Lindis River low flow investigations

Part A:
Surveys of critical riffles for fish passage under low flow conditions

June 2017

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Prepared for the Lindis Catchment Group

by

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1. Background

On 17 January 2017, the freshwater ecology experts (the technical group) involved in the Lindis River minimum flow environment court appeal held a meeting at the Otago Regional Council's Dunedin offices to discuss proposed scope and methodologies around investigations into the effects of low flows on water temperature and fish passage in the Lindis River.

With respect to fish passage, the experts agreed on the following approach[1]:

a). An assessment to focus on the reach from Clutha confluence to "The Point" (upstream extent of upper losing reach near Rutherford's water take), broken into 3 sections:

- Lower losing reach (Ardgour Road flow recorder – Clutha confluence)
- Gaining reach (Ardgour Road bridge – Ardgour Road flow recorder)
- Upper losing reach ("The Point" – Ardgour Road bridge)

These reaches are identified in Figure 1.

b). During the site selection phase, the technical group will identify 2-3 critical riffles (bottlenecks to fish passage) within each reach, resulting in 6-9 cross-sections in total.

c). Each cross-section will be accompanied by a nearby gauging to get the most accurate estimate of flow possible due to the errors associated with gauging in the very shallow riffles where cross-sections to assess fish passage are likely to be placed in.

d). A need for small off-set distances when surveying cross-sections to maximise accuracy of modelling predictions (with respect to water depths and fish passage).

e). Modelling to be run on 2 scenarios: Actual flows observed at time of survey (i.e. observed groundwater losses), and, if observed losses to groundwater are <350 L/s, and (ii) "worst case" losses to groundwater, assuming constant loss of ~450 L/s between the Ardgour Road flow recorder and Clutha confluence and 500 L/s between The Point – Ardgour Road bridge (note: there is some uncertainty regarding the magnitude of losses in the upper losing reach).

f). Surveys to be undertaken at the following flows:

- 450 L/s

[1] Olsen D. 2017. Final notes from the meeting of experts to discuss fish passage and temperature assessments for the Lindis River. 18 January 2017.

- 600 L/s
- 900 L/s
- 1500+ L/s (~MALF*)

* Since the January 2017 meeting, an Otago Regional Council file note from Hydrologist Xiaofeng Lu updated the naturalised 7-day MALF estimation at the Ardgour Road hydrological site to 1,787 L/s (hydrological year July-June)[2].

g). Passage criteria to be considered include adult, yearling and young of year trout and longfin eel. It was agreed that passage for yearling and/or adult trout would provide sufficient water depths for other fish species present in the Lindis River.

2. Site visit

Selection of critical riffles for fish passage consisted of the experts undertaking a walkover of the lower Lindis River on 23 February 2017. Participants included:

Matthew Dale (Te Rūnanga o Ngāi Tahu)

Morgan Trotter (Otago Fish & Game Council)

Matthew Hickey (Water Resource Management)

Dr Dean Olsen (Otago Regional Council)

Murray Neilson (Clutha Fisheries Trust)

Dr Greg Ryder (Ryder Consulting)

Critical riffles were selected by mutual agreement among the experts. Banks on either side were then marked with flag tape and/or marked stones (spray paint).

A total of 8 sites were selected (Figure 1). Three sites were located in the reach downstream of the SH8 road bridge (Lower Lindis losing reach down to the Clutha confluence), two in the gaining reach (Ardgour Road bridge – Ardgour Road flow recorder) and three in the upper losing reach ("The Point" – Ardgour Road bridge). Details for each critical riffle site are presented in section 5.

3. Field methods

Riffle transects were surveyed using the general approach outlined in the California Department of Fish and Wildlife's standard operating procedure for critical riffle analysis (Woodard 2013[3]). At each site, a transect from bank to bank was identified and pegged out following the contour of shallowest course. A measuring tape was then secured to the pegs using small spring-loaded clamps.

[2] Lu. 2017. Updated naturalised 7dMALF at Lindis at Ardgour Road. Otago Regional Council file note A995461. 13/04/2017.
[3] Woodard, M. 2013. Critical riffle analysis for fish passage in California. California Department of Fish and Wildlife Instream Flow Program Standard Operating Procedure DFG-IFP-001, October 2012, updated February 2013.

Figure 1. *Lindis River critical riffle sites for fish passage analysis.*

The interval sizes (offsets) at which to measure water depth along the transect followed the recommendations in Woodard (2013). That protocol recommends that water depth should be measured at a minimum of 20 evenly spaced intervals along the transect, with a minimum sampling interval of 1 ft (30 cm) for sites with critical riffles of greater than 20 ft (6 m) from bank to bank. Exceptions to this approach were made when the bed was uniform and depth did not alter significantly, and so larger intervals were used, or when depths became shallower over an uneven bed, in which case shorter intervals (e.g., 10-20 cm) were used. Areas where exposed cobbles were present were marked as 0+ cm and OW (out of water).

Using the above approach, water depth was measured at each offset interval using a measuring rod marked with 1 cm graduations. Graduations were re-checked each day prior to a new survey commencing.

Transect data was transcribed into a water-proof notebook and later entered into Excel spreadsheets for detailed fish passage assessment.

All sites were also extensively photographed on each survey date. In addition to ground photos, a drone was used to collect oblique and vertical aerial photos at each site where possible, and of the wider channel in the losing reaches below the SH8 bridge and upstream of the Ardgour Road bridge. On some occasions, the low angle of the sun hindered useful application of the drone.

On the same day as the transect surveys took place, Otago Regional Council hydrologists gauged the river at several locations (Figure 2). Where possible, sites were positioned as close as possible to the fish passage transects, often within 20-100 metres (see below).

4. Survey flows

Transects were surveyed under 5 flow conditions (Table 1). The first four flows took place over a four day sequence between 24 February and 27 February 2017. The fifth survey took place on 24 April 2017 to coincide with a flow close to the 7-day MALF as determined at the Ardgour Road recorder site.

Figure 3 presents the longitudinal flow profiles for the river for the five survey dates.

Figures 4a to 4h present the relationships between the flow at each critical riffle and the flow at the Ardgour Road recorder site. A best fit regression line has been included.

Figure 2. *Lindis River flow monitoring sites used in this investigation (not shown is the site above Cluden Stream).*

Table 1. *Lindis River longitudinal flow gaugings. See Figure 2 for site locations. (Flow data supplied by Jono Young, Otago Regional Council)*

Flow monitoring site	Approximate distance from Clutha River confluence (m)	Survey Date / Flow (L/s)				
		24/02/2017	25/02/2017	26/02/2017	27/02/2017	24/04/2017
Site 1 (Lindis Confluence)	75	342	116	57	37	1,277
Site 2 (Lindis Confluence flow site)	270	365	158	96	68	1,077
Site 3 (Downstream of SH8 Bridge)	860	521	279	183	136	1,417
Site 4 (Lindis SH8 Flow Site)	1,490	613	388	258	no data	1,620
Site 5 (Lindis Ardgour Road)	4,090	899	575	513	480	1,603
Site 6 (Lindis Gaining Reach - Bottom Site)	5,490	680	482	388	no data	1,542
Site 7 (Lindis Gaining Reach - Top Site)	7,090	795	618	505	no data	1,674
Site 8 (Lindis At Ardgour Bridge)	11,790	201	159	120	no data	936
Site 9 (Above Ardgour Bridge - Bottom Site, T1)	12,450	185	141	106	29	1,073
Site 10 (Above Ardgour Bridge - Top Site, T2 & T3)	12,630	188	151	113	no data	1,057
Site 11 (Lindis Above Cluden Stream)	24,830	1,593	1,458	1,500	no data	1,854

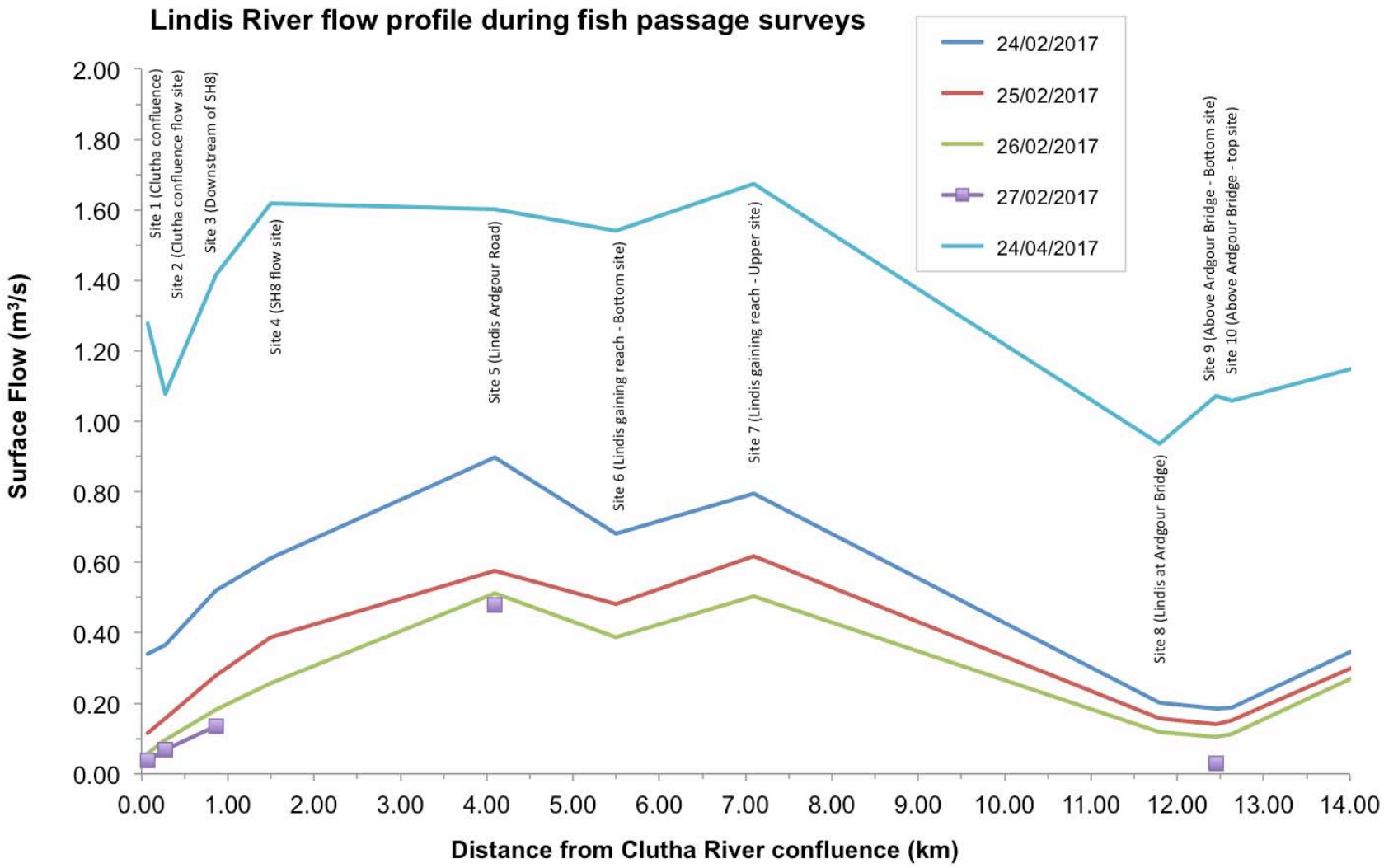

Figure 3. *Lindis River longitundinal flow profile from the Clutha River confluence to the Ardgour Bridge reach. See Table 1 for flow details.*

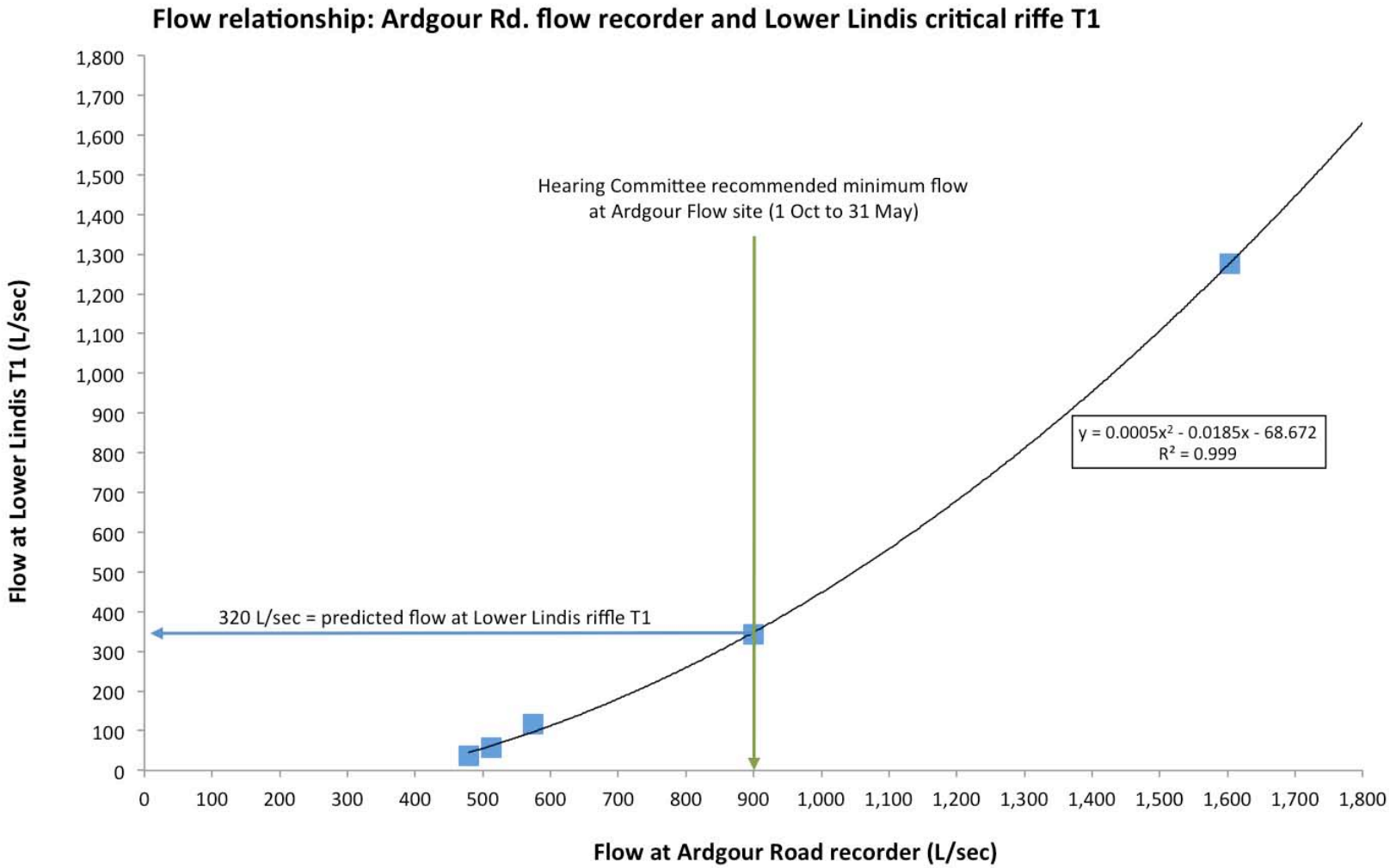

Figure 4a. *Relationship between flows at the Lower Lindis critical riffle T1 and the Lindis Ardgour Road flow recorder. See Table 1 for raw data.*

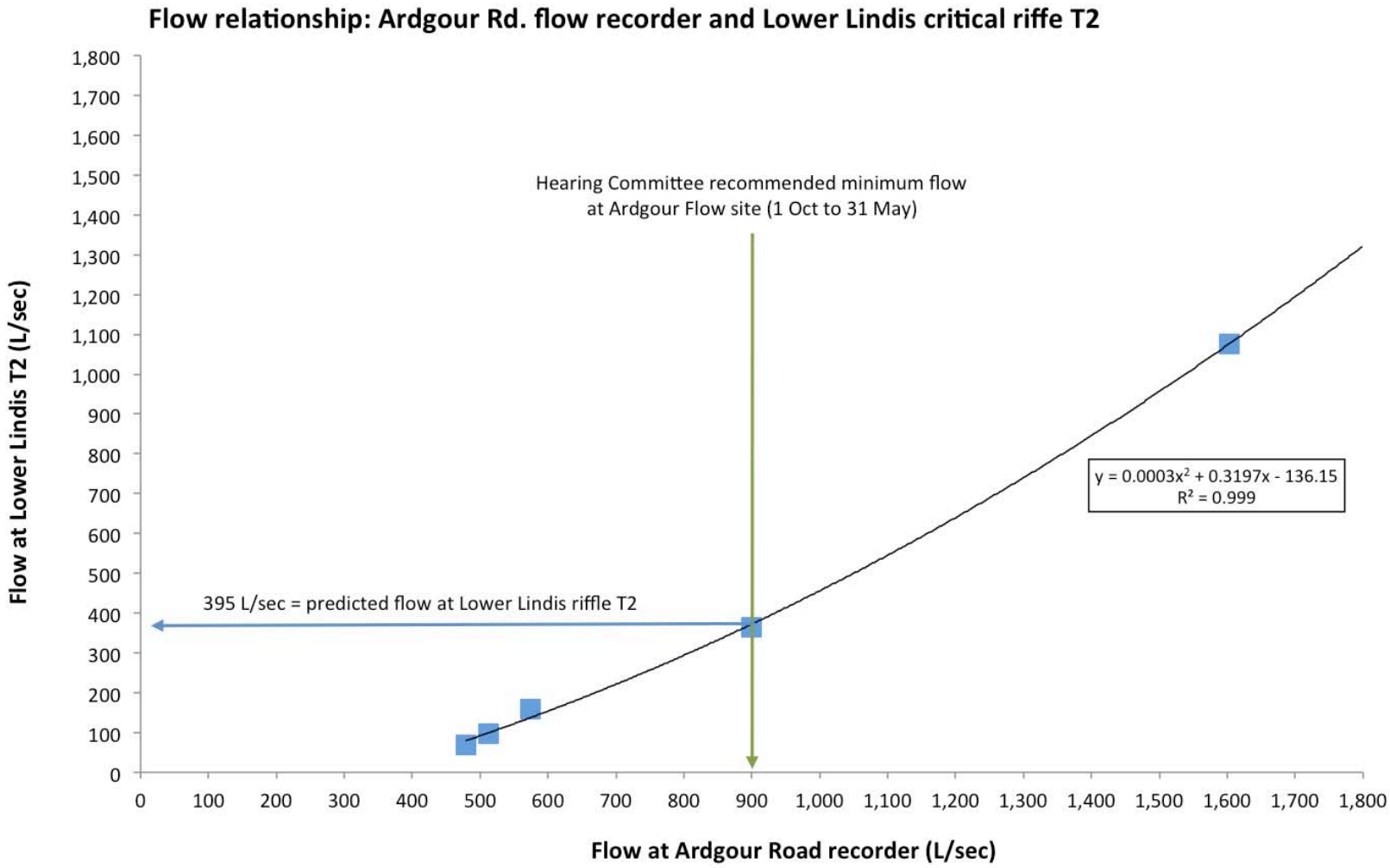

Figure 4b. *Relationship between flows at the Lower Lindis critical riffle T2 and the Lindis Ardgour Road flow recorder. See Table 1 for raw data.*

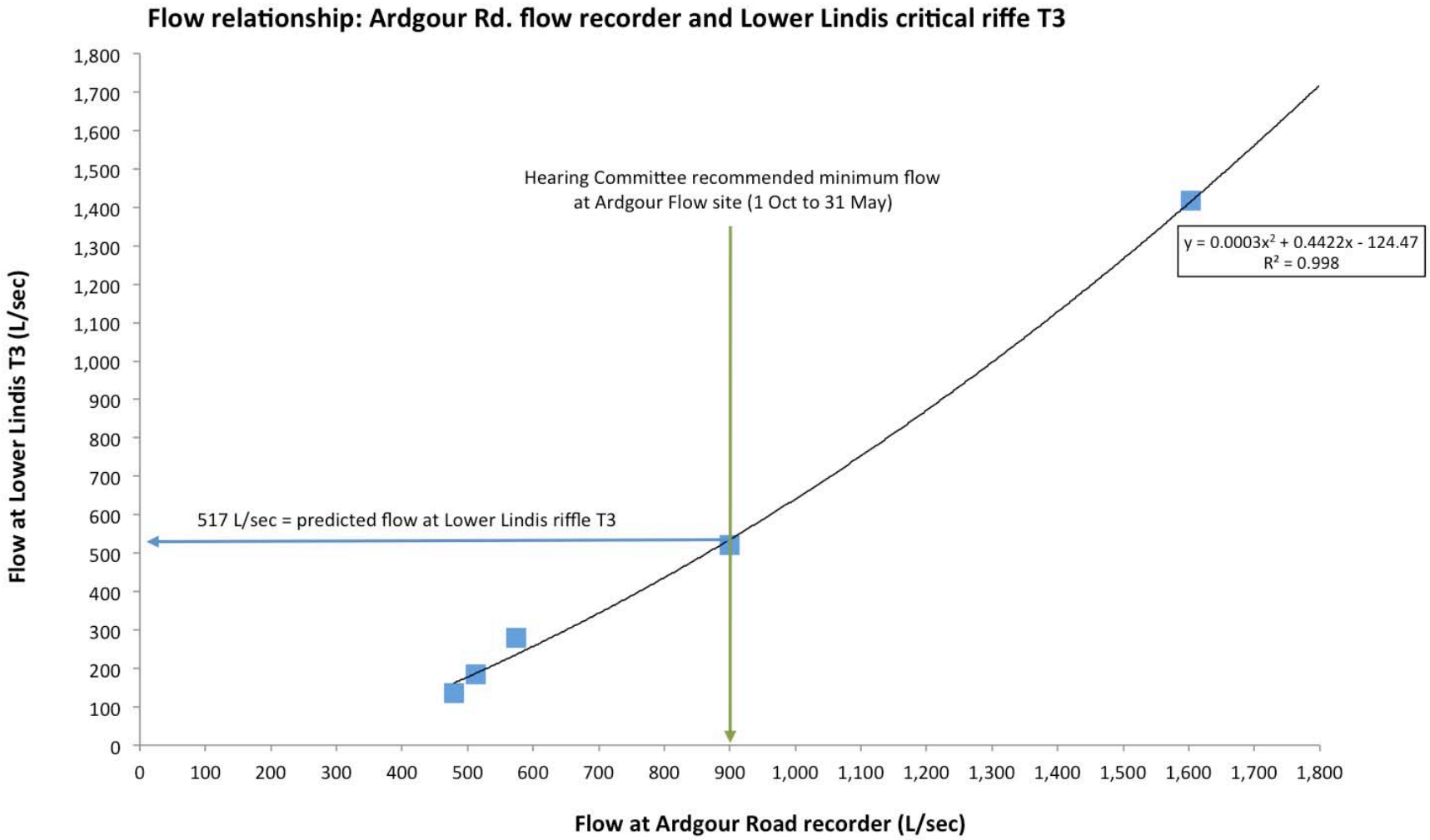

Figure 4c. *Relationship between flows at the Lower Lindis critical riffle T3 and the Lindis Ardgour Road flow recorder. See Table 1 for raw data.*

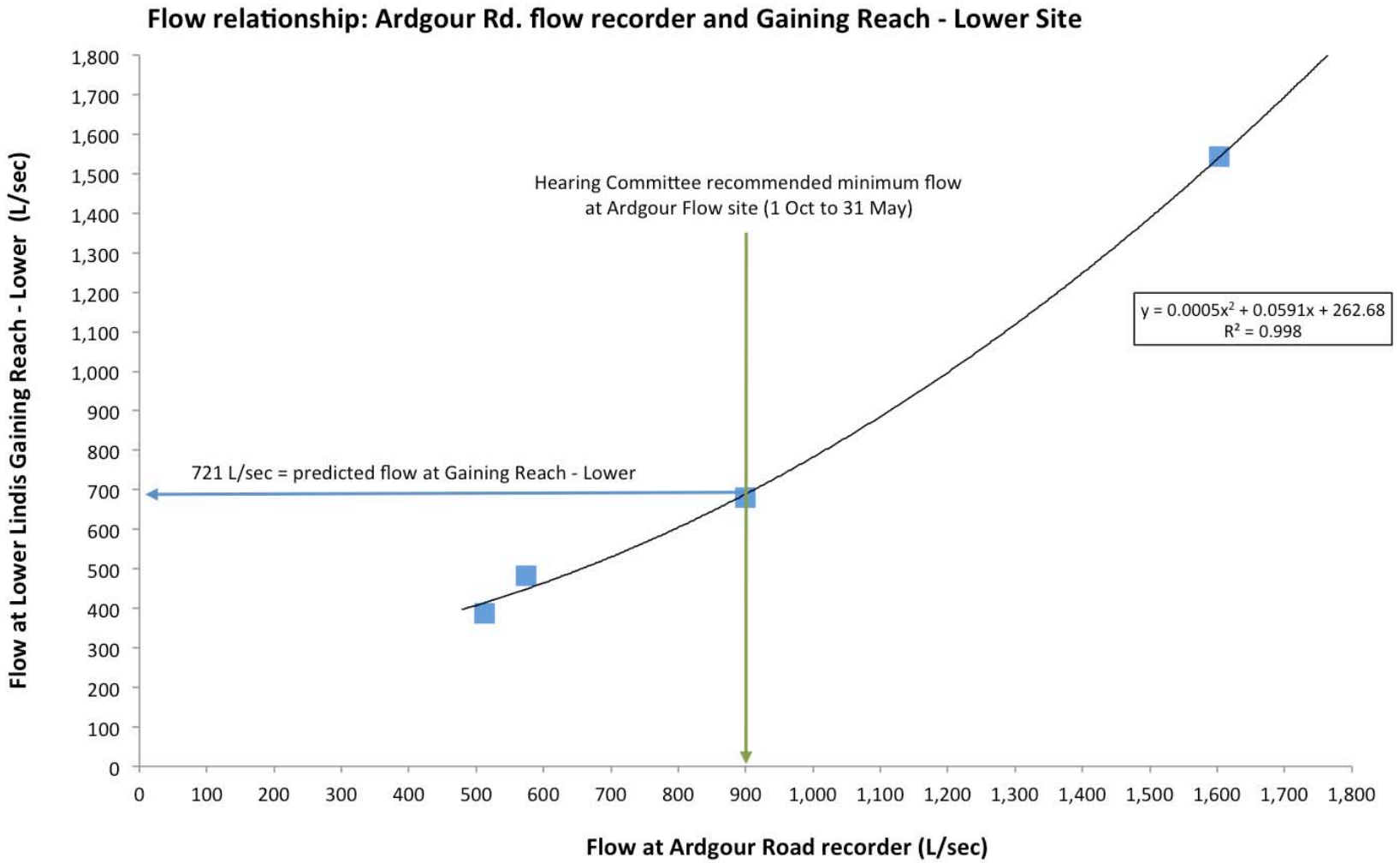

Figure 4d. *Relationship between flows at the Lindis gaining reach critical riffle lower and the Lindis Ardgour Road flow recorder. See Table 1 for raw data.*

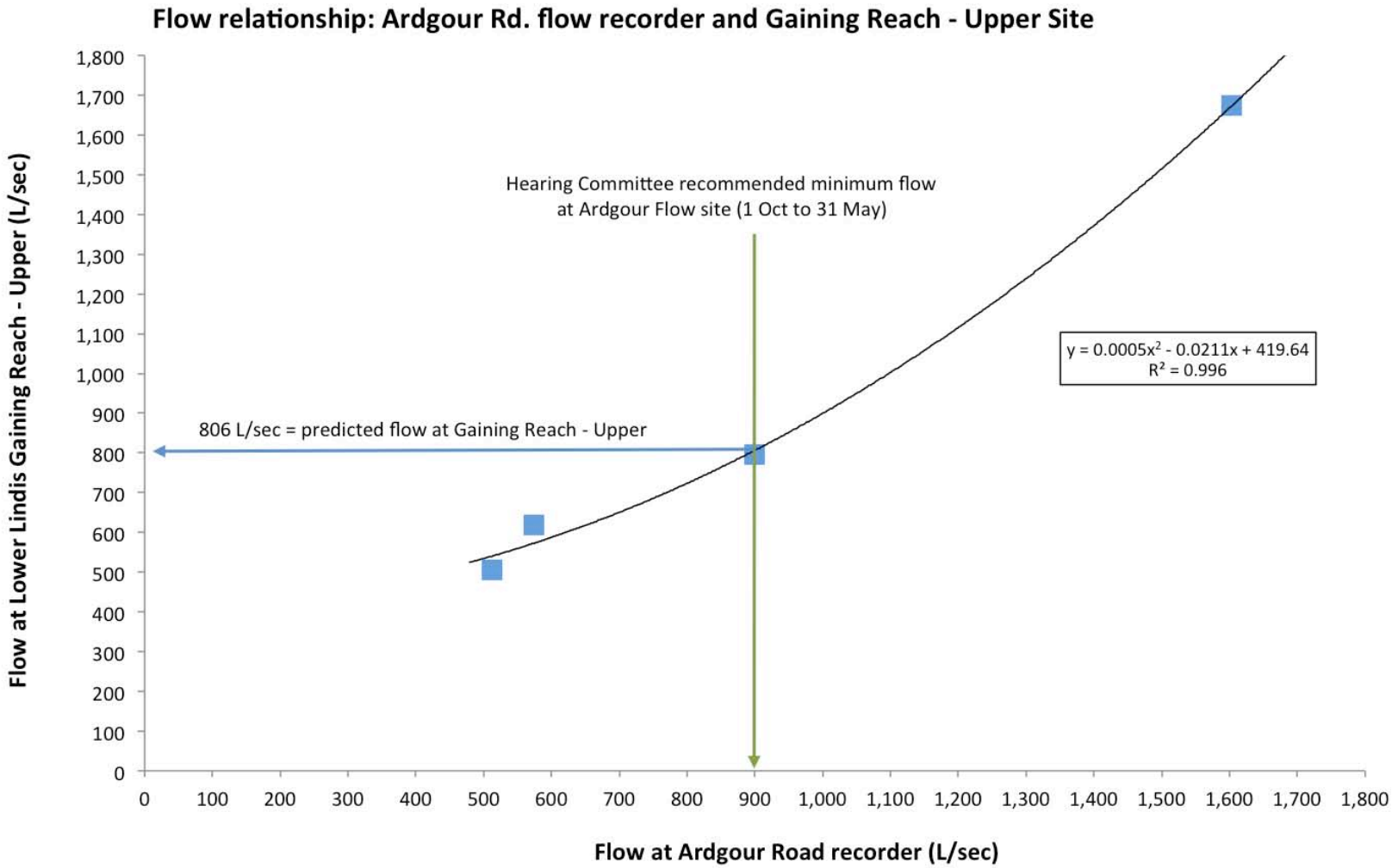

Figure 4e. *Relationship between flows at the Lindis gaining reach critical riffle upper and the Lindis Ardgour Road flow recorder. See Table 1 for raw data.*

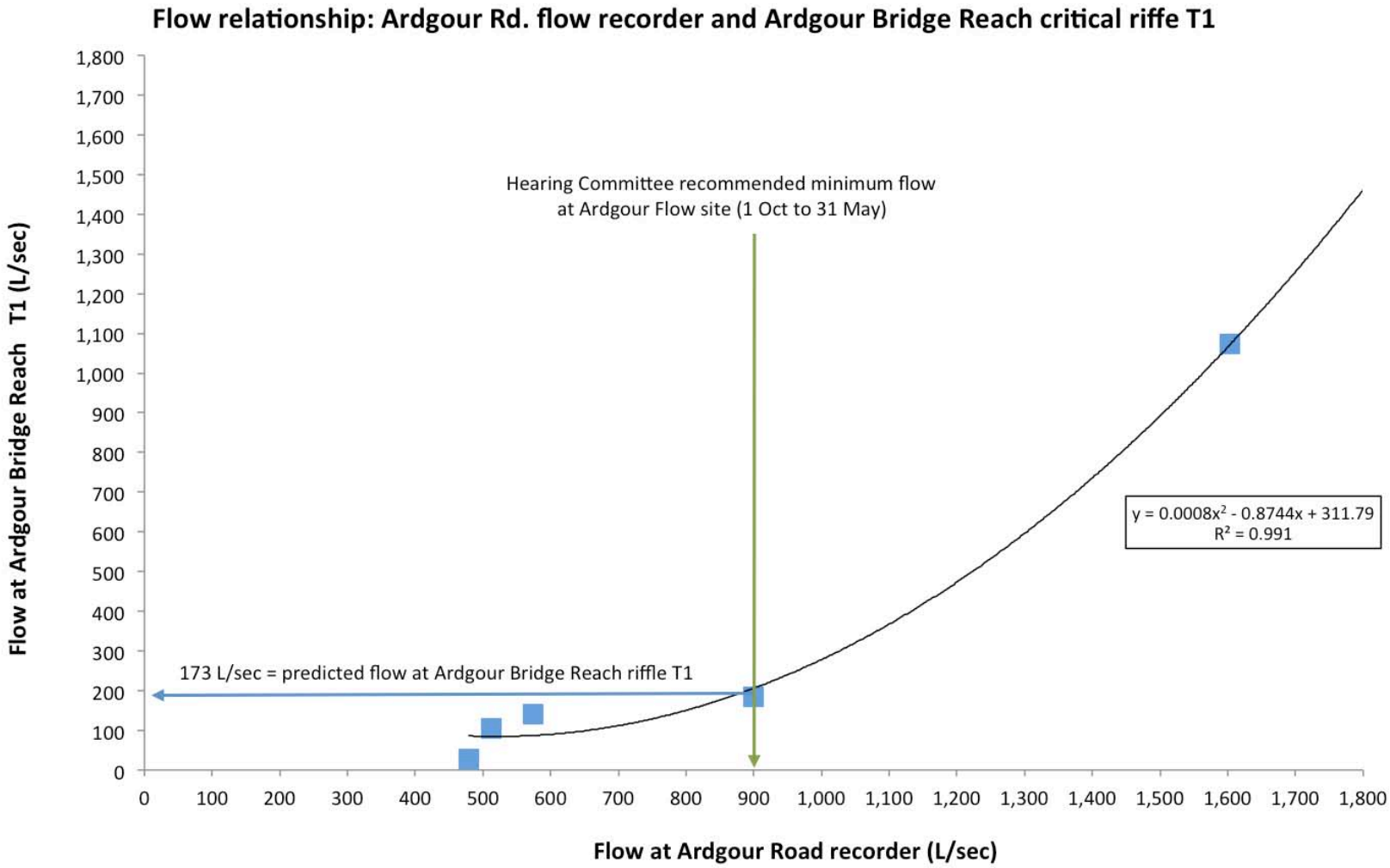

Figure 4f. *Relationship between flows at the Lindis Ardgour Bridge reach critical riffle T1 and the Lindis Ardgour Road flow recorder. See Table 1 for raw data.*

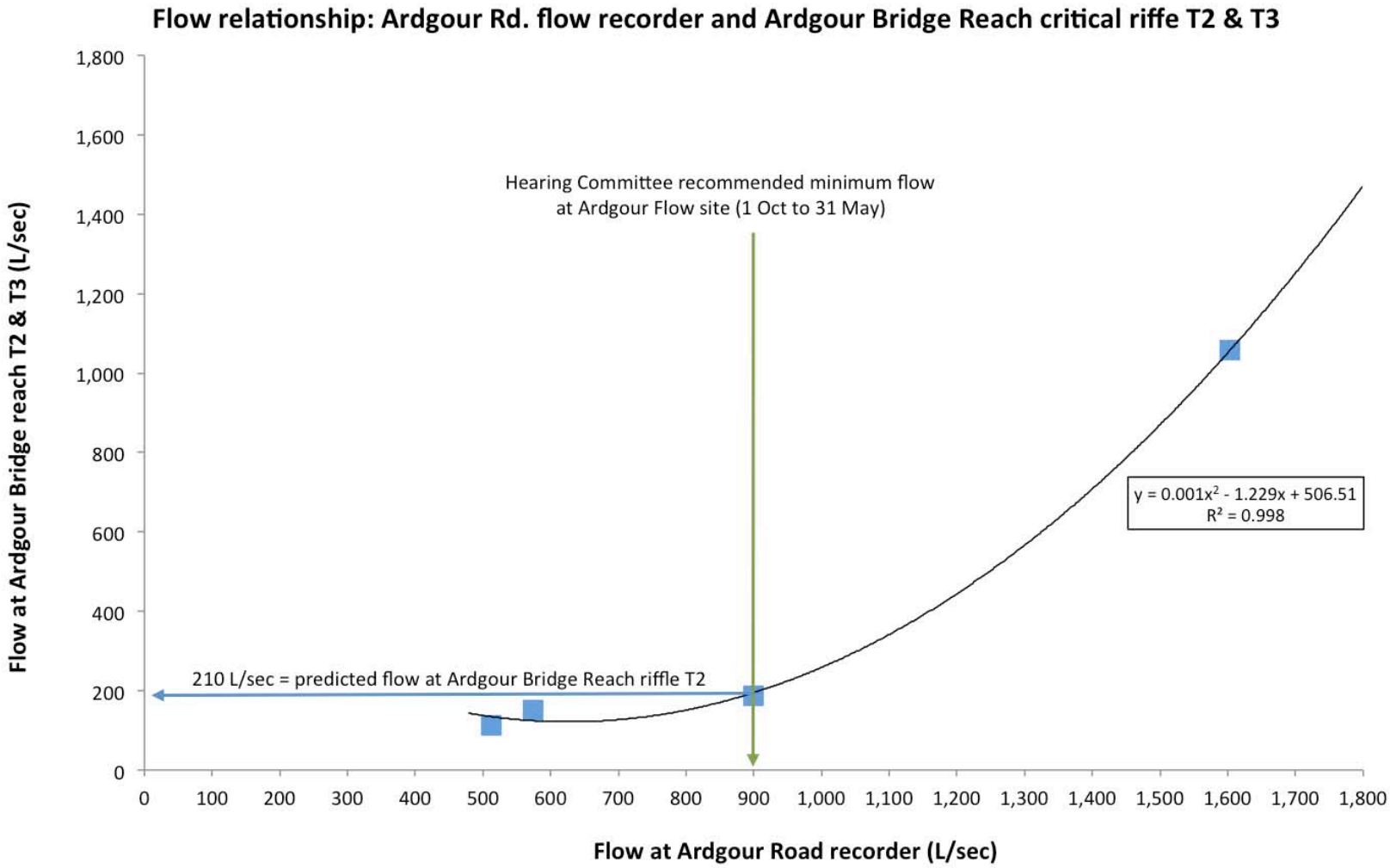

Figure 4g. *Relationship between flows at the Lindis Ardgour Bridge reach critical riffle T2 and T3 and the Lindis Ardgour Road flow recorder. See Table 1 for raw data.*

5. Critical riffles descriptions

Approximate locations of all riffles surveyed for fish passage are shown in Figure 1. Photographs of each site and plots showing changes in water depth with flow are presented on the following pages in figures 5a to 12b. Additional photos of all sites are available upon request.

5.1 Lower Lindis T1

Lower Lindis T1 riffle is located approximately 75 metres from the confluence with the Clutha River. The surveyed transect line ran more or less immediately above where a single channel split into two which then ran directly into the Clutha River.

Figure 5a. *Lower Lindis critical riffle T1. Flow figures are from nearest flow gauging site.*

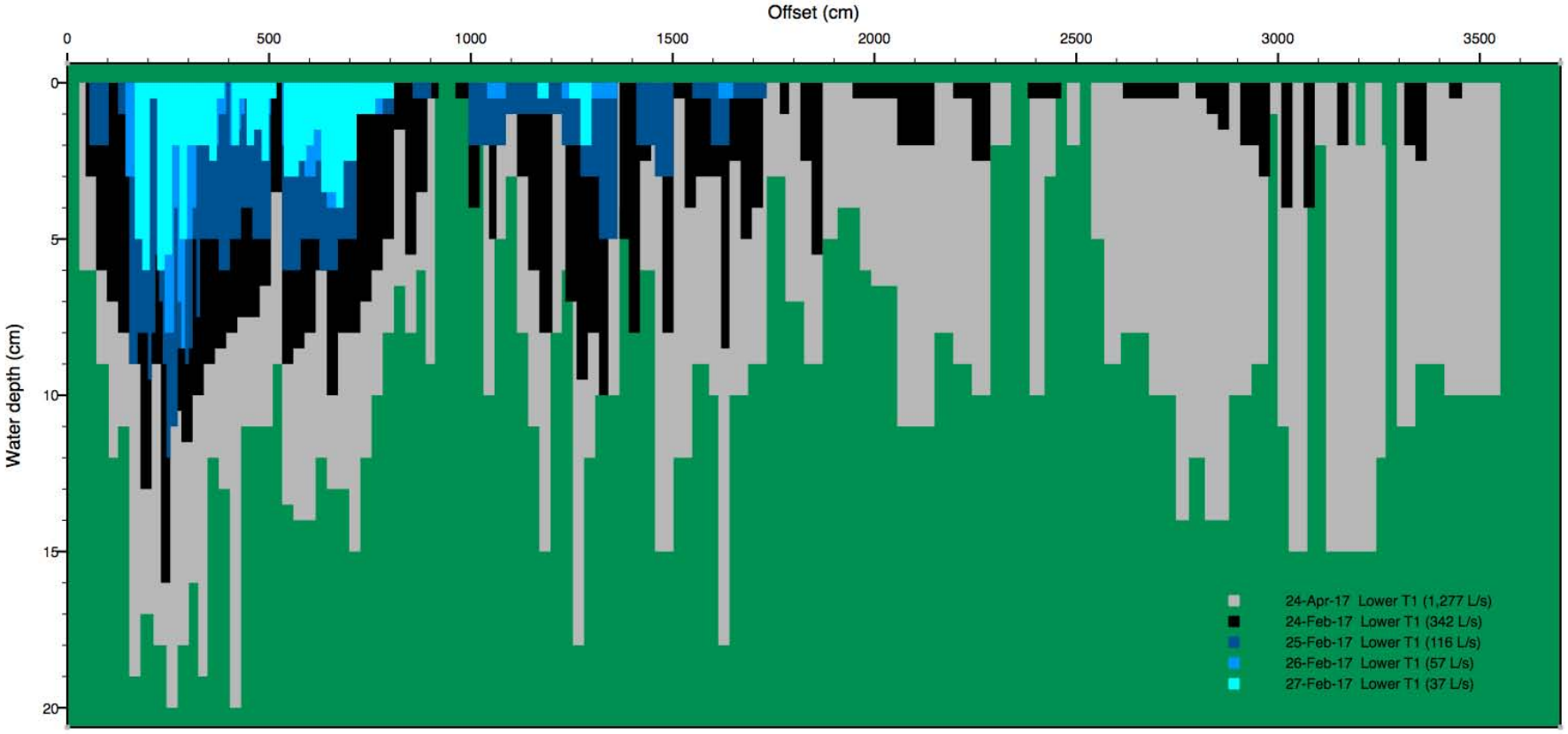

Figure 5b. *Lower Lindis critical riffle T1. Water depth across the transect for each survey date. Flow figures are from nearest flow gauging site.*

5.2 Lower Lindis T2

Lower Lindis T2 riffle is located approximately located approximately 270 metres from the confluence with the Clutha River.

Figure 6a. *Lower Lindis critical riffle T2. Flow figures are from nearest flow gauging site.*

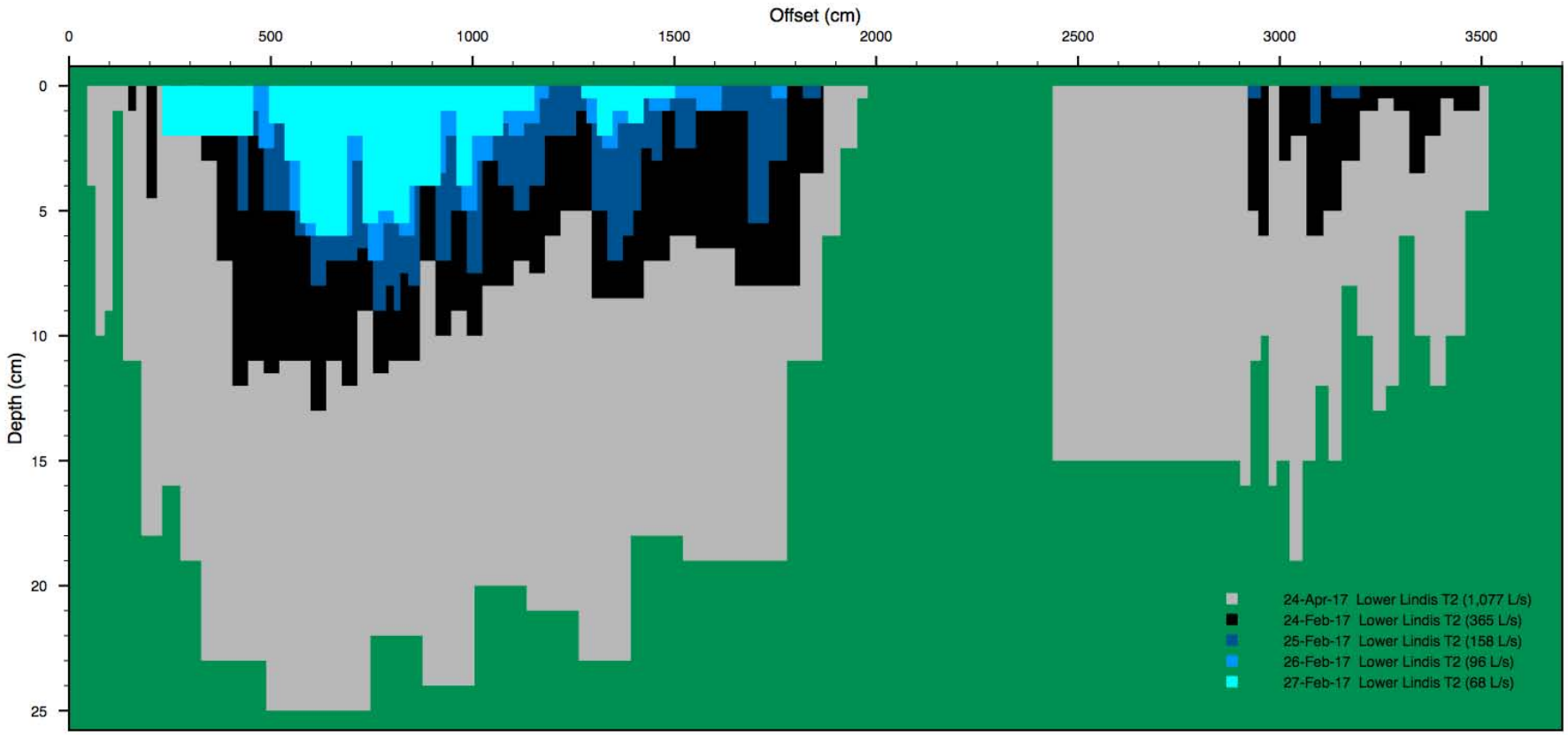

Figure 6b. *Lower Lindis critical riffle T2. Water depth across the transect for each survey date. Flow figures are from nearest flow gauging site.*

5.3 Lower Lindis T3

Lower Lindis T3 riffle is located approximately 860 metres from the confluence with the Clutha River. It splits extensively into multiple channels, many of which are short and narrow. It also has a small braid on the true left side which is quite separate from the other channels.

Figure 7a. *Lower Lindis critical riffle T3. Flow figures are from nearest flow gauging site.*

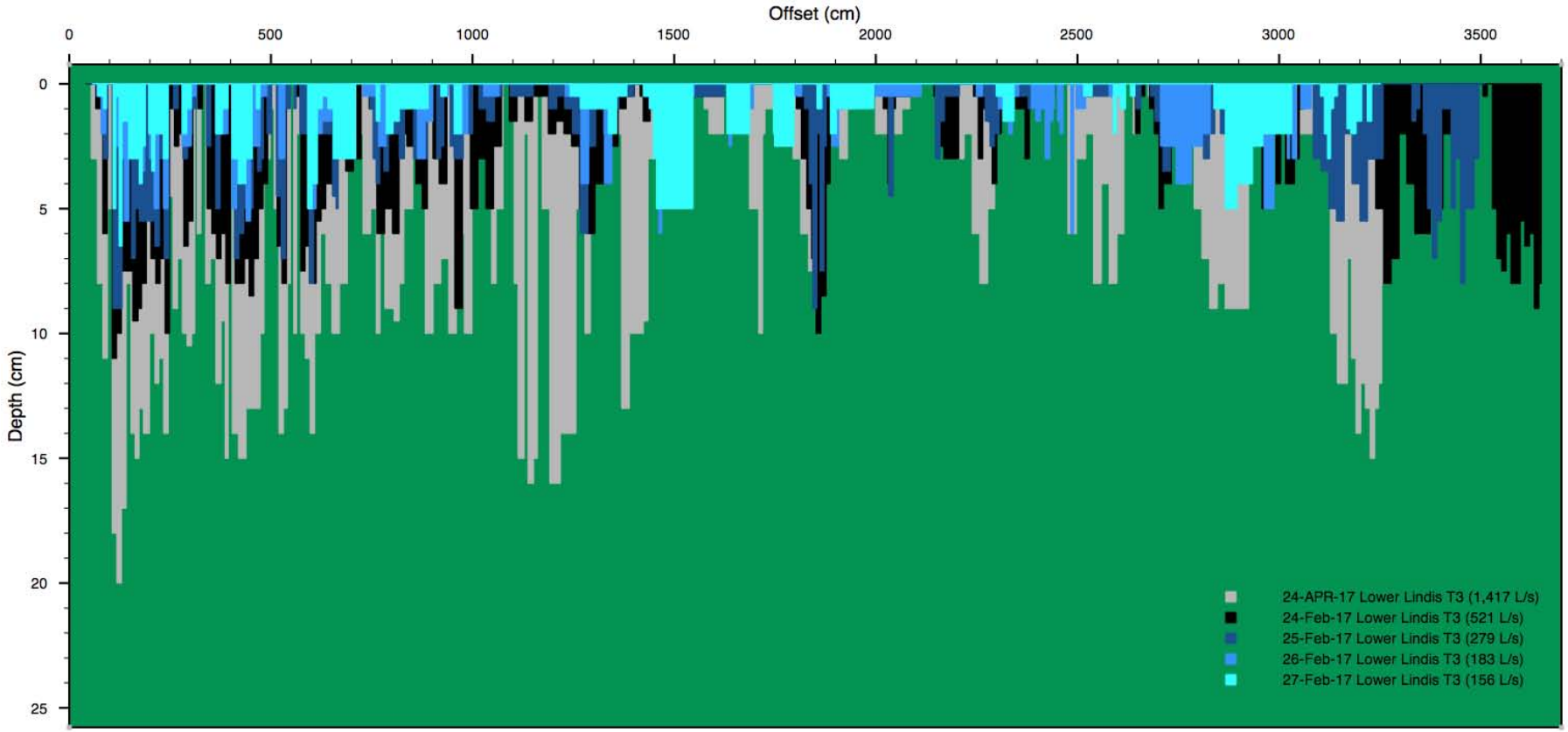

Figure 7b. *Lower Lindis critical riffle T3. Water depth across the transect for each survey date. Flow figures are from nearest flow gauging site.*

5.4 Gaining Reach – Bottom Site

The Bottom Site in the Gaining Reach is located approximately 5.3 metres from the confluence with the Clutha River. The riffle is located on a single, gently curved channel.

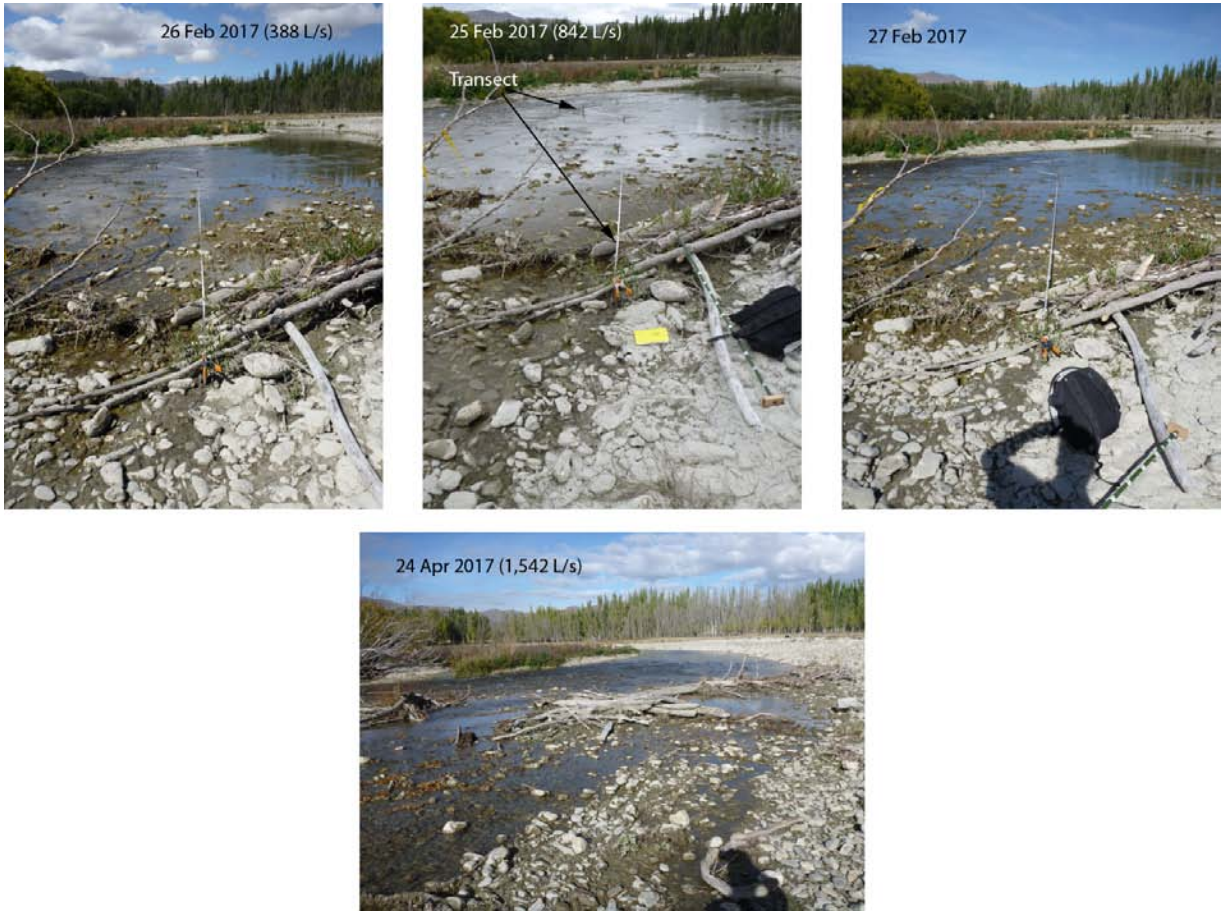

Figure 8a. *Lindis Gaining Reach – lower or bottom site . Flow figures are from nearest flow gauging site.*

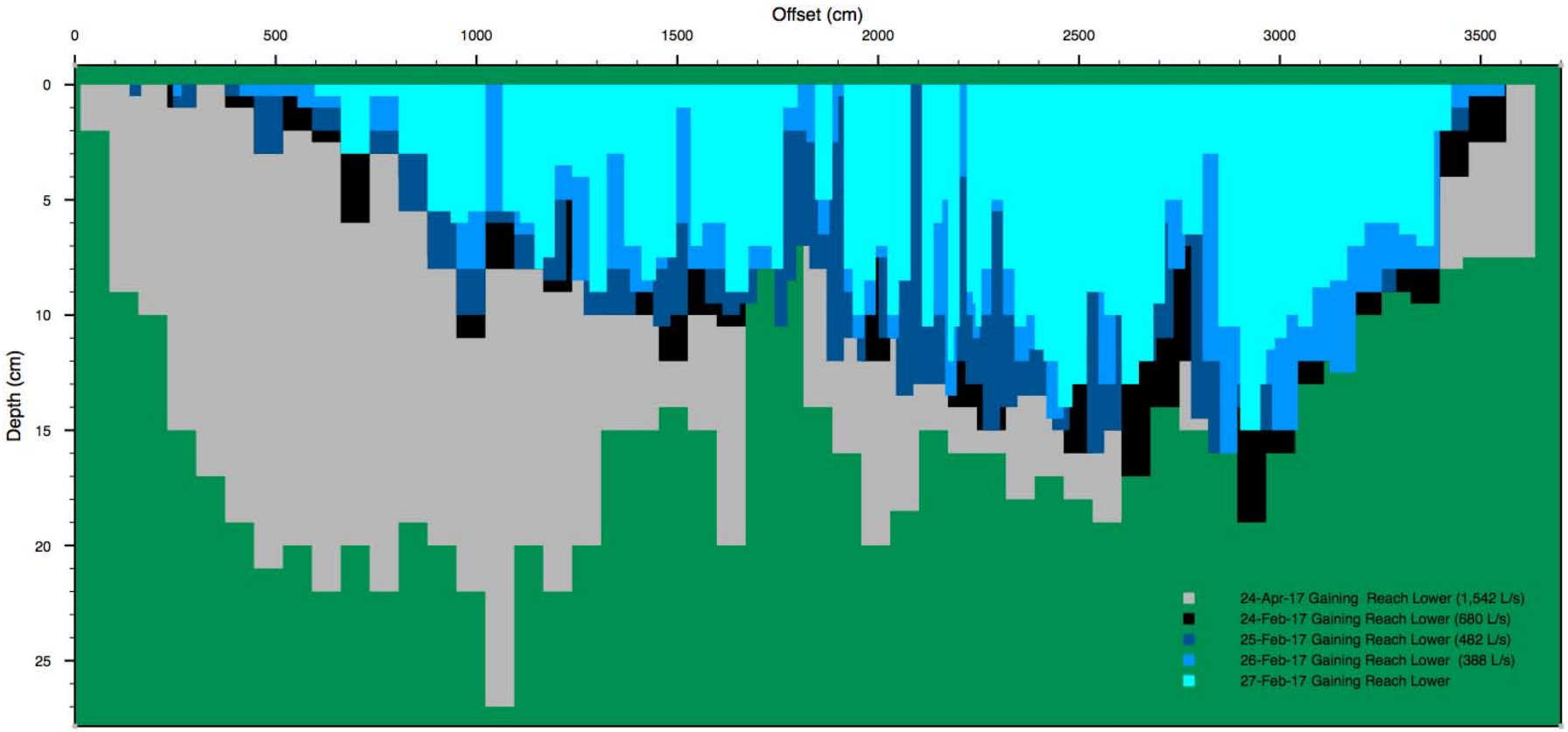

Figure 8b. *Lindis Gaining Reach – lower or bottom site. Water depth across the transect for each survey date. Flow figures are from nearest flow gauging site.*

5.5 Gaining Reach – Top Site

The Top Site in the Gaining Reach is located approximately 7 km from the confluence with the Clutha River. The riffle is located on a single, low gradient, straight channel.

Figure 9a. *Lindis Gaining Reach – upper or top site . Flow figures are from nearest flow gauging site.*

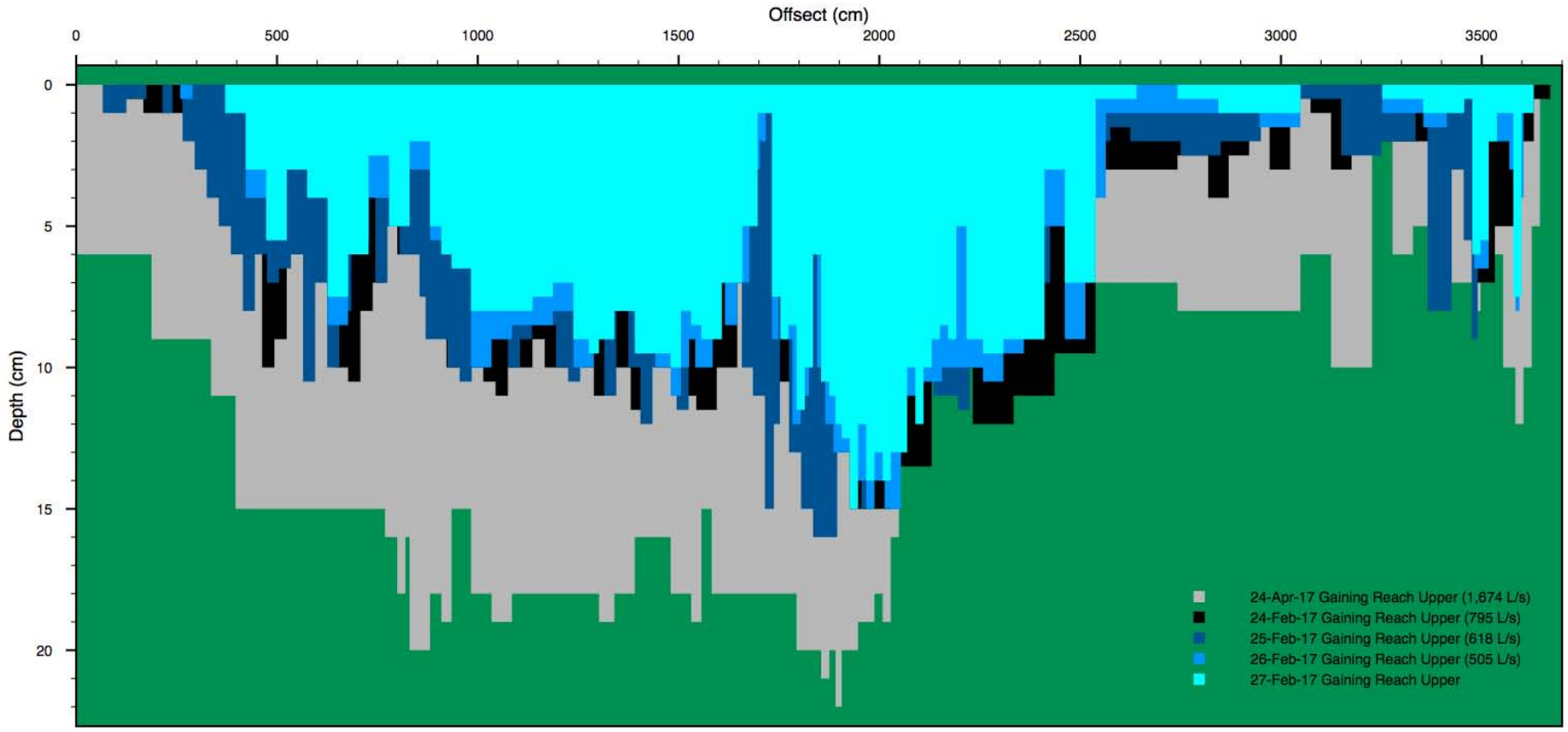

Figure 9b. *Lindis Gaining Reach – upper or top site. Water depth across the transect for each survey date. Flow figures are from nearest flow gauging site.*

5.6 Ardgour Bridge Reach T1

The Ardgour Bridge Reach T1 riffle is located approximately 12.45 km from the confluence with the Clutha River. The riffle is located on a single, gently curved channel.

Figure 10a. *Ardgour Bridge Reach – site T1. Flow figures are from nearest flow gauging site.*

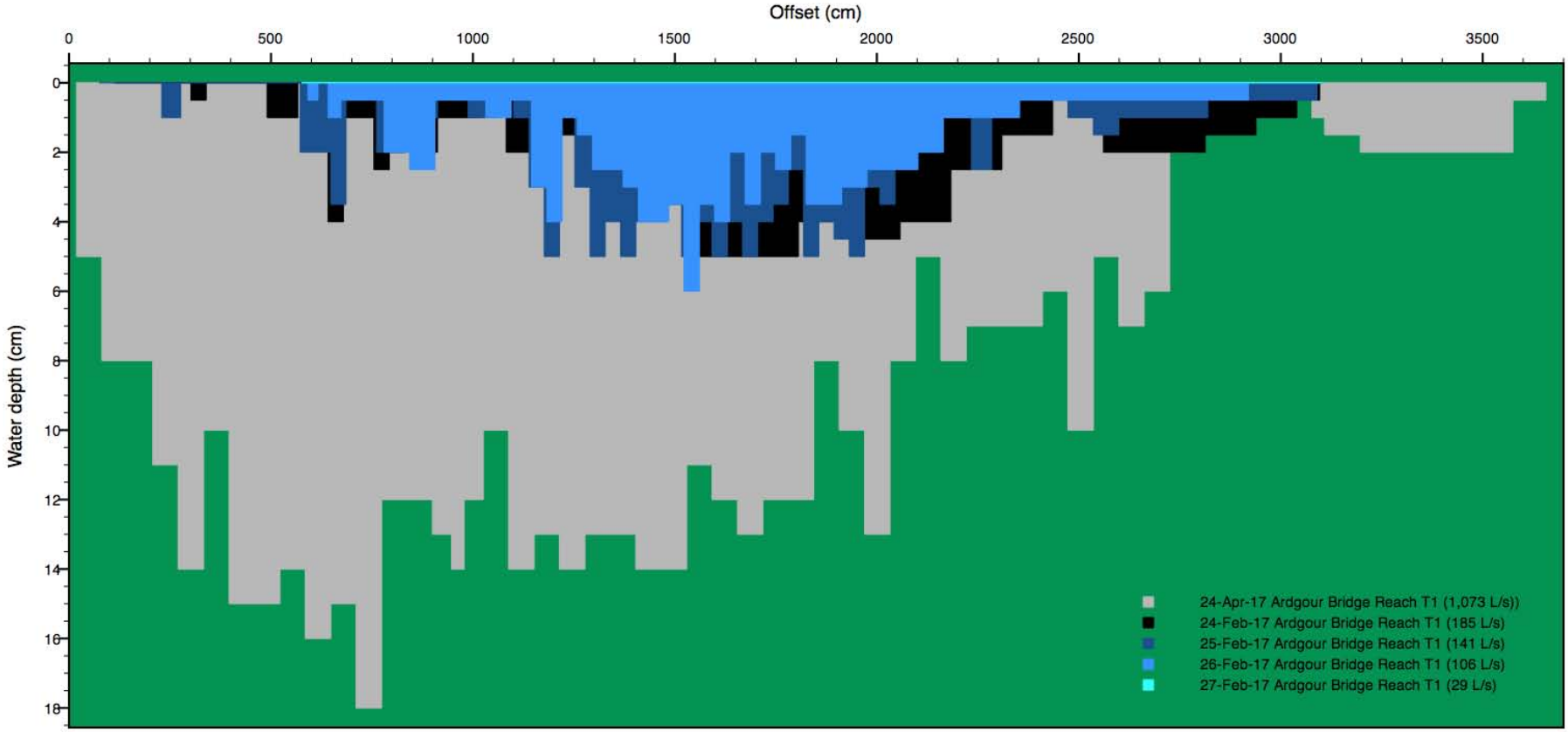

Figure 10b. *Ardgour Bridge Reach – site T1. Water depth across the transect for each survey date. Flow figures are from nearest flow gauging site.*

5.7 Ardgour Bridge Reach T2

The Ardgour Bridge Reach T2 riffle is a relatively straight single channel located approximately 12.6 km from the confluence with the Clutha River.

Figure 11a. *Ardgour Bridge Reach – site T2. Flow figures are from nearest flow gauging site.*

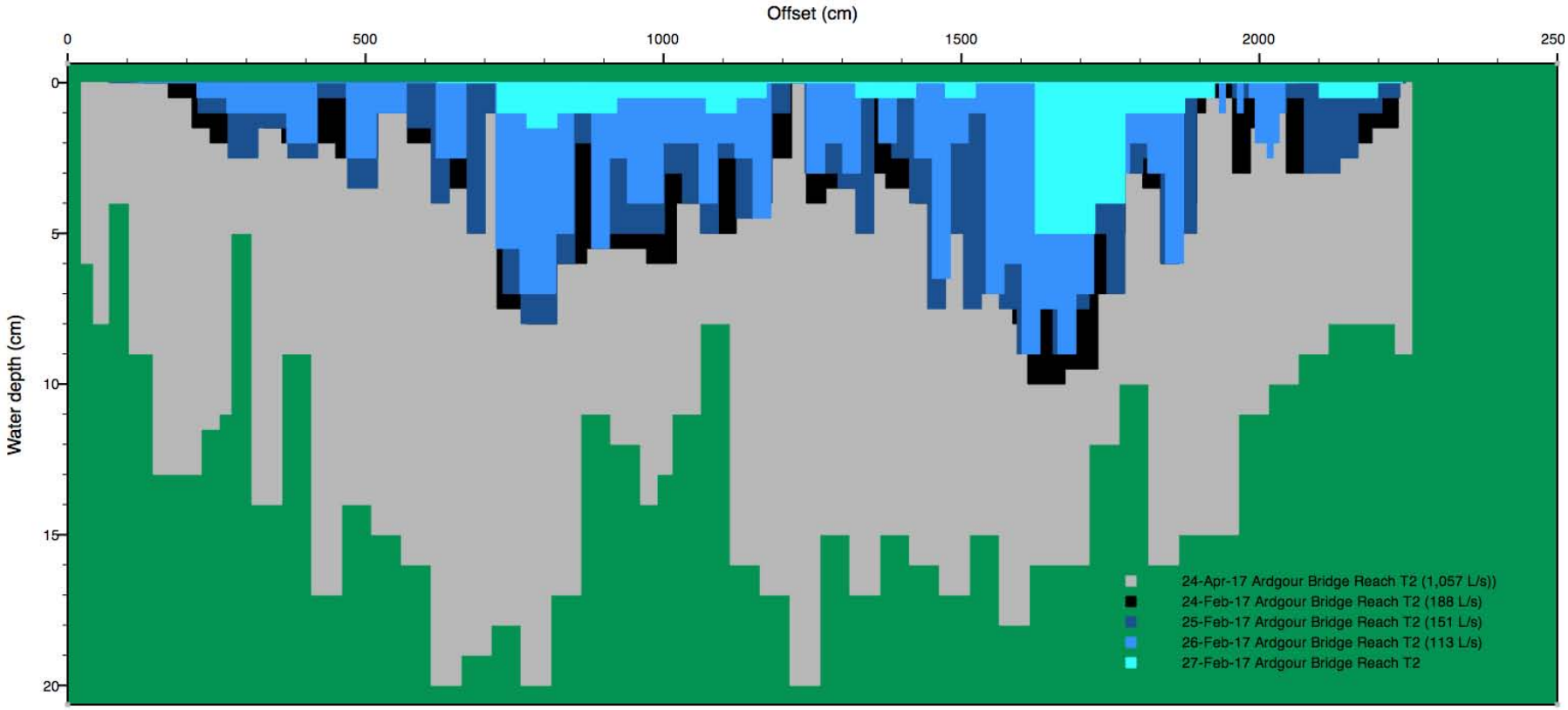

Figure 11b. *Ardgour Bridge Reach – site T2. Water depth across the transect for each survey date. Flow figures are from nearest flow gauging site.*

5.8 Ardgour Bridge Reach T3

The Ardgour Bridge Reach T3 riffle is located approximately 12.6-12.7 km from the confluence with the Clutha River. The survey at this site consisted of two separate transects associated with two braids separated by approximately 90-100 metres.

Figure 12a. *Ardgour Bridge Reach – site T3. Flow figures are from nearest flow gauging site.*

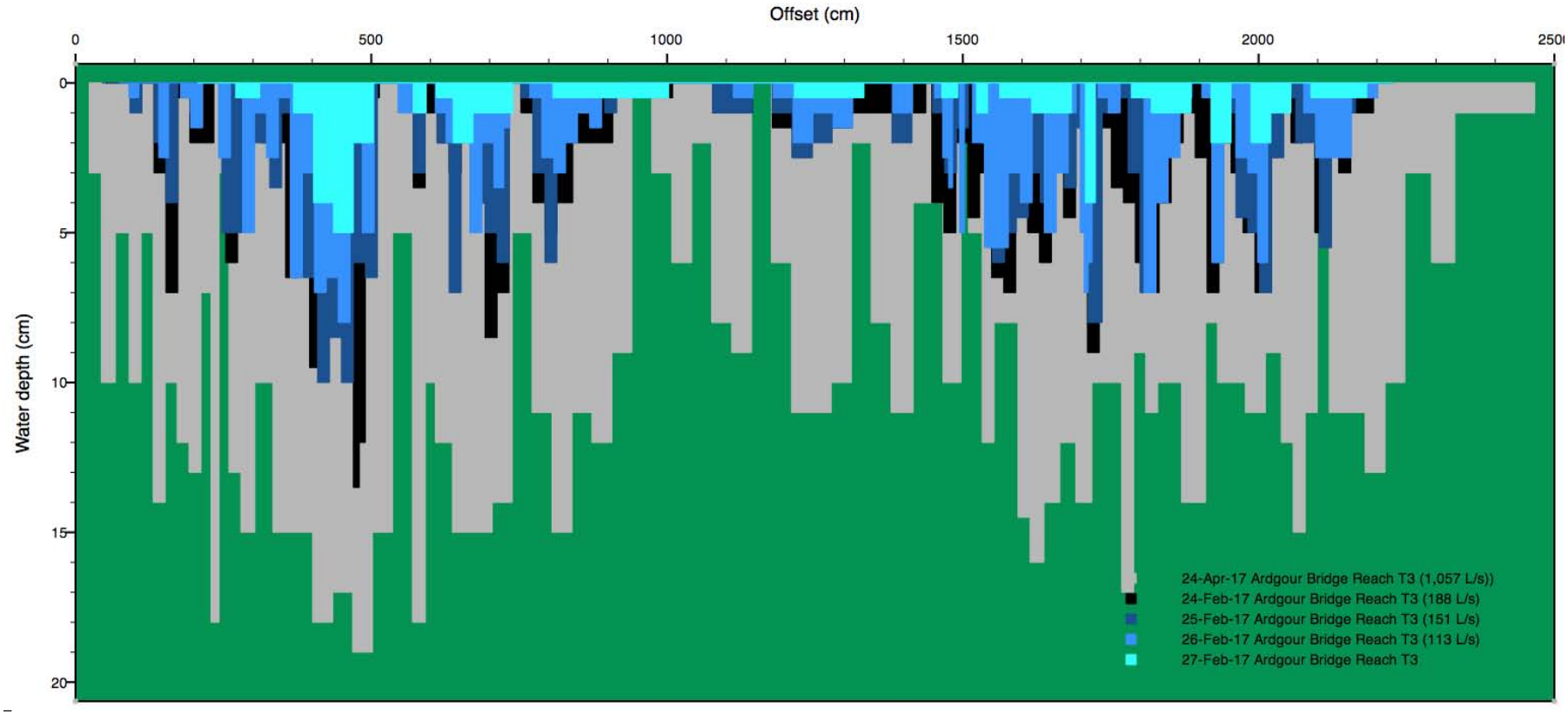

Figure 12b. *Ardgour Bridge Reach – site T3. Water depth across the transect for each survey date. Flow figures are from nearest flow gauging site.*

6. Fish passage criteria

Gabrielsson and Hay (2017[4]) prepared a summary of recommended fish passage criteria for the Lindis River (Table 2). The recommendations include a minimum water depth for various fish life stages and also a contiguous passage width of 1 m for all life stages, although the authors acknowledge that this is a fairly arbitrary figure. Gabrielsson and Hay also recommended modelling fish passage conditions at identified critical riffles under natural occurring low flow conditions (e.g., the estimated naturalised 7-d and/or 30-d mean annual low flow or MALF) to provide a baseline for comparison. The survey of 24 April 2017 addresses this recommendation.

Table 2. *Recommended minimum water depth and width criteria for maintaining salmonid passage during the late summer low flow period, based on a review of commonly adopted fish passage criteria in New Zealand and overseas. (source: Gabrielsson and Hay, 2017).*

Fish life stage	Fish length indicative size range (cm)	Minimum water depth for passage (m)	Minimum contiguous passage width (m)
Young-of-the-year trout	10 – 15 *	0.10	1
Yearling trout	18 – 25 *	0.15	1
Adult trout	> 40	0.20	1
Salmon / Very large trout	> 60	0.25	1

** Expected size range during late summer / autumn (February – April)*

The above criteria were applied to the cross sectional water depth data for the Lindis River transects. Spreadsheet formulas were used to determine critical depths for the life stages identified in Table 2 and to determine contiguous widths of water that had suitable depths for passage.

7. Results of fish passage analysis

The results of the above analyses are presented in plots on the following pages. Each plot summaries passage data for one of the critical riffle transects shown in Figure 1 over the five occasions assessed, starting with the site closest to the Clutha River and working upstream. Suitable passage at each transect site has been benchmarked against the flow at the Ardgour Road flow recorder site on the same day, given this is the preferred site for assessing minimum flows in the Lindis River.

Where a fish life stage exceeds the 1 m contiguous width criteria (marked as a horizontal line on each plot) it can be assumed that there was sufficient water depth as defined in Table 2 and, as such, the criteria for both depth and width are met at the site for the relevant flow as measured on the day at the Ardgour Road recorder site.

[4] Gabrielsson, R. and Hay, J. 2017. Review of fish passage criteria for assessing implications of minimum flow options. Prepared for Otago Fish & Game Council. Cawthron Report No. 3014.

A summary of the estimated minimum flow requirements for fish at each critical riffle, based on the fish passage criteria in Table 2 and the best fit relationships between these and flow at the Ardgour Road flow recorder, is presented in Table 3.

Table 3. *Lindis River estimated minimum flows to meet fish passage criteria at critical riffle sites surveyed between February and April 2017.*

Critical riffle for fish passage	Approximate distance from Clutha River confluence (m)	Minimum flow at Ardgour Road recorder to achieve fish passage criteria* (L/s)			
		Young-of-the-year trout/native fish	Yearling trout	Adult trout	Salmon / Very large trout
Lower Lindis T1	75	835	1,250	>>2,000	>>2,000
Lower Lindis T2	270	730	1,000	1,050	1,345
Lower Lindis T3	860	1,300	1,650	>>2,000	>>2,000
Gaining Reach – Lower (bottom)Site	5,490	480	780	1,247	1,950
Gaining Reach – Upper (top) Site	7,090	480	890	1,370	>>2,000
Ardgour Bridge Reach – T1	12,450	1,000 (380)	1,290 (720)	>>2,000	>>2,000
Ardgour Bridge Reach – T2	12,630	970 (265)	1,100 (520)	1,960 (1,425)	>>2,000
Ardgour Bridge Reach – T3	12,880	1,095 (345)	1,245 (670)	>>2,000	>>2,000

* Figures in brackets relate to flows at the Ardgour Bridge Reach.

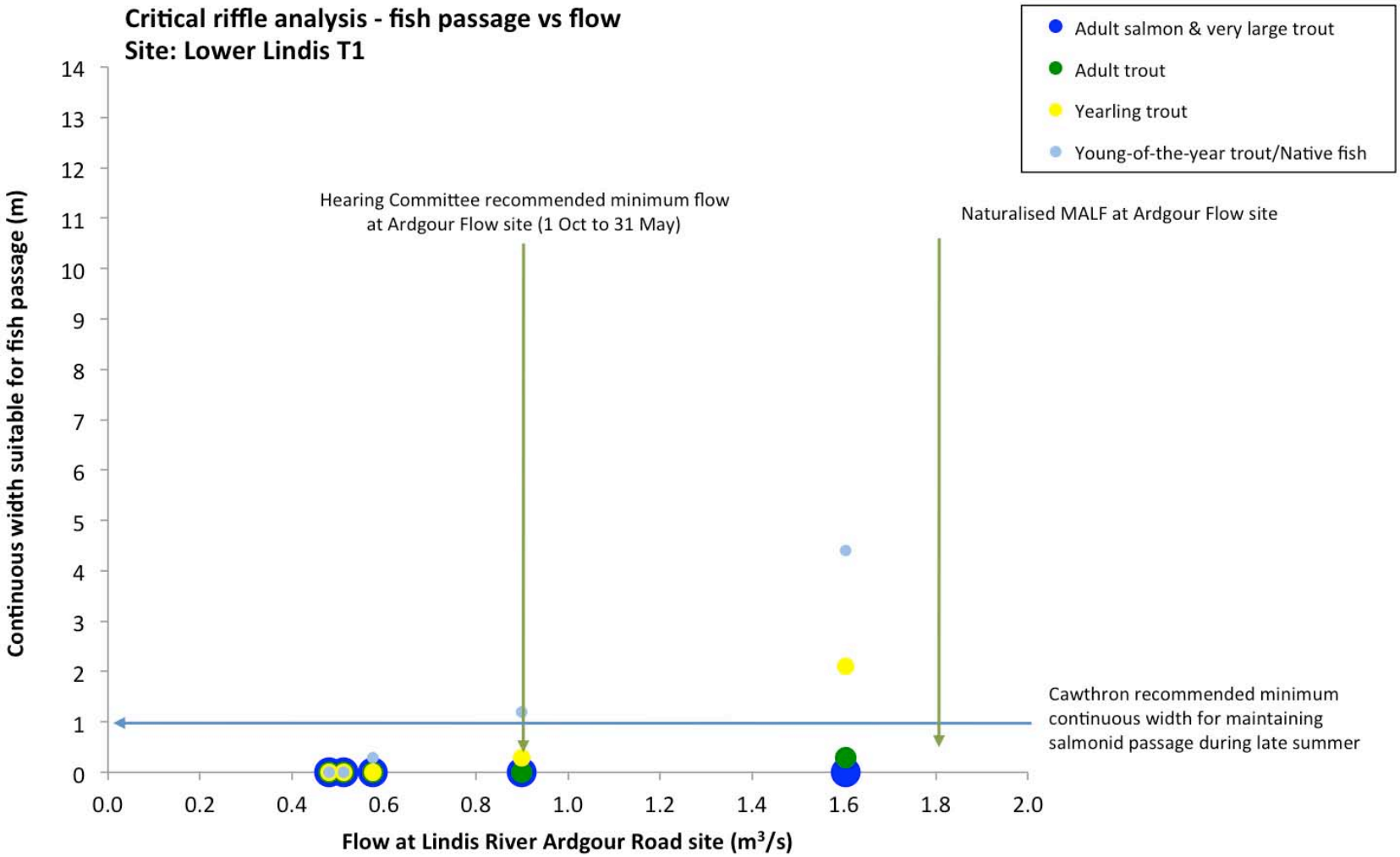

Figure 13a. *Relationship between flows at the Lower Lindis critical riffle T1, fish passage criteria as set out in Table 2 and key flow markers at Ardgour Road.*

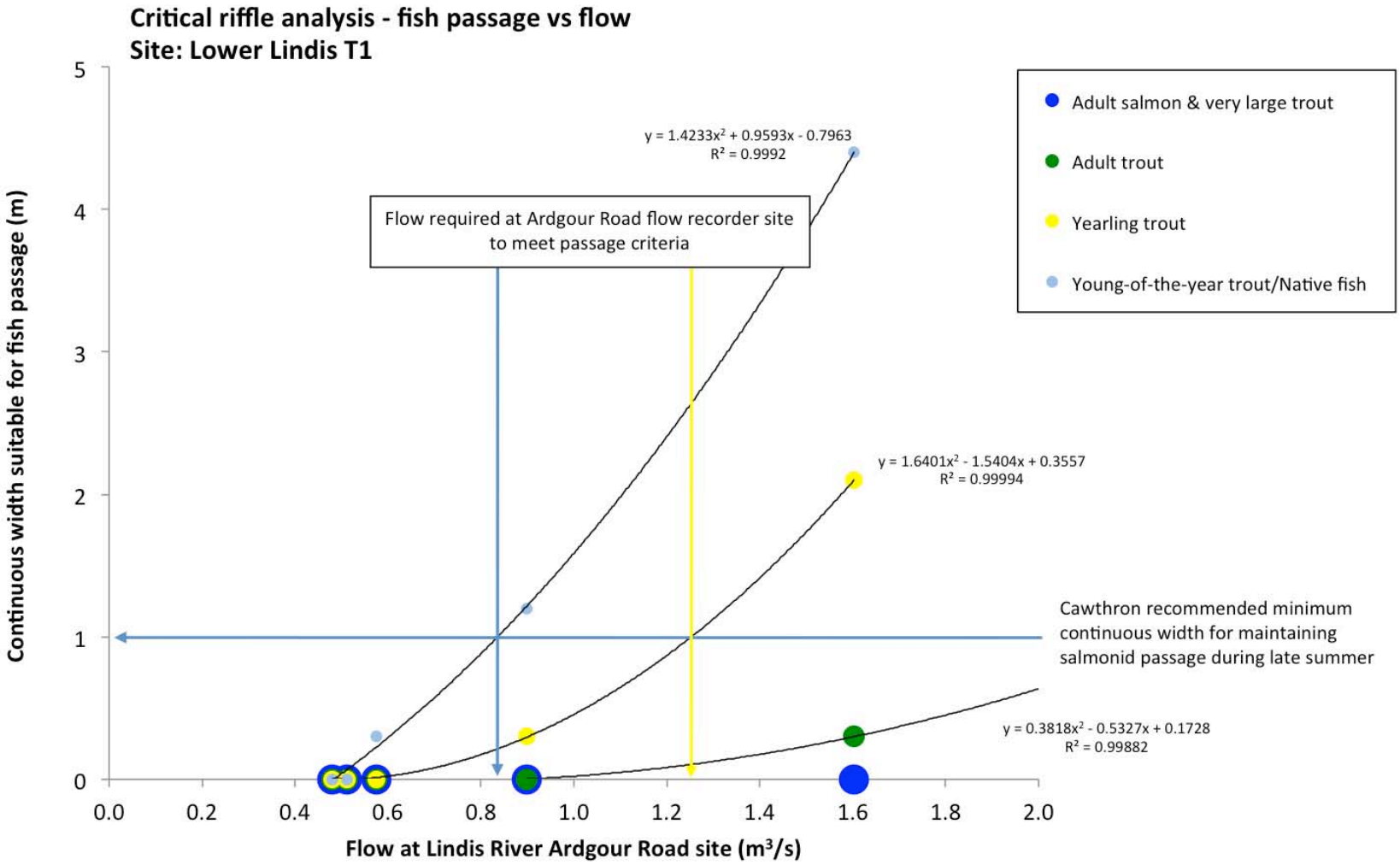

Figure 13b. *Lower Lindis critical riffle T1. Predicted flow at Ardgour Road flow recorder to meet fish passage criteria as set out in Table 2. No vertical line for a particular fish or life stage indicates passage criteria would not be met at flows less than 2.0 m^3/s at Ardgour Road.*

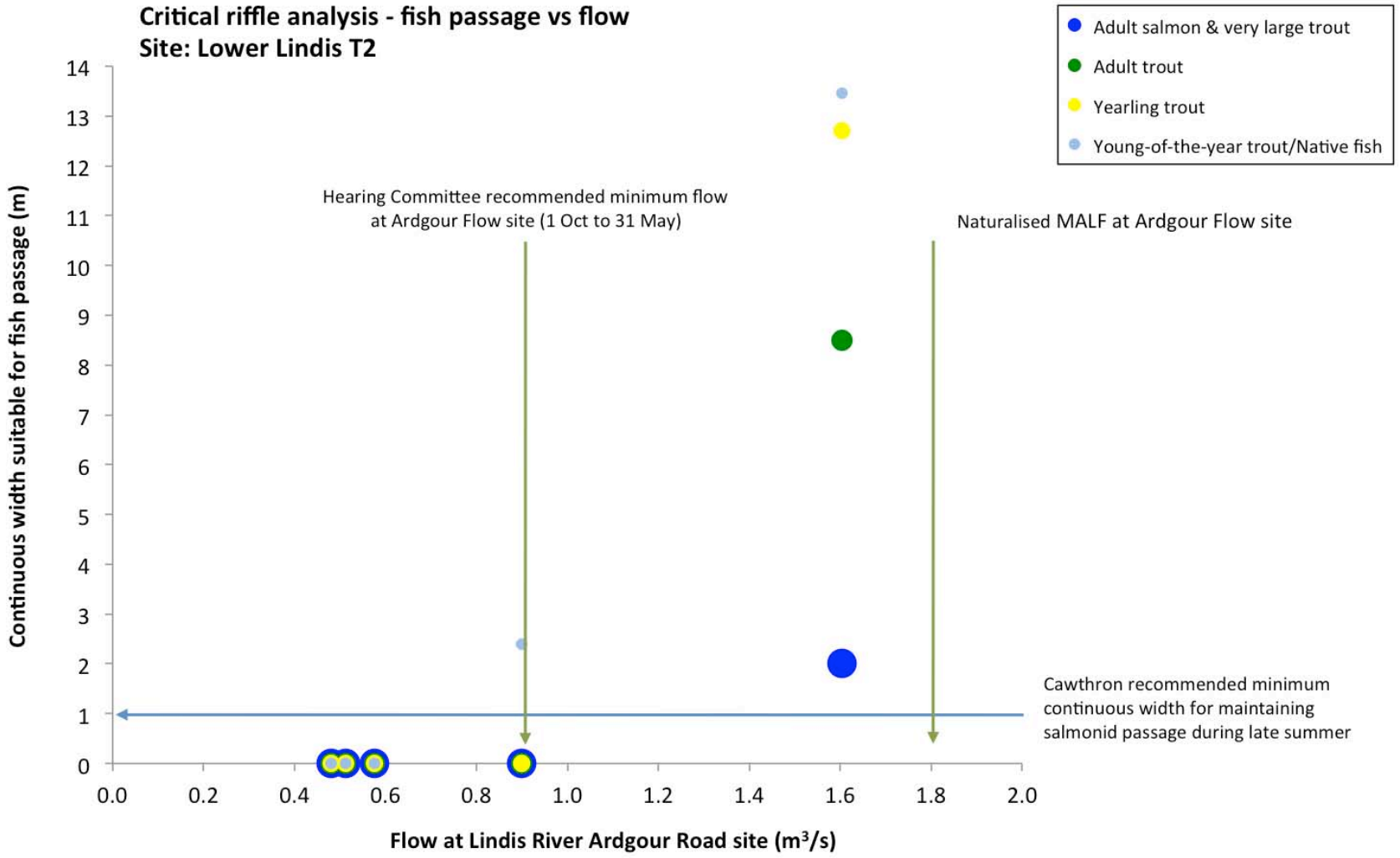

Figure 14a. *Relationship between flows at the Lower Lindis critical riffle T2, fish passage criteria as set out in Table 2 and key flow markers at Ardgour Road.*

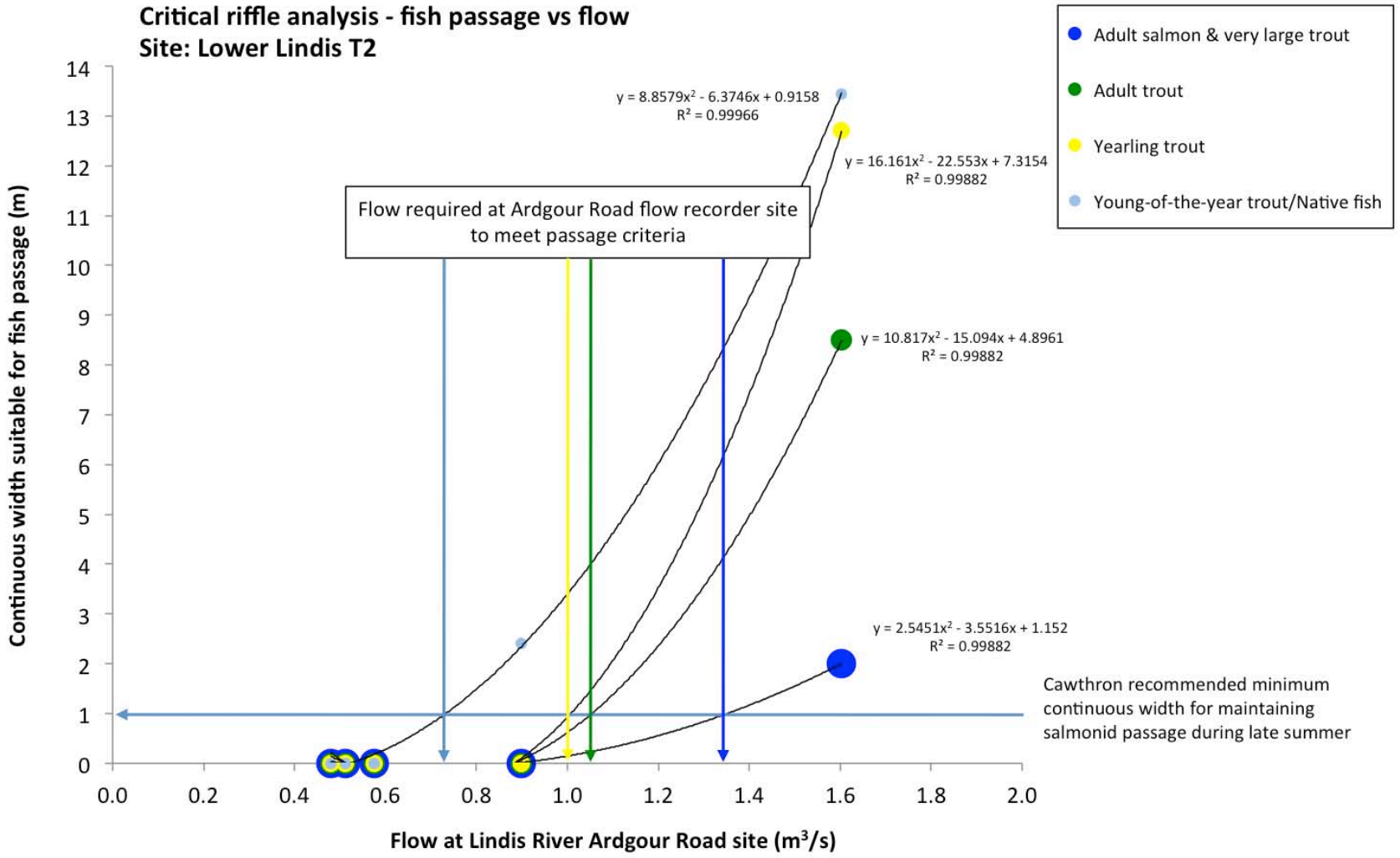

Figure 14b. *Lower Lindis critical riffle T2. Predicted flow at Ardgour Road flow recorder to meet fish passage criteria as set out in Table 2. No vertical line for a particular fish or life stage indicates passage criteria would not be met at flows less than 2.0 m^3/s at Ardgour Road.*

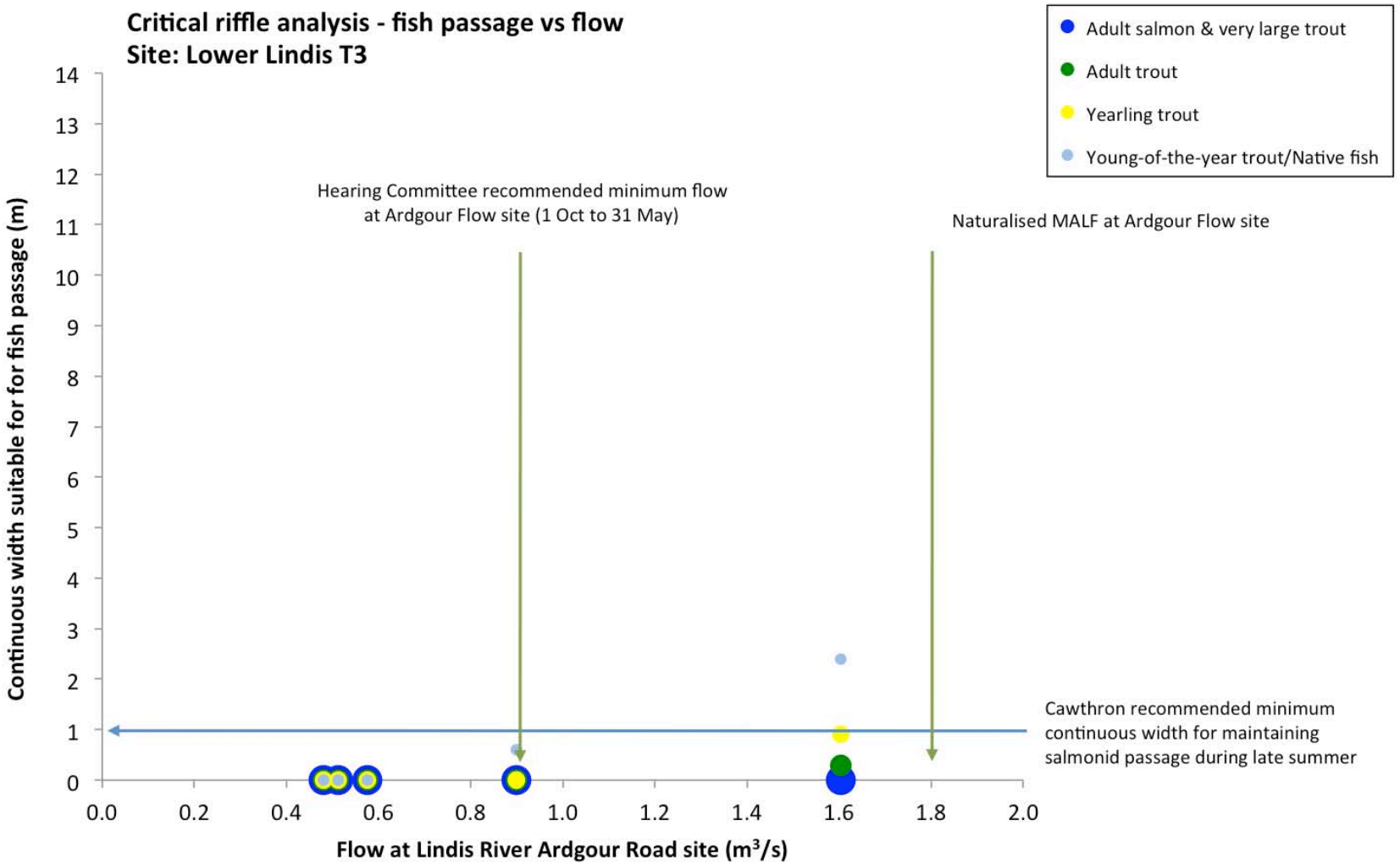

Figure 15a. *Relationship between flows at the Lower Lindis critical riffle T3, fish passage criteria as set out in Table 2 and key flow markers at Ardgour Road.*

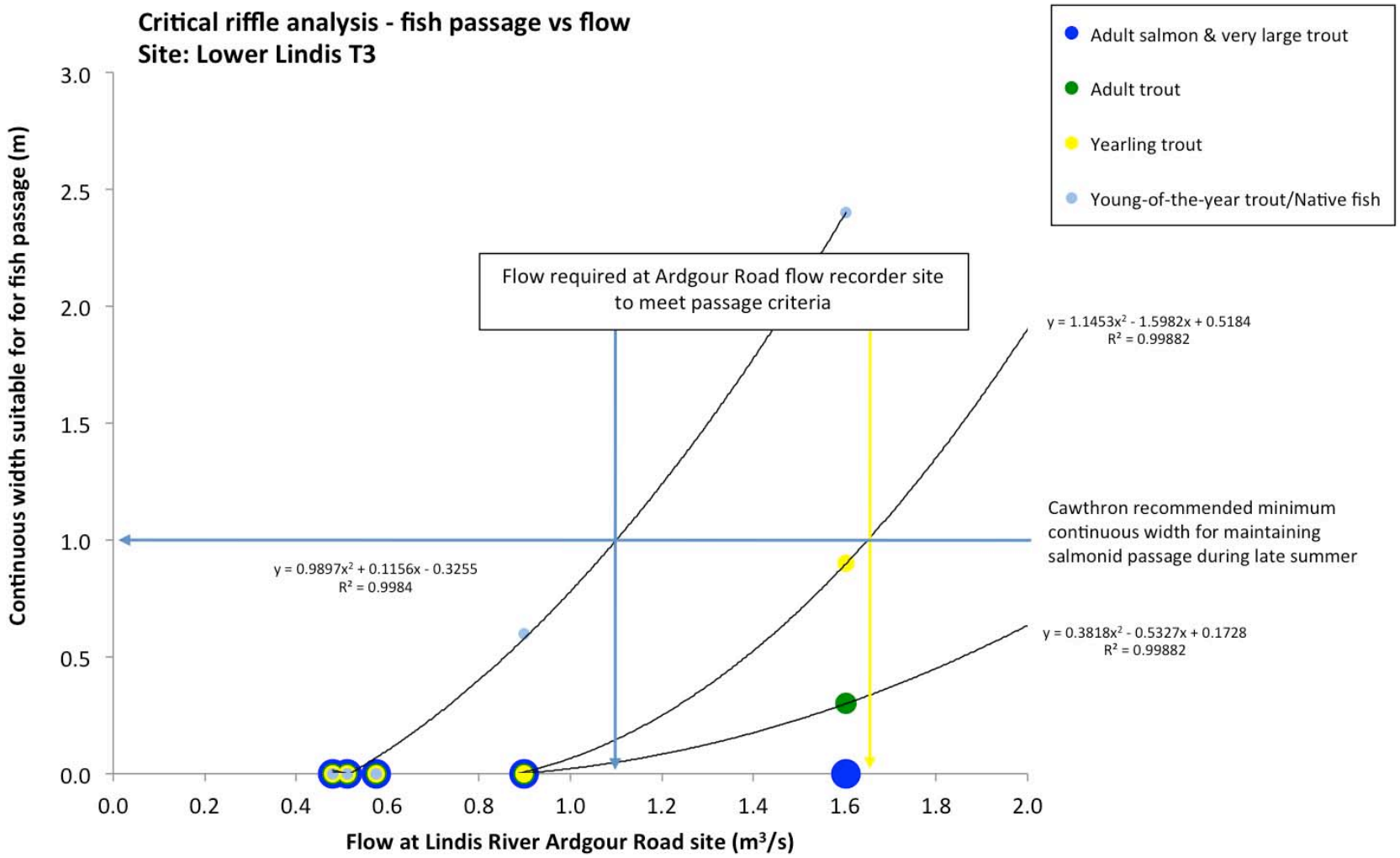

Figure 15b. *Lower Lindis critical riffle T3. Predicted flow at Ardgour Road flow recorder to meet fish passage criteria as set out in Table 2. No vertical line for a particular fish or life stage indicates passage criteria would not be met at flows less than 2.0 m^3/s at Ardgour Road.*

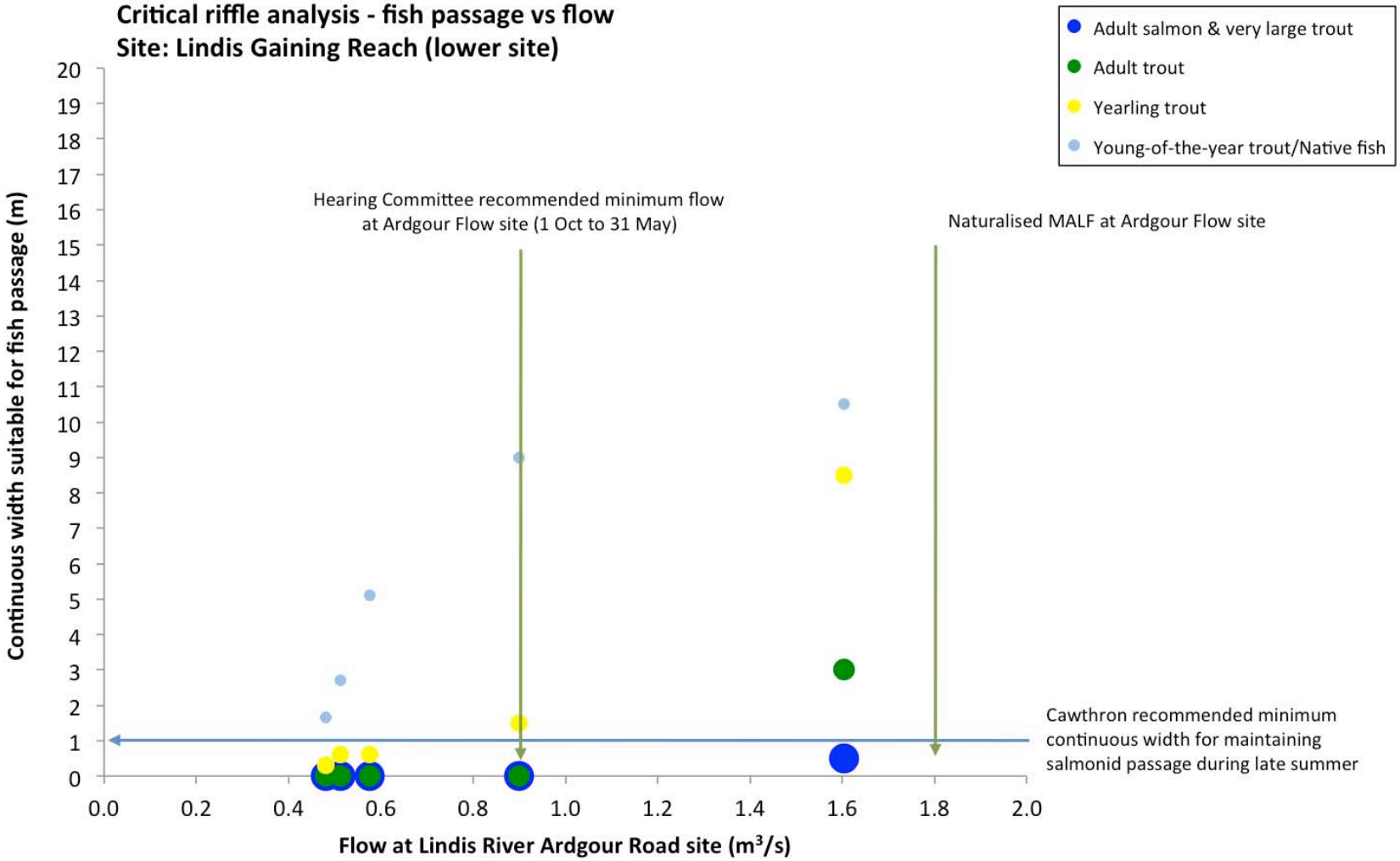

Figure 16a. *Relationship between flows at the Lindis gaining reach critical riffle lower, fish passage criteria as set out in Table 2 and key flow markers at Ardgour Road.*

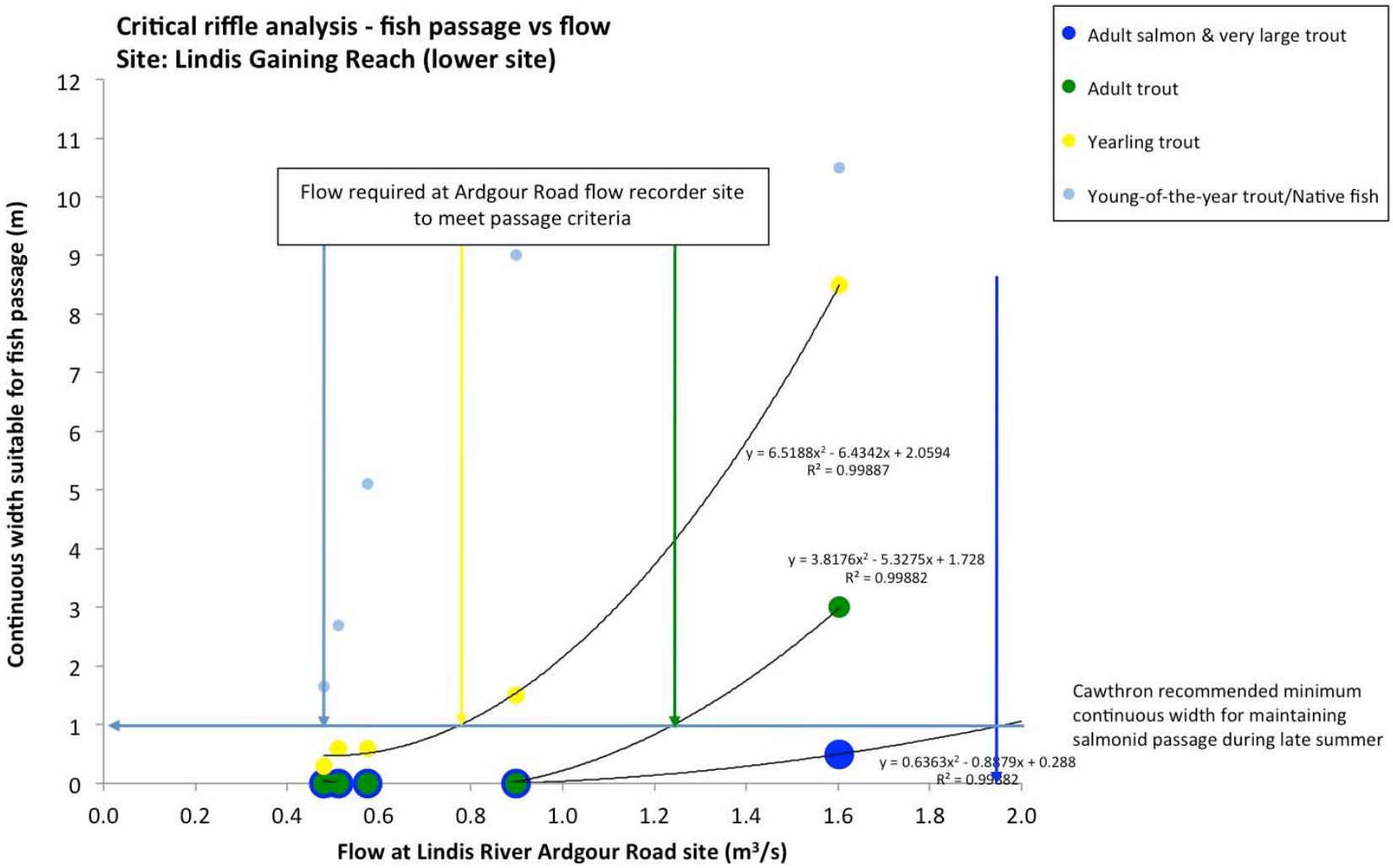

Figure 16b. *Lindis gaining reach critical riffle lower. Predicted flow at Ardgour Road flow recorder to meet fish passage criteria as set out in Table 2. No vertical line for a particular fish or life stage indicates passage criteria would not be met at flows less than 2.0 m^3/s at Ardgour Road.*

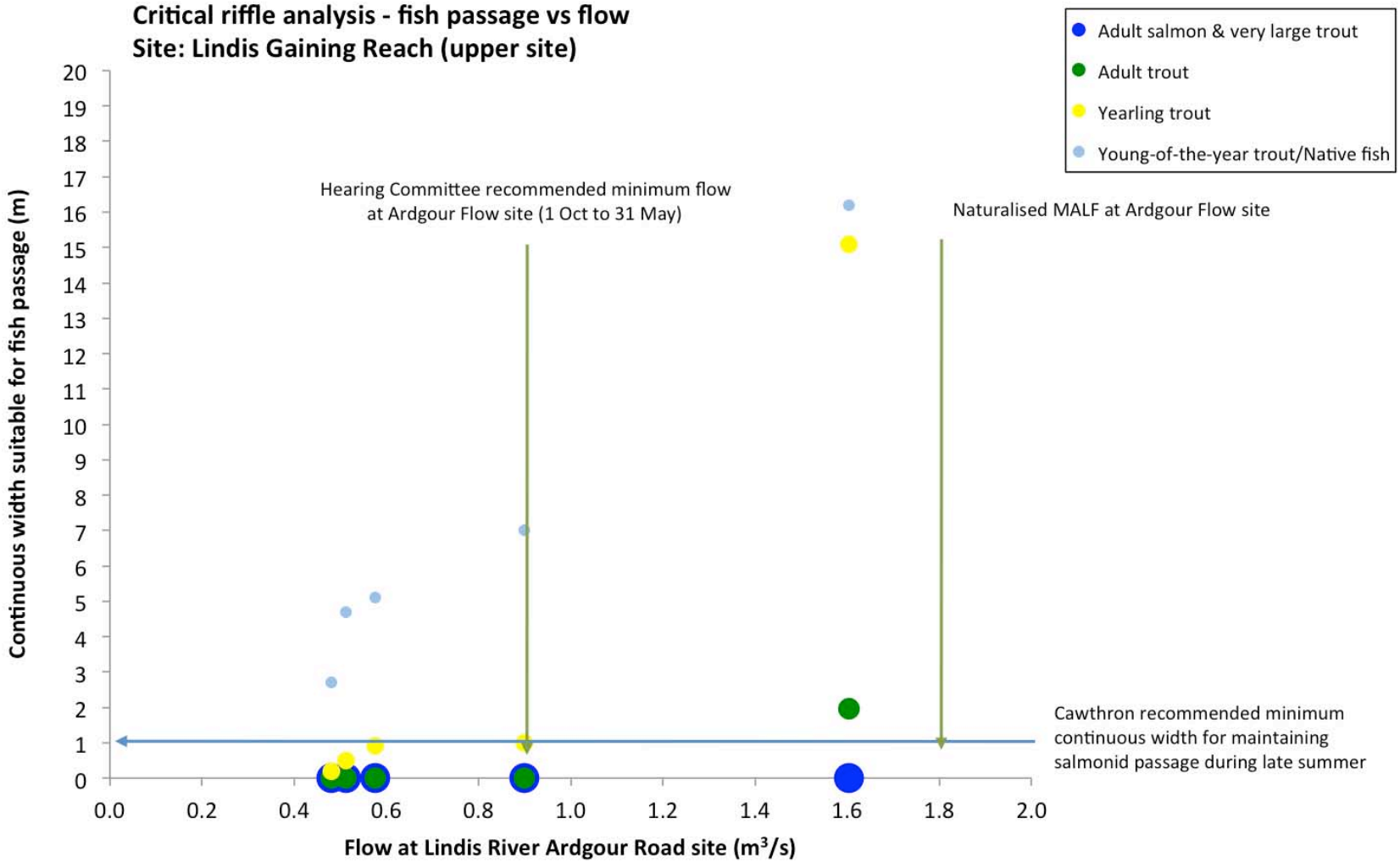

Figure 17a. *Relationship between flows at the Lindis gaining reach critical riffle upper, fish passage criteria as set out in Table 2 and key flow markers at Ardgour Road.*

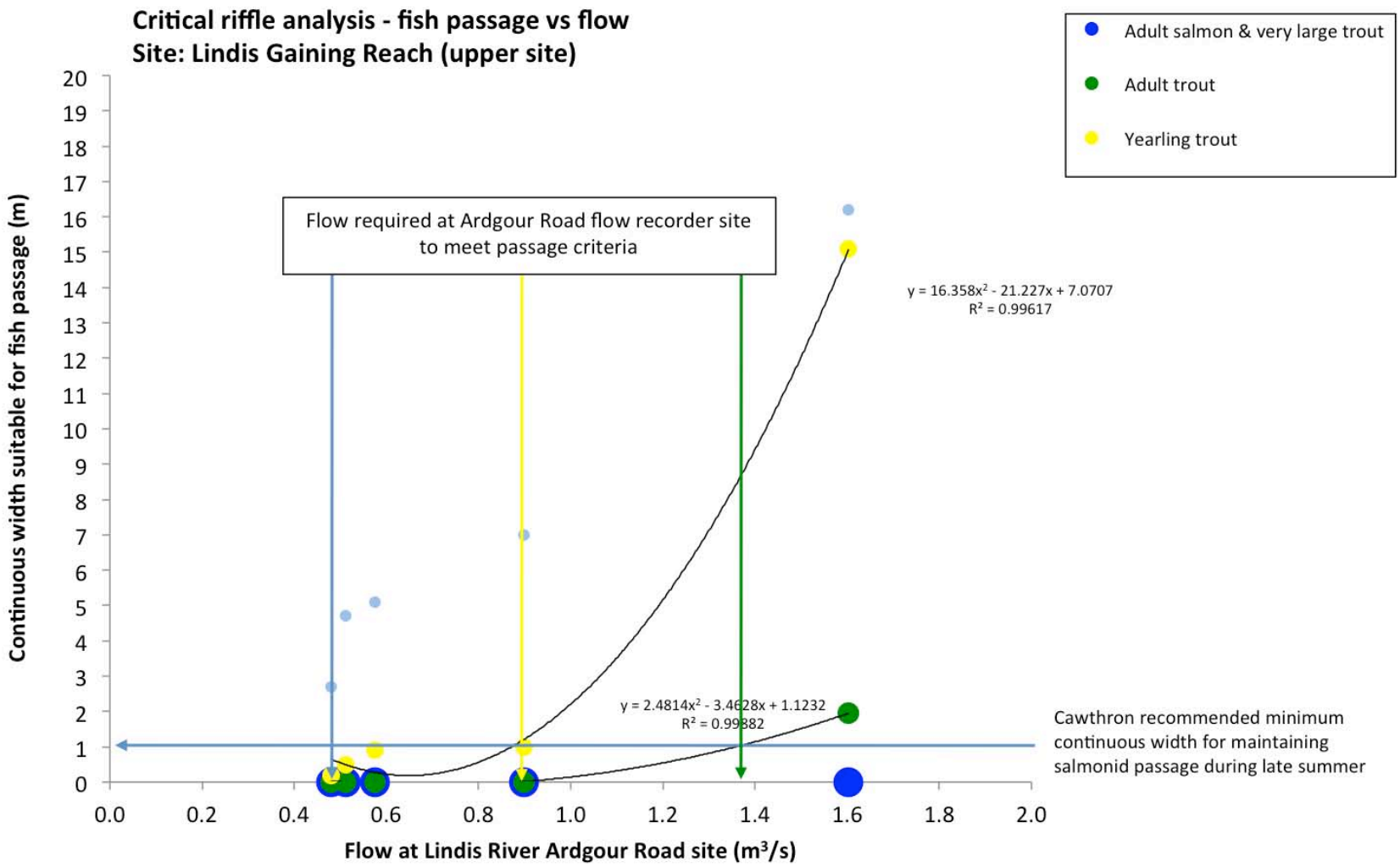

Figure 17b. *Lindis gaining reach critical riffle upper. Predicted flow at Ardgour Road flow recorder to meet fish passage criteria as set out in Table 2. No vertical line for a particular fish or life stage indicates passage criteria would not be met at flows less than 2.0 m^3/s at Ardgour Road.*

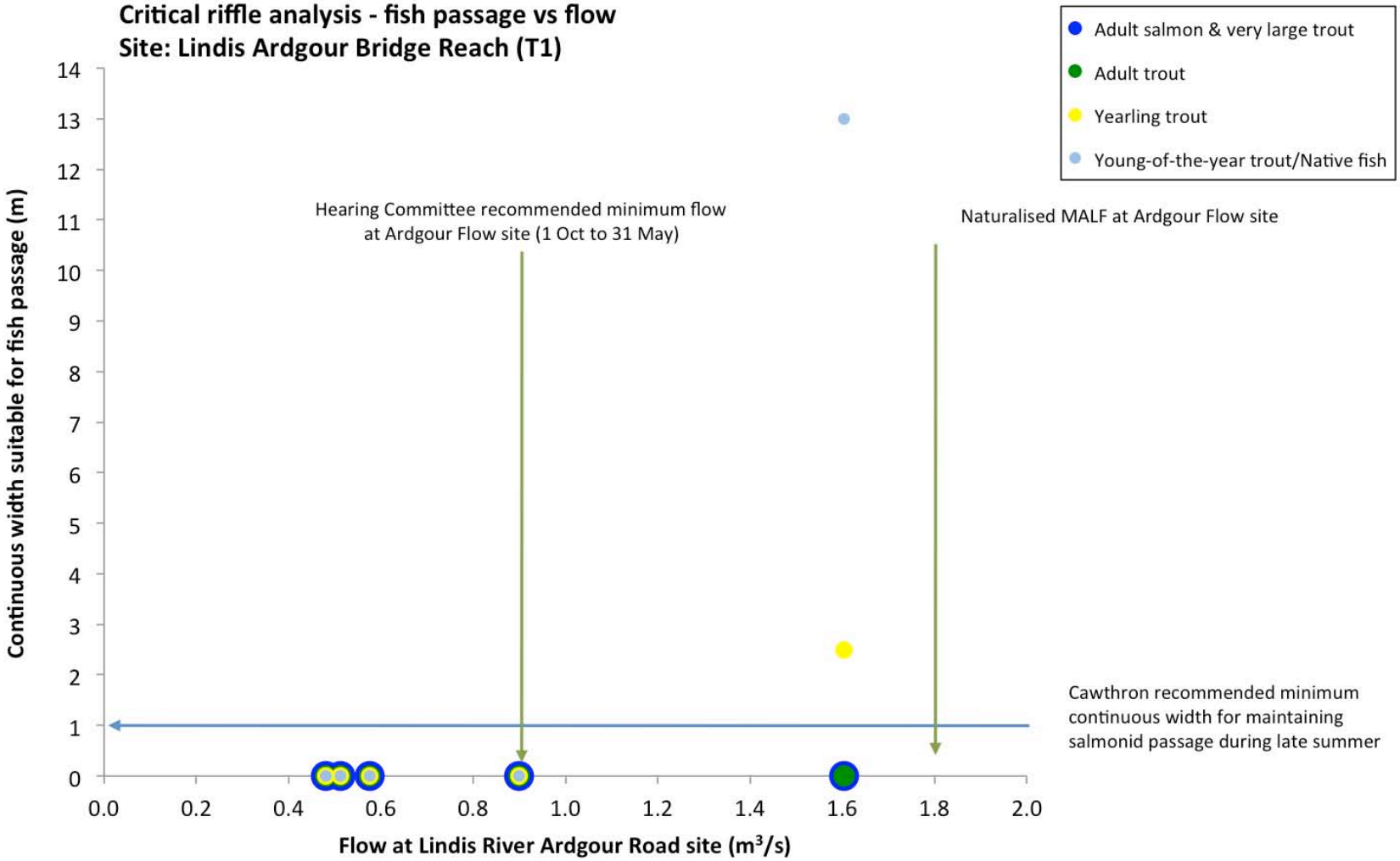

Figure 18a. *Relationship between flows at the Ardgour Bridge reach critical riffle T1, fish passage criteria as set out in Table 2 and key flow markers at Ardgour Road.*

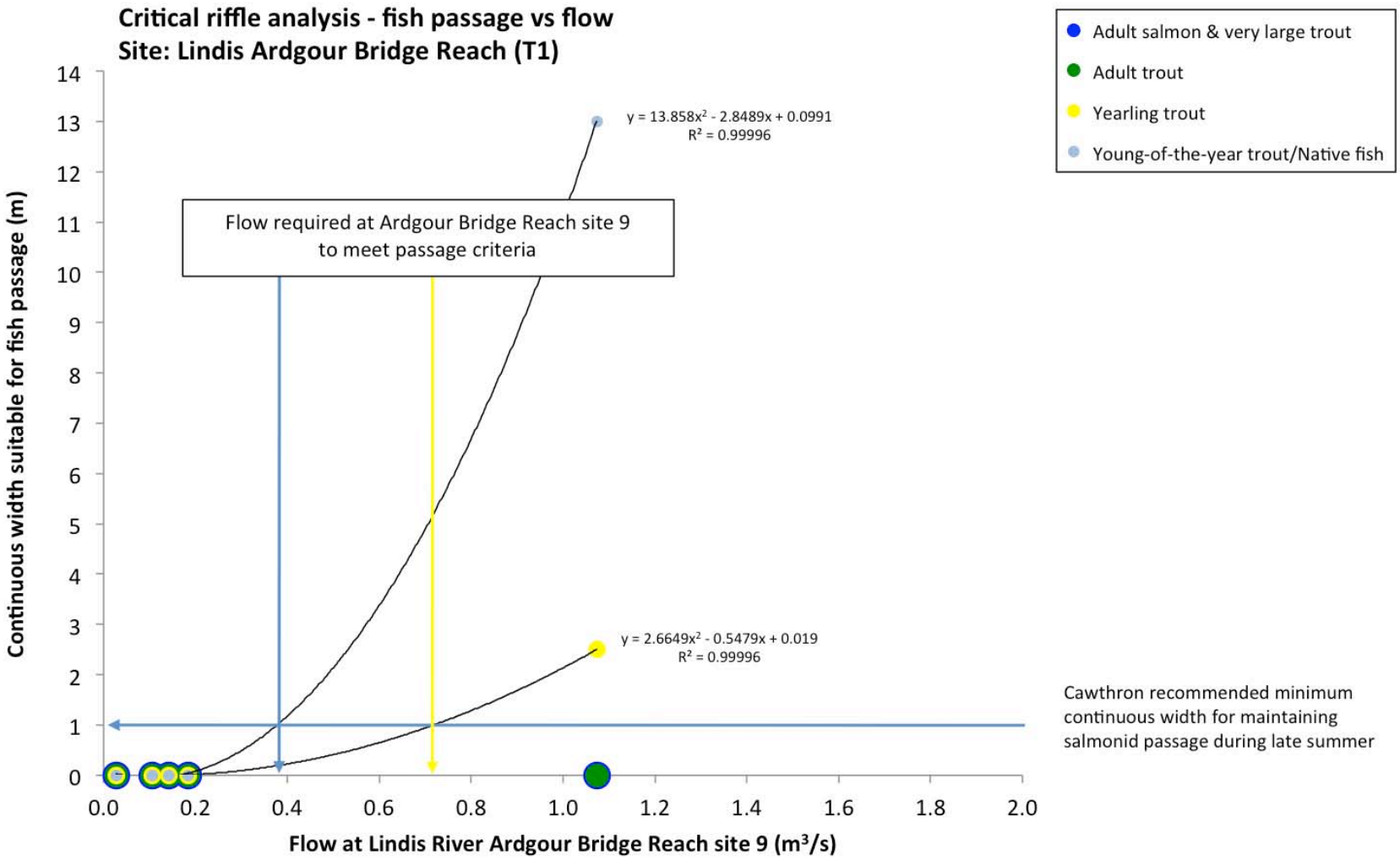

Figure 18b. *Ardgour Bridge reach critical riffle T1. Predicted flow at Ardgour Road flow recorder to meet fish passage criteria as set out in Table 2. No vertical line for a particular fish or life stage indicates passage criteria would not be met at flows less than 2.0 m^3/s at Ardgour Road.*

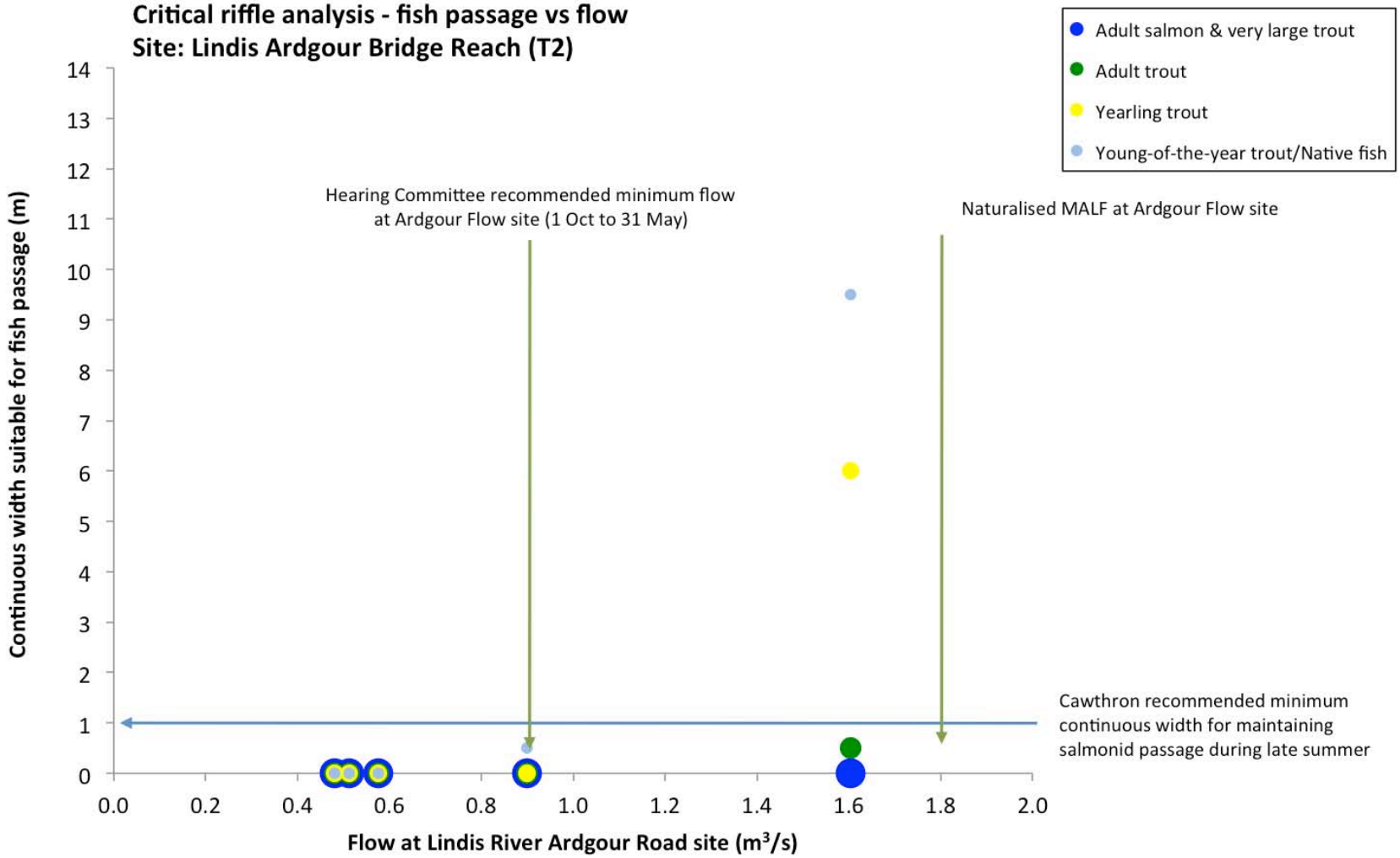

Figure 19a. *Relationship between flows at the Ardgour Bridge reach critical riffle T2, fish passage criteria as set out in Table 2 and key flow markers at Ardgour Road.*

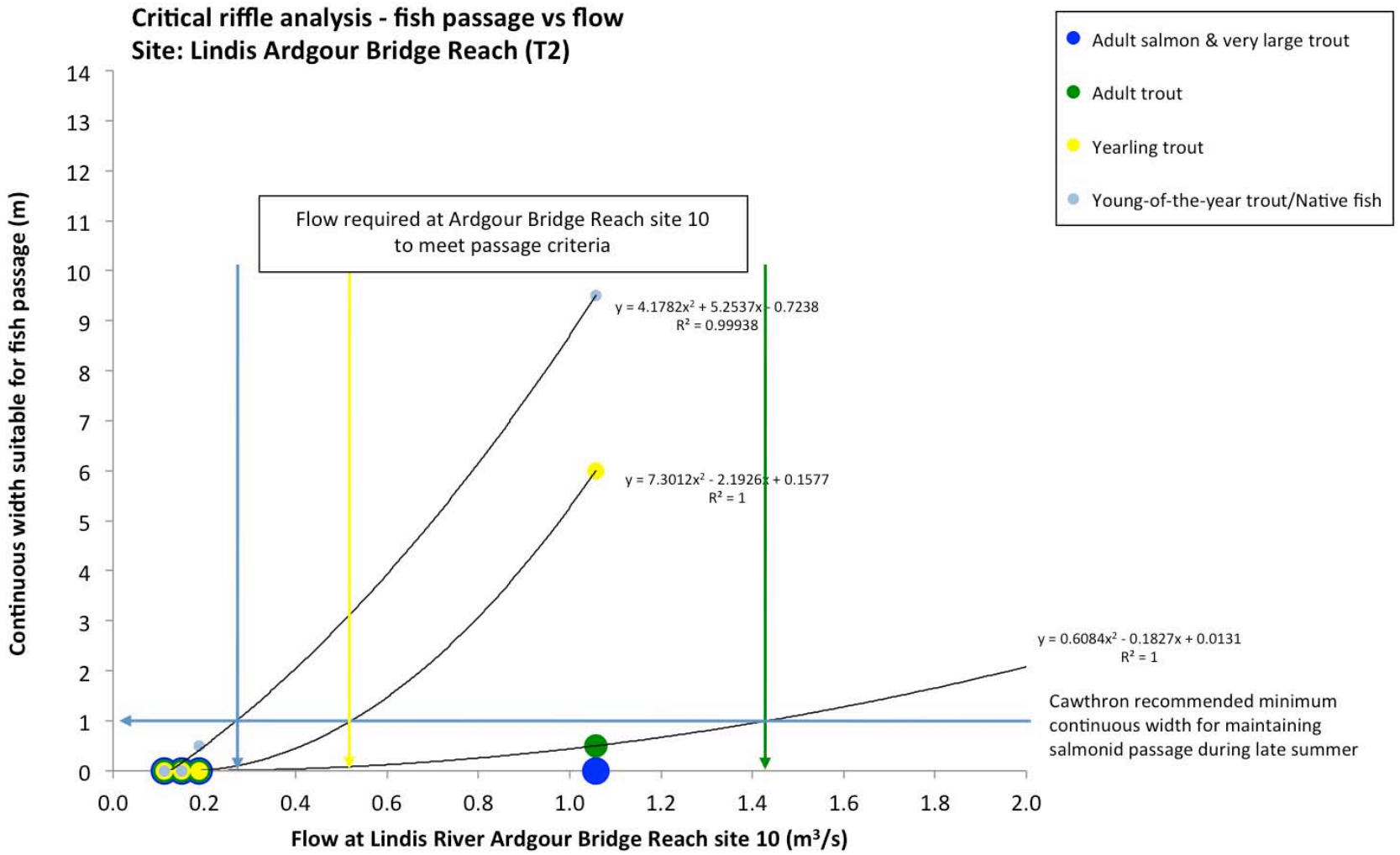

Figure 19b. *Ardgour Bridge reach critical riffle T2. Predicted flow at Ardgour Road flow recorder to meet fish passage criteria as set out in Table 2. No vertical line for a particular fish or life stage indicates passage criteria would not be met at flows less than 2.0 m^3/s at Ardgour Road.*

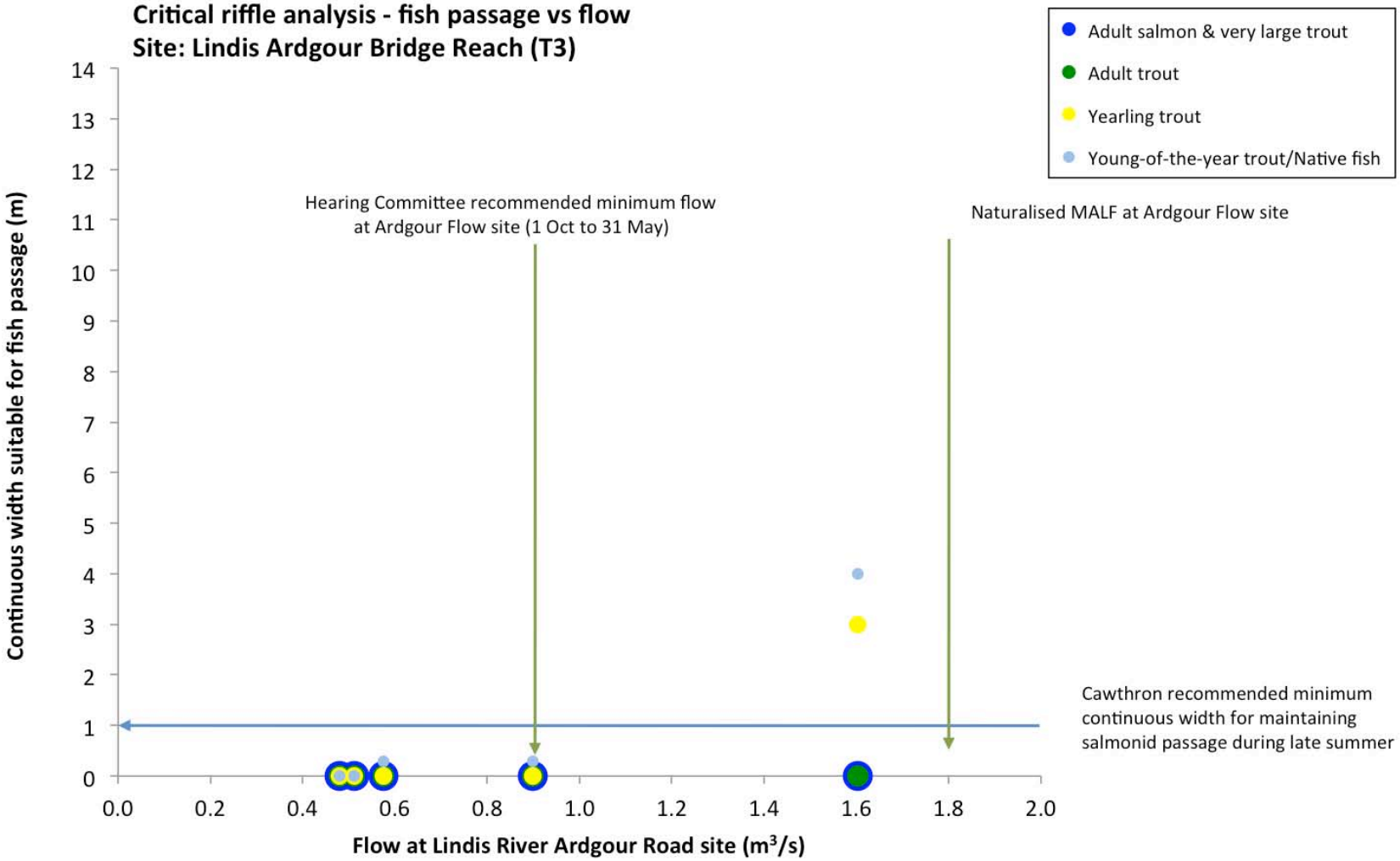

Figure 20a. *Relationship between flows at the Ardgour Bridge reach critical riffle T3, fish passage criteria as set out in Table 2 and key flow markers at Ardgour Road.*

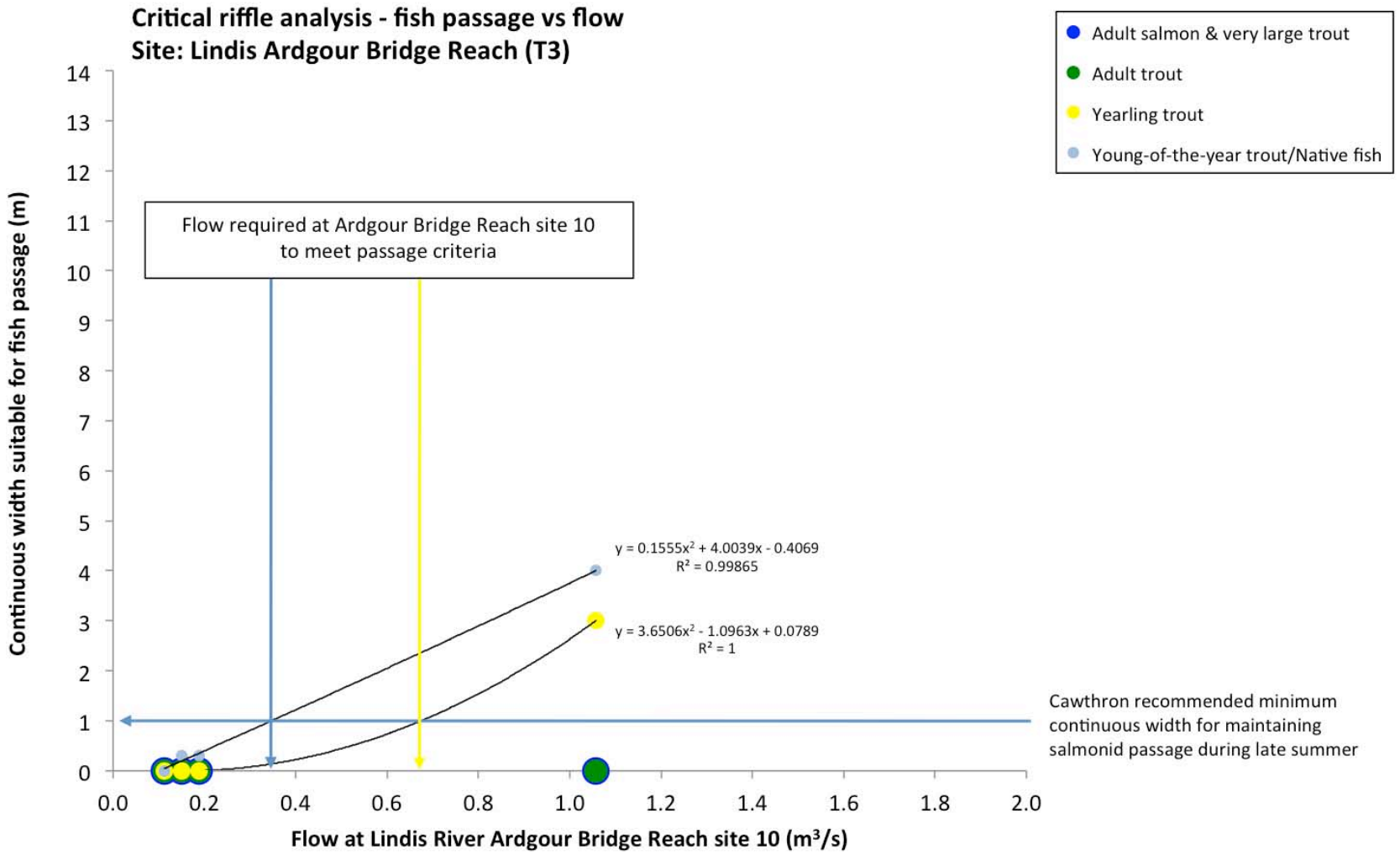

Figure 20b. *Ardgour Bridge reach critical riffle T3. Predicted flow at Ardgour Road flow recorder to meet fish passage criteria as set out in Table 2. No vertical line for a particular fish or life stage indicates passage criteria would not be met at flows less than 2.0 m^3/s at Ardgour Road.*