(Lecture Notes)

HUMAN IMPACTS ON RIVER BASINS AND FLUVIAL SYSTEMS AND ECO-GEOMORPHOLOGY

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INTRODUCTION: The watercourse

Natural streams are essentially open hydraulic systems in equilibrium. The variables are those that govern discharge and are: -

- CHANNEL WIDTH
- BOUNDARY ROUGHNESS
- SIZE AND CONCENTRATION OF SEDIMENT LOAD
- DEPTH AND SLOPE

A change in any one of these interdependent variables must be compensated for by a change in the others.

Fluvial processes and the shaping of rivers

Several natural factors govern the physical process in rivers and hence their morphology. As water works its way downstream, energy is expended on the transportation and rearrangement of materials in the river channel and on the flood plain. Meanders can migrate, banks may erode, new channels may form and old ones cut off creating backwaters.

Schumm(1977) assigned three zones to the land-water interactions within fluvial hydrosystems:-

ZONE 1: Sediment supply zone

The upper zone within the catchment. This zone is characterised by valley slopes impinging almost directly onto the channel. There are coarse channel sediments and these arise from bank and slope erosion inputs. The high-gradient upland stream is dominated by cold temperatures, highly oxygenated water and fastwater habitats.

Figure 1: Upland river

ZONE 2: Sediment transfer zone

Comprises mainly the lowland reaches of the river where the channel is often bordered by a wide floodplain. In this zone the rivers redistributes sediment derived from upstream and bank and bed erosion. Sediment varies from cobble and gravel- sized material in the upper reaches to silt, clay and alluvium in the lower reaches. Meander bends migrate laterally and fine sediments can be stored on the floodplain after a flood

Fig 2. Lowland river

ZONE 3: Depositional zone

Sediment is deposited in estuary.

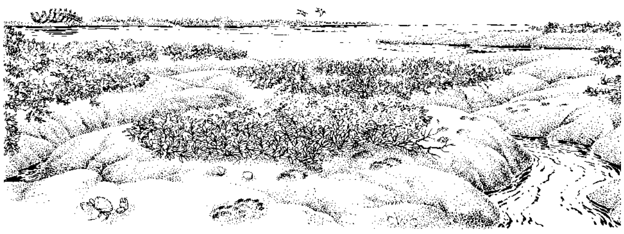

Fig 3. Tidal river

The range of substrates found within the 'production' and 'transfer' zones together with their hydrological regime, determine the habitat characteristics of the river. In a natural/unmodified river it is the range of natural habitat features, which represents its maximum wildlife potential and it is this that may be degraded or altered by river engineering works.

Morphology of natural channels

The full range of the plan geometry/pattern has never been identified: however, it includes straight, meandering and braided. Broadly speaking, meandering is characteristic of lowland rivers with slack slopes, and braiding is characteristic of steeper upland reaches.

Although a range of factors, for example, the nature of the bed/bank substrate influences channels form, it is largely determined by stream power. Stream power increases with discharge. However, even though discharge increases in the downstream direction, stream power per unit area typically decreases because the gradient decreases.

Straight channels

Meander patterns are often present in straight channels, since the thalweg is often found to swing from one side to another. The depth can also vary along the longitudinal profile resulting in a series of pools and riffles. Details on meanders and pools and riffles follow.

Meandering channels

Meandering channels are single channels that are sinuous in plan. Meandering channels are efficient equilibrium features that represent the channel plan geometry, where single channels deviate from straightness. This deviation is related in part to the cohesiveness of channel banks and the abundance and bulk of midstream bars.

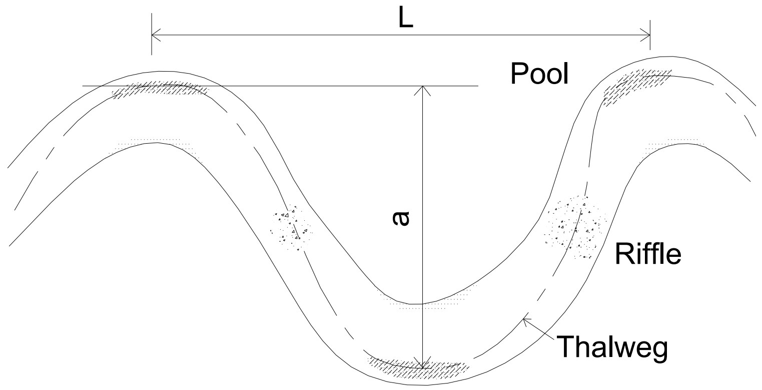

Fig 4. Meandering channel

Riffles and pools

Straight rivers are rare in nature. This is in part linked to the fact that velocity at a river cross section is unevenly distributed. As a consequence, convergent and divergent patterns of downstream flow result in the development of a longitudinal sequence of pools and riffles. The bed of a meandering stream includes pools at (or slightly downstream of) the bends and riffles between the bends.

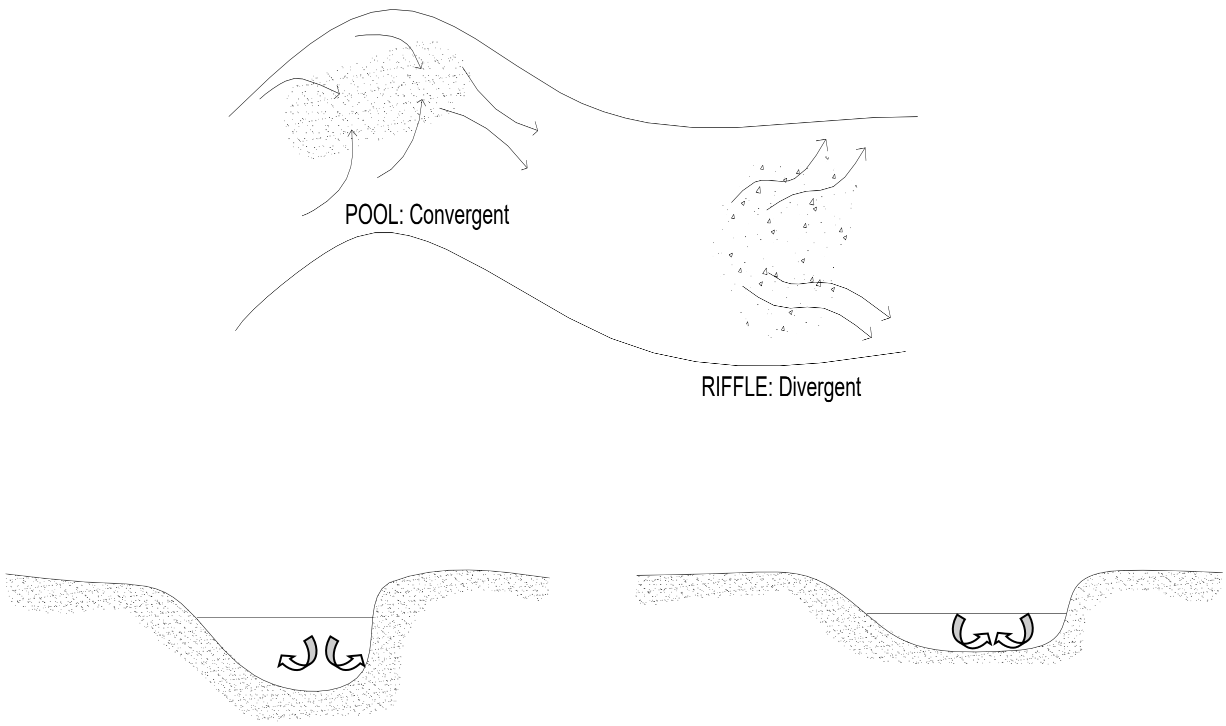

Fig 5. Pool (scour) & Riffle (fill)

Meander wavelength

Meanders may be characterised by their length, L, and amplitude, a, (See fig 4). Meander wavelength, the distance between two successive bends has been the subject of much research. Measurements of meandering watercourses show that there is a pattern to the shape of the meanders. Approximate wavelengths of one full meander may be summarised as follows:

- Approximately 10 to 14 times the bank full width of the watercourse.
- Concentrated between 8 and 10 bedwidths.
- $7<L/B<11$

Because bed width is related to discharge, meander wavelength is also related to discharge. There are a number of equations showing this relationship, for example:

- $L = 46Q^{0.39}$

Braided channels

Braiding is a feature of channels with steeper slopes, where flows have high energy. Braided channels are subdivided at normal flows by midstream bars of sand or gravel. At high water, many or all bars are submerged. A single meandering channel may convert to braiding where one or more bars are formed, where for example, downstream of a tight bend material is brought up from the pool bottom. Each of the subdivided channels is less efficient, being smaller than the original single channel and this is often compensated for by an increase in slope (i.e., by down cutting).

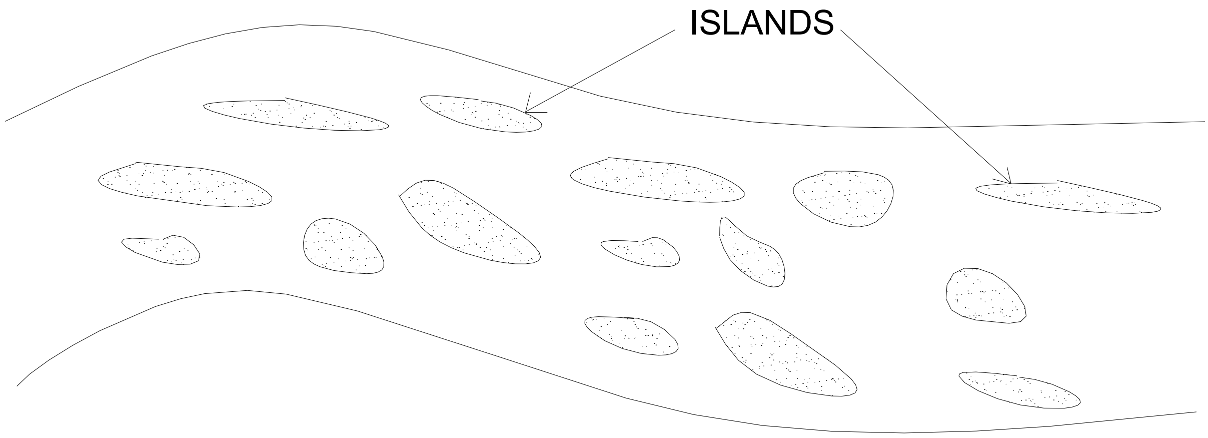

Fig 6. Braided Channel

River and flood plain habitats

The lateral continuum of river and flood plain habitats

Rivers and their flood plains can encompass a great variety of habitats for wildlife. Relatively unmanaged rivers have a diverse physical structure with pools, riffles, secondary channels, backwaters, fringing marshes and flood plain wetland. Historically engineers have tended to regard rivers as a downstream continuum comprising only the main channel and river ‘corridor’. A more integrated approach to rivers and floodplains is now developing. Detailed examination of river and floodplain habitat (particularly lowland rivers) in its unconfined natural state reveals it is characterised by a continuum of habitats from the flowing main channel to aquatic, semi-aquatic and terrestrial environments.

terrestrial ← **Lateral continuum** → **aquatic**							
Riparian / flood plain wood land	**Marsh**	**Fen/swamp**	**Areas of floodplain grassland/marsh subject to periodic inundation. Characterised by seasonal high water tables**	**Backwaters without permanent connection to river. Rarely influenced by floods.e.g.abandoned channels**	**Backwater connected to main river at downstream end only e.g. side arms**	**Continuously flowing side arm**	**In-channel features: Pools Riffles gravel bars islands banksides**

Table 1: River and floodplain habitat continuum

Importance of habitat diversity to riverine ecosystems

Rivers and floodplains are dynamic systems. They are continuously adjusting to changes in discharge and sediment load. Such changes affect the channels, altering courses, creating new ones, and cutting off old channels as they migrate laterally. The continual changes in river form are critical to wildlife. Natural watercourses have an intricate pattern of strong and weak currents and there is an array of different habitats available, as follows:

- In channel riffles are spawning areas for fish species. Gravel bars may support a wide range of invertebrates.
- Eroding bankside cliffs provide nesting locations for a range of birds.
- Channel margins, backwaters and lowland wet grassland with high water tables are particularly valuable habitats for wetland plants.

- Backwaters are important refuge areas for fish, birds, mammals, invertebrates and amphibians as well as plants.
- Wet grassland and wet woodland within floodplain provide a range of feeding and breeding areas for a number of birds. Plants found in backwaters and on wet grassland provide both seeds and habitat for invertebrates, which are food for a variety of waterfowl.
- Flood plain grassland provides a continuous habitat range from drier to wetter areas, which is used by breeding waders..
- Amphibians thrive in floodplain pools that occasionally dry out during the summer.

River degradation - Environmental problems in rivers

A wide range of human activities may lead to environmental degradation of rivers. The major activities are listed below:-

- ❑ Supra-catchment effects

Acid deposition and Inter-basin transfer

- ❑ Catchment land use change

Afforestation and deforestation; Urbanisation; Agricultural development; Land drainage/flood protection

- ❑ Corridor engineering

Removal of riparian vegetation; Flow regulation/dams; Channelization; Dredging and mining

- ❑ Instream impacts

Organic and inorganic pollution; Thermal pollution; Abstraction; Navigation; Exploitation of native species; Introduction of alien species

River regulation

River regulation is a general term describing the physical changes that man imposes on watercourses. Various human activities that physically influence/regulate rivers are listed below:

Table 2: Human activities physically influencing river systems

• Land drainage	• Channelization
• Flood protection	• Interbasin water transfer
• Reservoirs	• Navigation
• Dams	• Dredging

River channelization

Channelization is the term used to embrace all processes of river channel engineering for the purposes of flood defence, land drainage, navigation, erosion control and river relocation for transport purposes. Of the specific reasons for channelization the requirement to defend land and property from the risk of flooding is the most important. This has long been the policy of the successive governments.

Traditional Flood Alleviation Methods

When a river is channelized the objective is to reduce the period of flooding on adjacent land and provide better freeboard to improve drainage. The traditional methods outlined here may be thought of as 'hard' engineering methods.

Resectioning

This involves dredging and/or widening the main channel to increase the discharge capacity. In addition bed slope may be steepened to increase flow velocities and increase flood capacity. In urban areas rectangular flume-like channels, or culverts, are often constructed due to limited space. In order to maintain a stable bank, vertical sheet piling, concrete or masonry is used to line the channel.

Widening and deepening

Flood wall lining

Culverting

Figure 7. Examples of widening and deepening, flood wall lining and culverting

Realignment

Straightening the channel increases the gradient of the river and thereby, flow, velocity and flood capacity. This is often carried out in association with resectioning.

Figure 8. A straightened watercourse

Adjacent flood banks

The construction of flood banks is a very common engineering solution to flood control. Conventionally these are constructed close to the river and, as a consequence, they need to be higher than distant flood banks to achieve the same level of protection.

Figure 9. Construction of embankments

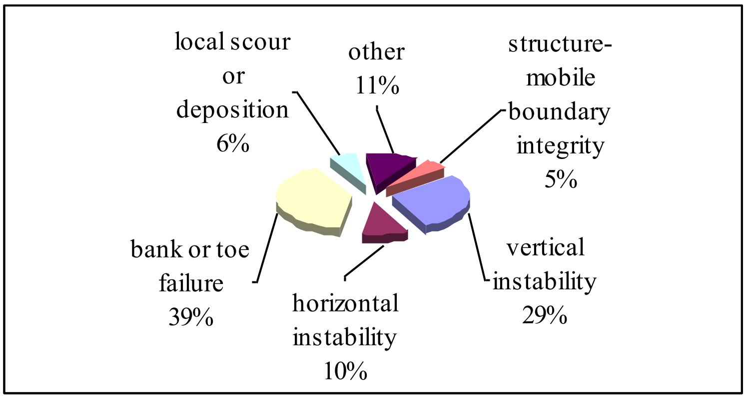

Figure 10. Post construction problems on flood control channels

Physical effects of channelization

Channelization involves changing one or more of the interdependent hydraulic variables of slope, width, depth, roughness or size of the sediment load. Channelization has a great impact on a river because it disrupts the existing physical equilibrium of the watercourse. To compensate for the alteration in one or more of the hydraulic variables, and to establish a new, stable equilibrium, other parameters will change.

The pathways to river degradation as a result of physical regulation is shown below:

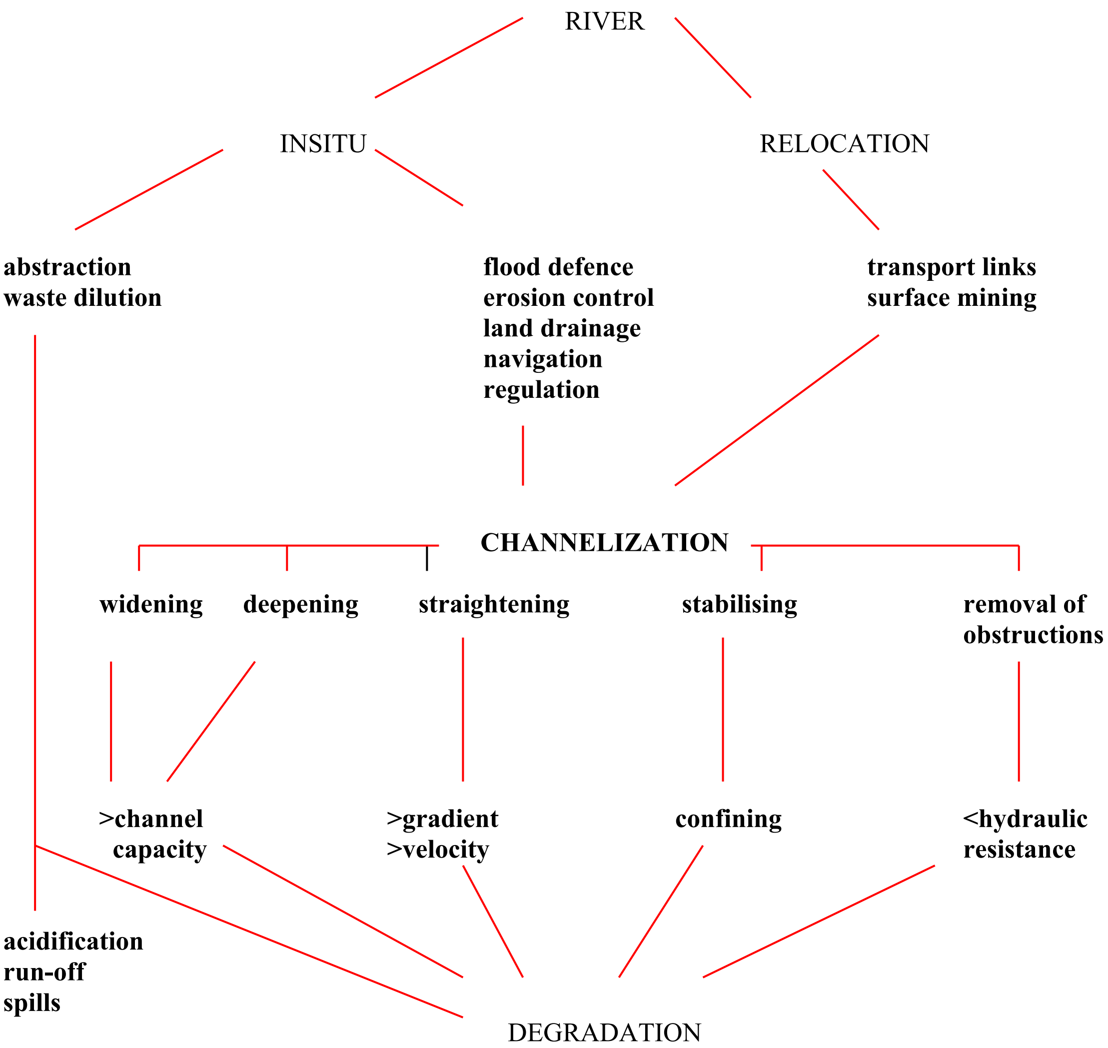

Figure 11. The pathways of riverine modification

Effect on channel stability

The gradient and the velocity of flow determine the erosion and transport of material. The gradient and velocity of flow are increased by channelization and as a consequence the equilibrium is brought out of balance. The watercourse will attempt to regain it's state of equilibrium as a result, the increased waterpower can cause bank erosion and the channel may suffer serious scour and ultimately failure, that is if no protective revetment is installed. River channelization often leads to a significant legacy in terms of maintenance and bank/channel stabilisation.

Hydrological impact on floodplain habitat and power of self-purification

The most serious impact of river engineering works, in order to meet the needs of flood defence, and land drainage, has been to isolate floodplains from flows in the main channel. Another effect of the channelization of rivers and the drainage of wetlands may be increased nutrient and organic matter loading of rivers. While the annual nitrogen removal capacity of wetlands and natural rivers is several hundred kg N per hectare that of channelized rivers and drained wetlands is significantly reduced. Naturally riparian zones therefore play an important role in balancing and ecological interest.

The powers of self-purification are now well recognised and SEPA and EA(1997) outlines Best Management Practises for urban drainage, which are now encouraged in the UK.

Effects of the removal of bankside vegetation

Channelization can also have a great impact on the riparian vegetation; trees are often logged to allow channel maintenance by machines and scrub areas are cut to ensure efficient drainage. This increases solar radiation at the stream surface, thereby increasing the water temperature, reducing the concentration of dissolved oxygen. In nutrient-rich watercourses this results in enhanced growth of bottom living/ benthic phytoplankton, filamentous algae, or macrophytes.

Downstream effects and exacerbation of flood risk

The risk of flooding can increase where water from drained agricultural land or from developments on natural floodplains has been channelled artificially higher up in the catchment.

Biological effects of channelization

The uniform channelized watercourse is suitable for few, if any plant species. Furthermore, as the uniform water flow precludes areas with little or no flow, resting sites for fish and invertebrates are virtually absent. The general effect of channelization is therefore a reduction in habitat number and diversity. Similarly, the biomass of fish and invertebrates is usually lower in channelized watercourses. The riparian zones are also affected by channelisation.

Thus animal species foraging and/or breeding on the banks decline in number. In addition, a number of plant species that are confined to the more or less water-saturated soil adjacent to the river are also affected. The overall result of channelization is a reduced diversity of the riparian zone.

Flood defence

The government department responsible for flood defence is the Ministry of Agriculture Fisheries and Food, MAFF. MAFF and the operating authorities, namely, the Environment Agency, Internal Drainage Boards and local authorities have duties under a range of domestic legislation and EC Directives. When planning flood defence works, they must:

- Further the conservation and enhancement of natural beauty, and the conservation of wildlife and geological features of special interest wherever possible
- Have regard to the desirability of protecting and conserving buildings and sites of archaeological, architectural or historic interest
- Consider the effects the proposals would have on the beauty or amenity of the area.

When assessing schemes, MAFF works on the principle that natural rivers should not be disturbed unless life or valuable assets are at risk. MAFF, has published environmental guidelines in MAFF(1996) and the strategy for flood defence and coastal defence, in England and Wales in MAFF(1993).

Operating authorities

- The Environment Agency supervises all matters relating to flood defence in England and Wales. Through measures agreed by its Regional Flood Defence Committee it helps to reduce the risks of flooding from designated rivers (called 'main rivers') and the sea.
- Internal Drainage Boards (IDBs) have powers to carry out measures to alleviate flooding in districts with special drainage needs, such as the Fens in East Anglia, other than on main rivers.
- Local Authorities have similar powers to carry out works on watercourses, other than on main rivers or in IDB districts.

Strategic framework

MAFF(1996) outlines strategic planning within which consensus between competing/conflicting objectives may be developed. Some examples of strategic planning are:

- Local Environment Agency Plans (LEAPs)
- Shoreline management plans (SMPs) for coasts and estuaries

- Water Level Management Plans

LEAPs (formerly NRA Catchment Management Plans) should include a flood defence strategy for the areas concerned, which will provide a framework within which flood defence works can be developed to take into account wider environmental requirements. They also provide an opportunity for addressing wider strategic matters in relation to the water environment such as the need to maintain viable areas and populations of habitats, species and historic resources.

River restoration

One of the principal achievements of the United Nations Conference on the Environment and Development (Otherwise known as the Earth Summit) held in Rio de Janeiro in 1992 was the signing of the Convention on Biological Diversity by many countries, including the USA and virtually all the European countries. The European Environment Agency published in 1995 an example of more recent initiatives, namely, the Dobris assessment of Europe's environment. It identified 12 major environmental issues to be addressed in Europe. Among these issues are the management of fresh water ecosystems and the loss of biodiversity.

The loss of species, habitats and landscapes has been so great that it has become a political necessity to support remedial as well as protective conservation measures. Rivers and floodplains are prime candidates for restoration as their high ecological, sociological and econonmic value has been systematically degraded by previous generations.

Restoration - The complete structural and functional return to a pre-disturbance state. However, the pre-disturbance condition can rarely, if ever, be achieved.

Rehabilitation - Partial return to a pre-disturbance state. Rehabilitation is the sensible alternative to full restoration and the needs of many user groups may be incorporated, for example, flood defence requirements, habitats and landscapes.

Enhancement - Any improvement in environmental quality. This is usually carried out on a smaller scale and works may be putting in place in-stream features, for example, gravel enhancement for degraded salmonid spawning grounds.

Creation - Development of an ecosystem that did not previously exist at that site.

Many rivers have the ability to adjust and recover from their degraded state. In its attempts to attain a regained equilibrium a channelized river may erode and deposit sediment from its bed and banks thus creating a meandering or braided course. The process can be assisted by removing redundant bank revetment and by reducing the frequency of maintenance operations. All that may be needed is to monitor whether lateral migration is causing problems in respect of prejudicing flood defence requirements.

Non structural - natural recovery

Non structural methods can be summarised as: -

- Catchment planning - In the form of Local Environment Agency Plans (LEAPS) - leading to the integrated management of water quality, water quantity, and the physical environment, with an emphasis on non-structural methods.
- Land use changes - There are currently opportunities to secure sympathetic land use in river corridors as a result of EC directives encouraging farmers to take areas of their farms out of production. For example; Set aside (MAFF), Countryside stewardship scheme (Countryside Commission).
- Species reintroduction and species-centred restoration - Such as enhanced spawning grounds for salmonids. This has involved the removal of silty bed substrate and replacement with single size gravel, which may be used as spawning grounds.