Figure 4.1: *Astacopsis gouldi* captured in Jean Brook downstream of the proposed offtake. Carapace size 56mm

4.1.3.5 Freshwater snails

The NVA database shows that five species of listed freshwater snails from the genus *Beddomeia* occur within a 5 km radius of the Nietta Creek study reach. One of these species also occurs within a 5 km radius of the Jean Brook offtake. Richards (2010) also describes four morpho-type species (individuals who share similar shell characteristics between two or more species of *Beddomeia*) as occurring in the Castra Rivulet catchment (which includes Nietta Creek).

Aquatic snails were not detected in the riffle samples or targeted snail surveys in Jean Brook. However, aquatic snail samples collected at two locations in Nietta Creek (i.e. the washed samples, which included riffle and deeper runs) detected two aquatic snail species. One species is likely to be *Fluvidona sp.* (Figure 4.2) which was detected at the location immediately downstream of Castra Falls and is common to Tasmania streams. A second species was also detected at both sites and is likely to be the threatened snail *Beddomeia fallax,* which has been previously recorded in Nietta Creek (Richards 2010, Karen Richards, DPIPWE, Senior Zoologist, 2015, pers comms, Figure 4.3).

Beddomeia has a narrow range being an endemic headwater stream specialist that requires stable habitat (Bryant and Jackson 1999; low flow velocity flows where course particulate organic matter (CPOM) can accumulate (Richards 2010) and is generally found under rocks (see type specimen localities in Ponder et al. 1993). Richards (2010) demonstrated that the abundance of *Beddomeia* is greater on basalt, than on siltstone or transition geology. The genus is highly associated with allochthonous course particulate matter (i.e. leaf litter) and prefers coarser substrate (i.e. is found in low densities in fine sediments). Details of the aquatic habitat where aquatic snails were sampled are provided in Table 4.6.

Figure 4.2: Fluvidona sp. detected from the sample collected immediately downstream from Castra Falls

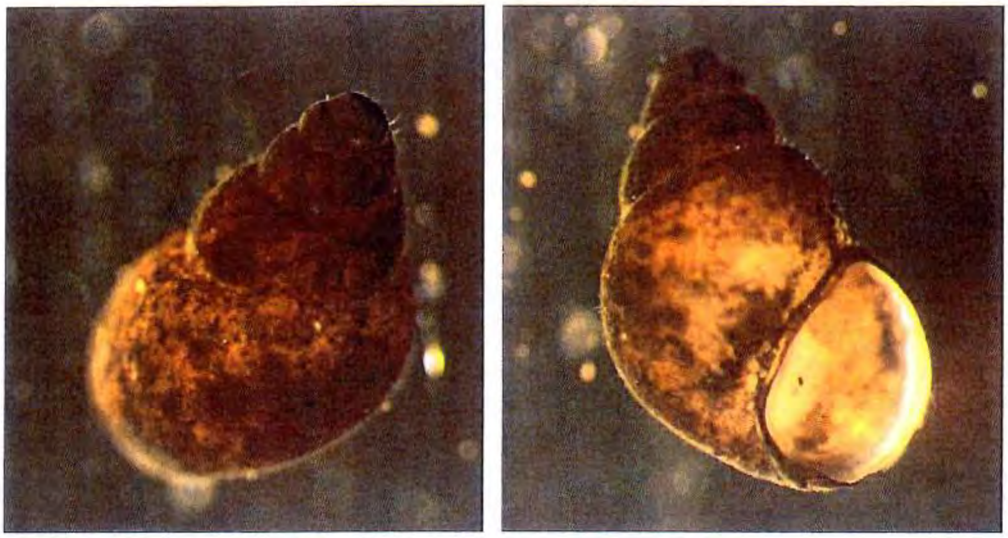

Figure 4.3: *Beddomeia fallax* detected from the sample collected upstream from the confluence with Castra Rivulet

Table 4.6: Aquatic habitat in Nietta Creek at the aquatic snail sampling locations

	% Substrate						% Cover				% habitat				CWD sampled	Leaf litter sampled	Stream width (m)	Mean depth (m)
	Boulder	Cobble	Pebble	Gravel	Sand	Silt	Algae	Silt	Detritus	Moss	Snag	Riffle	Run	Pool				
Immediately downstream from Castra Falls	20	40	30	10	5			50	5			90		10	Very little present, not sampled	Very little present, not sampled	3	0.6
Approximately 25m upstream from the confluence with Castra Rivulet	5	25	20	25	20	5		70	20			20	80		Sticks	Very little present, not sampled	3	0.3

4.1.3.6 Flora species

The PMT tool identified riverbed wintercress (*Barbarea australis*) habitat as potentially occurring within 5 km of the proposed Nietta Creek and Jean Brook offtakes. It is a riparian species which occurs in disturbed open areas on river margins, creek beds and along flood channels adjacent to rivers. *Barbarea australis* usually occurs as a small number of individuals scattered along a stretch of river bed or bank where it grows in alluvial silt in rock slabs or amongst small to large cobbles at sites which are frequently disturbed by fluvial processes (Threatened Species Section 2010). No *Barbarea australis,* or suitable habitat for the species, was observed during the field surveys. According to the NVA database, the closest confirmed observations of *B. australis* are 28 km to the north west (near Hampshire in the Emu River catchment) and 22 km south west (Mersey River downstream from Lake Parangana) of the Jean Brook offtake.

4.1.4 Habitat

The following sections describe the aquatic habitat conditions downstream from the proposed offtakes in Nietta Creek and Jean Brook, with site photos provided in Appendix C. Table 4.7 shows habitat data for the AusRivAS sampling sites.

4.1.4.1 Nietta Creek

There are three distinct aquatic habitat zones in Nietta Creek downstream from the proposed offtake. The reach from the proposed offtake down to Gaunts Road (~1 km) is a low gradient and depositional, dominated with silty substrate and abundant woody debris (Figure 1.1). The channel was incised with bends, undercut banks and woody debris providing habitat. Only a single riffle with pebbles and gravels was located (Figure C.1 and Figure C.2).

The ~ 600 m reach downstream of Gaunts Road, and immediately downstream of Castra Falls, is a steep gradient reach dominated by boulder and cobble in a sequence of small cascades and short runs (Figure C.3). Below this steep section, the gradient decreases in the last 400 m before it joins Castra Rivulet. This reach is characterised by short (2 – 8 m) and shallow (~ 2 – 8 cm depth) cobble and pebble riffles flowing between more depositional, deeper run/pool habitats (up to 50 cm depth) dominated by gravels and sands. Large woody debris, detritus and undercut banks are relatively abundant throughout this section (Figure C.4 and Figure C.5).

Many of the cobbles and boulders in Nietta Creek below Gaunts road are embedded and had an overlaying layer of fines on their surface (Figure C.3 to Figure C.5). It is possible that additional sediment (e.g. from Gaunts Road, earthworks upstream) is being washed down Castra Rivulet causing sediment to become embedded and silts to settle on the substrate. Throughout these reaches, the riparian zone is well vegetated and shaded by mixed wet forest species.

Table 4.7: General aquatic habitat in Nietta Creek and Jean Brook downstream from the proposed offtakes

	% Substrate						% Cover				% habitat				Stream width (m)	Bank height (m)	Mean depth (m)
	Boulder	Cobble	Pebble	Gravel	Sand	Silt	Algae	Silt	Detritus	Moss	Snag	Riffle	Run	Pool			
Nietta Creek U/S Gaunts Road (riffle)			60	20	15	5			10		40	5	95		3	1.2	0.3
Nietta Creek U/S Gaunts Road (representative)				10	10	80					40	5	95		3	1.2	0.3
Nietta Creek D/S Gaunts Road (AusRivAS location)	5	20	40	20	30		10	80			70	70	30		2.5	1	0.2
Jean Brook upstream from the Loongana Road Bridge	15	40	50	5			70		5	10	15	70	30		11	1.5	.15

4.1.4.2 Jean Brook

Jean Brook is in a natural, relatively undisturbed state and is a typical cobble/pebble dominated headwater stream dominated by riffle and run habitat and abundant woody debris. Additional in-stream habitat is present as slower flowing backwaters, particularly behind fallen trees. The riparian vegetation is intact and dominated by native trees. The stream is well shaded by overhanging vegetation, however, trailing bank vegetation is sparse. The stream is productive, as evidenced by the dominant algae layer on the substrate, which given the shading and intact riparian vegetation may be due to nutrient inputs from surrounding land use (Figure C.10 and Figure C.11).

4.1.4.3 Castra Rivulet channel capacity

The channel capacity survey showed that flows up to the peak flow under the operation of the proposed Jean Brook diversion (i.e. >Q1 flows, i.e. flows that occur less than one percent of the time) are unlikely to reach bank full or spill onto the floodplains at the locations surveyed along Castra Rivulet (Table 4.8 to Table 4.10). Similarly, it is unlikely that flows up to peak flow under the operation of the power station in Castra Rivulet downstream from the power station tailrace will reach bank full or spill onto the floodplains at the locations surveyed (Table 4.11). However, given the secondary flood channels and varying bank height, the online tool is only a very approximate representation of hydraulic conditions in the Castra Rivulet downstream of the tailrace outflow.

Table 4.8: Cross-section 1 (less constricted) and cross-section 2 (average) – Castra Rivulet immediately downstream of Maxfields Road and the proposed Jean Brook diversion outflow

Stream width (m)	Max bank height (m)	Side slope (deg)	Flow (cumecs)	Flow (ML/day)	Q flow proposed	Q flow current	Stream slope (deg)	Manning's n	Flow depth (m)	Flow velocity (m s^{-1})
Less constricted										
4.1	0.45	30	0.13	11.2	Q50	~Q11	0.009	0.1	0.11	0.167
4.1	0.45	30	0.20	17.3	~Q40	~Q4	0.009	0.1	0.13	0.188
4.1	0.45	30	0.40	34.6	~Q19	>Q2	0.009	0.1	0.18	0.227
4.1	0.45	30	0.80	69.1	~Q2	>Q2	0.009	0.1	0.25	0.271
4.1	0.45	30	1.00	86.4	>Q2	>Q1	0.009	0.1	0.28	0.288
4.1	0.45	30	1.23	106.0	>Q1	>Q1	0.009	0.1	0.31	0.303
Average										
2.9	0.65	67.5	0.13	11.2	Q50	~Q11	0.009	0.1	0.10	0.141
2.9	0.65	67.5	0.20	17.3	~Q40	~Q4	0.009	0.1	0.12	0.158
2.9	0.65	67.5	0.40	34.6	~Q19	>Q2	0.009	0.1	0.16	0.188
2.9	0.65	67.5	0.80	69.1	~Q2	>Q2	0.009	0.1	0.21	0.224
2.9	0.65	67.5	1.00	86.4	>Q2	>Q1	0.009	0.1	0.23	0.237
2.9	0.65	67.5	1.23	106.0	>Q1	>Q1	0.009	0.1	0.25	0.249

Figure 4.4: Cross-section 2 in Castra Rivulet (average channel geometry) looking downstream

Table 4.9: Cross-section 3 Castra Rivulet ~ 2.8 km downstream from the proposed Jean Brook diversion outflow

Stream width (m)	Max bank height (m)	Side slope (deg)	Flow (cumecs)	Flow (ML/day)	Q flow proposed	Q flow current	Stream slope (deg)	Manning's n	Flow depth (m)	Flow velocity (m s^{-1})
7.2	0.4	42.5	0.13	11.2	Q50	~Q11	0.009	0.05	0.06	0.240
7.2	0.4	42.5	0.20	17.3	~Q40	~Q4	0.009	0.05	0.07	0.274
7.2	0.4	42.5	0.40	34.6	~Q19	>Q2	0.009	0.05	0.10	0.336
7.2	0.4	42.5	0.80	69.1	~Q2	>Q2	0.009	0.05	0.15	0.408
7.2	0.4	42.5	1.00	86.4	>Q2	>Q1	0.009	0.05	0.16	0.434
7.2	0.4	42.5	1.23	106.0	>Q1	>Q1	0.009	0.05	0.18	0.459

Figure 4.5: Cross-section 3 in Castra Rivulet looking upstream

Table 4.10: Cross-section 4 (constricted) and cross-section 5 (average) – Castra Rivulet ~3.8 km downstream from the proposed Jean Brook diversion outflow

Stream width (m)	Max bank height (m)	Side slope (deg)	Flow (cumecs)	Flow (ML/day)	Q flow proposed	Q flow current	Stream slope (deg)	Manning's n	Flow depth (m)	Flow velocity ($m\ s^{-1}$)
Average										
4.6	0.6	30	0.13	11.2	Q50	~Q11	0.015	0.05	0.06	0.324
4.6	0.6	30	0.20	17.3	~Q40	~Q4	0.015	0.05	0.08	0.369
4.6	0.6	30	0.40	34.6	~Q19	>Q2	0.015	0.05	0.11	0.450
4.6	0.6	30	0.80	69.1	~Q2	>Q2	0.015	0.05	0.16	0.544
4.6	0.6	30	1.00	86.4	>Q2	>Q1	0.015	0.05	0.18	0.577
4.6	0.6	30	1.23	106.0	>Q1	>Q1	0.015	0.05	0.19	0.610
Constricted										
2.5	0.6	30	0.13	11.2	Q50	~Q11	0.015	0.05	0.08	0.344
2.5	0.6	30	0.20	17.3	~Q40	~Q4	0.015	0.05	0.10	0.386
2.5	0.6	30	0.40	34.6	~Q19	>Q2	0.015	0.05	0.13	0.464
2.5	0.6	30	0.80	69.1	~Q2	>Q2	0.015	0.05	0.18	0.554
2.5	0.6	30	1.00	86.4	>Q2	>Q1	0.015	0.05	0.20	0.587
2.5	0.6	30	1.23	106.0	>Q1	>Q1	0.015	0.05	0.22	0.619

Figure 4.6: Cross-section 5 in Castra Rivulet looking downstream

Table 4.11: Cross-section 6 Castra Rivulet downstream from the power station tailrace outflow

Stream width (m)	Max bank height (m)	Side slope (deg)	Flow (cumecs)	Flow (ML/day)	Q flow proposed	Q flow current	Stream slope (deg)	Manning's n	Flow depth (m)	Flow velocity (m s^{-1})
6.8	1.2	30	0.52	45.0	Q50	~Q42	0.021	0.05	0.10	0.525
6.8	1.2	30	1.00	86.4	~Q34	~Q22	0.021	0.05	0.14	0.635
6.8	1.2	30	2.00	172.8	~Q8	~Q6	0.021	0.05	0.20	0.771
6.8	1.2	30	4.00	345.6	>Q2	>Q2	0.021	0.05	0.28	0.929
6.8	1.2	30	13.63	1178.0	>Q1	>Q1	0.021	0.05	0.49	1.278

Figure 4.7: Cross-section 6 in Castra Rivulet looking downstream

4.1.5 Macroinvertebrate community

Macroinvertebrate assemblages in Nietta Creek upstream of Gaunts Road differed from those downstream of Gaunts Road, which is likely due to the differences in aquatic habitat and hydraulic conditions. In contrast, the macroinvertebrate assemblage in Nietta Creek downstream from Gaunts Road was similar to the macroinvertebrate assemblage in Jean Brook (Table 4.12). Assemblage patterns include:

- Nietta Creek upstream Gaunts Road
  - Oligochaete worms more abundant than the other two sites
  - Greater diversity of dipteran families than the other two sites
- Nietta Creek downstream Gaunts Road
  - Greater abundance of mayflies and caddisflies than upstream of Gaunts Roads
- Jean Brook
  - Similar assemblage to Nietta Creek downstream of Gaunts Road with the exception of a higher abundance of amphipods.

Differences in the macroinvertebrate community in Nietta Creek upstream and downstream of Gaunts Road reflects the different aquatic habitat as described in Section 3.2. The abundance of oligochaete worms and dipteran fly larvae are indicative of slower flowing water and softer, finer substrates. In contrast, the higher abundance and diversity of mayfly and caddisfly families (i.e. flow obligate species) reflect faster flowing water, with cobbles and pebbles. The abundance of amphipods (shredders) in Jean Brook may reflect an aspect of the food web whereby the abundance of leaf litter favours this family due to the thick, overhanging riparian vegetation.

Holes created by burrowing crayfish were observed within the riparian zone of Nietta Creek. It is not know which species that they belong to.

Table 4.12: Macroinvertebrate taxa identified from samples collected during the field surveys

	Site	**Nietta Creek upstream Gaunts Road**	**Nietta Creek downstream Castra Fall**	**Jean Brook**
Order	**Family**			
Oligochaeta		43	5	3
Nematoda		1		
Acarina	Acarina	1	1	1
Amphipoda	Parameletidae		3	36
Isopoda	Phreatoicidea		2	
Coleoptera	Elmidae Adults	13	8	8
	Elmidae Larvae	2	1	2
	Psephenidae			1
	Scirtidae	2		2
Mecoptera			1	
Diptera	Ceratopogonidae	2		1
	Chironominae	12	12	5
	Diamesinae			3
	Orthocladiinae	18	7	38
	Podonominae	3	3	1
	Simuliidae	10	8	1
	Tanyderidae	2		
	Tanypodinae	2		
	Tipulidae	7	1	
Ephemeroptera	Leptophlebiidae	35	71	43
	Baetidae		5	
Odonata	Telephlebiidae			1
Plectoptera	Gripopterygidae	7	15	43
	Notonemouridae	1		

	Site	Nietta Creek upstream Gaunts Road	Nietta Creek downstream Castra Fall	Jean Brook
Trichoptera	Conoesucidae			2
	Glossosomatidae	1		1
	Helicophidae	5	1	
	Hydrobiosidae	6	13	14
	Hydropsychidae		1	15
	Leptoceridae	1	3	
	Philopotamidae		10	
	Philorheithridae		9	7
Taxa number		**174**	**180**	**228**
Total abundance		**21**	**21**	**21**

5. Environmental flow assessment

5.1 Environmental flow objectives

The environmental flow objectives (Table 5.1 and Table D.1) were developed to meet the aquatic flow and habitat requirements of aquatic values identified in Section 4 by describing flow linkages for each identified aquatic value based on the scientific literature. It is against these objectives that a risk assessment has been conducted in Section 6 against the default cease-to-take (CTT) for Nietta Creek, the proposed CTT for Jean Brook and additional event based flows that may be required in both watercourses.

Table 5.1: Environmental objectives and associated flow linkages for identified aquatic values in Nietta Creek and Jean Brook

Objective	Important flow components				
	Floods/ overbank flows	Floods/ bank full	Winter high flows	Freshes	Low flows
Maintain populations of native fish	✓	✓	✓	✓	✓
Maintain diversity and abundance of macroinvertebrate communities in the river system	✓	✓	✓	✓	✓
Maintain populations of platypus			✓		✓
Maintain productivity and of benthic metabolism of riverine ecosystem	✓	✓	✓	✓	✓
Sustain existing riparian and floodplain vegetation	✓	✓	✓	✓	
Maintain fluvial geomorphological processes that shape the river channel and riparian areas)	✓	✓		✓	
Ensure the adequate replenishment of local groundwater resources	✓				

5.2 Low flows

5.2.1 Rationale

In the absence of a detailed, site specific, environmental flow study, water abstraction projects in Tasmania are typically required to operate with cease to take (CTT) values calculated as the monthly 20th percentile flow in winter and the monthly 30th percentile flow value in summer. These "default" CTT rules are a deliberately conservative as they have a high probability of ensuring the seasonal flows responsible for many ecological processes are retained (Graham et al 1999).

Table 5.2 shows what the default CTT values for Nietta Creek and Jean Brook equate to in terms of percentile flow values calculated as monthly daily average flows calculated using the monthly daily average. The default values are approximately equivalent to median daily flows in Nietta Creek and elevated base flow/ high flows in Jean Brook (Table 5.2).

The proposed CTT rules for May to November in Jean Brook have been based on maintaining a high proportion of the aquatic habitat and maintaining all elements of the flow regime. The proposed CTT rules are assessed against the aquatic habitat maintained by the flow estimated to provide the maximum aquatic habitat through the study reach.

Table 5.2: Monthly cease to take flows calculated under the default CTT values

Month	Jean Brook		Nietta Creek	
	Default CTT (based on 20%ile monthly average) (ML/day)	Equivalent percentile (based on daily average) (approx. %ile)	Default CTT (based on 20%ile monthly average) (ML/day)	Equivalent percentile (based on daily average) (approx. %ile)
May	17.43	38	1.39	51
June	39.03	43	3.09	51
July	47.66	34	5.01	48
August	63.03	41	6.86	53
September	39.84	36	3.60	47
October	18.97	34	2.01	50
November	11.50	39	1.14	56

5.2.2 Proposed cease-to-take low flows for Jean Brook

5.2.2.1 Habitat assessment criteria

Wetted perimeter, maximum (thalweg) depth, average depth and flow velocity within the river channel are related to discharge and the availability and quality of aquatic habitat. The channel (up to overbank flows) and parameters were defined in the hydraulic model and used to assess the change in habitat availability/quality with the scheme operating under the default and proposed monthly CTT values. The importance of each criterion is discussed further below.

Wetted perimeter

Wetted perimeter is the portion of the channel in contact with flowing water and, unless the channel is a perfect prism, will increase with increasing discharge. Thus, wetted perimeter can provide a useful measure of the availability of aquatic habitat as flow changes. Figure 5.1 shows the relationship between discharge and wetted perimeter (averaged across all cross-sections) and Figure 5.2 shows the same relationship for the steepest riffle section (cross-sections 20 – 25). As is typical in streams, increases in wetted perimeter in the study reach are rapid at low discharges but become more gradual as flows increase. The transition from a steep, positive slope at low discharges to a gentler, gradual slope at higher discharges is referred to as the inflection point, the point of maximum curvature or first break in slope (Gordon 1994). The inflection point for the study reach averaged across all cross-sections was approximately 27 ML/day (Figure 5.1) and 24 ML/day for the steepest section (cross-sections 20-25; Figure 5.2). Beyond the inflection point, gains in wetted perimeter as the flow increases are minor. The average observed flow during the field survey was 4.12 ML/day (average of six flow estimates measured over one day), whereby the flow stage was lower than the bank toe.

For the purpose of this report, maximum wetted perimeter is defined as the flow required to inundate the stream channel from the toe of the left bank to the toe of the right bank. The maximum wetted perimeter was estimated within the representative riffle (cross-section 20 – 25) from the modelled cross-section photos and water depth that would be typical for riffle habitat under at least elevated base flow conditions. For example, the modelled cross-section 22 (representative of the cross-sections through the steep riffle) indicates that full wetted perimeter is achieved at approximately 24 ML/day (Figure 5.3). Under a 24 ML/day flow the model shows average depth through this cross-section of 10 cm with a thalweg as 28 cm, which would provide good riffle habitat and connectivity through this section.

The photo in Figure 5.4 shows the right bank and the clear transition from river cobbles and boulders to fine bank sediment and riparian vegetation, which supports the assumption that this point in the section represents the point where maximum wetted perimeter is reached.

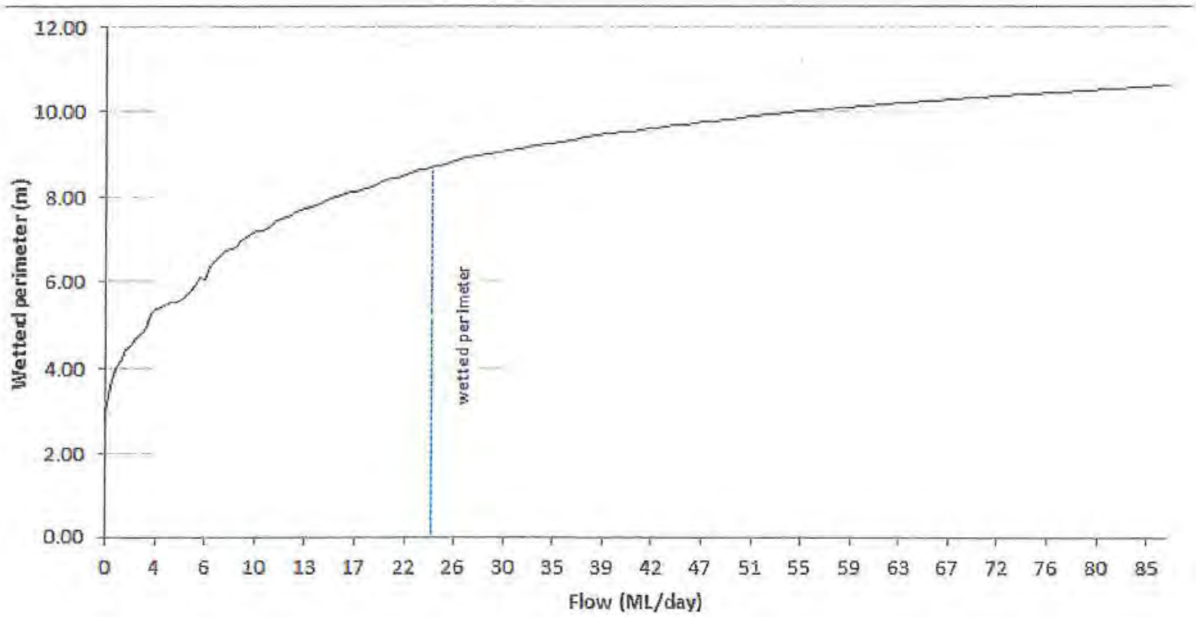

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Figure 5.1: Relationship between discharge (ML/day) and average wetted perimeter across all cross-section

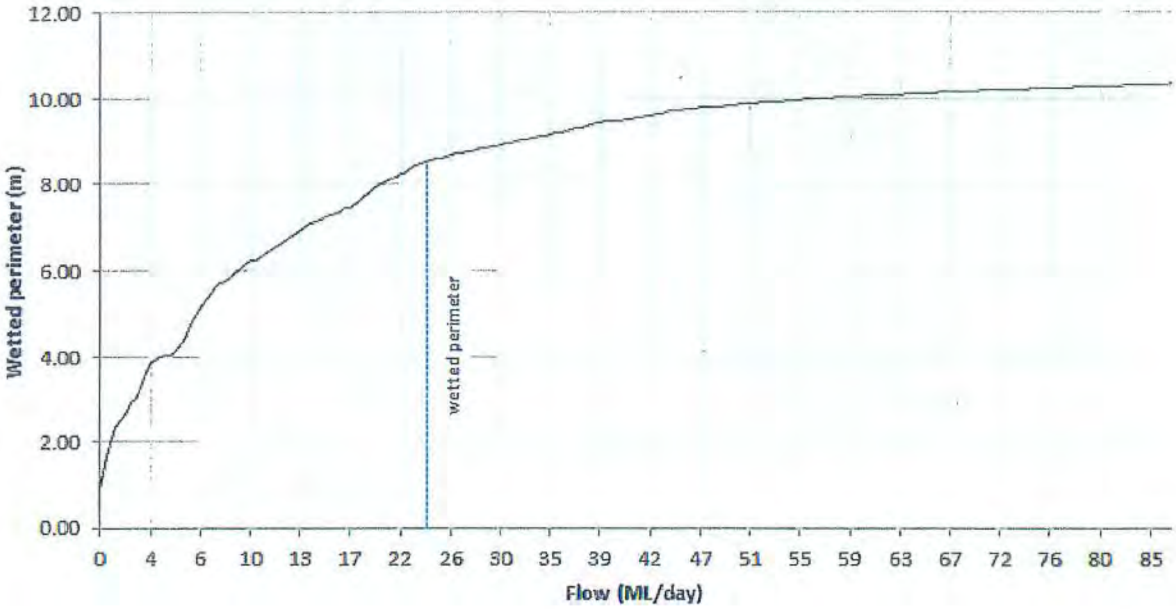

Figure 5.2: Relationship between discharge (ML/day) and average wetted perimeter across the steepest riffle cross-section 20 to 25

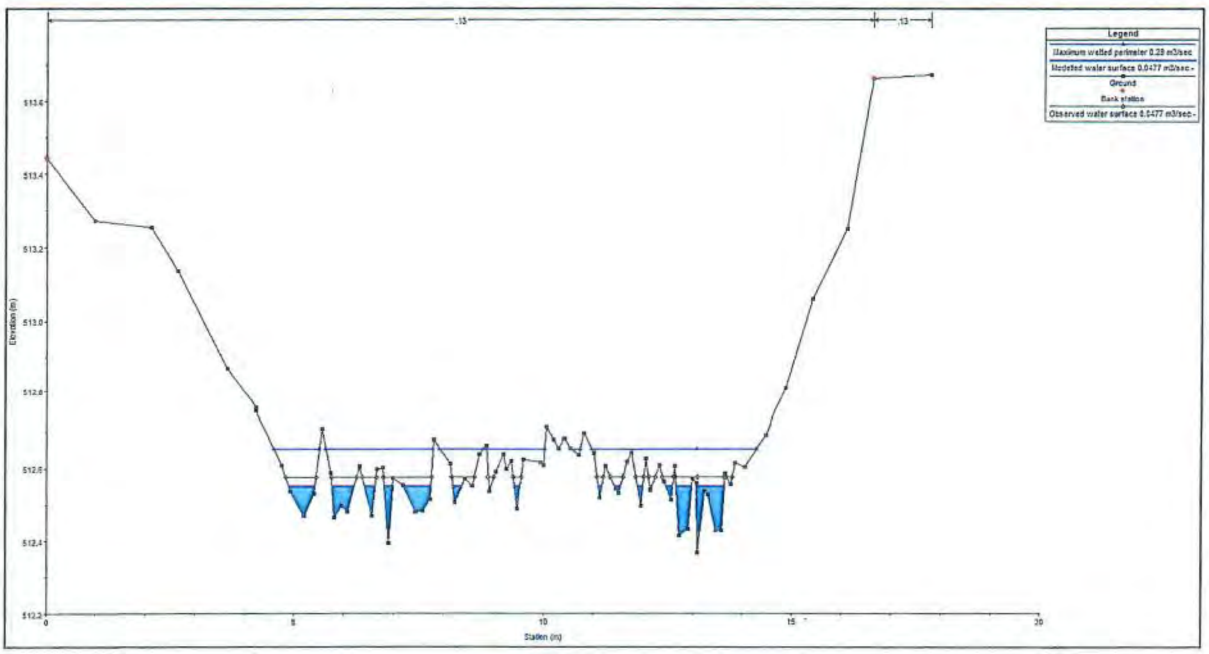

Figure 5.3: Cross-section 22 (representative of the steep riffle) showing the flow observed during the field survey (equiv. 4.12ML/day) and the bank tow wetted perimeter of 24.19ML/day

Figure 5.4: Photo of the right bank of cross-section 22. The lateral transition from river cobbles and boulders to fine sediment bank material and riparian vegetation at the base of the steep bank approximates the toe of the bank

Water depth

Water depth is related to discharge and wetted perimeter and is an important flow parameter in streams that contributes to the availability and quality of aquatic habitat. For example, many species have different depth preferences which determine the distribution of different species and of varying life history stages within species. Even in the absence of other structures, depth provides physical cover and at low discharges, insufficient depth can become a critical limiting factor in habitat availability. For example, insufficient depth through shallow riffle sections may limit the migration of aquatic species, disconnect stream habitats and promote poor water quality. Impacts during operation on the maximum and average water depth will be assessed in Section 6.1.1.

Flow

Flow can have direct and indirect effects related to aspects such as flow velocity, turbulence and erosive force. For example, flow has important effects on the maintenance of stream geomorphological processes which influence the availability and quality of aquatic habitat. As for depth, many aquatic biota also have preferences for flow conditions and variable flow conditions shapes the distribution of stream communities at small (e.g., within a single riffle or pool) and at large scales (i.e. reach scale). Seasonal changes in flow also provide life-history cues for many species. Thus flow it is an important habitat variable in streams, related to discharge and channel morphology. Impacts during operation on average flow velocity will be assessed in Section 6.1.1).

Habitat focus

Section 6.1.1 will examine changes in riffle habitat conditions in a 15 metre section (cross-sections 20-25) which is the steepest riffle section (average slope 0.048) of the study reach (Figure 5.5). This high gradient section provides good aquatic habitat and would also experiences the greatest loss of habitat as a result in decreases in wetted perimeter, depth, and flow velocity. At extremely low flows, flow between the deeper, lower gradient section upstream and downstream of this section may become disconnected. Section 6.1.1 will examine changes in pool habitat conditions in a 13 metre section (Cross-sections 3 – 7) of the study reach (Figure 5.5). Pool habitat is an important component of the aquatic habitat in Jean Brook in supporting identified aquatic values.

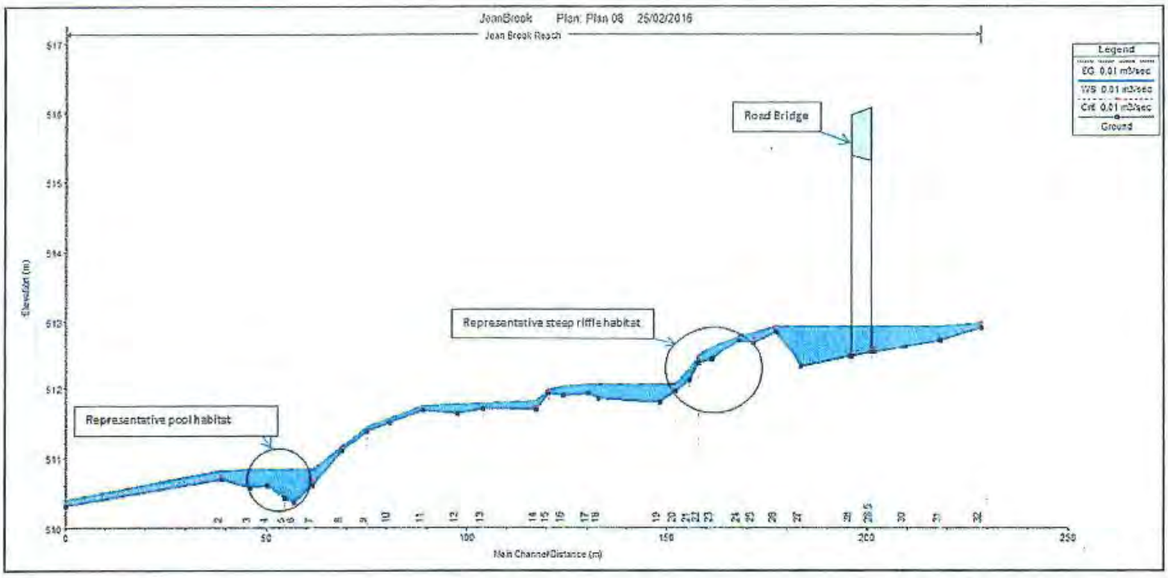

Figure 5.5: HEC-RAS profile plot of study reach showing water level at 0.01 m^3/s discharge showing the location of the representative riffle and pool

5.2.3 Proposed cease to take rules for winter (May to November)

The proposed CTT flows for Jean Brook during winter are provided in Table 5.3 and are based on maintaining a similar amount of aquatic habitat (assessed by changes in wetted perimeter, depth and flow velocity) as the default CTT values and the flow which is estimated to provide maximum wetted perimeter.

Table 5.3: Proposed monthly cease to take values for winter and associated rationale (May to November)

Month	Proposed CTT (ML/day)	Rationale
May	12.5	Maintain 90% of wetted perimeter (m) provided by default CTT
June	23.8	Maintain 90% of wetted perimeter (m) provided by default CTT
July	24.2	100% wetted perimeter in the channel (toe to toe)
August	38.2	Maintain 110% of wetted perimeter (m) provided by default CTT
September	24.2	Maintain 90% of wetted perimeter (m) provided by default CTT
October	14.3	Maintain 90% of wetted perimeter (m) provided by default CTT
November	8.6	Maintain 90% of wetted perimeter (m) provided by default CTT

5.2.4 Habitat availability during operation of the proposed CTT rules

This section documents the changes in average wetted perimeter, maximum depth (thalweg), mean depth and flow velocity through the riffle section of the study reach (cross-sections 20-25). The assessment assumes the maximum possible take in each month. That is, when water is available it is taken independent of storage capacity (assumes unlimited storage capacity in Castra Dam). In this section, the risk assessment is based on the Jean Brook diversion operating at all times when the proposed CTT is being met, however, in reality the diversion will only be able to divert water when the Castra Rivulet dam is not full.

Cross-sections are provided in Appendix D shows water levels provided by the default CTT for each month; water levels under provided by the flow assumed to represent 100% wetted perimeter (24.19 ML/day) water levels provided by proposed monthly CTT; and water level observed on the day. Water levels through cross-section 25 are shown as it is representative of a typical cross-section through the representative riffle section of the study reach (Appendix D).

The proposed CTT is calculated to ensure the change in wetted perimeter is minimal (Figure 5.6), however, the relationship between wetted perimeter and flow in the rating curve from the hydraulic model (Figure 5.2) shows that considerably less flow is required to make small changes to the wetted perimeter (Figure 5.7).

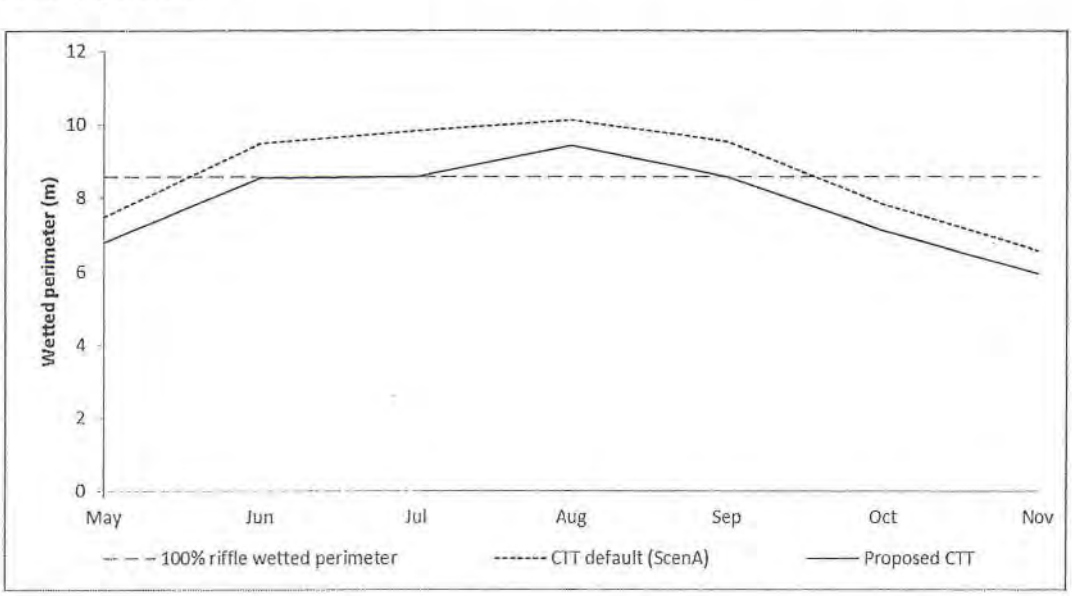

Figure 5.6: Comparison of wetted perimeter between toe to toe for maximum wetted perimeter (24 ML/day), the default CTT and the proposed CTT for each month within the winter period

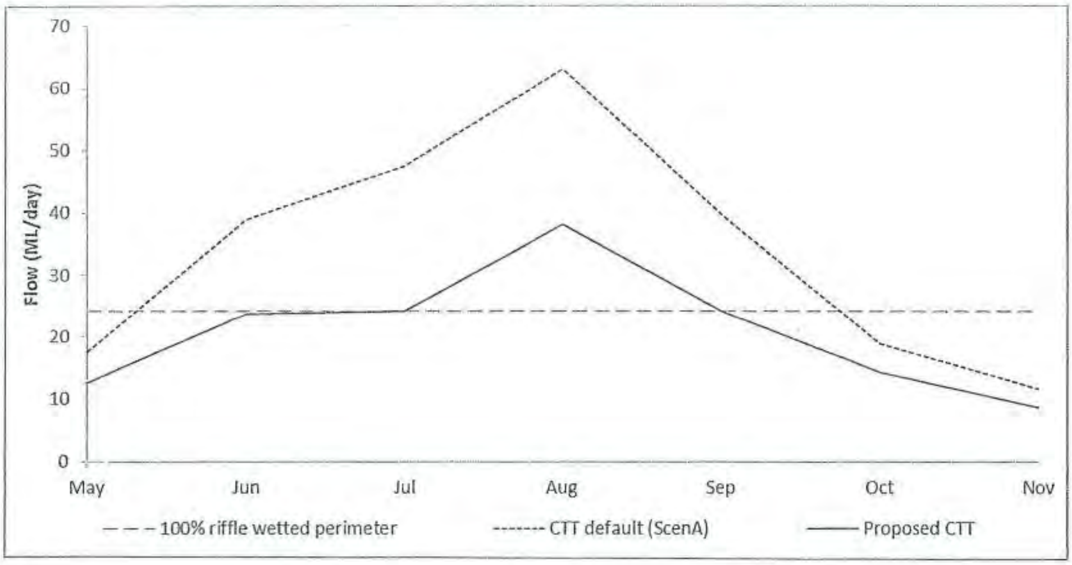

Figure 5.7: Comparison of flow between toe to toe for maximum wetted perimeter (24 ML/day), the default CTT and the proposed CTT for each month within the winter period

5.2.4.1 May

The proposed CTT for May is based on maintaining 90 percent of the wetted area perimeter that is provided by the default CTT.

The proposed May CTT flow of 12.53 ML/day maintains an average 79 percent of the wetted perimeter that is provided under a 24 ML/day flow (the flow where effective maximum wetted perimeter was assessed to be obtained (Section 5.3.1, Table 5.4). The proposed CTT equates to 91 percent of the wetted perimeter maintained under the default CTT flow for May (17.43 ML/day). The proposed CTT maintains 83 percent of the maximum depth (thalweg) and 77 percent of the average depth under a 24 ML/day. The mean flow velocity through the riffle is 92% of the flow velocity under a 24 ML/day flow (Table 5.4).

5.2.4.2 June, July and September

The proposed CTT for June (23.8 ML/day) and September (24.2 ML/day) are based on maintaining 90 percent of the wetted area under that is provided by the default CTT. The proposed CTT for July is based on maintaining 100% of the wetted perimeter.

The proposed CTT flow of 23.8 ML/day in June, 24.2 ML/day in July and September maintains 100% of the wetted perimeter as the flow assumed to provide 24 ML/day (and consequently 100% of the thalweg, average depth and flow velocity) during those months. However, the default CTT maintains a flow stage in the channel that exceeds the maximum wetted perimeter (i.e. the water level is higher than the toe of the bank) during these months. The proposed CTT maintains 90 percent of the default CTT wetted perimeter in June and September and 87 percent of the default CTT wetted perimeter in July (Table 5.4).

5.2.4.3 August

The proposed CTT flow of 38.2 ML/day in August maintains 110% percent of the wetted perimeter that is provided by a 24 ML/day flow and 93 percent of the wetted perimeter provided by the default CTT (63 ML/day) and maintaining a seasonal pattern of high base flows in the hydrographs. Under the proposed CTT, the consequently the thalweg, and average depth and flow velocity under the proposed CTT is greater than under 24 ML/day (Table 5.4).

5.2.4.4 October

The proposed CTT for October is based on maintaining 90 percent of the wetted area under that is provided by the default CTT.

The proposed CTT for October of 14.3 ML/day maintains 83 percent of the wetted perimeter provided by 24 ML/day and approximately 91 percent of the wetted perimeter under the default CTT. Consequently, the proposed CTT maintains, 86 % percent of the thalweg depth and 80 percent of the mean depth is maintained in the riffle under the proposed CTT compared with the default CTT. The flow velocity maintains 96 percent of the flow velocity when the channel is wetted to the toe of the bank and is the same when compared with the default CTT (Table 5.4).

5.2.4.5 November

The proposed CTT for November is based on maintaining 90 percent of the wetted area perimeter under the default CTT.

The proposed CTT for November of 8.64 ML/day maintains 69 percent of the wetted perimeter provided by 24 ML/day and approximately 91 percent of the wetted perimeter under provided by the default CTT. Consequently, 76 percent of the thalweg depth and 67 percent of the mean depth is maintained in the riffle under the proposed CTT when compared with the default CTT. The flow velocity of the proposed CTT maintains 83 percent of the flow velocity when the channel is wetted to the toe of the bank (Table 5.4).

5.2.4.6 Changes through pools

Table 5.5 shows changes in wetted perimeter, maximum (thalweg) depth and flow velocity in the most downstream pool section of the study reach (cross-sections 3 to 7). Cross-sections are provided in Appendix E to show water levels provided by the default CTT for each month, water levels under 24 ML/day, water levels provided by proposed monthly CTT and water level observed on the day of the field survey. Water levels through Cross-section 3 are shown as it is representative of a typical cross-section through the representative pool section of the study reach (Appendix E).

The proposed CTT values maintain a higher percentage of wetted perimeter, maximum and mean depth through the pool section than in the riffle section discussed above (Table 5.5, Sections 5.5.1 to 5.5.5). However, mean flow velocity is affected slightly more in the pool section than in the riffle under 24 ML/day, the default CTT and the proposed CTT (Table 5.5).

Table 5.4: Mean wetted perimeter, depth and flow velocity in riffle section (cross-sections 20 – 25) at 24.19 ML/day, default CTT and proposed CTT for each winter month

Month	Flow conditions (ML/Day)	Wetted perimeter			Maximum depth			Mean depth			Mean flow velocity		
		metres	% of maximum	% of habitat provided by default CTT	metres	% of maximum	% of habitat provided by default CTT	metres	% of maximum	% of habitat provided by default CTT	metres per second	% of maximum	% of habitat provided by default CTT
May	Maximum habitat (24.19)	8.56	100		0.35	100		0.13	100		0.34	100	
	Default CTT (17.42)	7.47	87		0.31	90		0.12	90		0.34	100	
	Proposed CTT (12.52)	6.77	79	91	0.29	83	91	0.10	77	86	0.31	92	92
June	Maximum habitat (24.19)	8.56	100		0.35	100		0.13	100		0.34	100	
	Default CTT (39.03)	9.48	111		0.40	114		0.17	128		0.37	110	
	Proposed CTT (23.76)	8.53	100	90	0.34	99	87	0.13	100	77	0.34	100	91
July	Maximum habitat (24.19)	8.56	100		0.35	100		0.13	100		0.34	100	
	Default CTT (47.66)	9.83	115		0.42	121		0.19	143		0.39	115	
	Proposed CTT (24.19)	8.56	100	87	0.35	100	83	0.13	100	70	0.34	100	87
August	Maximum habitat (24.19)	8.56	100		0.35	100		0.13	100		0.34	100	
	Default CTT (63.02)	10.11	118		0.46	132		0.22	165		0.43	126	
	Proposed CTT (38.20)	9.41	110	93	0.40	114	86	0.17	125	76	0.37	109	87
September	Maximum habitat (24.19)	8.56	100		0.35	100		0.13	100		0.34	100	
	Default CTT (39.84)	9.51	111		0.40	115		0.17	129		0.37	110	
	Proposed CTT (24.19)	8.56	100	90	0.35	100	87	0.13	100	77	0.34	100	91
October	Maximum habitat (24.19)	8.56	100		0.35	100		0.13	100		0.34	100	
	Default CTT (18.97)	7.82	91		0.32	93		0.12	90		0.34	100	
	Proposed CTT (14.26)	7.08	83	91	0.30	86	93	0.11	80	89	0.32	96	96
November	Maximum habitat (24.19)	8.56	100		0.35	100		0.13	100		0.34	100	
	Default CTT (11.50)	6.55	77		0.28	82		0.10	75		0.31	90	
	Proposed CTT (8.64)	5.95	69	91	0.27	76	94	0.09	67	90	0.28	83	92

Table 5.5: Mean wetted perimeter, depth and flow velocity in the pool section (cross-sections 3-7) at 24.19 ML/day, default CTT and proposed CTT for each winter month

Month	Flow conditions (ML/Day)	Wetted perimeter			Maximum depth			Mean depth			Mean flow velocity		
		metres	% of maximum	% of habitat provided by default CTT	metres	% of maximum	% of habitat provided by default CTT	metres	% of maximum	% of habitat provided by default CTT	metres per second	% of maximum	% of habitat provided by default CTT
May	Maximum habitat (24.19)	5.27	100		0.59	100		0.33	100		0.19	100	
	Default CTT (17.42)	4.89	93		0.55	93		0.30	92		0.16	83	
	Proposed CTT (12.52)	4.68	89	96	0.52	87	94	0.28	84	91	0.13	68	81
June	Maximum habitat (24.19)	5.27	100		0.59	100		0.33	100		0.19	100	
	Default CTT (39.03)	5.76	109		0.67	113		0.38	116		0.25	130	
	Proposed CTT (23.76)	5.26	100	91	0.59	100	89	0.33	101	86	0.19	98	75
July	Maximum habitat (24.19)	5.27	100		0.59	100		0.33	100		0.19	100	
	Default CTT (47.66)	5.93	113		0.70	119		0.41	125		0.28	146	
	Proposed CTT (24.19)	5.27	100	89	0.59	100	84	0.33	100	80	0.19	100	69
August	Maximum habitat (24.19)	5.27	100		0.59	100		0.33	100		0.19	100	
	Default CTT (63.02)	6.20	118		0.76	128		0.45	138		0.32	168	
	Proposed CTT (38.20)	5.74	109	93	0.66	111	87	0.38	116	85	0.25	130	78
September	Maximum habitat (24.19)	5.27	100		0.59	100		0.33	100		0.19	100	
	Default CTT (39.84)	5.78	110		0.67	113		0.39	117		0.25	132	
	Proposed CTT (24.19)	5.27	100	91	0.59	100	88	0.33	100	85	0.19	100	76
October	Maximum habitat (24.19)	5.27	100		0.59	100		0.33	100		0.19	100	
	Default CTT (18.97)	5.00	95		0.56	95		0.31	95		0.17	88	
	Proposed CTT (14.26)	4.72	90	94	0.53	89	94	0.29	87	92	0.14	73	83
November	Maximum habitat (24.19)	5.27	100		0.59	100		0.33	100		0.19	100	
	Default CTT (11.50)	4.65	88		0.51	85		0.27	82		0.12	65	
	Proposed CTT (8.64)	4.55	86	98	0.48	81	95	0.25	75	92	0.10	54	84

5.3 Event based flows

5.3.1 Rationale

The CTT aspect of the environmental flow is targeted at addressing low flows (i.e. base flows); however, high flow events such as freshes, bank full floods flows and overbank floods flows are also important components of the natural flow regime (Poff et al 1997). Flows of these magnitudes are not fully addressed in a CTT prescription and can still be affected by a development if the maximum take represents a significant proportion of the flow. Flow magnitudes that equal to the 70 percentile through to the 90 percentile flow typically represent 'freshes'. Flows of these magnitudes are often affected as a development may have the ability to harvest all the majority of the flow with the exception of large floods that far exceed the capacity of the development offtake.

An event analysis of the 70 percentile monthly daily flows is shown in Table 5.7 for Nietta Creek and Table 5.9 for Jean Brook. The analysis was based on the default CTT for Nietta Creek and the proposed CTT for Jean Brook using modelled data based on the assumptions outlined in Appendix A. The proposed Jean Brook diversion will have a peak capacity of 69.12 ML/day (800 l/sec) and the proposed Nietta Creek diversion will have a peak capacity of 17.28 ML/day (200 l/sec); therefore, flow events will not pass down the natural watercourses until the each diversion reaches full capacity. However, it is recognised in the hydrological model assumptions that this maximum capacity would be rarely realised given that the Castra Rivulet dam will be managed at 75% capacity and that the power station has a maximum capacity of 800 l/sec. The 70 percentile represents the smallest 'fresh' threshold for defining an event rule; however, by allowing the peak flow to pass during the event will ensure that higher magnitude events are also maintained.

The management of event based flows would be based on natural inflows, which, concurrently will also control the rate of rise and fall for each event. That is, when the first event for a specified month reaches the threshold, all flows shall pass until such time as the flows recede back to the event threshold or the maximum duration specified for each month. If the maximum duration is reached, but the event has not naturally receded, then the event should be ramped down at the specified rate of fall for that month to ensure that fish are not stranded in the watercourse. The rate of fall is approximately equivalent to the mean greatest rate of fall for that month in the modelled natural flow time series.

5.3.2 Proposed event based flows for Nietta Creek

The proposed event based environmental flow rules for Nietta Creek are shown in Table 5.6 and are based on ensuring that the 70 percentile flow based on natural inflows is exceeded downstream from the proposed offtake at least once during May, October and November.

From June to September, the number and peak of 80 and 90 percentile flows are only marginally altered by 17% or less under the operation of the proposed offtake during operation (Table 5.7). The number and peak of 70 percentile events are more altered in May (number of events reduced by 23%) and October/November (number 31 and 53 % reduced; peak 41 and 27 % reduced respectively) (Table 5.7)/however, 70 percentile flow events in May, October and November are affected in relation to the number and duration of events). The duration of 70 percentile flow events are most reduced in May and November (Table 5.7).

November appears to be the most effected with the number and duration of flow events being reduced by approximately half. Based on this analysis, an event rule is required for May, October and November to meet the objectives of the environmental flow assessment (Table 5.7).

Note that the bank full flow for the representative reach is an average 369 ML/day, but is as low as 86.4 ML/day at cross-section 14 where flows can break out of the channel. Given this variability, bank full flows are considered to only occur during large flood events (i.e. >90 percentile).

Table 5.6: Proposed event based environmental flows for winter in Nietta Creek

Month	Number of events	Threshold magnitude (ML/day)	Duration (days)	Greatest rate of fall (ML/day/day)
May	1	3.2	5.9	1.8
October	1	3.84	4.6	2.7
November	1	2	5.2	1

Table 5.7: Event analysis of Nietta Creek at the proposed offtake for 70%ile, 80%ile and 90%ile monthly flows under the natural flow regime and the default CTT

Month		Greatest rate of fall for the whole period (ML/day/day)	70th percentile flow (ML/day)	Mean number of 70%ile events per month	Mean peak of events > 70th percentile flow (ML/day)	Mean duration of events > 70th percentile flow (days)
May	Current	1.814	3.2	1.711	10.755	5.879
	Scheme	1.768		1.316	11.911	4.241
	% change	*-2.5*		*-23.1*	*10.7*	*-27.9*
June	Current	2.450	5.45	2.053	13.226	4.594
	Scheme	2.245		1.711	14.618	3.675
	% change	*-8.4*		*-16.7*	*10.5*	*-20.0*
July	Current	4.270	8.61	2.053	21.543	4.463
	Scheme	4.380		1.895	22.507	4.075
	% change	*2.6*		*-7.7*	*4.5*	*-8.7*
August	Current	4.574	11.17	2.026	25.375	4.875
	Scheme	4.639		2.053	25.128	4.081
	% change	*1.4*		*1.3*	*-1.0*	*-16.3*
Sept	Current	3.137	6.79	2.000	18.461	4.620
	Scheme	3.029		1.816	19.835	3.718
	% change	*-3.4*		*-9.2*	*7.4*	*-19.5*
October	Current	2.741	3.84	1.947	11.419	4.581
	Scheme	3.486		1.342	16.144	3.729
	% change	*27.2*		*-31.1*	*41.4*	*-18.6*
November	Current	1.055	2	1.895	6.133	5.207
	Scheme	1.320		0.895	7.767	2.063
	% change	*25.1*		*-52.8*	*26.6*	*-60.4*

5.3.3 Proposed event based flows for Jean Brook

The impact on the 70 percentile flows in Jean Brook under the operation of the proposed offtake is variable; however, flow events are impacted for all months. Based on this analysis an event rule is required for all months from May to Nov. The proposed event based environmental flow rules for Jean Brook are shown in Table 5.8 and are based on ensuring that to 70 percentile flow threshold is exceeded downstream from the proposed offtake at least once during May, October and November based on natural inflows.

Table 5.8: Proposed event based environmental flows for winter in Jean Brook

Month	Number of events	Threshold magnitude (ML/day)	Duration (days)	Greatest rate of fall (ML/day/day)
May	1	46.24	5.9	14.9
June	1	70.58	4.9	17.1
July	1	98.07	4.4	29
August	1	110.43	4.5	33.4
September	1	79.26	4.7	24.6
October	1	49.09	5	18.2
November	1	26.27	6.3	9.5

Table 5.9: Event analysis of Jean Brook at the proposed offtake for 70%ile, 80%ile and 90%ile monthly flows under the natural flow regime and the proposed CTT

Month		Greatest rate of fall for the whole period (ML/day/day)	70^{th} percentile flow (ML/day)	Mean number of 70%ile events per month	Mean peak of events > 70^{th} percentile flow (ML/day)	Mean duration of events > 70^{th} percentile flow (days)
May	Current	14.890	46.24	1.684	111.391	5.935
	Scheme	14.076		0.921	132.414	4.072
	% change	*-5.5*		*-45.3*	*18.9*	*-31.4*
June	Current	17.135	70.58	1.947	127.245	4.921
	Scheme	15.192		1.342	133.621	3.116
	% change	*-11.3*		*-31.1*	*5.0*	*-36.7*
July	Current	29.010	98.07	2.211	170.502	4.408
	Scheme	29.928		1.500	194.083	4.321
	% change	*3.2*		*-32.2*	*13.8*	*-2.0*
August	Current	33.389	110.43	2.342	197.703	4.489
	Scheme	33.287		1.737	209.230	3.971
	% change	*-0.3*		*-25.8*	*5.8*	*-11.5*
Sept	Current	24.559	79.26	1.868	162.276	4.724
	Scheme	24.425		1.579	180.560	3.442
	% change	*-0.5*		*-15.5*	*11.3*	*-27.1*
October	Current	18.248	49.09	1.842	108.242	5.002
	Scheme	18.737		0.947	143.181	4.119
	% change	*2.7*		*-48.6*	*32.3*	*-17.7*
November	Current	9.500	26.27	1.632	71.339	6.252
	Scheme	9.397		0.500	95.335	3.385
	% change	*-1.1*		*-69.4*	*33.6*	*-45.9*

6. Predicted impacts on instream fluvial processes, habitats and species

Impact risk assessments typically provide a magnitude statement for the impact which range from high/severe, medium, low, and negligible to no impact and is based on the best available lines of evidence. For example, a high impact on hydrology could be defined as a permanent and large change to the flow regime that is likely to result in a fundamental change in some aspect of the aquatic environment (e.g. channel morphology, specific habitat niche). Riverine ecology is intrinsically linked to the flow regime and thus significant changes to flow will impact habitat use and availability, water quality, life history cues, behaviour and population dynamics.

The objective of the environmental flow rules presented in this report is to have low to negligible (i.e. practically undetectable) impact on the aquatic values of Nietta Creek immediately downstream from the proposed offtake to the confluence with the Wilmot River and Jean Brook immediately downstream from the proposed offtake to the confluence with the Leven River. For example, a low or negligible impact on flow regime and associated values could be defined as:

- Little or no change in AusRivAS condition scores for macroinvertebrate communities
- Little or no change in fish community
- Little or no change in downstream habitat quality (i.e. no change in connectivity within the channel or between the channel and floodplain; no change to the morphology of the system ; no change in the quality of habitat that supports general aquatic ecology or threatened species)
- Little or no change in downstream water quality.

Stream flow is strongly correlated with critical physicochemical characteristics of rivers including water temperature, channel geomorphology and habitat diversity (Poff et al. 1997). Therefore, flow is the main physical driver in riverine systems that limits the distribution and abundance of riverine species and regulates the ecological integrity of flowing waters (Poff et al 1997).

The natural flow regime is critical in maintaining the function and diversity within a river system (Poff et al 1997). Flow regimes contain the following five key components:

- *magnitude* – quantity of flow components
- *frequency* – how often do zero flows, freshes, floods occur annually, seasonally, and monthly
- *duration* – how long to flow events occur for
- *rate of change* – how quickly do flow events rise and fall
- *timing/predictability* – at what time of year do flow events occur.

A holistic environmental flow, or assessment of changes to a flow regime, should consider these five flow components (Arthington 2012).

Table D.1 summarises the general flow objectives and values, critical flow components that affect those values and the predicted impact that operation of the scheme will have on those values in Nietta Creek and Jean Brook and associated riparian and floodplain habitats. Table 6.1 summarises the predicted impacts on specific listed aquatic and riparian values that have been recorded in Nietta Creek and Jean Brook or have a high potential to occur in the Nietta Creek and Jean Brook catchments.

6.1 Impacts on low flow aquatic habitat

6.1.1 Low flows in Jean Brook

The impact on the aquatic habitat under low flows is based on change in the wetted perimeter with changes in the maximum depth (thalweg), average depth and flow velocity used as additional lines of evidence to undertake the risk assessment of the likelihood of a significant impact on aquatic habitat in Jean Brook.

6.1.1.1 Riffles

Based on hydraulic modelling, the proposed CTT values maintain over 90 percent of the wetted perimeter provided by the maximum wetted perimeter flow (24 ML/day) in May, June, September, October and November, 100% in July and 110% in August (Section 5.3.3.1). A 10% reduction in wetted perimeter in May, June, September, October and November and will have a low impact on aquatic values as it will maintain a seasonal signal in the low flow aquatic ecology. Therefore, the scheme is predicted to have a **low adverse** impact on the amount of aquatic habitat through changes in wetted perimeter.

Changes in maximum and average depth are most pronounced in percentage terms in May, October and November and undetectable during the other winter months. However, this change is not significant when actual depths are examined. For example, the typical maximum depth in May, October and November range from 25 cm to 30 cm under natural conditions at 100% wetted perimeter. These depth decrease <10 cm under the proposed CTT. Another example is that the average depth in the riffle is 67% of the wetted perimeter in November, but the actual change in depth is 13 cm down to 9 cm. Maximum depth and average depth increases in the other months when compared to the wetted perimeter under the proposed CTT. Therefore, the scheme is predicted to have a **low adverse** impact on depth in May, October and November and a **negligible** impact during the remaining months.

The change in flow velocity in the riffles habitat is largely unchanged under the proposed CTT, with the exception of November, when the proposed CTT only provides 83 % of the flow velocity when compared to the flow velocity when the wetted perimeter is 100%. However, this only equates to a change from 34 cm/sec to 28 cm/sec in real terms. Therefore, the scheme is predicted to have a **negligible** impact on flow velocity in riffles.

Overall, the impact on the amount and quality of aquatic habitat through riffle habitat during operation under the proposed CTT is assessed as **low adverse to negligible.**

6.1.1.2 Pools

Similar to the representative riffle, the reduction in the wetted perimeter in the representative pool is most pronounced in May, October and November. For example, the wetted perimeter is 89% in May (96% of the default CTT) and 86 % in November (98 % of the default CTT) under the proposed CTT when compared with 24 ML/day. However, the change in November is 5.27 m down to 4.55 m in real terms. The wetted perimeter is unchanged in July and September and exceeded in August.

Therefore, the scheme is predicted to have a **low adverse** impact on wetted perimeter in May, October and November and a **negligible** impact during the remaining months.

The impact on the maximum depth (thalweg) and mean depth in the representative pool reach follows a similar pattern to the representative riffle reach, whereby with the greatest change is in depth during May, October and November. For example, in November, the maximum depth is 81 % (96 % of the default CTT) 81% of the depth provided by 24 ML/day, however, in real terms this equates is to a reduction of 9 cm (from 59 cm down to 48 cm). Similarly, the average depth in November is 75 % (92 % of the default CTT) of the wetted perimeter average depth, which is equates to an 8 cm drop reduction in average depth (33 cm down to 25 cm). The maximum and average depth increases under the proposed CTT when compared to 24 ML/day during other months. Therefore, the scheme is predicted to have a **low adverse** impact on depth in pools in May, October and November and a **negligible** impact during the remaining months.

The impact on flow velocity follows the same pattern in pools, with the most pronounced change in May, October and November. For example, the flow velocity in November is 54% of the flow velocity provided by 24 ML/day (84 % of the default CTT). However, this change is 9 cm/sec in the pool (19 cm/sec down to 10 cm/sec). Given pools are semi-lentic habitats and the volume of the pools is low, the change in flow velocity is unlikely to cause significant changes in habitat quality. The flow velocity is largely unchanged in July and September and increases in August. Therefore, the scheme is predicted to have a **low adverse** impact on flow velocity within the pool in May, October and November and a **negligible** impact during the remaining months.

6.1.2 Nietta Creek

Given that a TEFF-style environmental flow assessment was not undertaken for Nietta Creek, specific habitat parameters cannot be assessed. It is assumed that the default CTT encompasses all low flow habitats and that the assessment of impact can be assessed using a hydrological approach, which is discussed in the section 6.2.2.

6.2 Impacts on flow regime

Duration curves (based on daily data) for current and proposed flows in Nietta Creek, Castra Rivulet and Jean Brook on an annual and monthly basis are shown in Appendix G. The current flow conditions in Castra Rivulet are defined as the flows under current power station operation and not the pre-development condition that was assessed by Entura (2012a). Additional duration curves are provided for scheme operation including the harvest yield from each diversion, headwater storage operation, the current environmental flow in Castra Rivulet and power station flow. Note, however, that the duration analysis does not include the requirement for the proposed event based environmental flow rules due to time and budget constraints. Rather comment is made here in relation to the event based rules and hydrographs during example events. The risk assessment is based on the assumptions ion of the hydrological model, which include maintaining the Castra dam at a nominal volume and prioritising Jean Brook offtake over the Nietta Creek offtake (Appendix A1).

6.2.1 Nietta Creek (May-Nov)

The current mini hydro power station does not source water from Nietta Creek but does affect flow in the Castra Rivulet, of which Nietta Creek is a tributary. Under operation of the proposed Nietta Creek diversion, including the default CTT, the diversion will divert flow up to 200 L/sec (17.28

ML/Day). Once the diversion reaches its capacity (200 L/sec), all remaining flows will be spilled down Nietta Creek.

Low and median flows

The duration analysis of flows immediately downstream from the proposed Nietta Creek offtake (Figure E.1) and immediately upstream of the confluence with Castra Rivulet (Figure E.2) shows that the low and median flows during the winter period are maintained by the default CTT environmental flow rule in place for each month. The annual duration curve shows a reduction in median flows because it shows an average of the monthly median flow figures for all months including the summer period (Figure E.1).

Freshes (70-80%ile flows), high flows (85-95%ile) and peak floods (>95%ile)

Fresh events are affected in May, October and November and to a lesser extent in June and September; however, fresh events still occur in July and August but are of slightly lower magnitude and duration. The magnitude and duration of high flows and floods remains relatively unchanged (Figure E.1). This pattern remains evident down to the confluence with Castra rivulet (Figure E.2); however, at this point the change in fresh events are less pronounced and more closely resemble the natural flow regime due to natural pickup from tributary inflows. The requirement to release a fresh event in May, October and November (section 5.3.2), coupled with downstream catchment pickup will mitigate the impact on fresh events in Nietta Creek.

6.2.1.1 Downstream changes in Castra Rivulet (May-Nov)

An environmental flow is currently released from the headwater dam (Entura 2012b) and is based on environmental flow releases matching inflows up to a monthly maximum value whereby a constant flow is released until such time that the inflows fall back below the monthly maximum environmental flow value and all inflows are again released down Castra Rivulet. In addition, a fresh flow event of 70 ML/day is required in April, October and November, which are triggered by natural inflows into the headwater dam (Figure E.3).

Under operation of the proposed Jean Brook and Nietta Creek diversions (which includes optimising the volume of the headwater storage), the magnitude and duration of the environmental flow release from the headwater dam would remain largely unchanged; however, fresh events will increase in magnitude and duration due to inflows from the diversions, causing additional spill events down Castra Rivulet (Figure E.3).

Low and median flows

The duration analysis of flows in Castra Rivulet immediately downstream from the Nietta Creek confluence and upstream from the power station tailrace outflow shows that the low and median flows during the winter period are maintained by the default CTT monthly environmental flow rule from the headwater dam and the proposed Nietta Creek diversion (Figure E.4 and Figure E.5).

In contrast, median flows in Castra Rivulet downstream of the power station tailrace increase due to additional water from the inter-basin transfer from Jean Brook. However, low flows remain unchanged possibly due to the power station not operating when flows in Jean Brook, Nietta Creek and the existing water sourced from Castra Rivulet are less than the CTT prescribed for each offtake (Figure E.6).

Freshes (70-80%ile flows), high flows (85-95%ile) and peak floods (>95%ile)

The impact of the proposed diversion on freshes and high flows varies from month to month; for example, the magnitude and duration of fresh events in May, October and November are reduced, whereas high flows and floods are increased. This is likely due to the impact on freshes in Nietta Creek coupled with the increase in high flows from the headwater dam. In contrast, the magnitude and duration of fresh events are increased in June, July, August and September, possibly due to additional fresh and high flow events occurring from the headwater dam (Figure E.4 and Figure E.5).

Freshes and high flows are increased in Castra Rivulet downstream of the power station tailrace proportional to the capacity of the power station, due to additional water from the Jean Brook inter-basin diversion (Figure E.6).

The requirement to release a fresh event in May, October and November (section 5.3.2), coupled with downstream catchment pickup will mitigate the impact on fresh events in Castra Rivulet.

Overall impact on flow regime in Nietta Creek and downstream in Castra Rivulet

Based on the conservative default CTT environmental flow, the proposed event rules, the maintenance of the existing environmental flows in Nietta Creek and the existing environmental flow prescription for Castra Rivulet and downstream inflow pick up the scheme is predicted to have a **low adverse** impact on the flow regime.

6.2.2 Jean Brook (May-Nov)

Under operation of the proposed Jean Brook diversion, including the proposed CTT, the diversion will divert flow up to 800 L/sec (69.12 ML/Day). Once the diversion reaches capacity, remaining flows will be spilled down Jean Brook.

Low and median flows

The duration analysis of flows immediately downstream from the proposed Jean Brook offtake (Figure E.7) and immediately upstream of the confluence with the Leven River (Figure E.8) shows that the low flow flows during the winter period regime is are maintained by the proposed CTT monthly environmental flow rules; however, the magnitude and duration of the median and fresh flows are reduced down to the confluence with the Leven River.

Similarly, the magnitude and duration of low flows in the Castra Rivulet downstream of the Jean Brook diversion outflow are maintained. However, the magnitude and duration of median and fresh flows are augmented by flows from the Jean Brook diversion (Figure E.9).

Freshes (70-80%ile flows), high flows (85-95%ile) and peak floods (>95%ile)

Fresh events are generally replaced with the proposed CTT environmental flow in May to June and September to November; however, fresh events still occur in July and August but are of slightly lower magnitude and duration. The magnitude and duration of high flows and floods remains relatively similar to current (Figure E.7). This pattern remains evident down to the confluence with the Leven River (Figure E.8); however, at this point the change in the magnitude of high flows and floods are less pronounced and more closely resemble the natural flow regime due to natural pickup from tributary inflows. The requirement to release a fresh event each month (Section 5.3.3), coupled with downstream catchment pickup will mitigate the impact on fresh events in Jean Brook.

The magnitude and duration of freshes, high flows and floods are increased in Castra Rivulet downstream of the Jean Brook diversion outflow throughout winter due to the augmentation of flow from the Jean Brook diversion (Figure E.9).

Overall impact on flow regime in Jean Brook

Based on the proposed CTT environmental flow, the proposed event rules and downstream inflow pick up the scheme is predicted to have a **low adverse** impact on the flow regime.

6.3 Operational hydrology and generation yield

The hydrological model was able to optimize the volume of the headwater storage between 60 ML and 80 ML (Figure E.10), which also means the current environmental flow regime downstream of the headwater dam remains largely the same with the two proposed offtakes in operation (Figure E.3). As a result, the power station is able to maintain a high volume of generation in all months, and is able to remain running for longer in all months except May (Figure E.11).

6.3.1 Example hydrographs

Example hydrographs for a wet winter (1996) and dry winter (2006), based on Figure 2.1 are provided in Figure 6.1 to Figure 6.4. The example hydrographs incorporate the default CTT and event rules for Nietta Creek and the proposed CTT and event rules for Jean Brook. Examination of the selected hydrographs demonstrates how flows will be managed in Nietta Creek and Jean Brook. For example, 1996 represents a wet year; however, flows during May, October and November are lower compared to June, July August and September, with the CTT rules maintaining all the flow in both watercourses (Figure 6.1, Figure 6.2). During July, August, September and October, most of the water harvested is sourced from Jean Brook due to its priority; however, inflows to the Castra Dam are maintained mainly by natural inflows from Castra Rivulet. Therefore, during 1996, low flow months were maintained by the CTT; however, the environmental rules were overshadowed by abundant flows in the Castra Rivulet. Under some circumstances, more than one fresh event can be passed down Nietta Creek and Jean Brook, which is evident during June in Jean Brook (Figure 6.2), whereby the first event is passed downstream as required, and then a second event is passed downstream due to the Castra Dam being full and unable to receive more water from Jean Brook.

In contrast, 2006 represents a dry year, with the majority of flows maintained by the environmental flow rules. For example, all flows in Nietta Creek and Jean Brook are passed during October and November (Figure 6.3, Figure 6.4). Events are passed down both watercourses in May, June July and September based on the event rules, with the majority of water harvested from Jean Brook due to its priority over Nietta Creek in the hydrological model.

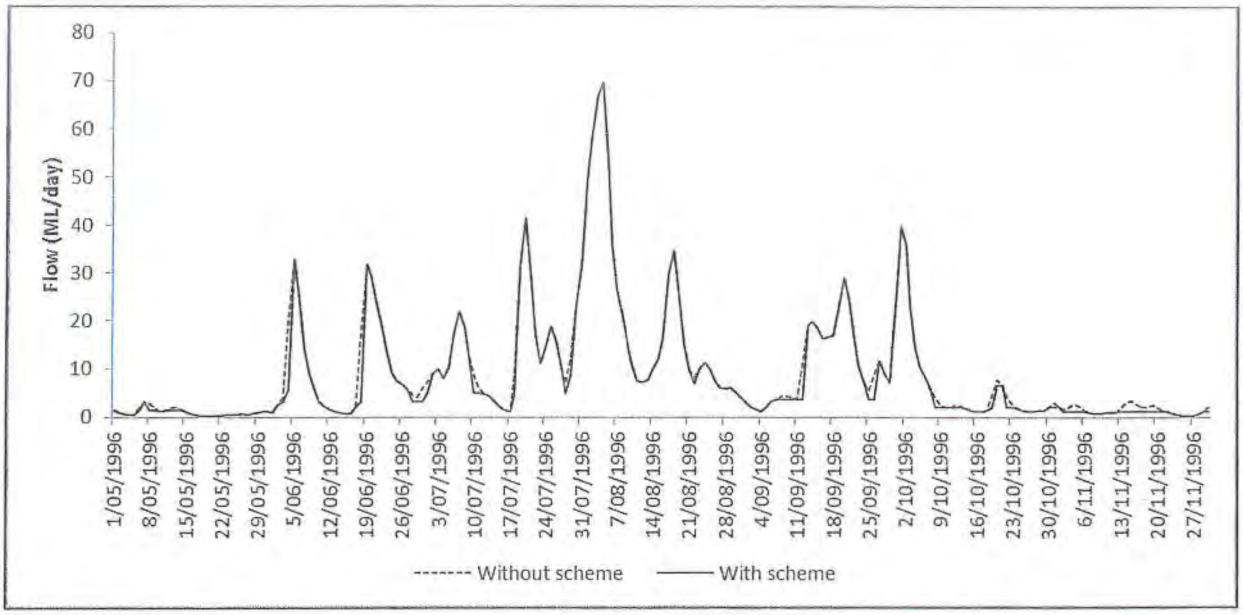

Figure 6.1: Example hydrograph of Nietta Creek immediately downstream of the proposed offtake during a wet winter (1996)

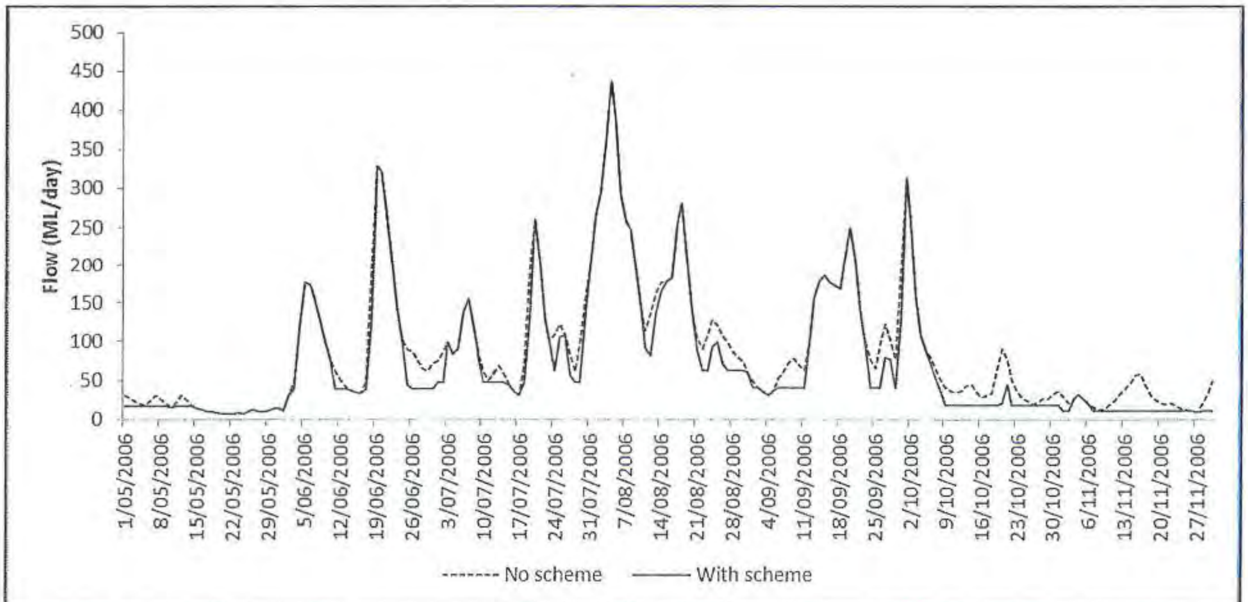

Figure 6.2: Example hydrograph of Jean Brook immediately downstream of the proposed offtake during a wet winter (1996)

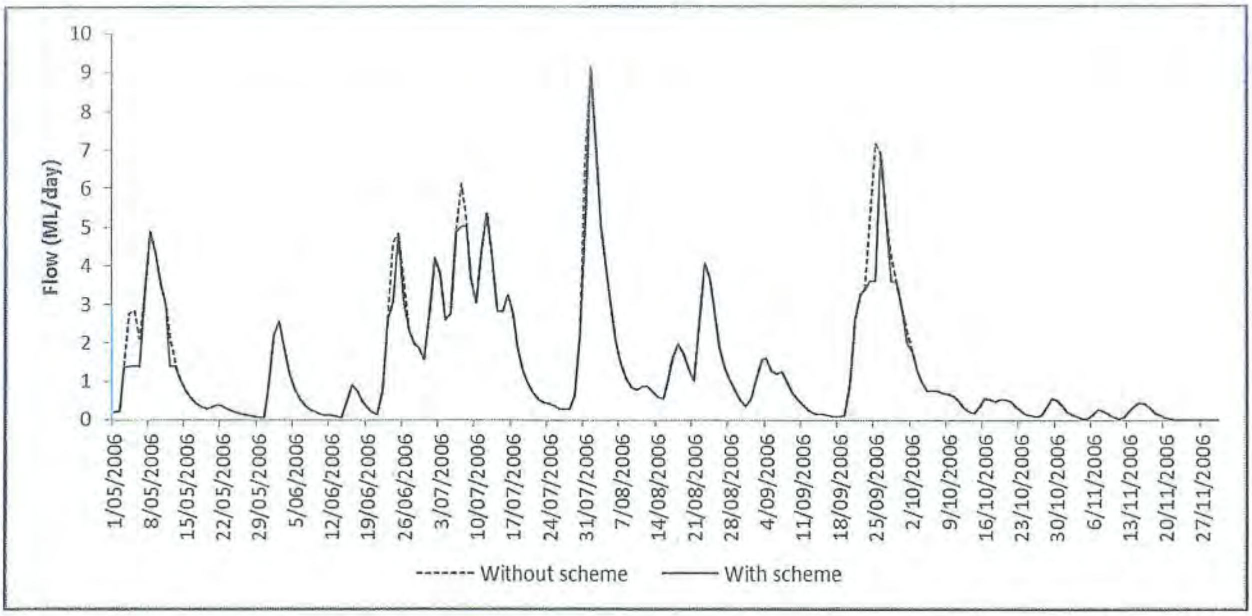

Figure 6.3: Example hydrograph of Nietta Creek immediately downstream of the proposed offtake during a dry winter (2006)

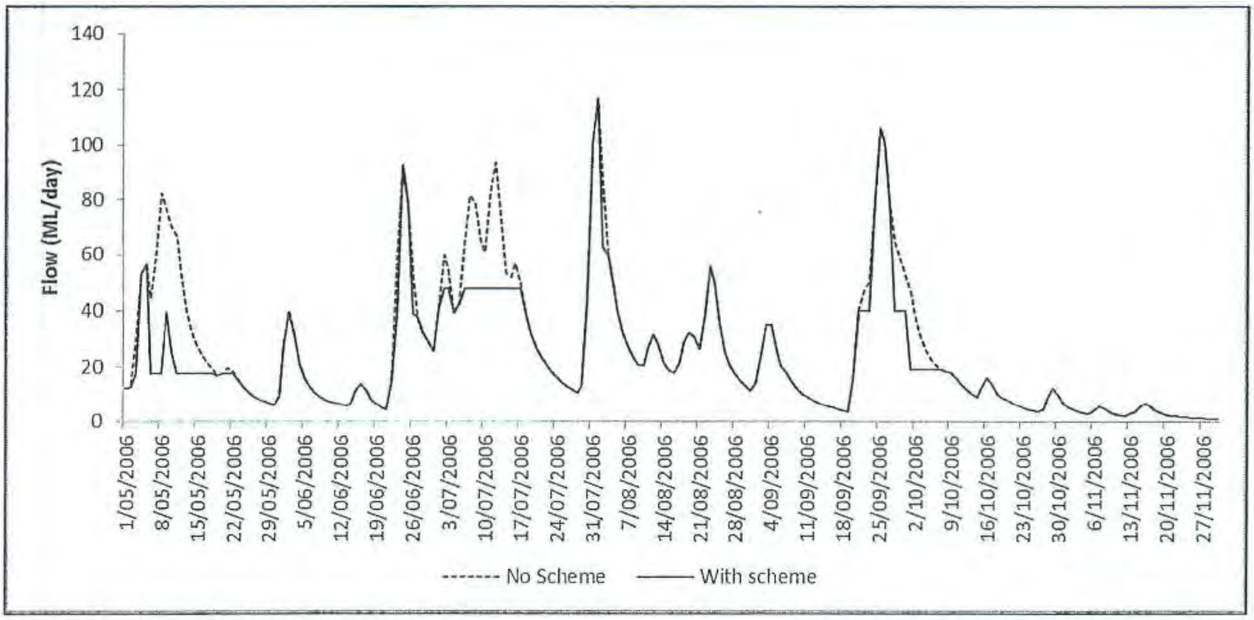

Figure 6.4: Example hydrograph of Jean Brook immediately downstream of the proposed offtake during a dry winter (2006)

6.4 Fluvial geomorphological process

Fluvial geomorphological process in Nietta Creek and Jean Brook, which maintain river, riparian and floodplain zones will be retained during operation of the proposed scheme (i.e. freshes, minor floods and over-bank floods for scouring and transport of fine materials, redistribution of larger sediments connectivity of flow between the river and flood plain). Based on the default CTT in Nietta Creek, the proposed CTT for Jean Brook, the proposed event rules and downstream inflows, the scheme is predicted to have a **low adverse** impact on fluvial geomorphological processes in Nietta Creek and Jean Brook.

6.5 Macroinvertebrate communities

Fluvial geomorphological processes in Nietta Creek and Jean Brook, which maintain habitat for macroinvertebrates is not predicted to alter substantially during operation (see section 6.3). Impacts on flow cues, variability and seasonality in flow conditions will also remain low as current (section 6.2) and the water extraction is predicted to result in a minor loss of habitat (section 6.1). Energy inputs into Nietta Creek and Jean Brook are predicted to remain similar (i.e. allochthonous leaf litter and large woody debris). Therefore, the scheme is predicted to have a **low adverse** impact on the structure and diversity of the macroinvertebrate community

6.6 Fish communities

High flow cues that trigger migratory movements of diadromous fish species and initiate life history cues for non-migratory fish species will remain during operation. Also, in the flow regime and aquatic instream habitat and macroinvertebrate prey resources are not predicted to change considerably during operation thus remaining similar to current conditions. The small reduction in flows is minor in terms of changes to the hydrograph and loss of habitat and overall the scheme is predicted to have a low impact on the migratory behaviour of diadromous fish species. The scheme will not take water during periods that constitute low flows in any month (i.e. flows low enough to affect fish passage) and thus the longitudinal connectivity between habitats will not be affected by the scheme. Therefore, the scheme is predicted to have a **low adverse** impact on diadromous migration cues, life history cues for non-migratory species, energy pathways and general aquatic habitat for fish in Nietta Creek and Jean Brook.

6.7 Listed and high conservation value species

Listed aquatic/riverine species or species of conservation significance are unlikely to be impacted by the Nietta Creek and Jean Brook offtakes if the environmental flow requirements are met (Table 6.1). The aquatic habitat is expected to be maintained during low flows (section 6.1); aquatic processes will be maintained by the provision of events and maintaining floods retaining all elements of the flow regime (Section 6.2). Subsequently, geomorphologically driven habitat and change processes will be maintained (Section 6.3) and energy inputs and ecological processes will be maintained (Section 6.4 and 6.5). Therefore, the scheme is predicted to have a **low adverse** impact on listed and high conservation value species.

6.8 Riparian values

The frequency, magnitude, timing and duration of over-bank flows will be unaffected during operation of the scheme and therefore flows that maintain riparian condition and recharge any floodplain dependent habitats will continue as current. Therefore, the scheme is predicted to have a **low adverse** impact on riparian and floodplain values.

6.9 Downstream karst

The degree of connectivity between the Loongana karst system and Jean Brook is unknown; however, Jean Brook flows across a basalt outcropping and the surface waters do not come into contact with the Karst area until the confluence with the Leven River. Over-bank flows are expected to be maintained, which are likely to be the likely contribute to the hydrological recharge of the karst system. In addition, the Loongana karst system is large in percentage terms when compared to the

Jean Brook catchment and is likely to be more dependent on the Leven River proper for recharge and physical and ecological processes. Therefore, the Jean Brook diversion is predicted to have a **negligible** impact on the Loongana karst system.

6.10 Summary

Operation under the proposed environmental flow rules is predicted to have **negligible** to **low adverse** impacts on the flow regimes of the affected watercourses and on associated aquatic habitat, species and geomorphology. The overall risk assessment of the likelihood of a significant impact on identified values is **low adverse.**

Table 6.1: Predicted impacts of operation on listed and high conservation value species

Value name		Habitat	Potential flow dependency	Predicted impacts from operation in Nietta Creek and Jean Brook
Astacopsis gouldi	Giant Freshwater Crayfish	Rivers/streams	All elements of the flow regime to retain habitat quality/quantity and prey/food resources	Low adverse
Gadopsis marmoratus	Blackfish	Rivers/streams	All elements of the flow regime to retain habitat quality/quantity and prey/food resources and life history cues	Low adverse
Barbarea australis	Riverbed Wintercress	Riverine	High flows and disturbance of cobble bars	Low adverse
Beddomeia fallax	Hydrobiid Snail (Heathcote Creek)	Headwater streams	All elements of the flow regime to retain habitat quality/quantity and prey/food resources Maintenance of slow edge waters, leaf packs and woody debris maintained by the flow regime and riparian condition	Low adverse
Beddomeia hallae	Hydrobiid Snail (Buttons Rivulet)			
Beddomeia inflata	Hydrobiid Snail (Heathcote Creek)			
Beddomeia lodderae	Hydrobiid Snail (Upper Castra Rivulet)			
Beddomeia wilmotensis	Hydrobiid Snail (Wilmot River)			

Oxyethira mienica	Invertebrate -Caddis Fly (Ouse River)	Rivers/streams	All elements of the flow regime to retain habitat quality/quantity and seasonal cues	Low adverse
Ceyx azureus diemenensis	Tasmanian Azure Kingfisher	Riparian	All elements of the flow regime maintained for bank maintenance for nests	Low adverse
Haliaeetus leucogaster	White-Bellied Sea-Eagle	Aquatic food source	Biological components of the aquatic ecosystem maintained; therefore, fish as a food source is maintained	Low adverse
Ornithorhynchus anatinus	Platypus	Rivers/streams	All elements of the flow regime to retain habitat quality/quantity and prey/food resources	Low adverse
Prototroctes maraena	Australian Grayling	Rivers/streams	All elements of the flow regime to retain habitat quality/quantity and seasonal cues	Low adverse

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Appendices

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A Hydrological model

A.1 Model assumptions

The results from the hydrological model are dependent on the operational assumptions coded into the model.

A.1.1 Environmental flows

Current scenario

An environmental flow is currently in operation downstream from the headwater dam in Castra Rivulet and is described in the current operational environmental management plan (Entura 2012). This environmental flow includes a passing flow (based on a modified 20/30 rule) and a requirement for the release of freshes (i.e. low magnitude, short duration flow events that mimic small floods during certain months). This environmental flow passed downstream under the current flow scenario. The environmental flow requirement has been assigned in the model as a monthly profile. In periods when the inflow to the storage is less than the monthly environmental flow requirement, the environmental flow requirement is reduced to equal the inflow. This operating rule ensures that the storage is not drawn down to meet environmental flow requirement.

Proposed scenario

Based on the initial yield assessment undertaken using the DPIPWE online water assessment tool and subsequent phone discussions with Nietta Hydro Pty Ltd and DPIPWE, the default CTT rule was applied to the proposed Nietta Creek and the proposed CTT rule applied to Jean Brook offtakes (Table A.1). This allows the actual volume of water yield available from each offtake to be calculated based on DPIPWE's default environmental flow requirement and to assist in informing whether further environmental flow studies are required should Nietta Hydro Pty Ltd wish to apply for additional water beyond the yield that is currently available.

Table A.1: Monthly environmental flow requirements for Nietta Creek (default CTT) and Jean Brook (proposed CTT) at the proposed offtakes

Month	Nietta Creek (ML/day)	Jean Brook (ML/Day)
May	1.39	12.53
June	3.09	23.76
July	5.01	24.19
August	6.86	38.20
September	3.60	24.19
October	2.01	14.26
November	1.14	8.64

A.1.2 Power scheme headwater storage dam

Inflows to the power station are regulated using a headwater dam. The operational assumptions used by Entura (2012) were retained, whereby:

- The storage capacity of the headwater dam is 80ML;
- The optimum storage level for power generation will be 75% of the headwater storage dam capacity (i.e. 60ML); therefore, the power station is managed to keep the storage at this level;
- Evaporation from the storage has not been modelled as these affects are deemed to be insignificant due to the small storage size; and,
- Inflows in excess of the environmental flow requirement and the maximum power station capacity are released as spill. The storage size is small (relative to the inflow) and this means that the storage retention capacity is small.

A.1.3 Diversion operation

Diversion operating rules were developed to optimise the scheme, meet the requirements of the current operational environment management plan (Entura 2012b) and minimise spill from the headwater dam.

The diversion rules optimised to:

- At each time step in the model, the water balance is optimised to maintain at least 60 ML in the storage dam plus the generation capacity of the power station;
- Jean Brook diversion is prioritised over Nietta Creek to preserve the smaller allocation from Nietta Creek and take advantage of the additional water available from Jean Brook(Chris Miles pers comms);

Therefore, the operating rules in the model are:

1. Diversion 1 (Jeanne Brook) is limited to available storage + power station capacity – (previous day headwater dam natural inflows – head water dam environmental flow)
2. Diversion 2 (Nietta Creek) is limited to available storage + power station capacity – (previous day headwater dam natural inflows – head water dam environmental flow) – diversion 1.

A.1.4 Power station operation

The maximum water demand of the power station is 900 L/sec. On a daily basis this equates to a maximum extraction of 77.76 ML/day. In practice the power station will be operated to optimize water consumption and power prices. This will mean the station may only operate for a few hours on some days and the daily extraction will significantly less than the daily maximum extraction rate of 77.76 ML/day.

A.1.5 Unlimited allocation

The model assumes that the allocation from the proposed offtakes in Nietta Creek and Jean Brook are uncapped. That is, whenever there is water available for harvesting (i.e. all upstream allocations and environmental flow rules are met), water will be harvested up to the capacity of each diversion. However, in practice, a capped water allocation is usually defined on a water licence. Once this volume has been determined, the model can be re-run for future versions of this assessment.

A.2 Model development

The hydrological model developed by Entura (2012) for the original Nietta Hydro Pty Ltd development was extended to include the proposed offtakes in Nietta Creek and Jean Brook (Figure A.2) using the input parameters and flow routing rules in Table A.2

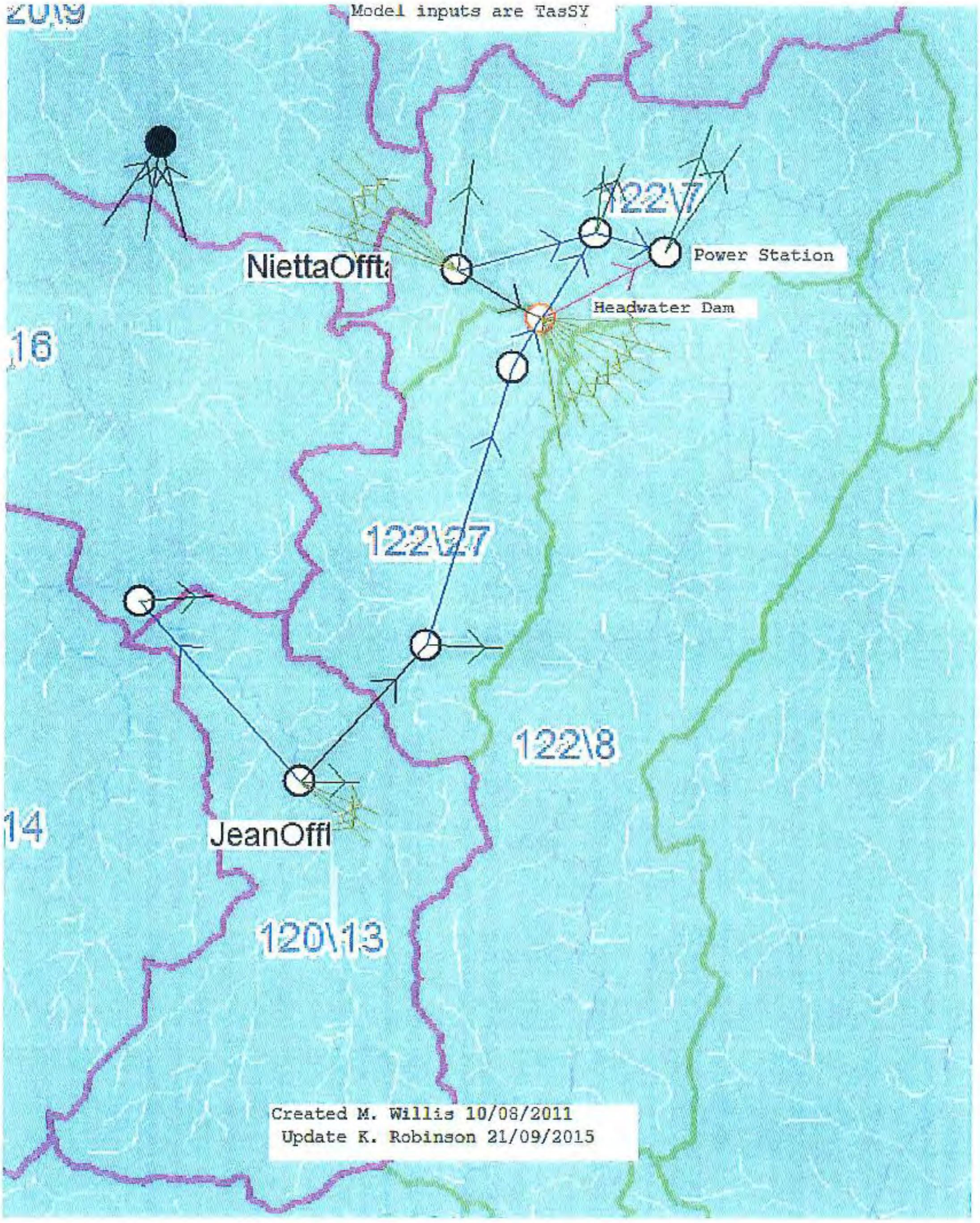

Figure A.1: Hydrological model schematic of the current scheme and the proposed offtakes