To: Manuherekia TAG

From: Richard Allibone, Water Ways Consulting Ltd

Date: 26 July 2023

Subject: Manuherekia physical habitat models- risk assessment for fish results for scenarios

Dear TAG,

Introduction

I have assessed the Campground minimum flow scenarios using the 7dMALFs calculated from the Manuherekia hydrology model for each scenario at the node points in the model (Table 1).

Table 1: 7dMALF flows calculated using the Manuherekia hydrology model.

Flow Scenario	7dMALF at node points					
	Campground	Ophir	Chatto	Thomsons	Lauder	Dunstan
900	0.99	2.02	0.09	0.04	0.1	0.27
1100	1.16	2.09	0.11	0.07	0.13	0.44
1200	1.25	2.13	0.12	0.08	0.14	0.48
1500	1.53	2.25	0.13	0.09	0.17	0.56
1700	1.79	2.34	0.13	0.1	0.2	0.62
2000	2.06	2.46	0.15	0.12	0.21	0.71
2500	2.48	2.72	0.16	0.14	0.26	0.85
3000	2.97	2.98	0.17	0.16	0.31	0.97
Falls Dam full, no irrigation	4.04	3.4	0.22	0.19	0.35	1.11

This risk assessment is though just for changes to predicted habitat for fish species and/or their life history stages. It does not consider other flow dependent factors such as fish passage, the effect of flow on the provision of food for drift and filter feeding fish and whether declining habitat area will trigger density dependent interactions such as competition for food and space, changes to predator prey interactions and any territorial interactions.

This assessment as not included reaches of the Manuherekia River upstream of the Dunstan Creek confluence. The reach from Falls Dam to Blackstone Irrigation Company water take is subject to flow augmentation as water is released from Falls Dam. The habitat model (Duncan & Bind 2016[1]) for the reach between the Blackstone Irrigation company and the Omakau Irrigation Company water takes indicates this water augmentation can significantly alter habitat for fish species. However, there are no flow statistics available for this reach from the Manuherekia hydrology model and the habitat model is not suitable for modelling reaches of the river upstream of Blackstone Irrigation Company take where the flow modification is the greatest.

The risk assessment for the Campground/Galloway reach of the Manuherekia River has been conducted in workshops by the TAG but has been included here for completeness.

[1] Duncan, M & J Bind (2016). Instream habitat, and minimum flow requirements in the Manuherikia River. NIWA Client Report CHC2016-034. Prepared for the Otago Regional Council.

Manuherekia River at Campground- Galloway

The Manuherekia River at Campground-Galloway 7dMALF flows range from 0.99 m^3/s for the 0.900 m^3/s minimum flow scenario to 4.04 m^3/s for the full dam no irrigation scenario, a 3.05 m^3/s flow range (Table 1).

Analysis for habitat for Manuherekia River at Campground- Galloway

The results of this analysis are summarised in Table 2.

Primary consumers - fish – juvenile lamprey are filter feeders and can be considered a primary consumer and a secondary consumer. The two HSCs for lamprey (Jowett & Richardson 2008, Jellyman & Glova 2002) show no change in habitat available across the scenario flow range and therefore the risk of habitat loss is considered a very low risk for all scenarios. But how lamprey feeding rates vary with flow or how lamprey density varies with flow as feeding rate changes has not been investigated.

Secondary consumers - fish. This includes upland bully, Central Otago roundhead galaxias and longfin eel < 300 mm.

Central Otago roundhead juvenile and Central Otago roundhead adult habitat both have their peak habitat at or below the lowest flow scenario and habitat declines as flow increases. Therefore, the galaxiid is assessed as having a very low risk. However, there is some uncertainty as to the importance of this assessment as Central Otago roundheads have not been found in this reach of the river.

It is also worth noting only juvenile galaxiids have been found near the model site and adults have only been reported in reaches upstream of the model reach. This means the Thomsons Creek model is possibly of limited value for assessing the flow scenario effects on adult Central Otago roundhead galaxias habitat.

Upland bully habitat peaks at the lowest flow in the scenario range and is assessed as having a very low risk for all scenarios.

Small longfin eels (< 300 mm). The two habitat preference curves show different trends with one having habitat slowly increasing as flow increases and one having habitat stable through the scenario flow range. The Jellyman et al (2003) HSCs has a 48% decline from the full dam no irrigation scenario to the 0.900 m^3/s minimum flow and the 1100 m^3/s and 1200 m^3/s are also greater then 40 % declines. The habitat loss at the 1500 and 1700 minimum flows is in the 60-70% range of moderate risk. Given the differences in the two HSC predictions the risk is assessed sa one level less than predicted from the Jellyman et al (2003) HSC.

Trout fry (< 100 mm) are either predicted to be stable or decline slowly as flow increases. Therefore, all scenarios are considered to have a very low risk of habitat loss for trout fry.

Tertiary consumers – large longfins (>300 mm). Both the two habitat preference curves indicate available habitat is decreasing, albeit at different rates with increasing with flow. However, as the higher flows have less habitat than the lower flows the effect on large longfin eel habitat is considered very low risk.

Juvenile and adult trout life history stages. The two yearling trout habitat HSCs show a decline in habitat as flow increases. The habitat for juvenile trout (juvenile trout Wilding) does peak in the 2.0 to 3.0 m^3/s flow range and declines below 2.0 m^3/s so that the 0.9 m^3/s minimum flow is predicted to have a 24% drop in habitat compared to the full dam no irrigation scenario flow. This indicates a low risk but this contrasts to the other two HSCs that peak habitt near 1.0 m^3/s Therefore, the risk to juvenile trout is considered very low risk of habitat loss for the flow scenarios.

Adult trout habitat (HSC, adult trout Wilding) increases as flow increases. The three lowest minimum flow scenarios are all predicted to have between 50-60% decline in habitat compared to the full dam no irrigation scenario and can be consider high risk. Only the 2.5 m^3/s and 3.0 m^3/s minimum flow scenarios are in the very low risk category of less than 20% habitat decline. However, the Hayes & Jowett (1994) HSC for adult brown trout has its peak habitat at 2.2 m^3/s and habitat decreases either side of this flow. The predicted habitat at the full dam no irrigation scenario is 24% greater than the at the 0.9 m^3/s minimum flow and all other scenarios are a less than 20 % change in habitat for adult brown trout. The difference between the two HSCs is likely to be the influence of rainbow trout on the adult trout HSC (Wilding HSC). For the risk assessment for adult trout the 0.9 m^3/s to 1.2 m^3/s minimum flows represent habitat loss using both HSCs and is considered high risk. For higher minimum flows the risk is moderate

Table 2: Risk result table for the Manuherekia River at Campground-Galloway fish habitat.

	Species				
Flow Scenario /Campground	**Lamprey**	**Upland bully**	**Roundhead galaxias juv/adult**	**Longfin eel < 300 mm/ >300 mm**	**Trout fry/juvenile / adult**
900/0.04	VLR*	VLR	VLR / VLR	MR / VLR	VLR / VLR/ HR
1100/0.07	VLR	VLR	VLR / VLR	MR / VLR	VLR / VLR/ HR
1200/0.08	VLR	VLR	VLR / VLR	MR / VLR	VLR / VLR / HR
1500/0.09	VLR	VLR	VLR / VLR	LR / VLR	VLR / VLR / MR
1700/0.1	VLR	VLR	VLR / VLR	LR / VLR	VLR / VLR / MR
2000/0.12	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / LR
2500/0.14	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
3000/0.16	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR

*risk assessment abbreviations: VLR- very low risk; LR – low risk; MR moderate risk; HR – high risk; VHR – very high risk

Manuherekia River at Ophir

The Manuherekia River at Ophir 7dMALF flows range from 2.02 m^3/s for the 0.900 m^3/s minimum flow scenario to 3.40 m^3/s for the full dam no irrigation scenario, a 1.38m^3/s flow range. However, the actual flow at the model site is upstream of the Thomsons Creek confluence so has less flow than the hydrology model node point at the Ophir flow gauge on the Manuherekia River. Therefore, this risk assessment uses the Manuherekia at Ophir 7d MALFs minus the corresponding Thomsons Creek 7dMALFs.

Analysis for habitat for Manuherekia River at Ophir

The results of this analysis are summarised in Table 4.

Primary consumers - fish – juvenile lamprey are filter feeders and can be considered a primary consumer and a secondary consumer. The two HSCs for lamprey (Jowett & Richardson 2008, Jellyman & Glova 2002) show different responses to the change in flow with one having a constant low rate of habitat increase with increasing flow and the second showing a more rapid decline in habitat as flow increases. While the responses to changing flow are different both HSCs predict relatively little habitat is present for lamprey. The HSCs that predict habitat decreases with flow can be assessed as having a very low risk of habitat loss for all the minimum flow scenarios as all will lead to a reduction in flow. The HSCs with the slow increase in habitat with flow retains 80% or more of the full dam no irrigation scenario habitat and is therefore also considered a very low risk. But how lamprey feeding rates vary with flow or how lamprey density varies with flow as feeding rate changes has not been investigated.

Table 3: Estimated 7dMALF flows for the Manuherekia River at Ophir.

Flow Scenario	Manuherekia at Ophir 7dMALF flows	Manuherekia at Ophir – Thomsons Creek 7dMALFs
900	2.02	1.98
1100	2.09	2.02
1200	2.13	2.07
1500	2.25	2.16
1700	2.34	2.24
2000	2.46	2.31
2500	2.72	2.58
3000	2.98	2.81
Falls Dam full, no irrigation	3.40	3.21

Secondary consumers - fish. This includes upland bully, Central Otago roundhead galaxias and longfin eel < 300 mm.

Central Otago roundhead juvenile and Central Otago roundhead adult habitat both have their peak habitat at the lowest flow and habitat declines as flow increases. Therefore, the galaxiid is assessed as having a very low risk. However, there is some uncertainty as to the importance of this assessment as they are only occasional observations of galaxiid fry near the Chatto Creek confluence and juvenile and adult Central Otago roundheads have not been found in this reach of the river.

Upland bully habitat peaks at below the lowest flow scenario range and is assessed as having a very low risk for all scenarios.

Small longfin eels (< 300 mm). The two habitat preference curves show different trends with one having habitat slowly increasing as flow increases and one having habitat slowly decreasing as flow increases. Neither HSCs predicts a change greater than 20% so the risk is considered very low.

Trout fry (< 100 mm) are either predicted to be stable or decline slowly as flow increases. Therefore, all scenarios are considered to have a very low risk of habitat loss for trout fry.

Tertiary consumers – large longfins (>300 mm). Both the two habitat preference curves indicate available habitat is decreasing with increasing with flow. The change in habitat over the full flow range is 10% and 30% for the two different HSCs. As the higher flows have less habitat than the lower flows the effect on large longfin eel habitat is considered very low risk.

Table 4: Risk result table for the Manuherekia River at Ophir fish habitat.

Flow Scenario /Ophir	Species				
	Lamprey	Upland bully	Roundhead galaxias juv/adult	Longfin eel < 300 mm/ >300 mm	Trout fry/juvenile / adult
900/0.04	VLR*	VLR	VLR / VLR	VLR / VLR	VLR / VLR/ VLR
1100/0.07	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR/ VLR
1200/0.08	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
1500/0.09	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
1700/0.1	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
2000/0.12	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
2500/0.14	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
3000/0.16	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR

Juvenile and adult trout life history stages. The juvenile, and yearling trout habitat declines as flow increases generally by less than 20%. Therefore, there is a low to very low risk of loss of juvenile and yearling trout habitat for the flow scenarios. Adult trout habitat increases as flow increases. The Hayes & Jowett (1994) HSCs has its peak habitat at 2.9 m^3/s and change in habitat for flows either 0.2 m^3/s less or 0.1 m^3/s more are minor. The Wilding general adult trout HSC has a near constant rate of increase as flow increases throughout the flow range. However, the predicted habitat available at the lowest minimum flow scenario (0.9 m^3/s) is only 20% less than the full dam, no irrigation scenario. Therefore, the risk to adult trout habitat is assessed as very low risk.

Thomsons Creek

The Thomsons Creek 7dMALF flows range from 0.04 m^3/s for the 0.900 m^3/s to 0.19 m^3/s for the full dam no irrigation scenario, a 0.15 m^3/s flow range. However, the actual flow at the model site will be less than the 7dMALFs used here as the model reach is upstream of the Sludge Channel confluence so will have lower 7dMALFs than provided by the Manuherekia hydrology model node point at the confluence with the Manuherekia River. The NIWA national hydrology model (NZ River Maps (niwa.co.nz)) indicates that the MALF for Thomsons Creek is 0.1313 m^3/s and for the Sludge Channel its MALF is 0.1075 m^3/s. Therefore, the assessment has used the Thomsons Creek flows statistics calculated at the confluence with the Manuherekia River from the Manuherekia hydrology model and conducted a second analysis using 55% of this flow (Table 5) as estimates of the scenario 7dMALF flows immediately upstream of White Road where the habitat model is located.

Table 5: Estimated 7dMALF flows for Thomsons Creek at the Manuherekia River confluence and upstream of White Road.

Flow Scenario	Thomsons Creek 7dMALF flows	
	Thomsons at confluence	Thomsons at White Road
900	0.04	0.022
1100	0.07	0.039
1200	0.08	0.044
1500	0.09	0.05
1700	0.1	0.055
2000	0.12	0.066
2500	0.14	0.077
3000	0.16	0.088
Falls Dam full, no irrigation	0.19	0.105

Thomsons Creek Analysis for habitat at Manuherekia River confluence

This analysis assumes habitat in Thomsons Creek near the confluence with the Manuherekia River is the same or similar enough that the habitat model provides reliable predictions of the habitat at in Thomsons Creek near the confluence. The results of this analysis are summarised in Table 3.

Primary consumers - fish – juvenile lamprey are filter feeders and can be considered a primary consumer and a secondary consumer. There is no change in habitat available across the 0.04 m^3/s to 0.19 m^3/s flow range. Therefore, the risk of habitat change across the scenarios is very low risk. However, as a filter feeder an increase in flow is likely to increase feeding rates as more particles are likely to be present in the water column at higher flows. But how lamprey feeding rates vary with flow or how lamprey density varies with flow as feeding rate changes has not been investigated.

Secondary consumers - fish. This includes upland bully, Central Otago roundhead galaxias and longfin eel < 300 mm.

Central Otago roundhead juvenile habitat does not change in the scenario flow range so is considered very low risk.

Central Otago roundhead adult habitat peaks within the scenario flow range in the flows between 0.5 to 0.1 m^3/s. Outside this range there are small declines in habitat. However, given the small absolute size of the habitat changes and model errors the change in habitat is unlikely to be significant.

It is also worth noting only juvenile galaxiids have been found near the model site and adults have only been reported in reaches upstream of the model reach. This means the Thomsons Creek model is possibly of limited value for assessing the minimum flow scenario effects on adult Central Otago roundhead galaxias habitat.

Upland bully habitat peaks within the scenario flow range at around 0.08 m^3/s and declines either side of this flow. The decline is 10% or less of the maximum habitat in the flow range of 0.04 m^3/s to 0.19 m^3/s. Given the small size of the habitat changes and model errors the change in habitat is unlikely to be significant. Therefore, the risk of habitat change across the scenarios is very low risk.

Small longfin eels (< 300 mm). The two habitat preference curves available both show available habitat is stable at flows above 0.1 m^3/s. Between 0.04 and 0.1 m^3/s the two curves differ but both decline below 0.04 m^3/s. The mixed response in the flows between 0.0 4 and 0.1 m^3/s indicate there is some risk of rapid habitat loss below 0.1 m^3/s and the Campground 0.9 m^3/s minimum flow is considered to have moderate risk of the loss of habitat for small longfin eels.

Trout fry (< 100 mm) habitat peaks at 0.15 m^3/s and remains stable up to at least 0.2 m^3/s and there is only a small decline as flow decreases to 0.07 m^3/s. Only the 0.04 m^3/s flow drops habitat below the 80% threshold.

Tertiary consumers – large longfins (>300 mm). The two habitat preference curves indicate available habitat is either stable or rising with flow. The Jowett & Richardson (2008) curves predict significant decline in habitat as flow decreases. The Campground 0.9 m^3/s minimum flow may reduce habitat by 50% and only the Campground 2.5 m^3/s and 3.0 m^3/s provide 80% or more of the full d, no irrigation scenario habitat using the Jowett & Richardson (2008) HSCs. However, the Jellyman et al (2003) HSC indicates less habitat change.

Table 3: Risk result table for Thomsons Creek fish habitat at the confluence with the Manuherekia River.

Flow Scenario /Thomsons flow	Species				
	Lamprey	Upland bully	Roundhead galaxias juv/adult	Longfin eel < 300 mm/ >300 mm	Trout fry/juv/adult [2]
900/0.04	VLR*	VLR	VLR / VLR	MR / VHR	LR / VHR/ LR
1100/0.07	VLR	VLR	VLR / VLR	MR / HR	VLR / HR/ LR
1200/0.08	VLR	VLR	VLR / VLR	MR / MR	VLR / MR / LR
1500/0.09	VLR	VLR	VLR / VLR	MR / MR	VLR / LR / LR
1700/0.1	VLR	VLR	VLR / VLR	VLR / MR	VLR / LR / LR
2000/0.12	VLR	VLR	VLR / VLR	VLR / LR	VLR / VLR / LR
2500/0.14	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
3000/0.16	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR

Juvenile and adult trout life history stages. The juvenile, yearling and adult trout habitat predictions all tend to have little change above 0.1 m^3/s aside from the Wilding juvenile trout results that shows habitat increases throughout the 0.04 m^3/s to 0.2 m^3/s flow range. This most likely being the influence of rainbow trout habitat use in this habitat preference. The change in flow for the scenarios does lead to relatively large changes in habitat for the juvenile trout with the lower minimum flows giving a high to very high risk of habitat loss.

[2] HSCs for adult trout are based on habitat used by trout 40-65 cm (fork length) so these HSCs refer to a size class not the life history state of mature, spawning trout.

The adult trout prediction show very little habitat is provided in the model reach. The percentage change in habitat as flow declines does exceed 50% so there is a very high risk of habitat loss, but the amount of habitat at any flow is small so it is possible the reach doesn't support many if any adult trout due to the very limited amount of habitat and the habitat change is risk is assessed as low at flows below 0.1 m^3/s due to the limited probability of large adult trout (40-65 cm) being present.

Thomsons Creek Analysis for habitat upstream of White Road

This analysis assumes the flow upstream of White Road is 55% of the flow in Thomsons Creek at the Manuherekia River confluence and the 7dMALFs for each scenario are also 55% of the 7dMALFs at the confluence. The results of this assessment at summarised in Table 4.

Primary consumers - fish – juvenile lamprey. There is no change in habitat available across the 0.02 m^3/s to 0.105 m^3/s. Therefore, the risk of habitat change across the scenarios is very low risk. However, as a filter feeder the increase in flow is likely to increase feeding rates as more particles are likely to be present in the water column at higher flows. But how lamprey feeding rates vary with flow or how lamprey density varies with flow as feeding rate changes has not been investigated.

Secondary consumers - fish. This includes upland bully, Central Otago roundhead galaxias and longfin eel < 300 mm.

Central Otago roundhead juvenile habitat begins to decline as the flow either exceeds or declines from 0.04 m^3/s. The rate of habitat decline is slow as flow increases above 0.04 m^3/s with a less than 20% decline so is a very low risk. The decline in habitat as flow drops from 0.04 m^3/s to 0.02 m^3/s.

Central Otago roundhead adult habitat peaks within the scenario flow range in the flows between 0.5 to 0.1 m^3/s. When the flow drops below 0.04 m^3/s the predicted available habitat declines steeply and halves between 0.04 and 0.01 m^3/s and the 0.022 m^3/s provides only 55% of the habitat the full dam no irrigation scenario provides.

It is also worth noting only juvenile galaxiids have been found near the model site and adults have only been reported in reaches upstream of the model reach. This means the Thomsons Creek model is possibly of limited value for assessing the flow scenario effects on adult Central Otago roundhead galaxias habitat as they do not occupy this reach and are restricted areas upstream of the model reach.

Upland bully habitat peaks within the scenario flow range at around 0.08 m^3/s and declines either side of this flow. This decline steepens as flow drops below 0.04 m^3/s and at 0.02 m^3/s the predicted habitat available is 61 % of that available at the full dam no irrigation scenario and that this low flow has a moderate risk of impact on upland bully.

Small longfin eels (< 300 mm). The habitat preference curve of Jowett & Richardson (2008) shows that habitat declines relatively constantly between 0.02 m^3/s and 0.1 m^3/s with 0.02 m^3/s providing 39% of the habitat the full dam on irrigation scenario does. The Jellyman et al (2003) also shows habitat declining more steeply as flow drops below 0.06 m^3/s and at 0.02 m^3/s habitat is 62% of that available at the full dam no irrigation scenario. The magnitude of the declines differs between the two HSCs, but both indicate there is some risk of rapid habitat loss below 0.1 m^3/s and very high risk and high risk are assigned to the two lowest flow scenarios.

Trout fry (< 100 mm) habitat peaks at 0.15 m^3/s and remains stable up to at least 0.2 m^3/s and there is only a small decline down to flows of 0.07 m^3/s below which the decline rate increases. Only the 0.04 m^3/s flow drops habitat below the 80% threshold and at 0.02 m^3/s approximately 60% of the habitat at the Full Dam no irrigation scenario is left.

Tertiary consumers fish – this group includes large longfin eels and yearling and adult trout.

Large longfins (>300 mm). The two habitat preference curves indicate the available habitat is either stable or slowly rising with flow. The Jowett & Richardson (2008) curves do predict significant decline in large longfin eel habitat. The Campground 0.9 m^3/s minimum flow may reduce habitat by over 50% and only the Campground 2.5 m^3/s and 3.0 m^3/s provide 80% or more of the Fall Dam habitat.

Yearling and adult trout life history stages. The juvenile, yearling and adult trout habitat predictions all tend to have little change above 0.1 m^3/s aside from the Wilding juvenile trout results that shows habitat increases throughout the 0.04 m^3/s to 0.2 m^3/s flow range. This most likely being the influence of rainbow trout habitat use in this habitat preference. The change in flow for the scenarios does lead to relatively large changes in habitat with the lower minimum flow scenarios giving a high to very high risk of habitat loss at these low flows.

The adult trout prediction shows very little habitat is provided in the model reach. The percentage change in habitat as flow declines does exceed 50% so there is a very high risk of habitat loss, but the amount of habitat at any flow is very small so it is possible the reach doesn't support many if any adult trout due to the very limited habitat and the habitat change is risk is assessed as low at flows below 0.1 m^3/s due to the limited probability of adult fish being present.

Table 4: Risk assessment result table for Thomsons Creek fish habitat at upstream of White Road.

Flow Scenario /Thomsons flow	**Species**				
	Lamprey	**Upland bully**	**Roundhead galaxias juv/adult**	**Longfin eel < 300 mm/ >300 mm**	**Trout fry/juv/adult**
900/0.022	VLR	MR	LR / HR	HR / VHR	HR / VHR / LR
1100/0.039	VLR	LR	VLR / LR	MR / HR	MR / HR / LR
1200/0.044	VLR	VLR	VLR / VLR	MR / MR	LR /HR/ LR
1500/0.05	VLR	VLR	VLR / VLR	LR / MR	VLR / HR/ VLR
1700/0.066	VLR	VLR	VLR / VLR	LR / MR	VLR / MR / VLR
2000/0.077	VLR	VLR	VLR / VLR	VLR / LR	VLR / LR / VLR
2500/0.088	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
3000/0.105	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR

Lauder Creek at Rail Trail

The Lauder Creek flow ranges from 0.1 m^3/s for the 0.900 m^3/s to 0.35 m^3/s for the Full dam no irrigation scenario, a 0.25 m^3/s flow range. The model site at the Rail Trail is a small distance upstream from the confluence and there are no tributary inflows, so the confluence flows appear appropriate for assessment of habitat in the habitat model reach. The results of this assessment at summarised in Table 6.

Primary consumers - fish – juvenile lamprey are filter feeders and can be considered a primary consumer and a secondary consumer. There is no change in habitat available across the 0.1 m^3/s to 0.31 m^3/s. Therefore, the risk of habitat change across the scenarios is very low risk. However, as a filter feeder the increase in flow is likely to increase feeding rates as more particles are likely to be present in the water column at higher flows. But how lamprey feeding rates vary with flow or how lamprey density varies with flow as feeding rate changes has never been investigated.

Secondary consumers - fish. This includes upland bully, Central Otago roundhead galaxias and longfin eel < 300 mm.

For adult and juvenile Central Otago roundhead galaxias and upland bully the predicted habitat in the flow range 0.1 to 0.31 m^3/s is lowest at 0.31 m^3/s. The habitat model indicates that habitat increases as flow declines and all flow scenarios present a very low risk of habitat loss for the galaxiid and the bully.

It is also worth noting that Central Otago roundhead galaxiids have only been reported in a reach approximately 5.5 km upstream of the rail trail. This means the Lauder Creek model is possibly of limited value for assessing the flow scenario effects on Central Otago roundhead galaxias habitat.

Small longfin eels (< 300 mm). The two habitat preference curves available both show available habitat is declining as flow drops across the 0.1 m^3/s to 0.31 m^3/s flow range. This habitat decline is gentle and the predicted decline in habitat only drops the risk to low risk in the three lowest flow scenarios otherwise it remains at very low risk.

Trout fry HSCs show habitat is either relatively stable or slowly declining with the loss of habitat only entering the low-risk category when flow drops below 0.13 m^3/s.

Tertiary consumers – large longfins (>300 mm). The two habitat preference curves indicate available habitat is either stable or rising with flow. The Jowett & Richardson (2008) curves predict significant increase in habitat as flow increases. The Campground 0.9 m^3/s minimum flow may reduce habitat to just under 70%. However, flows greater than 0.15 m^3/s provide 80% or more of the full dam no irrigation habitat. The Jellyman et al (2003) HSC indicate less habitat change and all flow scenarios retain at least 80% of the full dam no irrigation habitat and can be considered very low risk.

Juvenile and adult trout life history stages. Both the adult trout habitat predictions and the juvenile trout show habitat increases throughout the 0.01 m^3/s to 0.31 m^3/s flow range. For adult brown trout the lowest flow (0.1 m^3/s) retains just over 50% of the predicted habitat at the full dam, no irrigation flow of 0.35 m^3/s and a flow over 0.15 m^3/s is required to retain 80% of the habitat. For juvenile trout a flow over 0.15 m^3/s presents a very low risk and the flows between 0.1 m^3/s and 1.5 m^3/s a low risk.

Table 6: Risk assessment result table for Lauder Creek fish habitat at the confluence with the Rail Trail.

Flow Scenario /Lauder flow	Species				
	Lamprey	Upland bully	Roundhead galaxias juv/adult	Longfin eel < 300 mm/ >300 mm	Trout fry/juv/adult
900/0.1	VLR	VLR	VLR / VLR	LR / LR	LR / LR / HR
1100/0.13	VLR	VLR	VLR / VLR	LR / LR	VLR / LR / HR
1200/0.14	VLR	VLR	VLR / VLR	LR / LR	VLR / LR / MR
1500/0.17	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / LR
1700/0.2	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
2000/0.21	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
2500/0.26	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
3000/0.31	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR

Chatto Creek

The Chatto Creek flow ranges from 0.09 m^3/s for the 0.900 m^3/s scenario to 0.22 m^3/s for the full dam no irrigation scenario, a 0.13 m^3/s flow range at the confluence with the Manuherekia River. However, the actual flow at the model site will be less than the confluence site flows as the model reach is upstream of both State Highway 85 and the confluence of Chatto Creek and Young Hills Creek. The NIWA national hydrology model (NZ River Maps (niwa.co.nz)) indicates that the MALF for Chatto Creek at the confluence with Young Hills Creek is 0.165 m^3/s and for Young Hills Creek its MALF is 0.046 m^3/s. Therefore, the assessment has used the Chatto Creek flows statistics calculated at the confluence with the Manuherekia River from the Manuherekia hydrology model and conducted a second analysis using 78% of this flow (Table 7) as estimates of the scenario flows upstream of State Highway 85 where the habitat model is located.

The Chatto Creek flow range estimate for the reach upstream of SH 85are from 0.07 m^3/s for the 0.900 m^3/s scenario to 0.17 m^3/s for the full dam no irrigation scenario, giving flow range of a 0.10 m^3/s flow range at the model reach.

Table 7: Estimated 7dMALF flows for Chatto Creek at the Manuherekia River confluence and upstream of State Highway 85.

Flow Scenario	Chatto Creek 7dMALF flows	
	Chatto at confluence	Chatto at SH 85
900	0.09	0.07
1100	0.11	0.09
1200	0.12	0.095
1500	0.13	0.1
1700	0.13	0.1
2000	0.15	0.12
2500	0.16	0.12
3000	0.17	0.13
Falls Dam full, no irrigation	0.22	0.17

Chatto Creek Analysis for habitat at Manuherekia River confluence

This analysis assumes habitat in Chatto Creek near the confluence with the Manuherekia River is the same or similar enough to the habitat model reach at SH 85 when the model was developed in 2003 to provide reliable predictions of the habitat at different flows. The results of this analysis are summarised in Table 8.

Primary consumers - fish – juvenile lamprey are filter feeders and can be considered a primary consumer and a secondary consumer. There is very little change in habitat available across the 0.09 m^3/s to 0.22 m^3/s flow range. Therefore, the risk of habitat change across the scenarios is very low risk. However, as a filter feeder the increase in flow is likely to increase feeding rates as more particles are likely to be present in the water column at higher flows. But how lamprey feeding rates vary with flow or how lamprey density varies with flow as feeding rate changes has not been investigated.

Secondary consumers - fish. This includes upland bully, Central Otago roundhead galaxias and longfin eel < 300 mm and brown trout fry.

Habitat for upland bully increases in the flow range 0.09 m^3/s to 0.18 m^3/s before levelling off and beginning to decrease as flow increases above 0.2 m^3/s. However, the habitat available between the

flows of 0.09 m^3/s and 0.22 m^3/s remains greater than 80% of that available at the 0.22 m^3/s at all times (maximum habitat decrease is a loss of 18% of the habitat). Therefore, the risk to upland bully is considered to remain with the very low risk category.

For the Central Otago roundhead galaxiid juvenile's habitat slowly increases as flow decreases in the 0.09 m^3/s to 0.18 m^3/s flow range and this means the risk to juvenile galaxiids is very low. Habitat for adult Central Otago roundhead galaxias also increases as flow decreases in the 0.09 m^3/s to 0.18 m^3/s flow range. Therefore, the adults galaxiids are also considered to be at very low risk.

The two habitat preference curves available for small longfin eels (< 300 mm) show available habitat decreases as flow decreases in the 0.09 m^3/s and 0.22 m^3/s flow range. Neither HSC for the small longfin eels indicates a more than 50% reduction in habitat so very high risk is not present and both HSCs also predict flow above 0.175 m^3/s provide 80% or more of the full dam no irrigation scenario habitat so above this flow the risk is considered very low. The flow at 0.09 m^3/s is considered high risk as it retains less than 60 % of the habitat for one of the two HSC and the 0.11 m^3/s flow is considered moderate risk as one HSC retains less than 70 % of the small longfin eel habitat.

Trout fry (< 100 mm) habitat increases with flow through the 0.09 m^3/s to 0.22 m^3/s flow range and the second fry HSC (Bovee 1978) has a habitat peak at 0.21-0.22 m^3/s and a maximum reduction across the flow range of 83%. Therefore, all the minimum flow scenarios result in a reduction in brown fry habitat. Assessing the risk has considered the average decline shown by the two HSCs and the two lowest flow scenarios moderate risk and risk decreases as flow increases.

Tertiary consumers – large longfins (>300 mm). The two habitat preference curves indicate that available habitat declines with declining flow. The Jowett & Richardson (2008) curves predict significant decline in habitat. The Campground 0.9 m^3/s minimum flow may reduce habitat by 60% but the Campground minimum flow scenarios higher than 1.2 m^3/s provide 80% or more of the full dam, no irrigation habitat. The Jellyman et al (2003) HSCs indicate a less habitat change with greater than 80% habitat retained at all minimum flows. Given the different decline rates risk has been assessed as an average of the two HSCs, giving low risk at 0.9 m^3/s and 1.2 m^3/s and very low risk at higher minimum flows.

Table 8: Risk assessment result table for Chatto Creek fish habitat at the confluence with the Manuherekia River.

Flow Scenario /Chatto flow	Species				
	Lamprey	Upland bully	Roundhead galaxias juv/adult	Longfin eel < 300 mm / 300 mm	Trout fry/juv/adult
900/0.09	VLR	VLR	VLR / VLR	HR / LR	MR / LR/ LR
1100/0.11	VLR	VLR	VLR / VLR	MR / LR	MR / LR/ LR
1200/0.12	VLR	VLR	VLR / VLR	LR / VLR	LR / LR / VLR
1500/0.13	VLR	VLR	VLR / VLR	LR / VLR	LR / VLR / VLR
1700/0.13	VLR	VLR	VLR / VLR	LR / VLR	LR / VLR / VLR
2000/0.15	VLR	VLR	VLR / VLR	LR / VLR	VLR / VLR / VLR
2500/0.16	VLR	VLR	VLR / VLR	LR / VLR	VLR / VLR / VLR
3000/0.17	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR

Juvenile and adult trout life history stages. The juvenile, yearling and adult trout habitat predictions all decline with declining flow, but none decline to less than 60% of the full dam no irrigation scenario for any minimum flow scenario.

The adult trout prediction shows that very little habitat is provided in the model reach, (using Hayes & Jowett 1994 HSCs) and it ranges between 0.02 m^2/m and 0.04 m^2/s. The percentage change in

habitat as flow declines does reach 40% loss so there is a high risk of habitat loss, but the amount of habitat at any flow is small so it is possible the reach doesn't support many, if any, adult trout due to this very limited amount of habitat and the habitat change is risk is therefore assessed as low or very low.

For the juvenile and yearling trout the maximum decline is predicted for juvenile trout (Wilding HSCs) with nearly 50% decline. For other HSCs all scenarios retain at least 70% of the habitat available at the full dam no irrigation scenario, so risk is assessed as low or very low for juvenile trout.

Chatto Creek Analysis for habitat upstream of SH 85

This analysis assumes the flow upstream of SH 85 is78 % of the flow at the Manuherekia River confluence and the 7dMLAFs for each scenario are also 78% of the 7dMALFs at the confluence. It also assumes the model habitat data collected in 2003 is still appropriate for this reach. The results of this assessment at summarised in Table 9.

The flow range assessed is from 0.07m^3/s to 0.13m^3/s giving a flow range of 0.06 m^3/s. This is a very small flow range and while the assessment has been conducted it is possible that the differences is predicted habitat are within the margin of error of the modelling and therefore real differences between the scenarios, which will be small, are not measurable with the habitat model.

Primary consumers - fish – juvenile lamprey There is no change in habitat available across the 0.07 m^3/s to 0.13 m^3/s. Therefore, the risk of habitat change across the scenarios is very low risk. However, as a filter feeder the increase in flow is likely to increase feeding rates as more particles are likely to be present in the water column at higher flows. But how lamprey feeding rates vary with flow or how lamprey density varies with flow as feeding rate changes has never been investigated.

Secondary consumers - fish. This includes upland bully, Central Otago roundhead galaxias and longfin eel < 300 mm.

Central Otago roundhead juvenile habitat is stable in the 0.07 m^3/ to 0.13 m^3/ flow range and is assessed as very low risk.

Central Otago roundhead adult habitat peaks within the scenario flow range in the flows between 0.1 m^3/s. The habitat decreases either side of this flow but by less than 20% for the flow range of interest and risk is assessed as very low.

Upland bully habitat rises through the 0.07 m^3/s to 0.13 m^3/s flow range but smallest amount f habitat provided at a flow of 0.07 m^3/s is still over 80% of the full dam no irrigation scenario habitat and as such the risk is assessed as very low.

Small longfin eels (< 300 mm). The two HSCs show habitat for small longfin eels declines in the 0.06 m^3/s flow range, with maximum declines of 17% and 26% for the two HSCs. This indicates the risk is low or very low for changes in habitat across the scenario flow range.

Trout fry (< 100 mm) HSCs indicate that habitat is stable through the flow range aside from one HSC that indicates a small decline in habitat with a maximum decline of 25%. The risk is considered low at the lowest minimum flow and for all other flows very low risk.

Tertiary consumers fish – this group includes large longfin eels and yearling and adult trout.

Large longfins (>300 mm). The two habitat preference curves indicate available habitat is declining with decreasing flow. The Jowett & Richardson (2008) curves predict a decline of just over 20% and the Jellyman et al (2003) HSC predicts a maximum decline of 10%. Therefore, the risk is assessed as low for the lowest flow scenario and very low risk for all other scenarios.

Yearling and adult trout life history stages. The juvenile, yearling and adult trout habitat predictions all tend to have little change above 0.1 m^3/s aside from the Wilding juvenile trout results that shows habitat increases throughout the 0.07 m^3/s to 0.13 m^3/s flow range. This most likely being the influence of rainbow trout habitat use in this habitat preference. Habitat for adult trout also declines as flow declines and the 0.9 m^3/s scenario results in a reduction of just over 20% and is considered low risk and all other scenarios at very low risk. Given the small flow range for this assessment the actual change in habitat is not large and actual effects are not likely to be noticeable.

Table 9: Risk assessment result table for Chatto Creek fish habitat at upstream of SH 85.

Flow Scenario /Chatto flow	Species				
	Lamprey	Upland bully	Roundhead galaxias juv/adult	Longfin eel < 300 mm/ >300 mm	Trout fry/juv/adult
900/0.07	VLR	VLR	VLR / VLR	LR / LR	LR / LR / LR
1100/0.09	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
1200/0.095	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
1500/0.1	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
1700/0.1	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
2000/0.12	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
2500/0.12	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR
3000/0.13	VLR	VLR	VLR / VLR	VLR / VLR	VLR / VLR / VLR

Dunstan Creek at confluence with Manuherekia River

The Dunstan Creek flow ranges from 0.27 m^3/s for the 0.900 m^3/s to 1.11 m^3/s for the full dam no irrigation scenario, a 0.84 m^3/s flow range. The model has been developed to represent the stream from Loop Road downstream to within 1000 m of the confluence with the Manuherekia River. The lower most 1000 m of the stream has some open semi-braided sections that the habitat model does not represent (Figure 1). Another 500 m upstream from this lower 1000 m section there is a water abstraction and the confluence flow statistics in Table 1 will not apply. Therefore, this assessment can be used for the 1000-1500 m reach upstream from the confluence and parts of the 1000 m distance immediately upstream of the confluence. The results of this assessment at summarised in Table 10.

Primary consumers - fish – juvenile lamprey are filter feeders and can be considered a primary consumer and a secondary consumer. The two HSCs for lamprey show different trends with habitat increasing with flow for one and habitat decreasing with increasing flow for the other. Both HSCs do indicate the amount of habitat available for lamprey is small and therefore while the percentage changes in habitat show a 30% gain or a 35% loss between the highest flow and the lowest flow the actual change in habitat is relatively small. Given the mixed response indicated by the HSCs and the limited amount of predicted habitat the two lowest flow scenarios are assessed as low risk and the higher flows as very low risk.

However, as a filter feeder the increase in flow is likely to increase feeding rates as more particles are likely to be present in the water column at higher flows. But how lamprey feeding rates vary with flow or how lamprey density varies with flow as feeding rate changes has not been investigated.

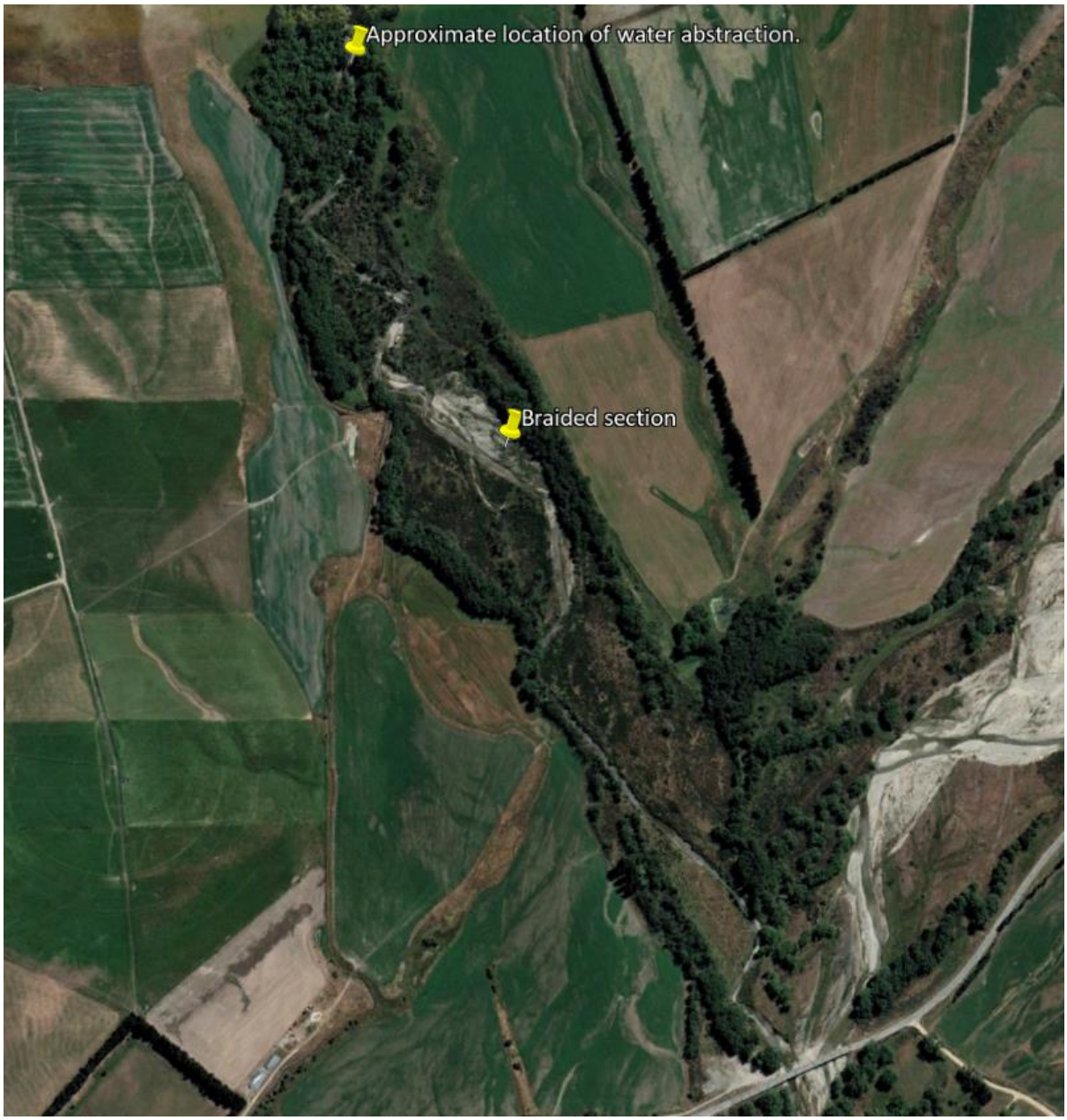

Figure 1: The lower reach of Dunstan Creek show water abstraction and braided section.

Secondary consumers - fish. This includes upland bully, Central Otago roundhead galaxias and longfin eel < 300 mm.

For adult and juvenile Central Otago roundhead galaxias the predicted habitat increases as flow decreases and all flow scenarios present a very low risk of habitat loss for the galaxiid. Habitat for upland bully peaks at a flow of 0.4 m^3/s and decreases either side of this flow. The habitat present at the full dam, no irrigation scenario flows is the lowest predicted amount of habitat for all flows and as such the all scenarios represent an increase in available habitat and are assessed as very low risk.

It is also important to note that Central Otago roundhead galaxiids have not been reported in lower Dunstan Creek. This means that this assessment of habitat in lower Dunstan Creek is of limited value for assessing the flow scenario effects on Central Otago roundhead galaxias habitat that is present

further upstream and the assessment should be conducted further upstream and if the flow range can be adjusted accordingly.

Small longfin eels (< 300 mm). The two habitat preference curves show contrasting habitat predictions. One predicts habitat peaks at 0.6 m^3/s with very similar decline rates from this peak out to the extreme low and high flow scenarios flows. The second HSC predicts a continuous increase in habitat as flow increases across the whole flow range. Both HSCs do predict habitat declines once flow drops below 0.6 m^3/s so the four minimum flow scenarios between 0.9 m^3/s to 1.500 m^3/s (Table 9) all have Dunstan Creek flows below 0.6 m^3/s and represent habitat loss scenarios. These are all assessed as moderate risk and the high flow scenarios as either low risk or very low risk.

Trout fry HSCs show a varied response to the flow changes with some increasing habitat, some stable habitat, and some decreasing habitat with increasing flow. Given the varied response predicted to occur and that the maximum change is a loss of 30% the scenarios are assessed as low risk. A very low risk assessment is not recommended to account for the uncertainty with regard to the change in habitat with flow.

Tertiary consumers – large longfins (>300 mm). The two habitat preference curves indicate available habitat declines as flow increases. The rate of change varies significantly but as the trend is the same for both HSCs the risk of habitat loss with declining flow is assessed as very low.

Table 10: Risk assessment result table for lower Dunstan Creek fish habitat.

Flow Scenario /Dunstan flow	Species					
	Lamprey	Upland bully	Roundhead galaxias juv/adult	Longfin eel < 300 mm	Longfin eel > 300 mm	Trout fry/juv/adult
900/0.27	LR	VLR	VLR / VLR	MR	VLR	LR / LR/ HR
1100/0.44	LR	VLR	VLR / VLR	MR	VLR	LR / LR/ MR
1200/0.48	VLR	VLR	VLR / VLR	MR	VLR	LR / LR /MR
1500/0.56	VLR	VLR	VLR / VLR	MR	VLR	LR / VLR / LR
1700/0.62	VLR	VLR	VLR / VLR	LR	VLR	LR / VLR / VLR
2000/0.71	VLR	VLR	VLR / VLR	LR	VLR	LR / VLR / VLR
2500/0.85	VLR	VLR	VLR / VLR	VLR	VLR	LR / VLR / VLR
3000/0.97	VLR	VLR	VLR / VLR	VLR	VLR	LR / VLR / VLR

Juvenile and adult trout life history stages. Both the adult trout habitat predictions show an increase in habitat with flow from 0.2 m^3/s to 0.7 m^3/s. Above 0.7 m^3/s the habitat predictions vary with one showing a slow increase with increasing flow (Wilding HSC) and the other declining (Jowett & Hayes 1994). For the brown trout predictions (Hayes & Jowett 1994) the variation in habitat remains with 20% of that available at the full dam no irrigation scenario for all scenarios apart from the very lowest flow scenario (0.9 m^3/s) where habitat drops to 77% of the full dam no irrigation scenario. Therefore, the adult brown trout habitat risk is assessed as very low risk. The Wilding HSCs predict a 50% drop in habitat from the full dam no irrigation scenario to the 0.9 m^3/s minimum flow. However, habitat increases rapidly with flow for this HSC and exceeds 70% retain for the 1100 m^3/s scenario and exceeds 80% habitat retained for the 1.7 m^3/s scenario and is then very low risk at and above this flow.

Regards

Richard Allibone

Habitat Suitability Curve (HSC) References

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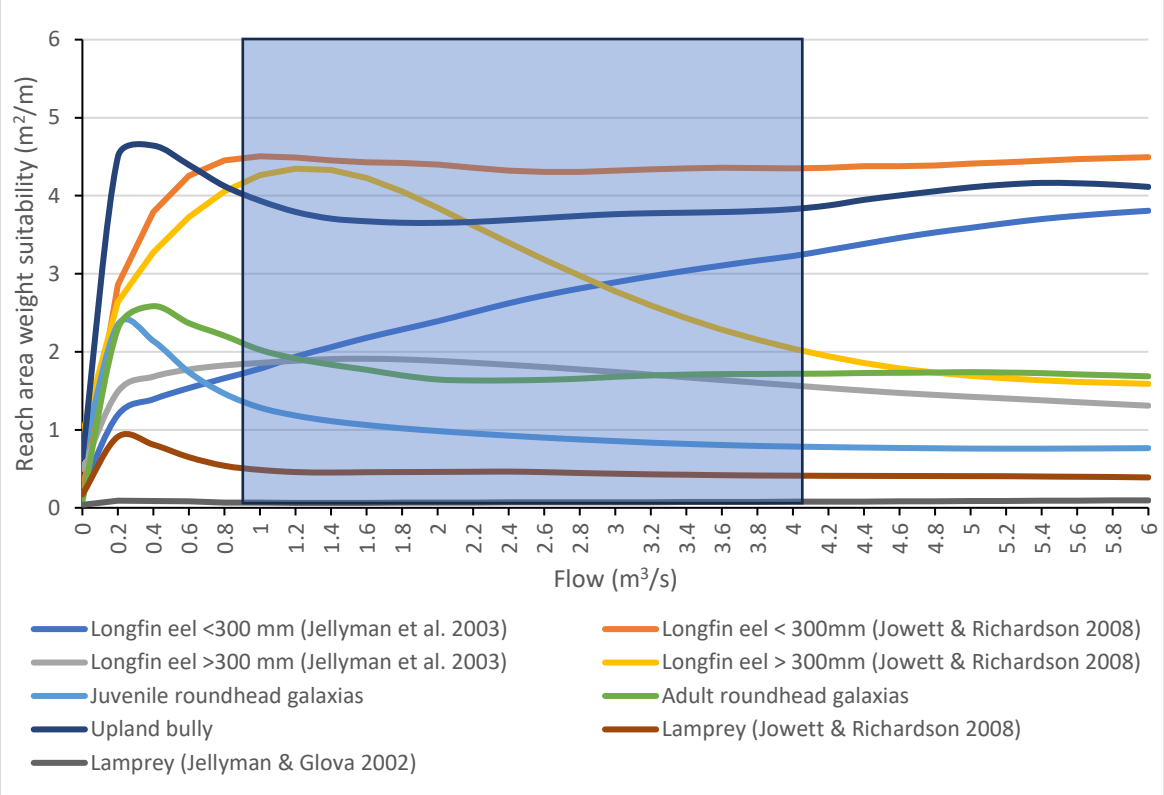
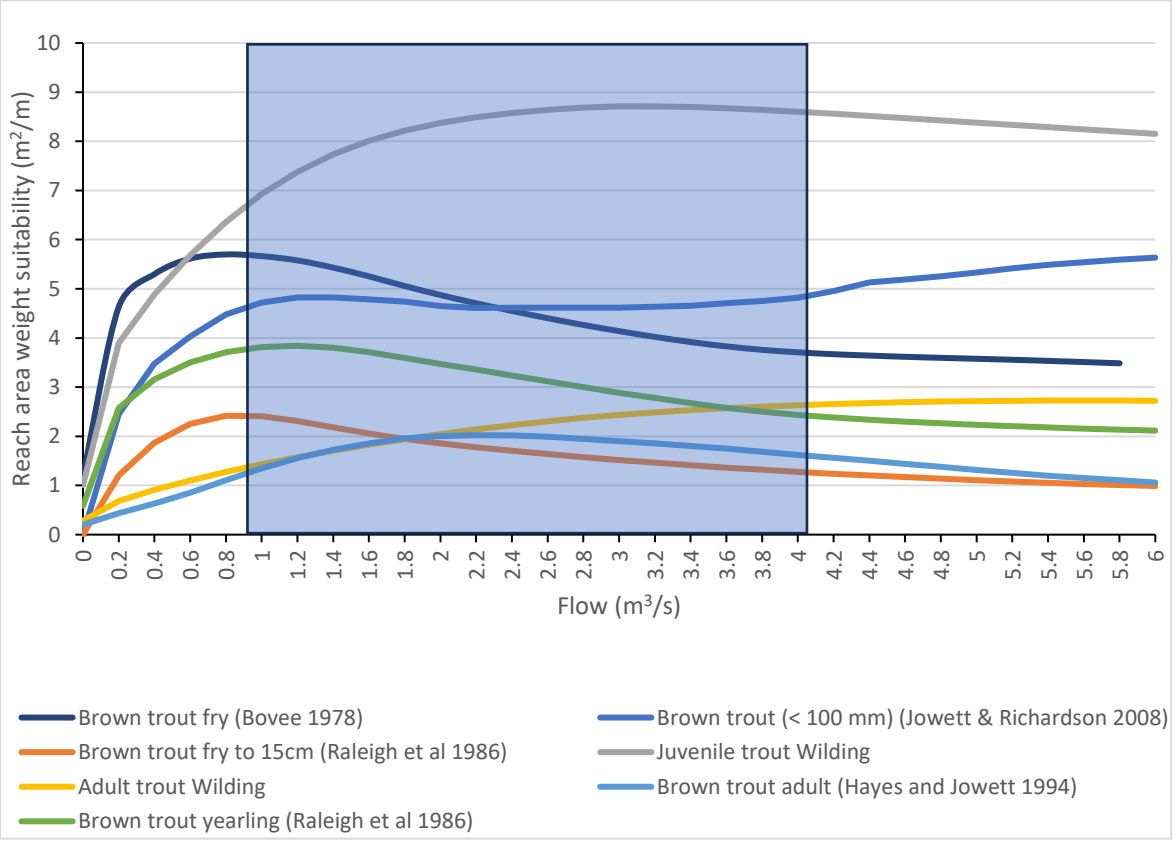
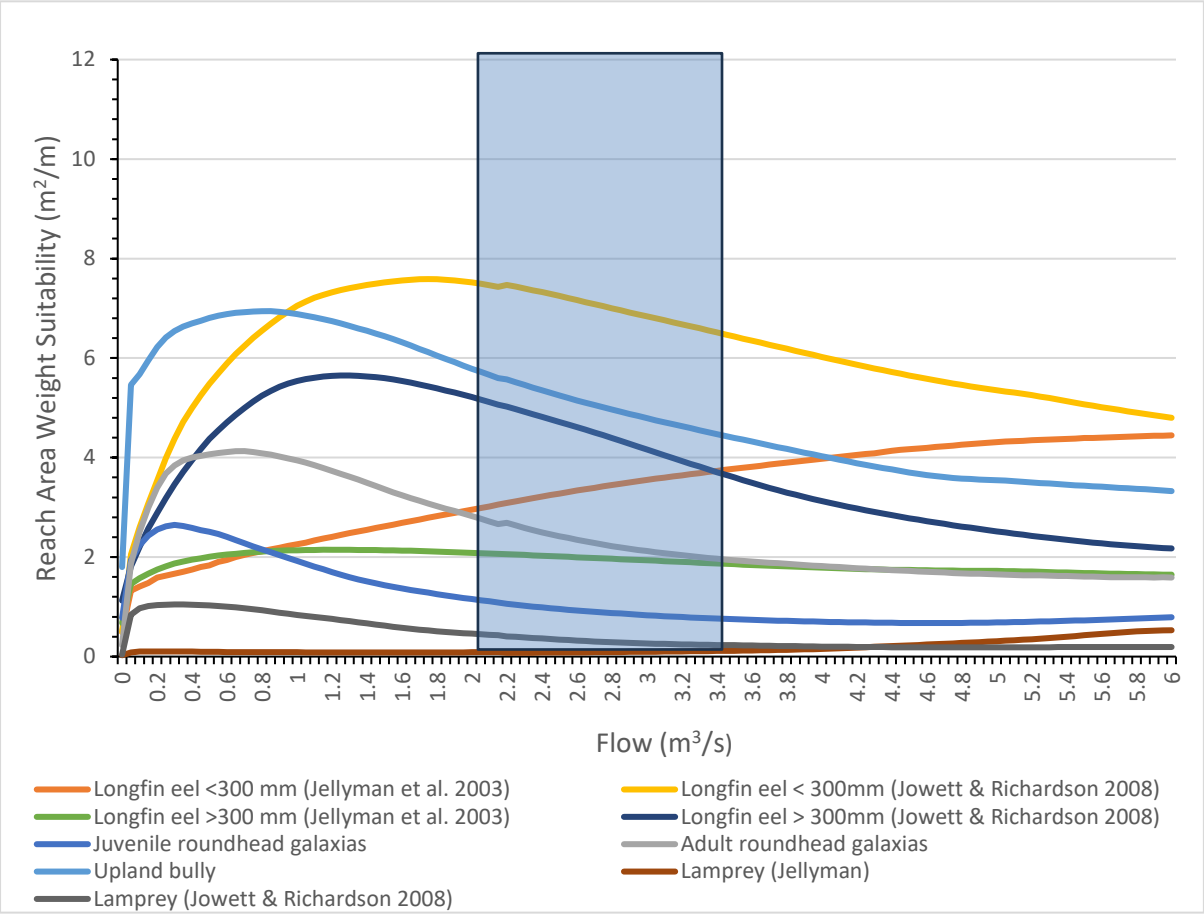
Habitat model outputs

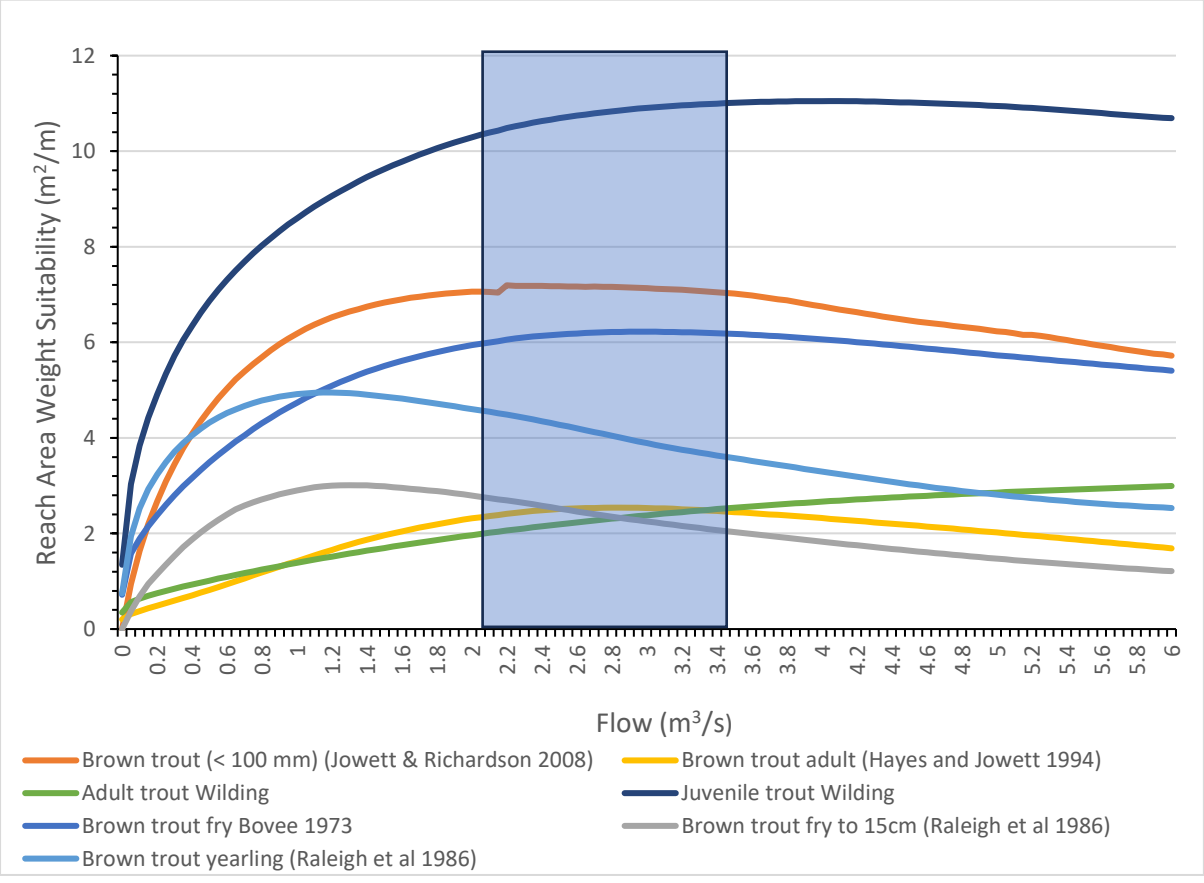
Campground -Galloway reach SEFA outputs – shaded area is the minimum flow scenario 7dMALF flow range.



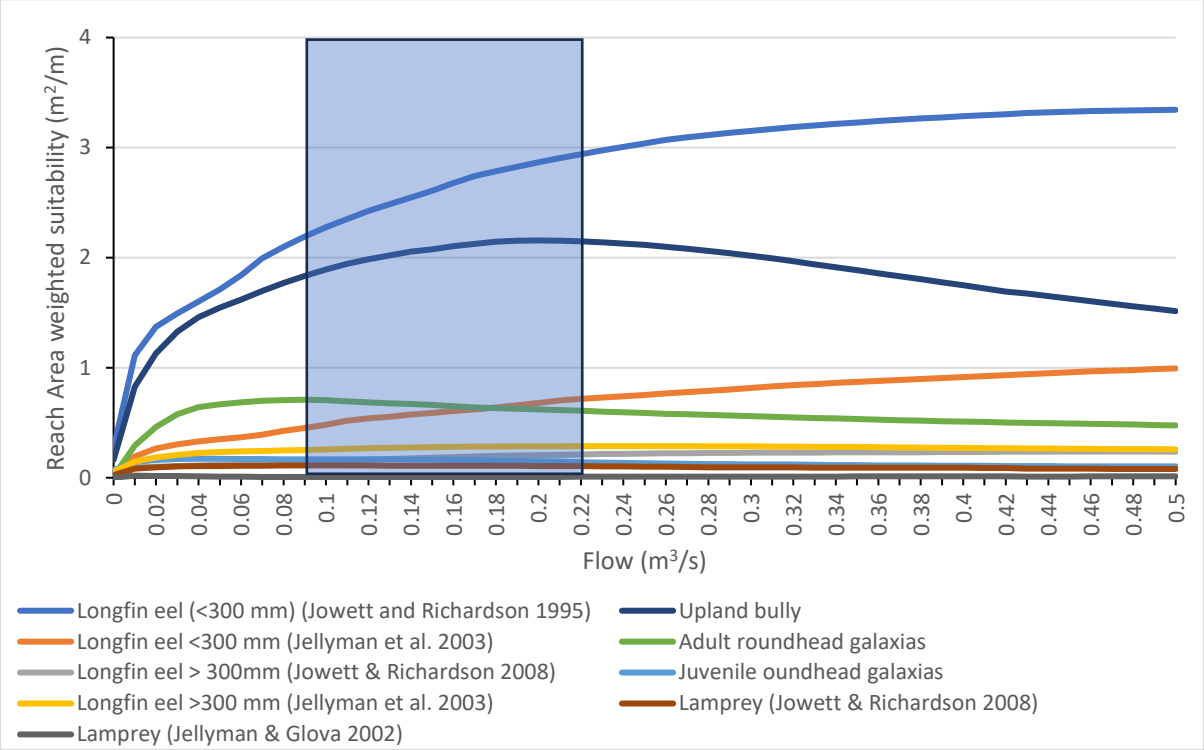


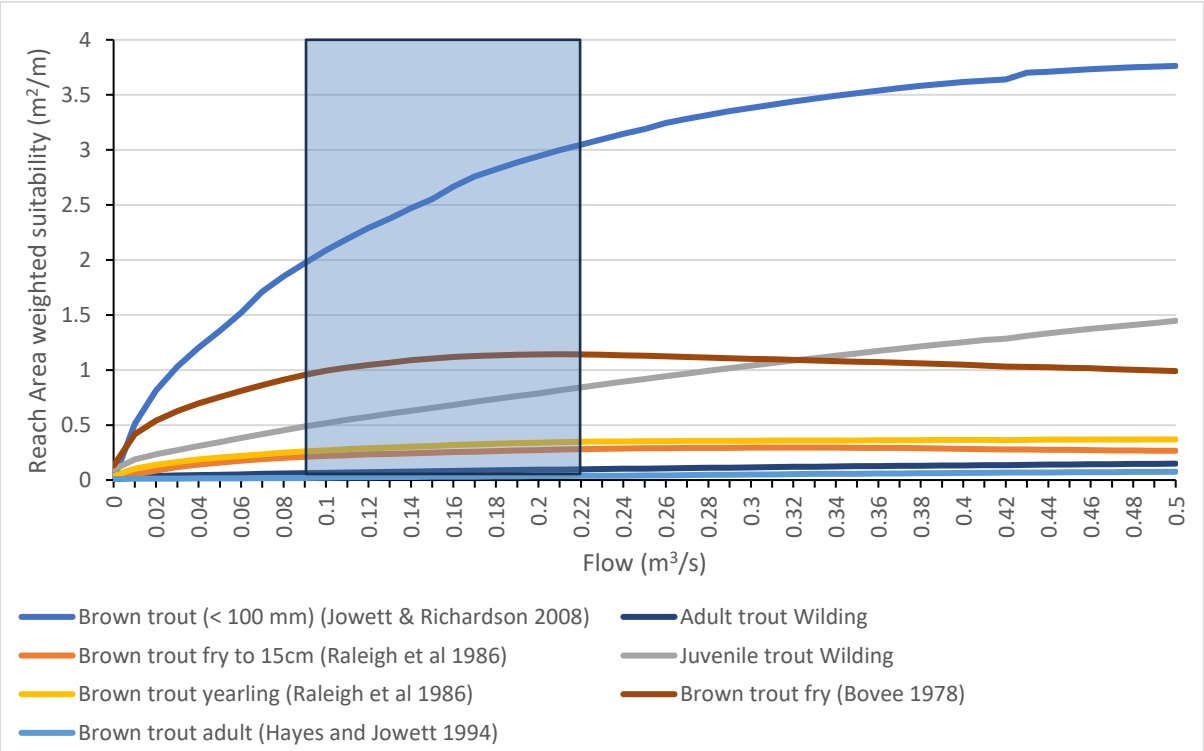
Ophir reach SEFA outputs – shaded area is the minimum flow scenario 7dMALF flow range.



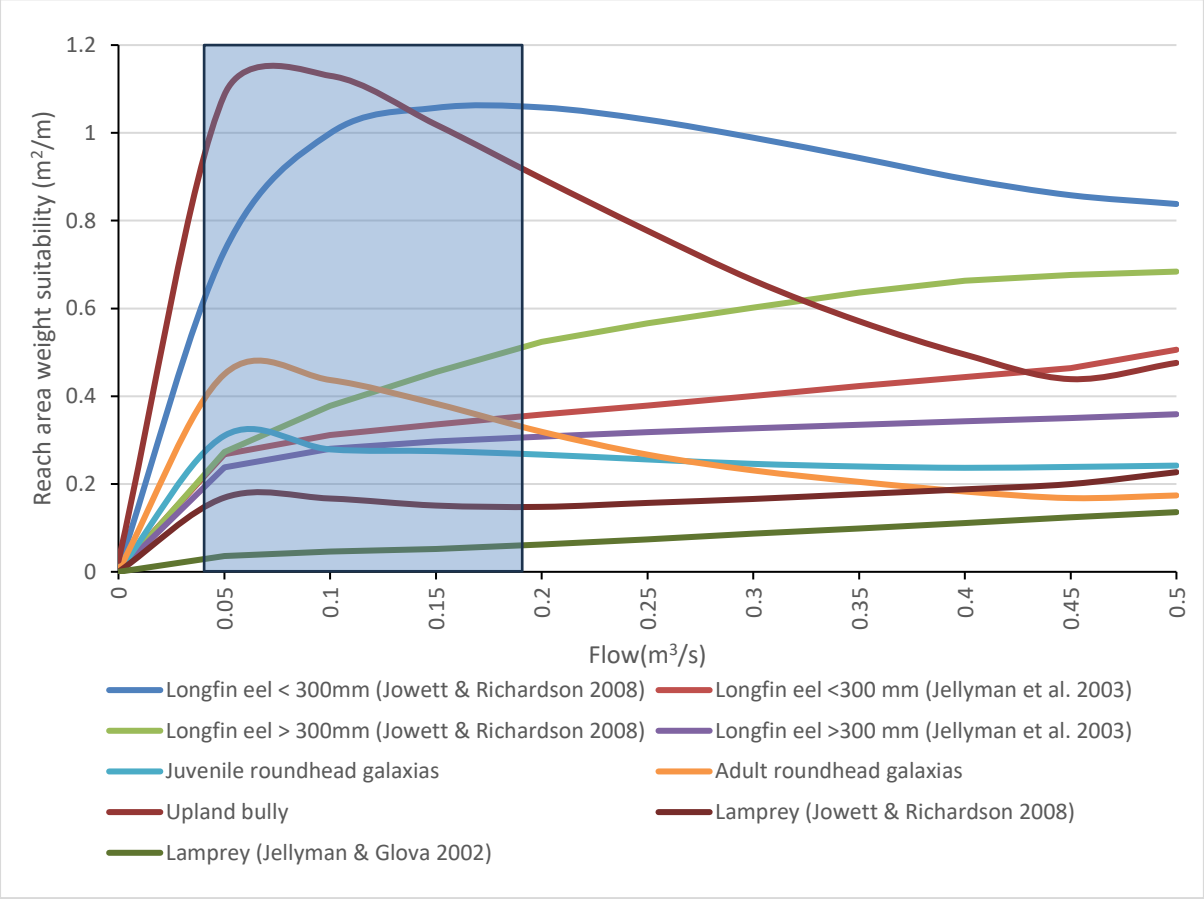


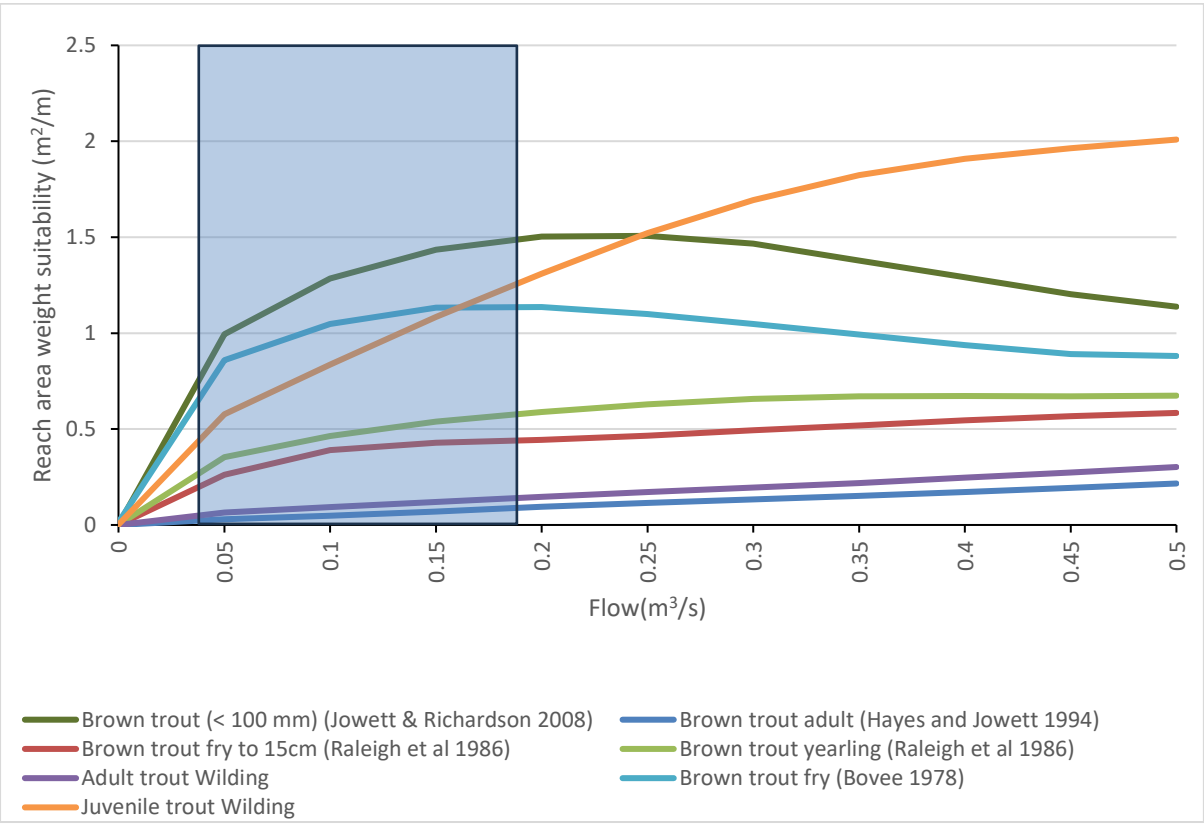
Chatto Creek shaded area is the minimum flow scenario 7dMALF flow range at confluence.



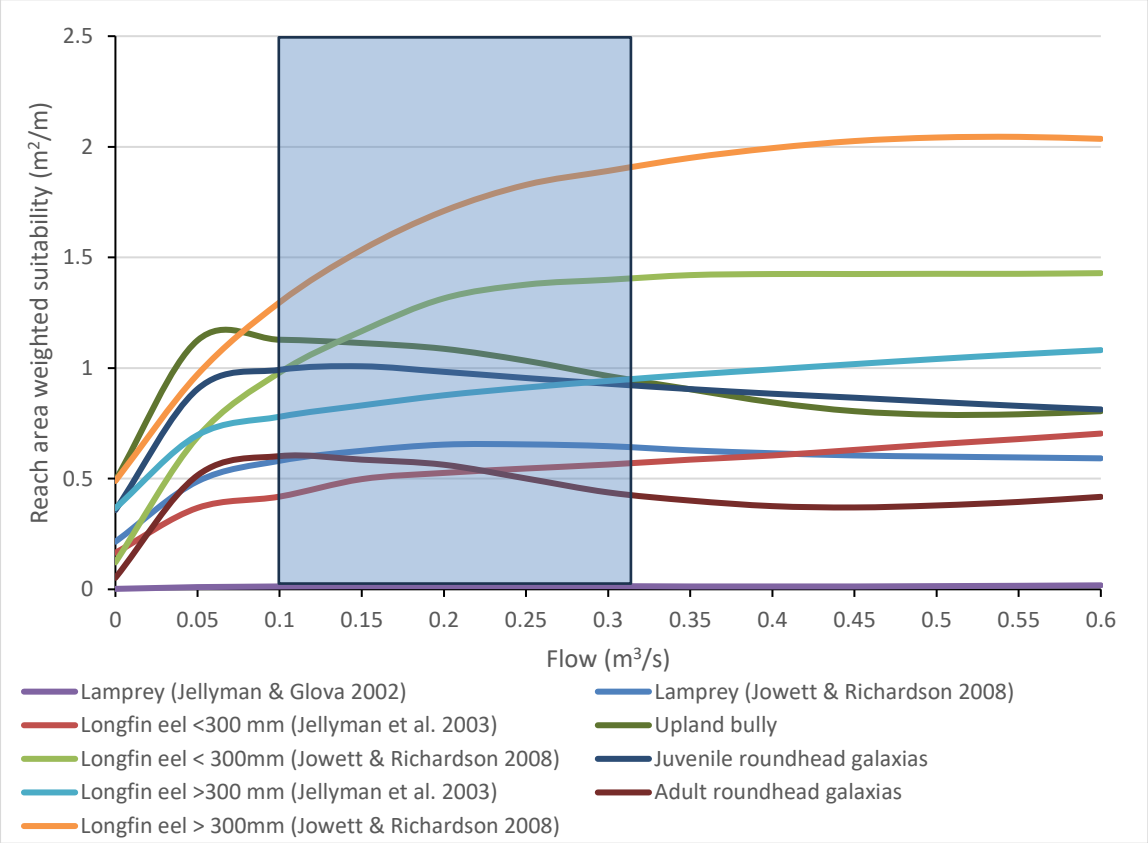


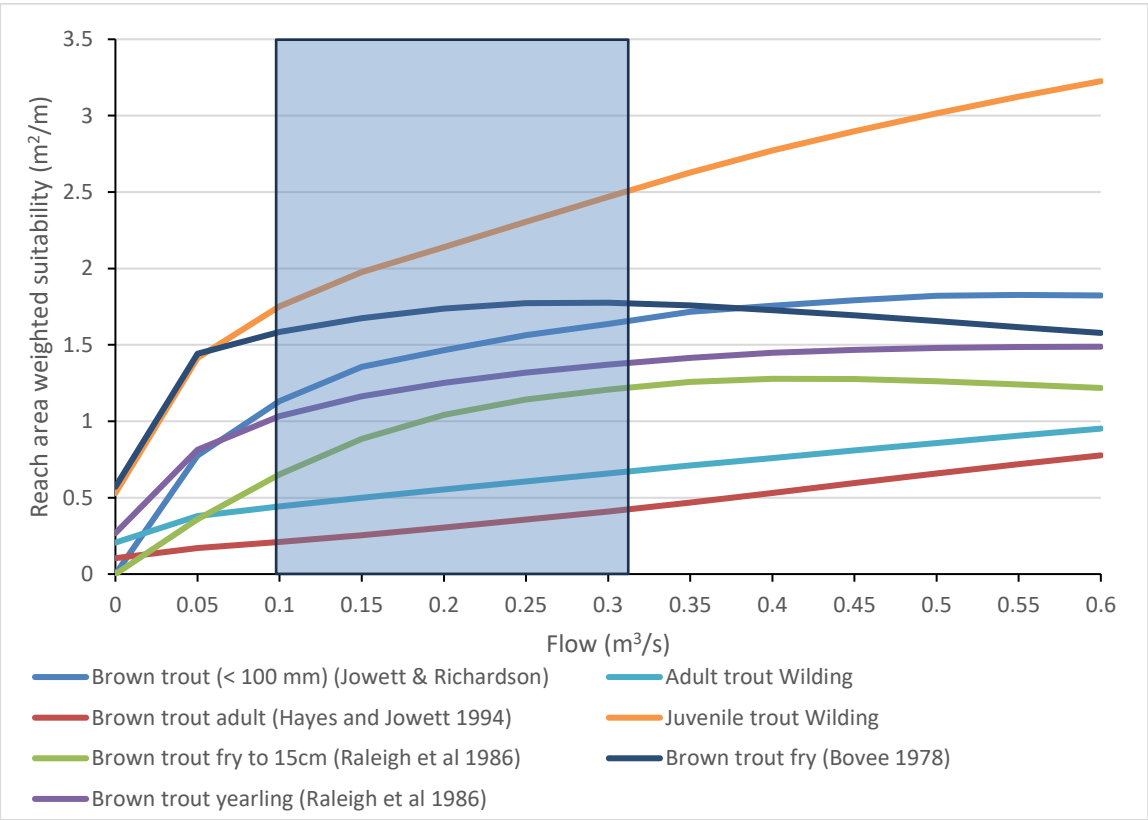
Thomsons Creek shaded area is the minimum flow scenario 7dMALF flow range at confluence.





Lauder Creek shaded area is the minimum flow scenario 7dMALF flow range at confluence.





Dunstan Creek shaded area is the minimum flow scenario 7dMALF flow range at confluence.