Water Quality

This guideline expands on what is expected by the criteria statements in the Hydropower Sustainability Assessment Protocol for the Water Quality topic, relating to Assessment, Management, Conformance/Compliance and Outcomes. Water quality good practice criteria are expressed for the different life cycle stages of the Protocol tools, contained in topic P-21 for the Preparation stage, topic I-17 for the Implementation stage, and topic O-17 for the Operation stage. Insets show the exact criteria statements from the Protocol topics.

This guideline addresses the management of water quality issues associated with the hydropower project development and the operating hydropower facility. The intent is that water quality in the vicinity of the project or the operating hydropower facility is not adversely impacted by project activities or activities of the operator; that ongoing or emerging water quality issues are identified, monitored and addressed as required; and commitments to implement measures to address water quality are fulfilled.

Hydropower developments may fundamentally change water movement along a river, which in turn can generate associated water quality impacts. Water impounded behind a dam can either create a new lake or raise the level of an existing lake. The flow rates and patterns may change significantly. Impoundments can become **stratified** (i.e. layered with respect to certain characteristics such as oxygen and temperature), or stratification patterns in existing deep lakes can change. Sediments and pollutants may be transported into the waterway from upstream sources (e.g. wastewater discharges, landslips, agriculture, mining, erosion) or may result from operation of the infrastructure (e.g. oil spills). All of this can change the processes governing water quality in the lake and downstream. Both construction and operation stage activities can be sources of water quality impacts to the receiving environment, with consequent issues for ecosystem processes and services as well as socio-economic uses and values. Adverse water quality can also cause problems for asset performance and longevity, and a hydropower facility operator may be under pressure to resolve downstream water quality issues not caused by the facility through controlled water releases.

The geographic scope of the water quality assessment and management must consider:

- surface water, groundwater and drinking water;
- the catchment area for the reservoir – to determine the present and likely future condition and the surrounding influences on

water quality;

- the reservoir – to determine the water quality conditions in the reservoir water;
- downstream river reaches below the dam and power house – to determine the present and likely future water quality conditions in the river reaches that will be affected by the project as far downstream as the flows are significantly project affected;
- the construction areas – e.g. reservoir preparation works, dams (coffer, main, saddle), adits, tunnels, power house, mitigation measures (e.g. fish passage facility);
- ancillary structures and activities – e.g. worker camps, offices, concrete batching plants, water supply intakes, material fabrication areas, supply storage areas, quarries, waste disposal areas, roads, supply transport activities; and
- mitigation measure areas – e.g. fish hatchery, reforestation activities, local benefits.

Assessment

Assessment criterion - Preparation Stage: A water quality issues assessment has been undertaken with no significant gaps.

The project Environmental and Social Impact Assessment (ESIA) should include evaluation of the water quality impacts of the proposed hydropower project. A systematic approach to identifying and evaluating water quality status and potential impacts and risks needs to be taken. Professionals working in this area can include: water quality specialists; aquatic chemists; geochemists; limnologists, who study stratification in lakes and reservoirs; fluvial geomorphologists, who study river morphology and sedimentation and need to understand the interlinkages with turbidity and riverine transport of, for example, organic compounds; macroinvertebrate taxonomists, who classify and count aquatic bugs and understand the relationships between water quality and the needs of these species; and aquatic ecologists, who study freshwater ecosystems.

The preparation stage assessment starts with establishment of the pre-project baseline. Baseline studies should utilise appropriate expertise for the water quality sampling design, data collection, data analysis and interpretation. Available sources of secondary data should be identified and included, as well as local knowledge and information. More emphasis should be given to relatively recent secondary data and checks should be made to see if there have been changes in any conditions affecting that data. For primary data, a strategic approach should be used for the selection of water quality sampling sites to ensure a meaningful geographic spread and to include areas of likely water quality change or sensitivity to water quality impacts. At a minimum there should be four sampling locations: upstream of the future reservoir backwater, in the inundation area of the future reservoir, immediately downstream of the future dam site, and downstream of the next major tributary downstream of the future dam site. If possible and ideally, more locations would be included, such as upstream and downstream of other major tributaries, townships, development activities and point-source discharge points as well as from within significant tributaries. It can be advantageous to collect water quality data from locations at which the findings can be linked to hydrological data, and where practicable also to sediment and aquatic biodiversity monitoring data, as this can help with interpretation of findings.

During the preparation stage, sampling data should be collected over a period of at least 12 months. The number and timing of sampling trips should be designed to obtain the most representative data given the factors that could influence the results. For river sampling, this should cover all seasonal conditions of the region. Timing of sample collection should be sure to capture very different flow conditions, including during the low flow season, the onset of the wet season (noting this is the most significant time for fluvial transport), and the high flow season.

Water quality sampling results should be presented and described in accordance with any legal requirements and interpreted with respect to all relevant environmental standards. During the preparation stage, sampling results should be used to clearly establish the pre-project baseline conditions and the major influences on the results. Results should explain the pre-project status, trends and issues, taking into account flow, season, surrounding land uses (e.g. locations of settlements and industrial and agricultural activities), major tributaries, and points of water abstraction, treatment and discharge.

Sources and types of water quality risks that should be assessed relevant to the construction stage should include:

- quality standards of water used within worker camps and for construction site activities;
- sewage and solid waste from worker camps;
- sewage and solid waste from the increased population attracted to the area;
- dumping of excavated materials into or close to waterbodies;
- contaminated surface or groundwater from drilling, blasting, quarrying and stone crushing activities; and
- oil and chemical spills from workshops, storage areas and during transport.

Reservoir filling and project commissioning stage water quality risks should include consideration of the implications of changed flow regimes on water quality in the downstream river and any potentially adverse impacts, for instance due to reduced flows or intermittent discharges of low quality water.

Sources and types of water quality risks that should be assessed relevant to the operation stage should include:

- pollutant inflow to the reservoir or downstream reaches from surrounding activities;
- algal blooms during dry periods in areas with surrounding use of fertilisers;
- stratification and seasonal circulation within the reservoir;
- reservoir turbidity due to erosion in the reservoir rim;
- release of toxicants (e.g. heavy metals) from inundated sediments and contaminants in the reservoir;
- reduced oxygenation in the reservoir and downstream;
- gas supersaturation in the releases downstream;
- unseasonal temperatures in the reservoir and in the releases downstream;
- releases of highly turbid water through the low level release valve or through flushing of the desilting chamber;
- pollution from permanent offices and project infrastructure, such as the power house;
- chemical or waste spills from the power station or surrounding buildings; and
- turbidity increases due to riverbank erosion in rivers subject to hydropeaking, or 'aggressive river' effects (also known as 'hungry water'), meaning that the river's erosive capacity below the dam is enhanced due to sediment trapping within the reservoir.
- Water quality opportunities should also be assessed. These may include:
- addressing pollutants from non-project activities such as sewage, wastes, or contaminated sites;
- improving water quality compared to pre-project conditions;
- using new monitoring or treatment technologies such as increased automation; and
- forming partnerships with community waterway health monitoring groups.

Assessment

Assessment criterion - Implementation Stage: Water quality issues relevant to project implementation and operation have been identified through an assessment process utilising appropriate expertise; and monitoring is being undertaken during the project implementation stage appropriate to the identified issues.

Assessment criterion - Operation Stage: Ongoing or emerging water quality issues have been identified, and if management measures are required then monitoring is being undertaken to assess if management measures are effective.

Water quality related issues during the implementation and operation stages should consider changes to the baseline water quality condition and processes and the implications of these changes for other social, environmental and/or economic objectives. Water quality during the project implementation stage requires a particular focus on construction-related issues and downstream impacts related to the river diversion, whereas the operation stage often involves longer-term issues, multiple-use issues, and periodic incidents.

Water quality monitoring objectives need to be clearly expressed, linked to risks and impacts, and defined separately for the construction and operation stages. The basis for the locations, timing, parameters and methodologies adopted should be clearly explained. Sampling locations and techniques used for the baseline data gathering during the ESIA work should be continued as far as practical. In deep reservoirs, depth-profiles should be undertaken at several locations to detect stratification and be linked to seasonal and operational variability. Depending on the exact focal area required in relation to risks, the parameters used for water quality monitoring may be some or all of the following:

- physico-chemical water quality characteristics: temperature, pH, electrical conductivity, acidity, clarity, alkalinity, dissolved oxygen in surface and sub-surface water;
- turbidity;
- metals, which may include: total and dissolved iron, manganese, zinc, mercury, arsenic, cadmium (plus others if known to be of local concern);
- nutrients and carbon (total and dissolved); and
- indicators of organic pollution (Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), E. coli).

Where relevant, findings should be compared to the relevant environmental standards and interpreted in light of influential factors such as flow, water level, season, and activities.

Management

Management criterion - Preparation Stage: Plans and processes to address identified water quality issues have been developed for project implementation and operation with no significant gaps.

The water quality section of the Environmental and Social Management Plan (ESMP) needs to contain, at a minimum, the following outlined separately for construction and operation:

- all identified potential risks and impacts for water quality;
- mitigation measures for all risks and impacts listed, with the objectives and measures of success;
- monitoring schedules clearly linked to the risks and mitigation objectives;
- reporting schedules and formats;
- budgets and responsible parties, including any handover arrangements to different agencies over time; and
- audit, review and evaluation provisions.

Adaptive management measures for unpredicted water quality impacts are also ideally included. These would focus on issues that might be identified through the monitoring and surveillance and what the response would be (including responsible parties and contingency budget set aside).

There is considerable knowledge and experience globally of the mitigation measures that can be employed to avoid, minimise and mitigate water quality related impacts from hydropower developments.

Measures to address water quality risks and impacts arising from the project site could include some of the following:

- Mitigate insufficient water of appropriate quality for worker camps and industrial activities: water quantity and quality needs are thoroughly identified in the design and feasibility studies, sources are confirmed as available, and water supply infrastructure is built into designs including with treatment facilities if required.
- Mitigate sewage, solid waste and polluted run-off from worker camps, workshops, buildings: waste and run-off generation is conservatively (i.e. over-) estimated for construction and operation stages; well-designed drainage collection points; run-off and wastewater treatment plants are of an appropriate capacity with discharge points in high velocity flow areas away from water users.
- Mitigate run-off from dumping of excavated materials: conservative (i.e. over-) estimation of excavated materials and their volumes; clearly identified dumping areas that as far as possible avoid steep slopes, riparian zones, and the risk of materials entering waterbodies; spoil containment and drainage management measures; closing off of contaminant transport pathways; machinery access built into designs so that compaction, slope stabilisation and revegetation are implemented progressively.
- Mitigate contaminated surface or groundwater from activities such as drilling, blasting, tunnelling, quarrying and stone crushing: sediment traps and settling tanks, along with well-planned access for machinery to periodically clean them out, and clearly identified dumping areas for any sludge.

- Mitigate oil and chemical spills from workshops and storage areas: fully identified workshop and storage areas with specific locations for oil, fuel and chemical storage and refuelling, at which bunding of an appropriate volume is provided.
- Mitigate oil spills and leakages in the power station: careful estimation of oil needs and exploration of minimisation options, such as equipment choice and design (including water-lubricated turbines), appropriately sized and placed sumps, and regular inspections and maintenance of oil-containing vessels.

Measures to address externally generated water quality risks and impacts could include some of the following:

- Mitigate catchment area generated pollution: catchment management measures such as reforestation, protected areas, check dams, drainage works, rehabilitation, and fertiliser use reduction strategies.
- Mitigate sewage and solid waste from increased population attracted to the area: dialogue with the local municipality about capacities of existing solid and wastewater collection and treatment facilities; partnerships on upgrade or augmentation measures in a timely manner.

Measures to address within reservoir water quality risks and impacts could include some of the following:

- Mitigate the formation of reservoir stratification in relatively deep lakes, potentially leading to deoxygenated and unseasonal temperature water released to downstream, and in cases release of heavy metals in the sediments: reservoir siting and design to minimise the likelihood and/or degree of stratification; reservoir design and operating rules to minimise water residence time and ensure through-flow; if stratification will occur, selective or multi-level offtakes incorporated for projects within deep reservoirs to limit the amount of water drawn into the power station from cold, anoxic depths; seasonal management of lake levels to ensure releases of oxygenated water at seasonally appropriate temperatures; air injection facilities in the power station; aerating turbines.
- Mitigate increased turbidity due to erosion of the reservoir rim: reservoir operating rules governing the rates of water level rise and fall to minimise shoreline erosion; reservoir rim treatment works for erosion prevention; rules limiting boat speeds and planning rules limiting shoreline development and activities; creation of a reservoir buffer zone.
- Mitigate organic decomposition in the reservoir during the early years of operation leading to the consumption of oxygen: clearing of vegetation and organic materials in the reservoir in identified priority locations prior to inundation.
- Mtigate risks in shallow lakes in windy, exposed settings of turbidity caused by resuspension of bottom sediments: mechanisms such as baffles to direct circulation and ensure adequate water flow-through and mixing; wind barriers (built or planted) to reduce wind-induced mixing; planting and managing appropriately selected macrophyte communities (aquatic vegetation).

Measures to address downstream water quality risks and impacts could include some of the following.

- Mitigate downstream gas supersaturation: inclusion of stilling basins, spillway design, or through structures that favour degassing.
- Mitigate inadequate mixing of power station discharges with water of ambient characteristics: siting of the tailrace discharge point upstream of a significant tributary.
- Mitigate releases of highly turbid water through the low level release valve or through flushing of the desilting chamber: careful consideration of the locations, capacities, timing and operating patterns for use of the low level release valve and flushing of the desilting chamber and the location of the discharge points to seek to minimise highly concentrated pulses released into the downstream environment.
- Mitigate turbidity increases due to riverbank erosion in rivers subject to hydropeaking or aggressive river effects: built measures to dampen fluctuations such as a re-regulation weir; flow management to dampen fluctuation such as minimum flows (to reduce range and water surface slope of pulses); ramp-down rules; bank protection works.

Management

Management criterion - Implementation Stage: Processes are in place to ensure management of identified water quality issues and to meet commitment, relevant to the project implementation stage; and plans are in place for the operation stage for ongoing water quality issues management.

Management criterion - Operation Stage: Measures are in place to manage identified water quality issues.

During the implementation and operation stages, the water quality related plans developed based on the ESIA assessment work are put into action. For projects that did not have sufficiently thorough water quality assessment work as outlined in this guideline, water quality management plans can still be developed based on assessment work focussed on identifying issues and risks.

The important management requirements at the implementation and operation stages are to ensure that processes are in place that will enable water quality issues to be identified and responded to. Such processes may include: clear statements of business commitment to water quality within an environmental or sustainability policy; dedicated staff with water quality related qualifications and role requirements, and/or a partnership with a more water quality focussed organisation; allocation of budget and resources to enable monitoring and issues identification and response; and decision-making processes to ensure that issues arising have actions assigned (e.g. through a corporate environment committee).

Conformance/Compliance

Conformance/Compliance criterion - Implementation and Operation Stages: Processes and objectives in place to manage water quality issues have been and are on track to be met with no significant non-compliances or non-conformances, and water quality related commitments have been or are on track to be met.

Good practice requires evidence that water quality measures are compliant with the relevant government requirements, which may be expressed in licence or permit conditions or captured in relevant 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. Conformance refers to delivering what is in the plans. Commitments may be expressed in policy requirements of the developer or owner/operator, in 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 a major mitigation commitment such as a wastewater treatment plant is a significant non-compliance, 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 negative water quality impacts arising from project activities with no significant gaps.

Outcomes criterion - Implementation Stage: Negative water quality impacts arising from project activities are avoided, minimised and mitigated with no significant gaps.

Outcomes criterion - Operation Stage: Negative water quality impacts arising from activities of the operating hydropower facility are avoided, minimised and mitigated with no significant gaps.

To show that plans avoid, minimise, mitigate and compensate negative water quality impacts from project activities, mitigation measures in the plans should be able to be directly linked to all identified water quality issues and 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 negative water quality impacts arising from project implementation and operation activities are avoided, minimised, mitigated and compensated with no significant gaps. The developer and owner/operator should demonstrate that responsibilities and budgets have been allocated to implement water quality plans and commitments. Monitoring reports and data in the implementation and operation stages should clearly track performance against commitments and objectives, and capture water quality impacts. It should be possible to provide examples to show how identified risks from the assessment were avoided or minimised. It should also be possible to table evidence to show that mitigation plans have been implemented and are being monitored. Implementation of measures for water quality, such as aeration weirs, should be evident, and monitoring should show how they are achieving their stated objectives.