Large-scale hydraulic engineering

Contents

1. Scope

The term **hydraulic engineering** embraces all **structural work** carried out for the purpose of **using water** and **protecting against water. "Large-scale hydraulic engineering"** is understood to include **major barrier structures** which serve to **impound water.** These structures include not only **dams** proper, but also **weirs** for **impounding rivers**, e.g. for abstracting water, and structures to allow the **power-generating industry to make use** of the **water power** obtainable from the impounded water. The present sector also covers all **installations for navigation purposes** such as ports, canals, locks, etc. Major hydraulic engineering projects also embrace **land reclamation measures, tidal barrages, river diversions** and **aqueducts**. **This brief** is concerned **exclusively** with **impoundment works** (dams, weirs) and **hydroelectric power stations.**

Impoundment works will be understood to mean **barrier structures** and their associated reservoirs. These are erected for the **purpose** of **regulating water** in flowing or static bodies of water by damming so that it can be used by the **water and/or power industry.** The **barrier**

structures may be **dams**, which **close off** entire valleys or sections of valleys, or they may be **impoundment works** which simply **raise** the **water level** slightly in running watercourses.

The main purpose of **dams** is to **dam up water** for effective **management** of the **principal applications** (e.g. flood protection, hydroelectric power generation, irrigation, water supply), i.e. converting the **unregulated, natural discharge of the watercourse** into a **discharge determined** by **economic (and possibly also ecological) criteria**, and **creating a large reservoir.** The term **dam** is used to describe a **vast variety of structures** or **systems**. The **range** of possible variants includes:

- small/large dams
- shallow/deep dams
- dams in arid or humid, tropical or temperate climatic zones
- dams in upland or mountainous regions
- dams in sparsely or heavily populated areas.

The main purpose of **weir structures** is to guarantee a **certain water level** at a certain point in the **watercourse,** e.g. for extraction through a lateral canal (irrigation, hydroelectric power, water supply), for guaranteeing a minimum water depth for shipping, as head water for a power station inlet, or to guarantee a **certain groundwater level** in the **floodplain** (crop damming). The fundamental **differences** between the weir structure and the **dam** are that with weirs the **storage function is of subordinate importance**, with the result that they only **marginally influence** the **discharge regime of the watercourse**, and that they discharge water to a far greater extent over their crest and are therefore almost exclusively constructed of **masonry** or **concrete** (see also the Environmental Brief River and Canal Engineering).

Hydroelectric power stations may be installed both on the **flow** of a **barrage wall** and on that of a **weir**; they utilise the potential energy inherent in the water and convert it to **electrical energy**. **Hydroelectric power** is one of the **renewable forms of energy** which can be used **without emissions of trace gases.** Their use is characterised by **a long life,** which is extraordinary among technical installations, and **reliability.** Used in conjunction with **retaining dams** it is possible to **store energy** which can be made **available** when needed, almost **immediately.**

2. Environmental impacts and protective measures

2.1 Overview

Hydraulic engineering works interfere with the natural environment. Even if the hydraulic engineering works are designed, dimensioned and constructed according to the state of the art, with the aim of doing the least possible harm to the environment, **conflicts of purpose** nevertheless occur, among other things in terms of **nature conservation** and the **use of the natural resources of land and water**. The design, dimensioning and operation of hydraulic engineering works are therefore dependent on a number of **deliberation processes** which must necessarily result in a **compromise:**

- In the design phase of the project, for example, the height of damming, the costs to the national economy and the ecological costs of the associated **area consumption (usage)** must be weighed against the benefits derived from the additional **power generation.**
- In order to minimise the **use of rural land, material extractions** (quarries) for the construction work should be located, if possible, **within the subsequent area of damming** - provided that this does not incur unreasonably high transport costs.
- In the case of **flood protection measures** the extent of the retention of high waters must be defined very accurately and the **high waters important** for certain purposes (e.g. meadow woods, wet meadows, groundwater reformation, species protection, post-flood irrigation) **must also be allowed**, and if necessary must even be **specifically produced.**
- A classic operational conflict is the **competing use** of a reservoir for **irrigation** and **hydroelectric power** and the resultant difference in water flow rate in the lower course. A **minimum quantity of water** must be emitted into the watercourse below a retaining dam, particularly in low-water periods, to avoid damage to the watercourse (temporary drying up, formation of breeding grounds for pathogens in remaining pockets of water, if applicable excess loading of the residual water by the discharge of wastewater below the dam).

2.2 Dams

Dams divide a **river basin** into **three areas:**

- catchment area (above the dam root)
- storage lake area (from the dam to the dam root)
- lower course area (below the dam).

The impacts on each of the three areas are considered separately in the following and finally general impacts are described, such as those deriving from the construction work.

Ÿ Impacts of dams and protective measures in the catchment area

The **development in the catchment area** of the storage lake is of significance to **sedimentation** and **water quality** in the **storage lake.** A particular **problem** in these areas is often encountered in terms of **clearance** and **agricultural use of steep sections,** particularly on sloping sites.

Because of the damming up of the reservoir local residents may be displaced from that area to the catchment area above the storage lake (possibly steep slopes, marginal soils). Here **more intensive settlement** can lead to **uncontrolled deforestation** and **non-adapted land use**, thereby increasing **erosion** and the **ingress of sediment**, and in some cases also the **emission of means of nutrient and plant protection** into the river system. This may **impair water quality** and also the **use of the storage lake;** the **duration of use of the storage area** depends very much on the **ingress of sediments.** If such developments are to be expected **afforestation** and **erosion protection measures** should be provided from the very beginning in the catchment area of the dam when designing the project. On questions of resettlement see below.

Sediment deposits in the area of the dam root can result in **rises in the water level** above the dam root. However, since flood waters frequently re-erode the sediment deposit in the area of the dam root, and since the gradient on this stretch of the river is generally very high, the **impacts** of any rises in water level are **limited** (rises in groundwater level, flooding of areas close to the bank). In the lower course of tributaries whose sediment load could actually present problems, the **construction of front barrages** is required for retaining the sediment under certain circumstances.

Ÿ **Impacts in the area of the storage lake, protective measures**

This is where the **most striking change** occurs due to **flooding** of very extensive **areas** in some cases. Areas which are partly fertile, and often intensively used, including tropical forest areas and ecologically valuable river landscapes, or even places of worship, are **irretrievably lost.** The project location and the height of damming should be selected so that these losses are minimised. Because intact prime forest areas are worthy of special protection, the **installation of storage lakes in primary forest areas** should only be permissible in **justified exceptional cases** and where special protective measures are weighed against the effects of development.

The **loss of agricultural useful areas** is **compensated for** in cases where the supply of the water in the area below the reservoir actually **enables agricultural use** or **improves** the **production conditions** for agriculture in those areas. Because of the **establishment of nature conservation areas** in the area surrounding the reservoir, in the area of dammed up islands, or in other nearby comparable nature conservation areas, the **loss of countryside and natural habitats** can possibly be **compensated for to a certain extent.**

The **resettlement** of the residents of the overdammed area, which is sometimes necessary, the establishment of **infrastructural installations**, and the **areas required for the construction work,** should be clarified **at an early stage** before a project decision which **includes the persons concerned.** For the **persons concerned** not only **economic**, but also **social** and **cultural problems** may arise. Because of the **far-reaching**, **lasting effect on the living conditions** of a large number of people, all aspects of a possible resettlement must be **clarified** extremely **carefully** and at an **early stage.** In **compensating** the population to be resettled reasonable **consideration** must be given to the **social** (supply of housing and a sanitary and social infrastructure in the new location), **economic** (replacement of the industrial base, land ownership) and **cultural** (transfer of cemeteries or other cultural/religious institutions, ethnological relationships) conditions. The **measures** considered necessary must be **implemented completely** and **promptly during the construction period.**

The **installation of a reservoir** often **interrupts paths of communication**, resulting in economic and social disadvantages to the local residents and to the region. Suitable **compensatory measures**, e.g. by routing a **road** round the reservoir or subsidy for the purchase of **boats** for establishing a **ferry business**, should form **part of the project.**

The **terrestrial system** is converted by **damming** to an **aquatic system.** The **land-bound flora** is **destroyed.** Because individual species (flora and fauna) often only occur in closely confined spaces, it must be determined, in particular, whether flooding will result in or contribute considerably to the destruction of such species. **Protected areas** should possibly be designated for siting on the **edge of the reservoir** so that the animals driven out of the overdammed area can withdraw to those areas. In the provision of such areas, however, **consideration** must be given to **limitations** arising from their **loading capacity**. If it is not possible for the fauna to escape into the surrounding area a **conversion program** should be implemented for species particularly at risk and/or worth preserving, if possible.

The **aquatic fauna and flora** formed is determined by the **condition of the water in the reservoir** (temperature, turbidity, incidence of light, nutrient content, dissolved substances). Generally speaking **rapid, spontaneous** or, in some cases also **specifically encouraged settlement by fish species** takes place favouring the development of a corresponding intensive **fishing industry** (artificial stocking with suitable fish species, development of a management plan). Angling in storage lakes may make a valuable contribution to covering the protein requirement of the population.

The **enrichment of plant nutrients** in the storage lake can, of course, trigger extremely **serious consequences,** particularly in hot climatic zones. Because of greatly accelerated growth of algae and higher water plants resulting in **oxygen exhaustion,** the **use** of the lake for **drinking water purposes**, for example, can be made **more difficult,** the **growth of fish impeded** and even **fish mortality** in the **storage lake** and **underwater** may be **triggered.** If the water quality deteriorates further **concrete and steel structures** and **turbines** may be subject to considerable **chemical attack**. These risks increase with the expansion of the deep water zones, the holding time of the water in the storage lake and the accumulation of plant nutrients, e.g. from wastewater, fertiliser residues, manure from grazing cattle or elutriation from soil and the basement complex. The **introduction of nutrients** into the storage lake should therefore be **minimised.** The **loss of timber and firewood** should be avoided wherever possible and the possible negative effect of vegetation remaining in the storage lake on the water quality should be reduced. **Trees** remaining in the damming area may also **impede shipping** and **angling;** floating branches and twigs may impair the safe operation of the extraction and load relief structures of the retaining dam. **Methane emissions** of the biomass remaining in the reservoir may, in extreme cases, reach a **greenhouse potential** comparable to combined heating and power stations. To avoid these risks the **reservoir area** should be **fully deforested** and cleared, if possible. In the **tropics** there is as yet **no functional method** available of **predicting water quality** as a function of the reduction in nutrient supply (e.g. by removing vegetation, clearing the subsoil, suppressing other sources of introduction). Even today there are still **too few** or **no opportunities** for **regulating** factors which influence the **quality of the water introduced** (e.g. by means of human activities in the catchment area).

Due to the **change in runoff conditions**, generally accompanied by an extension of the shallow water zones on the bank, suitable biospheres (habitats) for intermediate hosts/vectors are created, particularly in hot climatic zones, for the **transmitters/carriers of water-bound infectious diseases (pathogens)**, particularly malaria, bilharziosis and gastrointestinal infections. The spread of **river blindness** (onchocerciasis) is generally **retarded** to a considerable extent in the storage lake area but can be intensified below the dam installation due to the replenishment of the oxygen-rich low water runoff.

In the case of **settled bank stretches**, and given the frequent contacts in this area, there is a **potential health risk** to the population which can only be partially counteracted by increasing the quantity of water passing through the storage lake. The **population** should be **informed** of these **risks** and of suitable **protective measures;** as part of the project it should also be determined how far **precautions** can be taken by the **local health authorities**, and if necessary **supporting measures** should be provided for here.

In the event of the expected increase in settlement in the bank zones of the storage lake it must be borne in mind that **traditional uses of the water**, e.g. for drinking water, cannot **continue without restriction** after damming: Compared with running water, **stagnant water** has a much **lower self-cleaning capacity, influxes** are no longer **discharged** as **quickly**, **pathogens** frequently **survive longer** because of the greater water depth, the **oxygen admission** is **lower** and **biochemical changes impair** the **water quality.** Very often it is the **shallow bank zones** and **bays**, with very calm waters, which are particularly **attractive** for **intensified use** by the local residents. In the **area surrounding the storage lake** controlled **drinking water supplies, and above all wastewater disposal** should therefore be provided to **avert** the above-mentioned **health risks** to the local residents and **prevent a deterioration in water quality.** The **interior of the reservoir** should be designed so that **no ponds** and **residual water quantities** are formed.

In the case of **storage lakes with shallow banks** far-reaching **changes may occur in the groundwater level** which may subsequently **facilitate** the **agricultural use** of these areas but might also **necessitate drainage measures**. Due to **water level fluctuations**, the extent of which is determined by the topography and operating regulations, **bare bank edges** are sometimes formed which are, under certain circumstances, **subject to erosion** and - where there is sufficient moisture - may represent favourable **breeding grounds for disease transmitters/pathogens.**

The creation of a **large body of water** results in **changes in the microclimate** of the storage lake area, generally with a tendency to **equalise extremes** (of temperature, humidity).

Due to the interruption in the river flow the **habitats of migrating species** (fish, amphibians, insects) are **restricted** or **cut off.** It must be determined in the individual case what species are affected by this, whether comparable habitats are still available for endemic species and whether there are **any remedial measures** which can be taken, e.g. fish ladders.

Ÿ **Impacts and protective measures in the lower course area**

The most striking impact throughout the area below the barrage is the **change in runoff rate: high water peaks** and **extreme low water levels** are generally **reduced** or even **avoided** with conceivable **desirable** and **undesirable consequential effects.** Whilst **bank erosion** in the **lower course** is **reduced** by the absence of the high waters, **erosion in the watercourse cross-section** may **increase** until a new state of equilibrium is reached due to the interruption in sediment transfer. This may result in the creation of indentations which may have undesirable **consequences,** such as **pumping stations running dry** on the river. **Countermeasures** may include the adaptation of existing structures to the new state of equilibrium, or the new building of additional hydraulic engineering works such as supporting weirs or slit walls parallel with the river.

The **change in the runoff rate** may also affect **groundwater sources** downstream. The newly created infiltration conditions can **influence** the **groundwater reformation** as well as the **groundwater runoff.** The main **negative consequences** that are possible are **reduced groundwater reformation** from used groundwater supplies or an **undesirable raising of the groundwater level** - the latter, for example, in the catchment area of canals.

The **absence of flooding of agriculturally used areas** prevents natural nutrient supply, and can **influence agricultural practices** (type of management, use of fertiliser).

The **changed runoff rate, water quality** and **sediment load** may affect the **coastal morphology** and **river delta**, e.g. due to the displacement of the boundary with the **brackish water area**, particularly in the case of offshore lagoons, to flora and fauna in the underwater area. In these areas **further regulation of the flow** may be required for reasons of nature conservation.

In the lower course area the number and peak runoff of high water events are reduced after the construction of a dam. As a result of this the river dwellers will tend increasingly to use otherwise regularly flooded **bank strips (sections) for agricultural** or even **residential purposes.** In the case of a rare **high water event (flood)** which, although meeting the design criteria for the dam, is no longer regarded as a possible event by the persons concerned, **serious damage** and even **deaths** will be regrettable. Suitable **bans on certain uses** must be implemented.

When **construction work** is carried out, and even during the subsequent **operation of the dams** - particularly when damming up the reservoir - care must be taken to ensure that a **quantity of residual water** corresponding to the use (water extraction, animal drinking) is **continuously discharged** and that the **river bed** below the valley bed does **not run completely dry**.

In the case of the **breach of a dam**, or even as a result of very substantial **embankment slips**, **maximum damage** must be expected over a long length in the lower course area. Provision must be made for **regular inspections** of the structure.

Ÿ **General impacts and protective measures**

If a **dam complex** is constructed and operated in a **region** which has so far been **inaccessible** and therefore **unsettled,** the construction of an **access road** to the building site is essential. This will enable a start to be made on **developing the region**, which may initiate **rapid, uncontrolled settlement.** This may be accompanied by arbitrary **clearance** to create productive agricultural land, together with **deforestation** and **removal of valuable timber** from the remaining **(forest) stocks**. This may set in train a **chain of action (events)** which **far exceeds** the **direct effects** of the dam complex. Effective **control** of such **haphazard settlement** is **hardly possible** given the national **pressure of population** prevailing in most such cases. In suitable projects such effects must be taken into consideration from the start, and these consequential effects must be reflected in all the advantages and disadvantages of a project. Major projects should be incorporated in a **regional development plan** which also takes into account environmental aspects. If necessary the scope of the project should also include measures, e.g. the creation of an administrative and social infrastructure, with which **settlement** can be **controlled.** However, the dam can also have

positive effects as far as settlement is concerned in that **housing space** is **created** in downstream irrigation areas, thereby **relieving marginal** and **sensitive areas** upstream from the **settlement pressure.**

The **establishment of material extraction points/quarries** for obtaining earth fills for the construction site can affect the entire catchment area. Since their positions are determined by the geological conditions and the requirements regarding the building materials, they cannot always be established in the subsequent damming area, as would be desirable. If they are **sited outside the damming area** there is **further land usage**, and if the **vegetation cover is damaged** there is an increased **risk of erosion.** On completion of the work the areas concerned should be **rehabilitated** as far as possible and laid out so that erosion and other risks do not arise. The same applies to areas which are used for **construction site installations**. They must be cleared, **freed** of any **contamination** and **rehabilitated.**

In the **storage of very large quantities of water** there is the possibility, under certain circumstances, of triggering an **earthquake** - although this risk must be considered **very low**, the **risk** should nevertheless be **taken into consideration** in **design** and **selection of the location.**

2.3 Weirs

The **impacts** of **weirs** are similar to those of **dams**, but they are generally **less serious.** In some cases there are **differences** in the following areas:

- Because of the **low height of damming** it is **easier** in the case of weirs to enable **migrating species to overcome** the effects of the **weir** by additional structural measures.
- The **loss of land** due to flooding is **limited** to a narrow bank area. Since it is not generally necessary to dam large quantities of water in weir installations, lateral protective embankments are erected where large, flat floodplains might be flooded.
- **Resettlements** will only be necessary to a **small extent** when weirs are erected - if at all - and the **distances** involved will be **short.** Here too disadvantages suffered by the persons concerned must be recorded accurately and their removal should form part of the project.
- Since weirs are being installed more frequently on stretches of watercourses with a comparatively low gradient and shallow banks, more attention must be paid to **changes in the groundwater level**. Protective walls running parallel with the river or surface drainage may be considered as suitable protective measures.

2.4 Hydroelectric power stations

Hydroelectric power stations have a **land usage** effect but this is **very limited** compared with dam structures and tends towards zero in the case of underground hydroelectric power plants or low pressure plants (integrated in the weir body). **Hydroelectric power stations** which guide the **driving water parallel with the watercourse** in long above- and/or underwater systems, **take all or most** of the **runoff** from it in this so-called discharge section. This leads to a **drastic change** not only in the **flora** and **fauna** but also in the **river morphology.** To prevent this and ensure that a **sufficiently dimensioned basic runoff** is maintained in the discharge section,

- the appropriate **quantities of water** must be **provided** for these purposes as early as the design stage;
- the operating regulations must contain **clear instructions** on the **control water discharge**;
- in countries were **formal procedures according to water laws** are prescribed, the **quantities of water** must be suitably **allocated** and **applied for.**

Despite the discharge of a compulsory quantity of water in the discharge section there may be a permanent **lowering of the groundwater level** in that section, with **harmful effects** on the **vegetation** and **agricultural production conditions.** Here it must be decided in the **individual case** whether **countermeasures**, e.g. the installation of slit walls running in parallel with the watercourse, are appropriate taking into consideration all the technical and economic arguments.

In **special cases hydroelectric power stations** make use of the **difference in height** between **adjacent catchment areas**, and transfer water into an adjacent catchment area. In this case **serious disadvantages, in terms of water management**, may arise particularly in the **original catchment area** due to the reduction in water runoff (e.g. diluting effect for intakes). These disadvantages must be carefully examined and considered.

3. Notes on the analysis and evaluation of environmental impacts

The **environmental impacts** of the projects in large-scale hydraulic engineering are often **extremely complex** and are also **subject to temporary interactions** which are **difficult to record.** The **impacts** of each individual dam are **different**. Moreover, **similar** or **identical impacts** must be **evaluated differently** (e.g. the loss of a unit of area of agricultural productive land caused by overdamming as opposed to a fallow area which cannot be used). There are no **generally valid limit values** or **rules of evaluation**.

The **questionnaire** attached as **Appendix 1** may be used as an **initial sounding of the possible environmental impacts** of a major hydraulic engineering project. The **impacts** thus surveyed should be **distinguished** as follows:

- impacts which can be varied or influenced
- impacts which can or cannot be forecast
- positive and negative impacts
- tolerable, intolerable impacts.

On this basis the **questionnaire** can be used to carry out an **initial weighting** of the expected impacts and an **estimate of the risks.** Furthermore **design alternatives** (e.g. different damming height) can be **examined** for the possibility of avoiding negative environmental impacts.

A **comparison** of the project with **existing major hydraulic engineering works**, or in the case of dams, with natural lakes in similar areas, climatic zones or under similar topographical conditions, may be a **useful method** of reaching relevant conclusions.

The **environmental impacts of hydroelectric power stations** must also be **weighed,** in an overall assessment, against the impacts which the generation of a corresponding quantity of electrical energy in **thermal plants** would produce. For the impact of the transmission of electricity see the Brief Power Transmission and Distribution.

4. Interaction with other sectors

The "large-scale hydraulic engineering" sector has **very close points of contact** with practically all **sectors** which have to do with **water**: particular mention must be made of **agriculture**, including **rural hydraulic engineering**, which is influenced by all major hydraulic engineering projects, whether because the same supply is used for **irrigation**, or because of changes in land use or destruction of the terrestrial flora and the superposition of secondary impacts.

Mention must also be made of the **supply of drinking and industrial water.** Water supply, which occupies a priority position in terms of the development of an area, must always be incorporated in planning, in all projects and sectors, and water supply interests must also be given priority.

All projects in the field of **transport hydraulic engineering:** port, river and canal engineering, are closely related. Reference is made to the corresponding briefs.

5. Summary assessment of environmental relevance

Obviously large-scale hydraulic engineering work has a visible effect on the environment. Whilst the **benefit** which a large-scale hydraulic engineering project brings can generally be **clearly quantified,** the **environmental impacts** of such projects are generally **difficult to determine**, for there are no universally applicable limit values or rules of evaluation.

The **final assessment** must represent the **main benefit and subsidiary benefits** of the project as clearly as possible and must compare them with the **impairments in terms of use** and **environmental impacts.** Since large-scale hydraulic engineering projects are generally **multi-purpose projects** a **comparison of the project** with the effects of the individual **alternatives** in terms of power generation, increasing agricultural production, flood protection, rendering waterways navigable, etc., must also be included in a **consideration of the environmental impacts.**

6. References

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Appendix:

Questions regarding the initial assessment of the environmental impacts of a large-scale hydraulic engineering project

(See notes in Number 3 of the brief)

1. What type of **areas** are flooded (present land use, present vegetation, etc.)? What type of **vegetation** is irreversibly destroyed? What value has this vegetation?

2. How many **people** are affected by the damming up of the reservoir or by associated measures? Is their natural biosphere (living space) destroyed, or is their basis of existence taken away from them? Can they continue operating their traditional land-use in the new areas assigned to them?

3. Will the new economic activities or the development of the infrastructure in the area surrounding the reservoir limit or change the existing **land-use**? Will the project open up new possibilities of land-use?

4. Will the damming up of the reservoir open up new possibilities or provide other forms of **water-use**, e.g. fishing, irrigation, water supply, recreation, tourism, etc.? What environmental impacts may be expected from these new activities?

5. Will the damming, the changes in the runoff rate or even the raising of the groundwater level lead to a deterioration in the **habitats** of rare animals and plants or those threatened with extinction?

6. Will the dam, the reservoir, any roads and infrastructural installations or the power transmission line represent **obstructions to wild animals**?

7. Will the **construction work** impair or destroy habitats of valuable animals and plants or those worth protecting?

8. Can the reservoir alter the local **climate**?

9. Will **cultural monuments** or other **cultural centres** (including places of worship) important to the local population be flooded or impaired by the construction work?

10. Will the work alter particularly beautiful or unique sections of the **watercourse**? Will the watercourse itself change?

11. Will the project alter the **flood risk**? What will be the consequences of this? Can these changes be quantified (e.g. number of people affected by flooding, arable land affected by flooding, etc.)?

12. Is the reservoir located in an area **subject to earthquakes**? Does this present special risks? What would be the effects of a breach of the dam? Can the project itself trigger earthquakes?

13. Can major reductions in the total runoff be expected due to increased **evaporation**?

14. Will reductions or changes in the **quantities of water** discharged over time have a detrimental effect on access of the local population to drinking water, or the use of the water for irrigation purposes, drinking water for cattle or wild animals?

15. If the **groundwater level** is altered because of the damming, what will be the effects of this on the natural vegetation, water supply and agriculture? What will be the effects on useful sources of groundwater located in the damming area or downstream from it? Both the areas surrounding the reservoir and areas along the watercourse should be examined for this.

16. Is there a risk of a permanent or temporary deterioration in **water quality** due to a reduced runoff and the associated increase in concentration and dwell time of substances introduced into the water? Is there a risk of special pollution of the river water during the construction work as a result of tunnel work, excavations, etc.?

17. Is there a risk of **erosion** due to the condition of the soil in the planned reservoir, e.g. landslips in the damming area? Will the project contribute to greater erosion?

18. Will the planned reservoir favour the **deposition** of sediments and nutrients in the watercourse? To what extent will this detract from the service life of the reservoir?

19. Will the deposition of sediments in the reservoir lead to increased **erosion** downstream from the reservoir? Is there a risk that the increased nutrient enrichment in the water of the storage lake will result in the **growth of water plants** in the reservoir? Will the deposition of sediments

and nutrients lead to reduced agricultural productivity and lower fish catches in the lower course? Will possible changes in the volume and runoff rate of the water, floods, have any effects on fish production and fishing in the lower course or on the river estuary area?

20. Are there any rare **fish species** threatened with extinction, or of economic importance, in the river area, forced to migrate in search of food and to spawn in the river? To what extent will the construction work or the structure itself prevent this migratory movement? Will this impair the production of important fish species in terms of quantities?

21. Will the damming of the reservoir or the altered watercourse in the regulated river bed improve conditions for the propagation of **pathogens**? Will the density of settlement on the edge of the reservoir be increased by the project, resulting in increased risks of infection? Is there a risk that the water in the reservoir may serve both as a source of drinking water and as a depository for wastewater?

22. Will the project lead to a marked **increase in population** in the area surrounding the reservoir? Is there a risk of conflicts between new population groups and the original residents due to competition for limited resources, different cultural or ethnic roots, lifestyles, different power situations? Are the natural essentials of life adequate and sufficiently stable to support the additional population? Is there a regional plan?

23. Will traditional **ways of life** - adapted to the local conditions - **change**, or will they be at risk because of the change in the natural environment, changes in production methods or by influences from new population groups? Will the ecological loading capacity of the area be impaired?

24. Will the possible **socio-cultural effects** of the project affect specific population groups (ethnic groups, sex-specific effects, etc.)?

25. Will the construction of the reservoir or associated activities lead to a situation where **traditional uses** of the area (e.g. agriculture, rearing of animals, etc.) will have to be transferred to ecological less sustainable areas?

26. Will the construction work or subsequent activities increase still further the **demand for water and firewood** in areas with a shortage of resources?

27. Will the **improved access to the project area** due to the development of the infrastructure lead to new economic activities, e.g. agriculture before industry, etc. To what extent will these activities have a detrimental effect on the environment?

28. What other project-specific direct and indirect impacts must be considered?