Study on Restoration Design of River Water Ecosystem in the New Period

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Abstract. All focusing on the thinking of water management in the new period, the STS model of river ecosystem restoration design is established, and the spiral development model of water ecosystem restoration is proposed. The role of science, technology and society in the restoration process and the relationship among them are systematically elaborated. The key procedures of each element operation are summarized under the framework of the model. It provides a reference for river ecosystem restoration in the new period.

1. Introduction
Rivers are an important way of water circulation on the earth, and they play an important role in the transfer and transportation of materials and energy around the world. In order to solve the problem that the integrity of river ecosystem structure and function is destroyed, it is necessary to accelerate the pace of river ecosystem protection and restoration.

In the new period of promoting the construction of ecological civilization in China to a new level, this paper, based on the restoration idea of "scientific guidance, technical support and social supervision", builds STS (Science-Technology-Society) model, and systematically sorts out the key procedures of three elements (Science, Technology and Society), which is of great significance to restore and promote the harmonious coexistence of various elements of river ecosystem.

2. Design model of river ecosystem restoration

2.1. Model connotation
Based on the consideration of river ecosystem restoration design in the new period, the STS model of river ecosystem restoration design based on process is established. The three-dimensional model can be simplified into two parts: horizontal "wheel" diagram and vertical spiral development diagram (as shown in Figure 1). The corresponding meanings of symbols in STS model are shown in Table 1. Using the method of system theory, the model comprehensively considers the scientific, technical and social factors related to river ecosystem restoration.
Table 1. Meanings of symbols in STS model.

| Symbol | Representative content                                      |
|--------|------------------------------------------------------------|
| ①     | Evaluation of river water ecological status               |
| ②     | Identify key degradation factors                           |
| ③     | Determine the base point and target of ecological restoration |
| ④     | Formulate ecological restoration plan                     |
| ⑤     | Implementation of ecological restoration measures          |
| ⑥     | Repair effect monitoring                                  |
| ⑦     | River suitability management                              |
| ⑧     | Post project evaluation and technology promotion           |
| L      | Legal system                                               |
| S      | System of organization                                    |
| M      | Mechanism                                                  |
| R      | "Wheel" radius (larger R, longer repair time)              |
| 10~50  | Indication length                                         |
| t      | Time axis                                                  |

The "wheel" diagram describes the elements involved in the process of ecological restoration and the levels of each element, which are divided into three layers. The innermost layer is the scientific layer; the middle layer is the technical layer, including the restoration design link ①~⑧; the outermost layer is the social layer, including three kinds of social supervision modes; the link ①~⑧ in the spiral development chart of aquatic ecosystem restoration is a cycle. At the end of each restoration cycle, the deviation in the restoration process should be analyzed according to the synchronous monitoring data. The next restoration cycle should be planned through the feedback mechanism of negative feedback, and the spiral development chart of water ecosystem restoration was formed. On the whole, the period of artificial intervention and restoration will be longer and longer (indicated length: 10 → 20 → 30 → 40 → 50). Under the continuous artificial intervention, the whole river ecosystem restoration process should change to the natural and self-sustaining state, until it is separated from the artificial intervention and truly restored to the natural state.

2.2. The relationship among the three elements of the model

The three elements of science, technology and society in the model are at different levels of "wheel", representing different roles and importance in the process of river ecosystem restoration. The impact of the relationship between science, technology and society (STS) on river ecological restoration is shown in Figure 2.
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Figure 2. Impact of the relationship between science, technology and Society on river ecological restoration.

Science is the core layer of river ecosystem restoration. The interdisciplinary knowledge can promote the development of remediation technology and ensure the comprehensive restoration of water ecosystem in the restoration process. In the long run, if the public lacks scientific ideas, the chances of successful restoration projects will be very low.

Technology is the backbone of river ecosystem restoration. Due to the complexity and uncertainty of river ecosystem restoration, it is necessary to strengthen the scientific and technological content in the whole restoration process.

Society is the outermost layer of river ecosystem restoration, which acts as a catalyst. From the social point of view, the adaptive change of social supervision mode accelerates the speed of river water ecosystem restoration, makes the whole restoration process have laws and regulations to follow, and greatly strengthens the sustainability of project restoration.

In each restoration cycle, scientific guidance, technical support and social supervision are needed to make the "wheel" of restoration turn faster and make the river ecosystem recover better.

3. Key procedures of river ecosystem restoration design

3.1. Science: core level
In the process of river ecosystem restoration, without science, technology will have no source and drive for development. [1] In the process of ecological restoration, according to the phenomenon of ecosystem degradation, the causes of ecosystem degradation are explored; the existing knowledge base is used to explore the methods to solve the degradation problem, and the restoration theory is innovated; the innovation knowledge is verified by experiments and numerical simulation, and the feasibility of the innovation theory is confirmed; incorporate the verified new knowledge into the theoretical knowledge system, and merge the new and old knowledge; guide innovative restoration technologies according to the needs of ecosystem restoration; while using new technology to solve problems, there will be new problems in the field of river ecological restoration, and then enter a new cycle. The design idea of scientific layer is shown in Figure 3.
3.2. Technology: backbone layer

In the whole process of water ecosystem restoration, the technical layer can be divided into three stages: planning stage before restoration (①, ②, ③, ④), control stage during restoration (⑤), and monitoring management stage after restoration (⑥, ⑦, ⑧). The design idea of technical layer is shown in Figure 4.
3.2.1. Evaluation of river ecological status. Data collection and analysis play an important role in the assessment of ecological status and even in the whole restoration plan. [2] Two preparations should be made for data collection: confirming the data requirements at the technical and institutional levels, and preparing appropriate data acquisition equipment.

3.2.2. Identify key degradation factors. According to the evaluation results of ecological status, the approximate range of factors affecting river ecosystem degradation is determined, and the sensitivity of factors to the impact of system degradation is analyzed. Then, the key factors that promote ecosystem degradation are identified based on the field investigation results, so as to strengthen the supervision of key factors or control factors in the process of restoration planning and implementation, and ensure the smooth implementation of the restoration project.

3.2.3. Determine the base point and target of ecological restoration. The basic point of ecological restoration is the reference point of ecological restoration, and the restoration goal is the expected point of ecological restoration. In general, the determination of the base point is based on the healthy natural state of the river without human interference or less interference. Different restoration bases should be selected in different restoration levels (hydrological situation, connectivity, water quality, etc) and in different restoration spaces (upstream, midstream, and downstream). [3] The objectives of river ecological restoration mainly include strengthening the rhythm and connectivity of hydrological situation, improving water quality, stabilizing riparian zone, increasing habitat, and rich biodiversity, etc.

3.2.4. Formulate ecological restoration plan. Ecological restoration should be carried out in accordance with the principle of "unified planning, phased layout and gradual progress". In order to determine the best restoration strategy and resource allocation plan, priority selection model should be carried out based on the assessment results of ecological status and identification of key factors of ecological degradation.

3.2.5. Implementation of ecological restoration measures. The implementation of ecological restoration measures is an important guarantee for the implementation of river ecological restoration planning. From the aspect of specific ecological restoration measures, the ecological damaged rivers mainly include the following technical measures: ① water quality purification and improvement measures, including physical, chemical and biological aspects; ② ecological water resources regulation measures; ③ natural transformation measures of riparian wetland; ④ quasi naturalization measures of river structure; ⑤ fish passing facilities. [4]

3.2.6. Repair effect monitoring. Ecosystem monitoring is divided into synchronous monitoring of project implementation process and post project monitoring. The synchronous monitoring during the implementation of the project mainly affects the ecosystem during the implementation of the restoration measures, and the post project monitoring is aimed at the monitoring of the restoration effect of the ecosystem after the completion of the restoration project. The main monitoring contents include hydrological monitoring, water quality monitoring, biological monitoring and human interference monitoring.

3.2.7. River suitability management. In the process of river ecological restoration, it is difficult to achieve the goal of restoration in a short time by artificial restoration measures. Therefore, in order to achieve the expected restoration effect, it is necessary to follow the natural law of the ecosystem, establish a circular negative feedback regulation mechanism through adaptive management, and gradually narrow the gap between the river ecological status and the healthy natural state, so as to make the ecosystem stable and better. [5]
3.2.8. **Post project evaluation and technology promotion.** This link is mainly to carry out systematic and objective analysis on the implementation process, benefit, function and impact of the completed restoration project. Through the inspection and summary of the actual effect of the repair project, determine whether the expected goal of the project is achieved, whether the project or planning is effective, summarize experience and training, and prepare for technical improvement.

3.3. **Society: catalyst**

The social supervision of river water ecosystem should take the problems in the process of ecological restoration as the guidance, take the improvement of the restoration effect as the goal, strictly accountability for the behaviors violating the rules and regulations, and establish a set of efficient supervision system. From the legal point of view, we should establish and improve the laws and regulations, departmental rules, standards and specifications, implementation measures and other systems of water conservancy supervision, and clarify the supervision content, supervision personnel, supervision methods, supervision responsibilities and disposal measures in the process of water ecosystem restoration and maintenance. In terms of system of organization, we should make clear the responsible organization and staffing of supervision, and establish a supervision team with unified leadership, comprehensive coverage, hierarchical responsibility and coordination. In terms of mechanism, internal operation rules and regulations should be established to ensure that the supervision team can conscientiously perform their duties and carry out their work smoothly. [6] The design idea of social layer is shown in Figure 5.

![Design ideas of social layer.](image)

**Figure 5.** Design ideas of social layer.

4. **Conclusion and Prospect**

The most fundamental problem of river ecosystem restoration is not only the problem of human beings, but also the problem of restoration ideas. Under the idea of river ecosystem restoration in the new era, we will focus on the overall situation, start from the basin scale, take the whole river water ecosystem as the research object, and carry out the restoration work according to the idea of "artificial intervention in the initial stage, and gradually self-healing in the later stage".

The change of thinking about the restoration of river water ecosystems has increased the possibility of successful restoration. However, in order to achieve better restoration effects, the following research still needs to be carried out in the future development:

1. The ecological restoration of aquatic ecosystems should strengthen the integration of multiple disciplines and technologies, and optimize the configuration. There is a great deal of complexity and uncertainty in the whole restoration project. Therefore, it is necessary to strengthen the integration of multiple disciplines and technologies, and achieve the best effect by optimizing the configuration.

2. The determination of spiral advance period of aquatic ecosystem. In order to achieve the self-sustaining state of water ecosystem, it needs several spiral propulsion cycles. How to select the appropriate cycle should be determined by combining with the monitoring data of remediation effect and remediation experience. For rivers in different regions, corresponding standards should be established to facilitate the promotion of restoration work.
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