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INDUSTRIAL DEVELOPMENT ORGANIZATION

Technical Guidelines for the
Development of Small Hydropower Plants

DESIGN

Part 8: Social and Environmental Impact Assessment

SHP/TG 002-8:2019

DISCLAIMER

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Further recommendations and suggestions for application for the update would be highly welcome.

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Foreword

The United Nations Industrial Development Organization (UNIDO) is a specialized agency under the United Nations system to promote globally inclusive and sustainable industrial development (ISID). The relevance of ISID as an integrated approach to all three pillars of sustainable development is recognized by the 2030 Agenda for Sustainable Development and the related Sustainable Development Goals (SDGs), which will frame United Nations and country efforts towards sustainable development in the next fifteen years. UNIDO's mandate for ISID covers the need to support the creation of sustainable energy systems as energy is essential to economic and social development and to improving quality of life. International concern and debate over energy have grown increasingly over the past two decades, with the issues of poverty alleviation, environmental risks and climate change now taking centre stage.

INSHP (International Network on Small Hydro Power) is an international coordinating and promoting organization for the global development of small hydropower (SHP), which is established on the basis of voluntary participation of regional, subregional and national focal points, relevant institutions, utilities and companies, and has social benefit as its major objective. INSHP aims at the promotion of global SHP development through triangle technical and economic cooperation among developing countries, developed countries and international organizations, in order to supply rural areas in developing countries with environmentally sound, affordable and adequate energy, which will lead to the increase of employment opportunities, improvement of ecological environments, poverty alleviation, improvement of local living and cultural standards and economic development.

UNIDO and INSHP have been cooperating on the World Small Hydropower Development Report since year 2010. From the reports, SHP demand and development worldwide were not matched. One of the development barriers in most countries is lack of technologies. UNIDO, in cooperation with INSHP, through global expert cooperation, and based on successful development experiences, decided to develop the SHP TGs to meet demand from Member States.

These TGs were drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of these TGs may be subject to patent rights. UNIDO and INSHP shall not be held responsible for identifying any such patent rights.

Introduction

Small Hydropower (SHP) is increasingly recognized as an important renewable energy solution to the challenge of electrifying remote rural areas. However, while most countries in Europe, North and South America, and China have high degrees of installed capacity, the potential of SHP in many developing countries remains untapped and is hindered by a number of factors including the lack of globally agreed good practices or standards for SHP development.

These Technical Guidelines for the Development of Small Hydropower Plants (TGs) will address the current limitations of the regulations applied to technical guidelines for SHP Plants by applying the expertise and best practices that exist across the globe. It is intended for countries to utilize these agreed upon Guidelines to support their current policy, technology and ecosystems. Countries that have limited institutional and technical capacities, will be able to enhance their knowledge base in developing SHP plants, thereby attracting more investment in SHP projects, encouraging favourable policies and subsequently assisting in economic development at a national level. These TGs will be valuable for all countries, but especially allow for the sharing of experience and best practices between countries that have limited technical know-how.

The TGs can be used as the principles and basis for the planning, design, construction and management of SHP plants up to 30MW.

- The Terms and Definitions in the TGs specify the professional technical terms and definitions commonly used for SHP Plants.
- The Design Guidelines provide guidelines for basic requirements, methodology and procedure in terms of site selection, hydrology, geology, project layout, configurations, energy calculations, hydraulics, electromechanical equipment selection, construction, project cost estimates, economic appraisal, financing, social and environmental assessments—with the ultimate goal of achieving the best design solutions.
- The Units Guidelines specify the technical requirements on SHP turbines, generators, hydro turbine governing systems, excitation systems, main valves as well as monitoring, control, protection and DC power supply systems.
- The Construction Guidelines can be used as the guiding technical documents for the construction of SHP projects.
- The Management Guidelines provide technical guidance for the management, operation and maintenance, technical renovation and project acceptance of SHP projects.

Technical Guidelines for the
Development of Small Hydropower Plants

DESIGN

Part 8: Social and Environmental Impact Assessment

1 Scope

This part of the Design Guidelines sets out the general principles, contents and requirements for an environmental impact assessment of an small hydropower (SHP) construction project. As countries typically have robust policies inplace for social impact assessment, resettlement and soil and water conservation impact assessment, specialstudies are usually carried out by the departments designated by the country; this document only providesgeneral technical guidance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

SHP/TG 001, *Technical guidelines for the development of small hydropower plants —Terms and definitions.*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in SHP/TG 001 apply.

4 Environmentalimpact assessment

4.1 Assessment basis and requirements

4.1.1 Basis of formulation

The environmental impact assessment shall be carried out mainly in accordance with the relevant laws, regulations, provisions, technical standards and specifications of the country, as well as the planning and engineering technical documents relating to the relevant basin or area.

4.1.2 Assessment factor and assessment standard

4.1.2.1 Assessment factors

Environmental impact assessment factors shall be selected on the basis of the technical standard and management requirements for water environment, acoustic environment, air environment and soil, as wellas for socioeconomic requirements, in order to determine the assessment standards. The assessment factors should be selected in accordance with the following principles:

a) Surface water environmental assessment factors shall include water quality index, such as DO, pH, COD_{Mn}, BOD_5, NH_3-N, TN, TP, petroleum, and coliform group, and hydrologic runoff index, such as water surface area, water retention capacity, water temperature, runoff process, water depth, flow rate, and change of scour and silting, according to water function.

b) Appropriate underground water environmental assessment factors should be underground water level, pH, nitrite, volatile phenol, ammonia nitrogen, arsenic, permanganate index, mercury, nitrate and hexavalent chromium.

c) Appropriate acoustic environmental assessment factors shall be equivalent to continuous sound level LEQ (A).

d) Appropriate air environmental assessment factors should be CO, $NO_{2,}$ PM_{10}, TSP.

e) Appropriate soil environmental assessment factors should be pH, TP, TN, organic matters.

4.1.2.2 Assessment standards

The environmental impact assessment standards are divided into environmental quality assessment standards and pollution discharge standards, which shall comply with the quality control standards of the country and region.

4.1.3 Assessment levels and assessment scope

The environmental impact assessment levels and scope shall be selected on the basis of the scope and extent of both the engineering direct impact, scope and extent, as well as possible indirect impact, scope and extent, in accordance with the classification criteria in the relevant technical specifications.

The assessment scope shall be determined on the basis of the assessment levels of different environmental elements.

4.1.4 Assessment focus

The focus of the social and environmental impact assessment shall be determined on the basis of the engineering characteristics, pollution discharge characteristics, and the operation mode and sensitivity of the environment protection objectives. Generally, the assessment mainly focuses on the barrier of engineering construction to river ecological system, runoff regulating effect and incurred influence on water environment and ecological environment.

4.1.5 Protection objectives

Environment protection objectives shall meet the following requirements:

a) Ecological environment protection objectives: This shall be defined on the basis of the current ecological environment status within the construction area and the protection requirements of the environmentally sensitive regions, including species, community and diversity protection objectives for both terrestrial ecology and aquatic ecology.

b) Water environment protection objectives: This shall be defined on the basis of the water quality and the water volume requirements within the construction area and upstream and downstream water environmentally sensitive regions.

c) Atmospheric environment protection objective: This shall be defined on the basis of the current (ambient air)atmospheric environment status within the construction area and the protection requirements of atmospheric environmentally sensitive regions.

d) Acoustic environment protection objective: This shall be defined on the basis of the current acoustic environmental status within the construction area and the protection requirements of acoustic environmentally sensitive regions.

4.2 Engineering analysis

4.2.1 Engineering analysis shall cover conformity of the project with the relevant laws and regulations and planning, engineering environment rationality analysis, construction analysis, project land occupation and resettlement analysis, project operation analysis, and identification and selection of environmental impacts.

4.2.2 Major social and environmental protection laws and regulations, resources utilization and industrial policies and planning associated with the project, shall be delineated and their conformity, and coordination, with these documents, policies and plans shall be analysed.

4.2.3 Environmental rationality analysis shall be undertaken from the perspective of general layout, development mode, water reservoir dam location, dam model, stock yard, spoil area, operation dispatching mode and the satisfaction with ecological flow,and a recommended an alternative scheme shall be proposed. If the basin is under cascade development, the feasibility and necessity for the project to coordinatewith the existing SHP projects shall be analysed from perspectives such as operation mode, ecological scheduling and requirements and ecological restoration measures for degraded river sections.

4.2.4 The construction analysis shall meet the following requirements:

a) Estimate the volume of spoilon the basis of earth-rock excavation and backfill, and analyse the impact of spoil transportation and piling on the surrounding environment on the basis of the spoil area arrangement and spoil disposal plan.

b) Analyse the intensity and impact scope of noise sources on the basis of construction machinery and vehicle transportation, and analyse the impact of construction vehicle transportation on the lives and traffic of local residents in the area.

c) Estimate the discharge quantities of live sewage, live garbage and production wastewater on the basis of the number of construction personnel and production water consumption, and analyse the possible generating approaches and impact of pollution on the basis of the surrounding environmental status.

d) Analyse the impact caused by construction on irrigation, water supply, aquatic ecology and traffic transportation, on the basis of construction diversion and general layout.

e) Analyse the impact approaches and scope of the construction on environmentally sensitive objects and the impacts on surface vegetation, topsoil and water loss, on the basis of construction land occupation and surface disturbance.

f) Analyse the impact of construction activities on the habitats in environmentally sensitive areas and on the main flora and fauna in the region.

4.2.5 Analyse the possible social and environmental impact factors on the basis of inundation and land occupation, resettlement mode and migrant construction personnel. Analyse social and environmental constraints if the construction involves environmentally sensitive areas, religious areas, national, interstate and international relationships, folk culture, cultural relics and landscape.

4.2.6 Analyse the impact of the construction on ecological, industrial and agricultural water consumption, water environment, existing hydropower station operation and scheduling, and the downstream ecological environment, on the basis of changes in the distribution of water resources, hydrological and sediment conditions and urban obstructions.

4.2.7 List all the environmental elements and factors which may be affected by the construction, and which have been restricted or affected by the existing projects or current environmental status, and identify the nature and extent of such impacts; categorize the main environmental elements and factors on the basis of the identification of environmental impacts, and take them as important inputs for prediction and assessment.

The environmental impacts may be identified and sorted with methods such as the analogy the analysis method, the matrix method and expert opinions.

4.2.8 The project environmental impact assessment grade can be divided into the following three levels according to the type, location, sensitivity and scale of the project, as well as the characteristics and size of potential environmental impact:

Level 1: the project will have significant adverse environmental impacts that may extend beyond the scope of the project site or facilities. It's environmental assessment shall include: analysis of the potential positive and negative environmental impacts of the project; a comparison with other viable alternatives (including a "no project" option); proposals of various measures to prevent, reduce, mitigate or compensate adverse impacts and improve environmental performance; and preparation of environmental impact assessment reports.

Level 2: the adverse environmental impact of the project on people or important environmental areas, including wetlands, forest, grasslands and other natural habitats, is less than Level 1, and the scope of impact is limited to the project site. The environmental assessment shall include the potential positive and negative environmental impacts of the project and shall propose measures that can be used to prevent, reduce, mitigate or compensate for adverse impacts and improve environmental performance.

Level 3: after environmental screening, the project has little or no adverse impact on the environment, and no further environmental assessment is required.

4.3 Survey and assessment of currentstatus quo

4.3.1 The present environmental status survey and assessment shall include the regional present environmental status survey and assessment, the present environmental quality status survey and assessment, and present regional pollution source survey and assessment.

4.3.2 The regional present environmental status survey and assessment shall include the following:

a) Topographical and geological survey, including topographical characteristics and types, geological structure, formation lithology, collapse, landslide, debris flow and other unfavorable geological phenomena.

b) Meteorological survey, including annual precipitation and its annual distribution, annual evaporation, wind intensity, predominant wind direction, extreme temperatures, rainstorm and other severe weather characteristics.

c) Hydrographic and sediment survey, including runoff and its composition, monthly average flow rate, monthly average sediment content, sediment grains gradation, lean flow and flood characteristics;

d) River system survey, including surface water hydrological characteristics, division of water systems, basin and sub-basin characteristics, water environment function zoning, water quality and water resources utilization, as well as the relationship between the main works of the project and the water system in the construction area. A surface water hydrographical chart shall be provided. If the upstream and downstream rivers involve reduced and dry river sections, the length, scope, cause, and restoration of such sections shall also be surveyed.

e) Soil survey, including soil type, physical/chemical nature, and fertility of the soil.

f) Terrestrial organism survey, including the types, distribution, coverage, and dominant species of vegetation and the distribution and physiological and ecological habits of rare and endangered animals/plants; aquatic organism survey, including the composition and dominant species of fish, living habits of migratory fish, distribution of spawning grounds, types, quantity, habits, habitat distribution and protection levels of rare aquatic organisms in the waters affected by the construction.

g) Environmental sensitive area survey, including types, levels, geographic positions, scopes, function zoning, protection objects, protection requirements, and spatial relationships with the main works, as well as seismic history/disaster or natural calamity history.

h) Water and soil loss survey, including types, cause, soil erosion modulus and treatment.

4.3.3 The present environment quality status survey and assessment shall include:

a) Surface water environment, groundwater environment, ecological environment, acoustic environment and air quality environment. Regional environment quality shall be assessed on the basis of the survey of present environment quality status to indicate the trend of environmental quality changes and totrack any changes in environment quality due to the project.

b) Present environment quality assessment shall be made by using present environment quality status monitoring or recent routine environmental monitoring data. Present environment quality monitoring shall comply with relevant environmental quality monitoring standards, environmental protection standards and technical guidance for social and environmental impact assessment.

c) Regional main environmental problems shall be surveyed and the survey shall include water and soil loss, treatment of reduced and dry river sections due to hydropower development, pollution source, effluent management and water quality compliance, river ecological protection and ecological flow rate protection. The causes of regional main environmental problems and environmental constraints shall be analysed.

4.3.4 The regional pollution source survey and assessment shall include:

a) Main pollution factors and characteristic pollution factors of environmental quality, selected as main survey objects in the surveyed region.

b) Pollution source survey, including wastewater and sewage discharging outlet, agricultural non-point (diffused) source pollution, pesticide and fertilizer use in any similar project in close proximity, as well as the main noise and air pollution sources.

4.4 Prediction and assessment

4.4.1 Basic requirements for environmental impact prediction/assessment:

a) The environmental impact prediction/assessment scope shall be determined on the basis of the assessment work level, project characteristics and environmental characteristics, as well as local environmental protection requirements.

b) Environmental impact prediction and assessment may be divided into construction period and operation period.

c) Environmental elements and factors shall be assessed on the basis of the relevant environmental standards and environmental functional requirements. For environmental elements and factors that are not covered in any environmental standards, their environmental background value and thresholds may be assessed instead.

d) During prediction assessment, it's necessary to focus on the influence of hydrological regime, water temperature and water quality, to predict the impact on river ecosystem, and propose discharge process of ecological flow of the project.

e) Environmental impact prediction/assessment may be made by using mathematical modeling methods, physical modeling methods, analogy methods, landscape ecological methods, graphic overlay methods and professional judgement.

4.4.2 The contents and method of such predictions/assessments shall comply with the following requirements:

a) If the project operation is likely to change the downstream hydrological regime, the impact of the construction on downstream living, production and ecological environment and water consumption shall be predicted. For diversion-type power generation projects or SHP stations that have a regulating water reservoir, the satisfaction of downstream ecological flow shall be analysed. The composition and determination method of ecological flow are described in Appendix A.

b) The influence of stratified reservoir construction on water temperature should be predicted, and the influence of low-temperature water discharge on downstream ecology and agriculture should be analysed.

c) For an SHP station project that is rated as "sensitive to" the groundwater environment, it's impact on the groundwater environment shall be assessed.

d) The impact of reservoir inundation and the effect of submergence on land resources, cultural relics and historic sites, folk culture and landscape resources shall be predicted.

e) When affected residents need to be resettled, the impact of such resettlement on the quality of life and employment of the affected residents, health care,education,infrastructure, religious and national customs, community reconstruction, resettlement environment quality, and water and soil loss shall be assessed.

f) The impact of inundation, land occupation, resettlement, and construction activities on wild plants and rare wild animals and habitats of endangered wild animals shall be predicted.

g) When there are rare fish, endangered fish, unique fish and migratory fish in the rivers involved in the project, the impact of project construction on such fish species shall be analysed.

h) When the project involves natural reserves and other environmentally sensitive areas, the impact on the structures and functions of the objects to be protected, scope of protection objects, protection scopes, and protected areas in such environmentally sensitive areas (zones)and the impact on the river ecological system shall be predicted.

i) When a preliminary geological survey determines that the construction may affect the environmental geology, the impact on landslides, bank collapse and other environmental geological conditions,the impact on environment shall be predicted.

j) The impact of wastewater/sewage and solid wastes, and the impact on water and soil loss, during the construction period shall be predicted.The impact of the construction on the ambient air, acoustic environment and human health shall also be predicted.

k) Analyse the impact of the project on local employment, economic development, resource utilizationand people's living conditions.

l) Areas prone to disasters and natural calamities should also be studied.

4.5 Protection measures

4.5.1 Protection measures shall be technically feasible, economically reasonable, operationally reliable and practical for achieving the environmental protection objectives.

4.5.2 Protection measures shall meet the following requirements:

a) If the project operation affects downstream habitation, production and ecological water consumption, then improvement, mitigation and compensation measures shall be proposed and the measures to be taken to ensure release of ecological flow during construction and operation periods shall be defined.

b) If the project operation affects the downstream agricultural irrigation or aquatic ecology, stratified intake measures or other water temperature restoration measures shall be set up to mitigate the influence of low-temperature water.

c) If the project affects a groundwater sensitive area, protection measures for groundwater environment protection shall be proposed.

d) If the resettlement of affected residents affects the ecological environment, ecological environment protection requirements shall be proposed.

e) If the project construction affects rare wild animals/plants, transplantation measures, animal habitat protection measures or rehabilitation measures shall be taken.

f) If the project construction affects sensitive areas such as nature reserves, reserves, sanctuaries or parks, the protection measures for avoidance measures shall be taken.

g) The impact on migratory passage of migratory fish may be addressed by building fish pass facilities and/or by artificial manual propagation and release.

h) If sewage fails to comprehensively meet these wage discharging standard during the construction period, sewage treatment measures shall be proposed.

i) Engineering measures and biological measures shall be proposed for surface restoration (to mitigate the adverse impact caused by the engineering construction)including spoil areas, to prevent water and soil loss.

j) Spraying dust suppression measures and temporary sound insulation devices, such as echo barriers,may be used to control dust and noise produced during the construction.

k) Hygiene and waste disposal measures shall be proposed on the construction site to avoid impact to human health in the construction area.

l) Risk prevention measures shall be proposed for projects which involve environmental risks.

m) With respect to the resettlement area for affected residents, the plan for improving the living conditions and reconstructing the community, as well as the measures for preventing and controlling pollution and water loss and soil erosion, shall be proposed.

n) Protective or compensation measures to protect local culture, cultural relics and historic sites, and landscape, shall be proposed.

4.6 Management and monitoring

4.6.1 Environmental management and monitoring shall be carried out during the construction and operation periods. Targeted and practicable environmental management measures, monitoring plans and environmental protection acceptance objectives for different phases of the construction project shall be proposed.

4.6.2 In light of the impact characteristics of the construction project, follow-up monitoring plans for environmental quality, pollution sources, ecological and social environmental impacts shall be formulated.

4.6.3 As for abnormal discharging and accidental discharging, especially for associated environmental risks and problems that may arise from accidental discharging, prevention and emergency response plans shall be proposed; and for construction projects with long construction periods and wide impact scopes, specific requirements for environmental supervision during the construction period shall also be proposed.

4.7 Investment and analysis of economic gains/losses

4.7.1 The social and environmental protection investment estimation shall show a clear basis, expenses and standard. Project quantities and specifications of proposed measures and their expense standards for rates shall be proposed on the basis of proposed protection measures. The total social and environmental protection investment and annual investment arrangements shall be calculated.

4.7.2 The economic value of the social and environmental impact generated from the construction project shall be estimated both qualitatively and quantitatively on the basis of its positive and negative environmental impacts, and this value shall be included in the cost-benefit analysis as a basis for judgements about the feasibility of the construction project.

4.7.3 The predicted impact after the implementation of the construction project shall be compared with the present social and environmental status. Social and environmental impact measures that are required, or possibly required, in economic assessment shall be sorted into aspects of environmental elements, resource types and social culture. The quantified social and environmental impact shall be monetized, and the results shall be included in the economic analysis of the construction project.

5 Resettlement

5.1 Physical survey of land acquisition for construction

5.1.1 The scope of land acquisition for construction includes the project construction area and reservoir submerged area.

a) The project construction area includes the construction area for permanent constructions (structures) such as the dam and power station, the land for external traffic and the management area, and the scope of permanent land acquisition, as well as the land for the material yard, waste yard, operation area, temporary roads, construction camp, material transportation and transfer station, land for other temporary facilities and the area affected by construction blasting.

b) The submerged area affected by the reservoir includes the reservoir submerged area and the area affected by the reservoir water storage. The reservoir submerged area refers to the temporary submerged area caused by the flood backwater, wind and waves, boat wave and ice jam; the reservoir impoundment affected area refers to the geological disaster area caused by reservoir impoundment, such as immersion, bank collapse, landslides, waterlogging, reservoir leakage areas and other areas affected by reservoir impoundment, such as isolated islands.

5.1.2 The designed flood standard for reservoir submerged objects is expressed with a recurrence period (year) and can be determined in accordance with Table 1.

Table 1 – Designed flood standards for different submerged objects

Submerged object	Recurrence period (year)
Cultivated land, garden land	2~5
Woodland, grassland, unused land	Normal water level
Rural residential areas and towns, general towns and general industrial and mining areas	10~20
Medium city, medium industrial and mining area	20~50

5.1.3 The physical object of land acquisition refers to the population, land, buildings (structures), other attachments, mineral resources, cultural relics and historical sites, buildings, sites, municipal engineering, public facilities and infrastructure with social utility, and national customs within the scope of land acquisition.

5.2 Resettlement planning

5.2.1 Resettlement planning includes the resettlement methods, selection and design of the resettlement sites, infrastructure and supporting facilities of municipal public utilities and protection of the reservoir area.

5.2.2 The approach to resettlement shall be in accordance with local laws and regulations; and the most suitable mode of resettlement shall be chosen based on the local natural conditions, social and economic conditions and the willingness of migrants.

5.2.3 Migrant resettlement tasks shall be reflected by the population to be resettled, including production resettlement population and relocation resettlement population.

a) Production resettlement population refers to the population who have lost land and other means of production due to the project construction and who need to rearrange their production methods.

b) Relocation resettlement population refers to the populations, and their housing, that must be relocated due to the project construction.

c) The resettlement population in the base-year shall be determined through on-site investigations and in combination with relevant local regulations.

5.2.4 The natural growth rate of the population from the survey base-year to the design level year shall be considered in the resettlement of immigrants, which can be determined according to the formula (1).

$$B=B_0(1+R)^{(n_1-n_2)} \quad \text{..} \quad (1)$$

where

B is the population at the design level year, in person;

B_0 is the population at survey base-year , in person;

n_1 is the design level year, in year;

n_2 is the survey base-year, in year.

5.2.5 The resettlement target refers to the overall level that can be achieved at the design level year after resettlement, including economic development goals and social development goals:

a) Economic development goals include *per capita* net income and *per capita* food availability.

b) Social development goals include development goals for social utilities and infrastructure in the resettlement areas.

c) Generally, the resettlement objectives shall be determined in line with the principle that the production and living standards of the resettled immigrants have reached or exceeded the original level before the relocation.

5.3 Compensation investment

5.3.1 The calculation of compensation investment is based on the relevant laws and regulations of the country and local government, and the results of physical surveys of land acquisition and resettlement planning for construction, includingmainly compensation and subsidies, project construction fees and other expenses.

5.3.2 Compensation subsidies mainly include land compensation and resettlement fees, temporary acquisition land compensation fees, housing and ancillary building compensation, compensation for house decoration, plant compensation, forest compensation, agricultural and sideline facilities compensation fees, industrial enterprise compensation fees, relocation allowances, poor-migrant housing subsidies, culture and education and health subsidies, and relocation transitional allowance.

5.3.3 The project construction fee includes infrastructure projects and professional projects, protection projects, reservoir bottom cleaning and other costs in the resettlement area.

5.3.4 Other expenses include pre-work fees, comprehensive survey and design fees, consulting service fees, technical training fees and taxes.

6 Soil and water conservation

6.1 Objectives and requirements of soil and water loss prevention and control

6.1.1 Scope of land disturbance for project construction, including permanent and temporary land acquisition and other land managed and used.

6.1.2 Objectives of soil and water loss control include:

a) Human disturbance to the original landform shall be minimized;

b) Soil and water loss caused by project construction shall be effectively controlled;

c) The abandoned slag shall be stored in the slag yard and protective measures shall be taken;

d) After the completion of construction, except for permanent structures and water surface, other lands shall be restored to vegetation or original land-use functions;

e) Vegetation shall be restored in areas where vegetation can be restored.

6.2 Measures system for soil and water loss prevention and control

The prevention and control measures for soil and water loss mainly include slag retaining projects, slope protection projects, land improvement projects, flood control and drainage projects, precipitation and seepage storage projects, wind prevention and sand control projects, vegetation restoration and construction projects and temporary projects. Corresponding prevention and control measures shall be taken according to the context of the particular construction project in question.

6.3 Investment in water and soil conservation

The cost in water and soil conservation includes engineering measures costs, plant measures costs, temporary measures costs, miscellaneous costs and other costs stipulated by the country.

7 Social impact assessment

Social impact assessment is mainly reflected by public participation.

The survey of the social environment shall include the population, land, employment, income, public facilities, public health amenities, religion and nationality, community structure, cultural relics and historic sites, and landscape resources in the affected area.

Social environment protection objectives shall be defined on the basis of the local living standards, religious and national customs, community structures, cultural relics, landscape protection requirements and protection of rights of the people under direct or indirect influence of the proposed project.

The public participation shall involve the affected residents and organizations (stakeholders), competent authorities, experts and social organizations. The method and procedure to consult of stakeholders (including resettled inhabitants and residents of resettlement areas) shall be determined. Opinions gathered from public participation shall be analysed, the main conclusions shall be drawn, and decisions taken as to whether the opinions should be adopted or not, and the reasons for the same shall be clarified.

8 Conclusion of assessment and advice

On the basis of an assessment summary, the relationship between production and living activities in this construction project and local community and environment during different implementation phases shall be summarized concisely, accurately and objectively; the social and environmental impact of the construction project under normal and specific circumstances shall be clarified; protection measures shall be proposed; conclusions from public participation shall be considered; and a conclusion as to whether the construction project is feasible from the perspective of social and environmental protection shall be arrived at.

Appendix A
(Normative)
Calculation method of ecological flow of SHP station

A.1 Water demand necessary for maintaining stability of aquatic ecological system

The water demand necessary for maintaining the stability of an aquatic ecological system can be calculated by using the hydrological method, the hydraulics method, the combination method, the comprehensive method and the ecological hydraulic method.

A.1.1 Hydrological method

The hydrological method is used to determine the water demand of a river ecological environment from simple hydrographic indicators on the basis of historical flow rate. The most commonly used representative methods include, the Tennant method and the minimum monthly average run-off method.

A.1.1.1Tennant method

a) Calculation method: Describe the conditions of flow in a river on the basis of the hydrological data, expressed by the annual average run-off percentage.

b) Protection objectives: Fish, aquatic birds, mammals, reptiles, amphibians, molluscs, aquatic invertebrates and all relevant life forms which compete for water with human beings.

c) Calculation standard:

Table A.1 – Flow rates of rivers with protected fish, wild animals, recreational purposes and environmental resources

Description of flow conditions	Recommended base flow (lean flow period) (per cent average flow rate)	Recommended base flow (high flow period) (per cent average flow rate)
Inundation or maximum		
Best scope	60~100	60~100
Very good	40	60
Good	30	50
Moderate	20	40
General or bad	10	30
Bad or minimum	10	10
Extremely bad	0~10	0~10

d) Basic requirements:

1) Hydrological data for different areas, different water demand purposes and different protection objects shall be carefully analysed; data on relevant river sections shall be analysed; and flow rate standards shall be adjusted to account for local river situations.

2) Aquatic organisms have different flow rate requirements in different seasons. A discharged flow duration curve for the year shall be prepared on the basis of different flow rate requirements in different months and different seasons in the ecological system, and the curve shall meet the habitat requirements of the relevant aquatic organisms.

e) Applicable conditions: The hydrological method may be used for the initial objective management and strategic management of rivers.

A.1.1.2 Minimum monthly average run-off method

a) Calculation method. The multi-year average value of minimum monthly average measured run-offs is regarded as the basic ecological environmental water demand of a river:

$$W_b = \frac{T}{n}\sum_{i=1}^{n}\min(Q_{ij})\times 10^{-8} \qquad \text{(A.1)}$$

where

W_b is the basic ecological environment water demand of river, in $10^8 m^3$;

Q_{ij} is the monthly average flow rate of Month j in Year i, in m^3/s;

n are the statistical years;

T is the conversion coefficient, for which the value is 31.536×10^6s.

b) Assumed conditions: Under this flow rate, the downstream water demand can be satisfied, and the flow of the river will not get interrupted.

c) Scope of application: Applicable to arid and semi-arid areas and rivers with complex ecological environmental objectives. The calculation result may be an overestimation if it is applied to areas with simple ecological environmental objectives.

A.1.2 Hydraulics method

The hydraulics method is a model designed for habitats requiring different types of protection. The main methods include the wetted perimeter method and the R2-CROSS method.

A.1.2.1 Wetted perimeter method

a) Calculation method: In the wetted perimeter method, wetted perimeter (See Figure A.1) is adopted as a quality indicator of habitat,and is used to draw a wetted perimeter-flow rate curve for the critical habitat area (usually shoal); it determines the recommended flow rate of the river at the turning point of the curve (See Figure A.2).

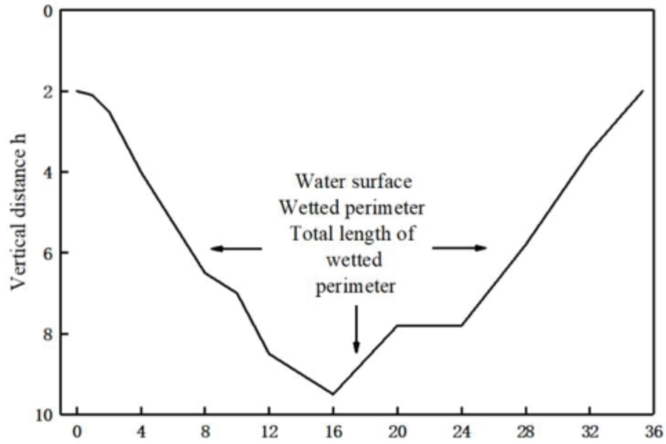

Figure A.1 – Definition of Wetted Perimeter

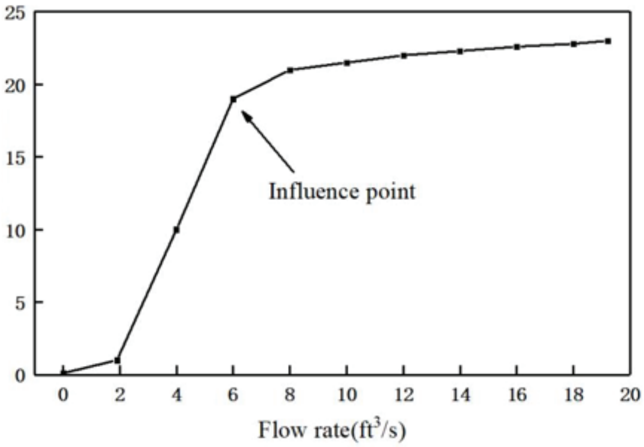

Figure A.2 – Wetted Perimeter-Flow Rate Relationship

NOTE: lft^3 (cubic feet)=0.0283168m^3

b) Constraints: The wetted perimeter method is greatly influenced by the shape of the river. For example, the curve of a triangular river does not show significant growth changes; whereas rivers where the riverbed shape varies over both distance and time cannot be represented in a stable wetted perimeter-flow rate curve and hence no reliable relationship can be established.

c) Scope of application: Applicable to wide-shallow rectangular and parabolic rivers with stable riverbed shapes.

A.1.2.2 R2-cross method

a) Calculation method: This method employs river width, average water depth, average flow rate and wetted perimeter rate as factors to evaluate the protection level of the river habitat and thus determine the river objective flow rates. In this method, the wetted perimeter rate is the percentage of a wetted perimeter of a cross section at a flow rate to the full wetted perimeter at the multi-year average flow rate.

b) Calculation standard

Table A.2 – Standard for determining minimum flow rate with the R2-cross method

River top width (m)	Average water depth (m)	Wetted perimeter rate/ per cent	Mean velocity (m/s)
0.3~6.3	0.06	50	0.3
6.3~12.3	0.06~0.12	50	0.3
12.3~18.3	0.12~0.18	50~60	0.3
18.3~30.5	0.18~0.3	≧70	0.3

c) Constraints

1) The velocities in seasonal streams cannot be reliably determined.

2) Lower precision: When parameters determined on the basis of the measured data at a particular cross section are used to represent the whole river, errors can easily occur and the calculation results can be greatly affected by the selected cross section.

3) Simple standard: The standard can be applied to both triangular rivers and wide-shallow rivers in determining hydraulic parameters.

4) Small standard scope: The maximum river width that this method can be used for is 30m.

d) Scope of application. It is applicable to small perennial rivers. It also provides the hydraulic basis for other methods.

A.1.3 Combination method (hydrological-biological analysis method)

a) Calculation method: This is a multi-variable regression statistical method that builds a relationship between the initial biometric data (species biomass or diversity) and environmental conditions (flow, flow rate, water depth, chemical contents, and temperature) to judge the organisms' demand on the flow rate of a river and the impact that a change in flow rate has on the biotic population.

b) Object of study: Fish, invertebrates (insects, crustaceans, and molluscs) and large plants (advanced plants).

c) Applicable conditions: Applicable to rivers which are less affected by human beings.

A.1.4 Ecological hydraulics method

A.1.4.1 Calculation method:

a) This is a habitat simulation method that determines the appropriate flow rate in a hydraulic habitat of aquatic organisms. It assumes that water depth, flow rate, wetted perimeter, water surface width, cross-sectional area, water surface area and water temperature are the main hydraulic habitat parameters that impact the quantity and distribution of species by flow rate change, and that torrents, slow flows, shoals and deep pools are the main hydraulic parameters for such impact.

b) The model is divided into three parts (see Figure A.3). The first part is a description of the river aquatic habitat. This module analyses the most basic requirements on water depth, flow rate and other hydraulic habitat parameters for aquatic organisms to survive; the impact of water temperature changes on aquatic organisms; and the basic requirements on torrent and other hydraulic forms for aquatic organisms to survive. The second part is a river hydraulic simulation. Thisuses 1D, 2D or 3D hydraulic models to simulate the hydraulics of the studied river section and calculates changes in the hydraulic habitat parameters of the section under differing flow rates. The first and second modules are then analysed to develop a hydraulic habitat indicator system. The third module is making decisions on the river aquatic ecological flow rate. Professionals engaged in hydrographic resources, hydraulics, environmental assessment and aquatic ecology determine the river's ecological flow on the basis of the hydraulic habitat indicator system, while also allowing for the economic uses of water, in consonance with the local socioeconomic development and policies.

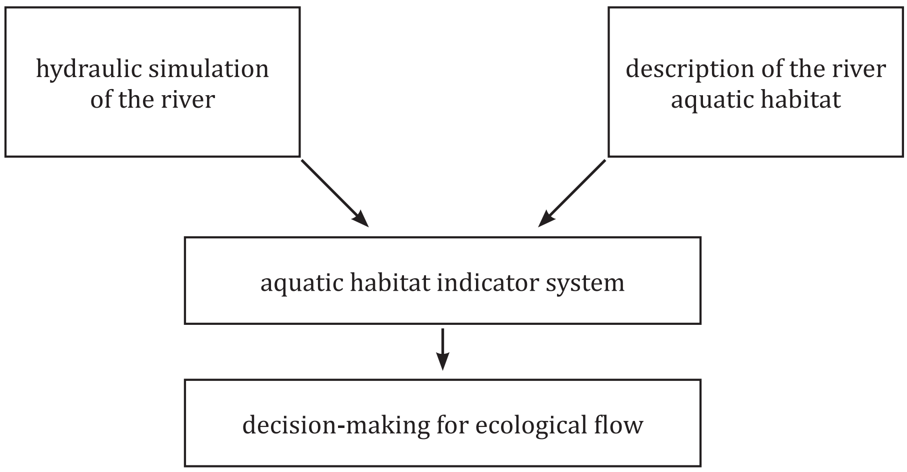

Figure A.3 – Schematic block diagram for the ecological hydraulic method

A.1.4.2 Indicator system for lean flow period:

a) Full-stream hydraulic habitat parameters: Calculate the hydraulic parameters for different sections of the river with varying lengths and determine the percentage of each river section length with respect to the length of the whole river section. This eliminates erroneous judgements based solely on the parameters of a small section of river that forms a very small percentage of the whole river length.

b) Water surface area: Calculate the water surface area under different flow rates and determine the percentage of surface area these represent relative to the multi-year average flow rate during the lean flow period.

c) Hydraulic form: Calculate the number of sections with slow flow, torrential flow, relatively torrential flow, and relatively slow flow, under different flow rates, and determine their total length and respective percentage of the total section length. Calculate the number of shoals and deep pools under different flow rates.

d) Water temperature: Establish a monthly full stream water temperature change curve; list monthly water temperatures under different flow rates at the cross sections where extreme water temperatures occur.

e) Annual changes in typical cross section water depth and other hydraulic habitat parameters: Compare variations of hydraulic habitat parameters within the year at the cross sections where large tributaries join the main stream.

A.1.4.3 Standards for indicators:

Table A.3 – Standards for determining the hydraulic habitat parameters of large rivers under minimum flow Rate with the ecological hydraulics method

Habitat parameter indicator	Minimum standard	Percentage of accumulated river section length, per cent
Maximum water depth	2~3 times body length of fish	95
Average water depth	≧0.3 m	95
Average speed	≧0.3 m/s	95
Water surface width	≧30 m	95
Wetted perimeter rate	≧50%	95
Flow crosssection area	≧30 m^2	95
Water surface area	≧70%	
Water temperature	Suitable for survival and reproduction of fish	
Habitat form indicator	Concept definition	
Torrential flow	Average flow rate ≧1 m/s	No big change in section number, the length of accumulated river length with torrential flow and relatively torrential flow is reduced < 20
Relatively torrential flow	Average flow rate 0.5~1 m/s	
Relatively slow flow	Average flow rate 0.3~0.5 m/s	
Slow flow	Average flow rate ≦0.3 m/s	
Deep pool	Maximum water depth ≧10 m	No big changes in number
Shoal	River bank slope ≦10°, water depth within 5 m scope ≦0.5 m	

A.1.4.4 Applicable conditions: Applicable for calculation of ecological flow rates of large and medium rivers. For medium rivers, the above-mentioned standard may be adjusted downwards appropriately.

A.2 Minimum diluted and purified water volume needed to maintain river water environment quality

A.2.1 7Q10 method

The average water volume that has a 90 per cent chance of lowest flow for seven consecutive days is used as the minimum river flow rate design input.

A.2.2 Stable water quality model

The river is divided into several sections adjacent to every discharging outlet. For general inland river sections, the formula of allowable pollutant discharging quantity is:

$$W_i = C_s(Q_0 + q_i) - C_0 Q_0 \exp(-\frac{Kx_i}{u}) \qquad \text{(A.2)}$$

For tidal river sections and networked sections, the formula of allowable pollutant discharging quantity is:

$$W_i = C_s(Q_0 + q_i) - C_0 Q_0[\exp(-\frac{u}{2E_x}(1-\sqrt{1+4KE_x lu^2})x_i)] \qquad \text{(A.3)}$$

As for the whole river section, the total allowable quantity of pollutants, W, is the sum of the allowable quantity of pollutants for each river section, W_i.

where

W_i is the allowable discharging quantity of pollutants for a river section i, in g/s;

C_S is the water environment quality standard for concentration of pollutants from a cross section, in mg/L;

Q_0 is the upstream incoming flow rate, in m^3/s;

q_i is the sewage flow rate of river section i, in m^3/s;

C_0 is the concentration of pollutants in water coming from upstream, in mg/L;

K is the pollutantattenuation coefficient, in d^{-1};

x_i is the combined length of river section i, in m;

u is the average flow rate of water body, in m/s;

E_x is the longitudinal dispersion coefficient, in cm^2/s.

A.2.3 Environmental functioning method

This method is used to calculate the water demand for environmental functions, such as the dilution and self-cleaning of the river,on the basis of the water quality protection standards for the river and the concentration of discharging pollutants.

Divide the river (river section) into i small sections, and assume every small section as a closed catchment area. On the basis of the water-volume balance method and water quality model, calculate the riverwater demand of each section, Q_{vi} (i=1, 2, ..., n,), and then add these together to obtain the environmental water demand for the whole river (river section). Q_{vi} shall meet the following equations:

$$\begin{aligned} Q_{vi} &\geq \lambda \times Q_{v} \\ Q_{vi} &\geq Q_{ni}(p \end{aligned} \qquad \text{(A.4)}$$

where

λ is the river-diluting coefficient;

Q_{wi} is the reasonable total sewage discharging quantity of i small sections, referring to the volume of sewage that meets the discharging standards;

Q_{ni} *(p)* is the the flow rate of i small sections under guaranteed rates (monthly guaranteed rate, e.g. p_0=90%, or p_0=80%) designed for different hydrological years (such as multi-year average, low flow year, and normal flow year).

A.3 Sediment-transport water demand for the River

$$W_i = S_i \Big/ \frac{1}{n} \sum_{i \neq 1}^{n} \max(C_{ij} \qquad \text{(A.5)}$$

where

W_i is the sedimenttransport water demand, in m^3;

S_i is the multi-yearaveragesedimentvolume, in m^3;

c_{ij} is the monthly average sediment content of Month j in Year i, in m^3;

N are the statistical years.

A.4 River evaporation water demand

$$V = H_0(A - P) \qquad \text{(A.6)}$$

where

V is the net evaporation loss of water body during observation period, in m^3;

H_0 is the evaporation depth of water surface during observation period, in m;

A is the average impoundment area of water body during observation period, in m^2;

P is the precipitation during observation period, in m.

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