Watercourse Recovery Process - The Role and Importance of Water Monitoring

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Abstract. Social, economic, and political development, both in the past and today, is largely linked to the availability and distribution of freshwater contained in rivers. However, very often, and especially in recent decades, rivers are brought into the context of danger to humans, either in the event of high waters or because of their increasing pollution. Human development, population growth, urbanization, and climate change, are just some of the causes that have led to a significant decline in river health globally. The importance of preserving the quality of watercourses, and preserving the amount of water, is gaining weight, especially after the realization of the lack of it for many human needs. Unfortunately, water pollution is increasing day by day. Industries and households discharge their wastewater into rivers, household waste is usually dumped directly into it, and various chemical fertilizers and pesticides, which are mostly used unplanned in agriculture, are filtered into groundwater and surface water.

Hydrotechnical facilities in the riverbed significantly change the natural water regime and the sediment transport regime, which in turn has an irreversible negative impact on aquatic ecosystems. Raising public awareness of ways, measures, and opportunities for conservation of water resources in general, with all technical and technological measures implemented in society, must inevitably be raised to a higher level. be simple.

The paper will analyze the contemporary attitude of man towards watercourses, considering the historical heritage that influenced this relationship. Special attention will be paid to passive and active measures of watercourse recovery, and recovery monitoring.

Keywords: Ecological revitalization · Monitoring · Watercourse recovery · Measures

1 Introduction

People have always inhabited river valleys and river banks. The first civilizations arose on fertile land near the Tigris and Euphrates in Mesopotamia, the Nile in Egypt, and the

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Yellow River in China. Possibility of using watercourses as a waterway, more favorable climatic conditions in river valleys, favorable conditions for agricultural production, use of water potential for electricity production, in industry, use of river water for cooling thermal power plants, fishing, recreation, and water sports are just some from the reasons that attracted people to the river valleys. Rivers have always been the most important source of fresh water for man. And not only that, often rivers in their natural state, through natural retentions and backwaters were the best defense against floods, and coastal vegetation had a significant impact on the purification of water that infiltrates from watercourses underground.

Watercourses are non-stationary watercourses, with very frequent changes in water quantity and sediments over time, but they can also be with significant changes in water quality over time and space. Pollution that reaches rivers can spread very quickly and spread spatially along watercourses. Preventing river pollution and pollution is crucial, but it is neither easy nor simple to put into practice. It can be reduced, first of all, through measures of industrial and domestic wastewater treatment, through measures to replace the use of chemicals and pesticides in agriculture and the transition to organic production, or by applying good agricultural practices. The application of integrated water resources management within the catchment area, guided by the principles of sustainable development, could ensure the health of watercourses and associated ecosystems in the long run, [1].

Through practice, it has been shown that watercourses, as an integral part of nature, cannot be controlled by force, but only by understanding its natural processes. As a result of the continuous flow of energy and matter through the changing space in which they move, watercourses are extremely dynamic, open, and living systems. That is why they have played a key and hitherto insufficiently understood and studied role in the history of the planet, and especially in the development of civilization. The fact is that their indisputable great significance has not been sufficiently recognized for a long time, not only by the general public but also by experts who study watercourses and all (natural and social) phenomena related to them. The state of awareness of this interdisciplinary issue has changed significantly in recent times, and many aspects related to watercourses have begun to be studied intensively and interdisciplinary, and much more care has been taken of watercourses. Such, one might say, necessary and positive trends have occurred as a result of the fact of numerous and major catastrophes caused primarily by human interventions.

When analyzing the processes related to watercourses, one should be aware of the fact that all these aspects, but also many others, are strongly interconnected. Another problem is the fact that science has not yet sufficiently understood and explained these connections, which makes it difficult and impossible to take sustainable measures to protect watercourses and their functions, [1].

2 Ecological Revitalization of Watercourses and Its Relevance within a Theory of Sustainable Development

Ecological revitalization of watercourses refers to a variety of measures aimed at establishing the natural state and functioning of the river and the river environment. Through the establishment of natural conditions and processes, the revitalization of watercourses is planned to create a framework for sustainable, multipurpose river use (ECRR). Technical structures such as hydropower overflows and dams, reinforced embankments to prevent erosion, construction of canals to protect against floods, pollution of water bodies with wastewater or chemicals, and extracting sediment from rivers to increase navigability are just some of the examples of human activities and their impact on rivers.

In European countries, there is hardly a single river that avoided this kind of human influence, resulting in a more or less disturbed river system. In addition to visible disturbances, there are a number of hidden effects of human activity (changes in water regime that lead to changes in characteristic natural processes in river systems, such as processes of erosion and deposition of sand and clay, annual or seasonal flooding rhythm with a high risk of damage; summer droughts, etc.).

All of this has often not been considered important in recent history or problematic but has now been identified as an important factor in reducing the natural values of water-dependent habitats and ecosystems across Europe. Along with water quality problems and possible effects of climate change, many river systems in Europe today are far from their so-called. Intact. As a result, in many cases, characteristic riverine habitats have declined rapidly in recent decades, and some have even disappeared from certain river systems. The same is true for many plant and animal species in these habitats and ecosystems. At the EU and national level, EU Member States have made some progress in recent decades on endangered river systems. Meanwhile, many states have taken steps to ensure that water quality in streams and rivers does not deteriorate further.

Improving water quality is a continuous process, which began in the 1970s with the adoption of general legislation on water quality and which resulted in an integrated approach to water quality in 2000 (entry into force Water Framework Directives). In a number of cases, the state of water quality has even improved markedly. Chemical pollution and wastewater discharge are strictly regulated and kept to a minimum. The chemical load is reduced and the oxygen levels in the water are increased. Many fish and other animal species are re-inhabiting rivers.

This is already a good result, but the current overall reduction in biodiversity suggests that much remains to be done. EU countries have agreed to implement the Water Framework Directive in order to guide the development of watercourse revitalization plans to ensure that signs of improvement continue in the coming decades. EU countries need to implement River Basin Management Plans as instruments to take action to be aimed at further improving freshwater systems in Europe. These measures will not only focus on water quality but specifically on improving the hydro morphological status of watercourses and lakes. The overall goal is to “rebuild” the system as best we can, using reference conditions for water bodies in their natural, undisturbed state.

2.1 Chronological Overview of Water Use Phases

Today there are very few watercourses in the world or only their individual sections where the natural regime has not been changed. Natural watercourses undisturbed by human interventions, in addition to being indicators of the health of the entire environment, represent places of the highest aesthetic values. In the middle of the nineteenth century, the man began mass activities to "tame" rivers and control their natural processes. These works were especially intensified in the middle of the twentieth century when the development of technology enabled the rapid execution of the most complex construction projects. At first, everything looked ideal. Man achieved his goals by controlling nature according to his needs. It seemed as if the man was creating "paradise on earth." The short-term and selfish needs of people were primarily taken into account, without considering the needs of nature and the environment. It was only when cracks appeared in the ideally conceived process of controlling the nature of open watercourses, and this began to happen particularly intensely in the twentieth century, that man realized that much had gone in the wrong direction. Man has neglected the key role of watercourses in ecological terms [1, 2]. That role had been hinted at before, but people didn't pay enough attention to it. It was thought that possible omissions could be corrected relatively easily by additional interventions.

The human attitude towards watercourses changed over time and depended primarily on the level of technical and technological development at which man was. Rivers have been significant to man since the time of the first human communities, which used fertile floodplains around rivers for agricultural production. With the increase in water demand in arid areas, facilities for controlling and diverting river flow were built. It is believed that King Menes 3100 p.K., blocked the Nile near Memphis to protect the city from river overflow. Biswas [3] chronologically presented the engineering works of the Sumerians, Egyptians, and Harapans, who in 2500 BC, developed very strong civilizations in the Indus River Basin. This includes the establishment of the first water laws of the "codex", such as the Hammurabi Code of 1750 BC. in ancient Babylon, and about 200 BC, in China, when Emperor Yu began to control rivers in the interest of soil improvement and land reclamation.

Ways of using river waters can be observed in phases throughout history, noting that not all phases can be applied to every geographical region. Each phase of river use was associated with special requirements which, at the time of the so-called hydrotechnical civilizations, were associated with the use of large amounts of water, in a larger area. The achievements of these first so-called hydro-technical civilizations, as Wittfogel called them [4], were quite astonishing, given the lack of any theoretical knowledge and hydraulic calculations. In the period before the Industrial Revolution, watercourses were used with very few morphological changes, but with very intensive use of the surrounding land (most often deforestation), which in any case had a great impact on watercourses.

With the industrial revolution, the imperative was to use new technologies. Many industries have been located along rivers to facilitate the use of available water for a variety of purposes. During this period, river transport developed, as well as coal and other industrial materials, even before the beginning of the development of railway transport. As a consequence of the industrial revolution, the first water supply systems were established, as well as direct abstractions of river water for the needs of industry or the population. The late 1990s and the first half of the 20th century again led to more extensive use of rivers, based on the use of available technologies.

This phase can best be described by the sentence "technology can fix it", [5]. With the development of large cities come the beginnings of integrated watercourse management at the catchment level, however, on the other hand, there is an intensive regulation of rivers, construction of dams, and other facilities to regulate the water regime, which can be considered the fifth phase. The realization of the effects of human activities on aquatic ecosystems and the environment leads to the development of the idea of sustainability in the late twentieth and early 21st century. The aim is to prevent further degradation of the river environment by applying mitigation, improvement, and restoration techniques, i.e., restoring rivers to their original state.

2.2 Human-Watercourse Relationship

The processes that take place in watercourses and their catchments are subject to constant and sudden changes due to natural and increasingly anthropogenic influences whose short-term and even more long-term consequences are difficult and often impossible to control. When human activities on rivers carry out massive interventions that significantly change the natural hydrological and/or morphological regime, there is a disturbance or even complete loss of dynamic balance. The consequences of this can be devastating. We are just witnessing many of them. The following occur: (1) More frequent and stronger floods; (2) Water quality degradation; (3) Habitat losses for fish and other animals and plants related to the river and its natural hydrological variations; (4) Complete and often irreparable devastation of the entire ecosystem of watercourses and basins, and as a consequence destabilization of economic, social and political structures and processes in these areas.

In addition to the above, the loss of aesthetic and other values of natural watercourses that can negatively affect the development of tourism, recreation, sports activities, etc. should not be neglected.

3 Basic Principles of Watercourse Recovery

The repair process gained momentum in the 1970s and 1980s. It first started in developed countries such as the US, EU countries, and Australia. However, significant progress in the application of various measures to the recovery of watercourses can also be found in developing countries. The goals of recovery should be defined by an interdisciplinary approach by decision-makers, with the consensus of interdisciplinary technical teams and other participants in social and political life. They should be the integration of two important groups of factors: (i) relating to future conditions to be achieved (ecological reference status), (ii) and arising from knowledge of social, political, and economic values in the basin or part of the basin under consideration.

The ecological state of watercourses, which is to be achieved by applying watercourse recovery measures, is often based on a commonly accepted idea of how natural watercourses once looked and functioned. Consequently, it represents an ideal state for recovery, regardless of whether this reference state can be achieved or not. This ideal situation is given by the term "potential" and can be described as the highest ecological status that an area can achieve, without political, social, or economic constraints [6]. However, the fact is that through the recovery process, the set goals usually have to be corrected and replaced with more realistic and specific recovery goals, i.e., those that can be reached.

Namely, defining the goals of recovery must also include important political, social, and economic characteristics, and other issues, which differ from watercourses, watersheds, regions, states, and the like, and are in fact nowhere the same. When these considerations are processed into an analysis, realistic goals of a recovery project can be identified, based on the ability of watercourses to achieve a targeted ecological status. Identification of realistic goals is key to the success of watercourse recovery because it sets the framework for adaptive management within the realistic framework of expected results. Unrealistic recovery goals create unrealistic expectations. In defining realistic recovery goals, it may be useful to divide them into two separate but interrelated categories - **primary and secondary**.

The primary goals should be to identify and analyze problems/opportunities, and include a vision of the desired future situation, considering possible constraints on the success of the recovery process, and issues such as the spatial scale of recovery, specific requirements for a specific target or endangered species. Space users and the like. The primary goals are usually those that drive the whole project, such as stabilization of watercourse river slopes, sediment control, water quality protection, flood control, improvement of the condition of aquatic and terrestrial ecosystems in the considered area, and improvement of environmental characteristics. **Secondary goals** should be developed to directly or indirectly support primary recovery goals.

According to the set goals and realistic possibilities for their implementation, the recovery of watercourses is planned. In doing so, several possibilities for watercourse recovery should be distinguished: restoration, rehabilitation, and remediation (Fig. 1).

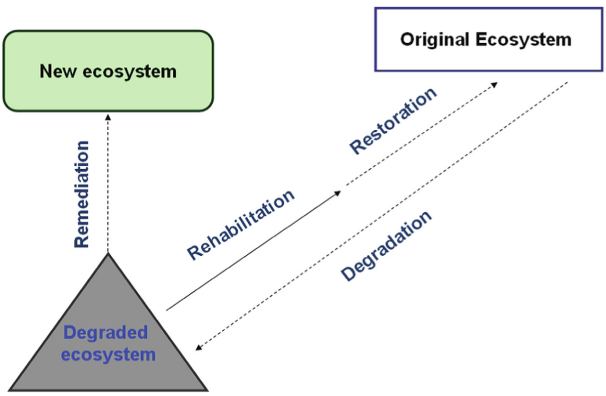

Fig. 1. Graphic representation of the difference between restoration, rehabilitation, and remediation, [7].

The first and most demanding activity, restoration, involves returning the river to its original ecological state, according to all relevant ecological parameters (flow regime, bottom substrate, indigenous aquatic and coastal ecosystems, environmental conditions), [8] According to Wade et al. [9], the restoration is aimed at the reconstruction and return of the intact physical, chemical and biological state of the watercourse. In its purest sense, it means a complete structural and functional return to the state before the disorder.

Since in a number of cases this task is not realistic, rehabilitation is resorted to. Rehabilitation is usually a realistic and achievable activity and includes works and measures that significantly improve the ecological conditions in the river and bring it closer to the former balanced ecological conditions. It is a very complex, long-lasting, and expensive activity, but it is increasingly treated as inevitable, in order to avoid negative environmental, social, and even political consequences. However, already performed rehabilitation works in a number of metropolises around the world show that such works have economic and developmental significance, while sociological and political significance is undoubted, [8]. Rehabilitation indicates a process that can be defined as a partial functional and/or structural return to a former or pre-degradation state, especially in terms of environmental conditions. In conclusion, rehabilitation measures relate only to changes in some elements within the degraded water system but still aim to return the ecosystem closer to its original state.

If the level of degradation of the river ecosystem is so great that the rehabilitation of the system is not feasible, remediation should be approached. Remediation implies such an improvement of ecological conditions, that the river system is translated into a new ecosystem, in another space of ecological conditions, but with a much better status than the anthropogenically degraded river system. The remediation process often has to be done on rivers that are in urban conditions, when a radically canalized and ecologically destroyed and dead river need to be made attractive to people again, which beautifies the city and enriches it, but with some other ecological conditions compared to the original, [8].

3.1 Watercourse Recovery Measures

New approaches and solutions seek to accelerate positive natural processes and the use of artificial interventions in a way that functions as natural. In this sense, two significantly different approaches and the corresponding methods of recovery of open watercourses have been crystallized, called: (1) Passive measures; (2) Active measures.

Passive measures include recovery approaches and methods that seek to stimulate processes in the watercourse that will themselves help its recovery. These are interventions that make small changes in the watercourse and which are therefore slower. These include environmental engineering.

Active measures include approaches and methods of restoration that are mostly classical engineering but that carefully take into account the environmental effects. The simplest example of the difference between passive and active watercourse recovery measures can be given by showing the different protections of the banks of open watercourses. Passive measures include any kind of encouragement of the growth of natural vegetation, while active measures include the installation of stone embankments, the construction of coastal fortifications, the installation of geotextiles, or other types of artificial protection. In practice, passive and active measures are often combined and such approaches often give the best results.

Passive Watercourse Recovery Measures.

Passive measures are divided into the following two groups: (1) Restoration of natural flora and fauna; (2) Removal of unnatural species. Gordon et al. [10], believe that the biggest disadvantage of passive measures lies in the fact that in this way the open watercourse is slowly restored, and the processes last between 10 and 100 years, which is often unacceptable for practical reasons. They advocate the application of the principle of eliminating sources that create problems, control of the spread of harmful plant and animal species, and the application of preventive measures. As a very educational example, Erskine and Webb [11], report on the negative consequences of open water management measures in southeastern Australia, which were applied in the period from 1886 to 1995. It was a mass felling of coastal vegetation and cleaning of leafy and wood waste from riverbeds and shores. These measures were implemented in accordance with applicable laws and were funded by the state.

The consequences they have caused are many times negative. Increased water flow velocities have caused a strong deepening of the riverbed, destabilizing the shores, widening the open watercourses, and massive loss of fish habitats. These negative consequences have indicated the need to implement different measures that will take joint care of land and water resources management, in order to protect the environment, and in particular to support biodiversity. Erskine and Webb [11], therefore propose that the introduction of massive leafy and wood waste into riverbeds and shores be introduced as a measure to rebuild open watercourses in South East Australia. The basic problem for the efficient execution of this task is the lack of sources of the mentioned waste. If this work were left to nature itself, i.e., if only passive measures were strictly applied, they estimate that the restoration process would take more than 100 years.

Coastal vegetation has a multiple role in the ecosystem of open watercourses. It helps stabilize shores, regulate nutrients, filter sediment, create shade, represents areas where birds nest, and also serves as a hiding place for larger animals. The vegetation cover has a mitigating effect on the water temperature in open watercourses. It prevents it from warming up in summer and reduces cooling in winter, [10]. Measurements have shown that coastal ice is formed on sections of watercourses that are not covered by vegetation and that watercourses that do not have coastal vegetation dry out longer and more often than watercourses along whose shores dense vegetation grows. Coastal vegetation seems to influence the open watercourse to act as an accumulation, i.e., to retain runoff and slowly release it downstream.

The biggest advantage of vegetation over artificial engineering materials such as steel and concrete is the possession of self-regenerating properties. Thanks to this property, coastal vegetation recovers very quickly, within a few years, after decay caused by natural or anthropogenic factors. It is a process that costs nothing and can be supported and accelerated by human-led measures.

The new trend of open watercourse management is aimed at supporting a stable and self-sustaining natural vegetation cover. It is recommended to use domestic species, wherever possible. Of particular importance is the role of vegetation as a habitat and shelter for wildlife, birds, fish, invertebrates, etc. Vegetation must be carefully selected, considering the speed and properties of its growth, its shape and aesthetic values, its endangerment, etc. planning the process of vegetation restoration along watercourses, special attention must be paid to different sections of watercourses, but also to different cross-sectional zones related to hydrological and hydraulic properties of water flow. Cultivation of exotic plant species is not recommended. When artificially growing coastal vegetation, care should be taken not to use measures and procedures that could harm other parts of the ecosystem. This primarily refers to the application of herbicides and fertilizers that can harm other plant and animal species.

As a frequent passive measure, artificial reed cultivation is carried out, which aims to increase the value of habitats by increasing nutrient production, creating protection for fish and shadows on the water face. If the reed is grown in slow-flowing zones on the inner sides of the curves, in parts of the riverbed that are sinusoidal, the reed will act as a deflector, i.e., it will divert water. It will affect the narrowing of the riverbed in low waters, locally increase flow rates creating natural meanders and other diverse forms of bottom suitable as habitats for fish development in different parts of their life cycle. Reeds will help stop fine sediments at the edges of the riverbed, thus reducing the need to clean them. Reeds cannot survive in water deeper than 50 cm for a long period of time. Its development requires water speeds of less than 0.2 m/s because higher speeds can erode its root system. In the case when the watercourse has steep banks, and it is desired to grow reeds on them, it is necessary to reshape them, i.e., to soften them.

A special problem with the cultivation of coastal vegetation occurs because it can increase the risk of floods, which should be taken into account, not only for technical but also for some other reasons. Also, care should be taken that dense vegetation, even in the coastal area during dry periods, can be endangered by forest fires. In order to reduce the risk of fire, it is necessary to take the same measures of cultivation and cleaning of coastal vegetation as in the continental forests. The health of the coastal ecosystem depends not only on a plant but also on animal species that live in that area. There are ways to speed up the process of restoring animal species in the coastal area. To perform this task, it is necessary to know the usual or optimal density of individuals of a particular animal species in an area.

Re-colonization of invertebrates is the fastest, provided that there is a favorable substrate in the space with enough nutrients. For some species whose migration abilities are limited, larval sowing procedures have been developed. There are numerous and rich experiences with the restocking of watercourses, which have pointed out the importance of rivalry between species and the important role of predatory fish in the ecosystem of open watercourses. Gordon et al. [10], believe that a number of realistic options should be assessed in the planning phase of water management projects. Criteria for choosing the best must be found considering the price, efficiency, and environmental impact. The use of passive measures reduces the need for later work on system rehabilitation. Planning must be linked to different space valuations.

Some less, valuable ones, such as car parks and gardens, can be used as retentions during floods, while others need to be protected by expensive and safe measures. In watercourses where large-scale regulatory works are inevitably carried out in order to protect against floods and ensure the navigation, measures should be taken to mitigate the negative effects on the environment as much as possible. In this sense, passive measures have proven to be more effective, long-lasting, and cheaper than active ones. The main disadvantage in relation to active measures is their slowness. Therefore, engineers, but also politicians are more inclined to take active measures because they give the impression that something significant and safe has been done and that the problem is definitely solved.

Compared to passive measures, active measures to rehabilitate open watercourses are more direct, but also often more expensive. The purpose of changing the shape of the open watercourses and the construction of buildings in the riverbed is to restore the number and diversity of physical habitats, which were degraded by previous works. Meanders, lakes, furrows, islands, false riverbeds, coastal vegetation, fish shelters, diverters, etc. contribute to biodiversity by creating numerous and diverse physical habitats in open watercourses, increasing water turbulence in places and reducing their speed in places, creating sections of eroding riverbeds and parts where sediment and nutrients are deposited, shading shaded and sunny areas of watercourses, etc.

4 Recovery Monitoring

Successful recovery of watercourses is almost impossible without well-planned and performed monitoring. The process of collecting qualitative or quantitative data, using predetermined indicators of process progress, is monitoring recovery. It is important to note that monitoring should be planned at the time of preparation of the recovery project when it should actually begin with it. As the effects of the implemented measures, on the selected section of the watercourse or catchment, are measurable even in the years after the performed activities, the recovery process is not considered completed after the recovery project has been performed.

Monitoring during the implementation phase of the recovery process provides all necessary information on the course of the recovery process and is performed primarily to ensure proper implementation of recovery plans, while actual monitoring of the successful recovery plan is performed later, after the implementation of the planned recovery activities. In this sense, the monitoring carried out after the activities carried out on the recovery of watercourses is extremely important, in order to assess the effectiveness of the implemented measures. Hadžić & Bonacci [1], believe that monitoring can provide invaluable knowledge that will lead to improved recovery practices, including identifying approaches that have not been successful and why.

The key activities that continuously monitor the monitoring process, and which need to be undertaken to ensure the successful recovery of watercourses, *in addition to monitoring, are the process of evaluation and adaptive management*. These activities are carried out at different levels, depending on the size and scope of the recovery project. Each recovery project is specific due to the diversity of the watercourse itself, due to different recovery objectives, and therefore there is no single template that would indicate which approach to developing a monitoring plan or which approach to the evaluation should be applied. They must be developed together with the watercourse recovery project, considering the physical, environmental, and socio-economic specifics.

The evaluation describes a process in which, based on the analysis of monitoring data, recovery progress is assessed and adaptive management options are considered. Adaptive management also reflects the need for flexibility in meeting/failing to meet set goals or their continuous adjustment, and in relation to the results achieved, through monitoring and evaluation. It is formally described in the literature as a structured, iterative decision-making process, with the aim of reducing the uncertainty of recovery success, certainly with the help of continuous monitoring, [6].

Although monitoring and evaluation of watercourse recovery and adaptive management are common in science, practice, and business, they are most often not adequately planned through watercourse recovery and are ultimately implemented inadequately. Thus, for example, there are very few documented examples of good adaptive management in recovery projects. The costs associated with the poorly designed recovery and monitoring programs are significant, both in terms of potentially negative impacts on the ecosystem and society, and in terms of the once unnecessary loss of financial resources.

4.1 The Role of Monitoring in the Recovery Process

As already pointed out, as part of the process of recovery of watercourses, monitoring is performed before and after the implementation of recovery measures, and certainly during their implementation. Each of the mentioned types of monitoring is equally important for achieving success in the recovery process, and for gaining new knowledge in order to improve existing approaches, but also the results of recovery. Monitoring should provide all the necessary information on the course of the recovery process. Evaluation of the recovery process as well as adaptive management are directly related to monitoring. Using the information obtained from the evaluation of the monitoring process, it is possible to assess the effectiveness of the steps taken in the recovery process, i.e., implemented measures and activities, in order to achieve the goals and objectives of recovery and to avoid future mistakes.

Even with the best recovery projects and their implementation, monitoring will often result in the identification of some unforeseen problems and require corrections either during or immediately after the implementation of certain measures, [7]. Thus, most of the measures and activities carried out in the process of recovery of watercourses, require some supervision of the implementation of activities through monitoring, while adaptive management. Namely, very often, due to different outcomes in relation to the planned outcomes of the recovery process, it is necessary to make management decisions regarding the continuation of the recovery process, but in the light of new knowledge. Due to the complexity and variability of watercourses, recovery measures can generally be viewed as experiments, most often with an uncertain outcome. Since each watercourse is specific, so is each recovery project or program, and therefore the monitoring plan is completely specific.

A good monitoring plan should strive to be accessible, adaptable, transparent, interdisciplinary, scientifically reliable, responsible, and realistic. Among other things, they should (yes) answer a number of questions, including the choice of parameters to be monitored, how this monitoring is carried out, who is responsible for undertaking monitoring, how often measurements need to be carried out, and in what period, as well as a number of others. Issues which will be discussed in more detail below. Developing an effective monitoring plan requires consideration of many issues, including those related to scientific, logistical, and financial aspects, as well as the specific objectives of watercourse recovery. Also, a good monitoring plan will enable continuous monitoring in achieving the recovery goals and will enable the improvement of planned measures and activities if the results of monitoring and evaluation show it.

According to the FISRWG [12], the monitoring plan should provide answers to important and specific questions related to the recovery of watercourses:

1. What was the condition of the watercourse at the beginning of the recovery process (so-called baseline monitoring)?
2. Has the recovery been done entirely according to the project (so-called monitoring of activities or implementation of recovery activities)?
3. Are the recovery costs well planned or are the planned amounts exceeded (so-called financial monitoring or monitoring costs)?
4. Were they performed river repair activities successful in terms of meeting realistic project objectives (e.g., restoration of ecosystem functions and services and consequent environmental or socio-economic outcomes, in relation to the stated project objectives) (so-called monitoring of achievement of objectives)?
5. What else is happening in the watercourse that was not known at the beginning of the recovery process planning (so-called supervisory monitoring)?

In Table 1. The development of a monitoring plan as part of the watercourse recovery process is presented.

Table 1. Development of a monitoring plan, according to The Federal Interagency Stream Restoration Working Group-FISRWG, [12].

A. Planning	
Step 1	**Defining goals and tasks of watercourse recovery**
Step 2	**Development of a conceptual model**
Step 3	**Selection of criteria for performance evaluation:**
	▪ Relationship between performance and goals
	▪ Criteria development
	▪ Determining reference locations
Step 4	**Selection of parameters and monitoring methods:**
	▪ Selection of efficient parameters and monitoring methods
	▪ Overview of activities within the catchment area
	▪ Selection of methods and techniques required for testing and sampling
	▪ Conducting sociological research
	▪ Reliance on "instream" organisms to evaluate the success of projects
	▪ Minimize unnecessary measurements
	▪ Insert subsequent parameters
Step 5	**Cost estimate:**
	▪ Costs of the monitoring plan itself
	▪ Quality assurance
	▪ Data management
	▪ Field research
	▪ Laboratory research
	▪ Data analysis and interpretation report preparation
	▪ Presentation of results
Step 6	**Categorization of data types**
Step 7	**Determining the level and duration of monitoring:**
	▪ Involvement of landscape ecology
	▪ Determination of sampling time, frequency, and duration
	▪ Development of a statistical framework for data analysis
	▪ Sampling level selection

B. Implementation and management
▪ Existence of a vision for the duration of the monitoring plan
▪ Roles and responsibilities must be clearly defined
▪ Quality assessment procedures must be adopted
▪ Clear interpretation of results
▪ Data management
▪ Providing contacts

C. Responsibility for monitoring results
▪ No action
▪ Maintenance
▪ Add, abandon, or modify plan elements
▪ Modification of project objectives
▪ Adaptive control
▪ Documentation and reporting
▪ Dissemination of results

5 Concluding Remarks

Experiences gained through implemented watercourse recovery projects have shown that insufficient attention has been paid to monitoring and evaluation of ecological and ecosystem indicators of watercourse recovery. Although progress in the implementation of monitoring has generally been observed in the last decade, it can be concluded that there has been no progress in monitoring and evaluating the socio-economic performance indicators of the already implemented recovery measures.

Obstacles to effective monitoring and evaluation are, according to Speed et al. [7], most often occur as a consequence of:

(i) Insufficiently defined, unclear and immeasurable goals to be achieved by recovery, and thus inadequate recovery projects.

(ii) Ignorance of the river system as a whole, its complexity, and inability to accurately predict the consequences, which makes it difficult to distinguish the results of applied recovery measures from changes in river systems. Morandi et al. [13], argue that for many projects, monitoring and evaluation have been more affected by the nature and severity of the recovery institution than by actual changes due to the application of recovery measures.

(iii) Lack of technical and scientific pragmatism in defining appropriate indicators and measurements, and collecting insufficiently clear, comprehensive, and valid data. Namely, Ayres et al. [15], believe that very often recovery monitoring provides a wealth of useful but also unusable information on ecosystem services.

Even when considering the impact of recovery on the ecological status of watercourses, monitoring generally focuses on physical changes in biotopes or biocenoses, not considering the impact on the wider area and even the entire basin, as well as the impact on watercourse health. Monitoring results are thus limited to individual projects or case studies, which do not necessarily reflect a wider basin or region. Moreover, monitoring different physical, biological, and socioeconomic variables can provide conflicting results, which call into question the success of the recovery process.

(iv) The need to monitor recovery outcomes at various time intervals, including monitoring before and after recovery activities. Feld et al. 15], believe that, in order to understand the function of aquatic ecosystems, monitoring should begin, not one year as was the practice, but several years before the start of watercourse recovery activities. According to Morandi et al. [13], post-recovery monitoring is rarely extended by more than 10 years, which can often be insufficient. It is also worth mentioning that monitoring the results of the recovery process should be monitored in the long term, as most monitoring ends after a few years, which according to Feld et al. [14], considers insufficient.

(v) Lack of money for monitoring and evaluation. Namely, it is certain that insufficient attention is paid to the planning of financial resources for monitoring and evaluation during the recovery process of watercourses, especially when it comes to smaller projects.

The lack of monitoring makes it difficult, not only to assess progress in achieving the goals of the recovery project but also to make appropriate management decisions to maximize progress. Moore and Michael [16], believe that even when monitoring is sufficient, a lack of expert analysis and evaluation of the data collected can also reduce the effectiveness of adaptive management. Although adaptive management has a very long history of application, and although it has proven to be an extremely important tool in achieving goals, its application is rather limited. When planning a recovery, most often only the theoretical possibility is left, which allows adaptive management to change the priorities and tasks in the recovery process. Consequently, recovery projects rarely allow for practical modification of management, based on monitoring of the information obtained.

Adaptive management should not be considered only as "adaptation management", but as a way of testing hypotheses identified at the beginning of planning through the recovery process, which can be considered as an experiment to test initial hypotheses. We can say that the key challenge in using an adaptive approach to management is to find the right balance between knowledge gained in the past, achieving the best results based on current knowledge, and acquiring new knowledge during the recovery process to improve future management.

Adaptive management involves adjusting the direction of management as new information becomes available during the recovery process that was often not planned at the very beginning of the process (Fig. 2). It is certain that such an approach requires a willingness to experiment, with uncertain results, and acceptance of occasional failures, which should be a lesson for future processes.

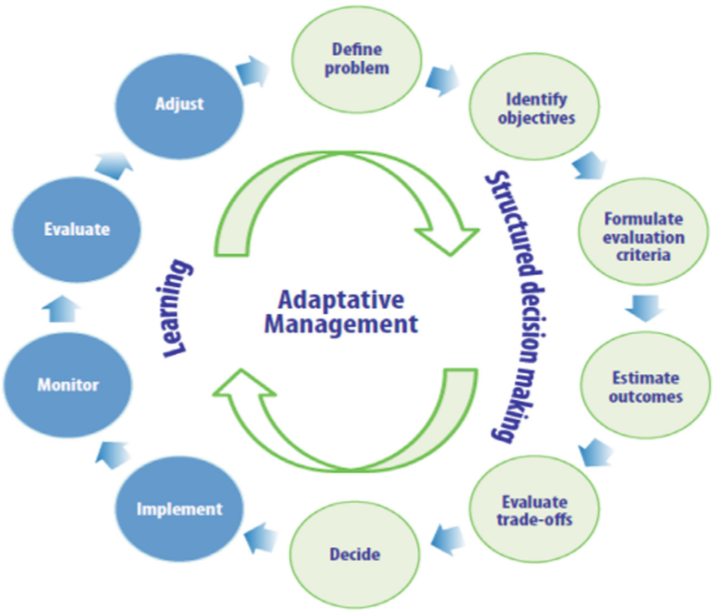

Fig. 2. Adaptive taking t, characterized as "learning by doing", [7].

The most common reasons why adaptive management is not implemented effectively can be sublimated as: excessive reliability in recovery results; unwillingness to stop unproductive activities because they are reluctant to give up efforts in which a lot of time and energy has been invested; lack of effective monitoring, scientific and substantial evaluation of the process. Projects often continue tasks and working elements, even when monitoring results indicate that recovery goals cannot be achieved.

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