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Research on Landscape Regeneration Strategy of Abandoned Mines Based on Ecological Restoration: A Case Study of Jurong in Zhenjiang, China

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Abstract

With the long-term development of mineral resources, a large number of abandoned mines are facing problems such as terrain damage, vegetation degradation, hydrological changes, and declining land use functions. This article takes the abandoned mine of Gaolishan in Biancheng Town, Jurong City, Zhenjiang City, Jiangsu Province as the research object, and explores the landscape regeneration strategy of abandoned mines from the perspective of ecological restoration.

The research adopts methods such as literature analysis, case comparison, field investigation, GIS and remote sensing analysis, and landscape design to construct a research framework of "ecological diagnosis ecological restoration spatial regeneration functional utilization", and combines the terrain, water bodies, vegetation, cultural resources, and usage needs of Gaoli Mountain to analyze the site problems and development potential. On this basis, strategies such as ecological restoration, water and wetland restoration, sustainable landscape, public space, and cultural display are proposed, and an overall spatial structure of "one core, two belts, and multiple nodes" is formed. The strategy transformation is achieved through the design of wetlands, rock wall views, forest trails, public leisure, and geological cultural education.

Research suggests that the regeneration of abandoned mine landscapes should be based on ecological restoration, determining the intensity of protection, restoration, and utilization according to the ecological conditions of the site, and making reasonable use of existing features such as mine water bodies, rock walls, and elevation differences. This article provides some reference for ecological restoration and landscape regeneration of abandoned mines through conceptual landscape design of Gaolishan.

Keywords: abandoned mines; Ecological restoration; Landscape regeneration; Gaoli Mountain; Landscape Design

Introduction

1.1 Research Background and Significance

The development of mineral resources provides an important material foundation for industrial production, infrastructure construction, and regional economic development, but mining activities can also cause sustained disturbance to the original natural environment. Especially in open-pit mining, surface soil stripping, vegetation removal, terrain cutting, and rock exposure often occur, causing changes in the original soil structure, hydrological processes, and biological habitat environment. After the mine stops mining, if there is a lack of systematic management, the site may be in a state of ecological degradation and inefficient utilization for a long time. Cooke and Johnson pointed out that mining restoration should not be limited to surface greening, but should be understood as ecosystem reconstruction, which gradually restores the ability of land to retain water, cycle nutrients, and support the survival of plants and other organisms[1].

With the advancement of ecological civilization construction and ecological restoration of national territory, the management of abandoned mines in China is gradually shifting from geological safety management, land reclamation, and vegetation restoration to comprehensive ecological restoration. A study on abandoned open-pit mines along the Yangtze River in Jiangsu Province shows that different models of mine management have been formed, including ecological engineering, land consolidation, landscape reconstruction, and natural restoration. In actual projects, appropriate restoration methods need to be selected based on geological environment, degree of ecological degradation, and subsequent land use

requirements[2]. This study has strong regional relevance to the Jiangsu region where this article is located, indicating that there is no completely unified technical path for the restoration of abandoned mines.

At the policy level, there is also a shift from single governance to system repair. In 2021, the General Office of the State Council issued the "Opinions on Encouraging and Supporting Social Capital to Participate in Ecological Protection and Restoration", which clearly put forward the principle of "protection priority, systematic restoration", emphasizing the adherence to natural laws, with natural restoration as the main approach and necessary artificial measures as a supplement, while attaching importance to long-term management and rational utilization after ecological restoration[3]. Therefore, the management of abandoned mines is no longer just an environmental engineering issue, but also involves multiple aspects such as ecological protection, land reuse, public space, and long-term operation.

From the perspective of landscape design, abandoned mines have the characteristics of ecological problems and coexistence of landscape resources. The height difference, exposed rock walls, water accumulation areas, and special landforms formed by mining may bring safety and ecological limitations, but these characteristics also constitute site conditions that are difficult to replicate in ordinary urban green spaces. Therefore, the regeneration of mine landscape should not simply eliminate mining traces through large-scale landfilling or artificial greening, but should first restore basic ecological functions, and then organize recreational, ecological education, cultural display and other functions according to the carrying capacity of the site. The relationship between mining disturbance,

ecological restoration, and subsequent landscape regeneration is summarized in Appendix A (Figure A1).

This study selects the abandoned Gaolishan mine in Biancheng Town, Jurong City, Zhenjiang City, Jiangsu Province as a case study to explore its landscape regeneration methods based on ecological restoration. The research significance is mainly reflected in three aspects: firstly, coordinating soil, water, vegetation, and habitat restoration at the ecological level; Secondly, exploring the rational reuse of abandoned mining sites at the spatial level; The third is to form a landscape regeneration method that can be used as a reference for similar open-pit mines through specific design at the practical level.

1.2 Research Objectives and Research Questions

The overall purpose of this study is to construct a landscape regeneration strategy suitable for abandoned mines in Gaolishan based on ecological restoration, and explore the coordinated relationship between ecological restoration, spatial reuse, public functions, and site culture through specific design.

The research mainly includes four objectives.

Firstly, identify the main ecological and spatial issues faced by abandoned mines and the Gaolishan site, with a focus on terrain, soil, water bodies, vegetation, and habitat conditions.

Secondly, sort out the relevant theories of ecological restoration, sustainable development, and post mining land reuse, and establish the connection between ecological restoration and landscape design.

Thirdly, by comparing domestic and international cases with the analysis of the Gaolishan site, targeted ecological restoration and spatial utilization strategies are proposed.

Fourthly, translate the above strategies into specific design contents such as overall planning, ecological wetlands, trails and viewing spaces, plant configuration, cultural exhibitions, and public activity spaces.

1.3 Current Research Status at Home and Abroad

Early research on ecological restoration of domestic mines mainly focused on technical directions such as land reclamation, soil improvement, vegetation restoration, and plant restoration. After a systematic review of ecological restoration research on abandoned mining sites in China, Li pointed out that land degradation, soil erosion, and related ecological problems caused by mining activities have promoted the development of research on mining area restoration in China. However, early practices generally focused more on specific restoration techniques and vegetation reconstruction[4]. In recent years, related research has gradually expanded towards landscape reconstruction, ecosystem services, land reuse, and regional comprehensive governance.

Research on the restoration of mining areas abroad places greater emphasis on the process and long-term evaluation of ecosystem restoration. The international principles for ecological restoration of mines proposed by Young et al. emphasize that restoration goals should be determined based on the ecological conditions of the site, and reference ecosystems, stakeholder participation, ecological process restoration, and monitoring and evaluation should be included in the entire process

of mine restoration[5]. This indicates that modern mine ecological restoration has gradually shifted from simple land reclamation to comprehensive management of ecosystem functions and long-term recovery trajectories.

In terms of post mining land use, research has also begun to focus on the coordination between ecological restoration and socio-economic functions. Worlanyo and Li's review suggests that post mining land can be transformed into ecological protection, forest land, agriculture, leisure and entertainment, or other uses according to different natural conditions and social needs, but land use must comprehensively consider environmental conditions, safety, economic feasibility, and social needs[6]. Therefore, the focus of current research has gradually expanded from "how to repair" to "how to use it reasonably after repair".

Overall, there have been abundant theoretical and practical achievements in the ecological restoration of mines both domestically and internationally, but there is still some room for transformation between ecological restoration technologies and specific landscape spaces. Especially in abandoned mine projects, how to determine spatial development intensity based on ecological sensitivity and further coordinate ecological restoration, public activities, and site culture is a key issue that landscape design research needs to address. This article will focus on the spatial transformation from ecological restoration principles to landscape regeneration strategies.

1.4 Research Methods and Technical Roadmap

This study mainly adopts five research methods.

Literature research method. By reviewing relevant research on mine

ecological restoration, landscape regeneration, and land reuse both domestically and internationally, establish the theoretical foundation for the paper.

Case comparison method. Select representative domestic and foreign mining restoration cases, compare them from ecological issues, restoration measures, space utilization, and later functions, and extract design methods that can be used as references for Gaolishan.

Field research method. Conduct on-site surveys, photographic records, and spatial observations to investigate the terrain, water bodies, vegetation, transportation, surrounding environment, and actual usage of the Gaolishan mine pit. For issues such as water pollution and soil pollution that cannot be determined through on-site observation, no definitive conclusions without testing basis shall be drawn.

GIS and remote sensing analysis methods. Combining satellite imagery and spatial data to analyze the terrain, slope, vegetation, water bodies, and surrounding land relationships of the mine pit, providing a basis for ecological sensitivity assessment and spatial planning.

Landscape Design Law. Translate theoretical research, case experience, and site analysis into design content such as overall layout, ecological restoration, wetlands, trails, viewing spaces, plant configuration, and cultural exhibitions. Based on the above research methods, the overall technical route of this study is presented in Appendix A (Figure A2).

Theoretical Basis for Ecological Restoration and Landscape Regeneration of

Abandoned Mines

2.1 Ecological degradation characteristics of abandoned mines

Open pit mining usually requires topsoil stripping, vegetation removal, and rock excavation, resulting in significant changes to the original soil structure and surface morphology. Bradshaw believes that during the mining process, the native soil may be removed, buried, or severely disturbed, resulting in a decrease in organic matter and nutrient cycling ability. Plant replanting and subsequent natural succession are important processes that promote the gradual recovery of soil function in mining areas[7]. Therefore, ecological restoration of mining pits first needs to focus on substrate stability and plant growth conditions, rather than simply achieving short-term greening effects through surface soil cover.

There are significant differences in the properties of soil and waste matrix in different mining areas. After reviewing the research on plant remediation of mine tailings, Wang et al. found that some tailings substrates may have characteristics such as low organic matter content, insufficient water holding capacity, high salt content, and potential metal pollution, which can limit natural plant colonization[8]. Therefore, in specific projects, improvement measures and plant species should be selected based on on-site soil or substrate testing results to avoid directly applying pollution characteristics from other mines to the research site.

Mining will also alter the original water collection and drainage processes on the site. After the formation of the mine, precipitation may gather in low-lying areas and form new mine water bodies. Some mining areas may also experience acidic mine drainage under specific geological and hydrochemical conditions. Pat

Espadas et al. found that for sites with confirmed acidic mine drainage, artificial wetlands can participate in water quality improvement through sedimentation, substrate action, plant and microbial processes[9]. But the application of this technology must be based on water quality testing, so this article will not only judge the pollution type based on the color or appearance of the water in the Gaolishan mine.

In addition to soil and water bodies, vegetation removal and surface disturbance caused by mining can also alter the habitats of animals and plants. Sonter et al. pointed out that mining activities have multiple pathways of impact on biodiversity and may extend beyond actual mining boundaries. Therefore, mine protection and restoration should not only focus on the interior of the mine, but also consider the surrounding habitats and their spatial connections[10]. Based on the above analysis, the main ecological degradation processes of abandoned mines and their interactions are summarized in Appendix A (Figure A3).

2.2 Ecological Restoration Theory

Ecological restoration emphasizes the auxiliary restoration of degraded, damaged, or destroyed ecosystems. Its focus is not on creating an environment that looks similar to nature, but on promoting the ecological process of rebuilding the structure, function, and sustainable development of the ecosystem.

The International Principles and Standards for Ecological Restoration Practice proposed by Gann et al. emphasize that ecological restoration should have clear ecological goals and comprehensively consider the reference ecosystem, stakeholder participation, ecological restoration process, and post monitoring.

Restoration projects need to determine the achievable level of restoration based on the actual degree of damage to the ecosystem, rather than solely evaluating the success of restoration based on short-term landscape effects[11]. This theory suggests that the goal of mine restoration should shift from "increasing green coverage" to long-term improvement of ecological structure and function.

However, mining sites have unique characteristics. Long term mining may result in new terrain, exposed rock walls, artificial water bodies, and soil conditions that are completely different from their original state, so not all mines can be fully restored to their pre mining state. Doley and Audet pointed out that mining disturbances may form new combinations of landforms and ecological environments, and in some sites, restoration goals need to be adjusted based on existing environmental conditions and future ecological development potential[12]. This means that the ecological restoration of mining pits should avoid mechanical replication of so-called 'primitive nature', and should establish a reasonable ecological restoration direction based on the actual site.

From the perspective of landscape design, this theory can be further transformed into varying degrees of spatial intervention. Areas with good vegetation and natural restoration of ecological processes should reduce artificial construction and promote natural succession; In areas where vegetation is damaged but still has a foundation for recovery, auxiliary measures such as soil improvement and restoration of native plants can be adopted; Areas with severe terrain disturbance or safety issues require necessary engineering treatment before ecological restoration. Accordingly, ecological restoration can be understood as a

gradient of intervention ranging from conservation and natural regeneration to assisted restoration and ecological reconstruction; this intervention gradient is illustrated in Appendix A (Figure A4).

2.3 Post mining land restoration and sustainable reuse

Ecological restoration solves the problem of how to restore damaged sites, while post mining land reuse further answers the question of how to use them after restoration. For landscape design research, the two need to form a continuous relationship.

The commonly used concepts in international research, such as restoration, rehabilitation, reclamation, land development, and rejuvenation, are not entirely the same. Kaźmierczak et al. systematically reviewed the terminology of post mining land use and pointed out that reclamation usually emphasizes the restoration of post mining land to a safe and usable state; Rehabilitation emphasizes the restoration of some ecological functions; Restoration is closer to the restoration of ecosystem structure and function; And land development further involves the restoration of land use and spatial functions after completion[13].

For this article, 'landscape regeneration' is not equivalent to pure ecological restoration, nor is it equivalent to commercial development. The basic logic is to re-establish reasonable use functions based on land suitability on the basis of improving the ecological conditions of the site. For example, ecologically sensitive areas can undertake habitat protection and natural restoration functions; Wetlands and ecological education spaces can be formed around the water body of the mine pit when safety conditions permit; Areas that are stable and have good accessibility

can be equipped with pedestrian systems and observation facilities; Representative mining relics can become part of the site's historical memory through moderate protection and display.

Favas et al. proposed in their comprehensive study on the management of abandoned mines that mine restoration should form a continuous process from preliminary environmental investigation, final goal determination, environmental risk analysis, restoration plan formulation to final verification and monitoring, rather than separating different technical measures from each other[14]. This holistic approach has important implications for landscape planning: functional settings must be based on site diagnosis and ecological restoration, rather than first determining tourism or construction functions and then adjusting the ecological environment in reverse.

2.4 Theoretical framework for landscape regeneration based on ecological restoration

Based on the above theory, this article categorizes the regeneration of abandoned mine landscapes into four consecutive levels:

Firstly, ecological diagnosis. Investigate terrain, soil, water bodies, vegetation, and habitat conditions to assess ecological issues, restoration potential, and environmental risks in different regions.

Secondly, ecological restoration. According to the actual degree of damage, natural restoration, auxiliary restoration, and necessary artificial restoration measures will be adopted to gradually restore a stable ecological foundation to the site.

Thirdly, space regeneration. Translate ecological sensitivity, terrain safety, and land suitability into spatial design conditions to determine the intensity of protection and utilization in different areas.

Fourth, importing functions. Set up functions such as recreation, ecological education, sightseeing, and cultural display within the scope of ecological carrying capacity, and realize the transformation of abandoned mining areas from a single production space to a composite public landscape.

The current "Technical Specification for Ecological Restoration of Mines Part 1: General Principles" in China has incorporated ecological restoration of mines into the standardized technical system and formed a series of technical standards based on different types of mines[15]. This indicates that the ecological restoration of mines itself has significant site differences and technical specificity, and subsequent designs cannot simply replicate specific measures from other mining areas. Based on the above theoretical discussion, this study establishes an integrated framework consisting of ecological diagnosis, ecological restoration, spatial regeneration and functional utilization. Monitoring and adaptive management operate as a continuous feedback mechanism throughout the process; the integrated framework is presented in Appendix A (Figure A5).

Comparison of Ecological Restoration and Landscape Regeneration Cases in Abandoned Mining Areas

3.1 Case selection and analysis methods

This study mainly selects cases based on three principles.

The first is the representativeness of ecological restoration. The case requires significant mining disturbance and the implementation of land, vegetation, water or habitat restoration, rather than simply transforming the mine into a commercial or tourist facility.

The second is the relevance of landscape reuse. After restoration, the site should undertake new functions such as ecological protection, public recreation, environmental education, or regional development, so that it can provide reference for landscape design research.

The third is the reliability of the data. The case must have searchable academic research or official materials that can confirm the project background, main measures, and repair effects.

The comparison mainly focuses on four aspects: the original ecological problems, the main restoration measures, the spatial functions after restoration, and the applicable inspirations for Gaoli Mountain.

3.2 Ecological restoration of Pan'an Lake coal mining subsidence area in Xuzhou

Pan'an Lake is located in Jiawang District, Xuzhou City, Jiangsu Province, and is a typical coal mining subsidence area formed by long-term coal mining. The geographic location of Pan’an Lake and its relationship with Jiawang District and Xuzhou City are provided in Appendix A (Figure A6). Underground coal mining has caused some land subsidence and waterlogging, affecting the original agricultural and construction space. As coal resources gradually deplete, the local area has begun to reorganize mining damaged land through land reclamation,

ecological environment restoration, and wetland construction.

Xu et al. used remote sensing images from 2008 and 2017 to study the changes before and after land reclamation in Pan'an Lake. They found that during the restoration process, some coal mining subsidence water bodies were reorganized into artificial wetlands, and the proportion of ecological spaces such as forests, grasslands, and water bodies increased. The regional ecosystem service value also showed an upward trend[16]. The study also pointed out that although the significant expansion of wetland areas has improved ecological services such as water conservation, leisure, and biodiversity, excessive expansion of a single water body may also reduce the diversity of some landscape types. Therefore, the restoration of water bodies in mining areas is not simply about maximizing wetland areas, but requires coordinating the proportions between water bodies, forests, grasslands, and other land types. The changes in major landscape types before and after land reclamation are compared in Appendix A (Figure A7).

The comparison shows that reclamation involved a comprehensive redistribution of water bodies, woodland, grassland and built-up land rather than the isolated expansion of wetland area.

An important characteristic of Pan'an Lake is that it does not completely consider subsidence and waterlogging as a problem that needs to be eliminated, but rather transforms it into wetland landscape resources based on its terrain and hydrological characteristics. In the overall governance, land reclamation, subsidence area management, ecological environment restoration, and wetland landscape construction are combined to gradually form a new landscape structure

based on wetland ecosystems on inefficient land originally affected by mining.

On the basis of ecological restoration, Pan'an Lake has gradually introduced leisure experiences, science popularization exhibitions, and public recreational functions. Li et al.'s study in 2025 showed that the overall social landscape performance of Pan'an Lake National Wetland Park after restoration has reached a good evaluation level, but there is still room for further optimization in terms of waterfront space comfort, accessibility, educational facilities, and the needs of different user groups[17]. This result indicates that after the transformation of the mining area from an ecologically damaged site to a public landscape, subsequent design should not only focus on ecological indicators, but also continuously consider the actual user experience of tourists and local residents.

Recent tracking studies have shown that the governance of Pan'an Lake was not completed in one go, but went through multiple stages such as land management, vegetation restoration, transportation improvement, environmental monitoring, landscape construction, and tourism resource introduction, gradually expanding from simple ecological governance to regional green transformation[18]. At the spatial level, these restoration and public-use objectives are further reflected in the functional zoning of the wetland park, presented in Appendix A (Figure A8).

The zoning illustrates a clear hierarchy from ecological conservation and restoration to environmental education, recreational experience and management services, providing a useful reference for controlling different levels of human intervention.

For Gaolishan, the most valuable reference for Pan'an Lake is not its specific

wetland form, but the idea of "utilizing existing hydrological conditions for adaptive restoration". Gaolishan also has obvious mine water accumulation, so in the design, the safety, hydrological conditions, and ecological potential of the water body should be analyzed first, and then the layout of wetlands, waterfront vegetation, and tourist spaces should be decided, rather than simply burying the mine pit or completely artificially transforming the entire water body.

3.3 Ecological Restoration of Sudbury Mining Area in Canada

Sudbury, Ontario, Canada is a world-renowned region for nickel mining and smelting. Long term mining and smelting activities have caused extensive land exposure, soil acidification, and vegetation decline. After the 1970s, the local area gradually launched a large-scale "Regreening" ecological restoration plan, and formed a long-term governance mechanism involving the government, scientific research institutions, mining enterprises, and communities.

After conducting research on Sudbury's environmental transformation, Boerchers et al. pointed out that local ecological improvement not only relies on engineering technology, but is also closely related to long-term cooperation between local governments, businesses, researchers, and communities. Organizations such as VETAC, which are composed of multiple entities, promote scientific research achievements into the actual restoration process, gradually developing ecological restoration from a single project to a long-term regional governance action[19].

The early recovery of Sudbury first addressed the problem of difficult plant colonization. In response to soil acidification and metal pollution, lime is used to

regulate soil acidity in some areas, followed by fertilization, sowing of herbaceous plants, and gradual planting of trees. The principal operational stages of the Sudbury Regreening Program are summarized in Appendix A (Figure A9). After studying sites that have been repaired for 14-37 years, Kellaway et al. found that lime treatment still has long-term effects on pH and exchangeable base ions such as calcium and magnesium in some soil layers, and can reduce the bioavailability of some metals. However, the restoration effect still varies significantly between different sites[20]. This study suggests that soil remediation is not a one-time application of improved materials that can permanently solve the problem, but requires continuous monitoring over time.

The effect of long-term vegetation restoration has also been further validated. After studying forests with different restoration years in Sudbury, Levasseur et al. found that as the restoration time increased, the aboveground biomass and nutrient storage of trees continued to increase. Some forests restored for about 40 years had already shown tree growth levels similar to normal coniferous forests, but new ecological problems such as potential phosphorus limitations began to emerge in aging restoration areas[21]. Therefore, the restoration goal should not be judged solely by whether the trees are alive, but should focus on whether the plant community can continue to evolve and whether the soil vegetation system gradually establishes a stable relationship.

The most important inspiration for Mount Gao Li from the Sudbury case is to establish a phased and long-term ecological restoration mindset. The vegetation design of Gaolishan should not pursue mature landscape effects at once, but can

form a process of avant-garde vegetation, shrub and grass restoration, and gradual development of shrub and grass communities according to different site conditions. At the same time, the actual engineering stage should also determine whether substrate improvement is needed based on soil testing results, to avoid directly applying lime, fertilizers, or pollution control technologies from other mining areas without testing.

3.4 Case Comparison and Implications for Gaoli Mountain

Although there are significant differences in mineral species, terrain, and restoration scale between Pan'an Lake and Sudbury, their common feature is that they do not understand ecological restoration as simple greening, but rather adopt sustainable management measures based on site issues. The major differences, shared characteristics, and transferable lessons from the two cases are summarized in Appendix B (Table B1).

Combining the two cases, the four most direct inspirations for Gaoli Mountain can be formed.

Firstly, respect the characteristics of the site formed after mining. Not all of the water bodies, elevation differences, and exposed rock walls in the mine pit need to be eliminated, and some of them can be transformed into new landscape resources under safe and ecological conditions.

Secondly, different restoration strategies are adopted for water bodies and land. The water body part focuses on wetlands, habitats, and waterfront ecosystems; The natural restoration or artificial assisted restoration methods for land areas are determined based on soil conditions, slope, and existing vegetation.

Thirdly, the repair process is time sensitive. Vegetation landscape should not be solely focused on short-term landscaping, but should consider the establishment of pioneer plants, community succession, and long-term maintenance.

Fourthly, a priority relationship should be established between ecological restoration and public utilization. Firstly, determine the protection and restoration areas based on ecological sensitivity, and then arrange trails, viewing platforms, environmental education, and cultural exhibition facilities in spaces with high carrying capacity.

Investigation and Current Situation Analysis of the Abandoned Mining Site in Gaolishan

4.1 Regional Location and Surrounding Environment

The abandoned Gaolishan mine is located in the Gaolishan area of Biancheng Town, Jurong City, Zhenjiang City, Jiangsu Province. The area of Biancheng Town is approximately 128 km ^{2}, with 14 administrative villages and 2 communities under its jurisdiction, and a population of about 40000 people. The town is located in an important connecting area of the Ningzhen region, with transportation routes such as the Shanghai Nanjing Expressway and Provincial Highway 243 passing through the area, which can form regional transportation connections with Jurong, Zhenjiang, and Nanjing directions[22]. Therefore, although Gaoli Mountain is not located in the city center, it has the location conditions to connect urban residents, surrounding villages, and outdoor tourism resources. The regional landscape of Gaolishan is characterized by continuous low

mountains and extensive natural vegetation, as documented in Appendix A (Figure A10).

According to the preliminary design data and site investigation, the scope of the mine involved in this study is approximately 40 hectares, and the site is mainly composed of abandoned open-pit mining pits, rock walls, water accumulation spaces, and surrounding mountains. The natural environment around the mine is mainly composed of mountains, forests, and agricultural landscapes, which are significantly different from high-density urban built-up areas. This environmental condition means that the site will be more suitable for ecological restoration, natural experience, and low-intensity public recreation as the main directions in the future, rather than adopting a high-intensity urban park style development model.

From the perspective of regional development background, Gaoli Mountain has gradually formed a certain cultural and tourism connection with the surrounding Lunshan Lake. The 2024 government work report of Jurong City proposes to launch the creation of the "Lunshan Lake Gaolishan Provincial Tourism Resort"[23]. This planning background indicates that the regeneration of Gaolishan Mine is not only a problem of repairing a single abandoned site, but also needs to consider its connection with surrounding mountain and water resources, outdoor sports, and regional tourism development.

From a regional perspective, the Gaolishan mine has spatial characteristics of "mountain ecological environment abandoned mine surrounding rural areas tourism resources" interconnected. Subsequent planning should maintain the continuity between the mine pit and the surrounding natural system, avoiding

isolating the site.

4.2 Natural Conditions and Ecological Status

Gaolishan is a representative low mountain and hilly area in Ningzhen region. Public information shows that the main peak of Gaoli Mountain has an elevation of 425.7 meters and is one of the higher peaks in the Zhenjiang area. The mountain is composed of multiple continuous peaks with obvious terrain undulations, and has long been an important place for local outdoor hiking activities[24].

The preliminary investigation of the site showed that abandoned mining has changed the local original terrain, forming features such as exposed rock walls, obvious height differences, steep slopes, and water accumulation at the bottom of the pit. From a landscape perspective, this terrain has both limitations and resources: steep slopes increase the difficulty of safety and ecological restoration, while rock walls, elevation differences, and mine water bodies form visually recognizable spaces. The subsequent design needs to distinguish between different areas that require protection, restoration, and appropriate moderate utilization, and cannot eliminate the original landform features through large-scale slope cutting or pit filling. The major existing mining-landform characteristics observed during the field investigation are documented in Appendix A (Figure A11).

Gaoli Mountain also has certain geological scientific value. The Gaolishan Formation "is the official stratigraphic name in the study of early Carboniferous strata in China, and its name is closely related to the Gaolishan area in Jurong. Wu Xiuyuan and Zhao Xiuhu conducted specialized research on the plant fossils of the Gaolishan Formation in Jurong, Jiangsu, indicating that this area has long been a

subject of stratigraphic paleontology research[25]. Therefore, representative rock layers and exposed rock masses in the site not only serve as landscape backgrounds, but also have potential geological popularization value.

From the hydrological conditions, after the cessation of mining, a relatively obvious water accumulation space was formed inside the mine pit, which became one of the most recognizable landscapes on the site. The preliminary design materials and on-site observations indicate that water bodies occupy an important position in the overall spatial structure of the site.

In terms of vegetation, the surrounding mountains of the mine still retain a certain amount of forest land, shrubs, and natural vegetation foundation, while the areas directly disturbed by mining have phenomena such as bare rock, thin surface matrix, and discontinuous vegetation distribution. The focus of ecological restoration on the site is not simply increasing the green area, but utilizing the existing vegetation on the periphery as the ecological foundation, gradually improving the continuity of vegetation inside the mine pit, and reducing further human disturbance.

Overall, the natural conditions of Gaolishan can be summarized into three main features: significant terrain elevation differences, prominent water bodies in mining pits, and a good foundation of natural vegetation in the periphery. These three characteristics not only determine the limitations of site ecological restoration, but also constitute the most important natural resources for subsequent landscape regeneration.

4.3 Historical and cultural resources and usage needs

The Gaolishan area not only has natural and geological features, but also has a prominent historical and cultural background. On June 17, 1938, the advance detachment of the New Fourth Army launched the Battle of Weigang in the Weigang area near Gaoli Mountain, which was one of the important battles after the New Fourth Army advanced into southern Jiangsu. The Jiangsu Provincial Archives has preserved and made public relevant historical archives. At the foot of Gaoli Mountain, there is still the Weigang Battle Victory Monument and related commemorative facilities[26]. The Weigang Battle Victory Monument remains an important physical carrier of the historical memory associated with the Gaolishan area; the monument is documented in Appendix A (Figure A12). Therefore, the Gaoli Mountain area has multiple memories of natural scenery, geological resources, and red culture.

In terms of usage requirements, based on preliminary on-site investigations, design data, and regional activity characteristics, the main potential users can be summarized into four categories.

The first category includes nature enthusiasts, hikers, and photography enthusiasts. Gaoli Mountain itself has a relatively mature foundation in mountaineering activities, and related mountaineering festivals and outdoor activities have been ongoing for many years. The sports and leisure materials released by the Jiangsu Provincial Sports Federation in 2024 also introduce Gaoli Mountain, Lunshan Lake, and Wangxian Lake as regional outdoor leisure resources[27].

The second category is ecotourism and family tourists. Its main needs include

natural landscape experience, safe walking, sightseeing, rest, and environmental education, so it is necessary to balance ecological protection and basic public facilities.

The third category is the historical, cultural, and academic community. The geological resources of the Gaolishan Formation, the history of the Weigang Battle, and the mining site itself can form a multi-level educational content, with a demand more inclined towards geological, ecological, and local historical interpretations.

The fourth category is the surrounding residents. For local residents, the value of mine regeneration lies not only in attracting foreign tourists, but also in improving the surrounding environment and providing daily walking, leisure, and communication spaces.

Therefore, the future public functions of Gaoli Mountain should not solely target tourist flow, but also meet different needs such as outdoor experience, ecological education, local culture, and community leisure on the basis of nature conservation.

4.4 Main Issues and Development Potential

Based on the aforementioned site investigation, the current problems of Gaolishan Mine can be summarized into four aspects.

Firstly, there are issues of terrain disturbance and spatial security. Mining has resulted in significant elevation differences and exposed rock walls, with some areas having steep slopes that are not suitable for direct public activities. Subsequent planning must first assess the stability of the slope and determine the

scope of enclosure protection, ecological restoration, or tourism utilization based on the level of safety.

Secondly, the water environment status is still unclear. The water in the mine has become one of the most important landscape resources on the site, but there is currently a lack of complete water quality testing data. Therefore, water bodies cannot be simply used as ordinary landscape lakes, nor can they be directly identified as polluted water bodies without testing. The basic sequence of "detection evaluation repair utilization" needs to be established in the future.

The third issue is the lack of continuity between vegetation and habitat. The surrounding mountains and forests have a good ecological foundation, but the interior of the mine has been disturbed by mining, resulting in bare rocks, bare land, and vegetation fractures. How to gradually establish a continuous plant community using existing natural vegetation is the core task of site ecological restoration.

The fourth issue is the lack of systematic connection between existing tourism activities and venue interpretation systems. Gaoli Mountain already has a foundation for hiking, photography, and tourism activities, but the geological formation of the mine, the process of ecological restoration, and the local history have not yet formed a complete spatial narrative. Therefore, it is necessary to improve the comprehensibility of the site through a reasonable walking system, viewing space, and educational facilities while protecting the ecological environment.

At the same time, the venue also has significant development potential. The unique mining terrain can create a spatial experience that is different from ordinary

parks; Existing water bodies can become the foundation for wetland and aquatic ecosystem construction after detection and ecological assessment; Peripheral forests can serve as important ecological sources for vegetation restoration and habitat connectivity; The Gaolishan Formation, Weigang Battle, and mining landscape relics can form educational resources that combine geology, history, and ecology. These existing resources and potential values are spatially summarized in Appendix A (Figure A13). The core contradiction of Gaolishan Mine is not "how to build an abandoned mine into a more beautiful park", but how to address ecological and safety issues while preserving site features, and re-establish a reasonable relationship between humans and mines within the limits of ecological carrying capacity.

Landscape Regeneration Strategy of Gaolishan Mine Based on Ecological Restoration

5.1 Overall Regeneration Concept and Spatial Planning

The core concept of this design is' Return to the Source '. Returning to the source "does not require fully restoring the mine to its pre mining state, but rather restoring the site to a stable ecological foundation through ecological restoration, while preserving identifiable rock walls, water bodies, and mining landforms, allowing natural restoration and site memory to jointly form new landscape features.

From the perspective of spatial planning, Gaolishan should avoid adopting high-intensity and homogeneous park development methods, and instead form

varying degrees of artificial intervention based on ecological sensitivity, terrain safety, landscape resources, and accessibility. Ahern proposed that resilient landscape planning should emphasize multifunctionality, ecological connectivity, spatial redundancy, and adaptive design, rather than relying on a "fail safe" model that fully controls natural processes[28]. This viewpoint is particularly significant for abandoned mines, as mines themselves are a continuously changing ecosystem, and their design should preserve space for natural succession and future adjustments.

Based on the site conditions, this article proposes an overall structure of "one core, two belts, and multiple nodes".

The "one core" is the landscape and ecological core formed by the water body of the mine and its surrounding ecological space, which undertakes the main functions of water ecological restoration, habitat creation, and natural landscape display.

The "two zones" refer to the ecological restoration zone formed along the edge of the mine, as well as the low-intensity recreational zone connecting the surrounding forests and main public spaces. The former focuses on vegetation restoration and habitat continuity, while the latter mainly undertakes walking, observation, and environmental education.

Multi node" refers to setting up spaces such as entrances, scenic spots, rest areas, science popularization, and cultural exhibitions in locations with high ecological carrying capacity, connected by a trail system, rather than evenly arranging artificial facilities throughout the entire mine area.

The core of this spatial structure is to establish a gradually increasing usage gradient from" strict protection ecological restoration low-intensity experience public activities", so that functional zoning corresponds to ecological sensitivity. The overall spatial planning diagram and regeneration strategy are presented in Appendix A (Figures A14 and A15).

5.2 Ecological Restoration and Natural Landscape Reconstruction Strategies

The ecological restoration of Gaolishan is mainly carried out from three aspects: terrain and substrate, vegetation, and habitat connection.

Firstly, the existing mine terrain should be preserved to the greatest extent possible, reducing unnecessary large-scale excavation and filling. For exposed rock walls and areas with significant height differences, engineering safety assessments should be conducted first. Slopes with stability risks need to be treated through professional geological engineering measures, while stable and landscape valuable rock walls can be appropriately preserved as mining landforms and geological display resources. Thus, a dual approach of "necessary governance" and "moderate retention" is formed.

Secondly, vegetation restoration should be carried out in stages. There are already forests and natural vegetation around the site that can serve as a foundation for restoration, while natural restoration, assisted restoration, and artificial community reconstruction are used inside the mine pit according to the substrate conditions. The initial focus is on improving the stability of bare land and establishing plant cover, gradually increasing the levels of shrubs and trees in the middle stage, and the long-term goal is to improve community stability and natural

regeneration capacity, rather than immediately forming mature forest landscapes upon design completion.

After reviewing over 50 years of global research on mine restoration, Harries et al. pointed out that evaluating mine ecological restoration should not only observe vegetation cover, but also pay attention to natural plant regeneration, soil processes, habitat development, ecological resilience, and whether it can gradually form self-sustaining ecosystems[29]. Therefore, the evaluation of plant restoration in Gaolishan should shift from "how many plants have been planted" to "whether the plant community can sustainably develop".

Thirdly, the habitat connection between the interior of the mine and the surrounding mountains and forests should be strengthened. By connecting existing natural areas through continuous forest belts, shrub and grass communities, wetland plants, and small habitat patches, the degree of isolation of the internal landscape of the mine is reduced. Walkways and public facilities should avoid ecologically sensitive areas as much as possible to minimize continuous interference with the activities of birds, insects, and other wildlife.

5.3 Ecological restoration strategies for water bodies and wetlands

The water in the mine pit is one of the most recognizable natural elements of Gaoli Mountain and an important core of future landscape design.

Wetland buffer spaces can be constructed in areas with shallow water bodies and relatively stable bank slopes, increasing the transition between land and water bodies through aquatic plants, shallow water areas, and ecological shorelines.

Artificial wetland is an ecological engineering method that utilizes wetland plants, soil or substrate, and related microbial processes for water environment management. Its specific type needs to be selected based on water quality objectives and hydrological conditions[30].

The wetland design of Gaolishan should not transform the entire mine water into an artificial wetland, but should focus on addressing suitable shallow water shorelines and rainwater inflow areas. This can not only preserve the original landscape features of the deep water space in the mine, but also create different habitats such as reeds, wet herbaceous plants, shallow water, and forest edges.

At the same time, a buffering relationship should be established between the rainwater on the site and the water in the mine pit. The surface runoff generated by peripheral roads and public spaces should not enter the mine directly without treatment. It can be intercepted and stored through vegetation buffer zones, ecological shallow ditches, and rain gardens to reduce the impact of artificial construction on the original hydrological system.

Therefore, in this design, the water body of the mine has three functions: ecological foundation, landscape core, and environmental education resources, rather than simply serving as an ornamental water feature.

5.4 Sustainable Landscape and Public Space Strategies

The regeneration of mine landscape requires meeting reasonable public use needs while protecting the ecosystem. Therefore, public facilities should adopt centralized layout and low impact construction methods, so that artificial activities mainly occur in areas with stable terrain, low ecological sensitivity, and good

accessibility.

In terms of rainwater management, the concept of low impact development can be adopted. After reviewing the research on low impact development, Eckart et al. pointed out that measures such as permeable paving, biological retention, green roofs, and rainwater collection can reduce the impact of rainwater runoff through decentralized management, but their actual effects are closely related to site conditions, design parameters, and later maintenance[31]. Therefore, Gaolishan does not require the mechanical installation of all LID facilities, but should focus on using them in areas with relatively high artificial hardening, such as entrances, parking, buildings, and main activity spaces.

Green infrastructure should also have multifunctionality. Hansen and Pauleit pointed out that green infrastructure planning needs to consider ecosystem services, spatial networks, and social needs simultaneously, so that the same green space can undertake multiple functions such as ecology, environment, and public use[32]. In Gaoli Mountain, this means that an ecological trail can serve as both a slow walking function and a popular science path for observing natural succession; Wetlands not only undertake aquatic ecological functions, but also serve as spaces for environmental education; Vegetation buffer zones not only serve as habitat connections, but also improve the environmental quality of pedestrian spaces.

Public spaces mainly serve nature enthusiasts, hikers, family tourists, students, and surrounding residents. The spatial design should focus on walking, connecting different landscape areas through the main sightseeing path and low-intensity ecological trails, and setting up viewing and resting nodes in locations with good

visibility and safe terrain. High risk slopes and deep water areas should be restricted from direct access, and the landscape experience should be achieved through remote viewing.

Tzoulas et al. pointed out that continuous green infrastructure not only has ecological functions, but also has close relationships with public health, outdoor activities, and environmental quality[33]. Therefore, public spaces in Gaolishan should avoid being dominated by large entertainment facilities, and emphasize more on walking, observation, rest, and natural experiences.

This approach can not only meet basic public needs, but also reduce the interference of landscape development on the ecological restoration process of mines.

5.5 Cultural Interpretation and Long term Management Strategies

In addition to restoring the ecological environment, the regeneration of the Gaoli Mountain landscape also requires establishing the cultural readability of the site. Cultural display mainly includes three levels: geological environment, mining site memory, and regional historical culture. Utilize representative exposed rock layers, mine landforms, and the "Gaolishan Formation" to conduct geological science popularization, enabling tourists to understand the natural foundation of the site formation. On the other hand, it is necessary to preserve and interpret the confirmed mining landforms and related relics, and explain the process of transforming the mining pit from a resource extraction space to an ecological restoration space through photos, archives, models, or on-site explanations.

Research on mining heritage shows that when transforming mining history

into tourism and public cultural resources, it is necessary to simultaneously address the relationship between protection, local identity, community participation, and tourism development, rather than just treating relics as visual consumption objects[34]. Therefore, the cultural display of Gaolishan should serve the public's understanding of the site, rather than forming large-scale themed construction unrelated to ecological restoration.

The ecological restoration of mining pits still requires the establishment of a long-term monitoring mechanism. The monitoring content can include vegetation coverage and natural renewal, habitat changes, basic water quality indicators, operation of rainwater facilities, and interference of tourist activities on sensitive areas. The monitoring results are used to determine whether to adjust plant management, trail opening scope, and maintenance intensity.

The current industry standard in China, "Acceptance Specification for Mine Ecological Restoration Engineering," has included geological environment governance, land restoration, ecosystem function, and later management and protection of mines in the acceptance content of ecological restoration engineering[35]. Therefore, the landscape regeneration of Gaolishan should consider "post construction management" as part of the design system, rather than additional work after the completion of the project.

Application of Landscape Design for Abandoned Mines in Gaolishan

6.1 Overall layout and spatial structure

The overall plan fully utilizes the existing water bodies, rock walls, terrain

height differences, and surrounding forest conditions of the mine pit, and reorganizes the ecological space, recreational space, and public activity space on the basis of reducing large-scale terrain transformation.

The overall space forms a layout structure of "one core, two belts, and multiple nodes". The "One Core" takes the water body of the mine pit and its surrounding areas as the main landscape core, forming the most recognizable ecological landscape of the site through wetland restoration, waterfront plants, and viewing spaces. The "two belts" refer to the ecological restoration landscape belt along the periphery of the mine and the mountain recreation experience belt connecting the main public spaces. The former undertakes vegetation restoration, habitat connection, and ecological buffering functions, while the latter organizes tourist activities through a slow travel system. Multiple nodes "are set along the main tourist routes based on the terrain and functional requirements of the site, including wetland experiences, mine views, forest recreation, public activities, and cultural exhibitions in different types of landscape spaces.

The spatial layout emphasizes the differences in the degree of manual intervention in different regions. Ecological sensitive spaces such as mine water bodies, steep rock walls, and surrounding natural forests are mainly protected and ecologically restored; Areas with relatively stable terrain serve as pathways, scenic spots, and natural experiences; Necessary public activities and service spaces are concentrated in areas with convenient entrances and transportation. Through this spatial relationship that gradually transitions from ecological protection to public use, a clear hierarchy is formed between natural landscapes and artificial activities.

The original water bodies, elevation differences, and rock walls in the mine have not been completely eliminated, but have become important spatial conditions for organizing the overall landscape. The design connects the originally scattered landforms, water bodies, and forest spaces through paths, vegetation, and landscape nodes, creating a continuous system of tourism and landscape experiences within the mine. The existing design materials also include wetlands, trails, viewing platforms, and public leisure spaces as important components of the mine design. The overall plan is provided in Appendix A (Figure A16).

6.2 Landscape Flow and Spatial Experience System

The unique terrain conditions of the mine not only provide a connecting function for traffic flow, but also become an important way to experience the site. Therefore, the design focuses on a slow-moving system, creating a continuous landscape experience through paths at different heights and in different environments.

The overall tour process can be summarized as follows:

Entrance to know the mine pit

→ Entering the mountains and forests

→ Rock Wall Experience

→ High altitude viewing

Observation of Wetlands and Water Bodies

→ Public Activities and Rest

→ Cultural and Ecological Exhibition

→ Return to the entrance.

This spatial sequence allows tourists not to immediately see the entire landscape upon entering the site, but to gradually get to know the mine as they move around.

The main tourist route connects the entrance, main public spaces, core viewing areas, and wetland spaces, with relatively strong scale and recognizability; The secondary ecological trail runs through forests, restores vegetation, and surrounds water bodies, emphasizing more on natural experiences; Only observation paths or management routes are set up in some ecologically sensitive areas to control the intensity of tourist entry.

Lynch proposed that spatial elements such as paths, boundaries, nodes, and landmarks can help users establish clear environmental awareness[36]. The spatial system of Gaoli Mountain therefore utilizes the water body of the mine pit as the core visual symbol, forming a continuous path with trails, forming boundaries with rock walls and forests, and then forming main nodes through viewing platforms, wetlands, and public activity spaces, giving the entire mine pit landscape a clear tourism structure.

The viewing system creates different experiences according to the terrain. The high-altitude viewing platform is mainly used to observe the overall shape of the mine, water bodies, and surrounding mountains; The central trail mainly observes rock walls, plant communities, and terrain changes; Low level space is connected to wetlands and water bodies. By converting between different elevations, the original elevation difference of the mine pit is transformed from a limiting condition into a landscape experience resource.

6.3 Main Landscape Space Design

6.3.1 Ecological Wetland Space in Mining Mines

Wetland space is the area in the entire mine design that best embodies the theme of ecological restoration. Design and utilize the existing water bodies and shoreline conditions of the mine pit to form wetland plant communities in shallow water and water land interface areas, forming a wetland landscape with hierarchical changes through emergent plants, wetland plants, natural shorelines, and local ecological islands. Wetland spaces serve both tourism and educational purposes. Set up elevated walkways and small observation platforms without damaging the main ecological space, allowing tourists to observe aquatic plants, birds, and wetland environments up close. A certain distance is formed between the trail and the plants, which concentrates human activities in a linear space rather than freely entering the entire wetland area. Avoid using fully regularized artificial lakeshores in the landscape, and instead create relatively soft spatial relationships through vegetation, water surfaces, and natural edges.

6.3.2 Viewing Space for Rock Walls and Mines

The exposed rock wall is one of the most visually striking landscape features of the site. The design considers it as an important component of the mine site memory, without comprehensive vegetation coverage, and contrasts it with local vegetation restoration and bare rock preservation.

Set up a viewing platform in a location with good visibility, allowing tourists to observe the overall terrain of the rock walls, water bodies, and mines from a safe distance. The platform form should be as simple as possible, maintaining visual coordination with the rock wall, making the designed structure a medium for viewing the site, rather than replacing the mine itself as the visual center. Some rock layers can also be interpreted and marked with geological knowledge, mine formation, and ecological restoration content, making the viewing process also environmentally educational.

Nassauer proposed that natural ecological processes themselves are often difficult for the general public to directly understand, so design can express human management and protection intentions through clear "care cue" or artificial order in naturalized landscapes[37]. In Gaoli Mountain, clear pedestrian boundaries, observation platforms, signage, and locally tidy management areas can contrast with natural succession, allowing the restoration of the mine landscape to maintain naturalness without appearing as unmanaged abandoned space.

6.3.3 Forest Ecological Trail Space

There are already mountainous and forested environments around the mine, so the mountainous areas mainly emphasize low intervention natural experiences.

The trail is developed along the existing terrain to avoid the formation of overly regular urban park roads through a large amount of earthwork. A small number of rest platforms and observation points are set up along the route, allowing tourists to experience the landscape of understory space, slope changes, and different angles of the mine. The plant landscape adopts a more natural structure of trees, shrubs, and grasses, while retaining some existing plants, gradually integrating the newly built plant community with the surrounding mountains and forests.

The mountain trail also serves as a connection, organizing the entrance, mine core, water wetlands, and other public spaces into a continuous system. Therefore, it serves as both a transportation space and an important landscape corridor for experiencing the ecological restoration process throughout the entire project.

6.3.4 Comprehensive leisure and family activity space

Public activity spaces are mainly concentrated in areas with relatively flat terrain and good accessibility to meet the needs of local residents, family tourists, and general tourists, such as setting up open grasslands, small squares, rest pavilions, shaded spaces, and children's and family activity facilities.

Unlike traditional large-scale amusement facilities, this design emphasizes more on the connection between the activity and the natural environment of the mine. For example, children's spaces can create activity environments with natural exploration features through rocks, wood, slopes, and plants; Open spaces can serve multiple functions such as rest, communication, small-scale activities, and natural observation.

6.3.5 Geological Culture and Ecological Education Space

Cultural exhibitions do not form a closed museum system independently, but are integrated with the process of site visits. The presentation mainly revolves around three clues:

Geological formation - mining activities - ecological regeneration.

Tourists first learn about the natural formation background of Gaoli Mountain through geological landscapes, then understand the changes that mining activities have caused to the site, and finally understand how the mine has entered a new stage of ecological succession through wetlands, plant restoration, and ecological facilities. Tilden emphasizes in the theory of heritage interpretation that the

purpose of interpretation is not simply to list facts to tourists, but to stimulate understanding and interest through the connection between information and experience[38]. Therefore, the display of Gaolishan culture should not have a large number of text display boards, but can be combined with rock walls, plants, water bodies, and on-site relics to connect the explanatory content with real landscape objects. In this way, "cultural display" and "ecological education" are no longer independent functions, but become continuous landscape narratives throughout the entire tourism process.

6.4 Plant Landscape and Ecological Design

The plant design follows the principle of "local priority, suitable trees, natural communities, and seasonal changes", and forms differentiated configurations according to different environments in the mine. The surrounding mountainous areas of the mine are mainly connected by the restoration of trees and shrubs and natural forest land, forming multi-layered communities through trees, sub trees, shrubs, and ground cover.

Sloping and bare land areas focus on utilizing plants with well-developed root systems and strong adaptability to form initial cover, and gradually increase shrubs and trees to enable plant communities to have a succession process. A plant gradient is formed around the water body from deep water, water edge, wetland to land, with aquatic, wetland, and shore plants forming a natural transition.

In public activity areas, plants with shading, seasonal and ornamental value should be appropriately added to give artificial activity spaces a clear landscape quality.

Rainwater management is also integrated with plant design. The entrance, square, and main public spaces are equipped with permeable paving, rain gardens, and vegetation recessed spaces, integrating rainwater retention, plant configuration, and public landscapes together.

6.5 Landscape Nodes and Design Effects

On the basis of the overall spatial structure, this plan selects representative landscape spaces for node deepening, so that the ecological restoration strategy can be reflected through specific spatial forms. The main nodes include mining wetland space, rock wall viewing space, forest ecological trail, public leisure activity space, and geological and cultural exhibition space.

The mining wetland nodes are designed based on the existing mining water bodies and local shorelines, forming a natural water land transition space through

aquatic and wetland plants, and organizing tourist activities in conjunction with boardwalks and viewing platforms. On the basis of preserving the main form of the mine water body, this node strengthens the wetland landscape features, further transforming the water body from the original abandoned mine landscape to the ecological core of the site. Wetlands, trails, and viewing platforms are also important design elements that have been clearly identified in the existing graduation design materials.

The rock wall viewing node mainly utilizes the exposed rock walls formed by mining and the obvious terrain height difference. Design to preserve representative mine landforms, and set up viewing platforms in relatively safe and spacious locations to allow visitors to observe the spatial relationships between the mine's water bodies, rock walls, and surrounding mountains and forests. Combining concise geological and mining information display, the rock wall not only exists as a visual landscape, but also becomes an important carrier for understanding the formation process of the site.

The nodes of the forest ecological trail are located in areas with relatively good vegetation conditions around the mine pit. The trail follows the mountainous terrain and existing plant space, creating a more natural understory experience through trees, shrubs, and ground cover plants. Partial rest spaces and observation points are set up to enable tourists to complete the transition from the peripheral natural space to the core space of the mine pit in the mountainous environment, while reducing the interference of large-scale hard paving on the existing mountain environment.

Public leisure activity nodes are mainly located in areas with relatively flat terrain and good accessibility, meeting the daily needs of local residents and tourists through open grasslands, rest spaces, small activity venues, and family friendly facilities. This area maintains a certain distance from highly ecologically sensitive spaces, so that concentrated public activities do not directly interfere with the core ecological restoration area of the mine.

The geological and cultural display nodes are combined with the characteristics of the mine rock layers, mining sites, and regional cultural backgrounds to form an environmental education space. The display method mainly relies on the on-site landscape, establishing a cognitive relationship of "natural geology mining activities ecological restoration" through explanatory signs, small-scale displays, and tour paths, so that tourists can understand the changes that have occurred in the mining pit space during the tour, rather than

placing cultural displays independently of the landscape.

Discussion and Conclusion

7.1 Main Research Conclusions and Discussion

Through the aforementioned research, the following three main conclusions can be drawn.

Firstly, ecological restoration should become the foundation for the regeneration of abandoned mine landscapes, rather than an additional measure after landscape design is completed. The soil, water, vegetation, and habitat issues in mines are interrelated, and are also influenced by terrain and mining disturbance methods. Therefore, landscape planning needs to first identify ecologically sensitive areas, natural restoration potential, and spatial safety conditions, and then determine the construction intensity of different areas. This article establishes the basic research logic of "ecological diagnosis ecological restoration spatial regeneration functional utilization" and further transforms it into the spatial design of Gaoli Mountain.

Secondly, the disturbed topography of the mine pit is both a limiting condition and a landscape resource. The height difference, rock walls, mine water bodies, and surrounding mountains and forests together form the unique characteristics of the Gaoli Mountain area that distinguish it from ordinary urban parks. The design did not aim to completely fill the mine pit or achieve comprehensive artificial greening. Instead, it preserved some identifiable landforms on the basis of safety and ecological conditions, and reorganized the relationship between people and the site through wetlands, forest trails, and viewing spaces. Therefore, mine regeneration is not simply about" restoring to the past", but establishing new ecological and spatial relationships based on the recognition that the site has undergone changes.

Finally, a reasonable spatial gradient needs to be established between ecological restoration and public use. Not all recovery areas are suitable for opening, and not all public activities need to be concentrated in the core of the mine. The Gaolishan plan adopts a spatial structure of "one core, two belts, and multiple nodes", with the mine water body and ecological space as the landscape core, establishing connections between ecological restoration zones and recreational experience zones, and then arranging public activities, sightseeing, and cultural education nodes in areas with relatively high carrying capacity. This can

reduce direct conflicts between public activities and core ecological spaces.

In summary, this study suggests that the key to the regeneration of abandoned mine landscapes is not to add more functions, but to establish a corresponding relationship between ecological conditions, spatial utilization intensity, and landscape experience.

7.2 Applicability and practical value of research results

The specific spatial form formed by the Gaolishan case has site specificity, and its wetland location, trail relationship, viewing method, and plant configuration cannot be directly replicated to other abandoned mines. However, the research methodology developed in this article has certain reference value, namely:

Investigate the current situation of the site → Determine ecological issues → Evaluate restoration potential → Determine spatial intervention intensity → Organize subsequent land functions → Transform into specific landscape design.

In recent years, research on post mine land use has shown that the land use after mine closure has strong diversity. Ecological protection, public space, agriculture, forestry, tourism, and other reuse methods may all be choices, and the final decision needs to consider natural conditions, regulations, land suitability, and socio-economic needs[39]. Therefore, what the Gaolishan plan can truly serve as a reference for similar projects is not a fixed landscape form, but the process of differentiated selection based on site conditions.

From the perspective of landscape design practice, this article has two other aspects of value.

On the one hand, through spaces such as wetlands, rock walls, forests, and trails, the content that is difficult for the public to directly perceive in the process of ecological restoration can be transformed into landscape experiences, making ecological restoration not only exist at the technical level, but also have environmental education and public cognitive value.

On the other hand, the design preserves existing features such as mine terrain and water bodies, reducing the tendency to establish "new parks" through large-scale reshaping, thus making abandoned mines an important foundation for landscape design.

But the applicability of this method also has boundaries. There are significant differences in mineral types, pollution levels, hydrological conditions, regional economy, and community needs among different mining areas. After reviewing the research on post mining transformation, Measham et al. also pointed out that

existing successful experiences often have obvious regional conditions, and their direct transplantation ability is limited. Post mining transformation needs to consider ecological, engineering, social, economic, and regional scale factors simultaneously[40]. Therefore, the results of this article are more suitable as a reference for design methods, rather than a standard answer that is universally applicable to all abandoned mines.

7.3 Research Limitations

There are still several significant limitations to this study.

Firstly, the basic data of the venue is still insufficient. At present, research mainly relies on on-site observation, public data, remote sensing information, and existing design materials for analysis, and there is still a lack of systematic soil, water quality, and ecological background detection. Therefore, the paper did not make a definitive judgment on whether there are issues such as excessive heavy metals and acidic mine drainage in the Gaolishan mine. The wetland and water ecological restoration and substrate improvement proposed in the design are strategic plans, and the actual technology used still needs to be based on professional testing results.

Secondly, there is a lack of long-term ecological verification after completion. This project is a graduation project research and has not been implemented in practice. Therefore, the plant restoration, wetland habitat improvement, and biodiversity improvement mentioned in the paper are all expected goals and cannot be considered as already achieved ecological performance. The rendering reflects the design status, not the empirical results.

Thirdly, research on public demand still relies mainly on qualitative analysis. This article summarizes the users based on the current usage status and potential population of the site as nature enthusiasts, hikers, family tourists, cultural and academic groups, and local residents, but does not conduct large-scale questionnaires, interviews, or participatory designs. Therefore, the specific needs of different groups of people for functionality, openness, and management methods still need further verification.

Fourthly, this study is based on a single case of Gaolishan. Although the method developed has certain reference significance for similar abandoned open-pit mines, there are significant differences in natural and social conditions in different regions. Therefore, the promotion of research conclusions still requires more case comparisons.

7.4 Future research and conclusions

Future research should first strengthen the investigation of site basic data. Establish an ecological background through soil, water quality, vegetation, and biodiversity surveys, and further determine the protection and open boundaries of different areas by combining slope stability and hydrological analysis. On this basis, ecological restoration measures can be further transformed from conceptual strategies into targeted technical solutions.

Secondly, a long-term ecological monitoring system can be established. Hooper et al. pointed out that ecological restoration monitoring needs to simultaneously pay attention to physical, chemical, and biological indicators, and determine whether the restoration process is progressing towards the established goals through monitoring results, thereby providing a basis for subsequent adjustments[41]. Therefore, if Gaoli Mountain enters a further deepening stage in the future, water quality changes, vegetation coverage and natural renewal, habitat utilization, and tourist disturbance can be used as long-term evaluation indicators.

At the same time, subsequent research should also increase the participation of local residents, tourists, and managers, and further determine the functional requirements of the site through questionnaires, interviews, or participatory design. In terms of design technology, higher precision terrain data, GIS ecological sensitivity analysis, hydrological simulation, and long-term remote sensing monitoring can also be combined to improve the correspondence between landscape schemes and ecological processes.

In summary, this study believes that the landscape regeneration of abandoned mines should not be understood as a simple beautification of industrial waste spaces, but should be based on the common foundation of ecological restoration, site feature protection, and rational land reuse. The design of Gaolishan Mine proposes a design path from ecological problem identification to landscape spatial transformation through the reorganization of water bodies and wetlands, rock landscape, forest vegetation, slow-moving systems, and public nodes.

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APPENDIX A: Visual Material for the Text

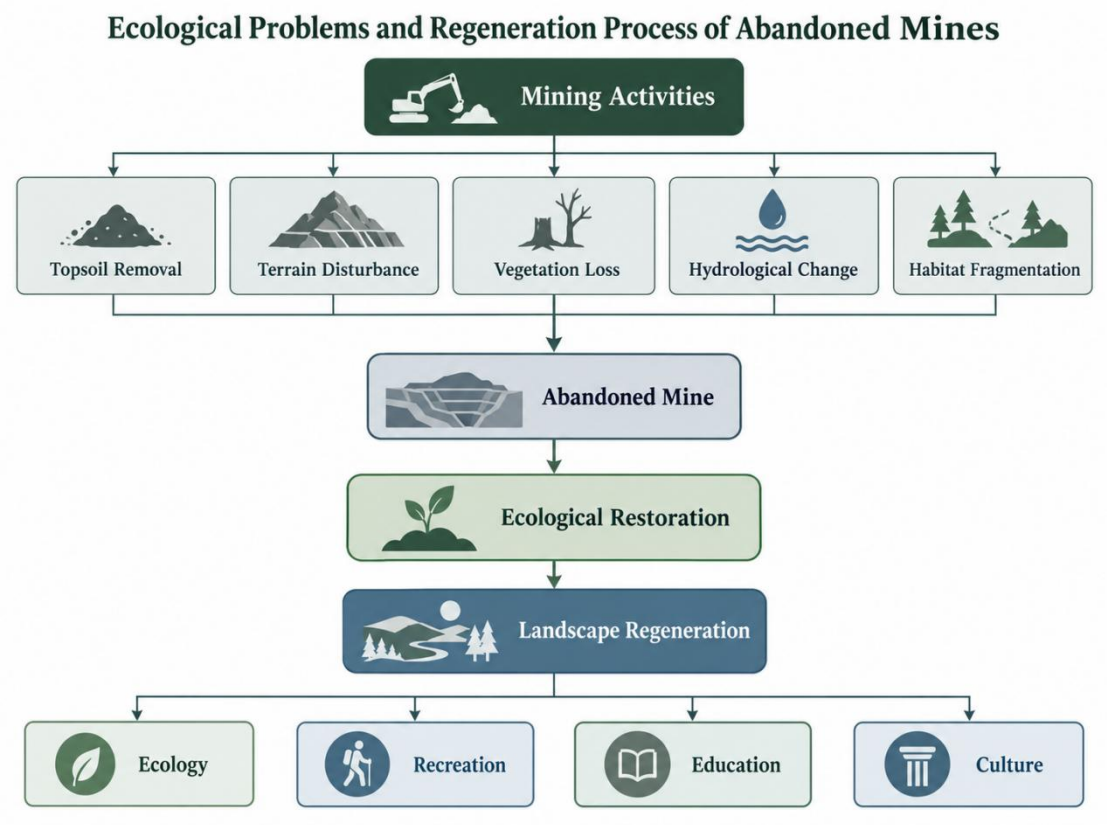


Figure A1 Ecological Problems and Regeneration Process of Abandoned Mines

Source: Drawn by the author.

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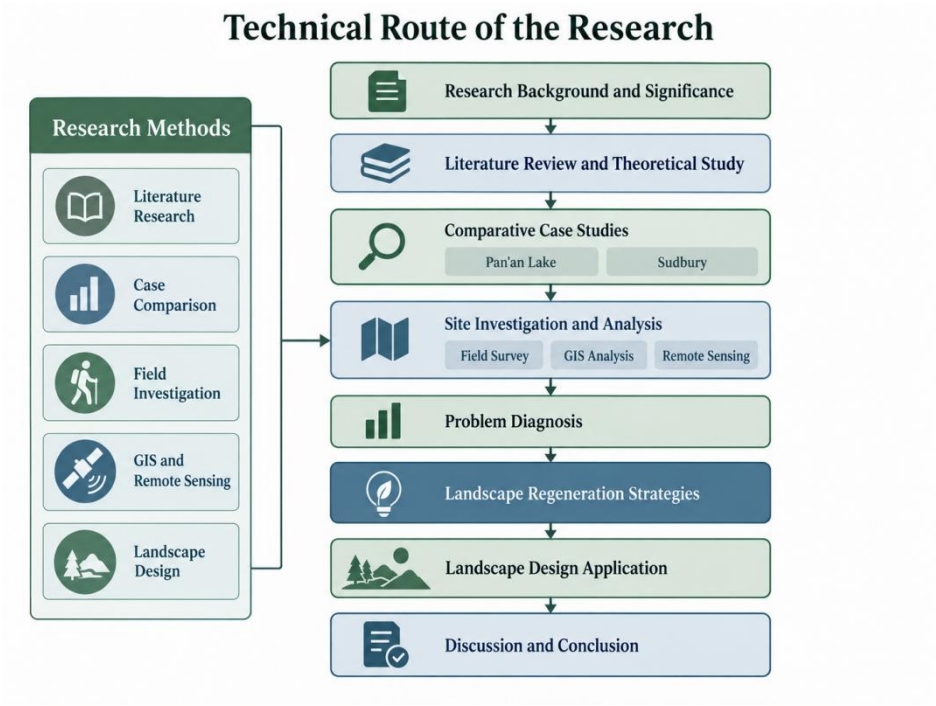


Figure A2 Technical Route of the Research

Source: Drawn by the author.

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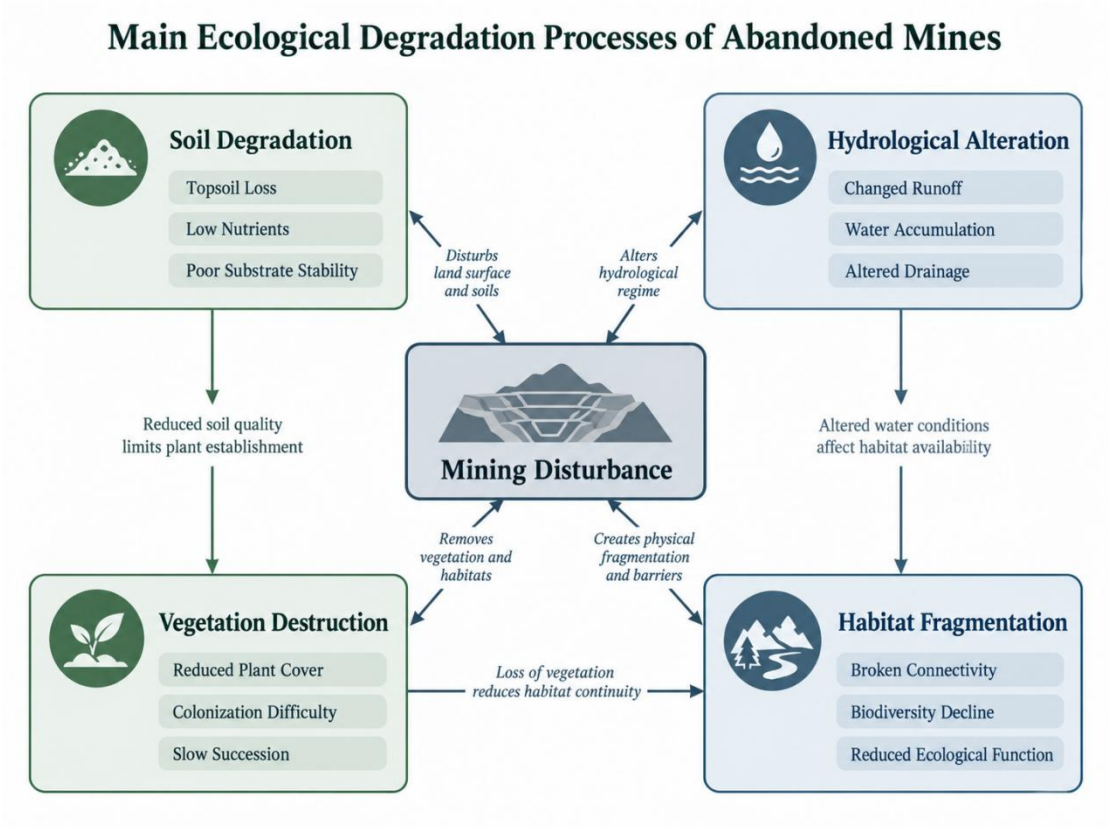


Figure A3 Main Ecological Degradation Processes of Abandoned Mines

Source: Drawn by the author.

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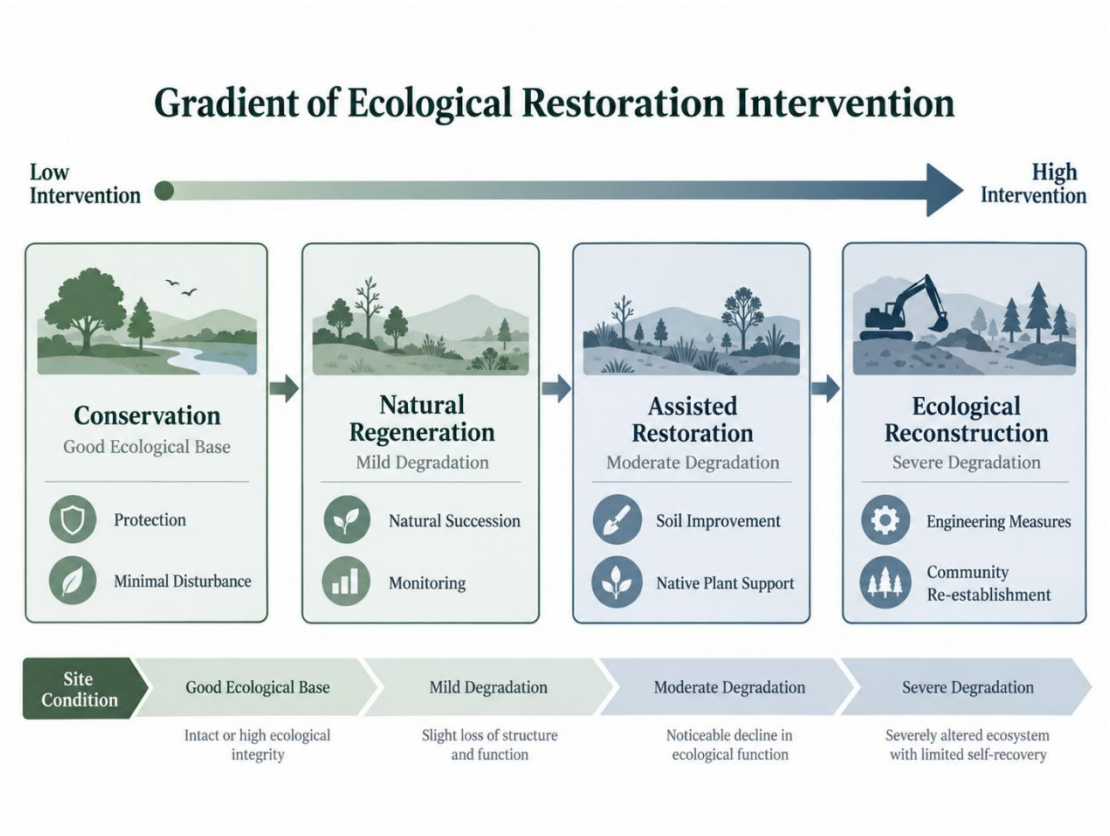


Figure A4 Gradient of Ecological Restoration Intervention

Source: Drawn by the author.

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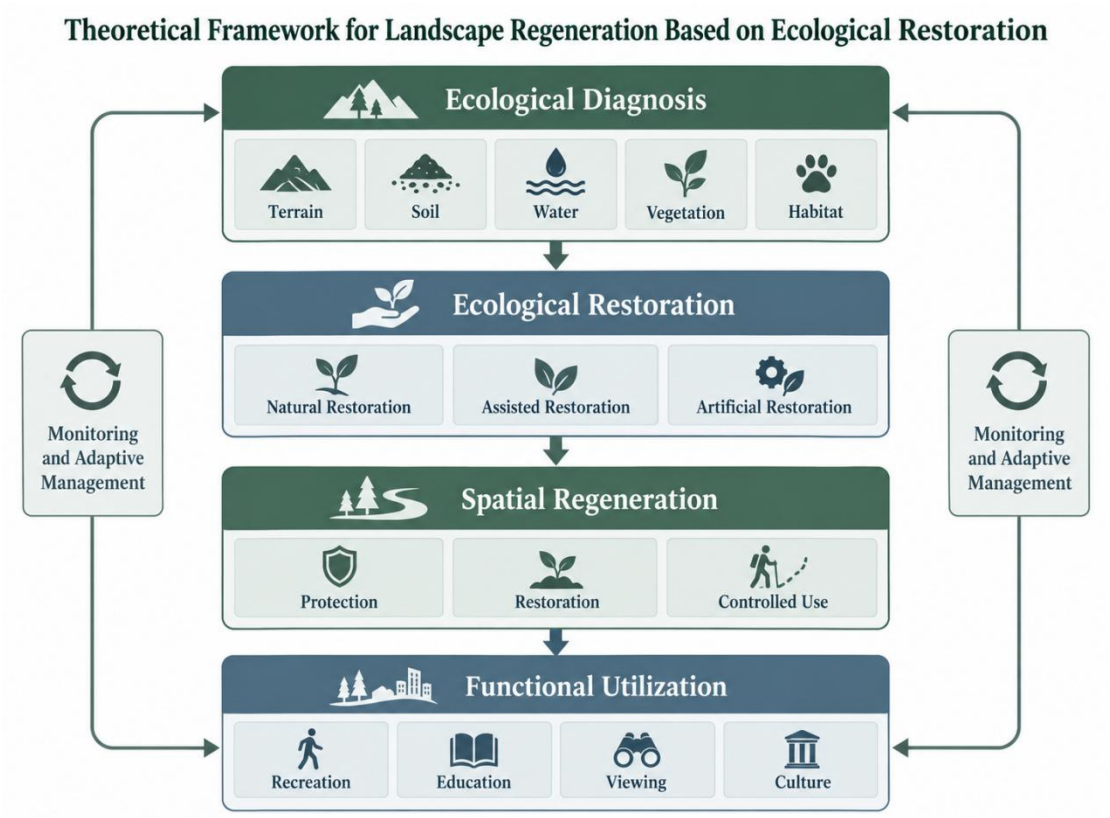


Figure A5 Theoretical Framework for Landscape Regeneration Based on Ecological Restoration

Source: Drawn by the author.

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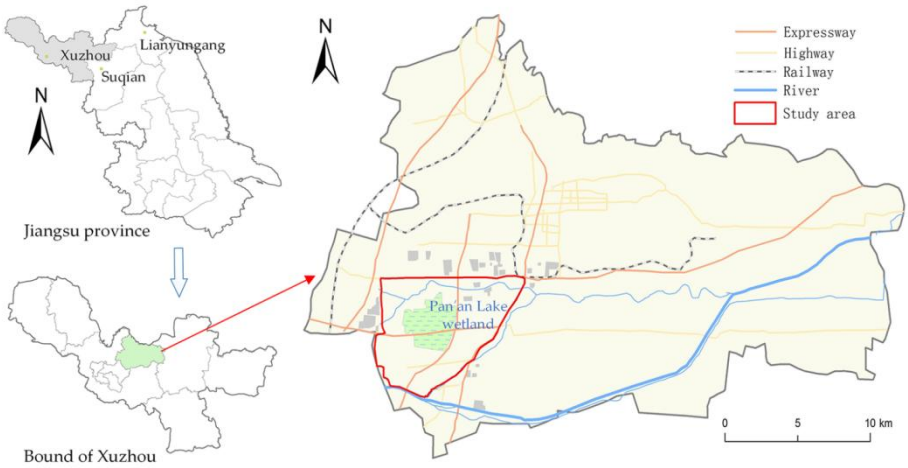


Figure A6 Location of Pan'an Lake Wetland in Jiawang District, Xuzhou

Source: Xu et al. (2020).

Originally presented as Figure 3.1 in the main text.

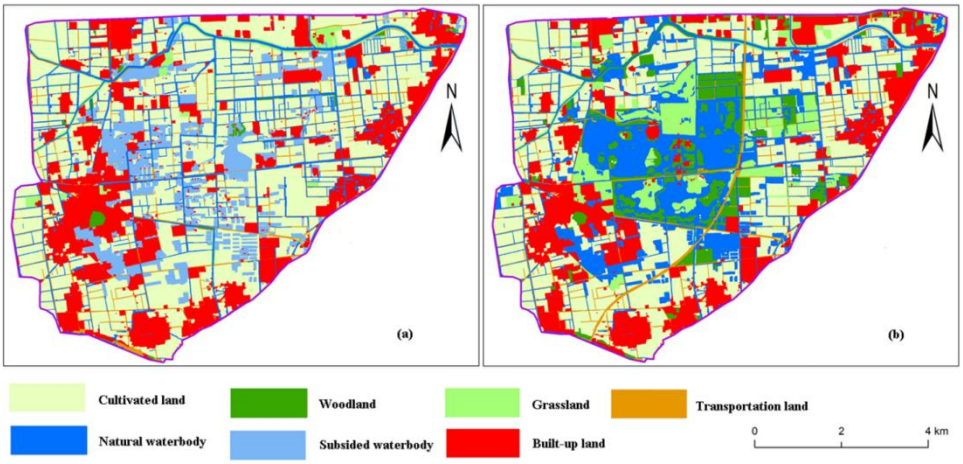


Figure A7 Landscape Patterns Before and After Land Reclamation in the Pan'an Lake Subsidence Area

Source: Xu et al. (2020).

Originally presented as Figure 3.2 in the main text.

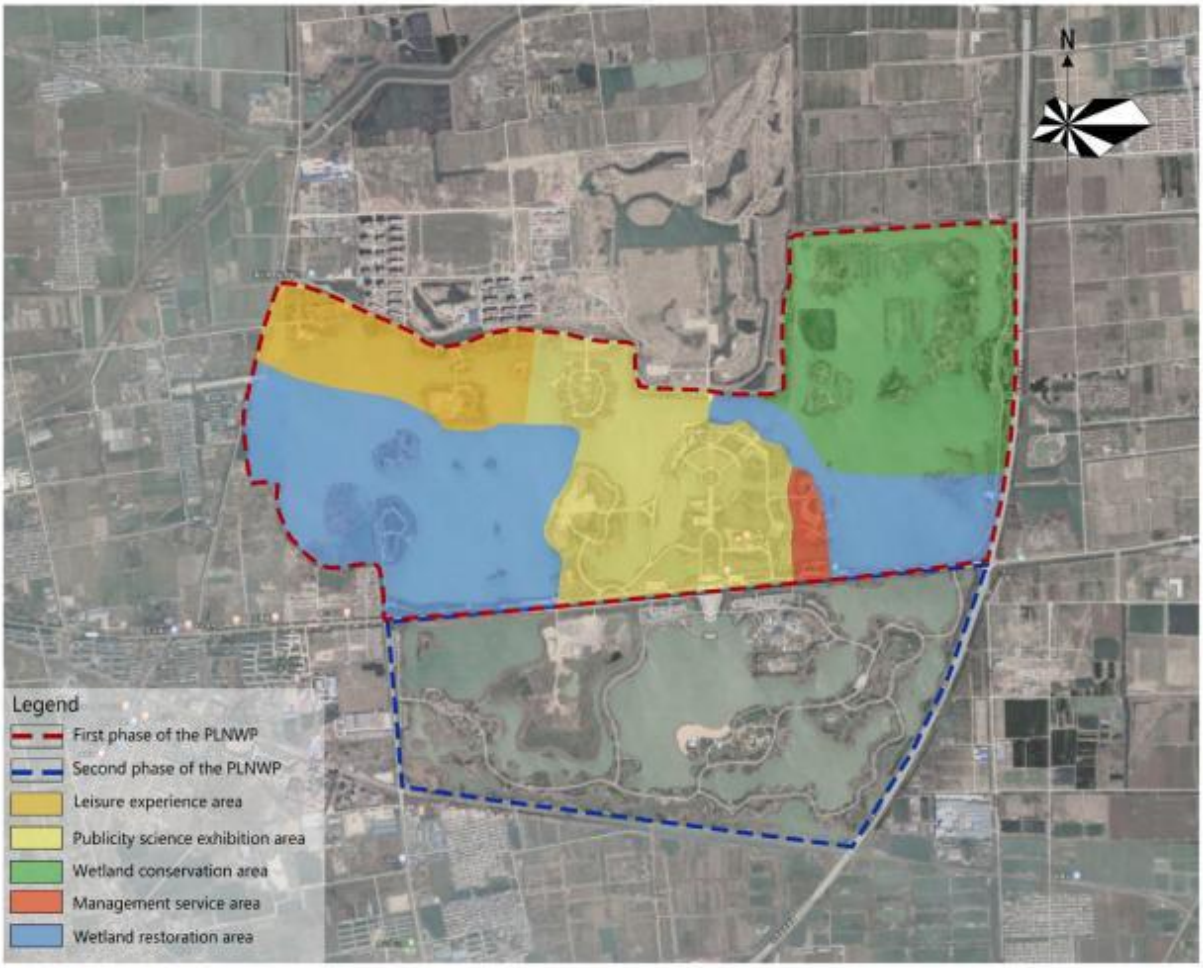


Figure A8 Functional Zoning of Pan'an Lake National Wetland Park

Source: Li et al. (2025), Figure 2.

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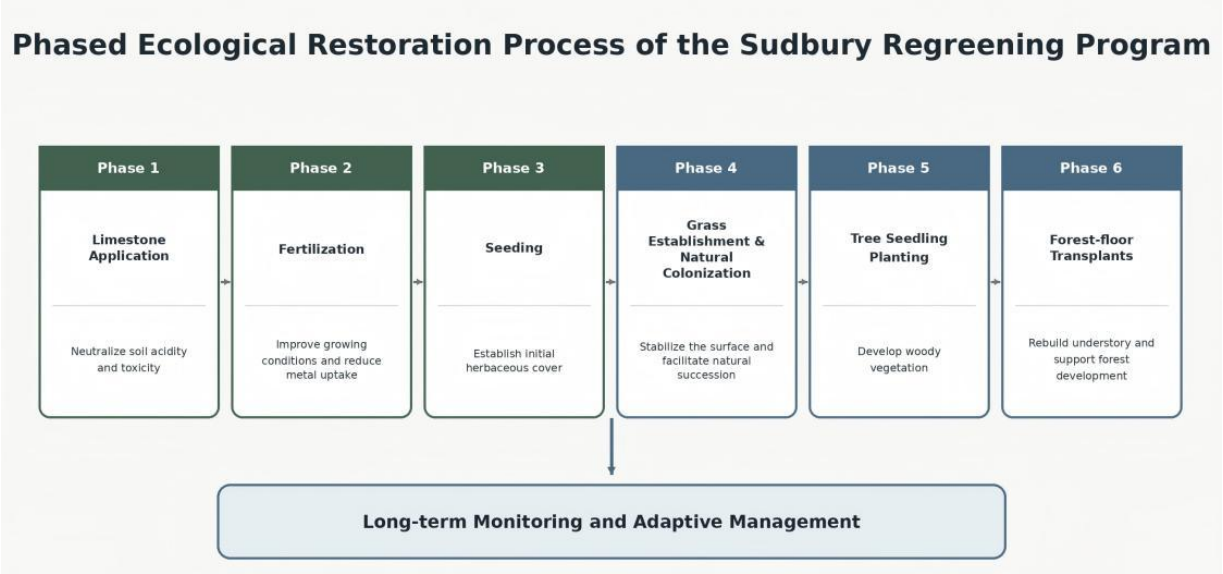


Figure A9 Phased Ecological Restoration Process of the Sudbury Regreening Program

Source: Drawn by the author based on the City of Greater Sudbury Regreening Operations.

Originally presented as Figure 3.4 in the main text.



Figure A10 Regional Landscape of Gaolishan, Jurong

Source: Cjsy2026, Wikimedia Commons, 2022, CC BY-SA 4.0.

Originally presented as Figure 4.1 in the main text.



Figure A11 Existing Mining Landform and Ecological Conditions of the Study Site

Source: Photographed by the author during the field investigation.

Originally presented as Figure 4.2 in the main text.



Figure A12 Weigang Battle Victory Monument at the Foot of Gaolishan

Source: Xinhua News Agency, 2025.

Originally presented as Figure 4.3 in the main text.

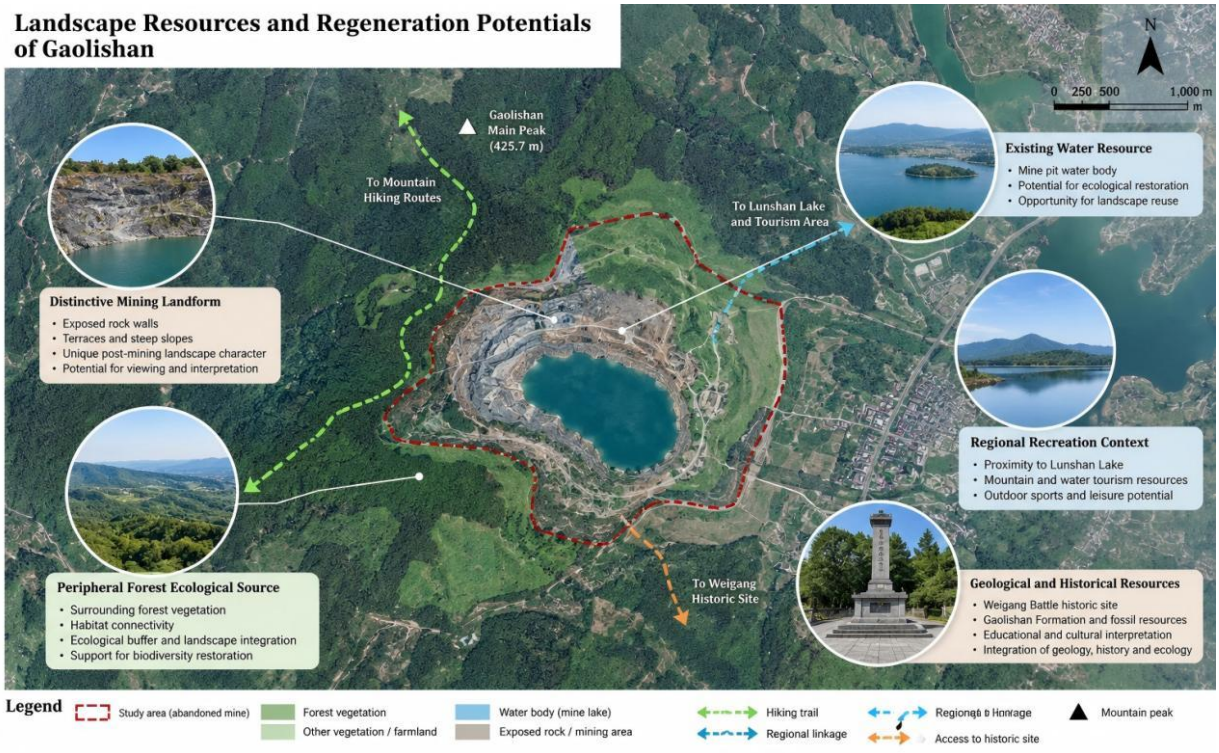


Figure A13 Landscape Resources and Regeneration Potentials of Gaolishan

Source: Drawn by the author based on Google Earth imagery, field investigation, and publicly available geological, historical and regional recreation data.

Originally presented as Figure 4.4 in the main text.



Figure A14 Overall Spatial Planning Diagram

Source: Drawn by the author.

Originally presented as Figure 5.1 in the main text.



Figure A15 Regeneration Strategy

Source: Drawn by the author.

Originally presented as Figure 5.2 in the main text.

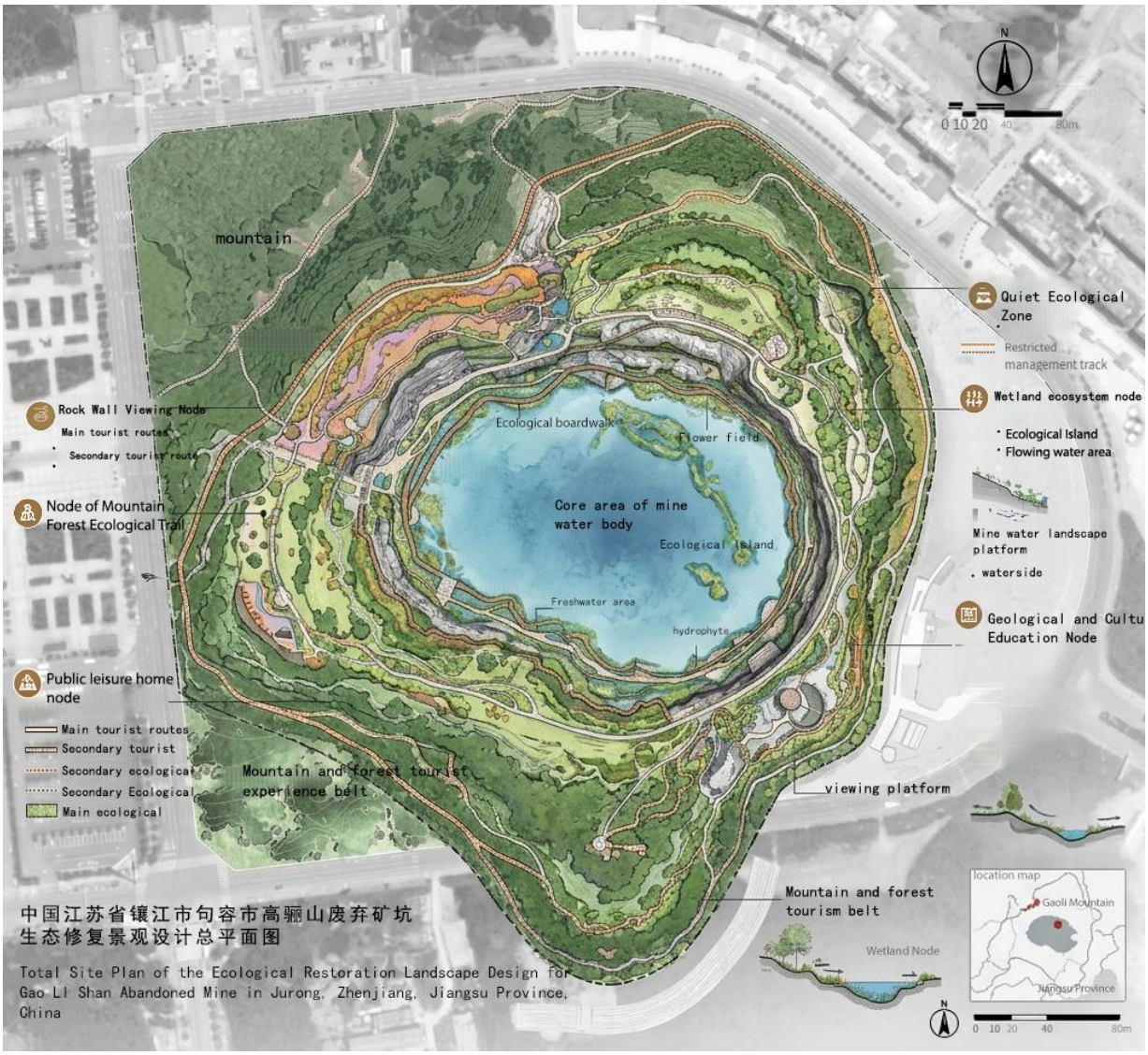


Figure A16 Total Site Plan of the Ecological Restoration Landscape Design for Gaolishan Abandoned Mine in Jurong, Zhenjiang, Jiangsu Province, China

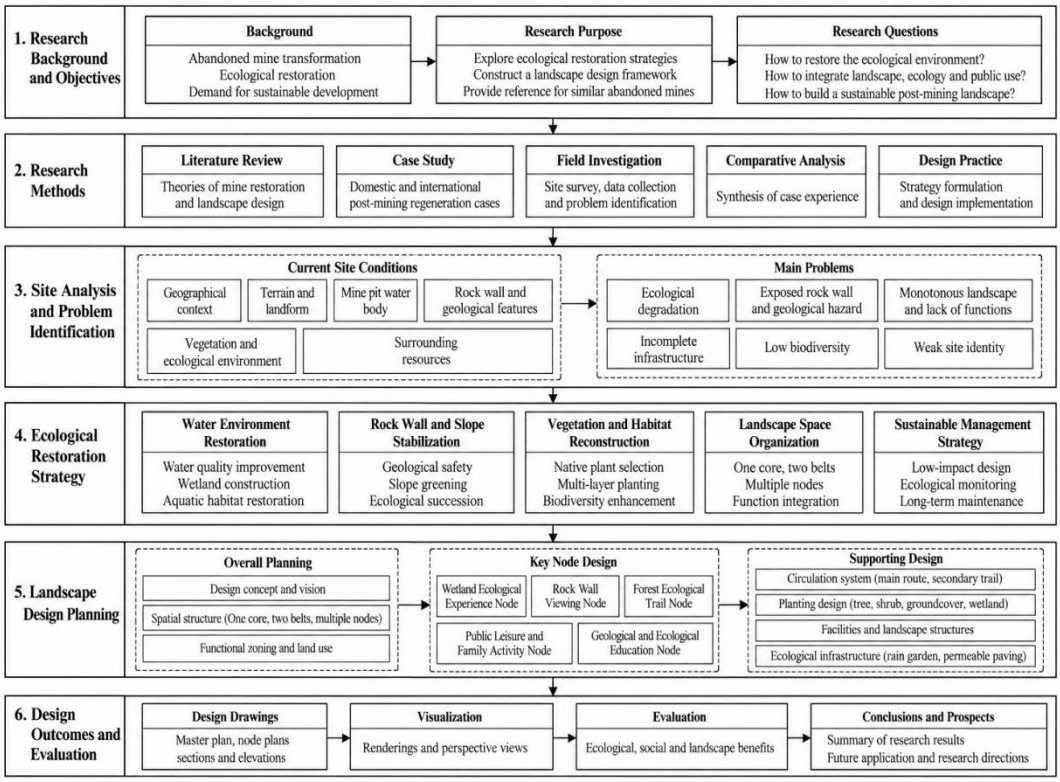
Source: Drawn by the author based on the satellite map.

Originally presented as Figure 6.1 in the main text.

APPENDIX B: Tables

Comparative Analysis	Pan'an Lake	Sudbury	Insights from Gaolishan
Primary problem	Coal mining subsidence, water accumulation, and land function degradation	Soil acidification, metal contamination, and severe vegetation degradation	First, determine the type of problem based on actual field investigations.
Core measures	Land reclamation, wetland restoration, and vegetation rehabilitation	Soil improvement, sowing, tree planting, and long-term restoration	The aquatic and terrestrial ecosystems shall be addressed with targeted measures, respectively.
Water body utilization	Convert partially subsided water bodies into wetland systems.	Not a primary landscape strategy	The Gaolishan area can make optimal use of existing mine drainage water bodies.
Revegetation	Wetlands, forests, and grasslands are restored together.	Evolution from herbaceous communities to forest communities	Adopt a phased, near-natural vegetation restoration approach.
Subsequent features	Wetland conservation, science outreach, recreation, and tourism	Ecological restoration, community participation, environmental education	Integrate public functions into ecological conservation efforts.
Management characteristics	Integrating ecological governance with regional transformation	Multi-stakeholder participation and long-term monitoring	Establish a long-term ecological monitoring and management mechanism.

APPENDIX C: Technology Roadmap



APPENDIX D: Plant Analysis

B.1 Trees

No.	Plant Species	Type	Main Function & Application	Photo
01	Camphor Tree — *Cinnamomum camphora*	Evergreen Tree	Shade and microclimate improvement; courtyards and recreation areas	
02	Southern Magnolia — *Magnolia grandiflora*	Evergreen Tree	Evergreen structure and ornamental flowering; architectural spaces	
03	Ring-cupped Oak — *Quercus glauca*	Evergreen Tree	Ecological restoration and woodland structure; buffer zones	
04	Chinese Holly — *Ilex chinensis*	Evergreen Tree	Evergreen background and habitat enrichment; walking areas	
05	Japanese Zelkova — *Zelkova serrata*	Deciduous Tree	Shade and seasonal foliage; walking paths and entrances	
06	Chinese Hackberry — *Celtis sinensis*	Deciduous Tree	Ecological restoration and shade; woodland and buffer zones	
07	Chinese Sweet Gum — *Liquidambar formosana*	Deciduous Tree	Autumn foliage and seasonal landscape; scenic nodes	
08	Chinese Tallow Tree — *Triadica sebifera*	Deciduous Tree	Seasonal color and waterfront transition; waterside areas	
09	Ginkgo — *Ginkgo biloba*	Deciduous Tree	Autumn color and landmark planting; entrances and courtyards	
10	Flowering Cherry — *Prunus serrulata*	Flowering Tree	Spring flowering and seasonal interest; walking and courtyard areas	

No.	Plant Species	Type	Main Function & Application	Photo
11	Black Locust — *Robinia pseudoacacia*	Restoration Tree	Rapid revegetation and soil stabilization; mine slopes	
12	Chinese Arborvitae — *Platycladus orientalis*	Evergreen Tree	Drought tolerance and slope stabilization; exposed slopes	
13	Paper Mulberry — *Broussonetia papyrifera*	Restoration Tree	Pioneer revegetation and rapid canopy establishment; restoration areas	
14	Siberian Elm — *Ulmus pumila*	Deciduous Tree	Soil stabilization and ecological restoration; mine slopes	
15	Dawn Redwood — *Metasequoia glyptostroboides*	Wetland Tree	Waterfront woodland and seasonal scenery; wetland areas	
16	Pond Cypress — *Taxodium ascendens*	Wetland Tree	Wetland restoration and habitat creation; shallow-water areas	
17	Chinese Wingnut — *Pterocarya stenoptera*	Wetland Tree	Bank stabilization and shade; waterfront zones	
18	Weeping Willow — *Salix babylonica*	Wetland Tree	Waterfront shade and bank protection; lakeside areas	

The tree selection follows the plant categories and application areas established in the thesis, particularly the distinction between evergreen, deciduous, drought-tolerant and wetland trees.

B.2 Shrubs & Groundcovers

No.	Plant Species	Type	Main Function & Application	Photo
19	Chinese Crabapple — Malus spectabilis	Flowering Plant	Spring flowering and seasonal interest; walking and courtyard areas	

No.	Plant Species	Type	Main Function & Application	Photo
20	Crape Myrtle — Lagerstroemia indica	Flowering Shrub	Summer flowering; recreation and courtyard areas	
21	Azalea — Rhododendron simsii	Flowering Shrub	Woodland-edge flowering; shaded walking areas	
22	Hydrangea — Hydrangea macrophylla	Flowering Shrub	Seasonal flowering and understory planting; courtyard areas	
23	Firethorn — Pyracantha fortuneana	Slope Shrub	Soil stabilization and habitat creation; mine slopes	
24	Shrub Bushclover — Lespedeza bicolor	Slope Shrub	Erosion control and pioneer restoration; degraded slopes	
25	False Indigo Bush — Amorpha fruticosa	Slope Shrub	Soil improvement and erosion control; restoration areas	
26	Chaste Tree — Vitex negundo var. heterophylla	Slope Shrub	Drought-tolerant revegetation; rocky slopes and buffer zones	
27	Red-barked Dogwood — Cornus alba	Shrub	Seasonal stem color and waterside planting; waterfront zones	
28	Greenstem Forsythia — Forsythia viridissima	Flowering Shrub	Spring flowering and woodland-edge planting; walking areas	
29	Fragrant Plantain Lily — Hosta plantaginea	Groundcover	Shaded groundcover and soil protection; understory areas	
30	Bermuda Grass — Cynodon dactylon	Groundcover	Rapid ground coverage and erosion control; restored slopes	
31	Tall Fescue — Festuca arundinacea	Groundcover	Slope revegetation and soil stabilization; restoration areas	
32	Japanese Zoysia — Zoysia japonica	Groundcover	Erosion control and lawn establishment; slopes and activity lawns	

For the mine-slope restoration areas, the thesis specifically proposes Firethorn, Bushclover, False Indigo Bush and Vitex, combined with Bermuda Grass, Tall Fescue and Japanese Zoysia to establish vegetation cover and improve slope stability.

B.3 Wetland & Aquatic Plants

No.	Plant Species	Type	Main Function & Application	Photo
33	Common Reed — Phragmites australis	Emergent Plant	Water purification and habitat creation; constructed wetlands	
34	Oriental Cattail — Typha orientalis	Emergent Plant	Water purification and wetland restoration; shallow-water zones	
35	Sweet Flag — Acorus calamus	Emergent Plant	Water purification and shoreline planting; wetland edges	
36	Iris — Iris spp.	Wetland Plant	Seasonal flowering and waterfront transition; wetland edges	
37	Indian Shot — Canna indica	Wetland Plant	Ornamental flowering and wetland planting; waterfront nodes	
38	Sacred Lotus — Nelumbo nucifera	Aquatic Plant	Aquatic habitat and summer flowering; shallow-water areas	
39	Water Lily — Nymphaea spp.	Floating-leaved Plant	Water-surface planting and aquatic habitat; landscape ponds	

The wetland planting system in your thesis uses reeds, cattails, sweet flag, iris and canna as wetland plants, together with lotus and water lilies, while wetland trees create the transition between terrestrial and aquatic habitats.

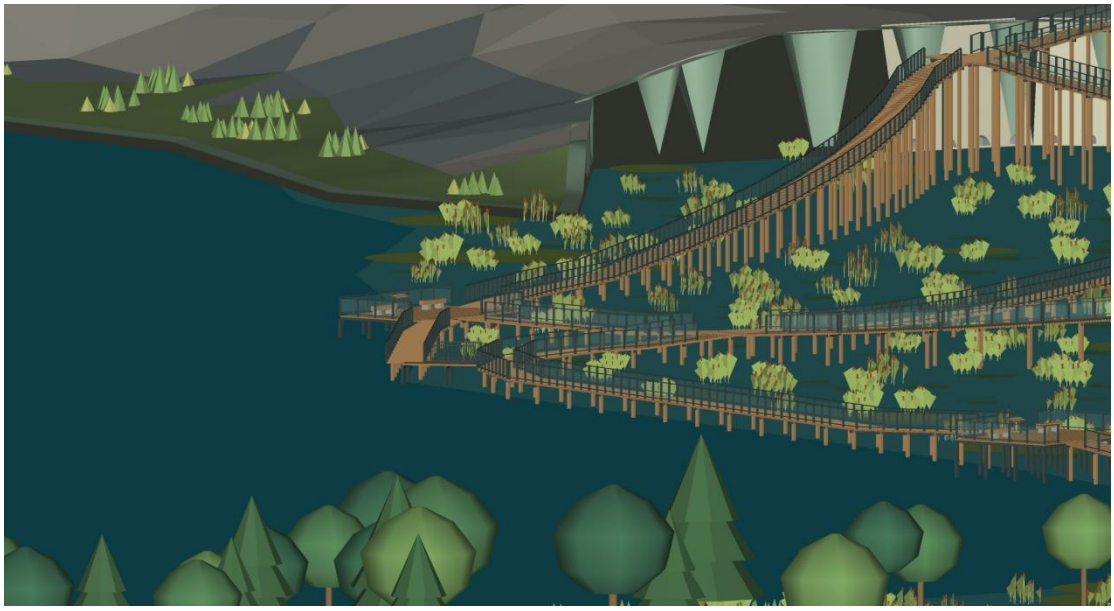
APPENDIX E: Design Model Diagram



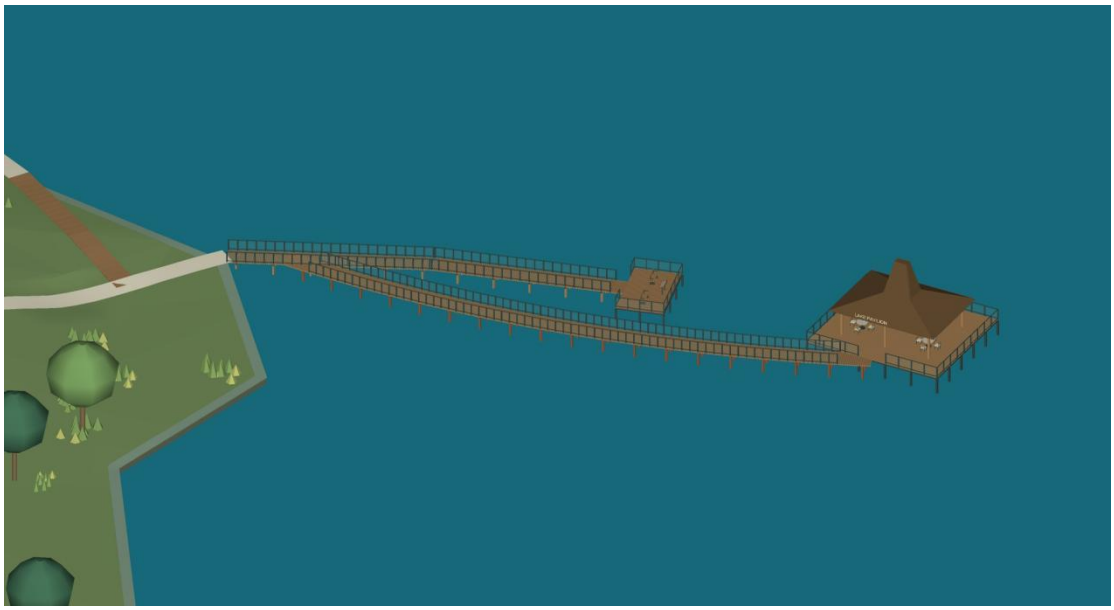
Project Color Plan



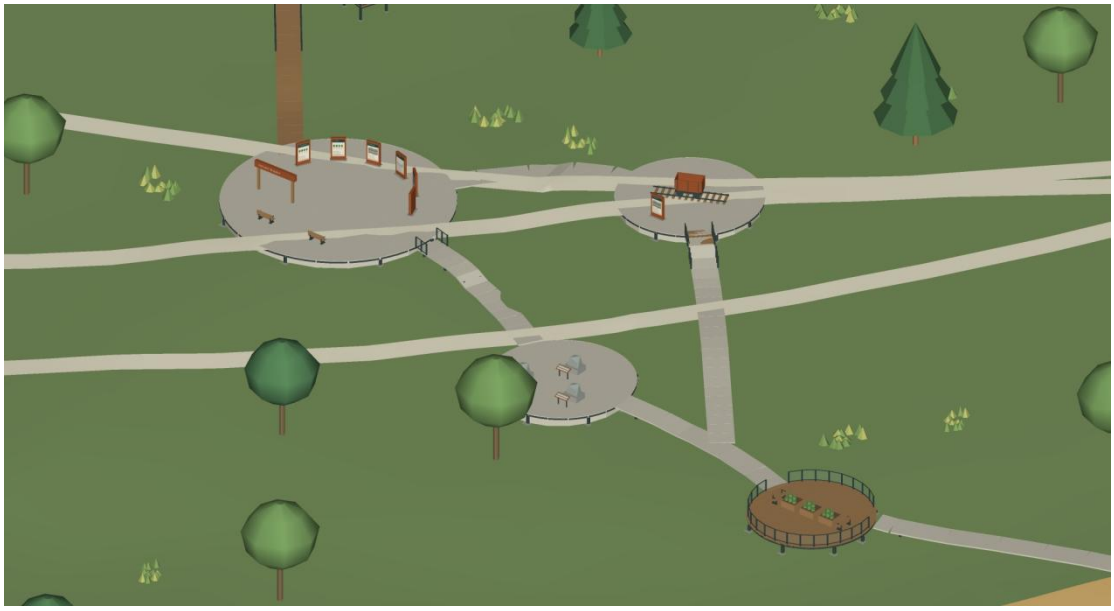
Project Bird's-eye View



Model diagram of waterfront boardwalk



Model diagram of waterfront viewing platform



Geological Education Landscape Wall Model Diagram (1)



Geological Education Landscape Wall Model (2)



Model diagram of children's natural play area



Model diagram of pink, black, messy grass, flower field



Model diagram of forest boardwalk



Camping Site Model Diagram



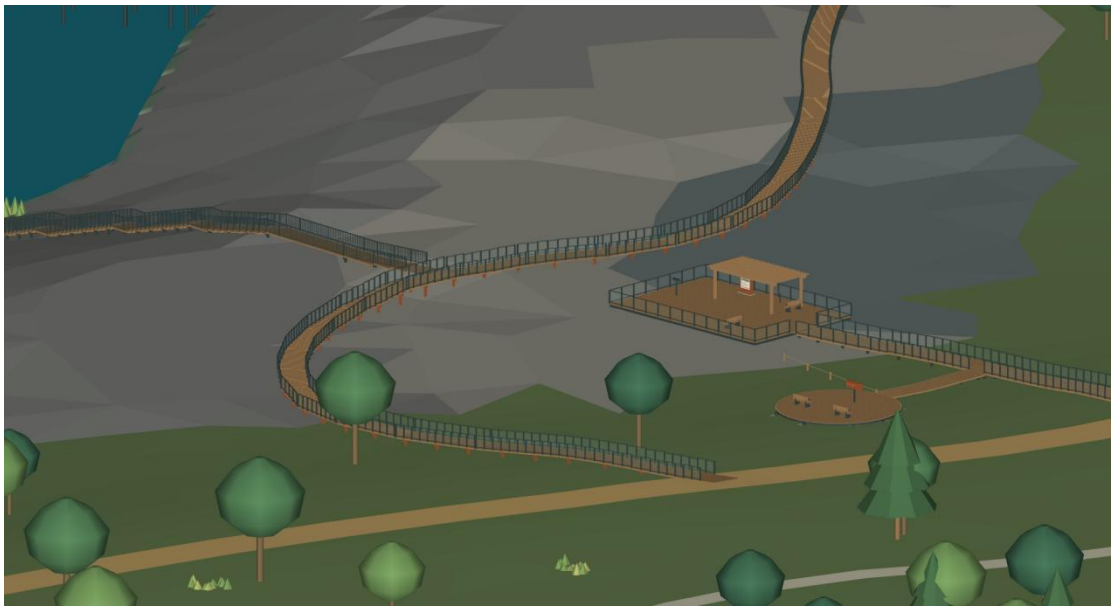
Model diagram of grass mound leisure area



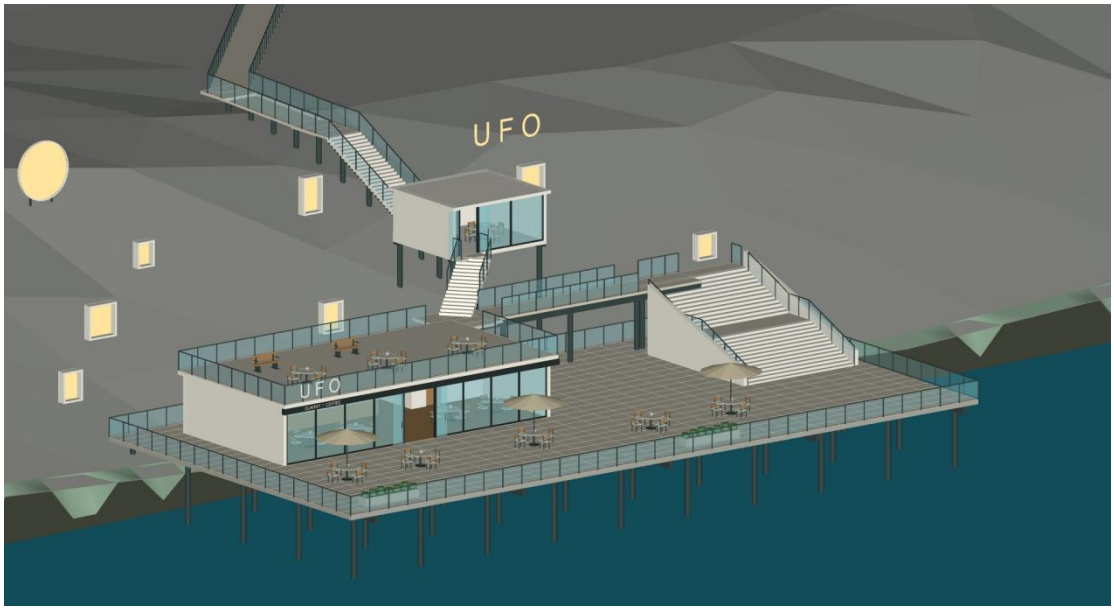
Wetland boardwalk model diagram



Model diagram of understory rest platform



Model diagram of rock wall viewing trail



Rock View Cafe Model（1）



Rock View Cafe Model （2）

APPENDIX F : Rendering presentation



Floor plan



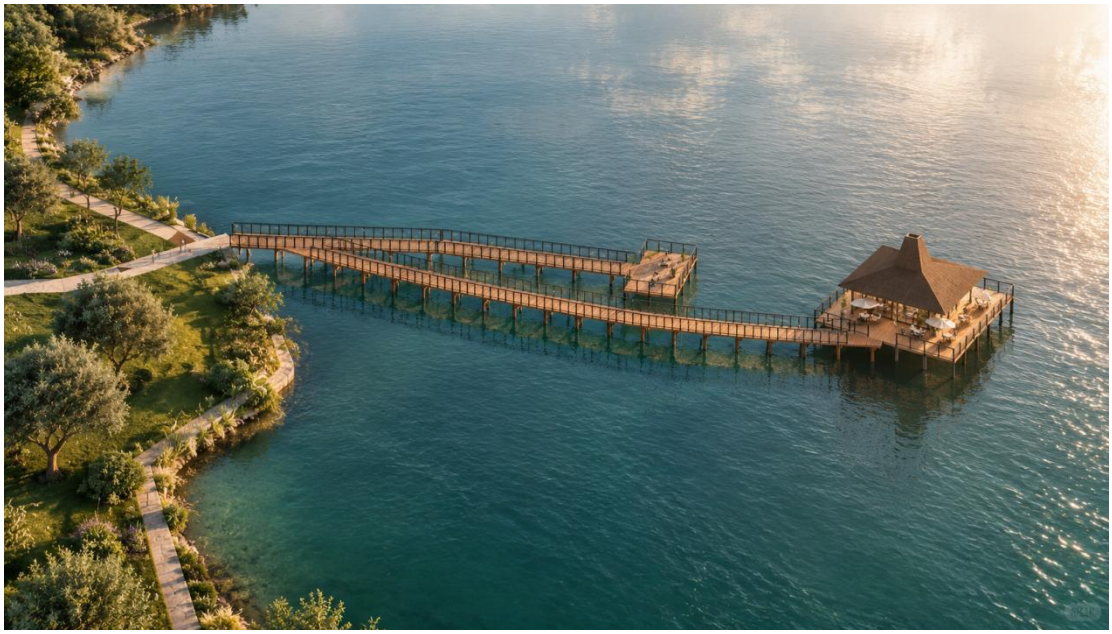
Geological Education Landscape Wall (1)



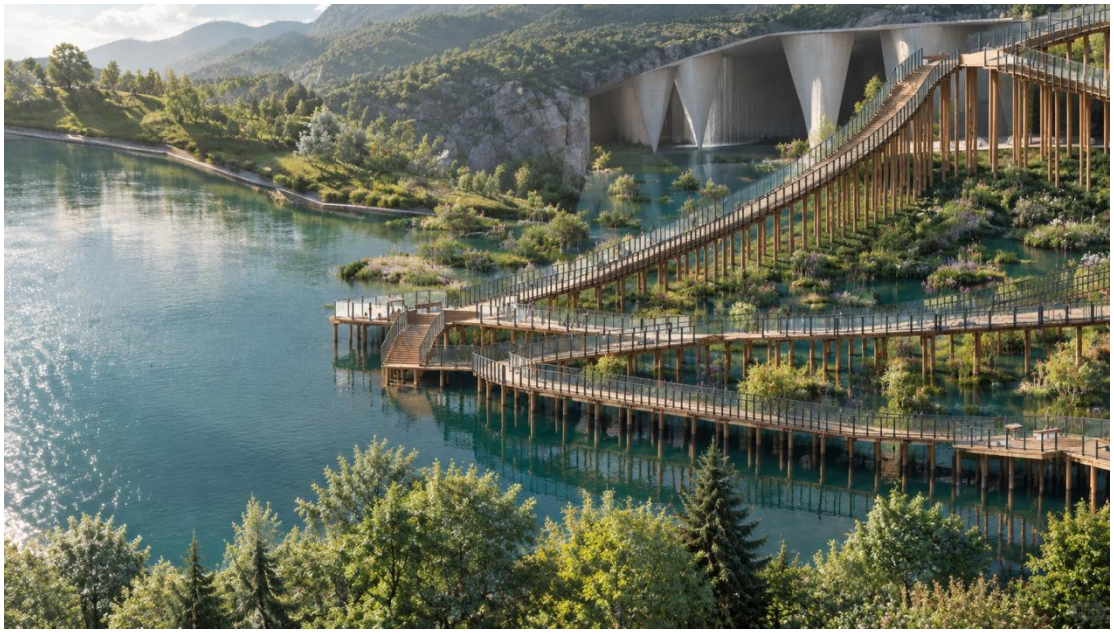
Geological Education Landscape Wall (2)



Geological Education Landscape Wall (3)



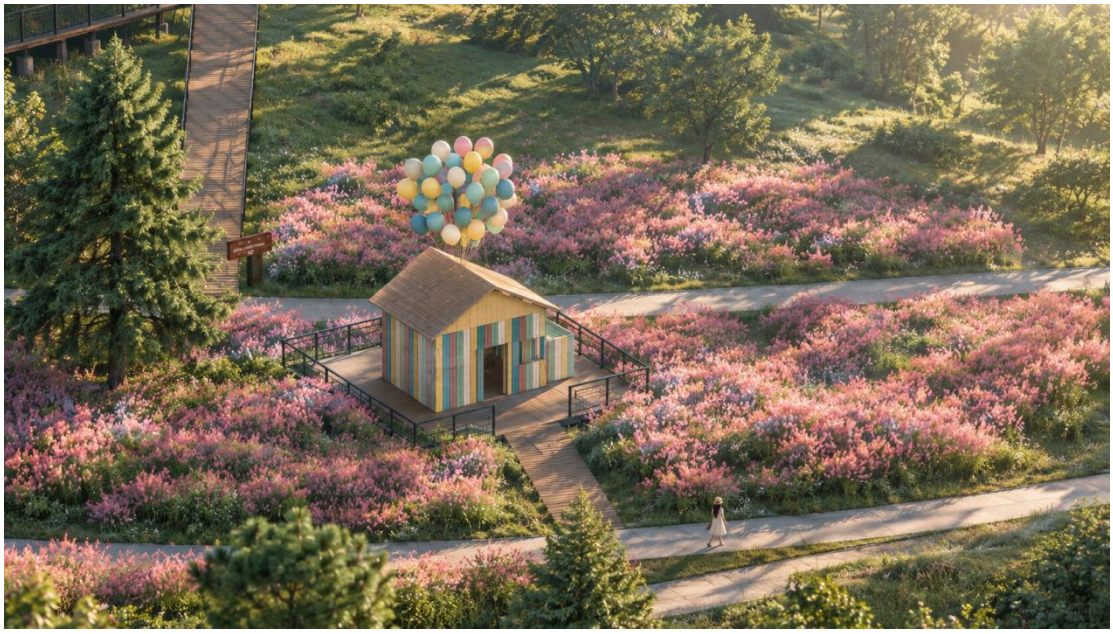
Waterfront viewing platform



Waterfront boardwalk



Children's natural play area



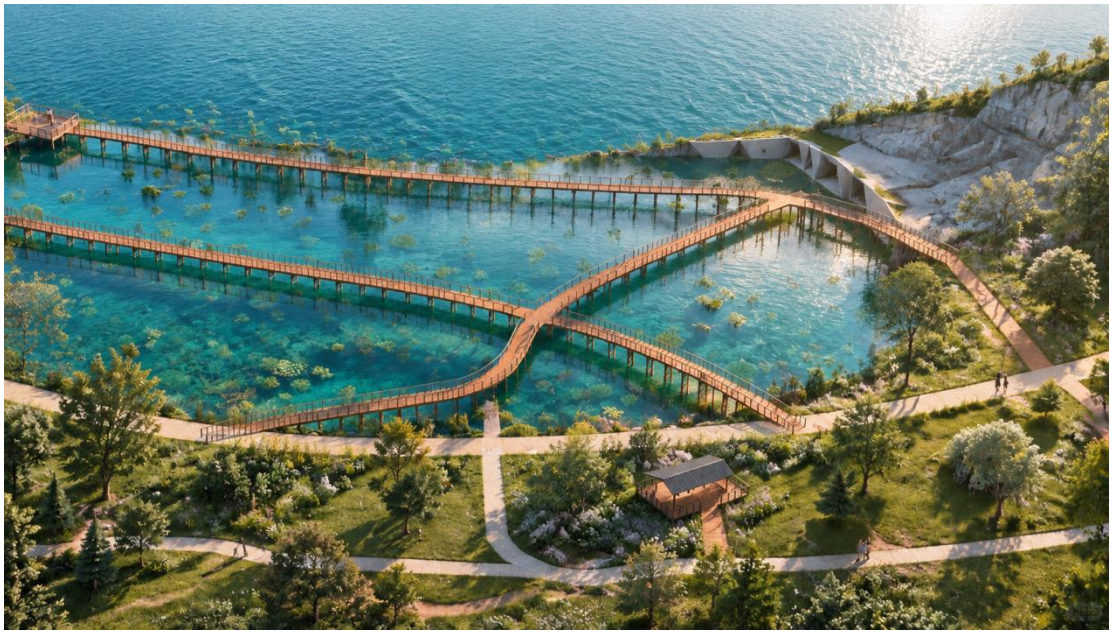
Pink, black, messy grass, flower field



Camping Site



Grass mound leisure area



Wetland boardwalk



Understory rest platform



Rock wall viewing trail



Rock Wall Observation Deck



Rock View Cafe