River Restoration and Geomorphology Training workshop

Wednesdy 25th April 2001
Britannia Hotel, Coventry City Centre

Organised by *the* River Restoration Centre

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RIVER RESTORATION AND GEOMORPHOLOGY TRAINING WORKSHOP

Aim of the workshop

The focus of the day was to emphasise the need for sound geomorphological assessment in river restoration. It is hoped that participants have gained an understanding of the complexity of the fluvial system and are now in a better position to recognise situations where there is the need to call upon expert geomorphological assistance.

Overview

Participants were introduced to Fluvial Geomorphology through 5 expert led tuition sessions. These included sediment transfer, river stability and change, impacts on ecology and engineering, and data collection.

Short presentations were invited to either illustrate various examples of geomorphology in practice, or discuss current projects in need of geomorphological input.

Through group work participants addressed a specific restoration/enhancement opportunity (lowland rural, lowland urban, upland rural). The aim of the group work was to develop proposals for the subject reach and discuss decisions and rationale.

To provide an overview of the needs of different river types, group scenarios were summarised, followed by the presentation of all three 'actual' case studies to ALL participants, outlining the geomorphological approach to the design.

The following document provides summaries of the presentations given in the morning session and of the case study workshop sessions in the afternoon.

The River Nith Workshop Group led by Dr David Gilvear

PROGRAMME OF EVENTS

PROGRAMME

Wednesday 25th April 2001 (Connaught Suite)

(Three Spires Suite)

9:30	**Coffee and registration for workshop sessions**	
10.00	**Introduction**	Dr David Sear
10:15	**Tuition Sessions**	

The basics of geomorphology

Geomorphology in a catchment context — Prof. Malcolm Newson

- The fluvial system
- Sediment transfer through catchments

The basics of river channel morphology and behaviour — Prof. Chris Soulsby

- Stability of different rivers in different environmental settings
- Channel widening and braiding

Linking geomorphology to nature conservation and engineering

Geomorphology and ecology — Dr. David Gilvear

- Geomorphic processes that control in-stream biota and riparian vegetation

Geomorphology and engineering — Prof. Colin Thorne

- Sediment transport and engineering structures

Geomorphology and data collection

The need for and ways of obtaining relevant geomorphic data — Dr. David Sear

- Existing geomorphic data held within organisations
- Methods of stream reconnaissance
- Specific information for channel design
- Sediment traps

11:30 **Short presentations**

An opportunity for delegates to raise specific examples with the geomorphologists present. Discussing either current work in need of geomorphogical input/assessing or presenting work where geomorphology has played an important role. — Open

12.10	**General Discussion**	Prof. Chris Soulsby
12.30	**Lunch**	

Delegates split into workshops

1.30 **Workshops (**Syndicate Rooms)

These will centre on 3 case studies.

Workshop Group 1 - Lowland rural watercourse - restoring meanders and pools and riffles **(Courtyard Suite)**	Dr David Sear
Workshop Group 2 - Lowland rural watercourse - restoring meanders and pools and riffles **(Pine Suite)**	Prof. Malcolm Newson
Workshop Group 3 - Lowland urban watercourse - enhancing an urban watercourse **(Connaught Suite)**	Dr Helen Dangerfield Dr Kevin Skinner
Workshop Group 4 - Upland rural watercourse - creation of an environmentally acceptable channel **(Cavendish Suite)**	Dr. David Gilvear Dr. Katherine Leys

Details will be circulated and a presentation of the problem will be given by the facilitator. Small workgroups will be charged with assessing and designing the project.

2:30 **Group presentations over Coffee**

Each workgroup will present their proposals and the rationale behind their decisions.

Delegates reconvene

3:15 **Project reporting and reality** **(Connaught Suite)**

The workshop leaders will summarise the groups proposals.
The workshop leaders will present a brief report of what actually happened, successes and failures.

Lowland Rural	Dr. David Sear
Lowland Urban	Dr Helen Dangerfield
Upland Rural	Dr. David Gilvear

4.30 **Summary**

The need for sound geomorphological assessments in river restoration.	Prof. Malcolm Newson
4:45 **Close**	Martin Janes

Speakers/facilitators

Dr David Sear	(University of Southampton)
Prof. Malcolm Newson	(University of Newcastle)
Prof. Chris Soulsby	(University of Aberdeen)
Dr David Gilvear	(University of Stirling)
Prof. Colin Thorne	(University of Nottingham)
Dr Helen Dangerfield	(Babtie Group Ltd)
Dr Kevin Skinner	(University of Nottingham)
Dr Katherine Leys	(Scottish Natural Heritage)

Tuition session 1: The Basics of Geomorphology

Geomorphology in a Catchment context

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<u>The Fluvial System - its processing of sediments to make channel form</u>
The context for all sustainable river rehabilitation and restoration

<u>The catchment</u> is the basic unit for sediment supply and the flows to transport it (98% of both); we understand the key system variables and know the 'usual outcomes' but the full picture of sediment storage, supply and transport is only decipherable in big floods or during decades of observation or measurement.

It therefore becomes necessary to
- make the best possible effort to gain a catchment-wide picture;
- locate, map and attempt to quantify the main active sediment 'packages';
- apply the best predictive techniques to processes operating in a given reach.

THESE CORRESPONDED WITH RECOMMENDED GEOMORPHOLOGICAL PROCEDURES IN USE BY ENVIRONMENT AGENCY

<u>Sediment supply</u> is of vital concern in the UK environment - transport in the channel network is seldom limiting to sediment throughput, even if it is 'jerky' in time. Optimum flows for sediment transport and the formation of channel *dimensions* tend to be floods which fill the channel but the full flow range impacts on *forms* via longer-term processes, like deposition. River channels have memory (forms endure changes) - the degree to which memory dominates response is vital.
- Sediments are released for transport by digging them up (i.e. human development activities)!
- Sediments are bound by moist, cohesive soils and a natural vegetation cover;
- From river banks, sediments are released by many more processes than just river scour e.g. slip, freeze/thaw;
- From river beds, sediments may be hard to transport because of armour/structure

<u>Sediment transport</u> is far from exact science!
Given AVAILABILITY, *stream-power* provides some good clues as to 'stability' and sediment loads but says nothing about channel forms and for scientific rehabilitation we really need to know more than 'will the restored channel be stable?' - we really need to get a handle on sediment transport at the biotope scale to describe how instream physical habitat performs in a dynamic way.

<u>Observations and data in fluvial geomorphology</u> - some of this is 'bird-spotting' but much is not! - beware that simple observations may come easy but linkages need experience. Observations within the same system are likely to be most value in guiding the restoration contexts at a site (unless you use an undamaged neighbour);
We can group the necessary techniques via the geomorphological procedures:

a. Catchment Baseline Survey
List all likely documentary sources of e.g.
- geology/soils;
- land-use (now and past);
- published geomorphological papers;

Plus obvious (e.g. EA) national archives
- River Corridor Surveys - (under-utilised given channel dimensions and erosion sites listed);
- River Habitat Surveys

b. Fluvial Audit

Gotta get out there!

- 50%+ must be walked - use every opportunity to get all poss. Info - heavy backpack or good camera!
- Produce 1:10,000 map of all relevant features - including catchment sources

But also plenty of background work to do indoors:

- Records of floods, maintenance etc : diary!

c. Dynamics Assessment

Reserve for the selected reaches, but extend upstream and downstream of project reaches.

- Professional field survey (EDM, GPS) of the channel dimensions (width, depth, slope) according to how they vary - plan it first!
- Sediment size data in detail;
- ‘Energy data’ - flood marks, backwater etc.
- Bank erosion using EA 1999 guidance

Conclusions

Excellent schemes of channel restoration or rehabilitation are possible *without* a formal geomorphological input (but most of them are in fact informed by excellent local knowledge which includes informal elements of what is described here!). However, we live in a responsible science-guided society which attempts to set standards and to explain failures; of the scientific contexts available for river restoration planning and actions, fluvial geomorphology provides a robust, empirical, understandable body of information.

EA and SNH have provided a lead in employing academic geomorphologists to provide R&D, simple guides and training courses; in future a web-based training system is likely to be available and meanwhile sites produced in the USA and in Australia can be found using simple search procedures.

Tuition session 1: The Basics of Geomorphology

The Basics of River Channel Morphology and Behaviour

Professor Chris Soulsby, Department of Geography and Environment, University of Aberdeen. AB24 3FX
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River channel morphology and behaviour: a brief introduction

1. Introduction

River channels display widely varying characteristics in both space and time. Partly this reflects their geographical location within a particular catchment and fluvial system. However, it also reflects the interaction of a range of controlling factors, some of which may operate at the catchment scale, some of which may be more localized. This brief presentation aims to:

- outline the main physical processes and characteristics which influence channel morphology.
- examine how river channels behave in response to changes in these controlling factors.
- demonstrate how some channels may be relatively stable and insensitive to change, whilst others may be highly dynamic and responsive.

The overall objective is to provide delegates with some background context to help in assessing case work where there may be particular problems (eg unstable channels) or management proposals which raise concerns over environmental impacts.

2. Controls on channel morphology

Catchment context
River channels are intimately linked to their catchments. Thus at the macroscale, the geographical location of a particular catchment determines its climate, geology, topography, soil cover and land use. In turn, these characteristics determine the delivery of water and sediment to the river channel.

Driving variables
The volume and timing of water fluxes to the channel network determines a catchments hydrological regime and is usually closely linked to the volume, timing and nature of sediment fluxes.

Boundary conditions
As water and sediment is transferred through a channel network, often in an irregular and unsteady manner during high flow events, physical forces act upon the material comprising the channel bed and banks (including vegetation) to sculpt the channel morphology.

CHANNEL CHARACTERISTICS
The morphological characteristics of river channels include; (i) the plan form, (ii) cross-sectional characteristics and (iii) channel gradient or long-profile.

3. River channel types

The interaction of catchment geography, driving variables and particular boundary conditions create an almost bewildering array of river channel morphologies. However, there are a range of typologies or classification schemes which seek to group particular channel types and establish functional relationships with their controlling factors. Unfortunately, deterministic and quantitative predictions of stream behavior are usually only available at intensively studied research sites. Nevertheless, research in fluvial geomorphology means that some of the functional relationships between channel morphology and controlling variables are sufficiently well understood to allow qualitative predictions of the likely impacts of changing the main driving variables and boundary conditions on channel characteristics.

4. <u>River channel change</u>

EQUILIBRIUM IN RIVER CHANNELS

Even in undisturbed catchments, river channel morphology changes through time. In most cases, however, the timescales over which major changes become evident are relatively long (i.e. centuries, millennia etc.), thus on the timescale of human experience river channels appear to be stable or in equilibrium (or more properly metaequilbrium). This does not mean that a river doesn't erode its bed or banks, but that this erosion is usually a relatively slow process, with the channel morphology only changing gradually as the river adjusts to transfer water and sediments.

GEOMORPHOLOGICAL SENSITIVITY

With increasing human activity affecting virtually all river basins, however, all the main influences on channel morphology are potentially susceptible to change. In some cases channels may be relatively insensitive to such changes (eg. bedrock-lined channels or armoured cobble-bed rivers with well vegetated cohesive banks. In other cases, channels may be highly susceptible to change , should some threshold in the state of a controlling variable be exceeded. For example, in the uplands, many channel networks have become increasingly unstable over the last few hundred years as high grazing densities have changed catchment vegetation, increased runoff rates and increased sediment inputs into river channels. Channel changes may be manifest in a number of ways as the rivers adjust to changes in driving variables or boundary conditions, for example, upland channels may change their width, depth and paln form in response to increased erosion and runoff.

5. <u>Implications for channel management</u>

Even at this very simple level it is clear that the influences on channel morphology and behaviour are relatively complex, but can be sensitive to anthropogenic influences. In many instances, various kinds of activities impact on river channels directly or directly through influence on controlling variables. Examples of the former are flood defence schemes, fishing habitat modification, riparian management and bank protection works. Examples of the latter include land use change, stocking densities and agricultural drainage schemes. Whether such activities cause major channel instability or habitat degradation depends upon the specific geographical setting and the contemporary interaction of controlling factors.

Historically these have been rarely considered by river managers, fortunately this situation is changing, but often changes are slow, and many schemes still pay scant regard to the geomorphological context within which a scheme is being implemented. Not surprisingly, many such schemes prove to be unsuccessful, unsustainable or in some cases exteremely damaging. Unfortunately there is no substitute for site-specific geomorphological assessment as part of river management schemes. The assessment should involve an experienced geomorphologist who can work as an integral part of the design team. Part of the problem with in terms of adequately incorporating geomorphological factors into particular schemes is a failure to recognise how a particular reach of river (i.e. the scale of management) is contextualized in terms of the spatial and temporal scales over which geomorphological processes operate.

6. Further reading

Brookes, A. and Sheilds, F.D. (1996) *River channel restoration*, Wiley, Chichester.

Rosgen, D. (1996) *Applied River Morphology.* Wildland Hydrology, Colorado.

Thorne, C. (1998) *Stream reconnaissance handbook*. Wiley, Chichester.

Thorne, C., Hey, R.D. and Newson, M.D. (1997) *Applied fluvial geomorphology for river engineering and management*, Wiley, Chichester.

Tuition session 2: Linking Geomorphology to Nature Conservation and Engineering

Geomorphology and Ecology

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Outline

This tuition session will focus on the linkage between geomorphic attributes of stream systems and instream and riparian biota. It will stress that the morphology of a river channel, bed material type and hydrological regime together form a habitat template for biota. The size of channel, particularly when coupled with the volume of flow maintained is also important in terms of the overall carrying capacity, in the absence of bottlenecks, for some populations. At the macro-scale, this fact manifest itself in the form of downstream changes in the biota of a river in response to the physical changes that occur. This is centrally important to the river continuum concept. At the meso-scale most of us will be familiar with the role of pools and riffles in the life cycle of salmonids.At the micro-scale channel roughness, substrate sedimentology, and undercut river banks all have important ecological implications. At all scales biodiversity is likely to be increased in areas of high morphological diversity both within instream environments and riparian areas.

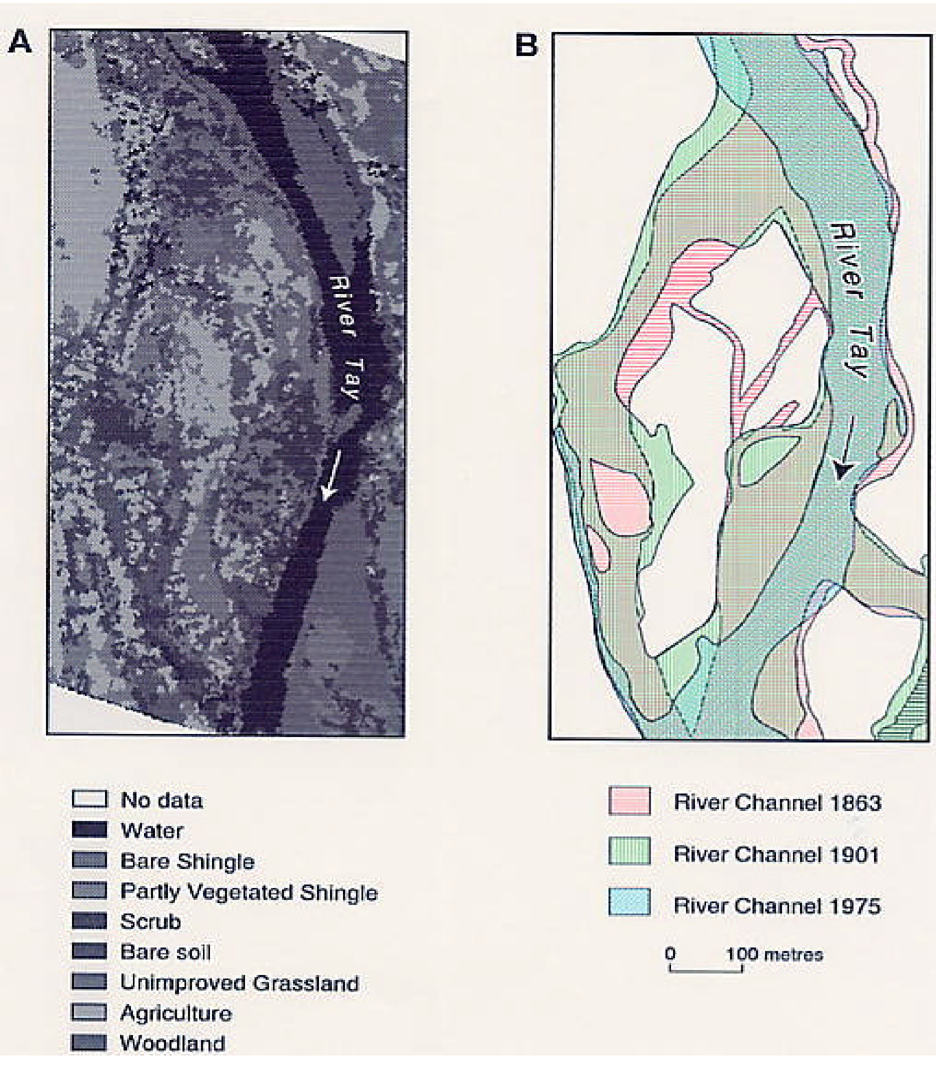

Figure 1 Riparian habitats surviving on the floodplain of the River Tay in relation to channel changes during the 19th century.

The session will also focus on the role of disturbance. Fluvial disturbance occurs in a number of ways. Floods can wash out biota, allowing pioneer species to colonise disturbed areas. Channel bed instability and sediment transport can disrupt benthic communities while bank erosion with concomitant deposition of sands and gravels can restart vegetation succession in riparian areas and renew links with the floodplain.Thus some disturbance and channel in-stability is a beneficial component of river ecosystems particularly where morphological diversity can buffer its affects.

Morphological diversity can create areas of slow flow and stable substrate even in times of spate

These provides shelter and thus refugia for plants and animals. The channel substrate and linkages between the channel and its floodplain are vitally important in this context. These issues will be explored in the context of river restoration and in relation to theoretical principles and case studies. It will illustrate precisely why straightened rivers, rivers straight-jacketed by embankments and rivers with artificial bed and banks need to be restored to recover a semblance of their former biodiversity and the central importance of fluvial geomorphology, via its study of landforms and sediment transport, to this process.

Plants colonising coarse gravels that have been remained stable over a number of years

Tuition session 2: Linking Geomorphology to Nature Conservation and Engineering

Geomorphology and Engineering

Professor Colin Thorne, School of Geography, University of Nottingham, Nottingham NG7 2RD, Email: colin.thorne@nottingham.ac.uk

Restoration design for meandering streams: river engineering and structures

Introduction

Successful river restoration requires that a project achieves its goals in a sustainable and cost-effective manner. In most, perhaps practically all, cases the goals of river restoration are multi-functional. Consequently, engineering functions such as flood defence and channel stabilisation may sit alongside wildlife conservation, increased biodiversity and aesthetic enhancement as legitimate intended outcomes of a restoration scheme. In such cases there is clearly a case for employing engineering design approaches to ensure stability in the restored channel and for applying engineering analyses to the selection of appropriate techniques for bank protection. Even if there is no engineering dimension to the project, a geomorphic-engineering design may still be an appropriate way to approach the problem of ensuring that the restored channel is capable of transporting the sediment load supplied from upstream - so satisfying continuity in the sediment transfer system.

This short review uses a geomorphic-engineering approach recently developed at the University of Nottingham under a research project sponsored by the US Army Corps of Engineers, Engineering Research Design Center, Vicksburg to illustrate how principles developed for the design of stable flood control channels may be modified for restoration design. It goes on to use a case studies from the Bluff-line streams of North Mississippi and the River Medway in Kent to demonstrate how bio-engineered structures may be used to provide essential grade control and bank stabilization that is effective, economical and even perhaps not out of place in a restored channel.

Geomorphic-Engineering Design Approach

The geomorphic-engineering approach uses 4 phases to design a stable configuration for restoration purposes:

Phase 1 – establishes the design discharge and sediment load for the restoration reach, based on conditions in the approach reach upstream that supplies water and sediment to the project reach. Selection of the design discharge depends on the degree to which the supply reach is natural and stable. If it is both natural and stable then it may be used as a 'reference reach' and the design discharge may be represented by its bankfull flow. If it is either unstable or modified then its effective discharge (that flow responsible for the most sediment transport over the long-term), determined from a magnitude-frequency analysis, may used as the design flow (Soar 2000). The sediment transport rate used in the initial design is that associated with the design discharge.

Phase 2 – involves careful investigation of the restoration reach using detailed stream reconnaissance, field survey and a geomorphic dynamics assessment (Thorne 1998). This will yield the data and parameters necessary to characterize the present channel geometry, its stability status, its bed and bank materials, and the configuration of the floodplain (including identification of site constraints and available land-take for restoration.

Phase 3 – uses a rational method to produce the initial design for the reach-averaged geometry of the restored channel. First the target 'type' for restored channel is selected, based on present conditions (identified in Phase 2) and the agreed goals of the project. In this context different 'types' are defined by their bed material (sand or gravel), meander planform (equi-width, wider at bends with point bars, or wider at bends with point bars and chute channels) and bank characteristics (bare and erodible, or vegetated and erosion resistant). The stable, regime width for the restored channel is determined from the design discharge and a hydraulic geometry equation appropriate to the target channel type. While the user may select an equation of their choice, Soar (2000) has produced a series of width equations optimized for restoration design purposes. The stable depth and slope are then found using the Copeland Method through simultaneous solution of equations for continuity, flow resistance, and sediment transport. Finally, the sinuosity is determined from the ratio of the stable channel slope to the valley slope and the meanders are laid out using morphological scaling relations such as those developed by Soar (2000). Local variability is added to the initial, reach-averaged design using empirical equations relating cross-sectional geometry to position in the meandering planform (Soar 2000). Finally, a sediment capacity-supply ratio is used to check that the long-term sediment transport capacity of the restored channel is matched to the sediment load supplied from upstream. Any imbalance between supply and transport capacity will lead to channel instability either through scour (input < capacity) or siltation (input > capacity) that will require engineering or maintenance to preserve channel (and therefore habitat) stability. The initial design is modified through incremental adjustments to the slope and sinuosity until a capacity-supply ratio close to unity is achieved.

Phase 4 – consists of detailed design specification through production of engineering drawings and accompanying notes using a suitable CAD package. Experience shows that this step is vital to ensuring that the morphological design is translated into a form that can be accurately followed by site engineers and machine operators actually responsible for implementation.

The geomorphic-engineering approach is far from a 'cook book' for restoration design and both geomorphic understanding and sound engineering judgment on the part of the designer are essential at all stages. The approach requires beta testing before it can be made operational, but it holds the promise of combining the natural insight provided by geomorphology with the design rigor provided by engineering.

Structures in Restored Channels

Grade Control – may be required in restored meandering channels where limitations to the available 'land take' or right-of-way mean that the maximum sinuosity that it is feasible to introduce is too low to match the channel slope to the stable design slope. This was the case during rehabilitation of incised bluff-line streams in north Mississippi under the Demonstration Erosion Control project. It was not feasible to raise bed levels several metres and re-connect channels to their floodplains (now terraces) and although overly wide compared to a regime condition, the incised channels did not provide sufficient room for meanders. To achieve a reduced and stable slope, low-head grade control structures were installed at intervals along the channel. Each structure consisted of a sheet-pile weir surrounded by riprap and with a deep stilling basin downstream to dissipate flow energy. Not only have the grade control structures stabilized bed elevations and slopes, but they also provide valuable habitats missing from the incised channels such as deep pools, shallow fast flowing flows, re-circulating zones, depositional bars and coarse substrates. The structures have quickly become colonized by fish, turtles, snakes and invasive vegetation has softened and masked the hard structural elements. The severity of instability and the high degree of incision dictated that structural grade control was an essential element in the rehabilitation of the DEC streams. In the event, the low drop structures represent some of the most valuable habitat in the restored systems while fulfilling their engineering function.

Bank Stabilization – is necessary to prevent retreat of the banklines in restoration schemes where, for whatever reason, the channel cannot be allowed to shift laterally. This was the case on the River Medway in Kent where a section of unstable bankline at the outside of a meander threatened the tow path – a public right-of-way. It was essential to stabilise the bank, but in a way that was consistent with the tenets of the 'Medway Plan' – a blueprint for long-term, sustainable enhancement and management of the river.

The selected solution employed a combination of structural and bio-engineered materials that simultaneously met the requirements for navigation, channel stabilization and environmental enhancement. A 'Reno' mattress of gabions was laid on the lower bank, extending out across the bank toe and providing heavy protection of that vulnerable area. This effective, but unsightly structure was well below the minimum water level in this regulated river and so has no aesthetic impact. A wall of chesnut faggots, backed by planting of an assemblage of riparian species including willows, was used to protect the upper bank. The composite structure so produced has been 100% effective in halting erosion and provides excellent sub-aqueous and riparian habitats. It has also achieved both engineering and restoration goals at a cost that is a fraction of that of conventional sheet piling.

Conclusions

This brief review attempts to demonstrate that restoration design can benefit from an engineering approach, provided that guiding principles of geomorphic-engineering are adopted and implemented. While in an ideal world restored channels would have no need of structures to provide grade or bank stability, in practice some controls may be essential. However, so long as materials and construction methods are carefully selected, inclusion of a structural element in the restored channel will still be consistent with multi-functional and achievable project goals.

References

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Hey, R D & Thorne, C R (1986) "Stable Channels with Mobile Gravel Beds" Journal of Hydraulic Engineering, American Society of Civil Engineers, 112, No 8, pp 671-689
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Tuition session 3: Geomorphology and Data Collection
Geomorphology and Engineering
The Need for and Ways of Obtaining Relevant Geomorphic Data

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What type of data do Geomorphologist's require

By the time that you have reached this session you will have been made aware of a range of different types of information and data that geomorphology routinely uses for investigating river processes. Principle among these are:

- Measures of river channel morphology
- Measures of bed and bank materials
- Measures of water and sediment discharge
- Measures of the adjustment or change in channel morphology

Whilst measurement and monitoring are important, they are nothing without interpretation. Carefully designed monitoring programmes that use standard, appropriate measurement techniques and methodologies yield high quality data, but it is the analysis of this data and the information it provides that is most useful as input to restoration project development and post-project appraisal. The scale of geomorphological input is again dependent on the nature of the project and the reason for monitoring. Some information can be attained and interpreted by relative novices (e.g. lists of features and changes in these), but it is the interpretation of why change is occurring that demands a specialist input. Remember information is power! But poor information is dangerous!

What sources exist for this data?

It is a National disgrace that so much information is collected and then disposed of, and at a time when long term data is becoming increasingly important for assessing the change in the state of our environment. Many who have worked in the water and environment sector have come across the frustrations of "mythical data" that used to exist before the recent "re-structuring" in the company/agency. The types of data that exist in the Agency and similar institutions include:

- Air photographs, LIDAR and CASI imagery
- Maps, plans, long profiles, cross-sections and photographic records dating back to the first half of the 20th Century (information on channel scale and form and how these have changed).
- Records of the type, extent and location of river maintenance and modification dating back to the 1930's
- River Corridor Surveys (Records features (Quantitative) and locations (Qualitative) in River Network, identification of suitable "analogue" reaches)
- River Habitat Surveys (Standardised methodology, permits comparison against "benchmarks", information on appropriate habitat elements)
- Water quality data including suspended sediment loads (often not sampled at sufficient frequency).
- Stream flow data (peaks, duration, long-term trends)
- Sediment transport surrogate data (e.g. gravel trap maintenance etc.).

Preservation and collation of this data is now possible using scanning and CD storage of files. The question is how to use it. Often the most valuable data is the historical information that can assist in the interpretation of channel form and adjustment. Similarly, at a project scale, information is available to permit calculation of some of the basic geomorphological indicators of channel adjustment (e.g. Stream Power, Shear stress etc.). However, the geomorphological input most often required is interpretation of the information and identification of “missing” data. To assist in this, the EA has developed under contract, a suite of methodologies for the collection of geomorphological information. These are reviewed in the Table 1 below and further details are available through Geomorphology: A Practical Guide for River Management, published by the EA. The broad guidance is that the further across the Table one moves, the more intensive and specialised the data required. However, the scales of geomorphological input map onto different components of a project so that few will require all levels of input at once. Indeed, it is possible in almost 40 catchments across the EA, to access Detailed Catchment Baseline surveys or Fluvial Audits in support of river restoration.

Post –Project Appraisal: Monitoring important geomorphological variables

River Restoration has geomorphological impacts on the local river system. Adjustments in restored rivers need to be monitored as input to adaptive management of the site. To date, relatively little attention has been given to the Post-Project assessment of river restoration projects. The types of information that could usefully be monitored include:

- Repeat survey of channel form (Physical habitat diversity and adjustment)
- Repeat measurement of sediment characteristics of rehabilitated features (Quality and change in sediments)
- Water levels at fixed locations (monitor hydraulic performance)
- Photographic records from fixed locations (Vegetation colonisation, habitat change)

The density of these measurements and the frequency with which they are taken are important considerations and again geomorphological input is probably necessary to devise strategies that are appropriate to the project under consideration.

MEASURING AND MONITORING SEDIMENTS AND SEDIMENT TRANSPORT

An important component of the UK river environment that is not routinely monitored is the sediment load. In part this is because it is deemed to be small and insignificant, compared to other attributes (e.g. Water Quantity and Chemistry, River Ecology). It is also relatively difficult to measure, particularly when it comes to bedload. However, being able to assess changes in sediment load particularly over time would be extremely useful. Knowing the sediment load in a channel is in fact part of the needs for effective channel design. Current sediment transport models tend to over-predict sediment loads and this can lead to over-design (where any consideration is given at all!). Contrast this with North America where suspended and bedload transport rates are routinely monitored at a wide range of gauging stations. A range of continuous recording probes exist that are relatively inexpensive and can be deployed (provided they are routinely calibrated) to measure suspended solids levels and even bedload. For specific projects, sediment transport modelling can be undertaken, again provided that the boundary conditions are carefully matched against the conditions under which the models were developed, and tracer and trapping now enables reliable estimation of bedload transport that can be used to validate model outputs.

Table 1 Geomorphological procedures recommended by Environment Agency, 1998 (Source M.D.Newson)

STAGE	**PLANNING**	**PROJECT**		
Procedure	**Catchment Baseline Study**	**Fluvial Audit**	**Geomorphological Dynamic Assessment**	**Geomorphological channel design**
Aims	Overview of the basin sediment system and morphology	To suggest sustainable, geomorphologically-based options for problem sites	To relate reach processes and rates to morphology, allowing management of either.	To design channels within the context of the basin system and local processes
Scale	Often a gauged catchment (modal size 100-300km^2)	Those reaches identified in CBS or by managers	Problem or project reach	Project length
Methods	Data collation, inc. RHS; consultation; reconnaissance fieldwork at key points throughout catchment.	Detailed field studies of sediment sources, sinks, transport processes, floods and land use impacts	Field survey of channel form and flows; hydrological and hydraulic data	Quantitative description of dimensions and location of features, substrates, revetments
Core information	*Characterisation* of river lengths and sediment management problems.	Identifies *range of options* and 'potentially destabilising phenomena'	Sediment transport *rates* and morphological *stability/trends*. 'Regime' approach where appropriate	The 'appropriate' *features* and their *dimensions* within a functionally-designed channel
Outputs	5-10 page report; maps or GIS; field forms and photos	Maps at 1:10,000; time chart; report; recommendations	Quantitative guidance to intervention (or not) and predicted impacts on reach and beyond	Plans, drawings, tables and report suitable as input to QS and engineering costings
Destination	LEAPs; Feasibility studies for rehab/restoration	Investment/management staff or policy forums	Engineering managers and project steering groups	Funded projects of flood defence, erosion protection, rehabilitation or restoration
Follow-up	GEOMORPHOLOGICAL POST-PROJECT APPRAISAL			

TAKE HOME POINTS

- Measurement and monitoring is an important part of adaptive river management and should be viewed as part of the restoration process!
- BUT Don't just measure or monitor for the sake of it! Define the aims of the monitoring programme in advance and design the measurements around these aims
- Don't assume that a river has no sediment load – all do, and it changes over time with supply as well as with the ability to move it!
- Consider what information already exists in your office – ask yourself what is it's value to future environmental managers?
- Never throw away anything without considering what it's geomorphological value might be to future generations!
- Measurement of sediment loads is possible and practical but requires investment. Be sure you need to first!
- If you don't know what to do ask a professional geomorphologist.

Workshop Group 1 and 2: Lowland Rural Watercourse – Restoring meanders and pools and riffles
Case Study: The River Waveney (Norfolk)

The Challenge

Rehabilitation of riffles in rural watercourses

The Challenge
The River Waveney has been identified as a candidate watercourse for coarse fish habitat rehabilitation using riffles. The challenge lies in applying geomorphology to
1) identify where in the main trunk stream, riffle rehabilitation can be sensibly undertaken
2) how one might undertake the design and
3) what form of post-project appraisal is necessary to produce the most effective and sustainable solution.

Background
The River Waveney drains a catchment of 660km2, with an average slope of 1:2250, falling to 1:5500 downstream of Billingham. Floodplain slopes are of the order of 1:2200. In contrast, tributary slopes are of the order of 1:450 – 1:1100. Catchment geology is characterised by chalk overlain with boulder clay. Notable outcrops of glacial sands and gravel's occur in the upper catchment upstream of Bungay. Many of the upper tributaries cut through this fluvio-glacial material. Land use is principally arable with some mixed dairy and piggery units. Free-range piggeries occupy the upper tributaries. The floodplains are grazing pasture, with SSSI status in 15 sites upstream of Bungay. The headwaters rise in Lopham and Redgrave Fen, SSSI. Channel maintenance is undertaken on a 5 year rolling programme of de-silting, with an annual weed cut in August/September. The channel is heavily modified, being over-wide and over-deep, providing a 1:5 year flood protection along the agricultural areas, rising to 1:75 year at Diss. Gravel riffles occur at or downstream of bridges, and on tributary streams, where maintenance has not been undertaken. Throughout the river, mill weirs and sluices exist to support elevated water levels in summer and flood control in winter.

Constraints
- A modified watercourse with few natural analogues in the catchment.
- Low gradients along most of the river network heavily influenced by mill weirs.
- Multiple land ownership.
- Requirement from flood defence that rehabilitation does not compromise current levels of flood protection.
- A catchment that is exporting significant quantities of fine sediment.
- A finite and small budget (£40,000 including installation).

The Task
is to specify the geomorphic principles you would follow to:

1. Identify the most appropriate sites for riffle rehabilitation
2. Develop an appropriate design methodology for riffle rehabilitation.
3. Develop a suitable post project appraisal system for the rehabilitated reaches

As One Group
To help you achieve this, make a list of the key geomorphic variables that you might consider as necessary to acquire, and suggest possible sources for that information. What cost would you allocate from your budget?.

As Sub-groups
You will be organised in to small groups to discuss one of the following aspects of the design although you should be aware that they are not independent components!

- Catchment issues of significance for riffle rehabilitation (what's important to know before we start? And how might we acquire this information?)
- Riffle location – (where is suitable? How to define/identify suitable sites?)
- Riffle morphology (How many? How far apart? how long?, how high? how steep? What substrate and from where?)
- Riffle hydraulics? (what impacts might they have on flood levels?)
- Monitoring for project appraisal (What's relevant? how often? how long for?)

Plenary session as One Group

Feedback from sub-groups to develop the whole project.
Develop presentation for the workshop.

D.A.Sear/M.D.Newson 2001

Both Workshop leaders have considerable experience of applied geomorphology and river restoration. They run 1 or 2-day training courses in geomorphology for river management and are available for consultancy. Contact information.
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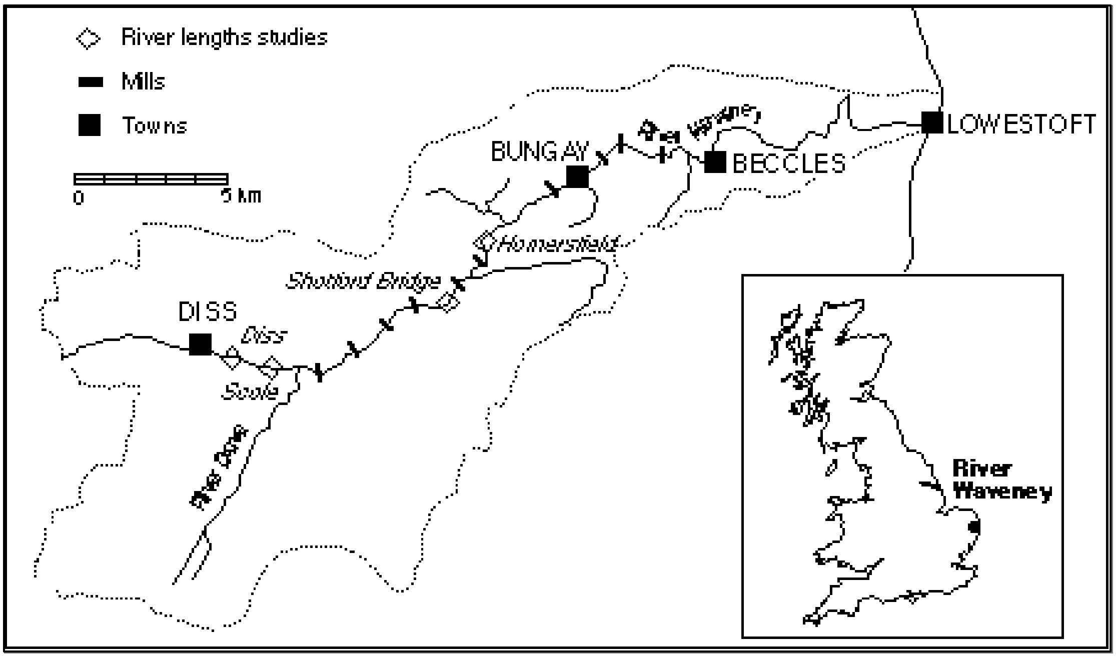
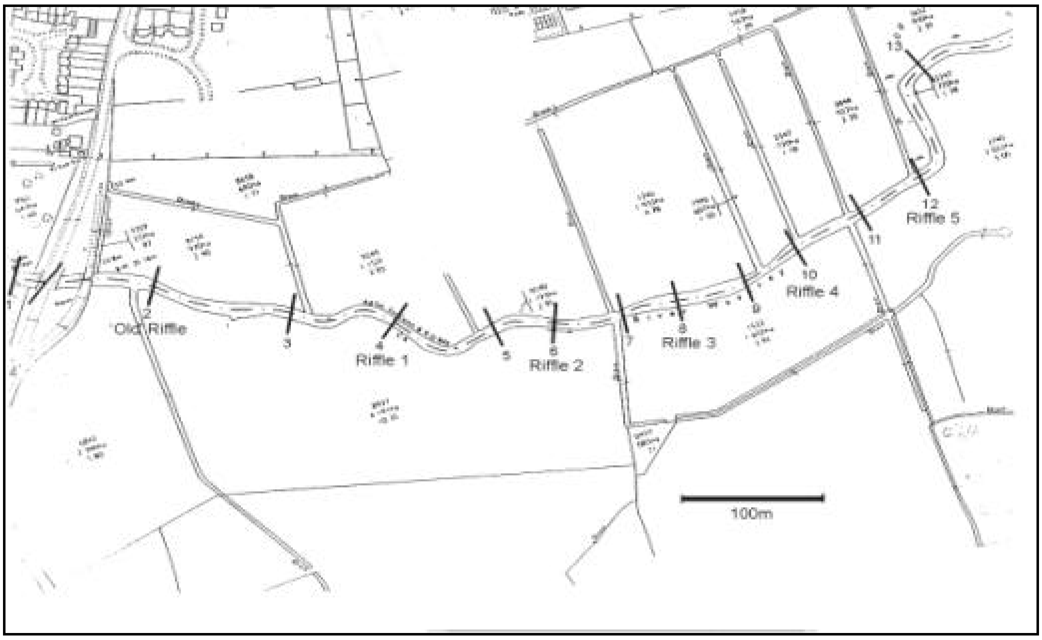
Prof. Malcolm Newson
Dept. of Geograhy, University of Newcastle-upon-Tyne, Daysh Building, Claremont Road, Tyneside, NE41 7RU, tel:0191-222-6425, email M.D.Newson@ncl.ac.uk

River Waveney catchment and tributaries



Riffle Rehabilitation site: Planform



Long Profile of River Waveney

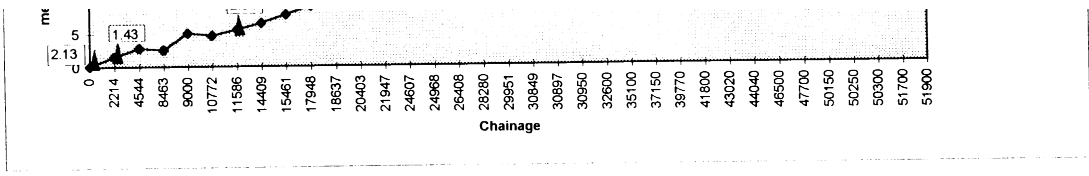
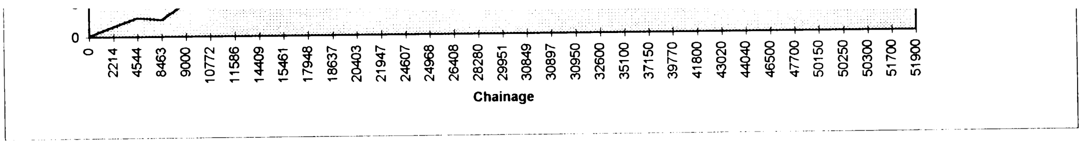
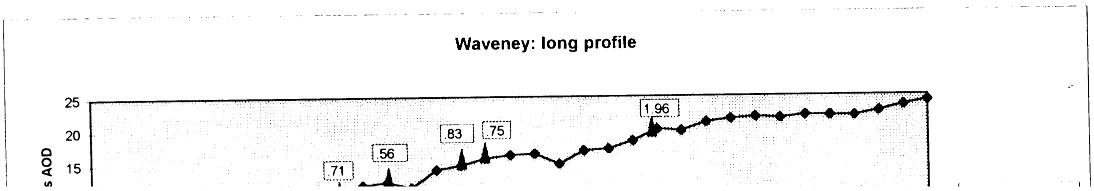
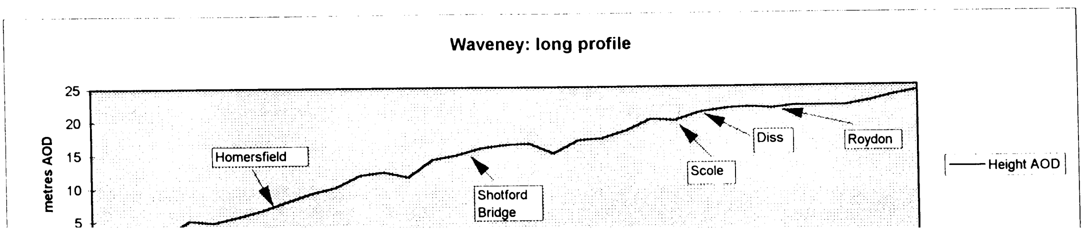


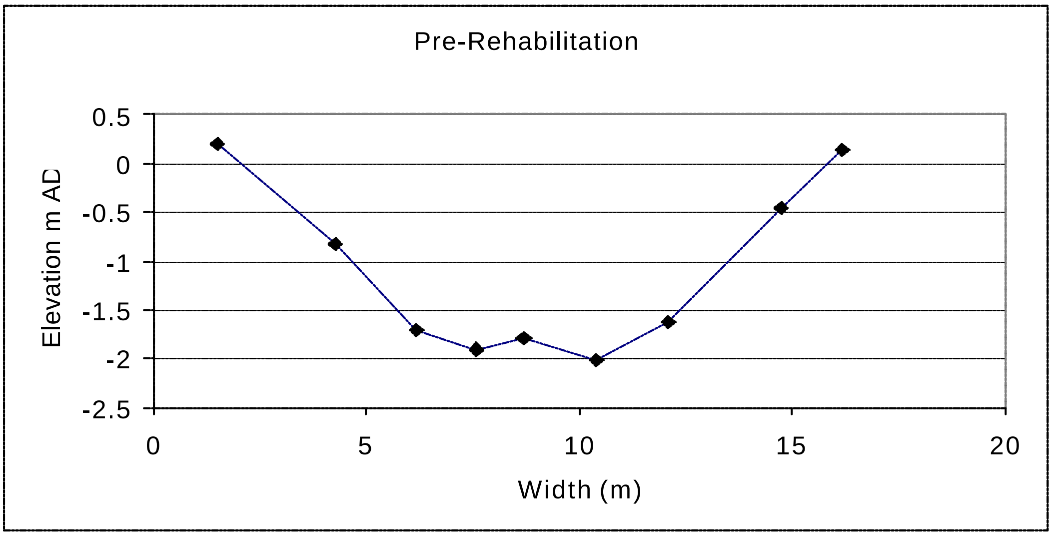
Figure 4: The long-profile of the Waveney
(a) Plotted from selected elevations in the ADAS survey,
(b) Showing the relative elevation (m) of the major weirs and sluices



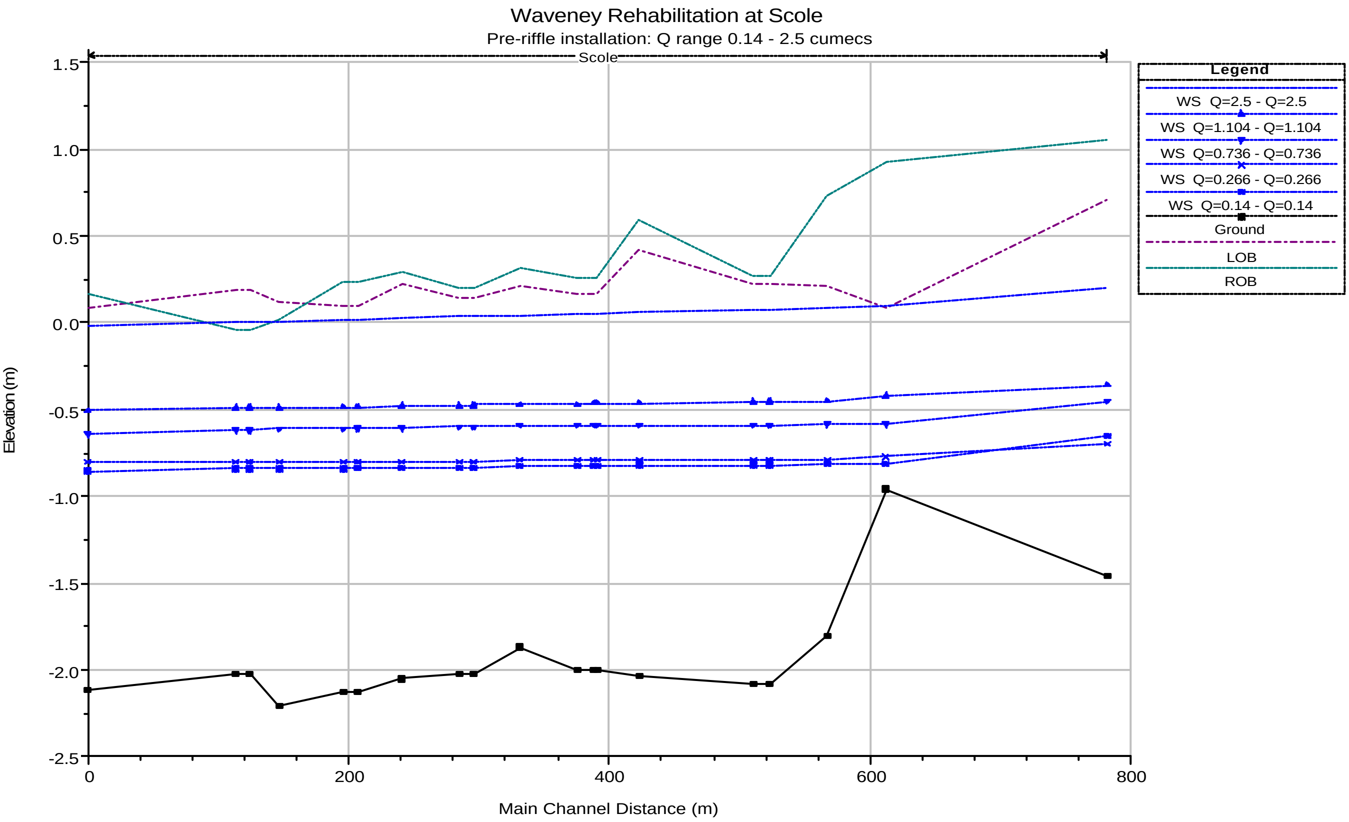




Riffle Rehabilitation site: Typical Cross-section



Riffle Rehabilitation site: Long Profile, bank and water surface elevations



What actually happened

The Waveney restoration scheme - what actually happened at Scole?

To fulfil current performance criteria of sustainable design and a positive benefit-cost ratio, it is essential to have a geomorphological assessment of rehabilitation proposals to define the following:

- the features considered as typical of this type of river in this part of Britain;
- the location of the segments/reaches suitable for works;
- the potential threats posed by current sediment dynamics and channel/catchment management;
- the design specification of the features selected;
- the stability of the features once emplaced;
- the influence of the features on physical habitat (flow types/biotopes).

The non-tidal Waveney was given a Catchment Baseline Study, Fluvial Audit and Dynamics Assessment (see procedures used by EA derived from geomorphological R&D). The Catchment Baseline Study (CBS, Table 1) identifies more than 20 'lengths' based on channel character in the field and heavily influenced by the backwater conditions created by the many mill structures in the channel. The basic channel character of the Waveney is the result of the amount of available gradient (and therefore flow types/ morphological features), local sediment sources and riparian tree cover (which in turn controls instream macrophyte growth). The more active tributaries were, however, divided into reaches (in the more conventional geomorphological sense, based on sediment sources and sinks).

As a result of the Waveney Catchment Baseline and Fluvial Audit the Anglian Region of the Environment Agency decided to proceed with a Dynamic Assessment of four reaches deemed suitable for the rehabilitation of 'riffle' features to improve a declining coarse fishery. These were at Diss, Scole, Shotford Bridge (Harleston) and Homersfield. The Dynamic Assessment was unusual in not addressing a problem of erosion or deposition, as such, but in establishing the appropriate dimensions, sedimentology and likely stability of artificially created 'riffles' as habitat features for a coarse fishery (Table 2).

The rehabilitation of pool-riffle sequences must start on the basis of an understanding of the 'natural' functions (hydraulic, sedimentological and ecological) of these features within the channel, followed by a decision on what functional service is to be the focus of their reinstatement. Specific geomorphological guidance on rehabilitating riffles can be gained from the research literature (Table 3) but most of the published studies of pool-riffle sequences are derived from streams with gradients, stream power and sediments much larger than those experienced in East Anglian streams. This makes monitoring and post-project appraisal essential to both management and research in lowland rehabilitation.

Fortunately, riparian owners cooperated with the Environment Agency in selecting the reach immediately downstream of Scole for the installation of six rehabilitated gravel 'riffles' (Table 4), permitting an innovative approach to post-project appraisal in the hydraulic and geomorphological senses. Monitoring included surveys of benthic invertebrates and fish as well as morphology, sediments, water levels and flows.
The chosen dimensions for the 'riffles' are given in Table 5 above. The gravel selected for the works was first piled on the river banks; size analysis shows the overwhelmingly unimodal distribution around 16mm (mainly angular flint particles), compared with the 10mm calculated as the minimum stable sediment size from streampower ($18.4W.m^2$ at bankfull) and shear stress calculations ($9.8N.m^2$).

Rehabilitation work was carried out on the reach during a spell of dry anticyclonic weather in late April and early May 1999; the total duration of work (including gravel carting from a roadside delivery point) was x days; a geomorphologist was on site during only three of these days in order to offer advice and carry out survey work.

The impact of the 'riffles' (both singly and jointly) on upstream water levels was of prime interest to this study and installation of twelve gauge boards two months in advance of the scheme allowed pre-'riffle' water levels to be recorded on seven separate occasions; surveys of both the gauge-board datums and adjacent cross sections were also made and tied into two stable temporary benchmarks.

The Waveney project has, in many ways, been a model of how to proceed. Geomorphological inputs have aided in the selection of rehabilitation sites and in the design of the features. However, in such circumstances any relevant science is essentially 'learning' from participation and the monitoring scheme at Scole has proved invaluable in refining our criteria for rehabilitation. Calibration of the 'HECRAS' hydraulic model using the data from the Scole gauge boards has indicated that, whilst the impact of the 'riffles' is negligible upon upstream flood levels it is also relatively restricted on the distribution of physical biotopes in the river except at low winter flows (in summer the luxuriant growth of macrophytes tends to dominate the reach hydraulics). Nevertheless, the use of gravel 'riffle' mimics on the Waveney was principally to improve the spawning opportunity for Chubb and Dace, not to increase aeration or to promote particular patterns of erosion and deposition around the new features. In this sense the Scole scheme is a successful compromise and in a site with slightly more flow energy the same restoration principles would have achieved even greater success.

Table 1 Summary and conclusions of Waveney Catchment Baseline study

GEOMORPHOLOGICAL CONSIDERATIONS
• Sedimentation
Low slope and structures produce ponded flow allowing siltation Increasing stream power to 'self-cleansing' levels impracticable Coordinated sluice operation and bed disruption might aid desilting Steeper tributaries generate and transport fines to main channel in high flows
• Flow regime
Recent low flows, abstraction and lack of effective floods a problem Flow augmentation is geomorphologically irrelevant in volume and timing Hard to predict effect of each control structure at all flows without a model
• Channel maintenance
Dredging in the past has removed much of the morphological diversity Current maintenance levels low, except in some tributaries Weed growth is part of the siltation problem; may be options for control
REHABILITATION CONSIDERATIONS
• Siltation
Siltation might be ameliorated locally by 'harder' maintenance Alternatively, in certain sections, reduced weed removal may speed flow Siltation is a threat to rehabilitation features, especially in gravels, but proper design can aid self-cleansing
• Flow regime
Sediment transport rates will never be high in main channel - active forms such as natural bars and riffles may not be an option Flood frequency may be increased immediately upstream
• Habitat change
Full restoration would require a habitat model of pre-control or analogues All schemes must be matched with changing climate and land use

Table 2: Riffles and 'riffle' mimics, some distinctions

Riffle (in active sediment system)	Mimic for rehabilitation
Sediment 'queueing' in active transport system (location normally stable)	Stable by design; coarser material and low amplitude part of the stability
Induces unbroken standing waves at low to moderate flows	May induce broken standing waves at low flows - as part of an aeration function
Amplitude, spacing and mobility of sediments reduces impacts on flood flows	May have a calculable impact on upstream flood levels as a result of effect on channel capacity and roughness
Regular spacing 5-7 channel widths Channel wider at riffle - accommodates floods	Location often depends on access, riparian land management and fisheries interests Width may not be enhanced

Table 3 Riffle morphology derived from the scientific literature.

Variable	Mean	Range
Slope	0.00541 m/m	0.00093 - 0.016 m/m
Riffle spacing	172 m	17 - 1200 m
Riffle length (L)	72 m	9 - 400 m
Riffle length as % spacing	45%	17 - 76%
Riffle amplitude (H)	0.6 m	0.24 - 2.00 m
Riffle slope u/s of crest*	0.038 m/m	0.004 - 0.141 m/m
Riffle slope d/s of crest	0.022 m/m	0.003 - 0.057 m/m
Aspect ratio (L/H)	222	47 - 600

* crest is at 35% of riffle's length

Table 4. 'riffle' designs for the River Waveney. All values are in meters unless specified.

Site	Reach Length	'riffle' Spacing	'riffle' Length	No. 'riffles' / reach	'riffle' amplitude at crest	u/s length to crest	d/s length from crest	Bed width max at crest
Diss	275	65	29	7*	0.3	10	19	15% section average
Scole	475	45	20	6$	0.3	7	13	15% section average
Shotford Bridge	257	122	55	3	0.25 - 0.4	20	35	15% section average
Homersfield	235	100	45	3	0.25 -0.4	16	29	15% section average

*for Diss this includes a number of point bars if further work is carried out in design
$ actually 7, but one has been emplaced already (April, 1998)

Workshop Group 3: Lowland Urban Watercourse – Enhancing an Urban Watercourse
Case Study: The River Wandle (South London)

The Challenge

Dr Helen Dangerfield, Babtie Group Ltd, Simpson House, 6 Cherry Orchard Road, Croydon, Surrey, CR9 6BE, Email: helen.dangerfield@babtie.com

Part A   The challenge

The project involves the restoration of a watercourse which runs through a historic urban park approximately 11 acres in extent. The park lies alongside and to the east of the River Wandle in Colliers Wood, South London. The local Borough Council and the National Trust have joined to support works to improve the watercourse which is polluted, has a low flow problem and is geomorphologically, ecologically and aesthetically poor.

The Wandle Park river is currently a concrete lined channel fed from storm water which arrives via a piped sewer outlet. The sewer runs along the left hand bank of the River Wandle and then underneath the bed of the River Wandle before it enters the park. The water from this outlet contains a high level of heavy metals and hydro-carbons and more importantly large quantities of silt (particularly in storm-water conditions). It is this silt in particular which prevents the existing channel from supporting vegetation or wildlife. During dry conditions the low gradient of the channel (0.00075) and low flows result in stagnant standing water.

The challenge is to identify the key geomorphological concepts which underpin this project. This should be accompanied by a list of possible investigations and techniques which may be used. Following issues need to be addressed (in small groups):

- Reducing channel siltation
- Planform of the restored river
- Channel morphology
- Substrate and bed topography

This will enable the whole group to make a summary of the key criteria necessary to ensure successful application of geomorphological principals at the design stage.

Constraints

Flood standard must not be compromised – Wandle Park is an important element of the EA’s flood defence strategy as it lies in the floodplain and can be expected to flood on a regular basis. Flooding occurs from backing up of water at the downstream confluence of the Wandle Park Channel with the River Wandle.

Archaeology. The whole of the park lies within a designated ‘conservation area’ and English Heritage have advised that this park is of high archaeological value.

Ecology. Many of the trees within the park have an important landscape value and should not be disturbed. Trees follow the current planform of the channel in places.

Services. A high pressure gas main crosses from west to east under the park and a high voltage cable runs from north to south over the park with an associated underground cable. There are also a number of trunk sewers which run under the park. Remains of an old swimming pool and air raid shelters are further constraints on construction.

Contaminated land. Preliminary feasibility studies have shown that there are pockets of contaminated land within the park.

Plate 1 A view of the existing Wandle Park Channel illustrating the extensive siltation.

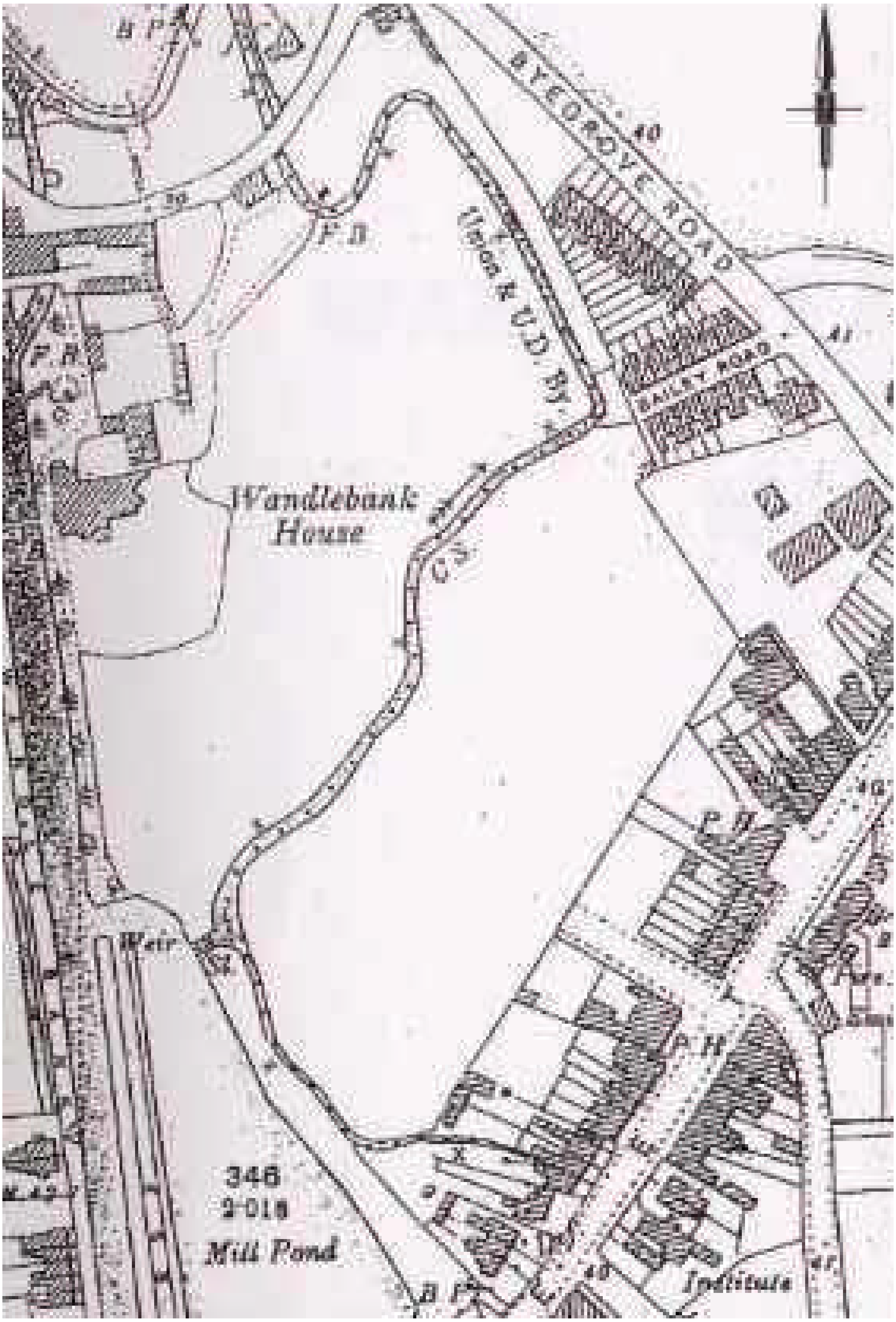


Figure 1 Map of the Wandle Park and Channel in 1894

Helen Dangerfield, Babtie Group (with permission from EA Thames Region)

What actually happened

<u>Restoration of an Urban Watercourse – Wandle Park Channel, London.</u>

The group identified that there were a number of key problems that needed to be tackled if the Wandle Park Channel was to be restored successfully. These included:

- What to do with the storm water that enters the current channel and how to create a more perennial flow pattern.
- What form should the new channel take, both in terms of the planform and the channel cross-sections.
- How to ensure the new design would not interfere with pockets of contaminated land that were thought to be located in the Park
- **How to improve the general ecological functioning of the channel**

1. Flow in the Wandle Park river

The general consensus amongst the group was that it was necessary to improve the water quality of the storm water before it entered the current channel in Wandle Park. It was decided that the best method would be to create some kind of settling pond before the start of the Wandle Park River to encourage settling of contaminated silt. The planting of a reed bed was suggested as a good solution to this problem.

The other issue, with respect to the water quality, was the need to restore perennial flow in the river. Presently flow is intermittent leading to the establishment of standing, stagnant water. The solution for this was to divert some of the flow from the River Wandle into the Wandle park channel. A concern was raised about the water quality within the Wandle and it was decided that this would need to be examined before any scheme was implemented. A control structure would need to be installed on the diffluence of the Wandle and the Wandle Park river to ensure that a minimum low flow would be diverted throughout the year.

2. Channel form

There were several discussions amongst the sub-groups about the path of the new channel. Some groups suggested that the current planform should be maintained whilst others recommended that a new planform should be constructed completely. A concern was raised about this approach as pockets of contaminated land had been discovered in the park and thus the creation of a new planform could raise the project costs if any contaminated land needed to be dealt with in the design of the new longitudinal profile. It was decided that an investigation should be made to distinguish whether any historic channel planforms could be delineated and whether any of these could be used as a model for the design. Alternatively, reference reaches within neighbouring catchments should also be examined to determine potential planform configurations.

There was widespread agreement within the subgroups for the removal of the concrete channel in the Wandle Park River in favour of a 2 stage channel design. It was recommended that the banks be re-profiled to incorporate a low flow zone within a larger flood defence channel. The maintenance of the flood protection was critical for the new schemes design. The issue of contaminated land was raised again in the removal of the concrete channel. An important consideration was to ensure that no contaminated soils were made available for the river to transport downstream. In defining the shape of the channel cross-section it was identified that cross-sectional variability was an important feature that should be incorporated into any new design. Habitat heterogeneity would provide improved habitat quality throughout the reach.

At particular locations in the Wandle Park it was recognised that harder bank protection might be required. It was also identified that a new alignment might be necessary where the channel currently flows under an electricity pylon.

3. Contaminated land

The issue of contaminated land arose throughout the discussion on the new channel design. It was recommended that a full soil survey should be performed to determine the location of the pockets of contaminated land as a part of a preliminary baseline survey. This should be used to guide the designs and determine which of the options would be most suitable.

4. Ecological functioning of the river

It was identified that a key benefit in keeping the current channel planform configuration was the mature vegetation that existed in the riparian corridor. Riparian cover should be maintained in the design of the new channel. It was also suggested that valuable habitat could be created by importing gravels into new riffle zones. This could provide new spawning habitat.

The restoration design, completed 1999.

The rectangular concrete channel was removed and replaced with a variable width, two-stage channel. The bankfull channel capacity was designed to the same flood protection, with the meandering low flow channel free to adjust its planform within the bankfull channel. Low flows were maintained through the channel by abstracting 0.15 cumecs from the main River Wandle. This discharge was designed to increase to a maximum value of 0.5 cumecs when the flows in the main Wandle reach a maximum of 11.72 cumecs (Tr = 2 years). Flows are controlled by an offtake structure at the upstream end of the park which then enters into a newly constructed two-stage channel which links up with the existing channel. The original planform of the channel was maintained, largely because there was no significant alteration from the 1847 watercourse when the river was first concreted. In addition, it was important to preserve as many of mature trees which line the channel as possible throughout the park. However, the channel was diverted away from the pylon at the downstream end of the park.

The scope for the natural development of pool-riffle sequences was limited by low channel gradient and low average velocities. Local diversity of the bed configuration was therefore introduced during construction, which has resulted in some adjustment during higher flow events. The capacity of the channel to convey suspended sediment was also limited resulting in a siltation problem. Sampling of the sediment indicated that it contains elevated levels of PAH’s and heavy metals. The storm water outflow was therefore removed from the main channel and diverted into a settling pond and reed bed before flowing back into the Wandle Park Channel downstream. The reed bed was sized and configured to achieve a compromise between water quality improvement, landtake, preservation of trees and cost constraints.

Mixed gravels obtained were reinstated to the new channel downstream of the offtake structure. Gravels arising from excavation from remnant fluvial deposits were used after they were verified as river deposits supplemented by gravels of a similar grade, based on remnant deposits and the sediment survey of rivers in Thames Region.

Dr. Kevin Skinner, University of Nottingham
Dr. Helen Dangerfield, 1b

Workshop Group 4: Upland Rural Watercourse – Creation of an Environmentally Acceptable Channel
Case Study: The River Nith (Dumfries and Galloway)

The Challenge

Dr David Gilvear, Department of Environmental Science, University of Stirling, FK9 4LA, Tel: 01786 467845, Email: DJG1@stir.ac.uk

PART A The challenge

Assume you have been asked to design an ecologically sound river diversion on the River Nith because the existing natural river lies in an area of valley floor that is to be mined. The river has a flashy river regime and has a coarse gravel bed. The length of river to be diverted is approximately 3 kilometres, channel width 8-10 metres (See Figure 1;Plate 1).and here the Nith cross a large expanse of relatively low gradient (slope 0.006) valley floor.

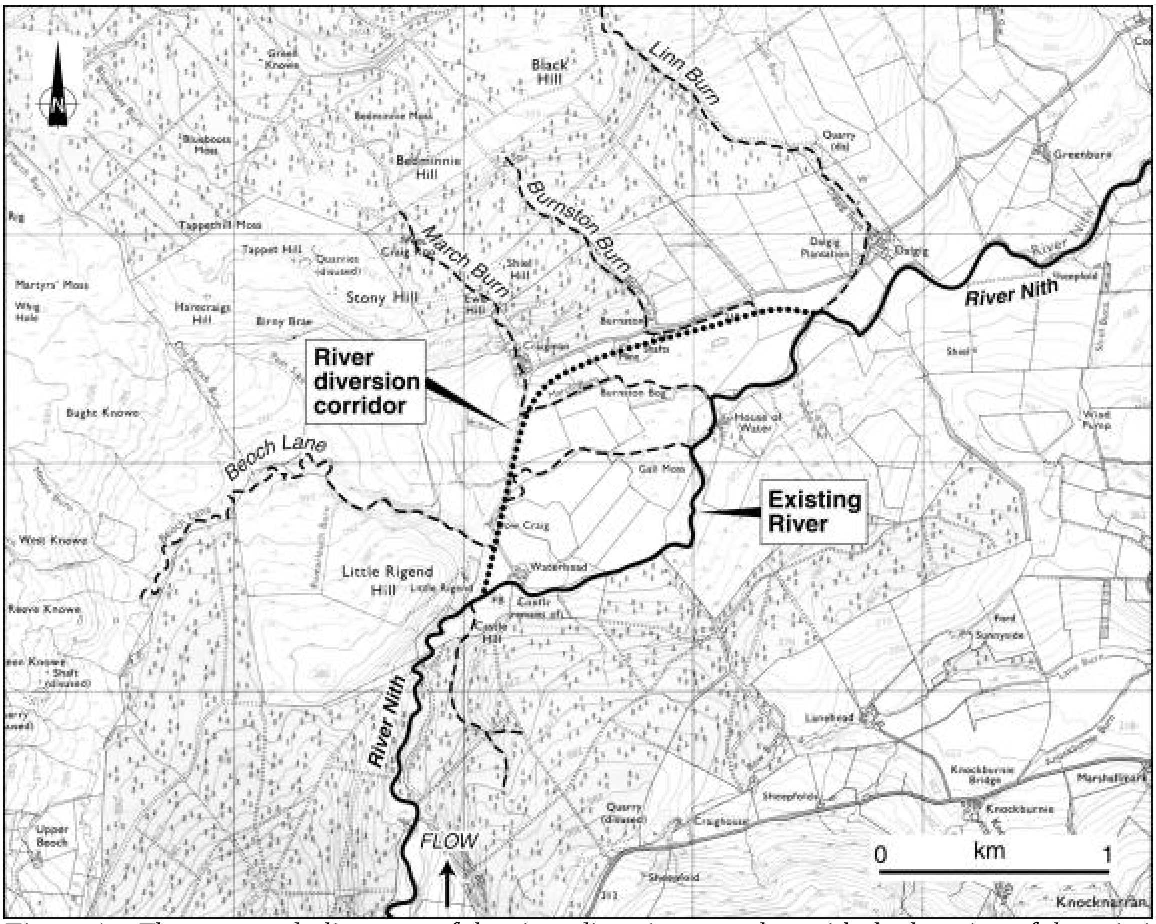


Figure 1 – The proposed alignment of the river diversion, together with the location of the existing reach of the River Nith and its tributaries

The major constraint is that you are restricted to a narrow river corridor running along the northern edge of the floodplain and that floods have to be contained within the corridor by flood embankments at the edge of the corridor. The task is to specify the geomorphic principles you would follow to produce an appropriate design, make a list of the key geomorphic criteria that would result in a river channel morphology based on sound geomorphic criteria and investigations you might undertake to provide the information required.

You will be organised in to groups to discuss one of the following aspects of the design although you should be aware that they are not independent variables

Channel slope
Channel planform and sinuosity
Channel morphology
Channel substrate

Plate 1 A typical view of the existing river Nith

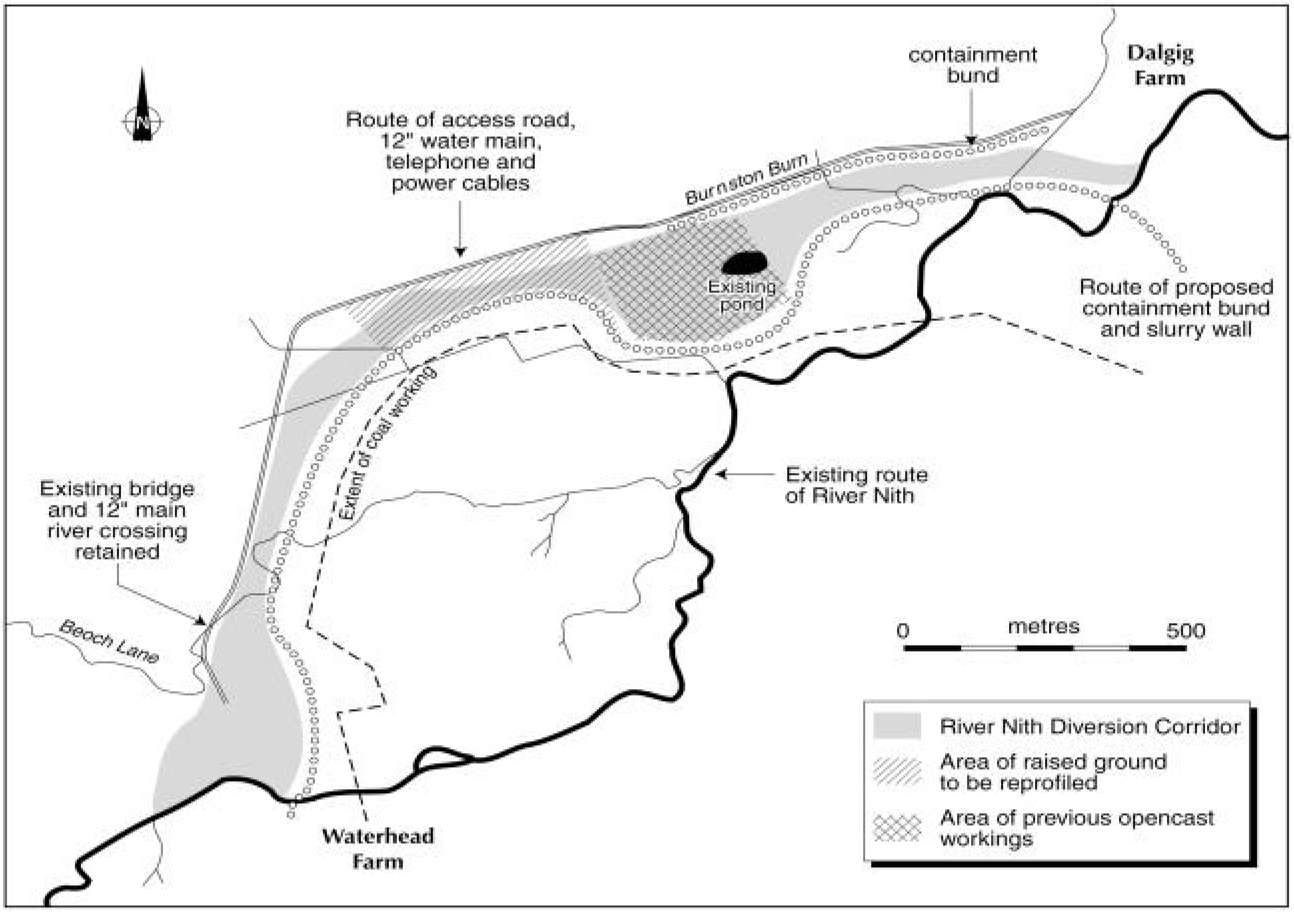


Figure 2 A detailed view of the River corridor within which you can build your river diversion. The mine working area will create an excavation of 40 metres plus depth

02/04/01
DJ Gilvear (with permission of Halcrow Crouch)

What actually happened

Building a river diversion – The River Nith, House of water

Outcomes of the delegated discussions with regard to the task of building a river diversion on an upland river system

The challenge was for workshop participants to providing some geomorphologically sound guiding principles for the design an ecologically sound river diversion on the River Nith in South West Scotland. The requirement for the diversion was due to the need to move the natural channel to make way for coal mining operations (Figure 1). The participants worked in sub groups on the following aspects of channel design: Channel slope, Channel planform and sinuosity, channel cross-sectional morphology and channel substrate. It was realised that these morphological aspects of channel design were interrelated.

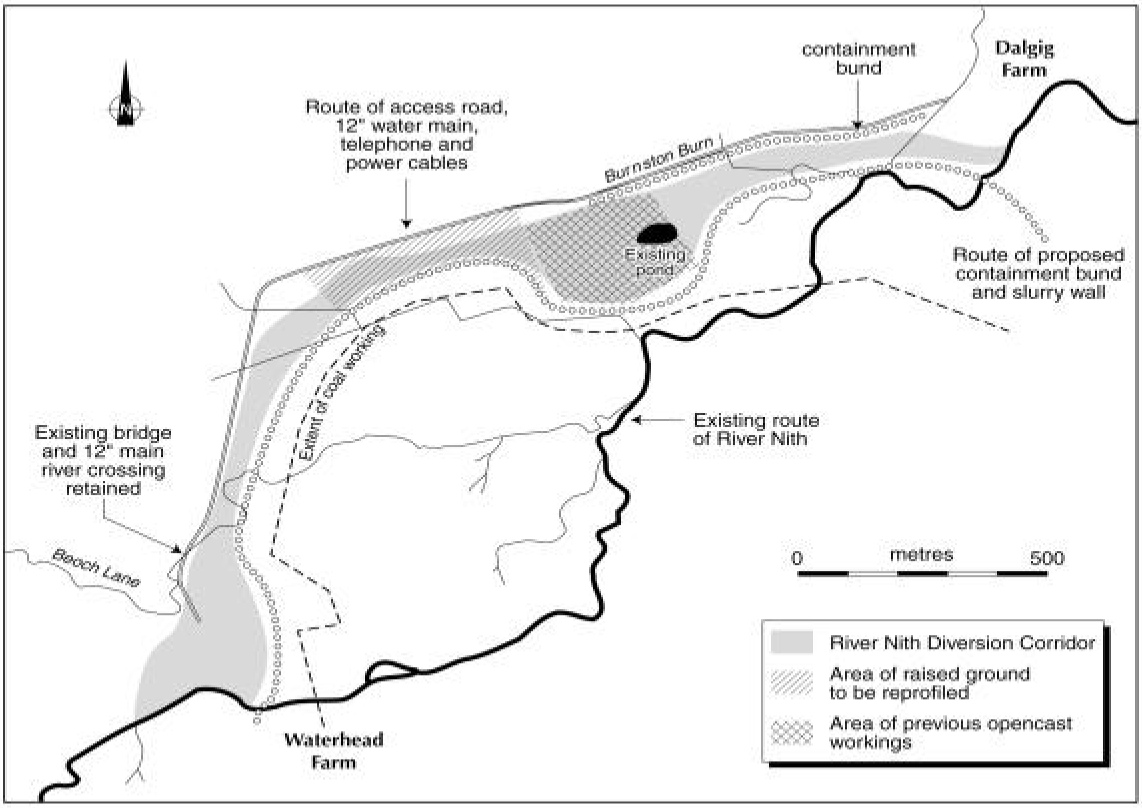


Figure 1 - The site layout with the planform of the diversion corridor indicated.

5. Channel slope

The general consensus amongst the group was that it was necessary to try and maintain the channel slope similar to that of the existing channel. This was because otherwise stream power would be altered and aggradation and degradation problems could arise due to an altered sediment transport capacity. It was realised that there were two difficulties with fulfilling this wish. Firstly within the constraints of the river corridor available for routing the channel, the length of diversion would have to be a little shorter than the existing channel. The second problem that was identified by one of the group members was that incoming tributaries would meet have their confluence with the new channel at a different elevation than that of their previous confluence. It was suggested that steps might need to be taken to prevent morphological change at these confluence areas.

6. Channel planform and sinuosity

There were several discussions amongst the sub-groups about the path of the new channel. Some groups suggested that the basic planform of the existing channel should be used as a template and that even a "mirror-image" could be used. Scrutiny of problem showed that such an appealing approach would not be feasible given the river corridor width available. It was decided that the course should approximate the existing channel by maintaining similar meander forms and sinuosity. At particular locations it was recognised that harder bank protection might be required to safeguard the embankment preventing floodwaters entering the mine site. Backfilling trenches away from the river channel to act as "backstops" was suggested.

7. Channel morphology

The consensus was simple that the diversion should be built with a channel cross-section that had the same width and depth dimensions as the existing channel. Some mention was made as to whether there was need to construct in-channel features but their was little consensus on the matter. The linkage between channel planform and cross-sectional morphology was highlighted but the effect of slope variability along the channel on morphology was noy discussed.

8. Channel substrate

It was identified that dewatering of the channel was a potential problem due to the adjacent mine and that a liner of some description would be required. The need to create a channel substarte with the same particle size characteristics was also appreciated. Their was some discussion of whether there was the need for pool and riffle creation given the high stream powers and potential for widespread sediment movement. The problem of pool-riffle spacing and dovetailing this with the channel planform was also raised.

<u>The diversion design (September 2000) and geomorphological performance,</u>

The workshop participants were informed that a 2.7km river diversion was built with a channel morphology that maintained the main planform and substrate features of the existing channel but was not a mirror image. The channel incorporated pools and riffles and a natural bed with a substrate particle size range similar to that of the existing channel. Outer riverbanks in critical locations were rip-rapped with "degradable" sandstone. The diversion design was primarily the work of Halcrow Crouch with the construction being undertaken by Bachy Soletanche.

It was indicated to the delegates that subsequent scutiny of the long profile showed that there were two adjacent reaches that maintained a slope which were respectively of higher and lower gradient than the previously existing natural channel gradient. This in part was due to the terrain over which the new course had to be built. Another feature pointed out was the fact that the tributaries had by necessity their lower courses truncated and their stream bed elevation did not necessarily match that of the diversion bed level.

The robustness of the river diversion was tested fully in the autumn of 2000 as a result of the occurrence of two large flood events (estimated return periods exceeding 1 in 10 years) in close succession. The river diversion survived the floods pretty much intact with bank erosion being localised. The area of greatest geomorphological change occurred in the area where there was localised deviation of the channel slope away from that of the natural river that once existed. Bedload movement occurred in the steeper upstream section and this material was deposited in the low gradient reach downstream in effect infilling the channel and creating a new bed level close to the general valley floor elevation (Figure 2a). It demonstrates the sensitivity of upland stream system to river diversion and restoration design and the need to maintain the sediment transport capacity of engineered reaches at a level that will convey the natural sediment load. The same flood also created a variety of point bar and mid-channel bar features and sorted the river bed sediments enhancing the morphological diversity of the channel (Figure 2b). Tributary junctions were also an area of morphological change with a 'knick point' and upstream bed degradation (now halted by rock placements) occurring on one of the tributaries. Overall the success of the diversion was illustrated but the occurrence of the large floods demonstrated that if there is inadequate attention given with regard to geomorphological processes and design criteria, problems can rapidly occur in high energy upland channel. It also demonstrates that river restoration on upland channel need not worry unduly about meso-scale geomorphological features because the first major flood will "construct" such features as point and mid-channel bars.

A)

B)

Figure 2 (A) A depositional reach on the new diversion showing the bed level approximating that of the valley floor (B) Creation of point and lateral gravel bars on the river diversion following the autumn floods