
Scenario 4(2)	209	223	207	201	200	215
Scenario 5(2)	163	228	214	207	204	216
Scenario 4(3)	186	188	198	180	178	177
Scenario 5(3)	144	193	203	182	178	178
No irrigation	201	194	196	207	184	193

(1) Average of the [maximum days of accrual between Fre3 events (flow greater than 3×median flow) for each hydrological season (1 July – 30 June)].
(2) Given a Falls Dam fresh release flow of 15 m^3/s.
(3) Given a Falls Dam fresh release flow of 25 m^3/s.

For the Manuherikia River it is possible that invertebrate graziers (e.g mayfly larvae, snails), rather than fresh flows may be the main mechanism for periphyton removal. This is because fresh flows are infrequent, and the stony substrate stable flow mean conditions are ideally suited for a build-up of grazer populations. If this is the case fresh flow frequency would have much less of an impact on maximum periphyton cover. This requires further investigation.

Strong grazer control of periphyton is most likely to occur in streams that lack frequent bed-disturbing flows and have good in-stream habitat (e.g. low levels of sediment, good water quality, cool temperatures, and suitable riparian forest for insect life history completion) (NIWA 2007).

To better understand the periphyton growth and removal dynamics we recommend periphyton cover estimates be made as part of regular water quality sampling at Ophir and Galloway. We recommend using the National River Water Quality Network (NRWQN) protocol. We recommend that the water quality sampling frequency be increased to monthly, up from two monthly, for a period of 12 months.

We also recommend a macro-invertebrate survey in late summer, following a long period of low flows. This information will help with understanding periphyton removal dynamics, and would complement the survey undertaken in the wet summer of 2010/11.

3 Existing water quality

ORC undertook extensive water quality monitoring in the Manuherikia Catchment from September 2009 to September 2010. Study results are described in "Water quality and ecosystem health in the Manuherikia Catchment" (ORC 2011). This study produced a very valuable dataset, with fortnightly monitoring of nitrate, phosphorus, EColi and turbidity at 17 sites across the catchment. Overall ORC concluded that water quality in the Manuherikia catchment is generally good. A analysis of monitoring results are provided below.

ORC has also done extensive monitoring of contour and flood irrigation runoff. This is described in "The effect of irrigation runoff on water quality" (ORC 2006). The study concluded that water qualities in all tributaries monitored were degraded due to flood irrigation practices during the summer period.

3.1 EColi

EColi are a measure of bacterial contamination. High EColi may mean water is not safe for swimming. EColi sampling results are summarised in Table 6. Values below 260 indicate water quality is safe for swimming (MfE 2003). Table 6 shows that most of the time the Manuherikia Main Stem, the main stream used for swimming, is safe to swim in. EColi contamination is evident in some tributaries, probably due to stock access and irrigation runoff.

Table 6: Measured EColi Oct 2009 – Apr 2010

Class	Location	EColi (mpn/100ml)		
		Median	80%ile	Maximum
High country streams	Manuherikia @ Loop Road	8	11	52
	Thomsons @ Diversion Weir	20	40	110
	Ida Burn @ SH85	13	26	150
	Median	**13**	**26**	**110**
Manuherikia Tributaries	Dunstan Ck @ Beatties	41	80	140
	Ida Burn @ River side	180	324	5300
	Lauder Ck @ Rail Trial	330	664	2000
	Thomsons @ SH85	560	2020	3400
	Chatto Ck US Manuherikia	350	750	1500
	Average	**330**	**664**	**2000**
Manuherikia main stem	Manuherikia @ Blackstone	50	124	180
	Manuherikia US Ida Burn	64	96	280
	Manuherikia @ Omakau	32	103	270
	Manuherikia @ Ophir	237	286	1500
	Manuherikia US Chatto	60	152	1500
	Manuherikia @ Galloway	62	177	570
	Average	**61**	**138**	**425**

3.2 Ammonia

Ammonia can be toxic to fish. High ammonia concentrations can indicate dairy effluent runoff. Figure 3 illustrates that ammonia levels are low everywhere in the Manuherikia catchment, with over 400 samples at 15 locations all recording ammonia levels well below ORC's limit. This is probably due to the lack of dairying in the catchment and the free draining soils.

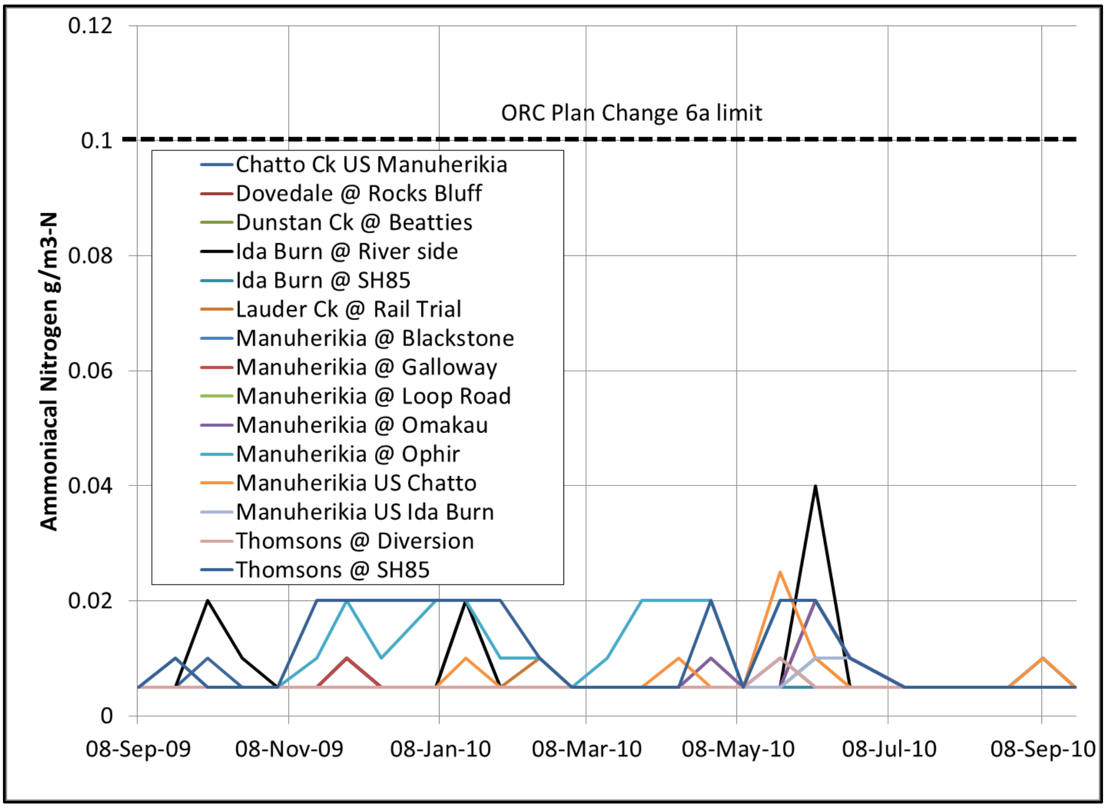
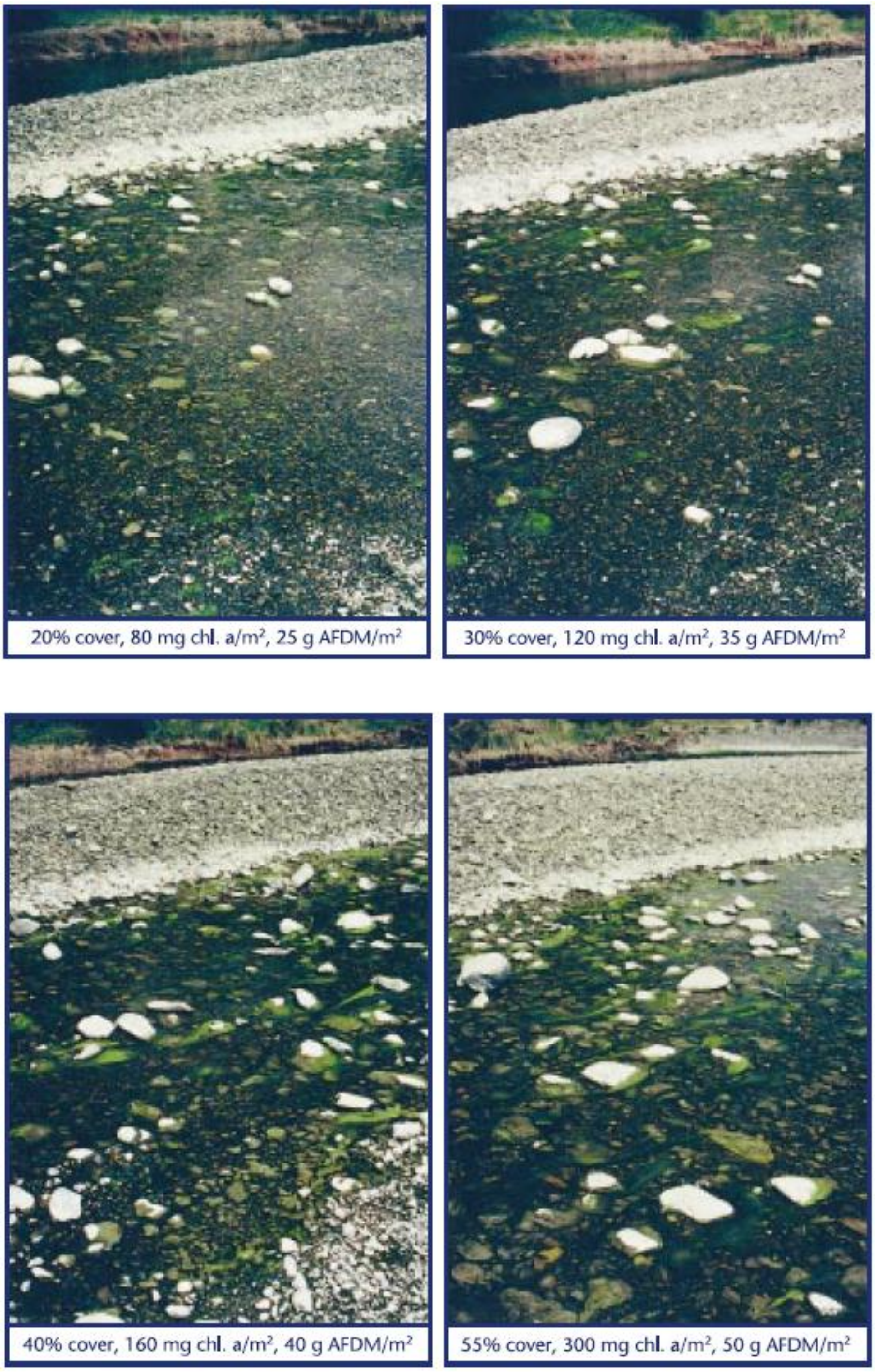


Figure 3: Ammonia concentrations in the Manuherikia Catchment

3.3 Periphyton cover

Periphyton cover or ‘Chlorophyll a’ measurements are the best indicator or whether or not nuisance periphyton build-up is a problem. Periphyton cover is illustrated in Figure 4. Unfortunately in the Manuherikia Catchment are no records of periphyton cover. This is an important parameter to be measuring and we recommend this be assessed as part of regular water quality sampling at Ophir and Galloway.



20% cover, 80 mg chl. a/m², 25 g AFDM/m²

30% cover, 120 mg chl. a/m², 35 g AFDM/m²

40% cover, 160 mg chl. a/m², 40 g AFDM/m²

55% cover, 300 mg chl. a/m², 50 g AFDM/m²

Figure 4: Increasing periphyton cover (Biggs 2000)

Periphyton cover is affected by a number of factors including nutrient loadings, water temperature, water clarity, bed substrate, low flows, invertebrate grazer concentrations and fresh flow frequency. Nuisance algae growth is at greatest risk of occurring during summer, due to high temperatures, low flows, and higher sunshine hours.

Anecdotally, low flows and not algae are the main issue in the Manuherikia Main Stem. Justin Kitto of ORC, who undertook all the water quality sampling in 2009 and 2010 reported that in the Manuherikia Main Stem there was generally only a film of algae on rocks, but not long strands. Photos taken during this sampling program support the view algae cover is generally low in a dry year. This sampling occurred during a pretty typical summer, which included a 6 month period without even a Fre2 fresh flow, and a long period of low flows from January to April.

Figure 5: Manuherikia at Omakau (ORC 2011)

An interesting comment one of the farmers made during this sampling program is when there is algae in the river it generally means you have had a good year (i.e. lots of summer rain). An explanation could be that in wetter years nitrogen losses are higher, which increases algae growth.

3.4 N:P ratio

Currently algae growth is strongly limited by nitrogen rather than phosphorus. This is illustrated in Table 7, where the N:P ratio is 7 or less at every sampling location. A N:P value of less than 10 indicates nitrogen availability limits plant growth, while a value greater than 20 indicates phosphorus limits plant growth. This trend is evident across all stream types: high country streams, Manuherikia tributaries where irrigation runoff is the dominate source of water, and the Manuherikia Main Stem where nutrient concentrations increase in the lower river reaches. We expect the low N:P ratio is partly due to lower nitrogen losses from land during the irrigation season, and partly due to elevated phosphorus from surface irrigation runoff.

Table 7: Nitrogen and phosphorus concentrations Dec 2009 – Apr 2010

Class	Location	DIN(1) (mg-N/m^3)	DRP(2) (mg-P/m^3)	D:P(3) ratio
High country streams	Manuherikia @ Loop Road	11	4	3
	Thomsons @ Diversion Weir	10	7	2
	Ida Burn @ SH85	11	5	2
	Average	**11**	**5**	**2**
Manuherikia Tributaries	Dunstan Ck @ Beatties	42	8	5
	Ida Burn @ River side	47	77	1
	Lauder Ck @ Rail Trial	18	21	1
	Thomsons @ SH85	44	66	1
	Chatto Ck US Manuherikia	259	36	7
	Average	**82**	**42**	**3**
Manuherikia main stem	Manuherikia @ Blackstone	9	6	2
	Manuherikia US Ida Burn	15	15	1
	Manuherikia @ Omakau	22	18	1
	Manuherikia @ Ophir	35	33	1
	Manuherikia US Chatto	25	26	1
	Manuherikia @ Galloway	23	20	1
	Average	**22**	**20**	**1**

(1) Dissolved inorganic nitrogen (average of fortnightly samples)
(2) Dissolved reactive phosphorus (average of fortnightly samples)
(3) DIN/DRP

The major risk of elevated inorganic nitrogen and phosphorus concentrations is nuisance periphyton growth. Current nutrient levels are one to two orders of magnitude less than concentrations that are even remotely toxic to fish, or the Drinking Water Standard limits, consequently these other risks are negligible.

Elevated nutrient levels are mainly a risk in the period Dec – April, when river flows are low and temperature and sun-shine hours are high. Since the N:P ratio is very low, and water clarity is high, the amount of nitrogen reaching the Manuherikia River is the main factor that determines the amount of periphyton growth.

3.5 Nitrogen uptake

Nitrogen loading is not the same as nitrogen concentrations. Ultra-low inorganic nitrogen concentrations are due mainly to algae growth being nitrogen limited, rather than ultra-low nitrogen loadings. When inorganic nitrogen enters a water way in summer it is generally quickly taken up by algae and plants. If the N:P ratio were not low (due to lower phosphorus levels) inorganic nitrogen concentrations would be higher simply because there would be less uptake by algae and plants. In this situation even though nitrogen concentrations would go up, periphyton growth would actually reduce. This illustrates that it can be misleading to consider either nitrogen or phosphorus concentrations in isolation of each other, or indeed of other stream and biological processes.

Actual nitrogen loadings to water ways are probably much higher than concentrations indicate. Nitrogen concentrations in land drainage in the Upper Manuherikia Valley are probably round 6,000 mg-N/m^3 (see Table 8). In all the Manuherikia Tributaries except Dunstan Creek, during low flow periods virtually all of the water that enters the Manuherikia River will be irrigation drainage water. Although most of this water would have passed through or over land, nitrogen concentrations in the water are generally only about 1% of the expect drainage water concentration. This would suggest the remaining 99% of the inorganic nitrogen is taken up by plants and algae in wetlands, riparian margins, and within the water ways.

Table 8: Estimated nitrogen losses given an average rainfall of 600-700 mm/y.

Land use	Drainage (mm/y)	Inorganic nitrogen losses		Source
		Drainage concentration (mg-N/m^3)	Load (kg-N/ha/y)	
High country sheep	100	2,000	2	Snow (2009)
Lowland sheep, dryland	80	6,000	5	ECan (2010)
Sheep, surface irrigation	400	6,000	24	
Beef, dryland	80	12,000	10	
Beef, surface irrigation	400	12,000	48	

During dry periods water in the Lower Manuherikia Main Stem will also be dominated by irrigation drainage water, not high country stream water. Despite this, measured inorganic nitrogen concentrations are less than 1% of expected drainage water concentrations.

The one tributary that has slightly elevated inorganic nitrogen concentrations is Chatto Creek. Nitrogen concentrations may well be higher because the stream is well shaded, which limits nitrogen uptake (see Figure 6). Dunstan Creek is another water way that would probably have lower nitrogen concentrations if the stream weren't well shaded by trees.

Figure 6: Chatto Creek at SH85, showing shading by willow trees

The removal of inorganic nitrogen within the Manuherikia River stream bed can be illustrated by observing what happens to the inorganic nitrogen from Chatto Creek during the dry period from January to March 2010 (refer Figure 7). During this period we estimate Chatto Creek contributed 40-50% of the flow in the Manuherikia River. Upstream of Chatto Creek Nitrite/Nitrate Nitrogen (NNN) concentrations were very low. Chatto Creek meanwhile had NNN concentrations 20 times higher, possibly because the lack of light in the stream meant NNN was not fully taken up by algae and plants. Below the Chatto Creek confluence we estimate NNN concentrations would have increased 10 fold as Chatto Creek water mixed with Manuherikia Water. However, by the time this water reached Galloway, 10 km downstream, NNN concentrations were even lower than upstream of the Chatto Creek confluence. The likely reason for this is because of NNN uptake between Chatto Creek and Galloway by algae on the stream bed.

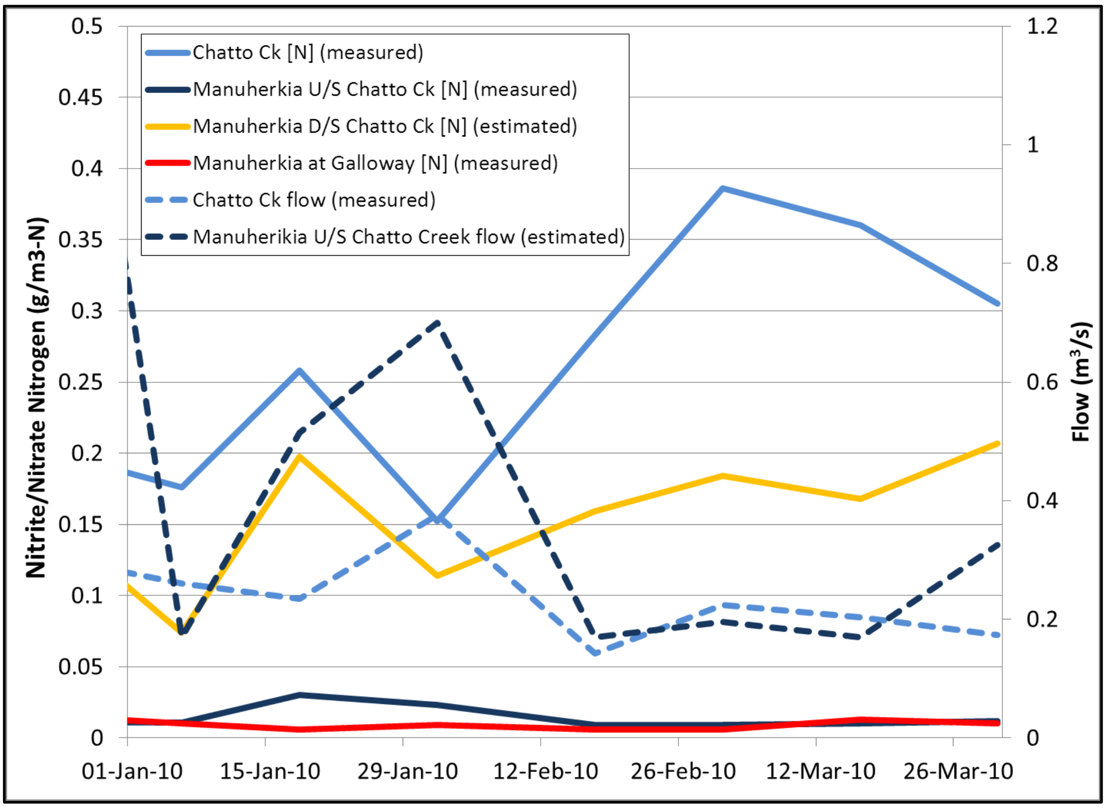


Figure 7: Inorganic nitrogen removal below Chatto Creek

3.6 Nitrogen loadings

Inorganic nitrogen is the only form of nitrogen that plants and algae can take up. Unfortunately inorganic nitrogen losses cannot be estimated from nitrogen concentrations in streams, because during low flows most of the available nitrogen is probably taken up by plants and algae.

Despite the inability to directly measure nitrogen losses, we expect nitrogen loadings during summer to be low for several reasons:
(1) The dry climate;
(2) The lack of groundwater storage;
(3) Free-draining soils with low organic content; and
(4) Lower intensity farming systems.

By a lack of groundwater storage we mean a reasonable amount of the water that passes through the soil profile re-appears in streams a relatively short distance away without spending long periods (i.e. less than 2-3 months) underground. Anecdotally, overland or near surface flow dominates in some parts of the valley, but in other parts of the valley groundwater storage may play a role with water re-appearing some distance away from the source. What is known is that groundwater yields are generally very low.

The dry climate and the general lack of groundwater storage are features of the natural environment that will not change as a result of irrigation or land use intensification.

The dry climate means that during the summer and autumn, without irrigation there is little soil drainage from December to April. Without soil drainage nitrogen remains in the soil since it takes water to transport nitrogen. Consequently virtually all nitrogen loss from dryland occurs in winter during periods of heavy rain and high stream flows.

The lack of groundwater storage is a critical factor in reducing inorganic nitrogen entering water ways in summer. Without groundwater storage, inorganic nitrogen enriched water in winter finds is way quickly into water ways without spending time in groundwater. This means nitrogen is primarily flushed out in winter, when it causes little problem, compared with re-immerging in summer as occurs in more groundwater dominate systems.

Measured Total Nitrogen mass flux appears to support the view that most nitrogen enters water ways during periods of high flows (see Figure 15). The mass flux is calculated by multiplying the concentration by the flow. Measurements at Galloway indicate that only about 1% of the annual TN from the Manuherikia River to the Clutha River flowed out during the low flow period from January to mid April 2010.

An interesting observation is Total Nitrogen (TN) is well correlated with Dissolved Reactive Phosphorus (DRP) (Figure 16). This could be because both are good indicators of on-farm nutrient losses. Measured nitrogen in most Manuherikia water ways is mainly organic nitrogen. This organic nitrogen may be from inorganic nitrogen that algae have converted. It could also be from irrigation runoff.

The trend in a strong correlation between TN and DRP is evident in many New Zealand Rivers (NIWA 2012). Across New Zealand, TN is also more strongly correlated to periphyton cover than NNN (NIWA 2012); illustrating TN concentrations can better represent the inorganic nitrogen loading to streams, than actual inorganic nitrogen concentrations.

Free draining soils with a low organic content are another reason we would expect nitrogen losses to be lower. Irrigating pasture will tend to improve soils, by increasing the organic content. Over a long period (15 – 30 years) this will result in soils becoming fully developed, which may increase nitrogen losses.

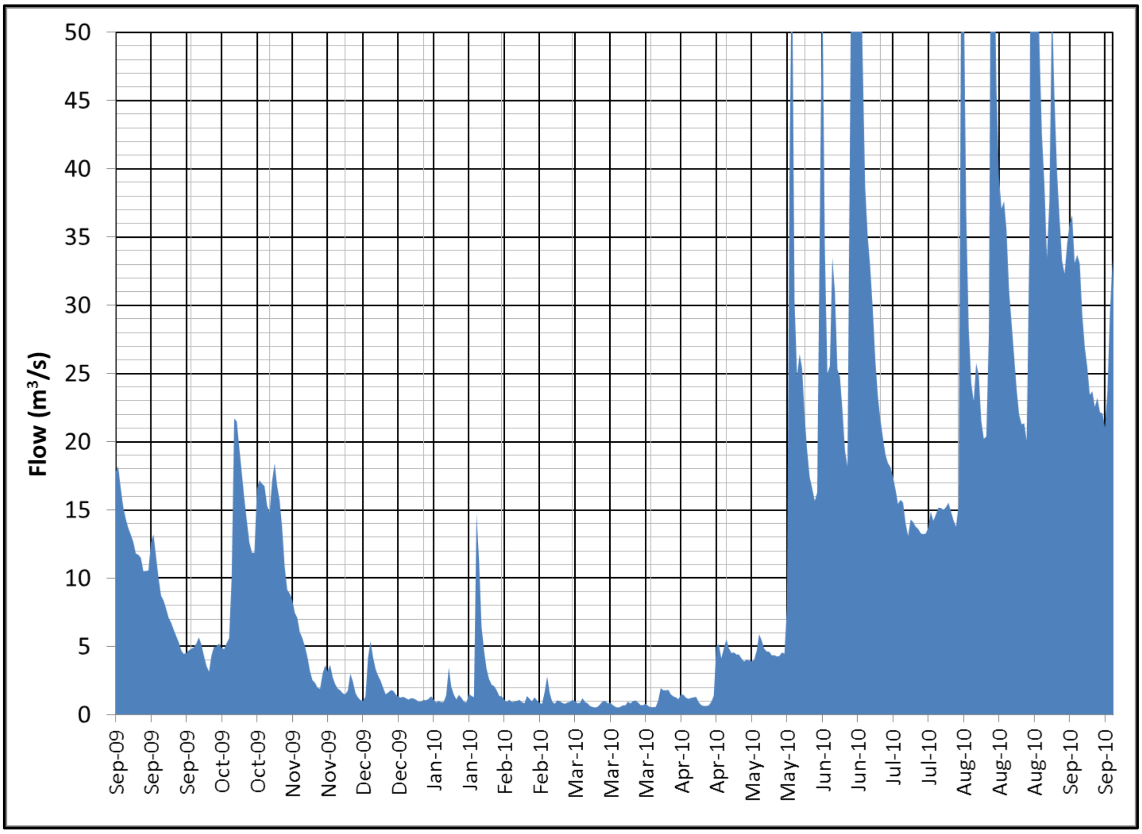


Figure 8: Manuherikia River flows at Campground: Sept 2009 – Sept 2010

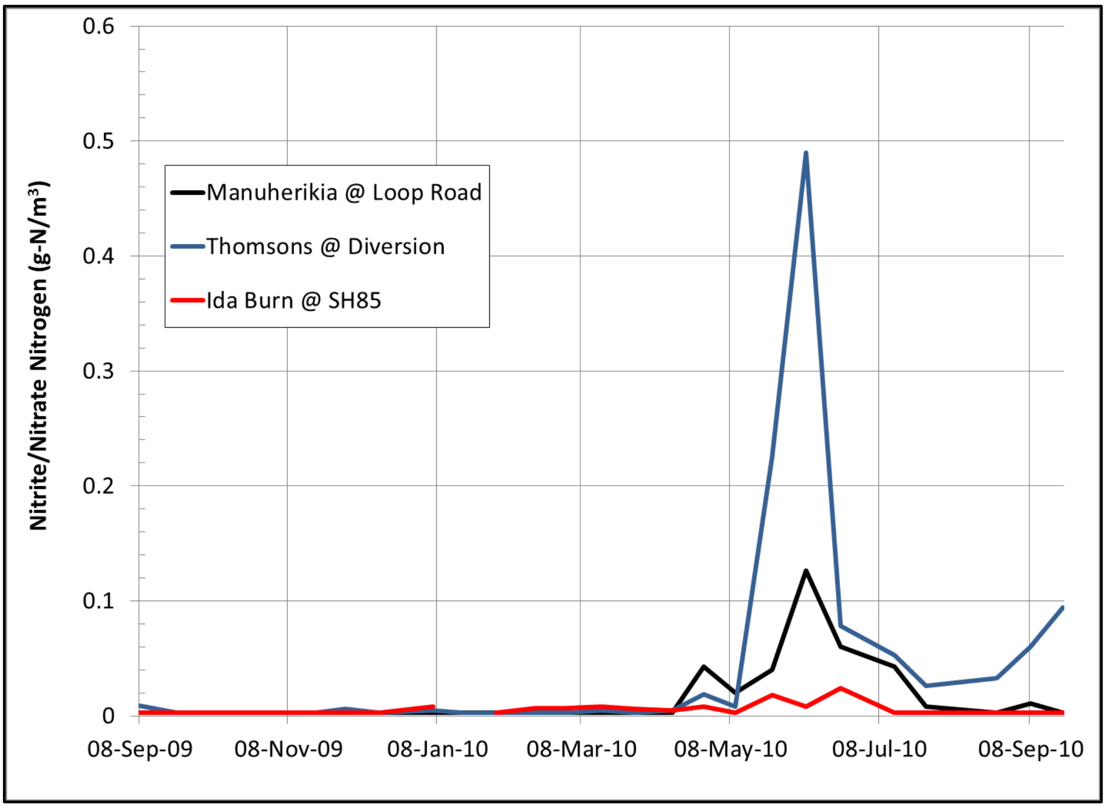


Figure 9: NNN concentrations in high country streams (no upstream irrigation)

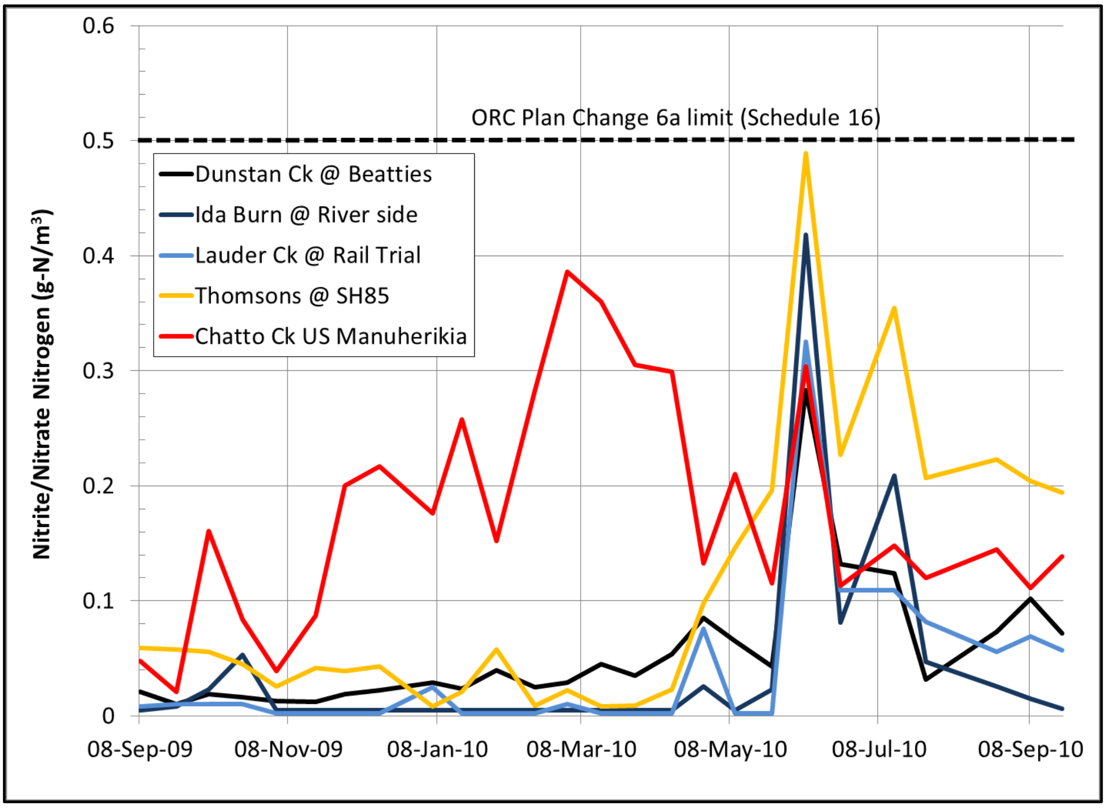


Figure 10: NNN concentrations in Manuherikia tributaries

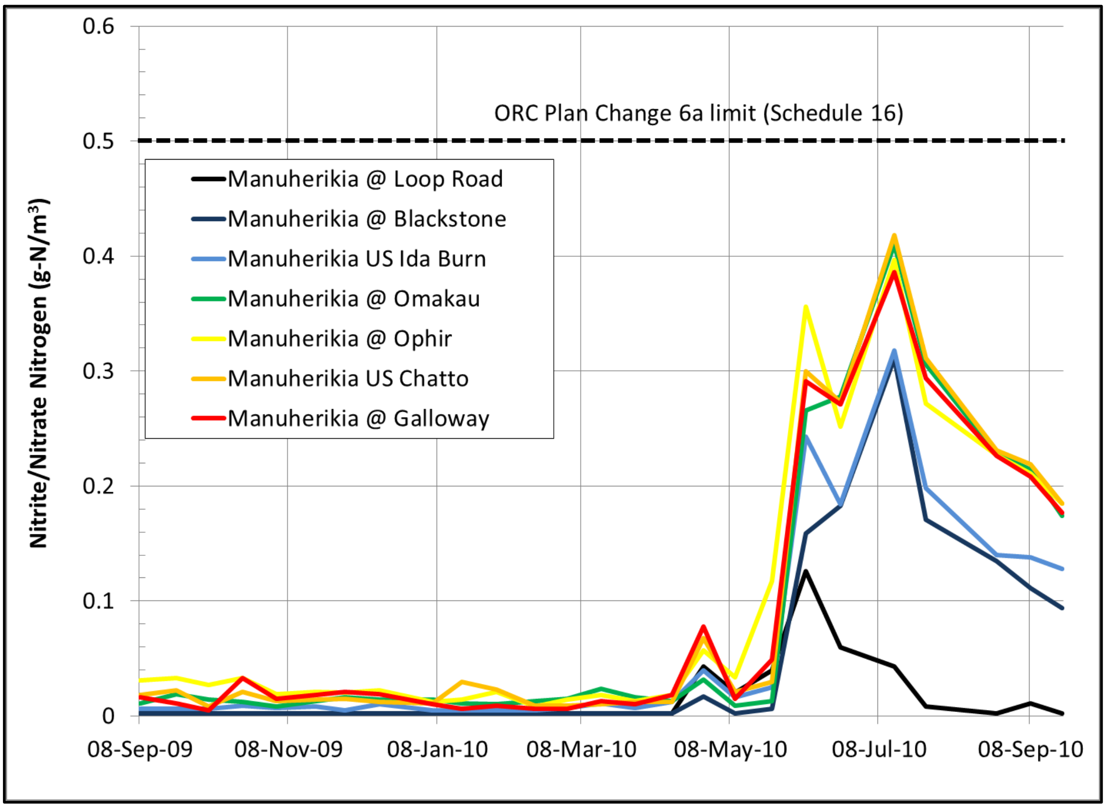


Figure 11: NNN concentrations in Manuherikia Main Stem

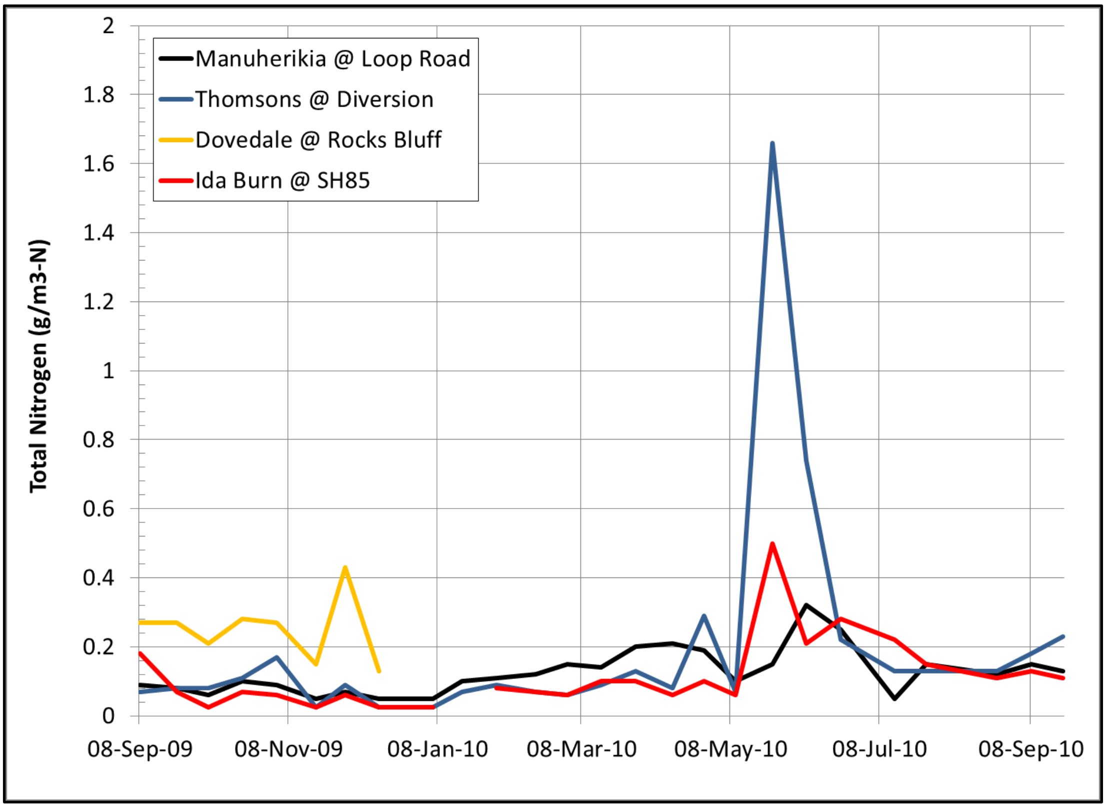


Figure 12: TN concentrations in high country streams (no upstream irrigation)

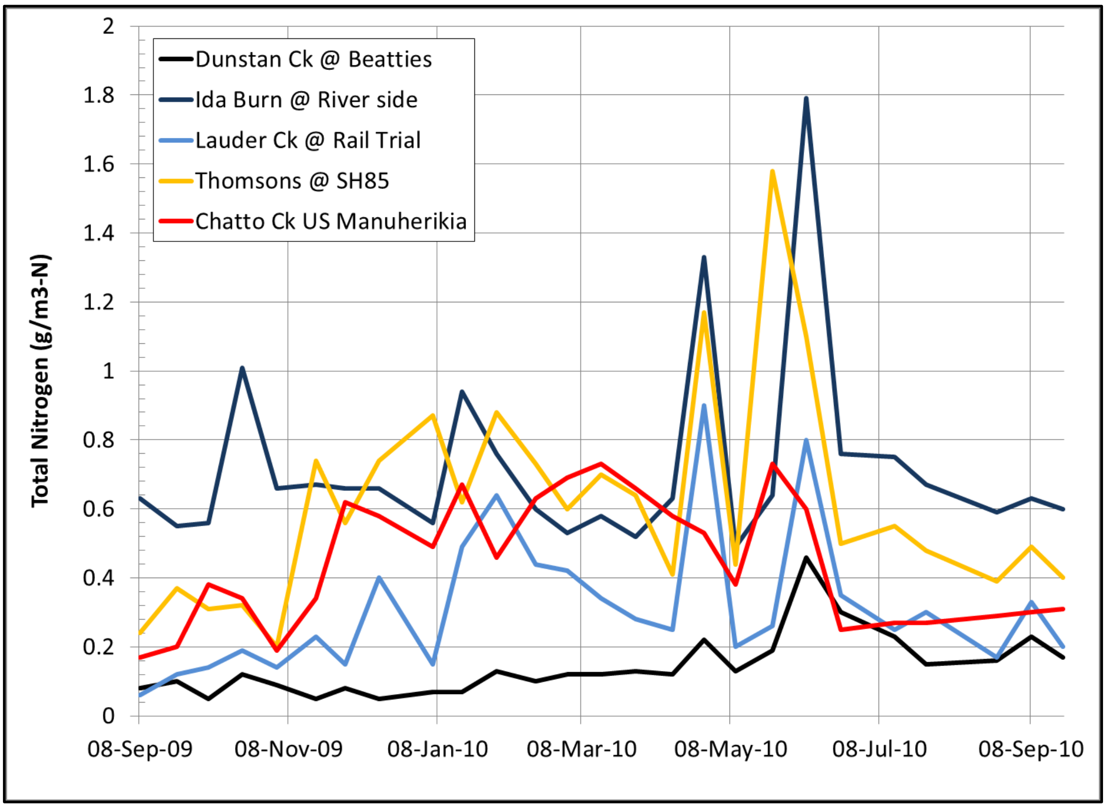


Figure 13: TN concentrations in Manuherikia tributaries

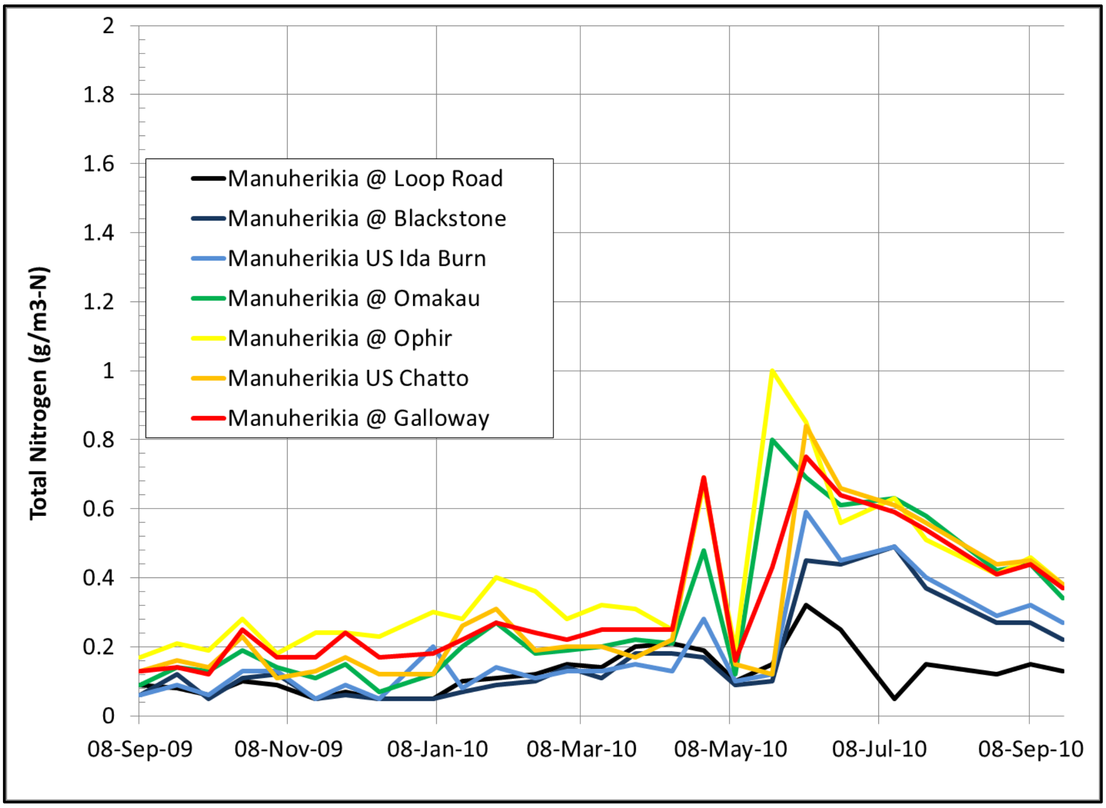


Figure 14: TN concentrations in Manuherikia Main Stem

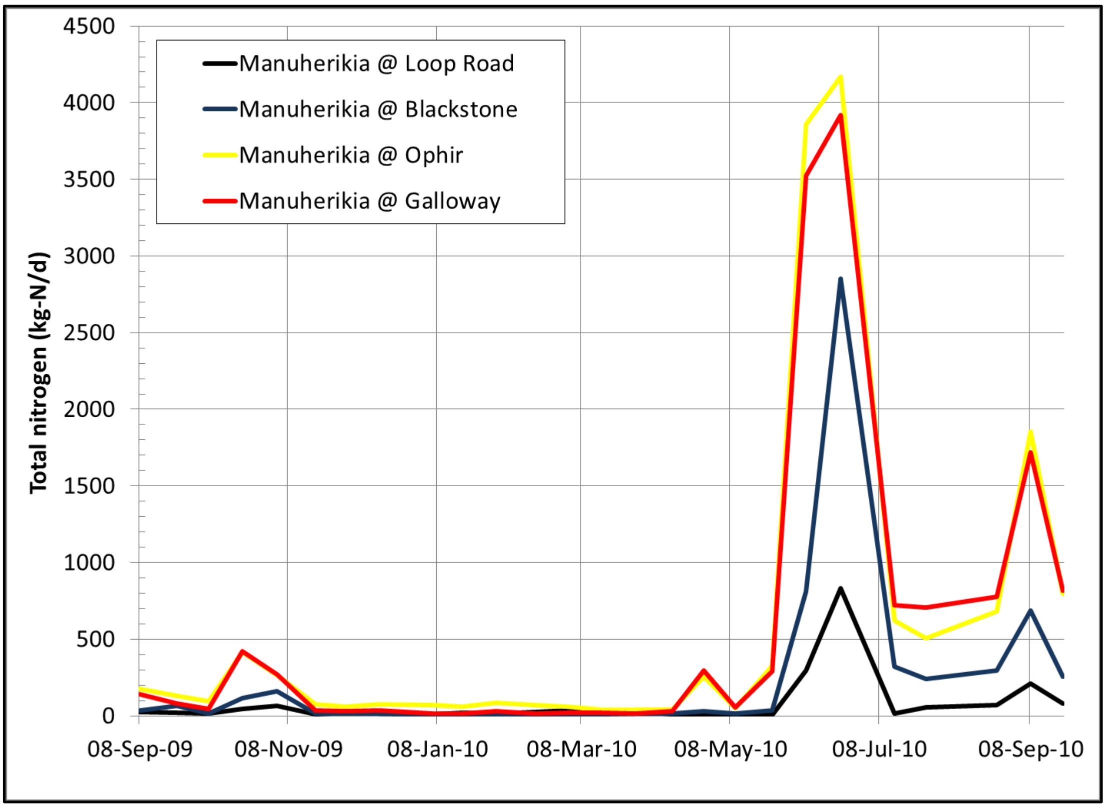


Figure 15: TN mass flux in Manuherikia Main Stem

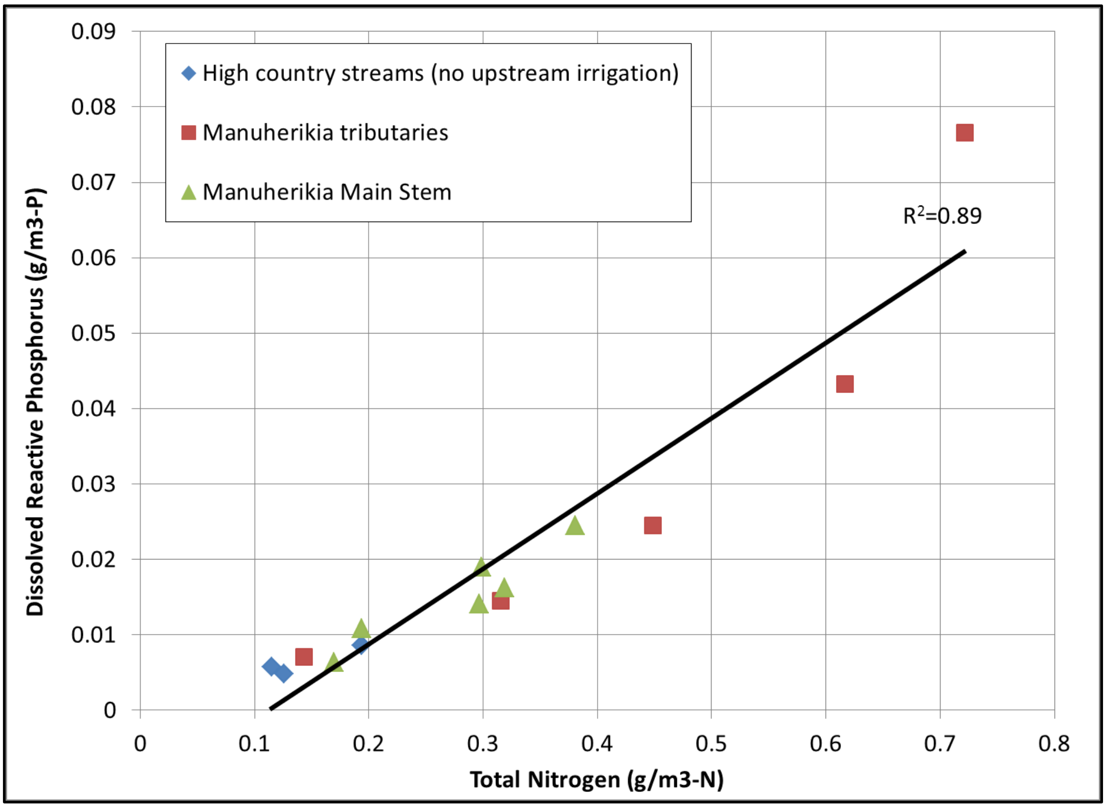


Figure 16: Relationship between average annual TN and DRP concentrations

3.7 Phosphorus loading

The proportion of phosphorus removed in-stream will be much less than for inorganic nitrogen, because algae uptake is nitrogen limited. Therefore phosphorus concentrations give at least a ball-park estimate of phosphorus loadings. Phosphorus concentrations in the high country streams, upstream of irrigation, are generally very low (Figure 17). In tributaries which receive a high proportion of irrigation drainage water phosphorus concentrations are 5-10 times higher than high country streams, during the irrigation season (Figure 18). Manuherikia Main Stem concentrations are in-between, since the water is a mixture of high country streams and irrigation run-off (Figure 19).

Irrigation runoff from wild flooding and contour irrigation will be a major source of phosphorus. Reducing irrigation runoff will reduce phosphorus loadings, which should result in a reduction in phosphorus concentrations.

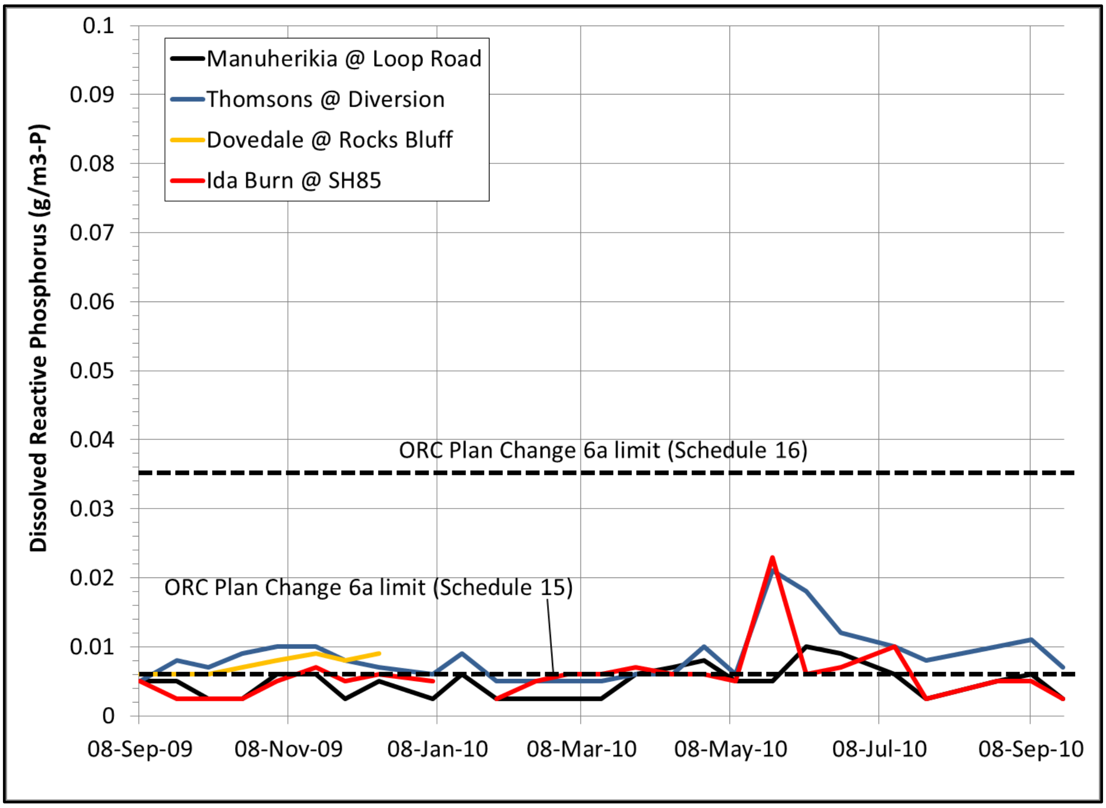


Figure 17: Phosphorus concentrations in high country streams (no upstream irrigation)

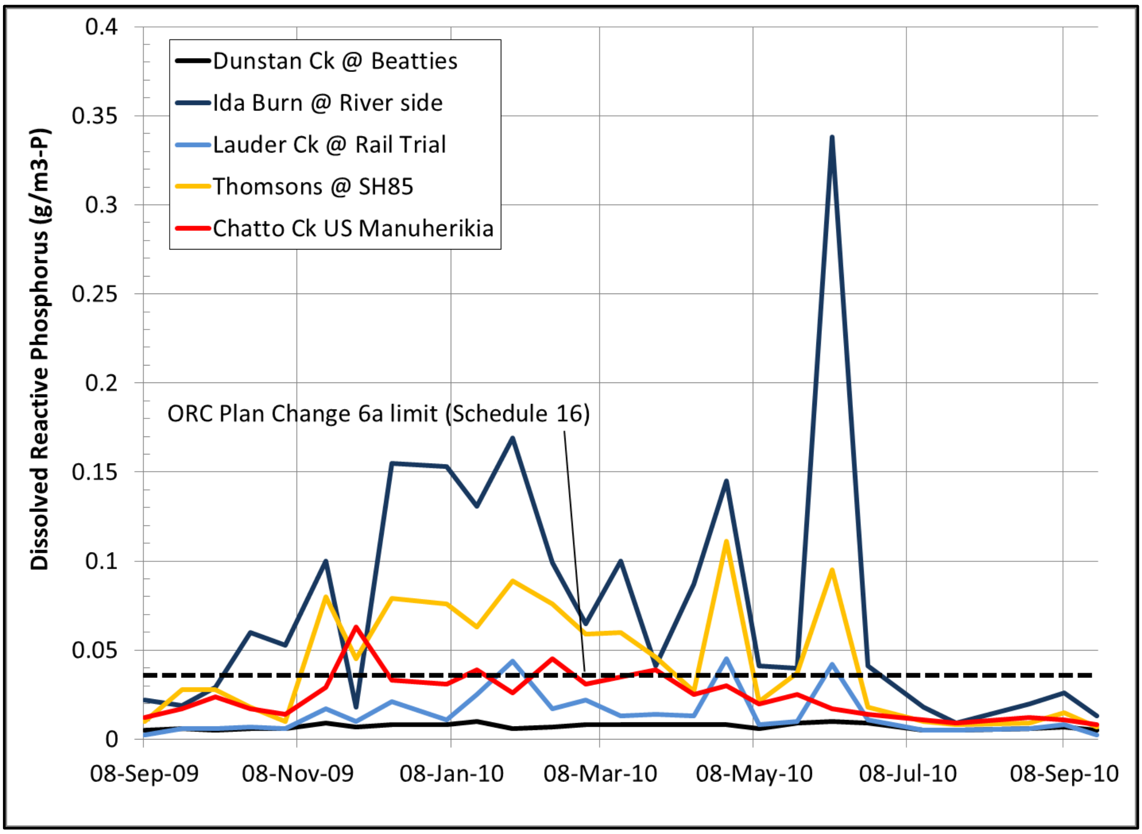


Figure 18: Phosphorus concentrations in Manuherikia tributaries

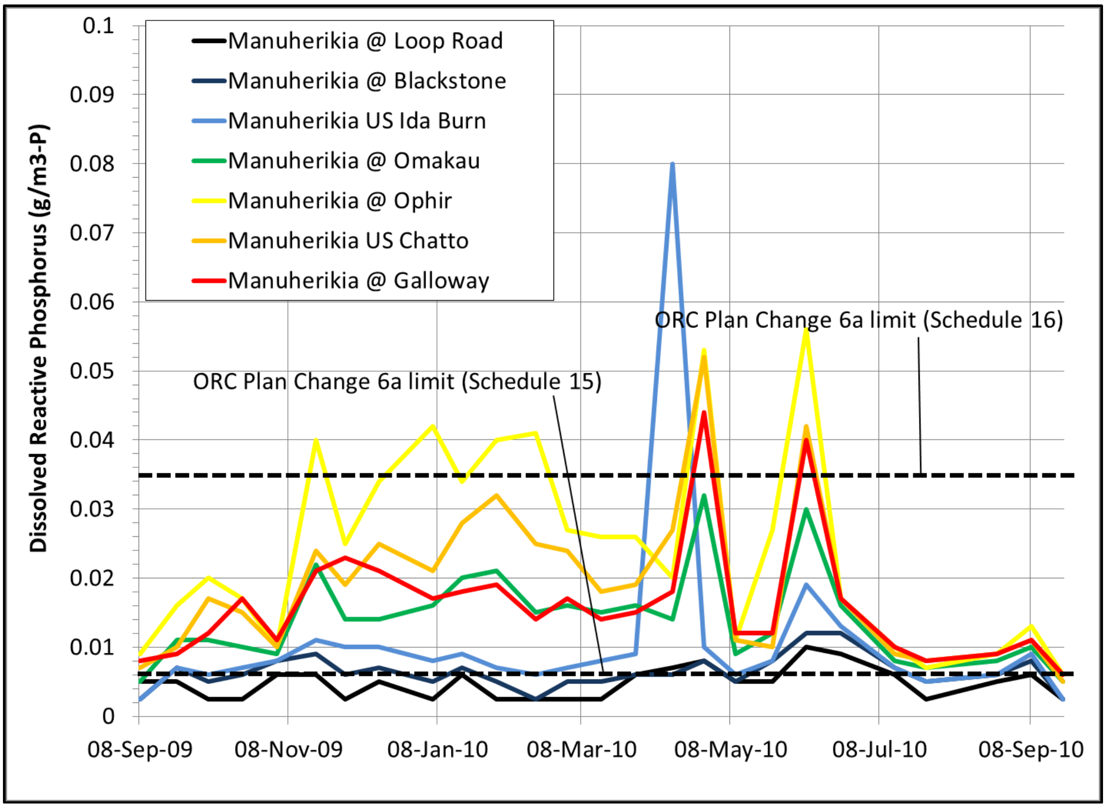


Figure 19: Phosphorus concentrations in Manuherikia Main Stem

4 Water quality impacts

Land use intensification can pose a risk to water quality. The most important risks are probably EColi, sediment, and ammonia contamination. These point source contaminates can be minimised through good effluent and riparian management, and preventing irrigation runoff.

Another concern with land use intensification is more algae growth as a result of increased nitrogen and phosphorus. Managing these diffuse source contaminates can be more challenging. There is however some factors that mean the Manuherikia River is at less risk of nutrient problems compared with some other catchments in Otago. These factors include the dry climate, the lack of groundwater, the irrigation command area being relatively flat, and the free draining soils.

Water quality is particularly important in Dunstan Creek and the Manuherikia Main Stem. These water ways are valued for their aesthetic value and their trout fishery.

We expect converting surface irrigation to spray irrigation will reduce both phosphorus and nitrogen losses during the irrigation season, because without overland flow and soil drainage both phosphorus and nitrogen will remain in the soil.

The dry climate and lack of groundwater means with efficient irrigation most nitrogen losses from land will probably enter water ways during periods of high river flows, at a time when nutrients do not cause any problems. In the Manuherikia, efficient irrigation is probably the single most important factor in minimising nutrient losses during the critical summer and early autumn period. Nitrogen is only lost when soil drainage occurs, so if soil drainage is well controlled during the irrigation season losses will be low. The limited groundwater storage means winter nitrogen losses from land should generally not reappear in summer.

Other factors that mitigate the nutrient risk are higher minimum flows and potentially artificial fresh flows.

We recommend further monitoring and data analysis be done to understand periphyton growth and removal dynamics. Until this work is done it is not possible to say for sure how periphyton cover may be affected by land use intensification and/or land use change.

Early indications are that it will be possible to fully irrigate the Manuherikia Valley and to farm effectively, while at the same time maintaining good water quality, provided land use remains predominately sheep farming. Good irrigation management and farming practices will be necessary. What is less clear is whether the catchment could also accommodate a large scale shift in land use to higher risk activities such as cropping and dairying, without compromising water quality.

An audited farm plan system has proven to be an effective tool in minimising environmental risks in the North Otago Irrigation Scheme and Morven Glenavy Irrigation Scheme. We recommend a similar system be applied in the Manuherikia Valley if there is large scale irrigation development.

Although no irrigation is proposed above Falls Dam, increasing Falls Dam storage may increase nitrogen levels in and downstream of the lake in summer. The reason is because increased Falls Dam storage may mean some of the nitrogen losses from land in winter may remain in the lake until summer. Whether there is an increase or not will depend on the level of nutrient uptake within the reservoir. While we expect nutrient uptake within the reservoir will result in very low nutrient concentrations in summer, this requires checking. Water quality sampling of the Upper Manor Burn and Pool Burn reservoirs would provide a good indication of how Falls Dam reservoir nutrient concentrations could change, since these lakes carry winter high country runoff water through to the summer.

5 Plan Change 6a

We expect Plan Change 6a nutrient limits will be significantly revised before the plan is finalised. Notified plan limits ignore a number of important stream and biological processes, and therefore values are somewhat arbitrary. Until the final version of the plan is known, we cannot say how well irrigation development scenarios align with the plan.

In its notified form, it is unlikely the plan could be complied with irrespective of whether irrigation development occurs. For example ORC's proposed Schedule 15 nitrogen and phosphorus targets may be difficult to achieve, even without irrigation development, because of the inter-relationship between inorganic nitrogen and phosphorus. As one of these nutrients goes down, the other will go up, because of reduced algae and plant uptake. Schedule 15 targets are very low (DRP<6mg-P/m^3, Nitrite/Nitrate-N<75mg-N/m^3) and achieving both very low nitrogen **and** very low phosphorus downstream of lowland farming would be difficult. Achieving one or the other of these targets is much more achievable.

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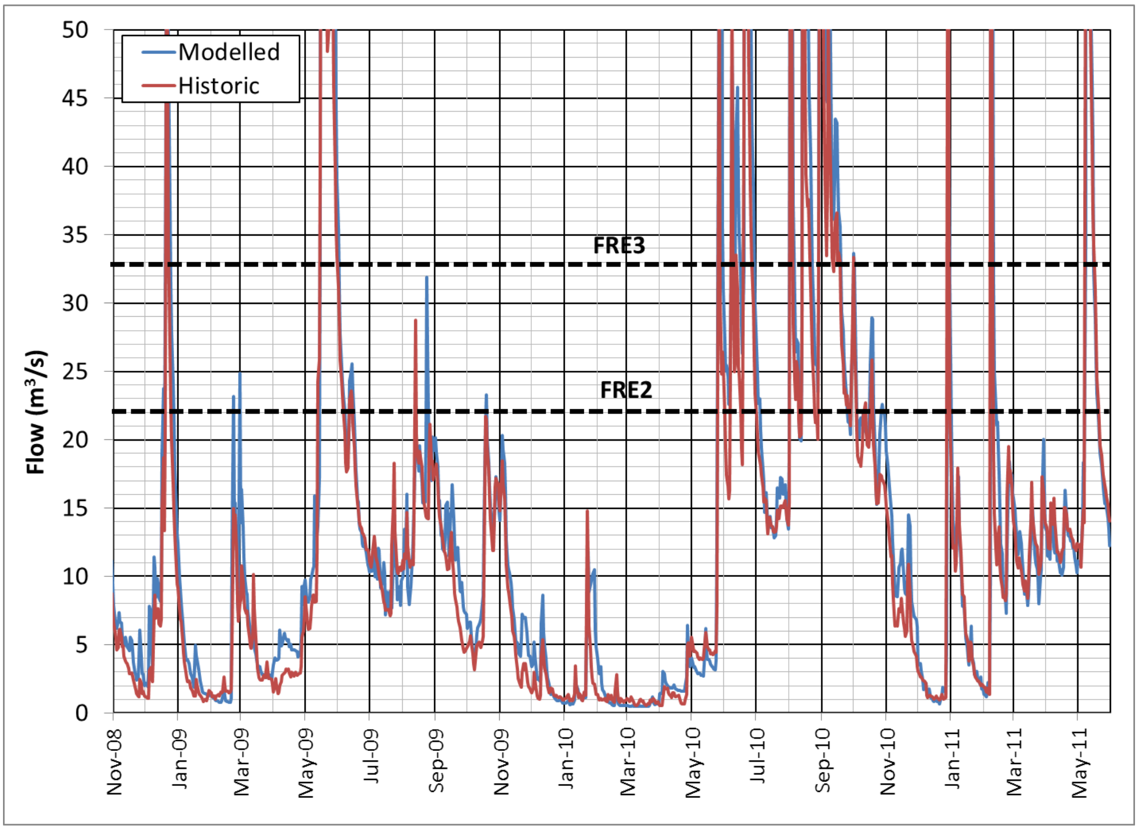
Appendix A: Manuherikia flow at Campground



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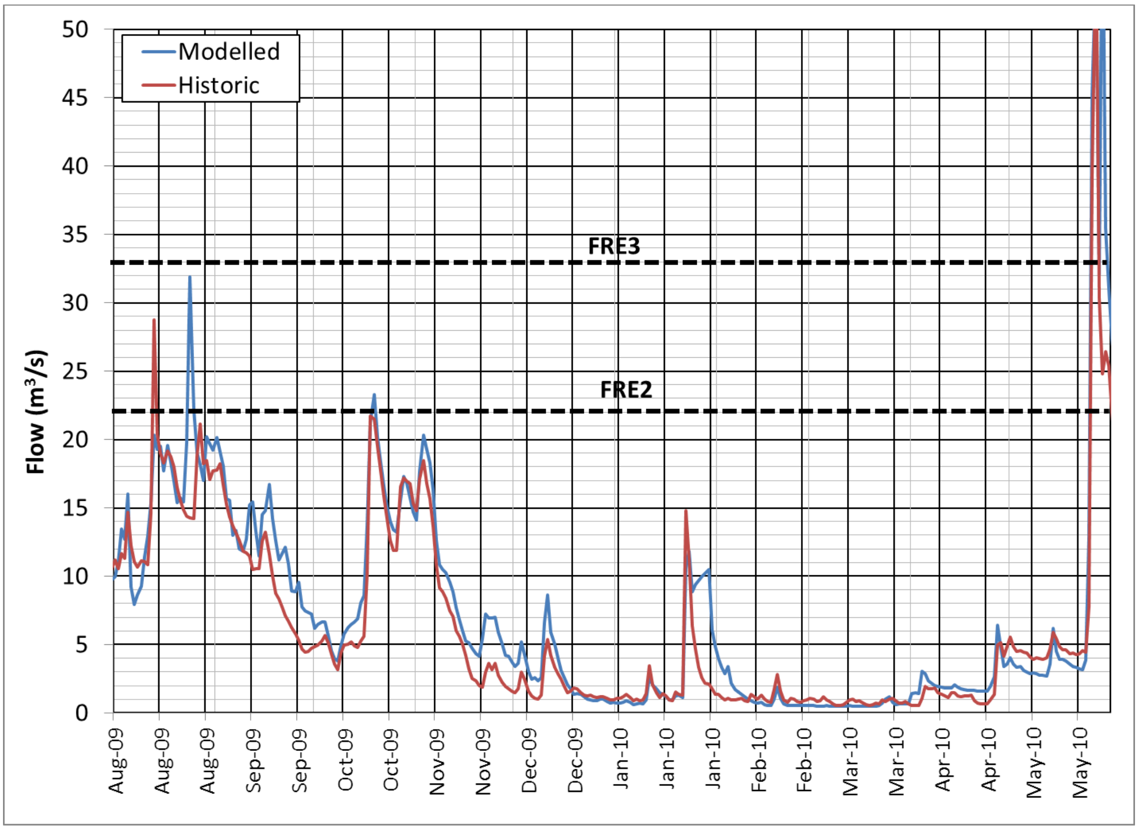

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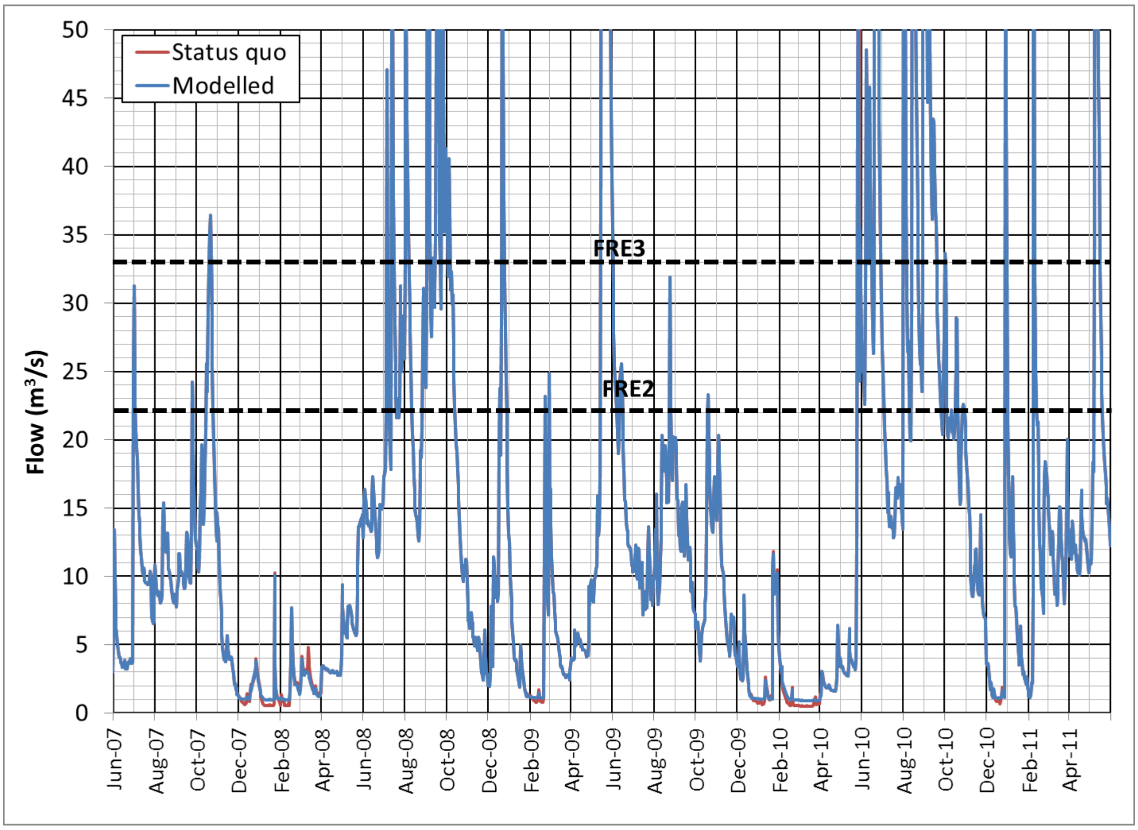

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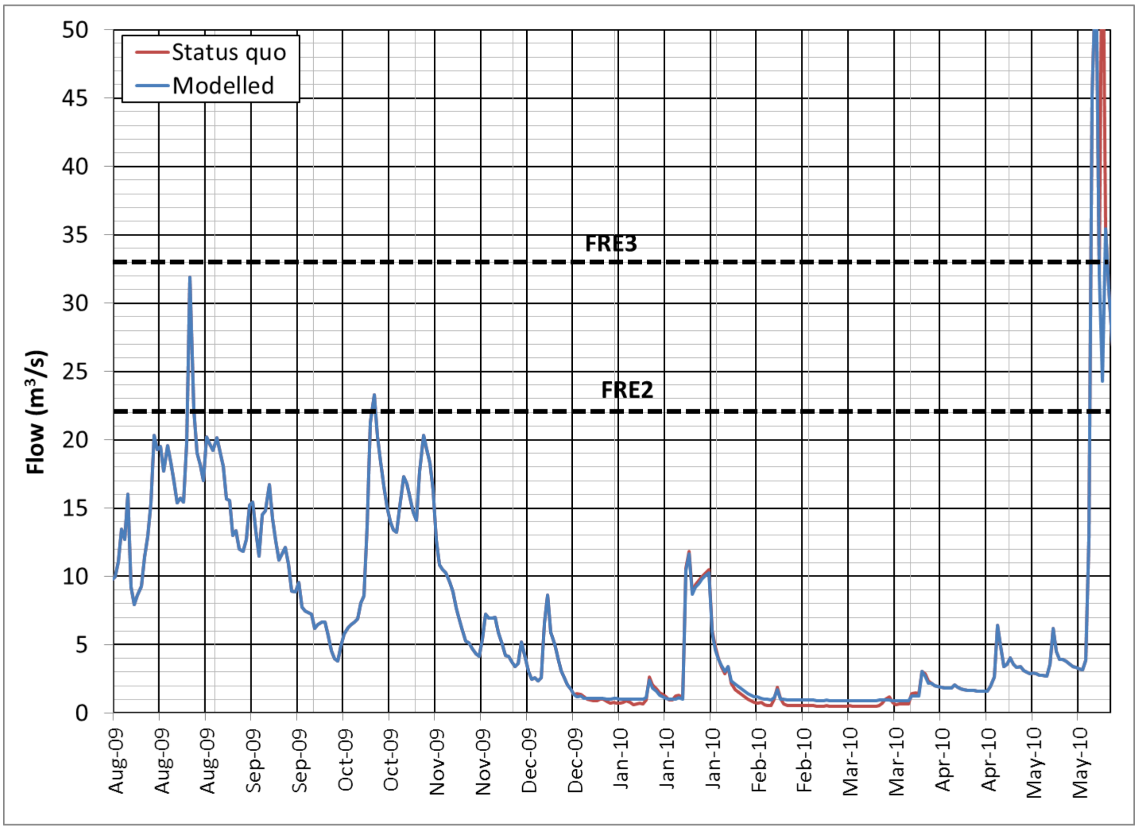

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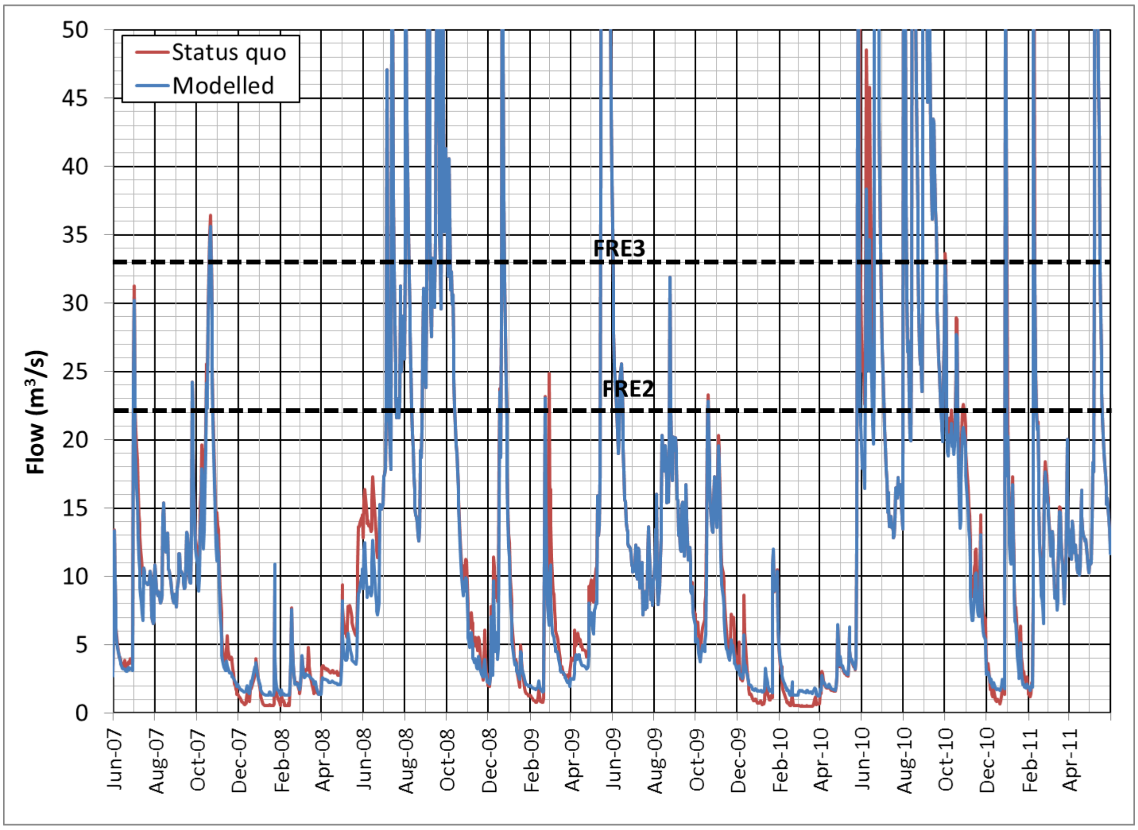

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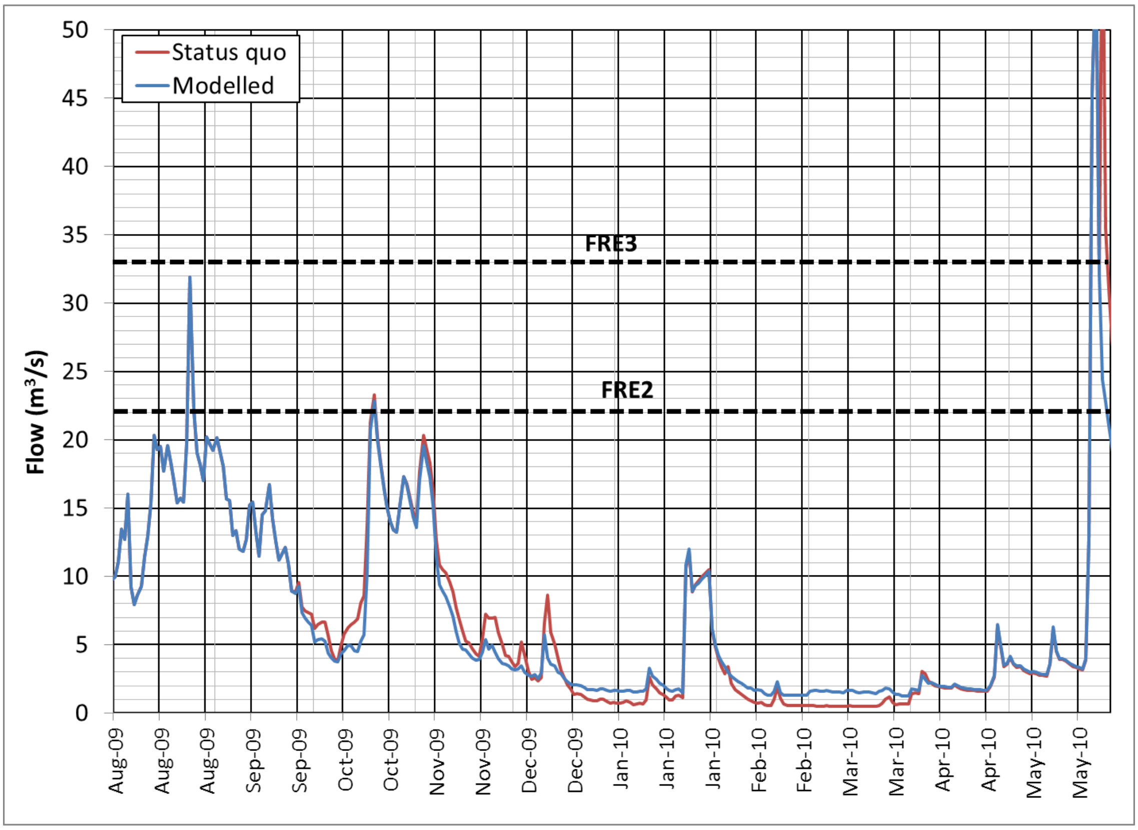

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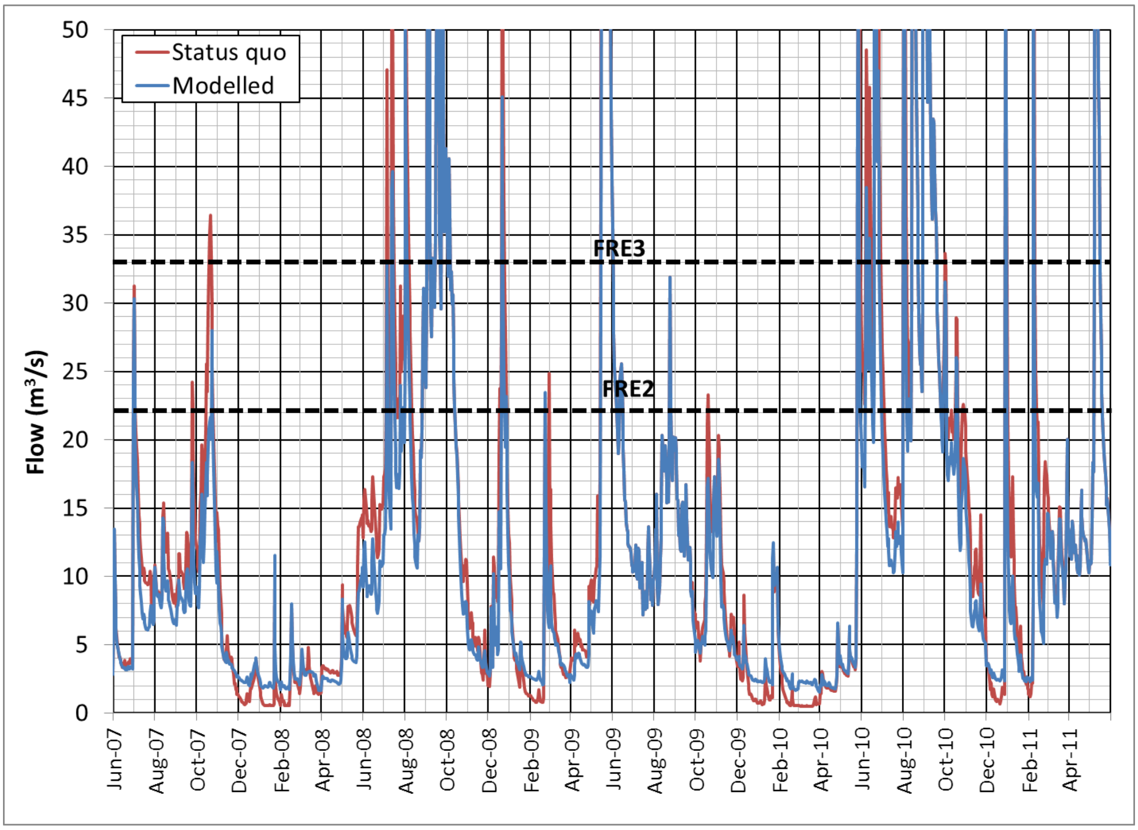

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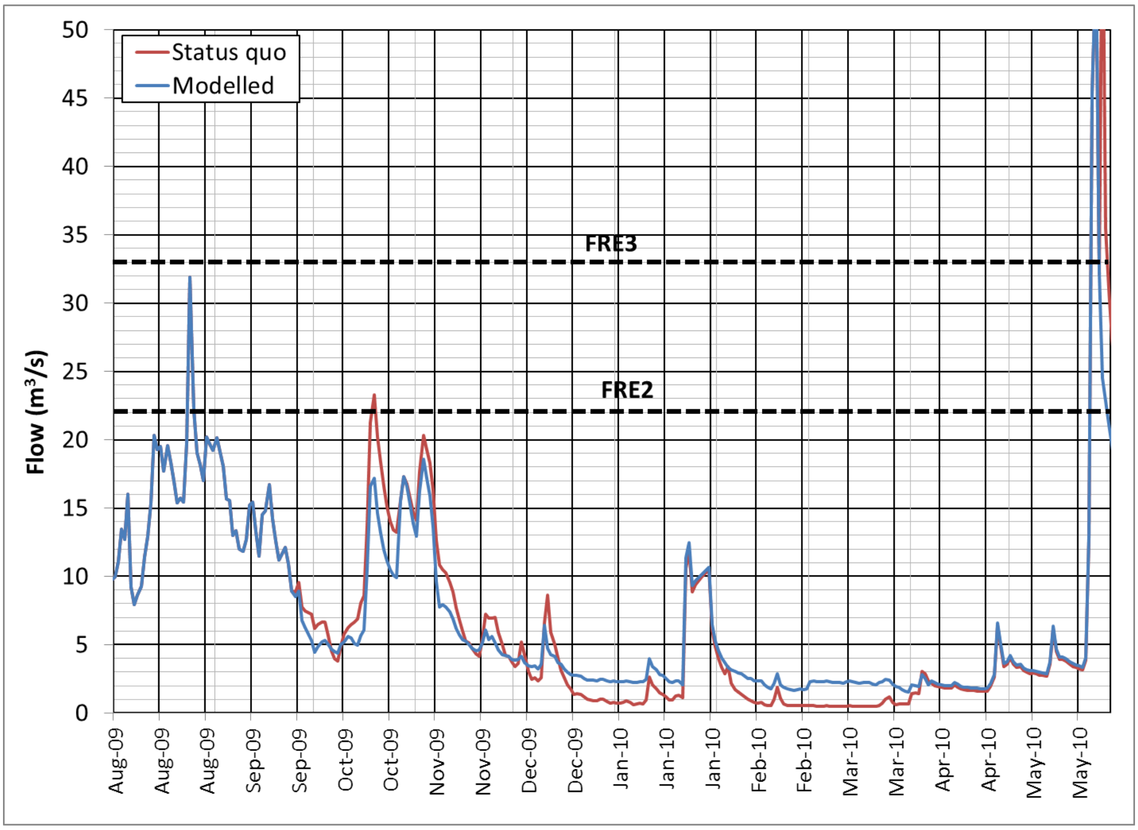

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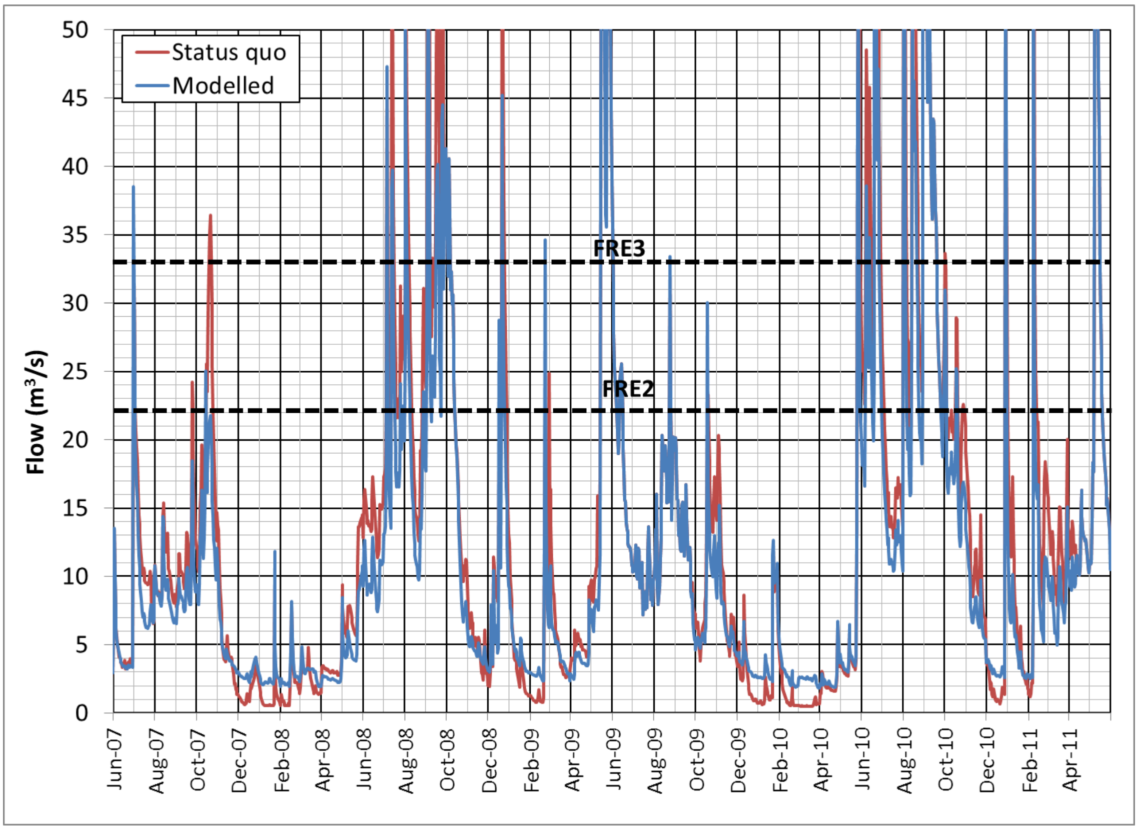

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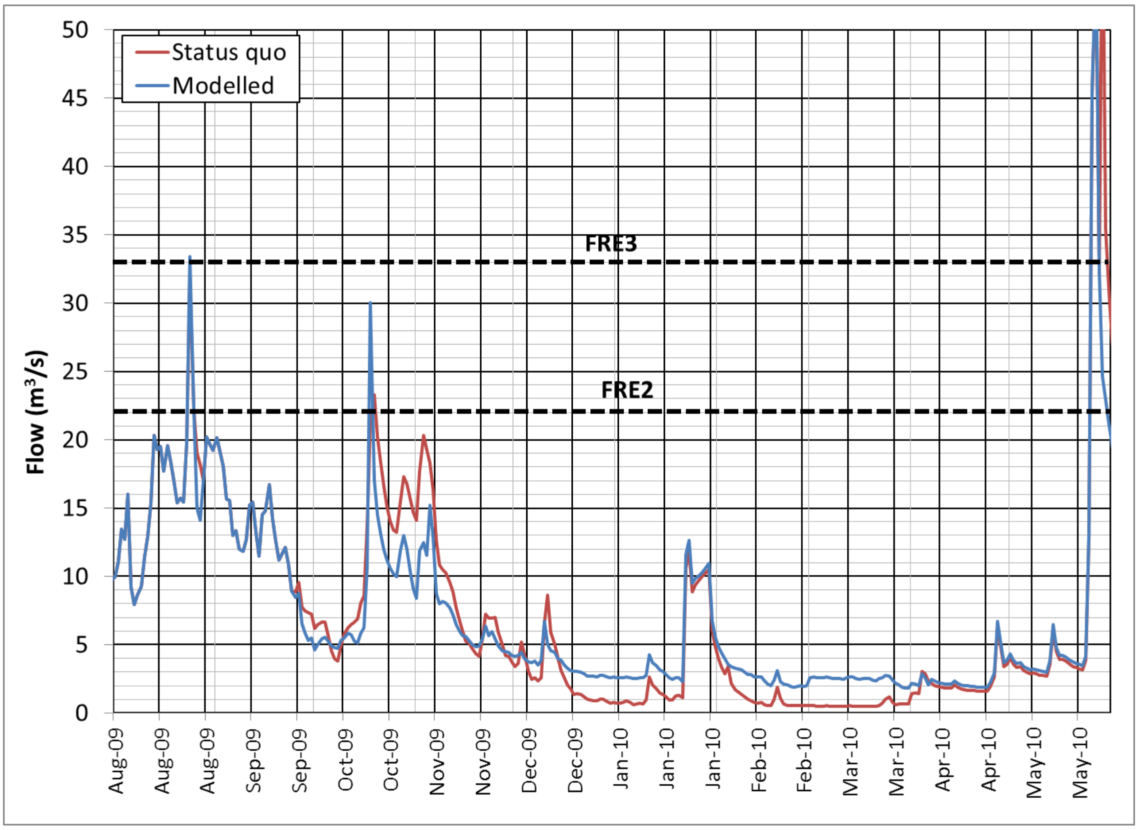

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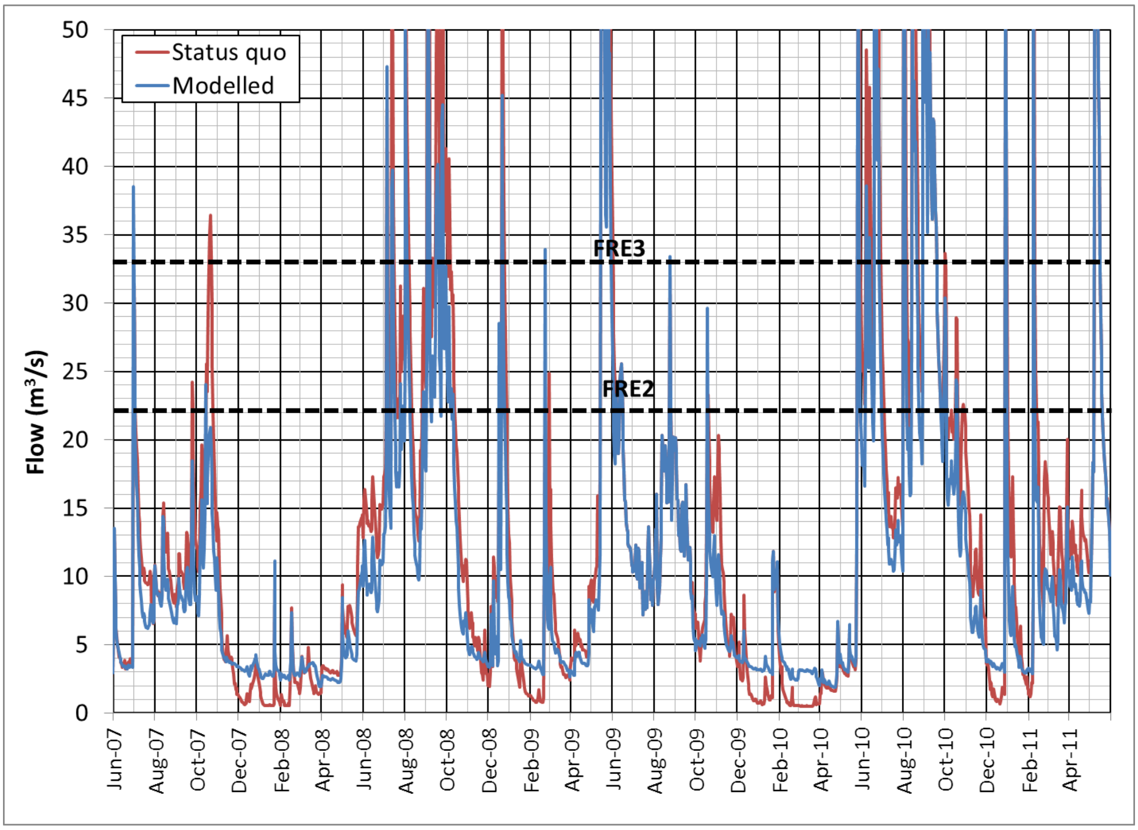

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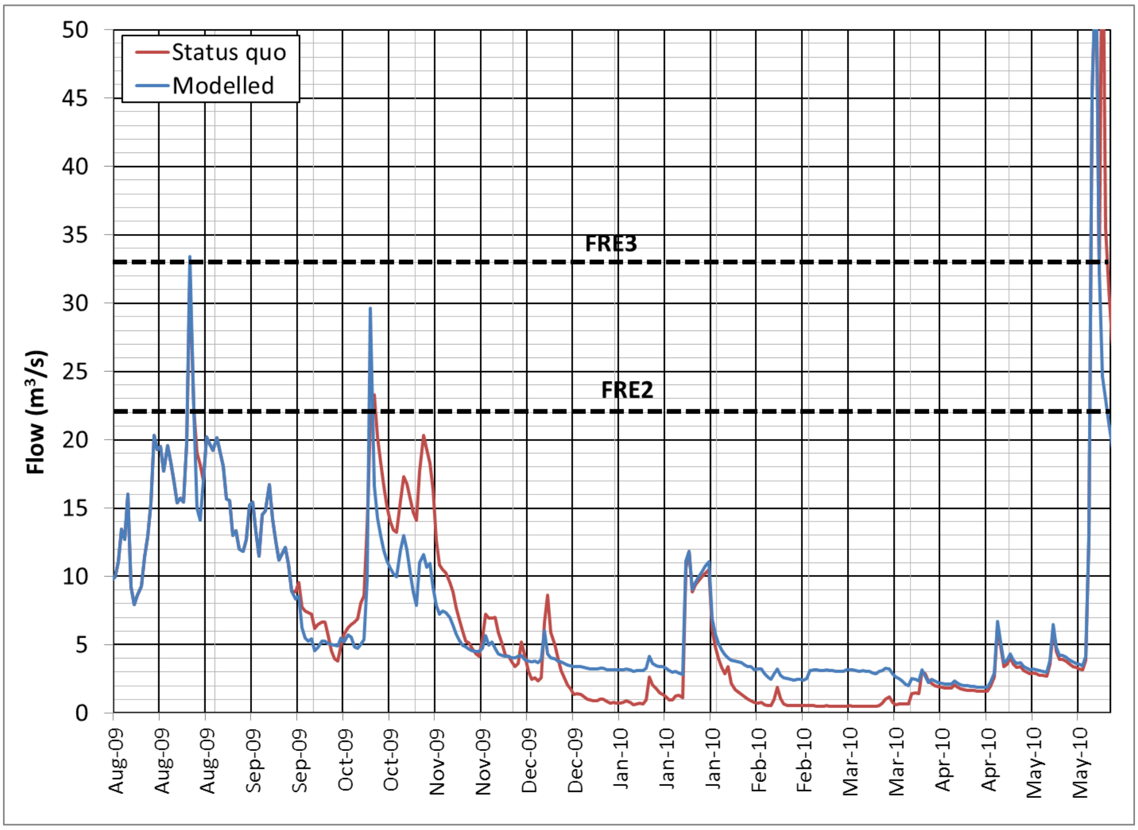

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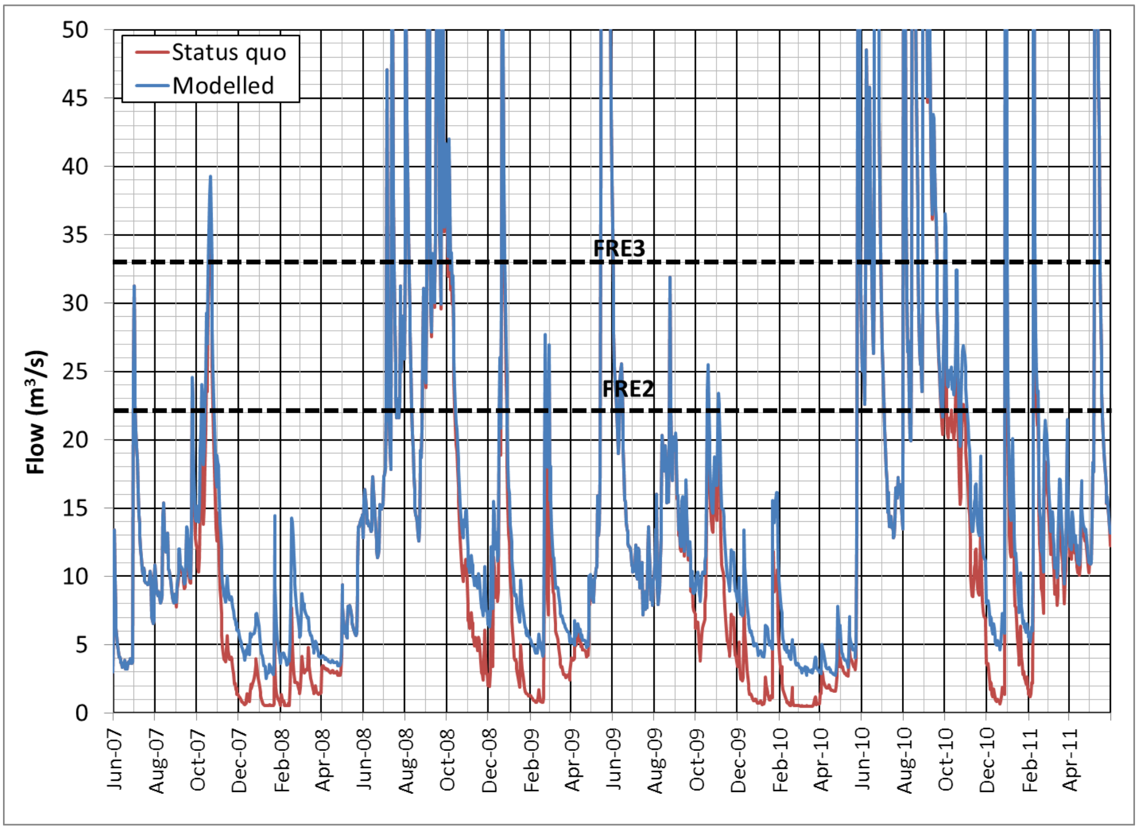
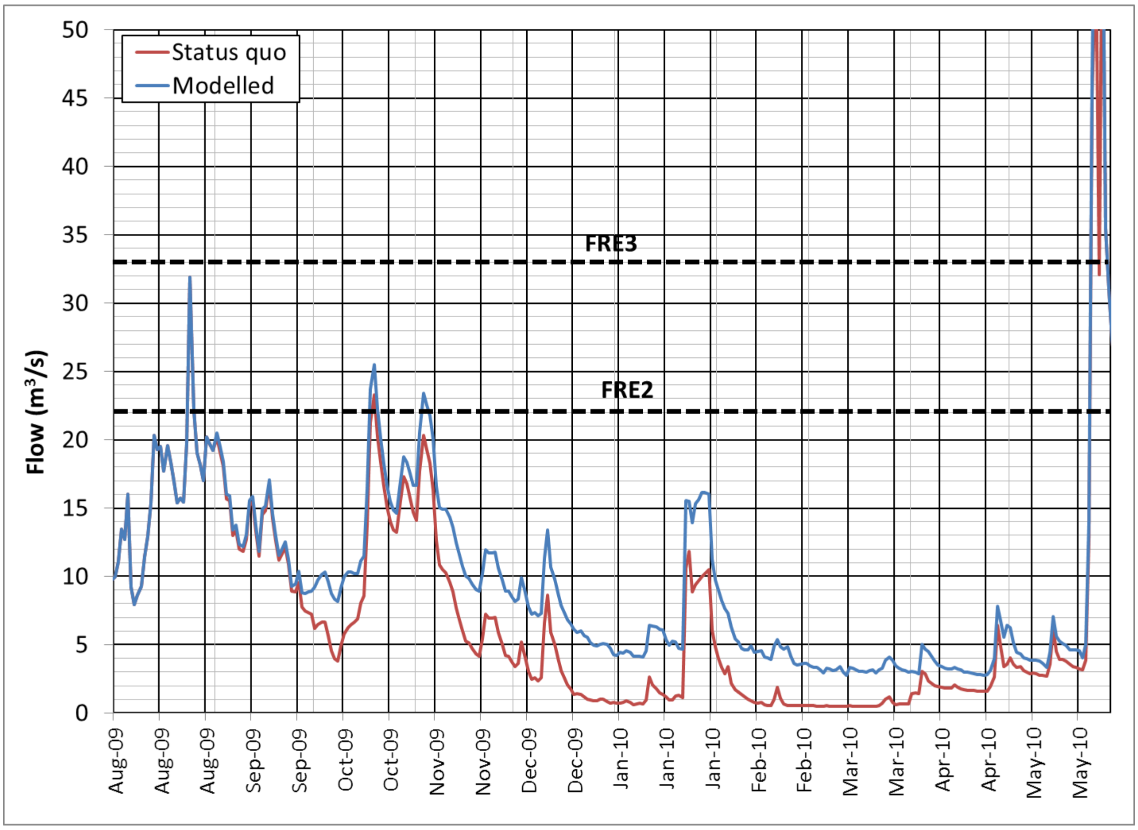
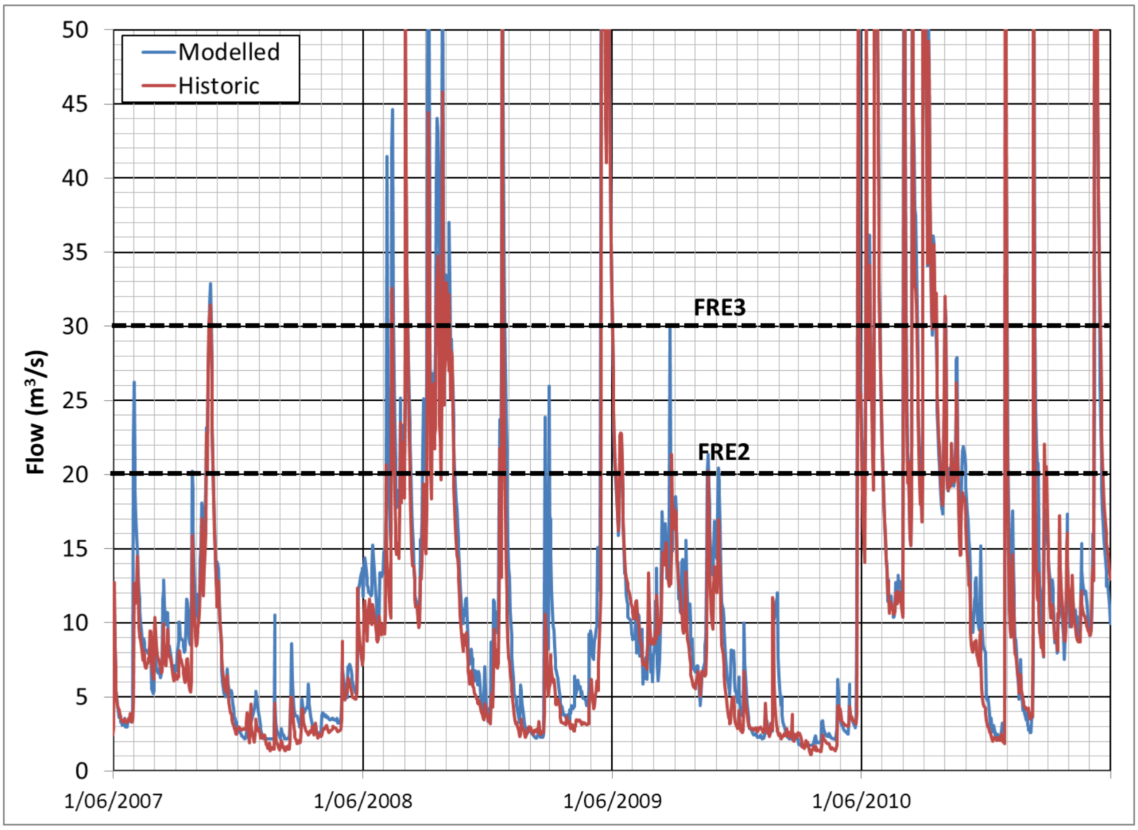


No Manuherikia Valley irrigation, but status quo Mt Ida Race and Ida Valley water use



No Manuherikia Valley irrigation, but status quo Mt Ida Race and Ida Valley water use

Appendix B: Manuherikia flow at Ophir



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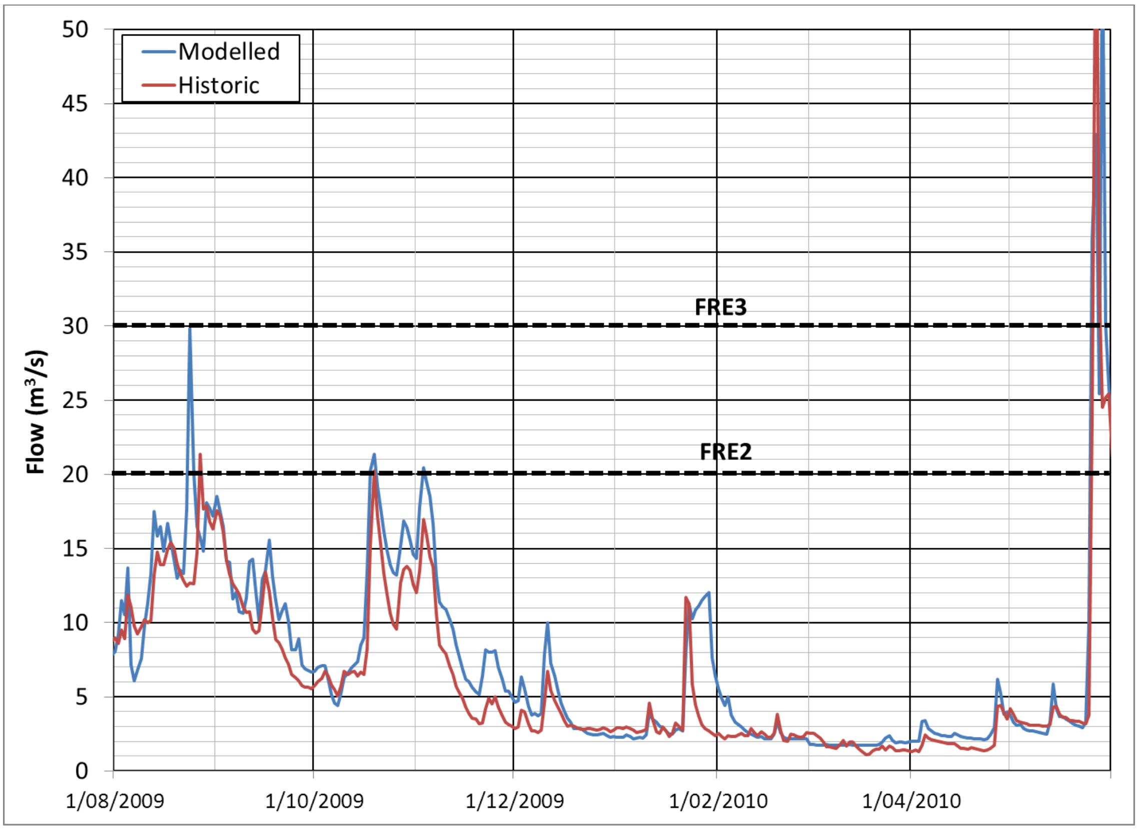

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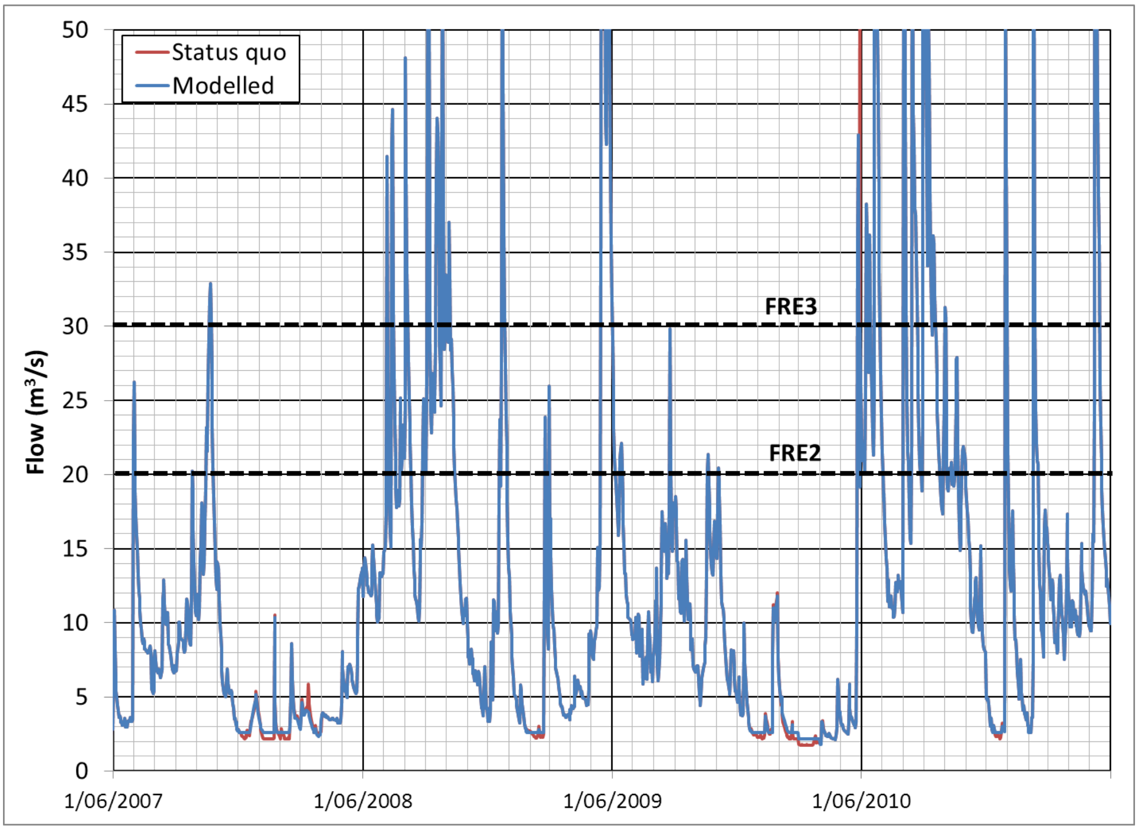

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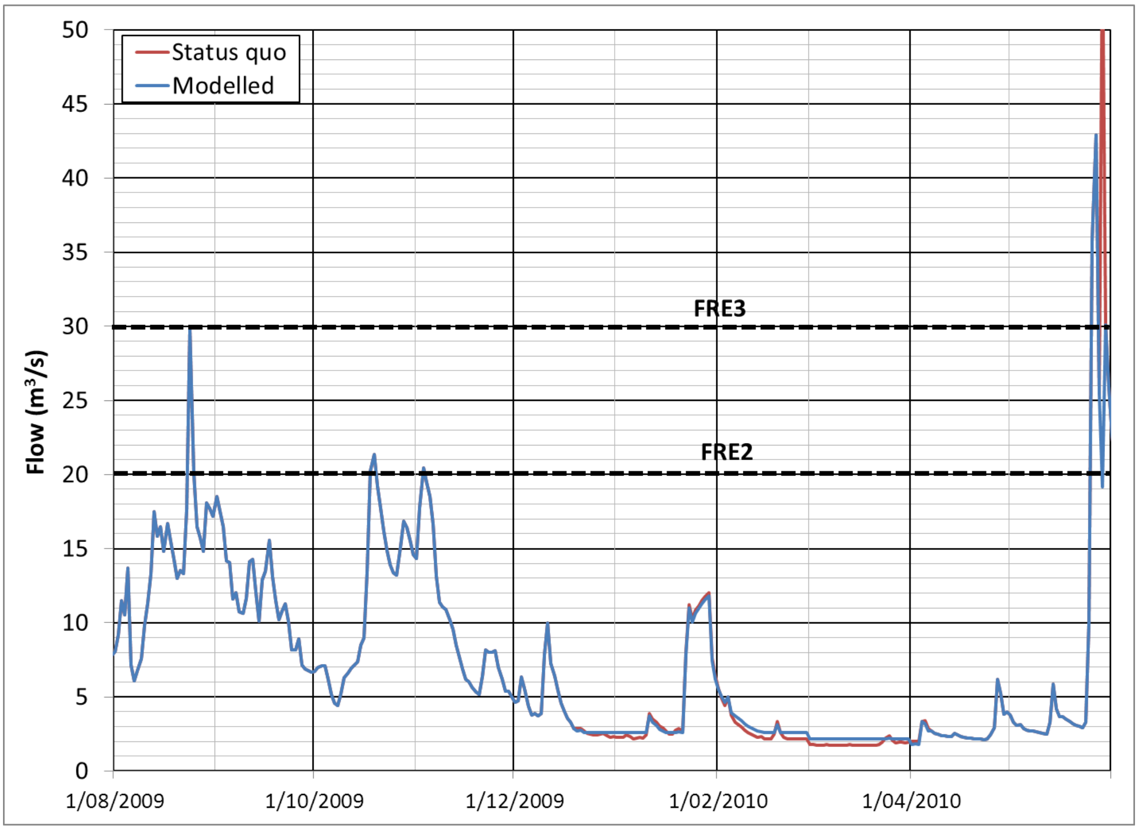

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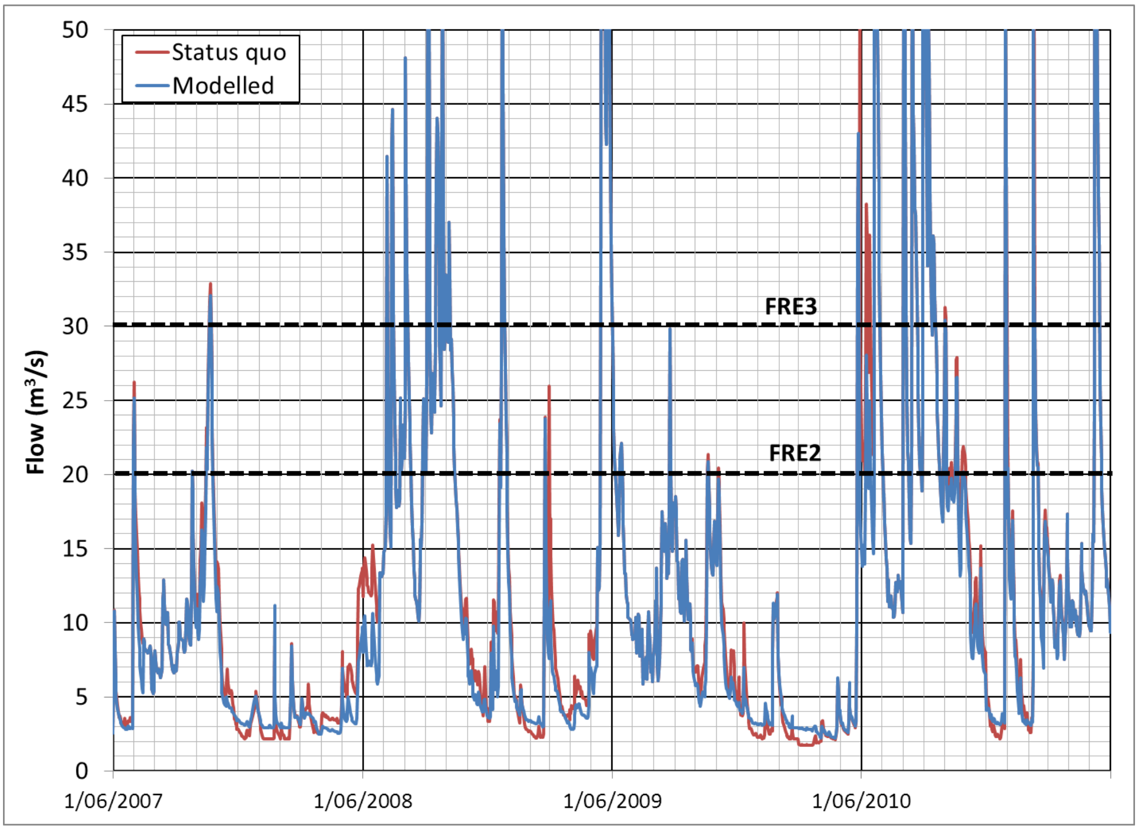

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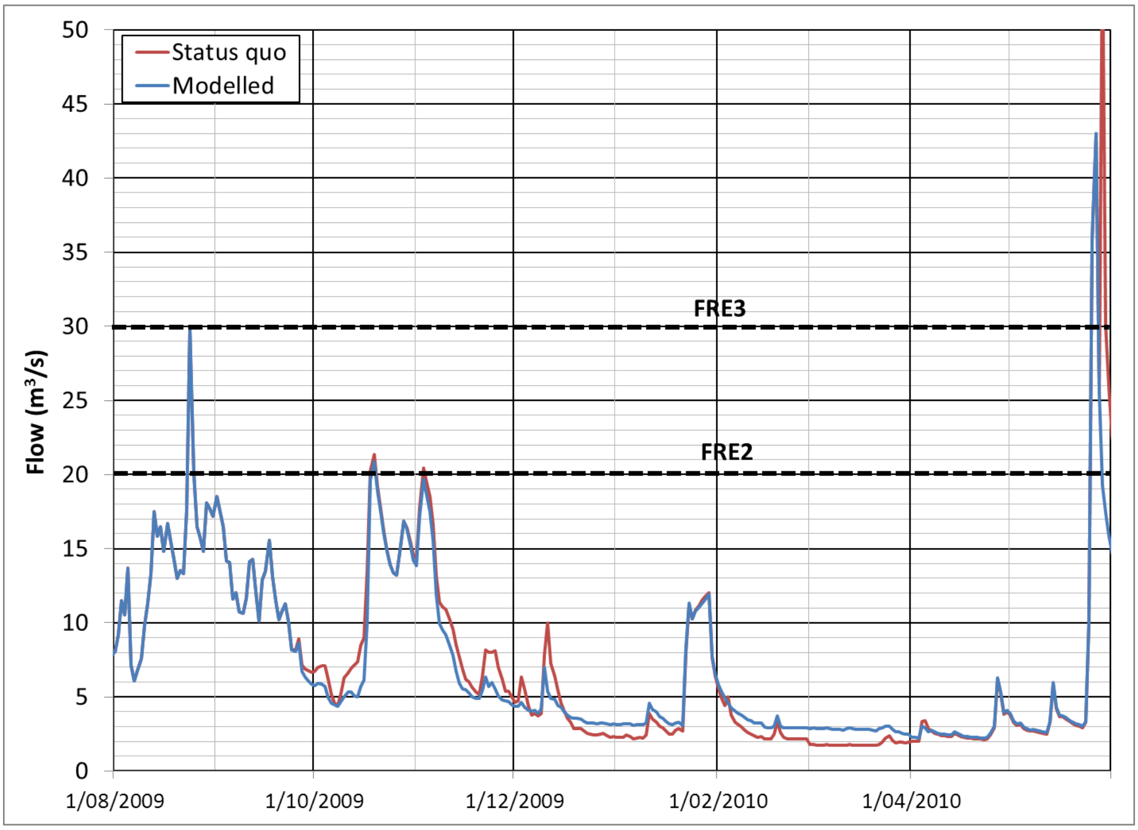

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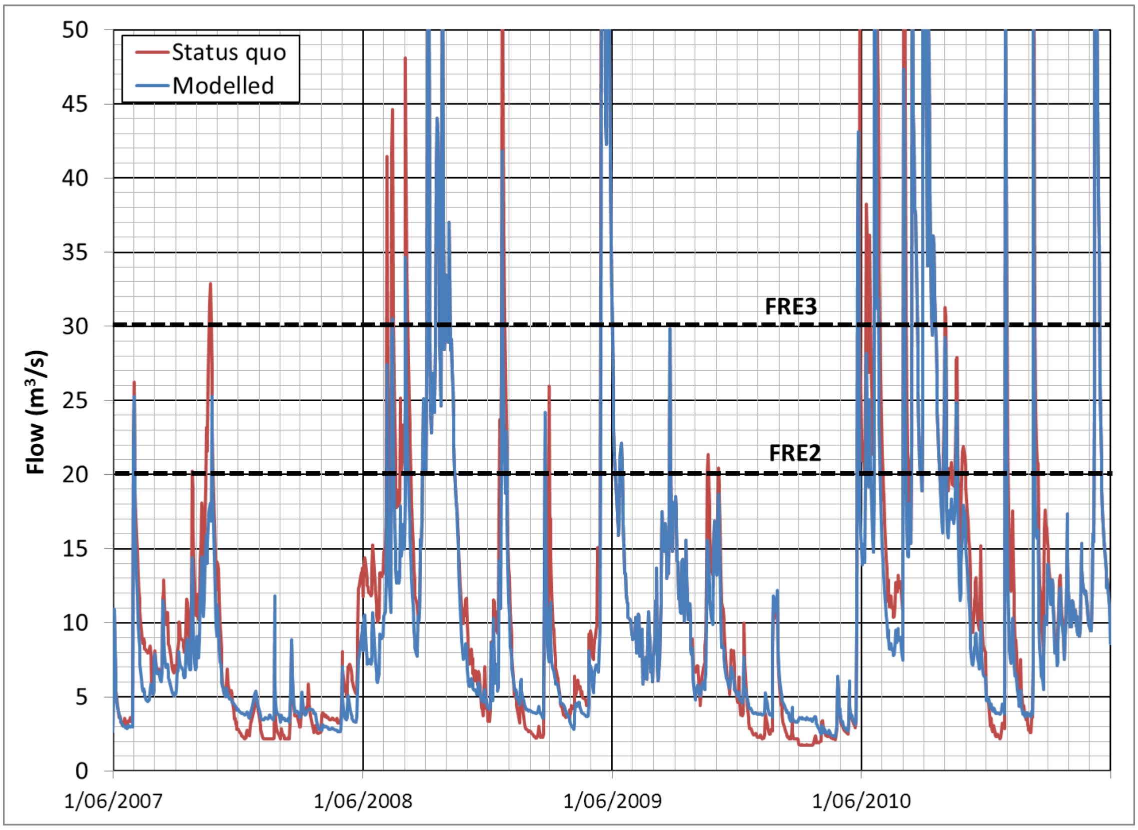

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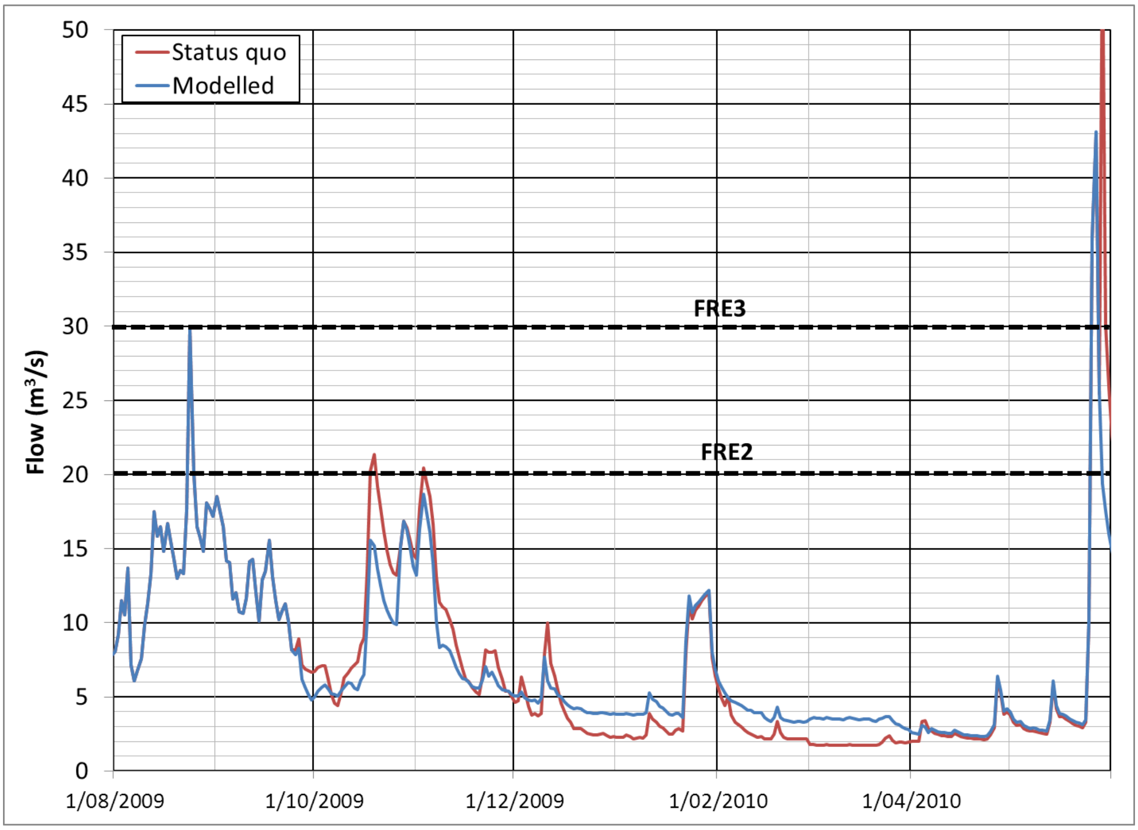

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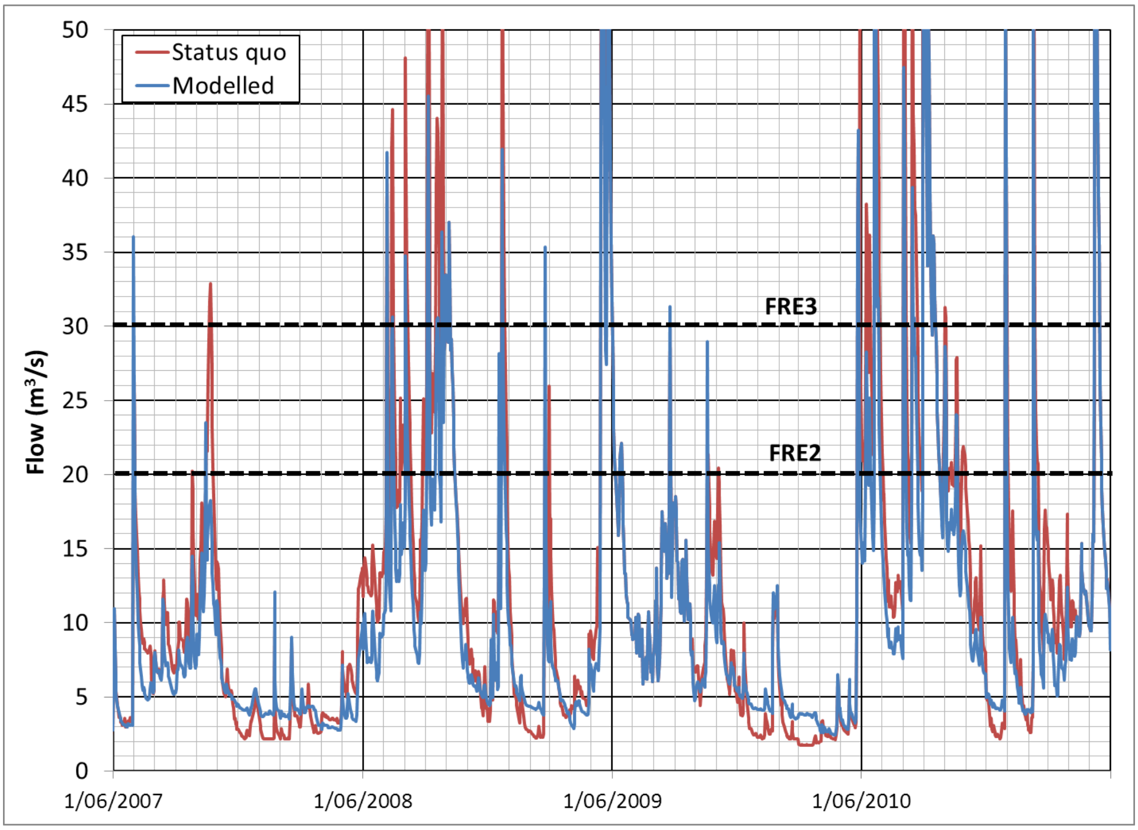

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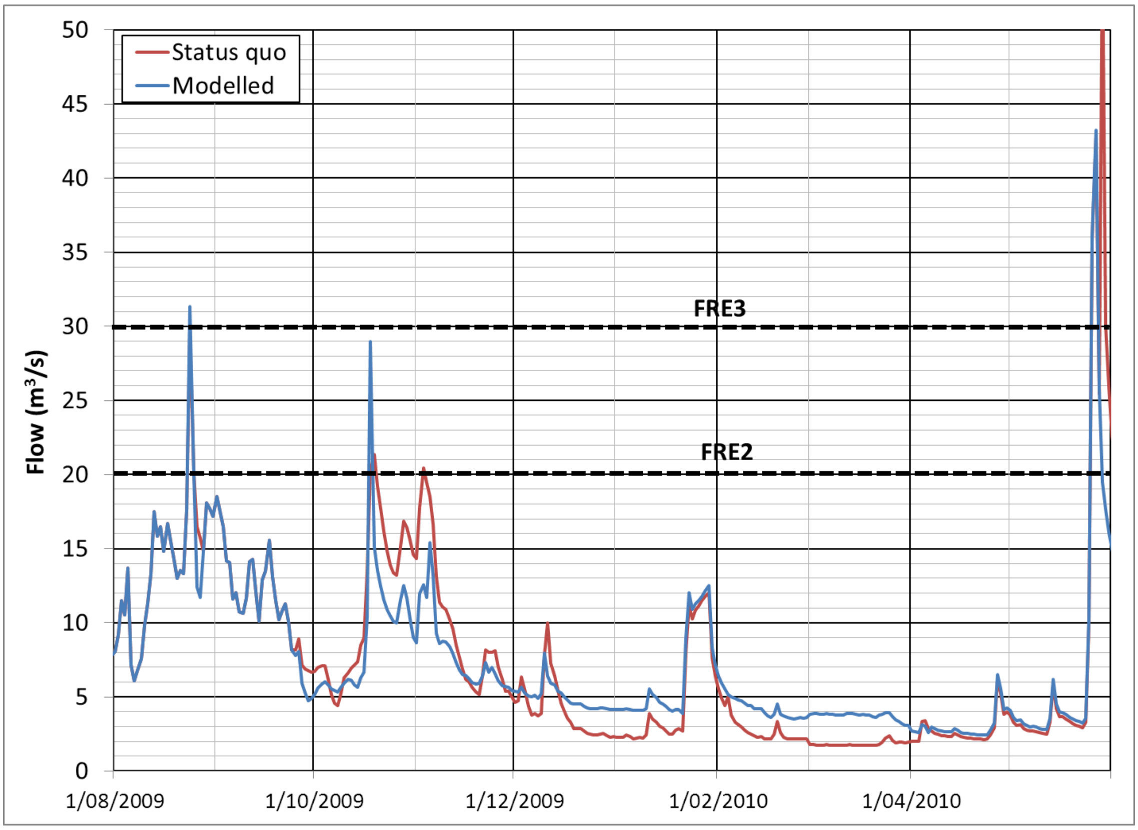

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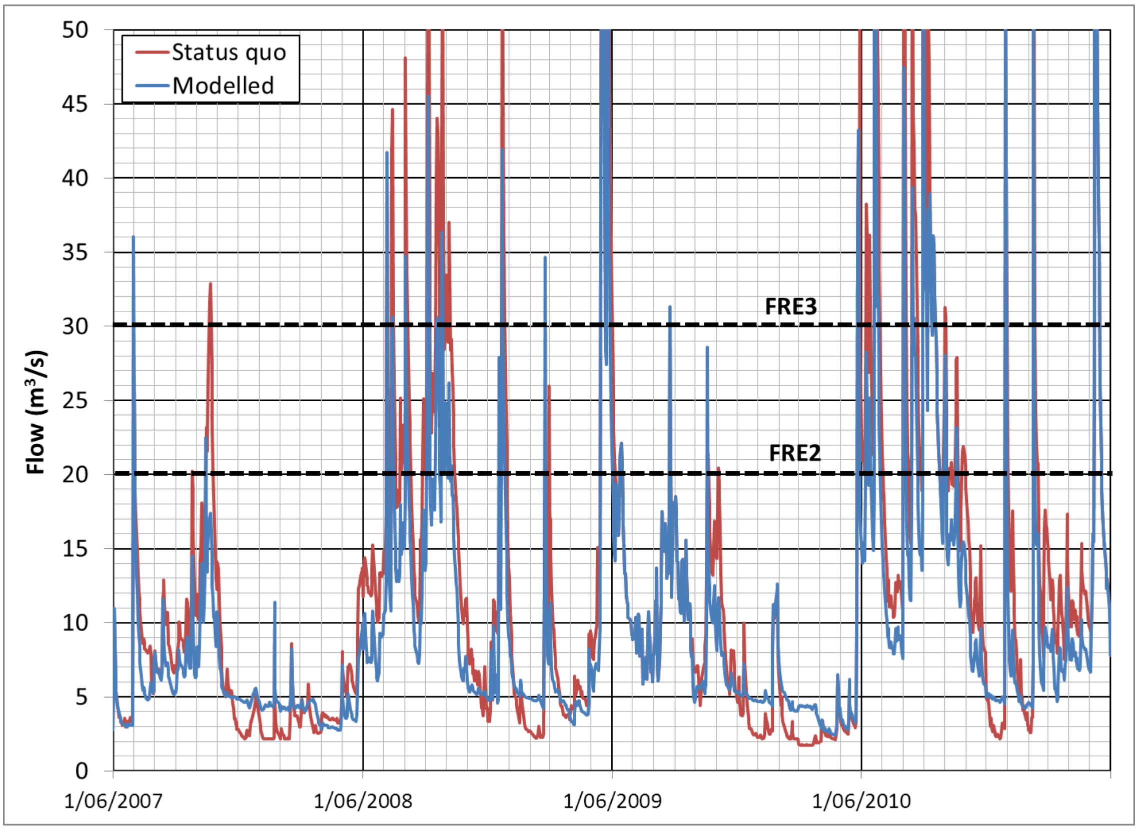

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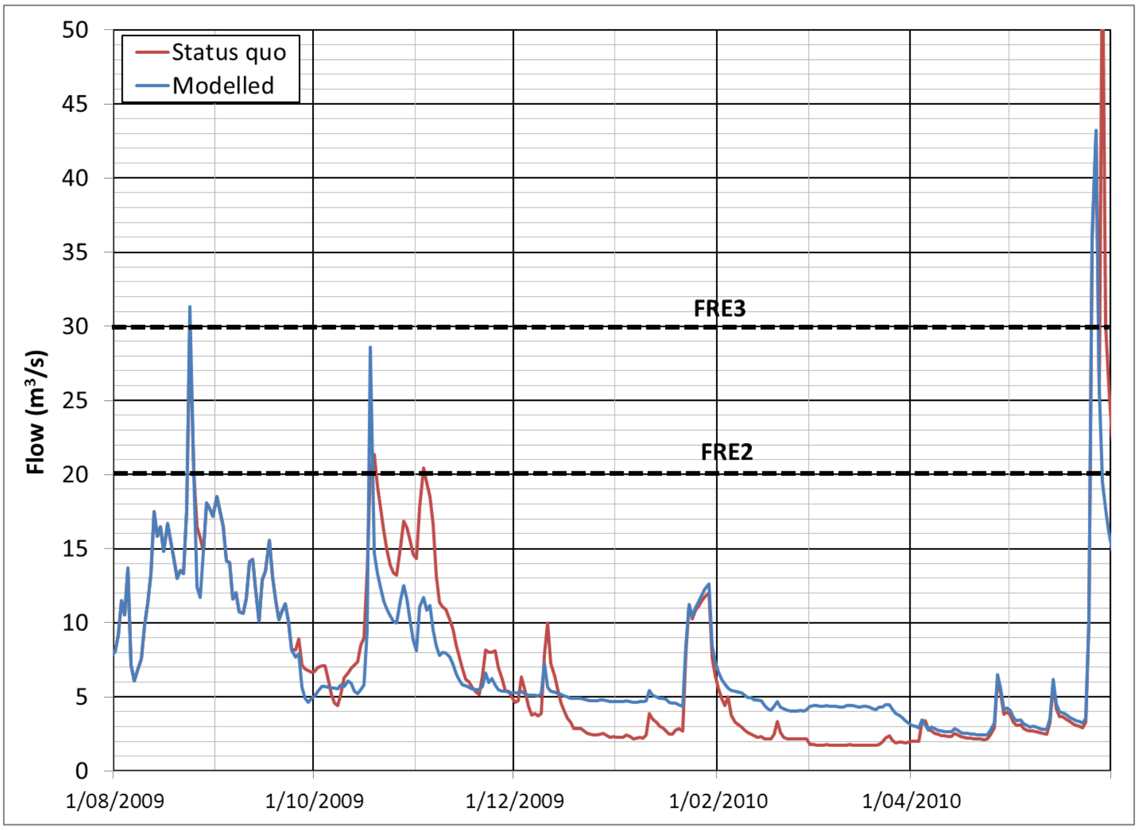

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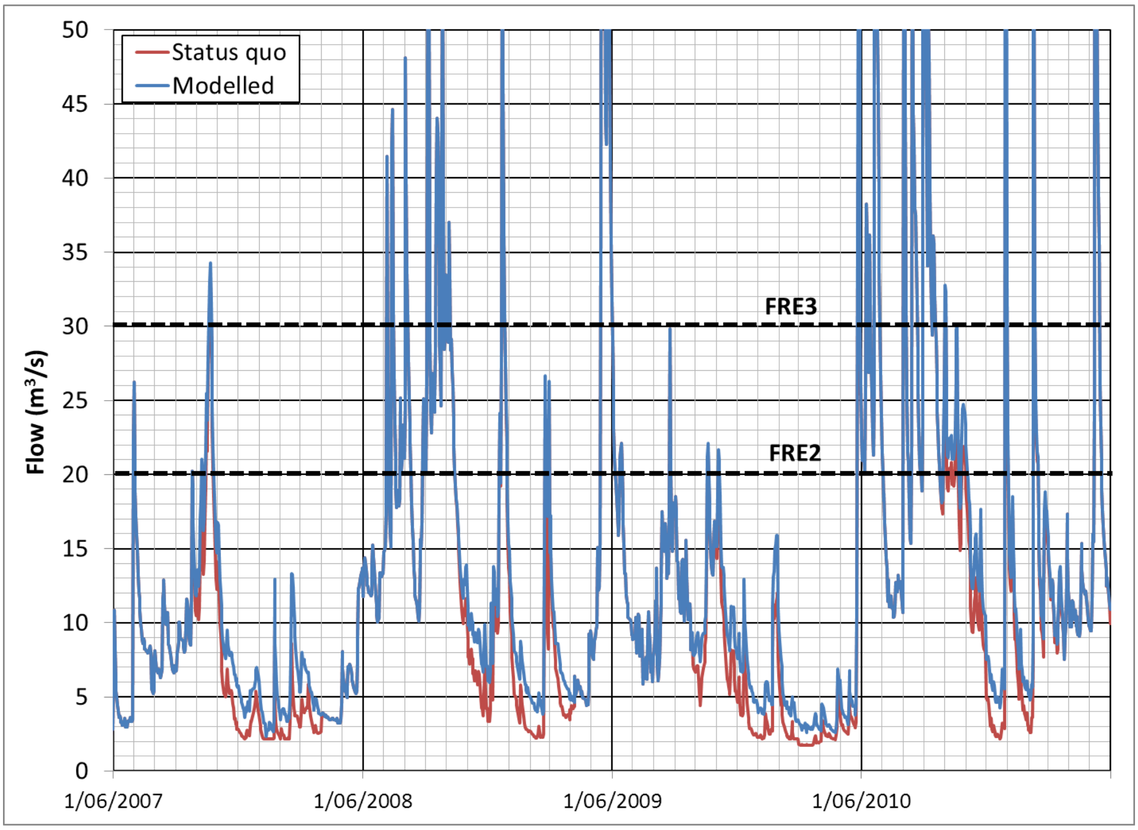
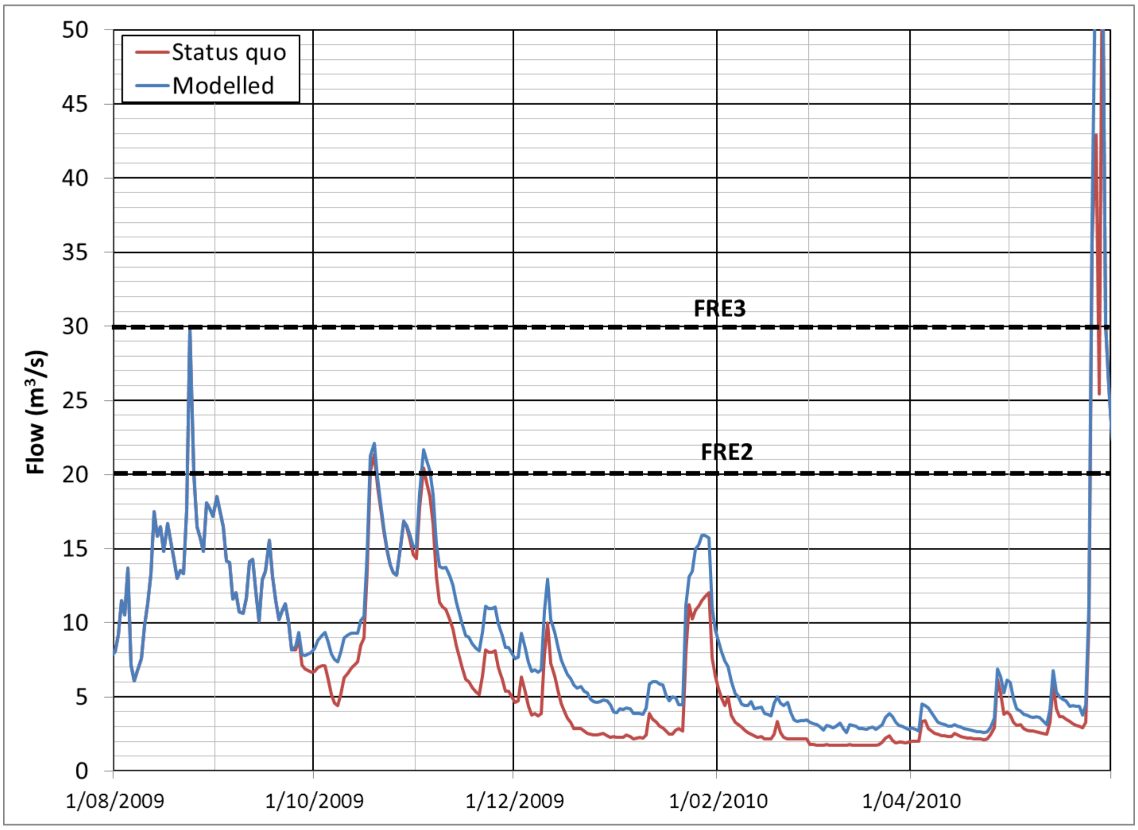
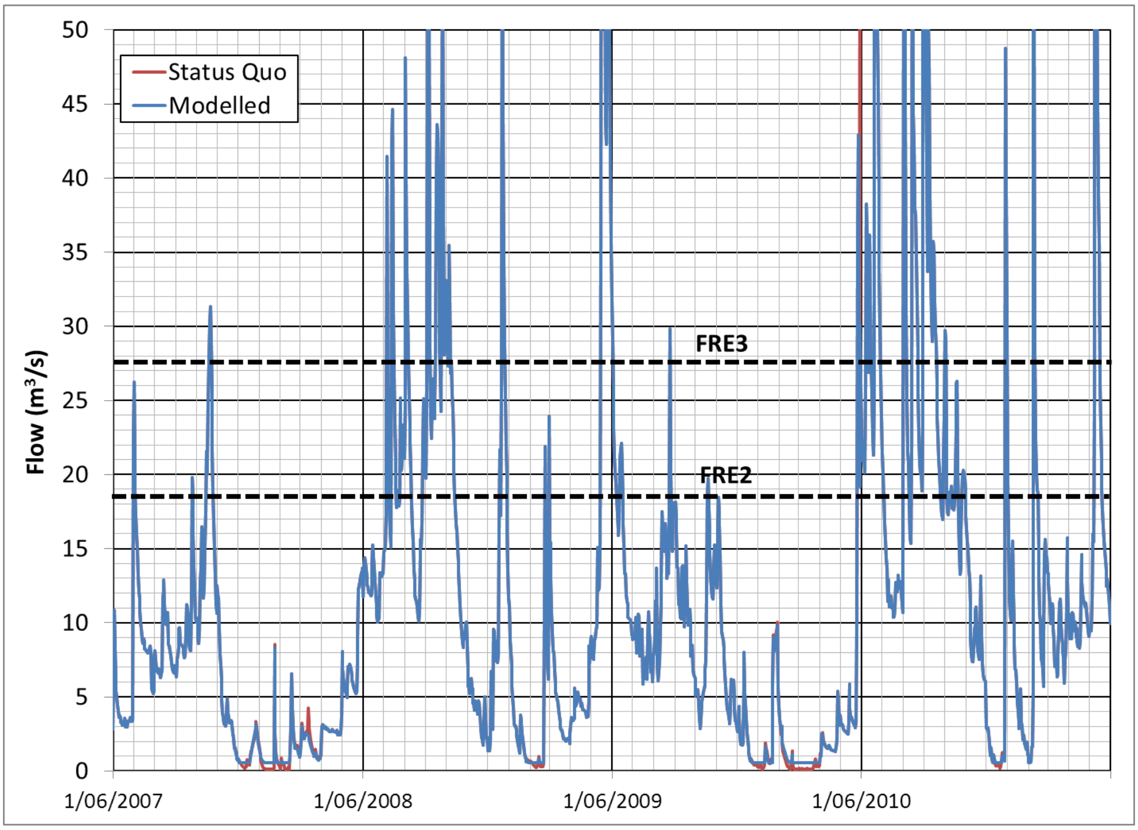


No Manuherikia Valley irrigation, but status quo Mt Ida Race and Ida Valley water use



No Manuherikia Valley irrigation, but status quo Mt Ida Race and Ida Valley water use

Appendix C: Manuherikia flow D/S of MIS intake



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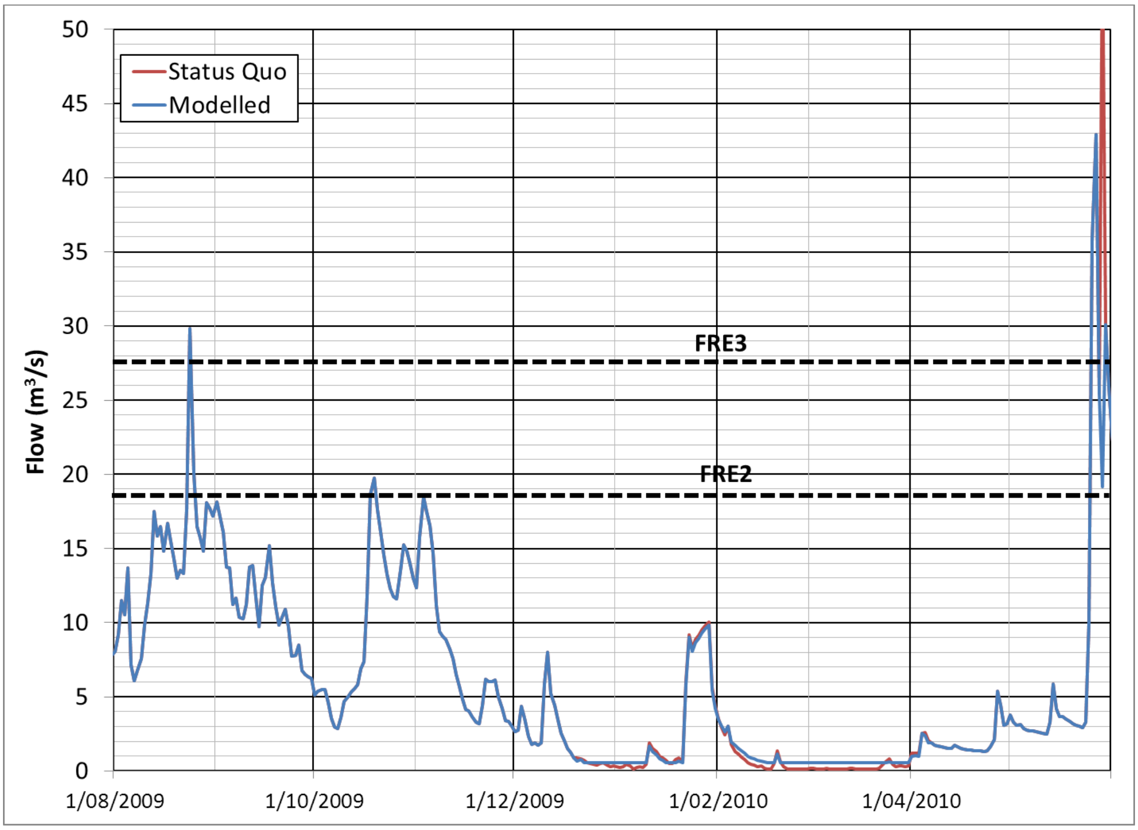

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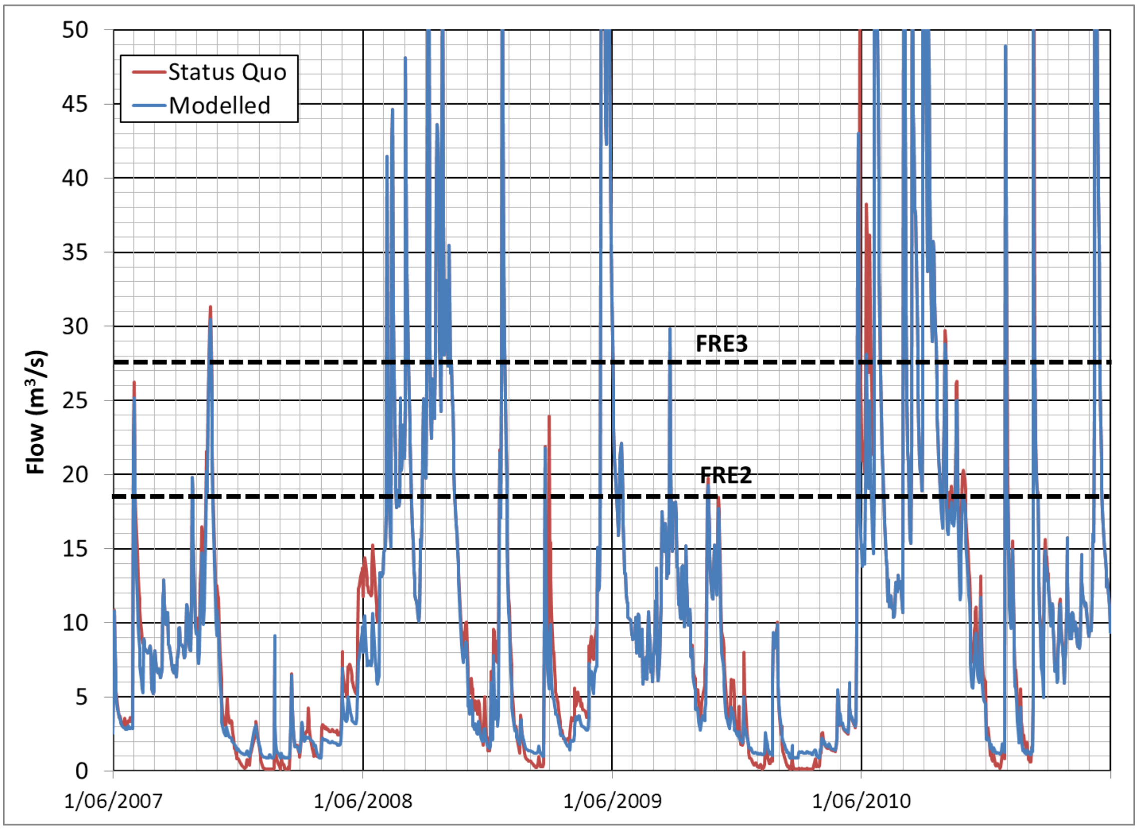

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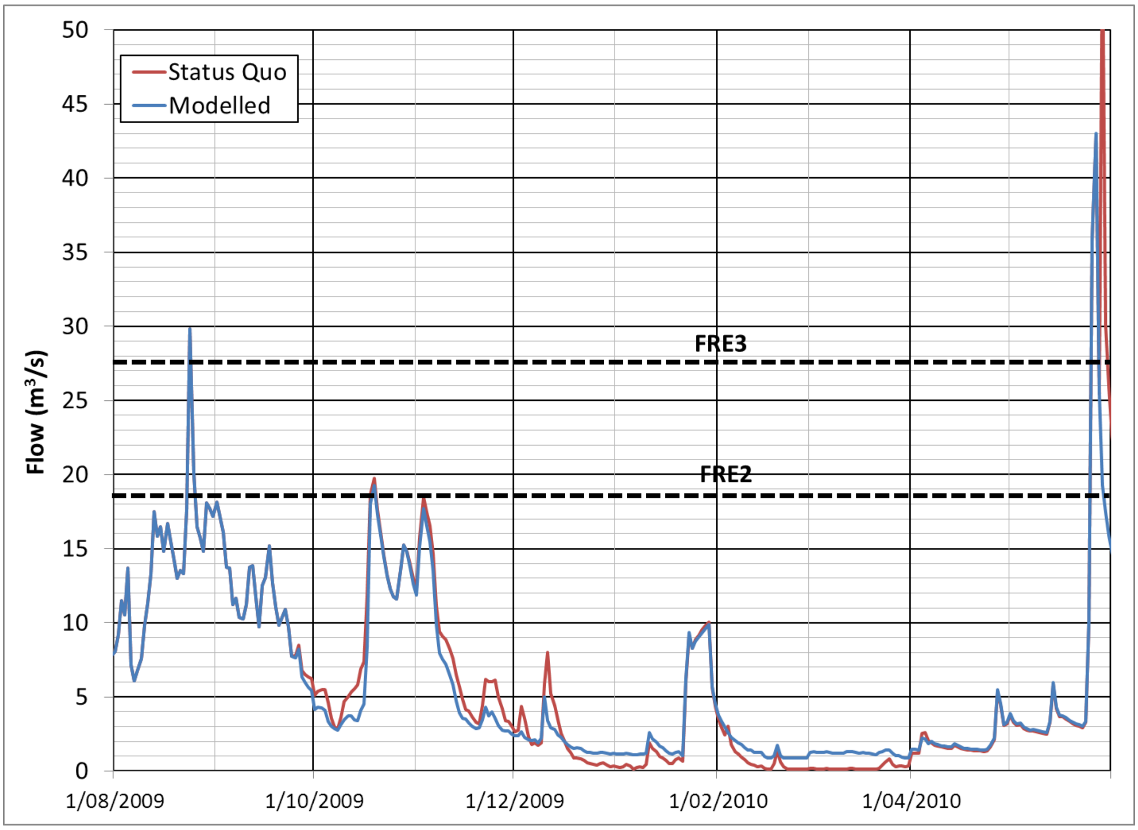

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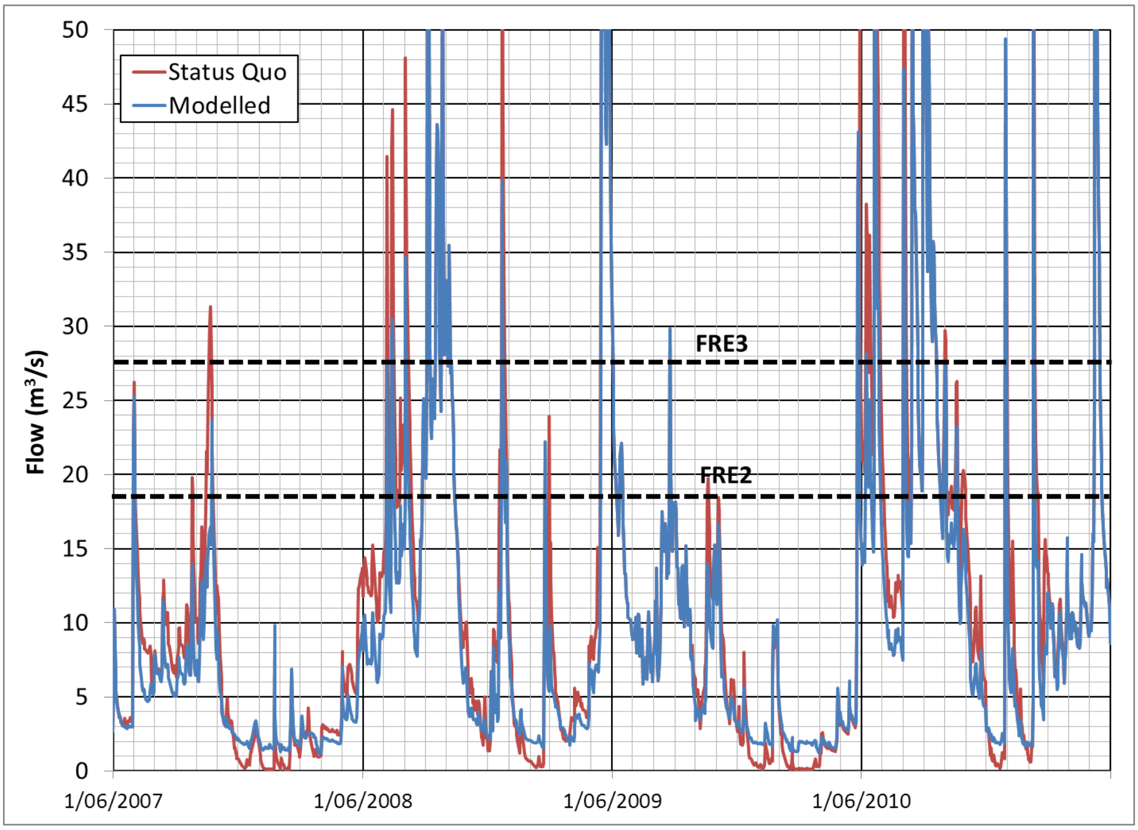

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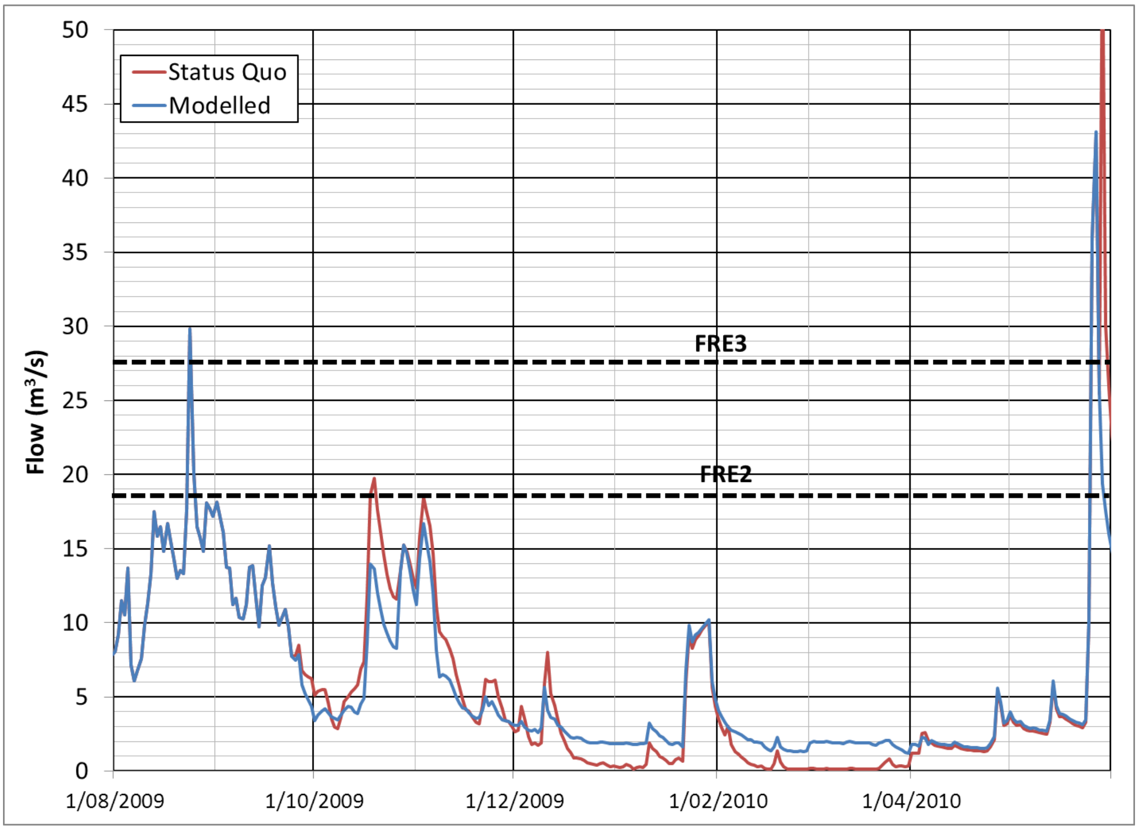

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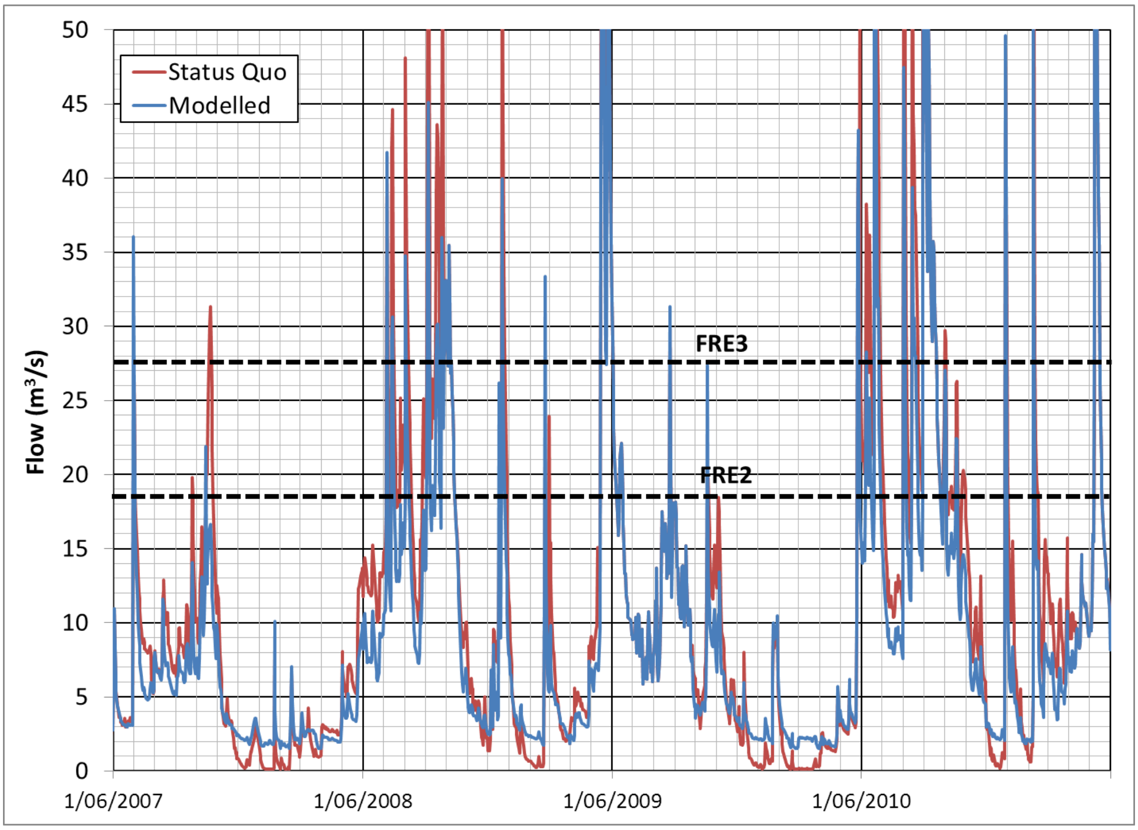

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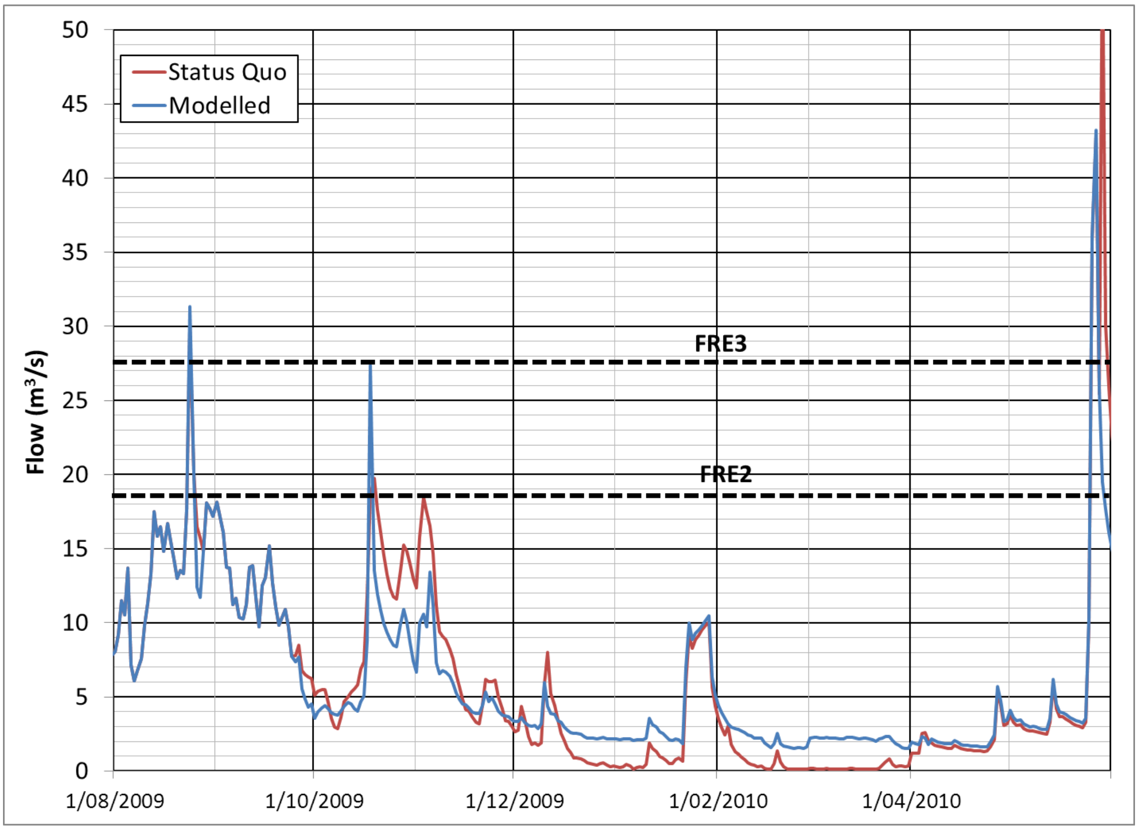

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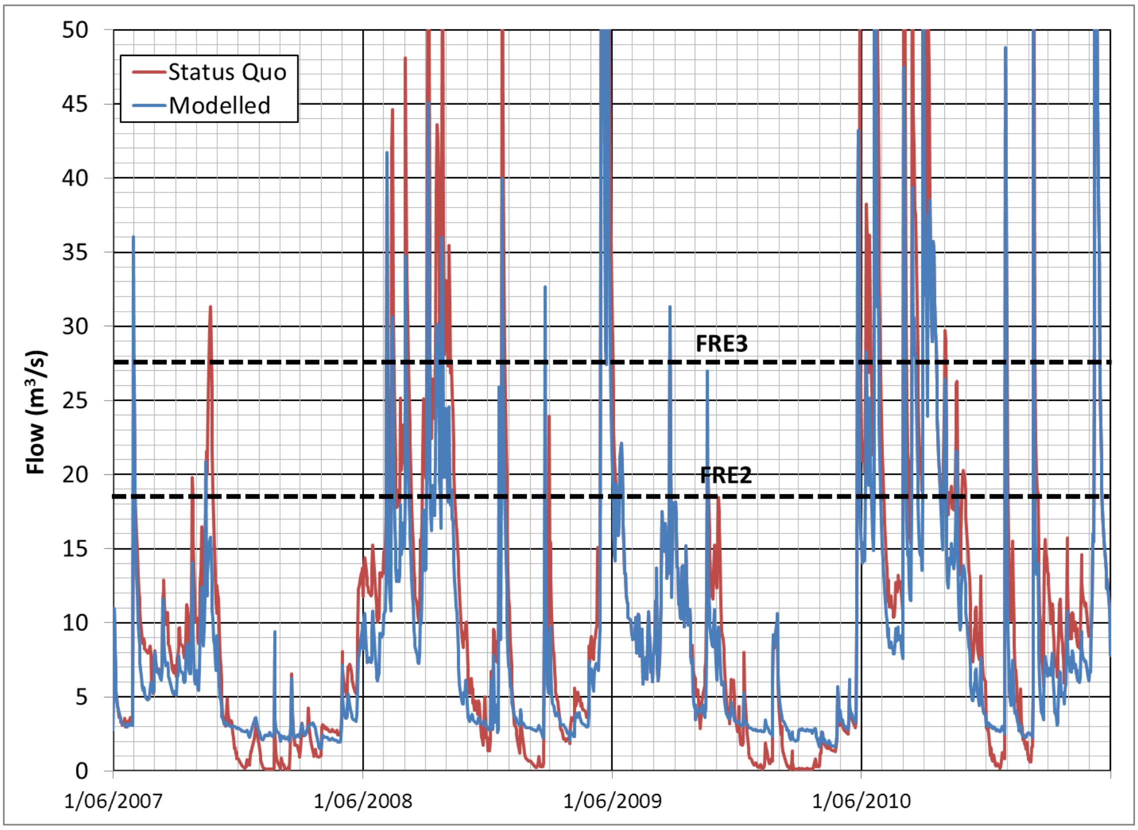

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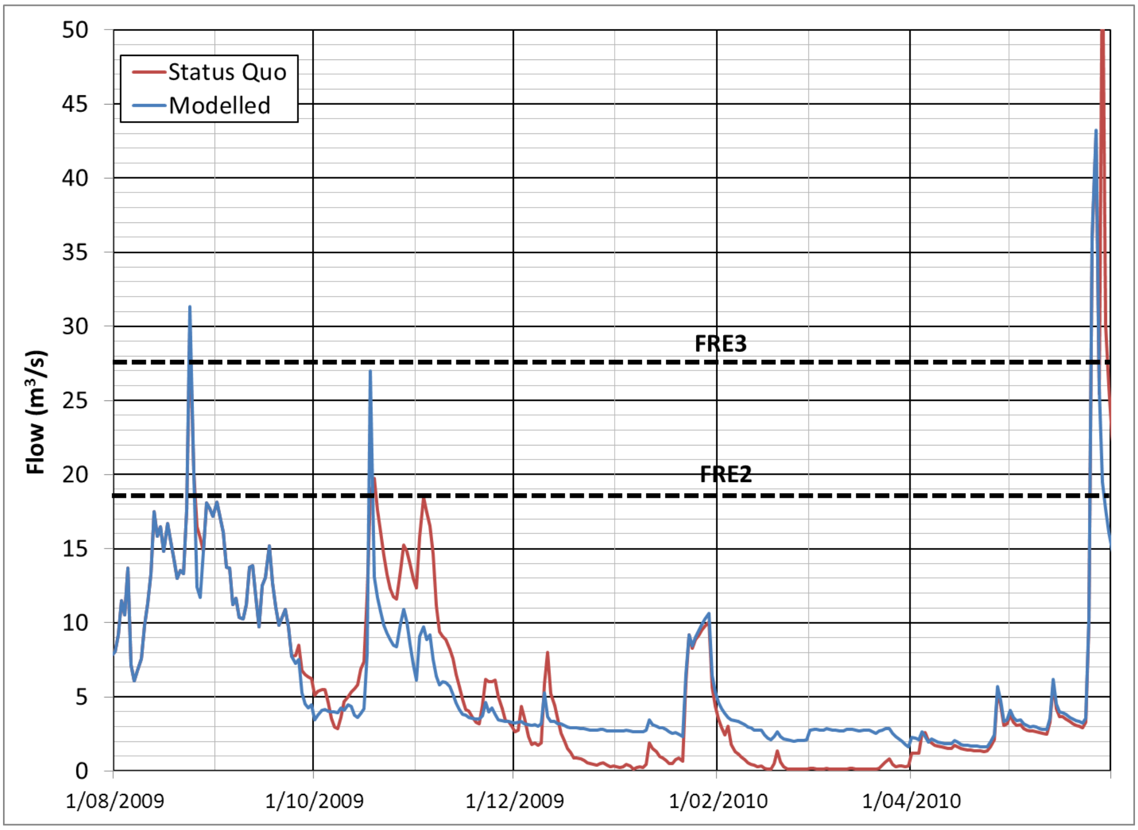

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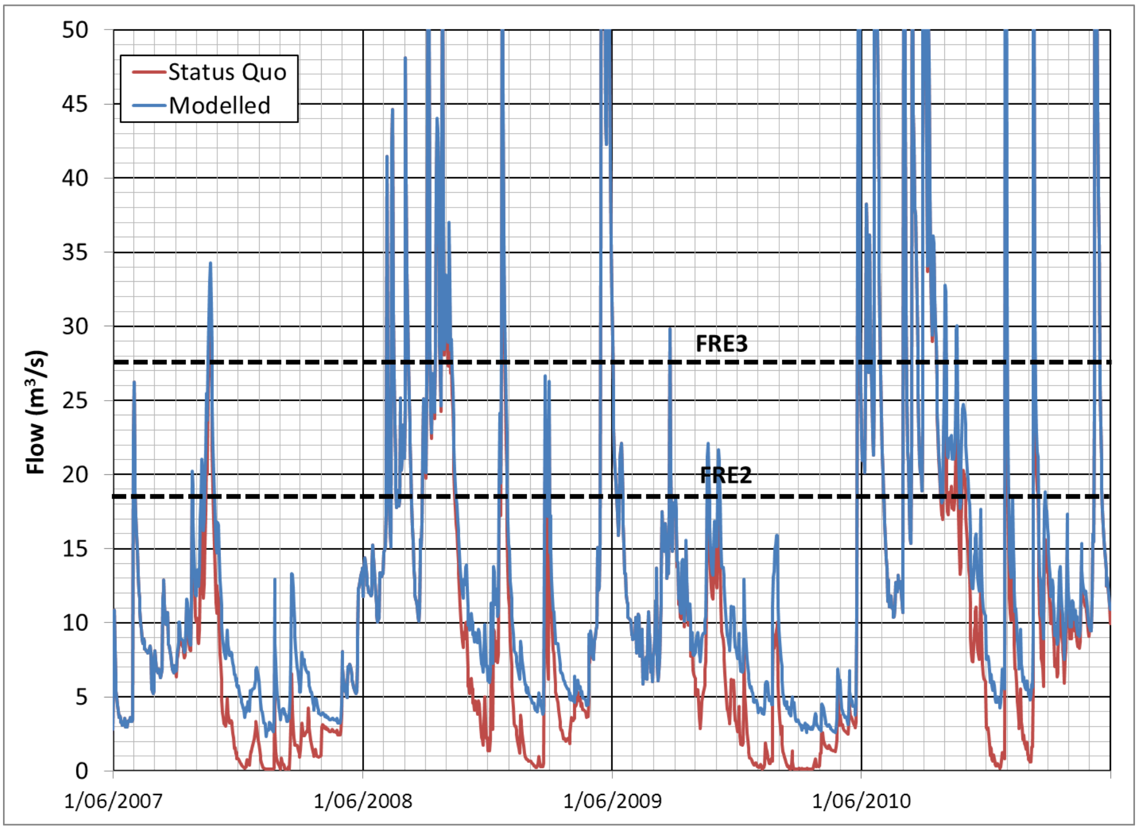
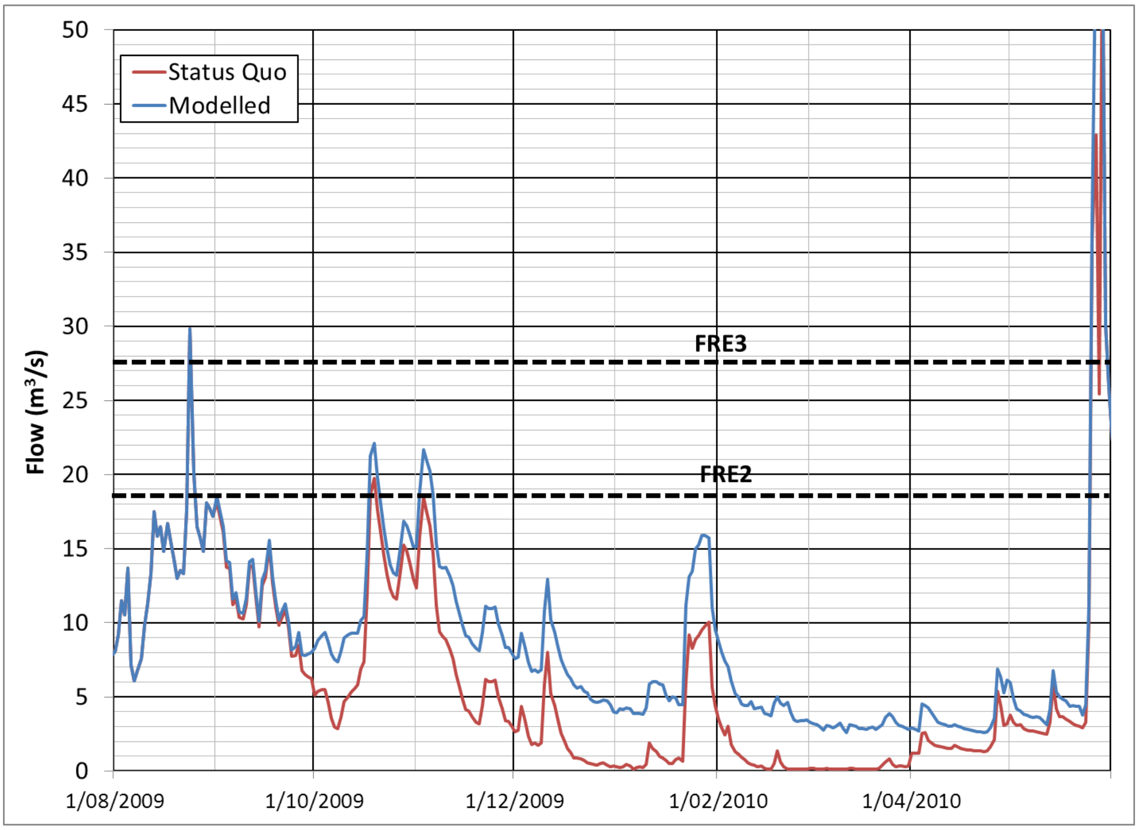
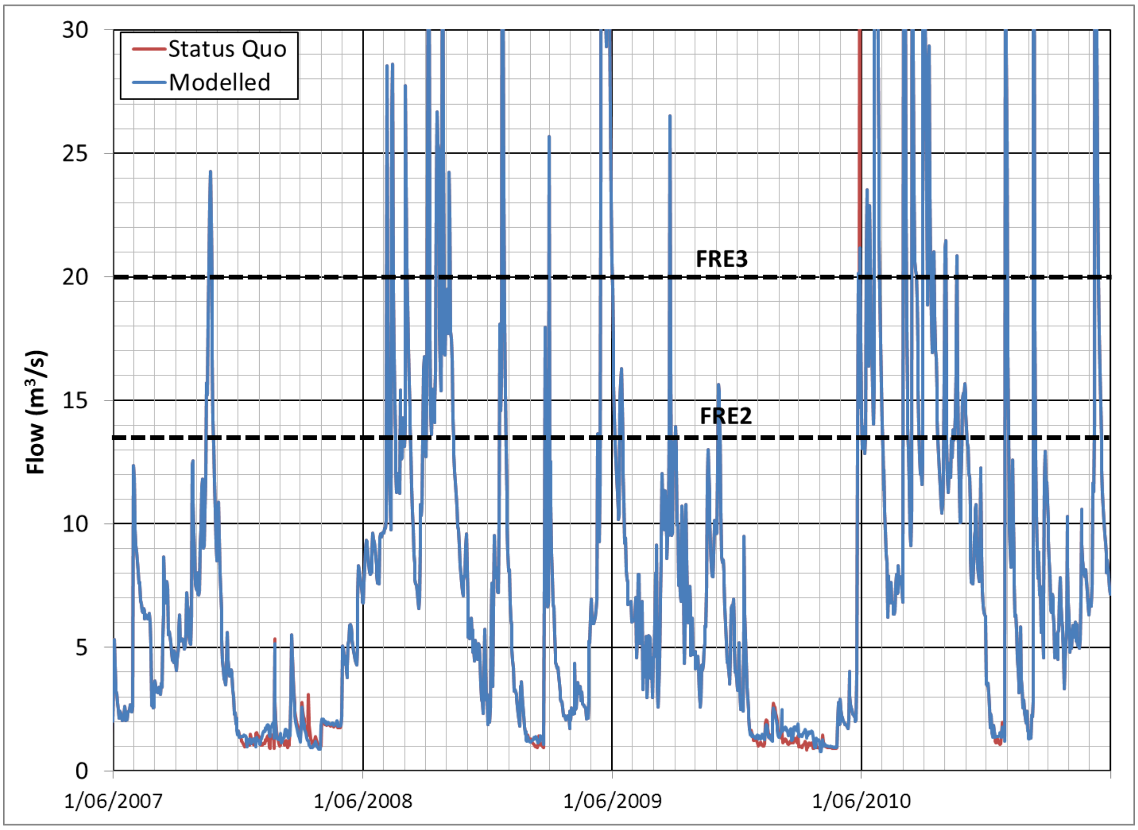


No Manuherikia Valley irrigation, but status quo Mt Ida Race and Ida Valley water use

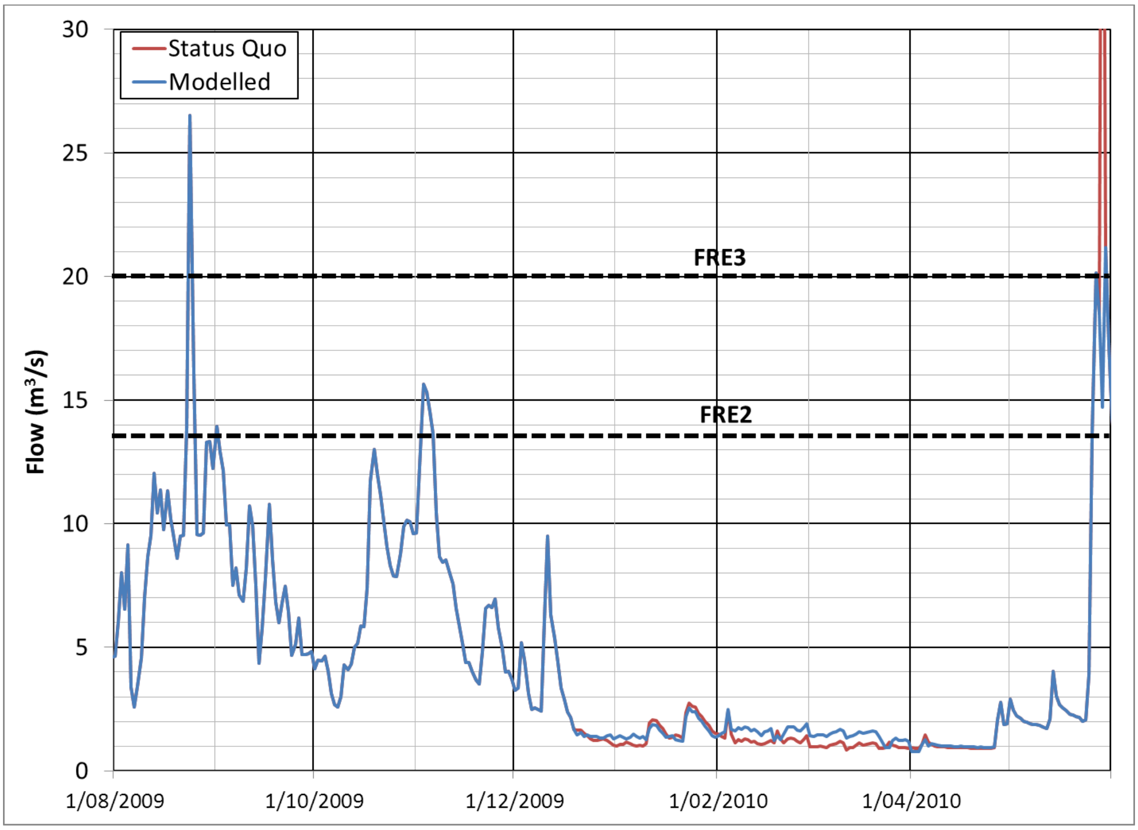


No Manuherikia Valley irrigation, but status quo Mt Ida Race and Ida Valley water use

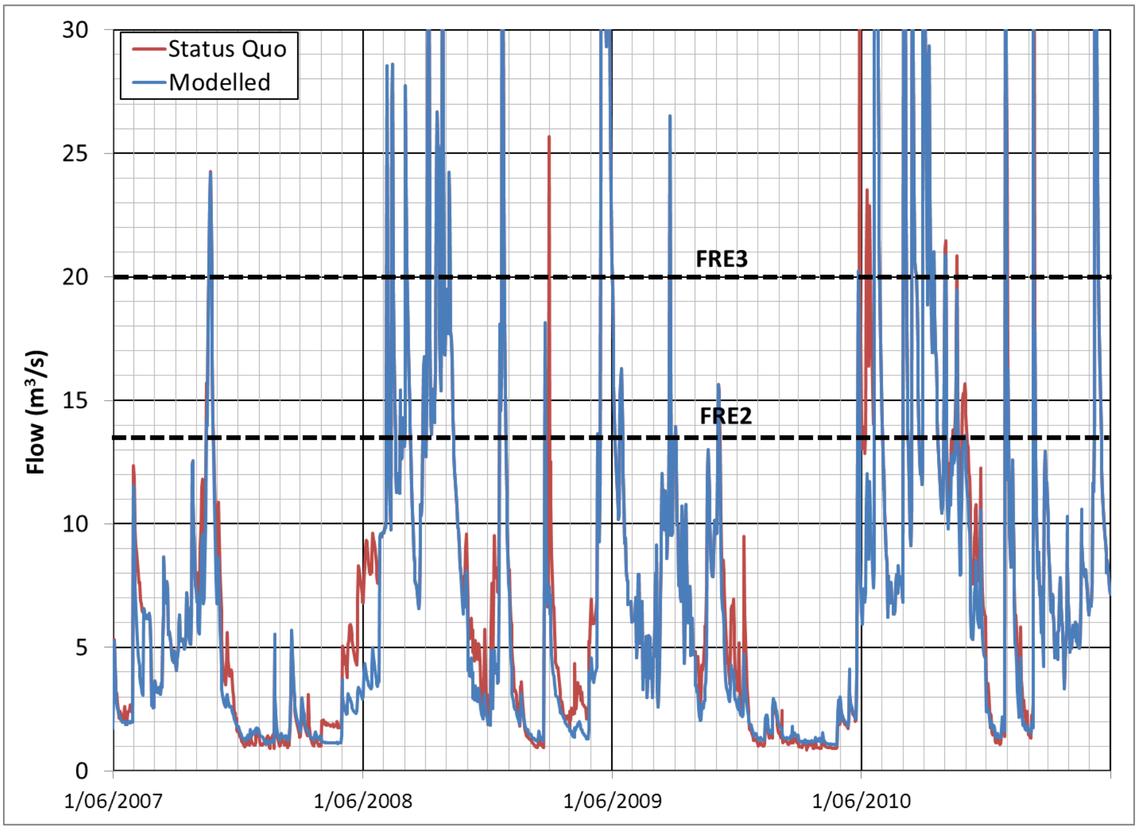
Appendix D: Manuherikia flow at SH 85 Bridge



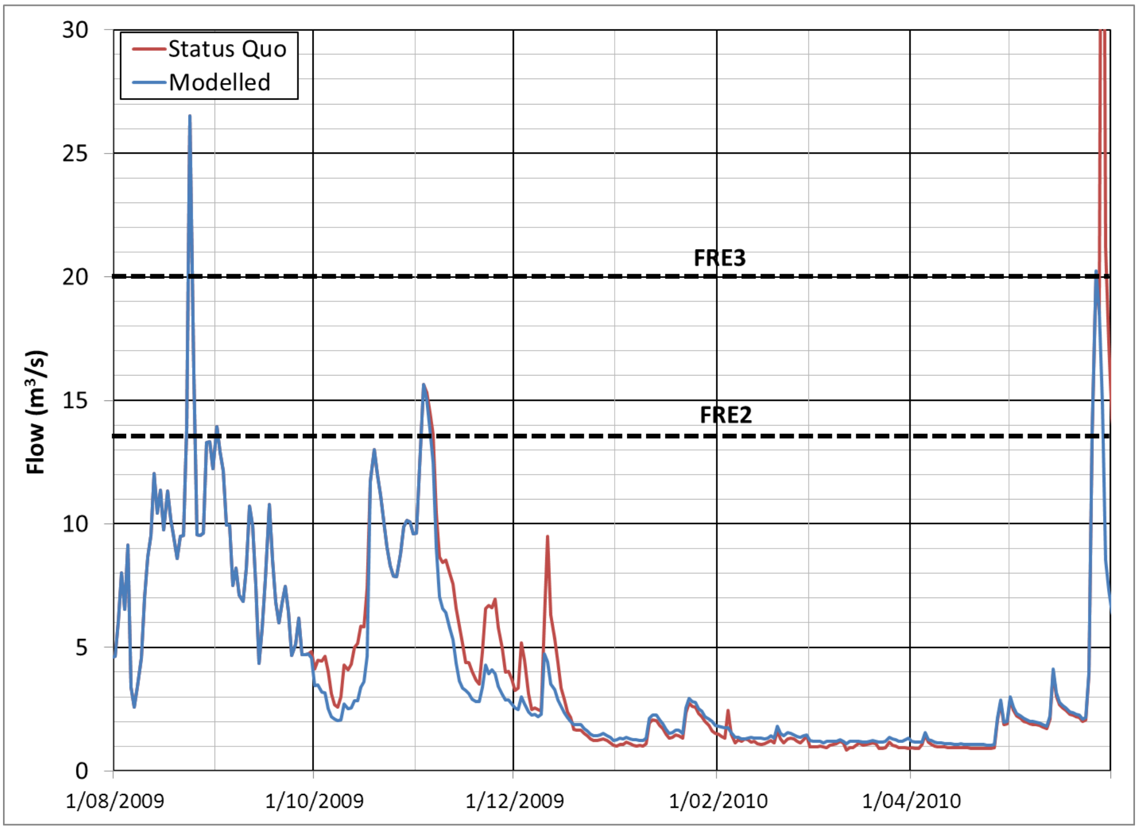
Scenario 1



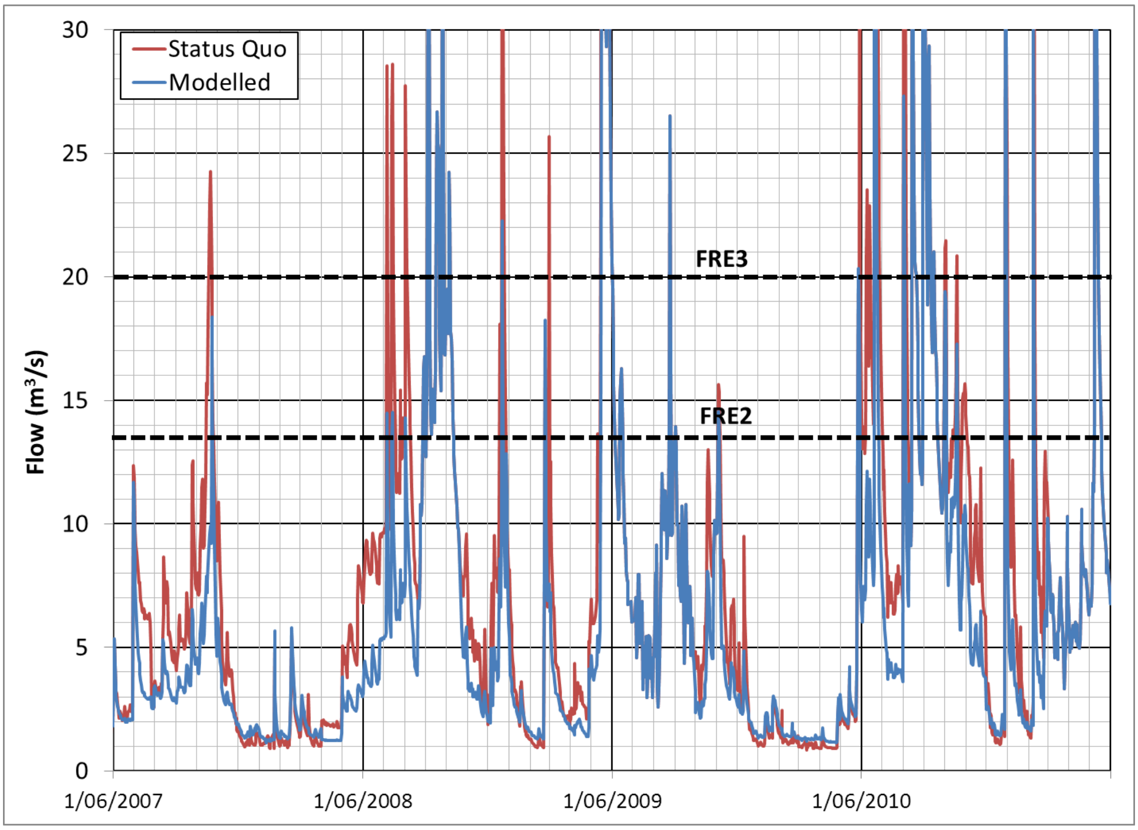
Scenario 1



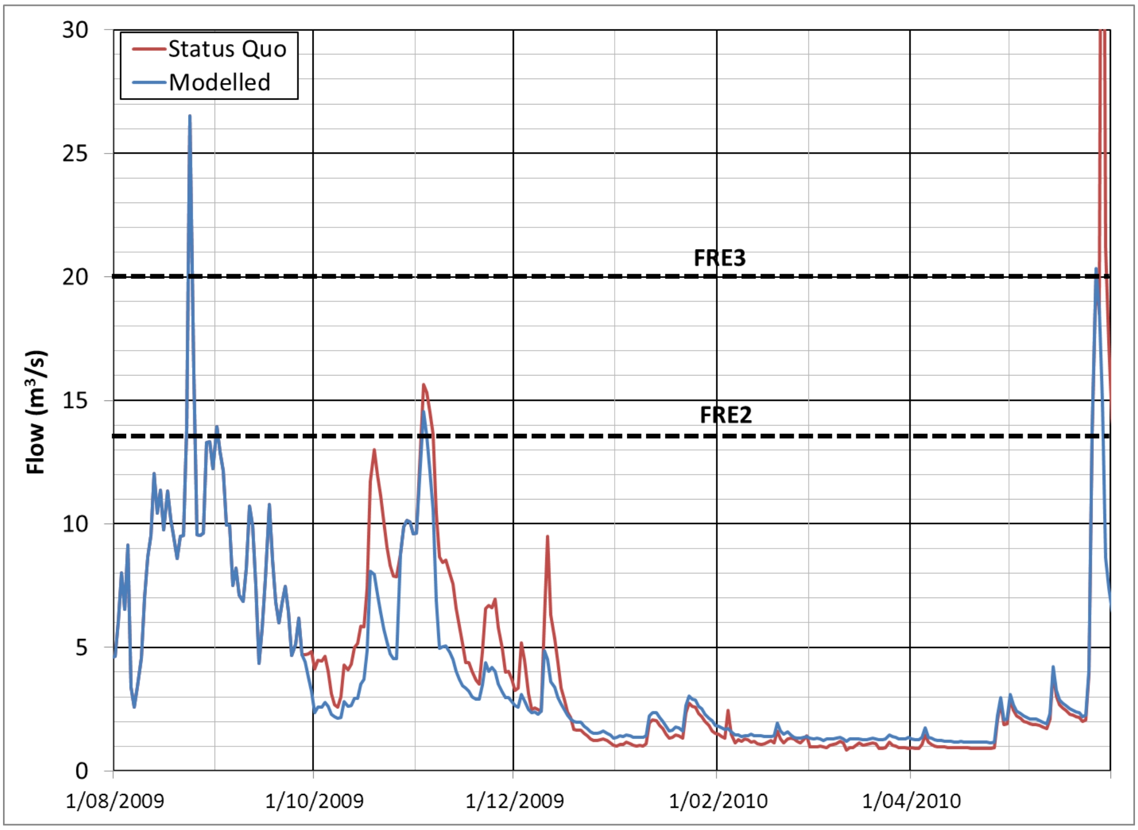
Scenario 2



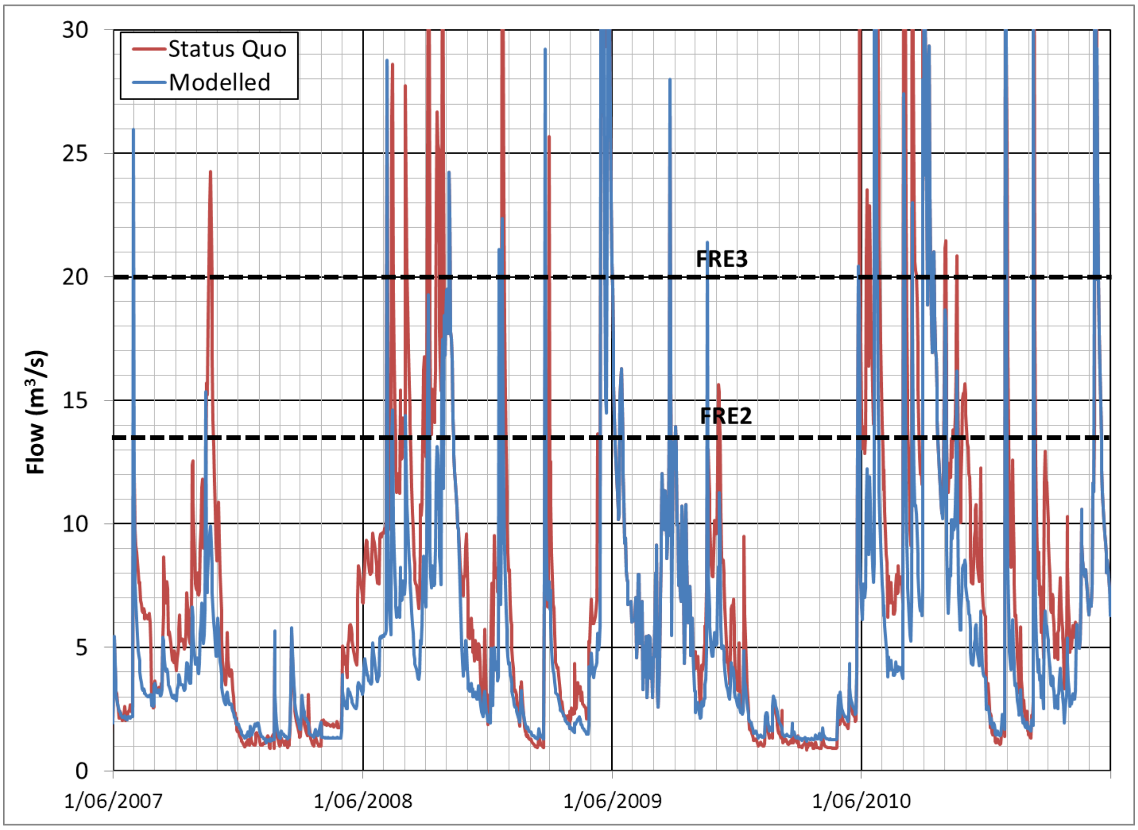
Scenario 2



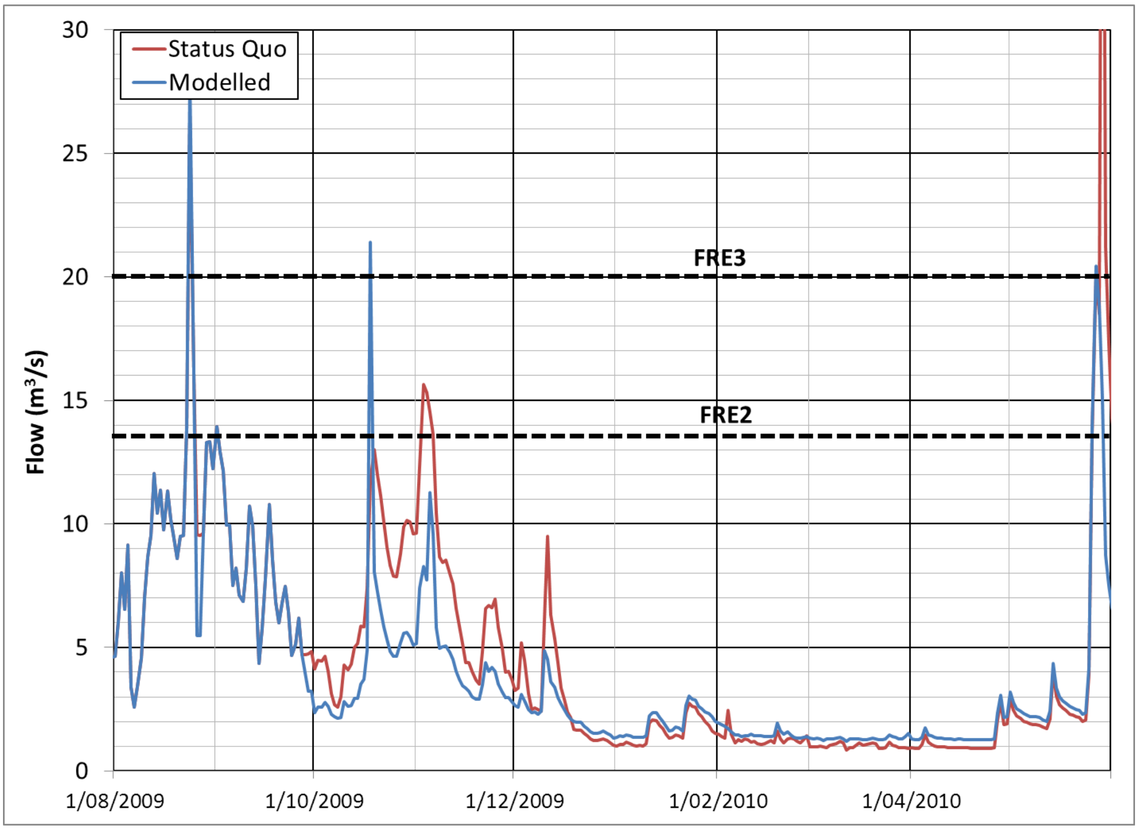
Scenario 3



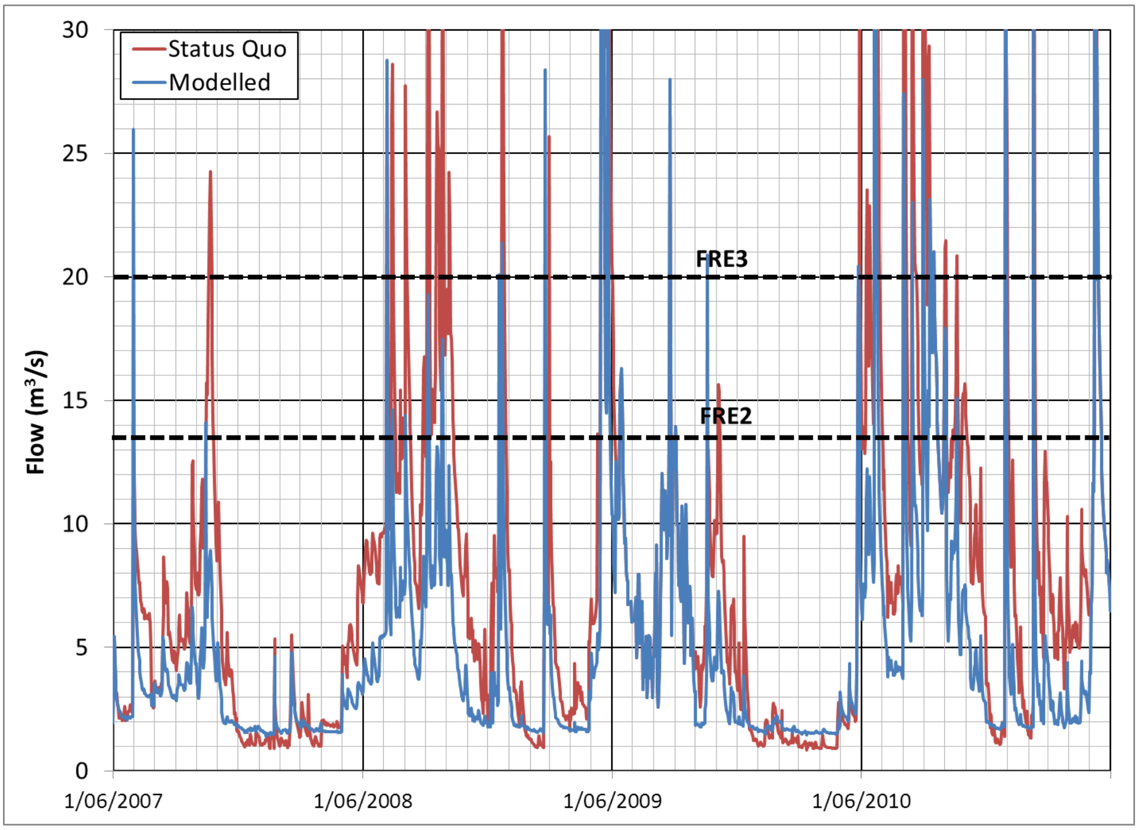
Scenario 3



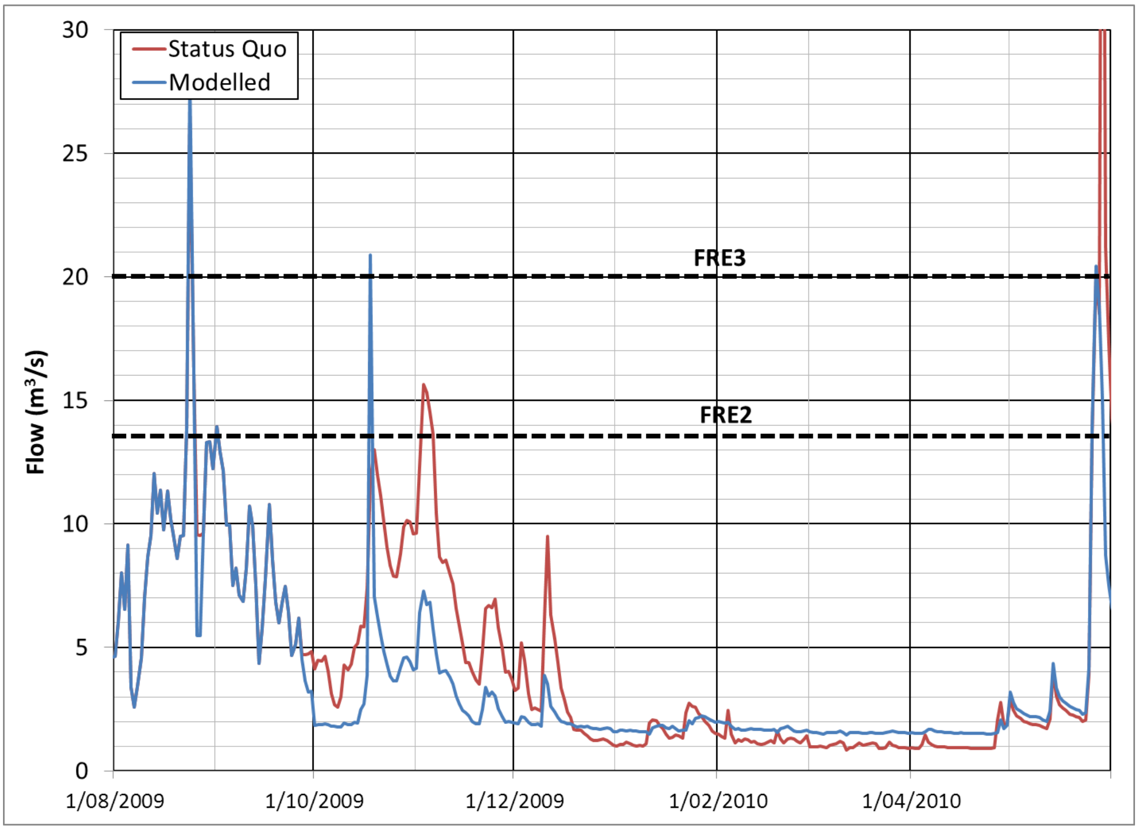
Scenario 4



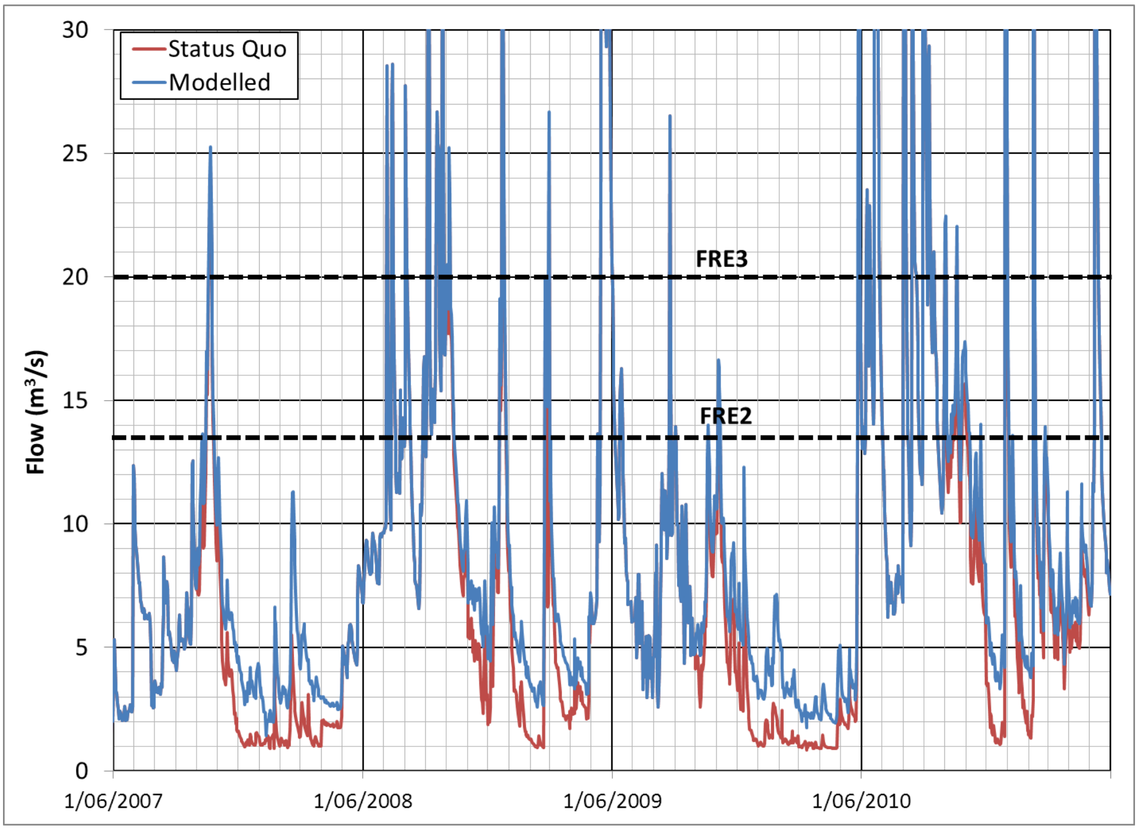
Scenario 4



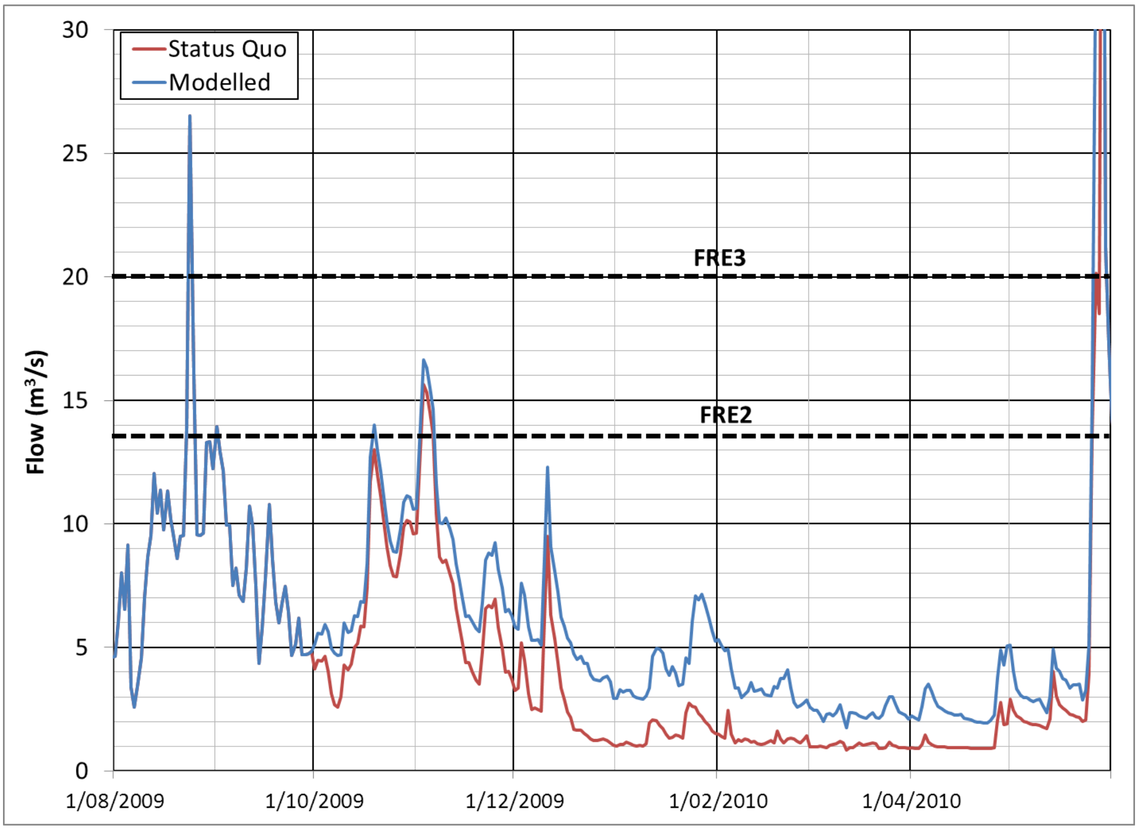
Scenario 5



Scenario 5

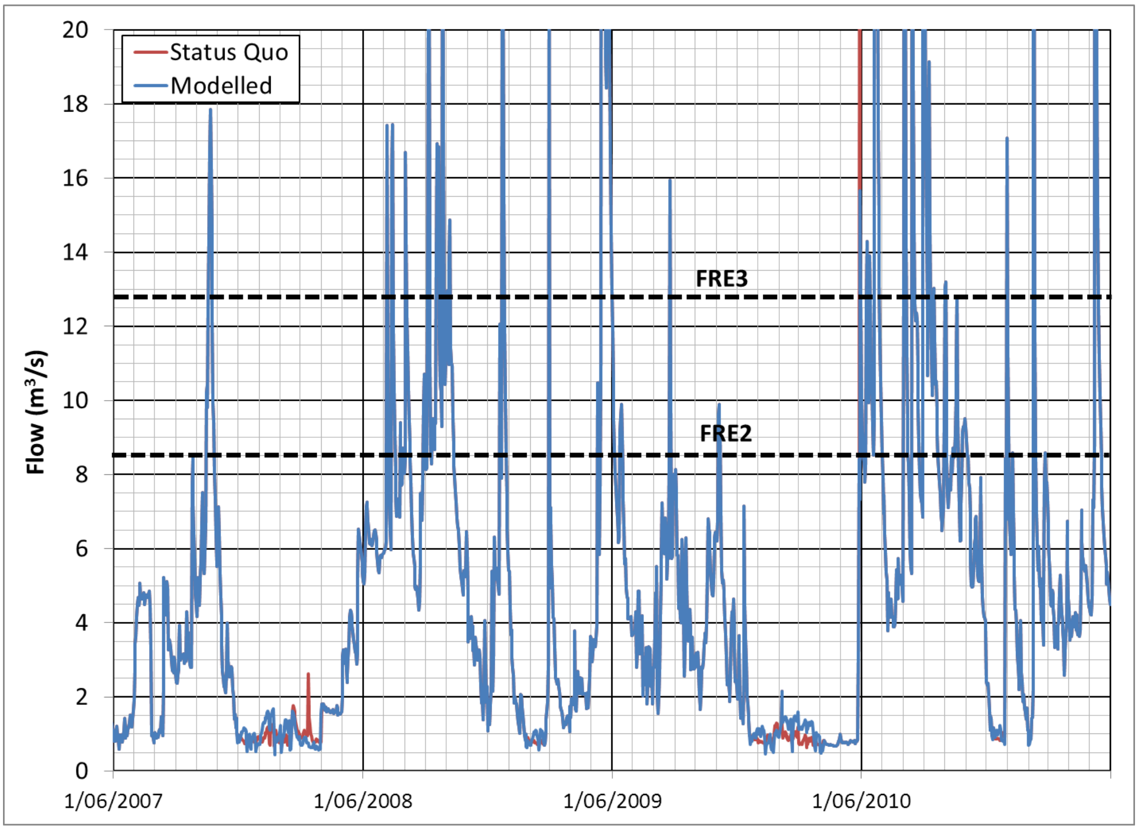


No Manuherikia Valley irrigation, but status quo Mt Ida Race water use

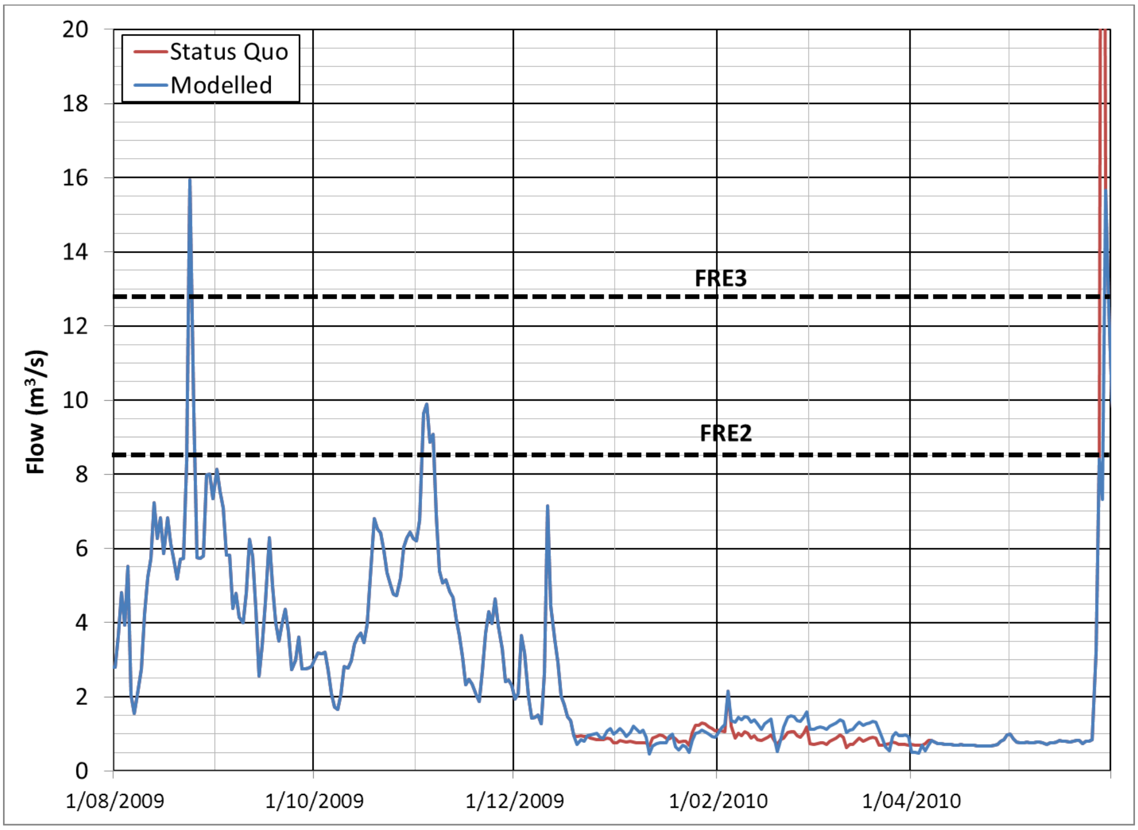


No Manuherikia Valley irrigation, but status quo Mt Ida Race water use

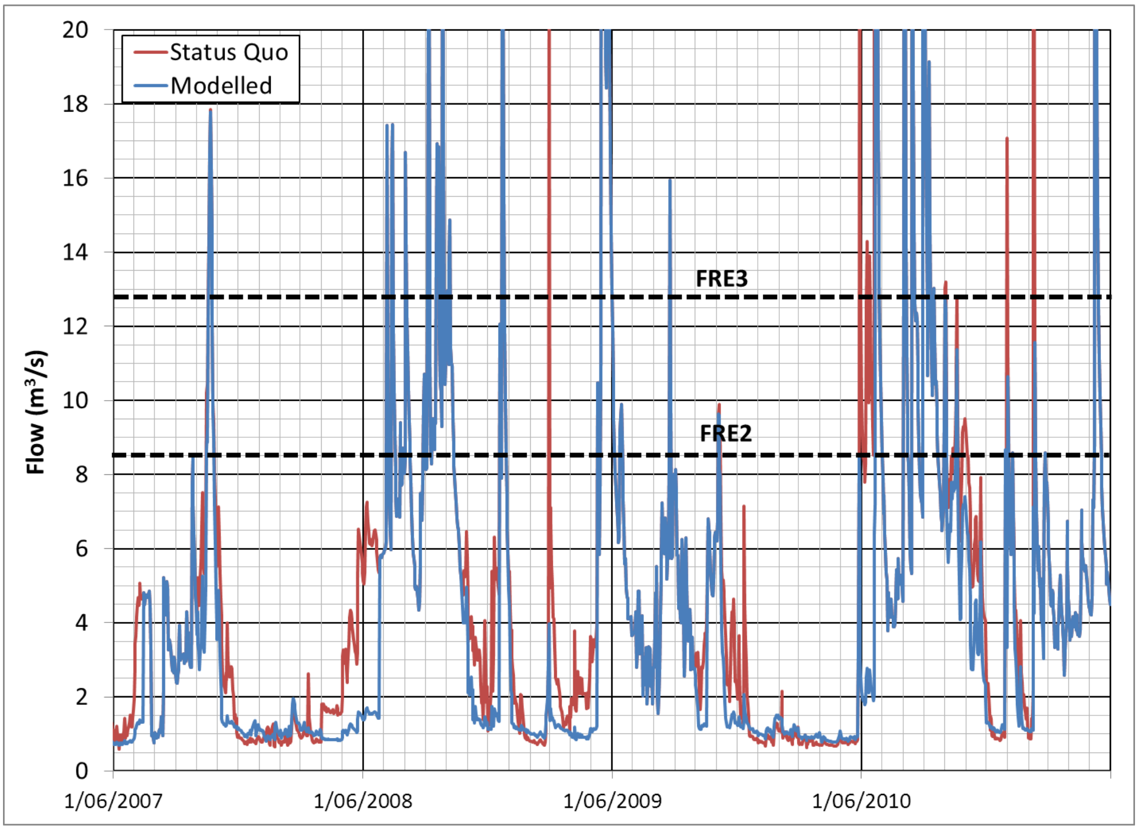
Appendix E: Manuherikia flow D/S of Omakau Intake



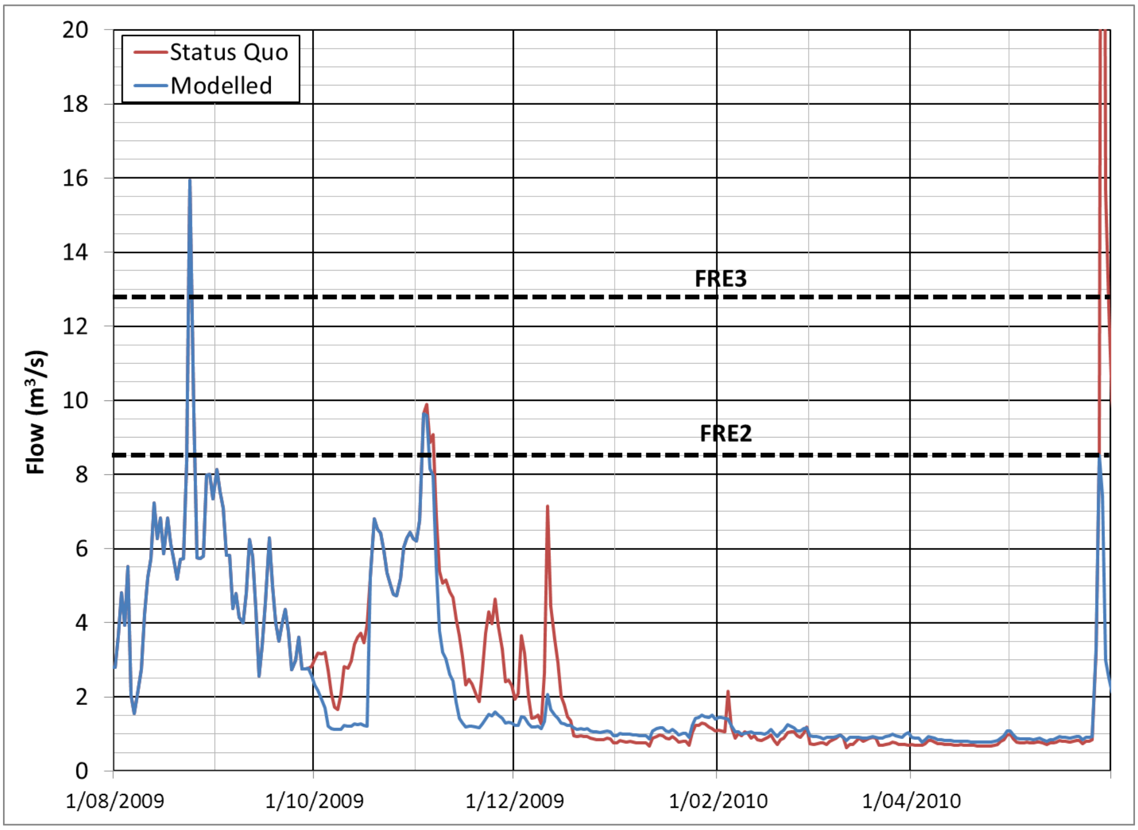
Scenario 1



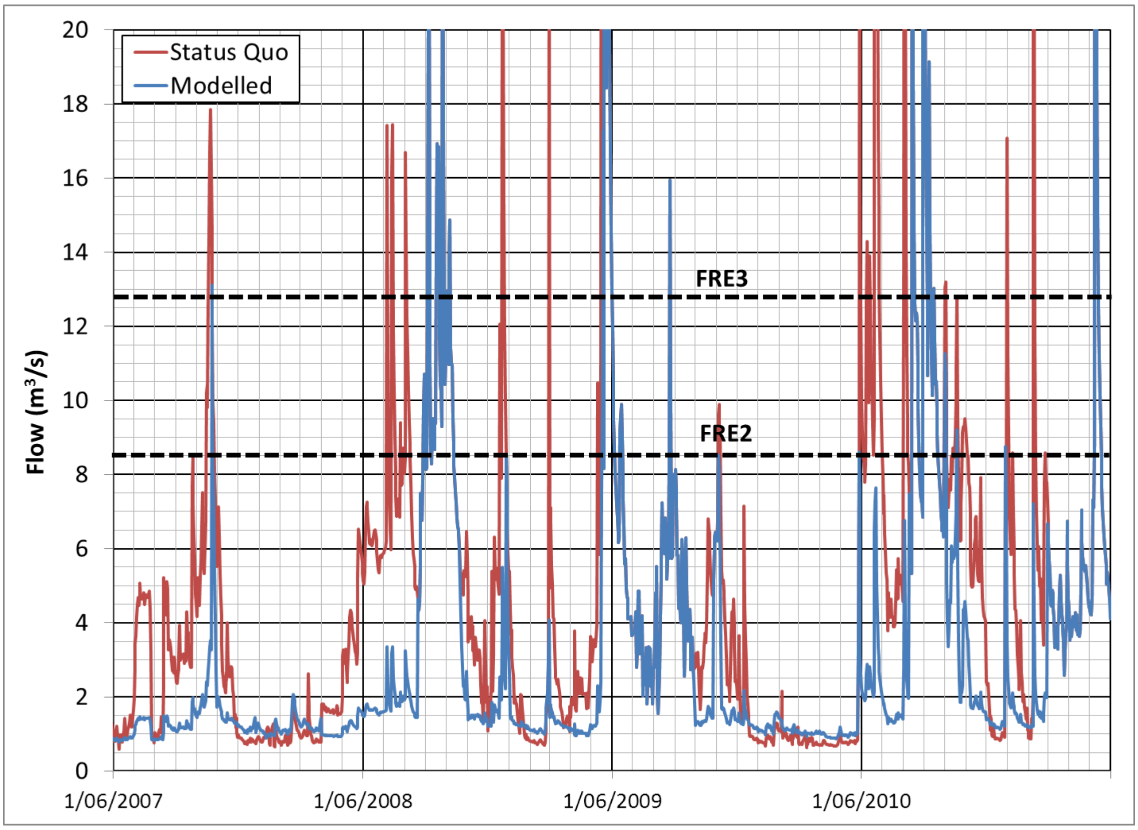
Scenario 1



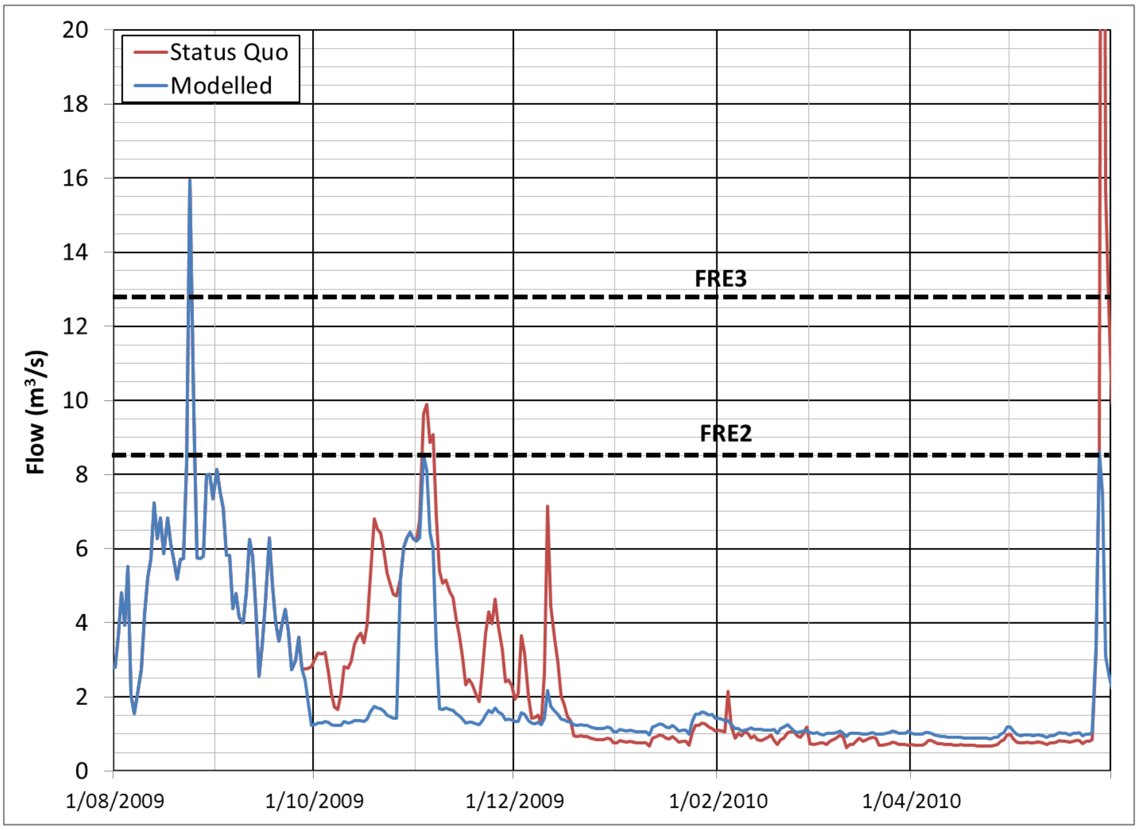
Scenario 2



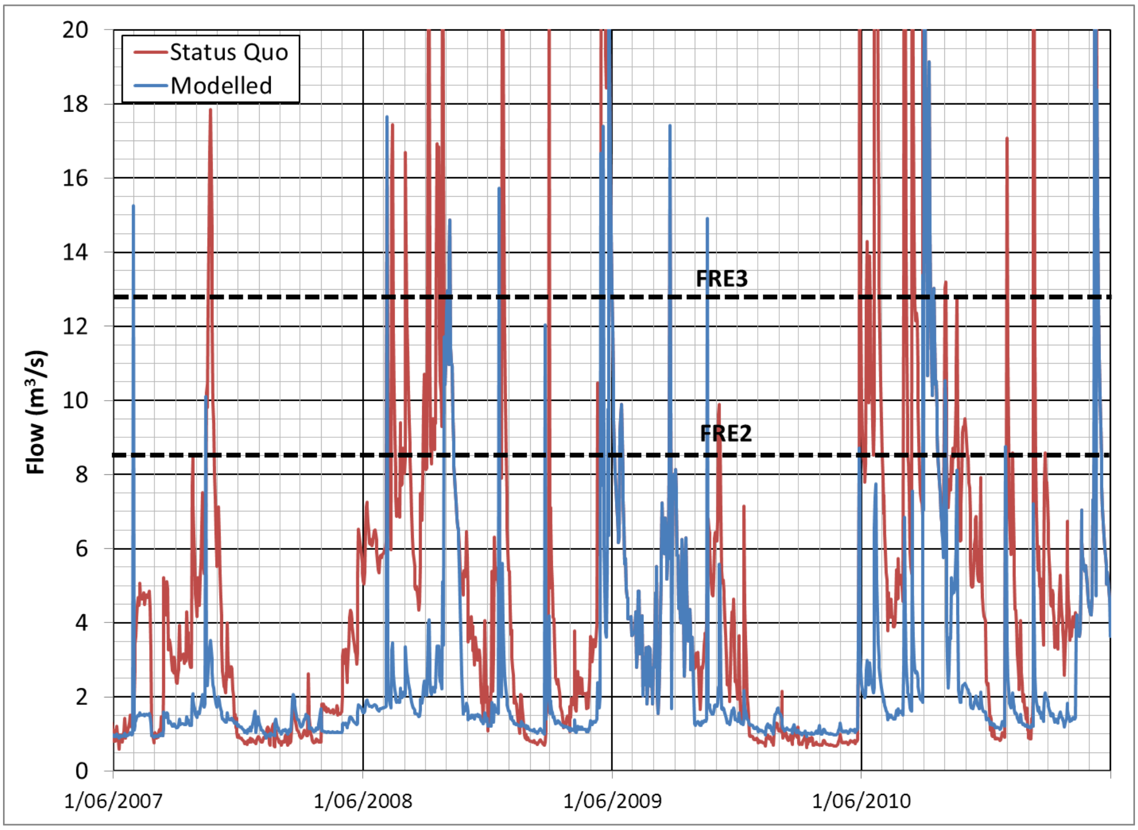
Scenario 2



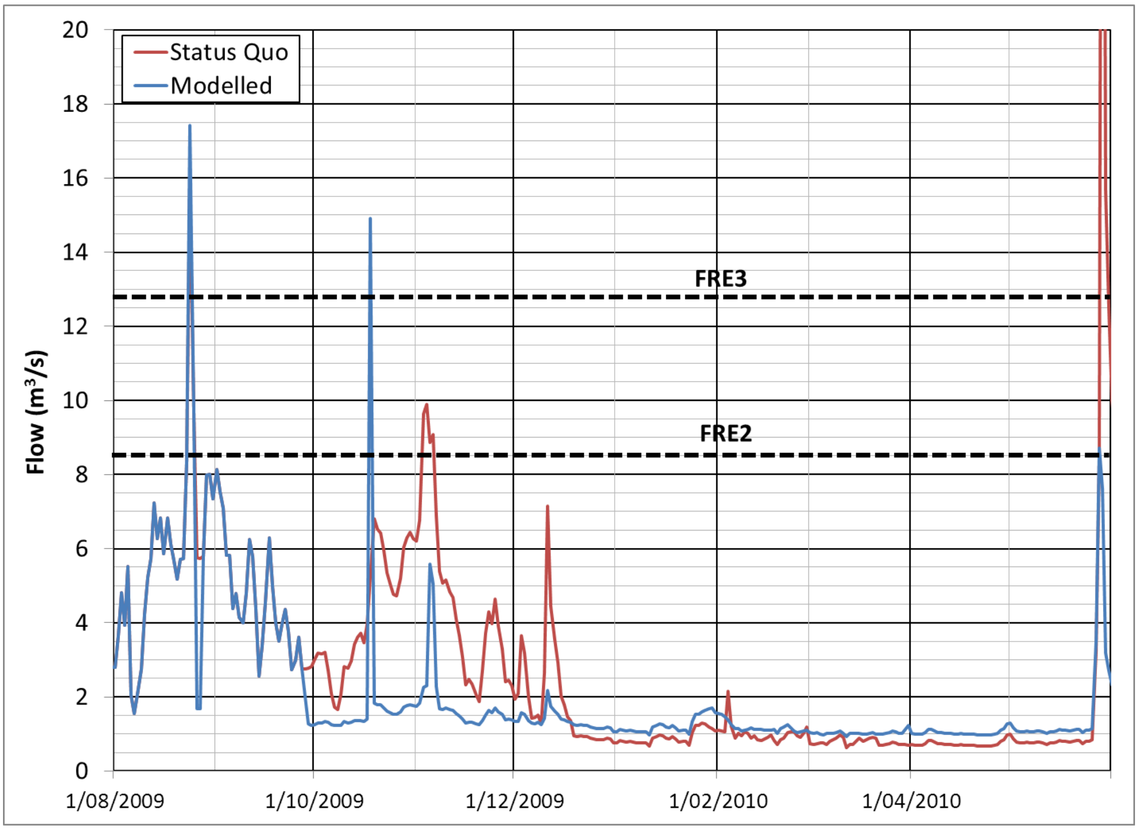
Scenario 3



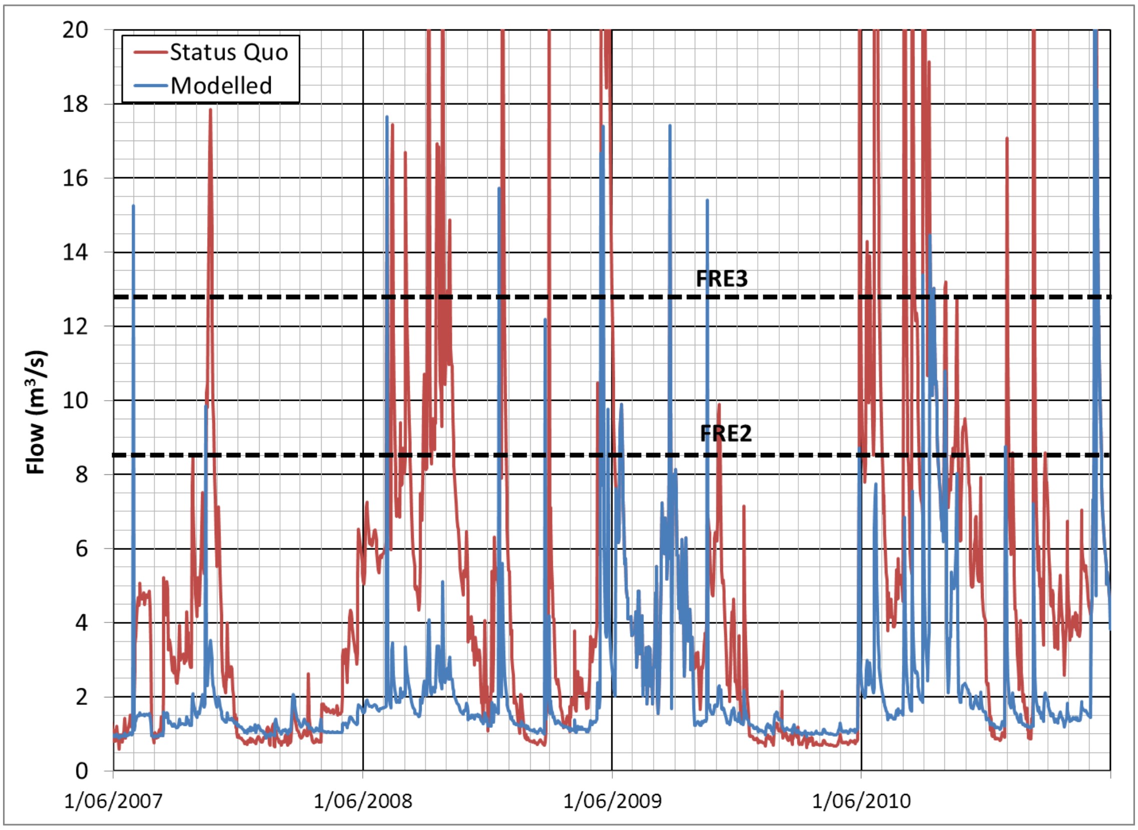
Scenario 3



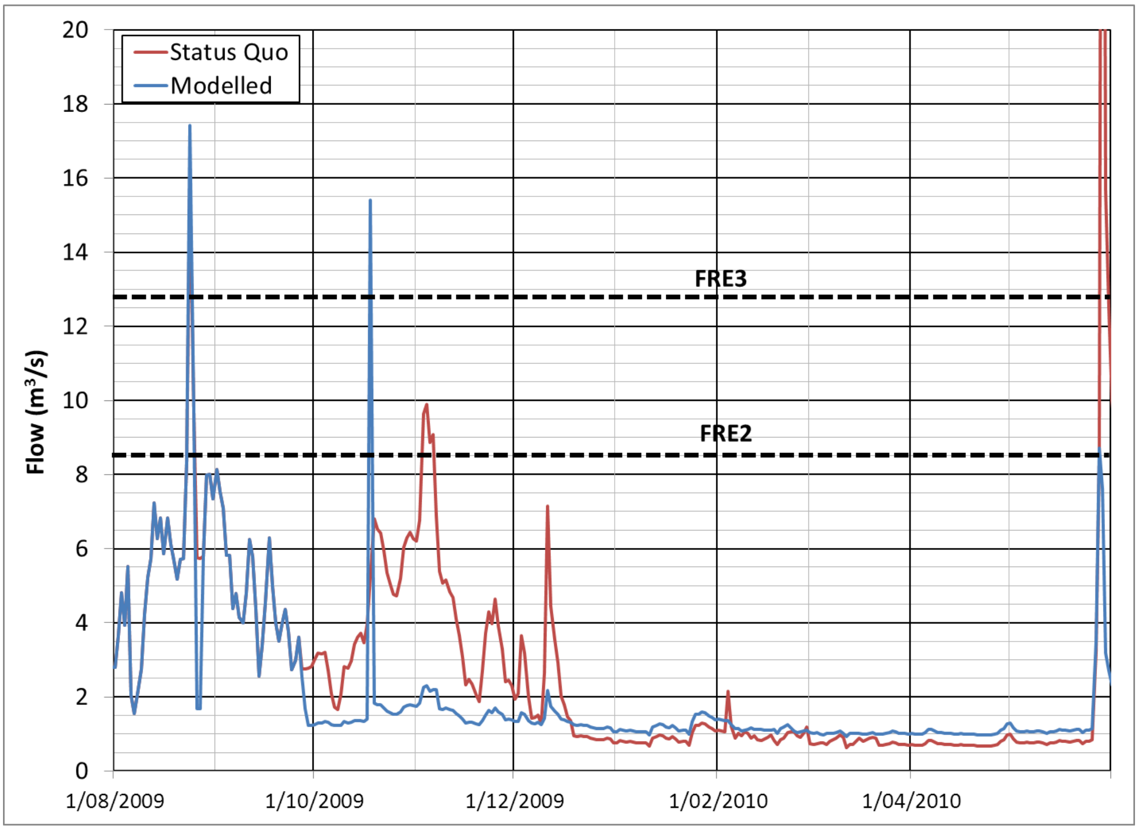
Scenario 4



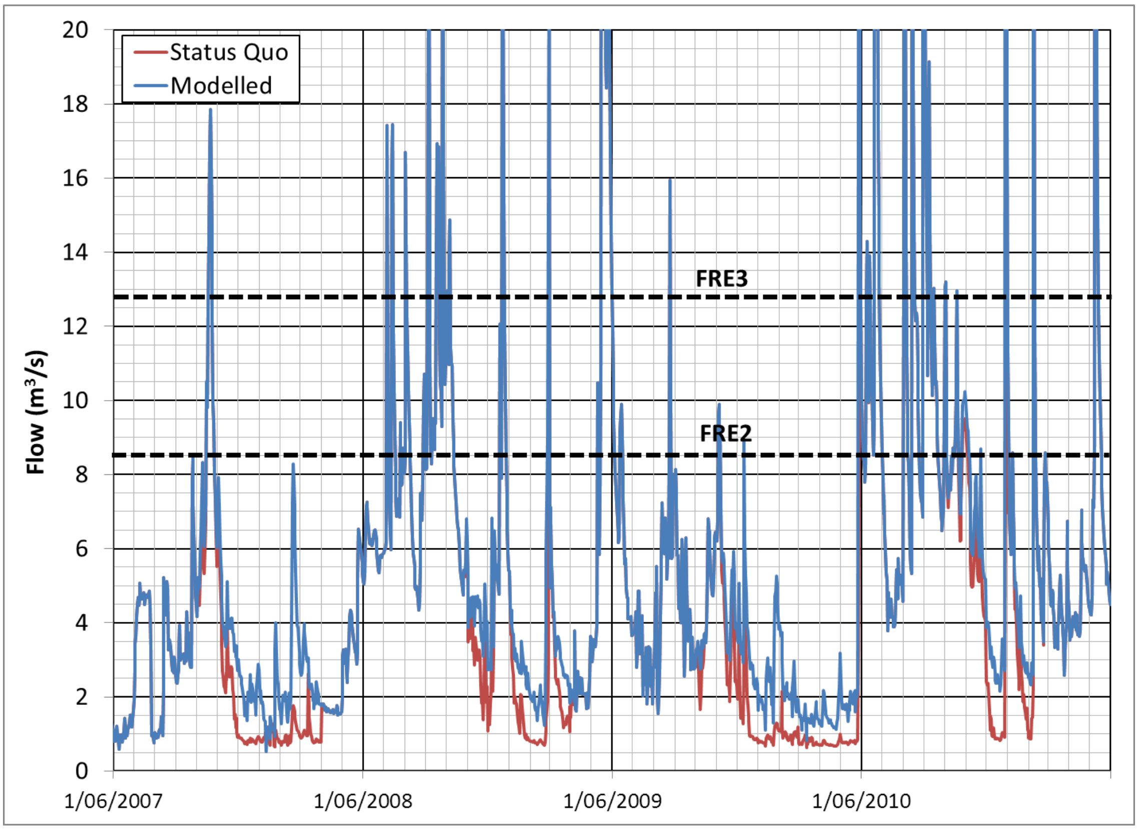
Scenario 4



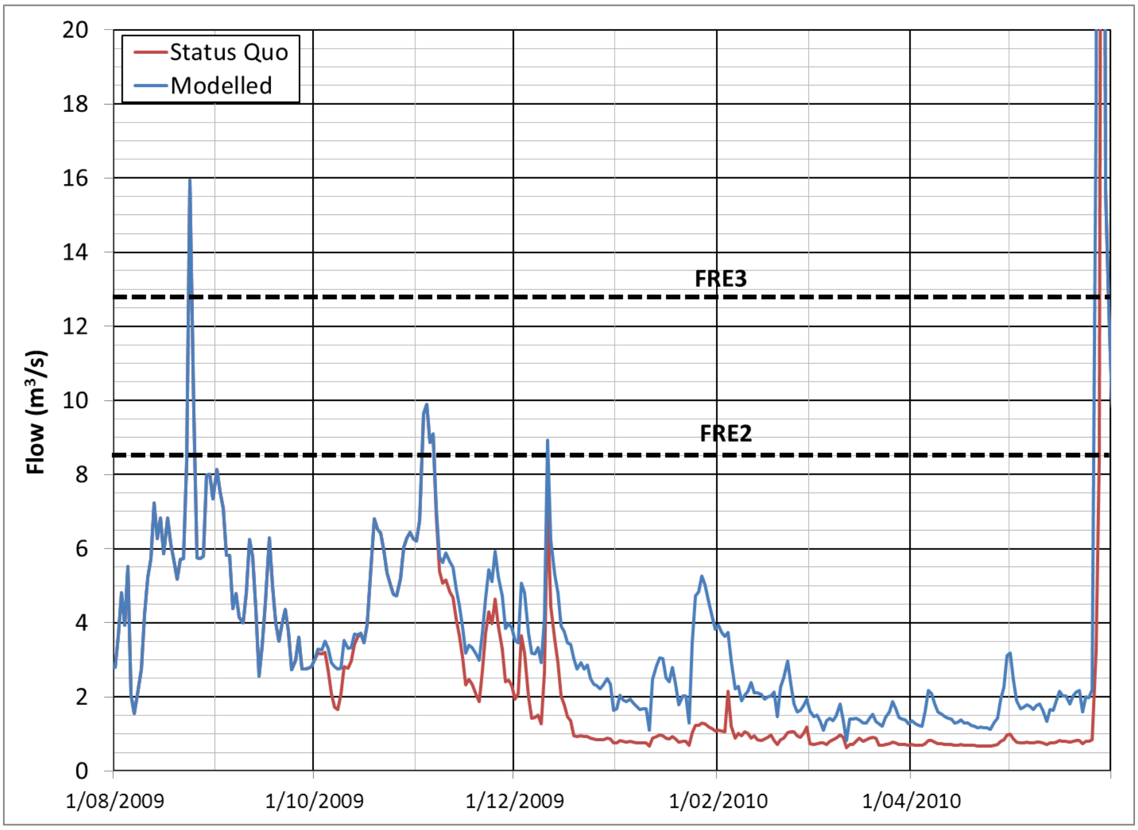
Scenario 5



Scenario 5

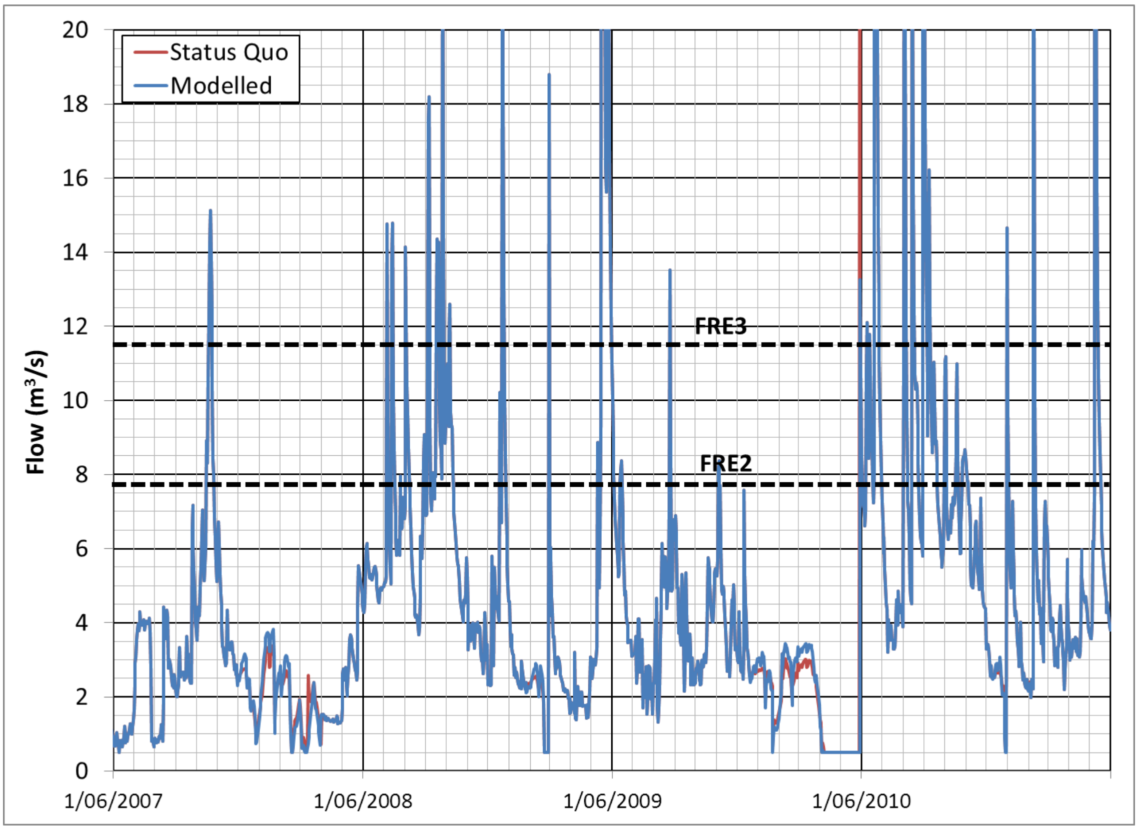


No Manuherikia Valley irrigation, but status quo Mt Ida Race water use

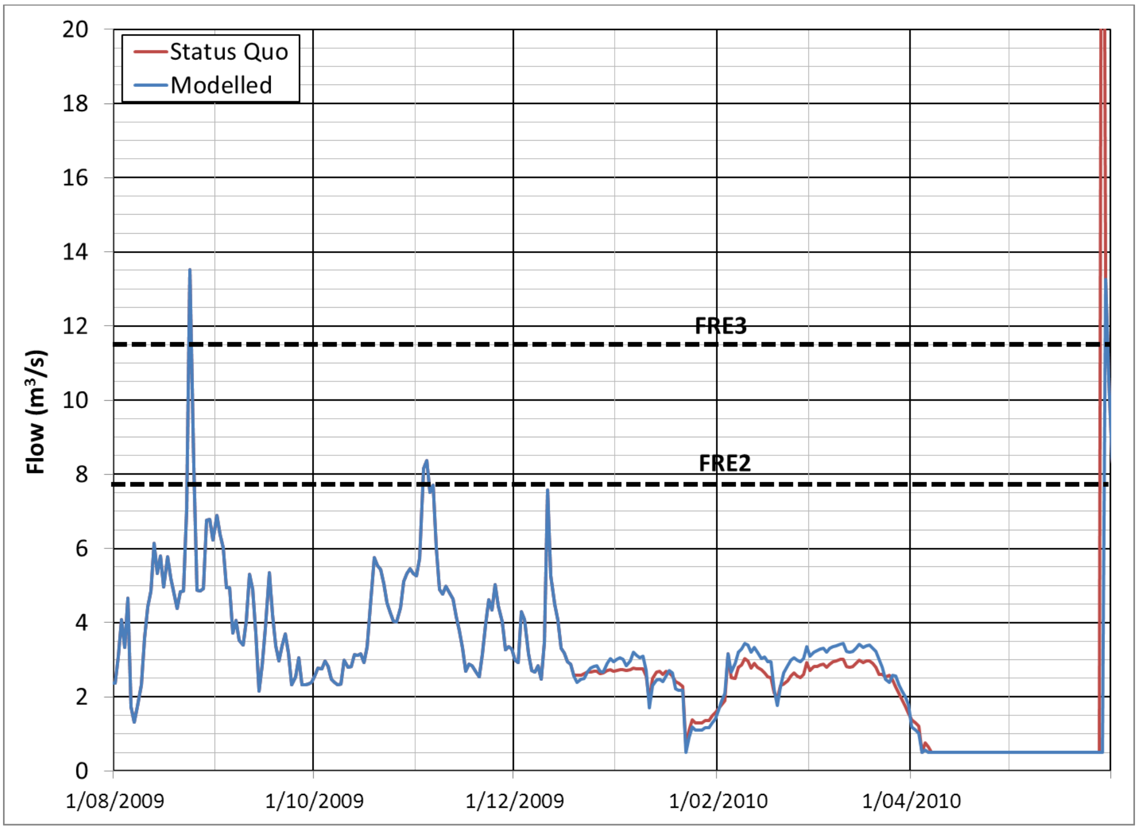


No Manuherikia Valley irrigation, but status quo Mt Ida Race water use

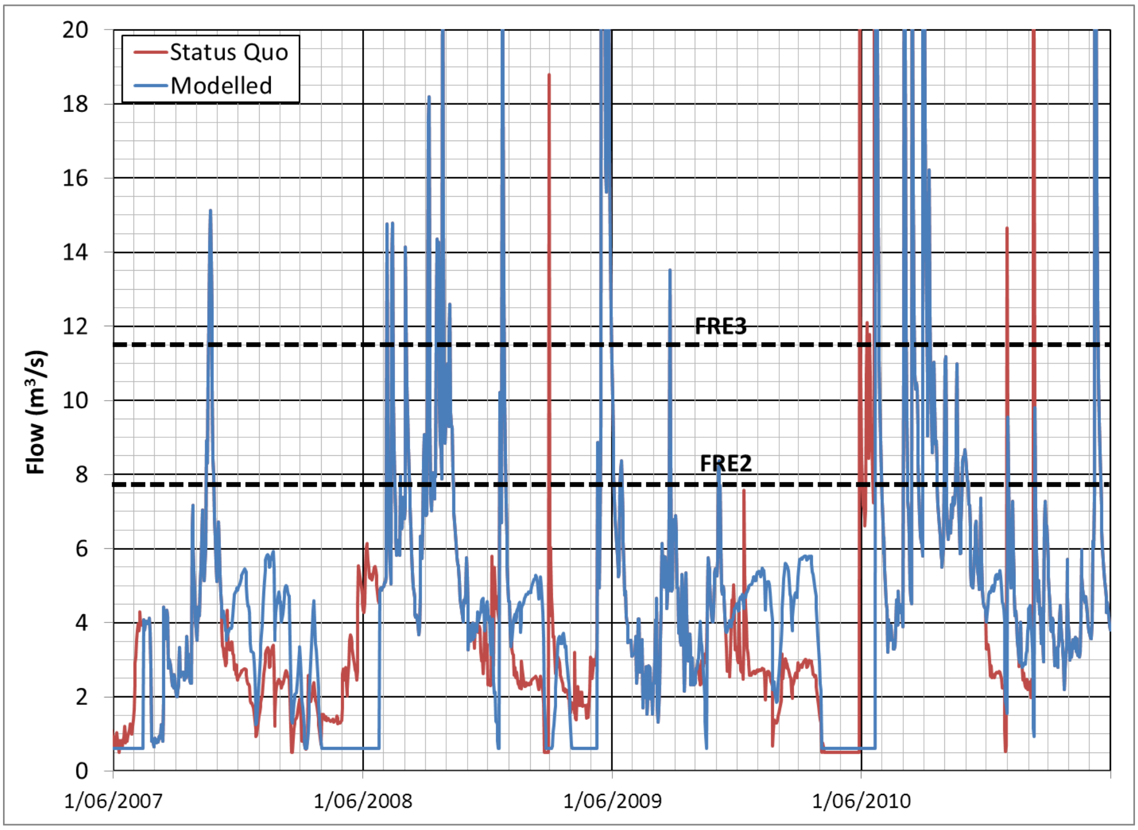
Appendix F: Manuherikia flow D/S of Falls Dam



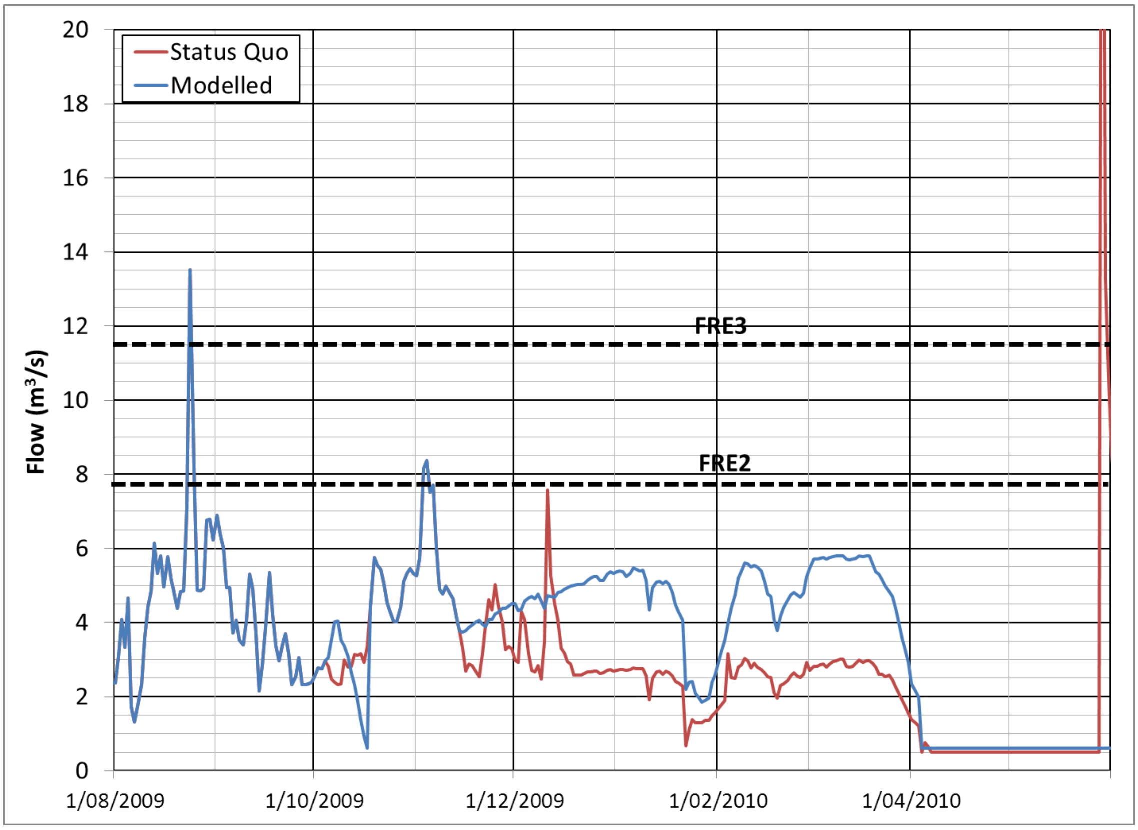
Scenario 1



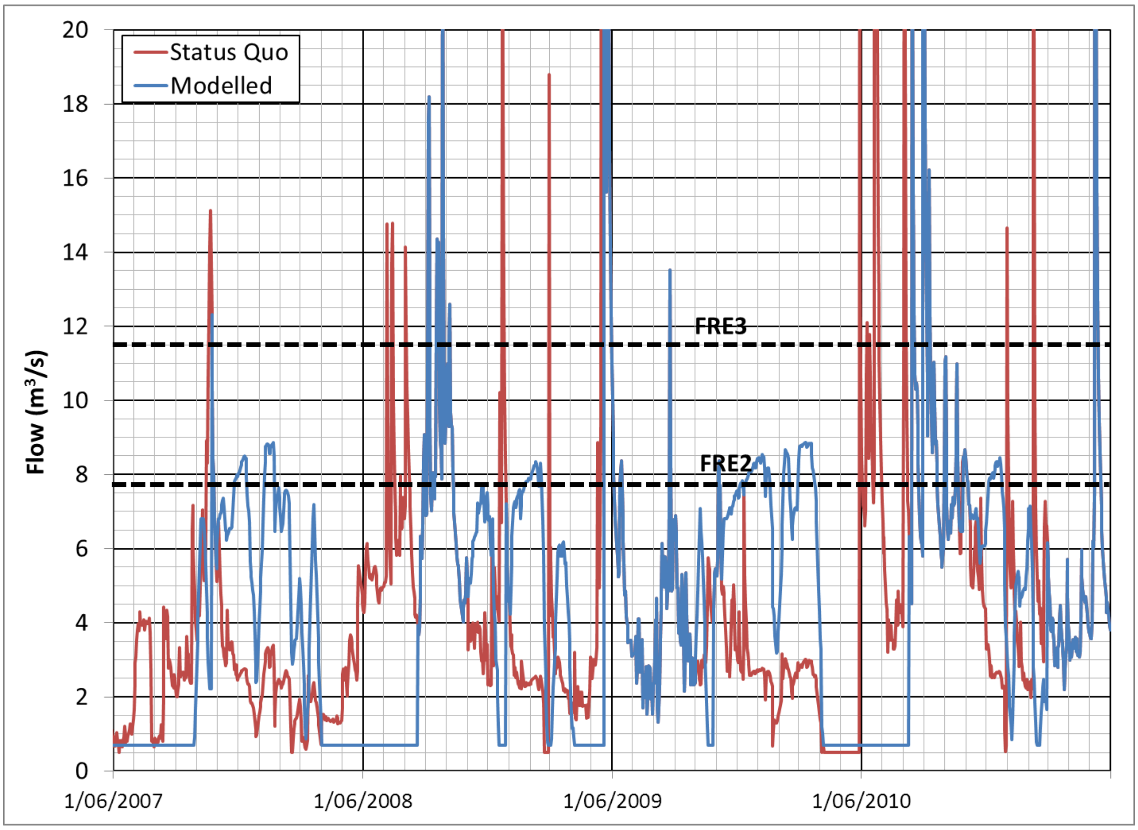
Scenario 1



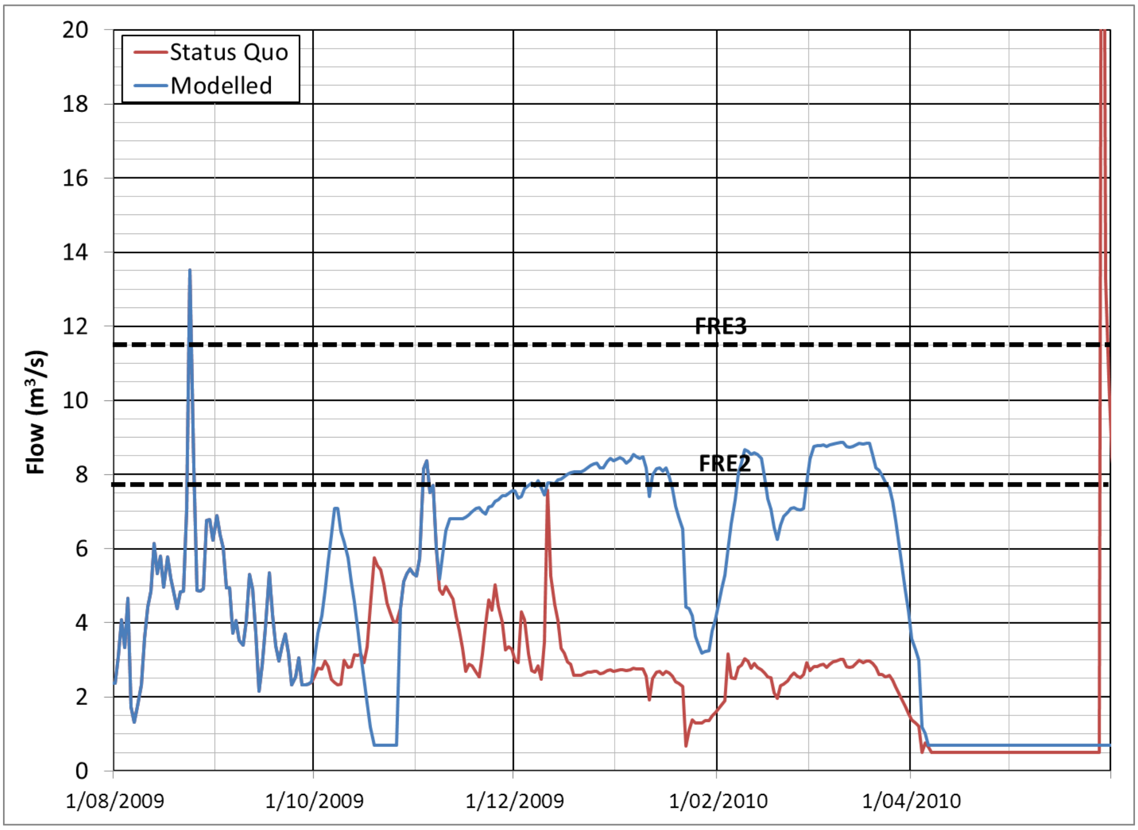
Scenario 2



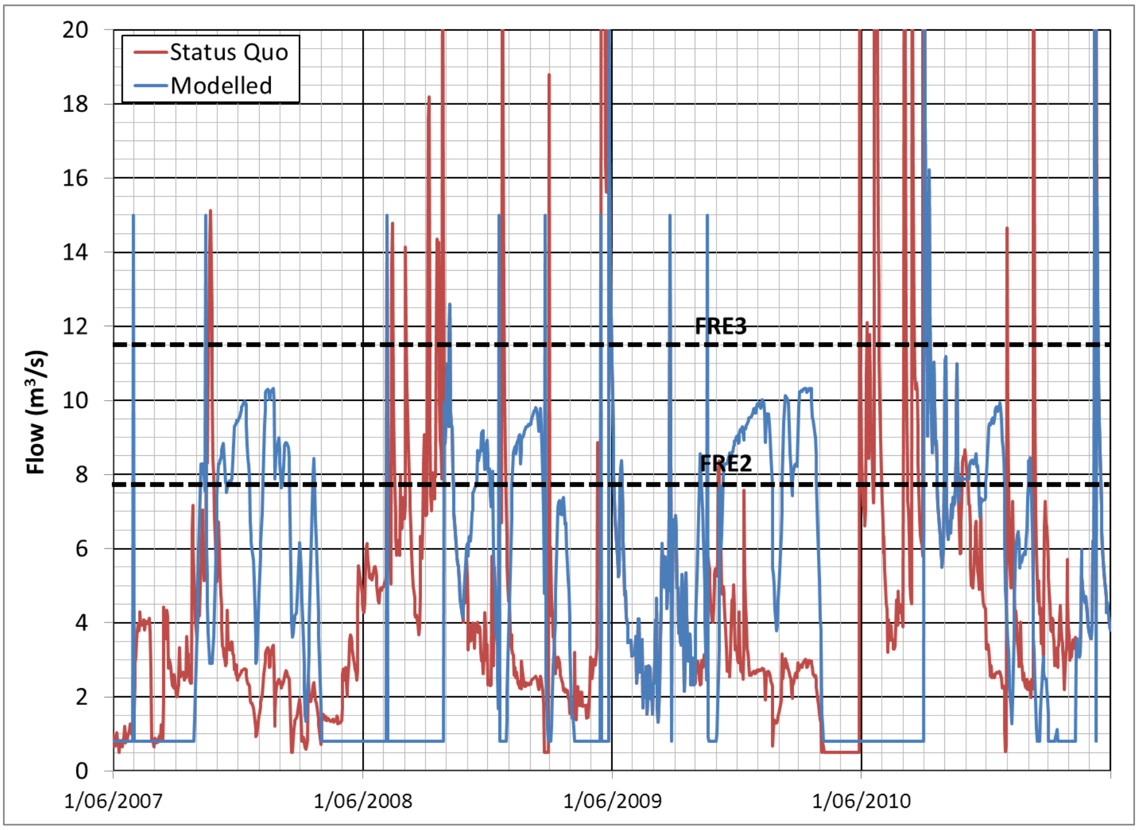
Scenario 2



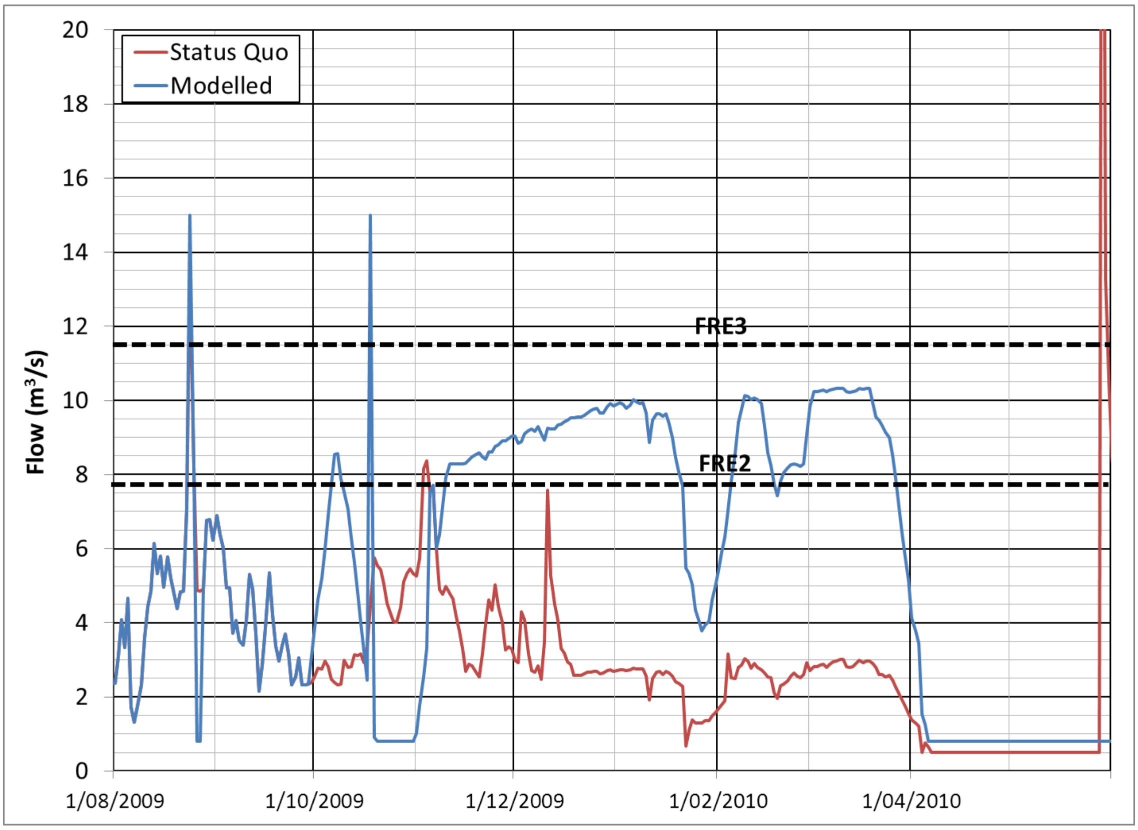
Scenario 3



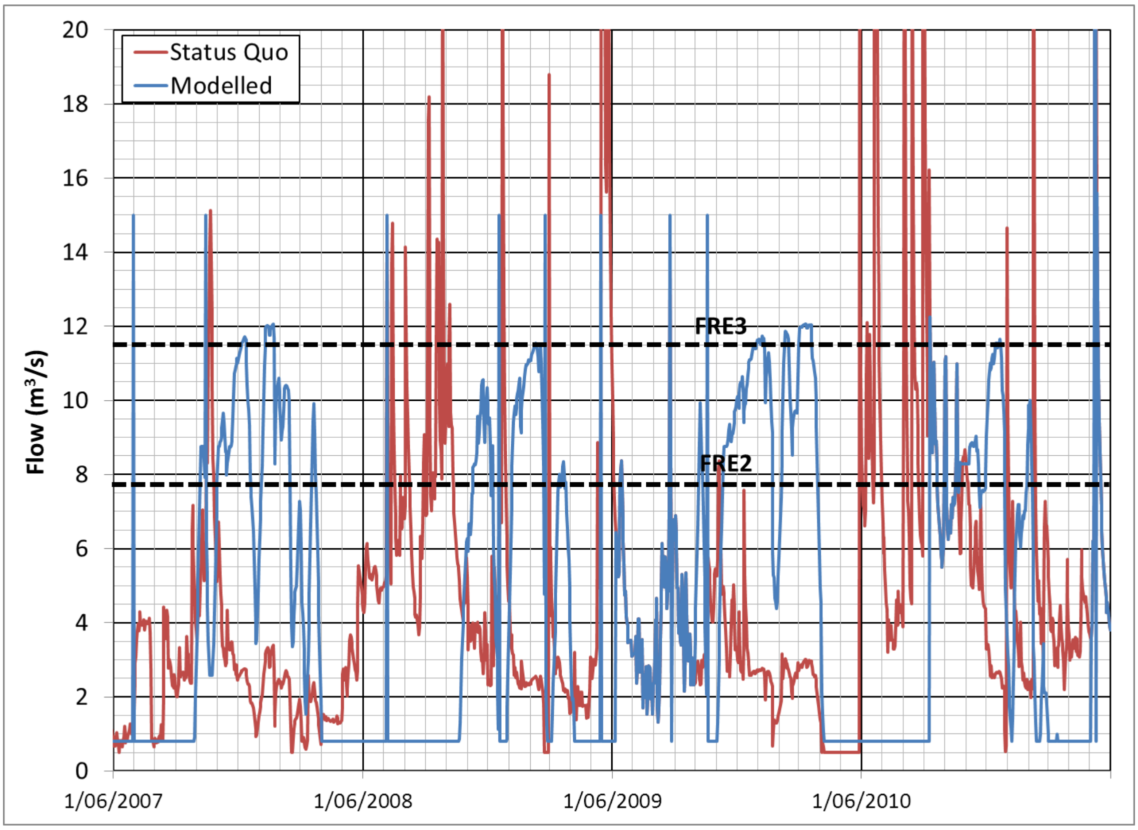
Scenario 3



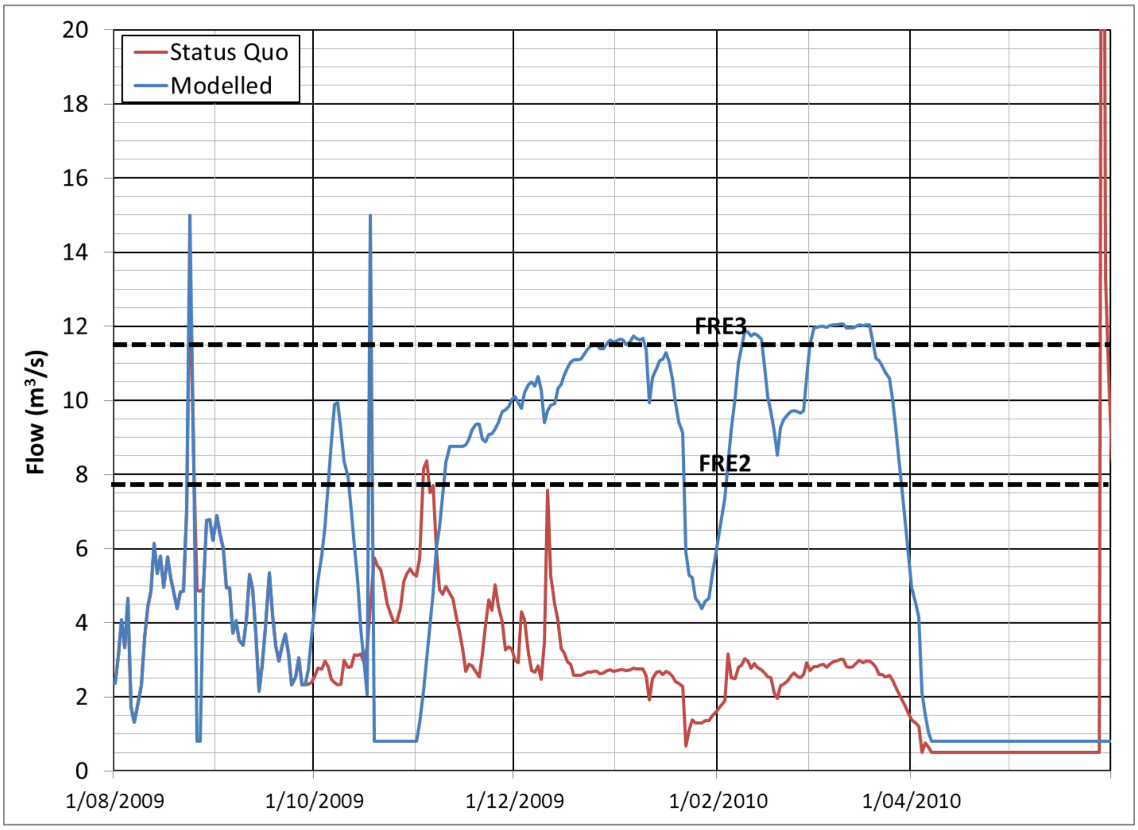
Scenario 4



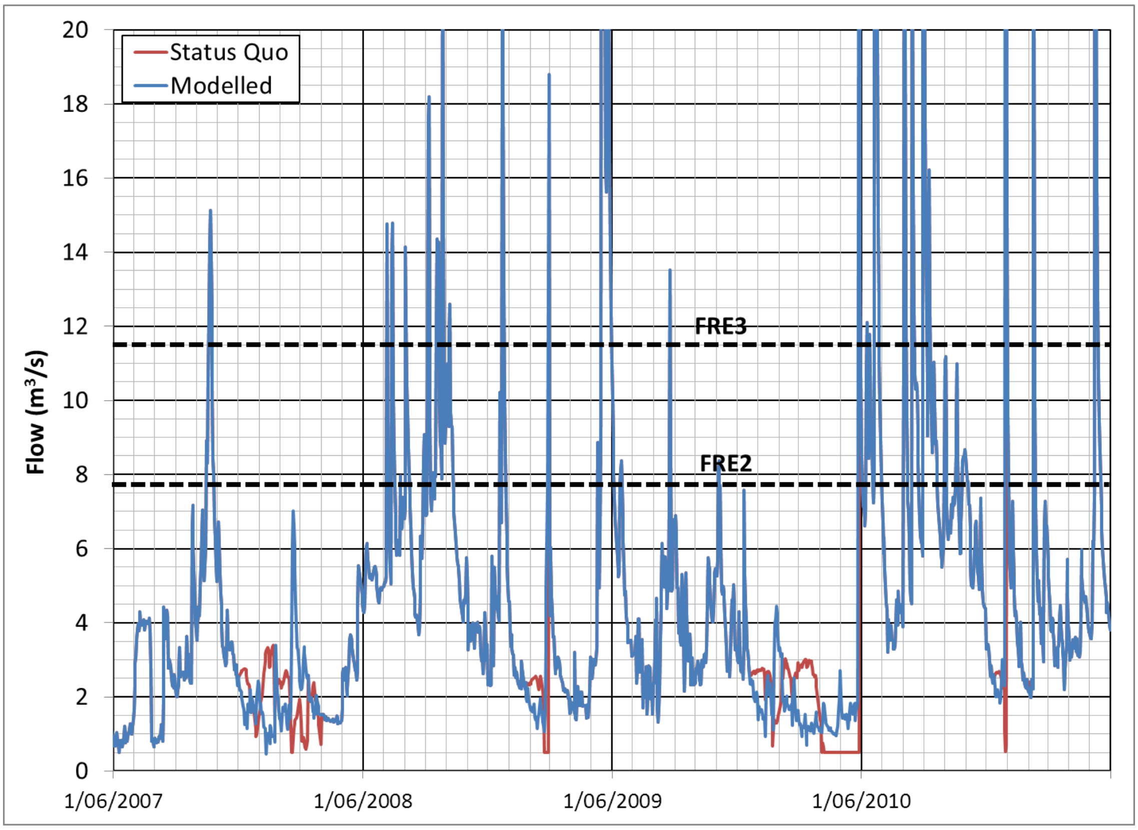
Scenario 4



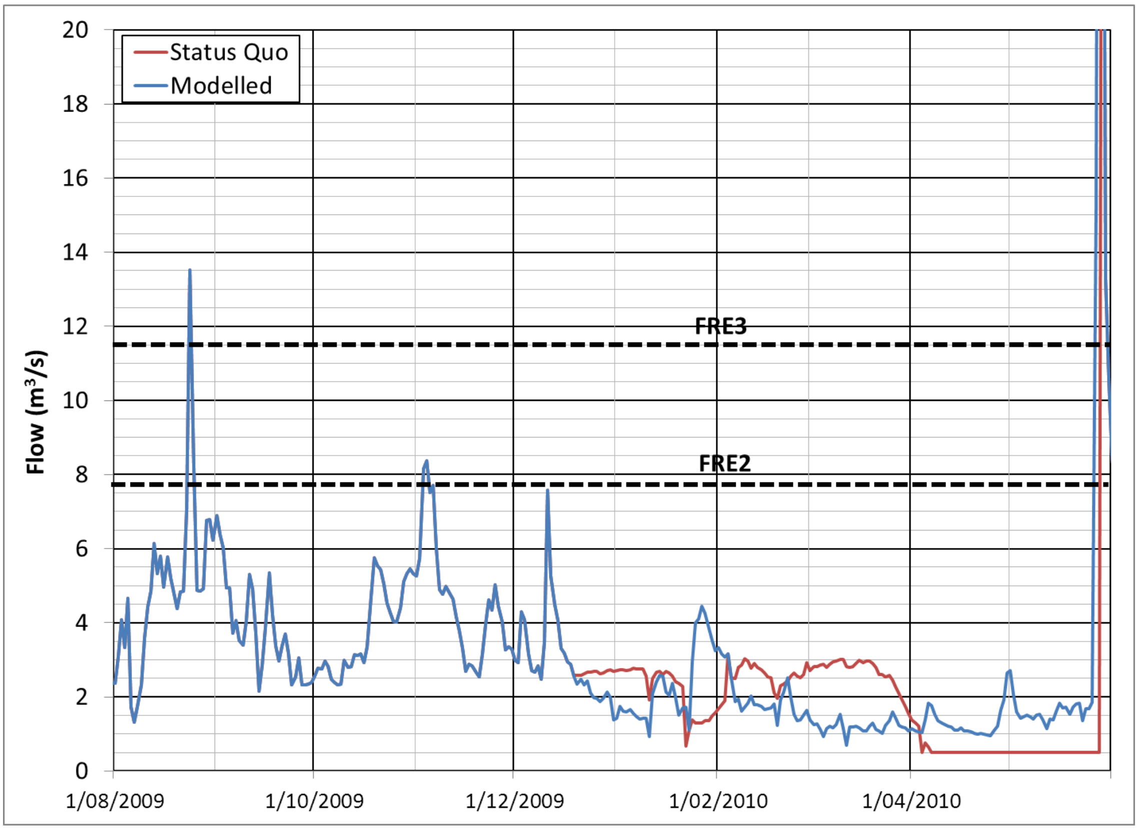
Scenario 5



Scenario 5

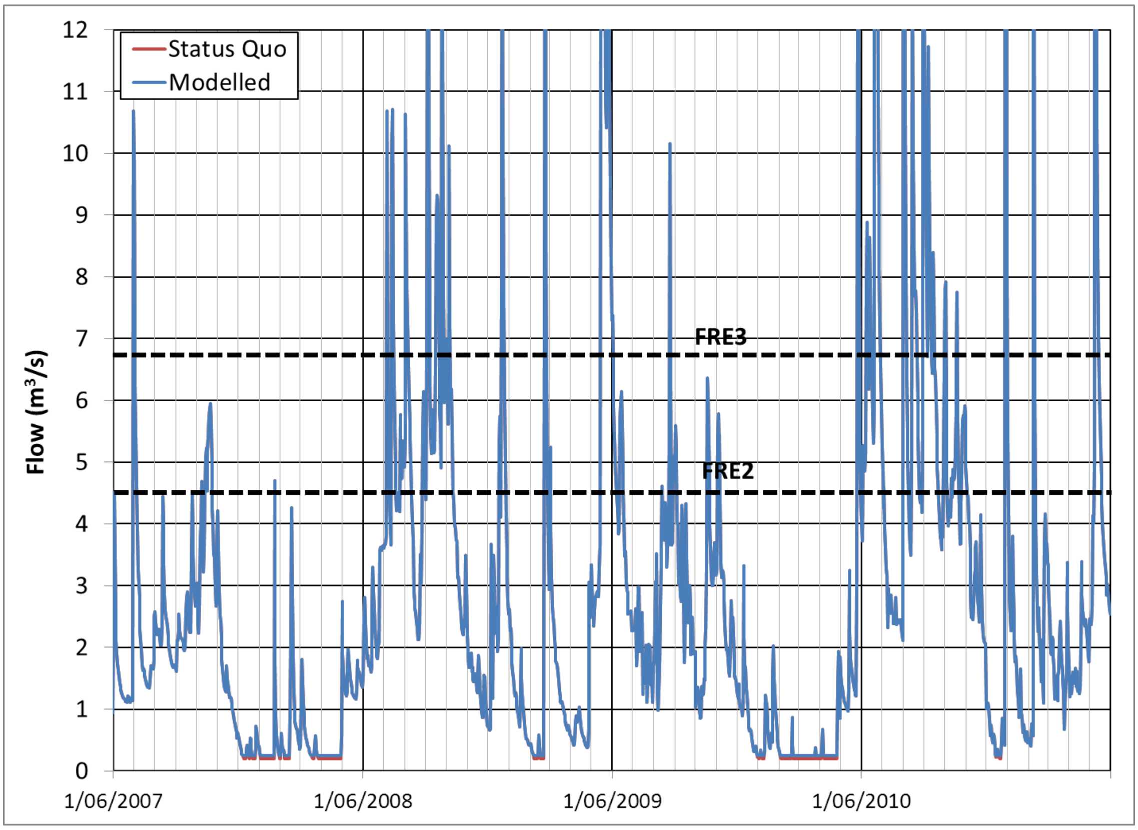


No Manuherikia Valley irrigation, but status quo Mt Ida Race water use

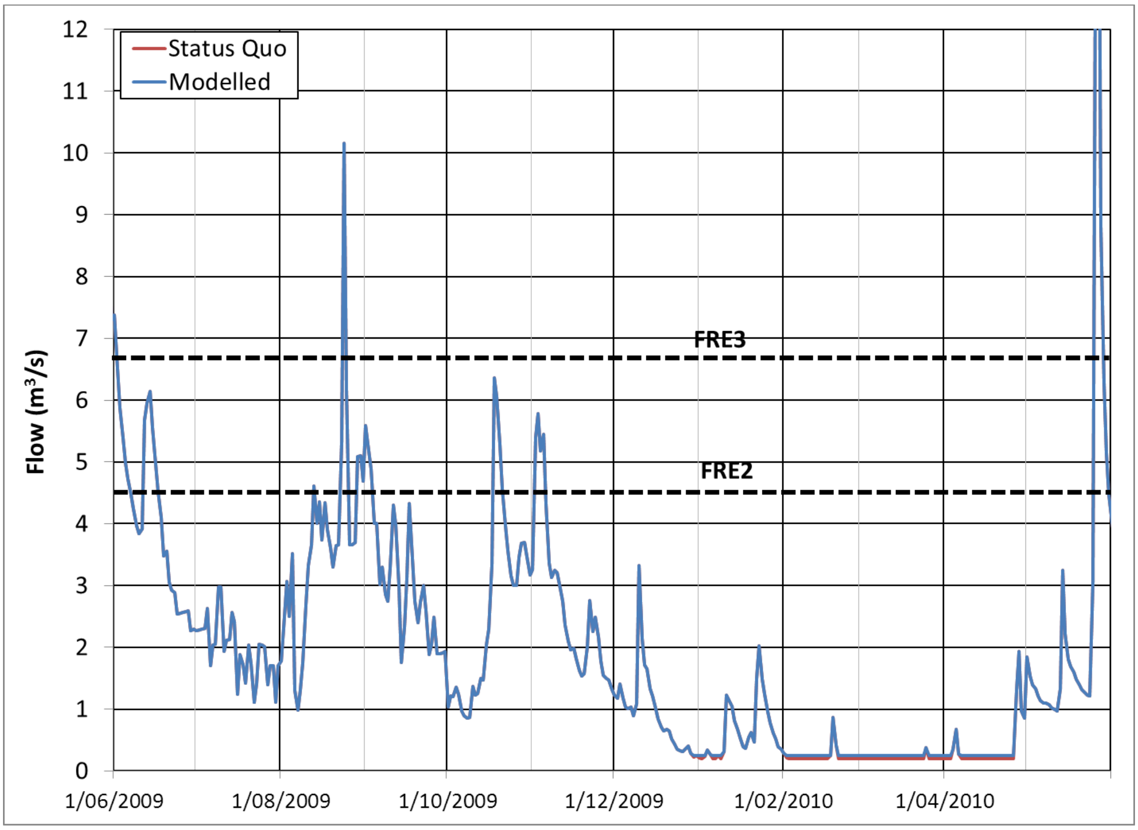


No Manuherikia Valley irrigation, but status quo Mt Ida Race water use

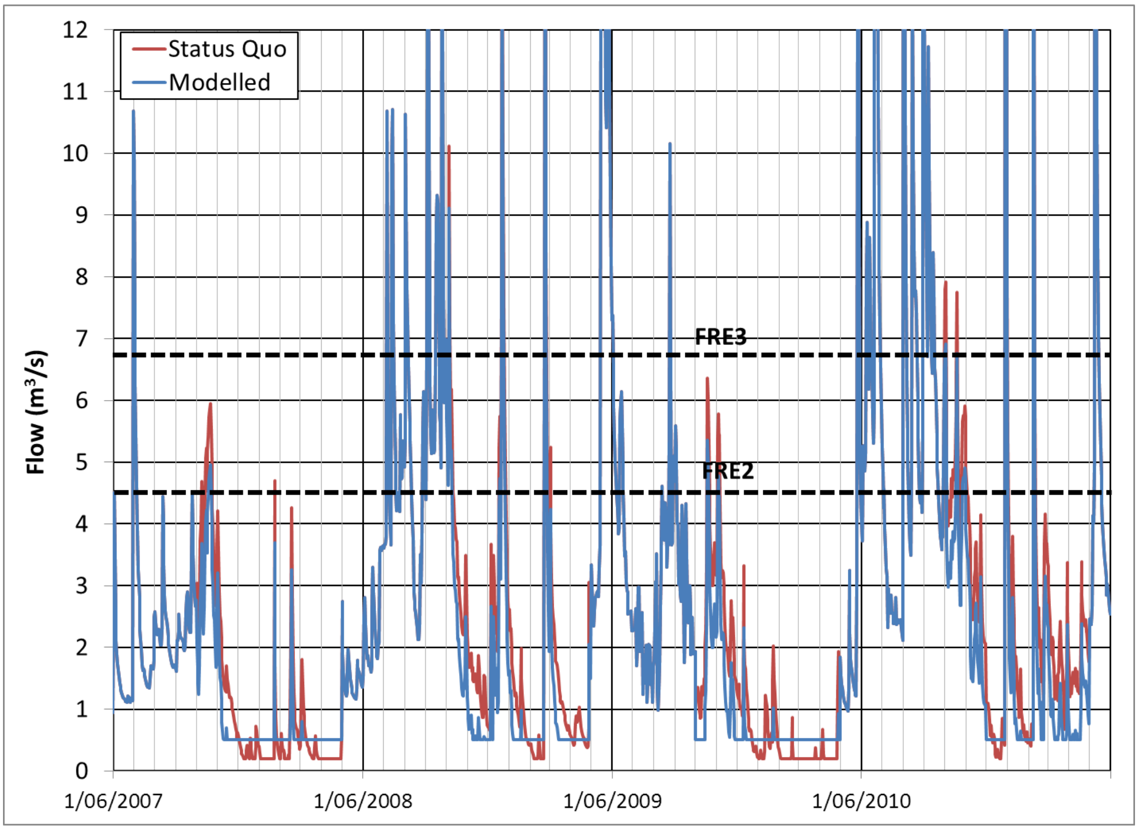
Appendix G: Dunstan Creek at confluence



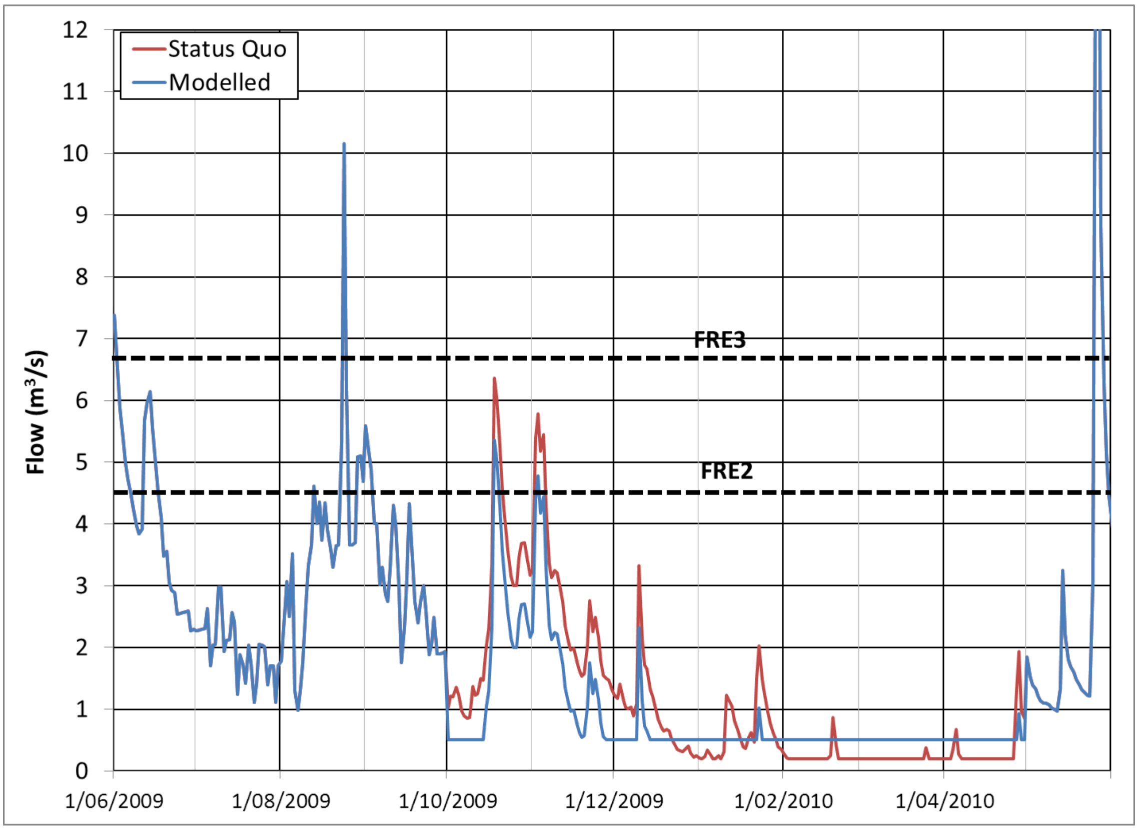
Scenarios 1-4



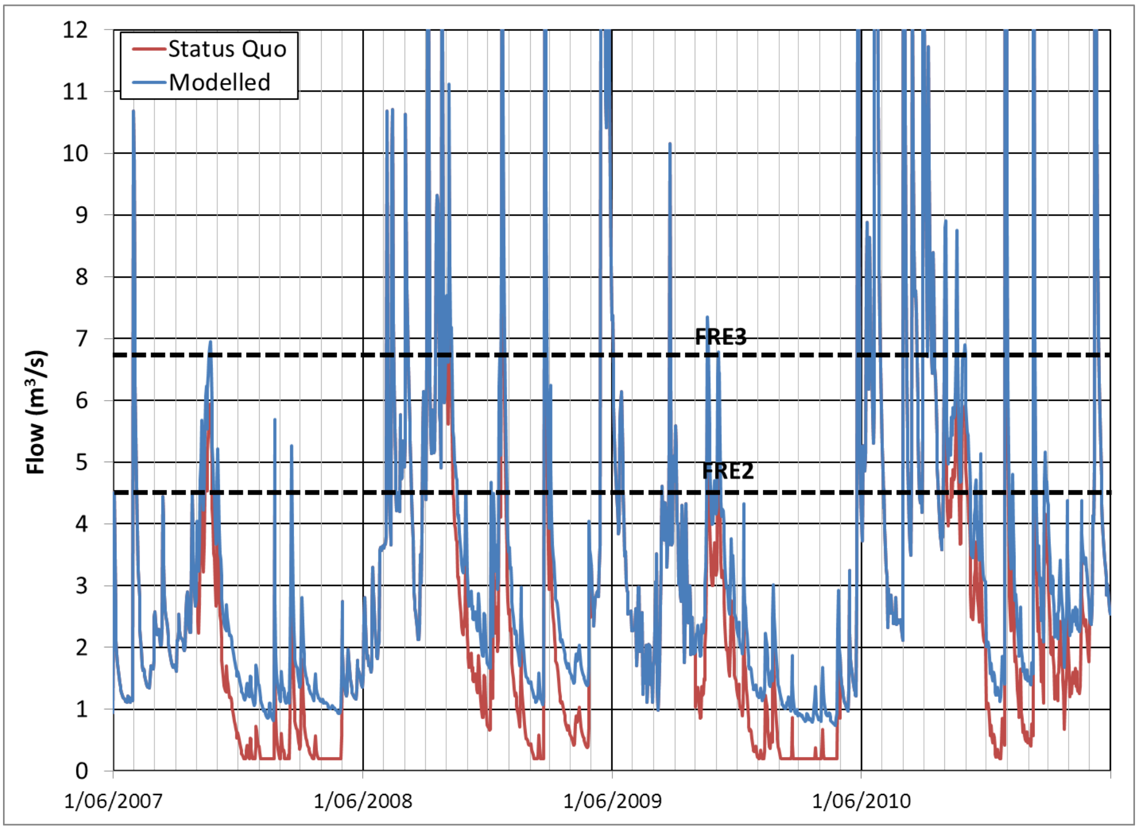
Scenarios 1-4



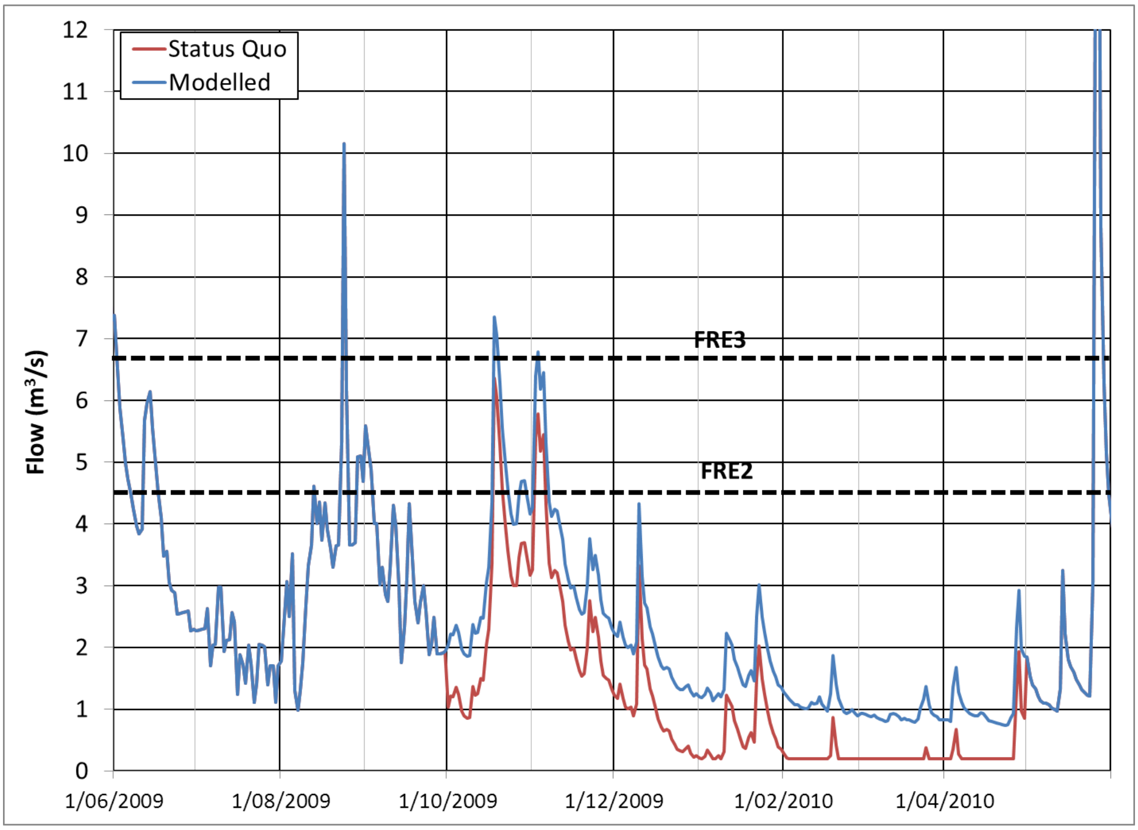
Scenario 5



Scenario 5

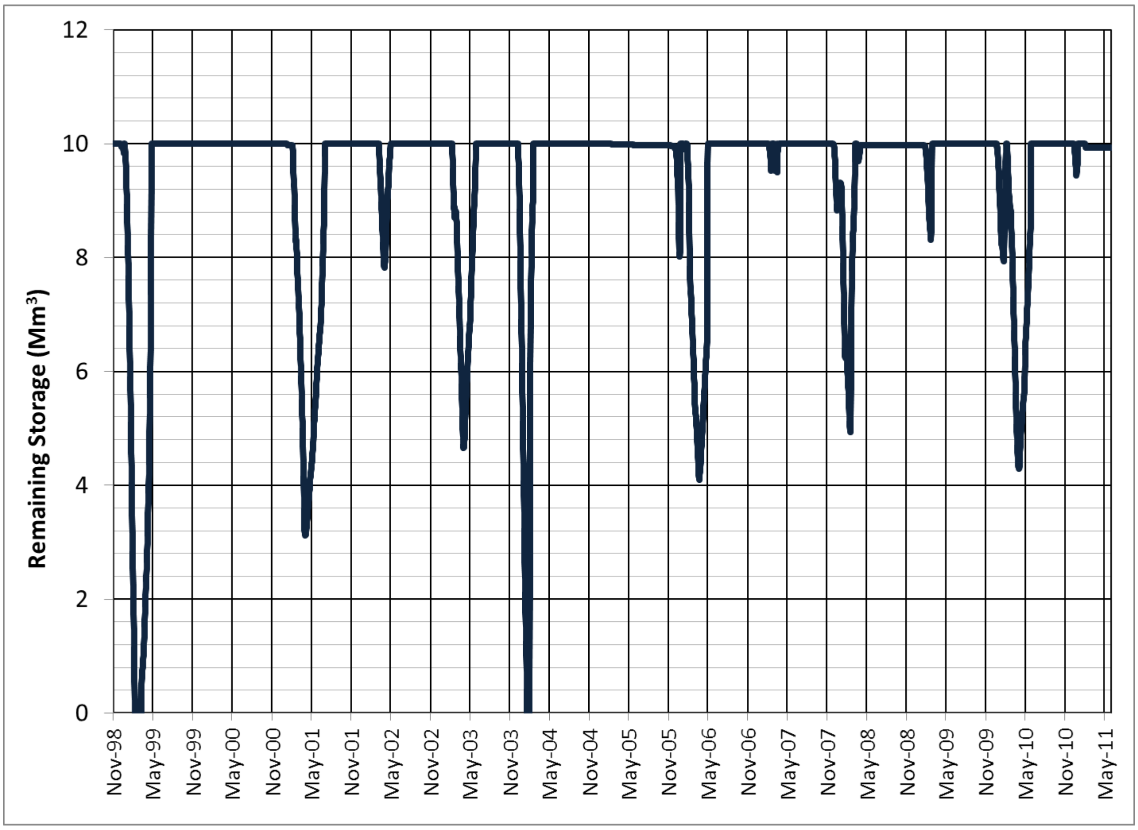


Naturalised flow

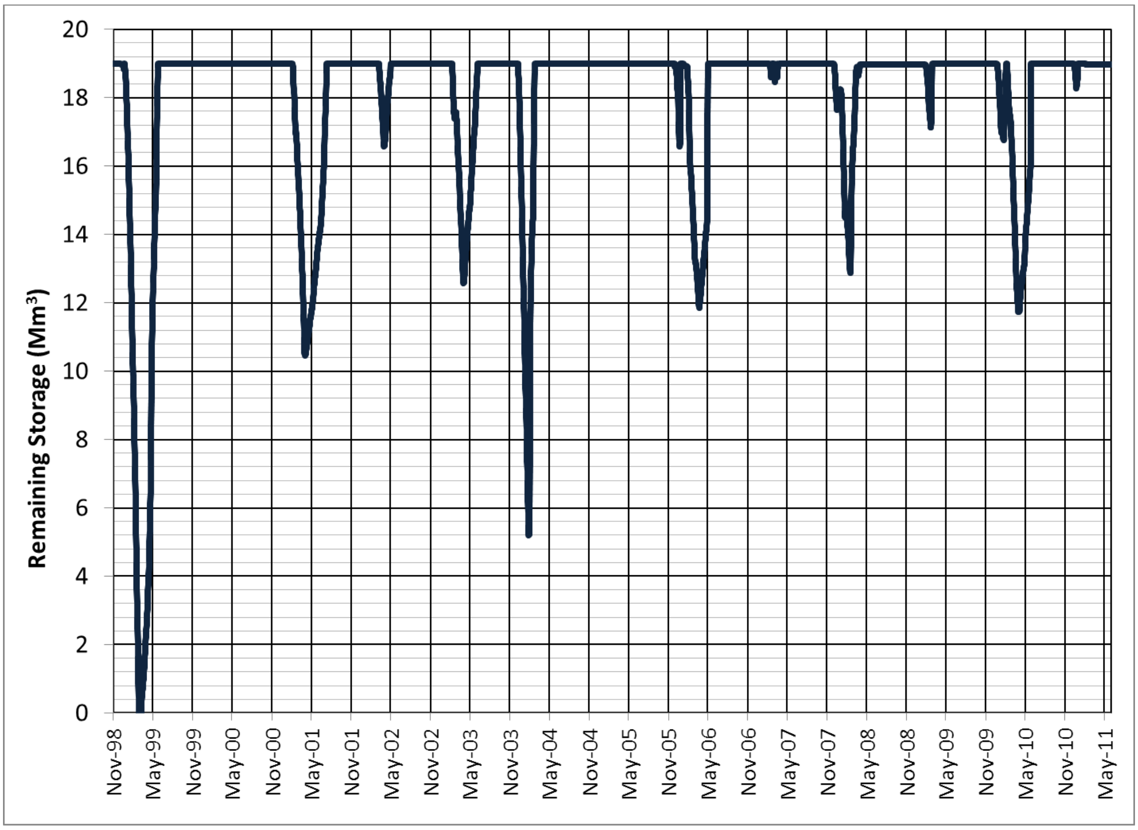


Naturalised flow

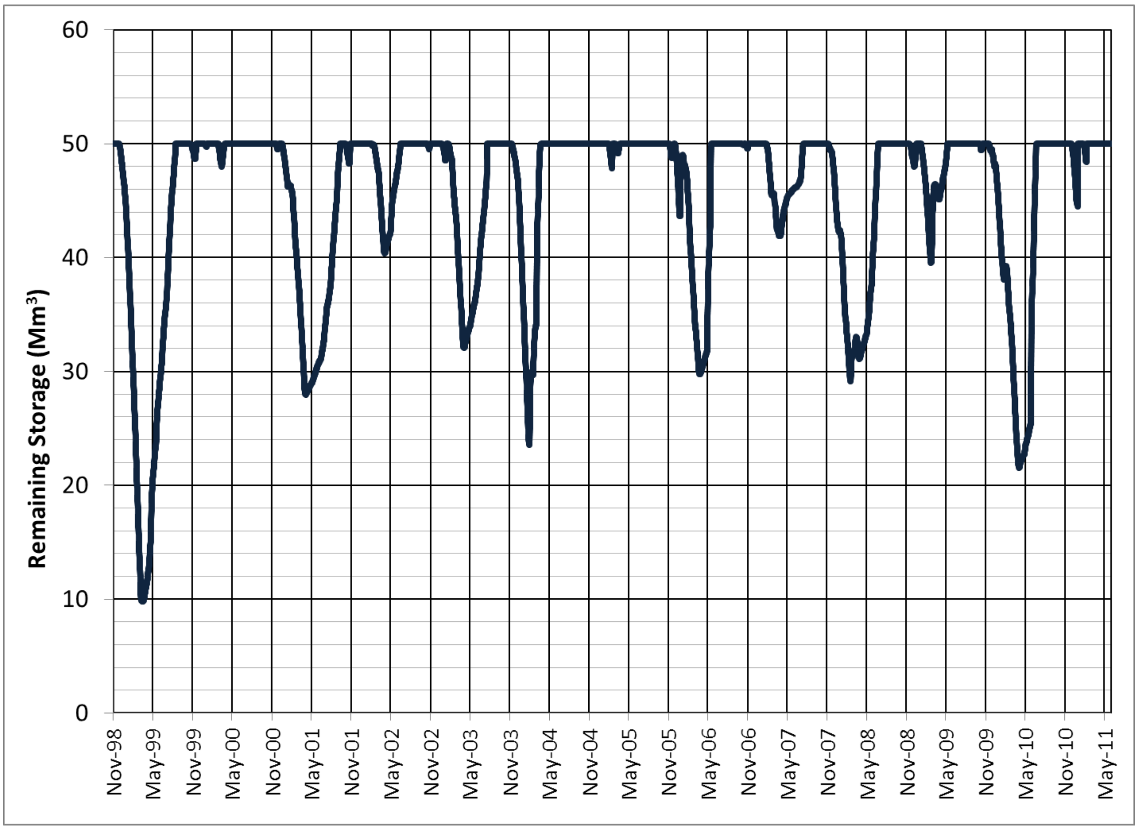
Appendix H: Falls Dam storage



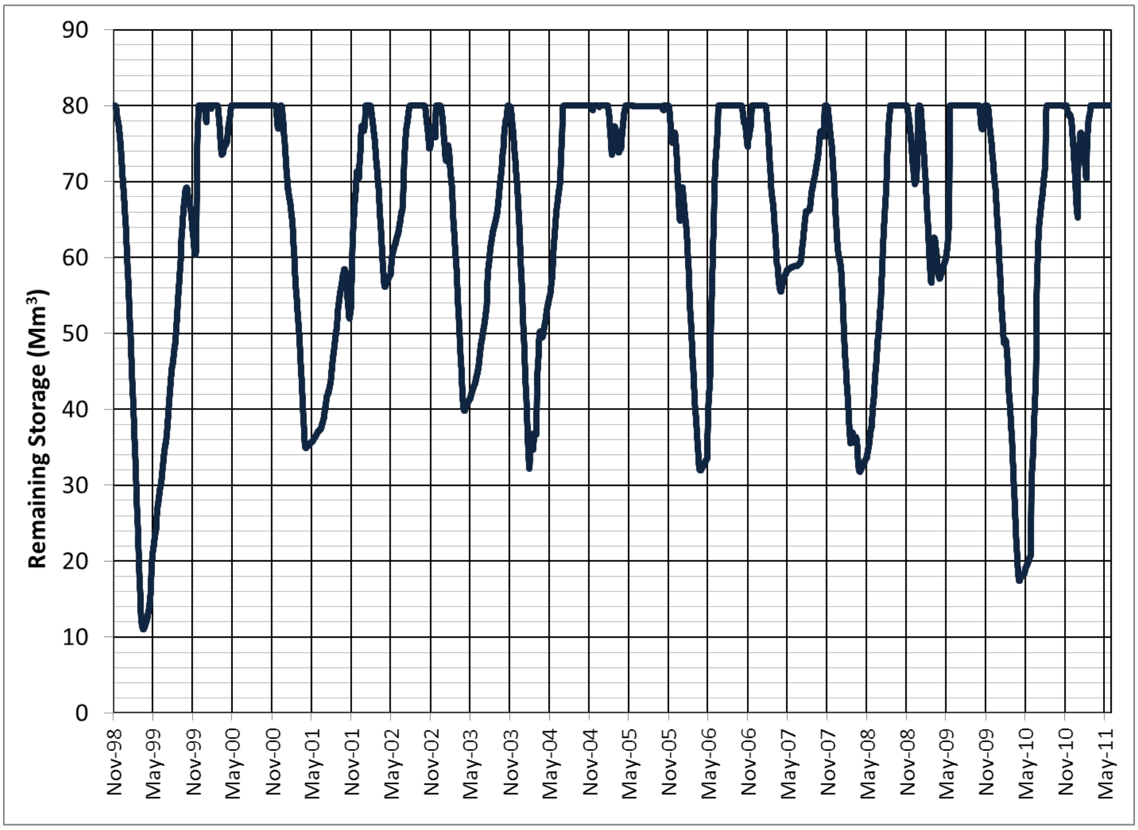
Status quo



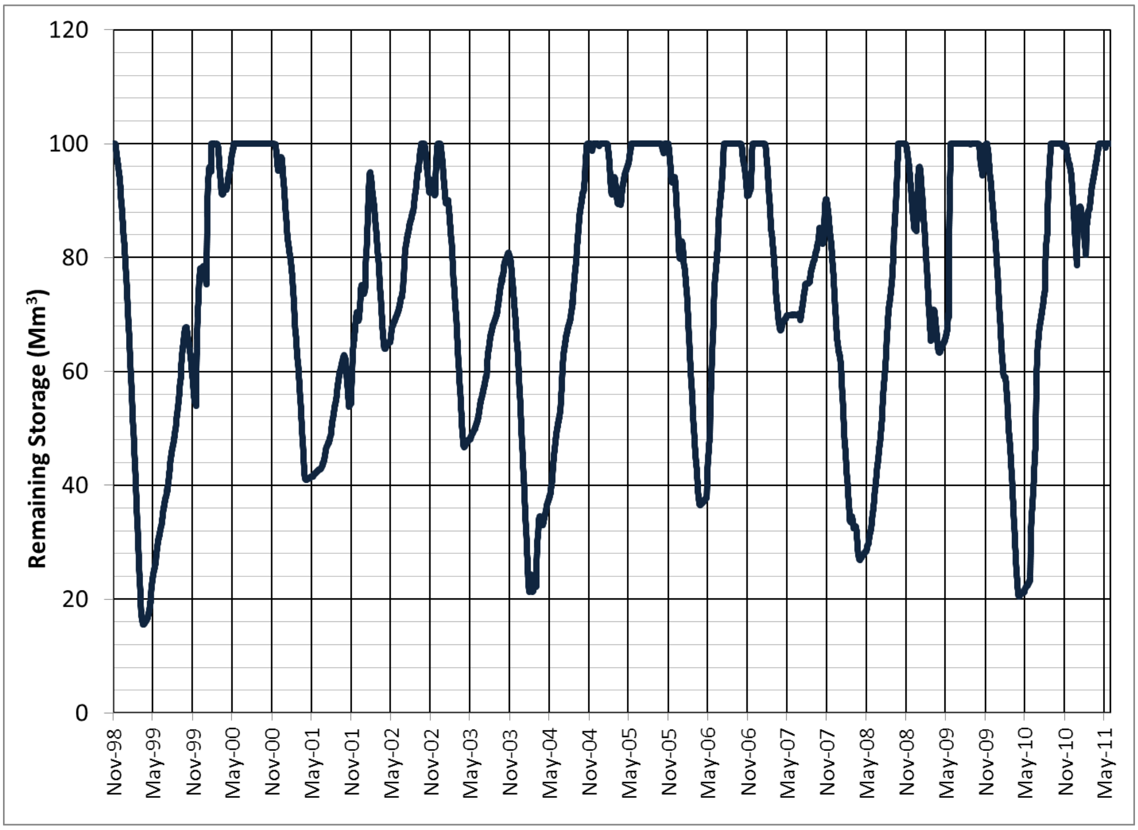
Scenario 1



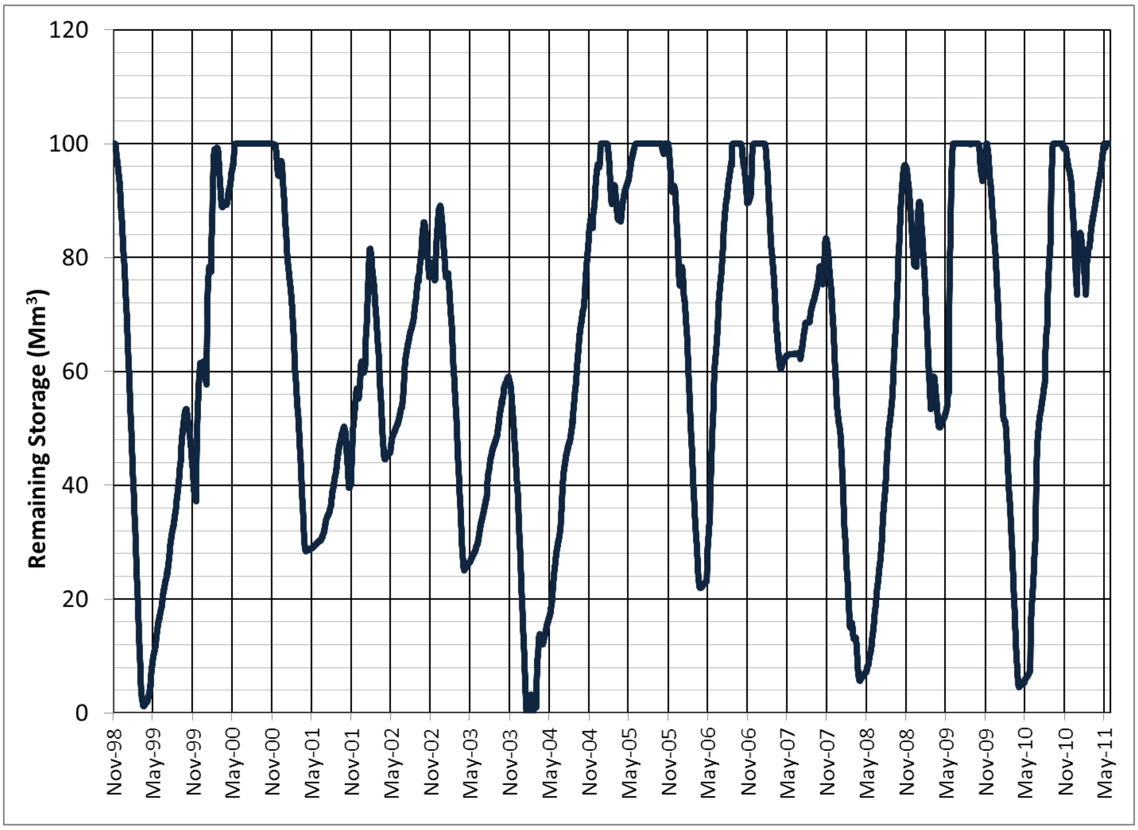
Scenario 2



Scenario 3



Scenario 4



Scenario 5

(Jan 04. was the only time from 1973 – 2011 when Falls Dam was empty)