FISHTEK CONSULTING

Geomorphological impact assessment

Staverton Hydropower Project

Client: Staverton Hydro Community Benefit Society

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1. Introduction

This report assesses the potential Geomorphological impact of a proposed hydropower scheme upon the rates of sedimentation and erosion in the deprived river reach of the river Dart below Staverton in Devon. Staverton Hydro Community Benefit Society (SHCBS) commissioned Fishtek Consulting to conduct an impact assessment that would form part of the application to the Environment Agency for an abstraction license.

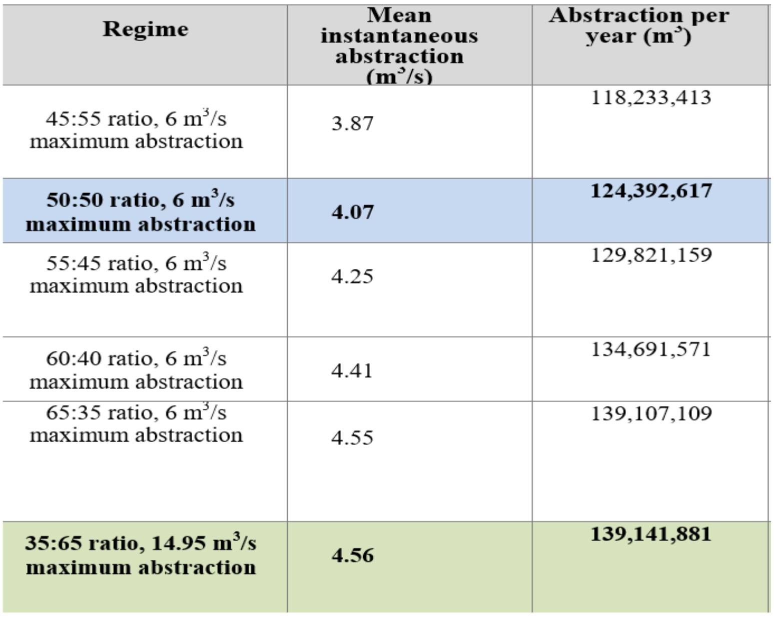
1.1 Details of site proposal

SHCBS propose to install a single 100 kW Archimedean screw turbine at the downstream end of an existing leat on the River Dart, immediately south of Staverton, Devon, creating a potentially deprived reach (PDR) of approximately 700 m. A map of the site is given in figure 2. The velocity and depth profiles and predominant substrate type across the PDR are given in the appended figures 2.1-2.6.

The leat was initially constructed to power two Kaplan turbines that provided electricity to the Dartington Estate from the 1920s through to the 1960s.

The proposed scheme would have a maximum abstraction rate of 6.0 m^3/s. A Q95 hands-off flow (HOF) would be enforced, with a proportional flow take of 50/50 above the HOF. In view of the relatively low maximum abstraction, (approximately 40% of the 1.3 x Q mean permitted), the total abstraction is precautionary in terms of the Environment Agency's best practice guidelines for hydro power. Table 1 below gives the mean instantaneous abstraction of 4.07 m^3/s (total 124,392,617 m^3) for the proposed regime compared to the most sensitive EA river band 35:65 split in favour of the river that would give a higher instantaneous rate of 4.56 m^3/s and a higher total abstraction of 139,141,881 m^3., assuming a 1.3 x Qmean max. abstraction. Thus, indicating that the proposed abstraction is relatively precautionary in terms of the EA's best practice guidance.

Table 1: comparative abstraction regimes



Regime	Mean instantaneous abstraction (m^3/s)	Abstraction per year (m^3)
45:55 ratio, 6 m^3/s maximum abstraction	3.87	118,233,413
50:50 ratio, 6 m^3/s maximum abstraction	**4.07**	**124,392,617**
55:45 ratio, 6 m^3/s maximum abstraction	4.25	129,821,159
60:40 ratio, 6 m^3/s maximum abstraction	4.41	134,691,571
65:35 ratio, 6 m^3/s maximum abstraction	4.55	139,107,109
35:65 ratio, 14.95 m^3/s maximum abstraction	**4.56**	**139,141,881**

1.3 Site flows

The nearest gauging station to the site is Austins Bridge gauging station (station number 46003), approximately 7 km upstream of Staverton. Naturalised flows based on a 59 year data set (1958-2017) obtained from Austins Bridge were used for this assessment. The flow duration curve for the site is given in figure 2.

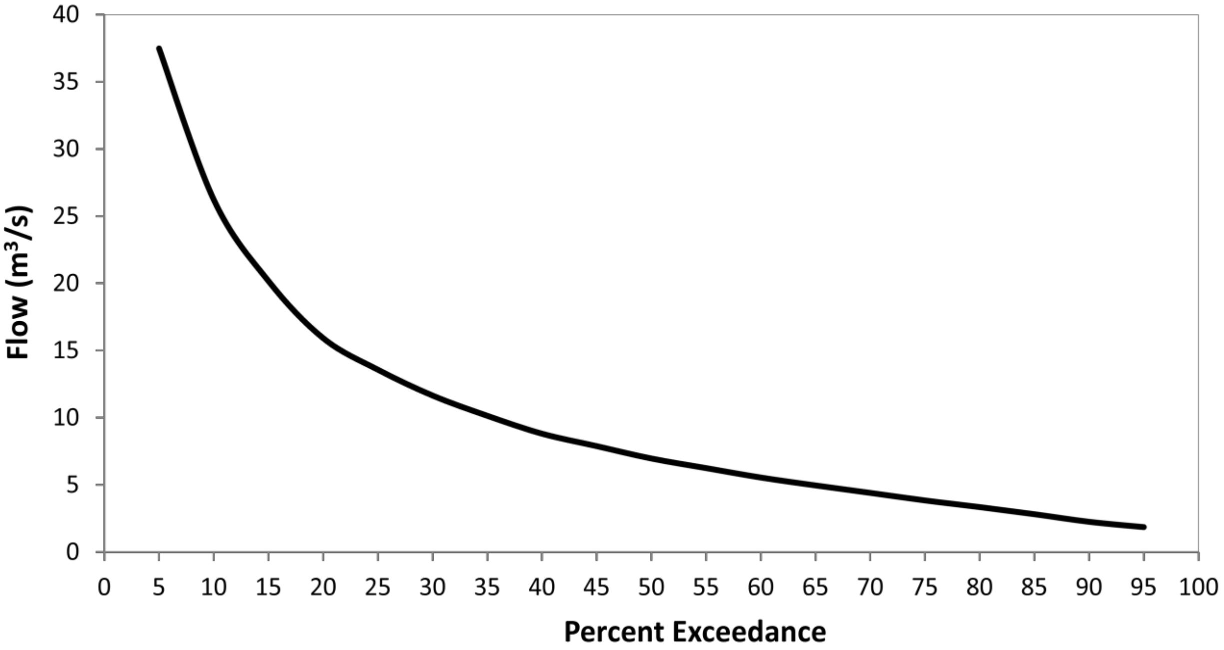


Fig 2: Flow duration curve for the Staverton site.

Figure 1. An aerial view of the site, showing the proposed turbine location in relation to the main river channel.

2. Methodology

The potential impact to geomorphology was assessed by modelling flow in the deprived reach using HEC_RAS 5.0.3. Flows were modelled for two representative channel reaches (riffle and pool) under 10 different flow scenarios, as given in **Error! Reference source not found.**. The existing flow represents current non-abstracted (Nab) conditions and the predicted flow is the flow in the deprived reach assuming a 50% abstraction above a Q95 hands-off flow until turbine satiation (Ab).

Channel cross-sectional data was collected on 30/10/2018 when river discharge was approximately 4 m^3/s, (Q70). Three cross-sections were measured for each channel reach (thus 6 in total) and chainage was recorded between cross-sections using a tape. A laser level was used to measure bed elevation at 1m intervals along each cross-section for the full channel width between estimated bank-full levels. Data was recorded to a temporary benchmark and a Manning's n roughness coefficient estimated based on definitions given by (Chow, 1959).

Table 2: Flow scenarios applied to each channel reach representing the existing and predicted scenarios

Q	Flow existing Nab (m^3/s)	Flow predicted Ab (m^3/s)
10	26.59	20.59
Qmean	11.76	6.72
50	7.26	4.77
70	4.34	3.01
90	2.16	1.92

Cross-sectional data was inputted into HEC_RAS along with the flow scenarios and Manning's n values and the model was run to obtain depth and velocity output data for each channel cross-section. Output velocities were compared against know sediment deposition and erosion velocities as defined by the Hjulström diagram (see **Error! Reference source not found.**). The relationship comprises two curves on logarithmic axis. The upper curve displays the critical erosion velocity as a function of particle size, whist the lower curve displays the deposition velocity as a function of particle size. For non-cohesive particles, the curves follow each other closely and the erosion velocity increases with particle size. However, for cohesive substrates such as silt and clays, the relationship is inversed due to the importance of cohesive forces. The area between the two curves represents sediment that is either transported as bed load (large sediment) or held in suspension (small sediment).

For reporting purposes focus is given to velocities <0.2 m/s and >0.8 m/s, which are critical thresholds for the deposition of fines and transportation/erosion of gravels respectively. The specific velocity required for deposition or transportation of a given particle is a factor of its size and thus actual critical velocities may vary slightly around these given thresholds. The thresholds are deemed critical as increased settlement of fine sediments or wash-out of gravels would have the greatest impact to habitats and organisms including fish and macroinvertebrates.

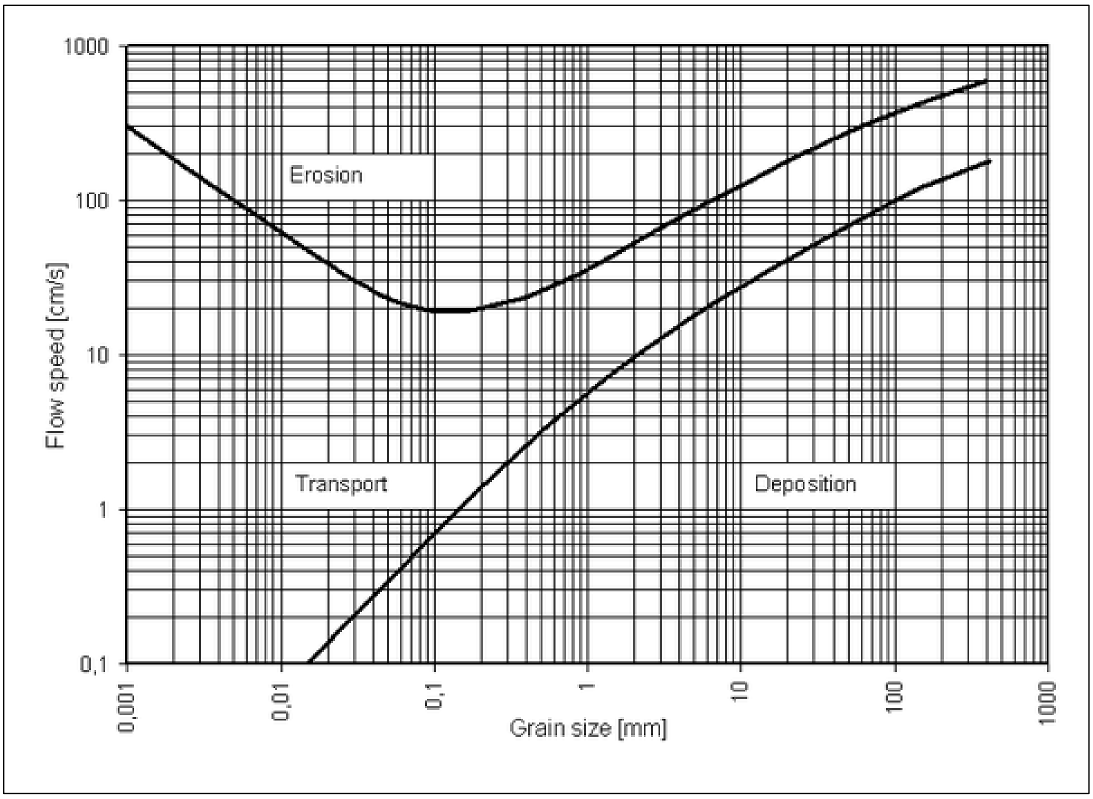
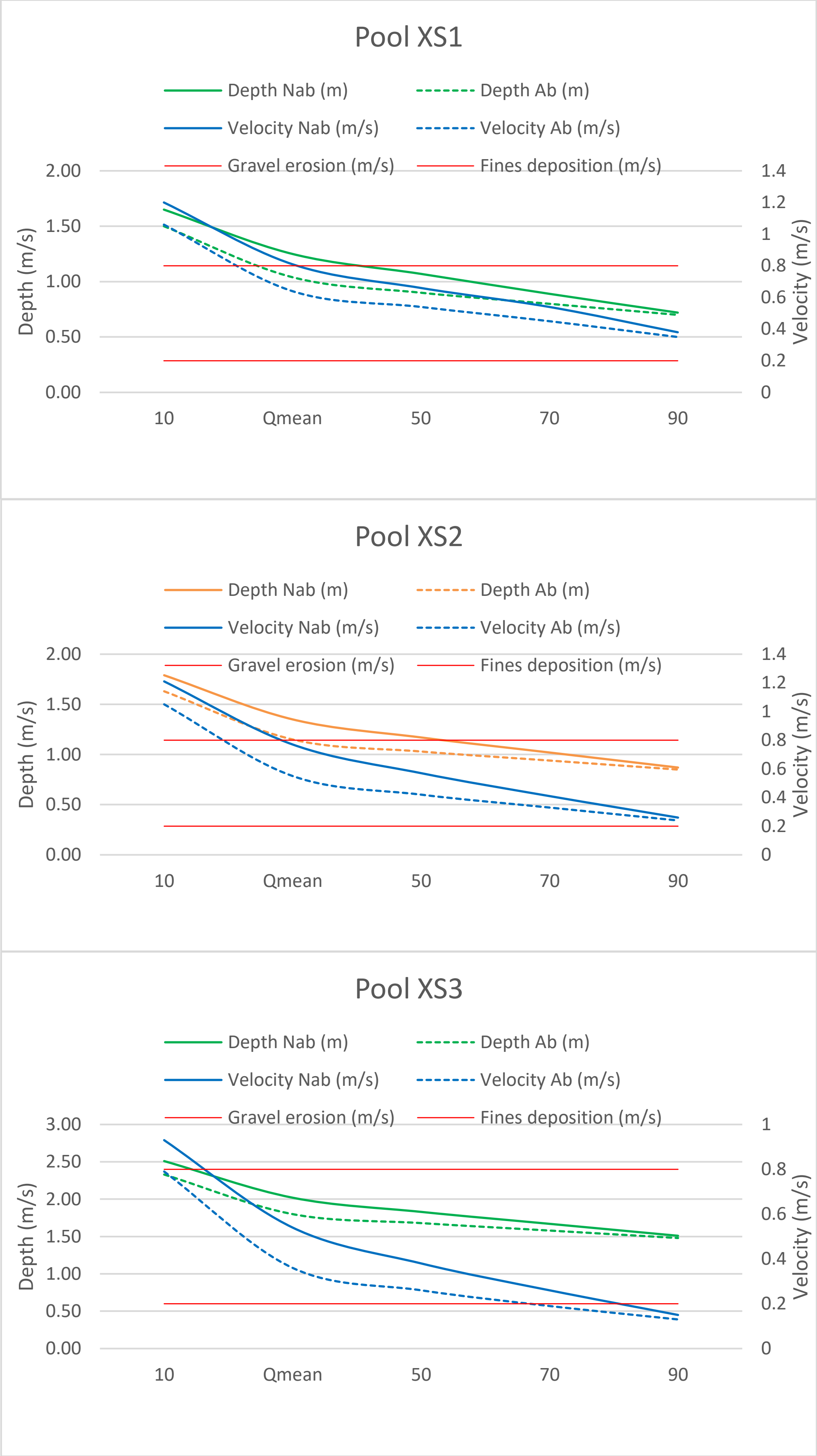


Figure 3 Hjulström diagram of sediment transport, erosion and deposition.

3. Results

Velocity and depth outputs from the HEC-RAS model for the representative pool and riffle cross-sections under each flow scenario are given in **Error! Reference source not found.** and **Error! Reference source not found.** respectively. For each scenario there is a slight reduction in depth and velocity across the flow duration curve. Velocities only drop below the deposition threshold for fine sediments for a single cross-section at low flows, Pool XS3. The model predicts that under normal flows velocities in Pool XS3 are low enough for the deposition of fine sediments below approximately Q80 river discharge, whereas under the abstracted scenario this will occur at approximately Q70.

Velocities required for erosion of gravels occurs at a slightly higher river discharge under the abstracted scenario compared to the non-abstracted scenario for all cross-sections.



Pool XS1

Pool XS2

Pool XS3

Figure 4: Modelled depths and velocities within pool channel cross-sections under the non-abstracted (Nab) and abstracted (ab) scenarios. Chainage between cross-seciotns = 35 m average gradeint = 0.2 %. Manning's n =0.04

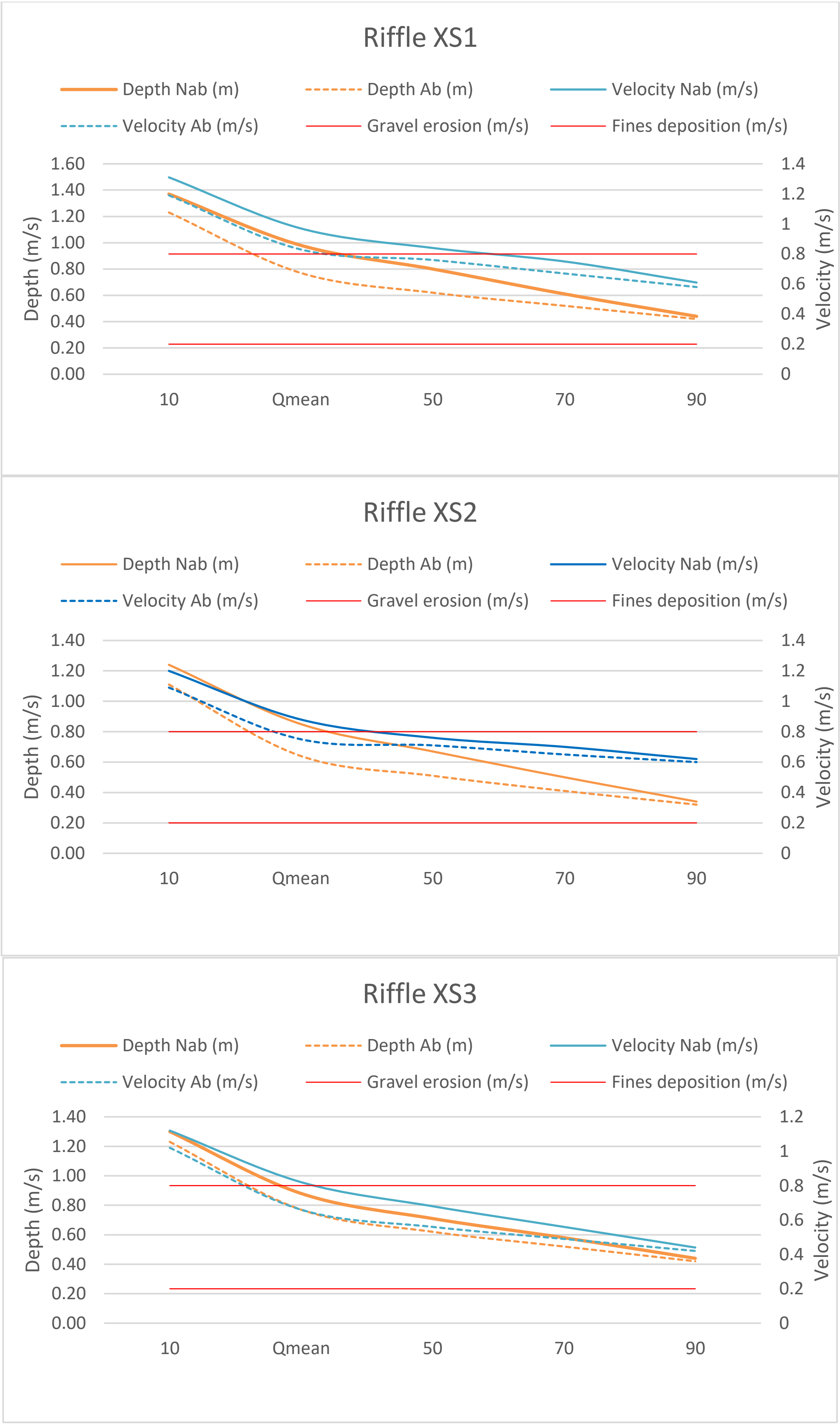


Figure 5: Modelled depths and velocities within pool channel cross-sections under the non-abstracted (Nab) and abstracted (ab) scenarios. Chainage between cross-sections = 55 m, average gradeint = 0.5 %. Manning's n =0.045

4. Discussion

The proposed abstraction regime will have a negligible impact on geomorphology in the deprived reach. Slightly reduced velocities at low river discharge will result in a minor increased risk of sedimentation, but there will remain adequate periods of higher velocities required for erosion and transportation. The model did not consider flows greater than Q10 and it should be noted that at very high flows above Q1 the scheme would likely shut down anyway. Similarly, at low flows below the HoF (Q95) there would be no abstraction and hence no change to the existing flow regime.

Figure 2.1. The depth (m) of the upstream half of the PDR and the intake to the leat at approximately Q82 flow

2Figure 2.2. The depth (m) of the downstream half of the PDR at approximately Q82 flow

Figure 2.3. The velocity (m/s) of the upstream half of the PDR and the intake to the leat at approximately Q82 flow

Figure 2.4. The velocity (m/s) of the downstream half of the PDR at approximately Q82 flow

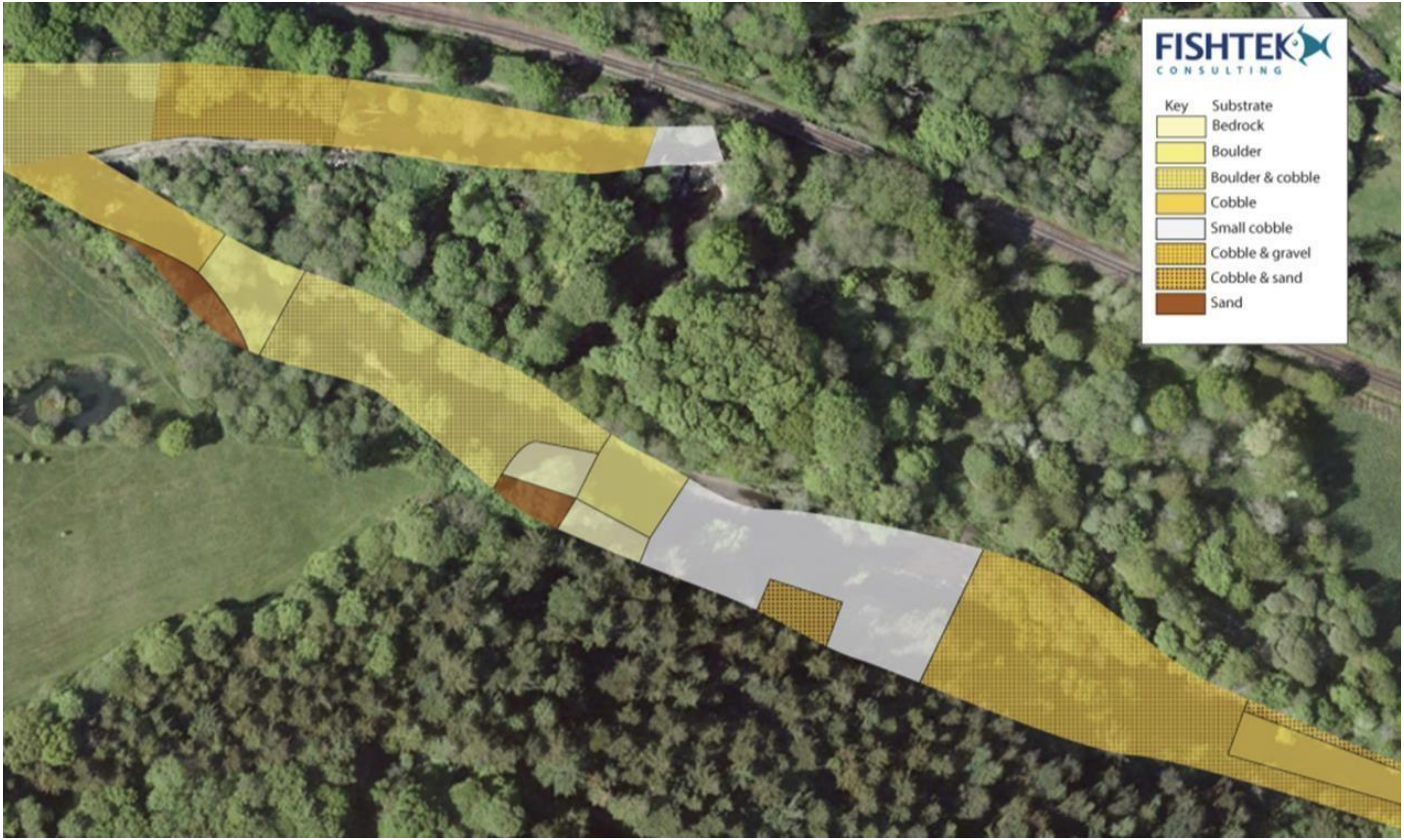


Figure 2.5. The predominant substrate composition of the upstream half of the PDR and the intake to the leat

Figure 2.6. The predominant substrate composition of the downstream half of the PDR