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MEMORANDUM

To:	Manuherekia Technical Advisory Group (TAG)
From:	Ian Lloyd, Davis Ogilvie
Date:	21 May 2021
Subject:	Manuherekia Hydrology Model – Ecology Memorandum – Final Draft

1.0 BACKGROUND

This Ecological Memorandum was originally developed to provide initial ecological output from the Manuherekia Hydrology Model to facilitate discussion by the Manuherekia Technical Advisory Group (TAG). It is principally aimed at briefly describing the ecology part of the model and providing a brief summary of the ecological output from various model runs.

Earlier drafts of this Ecology Memorandum dated 5, 12 February and 22 March 2021 were circulated and subsequently updated based on feedback from TAG. This Ecology Memorandum replaces the earlier versions.

The Manuherekia Hydrology Model is to be documented in a formal model report. However, as at 21 May 2021 the model report had not been commissioned. It is anticipated that the contents of this memorandum will feed into the Model Report.

The Otago Regional Council (ORC) are in the process of developing a water management plan for the Manuherekia Catchment and have developed various consultation documents which are scheduled for release on 21 May 2021. In the absence of a Model Report this Ecological Memorandum along with two other memorandums[1] have been updated in order to provide background to ORC's consultation documents. It is noted that three memorandums were originally produced as internal documents to facilitate discussion and provide model output. They were not intended to be public documents and as such all three updated memorandums continue to be issued as drafts. The Model Report will be the official documentation of the model. This Ecological Memorandum updates and replaces the earlier draft dated 22 March 2021. It has been reviewed internally by Davis Ogilvie but has not been reviewed or formally adopted by either the Manuherekia Hydrology Group or the TAG. At the time of updating this Ecology Memorandum (21 May 2021) the Manuherekia Hydrology Model has not been documented, reviewed nor has it been formally adopted or approved by either the Manuherekia Hydrology Group or the TAG.

[1] A Calibration Memorandum (dated 21 May 2021) which briefly describes the model build process and model calibration / verification, and a Scenario Memorandum (dated 21 May 2021) which provides model output requested by ORC in relation to various water management scenarios that were developed by ORC.

2.0 MODEL BUILD

Development of the Manuherekia Hydrology Model was informed by the scoping document dated 6 July 2020 (previously supplied to TAG). Details of the model build and the calibration/verification process are briefly outlined in a draft memorandum entitled "*Manuherekia Hydrology Model – Calibration Memorandum – Final Draft*" dated 21 May 2021. Model output from various water management scenarios developed by ORC is briefly outlined in a draft memorandum entitled "*Manuherekia Hydrology Model – Scenario Memorandum – Final Draft*" dated 21 May 2021.

3.0 ECOLOGICAL PART OF THE MODEL

A draft version of the Manuherekia Hydrology Model was presented to TAG, during their meeting on 30 November and 1 December 2020. During the meeting TAG requested that ecological parameters be added to the model to allow estimation of habitat area for various species under different flows both at various locations on the main stem of the Manuherekia River and for various main stem river reaches. The Manuherekia Hydrology Model was subsequently updated as requested.

Spreadsheets containing habitat area information for 11 species[2] at three locations (Blackstone, Ophir and Galloway) under different flows was provided by Water Ways Consulting[3] and was included as various lookup tables into the Manuherekia Hydrology Model. As the ecological assessment is predominantly focused on low flows the habitat area spreadsheets contained habitat data for flows up to 6 m^3/s at Blackstone and Ophir and up to 7 m^3/s at Galloway[4]. As the hydrology model requires data for all potential flows it was assumed that the habitat area values for all flows above the maximum specified in the spreadsheets were the same as the maximum value.

The Manuherekia Hydrology Model estimates average daily flow for the period 1 June 1973 to 31 May 2020 at numerous locations down the main stem of the Manuherekia River. The modelled flow was used to estimate how habitat area changes over time for the different species at the various locations. The Blackstone habitat areas were applied to the main stem of the Manuherekia River from Falls Dam to above the Lauder Creek confluence, the Ophir habitat areas were applied from below the Lauder Creek confluence to Ophir and the Galloway habitat areas were applied from below the Chatto Creek confluence to Campground. Habitat values for each river reach below Falls Dam were estimated by averaging the values at the top and bottom of the reach and multiplying by the length of the reach. An overall main stem habitat value for each species was determined by adding the various main stem river reaches together. The overall main stem habitat values were estimated in order to account for the longitudinal flow changes associated with the various flow scenarios. In summing the main stem river

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[2] The 11 species were Diatoms, Aoteapsyche (net-spinning), Deleatidium (mayfly), Maoridiamesa (Diptera), Brown Trout < 100 mm, Brown Trout H&J, Longfin Eel < 300 mm, Longfin Eel > 300 mm, Adult Rainbow Trout (Wilding), Juvenile Rainbow Trout (Wilding) and Brown Trout Spawning (Shirvell and Dungey 1983).
[3] Richard Allibone Director and Principal Ecologist at Water Ways Consulting provided the spreadsheets.
[4] Habitat data for Adult Rainbow Trout (Wilding), Juvenile Rainbow Trout (Wilding) and Brown Trout Spawning (Shirvell and Dungey 1983) was provided for flows up to 6 m^3/s at Galloway. Habitat data for remaining species was provided for flows up to 7 m^3/s.

reaches, gorge sections (namely Falls Dam to Loop Road and Ophir to the Chatto Creek confluence) were excluded as habitat was assumed to not change with flow in gorge sections. Similarly there was uncertainty regarding the wide braided river reach between Loop Road and the Blackstone Intake, and whether the Blackstone habitat areas were applicable, as they were derived from measurements below the Blackstone Intake where the river, while braided, is more confined than the reach below Loop Road. An option was included in the Manuherekia Hydrology Model to both include and exclude the reach from Loop Road to the Blackstone Intake in the overall main stem habitat values.

4.0 MODEL SCENARIOS

The ORC initially requested that nine scenarios (Estimated Existing or Status Quo scenario (namely the model calibration run), seven future scenarios and a Full Dams and No Irrigation scenario) be run through the Manuherekia Hydrology Model. Following a Manuherekia Reference Group (MRG) meeting on the 4 and 5 March 2021 ORC requested that the following additional future scenarios be run:

1. Various scenarios to assess the implications of the current Falls Dam management practices of:
   - (a). Imposing voluntary irrigation restrictions on irrigators in the Manuherekia Valley in order to retain storage in Falls Dam.
   - (b). Using storage in Falls Dam to augment minimum flows at Campground.

In preparation for an ORC Manuherekia Flow Regime and Allocation meeting held on 25 March 2021 ORC request that the following additional scenarios be run:

1. Various scenarios to assess the implications of the following components of a potential Manuherekia Flow and Allocation regime:
   - (a). Minimum flow.
   - (b). Residual flow.
   - (c). Flow sharing.
   - (d). Allocation.
   - (e). Irrigation restrictions to maintain storage in Falls Dam

The requested additional future scenarios have resulted in a total of 30 scenarios being assessed. Scenario details are briefly provided below.

For all scenarios:

- The area irrigated remains the same (other than for the *"Full Dams and No Irrigation"* scenario where there is no irrigation anywhere in the catchment although Mt Ida Race remains operational). For the four scenarios which assess allocation, the unit irrigation demand for the Manuherekia Valley was reduced which has the same effect as reducing the irrigated area.
- There is no flow sharing other than for the one flow sharing scenario for Lauder Creek.
- Supply priority is given to minimum flows and residual flows over irrigation.
- Storage in Falls Dam is used to supplement downstream main stem minimum flows. Does not apply to the *"Status Quo"*, *"Full Dams and No Irrigation"* and the eight of the thirteen future scenarios designed to assess the effect of Falls Dam augmentation.
- Management imposed irrigation restrictions based on storage in Falls Dam are applied to all irrigation within the Manuherekia Valley (other than Crawford Hills and that part of the Galloway Scheme supplied from the Manor Burn). Does not apply to the *"Full Dams and No Irrigation"*, the thirteen future scenarios designed to assess the effect of the management imposed irrigation restrictions and six of the eight future scenarios designed to assess components of the flow and allocation regime.
- The Ida Burn, Pool Burn and Manor Burn sub-catchments remain the same for all the scenarios and theses sub-catchments have no minimum flows or residuals. Does not apply to *"Full Dams and No Irrigation"* scenario for which there is no irrigation anywhere in the catchment.
- For eighteen of the scenarios (i.e. all scenarios other than *"Status Quo",* "900", and *"Full Dams and No Irrigation"* scenarios plus four of the future scenarios designed to assess the effect of Falls Dam management imposed irrigation restrictions and augmentation and five of the eight future scenarios designed to assess components of the flow and allocation regime), ORC requested flow proportional minimum flows for the Dunstan, Lauder, Thomsons and Chatto Creek tributaries. These were estimated using the relative contribution of the four tributaries to flow at Campground as derived from modelled 5th percentile flows under the *"Full Dams and No Irrigation"* scenario and assuming all other tributaries do no contribute to flow at Campground.

Details of the scenario runs and the hydrological output (including longitudinal flow plots down the main stem of the Manuherekia River and various flow statistics) from the scenario runs are outlined in a draft memorandum entitled "*Manuherekia Hydrology Model – Scenario Memorandum – Final Draft*" dated 21 May 2021.

Table 1: Manuherekia Hydrology Model Scenarios – Requested by ORC

Scenario		Total irrigated area (ha)	Falls Dam outlet restrictions	Falls Dam irrigation restrictions	Falls Dam storage used to supplement minimum flows at Campground	Below Falls Minimum flow (L/s)	Ophir Minimum flow (L/s)	Campground Minimum flow (L/s)	Main stem residuals below takes (L/s)	Dunstan Confluence Minimum Flow (L/s)	Dunstan Residual below take (L/s)	Lauder Confluence Minimum flow (L/s)	Lauder Residual below take (L/s)	Thomsons Confluence Minimum flow (L/s)	Thomsons Residual below take (L/s)	Chatto Confluence Minimum flow (L/s)	Chatto Residual below take (L/s)	Flow Sharing (%)	Comment
Full Dams and No Irrigation		0	N/A	None	N/A	0	0	0	0	0	0	0	0	0	0	0	0		This scenario was designed to assist with the ecological interpretations, it is designed to estimate no take and no storage conditions. It is not designed to represents "natural" hydrological conditions. Caution is required when interpreting the model output for this scenario as the model was not developed to assess such a major change from current conditions.
Existing calibration (Status Quo)								400		0		0		0		0			Low minimum applied at Campground to ensure we model measured flows
900								900											Scenario designed to represent current water management objectives.
1200								1200		410		130		70		70			
1500		27,210	Current	Yes - apply to whole Manuherekia Valley		500	820	1500	100	510	30	160	10	80	10	90	10		Future scenarios developed by ORC.
1700								1700		580		180		90		100			
2000								2000		680		210		110		120			
2500					Yes			2500		850		260		140		150			
3000								3000		1020		320		170		180			
No Falls Irrigation Restrictions	Status Quo							400		0		0		0		0			Designed to assess implications of the Management imposed restrictions. Outlet restrictions removed to allow clearer comparison.
	900							900											
	1200							1200		410		130		70		70			
	1500							1500		510		160		80		90			
	3000					500		3000		1020		320		170		180		0	
No Falls Irrigation Restrictions and no Augmentation.	Status Quo							400		0		0		0		0			Designed to assess implications of the use of storage in Falls dam to augment minimum flows at Campground. Outlet restrictions removed to allow clearer comparison.
	900							900											
	1200							1200		410		130		70		70			
	1500							1500		510		160		80		90			
	3000							3000		1020		320		170		180			
No Falls Irrigation Restrictions no Augmentation higher residual below Falls	1200				No	620		1200		410		130		70		70			Designed to assess implications of the use of storage in Falls dam to augment minimum flows at Campground but with higher residual flows below Falls Dam. The higher residual flows below Falls Dam have been estimated using the relative contribution of the Falls Dam Catchment to flow at Campground as derived from modelled 5th percentile flows under the "Full Dams and No Irrigation" scenario and assuming only Falls Dam and the four main tributaries contribute to flow at Campground, plus 100 L/s to be consistent with current 500 L/s residual). Outlet restrictions removed to allow clearer comparison.
	1500		None	None		760		1500		510		160		80		90			
	3000					1410		3000		1020		320		170		180			
Flow regime components Lauder Creek 1500 base	Nothing											0	0						Designed to show the effects, that each of the various components, that make up a potential flow and allocation regime, have on flow. The Lauder Catchment is used to highlight the effects.
	Min Flow											160							
	Residual (50)												50						
	Flow sharing				Yes	500		1500		510		0		80		90		50	
	Allocation 80	20% less											0						
	Allocation 50	50% less																0	
Allocation Manuherekia Valley 1500 base	Allocation 80	20% less		Yes								160	10						Designed to show the effects that differing levels of allocation across the Manuherekia Valley have on flows at Campground.
	Allocation 50	50% less																	

Notes:

The 6 yellow shaded scenarios (existing and 5 future ones) are the scenarios that ORC initially requested feed into the production modelling and economic assessment. ORC subsequently requested that the orange shaded scenario (1200) be included in the economic assessment.

5.0 MODEL ECOLOGICAL OUTPUT

Ecological output plots from the Manuherekia Hydrology Model for each of the 11 species are shown in sections 5.1 to 5.11 below. The following four plots are shown for each species and flow situation:

1. Habitat area at a cross section immediately below the Blackstone intake. Represents how habitat area changes with flow in the upper reaches of the river where summer low flows are significantly enhanced above natural due to irrigation releases.
2. Habitat area at a cross section at Ophir. Represents how habitat area changes with flow in the middle reaches of the river where summer low flows are enhanced by irrigation releases to a level similar to natural.
3. Habitat area at a cross section at Campground. Represents how habitat area changes with flow in the lower reaches of the river where summer low flows are lower than natural due to upstream irrigation takes.
4. Overall Habitat Area for the main stem of the Manuherekia River from Falls Dam to Campground excluding the gorge sections and the Loop Road to Blackstone Intake reach. Represents a summary for the whole river. Excluding the Loop Road to Blackstone Intake reach which has significantly enhanced low flows due to irrigation releases both lowers the overall habitat area and increases the influence of the lower river reaches.

While the analysis was undertaken for the full model period 1 June 1973 to 31 May 2020 the above four plots are provided for the following three time periods:

1. 1 June 2014 to 31 May 2015 - a very dry irrigation season with significant management imposed irrigation restrictions due to storage in Falls Dam dropping to a low level.
2. 1 June 2011 to 31 May 2012 – a relatively wet year with lower than average irrigation demand and no management imposed irrigation restrictions due to storage in Falls Dam remaining high.
3. 1 June 1991 to 31 May 1992 - an average year with a dry autumn, with lower than average irrigation demand, limited management imposed irrigation restrictions which only started late in the season (i.e. mid March) when storage in Falls Dam dropped to a relatively low level.

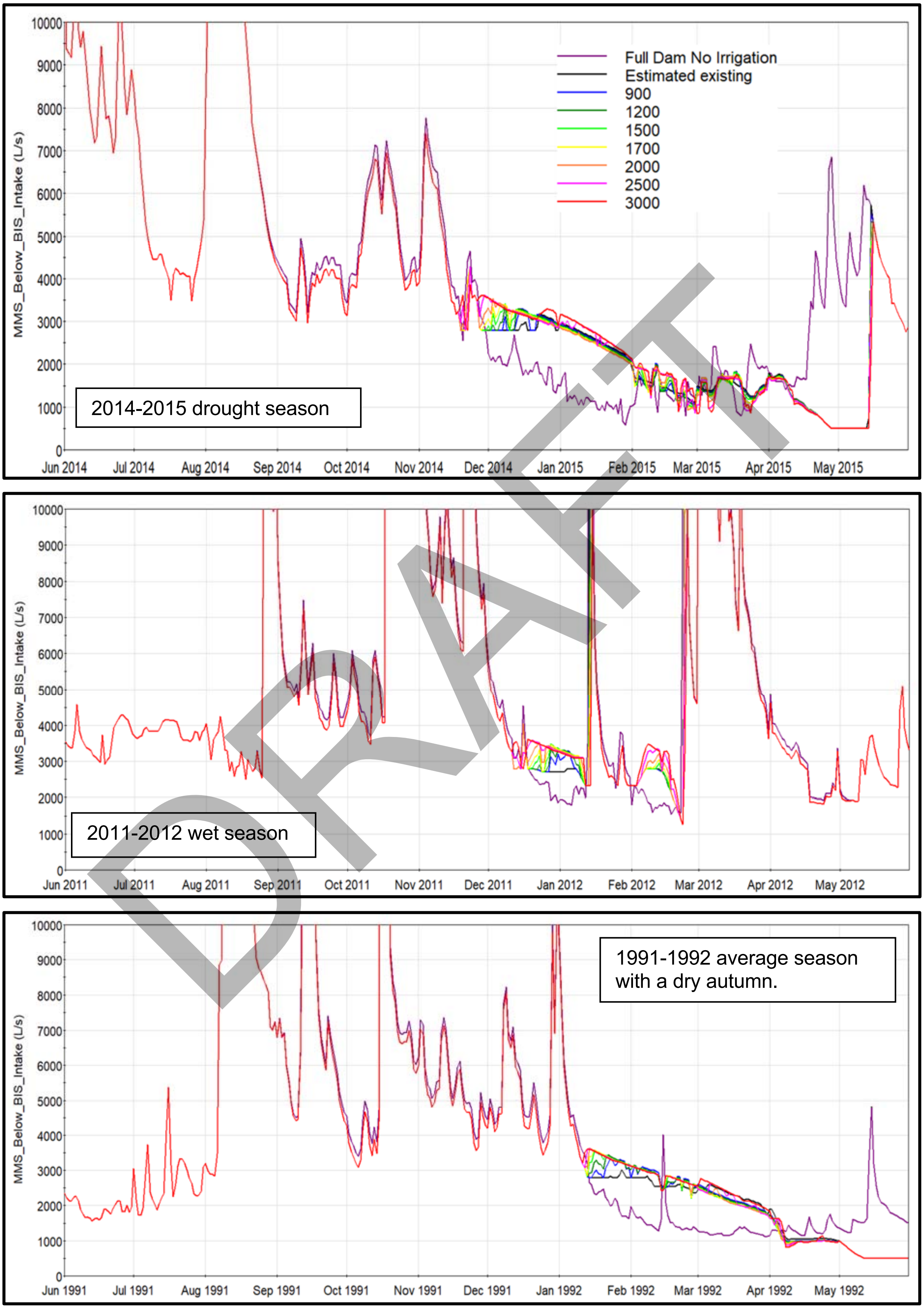
The plots include output for the nine scenarios initially requested by ORC namely the Estimated Existing or Status Quo scenario (i.e. the model calibration run), seven future scenarios and the Full Dams and No Irrigation scenario.

As the *"Status Quo"* and all 7 of the future scenarios include: supply priority for minimum and residual flows, management imposed irrigation restrictions, Falls Dam outlet restrictions and the use of storage in Falls Dam to supplement downstream minimum flows; Falls Dam essentially never drains, as irrigation supply is simply cut back as storage gets low and there is a shift from releasing water for irrigation to releasing water to sustain the minimum flow.

To assist with interpretation of the habitat plots, various hydrological plots for the three sites over the same periods are provided below. Plots of flow at Campground, Storage in Falls Dam and water supply reliability for the Omakau Irrigation Scheme Main race intake over the same time periods are also included below.

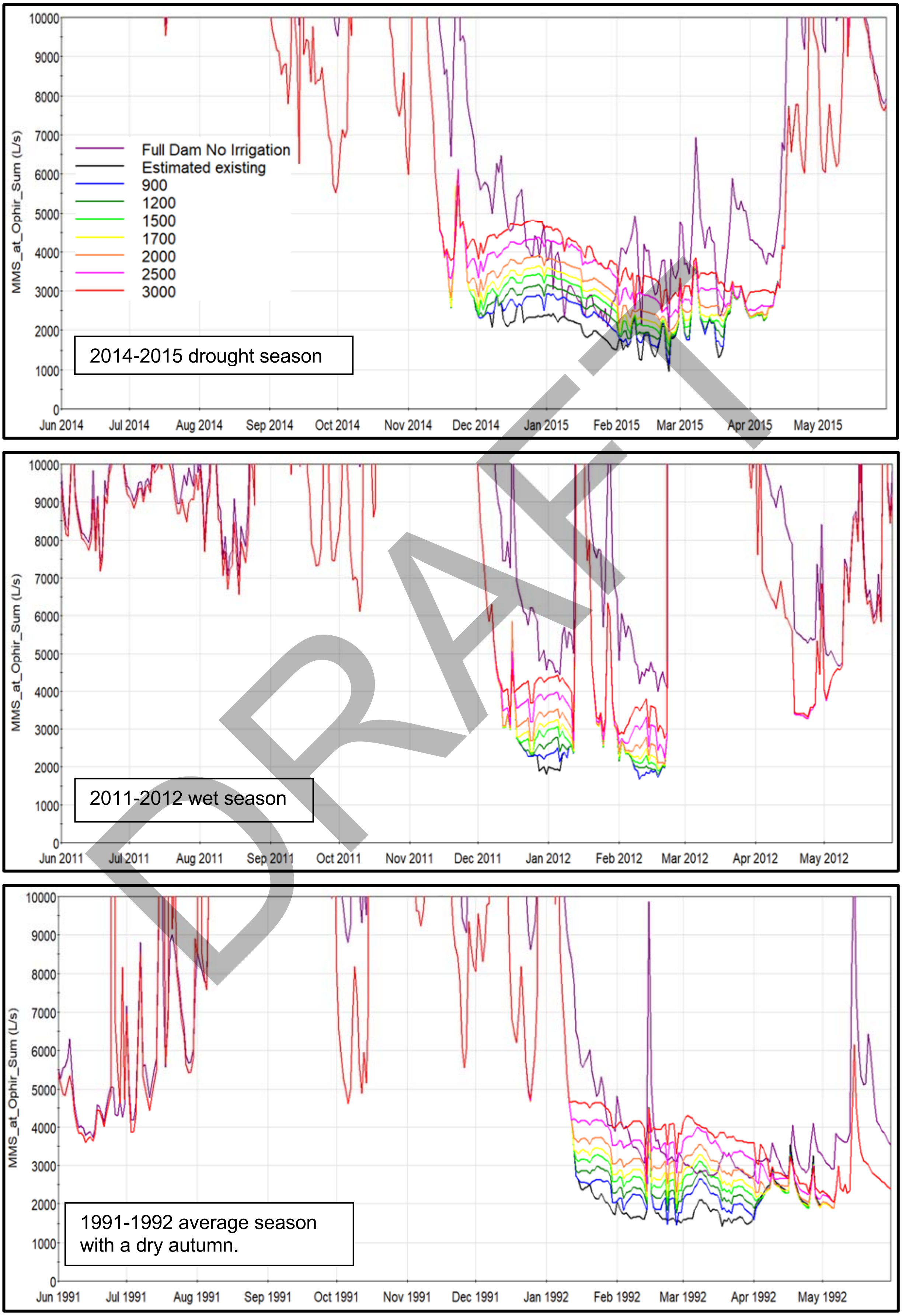
In addition to this Ecological Memorandum and the plots below the ecological output data from the Manuherekia Hydrology Model was provided to Water Ways Consulting.

Flow Below Blackstone Intake



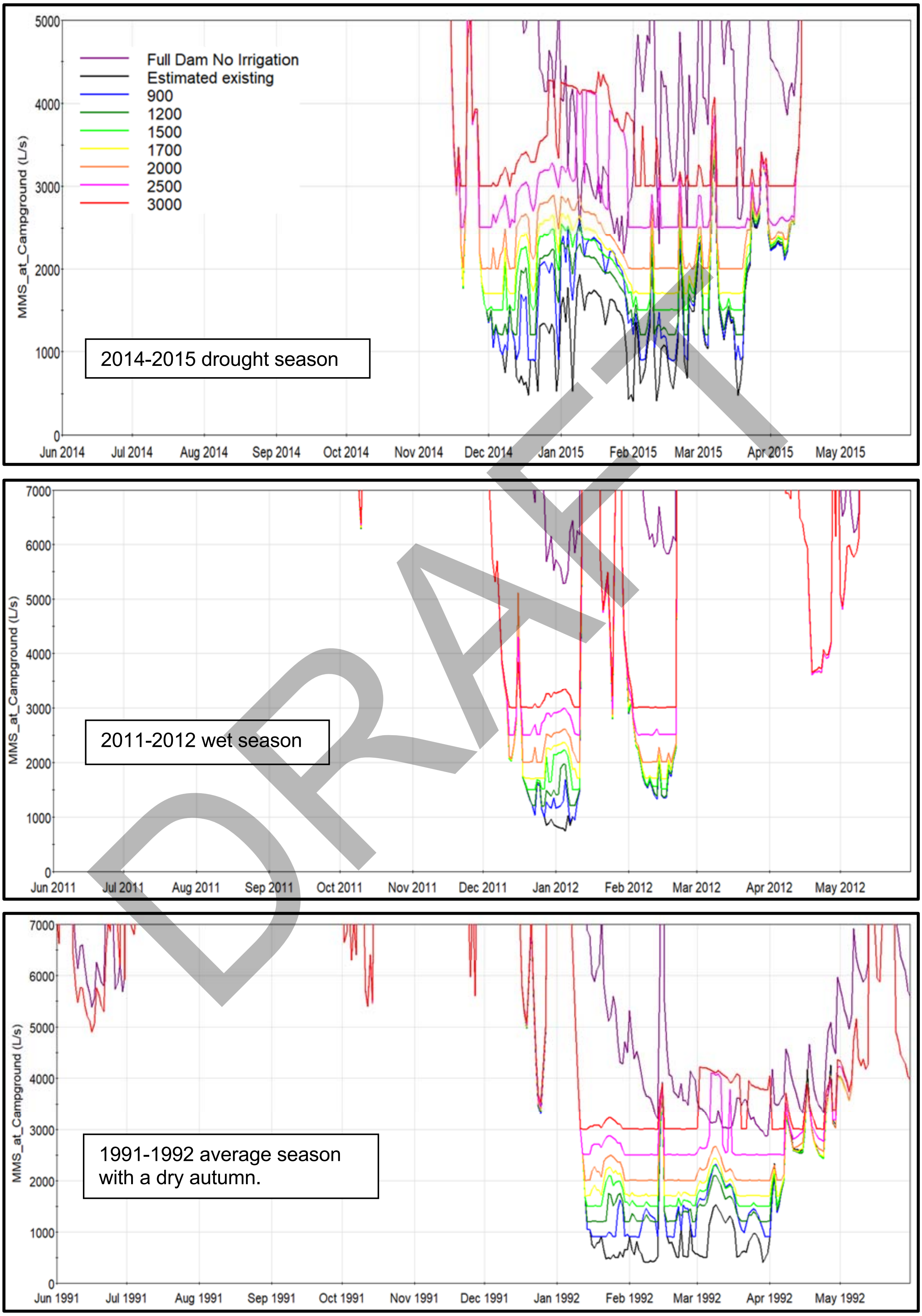
The stable low flows in April and May in both 1992 (bottom plot) and 2015 (top plot) are due to refilling of Falls Dam after the end of the irrigation season. In practice refilling occurs gradually over winter.

Flow at Ophir



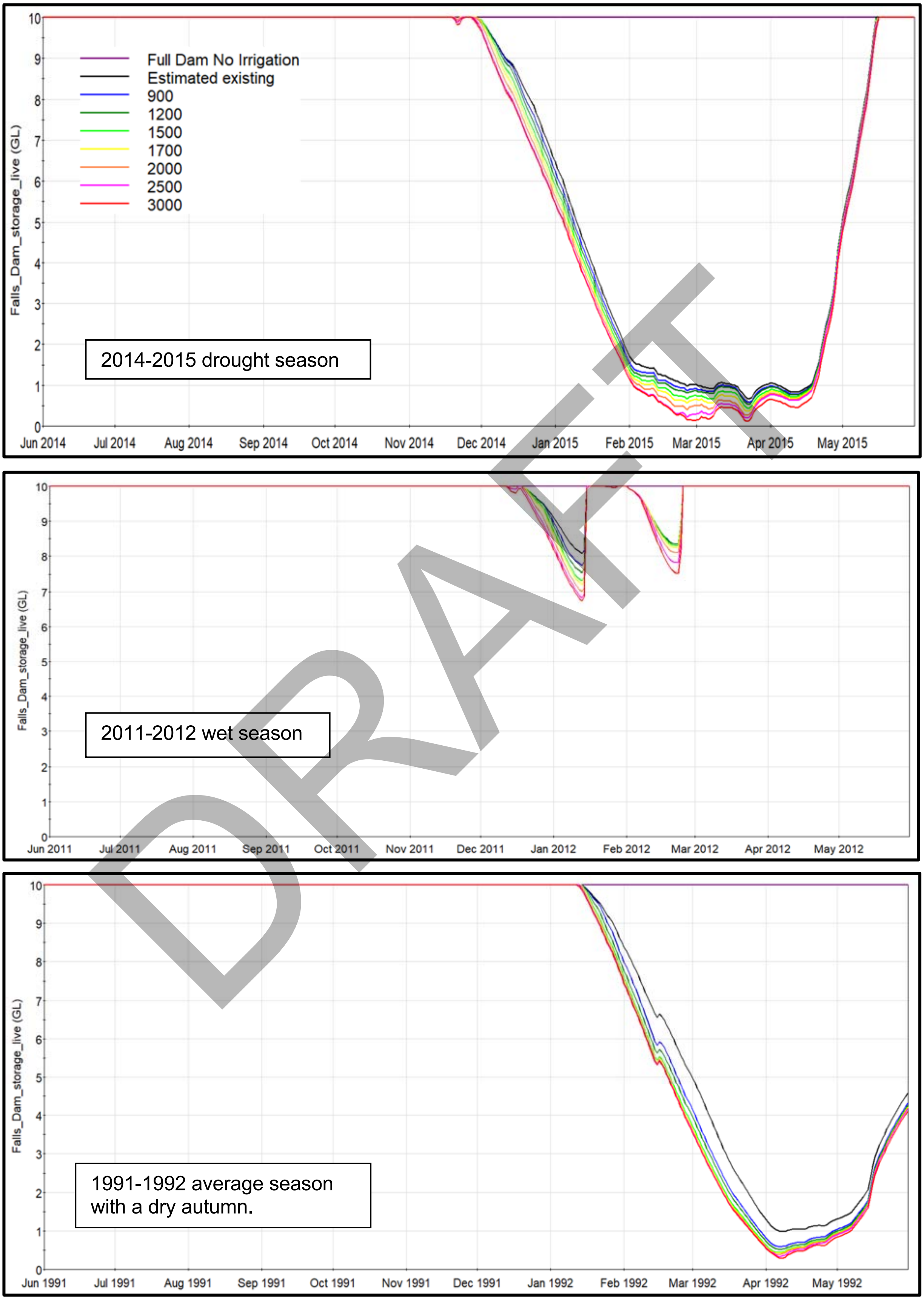
Under all scenarios flow at Ophir does not drop below the current minimum flow of 820 L/s.

Flow at Campground



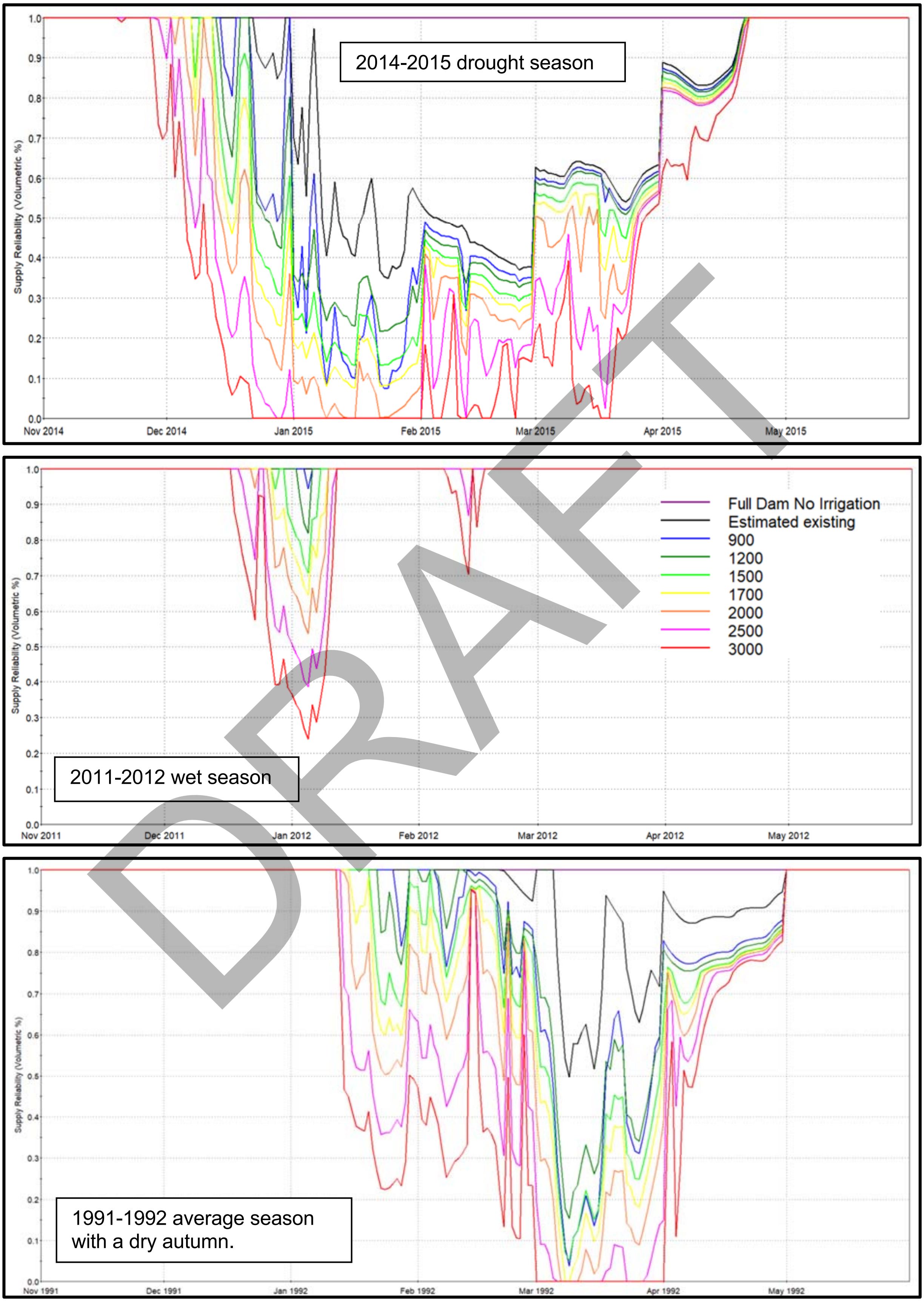
Under all scenarios flow at Campground does not drop below stated minimum i.e. can always maintain minimum due to the storage in Falls Dam and the management imposed irrigation restrictions.

Falls Dam Live Storage



Live Storage in Falls Dam does not change markedly between scenarios. In many years storage drops to a low level but never completely empties.

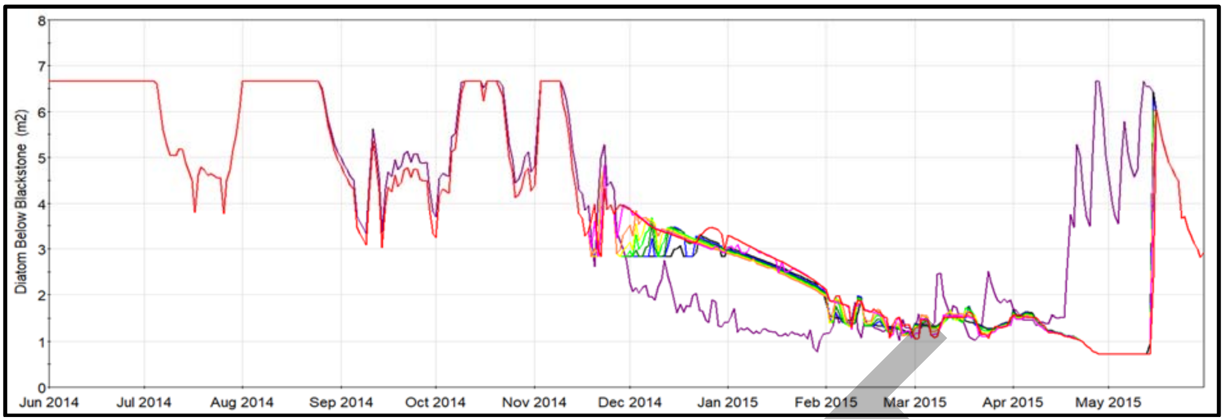
Daily Volumetric Supply Reliability for Omakau Irrigation Scheme's Main Race intake



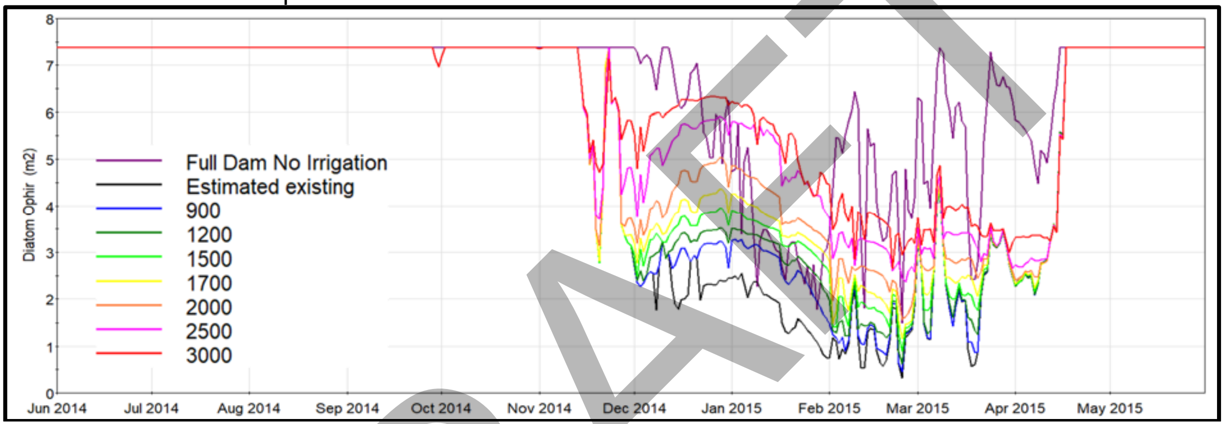
Significant change in supply reliability for main stem takes between scenarios. Restrictions start earlier and are harder as minimum flows increase.

5.1 Diatoms 2014-2015 drought season

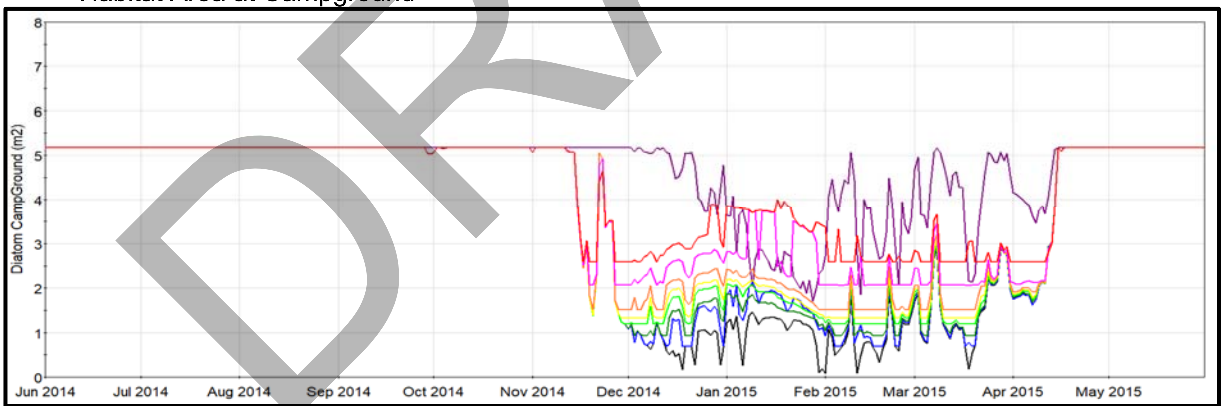
Habitat Area below Blackstone Intake:



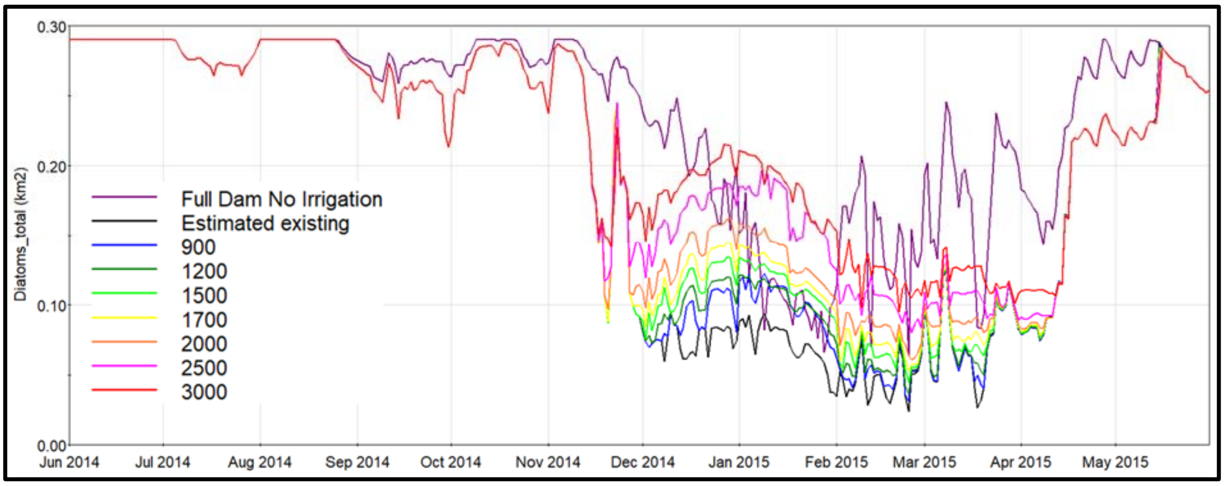
Habitat Area at Ophir



Habitat Area at Campground

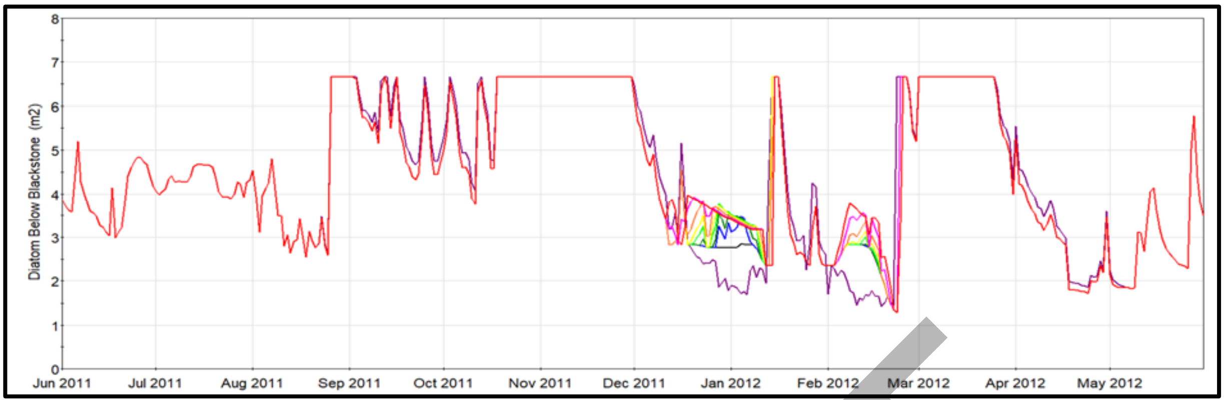


Overall Habitat Area for the Main Stem of the Manuherekia River.

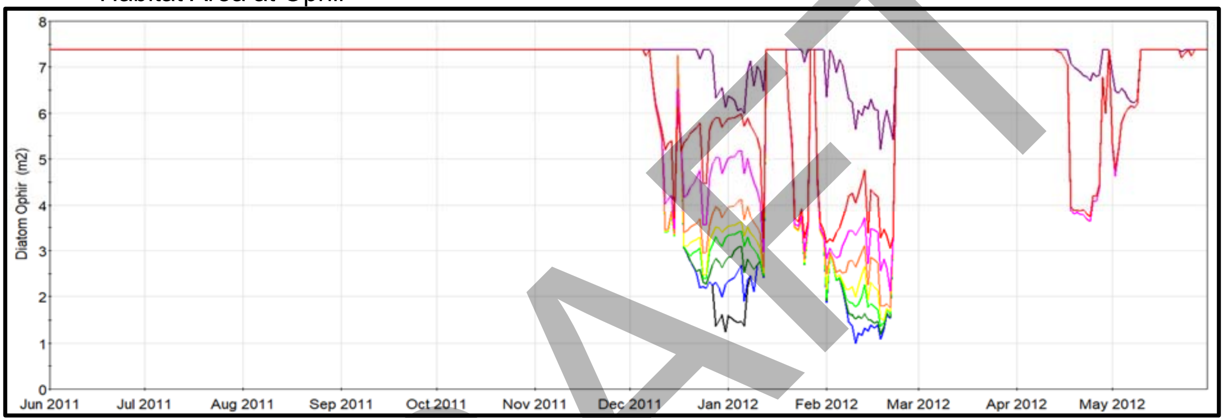


Diatoms 2011-2012 wet season

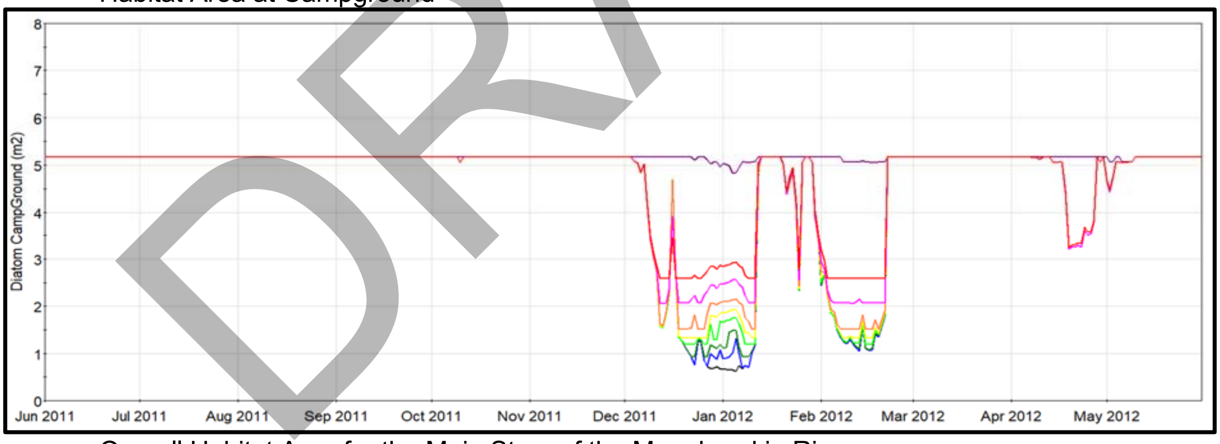
Habitat Area below Blackstone Intake:



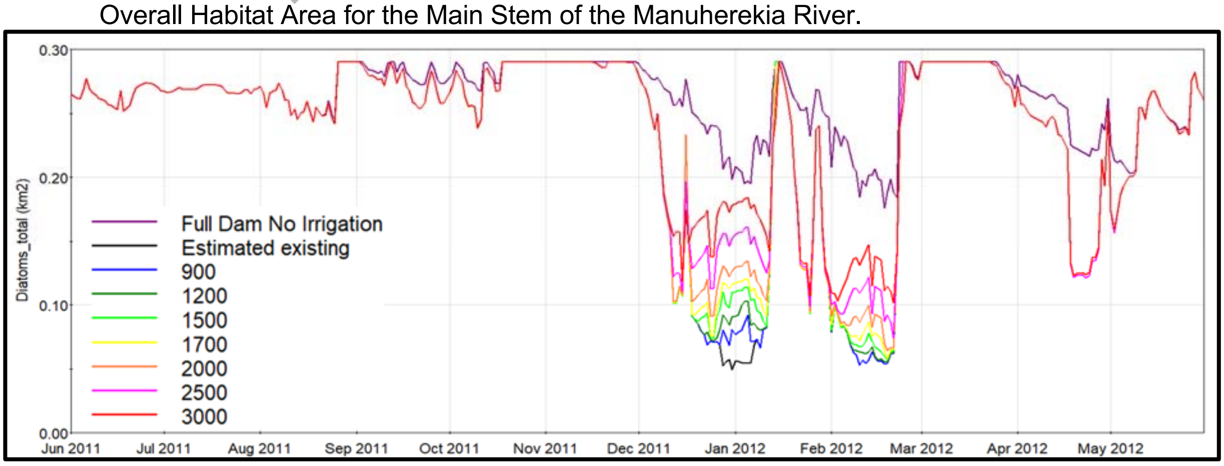
Habitat Area at Ophir



Habitat Area at Campground

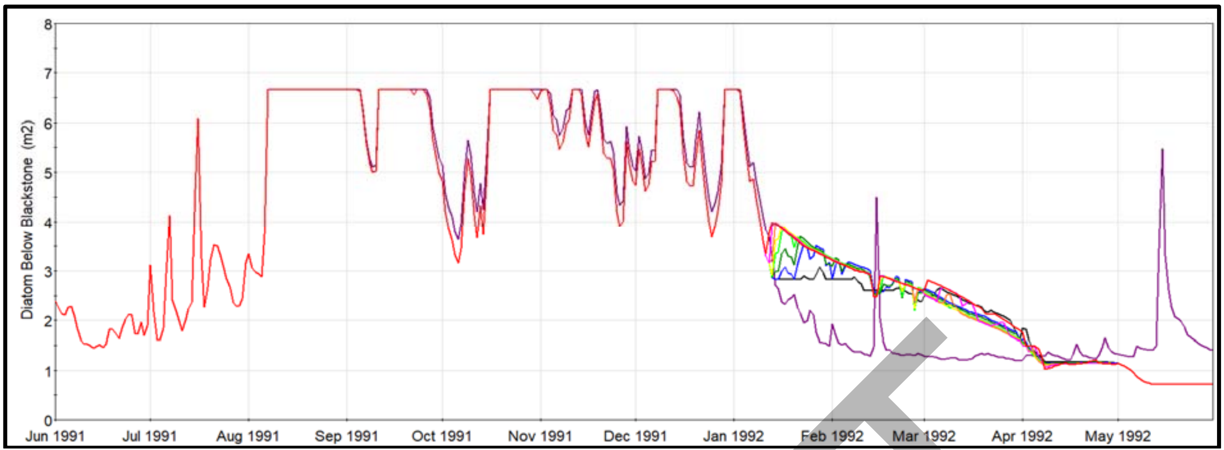


Overall Habitat Area for the Main Stem of the Manuherekia River.

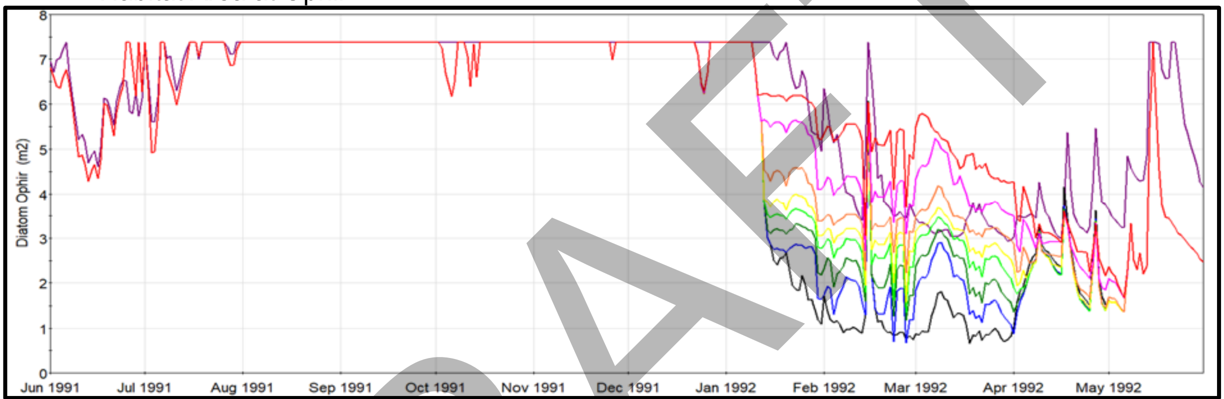


Diatoms 1991-1992 average season with a dry autumn

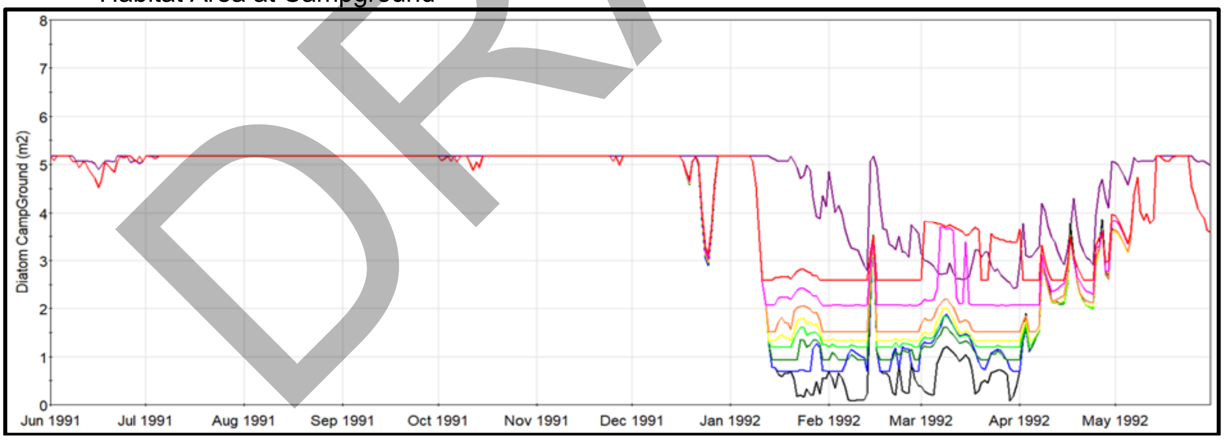
Habitat Area below Blackstone Intake:



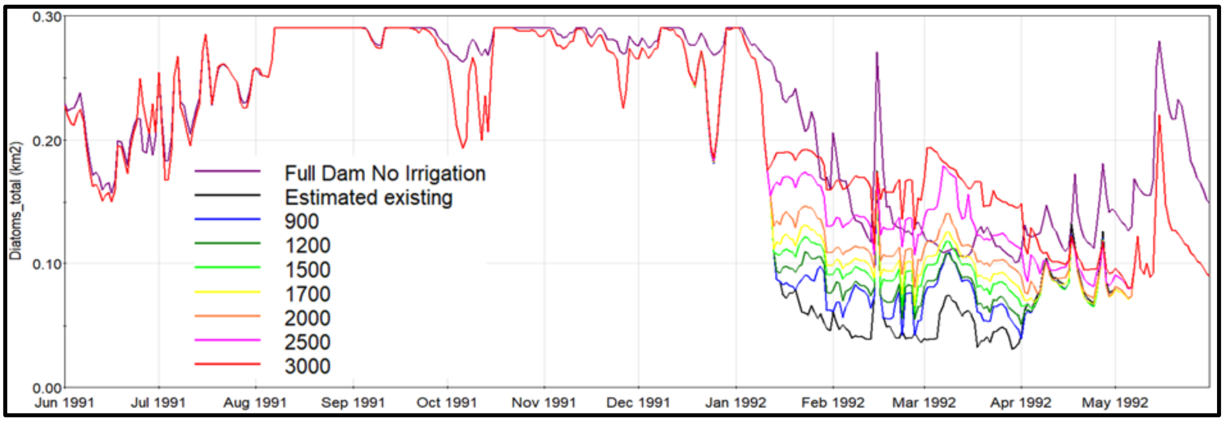
Habitat Area at Ophir



Habitat Area at Campground

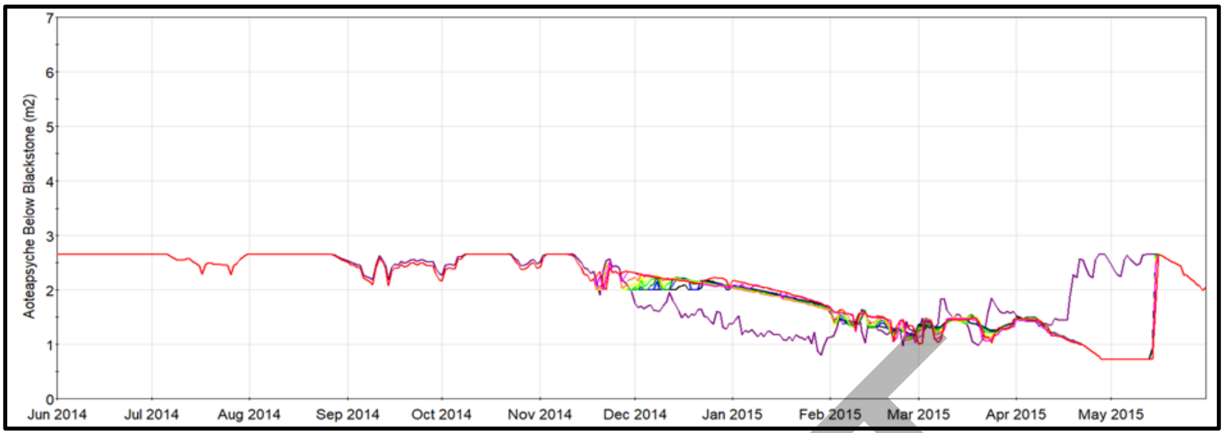


Overall Habitat Area for the Main Stem of the Manuherekia River.

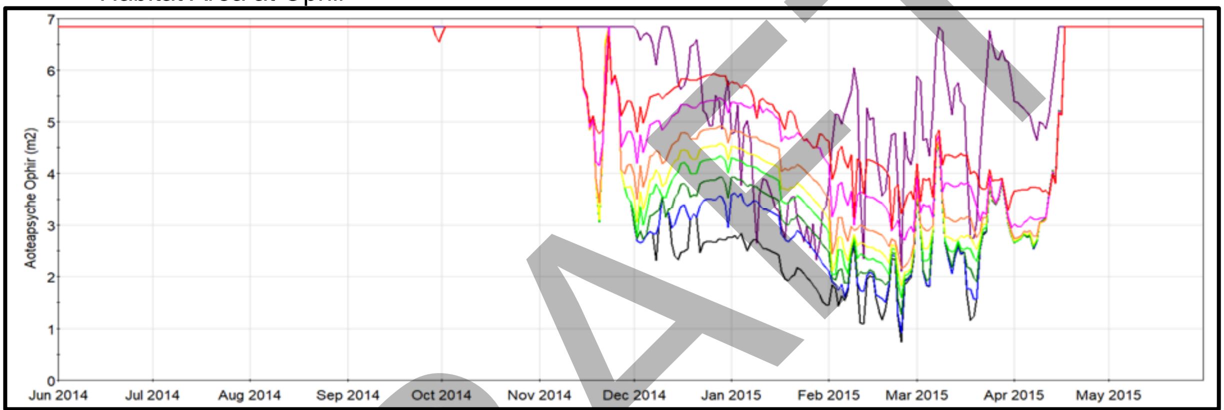


5.2 Aoteapsyche (net-spinning) 2014-2015 drought season

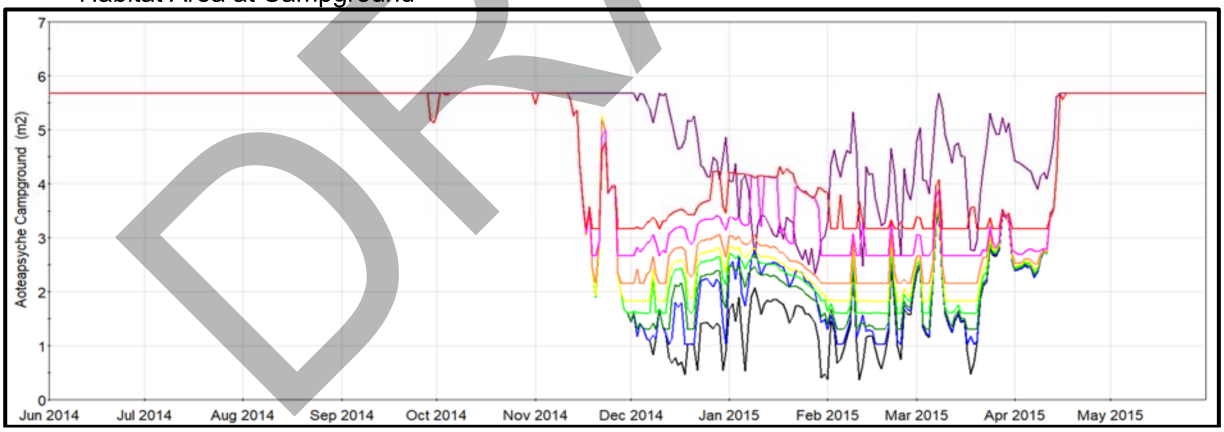
Habitat Area below Blackstone Intake:



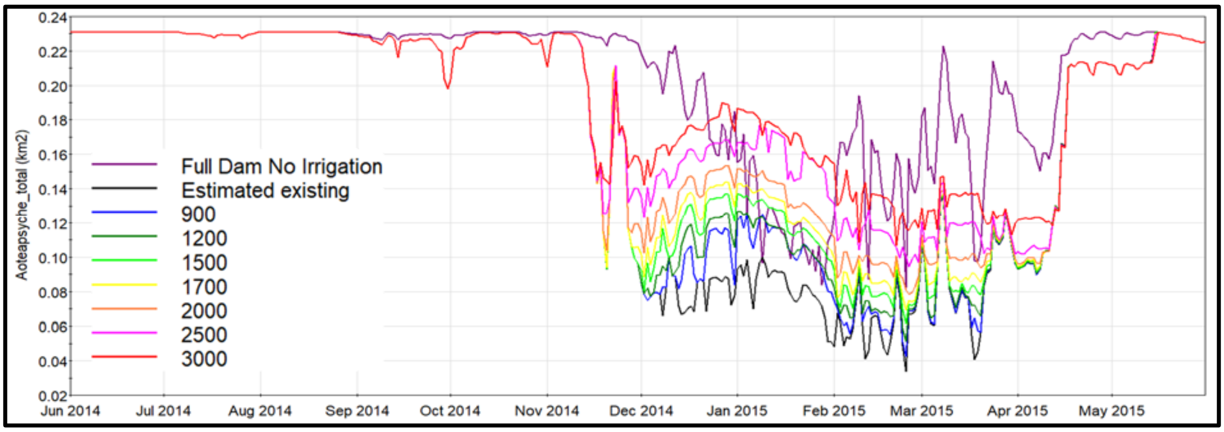
Habitat Area at Ophir



Habitat Area at Campground

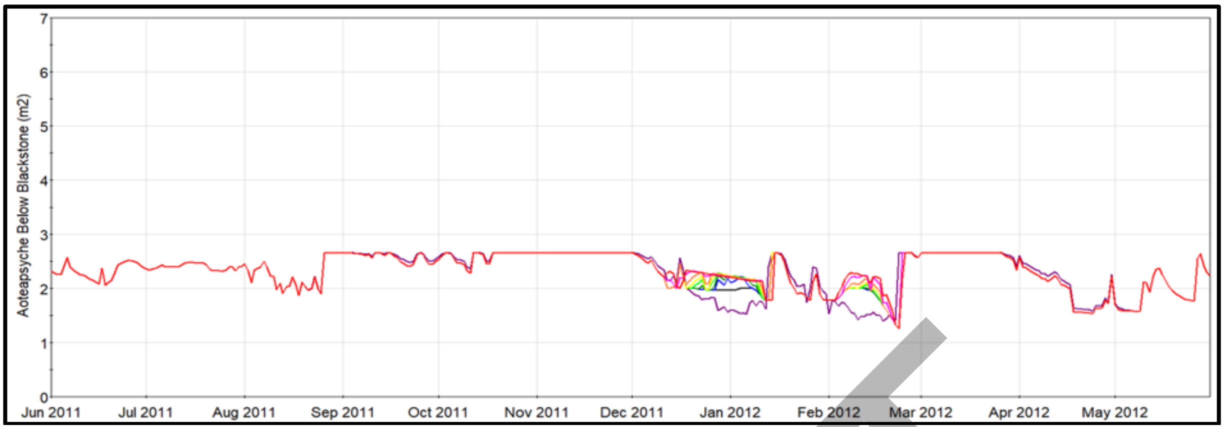


Overall Habitat Area for the Main Stem of the Manuherekia River.

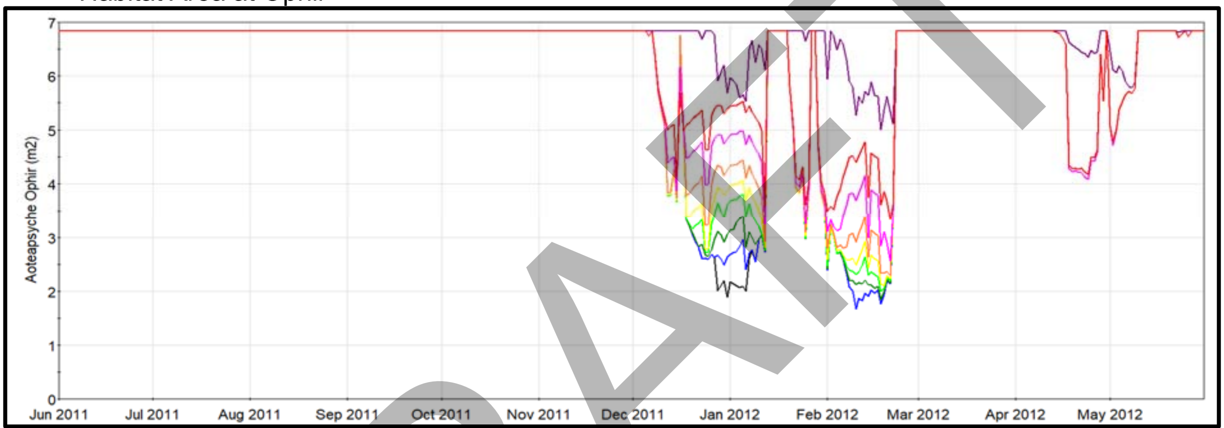


Aoteapsyche (net-spinning) 2011-2012 wet season

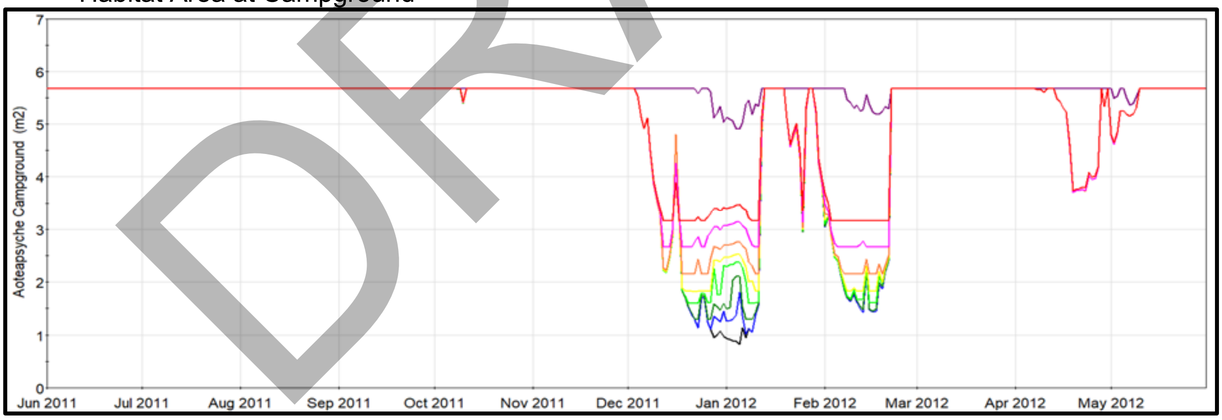
Habitat Area below Blackstone Intake:



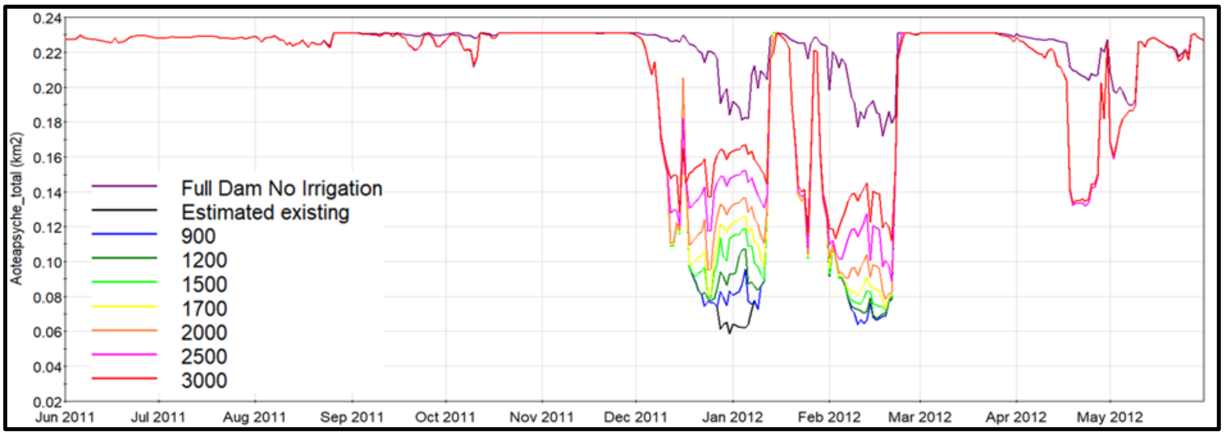
Habitat Area at Ophir



Habitat Area at Campground

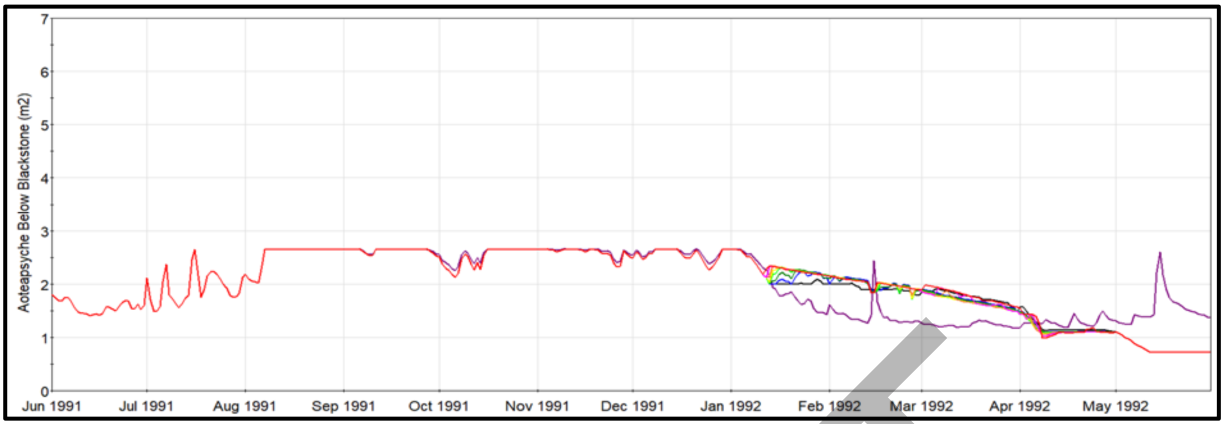


Overall Habitat Area for the Main Stem of the Manuherekia River.

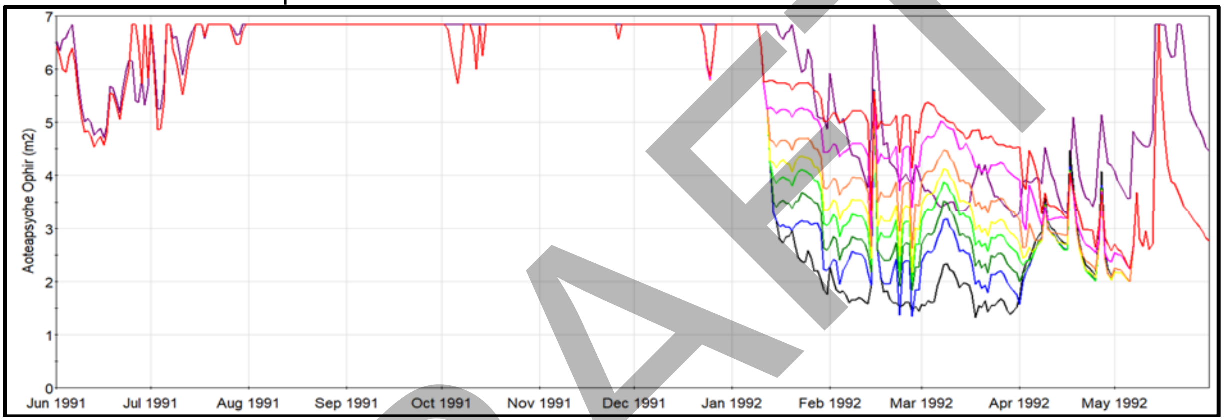


Aoteapsyche (net-spinning) 1991-1992 average season with a dry autumn

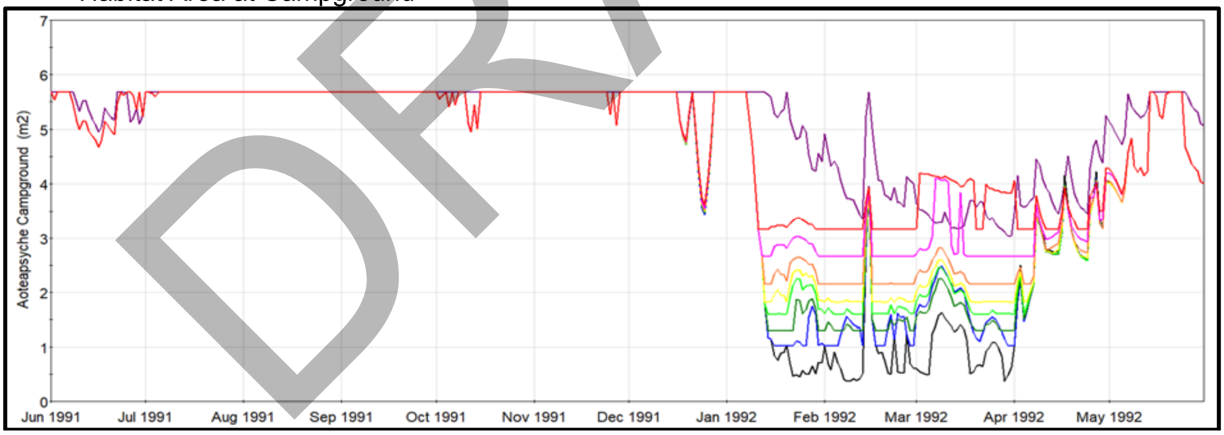
Habitat Area below Blackstone Intake:



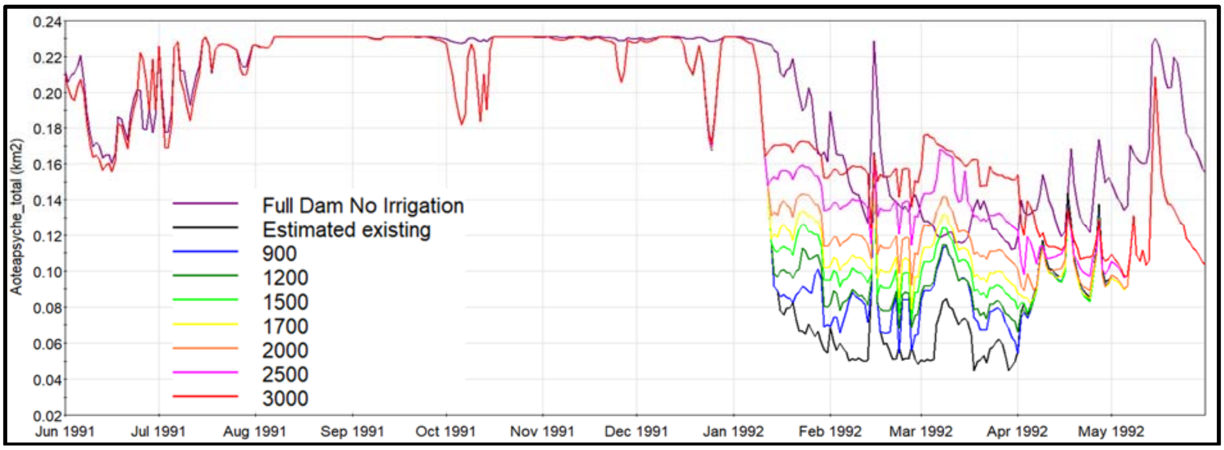
Habitat Area at Ophir



Habitat Area at Campground

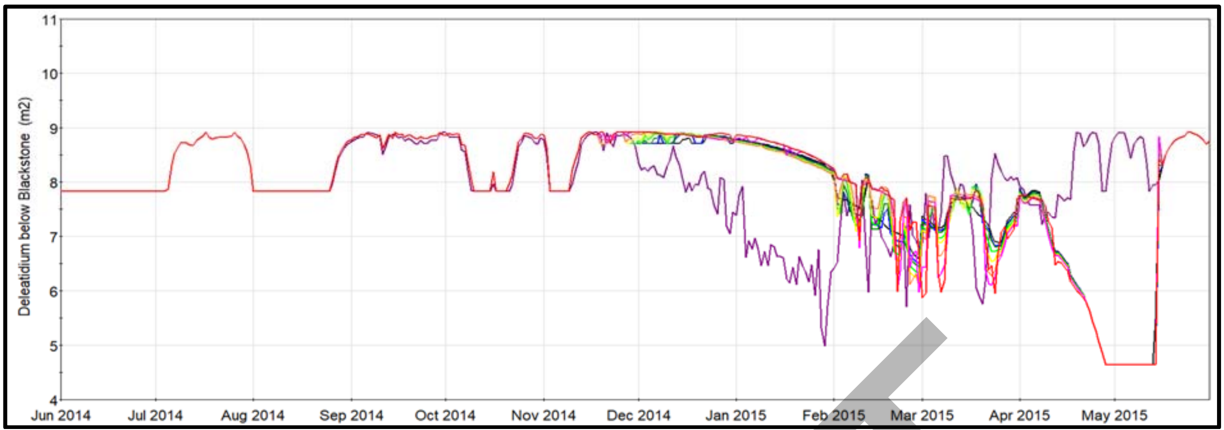


Overall Habitat Area for the Main Stem of the Manuherekia River.

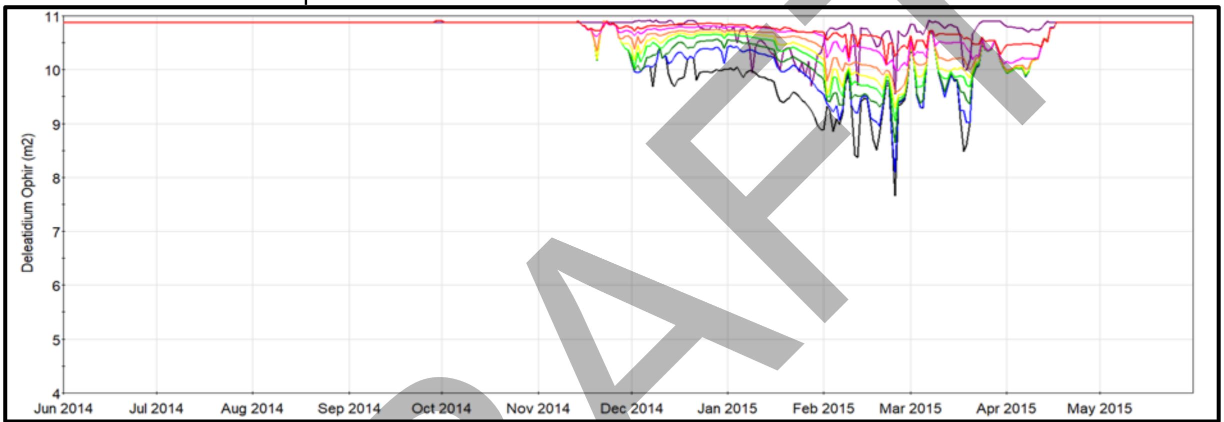


5.3 Deleatidium (mayfly) 2014-2015 drought season

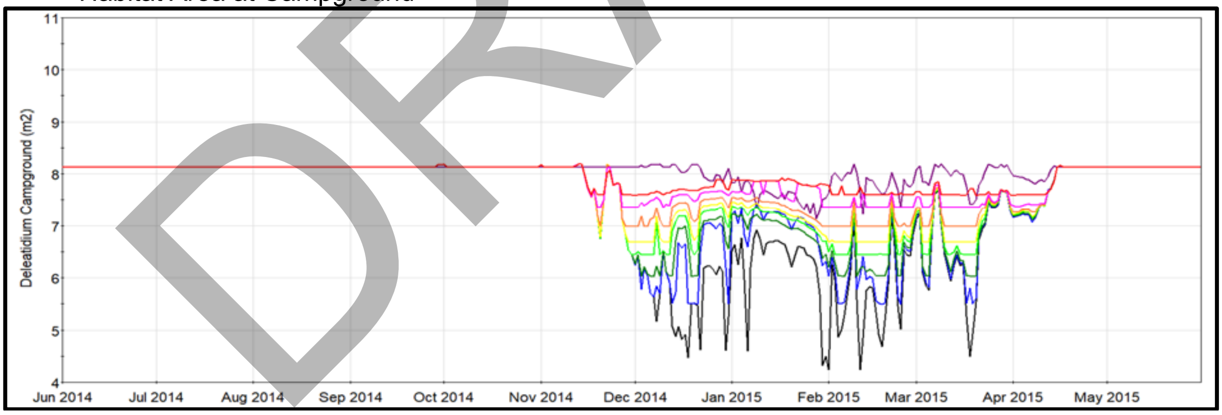
Habitat Area below Blackstone Intake:



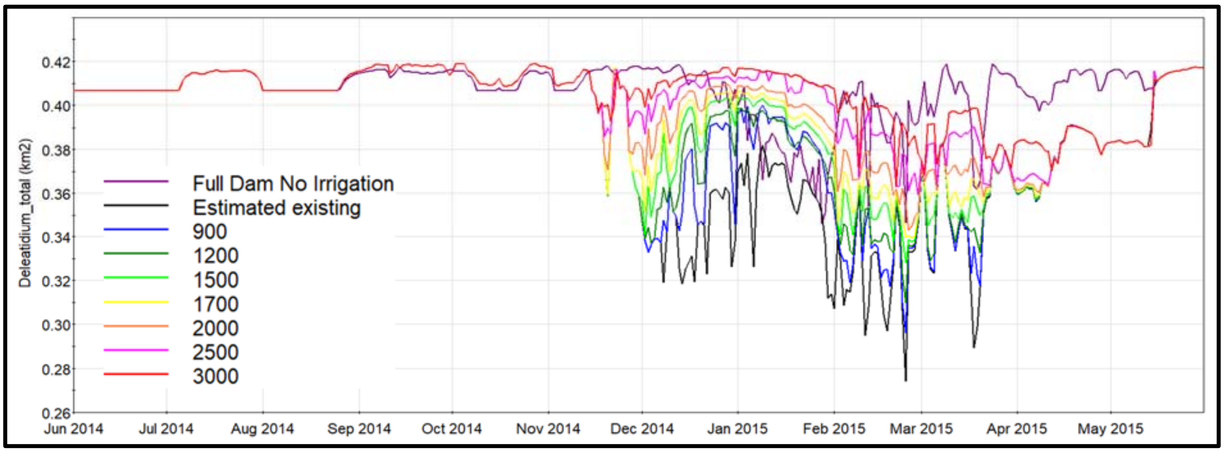
Habitat Area at Ophir



Habitat Area at Campground

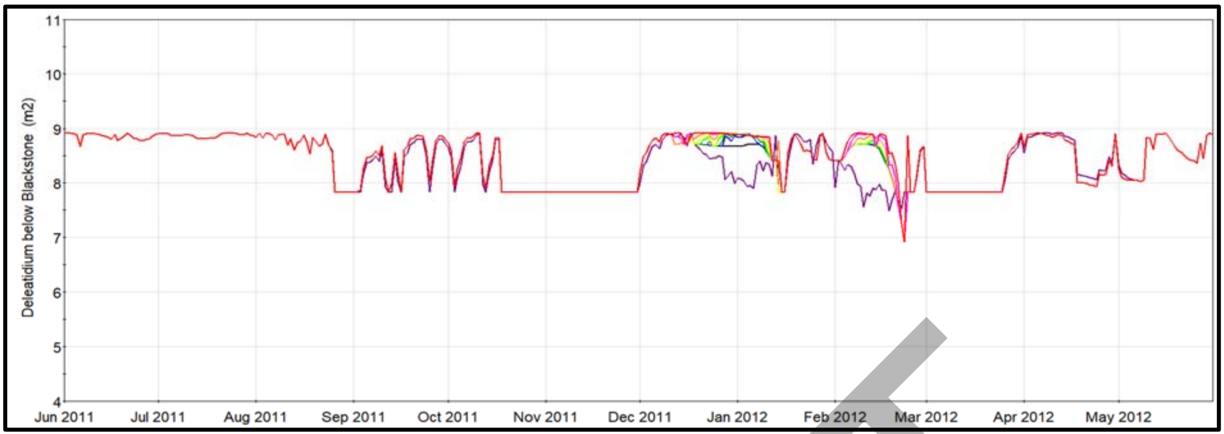


Overall Habitat Area for the Main Stem of the Manuherekia River.

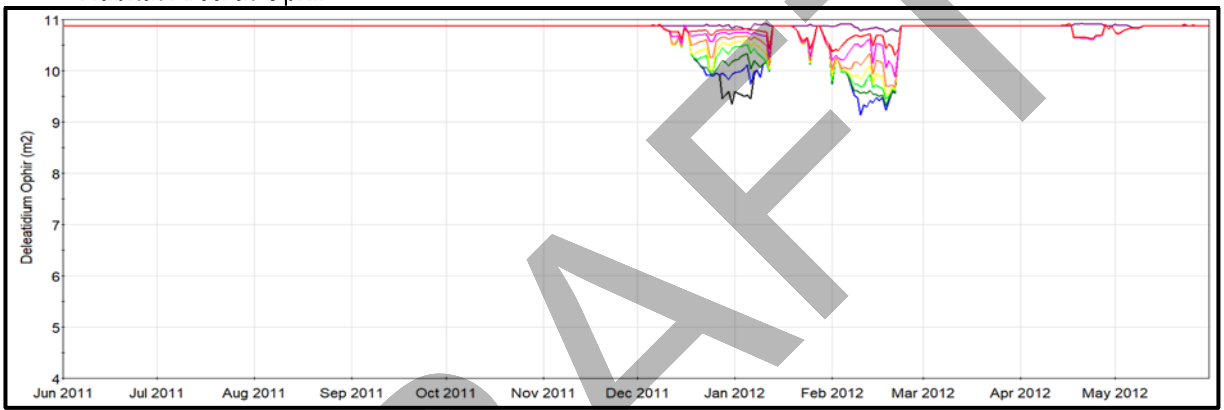


Deleatidium (mayfly) 2011-2012 wet season

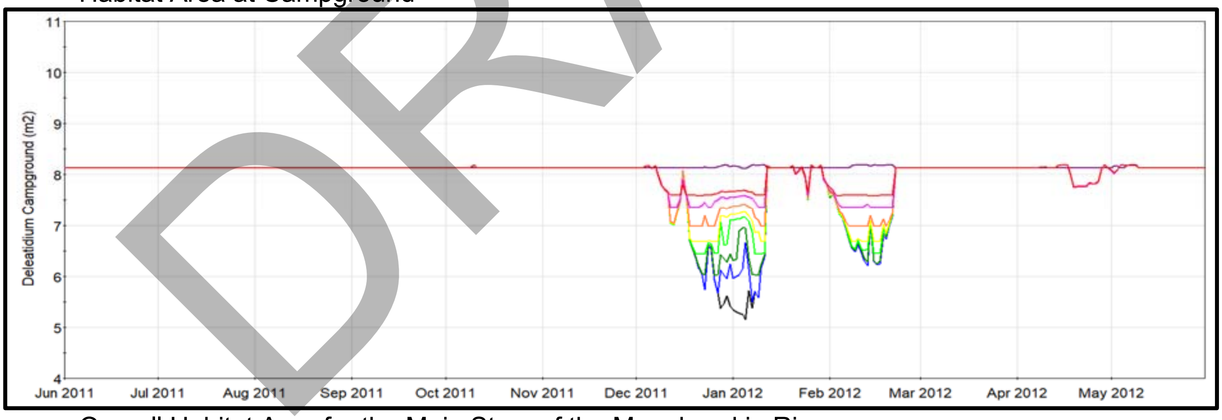
Habitat Area below Blackstone Intake:



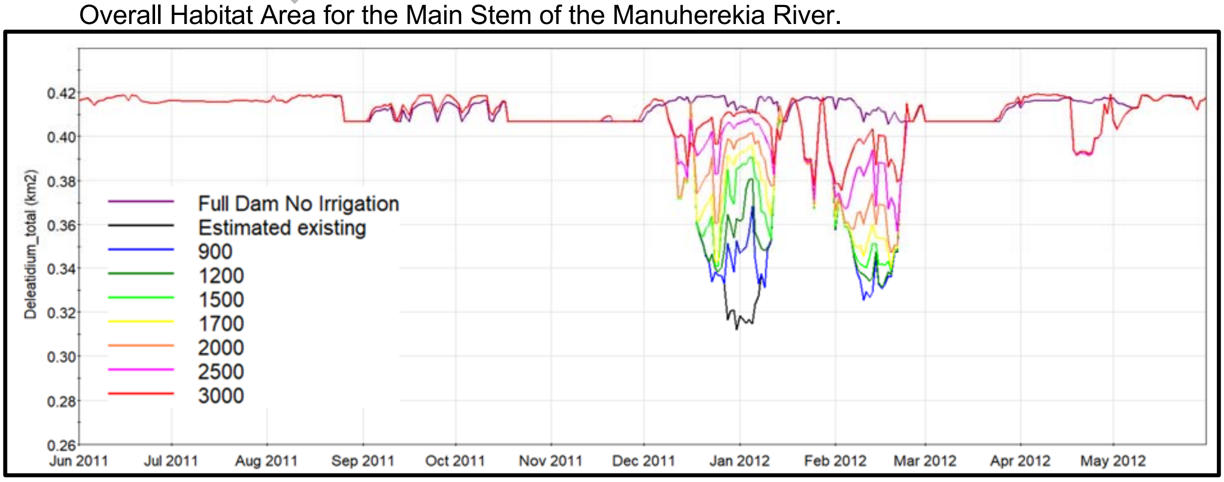
Habitat Area at Ophir



Habitat Area at Campground

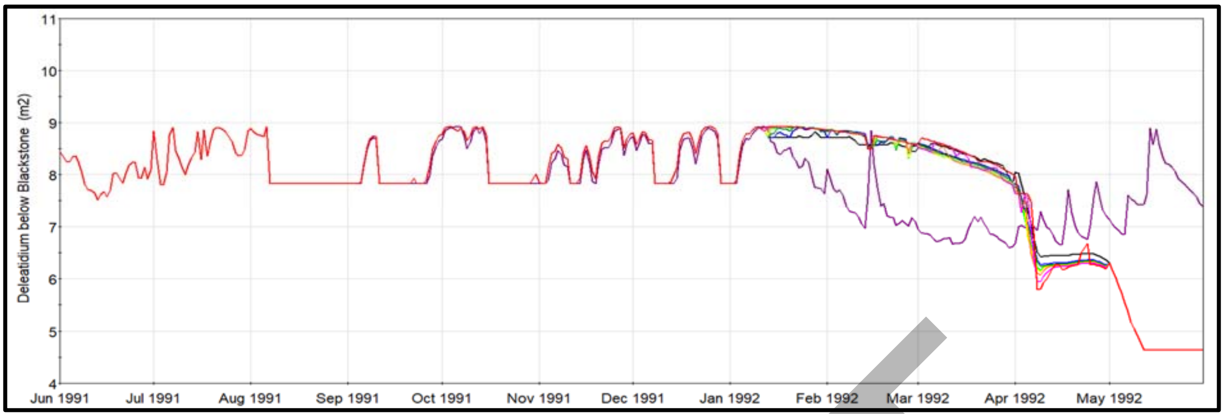


Overall Habitat Area for the Main Stem of the Manuherekia River.

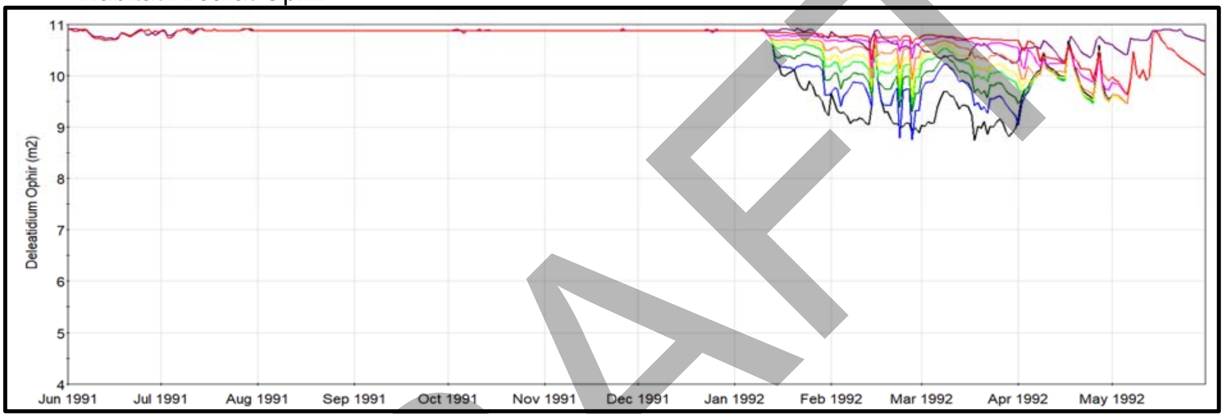


Deleatidium (mayfly) 1991-1992 average season with a dry autumn

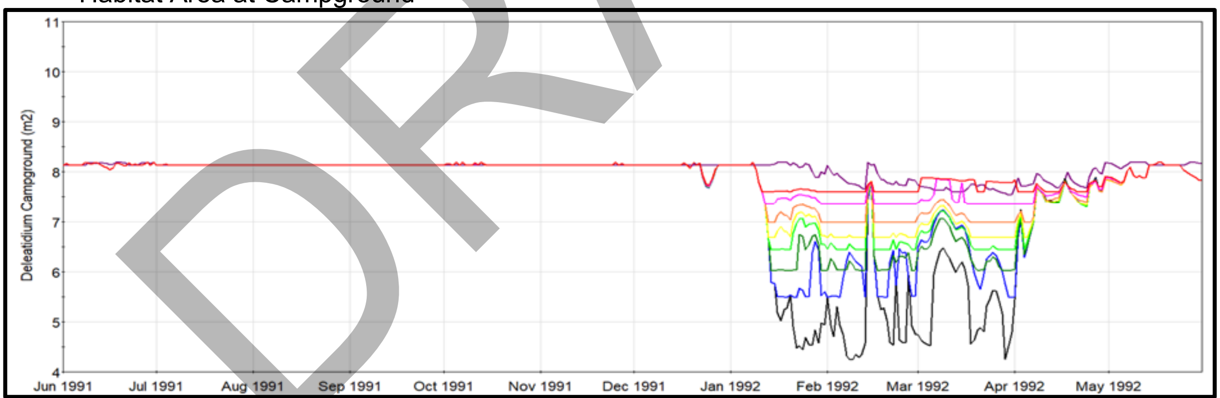
Habitat Area below Blackstone Intake:



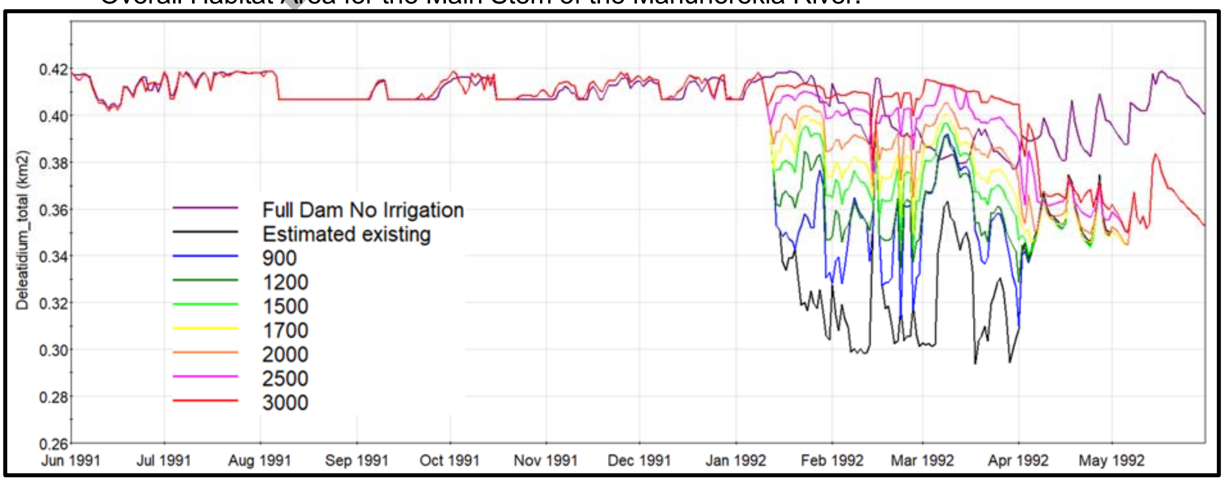
Habitat Area at Ophir



Habitat Area at Campground

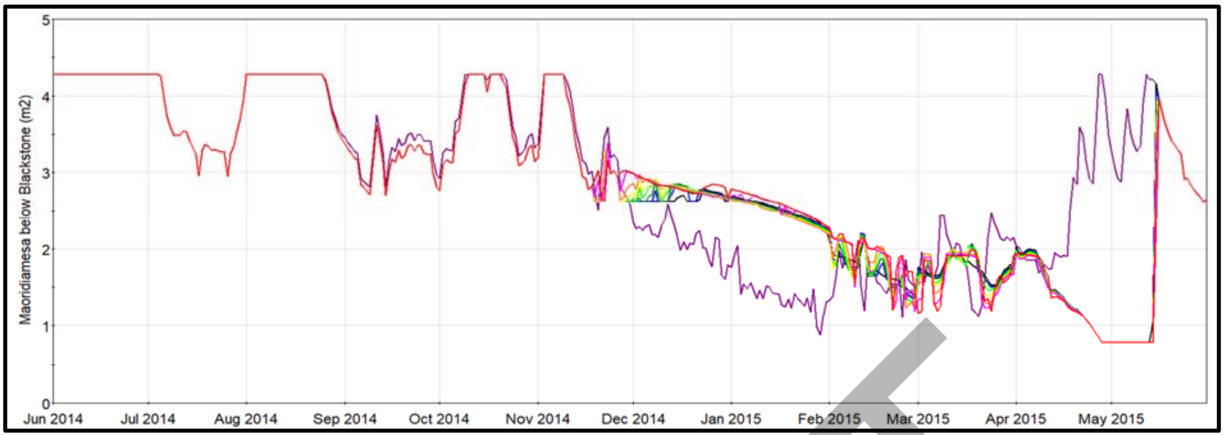


Overall Habitat Area for the Main Stem of the Manuherekia River.

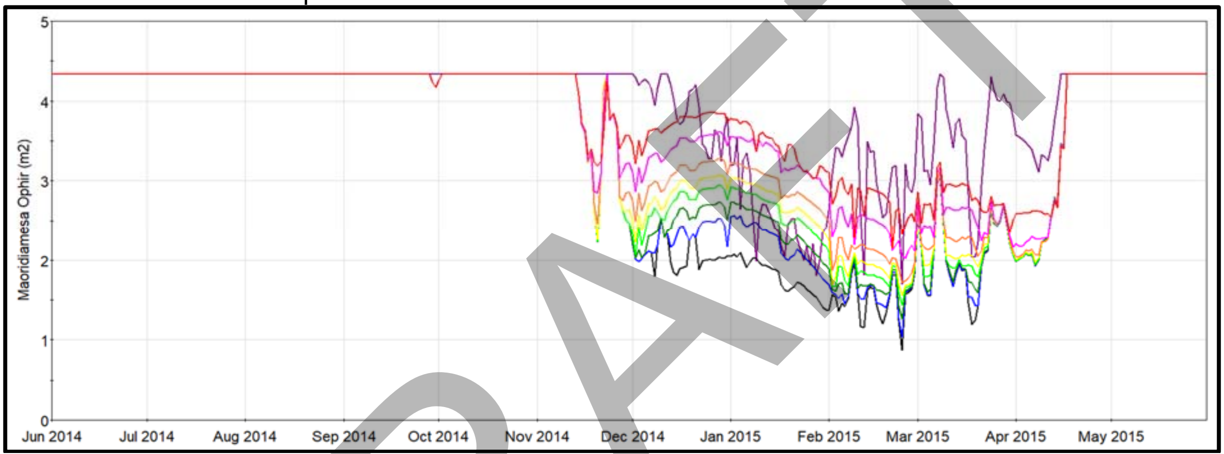


5.4 Maoridiamesa (Diptera) 2014-2015 drought season

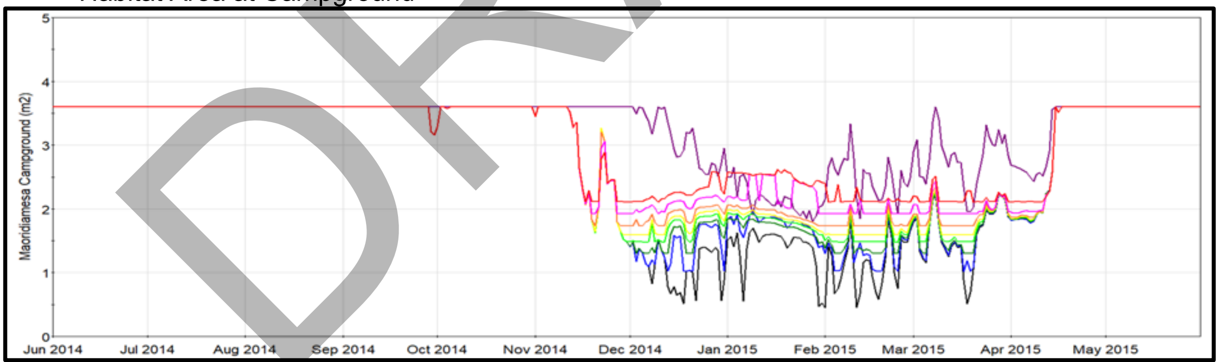
Habitat Area below Blackstone Intake:



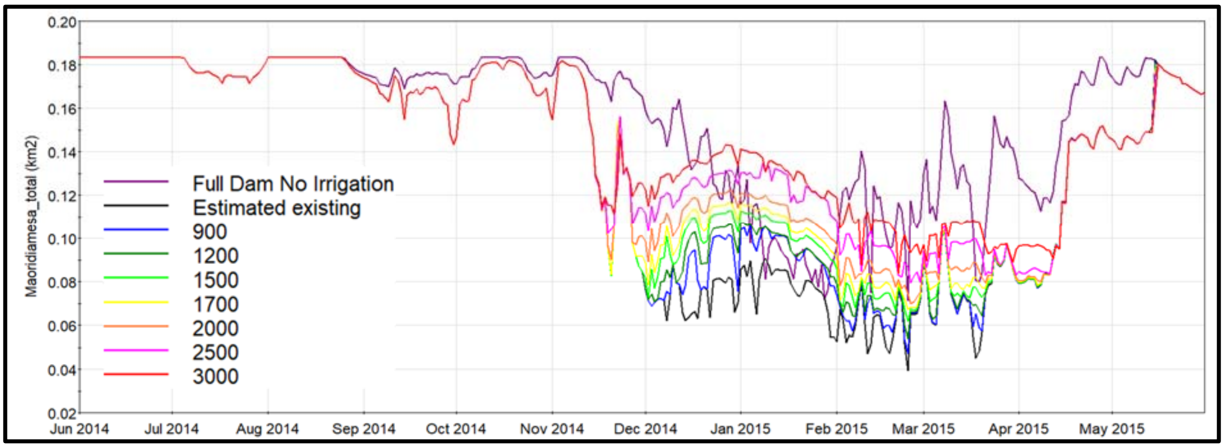
Habitat Area at Ophir



Habitat Area at Campground

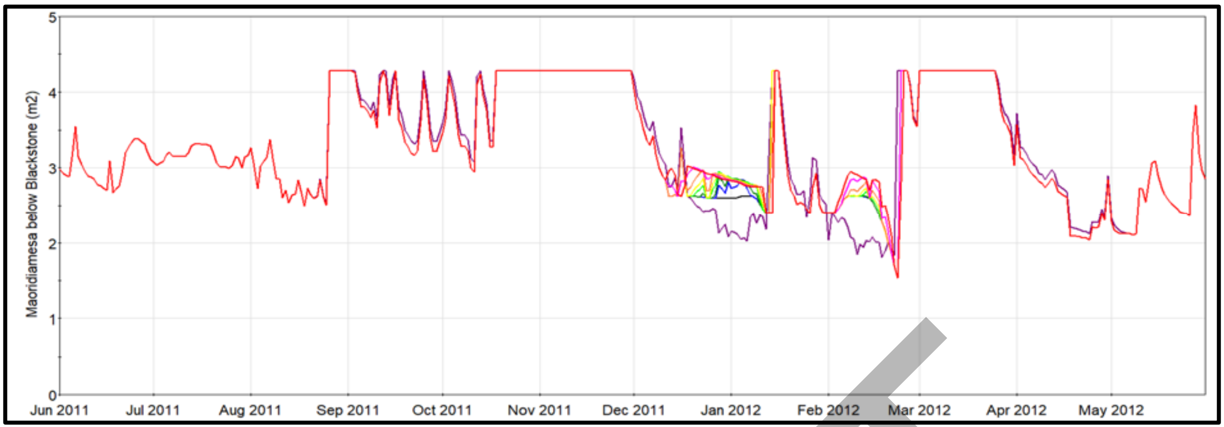


Overall Habitat Area for the Main Stem of the Manuherekia River.

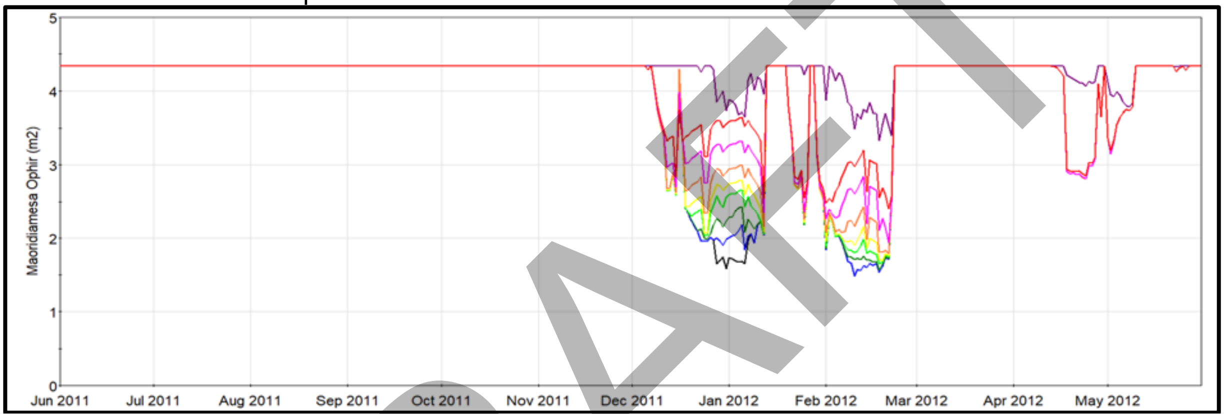


Maoridiamesa (Diptera) 2011-2012 wet season

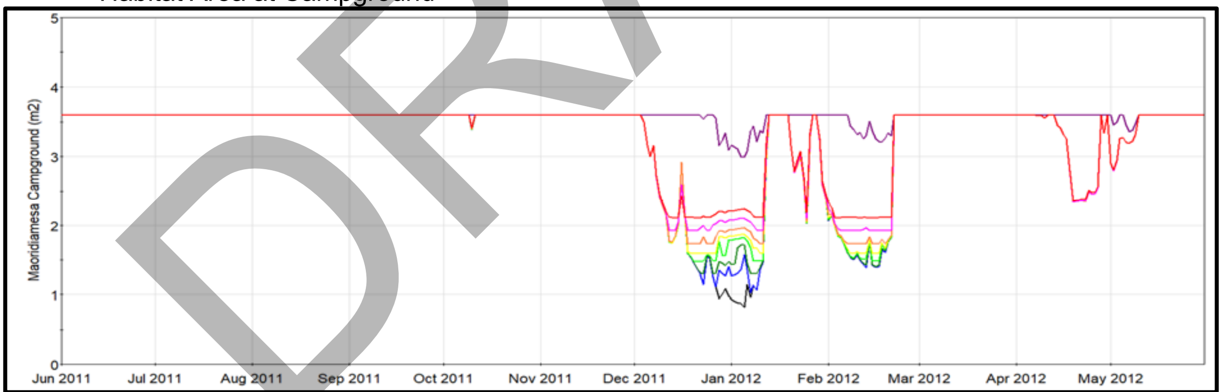
Habitat Area below Blackstone Intake:



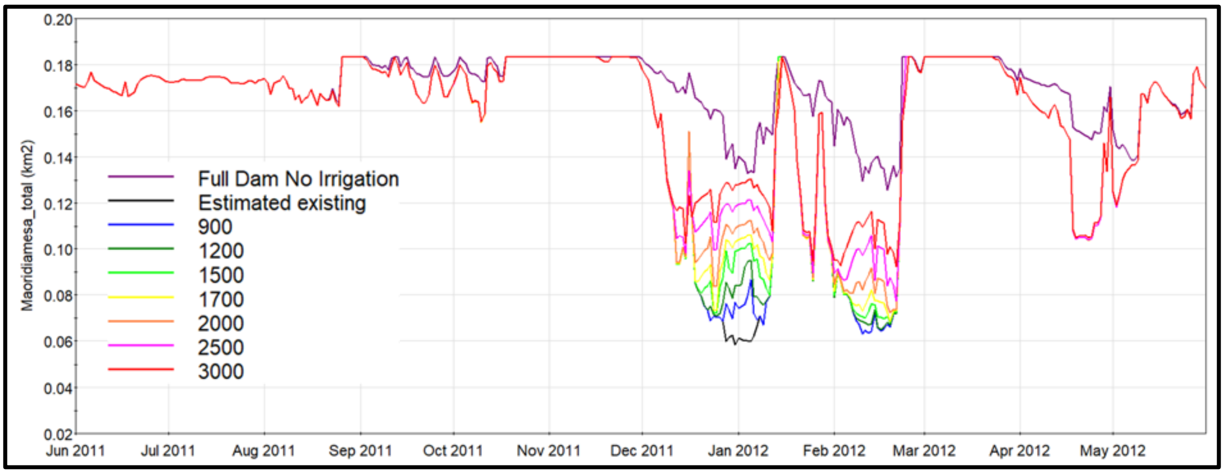
Habitat Area at Ophir



Habitat Area at Campground

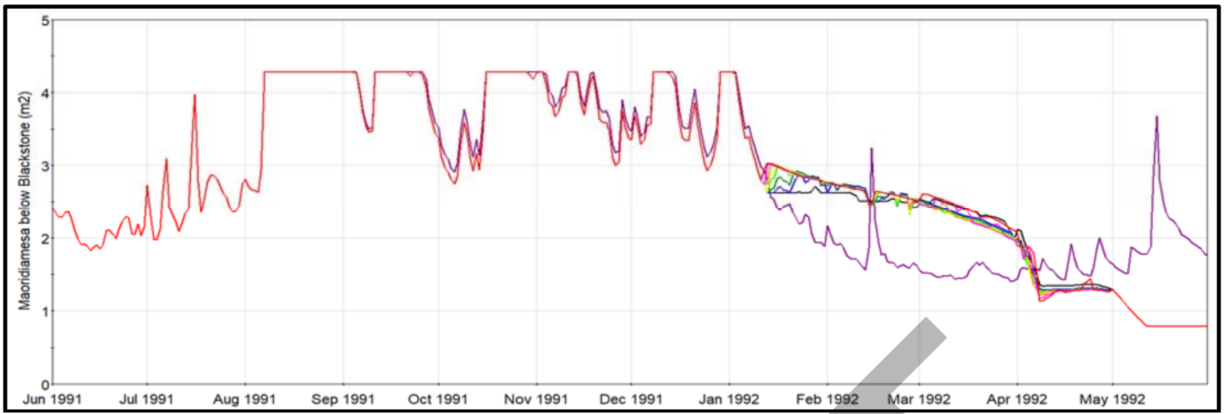


Overall Habitat Area for the Main Stem of the Manuherekia River.

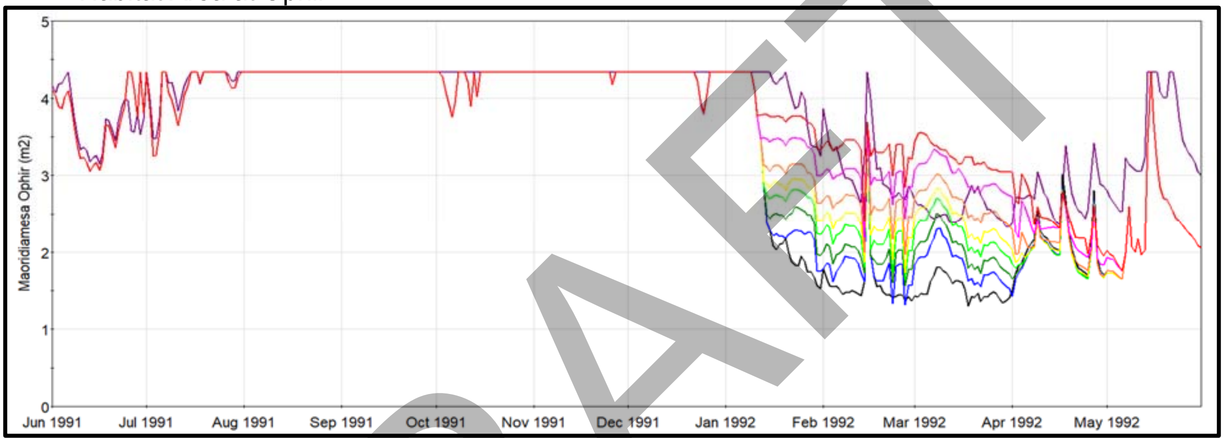


Maoridiamesa (Diptera) 1991-1992 average season with a dry autumn

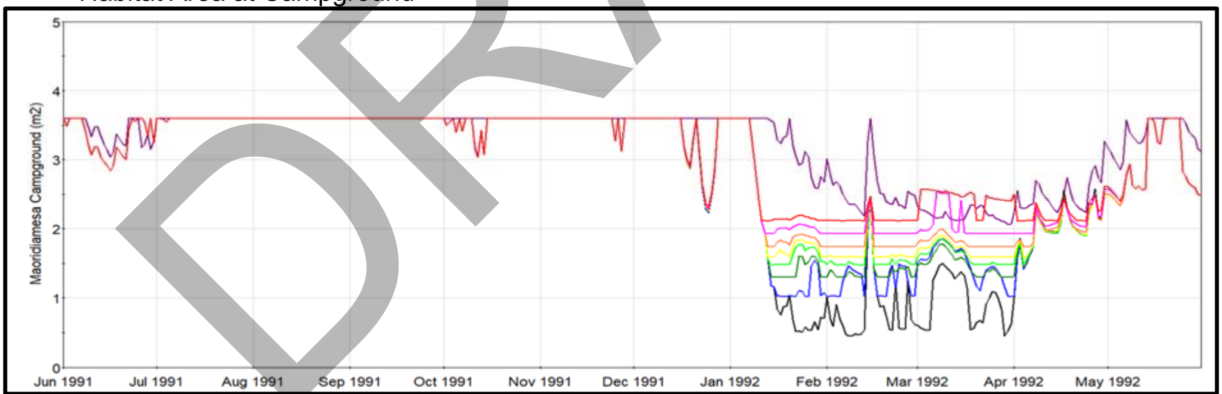
Habitat Area below Blackstone Intake:



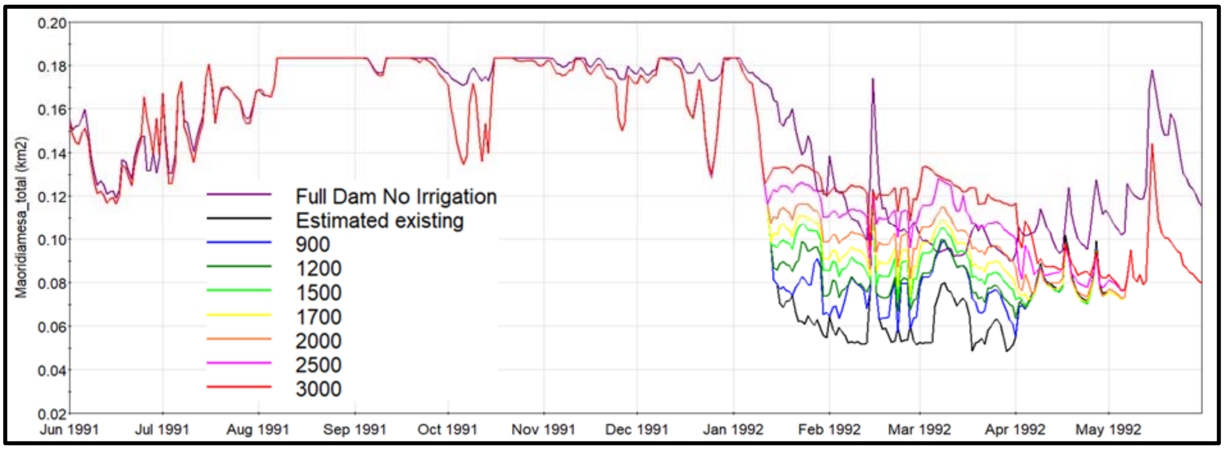
Habitat Area at Ophir



Habitat Area at Campground

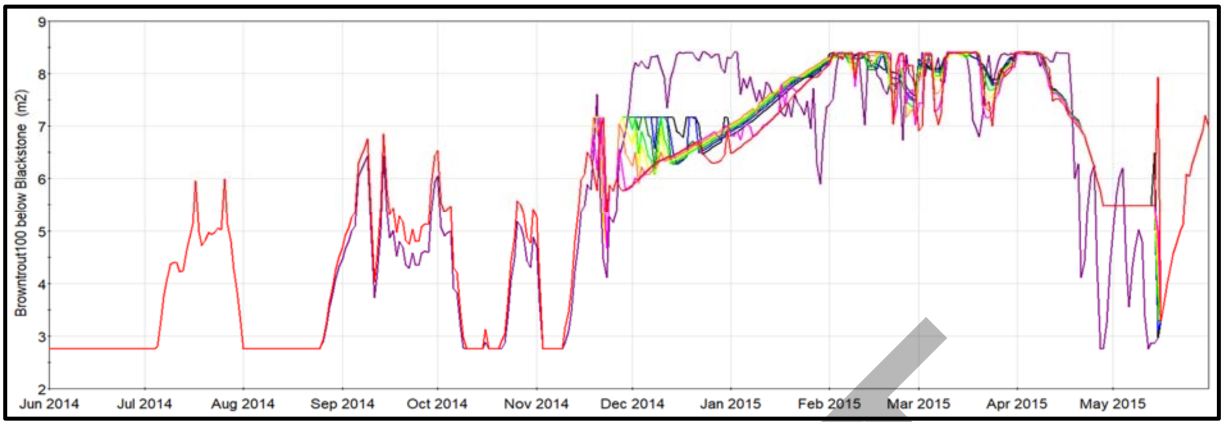


Overall Habitat Area for the Main Stem of the Manuherekia River.

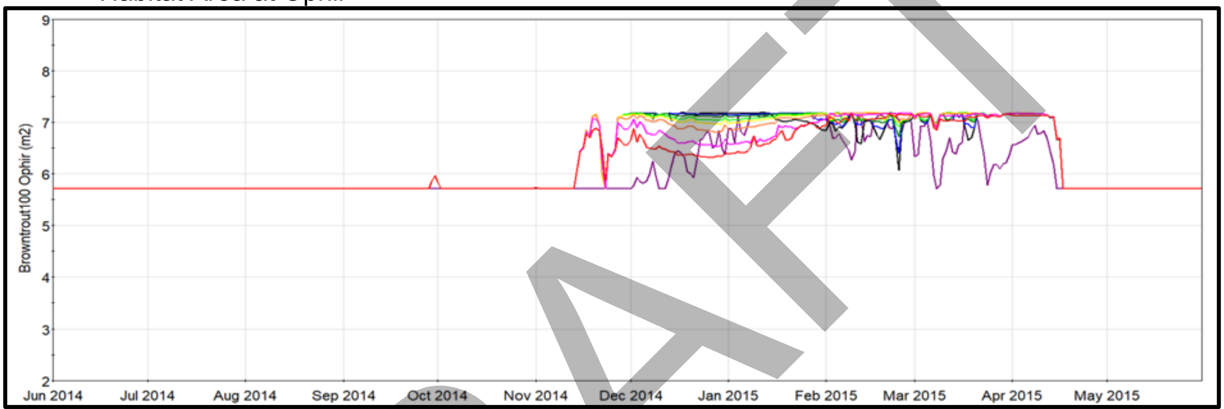


5.5 Brown Trout < 100 mm 2014-2015 drought season

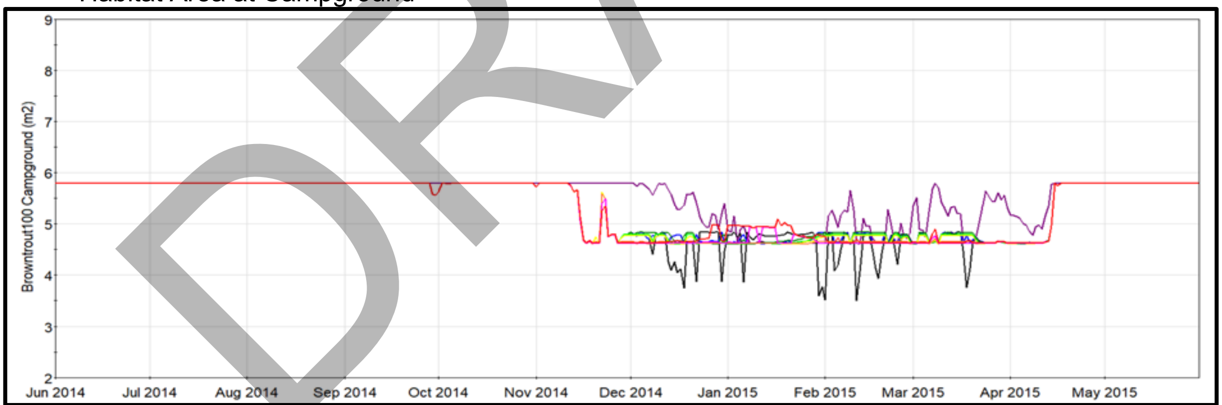
Habitat Area below Blackstone Intake:



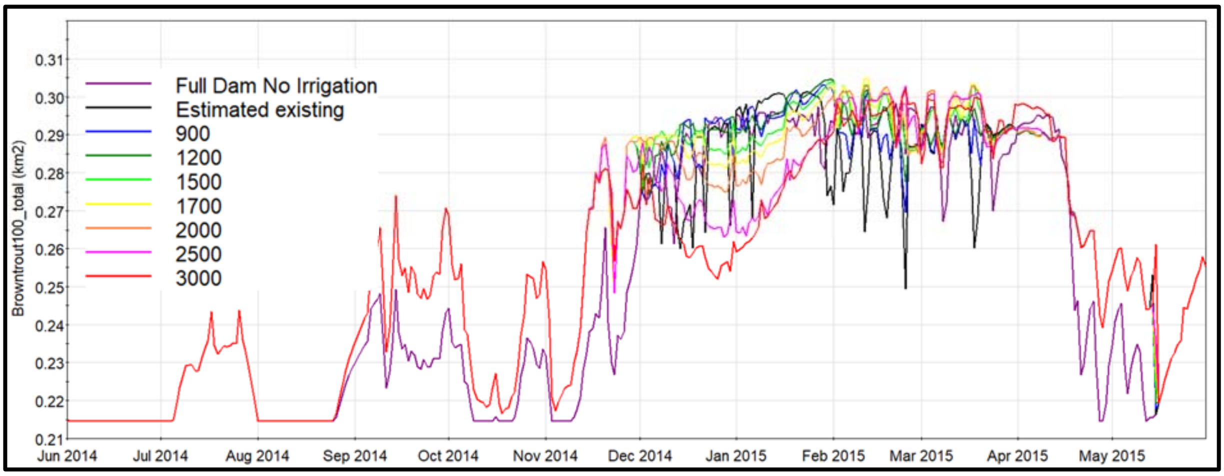
Habitat Area at Ophir



Habitat Area at Campground

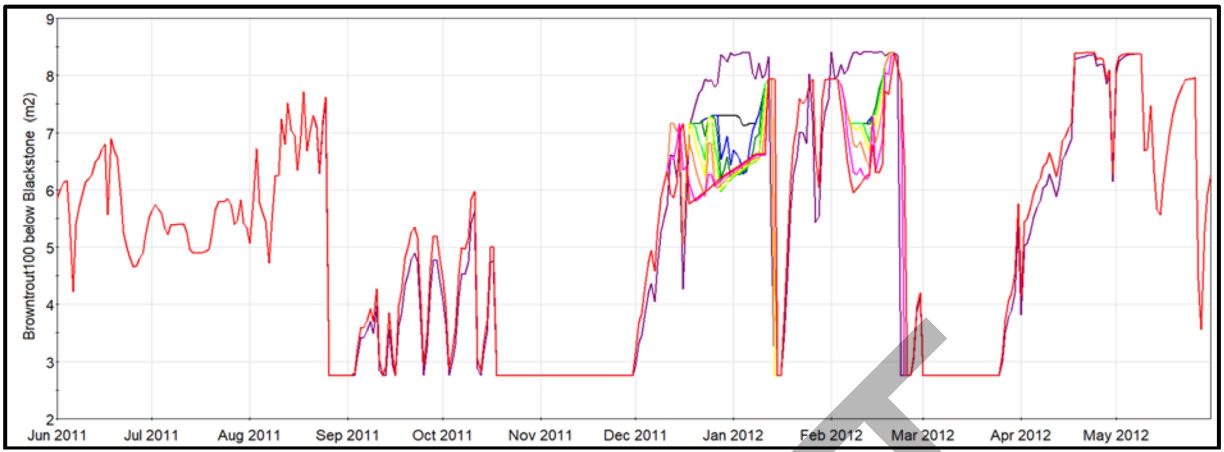


Overall Habitat Area for the Main Stem of the Manuherekia River.

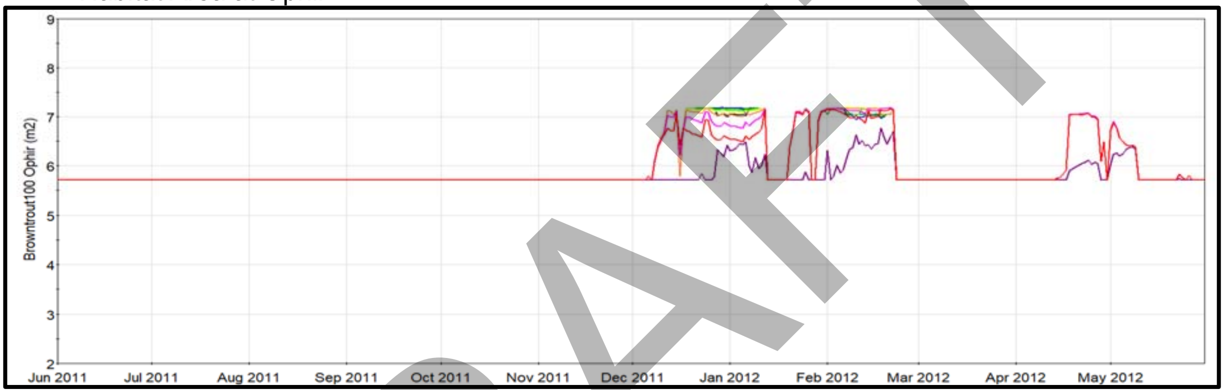


Brown Trout < 100 mm 2011-2012 wet season

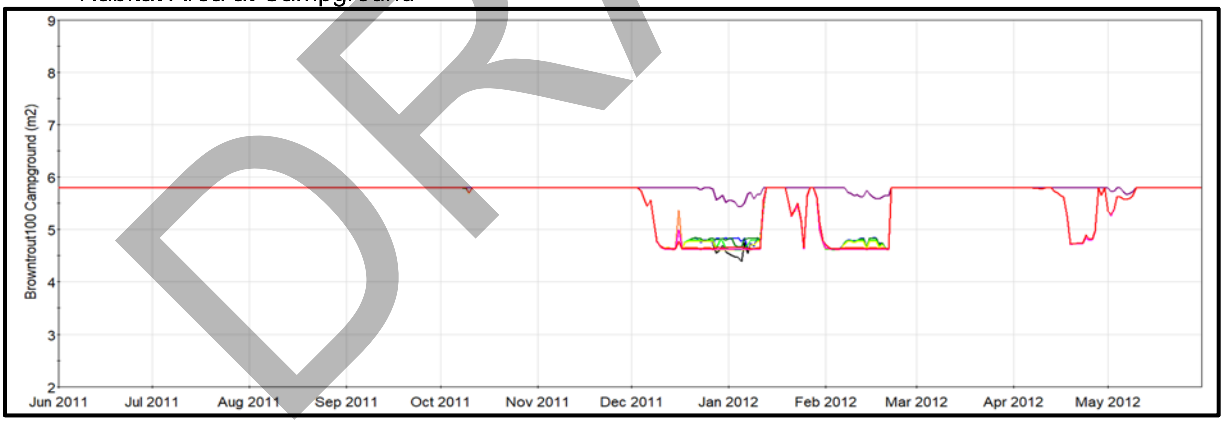
Habitat Area below Blackstone Intake:



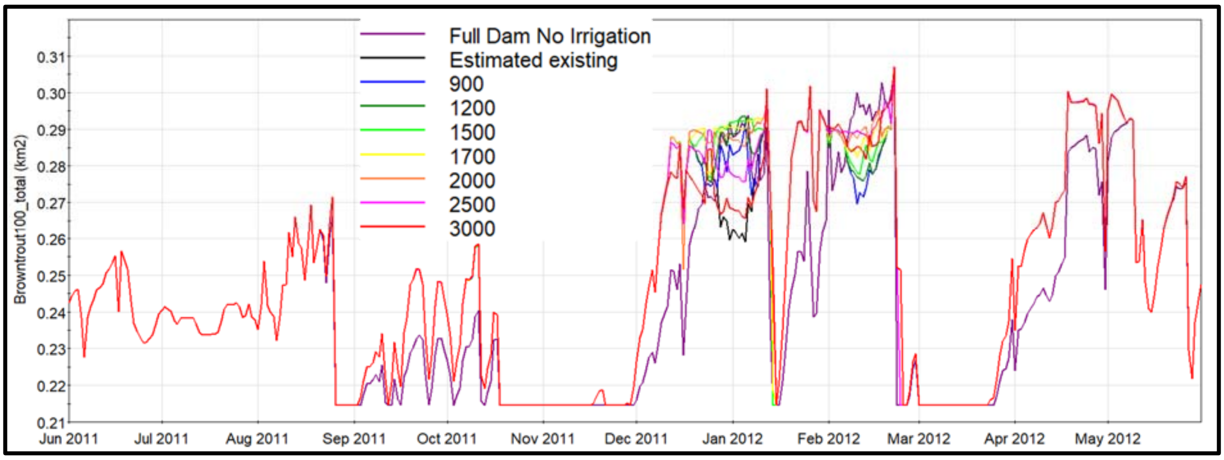
Habitat Area at Ophir



Habitat Area at Campground

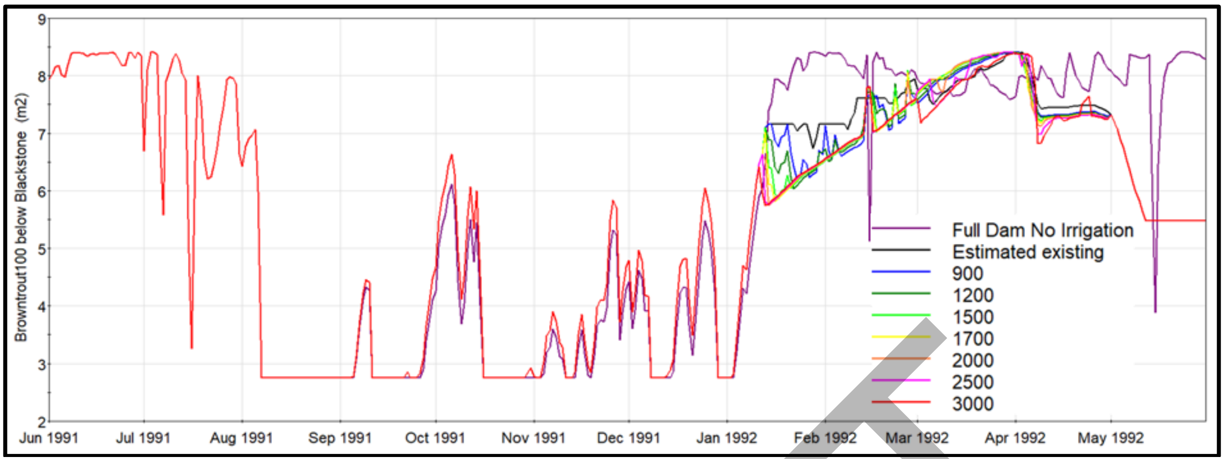


Overall Habitat Area for the Main Stem of the Manuherekia River.

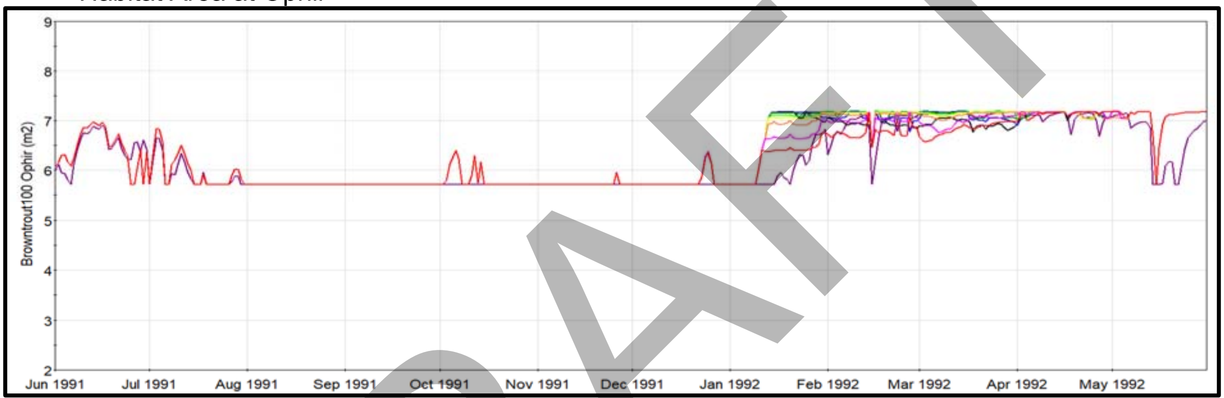


Brown Trout < 100 mm 1991-1992 average season with a dry autumn

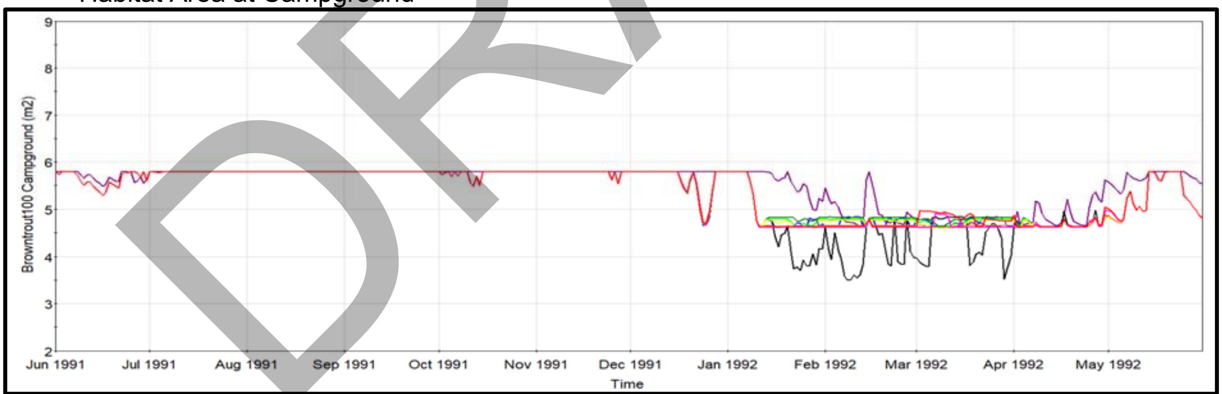
Habitat Area below Blackstone Intake:



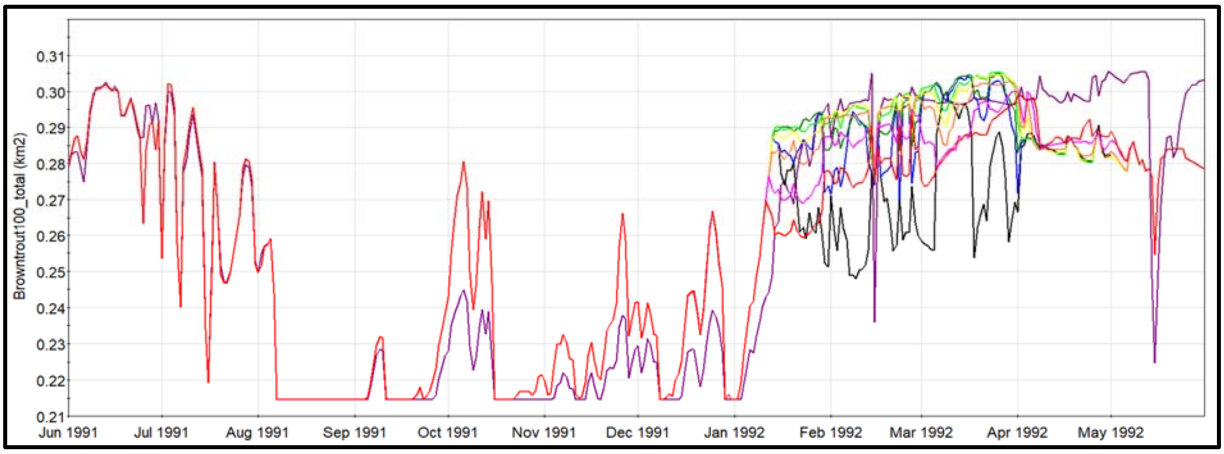
Habitat Area at Ophir



Habitat Area at Campground

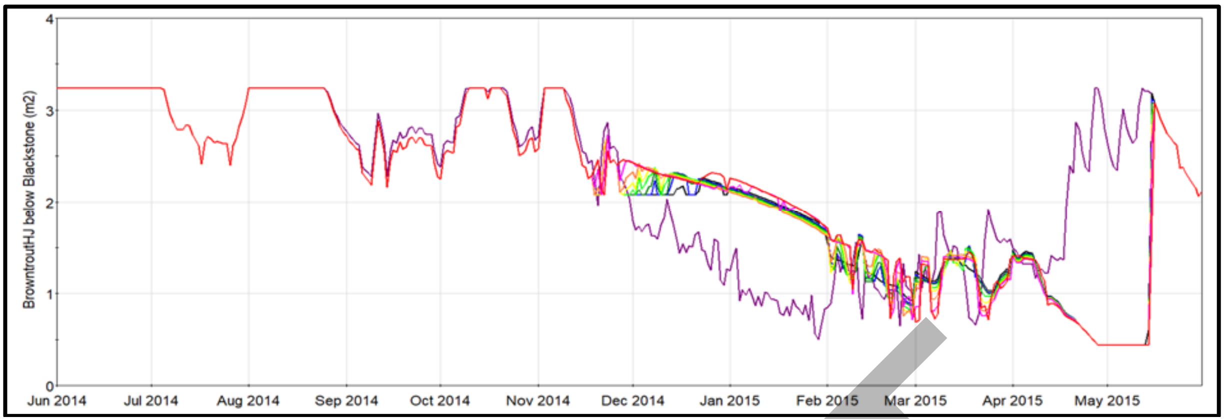


Overall Habitat Area for the Main Stem of the Manuherekia River.

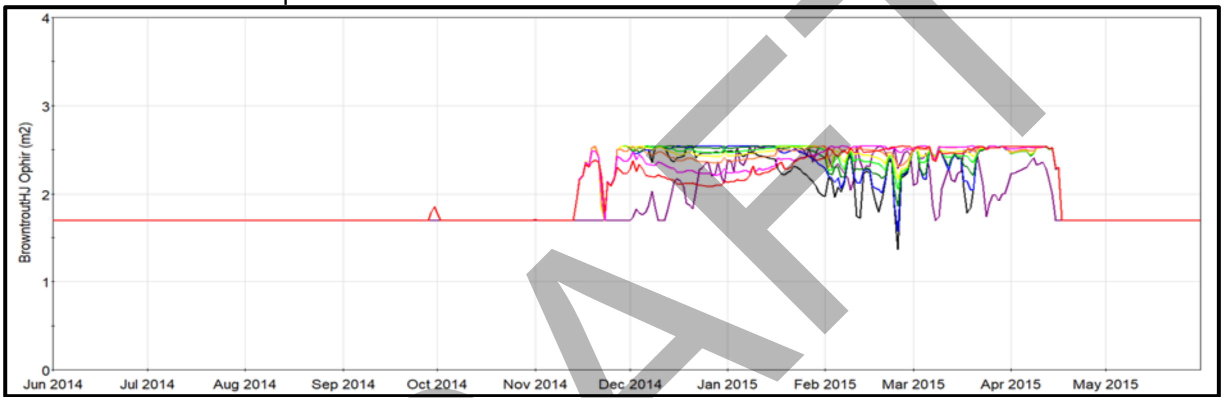


5.6 Brown Trout H&J 2014-2015 drought season

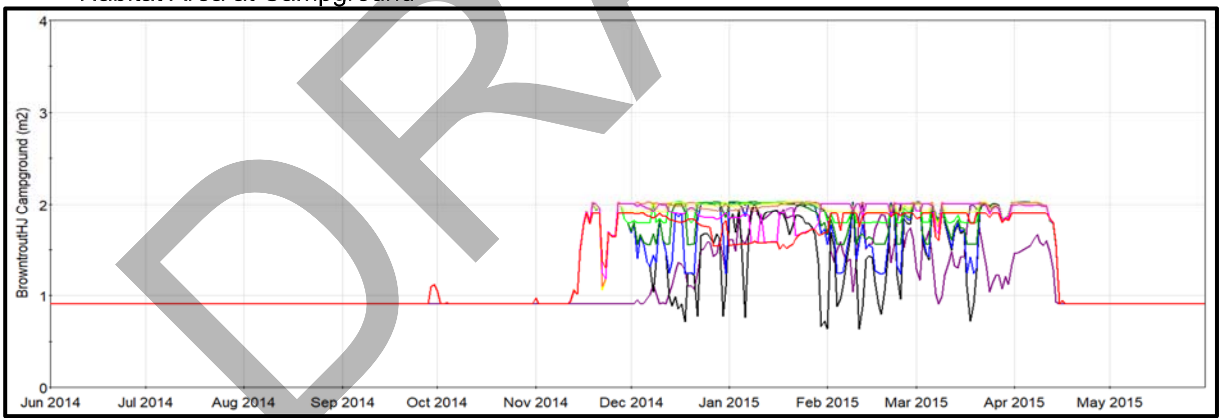
Habitat Area below Blackstone Intake:



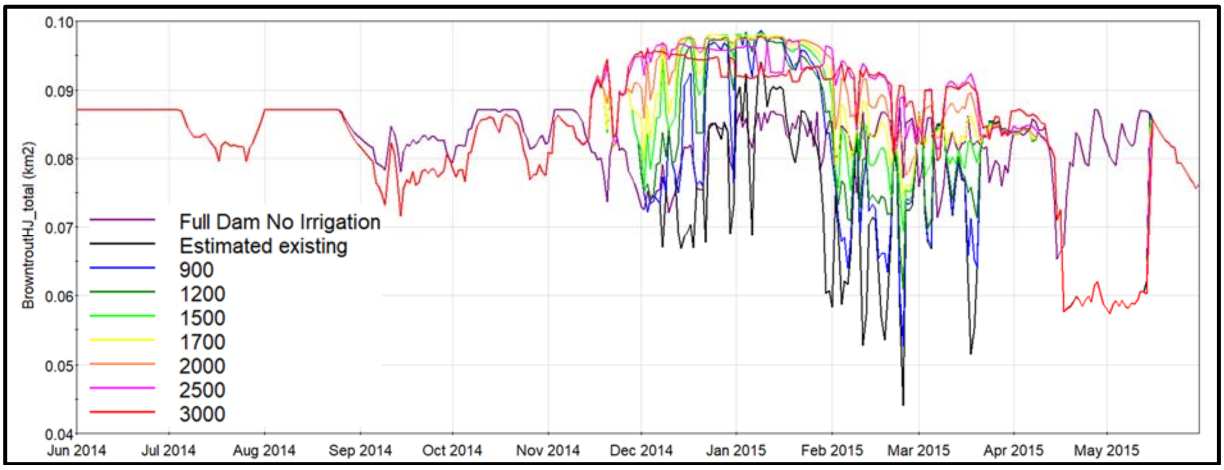
Habitat Area at Ophir



Habitat Area at Campground

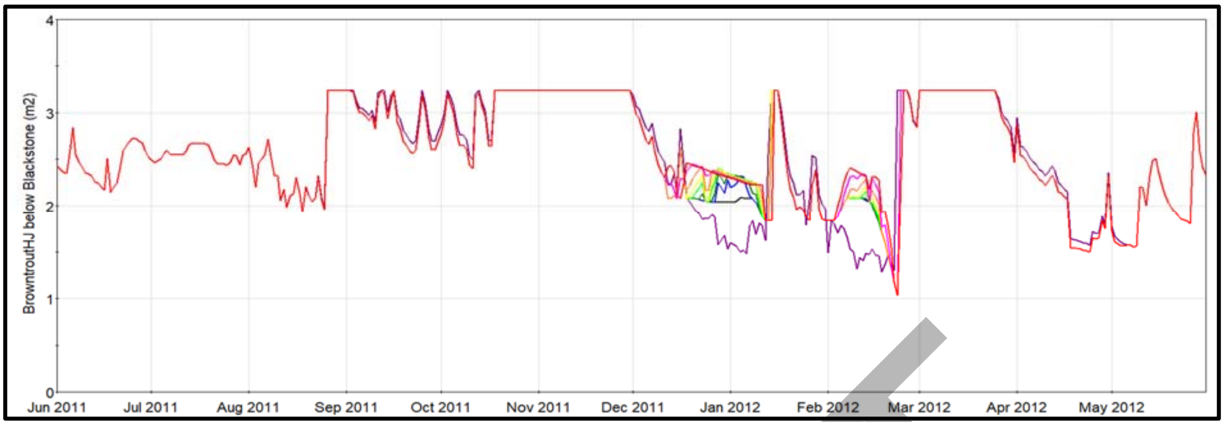


Overall Habitat Area for the Main Stem of the Manuherekia River.

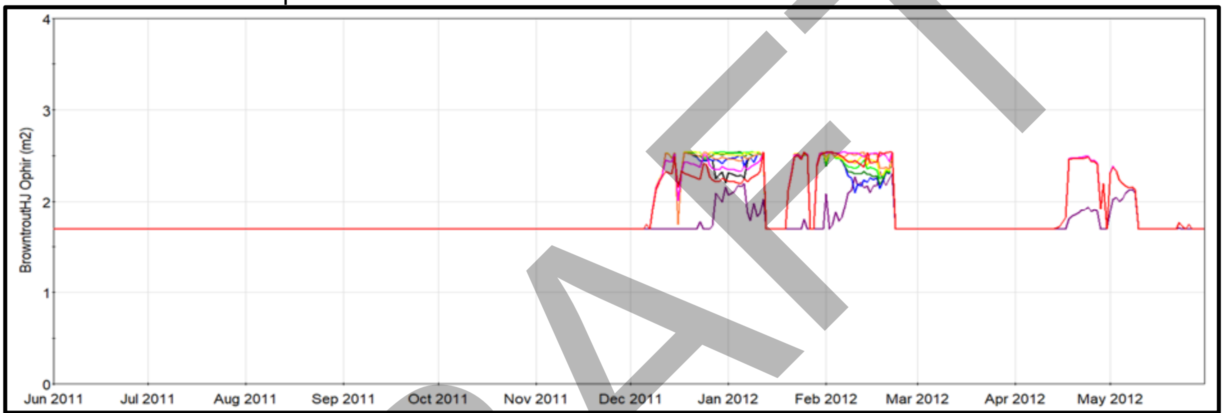


Brown Trout H&J 2011-2012 wet season

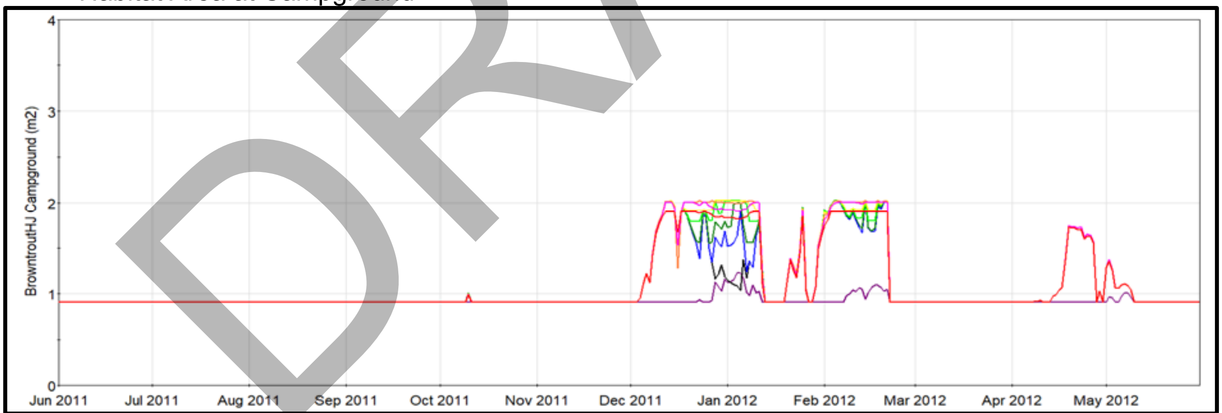
Habitat Area below Blackstone Intake:



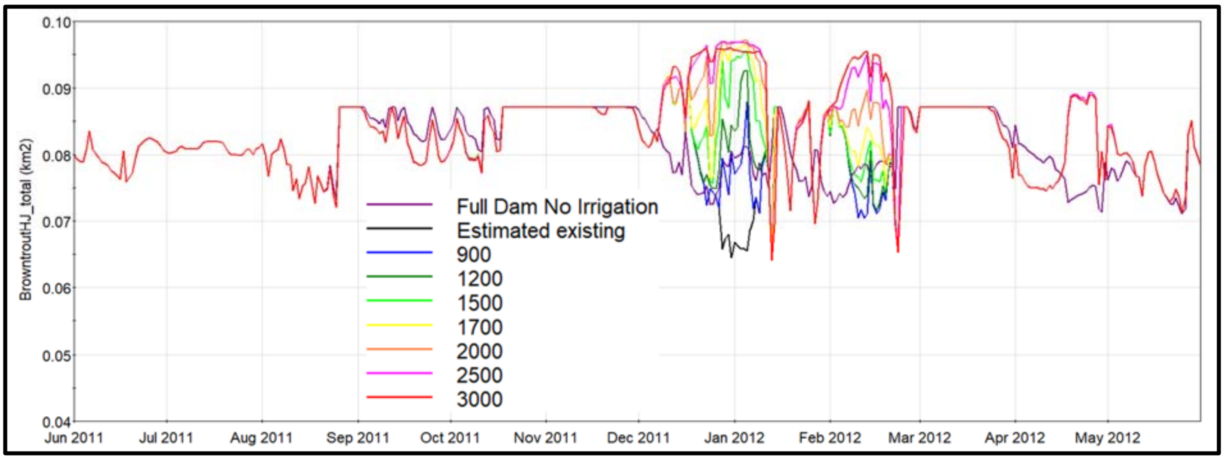
Habitat Area at Ophir



Habitat Area at Campground

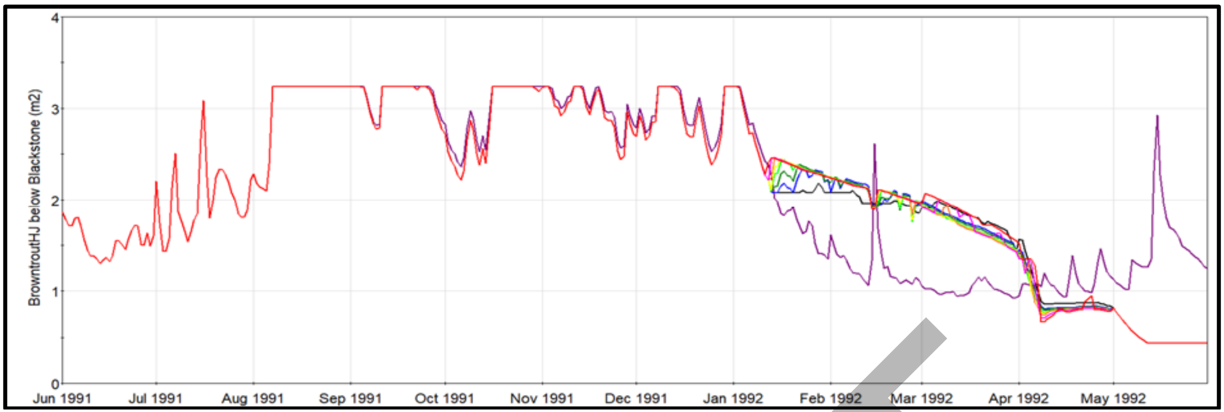


Overall Habitat Area for the Main Stem of the Manuherekia River.

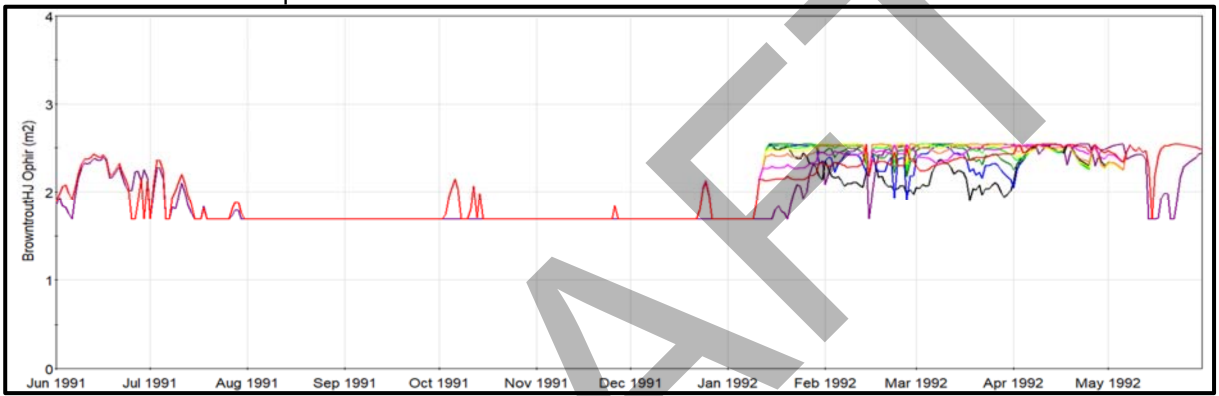


Brown Trout H&J 1991-1992 average season with a dry autumn

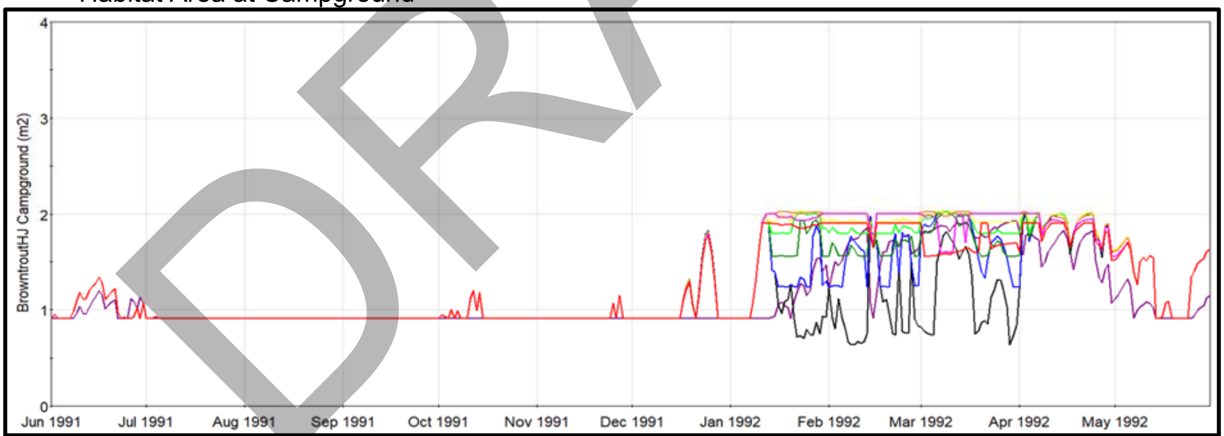
Habitat Area below Blackstone Intake:



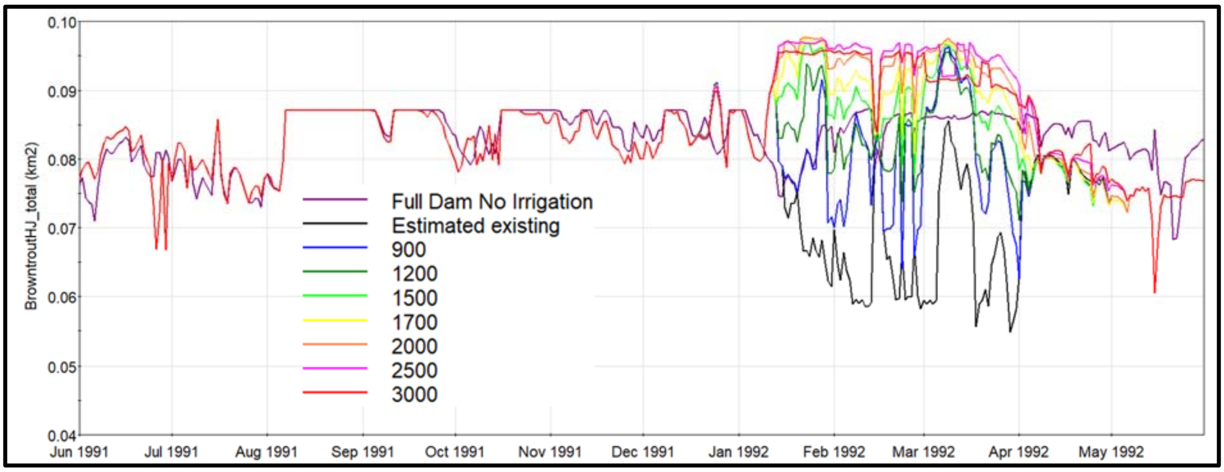
Habitat Area at Ophir



Habitat Area at Campground

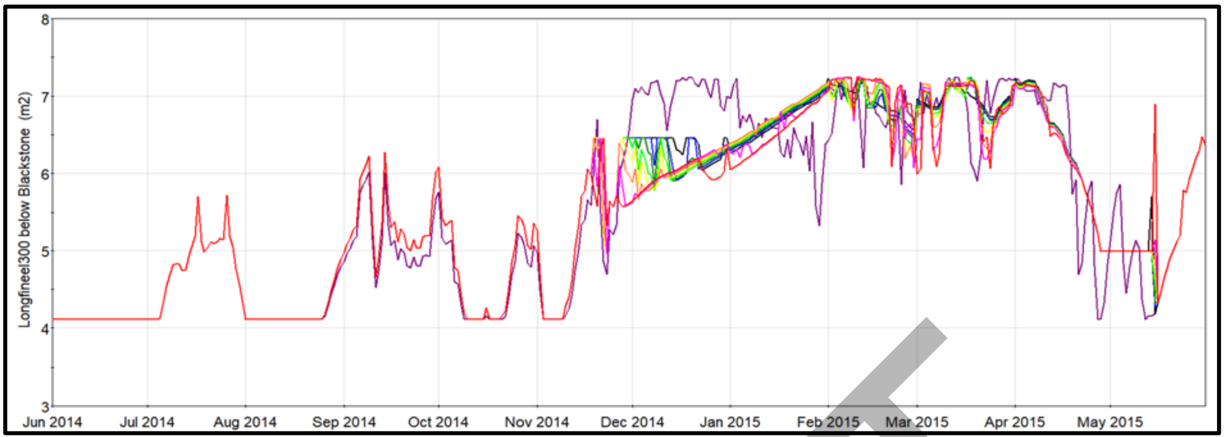


Overall Habitat Area for the Main Stem of the Manuherekia River.

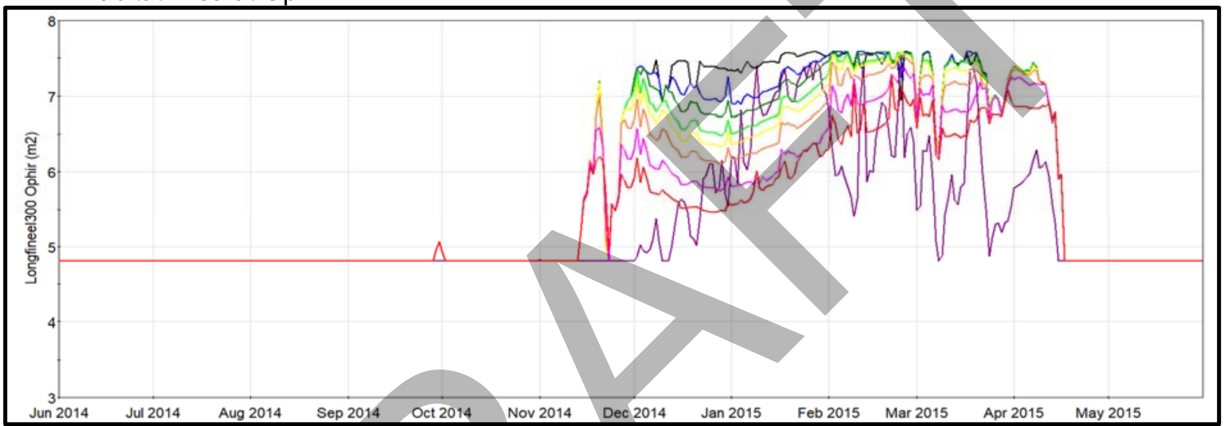


5.7 Longfin Eel < 300 mm 2014-2015 drought season

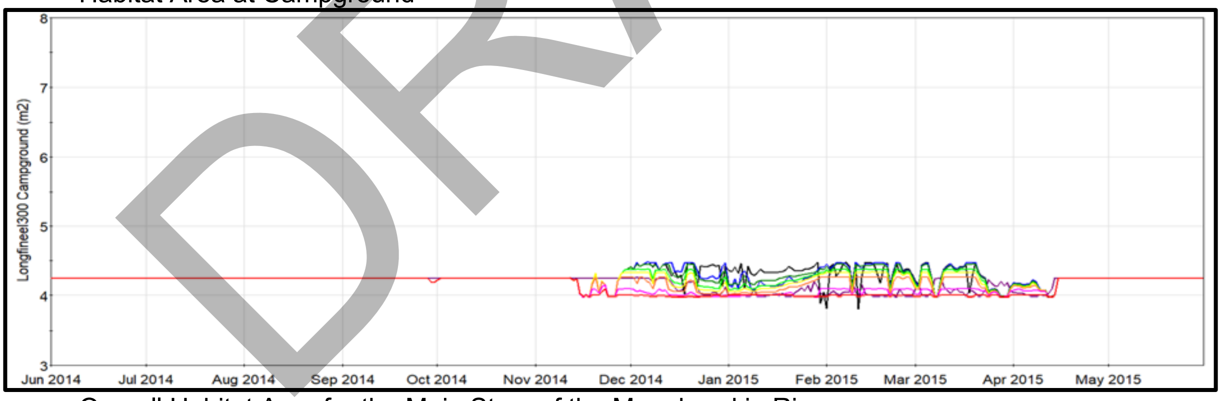
Habitat Area below Blackstone Intake:



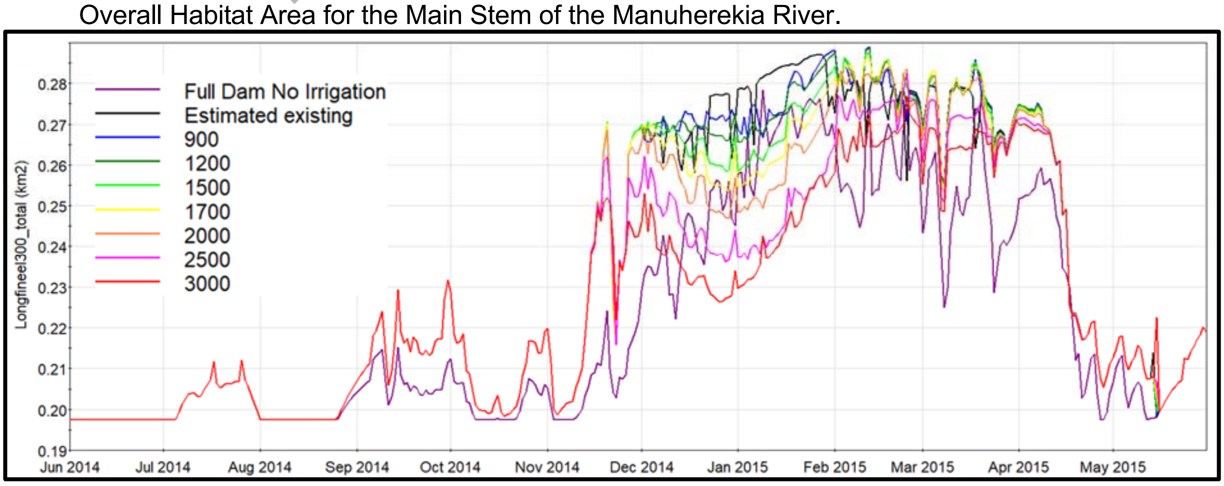
Habitat Area at Ophir



Habitat Area at Campground

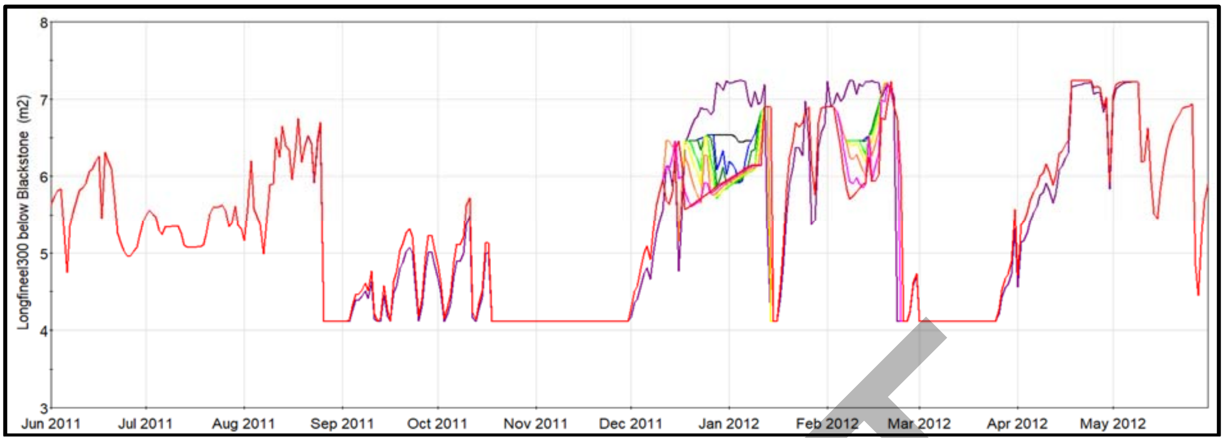


Overall Habitat Area for the Main Stem of the Manuherekia River.

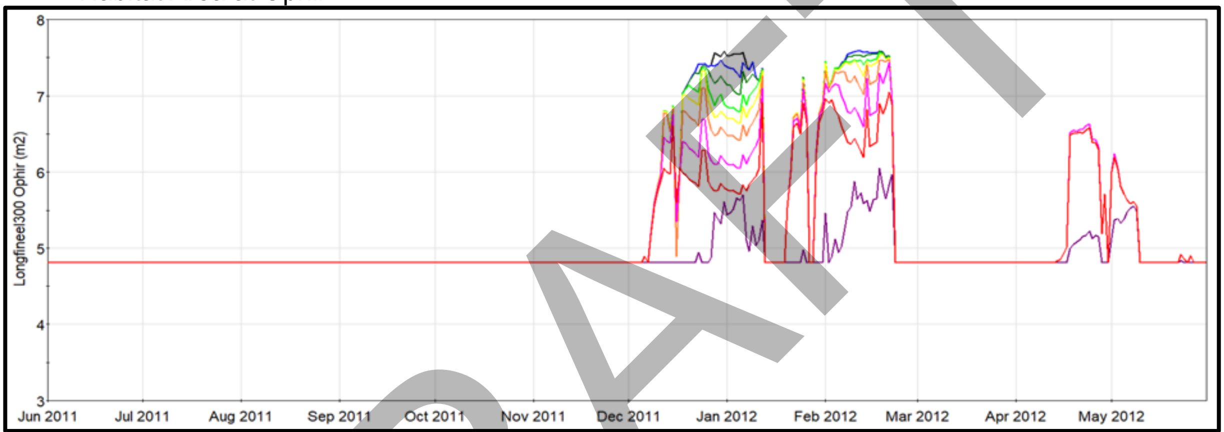


Longfin Eel < 300 mm 2011-2012 wet season

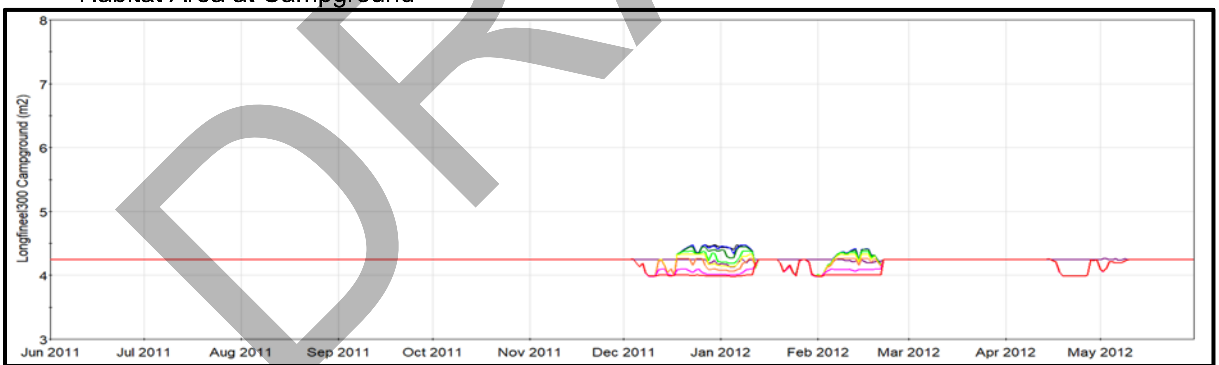
Habitat Area below Blackstone Intake:



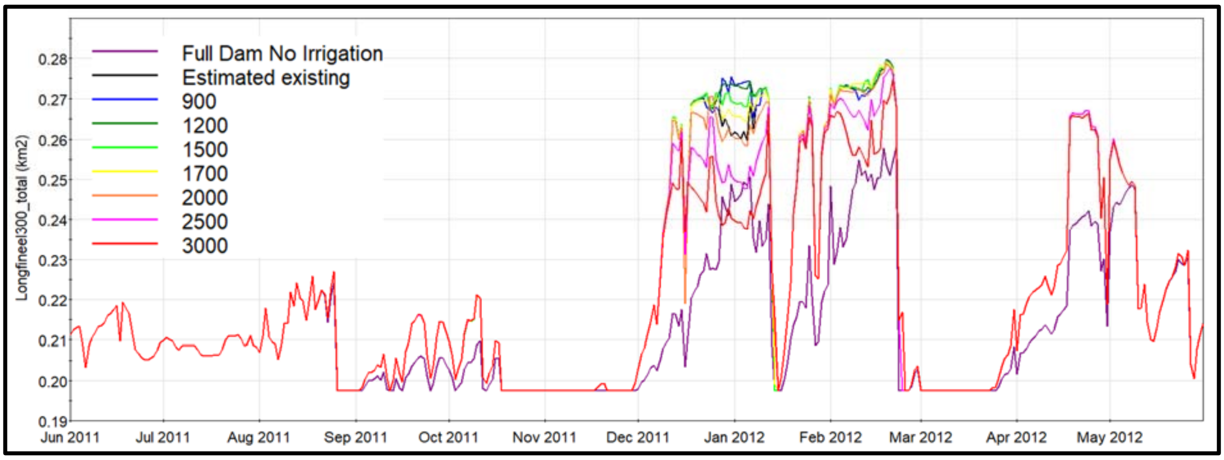
Habitat Area at Ophir



Habitat Area at Campground

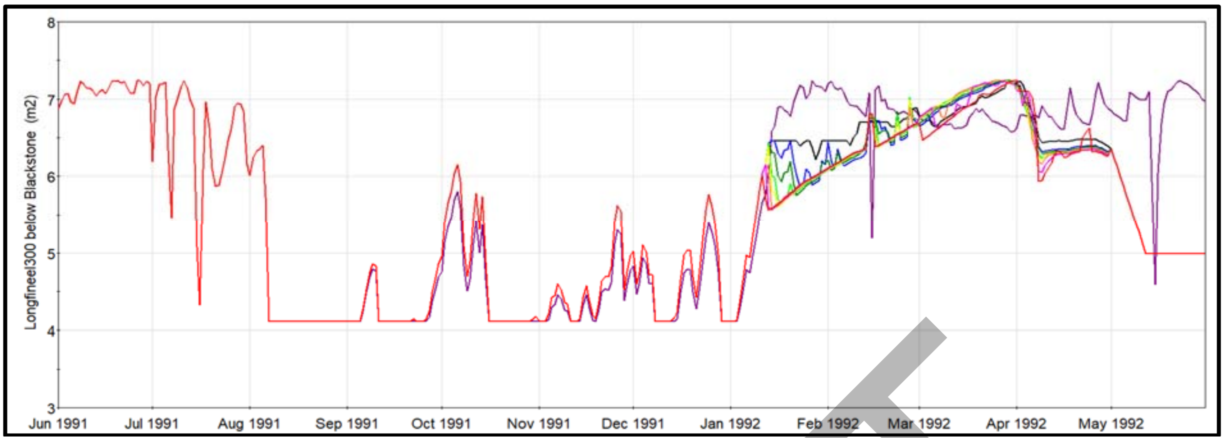


Overall Habitat Area for the Main Stem of the Manuherekia River.

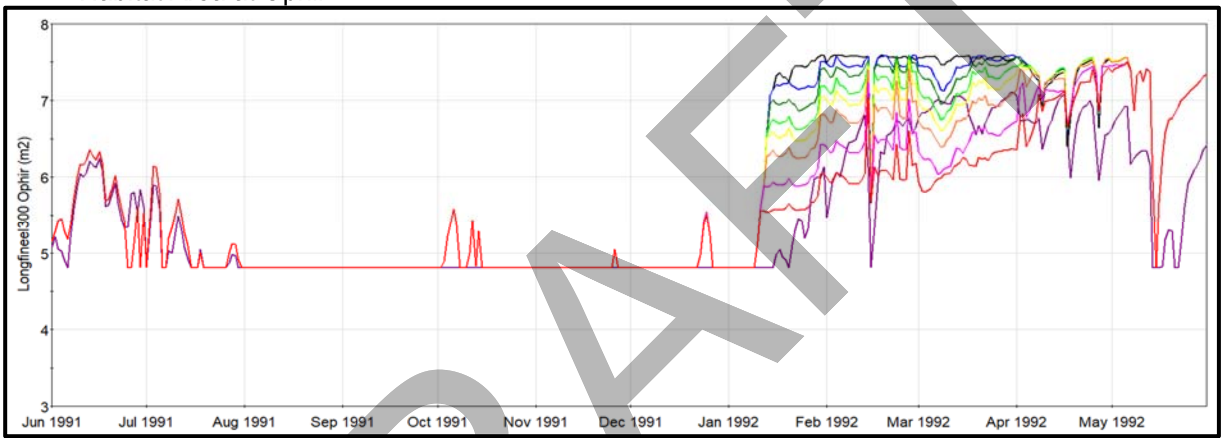


Longfin Eel < 300 mm 1991-1992 average season with a dry autumn

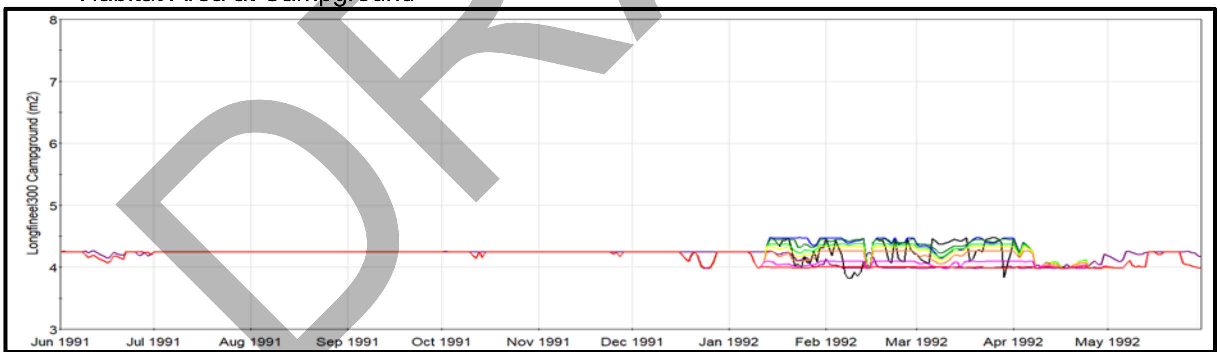
Habitat Area below Blackstone Intake:



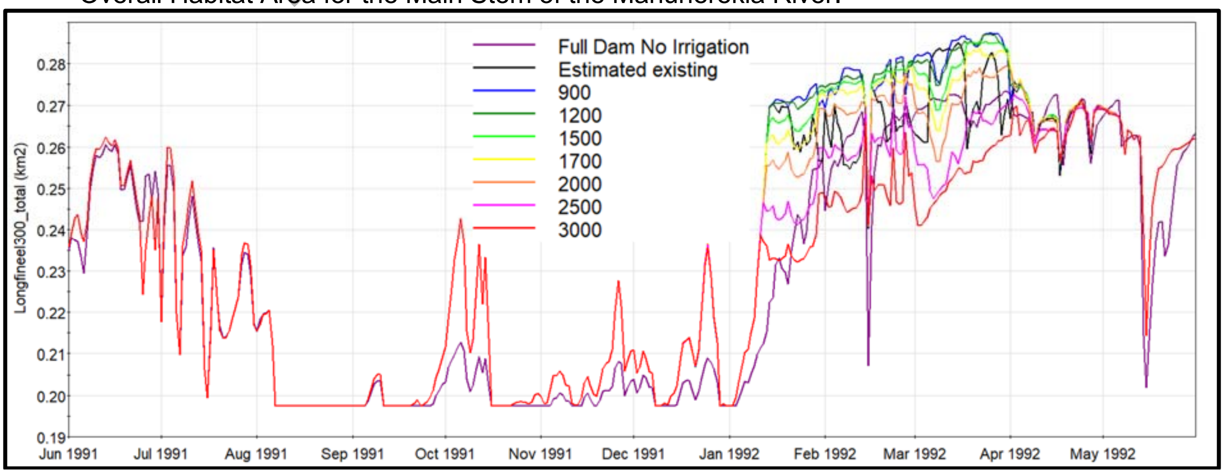
Habitat Area at Ophir



Habitat Area at Campground

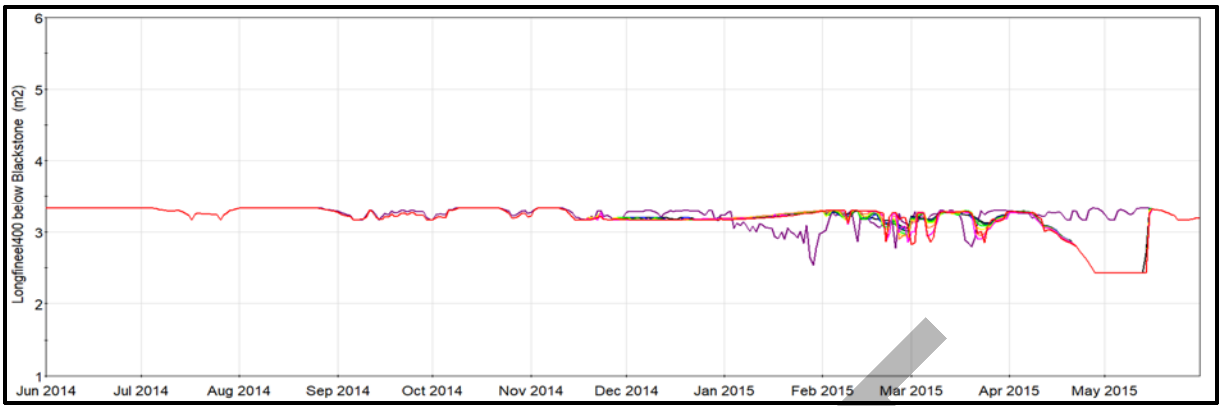


Overall Habitat Area for the Main Stem of the Manuherekia River.

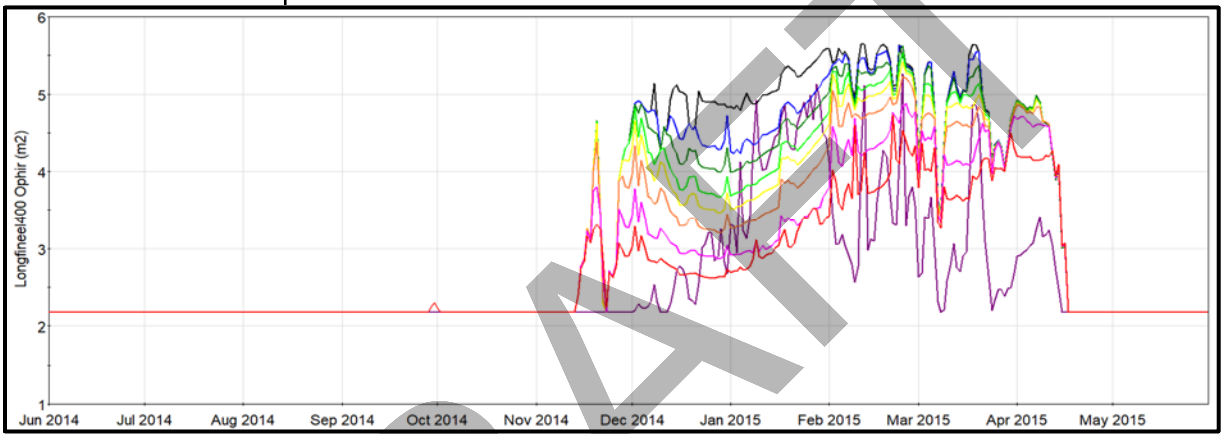


5.8 Longfin Eel > 300 mm 2014-2015 drought season

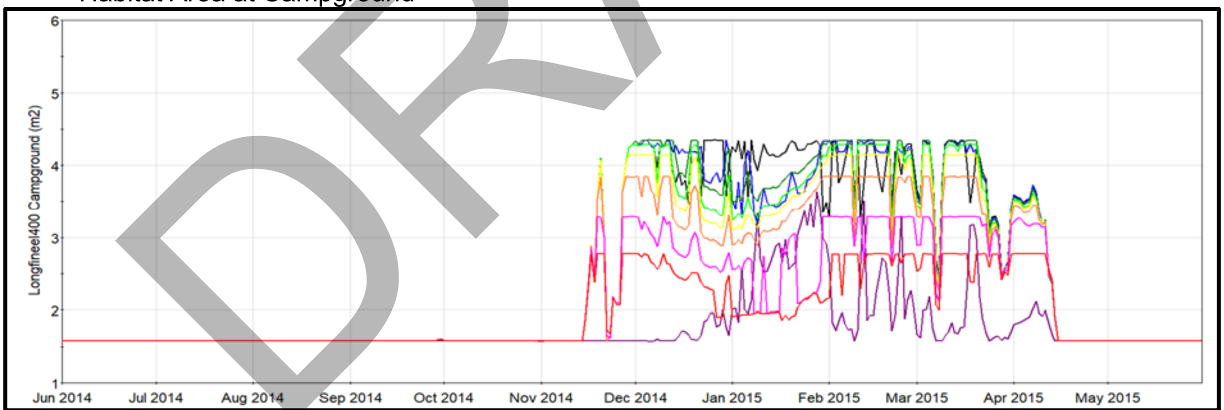
Habitat Area below Blackstone Intake:



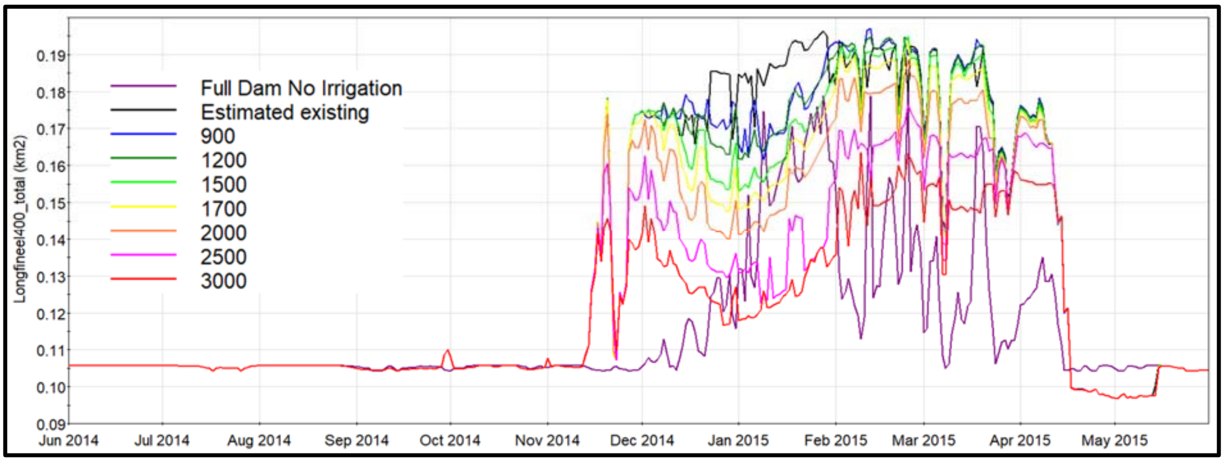
Habitat Area at Ophir



Habitat Area at Campground

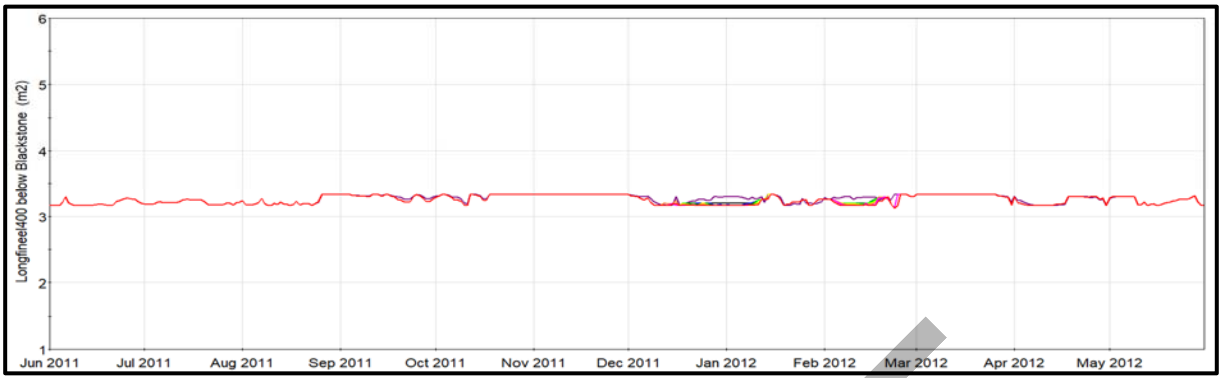


Overall Habitat Area for the Main Stem of the Manuherekia River.

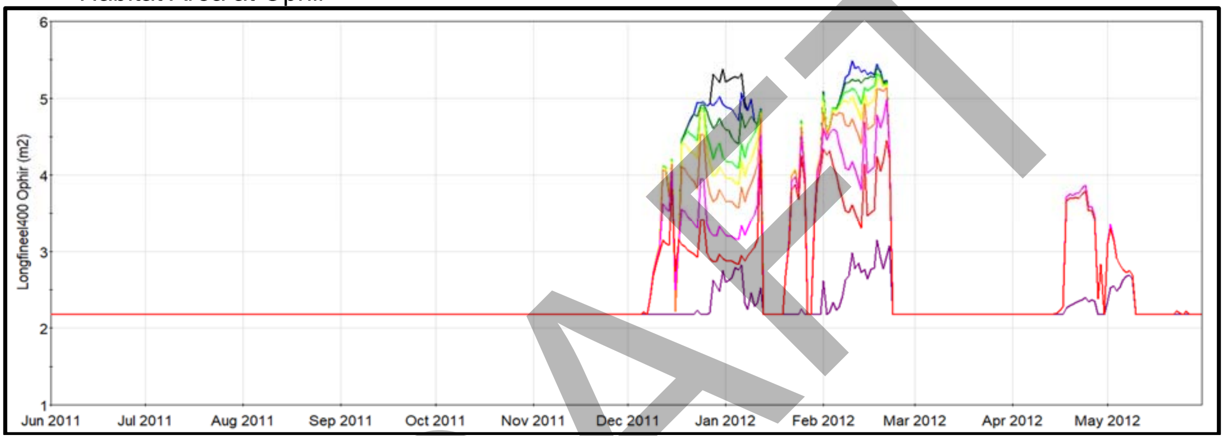


Longfin Eel > 300 mm 2011-2012 wet season

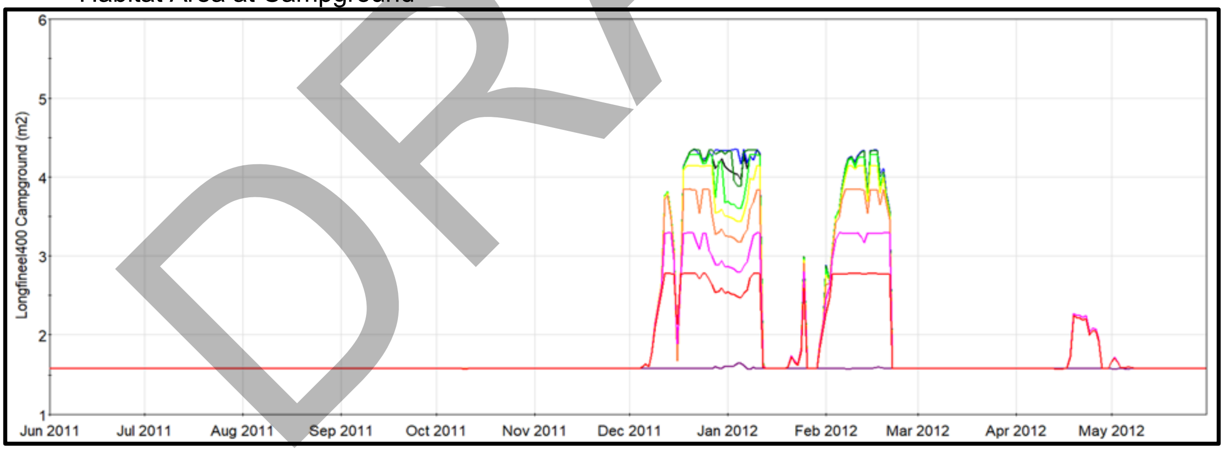
Habitat Area below Blackstone Intake:



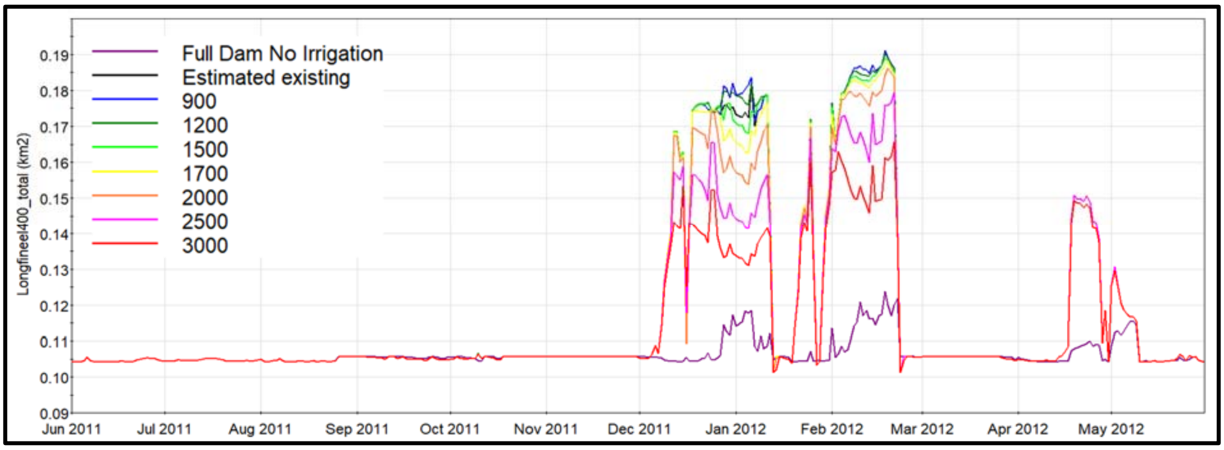
Habitat Area at Ophir



Habitat Area at Campground

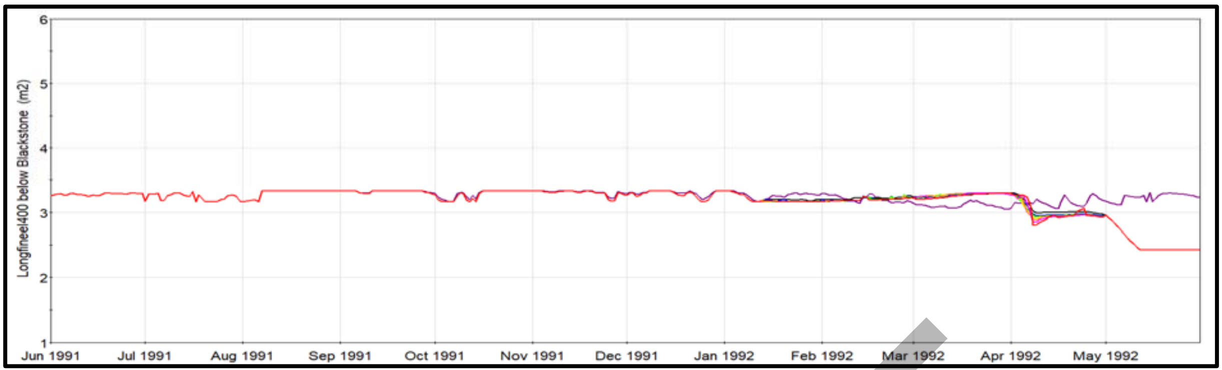


Overall Habitat Area for the Main Stem of the Manuherekia River.

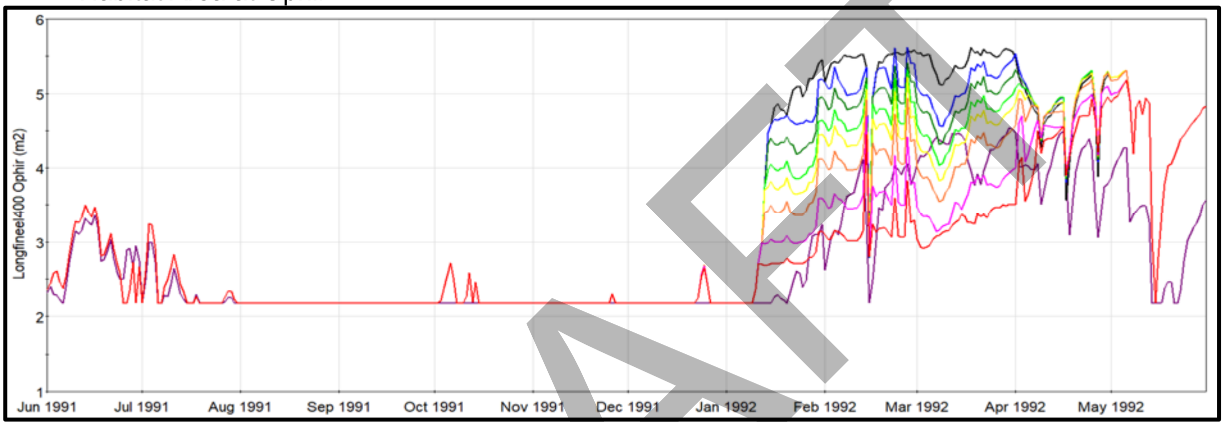


Longfin Eel > 300 mm 1991-1992 average season with a dry autumn

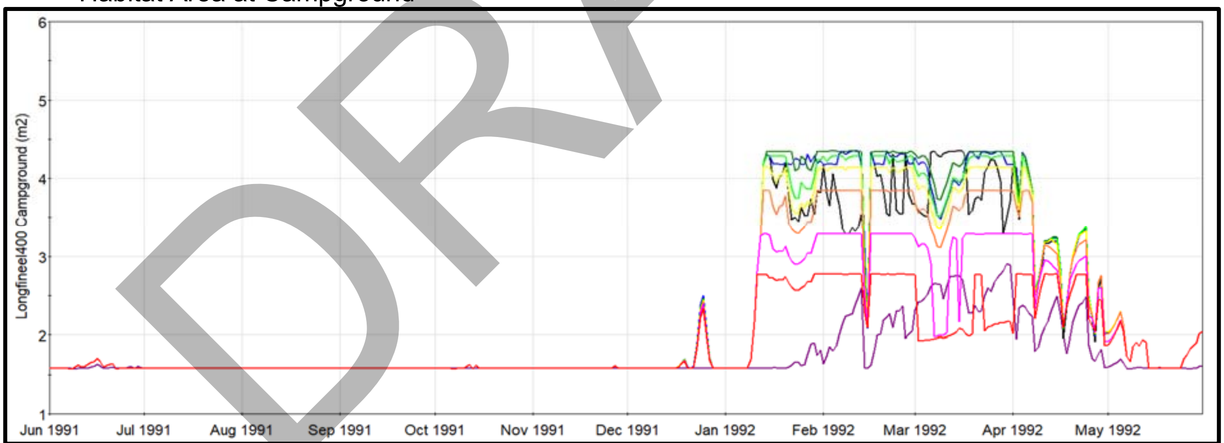
Habitat Area below Blackstone Intake:



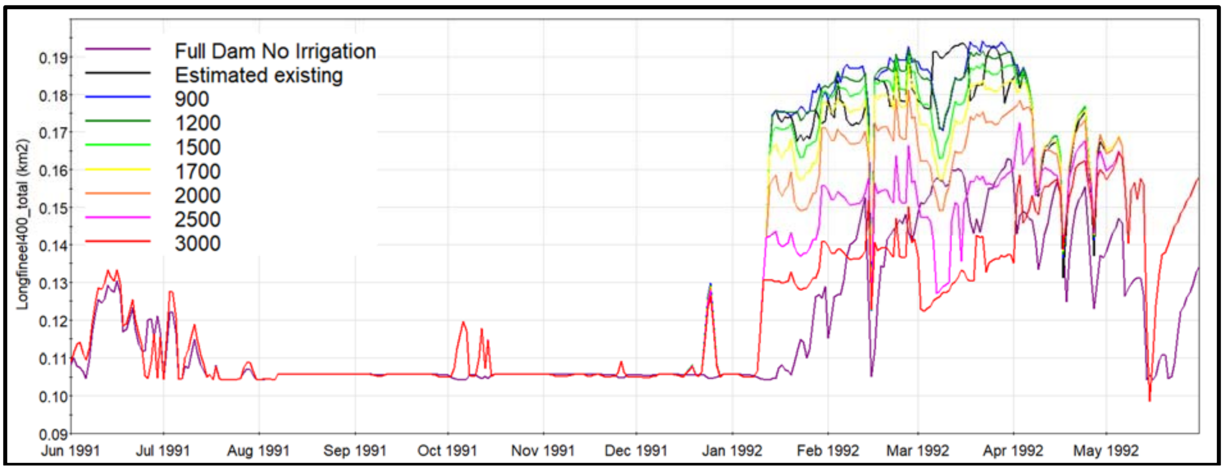
Habitat Area at Ophir



Habitat Area at Campground

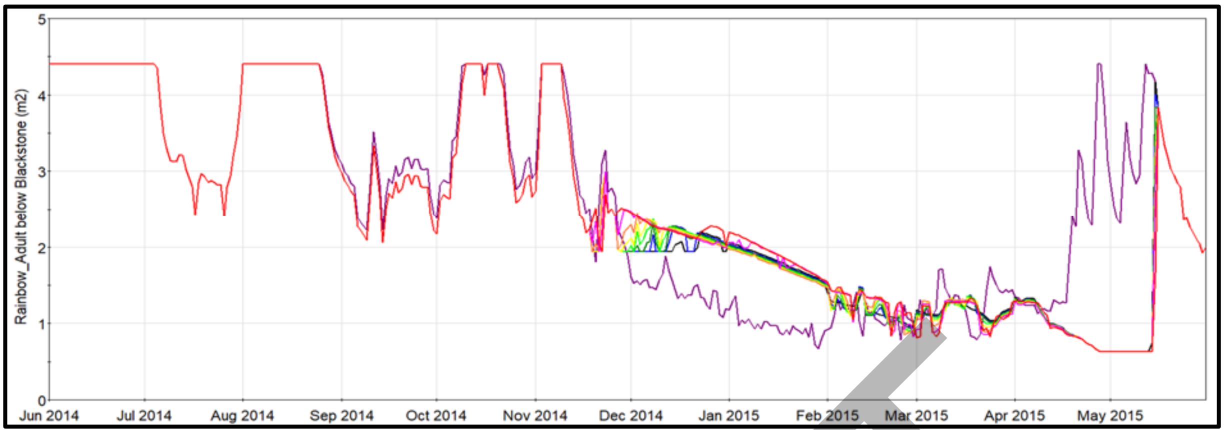


Overall Habitat Area for the Main Stem of the Manuherekia River.

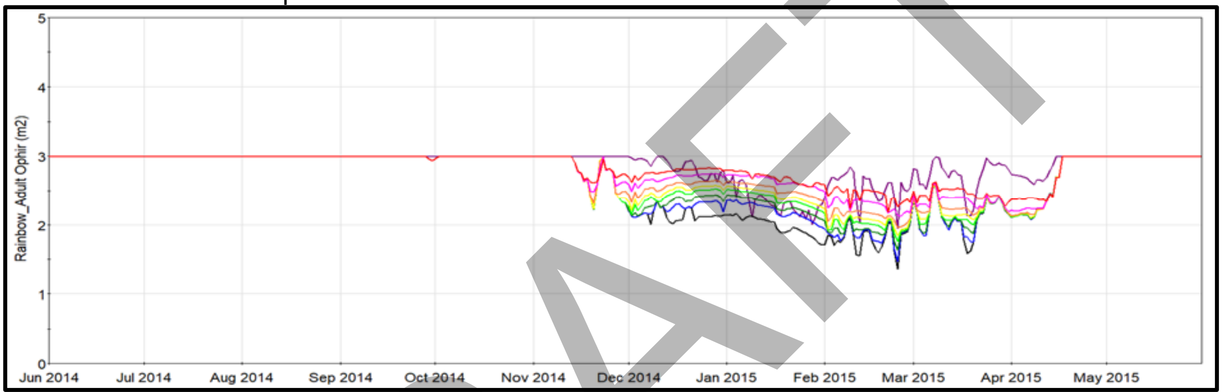


5.9 Adult Rainbow Trout (Wilding) 2014-2015 drought season

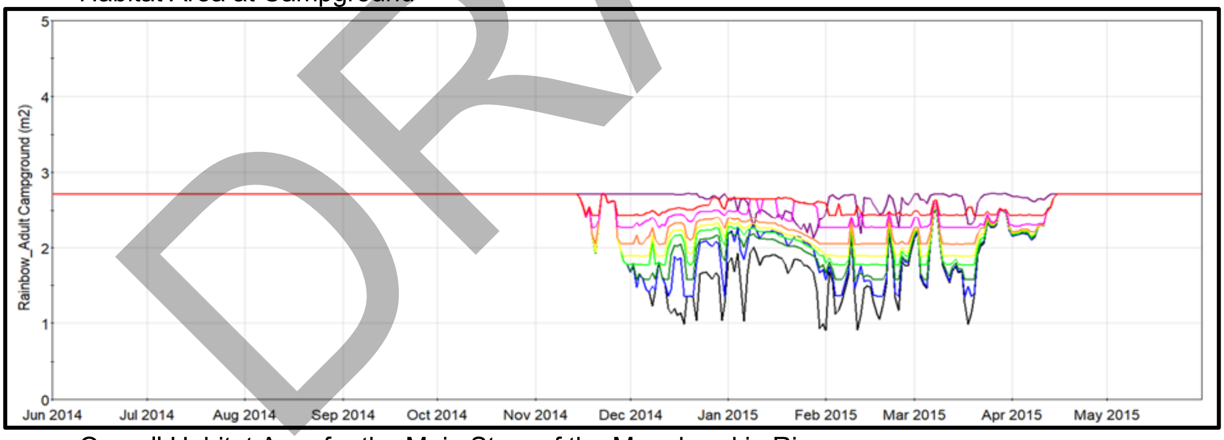
Habitat Area below Blackstone Intake:



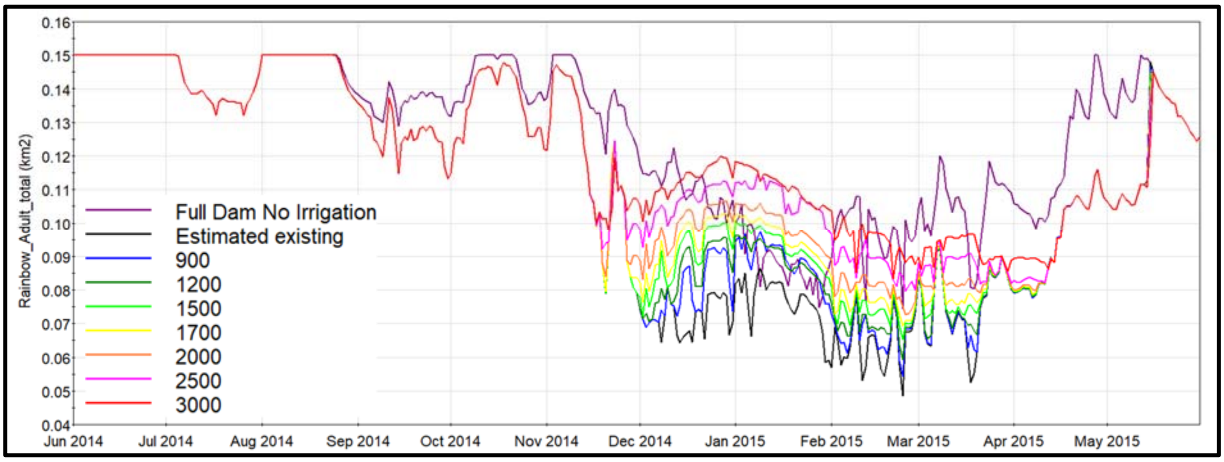
Habitat Area at Ophir



Habitat Area at Campground

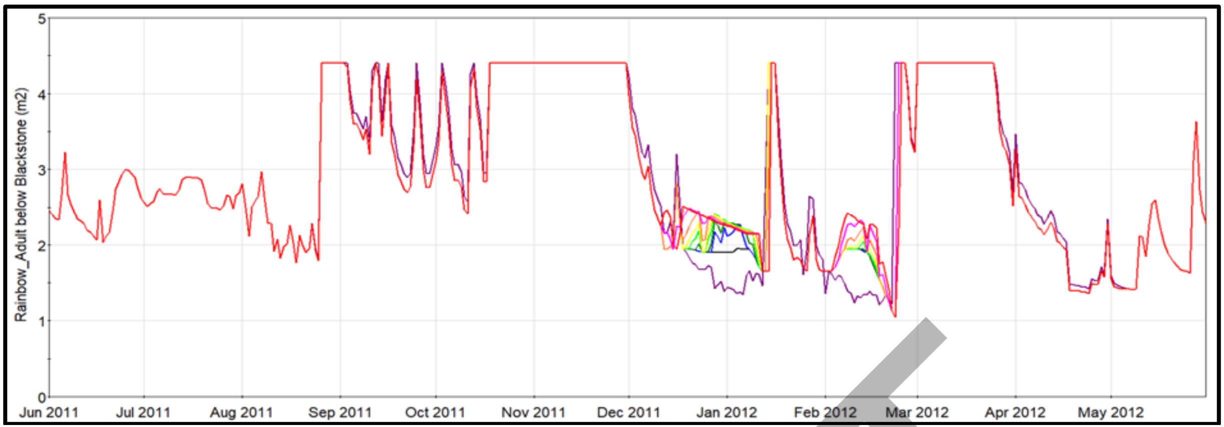


Overall Habitat Area for the Main Stem of the Manuherekia River.

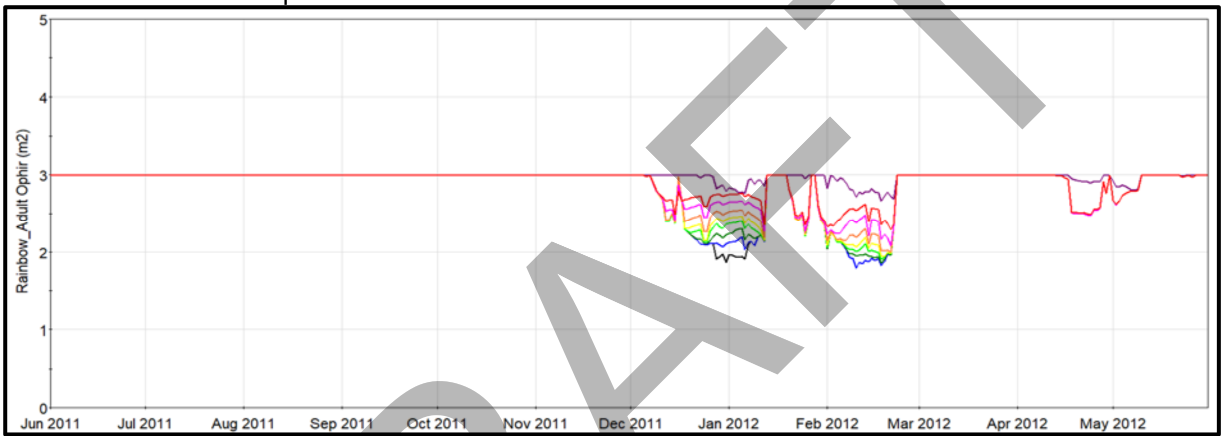


Adult Rainbow Trout (Wilding) 2011-2012 wet season

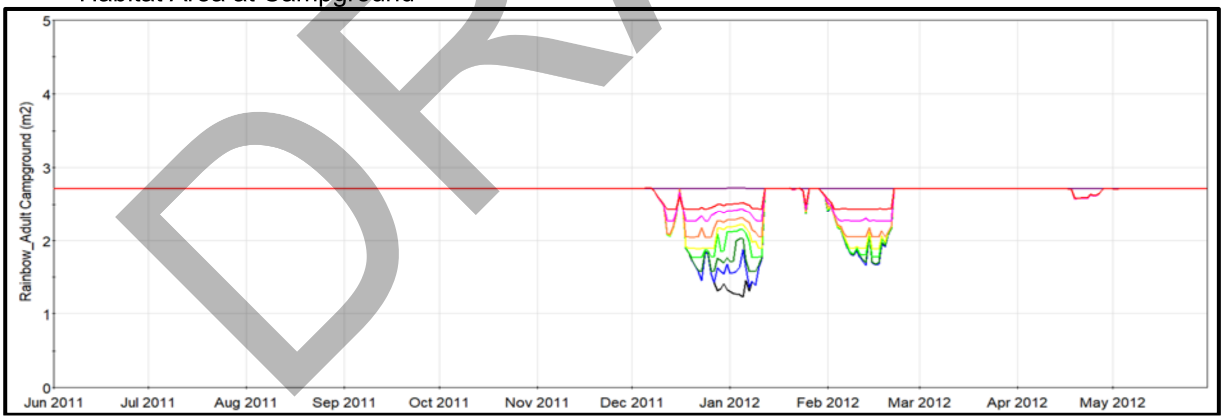
Habitat Area below Blackstone Intake:



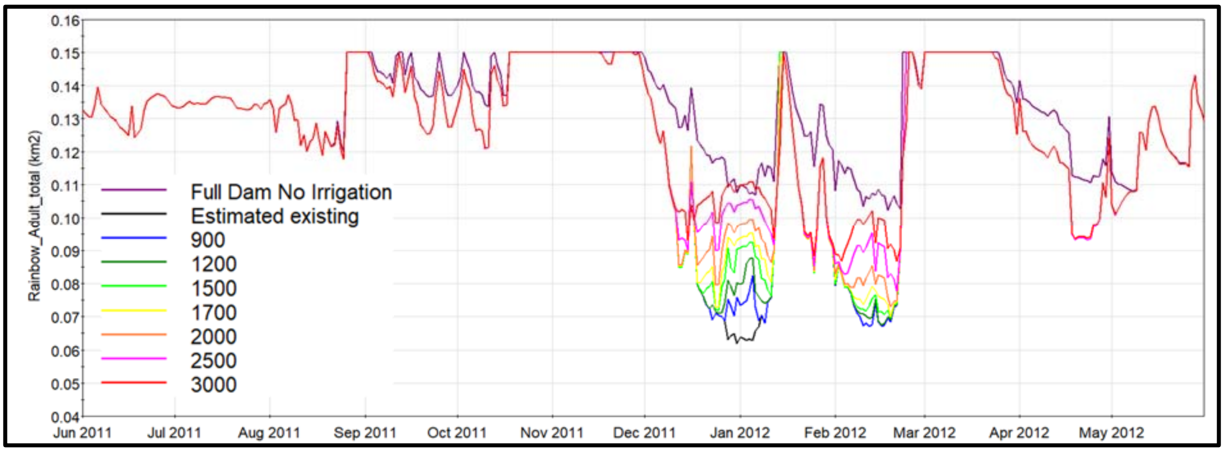
Habitat Area at Ophir



Habitat Area at Campground

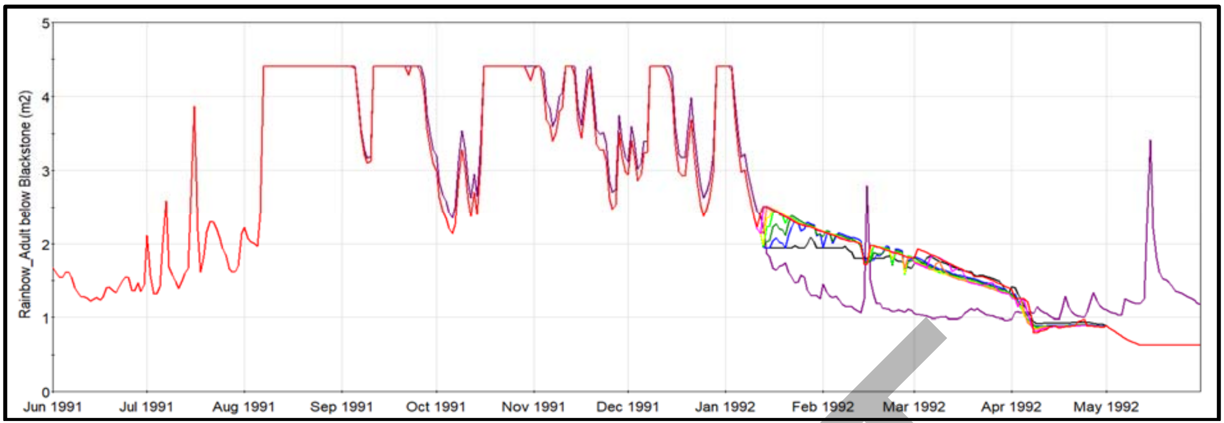


Overall Habitat Area for the Main Stem of the Manuherekia River.

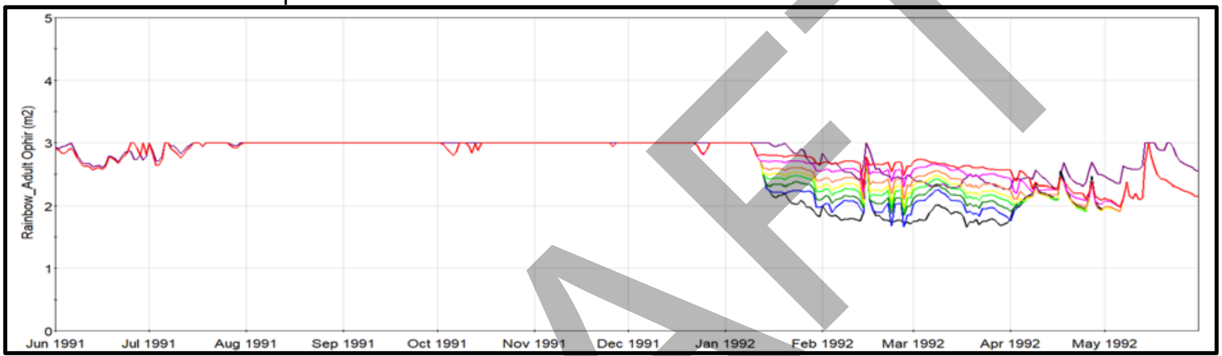


Adult Rainbow Trout (Wilding) 1991-1992 average season with a dry autumn

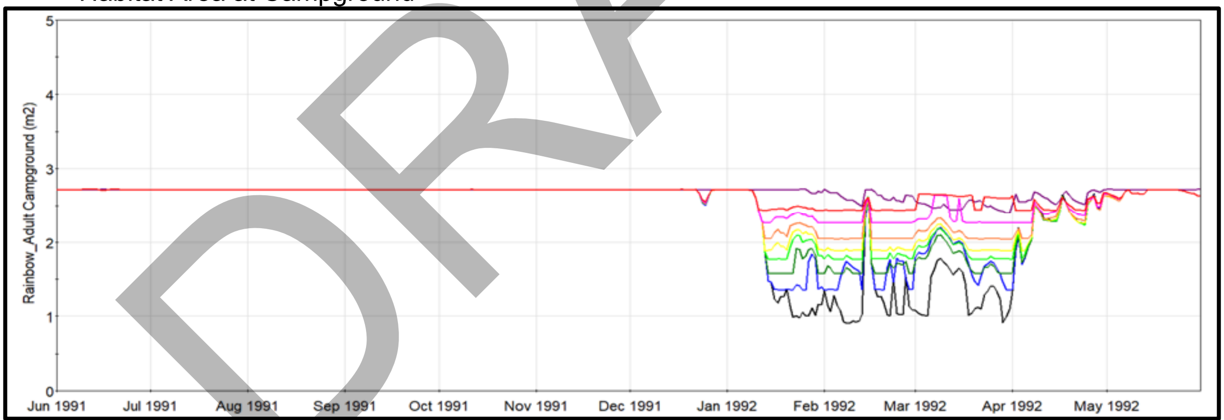
Habitat Area below Blackstone Intake:



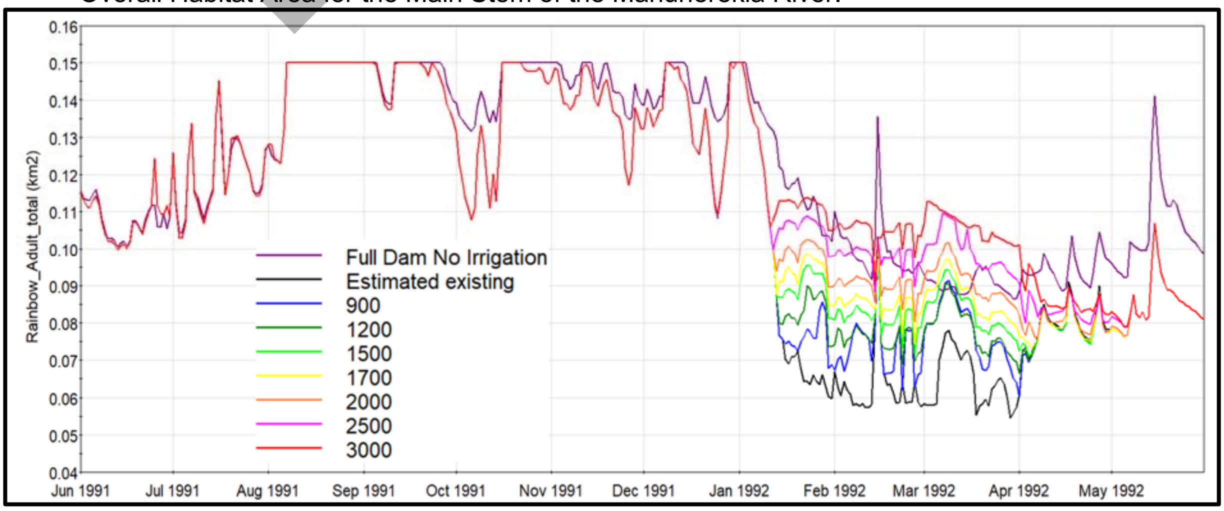
Habitat Area at Ophir



Habitat Area at Campground

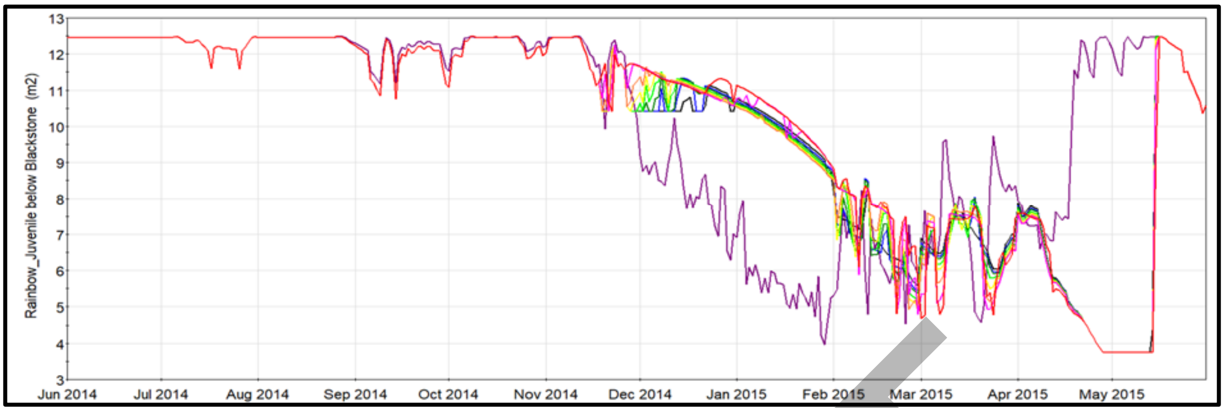


Overall Habitat Area for the Main Stem of the Manuherekia River.

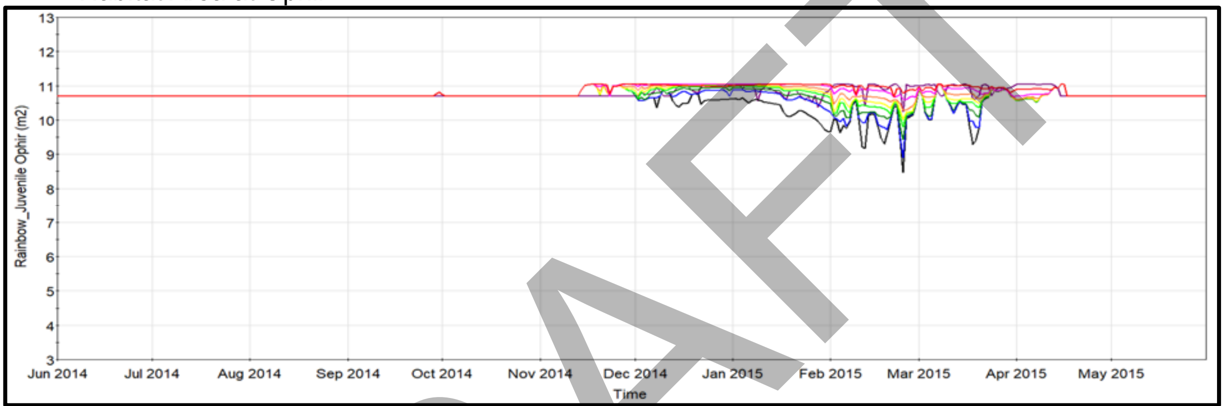


5.10 Juvenile Rainbow Trout (Wilding) 2014-2015 drought season

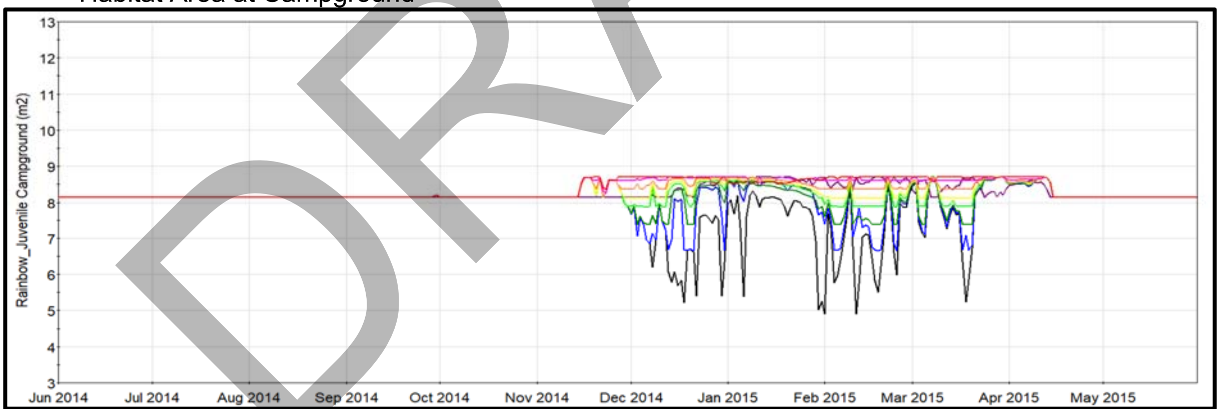
Habitat Area below Blackstone Intake:



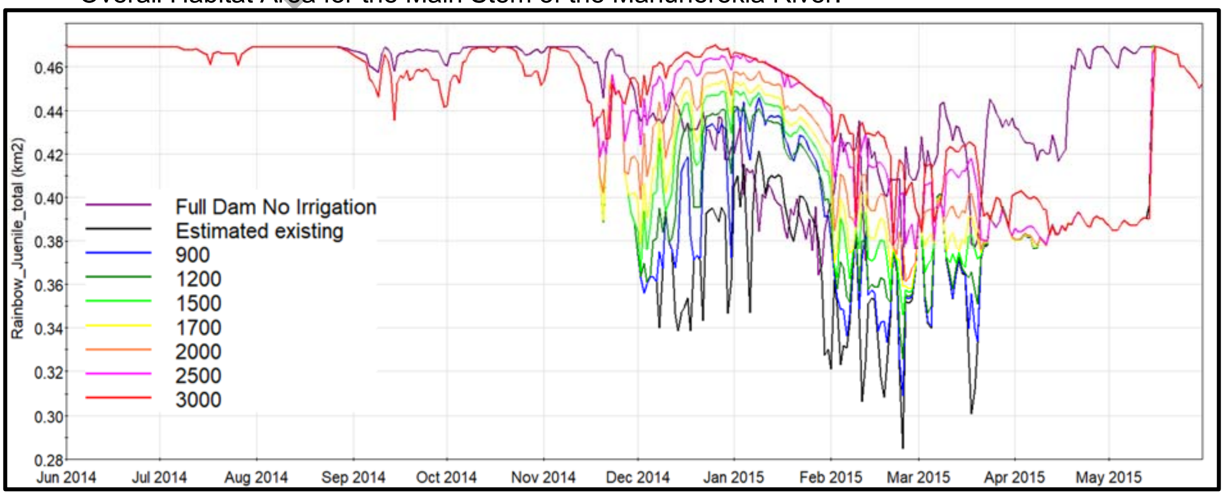
Habitat Area at Ophir



Habitat Area at Campground

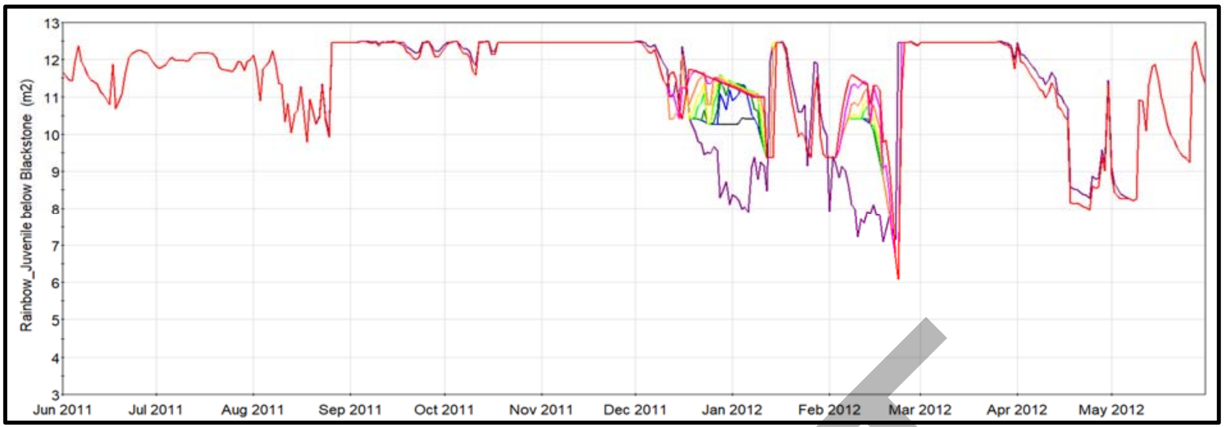


Overall Habitat Area for the Main Stem of the Manuherekia River.

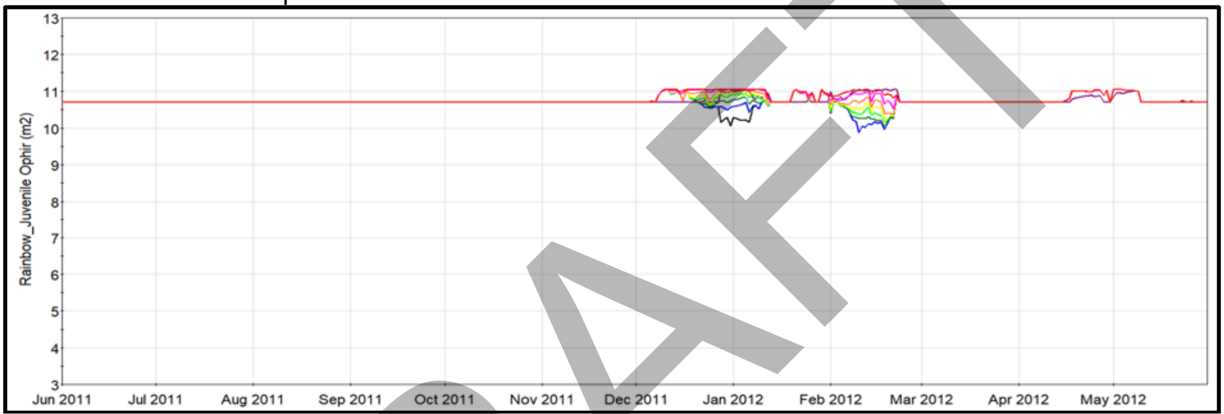


Juvenile Rainbow Trout (Wilding) 2011-2012 wet season

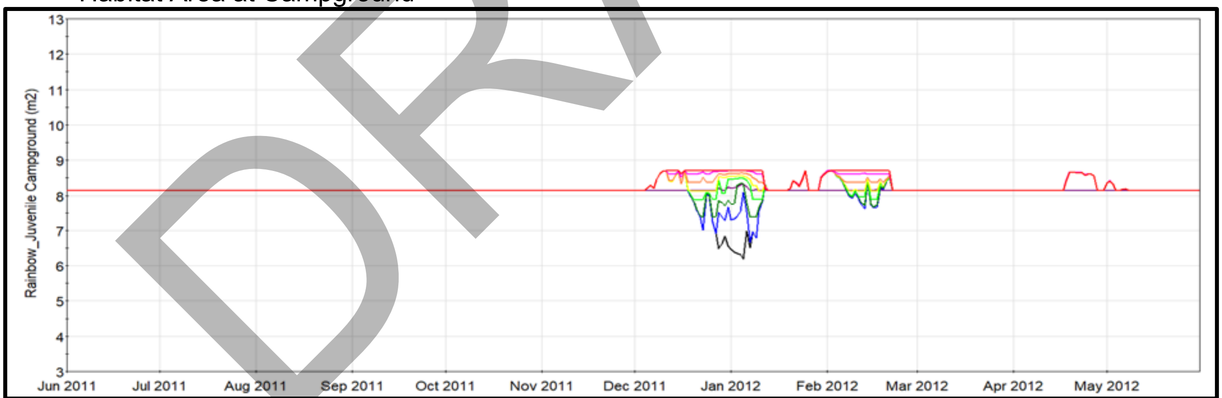
Habitat Area below Blackstone Intake:



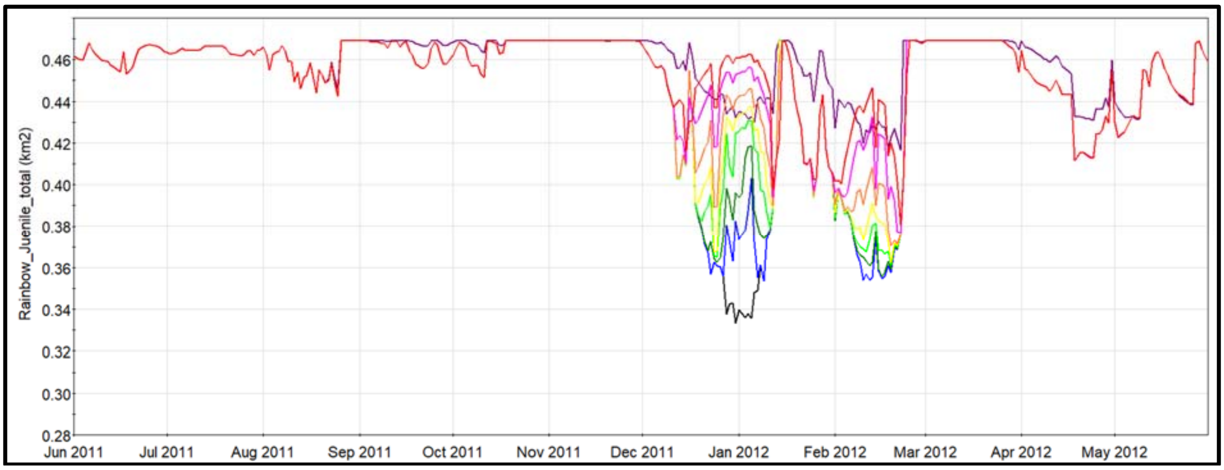
Habitat Area at Ophir



Habitat Area at Campground

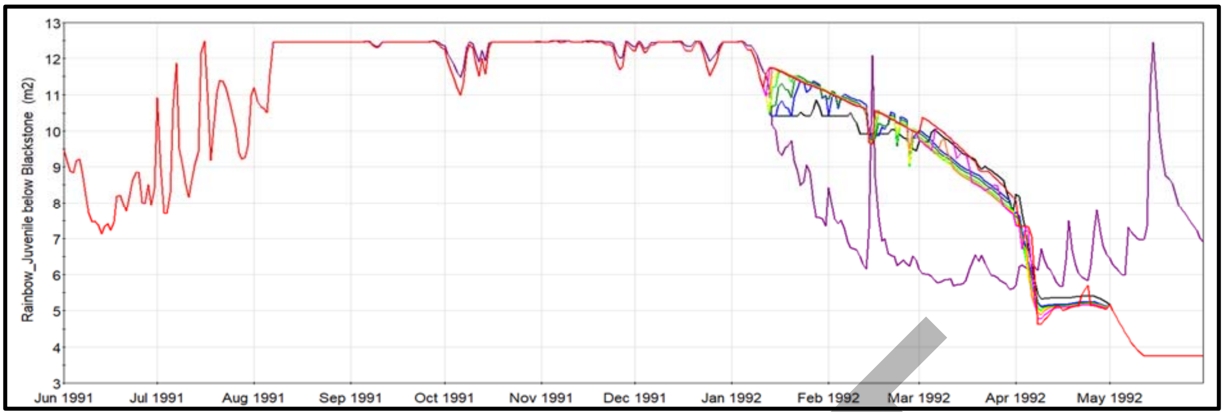


Overall Habitat Area for the Main Stem of the Manuherekia River.

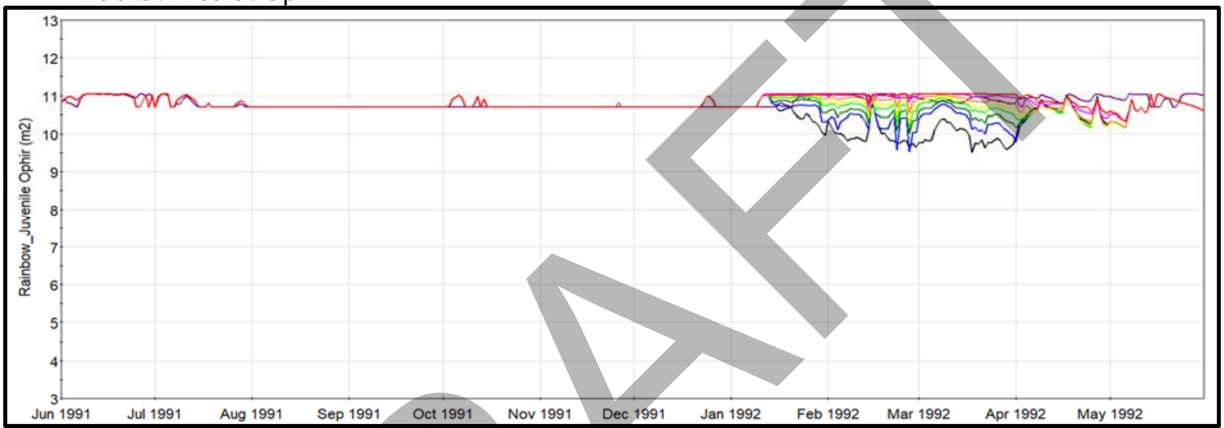


Juvenile Rainbow Trout (Wilding) 1991-1992 average season with a dry autumn

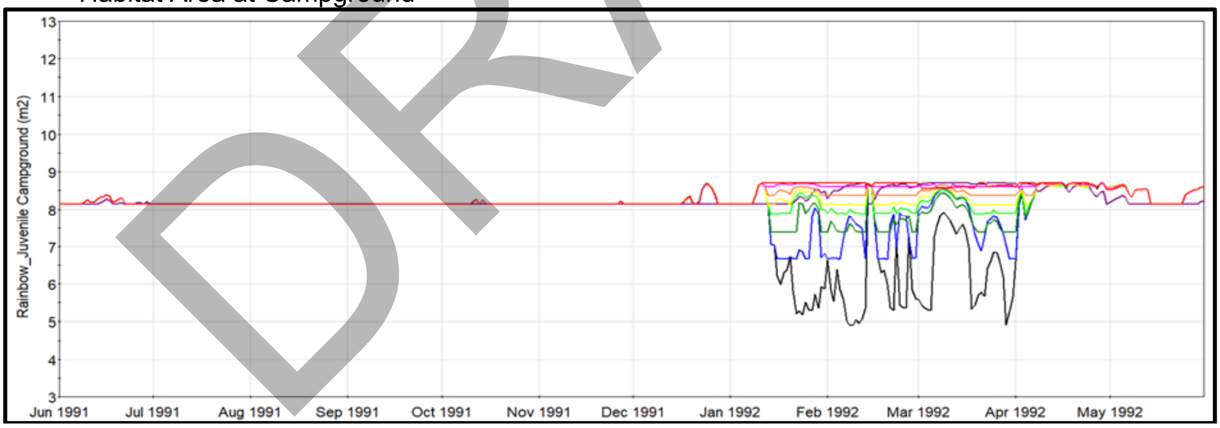
Habitat Area below Blackstone Intake:



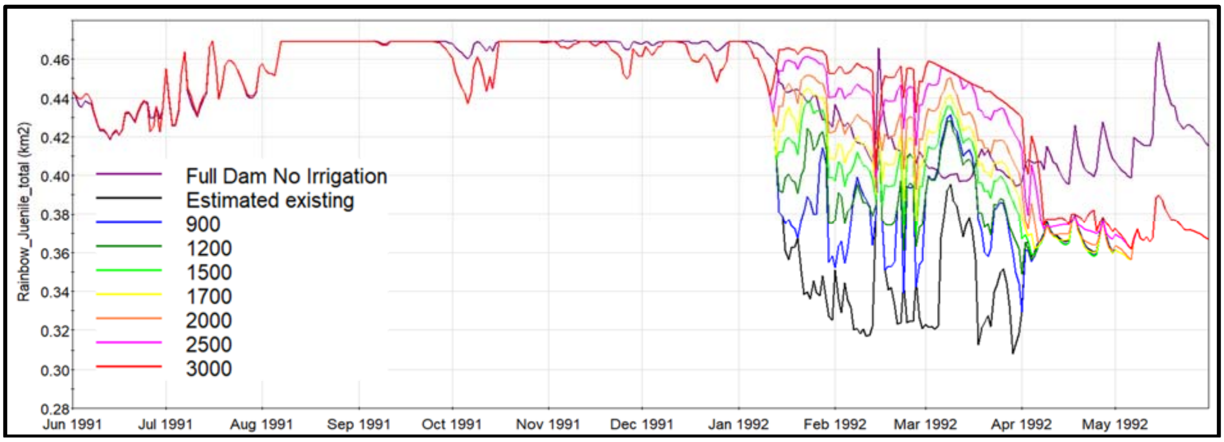
Habitat Area at Ophir



Habitat Area at Campground

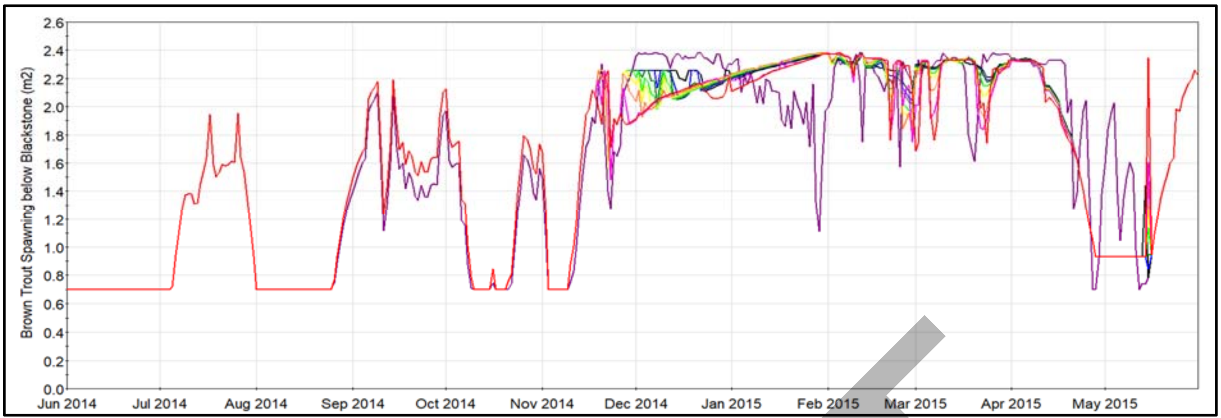


Overall Habitat Area for the Main Stem of the Manuherekia River.

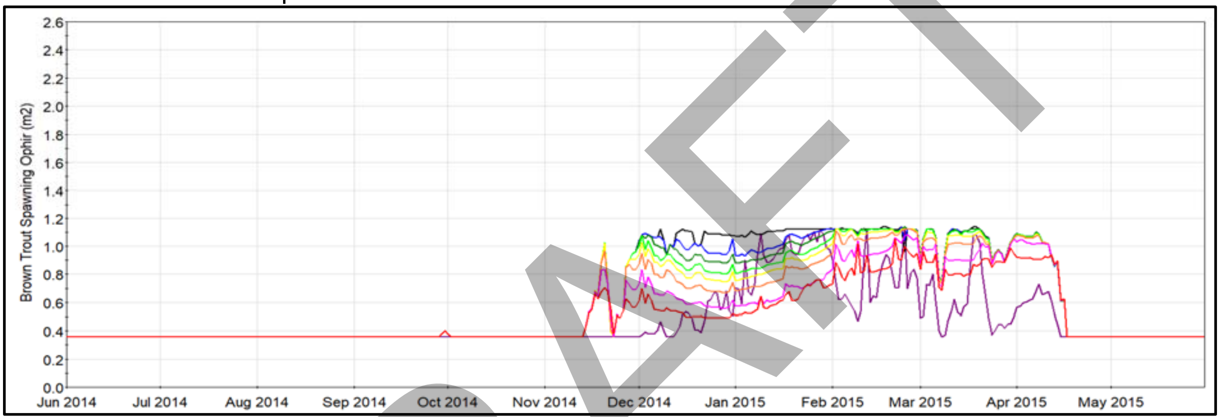


5.11 Brown Trout Spawning (Shirvell and Dungey 1983) 2014-2015 drought season

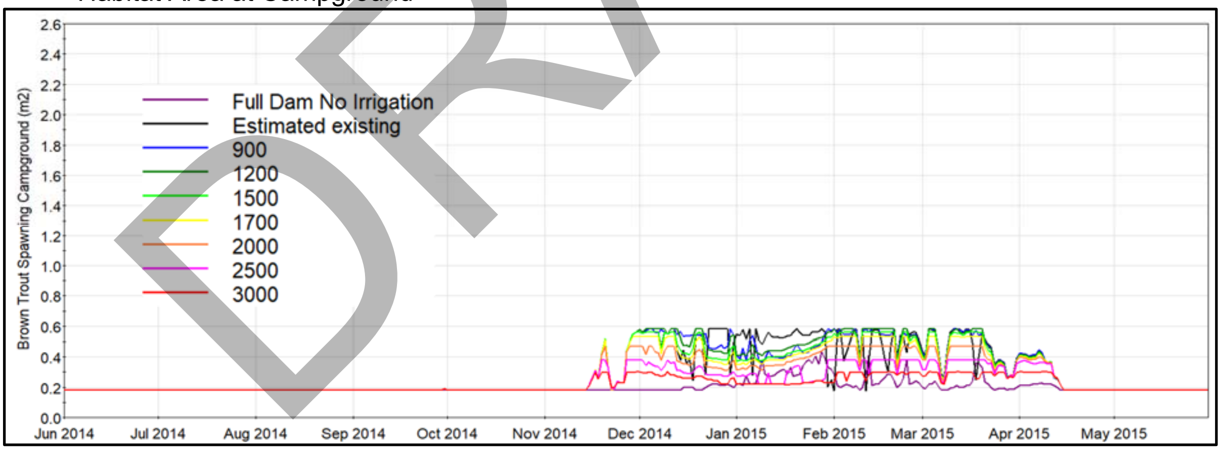
Habitat Area below Blackstone Intake:



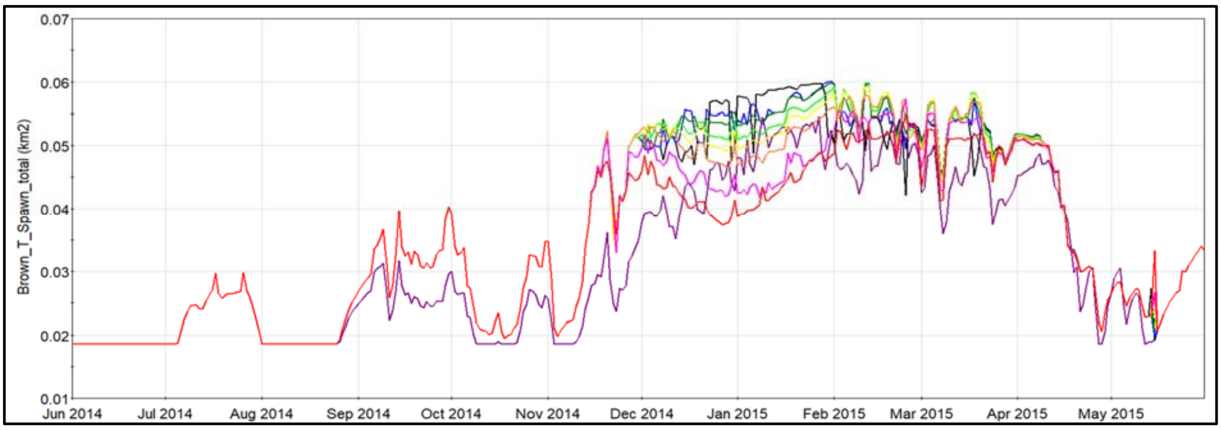
Habitat Area at Ophir



Habitat Area at Campground

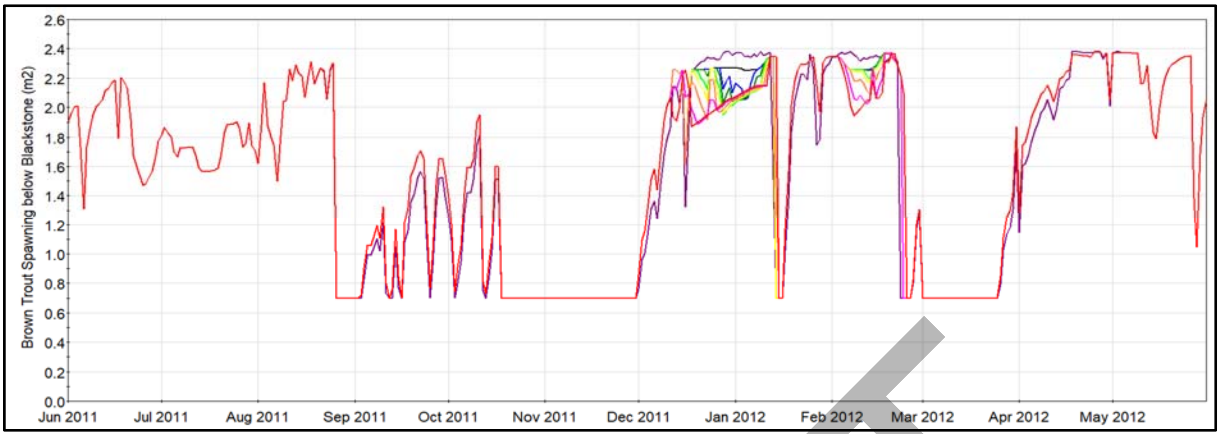


Overall Habitat Area for the Main Stem of the Manuherekia River.

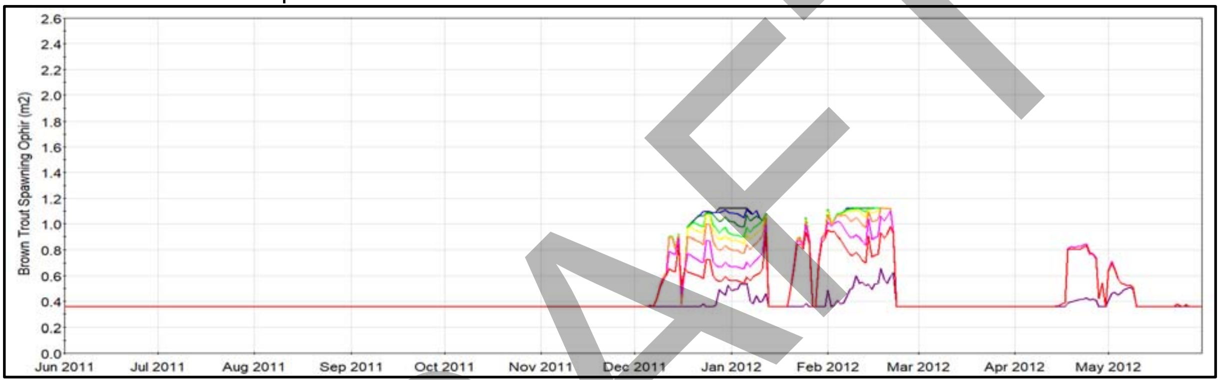


Brown Trout Spawning (Shirvell and Dungey 1983) 2011-2012 wet season

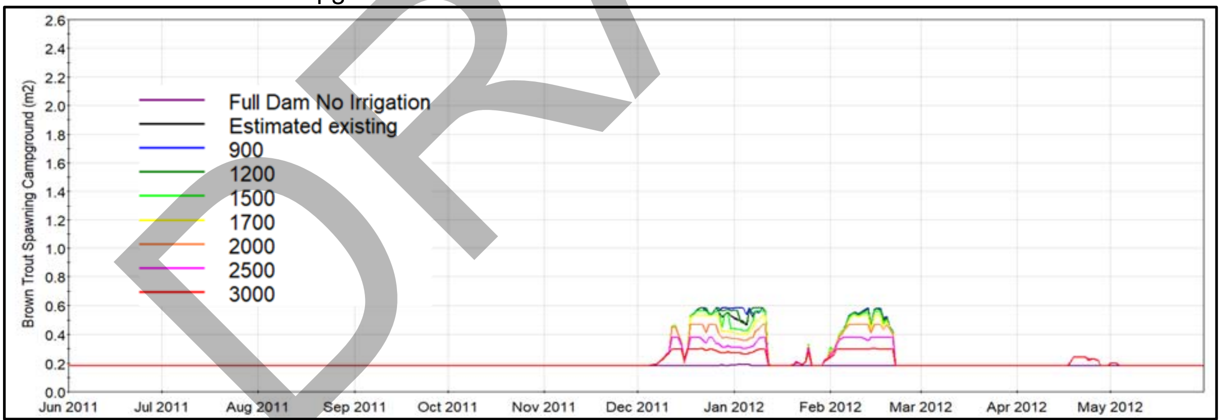
Habitat Area below Blackstone Intake:



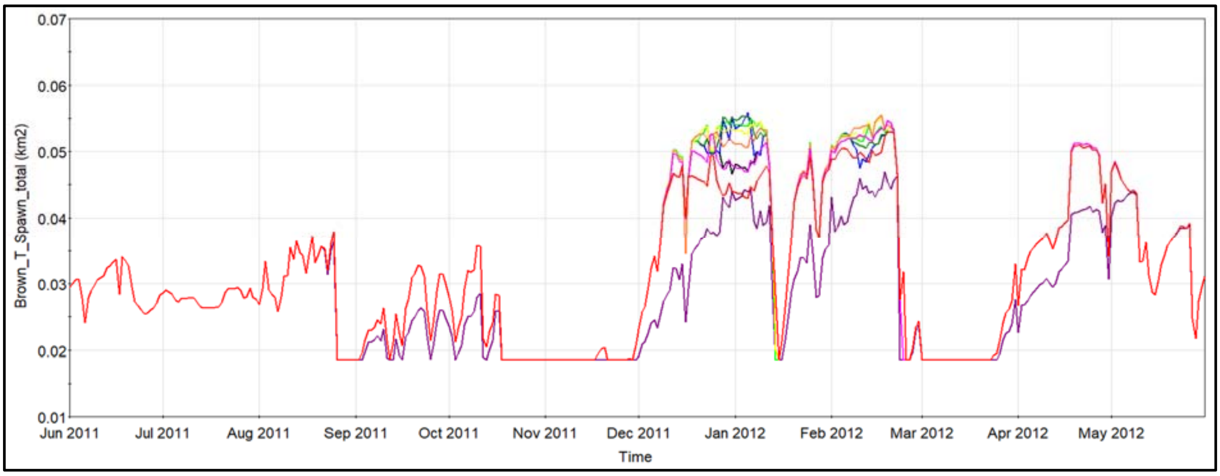
Habitat Area at Ophir



Habitat Area at Campground

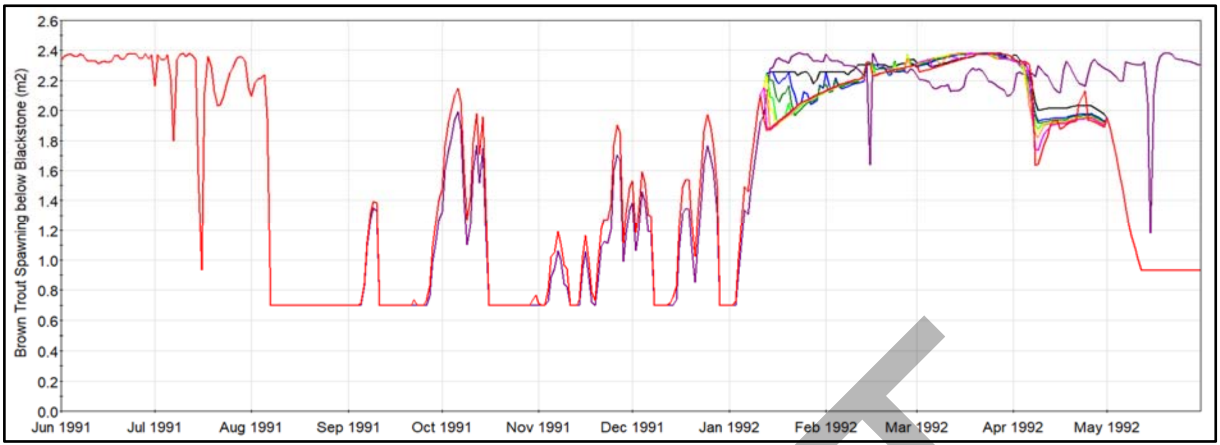


Overall Habitat Area for the Main Stem of the Manuherekia River.

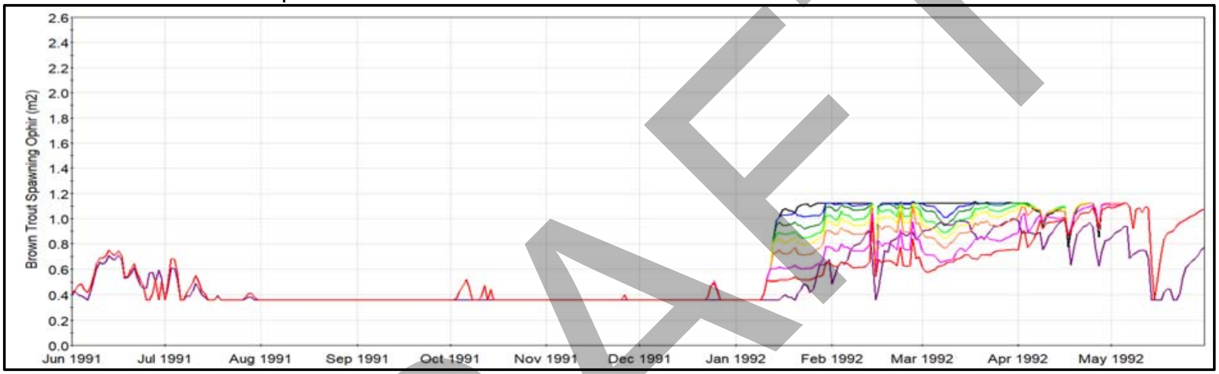


Brown Trout Spawning (Shirvell and Dungey 1983) 1991-1992 average season dry autumn

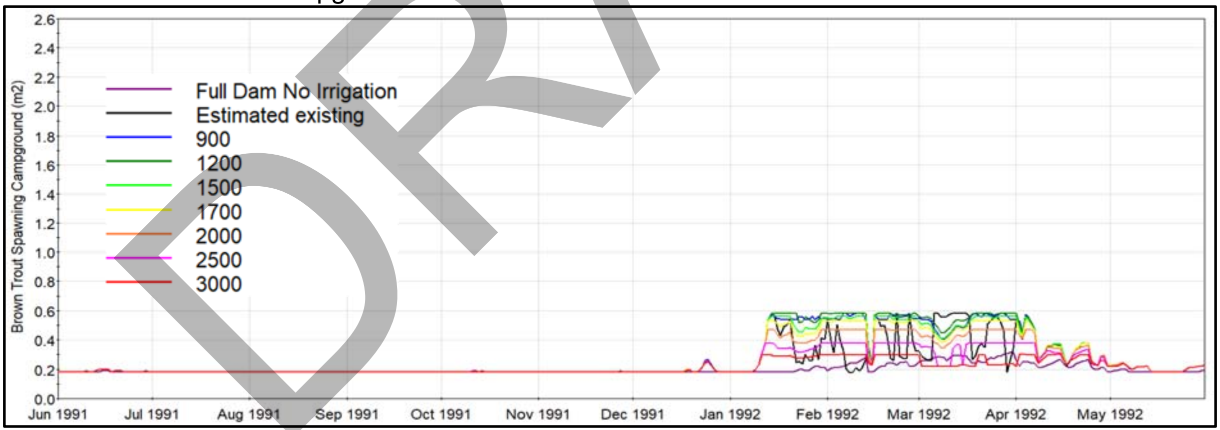
Habitat Area below Blackstone Intake:



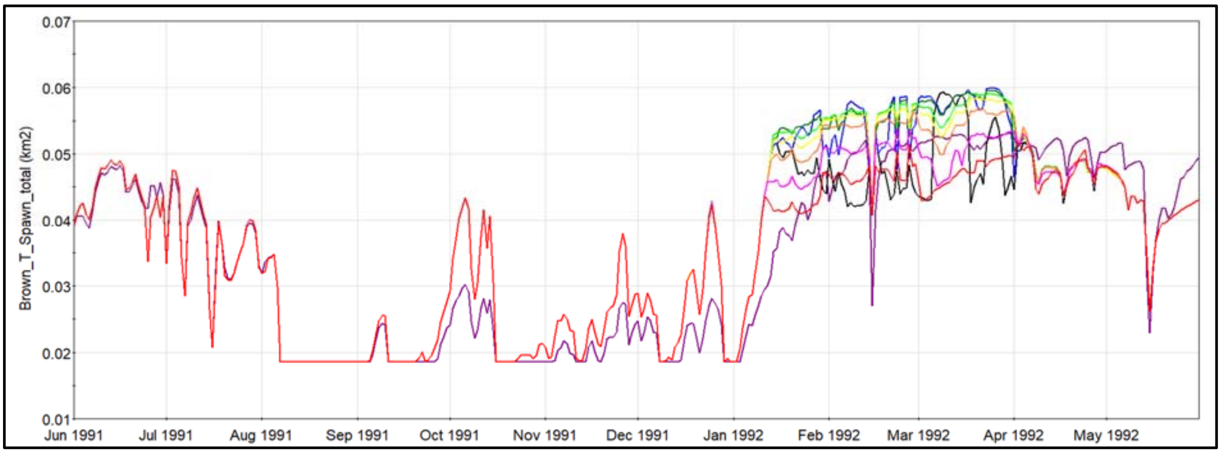
Habitat Area at Ophir



Habitat Area at Campground



Overall Habitat Area for the Main Stem of the Manuherekia River.



6.0 MODEL USE

As outlined in Section 1 there have been various drafts of this Ecological Memorandum. Each draft represents either a requested update to the ecological parts of the Manuherekia Hydrology Model[5] or a request for additional ecological output. The last ecological output from the model was provided on 22 March 2021 and included model output from the nine scenarios initially requested by ORC namely the Estimated Existing or Status Quo scenario (i.e. the model calibration run), seven future scenarios and the Full Dams and No Irrigation scenario. As highlighted in Section 4 the Manuherekia Hydrology Model has to date (21 May 2021) been used to run 30 scenarios and ecological output is available for each.

It is currently not envisaged that the Manuherekia Hydrology Model will be used to provide any further ecological output. However, the model is set up to easily run additional future scenarios and provide ecological output as required.

Due to the complexity of the model and how the model adjusts to changes care is required when developing scenarios and accessing model output.

7.0 CLOSURE

Yours faithfully,
DAVIS OGILVIE & PARTNERS LTD

IAN LLOYD
Senior Water Engineer
MSc (Environmental Science), BE (Civil), BSc (Geology)

Email:ian@do.nz

[5] Note each update to the model required the model to be re-run and the various scenarios reassessed.