Archimedean Screw Hydropower scheme at Guyzance Meander

Hydrology Assessment

20th October 2018

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Version control

08.10.2018 first issue

20.10.2018 updated with additional text and minor amendments

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20.10.2018

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20.10.2018

Executive summary

Hydrology of the affected watercourse, the River Coquet, is characterised from long-term local flow data. The data is used to model the relative extent of flow changes under the proposed operating regime, which has been intentionally designed so as to have least environmental impact while still allowing a viable hydropower scheme. The proposed regime is as protective as EA default guidance, or more so, and significantly exceeds guidance in terms of minimum residual flow.

Catchment character

The behaviour of the River Coquet is well-documented, with a long sequence of gauged flow data available. Flow data for the years 1963-2018 is available from the Environment Agency (EA) Morwick gauging station (ID# 22001), where the Coquet's behaviour is considered a *"responsive natural regime"*. The catchment is characterised as follows: *"predominantly upland… draining from Cheviots. Largely Carboniferous Limestone and low permeability Devonian Igneous series, two thirds [being] overlain by superficial deposits. Half the catchment is grassland, some upland afforestation and arable in low-lying areas. Progressive afforestation and associated drainage on upland Cheviot tributary valleys."* https://nrfa.ceh.ac.uk/data/station/spatial/22001

Flow duration curve

Using a long data sequence is standard good practice. Gauged data 1963-2018 has been used to produce a Flow Duration Curve of the expected flows at this site. The gauging station lies a little distance downstream, and its data therefore represents a larger catchment to which the catchment at Guyzance Meander contributes 97.53% of area. Gauged data was therefore adjusted downwards by this ratio to represent the smaller catchment. (Given the small difference in these areas, no special allowances were made for any difference in rainfall between areas of lower and higher elevation etc.)

The influence of abstractions from and discharges to the river in the short distance between the site and the gauge is assumed to be nil or negligible. Information on licensed abstractions and discharge consents has been requested from the EA.

The data is analysed statistically and broken down into different flow bands, each occurring for 5% of the year. Each band then represents the percentile flow available, or minimum flow in the river for that percentage of the year. For example, Q90 flow means that for 90% of the year the flow is at this level or more. This data is then presented in the form of a Flow Duration Curve, indicating how often a given flow has occurred (see over).

When proposing a hydropower scheme, two important hydrological factors which need to be established are how much water may be taken by the proposed scheme – the Design Flow - and how much water must be left in the river at any time – the Residual Flow.

Note: In some cases the EA prefers to see hydrological assessment conducted using a modified version of catchment flow data, e.g. naturalised flows. If the EA wishes to provide naturalised flow data to be used in assessment for this site, the same exercise will be repeated with that data. The proposed modified hydrological regime may then differ in absolute numbers, but the percentile distribution of flows (Qn) is expected to remain similar to that presented here, so the proposal regime and its rationale will not change to a significant degree.

Residual flow

The installation of a hydro scheme could hypothetically divert all of the water that currently passes over the weir into the hydro system. Protection of the river environment means that this must not happen. Thus the EA seeks to minimise the length of 'depleted reach' created by a scheme. Ensuring that a residual water flow continues to bypass the scheme is achieved by the EA imposing a **minimum** residual flow as a condition of the EA licence. Other factors may increase this amount (see below), but the **minimum residual flow** is a baseline condition below which abstraction will never take place.

EA licensing practice allows that the minimum residual flow is shared between any spills in the depleted channel - e.g. weir crests, sluices, fish easements or fish passes – hence its value is agreed so as to provide minimum flow for those features as well as to protect the form of the channel. Because of this, whenever the hydro runs, even the minimum flow left is sufficient to ensure continued functioning of any fish passes or other required services.

The latest published EA guidance (issued Dec 2013, in force April 2014 to 2016) continues to form the basis on which EA licensing decisions are made. The scheme proposed here is low-head (having a fall of less than 10m) and creates a depleted reach (by bypassing part of the river), so the scheme is not defined as “on-weir”. It therefore falls into Table A, the “starting point” for EA flow allocation guidance for hydropower schemes. This proposes that the minimum residual flow is set at the Q95 percentile of the river’s annual flow, or Q97 if “high baseflow”. The Coquet is considered to have medium baseflow; so default guidance here would be a minimum residual flow of Q95, even for a river location such as the Coquet which is classified as highly sensitive to abstraction (ASB3). Q95 is a value typically agreed by the EA for most low-head hydro schemes, in the absence of any other special concerns.

The additional protection which EA Table A suggests by default (for schemes not “on-weir”) is that, above the agreed minimum, abstractions may only ever take a proportion of the available flow. The default guidance indicates that 35% may be taken without the need to present further evidence. “Higher levels [will] be considered” - up to 100% of flows, even with a depleted reach (Table A), if suitable additional information is presented.

The present scheme proposal is informed by SEPA standard licensing practice in Scottish salmon rivers, as this has been applied to depleted-reach Archimedean screw hydropower schemes which have operated without evidence of detriment. This regime allows a 50% flow split after leaving at least Q90 minimum residual flow. One example is the Craigpot (80kW) Archimedean screw scheme – bypassing a depleted reach on the Aberdeenshire Don, with no co-located fish pass and no fish exclusion screening - where the arrangement licensed under this regime has been found to pose had no significant harm to salmonids or impact on their migratory movement (Brackley, R. 2016. “Interactions between migrating salmonids and low-head hydropower schemes”. PhD thesis. Glasgow University).

The present scheme proposal is for a 50% flow split; but starting only after leaving a minimum residual flow of Q75. The project’s fisheries consultant witnessed this flow (calculated as 2.18 m3/s using present data) as being sufficient to ensure passability of the entire meander, including Guyzance Mill weir. This flow regime therefore retains water in the river to an extent which maintains the potential for fish to ascend the main channel. No flow will be taken in low conditions, only the minority of flow will ever be abstracted at any given time, and the effect of this abstraction will be to marginally suppress flow in the fish easement of Guyzance Weir during medium flow conditions. This maintains existing passage flows (by not abstracting) in low-medium conditions, and in higher flows, it will improve passage by reducing overcharging. The fisheries assessment concludes that this regime will confer a marginal improvement.

Design flow

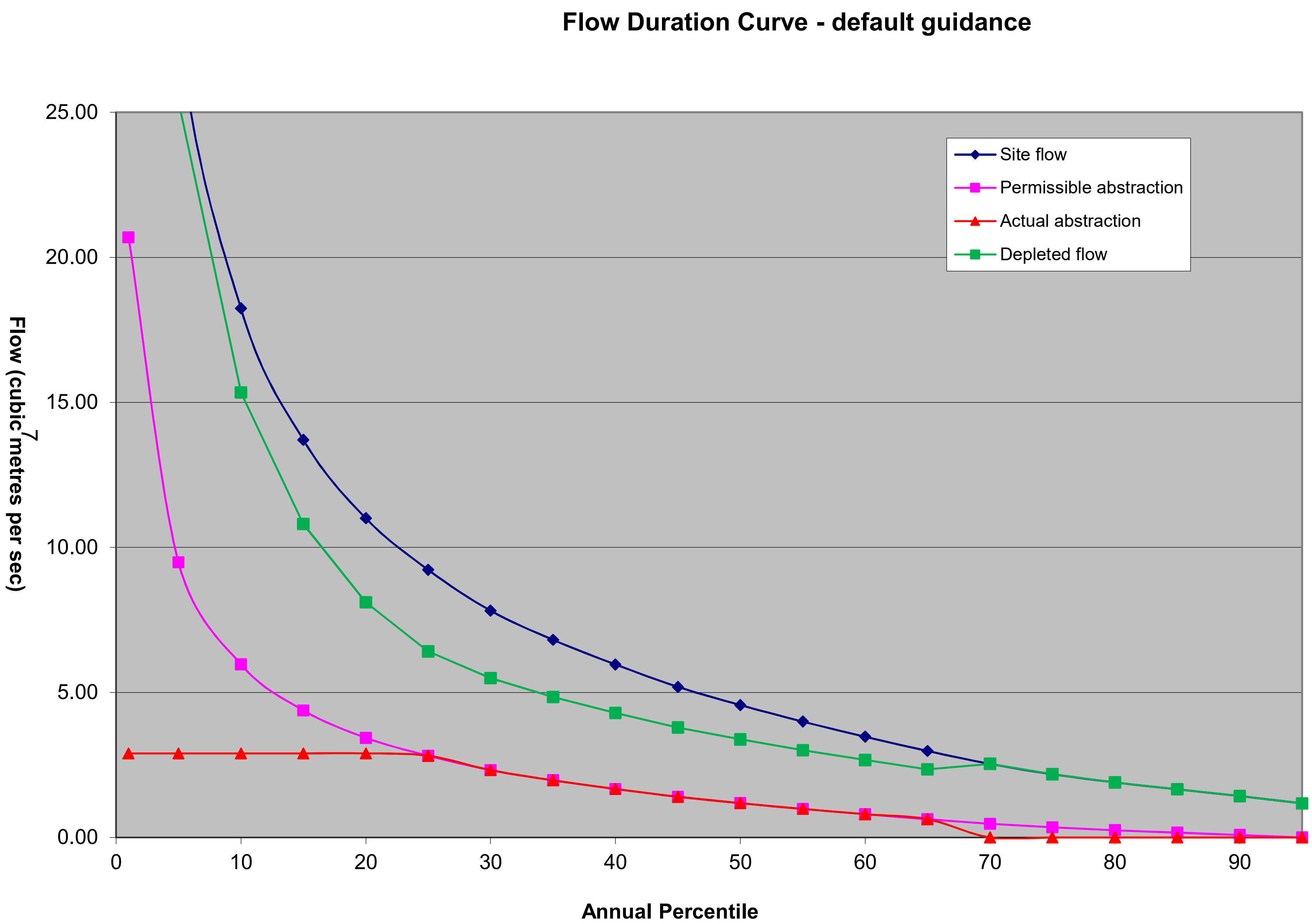
EA guidance in Table A indicates that the default maximum for the value of a low-head hydropower abstraction where a depleted reach is created, even on a river of ASB3 sensitivity with low or medium baseflow (as here), would be 1.3x the river’s annual mean flow at the site. Present data at this site (as calculated above) gives a mean flow of 8.38 m3/s (~Q26.5) and a default maximum allowed abstraction of 1.3x Qmean, being 10.89 m3/s (~Q20). An application to abstract up to 10.89 m3/s would therefore fall within the conventional EA guidance without additional justification.

This project, however, seeks a maximum abstraction which is very much less than the river’s mean flow, and hence very far within the EA’s guidance limits.

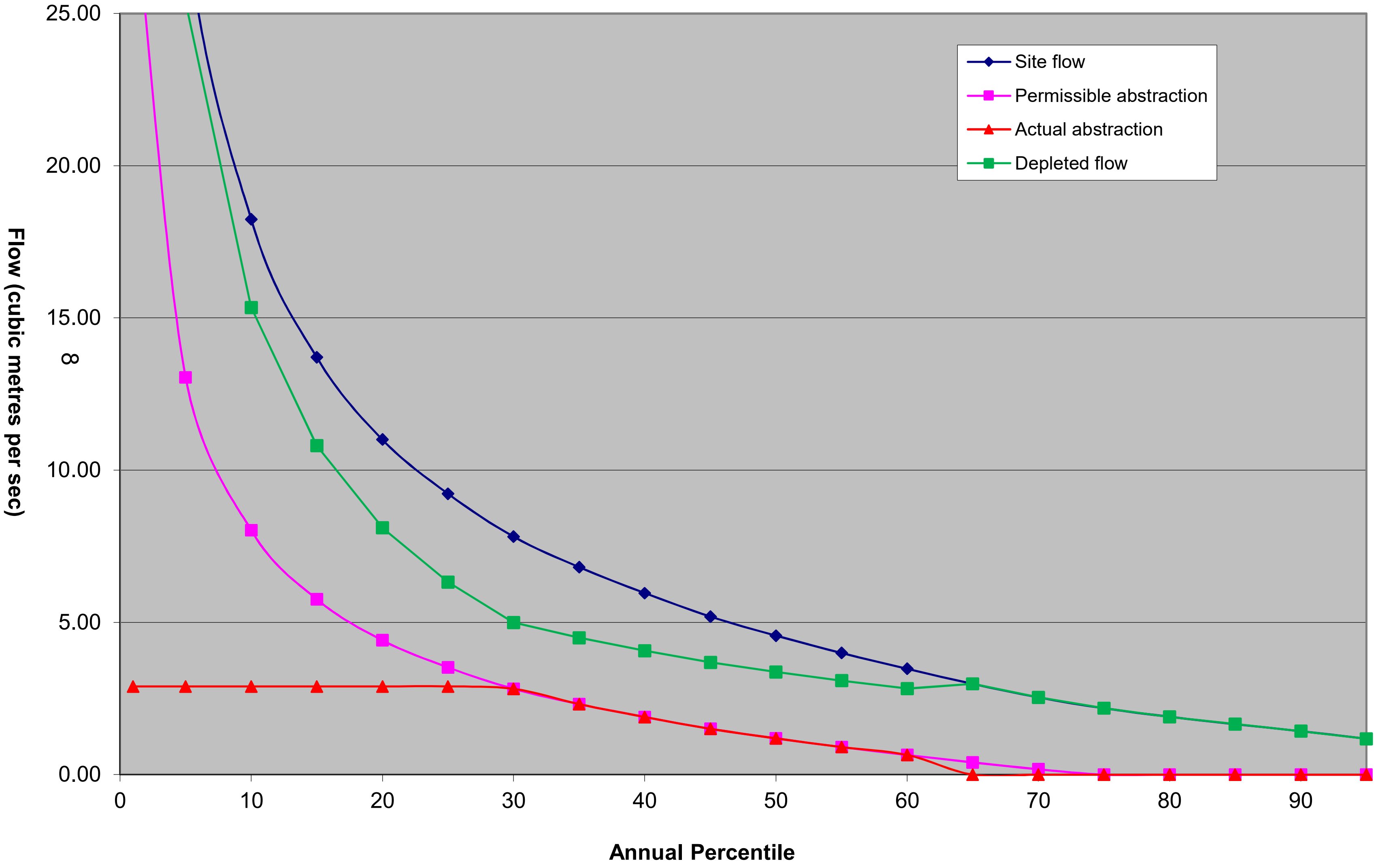
The proposed maximum abstraction is 2.90 m3/s (equivalent to the river’s Q66 flow in present data) – and this amount to be taken at peak operation only. An abstraction varying up to this maximum amount will efficiently supply a hydropower scheme of the proposed design which represents economic viability to the applicant.

NB: Where a technical fish pass is proposed to be co-located with the screw, a dedicated minimum flow for this would be calculated in relation to the size of the hydropower abstraction. It is anticipated that a co-located fish pass would not be an acceptable option in this project, as it would attract fish out of the natural channel and into the new piped culvert where they must then swim against the hydropower inflow to exit. Therefore this option is not considered. This does not preclude existing passage option/s at the weir, for which flow is found out of the main channel residual flows. It is anticipated that statutory authorities will favour retaining fish in the main channel, where demonstrated passable conditions will be preserved, as above.

Flow duration curves are shown below for the EA default guidance and for the proposed regime at this site, as discussed above.


Flow Duration Curve - default guidance
25.00
20.00
15.00
10.00
5.00
0.00
0
10
20
30
40
50
60
70
80
90
Flow (cubic metres per sec)
Annual Percentile
Site flow
Permissible abstraction
Actual abstraction
Depleted flow

Flow Duration Curve - proposed



Comparison of regimes

See two graphs above. In each case: the blue line on the curve shows how much water is available in the river. The green line shows how much is left in the main channel while abstracting. The red line shows the amount which would be abstracted - peaking at the turbine's maximum capacity - and constrained at both higher flows and lowest flows. Productive output then depends on area beneath the red line.

When compared with EA default guidance, the proposed regime creates no greater impact in high flows, leaves more water in the river in low flows – so on balance is LESS detrimental than the EA's default guidance.

For the proposed regime, source data is presented in tabular form.

Q%	*Flow Data in m3/s* *Gauging station flow*	*BEFORE* *Site flow*	*AFTER* *Depleted flow*	*Proposed regime:* *Actual abstraction*	*Proposed regime:* *% of total flow*
1	62.47	60.30	57.40	2.90	5%
5	29.30	28.28	25.38	2.90	10%
10	18.90	18.24	15.34	2.90	16%
15	14.20	13.71	10.81	2.90	21%
20	11.40	11.00	8.10	2.90	26%
25	9.56	9.23	6.33	2.90	31%
30	8.10	7.82	5.00	2.82	36%
35	7.06	6.81	4.50	2.32	34%
40	6.18	5.97	4.07	1.89	32%
45	5.38	5.19	3.69	1.51	29%
50	4.73	4.57	3.37	1.19	26%
55	4.14	4.00	3.09	0.91	23%
60	3.60	3.47	2.83	0.65	19%
65	3.09	2.98	2.58	0.40	13%
70	2.63	2.54	2.36	0.18	7%
75	2.26	2.18	2.18	0.00	0%
80	1.97	1.90	1.90	0.00	0%
85	1.72	1.66	1.66	0.00	0%
90	1.48	1.43	1.43	0.00	0%
95	1.22	1.18	1.18	0.00	0%

Interpretative notes:

- Flow at the site intake (green) is derived by area ratio from gauging station flow.
- The proposed regime (blue) follows the formula "50/50 after having left Q75".
- Hydropower abstraction only takes place at flows above Q75 (blue).
- The EA licence will also specify the maximum instantaneous abstraction (2.90 m3/s), which recognises that the proposed scheme size takes far less than 50/50 at higher flows (red %).

Changed flow distribution

Site assessment by the fisheries consultant in Q75 flow conditions (see report) concluded that the flows witnessed on that occasion without abstraction were suitable to provide the necessary services at all points in the meander, including that the weir itself was passable at the existing easement (for species able to use this easement at all); and that higher flows would not necessarily improve passability as they would challenge poorer swimmers.

On this basis, the proposed regime of Q75 plus 50% retains a naturalistic variation in levels and flows upwards from that passable baseline state. This ensures that rising velocities continue to be provided in the main channel, as behavioural cues or signals to alert migrants to rising flow events upstream which may prompt them to move; and that higher flows continue to operate to mobilise bedload and woody debris. At the same time, the regime suppresses more challenging effects of high flows for upstream migrants.

The potential for the proposed flow changes to significantly affect fluvial geomorphology is therefore considered likely to be low. This subject is given fuller consideration in a separate specialist report.

Method of controlling the proposed regime

The “hands-off” condition would be controlled by a conventional electronic level sensor (submerged pressure transducer) at the hydropower intake, connected to the control system and operating to ensure that the hydropower scheme could not begin or continue to abstract unless the Q75 proxy water level could be maintained at the intake. In conditions above this, the system would record instantaneous flow in the turbine itself, and continuously compare this with river flow to ensure compliance with percentage flow split.

The equation to achieve this can be detailed in writing as a condition of the licence, based on field testing at commissioning using the system sensors, prior to commencing hydropower abstraction. If this method is not acceptable, an alternative (proven in use at several sites in EA Thames region) would be to add a GSM & Modbus (or equivalent) telemetry link to obtain real-time flow data from the EA’s Morwick gauging station. This method can be detailed as failsafe (stop the system) or revert to an agreed backup regime.

Stage data (water levels)

The proposed design is predicated on a known minimum water condition at the proposed intake (Q75), and on making no change to river behaviour at flows/levels below this datum state. It is therefore unnecessary to represent a stage/discharge relationship to vouchsafe protection of the river at low flows. In high flows, hydropower operation will be suspended, and will have zero net impact. It is therefore unnecessary to represent a stage/discharge relationship for high water or flood purposes. Sensors have been deployed at site to obtain natural values of water level for gauged flows of known occurrence. When this data is downloaded, it will inform the equation which will be conditioned by the EA to control operation of the system during medium flows, ensuring that the agreed proportion is taken.

Cumulative impacts and lifecycle impacts

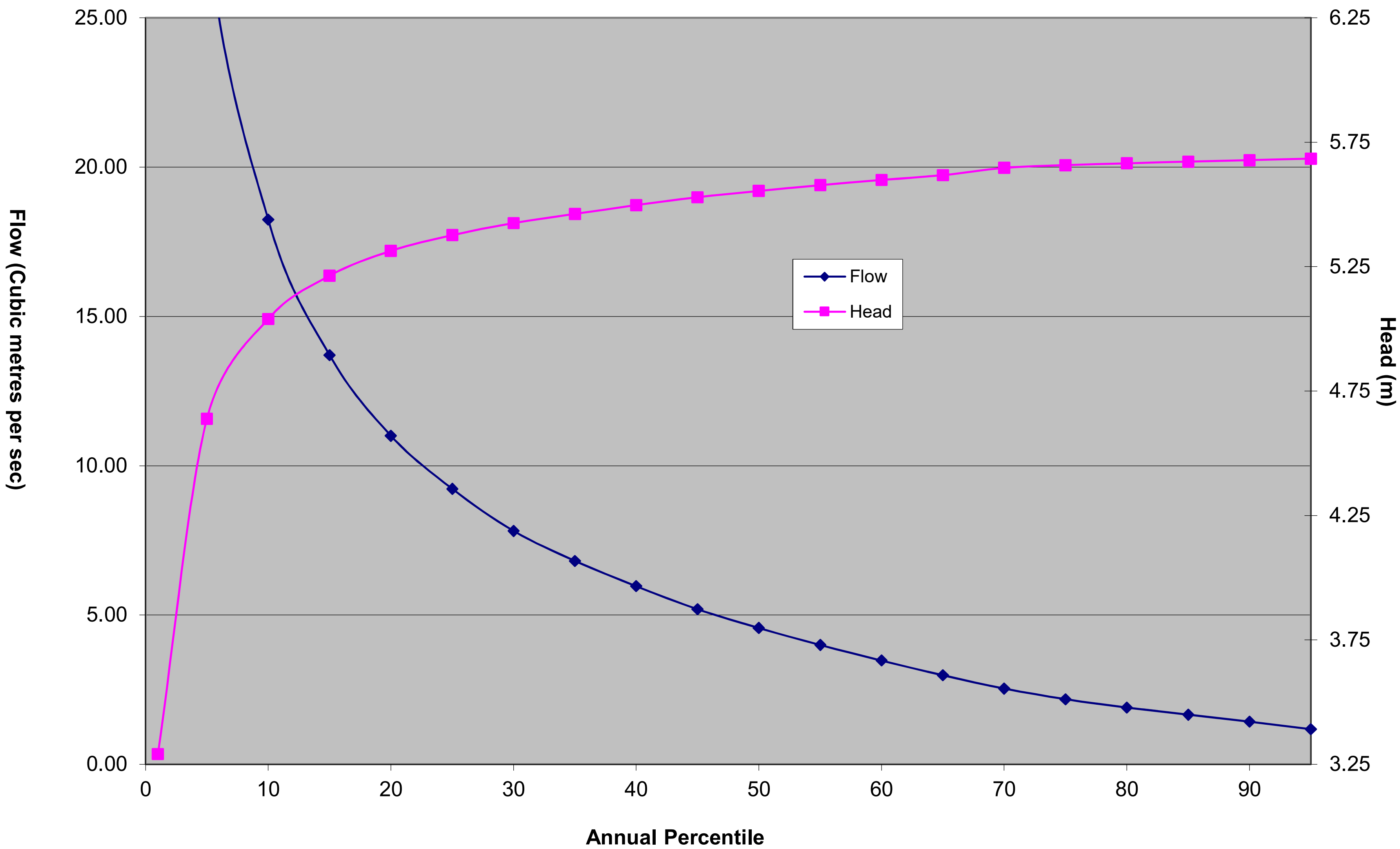
There are no cumulative impacts on hydrology, as the scheme's effect ceases at the point of discharge. In lifecycle terms, hydrological impacts of the project are largely limited to its operational lifespan. Construction involves only small temporary cofferdams close to the bank line. Decommissioning of the project at some future stage requires only the dismantling of steel mechanical parts from the offline channel, and the backfilling of the intake and channel if so desired. The sluice gate can remain in place as part of this closure. The river itself needs no remediation. After cessation, all flows remain in the river channel as at present.

Head duration curve

The height that the water falls over the hydropower site is known as the head. This varies with the flow in the river. Site measurements have indicated a gross head of 5.70m between the water levels at the intake and discharge, in conditions representative of lower flows. Having then allowed for intake design and losses, the net head available is some 5.20m for an Archimedean screw turbine, reducing gradually as the tailwater rises in higher conditions.

Effect of likely tailwater rise at this site, based on sites of similar geometry, is presented in an indicative graph below. As the river flow increases (blue) towards the left, the head decreases (pink). Head does not diminish to zero until close to bank-full conditions.

Head Duration Curve



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