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## **Technical guidelines for the development of small hydropower plants —**

### **Part 2: Site selection planning**

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# Contents

	Page
<b>Foreword</b> .....	<b>v</b>
<b>Introduction</b> .....	<b>vi</b>
<b>1 Scope</b> .....	<b>1</b>
<b>2 Normative references</b> .....	<b>1</b>
<b>3 Terms and definitions</b> .....	<b>1</b>
<b>4 Planning principles</b> .....	<b>1</b>
<b>5 Planning scope</b> .....	<b>2</b>
<b>6 Planning methods and steps</b> .....	<b>2</b>
<b>7 Basic data collection and analysis</b> .....	<b>3</b>
7.1 Data collection.....	3
7.2 Data analysis.....	4
<b>8 Computation of river basin or sub-basin hydropower potential</b> .....	<b>5</b>
<b>9 Preliminary planning of site</b> .....	<b>7</b>
9.1 Planning content and main considerations.....	7
9.2 Types of SHP stations and applicable conditions for development.....	7
9.2.1 Dam-type hydropower station.....	7
9.2.2 Diversion-conduit-type hydropower station.....	7
9.2.3 Reservoir-based, run-of-river hydropower station (hybrid).....	8
9.3 Utilization of several special geographical conditions of rivers.....	8
9.3.1 Utilization of natural waterfalls.....	8
9.3.2 Utilization of rapids or natural waterfalls.....	8
9.3.3 Utilization of river bends.....	8
9.3.4 Utilization of the fall on an irrigation channel.....	8
9.3.5 Utilization of kinetic energy of flowing waters in a river or canal.....	8
9.4 Estimation of the development scale of a hydropower station.....	8
<b>10 Site surveys and investigations</b> .....	<b>9</b>
10.1 Hydrological surveys.....	9
10.2 Surveys on the planning site.....	10
10.2.1 Dam site surveys.....	10
10.2.2 Plant site surveys.....	10
10.2.3 Water conveyance line surveys.....	10
10.2.4 Reservoir survey.....	10
10.3 Preliminary determination of available water heads for the hydropower station.....	10
10.4 Other construction conditions for investigation.....	10
<b>11 Preparation of site construction plan</b> .....	<b>11</b>
11.1 Selection of installed capacity.....	11
11.2 Selection of turbine types.....	11
11.3 Number of units.....	11
11.4 Selection of dam type.....	11
11.5 Selection of spillway structures.....	12
11.6 Selection of water intake structures.....	12
11.7 Selection of diversion structures.....	12
11.8 Types of powerhouse.....	13
11.9 Location of switchyard.....	13
11.10 Location of tailrace.....	13
11.11 Layout of main structures.....	13
<b>12 Preliminary assessment of social and environmental impacts</b> .....	<b>13</b>
<b>13 Assessment of power demand</b> .....	<b>14</b>

<b>14</b>	<b>Cost estimation and benefits assessments</b> .....	<b>14</b>
<b>15</b>	<b>Evaluation of planning site and development sequence recommendations</b> .....	<b>15</b>
<b>16</b>	<b>Preparation of site selection planning report</b> .....	<b>15</b>
<b>Annex A</b> (informative)	<b>Computation of theoretical potential of river water energy, estimation formula for installed capacity on a planned site</b> .....	<b>16</b>
<b>Annex B</b> (informative)	<b>Schematic diagram of development types and special terrain utilization of SHP stations</b> .....	<b>19</b>
<b>Annex C</b> (informative)	<b>Outline of a site selection planning report</b> .....	<b>24</b>
<b>Annex D</b> (informative)	<b>Workshop contributors</b> .....	<b>29</b>

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

International Workshop Agreement IWA 33 was approved at a workshop hosted by the Standardization Administration of China (SAC) and Austrian Standards International (ASI), in association with the International Center on Small Hydro Power (ICSHP), held in Hangzhou, China, in June, 2019.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

A list of all parts in the IWA 33 series can be found on the ISO website.

## 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, in North and South America and in 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.

The technical guidelines for the development of small hydropower plants contained in this document 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 this document 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. This document 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.

This document is the result of a collaborative effort between the United Nations Industrial Development Organization (UNIDO) and the International Network on Small Hydro Power (INSHP). About 80 international experts and 40 international agencies were involved in this document's preparation and peer review. This document can be used as the principles and basis for the planning, design, construction and management of SHP plants up to 30 MW.

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# Technical guidelines for the development of small hydropower plants —

## Part 2: Site selection planning

### 1 Scope

This document specifies the general principles of site selection planning for small hydropower (SHP) projects, and the methodologies, procedures and outcome requirements of SHP plant site selection.

### 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.

IWA 33-1, *Technical guidelines for the development of small hydropower plants — Part 1: Vocabulary*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IWA 33-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

### 4 Planning principles

**4.1** Site selection shall be carried out in accordance with the laws and regulations of the relevant state/provinces/country.

**4.2** Site selection shall follow the principles of localized planning, subject to overall national integrated water resources planning and to comprehensive river basin planning with the systematic prospection of potential sites.

**4.3** Site selection shall meet the requirements of the environmental needs of the river and surrounding areas and also have preliminary plans to mitigate the negative impacts likely to be caused by the SHP projects to the river and its surrounding environment.

**4.4** Site selection shall be determined based on the water resources and topography with the purpose of sustainable development, utilization, and along with comprehensive consideration of all other factors.

**4.5** Site selection shall consider comprehensively the correlation of hydropower resource development over the entire length of the river, with due attention to the interrelationship of upstream and downstream cascade development, so that the layout of upstream and downstream sites are properly coordinated. For multipurpose requirements for water supply, flood control, irrigation, ecology, tourism, navigation

and community development, the SHP projects shall be planned in accordance with the primary and secondary development purposes.

**4.6** Site selection shall take into account the long-term electricity demand projection based on the social and economic development of the area. Where indirect selling of electricity to other region(s) is foreseen through the power grid, the current status and development plan of the grid shall be considered, and the growth potential of the external power market shall be evaluated. According to the development needs of the power market, planning should be carried out accordingly to meet the relevant short-, medium- and long-term development goals.

**4.7** Site selection shall make a justification of the selection of SHP in relation to other possible rural electrification technologies.

**4.8** Site selection shall take into account relevant local, regional and international integrated development plans relevant to the area under study.

**4.9** Site selection shall be coordinated with other relevant development plans of the area under study, including planning indicators, terminology, units of quantities and values, implementation plans, and shall be consistent and avoid conflicts.

## 5 Planning scope

**5.1** The planning scope for site selection of SHP development shall be based on the level (local/state/national) of the planning organization of the country.

**5.2** If the SHP resource development plan is part of the comprehensive planning of the administrative area (local/state/provinces), the scope of the site selection planning shall be defined in accordance with the administrative divisional plan.

**5.3** SHP development planning shall be based on the detailed and homogeneous definition of the river network and catchments in the river basins.

**5.4** Within exclusive economic development zone and nature reserve areas, site selection planning of SHP development shall consider the multipurpose needs.

## 6 Planning methods and steps

The methods and steps described in [Clauses 7](#) to [16](#) shall be taken according to the actual process of site selection planning of SHP resource development (see [Figure 1](#)).

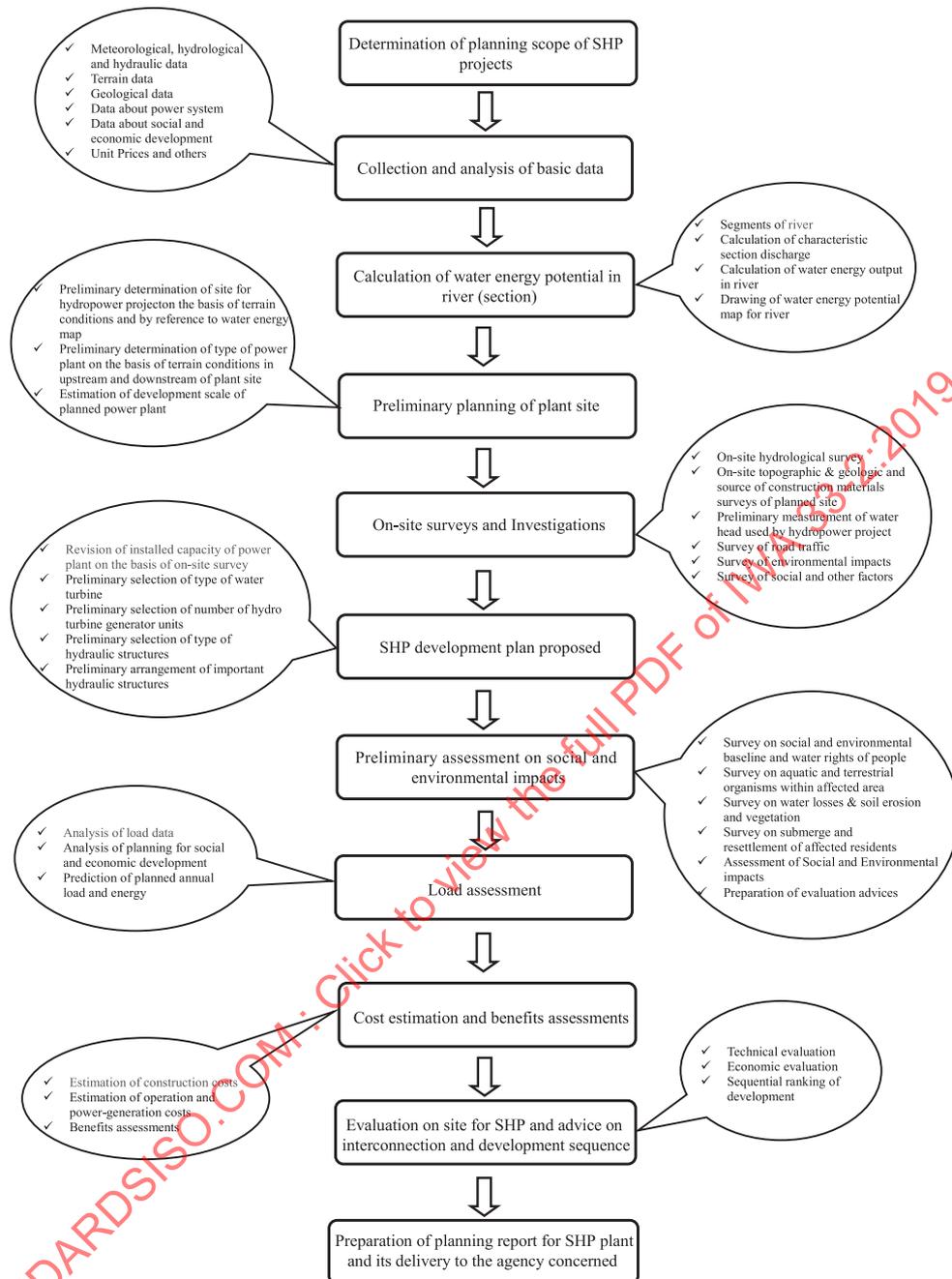


Figure 1 — Flow chart of activities for SHP site selection planning

## 7 Basic data collection and analysis

### 7.1 Data collection

**7.1.1** Adequate basic data shall be collected and analysed. Consideration shall be given to the use of digital natural resource databases and geomatics technology (remote sensing and Geographical Information System [GIS]). The authenticity, accuracy, timeliness and applicability of the collected data shall be tested and confirmed.

**7.1.2** The following basic data shall be included.

- a) Hydrometeorological data, including series of measured data, such as precipitation, flow in rivers, evaporation, water level, sediment and ice. For the locations lacking the measured data, relevant data on adjacent river basins and hydrological maps issued by the national or regional authority should be collected.
- b) Data of natural geography of river basin and river characteristics, including the topographic map of the river basin (scale not less than 1:50 000), road map of administrative area, longitudinal and cross-sections of river. Data on digital elevation/terrain models are available at 30 m, and better resolution may also be used. If the hydro-meteorological data of adjacent river basins needs to be utilized, the topographic maps of adjacent river basins shall also be collected.
- c) Geological data, including regional geological, tectonic, seismic zoning maps, geological reports, and records of major geological events such as earthquakes in the planning area.
- d) Resource information, including land use, minerals, energy, forestry, tourism, rare animals and plants.
- e) Power system data, including power source, power demand, annual power supply, load structure, load curve, power grid structure, power markets, regulations and power-development planning in the area.
- f) Existing facilities data, including as-built design documents of existing hydropower stations, irrigation, water supply, rafting, navigation and other projects within the planning river reach.
- g) Socio-economic data, including the demography, industrial and agricultural production, road network, gross national product, per capita income, and national economic development plans in the area.
- h) Other data, including natural disaster records, legal requirements, archaeology, historic sites, protected areas and natural heritage.

**7.2 Data analysis**

**7.2.1** Analysis of hydrometeorological data shall include the following.

- a) Qualitative analysis
  - 1) The data series shall be accurate, reliable and have no data gaps as far as possible.
  - 2) The data shall be applicable to the river basins under study.
  - 3) The accuracy of the data shall meet the analysis requirements. The precipitation/rainfall data should be, as far as possible, "daily rainfall". The measured data of flow shall be as precise as "average daily flow".
  - 4) Appropriate analytical methods shall be used for quality control.
  - 5) A reliable long-term daily discharge series specific to every river reach in the network should be determined, based on distributed hydrologic modelling that is appropriately calibrated.
- b) Quantitative analysis
  - 1) Frequency analysis: The measured flow data series should be analysed and calculated according to the probability formula of statistics, and the frequency curve should be drawn according to the analytical results.
  - 2) Correlation analysis: Correlation analysis shall be done when the measured flow data are not on the location of the selected site for SHP development.
  - 3) Average flow duration curve: Based on the data of frequency computation, select the flows corresponding to the frequency of high flow, median flow and low flow. Then select a similar

year from the flow series for annual distribution, if available, and distribute the average daily flow within the next three years, plotted as an "average flow duration curve".

**7.2.2** Topographic map data analysis shall include the following.

- a) Scope analysis: The topographic map shall include the drainage area of the river basin under study. If rainfall or flow data of adjacent river basins are utilized, the topographic map shall also provide the drainage area of the adjacent river basin.
- b) Accuracy analysis: The scale of the topographic map used for the site selection should be no less than 1:50 000. If the scale of the collected topographic map is smaller than the specified requirements, encryption measures shall be taken to improve the accuracy of contours. Global geometric data of 30 m or better resolution may also be used.

**7.2.3** Geological data analysis shall meet the following requirements.

- a) Incorporating the conclusions of the regional geological structural stability assessment, major fault lines and the ground motion parameters determined for the project area.
- b) It can reflect regional topography and geomorphology, stratigraphic lithology, geological structure, hydrogeological conditions and physical geological phenomena.

**7.2.4** Power system data analysis shall include the following.

- a) Present status of the power grid and analysis of the power grid plan: including power grid structure, geographical distribution, voltage levels and the relationship with, and impact on, proposed and planned SHP development.
- b) Power source and demand (load) status and planning analysis: including power source and demand (load) structure, annual maximum power demand (load), annual minimum power demand (load), annual demand (load) distribution, annual power supply, power growth rate, power markets, regulations, impact of integration with other renewable energy such as wind and solar.

**7.2.5** Other data analysis shall include a comprehensive assessment on the authenticity, timeliness and relevance of the data.

## **8 Computation of river basin or sub-basin hydropower potential**

**8.1** The theoretical water energy potential of the river (reach) shall be expressed in terms of average annual output (power) (kW) or average annual energy (kWh). The average annual output and the average annual energy shall be mutually converted by the means of [Formula \(A.1\)](#).

**8.2** The theoretical water energy potential of the river (reach) shall be calculated in segments. The river shall be segmented in accordance with the following criteria.

- a) A larger tributary entry point should be used as a segmentation point for river water energy computation. Taking the tributary entry point as the interface, the adjacent section upstream is the lower section of the upper reach, and the adjacent section downstream of the entry point is the upper section of the lower reach.
- b) The reach with a large change in the longitudinal slope of the riverbed shall be regarded as a segment.
- c) The reach having particularly advantageous development conditions shall be regarded as a segment.

**8.3** The annual average flow at each analysis segment of the river shall be calculated, with their area ratios based on the collected hydrologic data series of the river and the catchment areas of each analysis segment of the river. If the flow data of the river basin is inadequate or unavailable, the information should be obtained by the following methods.

- a) If there is rainfall data on this river basin, the appropriate runoff coefficient should be converted to the runoff in the same period with reference to [Formula \(A.2\)](#) or any other suitable formula or methods.
- b) If there is hydrological flow data on an adjacent river basin, the correlation with the river basin shall be analysed, and the relevant data after revision may be used for water energy computation.
- c) The hydrological flow parameters of the river basin can be obtained by using the hydrological contours or effective charts issued by the hydrological or relevant department.
- d) On-site measurement method.

**8.4** The topographic map with a scale of 1:50 000 or higher should be used to verify and calculate the elevation difference between the upper and lower sections of the reach by appropriate interpretation. Use of Digital Elevation Model (DEM)/Digital Terrain Model (DTM) is encouraged.

**8.5** Based on the flow rate of the upper and lower sections of the river reach and the elevation difference between the upper and lower sections, the average annual output  $N_i$  (kW) of the reach shall be calculated by the means of [Formula \(A.3\)](#). The average annual energy  $E_i$  (kWh) is calculated by [Formula \(A.1\)](#).

**8.6** With the average annual output of water energy in each reach being accumulated,  $\sum N_i$ , and the average annual power energy in each reach being accumulated,  $\sum E_i$ , the theoretical water energy potential of the river (reach) may be obtained.

**8.7** According to the above computation results, the theoretical potential of river water energy can be calculated:

- a) The relation curve between river elevation  $Z$  (m) and river length  $L$  (km):  $Z = f(L)$ . Calculate the  $Z$  and  $L$  values and draw the  $Z = f(L)$  curve on the rectangular coordinates. The curve shall show the gradient of river water surface (or thalweg) along the river length.
- b) The relation curve between river flow  $Q$  (m<sup>3</sup>/s) and river length  $L$  (km):  $Q = f(L)$ . According to the flow rate  $Q$  calculated in [8.3](#), the value  $L$  is verified and calculated by using a topographic map or DEM/DTM. Draw  $Q = f(L)$  curve on rectangular coordinates. This curve reflects the variation of river flow along the river length.
- c) Accumulation curve of river water energy potential  $\sum N_i = f(L)$ ; The  $\sum N_i$  (kW) value may be obtained by directly using the computation result in [8.6](#), the value  $L$  is verified and calculated by using topographic map/DEM/DTM. Draw  $\sum N_i = f(L)$  curve on rectangular coordinates. The ordinate value of a certain point on the curve indicates the total potential of water energy from the upstream starting point (for example, from the river source) to the section.
- d) Curve of unit potential of river:  $N_d = f(L)$ . That is, the distribution of the energy value  $N_d$  (kW/km) of the unit river length of the reach along the river length  $L$  (km). This curve reflects the energy density of the reach.  $N_d$  is calculated by the [Formula \(A.4\)](#). The diagram of theoretical water energy potential is shown in [Figure A.1](#).

## 9 Preliminary planning of site

### 9.1 Planning content and main considerations

**9.1.1** Preliminary planning of the SHP development scheme shall include selection of the site, development type and construction scale of the SHP plant.

**9.1.2** The preliminary planning of the hydropower station site shall involve the following considerations.

- a) The topography and geology shall be suitable for planning the relevant structures of the hydropower station.
- b) The hydropower potential should be relatively concentrated, and the hydro energy density of the river reach be relatively higher.
- c) Power evacuation/transmission: the hydropower station is close to the load areas or close to the power grid.
- d) Access and transportation with different options shall be evaluated and available.
- e) Minimal inundation of farmland, villages or towns, forests and other natural and social resources.
- f) Avoiding natural resources, protected areas, heritage areas and cultural heritage sites.
- g) The electricity market demand and the additional requirements of the power system for utilization of power from the proposed SHP plant.
- h) Comprehensive integration of water supply, irrigation, tourism and navigation.
- i) Avoid conflicts with existing national and local water related existing schemes and future plans and manage the conflicts between different plans in accordance with the local/state/national planning principles.

### 9.2 Types of SHP stations and applicable conditions for development

#### 9.2.1 Dam-type hydropower station

Dam-type hydropower stations may be classified into two types, namely in-stream hydropower stations or dam-toe hydropower stations.

- a) The in-stream hydropower station (along river channel) mostly applies to the river reach in relatively plain areas with relatively small head (less than 15 m), where the river is relatively wide; it is also used for irrigation channels or water supply with a certain drop. See [Figure B.1](#) and [Figure B.2](#) for schematic diagrams.
- b) The hydropower station at a dam toe applies to a wide range of water heads, ranging from a few metres to more than 100 metres. See [Figure B.3](#) for a schematic diagram.

#### 9.2.2 Diversion-conduit-type hydropower station

The diversion-conduit-type hydropower station is suitable for river sections where the river channel is relatively narrow, the slope of the river section is relatively steep, and the geological conditions of the riverbank slopes are favourable. Applicable heads range from a few metres to a few hundred metres. See [Figure B.4](#) for a schematic diagram.

### 9.2.3 Reservoir-based, run-of-river hydropower station (hybrid)

The commonly known as run-of-river with diversion or storage dam hydropower station is suitable for river sections where the upstream of the dam site can easily form storage capacity (diurnal, seasonal or annual), and the downstream of the dam site has a relatively concentrated drop. See [Figure B.5](#) for a schematic diagram.

## 9.3 Utilization of several special geographical conditions of rivers

### 9.3.1 Utilization of natural waterfalls

The natural waterfall has a relatively concentrated drop. The barrage may be built at the appropriate location on the steep slope of the waterfall and then the water is diverted by the conduit into the turbine generator unit in the powerhouse to generate electricity. See [Figure B.6](#) for a schematic diagram. However, such schemes shall be carefully planned in coordination with the relevant tourism department, including scheduling of flow for waterfalls and power generation.

### 9.3.2 Utilization of rapids or natural waterfalls

Rapids or natural waterfalls are easily formed in river courses in mountainous areas. For such river sections, low-height weirs may be built depending on the actual situation, and, by rational use of the terrain, water may be diverted into the powerhouse through a diversion canal to generate electricity. However, for such hydropower stations, special attention shall be paid to flood control issues. See [Figure B.7](#) for a schematic diagram.

### 9.3.3 Utilization of river bends

In mountainous areas, the river channels are mostly curved, and the curve distance is relatively small. A low-height dam may be built upstream of the curve, to connect the curves by using a diversion canal (or tunnel); cut-off the curved river channel and obtain the river bend drop, and the powerhouse may be built on a suitable location on the diversion canal (or tunnel). See [Figure B.8](#) for a schematic diagram.

### 9.3.4 Utilization of the fall on an irrigation channel

The waterfall on an irrigation channel may be used to build a hydropower station in the channel. For diversion-channel-type hydropower stations, the tail water after power generation shall return to the original irrigation channel. See [Figure B.2](#) for a schematic diagram.

### 9.3.5 Utilization of kinetic energy of flowing waters in a river or canal

The kinetic energy of flowing waters in a river or canal may be used to produce electrical power. Because this is powered by kinetic energy instead of potential energy, it is known as "velocity" power generation. See [Figure B.9](#) for a schematic diagram.

## 9.4 Estimation of the development scale of a hydropower station

9.4.1 The mean annual flow at the planning site may be found by using the curve in the diagram of theoretical water energy potential  $Q = f(L)$ .

9.4.2 The usable drop at the planning site may be checked and calculated.

9.4.3 The mean annual output of the hydropower station at the planning site may be calculated by using [Formula \(A.5\)](#). The minimum ecological flow shall be maintained in accordance with the regulations of the state/country; if there is no specific regulation in the country, it may be calculated as 10 % of the mean annual flow.

**9.4.4** The annual energy of hydropower station may be preliminarily determined by the annual utilization hours:

- a) Select the expected annual utilization hours for the hydropower station. The following selection principles shall be followed.
  - 1) A small value is taken if the difference in precipitation between the wet and dry seasons is obvious; a medium to large value is taken if the difference in flow between the wet and dry seasons is not obvious.
  - 2) A small to medium value is taken for the hydropower station operating in a network connected to the grid; for an isolated power station, a large value is taken.
  - 3) A medium to large value is taken for a hydropower station without regulation function; a median value is taken for a hydropower station with regulation function.
  - 4) Installed capacity of the SHP plant shall be based on optimization studies, taking into account flow duration and the energy market.
- b) After selecting the desired number of annual utilization hours, the installed capacity shall be estimated in accordance with [Formula \(A.6\)](#).

## 10 Site surveys and investigations

### 10.1 Hydrological surveys

Hydrological surveys shall include surveys of rainfall consistency, field investigation of runoffs, investigations of historical floods, and investigations of historical dry flows. The survey content is generally as follows.

- a) Survey of rainfall consistency: For areas with short historical data, especially those sites lacking records, the survey may be carried out by visiting the site and talking to the residents along the river to understand qualitatively the rainfall pattern over the years, the distribution consistency within the year and the duration of rise and fall of the river.
- b) Runoff measurement: An approximate measurement of the flow of the river section may be studied by a portable flowmeter, or a simple float flow measurement method, to compare it with the historical record in the same period.
- c) Historical flood surveys:
  - 1) Preparation for surveys: It is necessary to make full use of basic data collected in the previous work, such as vertical and horizontal sections of the river, including highest flood levels; the historical data should be considered in advance to understand the number, magnitude and timings of the occurrence of historical floods.
  - 2) Site surveys: Importance shall be attached to selecting a straight river section, focusing on bridges, ancient monuments, bends, and river meandering, to check the traces of flood marks.
  - 3) Investigation and visit: Visit the older residents along the river to determine the year and month of historical floods, the traces/high flood marks left and the flooding process.
  - 4) Field measurements: The elevation of the flood trace/high flood marks, and the vertical and horizontal sectional map of the nearby river section, shall be included.
- d) Investigation of the historical dry season: The survey process is similar to the flood survey.

## 10.2 Surveys on the planning site

### 10.2.1 Dam site surveys

The specific location shall be verified on site in line with the dam/diversion structures site selected on the topographic map. According to the basic principles of dam site selection, the left and right banks and the surrounding terrain of the dam site, the subsurface strata and rock structure of the dam site shall be initially evaluated to determine its suitability as the best location for the construction of a dam/diversion structure.

### 10.2.2 Plant site surveys

The location of the powerhouse selected on the topographic map shall be verified to make sure it meets the basic requirements from topographical and geological considerations. At the same time, the relative positional relationship between the powerhouse and the dam shall be studied to justify whether the water head utilization level in the preliminary plan is met.

### 10.2.3 Water conveyance line surveys

The topographical and geological conditions along the water conveyance line shall be surveyed. Unfavourable landforms such as landslides, collapse and large spans of aqueducts shall be specifically evaluated.

### 10.2.4 Reservoir survey

The geological structure of the bed of the reservoir area shall be investigated and attention shall be paid to whether there are buried channels, river deposits, fossil valleys, karst caves, fractures and faults. Basic assessment of reservoir rim slope stability shall be ensured.

## 10.3 Preliminary determination of available water heads for the hydropower station

**10.3.1** The water surface upstream of the dam site and the surface downstream of the powerhouse shall be used as measuring points, and the natural drop at the planning site shall be measured by using elevation instruments such as a hand-held GPS instrument, a level gauge or total station.

**10.3.2** The natural drop plus the storage height of planned water retaining structure may be adopted as the gross head of the hydropower station. The characteristic water level upstream of the water-retaining structure shall be determined after the scheme comparison and evaluation in the design stage.

## 10.4 Other construction conditions for investigation

**10.4.1** Assess the transportation conditions of the planned site and the feasibility of new road construction or other options such as rope ways.

**10.4.2** Verify that the rare animal and plant species near the planning site are consistent with the data.

**10.4.3** Visit the historical sites and their distribution according to the records.

**10.4.4** Investigate the population density and distribution, land use and ownership near the planning site and within the reservoir area.

**10.4.5** Investigate important buildings and other public facilities in the planning area.

**10.4.6** Investigate other relevant plans for the river basin.

10.4.7 Investigate the availability of construction materials.

## 11 Preparation of site construction plan

### 11.1 Selection of installed capacity

The installed capacity of the SHP plant shall be selected according to the hydrologic data survey and the measurement of the usable drop at the site.

### 11.2 Selection of turbine types

The appropriate turbine type shall be initially selected in the turbine type table or utilization range chart based on the water head and discharge of the hydropower station.

### 11.3 Number of units

According to the revised installed capacity of the power station, the number of units is selected and shall meet the following requirements.

- a) In order to facilitate maintenance and management, units with the same capacity shall be selected.
- b) Considering the reliability requirements of the power supply, two or more units should be used.
- c) When the distribution of runoff is severely unbalanced in wet and dry seasons, units of two different capacities should be selected.
- d) When selecting the capacity of a single unit, the convenience of manufacturing, transportation and adequacy of utilization shall be taken into account.

### 11.4 Selection of dam type

The type of dam shall be selected according to the topography, geology, hydrology and construction materials, as well as the preliminary planning results of the selected sites, including mainly the following.

- a) Gravity dam: This should be built on a rock foundation, but a gravity weir may be built on a soft foundation.
- b) Arch dam: This should be built on dam sites with narrow river gorges, symmetrical and continuous hills on both banks, and good geological conditions.
- c) Earth/rock fill dam: This is suitable for local dam construction where there are abundant materials that are convenient for construction and transportation; it has relatively low requirements for foundation geological conditions.
- d) Sluice dam/barrage: This is applicable to low water head hydropower projects in river channels or plain areas. It is generally built on a rock foundation or homogeneous soil, or on a non-rock foundation such as sandy gravel and soft clay. However, construction partially on rock foundation and partially on non-rock foundation shall be avoided.
- e) Shutter dam/weir: This is applicable to locations where the water depth is less than 5m and the requirement for riverbed flooding is high. Foundation requirements for a shutter dam are the same as those for a sluice dam.

### 11.5 Selection of spillway structures

Appropriate flood discharge measures and spillways shall be selected according to the dam type and surrounding topography. The main forms are as follows.

- a) The flood discharge through the dam may be classified into surface spillway flood discharge and medium and low sluice flood discharge.
- b) Riverside flood discharge may be classified into spillway and spillway tunnel.
  - 1) Spillway: The spillway shall be placed on a stable foundation and the axis should be straight. The flow shall maintain a safe distance from other structures and connect to the downstream river. The spillway is classified as chute spillway or side spillway, according to the relationship between its axis and the axis of the barrage or dam.
  - 2) Spillway tunnel: Economic and technical comparisons shall be made to choose a pressure or a non-pressure tunnel. The construction diversion tunnel may be used as a spillway tunnel.

All spillways shall have suitable space for energy dissipating structures, depending on the type of spillway, topographical and geological features.

### 11.6 Selection of water intake structures

The water intake structures inside or outside of the dam shall be selected according to different types of hydropower station. The water intake of the hydropower station at a dam toe may be installed inside the dam. The diversion type of hydropower project shall have the water intake installed outside the dam. The water intake outside the dam may be located on one side of the riverbanks. For sediment-laden rivers, a sedimentation basin should be installed adjacent to the water intake. When restricted by terrain conditions, or head of sand-flushing water is not sufficient, it can be moved down to the appropriate position along the diversion channel.

### 11.7 Selection of diversion structures

The water conductor system of the hydropower station includes the channel, tunnel, sedimentation basin, forebay, penstock, surge chamber, fish passage and tailrace. The selection of each part shall respect the following conditions.

- a) Channel: The channel route should be chosen along the contour line. The shorter and more feasible route is preferred.
- b) Tunnel: The tunnel may be classified as a pressure tunnel or a free-flow tunnel. In order to reduce the length of the channel, the tunnel may be excavated if the geological conditions of the mountain meet the requirements. The tunnel shall be kept away from geological structures such as faults, fractures and karst caves.
- c) Sedimentation basin: According to the sediment content, sediment particle size and hydropower station water head, the necessity of installing a sedimentation basin shall be judged. The sedimentation basin shall be located on a stable foundation and shall be capable of conveniently discharging sediment.
- d) Forebay: The forebay shall be located at the end of the non-pressure water diversion system and before the penstock directs water into the turbine. The pressure forebay shall be kept away from landslides, downslope fracture development or steep slopes. The forebay shall be located on a solid foundation with low permeability and in combination with the penstock and powerhouse location.
- e) Penstock: The form, parameters and support methods for the penstock shall be determined by subsequent design.
- f) Surge chamber: In a hydropower station's pressure diversion system, if there is a possibility of direct hammer – based on the turbine regulation firm calculation result, a surge chamber shall be

installed in a suitable position of the pressure pipe, prior to the turbine. If geographical conditions permit, the surge chamber shall be installed near the hydropower station. It shall be installed on the solid foundation with low water permeability.

- g) Fish Passage: Suitable fish passage may be provided in the diversion structure.

### 11.8 Types of powerhouse

The type of powerhouse shall be selected through economic and technical comparison according to the topographic and geological conditions, upstream and downstream water level and other factors. The powerhouse types include surface, underground, semi-underground, overflow and within-dam.

### 11.9 Location of switchyard

The switchyard shall be close to the powerhouse, as far as possible, in combination with the topographic characteristics. Subsidence prone and low-lying locations shall be avoided.

### 11.10 Location of tailrace

The tailrace shall be located with consideration to the smooth discharge of flow and shall avoid the influence of water flow at the outlet of spillway structures.

### 11.11 Layout of main structures

Under the premise of satisfying the geological and other construction conditions, the layout principles mainly include the following:

- a) the topographic conditions shall be fully utilized to optimize the quantity of construction work;
- b) the powerhouse shall be close to the dam, as far as possible;
- c) the switchyard shall be close to the powerhouse, as far as possible;
- d) consideration shall be given to the convenience of transportation of equipment, especially the possibility of transportation of the largest and heaviest equipment;
- e) adequate consideration shall be given to flood prevention;
- f) cultural heritage shall be avoided;
- g) the ease of construction shall be considered;
- h) the harmonic and elegant appearance of the overall layout of the main structures shall be taken into account;
- i) facilitation of educational and tourist visits should be accommodated when part of local regulation.

## 12 Preliminary assessment of social and environmental impacts

**12.1** The present status of natural and social environment shall be investigated in and around the hydropower station site, reservoir area and the areas possibly affected by construction; this shall be used as the baseline to evaluate the social and environmental impacts of the project.

**12.2** The impact on aquatic and terrestrial organisms within the construction and downstream areas shall be evaluated according to the development type, scale and operation mode of the hydropower station.

**12.3** The extent of permanent impact on the vegetation surrounding the project after the restoration measures are taken shall be evaluated, based on the area required for the hydropower station including the construction phase.

**12.4** The degree of inundation of forests, crops, farmland and woodland in the reservoir area shall be estimated.

**12.5** The number of relocations of houses and the population of resettlement shall be estimated.

**12.6** Based on the survey results, preliminary assessment opinions (public hearing) on the environmental impact of the project shall be made according to the environmental assessment criteria of the country.

### **13 Assessment of power demand**

**13.1** According to the current status of power demand and the socio-economic development plan, the forecast of load in short, medium and long term shall be carried out for the direct power supply area, including the load profile, types of loads like domestic, commercial, industrial, institutional, seasonal and annual variations.

**13.2** The development trend of the electricity market shall be evaluated according to the current status of the load and the national economic development plan.

### **14 Cost estimation and benefits assessments**

**14.1** The cost estimation methods include the sub-item estimation method and comprehensive cost computation method, which shall meet the following requirements.

- a) Sub-item estimation method: First, the project quantities of different components of the hydropower station are estimated according to the proposed scheme, then the unit price analysis is conducted according to the local price index, after which the project cost is estimated according to the project quantities and unit price. The cost of electromechanical equipment may be estimated by sets. After the subproject costs are summarized, the total cost of hydropower station construction will be obtained.
- b) Comprehensive cost computation method: The total construction cost of the hydropower station is the product of the comprehensive unit price (cost per kilowatt) of the same kind of local hydropower station and the installed capacity of the hydropower station.
- c) Parametric and empirical cost studies may be used for cost estimation.

**14.2** Estimate the static total cost of the project. Analyze and calculate economic indexes of the hydropower station, such as cost per kilowatt and cost per kilowatt-hour.

**14.3** The annual power generation and operation cost of the hydropower station may be calculated according to the statistical index of the country, that is, the ratio of the power generation and operation cost of the hydropower station to the construction cost.

**14.4** Benefits from the schemes from the SHP plant shall be assessed based on the utilization of electricity, area development and socio-economic benefits.

## 15 Evaluation of planning site and development sequence recommendations

**15.1** The technical evaluation of the planning site shall be carried out from the aspects of hydro energy utilization, construction difficulty and comprehensive utilization.

**15.2** A preliminary economic evaluation of the planning site shall be carried out based on the preliminary estimated cost by means of the static or dynamic method.

**15.3** A social benefit evaluation shall be carried out based on the contribution that the hydropower station may provide to the society after its completion.

**15.4** Suggestions on the development sequence shall be made according to the resource conditions and development conditions of the planning site and the following factors:

- a) meeting the current electricity needs of the region, as well as the needs of socio-economic and load development;
- b) meeting the local power requirements of the power system;
- c) aligning with investment capacity and construction technology level;
- d) coordinating with the overall planning and development plan for the river basin.

## 16 Preparation of site selection planning report

The site selection planning report shall contain the following:

- a) the results of site selection planning for SHP development, including natural conditions of the river basin, status of hydropower resources in the river basin, results of site selection, comprehensive evaluation of the site and development sequence;
- b) the authenticity, timeliness and applicability of hydrological data and other materials;
- c) the compilation, analysis, interpolation and citation of data;
- d) the planning principles, planning methods and technical stages;
- e) the construction conditions of each planning site shall be explained, including river sediment, engineering geological condition, water conservancy and hydro energy, reservoir inundation extent, construction plan and engineering layout, social and environmental impact assessment, load assessment, cost and benefit estimation, economic and technical evaluation;
- f) along with the summarized planning results, a comprehensive evaluation of the SHP projects;
- g) the site selection planning report in accordance with the outline in [Annex C](#), with relevant charts attached.

## Annex A (informative)

### Computation of theoretical potential of river water energy, estimation formula for installed capacity on a planned site

#### A.1 Conversion formula of mean annual output of water energy and mean annual power of water energy

$$N = \frac{E}{8\,760} \quad (\text{no. of hours in a year}) \quad (\text{A.1})$$

where

- $N$  is the power output (capacity), in kW;
- $E$  is the water energy (electricity), in kWh.

#### A.2 Conversion formula for rainfall and runoff depth (applicable for microcatchment;) also known as the rational method

$$x = \alpha \cdot y \quad (\text{A.2})$$

where

- $x$  is the rainfall, in mm;
- $y$  is the runoff depth, in mm;
- $\alpha$  is the runoff coefficient.

#### A.3 Computation formula for theoretical water potential of reach

$$N_i = 9,81 \frac{Q_1 + Q_2}{2} H_i \quad (\text{A.3})$$

where

- $N_i$  is the power output (capacity) of reach  $i$ , in kW;
- $Q_1$  is the mean annual flow at the upper section of the reach  $i$ , in m<sup>3</sup>/s;
- $Q_2$  is the mean annual flow at the lower section of the reach  $i$ , in m<sup>3</sup>/s;
- $H_i$  is the difference between elevations of the upper and lower sections of the reach  $i$ , in m.

#### A.4 Formula for water energy density per unit length of river reach

$$N_d = \frac{N_i}{L_i} \quad (\text{A.4})$$

where

$N_d$  is the water energy density in unit length of reach  $i$ , in kW / km;

$N_i$  is the water output (power) of reach  $i$ , in kW;

$L_i$  is the length of reach  $i$ , in km.

#### A.5 Formula for mean annual output of SHP planning site

$$N_j = 9,81QH\eta_1\eta_2 \quad (\text{A.5})$$

where

$N_j$  is the mean annual output (power) of the planned hydropower station, in kW;

$Q$  is the mean annual flow of planning site, in m<sup>3</sup>/s;

$H$  is the usable water head at the planning site, in m;

$\eta_1$  is the coefficient of water intake at the planning site (0,9 is taken, while the remaining 10 % of the mean annual flow is considered as a normal ecological flow.);

$\eta_2$  is the overall efficiency coefficient of the units (0,75 to 0,85 is taken).

#### A.6 Estimation formula for installed capacity of SHP station

$$P = 8\,760 \frac{N_j}{h_{nl}} \quad (\text{A.6})$$

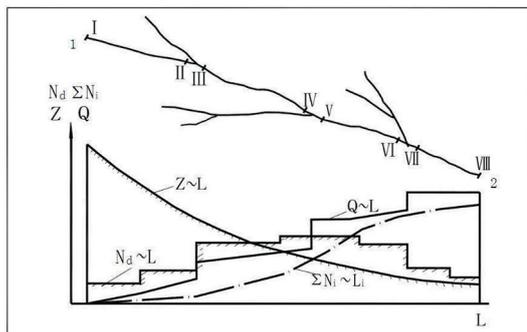
where

$P$  is the installed capacity of the planned hydropower station, in kW;

$N_j$  is the mean annual output of planned power (power), in kW;

$h_{nl}$  is the annual operational hours of planned hydropower station, in h.

**A.7 Diagram of theoretical potential of river water energy**



- Key**
- 1 river source
  - 2 river mouth
  - I to VIII river reach

**Figure A.1 — Diagram of theoretical potential of river water energy**

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## Annex B (informative)

### Schematic diagram of development types and special terrain utilization of SHP stations

#### B.1 Schematic diagram of development types of SHP stations

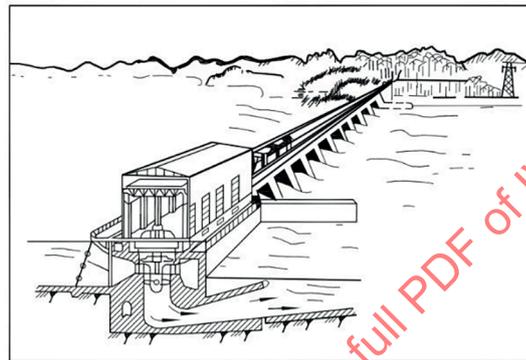


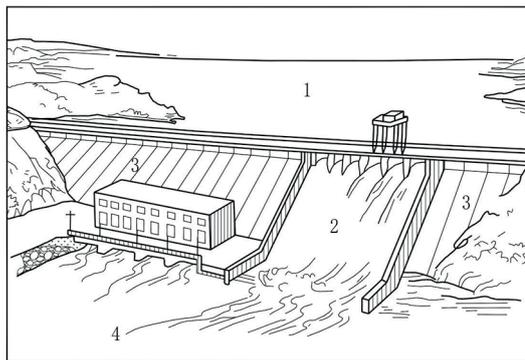
Figure B.1 — In-stream hydropower station



#### Key

- 1 irrigation canals
- 2 graduating valve
- 3 powerhouse

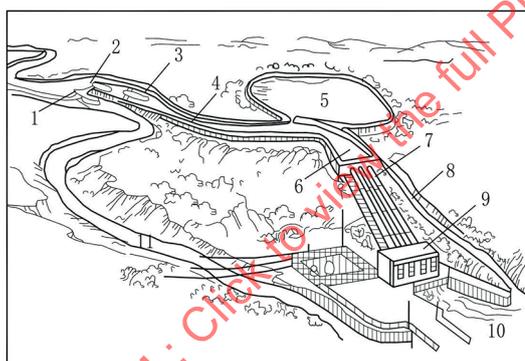
Figure B.2 — Hydropower station canal fall



**Key**

- 1 reservoir
- 2 overflow dam
- 3 non-overflow dam
- 4 riverbed

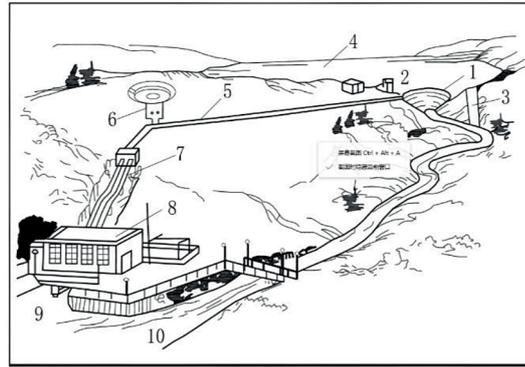
**Figure B.3 — Dam-toe hydropower station**



**Key**

- 1 overflow dam
- 2 water inlet
- 3 grit basin
- 4 diversion canal
- 5 regulating reservoir
- 6 pressure forebay
- 7 penstock
- 8 irrigation channel
- 9 powerhouse
- 10 tailrace
- 11 riverbed

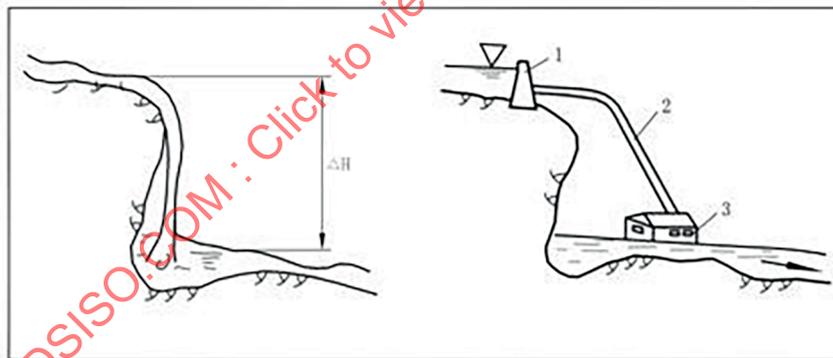
**Figure B.4 — Diversion-type hydropower station**

**Key**

- |   |                 |    |             |
|---|-----------------|----|-------------|
| 1 | dam             | 6  | surge shaft |
| 2 | water inlet     | 7  | penstock    |
| 3 | spillway        | 8  | powerhouse  |
| 4 | reservoir       | 9  | tailrace    |
| 5 | pressure tunnel | 10 | riverbed    |

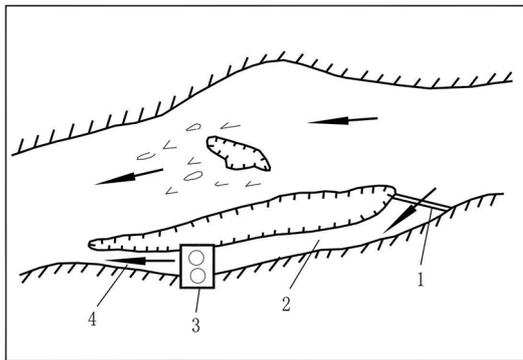
Figure B.5 — Reservoir based run-of-river hydropower station

## B.2 Schematic diagram of the utilization of several special geographical conditions in the river channel

**Key**

- |   |            |
|---|------------|
| 1 | dam        |
| 2 | penstock   |
| 3 | powerhouse |

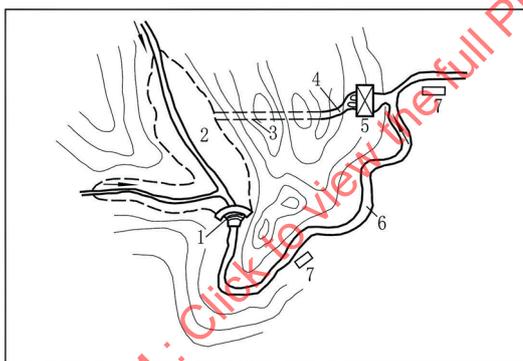
Figure B.6 — Utilization of natural waterfalls



**Key**

- 1 water inlet
- 2 diversion canal
- 3 powerhouse
- 4 diversion canal

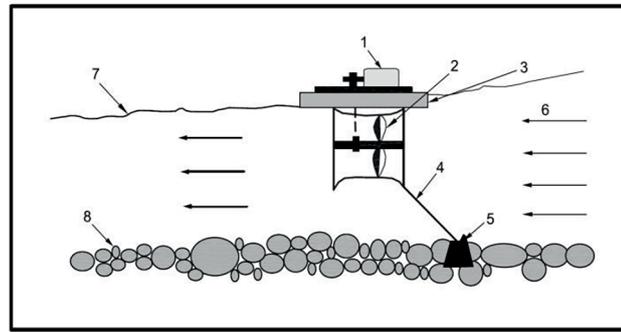
**Figure B.7 — Utilization of torrent rapids or natural waterfall**



**Key**

- 1 masonry arch dam
- 2 reservoir
- 3 tunnel
- 4 penstock
- 5 powerhouse
- 6 river
- 7 village

**Figure B.8 — Utilization of river bend**

**Key**

- |   |                 |   |               |
|---|-----------------|---|---------------|
| 1 | generator       | 5 | base or nail  |
| 2 | turbine blade   | 6 | water flow    |
| 3 | float           | 7 | water surface |
| 4 | anchoring cable | 8 | riverbed      |

**Figure B.9 — Utilization of kinetic energy of flowing waters in a river or canal**

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## Annex C (informative)

### Outline of a site selection planning report

#### C.1 Outline

- **Table of contents**
- **Related photographs of site, figures and maps**
- **Chapter I: General description**
  - 1) Geographical location, administrative area, and the water system of the river (reach) in which the planning site is located.
  - 2) The natural conditions of the adjacent areas of the river basin, including geographic trends, topography, hydrometeorology, forest vegetation, regional geology and mineral resources.
  - 3) The socio-economic conditions within the river basin, including population distribution, economic status, industrial structure, grain and crops, lifestyle, religious beliefs and administrative management.
  - 4) The status of hydropower resources within the planned river basin, including total hydropower resources, resource distribution, resource characteristics and exploitable capacity.
  - 5) Summary of planning results, including total capacity of resource development, number of hydropower stations, site distribution and technical and economic indicators.
  - 6) Figures and tables:
    - Schematic diagram of the location of the planned hydropower station (see [Figure C.1](#));
    - Schematic diagram of the location and longitudinal section of the planned hydropower station (see [Figure C.2](#));
    - Summary table of engineering characteristics of the planned hydropower station (see [Table C.1](#)).
- **Chapter II: Description of data**
  - 1) Data collection and compilation; including the type of data, source of data, collection methods, filing and so on.
  - 2) Basic evaluation of data; including the integrity, timeliness, authenticity and applicability of the data.
  - 3) Technical analysis of data; including the data series supplement, consistency analysis, results evaluation and application value.
- **Chapter III: Planning principles and methods**
  - 1) Description of planning principles, including planning basis, planning objectives, environmental control.
  - 2) Description of planning methods, including planning procedures, main technical methods, quality control of results.