15. Erosion control

Contents - **Previous** - **Next**

Contents

1. Scope

Erosion is the **carrying away of solid matter** and its **subsequent deposition**. These are part of the cycle through which matter passes and are thus **natural processes** observable as action and reaction everywhere in the ecosystem's intrinsically balanced operation. It is only major **interference** with this system coming from outside that may so **change the state of equilibrium** that corrective measures, even including direct protection for structures, may become necessary. Such **external interference** may take the form of:

- land use (depending on its nature and extent),
- damage to the vegetative cover, due in particular to deforestation and grazing,
- interference with the structure of the terrain, e.g. by road building and human settlements,
- interference with the watercourse system by straightening, channelisation, shortening or impoundment of flowing waters.

The term **"erosion control"** means any measures taken to control erosion by **physical**, **biological**, or **biotechnical** means. Its **goal** is to **reduce soil erosion**, i.e. the weathering away and carrying off of soil by wind, water or natural mass movement that may occur as a result of human action or natural factors (terrain, vegetative cover, climate). Erosion control measures are normally carried out to **counter threats** to the human habitat and thus to preserve the basic necessities of life. Hence, their primary function is as **protective measures** (often intended to protect infrastructural and farming facilities and structures) but secondarily and in the medium to long term they also help to benefit human beings and to **improve environmental conditions**.

With regard to the **forms and impacts** of soil erosion resulting from disturbance or destruction of the natural vegetative cover, a **distinction** can be made between:

- **sheet erosion**, or the carrying off of soil from the surface of an area, particularly by heavy precipitation or strong winds, leading to losses of or damage to the natural flora and fauna or soil used for crop growing,
- **rill erosion**, or the cutting by runoff water of anything from rills through trenches to gulleys that occurs when the surface runoff is higher, resulting in fissuring and fragmenting of the terrain in a more pronounced form of sheet erosion,
- **gulley erosion**, or erosion caused by streams of flowing runoff water producing deep cuts, deepening of the stream beds, erosion of the stream sides or banks, and shifts in the position of the stream beds, with all the consequences this may have for runoff, groundwater, vegetation, crop cultivation and the human infrastructure,
- **landslides and land slips**, these being erosion-related phenomena caused by gravity acting in combination with natural or anthropogenic triggering factors that may cause damage to the environment and infrastructure,
- **sedimentation and alluvion**, these being the deposit and build-up of solids eroded elsewhere that have been transported by wind or water, with all the undesirable consequences this may have such as the silting up of dams,

canals and watercourses, the encroachment of sand dunes and the burying by sand of villages and areas of vegetation.

By making the widest possible use of biological measures, endeavours should be made wherever possible to employ **natural erosion control suited to the landscape**. Control of this type will be orientated towards **restoring the natural balance of solid matter** in the given ecosystem (soil loss tolerance level) and constitutes positive environmental action. However, physical erosion control too, aimed at directly **safeguarding/protecting the existing infrastructure**, may allow beneficial environmental impacts to be obtained by a feedback process (e.g. protecting a village by terracing a hillside in danger of slipping will cause a reduction in slope erosion and will also protect the vegetation).

Although in most projects it will be a question of providing **aftercare**, wherever possible it should not be simply the localised effects (damage and destruction) that are dealt with. **Attention should also be given to the causes** situated elsewhere in the watershed which, in the final analysis, constitute the **triggering factors** (watershed management): for example, upstream erosion control to improve retention capability will reduce the high water discharge responsible for bank collapse downstream. **Integral erosion control programmes** are seldom feasible, the reasons for this being not simply economic and technical reasons but social or political too. Restricting human activity over a large area for the benefit of nature (creating a reserve), even to the extent of stopping settlement, infrastructural development and agriculture, is something that is felt to present considerable problems.

The objective of any steps taken to control erosion is to reduce the **human- accelerated rate of erosion** to the **natural level specific to the site**. Erosion control therefore consists of measures to **control the symptoms** of an imbalance not peculiar to the site and the **causes** of those symptoms, remembering that the **triggering factors**, such as human beings, wind, water and mass movement, can be **totally eliminated only in exceptional cases**. **Measures** of this kind are generally of a **physical and biotechnical nature** and they **include**:

- **keeping in place of areas of soil threatened by erosion** (biotechnical erosion control by afforestation, planting of vegetation, construction of wind-breaks and embankments to restore vegetative cover),
- **landshaping techniques** to retain erosive surface runoff and discharge it in such a way that no damage is done,
- **changes to the structure of the terrain**, e.g. by terracing and embankment building,

- **stabilisation of slopes at risk of slipping**, e.g. by planting of vegetation and erection of retaining walls,
- **stabilisation and lining of eroded trenches**,
- **river engineering operations in watercourse beds** to stabilise bed and banks and alter bed roughness and cross-section
- **changing of flow velocities** in watercourses by impeding flow (deceleration by in-stream structures) or by contraction/shortening length (acceleration of flow by transverse dykes, reductions in cross-section, cutoffs and straightening),
- **constructional activities** carried out to provide direct protection for infrastructural facilities of general public utility.

2. Environmental impacts and protective measures

2.1 Overview

The primary distinction that has to be made in the field of erosion control is between measures to **protect**, **preserve** or **support parts of an anthropogenically disturbed ecosystem**, though in particular cases these parts may also be parts of the

infrastructure. Just as with biotechnical erosion control, so too may making physical changes to the existing conditions produce **environmental impacts**, and these impacts can be divided up as follows by path of impact and duration into:

- (adverse) environmental impacts that are **direct** but **of limited duration** and that occur during the implementation phase when physical erosion control measures are being implemented, and
- **indirect** impacts **of unlimited duration** that occur once the measures have been completed and that have to do with:

- changes to

(A) the natural environment in the

(a) physical-geographical sphere, and
(b) the biological sphere, and

- improvements or deterioration in

(B) the sphere of uses and
(C) the human sphere.

The impacts on **spheres (B) and (C)** are closely connected. Often they are not simply side-effects (especially not in the case of protection for infrastructural facilities) but **consciously planned parts** of an erosion control programme where the programme is of the type that may lead to restrictions on settlement and use of land and water and to infrastructural operations (e.g. road and footway building).

2.2 Control of sheet erosion

2.2.1 Objectives

Control of the erosion of areas of land should be achieved principally by **biotechnical measures** - afforestation, vegetative cover, choice of suitable cultivated crops and farming methods, which measures may be accompanied where necessary by **minor physical measures** (e.g. sand arresting fences, embankments following contour lines). **Collaboration with farmers and foresters and their industries** is vital in this case.

However, in the present case **physical erosion control** may also be deployed in preparation for, as a back-up to, or a contributory measure to **slope stabilisation**. When this is the case, preference should be given to using **natural materials** and **materials** and **building methods suited** as far as possible to local conditions (e.g. wood, dry masonry, or gabions rather than concrete). **Measures** that can be employed for this purpose are ones such as:

- terracing, correction of relief (levelling), rock anchoring, structures for protection against rockfalls, incorporation of berms, slope drainage, intercept channels, drainage ditches, geomeshes, retaining walls, reinforced earth.

2.2.2 The natural environment

(a) The physical-geographical sphere

Adverse changes to **terrain structures** and **soil quality** and **re-ordering of layers** in existing soils are all possibilities. While measures to control sheet erosion are being carried out, there may for a time be quite considerable **soil losses** due to the loosening of the soil caused by the earth-moving operations.

(b) The biological sphere

Damage (generally only **temporary)** may be done to the existing flora and fauna as a result of the measures carried out and due to changes to the local conditions caused by changes to the surface configuration and soil quality, thus affecting species diversity. Such **changes** are often **planned and desired** with a view to agricultural use.

2.2.3 The use sphere

Particularly where erosion control measures to improve retention (e.g. by afforestation) are aimed at reducing the entry of sediments into watercourses/reservoirs, an attempt must also be made to **restrict land use in the watershed at risk from erosion**: a ban or restrictions on grazing, logging, farming and settlement.

Not only do **measures to control sheet erosion** lay **positive foundations** for ensuring that **agricultural use** will in fact become possible again, in the majority of cases they are also **vital** for the **long-term preservation of soil resources** for agricultural use.

2.2.4 The human sphere

Impacts in the human sphere are directly related to those in the sphere of land use. These impacts are adverse for the population, herders and farmers affected due to the **restrictions on settlement and use**, but they have to be viewed as unavoidable for the purpose of **preserving the environment** or **infrastructural items** (e.g. earth dams) of general benefit. **Corrective measures**, and **programmes to prevent social impacts** aimed specifically at women in their frequent role as farmers/subsistence producers, must be designed and executed with the full participation of those affected.

However, erosion control measures on existing agricultural land may cause increases in production and hence an **improvement in existing living conditions.** They do however have **cost implications** and management repercussions because it is very often the land users who have to carry them out and maintain them.

The **alternative** is **total loss of the soil by erosion**.

2.3 Erosion control in water runoff channels and watercourse beds

2.3.1 Objectives

With the aim of ensuring **safe discharge of water** and preventing bank collapses, scour, etc., preference should be given in the present case, as with land erosion control, to biotechnical or combined controlling measures wherever possible. Endeavours should be made to employ **biotechnical stabilisation** in the form of a combination of natural building materials, building methods and plant cover. It should also be borne in mind that changes in the **sediment charge**, due for example to erosion control in the watershed, will also affect the **erosion and sedimentation regime in the receiving waters**.

2.3.2 The natural environment

(a) The physical-geographical sphere:

Stabilisation and lining of eroded channels and stream and river channels may amount to **severe interference with the landscape**. The control measures will mean that the flowing water will contain less solids and although this may raise its carrying capacity and thus its potential erosive power, bed sills will normally be constructed at the same time to **decrease the gradient** and hence the **flow velocity**, which is a cause of erosive damage to beds and banks.

Despite this, unprotected reaches lying further **downstream** may become exposed to **more severe attack** as a result of control measures upstream, the possible consequences of which should be considered in each particular case; broadly speaking, the downstream area should always be preserved from any damage.

The environmental briefs Rural Hydraulic Engineering, River and Canal Engineering, and Large-scale Hydraulic Engineering should be consulted for **other impacts** caused by erosion control measures applied to surface waters.

(b) The biological sphere

Deleterious effects may occur in watercourses that carry water at all times. However,

stabilising the bed of the watercourse will have **hardly any impact** on the aquatic flora and fauna, providing steps are taken to ensure the **use of natural materials** and particularly if biotechnical stabilisation is employed, something which should always be striven for (plants soon grow through and over rubble and broken stone). The **slowing-down of discharge** by bed sills however, though planned as a corrective measure, will have impacts on living and migratory conditions and hence on the **spawning and feeding opportunities for fish** (which is why fish ladders should be built) and on the surrounding vegetation (beneficial effect on the groundwater level).

Due to the change in flow regime upstream of sills, weirs and similar structures, **areas of dead water** may be created in which **oxygen intake** is **severely reduced**. The consequences may be both **disruption of the fauna in the water** and **invasion by disease bacteria**, and the latter may be transmitted in turn from the water to humans and animals. To prevent this from happening, thought should be given to fencing off the areas in question.

2.3.3 The use sphere

Generally speaking, **erosion control measures in water runoff channels and watercourse beds** have a **beneficial** impact in the sphere of land use, provided they are carried out with the aim of **stopping land losses** and **protecting infrastructure** along, in and on the bed of watercourses.

However, the possibility of **detrimental effects on fishing** cannot be ruled out in watercourses that carry water at all times (see above). It is while erosion control measures are being carried out that such effects are particularly likely.

Where measures are implemented with a view to retaining material that could become sediment and bed load, for example by **shoring watercourses or eroded channels** (which is often done in the higher and steeper parts of a watershed which are more susceptible to erosion), then detrimental effects need only be anticipated in the event of **failure of the shoring**. If this happens, it is likely to cause landslips, earth flows, and major erosive and sedimentation damage on and about land and structures devoted to human use. At the same time however, the measures will also reduce the opportunities for obtaining gravel and aggregates for building purposes downstream.

2.3.4 The human sphere

The **impacts** in this case are the same as in the use sphere but despite the potential risks described above (the improbability of whose occurrence makes them exceptional risks), they are wholly **beneficial**. It is however **essential** that the **planning** of erosion control measures for flowing watercourses should be **properly** carried out, that the

population (the riverside inhabitants) **are involved in good time**, and that they are **informed** of the purpose and utility of the measures.

3. Notes on the analysis and evaluation of environmental impacts

In the majority of cases, extensive **erosive and sedimentation damage** is an **indirect consequence** of **population pressure**, **uncontrolled settlement** and **heavy use of resources**, all of which lead to a reduction in the retention capability of a region.

By calling on the widest possible armoury of biotechnical measures, an attempt should be made to obtain erosion control that is as natural and as well suited to the landscape as possible and whose object is to **restore a natural solids balance** in the ecosystem in question. If at all possible, it should be not just the localised **effects** (damage and destruction) that should be dealt with but, **above all**, the causes situated in the rest of the watershed which, in the final analysis, constitute the **triggering factors**.

If it is to be possible for the impacts on nature and the environment to be analysed and evaluated, then a specific **study of the natural conditions** will need to be made at the start of any project and due consideration will need to be given in this study not just to **technical and scientific questions** but to **socio-economic aspects** too. The **population** and the **organisation in charge** should be **involved** as **early** and as **fully** as possible, and great importance should be attached to the **involvement of women**.

To be specific, what **the analysis and evaluation of environmental impacts** involves is:

- as full as possible a **description** of the **actual situation** and of the existing interactions,
- the collection of an adequate volume of reliable **basic data** for **technical planning** and **construction work** (precipitation/runoff ratios, winds, foundation soils, studies of demand and cost-benefit, estimates of secondary costs, and means of ensuring ongoing maintenance),
- the development of alternative **project schemes** with the aim of obtaining an environment-friendly solution that cannot be bettered in socio-economic or socio-cultural terms and that allows for the aims of the original project and ensures they are achieved to the maximum possible degree (e.g. that includes complementary measures to minimise undesirable side-effects that may arise as a result of conflicts of interest).

Universally applicable **standards** to allow the impacts of erosion control to be quantified **do not exist as yet**. In each **individual case**, it is both feasible and to the point for **comparative surveys** of the existing soils (and vegetation), of dimensions (areas/volumes) and of long-term groundwater measurements to be made before and after the erosion control measures are implemented for the purpose of quantifying and thus evaluating the environmental impacts. **Potential detrimental effects** (areas of dead water, invasion by pathogens) should be included. There are however two **key questions** that always require critical analysis and evaluation given that even erosion control constitutes interference with nature and the landscape and these are:

- Physical erosion control measures (including ones working in combination with biotechnical measures) may be beneficial to the environment and may be intended to correct the impacts of other actions or changes, but are they really necessary or are they simply providing **technical support for wholesale exploitation of and changes to the landscape**?
- Do erosion control measures (irrespective of whether they are physical and/or biotechnical, as in the case of river straightening for example) merely **shift problems** downstream, without there being any solutions ready for them?

Comprehensive erosion control programmes in the form of integrated programmes covering large watersheds require suitably **wide-ranging planning** that must include sex-specific and group-specific analyses of the **socio-economic and socio-cultural needs of the resident population** and an examination of **policy-based constraints** in the region concerned. **Collaboration**, e.g. with structural and regional planners, with farmers and foresters and their industries and with fishing interests, is **essential**.

4. Interaction with other sectors

It can be expected that there will be **two-way influences** between physical erosion control and **all the sectors** that interfere with the existing **balance of nature and the landscape**.

Although **physical erosion control measures** are **preventative in nature**, or in other words are devoted to directly protective purposes, they are often carried out as a **result of adverse (external) environmental impacts** (caused by action in other sectors) and are aimed at the prevention of further stresses. The impacts in question may be **caused by activities** in a wide variety of sectors such as agriculture, infrastructure, energy/mining, and trade and industry.

Where there are **closer points of contact** is particularly with planning and activities in the following sub-sectors aimed directly or indirectly at **making use of soil and water resources**:

- Water Framework Planning
- Rural Water Supply
- Rural Hydraulic Engineering
- Solid Waste Disposal
- River and Canal Engineering
- Large-scale Hydraulic Engineering
- Spatial and Regional Planning
- Transport and Traffic Planning
- Road Building and Maintenance
- Provision and Rehabilitation of Housing

and in the agricultural sector, the areas of:

- Plant Production, Plant Protection, Forestry, Fisheries and Aquaculture and Irrigation.

5. Summary assessment of environmental relevance

Erosion control measures should always be planned and executed to be beneficial to the environment and to **support and improve the threatened or damaged ecosystem**. Hence their role is to **correct** the consequences of other measures that interfere with nature and the landscape.

A **significant place** must be accorded in the planning to the presence and activities of **human beings** and their socio-economic and socio-cultural needs. This being the case, the measures may be devoted directly to protecting infrastructure and may thus, by feedback, have beneficial impacts on the ecology.

It is **possible in principle** for erosion control measures to have **impacts damaging to the environment** though if they do it runs contrary to the intention of projects in this sector. Such impacts are only likely if **the aims being pursued in the planning are too narrow** or if there have been **errors in planning or execution**; what are possible as a result of erosion control measures on the other hand are conflicts of interest resulting in restrictions on use (e.g. in the areas of settlement, farming and forestry).

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Contents - **Previous** - **Next**

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

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16. Road building and maintenance, building of rural roads

Contents - **Previous** - **Next**

Contents

1. Scope

The term "road building" covers **public roads and footways** of all kinds inside and outside built-up areas that are used for the **movement of persons and goods**.

The roads involved will generally be two-lane rural roads or single or two-lane rural footways that are intended to establish a **traffic link** between two specified points or to open up a region in a practical way by providing a new or expanded transport network. For this reason we will not be considering here the special problems of urban roads or developments of the motorway type (such as the stress on the population in centres of population).

As dictated by purpose, volume of traffic, and the given natural morphological conditions in the landscapes to be crossed, the **design standards** (right-of-way width, vertical and horizontal alignment, structures, and carriageway pavements) that the planners elect to adopt in the light of vehicle characteristics will be more or less generous.

Despite the wide variations in topography, climate, hydrography, soil types and vegetation that exist, there are **relatively standard rules** for planning and construction that govern the three main stages of building a road:

- deposit a fill of the minimum height required using suitable soil that if possible is available from nearby sources,
- protect this fill with a system of passages through it and ditches to drain away rainwater and any constantly occurring surface water,
- pave the carriageway with bound (with cement, bituminous material, etc.) or unbound mineral layers in a manner suited to the wheel loads anticipated and their frequency of passage.

All roads require constant **maintenance**, though the amount will vary with heaviness of use (crown to be kept free of vegetation, drainage system to be kept fully operational, erosive damage to be made good where cut and fill methods were employed, carriageway to be repaired).

2. Environmental impacts and protective measures

The criteria that should be applied are those developed over the last few years for environmental protection in the road building field, as modified to suit different environmental conditions and the different weights given to the factors evaluated.

The present environmental brief will deal **not** with the **effects** stemming directly from the movement of traffic on roads and from the operation of vehicles (see the environmental brief Road Traffic for these) but simply with the **impacts** in both a wider and a narrower sense that, due to the interference there has to be with the natural environment, arise **from the reasons for building** the roads and from the subsequent **maintenance** these roads will need.

These impacts can be divided into

- widespread direct impacts
- linear indirect effects
- spot effects
- consequential impacts.

2.1 Widespread direct impacts

(a) Regional adverse developmental effects

The opening up by a new road of a region previously inaccessible to motor traffic, or simply the upgrading of an existing artery, causes **changes to living conditions** in the areas affected, these changes being of greater or lesser severity in line with the smaller or larger potential that there is for development. The range of more intensive or new human activities that may arise as a result is vast, and it is therefore quite impossible for their effects (migratory movements, uncontrolled growth of settlements, changes in land use, etc.) to be looked at in detail here. As well as this there will also be changes in socio-cultural and socio-economic conditions, and these too, in their capacity as possible secondary impacts, will require careful consideration.

Thought will also need to be given to the ways in which adverse developmental effects can be avoided or mitigated by collateral measures (land use plans, migration regulations, and monitoring of compliance with these). See also the environmental brief Transport and Traffic Planning in this connection.

(b) Adverse effects on areas deserving of protection

The technical and economic aim will be to produce the shortest possible link between two points but the full achievement of this aim will be frustrated firstly by the need to allow for items whose position cannot be altered (for natural reasons or as part of the transport system) and secondly by the need to divert round areas deserving of protection. Such areas include ones containing **vegetation worth preserving**, ones subject or due to be made subject to **landscape protection** or **nature preservation** orders, ones of **high agricultural value**, and ones containing high-density or **historically important buildings**, and also, in particular cases, specific, small **biotopes**, **game reserves** and **fauna stocks**.

2.2 Indirect linear impacts and spot impacts

(a) Effects on the appearance of the landscape

Applying the traditional rules of road building may help to moderate the look of the artificial changes made to nature. Where these rules are not followed as closely as they should be, such things as deep cuts and over-high fills will break up the natural lines and disrupt the appearance of the landscape.

(b) Fragmenting impacts of roads cutting across existing ecosystems, and changes to the microclimate

A road cuts the land it crosses into two, and it does so the more positively the greater is the difference in elevation between the carriageway and the natural terrain. It creates a **barrier** to humans and animals and stops geographical interchanges (e.g. migratory movements). By obstructing the movement of water and air, by causing a shadowing action, by preventing heat and cold from dissipating, by withdrawing or building up moisture, and by producing drifts of wind-blown material, it causes **changes in the microclimate** that may damage or destroy the existing systems.

(c) Landscape uptake and demand for land

A road takes up a **strip of land** of greater or lesser width which is demarcated physically by the road fill or cut including the ditches and other ancillary works and which is legally defined by the ground acquired (the right of way). It is also standard practice in many countries for the soil needed for the fill to be dug by an excavator or bulldozer from shallow trenches immediately adjacent to the road in a process known as "side borrowing". This method saves on transport but it also creates a demand for fairly large amounts of additional land and leaves behind it, unless levelling up is explicitly demanded, troughs following the line of the road that are at risk from erosion and that may also harbour **pathogens** if for example they turn into mud holes. Even when soil or rock borrowing is confined to pits or quarries, these should be left in as near natural a state as possible after work at the site has been completed.

Similarly, site waste, residual quantities of unused soil and building materials and so on should disposed of with due care for the environment.

After a new road has been completed, animal-drawn farm carts and herds of livestock are sometimes relegated from the carriageway to an unpaved strip by the side of the road. Depending on the type of soil and the amount of use they receive, such **cattle tracks** may be further deepened by wind and water erosion or may become impassable at certain times of the year. Also, constant use will make them wider and wider. To prevent this happening, they should receive the appropriate maintenance in the same way as the road.

Newly built roads should be positioned an adequate distance away from the traditional tracks used for livestock herds.

(d) Removal of vegetation and top-soil

In some cases, the **corridor** cleared for the building of the road will be made sufficiently wide at the outset to stop trees and bushes from growing back to the edges of the road too quickly. It also needs to be ensured that, when the margins of forests or woodland are cut back, trees brought down by the wind cannot fall onto the road. Ground is occasionally **cleared by burning off** and this, combined with the physical stress on the sensitive, thin layer of humus, can give rise to **soil erosion** during the building period.

Proper treatment of vegetation (and particularly forest and woodland), preservation of existing forest margins or isolated trees, re-afforestation, laying of humus cover, and planting of newly created areas of exposed soil together with reasonable long-term care for such areas must have compatible technical details specified for them in the plans and must be monitored by the authorities supervising the building, as also must the setting up of storage for the stripped top soil, the upkeep of the latter and the subsequent relaying of the soil.

(e) Production of soil erosion, and changes to soil structure

Improper land clearance, failure to observe the soil mechanics characteristics of the soils present, mis-assessment of the stability of cut or deposited slopes, or total neglect of this basic question, may lead to progressive **damage to the road pavement** itself and to its immediate or more distant **surroundings**. In the worst case, and particularly where the road is exposed to adverse meteorological conditions, such damage may be so severe that the road is totally destroyed and rendered impassable.

As well as this, there is also the possibility that earth may **slip**, **settle**, or be **washed away** over large areas, and this can produce extensive **erosion** which, particularly in hilly or mountainous country, may extend well beyond the area of the road proper and take in neighbouring slopes or valley floors. Even rock slopes that appear solid can become unstable if roads are cut in them without paying proper attention to the geological structure or by excessively heavy blasting.

Although soil erosion is usually caused by the action of water as a transporting medium, in arid and semi-arid zones it is necessary to pay heed to **wind erosion**, which is triggered or at least encouraged by removing even very sparse vegetation or by placing roads at an aerodynamically unfavourable elevation (dunes may be created!). Where use is made of fine-grained types of soil to form unbound base courses, simply the movement of traffic may enable erosion by wind (that creates dust) or water (that washes soil away) to destroy the carriageway.

As well as expert soil surveys, proper planning, and official supervision of the earthworks and rockworks to reduce vulnerability to damage to a minimum, the road and its surroundings must receive constant maintenance to remedy minor damage in its initial stages and prevent it from spreading.

It is particularly important for areas of exposed soil to be **planted** as quickly and as permanently as possible with native plants (grasses, ground cover plants) in order to obtain biotechnical stabilisation of the soil by deep-rooted plants, hedges, wattle fences, etc. A further important contribution will be made by the careful, non-destructive **drainage of surface and infiltration water**.

Particular care should be taken to stop erosion when building **roads of tertiary status** such as rural roads, feeder roads and developer roads. In this case road-building comes down essentially to questions of **hydraulic engineering and earthworks**. The road alignment should be along the crest of elevations and it should largely follow the terrain. Where watercourses have to be crossed, this should preferably be done by means of wholly or partly flooded **fords** which in no way obstruct **water runoff** and thus help to **prevent erosion**.

(f) Effects on the water balance

It is inevitable that there will be **interference, some of it considerable**, with the existing water balance in the course of road-building operations. If watercourses have to be diverted to prevent them crossing the line of a road, then if the laws of hydrology are not observed this may result in adverse changes to the discharge regime of the watercourses (caused by changes in the roughness, gradient or cross-section of the bed). There are many different ways in which the water balance may be affected and among them are deliberate or accidental **impoundment by road fill**, **draining of wetlands and swamps**, **lowering of the groundwater level**, **deepening of watercourses** by the extraction of excessive amounts of material from their beds, **bridgeworks built in watercourses** with the risk they create of blockage by flotsam, and the **creation of reservoirs** for livestock watering by exploiting the effect of the road fill, with its attendant problems of infection and pest breeding.

One disadvantage that will become apparent is that **reliable data** on the volume, frequency and duration of precipitation is **seldom** available and hence reliance has to be placed on empirical data combined with observations of nature and experience gained in comparable situations. Here too, great importance attaches to constant maintenance being put in hand at an early stage.

The risk of surface water and groundwater being polluted is particularly serious in countries where it is difficult for drinking water to be checked due to the special nature of the supply (e.g. decentralised withdrawal). In countries of this kind where the winters are cold, pollution from road salting should be prevented by selecting non-polluting materials for salting use.

(g) Reduced safety due to the risk of accidents

More serious and more frequent accidents may be caused by the higher speeds that become possible after road development, by inexperienced drivers, by pedestrians and animals crossing roads, and by the absence of a parallel route for slow-moving traffic (e.g. pedestrians, non-motorised transport, driven cattle).

Road building should therefore always be accompanied by or prepared for by **instruction in road safety** and **monitoring and inspection of vehicles for safety**.

(h) Effects on settled populations in towns and villages

Existing towns and villages are normally too densely built-up to allow the **building of a direct through-road**. If such a road is built nevertheless, the detrimental effects it will have are **noise**, **vehicle exhaust emissions** and a **greater risk of accidents** (see the environmental brief Road Traffic).

However, even with effects of this kind caused by more intensive land use, the density of building often rises in such areas, with attendant environmental impacts in the fields of, amongst others, hydrology and local climate.

If an attempt is made to stop such effects by building a **by-pass**, mature existing social structures are often damaged or destroyed and new buildings soon spring up along the by-pass, though these can be prevented from having any detrimental impacts by proper environmental planning (see the environmental brief Provision of Housing).

(i) Detrimental impact of lack of maintenance

A road that is not maintained will not last. A suitable **technical design** for the road and **good-quality building work** will serve to keep down the amount of maintenance needed, at least in the first few years. However, at that stage **maintenance work will certainly need to be done**, and if it is not the damage and adverse environmental impacts described above will inevitably ensue.

2.3 Consequential impacts

(a) Building noise

Where the volume of the works involved is small and the techniques employed are simple, building noise is only a minor consideration in road building.

(b) Re-use of bitumen

When the time comes to replace bituminous carriageway pavements, the binder should be recovered from the old pavement courses. Where the pavement is relatively thin (bituminous treatment mainly of surface layers), the old pavement will normally be needed to improve load-bearing capacity and it will be impossible for it to be re-used.

(c) Seismic damage

In the event of earthquakes, roads having only a few, simple structures (bridges and tunnels) along their routes will be far less susceptible to damage than ones with more complicated, highly engineered structures. Fissures and slips in the earthworks will be limited too due to the smaller dimensions.

(d) Beneficial impacts

Some additional measures with beneficial environmental impacts which can be taken in the course of road-building are as follows:

- Retention basins for the population/drinking troughs for livestock can be created by raising the vertical alignment of the road at watercourses.

- Borrow sites can be developed into biotopes/amenity ponds.
- Where roads passing through villages are paved and if there is an unpaved market place the road paving can be extended to include it.
- In the course of the building work, preparations can be made at the points where material is borrowed to ensure that sufficient material will be available for maintaining the road.
- The road can be used as a fire-break to stop large fires.
- Erosion control can be improved (especially in the course of maintenance).

3. Notes on the analysis and evaluation of environmental impacts

Binding, universal guidelines for any complex analysis of the many and diverse aspects of the possible environmental impacts generated by the building of roads **do not exist** and given the many different sides there are to the problems it would be virtually impossible for them to be satisfactorily drafted.

Even the **evaluation criteria** developed for German conditions have so far proved impossible to define **in quantifiable terms**, except that is for the criteria for noise emission and the emission of harmful air pollutants (see the environmental brief Road

Traffic). In view of the number of variables that there are, any ranking assigned to possible alternatives will continue to be largely subjective. The only answer to this problem is more thorough planning which brings out particular critical issues with greater clarity.

Preliminary **regional planning** and a detailed feasibility study including a comparative evaluation of all the adverse and beneficial impacts may therefore be a useful way of obtaining the information needed for assessing the widespread effects of a road-building programme.

An advance study of this kind will be made at an early stage and it is at this stage that a check should always be made to see whether the **alignment corridors**

- are suitable
- are suitable with the proviso that corrective measures still to be defined are carried out, or
- are not suitable.

For this purpose it will be necessary to draw up appropriate maps of protected areas, plans of the natural landscape, geological surveys, registers of land used for agriculture and forestry and maps of forests and woodlands, surveys of hydrological resources, and master building plans, to define the possible alignment corridors, and to evaluate alternative possibilities by a process of comparison.

The **measures** that will have to be taken to blend the road into nature and the landscape should be realistically shown and described in words in a special drawing (e.g. to a scale of 1 : 5000). After a comparative appraisal of the possible alternatives, all the details of these measures should be worked out and incorporated in the design drawings (e.g. on a scale from 1 : 2000 to 1: 500 with appropriate detail drawings).

Where it proves virtually impossible in the different planning phases for harmful factors to be quantified (and their impact to be rated or even costed) in relation to evaluation criteria and standards arrived at by analysis or ones for which standard procedures are defined, then **qualitative approaches to evaluation** may be successfully adopted.

4. Interaction with other sectors

There are a number of references in the above text to the direct interactions that exist with the **road traffic** sector.

There are also close relationships with projects in the field of **rural, village and urban development**, particularly with regard to the developmental effects that follow on from road building.

The benefit to road users conflicts with the interests of those using the land occupied by the road and its close and more distant environs.

There may in particular be **conflicts for agricultural or forestry reasons**.

Questions to be considered in this case are not simply the actual land occupied but also the **functional disruption** that road-building causes to existing, and in some cases sensitive, systems (e.g. the disruption caused by the road crossing irrigated rice-growing land, the heavier felling of commercial timber now that transport is easier, the erosion caused by different farming methods adopted for new crops made more attractive by transport, and the greater mobility and production levels encouraged by easier access to markets).

Impacts encouraging the **growth of trade and industry** which would not have occurred without the new road are generated in the same way (better locational advantages give rise to extra production).

Finally, there are often **reciprocal impacts** which a road-building project generates **with respect to other impending infrastructural projects** (e.g. where the building of an earth dam in a remote region cannot go ahead until access facilities exist; the commercial activity triggered by the building of a road will create a need for the disposal of waste water and solid waste; the use of fertilizer as a result of a recently built road will create stress on the environment that did not exist previously).

5. Summary assessment of environmental relevance

Road-building projects result in the opening up of regions that were difficult or impossible of access previously, or they at least improve conditions of movement on existing routes. This being the case, it is inevitable that they will always interfere with the natural situation in a region. As well as this **presence-related impact** there is also an **operating impact** due to the traffic the roads carry. And over and above these there will be direct and indirect impetuses for changes to take place in the socio-cultural and socio-economic status quo.

The variety of different questions that arise from this complex pattern is enormous and they all need to be considered in the course of carrying out a road-building project. What this means is that **each individual project must be treated as a special case**, in that the weight attached to the different environmental impacts of greater or lesser seriousness may vary and will thus have to be re-assessed in each individual case.

The object in making a summary assessment of a road building project is

- to minimise the stresses on the environment in the primary areas of soil protection, noise control, and preservation of clean air and water, and
- to preserve or reshape the natural environment by means of the building work specific to the project or in parallel with it, with major importance being attached to an alignment which fits as neatly as possible into the natural environment.

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Contents - **Previous** - **Next**

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

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17. Road traffic

Contents - **Previous** - **Next**

Contents

[6. References](#)

1. Scope

1.1 Function of roads

This environmental brief deals with the **environmental burdens** imposed by **road traffic,** i.e. by the **transport of persons or goods on highways and other roads.** The **effects of road building** are dealt with in a separate environmental brief (**Road Building**).

Roads are used **not only to relocate persons and goods** - in other words, purely for transport or traffic purposes - but also have **residential and access functions.** While roads generally perform **traffic functions** outside urban areas, **town and village roads** play an **important part in the residential function.** Accordingly, the term "environment" is not limited to the natural surroundings to the same extent as in undeveloped areas. Rather, the aim is to ensure that **traffic** can be managed in a way which **is compatible with the urban situation** - in other words, in a way that is also **socially acceptable.** This means that **transport and traffic planning must also take account of** traditional

lifestyles specific to the region.

1.2 Road traffic media

By far the majority of the **harmful effects** inflicted on the environment by road traffic are caused by **vehicular traffic** (cars, heavy goods vehicles, buses and coaches, motorcycles). However, when considering urbanisation processes (BECKMANN [1], DIOU [2], TOLBA [3]), it is vital to note that the **creation of a road environment which makes better provision for pedestrians and cyclists** can **help reduce environmental impact. Non-motorised traffic** - as the most environment-friendly type of movement - traditionally accounts for a **large proportion of total urban traffic** in certain regions.

A **strategy geared to the use of environment-friendly modes of transport** will only have any **prospect of success,** however, if **urban and regional development planning** on the one hand, and **methods of production** (including sale and distribution) on the other **take this into account.** If either people or goods **need to cover large distances,** the **opportunities for employing traditional means of transport will diminish.**

1.3 Purpose of the brief

The aim of the brief in the first instance is to **illustrate measures whereby** the **existing**

environmental impacts of motorised road traffic can be **reduced by prevention** or by **operating them in a way favourable to the environment.** In addition, the brief also provides **information on environmental burdens caused by projects which induce traffic.**

2. Environmental impacts and protective measures

One **particular characteristic** of the **environmental damage** caused by road traffic is that the **impact is made up of a large number of minor individual factors.** Sectors of the **infrastructure connected with the traffic system** (refineries, fuel transportation, workshops, dumps) also make a contribution. The **assumption** that these cause only a **negligible fraction** of the environmental burden will result in road users failing to **change their customary behaviour in the way that is needed.**

2.1 Emissions from road traffic

Although **road vehicles**, which mainly originate from industrialised countries, give off **similar emissions when new**, as required in the country of origin, they are generally **maintained** less well due to lack of supervision by the authorities and poor economic conditions. This means that the **individual vehicle** pollutes the **environment more heavily for the same mileage,** especially as regards the **sharp rise in emissions from a poorly maintained engine** (e.g. unburnt fuel, noise etc.) and **leakage of water-polluting liquids** (oil, fuel etc.). **Poor quality fuels** likewise produce **higher levels of pollutants,** and unleaded petrol is unobtainable in many countries.

(a) Air pollutants

Air pollutants are **not only harmful to human beings**, they can also present a hazard to **animals, the soil, vegetation** and the **climate. Remote effects** (i.e. remote both in **time** and in **space**) must be considered; one must also remember that **combinations of air pollutants** may be more harmful than the individual contaminants (synergetic effects). The principal **air pollutants emitted by vehicular traffic** are as follows:

- **Carbon monoxide** is not harmful to bloodless animals and plants, but sustained concentrations, even if small, can have an impact on both humans and other vertebrates. Compounds formed with the haemoglobin in the blood restrict the oxygen supply to the tissues, and in this way can cause disorders of the central nervous system.
- Certain **hydrocarbons**, resulting from incomplete fuel combustion (such as benzol), are carcinogenic among humans.

- **Nitrogen oxides** are irritants to human beings, and can damage the organs of respiration. In areas of high population density, nitrogen oxides contribute to smog formation. Plants are not directly damaged by nitrogen oxides at concentrations below 200 g/m^3 air [4].
- Under ultraviolet radiation, **ozone** is produced from nitrogen oxides and hydrocarbons. High ozone concentrations may cause smog and afflict the respiratory tract and circulation in humans. Moreover, ozone can cause serious damage to woodland and also, if present in sufficiently high concentrations, to crops such as vegetables and tobacco plants. Ethylene can have an unfavourable effect on the growth and ageing of plants. The numerous chemical interactions involved have not yet been fully explained.
- **Lead and other heavy metals**, which are deposited in the bones, are poisonous to humans and can cause disorders of the central nervous system. Lead aerosols are dispersed mainly over an area up to 30 to 50 metres from the roadway, while traces can be carried as far as 100 to 200 metres, depending on wind conditions. Plants absorb lead from the air by surface contact (dust deposits), or from the soil through their roots. As well as growth damage to the plant itself, follow-on effects through absorption into the food chain should also be noted (e.g. milk produced from pastures near busy roads).

- **Soot burdens** are mainly due to the high proportion of diesel engines, particularly among heavy goods vehicles. Soot emissions are substantially aggravated by inadequate vehicle maintenance. The danger posed by soot arises principally from the deposition of toxic combustion residues.

Carbon dioxide, which is released by the **combustion of fossil fuels,** is **not a directly harmful gas**, but it does **increase the CO_2 concentration in the earth's atmosphere**. The solar radiation reflected on the surface of the earth is accordingly absorbed by the air, causing the air to heat up (the **"greenhouse effect"**). Unlike the other air pollutants, emission of the carbon dioxide responsible for the "greenhouse effect" cannot be reduced by catalytic converters.

Though **developing countries' contribution to the "greenhouse effect"** is still small by comparison with the industrialised nations, a comparison by the Worldwatch Institute of the levels of motorisation of Western industrialised nations and developing countries for 1986 (Figure 1) shows the **consequences** of a sharp **increase in motor vehicle use**, even if the level of motorisation of the industrial nations were not to be reached. The **overall effects on the climate** (and on **oil consumption**) **would be intolerable.** This means not only that industrialised countries' traffic conditions cannot simply be imported, but also that the industrialised nations must restrict **private vehicle use,** if developing countries are to be allowed any scope for **increasing general**

living standards, without jeopardising climatic conditions and the supply of oil on a global scale.

Fig. 1 - **Comparison of the degree of motorisation of the USA, Western Europe, Africa and China for 1986**

The following **causes of air pollutant emissions** are of particular importance:

- inadequately maintained and elderly vehicles with increased pollutant output (carburettors, ignition, fuel injection systems, exhaust systems)
- deficient technical inspection and supervision of both fuel production and vehicles (emission tests)
- low quality fuels (unfavourable combustion processes)

The **intensity of air pollution** in a given area depends on:

- the volume of traffic,
- the ratio of internal combustion to diesel engines,
- driving habits (speed and gear selection as well as acceleration and braking behaviour),
- the condition of the engines,

- the quality of the fuel used,
- climatic and topographical conditions (air renewal).

(b) Noise

Noise is defined as **all sounds which are "perceived by people as disturbing or oppressive"** [6]. The consequences range from **disturbances of general well-being** or **hindrance of speech comprehension** to **serious intrusions** (disturbance of sleep, prevention of relaxation and interference with human performance) and **illnesses** (hearing impairment, damage to the cardiovascular system).

In addition to **noise from engines and other vehicular sources** (running and wind noise), **individual driver habits** (sounding the horn, slamming doors) all contribute to traffic noise. **Vehicle noise** also depends not only on the technical condition of the vehicle but also on **individual driving behaviour** (speed and gear selection, acceleration and braking).

Measures to prevent noise include the following:

- regular technical inspection of vehicles,
- selection of low-noise road surfaces,

- speed restrictions in relevant areas,
- road layout and gradients optimised to help avoid unnecessary gear changes,
- reduction of through-traffic in the vicinity of town centres, residential areas, hospitals, schools and places of worship, as well as other areas sensitive to noise,
- restricted access at certain times to protected areas (e.g. heavy goods vehicles banned from inner urban areas at night),
- driver education, for lorry drivers in particular, but also for bus and coach drivers.

Many countries have no noise abatement laws. Vehicles and driving habits there will long continue to produce an unnecessary amount of noise compared with standards in the industrialised nations. Periodic **vehicle inspections and bans on night driving, sounding horns** etc. can only **be introduced gradually**, if at all. **Noise measurements** or **passive noise protection measures** such as noise-abating embankments, walls or windows are only feasible in **special cases.**

Nevertheless, it is essential to work towards **long-term reduction of noise from road traffic** through primary noise abatement measures. **Secondary noise reduction**, as governed by guidelines in the Federal Republic of Germany, is **difficult to implement** in many countries (due to cost, administrative effort etc.).

(c) Wear and oil losses

The **frequently uneven and rough road surfaces** cause **wear** on tyres and road coverings, which contain **poisonous substances. Wear on brake and clutch linings** may give off highly **toxic substances** such as nickel and asbestos. **Unmade road surfaces** are sources of irritant **dust** which increases the **risk of accidents** and, in the absence of rainfall, may **adversely affect vegetation. Oil** often leaks from the **engines and pipes** of **poorly maintained vehicles.**

One **particular problem** is **poor drainage**, which may cause **pollutants** in wear products and also **oil** leaking from pipes and engines to be **discharged** into the environment during periods of rainfall, thereby endangering not only the **soil** but also the **groundwater**.

By contrast with air pollutants, **toxic wear products** and **oil** are not directly harmful to humans, but can indirectly deprive them of the conditions on which life depends if the land can no longer be worked without **risk to health** or is no longer **habitable**.

Only part of the **damage caused by vehicle emissions** referred to under (a) to (c) can be reduced and limited, if not eliminated altogether, by regular inspection of vehicles, monitoring and improvement of fuels and concentration of traffic in particular areas. The best way to achieve a **lasting reduction** is to reduce the **volume of road traffic**, something which should be aimed for in order to protect the earth's atmosphere (see above). The **following measures** might be considered as **incentives** to this end (see also the environmental brief Transport and Traffic Planning):

- petroleum tax,
- emission-based vehicle tax,
- road tolls,
- access restrictions at certain times,
- inner city parking restrictions,
- fiscal incentives for vehicle user-groups
- separate lanes for local public transport vehicles and vehicle user-groups (e.g. joint use of bus lanes).

(d) Energy consumption

At present nearly all **motor vehicles** require **petroleum-based fuels.** In many countries, not just the **transport sector** but rather the entire **energy sector** depends on petroleum. Because the overwhelming majority of these countries need to **import** most, if not all, of their petroleum requirement [4], **promoting vehicle traffic at the expense of other sectors** would mean devoting substantial resources to **fuel supplies**, thereby depriving other sectors of **energy supplies.** This could in turn **prevent** the sought-after **rise in living standards**, despite the expansion of the transport system.

Where there is **no alternative to using motor vehicles**, **economical vehicles** with **minimal fuel consumption** or driven by **alternative fuels** should be used. While the exclusive use of plant matter as a fuel substitute is problematic because of competition with foodstuffs (as in Brazil), **bio-fuels** derived from waste products do offer a solution (e.g. the biogas buses used in China, see [7]). In countries where electricity can be generated cheaply by hydroelectric plants, particularly in urban areas, the possibility of using **electrically driven vehicles** (trams, electric buses, dual system buses) should be investigated. The use of liquid gas as a coupled product from refineries would reduce petroleum consumption and pollutant emissions.

In the **passenger transport** sector, every effort should be made to meet transport demand with **trams** or **buses** which, with the appropriate number of passengers, have a **lower specific energy consumption** than private cars. For **short journeys**, optimum conditions should be created for **pedestrians** and **cyclists**. **Town planners** should furthermore aim to include or create structures enabling people to reach their destinations on foot or by bicycle. People should **not** be forced to **travel long distances** by doing away with mixed areas in favour of widely separated areas devoted exclusively to e.g. housing, working, recreation, administration etc.

2.2 Traffic safety

Because of its importance, traffic safety is not usually subsumed under the heading of the "environment", being regarded as a sector in its own right. Nevertheless, **traffic safety**, which covers more than the prevention of accidents, is an important **aspect of the quality of life**, and therefore needs to be discussed here.

A vital means of **reducing the risk of accidents** for all groups of transport users is the imposition of **vehicle speed restrictions**, which differ according to locality (highways outside urban areas, main traffic routes in town and city centres, access routes etc.), and according to the state of development and condition of the road.

In addition, the accident risk can be reduced by intensive **road safety training, technical inspection of the vehicles, tougher safety regulations** (such as the mandatory wearing of seatbelts, driving tests administered by properly qualified persons or the banning of drink-driving). Furthermore, efforts should be made to improve the **working conditions of professional drivers**, particularly lorry drivers. Appropriate measures include not only requiring certain standards of comfort in the "workplace" (e.g. heat-shielding vehicle roofs), but also properly **supervised driver working hours** so as to **prevent accidents due to fatigue.**

Accidents involving hazardous goods transports can put not only **human beings and animals at risk**, but can also cause **local environmental damage** on a considerable scale. The **same** applies to the **escape of hazardous substances** during **regular journeys. In particular,** there is a **risk** of **contamination of watercourses** and **groundwater**.

Serious damage and severe curtailment of the service life of road surfaces is caused by **overloading** (an axle loading increased by 30 % trebles the stress on the sub-base); this may **increase the risk of accidents.** To **repair the damage** (usually with a complete new bituminously bonded roadway surface) is not only expensive but also uses up **valuable natural resources**.

2.3 Reducing road traffic and transfer to other transport media through regional development planning and an integrated transport concept

A **transport master plan** is needed, coordinated with the regional development plan, concentrating primarily on making **transport more environment-friendly** and less costly to the national economy as a whole. This can be done by observing the following **principles** (see also environmental brief Transport and Traffic Planning):

I) **Decentralisation** of residential, industrial and supply facilities, with the aim of reducing transport distances;

II) In urban passenger transport, increasing the attractiveness of "**environment-friendly combinations**" (foot, bicycle, cart, bus, tram and light rail);

III) In **urban goods transport**, deliveries by **vehicles which are compatible with urban conditions** (small goods vehicles with low noise and pollutant emissions), loaded to the correct capacity. In **long-distance goods transport,** controlled transfer to **rail and ship** wherever possible. This calls for **effective logistical infrastructural measures** to **optimise** the interfacing of short-distance and long-distance transport and the **system interchange points** between different transport media (e.g. goods traffic centres);

IV) For simply structured transport tasks, as in the case of **raw materials projects**, **special transport systems** such as pipelines, light railways, or cableways might be not only more environmentally acceptable but also more economical than lorries, railways or ships.

In **highly populated areas**, the **adverse effects** of road transport are **directly felt.** The rapidly growing **cities** are already **chronically overburdened.** As in the industrialised nations, looking realistically at the general conditions, it is **impossible** to create the

infrastructure to cope with the **potential demand for private car transport,** as this would destroy vital urban functions. Therefore the **planning must be geared to needs**, favouring categories of traffic which rely on the **use of motor vehicles** (e.g. urban commercial traffic).

2.4 Administrative, regulatory and financial measures

Administrative, regulatory, and financial measures are also **important means of** stemming the **growth of road traffic** and **reducing the associated environmental burdens.** Some of these have been mentioned in Section 2.1 (petroleum taxes, road tolls, parking restrictions). A **more detailed description** is given in the environmental brief **Traffic and Transport Planning**.

3. Notes on the Analysis and Evaluation of Environmental Impacts

Physically measurable limits and standards are available for only **certain** of the **emissions** listed under 2.1 and these **vary widely** even within the industrialised countries. This is because the **direct links between traffic emissions,** existing **overall burdens** and the effect of these **burdens on people and the environment** cannot be

precisely described, and may also vary **for different risk groups** (children, pregnant women etc.). This being so, it is not possible to "calculate" the volume of traffic which will, for example, reach or exceed certain pollutant limits. **Fixed limits**, as exist in most industrialised nations, are the **result of politically negotiated compromises**, and are liable to change over time.

It does not therefore seem sensible, within the scope of this brief, to quote the limits which currently apply in, for example, Germany, and which even there are to be regarded as temporary. Moreover, **effective monitoring of adherence to limits is highly labour-intensive,** and the mere fact of a limit being exceeded does not give any indication as to how emissions may be reduced. Therefore only the titles of those **decrees in Germany** which impose **limits** for noise and pollutant emissions are quoted:
- The sixteenth ordinance for the implementation of the Federal Emission Control Act (traffic noise protection decree)
- Memorandum relating to air impurity on roads (MLuS-82) [8]
- Official Journal of the European Communities No. L 36, ECE R 49 (pollutant limit values, [9])

An **example** of the general trend in **determining limits** in the industrialised nations is shown in Figure 2, using the example of **diesel traffic**. Extreme reductions are being demanded, especially in the USA, for soot particles and nitrogen oxides [10].

Fig. 2 - **Limits in USA and Europe (from [10])**

Therefore, **early (qualitative) analysis** of all traffic-related projects in order to determine their potential effects is more important than specifying quantitative limits. The **investigation** may comprise the following stages:

1. An estimate of the **potential volume of traffic** and its effects to be generated by the project in the widest sense (including an estimate of expected emissions),

2. An investigation into **possible ways of reducing traffic** and its effects through appropriate technical, economic, legal and political measures, and an assessment of their costs (e.g. construction of by-passes),

3. **A reduction in the environmental impact** of unavoidable motorised road traffic through appropriate route designs, additional traffic regulations, use of appropriate vehicles (e.g. minibuses during off-peak periods), regular maintenance and inspection of vehicles and through education of transport users to produce conscious avoidance of unnecessary emissions.

4. The assurance of **proper methods of disposal** of waste oils, lubricants, tyres and scrap, as a condition of supply of vehicles.

4. Interaction with other sectors

This sector **directly interacts** with **road building** which, through the routing and grading of highways, is decisive for certain **important aspects of the environmental burden** imposed by traffic (intersection of unspoilt and developed areas, traffic speed and thus exhaust emissions and accident risks, dangers to groundwater and soil etc.). Conversely, the **nature and intensity of the traffic** determines the later **need for maintenance, development and new construction**. Therefore to **reduce the environmental impact** of traffic, it is essential to achieve **harmonisation** between the two sectors. **Restricting road traffic** simply by **reducing road capacity** (often unintentionally through lack of maintenance), without at the same time improving alternative means of transport, will only lead to **higher specific emissions** and higher costs to national economies through greater wear and tear on vehicles and roads alike, and lower transport capacity.

The interactions within individual transport systems and with other sectors, dealt with in the environmental brief Transport and Traffic Planning, as applicable to road traffic (see also the **summary in Table 1**), are briefly as follows:

The **road traffic sector** is a **part of the overall transport system**. **Environment-oriented transport planning** will accordingly seek to find **alternative transport concepts** (such as combined transport and non-motorised transport). **Road traffic** overlaps in certain important ways with the tasks of n**ational, regional, and urban planning**, because appropriate planning measures on the one hand may reduce the need for road traffic and on the other may minimise its effects from the outset.

As a system which is largely based on petroleum, **road traffic** accounts for a major part of a country's **overall energy consumption**; therefore this sector interacts with the e**nergy planning** sector.

This sector continually interacts with the **promotion of industrial and commercial development**, **agricultural and forestry projects** and **extraction** of all other **natural resources** in terms of the potential environmental impact.

5. Summary assessment of environmental relevance

Road traffic is a **necessary part of the development and opening up of urban and rural areas. Increased road traffic**, which is generally inevitable as infrastructure grows, has far-reaching **environmental effects** which can only be **minimised** through extensive efforts in the way of **planning, administration** (including informing and educating the public) and **engineering**.

To limit adverse environmental impact effectively, **road traffic** must be included within **an integrated transport plan** which **adequately takes account of the interactions with other sectors** of transport planning, urban planning, and national development planning. When making an **overall evaluation** of projects, it needs to be borne in mind that the **environmental consequences of motorised road traffic** are **not all bad;** in many cases it may also provide a **basis for improving living conditions** (e.g. through improving supplies of food and medical care) or may be a necessary part of this process (construction of industrial establishments or housing). As with all planning decisions, both the **positive and negative effects** of road traffic projects need to be **weighed up carefully** on a case-to-case basis.

In **regions** where **major environmental problems** already exist, there is an urgent need for **remedial measures** to reduce environmental burdens and improve safety. **Administrative measures to reduce traffic**, **raising the training level of mechanics, technicians etc.** and **proper methods of disposal of pollutants** (such as waste oil) will help to achieve this objective. Experience has shown that **disposal tasks** are best **assigned to small commercial enterprises**. By contrast, **state bodies** appear to be more suitable for conducting technical inspections.

In **regions where the burdens are currently less severe,** the prime task is to **conserve the environment**. This is essentially a matter of **working to prevent undesirable developments** through **environment-oriented regional development planning and transport and traffic planning.**

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Contents - **Previous** - **Next**

Home"" """""> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

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18. Railways and railway operation

Contents - Previous - Next

Contents

1. Scope

The sector of railways and railway operation encompasses the construction of **railway lines and systems** as well as actual **railway operation.**

The railway sector is strongly characterised by its economic environment; its aim is to provide **transport services** by rail, making use of relevant resources. Its efficiency depends on the resources used, the manner in which they are employed and the infrastructure of fixed-location facilities.

Various kinds of tractive power are used, **mainly diesel locomotives.** The types of waggons and loading facilities and the operations management depend on the volumes of passengers and goods carried. For the transport of hazardous materials, special requirements must be met in order to avoid the risk of environmental damage.

To a greater extent than other sectors, such as agriculture or the foodstuffs industry, railways largely use standard technologies, so that the potential environmental effects and the means of avoiding them are largely similar.

Railways generally have their **own comprehensive infrastructures**, normally encompassing all rolling stock and track. They undertake tasks which are also performed by commercial operators, such as engine maintenance works.

Railways are generally **state-run**, although other companies are often responsible for monitoring observance of government regulations.

2. Environmental impacts and protective measures

Railway construction and operation have **unavoidable effects** on the environment, such as incursions into the landscape or emissions of exhaust gases and noise.

Other effects such as emissions of pollutants in workshop areas and in the event of accidents depend largely on the **equipment and the care with which work is carried out.**

2.1 Overview

Environmental impacts in the case of railways and railway operation are derived from

- the planning and implementation of the **infrastructure**, especially of the track,
- the characteristic features of the **rolling stock** used (traction method, age and condition, technical standards, safety equipment)
- the **operational condition** of the track and fixed-location installations (condition of the track, signal systems, stations, marshalling yards, workshops)
- the **operations management**, including the qualifications of the personnel and the maintenance measures. In this context, awareness of environmental problems on the part of management and workforce is crucially important
- the nature, handling and **risk potential of the goods being transported**
- the volume of passengers and freight and the resulting **degree of utilisation**.

2.2 Fixed track installations, track layouts

Effects on the soil

Due to the space which they occupy, railway tracks may cause valuable areas of land to be taken up (loss of agricultural land or biotope, lines laid through rainforest etc.); lines intersect residential areas and may initiate economic activities which lead to the destruction of natural resources as a background effect or consequence (establishment of charcoal-fired blast furnaces along a line, construction/utilisation of a line for transport of tropical timber etc.).

When railway lines or systems are constructed, earth is displaced. Embankments need to be built, for example, and the earth required for this is derived from elsewhere. The spoil from tunnel construction needs to be disposed of in an environmentally acceptable way, if it cannot be used for embankment construction nearby. The same applies to the construction of lines in cuttings. When the soil is exposed, there is a risk of erosion. In the area of railway installations (such as stations), surface construction causes the ground to become sealed and compacted.

Surface water

Both on embankments and - more particularly - in cuttings, which often have considerable water discharge areas above them, care must be taken to ensure effective methods of lateral **water drainage**. Water courses, rerouted if necessary, must be large enough to lead the surface water away effectively. Recultivation and replanting are needed to combat **erosion** due to rainwater and landslip.

Even if railways, unlike other transport systems, do not seal the surface so that rainwater is still able to soak away, it must be assumed that errors in layout and design will cause water pooling and consequent damage. Streams and other water collection points may be polluted unless they are screened against the ingress of surface water.

2.3 Exhaust gas emissions

The incidence of exhaust gas depends in the first instance on the type of traction involved.

Electric locomotives do not of themselves produce any exhaust gases. The effects of power generation are not dealt with here; refer to the appropriate environmental brief.

Steam locomotives will not be considered here either, being now very rare.

The essential **pollutants** in exhaust gas from **diesel engines** are:

- carbon monoxide (CO)
- hydrocarbons (HC)
- nitrogen oxide (NO_x)
- sulphur dioxide (SO_2)
- particle emissions (soot).

The extent of the emissions from **diesel engines** depends essentially on these factors:

- the load and speed of the engine
- the load depends in turn on the weight of the train (the train burden) and the speed of travel, which in most cases is determined by the track
- combustion processes (direct, precombustion chamber)
- operating process (two-stroke, four-stroke)
- standard of maintenance
- quality of fuel

As regards the **degree of utilisation,** trains may be under-utilised or they may be loaded to the limit of their capacity.

The causes of **under-utilisation** are:

- too few passengers on passenger trains,

- goods trains travelling with too little freight. Because the number of waggons in this case is also low, the weight which is being transported to no purpose remains limited to the relevant proportion of the locomotive's weight.
- slow travelling speeds because of the condition of the track. The travel resistance which the locomotive is required to overcome drops at lower speeds.

The causes of locomotives being **loaded to the limit of their capacity** are:

- coupling loads are exceeded
- long gradients
- shortage of locomotives.

2.4 Utility materials and residues

2.4.1 Lubricants

The main lubricants used are as follows:

Lubricant		Area of use
Engine oil	**in**	**combustion engines**

Viscous oils	in	**gear boxes**
		link drive systems
		axle bearings
Hydraulic oil	in	**track machinery**
		axle drives
		hydraulic gears

Oil consumption in engines contributes to exhaust gas emissions, but is less than 0.5 % of fuel consumption.

Another factor which likewise cannot be avoided is the emission of lubricating oil from locomotives with link or chain drives, which can lead to contamination of soil, groundwater, and surface water.

These types of drives are obsolete and should no longer be used when new equipment is procured.

When procuring any kind of oil, care should be taken to ensure that they are free of PCB (polychlorine biphenyl) components. These produce highly poisonous dioxins on combustion.

Another major environmental problem is the disposal of waste oil.

The aim of establishing a regulated system for dealing with used oil is to transfer recyclable used oil to a processing point, laying down appropriate conditions (such as pollutant content, products to be recovered separately, bans on mixing) and thereby minimising the proportion of waste oil which cannot be processed and therefore requires costly disposal. On the one hand this ensures the most environment-friendly possible method of disposal, and on the other it helps keep costs down. Waste oils of different types and containing different pollutants should, as far as possible, be collected and led away for processing or disposal separately.

Basically there are three groups of waste oils:

> **Waste oil group 1: Waste oils whose composition and place of origin are such that they are suitable for recycling**
> **Waste oil group 2: Waste oils which can be used for energy production**
> **Waste oil group 3: Waste oils which require disposal as refuse.**

2.4.2 Rehabilitation of oil-contaminated ground

There are well established processes for the rehabilitation of ground which has been

contaminated by oil and certain kinds of chemicals; specific kinds of bacteria are applied to the contaminated ground, which feed on the oils and chemicals in the soil. Clay soils can be cleaned to a depth of one metre and sandy soils to a depth of two metres by applying the bacteria to the surface, with additional nutrients if need be. Cleaning is more difficult at greater depths, where it is necessary to introduce atmospheric oxygen.

High ambient temperatures are ideal for biological cleaning. The bacteria are active at temperatures of 10C and above.

The extent of the damage must be established by test bores and monitored throughout the cleaning process.

Alternatively, the soil can be removed and incinerated after the pollutant content has been assessed, using special incineration systems. It may be possible to use the residue in road construction.

2.4.3 Solvents

Solvents mostly involve halogenated hydrocarbons.

Used solvents must be stored separately according to the main component of the initial

product. These substances must not be used for normal cleaning purposes; as far as possible substitutes should be used for that purpose.

Every effort should be made to ensure that solvents are recovered by the supplier. If this proves impossible, they should not be disposed of other than as special waste.

2.4.4 Wood preservatives

If impregnated wood is used at all, e.g. for sleepers, any residues must be disposed of in special incineration plants, which may for example be connected to power stations. Impregnation agents with minimal environmental impact are to be preferred (take special care with wood preservatives containing PCPs).

2.4.5 Scrap

Before recycling scrap, care must be taken to ensure that any environmentally harmful substances have been eliminated in the proper manner, such as

- **waste oil**
- **coolant residues in lathe turnings.**

During the scrapping process, hazardous substances such as heavy metals must be

removed and disposed of in the least environmentally harmful way.

2.5 Wastewater

The wastewater from plants using acidic cleaning agents (e.g. for stainless steel waggons) or alkaline cleaning agents must be neutralised.

Cleaning plants for rolling stock produce wastewater contaminated with oil and grease, and engine oil changes result in waste oil. The wastewater can be adequately cleaned at source by simple oil separators. Chemical processing, which also removes emulsions from the wastewater, is complex and expensive.

Small quantities of waste oil should be incinerated using a system suitable for small volumes. The composition of the waste oil must be known, since there is a possibility of dioxin formation.

Where oil separators are installed, it is advisable to use pipe cleaning equipment to keep the outflows of the cleaning troughs clear, since they are prone to blockage.

The following safety precautions may be necessary for important groundwater areas:

- **diversion (relaying) of wastewater pipes out of the more confined protected**

zone,

- drainage of wastewater within the protected area through impermeable pipes,

- impermeable drainage pipes and fortified trench beds instead of unfortified side ditches.

2.6 Transfer systems

Railways operate a series of discharge systems for petroleum products which constitute a hazard to water, such as fuel, waste oil and fuel oil. Transfer takes place, for example, from railway tank waggons to road tankers or fixed-position tank farms, and during the fuelling of diesel locomotives. The systems are to be planned and operated in such a way that the oils cannot overflow or escape, i.e. so that no bodies of water can be contaminated. In the first instance, as many transfer points as possible are to be combined to form a few centrally located and intensively used facilities. Systems such as these are to be avoided in water conservation areas or headwater regions. Protection of transfer facilities essentially involves paving the surfaces and drainage with separation. Limit monitors are of course necessary.

Full-hose dry couplings offer far greater protection against losses during transfer. If couplings such as these are used, only a small area at the edge of the track needs to be

paved.

2.7 Weed control

The trackbed needs to be kept free of weeds for a number of reasons (e.g. to prevent derailment). Depending on the vegetation of the terrain through which the track runs, chemical weed eradication may be possible, though alternative methods such as manual weeding are to be recommended.

2.8 Faecal matter

Lines which carry passenger traffic are subject to contamination with faecal matter. The faeces leave the coach through a downpipe and land on the track.

Epidemiological research has revealed that:

- **The UV fraction in sunlight kills micro-organisms within a period of 2-3 hours,**
- **No bacteria will reach the groundwater.**

At high speeds, it is possible that the pressure wave created by two trains meeting in a tunnel will cause a blowback. New coach designs allow for the faeces to be deposited in

containers. In any event, orderly disposal is to be ensured.

2.9 Hazardous goods transport

A basic principle in conveying hazardous goods must be that every substance is handled in accordance with specific rules. Areas affected by this rule are:

- **packing**
- **load securing**
- **transportation**
- **packing together with other substances**
- **action in emergencies.**

Rule-books must be adopted covering all substances liable to be transported.

It is also recommended that international uniform hazardous goods codes be used, classified according to the UN numbering system which describes methods of handling many different substances.

The most hazardous types of goods fall into the following categories:

- **inflammable liquid substances (fuels)**

- toxic substances
- corrosive substances
- explosive substances.

The substances are to be designated precisely in the waybill. Instructions on handling, action in emergencies etc. for the individual hazardous substances should be available in every station and in every locomotive.

The weak points in handling hazardous substances on railways occur in the following areas:

- Unsuitable packaging
(e.g. flat pallets with film instead of grid box pallets as specified for the materials concerned)
- Incorrect or absent load securing
- Marshalling, reloading
- Most accidents occur with very small consignments which do not fulfil the requirements outlined above. Accidents involving tank waggons etc. are rare
- Untrained personnel, missing documents.

Standard equipment for rescue services includes envelope containers, pumping

equipment and tank waggons. The fire services often perform these tasks, on the railways as well.

Every railway company should employ a hazardous goods officer to whom the regional hazardous goods managers are subordinate. Appropriate training and advanced training must be provided in this area.

2.10 Noise abatement

Railways generate varying levels of noise, including noise from actual rail traffic (rail traffic noise) and from the infrastructures involved in railway operation, such as marshalling yards, transfer stations for combined load traffic or workshops. Noise emissions depend on the intensity of operation and the location of the railway engineering facilities being used. Noise immissions provoke physical and psychological reactions in people, and to that extent railway noise is considered to be less of a burden than road traffic noise.

Because of their extensive track and ancillary systems, marshalling yards cover the largest area of any train formation facilities. The wide range of operational procedures involved in train shunting and train formation and the operations which the ancillary systems involve produce noise emissions of differing levels and frequency of

occurrence. The active and passive noise abatement measures which can be applied when constructing new marshalling facilities or converting existing ones generally fall into the following individual areas:

- **general structural layout of a marshalling yard system,**
- **distance from other buildings,**
- **rolling stock,**
- **organisation of operations and**
- **marshalling equipment.**

The most effective way of improving the noise situation of marshalling yards is through automation.

2.11 Organisational measures

From what has been said in sections 2.4 to 2.9, it is clear that the environmental impacts of railway operation are attributable in large measure to human actions.

The measures needed in this context are, in particular:

- **Adequate and comprehensive education and training of personnel. Cooperation with other transport operators such as harbour companies,** airlines and road hauliers is recommended.

- Improving the training and manpower of the operating organisation.
- The creation of a technical and administrative infrastructure (disposal and supervision of disposal, monitoring of technical and personnel standards etc.). Deployment of personnel with responsibility for problem areas such as hazardous goods etc.
- The use of detergents which are "environment-friendly" or which can be satisfactorily disposed of under the local circumstances.

Environmental damage can only be successfully avoided by creating an adequately equipped organisation responsible for the administration, maintenance, operation and supervision of environmentally hazardous undertakings, and by strengthening and motivating it to deal with the tasks in hand.

3. Notes on the analysis and evaluation of environmental impacts

Emissions from railway vehicles and systems in operation, resulting from the design and build quality, can be determined from manufacturers' specifications or from measurement results.

Railway administrations have made numerous attempts to determine the extent of noise from rail traffic and to test the effectiveness of noise abatement measures. Thanks to these experiments, appropriate measures can be taken in future to prevent excessive noise.

Hazardous goods regulations should be established for the domestic and international forwarding of hazardous goods, determining which hazardous goods may be conveyed, how they are to be packed and marked, how the vehicles are to be constructed and equipped and when and how they are to be inspected, how the vehicles are to be identified and matters to be taken into account upon loading and unloading as regards loading methods and stowing, as well as the transport itself.

Environmentally correct methods of treating wastewater and solid wastes are well known and must be implemented.

However, since environmental pollution occurs in railway operation due to ignorance of the consequences, negligence or deliberate action (to economise on disposal), the supervisory authorities must be enabled (and provided with the necessary equipment and measuring devices):

- **to identify and analyse environmental impacts**

- to evaluate them with a view to avoidance

- to ensure adequate monitoring and

- to implement suitable administrative measures (orders and prohibitions, fines, criminal prosecution, organisation of disposal resources etc.) in an effective manner.

4. Interaction with other sectors

Goods are frequently transferred between railways and ships. See the environmental brief Shipping regarding the construction and operation of harbour and port installations.

Some parts of the road transport and inland waterway systems have similar problems to railways, particularly in the area of vehicle and ship maintenance. In this regard, see the environmental briefs Wastewater Disposal, Solid Waste Disposal and Disposal of Hazardous Waste.

The railway sector, being primarily devoted to the transport of passengers and goods, also ties in with the environmental briefs Spatial and Regional Planning and Transport

and Traffic Planning.

5. Summary assessment of environmental relevance

Railway lines intersect landscapes and regions, but thoughtful planning and execution will alleviate these partitioning effects. Electric trains do not of themselves cause any air pollution, while diesel trains cause slight pollution. Rail traffic noise is less than road noise and is felt to be less unpleasant. Railway lines should be routed out of the way of settled areas. In densely populated areas and where trains travel at high speeds, noise abatement measures may prove necessary.

International standards should be used as the basis for regulations on the construction and safety of railway vehicles and handling facilities; this will lead to the use of railway equipment generally enabling safe and environment-friendly transportation on the basis of an appropriately planned and executed network infrastructure. In certain cases it may however be necessary to impose construction measures which go beyond these rules, or deviate from them, in order to take account of particular local conditions.

A further requirement is that the personnel and the controlling and supervising

authorities and operating organisations should be fully aware of the potential environmental effects, risks and preventive measures; they should have appropriate training and receive institutional support in carrying out their tasks.

To this end, the training courses, the resources for performing monitoring and supervision tasks and financing must be made available in good time.

An environmentally acceptable railway system can only be created with

- safe, state-of-the-art transport equipment (rolling stock, handling facilities),
- equally safe operation by trained personnel,
- and institutionally strong operating organisations to maintain the rolling stock and systems, to control traffic operations and to inspect and monitor the effects on the environment, with close harmony between these three areas.

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Contents - Previous - Next

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

19. Airports

Contents - Previous - Next

Contents

1. Scope

The aim of this environmental brief is to illustrate the environmental effects of the construction and operation of an airport and the appropriate measures for protecting the environment.

The construction of an airport and its operation are often of national significance, because the airport is expected to generate a wide range of economic activities which should help national development, and also because an airport is generally felt to represent its country.

The specific airport planning must take into consideration:

- **possible ways of incorporating the necessary operational areas of the airport into existing urban or regional planning schemes (pressure for residential and commercial development),**
- **the service capacities and scope for extension of the existing transport infrastructure,**
- **the existing or extendable capacities of supply and disposal facilities,**
- **the suitability of the construction site,**
- **the situation regarding bodies of water and groundwater,**
- **possible ways of restoring the ecological balance,**
- **the optimum design of the installations to meet human needs and the**

incorporation of those installations into the surroundings,
- the nature and quantity of planned aircraft movements,
- the relevant national and international air safety regulations.

If serious environmental impacts cannot be avoided, either the planned location must be rejected or its use must be restricted (bans on night flying etc.).

2. Environmental impacts and protective measures

2.1 Socio-economic structures

Major airports are, as a rule, constructed on the peripheries of densely populated areas. The airport planning should therefore be incorporated into any existing urban or regional planning schemes.

The effects of the construction of an airport on a region's socio-economic structures are many and varied and it is difficult to say where one ends and another begins. The main points are as follows:

- changes in land-use,

- changes in price structures (price of land, food supplies etc.)
- changes of ownership,
- changes in the quality of residential life in the surrounding area,
- changes in occupation structure, which can result in extreme polarisation between the wealthy (international) organisations (hotel chains, restaurants, travel agencies, businesses etc.) and the poorer national surroundings,
- increased land settlement pressure from commercial and industrial establishments and transport companies,
- changes in local job market in terms of qualifications and pay,
- changes in social behaviour

(upward social mobility on the one hand, and corruption, theft, drug dealing etc. on the other).

The extent of these changes can be influenced to some degree by the planning parameters and by an appropriate choice of location. To some extent however these social changes are unavoidable, and can only be alleviated by appropriate supporting measures. To this end, it will be helpful to determine the social structure in the planning area and implement a promotional programme based on this for the population groups affected.

2.2 Ecosystem

Airports represent a serious encroachment on the landscape because of the large tracts of land which are sealed off and because of the far-reaching effects on the surrounding area.

The results of analyses of plant and animal life are a vital consideration when assessing the choice of location. Nature reserves and rare, large-area or interlinked biotopes may be reasons for ruling out locations, if the loss of these areas cannot be compensated for or natural substitute areas are not available. The more successful the efforts to incorporate local natural ecosystems into the new arrangement, the smaller the adverse effects on the surroundings.

Displacement of plants and animals in the areas directly affected by airport facilities and accompanying infrastructure is unavoidable, as a result of construction activities etc. In addition, the site must be cleared of obstacles and it may be necessary to create specific vegetation cover, which will bring different forms of population with it. Special precautions are necessary at airports to reduce the risk to air traffic of bird strike. Such measures are vital and basically involve restrictions on land-use and certain forms of production in the surrounding area. All the environmental conditions in those areas which encourage birds to congregate need to be changed in such a way that they

become unattractive as a habitat or as a small-area and frequently visited migratory goal. Common measures include the filling in of bodies of water or their reduction or partition into smaller areas, and the prevention of new bodies of surface water forming. In certain circumstances it may also be necessary to remodel river banks and vegetation and prevent the cultivation of crops which attract birds. It is essential to prevent or close any rubbish tips in the immediate vicinity of airports; they are particularly attractive to birds in their quest for food, and by their nature they provide suitable feeding grounds for other small animal populations, thereby attracting birds of prey, which in view of their size pose an extreme hazard to aircraft in the event of collision, particularly in the area of the engines.

As regards landscape ecology measures, the aim should be to incorporate landscape-related ecosystems into the construction areas, and to distribute the building mass in such a way that the planned system has sufficient surface area available to achieve inherent stability. Inherent stability also has considerable financial significance in that it may reduce the investment and maintenance costs. Ecosystems should be combined within the airport facilities and at the same time they should be connected to the systems adjoining the airport; buffer zones help ameliorate the effects of the necessarily monostructural surroundings of the airport operational areas, bringing an ecological balance to the overall system and integrating it into the surrounding area.

2.3 Airport construction

The construction of an airport generally requires substantial earth movements and large quantities of construction materials.

The environmental impact which unavoidably results should be kept within limits through appropriate planning. The following are particularly important:

- **optimisation of transport routes,**
- **utilisation of natural regional resources (e.g. soil from the surrounding area),**
- **use of construction materials which are available in the region or locally produced,**
- **use of local and environmentally aware construction companies,**
- **ecologically oriented remodelling of drainage conditions.**

Airport construction requires a large building site, occupying a large area of land over a long period of time.

2.4 Airports as workplaces

The personnel employed in the operational areas of airports are exposed to safety

risks and extreme noise.

The safety risks are to be reduced as far as possible by forward planning measures, e.g.:

- **clear identification of transport routes,**
- **relevant operating instructions for equipment,**
- **technical supervision of equipment,**
- **physical and organisational precautions for handling hazardous substances (fuels, working supplies, dangerous cargoes etc.).**

In addition, a list should be prepared which includes all hazardous materials which are normally used or frequently handled, giving details of their specific risks, the regulations under labour law concerning the handling of these substances and the emergency medical procedures to be adopted in the event of accidents involving the hazardous substance. The first-aid post must be equipped accordingly.

People who are exposed to extreme noise on the airport site must be protected by appropriate regulations. The corresponding German standards may serve as a guideline in this respect.

2.5 Bodies of water and groundwater protection

Precautions must be taken in the construction engineering to ensure that the groundwater balance and quality are not impaired by the construction and operation of the airport. In addition, the groundwater must be regularly monitored with upstream and downstream wells.

Because the soil is sealed over large areas due to the runways, buildings etc., the rainwater drainage systems need to be planned with particular care. To this end, a quantitative examination of the drainage conditions and the drainage capacities is required at the location selection stage. The basic data (frequency of rainfall, peak loads and frequency) for assessing the necessary rain retention basins and requisite drainage capacities should form part of a climatic survey or of a survey of the flying weather conditions. Likewise, the drainage coefficient of the relevant ground surface types should be taken into account.

Basically it must be assumed that rainwater can be contaminated on all sealed surfaces on the airport site. The runways and taxiways are affected by virtually unavoidable pollutants, foremost among which are: oil residues, fuel residues, de-icing agents (if used), cleaning agents and tyre wear residues.

The airport site must be provided with a sealed catchment and drainage system for rainwater. The collected rainwater is taken to a purification system with oil and petrol separators, before being discharged.

Sewage and wastewater produced on the airport site are led to a treatment system.

At airports, large quantities of substances hazardous to water such as fuels, mineral oils, chemical cleaning agents and solvents are stored, transferred and used. It must be guaranteed that they can be stored in accordance with regulations, and in a manner which is secure against leakage. Appropriate regulations must be established for handling substances hazardous to water, so as to minimise the risk of uncontrolled escape of these materials.

Steps must be taken to train personnel and make them aware of the problems.

There is always a possibility of accidents occurring, in which substantial volumes of substances hazardous to water may be released. There is the risk of contamination of surface water and groundwater alike. For this reason, airports should not be situated in surface water or groundwater conservation areas, especially if the water occurring is used as drinking water.

The gate which separates the catchment area from the retention basin to protect the groundwater in case of accident must be connected to an alarm system and operate automatically; alternatively the manual closure of the gate must be included as an item on a general accident checklist.

The fuel tank farms are to be protected against leakage in accordance with national and international regulations (e.g. collecting basins for escaping fuel), as well as against fire and explosion. Storage containers and pipelines are to be included in a leakage warning system.

2.6 Aircraft noise

Aircraft noise is generally regarded as the "the very worst noise of all", yet the noise pollution inflicted by aircraft on the areas surrounding airports is unavoidable.

Regional planning for the area around an airport must take account of these factors; land-use restrictions (industrial, commercial and residential areas) should be determined for noise protection areas, classified according to a noise level scale to be specified. The slum settlements which can be seen in many countries in the vicinity of airports should be avoided for safety reasons, and should be prevented as far as possible by means of landscaping measures (e.g. by extending the perimeters of the

airport, appropriate transport route planning etc.).

The intensity and effects of the noise generated by airport operations are determined by the following factors:

- **time of takeoffs and landings (day/night),**
- **the number of takeoffs and landings,**
- **the type of takeoff and landing procedures,**
- **the type of braking technique (reverse thrust),**
- **the type of aircraft,**
- **other noise emissions in the airport operations areas (turbine test runs, auxiliary turbines etc.),**
- **the location of takeoff and landing runways and taxiways.**

Noise emissions can be reduced by technical measures such as the following:

a. **manufacturer's efforts to reduce engine noise,**
b. **runway configuration designed taking the surrounding areas into account,**
c. **sound-proofing measures for fixed emission sources (power plant testing, auxiliary turbines etc.) and**
d. **measures to protect existing buildings in areas exposed to high levels of noise.**

In addition, noise emissions can be reduced through operational regulations:

a. **restrictions on takeoff and landing times,**
b. **specifying approach and departure flight paths, changing these on a regular basis if necessary,**
c. **using less noisy takeoff and landing procedures,**
d. **reducing braking by means of reverse thrust,**
e. **charging higher takeoff and landing fees for older types of aircraft with loud engines (which may lead to less frequent use),**
f. **operating an aircraft noise monitoring system in order to detect possible contravention of the noise abatement regulations.**

At transport policy level too, steps can be taken to reduce noise emissions (switching to other modes of transport, ban on short-haul flights etc.); for further information see the environmental brief Transport and Traffic Planning.

2.7 Traffic noise

The noise generated inside airports by ground traffic is usually negligible because of the extreme spaciousness of the airport installations. The additional noise generated by traffic on the main access roads to airports is normally no higher than that to be

expected from general use, provided these roads are efficient.

If heavily used roads pass through areas sensitive to noise, measurements must be taken to determine the overall burden. Protective measures must be taken to deal with the burden as a whole, or alternatively the transport flows must be rerouted. Splitting the traffic flows into a number of less heavily burdened routes is not a sensible approach.

It is a good idea to have low-noise modes of transport (rail systems) serving the airport.

2.8 Air quality

Particularly in areas of high population density, large volumes of pollutants are discharged into the atmosphere every day by traffic, building heating systems, industry and power stations. The emissions produced by an airport are to be regarded as an additive component in the field of ground-level pollution.

The emissions from air traffic and (road vehicle) feeder traffic are very similar in composition, and are technically very difficult to trace to their respective sources. Because of the quantity of emissions produced by aircraft and the air-chemical and

meteorological context, it may be assumed that the pollution caused by emissions from air traffic is low compared with the ground-level sources in urban areas. Emissions produced during flights at altitudes of 6-12,000 metres have additional effects whose damage potential has not yet been fully researched.

Increased immissions (HC, CO, NO_X) may occur in the immediate vicinity of airports with large numbers of aircraft movements (and resultant high volumes of feeder traffic), particularly in areas with unvarying weather patterns. It is therefore a good idea to aim towards integrating the airport area into a regional air monitoring system.

If specified limits are exceeded, appropriate administrative measures can be applied to restrict road traffic initially, and also air traffic if necessary.

An assessment of the frequency of inversion weather patterns in the region of the airport should form part of a climate evaluation study, or of a survey of the flight weather conditions.

2.9 Odour

Air traffic may generate unpleasant odours, but these are generally limited to the airfield itself and the immediate vicinity.

Road vehicle feeder traffic likewise generates odours which may cause annoyance, particularly in nearby residential areas.

2.10 Microclimate

Construction activities over large areas generally cause changes in the natural climatic conditions. The main causes, which lead to the formation of a separate microclimate ("town climate"), have to do with the extensive changes to the heat balance, water balance and local wind patterns. The accumulation of pollutants in the air also has an effect. How marked this microclimate is depends primarily on the size of the developed area, the building structure, the terrain and the proportion of open space.

Possible ways of influencing the microclimate in the construction and planning must be determined by means of a climatic survey.

3. Notes on the analysis and evaluation of environmental impacts

3.1 Airports as workplaces

To limit the noise burden on the airport personnel, the German workplace regulations

Arbeitsstttenverordnung (which have the authority of law) and the accident prevention regulations on noise *Unfallvrehtungsvorschrift "Lrm"* (regulations adopted by the *Berufsgenossenschaften* (employers' liability insurance associations)) allow for a maximum evaluated level (A-evaluated equivalent sustained noise level over 8 hours) of 85 dB(A); above this level, personal noise protection must be provided, and above 90 dB(A) its wearing is compulsory.

3.2 Aircraft noise

A number of different procedures are or have been applied or proposed in different countries for evaluating aircraft noise.

These calculation processes take into consideration the number, duration and level of individual noise events and their distribution over the course of a day. These results are not directly comparable with one another because of the different weightings involved.

In Germany, the DIN standard 45 643, "Messung und Beurteilung von Flugzeuggeruschen" (Teil 1: Me- und Kerngren; Teil 2: Fluglrmberwachungsanlagen im Sinne von Paragraph 19a Luftverkehrsgesetz; Teil 3: Ermittlung des Beurteilungspegels fr Fluglrmimmissionen), serves as the basis for evaluating guideline values.

There are a large number of studies available regarding the effect of noise on the physiological, psychological and social functions of human beings. Special investigations into aircraft noise burdens conducted on sections of the population in the areas surrounding airports are likewise available; one of the most important of these is the study by the Deutsche Forschungsgemeinschaft (DFG- German Resarch Foundation).

3.3 Traffic noise

The German DIN standard 18005 can be applied for calculating and forecasting traffic noise, although the orientation values (guideline values) are not applied.

3.4 Air

Table 1 lists the emissions from different jet engines. The guideline, reference and limit values for the acceptability of air pollution by carbon dioxide, sulphur dioxide, nitrogen oxide, ozone and dust apply as shown in Table 2. "Maximum immission values" have been established by the Commission of the Verband Deutscher Ingenieure (Association of German Engineers - VDI) to maintain air purity and avoid damage to public health and particularly the health of children, the elderly and the sick, and to protect animals, plants and property from damage. These values have a

firm scientific basis and are derived from empirical findings with medical indications.

***Table 1* - Emissions from jet aircraft engines**

Aircraft type	Takeoff weight	Engine	HC	CO	NO_x
		(to)	kg/LTO[2]		Cycle
B747	348	4 x JT9D-7	36.0	76.1	57.6
DC 10	251	3 x CF6-50C2	34.3	68.1	41.6
L 1011	196	3 x RB 211-22	70.3	115.0	41.5
B 720/B	149	4 x JT3C-3B	97.7	92.0	14.7
707/DC 8					
A 300	137	2 x CF6-60C2	22.9	45.4	27.7
A 310	125	2 x CF6-80A	3.3	14.8	22.2
B 727	81	3 x JT8D-7	7.4	24.6	11.1
B 737-300	56	2 x CFM 65-3	0.7	12.5	7.8
B 737-DC	51	2 x 7T8D-7	5.0	16.4	7.4

9/S 210					
BAC 1-11	43	2 x S Mk 511	22.6	39.7	11.7
Fk 28	21	2 x S Mk 555	34.3	34.1	4.6
Car/lorry			mg/metre of vehicle		
traffic				11.8	4.0

1) LTO = Landing and take off

***Source*: Umweltbundesamt [German Federal Environmental Agency]: Luftbelastung durch den Flugverkehr (air burden caused by air traffic); Report II, March 03, 1984**

***Table 2* - Guideline, reference, and limit values for air pollutants in g/m^3**

Pollutant	TA-value	MI	WHO	EC limit value standard	EC	ended	Recomm	Luft*
SO_2								

I_1				140	50	40-60	80-200	50
I_2			400				250-350	140
24 h				300	125		100-150	100
1/2 h				1000				200
SO_2								
I_1		80			50			50
I_2		200				135	200	140
24 h			100	150				100
1/2 h			200	400			200	
O_3								
I_1						50		
1/2 h		120	150-200			150		
Dust								
I_1	150				40-60		80	75

I_2	300						250	150
24 h			300	120	100-150			150
1/2 h			500					
CO								
I_1	10,000	10,000				10,000		
I_2	30,000					14,000		
24 h		10,000						
1/2 h		50,000	60,000				20,000	

The meteorological data such as temperature, air humidity, precipitation, air pressure, wind, cloud cover and radiation do not act in isolation on human beings, therefore a combined assessment is required. Above all, it is the combination of thermal effects which exerts a bioclimatic effect. In bioclimatology, one speaks of complex attributes such as sultriness, comfortableness, perceived temperature etc.

The assessment of the microclimate is indeed subjective, and depends on the daily constitution of the individual person; nevertheless, defined limits have been

established (Hppe 1986, "Schwlemass"; Jendritzki 1979, "PMV Index", and "Behaglichkeitsberechnungen").

4. Interaction with other sectors

In airport planning, a whole series of interactions with other sectors must be taken into account, including in particular the following:

- **Regional Planning**
- **Town Planning**
- **Transport Planning**
- **Industrial Planning**
- **Provision and Rehabilitation of housing**
- **Energy Planning**
- **Public Institutions, Schools, Health Management, Hospitals**
- **Water Framwork Planning**
- **Urban Water Supply**
- **Wastewater Disposal**
- **Solid Waste Disposal**

* Disposal of Hazardous Waste
* Road Building and Maintenance, Rural Road Building
* Road Traffic
* Railways and Railway Operation.

In particular, attention must be paid to the protection of bodies of water and groundwater in order to avoid large-scale environmental impairment due to an airport project. Interlinking with town and regional planning and water management planning is therefore essential.

5. Summary assessment of environmental relevance

The construction of an airport entails unavoidable disturbances of the environment.

As a first step, it should be established whether limit values or other relevant standards can be adhered to and the environmental impacts minimised both during construction and during operation. An analysis should then be made to determine the costs of minimising the environmental impacts. Weighing up the economic benefits on the one hand and the costs on the other will reveal the project's financial viability.

The population groups affected should be involved in the project preparation as early as possible; in this context, questions regarding the environmentally acceptable execution of the project are particularly important in the initial phase. Where agricultural land is liable to be used, alternative sources of income for the local population, and for women in particular, should be looked into.

Parameters should be set in the project planning and requirements laid down in the project execution to ensure that:

- **environmental impacts are kept to a minimum,**
- **damage is avoided or, where this is not possible, limited,**
- **long-term damage is avoided as far as possible.**

Emission limits to protect the environment can only be implemented and monitored if the necessary supervisory bodies are properly institutionalised and function adequately. This must be taken into account when establishing the relevant planning parameters. It is advisable to appoint environmental protection and worker safety officers, who should receive training, further training and technical support to enable them to perform the appropriate supervisory tasks and generally uphold the interests of environmental protection and worker safety in all relevant activities.

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Blatt 6: Normsichtweite
Blatt 7: Niederschlag
Blatt 8: Aerologische Messungen
Blatt 9: Visuelle Wetterbeobachungen

VDI 3787

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Contents - Previous - Next

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

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20. River and canal engineering

Contents - Previous - Next

Contents

1. Scope

The term river and canal engineering covers all building works that cause a radical change in the natural water-balance conditions in or along watercourses, or in a region affected by new canal building.

River engineering embraces all hydraulic engineering work undertaken for the purposes of

- **river straightening,**
- **flood protection,**
- **changing the use to which a watercourse is put,**

- improving navigability, and
- channelising natural watercourses.

Canal engineering covers operations such as the building of

- artificial waterways (inland waterways and canals),
- large supply and discharge canals such as relief or irrigation canals,
- large canals for sea-going vessels (e.g. the Panama or Suez Canal), and
- artificial approaches to inland ports.

Though this varies with the size of the river, engineering works on rivers are generally multi-purpose, i.e. are intended to meet a variety of requirements such as navigation, power generation, irrigation and water supply, flood protection, and maintenance of or change to existing groundwater levels in river plains.

Though canals are likewise built for navigation and power generation, they also serve supply and discharge purposes (an example of a large supply canal is the Bahr el Youssef canal supplying the Fayum oasis in Egypt). River and canal engineering can thus perform both productive and protective functions.

In canals, the water level is usually held constant, or is varied only within specific preset

limits. This being the case, canals are, with a few exceptions, "zones of dormant water" rather than "watercourses". Losses through percolation and evaporation are inevitable and because of this canals often need an artificial "feed" (e.g. the Eder dam reservoir in Germany feeds the Mittelland canal).

Where in certain stretches the water level in canals is above the natural lay of the land, or where the canals run along a slope, particularly close attention must be paid to ensuring that the canals are watertight and the ground is secure against shear failure, to prevent the risk of flooding.

2. Environmental impacts and protective measures

2.1 Overview

River and canal works have an impact on the whole of the environment.

As well as the direct impacts, there will also be indirect or secondary impacts outside the area affected by the building operations proper.

This will for example be the case with building works in the upper reaches of large

rivers, which may have direct and/or indirect impacts down to the estuaries of the rivers and out to the landscape regions that are affected by the river via aquifers. Changes in flow velocity for example may under certain circumstances have an adverse effect on the oxygen balance of a watercourse and thus on its self-cleansing action produced by micro-organisms. These micro-organisms are a primary food for a wide variety of flora and fauna and the latter in turn for higher lifeforms (the food chain).

2.2 River engineering operations

2.2.1 Objectives of river engineering operations

River engineering operations are generally undertaken for economic reasons and they are subject to highly complex requirements in respect of the impacts being aimed for and those that have to be taken into account. For example, changes to wetlands or floodplains caused by river engineering lead to changes in the flora and fauna living in these areas and to the living conditions for different species. Such changes may offer major benefits locally, e.g. for utilisation and the human population, but they are acceptable only so long as displaced species and flora and fauna will find adequate living conditions in neighbouring regions and a wide diversity of species will be maintained.

Hence river and canal engineering operations are normally subject to a conflict of uses

and must therefore be planned and executed with due allowance for the widest possible balance of interests.

Identical or similar river engineering operations can be carried out for different purposes and for this reason the impact descriptions given below are classified under headings relating to broadly defined engineering operations and works.

2.2.2 Impacts from dredging operations

Dredging operations (momentary or repeated dredging operations to obtain or maintain given depths of water) have an impact on the natural environment firstly because of the resulting change in the longitudinal or cross-sectional profile of the river, which normally causes a change in its flow regime, and secondly as a result of changes in the surroundings of the river if the dredged material is going to be deposited away from the river bed. There may also be changes in the groundwater level if any permanent changes are caused to strata lying at this level.

Changes in the flow regime of a river, such as an acceleration of discharge in its middle reaches, may create a risk of flooding in its lower reaches. If a cut is made into certain soil formations, dredging may trigger off erosion phenomena whose action counteracts that of the dredging.

Depending on its consistency, dredged material pumped out or deposited by the side of the river may causes changes in the flora and fauna and in the natural landforms. Contaminated dredged material (which may be caused by pollution in the river water and thus in the sediments being dredged out) may in some cases have to be taken to special dumps, where care must be taken to protect the groundwater.

Improperly dumped dredged material, and especially contaminated material, may have detrimental impacts in the human sphere via changes to flora and fauna.

2.2.3 Transverse dykes and training structures

The purpose for which transverse dykes and training structures are intended is normally the artificial creation of given discharge channel cross-sections or a given longitudinal profile with the aim of maintaining certain flow velocities, directions of flow and depths of water at low or medium flow.

Transverse dykes and training structures have an impact on the natural flow regime of a river in that, where there are resulting changes in the groundwater level, they create a risk of erosion. They also have an impact on the floodplain region of a river (waterlogging or desiccation damage with the respective impacts these have on the flora and fauna; natural river-bank areas that would otherwise be diversified generally

change for the worse).

Generally speaking, they are an ideal means of obtaining navigable depths of water and given directions of flow with as few detrimental environmental impacts as possible. The construction of transverse dykes and training structures often has the effect of making other river engineering operations, e.g. dredging, unnecessary.

2.2.4 Revetments

Revetment operations are often carried out upstream or downstream of weirs, weirs with locks, and locks for hydrodynamic reasons (as also is bed stabilisation in some cases), their purpose being to stop erosion and scouring processes. The revetments are generally composed of dumped stone (rip-rap), which is laid on geo-textiles (as a bedding) to prevent undermining and underwashing. In special cases they may consist of bituminous coatings or interlocked revetments.

It is mainly the impermeable bituminous or interlocked revetments that have an impact on the natural environment in that they partly interrupt the exchange between flowing water and ground water. These impacts can however be classified as slight because the exchange through the bed of the river continues to operate.

Where there are major impacts is on the flora and fauna living on the margins of the river banks, because they are generally displaced. Heavy bank revetment may for example cause spawning grounds for fish or species of frogs and toads to be lost. A river confined by revetments often has a disagreeable impact on human beings due to its unnatural appearance. The beneficial impacts however, such as the reduced risk of bank collapses and erosion, promote safe living conditions on the banks.

2.2.5 Embankments

Embankments are built to provide protection against flooding.

Embankments have an impact on the natural environment firstly by preventing the flooding of extensive, and possibly settled, floodplains and secondly by affecting the regime of the river at times of high water discharge. The absence of flooding, of for example agricultural land on a floodplain, may sometimes cause major changes in the moisture content of soil, and there will be no "fertilizing" action of the kind produced by suspended materials deposited after floods (which action may have to be compensated for artificially where necessary). Both the above impacts give rise to further impacts on the flora and fauna of a floodplain.

Embanked stretches of a river affect surges of flood discharge in the same way as

stretches of a canal and cause accelerated discharge, the possibility of bed erosion, and a risk of flooding in unprotected areas along the lower reaches of the river.

Embankments also act as barriers to the natural surface runoff from the floodplain into the river. On the lower reaches of a river close to the sea (where embankments are usually essential to deal with storm tides), the land behind the embankment therefore has to be artificially drained.

Embankments have a crucial impact on terrestrial and aquatic flora and fauna. The change in the water balance for example causes changes in the habitats available to animal life of all kinds and plants. The fast discharge in the embanked channel that occurs at times of flood precipitation will be particularly destructive of spawning and breeding grounds located in areas of dormant water.

The adverse impacts of embankments, such as high discharge velocities and the possibility of river bed and bank erosion, may also have indirect detrimental effects on navigation and fishing.

Agriculture in the areas protected by embankments will suffer considerable deprivation due to the above-mentioned change in soil moisture content and to the absence of alluvial loam.

Embankments hamper free access to watercourses and need to be scrupulously managed and maintained to prevent any risk of breaches occurring in them.

Where in special cases embankments are revetted with stone or bituminous materials to protect them against wash or wave action, they also disfigure the landscape.

2.2.6 Bottom sills, step sills, weirs (alone or in combination with locks or run-of-river hydroelectric stations)

Bottom sills, step sills and weirs are generally built to improve navigation and exploit water power, but they are also built for reasons connected with water management.

To control water levels and discharge, weirs can be designed to be either fixed or with adjustable spillways or sluices. At the same time, weirs are also built in association with locks and/or hydroelectric stations or in association with abstracting structures to divert water into other channels (generally for irrigation).

Low bottom sills or step sills produce small to medium changes in the flow gradient. All the impacts generated by such structures are proportional to their size and to make things simpler the following description is confined to weirs but the impacts of bottom sills and step sills can be inferred from what is said:

Weirs constitute a major interference with the discharge regime of a river and they divide the river into an upstream section and a downstream section which are precisely separated by the structure itself. This causes a break in the transport of bed load and sediment. The division into two, combined with the raising of the water level in the upstream section, will cause sedimentation to occur in this section; in the downstream section, the greater tractive force of the water, which is free of sediment, will increase sediment uptake, or in other words there will be pronounced erosion from the river bed and banks.

In the upstream section, the rise in the water level will cause a change in the groundwater level in the foreshore back to the point where the incoming flow joins the water at the higher level. Because of the rise in the water level, embanking of the foreshore will often be necessary to stop flooding at times of flood discharge (see "Embankments").

Due to the change in flow velocity in the upstream section, the river's self-cleaning action will be seriously affected and this will lead to a deterioration in water quality that will be particularly pronounced during low water periods.

The raising of the groundwater level will have considerable effects on the terrestrial flora and fauna:

- The division of the river into two will hamper the natural migration of fish (there is a limit to how far fish ladders are able to solve this problem);
- Spawning grounds may become difficult or impossible to reach, and as a result certain species may die out or stay away;
- As a result of the reduction in flow velocity upstream of the weir

• water plants may proliferate again;
• breeding grounds for anopheles mosquitoes and insects may arise in areas of dormant water;
• snails which act as intermediate hosts for bilharzia (schistosomiasis) may take up residence on the banks, thus helping to spread the disease;
• there will be impacts on the aquatic flora and fauna as a result of the deterioration in water quality mentioned above (caused by the oxygen;
• there may be detrimental effects on fishing;
• special measures may in certain cases have to be taken to provide flood protection because the weir contracts the cross-section of the channel and the level of the water impounded upstream rises above the original flood mark;
• to combat the risk of erosion in the area downstream of a weir, sediment and bed load may have to be added to the flow artificially.

For the population, the direct impacts that occur will generally be beneficial (safety

from flooding, a supply of water and power). Detrimental impacts have to do with changes to the landscape and the health of the population. The latter

may be adversely affected by the spread of disease vectors. When this is the case, action should be taken in good time to inform the population and make them more aware, particularly women, who have traditionally been responsible for water and matters of hygiene.

2.2.7 River straightening or channelisation

The straightening of rivers is carried out for a variety of purposes and may be done for reasons of water management or on use-related grounds.

The impacts of straightening or channelisation vary with the way in which the operation is carried out. A distinction can be made between the following operations:

- **cutting off a loop of the river while preserving the loop as a cut off arm (a body of dormant or flowing water serving to drain off flood water or for other purposes). The operation is performed for the purposes of power generation (to increase head) and/or to improve navigability.**
- **straightening and shifting the course of the river without preserving the old**

bed. A water management operation for flood protection purposes or the like.

Cutting off as defined above normally breaks down into the following parts:

the cut, the cut off arm, weir structures in the cut off arm and the cut to raise the water level upstream, and building of a lock associated with one of the weirs or construction of one of the weirs as part of a hydroelectric generator station.

Channelisation is generally a hybrid undertaking consisting of river straightening (cutting off) and lining of the natural bed to create a uniform channel cross-section (in the interests of navigability). The impacts of channelisation will be dealt with in the section on canal engineering.

2.2.7.1 Cut-offs

A cut-off will alter the flow regime of the river. The shortening of the distance flowed produces an increase in the bed gradient and a rise in flow velocity in the cut.

Without weirs the cut off arm would dry up. The rise in flow velocity may cause a drop in water level upstream of the cut, heavier erosion of the river bed (upstream and in the cut), and sedimentation downstream. The high water peaks become higher and produce a greater risk of flooding in downstream areas.

Groundwater levels will be adversely affected upstream of and in the area where the operation is carried out. In the long term there will be a lowering of the groundwater level. As an example, the Jongley canal (a cut-off on the White Nile from Malakal to Juba) was built a) to shorten the length of the journey by boat and b) to increase the average daily discharge by 40 x 10 m^3 (approx. 460 m^3/s) by draining the marshes south of Malakal.

When there are weir structures (a weir with or without a lock in the cut and a hydroelectric generator station situated on the cut off arm, or vice versa, or the cut off arm blocked off underwater and all the structures situated in the cut), they produce the impacts described above under "weirs" in the areas upstream and downstream.

In the region of the cut, the impacts depend on the groundwater conditions in the environs of the location of the structure (at the upstream or downstream end of the cut).

In the cut off arm, there may be changes in water quality if nothing is done to ensure circulation by providing a link with the main watercourse (e.g. there may be eutrophication = a change in balance in the body of water due to heavy enrichment with nutrients, excessive algal growth, and severe oxygen deficiency).

Cuts without weirs have a pronounced effect on the flora and fauna in and in the environs of the former river bed (the cut off arm). Here, the change in groundwater levels (the channel acts as a drain) will certainly have an adverse effect on the flora, and the old riparian vegetation whose growth is controlled by areas of moisture will die out. As a result the possibility of adverse impacts on the fauna cannot be ruled out.

In the case of cuts with weirs, there are impacts similar to those from weirs in the upstream and downstream areas. In the region of the cut off arm, there are additional adverse impacts that can be anticipated:

- **When the cut off arm is made dormant, the water in it may undergo eutrophication. In tropical regions, water hyacinths may overgrow the entire surface of the water, with corresponding adverse effects on the fauna.**
- **Cut off arms provide the right conditions for becoming breeding grounds for insects and disease vectors (waterborne and vector-borne diseases).**
- **In cut off arms, there may be a sharp rise in the fish population, and when this is the case there will be a change in the species represented (fish living in flowing water move away and those living in still water become more populous).**

Hydroelectric generator stations will change the discharge regime downstream, and as

a result there will be changes to the flora and fauna (levelling out of discharge, peak capacity operation will cause rises and falls, etc. see the environmental brief Large-scale Hydraulic Engineering). The running of the turbines themselves may produce a deathtrap for fish.

Changes in water quality in the cut off arm and the breeding of waterborne and vector-borne pathogens will create a threat to the health of the population (see also page 11).

2.2.7.2 Straightening of watercourses

The shortening of the path of flow (e.g. by the straightening of meanders) causes a rise in discharge velocity and a result of this, flood waves are dissipated more quickly. As a consequence:

- the foreshore is no longer immersed or is not immersely as deeply as previously and because of this

• infiltration into the groundwater decreases and groundwater recharge is adversely affected;

- there is a change in the position of the groundwater table;
- bed and bank erosion begin to occur unless suitable bed stabilisation and

bank protection are applied;

- in the estuary region or in areas where the bed gradient is shallow, embankments must be built for protection against flooding caused by peak high water discharge.

Changes in the groundwater will produce impacts on the flora. The drying up of areas of marsh or swamp will mean changes in the diversity of plant species.

The fauna will be adversely affected likewise; the composition of the fish population will be altered by the removal of spawning grounds and that of the population of other organisms by the removal of areas of still water and changes to riparian zones.

The low risk of flooding will have an economically beneficial impact on the usefulness of the foreshore. Draining may enable economic use to be made of areas of marsh or swamp. Entire regions may be turned over to agricultural use by constructing drainage channels and setting up pumping stations which feed into the channelised river. This will necessarily mean a change in the flora and fauna of the land involved.

The straightening operations will also interfere with the appearance of the landscape. Riparian vegetation which was characteristic of the landscape and peculiar to it will disappear.

In socio-economic terms, the impact of the operations in question will be beneficial in that there will be fewer floods and less damage of various kinds.

2.3 Canal engineering

The building of canals and navigable waterways is generally carried out for economic reasons to provide a cheap mode of transport or to divert watercourses or lift them over obstacles.

When serving as links between seas and/or river systems, canals often run through regions in which there would not normally be any great abundance of surface water. To overcome differences in elevation, locks and boat lifts have to be constructed. Artificial waterways of this kind have to be fed with water because evaporation, seepage, locking operations, etc. cause water losses and the water in the canal has to be kept at a certain level for proper navigation or for the sake of other users.

This being the case, impacts arise from the supply of water to the canal, where the water used is impounded water, and from the routing of the canal.

Canals have impacts on the water balance over a large area. For example:

- the groundwater level may undergo changes because canals act as giant

drainage channels;

- water quality may deteriorate due to the discharge of wastewater and solid waste by vessels.

In addition to this, the change in the water balance may also occasion local changes in microclimate, which in turn will have secondary impacts.

Breaches in raised sections of canals may cause considerable damage to the canal itself and in surrounding areas.

The changes in the water balance in the region will have consequences for the terrestrial flora and fauna. Certain species of plants may be totally destroyed, i.e. wet biotopes and their flora may be destroyed if, for example, the supply of water for the canal is obtained by draining areas of marshland. Canals also cut across the natural migration routes of game and small animals and may fragment habitats.

Dried wetlands will undergo a change of use, i.e. they will be converted into farmland or forest land.

It is possible that there may also be adverse impacts, particularly on the landscape due to the routing of the canal and due to the structures required such as embankments,

locks, boat lifts, aqueducts and road bridges.

As well as this, there is also a considerable risk to humans and animals in the event of breaches in the banks or bed of the canal in raised sections or on aqueducts.

A canal will cut across traditional connecting routes and channels of communication. Bridges will need to be built to allow roads and footways to cross the canal, but it will be found that the problems created by divisions of this kind are not amenable to a total cure. On the other hand, canals may have a high leisure amenity value for watersports.

3. Notes on the analysis and evaluation of environmental impacts

Specifically in the case of rivers it should be remembered that, generally speaking, impacts may arise along their entire course. Due to the water supply that they require, canals too have wide-ranging impacts.

What will give trouble when evaluating the environmental impacts in this case is the question of quantifying the impacts. Qualitative descriptions are one option but to allow others to appreciate all the implications of what is being said they should be as detailed

as possible.

Due to the complex interrelationships involved and current ignorance as to the real causal factors that contribute to an impact (it is only seldom that a single factor is responsible for an impact), the possibility of misinterpretations cannot be ruled out. In this case a useful method of arriving at genuinely relevant conclusions may be to make a comparison with the impacts generated by existing river and canal engineering operations in similar situations, climates, topographical conditions etc. However, when doing so it is important to identify factors that are relevant to the impacts in the particular environmental areas and to bring out the relationships that exist between the action taken and its impact. Particular importance should be attached to the questions of species protection, changes in biotopes and maximum permitted changes in groundwater levels.

4. Interaction with other sectors

The closest points of contact that river and canal engineering operations have are with sectors that generate an additional demand for water. Existing water rights will need to be taken into account in this case.

The main sector that should be mentioned is agriculture, because this is affected by all river and canal engineering projects either because it makes use of the same resource for irrigation purposes or because there is a change in the use of land or because terrestrial fauna are affected or because there are added secondary impacts.

Mention should also be made of the supply of water. Water supply, which is one of the priority concerns for developing an area, must always be covered in the planning for all projects in all sectors and the demands it makes should always be considered as a matter of priority.

Aspects of rural hydraulic engineering and large-scale hydraulic engineering projects and port and harbour construction projects often have a bearing on river and canal engineering.

In this connection, the reader is referred to the relevant environmental briefs Rural and Large-scale Hydraulic Engineering, Water Supply, etc. and the environmental briefs of more general ambit on planning should also be consulted.

5. Summary assessment of environmental relevance

In principle, it is perfectly feasible for river and canal engineering projects to be planned and executed with only minor environmental impacts. Planning procedures and the engineering means both exist. However, all over the world there has been experience of adverse effects on the environment. The reason for this was that in planning and executing river and canal engineering works it was only the purpose, such as water power, irrigation, flood protection, protection of drinking water, or navigation and handling of goods, that was considered, or in other words attention was only paid to the use aspect, and the impacts the projects would have on the natural environment and in the human sphere, with all the problems of settlement/resettlement and changes in socio-economic and socio-cultural conditions, were either totally ignored or given only cursory scrutiny.

When major projects for making rivers navigable or for building canals (which fragment the landscape) are mooted, sex-specific and group-specific socio-economic analyses should be carried out to see how far specific groups within the society will be affected by the adverse effects of carrying out the project or can share in its expected benefits. Hydraulic engineering operations have a particularly marked effect on women.

River and canal engineering operations should always be planned and executed in such a way as to minimise the risk to the environment posed by the planning and building. By

careful analysis of all the impacts and by making corrections at the planning stage it will be possible to keep the consequences of man's interference with the ecosystem and with the human environment within acceptable bounds. The presence of human beings and the needs these human beings have are factors that must be accorded an essential place in the planning.

This should be achieved by means of participatory decision-making processes that provide the persons affected with an opportunity to assert their justified interests and desires at all stages of the planning and execution of a project.

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Contents - Previous - Next

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

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21. Rural hydraulic engineering

Contents - Previous - Next

Contents

(b) Biosphere

2.2.3 Human sphere

2.3 Head races/receiving bodies

2.3.1 Objective

2.3.2 Natural environment

(a) Physico-geographical sphere
(b) Biosphere

2.3.3 Human sphere

2.4 Detention basins

2.4.1 Objective

2.4.2 Natural environment

(a) Physico-geographical sphere
(b) Biosphere

1. Scope

Hydraulic engineering can be divided into the following areas:

- **large-scale hydraulic engineering**
- **(small-scale) rural hydraulic engineering and**
- **river and canal engineering.**

In brief, "rural hydraulic engineering" can be said to cover the following water management works carried out in rural areas:

- **weirs and bottom sills for retaining water for use in small hydroelectric power stations, for irrigation and water supply, and for regulating watercourses;**
- **head races (receiving bodies and drainage systems) for receiving discharged water;**
- **detention basins for flood protection in smaller watersheds;**
- **small earth dams, low in height, for the storage of water and for flood protection;**

- **bank and bed stabilisation work, erosion protection measures;**
- **channelisation (embanking) of watercourses.**

These works are generally carried out for economic reasons, either for improved utilisation of water resources for humans, animals, production (agriculture, industry) or services, or to prevent damage being done by the water itself (floods, erosion; this also includes consequential damage caused by poorly executed construction work).

Most rural hydraulic engineering work may produce structures serving both productive and protective purposes. For example, a small reservoir may be used not only for water supply but also for retaining rainwater and hence for flood protection and also for fish production.

2. Environmental impacts and protective measures

2.1 Overview

Hydraulic engineering work in rural areas exerts an influence on the environment, and constitutes interference with nature and the landscape; changes in the natural

conditions and hence in living conditions may be brought about by:

- construction work on water and land, and the associated interference with the natural discharge regime, groundwater balance and regional water cycle and
- the resulting use of water resources by man and animals, for production (agriculture, industry) and for services.

Prerequisites for environmentally and socially orientated rural hydraulic engineering work are that:

- the planning must take account of all the defining conditions and of their consequences (including long-term consequences) and the works must be sized in the light of reliable estimates of demand and growth in demand and of the beneficiaries' ability to pay,
- interference must be minimised, adverse effects must be reduced by taking corrective measures, and irreversible processes must not be allowed to occur.

As far as economic use is concerned it is important to alert the responsible workers and participants, through increased awareness/training, to environmental impacts and ways of avoiding or reducing them, and to ensure that the works will be usable in the

long term (operation/maintenance); these factors must be taken into consideration as early as the planning stage.

The possible environmental impacts and environmental protection measures resulting from construction work relate to the following spheres:

(A) THE NATURAL ENVIRONMENT:

(a) the physico-geographical sphere and
(b) the biosphere

(B) THE HUMAN SPHERE: with all its social, socio-economic and socio-cultural aspects (including the use made of water resources) and the effects on human life and quality of life.

The impact of rural hydraulic engineering works tends to be localised, and because of this, less serious interference and less severe environmental damage can be expected than from large-scale hydraulic engineering and river and canal engineering.

2.2 Weirs and bottom sills

2.2.1 Objective

Weirs and bottom sills are constructed mainly with the intention of impounding water so that it can then be abstracted from the impounded body of water for various purposes. In most cases the water is extracted in free fall by means of a discharge channel (see also 2.3: Headraces) or pipe but abstraction by means of syphons or pumps (manually, animal or motor-operated) is also possible.

Weirs generally constitute a greater interference with the natural watercourse than lower bed sills, but both structures alter the discharge conditions, such as channel cross-section, gradient, and bed roughness and hence volume and velocity of discharge. Because they reduce the flow gradient most bottom sills merely perform the tasks of stabilising the river or stream bed and reducing bed and bank erosion. From the hydraulic point of view small weirs operate on the same principle as large impounding weirs, but the intensity of the impacts on the environment is generally much smaller.

2.2.2 Natural environment

(a) Physico-geographical sphere:

There will be impacts on the water balance, and particularly on the groundwater conditions, downstream of a small weir only if the quantity of water abstracted is a

relatively high proportion of the undisturbed discharge of the watercourse (e.g. only if the weir brings the discharge below the mean low water discharge (MLQ). However, if the total discharge is abstracted, which rarely happens, the watercourse will run dry and the groundwater level will drop. It much be checked in each particular case, and an estimate made from the results, of whether and how the quantity of water abstracted (less the losses, e.g. as a result of utilisation) can be returned to the watercourse or groundwater aquifer concerned. In doing so it must be considered very carefully whether 100% abstraction is justified in the light of the serious impacts on the water balance downstream.

If the quantity of water abstracted is returned to the river a short distance downstream of the weir (as in the case of small hydroelectric power stations, for example), an impact occurs in the intervening section, e.g. due to interruption in the transport of sediment and bed load caused by their trapping in sand.

If the water abstracted is used in the area close to the banks for irrigation, it can generally be expected that a high proportion will return to the watercourse above and below ground as drained and percolating water. However, use of the water for irrigation agriculture, which must be regarded as beneficial, has accompanying adverse effects such as salination or other changes in quality of the water used (due to fertiliser and pesticide incursion etc.), which may lead to a considerable deterioration

in the quality of the watercourse over long sections.

Depending on the suspended matter and bed load carried (i.e. depending on the soil type and plant cover in the watershed), the river bed will silt up particularly heavily in front of the weir (more rarely in front of the bottom sill), thereby causing the channel cross-section and the water level to vary. This may result in waterlogging of the riparian areas, which may even extend to flooding, so that as in the case of large river structures, embankments may be necessary upstream to act as protective structures, which in turn constitute an interference with the environment and landscape. Their consequences must also be considered.

Variations in the watercourse level may also affect the groundwater level, depending on the hydrogeological conditions. Thus a stabilising effect, which in some cases even raises the groundwater level, extends upstream from the area of the weir impoundment, whereas downstream there may be a lowering of the groundwater level. However, the effects of minor, isolated measures, are only of local significance, although a string of small weirs may have a more far-reaching effect.

Erosion resulting from sediment retention at the weir may occur downstream, depending on the nature of the watercourse bed.

(b) Biosphere:

Plants can react extremely sensitively to variations in groundwater level, and among other factors, the quantity of available water affects species diversity.

For example, if the river bed runs dry for a prolonged period downstream from a small weir, due to relatively heavy abstraction in the dry season, this will cause damage to the variety of species of fish, insects, birds and other local species. Furthermore consideration should be given to the division into upstream and downstream regions caused even by small weirs, in terms of their impacts on living and migration conditions of fish (fish ladders may be needed).

Upstream from weirs dormant water areas may be formed due to the change in flow regime, and in these areas the oxygen intake is greatly reduced. The consequences of this may be either disturbances to the fauna in the water or the growth of pathogens, which are in turn transmitted to man and animals through the water.

Further negative impacts on the environment may arise due to the clearing of forests and the construction of access roads required to erect the structure.

2.2.3 Human sphere

Hardly any negative effects may be expected if there is expert planning and if at the same time the interests of the population, the area directly adjacent to the river and existing water rights are considered (no measure must do harm to the downstream area).

The possible formation of dormant water areas upstream from weirs, with reduced oxygen intake and the growth of waterborne pathogens, poses a potential health risk.

However, it must be determined in each case what effect the project measures have on the work load on women given the sex-specific division of labour in the traditional areas of water collection, agriculture, etc. and on their economic situation.

2.3 Headraces/receiving bodies

2.3.1 Objective

Headraces are set up to discharge water from weirs and other river abstraction points. When in the form of artificial receiving bodies they also absorb the seepage and drainage water from adjacent (in some cases agriculturally used) areas flowing into them by force of gravity, and are therefore used to avoid waterlogging.

2.3.2 Natural environment

(a) Physico-geographical sphere

The construction of headraces/receiving bodies constitutes interference with the slope or terrain. It must be ensured, through the choice of suitable parameters, and depending on the soil material, the construction method and the size of the canal (width, depth, water supply):

- that the stability of the slope is not impaired by the cutting in the slope to the extent that landslips occur;
- that seepage flows, extending to escapes of water, do not cause landslips and erosion at the foot of the slope or embankment where they are too steep and/or are leaking. Subsequent rainfalls may considerably increase the damage, giving rise to additional damage due to the erosion of unplanted outer embankments. Moreover, gust of winds may erode inner embankments.

(b) Biosphere

Negative impacts are caused by the above sources of erosion and landslip. Otherwise the headrace/receiving body may have a positive effect, as a small biotope, on the flora/fauna along its route, as many examples show (e.g. in the Peruvian Andes:

vegetation along the old Inca canal routes in otherwise desert-line areas).

2.3.3 Human sphere

Direct negative effects are not expected. However, they may occur as secondary effects with injuries to man resulting from landslips (including flooding).

2.4 Detention basins

2.4.1 Objective

Detention basins serving as protective structures for averting the risk of flooding in small, rural catchment areas, affect all spheres; negative effects may therefore be expected from inexpert planning/execution of the work (failure of the structure) and due to incorrect operation of the plant. The determination of the highest high water level, required for dimensioning both the detention basin and the barrier structure, is often extremely difficult in many countries because of the lack of basic water resource data. However, it is not always possible to plan on the safe side for reasons of cost.

2.4.2 Natural environment

(a) Physico-geographical sphere

The installation of the barrier structure and the operating outlets, which are normally open, do not constitute an impairment of the runoff behaviour.

In the case of high water (flooding) a portion of the high water level is stored in the outlets by partial closing of the locking mechanisms, and the emission downstream is reduced correspondingly; this can have the following effects:

- the runoff downstream is stabilised by capping the high water peak (intermediate storage);
- erosion and sedimentation are reduced in the downstream area because high runoff peaks no longer occur. However, this positive effect is offset by the mineral undersupply of the banks and watercourse beds due to reduced underwater sedimentation (this may have consequences for the flora/fauna);
- if there is no sealing of the soils due to depositions of fine sediments (depending on the soil material in the catchment area), the infiltration area in the dam area (or river bed) is increased on the one hand, and the infiltration times may be extended on the other due to the intermediate storage with subsequent more uniform runoff, which has a positive effect on groundwater renewal;
- the deposition of clayey-silty material in the dam area (often laterite) results in sealing of the sill, the positive effect of which is the sealing of the

reservoir and hence longer availability of water. However, this may have a negative effect on the groundwater conditions in the reservoir area, and as the material penetration continues, the reservoir capacity and hence the efficiency of the detention basin, will ultimately be reduced (for effects due to damage to the barrier or dam structure of the detention basin see 2.5).

(b) Biosphere

In the reservoir area the flora is not substantially damaged by the overdamming times and intervals during the period of rain, which are normally only very short.

Sediment penetration and depositions on forelands and in the actual core area of the detention basin may both impair and promote plant growth, depending on the nature of the sediment (humus proportion).

The fauna is greatly affected by damming in the detention basin; animals must escape very quickly from the rising water due to rapid filling following heavy rain in the mostly small catchment areas; for many animals this may be problematic and may even lead to destruction.

For the fauna (particularly birds) living in flood areas, and water-bound flora,

reductions in runoff due to intermediate storage may have considerably negative effects which would have to be investigated in the individual case. Habitats may be dried out.

2.4.3 Human sphere

With expert planning, construction and operation, overwhelmingly positive effects may be assumed in the human sphere. However, if there are incorrect planning estimates of the expected high water level, which is increasingly observed due to a lack of basic data, or if the detention basin is incorrectly operated, flooding, an intensification of the high waters and damage both up- and downstream may occur.

Explaining to the population the logic, purpose and mode of operation is necessary at the initial planning stage, and this may allay fears and uncertainties. Flood and utilisation plans must be drawn up for the detention basin, agreed with the local residents and implemented by a member of the village trained for this task and competent to operate the plant.

2.5 Smaller earth dams/installation of reservoirs

2.5.1 Objective

Low-level earth dams (only a few metres high) are often erected on or in the river/watercourse or in the associated catchment area at the foot of suitable valley troughs or cuttings in the land for storing surface water for different purposes (e.g. water supply, irrigation), and for making it available for the longest possible periods, or all year round.

Environmental effects are caused by the small dams and by the reservoirs formed by them.

In some cases small dams are not planned with the same care as large barrages. This is because non-experts also venture into the field of dam construction and fail to observe simple rules. Although the damaging effects in the event of the failure of a large dam are considerably more serious, the small earth dam is equivalent to the large dam in terms of basic hydraulic engineering data.

Numerous examples of destroyed smaller earth dams point to causes of damage which are attributable both to planning and construction errors and defective maintenance, and are responsible for damage as well as environmental impacts. In most cases slope inclinations which are too steep, flood overflows which are dimensioned too small and which are inadequately secured against the flowing water, unsuitable installation material and little or insufficient compaction are the main reasons. Newly erected

earth dams should be kept free from grazing animals for a sufficient length of time to allow consolidation and growth of soil covering grasses/plants (fencing).

2.5.2 Natural environment

(a) Physico-geographical sphere

The artificial/storage lake or reservoir has a similar effect on the environment, taking into consideration the various interrelationships, as the large barrages (see the environmental brief Large-scale Hydraulic Engineering).

In the case of relativey shallow lakes deterioration in water quality resulting from the permeation of light as far as the bottom of the reservoir, algae and plant growth and considerable heating of the water may be expected. If there is an abundant supply of nutrients with only a small water exchange, eutrophication processes may be triggered. Sedimentation dependent on soil type and soil cover in the catchment area and -where fertilisation takes place - phosphate penetration (or the penetration of other agrochemicals), directly or via the sediments, promote these negative changes in water quality and the warping of the reservoir.

If cattle use the reservoir for drinking and also remain in the reservoir for a long time

(depending on the water depth), this effect is greatly intensified and the water quality is impaired to such a degree that use of the reservoir water as drinking water is called into question.

The groundwater horizon in the more immediate reservoir area may be lowered as a result of extraction from otherwise seeping surface water.

Dam fracture may result from defective construction or maintenance of the earth dam, with considerable damage downstream, and total loss of water into the subsoil.

(b) Biosphere

In the shallow and stagnant water zones of the reservoir area, particularly in tropical regions, there may be a multiplication of insects. Moreover, if the reservoir is used by cattle for drinking, and if animal excrement occurs in the bank areas or throughout the lake (depending on water depth), the risk of the transmission of water-induced diseases increases substantially.

The flora which originally existed before the construction of the earth dam in the reservoir area is destroyed by the damming of the water. It is replaced by an aquatic flora, and algae growth is particularly promoted. The development of the fish

population depends on the type and quantity of vegetation existing in the reservoir area. Water hyacinths may propagate to such an extent in a tropical climate that they will cover the entire surface of the lake in a short time, thereby substantially impairing the fauna.

2.5.3 Human sphere

Waterborne diseases, such as bilharziosis and malaria etc., may occur more frequently under tropical conditions prevailing in water reservoirs unless adequate precautions are taken in terms of local separation of washing, collection of water and animal drinking (if possible below the dam), together with suitable water treatment measures (e.g. sand filters) and disposal of water (e.g. VIP[1)] latrines) as part of the comprehensive hygiene education of the consumers.

[1)] VIP latrine = Ventilated improved pit latrine

Positive socio-economic effects may be expected from a reservoir assuming population-orientated planning and implementation in terms of self-help, including women in particular, for the purpose of selecting suitable standpipe sites (social integration), point out cash crop growing areas (improvement in income situation) and proper use and care.

The erection of smaller reservoirs may require the relocation of resident populations; a dam fracture may endanger human life.

2.6 Bank and bed stabilisation

Bank and sill defences, as erosion protection measures in limited areas of small flowing watercourses or on coastal structures in hydraulic engineering in rural areas have hardly any negative effects on the different spheres if environmentally friendly materials and materials adapted to the local conditions are used, and if such defences are properly constructed. However, this must be determined in the individual case according to the scope of the measure taken.

2.7 Channelisation (embanking)

Generally speaking negative effects on the different spheres, as already described in the Environmental Brief River and Canal Construction, may also be found in minor channelisation and embanking works.

However, if such works, limited locally as protective structures, are only erected in the area of the village for averting seasonally restricted high water (flood) risks to man, animals and material (e.g. harvest yields), and if a transition to the natural water

course, adapted to the conditions, is guaranteed up- and downstream, hardly any negative effects may be expected.

3. Notes on the analysis and evaluation of environmental impacts

As the general representation of the possible effects on rural hydraulic engineering works on the environment shows, the relationships may be complex and difficult to record and demonstrate because of the small-scale measures taken in most cases.

Interactions are not as clearly recognisable as in other major hydraulic engineering subsectors.

In order to conduct any analysis and evaluation of the effects on nature and the environment an examination of the natural conditions, not only from the technical and engineering point of view (hydraulic engineer), but also, in particular, the socio-economic and socio-cultural points of view (socio-economy, ethnology), must therefore be carried out at the beginning of each project.

In this case the consumers (men and women/executing organisation) must be involved

as early and as comprehensively as possible, with emphasis placed on the integration of women. The analysis and evaluation of the environmental impacts includes:

- as complete a description as possible of the prevailing actual situation, and of the interactions;
- the establishment of adequate, protected basic data for the technical planning and construction work (precipitation-runoff ratios, useful water supply, building land, consumption and cost/benefit analysis), involvement of the population and guarantee of readiness for subsequent management (staff, costs, fees);
- the surveying of the social behaviour of the consumers relating to the management of the very often sensibly handled resource water (marketing, cost structures, traditional way of life, self-administration, agricultural cultivation and marketing methods, cattle and forest management);
- the development of alternative project concepts for arriving at the most environmentally friendly solution and the best solution from the socio-economic and socio-cultural points of view, taking into consideration the original project objectives and their maximum attainability (including, for example, supplementary measures for minimising undesirable side-effects).

Difficulties are often encountered in analysis and evaluation arising from a weak

database, so that although the effects of measures and interference with nature and the socio-economic environment can be described qualitatively, they cannot be quantified very accurately. Here comparisons of existing rural hydraulic engineering projects with similarly structured peripheral and general conditions (population, climate, landscape etc.) may be helpful in arriving at better supported statements and solutions. So far no universally applicable standards have been established for quantifying effects.

However, each project should try, by suitable sensitisation and explanation, to meet the most stringent requirements possible for protecting the environment, according to the socio-economic conditions, during planning, construction and operation.

4. Interaction with other sectors

Hydraulic engineering in rural areas may have points of contact with all plans/measures whose direct or indirect objective is the use of water in the following subsectors:

- **water framework planning**

- rural water supply
- solid waste disposal
- river and canal engineering
- erosion control
- large-scale hydraulic engineering
- spatial and regional planning

and from the agricultural sector, the areas of:

- plant production,
- plant protection,
- forestry,
- fisheries and aquaculture and
- irrigation.

The superimposition of negative effects of rural hydraulic engineering on effects of the above-mentioned projects (compare the applicable briefs) with negative effects can result in major damage.

5. Summary assessment of environmental relevance

The environmentally oriented planning and implementation of rural hydraulic engineering projects is possible, and technical solutions are available, but they must be supplemented by the general socio-economic and socio-cultural conditions. The opinion, still widely held, that rural (i.e. small-scale) hydraulic engineering projects only involved a low planning cost, and had little or no environmentally relevant effects, because in most cases they were on such a small scale, thereby rendering their examination generally superfluous, is incorrect.

With careful planning and implementation of rural hydraulic engineering work by experts, less marked (negative) environmental impacts may be expected than in large-scale hydraulic engineering work or river and canal engineering work. Regular inspection and maintenance of the plant must be guaranteed.

Possible damage to the natural environment and in the human sphere must, in particular, necessitate an examination of the environmental and social relevance of the work, even in the case of small-scale hydraulic engineering works, to achieve a maximum level of safety, if necessary by providing alternatives.

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Contents - Previous - Next

22. Large-scale hydraulic engineering

Contents - Previous - Next

Contents

Questionnaire relating to the initial evaluation of the environmental impacts of a large-scale hydraulic engineering project.

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.

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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?

Contents - Previous - Next

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

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23. Inland ports

Contents - Previous - Next

Contents

1. Scope

The inland ports sector covers all the operations performed for the purpose, at inland ports, of transporting people (e.g. at ferry ports) or ensuring the safe transfer, transit storage, and movement in transit of solid, liquid, and gaseous materials of all kinds in the course of transferring such materials from landborne to waterborne modes of transport or vice versa (the primary function of a port).

Landborne modes of transport	Waterborne modes of transport
Railborne vehicles Road vehicles	Inland waterway vessels, ferries, barges, push tugs

Pipelines	

The "inland port infrastructure" sub-sector covers all the shore-side and water-side facilities at an inland port that it requires in order to perform its primary function or that come into being at the port in the form of industrial, trading or service facilities, i.e. to allow it to perform its secondary function.

The shore-side facilities include, amongst other things:

- roads, railways and land for other transport uses;
- open storage and stacking areas, storage sheds and silos, tank farms, crane tracks,
- bridges, viaducts, overpasses, underpasses, pipelines, etc.,
- supply and disposal facilities (for water, power, wastewater, refuse, etc.)
- flood protection structures, embankments, etc.
- buildings, such as office buildings and fitting-out and repair shops,
- industrial facilities and buildings for port-related and secondary industries, e.g. shipyards and shipyard buildings.

The water-side facilities include, amongst other things:

- harbour basins and entrances, approach channels, locks, moles, safety gates,

ship lifts, etc.,

- cargo handling quays and piers, bank revetments, ro-ro and ferry facilities, dolphins and landing piers,

- shipyard slipways and fitting-out quays.

The nature, design and location of all facilities in the inland port infrastructure sub-sector will depend on:

- the local water-side and shore-side conditions,

- the nature of the goods in transfer and the volumes involved (general cargo: conventional, containers, ro-ro; bulk cargo: bulk general cargo, loose cargo such as ore, coal, grain, and industrial salts, or bulk liquid or gaseous materials such as oil, LNG, etc.);

- the associated water-side and shore-side modes of transport (see above);

- the operating requirements and schemes arising from the above;

- the links with the hinterland by road, rail, inland waterways (canals) and pipelines,

- the existing or incoming structures in the environs (trade and industry).

The "inland port superstructure" sub-sector covers all the non-permanent shore-side and water-side facilities at an inland port that are related to its primary or secondary

functions. These include, amongst other things:

- dredgers and other maintenance and repair facilities,
- mobile supply and disposal facilities and fire-protection and disaster control facilities (e.g. vehicles and vessels for dealing with oil spills).

Non-permanent suprastructural facilities in the port environs or serving its secondary function can be briefly classified under the following headings:

- the supply and disposal superstructure,
- transport superstructure,
- the maintenance and repair superstructure provided by port-related trade and industry.

A distinction also needs to be made between general ports, and specialist ports that handle only goods of a specific type. Even at "general" ports, it is becoming increasingly common for goods of only one kind or category to be handled at dedicated facilities known as terminals (oil terminals, ore or grain terminals, ro-ro terminals, etc.). This is done either for safety reasons or because of the specialised equipment needed.

On the basis of their location, inland ports also have to be divided into river and canal

ports.

River ports	Canal ports
Ports on river banks or extending parallel to estuaries,	Artificial harbour basins and approaches,
Ports in bays	Ports on or parallel to canal banks

The setting up of natural ports generally calls for less far-reaching interference with the natural environment.

2. Environmental impacts and protective measures

2.1 Overview

The environmental impacts generated by inland ports are generally considerable and they result firstly from the building, conversion or extension of inland port facilities (infrastructural and suprastructural), but secondly and to a major degree they arise from the operation (on both land and water) of all the port facilities, of trade and

industry and of the transport systems.

The environmental impacts affect water, land, air, flora and fauna of all kinds (both on land and in the water), and human beings.

Causes	Impacts on
New construction	Water
Conversion	Ground
Development/extension	Air
Operation of all facilities	Flora and fauna (aquatic and terrestrial)
	Human beings

In principle, the environmental impacts will be greater, the larger is the building or extension project or the busier are cargo handling activities at a port (measured in t/a).

Impacts of specific kinds arise from dangerous goods classified as such in the IMDG code (International Maritime Dangerous Goods Code), even if they are only in small quantities.

In broad terms, in the "infrastructure and superstructure" field environmental impacts are created:

- primarily by the port itself, viewed as the totality of all the water-side and shore-side structures used for the purposes of shipping and cargo-handling operations, and
- secondarily by the industrial concerns, generally ones with a close connection with seaports, which come into the area to serve as an infrastructure for processing and refining goods and raw materials and which, by being set up, cause changes in the natural conditions and which must therefore be viewed as an interference with nature and the landscape.

In the sphere of "operations", impacts are created

- primarily by all activities carried on, such as movements of vessels, loading, unloading, storage, transport, supply and disposal, and maintenance and repair, and
- secondarily by all the activities carried on in the contiguous industrial area for the purposes of processing and refining.

The above activities entail changes in the natural conditions and conditions of life and

may thus have an effect on human beings, animals, nature and the landscape.

2.2 Construction or expansion of inland port infrastructure or superstructure

2.2.1 Shore-side facilities

Although this varies with the projected volumes and kinds of cargo to be handled, a port normally takes up large areas of land, particularly when there is provision for open storage areas, storage sheds and industrial estates. This being the case, a port always involves considerable interference with the existing natural landscape in that river banks and wetlands, etc. are artificially stabilised and built over, and land is levelled and sealed. This produces impacts on/changes to, in particular, sensitive areas such as woodland and forest, wetlands, farmland, and residential areas, these impacts/changes resulting from excavation/replacement of soil or filling operations, surface sealing, drainage/drying operations, high ground loads and somewhat unattractive special-purpose structures. Although the above are obviously determined in essence by the purpose for which they are intended, it is still possible for shore-side environmental protection measures to be implemented by making provision for them in the infrastructural planning at the outset.

Open cargo handling, storage and holding areas should be designed to satisfy the

following criteria in the light of the nature of the goods to be handled, the volumes involved, and the mode of operation:

a) With ore, coal and salts, care must be taken to see that

- as dictated by the bulk weights and dumped heights involved, storage areas are designed to be sufficiently strong and well sealed to stop the subsoil and the surroundings from being affected by settlement;
- a drainage system extending around and across these areas and sized to suit the expected precipitation levels is planned in such a way that polluted surface water and surface water charged with heavy metals will not be able to penetrate or seep into the soil and rivers/canals or run into them (settling basins and, where necessary, treatment plants will be required).

b) Where bulk goods are stored, covers built over sheds and sprinkler systems may be provided as an effective means of keeping down dust but they are expensive to build and maintain.

- Bulk goods that are vulnerable to the weather must always be stored under cover or in silos.

c) Where oil and other liquids are to be handled, provision must be made for the ground in loading and discharge areas and tank farms to be sealed to suitable standards of liquid-tightness and for oil separators or other waste-water cleaning facilities to be installed; otherwise the only way in which the pollution of groundwater and lake water by leaking liquids can be combatted is by way of operating procedures.

Shore-side port extensions must be planned well in advance so that the land required can be earmarked and kept clear in good time. It is observed that ports tend to encroach on established settled areas or areas that should be protected, resulting in forced resettlement and land clearance, and the advance planning mentioned is the only way in which such encroachment, and the advance of uncontrolled settlement that may equally well occur, can be prevented.

Tall buildings, special-purpose structures, industry and residential settlements have an essential part to play in the development of a port region. The following will help to ensure that their planning and design is environment-orientated:

- **areas intended for different purposes should be kept separate from one another;**
- **environment-friendly building materials should be used;**
- **an optimum balance should be struck between building height/usable height**

and ground area occupied;

- land should not be wasted;

- the architecture of tall buildings and special-purpose structures should follow the building style of the country concerned;

- an open layout should be adopted by planting/grassing the open spaces around buildings and, where possible, the margins of the open storage spaces in the port;

- where industries move into the port area they should use techniques considerate of the environment;

- an infrastructure for water supply and wastewater discharge should be built aimed at preserving groundwater and surface water resources and keeping lake water clean.

The development of a port often entails the movement into it of industries. Experience shows that the new jobs created, or often just a hope of gainful employment, lead to a greater and sometimes uncontrolled influx of workers and their families. It is therefore essential when ports are being planned that attention is paid to providing living conditions fit for human beings in the fields of housing and sanitation. In this connection suitable allowance must be made for needs specific to women. A particular risk that exists is that of creating ghettos near the port.

The development of a port area and the associated industrial areas places an enormous burden on all the supply and disposal facilities and services. The demand for water and the amount of wastewater occurring should be highlighted in this connection because of the impacts they may have on the environment. However, it is not just water but the consequences for air and the land, the spoiling of the landscape and the effects of traffic that also need to be pondered, particularly in the planning phase.

2.2.2 Water-side facilities

Water-side port facilities (e.g. turning basins, port entrances, etc.) generally cover a large area and therefore constitute a major interference with nature and the landscape. It is however possible by careful planning to keep down the environmental impacts[1]. The aim in planning and installing the water-side facilities in a port should always be to use preliminary surveys of natural data and, where appropriate, model tests to familiarise oneself with prevailing environmental conditions, such as

[1] As far as possible, port facilities should be blended in with the general look of the landscape.

- **wind and wave conditions,**
- **current and sedimentation conditions,**

- water, soil and air conditions,

and to build in harmony with these defining conditions and not in conflict with them.

The buildup of sediment will make it necessary for regular maintenance dredging operations to be undertaken to maintain the appropriate depths of water but pumping out or dumping into the water of dredged material creates major environmental problems, especially because:

- the mud in question may have been contaminated by general water pollution, by discharged wastewater, or by oil or heavy metals;
- over long periods it becomes necessary for large areas to be given over to pumped out or dumped material, and such areas are difficult and expensive to recultivate;
- dumping into the water causes changes in the bed configuration and in the aquatic flora and fauna.

These consequential impacts can best be avoided by planning structures geared to the existing currents well in advance and by providing suitable disposal facilities.

The design of port facilities should take advantage of the natural effects of the river

current and also of the differing seasonal water levels in the river, e.g. to keep approaches clear, which can be achieved by the careful siting both of training dykes to guide and concentrate the current (for a flushing action), and of harbour enclosing works (particularly in the approach area with a view to preventing lee erosion) and of wharfage, which if possible should not be positioned in areas of dead water. Port facilities should not be sited in areas where the water is brackish (where salt water and fresh water meet, resulting in greater volumes of silt being deposited).

Fishing grounds and aquaculture areas supporting river fishing activities, together with natural flora and fauna, may be adversely affected by port construction because it causes the loss of large areas of water and valuable breeding grounds and habitats.

Consequential impacts that may follow on from the adverse effects on fish stocks may be health risks from eating fish, and these in turn may result in job losses in the fishing industry. Extensive involvement of fishing interests should therefore be aimed at right from the stage when port facilities are being planned.

Other hazards that may arise directly from a port facility are the types of consequential damage that are caused by wastewater discharge or changes in the groundwater level in the area of the port. Remedial measures to reduce water pollution in the port will mainly consist of ensuring that discharges remain as low as possible or of

permitting the discharge of treated water only.

No adverse environmental impacts need be expected from the building materials that are normally used to construct port facilities (concrete, broken stone).

Steel sheet-piling on the other hand will suffer severe corrosion in hot regions when exposed to salt water and above all brackish water, and it should therefore only be considered for use if it can be protected with anti-corrosion media. The suitability of wood for use as a building material is only limited (its working life is questionable because of the rot that occurs in parts exposed to water and air alternately). Although they are greatly valued as a building material because of their strength and long life, tropical hardwoods should not be used.

2.3 Port operation

In what follows, port operation will be understood to mean not just the classic activity performed at a port (the handling of goods) but all the operating activities which take place on land and water in the services, commercial and transport sectors on the basis of the port's existing infrastructure (including its industries).

2.3.1 Shore-side port operation

The possible environmental impacts from the shore-side workings of the port, and the hazards they create, will be mainly determined by the nature of the goods and materials being handled. The method of handling will also be important.

The environmental impacts that are possible, classified by type of goods as given below

- **bulk liquid materials,**
- **bulk solid materials,**
- **general cargo,**
- **containers,**

are as follows:

(a) Where oil, liquid chemicals or other liquid materials are being handled, it is possible that lake water and groundwater may be polluted; fires and explosions may occur, resulting in smoke, fumes and gases being generated; oil, petroleum derivatives, liquid chemicals or other liquid materials may accidentally leak or be discharged; petroleum derivatives such as petrol, diesel fuel and kerosene may unintentionally be mixed, e.g. by misconnection of hoses or use of the wrong pipelines or in the course of pigging (cleaning of the interior of a pipe with a "pig"), thus raising the flash point; people may smoke or cook in the immediate vicinity of tank farms or discharge terminals or on

tankers without appreciating what they are doing; tanks may be drained on the vessel (i.e. on the water) or on land, thus allowing dangerous gases to develop.

If steps are to be taken to prevent environmental damage in connection with bulk liquid materials, it will therefore be necessary to provide not only an adequate infrastructure in the loading, unloading and tank farm areas but also and above all an efficient corporate scheme of organisation in which duties and responsibilities are clearly defined. It must also be ensured that the personnel working in these areas are thoroughly trained (see in this connection the MARPOL Convention).

On the equipment side, the following safety precautions and items of equipment will be needed:

- **skimming equipment (oil booms and skimmers)**
- **oil-binding substances (for small amounts only)**
- **supplies of sand**
- **fire-fighting systems with hydrants**
- **sprinkler systems**
- **foam-generating systems**
- **an emergency power supply**
- **individual pumps for supplying water**

- impounding walls on the tank farm
- safety intervals between tanks and between tanks and other installations.

Where a project includes the commissioning of oil terminals, tank farms or refineries, for the planning to be environment-orientated it will need to make provision for training and instruction programmes for the personnel employed which will ensure that they are trained in good time.

(b) Where bulk solid materials such as grain, livestock feed, ore, coal and industrial salts are being handled, the environmental impacts that may arise are ones such as pollution of groundwater and lake water and considerable dust and noise pollution. Also, systems for feeding bulk materials are an unavoidable intrusion into the natural landscape because of their size and are a dust-explosion and fire hazard.

Provided that there is an adequate building infrastructure, then here too there will be a need for the personnel to be organised and trained by the company. It will also be necessary for use to be made of only the allocated storage areas properly sealed off to protect the groundwater, and for regular maintenance and repair work to be carried out (such as keeping the inlets to the drainage system for rainwater clear in the storage areas). Normally, there is no way of stopping dust and noise except by fitting up covers, dust removal systems and dust-laying sprinkler systems or by building sheds. Loading

and interface points should be enclosed wherever possible, and materials that generate dust should not be allowed to travel in free fall. Depending on its composition and fineness, dust may create chemical, biological, mechanical and electrical/electrostatic problems.

(c) Where general cargo and containers are being handled, the large items of equipment required (e.g. container gantries that may be up to 70 m in height with the jib nearer the water raised) are a major intrusion into the landscape.

The items of equipment in question work fast and to high standards of accuracy, and the only conceivable alternatives are using ship's gear or mobile shore equipment (straddle carriers, large fork-lifts). These however entail a major sacrifice of speed and safety.

To avoid the need for frequent movements while in transit, containers are stacked, generally no more than three high, by special items of horizontal and vertical handling equipment. This means a high land uptake.

Depending on the type of horizontal and vertical handling equipment used and its manoeuvrability, extra space may be needed for manoeuvring, and the equipment in question will also produce noise and exhaust emissions. Further uptake of land will be

caused by the need for entry and exit areas and areas for connecting traffic. Such areas of land are generally sealed and they will therefore require an efficient drainage system with dedicated water treatment facilities.

Even the handling of conventional general cargo is undergoing a process of mechanisation, and this process is producing environmental impacts on the people working in ports. Traditional jobs are being destroyed in many cases. An adjustment process to adapt to these changes can only be brought about by means of social planning and re-education, backed by training/retraining which should be catered for back at the planning stage.

Mechanised cargo handling also means a great deal of nuisance from exhaust emissions and noise, except where electrically driven equipment is used. Low-noise, emission-controlled equipment should be used.

Containers and unitised and conventional general cargoes may also include consignments of dangerous solid or liquid materials (chemicals, etc.) that may cause environmental damage if the receptacles containing them are incorrectly handled/damaged.

The risk that exists in this case must be kept to a minimum by giving the personnel

concerned thorough training and by providing proper safety equipment and taking the appropriate safety precautions.

(d) If not correctly handled or stored (it may be easily damaged with some types of packing; requisite protection from the weather may not be provided in store), conventional general cargo may, depending on its nature, produce direct or indirect consequential impacts. Cargo that has been damaged or wrongly stored is usually of no value to the consignee and will therefore have to be disposed of. The risk of incorrect disposal can only be avoided if the personnel are adequately trained and if an appropriate disposal infrastructure exists.

(e) The environmental impacts generated by trade and industry in the port area, and the associated environmental protection measures, will depend on the nature of the goods and raw materials that are being processing or refined. Details of these impacts and measures can be found in the appropriate environmental briefs.

2.3.2 Water-side port operation

The characteristic features of this aspect of the business of a port are inland navigation activities and the related operations such as

- ensuring ease of inland navigation (meaning in particular maintaining depths of water and hence performing maintenance dredging);
- supply to and disposal from vessels;
- vessel-to-vessel transshipments.

These activities, which are necessary for carrying on the water-side operations of the port, often have to be undertaken from vessels or floating equipment, and this being the case there will be adverse environmental impacts on the water and in the aftermath on the flora and fauna and groundwater, especially at the time of:

- berthing and casting-off manoeuvres (risk of damage to the vessels and leaks)
- refuelling
- discharge and loading and also lightening
- disposal (of wastewater and refuse)
- cleaning of tanks/holds
- repair work.

These environmental impacts can only be stopped by giving training to the persons working in the above areas and supplying them with the appropriate equipment in the form of tugs, supply vessels, lighters, pumps, oil booms, etc. The principal initiators of

such efforts should be the port authorities or the port operators, as the case may be.

Another focus for adverse environmental impacts will be maintenance dredging operations carried out in the port and its approaches. The dumping of dredged material almost always constitutes interference with nature and the landscape, particularly when the dredged material in question is contaminated due to environmental pollution in the port (discharges). Because of the risk to the flora and fauna and to the groundwater, such material should be pumped out not in tributaries of the river but on dumps suitably sealed off from the groundwater (spoil areas) situated as far away as possible from residential settlements. Any later effects which may be caused by such areas must be considered in good time and minimised by recultivation measures. The same is true of disposal by the port operator of wastewater and refuse arising in the port.

The hazards to the environment mentioned can only be prevented if the masters of vessels and the persons operating equipment act responsibly and if shipping traffic is monitored (threat of statutory penalties). Damage and its possible consequence of large-scale harm to the environment can be avoided on inland waterways and the approaches to inland ports if a system for directing shipping is provided. This system should be as simple as possible and geared to local conditions.

3. Notes on the analysis and evaluation of environmental impacts

For risks to the environment to be estimated and evaluated in this sector, it is first of all necessary for there to be accurate planning documents detailing the nature and volumes of the goods to be handled and for reliable targets to be set for future development. This includes both investigating opportunities for the processing and onward movement of goods and a careful survey both of physical conditions on site (terrain, soil, climate, groundwater, existing infrastructure, etc.) and of social conditions.

It is suggested that provision be made for integrated institutional planning of construction and operation, and that international or comparable German standards be adopted for defining and sizing all facilities and operations in order to rule out the possibility of consequences deleterious to the environment resulting from incorrect sizing.

The requirements applicable to facilities are, amongst others:

- **international standards laid down by the MARPOL convention (Maritime Pollution Convention),**
- **strength, stability and durability criteria, such as those laid down in German**

DIN standards or recommendations of the German working committee on bank revetments *EAU*,
- disposal techniques (for wastewater and refuse) meeting international standards, plus comparable discharge levels for given types of wastewater,
- techniques for keeping the air clean, e.g. as laid down in the *TA-Luft* (Technical Instructions on Air Quality Control).

For the planning of the port, a detailed locational analysis will be needed. The most important parts of this analysis will be:

- measurement of current conditions and river engineering data or determination of hydraulic engineering conditions in existing or planned canal systems,
- physical and mathematical model tests to establish an optimum current regime and to prevent sedimentation,
- traffic analyses.

Particular attention should be paid to ensuring that standards are observed. For this purpose, port operating authority staff should be given appropriate specialised training and should be made aware, by means of suitable programmes, of the responsibility they have to preserve the environment. For this purpose it is crucially important for them to

be equipped with inspection and monitoring gear and with equipment for combatting actual threats.

4. Interaction with other sectors

Inland ports and their approaches normally constitute major changes to the existing natural and socio-economic and socio-cultural structure of a region. This wide impact is due to the goals implicit in the construction of an inland port, namely to promote the development of a region on a broad front. Consequently, the present sector may interact with virtually any other sector, as dictated by the areas of development that are being singled out for attention.

What is supremely important here is the planning phase, in which is it is vital that the wide range of possible impacts are recognised in good time. Hence there will be a need for regional planning, transport and traffic planning, water framework planning and overall energy planning.

5. Summary assessment of environmental relevance

Generally speaking, it will not be possible to avoid impacts on the environment. However, it is possible for projects to be planned and executed with a large measure of consideration for the environment if:

- the goals set for the project are clearly defined;
- the operating and structural requirements are formulated by an integrated process;
- the existing framework conditions in the immediate and larger areas covered by the plan are properly established by detailed investigations;
- all conceivable inter-relationships and conflicting uses are covered right from the outset;
- from the start, the approach adopted is to observe strict environmental standards while employing the simplest possible designs/techniques geared to local requirements;
- the facilities built are ones which, when completed, can operate in a largely environment-friendly way.

If, on completion, the operation referred to is to be carried on by the operators in an environment-friendly manner as far as is technically feasible, then the objects of the

planning process must also include:

- making full allowance at the outset for operating requirements;
- making provision for suitably comprehensive training to be given to the operators, the basis of this training being to instill an awareness of impacts on and damage to the environment.

The early involvement in the planning and decision-making processes of sections of the population likely to be affected, and particularly women, will enable their interests to be taken into account and will help to mitigate any environmental problems (conflicting land uses, environmental stress on residential areas by transport, etc.).

Only by ensuring an interplay of this kind between environment-orientated planning and execution of the project and environment-orientated operation of its results at a later date will it be possible for a lasting contribution to be made to improving economic conditions in the country concerned.

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Contents - Previous - Next

24. Shipping on inland waterways

Contents - Previous - Next

Contents

[6. References](#)

1. Scope

Shipping on inland waterways covers all commercial shipping, and the subject includes both the craft concerned (inland waterway vessels and ferries) and their activities on the relevant transport routes (inland waterway traffic).

The purpose of inland waterway shipping is to provide transport services with the appropriate types and sizes of vessels. Its efficiency depends on the craft, the manner in which they are used and, finally, on the infrastructure of the waterway or inland port.

Inland waterway vessels fall into various categories depending on the nature of the cargo and their technical design, namely:

- **towed trains (tugs and barges are now rare because of their lack of mobility),**
- **self-propelled motor vessels,**
- **pushing units made up of a push boat and a number of lighters (including**

those with mothership lighter systems such as "Seabee" and "Lash").

In the case of ferries, which usually carry a combination of goods, vehicles and passengers, different systems are used depending on the task in hand:

- pure river or canal ferries intended only for making crossings as self-propelled motor ferries, and cable- or chain-guided pontoon ferries driven by the current or by towing cables, and
- larger ferries for longer-distance river or lake transport.

2. Environmental impacts and protective measures

Inland waterway vessels are basically on a par with ocean-going vessels in terms of possible environmental impact, yet they are not subject to any international standards. It is true that treaties relating to inland waterway shipping and bilateral agreements exist in parts of Europe, but safety, and thus also the likelihood of environmental impact, is to a very large extent governed by national regulations. The only internationally applicable regulations are the more or less voluntarily observed classification regulations of the classification societies and regulations for individual

waterways, such as the regulation for the transport of dangerous substances on the Rhine (ADNR).

Therefore any analysis of individual technical installations and protective measures should be made on the basis of the appropriate technical standards, taking account of the particular circumstances of the country concerned (such as the characteristics of the route, the absence of repair facilities, no assistance in case of emergencies, no protection for local residents etc.).

2.1 Overview

Environmental impacts occur individually or in combination as a result of:

- **the characteristics of the vessels used (ships or ferries, age of vessel, condition of vessel, technical standard, safety standard, suitability for particular types of transport etc.);**
- **the management of the ship-owning and ship-operating companies, including the crew's qualifications, repair and maintenance activities and**
- **the nature, volume, handling and environmental danger of the transported goods, taken in conjunction with the ease of navigability of the waterway (be it river, canal or lake), the weather conditions, the capacity and usage of the**

waterway and the water's self-cleaning capability.

Provided the infrastructural measures such as inland channels, dredging, inland ports etc. are planned and implemented with due consideration for the environment (see environmental brief Inland Ports), the environmental impact of shipping on inland waterways is very largely attributable to human action in the operation of the vessel in conjunction with the standard of the vessel itself.

Besides ensuring that the means of transport (ships) and any necessary special facilities satisfy the appropriate technical standards, the aim should be to alert the men and women involved in shipping operations to the environmental impact of shipping by providing suitable training, and to take steps to prevent or minimise such impact.

2.2 Technical design of inland waterway vessels and ferries

Before a vessel or ferry is used at all for operations on inland waterways, construction and safety regulations relating to the navigation area and type of cargo must be adhered to.

These are mainly in the form of environmental protection measures on the vessel itself in the area of marine and mechanical engineering, aimed at preventing negative impact

on the environment through later operation of the vessel, based on:

- **conditions in the intended navigation area (wind, waves, currents, consistency of water depth, conditions on the bed, traffic volumes, proximity of land etc.),**
- **the goods/raw materials to be transported, their quantities and the risk they pose to the environment,**
- **and questions regarding the required or desired speed of the vessel and voyage durations.**

Besides general safety and rescue precautions for passengers and crew (lifeboats, life rafts, floats etc., which are beyond the scope of this brief), the following cargo-related precautions should also be taken:

a) in the transport of petroleum derivates, such as petrol, diesel oil or kerosene, which pose a serious environmental hazard in terms of water and soil contamination and also carry risks of explosion and fire during transport and transfer and the risk of leakage and escape of large volumes of these substances; this can have serious effects on drinking water and groundwater, and thus on health, the ecosystem, fisheries and irrigation. Measures which help to avoid this are:

- flame-proof design of propulsion plant and electrical system;

- twin-screw propulsion by means of two separate engines (on both self-propelled vessels and push boats) and other manoeuvring aids (such as lateral thrust systems);

- tank venting systems to avoid the risk of gas formation in empty tanks;

- devices for earthing the pumping system to avoid the risk of electrostatic charging;

- separate pipelines for petrol and kerosene;

- fire protection and sprinkler systems for extinguishing or cooling the tanks, including active and back-up pumps;

- the provision and adequate dimensioning of slop-tanks for collecting tank cleaning residues, which must be disposed of in the inland harbours;

- the use of double-hulled tanker vessels where applicable;

- the introduction of effective tank-stripping systems, with the possibility of attaining 100 % cargo discharge.

b) in the transport of mass goods such as ore, coal or salts, which pose risks of water and air contamination and the destruction of ecosystems if the vessel should run aground or suffer damage:

- coverable loading hatches to provide a tight seal;

- double hulls in the area of the holds.

c) in the ferry transport of personnel, motor vehicles and goods, where the potential risks are to human safety and water purity:

- adequate rescue facilities;
- entrances, exits and gangways guiding the flow of people separately from the flow of vehicles, separate passenger decks;
- specially designated areas for vehicles and goods;
- fire protection equipment;
- sanitation installations including water and sewage tanks and disposal facilities in inland harbours.

All vessels must have an adequate water supply as an inherent design feature, irrespective of the goods being transported; the same applies to the navigational equipment, which must be appropriate to the navigation area (radio, echo sounding, radar etc.), to guard against accidents.

With regard to refuse and sewage, there should be sufficiently large collection containers or tanks and/or clarification equipment to meet the anticipated demand. Corresponding disposal facilities must be installed or guaranteed on land.

In the case of smaller river or canal ferries, close attention must be paid to manoeuvrability with a view to avoiding accidents, so that movable propeller propulsion systems are preferable to conventional fixed-screw propulsion systems.

When equipping vessels with loading gear or ferries with movable landing ramps for embarkation and disembarkation, the simplest possible designs should be used. Cable winches run off the on-board power supply or operated manually are preferable to hydraulic mechanisms, because of their reduced risk of breakdown, minimal maintenance requirement, and simpler repair; moreover, with hydraulic equipment there is the risk of hydraulic oil leakage, leading to water and soil contamination.

Ensuring that vessels and ferries are safely equipped and providing better training for crews in the interests of the environment often leads to higher costs, but in the medium term these measures will pay for themselves through the reduction in errors etc.

2.3 Operation

Inland waterway traffic involves all the different kinds of environmental impact liable to occur in the navigation of inland waterways (canals, navigable rivers, lakes), such as those to which:

- **the water conditions and weather;**
- **the ship or ferry herself including her cargo and**
- **other waterway users (vessels)**

give rise, and activities associated with this waterbound form of transport, including measures to guarantee the safety and ease of navigation (waterway maintenance, pilotage, navigational aids etc.).

Assuming the shipping operations are planned and implemented according to the state of the art and in a manner appropriate to the prevailing general conditions, the environmental impact of inland waterway traffic will largely be due to the vessels themselves, including the way they are operated and loaded:

a) Particularly in the case of older inland waterway vessel designs, poorly maintained vessels or careless disposal of waste, there is a risk to water quality, with repercussions on the flora, fauna, drinking water and groundwater, and therefore on the health of the population and agricultural irrigation as a result of e.g.:

- **oil leaking into the cooling water circuit or emerging through the stern tube,**
- **oil-contaminated bilgewater, hold-cleaning and tank-cleaning residues (slop) and spillages upon refuelling or lubricating oil changes and**

- sewage and refuse being discharged or thrown overboard instead of being disposed of properly in an inland harbour.

b) In the transportation of petroleum derivates (petrol, diesel oil, kerosene), there is a the risk of fire and explosion where the general safety rules are not adhered to, where these materials are improperly handled on the inland waterway vessel and where, in addition,

- general cargo is also allowed to be carried on these special vessels (or in pusher trains);
- the crew, unaware of the risks involved (particularly when navigating with empty tanks or partly gas-filled tanks) create naked flames (e.g. by smoking), and
- passengers are carried on deck above the tanks and are accustomed to prepare food in situ over open fires (particularly common in Africa).

c) During ferry operations (passengers, vehicles, goods) on inland waterways in developing countries, there is always a risk of vessels being overloaded or unevenly loaded and thus destabilised, so that under adverse conditions (visibility, bad weather, shallow waters) serious accidents may occur in which the vessel may even sink.

In addition, there is a risk of accident to vessels on inland waterways as a result of:

- **inadequate precautions to guarantee the water depth (e.g. inadequate maintenance dredging),**
- **lacking or inadequate lighting of vessels, particularly in places where there is a rapid transition from twilight to darkness,**
- **lacking or non-functional navigational aids such as buoys, guiding beacons, shallows markers etc.,**
- **lack of waterway traffic control,**
- **bad weather and visibility conditions.**

There is a particular risk of accident from ferries regularly crossing the main direction of shipping on the canal or river; because the same, usually short routes are always travelled, there is a strong tendency to become careless.

On lakes, and particularly artificial lakes, submerged trees which have not been broken up may be a danger to shipping.

Accidents are frequently caused by another problem on inland waterways: Wrecks of sunken ships, which are obvious obstacles to shipping in or close to the shipping channel, and which often cannot be seen at high water, are not removed. This also has

environmental effects on water quality, because rapid corrosion of the wreck at high temperatures, above and below water, may release considerable quantities of heavy metals.

If shipping traffic is dense and fast-moving, erosion and pooling may be caused by the primary and secondary waves from the swell created by the vessel, particularly on unprotected natural banks, leading to damage and eventually the dislodging of the bank and its vegetation (trees, bushes).

Environmental protection measures to guard against the environmental impacts of inland waterway traffic include, in particular:

- **the provision of reliable, safe and properly equipped vessels;**
- **comprehensive training and instruction of crews;**
- **the necessary hydraulic construction measures;**
- **the necessary staff training and strengthening of the supervisory body;**
- **the creation of a technical and administrative infrastructure (waste disposal and its supervision, technical and personnel monitoring and inspection etc.);**
- **the use of environment-friendly detergent for cleaning machinery and mechanical systems.**

To achieve the above, it is essential to create an organisation (waterways authority) which is responsible for administration, maintenance, shipping operations and monitoring of environmental hazards, and which is adequately equipped and sufficiently powerful and motivated to deal with these tasks in a responsible manner, thereby enabling the successful prevention of environmental damage in the inland waterway shipping sector.

This organisation must be in a position:

- **to identify and analyse environmental impacts,**
- **to evaluate these with a view to their avoidance,**
- **to provide suitable monitoring and supervision, and**
- **to implement the appropriate administrative measures in an effective manner (requirements and prohibitions, fines, prosecutions, organisation of disposal facilities etc.).**

The imposition of the desired standards will be based not least on a body of legal standards. In this regard it will be necessary to maintain suitable disposal facilities in inland harbours for the disposal of sewage, refuse, slop etc.

The river police may be able to carry out the necessary administrative supervision and

inspections.

3. Notes on the analysis and evaluation of environmental impacts

The environmental impacts resulting from the design and build quality of vessels and ferries can be analyzed and evaluated on the basis of the standards to be adhered to.

These construction and safety standards are based on the provisions and guidelines of the various international classification societies for construction of new vessels, as well as on the further rules to be respected by the shipyard under national standards (such as DIN in the case of Germany). These societies include, to name but a few, Lloyd's Register (UK), American Bureau (USA), De Norske Veritas (Norway), Bureau Veritas (France) and Germanischer Lloyd [GL] (Germany). GL regularly carries out inspections (surveys) not only when putting vessels into service but also at a later stage if required or in order to issue a classification (e.g. general inspections are carried out approximately every 5 years under GL rules for inland waterway vessels).

4. Interaction with other sectors

The environmental brief Shipping on Inland Waterways is closely linked to the environmental brief Inland Ports; indeed it more or less constitutes the latter's "operational section". Each sector is of economic benefit to the other, so that conflicts are ruled out (except in the case of obvious misplanning).

Because rivers and canals are used by inland waterway vessels and craft which serve the seaports by delivering cargo or providing onward transportation on inland waterways, this brief also interacts with (i.e. supplements and intersects):

- **Ports and Harbours, Port Construction and Operations,**
- **River and Canal Engineering**

and in a broader sense, with Large-scale Hydraulic Engineering and Erosion Control.

With regard to the disposal procedures for vessels and ferries on inland waterways, there are links with Wastewater Disposal, Solid Waste Disposal and Disposal of Hazardous Waste. Measures in these sectors also help the environmentally acceptable operation of inland waterway shipping.

Conflicts of use may occur if the river or canal water is not only a transport medium for inland shipping but is also used for water supply by direct extraction and/or bank filtration, and if contamination by inland waterway traffic cannot be ruled out (due to leakage, accident etc.); in this case, the sectors affected are:

- Urban and Rural Water Supply.

Ferry traffic, as a sector which primarily serves for the transportation of personnel and vehicles, is also linked in a wider sense with the environmental briefs

- Spatial and Regional Planning and Transport and Traffic Planning,

as regards the selection of routes and destinations and also cross-traffic.

5. Summary assessment of environmental relevance

Provided the standards of the classification societies performing international inspection and monitoring activities are taken as the basis for the construction and safety regulations applicable to inland waterway vessels and ferries, and assuming a properly planned and implemented waterway infrastructure, the vessels used for inland

shipping will provide a safe and environmentally acceptable means of transport. In certain cases, however, it may be necessary to apply construction measures which depart from or go beyond these rules in order to take account of particular local needs, in which case the most environmentally acceptable rules must be tested and selected.

A further condition is that the operators of inland waterway vessels and the authorities or supervisory bodies which control and monitor inland waterway traffic must be instructed and trained in the avoidance of risks and the measures to be taken in respect of the potential environmental impact of shipping (particularly the impairment of water quality), and are developed into strong institutions to enable them to perform their tasks.

To achieve this, the training courses, the physical resources needed to perform the supervision and monitoring tasks and the requisite financial resources must be available in good time.

An inland waterway traffic system that is environmentally sound can only be achieved through a combination of:

- **safe, state-of-the-art vessels (ships and ferries),**
- **safe operation by trained personnel,**

- institutionally strong supervisory bodies to maintain the waterways, control the traffic and carry out environmental monitoring and inspection.

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Contents - Previous - Next