A GUIDE TO ASSESSING RIVER CONDITION
Part of the Rivers and Streams Component of the BioDiversity Net Gain Metric

A.M.Gurnell[1,2], J. England[3], S.J.Scott[3], L.J. Shuker[2,4]

With contributions from
I.D.L. Foster[5], R.C. Grabowski[6], D.J. Gurnell[2], R. Jeffries[3]

[1] Queen Mary University of London, [2] Cartographer Studios
[3] Environment Agency, [4] Thames21, [5] University of Northampton
[6] Cranfield University

Beta test version: March 2020

GLOSSARY

Alluvial bed material: mineral sediments deposited or reworked by rivers on their beds. The sediment may vary widely in size, including boulders, cobbles, gravel-pebbles, sand, silt, or clay.

Anabranching river: river that is naturally divided by vegetated islands into at least two separate channels.

Bank: side of a river channel or island which extends above the normal (e.g. mean) water level and is only completely submerged during periods of high river flow

Bankfull: level at which water begins to spill out of a river channel onto the floodplain

Bar: in-channel, elevated sediment deposit exposed during periods of low flow, which may be a side bar or a mid-channel bar.

Bed material: material making up the bed of a river, which may include exposed bed rock, mineral sediments, and organic material.

Berm and **Bench:** A berm is a flat-topped vegetated feature located at the base of the river bank and composed of sediments deposited by the river up to the typical low flow water level. A berm may evolve into a bench as further deposited sediment raises its surface to higher elevations that are clearly above the typical low flow water level but still below bank top level.

Braided river: river whose bankfull channel is naturally divided by mid-channel bars into at least two separate flowing threads at low flow.

Cascade: stream bed covered with disorganized boulders in steep confined channels, causing the flow to typically form areas of chute flow, broken and unbroken standing waves.

(River) Condition indicator score: an indicator of the positive or negative condition of the bank tops, bank faces, channel-water margins or bed within a **subreach** of river. Each river condition indicator score is expressed as a positive or negative value in the range 0 to +4 or 0 to -4 to represent near-natural (positive) or human-modified / impacted (negative) properties of a river, respectively.

(River) Final condition score: one of five possible condition scores (5-good, 4-fairly good, 3-moderate, 2-fairly poor, 1-poor) that can be assigned to a **subreach** according to its **river type** and preliminary **condition score**.

(River) Preliminary Condition score: is a score for the condition of a subreach, calculated as the sum of the separate average positive and negative **river condition indicators scores** and is subsequently translated into a **Condition score (Final)** according to its **river type**.

Confinement: degree to which the lateral movement of a river channel is confined by the presence of valley sides or terraces.

Floodplain: valley floor adjacent to a river that is (or was historically) inundated periodically by flood waters and is formed of sediments deposited by the river.

Free fall: refers to water falling vertically through the air without contact with the river bed. Free fall is typical of **waterfalls** and is often observed on **steps** in the river bed.

Hydromorphology: the morphological and hydrological characteristics of rivers including the underlying processes from which they result

Indicative river type: a group of river channels displaying similar planform and bed material characteristics (see also **river type**).

Island: flat-topped, vegetated, mid channel feature whose surface level approaches that of the **floodplain**.

Meandering river: river displaying a series of often regular bends along its course such that the total river channel length along its centre line is greater than 1.5 times the down-valley length.

Planform: the geometric form of a river channel viewed from above

Large wood: piece of wood that is more than 1 m long and 10 cm in diameter

Low flow: sustained component of streamflow, usually resulting from drainage of groundwater and soil moisture, but also from drainage of large lakes, swamps, soils, snow and ice packs

MoRPh module: short length of river (approximately two channel widths in length) along which a single MoRPh survey is conducted.

MoRPh5 subreach: a short river reach with a length equal to 5 MoRPh modules (approximately 10 channel widths in length, see also MoRPh **module** and **reach**)

Pool: distinctly deeper part of a river bed that is usually no longer than one to three times the channel's bankfull width, and where the hollowed river bed profile is sustained by scouring

Reach: section of river along which boundary conditions are sufficiently uniform that the river maintains a near consistent internal set of process–form interactions.

Reinforcement: strengthening of river beds and banks for various purposes (e.g. erosion control) using materials such as boulders, sheet piling, geotextiles, etc.

Riffle: fast-flowing shallow water area of a river bed with a distinctly broken or disturbed water surface (typically broken or unbroken standing waves) over a gravel/pebble or cobble substrate

Riparian zone: transitional, semi-terrestrial area of land adjoining a river channel (including the river bank top and face) that is regularly inundated and influenced by fresh water and can influence the condition of the aquatic ecosystem (e.g. by shading and leaf litter input and through biogeochemical exchanges)

River channel cross profile: two-dimensional representation of river channel shape and dimensions perpendicular to the flow

River type: group of river channels displaying similar planform, bed material and morphological features and dynamics reflecting the flow and sediment transfer processes to which it is subject (see also **indicative river type**).

Sinuosity: the distance from upstream to downstream along the channel centre line between two points, divided by the distance along the valley course between the same points

Standing waves: waves on the water surface that may vary in amplitude but they remain in the same place. Standing waves can be subdivided into **broken standing waves**, which have a frothy crest, and **unbroken standing waves**, which do not.

Step: accumulation of boulders (> 256 mm diameter) and/or exposure of bedrock transverse to and crossing the river channel creating a step (< 2 m high) in the river's long profile and characterised by chute flow often with some free falling water.

Wandering river: a transitional river planform between single-thread and multi-thread (braiding, anabranching) displaying a single flowing thread within the bankfull channel that splits locally into two or more threads separated by bars or channels separated by islands.

Waterfall: exposure of bedrock and/or accumulation of boulders (> 256 mm diameter) transverse to and crossing the river channel to create a near-vertical step in the river's long profile that is > 2 m high and characterised by free falling water and chute flow.

Weir: artificial structure across a river for controlling flow and upstream water surface level

Wetlands: habitats that are transitional between permanently inundated and generally dryer environments, where the water table remains at or close to the land surface.

1. OVERVIEW

1.1 INTRODUCTION

The character of naturally-functioning rivers and streams is highly variable, depending primarily upon a set of physical factors and processes (valley gradient, flow regime, substrate calibre and sediment supply) but also upon the nature of any interactions between riparian and aquatic vegetation and these physical factors and processes. As a result, naturally-functioning rivers and streams can take on a variety of forms and dynamics, such that the habitats they display and their rate of turnover are also highly variable. Superimposed upon this natural variability, numerous pressures and direct interventions by humans affect the nature and dynamics of the river's habitat mosaic and inevitably have an impact on the biota that they can support. The river condition assessment takes account of these factors by using data from a desk study and field surveys:

(i) At the reach scale, the apparent (indicative) type of river or stream that is being considered is classified, based mainly upon a desk study but supported with bed material information extracted from MoRPh5 subreach field surveys.

(ii) At the subreach scale: river condition is assessed in relation to what is achievable for the river type if it were functioning naturally. This assessment takes account of the local range and extent of the physical habitats and human influences observed in field surveys of 5 contiguous MoRPh modules (A MoRPh5 subreach field survey).

Figure 1 illustrates the relationship between a river reach of a single indicative river type, which contains a project site whose river condition is captured by one or more MoRPh5 surveys. The preliminary condition score for each subreach is based on MoRPh5 survey data. This preliminary score is then translated into a final score according to the (indicative) river type for a longer reach containing the project site. The reach scale and subreach scale elements of the methodology can be conducted in any order or in parallel, but the reach scale classification of the indicative type of river cannot be completed without field survey data describing the river bed material.

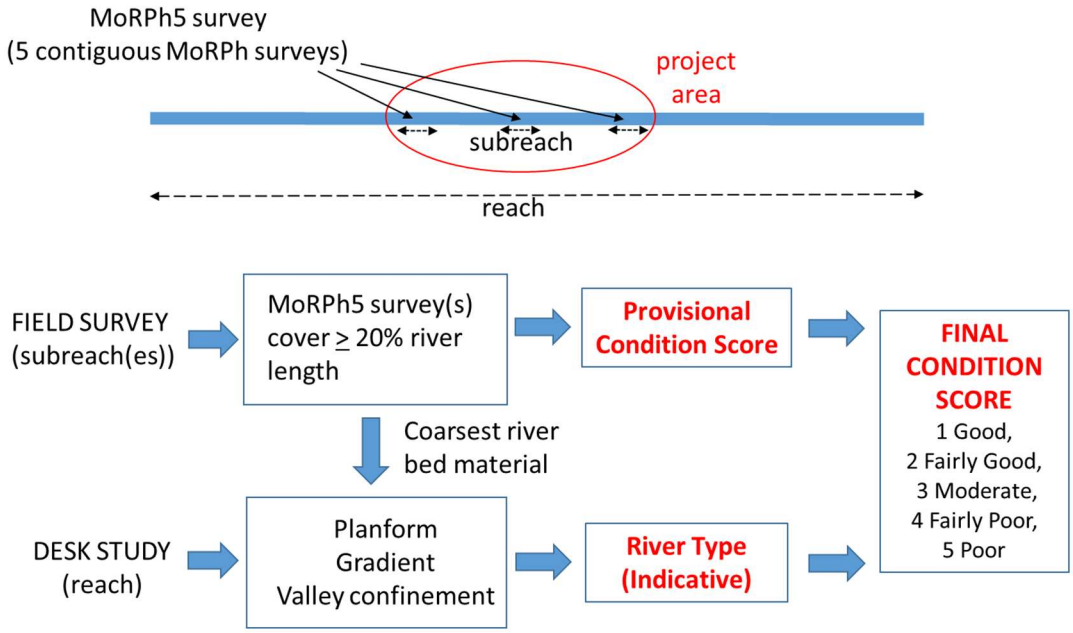

Figure 1 Reach and subreach scale components of the river Condition Assessment. Above: Schematic layout of reach and subreach scale elements. Below: Flow diagram illustrating how the Provisional Condition Score for a MoRPh5 subreach is translated into a Final Condition Score according to the (indicative) River Type.

1.2 THE MORPH5 FIELD SURVEY

The 'MoRPh' survey (Shuker et al., 2017, Gurnell et al., 2019) is used in the river condition assessment to collect field information for subreach(es) of a river (Figure 1) with the aim of surveying at least 20% of the total river length within the area of a proposed development.

MoRPh field surveys should normally be conducted at low flow and preferably during Spring or early Summer to capture information on both vegetation and physical properties of the river and its margins. If surveying has to be conducted between mid-summer and autumn, care is needed to accurately identify and quantify physical features that may be obscured by vegetation. If surveys have to be conducted in Winter, observations of remnant and decaying vegetation from the previous summer should be used to estimate the potential presence and likely typical abundance (during the late spring-early summer) of short and tall herbs/grasses on the bank top and bank face, and aquatic vegetation morphotypes along the water-channel margin and on the river bed. MoRPh field surveys should not be conducted during high flows when deep, often murky water will obscure the bed and much of the bank faces. However, even at low (or intermediate) flow, bed visibility may often be restricted. Under these circumstances and if you feel confident, you may be able to estimate bed material types and likely cover using those parts of the bed that are visible. In addition, you may be able to infer major bed features (pools, riffles) from water surface disturbance patterns (broad flow type patterns).

MoRPh surveys capture information on short lengths (modules) of river (Figure 1) that are approximately twice the river width (width < 5 m, length = 10 m; width ≥ 5 m and < 10 m, length = 20 m, width ≥ 10 m and < 20 m, length = 30 m, width ≥ 20 m and < 30 m, length = 40 m). For 'canals and navigable rivers' and for 'large rivers', where the bed material and submerged bed features are not visible (i.e. many rivers > 20 m width and all > 30 m width), module lengths should be 50 m.

For assessing river condition, a MoRPh5 subreach survey is comprised of 5 contiguous MoRPh module surveys to capture information for subreaches of 50, 100, 150, 200 m in length according to the river width (250 m for canals, navigable and large rivers). MoRPh5 surveys for these different river widths should be undertaken, respectively, within every 250, 500, 750 or 1000 m river length (1250 m for canals, navigable and large rivers) to provide a minimum survey of 20% of the total river/canal length and to represent the range of local river conditions. In particular, one subreach must be located to capture the most physically degraded part of the river within the project site.

MoRPh surveys extend away from the river to 10m from the bank top on both banks and record information relating to the bank tops, bank faces, channel-water margin and the river bed. The surveys are designed to be conducted on a single river thread. For distinctly multi-thread rivers, MoRPh surveys should be conducted on the thread(s) within the area of the proposed development. The survey captures the extent and character of (a) bank and bed sediments, (b) morphological and hydraulic features / habitats, (c) riparian and aquatic vegetation extent and structure, (d) presence and extent of non-native invasive plant species (NNIPS), (e) bank top land use pressures, (f) human interventions within the river channel.

1.3 INDICATIVE RIVER TYPE

River condition is assessed in the context of different river types. Although a continuum of river characteristics are present in nature, it is useful to identify the broad types or classes of river that may be encountered (Gurnell et al., 2016, Castro and Thorne, 2019) to provide a datum against which to assess the river's condition. At a European scale, 22 broad river types have been identified (Rinaldi et al., 2016). For the present application, these have been reduced to 15 types (canals and navigable

rivers, large rivers, 13 river planform-bed material types (A to M)). Discrimination of these types is based mainly upon a reach-scale desk study but is supported by bed material information from MoRPh5 subreach-scale field surveys.

The river reach used to determine the river type needs to contain the subreaches where MoRPh5 surveys have been conducted and should be long enough (usually several kilometres) to determine its type robustly. The main requirement is that the reach broadly shows a similar width and planform along its length. Such a reach may contain small weirs and may receive small tributaries but should not include large structures (dams) or large tributaries (width exceeding a quarter of that of the river channel being typed).

River types A to M (Figure 2) are defined primarily by their planform and bed material, supported by the degree to which they are confined by their valley and also the valley gradient. These 13 types represent the range of near-natural river types likely to be encountered in England. Most rivers in England are currently single thread. However, wandering and multi-thread rivers are occasionally encountered and they would be found far more frequently under near-natural conditions.

Large rivers are those that are too wide or deep for reliable bed material information to be collected during a MoRPh field survey. Although full MoRPh surveys may be feasible on quite wide rivers, accurate survey of bed material often becomes challenging on rivers wider than 20m. Without a survey of bed material, these larger rivers cannot be allocated to one of river types A to M.

Canals and navigable rivers form the final river type. Their modified nature prevents the assignment of an indicative 'near-natural' type.

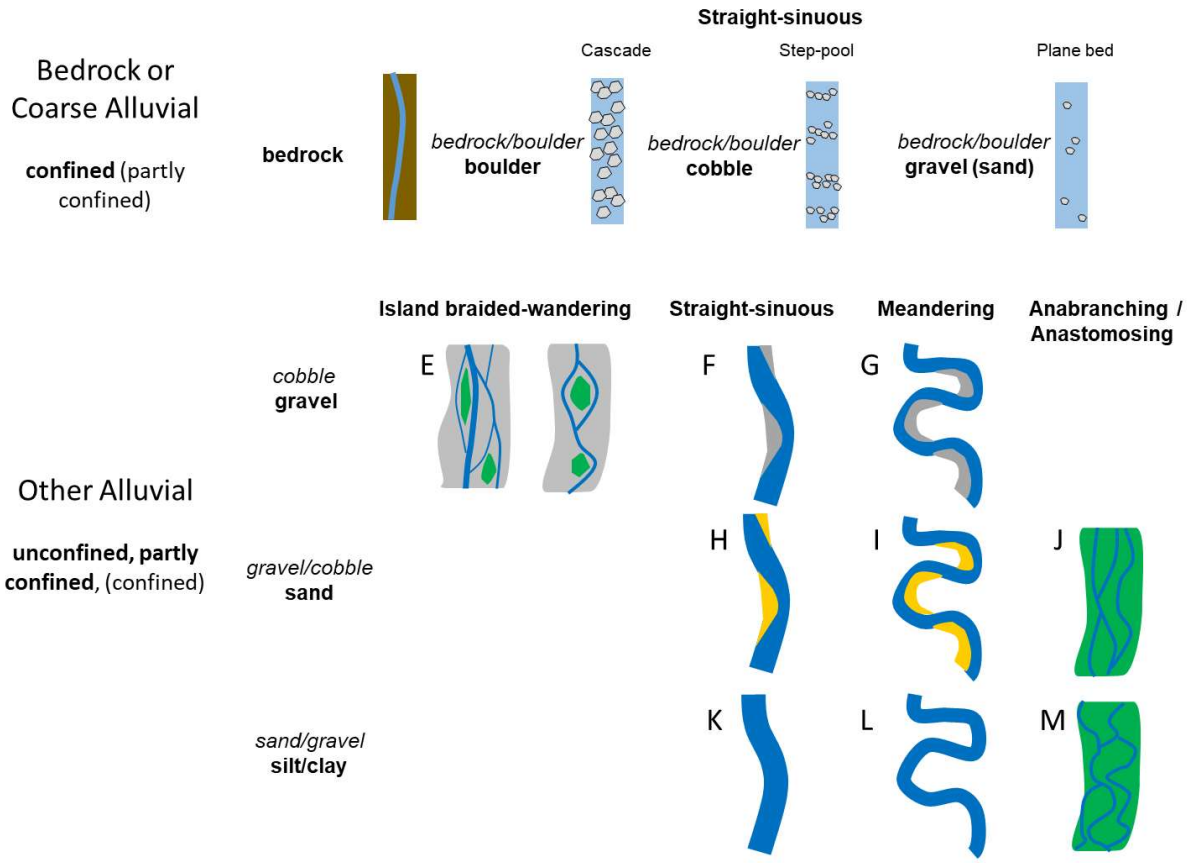

Figure 2: Thirteen near-natural river types that might be encountered in England.

We refer to 'indicative' river types because the river planform may have been altered by human activities rather than natural processes. The river type can only be confirmed with field observations that illustrate that the river is functioning as that type or is being constrained by various levels of human interventions/pressures. Further details of the assessment of the indicative river type are provided in section 2.

1.4 ASSESSING RIVER CONDITION

River condition is assessed using 32 condition indicators that are automatically extracted from MoRPh5 field surveys once the data have been uploaded into the information system. Each river condition indicator is assigned a score of 0 to +4 (positive indicators) or 0 to -4 (negative indicators). Positive indicators represent the diversity (richness) and abundance (extent) of physical habitats offered by vegetation, sediment, vegetation-sediment-related physical features, and hydraulic habitats that can be observed at low flow. Negative indicators represent the extent and severity of local human interventions or pressures.

The Preliminary Condition Score for each MoRPh5 subreach is calculated as the sum of the average of the positive condition indicator scores and the average of the negative condition indicator scores for the subreach. The Preliminary Condition Score is translated into a Final Condition Score (5-good, 4-fairly good, 3-moderate, 2-fairly poor, 1-poor) based upon the River Type.

Further details of the assessment of the Preliminary Condition Score and the Final Condition Score are provided in section 3.

2. INDICATIVE RIVER TYPES

2.1 RIVER TYPES

The river type is determined using an extended reach that contains subreaches where MoRPh5 surveys have been conducted. The reach selected for analysis should be long enough (usually several kilometres) to determine its type robustly. The main requirement is that the reach broadly shows a similar width and planform along its length. Such a reach may contain small weirs and may receive small tributaries but should not include large structures (dams) or large tributaries (width exceeding a quarter of that of the river channel being typed).

There are a total of 15 river types incorporated in the river condition assessment:

Canals and navigable rivers: These are identified by the surveyor based on their function. MoRPh modules surveyed on canals and navigable rivers are 50m long.

Large rivers: These are identified by the surveyor to be too large and deep to obtain a reasonably accurate assessment of their bed material types and abundances. Although full MoRPh surveys may be feasible on quite wide rivers, surveying of bed material often becomes challenging on rivers wider than 20m. Without a survey of bed material, these larger rivers cannot be allocated to one of river types A to M (see below), and so the assessment of their condition is adjusted to allow for the lack of observations of bed material and submerged features. MoRPh modules surveyed on large rivers are 50m long.

Indicative river types A to M: Rivers that are not navigable or deemed to be 'large' are assigned to one of 13 types based on their planform and bed material and supported by their degree of confinement and valley gradient (Figure 2).

2.2 INDICATORS OF RIVER TYPES A TO M

Eight river type indicators are combined to determine the indicative river type (Table 1). Five indicators (A1-A5) are assessed by a desk study of an extended 'homogenous' reach within which the project area is located. A further three (A6-A8) are automatically estimated from MoRPh5 subreach field survey data once it has been uploaded into the information system.

Table 1: Indicators derived from desk study and MoRPh5 field survey that contribute to assessing the river type and function

Source	Code	Name
Desk study	A1	Braiding index (BI)
Desk study	A2	Sinuosity index (SI)
Desk study	A3	Anabranching index (AI)
Desk study	A4	Level of confinement (U, PC, C)
Desk study	A5	Valley gradient
Field survey	A6	Bedrock reaches
Field survey	A7	Coarsest bed material size class
Field survey	A8	Average alluvial bed material size class

2.2.1 Indicators A1 to A5 are derived from maps or aerial images. Google Earth Pro is the recommended data source as it provides both image and topographic information and it also allows images from several dates to be searched so that the image that most clearly displays the river ***at low flow*** can be used.

A1 Braiding index (*BI*) assesses whether the river reach typically shows: a single flowing thread of water or more than one thread. The threads of water may be separated by mid-channel bars or split into distinct channels by vegetated islands. The *BI* is the average number of distinct flowing threads counted across 10 equally-spaced cross-sections of the river corridor (typically spaced by at least the width of the bankfull river channel) ***under low flow conditions*** (i.e. not during a flood). Reaches may be single thread ($BI \leq 1.1$) or multithread ($BI > 1.1$). Note that for application in Britain, this index is mainly used in coarse-bed rivers (where A8 is gravel or coarser) to discriminate single thread from multi-thread (wandering or braided) rivers. Wandering and braided rivers are not separated because both are extremely rare in Britain. Input your measured *BI* into the information system. For single thread rivers *BI*=1.

A2 Sinuosity index (*SI*) is assessed for river reaches that typically show a single thread ($BI \leq 1.1$). *SI* is the ratio of the river reach length along the centre line of the (main) river channel divided by the length of the broad river or valley course. For confined rivers the valley course length should be measured along the valley centre line. For partly confined and unconfined river sections join the points of inflection between major bends with straight lines to define the valley course unless the valley side is encountered, where the line must curve to remain in the valley bottom. Reaches may be straight-sinuous ($SI < 1.5$), or meandering ($SI \geq 1.5$). Input the valley and river channel length into the information system and it will calculate the *SI* automatically.

A3 Anabranching index (*AI*) assesses for multi-thread reaches, how many threads are typically separated by well-vegetated areas (islands) into distinct channels rather than flowing around bare or sparsely vegetated bars. The *AI* is the average number of distinct flowing channels separated by islands, counted across 10 equally-spaced cross-sections of the anabranching river system (typically spaced by at least the width of the anabranching belt) ***under low flow conditions*** (i.e. not during a flood). Although rivers with occasional islands ($1.05 < AI < 1.5$) could be discriminated, for application in Britain, this index is only used in rivers where A8 is sand or finer to discrimate single thread from multi-thread, anabranching rivers. The latter are very rare and are discriminated where $AI \geq 1.5$. Input your measured AI into the information system

A4 Level of confinement (U, PC, C) is estimated from the approximate proportion of the river reach's bank length that is in contact with (close proximity to) valley side slopes or ancient terraces. This can be estimated visually from map contours or from a 3-D visualisation of the reach on Google Earth.

Confined reaches have more than 90% of the total river bank length in contact
Unconfined (U) reaches have less than 10% of their total river bank length in contact
Partly confined (PC) reaches have an intermediate level (between 10 and 90%) of bank-hillslope contact.

A5 Valley gradient is the difference in elevation between the start and end of the river reach divided by the length of the broad valley course. See A2 for method of valley course length measurement. If assessing elevations from Google Earth, search for the lowest local elevation close to each end of the reach. Input the upstream and downstream elevations into the information system and the gradient will be automatically calculated from the difference between the two elevations divided by the valley course length that is also required for A2. Input the upstream and downstream elevations into the information system and it will automatically calculate the valley gradient from these values and your previously entered value of valley length.

2.2.2 Indicators A6 to A8 describe the river bed material and are derived from MoRPh5 subreach field surveys. If more than one MoRPh5 subreach has been surveyed, data from the subreach with the coarsest bed material should be used to estimate the indicative river type. The information system

will automatically extract data from the coarsest MoRPh5 subreach by first considering the value of A6 to separate bedrock reaches, and then considering A7 followed by A8.

A6 Bedrock reaches are recorded (i.e. A6=1) where bedrock is observed as 'extensive' (i.e. >33% cover) in at least 3 survey modules or is 'extensive' in 2 modules and 'present' (i.e. 5 to 33% cover) in the remaining 3 modules of the subreach.

A7 Coarsest bed material size class records the coarsest bed material size class that is observed as present or extensive in any module in the subreach (i.e. clay, silt, sand, gravel, cobble, boulder and bedrock). If more than one subreach has been surveyed, use the coarsest value from any of the subreaches.

A8 Average alluvial bed material size class is a weighted average of the alluvial bed material size classes (i.e. excludes bedrock) recorded as present or extensive in all 5 modules within the subreach (clay, silt, sand, gravel, cobble, boulder). The average size in phi units is calculated using the following equation:
=((10*CL)+(6.5*SI)+(1.5*SA)+(-3.5*GP)+(-7*CO)+(-9*BO))/(CL+SI+SA+GP+CO+BO)
Where CL, SI, SA, GP, CO, BO are the total cover of clay, silt, sand, gravel, cobble, boulder recorded as P (19 %) or E (67 %). The derived average (phi units) is assigned to a size class as follows:

	Minimum size (phi)	Maximum size (phi)
Clay (CL)		≥ 9
Silt (SI)	< 9	≥ 4
Sand (SA)	< 4	≥- 1
Gravel (GP)	<- 1	≥- 6
Cobble (CO)	<- 6	≥ - 8
Boulder (BO)	< - 8	

If more than one subreach has been surveyed, use the coarsest value from any of the subreaches.

2.3 COMBINING INDICATORS TO DEFINE THE INDICATIVE RIVER TYPE A TO M.

Once values of indicators A1 to A8 are entered into the information system, an indicative river type is generated automatically according to a decision tree (Figure 3).

NOTES:

1. If key data are missing, a river type may not be automatically generated.
2. Furthermore, automatic assignment of a river to a type is not always straightforward because many rivers show mixed / intermediate characteristics. Therefore, it is crucial to 'sanity check' the derived river type. If a type is not allocated or, for some reason, does not seem appropriate, the derived class can be overriden with one that is more appropriate. Such a choice can be guided using Figure 2.
3. The widespread use of boulders to stabilise river beds/banks, create fish passes or provide rocky habitat in rivers and streams that would not naturally display boulders, and the frequent incorporation of washed-out reinforcement materials into river beds may lead to misclassification. Therefore, if a reach is initially allocated to classes B, C or D, it is important to check whether its gradient is sufficiently steep for it to be likely to naturally display such a coarse bed. The decision tree includes a threshold valley gradient of 0.01 which should separate most potentially naturally functioning type D reaches from lower-gradient but relatively coarse bed rivers (particularly types F and H). In all cases, if the gradient is less than 0.01 and boulders are recorded as the coarsest bed material, it is important to check whether the boulders are of anthropogenic origin. If they are artificial elements of the river, then the river type should be assessed using the average alluvial bed material size class (A8)

to also represent indicator A7. This can be done by replacing the initial value for A7 by that for A8 in the information system to derive a more realistic river type.

4. Another 'sanity check' on the river type classification is whether the type is normally associated with the recorded level of confinement. Types A, B, C and D are normally confined or, at least, partly-confined by their valleys (Figure 2).

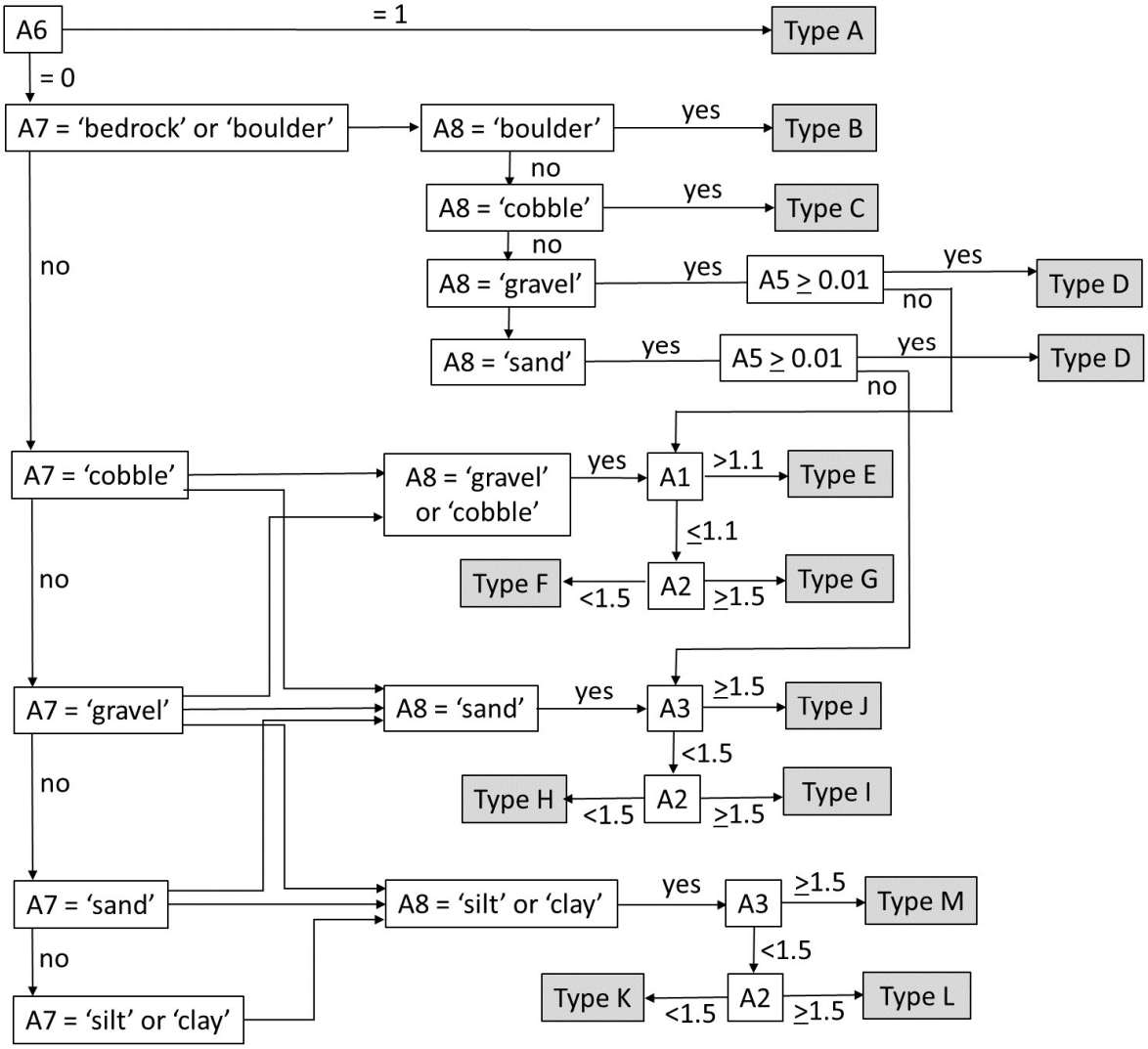

Figure 3: The decision tree used by the information system to discriminate river types using indicators A1 to A8.

2.4 MORPHOLOGICAL FEATURES EXPECTED OF RIVER TYPES A TO M

The indicative river type is used within the River Condition assessment methodology to translate the Preliminary Condition Score into a Final Condition Score (5-Good, 4-Fairly Good, 3-Moderate, 2-Fairly Poor, 1-Poor) that is appropriate for the type of river under consideration.

Although not a formal part of the condition assessment, the degree to which surveyed subreaches display specific geomorphic features appropriate to their indicative river type provides useful information to complement the condition assessment. Appendix 1 provides a check list of features recorded in MoRPh5 field surveys that are expected to be observed (brown shading) or are typically observed (yellow shading) in functioning rivers of the 13 different types A to M. A simple way to use Appendix 1 to assess whether a river is functioning according to its type is to score the presence of the listed features for the relevant river type as follows:

If some or all of the expected features are observed, score of 2 or 4, respectively.

If some or all of the typical features are observed, score of 1 or 2, respectively

Here 'observed' refers to the features being recorded within the MoRPh5 field surveys as either 'extensive' or as a minimum count of 1 in any of the 5 surveyed modules or as 'present' in at least 3 surveyed modules.

The sum of the scores for the listed features (a possible minimum value of 0 and a maximum value of 6 in each case) provides an indication of the degree to which the river appears to be functioning according to its indicative type (no function (0), little function (1 or 2), moderate function (3 or 4), good function (5 or 6)

NOTES:

1. If you wish to apply the above to 'large rivers' indicators A1 to A5 can be used to identify a river planform type (straight-sinuous, meandering, anabranching) and then a relevant gravel-sand or sand-silt type can be estimated from the apparent flow velocity/energy of the river during low flow conditions using lower energy flow types. Rivers with clearly sluggish flow (entirely 'no perceptible flow' or 'smooth flow') can be assigned to the relevant sand-silt type, whereas those showing more than traces of faster flow (rippled, unbroken standing waves) can be assigned to the gravel-sand type in order to gain an impression of the features that they may be expected to display from Appendix 1.
2. Function assessment is not applicable to 'canals or navigable rivers' because of their artificial or heavily modified nature.

3. RIVER CONDITION INDICATORS, PRELIMINARY AND FINAL CONDITION SCORES

3.1 RIVER CONDITION INDICATORS

River condition indicator scores are automatically extracted from MoRPh5 field surveys. Indicators summarise either the 'natural' morphology-, sediment- and vegetation-related (i.e. positive) aspects of a MoRPh5 subreach or local human interventions and pressures (i.e. negative aspects). These positive and negative indicators are listed in Table 2. Each river condition indicator is automatically assigned a score from 0 to 4 (positive indicators) or 0 to -4 (negative indicators) once the MoRPh5 field survey data have been uploaded into the information system. These condition indicators not only feed into the final condition assessment but they also provide information on why the subreach has been assigned a particular condition and where to focus effort when attempting to improve condition. Appendix 2 describes how each river condition indicator is assigned a score.

Table 2 River condition indicators extracted from MoRPh5 field surveys

(NNIPS = non-native invasive plant species, positive indicators underlined, *negative indicators in italic font*)

Location	Code	Name
Bank top	B1	Bank top vegetation structure
	B2	Bank top tree feature richness
	B3	Bank top water-related features
	B4	*Bank top NNIPS cover*
	B5	*Bank top managed ground cover*
Bank face	C1	Bank face riparian vegetation structure
	C2	Bank face tree feature richness
	C3	Bank face natural bank profile extent
	C4	Bank face natural bank profile richness
	C5	Bank face natural bank material richness
	C6	Bank face bare sediment extent
	C7	*Bank face artificial bank profile extent*
	C8	*Bank face reinforcement extent*
	C9	*Bank face reinforcement material severity*
	C10	*Bank face NNIPS cover*
Channel – water margin	D1	Channel margin aquatic vegetation extent
	D2	Channel margin aquatic morphotype richness
	D3	Channel margin physical feature extent
	D4	Channel margin physical feature richness
	D5	*Channel margin artificial features*
Channel bed	E1	Channel aquatic morphotype richness
	E2	Channel bed tree features richness
	E3	Channel bed hydraulic features richness
	E4	Channel bed natural features extent
	E5	Channel bed natural features richness
	E6	Channel bed material richness
	E7	*Channel bed siltation*
	E8	*Channel bed reinforcement extent*
	E9	*Channel bed reinforcement severity*
	E10	*Channel bed artificial features severity*
	E11	*Channel bed NNIPS extent*
	E12	*Channel bed filamentous algae extent*

3.2 THE PRELIMINARY CONDITION SCORE FOR A RIVER SUBREACH

The preliminary condition score is an integration of the individual river condition indicator scores for a MoRPh5 subreach. It is automatically calculated once the MoRPh 5 field data have been uploaded into the information system. The preliminary condition score is calculated from the condition indicator scores using the following formula:

River condition score = *average of all negative condition river condition indicator scores* + average of all positive river condition indicator scores

3.3 THE FINAL CONDITION SCORE FOR A RIVER SUBREACH

The preliminary condition score for a MoRPh5 subreach is translated into a final condition score (5-Good, 4-Fairly Good, 3-Moderate, 2-Fairly Poor, 1-Poor) according to the river type under consideration. The boundaries for allocating preliminary condition scores to final condition scores are listed in Table 3. These boundaries were defined for each river type by subdividing the numerical gap between the estimated worst and best case preliminary condition scores for each river type into 5 classes according to the top 10% of the range (Good), the next 15% (F. Good), the next 20% (Moderate), the next 25% (F. Poor) and the bottom 30% (Poor).

Table 3: Likely best and worst preliminary condition scores for each river type and lower threshold values for allocating preliminary condition scores to final condition scores (5 - good, 4 – fairly good, 3 – moderate, 2 – fairly poor, 1 – poor).

River type	Canals/ navigable	Large	A	B	C	D	E	F	G	H	I	J	K	L	M
Likely best average condition score	1.8	2.5	2.4	2.7	2.7	2.7	2.7	2.8	3.0	2.9	3.1	2.8	2.4	2.4	2.4
Lower threshold for GOOD	>1.4	>2.0	>1.9	>2.2	>2.2	>2.2	>2.2	>2.3	>2.5	>2.4	>2.5	>2.3	>1.9	>1.9	>1.9
Lower threshold for FAIRLY GOOD	>0.7	>1.3	>1.2	>1.4	>1.4	>1.4	>1.4	>1.5	>1.6	>1.6	>1.7	>1.5	>1.2	>1.2	>1.2
Lower threshold for MODERATE	>-0.1	>0.3	>0.2	>0.2	>0.2	>0.2	>0.2	>0.4	>0.5	>0.5	>0.6	>0.4	>0.2	>0.2	>0.2
Lower threshold for FAIRLY POOR	>-1.2	>-1.0	>-1.0	>-0.9	>-0.9	>-0.9	>-0.9	>-0.9	>-0.9	>-0.9	>-0.8	>-0.9	>-1.0	>-1.0	>-1.0
Likely worst average condition scores	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5

3.4 DERIVING AND TESTING RIVER CONDITION INDICATOR SCORES, RIVER CONDITION SCORES AND RIVER CONDITION CLASSES

A separate document (Gurnell, 2019, Application and Testing of the River Condition Assessment using a Calibration Data Set) explains how river condition indicator scores are derived and then combined to produce a preliminary condition score and then a final condition score for a MoRPh5 subreach, based largely on a combination of expert judgement and testing and, where necessary, fine-tuning in the light of a calibration data set of 40 MoRPh5 surveys collected specifically for this purpose.

REFERENCES

Castro, J.M. and Thorne, C.R., 2019. The stream evolution triangle: Integrating geology, hydrology, and biology. *River Research and Applications*, 35(4): 315-326.

Gurnell, A.M., Rinaldi, M., Belletti, B., Bizzi, S., Blamauer, B., Braca, G., Buijse, T., Bussettini, M., Camenen, B., Comiti, F., Demarchi, L., García de Jalón, D., González del Tánago, M., Grabowski, R.C., Gunn, I.D.M., Habersack, H., Hendriks, D., Henshaw, A.J., Klösch, M., Lastoria, B., Latapie, A., Marcinkowski, P., Martínez-Fernández, V., Mosselman, E., Mountford, J.O., Nardi, L., Okruszko, T., O'Hare, M.T., Palma, M., Percopo, C., Surian, N., van de Bund, W., Weissteiner, C. and Ziliani, L., 2016. A multi-scale hierarchical framework for developing understanding of river behaviour to support river management. *Aquatic Sciences*, 78(1): 1-16.

Gurnell, A.M., England, J., Shuker, L.C. and Wharton, G., 2019. The contribution of citizen science volunteers to river monitoring and management: international and national perspectives and the example of the MoRPh survey. *River Research and Applications,* 35: 1359-1373.

Rinaldi, M., Gurnell, A.M., González del Tánago, M., Bussettini, M. and Hendriks, D., 2016. Classification of river morphology and hydrology to support management and restoration. *Aquatic Sciences*, 78(1): 17-33.

Shuker, L.J., Gurnell, A.M., Wharton, G., Gurnell, D.J., England, J., Finn Leeming, B. and Beach, E., 2017. MoRPh: a citizen science tool for monitoring and appraising physical habitat changes in rivers. *Water and Environment Journal,* 31(3): 418-424.

APPENDIX 1

Features recorded in MoRPh5 field surveys that are expected to be present (brown shading) or are typical (yellow shading) of a particular river type (A to M) when it is functioning as that type.

(Note: because of lack of bed visibility and/or level of modification, no feature list can be provided for large rivers or for navigable rivers / canals)

RIVER TYPE	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**
Confinement	Confined				Confined/Partly confined/Unconfined								
Threads: Single / Transitional / Multi	Single	Single	Single	Single	Multi / Transitional	Single	Single	Single	Single	Multi	Single	Single	Multi
Planform	Straight / sinuous	Straight / sinuous -	Straight / sinuous -	Straight / sinuous -	Island braided / Wandering	Straight / sinuous	Meandering	Straight / sinuous	Meandering	Anabranching	Straight / sinuous	Meandering	Anabranching
Coarsest bed material size class **Average alluvial bed material size class**	**Bedrock**	Boulder/Bedrock - **boulder**	Boulder/Bedrock - **cobble**	Boulder/Bedrock - **gravel**	Cobble - **gravel**	Cobble - **gravel**	Cobble - **gravel**	Gravel - **sand**	Gravel - **sand**	Gravel - **sand**	Fine sand - **silt**	Fine sand - **silt**	Fine sand - **silt**

CHANNEL BED

Water surface / hydraulic habitats

Free fall													
Chute													
Broken standing waves													
Unbroken standing waves													

Physical features

Exposed bedrock													
Boulders - unvegetated													
Boulders - vegetated													
Waterfall													
Step													
Cascade													
Riffle													
Pool													
Island													
Mid-channel bar - unvegetated													
Mid-channel bar - vegetated													

Vegetation types

Emergent broad- / linear-leaved													
Submerged broad- / linear- / fine-leaved													

RIVER TYPE	A	B	C	D	E	F	G	H	I	J	K	L	M
CHANNEL BANKS AND MARGINS													
Physical features													
V_Vo_Vu_Vt bank profiles													
Eroding cliff													
Stable cliff													
Toe													
Side bar - unvegetated													
Side bar - vegetated													
Berm / Bench													
Vegetation types													
Liverworts / mosses / lichens													
Emergent broad- / linear-leaved													
BANK TOPS / FLOODPLAIN EDGE													
Physical features													
Wetland (any types)													
Connected/disconnected backwaters and side channels													

APPENDIX 2

A value is calculated for each river condition indicator from the MoRPh5 survey data using a formula. The indicator value is then translated into a river condition indicator score of 0 to +4 for positive indicators or 0 to -4 for *negative indicators*. Each river condition indicator is listed below, the formula used to calculate its value is described, and a table illustrates how the indicator values are translated into river condition indicator scores (0 to +4 or 0 to -4).

The methods used to derive a score for each river condition indicator were based on judgements of likely scenarios and were further informed and fine-tuned using a calibration data set of 40 subreaches that was collected for this purpose. The river condition scores synthesise subsets of MoRPh5 field survey observations to characterise:

1. Positive aspects of the river corridor: the diversity (richness) and abundance (extent) of habitats offered by vegetation structure, sediment, vegetation- and sediment-related physical features and hydraulic habitats observed at low flow.
2. Negative aspects of the river corridor representative of local human interventions or pressures.

The river condition indicators synthesise properties separately for the bank tops, bank faces, channel-water margins, and channel bed. The following procedure was adopted in devising the river condition indicator scores:

(i) Indicators were formulated to represent coherent aspects of the river bank tops, bank faces, channel-water margin and channel bed. They each combine information from groups of related fields in subreach surveys to characterise particular aspects of the environment and, wherever possible, they were tested using the calibration data set.

(ii) The numerical evaluation of each indicator combined observations of the presence, count, or A, T, P, E abundance of each included element, sometimes also incorporating weights to reflect their relative positive or negative importance. Where the A, T, P, E abundance scale had been used in the field survey this was translated into 0, 2, 19, 67 to approximate the mid-point percentage of these abundance classes. The numerical evaluations generated positive values for indicators that characterised positive aspects of the subreach and negative values for negative aspects.

(iii) The resultant values calculated for each indicator across the 40 calibration subreaches were then described by summary statistics and frequency histograms.

(iv) Informed by this summary information, some indicators were revised to improve their discrimination and/or to simplify their computation. Stages (ii) and (iii) were then repeated.

(v) Finally, the values for each indicator were assigned scores of 0, 1, 2, 3 or 4 for positive indicators and 0, -1, -2, -3, -4 for negative indicators, based on a combination of judgements of likely scenarios and on any descriptive statistics and graphical outputs generated from the calibration data set. Because most of the indicator values displayed skewed frequency distributions, emphasis was placed on the median and quartile values derived from the calibration data when guiding threshold values to allocate the condition indicator scores of 0 to +/-4.

(vi) In a small number of cases indicators were not well represented within the calibration data. In these cases, class thresholds were entirely based on likely scenarios.

Group B: Bank Top Indicators

B1 Bank top vegetation structure This indicator is a count of the presence (Present (P) or Extensive (E) only) of 5 vegetation structural types that are recorded on the bank tops (mosses / lichens, short / creeping herbs / grasses, tall herbs / grasses, scrub / shrubs, saplings / trees) of the 5 surveyed

modules. The count is applied to each bank separately and then the values for the two banks are added together.

Condition indicator values and scores:

Indicator value	0	1 to 4	5 to 7	8	9 to 10
Indicator score	0	1	2	3	4

B2 Bank top tree feature richness This indicator is a count of the presence (P or E only) of 5 tree features that are recorded on bank tops (fallen trees, leaning trees, j-shaped trees, tree/shrub branches trailing into the river channel, large wood) of the 5 surveyed modules. The count is applied to each bank separately and then the values for the two banks are added together.

Condition indicator values and scores:

Indicator value	0	1	2 to 3	4 to 6	7 to 10
Indicator score	0	1	2	3	4

B3 Bank top water-related features This indicator applies the following look-up table to each bank and then adds the scores.

Water-related feature	**T**	**P**	**E**
Pond: disconnected	2	19	67
Pond: connected	2	19	67
Side channel	2	19	67
Wetland: Short non-woody vegetation (e.g. mosses, sedges)	2	19	67
Wetland: Tall, non-woody vegetation (e.g. reeds, rushes)	2	19	67
Wetland: Shrubs and trees (e.g. alder / willow carr)	2	19	67

Condition indicator values and scores:

Indicator value	0	<20	20 to <135	135 to <335	≥335
Indicator score	0	1	2	3	4

B4 Bank top NNIPS cover This indicator combines the number and extent of 6 non-native invasive plant species (NNIPS) on each bank by applying the following look-up table. The results for the two banks are added for each module and then summed over the 5 modules.

Species	**T**	**P**	**E**
Himalayan balsam	-2	-19	-67
Japanese knotweed	-2	-19	-67
Giant hogweed	-2	-19	-67
Floating pennywort	-2	-19	-67
Other species 1	-2	-19	-67
Other species 2	-2	-19	-67

Condition indicator values and scores:

Indicator value	0	<0 to -19	<19 to -67	<67 to -268	<-268
Indicator score	0	-1	-2	-3	-4

B5 Bank top managed ground cover This indicator assesses the potential severity (likely pressure on the river ecosystem) and extent of the dominant and sub-dominant artificial / managed ground cover types observed on each bank. The weightings for each cover type in the following table are multiplied

by -2, -19, -67, respectively according to their abundance T, P, E on each bank top, then summed across both bank tops and accumulated across the 5 modules in the subreach.

	Artificial managed ground cover A	**Weighting**
Tr	Transport infrastructure (road, railway, car park)	5
Ic	Buildings (commercial / industrial)0	5
Re	Buildings (residential)	5
Ld	Landfill area	4
Sy	Storage area	3
Fp	Pedestrianised, footpath	2
Ar	Arable agriculture / allotments	2
Pv	Permanently vegetated agriculture (e.g. pasture, orchard)	1
Pr	Permanently vegetated recreation (e.g. playing fields, parks, gardens)	1
Pw	Plantation woodland	1
Ow	Open water (e.g. canal, reservoir)	0

Condition indicator values and scores:

Indicator value	0	< 0 to -95	<-95 to -670	<-670 to -1340	<-1340
Indicator score	0	-1	-2	-3	-4

Group C: Bank Face Indicators

C1 Bank face riparian vegetation structure This indicator is a count of the presence (P or E only) of 5 vegetation structural types that are recorded on the bank faces (mosses / lichens, short / creeping herbs / grasses, tall herbs / grasses, scrub / shrubs, saplings / trees) of the five surveyed modules. The count is applied to each bank separately and then the values for the two banks are added together.

Condition indicator values and scores:

Indicator value	0	1 to 4	5 to 7	8 to 9	10
Indicator score	0	1	2	3	4

C2 Bank face tree feature richness This indicator is a count of the presence (P or E only) of 7 tree features that are recorded on bank faces (fallen trees, leaning trees, j-shaped trees, tree/shrub branches trailing into channel, large wood, exposed tree roots, discrete organic accumulations) of the five surveyed modules. The count is applied to each bank of the MoRP5 subreach separately and then the values for the two banks are added together.

Condition indicator values and scores:

Indicator value	0	1 to 3	4 to 6	7 to 9	10 to 14
Indicator score	0	1	2	3	4

C3 Bank face natural bank profile extent A maximum of 2 natural bank profile types are recorded on each bank. The indicator is the sum of the abundance of natural profiles recorded as P (19) or E (67) across both banks for each module and then these values are accumulated over the 5 modules.

Condition indicator values and scores:

Indicator value	0	1 to ≤335	>335 to 670	>670 to ≤1340	≥1340
Indicator score	0	1	2	3	4

C4 Bank face natural bank profile richness The indicator is a count of 7 different natural bank profile types (V, Vo, Vu, Vt, St, Gt, Cm) that are recorded as P or E along either bank of any module within the MoRPh5 subreach. A single count is applied across both banks (i.e. maximum possible value is 7)

Condition indicator values and scores:

Indicator value	0	1	2	3	≥4
Indicator score	0	1	2	3	4

C5 Bank face natural bank material richness Count of 10 different natural bank material types (BE, BO, CO, GP, EA, SA, SI, CL, PE, OR) that are recorded as dominant in the upper or lower parts of any of the bank profiles within the subreach (i.e. each type can only be counted once).
Condition indicator values and scores:

Indicator value	0	1	2	3	≥4
Indicator score	0	1	2	3	4

C6 Bank face bare (unvegetated) sediment extent The indicator value is the total abundance of bare sediment on the bank face across both banks along the subreach (T, P and E are counted as 2, 19 and 67).
Condition indicator values and scores: (note non-linear scale because intermediate abundances of bare sediment provide the most varied habitat):

Indicator value	0	>0 to 70 or >600	>70 to 135 or >535 to 600	>135 to 205 or >465 to 535	>205 to 465
Indicator score	0	1	2	3	4

C7 Bank face artificial bank profile extent A maximum of 2 artificial profile types from a possible set of 5 (Rs, Ts, Em, Sm, Pc) are recorded on each bank. This indicator is based on the total extent of all artificial profiles recorded across both banks (where T = -2, P = -19 or E = -67) within a single MoRPh module and then the values are summed across the 5 modules in the subreach.
Condition indicator values and scores:

Indicator value	0	<0 to -57	<-57 to -134	<-134 to -335	<-335
Indicator score	0	-1	-2	-3	-4

C8 Bank face reinforcement extent The indicator represents the vertical (T(top only) = 0.5, B(bottom only) = 0.5, W(whole) = 1) and horizontal (T = -2, P = -19, E = -67) extents of reinforcement multiplied together for each bank and then added across both banks and all 5 modules in the subreach.
Condition indicator values and scores: (reaches m to t only):

Indicator value	0	<0 to -34	<-34 to -168	<-168 to -335	<-335
Indicator score	0	-1	-2	-3	-4

C9 Bank face reinforcement material severity The indicator represents the sum of the severity level of the dominant reinforcement type observed on each bank. The values for the two banks in each module are added together and then accumulated for the 5 modules in the subreach.

	Dominant reinforcement type	**Severity**
CC	Concrete	-3
CB	Concrete & brick / laid stone (cemented)	-3
BR	Brick / laid stone (cemented)	-3
SP	Sheet piling	-3
WP	Wood piling	-2
RR	Rip-rap (large laid stone, uncemented)	-2
GA	Gabions	-2
BW	Builders Waste	-1
WO	Washed out	-1
WS	Willow spiling	0
RE	Planted reeds	0
BC	Biotex / coir	0

Condition indicator values and scores:

Indicator value	0	-1 to -3	-4 to -12	-12 to -18	<-18
Indicator score	0	-1	-2	-3	-4

C10 Bank face NNIPS cover This indicator combines the number and extent of up to 6 non-native invasive plant species (NNIPS) on each bank face by applying the following look-up table. The results for the two banks are added for each module and then summed over 5 modules.

Species	T	P	E
Himalayan balsam	-2	-19	-67
Japanese knotweed	-2	-19	-67
Giant hogweed	-2	-19	-67
Floating pennywort	-2	-19	-67
Other species 1	-2	-19	-67
Other species 2	-2	-19	-67

Condition indicator values and scores:

Indicator value	0	<0 to -19	<19 to -67	<67 to -268	<-268
Indicator score	0	-1	-2	-3	-4

Group D: Channel Margin – Water Edge Indicators

Indicator D1 - Channel margin aquatic vegetation extent

This indicator is the accumulated lateral extent of 4 aquatic morphotypes (liverworts/mosses/lichens; emergent broad-leaved; emergent linear-leaved; amphibious), scored T=2, P=19, E=67 for their lateral extent along each channel margin. Values are calculated for each bank of a module, summed for both banks and then the values for all 5 modules are added together.

Condition indicator values and scores:

Indicator value	0	>0 to 67	>67 to 335	>335 to 860	>860
Indicator score	0	1	2	3	4

D2 Channel margin aquatic morphotype richness This indicator is a count of up to 4 aquatic morphotypes (liverworts/mosses/lichens; emergent broad-leaved; emergent linear-leaved; amphibious) that are recorded as P or E in any module across both channel margins within a subreach.

Condition indicator values and scores:

Indicator value	0	1	2	3	4
Indicator score	0	1	2	3	4

D3 Channel margin physical feature extent This indicator records the total extent of 8 margin physical features recorded as P or E (unvegetated side bar, vegetated side bar, berm, bench, stable cliff, eroding cliff, toe, marginal backwater) and 1 that is recorded as a count (tributary junction). Abundances are scored 19, 67 for P or E and 67 is assigned for a count of at least 1. The values are summed across both banks and across all 5 modules within a subreach

Condition indicator values and scores:

Indicator value	0	>0-268	>268-536	>536 - 860	>860
Indicator score	0	1	2	3	4

D4 Channel margin physical feature richness This indicator counts the number of 9 different channel margin physical features that are recorded as P or E (unvegetated side bar, vegetated side bar, berm, bench, stable cliff, eroding cliff, toe, marginal backwater) or have a count of at least 1 (tributary junction). Each feature can only be counted once within a subreach (i.e. maximum count is 9).

Condition indicator values and scores:

Indicator value	0	1 to 2	3 to 4	5 to 6	7 to 9
Indicator score	0	1	2	3	4

D5 Channel margin artificial features The indicator scores pipes and outfalls, jetties and deflectors according to their number and weights jetties and deflectors according to their size (and thus relative potential impact) as follows:

Feature	Minor	Intermediate	Major
Jetty	-2	-19	-67
Deflector (includes bridge pier at/on bank face)	-4	-34	-134
	Score for each		
Pipes / outfalls (if appear potentially functional): RECORD AS COUNT	-19		

Condition indicator values and scores:

Indicator value	0	<0 - -76	<-76 - -134	<-134 - -268	<-268
Indicator score	0	-1	-2	-3	-4

Group E: Channel Bed Indicators

E1 Channel aquatic morphotype richness The indicator is a count of all aquatic plant morphotypes recorded on the channel bed as T, P or E apart from filamentous algae (i.e. 9 possible types).

Condition indicator values and scores:

Indicator value	0	1	2-3	4-6	>6
Indicator score	0	1	2	3	4

E2 Channel bed tree feature richness The indicator is a count of 6 tree features on the channel bed that are recorded as P or E (vegetation shading channel, submerged tree roots, large wood, discrete accumulation of organic material) or have a count of ≥1 (large wood dam, fallen tree). Each feature can only be counted once (i.e. maximum score is 7).

Condition indicator values and scores:

Indicator value	0	1	2 to 3	4 to 5	6 to 7
Indicator score	0	1	2	3	4

E3 .Channel bed hydraulic feature richness The indicator is a count of 8 possible water surface flow types (free fall, chute, broken standing waves, unbroken standing waves, upwelling, rippled, smooth, no perceptible flow) observed as P or E. Each feature can only be counted once (i.e. maximum score is 8).

Condition indicator values and scores:

Indicator value	1	2	3 to 4	5 to 6	7 to 8
Indicator score	0	1	2	3	4

E4 Channel bed natural physical features extent The indicator is based on 11 features, of which 7 (exposed bedrock, exposed unvegetated boulders, exposed vegetated boulders, unvegetated mid channel bars, vegetated mid-channel bars, islands, cascades) are recorded as T (=2), P (=19) or E (=67) and 4 (pools, riffles, steps, waterfalls) are recorded as a count (here assigned 19 for a count of 1 and 67 for a count of more than 1). The total for all features is summed over all 5 modules in the subreach.

Condition indicator values and scores:

Indicator value	0	>0 to 67	>67 to 201	>201 to 804	≥804

Indicator score	0	1	2	3	4

E5 Channel bed natural physical feature richness This indicator is a count of a possible 11 physical features (exposed bedrock, exposed unvegetated boulders, exposed vegetated boulders, unvegetated mid channel bars, vegetated mid-channel bars, islands, cascade, pools, riffles, steps, waterfalls) that are observed as P or E or have a count of at least 1. Each feature is only counted once giving a maximum value of 11 for the MoRPh5 subreach.

Condition indicator values and scores:

Indicator value	0	1 to 2	3 to 4	5 to 7	>7
Indicator score	0	1	2	3	4

E6 Channel bed material richness The indicator is a count of the 9 possible mineral and organic materials (peat, organic, clay, silt, sand, gravel-pebble, cobble, boulder, bedrock) that are observed as P or E on the channel bed. Each material type is only counted once giving a maximum value of 9 for the MoRPh5 subreach.

Condition indicator values and scores:

Indicator value	0	1	2	3 to 4	≥5
Indicator score	0	1	2	3	4

E7 Channel bed siltation The indicator is the sum of the weighted abundances of any patchy silt layer (T=-2, P=-19, E=-67) and continuous overlying silt layer (T=-4, P=-38, E=-134) across the bed of all 5 modules in the subreach.

Condition indicator values and scores:

Indicator value	0	<0 - -19	<-19 - -201	<-201 - -335	<-335
Indicator score	0	-1	-2	-3	-4

E8 Channel bed reinforcement extent The indicator is the extent of bed reinforcement (T=-2, P=-19, E=-67) summed across all 5 modules of the subreach.

Condition indicator values and scores:

Indicator value	0	<0 - -19	<-19 - -67	<-67 - -201	<-201
Indicator score	0	-1	-2	-3	-4

E9 Channel bed reinforcement materials severity The indicator is the severity of the dominant bed reinforcement type observed in a MoRPh module. Values for each module are summed for the MoRPh5 indicator:

	Dominant reinforcement type	**Severity**
CC	Concrete	-3
CB	Concrete & brick / laid stone (cemented)	-3
BR	Brick / laid stone (cemented)	-3
SP	Sheet piling	-3
WP	Wood piling	-2
RR	Rip-rap (large laid stone, uncemented)	-2
GA	Gabions	-2
BW	Builders Waste	-1
WO	Washed out	-1

Condition indicator values and scores:

Indicator value	0	-1 to -2	-3	-4 to -12	<-12
Indicator score	0	-1	-2	-3	-4

E10 Channel bed artificial features severity The indicator incorporates 7 artificial bed features which are assigned scores (see following table) to reflect the relative severity of their impact. The values for each module are summed across the 5 modules of the subreach:

Artificial feature	**T**	**P**	**E**
Large trash (car parts, trolleys, traffic cones etc)	-16	-152	-536
	Narrow	**Int.**	**Wide**
Bridge shadow (see **(iii)**)	0	0	-67
	Count≥1		
Major weir	-536		
Intermediate weir	-152		
Minor weir	-16		
Bridge pier in river bed	-152		
Culvert	-1072		

Condition indicator values and scores:

Indicator value	0	<0 - -16	<-19 - -152	<-152 - -536	<-536
Indicator score	0	1	2	3	4

E11 Channel bed NNIPS cover This indicator combines the number and extent of up to 6 non-native invasive plant species (NNIPS) on the channel bed and any exposed in-channel features such as islands and bars by applying the following look-up table. Thus the indicator represents the total cover of NNIPS (6 possible species each assigned T=-2, P=-19 and E=-67). The results for the observed species are added for each module and then summed over 5 modules.

Species	**T**	**P**	**E**
Himalayan balsam	-2	-19	-67
Japanese knotweed	-2	-19	-67
Giant hogweed	-2	-19	-67
Floating pennywort	-2	-19	-67
Other species 1	-2	-19	-67
Other species 2	-2	-19	-67

Condition indicator values and scores:

Indicator value	0	<0 - -19	<-19 - -38	<-38 - -134	<-134
Indicator score	0	-1	-2	-3	-4

E12 Channel bed filamentous algae cover The indicator is the extent (T=-2, P=-19 and E=-67) of filamentous algae on the channel bed and summed across the 5 modules of the MoRPh5 subreach.
Condition indicator values and scores:

Indicator value	0	<0 - -19	<-19 - -67	<67 - -201	<-201
Indicator score	0	-1	-2	-3	-4