APPENDIX A

FLUVIAL AUDIT METHOD STATEMENT

Fluvial Audit Methodology

INTRODUCTION

The procedure used to characterize the geomorphic and sedimentary regimes of the River Till is an adaptation of the 'Fluvial Audit' methodology proper as described in Sear et al. (1995). It has been developed by Dr. H. Moir over the last 10 years for the application to Scottish river systems and used in peer-reviewed, published scientific literature (Moir et al. 2004, Moir and Pasternack 2008) and a number of grey literature project reports.

The approach is explicitly more process-based than 'Fluvial Audit', classifying channel character in terms of observed morphology, the physical expression and integration of fluvial processes. 'Fluvial Audit' is process-based in principal but is designed to incorporate data from the River Habitat Survey (RHS) methodology which is not process-based. The inventory approach to classifying stream character in RHS tends to confuse form and process and is therefore not the best approach to inform as to controls on the geomorphic character of a river system. Where there is not access to existing RHS data there is little justification in employing the 'Fluvial Audit' methodology proper.

APPROACH

The approach adopted here has two central theoretical concepts that concern the controls on the distribution of geomorphic process regimes in a river network. These are:

1. The hierarchical organization of fluvial networks.

The physical characteristics of river systems are organized in a nested hierarchy, with physical processes operating at larger scales influencing those at successively finer resolutions (Frissell et al., 1986), ultimately controlling the micro-scale distribution of hydraulic and sediment transport processes (Figure A-1). The micro-, meso- and reach scales are therefore all equally critical elements within this hierarchy, with different geomorphic and ecological processes being relevant at each resolution. For instance, micro-scale factors will dictate the specific location that an animal selects habitat while the spatial distribution of meso-scale features will control the locations within a particular reach type where such conditions exist. The classification approach adopted here concentrates on the reach and morphological unit (meso) scales. The reconnaissance nature of the methodology precludes characterisation at the micro-scale that would require some degree of quantitative measurement and significantly increase survey time. Reach type is typically characterized at a relative scale of 10-100 channel widths in length with morphological units in the range 1-5 channel widths.

2. Basic physical controls on channel morphology.

The morphological character of the channel at a given location (i.e., reach type) is defined in terms of the relative balance between sediment supply and transport capacity (Figure A-2). In the case of Scottish upland gravel-bed streams, reach types typically progress from 'wandering' (Ferguson and Werritty, 1991) to pool-riffle to plane bed to step pool to cascade as the ratio of sediment supply to transport capacity decreases. This sequence represents a decreasing storage of alluvial sediment (mainly gravel and cobble sizes) within the active channel. The continuum also tends to be associated with increasing channel slope and mean substrate size and a decrease in the frequency of dynamic channel behaviour. Some stretches of a stream may exhibit features of more than one reach type and are therefore classified as having transitional morphologies (e.g. pool-riffle/plane bed). An additional reach type of 'slow glide' is required in lower energy systems. This is a morphology indicative of a channel condition with low sediment supply and transport capacity (Figure A-2). At the next spatial scale down, characteristic morphological units are associated with each reach type over a longitudinal scale of many (>10) channel widths (Montgomery and Buffington, 1997); indeed, the assemblage of morphological units to some extent defines reach type. Despite being explicitly linked through the concept of hierarchical organization, reach type and morphological unit scale data provide different information. Reach type indexes the general spatial distribution of 'geomorphic regime' of a river system (i.e., the approximate ratio of sediment supply to transport capacity) while morphological unit data provides higher resolution qualitative insight as to meso-scale hydraulic, sedimentary and instream habitat conditions.

Set within these central concepts, the spatial distribution of channel morphology classifications (at the reach and morphological unit scales) and factors that influence the sediment supply and transport capacity regimes are recorded. All spatial information is obtained from a hand-held Global Positioning System (GPS) with typical accuracy ±5m.

Reach type classification.

This is a qualitative, expert judgment classification approach and developed from established procedures (Mongomery and Buffington, 1997; Brierley and Fryirs, 2000). As discussed above, it is based on the physical character of the channel, particularly the presence and type of bedforms. Classification is not carried out based on a single point observation. Rather, channel condition is observed over at least 10 channel widths so that the classification is commensurate with the spatial resolution defined for reach type (Figure A-1).

Classification of controls on process regime.

Additional to the reach-scale morphological classification, factors that influence the process regime of the channel (i.e., those potentially influencing the delivery and movement of sediment to the channel) are also recorded. These data can subsequently be linked to the morphological data to provide some insight as to the dominant controls on spatial patterns of physical channel condition. These factors are recorded as linear (e.g., bank erosion, tree cover, bank protection) or point data (e.g., tributary input, large woody debris, weir). The upstream and downstream limits of linear features are recorded. Where relevant, the river bank the data is associated with is also recorded. Data is collected in the following three categories:

i) *Sediment input/ storage*:

a. Bank erosion (including poaching by livestock). Linear (often point for poaching). This is categorized in terms of severity depending on the condition of the bank, height of bank and other indicators as to sediment input rate (e.g., previously bank-side fences within channel. Collapsing bank-side trees, condition of adjacent channel bed).
b. Tributaries. Point. These are characterized as low, moderate or large relative sediment input depending on the character of main-stem channel at the confluence (e.g., presence of confluence bar) and the characteristics of tributary sub-basin (e.g., drainage area relative to the main-stem channel, relief, rainfall).
c. Depositional sedimentary features. Linear. The longitudinal extent, type (e.g., point, lateral, transverse, medial) and 'dynamic condition' of bar features is recorded. 'Dynamic condition' is a subjective definition depending on the appearance of the bar (e.g., vegetated or not, sorting, abrasion marks on clasts etc).

ii) *Vegetation*:

a. Bank-side tree cover. Linear. Recorded when tree cover is suffiently close to the active channel to influence fluvial process (e.g., local hydraulics, bank stability).
b. Large Woody Debris (LWD). Linear or point depending on extent of feature. The degree to which the feature spans the active channel (and, therefore, impacts fluvial processes) can be recorded.
c. Macrophytes. Linear. Sections of the channel bed exhibiting extensive macrophyte cover are recorded. Macrophythes can be a very important control on fluvial process in low energy river systems.

iii) *River engineering*:

a. Bank protection. Linear. The extent, type (e.g., gabions, boulder, wall etc) and state of repair of bank protection is recorded and then categorized in terms of likely impact to fluvial processes as low, moderate or high.
b. Bridges. Point. The number of bridge piers impacting fluvial process (i.e., piers within the active channel) and the clearance from the channel bed to the bridge span (indicating the likelihood of impedance of flood flows) are recorded.
c. Weirs. Point. The height and state of repair of weir structures are recorded.

d. Croys/ groynes. Point. The height, state of repair and extent into the active channel of croys/ groynes are recorded.

e. Fence crossings. Point. Fences that transversely cross the channel and potentially impact the movement of water, sediment and debris are recorded. Evidence of trapped debris or associated sedimentary deposits is recorded.

f. Ford crossings. Point. Vehicle ford crossings are recorded with the observed impact to the channel bed noted.

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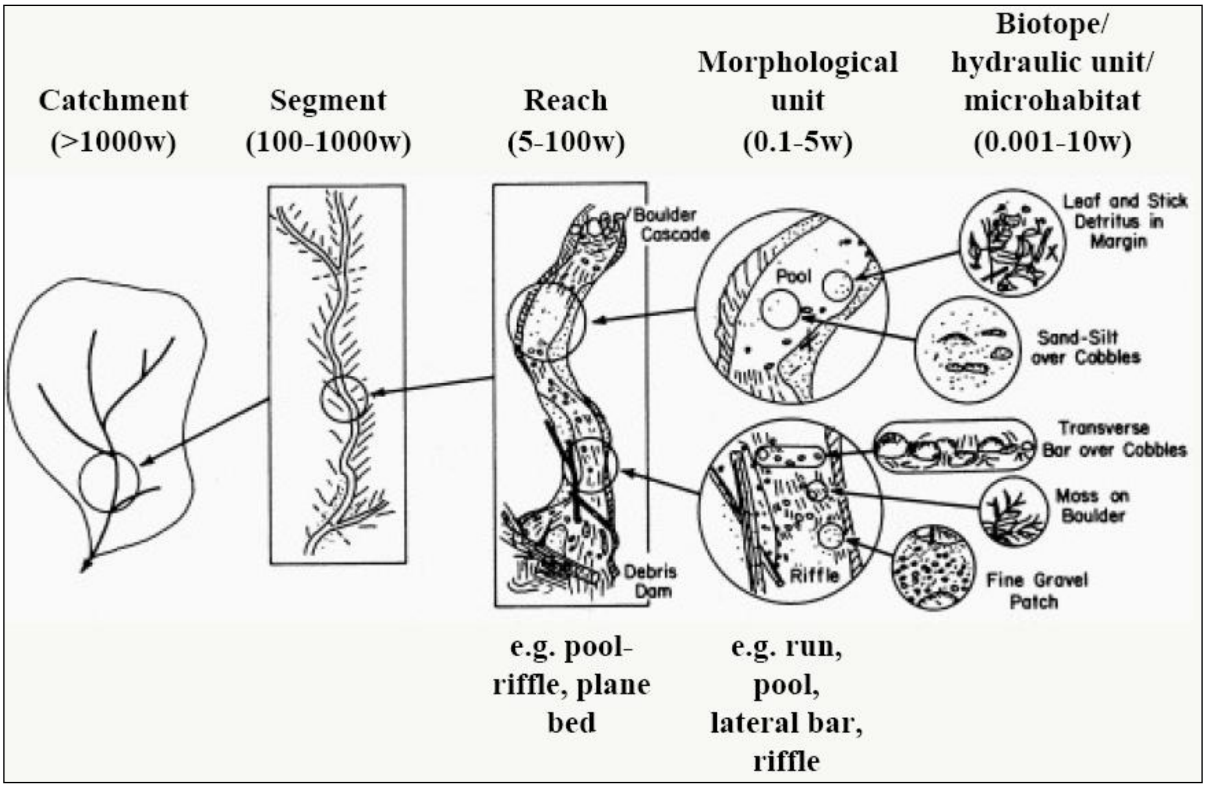

Figure A-1. Conceptual diagram of the spatial hierarchical organization of river networks (modified from Frissell et al. 1986).

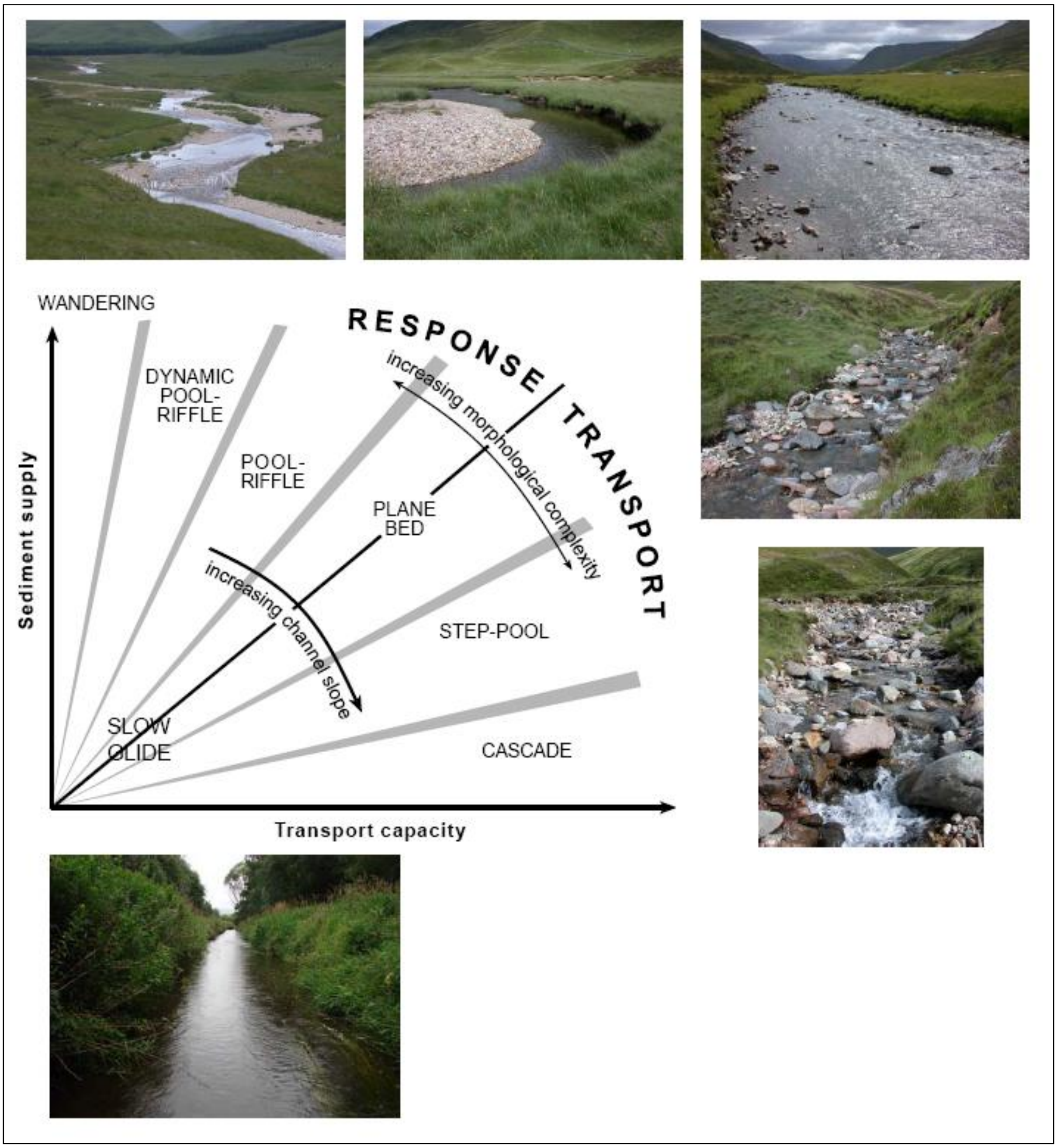

Figure A-2. Conceptual diagram of the physical controls on reach-scale channel morphology (modified from Moir et al. 2004).