River Restoration

– Danish experience and examples

National Environmental Research Institute

Editor: Hans Ole Hansen

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Hans Ole Hansen
Bent Lauge Madsen

Introduction

There are approximately 30,000 km of watercourse of natural origin in Denmark, and an equivalent length of man-made watercourses. This should provide good opportunities to enjoy nature, as well as a multitude of habitats for a diverse flora and fauna.

However, during the course of this century the majority of our watercourses have been channelized to drain agricultural land, freshwater fish farms, industry and urban areas. Channelization was often accompanied by the construction of weirs and other obstructions, and in many cases these effectively hindered the free passage of fish and stream macroinvertebrates. As a result, there are now only few watercourses that live up to our ideas of a natural watercourse. The situation is starting to improve, though, partly as a result of changes and improvements in the administration of our watercourses.

Danish watercourse administration

The two main laws governing Danish watercourses are the Watercourse Act and the Environmental Protection Act. From the administrative point of view, Danish watercourses are divided into three groups: County watercourses, municipal watercourses and private watercourses. The County is the watercourse authority in the case of county watercourses, while the Municipality is the watercourse authority for both municipal and private watercourses. The watercourse authority's task is to ensure compliance with the provisions of the Watercourse Act, for example with respect to watercourse maintenance.

Watercourse environmental quality objectives

The original Danish Environmental Protection Act from 1974 encompassed a planning system that in the case of watercourses, was implemented in the form of a system of specific quality objectives, a system that has played, and still plays, a crucial role in endeavours to safeguard watercourse environmental quality (Box 1.1). The environmental quality objective for each watercourse is set forth in the County Plan. In setting the objectives, the County takes into account the natural state of the watercourse, what impact man has had, the intended use of the watercourse, and what can realistically be achieved. Through this system of quality objectives it has been possible to differentiate between different watercourses and concentrate efforts where they are of greatest benefit.

Pollutional state of Danish watercourses

The County has supervisory responsibility for the pollutional state of all watercourses. Pollutional state is evaluated by investigating the macroinvertebrate fauna inhabiting the watercourse, and is rated on a scale from I to IV. I corresponds to a watercourse with a very varied macroinvertebrate fauna while IV corresponds to one with a very uniform or absent fauna. The national streampollution monitoring network comprises 220

The environmental quality objective for each Danish watercourse is set forth in the County Plan. The County Council can choose between a variety of environmental quality objectives, or they can formulate their own objectives. In principle, there are three groups of watercourse quality objectives: Stringent (A), basic (B) and eased (C, D, E, F). The objectives are as follows:

A: Areas of special scientific interest
B1: Salmonid spawning and nursery waters
B2: Salmonid waters
B3: Cyprinid waters
B4: Watercourses with a varied flora and fauna but of little value to fish
C: Watercourses to be used for drainage purposes
D: Watercourses affected by waste water
E: Watercourses affected by water abstraction
F: Watercourses affected by ochre

Box 1.1. Watercourse environmental quality objectives.

stations where pollutional state is monitored annually. In addition, though, the individual county authorities monitor pollutional state less frequently at many hundreds of additional stations.

Action Plan on the Aquatic Environment

In 1987, the Danish government passed a new Action Plan on the Aquatic Environment aimed at considerably reducing nutrient and organic matter loading of the aquatic environment. Since adoption of the Action Plan, the quality of the water in our watercourses has improved year by year, largely due to the upgrading of sewage works. However, clean water alone is not sufficient to ensure satisfactory watercourse quality. If the watercourse lacks physical variation, habitats for the flora and fauna will be limited in number and quality. At the same time, poor physical conditions often have a negative impact on water quality because oxygenation and self-purification will be less effective. Similarly, drainage of riparian areas can also have a negative effect on water quality due to increased loading with ochre, etc.

Restoration or rehabilitation

Considerable work still needs to be done to improve the physical condition of our watercourses if watercourse quality is to match up to the increasingly good quality requirements stipulated for stream water. This can be achieved through environmentally sound watercourse maintenance as well as through various types of restoration measure. Since these two approaches are usually combined with the general objective of improving the physical condition of our watercourses, it is useful to use a term that encompasses both environmentally sound maintenance and restoration measures.

In this book, we have chosen to use the term watercourse rehabilitation, a term gaining increasing acceptance in the scientific community. When the measure used only involves a change in the physical condition of the watercourse (excavation, etc.), we use the term watercourse restoration.

15 years' experience

With the advent of the new Watercourse Act some 15 years ago, it became legally permissible to rehabilitate Danish watercourses. This possibility has been exploited, and over the years, numerous rehabilitation projects have been carried out – ranging from the laying out of spawning gravel to major projects aimed at remeandering watercourses and improving the interplay between watercourses and their river valley.

However, rehabilitation projects are seldom followed up by studies of the impact of restoration on biological, chemical and physical conditions in the watercourses and their riparian areas. Similarly, the experience gained from the individual projects is seldom published, and hence is seldom of benefit to others working with watercourse rehabilitation. There is therefore a need to describe the various types of rehabilitation project and methods, and to evaluate their impact.

In 1994, the Danish Environmental Protection Agency, the National Environmental Research Institute and the 14 Danish Counties therefore initiated the project "Watercourse restoration – Methods and effects". The main aim of the project was to collect and collate existing knowledge on restoration methods and their effects. The present book, which is partly built up around examples from the counties, is the first result of this project.

A further aim of the project was to describe the physical conditions required by the fish inhabiting our watercourses. Fish are a good indicator of watercourse quality, and an understanding of their requirements is an important tool when planning restoration or changing maintenance practice. If conditions are good for fish, they are usually also good for stream macroinvertebrates and plants. The results of this part of the project have been published as a report describing the conditions required by all Danish freshwater fish (1).

The European Centre for River Restoration (ECRR)

Since the first international conference in 1991 in Lund, Sweden (2), on river restoration there has been an increasing European interest in restoring watercourses and river valley ecosystems for the benefit of wildlife. At the same time, there is increasing awareness that reinstating naturally functioning watercourse-river valley systems also yields catchment management benefits, particularly by increasing flood water storage capacity, enhancing nutrient retention and ameliorating low discharge. Sustainable management and restoration of watercourses and river valley ecosystems may also reduce river maintenance costs and provide better amenity and recreational facilities.

Danish regional and national authorities have accumulated considerable experience and know-how regarding watercourse and river valley management and restoration during the last decade, both with respect to legislation, conservation and administration, as well as to practical experience in carrying out different management and restoration measures in river systems and monitoring of their ecological effects.

Environmentally sustainable management and restoration of watercourses was included in the Danish Watercourse Act as early as 1982, and in 1987 nature restoration was introduced as an element of the 1987 "Strategy on Marginal Lands", the aim of which was to restore 20,000 ha of former wetlands. More than 1,000 small and larger-scale river restoration projects have so far been undertaken, primarily by the Danish Counties and Municipalities.

The National Environmental Research Institute (NERI) is the national platform in Denmark for monitoring and scientific research on watercourse and river valley management and restoration. In Denmark watercourse and river valley management and restoration projects are mainly undertaken by the Counties and municipalities with the support of the Danish Environmental Protection Agency and the Danish Forestry and Nature Agency. NERI collaborates with the local and central authorities on the collection of information on watercourse and river valley management and restoration and the dissemination of the experience gained through newsletters, workshops, training courses, technical handbooks, videos, etc.

In 1993, the EU Life Programme granted funds to establish a major European Demonstration Project in Denmark and the United Kingdom led by the Sønderjylland County. As part of this project the European Centre for River Restoration (ECRR) was established at NERI in Silkeborg in 1995.

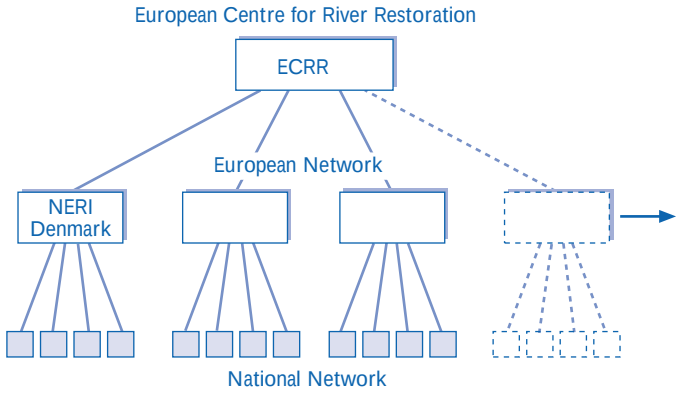

Figure 1.1. The European Centre for River Restoration and the European River Restoration Network.

NERI is a sectorial research institute under the Danish Ministry of Environment and Energy and is the Danish National Focal Point for the European Environment Agency (EEA). In addition, NERI departments currently participate in three European Topic Centres, undertaking projects for the EEA in international fora concerning monitoring, establishment of databases, etc. NERI currently has around 450 members of staff, as well as 30 PhD students and 56 MSc students.

The main aims of the ECRR are to promote sustainable watercourse and river valley management and restoration measures and ensure widespread take-up and dissemination of related management and restoration activities. The Centre focuses on establishing a state-of-the-art information base on watercourse management and restoration of natural habitats in damaged watercourses and their river valleys. This will be achieved using experience gathered in the European Countries concerning watercourse management and restoration concepts and methodology, as well as on the planning, execution and impact monitoring of restoration projects.

The aims of the ECRR will be achieved through developing a European Network of relevant national institutions (Figure 1.1). The Centre and the European River Restoration Network will collaborate on ensuring the collection and assessment of experience and knowledge obtained throughout Europe on watercourse and river valley management and restoration, as well as the dissemination of the information to the European audience through newsletters, conferences, workshops, technical handbooks, videos, etc. In addition, the ECRR and the Network will promote watercourse and river valley management and restoration through the initiation of Demonstration Projects in each European country. These activities will ensure that knowledge on river and river valley management and restoration will be communicated to the widest possible European audience for the benefits of Nature and Society.

The present volume is the ECRR's first handbook and is intended to demonstrate to the European audience the experience accumulated in Denmark on watercourse and river valley management and restoration. For further information you are welcome to contact the ECRR in Silkeborg. The Centre can demonstrate Danish experience via posters and videos and can arrange for tours to Demonstration Project sites in various parts of Denmark.

The ECRR's address and telephone number is as follows:

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Basis for watercourse rehabilitation

Watercourse rehabilitation is purposeful improvement of the physical and ecological condition of watercourses. It is a rapid and direct means of achieving the improvements one would like to see take place in watercourses, and in some cases

is the only means. In the present spirit of things in Denmark, rehabilitation only encompasses measures that improve the quality of watercourses as natural ecosystems or as angling waters. The specific aim of rehabilitation can be to change the watercourse's appearance, to create habitats for the fauna and flora, to restore free passage or to improve the watercourse's self-purification properties.

Rehabilitation (restoration) was incorporated in the new Danish Watercourse Act in 1982. The individual measures are described as five simple methods (Box 1.2) – methods that to present Danish eyes provide extremely limited possibilities to rehabilitate watercourses. That they are so limited is partly due to the misgivings with which the restoration concept was received by "drainage interests" at the time the Act was being drawn up, especially by the agricultural sector. Clear information was wanted about what restoration would mean for the watercourse of the future.

A further reason is that the inspiration to restore watercourses largely came from the USA. In places such as Michigan and Wisconsin, efforts had been made to improve habitats for salmonid fish in shallow watercourses resembling Danish watercourses (3). The aim of restoration in the USA was – and still is – to further improve fish waters that are already of good quality, i.e. to increase the catchable fish stock. One way of doing so was to create artificial overhanging banks using logs that often extended several metres into the adjacent terrain. These American experiences were the inspiration for the wording of the Danish Watercourse Act, and for the first Danish attempts to rehabilitate watercourses. Apart from these first projects, however, we have not been bound by the American examples. Moreover, methods of the type used in the USA introduce unnatural "hardware" into watercourses and are considered undesirable in the present Danish view of watercourses.

Watercourse Act of June 9, 1982

PART 8
Restoration of watercourses

37.— (1) In the case of public watercourses whose condition does not fulfil the regional water quality objectives, the watercourse authorities are empowered to improve conditions by means of the following measures:

(a) the establishment of artificial overhanging banks,
(b) the laying out of large rocks,
(c) the laying out of logs and the like on the watercourse bed,
(d) the establishment of current concentrators and
(e) the establishment of spawning grounds.

(2) The watercourse authorities defray the expenses of restoration.
(3) The Environmental Protection Agency can subsidize larger restoration projects.
(4) Anyone sustaining a loss as a result of a restoration project has the right to compensation.
(5) The Minister for the Environment lays down more specific regulations concerning restoration projects, including regulations concerning the cooperation between water authorities and between watercourse authorities and other authorities, as well as on the involvement of the public.

PART 6
Regulation of watercourses

16. Regulation of a watercourse is here taken to mean changing the physical characteristics of the watercourse, including its course, its width, the height of its bed with respect to Danish Zero Level and its slope, with the exception of measures encompassed by Parts 8 or 10.

17. Watercourses may only be regulated pursuant to the stipulations of the watercourse authority.

Act of June 14, 1995 amending the Watercourse Act

37 a.—(1) In watercourses where sluices are highly detrimental to watercourse quality, the County Council can decide pursuant to the provisions of this Act to implement whatever measures are necessary to restore satisfactory environmental quality, including regulating the watercourse.
(2) Measures pursuant to subsection (1) may not be implemented if to do so disregards significant historical interests.
(3) The provisions of Sections 3 (1.1), 3 (2) and 3 (3) of the Nature Protection Act do not apply to measures implemented by the County Council pursuant to subsection (1).
(4) The Environmental Protection Agency can subsidize the implementation of measures encompassed by subsection (1).

Box 1.2. Provisions of the Danish Watercourse Act pertaining to restoration and regulation.

Thus in contrast to this approach, current Danish philosophy instead favours rehabilitation measures that blend in with the natural conditions in the watercourse as simply as possible. For example, we now prefer to restore free passage at dams by means of riffles and bypass reaches, while as far as possible refraining from building fish ladders. The latter are considered too selective as they primarily facilitate the passage of strong salmonids, while other fish and macroinvertebrates are unable to pass. In contrast, a riffle or bypass reach can be traversed by all the

fish and macroinvertebrate species inhabiting the watercourse. In addition, riffles and bypass reaches function as a natural part of the watercourse, and in some cases do so better than upstream and downstream reaches (4).

Regulation as a rehabilitation measure

Despite the fact that the five methods mentioned in Part 8 of the Watercourse Act (Box 1.2) are extremely limited, in practice it has nevertheless been possible to use other and more extensive forms of rehabilitation. All that was needed was to obtain approval to regulate the watercourse under Part 6 of the Watercourse Act (Box 1.2). The watercourse regulation provisions were originally formulated with a view to easing water drainage through deepening, straightening and widening of the cross-sectional profile. However, rehabilitation also involves changing the physical form of a watercourse, and from the legal point of view is therefore regulation. It was thus on the basis of provisions on watercourse regulation that Nordjylland County undertook the first real rehabilitation projects in Denmark in 1980.

A 1995 amendment to the Watercourse Act – Section 37a – added a new provision to the Part dealing with rehabilitation (Box 1.2). This provision enables the County Council to improve conditions in watercourses in which summer discharge is poor, for example, immediately downstream of intakes to freshwater fish farms. In such cases, the County could limit the amount of water diverted to the fish farm by stipulating a minimum residual discharge in the watercourse.

Maintenance

It is not just through physical restoration that one can improve the condition and form of watercourses. This can also be achieved through watercourse maintenance.

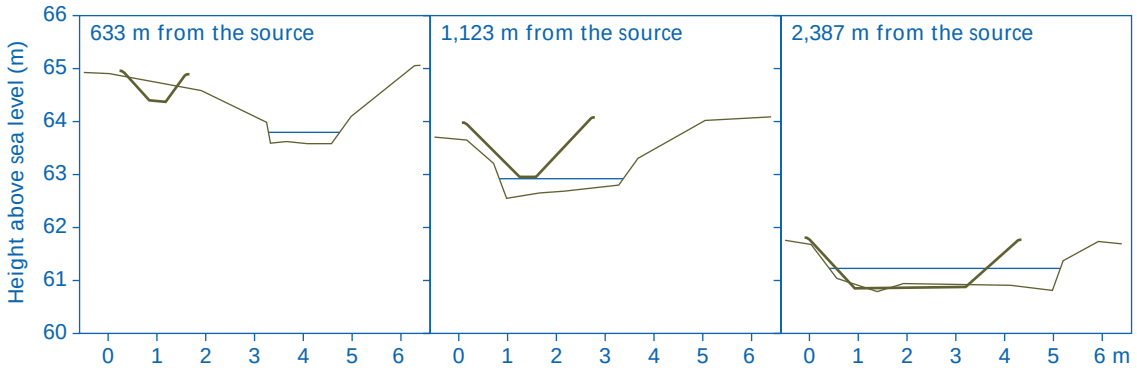


Figure 1.2. Three cross-sectional profiles of the upper reach of the river Gudenå. The thin line indicates the profile in 1992, while the thick line indicates the profile as it should be according to the Provisional Order of 1941 (5).

Maintenance of Danish watercourses has traditionally served the sole purpose of holding in check the natural changes that take place in watercourses so as toensure that the water could drain away sufficiently effectively. Thus with traditional maintenance, one removes vegetation in the watercourse and to some extent on the banks, removes mud and sand deposits, and removes gravel and sand. One works against the natural forces at work in the watercourse, and has therefore to repeat maintenance regularly to keep the watercourse in check.

With the advent of the new Watercourse Act, traditional maintenance of watercourses has in most cases been replaced by more environmentally sound maintenance. With the new practice, one works with the natural forces in the watercourse by limiting weed clearance, by clearing a current channel, and by not dredging outside the watercourse's stipulated cross-sectional profile. One no longer removes stones and gravel and one does not clear vegetation on the banks. One has still to ensure that the discharge capacity stipulated in the Provisional Order governing the watercourse is not diminished, however. There is usually considerable leeway to do so, though, since the cross-sectional profile of many of the watercourses is actually greater than that stipulated (5) (Figure 1.2).

Environmentally sound maintenance can have a markedly beneficial impact on the watercourse environment. In Funen County, it has thus been shown that the implementation of environmentally sound maintenance has led to a four-fold increase in the trout population of county watercourses in less than ten years (6) (Figure 1.3). Environmentally sound maintenance has primarily been implemented in the county watercourses, and to a lesser extent in the municipal watercourses (7).

Environmentally sound watercourse maintenance

Watercourse maintenance can be elaborated to environmentally sound watercourse maintenance. While traditional maintenance aims to "repair" the changes that take place in a watercourse, environmentally sound watercourse maintenance aims to actively change the watercourse in order to develop forms that make it a well-functioning habitat.

Restoration and environmentally sound maintenance supplement each other. They both improve physical conditions in watercourses. With environmentally sound maintenance, one can develop a narrow meandering course in a channelized watercourse using the forces at work within the watercourse. These new meanders primarily lie within the watercourse's cross-sectional profile and are usually formed in a process dominated by deposition in which the aquatic plants become replaced by marsh plants, which eventually merge with the banks. As a rule, the results are clearly apparent in the form of a narrow winding course that develops within the course of three years or less.

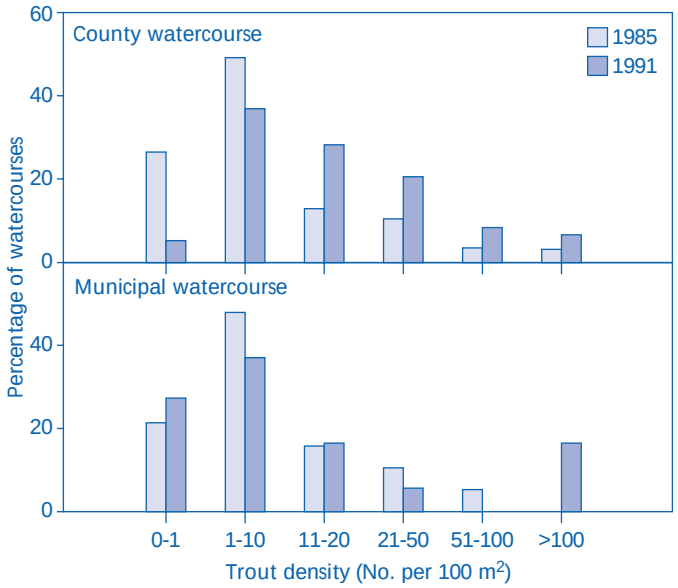


Figure 1.3. In county watercourses on Funen, the trout population has increased in step with the introduction of environmentally sound watercourse maintenance. In the municipal watercourses, in contrast, the trout population has remained sparse, probably largely due to hard-handed maintenance (6).

Such "deposit-based" meanders often have difficulty in cutting through the watercourse's cross-sectional profile and into the adjacent terrain to develop a natural freely meandering watercourse with erosion-based meanders. Given the relatively low slope of Danish watercourses, the development of "erosion-based" meanders will take a long time, often 100 years or more.

With physical restoration, the time frame is much shorter. Using an excavator one can rapidly excavate new meanders. Similarly, one can reopen culverted reaches, one can remove obstructions and one can lay out new stone and gravel beds in places where only a sandy bed remains. Moreover, when it comes to reopening culverted reaches or restoring free passage at obstructions such as weirs and dams, there is no alternative to physical restoration, not even in the long term.

Excavators are expensive to run, however. Thus the total length of watercourses improved over the last 10 years by remeandering and reopening of culverted reaches in Denmark is estimated to be less than 100 km – and perhaps even only half of that. In contrast, the implementation of environmentally sound maintenance practice has improved physical conditions in thousands of kilometres of Danish watercourse during the same period (7). Thus in the majority of Danish watercourses, good physical conditions will have to be ensured by environmentally sound maintenance. In addition, environmentally sound maintenance is often a precondition for fulfilment of the aims of a rehabilitation project. For example, environmentally sound maintenance can hold sand migration in check so that newly established spawning grounds can function (7). Environmentally sound maintenance is also a precondition if there are to be suitable hiding places for the trout fry.

Environmentally sound maintenance does not enjoy the same public attention as restoration projects. With restoration work, the public can see improvement in the watercourse from day to day. In contrast, the improvements brought about by environmentally sound maintenance take place gradually over longer periods. Restoration therefore has an impact over and above that on the watercourse reach in question, by creating general interest in the endeavours to improve our watercourses.

As mentioned in the introduction, this book primarily focuses on restoration. Thus despite the important role played by environmentally sound maintenance, it will not be discussed further.

The need for rehabilitation

When assessing the need for watercourse rehabilitation, a first step is to determine how many watercourses are impoverished in comparison with what one considers to be a naturally functioning watercourse. That a watercourse is naturally functioning does not necessarily mean that it is untouched. Thus even in the modern landscape, there are watercourses that have retained their natural functions to such an extent that they serve as good habitats for a diverse fauna andflora, and in which the ecological and hydrological processes function appropriately.

Another way of assessing the need for rehabilitation is to consider the large number of watercourses that do not yet live up to their quality objective. A Danish nationwide survey encompassing more than 11,000 watercourse monitoring stations revealed that at two thirds of the stations, the watercourse did not comply with the stipulated quality objective (8). While one reason for this is continued discharge of sewage effluent, in the vast majority of cases poor physical conditions are responsible. Thus, according to this Danish survey, 26% of watercourses under 2 metres in width failed to comply with their quality objective because of hard-handed maintenance and poor physical conditions (Table 1.1).

Watercourses of natural origin

As mentioned earlier, there are approximately 30,000 km of watercourse of natural origin in Denmark (7). These are watercourses created by the geological forces of nature.

In addition, there is an equivalent length of canals and drainage ditches. However, these are only the relics of a time when there were even more, many of the field drains having disappeared again after it became technically and economically feasible to drain the fields with drainpipes. No statistics are available as to how many kilometres are involved. Typically, though, nearly all the ditches and brooks in cultivated fields will have disappeared into drainpipes because they were in the way of work in the fields. On the other hand, the open ditches and brooks in woods and forests have been left open because tree roots would otherwise have rapidly blocked the drainpipes.

On the basis of cartographic studies, Brookes (9) has estimated that of the 30,000 km of Danish watercourse of natural origin, only about 900 km have retained their natural form. The percent-

Cause of problem	%
Poor physical variation due to channelization	15
Hard-handed maintenance	11
Sewage effluent from sparely built-up areas	27
Sewage works effluent	22
Loading from agriculture	7
Low water discharge	5
Ochre	5
Loading from freshwater fish farms	2
Miscellaneous	6

Table 1.1. Reasons for noncompliance with quality objectives for watercourses under two metres in width (8).

age of watercourses that have retained their natural form varies considerably from county to county (Figure 1.4). It is hardly surprising that the greater the former drainage intensity in a county, the lower the percentage of watercourses that have retained their natural form.

The watercourses have lost their natural form because of channelization and deepening, and the very hard-handed maintenance formerly practised – a maintenance practice that should rightly be called regulation.

It is common ecological knowledge that the more diverse the environmental conditions, the more diverse the fauna and flora (10). The uniformity of channelized and deepened watercourses, which is maintained by hard-handed maintenance, thus provides poor conditions for life.

In contrast, the great physical variation in current velocity, depth, bed sub-stratum, vegetation, and bank form that characterizes naturally meandering watercourses provides a wide variety of habitats for plants and animals.

In a naturally meandering watercourse, the distance between meanders is generally approximately 10–14 times the width of the watercourse when full to the edge (Figure 1.5). This distance is referred to as the meander wavelength. The current in a meandering watercourse affects its bed and sides with forces that are much smaller than in a corresponding channelized watercourse. This is especially so during periods of high discharge, when it is natural for the meandering watercourse to flood its banks. This reduces erosion in comparison with what would occur if discharge of corresponding magnitude was forced through a channelized watercourse. Erosion also takes place in meandering watercourses, but the special "corkscrew" form of the current ensures that the eroded material is deposited again immediately down-stream of a meander bend. Sand migration is thus considerably less in a meandering watercourse than in a channelized watercourse.

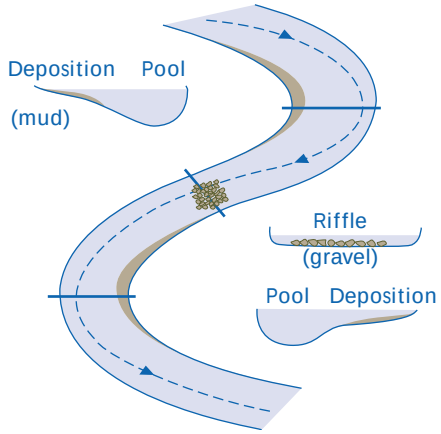


Figure 1.5. A watercourse meander. Current, bed and depth conditions follow fixed patterns along a watercourse's meanders (7).

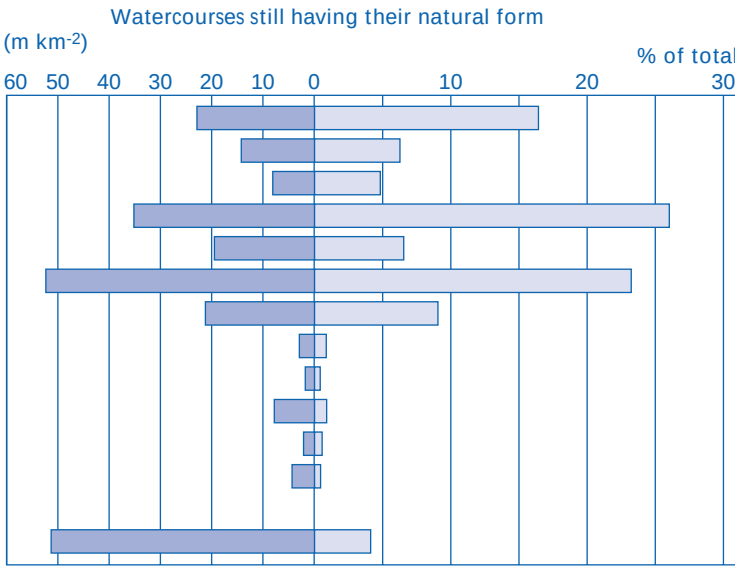
Flooding

Rehabilitating channelized watercourses in such a way as to restore a more natural path and enable the watercourse to flood its meadows often has a positive influence on hydrological conditions in downstream reaches. Thus allowing a watercourse to flood its immediate surroundings reduces the risk of flooding further downstream, where the consequences can be more severe due to the size of the watercourse and the magnitude of discharge. In addition, the flooded areas temporarily store the water such that oscillations between high and low discharge are less pronounced.

Flooding can also have a local impact. Thus it enhances the capacity of the meadows to denitrify nitrate derived from the cultivated fields because the anoxic zone is greater in a wet meadow.

In addition, flooding can reduce the risk of iron leaching from meadows containing pyrite. With channelized and deepened watercourses the groundwater

Figure 1.4. Percentage of watercourses having retained their natural form shown for each of the 14 Danish counties (7).



County	% drained	Drained area (1,000 ha)
Nordjylland	30	129
Viborg	40	109
Aarhus	45	136
Ringkjøbing	34	112
Vejle	48	98
Ribe	32	67
Sønderjylland	62	183
Funen	55	135
Vestsjælland	78	162
Roskilde	57	33
Frederiksborg	71	45
Storstrøm	80	198
Copenhagen	64	>
Bornholm	60	>22

table sinks in the adjacent fields. As a result, a greater area becomes oxic, and the pyrite present in the soil might be washed out as ochre. In some parts of the country, ochre contamination has effectively precluded the presence of a diverse watercourse fauna.

Remeandering of a watercourse can thus remedy some of the consequences of former channelization and deepening of the watercourse. Moreover, it can have a positive influence on water quality, not just in the watercourse itself, but also in other aquatic areas.

Restoring continuity between watercourse reaches

Uniform physical conditions is just one of the problems associated with channelized watercourses. Another is that the watercourse fauna is often hindered from moving freely upstream and downstream by dams and other obstructions.

Many of the obstructions were established in connection with channelization, when weirs were built to even out the former gentle fall over the meanders. Right up to the end of the 1970s, closely spaced obstructions were common even in relatively small river systems (11) (Figure 1.6). In some places, obstructions have hindered the free passage of fish for centuries. Despite concentrated efforts to remove the obstructions, considerable numbers still remain. An example is Ribe County, where large areas were still closed to migratory fish in 1993 despite considerable efforts to make the obstructions passable (Figure 1.7).

Despite the many rehabilitation projects that have already been undertaken in Denmark, there still remains a considerable need to carry out further projects in order to achieve the diverse flora and fauna that we expect in our watercourses.

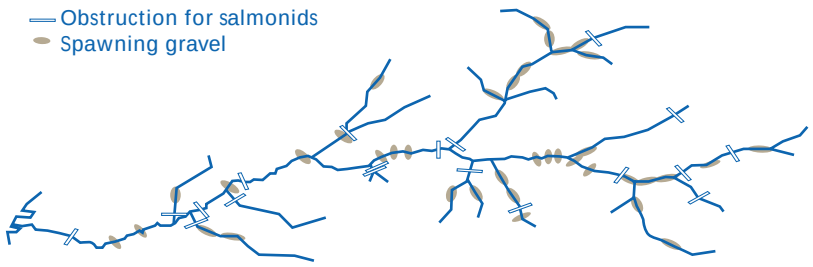


Figure 1.6. Obstructions in the Vegen river system late in the 1970s. The obstructions hindered trout in reaching the spawning grounds.

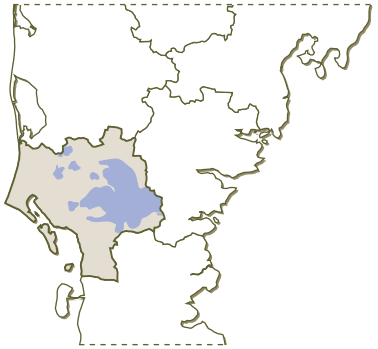


Figure 1.7. Watercourses of Ribe County that were still closed to migratory fish in 1993 (12).

References to Chapter 1

1 *Nielsen, J. (1995): Fish requirements as to watercourse physical condition – A selection of existing knowledge (in Danish with English summary).* – Environmental Project No. 293, Danish Environmental Protection Agency. 129 pp.

2 *Osborne, L.L., Bayley, P.B. & Higler, L.W. (eds.) (1993): Lowland stream restoration: Theory and practice.* – Freshwater Biology (special issue) 2: 187-342.

3 *Hunt, R.L. (1992): Evaluation of trout habitat improvement structures in three high-gradient streams in Wisconsin.* – Technical Bulletin No. 179, Department of Natural Resources, Madison. 210 pp.

4 *Nielsen, J. (1994): Fish passage at obstructions in Danish streams.* – Vejle County Council. 9 pp.

5 *Hansen, H.O. (in press): Remeandering of a Danish headwater stream: The river Gudenå demonstration project.* – Internat. Verein. Limnol.

6 *Wiberg-Larsen, P., Petersen, S., Rugaard, T. & Geertz-Hansen, P. (1994): Better watercourse maintenance increases the number of fish (in Danish).* – Vand & Jord 6: 263-265.

7 *Madsen, B.L. (1995): Danish Watercourses – Ten years with the new Watercourse Act: Collected examples of maintenance and restoration.* – Environmental News No. 11, Danish Environmental Protection Agency. 206 pp.

8 *Friberg, N., Græsbøll, P. & Larsen, S.E. (in press): Causes of the generally poor state of smaller Danish watercourses (in Danish).* – Environmental Project, Danish Environmental Protection Agency.

9 *Brookes, A. (1984): Recommendations bearing on the sinuosity of Danish stream channels.* – Technical Report No. 6, Freshwater Laboratory, Danish Environmental Protection Agency. 130 pp.

10 *Thienemann, A. (1950): Die Verbreitungsgeschichte der Süsswassertierwelt Europas (in German).* – Die Binnengewässer Band XVIII, Stuttgart.

11 *Ansbæk, J., Jensen, F., Schultz, K.E. & Aagaard, P. (1981): The significance of watercourses to society (in Danish).* – Freshwater Laboratory, Danish Environmental Protection Agency.

12 *Ejbye-Ernst, M. (1993): Watercourse fish populations (in Danish).* – Ribe County Council, Technical and Environmental Department. 39 pp.

2

Mogens Bjørn Nielsen

From idea to reality

The present chapter discusses the most important considerations, technical aspects and legally required approvals that are involved when undertaking a watercourse rehabilitation project in Denmark. As the examples in this book illustrate, the purpose of rehabilitation, the solutions, and the interests that have to be taken into consideration vary from watercourse reach to watercourse reach.

The chapter examines restoration step by step – from the initial idea until completion of the project in the field. In addition, a check list is included at the end of the chapter that Danish authorities should find useful when drawing up projects aimed at improving watercourses and riparian areas. If modified to take local conditions into account, the procedure could also be used by the authorities of other countries.

Course of a Danish rehabilitation project

Carrying out a watercourse rehabilitation project in Denmark is often a matter requiring patience. The following stages are normally involved:

- Initial idea
- Pilot studies
- Contact to landowners and provisional acceptance
- Coupling of interests between landowners, the public and the authorities, and drawing up of the project
- Approvals and processing by the authorities
- Clarification of financing
- Construction – the physical work
- Assessment and follow-up.

By far the majority of the projects are undertaken by the Counties and Municipalities in collaboration with one or more other parties. The Counties have drawn up a policy and strategy in the environment and nature area, and administer the majority of the laws pertaining to watercourses and the landscape. In addition, many of the Municipalities have plans for their watercourses, and in some cases also have restoration plans. There are also examples of projects having been undertaken by private interest groups or the State.

The European Centre for River Restoration at the National Environmental Research Institute in Silkeborg houses a large collection of reports and project descriptions pertaining to watercourse restoration. There one may obtain inspiration and benefit from the experience gained in earlier projects. In order to be able to expand the collection and build up a broad European base of information,

the Centre is very interested in receiving project descriptions, assessments and other experiences on restoration projects carried out in European countries.

Initial idea

The initial idea for a watercourse restoration project typically comes from:

- Private individuals
- Groups of landowners
- Residents associations
- Interest groups, e.g. angling associations, nature conservation societies, ornithological societies
- Municipal Councils, municipal technical departments
- County Councils, county landscape departments, county environmental departments.

Over the last few years, the Counties and Municipalities have increasingly received enquiries from landowners concerning restoration of watercourse reaches on their property. In some cases, the enquiries have come from residentsassociations. In fact, the question "Couldn't we have our former meandering stream back in the meadow?" once posed by the residents of Bevtoft in Sønderjylland County was the impetus for one of the first major remeandering projects in Denmark – the restoration of 2 km of Gelså stream (see Chapter 5).

Marginalization of riparian areas and the fact that an increasing number of rural properties are being overtaken by urbanites also increase the possibilities for undertaking watercourse restoration projects. Enquiries from established interest groups tend to be somewhat more organized, their members often having a very good knowledge of which watercourses would benefit from restoration. Ideas also arise in so-called "Regional Countryside Councils" set up by the Counties, and in which the "green" organizations are represented together with farming organizations, etc.

The fact that restoration can also lead to a more varied nature in the watercourse and its immediate surroundings, and thereby to better hunting and fishing, can sometimes help tip the balance in favour of undertaking such projects.

Pilot studies

In order to obtain a first impression of whether an idea is scientifically defensible, a pilot study or an outline project should be made. Relevant maps should be acquired, for example showing the former course prior to channelization, biological conditions should be investigated, various measurements made and soil samples collected. In addition, information on discharge in the watercourse or in the catchment area should be obtained, larger-sized technical structures in and alongside the watercourse should be checked, and possible legal constraints on the project be investigated. On this basis, an assessment should then be made of whether or not the project is technically realistic. The results of the pilot study will subsequently be incorporated in the detailed project description.

The stream Rind restoration project.

Contact to landowners and provisional acceptance

Assuming the pilot study or the outline project does not preclude the project being undertaken, thereafter follows what is often the most important phase. Thus beforeproceeding with the project, it is advisable to go over the project idea with the landowners involved. The first contact should be made personally to each individual landowner. It is very important that the project outline presented to them is clearly only a proposal. This ensures that it will be possible to incorporate local ideas and wishes into the project, something that is only normally possible provided one is not technically or politically bound to a particular solution beforehand.

It is inadvisable to arrange and undertake a large public meeting at too early a stage, when the basis for the project is too loose and only the basic idea and a summary pilot study are available. The democratic rights of parties involved are assured by the mandatory periods for the submission of objections and appeals during the various stages of the approval process (Figure 2.1). Thus the public meeting should not be held until such time as one has discussed the project with the landowners affected and incorporated some of their ideas and comments into the project, but is still open to possible further changes to the project.

The usual outcome is that not all the wishes and comments can be followed simultaneously, and the choice between possible solutions thus becomes a political decision. Hence it is normally a good idea that politicians from the responsible watercourse authority also participate in the public meeting. The involvement of politicians signals to participants that there is more to the project than just some technicians' idea. Moreover, one is more likely to accept solutions arrived at on a political basis when one has seen and heard the politicians in question.

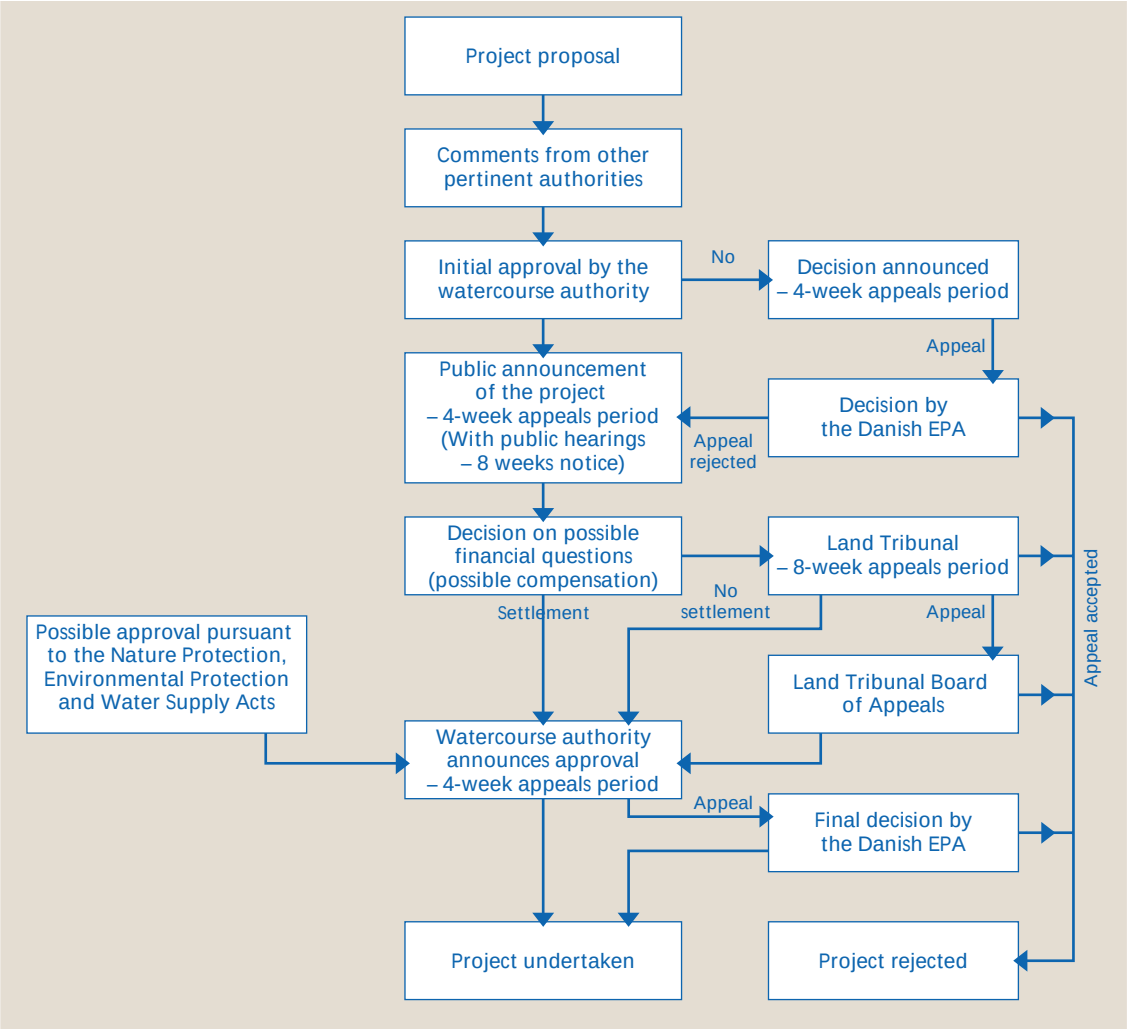


Figure 2.1. Schematic representation of the steps involved in the approval of watercourse regulation and restoration cases by the Danish authorities.

Coupling of interests between landowners, the public and the authorities, and drawing up the project

Before drawing up the project it is important to formulate one or more clear objectives. A restoration project can often take account of many different environmental and natural interests, and the wider the proposal is, the more backing it will often be possible to obtain. On the other hand, though, it is not possible to take account of all interests at the same time and place. Priorities have therefore to be established.

A watercourse restoration project comprising restoring the watercourse to its original meandering path involves more than just restoring the watercourse itself. Thus, riparian areas such as banks and meadows will often also be affected. In some cases, watercourse restoration involves raising the groundwater table and implementing ochre removal.

The objective when restoring watercourses and adjacent wetlands could be one or more of the following:

- Better physical conditions in the watercourse
- Enhanced self-purification capacity in the watercourse and greater denitrification of nitrogen in the wet meadows
- A more varied landscape
- A greater number of more varied habitats for (threatened) plant and animal species
- A greater number of more varied dispersal corridors for plants and animals
- Reduced ochre loading
- Protection of groundwater resources
- Enrichment of outdoor life, including angling and hunting
- Compliance with international obligations (conventions, protected wetlands, etc.).

With restoration projects involving remeandering and raising the watercourse bed, possible results include:

- A meandering watercourse with greater landscape value
- Less ochre loading (in cases where there is ochre in the vicinity of the watercourse)
- Wetter meadows with greater nutrient turnover
- Greater physical variation in both the watercourse and the adjacent areas
- A greater number of different species of animals and plants
- Better recreative possibilities, e.g. angling, walking, sailing, bird watching and hunting
- Enhanced quality of life.

When prioritizing possible projects, inclusion of the following considerations will help ensure the greatest environmental and natural return on the investment:

- Ensure that the investments and changes are permanent
- Aim for low costs for purchase and construction
- Ensure that there are only few or no maintenance costs once the project has been completed
- Take account of several interests simultaneously (as described above)
- Obtain good political and local backing.

Watercourse restoration projects often have to be drawn up using a multidisciplinary approach involving topics such as:

- Water quality
- Hydrology and discharge
- Biological conditions
- Technical installations, such as pipes and cables under and above ground at watercourses, bridges, houses and other structures, etc.
- Legal aspects, as described below.

A new watercourse being excavated.

Approvals and processing by the authorities

Restoration is governed by Part 8 of the Danish Watercourse Act (Box 1.2). This aims to improve a watercourse's quality so that it corresponds to the quality objective for the watercourse stipulated by the County Council pursuant to the Environmental Protection Act. In addition, though, it requires that the watercourse's drainage capacity should not be affected to any great extent.

Developments in the restoration area have overtaken legislation, however, which stems from the early 1980s. Thus, many of the restoration measures in use in the 1990s include elements of watercourse "regulation" in the form of the remeandering of channelized reaches, and hence are encompassed by Part 6 Section 16 of the Watercourse Act (Box 1.2).

From the legal point of view, the following measures are also watercourse regulation:

- Remeandering of a watercourse
- Various improvements at weirs, including:
  - Construction of fish ladders
  - Split-stream bypass reaches
  - Rebuilding or removal of weirs/dams
  - Reopening of culverted reaches.

The regulations governing how the authorities are to process projects aimed at improving watercourses are stipulated by the Ministry of Environment and Energy in a 1983 Statutory Order. This covers both watercourse regulation and watercourse restoration. These regulations have to be followed by the watercourse authority in all cases, irrespective of from where and whom the original idea or initiative for the project derives. The approval process is shown schematically in Figure 2.1.

Proposals for watercourse regulation and restoration are submitted to the County Council or Municipal Council with a view to obtaining the political decision of the watercourse authority to proceed with the case.

The proposal shall include:

1. An account of the purpose of the regulation project and a justification of the project.
2. The necessary outline maps and detailed plans.
3. A summary of the properties affected by the project and a list of landowners and users who should be involved in the project.
4. An estimate of costs including a proposal for their apportionment.
5. A timetable for the work.

If the project is undertaken as an actual restoration project, the proposal must include the following:

1. An account of the quality objective for the watercourse and the aim of the proposed restoration project.
2. An account of the pilot studies on which the project is based.
3. An account of the consequences of the restoration project for discharge and drainage.
4. Information on the watercourse's present and future form and discharge capacity, and on the associated water table conditions.
5. Information on the planned restoration measures and their location in the watercourse.
6. The necessary sketches and maps, including an outline plan in a suitable scale.
7. A timetable for the work.
8. An estimate of construction and running costs.

If the watercourse authority decides to proceed with the case, the proposal is laid open to the general public for a period of at least 4 weeks in regulation cases, and at least 8 weeks in restoration cases. Announcements are usually made in the daily press or in local newspapers. Landowners and other interested parties are informed in writing. At the same time, the proposal is sent to organizations having the right of complaint (The Danish Anglers Federation and the Danish Society for the Conservation of Nature). As many projects involve riparian areas in the open countryside, it is often also a good idea to inform the local agricultural organizations. The proposal is simultaneously submitted for hearing at the relevant authorities, which is always the County Council, but sometimes the Municipal Council as well.

In all cases, it is required to submit an evaluation of the project in relation to the quality objective for the watercourse stipulated by the County Council pursuant to the Environmental Protection Act. The majority of cases also require the approval of the County Council pursuant

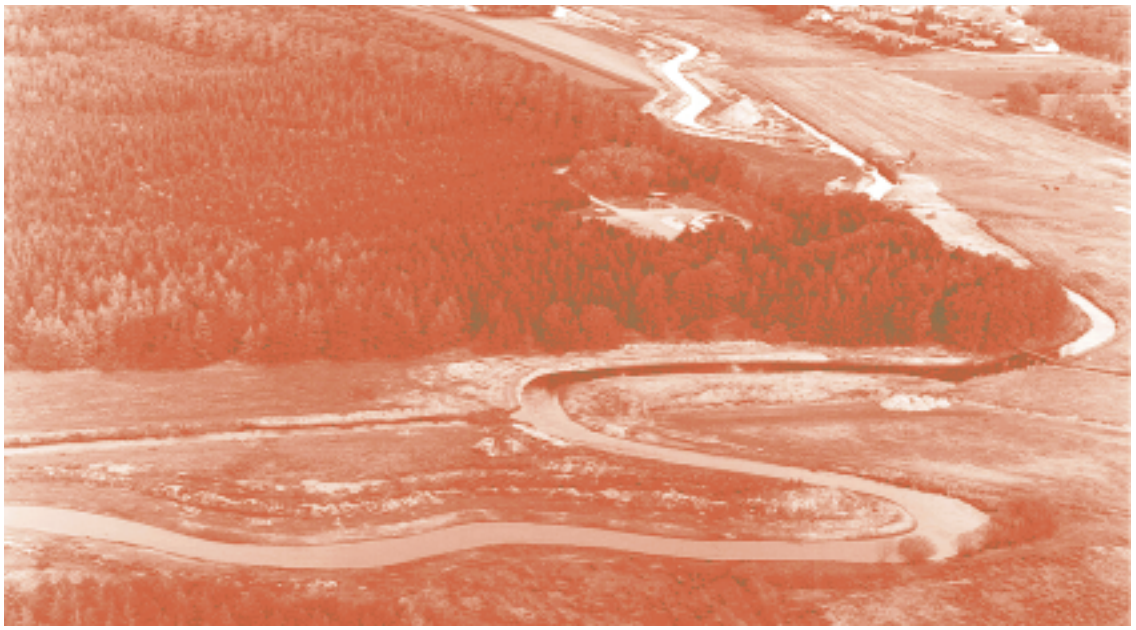
to the provisions of the Nature Protection Act. With such approvals, there is also a statutory 4-week complaints period. In rare cases, approval is also required from the Ministry of Agriculture and Fishery pursuant to the Freshwater Fishery Act. Thus Section 33 of the Act states that "before permits are issued or decisions reached concerning measures that can affect the passage of fish, fishery and the fish fauna in general, the plans shall be submitted to the Ministry of Agriculture and Fishery for comment".

Due to the often rather complicated legal procedures involved, it is advisable to contact the relevant county authorities in advance to find out what approvals are necessary for the watercourse reach in question and the measures planned. In addition, when drawing up the detailed project it is advisable to evaluate how comprehensive the impact assessment studies should be (see below under the heading "Evaluation and follow-up"). When agreeing to subsidize larger-sized projects, the Danish Environmental Protection Agency will normally require that the environmental impact of the project be documented in some way or other.

Based on the project proposal and whatever comments arise during the public hearing phase, the watercourse authority issues final approval for the project.

Before this can be done, however, the financial aspects have to be clarified (see below) and, as mentioned above, whatever other approvals might be necessary have to be obtained.

Thereafter follows a 4-week appeals period pursuant to the Watercourse Act, irrespective of whether the case concerns regulation or restoration. The possibility of appeals is intended as an emergency brake in that the watercourse authority's approval should already have taken fully into account the various interests involved and the comments and remarks submitted.



The river Brede restoration project.

Appeals have a postponing affect such that a project may not be initiated before the appeal authority has issued a ruling. In these cases, the appeal authority is the Danish Environmental Protection Agency. However, in cases where it seems most likely that the appeal will be denied, the Agency can issue approval for initiation of construction work. Some appeals are processed relatively rapidly, while some can take several months.

With some projects, it is necessary to change the existing ownership conditions and property boundaries. The landowners can have an interest in exchanging land, for examples if their fields are scattered rather than being congregated near thefarmhouse. In addition, it is a legal requirement that property boundaries and ownership records be corrected when a piece of land changes hands. The most natural would be for the authority responsible for the project to take care of the task of updating the Land Registry.

Financing

Before the watercourse authority can issue final approval for a watercourse project, financing has to be clarified. Many projects are in effect collaborative endeavours, and financing often derives from a number of sources in the form of cash subsidies or labour. In some cases, labour undertaken by landowners and angling clubs is part of the financing. In other cases, land is provided free of charge or compensation.

Restoration can sometimes help solve recurring problems with the maintenance of a watercourse. Examples are reaches which continually silt up or where the banks continually collapse, or culverted reaches where costly replacement of the pipes is needed. In such cases, the relevant watercourse authority could profitably capitalize future maintenance costs and instead solve the problem by restoring the watercourse.

The most important additional sources of financing are:

- Local sources: Landowners, associations (residents associations, tourist associations, anglers) and the Municipal Council
- Regional sources: County funds for watercourse restoration, countryside rehabilitation and management, and subsidies for specific use of the riparian areas, e.g. for grazing

- State sources: The Danish Environmental Protection Agency's funds for watercourse restoration and ochre removal, the National Forest and Nature Agency's central pool for countryside rehabilitation
- Various funds, firms, companies and private individuals
- In a few cases, subsidies for very large projects have been obtained under the EU LIFE programme (e.g. the river Brede, the Skjern river delta, and the headwaters of the river Gudenå).

A new stone riffle and two-step profile.

Construction

How extensive this part of the project description needs to be depends on the extent of the planned construction work. If the watercourse authority decides that the project shall be undertaken by contractors, a call for tenders will have to be prepared. The call for tenders includes special descriptions of the work which, together with the detailed project, form the basis for the contractor to undertake the construction work. The rules in the Competitive Tendering Act apply in Denmark in connection with the protection of tenders, and it is recommended to seek the advice of persons with a sound knowledge of the Act.

An important task is to ensure effective supervision of the construction work. This ensures that the project is undertaken in accordance with the stipulated conditions, dimensions, etc. Among other things, this is important for drainage from the individual landowner's property, as well as for future physical conditions in the watercourse and consequently for nature and the environment. In addition, supervision ensures that the funds expended on the work are used in a defensible and politically approved manner.

The call for tenders only has to be made at the EU level in the case of very large construction projects, i.e. projects where the total construction costs amount to ECU 5 million or more.

Evaluation and follow-up

Prior to each individual project, one should assess how comprehensive the impact assessment studies should be. In all cases, follow-up should be undertaken for a period following completion of construction work to ensure that possible damage or undesirable consequences of the project are remedied. In addition, a scientific evaluation of the project by the authority in charge is also necessary. This ensures that valuable experience is gathered for use in future projects.

Another important matter is to reach agreement concerning maintenance obligations and division of responsibility. Ideally, this should be clarified in connection with approval of the project. However, from experience we know that this is not usually done until after completion of the work.

Check list for the project description

A useful way of arranging a detailed project description that complies with legal regulations and requirements regarding both regulation and restoration projects is as follows:

A. Introduction

- Origin of the idea and location of the area
- Purpose of the project
- Summary of the physical measures intended specifying exactly what is to be done.

B. Description of existing conditions

- General description of the locality (location, terrain, physical conditions, surveys)
- Preservation and regional planning constraints, i.e. the Preservation Scheme, preservation orders and constraints stipulated in the County Plan (raw material reserves, EU Bird Protection Areas, environmentally vulnerable agricultural land, etc.)
- Land use (cultivation, recreational or other uses)
- Fauna and flora (collation of existing knowledge/reports and new, supplementary investigations)
- Quality objectives and water quality (recipient quality plan, pollutional state)
- Drainage and discharge conditions (water level, discharge, catchment size and character, groundwater conditions, drainage conditions and the provisions stipulated in the Provisional Order governing the watercourse)
- Soil conditions. Information on special conditions such as soft bed or potentially ochreous areas. Valuable information can often be obtained from existing studies in the area. In addition, one should be aware that it is sometimes necessary to undertake sediment analyses, typically for the heavy metals lead, cadmium, mercury and nickel. This has to be done if the excavated earth is to be dispersed on agricultural land. The county authorities have information on registered contaminated lands and ochreous areas
- Technical installations, e.g. various cables and pipes (water, sewage, telephone, gas and electricity), roads, footpaths and other crossings, masts, structures (weirs, dams, etc.), overflows, inlets, etc. Local utility companies and the Municipality's technical department have the relevant information
- Ownership (private, public, Land Registry entries, cadastral maps).

C. Planned measures

- Description of the planned construction work suitable for preparing the call for tenders
- Follow-up work, including re-establishment, sowing, planting, fencing, bridges and footpaths.

D. Results and consequences

- Expected future conditions, including water levels, discharge, groundwater conditions, water quality, and flora and fauna
- Consequences for land use
- Future ownership
- Monitoring and impact assessment.

E. Necessary permits – summary

- Pursuant to the Watercourse Act
- Pursuant to the Nature Protection Act
- Pursuant to the Freshwater Fishery Act
- Pursuant to the Ochre Act
- From landowners. Review of the property's entry in the Land Registry to determine ownership, and to ensure that registered rights and easements are not violated. In addition, easements can reveal information on the location of technical installations, pipes and cables, road rights, etc. When clarifying ownership and agreements with landowners, one has also to take into account the possible rights of third parties. Such rights are not necessarily recorded in the Land Registry entry for the property, and in agricultural areas will often concern leasehold agreements. Ask the owner about such rights and enter into an agreement with the owner that clarifieswho is to cover, for example, a leaseholder's crop losses caused by construction work.

F. Timetable

- Pilot project
- Preliminary discussions with landowners
- Political processing of the project application
- Possible public hearing
- Public phase
- Final clarification of financing
- Necessary approvals additional to those under the Watercourse Act, incl. appeal periods
- Final approval pursuant to the Watercourse Act, incl. appeal periods
- Construction phase
- Follow-up, including updating the Land Registry and deciding future division of maintenance obligations and responsibility.

G. Economic aspects

- A precise budget estimate and a summary of financing.

H. Annexes

For a typical major project the following annexes will be relevant:

- Outline maps in scale 1:100,000 and 1:25,000
- Old maps of the area
- Survey/survey maps
- Planning conditions
- Existing longitudinal and cross-sectional profiles
- Water discharge, water level, hydrographs
- Present ownership
- Present land use
- The measures planned in the project
- Coming longitudinal and cross-sectional profiles
- Miscellaneous detailed drawings
- Future ownership
- Future land use.