Gunthorpe Weir Hydropower Scheme:

Fisheries and Geomorphology assessment

Renewables First
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Paul Gratton, Dr Timothy Meadows, Tom Brook

Client:	**Renewables First**
Address:	**The Mill** **Brimscombe Hill** **Brimscombe** **Stroud** **GL5 2QG**
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Project Director:	**Nicola Teague**
Project Manager:	**Paul Gratton**
Other:	**Timothy Meadows, Tom Brook, Elisa Phillips**

Riverview A17 Embankment Business Park,
Heaton Mersey,
Stockport,
SK4 3GN

Tel: 0161 442 8938

Registered in England No. 2530851

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1. Introduction

Renewables First proposes to construct a low-head hydro-electric power (HEP) scheme at Gunthorpe Weir on the River Trent, 10 km northeast of Nottingham. Following advice received from the Environment Agency as part of a pre-application response, Renewables First commissioned APEM to undertake a geomorphology and fisheries assessment of the proposed scheme.

1.1 Site details

Gunthorpe Weir comprises a ca. 110 m wide concrete broad crested weir followed by a number of stepped structures along the weir face. Due to health and safety constraints it was not possible to obtain measures of the weir structure or flows over the face during the site visit. Historic engineering drawings for the reconstruction of the weir in 1960 do, however, indicate that the face comprises a total of five stepped structures. There is a head drop of ca. 0.31 m across each step and a horizontal distance of ca. 0.94 m between each step.

There is an old triangular pool and traverse fish pass structure at the upstream end of the weir adjacent to the left bank between the lock island and the main weir crest (Figure 1-1). The pass comprises a total of three pools and four traverses, equating to a mean head drop of approximately 0.5 m across each traverse. Based on the conditions observed during the site visit the fish pass is considered to be sub-optimal and is unlikely to adhere to modern fish pass design guidance (EA, 2010) due to individual head drops exceeding the maximum permitted values and the excessive energy densities (high turbulence) within each pool.

Figure 1-1. Gunthorpe Weir looking towards the right/eastern river bank on 05 June 2018.

1.2 Scheme proposals

It is proposed to install twin Archimedes screw turbines on the true right (eastern) side of Gunthorpe weir. Water would be abstracted approximately 25 m upstream of the weir crest into two intake channels and discharged into the weir pool at the toe of the weir. The scheme would include a multi-species Larinier fish pass located on the western side of the turbines closest to the main weir. A plan view schematic of the proposed arrangement is provided in Figure 1-2.

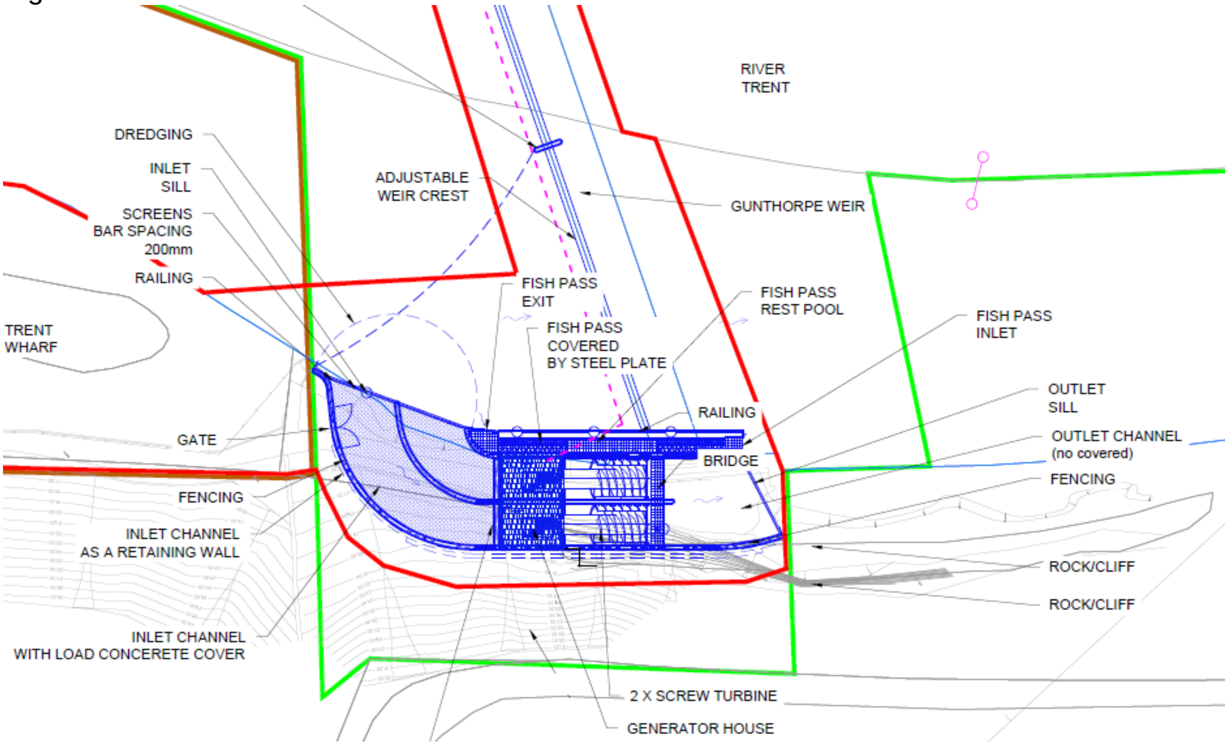

Figure 1-2. An overview of the proposed HEP scheme and fish pass on the right bank of Gunthorpe Weir.

In addition to the scheme at Gunthorpe, it is proposed to install HEP schemes at two other weirs on the River Trent – Stoke Weir and Hazelford weir which are located upstream and downstream of Gunthorpe, respectively, in addition to a fourth site on the River Soar at Kegworth. A map showing the location of all four sites is provided in Figure 1-3.

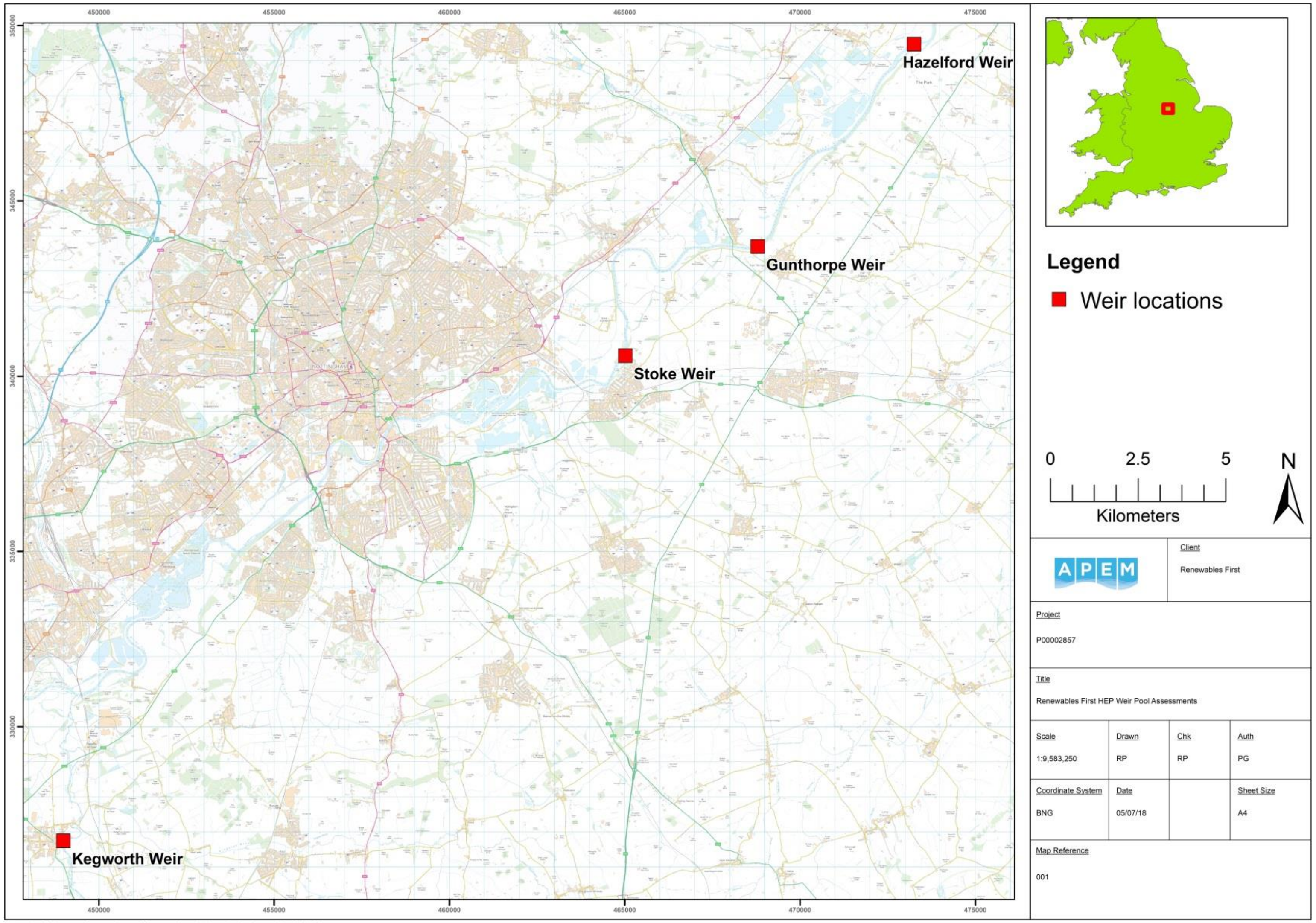

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Figure 1-3. The location of Gunthorpe Weir in relation to other sites under assessment (Stoke Weir and Hazelford Weir on the River Trent and Kegworth Weir on the River Soar).

1.3 Hydrology

The proposed HEP scheme would operate under a hands-off level that is equivalent to a water depth of 50 mm over the weir crest; when the depth of water falls below this level water cannot be abstracted by the HEP scheme. The hands-off level corresponds to a total hands-off flow (HOF) of *ca.* 2.49 m^3/s, comprising 1.77 m^3/s over the weir crest and 0.72 m^3/s through the new fish pass structure.

The turbines would abstract a total maximum flow of 20 m^3/s (10 m^3/s per turbine), therefore reaching maximum abstraction when the River Trent flow reaches 22.49 m^3/s, equivalent to a flow percentile of <Q99. Therefore, for the vast majority of the year (> 99 %) there would be additional flow above the HOF and turbine abstraction which would pass via the weir crest as per the current arrangement, as well as via the new fish pass.

Flow duration curves for Gunthorpe Weir is provided in Figure 1-4. Under current conditions, the site has a base flow index of *ca*. 0.64; indicative of a moderate baseflow and consistent with a river of this size. Under the proposed scheme, flows would be as reduced below their current range for nearly thirty percent of the time.

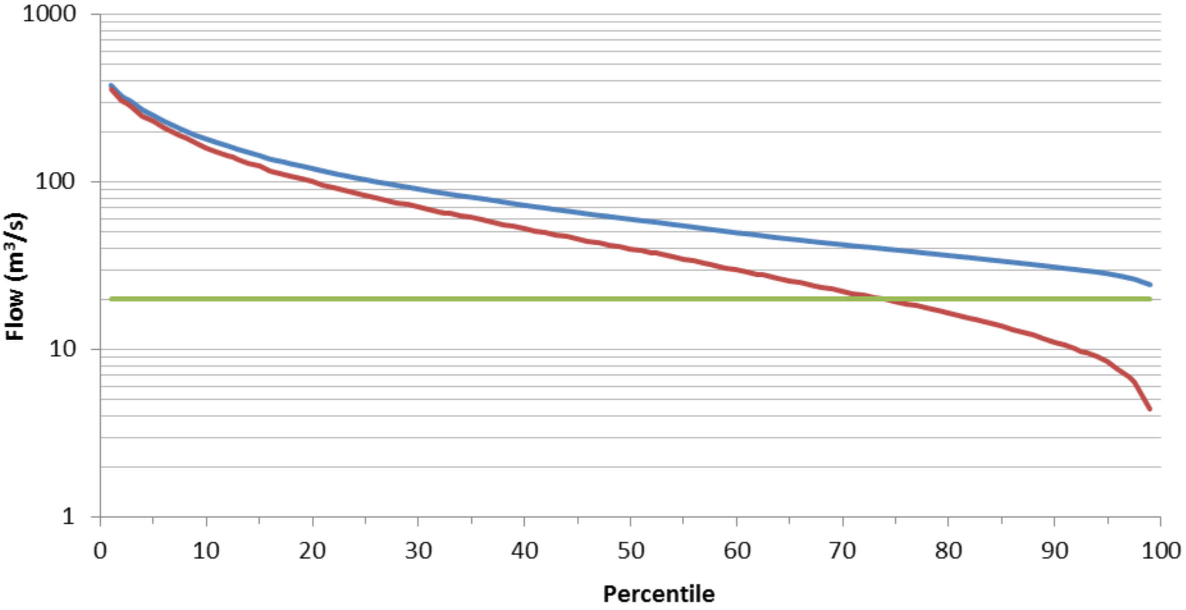


Figure 1-4. Flow duration curve for the River Trent at Gunthorpe Weir showing total gauged river flow (blue), abstracted HEP flow (green) and residual river flow (red).

Key flow percentile values for the site are provided in Table 1-1.

Table 1-1. Flow percentiles for the River Trent at Gunthorpe Weir.

Percentile	Flow (m^3/s)
Q10	180.24
Q20	120.09
Q50	59.84
Q70	42.22
Q80	36.35
Q90	30.99
Q95	28.33

1.4 Report purpose and aims

Whilst the proposals would not create any significant length of depleted reach, during a pre-application response the EA noted that the weir pool at Gunthorpe is of high ecological value owing to the rarity of similar morphological features along the main stem River Trent and the associated aquatic species it is likely to support. Consequently, the EA raised concerns regarding potential impacts on changes in flow dynamics within the downstream weir pool upon geomorphological processes and fish habitat.

The aims of this report are to:

1. Assess the likely impacts of the proposed hydropower scheme on hydromorphology and sediment transport processes within the weir pool downstream of Gunthorpe Weir;
2. Based on the predicted geomorphological and hydraulic changes within the weir pool, assess changes in the quality and extent of fish habitat in the weir pool;
3. Assess the likely impacts of the proposed hydropower scheme on upstream hydromorphology and riparian habitat arising from an increase in the height of the weir;
4. Determine the current passability of Gunthorpe Weir to fish species populating the River Trent under the current baseline scenario using the SNIFFER WFD111 barrier assessment compared to a future scenario with the HEP scheme and fish pass operational.

1.5 Fish population data

The EA undertake regular surveys of fish populations on the River Trent to assess changes in population composition and inform the ecological status of the waterbody under the Water Framework Directive (WFD). Surveys have been completed at a number of monitoring locations in close proximity to Gunthorpe Weir in recent years, including at Stoke Bardolph (Site ID 3500; NGR SK6498041715), and Kneeton (Site ID 41973; Site a NGR SK7083146431, Site b NGR SK 70865 46458). Due to the turbidity, width and depth of the River Trent at Gunthorpe all surveys are completed using depletion seine netting, rather than electric fishing which is more commonly used on smaller rivers.

Table 1-2. A summary of data from EA seine netting surveys at monitoring sites in close proximity to Gunthorpe Weir.

Species	Stoke Bardolph		Kneeton (Site a)		Kneeton (Site b)
	2014	2015	2014	2015	2012
Barbel (*Barbus barbus*)	9	0	0	0	5
Chub (*Leuciscus cephalus*)	260	3	61	62	17
Dace (*Leuciscus leuciscus*)	82	171	208	158	32
Bleak (*Alburnus alburnus*)	1	0	71	4	1
Common bream (*Abramis brama*)	26	5	0	0	1
Gudgeon (*Gobio gobio*)	133	17	5	40	31
Roach (*Rutilus rutilus*)	6	1	0	38	70
Perch (*Perca fluviatilis*)	5	0	1	7	0
Minnow (*Phoxinus phoxinus*)	112	12	2	0	207
3-spined stickleback (*Gasterosteus aculeatus*)	0	1	0	0	8
Bullhead (*Cottus gobio*)	0	0	0	0	1

The species composition at each monitoring site is typical of a large lowland river system, being dominated by cyprinid coarse fish species. The most abundant species across the three sites were dace, chub and gudgeon. Lower numbers of roach and perch were recorded during the monitoring surveys, primarily at the two Kneeton sites downstream of Hazelford weir. These species are considered to be eurytopic in nature and therefore generally exhibit a wider adaptability to environmental or hydraulic conditions, albeit with a preference towards slacker channel areas with greater macrophyte coverage or riparian vegetation (EA, 2004).

The River Trent is also known to be an important corridor for recovering populations of migratory salmonids. Whilst neither Atlantic salmon (*Salmo salar*) nor sea/brown trout (*Salmo trutta*) have been recorded during recent EA monitoring surveys in close proximity to Hazelford Weir, data from a fish counter installed at Cromwell Weir approximately 30 km downstream of Hazelford indicates that populations of migratory salmonids are present on the River Trent. Spawning and rearing of juvenile salmonids is unlikely to occur on the main stem Trent (instead adults will migrate to tributaries higher in the catchment) and thus consideration of habitat associated with these species are not of concern to this assessment. Instead, the key concern with regard to salmonids is the ability for fish to migrate upstream of Hazelford weir and current levels of delay incurred whilst fish attempt to pass upstream.

Additionally, whilst they were not recorded during recent EA monitoring surveys, it is considered probable that European eel (*Anguilla anguilla*) are present on the River Trent in close proximity to the site. The weir itself is likely to pose a barrier to upstream migration (considered through a formal passability assessment in Section 5), although small numbers may move upstream via the navigation lock. The River Trent is tidally influenced as far upstream as Cromwell Lock, located 30.02 km downstream of Gunthorpe Weir based on the WFD river dataset. Therefore, based on EA (2014) guidance, any screening or passage provisions for eels required under the Eels (England and Wales) Regulations 2009 would need to consider adult yellow eel (> 30 cm) and silver eel.

2. Flow modelling

To inform the geomorphology and fisheries assessments at the site, two dimensional (2D) flow modelling was undertaken by Hydropol for the current baseline scenario (i.e. no HEP scheme operating) and the future scenario whereby the HEP scheme is abstracting water in accordance with the proposed abstraction regime outlined in Section 1.3. The following section provides an overview of the methodology and results obtained from the modelling.

2.1 Methodology

A bathymetric survey was carried out by Renewables First in April 2018 using a vessel mounted acoustic transducer, with multiple paths made across the entire weir pool area. Position co-ordinates were logged using DGPS. The data provide a good level of coverage with an error margin in collected depth measurements of ± 0.05 m. After accounting for stages of data processing, including calibration, level-logging and interpolation, the overall error margin of depth measurements was ±0.10 m. A stage-discharge model was also created, which included detailed fish pass flow parameters and was calibrated against empirically measured logger data.

The downstream water level at Gunthorpe Weir is subject to a backwater effect from the weirs at Hazelford. The downstream water levels in the proposed scenario were therefore calculated for each flow condition by Renewables First using the Environment Agency's 2011 ISIS model for the River Trent.

A 2D hydraulic model was created for the weir pool area using HEC-RAS software. The model used the 2D Saint Venant equations, with equation solving via an implicit finite volume algorithm. The modelling was carried out using values for the downstream water level, crest levels and flow splits as derived from the stage-discharge model. The estimated overall errors in the velocity and shear stress results, taking into account the error in depth measurements, were calculated as 0.5 Pa and 0.03 m/s, respectively. These error bands are relatively small when considered in the context of optimal preference ranges for the fish species under assessment in the habitat modelling (Section 4).

2.2 Results

Flow modelling outputs for weir pool depth at Gunthorpe are provided in Figure 2-1. Under baseline low flow (Q95), the weir pool is characterised by an area of moderately shallow (0.2 – 0.6 m) water adjacent to each bank, whilst the centre of the weir pool and the weir toe are deeper (> 1 m). Water depths in the weir pool increase at Q75 and Q50 due to an increase in the downstream water level at the site with the shallower margins of the weir pool increasing to a depth of 0.4 – 0.8 m. Under the future scenario with the HEP scheme operating, water depth increases only marginally throughout the weir pool under the Q75 and to an extent even under the Q50 flow scenarios. Many of the shallower marginal areas evident at Q95 remain present, although depths increase to *ca.* 0.4 – 0.8 m.

Flow modelling outputs for weir pool velocity at Gunthorpe are provided in Figure 2-2. Under the baseline scenario mean velocities are relatively low at the toe of the weir (0.25 – 0.50 m/s) due to the greater water depth in this area, peaking at 1.00 – 1.50 m/s across the shallower channel in the centre of the weir pool. An attraction plume leading to the pool and traverse fish pass on the far left side of the weir is evident under all three flow scenarios. The most marked differences in velocity following installation of the HEP scheme are evident at low flow (Q95) as the turbines would be abstracting a greater proportion of total river flow compared to the Q50 or Q25 flows. The HEP scheme leads to an increase in water velocity immediately downstream of the tailrace (peaking at 1.0 – 1.5 m/s), with a reduction in velocities across the centre and left sides of the weir pool.

Differences in velocity between the pre- and post-HEP scenario become progressively smaller at the Q50 and Qmean flows due to the turbines reaching maximum abstraction at <Q99 and additional flow passing via the weir crest as per the current arrangement. There is a small reduction in velocity at the toe of the weir under the post-HEP scenario, although velocities in the centre of the weir pool are not materially different. An attraction plume to the existing pool and traverse fish pass remains evident at the Q50 and Qmean flows under the post-HEP scenario. The flow modelling outputs are used to inform the geomorphology assessment and fisheries assessment in Section 3 and Section 4, respectively.

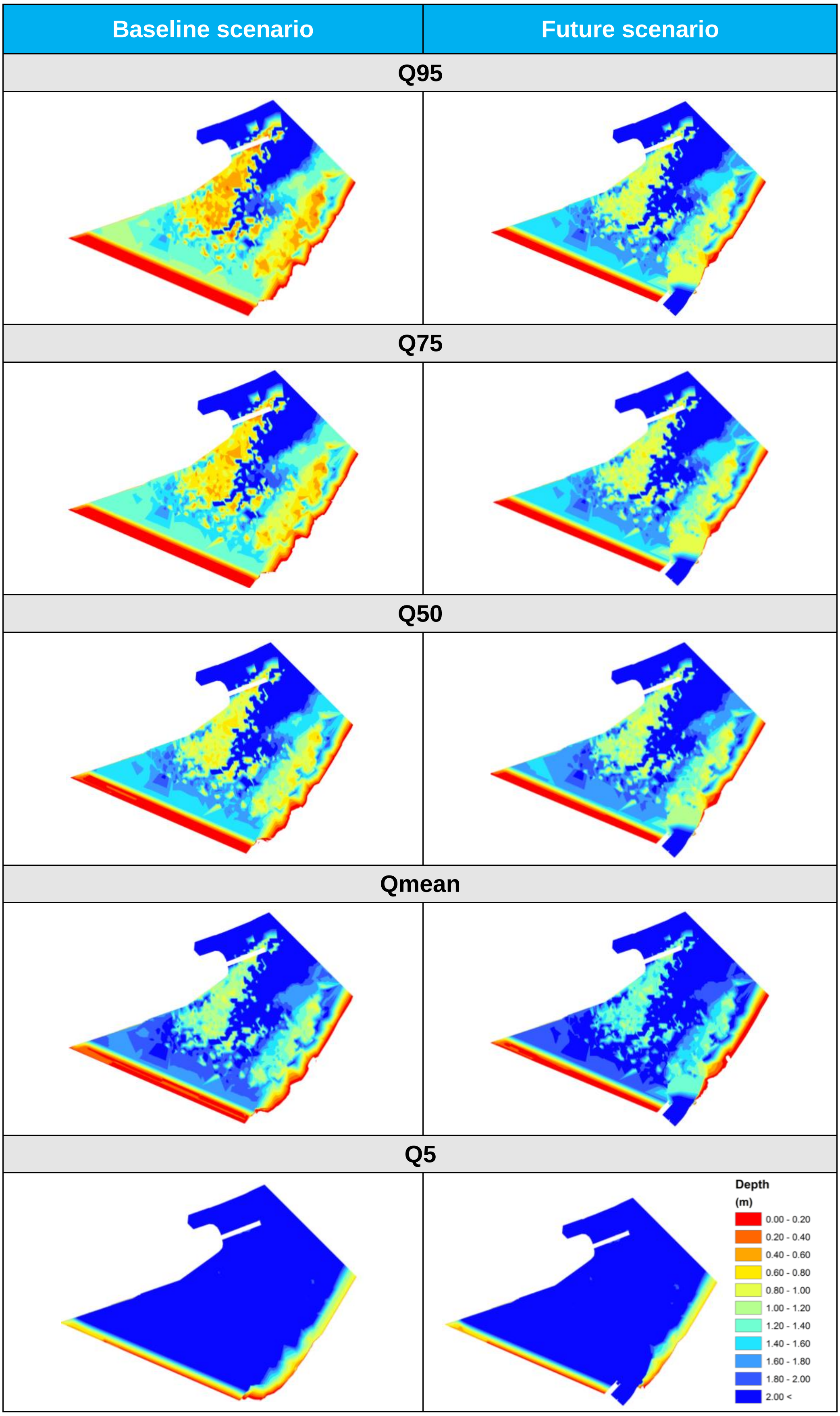


Figure 2-1. 2D flow modelling outputs for weir pool depth at Gunthorpe pre- and post-HEP installation.

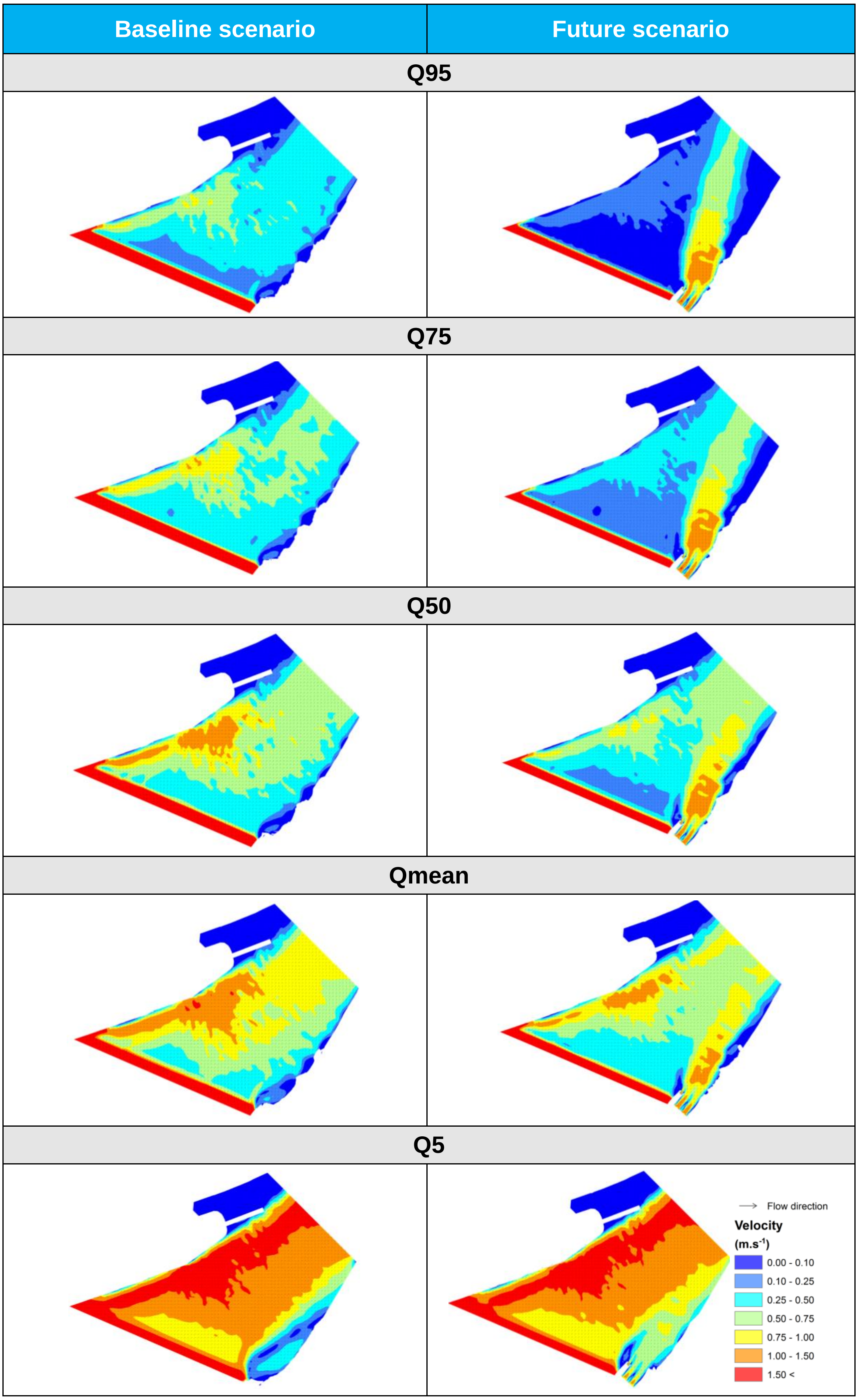


Figure 2-2. 2D flow modelling outputs for weir pool depth at Gunthorpe pre- and post-HEP installation.

3. Geomorphology assessment

As previously outlined, the weir pool at Gunthorpe is of high ecological value owing to the rarity of similar morphological features along the main stem River Trent and the associated aquatic species it is likely to support. There is a requirement to assess whether the proposed hydropower scheme could have an impact on physical habitat provision within the weir pool by altering flow dynamics and, consequently, processes of sediment erosion, transport and deposition.

To assess any possible impacts of the proposed scheme on weir pool morphology, the following information was compiled and reviewed:

1. Aerial photography, ground-based photographs and channel bathymetry data to characterise existing (baseline) weir pool morphology.
2. Sediment size data derived from grab sampling; *and*
3. Boundary shear stress for baseline and post-installation (design) scenarios derived from 2D hydraulic modelling.

3.1 Baseline weir pool morphology

Modelled flow depths provide an indication of the baseline channel morphology, including the extent and distribution of physical habitat features such as pools and bars (Figure 3-1). A pool is apparent immediately downstream of the weir and there are two areas of shallower flow a short distance downstream of the pool on both the left and right banks. It is assumed that these shallower areas represent gravel deposits formed from the excavation of sediment from the weir pool. A thread of predominantly deeper flow is present approximately along the channel centreline.

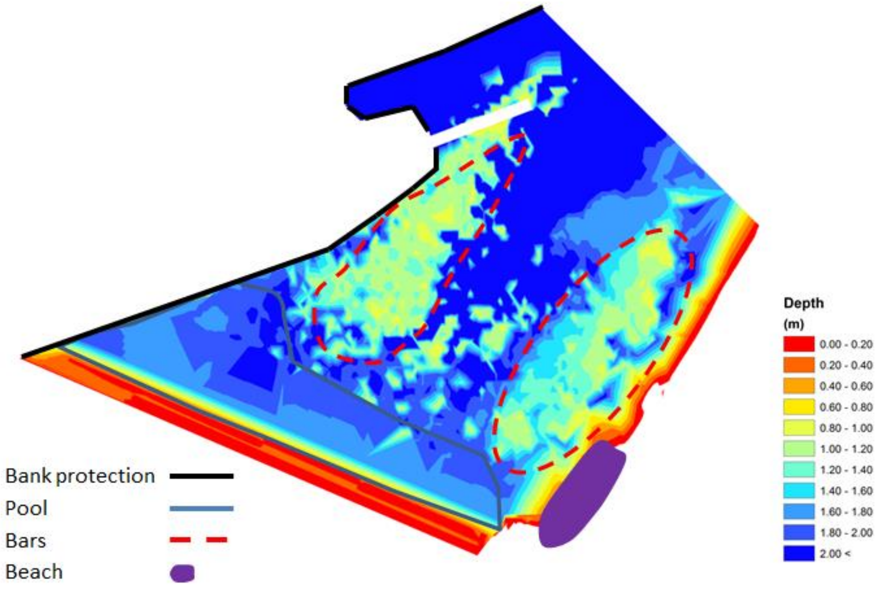


Figure 3-1. Key morphological features downstream of Gunthorpe Weir (depths at Qmean).

The left channel bank is reinforced with a concrete revetment that supports an artificial island constructed to facilitate boat navigation via the lock. With the exception of a short concrete abutment immediately downstream of the weir, the right channel bank is largely unmodified. Immediately downstream of the abutment, the right hand bank is unvegetated and takes the form of a narrow beach (Figure 3-2) predominantly composed of sediment in the medium to fine gravel range (4-16 mm) (Figure 3-3). This feature is backed by a steep cliff composed of sedimentary mudstones of the Gunthorpe Member (BGS, 2018) (Figure 3-4). The cliff is largely unvegetated, and there are loose accumulations of fallen material at its base indicating active slope failure processes. Several veins of gypsum, which is somewhat soluble in water, are exposed on the cliff face.

Figure 3-2. Beach and exposed cliff on the right bank downstream of Gunthorpe weir (highlighted in red).

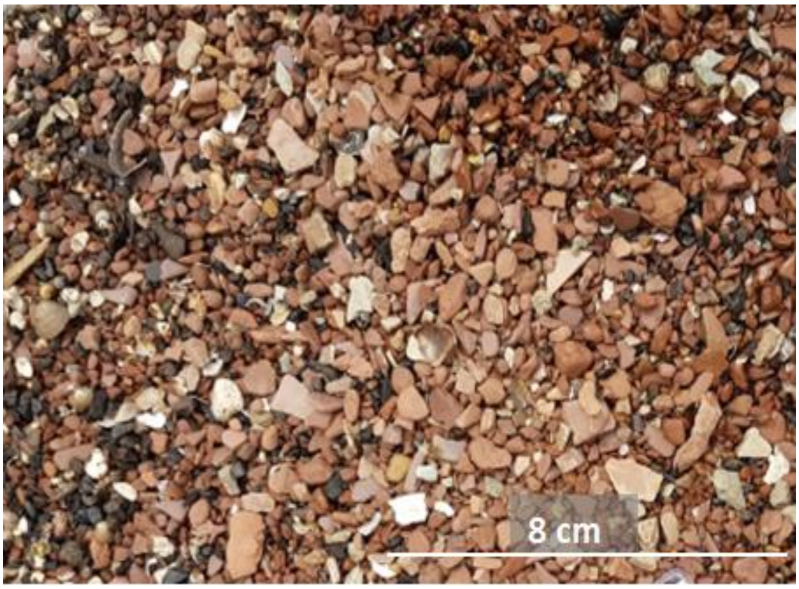


Figure 3-3. Beach material on the right bank downstream of Gunthorpe weir.

Figure 3-4. Cliff face material on the right bank downstream of Gunthorpe weir.

3.2 Bed sediment size

Bed sediment sampling was undertaken by Exo Environmental Ltd in October 2018 using a method agreed with the EA. Full details of the sampling methodology are provided in Exo Environmental (2018), whilst a summary is provided below.

Where water depth exceeded 0.5 m, a 3.4 litre Van Veen grab sampler was used to retrieve a sample, whilst a 1.5 litre hand scoop was used in shallower water. The location of each sampling point was determined using a Trimble GNSS receiver and controller. Sample locations were chosen to provide broad coverage of the weir pool and were not based on any prior knowledge of the site or habitat conditions. Samples were dried and passed through sieves with mesh widths of 63, 45, 32, 22, 16, 8 and 2 mm. Particles not passing the 63 mm sieve were measured manually. Particle size distributions were constructed to facilitate computation of relevant percentile values for sample characterisation.

Fourteen samples were recovered from the River Trent downstream of Gunthorpe weir, with no sample recovery possible at four locations (Figure 3-5). Failure to recover a sample at locations G04 and G15 was due to the 'hard bed, sediment between bedrock 'slabs' and strong current' (Exo Environmental, 2018, p. 7). Samples G02 and G16 were not included in the analysis as it was not possible to determine D50 precisely, where D_{50} fell within the <2 mm and >63 mm classes respectively. Sampling was undertaken between 18 – 20 October 2018 during a flow range of Q70 – Q84 and approximately four weeks following a flow peak approximating to Q18. The data collected by Exo Environmental are likely to have been affected by this high flow and may be somewhat coarser than would have been the case if sampling had been conducted following a prolonged period of low to moderate flows.

Calculated median grain size (D_{50}) for samples ranges from 1.9 mm (very coarse sand) at G01 to 67.8 mm (fine cobble) at G08, with an overall mean D_{50} of 30.0 mm (coarse gravel). Spatial variations in sediment size are also evident (Figure 3-5) with the two highest D_{50} values (G08 and G11) present in the centre of the channel, suggesting – as might be expected - that this area may be coarser than the margins. Samples G01 and G06 represent the lowest D_{50} values and were taken in close proximity to the beach and exposed cliff shown in Figure 3-2.

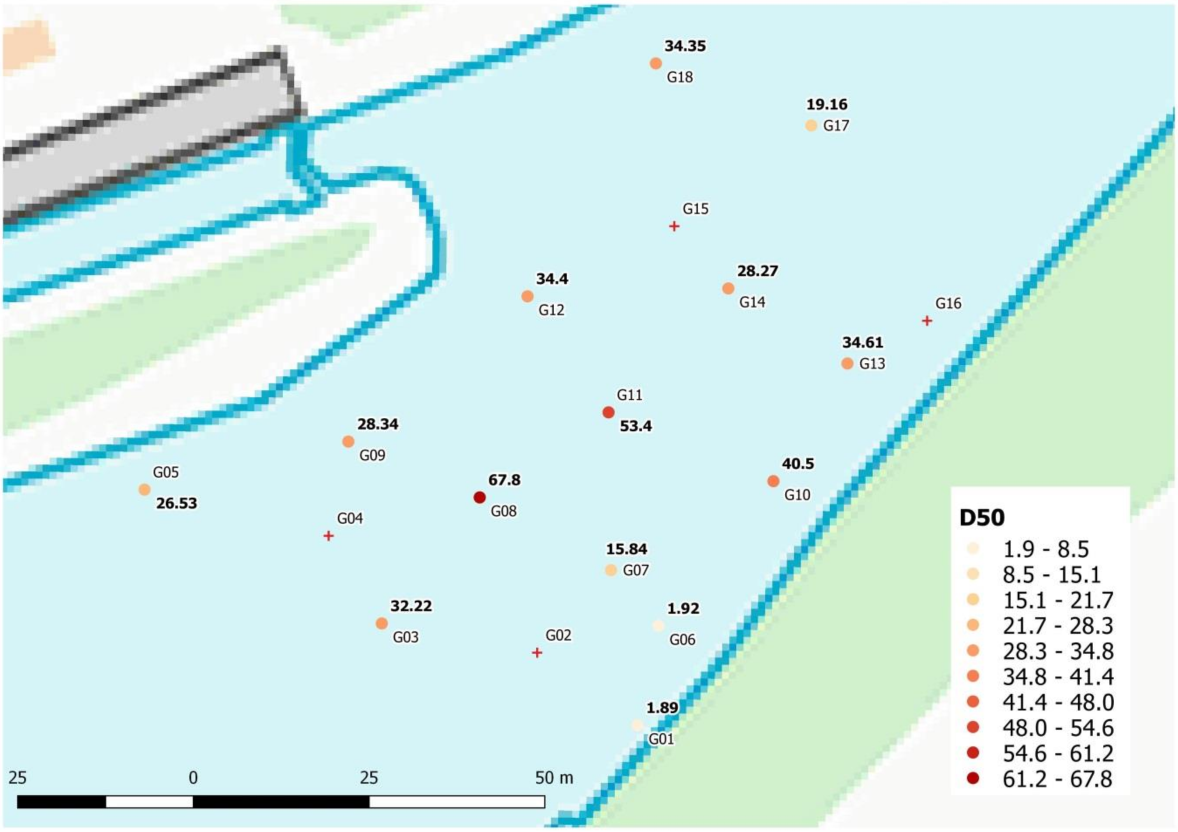


Figure 3-5 Location of sediment samples downstream of Gunthorpe Weir. Red crosses indicate failed sampling attempts.

3.3 Shear stress analysis

3.3.1 Introduction

Shear stress is the force per unit area (N m^{-2} or Pa) exerted by the flow on the bed and determines the capability of the flow to entrain and move sediment. Sediment entrainment occurs when boundary shear stress (τ_0) exceeds the critical shear stress (τ_{cr}) of a given particle. τ_{cr} can be calculated using the following equation:

$$\tau_{cr} = \theta g(\rho_s - \rho)D \qquad (1)$$

Where θ = dimensionless Shields parameter (after Shields, 1936); g = gravitational acceleration (9.81 m s^{-2}); ρ_s = sediment density (typically taken to be 2,650 kg m^{-3}); ρ = water density (1,000 kg m^{-3}); and D = particle diameter (m). On hydraulically rough gravel beds (with median grain size in excess of 2 mm), θ is typically accepted to range from 0.045 to 0.06 (Rouse, 1939; Knighton, 1998; Julien, 1998), although the structure of bed sediments can also be important and a value of 0.08 has been suggested to represent armoured beds with a strong surface structure (Hickin, 1995).

τ_{cr} was calculated for the D_{50} particle size at each sediment sampling location using two values of θ to represent two possible bed states (i.e. the nature of the bed structure, which is currently unknown): 0.06 represents a ‘normal’ bed state (not over- or underloose); and 0.08 represents an underloose, or armoured, bed. Equation 1 was also rearranged to derive a critical particle size (D_{cr} in mm) that will be entrained for a given shear stress and θ:

$$D_{cr} = \frac{\tau_0}{g(\rho_s - \rho)\theta} \qquad (2)$$

Spatially distributed boundary shear stress (τ_0) has been modelled downstream of Hazelford weir for both baseline and design scenarios at flows of Q95, Q75, Q50, Q25 and Q5. At each sediment sampling point, modelled values of τ_0 for each flow were extracted and compared with τ_{cr} calculated using equation 1 for both values of θ. This provides an indication of bed sediment mobility at a range of flows under both baseline and design scenarios. Comparison of sediment mobility under the two scenarios provides an indication of changes in geomorphological processes (i.e. sediment erosion, transport and deposition) caused by the proposed scheme.

3.3.1 *Effects on shear stress*

Differences in modelled boundary shear stress (τ_0) between baseline and proposed conditions are provided in Appendix 1 (Table 1) as both absolute and percentage changes at sediment sample locations. Modelled boundary shear stress is lower under proposed conditions than baseline conditions at eight sample locations at Q95, Q75 and Q50, nine sample locations at Qmean, and 11 sample locations at Q5 (Appendix 1, Table 1). All of the locations with an increase to modelled shear stress are towards the right hand channel margin, with the exception of G14 which is in the centre of the channel. At most points under both baseline and proposed conditions there is an increase in boundary shear stress (τ_0) in the modelled reach as flows increase from Q95 to Q5 (Appendix 1, Tables 2 and 3). Percentage reductions in shear stress typically decrease from Q95 to Q5 due to the reduction in abstraction volume relative to the overall river flow. At Q95, percentage reductions exceed 90% at the majority of locations, whilst percentage reductions in modelled shear stress are typically less than 20% at Q5. Percentage increases in shear stress at G01 (at all flows) at G06 (at Q95 - Qmean) and at G07 (at Q95 - Q75) are substantial and often exceed those under equivalent baseline flows by many times.

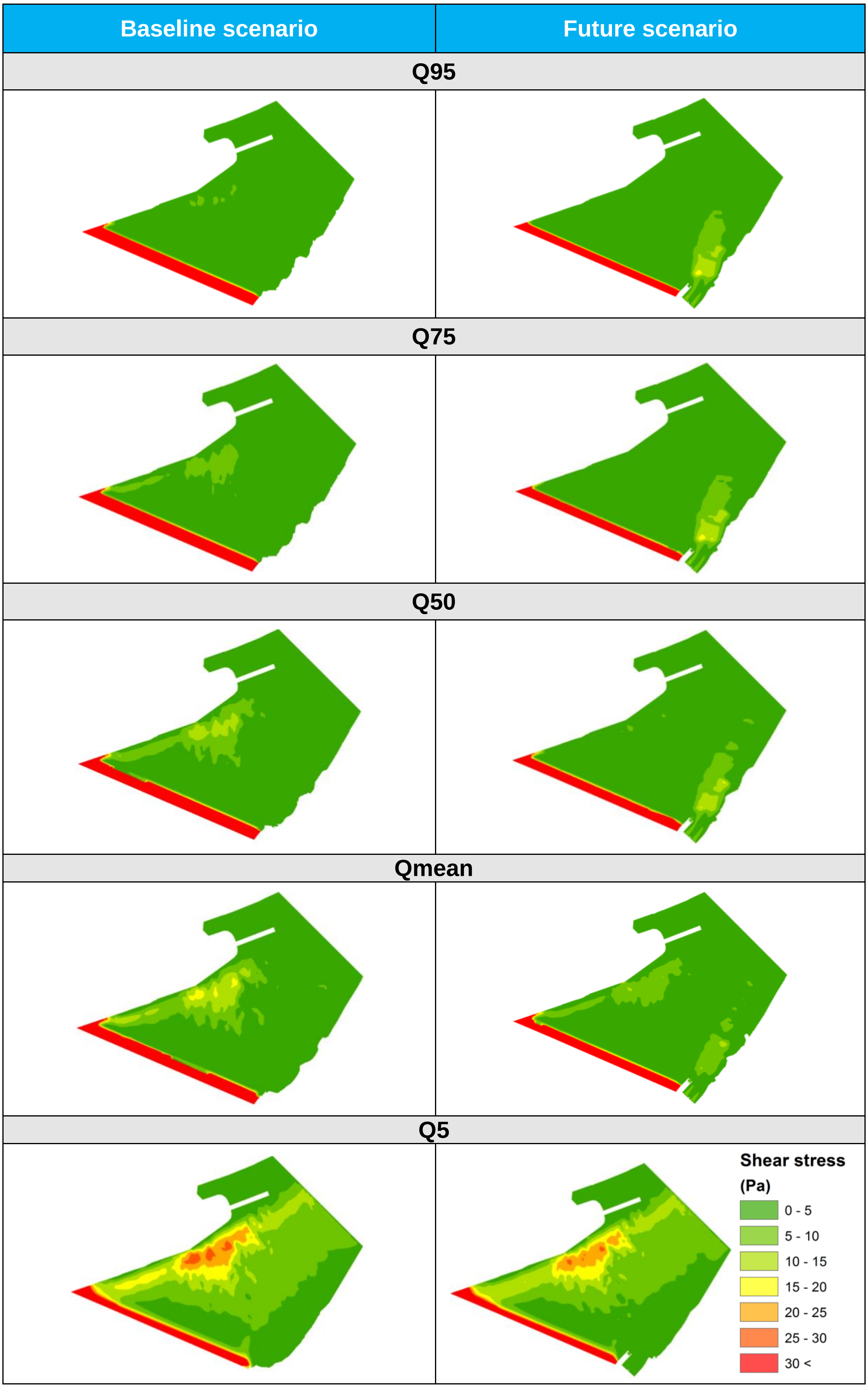


Figure 3-6. Modelled shear stress for baseline and design conditions for a range of flows downstream of Gunthorpe Weir.

3.3.1 Effects on sediment mobilisation

An overview presenting the percentage of sample sites where D_{50} is above, below or at the calculated threshold of motion is shown in Appendix 1, Table 4. The percentage of sites which fall below the threshold for motion has a maximum range from 100% (baseline) to 86% (proposed) when θ = 0.06 and from 93% (baseline) to 79% (proposed) when θ = 0.08.

Maps showing whether the D_{50} grain size is above, below or approximately at the threshold of motion are presented in Appendix 1, and the underlying data are listed in Tables 2 and 3 of Appendix 1. With the exception of locations G01 and G06, these reveal minimal changes in sediment mobility at all flows between baseline and design scenarios for both values of θ. For the majority of locations, the results suggest that the bed material downstream of Gunthorpe weir is rarely mobilised under current conditions, and this situation is unlikely to be changed by the proposed HEP scheme.

At G01, the D_{50} grain size is expected to be entrained at a flow somewhat lower than Q95 under the proposed scenario whilst, under equivalent baseline flows, boundary shear stress (τ_0) is substantially below critical shear stress (τ_{cr}) for all flows. A similar though less pronounced result is evident at location G06, where the D_{50} grain size is expected to be entrained at a flow somewhat lower than Q95 under the proposed scenario in contrast to a flow between Qmean and Q5 under baseline conditions. G01 and G06 are on the right hand bank a short distance downstream of the weir. The sediment entrainment predicted under the proposed scenario is a result of both the elevated shear stress downstream of the turbine tailrace with the HEP scheme in place and the small D_{50} calculated at these locations.

Reductions in modelled τ_0 between baseline and proposed conditions at most flows and most sediment sample points result in commensurate reductions in the maximum mobilised particle size (D_{cr}) (Appendix 1; Table 5 and 6). Under baseline conditions, modelled boundary shear stress (τ_0) is typically sufficient to mobilise particles in the fine silt to fine gravel range at Q95, with the lowest calculated D_{cr} being <0.00 mm (fine silt) at G18. Maximum mobilised particle size generally increases progressively up to Q5. Under proposed conditions, D_{cr} has a wider range at Q95 from fine silt (D_{cr} <0.00) to medium gravel (D_{cr} = 9.75 at G01). Maximum mobilised particle size generally increases with increasing flow, and at Q5, differences in D_{cr} between baseline and proposed conditions are immaterial.

3.3.1 Effects on the character of bed substratum and geomorphological function

The results of modelling downstream of Gunthorpe weir demonstrate spatial variability in the likely impact of the proposed HEP scheme. Increases in shear stress are most pronounced at locations towards the right hand bank, whilst the largest decreases in shear stress are present towards the left hand bank.

Where modelled reductions in shear stress occur, these reductions are unlikely to have tangible impacts on coarse sediment dynamics downstream of Gunthorpe weir given that flows are not competent to entrain the D_{50} particle size under either baseline or proposed conditions. It is possible that at these locations, some additional temporary deposition of fine sediment may be possible due to the operation of the HEP scheme. Suspended sediment is the finest grain fraction of the total sediment load and typically consists of particles <0.062 mm in diameter. Calculated D_{cr} values suggest that shear stress will be insufficient to entrain particles somewhat smaller than this at G03, G08, G13 and G18 at Q95 under the proposed scenario. However, at Q50 modelled τ_0 is sufficient to mobilise coarse sand-sized particles, at all locations except G18. This implies that any fine sediment deposited during low flows will be re-entrained during a relatively low magnitude, high frequency flow. As such, any changes in bed sediment composition as a result of fine sediment deposition during low flows are likely to be temporary and localised. G18, as an exception, is a fine sediment sink but represents no change between baseline and proposed scenarios.

Modelled increases in shear stress as a result of the proposed HEP scheme are predicted to occur at a number of locations and flows. This is likely to have the most pronounced impact at locations G01 and G06 due to the smaller D_{50} grain size at these locations (very coarse sand) whilst elsewhere, D_{50} is medium gravel and larger. The increase in boundary shear stress (τ_0) at Q95 is expected to be sufficient to mobilise the D_{50} particle size at these locations under the proposed scheme. In the case of G06, the D_{50} particle size is also predicted to be mobilised at a flow somewhat greater than Qmean under existing conditions. This suggests that the proposed HEP scheme is not expected to increase boundary shear stress (τ_0) at G06 much beyond the range currently experienced at this point, meaning that substantial geomorphic changes are unlikely to occur. In contrast, at G01, the D_{50} particle size is not expected to be mobilised at any flows under the baseline scenario. This therefore represents a significant change in the sediment dynamics at location G01, which is likely to result in stripping of finer material and coarsening or possible reduction of the marginal gravel bar.

Overall, the modelling results indicate a limited change in entrainment and transport of material at the majority of locations. However, there is a possible impact from the tailrace discharge on the right hand bank a short distance downstream of Gunthorpe weir, which coincides with the narrow gravel shoal and mudstone cliff face identified in Section 3.1. Given that the cliff face is composed of readily erodible sedimentary mudstone, it could be at risk of increased erosion if it is exposed to hydraulic action and elevated shear stress imparted by the turbine flow. An increased risk of erosion is only likely to occur at flows in excess of approximately Q10 - at flows below Q10 the downstream water level will be below the base of the cliff.

Erosion of the beach feature and cliff face may lead to further morphological adjustments downstream where eroded sediment is deposited. As such, some form of scour protection may be advisable at this location to minimise risk of morphological changes. Alternatively, consideration could be given to reducing the rate of abstraction above Q10 (when the base of the cliff starts to become wetted), to minimise the risk of erosion.

3.3.1 Uncertainties

Assessing the likely impacts of changes in flow competence on bed substrate composition in the weir pool is complicated by uncertainties associated with the quantity and calibre of sediment supplied from upstream. Specifically, it is currently unknown which size fractions are able to pass over the weir and under which flows over-weir transport occurs. It is possible that the weir acts as a physical barrier to the transport of coarse sediment as bedload, whilst flow competence in the over-wide and impounded reach upstream may be insufficient to deliver sediment to (and subsequently over) the weir.

The structure of the bed is unknown, but the higher value of Shields parameter (0.08) used in the calculations of critical boundary shear stress (τ_{cr}) and critical particle size (D_{cr}) is considered to be a better representation of likely channel conditions downstream of the weir than a Shields parameter of 0.06. This is because it is assumed that the channel downstream of the weir is armoured with a strong surface structure, owing to a history of sediment starvation and resultant winnowing of fine sediment. Observations made during field sampling support this contention (Exo Environmental, 2018). In general, differences in sediment mobility (in terms of whether or not critical boundary shear stress (τ_{cr}) is exceeded at sample points) between baseline and proposed conditions are less substantial when θ = 0.08 than when θ = 0.06, indicating that the analysis presented above may be conservative, and that the channel is likely to be more resilient to changes in shear stress given the armoured nature of the bed substrate.

4. Fish habitat assessment

Individual species and life stages of fish display differing habitat requirements which are necessary to fulfil particular life events (e.g. spawning habitat, juvenile rearing habitat and adult foraging/feeding habitat). Both the quality and quantity of habitat available for individual life stages can be directly influenced by flow. Decreases in flow can cause a reduction in depth and wetted width of river channels, in turn reducing the usable habitat area that can be occupied by fish. Similarly, flow reductions can lead to changes in depth and velocity within particular areas of the river channel, affecting the quality of habitat for individual species.

The following section considers the potential impacts of the proposed HEP scheme in relation to the quality and extent of fish habitat available within the potentially depleted section of river channel between Gunthorpe Weir and the HEP tailrace. Using the outputs from the 2D flow modelling a quantitative assessment of the change in habitat quality under the five flow scenarios following the construction of the proposed HEP scheme is provided.

4.1 River Trent fish ecology

Assessment focus

As outlined in Section 1, the River Trent at Gunthorpe is primarily populated by cyprinid coarse fish, the main species being chub, dace and gudgeon that are rheophilic in nature. There are lesser populations of generalist/eurytopic coarse fish species (i.e. those tolerating a wider range of environment conditions, e.g. perch, roach), which each display broadly similar habitat requirements. Due to their tolerance of a wider range of environmental conditions, the impacts of flow depletion on generalist species are likely to be relatively minor. Impacts are most likely to manifest during the spawning and juvenile life stages of eurytopic species due to their more specific habitat requirements when compared to adult life stages which are able to occupy a wider range of habitat conditions (EA, 2004). These two life stages have there been included within the fisheries assessment for the proposed scheme, using published habitat preferences of roach as a representative species. However, adult eurytopic species are also of interest to anglers in close proximity to Gunthorpe weir and therefore the adult life stage of roach has also been included within the assessment.

In contrast to eurytopic species, dace, chub, gudgeon and barbel are all rheophilic in nature and populate areas of faster flowing water, typically characterised by a coarse bed substrate of gravel or cobble. These areas can be sensitive to changes in flow, either due to a reduction in water depth (and therefore a physical contraction in habitat area) or alterations to velocity.

Several studies have established that the bottleneck to production for many coarse fish species on UK rivers is driven by access to, and availability of, suitable spawning habitat (e.g. EA, 2004). This is primarily due to adult life stages of coarse fish species tolerating a much wider range of environmental conditions than eggs undergoing incubation or juvenile fish of less than one year old (termed young of year fish) (EA, 2004). Therefore, a change in the availability of suitable habitat for adult coarse fish species (whether that be a decrease or an increase) is unlikely to result in a significant change to overall production and recruitment compared to a comparable change in the availability of spawning or juvenile habitat. Spawning and juvenile life stages are therefore two key focus areas for the assessment of rheophilic species. However, in common with the generalist species, a number of rheophilic species are targeted by anglers as adults and therefore this life stage has been included within the assessment. For the purposes of assessing impacts on rheophilic species, habitat preferences for chub have been used as a representative example species.

Although salmon have been recorded in tributaries of the Trent further upstream of Gunthorpe (e.g. Dove and Derwent), no juvenile salmon have been recorded by the EA at monitoring sites near Gunthorpe weir. It is likely that the extent of suitable breeding habitat is limited in the affected reach downstream of the weir, with the passability of the weir structure remaining the primary concern to migratory salmon to allow access to areas of higher quality habitat further up the catchment.

Overview of habitat requirements

An overview of habitat requirements for rheophilic coarse fish species and salmonids of various life stages is summarised in a number of sources, including the EA's (2004) 'Flow and Level Criteria for Coarse Fish and Conservation Species'. Species such as chub, dace, gudgeon and barbel are assigned to similar functional groups/guilds and therefore display broadly comparable requirements in relation to suitable juvenile, adult, and spawning habitats. A summary of depth and velocity preferences for spawning habitat of rheophilic fish species recorded on the River Trent is provided in Table 4-1. In addition, due to their rheophilic nature, all species require a relatively coarse bed substrate (gravel to cobble size) in which to deposit eggs. The sediment survey undertaken for the assessment demonstrated that suitably sized substrate was present throughout the majority of the modelled reach, although this is discussed in greater detail within the results section.

Table 4-1. An overview of published habitat requirements for relevant fish species/guilds of the River Trent at Gunthorpe.

Species / Guild		Optimal water depth (m)	Optimal water velocity (m/s)	Source
Spawning Rheophilic	Chub	0.25 – 0.40	0.20 – 0.50	Arlinghaus and Wolter (2003)
	Dace	0.10 – 0.30	0.15 – 0.75	EA (2004)
	Barbel	0.15 – 0.40	0.25 – 0.49	EA (2004)
	Gudgeon	0.50 – 0.80	0.20 – 0.80	EA (2004)
Juvenile rheophilic		0.50 – 2.00	0.00 – 0.30	Cowx (2001)
Adult rheophilic		0.50 – 2.00	0.30 – 0.70	Cowx (2001)
Spawning roach		0.10 – 0.60	0.30 – 1.00	EA (2004)
Juvenile roach		0.10 – 10.0	0.00 – 0.20	EA (2004)
Adult roach		0.50 – 5.00	0.00 – 0.30	EA (2004)
Juvenile lamprey		0.00 – 2.00	0.10 – 0.30	Cowx (2001)
Spawning lamprey		0.25 – 0.50	0.20 – 0.50	EA (2004)

It is apparent from the data in Table 4-1 that all rheophilic species exhibit broadly similar habitat preferences, with a shared optimum depth range in the region of 0.15 – 0.40 m and a shared velocity range in the region of 0.15 – 0.50 m/s. Juvenile roach, as a generalist species, are tolerant of a wide range of depths, but prefer slow moving water (0.0 – 0.2 m/s). These preference ranges have been used to inform the habitat assessment approach for the proposed development, which is outlined in the following section.

Most lamprey spawning occurs on riffles and the lower ends of glides where there is flow through the substrate and clear well oxygenated water. Their requirements are largely similar to that of spawning salmon (Maitland, 2003). The velocity and depth requirements of spawning salmon as per the EA's (2004) 'Flow and Level Criteria for Coarse Fish and

Conservation Species' has therefore been used to represent suitable habitat for spawning lamprey.

4.2 Habitat assessment methodology

The habitat assessment methodology for the proposed HEP scheme has used a Physical Habitat Simulation System (PHABSIM) type approach to quantify changes in the quality and extent of habitat available for individual species and life stages. The method involves calculating the suitability of individual 'cells' based on depth, velocity and substrate data.

Beyond the optimal habitat range for each life stage there are depth and velocity values that are deemed sub-optimal (to varying degrees), but which may still be utilised as functional habitat. This may occur where optimal habitat is absent from a reach (in which case species are likely to be supported at lower population densities due to the reduced rearing capacity of the habitat), or where high densities of a particular species or life stage result in maximum utilisation of optimal habitat, potentially causing spill over into areas of less optimal habitat.

To account for this, individual habitat suitability curves covering depth, velocity and substrate have been used for each species and life stage. The depth and velocity suitability has been determined for each species/life stage at 0.01 m and 0.01 m/s intervals (e.g. 0.10 m, 0.11 m, 0.12 m etc.), with suitability values ranging from 0 (entirely unsuitable) to 1 (optimal) assigned to each depth and velocity value. Substrate suitability has been calculated in a similar manner, with suitability values assigned to intervals of D50 grain size diameter.

The flow modelling at Gunthorpe consists of a grid comprised of 5,250 nodes, each of which has an individual depth and velocity value calculated during the modelling exercise. Additionally, D50 grain size data has been interpolated from the sediment survey results (Figure 3-5) to produce an estimated D50 grain size for each node of the modelled grid. The interpolation used the triangulated irregular network methodology in GIS, which was chosen as it retains the measured D50 value at sampling locations rather than altering it through interpolation. There is inevitably some level of error associated with the interpolated values – the extent of which depends on the similarity of the surrounding sample results. Therefore, in addition to the calculation of habitat suitability across the site using the interpolated D50 data, suitability values have been provided for each of the sediment sampling locations based on the empirically measured D50 data (Appendix 3).

Suitability curves for each species and life stage under consideration are used to calculate the suitability for each of these three individual components. Suitability curves for each component range from a suitability of 0 (entirely unsuitable) to 1 (optimal for the particular species/life stage). The overall habitat suitability of each individual node is calculated by multiplying the suitability values assigned to each of the three individual parameters. For example, suitability values of 1, 0.8 and 0.6 for depth, velocity and substrate, respectively, would equate to an overall suitability value of 0.48 (1 * 0.8 * 0.6). Conversely, suitability values of 1, 0.8 and 0.0 for depth, velocity and substrate, respectively, would equate to an overall suitability value of 0 (1 * 0.8 * 0).

Following calculation of the habitat suitability of each individual node for a particular species and life stage, habitat suitability maps are exported graphically and area statistics are generated to quantify the change in the area of functional habitat for the pre- and post-HEP scenarios. For the purposes of reporting on the changes in usable habitat area, 'suitable habitat' discussed for each life stage has been defined as areas which have a habitat suitability value ranging from 0.5 – 1.0. Values are reported both in absolute terms (square metres) and proportional terms (percentage change between the baseline and HEP scenarios).

Given that the geomorphology assessment (Section 3) predicted minimal overall changes in sediment dynamics through the depleted reach associated with the HEP scheme, the existing substrate composition has been used in modelling habitat availability under the future HEP scenario. Where relevant, observations on the main anticipated impacts (i.e. a potential risk of temporary deposition of coarse sands during moderate flows) have been applied to the assessment of individual fish species and life stages. Although the geomorphology assessment has involved quantitative analysis to arrive at predictions of sediment entrainment, the data have been applied to the fish modelling in a qualitative manner only (i.e. quantitative predictions of future sediment composition have not been made due to the associated uncertainties).

4.3 Habitat assessment results

4.3.1 Spawning rheophilic

Modelled habitat suitability for rheophilic coarse fish spawning under the current baseline scenario and the future HEP scenario is provided in Appendix 2 for flow scenarios of Q95, Q75, Q50, Qmean and Q5.

Under baseline conditions much of the marginal areas of the weir pool provide optimal rheophilic spawning habitat at low flows (Q95 – Q75), particularly along the left bank. Areas of optimal habitat progressively decline at moderate to high flows (Q50 – Q5) under baseline conditions as water depths exceed the optimal range for spawning habitat. The majority of the central area of the weir pool is deemed unsuitable across all flow conditions due to excessive water depths. Following construction of the HEP scheme there is predicted to be a reduction in areas of optimal habitat at low flow (Q95), due to the increase in downstream water level associated with the proposed raising of Hazelford weir. At Q75 there is predicted to be a reduction in optimal spawning habitat in marginal areas adjacent to the right hand bank, although the majority of the optimal habitat towards the centre and left side of the weir pool is predicted to remain unaffected. At moderate to high flows (Q50 – Q5), the HEP scheme is predicted to increase the overall area of optimal spawning habitat through the central areas of the weir pool due to a reduction in velocities relative to baseline conditions.

Across the five modelled flow conditions, there is an average area of 529 m^2 of suitable habitat present under baseline conditions, which is predicted to remain broadly unchanged at 502 m^2 following construction of the HEP scheme. In proportional terms this equates to 13% of the modelled area comprising suitable habitat under both the baseline and future HEP scenarios.

4.3.2 Juvenile rheophilic

Modelled habitat suitability for juvenile rheophilic coarse fish under the current baseline scenario and the future HEP scenario is provided in Appendix 2 for flow scenarios of Q95, Q75, Q50, Qmean and Q5.

Much of the weir pool comprises of sub-optimal juvenile rheophilic habitat under low flows (Q95 – Q75) due to high water velocities. There is a small area of optimal habitat towards the downstream end of the weir pool in the channel margins adjacent to the left bank. The area of suitable juvenile habitat progressively declines under increasing flow, with the majority of the weir pool deemed unsuitable at the highest flows (Qmean/Q5). Construction of the HEP scheme is predicted to lead to the creation of areas of optimal habitat in the areas outside of the main turbine discharge plume. This includes a large proportion of the central and left areas of the weir pool, and a marginal area adjacent to the right bank at the downstream end of the weir pool. Within the discharge plume itself habitat is considered to be unsuitable for juvenile rheophilic life stages due to excessive water velocities, although the overall change is limited given the sub-optimal suitability of this habitat under the baseline scenario. A similar trend is evident at Q75, with a significant increase in the overall area of optimal habitat. At higher flows (Q50 – Q5), there are expected to be no appreciable changes in habitat quality following construction of the HEP scheme.

Across the five modelled flow conditions, there is an average area of 147 m^2 of suitable habitat present under baseline conditions, which is predicted to increase to 716 m^2 following construction of the HEP scheme. In proportional terms this equates to 4 % of the modelled area comprising suitable habitat under baseline conditions on average, compared to 18 % following construction of the HEP scheme.

4.3.3 Adult rheophilic

Modelled habitat suitability for adult rheophilic coarse fish under the current baseline scenario and the future HEP scenario is provided in Appendix 2 for flow scenarios of Q95, Q75, Q50, Qmean and Q5.

The vast majority of the weir pool comprises of optimal adult rheophilic habitat under baseline conditions at low flows, with the exception of a marginal area adjacent to the left bank which is deemed too shallow to offer suitable habitat. There is a gradual reduction in the area of optimal habitat at moderate flows (Q50 – Qmean), driven primarily by increases in mean velocity which exceed the preference range for rheophilic species. At Q5 the vast majority of the weir pool is deemed unsuitable, with the exception of two small marginal areas adjacent to each bank. Construction of the HEP scheme is predicted to cause a reduction in adult rheophilic habitat suitability at low flows (Q95 – Q75), which is attributable to reduced water velocities through the left side of the weir pool. Habitat remains optimal through the centre and right sides of the weir pool due to the presence of the HEP discharge plume in this area. At moderate to high flows (Q50 – Q5), there is negligible predicted change in habitat suitability compared to baseline, with much of the weir pool comprising of optimal habitat at Q50 and Qmean.

Across the five modelled flow conditions, there is an average area of 2,643 m^2 of suitable habitat present under baseline conditions, which is predicted to decrease to 2,177 m^2 following construction of the HEP scheme. In proportional terms this equates to 66 % of the modelled area comprising suitable habitat under baseline conditions on average, compared to 55% following construction of the HEP scheme.

4.3.4 Spawning roach

Modelled habitat suitability for roach spawning under the current baseline scenario and the future HEP scenario is provided in Appendix 2 for flow scenarios of Q95, Q75, Q50, Qmean and Q5.

The majority of the weir pool is deemed unsuitable for roach spawning habitat under the baseline conditions, with only a small area of optimal habitat present in close proximity to the weir toe at the location of the proposed tailrace under low flows (Q95 - Q75). At moderate to high flows (Q50 – Q5) the entirety of the weir pool is classified as unsuitable. The proposed HEP scheme is not predicted to significantly alter the available habitat compared to the baseline conditions as the weir pool would remain largely unsuitable at all flows.

Across the five modelled flow conditions, there is an average area of 12 m^2 of suitable habitat present under baseline conditions, which is predicted to decrease to 0 m^2 following construction of the HEP scheme. In proportional terms this equates to 0 % of the modelled area comprising suitable habitat under both the baseline and future HEP conditions.

4.3.5 Juvenile roach

Modelled habitat suitability for juvenile roach under the current baseline scenario and the future HEP scenario is provided in Appendix 2 for flow scenarios of Q95, Q75, Q50, Qmean and Q5.

The vast majority of the weir pool is deemed unsuitable for juvenile roach under baseline conditions across all five modelled flows. The exception to this is an area adjacent to the left bank at the downstream end of the weir pool, which comprises a small amount of sub-optimal habitat due to reduced water velocities in this region. Following construction of the HEP scheme there is predicted to be a modest increase in areas of suitable habitat at low to moderate flows, primarily in the upstream section adjacent to the right bank and the downstream section adjacent to the left bank, both of which are outside of the main HEP flow plume passing through the central weir pool. In common with the baseline scenario, habitat suitability is expected to decline at higher flows (>Q50), although overall suitability is predicted to increase at these higher flows following construction of the HEP scheme.

Across the five modelled flow conditions, there is an average area of 74 m^2 of suitable habitat present under baseline conditions, which is predicted to increase to 315 m^2 following construction of the HEP scheme. In proportional terms this equates to 2 % of the modelled area comprising suitable habitat under baseline conditions on average, compared to 8 % following construction of the HEP scheme.

4.3.6 Adult roach

Modelled habitat suitability for adult roach under the current baseline scenario and the future HEP scenario is provided in Appendix 2 for flow scenarios of Q95, Q75, Q50, Qmean and Q5.

Under the existing baseline conditions the weir pool comprises primarily of unsuitable habitat for adult roach, although pockets of sub-optimal habitat are present, particularly at low flows (Q95 – Q75) and in lower velocity marginal areas adjacent to the left bank. At higher flows the increased velocities under baseline conditions result in the vast majority of the weir pool being categorised as unsuitable.

There is predicted to be an increase in habitat suitability for adult roach following construction of the HEP scheme, leading to greater areas of moderate quality habitat. In common with juvenile roach, these areas of suitable habitat primarily occur in areas outside of the main HEP flow plume. The plume itself passes through the centre-left of the weir pool and results in this area remaining unsuitable for adult roach. At moderate to higher flows the HEP scheme is predicted to increase habitat suitability relative to the baseline scenario, although the overall habitat availability remains limited due to the high energy environment of the weir pool (roach instead typically preferring slower moving bodies of water).

Across the five modelled flow conditions, there is an average area of 277 m^2 of suitable habitat present under baseline conditions, which is predicted to increase to 970 m^2 following construction of the HEP scheme. In proportional terms this equates to 7 % of the modelled area comprising suitable habitat under baseline conditions on average, compared to 24 % following construction of the HEP scheme.

4.3.7 Juvenile lamprey

No lamprey habitat is present within the weir pool. The weir pool comprises primarily coarse sediment given the high energy environment. Therefore, the deposition of silt beds (and habitat for juvenile lamprey) is not present within the reach.

4.3.8 Spawning lamprey

Spawning lamprey habitat suitability under the current baseline scenario and the future HEP scenario is provided in Appendix 2 for flow scenarios of Q95, Q75, Q50, Qmean, and Q5.

The weir pool comprises primarily unsuitable habitat for spawning lamprey, particularly at high and moderate flows of Q5, Qmean, and Q50. Under baseline low flow conditions (Q75, Q95) there are regions of marginally suitable habitat (0.5 suitability score) mixed with pockets of optimal habitat (1.0) that are limited to areas adjacent to the left and right banks, with some isolated habitats within the 30m area immediately downstream of the weir toe.

There are no noticeable changes to the limited quality or extent of suitable habitat after construction of the HEP at high and moderate flows. However, the quality of habitat is significantly reduced under low flow conditions, with no optimal spawning habitat available under any of the five modelled flow conditions after commencement of the HEP scheme. The remaining habitat is predicted to be of poor quality for spawning lamprey (<0.5 score).

Across the five modelled flow conditions, there is an average area of 97 m^2 of suitable habitat present under baseline conditions, which is predicted to decrease to less than 1 m^2 following construction of the HEP scheme. In proportional terms this equates to 2.4 % of the modelled area comprising suitable habitat under baseline conditions on average, compared to <0.1 % following construction of the HEP scheme.

4.4 Summary

Overall, the habitat assessment indicates that the proposed HEP scheme would result in a decrease in areas of suitable habitat for rheophilic and lamprey spawning at low flows (Q95/Q75), which is driven primarily by changes in velocity associated with the reduced flow over the weir. However, this is partly offset for rheophilic spawning species by predicted increases in suitability at moderate flows (Q50 – Qmean). Similarly, the scheme is likely to reduce the suitability of the weir pool for adult rheophilic species at low flows (Q95), but would remain largely unchanged at all other flows.

The HEP scheme is predicted to result in an increase in areas of suitable habitat for both juvenile rheophilic species and adult and juvenile roach relative to baseline, due to a reduction in mean velocities outside of the main HEP plume. No significant changes in roach spawning habitat are anticipated given an absence of such habitat under the current conditions.

5. Fish Passage Assessment

The following section details a fish passability assessment for Gunthorpe weir under the current baseline scenario for fish species known to populate the site. The passability has then been assessed under the future HEP scenario using modelled hydrology and flow information.

5.1 Assessment methodology

The passability assessment uses the WFD111 methodology developed by Scotland and Northern Ireland Forum for Environmental Research (Sniffer) in collaboration with the EA and other regulatory bodies in the UK. The method requires on-site measurement or calculation of key parameters for the structure under assessment which are then related to the swimming (or leaping) ability and endurance of target fish species to determine the extent to which the structure is passable for upstream and downstream passage.

One or more transversal sections are identified, which provide potential routes for fish passage through the structure (Figure 5-1). Where a structure is largely homogenous along its length with little hydraulic variation (as is the case for Gunthorpe), a single transversal section is considered sufficient. Dependent on the structure type, for each transversal section, at the toe, mid-point and crest, hydraulic characteristics including water velocity and depth of water over the structure face are either directly surveyed or estimated where access to the watercourse is deemed unsafe. In addition, head loss, obstacle height, length of structure, presence/absence of a plunge pool, and flow type (e.g. turbulent, plunging, adherent flows, and/or presence of hydraulic jump) are either directly measured, estimated or described.

Figure 5-1. Example of transversal sections from the WFD111 field manual (WFD111, 2010a).

These hydraulic characteristics were recorded using the standard WFD111 proforma. Passability values were assigned for each hydrological aspect (e.g. depth and velocity) according to the physiology of the fish under consideration (specifically burst swimming speed, leaping capability and size range of fish present in the river).

The transversal section with the maximum passability score then determines the overall passability of the structure. The passability score is defined as:

"*The proportion of fish that encounter an impediment and then successfully pass it (during either an upstream or downstream migration) without undue delay (i.e. the probability of reaching the final destination, e.g. spawning or feeding grounds, is not compromised due to increased energetic expense or predation risk)*" (WFD111, 2010a).

Table 5-1 provides a definition for each passability score. To aid in visually comparing passability scores, colour coding has also been assigned to each classification.

Table 5-1. Passability scores as defined within the WFD111 assessment methodology.

Passability score	Passability classification	Colour coding
1.0	***No barrier:*** *the obstacle does not represent a significant impediment to the target species / life-stage, or species guild, and the majority of the population will pass during the majority of the period of migration (movement). This does not mean that the obstacle poses no costs in terms of delay, e.g. increased energetics, or that all fish will be able to pass.*	🟩
0.6	***Partial barrier low impact:*** *the obstacle represents an impediment to the target species / life-stage, or species guild, but most of the population (e.g. > two-thirds) will pass eventually; or the obstacle is impassable for a proportion of the time (e.g. < one-third).*	🟨
0.3	***Partial barrier high impact:*** *the obstacle represents a significant impediment to the target species / life-stage, or species guild, but some of the population (e.g. < one-third) will pass eventually; or the obstacle is impassable for a significant proportion of the time (e.g. > two-thirds).*	🟧
0.0	***Complete barrier:*** *the target species / life-stage, or species guild cannot pass the obstacle.*	🟥

Trialling of the methodology for quantifying the impacts of obstacles to fish passage was carried out by SNIFFER in December 2010 (WFD111, 2010b). This showed the importance of using expert judgment to modify scores, particularly where less quantifiable hydraulic aspects such as disorientation due to turbulence provides the critical limiting factor to passability. Consequently, moderation of the passability scores using expert judgment is incorporated within the WFD111 methodology.

The variation in water depth and velocity over the weir during the range of discharge conditions, with and without the proposed hydropower scheme were provided by Renewables First using modelled data for the proposed abstraction regime. To determine the effect of the installation of the proposed hydropower scheme on the passability of the weir, the associated changes in water depth, velocity, and head loss were entered into the WFD111 assessment tool. To consider how passability of the weir may change with flow, the following passability scenarios were run through the WFD111 tool:

- Q_5 without proposed hydropower scheme (current baseline scenario);
- Q_5 with proposed hydropower scheme;
- Q_{50} without proposed hydropower scheme (current baseline scenario);
- Q_{50} with proposed hydropower scheme
- Q_{95} without proposed hydropower scheme (current baseline scenario);
- Q_{95} with proposed hydropower scheme.

Where the structure acts as a barrier, the key limiting factor or factors have been highlighted and, where necessary, expert judgment applied to moderate the score, particularly where scores were sensitive to small changes in measurements.

5.2 Fish passage assessment results

Physical parameters that are likely to vary with flow and affect the passability of Gunthorpe Weir are provided in Table 5-2.

These values comprise a mixture of hydraulic data measured during site visits, longer term monitoring (for downstream and upstream stage levels) and modelled data for the post-HEP scenario. These values, accompanied by the physical shape characteristics of the weir (informed from site measurements and historic construction drawings for the weir), were input into the WFD111 tool to estimate changes in passability under a variety of flow conditions, under both the current baseline scenario and following construction of the proposed HEP scheme.

Table 5-2. Physical parameters, likely to change with flow, input into the WFD111 passability assessment tool.

Physical parameter	Flow condition					
	Q_{95} without proposed hydropower scheme (current baseline scenario)	Q_{95} with proposed hydropower scheme	Q_{50} without proposed hydropower scheme (current baseline scenario)	Q_{50} with proposed hydropower scheme	Q_5 without proposed hydropower scheme (current baseline scenario)	Q_5 with proposed hydropower scheme
Total hydraulic head (m)	2.04	2.03	1.94	2.12	1.21	1.19
Water depth on weir crest (m)	0.18	0.08	0.30	0.22	0.78	0.73
Water velocity on weir crest (m/s)	1.34	0.86	1.72	1.48	2.77	2.68
Standing wave likely to restrict passage?	No	No	No	No	No	No
Level of turbulence at weir toe	Moderate	Moderate	High	High	High	High

The WFD111 results for the upstream passage assessment at Gunthorpe Weir for all scenarios are provided in Table 5-3. Under the current baseline conditions the weir is deemed to pose a complete barrier to the upstream migration of cyprinid species (e.g. dace, chub, barbel), and juvenile/adult eel. Passability for these species is limited by the head drop across each stepped section of the weir face (*ca*. 0.30 m) and shallow, high velocity flow conditions along the length of the weir face. The existing pool and traverse fish pass on the left side of the weir is also deemed impassable due to the head drop across each traverse significantly exceeding the maximum passage capability of each species.

The weir was deemed to be a partial barrier (high impact) for Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*). Passability at Q95 is limited by shallow flow associated with each step on the weir face and an absence of suitable resting locations between steps. The pool and traverse fish pass adjacent to the left bank was classified as a partial barrier (low impact) for upstream salmon and trout passage. Whilst the head drop across each individual traverse through this section exceeds the stepped structures on the main weir face, there are greater depths of water in the pool structures downstream of each traverse that provide conditions more conducive to upstream passage (i.e. permitting burst swimming and leaping).

Under the future scenario with the proposed inflatable weir crest installed, the weir remains impassable to cyprinids, eel and lamprey. Additionally, the weir is considered to pose a complete barrier to upstream passage for salmon and trout due to the addition of the inflatable weir crest which would be fully inflated under the Q95 and Q50 flows and deflated at the Q5 flow. This structure provides an additional traverse at the upstream end of the weir with an insufficient depth of water on the downstream approach which is likely to prevent fish from being able to successfully negotiate it. However, as part of the development it is proposed to construct a multi-species Larinier fish pass which adheres to EA best practice guidance and provides suitable hydraulic conditions for upstream passage under all three flow levels. Therefore, the overall site passability increases for migratory salmonids, resident trout and cyprinid species. In addition, a separate eel pass is proposed which would provide passage opportunity for juvenile (elver) and adult (yellow) eel, in addition to lamprey.

Table 5-3. Results from the WFD 111 assessment of Gunthorpe Weir for upstream migrating fish at Q95, Q50 and Q5 flow percentiles under the current arrangement (no HEP) and the future modelled scenario (HEP scheme operating).

Physical parameter	Flow condition					
	Q_{95} without proposed hydropower scheme (baseline)	Q_{95} with proposed hydropower scheme	Q_{50} without proposed hydropower scheme (baseline)	Q_{50} with proposed hydropower scheme	Q_{5} without proposed hydropower scheme (baseline)	Q_{5} with proposed hydropower scheme
Migratory salmonids (adult salmon & sea trout)	0.60	1.00	0.60	1.00	0.60	1.00
Resident brown trout adults	0.60	1.00	0.60	1.00	0.60	1.00
Cyprinids	0.00	1.00	0.00	1.00	0.00	1.00
Eels - elvers and yellow phase	0.00	1.00	0.00	1.00	0.00	1.00
Lamprey (adult)	0.00	1.00	0.00	1.00	0.00	1.00

6. Changes in upstream water level

The following section considers potential impacts of raising the upstream water level at Gunthorpe during low to moderate flows on aquatic and riparian habitats and geomorphological processes.

6.1 Overview of hydraulic changes

The proposed HEP scheme includes the construction of an additional structure on the crest of Gunthorpe weir that can be inflated at certain flows to increase the hydraulic head at the site. Under the current proposals the additional weir crest would be fully inflated at a flow of Q99 up to Q41 and partially inflated thereafter up to a flow of Q9. At flows exceeding Q9 the weir crest would be fully deflated in order to minimise impacts on flood risk.

A comparison of the change in upstream water level as a result of the proposed inflatable weir crest compared to the current arrangement is provided in Figure 6-1.

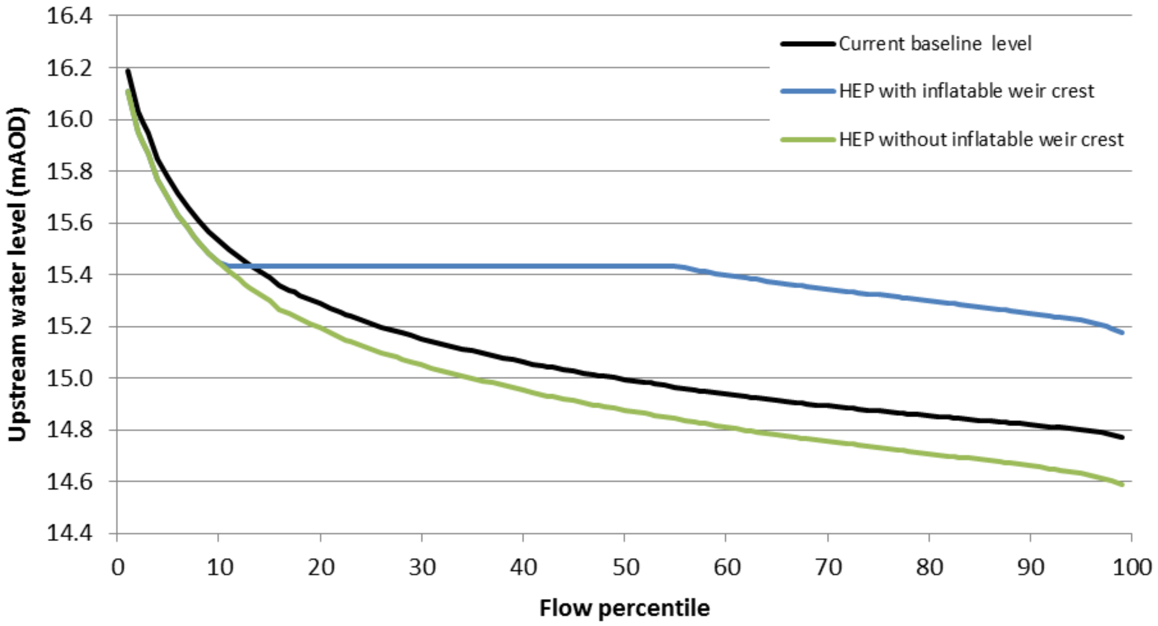


Figure 6-1. The upstream water level at Gunthorpe under the current operating arrangement and following construction of the HEP with and without the inflatable weir crest.

A summary of the change in upstream water levels at key exceedance values is provided in Table 6-1.

Table 6-1. A summary of changes in the upstream water level following the addition of the inflatable weir crest alongside the proposed HEP scheme at Gunthorpe.

Flow percentile	Upstream water level – baseline (mAOD)	Upstream water level - HEP (mAOD)	Change (m)
Q95	14.94	15.26	+0.32
Q70	15.03	15.37	+0.34
Q50	15.13	15.48	+0.35
Q20	15.37	15.54	+0.18
Q10	15.57	15.54	-0.03

The largest increase in upstream water level is predicted to occur under low to moderate flow conditions of Q85 – Q35, where a 0.32 – 0.36 m increase in the upstream water level is predicted. At high flow conditions (>Q9) the weir crest would be fully deflated and the upstream water level would be reduced marginally compared to the current arrangement due to the additional conveyance capacity of the HEP scheme.

6.2 Assessment of impacts

Ecology

The River Trent upstream of Gunthorpe weir is heavily modified; comprising a deepened river channel and hard engineered bank protection. Sheet piling extends for a length of *ca.* 320 m along the left river bank upstream of the weir. Surface flow in the reach between Gunthorpe weir and the next structure upstream (Stoke weir) is deep and slow flowing due to the impounding effect of Gunthorpe weir. Consequently, the river channel in this section comprises almost exclusively of deep, low velocity glide and pool surface flow types. Raising the upstream water level would lead to an increase in mean water depth upstream of the weir and a very marginal reduction in mean channel velocities under low to moderate flow conditions. From a fisheries perspective, however, the channel character would not change significantly compared to the current baseline scenario and therefore no significant changes to the extent and functionality of fish habitat in the main River Trent channel would be expected.

There are several smaller waterbodies that flow into the River Trent between Gunthorpe and Stoke weirs, two of which are encompassed within the Trent from Soar to The Beck WFD waterbody, and two that form separate WFD waterbodies – the Cocker Beck catchment (GB104028053290) and the Shelford Brook catchment (GB104028053110). There is the potential that increasing water levels may result in backing-up of water levels into these tributaries at low to moderate flows, causing impoundment and a reduction in flow diversity. The overall extent of any impact is likely to be relatively small, however, given the 0.36 m maximum increase in water level. On a tributary with a bed gradient of 0.2 %, for example, the backwater effect would extend for a length of *ca.* 180 m upstream of any existing backwater effects present under the baseline scenario.

The presence of water vole (*Arvicola amphibious*) and otter (*Lutra lutra*) in proximity to Gunthorpe weir is currently unknown, although surveys have been commissioned to identify potential signs of activity. Water vole burrows typically comprise of one or more submerged entrances below low water level, progressing up to a number of chambers used for nesting and food storage. The chambers are dry environments which are set above high (flood) water level to prevent inundation from the river (Water Vole Species Action Plan, 2000). The addition of the inflatable weir crest would only increase the water level of low to medium flows and would not increase the maximum water level at the site (instead it would be marginally reduced compared to the current regime when the HEP scheme is abstracting water). Accordingly, no significant impacts on water vole populations (if present) are anticipated.

Otter burrows (holts) may be constructed within river banks, although they are often set back a short distance from the waters edge. For example, during a study of otter populations on the River Severn, Coghill (1980) identified the majority of holts as being within 10 m of the waters edge, although some were as far as 50 m away. Regardless of the exact location, chambers within holt networks are predominantly dry environments which are positioned at an elevation above flood water levels (Chanin, 2003) and so impacts on these refuges from the inflatable weir crest are not anticipated. In addition, given that no significant impacts on fish populations in the upstream reaches are anticipated, there is unlikely to be an impact on the availability of food sources for any populations of otter that are present in the reach upstream of Gunthorpe.

Geomorphology

Under current conditions, Gunthorpe weir is likely to inhibit downstream transport of coarse sediment which is most relevant from the standpoint of channel form adjustment. Coarse sediment fractions typically move as bedload through rolling, sliding or saltation along the channel bed in a shallow zone only a few grain diameters thick. Gunthorpe weir therefore acts as a physical barrier to these transport mechanisms and, more importantly, reduces transport capacity of the flow upstream by reducing water surface slope. Raising the weir will result in a further reduction in water surface slope and, therefore, transport capacity, with possible consequences for coarse sediment transport across the weir. However, such impacts are likely to be negligible in the context of current conditions.

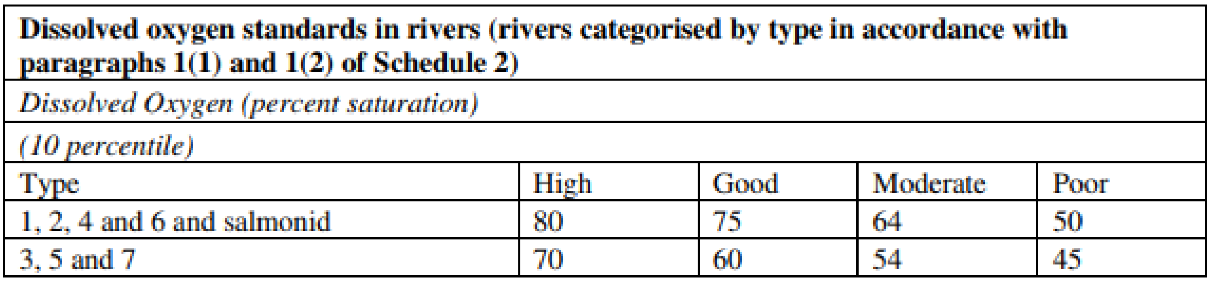
Moreover, the majority of bed load transport occurs during infrequent, high magnitude flow events (Simons *et al*., 1979; Kondolf, 1994), with the initiation of motion of coarse sediment fractions typically occurring at flows greater than Q50 (Knighton, 1998). Given that the additional weir crest at Gunthorpe will be partially deflated at flows between Q41 and Q9, and fully deflated at flows greater than Q9, the impacts of the weir modifications on sediment transport during geomorphologically significant events is likely to be minimal.

7. Dissolved oxygen

The following sections detail the DO requirements for fish species populating the River Trent at Gunthorpe and provides an assessment of the proposed scheme on DO concentrations downstream of the weir.

Classification boundaries for DO are published in The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 and are reproduced in Table 7-1. The classification boundaries are based on 10th percentile values – i.e. a monitoring location must exceed a given value for 90 % of the monitoring period.

Table 7-1. WFD classifications for DO standards. Source: The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015. The River Trent at Gunthorpe is classified under Type 3/5/7 and therefore the bottom row of standards apply.



Dissolved oxygen standards in rivers (rivers categorised by type in accordance with paragraphs 1(1) and 1(2) of Schedule 2)				
Dissolved Oxygen (percent saturation)				
(10 percentile)				
Type	High	Good	Moderate	Poor
1, 2, 4 and 6 and salmonid	80	75	64	50
3, 5 and 7	70	60	54	45

7.1 Ecological oxygen requirements

Fish

Individual fish species display varying requirements in relation to dissolved oxygen concentrations. As a general rule, salmonid species (e.g. salmon, trout) frequent cooler waters and require higher concentrations of DO than cyprinid fish species in warmer lowland waterbodies. The distinction of DO between fish species groups is reflected in the WFD DO standards for rivers, with upload salmonid rivers being assigned higher standards for a given threshold than lowland cyprinid rivers such as the Trent.

Concentrations below 5 mg/L were previously shown to produce adverse impacts on coarse fish populations (Nash et al. 2003), whilst Mann (1996) suggests that minimum concentrations of 6 mg/L at 10°C (equivalent to 53 % saturation) are sufficient to maintain healthy coarse fish populations. Therefore, it is suggested that a conservative threshold for coarse fish species on the Trent would be a DO concentration which remains above 60 % saturation (equivalent to Good WFD status). At 10°C this equates to a concentration of approximately 6.7 mg/L.

Invertebrates

Different macroinvertebrate taxa have different tolerances to oxygen concentration, and the basis of the WHPT scoring system used in WFD assessment is this differential tolerance, with taxa that can live in low oxygen concentrations having lower scores than those that require high concentrations. The WHPT system itself derives from previous assessments of organic pollution impact; it acknowledges that certain macroinvertebrates are extremely tolerant of reduced oxygen conditions, and that many groups are air breathers or have other adaptations that enable them to thrive in these conditions. Therefore mere presence of macroinvertebrates per se gives no indication of impact, and the actual composition of the community needs to be examined in order to determine whether there is an impact. The WFD classification is based on overall taxon richness and average score per taxon, and this latter metric effectively determines overall sensitivity to oxygen concentration. Therefore WFD class can be a useful indicator of potential oxygen stress on the community.

7.2 Assessment of DO concentrations

Dissolved oxygen saturations from monitoring undertaken by the EA immediately upstream of Gunthorpe Weir (NGR SK6821043757) in 2017 and 2018 are provided in Figure 7-1. Over the monitoring period DO saturation has ranged from a low of 82 % (June 2017) up to 102 % (June 2017). Throughout the period saturations have been consistent with High WFD status (>70 % saturation), which would represent an increase on the current WFD status.

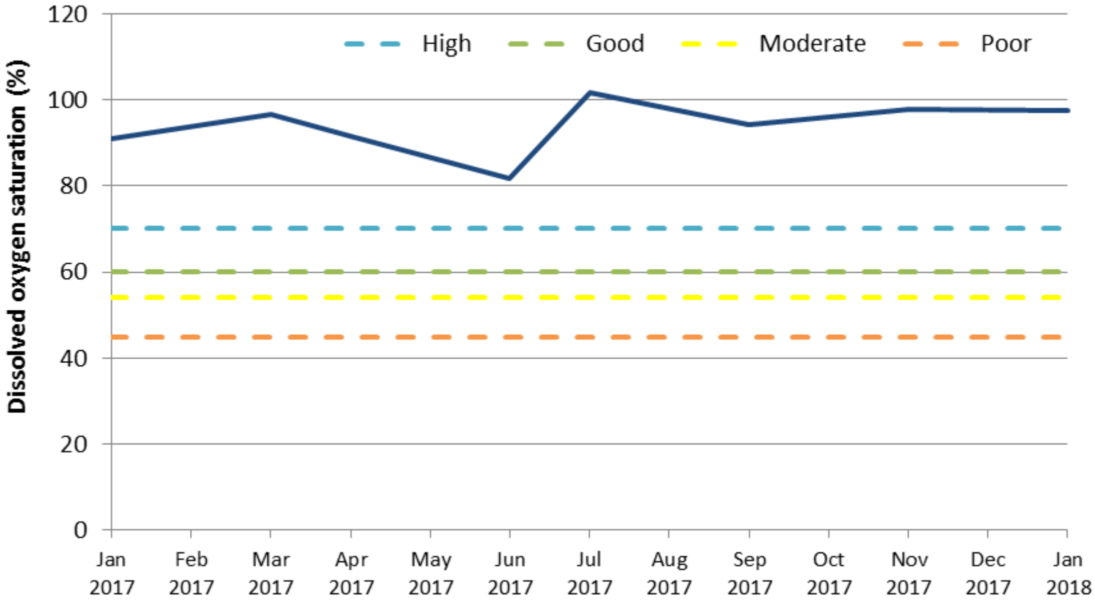


Figure 7-1. Dissolved oxygen saturations measured by the EA on the River Trent at Gunthorpe in 2017 and 2018 in relation to WFD classification thresholds.

The recent monitoring data indicates that DO concentrations in the River Trent have been well in excess of the threshold for the current Good WFD status. The proportion of flow passing over the weir would reduce following installation of the HEP scheme, although it should be noted that given the small abstraction (20 m^3/s) in relation to Qmean (87 m^3/s), the majority of flow at the site would still pass over the weir crest and be potentially subject to marginally greater re-oxygenation compared to the current scenario due to an increase in head across the weir.

Therefore, it is considered highly unlikely that the scheme would cause a material adverse impact on DO concentrations at the site and no deterioration in the WFD status of the physicochemical element of the Trent waterbody would be expected. Additionally, based on the DO thresholds established for fish and invertebrate populations, impacts on these two ecological receptors are not anticipated.

8. Conclusions

8.1 Weir Pool Geomorphology

Overall, the modelling results indicate a limited change in entrainment and transport of material at the majority of locations. However, there is a possible impact from the tailrace discharge on the right hand bank a short distance downstream of Gunthorpe weir, which coincides with the narrow gravel shoal and mudstone cliff face. Given that the cliff face is composed of readily erodible sedimentary mudstone, it could be at risk of increased erosion if it is exposed to hydraulic action and elevated shear stress imparted by the turbine flow. Such events would be restricted to flows of Q10 or above, when the downstream water level reaches the base of the cliff.

Erosion of the beach feature and cliff face may lead to further morphological adjustments downstream where eroded sediment is deposited. As such, some form of scour protection may be advisable at this location to minimise risk of morphological changes. Alternatively, consideration could be given to reducing the rate of abstraction above Q10 (when the base of the cliff starts to become wetted), to minimise the risk of erosion.

8.2 Fish habitat

The fish habitat assessment focused on potential impacts to adult, juvenile and spawning life stages of rheophilic coarse fish species and roach, as well as spawning lamprey established as the key species and life stages of concern during discussions with the EA.

Overall, the habitat assessment indicates that the proposed HEP scheme would result in a decrease in areas of suitable habitat for rheophilic and lamprey spawning at low flows (Q95/Q75), which is driven primarily by changes in velocity associated with the reduced flow over the weir. However, this is partly offset for rheophilic spawning species by predicted increases in suitability at moderate flows (Q50 – Qmean). Similarly, the scheme is likely to reduce the suitability of the weir pool for adult rheophilic species at low flows (Q95), but would remain largely unchanged at all other flows.

The HEP scheme is predicted to result in an increase in areas of suitable habitat for both juvenile rheophilic species and adult and juvenile roach relative to baseline, due to a reduction in mean velocities outside of the main HEP plume. No significant changes in roach spawning habitat or juvenile lamprey habitat are anticipated given an absence of such habitat under the current conditions.

8.3 Fish Passage

Gunthorpe Weir is currently deemed a complete barrier to the upstream passage of cyprinid species and eel due to excessive head drops and high velocities over the weir face and a low impact barrier to salmon and sea trout via the existing pool and traverse fish pass. Despite a reduction in the passability of the main weir structure due to the addition of an inflatable weir crest associated with the HEP scheme, the overall upstream passability at the site would increase significantly following construction of the HEP scheme due to the addition of a multi-species fish pass adhering to EA (2010) best practice guidance.

8.4 Changes in upstream water level

The proposed HEP scheme includes provision of an additional inflatable weir crest to raise the upstream water level by 0.32 – 0.36 m during low to moderate flows. The increase is not expected to significantly alter the character of the upstream river channel given the occurrence of low velocity glide/pool flow under the current baseline conditions.

The addition of the inflatable weir crest would not increase the maximum high water level under high flow events and thus impacts on water vole or otter populations (e.g. due to inundation of burrows) are not anticipated. The increase in upstream water levels has the potential to create a backwater effect on several tributaries of the River Trent between Gunthorpe and Stoke weirs which are designated as main rivers by the EA and encompassed within the ‘Trent from Soar to The Beck’ WFD waterbody or separate waterbodies (e.g. Cocker Beck, Shelford Brook). The extent of any impacts on these tributaries is likely to be relatively small given the maximum 0.46 m increase in water levels.
The proposed increase in weir crest height is unlikely to have a substantial impact on coarse sediment transport processes which are of most importance in influencing channel morphology. This is because the existing structure at Gunthorpe is likely to inhibit the majority of downstream sediment transport, and because the weir crest will not be raised during high flows (>Q9) which are responsible for the majority of coarse sediment transport.

8.5 Dissolved oxygen

EA monitoring of DO at Gunthorpe indicates that levels have been consistent with high status during 2017 and 2018. Due to the recent DO concentrations and low HEP abstraction relative it is considered highly unlikely that the scheme would cause a material adverse impact on DO concentrations at the site and no deterioration in the WFD status of the physicochemical element of the Trent waterbody would be expected. . Additionally, adverse impacts on fish and invertebrates are not anticipated.

8.6 Cumulative impacts

In addition to the HEP scheme at Gunthorpe, a further two schemes are proposed in close proximity at Stoke and Hazelford on the River Trent (see Figure 1-3). Potential fisheries and geomorphology assessment impacts have been considered at each site through the production of individual assessment reports. Consideration of cumulative impacts (or benefits) associated with the construction of all four schemes in parallel is assessed within a separate technical note.

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Appendix 1 - Geomorphology

Table 1. Change in boundary shear stress between baseline and proposed conditions at sediment sample points. Red cells indicate an increase; green cells indicate a decrease.

	Change in boundary shear stress (N m^{-2})					% change in boundary shear stress				
Point ID	Q95	Q75	Q50	Qmean	Q5	Q95	Q75	Q50	Qmean	Q5
G01	9.26	9.42	8.34	5.74	1.71	4434.86	3177.30	2085.57	901.30	342.20
G02	-	-	-	-	-	-	-	-	-	-
G03	-1.13	-1.50	-1.71	-2.28	-0.75	-97.70	-90.43	-73.62	-65.27	-11.35
G04	-	-	-	-	-	-	-	-	-	-
G05	-2.56	-3.52	-3.68	-3.63	-2.04	-94.15	-82.74	-59.04	-42.71	-13.12
G06	5.00	4.80	4.05	2.75	-1.81	757.95	522.77	344.09	187.86	-44.45
G07	3.95	2.83	0.39	-1.25	-0.67	300.86	158.59	17.21	-42.37	-10.23
G08	-0.71	-0.85	-0.93	-1.20	-0.49	-92.92	-72.52	-48.83	-42.05	-6.56
G09	-5.01	-6.82	-7.95	-7.07	-2.16	-95.35	-85.45	-66.70	-47.83	-8.63
G10	-0.82	0.11	1.99	1.45	-0.14	-72.83	6.62	79.23	44.42	-2.22
G11	-0.16	-0.91	-1.21	-1.60	-0.28	-14.73	-53.71	-43.74	-39.73	-2.98
G12	-0.30	-0.34	-0.50	-0.70	-0.06	-68.72	-38.68	-23.54	-16.58	-0.42
G13	-0.40	-0.34	0.55	0.50	-0.04	-99.73	-44.93	37.39	21.13	-0.69
G14	1.07	0.12	-0.63	-0.97	0.04	144.16	10.02	-32.22	-32.29	0.54
G15	-	-	-	-	-	-	-	-	-	-
G16	-	-	-	-	-	-	-	-	-	-
G17	-	-	-	-	-	-	-	-	-	-
G18	0.00	0.00	0.00	0.00	0.00	32.51	-85.21	-90.02	-84.05	-16.73

Table 2. Critical shear stress calculated using Shields parameter = 0.06 and modelled boundary shear stress at sediment sample points. Red cells indicate $\tau_0 > \tau_{cr}$; green cells = $\tau_0 < \tau_{cr}$; yellow = $\tau_0 = \tau_{cr}$ ±0.5.

			Shear stress (N m^{-2}) - Baseline					Shear stress (N m^{-2}) - Proposed				
Point ID	D$_{50}$ (mm)	τ_{cr} (N m^{-2})	Q95	Q75	Q50	Qmean	Q5	Q95	Q75	Q50	Qmean	Q5
G01	1.89	1.83	0.21	0.30	0.40	0.64	0.50	9.47	9.71	8.74	6.38	2.20
G02	-	-	-	-	-	-	-	-	-	-	-	-
G03	32.22	31.30	1.15	1.65	2.33	3.50	6.63	0.03	0.16	0.61	1.21	5.88
G04	-	-	-	-	-	-	-	-	-	-	-	-
G05	26.53	25.77	2.72	4.26	6.23	8.50	15.57	0.16	0.73	2.55	4.87	13.53
G06	1.92	1.87	0.66	0.92	1.18	1.47	4.07	5.66	5.72	5.22	4.22	2.26
G07	15.84	15.38	1.31	1.79	2.28	2.95	6.53	5.26	4.62	2.68	1.70	5.87
G08	67.80	65.84	0.77	1.18	1.90	2.85	7.48	0.05	0.32	0.97	1.65	6.99
G09	28.34	27.53	5.25	7.98	11.92	14.79	24.99	0.24	1.16	3.97	7.72	22.83
G10	40.50	39.33	1.13	1.73	2.51	3.26	6.33	0.31	1.85	4.49	4.71	6.19
G11	53.40	51.86	1.07	1.69	2.76	4.02	9.47	0.92	0.78	1.55	2.42	9.18
G12	34.40	33.41	0.43	0.88	2.11	4.23	14.73	0.14	0.54	1.62	3.53	14.67
G13	34.61	33.61	0.40	0.76	1.48	2.39	6.39	0.00	0.42	2.03	2.89	6.35
G14	28.27	27.46	0.74	1.17	1.95	3.00	8.20	1.81	1.28	1.32	2.03	8.25
G15	-	-	-	-	-	-	-	-	-	-	-	-
G16	-	-	-	-	-	-	-	-	-	-	-	-
G17	19.16	18.61	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
G18	34.35	33.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3. Critical shear stress calculated using Shields parameter = 0.08 and modelled boundary shear stress at sediment sample points. Red cells indicate $\tau_0 > \tau_{cr}$; green cells = $\tau_0 < \tau_{cr}$; yellow = $\tau_0 = \tau_{cr}$ ±0.5.

			Shear stress (N m^{-2}) - Baseline					Shear stress (N m^{-2}) - Proposed				
Point ID	D_{50} (mm)	τ_{cr} (N m^{-2})	Q95	Q75	Q50	Qmean	Q5	Q95	Q75	Q50	Qmean	Q5
G01	1.89	2.44	0.21	0.30	0.40	0.64	0.50	9.47	9.71	8.74	6.38	2.20
G02	-	-	-	-	-	-	-	-	-	-	-	-
G03	32.22	41.73	1.15	1.65	2.33	3.50	6.63	0.03	0.16	0.61	1.21	5.88
G04	-	-	-	-	-	-	-	-	-	-	-	-
G05	26.53	34.36	2.72	4.26	6.23	8.50	15.57	0.16	0.73	2.55	4.87	13.53
G06	1.92	2.49	0.66	0.92	1.18	1.47	4.07	5.66	5.72	5.22	4.22	2.26
G07	15.84	20.51	1.31	1.79	2.28	2.95	6.53	5.26	4.62	2.68	1.70	5.87
G08	67.80	87.79	0.77	1.18	1.90	2.85	7.48	0.05	0.32	0.97	1.65	6.99
G09	28.34	36.70	5.25	7.98	11.92	14.79	24.99	0.24	1.16	3.97	7.72	22.83
G10	40.50	52.44	1.13	1.73	2.51	3.26	6.33	0.31	1.85	4.49	4.71	6.19
G11	53.40	69.15	1.07	1.69	2.76	4.02	9.47	0.92	0.78	1.55	2.42	9.18
G12	34.40	44.54	0.43	0.88	2.11	4.23	14.73	0.14	0.54	1.62	3.53	14.67
G13	34.61	44.82	0.40	0.76	1.48	2.39	6.39	0.00	0.42	2.03	2.89	6.35
G14	28.27	36.61	0.74	1.17	1.95	3.00	8.20	1.81	1.28	1.32	2.03	8.25
G15	-	-	-	-	-	-	-	-	-	-	-	-
G16	-	-	-	-	-	-	-	-	-	-	-	-
G17	19.16	24.81	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
G18	34.35	44.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4. Percentage of sample sites where D_{50} is above, below or at the calculated threshold of motion.

		Percentage of sites – Baseline					Percentage of sites – Proposed				
		Q95	Q75	Q50	Qmean	Q5	Q95	Q75	Q50	Qmean	Q5
θ = 0.06	Above	0	0	0	0	7	14	14	14	14	0
	Threshold	0	0	0	7	0	0	0	0	0	14
	Below	100	100	100	93	93	86	86	86	86	86
θ = 0.08	Above	0	0	0	0	7	14	14	14	14	0
	Threshold	7	7	7	7	7	7	7	7	7	21
	Below	93	93	93	93	86	79	79	79	79	79

Table 5. Critical grain size at sediment sample points calculated using Shields parameter = 0.06.

	Critical grain size (mm) – Baseline					Critical grain size (mm) – Proposed				
Point ID	Q95	Q75	Q50	Qmean	Q5	Q95	Q75	Q50	Qmean	Q5
G01	0.21	0.31	0.41	0.66	0.51	9.75	10.00	8.99	6.57	2.27
G02	-	-	-	-	-	-	-	-	-	-
G03	1.19	1.70	2.40	3.60	6.83	0.03	0.16	0.63	1.25	6.05
G04	-	-	-	-	-	-	-	-	-	-
G05	2.81	4.38	6.41	8.76	16.03	0.16	0.76	2.63	5.02	13.93
G06	0.68	0.95	1.21	1.51	4.19	5.82	5.89	5.38	4.34	2.33
G07	1.35	1.84	2.35	3.04	6.73	5.42	4.75	2.75	1.75	6.04
G08	0.79	1.21	1.95	2.94	7.70	0.06	0.33	1.00	1.70	7.20
G09	5.41	8.21	12.27	15.23	25.73	0.25	1.20	4.09	7.95	23.51
G10	1.16	1.78	2.58	3.36	6.51	0.32	1.90	4.62	4.85	6.37
G11	1.11	1.74	2.84	4.14	9.75	0.94	0.81	1.60	2.49	9.46
G12	0.45	0.90	2.18	4.36	15.17	0.14	0.55	1.66	3.63	15.10
G13	0.41	0.78	1.52	2.46	6.58	0.00	0.43	2.09	2.98	6.53
G14	0.76	1.20	2.01	3.09	8.44	1.86	1.32	1.36	2.09	8.49
G15	-	-	-	-	-	-	-	-	-	-
G16	-	-	-	-	-	-	-	-	-	-
G17	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
G18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6. Critical grain size at sediment sample points calculated using Shields parameter = 0.08.

	Critical grain size (mm) – Baseline					Critical grain size (mm) – Proposed				
Point ID	Q95	Q75	Q50	Q25	Q5	Q95	Q75	Q50	Q25	Q5
G01	0.16	0.23	0.31	0.49	0.38	7.31	7.50	6.75	4.93	1.70
G02	-	-	-	-	-	-	-	-	-	-
G03	0.89	1.28	1.80	2.70	5.12	0.02	0.12	0.47	0.94	4.54
G04	-	-	-	-	-	-	-	-	-	-
G05	2.10	3.29	4.81	6.57	12.02	0.12	0.57	1.97	3.76	10.45
G06	0.51	0.71	0.91	1.13	3.14	4.37	4.42	4.03	3.26	1.74
G07	1.01	1.38	1.76	2.28	5.05	4.06	3.57	2.07	1.31	4.53
G08	0.59	0.91	1.46	2.20	5.78	0.04	0.25	0.75	1.28	5.40
G09	4.06	6.16	9.20	11.42	19.30	0.19	0.90	3.06	5.96	17.63
G10	0.87	1.34	1.94	2.52	4.89	0.24	1.43	3.47	3.64	4.78
G11	0.83	1.31	2.13	3.10	7.31	0.71	0.61	1.20	1.87	7.09
G12	0.33	0.68	1.63	3.27	11.37	0.10	0.42	1.25	2.73	11.33
G13	0.31	0.59	1.14	1.84	4.93	0.00	0.32	1.57	2.23	4.90
G14	0.57	0.90	1.51	2.32	6.33	1.39	0.99	1.02	1.57	6.37
G15	-	-	-	-	-	-	-	-	-	-
G16	-	-	-	-	-	-	-	-	-	-
G17	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
G18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

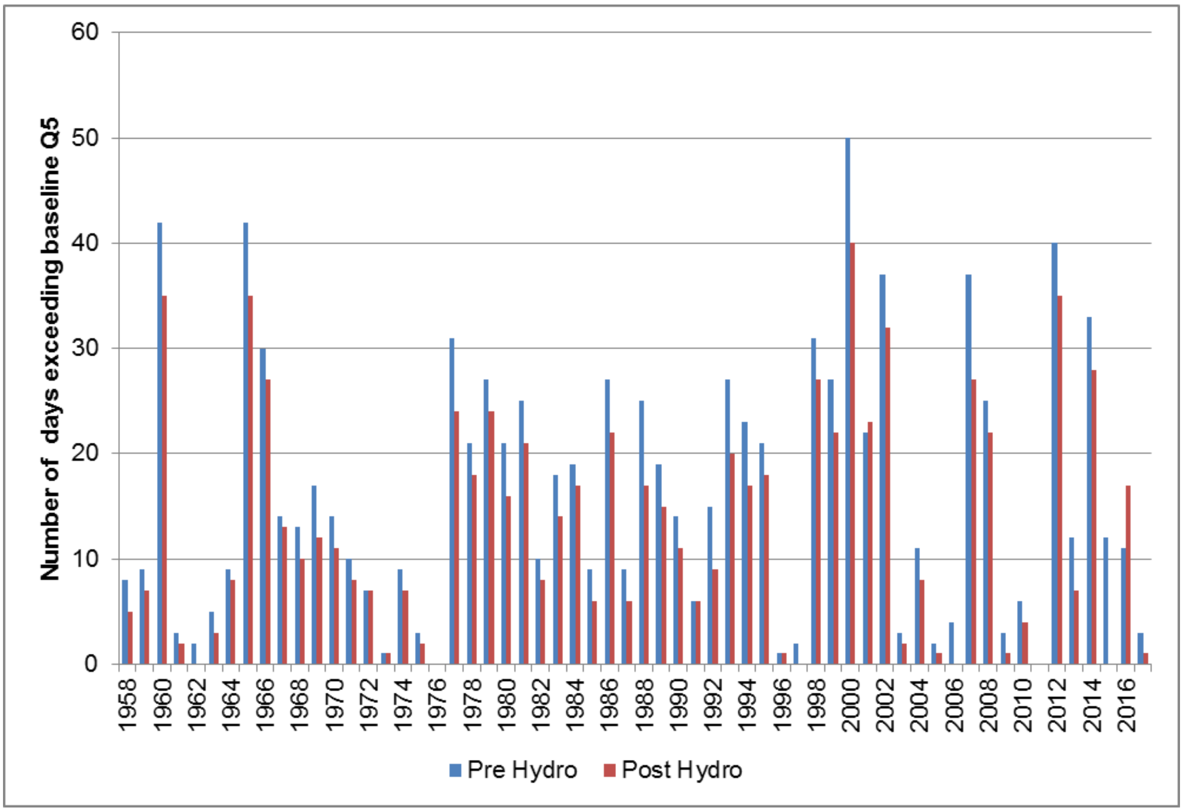


Figure 1 Number of days exceeding baseline Q5 under baseline and proposed conditions at the River Trent at Gunthorpe weir (using flow data from NRFA gauge number 28009 scaled by catchment area).

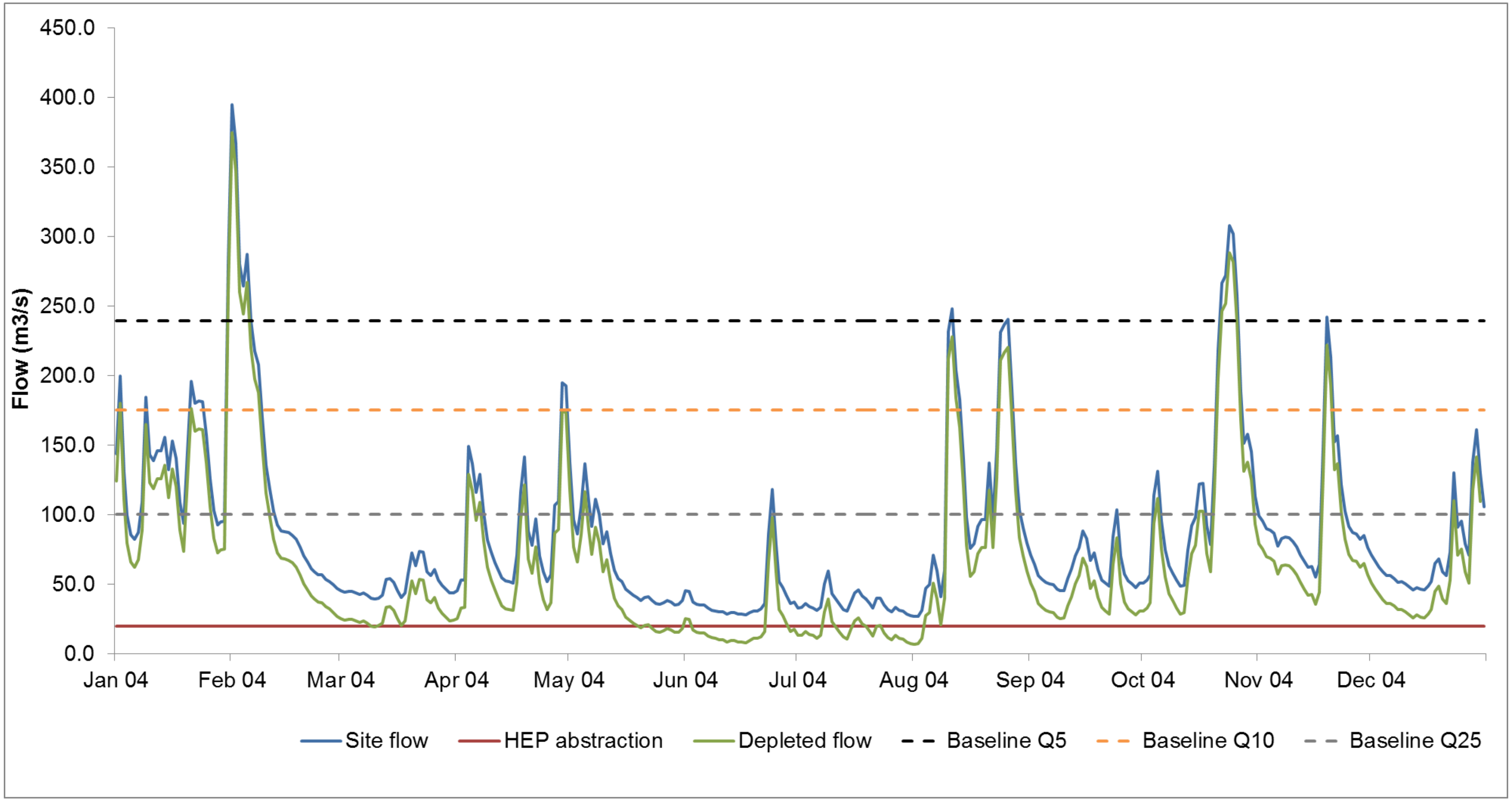
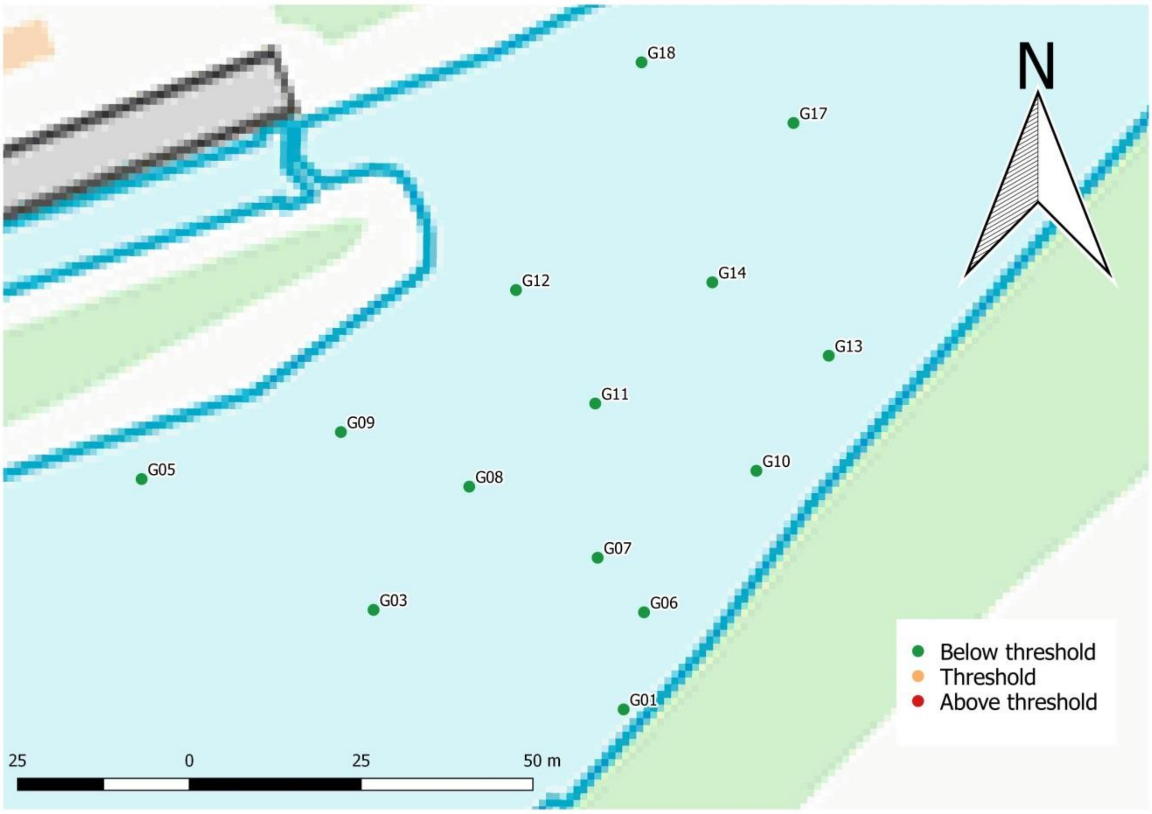
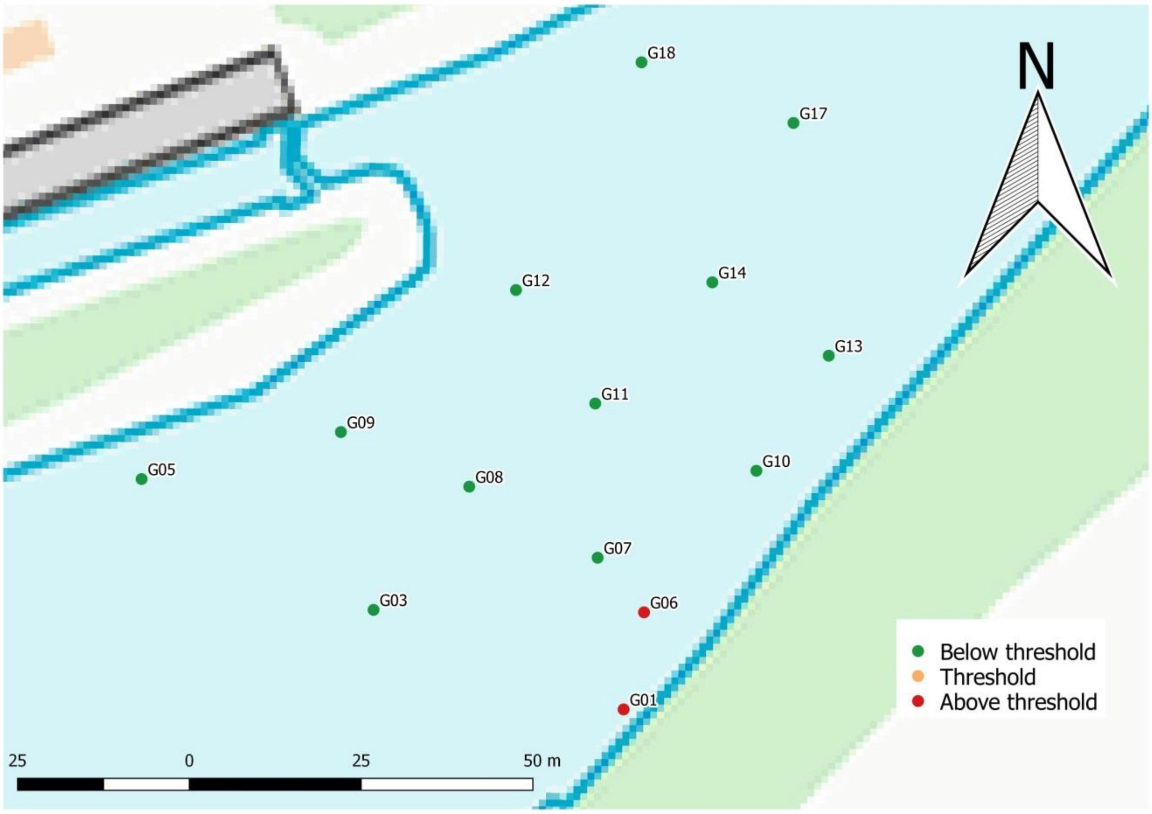


Figure 3. Hydrograph for a representative year (2004) showing the impact of the abstraction on flows in the depleted reach.

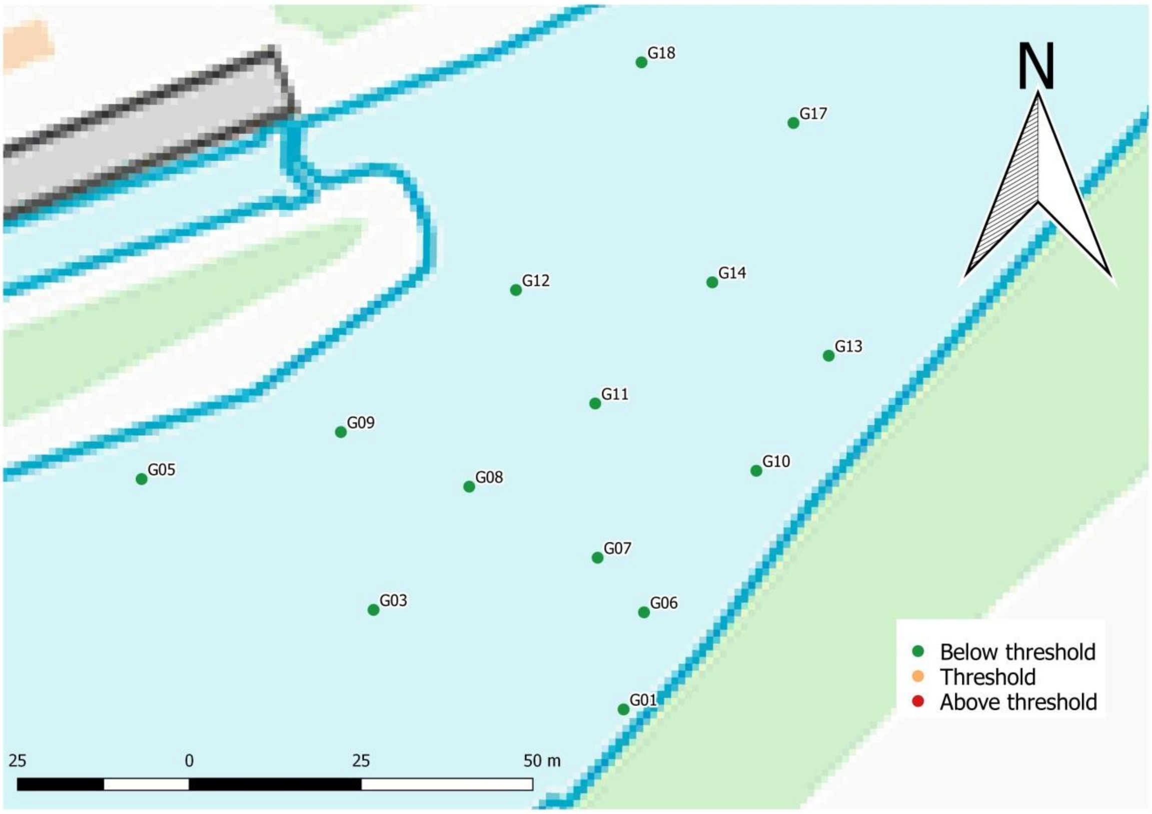
Q95 – current baseline scenario **Shields parameter = 0.06**



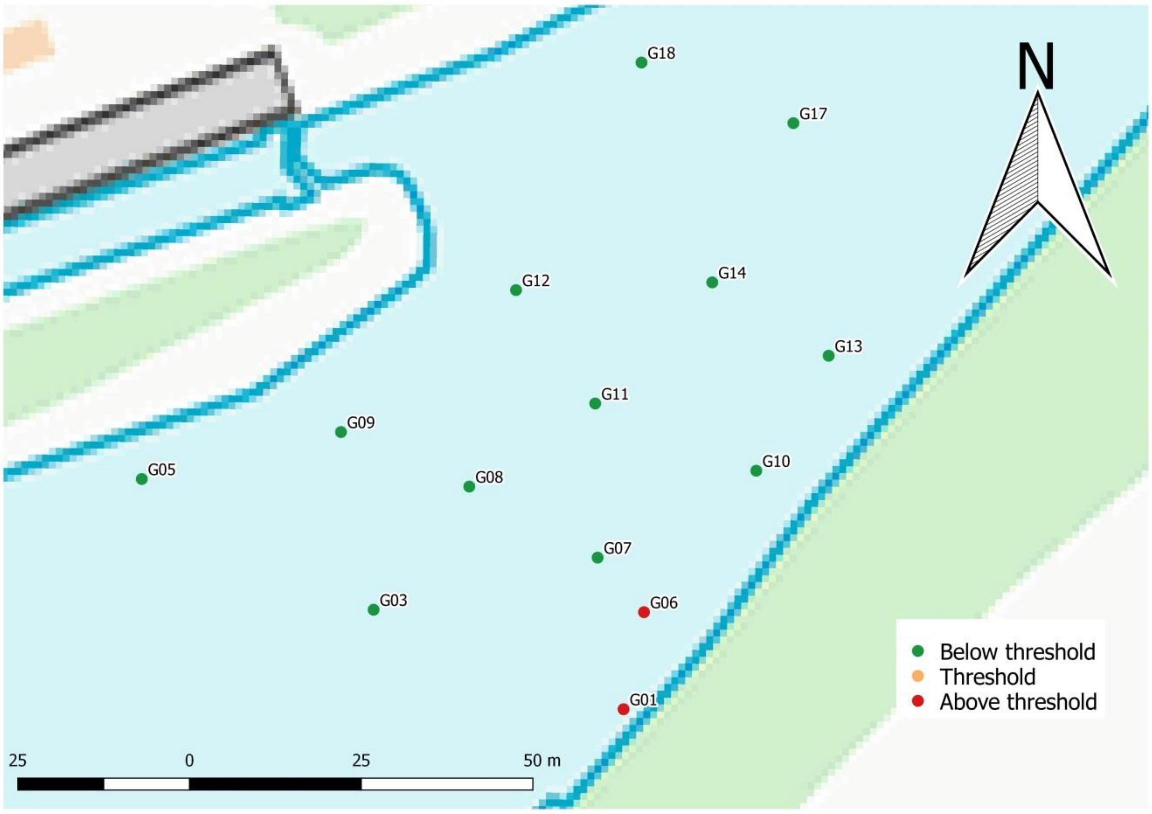
Q95 – future HEP scenario **Shields parameter = 0.06**



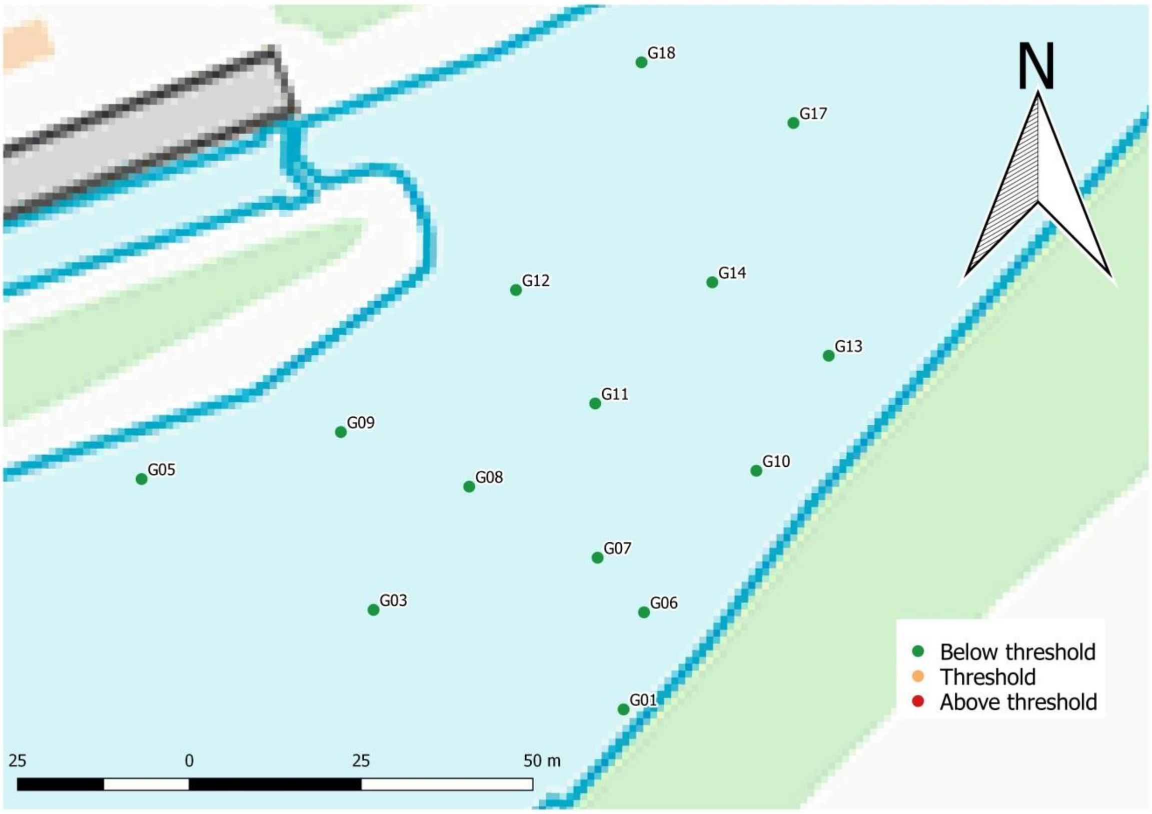
Q75 – current baseline scenario **Shields parameter = 0.06**



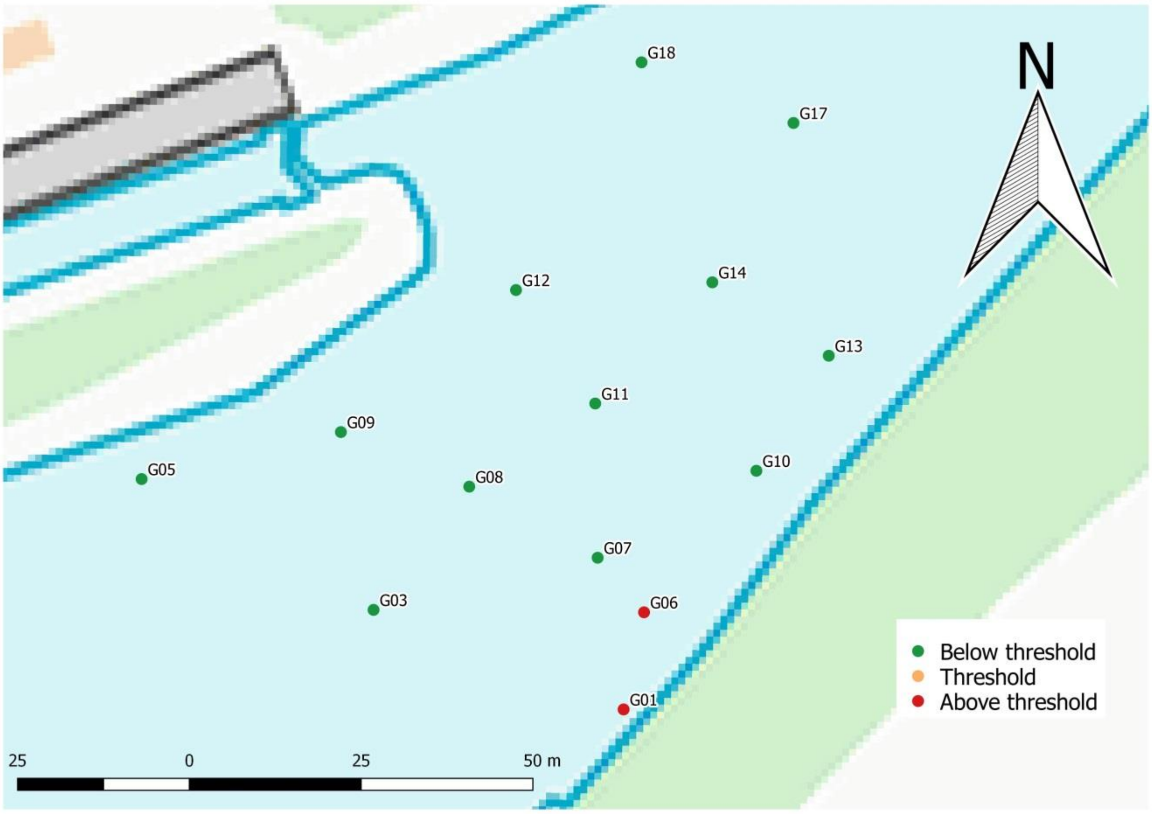
Q75 – future HEP scenario **Shields parameter = 0.06**



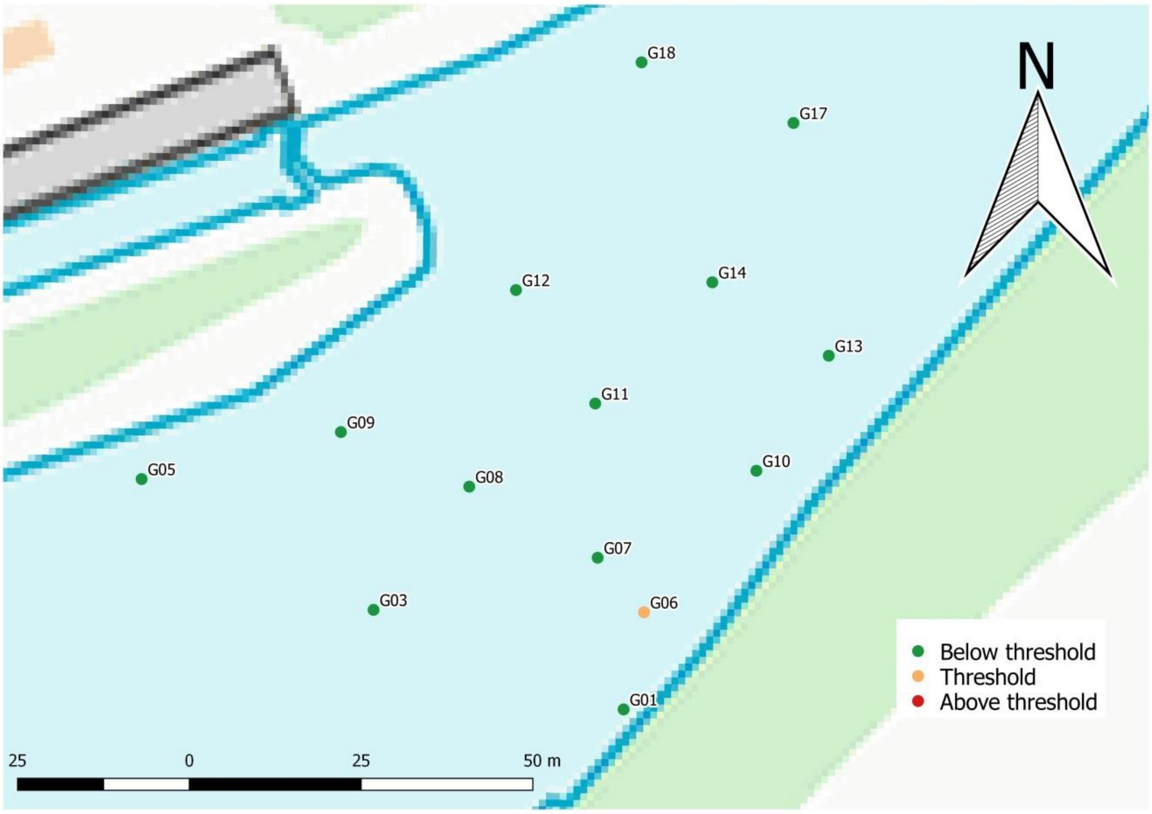
Q50 – current baseline scenario **Shields parameter = 0.06**



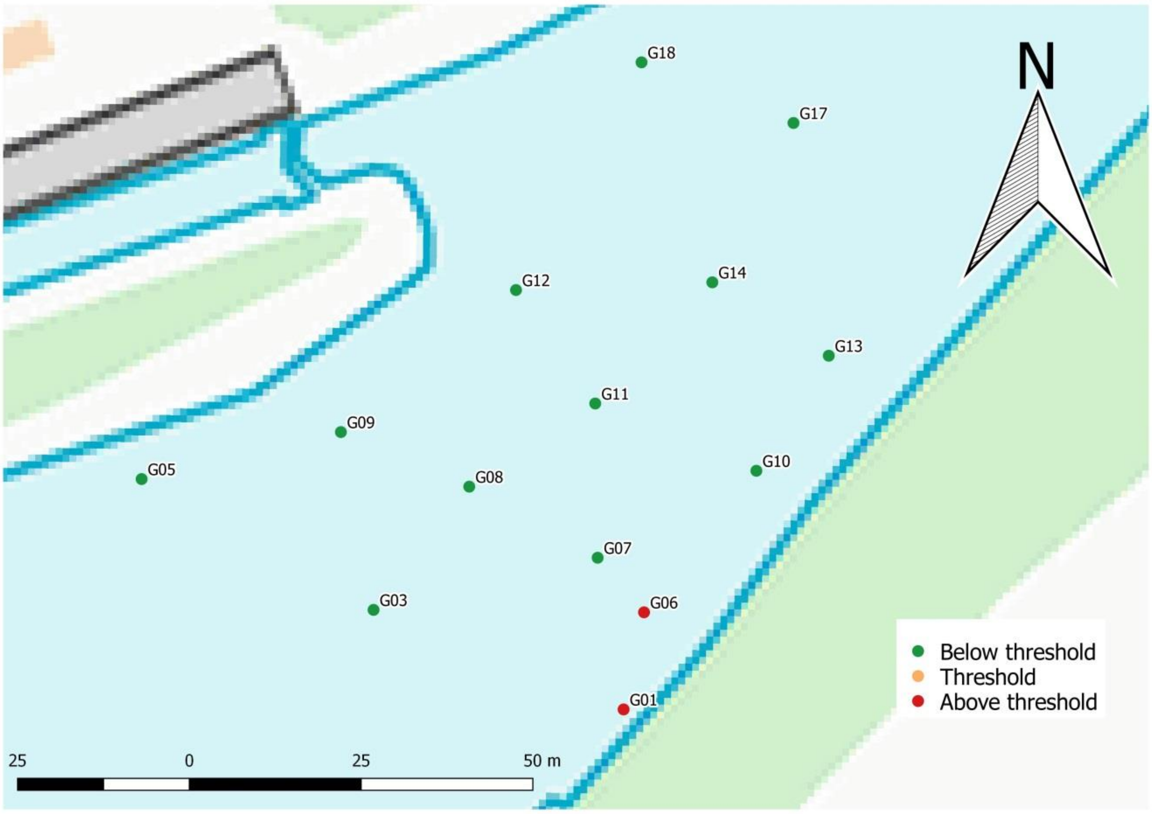
Q50 – future HEP scenario **Shields parameter = 0.06**



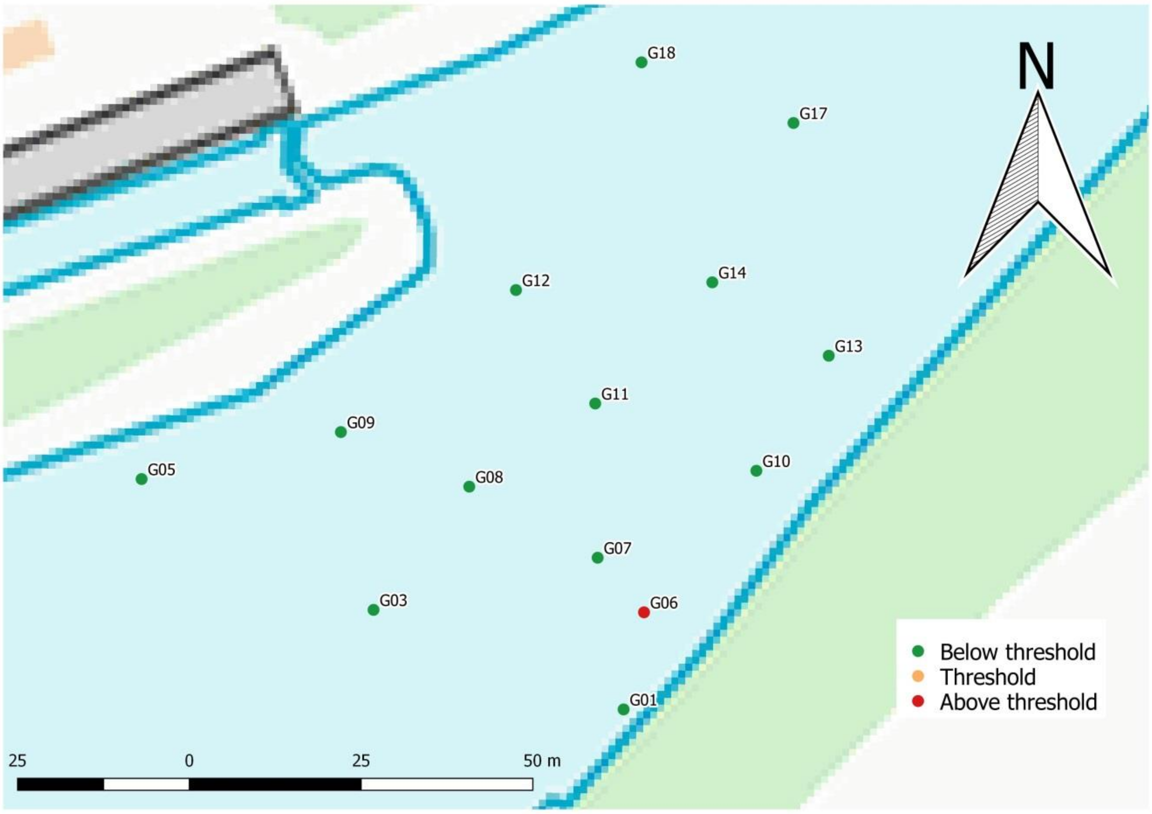
Qmean – current baseline scenario **Shields parameter = 0.06**



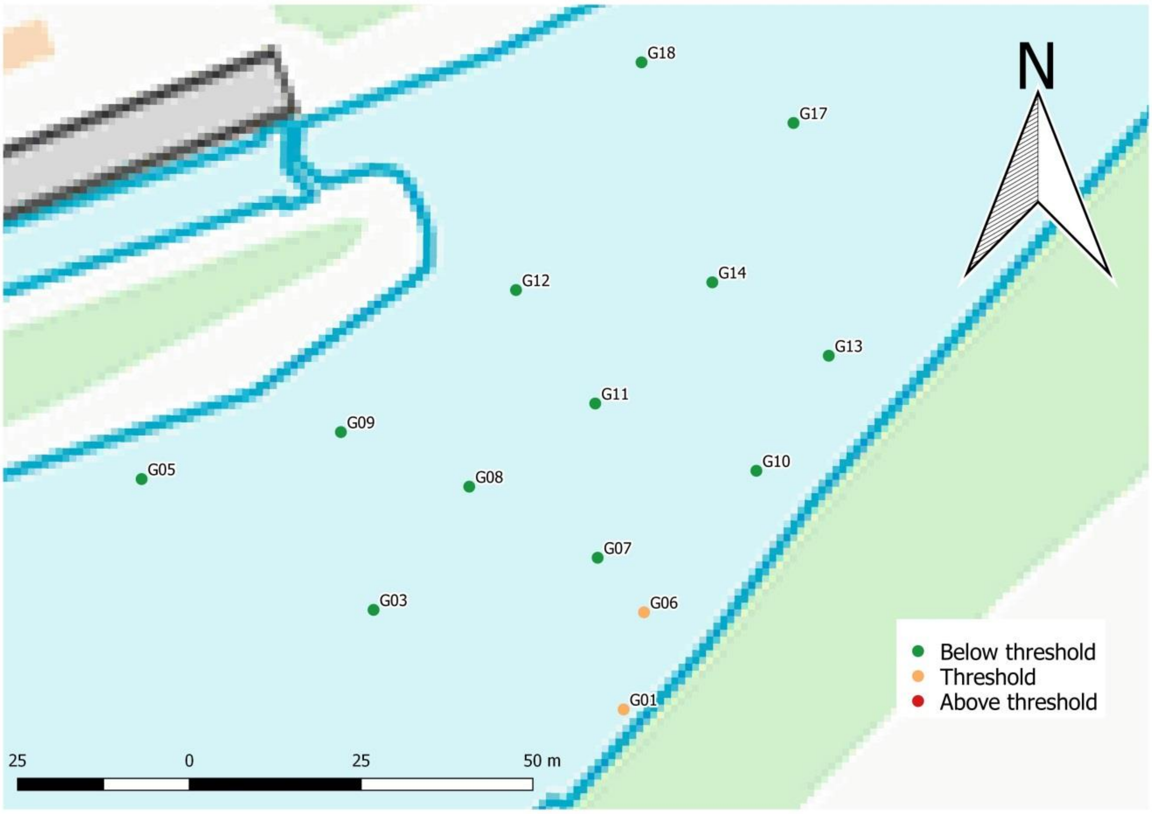
Qmean – future HEP scenario **Shields parameter = 0.06**



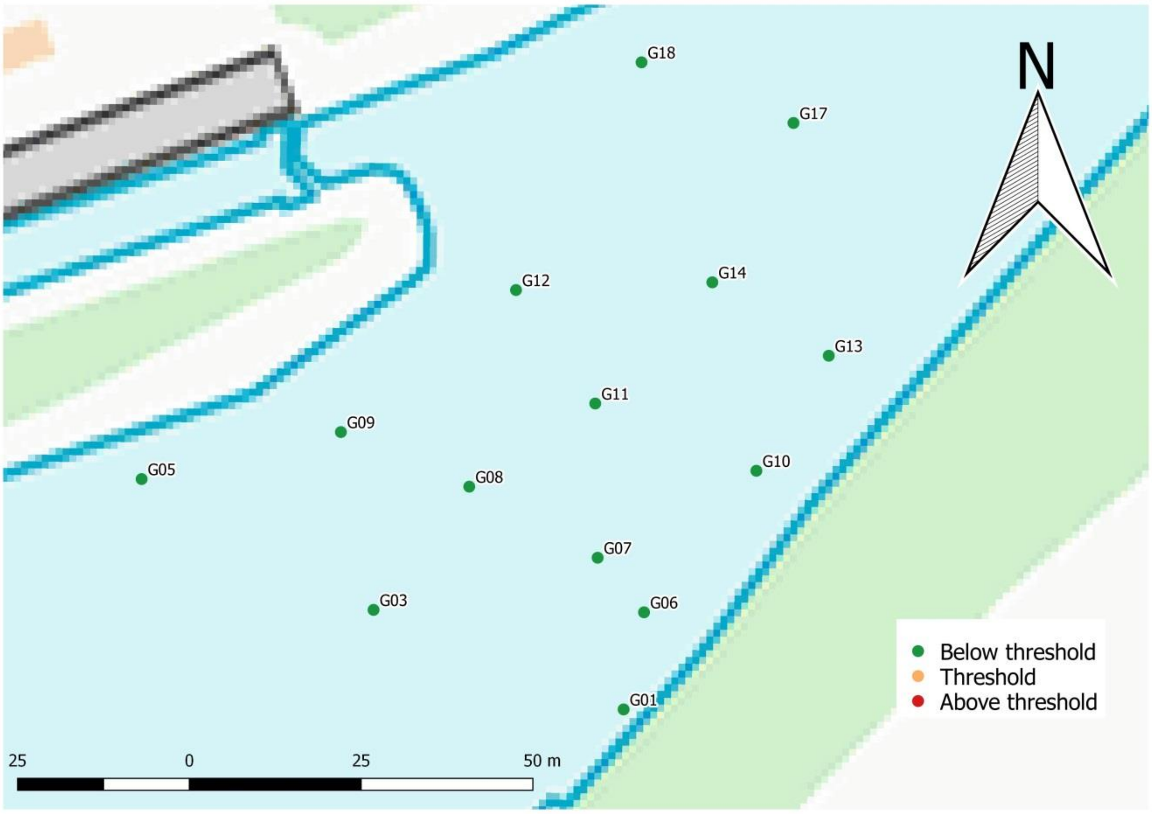
Q5 – current baseline scenario **Shields parameter = 0.06**



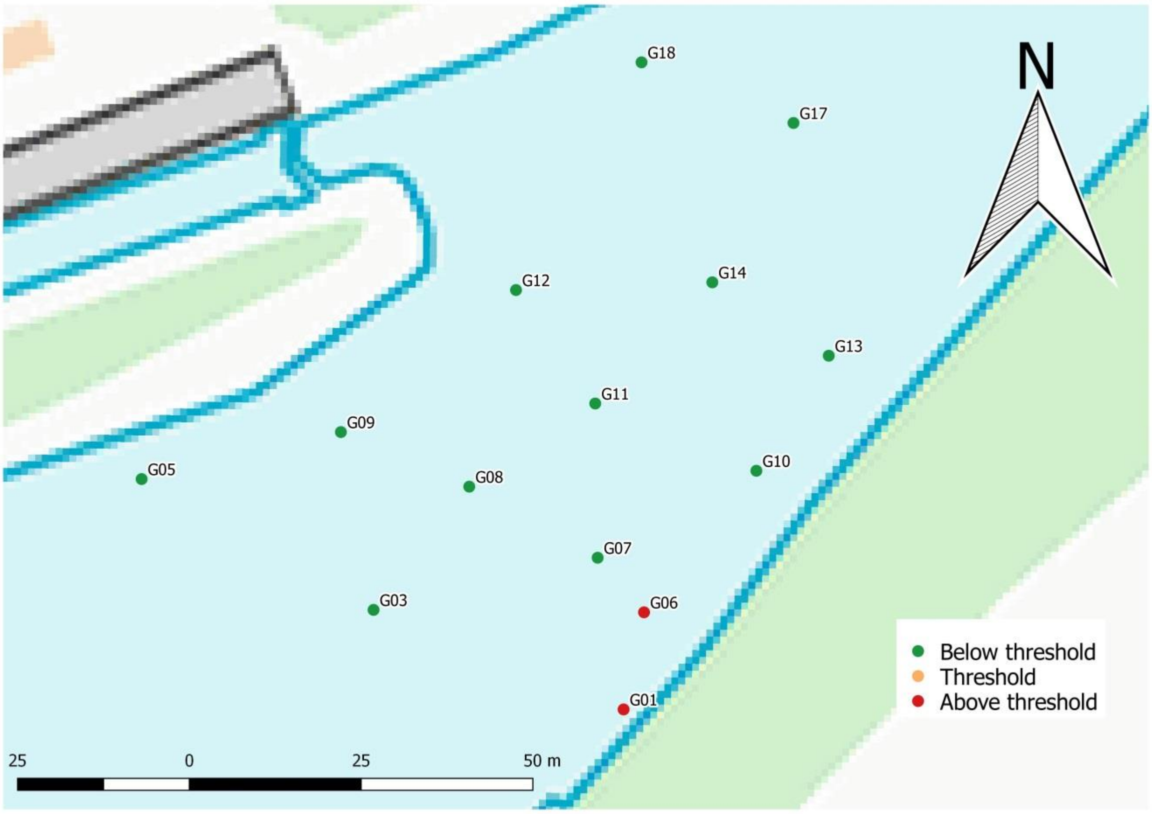
Q5 – future HEP scenario **Shields parameter = 0.06**



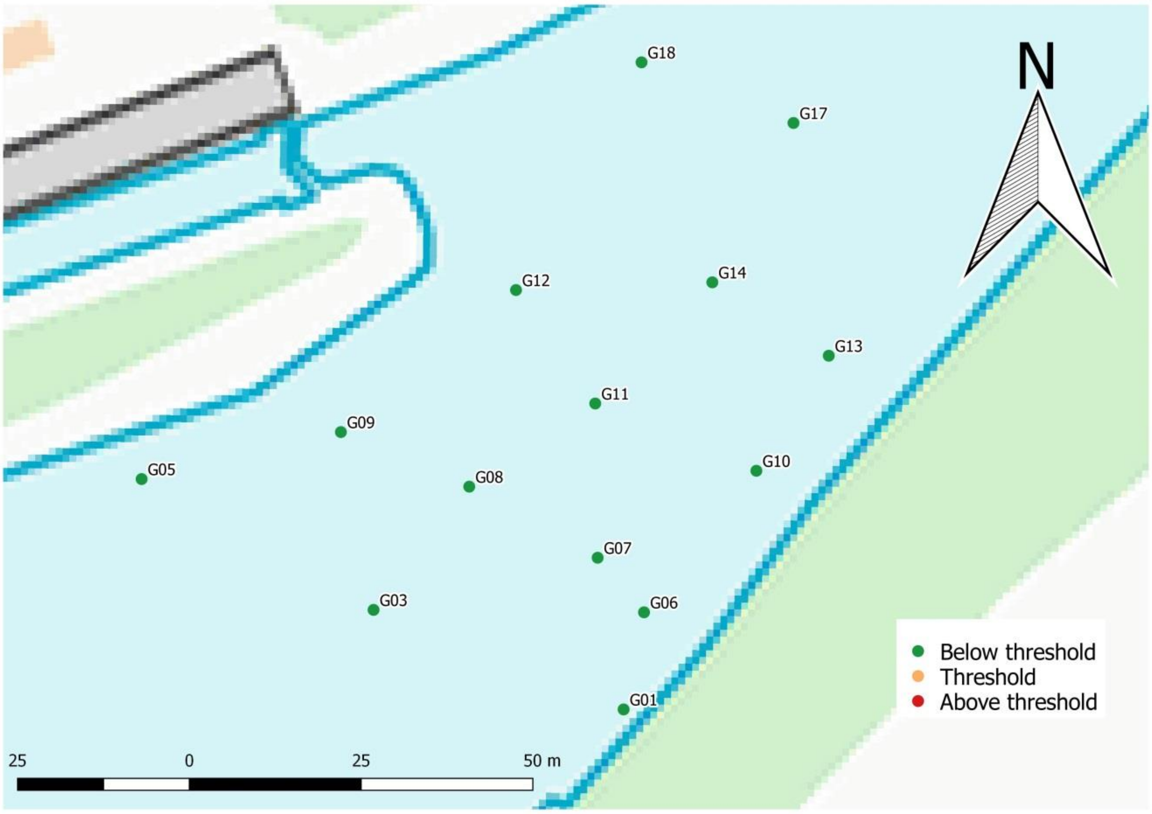
Q95 – current baseline scenario **Shields parameter = 0.08**



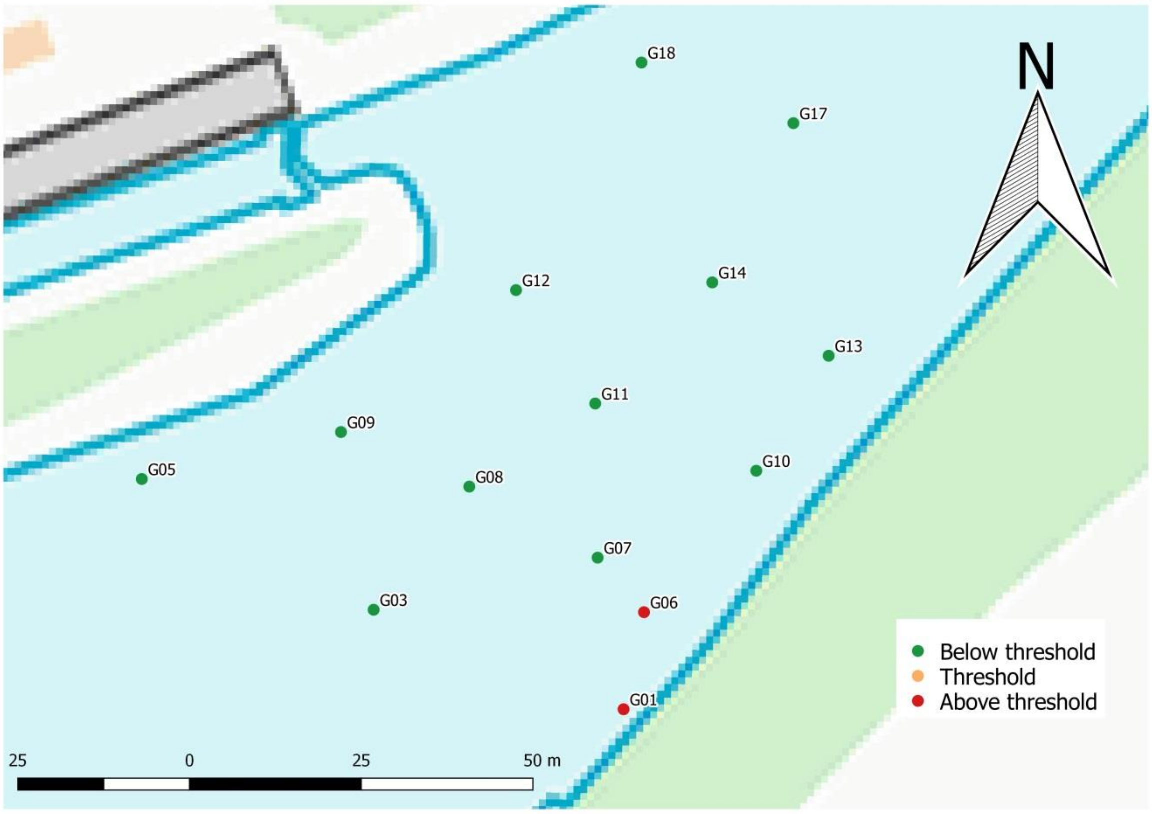
Q95 – future HEP scenario **Shields parameter = 0.08**



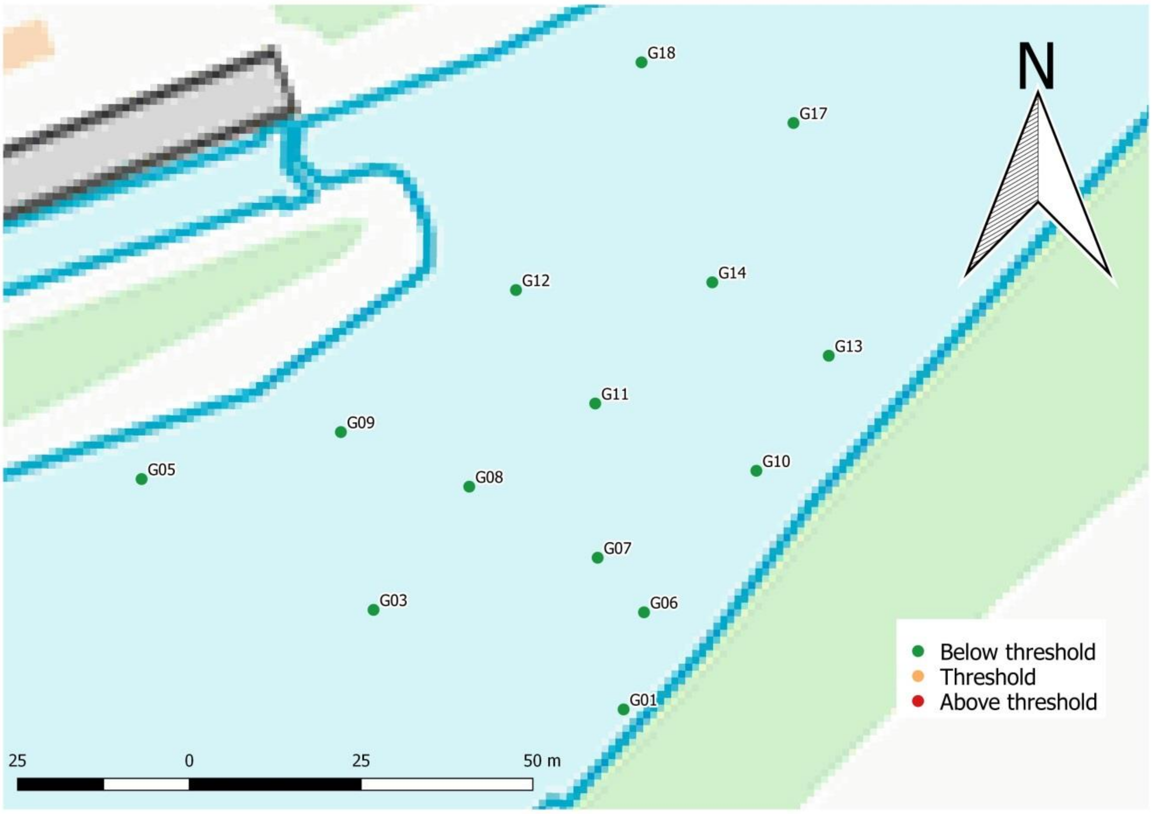
Q75 – current baseline scenario **Shields parameter = 0.08**



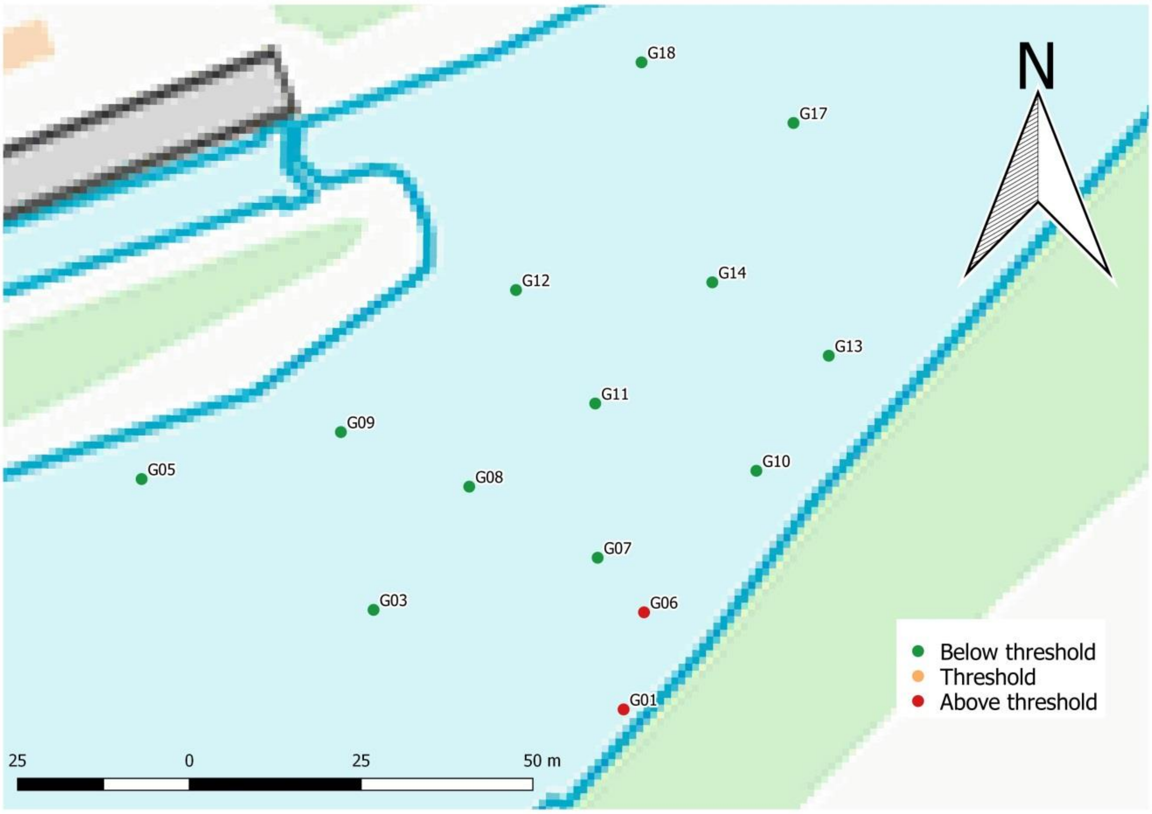
Q75 – future HEP scenario **Shields parameter = 0.08**



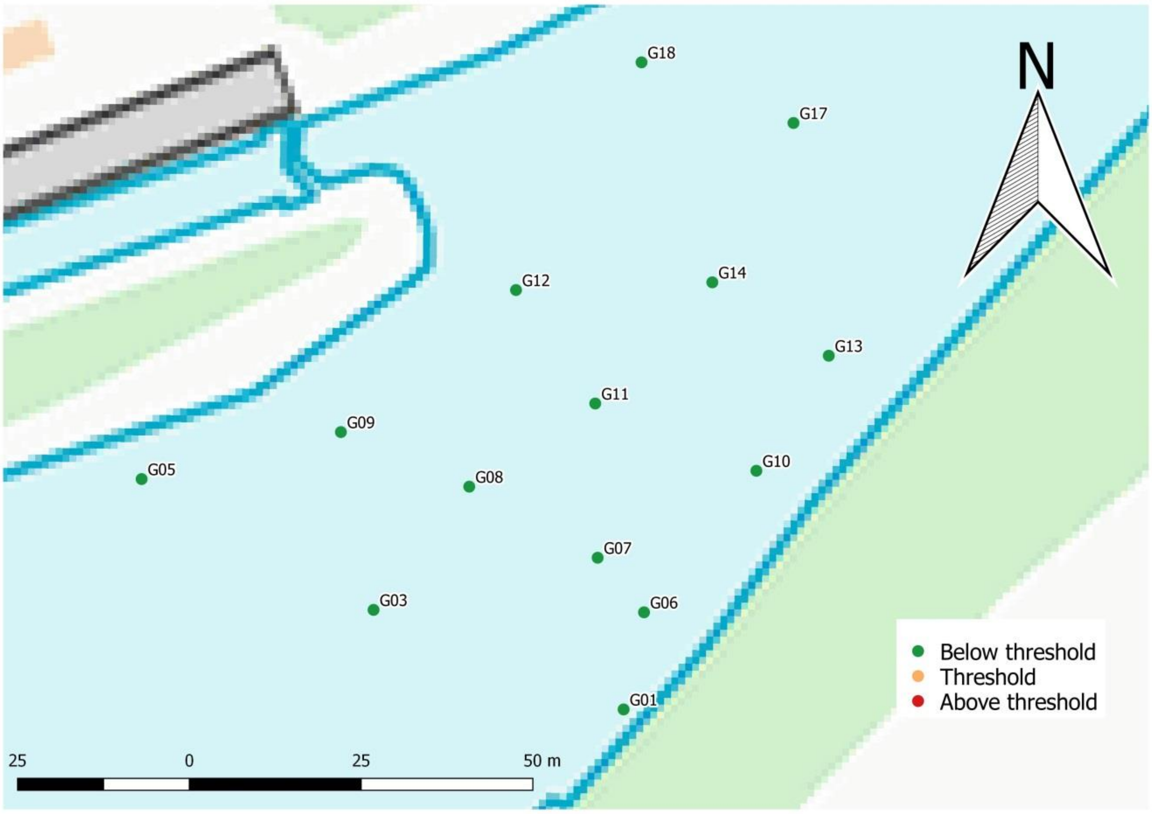
Q50 – current baseline scenario **Shields parameter = 0.08**



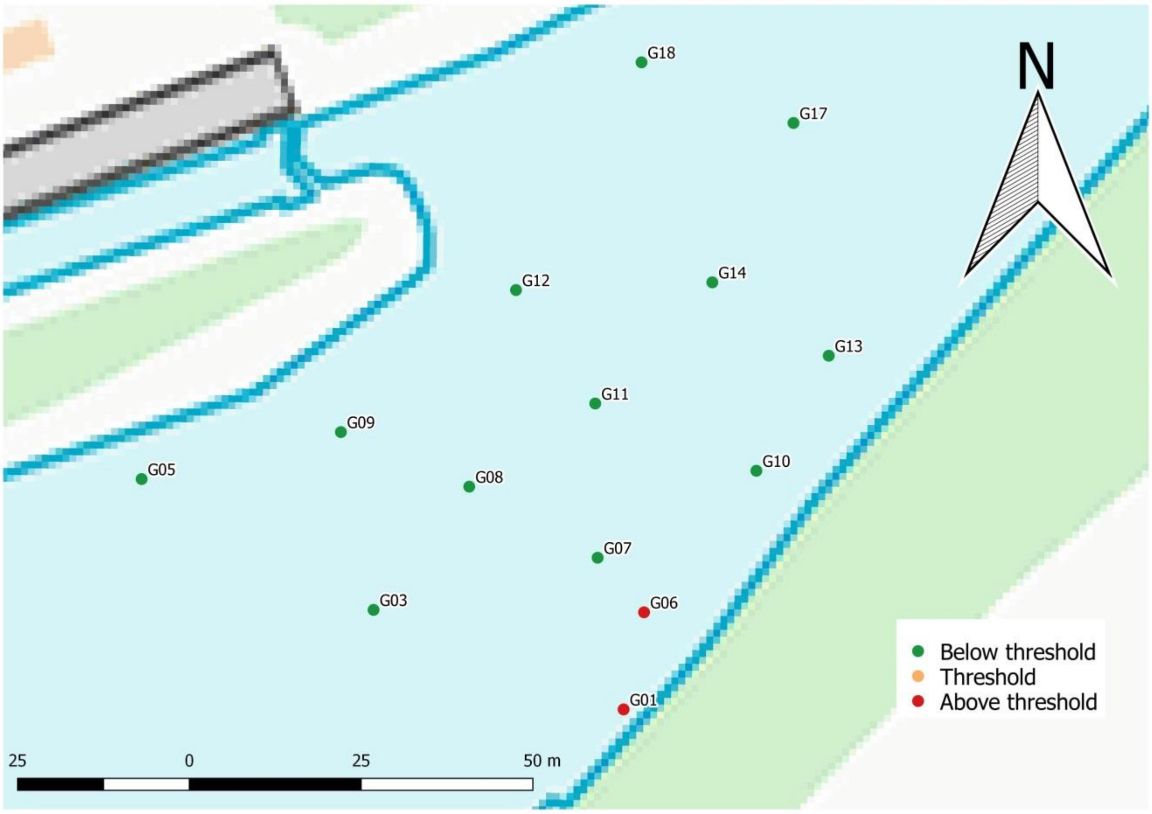
Q50 – future HEP scenario **Shields parameter = 0.08**



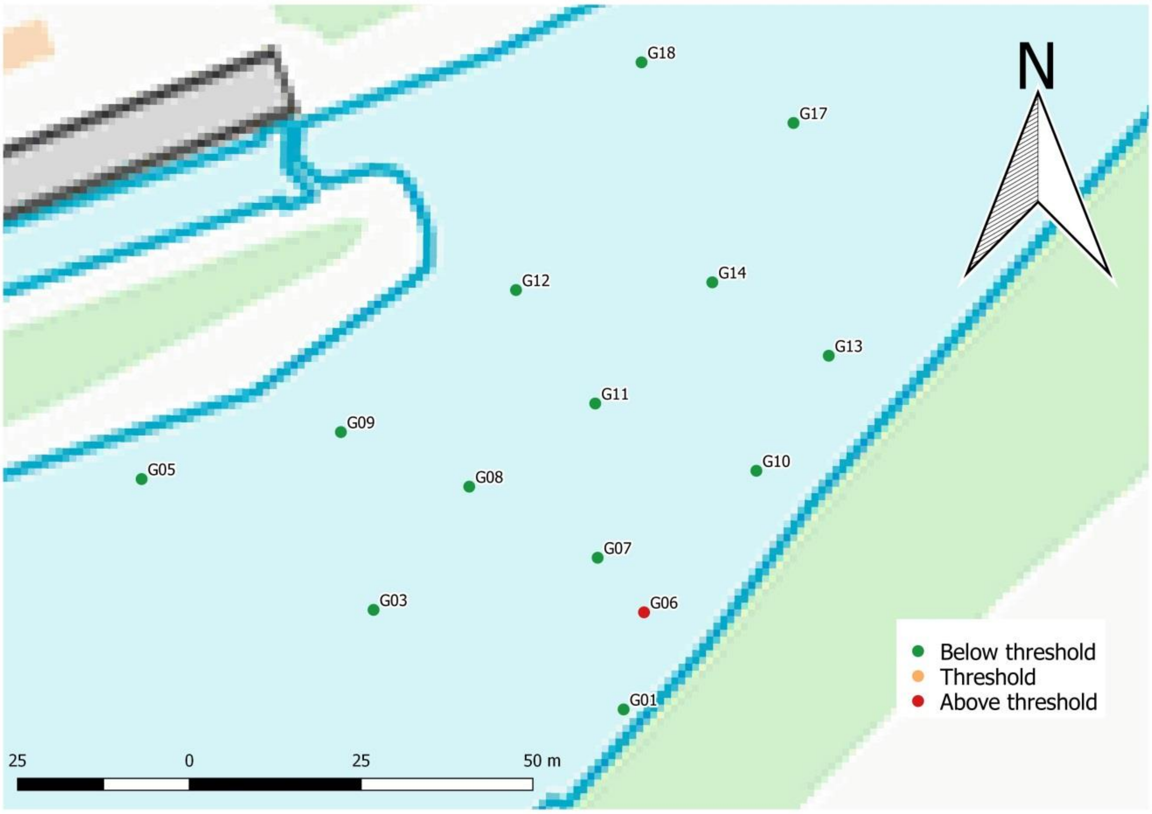
Qmean – current baseline scenario **Shields parameter = 0.08**



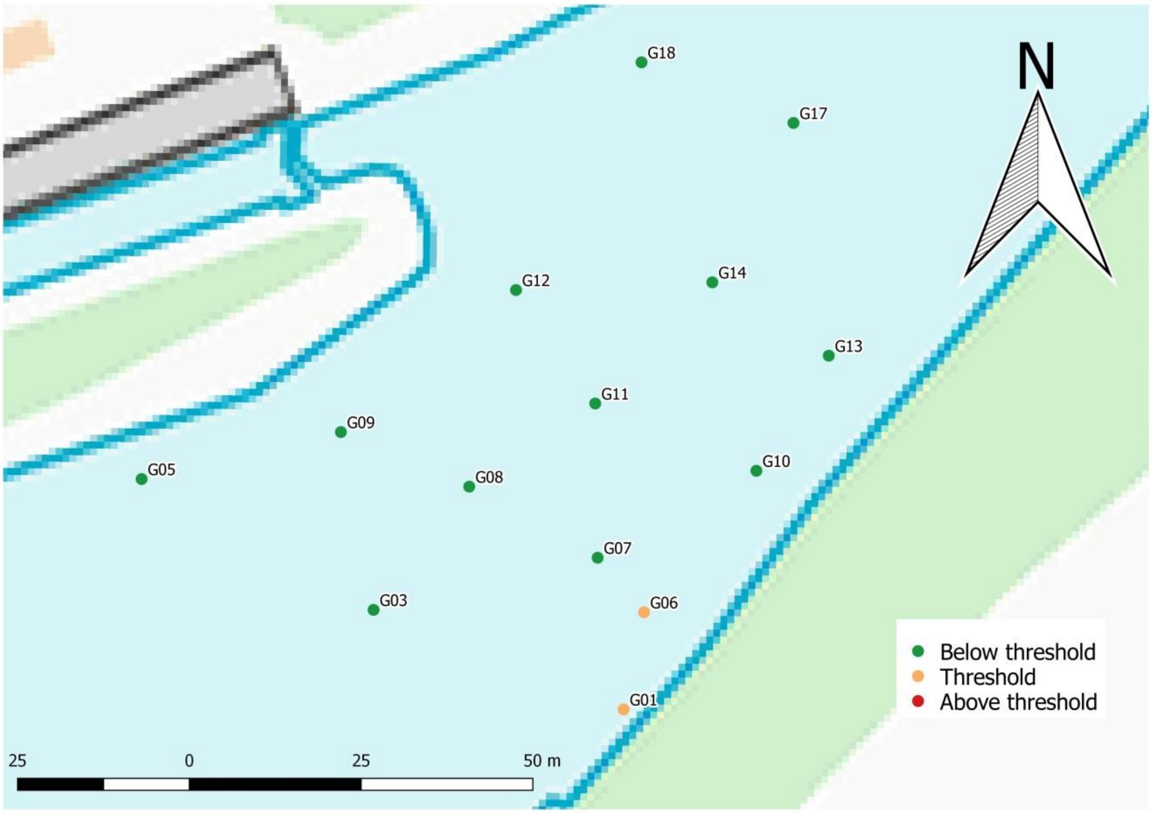
Qmean – future HEP scenario **Shields parameter = 0.08**



Q5 – current baseline scenario **Shields parameter = 0.08**



Q5 – future HEP scenario **Shields parameter = 0.08**



Appendix 2 - Fish Habitat Modelling

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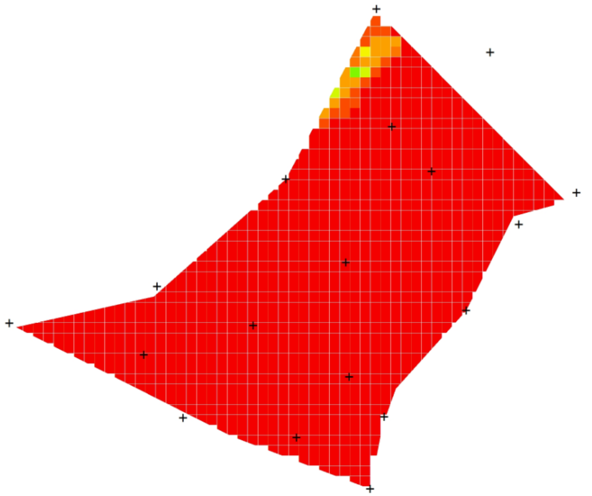
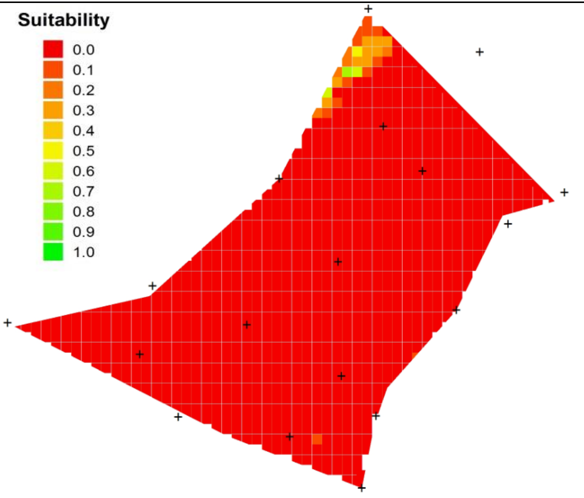
<tr><td></td><td> </td></tr>
<tr><th colspan="2">Qmean Spawning rheophilic</th></tr>
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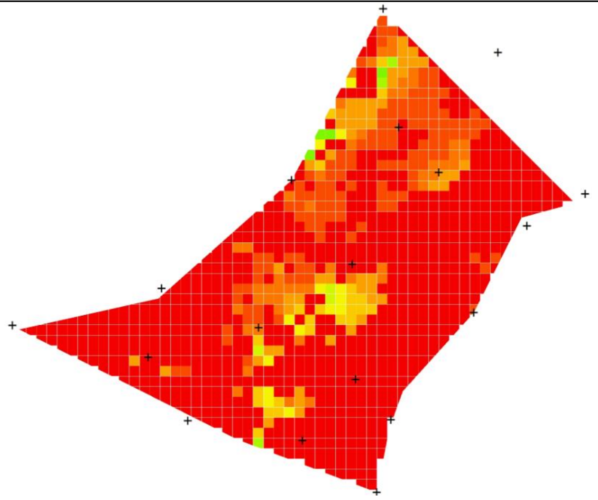
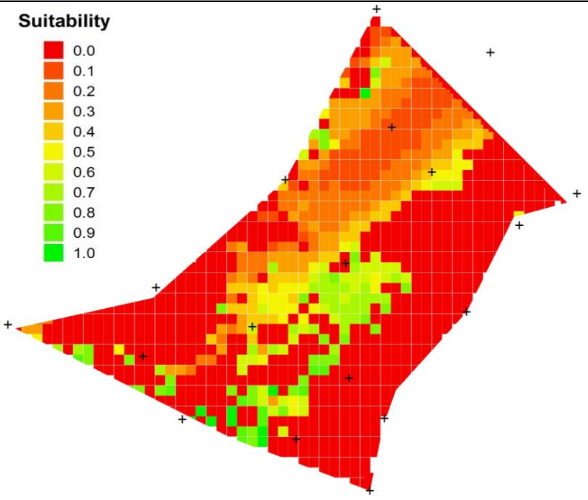
<tr><td></td><td> </td></tr>
<tr><th colspan="2">Q50 Spawning rheophilic</th></tr>
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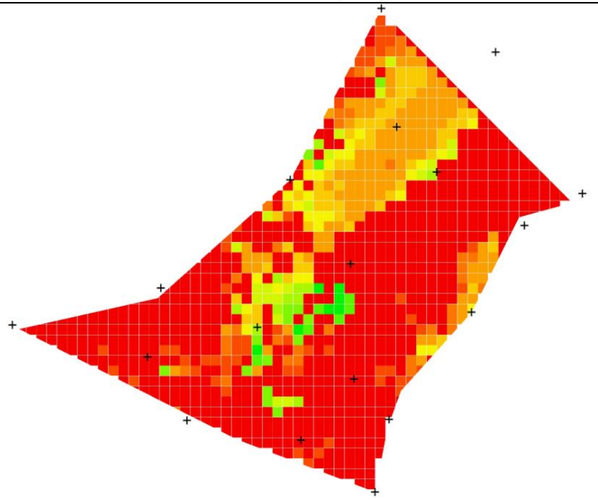
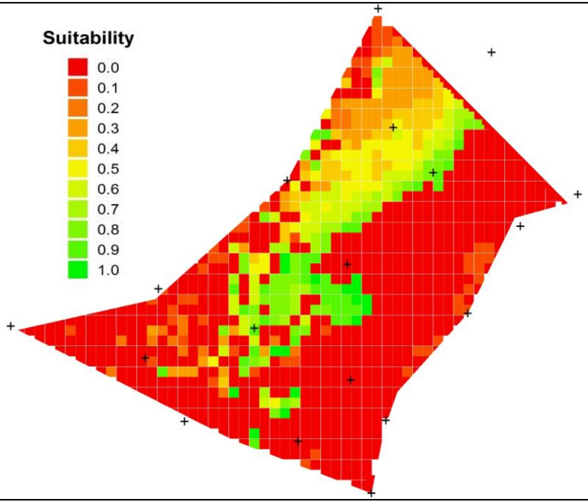
<tr><td></td><td> </td></tr>
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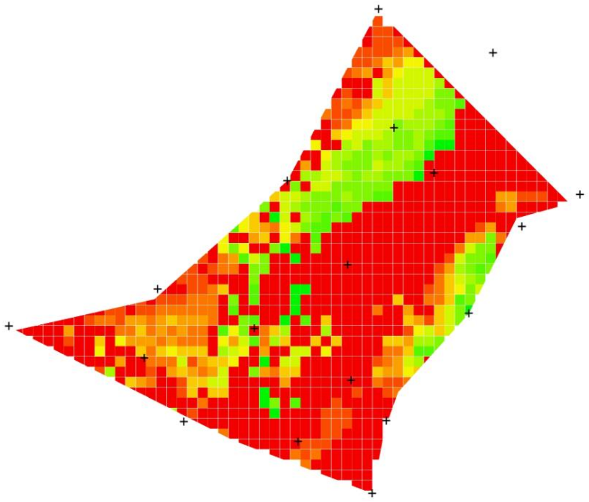
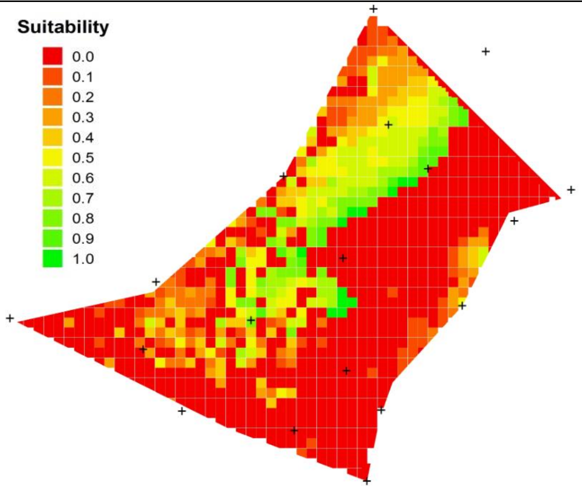
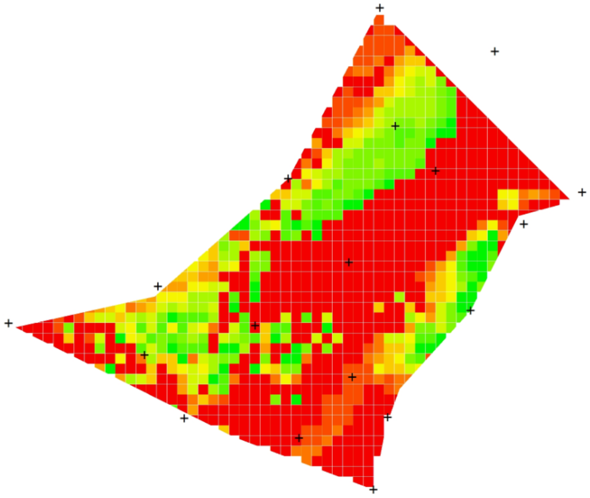
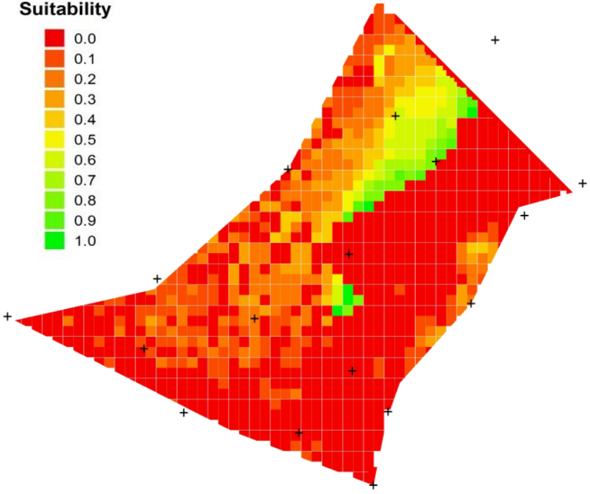
Q75 Spawning rheophilic

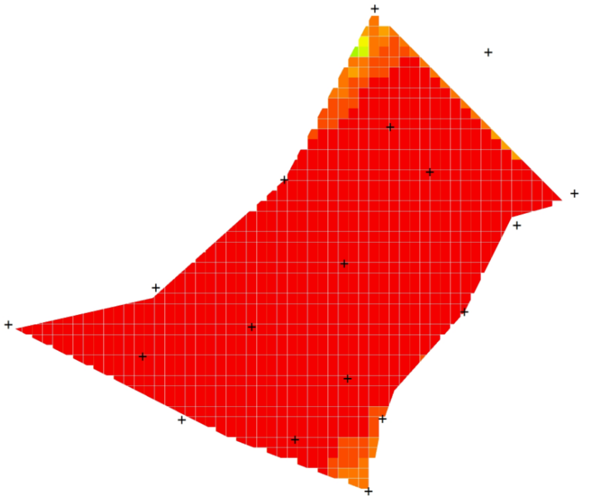
Existing	Proposed
	

Q95 Spawning rheophilic

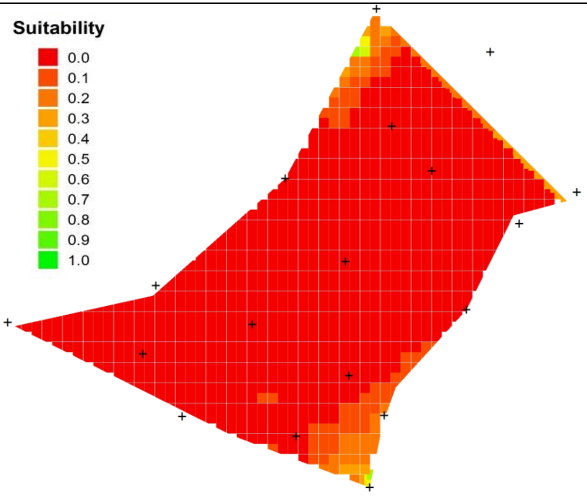
Existing	Proposed
	

Q5 Juvenile rheophilic

Existing

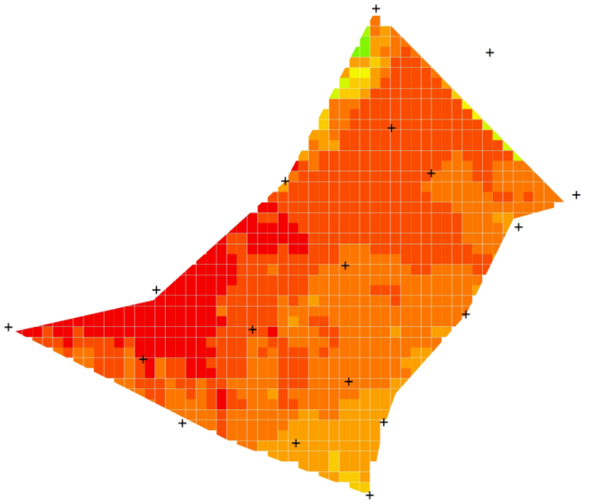


Proposed

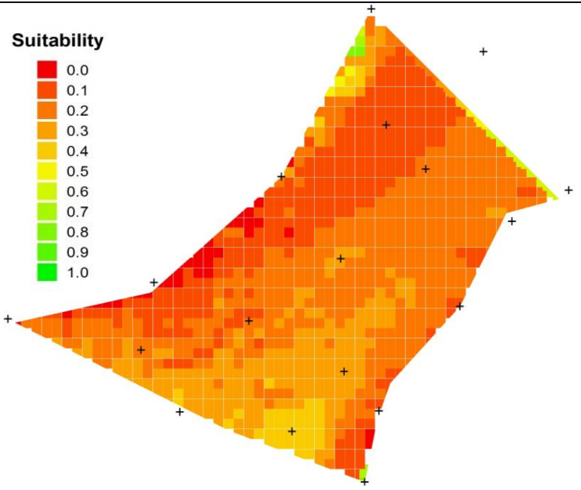


Qmean Juvenile rheophilic

Existing

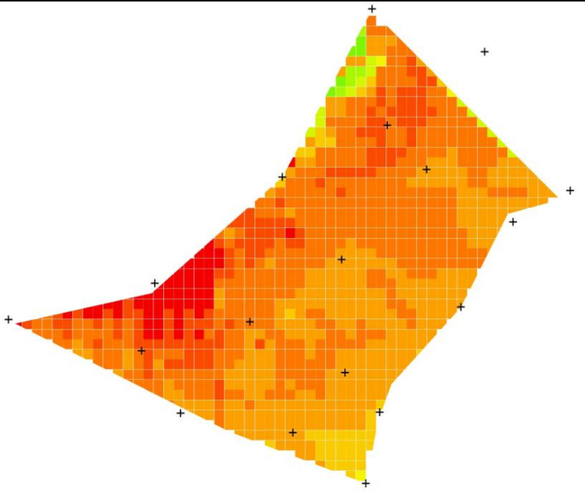


Proposed



Q50 Juvenile rheophilic

Existing



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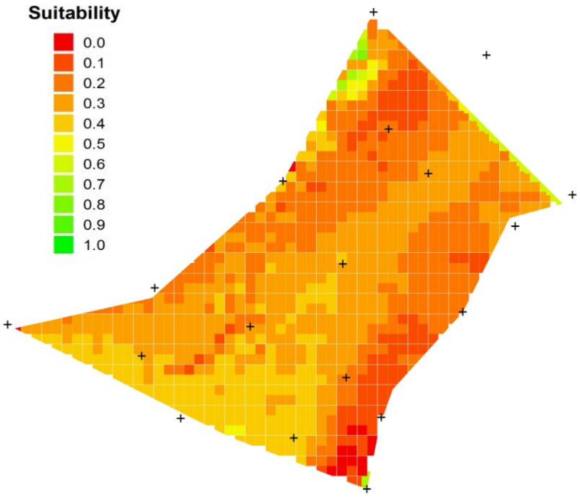
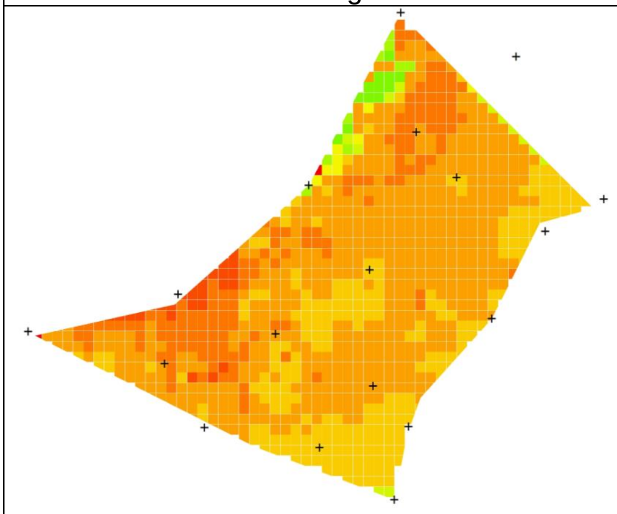
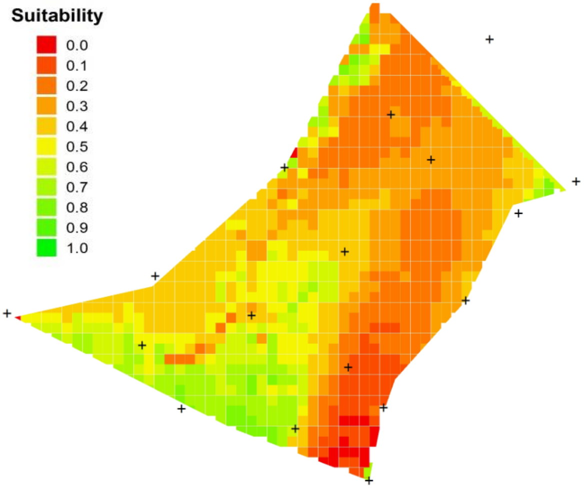
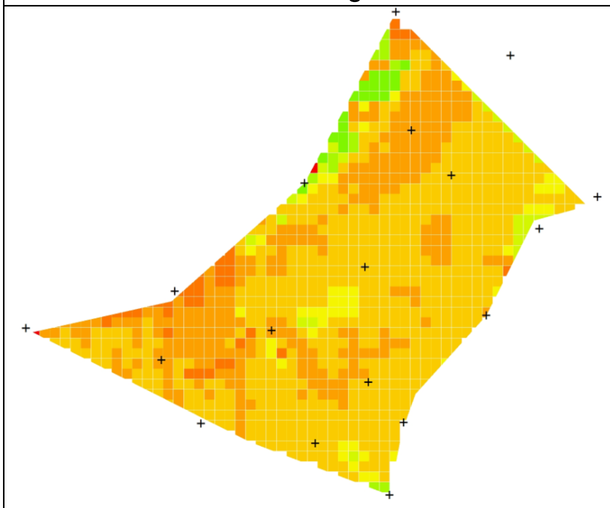
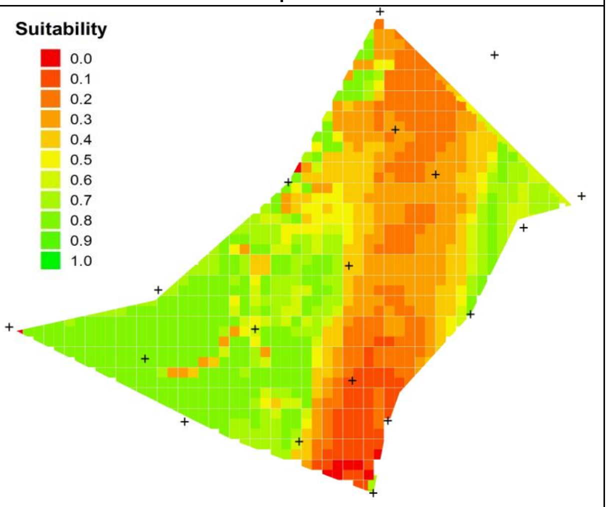
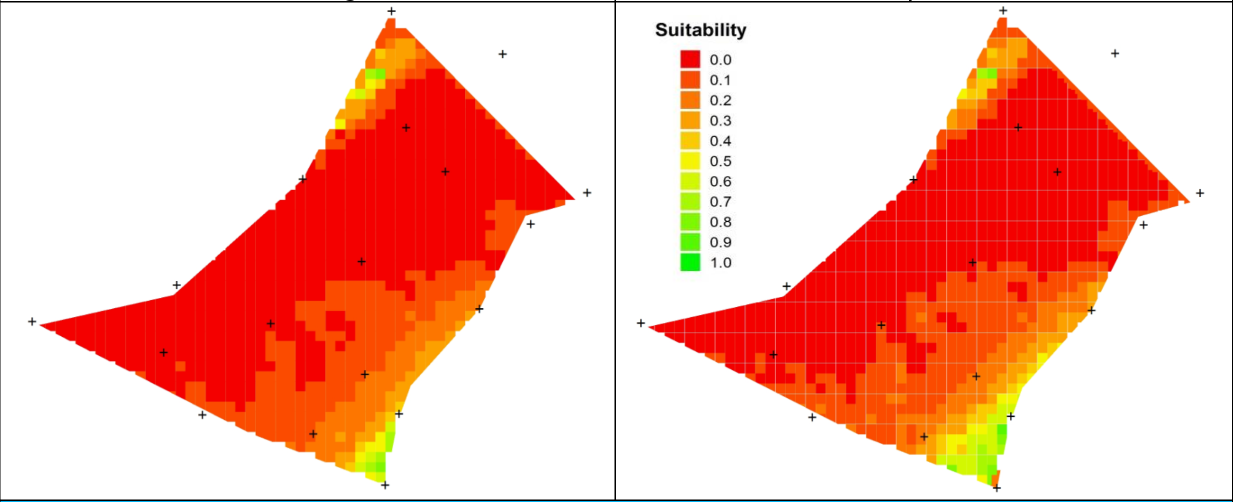


Q75 Juvenile rheophilic	
Existing	Proposed
	
Q95 Juvenile rheophilic	
Existing	Proposed
	

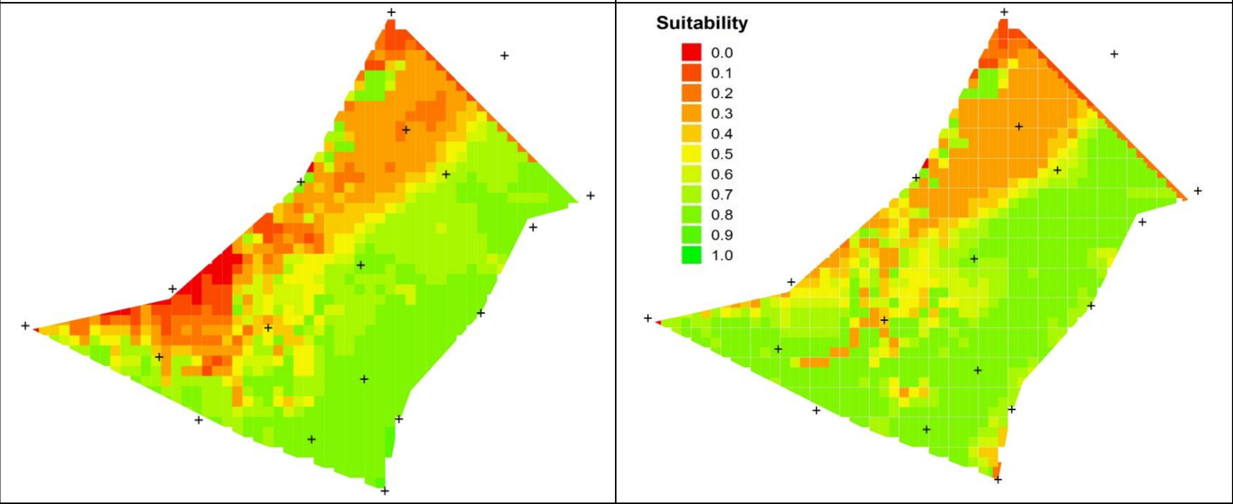
Q5 Adult rheophilic



Existing

Proposed

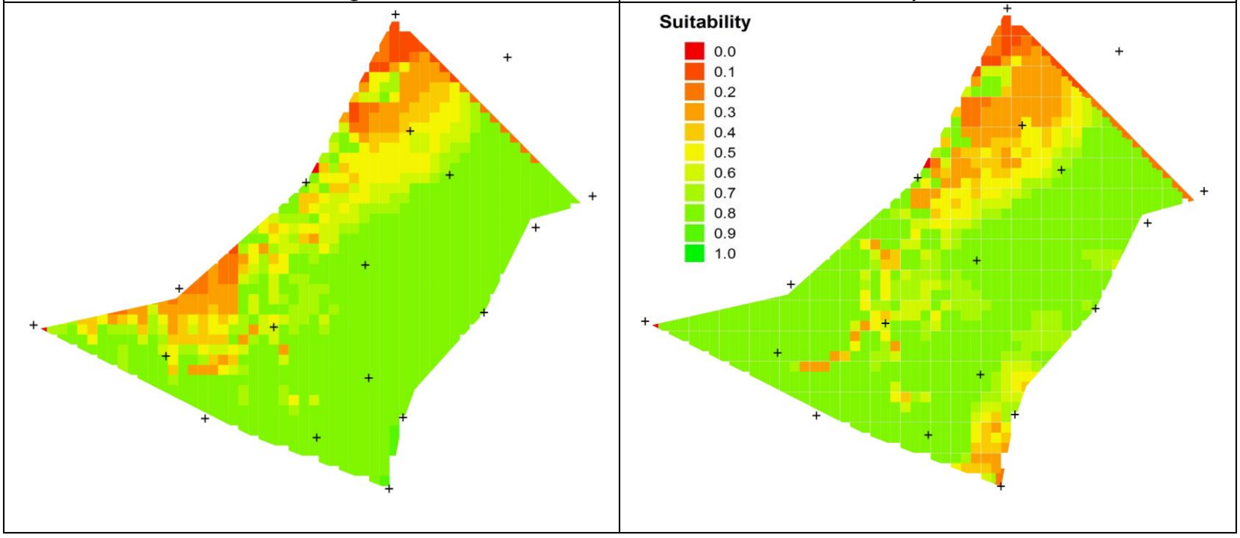
Qmean Adult rheophilic



Existing

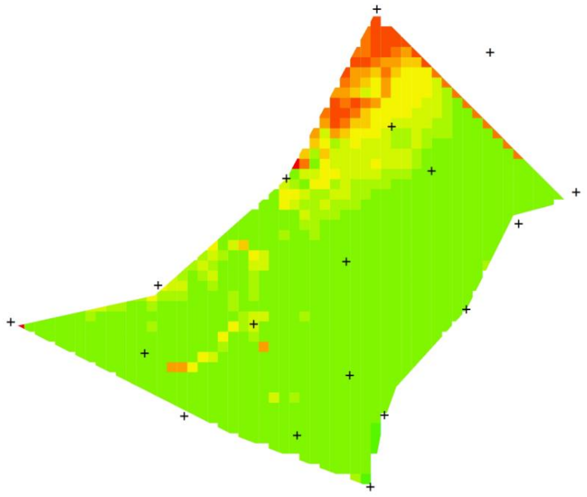
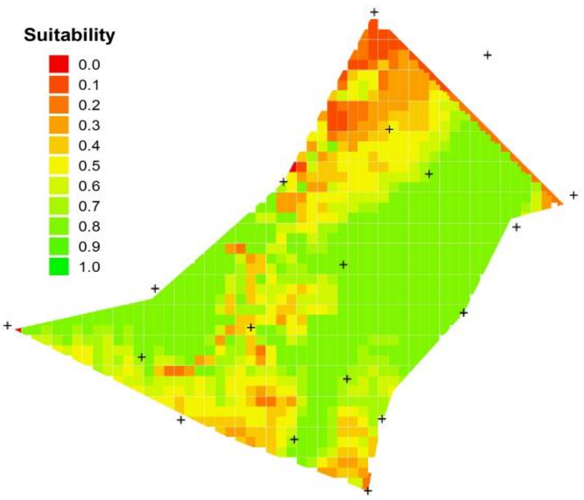
Proposed

Q50 Adult rheophilic



Existing

Proposed

<table>
<tr><th colspan="2">Q75 Adult rheophilic</th></tr>
<tr><td>Existing</td><td>Proposed</td></tr>
<tr><td></td><td>
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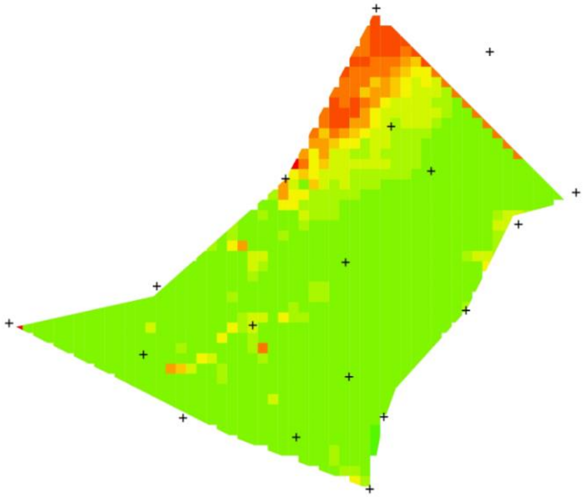
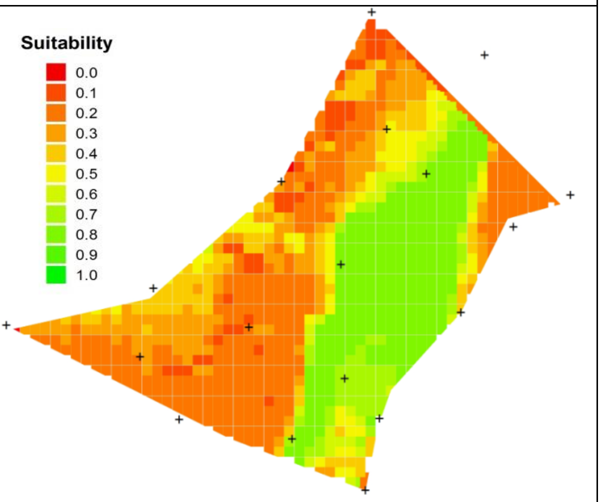
<tr><th colspan="2">Q95 Adult rheophilic</th></tr>
<tr><td>Existing</td><td>Proposed</td></tr>
<tr><td></td><td>
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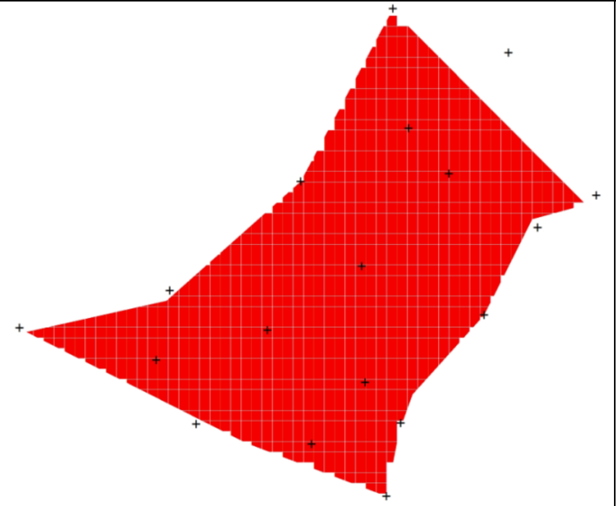
Q5 Spawning roach

Existing



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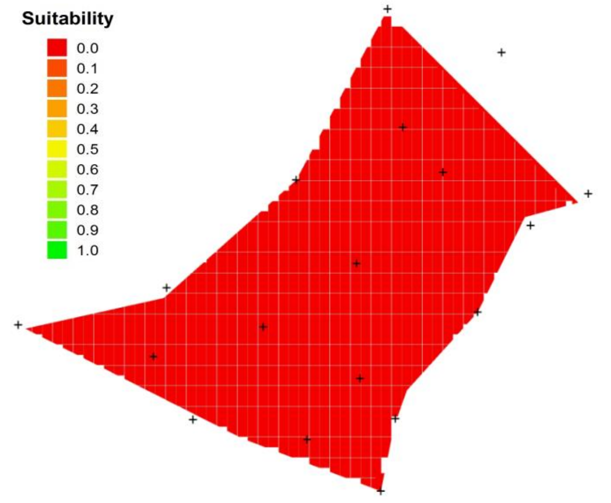
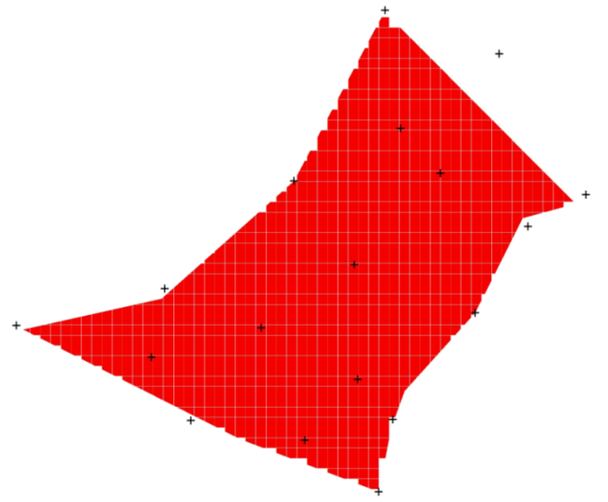


Qmean Spawning roach

Existing



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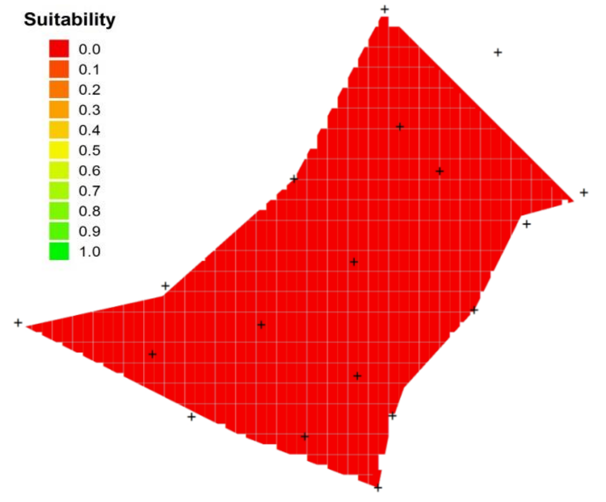
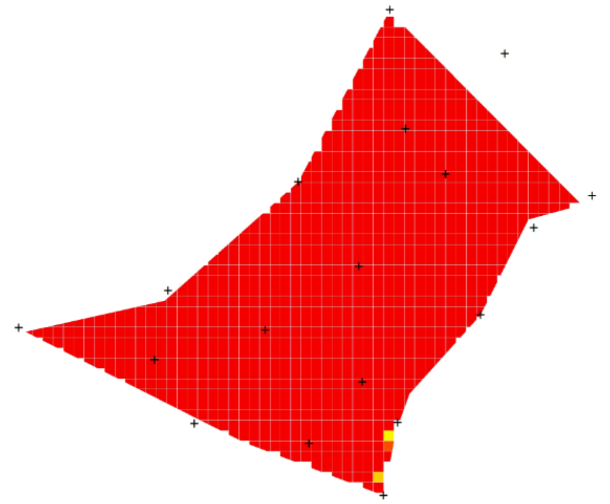
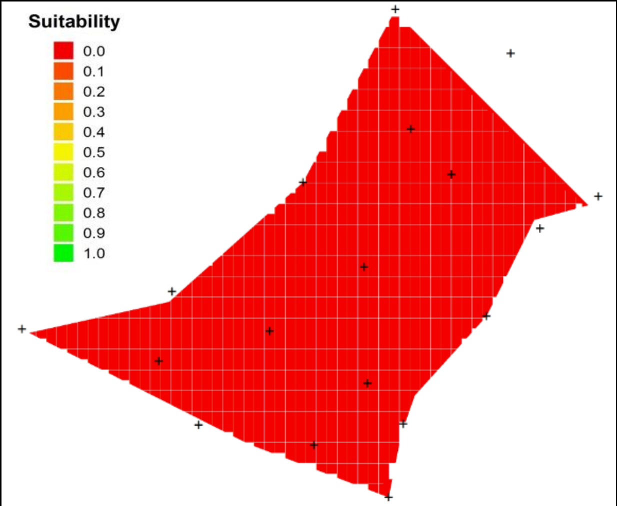


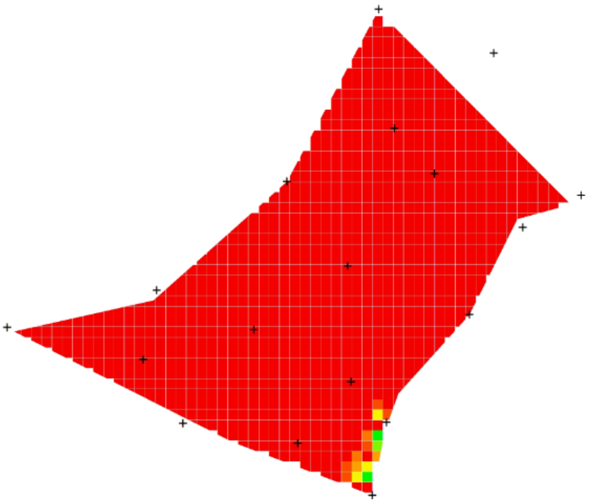
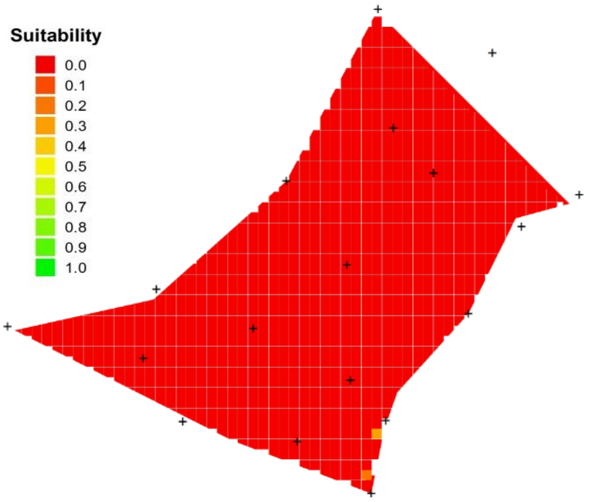
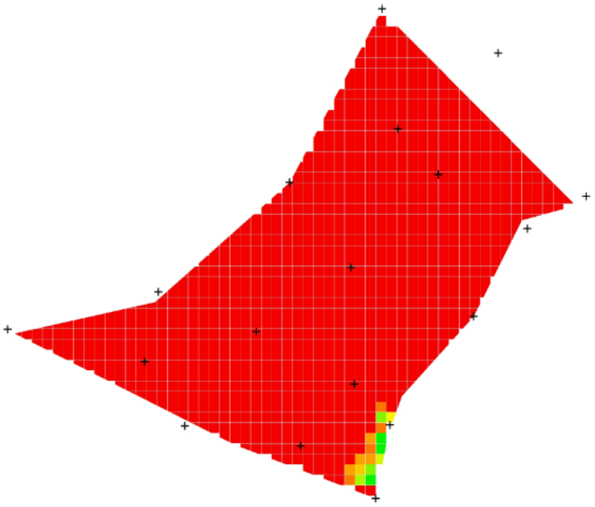
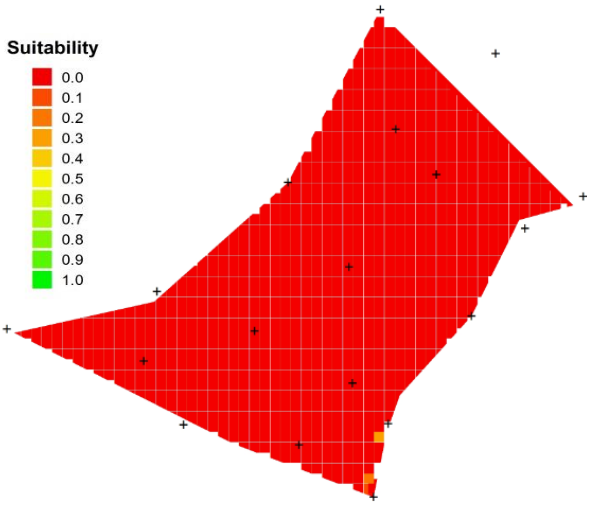
Q50 Spawning roach

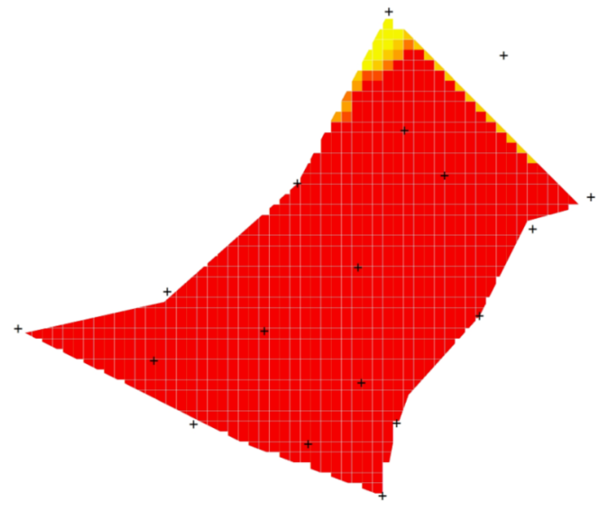
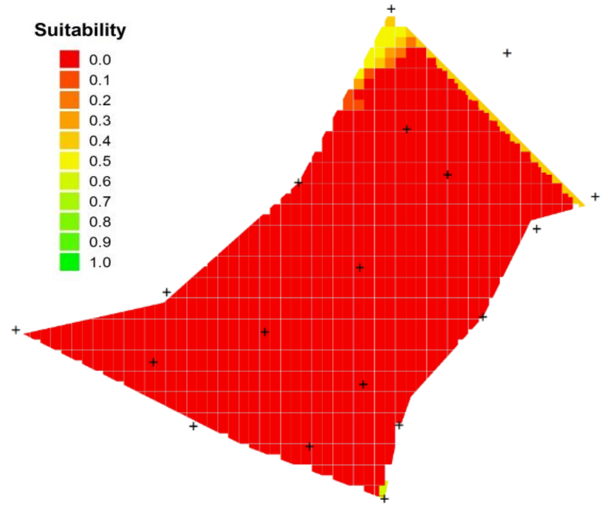
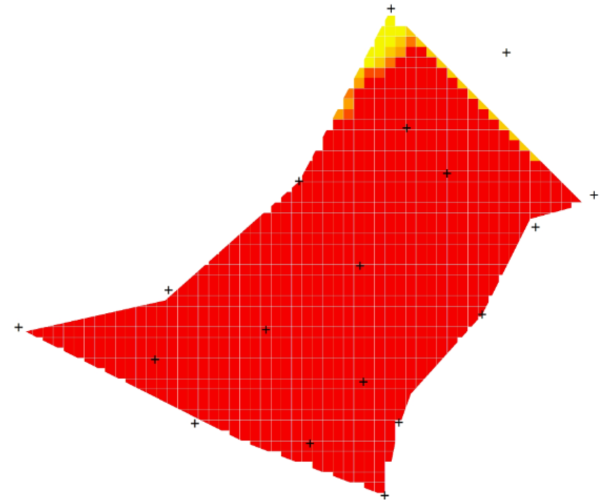
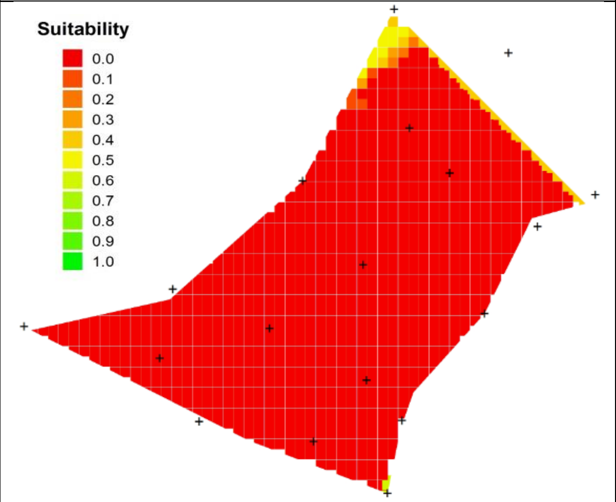
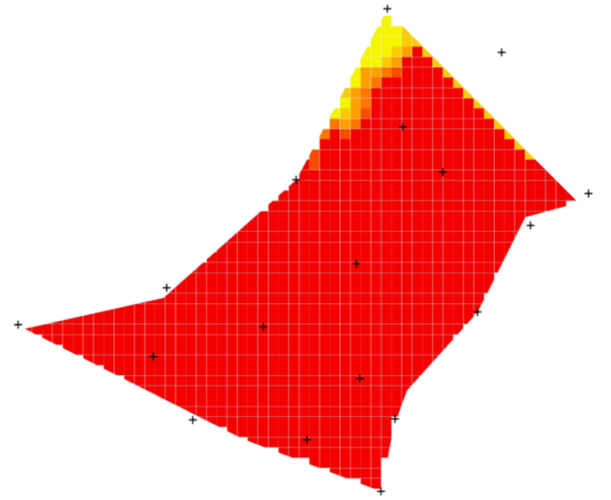
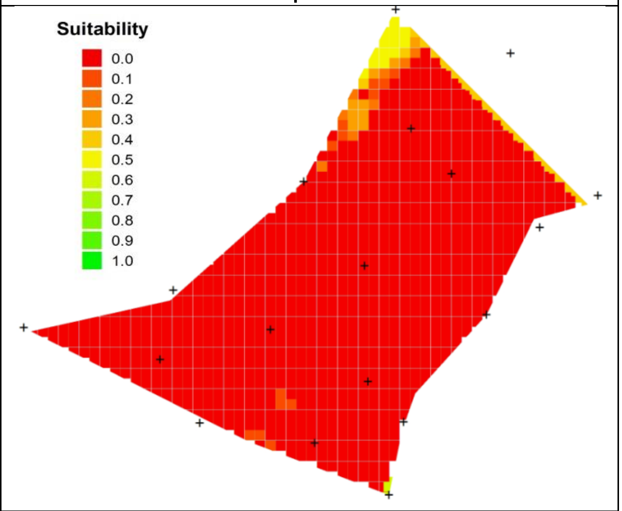
Existing



Proposed

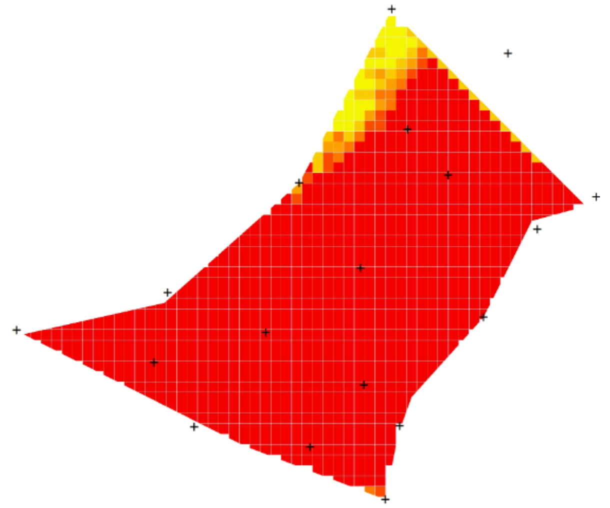


Q75 Spawning roach	
Existing	Proposed
	
Q95 Spawning roach	
Existing	Proposed
	

Q5 Juvenile roach	
Existing	Proposed
	
Qmean Juvenile roach	
Existing	Proposed
	
Q50 Juvenile roach	
Existing	Proposed
	

Q75 Juvenile roach

Existing



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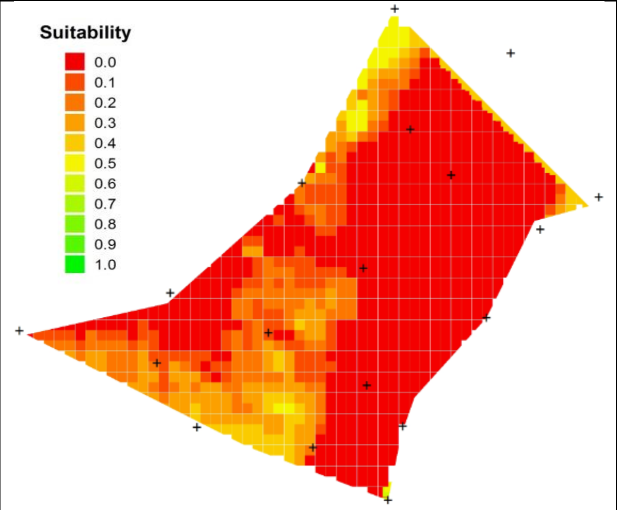
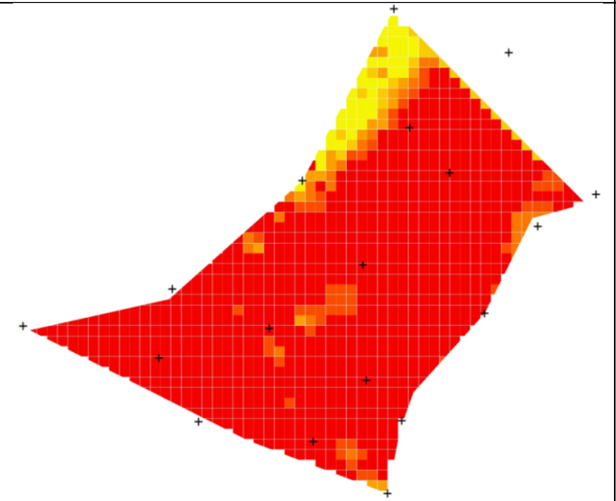
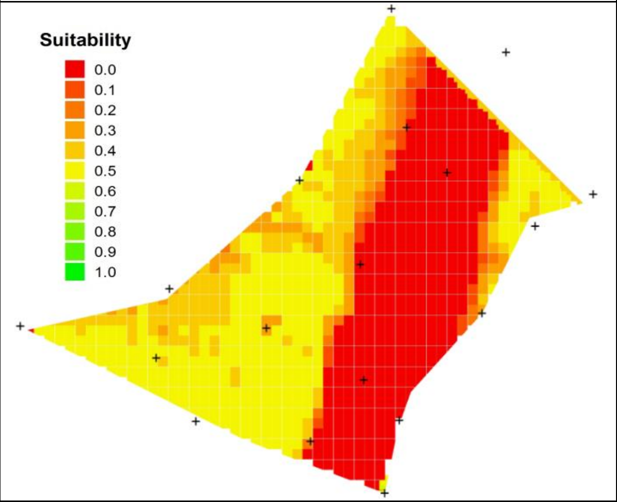


Q95 Juvenile roach

Existing

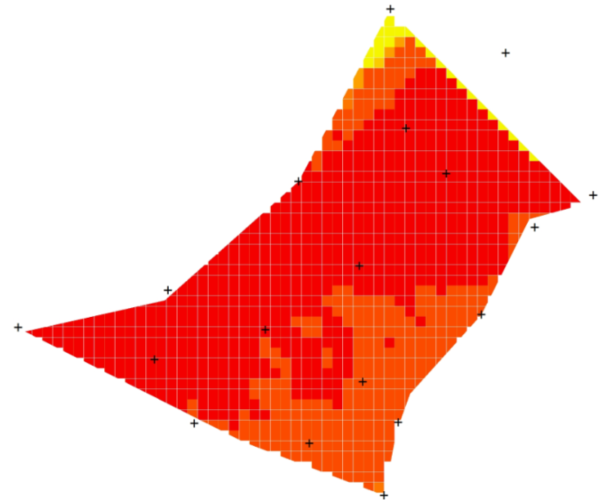


Proposed



Q5 Adult roach

Existing



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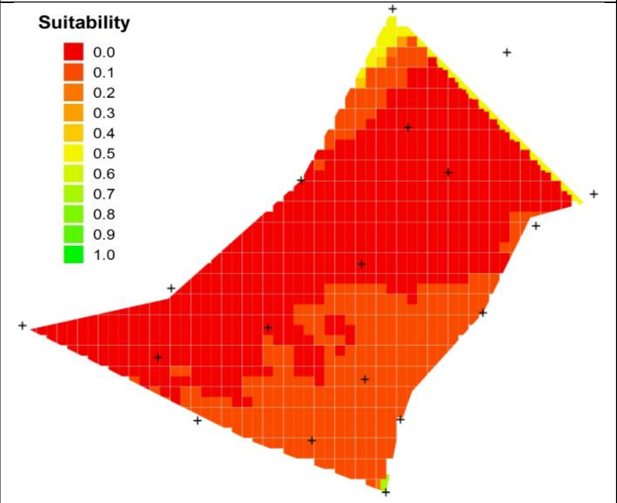
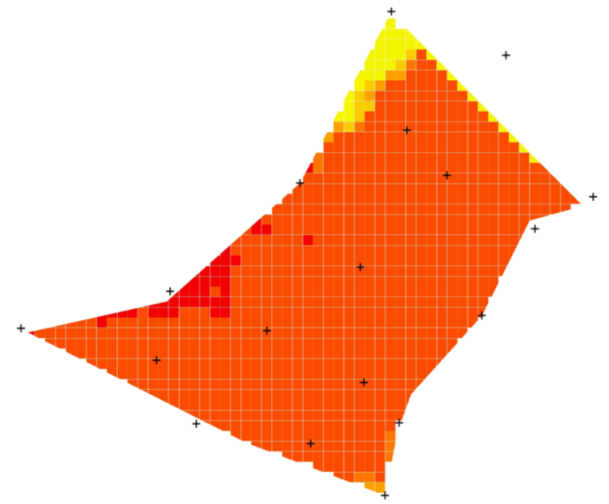
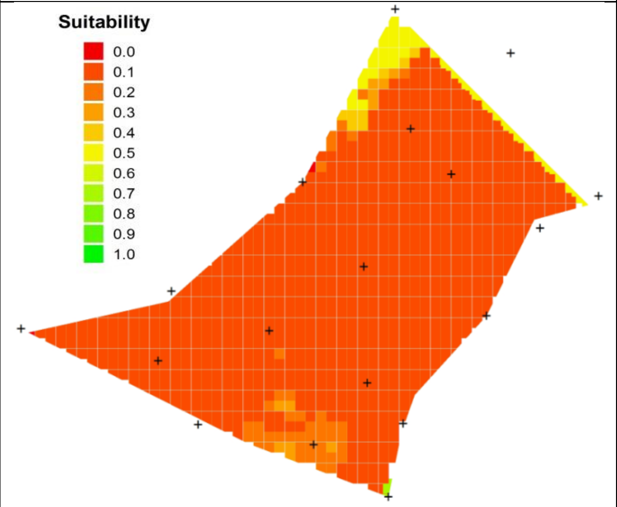


Qmean Adult roach

Existing

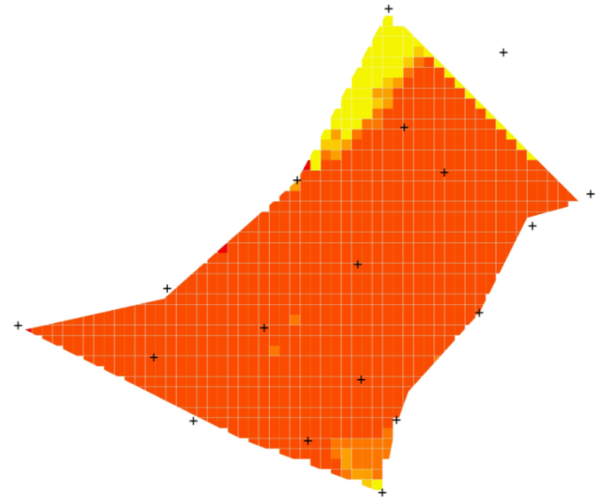


Proposed

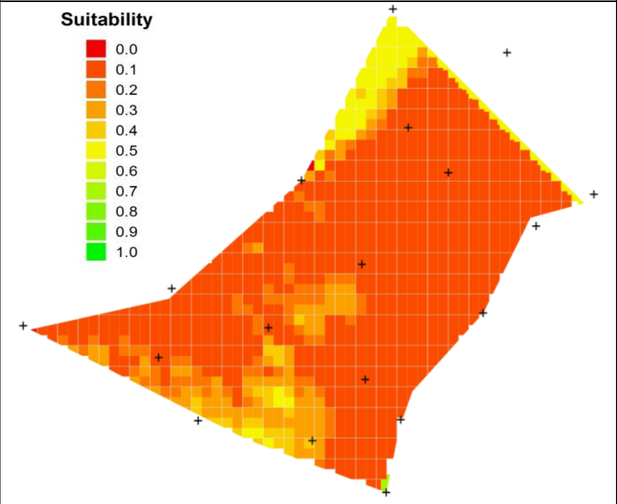


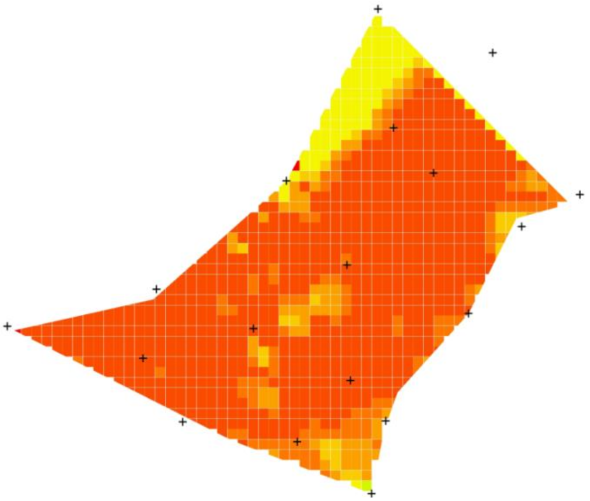
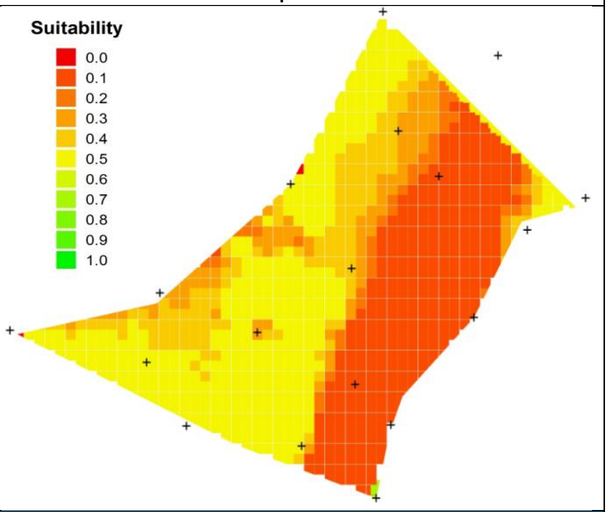
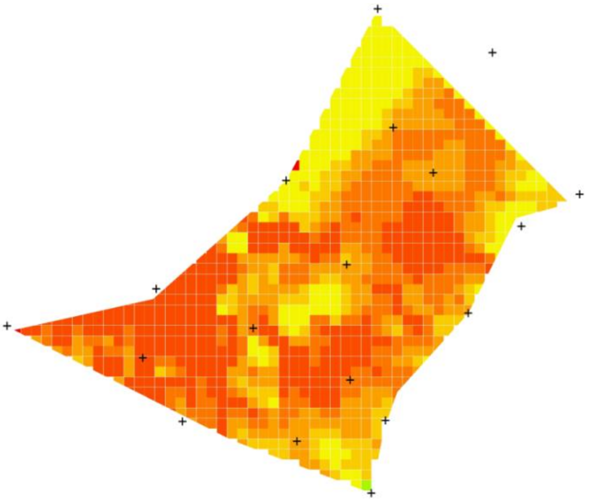
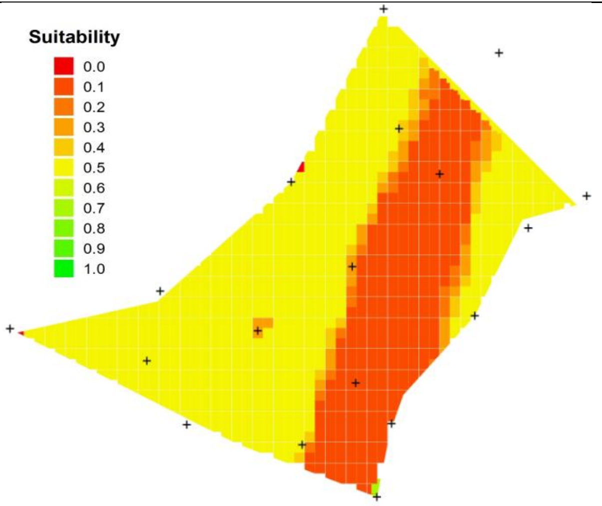
Q50 Adult roach

Existing



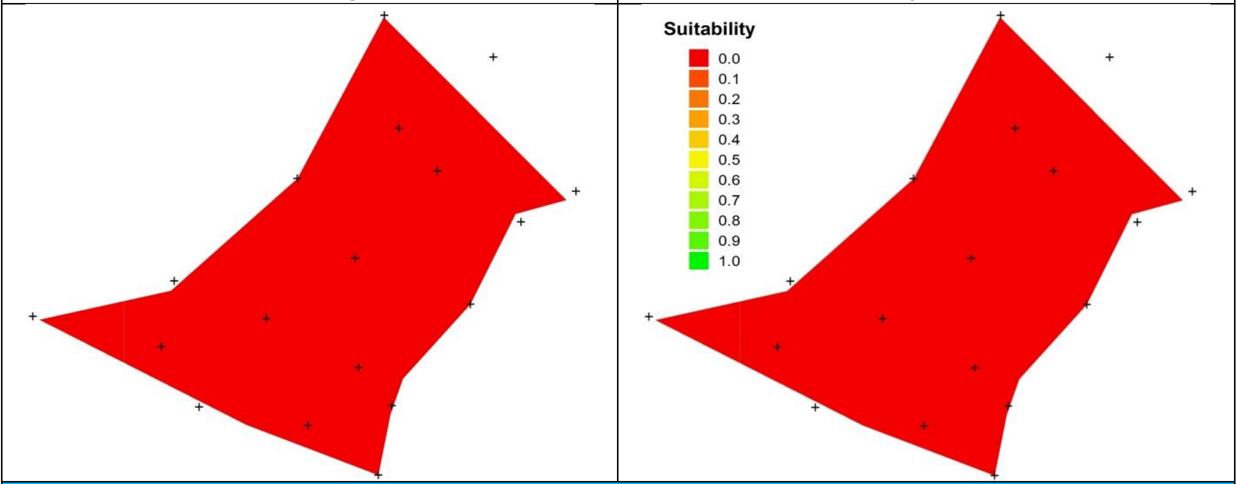
Proposed



Q75 Adult roach	
Existing	Proposed
	
Q95 Adult roach	
Existing	Proposed
	

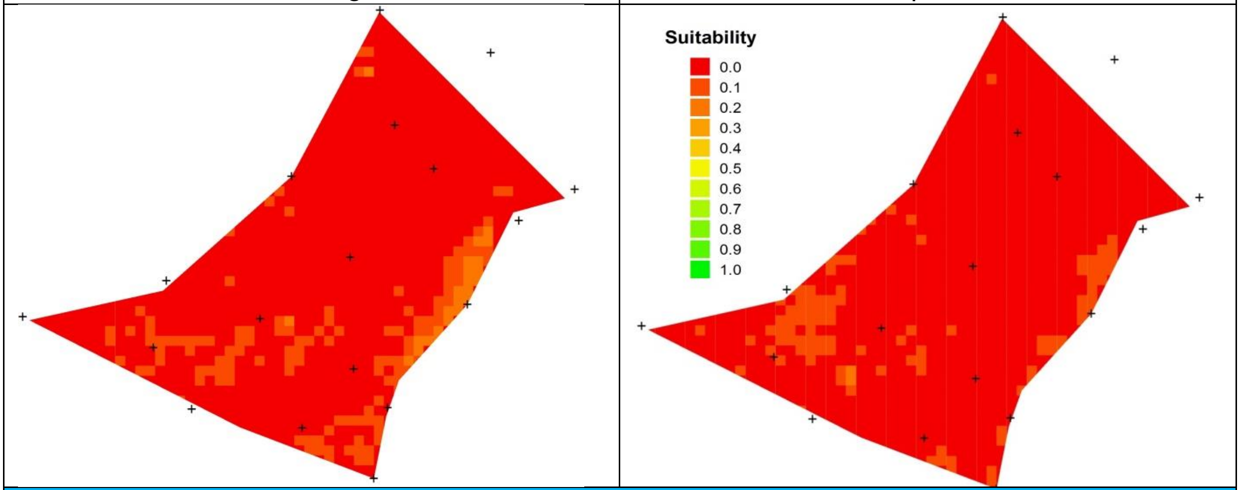
Q5 Spawning lamprey

Existing | Proposed



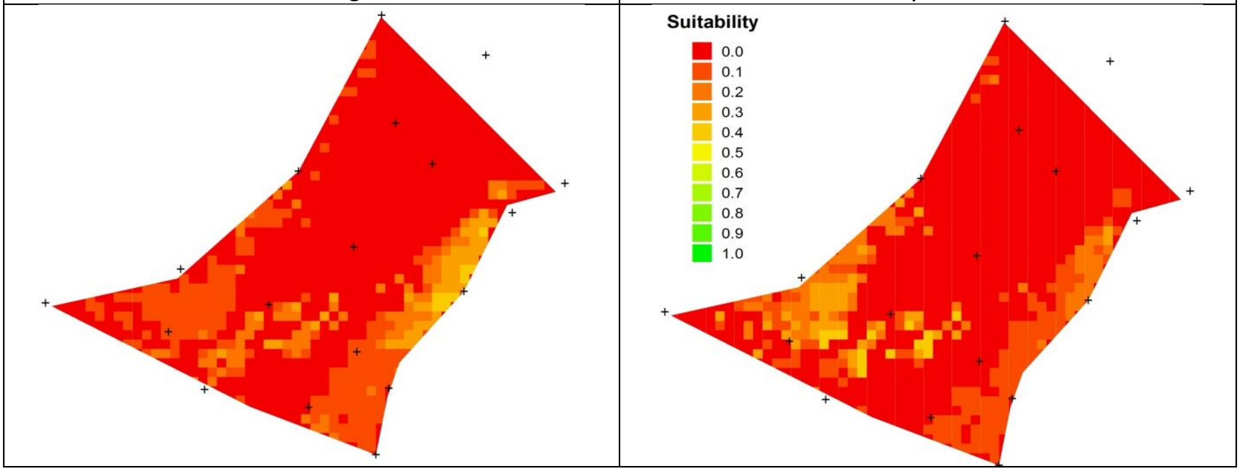
Qmean Spawning lamprey

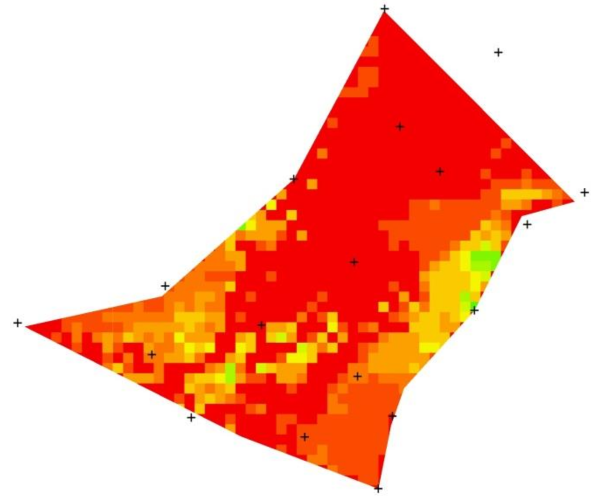
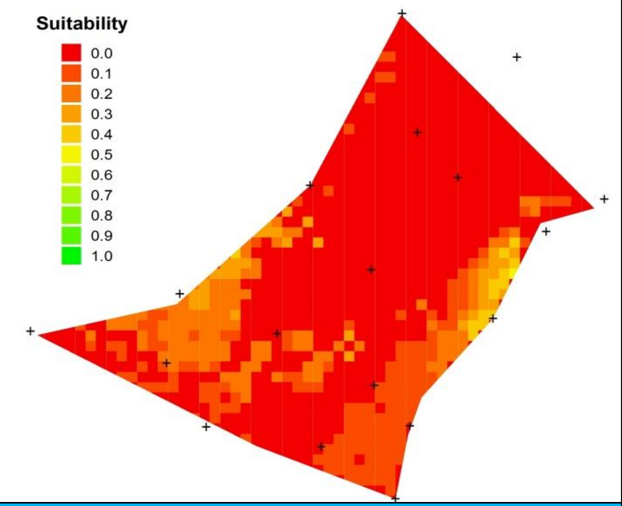
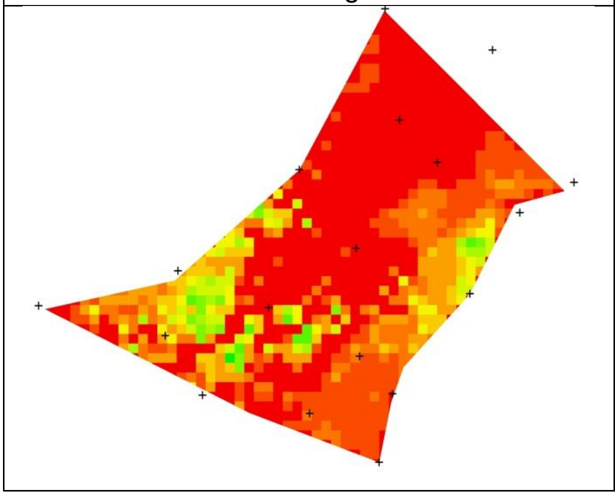
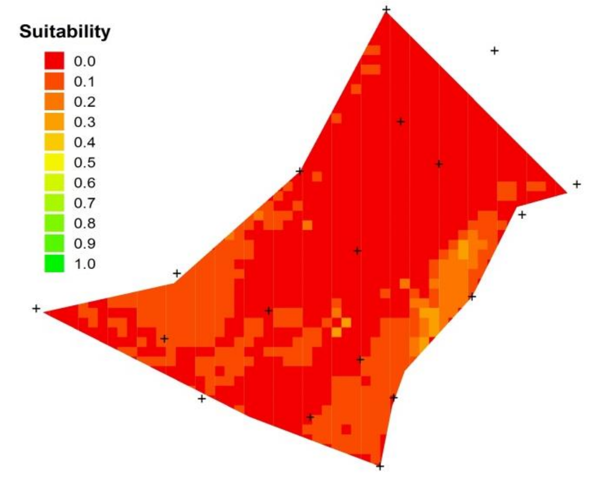
Existing | Proposed



Q50 Spawning lamprey

Existing | Proposed



Q75 Spawning lamprey	
Existing	Proposed
	
Q95 Spawning lamprey	
Existing	Proposed
	

Appendix 3 – Suitability changes at sampling points

Adult rheophilic – existing

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.184	2.613	0.522	0.248	1.479	0.900	0.197	1.231	0.900	0.164	1.030	0.828	0.133	0.932	0.648
G02	343705.3	468859.7	1.152	2.746	0.098	0.593	1.593	0.800	0.499	1.347	0.800	0.423	1.146	0.800	0.355	1.048	0.800
G03	343709.2	468837.5	1.209	3.058	0.043	0.784	1.884	0.736	0.604	1.634	0.800	0.486	1.428	0.800	0.395	1.327	0.800
G04	343721.5	468829.8	1.504	2.661	0.000	0.928	1.481	0.544	0.819	1.228	0.708	0.628	1.018	0.800	0.503	0.914	0.800
G05	343727.7	468803.5	1.672	3.244	0.000	1.181	2.040	0.000	0.985	1.783	0.000	0.792	1.562	0.000	0.624	1.451	0.000
G06	343709.4	468876.9	0.886	2.484	0.372	0.501	1.330	0.800	0.435	1.083	0.800	0.374	0.882	0.800	0.312	0.785	0.800
G07	343717.2	468870.0	1.183	2.661	0.090	0.712	1.506	0.792	0.611	1.261	0.800	0.524	1.060	0.800	0.441	0.964	0.800
G08	343727.2	468851.2	1.368	3.546	0.000	0.785	2.376	0.436	0.626	2.128	0.558	0.483	1.924	0.600	0.383	1.826	0.600
G09	343734.9	468832.4	2.143	2.180	0.000	1.451	1.039	0.000	1.238	0.795	0.108	0.967	0.597	0.460	0.765	0.500	0.760
G10	343730.1	468892.9	1.169	2.112	0.167	0.747	0.952	0.768	0.630	0.712	0.800	0.503	0.515	0.800	0.396	0.422	0.672
G11	343739.6	468869.4	1.397	3.009	0.000	0.793	1.857	0.728	0.628	1.615	0.800	0.476	1.417	0.800	0.373	1.324	0.800
G12	343755.9	468857.6	1.321	3.269	0.000	0.583	2.086	0.800	0.377	1.837	0.800	0.216	1.636	0.512	0.140	1.542	0.256
G13	343747.0	468903.2	1.199	3.027	0.058	0.660	1.875	0.800	0.503	1.634	0.800	0.347	1.438	0.800	0.246	1.345	0.576
G14	343757.4	468886.1	1.441	3.548	0.000	0.799	2.398	0.575	0.633	2.158	0.744	0.479	1.961	0.800	0.377	1.869	0.800
G15	343766.1	468878.3	1.678	3.990	0.000	0.918	2.851	0.263	0.703	2.612	0.510	0.505	2.419	0.632	0.385	2.327	0.688
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.925	0.048	0.000	3.793	0.048	0.000	3.556	0.048	0.000	3.363	0.048	0.000	3.272	0.048

Adult rheophilic - proposed

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.000	2.695	0.116	0.000	1.745	0.200	0.000	1.488	0.200	0.000	1.392	0.200	0.000	1.387	0.200
G02	343705.3	468859.7	1.032	2.727	0.155	0.409	1.767	0.800	0.348	1.505	0.800	0.256	1.404	0.640	0.245	1.398	0.608
G03	343709.2	468837.5	1.130	3.031	0.074	0.481	2.049	0.744	0.335	1.784	0.800	0.170	1.679	0.352	0.070	1.671	0.160
G04	343721.5	468829.8	1.424	2.631	0.000	0.674	1.634	0.800	0.466	1.366	0.800	0.245	1.258	0.608	0.109	1.250	0.160
G05	343727.7	468803.5	1.612	3.208	0.000	0.898	2.178	0.000	0.633	1.899	0.000	0.336	1.785	0.000	0.156	1.774	0.000
G06	343709.4	468876.9	0.690	2.458	0.547	0.845	1.504	0.660	0.872	1.243	0.612	0.860	1.147	0.636	0.839	1.144	0.660
G07	343717.2	468870.0	1.118	2.635	0.139	0.549	1.681	0.800	0.675	1.422	0.800	0.831	1.324	0.684	0.852	1.319	0.660
G08	343727.2	468851.2	1.302	3.517	0.003	0.603	2.547	0.390	0.450	2.284	0.516	0.253	2.184	0.446	0.103	2.179	0.112
G09	343734.9	468832.4	1.995	2.191	0.000	1.035	1.254	0.304	0.712	0.997	0.792	0.380	0.902	0.800	0.174	0.897	0.384
G10	343730.1	468892.9	1.108	2.073	0.248	0.861	1.131	0.648	0.794	0.872	0.728	0.470	0.783	0.800	0.165	0.784	0.352
G11	343739.6	468869.4	1.353	2.977	0.000	0.641	2.038	0.800	0.499	1.781	0.800	0.346	1.688	0.800	0.380	1.686	0.800
G12	343755.9	468857.6	1.680	2.349	0.000	0.745	1.411	0.674	0.485	1.155	0.800	0.277	1.063	0.640	0.140	1.060	0.224
G13	343747.0	468903.2	1.187	2.987	0.036	0.734	2.057	0.744	0.607	1.801	0.800	0.268	1.707	0.800	0.011	1.707	0.160
G14	343757.4	468886.1	1.413	3.512	0.000	0.664	2.580	0.520	0.521	2.324	0.632	0.488	2.234	0.688	0.546	2.233	0.688
G15	343766.1	468878.3	1.702	3.954	0.000	0.799	3.035	0.218	0.572	2.782	0.408	0.368	2.692	0.464	0.342	2.692	0.464
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.887	0.048	0.000	3.977	0.048	0.000	3.725	0.048	0.000	3.636	0.048	0.000	3.636	0.048

Juvenile rheophilic – existing

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.184	2.613	0.188	0.248	1.479	0.381	0.197	1.231	0.431	0.164	1.030	0.504	0.133	0.932	0.639
G02	343705.3	468859.7	1.152	2.746	0.000	0.593	1.593	0.238	0.499	1.347	0.294	0.423	1.146	0.333	0.355	1.048	0.372
G03	343709.2	468837.5	1.209	3.058	0.000	0.784	1.884	0.131	0.604	1.634	0.238	0.486	1.428	0.299	0.395	1.327	0.350
G04	343721.5	468829.8	1.504	2.661	0.000	0.928	1.481	0.051	0.819	1.228	0.114	0.628	1.018	0.221	0.503	0.914	0.288
G05	343727.7	468803.5	1.672	3.244	0.000	1.181	2.040	0.000	0.985	1.783	0.000	0.792	1.562	0.000	0.624	1.451	0.000
G06	343709.4	468876.9	0.886	2.484	0.032	0.501	1.330	0.277	0.435	1.083	0.310	0.374	0.882	0.350	0.312	0.785	0.383
G07	343717.2	468870.0	1.183	2.661	0.000	0.712	1.506	0.170	0.611	1.261	0.226	0.524	1.060	0.277	0.441	0.964	0.322
G08	343727.2	468851.2	1.368	3.546	0.000	0.785	2.376	0.078	0.626	2.128	0.154	0.483	1.924	0.224	0.383	1.826	0.266
G09	343734.9	468832.4	2.143	2.180	0.000	1.451	1.039	0.000	1.238	0.795	0.000	0.967	0.597	0.032	0.765	0.500	0.148
G10	343730.1	468892.9	1.169	2.112	0.000	0.747	0.952	0.154	0.630	0.712	0.221	0.503	0.515	0.288	0.396	0.422	0.294
G11	343739.6	468869.4	1.397	3.009	0.000	0.793	1.857	0.126	0.628	1.615	0.221	0.476	1.417	0.305	0.373	1.324	0.361
G12	343755.9	468857.6	1.321	3.269	0.000	0.583	2.086	0.243	0.377	1.837	0.361	0.216	1.636	0.616	0.140	1.542	0.752
G13	343747.0	468903.2	1.199	3.027	0.000	0.660	1.875	0.204	0.503	1.634	0.294	0.347	1.438	0.383	0.246	1.345	0.568
G14	343757.4	468886.1	1.441	3.548	0.000	0.799	2.398	0.099	0.633	2.158	0.200	0.479	1.961	0.305	0.377	1.869	0.361
G15	343766.1	468878.3	1.678	3.990	0.000	0.918	2.851	0.028	0.703	2.612	0.095	0.505	2.419	0.187	0.385	2.327	0.249
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.925	0.175	0.000	3.793	0.182	0.000	3.556	0.182	0.000	3.363	0.182	0.000	3.272	0.175

Juvenile rheophilic - proposed

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.000	2.695	0.406	0.000	1.745	0.700	0.000	1.488	0.700	0.000	1.392	0.700	0.000	1.387	0.700
G02	343705.3	468859.7	1.032	2.727	0.000	0.409	1.767	0.344	0.348	1.505	0.378	0.256	1.404	0.520	0.245	1.398	0.544
G03	343709.2	468837.5	1.130	3.031	0.000	0.481	2.049	0.283	0.335	1.784	0.389	0.170	1.679	0.704	0.070	1.671	0.704
G04	343721.5	468829.8	1.424	2.631	0.000	0.674	1.634	0.193	0.466	1.366	0.310	0.245	1.258	0.544	0.109	1.250	0.800
G05	343727.7	468803.5	1.612	3.208	0.000	0.898	2.178	0.000	0.633	1.899	0.000	0.336	1.785	0.000	0.156	1.774	0.000
G06	343709.4	468876.9	0.690	2.458	0.107	0.845	1.504	0.092	0.872	1.243	0.070	0.860	1.147	0.081	0.839	1.144	0.092
G07	343717.2	468870.0	1.118	2.635	0.000	0.549	1.681	0.266	0.675	1.422	0.193	0.831	1.324	0.103	0.852	1.319	0.092
G08	343727.2	468851.2	1.302	3.517	0.000	0.603	2.547	0.113	0.450	2.284	0.207	0.253	2.184	0.363	0.103	2.179	0.558
G09	343734.9	468832.4	1.995	2.191	0.000	1.035	1.254	0.000	0.712	0.997	0.170	0.380	0.902	0.355	0.174	0.897	0.688
G10	343730.1	468892.9	1.108	2.073	0.000	0.861	1.131	0.086	0.794	0.872	0.126	0.470	0.783	0.310	0.165	0.784	0.704
G11	343739.6	468869.4	1.353	2.977	0.000	0.641	2.038	0.210	0.499	1.781	0.294	0.346	1.688	0.378	0.380	1.686	0.355
G12	343755.9	468857.6	1.680	2.349	0.000	0.745	1.411	0.142	0.485	1.155	0.310	0.277	1.063	0.520	0.140	1.060	0.768
G13	343747.0	468903.2	1.187	2.987	0.000	0.734	2.057	0.176	0.607	1.801	0.232	0.268	1.707	0.394	0.011	1.707	0.584
G14	343757.4	468886.1	1.413	3.512	0.000	0.664	2.580	0.129	0.521	2.324	0.219	0.488	2.234	0.257	0.546	2.233	0.228
G15	343766.1	468878.3	1.702	3.954	0.000	0.799	3.035	0.044	0.572	2.782	0.100	0.368	2.692	0.169	0.342	2.692	0.250
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.887	0.175	0.000	3.977	0.168	0.000	3.725	0.175	0.000	3.636	0.175	0.000	3.636	0.197

Spawning rheophilic – existing

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.184	2.613	0.000	0.248	1.479	0.000	0.197	1.231	0.000	0.164	1.030	0.000	0.133	0.932	0.000
G02	343705.3	468859.7	1.152	2.746	0.000	0.593	1.593	0.000	0.499	1.347	0.000	0.423	1.146	0.000	0.355	1.048	0.000
G03	343709.2	468837.5	1.209	3.058	0.000	0.784	1.884	0.000	0.604	1.634	0.000	0.486	1.428	0.000	0.395	1.327	0.000
G04	343721.5	468829.8	1.504	2.661	0.000	0.928	1.481	0.000	0.819	1.228	0.000	0.628	1.018	0.000	0.503	0.914	0.180
G05	343727.7	468803.5	1.672	3.244	0.000	1.181	2.040	0.000	0.985	1.783	0.000	0.792	1.562	0.000	0.624	1.451	0.000
G06	343709.4	468876.9	0.886	2.484	0.000	0.501	1.330	0.000	0.435	1.083	0.000	0.374	0.882	0.000	0.312	0.785	0.000
G07	343717.2	468870.0	1.183	2.661	0.000	0.712	1.506	0.000	0.611	1.261	0.000	0.524	1.060	0.000	0.441	0.964	0.048
G08	343727.2	468851.2	1.368	3.546	0.000	0.785	2.376	0.190	0.626	2.128	0.670	0.483	1.924	0.000	0.383	1.826	0.000
G09	343734.9	468832.4	2.143	2.180	0.000	1.451	1.039	0.000	1.238	0.795	0.000	0.967	0.597	0.000	0.765	0.500	0.276
G10	343730.1	468892.9	1.169	2.112	0.000	0.747	0.952	0.032	0.630	0.712	0.418	0.503	0.515	0.980	0.396	0.422	1.000
G11	343739.6	468869.4	1.397	3.009	0.000	0.793	1.857	0.000	0.628	1.615	0.000	0.476	1.417	0.000	0.373	1.324	0.000
G12	343755.9	468857.6	1.321	3.269	0.000	0.583	2.086	0.000	0.377	1.837	0.000	0.216	1.636	0.000	0.140	1.542	0.000
G13	343747.0	468903.2	1.199	3.027	0.000	0.660	1.875	0.000	0.503	1.634	0.000	0.347	1.438	0.000	0.246	1.345	0.000
G14	343757.4	468886.1	1.441	3.548	0.000	0.799	2.398	0.174	0.633	2.158	0.632	0.479	1.961	0.000	0.377	1.869	0.000
G15	343766.1	468878.3	1.678	3.990	0.000	0.918	2.851	0.030	0.703	2.612	0.299	0.505	2.419	0.580	0.385	2.327	0.650
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.925	0.006	0.000	3.793	0.012	0.000	3.556	0.012	0.000	3.363	0.012	0.000	3.272	0.006

Spawning rheophilic - proposed

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.000	2.695	0.000	0.000	1.745	0.000	0.000	1.488	0.000	0.000	1.392	0.000	0.000	1.387	0.000
G02	343705.3	468859.7	1.032	2.727	0.000	0.409	1.767	0.000	0.348	1.505	0.000	0.256	1.404	0.000	0.245	1.398	0.000
G03	343709.2	468837.5	1.130	3.031	0.000	0.481	2.049	0.930	0.335	1.784	0.000	0.170	1.679	0.000	0.070	1.671	0.000
G04	343721.5	468829.8	1.424	2.631	0.000	0.674	1.634	0.000	0.466	1.366	0.000	0.245	1.258	0.000	0.109	1.250	0.000
G05	343727.7	468803.5	1.612	3.208	0.000	0.898	2.178	0.000	0.633	1.899	0.000	0.336	1.785	0.000	0.156	1.774	0.000
G06	343709.4	468876.9	0.690	2.458	0.000	0.845	1.504	0.000	0.872	1.243	0.000	0.860	1.147	0.000	0.839	1.144	0.000
G07	343717.2	468870.0	1.118	2.635	0.000	0.549	1.681	0.000	0.675	1.422	0.000	0.831	1.324	0.000	0.852	1.319	0.000
G08	343727.2	468851.2	1.302	3.517	0.000	0.603	2.547	0.520	0.450	2.284	0.860	0.253	2.184	0.744	0.103	2.179	0.186
G09	343734.9	468832.4	1.995	2.191	0.000	1.035	1.254	0.000	0.712	0.997	0.008	0.380	0.902	0.200	0.174	0.897	0.106
G10	343730.1	468892.9	1.108	2.073	0.000	0.861	1.131	0.000	0.794	0.872	0.057	0.470	0.783	0.440	0.165	0.784	0.194
G11	343739.6	468869.4	1.353	2.977	0.000	0.641	2.038	0.000	0.499	1.781	0.000	0.346	1.688	0.000	0.380	1.686	0.000
G12	343755.9	468857.6	1.680	2.349	0.000	0.745	1.411	0.310	0.485	1.155	0.000	0.277	1.063	0.000	0.140	1.060	0.000
G13	343747.0	468903.2	1.187	2.987	0.000	0.734	2.057	0.000	0.607	1.801	0.000	0.268	1.707	0.000	0.011	1.707	0.000
G14	343757.4	468886.1	1.413	3.512	0.000	0.664	2.580	0.364	0.521	2.324	0.758	0.488	2.234	0.860	0.546	2.233	0.791
G15	343766.1	468878.3	1.702	3.954	0.000	0.799	3.035	0.090	0.572	2.782	0.348	0.368	2.692	0.440	0.342	2.692	0.317
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.887	0.006	0.000	3.977	0.000	0.000	3.725	0.006	0.000	3.636	0.006	0.000	3.636	0.024

Adult roach – existing

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.184	2.613	0.122	0.248	1.479	0.234	0.197	1.231	0.442	0.164	1.030	0.572	0.133	0.932	0.650
G02	343705.3	468859.7	1.152	2.746	0.013	0.593	1.593	0.083	0.499	1.347	0.095	0.423	1.146	0.160	0.355	1.048	0.300
G03	343709.2	468837.5	1.209	3.058	0.008	0.784	1.884	0.059	0.604	1.634	0.083	0.486	1.428	0.096	0.395	1.327	0.220
G04	343721.5	468829.8	1.504	2.661	0.000	0.928	1.481	0.041	0.819	1.228	0.055	0.628	1.018	0.079	0.503	0.914	0.094
G05	343727.7	468803.5	1.672	3.244	0.000	1.181	2.040	0.000	0.985	1.783	0.000	0.792	1.562	0.000	0.624	1.451	0.000
G06	343709.4	468876.9	0.886	2.484	0.039	0.501	1.330	0.091	0.435	1.083	0.100	0.374	0.882	0.220	0.312	0.785	0.360
G07	343717.2	468870.0	1.183	2.661	0.009	0.712	1.506	0.068	0.611	1.261	0.080	0.524	1.060	0.091	0.441	0.964	0.120
G08	343727.2	468851.2	1.368	3.546	0.000	0.785	2.376	0.035	0.626	2.128	0.047	0.483	1.924	0.058	0.383	1.826	0.144
G09	343734.9	468832.4	2.143	2.180	0.000	1.451	1.039	0.000	1.238	0.795	0.004	0.967	0.597	0.038	0.765	0.500	0.063
G10	343730.1	468892.9	1.169	2.112	0.011	0.747	0.952	0.064	0.630	0.712	0.079	0.503	0.515	0.094	0.396	0.422	0.220
G11	343739.6	468869.4	1.397	3.009	0.000	0.793	1.857	0.058	0.628	1.615	0.079	0.476	1.417	0.098	0.373	1.324	0.260
G12	343755.9	468857.6	1.321	3.269	0.000	0.583	2.086	0.084	0.377	1.837	0.260	0.216	1.636	0.500	0.140	1.542	0.500
G13	343747.0	468903.2	1.199	3.027	0.009	0.660	1.875	0.075	0.503	1.634	0.095	0.347	1.438	0.340	0.246	1.345	0.500
G14	343757.4	468886.1	1.441	3.548	0.000	0.799	2.398	0.058	0.633	2.158	0.078	0.479	1.961	0.098	0.377	1.869	0.260
G15	343766.1	468878.3	1.678	3.990	0.000	0.918	2.851	0.050	0.703	2.612	0.078	0.505	2.419	0.120	0.385	2.327	0.340
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.925	0.500	0.000	3.793	0.500	0.000	3.556	0.500	0.000	3.363	0.500	0.000	3.272	0.500

Adult roach - proposed

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.000	2.695	0.700	0.000	1.745	0.700	0.000	1.488	0.700	0.000	1.392	0.700	0.000	1.387	0.700
G02	343705.3	468859.7	1.032	2.727	0.028	0.409	1.767	0.200	0.348	1.505	0.320	0.256	1.404	0.500	0.245	1.398	0.500
G03	343709.2	468837.5	1.130	3.031	0.019	0.481	2.049	0.098	0.335	1.784	0.360	0.170	1.679	0.500	0.070	1.671	0.500
G04	343721.5	468829.8	1.424	2.631	0.000	0.674	1.634	0.073	0.466	1.366	0.099	0.245	1.258	0.500	0.109	1.250	0.500
G05	343727.7	468803.5	1.612	3.208	0.000	0.898	2.178	0.000	0.633	1.899	0.000	0.336	1.785	0.000	0.156	1.774	0.000
G06	343709.4	468876.9	0.690	2.458	0.066	0.845	1.504	0.053	0.872	1.243	0.050	0.860	1.147	0.054	0.839	1.144	0.056
G07	343717.2	468870.0	1.118	2.635	0.018	0.549	1.681	0.089	0.675	1.422	0.073	0.831	1.324	0.053	0.852	1.319	0.050
G08	343727.2	468851.2	1.302	3.517	0.000	0.603	2.547	0.049	0.450	2.284	0.072	0.253	2.184	0.300	0.103	2.179	0.300
G09	343734.9	468832.4	1.995	2.191	0.000	1.035	1.254	0.028	0.712	0.997	0.068	0.380	0.902	0.240	0.174	0.897	0.500
G10	343730.1	468892.9	1.108	2.073	0.019	0.861	1.131	0.049	0.794	0.872	0.058	0.470	0.783	0.099	0.165	0.784	0.500
G11	343739.6	468869.4	1.353	2.977	0.000	0.641	2.038	0.076	0.499	1.781	0.095	0.346	1.688	0.320	0.380	1.686	0.240
G12	343755.9	468857.6	1.680	2.349	0.000	0.745	1.411	0.066	0.485	1.155	0.099	0.277	1.063	0.500	0.140	1.060	0.500
G13	343747.0	468903.2	1.187	2.987	0.010	0.734	2.057	0.069	0.607	1.801	0.081	0.268	1.707	0.380	0.011	1.707	0.500
G14	343757.4	468886.1	1.413	3.512	0.000	0.664	2.580	0.074	0.521	2.324	0.091	0.488	2.234	0.096	0.546	2.233	0.089
G15	343766.1	468878.3	1.702	3.954	0.000	0.799	3.035	0.063	0.572	2.782	0.090	0.368	2.692	0.340	0.342	2.692	0.500
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.887	0.500	0.000	3.977	0.500	0.000	3.725	0.500	0.000	3.636	0.500	0.000	3.636	0.500

Juvenile roach – existing

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.184	2.613	0.000	0.248	1.479	0.000	0.197	1.231	0.000	0.164	1.030	0.065	0.133	0.932	0.216
G02	343705.3	468859.7	1.152	2.746	0.000	0.593	1.593	0.000	0.499	1.347	0.000	0.423	1.146	0.000	0.355	1.048	0.000
G03	343709.2	468837.5	1.209	3.058	0.000	0.784	1.884	0.000	0.604	1.634	0.000	0.486	1.428	0.000	0.395	1.327	0.000
G04	343721.5	468829.8	1.504	2.661	0.000	0.928	1.481	0.000	0.819	1.228	0.000	0.628	1.018	0.000	0.503	0.914	0.000
G05	343727.7	468803.5	1.672	3.244	0.000	1.181	2.040	0.000	0.985	1.783	0.000	0.792	1.562	0.000	0.624	1.451	0.000
G06	343709.4	468876.9	0.886	2.484	0.000	0.501	1.330	0.000	0.435	1.083	0.000	0.374	0.882	0.000	0.312	0.785	0.000
G07	343717.2	468870.0	1.183	2.661	0.000	0.712	1.506	0.000	0.611	1.261	0.000	0.524	1.060	0.000	0.441	0.964	0.000
G08	343727.2	468851.2	1.368	3.546	0.000	0.785	2.376	0.000	0.626	2.128	0.000	0.483	1.924	0.000	0.383	1.826	0.000
G09	343734.9	468832.4	2.143	2.180	0.000	1.451	1.039	0.000	1.238	0.795	0.000	0.967	0.597	0.000	0.765	0.500	0.000
G10	343730.1	468892.9	1.169	2.112	0.000	0.747	0.952	0.000	0.630	0.712	0.000	0.503	0.515	0.000	0.396	0.422	0.000
G11	343739.6	468869.4	1.397	3.009	0.000	0.793	1.857	0.000	0.628	1.615	0.000	0.476	1.417	0.000	0.373	1.324	0.000
G12	343755.9	468857.6	1.321	3.269	0.000	0.583	2.086	0.000	0.377	1.837	0.000	0.216	1.636	0.225	0.140	1.542	0.425
G13	343747.0	468903.2	1.199	3.027	0.000	0.660	1.875	0.000	0.503	1.634	0.000	0.347	1.438	0.000	0.246	1.345	0.175
G14	343757.4	468886.1	1.441	3.548	0.000	0.799	2.398	0.000	0.633	2.158	0.000	0.479	1.961	0.000	0.377	1.869	0.000
G15	343766.1	468878.3	1.678	3.990	0.000	0.918	2.851	0.000	0.703	2.612	0.000	0.505	2.419	0.000	0.385	2.327	0.000
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.925	0.410	0.000	3.793	0.420	0.000	3.556	0.420	0.000	3.363	0.420	0.000	3.272	0.410

Juvenile roach - proposed

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.000	2.695	0.560	0.000	1.745	0.560	0.000	1.488	0.560	0.000	1.392	0.560	0.000	1.387	0.560
G02	343705.3	468859.7	1.032	2.727	0.000	0.409	1.767	0.000	0.348	1.505	0.000	0.256	1.404	0.125	0.245	1.398	0.150
G03	343709.2	468837.5	1.130	3.031	0.000	0.481	2.049	0.000	0.335	1.784	0.000	0.170	1.679	0.350	0.070	1.671	0.460
G04	343721.5	468829.8	1.424	2.631	0.000	0.674	1.634	0.000	0.466	1.366	0.000	0.245	1.258	0.150	0.109	1.250	0.500
G05	343727.7	468803.5	1.612	3.208	0.000	0.898	2.178	0.000	0.633	1.899	0.000	0.336	1.785	0.000	0.156	1.774	0.000
G06	343709.4	468876.9	0.690	2.458	0.000	0.845	1.504	0.000	0.872	1.243	0.000	0.860	1.147	0.000	0.839	1.144	0.000
G07	343717.2	468870.0	1.118	2.635	0.000	0.549	1.681	0.000	0.675	1.422	0.000	0.831	1.324	0.000	0.852	1.319	0.000
G08	343727.2	468851.2	1.302	3.517	0.000	0.603	2.547	0.000	0.450	2.284	0.000	0.253	2.184	0.075	0.103	2.179	0.300
G09	343734.9	468832.4	1.995	2.191	0.000	1.035	1.254	0.000	0.712	0.997	0.000	0.380	0.902	0.000	0.174	0.897	0.289
G10	343730.1	468892.9	1.108	2.073	0.000	0.861	1.131	0.000	0.794	0.872	0.000	0.470	0.783	0.000	0.165	0.784	0.273
G11	343739.6	468869.4	1.353	2.977	0.000	0.641	2.038	0.000	0.499	1.781	0.000	0.346	1.688	0.000	0.380	1.686	0.000
G12	343755.9	468857.6	1.680	2.349	0.000	0.745	1.411	0.000	0.485	1.155	0.000	0.277	1.063	0.125	0.140	1.060	0.450
G13	343747.0	468903.2	1.187	2.987	0.000	0.734	2.057	0.000	0.607	1.801	0.000	0.268	1.707	0.000	0.011	1.707	0.410
G14	343757.4	468886.1	1.413	3.512	0.410	0.664	2.580	0.400	0.521	2.324	0.410	0.488	2.234	0.410	0.546	2.233	0.000
G15	343766.1	468878.3	1.702	3.954	0.000	0.799	3.035	0.000	0.572	2.782	0.000	0.368	2.692	0.000	0.342	2.692	0.175
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.887	0.410	0.000	3.977	0.400	0.000	3.725	0.410	0.000	3.636	0.410	0.000	3.636	0.440

Spawning roach – existing

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.184	2.613	0.000	0.248	1.479	0.000	0.197	1.231	0.000	0.164	1.030	0.000	0.133	0.932	0.000
G02	343705.3	468859.7	1.152	2.746	0.000	0.593	1.593	0.000	0.499	1.347	0.000	0.423	1.146	0.000	0.355	1.048	0.000
G03	343709.2	468837.5	1.209	3.058	0.000	0.784	1.884	0.000	0.604	1.634	0.000	0.486	1.428	0.000	0.395	1.327	0.000
G04	343721.5	468829.8	1.504	2.661	0.000	0.928	1.481	0.000	0.819	1.228	0.000	0.628	1.018	0.000	0.503	0.914	0.000
G05	343727.7	468803.5	1.672	3.244	0.000	1.181	2.040	0.000	0.985	1.783	0.000	0.792	1.562	0.000	0.624	1.451	0.000
G06	343709.4	468876.9	0.886	2.484	0.000	0.501	1.330	0.000	0.435	1.083	0.000	0.374	0.882	0.000	0.312	0.785	0.198
G07	343717.2	468870.0	1.183	2.661	0.000	0.712	1.506	0.000	0.611	1.261	0.000	0.524	1.060	0.000	0.441	0.964	0.000
G08	343727.2	468851.2	1.368	3.546	0.000	0.785	2.376	0.000	0.626	2.128	0.000	0.483	1.924	0.000	0.383	1.826	0.000
G09	343734.9	468832.4	2.143	2.180	0.000	1.451	1.039	0.000	1.238	0.795	0.000	0.967	0.597	0.000	0.765	0.500	0.000
G10	343730.1	468892.9	1.169	2.112	0.000	0.747	0.952	0.000	0.630	0.712	0.000	0.503	0.515	0.000	0.396	0.422	0.000
G11	343739.6	468869.4	1.397	3.009	0.000	0.793	1.857	0.000	0.628	1.615	0.000	0.476	1.417	0.000	0.373	1.324	0.000
G12	343755.9	468857.6	1.321	3.269	0.000	0.583	2.086	0.000	0.377	1.837	0.000	0.216	1.636	0.000	0.140	1.542	0.000
G13	343747.0	468903.2	1.199	3.027	0.000	0.660	1.875	0.000	0.503	1.634	0.000	0.347	1.438	0.000	0.246	1.345	0.000
G14	343757.4	468886.1	1.441	3.548	0.000	0.799	2.398	0.000	0.633	2.158	0.000	0.479	1.961	0.000	0.377	1.869	0.000
G15	343766.1	468878.3	1.678	3.990	0.000	0.918	2.851	0.000	0.703	2.612	0.000	0.505	2.419	0.000	0.385	2.327	0.000
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.925	0.000	0.000	3.793	0.000	0.000	3.556	0.000	0.000	3.363	0.000	0.000	3.272	0.000

Spawning roach - proposed

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.000	2.695	0.000	0.000	1.745	0.000	0.000	1.488	0.000	0.000	1.392	0.000	0.000	1.387	0.000
G02	343705.3	468859.7	1.032	2.727	0.000	0.409	1.767	0.000	0.348	1.505	0.000	0.256	1.404	0.000	0.245	1.398	0.000
G03	343709.2	468837.5	1.130	3.031	0.000	0.481	2.049	0.000	0.335	1.784	0.000	0.170	1.679	0.000	0.070	1.671	0.000
G04	343721.5	468829.8	1.424	2.631	0.000	0.674	1.634	0.000	0.466	1.366	0.000	0.245	1.258	0.000	0.109	1.250	0.000
G05	343727.7	468803.5	1.612	3.208	0.000	0.898	2.178	0.000	0.633	1.899	0.000	0.336	1.785	0.000	0.156	1.774	0.000
G06	343709.4	468876.9	0.690	2.458	0.000	0.845	1.504	0.000	0.872	1.243	0.000	0.860	1.147	0.000	0.839	1.144	0.000
G07	343717.2	468870.0	1.118	2.635	0.000	0.549	1.681	0.000	0.675	1.422	0.000	0.831	1.324	0.000	0.852	1.319	0.000
G08	343727.2	468851.2	1.302	3.517	0.000	0.603	2.547	0.000	0.450	2.284	0.000	0.253	2.184	0.000	0.103	2.179	0.000
G09	343734.9	468832.4	1.995	2.191	0.000	1.035	1.254	0.000	0.712	0.997	0.000	0.380	0.902	0.000	0.174	0.897	0.000
G10	343730.1	468892.9	1.108	2.073	0.000	0.861	1.131	0.000	0.794	0.872	0.000	0.470	0.783	0.000	0.165	0.784	0.000
G11	343739.6	468869.4	1.353	2.977	0.000	0.641	2.038	0.000	0.499	1.781	0.000	0.346	1.688	0.000	0.380	1.686	0.000
G12	343755.9	468857.6	1.680	2.349	0.000	0.745	1.411	0.000	0.485	1.155	0.000	0.277	1.063	0.000	0.140	1.060	0.000
G13	343747.0	468903.2	1.187	2.987	0.000	0.734	2.057	0.000	0.607	1.801	0.000	0.268	1.707	0.000	0.011	1.707	0.000
G14	343757.4	468886.1	1.413	3.512	0.000	0.664	2.580	0.000	0.521	2.324	0.000	0.488	2.234	0.000	0.546	2.233	0.000
G15	343766.1	468878.3	1.702	3.954	0.000	0.799	3.035	0.000	0.572	2.782	0.000	0.368	2.692	0.000	0.342	2.692	0.000
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.887	0.000	0.000	3.977	0.000	0.000	3.725	0.000	0.000	3.636	0.000	0.000	3.636	0.000

Spawning lamprey – existing

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.184	2.613	0.000	0.248	1.479	0.000	0.197	1.231	0.003	0.164	1.030	0.013	0.133	0.932	0.013
G02	343705.3	468859.7	1.152	2.746	0.000	0.593	1.593	0.000	0.499	1.347	0.000	0.423	1.146	0.086	0.355	1.048	0.123
G03	343709.2	468837.5	1.209	3.058	0.000	0.784	1.884	0.000	0.604	1.634	0.000	0.486	1.428	0.000	0.395	1.327	0.042
G04	343721.5	468829.8	1.504	2.661	0.000	0.928	1.481	0.000	0.819	1.228	0.024	0.628	1.018	0.185	0.503	0.914	0.245
G05	343727.7	468803.5	1.672	3.244	0.000	1.181	2.040	0.000	0.985	1.783	0.000	0.792	1.562	0.000	0.624	1.451	0.000
G06	343709.4	468876.9	0.886	2.484	0.000	0.501	1.330	0.000	0.435	1.083	0.000	0.374	0.882	0.000	0.312	0.785	0.000
G07	343717.2	468870.0	1.183	2.661	0.000	0.712	1.506	0.000	0.611	1.261	0.027	0.524	1.060	0.185	0.441	0.964	0.194
G08	343727.2	468851.2	1.368	3.546	0.000	0.785	2.376	0.000	0.626	2.128	0.000	0.483	1.924	0.000	0.383	1.826	0.000
G09	343734.9	468832.4	2.143	2.180	0.000	1.451	1.039	0.000	1.238	0.795	0.000	0.967	0.597	0.066	0.765	0.500	0.272
G10	343730.1	468892.9	1.169	2.112	0.000	0.747	0.952	0.178	0.630	0.712	0.299	0.503	0.515	0.888	0.396	0.422	0.584
G11	343739.6	468869.4	1.397	3.009	0.000	0.793	1.857	0.000	0.628	1.615	0.000	0.476	1.417	0.000	0.373	1.324	0.000
G12	343755.9	468857.6	1.321	3.269	0.000	0.583	2.086	0.000	0.377	1.837	0.000	0.216	1.636	0.000	0.140	1.542	0.000
G13	343747.0	468903.2	1.199	3.027	0.000	0.660	1.875	0.000	0.503	1.634	0.000	0.347	1.438	0.000	0.246	1.345	0.000
G14	343757.4	468886.1	1.441	3.548	0.000	0.799	2.398	0.000	0.633	2.158	0.000	0.479	1.961	0.000	0.377	1.869	0.000
G15	343766.1	468878.3	1.678	3.990	0.000	0.918	2.851	0.000	0.703	2.612	0.000	0.505	2.419	0.000	0.385	2.327	0.000
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.925	0.000	0.000	3.793	0.000	0.000	3.556	0.000	0.000	3.363	0.000	0.000	3.272	0.000

Spawning lamprey - proposed

			Q5			Qmean			Q50			Q75			Q95		
Site	Northing	Easting	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability	Vel (m/s)	Dep (m)	Suitability
G01	343695.2	468874.1	0.000	2.695	0.000	0.000	1.745	0.002	0.000	1.488	0.008	0.000	1.392	0.007	0.000	1.387	0.008
G02	343705.3	468859.7	1.032	2.727	0.000	0.409	1.767	0.000	0.348	1.505	0.000	0.256	1.404	0.000	0.245	1.398	0.000
G03	343709.2	468837.5	1.130	3.031	0.000	0.481	2.049	0.000	0.335	1.784	0.000	0.170	1.679	0.000	0.070	1.671	0.000
G04	343721.5	468829.8	1.424	2.631	0.000	0.674	1.634	0.000	0.466	1.366	0.000	0.245	1.258	0.016	0.109	1.250	0.005
G05	343727.7	468803.5	1.612	3.208	0.000	0.898	2.178	0.000	0.633	1.899	0.000	0.336	1.785	0.000	0.156	1.774	0.000
G06	343709.4	468876.9	0.690	2.458	0.000	0.845	1.504	0.000	0.872	1.243	0.000	0.860	1.147	0.000	0.839	1.144	0.000
G07	343717.2	468870.0	1.118	2.635	0.000	0.549	1.681	0.000	0.675	1.422	0.000	0.831	1.324	0.000	0.852	1.319	0.000
G08	343727.2	468851.2	1.302	3.517	0.000	0.603	2.547	0.000	0.450	2.284	0.000	0.253	2.184	0.000	0.103	2.179	0.000
G09	343734.9	468832.4	1.995	2.191	0.000	1.035	1.254	0.003	0.712	0.997	0.138	0.380	0.902	0.152	0.174	0.897	0.059
G10	343730.1	468892.9	1.108	2.073	0.000	0.861	1.131	0.056	0.794	0.872	0.146	0.470	0.783	0.310	0.165	0.784	0.079
G11	343739.6	468869.4	1.353	2.977	0.000	0.641	2.038	0.000	0.499	1.781	0.000	0.346	1.688	0.000	0.380	1.686	0.000
G12	343755.9	468857.6	1.680	2.349	0.000	0.745	1.411	0.000	0.485	1.155	0.000	0.277	1.063	0.000	0.140	1.060	0.000
G13	343747.0	468903.2	1.187	2.987	0.000	0.734	2.057	0.000	0.607	1.801	0.000	0.268	1.707	0.000	0.011	1.707	0.000
G14	343757.4	468886.1	1.413	3.512	0.000	0.664	2.580	0.000	0.521	2.324	0.000	0.488	2.234	0.000	0.546	2.233	0.000
G15	343766.1	468878.3	1.702	3.954	0.000	0.799	3.035	0.000	0.572	2.782	0.000	0.368	2.692	0.000	0.342	2.692	0.000
G16	343753.2	468914.5	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G17	343780.7	468897.6	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA	0.000	0.000	NA
G18	343789.2	468875.4	0.000	4.887	0.000	0.000	3.977	0.000	0.000	3.725	0.000	0.000	3.636	0.000	0.000	3.636	0.000

Appendix 4 – Fish habitat suitability area statistics

Adult rheophilic

Existing	**Area m2**	**% cover**																				
	0.0		**0.1**		**0.2**		**0.3**		**0.4**		**0.5**		**0.6**		**0.7**		**0.8**		**0.9**		**1.0**	
Q5	2494.66	62.7%	911.74	22.9%	298.74	7.5%	170.71	4.3%	27.16	0.7%	31.04	0.8%	19.40	0.5%	19.40	0.5%	7.76	0.2%	0.00	0.0%	0.00	0.0%
Qmean	116.39	2.9%	178.47	4.5%	271.58	6.8%	593.60	14.9%	267.70	6.7%	232.78	5.8%	232.78	5.8%	818.62	20.6%	1253.15	31.5%	15.52	0.4%	0.00	0.0%
Q50	27.16	0.7%	73.71	1.9%	131.91	3.3%	244.42	6.1%	193.99	4.9%	325.90	8.2%	279.34	7.0%	310.38	7.8%	2378.27	59.7%	15.52	0.4%	0.00	0.0%
Q75	27.16	0.7%	77.59	1.9%	89.23	2.2%	65.96	1.7%	54.32	1.4%	174.59	4.4%	259.94	6.5%	283.22	7.1%	2933.07	73.7%	15.52	0.4%	0.00	0.0%
Q95	27.16	0.7%	89.23	2.2%	135.79	3.4%	69.84	1.8%	50.44	1.3%	100.87	2.5%	213.38	5.4%	322.02	8.1%	2960.23	74.4%	11.64	0.3%	0.00	0.0%

Proposed	**Area m2**	**% cover**																				
	0.0		**0.1**		**0.2**		**0.3**		**0.4**		**0.5**		**0.6**		**0.7**		**0.8**		**0.9**		**1.0**	
Q5	2234.59	56.1%	1049.12	26.4%	295.42	7.4%	174.22	4.4%	64.39	1.6%	53.02	1.3%	64.39	1.6%	22.72	0.6%	18.94	0.5%	3.79	0.1%	0.00	0.0%
Qmean	26.51	0.7%	83.32	2.1%	136.35	3.4%	681.74	17.1%	212.10	5.3%	231.03	5.8%	303.00	7.6%	534.03	13.4%	1772.52	44.5%	0.00	0.0%	0.00	0.0%
Q50	26.51	0.7%	79.54	2.0%	170.43	4.3%	310.57	7.8%	166.65	4.2%	257.55	6.5%	242.40	6.1%	356.02	8.9%	2370.94	59.6%	0.00	0.0%	0.00	0.0%
Q75	26.51	0.7%	106.05	2.7%	204.52	5.1%	223.46	5.6%	333.29	8.4%	496.15	12.5%	405.26	10.2%	386.32	9.7%	1799.03	45.2%	0.00	0.0%	0.00	0.0%
Q95	26.51	0.7%	212.10	5.3%	1261.22	31.7%	530.24	13.3%	382.53	9.6%	253.76	6.4%	143.92	3.6%	227.25	5.7%	943.07	23.7%	0.00	0.0%	0.00	0.0%

Juvenile rheophilic

Existing	**Area m2**	**% cover**																				
	0.0		**0.1**		**0.2**		**0.3**		**0.4**		**0.5**		**0.6**		**0.7**		**0.8**		**0.9**		**1.0**	
Q5	3689.62	92.7%	139.67	3.5%	116.39	2.9%	23.28	0.6%	0.00	0.0%	3.88	0.1%	3.88	0.1%	3.88	0.1%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Qmean	558.68	14.0%	1582.93	39.8%	1326.87	33.3%	403.49	10.1%	54.32	1.4%	15.52	0.4%	23.28	0.6%	3.88	0.1%	11.64	0.3%	0.00	0.0%	0.00	0.0%
Q50	256.06	6.4%	481.09	12.1%	1664.40	41.8%	1330.75	33.4%	147.43	3.7%	11.64	0.3%	50.44	1.3%	19.40	0.5%	19.40	0.5%	0.00	0.0%	0.00	0.0%
Q75	27.16	0.7%	108.63	2.7%	597.48	15.0%	2157.13	54.2%	927.25	23.3%	31.04	0.8%	50.44	1.3%	34.92	0.9%	46.56	1.2%	0.00	0.0%	0.00	0.0%
Q95	27.16	0.7%	0.00	0.0%	151.31	3.8%	1066.92	26.8%	2327.84	58.5%	186.23	4.7%	100.87	2.5%	46.56	1.2%	73.71	1.9%	0.00	0.0%	0.00	0.0%

Proposed	**Area m2**	**% cover**																				
	0.0		**0.1**		**0.2**		**0.3**		**0.4**		**0.5**		**0.6**		**0.7**		**0.8**		**0.9**		**1.0**	
Q5	3450.36	86.7%	223.46	5.6%	193.16	4.9%	90.90	2.3%	0.00	0.0%	11.36	0.3%	3.79	0.1%	7.57	0.2%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Qmean	162.86	4.1%	1083.21	27.2%	1674.05	42.1%	776.43	19.5%	162.86	4.1%	30.30	0.8%	68.17	1.7%	15.15	0.4%	7.57	0.2%	0.00	0.0%	0.00	0.0%
Q50	71.96	1.8%	390.11	9.8%	1234.71	31.0%	1435.44	36.1%	681.74	17.1%	41.66	1.0%	94.69	2.4%	26.51	0.7%	3.79	0.1%	0.00	0.0%	0.00	0.0%
Q75	75.75	1.9%	204.52	5.1%	810.51	20.4%	871.11	21.9%	829.45	20.8%	371.17	9.3%	401.47	10.1%	337.08	8.5%	79.54	2.0%	0.00	0.0%	0.00	0.0%
Q95	53.02	1.3%	208.31	5.2%	552.97	13.9%	662.80	16.7%	424.19	10.7%	181.80	4.6%	284.06	7.1%	515.09	12.9%	1098.36	27.6%	0.00	0.0%	0.00	0.0%

Spawning rheophilic

Existing	Area m2	% cover																				
	0.0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
Q5	3848.69	96.7%	54.32	1.4%	11.64	0.3%	50.44	1.3%	0.00	0.0%	3.88	0.1%	7.76	0.2%	0.00	0.0%	3.88	0.1%	0.00	0.0%	0.00	0.0%
Qmean	2894.28	72.7%	500.48	12.6%	197.87	5.0%	205.63	5.2%	89.23	2.2%	54.32	1.4%	11.64	0.3%	11.64	0.3%	15.52	0.4%	0.00	0.0%	0.00	0.0%
Q50	2576.14	64.7%	221.14	5.6%	128.03	3.2%	473.33	11.9%	240.54	6.0%	112.51	2.8%	77.59	1.9%	42.68	1.1%	54.32	1.4%	27.16	0.7%	27.16	0.7%
Q75	2141.61	53.8%	283.22	7.1%	248.30	6.2%	174.59	4.4%	186.23	4.7%	100.87	2.5%	225.02	5.7%	162.95	4.1%	279.34	7.0%	112.51	2.8%	65.96	1.7%
Q95	2021.34	50.8%	248.30	6.2%	151.31	3.8%	124.15	3.1%	186.23	4.7%	155.19	3.9%	201.75	5.1%	193.99	4.9%	279.34	7.0%	221.14	5.6%	197.87	5.0%

Proposed	Area m2	% cover																				
	0.0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
Q5	3866.98	97.1%	45.45	1.1%	18.94	0.5%	34.09	0.9%	0.00	0.0%	3.79	0.1%	7.57	0.2%	3.79	0.1%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Qmean	2363.36	59.4%	257.55	6.5%	352.23	8.8%	284.06	7.1%	151.50	3.8%	121.20	3.0%	143.92	3.6%	117.41	2.9%	113.62	2.9%	41.66	1.0%	34.09	0.9%
Q50	2556.52	64.2%	200.73	5.0%	71.96	1.8%	200.73	5.0%	151.50	3.8%	166.65	4.2%	178.01	4.5%	98.47	2.5%	162.86	4.1%	132.56	3.3%	60.60	1.5%
Q75	2370.94	59.6%	238.61	6.0%	193.16	4.9%	212.10	5.3%	170.43	4.3%	196.95	4.9%	246.18	6.2%	117.41	2.9%	140.14	3.5%	49.24	1.2%	45.45	1.1%
Q95	2359.58	59.3%	481.00	12.1%	439.34	11.0%	268.91	6.8%	102.26	2.6%	87.11	2.2%	106.05	2.7%	37.87	1.0%	53.02	1.3%	26.51	0.7%	18.94	0.5%

Adult roach

Existing	Area m2	% cover																				
	0.0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
Q5	2762.37	69.4%	1101.84	27.7%	11.64	0.3%	15.52	0.4%	3.88	0.1%	85.35	2.1%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Qmean	190.11	4.8%	3553.83	89.3%	34.92	0.9%	31.04	0.8%	31.04	0.8%	139.67	3.5%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q50	31.04	0.8%	3553.83	89.3%	104.75	2.6%	46.56	1.2%	27.16	0.7%	217.26	5.5%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q75	27.16	0.7%	2851.60	71.6%	426.77	10.7%	252.18	6.3%	108.63	2.7%	310.38	7.8%	3.88	0.1%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q95	27.16	0.7%	1132.88	28.5%	907.86	22.8%	834.14	21.0%	450.05	11.3%	624.64	15.7%	0.00	0.0%	3.88	0.1%	0.00	0.0%	0.00	0.0%	0.00	0.0%

Proposed	Area m2	% cover																				
	0.0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
Q5	2473.20	62.1%	1291.52	32.4%	7.57	0.2%	3.79	0.1%	7.57	0.2%	185.58	4.7%	0.00	0.0%	11.36	0.3%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Qmean	26.51	0.7%	3480.66	87.4%	162.86	4.1%	41.66	1.0%	30.30	0.8%	227.25	5.7%	0.00	0.0%	11.36	0.3%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q50	26.51	0.7%	2855.73	71.7%	291.63	7.3%	344.66	8.7%	132.56	3.3%	318.15	8.0%	0.00	0.0%	11.36	0.3%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q75	26.51	0.7%	1276.37	32.1%	166.65	4.2%	374.96	9.4%	564.33	14.2%	1560.43	39.2%	0.00	0.0%	11.36	0.3%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q95	26.51	0.7%	1121.08	28.2%	98.47	2.5%	121.20	3.0%	102.26	2.6%	2499.71	62.8%	0.00	0.0%	11.36	0.3%	0.00	0.0%	0.00	0.0%	0.00	0.0%

Juvenile roach

Existing	Area m2	% cover																				
	0.0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
Q5	3895.25	97.9%	0.00	0.0%	3.88	0.1%	7.76	0.2%	50.44	1.3%	23.28	0.6%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Qmean	3840.93	96.5%	11.64	0.3%	11.64	0.3%	15.52	0.4%	65.96	1.7%	34.92	0.9%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q50	3767.22	94.6%	19.40	0.5%	27.16	0.7%	34.92	0.9%	69.84	1.8%	62.08	1.6%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q75	3666.34	92.1%	38.80	1.0%	38.80	1.0%	34.92	0.9%	104.75	2.6%	96.99	2.4%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q95	3352.08	84.2%	197.87	5.0%	108.63	2.7%	77.59	1.9%	89.23	2.2%	155.19	3.9%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%

Proposed	Area m2	% cover																				
	0.0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
Q5	3783.65	95.1%	0.00	0.0%	3.79	0.1%	7.57	0.2%	151.50	3.8%	22.72	0.6%	11.36	0.3%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Qmean	3741.99	94.0%	11.36	0.3%	15.15	0.4%	7.57	0.2%	159.07	4.0%	34.09	0.9%	11.36	0.3%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q50	3651.09	91.7%	49.24	1.2%	30.30	0.8%	34.09	0.9%	155.29	3.9%	49.24	1.2%	11.36	0.3%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q75	2397.45	60.2%	401.47	10.1%	424.19	10.7%	363.59	9.1%	299.21	7.5%	87.11	2.2%	7.57	0.2%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q95	1458.16	36.6%	98.47	2.5%	102.26	2.6%	268.91	6.8%	712.04	17.9%	1333.18	33.5%	7.57	0.2%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%

Spawning roach

Existing	Area m2	% cover																				
	0.0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
Q5	3980.60	100.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Qmean	3980.60	100.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q50	3968.96	99.7%	3.88	0.1%	0.00	0.0%	0.00	0.0%	3.88	0.1%	3.88	0.1%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q75	3922.40	98.5%	19.40	0.5%	7.76	0.2%	7.76	0.2%	0.00	0.0%	11.64	0.3%	0.00	0.0%	0.00	0.0%	3.88	0.1%	0.00	0.0%	7.76	0.2%
Q95	3914.64	98.3%	0.00	0.0%	15.52	0.4%	15.52	0.4%	3.88	0.1%	3.88	0.1%	3.88	0.1%	3.88	0.1%	7.76	0.2%	0.00	0.0%	11.64	0.3%

Proposed	Area m2	% cover																				
	0.0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
Q5	3980.60	100.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Qmean	3980.60	100.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q50	3980.60	100.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q75	3973.03	99.8%	0.00	0.0%	3.79	0.1%	3.79	0.1%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q95	3969.24	99.7%	3.79	0.1%	3.79	0.1%	3.79	0.1%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%

Spawning lamprey

Existing	**Area m2**	**% cover**																				
	0.0		**0.1**		**0.2**		**0.3**		**0.4**		**0.5**		**0.6**		**0.7**		**0.8**		**0.9**		**1.0**	
Q5	3980.60	100.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Qmean	3421.14	85.9%	474.94	11.9%	88.55	2.2%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q50	2684.59	67.4%	792.90	19.9%	285.77	7.2%	181.12	4.6%	36.22	0.9%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q75	2129.16	53.5%	728.50	18.3%	342.11	8.6%	370.29	9.3%	277.72	7.0%	64.40	1.6%	28.17	0.7%	20.12	0.5%	16.10	0.4%	4.02	0.1%	0.00	0.0%
Q95	1960.11	49.2%	696.30	17.5%	410.54	10.3%	382.36	9.6%	177.09	4.4%	100.62	2.5%	112.70	2.8%	56.35	1.4%	48.30	1.2%	32.20	0.8%	4.02	0.1%

Proposed	**Area m2**	**% cover**																				
	0.0		**0.1**		**0.2**		**0.3**		**0.4**		**0.5**		**0.6**		**0.7**		**0.8**		**0.9**		**1.0**	
Q5	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Qmean	3594.21	90.3%	378.34	9.5%	8.05	0.2%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q50	2889.86	72.6%	559.46	14.1%	305.89	7.7%	165.02	4.1%	60.37	1.5%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q75	2704.72	67.9%	623.86	15.7%	462.86	11.6%	132.82	3.3%	52.32	1.3%	4.02	0.1%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Q95	2700.69	67.8%	1098.79	27.6%	144.90	3.6%	36.22	0.9%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%