



# Siting and Design

*This guideline expands on what is expected by the criteria statements in the Hydropower Sustainability Tools (HST) for the Siting and Design topic, relating to assessment, management, stakeholder engagement and outcomes. The good practice criteria are expressed for the preparation stage.*

*In the Hydropower Sustainability Assessment Protocol (HSAP), this topic is addressed in P-4. In the Hydropower Sustainability ESG Gap Analysis Tool (HESG), this topic is addressed in Section 1.*

This guideline addresses the evaluation and determination of project siting and design options, including the dam, power house, reservoir and associated infrastructure. The intent is that siting and design are optimised as a result of an iterative and consultative process that has taken into account technical, economic, financial, environmental and social considerations.

The siting and design of a hydropower project aim to:

- deliver the project objectives – the power station may be single purpose (hydropower generation only, which in turn may be for base load or peak load power, domestic use or export, or servicing rural or urban or industrial needs) or multi-purpose (e.g. the reservoir may also provide water supply for irrigation, aquaculture, or other industries, or be used for recreational, tourism and development purposes);
- optimise the constructed elements of the project – namely the dam type and size, generation capacity and efficiency, safety and access; and
- avoid, minimise and mitigate any issues associated with the development – these should not only consider technical and financial issues, but should also include social and environmental aspects.

**Optimal** in this context means best fit once all identified sustainability considerations have been factored in based on the outcomes of a consultative process. Project designers are skilled in optimising for technical and financial objectives, such as maximising power output for least cost. This guideline is focussed on ensuring that a broader set of objectives, including regulatory, social, environmental, safety and stakeholder priorities, informs and influences the optimisation process and conclusions for project siting and design.

Examples of sustainability considerations for siting and design include: prioritising alternatives that

provide opportunities for multiple use benefits; that are on already developed river systems; that minimise the area flooded per unit of energy (GWh) produced; that maximise opportunities for and do not pose unsolvable threats to vulnerable social groups; that enhance public health and minimise public health risks; that minimise population displacement; that avoid exceptional natural and human heritage sites; that have lower impacts on rare, threatened or vulnerable species; that maximise habitat restoration and protect high quality habitats; that achieve or complement community supported objectives in downstream areas (i.e. downstream flow regimes); that have associated catchment management benefits; that have lower sedimentation and erosion risks; and that avoid exceptional greenhouse gas emissions from reservoirs.

## Assessment

*Assessment criterion - Preparation Stage: Technical information has been analysed at an early stage alongside social, environmental, economic, financial, and regulatory considerations in order to develop a preliminary project design and some options around this.*

The siting of a hydropower project will initially be a location that offers an ability to technically generate hydropower due to:

- the head – i.e. the height through which water would fall to reach the turbine (the greater the head, the more power can be generated);
- the volume of water available – the more water available, the greater the number and/or size of the turbines that can be spun and the greater the power output of the generators; and
- the geological suitability for a dam – this is determined by the shape and size of the valley at the proposed construction site and the geology of the valley walls and floor.

The location selection for hydropower developments is generally (but not always) based on consideration of several location options, and the general layout that would suit each location option. Technically feasible sites for hydropower can be derived at a comparative level (i.e. to show more or less promising sites) from contour maps, hydrological statistics and geological maps, which

are usually readily available in most countries. Potential hydropower developments are often identified through national energy masterplans, which ideally involve analyses at the national or river basin scale to prioritise technically and economically feasible projects with relatively lower social and environmental impacts. An increasing level of attention has been dedicated to river basin planning tools and approaches to optimise river basin development plans for hydropower taking into account an array of sustainability considerations.

Regardless of the background to the identification of the individual project, the assessment process for that project needs to demonstrate that an options assessment approach has been taken to the determination of location and the general layout of the project. The options assessment should use a Multi-Criteria Analysis (MCA) approach. There are many degrees of sophistication that an MCA can take, and no single approach is recommended. Of importance is that the developer can demonstrate that:

- various location and general layout options have been identified based on initial information and stakeholder input;
- criteria and methods for MCA evaluation have been defined based on an engaged process with stakeholders;
- criteria reflect social and environmental considerations in addition to technical and financial aspects;
- methods of and outcomes from the MCA analyses are readily able to be understood by key stakeholders;
- information on technical, financial, economic, regulatory, social and environmental criteria is collected using appropriate expertise, and clearly informs the analyses of location and general layout options; and
- stakeholder inputs and views are clearly reflected in the options, the analyses, and the outcomes.

More detailed siting and design investigations are typically undertaken as part of project feasibility studies. This process tests the suitability of the location and the exact siting of the project components through on-site investigations (e.g. test drilling), develops the project design, and considers how to optimise a host of other

considerations within the siting and design. From a technical perspective, once the location is determined, the approach to project design often follows the following steps:

- selection of the most suitable general layout for the dam and power house locations and the general arrangement of the water conduits for power generation;
- optimisation of the dam height and selection of the maximum and minimum reservoir levels;
- optimisation of the installed capacity; and
- other detailed optimisations, such as the diameters of the water conduits, river diversion structures, and spillway design.

Of importance is that this optimisation process goes beyond technical and financial considerations, and clearly brings in social and environmental issues in a timely manner. Siting and design should be addressed through an iterative process. This may initially draw on information from a Strategic Environmental Assessment (SEA) at a broad geographical scale (e.g. river basin or national), and then draw on information from the Environmental and Social Impact Assessment (ESIA) studies as they advance for the proposed project. At the project level, this requires good coordination between the project manager for the engineering studies and the project manager for the environmental and social studies. Unfortunately, technical studies are often well-advanced before the environmental and social studies even begin. It is important to access high level information on environmental and social aspects before all of the siting and design optimisations are too far progressed; if not available through a broader-scale SEA, this can be obtained by commissioning early scoping studies and early stakeholder engagement on environmental and social issues. Based on the issues and solutions identified in the design and arising from information on social and environmental issues, site changes may occur. The design is then revised again to ensure compatibility with the new site and to incorporate social and environmental impact mitigation measures or enhancement of project benefits.

## Management

*Management criterion - Preparation Stage: An optimisation process has been undertaken to assess the project siting and design options.*

The design of project components must suit the site and can be used to address some of the issues associated with the site arising through the technical, environmental and social studies. Optimising the design may result in changes in the siting to improve design efficiency or to avoid or minimise negative impacts.

The siting and design of the project, and areas where trade-offs may be required, need to take into account many considerations including the following:

- Hydrological suitability – the amount of water the project will yield, the volume and velocity of water flowing into the site, the predictability of water yield, and the ability to meet power generation demand.
- Geomorphological suitability – the shape of the river channel, which influences the size and construction method of the dam, as well as the storage capacity and water retention ability of the reservoir.
- Geological suitability – the underlying geology at the dam site must be suitable to ensure water retention, and the geology of the project area must be able to provide long-term stability of the project infrastructure (e.g. tunnels, roads, housing).
- Location suitability – proximity to existing infrastructure such as transmission lines and roads, ease of access to the site and to the required materials, and suitability with respect to power markets.
- Financial considerations – e.g. cost of construction, costs of environmental and social mitigation measures, design to maximise revenue (e.g. to generate peaking power for export), and design considerations to conform with eligibility for financial support (e.g. Clean Development Mechanism funding).
- Regulatory requirements and design standards – there may be areas where there are no alternatives because of the need to meet compliance and standards, for example relating to infrastructure safety.
- Social and environmental considerations – avoidance and minimisation of social and environmental impacts through siting and design choices, based on sound environmental and social assessments, is far more cost-effective for a hydropower project than trying to manage and mitigate problems after they occur.

- Economic considerations – net costs and benefits of different siting and design alternatives, siting and design to provide for multiple use benefits to maximise the development contribution of the project.

Packaging and conveying such a complexity of information to facilitate engagement with stakeholders can be very challenging.

The ability to rearrange siting in response to issues may be highly restricted. Major changes to siting may require relocation of the dam site in order to avoid protected areas, resettlement, or impacts to migratory fish routes. Siting may be highly constrained by those locations with a suitable valley shape and size, plus necessary geological characteristics to site the dam. Alternatives for variations in siting may end up being more closely related to components of the project other than the dam (or dams), for example with the power house and water conduits (e.g. above ground or below ground) and associated infrastructure (e.g. roads, transmission lines, other buildings and site features). As an alternative to dam relocation there may be options around the height of the dam, which will affect the area of inundation but may require compromises in the amount of energy generated.

There are many examples of design features that address social and environmental impact mitigation or enhance social or environmental benefit. The optimisation process should consider avoidance and minimisation of social and environmental impacts first, and where they cannot be avoided, then the relative merits of different approaches to mitigation should be evaluated. Examples of measures that could be effectively built into project design, rather than added on later, include:

- selective or multi-level offtakes in deep reservoirs to limit the amount of water drawn into the power station from cold, anoxic depths;
- downstream stilling basins, variations in spillway design, or structures that favour degassing can avoid downstream gas supersaturation;
- air injection facilities and aerating turbines can avoid de-oxygenated water being delivered to the downstream river system;
- in shallow lakes, baffles can direct circulation and ensure adequate water flow-through and mixing, and can also inhibit wind-induced resuspension of lake bottom sediments;

- fish ladders or mechanical fish elevators can assist fish with their upstream migration, although these can be of mixed success and need to be very carefully researched and tested. Structures that facilitate catching and releasing of fish or fish nurseries and breeding projects can be designed to fit into the overall project layout;
- measures can be employed to divert fish away from the turbine intake to safer passageways to facilitate downstream fish migration, such as purpose built channels or pipes going around or through a dam wall; diversion methods such as fish screens, strobe lights, sound or air bubbles, and electrical fields; and dedicated design choices around turbine, spillway and/or overflow design can minimise fish injury or mortality on the downstream migration;
- strategically placed and purpose-designed barriers may restrict ranges for faunal pest species, such as anti-jump screens or even creating local flow velocity barriers;
- sediment bypass systems for floodwaters, gated structures for sediment flushing, and sediment trapping and filtration systems can help minimise reservoir sedimentation rates;
- downstream re-regulation storages can dampen rapidly fluctuating flow releases from power stations and attenuate the downstream flows; and
- construction of smaller off-stream storages to deliver minimum flows to address particular local issues could be a cost-effective alternative to environmental flow releases directly from the power station. Another approach is to have a dedicated turbine for delivery of the environmental flow that has its optimal electricity generation at that designated flow level.

Planning of temporary features that are necessary during construction should ideally be considered within the designs for permanent features. For example, new roads, temporary access tracks, works storage areas, quarry sites and excess spoil areas might be located below the minimum water levels of the future reservoir so that they are unobtrusive following inundation of the impoundment. Conversely, features required by the project in the short-term may be located and designed to provide a lasting community benefit in the longer-term, such as spoil dumping sites later providing sports grounds.

Climate change presents some further design considerations with new projects. Features may need to be put in to increase their flexibility to adapt to any possible climate change impacts. Examples include larger spillways for extreme floods or boat ramps and water abstraction points that will still be functional if the lake is drawn to very low levels during extreme drought. The project design can include features to increase the project's flexibility to deliver different flow levels over the long-term, which could be important in a river where climate change may affect what flow levels will be effective or expectations for flows may change over time. For example, turbines of different sizes can increase the ability to generate at different flow levels, thus increasing management flexibility.

Design documents should be produced at varying levels and should include preliminary designs, groupings of designs according to specialty area (e.g. civil, structural, electro-mechanical, geotechnical, hydraulic), and detailed designs for specific project components (e.g. weirs, spillways, tunnels and channels, pumping stations, surge tanks). Documentation should also include drawings, technical specifications, modelling works such as fluid computational modelling, and master designs and plans. Physical models may need to be developed to test different design components, for example hydraulic flumes to test sediment management approaches. Physical models of the project layout can also help stakeholders engage to discuss where there are issues to be avoided.

## Stakeholder Engagement

*Stakeholder Engagement criterion – Preparation Stage: The siting and design optimisation process has involved appropriately timed, and often two-way, engagement with directly affected stakeholders; ongoing processes are in place for stakeholders to raise issues and get feedback.*

Location and general layout options, and siting and design alternatives, should be identified based on a dialogue with directly affected stakeholders, and this engagement process should continue through the evaluation and optimisation process. This engagement often happens as part of the ESIA process so the

trade-offs among different alternatives can be recognised and evaluated. However this may be late in the process. The earlier that social, environmental, stakeholder and project benefit considerations can be brought to the attention of the project designers, the more efficient the iterative process of adjustment and refinement will be.

The developer should recognise and factor in that there is likely to be a necessary requirement for education of the stakeholder base about technical aspects of hydropower. There are many aspects of hydropower that are not well-understood by members of the public, such as types of energy, the market situation, and constraints on options arising from the physical and built environment.

Stakeholder mapping should identify directly affected stakeholders for various aspects of the project (see the Communications and Consultation guideline). 'Two-way' engagement means the stakeholders can give their views on siting and design considerations rather than just being given information without any opportunity to respond. Examples of two-way processes include public meetings and hearings, public comments on studies and options assessment documents, interactive participation in workshops, negotiation, mediation, and focus groups.

**Appropriately timed** means that engagement starts early enough in the preparation stage so that the project can respond to the issues raised; stakeholders can respond before the project takes decisions; and engagement takes place at times that are suitable for people to participate (e.g. with respect to seasonality or time of day).

Stakeholders should be supportive of the timing of engagement activities. Communities need sufficient time to receive information, be able to discuss it openly with the project representatives, then go through their own community dialogue processes before forming a consolidated community view to relay back into the evaluation processes.

Processes in place for stakeholders to raise issues could include, for example, a contact person and/or a 'contact us' space on the company website,

periodic public briefings or question/answer opportunities, or focal group meetings. Feedback on stakeholder issues could be demonstrated by means such as meeting minutes, media releases, or provision of responses to frequently asked questions on the company website. Ideally a register is kept by the developer of source, date and nature of issues raised during the siting and design process, and how and when each was addressed and resolved.

There is no expectation that all stakeholders will be satisfied and agree with conclusions drawn. The aim should be that stakeholders understand and respect the process that has been taken to get to conclusions, that they have been offered appropriate opportunities for two-way engagement, and that they feel their inputs have been incorporated fairly.

## Outcomes

*Outcomes criterion - Preparation Stage: The final project siting and design has responded to many sustainability considerations for siting and design.*

Sustainability considerations for project siting and design should arise from a process of research into this area as well as through engagement with directly affected stakeholders. Several examples of potentially relevant sustainability considerations to factor into siting and design have been provided at the start of this topic guidance. The project proponent should be able to demonstrate that any significant sustainability related considerations have been identified for the project, and in particular those that reflect social and environmental concerns. Documentation should show that alternatives for project siting and design have been evaluated against these criteria. The resultant proposed project should clearly be able to demonstrate that many of the sustainability considerations are met in the final siting and design.