ISSN: 1649-265X

channels & challenges

enhancing salmonid rivers

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Irish Freshwater Fisheries Ecology & Management Series No. 4

Citation for bibliographic puposes:
O'Grady, M.F., 2006. Channels & Challenges. Enhancing Salmonid Rivers.
Irish Freshwater Fisheries Ecology & Management Series: Number 4,
Central Fisheries Board, Dublin, Ireland.

Funded by the Central & Regional fisheries Boards National research Programme.

Published by:
The Central Fisheries Board,
Unit A,
Swords Business Campus,
Balheary Road,
Swords, Co. Dublin.
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Foreward

The use and application in the field of this training manual will greatly enhance the management of Ireland's salmonid fisheries in the future. The manual is a product of Dr. Martin O'Grady's commitment and dedication to the sustainability of Irish salmonid fisheries for both the recreational and commercial use and enjoyment of the Irish angler and anglers worldwide. The idea for a training manual was born as a result of the Irish Government's initiative in the 1990's to begin an in-depth restoration of Ireland's salmonid fisheries. Major funding was provided by the European Union (EU) under Ireland's National Development Plan 1994-1999 through the Tourism Angling Measure (TAM) to upgrade the quality of Ireland's angling resource.

Under the leadership of the Central Fisheries Board's Chief Executive Officer, John O'Connor and the technical guidance and programme development of Dr. Martin O'Grady and his colleagues in the Central and Regional Fisheries Boards, an active and ambitious programme was initiated and a total of €24 million was expended on this programme. Fisheries workers and engineers in major salmonid catchments in Ireland were involved and this became a learning experience for all using techniques heretofore not employed in Ireland, e.g. natural wood and timbers and rock and boulder materials. Most of the techniques for the use of natural materials came from North American fisheries workers where techniques had been "time tested" for over 50 years in diverse watersheds (catchments) under a myriad of hydrological conditions. Development and use of stream improvement techniques in most recent times stemmed from the period of the 1930s in the United States (US) when the government employed the Civilian Conservation Corps (CCC) to begin restoration of stream habitat on National Forests that had been degraded by excessive land use practices, i.e. grazing, timber harvest, mining. Renewed interest in stream restoration in North America (NA) was undertaken in the 1970s by State, Federal, and Provincial fisheries workers under the leadership of the American Fisheries Society (AFS). The AFS began a series of workshops in 1978, held at 2-year intervals, aimed at teaching and developing stream restoration techniques across North America. It was during these workshops, spread across NA that I first made acquaintance with Dr. O'Grady that developed into a friendship lasting over 20 years continuing to this day. The 13th International Salmonid Stream Restoration Workshop held in Westport, Co. Mayo, Ireland in September 2002 brought to light the successes of the Irish restoration works. The need for an extensive training manual to illustrate the successes of each habitat technique was discussed in earnest and a plan for its publication took seed.

Under the Irish fisheries enhancement programme (1994-1999) led by Dr. O'Grady, natural techniques were used to restore riverine habitats across Ireland resulting in over 250 miles of rivers and streams being recovered with fish stock numbers increasing up to 30 times greater than the pre-works conditions. Utilizing these natural techniques Dr. O'Grady and his colleagues developed some new and innovative modifications to some of the construction procedures leading to more effective and efficient hydrological utilization of the structures and usage by salmonids. This manual will be used extensively by Irish fisheries biologists, workers, engineers, and academia and will serve as a guide to river restoration in Ireland. Ireland has become a world leader in salmonid habitat management through their ambitious and successful river restoration programmes and this manual will further solidify their stature in the International fishing community since the stream habitat and hydrological techniques it so ably describes and illustrates will have application for any river and stream worldwide.

I have been fortunate to have been able to work with Dr. O'Grady and the CFB during these restoration programmes and lend whatever knowledge and experience I have gained over my career. I commend Dr.O'Grady and the CFB for producing this detailed and extensive training manual filled with schematics and photographs which show, in no uncertain terms, the successes of the techniques employed in Irish river restoration programme.

Donald A. Duff, Aquatic Ecologist
Forest Service-Trout Unlimited Partnership Program
U.S. Forest Service - Retired

As the last ice age retreated from Ireland, some 10,000 years ago, a bare post-glacial tundra was exposed. Rivers started to etch their course out across the landscape. Sea fishes, the ancestors of salmon, trout, char, eels and pollan slowly adapted to this new freshwater habitat evolving to become the species we know today (Anon, 2005a).

In time the landscape was covered in small trees (mostly Hazel). Later, Elm, Oak and Scots Pine started to colonise different parts of our island some 7,000 years ago (Anon, 2005a).

The first settlers are thought to have arrived in Ireland, from Britain, about 7,000 BC. These people were hunter gatherers. 5,000 years ago farming, as we know it today, was being practised - fields were defined with stonewall boundaries. These appeared to have been dairy farmers who also grew some grain crops (Anon, 2005b).

Gradually our forests were cleared. By the 12th century as little as 1% of Ireland was afforested. Today this figure is approximately 9%. The increased level of afforestation is largely due to plantings of exotic American species (Anon, 2004b).


A glacial river in Iceland.


A beehive hut thought to date from the 12th century. Corbelled buildings in Ireland date back to 3100 B.C. (Newgrange).


The plains of Munster. The forests are long gone.

Many Norman Castles and larger monasteries were built adjacent to major river channels. This was not a coincidence. Processing wool and catching and salting / smoking salmon was big business at that time. The river was also used to transport the produce to market.

Major physical interference with our river channels did not take place until people sought to harness the power of our rivers. A large number of water mills were built in Ireland since medieval times (Anon, 2005c). The larger structures built in the 1800's seriously altered many river channels. To power the mill a large stone weir was constructed to divert water through a mill race (opposite). These large weirs pond a length of river channel (see page 36) and created difficulties for migratory fish.

Serious efforts to make our larger rivers more navigable also resulted in major alterations (photo, bottom right). These involved major weir constructions and the excavation of canal loops often incorporating lock gates (photo, bottom right).

Trim Castle adjacent to the River Boyne.

A large watermill on the River Barrow - now derelict.

River Barrow Navigation Channel.

The most significant changes to our river channels since the last ice age have all taken place in the last century. Many channels were straightened, riparian zones were sometimes eliminated and heavy farm stocking rates contributed to bank trampling and excessive erosion.

Removal of a meander bend.

In broad terms surveys of river corridors indicate that those least altered by man usually support the best fish stocks. The undisturbed ecotone (river corridor) also clearly supports the most diverse flora and fauna.

We must be pragmatic - we cannot go back to a historic landscape in which mankind were hunter gatherers. However, we can learn from our mistakes. American fishery biologists had the good sense to look at the shape and form of undisturbed river corridors and mimic the features observed in river rehabilitation programmes. We have attempted a similar exercise in Ireland with a good degree of success. Our experience has been that giving nature a helping hand, not a handout, works. Wild salmon and trout stocks are perfectly capable of looking after themselves given good habitat and sensible cropping rates.

A nice balance in terms of a river and its riparian zone. Despite intensive land use the river corridoor has retained its essential character.

Acknowledgements

A text such as this cannot be fairly described as the work of one individual. It more accurately reflects the hard work, over many years, of a team of dedicated people - administrators, technical staff and the fishery officers at the "coalface". Indeed credit is also due to many of our former colleagues, at home and abroad, who pioneered works in the river enhancement area - in particular my mentor and friend Don Duff and my longtime confidant Ray White.

A special thanks is due to my colleague Karen Delanty who assembled this manuscript and contributed significantly to its design and layout. I am also very grateful to my colleague Myles Kelly whose skilled hand is responsible for all of the artwork. I feel that this book, in terms of both its content and layout, has been improved significantly by editorial comments from my colleagues Martin Butler, Hazel Dobbyn, Paddy Gargan and Tom Sullivan and my friends John Curtin and Tom Hayden. I appreciate Liz Clarkson and Sandra Doyles's hard work in typing this manuscript and many other related papers. Thanks are due to Dan O'Callaghan for finalising the design of the manuscript.

Many administrators in the Department of Communications, Marine and Natural Resources, the Central Fisheries Board and Regional Fisheries Boards played pivotal roles in organising these enhancement projects.

I would like to thank the Chief Executive Officer of the Central Fisheries Board, Mr. John O'Connor and his predecessor, Mr. Micheal Breathnach, for their encouragement and support. A special thanks are also due to the Chief Executive Officers of the seven Regional Fisheries Boards for their enthusiasm and financial support.

Many colleagues (past and present) in the technical area played crucial roles in carrying out baseline catchment surveys and helping to design enhancement programmes - in alphabetical order I must mention Colin Byrne, Joe Caffrey, Rose Carbonell, Trevor Champ, Declan Cooke, Karen Delanty, Paddy Fitzmaurice, Terry Gallagher, Paddy Gargan, Fran Igoe, Jimmy King, Michaela Kirrane, Milton Matthews, Sharon Molloy, Stephen Neylon, John O'Neill, Brian Purcell, David Smart and Willie Roche.

These acknowledgements would be very incomplete if they did not record the enthusiasm, dedication and ingenuity of all of the staff of the Regional Fisheries Boards who carried out the work on the ground.

In Ireland river enhancement programmes could not be carried out in most catchments without their being a close liaison between the Fisheries Boards and the Engineering Services Section of the Office of Public Works. My sincere thanks are due to a number of engineering staff in this organisation - John Curtin, John Gilmore, John G. Murphy, John Murphy, Michael Collins, Richard Dooley, Jim Dervin and Patsy Gallagher. Their concern to accommodate fisheries interests has contributed significantly to Irish riverine enhancement programmes.

This work has been enhanced greatly by the addition of many aerial photographs. A special thanks are due to the helicopter division of the Irish Air Corp who accommodated the Central Fisheries Board in compiling these images.

I am grateful to Dr. Aine O'Connor, National Parks and Wildlife Service, who provided me with background information on Irish pearl mussel populations.

I would like to thank a number of colleagues who provided me with some photographs - Jimmy King, Bridget Lehane and Tom Sullivan.

I am also grateful to Scottish Natural Heritage who provided me with pearl mussel images.

I would like to dedicate this
manuscript to the memory of
my friend and colleague
Michael Tolan. His enthusiasm,
camaraderie and dedication to duty
were an inspiration to all of us.
His memory will live on.

The Value of Baseline Surveys

In Ireland, most of our larger salmonid catchments have been surveyed by biologists from the Central Fisheries Board, with the assistance of their Regional Board colleagues, at some point since the mid 1970's.

These surveys indicate that a number of land management practices have depressed the production of salmon and trout in many catchments. When designing enhancement programmes, particularly in larger catchments, it is essential to stand back and obtain an overview of the situation.

What are the Objectives of Baseline Surveys from an Enhancement Perspective?

- To identify the degree and extent of habitat degradation and, having done so, to put the various problems in perspective.

- To home in on enhancement proposals for specific areas which are both cost-effective and will make a worthwhile contribution to increasing fish stocks.

- To avoid spending monies on projects of little value e.g. there would be little point in increasing fry production if the survey data showed that the primary factor limiting salmon smolt production was the availability of high quality habitat for salmon parr. Similarly expenditure on bankside or instream enhancement works would be fruitless in channels where there are serious water quality problems.

- To answer some of the broader fishery management questions:

- do juvenile stock levels suggest that spawning escapement is adequate?

- are angler cropping rates or, commercial salmon catches, seriously depleting stocks?

- which land management practices are a serious threat to fisheries. Can these practices be adjusted to limit degradation?

Some of the damaging land management practices which can be quantified in a baseline survey.

Water Quality Problems

Overgrazing

Drainage

Tunnelling

How does a Biologist Identify the Problems?

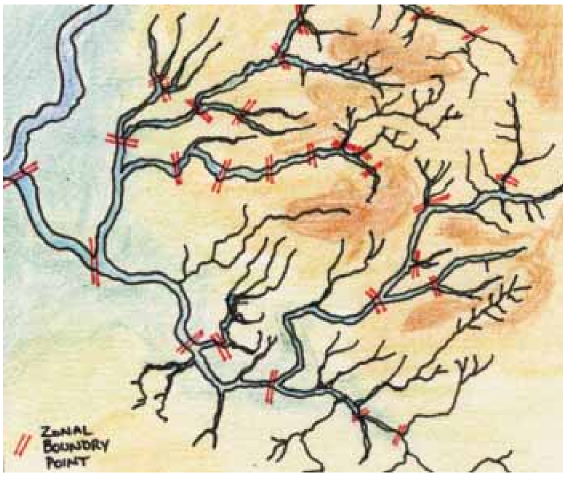
Firstly the catchment must be divided into discrete zones.

How?

If one, or more, of four variables in a channel changes significantly then the fish carrying capacity of the river or stream will be altered (O'Grady, 2002). The four variables in question are:-

- Bed gradient or slope
- Mean summer volume discharge (Q)
- Bed type (material)
- Nature of the riparian zone

Changes to one or more of these variables define the location of zonal boundaries as illustrated below.



Very obvious changes in bed gradient (slope) are evident in the three segments of channel illustrated (top right). Major differences in fish stocks will be evident between sections 1,2 and 3 because of the change in channel slope.

Changes in bed gradient (slope).

Once two channels of a significant size confluence one can expect to find changes in the fish stock downstream of the confluence compared to the populations in both tributaries (below).


Expect changes in fish stocks below the confluence.

The nature of the bed type can have a major influence on the salmonid carrying capacity of a channel. Smooth sheet rock (below) is a particularly unproductive medium for two reasons - few invertebrates are adapted to living on this medium. Water velocities over smooth rock tend to be high and fish have nowhere to rest.

Smooth sheet rock, a very poor salmonid habitat.

In contrast, a mixed boulder, cobble and gravel bed (below) is very productive salmonid habitat. Plants will colonise the larger more stable stones. A host of niches for macroinvertebrates are present. With the availability of food and many places to rest numerous fish will occupy this habitat.

A mixed boulder, cobble and gravel bed is a very productive habitat for salmonids.

Variation in the nature of vegetation in the riparian zone can influence the salmonid carrying capacity (see below).

An unbalanced bankside regime. A monoculture of sycamore trees is providing too much shade - a significant reduction in fish stocks is inevitable

Complete removal of shrubbery will also reduce fish stocks and lead to further habitat degradation.

In drained Irish catchments the initial division of river channels in a catchment into zones is not a major task. This is simply because the gradient, bed type and volume discharge data are all available in the records of the Engineering Services Section of the Office of Public Works (see Appendix I). Walkover surveys are required in relation to defining the nature of and variation between riparian zones. In this regard, the author has found the use of aerial photographic series to be a valuable resource.

Currently digital aerial photographic databases, as part of G.I.S., are being developed which will allow one to zone channels, to monitor change over time and calculate wetted area for each channel (Mcginnity *et al*, 2003). Terrain modelling of catchments will allow generation of gradient values for any particular channel reach.

Survey Details

Once the zones have been identified the biologist must select one or more typical reaches within each zone to study in detail. The level of physical detail one needs to record for each reach is considerable. In addition, the salmonid stock present, and all other fish species, if possible, should be quantified. Fish captured in a sample are measured and a proportion are scaled for subsequent age analysis.

CENTRAL FISHERIES BOARD

QUALITATIVE/QUANTITATIVE FISH STOCK ASSESSMENT SURVEY SHEET

SUB-CATCHMENT:
TRIBUTARY:
SITE NO. & LOCATION
GPS/GRID REF.
*CHANNEL CODE
*CHAINAGE:
POLLUTION STATUS EPA Q-value:
DRAINAGE STATUS
Undrained/drained/recently maintained
BANK HEIGHT (LHB) 1m
(RHB) 1m

RIVER:
PHOTOGRAPH: ✓
DATE:
GEAR TYPE: HANDSET×1 BOAT
OPERATOR:
WATER LEVELS (or gauge reading)
FLOW RATE (m/sec)
Mean channel width * length = AREA
m* m= m2

%POOL	30
%RIFFLE	10
%GLIDE	60

	YES	NO
FENCING	✓	
TRAMPLING		X
BANK EROSION	slight	
BANK SLIPPAGE		✓

THALWEG: none/moderate/well defined

RIVER BED DIVERSITY: uniform/broken eroding/depositing

BANK COVER TYPE (%cover) -LHB:
-RHB:

DEPTH	Riffle	Glide	Pool
RANGE			
MEAN			

SHADE: none (0%) light (<25%) medium (<50%) heavy (<75%)

LAND USAGE: grazing

MARGINAL VEGETATION (% cover)

INSTREAM VEGETATION (% cover)

GRADIENT (%)

SURFACE SUBSTRATE TYPES	Riffle	Glide	Pool
exposed bedrock sheet			
boulder (26-51cm)			
cobble (6-26 cm)			
gravel (0.4-6 cm)			
sand			
mud/silt			
Substrate summary			
'ROSGEN' CHANNEL TYPE			

INVERTEBRATES: Riffle areas only (State whether Abundant, Common or present)

OLIGOCHAETES		E.IGNITA	P	CHIRONOMIDAE	P
HIRUDINEA		BAETIDS	A	Red:	
ASELLUS		CAENIS		Green:	C
GAMMARUS		BEETLES		SIMULIDS	A
PLECOPTERA		TRICHOPTERA		SNAILS	A
EPHEMERA		Cased:		OTHERS	
RHITHROGENA/ECDYONURUS		Uncased:			

CURRENT STATUS/POTENTIAL: RECOMMENDATIONS

Spawning:
Nursery:
Angling:
General comments:

Survey information compiled at each sampling location.

(* see appendix I in relation to channel code and chainage values)

From an enhancement perspective the compilation and analysis of these data allow the various imbalances to be identified, quantified and costs set against their repair.

The three channel reaches above are all in the same catchment. Would you expect them to have the same fish carrying capacity?

Once a reach has been selected for detailed analysis the following electrofishing procedure is adopted to quantify fish stocks.

- Stop nets are secured in place at each end of the reach. The reach is electrofished in an upstream direction from the lower stopnet.

- Where the reach is relatively shallow and can be waded safely either backpack units or equipment powered by small generators are used. A single electrofishing unit is adequate to fish streams ≤3 metres in width. In bigger channels multiple units are required - one for every 3 meters of stream width.

- In deeper channels, that cannot be waded, large generators, mounted in boats, are used. One boat is adequate to electrofish a 5-meter wide channel. Multiple units are required in bigger channels - one unit for every 5 meters of stream width.

- A reach must be electrofished at least twice in order to quantify fish stocks. When stocks in a reach are relatively high or difficult to capture, because the reach is boulder strewn or heavily weeded, a third fishing may be required to achieve an accurate estimate. Population estimates can then be calculated using the two fishing depletion formula of Seber and Le Cren (1967) or the three fishing depletion method of Zippin (1956). Where confidence intervals are unacceptably high (>30%) or, if only a single fishing is possible, minimum densities values can be calculated (Crisp, *et al*. 1974). The choice of one methodology over time, for comparative purposes, is desirable.

Once fish densities have been quantified for one or more reaches in every zone then it is a simple process to estimate the standing crops of all fishes for the catchment as a whole. Many important management questions can then be answered:

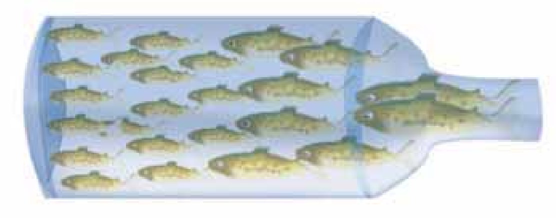
- Are fish stock levels lower than expected?
- Has serious habitat degradation been noted in any zone?
- Are there water quality problems evident in particular areas?
- Is salmon escapement adequate to fully spawn the catchment?

Electrofishing records for a particular reach.

What Type of Imbalances are Likely to be Found?

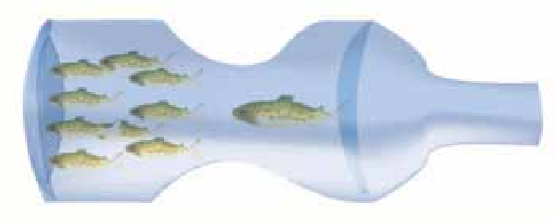
The following simplistic models summarise the type of imbalances one is likely to meet.

No Problems - There are adequate spawning areas. Fry production is sufficient to fully stock the nursery areas and adult zones for trout. In the case of salmon, fry numbers are sufficient to fully populate parr zones thereby optimising smolt production. There are adequate lies for returning adult salmon throughout the system and no serious impediments to their movement upstream towards the spawning beds.

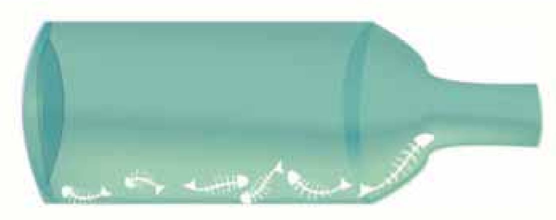


Inadequate Spawning Areas - A serious problem. If spawning areas are insufficient then the whole system is impaired. Inadequate fry production will automatically cap the production of older fish. Surveys have shown that this is not a common problem in Irish catchments.

Inadequate/Poor Quality Nursery Zones - In many rivers salmonid production has been impaired by a range of land management practices. Many of these channels still have significant spawning zones capable of producing large fry numbers. The problems arise thereafter - poor quality nursery areas limit the survival of salmon fry to the smolt stage. The limited quantity and quality of pool areas may significantly reduce the survival of trout fry to adulthood. These are the most common problems in Irish systems.

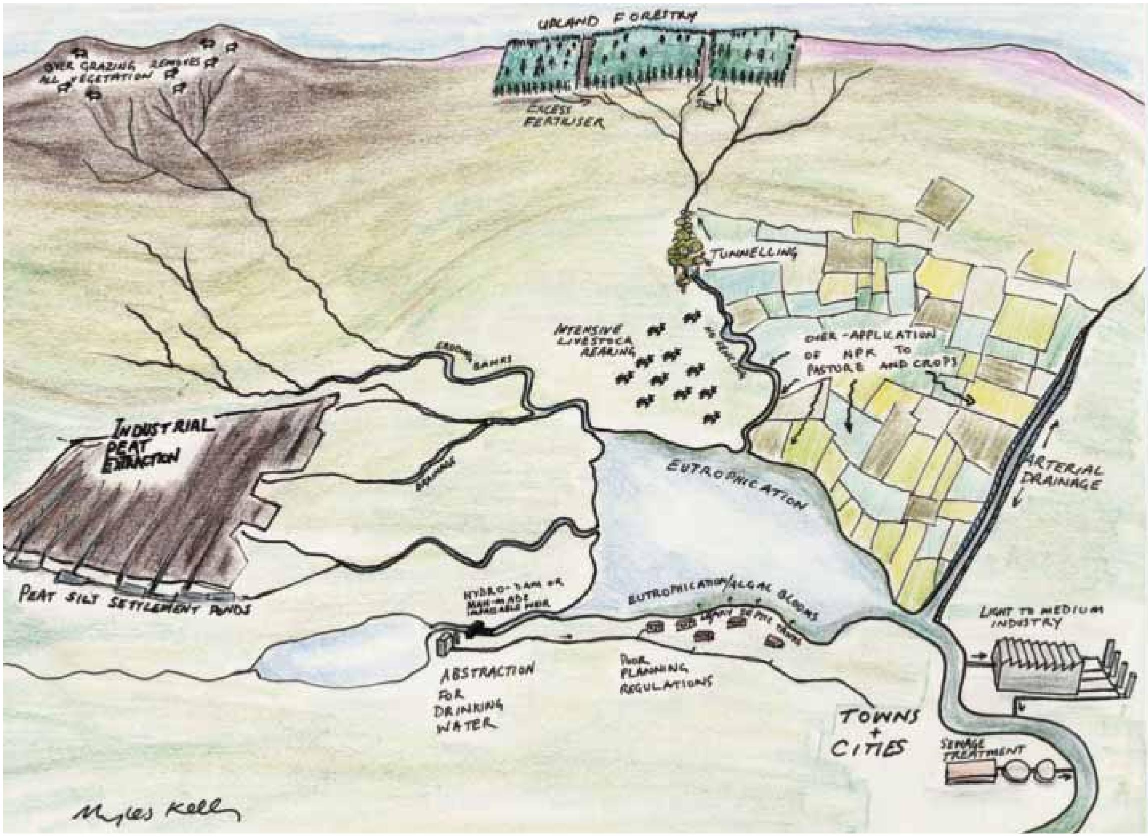


Poor Water Quality - The most serious problem. Forget about instream or bankside enhancement until water quality problems are resolved.



Problems in Irish Catchments

Baseline surveys in Irish Catchments have highlighted a range of activities which can lead to habitat degradation problems. The range of factors which can cause problems are illustrated below. The impacts of individual problem areas are detailed subsequently in Chapter 5. Techniques designed to repair these problems are detailed in Chapters 6 to 10. The benefits from addressing these imbalances for some individual channels are quantified in Chapter 11.



The type and location of potential problem areas in Irish Catchments.

Chapter 2

The Critical Importance of Water Quality

Extensive monitoring of riverine enhancement programmes has been carried out by Central Fisheries Board personnel over many years. Most of these programmes have been successful (see Chapter 11). Projects which failed can, in most cases, be related to circumstances where, following the completion of works, water quality in the stream or river in question deteriorated. It is critical therefore that any proposed stream rehabilitation project be prefaced by an examination of the water quality in the stream or river in question. Should an examination indicate poor water quality then one would be strongly advised not to invest in bankside or instream physical habitat improvements.

Recognising Poor Water Quality

Since 1973 the Environmental Protection Agency have been monitoring water quality in Irish river catchments by examining the macroinvertebrate fauna at 3,100 locations throughout the country. Each site monitored is revisited once every three years and the quality value updated (Toner *et al.*, 2005). The EPA assign a quality rating of Q1 up to Q5 for individuals sites - Q5 values indicate pristine conditions with declining quality indicated as the Q value falls.

One should check EPA records to see if there is a sampling station within the proposed reach targeted for rehabilitation. If a Q1 or Q2 value, based on macroinvertebrate populations, has been assigned to a reach then rehabilitation, for salmonid stocks, should not be attempted unless you are aware that the source of the pollution problem has been addressed and eliminated since the low Q value was recorded (Kelly *et al.*, 2005).

One should also check Regional and Central Fisheries Boards records to see if there are any historical records of pollution problems in the proposed works area.

If a detailed baseline survey has been carried out prior to implementing a development plan then the polluted zones will already have been identified.

A badly polluted stream.

Plant Indicators

Both the flora and fauna of a river channel can be used to identify organic pollution problems and thereby forewarn one that an investment in the restoration of the physical form of a polluted channel or, the re-establishment of a proper riparian zone, is simply a waste of resources.

Even streams draining steep mountain slopes have floral communities - generally speaking they are dominated by algae and mosses which colonise outcrops of bedrock and the larger more stable cobbles and boulders. Lower gradient steams and rivers draining floodplain areas tend to have much more diverse and complex floral communities.

However, the over-abundance of certain plants are a very clear indicator of organic enrichment problems.

Q 3-4: Moderate Water Quality

A monoculture and overproduction of fennel pondweed (*Potamogeton pectinatus*). This river has an organic enrichment problem.

Q 5: Pristine Water Quality

A clean upland stream where the flora is dominated by mosses.

Q 2-3: Moderate Water Quality

Excessive algal growth, a consequence of organic enrichment.

Q 4: Good Water Quality

A mosaic of plants in a clean lowland springfed channel.

Q 1: Poor Water Quality

Lots of sewage fungus. A stream grossly polluted by organic effluent.

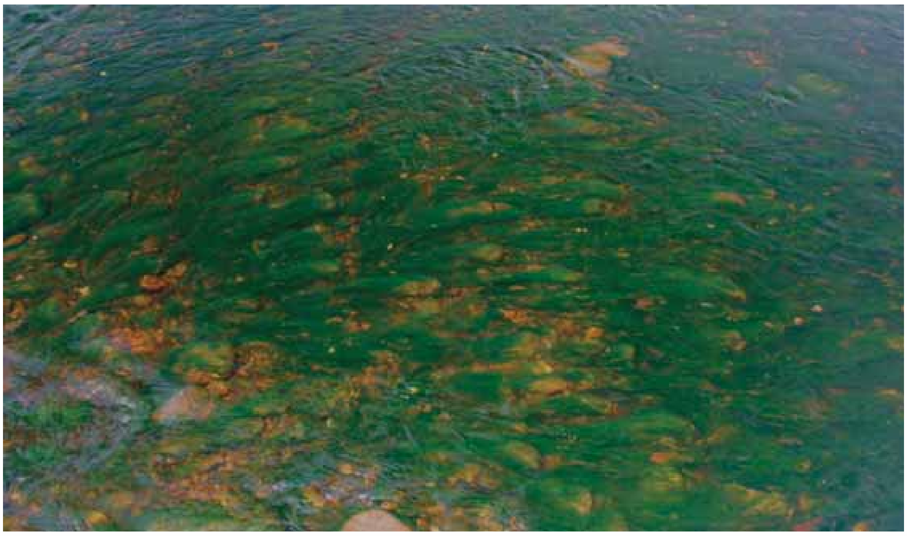
Macro-invertebrates

An EPA Q value, based on macroinvertebrates for a particular site, is assigned principally on the range of species present and their relative abundance. In fast-flowing shallow streams and rivers the absence of certain mayfly (Ephemeropteran) and stonefly (Plecopteran) species and/or an abundance of red midge larva (Chironomids), leeches Hirudinea), water louse (*Aselluse*) and shrimps (*Gammarus*) can indicate organically polluted conditions.

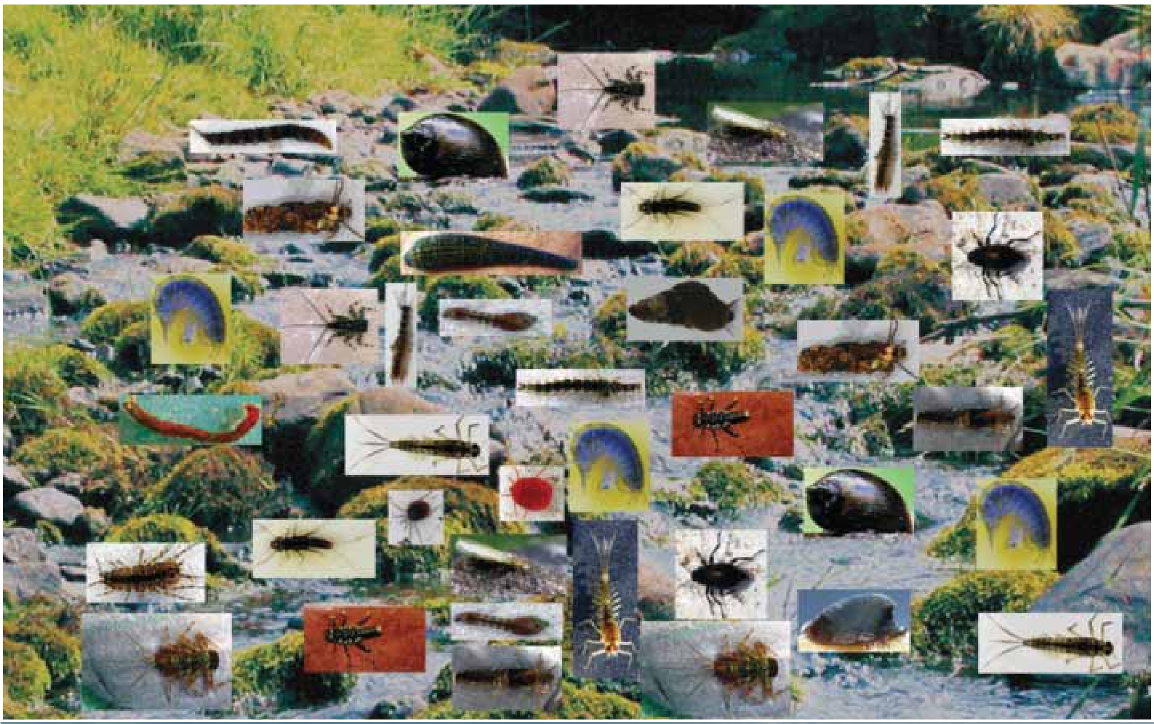
If, after an initial examination of a site, there are doubts about the water quality of a channel one should seek the assistance of trained personnel to establish the Q value.

The quality of the macroinvertebrate fauna in rivers should always be checked by sampling in shallow riffle areas - this is where most of the pollution-sensitive invertebrates live

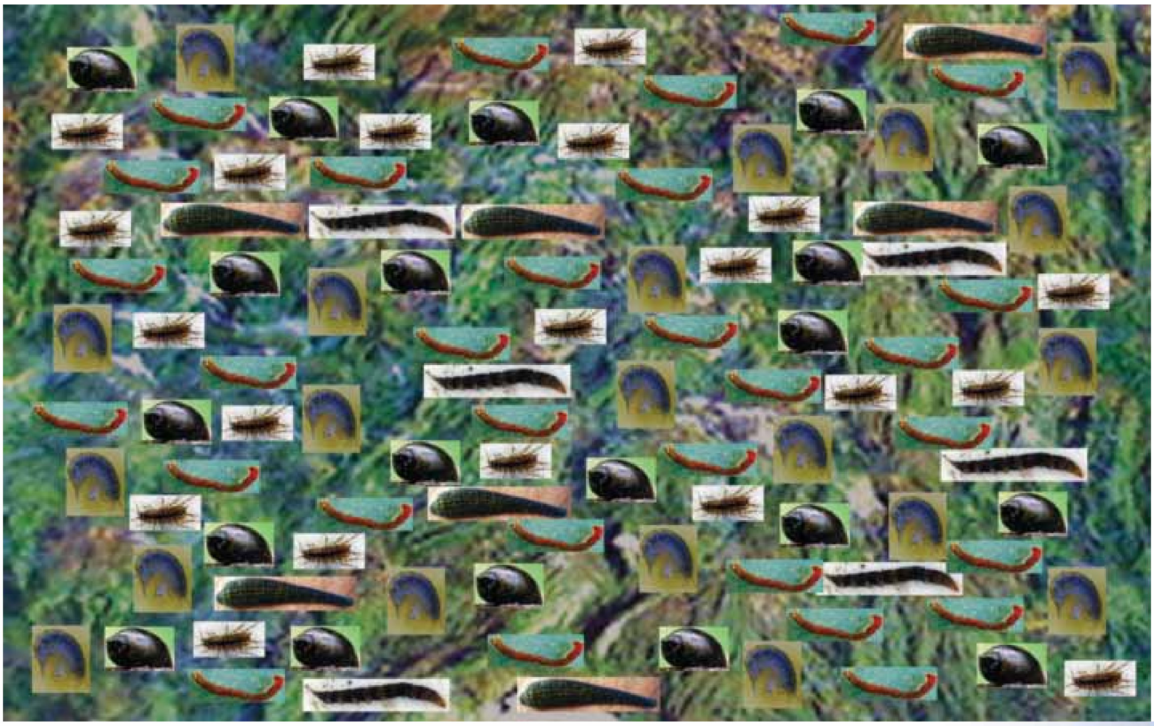
Collecting a macro-invertebrate sample.



The excessive algal colonies here hide the gravels and cobbles beneath. This reach is polluted by organic effluents. Large numbers of invertebrates may be present. However, only a small number of pollution tolerant species will be observed. In a stream such as this a Q value can be expected to be in the Q2 to Q3 range.



A very wide variety of species will be found in clean riffle areas.



One or more of these species will usually be super abundant in polluted riffles. Once polluted to this level many species, illustrated in the top photo, will disappear. All of these invertebrates may also be present in clean water sites but only in small numbers.

Gross Pollution

The Environmental Protection Agency in Ireland has reported a significant decline in the incidents of gross organic pollution over two decades (Toner *et al.*, 2005), thanks to the responsible attitude of most members of our community. Regrettably occasional gross pollution incidents do still occur. Their impacts are easily recognisable. The gravel/cobble bed of this small stream (below) is covered in organic sludge.

Discharge of effluent from a farmyard has covered the bed of this stream with organic sludge.

Note the red patches in the sludge. These are thriving colonies of pollution tolerant worms and midge larva (inset).

A sample of the sludge. The grey slimy material at the top of the net is sewage fungus (dense bacterial colonies). The large colonies of red worms (oligochaetes) and midge larva (chironomids), present in the organic sludge, are inset.

But don't despair! Once the effluent discharge is stopped a stream will quickly breakdown and flush out the excess organic material. The channel (below) was as badly polluted 2 years ago. Since it has recovered, the macroinvertebrates associated with clean water conditions have recolonised this stream. Enhancement of the physical condition of this stream, if required, could now proceed and prove fruitful.

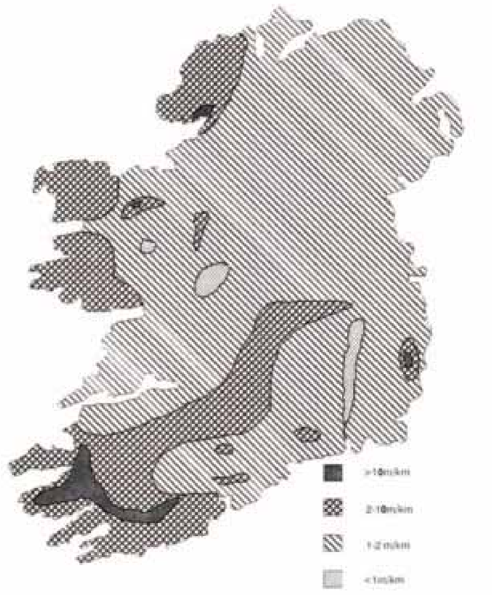
The contribution of the sludge washed downstream, to the cultural eutrophication problems in this catchment, is part of another story beyond the scope of this manual.

There is a need to co-ordinate information on plant communities, macroinvertebrates and water quality analysis when assessing the pollution status of a particular channel.

Chapter 3

The Natural Physical Form of Irish Channels

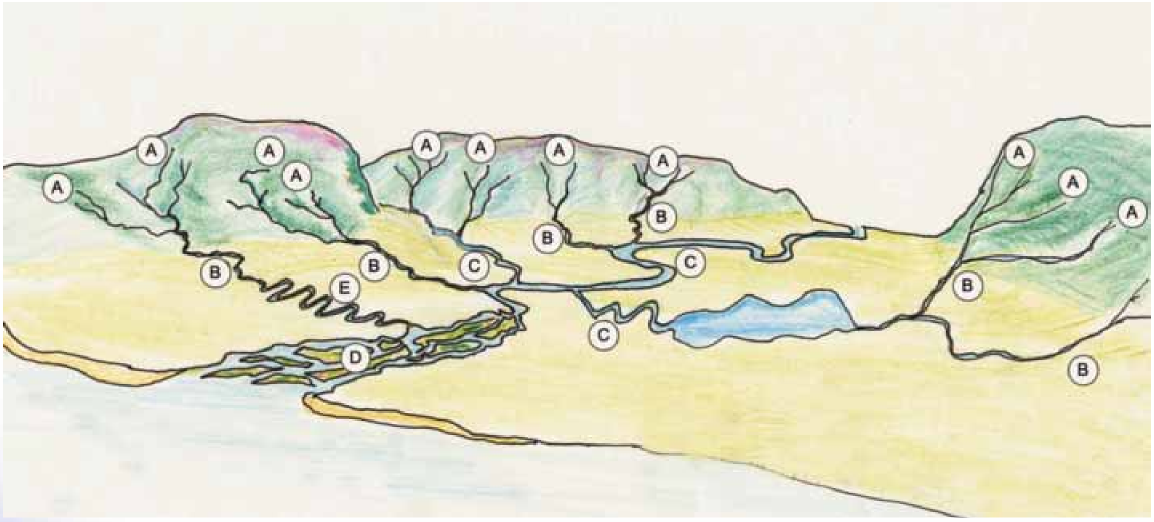
The topography of a region largely dictates the shape and form of its river channels. Ireland has a relatively flat landscape surrounded by coastal hills (see opposite). Consequently most channels fall into the A, B, C, D and E fluvial geomorphological categories as described by Rosgen (1996) (see below). A-type channels are too steep to be of value in salmonid terms. B,C and E-types provide both spawning and nursery habitat for salmon and trout. Most angling zones for salmon and trout, in Irish rivers, lie within C and E type zones. Estuarine reaches (D) can be important feeding areas for sea-trout. Lakes are a common feature of Irish catchments, they help to buffer flood flows by acting as temporary storage depots during flood events. Bogs also buffer the hydrology of catchments - acting like sponges, they soak up rainfall and, thereafter, gradually release the water.



Physiography of Ireland (from O'Grady & Curtin, 1993)

Why Worry About Natural Physical Form?

If land management practices have led to a serious alteration of natural channel form, one must be able to recognise the physical changes and take cognisance of such alterations when designing an enhancement programme. Any attempt to incorporate features of perhaps a C or E-type channel in a disturbed B-type zone or, vice versa, will almost certainly fail!



Channel features in a Typical Irish Catchment.

Channel Zones of Fishery Importance

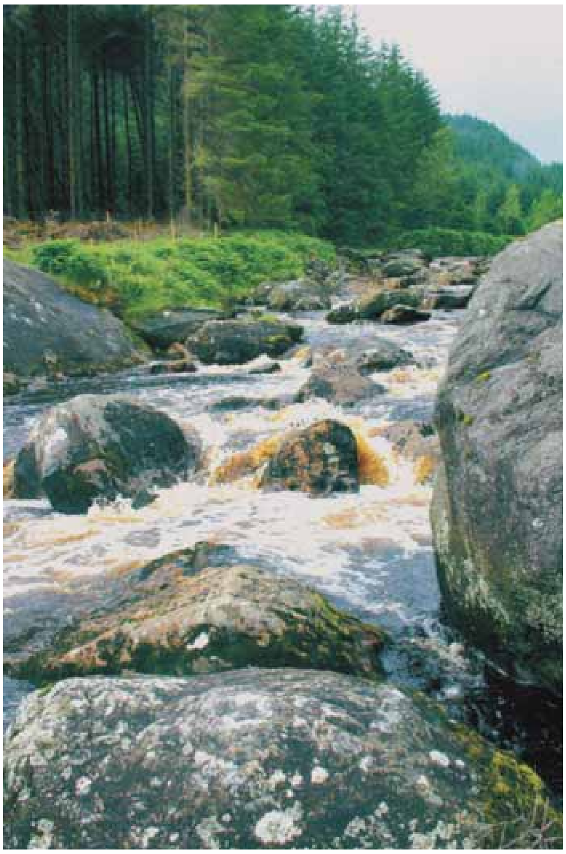
High Gradient B-Type Channels (2-4%)

High gradient channels (2-4%) draining the lower slopes of our hills have certain obvious physical characteristics:-

- Many are boulder strewn with a bed of cobbles and gravels.

- They are relatively straight channels with a repetitive cascade/pool or riffle/pool sequence (B-type channels - after Rosgen, 1996).

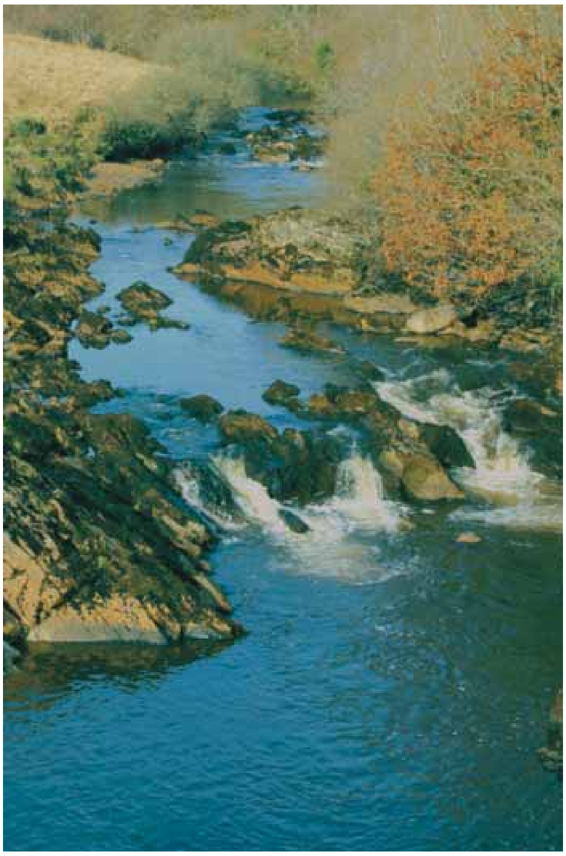
These can be important salmonid spawning and nursery zones provided they are not located upstream of impassable waterfalls.



A clean upland stream where the flora is dominated by mosses.

Many will have exposed shoals of bedrock partially worn down by river flows since the last ice age over 10,000 years ago.

In a relatively undisturbed landscape, upland channels will often have a well vegetated riparian zone including a variety of tree species.



Another upland reach traversing a bedrock shoal. Note the extensive bankside shrubbery.

Pools in B-type channels are usually spaced, on average, at 4 to 5 stream widths in distance apart - don't expect pools in any river to be equidistant in terms of their spatial distance. B-type channels are normally moderately entrenched and usually drain valleys with a narrow flood plain.

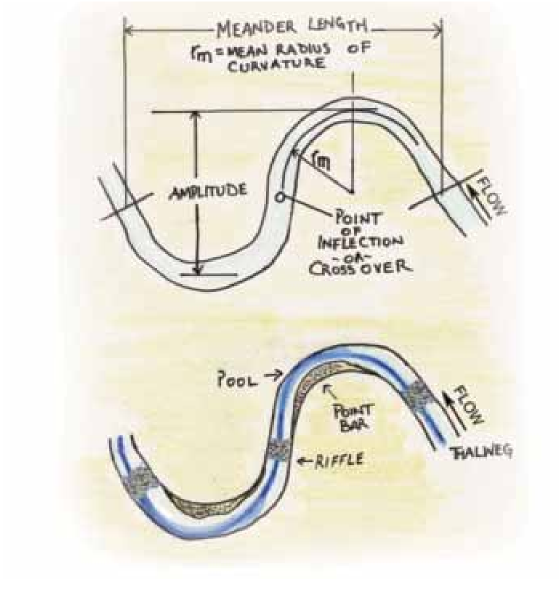
Lower Gradient C and E-Type Channels (<2%)

The lower gradient C and E- type channels draining our floodplains are the most important for salmonid fishes. They provide spawning opportunities for salmonids. Extensive nursery zones will be present adjacent to spawning areas. Pools on meander bends will provide lies for adult trout and resting places for adult salmon and sea trout returning to spawn.

A majority of Irish rivers traversing broad floodplains are C-type channels (after Rosgen, 1996). They are meandering in character. Their banks are relatively low - flood flows regularly spread onto the flood plain. Their banks, if undisturbed, are usually well vegetated - the channel above is clearly not in this category. However it was selected here to provide the reader with an unimpeded view of the physical form of such channels.

Size is not important. The same physical characteristics are evident in small streams and larger rivers once they are within the same fluvial geomorphological category.

Detail in relation to the physical form of C-type channels is provided in the graphic and photo below.



Graphic from White & Brynildson (1967) with measurements.

The thalweg, or sinous line or deep flow, so characteristic of meandering channels, is illustrated in the graphic (above). This feature is very evident in the tidal creek at low tide (below).

The thalweg is very evident here at low tide.

A typical E-type reach.

E-Type Channels

A second less common type of floodplain channel is evident in Ireland, particularly in the Munster Region. In physical terms E-type channels are similar to C-types with a meandering channel form though the meander pattern is even more sinuous in an E-type. The location and distribution of riffles and lateral scour pools is similar in E and C-type channels. The other significant difference is the fact that E-type zones tend to be more incised - i.e. the banks are higher resulting in minor floods being maintained within bankfull (see graphics). Similar flood events in C type channels would spill onto the flood plain. Irish E-type channels are generally good salmonid spawning and nursery waters and the larger rivers of this type usually provide quality salmonid angling.

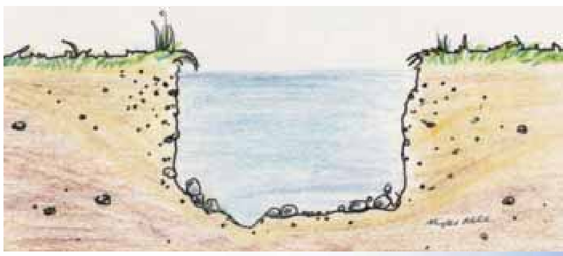
The essential differences between C and E-type cross-sections on a meander bend are illustrated in the graphics below.

Undisturbed Irish estuarine reaches are usually braided in character (D type channels, after Rosgen, 1996). However, many of our larger estuaries have been modified using groins to maintain a deep central channel to accommodate shipping interests (see below).

A Irish D-type reach modified to accommodate shipping.

The comments in this chapter on the fluvial geomorphological form of channels are merely an introduction to this subject. A comprehensive review of this topic is provided by Rosgen (1996) which includes a detailed sub-division of the aforementioned channel types and a very useful summary of the rehabilitation techniques which are appropriate in different channel forms in North America. Leopold (1995) should also be considered compulsory reading for the serious student.

C-type and E-type cross-sections on a meander bed.



A C-type channel.

Chapter 4

How to Recognise Healthy Channels from a Salmonid Perspective

Before looking at problem areas one should first be aware of what constitutes a balanced riverine condition from a fishery perspective. The basic information on channel form in Chapter 3 is provided to give one an overview of the most common natural physical form of river channels in Ireland.

In more general terms there are particular features which are indicative of a healthy status.

An upland stream.

A Balanced Riparian Zone

The three channel reaches illustrated (across) have very different riparian zones because of their geographical locations. Despite the differences they can all perform certain specific functions:

- Provide bank stability and prevent excessive erosion.
- Partially shade the channel. This provides a camouflage effect for fish and helps to reduce high summer temperatures.
- Provide decaying vegetation in the channel which is a food source for certain macro-invertebrates.
- Provide a special niche habitat for a host of invertebrates, nesting and/or feeding sites for many birds and roosting and feeding areas for a number of bat species. Frogs will often hibernate along river banks. Otter holts are usually located on well vegetated stable river banks.

A stable vegetated riparian zone can take many varied forms and still provide adequate bank stability and cover to accommodate fish.

These photographs provide some indication of the acceptable range of variability.

The middle reaches of a tributary in one of our larger catchments.

A lowland main stem.

The old adge - “if its not broken don't fix it” - should always be applied to river enhancement projects.

A Healthy Instream Regime

Flora

The aquatic flora in healthy Irish rivers is also very variable. Plant communities tend to become more complex as the gradient in a channel declines.

Mosses and algae dominate the flora in high gradient streams.

As the gradient declines rooted plants (macrophytes) become more prolific. Note the continued presence of mosses on the large cobbles.

The very different floral regimes illustrated here have evolved to suit the differing hydraulic and bed sediment types in a range of natural channels. They all represent the norm in particular undisturbed channel types.

Mosses and algae tend to be the dominant floral groups in boulder strewn upland B-type channels where they can colonise bedrock, stable boulders and large cobbles. As one travels downstream onto the floodplain gravel/silt deposits become more extensive in both C and E-type zones. Here the floral community changes with macrophytes (rooted plants) tending to dominate. The nature of the floral community may change again further downstream with more silt tolerant plants being present.

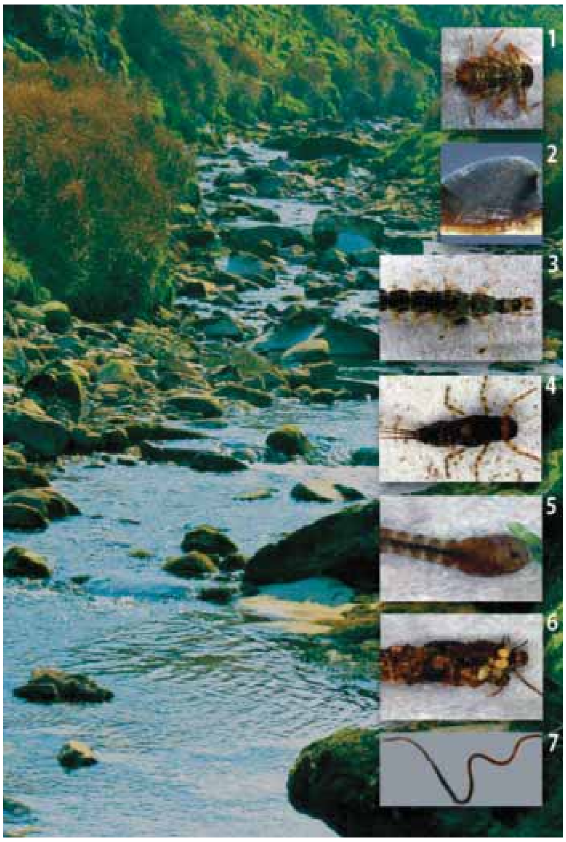
Do not expect uniformity in the floral community. For example if a channel traverses an isolated bed rock shoal in its lower reaches the floral community may revert to being dominated by mosses. Similarly in a terraced, low gradient reach at a high altitude a typical lowland type flora may be present.

In all undisturbed, unpolluted, channels expect to find a diversity of plant species in all areas. A complete dominance of one plant species is usually an indicator of a physically altered or, an organically polluted zone.

In lowland relatively unpolluted channels a complex mosaic of macrophytes should be present.

Macro-Invertebrate Fauna

The macroinvertebrate fauna, like the aquatic plant community, has evolved to fit the various ecological niches in different river zones.



Many of the life forms in high gradient channels are anchored or dorso-ventrally flat in shape to withstand high flows.

The macro-invertebrates illustrated in the high gradient (B-type) channel (left) have evolved, in different ways, to tolerate the often torrential conditions they experience here.

- Many of the mayfly (Ephemeropteran) larvae (1) living here are dorsoventral ly flattened so that they can cling to the stones and offer minimum resistance to the flow.
- The freshwater limpet (Ancylus) (2) uses a sucker to secure itself to hard surfaces.
- Other species like the caddis larva (Hydropschye) (3) and the mayfly (Ephemerella) (4) can crawl into moss colonies to seek refuge from flood flows.
- Midge larva (Simulids) (5) can spin threads to anchor themselves to rocks or vegetation.
- Cased caddis (Trichoptera) (6) can cling securely to the undersurface of boulders and stable cobbles.
- Aquatic worms (Oligochaetes) (7) can live in the pockets of fine sand found in eddies and backwaters.

An Example of Adaptation to Natural Conditions

The stonefly, a relatively primitive insect, is a good example of a macroinvertebrate which is very well adapted to conditions in boulder strewn torrential mountain streams.

The stonefly nymph (left) has a number of obvious features which make it particularly well adapted to these conditions:-

- With streamlined bodies they offer little resistance to flow. Their shape enables them to hide in crevices in the stream bed during flood flows.
- Their strong limbs allow them to move quickly along the stream bed.
- With claw like feet they can maintain a secure grip on rock surfaces.
- Their primitive plume - like external gills, along the sides of the thoracic segments, are adequate for breathing purposes in highly oxygenated streams.

Stonefly larva.

Stoneflies, as adults (below), hatch, mate and return to lay their eggs in the river and subsequently die all in a matter of days. They have two well developed pairs of wings which make them strong fliers - an obvious advantage for an insect living in exposed windy areas.

Adult Stonefly.

The physical alteration (simplification) of natural channels by straightening, artificially widening, or dredging the bed will inevitably lead to a loss of certain micro-habitats and their adapted macroinvertebrate community.

In meandering (C and E-type) channel reaches one can expect to find much more diverse and complex macro-invertebrate communities (below). This is due to the broader range of micro-habitats available here compared to upland B-type channels.

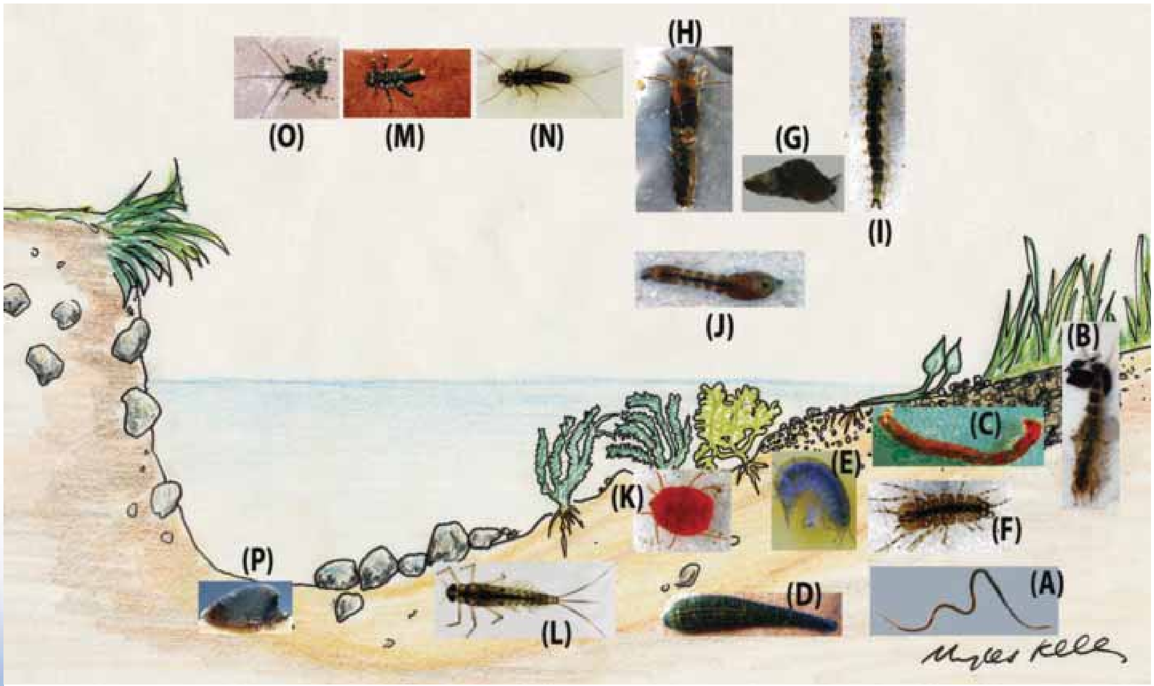
The cross-sectional sketch of a meander bend (below) illustrates the physical and floral variation one can expect in such circumstances. A wide variety of micro-habitats provide homes for many invertebrates which have evolved to suit a particular micro-habitat at some point across the channel.

Aquatic worms (A), some mayflies (B) and certain midge larva (C) will burrow into the soft sediment at the edge of the point bar. Leeches (D) will also be found here. Two crustaceans, shrimp (E) and the freshwater louse (F) are also likely to be present.

A quite different assemblage of invertebrates will live in the weeded zone. Here one is likely to find various snail species (including *Potamopyrgus* (G)), a variety of cased (H) and uncased caddis larva (I), shrimps (E) and water louse (F), midge larva (*Simulium* (J)), mites (K), swimming and crawling mayfly nymphs (L).

In the fast flowing deep area (thalweg) next the eroding bank a different assemblage of invertebrates will be found. These would include various stonefly larvae (M&N), dorso-ventrally flattened mayfly species (O) and the freshwater limpet (P).

The invertebrates illustrated here for these micro-habitats are not intended to be an exhaustive list of all species present. They merely illustrate the degree of specialisation which has evolved within the invertebrate community to occupy the wide variety of habitats in undisturbed rivers.



Cross-section of a meander bend.

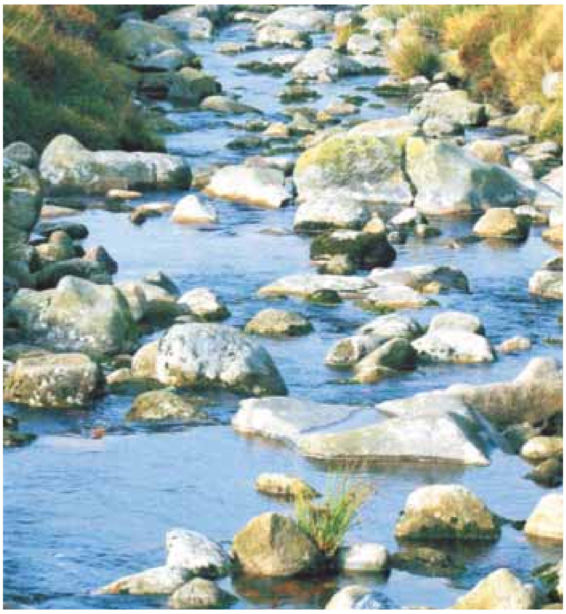
Some Features of Salmonid Stocks in Undisturbed Channels

The distribution of salmonids, like the flora and invertebrate fauna of channels, will be dictated in the first instance by the physical form of the channel.

In upland high-gradient B-type zones salmonid stocks will be dominated by younger fish, mostly 0+ and 1+ years of age. Larger, older trout (>2+ year old) will not be common place generally because few deep pools are present and the food supply is inadequate to sustain large numbers of such fish. Salmon may be entirely absent because of impassable waterfalls downstream or simply because adult salmon in Irish channels will rarely spawn in channels, with a base width ≤3.0m. Few, if any, non-salmonid fish species will be found.

Once a channel reaches its flood plain and becomes meandering in character its fish stock is generally more complex because a wider variety of micro-habitats are present. Large 0+ salmonid stocks will generally be present. In larger Irish main stem channels (≥15m) the majority of 0+ salmonids present are salmon. This is because the gravel deposits here to tend to be relatively large, in terms of pebble size, and therefore more suited to salmon than trout for spawning purposes. Few brown trout in Irish rivers exceed 2.0kg in weight. Most young trout recruit from tributaries to a main stem as yearlings. In glide areas 1+ and 2+ year old salmonids will dominate the fish stock with the larger older trout living in the lateral scour pools on meander bends (O'Grady, 2003).

In both C and E-type channels many other fish species have a niche available. These include one or more of the following species - 3 and 9 spined stickleback, minnow, stoneloach, gudgeon, dace, perch, pike, eels, roach and juvenile lamprey (brook, river and marine). The presence of one or more non-salmonid species reflects the wider availability of habitat types suited to these species.



An upland high gradient reach where fish stocks will be largely confined to 0+ and 1+ year old salmonids.

A lowland meandering reach where all age groups of salmonids and a number of other non-salmonid species may be present.

Chapter 5

When is a Channel Seriously Damaged From a Fishery Perspective?

Once you are familiar with the physical and ecological characteristics of a healthy channel damaged reaches are easily recognised.


Removal of a meander in a C-type channel.

The previous two chapters have outlined the extent of natural variety in riparian zones. The linkages between the physically diverse nature of a channel and its flora, invertebrates and fish fauna have also been illustrated. This chapter outlines in detail the negative effects of certain land management practices on the fishery function of channels.

A channel can be regarded as being seriously damaged in fishery terms when:

A) Arterial drainage programmes have created a very uniform physical regime with a consequential loss of ecological diversity at all levels.


Overgrazing has lead to excessive bank erosion . A C-type channel has now become braided.

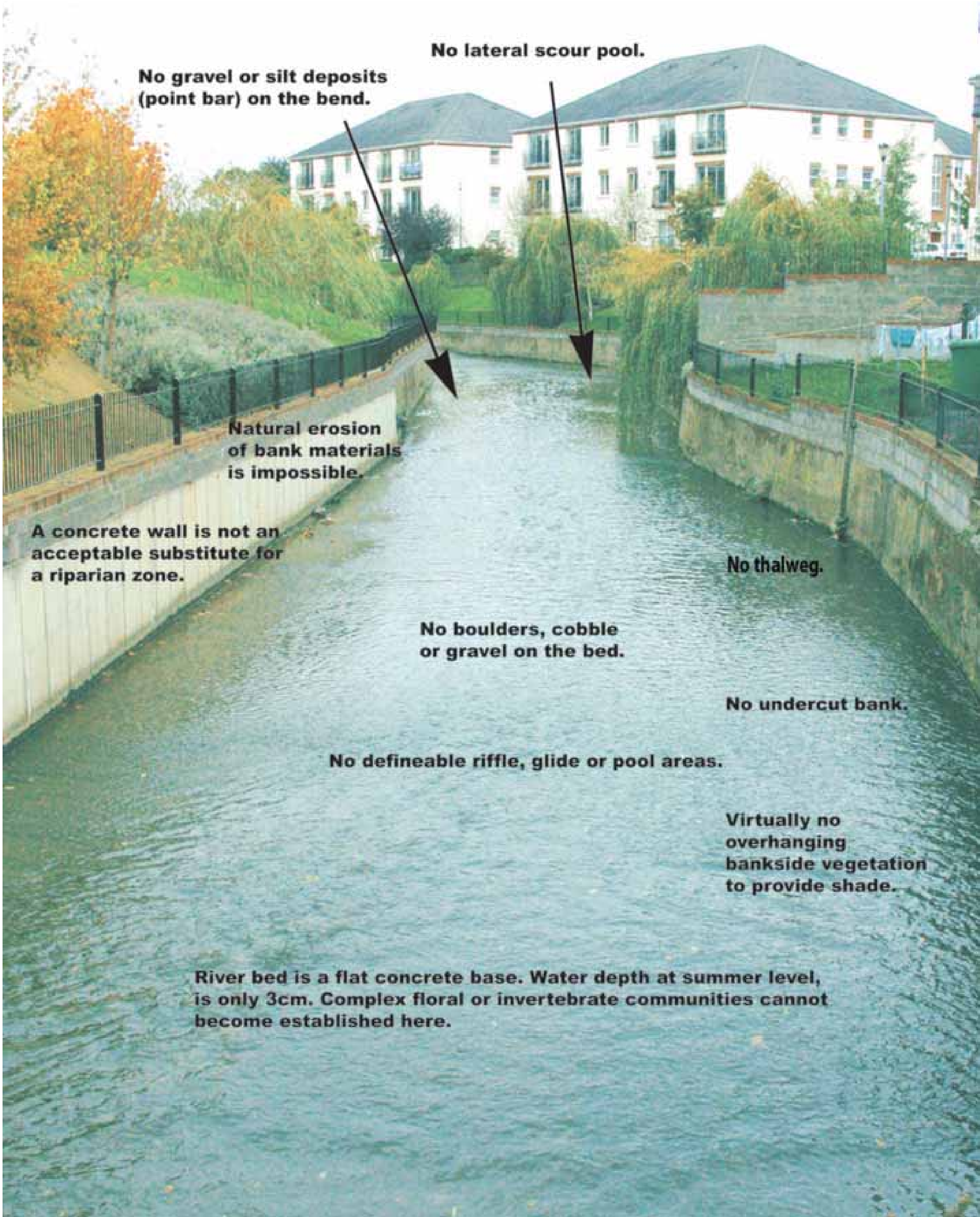
B) The riparian zone has been either entirely removed or has become dominated by one tree species (alder). Both of these processes will result inevitably in excessive bank erosion and general channel degradation in physical and ecological terms.

C) Overgrazing and/or bank trampling has resulted in a loss of the riparian zone and subsequently loss of physical and ecological diversity.

The land management practices which have impacted negatively on Irish rivers all have one feature in common - they have reduced the physical complexity of these channels resulting in a major reduction in general ecological diversity with a consequential reduction in fish stocks.


Excessive shade has lead to significant bank erosion resulting in the formation of a wide shallow silted channel.

The ultimate in river destruction! What's wrong? Just about every natural physical and ecological feature of a river corridor has been removed. If you can recognise all of the problems listed here then you are likely to recognise one or more imbalances on any particular channel. Thankfully few river reaches in Irish catchments fall into this category.



The Major Problem Areas

Specific details of the negative impacts of certain land management practices on the fishery aspect of channels are provided here.

Arterial Drainage Programmes - Long Term Impacts

The long-term impacts of drainage on the fish carrying capacity of Irish salmonid rivers is, in most cases, very significant. Surveys have shown little physical recovery of the natural form of channels even 60 years after drainage and, as a consequence, there are negative impacts on fish stocks. Available data suggest that, without enhancement programmes, most channels would not recover physically for hundreds of years and, in many cases, not at all.

WHY?

In most drained Irish catchments where the gradient is ≤ 1% channels do not generate sufficient energy to reshuffle bed material. The erosion of bankside materials may also be limited, particularly where the banks and bed are composed of hard boulder clay material. This means that there are inadequate quantities of mobile gravels and cobbles to form riffles and that new pools are not scoured out. In meandering channels significant point bars will not form. In their absence proper lateral scour pools will not be present and the spawning gravel deposits in riffles, located either side of a meander bend, will probably be too shallow for spawning opportunities. They may also be compacted with fine silt. Throughout the length of such channels a well-defined thalweg is never evident.

In general terms the physical effects of drainage:-

- simplify the physical form of channels. Uniformity of channel form significantly reduces ecological diversity.
- reduce spawning opportunities.
- seriously reduce the capacity of small streams to support significant salmonid numbers of 1+ year-old and older fish (less pools).
- reduce the number of lies (pools) for adult trout and salmon in larger rivers.

Where the riparian zone is removed in the course of drainage works and landowners subsequently do not fence off the channel, grazing and trampling by farm stock will often prevent any significant regeneration of bankside vegetation. Also, stock given access to channels will often consume semi-aquatic and aquatic plants.

A channel drained 40 years ago. Continuous shallow riffle/glide sequences are evident. No thalweg & no defined pool areas are present. The riparian zone has not recovered

Another gravel bed stream drained in the 1980's. No recovery of the physical channel form is evident although the riparian zone is regenerating because the banks have been fenced.

Exceptions to the Rule

A limited number of channel reaches in Ireland have recovered, post drainage, in broad ecological terms, without physical works programmes, even though the riverbed is at a lower level and the banks are artificially high (O'Grady 1991, O'Grady & King 1992).

In one east coast river (Trimblestown R.) the ecology of a reach, including the fish stocks, was assessed prior to and immediately after drainage works. These data indicate a significant loss in the fish carrying capacity of this reach and a general reduction in ecological diversity following drainage (McCarthy 1977 and 1983). When this site was re-evaluated in 1990 a recovery of its pre-drainage status, both in general ecological and fish stock terms, was evident (O'Grady, 1991).

Another stream, the Glenree (opposite), was drained in 1950. Ecological surveys carried out pre-drainage in the 1950's (Toner *et al*, 1965) and repeated thirty years after works (1980) show that the physical form of the channel and its aquatic flora, macroinvertebrate fauna and fish stocks had recovered by 1980 (O'Grady & King, 1992).

In both of these cases (Trimblestown and Glenree) the landowners maintained their fences after drainage allowing the riparian zone to recover. The drainage excavations did not expose a boulder clay bed. There were still substantial shoals of gravel on the bed post-drainage and additional gravels were eroded from the banks. This allowed both streams to reshape themselves at the new lower bed level and, thereafter, the ecology recovered.

This was a very important finding - it indicated that there was scope to enhance drained channels which had not recovered by implementing physical works programmes, i.e. if one could recreate the natural physical form of a river within the drained channel, even though the bed had been lowered and the banks were unnaturally high, nature was likely to respond positively (See Chapter 13). The recovery evident in these two streams provided the author with a basis for the restoration of drained channels where natural recovery was clearly limited. These data also illustrate the critical importance of fencing off channels to allow the riparian zone to recover.

1950 - Drainage works in progress. The channel has been widened and deepened. All riparian vegetation has been removed. Dredging had stopped for the day where the two people are standing. Note the extent to which the stream was being widened and deepened.

2004 - This is the same reach illustrated above. The extent of physical and ecological recovery is self evident.

The Influence of Large Weirs

Many large stone weirs were built in Irish rivers in the 18th and 19th centuries principally to power mills. Over time fish passes have been incorporated into these structures so that they no longer significantly impede migratory salmonids. However Irish rivers are relatively low gradient channels and consequently these weirs often impound a significant length of channel. Electro-fishing surveys have shown that the capacity of such individual ponded reaches to support both juvenile salmon and trout and adult trout are seriously impacted - in quantitative terms salmonid numbers in impounded reaches are usually ≤10% of that in adjacent free flowing zones (O'Grady, 2002).

WHY?

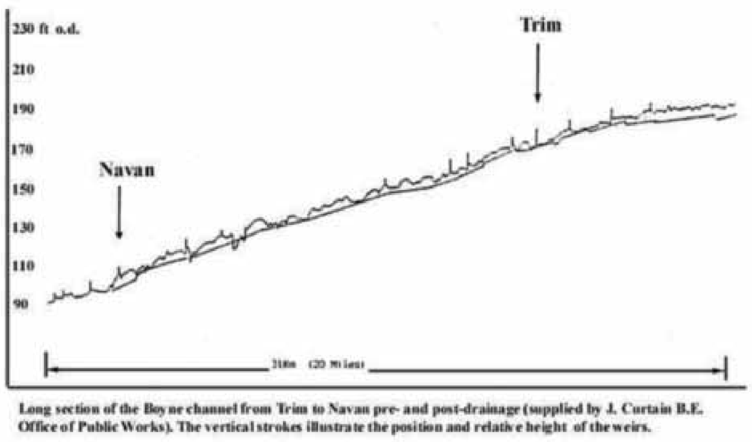
Given their preference for fast flowing shallow zones one would not expect to find juvenile salmon in significant numbers in impounded reaches. The trout are absent for a different reason. In rivers most macroinvertebrates live in riffle and shallow glide areas. Once a channel is impounded the fish food production of such areas is significantly reduced because shallow reaches within the impounded zone are flooded out.

In one of Ireland's larger rivers (the Boyne) a drainage programme in the 1980's involved the removal of a whole series of weirs and the large islands of silt which had accumulated in the channel because of the impounding effects of these structures. In this instance the drainage programme involved the restoration of the natural free-flowing channel. Qualitative electrofishing prior to the removal of weirs in the 1950's in this area indicated that significant salmon and juvenile adult trout numbers were confined to the fast flowing mill races. Some ten years after the weirs were removed, this zone was producing circa 30,000 salmon smolts per annum and supporting substantial resident stocks of adult trout up to 1.0kg in weight (O'Grady, 1998).

This is an example of a flood relief exercise which, in effect, lead to a restoration of the natural hydrology of the channel with very positive consequences for salmonid stocks.

The longitudinal section of the relevant Boyne reach in question and photographs, pre- and post-drainage, are provided (next page).

A typical mill weir on an Irish lowland river.



Longitudinal section of the Boyne River over 30km. Top line was the natural bed level. The spikes in this line were the weirs - to scale (approx.). The bottom line is the design bed level post drainage.

1965 - The Boyne River at Newtown, near Trim, pre-drainage. Note the large silt islands generated by the impoundment of the channel.

2005 - The Boyne at Trim 35 years after the weirs and silt islands had been removed.

Tunnelling

The excessive shading of a channel by bankside vegetation to a point where its salmonid carrying capacity has been reduced is often called tunnelling.

What are the Negative Impacts of Tunnelling?

Physical Problems

The roots of herbaceous plants play a crucial role in binding bank materials. They also tend to flatten down in flood flows thereby providing a protective mat. Once herbaceous plants are shaded out bank erosion levels increase significantly. Streams then become wider and shallower and pool areas are reduced in depth, or lost. Gravel deposits may become compacted.

An open reach of the same stream opposite.

Note the Key Differences

Adjacent open and tunnelled reaches of the same small steam are illustrated above. The open section, unlike the tunnelled zone, has:

- a healthy herbaceous border
- less bank erosion
- stream basewidth is only 57% of that in the tunnelled reach and therefore the steam is deeper
- aquatic mosses are present
- a greater trout fry stock density - 3.5/m^2 compared to 0.001/m^2 in the tunnelled area.

Heavy tunnelling - This shot could not have been taken without the aid of a flash gun. Note the excessively broad shallow nature of the channel and the virtual absence of aquatic flora.

Biological Problems

With reduced levels of sunlight reaching the steam bed aquatic plant communities die back. This in turn leads to a loss of macroinvertebrates both in terms of biomass and diversity and less food means less fish!

Few herbaceous plants due to excessive shading. The use of a flash gun was necessary to take this picture.

Features of Tunnelling

How does one recognise a tunnelling problem?

A.	Have the herbaceous bankside plants beneath the treeline died back?
B.	Is there a broader channel with a greater level of bank erosion in the tree-lined reach?
C.	Is there a significant reduction in the aquatic plant community in the tree-lined reach?

If the answer to A, B and C above are all YES then there is clearly a tunnelling problem in a fishery management context. Both coniferous and deciduous trees can cause this problem. The specific suite of problems which can be caused by coniferous afforestation are outlined in a separate section (Chapter 6, pages 45-47).

What length of tunnelled channel constitutes a fishery problem?

Research suggests that tunnelled channel reaches, once >100m in length, are likely to have a reduced salmonid carrying capacity (O'Grady, 1993).

Clearly a tunnelled reach. The dappled light is inadequate to promote either herbaceous bankside or aquatic plant growth.

An open reach on the same stream.

There is a river in there somewhere!

Does Channel Aspect Play a Role?

YES - channel reaches which flow along an east/west axis will receive more direct sunlight than those flowing along a north/south axis. The former therefore are less prone to heavy shading.

A tunnelled 19m wide channel which flows along a north/south axis. Few tunnelled channels in Ireland are >10m in width.

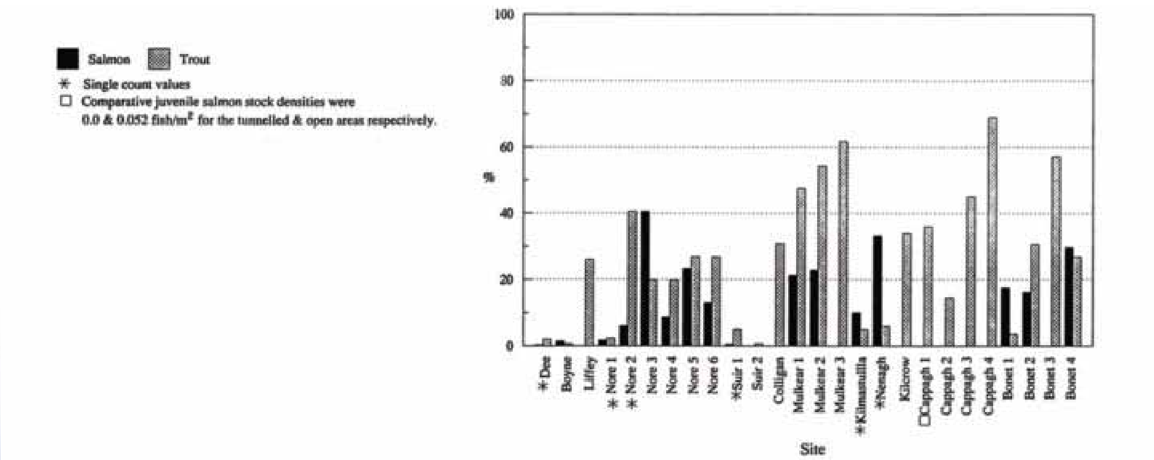
To What Extent are Salmonid Stocks Reduced by Tunnelling?

Tunnelled areas, ≥100m in length, rarely support more than 40% of the juvenile salmon numbers observed in adjacent open areas. Trout numbers are also significantly depressed in such circumstances (O'Grady, 1993). Specific examples of this trend are illustrated in the graphic below.

Does the Particular Assemblage of Trees along a Channel influence Tunnelling?

Yes - A monoculture of alders, a common feature on many drained Irish channels, can have a particularly heavy shading effect. In contrast a mixed assemblage of deciduous trees (such as Oak, Ash, Birch, Holly, Willow and Alder) tend to have different profiles and vary in height. This broken canopy will usually allow sufficient incident light to reach the bed and banks of the channel thereby preventing a tunnelling problem.

A healthy riparian zone beneath a mixed assemblage of trees.

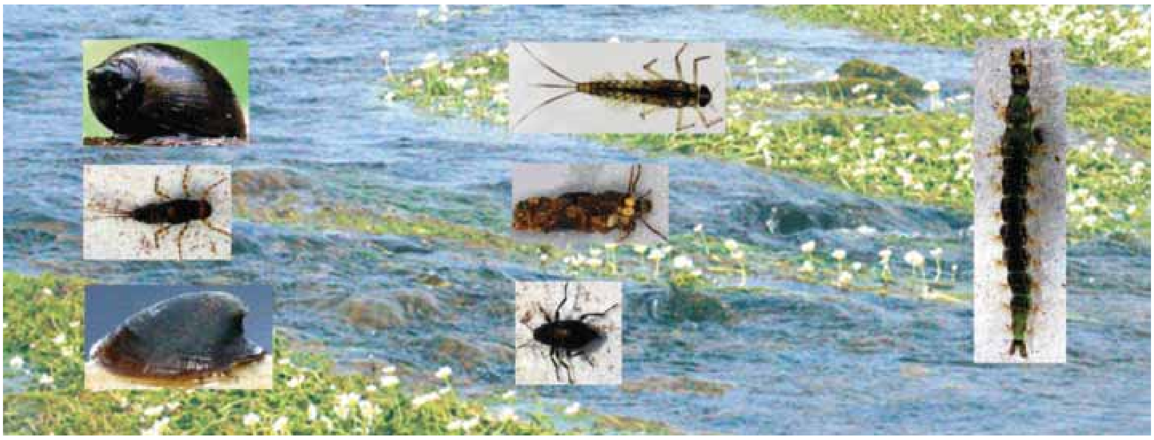


….showing the numbers of fish in tunnelled areas, as a percentage of the number in untunnelled areas of the same river. Seven of the above channel reaches did not have a juvenile salmon population (Suir, Colligan, Mulkear3, Kilcrow, Cappagh 1,2 and 3 and Bonet 3).

What Happens if the Riparian Zone is Lost?

The management of river corridors from a fishery perspective is all about balance - too little bankside vegetation can be equally damaging as having too much! The complete loss of vegetation in the riparian zone can have very negative effects on the ecology of the entire river corridor!

What happens if the Riparian Zone is lost?



Excessive mobility of the substrate will result in a loss of aquatic flora and fauna. The rooted plants and mosses in this reach will be replaced by shoals of loose cobble/gravel which will move in every flood event. Populations of the macroinvertebrates (inset) will be depressed.

Dippers have a similar diet to young salmonids. Excessive erosion will reduce the population of this species.

These are only some of the bird species which will disappear when a stable riparian zone is lost.

...there are serious consequences for the ecology of the river corridoor

With severe erosion, channels become artificially wide and shallow, loosing their capacity to support larger fish. The problem here has been caused by excessive sheep stock levels.

An absence of trees will increase water temperatures and reduce invertebrate numbers, many of whom feed on leaf litter.

Erosion at this level will cause major ecological problems.

Some ground nesting waterfowl will also disappear.

The rich ecology of the river corridor, both in the plant and insect world, will suffer with a loss of the riparian zone.

A Vegetated Riparian Zone Plays a Crucial Role in the Life Cycle of many Aquatic Insects.

The imagine has emerged.

A sub-imago resting and sheltering beneath a leaf.

Most aquatic insects have a life cycle which incorporates a brief period when the insect hatches, matures and mates. The females then return to the river to lay their eggs. During their short terrestrial phase a vegetated riparian zone provides them with places to rest and hide from predators. This is particularly important for ephemeropteran (Mayfly) species which hatch as sub-imagines. While resting on the under-surface of leaves they undergo a further metamorphosis - the sub-imaginal skin (shuck) splits and the imagine (sexually mature form) emerges. Removing all bankside vegetation creates difficulties for these insects in completing their life cycle.

A spent imago having layed her eggs and completed the life cycle.

A nymphal shuck. The sub-imagine has hatched.

Once the eggs hatch the nymph lives in the river bed sediment until hatching as a sub-imago.

Many mature aquatic insects are very delicate creatures and poor fliers. Shrubs and trees along river banks provide shelter thereby affording them more opportunities to mate and lay their eggs.

Coniferous Afforestation

Coniferous afforestation is a wide spread commercial practice in Ireland particularly in upland areas and on poor quality low lying agricultural lands. There is an awareness that these plantations can cause problems for fisheries interests.

Coniferous plantations in areas of poor base geology can sometimes cause acidification problems (Bowman and Bracken, 1993, Allott *et al*., 1997 and Kelly-Quinn *et al*., 1997).

A set of guidelines for afforestation, designed to minimise impacts on fisheries have been drawn up by a combination of forestry and fishery interests (Anon, 2000). Fishery officers should familiarise themselves with these guidelines and ensure that all new plantations comply with these recommendations.

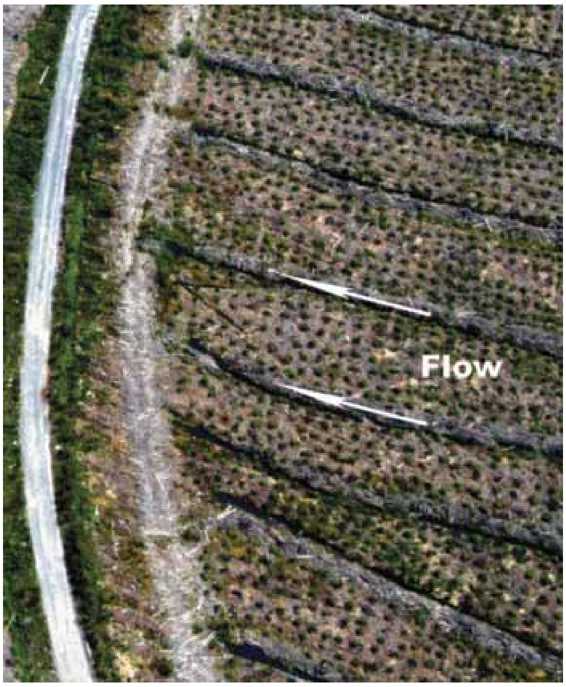
Extensive coniferous afforestation in an upland area. Note that most trees are some distance from the river bank which prevents excessive shading.

Coniferous plantations can cause different problems over their lifespan.

After the site has been drained and planted it is crucial that the drainage channels run into a sump. This helps to prevent the siltation of watercourses. In the longer term this sump will vegetate and function as a nutrient trap.

A margin of more than 10 metres either side of a watercourse should not be planted with conifers in order to avoid tunnelling problems.

A margin of greater than 10 metres may be required depending on the aspect of the channel or, in circumstances where a channel is an angling fishery.



A clearly defined sump area to trap silt runoff and nutrients is essential.

Even mature conifers along one bank can cause shading problems. The degree and extent of the problem will depend on the aspect of the channel and the time of year. If there were conifers on the existing open bank here then the productivity of this stream would virtually collapse.

A mixed assemblage of deciduous trees should be planted in the riparian band between the conifers and the river bank. The spacing of conifers and deciduous trees, along one bank in the photograph (right), is healthy from a fishery perspective.

A good buffer zone between the conifers and the river. Ideally the opposite bank should be fenced.

At harvest time problems are now becoming evident in relation to phosphorous releases from the forestry brash. This phenomenon is only evident following harvesting of plantations which are growing in peat which overlies acid bedrock (Cummins, 2000). These phosphorous releases can cause cultural eutrophication problems in watercourses further downstream. Resolutions to this problem are currently being reviewed. Possible options include;-

- Harvesting only a small percentage of such forestry plots each year.

- The harvesting of a plot in the lower slopes of such plantations might be carried out first. When this area revegetates it could be used as a soakway when the rest of the plantation is harvested.

- Lodgepoll pine stands, once harvested, might be allowed to regenerate naturally in order to avoid future problems.

Harvesting conifers growing on peat has special problems.

Peat Harvesting

Many peat bogs in Ireland are harvested on a large commercial scale to either, generate electricity or produce horticultural products. This operation can cause problems for fishery interests. Peat silt run-off can:-

- smother salmonid redds
- form berms or secondary banks and islands in rivers. These quickly vegetate, stabilise and can change the hydrology of a channel
- silt discharged to lakes can eliminate the flora and fauna on the lake bed.


Commercial peat harvesting operations.

Peat silt runoff to watercourses can be very effectively controlled by ensuring that all bog drains are routed through a series of silt traps (below). Ideally there should be a double set of traps - one set in use, while the second set is being maintained.

As a Fishery Officer working in these areas one should be conscious of the dangers of peat siltation. Silt trap systems should be checked regularly to ensure that maintenance programmes are adequate.


A series of peat silt traps. These must be maintained regularly to be effective.

Concretion of Gravels

In many Irish rivers and streams, draining limestone catchments, gravel deposits often become covered with a calcified layer. This cements the gravel material to a degree that limits and sometimes prevents salmonid spawning. This is a natural process - algae growing on the stones precipitate calcium carbonate as part of their metabolism. This forms a solid layer often several centimetres in depth over the gravel deposit.

Experience has shown that, once the calcium layer is broken and the gravels exposed, fish will return to spawn in these areas.

Tossing the bed with the bucket of a hydraulic machine is the most efficient way to free up calcified spawning gravels. This activity should be confined to the summer period.

A number of calcified timber weirs, built in Irish streams fifty years ago, were examined to look at the quality of the timber after this length of time. Sections showed the timber to be in perfect condition. Presumably the seal provided by the calcified layer helped to preserve the timber.

This calcification process is not a consequence of any land management practise. However the author decided to include it here because it is a significant fishery management problem in many catchments.

This piece of gravel, 8cm in diameter, lay just beneath the calcified crust. The extent of encrustation, five years after this grave had been placed in the stream, is self- evident.

Significant calcium deposits will often encrust timber weir structures. This is a help, not a hindrance. The calcified log will last longer. This timber weir is only five years old.

Chapter 6

Addressing Habitat Problems

Once the imbalance along particular river reaches have been identified, enhancement plans can be drawn up. Detail in relation to the various bankside and instream procedures which have proved successful in Irish channels are provided (chapter 6 to 10). A quantitative evaluation of the relative success of individual programmes is provided subsequently in chapter 11. Where there are a range of options available to solve a particular problem the pros and cons of the various alternatives are summarised. Again it must be emphasised that any such exercise is futile if water quality is poor (see chapter 2).

There are usually several options available to restore any particular physical imbalance in a channel. The option chosen will often depend on a number of variables including:-

- the energy level of the channel
- the availability and cost of local materials
- access to the site in order to draw in materials to the channel
- the availability of skilled labour and machinery

Remember that instream works, in most circumstances, should only be carried out between June and October. Work in winter time, apart from shrub pruning and fencing, may kill significant numbers of salmonid eggs. Young fry just emerging from redds cannot swim away from heavy machinery. Lampreys spawn in the same gravel shoals as salmon and trout in many Irish rivers in May/June. In such areas instream works should be confined to the August to October period. In streams and rivers where the pearl mussel (Margitefera margitefera) is present consultation with the National Parks and Wildlife Services prior to implementing any instream works is required (See Appendix II).

Instream works should only be carried out when flows are at summer levels.

Young salmonids cannot swim away from heavy machinery.

Remember, salmonid spawning times vary across the country.

A completed salmonid redd. Lamprey may spawn in the same gravels in summertime

Stabilising River Banks with Timber

Various combinations of logs, rocks and conifer tree tops have been used in Irish rivers to stabilise excessively eroding banks and rebuild banks trampled out by farm stock.

How do Logs and Tree Tops stabilise a River Bank?

The photo (right) illustrates the technique in action. During flood flows the buffering effect of the tree tops allows suspended silt to settle out within the tree tops.

River silt is rich in nutrients and quickly vegetates. In the photo below (bottom right) the secondary bank of silt trapped by the tree tops originally is clearly evident. It has since vegetated. The root mass of this vegetation has now stabilised the new bank and will, itself, trap additional silt during flood flows. The fence erected is clearly stock proof! At this point, seven years after the revetment was put in place, the tree tops have rotted and the logs pinned beneath them are buried in silt.

This photo illustrates the stilling effect of tree tops during flood flows which accommodates the settlement of suspended silt particles.

At works stage. Note the high level of bank erosion.

7 years after works.

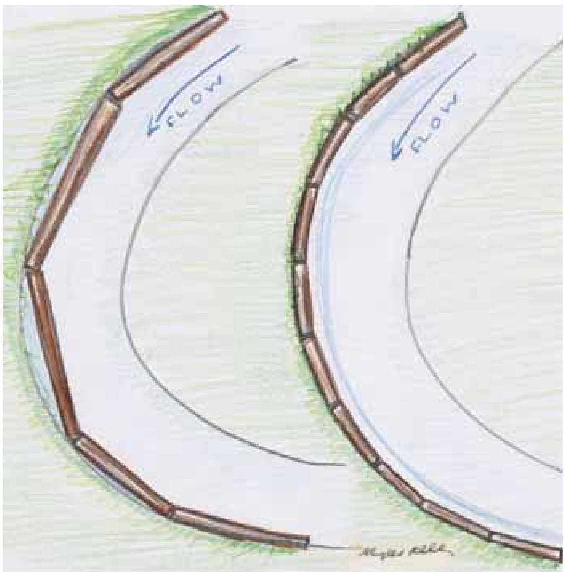
A Standard Log/Christmas Tree Bank Revetment Operation

Clean off the eroding bank to leave a smooth curve. Secure a line of logs along the toe of the channel. Standard 3m lengths circa 0.25m to 0.3m in diameter are ideal. Drill each log and secure with 2m lengths of iron rods circa 2.0cm in diameter - 2 rods per 3m length of timber. Logs >3m in length may require additional pins. Logs >0.4m in diameter and circa 3m long should be secured with three 3m long pins - increase pin numbers for longer logs.

Line of logs are in place. Pins not yet driven in.

One year post-works.

When carrying out log/Christmas tree revetments on gravel bed streams there is no need to restore natural stream form. Once the bank has become relatively stable the river will restore its natural form after the first few.



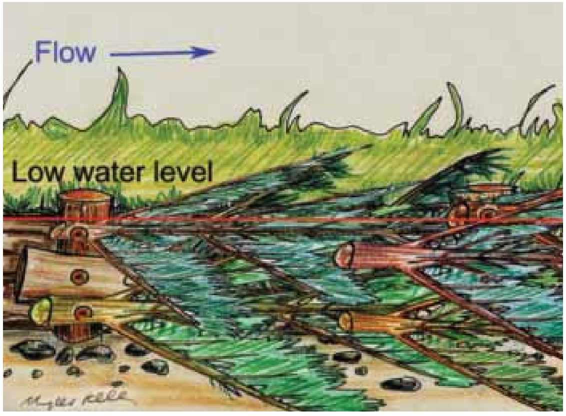
If the log sections do not fit snugly along the curvature of the bank, erosion may still be severe following works.

Note how a narrower deeper channel has developed here only one year after bank revetement works. No channel realignment works were carried out here. The river reorganised itself following bank stabilisation.

Coniferous tree tops (butt end upstream) should be secured to the logs with nails (two per top). Additional detail on the suitability of particular tree species and tree tops is provided on page 62 of Chapter 6.

Positioning Logs and Tree Tops

- Tree tops should be secured to the logs at two points with large nails.
- The tops should overlap each other along the longitudinal axis of the log by 50% (graphic).
- The positioning of tree tops around the axis of the log are illustrated in the graphic (below).
- Ensure that the branches of the tree tops on the outside lower face of the log are trailing on the river bed. This helps to reduce erosion beneath the log.
- The branches of the tops nailed on top of the log should be brushing against the bank.
- Remember, you can never use too many tree tops.



Side view of log/Christmas tree revetment.

Cross-sectional view.

A Few Tips!

Drill the logs while still on the bank. Secure the pins in the drilled holes.

Remember, logs are heavy. Use a hydraulic machine to lift logs into place. A machine in the 10 to 15 tonne range is adequate for this operation.

Freshly cut logs are very buoyant. Use the machine to hold the log snugly to the toe of the bank while the pins are driven home.

Once driven the final 5cms of pin can be bent over with a sledge hammer to secure the pin (as above). Sometimes bending over the top of the pin will pull it back up when bed materials are soft. A better way to secure the log is to slip a washer over the pin before driving it home. When driven home the flattened pin-head is secured by the washer.

A piece of metal piping secured by a short piece of wire to the shaft of the jackhammer helps to prevent the jackhammer from slipping off the pin when it is being driven home.

The Health & Safety Regulations which apply to building sites are equally applicable here.

For safety reasons one should only use iron pins to secure the logs. Steel pins, when being driven, can splinter and cause accidents.

Using a Double Line of Logs

A double line of logs has been used successfully to protect badly eroding banks in high gradient streams (≤2.8%). Observations in relation to the effectiveness of all log/Christmas tree operations completed to date in Ireland suggests that this procedure is usually unnecessary.

WHY? - Stream banks usually erode at the toe. As this material is lost the bank section above it slumps into the channel. The provision of enough bushy material on top to a single row of log is a better arrangement than a double row of logs because:-

- a single line of logs is sufficient to stop the toe eroding significantly.
- the tree tops will buffer flows better than a line of logs.
- the tree tops, by precipitating out silt during flood flows, will allow the bank to rebuild itself and subsequently vegetate and stabilise.
- the uppermost line of logs in a double row will probably be wet and dry periodically as river levels rise and fall and therefore rot more quickly.
- fitting a second row of logs doubles the work load thereby increasing costs considerably.

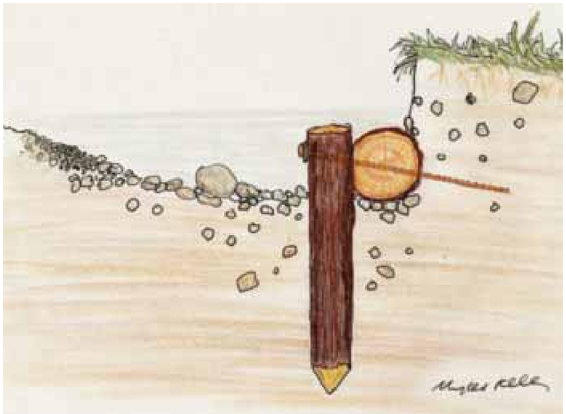
There is one circumstance where a double row of logs is essential. Stream reaches passing through mature woodland will never have a continuous dense layer of herbaceous plants along the bank. A double log arrangement here helps to protect the bank during major floods. This secondary berm will stabilise and vegetate partially in time (see below).

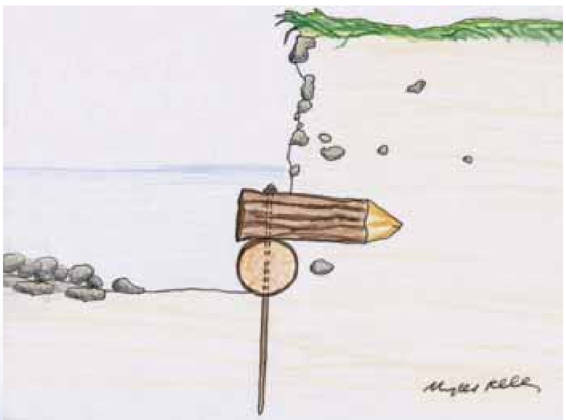
7 years post-works in a stream reach traversing mature deciduous woodland.

Variations on a Theme

Occasionally pins driven and riveted with a washer will fail to secure logs where there are deep stream bed deposits of fine sand or marl. Alternative techniques have been developed to overcome this problem. Use the bucket of a hydraulic machine to drive timber straining posts (circa 10cm in diameter) either directly into the bed or into the bank as illustrated below in the graphic. At least 0.75m of the post should be secured into the bank, or bed, as appropriate. Then a pin can be driven through the post and on through the log to secure the structure (below and opposite).

There was concern that, either, or both of these revetments would not prove stable in the longterm due to the destabilising back-eddies they might create during flood flows. This concern was unjustified, the tree tops nailed to the revetment buffered any such flows thereby preventing instability.

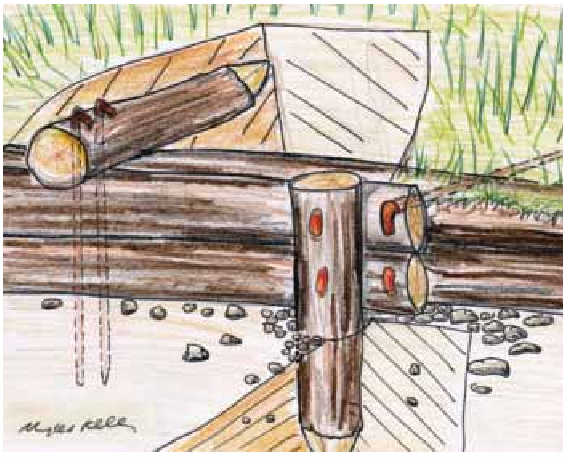


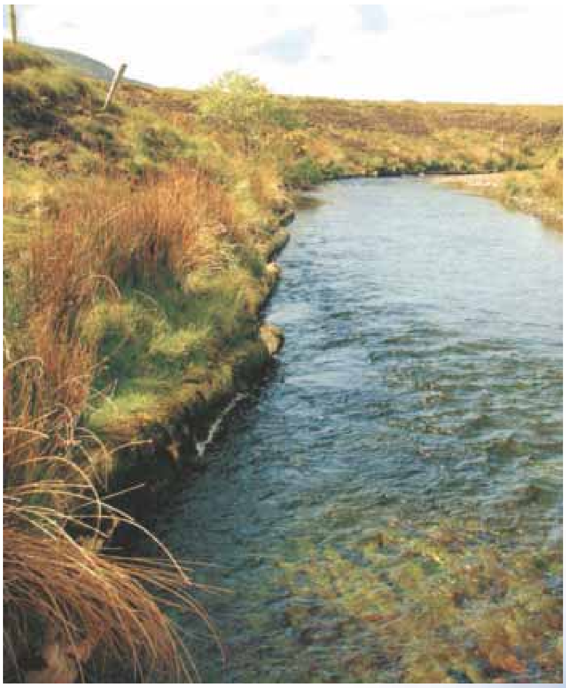


The most complex arrangement of poles used in Ireland to date to stabilise a bank is illustrated below both photographically and graphically. The coniferous tree tops have rotted. However the silt aggraded by the tree tops has vegetated and stabilised the bank.

An additional graphic and photo (below) provide the reader with another perspective. (The Christmas tree tops has been omitted from the graphic to show the pinning arrangement).

6 years after works.





Note that the horizontal poles here overlap by 1.0m and are positioned at a slight angle out from the bank in a downstream direction.

The complex timber revetment procedure, illustrated on the previous page, has been used here (below). It has worked well here in relatively high energy conditions. Ecological recovery of the riparian zone would have been accelerated here had the landowner permitted fencing off the channel.

Willow slips planted here failed to grow successfully largely because they were either eaten by, or trampled on, by farm stock.

Pre-works.

6 years post-works.

Fencing off Revetments is Vital

A log/Christmas tree revetment operation, carried out on two reaches of the same stream, is illustrated here four years post-works. Only one of two landowners allowed his stream reach to be fenced off.

The difference, four years later, is self evident. The conifer tree tops trapped a significant silt berm along the bank of both reaches. Willow slips and herbaceous vegetation are thriving on the fenced reach (below). However, continuous grazing along the bank on the unfenced section has limited revegetation (opposite). Sprouting willow slips here were also eaten by farm stock. The revetment operation on the unfenced reach is likely to fail in the long term because of an insufficient root mass of vegetation on the newly aggraded bank.

Fencing is an integral part of bank revetment operations in circumstances where farm stock are present.

Heavy bankside grazing will inevitably lead to this revetment being undermined.

The importance of the fence in terms of excluding farm stock is self evident.

Failures

Over the period 1996 to 2000 circa 100km of log/Christmas tree revetment has been completed on Irish rivers. Failure, assessed as further bank erosion behind the revetment, is currently < 2% where fencing has eliminated stock access to the bank.

There is no set pattern evident to explain why specific sections have failed. In the authors opinion it is most likely related to the bank material in these particular reaches being especially friable and/or the occurrence of a very large flood event immediately after revetment construction, prior to the aggradation of a significant quantity of silt.

REPAIRS? There are several options.

- Backfill behind the log in the breached area with more tree tops or rip rap (rocks).
- Rebuild the timber revetment using the more complex technique illustrated on page 57.

Expect minor problems.

One repair option.

Another Option

In smaller (≤4m basewidth) relatively low gradient (<0.1%) streams, with soft bed material, an alternative technique has proven successful (see photo and graphic below).

A line of fencing posts that have been hammered into the stream bed to a depth of circa 0.5m along the eroding toe of the channel. Circa 0.3m length of post is left above stream bed level. Coniferous tree tops are secured to the posts with wire or nails - two anchor points per tree tops. Tree tops should overlap each other by at least 50% - remember, you cannot use too many tree tops!

Note the heavily silted bed.

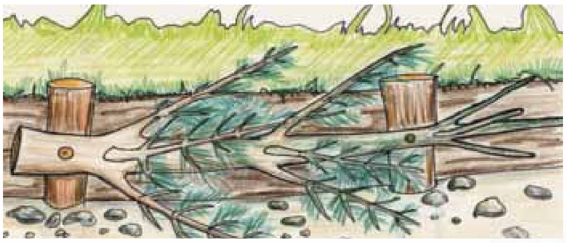
3 years post-works. The aggraded silt along the toe of the bank has revegetated and stabilised the bank.

Once bank stability has been restored excessive silt deposits on the bed will be scoured out.

Advantages - This operation can be carried out manually - i.e. the posts can be driven into the bed with sledgehammers provided the bed material is relatively soft. This removes the necessity for the availability of a hydraulic machine - a significant cost saving!

Disadvantages - This technique is unsuited to high energy rivers where the banks are badly eroding. In these circumstances a line of logs pinned along the toe of the eroding bank are essential in ensuring bank stability until the bank aggrades and vegetates.

Revegetation, post-works, in a lowland productive stream can be very fast. Note the absence of silt on the stream bed in the post-works shot above. A 0.5km long stream reach had been repaired upstream of this point.



Note that the distance between posts must allow two anchor points per tree top.

Suitable Logs and Tree Tops

In high gradient rocky steams where limited quantities of silt are suspended during flood flows one should use the hardest timber available because the logs may be exposed in the longterm. Currently in Ireland the best available, in commercial quantities, are Japanese Larch and Douglas Fir.

In alluvial rivers and streams, where silt loads in flood flow are relatively high, cheaper commercially available soft woods such as Lodgepole Pine and Sitka Spruce logs can be used.

Why? - because the line of logs will quickly be buried in silt, constantly wet and therefore will not rot for many years. In effect once the silt berm trapped by the tree tops becomes heavily vegetated the log has largely served its purpose.

Use the bushiest coniferous tree tops/thinnings available with the stiffest branches. A high density of stiff branches form the best silt trap in flood flows. Lodgepole pine tops or thinnings are the best available. Young Willow trees were tested as an alternative to coniferous tree tops. They largely failed because, in flood flows, their supple branches folded down and failed to trap substantial quantities of silt.

The photo series (right) illustrates the effectiveness of this procedure over time.

Trailing conifer branches colonised by mosses providing temporary cover and food for fish.

Pre-works.

Immediately post-works. Note the bushy nature of the tree tops used. Tree tops are secured to the logs with large nails.

7 years post-works. The willows on the left were planted as slips. Note that the point bar on the right has rebuilt itself and revegetated.

Associated Planting Procedures

Following the completion of a revetment operation willow slips - at least one per metre of bank length - should be planted between the log and the bank.

Note the following -

- Delay the planting until the willows are dormant (October to February).

- Time allowing, postpone planting until deposits of silt have been trapped by the tree tops i.e. after the first winter.

- Always use local material.

- Always plant fresh slips. If the material has been cut for over a week they may not take.

- Ideal slips are circa 30cms long and 2-3cms in diameter. Only the top 5cm should be above ground when planted.

- Be careful, do not plant the slips upside-down. They will probably still sprout but why make life difficult for the plant!

- If resources are available one should also consider planting a mixed assemblage of native deciduous trees in the riparian zone. Suitable species would include Oak, Ash, Holly, Birch, Whitethorn and Blackthorn. Ask your local forester for advise in relation to particular locations. When planting a variety of species ensure that individual stands of trees contain a number of different varieties - this should help to avoid tunnelling problems when the trees mature.

- Alder is a useful native riparian tree species. In Ireland they are almost always the first tree species to recolonise a river bank. There is no need to plant them; they will inevitably turn up!

- Avoid planting smaller streams (≤4m basewidth) with a lot of trees. If you do you will inevitably generate a tunnelling problem. In small channels herbaceous plants will provide adequate shade and cover for fish.

This river bank was fenced off 2 years ago. No trees were planted. Alders are already well established!

Silt aggraded by coniferous tree tops - an ideal planting medium for willow slips.

Other Revetment Options

Use of Root Wads

Root wads have been used widely and very successfully in North America as part of bank revetment structures (Duff et al, 1995). Their use in Irish programmes has been limited to date because of the cost of collecting and delivering them to the required sites.

If wind blown coniferous trees are available near a work site then the author would strongly advocate their use in the following way:

- pin a line of logs along the toe of the eroding bank.
- cut the trunk of the wind blown trees leaving a two metre length of timber stem on each root wad. Point the end of each stem.
- use the bucket of a hydraulic machine to push each pole into the bank until the root wad is flush with the bank. The roots on the lower face of the wad should overlap the line of horizontal logs. Adjacent root wads should over lap.
- nail tree tops to both the horizontal logs and some of the heavier roots.
- back fill any spaces between the root wad and the bank with cobbles or small rocks.
- plant willow slips and fence the bank.

The revetment, incorporating root wads (picture right centre), has trapped silt, woody debris and other floatsam to such an extent that it is difficult for the reader to visualise the original structure. A graphic is provided (right) to clarify the nature of this particular revetment.

An ideal root wad for bank revetment use.

5 years post-works. Root wads, logs, rocks and coniferous tree tops have stabilised this badly eroding bank and provided cover for fish (see graphic below).

Log/Rock Revetments

Some small (≤4m basewidth) Irish streams, have very hard boulder clay banks. These channels also have a hard boulder clay stream bed which forms a crust over very soft deposits of marl. This posed a number of problems. The hard boulder clay along the banks and the streambed meant that suspended solids levels, even in flood flows, were low. This meant that a log/Christmas tree revetment would not aggrade much silt. When one attempted to protect eroding banks with rocks the rip rap was unstable - i.e. stones broke through the hard crust on the surface of the stream bed and sank into the marl thereby destabilising the rip rap.

A solution to this problem was found by using a log/rock revetment (photo and graphic). Logs were pinned in series along the toe of eroding banks. Chocks were placed beneath each end of each log. Thus, the logs provided a cover shelf for small fish. This was important because the hard boulder clay vertical bank was never going to vegetate sufficiently to provide much overhanging cover. A line of rocks was placed on top of the logs to provide further protection to the toe of the bank. The chocks, beneath the logs, were slightly tilted towards the bank so that any erosion beneath logs, over time, would result in the rocks falling down behind the logs - i.e. between the timber and the freshly eroding bank thereby reducing further erosion.

The revetment type in question is illustrated (above, right). A graphic illustrating a section through this type of revetment is also provided (right).

Be careful - if you use this option try to ensure that the logs are at, or beneath, summer water level to ensure the longevity of the structure.

5 years post-works.

A section through the photo above.

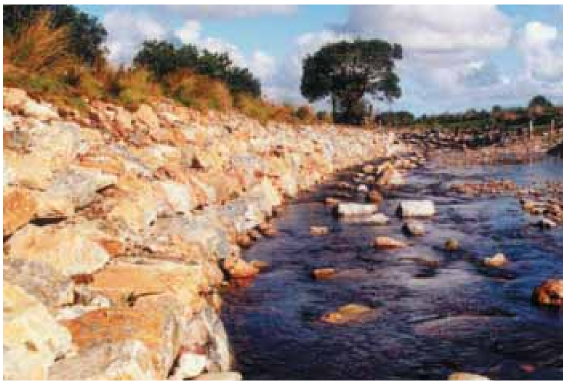
Stabilising River Banks with Stone

Rip rap is a term used to describe the protection of badly eroding banks with rock. In very high energy channels there is no other way to stabilise badly eroding banks. In North America various combinations of rocks, large logs and very big root wads have also been used successfully in high energy channels (Duff *et al*., 1995). This is not usually an option in Ireland because of the unavailability of very large trees.

KEY POINTS (see graphic)

- Ensure that the base line of rocks extend out from the bank beneath stream bed level.
- Slope the structure back at a 45^0 angle to the vertical.
- If only relatively small boulders are available then build the bank of stone at a more gentle angle ($<30^0$).
- Backfill behind each line of boulders with the largest river cobbles available.
- Where bank materials are very friable it may be necessary to build the rip rap to the top of the bank.
- Where a badly eroded bank has been rip rapped there is no need to rearrange the river bed in terms of its cross-sectional profile. The first few floods, post-works, will do so (see photograph).
- Place random boulders on the channel bed within the zone where a thalweg is likely to develop post-works.
- Fence off the bank and plant trees where possible.

Pre-works.



Immediately post-works. Note that stream basewidth has not been altered

7 year post-works. The stream has re-adjusted its width.

Rip rap and Bankcover

One disadvantage of using a standard rip rap procedure is that an undercut bank, which would provide cover for fish, cannot develop. There are two variations to the basic rip rap structure which will overcome this problem.

Rock Shelves

The rock shelf provides a solution in terms of providing cover. There are two limitations in relation to rock shelf construction:-

- very regularly shaped rocks (block stone) are required for building.
- construction is a very slow and consequently an expensive process unless suitable stone is available locally at a reasonable cost.

6 years after works. Trout up to 1.0kg are resident in this pool.

Rip rap and Willows

In the course of constructing rip rap it is possible to incorporate layers of willow slips into the structure thereby providing cover for fish. If you choose this as an option remember:-

- willow slips are only likely to take if this operation is carried out in October. The physical aspects of this operation cannot be undertaken between November and June because of possible interference with spawning fish and/or redds.
- sufficient levels of soil must be placed behind each layer of stones to nourish the willows.
- on very high banks willow slips may fail to take towards the top of the bank because of the dry nature of soils.

The extra cover and shade provided by this option is self-evident. Over time the leaf litter from the willows will add to the productivity of the channel and the trees will provide shelter for many aquatic insects (see also page 44 in chapter 5).

Immediately post-works.

3 years post-works.

Pre-works.

Rip Rap in Low Gradient Channels

A much simpler arrangement, using rocks, can be used to rebuild a bank in low gradient (≤ 0.1%) channels which have been impacted by bank trampling (above).

Cattle have completely trampled out the bank and filled in the thalweg which originally ran close to the far bank. The original bank line has been lost and the riparian zone completely eliminated.

A single line of rocks, two stones high, have been built to recreate the original bank line. River bed material was excavated to recreate the thalweg. This material was used to backfill behind the rocks thereby rebuilding a bank. This new bank was planted with willow slips and fenced.

5 years post-works.

A Summary of Bank REVETMENT Options - The Pro's and Con's of Different Systems

Log / Christmas Tree	Log / Rock	Root Wads	Standard Rip-Rap	Rock Shelves
The best revetment option where possible because:- • it allows a bank to rebuild itself. • does not eliminate erosion - ie reduces it to natural levels. • tree tops provide good cover for fish until they rot (5-7 years) at which point bankside vegetation will provide adequate cover. • the line of logs, once constantly wet and covered in silt, will provide relative stability along the toe of the bank for a long time (50 to 100 years). • easier to build than using mature conifers and usually cheaper when transportation costs of whole trees are considered.	• effective initially in limiting bank erosion. • will not accommodate aggradation of silt - ie bank will not rebuild itself and subsequently revegetate • more effective in the longer term than the log / christmas tree option in channels with very low suspended solids in flood conditions - ie where tree tops will not accumulate silt the log / rock option will last longer than the log / christmas tree option.	• very effective in stabilising banks in high energy channels. • difficult to source and transport to work sites at a reasonable cost in Ireland	• the only bank stabilisation option in very high energy channels particularly where banks have been completely washed out and have to be rebuilt. • has a number of disadvantages:- a) eliminates undercut bank as a shelter for fish b) stops all erosion of bankside gravels which is a natural physical process in our rivers - US studies show that continuous riprap work over many kilometres can eliminate salmonid spawning opportunities, ie gravels washed downstream over time are not replaced because of extensive riprap work upstream (ref.).	• accommodates an undercut bank not present in a standard riprap operation. • has a number of disadvantages:- a) eliminates the natural gravel erosion process b) one needs block stone to build stable structures c) slow and therefore expensive to build.

Chapter 7

Fencing

Dividing off discrete parcels of land is not a new phenomenon in Ireland. The oldest (5,000 years) known enclosed farmland area in the Western World (Ceide Fields) are in North Mayo. However in general terms our ancestors, up to the 16th Century, lived in a relatively open landscape. With the division of the landscape into relatively small holdings over the last few centuries, stone walls, hedge rows and more recently, wire and timber posts have been used to define boundaries and provide stock proof barriers.

Grazed pasture lands. This reach had been choked with silt because of mans activities further upstream.

Historically no such boundaries existed and our fish stocks survived. However with the intensity of land use today and with the current density of livestock, it is necessary to fence off channels in order to prevent the degradation of the riparian zone, or in many cases, to allow such areas to recover in vegetative terms. The serious consequences of riparian zone loss to a river corridor have already been outlined (Chapter 5, pages 42 and 43). This could have been avoided on many rivers if stock had been fenced out.

10 years later. The river was desilted, all farm stock removed and trees planted on the left bank are progressing. With complete destocking fencing was unnecessary. This eco-friendly development was undertaken by Intel Ireland on its property in Leixlip, Co. Kildare.

The photos (opposite) illustrate the very significant changes which can take place in a landscape in a very short space of time. This river had been choked with silt. The channel was desilted and reconfigured physically some ten years ago. At the same time all farm stock were removed and a deciduous forest was planted next the left bank. The remarkable visual change in this landscape shows how quickly the countryside can change once land management practices are altered. We do not need the level of change illustrated in these photographs to make progress from a fisheries perspective. A simple stock proof fence a few metres from the river bank is a major step forward.

This short chapter outlines the value of fencing operations in the context of broader stream enhancement programmes.

The implementation of instream and bankside enhancement programmes are of little value without a fencing programme in locations where farm stock levels are high.

ADVANTAGES

The advantages of fencing off channels are numerous. It:-

- allows a recovery of the riparian zone where it has been overgrazed or trampled. The various advantages of a balanced riparian zone to fishery interests have already been outlined (page 26).
- will act as a filter reducing silt and nutrient run-off.
- provides opportunities for ground nesting birds like mallard. Mallard production has reached densities of up to 30 birds per kilometre of fenced channel where, formerly, there were none (O'Grady, 2002).
- allows the re-establishment of a wide range of plant and invertebrates, which cannot survive on intensely fertilized or heavily grazed lands.
- ensures that the river corridor is a continuum. Once so, the mobility of many forms of wildlife is ensured through a network of channels across the countryside.
- the fence should ideally be a minimum distance of 3m from the river bank.
- trees should not be planted along the banks of small (≤ 4.0m in width) streams following fencing programmes as this will inevitably lead to a tunnelling problem. Grasses and other herbaceous plants will provide adequate shade and cover. Alders are likely to recolonise the banks following fencing.
- follow fencing programmes on small streams a shrub pruning programme will probably be necessary on a 15 to 20 year rotational basis even where no tree planting was carried out.

Fencing will encourage ecological diversity.

Fencing off river banks will not promote noxious weed growth. These plants, generally, only thrive in areas which are heavily fertilised.

Aquatic Plant Communities develop over time following Fencing

This small springfed stream had been badly damaged. Cattle were over-wintered on the land. The overgrazing and bank trampling problems are obvious (right). Note the complete absence of both aquatic and semi-aquatic plants. These had been grazed out.

Farm stock were fenced out. Dramatic changes in the aquatic floral regime were evident two years post-works (bottom left). Dense beds of water celery were virtually choking the stream because the cattle no longer had access to the channel. This was just a temporary phase in the evolution of the stream post-works.

Four years post-works (bottom right) further major change was evident. The colonies of water celery along point bars trapped and compacted silt shoals creating a medium more suited to semi-aquatic grasses. Excessive silt on the open stream bed has been scoured out leaving a clean gravel bed. It was the constant trampling of the cattle on the artificially wide eroding channel which maintained a soft silt/gravel mix, a medium ideally suited to water celery.

Pre-works: Overgrazing and bank trampling are evident. No instream or bankside aquatic plants evident.

2 years post-works. Lush water celery beds almost chocked the stream.

4 years post-works. Colonies of semi-aquatic grasses have replaced the water celery along the margins. Occasional clumps of celery still colonise the open channel areas.

Fencing - An Alternative Option

In North America large tracts of land are in state ownership. The grazing rights in such areas are leased to farmers. Over decades this often lead to serious over-grazing and damage to river corridors. To manage this situation whole valleys were rested for a few years to trigger vegetative recovery. Thereafter various strategies were developed which allowed grazing on a seasonal or rotational basis. Different strategies wee adopted to suit the climatic conditions in different areas (Chaney *et al*., 1993).

This strategy is unlikely to prove practical in Ireland because of the fragmented ownership of river valleys.

Sometimes the solution to an overgrazing problem can be very simple! In Yellowstone Park in western United States, where no hunting is allowed, herds of buffalo, deer and antelope increased to a point where they were causing serious overgrazing problems.

The solution to the problem was simplicity itself - reintroduce their natural predator, the wolf!

Overgrazed for decades.

Maintaining a balance in nature.

10 years after rotational grazing was introduced.

Chapter 8

Reconstructing Pools in Rivers

Pools are a natural physical feature of river channels. In most undisturbed rivers, pools reoccur at intervals of between 5 and 7 times the channel basewidth in distance apart i.e. in a channel with a basewidth of 5 metres one would expect to find a pool within every 25m to 35m of channel length.

Don't expect all pools to be equi-distant from one another in any channel!

Why are Pools a Rarity in many Irish Channels?

There are two reasons:-

- arterial drainage of many Irish rivers has lead to an artificial widening of channels and, in many cases, the exposure of very stable boulder clay river bed and banks. With a lack of mobile substrate, pools were not re-excavated by flood events after drainage operations.

- excessive bank erosion, irrespective of its cause (riparian removal, overgrazing, bank trampling or tunnelling) has lead to the formation of lengthy shallow riffle/glide sequences and a loss of pool areas in many channels. This is evident in both many straight and meandering reaches of channels.

A high gradient stream. Where are the pools?

An undisturbed high gradient (B-type) channel. Note the frequency of pool areas.

What Functions do Pools Provide?

Pool areas in rivers and streams serve a number of very important functions:-

- during severe drought conditions all salmonids (fry, parr and older fish) must take up temporary residence in the pools of spate rivers.
- the bigger trout in a river or stream live principally in pool areas.
- adult salmonids, returning to small channels to spawn, need pool areas both as resting place and a safe haven from predators.
- gravels moving downstream in flood flows tend to precipitate out in mounds immediately downstream of lateral scour pools in meandering channels and below plunge pools in straight reaches. These deep gravel deposits, with an up welling of water from the pool percolating through the stones, are the prime salmonid spawning areas.

A gravel shoal at the tail of a plunge pool with a fresh salmon redd in the foreground.

A spawning site at the tail of a lateral scour pool.

Adult trout resting in a pool prior to spawning.

Pool Reconstruction in Meandering Channels

Pools in meandering channels, often called lateral scour pools, are always located next to the eroding side of a bend (see page 24)

Channels with a Mobile Substrate

Excessive bank erosion in meandering channels results in either, a complete loss of or, a reduction in the quality of lateral scour pools as the river becomes excessively broad and shallow. In rivers with extensive loose gravel bed deposits construction of a bank revetment to restore relative bank stability is all that is required to restore lateral scour pools. This will allow substantial deposits of gravels, suited for spawning, to accumulate in the riffle areas upstream and downstream of the lateral scour pools.

In these channels the excavation of lateral scour pools and riffle creation following bank revetment is a waste of resources. The river will reorganise itself, after the first few floods (see below).

Pre-works. Note the excessively broad shallow channel.

6 months post-works. Bank revetment and fencing were the only works carried out here. Channel re-alignment was evident after just one major flood event.

Meandering Channels with a Hard Immobile Substrate

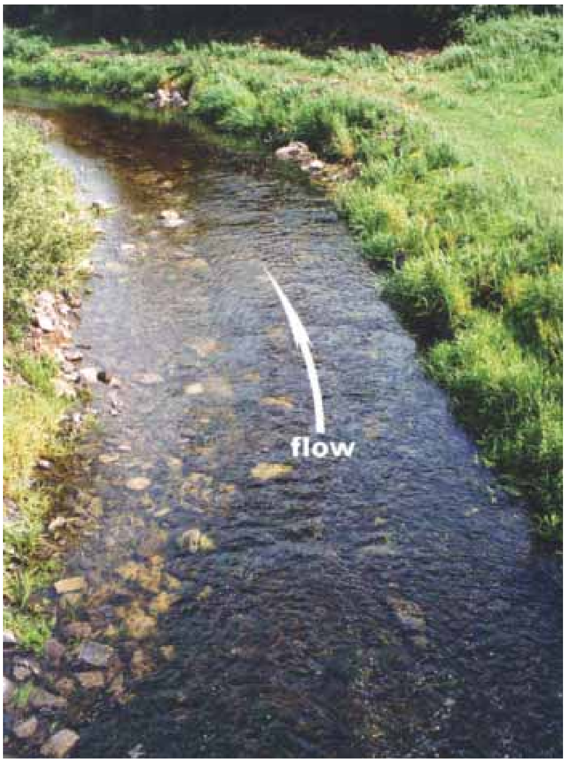
Many previously drained rivers in Ireland, as already outlined (page 34), have a very hard immobile substrate of boulder clay or bed rock. The creation of lateral scour pools, in these meandering reaches of channels, necessitates the excavation of pool areas and the importation of spawning gravels to create riffles upstream and downstream of the pools.

At this site (right) a machine was used to excavate a lateral scour pool next the right bank. The excavated boulder clay was deposited next the left bank to mimic a point bar. A single line of rocks was imported to form a stable edge to this shoal - boulder clay quickly sets and thereafter will not move in flood flows. This deflector ensures that all of the water, as summer level, flows through the lateral scour pool. Engineering records of the channel basewidth, pre-drainage, were used to calculate the desirable width of the new lateral scour pool. A number of large rocks were placed in the pool. A gravelled riffle was built downstream of the lateral scour pool (not in view in these photographs). Subsequently the site was fenced off.

Since enhancement, small deposits of silt, settling out on the point bar, have allowed semi-aquatic vegetation to become established. The value of the fence is self-evident.

Stocks of adult trout in many such channels recovered remarkably quickly following enhancement works - in only one to two years. This happened because many of these channels are feeder steams to large trout lakes. Some adult trout, returning to these steams to spawn, subsequently became resident in the new pools.

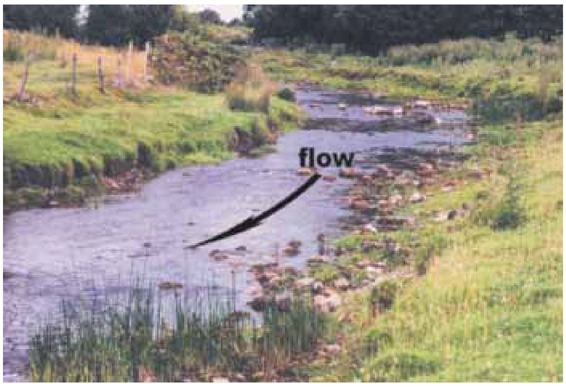
There is an ongoing maintenance requirement in this type of channel. Introduced gravel beds will gradually be washed downstream and will have to be replaced regularly - check and top up if necessary at 10 year intervals



Immediately post-works.

4 years later.

Two more examples of how a drained river with a hard bed were redesigned for fishery purposes are provided here.



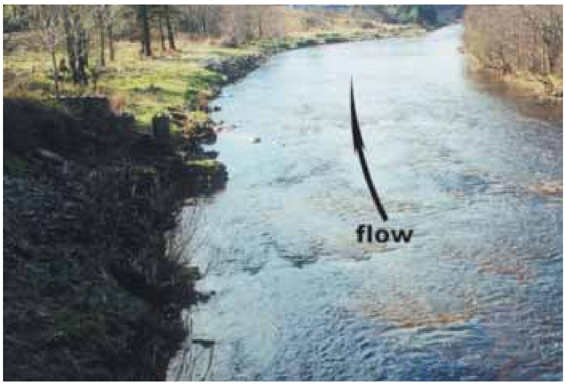
Pre-works.

The lack of fencing here (above, post-drainage) lead to serious bank trampling problems - channel basewidth was significantly increased since arterial drainage was carried out over fifty years ago. The reach illustrated above had a wetted width which is 3.5 times the pre-drainage basewidth.

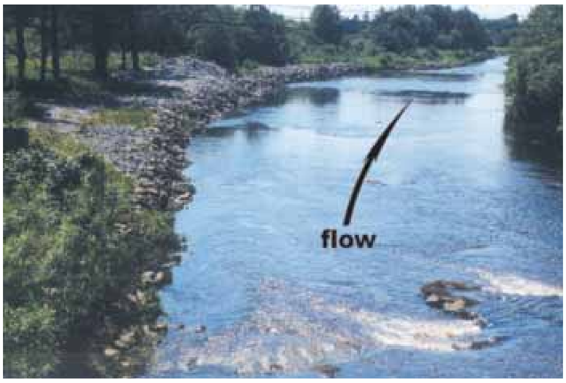
7 years post-works.

The nature of this stream, 7 years post-enhancement, is illustrated (above). Again lateral scour pools were excavated. Deflectors were built to maintain the natural stream summer channel basewidth. Spawning gravels were introduced at discrete locations. Farm stock were fenced out.

This channel (below) was drained forty years ago. The bedrock bed was drilled and blasted at that time. Draglines were used to remove the rock. Post drainage the bed was relatively flat in cross-section and <0.5m deep in summertime. A rock-breaker was used to excavate a thalweg across 1/3 of the channel basewidth next the left bank. Some of the broken rock was used to build a series of stepped pools in the new deep channel (bottom right). This is now a valuable salmon angling fishery. It began to function as such immediately after works.



A uniform shallow bedrock bed 40 years after drainage.



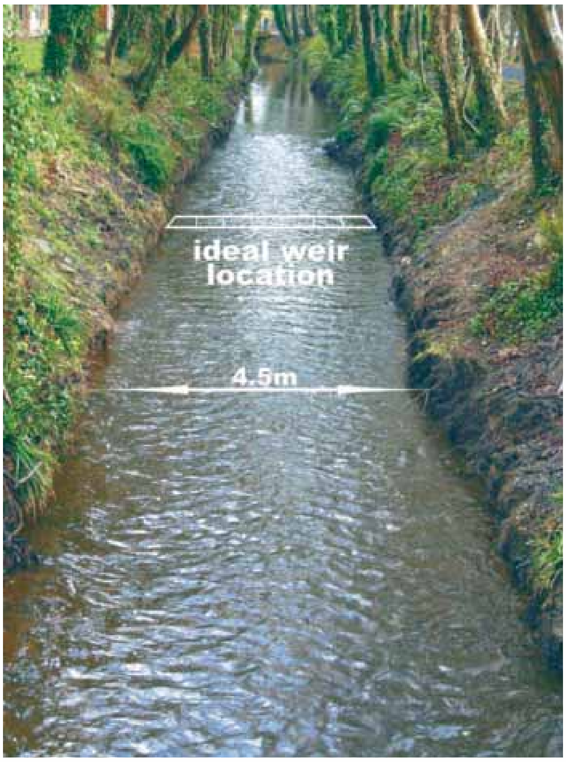
Some of the rock excavated from the thalweg was used to build rubble mats at intervals along the thalweg thereby creating a series of stepped pools next the left bank.

Reconstructing Pools in Straight Channel Reaches

In physically disturbed straight channel reaches the restoration of pool areas can only be achieved by constructing some type of weir or channel constrictor. The suitability of certain structures to particular channel reaches and their key construction features are outlined in the next chapter. However, the construction of any weir must be prefaced by proper site selection. This is the first critical step in the process.

Weirs should only be built near gradient break-points - i.e. where there is a sudden and visually obvious increase in the slope or gradient of the steam bed.

- The weir should be constructed downstream of the gradient break point where it will not significantly impound flows upstream and cause siltation problems.



Selecting a suitable site for a weir.

- There may be numerous gradient break points in a physically disturbed reach. Make sure that you select the steepest break points for weir construction.

- Weir constructed should be, at least, seven channel widths in distance apart except in high gradient (≥1.5%) channels where structures can be built at intervals of 5 channels widths in distance apart. Be careful - in artificially wide channels use the original (undisturbed) stream basewidth, not the existing basewidth, as your measure! Weir pools built at unnaturally close intervals will simply fill in over time.

Don't be fooled by this shot taken with a 400mm telephoto lens. These weirs are all 7 to 8 channel widths in distance apart. The reach gradient here was 0.72%.

If you choose the wrong construction site for a weir it will not function properly and may cause problems rather than solve them!

Options in Terms of Weir Structures

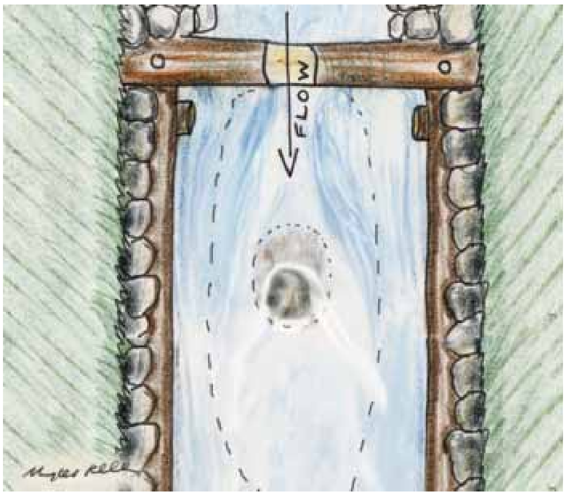
For Small Channels (≤ 4m basewidth)

In smaller (≤ 4m) channels a number of options are available in terms of selecting and building either a timber or stone weir structure.

A Note of Caution
Weirs should only be constructed when water levels are at low summer level. If you try to build a structure at a higher water level you will almost inevitably either cause ponding or end up constructing the weir at too low a level in which case it will not generate sufficient scour to maintain a pool.

Timber Weirs - There are two options, as illustrated below.


Straight centrally notched timber weir.



Side view of a centrally notched timber weir in graphic form.


Securing the two logs to provide a centrally placed V-notch concentrates flow.

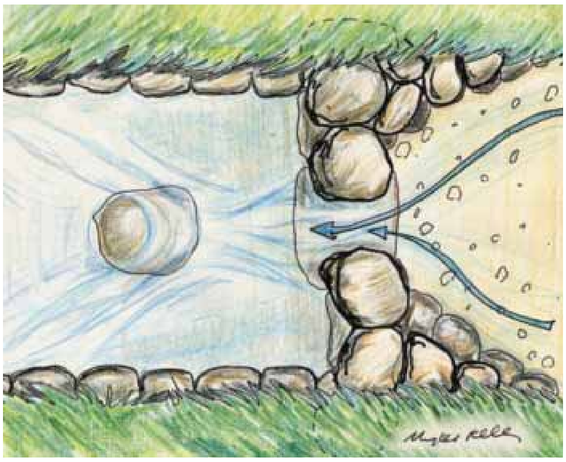
Section through a V-notched weir.

Stone Weirs

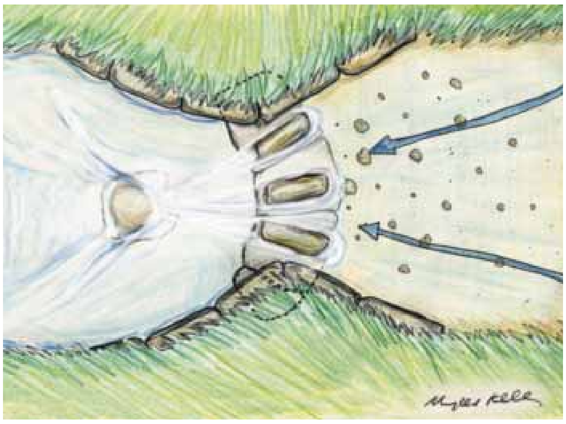
Three designs of stone weirs have all proved successful in Irish channels (below). The single notched stone weir is particularly useful in very small streams (≤3m basewidth).

The vortex weir has wider application. The vortex structure incorporating an apron is essential to ensure structure stability in high gradient (≥ 1.5%) channels which have a mobile substrate.

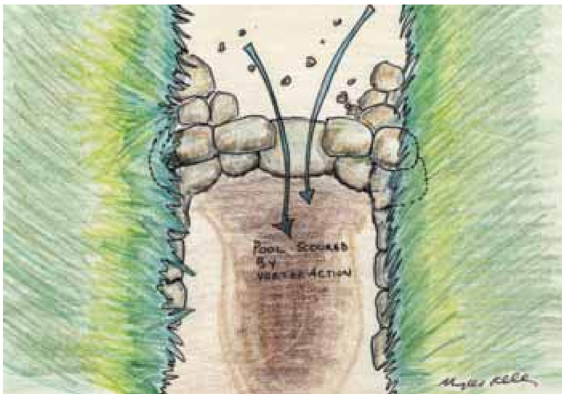

Single notched stone weir.


Single notched stone weir - A plan view.


Vortex stone weir.


Vortex stone weir - A plan view.


Vortex stone weir with an apron.



Vortex weir plus apron - A plan view.

Constructing Timber Weirs

In Ireland the construction of timber weirs has to be confined to small channels (<4.5m) simply because the large logs, required to build weirs in bigger channels, are not available commercially.

There are essentially three options in relation to using logs to build weirs.

Straight Notched Timber Weir

Having selected a suitable site (see page 79) get a machine to dig out the bank on both sides, level the bed and hold the log in position while the 2x2m long iron pins are being driven home.

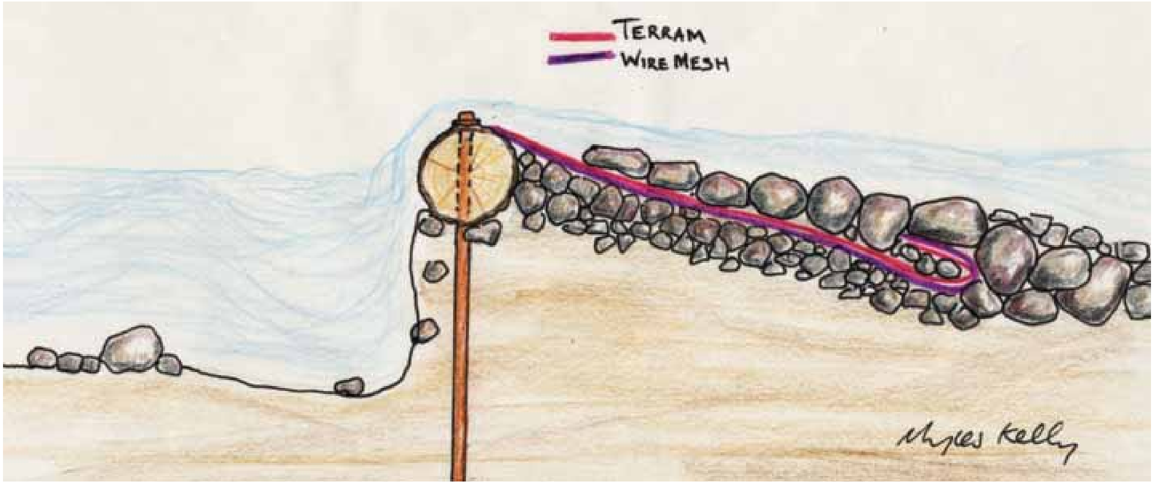
Securing the log with two iron pins.

Remember to slip a washer onto the pin before it is driven. The log, at both ends, should extend into the bank circa 0.5m on each side. The log used should be at least 30cm to 40cm in diameter.

Having secured the log at the desired height use the bucket of the machine to smooth off the bed upstream of the log and create a gentle slope downwards on this bed section in an upstream direction from the log for 3m. The required effect is illustrated in the graphic on the next page. Cut out a sheet of plastic coated wire which is 3m in length and 0.5m wider than the width of the stream. Staple one end of the wire sheet to the log. Then staple a sheet of terram of the same dimensions on top of the wire.

Make sure that the two securing pins are driven through the log left and right of the centre point of the channel so that they do not interfere with the cutting of a notch in the log at the mid-point of the stream.

Securing the wire sheeting to the log.



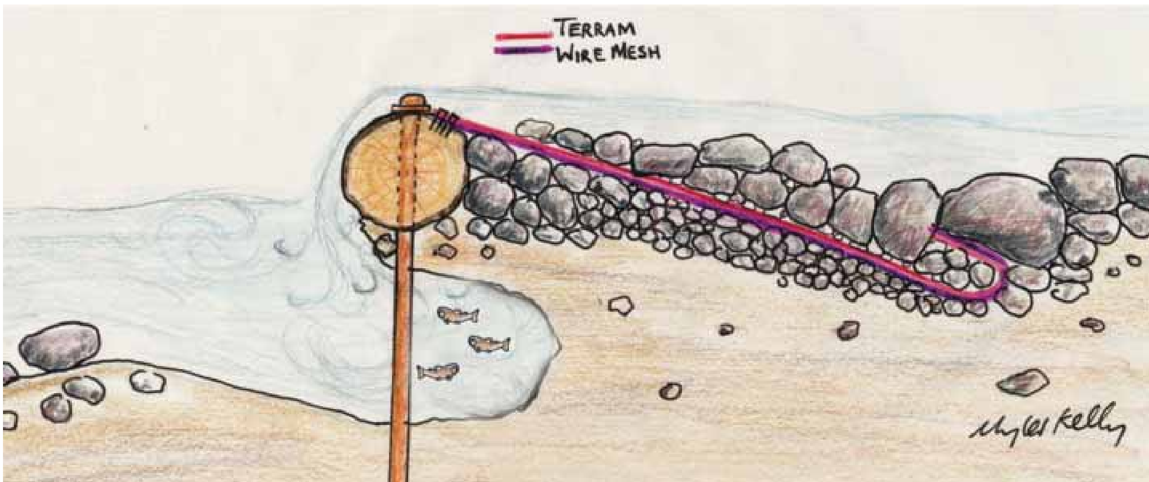
It is critical that the 0.5m of terram and wire sheeting, at their upstream end, be sloped down into the bed. The heaviest cobble available should be used to secure the upstream end of the sheeting.

Remember! The entire structure may fail if the terram and wire are scoured out from the upstream end.

Cover the terram and wire with the heaviest cobbles available. The function of the wire sheeting is to provide protection to the terram from underside localised pressure points when it is covered in cobbles and silt.

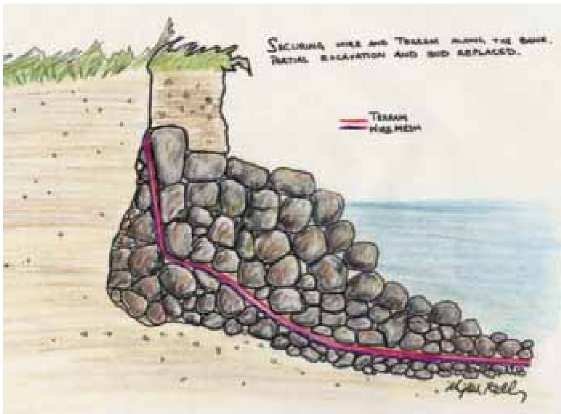
Over time the stream bed may scour out beneath the log from its downstream face. This is advantageous in that it provides cover for fish. However if the terram/wire layer were not sealing the bed the whole structure would be washed out.

Covering the terram and wire sheeting with cobble.



A hiding place for small fish.

Securing the terram and wire layers along both banks is also critical for obvious reasons. The flap of terram and wire at each bank should be folded over and secured in situ with a line of large stones. Once secured a double layer of stones should be built on top of the secured materials (see sketch below).



Securing the wire and terram along the banks.

Logs or half logs on chocks, are then lifted into the channel and secured along the bank immediately downstream of the weir log and pinned in place. Notched weirs of this type generate a significant level of back eddies along the banks during flood flows. In imperial terms one should remember that if a log weir is, say, 10 inches in diameter one should protect 10 feet of bank downstream of the weir - i.e. protect one foot length of bank for every inch in the diameter of the weir log (D. Duff, pers. com.). The chocks should be circa 15cm in height in order to provide a shelf beneath the log for small fish to hide.

Place a line of stones on top of the log to provide bank protection. Ensure that this line of stones lean back into the bank so that, should bank materials beneath the log erode out, the stone will fall into this space and limit further erosion.

3 years later.

7 years after construction.

Section through a v-notched weir.

Construction of a V-Notched Timber Weir

V-notched timber weirs are an alternative to straight notched log weirs in small channels. Construction procedures are along the same lines as have already been described for the straight notched weir (page 82). They are particularly useful in very low gradient (≤ 0.1%) channels. They concentrate stream flow to a greater extent and therefore tend to dig deeper pools than their straight log counterparts.

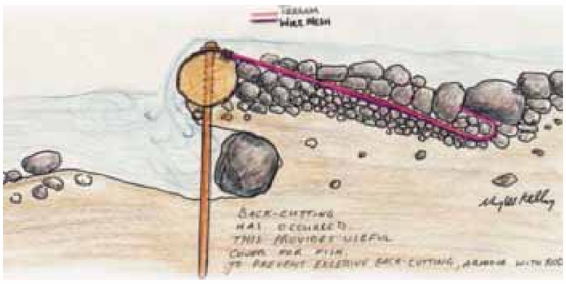
- Make sure that all logs are securely pinned together - use iron rod lengths *circa* 2cm in diameter as pins.
- Log dimensions should be the same as described for straight log weirs (page 82).
- They generate less back eddies in the pool area than straight notched weirs. Consequently a 3-metre length of bank protection is adequate for these structures.

Running Repairs!

It is difficult to judge the extent to which a stream will backcut upstream beneath the log in this type of structure - the extent of back-cutting will depend on a combination of the stream energy generated in flood flows and the nature of the stream bed material. Only about 1% of these weirs fail because of backcutting beneath the log.

An examination of both straight notched and V-notched timber weirs, one year after construction, will highlight the individual weirs which are likely to fail in this regard in the longterm. Where severe back cutting is evident a line of rocks pushed in beneath the log on the downstream side of the weir should limit further erosion of the stream bed and stabilise the structure in the longterm (see graphic below).


Note the concentration of stream energy towards the center of the pool. This limits back eddies and reduces bank erosion levels.

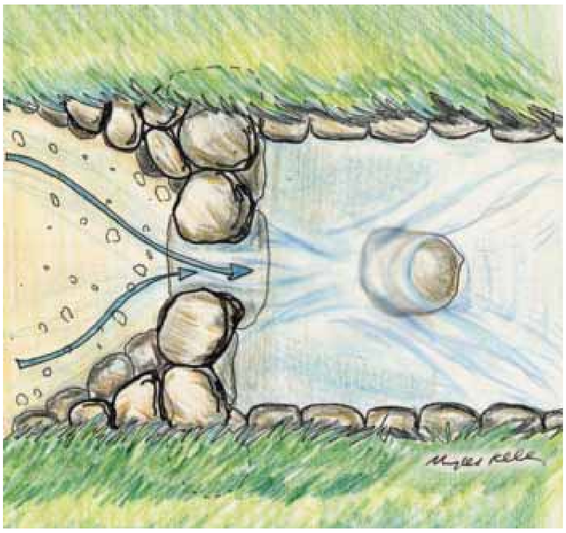

Limiting the back cutting effect.

Construction of Stone Weirs

As with timber weirs the same selection process applies in terms of picking suitable locations for weir construction (see page 79).

Single Notched Stone Weirs

A simple single notched weir is the most suitable stone weir structure for small channels (≤ 3.5m basewidth). A large number of these structures have been built in many trout spawning and nursery steams in Ireland. Monitoring data indicate that they have greatly increased the salmonid carrying capacity of small channels for 0+ and 1+ year-old fish (Chapter 11).



A plan view.

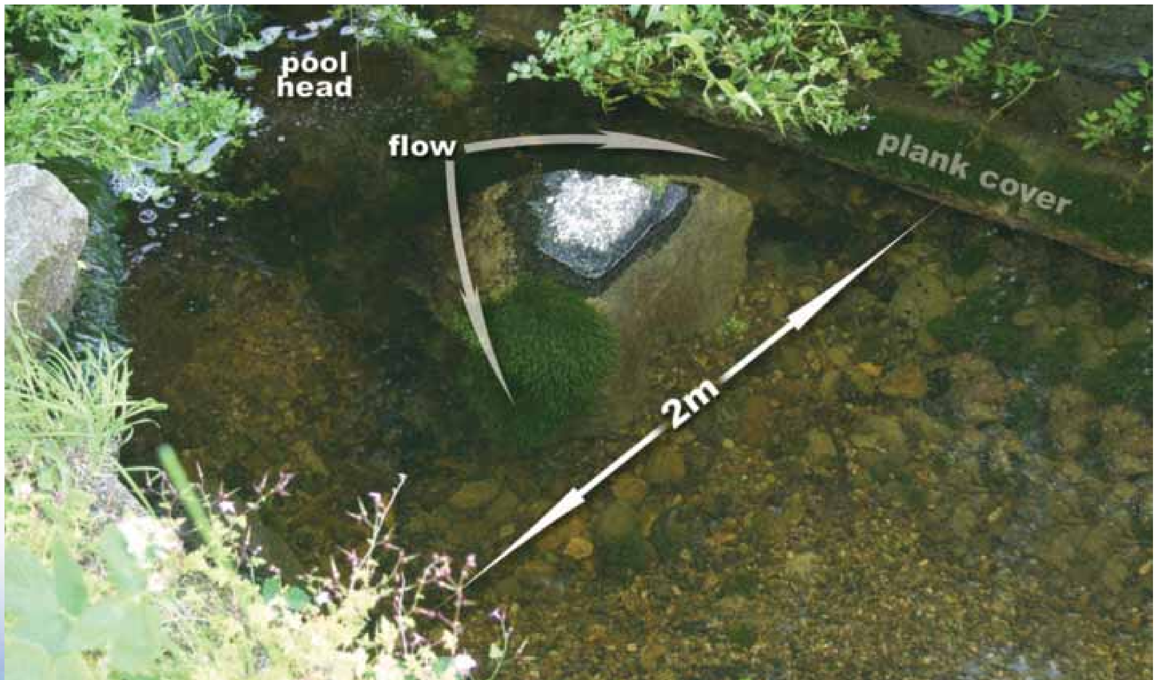
Having selected a suitable site excavate a trench across the stream and place a line of "footer" stones in the trench such that the surface of these rocks is flush with the bed level of the stream. Construct two triangular arrangements of rocks as shown in the graphic (opposite) with the most downstream positioned stones sitting on top of the "footer" stones. These rocks will deflect flows towards the central gap in the weir. The rocks in these deflectors should only exceed summer water levels by a few centimetres (see photo) - they only function is to guide all water, at summer levels, through the central gap in the weir. In higher water levels they should be submerged. Place one larger boulder in the pool excavated downstream of the weir.

A single notched stone weir in a stream with a 3.2m basewidth - 7 years after construction.

Single notched stone weirs, even in very small streams (≤2m basewidth), can be very effective in increasing standing crops of brown trout. In the weir pool illustrated (below) which had a surface area of 6m^2 an electrofishing operation in October caught one 2+ year old, five 1+ year old and fifteen 0+ year old brown trout. The relative size of these fish is illustrated (right). Prior to the construction of a series of weirs in this steam the trout population here was confined to fry (0+ year old) and an occasional yearling fish.

Where small steams are partially shaded and bankside vegetation is limited, cover logs or planks secured in pool areas can provide useful additional cover for small fish (below).

The occupants of this small pool.



6 years after construction.

Vortex Stone Weirs

These structures are more suited to streams and rivers where channel basewidth is ≥ 3.5m.

- A series of rocks are built into both banks upstream of the actual weirs. They are designed to deflect flows towards the center of the channel.

- The design is similar to that already described for the single notched stone weir. It differs in two ways - the line of "footer" stones across the stream are arched upstream (see photo and graphic) and one or more rocks are positioned on top of the footer stones in the central area of the stream.

- *Circa* 1/3 of the total channel basewidth should be open to the stream flow at summer water level.

- The number of rocks placed on top of the footer stones in the centre of the stream is determined by both steam width and energy i.e. in a high energy stream (gradient ≥1.5%), with a basewidth of 4m, a single stone placed centrally on top of the footer rocks is more desirable than using three stones as illustrated in the graphic.

Why? - the individual stones must be heavy enough to remain in situ in flood flows. In a 4m basewidth high energy stream the single centrally placed rock should weigh circa 0.25 tonnes. In building this type of structure the size of rocks used must also be balanced against the fact that 1/3 of the channel basewidth must be open to the stream at summer water levels.

Other features of the structure (bank protection and cover for fish) are as already described on page 84. Vortex weirs generate significantly less back eddies in the pool area than single notched weirs. This helps to limit bank erosion problems.

Note the concentration of stream energy towards the center of the pool.

The two views (below) of the same weir help to illustrate the hydraulic effects of this structure.

The deflection of flow towards the large rock in the centre of the pool is particularly evident in the top photo. This large rock splits the flow creating two scour channels. Each of these flows are further divided by the two rocks located towards the tail of the pool (bottom photo). This triangulated arrangement of rocks, strategically place to intercept flows, helps to increase the length and depth of the pool.

The hydrological changes caused by the weir have also allowed a substantial quantity of gravels to dump out at the tail of the pool providing a salmon spawning site. Fish spawned here in the first winter after weir construction. No gravels had been introduced to this stream as part of the enhancement exercise and no fish had spawned in this reach in the two year period prior to the construction of the weir.

The end result, from a fishery perspective, is that the weir structure is providing high quality habitat for juvenile salmon and trout and adult trout whilst also creating ideal spawning habitat. Large adult salmonids can rest here in wintertime adjacent to where they want to spawn.

Note the deflection of flows towards the rock in the centre of the pool.

The deflection of flows by the three boulders in the pool are self evident. Note the natural deposition of spawning gravels at the tail of the pool.

Vortex Weirs with Aprons

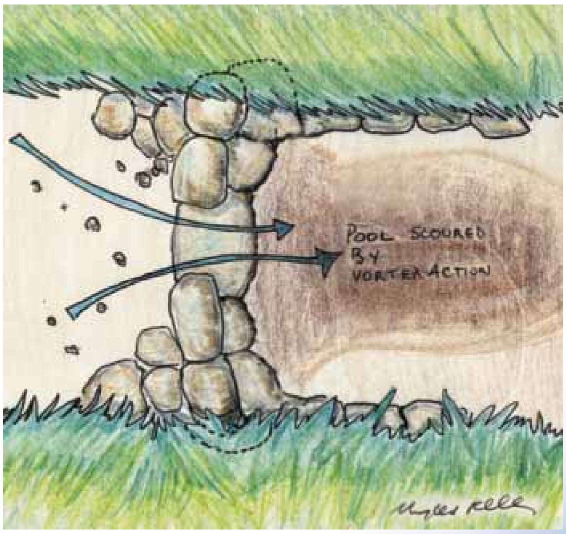
In high energy channels with a mobile cobble/gravel bed and a gradient ≥1.5% a different design of vortex weir is required to ensure structural stability. This design differs from the previously described structure in a number of ways:-

- a single layer of flat rocks are entrenched in the stream bed from bank to bank. The surface of these rocks are flush with the stream bed. This line of stones are arched slightly in an upstream direction (see graphic below).
- a complete second layer of stones is built on top of the bottom layer leaving only a central gap to accommodate the entire low flow discharge.
- the top layer of stones are arranged such that the bottom layer of stones protrude on the downstream face of the weir forming an apron. This helps to dissipate the energy during flood flows and prevents the weir from being undermined (photo below and graphic).

This slow shutter speed photo illustrates the extent to which stream energy is dissipated on the weir apron during flood flows and, thereafter, by the large rock in the centre of the pool.

The same weir, as above, in low flow conditions.

Note that this weir is slightly dished towards the centre. The availability of slab shaped rocks to build these structures is crucial.



A plan view. Some armouring of the banks may also be necessary.

Other Questions in Relation to Timber and Stone Weirs

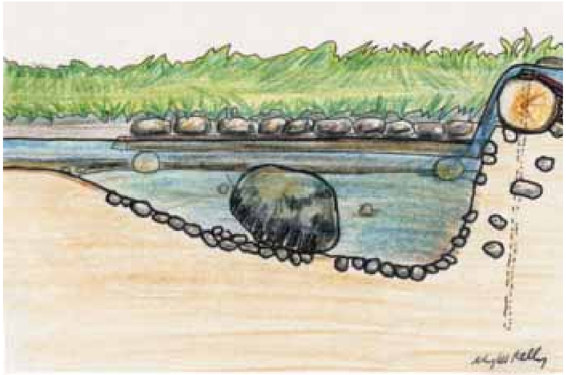
Should a pool be excavated after weir construction?

In channels with a hard boulder clay bed, a pool should always be excavated following weir construction - the shape, size and position of a suitable pool is illustrated in the graphics (x3).

Pool excavation.

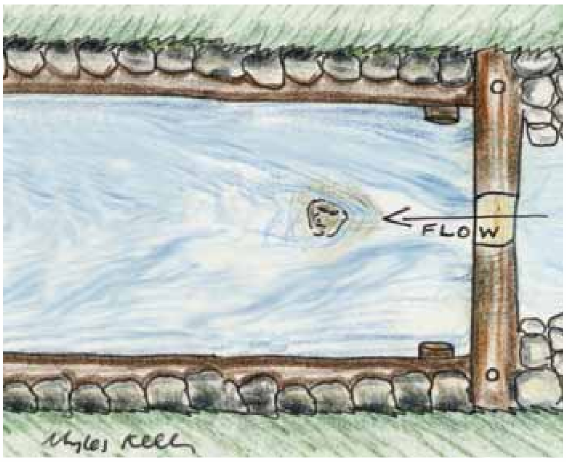
In streams with loose bed material, where the gradient is ≤ 1.5%, a pool similar in shape to that illustrated should be excavated (see graphics). The stream will probably re-adjust the shape of the pool over time. However, placement of rocks and/or timber cover structures in pools necessitate their excavation at works stage to accommodate the aforementioned structures.

In high gradient (≥ 1.5%) loose gravel bed channels pool excavation is unnecessary.



Long-section.

Cross-section.



Plan-view.

Channel Constrictors in Small Streams

Structures designed to constrict channel basewidth at summer level, thereby increasing flow velocity in the central channel area, can be equally successful in scouring out and maintaining pool areas. They are useful where one wants to minimise the impoundment of flow upstream of the proposed structure. They should only be used in circumstances where a channel is artificially wide - where bank trampling, excessive erosion or drainage has increased the natural basewidth. The use of constrictors in larger rivers is dealt with in Chapter 10.

In smaller streams one has the option of using log/rock or rock structures. A typical log/rock paired deflector/constrictor is illustrated just after construction (top right). Note that the same construction rules, outlined previously in relation to timber or stone weirs, apply here.

- Build the structure downstream of a significant gradient break-point.
- Protect the banks downstream of the structure - a log/rock revetment was used in this case.
- Place large rocks in the pool area to provide cover for small fish and increase the scouring rate.
- Place large rocks in the base of the triangular areas within the log frames to ensure that this material is not washed out in flood flows.
- Anchor the base of the logs at least 0.5m into the bank.
- Ensure that at least half the log is submerged at summer levels to increase longevity.
- In larger streams (>4.5m) plant trees which will eventually overhang the pool area and make sure that the stream is securely fenced.
- Dig out the pool area if the stream has a hard boulder clay bed.

Immediately post-works.

One year later.

3 years post-works. Dense bankside vegetation masked the particular view in the two photos above. Paired stone deflectors in small streams (≤4m) tend to be less effective at scouring out pools than the structure illustrated above.

Chapter 9

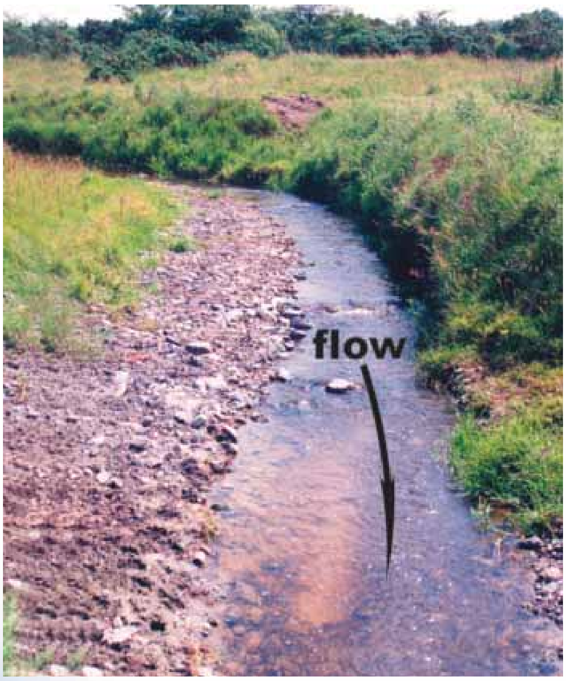
Two-Stage Channels

Restoring natural channel basewidth in arterially drained rivers and streams involves the construction of a two-stage channel. This is essentially a channel within a channel such that all of the water at low flow is confined to a defined sub-section of the total basewidth equal in width to the natural pre-drainage width of the channel. In order to accommodate the designed flood flows within bankful level the two stage channel needs to have at least the same cross-sectional area as the designed flood relief channel (Appendix I).

Two-Stage Channels in Meandering Rivers and Streams

Arterial drainage schemes in Ireland, since the 1970's, have generally involved a widening and deepening of channels without interfering with their natural meander pattern. Construction of a two-stage channel in these circumstances essentially involves a re-excavation of the original pre-drainage channel basewidth on the eroding side of the channel and the redeposition of this material next the depositing bank. The re-deposited material needs to be placed in a shape which parallels the bank curvature on the eroding side of the channel. An example of such an exercise is illustrated below. Graphics illustrating this exercise are provided on the next page.

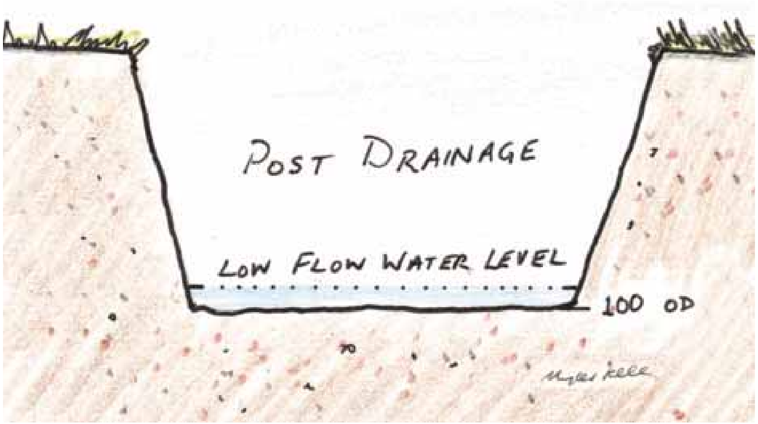
- Note how the excavated and re-deposited bed material mimics the natural meander pattern restoring pre-drainage basewidth at low water levels.
- In high energy channels the leading edge of the re-deposited berms may need to be stabilised by a line of stones or larger stocks trenched into the bed.
- Once stock are fenced out the re-deposited material is very quickly colonised by semi-aquatic plants which help to stabilise the new physical regime.
- When the low water natural basewidth has been restored additional features can be added - weirs, random boulders or spawning gravels as required.

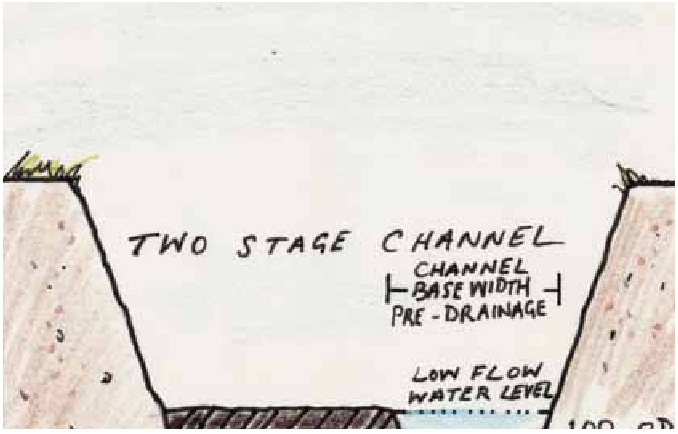


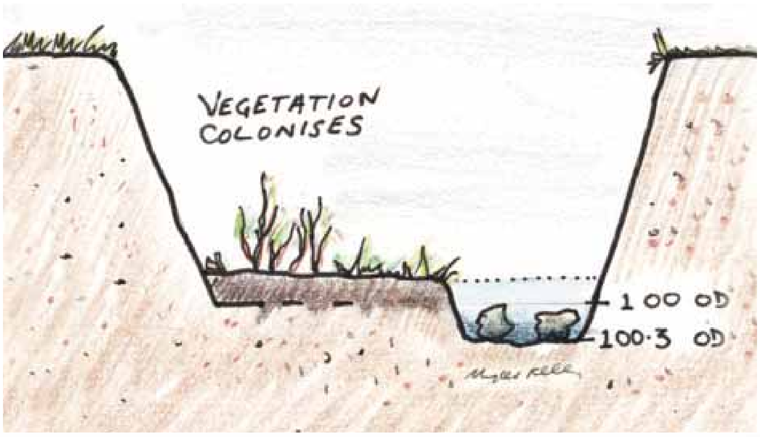
The two-stage channel has just been excavated. The excavated bed material has been deposited on the right hand side of this drained channel (on the left in the photo).


2 years post-works. The provision of a secure fence line along both banks was a critical part of this programme.

The physical alterations involved in creating a two-stage channel are illustrated below graphically. Note bed the levels in each graphic.







This is a typical example of the value of a two-stage channel in a relatively low gradient (0.1%) meandering river channel.

An artificially wide, shallow silted channel (pre-works).

Immediately post-works. Normal summer channel basewidth has been restored.

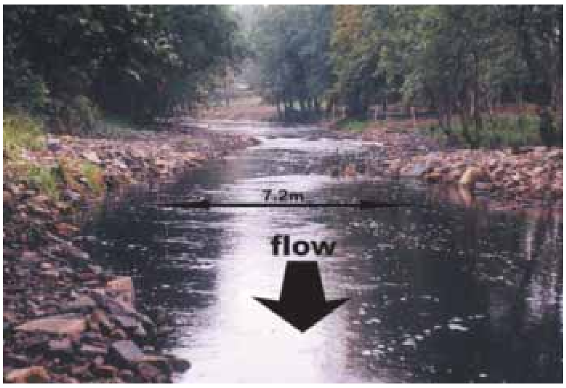
2 years post-works. Note the random boulders.

Prior to works here fish stocks were completely dominated by 0+ year-old salmon and trout - the artificially wide channel was too shallow to support older age groups of salmonids. Two years post-works a substantial population of 0+ and 1+ year-old salmon and trout were present. Significant numbers of larger trout (2+ and 3+ year-old) had also become resident here in this short period.

An aerial view of the same reach 5 years post-works is illustrated (below). Note that the new berm has vegetated. Random boulders placed in the channel and vortex weirs built following the channel narrowing can also be seen.

7 years post-works. Revegetation of the berm has increased and includes the establishment of numerous alders.

The construction of two-stage channels in high energy meandering reaches can be equally successful. The example provided here illustrates the type of works which can be carried out. The only critical difference between these operations and those described previously are that larger stone are required to secure the wetted edge of the berms. In some instances it may be necessary to blind the surface of the berms with larger stones to ensure that berm contents are not washed out during flood flows.



Immediately post-works.

Note

- In this case the restored narrow summer channel basewidth was excavated in the central channel area.
- The excavated bed material was placed in the channel along both banks.
- The excavated channel followed the natural meander pattern of this river.
- The provision of a berm along both banks in this instance provided a walkway for anglers.
- Random boulders (sub-surface) were placed in the thalweg.
- A vortex stone weir was constructed (background).
- After two years the berms had silted up and subsequently vegetated. No reseeding of the berms was carried out.
- Pre-enhancement this artificially wide shallow channel could only support 0+ and 1+ year old salmonids. It can now accommodate all age groups of trout and also provides lies for returning adult salmon.

2 years post-works.

Two-Stage Channels in Canalised (Straightened) Reaches

In low gradient channels which have both been artificially widened and straightened in the past and also lack gradient break points there is no opportunity to construct any type of weir. To do so, in such circumstances, would only make matters worse ecologically and could also increase flood risks.

Experimental work in Irish channels has shown that the construction of a series of low level alternating deflectors will greatly increase the salmonid carrying capacity of such reaches even though the natural meander pattern of such channels is not being restored. (O'Grady & Duff, 2000).

Why is this Approach Successful?

Alternating deflectors will narrow artificially wide channels with several obvious effects:-

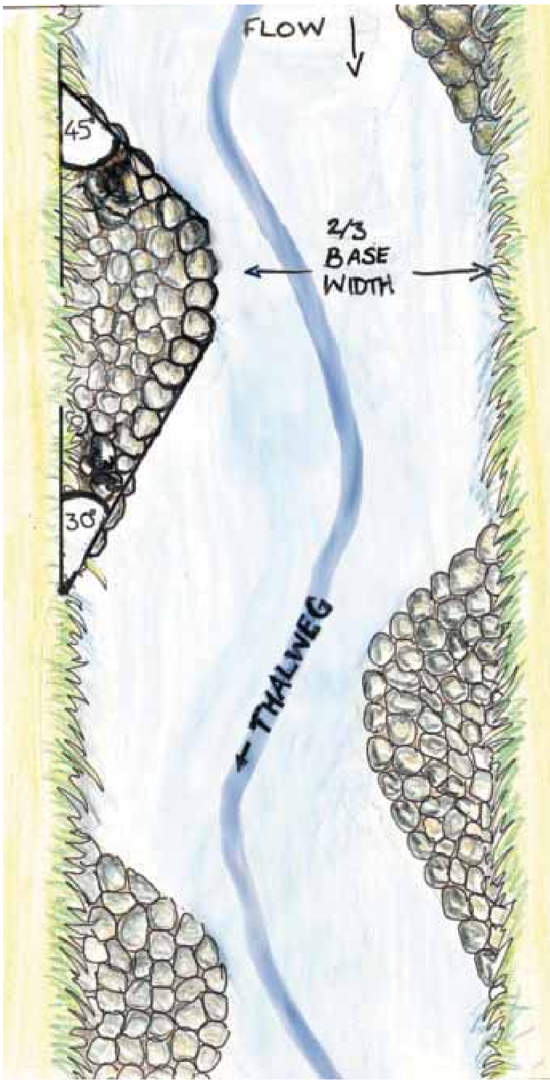
- the adjusted channel will be narrower, deeper and have higher water velocities at summer level. Channel length will also have been increased.
- the higher velocities will tend to scour out the finer bed sediment material. This will help to reduce dense growths of macrophytes in the newly developed thalweg.
- exposure of coarser bed material will increase macroinvertebrate production and may also provide some spawning opportunities.
- a narrower deeper channel will accommodate larger fish.

The effects of alternating deflectors in a low gradient (0.05%) channel reach - immediately post-works and 6 years later.

5 years post-works. Note the colonisation of the deflectors by semi-aquatic plants.

Some details on Design and Construction

- Where engineering records of the original channel basewidth are available deflector width should be set to restore natural channel width.
- The normal shape of the deflectors are illustrated. Deflector shape may have to be altered - smaller narrower structures than those illustrated (opposite) may be required to ensure that the new low-flow channel is not any narrower than the pre-drainage channel basewidth.
- Always start work at the top of the reach working downstream. Follow the flow- the second deflector should catch the deflected flow from the first structure before it reaches the bank.
- The outer frame of each deflector should be built first with heavy stones or rocks as appropriate and subsequently back-filled with excavated bed material
- Excavate the thalweg as you proceed downstream.
- Ensure that the channel, post-works, still has the capacity to discharge the flood flow. This may involve a further excavation of the bed, before deflector construction, in order to retain the desired cross-sectional area required for flood control.



Alternating deflectors.

6 years post works. This deflector series, now fully vegetated, is maintaining a narrow, deep, sinuous channel. This view is now obscured in summertime because of the height and density of vegetation - a bonus for the trout stock who now have adequate depth and cover.

Pre-enhancement, this trout spawning and nursery steam (opposite) was artificially wide and shallow because of bank trampling problems and an arterial drainage programme carried out forty years ago. Trout stocks were limited to small numbers of 0+ year old fish because of inadequate depth and an absence of cover.

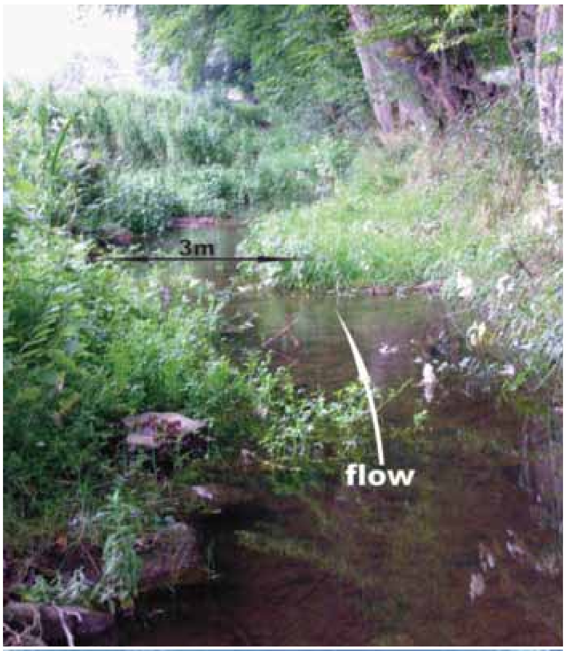
The works programme here involved a number of steps:-

- the left bank was securely fenced off.
- a series of alternating deflectors were built. The frames of these structures were built with imported stones.
- the narrower sinuous channel between deflectors was excavated and this material (gravel and silt) was used to fill the frames of the deflectors.
- the lower branches on the beech trees were pruned in order to increase the amount of incident light reaching the steam bed and its banks.

Six years post-works (opposite) the previously trampled bank line and the surface area of the deflectors are well vegetated. The deflectors are maintaining a narrower sinuous channel. This reach now supports a substantial stock of 0+ and 1+ year-old trout and an occasional 2+ year-old fish. There also appears to be a significant increase in the juvenile brook lamprey population here since works. Quantification of the level of effectiveness of this type of programme is provided in Chapter 11.

<u>Be Careful!</u> When undertaking programmes like this in drained channels ensure that the narrower channel, post-enhancement, has the same summer basewidth as it had pre-drainage (see Appendix 1).

Pre-enhancement.



6 years post-works.

A range of additional techniques have been employed to restore, or mimic, natural physical features in disturbed river channels in Ireland.

Channel Constrictors in Large Rivers

Channel constrictors, in the larger previously drained channels, have proved very effective in recreating pool areas. In this river, post-drainage, there were only eight angling pools within a seven kilometre reach. Construction of channel constrictors here were part of a programme designed to restore the natural physical features of a C-type channel (after Rosgen, 1996). Structures were built at significant gradient breakpoints.

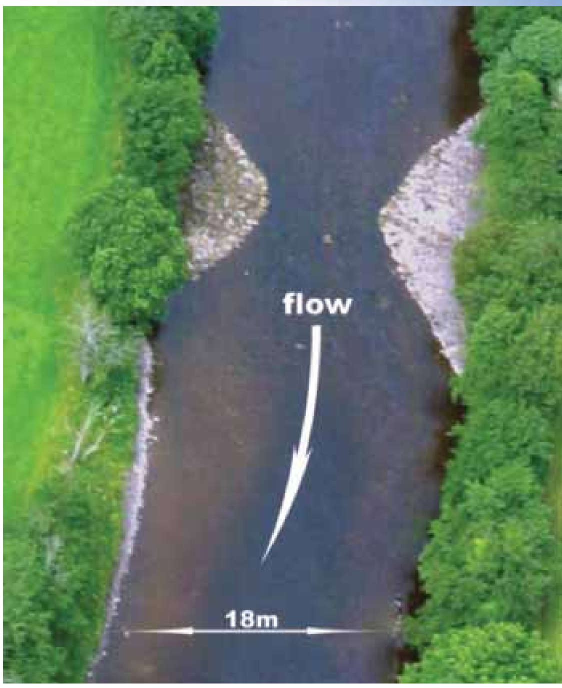
A trench was excavated following the outline of each groin - the gap in the centre of the channel was 1/3 channel basewidth. The shape of each individual deflector or groin has already been outlined on page 99.

A continuous line of large boulders, each 1-2 tonnes in weight, were embedded in the trenches. The largest rocks were located along the upstream face of each structure where erosion was most likely to occur.

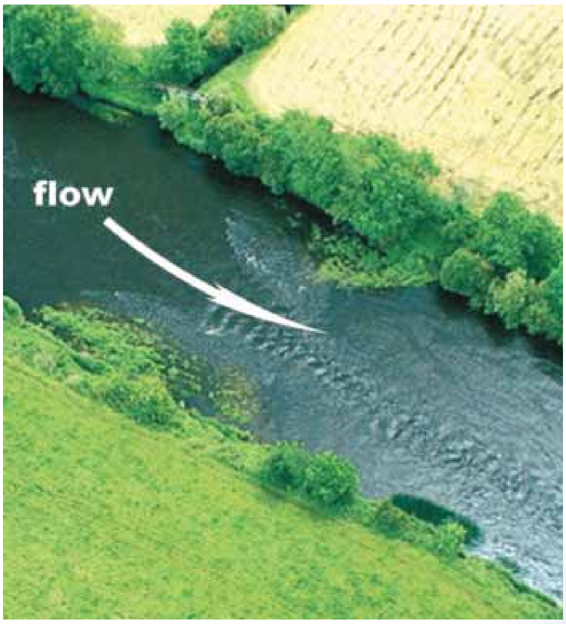
The boulders next the bank were 0.5m above summer water level. The surface boulder line was sloped downwards towards the tip of the structure where the stones were only 20cm. above summer water level.

A pool was excavated downstream of the groins in the center of the channel. Pool shape is evident in the photo (top right). The boulder clay excavated from the pool area was used to fill the groins. Even if the excavated material were loose sand, or gravel, it can still be used to fill the groins. However, having done so, one would need to blind the surface of the groins with stone which would not wash out in flood flows.

Three to four large (1-2 tonnes) flat boulders were placed in each pool - observations by salmon anglers suggest that square or rectangular shaped boulders, as opposed to round boulders, create better salmon lies.



Two years post-works. The excavated pool area can be seen clearly.



6 years post-works - the sloping nature of the groins, from the bank towards the centre of the channel, are evident in this minor flood event. Note the concentration and increased velocity of flow downstream of the groins.

Why Channel Constrictors?

Rubble mats (opposite) or large stone weirs might have been used as an alternative to the paired channel constrictors (groynes) illustrated on the previous page to recreate the pool areas. A baseline survey of this river indicated that channel constrictors, not weirs or rubble mats, should be used. The rationale for this selection was based on the following data.

Electro-fishing of this main channel reach during the baseline survey indicated that it supported large stocks of 1+ year-old salmon parr which were born in tributary sub-catchments and then migrated to this section of the main stem as year-old fish.

A baseline survey also showed that the distribution of aquatic plants (principally mosses) in this river was unusual. Their growth was confined to reaches which were ≤0.5m deep. Normally, in Irish rivers, plants would colonise much deeper areas. Their limited distribution here was due to the naturally high dissolved humic acid levels in the water. This is a natural phenomenon caused by run-off from peat bog areas. This natural discolouration limits light penetration through the water column thereby limiting the euphotic zone to channel reaches ≤ 0.5m deep.

The construction of weirs or large rubble mats, in this particular instance, would have impounded significant lengths of channel, thereby reducing the euphotic zone and indirectly reducing juvenile salmon production.

This is a good example of the care required in designing enhancement programmes and the value of reviewing all of your baseline data before arriving at a balanced enhancement programme.

Be careful! An enhancement programme which restores one feature of a channel, to the detriment of other areas, is of little value.

The aerial photograph (above), taken in flood flow conditions, illustrates a different circumstance. In this high gradient reach (2%) two weirs were constructed with two objectives in mind:-

I. To create two salmon angling pools in this formally drained river reach.

II. To raise the water levels, in low flow conditions, at the downstream face of the old eel weir, as migratory salmonids were experiencing difficulties in ascending this weir in summertime.

These objectives could be achieved here, without impounding flows significantly, because of the high gradient.

Rubble Mats

Rubble mats are a useful feature to introduce to some of the larger (>10m wide) channels which have been subjected to arterial drainage programmes in the past.

Following drainage a hard boulder clay bed has been exposed in many rivers. This material is so hard that, even fifty years after drainage, very little erosion of bed material is evident. A cross sectional trapezoidal shape and a smooth longitudinal bed profile in these drained channels is still in place in many reaches. In fishery terms such channels could be described as uniform glides. Electrofishing surveys have shown that they are generally very unproductive areas supporting few juvenile or adult salmonids. The construction of rubble mats in such zones can greatly enhance the fish carrying capacity of these channels (O'Grady *et. al* 1991).

Functions

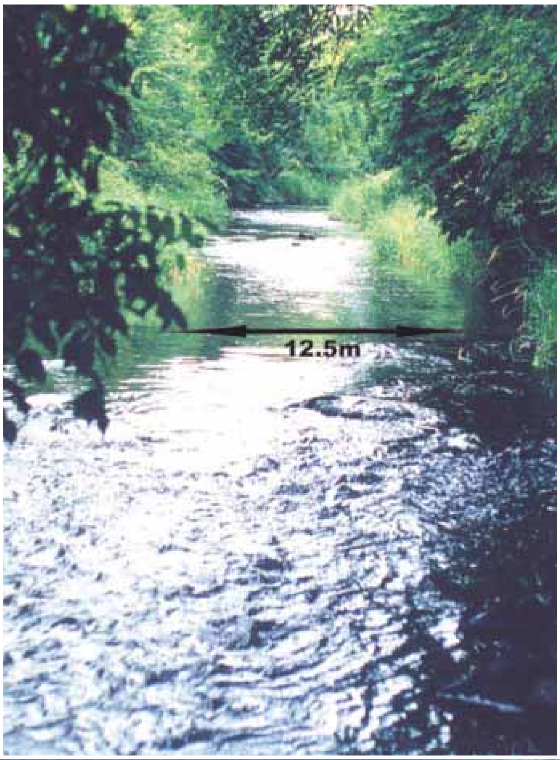
Rubble mats built in drained channels essentially mimic the natural riffle areas which were present pre-drainage. They serve a number of functions:

- construction of a rubble mat reduces the cross-sectional area of the river thereby increasing flow velocities at low summer flows. This results in important ecological changes. The faster flowing area on top of the rubble bed quickly becomes colonised by a range of plants. A large variety of macroinvertebrates favour such conditions and will colonise the rubble mate in a short period of time. The biomass of macroinvertebrates on rubble mats, three years after their construction, is similar to that present in natural riffle areas (Lynch and Murray, 1992).

- the fast flowing shallow nature of the channel over the mat provides suitable habitat for young salmon and trout and provides them with an adequate food supply.

- when the rubble mat is dished towards the center of the channel the velocity through the dished section may be adequate to maintain scour through a pool excavated downstream. Numerous adult trout will colonise such pools because there will be a constant drift of invertebrates from the rubble mat downstream into the pool area.

- such pools will also provide resting areas for adult salmon.



A series of rubble mats constructed on a previously drained uniform glide. Pools with a max. depth of 1.5m were excavated in the hard boulder clay bed sections between rubble mats.

Location of Mats

Rubble mats should never be constructed without reference to the authority responsible for flood relief in the drained river in question. Structures built to the wrong specification or, in the wrong location, could cause flooding problems.

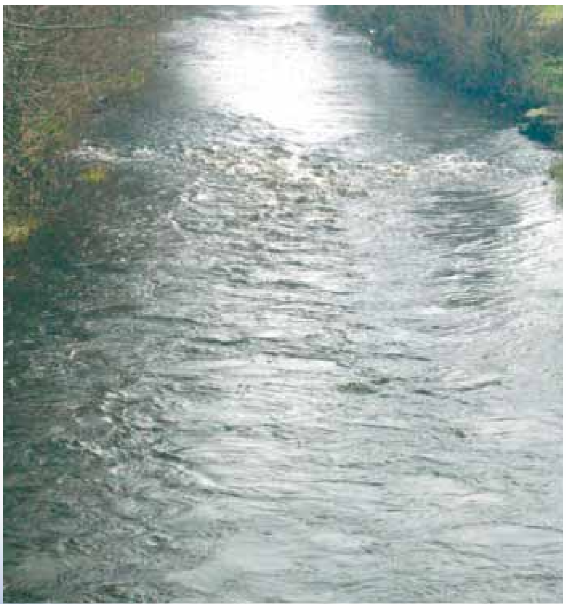
A physical survey of the river bed where rubble mat construction is proposed should be the first step. Essentially one needs to establish a longitudinal depth profile at summer level to establish where there are high points on the river bed - i.e. there may be minor accumulations of loose bed material deposited along a uniform previously drained glide at specific points. The shallower locations should be selected as potential rubble mat sites. However, care should be taken to ensure that mats are constructed at a distance apart such that their ponding effect is not significant. Successive rubble mats should be at least seven channel widths apart. However this distance, in any particular channel, should not be taken as a standard measurement of mat placement. The high points on the river bed should be given precedence as sites for works.

In meandering channels rubble mats should only be constructed on straight channel reaches between meanders. In these circumstances the mats mimic the natural riffle areas which would be present in such areas if the channel had not been disturbed in the first place.

In larger rivers (basewidth > 10m) broken quarried stone (15-25 cm diameter) is the ideal material for constructing rubble mats - the broken stones lock together to a greater extent than round cobble material. In smaller meandering channels (< 10m basewidth) spawning gravels could be substituted for rubble to create the riffle areas - gravel placement, as opposed to rock, has the advantage that it will provide spawning opportunities as well as increasing fish food supply.

What Size?

Individual rubble mats will function successfully where the mat is circa one channel width in length - i.e. in a 10m wide channel the mat needs to be 10m long.



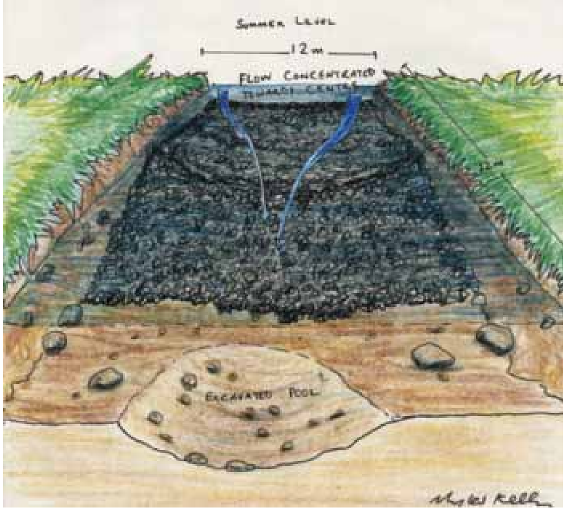
The mat is dished centrally to maintain scour in a pool area downstream.

The riffle area in view here is a rubble mat in a drained stream with a boulder clay bed.

Rubble Mat Construction

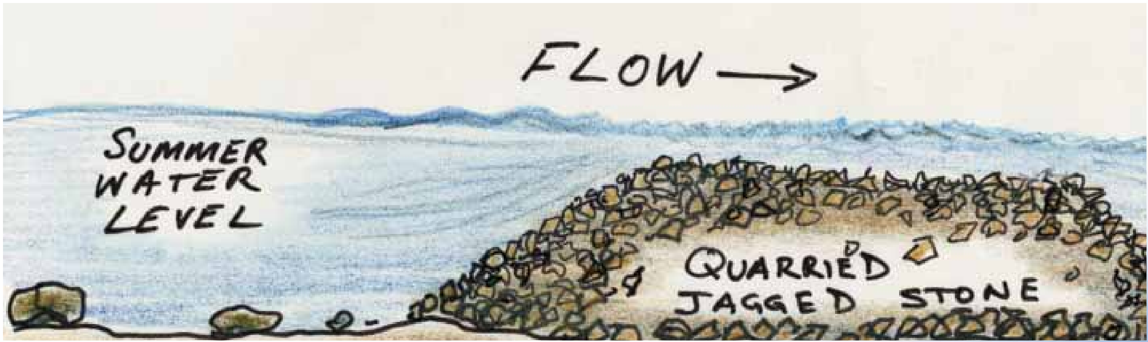
Once the site has been selected (see previous page) the quarried stone should be placed in the channel as illustrated in the graphics. Ensure that:-

- the rubble mat is submerged from bank to bank. This will maximise both the number of fish lies available and invertebrate production.
- dishing the mat centrally is important if you want to maintain a pool downstream.
- excavate the pool as previously outlined (page 92).
- small trout and salmon parr will colonise the surface area of the rubble mat with larger fish living in the pool downstream.



Plan view of a rubble mat.

In many of Ireland’s drained catchments, there is considerable recruitment of young salmonids, as yearlings, from tributries to the main stem. the construction of rubble mats, in main stemmed drained channels, provides a niche for salmon parr until they reach smolt age. These structures will also accomodate young trout. the pool areas, downstream of the mats, will provide a home for these trout as adults. (O’Grady *et al*, 1991).



Side view of a rubble mat.

Random Boulders

Large boulders are a natural physical feature of many high gradient salmonid channels.

They serve a number of functions:-

- they help to dissipate the energy of a stream in flood flows thereby limiting bank erosion levels. In such circumstances they also provide back eddies - i.e. resting places for fish during high floods.
- small salmonids can hide beneath the boulders.
- they provide a niche for a whole range of macro-invertebrates (see page 28). In the absence of boulders many of these species would not be present.


A natural boulder strewn high gradient salmonid river.


Cased caddis larvae securely attached to a large stone.


This photo, taken at a low shutter speed, illustrates how a large boulder helps to dissipate stream energy during a major flood event.

Boulders also serve some additional fishery functions.

- In many high gradient channels most spawning gravel deposits are of a relatively larger size and therefore only suited to salmon. In such channels, deposits of finer gravels often accumulate downstream of individual boulders. Trout will use these deposits for spawning. In other circumstances the addition of individual boulders may result in long narrow pool areas being scoured out downstream of individual stones after significant flood events (see page 110).

Finer gravels will often deposit in a slack area downstream of a boulder.

Note the pocket of fine gravels downstream of this boulder. This is a trout spawning location.

- In lower gradient channels, with a finer gravel/sand/silt bed, boulders help to scour out deeper channels in the bed thereby reducing silt deposits and providing lies for fish.

- Boulders placed in this formerly drained stream (below) help to scour out fine silt deposits during flood flows. The effects of their placement on stream bed morphology is very evident subsequently (bottom right). Juvenile trout stocks here increased substantially (x6) following boulder placement.

The scouring effect of the introduced boulders is obvious here.

Changes in stream bed morphology caused by the boulders is self evident. Trout numbers increased 6 fold here after boulder placement.

Salmonids, of all sizes, will use the hydraulic effects of stones on a river bed to their advantage. They will always seek out areas where flows are minimised as resting places - quite often in front of, or behind, a stone or boulder.

The adult trout (below) can hold station in the slack water downstream of a boulder with minimum effort. The fish can move quickly, to the left or right, to catch food items drifting downstream. Having done so the trout will invariably return to the same lie to conserve energy.

This very small (5cm) trout fry was holding station on the upstream face of a large cobble.

Trout and juvenile salmon are, sometimes, territorial animals. They settle for a smaller territory in circumstance where they cannot see their neighbour. Boulders and large stones on the bed of steams therefore increase the number of fish lies, as well as creating eddies where fish can hold station without using too much energy.

A trout holding station behind a boulder with little effort.

Random boulders - An integral part of this enhancement programme.

This is a naturally boulder strewn B-type channel. Comment on the last three pages summarise the function of boulders in this type of channel from a fishery perspective. If boulders have been removed from a channel like this, for whatever reasons, their replacement should be an integral part of any planned rehabilitation programme.

The following two pages (110 & 111) illustrate how the restoration of boulders to a stream can restore natural channel morphology. This example also illustrates how specific river bed sections can serve different fishery functions at different times of the year.

A Few Rocks Strategically Placed in this Spate Channel are Multi-functional.

This was a uniform glide with a flat, even bed composed of a gravel/cobble mix before the rocks were introduced. The hydraulic effect of the boulders has markedly changed the morphology of the channel to the advantage of the fish stocks. Specific channel areas have different functions on a seasonal basis.

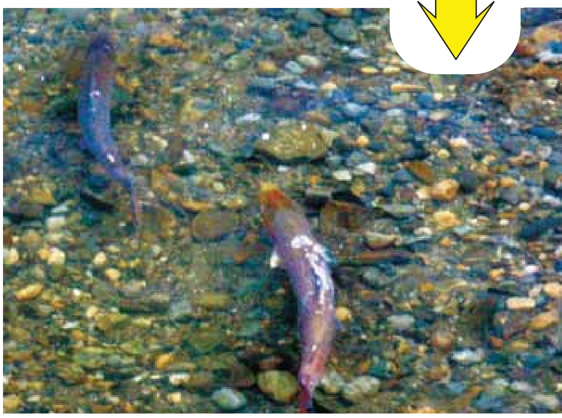
A shallow braided channel reach which can only support a few fry post-drainage. This gravel/cobble bed is compacted and unsuitable for spawning purposes. It is too shallow to support older salmonids.

The addition of three boulders has markedly changed the morphology of this previously drained channel reach to the advantage of fish stocks. Sub-sections of channel now have different functions seasonally.

Summer

A long narrow gully has been scoured out in the bed. In drought conditions over 140 1+ year old salmon and trout sought refuge here. This pool was only 12m long by 0.7m wide.

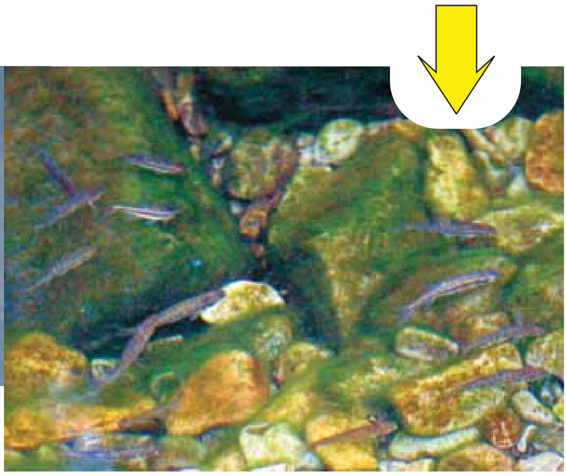
Winter



In winter time adult salmon congregate in the same pool prior to spawning.

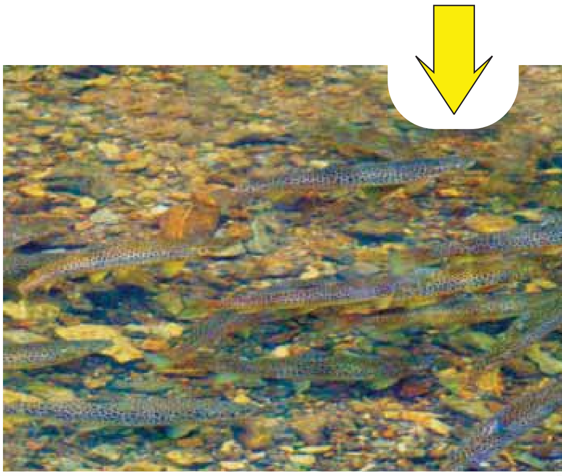
The Shallow Area, with Lighter Gravels, Has different Functions

Summer



A gravel shoal suited for trout spawning purposes has accumulated here. Minnow and salmonid fry feed here at normal summer levels.

Winter



Trout spawn here in winter time.

Breaking Sheet Rock

Excavation of sheet bedrock in formerly drained rivers is an attempt to restore the natural physical form of the channel at a lower bed level. This is both feasible and cost effective in many drained Irish rivers because one is dealing with relatively soft bedrock (mostly limestone) which can be broken and/or excavated quickly with modern machinery.

In many drained channels the natural deposits of gravel and cobble overlying bedrock shoals were removed during the course of drainage operations. In some cases the bedrock shoals themselves were blasted and removed to guarantee sufficient outfall for flood flows. Many such channels, post-drainage, have a flat uniform bed with few instream features.

Excavating the rock to create riffle/glide/pool sequences creates a more complex habitat and increases stocks of salmonids.

An excavator fitted with a rock breaker is digging a thalweg through a previously blasted flat bedrock bed. Many adult salmon and large trout have been caught at this location since the new pools were excavated.

A very powerful excavator (60 tonne) with a hard bucket was used to excavate a series of pools. The bedrock had been fractured by blasting operations during the original drainage over 40 years ago. These pools now provide salmon angling opportunities.

Gravel Spawning Deposits

Suitable Materials

This pair of salmon (opposite) are sitting on a partially excavated redd and will shortly spawn. This is a natural gravel shoal in a midland river. Note the very wide range of particle sizes in this shoal - from heavy cobble down to fine sand and silt. When ordering gravel from quarries to create artificial spawning beds avoid buying a particular uniform grade (size) of gravel.

What Should you Purchase?

A detailed study of gravel sizes in salmon and sea trout redds in a range of Irish rivers was carried out by Fluskey (1989). The ideal mix of sizes for artificial salmon/sea trout spawning areas is given (below). The least critical component of this mix is probably the fine gravel (4mm-8mm) because this material is the most mobile. Following a series of floods, artificial spawning areas tend to aggrade somewhat. Finer materials are washed downstream and settle out in the gravel shoal.

In small low gradient (≤0.1%) channels which provide spawning opportunities for brown trout, in the size range 0.5kg to 1.5kg, the mix (below, right) is recommended. The various gravel sizes here are as defined in Fluskey (1989).

A natural gravel shoal in an Irish river - an ideal salmon spawning site. Note the variation in particle size.

Cobble (64-190mm) - 10%
Very coarse gravel (32-64mm) - 35%
Coarse gravel (16-32mm) - 25%
Medium gravel (8-16mm) - 20%
Fine gravel (4m-8mm) - 10%
Composition of materials in Irish salmon and sea trout redds (from Fluskey, 1989).

Cobble (64-190mm) - 0%
Very coarse gravel (32-64mm) - 15%
Coarse gravel (16-32mm) -35%
Medium gravel (8-16mm) - 35%
Fine gravel (4m-8mm) - 15%
Composition of materials for Brown Trout (0.5-1.5kg).

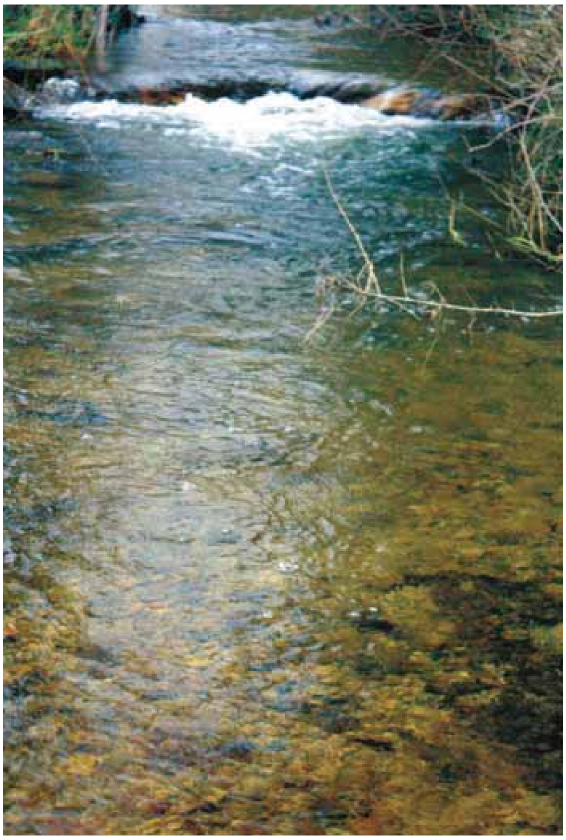
Location of Artificial Spawning Beds

Following arterial drainage programmes many channels were bereft of spawning gravel deposits. The exposed boulder clay bed and banks in many rivers provided little opportunity for the recruitment of gravels and cobbles and their subsequent deposition in shoals at appropriate locations.

Suitable locations for spawning gravel placement in rivers have already been outlined in chapter 8, page 75. The graphics, in chapter 3, illustrating the natural physical form of rivers, also help the reader to understand where one would expect to find gravel deposits.

In meandering channels gravel shoals should always be located upstream and downstream of lateral scour pools (see graphic on page 24). This is where gravel shoals will always be found in undisturbed channels. The placement of artificial spawning areas should always mimic their normal distribution in undisturbed channels.

In artificially straightened channels, lacking in spawning gravels, spawning beds can be provided by placing gravel deposits at the tail of weir pools. In natural straight channel reaches this is where one normally finds a sufficient depth of gravels for spawning purposes.



An introduced gravel shoal at the tail of a weir pool. Trout had spawned here recently.

A natural gravel deposit upstream of a lateral scour pool.

Natural Gravel Deposits in Excessively Eroded Channels

In channels subject to excessive bank erosion, whether it be caused by tunnelling, overgrazing of the riparian area or other factors there is always a reduction in the number and quality of pool areas. This applies both to straight and meandering channel reaches. This in turn, changes the shape, depth and degree of compaction in gravel shoals in both straight and meandering stream reaches. Gravels will still be present, however, they are spread in a flat thin compacted layer across the artificially wide channel (opposite). This significantly reduces the value of the gravel shoal both as a spawning site and as a nursery area for salmonid fry.

This high gradient reach (opposite) was excessively eroded because of a tunnelling problem. Following shrub pruning and bank revetment operations a series of three vortex stone weirs were constructed over a channel length of 250m. Annual redd counts are available for this steam for a thirty year period. No redds were ever recorded prior to the construction of the weirs. Post-construction, substantial shoals of gravel deposited out at the tail of each weir pool after the first few floods. Both salmon and trout are now spawning in these shoals. No additional gravels were placed in this channel when the weirs were being constructed. The alterations to steam hydrology caused by weir construction re-organised the distribution of existing natural gravels, thereby increasing spawning opportunities.

The nature of gravel deposits in an excessively eroded channel. This compacted bed is of little value in spawning terms and is too shallow to be a valuable nursery water

A fresh salmon redd is evident in the foreground. the nature of the river bed here, prior to weir construction, is illustrated above.

Once the excessive erosion problems are addressed on meandering channels narrower deeper gravel shoals will be deposited upstream (u/s) and downstream (d/s) of meander bends.

Braided Channel Repairs

Naturally braided channels (D-type channels as described by Rosgen (1996)) are a rarity in Ireland. However, braided channel reaches are now a feature of some B and C- type channels because of extreme overgrazing which has lead to unnaturally high bank erosion levels and destabilisation of river channels. In the longer term partial destocking of farm animals is the only solution to this problem. This process is now underway.

As an experimental measure attempts were made over the last decade to restore braided reaches to single C-type channels in locations where Ordnance Survey maps, drawn eighty to ninety years ago, had indicated that a single channel was present at that time. These studies were undertaken within the context of broader programmes - i.e. the excessive bank erosion problems which had led to the braiding effect downstream in the first instance were repaired with bank revetment and fencing programmes before attempts were made to correct the braiding.

In this example a single channel was excavated next the right bank (left hand side of the bottom photo) which was also rip rapped. This is the naturally eroding side of the channel. The cobble and gravels were reorganised with a hydraulic machine into a point bar next the right bank. The lines or rocks were trenched into the point bar at intervals over its length to stop the gravels unravelling and to provide temporary stability until the river form stabilised. This technique has proved successful at many locations.

Pre-works.

5 years post-works. Note that the leading edge of the two point bars in the foreground have been buried by depositing gravels.

Easement of Fish Passage

Baseline fishery surveys will identify both impassible natural and man made barriers to migratory salmonids. Repeated electro-fishing procedures, over a period of years, will also identify a number of obstructions, which are passable to migratory salmonids in some winters and not others.

In this example a fish pass incorporated into this weir (right and below) had proved unsatisfactory - fish had difficulty in locating the entrance to the pass. A rubble mat was built downstream of the weir to partially impound flood flows thereby reducing the weir sill height during high water events and allowing the fish, on such occasions, to jump directly over the weir. This has proved very successful.

An aerial view of this weir, fish pass and rubble mat (taken in low flow conditions) is illustrated (below) to provide an overview of the site.

Care should be taken to ensure that the rubble mat is built to a height which is lower than the weir sill upstream. The rubble mat should not impound flood flows upstream of the weir sill.

Rubble mat under construction. Note the weir sill height.

In flood flows the impounding effect of the rubble mat reduces sill height by 40%. Salmonids can now jump over the sill.

Rocks used in the rubble mat are from 1.5 to 4 tonnes in weight. The top two photographs were taken from the disused railway line marked (X) looking u/s to the weir.

Another Fish Passage Option

Salmonids migrating upstream had difficulty ascending this rock sill. A rock breaker was used to excavate a 3m wide trench, 0.5m deep, in a zig zag fashion through the rock. Resting pools were provided at each point where the trench turned. Large rocks were placed in the trench at intervals to act as buffers and provide resting places for fish. Salmon and trout can now ascend this channel without difficulty.

A rock sill which salmonids found difficult to ascend. During drainage operations this sill had been widened and left as a smooth sheet of rock.

The zig zagged trench cut through the sill accommodates the entire low flow regime and provides sufficient depth for fish passage.

Large rocks placed in the excavated channel act as baffles.

Benefits of Enhancement Programmes

Asking one what a river enhancement programme will achieve is akin to the old adage - how long is a piece of string! It depends entirely on how degraded the habitat has become.

A number of examples are provided in this chapter to illustrate the type of return which one can expect from investment in this area, in varying circumstances, and the way in which these returns should be quantified.

The objective of an enhancement programme should always be to restore the natural physical form of the channel, as far as is possible, and allow the riparian zone to recover.

One should never attempt to create physical conditions which might be to the benefit of one fish species and not another. The natural physical form of a channel will dictate the size and structure of the fish populations present. Any attempt to impose artificial conditions (too many riffles or pools) will inevitably fail. This is because it is almost impossible to impose a self-sustaining unnatural physical form on a channel indefinitely.

Restore natural channel form, fence out the stock and nature will do the rest.

2 years after fencing. Where lands are heavily grazed fencing out farm stock should always be ones first priority.

Examples

The Loughs' Ennell, Sheelin and Arrow Stream Catchments.

Brown trout in these three premier lake trout fisheries reproduce in small streams with a basewidth in the range 1.0m to 4.0m. Most of these channels were subjected to arterial drainage programmes. Fifty years, post-drainage, the streams had not recovered physically. Most remained excessively wide and shallow and lacked a defined thalweg and pool areas. The impacts of drainage were exacerbated by land management practices. Bank trampling by cattle and sheep sometimes further increased stream basewidth and eliminated the riparian zone (right).

Cattle trampling had greatly increased stream width. This zone was fishless.

Extensive rehabilitation programmes were undertaken in all three lake basins to restore natural stream form and repair damaged riparian zones. All three programmes were similar in type. A thalweg was excavated in every case. Stone and/or timber structures were used to build weirs and repair banks. All channels were fenced off. Specific tunnelled reaches were also partially debrushed to increase production.

2 years post-works. This reach now supports five 0+ trout/m^2 in mid-summer.

In the Lough Ennell streams an extensive monitoring programme was undertaken to assess the impact of the scheme (O'Grady *et al*., 2002(a)). This involved quantifying fish in 18 paired stream reaches within 6 of the 7 lake feeder streams. One reach in each pair was excluded from the enhancement programme so that, post-enhancement, the relative change in fish numbers could be assessed. In summary, five years post-enhancement, the standing crop of trout fry was reduced by 47% while the numbers of 1+ year-old trout had increased almost 9 fold (O'Grady *et al*., 2002(a)).

Lough Arrow Catchment

Changes in fish stocks, post-enhancement, in the Lough Arrow stream sub-catchments showed the same positive trends evident in both the Sheelin and Ennell systems. Enhancement programmes in the Lough Arrow steams were wide ranging including extensive shrub pruning followed by channel realignment, weir construction, fencing and tree planting programmes.

A canalised reach.

A meander pattern was restored to this canalised reach which:-

- restored a thalweg.
- increased scour rates thereby exposing gravels.
- enlarged the wetted area of stream over the length of the reach.
- provided a niche for 1+ year-old trout where, previously, only 0+ year-old fish were present.
- seven to ten fold increases in fish numbers (0+ year-old trout) in enhanced reaches of the Lough Arrow steams were commonplace two years post-works.

Restoration of a meander pattern.

Many reaches in the Lough Arrow streams had become completely tunnelled - principally by non-indigenous shrubs and trees - mostly laurel, rhododendron and sycamore. When the excess shrubbery was cleared the obvious effects of tunnelling were evident - excessively wide, shallow, silted channels with badly eroding banks.

Following pruning and channel realignment monitoring data indicate that:-

- 0+ and 1+ year-old trout standing crops will have increased substantially post-works. Five to ten fold increases in fish numbers are commonplace following this type of programme.
- the banks were not re-seeded post-works. All the grasses and herbaceous plants present two years post-works are part of a natural recolonisation process.
- four to five years post-works one can expect to find a significant recolonisation of this channel by mosses and aquatic macrophytes resulting in further increases in the productivity of the channel.
- substantial increases in juvenile salmonid stocks have been recorded following pruning operations (O'Grady, 1993).

Pre-pruning. This reach on the Douglas Stream was almost in total darkness.

Immediately post-pruning with channel realignment and bank revetments completed.

2 years post-works.

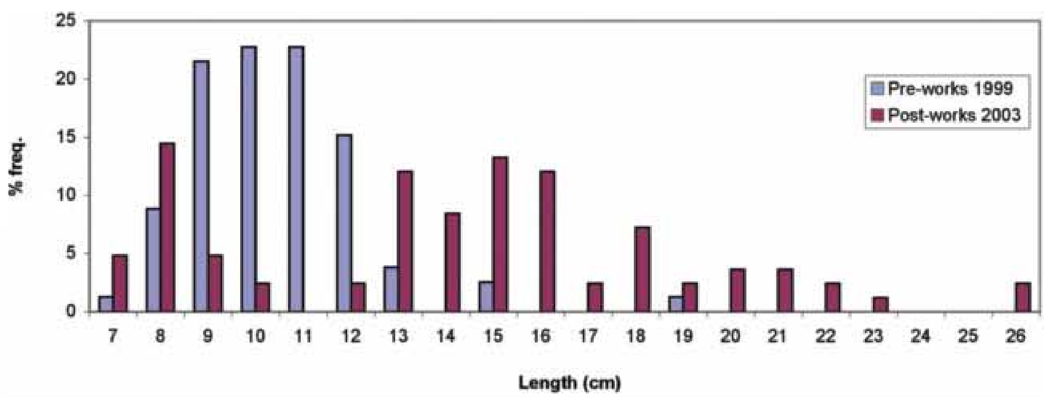
Channel Size will dictate the Length Frequency Distribution of Salmonids Present!

In one of the larger Lough Sheelin sub-catchments (upper Inny) the results differ from those measured in the smaller Arrow, Ennell and Sheelin streams. Bigger channels can support larger older fish once their natural physical form is restored. Sometimes, as in this case, the fry carrying capacity of an enhanced reach will decline as the numbers of larger older fish increase.

The histogram (below) illustrates the changes in the trout stock structure in a reach of the upper Inny, immediately prior to and, three years post-enhancement. In the longer term it is likely that a small population of adult trout may become resident in this stream. The upper Inny was known to support an adult trout population prior to being drained in the 1960's.

In this case the construction of stone weirs to restore pool areas and a fencing programme provided adequate depth and cover to accommodate older fish.

Length Frequency Distribution of Trout (≥ 1+) in the Upper Inny - L.Sheelin Catchment



The Glenglosh and Deel Rivers

These rivers are tributaries to Loughs Corrib and Conn respectively. Both were subject to overgrazing by sheep leading to excessive bank erosion resulting in the loss of a defined thalweg, a significant reduction in both the number and size of lateral scour pools and, in most zones, the elimination of a vegetated riparian zone. Log/Christmas tree bank revetments and, on parts of the upper Deel, rip rap were used to restore bank stability. Banks were fenced and planted with willow slips.

A monitoring of fish stocks in the Glenglosh River pre- and post-works, shows that the programme has been of benefit to all three fish species present - juvenile salmon, trout and minnow (O'Grady *et al*. 2002 (b)).

Pre-enhancement

Over a 7.5km long reach of the Glenglosh River, where bank revetment works, fencing and tree planting were carried out, estimated annual gains in salmonids are 3,685 1+ salmon and 6,615 1+ trout. In future years a resident adult trout stock is likely to become established in this channel.

2 year post-works.

SITE	YEARS		
	1998	2000	2002
Control	0	0	0
Experimental 1	(pre-works) 2	(post-works) 25	(post-works) 33
Experimental 2	(pre-works) 6	(post-works) 6	(post-works) 24
Experimental 3	(pre-works) 0	(post-works) 10	(post-works) 27

Minnow numbers as minimum density estimate values (after Crisp et. al., 1974) recorded in three experimental (developed) and one control (undeveloped) zone of the Glenglosh River pre-works (1998) and 2 and 4 years post-works.

Upper Deel River

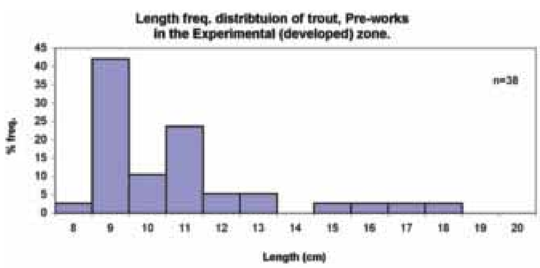
Positive results, in relation to both juvenile salmon and trout stocks, were achieved in this channel following enhancement works. However, they differ in some ways from those observed in the Glenglosh.

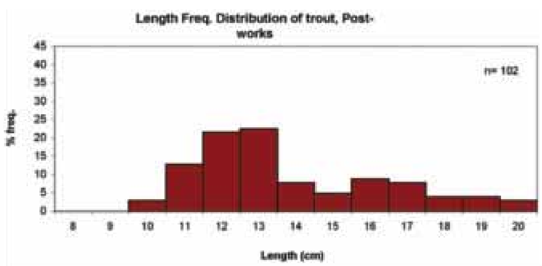
In this case the control (undeveloped) zone monitored was a high quality relatively undisturbed reach requiring no enhancement. In contrast, the experimental (developed) zone was poor quality habitat, prior to enhancement, with excessive bank erosion and a poor riparian zone. Therefore, post-enhancement, one would expect to see fish stocks in the experimental (developed) zone rise relative to those in the control zone.

This trend was evident in relation to salmon parr (1+ year-old) one year post-enhancement and in the two years thereafter (Table opposite).

A similar trend was not evident in relation to trout numbers. The relative difference in trout stock densities (for fish ≥ 1+ year-old) in the control and experimental zones remained unchanged post-enhancement. However, the structure of the trout population in the experimental zone changed significantly, post-enhancement, with substantial numbers of larger older fish being present (see histograms). In this case there were obvious gains in trout biomass. No such change took place in the control zone. Here, both pre- and post-enhancement, the trout population was composed solely of 1+ year-old fish.

YEAR	SALMON PARR (1+ year-old) as Nos./m^2	
	Control	Experimental
1996 (Pre-works)	1.07	0.35
1997 (Post-works)	0.73	0.68
1998 (Post-works)	Not Fished	0.70
1999 (Post-works)	0.8	0.75
YEAR	TROUT (≥ 1+ year-old) as Nos./m^2	
1996 (Pre-works)	0.08	0.1
1997 (Post-works)	0.06	0.1
1998 (Post-works)	Not Fished	0.12
1999 (Post-works)	0.07	0.1





Upper Cork Blackwater Catchment

Repairing a Braided Channel

In parts of the upper Cork Blackwater a combination of log/Christmas tree bank revetments and the construction of a two stage channel was used to restabilise a braided channel.

Braiding was caused here in the first instance by landowners who removed gravels from the river, thereby destabilising the channel.

The right bank was stabilised using a standard log/Christmas tree revetment.

The original channel basewidth was excavated next the right bank. Surplus cobbles and gravels were used to rebuild a bank along the braided section next the left bank. This berm was circa 10cm above summer water level at the waters edge. It was sloped up towards the original bank present at a time when the channel was braided. Three years post-works a stabilised regime is evident. The berm has now become partially vegetated. Complete re-vegetation of this berm is likely to take place in another 2-3 years once farm stock are fenced out. Gravel removal operations have ceased. Monitoring of various projects of this nature illustrate a consistent trend. Post-works salmonid fry (0+ year-old) numbers decline while fish numbers of ≥ 1+ year-old individuals increase significantly.

A braided channel with a badly eroding right bank, caused by gravel extraction.

5 years post-works. Revegetation of the berm is now advanced. The log/Christmas tree revetment next the right bank has accommodated vegetative recovery.

Pre-works. This fence line had only recently been erected.

Immediately post-works with log/Christmas tree revetment in place.

Extensive log/Christmas tree bank revetment works were carried out in the Allow, Dallow and upper Cork Blackwater main stem where landowners had removed the riparian zone. This had resulted in excessive bank erosion problems over many kilometres of channel. In this system very significant increase in the juvenile salmon and trout population have occurred post-enhancement.

The stock densities for three salmonid age groups (1+ year-old salmon and trout and trout ≥ 2+ year-old) in both the control and experimental areas, pre-enhancement, were not statistically different at 95% confidence intervals. Three years post-enhancement the numbers of fish in each of the three aforementioned categories were statistically significantly higher in the experimental (developed) zone compared to control (undeveloped) area (see table).

The data for Dace (*Leucius leucius*) numbers in the control and experimental zones three years post-works suggest that this salmonid enhancement programme may also have been of benefit to this species. However, we cannot be sure because Dace numbers were not quantified prior to implementing the enhancement programme.

5 years post-works. Note that the secondary silt bank trapped by the tree tops is vegetated and stable.

River Allow	Pre-Works 2001	Post-Works 2003
3 years post-works	Control	Experimental
	Nos./m^2	Nos./m^2
Trout (1+ year-old)	0.094	0.113
Trout ≥ 2+ year-old	0.054	0.144
Salmon (1+ year-old)	0.162	0.312
Dace (all age classes)	0.015	0.143

Grange River

The Grange River is a tributary to the Clare River, a major sub-catchment of Lough Corrib. The Grange had been drained in the 1950's - this involved a widening and deepening of the natural channel basewidth. In the course of drainage works a hard boulder clay bed and steam banks were exposed, consequently this river could not reconstitute it's natural physical form even forty years post drainage. There was very little erosion of gravels from the boulder clay banks back into the channel.

Enhancement involved the re-excavation of a natural channel basewidth within the drained channel, the excavation of lateral scour pools, the construction of stone deflectors and the addition of substantial quantities of gravels for salmonid spawning. All enhanced reaches were also fenced off and tree planting programmes were carried out.

50 years post drainage, artificially wide featureless channel. Fence breached by cattle on the right bank.

The resultant benefits to juvenile salmon and trout stocks were significant but not unexpected.

Fish stocks here, pre-works, were dominated by 0+ and 1+ year-old salmonids. Surprisingly substantial numbers ($0.1m^2$) of adult (3+ and 4+ year-old) trout were in residence here one year post-works. Presumably these were fish which had returned from Lough Corrib to spawn and subsequently became resident. This is not surprising. The Grange River, pre-drainage, was regarded as a quality trout angling stream.

Narrow sinuous channel rebuilt. Fence line secured.

7 years post-works. Note the recovery of the riparian zone inside the secure fence line and the colonisation of the deflectors by semi-aquatic plants.

Other Aquatic Beneficiaries

The physical enhancement of a river channel and the regeneration of its riparian zone should be of benefit at all ecological levels.

Riparian Zones

Changes in the riparian zone, once fenced off, are visually the most obvious. The author has not had the opportunity to quantify the changes in the diversity and biomass of plant life in riparian zones following fencing. However, illustrations throughout this book clearly show the very positive changes post-fencing.

Aquatic Flora

In a study of the Glenglosh River (see also page 124) the changes in the aquatic plant community and macro-invertebrates, as well as fish stocks, were measured post- enhancement (O'Grady *et al.*, 2002 (b)). Two years after excessive bank erosion was arrested, the dominant aquatic plants (mosses) expanded from minimal levels to provide ≤50% bed cover. There was also a parallel increase in the number of macro-invertebrate taxa present over the same period (below).

Cattle were overwintered in this field. Imagine the consequences for the river bank if it had not been fenced off!

No. of Macroinvertebrate Taxa Counted

Location \ Date	April 1998 (pre-works)	April 2000 (2 years post-works)
Experimental Site Enhanced Area	5	11
“Control” Sub-Catchment	17	15

Increases in the number of macro-invertebrate taxa in the experimental zone are clearly evident. Numbers of taxa in the unaltered quality control zone remained stable over this period.

Prior to fencing bankside grazing by stock had eliminated this habitat.

Bird Life

In the Glenglosh river study (O'Grady *et al*., 2002 (b)) there were significant increases in the number of bird species (7) along the course of the river two years post enhancement. They were Common Sandpipers (*Actitis hypoleucos* (Linnaeus)), Chaffinches (*Fringilla coelebs* (Linnaeus)), Goldfinches (*Carduelis carduelis*) (Schmiedeknecht)), Kingfishers (*Alcedo atthis* (Linnaeus)), Mergansers (*Mergus serrator* (Linnaeus)), Sandmartins (*Riparia riparia* (L.)) and Wrens (*Troglodytes troglodytes* (Linnaeus)). None of these species had been observed here in the two year period prior to implementing the enhancement programme. After two more years, the author noted the return of another two bird species - cormorants (*Phalacrocorax carbo* (Linnaeus)) and grey wagtails (*Motacilla cinerea* (Linnaeus)), two species which are closely associated with productive river corridors.

A merganser feeding in the Glenglosh river.

In a series of small (basewidth <4m) stream sub-catchments in the Moy an increase in Mallard numbers was noted two years after these steams had been fenced off. Duck numbers increased from zero to as many as thirty birds being produced per kilometre of steam length per annum (O'Grady, 2002).

A recovery in aquatic insect life, post enhancement obviously lead to the re-appearance of Grey Wagtails and other bird species.

Why? The regeneration of grasses inside the fences provided ideal nesting sites for the ducks. Prior to fencing bankside grazing by stock had eliminated this habitat.

The River Corridor Concept

All wildlife corridors are essentially highways allowing wild species to travel unhindered through an otherwise alien habitat. They may be in search of food, shelter or trying to satisfy reproductive needs. The corridor limits their contact with man. It enables them to move with relative freedom limiting the inbreeding problems they would face in isolation.

Stable river corridors support many complex communities. Why? - because they are the boundary of three ecotones - the terrestrial, semi-aquatic and aquatic. The mosaic of plants, insects and birds illustrated here, are only a tiny fraction of life forms within the corridor. Be they plants, insects, fish, birds or mammals, all need the freedom of movement within this corridor to ensure their survival.

For example, should a particular reach be seriously polluted, dredged or have its riparian zone stripped resulting in a major loss of flora and fauna, a recovery subsequently, will be hastened by this continuum. Once water quality is restored plant fragments washed downstream in flood events will lodge and recolonise the river bed and banks. Aquatic insect larvae and other invertebrates, which drift downstream as part of their life cycle, will quickly recolonise the reach. Many adult aquatic insects tend to fly upstream before depositing their eggs. This phenomenon will encourage recolonisation in reaches further downstream. Fish and bird populations will quickly move in to the recovered reach from both upstream and downstream zones once water quality is restored. Given that the recolonisation process can sometimes be either due to an upstream and/or downstream movement of animals the importance of the continuum is self evident

Epilogue

“Tempus fugit” ….. the addition of spawning gravels to the Annies Stream in the Lough Carra Cathment by our colleagues in 1965 was, at that time, a slow and laborious process. However, it proved very successful and encouraged staff to undertake other enhancement projects.

While such operations today may be more efficient with the availability of hydraulic machinery their success will still depend on a dedicated and informed staff doing the right thing in the right place at the right time.

I hope that this manual will be of some assistance to everyone in making such decisions.

A final word - don't forget your camera.

Martin O'Grady

Appendix I

Engineering Records for Drained Rivers

The Engineering Services Section of the Office of Public Works are the State body currently responsible for the arterial drainage of many Irish river catchments and their subsequent maintenance. Numerous catchments have been subject in whole, or in part, to drainage at some point since the 1840's (opposite). The largest such schemes were designed, implemented and subsequently maintained by the Office of Public Works from the 1950's to the 1980's - catchments drained during this period include the Boyne, Corrib, Glyde, Dee, Maigue, Maine and Moy systems.

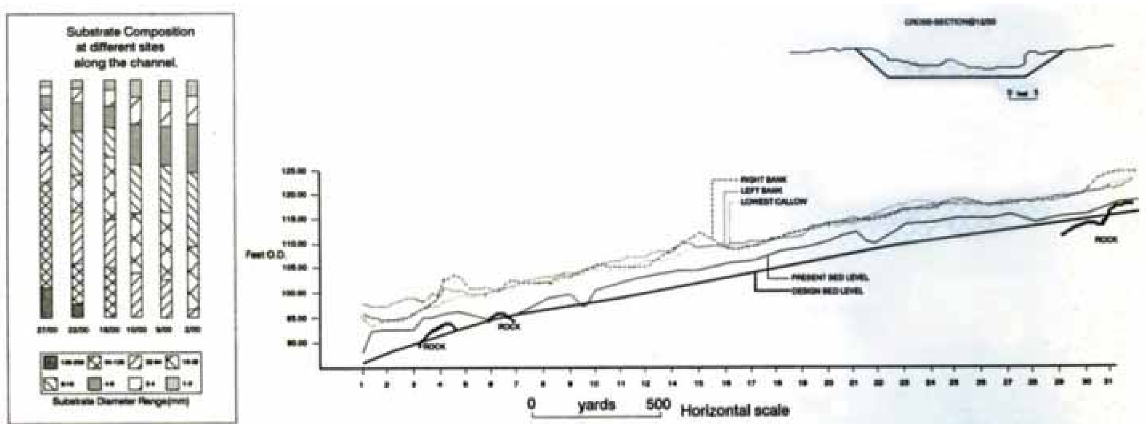
The physical records compiled by O.P.W's. staff, prior to designing and implementing these schemes, are probably the most comprehensive set of physical data ever compiled for river catchments anywhere in the world. While this physical record was compiled in the interests of ensuring efficient drainage design it has proved extremely valuable to fishery interests for a number of reasons:-

1. In Chapter 1 (Importance of Baseline Surveys) the importance of four factors is delineating river zones has been highlighted - channel slope (gradient), river substrate, summer volume discharge (Q) and the nature of the riparian zone. The first three of these four factors can be defined for drained channels by reviewing O.P.W. records. This represents a huge saving to fisheries staff when designing baseline surveys.

2. A review of O.P.W's natural channel and drainage design basewidths cross referenced with these data for the same locations to-day will often illustrate how the crossectional shape has changed since the original drainage programme - in many cases the channel basewidths have increased significantly since drainage works because of bank trampling by farm stock. This information was compiled for most rivers and streams in all drained catchments.

Catchments drained in ireland since the 1840's, (from O'Grady & Curtin, 1993).

An example of the detail available in relation to channel longitudinal and cross-sections in substrate type are illustrated below.



The physical detail recorded by O.P.W in relation to river channels.

O.P.W. have "chained" six inch maps for all drained channels in individual catchments (opposite). The channels are marked off in 100 yard sections called chains. Each tributary is chained separately from 0 at its outfall to the main stem working upstream. The main stem in a catchment is always coded as C1. As one proceeds upstream each tributary, as it confluences with the main stem, is assigned a related sub-code (left) and chained as an individual channel starting at 0.

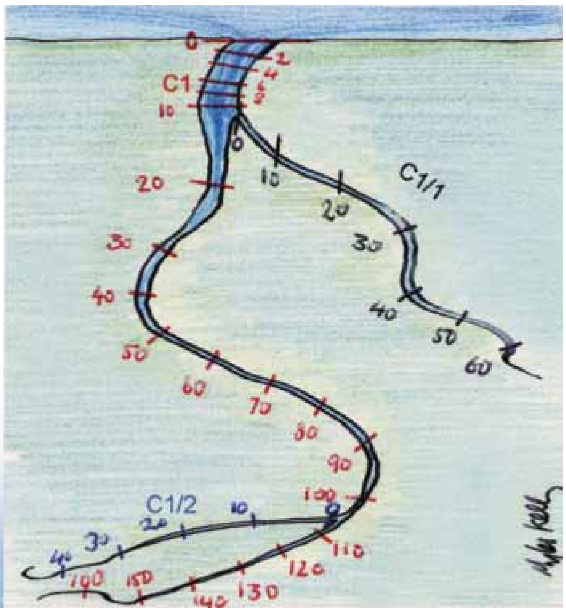
All of these data allow one to:-

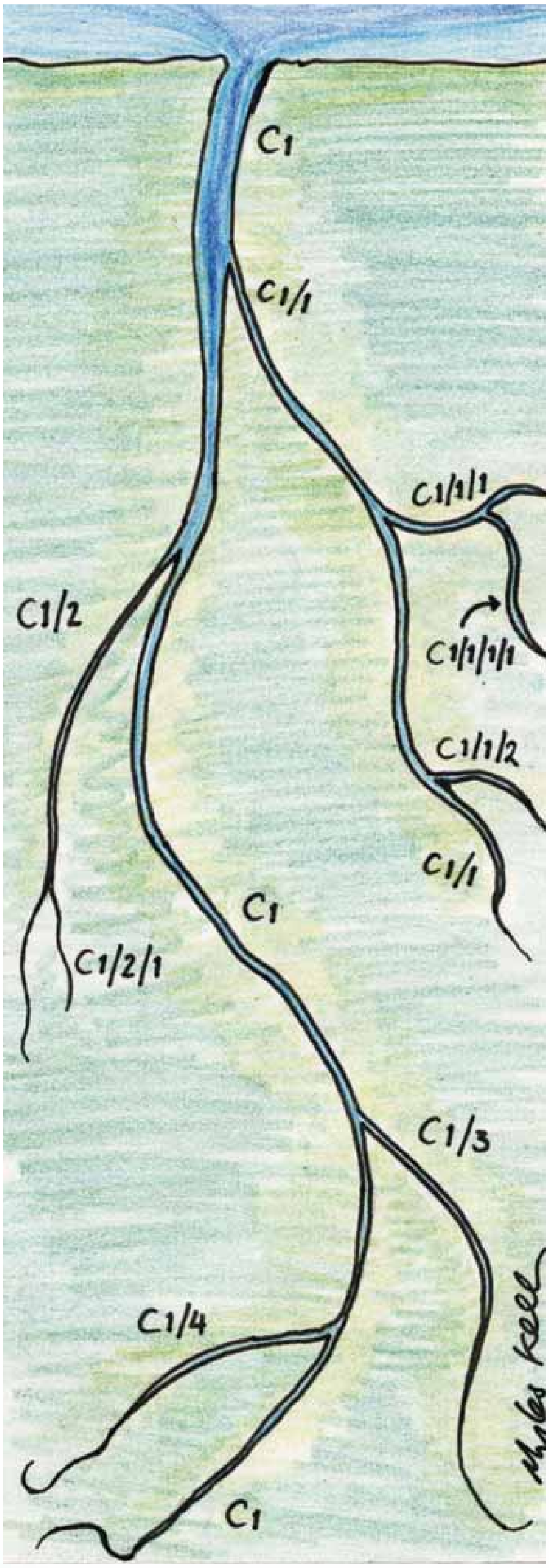
1. Zone a catchment from a fishery viewpoint once the additional riparian zone information is available.

2. Calculate overall channel lengths and/or areas for whole catchments where a particular suite of problems might exist.

3. Help one to define the degree and extent of imbalances in systems from a fishery viewpoint.

Currently all of these data are being digitised. The Office of Public Works have always been most co-operative in terms of providing copies of these data to Fisheries Boards' personnel.





Pearl Mussels

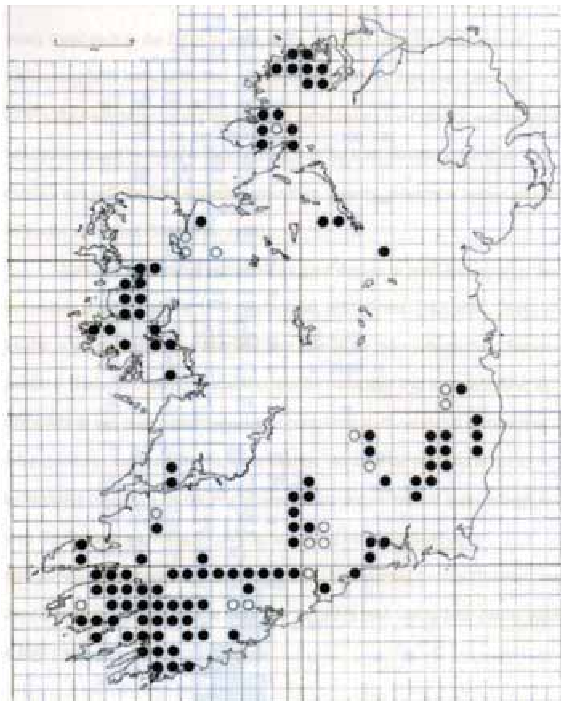
The freshwater pearl mussel (Margaritifera margaritifera (L.)) is distributed from the Artic and temperate regions of western Russia through Europe to the northeastern seaboard of North America (Skinner et al., 2003). Bauer (1986 and 1988) estimates a 95-100% decline in known populations in central and southern Europe.

While formerly widespread and abundant in England and Wales recent studies suggest that most populations are now virtually extinct in this area (Chesney and Oliver, 1998). This species has also declined in Scotland except for a few rivers in the Highlands (Skinner et al., 2003).

In Ireland pearl mussels are still widespread (Moorkens, 1999). However, Moorkens (1999) reports that a recent study of 32 populations found that only 8 of these stocks contained young individuals.

The current distribution of pearl mussels in Ireland has been illustrated by Moorkens (1999) (right). Most Irish pearl mussel populations are found in clean, oligotrophic fast flowing channels with relatively low calcium levels (Moorkens, 1999). The population in the River Nore is the only known stock in an alkaline river in Ireland (Moorkens, 1999).

Pearl mussels in feeding mode (courtesy of S.N.H).



Distribution of Pearl Mussels in Ireland, (from Moorkens, 1999).

Pearl mussels are one of the longest-lived invertebrates known - individuals can survive for over 100 years (Bauer, 1992). They have a complex life cycle. Males shed sperm which is inhaled by the females. The fertilized eggs are shed into the water column a few months later. These young mussels, known as Glochidia, must then attach themselves to the gills of young salmon, brown trout or sea trout to survive and continue their development. They drop off the fishes gills after about six months and must land in a clear sandy or gravely substrate to settle and grow (Skinner et al. 2003). Young mussels remain buried in the sand or gravel for about 5 years (Moorkens, 1999). As adults they remain partially embedded in the river bed.

In high quality habitat adult pearl mussels can colonise an area in very large numbers (across).

Moorkens (1999) notes that the last successful recruitment to some Irish pearl mussel populations dates back to the 1960's or early 1970's. She (Moorkens) relates the decline in pearl mussels stocks, in recent decades as being linked to river channel changes, intensive agriculture, afforestation and industrial/urban developments - the same changes which have lead to a decline in many salmonid stocks.

The lifecycles of salmonids and pearl mussels are clearly intertwined. Both will thrive in physically undisturbed and unpolluted rivers. Consequently the objectives of fishery riverine enhancement schemes, designed to optimise salmonid stocks, dovetail with the interests of conserving and/or re-establishing pearl mussel populations.

An adult pearl mussel shell.

Care is required to ensure that riverine enhancement programmes do not disturb the few remaining pearl mussel populations. Check with your local ranger from the National Parks and Wildlife Service before commencing a project to establish the status of pearl mussels in particular channels.

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Glossary of Terms

Definitions in relation to various technical terms used in this manuscript are provided here. Please note that these terms are being defined solely in the context of fishery enhancement programmes. Individual words or terms may have a broader, or, different meaning in the context of the English language.

Aggradation - The deposition (build up) of river bed and bank materials at some point next the banks of a channel.

Algae - Primitive plants usually green, yellow/green or brown in colour. There are numerous aquatic species in Irish rivers. Some of these plants thrive and become super abundant in organically polluted conditions.

Ancylus - A freshwater limpet. A member of the snail family. Only one species known in Ireland (Ancylus fluviatilis L.). Lives on cobbles and sheet rock.

Arterial Drainage - The lowering and widening of river channels to drain wetlands thereby increasing their agricultural productivity. Arterial drainage will also alleviate flooding problems.

Asellus - A small aquatic crustacean commonly occurring in Irish rivers and lakes. In unpolluted waters there are large asellus populations in slowflowing silted rivers, ponds and lakes. In high gradient gravel bed streams its numbers are limited except in organically polluted conditions.

Braided - A river bed with several discrete channels interlinked at irregular intervals.

Caddis Flies - Also known as Trichoptera. They are a very diverse insect group with aquatic larval and pupal stages and terrestrial adults. Some larval build nets or tubes to live in often covering the tubes with leaf fragments, twigs or pebbles. Different trichopteran species vary in their sensitivity to various types of pollution.

Chironomids - A very large family of insects whose eggs and larvae are aquatic. Larvae can be a variety of colours - most are green, amber or red. These two winged (Diptera) insects developed from larva to pupa. The pupa, on hatching into the adult phase, is terrestrial. Adults mate, lay their eggs and die usually in just a few days. The presence of large numbers of red Chironomid larva in shallow fast flowing streams can be an indicator of organically polluted conditions.

Concretion - A deposition of mineral material with a high calcium content which precipitates on the bed of rivers and streams.

Cultural Eutrophication - Eutrophication is the natural process by which a body of water gradually becomes enriched with nutrients. Cultural eutrophication is the unnatural acceleration of this process when excess nutrients are discharged to a waterbody.

Ecdyonurids - A group of mayflies whose larva are flattened dorso-ventrally allowing them to live in very fast-flowing turbulent conditions.

Ecotone - An area where organisms are abundant in the centre of a particular geographical area of ecological niche. Numbers of organisms decline over distance as one moves away from this particular location.

Enhancement - The alteration of a channels physical form and/or its riparian zone with the objective of improving its salmonid production capacity.

Ephemerella - A genus of mayfly nymphs. The only common species in Ireland is Ephemerella ignita (Poda) - known to anglers as a Blue-Winged Olive (Sub-Imago) and a sherry spinner (female Imago). The nymph is a squat relatively slow moving creature which lives in rooted aquatic vegetation and mosses.

Euphotic Zone - The extent of river bed area which receives sufficient sunlight for photosynthesis and the growth of green plants.

Fry - A term used to describe young salmon or trout, which are less than one year old - see also definitions for salmon and trout in this glossary.

Gammarus - A common freshwater shrimp in Irish rivers and lakes. There are a number of different species. Some gammarids are quite tolerant of organically polluted conditions.

Gradient - A term used to describe the slope of a river bed over a specified length of channel. For example a river bed which falls 1 metre in a 100 metre long reach would be said to have a gradient value of 1%.

Imago - An insect in its final adult sexually mature phase. A term commonly used by biologists in relation to mayfly species (see Mayfly).

Lateral Scour Pool - A typical pool in a meandering channel. This type of pool is close to the eroding bank upstream, through and downstream of the apex of the bend.

Leeches - A specialised group of segmented worms. Generally hide under stones or in aquatic plants. Many leeches are predators on other invertebrates. Some species are tolerant of organic pollution problems.

Macroinvertebrates - Animals such as insects or molluscs which lack a backbone or spinal column and are relatively large (visible to the naked eye).

Macrophytes - Macroscopic plants many of whom are aquatic in nature.

Mayflies - An Order of insects whose nymphs are aquatic. The nymphs emerge as sub-imagines (sexually immature forms). They subsequently molt to become imagines (sexually mature forms). After mating the females lay their eggs and the cycle starts again (see page 44). The nymphs feed on animal and plant debris. Most species are relatively intolerant of organic pollution problems. Many mayfly species are important from an angling perspective.

Mites - Aquatic mites are close relatives of spiders, all species having eight legs and soft bodies. Many species are virtually microscopic. Some are predatory feeding on small insects and other invertebrates. They in turn are preyed upon by larger macroinvertebrates and small fish.

Nymph - An immature stage of a mayfly. In this context a mayfly egg develops into the nymphal stage which subsequently hatches into a sub-imago. The sub-imago and subsequent imago are terrestrial phases in the mayflies lifecycle (see Mayfly definition).

0+ year-old - A reference in this book to young salmon and/or brown trout who are less than a year old.

1+ year-old - Young salmon and/or brown trout who are somewhere between one and two years of age.

Oligochaetes - Species of worms. Many of these animals live in river bed sediments and in the sediment trapped by aquatic moss colonies. Some oligochaetes are tolerant of organically polluted conditions.

Parr - A term used in this manuscript to describe a young salmon or trout which is ≥ 1 year-old and < 2 years of age.

Pearl Mussel - A relatively rare species of mussel which lives in some of our river systems (see Appendix 2).

Physiography - The shape or form of a landmass.

Point Bar - The deposition of river bed material on the slack (non-eroding) side of a meander bend opposite a lateral scour pool.

Redd - The mound of gravel on a river bed beneath which a salmonids fertilized eggs are deposited.

Revetment - A barrier (in stone or timber) along a river bank designed to reduce or stop excessive bank erosion.

Riparian Zone - The marginal area along the bank of a river.

Rip Rap - A layer of rocks placed along a bank to prevent erosion.

River Corridor - A corridor encompassing the river and its riparian zone.

Root Wads - The root ball of a windblown coniferous tree. Usually the lower 2-3m of the tree trunk are left attached to the root ball when these are used for bank revetment purposes.

Rubble Mats - A mattress of loose, broken stones placed on the bed of a drained river to recreate riffle areas and maintain scour in a pool excavated downstream of the mat.

Salmonids - This term, in this book, is used exclusively in relation to two fish species Atlantic Salmon (Salmo salar L.) and Brown Trout (Salmo truttal L.). These are the only two indigenous fishes in the genus Salmo in Ireland.

Secondary Bank - A berm or silt bank formed by the aggradation of silt within conifer tree tops secured alongside excessively eroding banks. The top of this berm will usually be at a lower level than the river bank.

Simulids - Dipteran aquatic insects closely related to Chironomids. The larval and pupal stages are aquatic while the adults are terrestrial. Some species thrive in organically polluted conditions.

Smolts - In the context of this publication the term smolt is a reference to a young salmon ready to migrate to sea.

Spate - Spate channels are those subject to sudden high energy flood events which often abate quickly due to the high gradient of the river or stream.

Stonefly - A relatively primitive group of aquatic insects most of whom live in well-oxygenated high gradient streams. They are an important food source for salmonids. Most stonefly species can only survive in unpolluted rivers. Stonefly larvae are aquatic while the adults, like mayflies, have a short terrestrial existence.

Sub-Imago - A term used to describe the first terrestrial stage of the mayfly (sexually immature at this point). A few days after its emergence the sub-imago will metamorphose into a sexually mature imago.

Terram - Geotextile cloth used primarily by construction engineers as a separation layer. It is made in various grades. The lighter grades are sufficient to seal the streambed, upstream of timber weirs, and stop the weir being "washed out".

Thalweg - The down-channel course of greatest cross-sectional depths. The thalweg wanders from near one bank to near the other bank:- from the old-fashioned German spelling Thal = Valley, Weg = way or path (from White & Bryndilson, 1967).

Toe - The point at which the bottom of the bank and the river bed intersect.

Topography - In the context of this publication topography is a reference to the configuration of the countryside.