NIWA
Taihoro Nukurangi

Review of the science supporting the proposed minimum flow regime for the Lindis River

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Executive summary

This report provides a summary of reports suggesting minimum flows for the Lindis River as well as a critical review (Appendix A) of studies providing information on which to base a flow regime for the Lindis River.

IFIM methods for setting minimum flows scientifically are defensible where instream habitat is the major factor for selecting a minimum flow, as is the case in the Lindis River.

On the lower reach of the Lindis River, which is important for spawning and juvenile brown trout habitat, the habitat study showed the optimum juvenile brown trout habitat is provided by a flow of 1400 l/s, while the inflection point for juvenile brown trout habitat occurs at 750 l/s. The proposed minimum flow of 750 l/s at Ardgour Road will also provide a continuous flow at the Clutha confluence.

The proposed environmental standards (NES) (MfE 2008) for rivers and streams with mean flows greater than 5000 l/s suggest a minimum flow of 80% of mean annual low flow (MALF) is 1490 l/s, but in this case the proposed minimum is half this flow (i.e. 40% of MALF).

The NES suggests an allocation limit of the larger of 50% of MALF or the current allocation. For the Lindis River at Ardgour Road 50% of MALF is 930 l/s. Thus the allocation should be capped at the proposed allocation level of 1500 l/s.

Otago Regional Council (ORC) have provided a report outlining their understanding of the hydrology, morphology and ecology in the lower reach of the Lindis River, however some gaps were found in this report, for example: An analysis of the residual flow variability and flushing flow potential, resulting from the proposed minimum flows and allocation limits compared to the historic residual flow regime and the naturalised flow regime at Ardgour Road is missing.

This high quality ecological study and good hydrological and morphological information provide a sound base for defending the choice of 750 l/s as the minimum flow. The choice of minimum flow and allocation would be enhanced by:

- Quantifying the broader-scale surface water losses to the Lindis Alluvial Ribbon aquifer from the Lindis River.
- Assessment of the flow flushing regime by comparing the naturalised flow regime at Ardgour Road with the historic residual flows and with the flow regime that will result from application of the proposed minimum flows and allocation.

1 Introduction

Otago Regional Council (ORC) is preparing a flow restriction and allocation regime for the Lindis River. A scientific report was prepared by ORC in 2008 covering the Lindis River morphology, hydrology and ecological information and addresses the management flows for aquatic ecosystems (ORC 2008). A further water resource study was completed in 2014 (ORC 2014).

The objective of this report is to review the quality and adequacy of the hydrological, morphological and ecological information used by ORC as the basis for recommending a minimum flow of 750 l/s, and to identify any gaps or deficiencies in that information that could affect their recommendation. The current and proposed minimum flow regimes are listed in Table 1-1.

Table 1-1: Naturalised mean annual low flow, current and proposed minimum flows and allocation limits.

Figures from ORC (2008), ORC (2014) and email (Dec 2014) from T De Pelsemaeker Policy Analyst, ORC.

Site	Current minimum flow regime and allocation (l/s)	Proposed minimum flow regime (l/s)	Proposed allocation regime
Lindis River at Ardgour Road (Naturalised MALF 1864 l/s)	No minimum flow or allocation limit Current allocation 4141 l/s	750 (Oct to May) 1600 (Jun to Sept)	Primary Limit 1000 l/s
		1250 (Oct to May) 2100 (Jun to Sep)	Supplementary allocation (1st block) 500 l/s

2 The IFIM approach to setting minimum flows

The proposed minimum flow for the Lindis River at the Ardgour Road site has been set primarily on the basis of the instream flow incremental methodology (IFIM). The analysis and recommendations of Jowett and Wilding (2003) on the Lindis River was accepted and discussed in ORC's 2008 report on 'Management flows for aquatic ecosystems in the Lindis River'.

The question therefore arises as to the robustness of the method and the version of it used in New Zealand. The IFIM variation RHYHABSIM, developed by Ian Jowett, is used widely in New Zealand and is probably superior to the original version developed in the USA because it has better hydraulic algorithms (Jowett 1995, Hayes 1997) and is easier to use (Duncan 2009).

Jowett et al. (2008) review six case studies involving trout, benthic invertebrate and indigenous fish communities, where minimum flow and flow regime recommendations have been made and implemented. In most of these cases minimum flows were increased based on IFIM analysis and resulted in increases in trout numbers, angling success, invertebrate numbers and favoured taxa (Duncan 2009).

Jowett et al. (2008) also documented the relationship between adult trout biomass and various environmental variables. The quality of brown trout habitat at mean annual low flow was more closely related to trout numbers than the habitat available at higher flows. The quality of habitat for food production (benthic invertebrate habitat) at median flow was more closely related to trout numbers than the amount at either low or mean flow (Duncan 2009).

The selection of optimum flows using IFIM approaches to set minimum flows is robust, proven and scientifically defensible. If that were not so it would not be used so widely around the world.

The proposed minimum flow for the Lindis River has been set primarily on the basis of the flow that gives either the maximum physical habitat, or weighted useable area (WUA) for the most demanding target species, or the flow that is most efficient at providing physical habitat (i.e., greatest WUA per wetted width). In some cases flow vs WUA relationships have a peak where the optimum flow is unequivocal. In other cases there are points of inflection below which WUA declines rapidly with decreasing flow. These inflection points are often taken as indicating a suitable minimum flow. It is commonly accepted that flows that provide WUA within 10% of the optimum are suitable as minimum flows (Duncan 2009).

3 Review of studies

3.1 Jowett and Wilding (2003) Flow requirements for fish habitat in the Lindis River

Jowett and Wilding (2003) report the results of a hydraulic analysis using a RHYHABSIM survey on the critical reach of the Lindis River above SH 8, to determine the flows required to maintain acceptable habitat for the fish species present from the determination of how the weighted usable area (WUA) for brown and rainbow trout and native fish habitat varies with discharge.

My interpretation of Jowett's data is that the Lindis River provides spawning habitat for brown and rainbow trout from the Clutha River and Lake Dunstan and the maximum habitat for brown and rainbow trout spawning is provided by 1400 l/s and 2200 l/s respectively. The maximum adult brown trout habitat is provided by 4000 l/s flow and falls sharply with flows below 2000 l/s. The maximum juvenile brown trout habitat was provided by 1400 l/s reducing sharply when flows fell below 750 l/s.

Native fish flow requirements were lower than trout, with maximum habitat provided by 400 l/s for upland bullies and flathead galaxias with a sharp reduction in suitable habitat as flows fell below 200 l/s.

3.2 ORC (2008) Management flows for aquatic ecosystems in the Lindis River

This report provides important background on the Lindis catchment, land use, soils, rainfall patterns, river hydrology, distribution of fish species and sports fish species.

The physical habitat survey provides more detail of the Jowett and Wilding (2003) RHYHABSIM study.

Key information is provided on the hydrology of the lower Lindis River, where the surface water groundwater interaction is explained, causing channel losses below Ardgour Road to the confluence with the Clutha. The derived 440 l/s channel loss is key to understanding the requirements of the minimum flow to be established at Ardgour Road. Further upstream flow losses recharge the Lindis Alluvial Ribbon aquifer

The detailed study of instream habitat and fish assemblages below the Lindis Crossing Bridge, provides an understanding of changes to physical habitat when flows decline, and electrofishing results show this to be an important area for young brown trout. The importance of stream morphology for refuge habitat coupled with the essential flows to retain connectivity between pools is well explained.

This report discusses and suggests management flows for aquatic habitat. The key suggestions related to the proposed minimum flow are:

- The optimum juvenile brown trout habitat is provided by a flow of 1400 l/s , while the inflection point for juvenile brown trout habitat occurs at 750 l/s.
- Monitoring in the lower Lindis River has shown this section is particularly important for both spawning and juvenile habitat.
- Monitored losses between Ardgour Road and Lindis Crossing average 220 l/s, with a further 220 l/s being lost between Lindis Crossing and the Clutha confluence.

- Given these losses to groundwater, a minimum flow of 750 l/s at Ardgour Road is assumed to provide a flow of 530 l/s at Lindis Crossing and 310 l/s at the Clutha confluence.

These points justify establishing a minimum flow of 750 l/s.

3.3 ORC (2014) Lindis catchment water resource study

This study provides an estimate of the naturalised MALF (1864 l/s) on the Lindis River at Ardgour Road as well as an indication of the amount of water abstracted from the river at MALF, of approximately 1300 l/s.

3.4 Assessment of quality and adequacy of studies for recommending a minimum flow of 750 l/s

Jowett's RHYHABSIM flow assessment was completed on the reach of interest in the lower Lindis River, so is directly applicable to this review.

I conclude that selection of optimum flows using IFIM approaches to setting minimum flows is robust, proven and scientifically defensible.

The ORC (2008) report provides the necessary hydrological understanding of the surface water groundwater interaction causing channel losses of 440 l/s between Ardgour Road and the confluence with the Clutha. The minimum flow of 750 l/s addresses the community's wish to have connectivity with the Clutha River of at least 300 l/s and reduces the risk of fish kills that occur when the river dries up.

Furthermore, the detailed study of instream habitat and fish assemblages below the Lindis Crossing Bridge, provides the understanding of changes to physical habitat, the importance of refuge habitat in the stream morphology when flows decline, clear evidence supporting the community's expectation to have continuous flow at the Clutha confluence. With a minimum flow of 750 l/s, river drying due to abstraction in this reach will cease.

4 Gaps or deficiencies following Schedule 2D of ORC Regional Plan

Schedule 2D was provided by T. De Pelsemaeker.

4.1 Matters and values to be considered when setting minimum flows and allocation limits

The ORC (2012) water plan states "Primary allocation limits and minimum flows will be added to Schedule 2A, to give effect to the objectives and policies in this Plan, through the plan change process following scientific investigation and consultation with the community and affected parties. The lists in 2D.1 and 2D.2 identify matters to which consideration will be given when setting these flows and limits. The lists are not exhaustive and consideration will be given to these and any other relevant matters."

Any issues identified in section 4.2 and 4.3 below that have not been discussed in Jowett and Wilding (2003), ORC (2008) or ORC (2014) are considered to be gaps in understanding when setting minimum flows for the Lindis River.

4.2 When setting minimum flows in Schedule 2A for a catchment, consideration will be given to the following matters (2D.1)

4.2.1 Any existing or previous minimum flow regime or residual flow

No previous minimum flow or allocation limits to consider.

4.2.2 The 7-day mean annual low flow

The 7-day mean annual low flow for the modified residual flow at Ardgour Road has been measured while the naturalised 7-day mean annual low flow has been derived (1864 l/s) from adequate information.

The proposed environmental standards (NES) (MfE 2008) for rivers and streams with mean flows greater than 5000 l/s suggest a minimum flow of 80% of mean annual low flow (MALF). For the Lindis River this equates to 1490 l/s, but the proposed minimum is half this flow.

4.2.3 Interaction among water bodies

There is an established hydrological understanding of the surface water groundwater interaction causing channel losses in the Lindis fan in the lower Lindis downstream of Ardgour Road. However, the quantity of losses to the Lindis Alluvial Ribbon aquifer from the Lindis River at a broader scale have not been described.

4.2.4 Ecological values, including the need for flow variability

ORC have completed appropriate studies to maintain and protect the rivers aquatic ecosystem and natural character during periods of low flow with the proposed 750 l/s minimum flow based upon the flow requirements for trout spawning and juvenile brown trout habitat. This minimum flow will enable a continuous Lindis River connection to the Clutha River.

If for any reason a lesser minimum flow were proposed, there would be a need for a more complete concurrent field study in the Lindis River lower reaches to prove: continuous connection with the Clutha; that water temperatures did not become too hot for trout; and the habitat for, and the population of, juvenile brown trout was maintained. Analysis would be required of the percentage of

time flows were achieved and the longest duration not achieved for the Lindis River at the Lindis Crossing and the Clutha confluence. Flow and water temperature records, along with physical habitat and fish assemblages would be required over a number of flow recessions. Audits of all hydrological records will be required to give assurance of the quality of flow values.

If flows have been low for 3 to 7 weeks and periphyton has built up to nuisance levels, then flows 3 times the median flow are needed to flush and revitalise the river. An analysis of the residual flow variability and flushing flow potential, resulting from the proposed minimum flows and allocation limits compared to the historic residual flow regime and the naturalised flow regime at Ardgour Road is missing. It is very likely that the proposed flow regime would provide more flushing events than the current regime and provide further justification for the proposed regime.

4.2.5 Demand for water, including community water supplies

Not required under this report's terms of reference.

4.2.6 Existing water uses and associated infrastructure

Not required under this report's terms of reference.

4.2.7 Environmental, social, cultural, recreational and economic costs and benefits of taking and using water before and after the implementation of a minimum flow regime; and any other relevant matter in giving effect to Part 2 of the Resource Management Act.

Not required under this report's terms of reference.

The environmental, social, cultural and recreational values will likely benefit from the proposed minimum flow and allocation regime. These will each require reporting on and a comparison made with the current flow regime to confirm the benefits.

While not part of the terms of reference for this study, abstractors might like to see an analysis of the economic costs of the proposed minimum flow and allocation regime. They might need to be informed of their expected reliability of supply, the average days on restriction per year, the longest period of restriction, and the number of years when restrictions will not be experienced. A means of establishing naturalised flows at the Ardgour Road site was established in the 'Lindis catchment water resources study' (ORC 2014) and could be used for answering these questions. An example of an irrigation roster could be beneficial to water users.

Due to the short record for the Lindis River at Ardgour Road the naturalised hydrological statistics for the site are uncertain. Hydrological knowledge of the site would be enhanced by the establishment of a naturalised flow record for Lindis River at Ardgour Road; this would entail a detailed concurrent stream gauging investigation to be completed to enable the transfer of the 38 year flow record from Lindis Peak downstream to Ardgour Road.

4.3 When setting primary allocation limits in Schedule 2A for a catchment, consideration will be given to the following matters (2D.2)

4.3.1 Amount of water currently allocated as primary allocation

Not required under this report's terms of reference, however, the amount is known.

4.3.2 Amount of water currently taken as primary allocation

Not required under this report's terms of reference, however, estimates can be made following the work described in 4.2.7 above.

4.3.3 Any other existing taking and using of water

Not required under this report's terms of reference.

4.3.4 The 7-day mean annual low flow

The NES suggests an allocation limit of the larger of 50% of MALF or the current allocation. For the Lindis River at Ardgour Road 50% of MALF is 930 l/s. Thus the allocation should be capped at the proposed allocation level of 1500 l/s.

4.3.5 Proposed minimum flow regime

Not required under this report's terms of reference.

There is no analysis showing the proposed minimum flow regime with the primary allocation limit and the supplementary allocation (1st Block) to assess the reliability of supply for these two groups.

4.3.6 Possible sources of water

Not required under this report's terms of reference.

4.3.7 Acceptable duration and frequency of rationing among consented water users

Not required under this report's terms of reference.

Refer to 4.2.7 and 4.3.5 regarding studies required for provision of reliability of supply information for irrigators

4.3.8 Social and economic benefits of taking and using water

Not required under this report's terms of reference.

Also refer to 4.2.7 for studies recommended.

5 Summary

A number of studies providing information on which to base a flow regime for the Lindis River have been critically reviewed (Jowett and Wilding 2003, ORC 2008, ORC 2014).

IFIM methods for setting minimum flows are scientifically defensible where instream habitat is the major factor for selecting a minimum flow.

On the lower reach of the Lindis River, important for spawning and juvenile brown trout habitat, an IFIM habitat study showed the optimum juvenile brown trout habitat is provided by a flow of 1400 l/s, while the inflection point for juvenile brown trout habitat occurs at 750 l/s, a flow which exceeds the maximum habitat requirement for native fish.

It was established that surface water losses to groundwater between Ardgour Road and the confluence with the Clutha are approximately 440 l/s, therefore the proposed minimum flow will enable a continuous flow at the Clutha confluence.

A minimum flow of 750 l/s is proposed based on the flow requirements for juvenile brown trout and the need to provide for continuous flow to the Clutha River confluence. The requirement for continuous flow came from community consultation and the desire to reduce the risk of fish kills that occur when the river dries up.

A high quality ecological study and good hydrological and morphological information provide a sound base for defending the choice of 750 l/s as the minimum flow. The choice of minimum flow and allocation would be enhanced by:

- Quantifying the broader-scale surface water losses to the Lindis Alluvial Ribbon aquifer from the Lindis River.
- Assessment of the flow flushing regime by comparing the naturalised flow regime at Ardgour Road with the historic residual flows and with flow regime that will result from application of the proposed minimum flows and allocation.

6 References

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Ministry for the Environment. (2008). Proposed national environmental standard on ecological flows and water levels. Ministry for the Environment publication number ME868, Ministry for the Environment, Wellington.

Otago Regional Council (2008) Management flows for aquatic ecosystems in the Lindis River. ISBN 1-877265-63-2. 54 p.

Otago Regional Council (updated 1 March 2012) Regional Plan: Water for Otago. Schedule 2D page 347

Otago Regional Council (2014) Lindis catchment water resource study. River flows, water use and flow statistics for the Lindis catchment October 2012 to April 2014. 2 p.

Pelsemaeker, T. (pers. comm). Email 17 December 2014.

Appendix A Study brief terms of reference

Review of Lindis River morphological, hydrological and ecological information 26 November 2014

ORC is setting a minimum flow for the Lindis River. ORC Staff have identified and assessed various options and recommend notifying a minimum flow of 750 l/s.

The ORC Executive wishes to confirm that there is an adequate (fit for purpose) evidential basis for notifying a value of 750 l/s. The selection of this particular value has been informed by hydrological, morphological and ecological work undertaken or commissioned by ORC. The executive has decided to commission an expert review of that information.

The objectives of the review are to:

1. Assess the quality and adequacy of the hydrological, morphological and ecological information used by ORC staff as the basis for recommending a minimum flow of 750 l/s.

2. Identify any gaps or deficiencies in that information that could affect that recommendation.

The deliverable is a written report describing the review process and the findings of the review.