URS CLASSIFICATIONS AND INDICES:

2015

Angela Gurnell, Lucy Shuker, Geraldene Wharton

Queen Mary University of London

ACKNOWLEDGEMENTS

The classifications and indices presented here were originally developed as part of the PhD thesis of Dr Angela Boitsidis (nee Davenport) (University of Birmingham 2001) under the supervision of Professor Angela Gurnell. In 2003 they were improved by Angela Boitsidis and Angela Gurnell as part of the SMURF project (LIFE02 ENV/UK/000144). Since that time, Angela Gurnell and Lucy Shuker (under funding from Queen Mary, University of London and an ESRC-NERC research studentship) and Geraldene Wharton have further improved the classifications and indices in the light of the increasing body of river survey data that has become available.

CONTENTS

TABLES

INDICES

A long list of indices are derived from URS survey data (Table 1). Many of these have been tested on such a large body of URS data that they can be considered stable, whereas others (notably those relating to channel adjustment and stability) depend upon recent additions to the URS survey. The latter cannot be considered stable, since insufficient survey data is available to fully test them, and so should be treated with caution.

The derivation of each index is explained in Table 1. The current list of indices is organised under the following headings:

Sediment calibre indices
Flow type indices
Bar type
Bank profile type indices
Vegetation indices
Bank protection indices
Pollution and nuisance plant species indices
Channel stability indices
Channel adjustment indices
Other (mainly cross-cutting) indices

Table 1 Indices derived from Urban River Survey measurements to describe the characteristics of the river and its margins

Short Name	Full Name	Description
SEDIMENT CALIBRE INDICES		
DomSub	Dominant Channel Substrate Type	The channel mineral bed substrate type recorded the most times in the spot checks, indexed from 1 to 9 in order of decreasing particle size (1 = artificial (paved / concrete), 2 = bedrock, 3 = boulder, 4 = cobble, 5 = gravel / pebble, 6 = sand, 7 = silt / mud, 8 = clay). Where two categories have equal frequency, the coarser category (smaller number) is used.
Sedcal	Bed Sediment Calibre Index	Converts the mineral, mobile bed sediment types recorded in the 10 spot checks into an approximate average particle size for the stretch in phi units compatible with the Wentworth scale, where BO, CO, GP, SA, SI, CL are the number of spot checks falling into the Boulder, Cobble, Gravel/Pebble, Sand, Silt/Mud, Clay categories (note AR, BE, PE, NV are not used – if all spot checks fall into these categories, no value will be recorded in the URS database and 'artificial' will be displayed on the website): $\text{Sedcal} = \dfrac{(-8*BO)+(-7*CO)+(-3.5*GP)+(1.5*SA)+(6*SI)+(9*CL)}{(BO+CO+GP+SA+SI+CL)}$
DomBkMat	Dominant Bank Material Type	The bank material type that is recorded the most times in the spot checks, indexed from 1 to 7 in order of increasing erodibility (1 = artificial, 2 = bedrock, 3 = boulder, 4 = cohesive, sticky clay, 5 = cobble, 6 = earth, 7 = gravel / sand). Where two categories have equal frequency, the less erodible category (smaller number) is used.
Bankcal	Bank Sediment Calibre Index	Converts the natural mobile bank sediment types recorded in the 10 spot checks into an approximate average particle size for the stretch in phi units compatible with the Wentworth scale, where BO, CO, GS, EA, CL are the number of spot checks falling into the Boulder, Cobble, Gravel/Sand, Earth, Clay categories (note AR, BE, NV are not used– if all spot checks fall into these categories, no value will be recorded in the URS database and 'artificial' will be displayed on the website): $\text{Bankcal} = \dfrac{(-8*BO)+(-7*CO)+(-1.5*GS)+(1.5*EA)+(9*CL)}{(BO+CO+GS+EA+CL)}$
NumBedSed	Number of Mineral Bed Sediment Calibre Classes	Number of different mineral bed sediment calibres recorded from BE, BO, CO, GP, SA, SI, CL (excludes AR (artificial) and PE (peat) to give a potential maximum value of 7)).

FLOW TYPE INDICES		
DomFlow	Dominant Flow Types	The flow type recorded most frequently in the spot checks, indexed from 0 to 10 approximately according to decreasing flow energy (1 = free fall, 2 = chute flow, 3 = chaotic flow, 4 = broken standing waves, 5 = unbroken standing waves, 6 = rippled, 7 = upwelling, 8 = smooth, 9 = no perceptible flow, 10 = dry channel). Where two categories have equal frequency, the higher energy (smaller number) is used.
NumFlow	Number of Flow Types	The number of different flow (patch) types recorded in the spot-checks (free fall - FF, chute - CH, broken standing waves - BW, unbroken standing waves - UW, chaotic flow - CF, rippled - RP, upwelling - UP, smooth - SM, no perceptible flow - NP, dry - DR).
NumFlowHab	Number of Flow Habitats	Number of different in-channel flow habitat types recorded in cumulative measurements (max 9 - CC, BL, RP, RI, RU, GL, PO, MD, PR)
PropPools	Proportion of Pools	The percentage of channel area (nearest 5%) occupied by pools (PO, cumulative measurements).
PropMarginalWater	Proportion of Marginal Dead Water	The percentage of channel area (nearest 5%) occupied by marginal deadwater (MD, cumulative measurements).
PropGlides	Proportion of Glides	The percentage of channel area (nearest 5%) occupied by glides (GL, cumulative measurements).
PropRiffles	Proportion of Riffles	The percentage of channel area (nearest 5%) occupied by riffles (RI, cumulative measurements).
PropRuns	Proportion of Runs	The percentage of channel area (nearest 5%) occupied by runs (RU, cumulative measurements).
PropPondedReach	Proportion of Ponded Water	The percentage of channel area (nearest 5%) ponded (PR, cumulative measurements).
PropRapid	Proportion of Cascades&Rapids	The percentage of channel area (nearest 5%) ponded (CC, RP, cumulative measurements).
CountHab	Count of in-channel habitats	CountHab is the total number of types of habitat identified in the counted and percentage cumulative measurements. To avoid double counting, the following are excluded from the list of percentage habitat types: riffle, pool, marginal deadwater

BAR TYPE INDICES		
CountVS	Count of Vegetated Side Bars	Total count of vegetated side bars (VS,.cumulative measurements)
CountUS	Count of Unvegetated Side Bars	Total count of unvegetated side bars (SB,.cumulative measurements).
CountSS	Count of Sand / Silt Deposits	Total count of sand and silt deposits (SL,.cumulative measurements).
CountMB	Count of Unvegetated and Vegetated Mid-channel Bar	Total count of unvegetated and vegetated mid-channel bars (MB, VM,.cumulative measurements).
CountPB	Count of Unvegetated and Vegetated Point Bar	Total count of unvegetated and vegetated point bars (PB, VP,.cumulative measurements).
NumBarTypes	Number of Bar Types	The number of different types of in-channel bars and sediment patches recorded in the cumulative measurements (i.e. discrete sand/silt deposits - SL, islands - MI, unvegetated mid channel bar - MB, vegetated mid channel bar - VM, unvegetated point bar - PB, vegetated point bar - VP, unvegetated side bar - SB, vegetated side bar - VS, discrete organic matter deposit - OM).
BANK PROFILE TYPE INDICES		
DomNatBk	Dominant Natural Bank Profile Type	The natural bank profile type recorded most extensively in cumulative measurements, indexed from 1 to 6 according to increasing steepness and decreasing complexity (0 = no natural bank profiles, 1 = natural berm (NBE), 2 = gentle (<45 degrees, NGT), 3 = composite (NCT), 4 = steep (>45 degrees, NST), 5 = vertical with toe (NVT), 6 = vertical / vertical+undercut / undercut (NV, NVU). If two types are equally common record the one with the higher number.
NumNatBk	Number of Natural Bank Profile Types	The number of types of different natural bank profile types recorded in the cumulative measurements (NV, NVU, NVT, NST, NGT, NCT, NBE).

NumNatBkHab	Number of Natural Bank Habitats	Count of presence of eroding cliff (EC), stable cliff (SC) from spot checks plus count of presence of undercut (NVU), vertical with toe (NVT), steep (NST), gentle (NGT), composite (NCT), natural berm (NBE) from cumulative measurements (excludes NV because replaced by EC and SC)
DomArtBk	Dominant Artificial Bank Profile Type	The artificial bank profile type recorded most extensively in cumulative measurements, indexed from 1 to 5 according to increasing level of modification and channel encroachment (0 = none, 1 = poached (APC), 2 = set back embankments (ASE), 3 = artificial two-stage (ATS), 4 = embanked (AEM),5 = resectioned / reprofiled (ARD). If two types are equally common record the one with the higher number.
NumArtBk	Number of Artificial Bank Profile Types	The number of types of different artificial bank profile types recorded in the cumulative measurements (APC, ASE, ATS, AEM, ARD)
PropNatBk	Proportion Natural Bank Profiles	The percentage (nearest 5%) of the banks occupied by natural bank profiles from the cumulative measurements.
PropNoBk	Proportion No Bank Protection	The percentage (nearest 5%) of banks with no bank protection / reinforcement from the cumulative measurements
PropArtBk	Proportion Artificial Bank Profiles	The percentage (nearest 5%) of the banks occupied by artificial bank profiles from the cumulative measurements.
VEGETATION INDICES		
AveVeg	Average Channel Vegetation Cover	The total percentage cover for all vegetation types (excluding 'none') recorded at each spot check is then averaged over the number of spot checks.
NumVeg	Number of Channel Vegetation Types	The number of different types of channel vegetation (excluding 'none') recorded across all spot-checks.
DomVeg	Dominant Channel Vegetation Type	The channel vegetation type recording the largest total percentage across all spot checks, indexed from 0 to 10 according to increasing approximate flow resistance (0 = none, 1 = liverworts / mosses / lichens, 2 = free-floating, 3 = filamentous algae, 4 = amphibious, 5 = emergent broadleaved herbs, 6 = submerged linear-leaved, 7 = submerged broadleaved, 8 = submerged fine leaved, 9 = floating leaved (rooted), 10 = emergent reeds/sedges/rushes).
CountTreeFeatures	Count of Tree	All of the tree features recorded in the cumulative measurements (channel shading, overhanging

	Features	boughs, exposed bankside roots, underwater tree roots, fallen trees, large woody debris) are scored 0, 1 or 2, according to whether they are absent, present or extensive. The scores are summed to produce the index.
ComplexityFace	Complexity Bank Face Structure	The bank face structure recorded at each spot-check as bare, uniform, simple or complex is scored 0, 1, 2 and 3 respectively and then the scores are summed for both left and right bank faces and divided by the number of spot-checks.
ComplexityTop	Complexity Bank Top Structure	The bank top structure recorded at each spot-check as bare, uniform, simple or complex is scored 0, 1, 2 and 3 respectively and then the scores are summed for both left and right bank faces and divided by the number of spot-checks.
ComplexityTree	Complexity Tree Cover	Tree distribution recorded along each bank in the cumulative measurements is scored (none = 0, isolated/scattered = 1, regularly spaced = 2, occasional clumps = 3, semi-continuous = 4, continuous = 5) and the two bank scores are summed to index the overall complexity of tree cover.
NumVegHab	Number of vegetation habitats	NumVeg plus the number of the following tree-related habitats: from habitat counts - wood debris (WD), wood jam (WJ); from tree features (if P or E): fallen trees, exposed bankside roots, underwater roots
		BANK PROTECTION INDICES
DomBkMatPro	Dominant Bank Material Protection Type	The bank protection material recorded the most times in the spot checks, indexed from 0 to 11 approximately according to increasing erosion resistance (0 = none NO, 1 = washed out WO, 2 = reeds RE, 3 = willow spiling / faggots WS, 3 = biotex / coir BC, 4 = wood piling WP, 5 = rubble (e.g. builders waste BW), 6 = gabions GA, 7 = rip rap RR, 8 = sheet piling SP, 9 = brick / laidstone BR, 10 = concrete and brick CB, 11 = concrete CC). Where two categories have equal frequency, the cumulative measurements are used to determine the dominant bank material protection type. If the two categories are still equal, the category with the most severe impact (i.e. the higher value) is used.
DomBkPro	Dominant Bank Protection Class	The class of bank protection recorded the most times in the spot checks, indexed from 0 to 3 according to increasing rigidity and permanence (0 = no hard bank protection (none, washed out), 1 = biodegradable (reeds; wood piling; willow spiling / faggots; biotex / coir); 2 = open matrix (rip-rap, gabions, builders waste), 3 = Solid (concrete; concrete and brick; brick / laidstone; sheet piling). Where two categories have equal frequency, the cumulative measurements are used to determine the dominant bank protection type. If the two categories are still equal, the category with the most severe impact (i.e. the higher value) is used.
NumBkPro	Number of Bank	The number of different types of bank protection ascertained from the cumulative measurements

<table>
<tr><td></td><td>Protection Types</td><td>(excluding washed out and none).</td></tr>
<tr><td>PropBio</td><td>Proportion Biodegradable Bank Protection</td><td>The percentage (nearest 5%) of banks occupied by biodegradable bank protection (planted reeds; biotex / coir, wood piling; faggots / willow spiling – i.e. willow stakes inserted and interwoven to provide a living structure to support the bank) estimated from the cumulative measurements.</td></tr>
<tr><td>PropOpenMatrix</td><td>Proportion Open Matrix Bank Protection</td><td>The percentage (nearest 5%) of banks occupied by open matrix bank protection (rip-rap; gabions; builders waste) estimated from the cumulative measurements.</td></tr>
<tr><td>PropSolid</td><td>Proportion Solid Bank Protection</td><td>The percentage (nearest 5%) of banks occupied by solid bank protection (concrete; concrete and brick; brick / laidstone; sheet piling) estimated from the cumulative measurements.</td></tr>
<tr><td>PropImmBk</td><td>Proportion Immobile Bank Materials</td><td>= (No. of spot-checks with immobile bank materials (concrete, concrete and brick, brick / laid stone, sheet-piling, bedrock) x 100) / No. of spot-checks</td></tr>
<tr><td>PropImmSub</td><td>Proportion Immobile Substrate</td><td>= No. of spot-checks with immobile bed materials (artificial, bedrock, boulder) x 100
No. of spot-checks</td></tr>
<tr><td colspan="3">POLLUTION AND NUISANCE PLANT SPECIES INDICES</td></tr>
<tr><td>NumPollution</td><td>Number of Pollution Indicators</td><td>The number of different pollution indicators observed in the cumulative measurements excluding gross pollution (i.e. water odours, sediment odours, oils, surface scum).</td></tr>
<tr><td>ExtentLitter</td><td>Extent of Trash and Gross Pollution</td><td>Assessed using A, P, E records for Gross pollution in the cumulative measurements and the number of records of Trash in the spot check measurements of channel features:
Extent Litter = 0 (Negligible); 1 (Low): 2 (Moderate): 3 (High): 4 (Very High) as follows:
<table>
<tr><td></td><td>Trash</td><td>0</td><td>0-2</td><td>2-5</td><td>5+</td></tr>
<tr><td>GrossPollution</td><td>A</td><td>0</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td></td><td>P</td><td>1</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td></td><td>E</td><td>3</td><td>3</td><td>3</td><td>4</td></tr>
</table></td></tr>
</table>

<table>
<tr><td>NumNuisance</td><td>Number of Nuisance Plant Species</td><td>The number of the seven different nuisance plant species recorded in the cumulative measurements (Himalayan balsam, Japanese knotweed, Giant hogweed, Floating Pennywort, Australian swamp stonecrop, Parrot’s feather, Creeping Water Primrose).</td></tr>
<tr><td>ExtentNuisance</td><td>Extent of Nuisance Plant Species</td><td>The extent of each riparian nuisance species (Himalayan balsam, Japanese knotweed, Giant hogweed, Floating Pennywort, Australian swamp stonecrop, Parrot’s feather, Creeping Water Primrose) from the cumulative measurements is scored (none = 0, single individual = 1, isolated clumps = 2, frequent = 3, extensive = 4), summed across all species present and then divided by the number of nuisance species present to obtain their typical extent.</td></tr>
<tr><td>NuisanceInvasion</td><td>Severity of Invasion by Nuisance Plant Species</td><td>NuisanceInvasion = 1 (Negligible); 2 (Low); 3 (Moderate) 4 (High); 5 (Very High) as follows:
<table>
<tr><td></td><td>ExtentNuisance</td><td>0-1</td><td>1-2</td><td>2-3</td><td>3-4</td><td>4+</td></tr>
<tr><td>NumNuisance</td><td>0-1</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td></td><td>1-2</td><td>2</td><td>3</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td></td><td>2+</td><td>3</td><td>4</td><td>4</td><td>5</td><td>5</td></tr>
</table></td></tr>
<tr><td>CountInput</td><td>Number of Input Pipes</td><td>The total count recorded in the cumulative measurements is converted into a score (0 pipes = 0, 1 = 1, 2 = 2, 3 = 3, 4 = 4, 5 = 5, 6-9 =6, 10-14 = 7, 15-20 = 8, 20-30 = 9, >30 = 10)</td></tr>
<tr><td>CountLeach</td><td>Number of Leach Points</td><td>The total count recorded in the cumulative measurements is converted into a score (0 points/patches = 0, 1 = 1, 2 = 2, 3 = 3, 4 = 4, 5 = 5, 6-9 =6, 10-14 = 7, 15-20 = 8, 20-30 = 9, >30 = 10)</td></tr>
<tr><td>CountInput&Leach</td><td>Number of Input and Leach Points</td><td>= CountInput + CountLeach</td></tr>
<tr><td>TotalPollIndicators</td><td>Potential River Pollution Intensity</td><td>Based upon NumPollution+ExtentLitter+CountInput&Leach:
TotalPollIndication is 0 (Negligible: if the sum is ≤ 1), 1 (Low: if the sum is 2-3); 2 (Moderate: if the sum is 4-6); 3 (High: if the sum is 7-9); 4 (Very high: if the sum is > 9)</td></tr>
</table>

CHANNEL STABILITY INDICES		
HeavyVeg	Heavily Vegetated Banks and Bars	1 if on all spot checks, bank face vegetation is simple or complex and all bars are vegetated. Otherwise 0
NoBkErosion	Negligible bank erosion	1 if 0% is recorded for all of the following natural bank profiles in the cumulative measurements: NV, NVU, NVT. Otherwise 0
ExtMatureTrees	Extensive Mature Trees along Banks	1 if both banks record a continuous or semi-continuous tree distribution in the cumulative measurements. Otherwise 0.
StableChannel	Stable channel	1 if HeavyVeg+NoBkErosion+ExtMatureTrees > 0 (i.e. channel is very stable). Otherwise 0 (some channel dynamics)
CHANNEL ADJUSTMENT INDICES		
Migrating	Evidence for Lateral Migration	Based on the 'one bank eroding' record in the cumulative measurements: 0 (if none recorded), 1 (negligible) 2 (local), 3 (extensive); 4 (very extensive).
Widening	Evidence for Channel Widening	Based on the 'opposite banks eroding' record in the cumulative measurements: 0 (if none recorded), 1 (negligible) 2 (local), 3 (extensive); 4 (very extensive).
Narrowing	Evidence for Channel Narrowing	Based on the 'opposite banks depositing' record in the cumulative measurements: 0 (if none recorded), 1 (negligible) 2 (local), 3 (extensive); 4 (very extensive).
BedIncisionLikelihood	Potential Channel Bed Incision	1 if from the cumulative measurements ((bankfull width) / (smaller of Left and Right bankfull height + water depth)) < 1.5
BedIncision	Evidence for Channel Bed Incision	Sum of A=0, P=1, E=3 for each of the following four cumulative measurements: Bed sediment exposed in bank profile, Trees with exposed roots / collapsing / leaning into channel on both banks, Heavily compacted and armoured bed, Exposure of foundations of structures PLUS for Opposite banks eroding none = 0, negligible/local = 1, extensive/very extensive = 3. Divide the sum by 5.
Aggradation	Evidence for Bed and/or Bank Aggradation	Sum of A=0, P=1, E=3 for each of the following five cumulative measurements: Buried soil within bank profiles, Burial of river bed with finer sediment, Burial of the base of structures, River channel narrow relative to bridge openings, Burial of base of established vegetation. Divide the sum by 5.

OTHER (MAINLY CROSS-CUTTING) INDICES		
Complexity	Number of river and margin habitats	NumBedSed + NumFlowHab + NumNatBkHab + NumVegHab
DisConnectivity	Extent of disruption of longitudinal continuity by in-channel structures	DisConnectivity is assessed using artificial features recorded in the cumulative measurements in the following equation: Disconnectivity = (No. culverts + No. major weirs / sluices) * 5 + (No. intermediate weirs / sluices) * 3 + (No. minor weirs + No. major deflectors / groynes + No. major bridges) * 2 + (No. intermediate bridges + No. intermediate deflectors / groynes) and is then expressed as an integer number
NumSpecialFeatures	Number of Special Features	Count of the number of special features recorded in the cumulative measurements from the following list: side channels, fen, marsh/bog, carr, water meadow, floating mat / reed bed (count 1 if P or E in special features list), bedrock, waterfall, connected backwater, disconnected backwater, wood jam (if count $\geq$ 1 on Habitat Feature counts).

CLASSIFICATIONS

1. INTRODUCTION

Currently there are eight classifications that are derived for individual river stretches from river survey measurements and indices:

Classifications of river stretch **Complexity, Stability,** channel **Condition,** and longitudinal **Connectivity** combine to support high level assessment of habitat and biodiversity in the study area.

The **Stretch Habitat Quality Index (SHQI)** also supports high-level assessment of habitat and biodiversity in the study area and it value is derived from three component classifications of the **Materials**, **Physical Habitat** and **Vegetation** characteristics of individual river stretches

2. CLASSIFICATION OF STRETCH COMPLEXITY, STABILITY, CONDITION, AND CONNECTIVITY

Table 2 describes how classifications of stretch Complexity, Stability, channel Condition,and longitudinal Connectivity are applied to some of the indices listed in Table 1,and how the classes can be interpreted

Table 2 Classification of Complexity, Stability, Condition and Connectivity

Short Name	Full Name	Description
ComplexityClass	Classes reflect the number of river and margin habitats present	1 (High) if Complexity = > 10; 2 (Above average) if Complexity = 9 - 10; 3 (Average) if Complexity = 6 – 8; 4 (Low) if Complexity = 4-5; 5 (Very Low) if Complexity < 4
StabilityClass	Evidence for Geomorphic Stability / Dynamics	1 (very stable) if StableChannel = 1, otherwise 0 (probably some dynamics) For channels where StableChannel = 0 2 (Slightly Dynamic) if all of Migrating, Widening, Narrowing, BedIncision, Aggradation have a score < 2 3 (Dynamic) if all of Migrating, Widening, Narrowing, BedIncision, Aggradation have a score of <4 4 (Highly Dynamic) if any of Migrating, Widening, Narrowing, BedIncision, Aggradation have a score of 4
ChannelCondition Class	Condition of Channel in relation to Pollution Potential and Nuisance Species Invasion	1 (Good: IF TotalPollIndicators = 0 AND NuisanceInvasion = 0); 2 (Average: IF TotalPollIndicators = 1 AND/OR NuisanceInvasion = 1); 3 (Poor: IF TotalPollIndicators = 2 AND/OR NuisanceInvasion = 2); 4 (Very Poor: IF TotalPollIndicators = 3 or 4 OR NuisanceInvasion = 3 or 4); 5 (Extremely Poor: IF TotalPollIndicators = 3 or 4 AND NuisanceInvasion = 3 or 4)
ConnectivityClass	Classifies strength of longitudinal Connectivity	1 (very high if DisConnectivity = 0); 2 (high if Disconnectivity = 1 or 2); 3 (moderately impeded if Disconnectivity = 3-4); 4 (poor if Disconnectivity = 5-9): 5 (extremely poor if Disconnectivity > 9)

3. CLASSIFICATION OF MATERIALS, PHYSICAL HABITAT, VEGETATION

3.1 Statistical derivation of the classifications

The three classifications were developed through cluster analysis of three groups of river survey indices describing the ‘Materials’, ‘Habitat’ and ‘Vegetation’ properties of surveyed stretches. Prior to analysis, all of the indices were reduced to a similar numerical range by dividing percentage indices by 10. The cluster analysis was based on Euclidean distance as the distance measure and Ward’s method as the clustering algorithm. Once each cluster analysis was complete, the number of clusters that best described distinct groupings or classes of stretches was identified using the cluster dendrogram and focussing on agglomerations to between 3 to 8 clusters. The validity and meaning of the clusters was assessed by (i) applying non-parametric (Kruskal Wallis) analysis of variance (ANOVA) to identify which of the individual river survey indices provided a statistically significant ($P<0.05$) discrimination between the clusters; (ii) inspecting box and whisker plots for each of the indices to further identify which clusters were discriminated by each attribute and the strength of the discrimination; and (iii) identifying whether the clusters were comprised of stretches with any distinct engineering types (i.e. combinations of cross profile, planform and level of reinforcement), which might suggest a causal impact of engineering on cluster characteristics.

Following the identification of clusters or classes of stretches according to their ‘Materials’, ‘Physical Habitat’ and ‘Vegetation’ properties, a simple decision tree was devised that allowed newly-surveyed stretches to be allocated to a class according to a small set of the original river indices.

3.2 Materials Classification

The URS indicators used within the Materials cluster analysis reflected the character of the natural bed (Sedcal) and bank (Bankcal) materials, the type and amounts of bank protection (DomBkMatPro, PropNoBk, PropOpenMatrix, PropSolid) and the extent of artificially reinforced river bed (PropImmSub). Although the engineering type was not included in the analysis, this was clearly reflected in the indicators describing the different levels and types of reinforcement and so, not surprisingly, each cluster is comprised of stretches that possess distinct types of engineering modification (Table 3). The combination of engineering and natural materials is reflected in the names given to the clusters.

3.3 Physical Habitat Classification

The indices used within the physical habitat classification included the total number of in-channel habitats (CountHab), and a range of other URS indices describing the number and nature of in-channel flow types, vegetated and unvegetated sediment habitats and also the extent, types and number of natural bank profiles. The cluster analysis identified six distinct classes (Table 4) and which once more can be linked to different degrees and types of engineering.

3.4 Vegetation Classification

A final cluster analysis was performed on observations of vegetation and pollution-related variables, namely: AveVeg, NumVeg, DomVeg, CountTreeFeatures, ComplexityFace, ComplexityTop, ComplexityTree, NumPollution, NumNuisance, ExtentNuisance, CountInput, CountLeach. Eight clusters were found to characterise the data well and, based on Kruskal Wallis tests, all the included variables showed statistically significant ($P<0.05$) discrimination between some of the clusters, apart from the variable ComplexityTop. Again, the clusters were associated with different types of channel engineering (Table 5).

3.5 Classification Decisions Trees

The Materials, Physical Habitat and Vegetation classifications indicate that the surveyed stretches can be allocated to 7, 6, 8 different classes, respectively. These classifications all appear to be related to the level and type of engineering to some degree, although the strongest associations are with Materials and the weakest are with Vegetation. In order to identify the class to which any new stretch should be allocated without re-running the entire cluster analysis, three decisions trees were developed (Figures 1 to 3) for this purpose. These decision trees enable a newly-surveyed stretch to be allocated to an appropriate ‘Materials’, ‘Physical Habitat’ and ‘Vegetation’ class. The decision trees do not incorporate all of the indicators that were used to define the classes because many of these are highly correlated. Thus, the decision trees incorporate the minimum number of key variables that are needed to allocate a newly-surveyed stretch to the various classes.

Table 3 Descriptions of the characteristics of stretches attributed to different Materials classes / clusters

Group Name: abbreviation	**Description of discriminating (Materials) indices**	**Description of broad Engineering Characteristics**
SEMI-NATURAL (COARSE): SNC	Low proportions of bank protection. Coarser substrates (Sedcal) and bank materials (average Bankcal).	More natural planforms and cross sections (developed through natural processes, recovery or restoration), typically with some sinuosity
SEMI-NATURAL (MIXED): SNM	Low proportions of bank protection, with mixed substrates typically corresponding to silt/sand with some gravels (Sedcal).	Artificial (mainly straight) planforms, and cross-sections but with limited reinforcement
SEMI-NATURAL (FINE): SNF	Low proportions of bank protection. Finer (typically clay) substrates (Sedcal) and bank materials (Bankcal).	Natural sinuous planforms and cross-sections with limited reinforcement
LIGHTLY ENGINEERED: LE	Coarser bed and bank materials (Sedcal, Bankcal). Moderate proportions (ca. 30-85%) of open matrix (gabions, rip rap etc) and biodegradable (e.g. toe boarding) protection.	Artificial (usually sinuous) planforms, and cross-sections with significant reinforcement
ENGINEERED: EN	High (ca. 90-100%) proportions of open matrix bank protection and moderate proportions (ca. 20-50%) of solid bank protection. Low proportions of immobile substrate.	Artificial (mainly straight) planforms and cross-sections with extensive reinforcement
HEAVILY ENGINEERED: HE	High proportions (50-90%) of solid bank protection (concrete, laid stone etc.) but low proportions of immobile substrate (i.e. bed reinforcement).	Artificial (mixed sinuosity) planforms and cross-sections with extensive reinforcement
VERY HEAVILY ENGINEERED: VHE	High proportions (ca. 100%) of solid bank protection (concrete, laid stone etc.) and immobile substrate.	Heavily engineered, straight planforms and high levels of reinforcement on the banks and the bed.

Table 4 Descriptions of the characteristics of stretches attributed to different Physical Habitat classes / clusters.

Group Name: abbreviation	Description of discriminating Indicators	Typical Physical Habitat Characteristics	Description of Broad Engineering Characteristics
SEMI-NATURAL (ACTIVE): SNA	Very high proportions of natural bank profiles (PropNatBk) and >7 different habitat types (CountHab) indicating both deposition and erosion.	Extensive riffle influenced flow patterns (up to 30% PropRiffle) and some pool formation as well as presence of vegetated/ unvegetated bars.	Unreinforced channels, with predominantly restored cross profiles and varied planforms (straight / sinuous,semi-natural).
SEMI-NATURAL (STABLE): SNS	Very high proportions of natural bank profiles (PropNatBk). $\leq$7 different habitat types (CountHab) indicative of both erosion and deposition but at a more modest level than SNA and RC channels.	Flow dominated by glides (PropGlides = 50-90%) with no evidence of pool formation.	Unreinforced channels with a mix of restored and semi natural cross profiles, with semi natural or straight planforms.
RECOVERING: RC	Intermediate to low proportions of natural bank profiles (PropNatBk 5% - 50%). < 7 different habitat types (CountHab) indicating both erosion and deposition.	Typically extensive steep banks and a variety of bar types indicating active bank recovery from engineering intervention. Some evidence of mixed flow types (5-20% riffle, > 50% glide).	Predominantly unreinforced, resectioned channels with straight or sinuous planforms
UNIFORM ACTIVE; UA	A small group of channels showing typically > 7 habitat types, with many indicative of sediment deposition and thus channel adjustment	Numerous bars of different types, particularly vegetated side bars (CountVS typically > 15) and both vegetated and unvegetated mid-channel bars (CountMB typically > 5).	Engineering includes fully or both bank-reinforced channels with mainly resectioned cross profiles and sinuous or straight planforms.
UNIFORM MODERATELY ACTIVE: UM	Low proportions of natural bank profiles (PropNatBk < 5%) and flows dominated by runs (PropRuns > 20%, PropGlides < 20%).	Run dominated but with some riffles (PropRiffles 0-40%) and typically only 2-4 habitats (HabCount) and no bars.	Predominantly fully reinforced, enlarged channels with straight planforms
UNIFORM STABLE: US	Low proportions of natural bank profiles (PropNatBk < 5%) and flows dominated by glides (PropGlides > 80%)..	Glide dominated channels with few habitats (HabCount typically < 3) and no bars.	A mix of unreinforced and fully reinforced channels with resectioned cross profiles and straight planforms

Table 5 Descriptions of the characteristics of stretches attributed to different vegetation classes / clusters.

Group Name: abbreviation	**Description of discriminating Primary (Vegetation) Indicators**	**Description of broad Engineering Characteristics**
Un-Vegetated channel, High bank Tree cover-connected to channel: UVHTconn	Low channel vegetation cover (typically < 15%), comprised mainly of free floating, lichens, liverworts and mosses. Well connected, high bank tree cover (semi-continuous to continuous) and high (>7) tree features,	Mainly unreinforced channels, with semi-natural planforms and semi-natural or recovering cross-sections
Low channel Vegetation cover in channel, High bank Tree cover connected to channel: LVHTconn	Low macrophyte cover (typically < 10%) comprised mainly of emergents Well connected, high bank tree cover (semi-continuous to continuous) and high (>7) tree features	Mainly unreinforced channels with straightened or semi-natural planforms and semi-natural or resectioned cross profiles
Medium channel Vegetation cover, Medium bank Tree cover: MVMT	Intermediate macrophyte cover (typically < 50%) mainly comprised of rooted submerged / floating leaved and emergent macrophytes. Occasional clumps to semi-continuous bank tree cover and fairly complex bank vegetationstructure	Mainly unreinforced, straight or sinuous, resectioned channels
High channel Vegetation cover, Low bank Tree cover: HVLT	High macrophyte cover (typically >60% and including near-choked channels), mainly rooted submerged /floating leaved and emergent macrophytes. Simple bank vegetation with few trees and tree features	Mainly unreinforced, straight or sinuous, resectioned channels
High Vegetation, Medium Trees: HVMT	High channel vegetation cover (typically >60% and including some choked channels), often dominated by algae. Fairly high (clumps to semi-continuous) bank tree cover and moderately complex bank vegetation cover but relatively few tree features	Mainly unreinforced, straight or sinuous, resectioned channels
Low channel Vegetation cover, Low bank Tree cover: LVLT	Low macrophyte cover (typically 0 to 35%) and dominated by algae. Low to intermediate bank vegetation development including isolated to occasional clumps of trees and a few to no tree features. Some channels display one or more bank leach points.	A mixture of all engineering types
Low Vegetation , High Trees-but disconnected from channel LVHTdisconn	Intermediate to low (<40%) channel vegetation cover, typically comprised of free floating, lichens, liverworts and mosses, and dominated by algae in over 50% stretches, Disconnected high tree cover	Mainly fully reinforced, straight or sinuous and enlarged channels
Un-Vegetated , High Trees-but disconnected from channel UVHTdisconn	Negligible or no macrophyte cover. Disconnected high tree cover. Channels in this group typically have high numbers of leach points (>5) and pipe inputs (>8)	Mainly fully reinforced, straight and enlarged channels

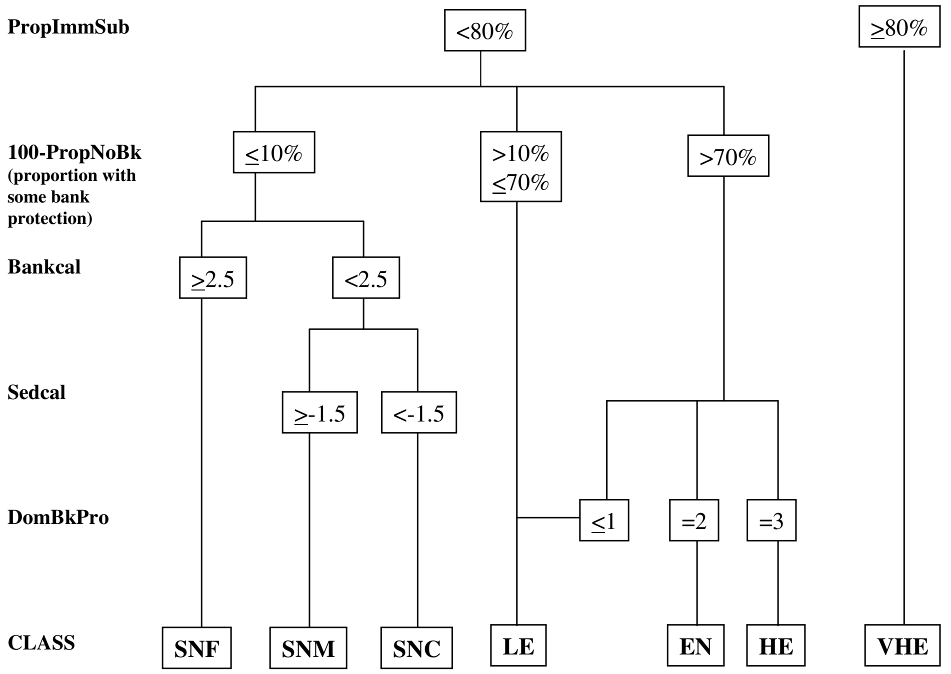

Figure 1: Flow chart for allocating urban river stretches to the relevant materials class

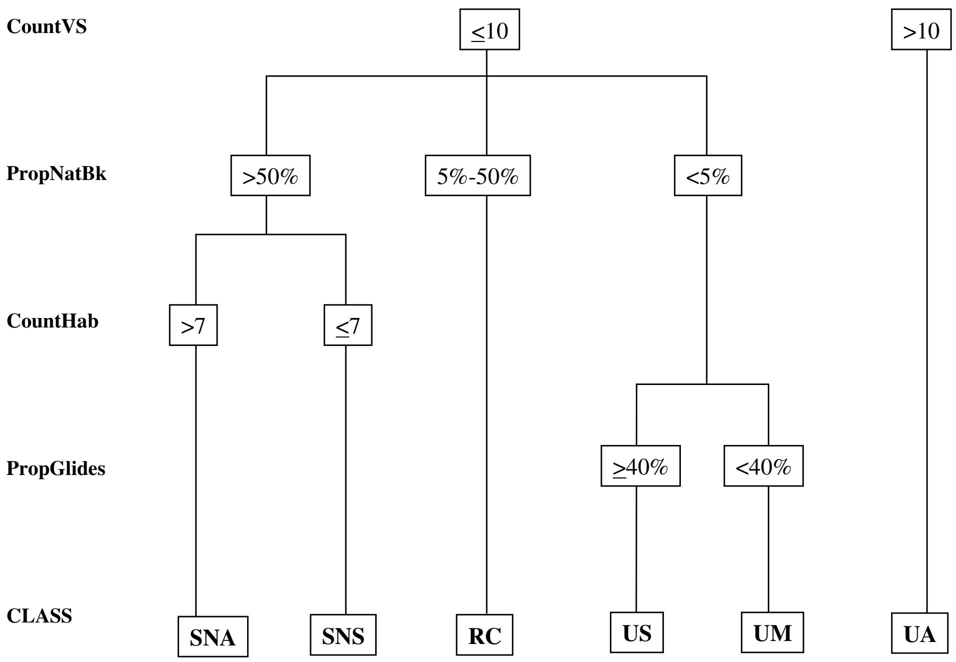

Figure 2: Flow chart for allocating urban river stretches to the relevant Physical Habitat Class

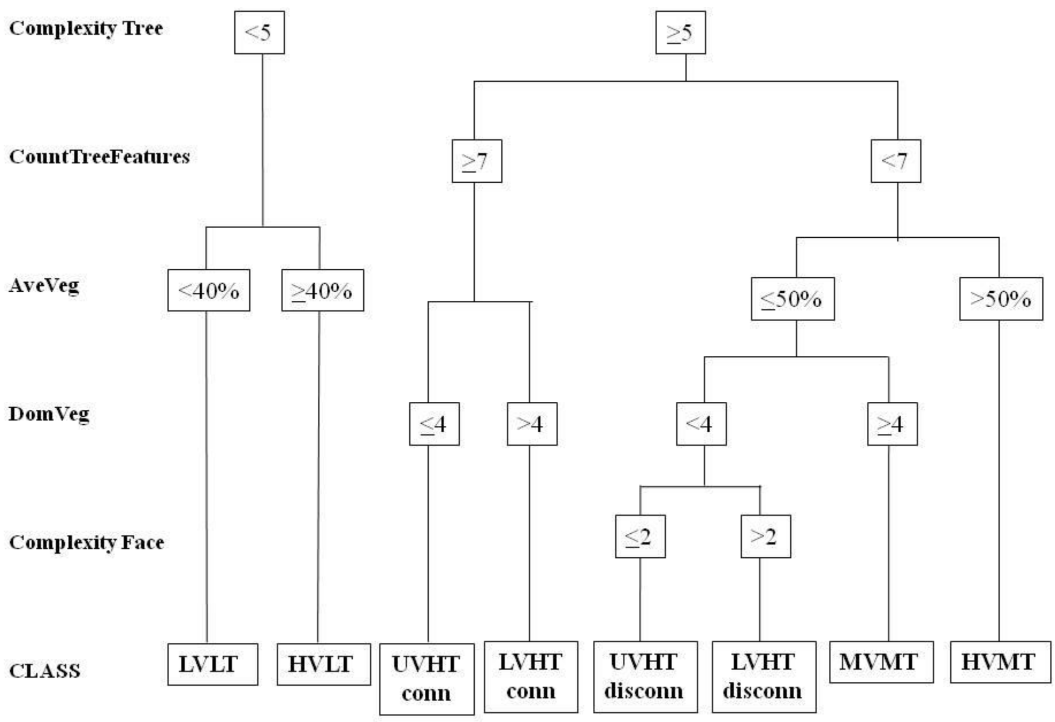

Figure 3 Flow chart for allocating urban river stretches to the relevant vegetation class.

4 COMBINING CLASSIFICATIONS TO PRODUCE A STRETCH HABITAT QUALITY INDEX (SHQI)

4.1 How the classifications were combined to derive the SHQI

In order to combine the three different classifications to produce a single index of the overall quality of a stretch, scores were assigned to each class /cluster within the Materials, Physical Habitat and Vegetation classifications (Table 6). These three scores are then added together to define an overall Stretch habitat Quality Index (SHQI), which ranges from 3 to 18 with the smallest scores representing the highest quality stretches

The scores assigned to the materials classes reflect the change from semi-natural (score = 1) to heavily engineered stretches (score = 6). The semi-natural coarse (SNC) and fine (SNF) classes essentially reflect the different alluvial sediments bounding the river channel and are, therefore, assigned the same score of 1. The semi-natural mixed class (SNM), with its relatively coarser banks and finer substrates is actually comprised of straightened channels with resectioned banks so is allocated a larger score of 2. The lightly engineered (LE) class also displays engineering modification but with more sinuous channels than SNM and with some reinforcement usually applied to eroding banks on the outside of the bends. As a result of the similar (low) degree of engineering modification both of these groups have been assigned a score of 2. The engineered (EN) and heavily engineered (HE) classes are distinguished from each other by the difference in dominant protection type (open matrix and solid, respectively) and both show a marked increase in the level of engineering from the SNC, SNF, SNM and LE classes and so have been assigned scores of 4 and 5. The final very heavily engineered (VHE) class comprises stretches that have both reinforced bed and banks and is assigned a score of 6

Scores assigned to the physical habitat classes reflect the degree to which the channel has been modified and the degree to which the channel is recovering either some or all of its physical habitat features. The semi-natural active and stable classes are assigned scores of 1 and 2, respectively, reflecting the fact that they both possess a significant degree of naturalness, but the former has more numerous and varied habitat types. The recovering class (RE) is characterised by some engineering intervention but also signs of structural recovery, and so is assigned a score of 3. The remaining, more heavily engineered classes display less habitat types and lower levels of recovery than any of the previously-discussed classes. The uniform active (UA), uniform moderately active (UM) and uniform stable classes (US) display decreasing levels of sinuosity, natural bank profiles and habitats with increasing channel stability and so these classes have been assigned scores of 4, 5, and 6 respectively.

Scores assigned to the vegetation classes reflect the level and type of in-channel vegetation, the character of the riparian vegetation and the degree to which the latter is connected to the channel as evidenced by, for example, the number of tree features observed within the surveyed stretch. Thus heavily tree-lined channels showing high values of CountTreeFeatures (UVHTconn, LVHTconn) are assigned a high quality score of 1, whereas those with low values of CountTreeFeatures are assigned low quality scores of 5 (LVHTdisconn – which retains some in-channel vegetation) and 6 (UVHTdisconn – which tends to be associated with fully reinforced channels with negligible vegetation). The remaining vegetation classes have intermediate to low bank tree cover and are differentiated along a gradient of relatively high to low quality according to the complexity of in-channel and bank vegetation. The highest quality is assigned to those channels with the most complex in-channel and bank vegetation structure (MVMT = 1). For channels that have a high macrophyte cover (HVLT, HVMT), a higher quality score is assigned to those with a higher riarian tree complexity (HVMT = 2) than those where tree complexity is relatively lower (HVLT = 3). A final relatively low quality vegetation class (LVLT = 3) is similar to HVLT but with a lower cover of in-channel vegetation. It should be stressed that a mixture of the higher quality classes (e.g. scores $\leq$ 3) is required at the catchment level, to provide variation along the river.

4.2 Management implications of the SQHI classes

The SHQI can be interpreted in relation to typical Materials, Habitat, Vegetation and engineering characteristics (Table 7) as a simple basis for understanding how the potential condition of a stretch may be defined, and how the stretch might respond to likely scenarios for rehabilitation. Table 7 defines 6 categories of river stretch, assigns the overall SQHI values associated with each category, defines the type of material, physical, and vegetation class that contributes to these SHQI values, and describes the type of management that might be undertaken to rehabilitate a stretch falling in each category and thus improve its SHQI to achieve a lower value.

Table 6 Scoring system for defining the quality and potential of urban river channels and the three scores that accumulate to form a Stretch habitat Quality Index (SHQI).

MATERIALS		PHYSICAL HABITAT		VEGETATION	
Class	Score	Class	Score	Class	Score
SNF (semi-natural fine)	1	SNA (semi-natural active)	1	UVHTconn (un-vegetated channel, high bank tree cover-connected to channel)	1
SNC (semi-natural coarse)	1	SNS (semi-natural stable)	2	LVHTconn (low channel vegetation cover in channel, high bank tree cover connected to channel)	1
SNM (semi-natural mixed)	2	RC (recovering)	3	MVMT (medium channel vegetation cover, medium bank tree cover)	1
LE (lightly engineered)	2	UA (uniform active)	4	HVMT (high channel vegetation, medium trees).	2
EN (engineered)	4	UM (uniform moderately active)	5	HVLT (high channel vegetation cover, low bank tree cover)	3
HE (heavily engineered)	5	US (uniform stable)	6	LVLT (low channel vegetation cover, low bank tree cover)	3
VHE (very heavily engineered)	6			LVHTdisconn (low vegetation , high trees-but disconnected from channel)	5
				UVHTdisconn (un-vegetated, high trees-but disconnected from channel)	6

Table 7 SQHI values ranges, associations with Materials, Physical Habitat, and Vegetation classes, and management recommendations associated with categories of SHQI values.

SHQI CATEGORY	SHQI VALUES	CLASSES MOST ASSOCIATED WITH SHQI VALUES (M=Materials; P=Physical; V=Vegetation)	MANAGEMENT RECOMMENDATIONS
Very Good	3-4	**M:** SNC/SNF **P:** SNA/SNS/RC **V:** UVHTconn, LVHTconn, MVMT	Predominantly semi-natural and recovering stretches, with well developed riparian vegetation, tree cover and in some cases diverse channel vegetation. The recommendation is to leave these stretches free of management and to protect them from development.
Good	5-6	**M:** SNC/LE **P:** RC/SNS/UA/UM **V:** UVHTconn, LVHTconn, MVMT	Semi-natural, recovering and a few uniform channels displaying some activity, with good vegetation complexity and tree cover. The recommendation is to remove any remaining reinforcement to allow the channel to recover more freely. These stretches should also be protected from further development.
Average	7-9	**M:** SNC/SNM/LE/ME **P:** RC/UA/US/SNS **V:** HVLT, HVMT, LVLT	Stretches with varying levels of engineering, but displaying some level of either recovery or activity, with reduced riparian vegetation complexity or excessive macrophyte growth. The recommendation is, where possible, to reduce the levels of immobile substrates and bank materials and increase sinuosity. Tree cover and bank top and face vegetation should be managed to provide increased variety and complexity. These channels show moderate to high levels of activity and should be targeted for rehabilitation where opportunities arise.
Below Average	10-12	**M:** SNC/LE/HE **P:** UA/UM **V:** HVLT, HVMT, LVLT	Stretches with varying levels of modification but showing high levels of activity, combined with low bank vegetation complexity and often channels are choked with macrophytes. These channels show moderate to high levels of activity and should be targeted for rehabilitation where opportunities arise. The recommendation is to reduce or alter the level and/or type of reinforcement and increase channel sinuosity where possible. Where macrophytes cover is excessive, increased tree cover through planting or channel narrowing to increase shear stresses are possible management options.
Poor	13-15	**M:** HE/ME/EN **P:** UM/US/UA **V:** HVMT, LVLT, LVHTdisconn / UVHTdisconn	Moderate to heavily engineered channels with low to moderate levels of activity, low complexity of bank vegetation and often algal dominated channels. The recommendation is to assess the water quality for improvement of in-channel vegetation diversity, and undertake a detailed assessment of the level of rehabilitation required to improve the physical condition of the channel. Where possible, a reduction of reinforcement level and/or type and an increase in sinuosity of the channel is desirable.
Very Poor	16-18	**M:** HE/VHE **P:** US/UM **V:** LVHTdisconn / UVHTdisconn	Heavily engineered, often algal-dominated, stable channels with little vegetation complexity. Significant improvements to water quality should be initiated, followed by a detailed assessment of rehabilitation needs. Aesthetic rehabilitation may be the best option in the short term. Wherever possible this should be followed by some reduction in the level of reinforcement and an increase in channel sinuosity.