Infrastructure Safety

This guideline expands on what is expected by the criteria statements in the Hydropower Sustainability Tools (HST) for the Infrastructure Safety topic, relating to assessment, management, conformance/compliance and outcomes. The good practice criteria are expressed for different life cycle stages.

In the Hydropower Sustainability Assessment Protocol (HSAP), this topic is addressed in P-8 for the preparation stage, I-5 for the implementation stage and O-6 for the operation stage. In the Hydropower Sustainability ESG Gap Analysis Tool (HESG), this topic is addressed in Section 4.

The infrastructure safety guideline seeks to ensure that populations affected by hydropower infrastructure are not put at risk at any point during the life of the hydropower project. While dam safety is one of the most critical infrastructure safety considerations, this topic also has a strong community safety focus and there are a broad range of risks to the community that need to be taken into account. The requirements and expectations for the developer and owner/operator differ during the life cycle stages - project preparation, implementation and operation. The intent at any life cycle stage is that life, property and the environment are protected from the consequences of dam failure and other infrastructure safety risks.

This guideline is primarily focussed on community safety but has the benefits of increased employee safety. More focussed guidance on employee safety is provided in the Labour and Working Conditions guideline.

Assessment

Assessment criterion - Preparation Stage: An assessment has been undertaken of dam and other infrastructure safety risks with appropriate expertise during project preparation, construction and operation, with no significant gaps.

For hydropower projects at the preparation stage, good practice requires that dam and other infrastructure safety risks are thoroughly identified for each project stage using appropriate expertise.

Short-term and temporary infrastructure safety risks that can arise during preparation activities could relate to, for example: temporary labour camps, access roads, test wells, helipads, fuel storage, and power supply. During preparation, structures may be built or assembled in previously undeveloped locations with no protection against community interactions. The assessment should consider risks inherent to the structures, the likelihood of community impacts, and options to avoid or minimise safety incidents (e.g. location, fencing or other barriers, security personnel, signage).

During the preparation stage, the evaluations that ensure adequate safety measures will be incorporated into the permanent project infrastructure design are critical. Dam and other infrastructure design choices are informed by numerous and varied assessments including: climatic, hydrological, hydraulic, geological, geotechnical, seismic, glacial (where relevant), and material properties.

For a hydropower project, dam safety is paramount and a highly specialised field. All potential failure modes, i.e. features or events in the systems that can lead to an asset failure, should be identified and addressed where possible in the dam design. Extreme events can trigger failures (e.g. floods, earthquakes, fire, landslips, landslides), as well as more incremental processes internal to the structure (e.g. cracks, settlement, instability). The design should address all identified failure modes and consider the following dam failure risks at a minimum:

- overtopping, which may be caused by inadequate spillway design, debris blockage of spillways, or settlement of the dam crest;
- foundation defects, which may arise due to settlement or slope instability;
- seepage-induced erosion (i.e. piping), which can occur around hydraulic structures such as pipes and spillways; through animal burrows; around roots of woody vegetation; and through cracks in dams, dam appurtenances, and dam foundations;
- structural failure of the materials used in dam construction; and
- inadequate monitoring and maintenance.

Calculation of the probable maximum flood and determination of the design flood for the spillway are critical assessment requirements for dam safety at the preparation stage. The methodologies used, hydrological datasets, and guiding standards all need to be well-considered and justified (see the Hydrological Resource guideline). Regional circumstances will influence the degree to which other types of risks require consideration (e.g. volcanism, seismicity, landslip hazard, glacial lake outburst floods). Cascading dam failure may be of importance in basins with multiple dam developments. Dambreak analyses should always be undertaken to determine the downstream risk zones, the populations or structures at risk, and propagation times for flood waves, and these analyses should inform emergency response planning.

All regulatory requirements for the jurisdiction, and relevant design standards for the infrastructure and risks, should be identified, well-documented and met.

Appropriate expertise must be used for infrastructure safety-related assessments. This refers to specialists with proven experience designing and constructing projects of a similar complexity. Particular attention should be given to engineering safety competencies, such as hydrological, geotechnical, structural, electrical, mechanical, and for key risk areas (e.g. seismology, volcanology, glaciology).

Important during the preparation stage is infrastructure safety risk assessment and planning for the implementation and operation stages. Any risk assessment should take a systematic approach to considering possible risks, monitoring instrumentation and procedures, and management responses to risks that may materialise during each project life cycle stage.

Assessment

Assessment criterion – Implementation Stage: Dam and other infrastructure safety risks relevant to project implementation and operation have been identified through an assessment process; and safety monitoring is being undertaken during the project implementation stage appropriate to the identified issues.

Infrastructure safety issues unique to the implementation stage include quality control, flooding risks, landslip risks (sliding of a landmass down a slope), landslide risks (breakup and downhill flow of rock, mud, water and anything caught in the path), and construction-related issues. Monitoring for quality assurance and quality control is essential to ensure that the infrastructure is constructed fully to design standards and any issues arising (eg variations in materials specifications or fault zones in excavation areas) are detected and addressed. Flooding, landslips and landslides can cause direct damage and also impact on the effectiveness of the coffer dams, diversion tunnels and other diversion works used to divert water around the construction site or fill underground excavation areas. Other construction-related public safety issues can include an increase in traffic, heavy machinery on roads, blasting activities, and/or chemical and hazardous material storage areas.

Assessment

Assessment criterion – Operation Stage: Routine monitoring of dam and infrastructure safety is being undertaken to identify risks and assess the effectiveness of management measures; and ongoing or emerging dam and other infrastructure safety issues have been identified.

During the operation stage, the infrastructure safety assessment focus should be on the systematic and routine monitoring and surveillance of infrastructure to ensure the safety objectives are achieved and on the emergency response processes that are in place. Infrastructure safety monitoring should be embedded within asset management and maintenance plans (see the Asset Reliability and Efficiency guideline).

In addition to infrastructure safety risks relating to asset failures, community safety risks during operations can include electric shock, hydrological risk, drowning, road accidents, and other types of accidents arising from community interactions with project structures. These risks all need to be well-identified, assessed, and monitored throughout the life of the project. As a project ages, communities and their activities evolve around the operating facility, and new types of risks can emerge. Regularly scheduled visual inspections of all infrastructure safety measures are essential to assess aspects such as vegetation growth, fencing status, condition of signage, cracks, land stability, and community interaction risks.

Monitoring for dam safety risks during operations usually involves a mix of instrumentation, manual inspections and readings, and alert and alarm mechanisms. The monitoring programme should be well-designed to match the identified risks and to verify that risk avoidance and management measures are achieving their objectives. Focal areas for dam safety monitoring must include leakage and deformation, regardless of the dam type. Uplift should be monitored for concrete dams, and pore pressure along seepage lines for embankment dams. Where relevant, the response to earthquakes should be monitored. Instrumentation often includes V-notch weirs and drainage holes for seepage, surveys against established reference points for deformation, settlement gauges for embankment dams, piezometers for uplift pressure, and seismographs for earthquakes.

At the operations stage, an important area for assessment processes is to periodically test the effectiveness of planned measures for the emergency response system. Such a system often includes notification and warning systems for downstream areas in the event of sudden releases of water that could cause harm downstream. Periodic evaluations should be made to ensure all aspects of the system are functional.

Management

Management criterion - Preparation Stage: Dam and other infrastructure safety management plans and processes have been developed for project implementation and operation in conjunction with relevant regulatory and local authorities with no significant gaps and provide for communication of public safety measures; emergency response plans include awareness and training programs and emergency response simulations; and dam safety is independently reviewed.

Infrastructure safety issues and responses are broad-ranging. They may be managed under a central asset management system in a

business or may be dispersed with management responsibilities for different safety issues allocated to different parts of a business. Linkages and overlaps between asset management planning and safety management planning should be clearly defined. Plans should outline what actions will be implemented for the important aspects of infrastructure safety identified through the assessment processes. Plans should make it clear how responsibilities are allocated, important timing requirements, budget allocations, and reporting and review procedures.

Examples of infrastructure safety management measures that may be included in relevant plans include: signage, exclusion zones, emergency preparedness and response, monitoring, inspections, training, incident response, and communications. Regulatory and local authorities should be consulted and involved in preparation of infrastructure safety plans, especially where they involve public safety measures.

Public safety measures need to be communicated as appropriate to the measure and populations. Examples of communications methods for public safety include: public signage, documentation appropriately lodged with local authorities, awareness raising through various types of community engagements, and verbal communications by on-site patrolmen.

Given the potential consequences of any dam safety incident to public safety, international good practice requires independent review of all aspects of dam safety to be undertaken at the preparation stage. Ideally, this should be an ongoing process that commences during the development of concept designs and continues right through the operation stage, with the frequency of independent reviews during the operations stage being commensurate with risks. Independent review refers to expert review by someone who is not employed by the project, has no financial interest in profits made by the project, is not unaligned with the project in any other manner, and is generally perceived as being objective. An expert is a person with a high degree of skill in or knowledge of dam and infrastructure safety as a result of a high degree of experience or training in that subject. Forms of independent review may vary. Examples include contracting an expert consultant to provide a written review of a particular assessment, plan or report, or inclusion of a safety expert in a panel of experts.

Management

Management criterion - Implementation Stage: Processes are in place to address identified dam and other infrastructure safety issues and to meet any safety-related commitments relevant to the project implementation stage, including providing for communication of public safety measures; a formal quality control programme is in place for construction; safety management plans for the operation stage have been developed in conjunction with relevant regulatory and local authorities; and emergency response plans include awareness and training programmes and emergency response simulations.

Management criterion - Operation Stage: Dam and other infrastructure safety management plans and processes have been developed in conjunction with relevant regulatory and local authorities with no significant gaps and provide for communication of public safety measures; emergency response plans and processes include awareness and training programmes and emergency response simulations.

During the implementation and operation stages, infrastructure safety plans relevant to those stages should be demonstrably put into action. The management arrangements are likely to be quite different given the large role of contractors in the construction processes versus what is probably a more permanent and smaller staff during operations. Consequently, it is essential to have plans catering to each of these stages and the relevant risks and mitigation measures that have been identified. Because of the long time frame applicable to the operations stage, review and updates to plans should be made at meaningful time intervals.

During implementation, the quality control programme to ensure that infrastructure is built to design specifications is of very high importance. Quality control process examples include procurement specifications and factory assessment tests, materials testing away from and on-site, supervision procedures, and involvement of design engineers during construction monitoring. Quality control processes should

reflect a systematic approach to achievement of the design objectives that address infrastructure failure modes. The independent review panel discussed under the Preparation stage criterion can be an effective aspect of an overall quality control programme, which can be continued into the operations stage.

Infrastructure safety plans during operations often involve considerable ongoing monitoring, as well as asset repairs and upgrades that should be embedded within asset management plans. A systematic and routine approach to monitoring and responding to infrastructure safety issues should be demonstrated, both relating directly to asset condition and indirectly to community interactions with the assets. Data should be analysed and linked to identified failure modes or specific safety risks. In cases where the data indicates an event or issues, there should be evidence that a response has been taken to address that issue.

To ensure good ongoing communications on public safety matters, reports should be regularly made to those with the ultimate responsibility and authority for all public safety matters (this could be the company board of directors and may also extend to regulatory authorities). Reports should be based on agreed indicators that meaningfully alert those responsible to any issues or new risks arising and prompt management responses to address those risks, with agreed indicators that meaningfully alert those responsible to any issues arising.

During the operations stage, measures should ensure that emergency response plans are current, relevant, and widely understood by all those who would be involved in their implementation. A risk to avoid is that plans for emergency response have not been practiced or are not familiar to responsible parties when an actual emergency arises. Measures to address this risk should be demonstrated, such as regular updates to plans, and regular training programmes. Exercises should be periodically conducted for company staff and relevant authorities; these exercises should include simulations of emergency scenarios and test how well the plans address the scenarios and how capable the parties and resources involved are to undertake the required tasks. Emergency response exercises should be followed by evaluations and updates to plans and measures to address any identified human resource, communications or equipment gaps or issues.

Conformance/Compliance

Conformance/Compliance criterion - Implementation and Operation Stages: Processes and objectives relating to safety have been and are on track to be met with no major non-compliances or non-conformances, and safety related commitments have been or are on track to be met.

Assessment processes and management measures relating to infrastructure safety need to be compliant with relevant legal or administrative requirements. These may be expressed in licence or permit conditions or captured in legislation. Compliance requirements may relate to, for example, standards to be met, the frequency and type of monitoring to be performed, and reporting to be submitted by the owner to government. Meeting of design standards is of particular importance for infrastructure safety, and quality control and independent review processes should be thorough and credible and include documentation to verify that all design standards are fully met.

Conformance refers to delivering what is in the plans. These planning inclusions may go beyond compliance requirements or detail steps the business will make that ultimately lead to ensuring compliance. Examples include budgetary allocations, designation of roles and role expectations, and provision of internal training.

Commitments may be expressed in regulatory requirements for addressing infrastructure safety, in relevant policy requirements of the developer or owner/operator, or in any relevant company statements made publicly or within management plans. Evidence of adherence to commitments could be provided through, for example, internal monitoring and reports, government inspections, or independent review. Variations to commitments should be well-justified and approved by relevant authorities, with appropriate stakeholder liaison.

The significance of not meeting a commitment is based on the magnitude and consequence of that omission and will be context-specific. For example, a failure to demonstrate delivery of an infrastructure safety commitment such as implementation of an alarm system is a significant non-conformance, whereas a slight delay in delivery of a monitoring report could be a non-significant non-conformance.

Outcomes

Outcomes criterion - Preparation Stage: Plans avoid, minimise and mitigate safety risks with no significant gaps.

Outcomes criterion - Implementation and Operation Stages: Safety risks have been avoided, minimised and mitigated with no significant gaps.

Of utmost importance is that public safety risks relating to infrastructure are recognised and addressed to a justifiable level of residual risk.

To show that plans avoid, minimise and mitigate infrastructure safety risks, they should include a thorough outline of relevant risks. Mitigation measures in the plans should also be directly linked to all identified risks. The assessment and planning should be informed by appropriate expertise. The assignment of responsibilities and resource allocation for implementation, monitoring and evaluation should be appropriate to the planned actions.

An evidence-based approach should demonstrate that infrastructure safety risks during project implementation and operation have been avoided, minimised and mitigated with no significant gaps. The developer, owner and operator should demonstrate that responsibilities and budgets have been allocated to implement infrastructure safety plans and commitments. Monitoring reports and data in the implementation and operation stages should clearly track performance against commitments and objectives, and have a systematic approach to data collection, analysis and reporting so that incidents and trends are fully evident. It should be possible to provide examples to show how identified risks from the assessment were avoided or minimised. Evidence should show that mitigation plans have been implemented and are being monitored. Implementation of measures for infrastructure safety should be evident, such as signage, fencing, alarms, security personnel, a quality control lab on the construction site, actions taken to reject materials that failed testing, minutes of meetings with local emergency services, and photo records of emergency response simulation exercises. Records should be kept of any safety incidents, including near misses, and these should inform improvements of plans and processes. Ideally, plans and processes should reflect a continuous improvement approach and should be adapted to ensure that incidents that have occurred are unlikely to be repeated. Monitoring should show how plans are achieving their stated objectives.