C1 Scoping the environmental impacts of barrages

Explanatory note

For projects which require Environmental Impact Assessment (EIA), a scoping exercise should be undertaken early in the planning stages of the project. This enables the project to be designed to avoid or minimise negative environmental impacts and provides an opportunity to incorporate positive environmental enhancements into the project. Early consultation with all interested parties, including the Environment Agency, is an essential part of scoping. Even if a project does not require EIA under EIA legislation, it may be advisable (and in some cases necessary) to undertake a scoping exercise in any case (e.g. to support applications for other relevant consents and authorisations needed to carry out the project).

This guidance note aims to promote a good practice approach to scoping as part of the EIA process which in some respects goes beyond the statutory EIA requirements. When scoping a project, developers, or their consultants, should satisfy themselves that they have addressed all the potential impacts and the concerns of all organisations and individuals with an interest in the project.

This guidance note provides information on the most likely potential environmental impacts of barrages. However, each project must be considered on a case-by-case basis as the detailed characteristics of the proposal and the site will determine the potential impacts.

This guidance is based on the main legal requirements on EIA stemming from the EC Directive and the UK Regulations. However, developers should seek independent legal advice to ensure that the proposed development is carried out in compliance with the requirements of this and any other relevant legislation relating to planning as well as to pollution control.

This guidance note must be read in conjunction with the *Scoping Handbook*, which provides general guidance on the EIA process and the scoping of projects.

ENVIRONMENT AGENCY

This guidance note must be read in conjunction with the *Scoping Handbook,* which provides general guidance on the EIA process and the scoping of projects.

In addition, the following scoping guidance notes are relevant to *all* barrage projects:

- **A1** Construction work
- **A4** Vegetation management and conservation enhancements
- **I6** Tidal power developments

The following scoping guidance notes *may* be relevant in certain circumstances:

- **A3** Redevelopment and clean-up of contaminated land
- **B3** Control of pest species, including disease vectors
- **B4** Deliberate introduction of non-native and genetically modified species
- **C3** Ports, harbours, piers and jetty developments (including navigation works)
- **D1** Dredging of riverine and estuarine sediments
- **F6** Water-based recreation
- **F7** Angling and sport fishing, including fish stocking
- **K4** New roads, road widening and other road improvement schemes
- **J1** River channel works and bank protection
- **J4** Flood storage areas and flood embankments
- **J8** Restoration and enhancement of river channels

Contents

1 Introduction

1.1 This guidance note, in conjunction with the *Scoping Handbook* and the notes listed on the previous page, seeks to help developers and other interested parties identify the potential impacts of barrages on the environment as a whole. It should be emphasised that the list of impacts is by no means exhaustive and that a full investigation into positive and negative impacts should be undertaken. Early consultation with the Environment Agency and other relevant organisations will enable the identification of environmental issues and constraints and the avoidance of sensitive areas, thus reducing the need for redesigning and mitigating avoidable impacts at a later stage.

1.2 Following this brief introduction, an overview of the legal requirements for EIA in relation to barrages is provided. The potential environmental impacts of such projects are identified in Section 3. The text and summary table in this section will enable the reader to begin to identify the likely impacts arising from the particular proposal under consideration. The subsequent sections present the mitigation measures that may be relevant to barrages, followed by key references and further reading.

Background to development type

1.3 Barrages are generally constructed across estuaries. This is likely to involve water impoundment and significant alterations in flow regimes. Such projects can be used to generate power, improve transport access, provide flood protection and improve the appearance of areas. However, as mentioned, they invariably change the flow regimes of rivers and can change tidal ranges, destroy habitats (commonly those of wading birds), affect groundwater resources and have a detrimental effect on the migration and distribution of fish. Fish that must migrate to and from rivers are most vulnerable, as are marine fish using estuaries as nursery areas. A thorough scoping exercise and careful consideration of alternatives are, therefore, of prime importance.

2 Development control and EIA

Development control

2.1 Barrages are likely to require planning permission under the town and country planning regime. Developers should contact their local planning authority to confirm whether or not their proposals require planning permission (or are subject to any other form of development control). They should also seek advice on the impact on their proposals of other planning-related legislation (for example the Conservation (Natural Habitats & c.) Regulations 1994 (as amended), SI No. 94/2716.

Environmental Impact Assessment

2.2 Barrages designed to hold back more than 10 million cubic metres of water are included in Schedule 1 of the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 (SI 1999 No. 293) and EIA is therefore mandatory. Barrages smaller than this, but designed to generate electricity, fall under Schedule 2 of these regulations. The regulations list applicable thresholds and criteria which apply to Schedule 1 and Schedule 2 developments. If the thresholds are not exceeded, then EIA is not required and so these thresholds and criteria are termed "exclusive criteria". In cases where the thresholds are exceeded, Schedule 1 developments require an EIA (mandatory) but Schedule 2 developments only require an EIA if the development is likely to have significant effects on the environment by virtue of factors such as its nature, size or location. The exclusive criteria for Schedule 1 developments are taken from the EIA Directive, but those for Schedule 2 developments have been laid down in the UK Regulations, as provided for by the Directive. In addition to the specific criteria and thresholds set out in Schedule 2, all developments listed in Schedule 2 may require an EIA if any part of the development is to be carried out in a sensitive area.

2.3 The former DETR published guidance (referred to in the *Scoping Handbook*) which helps in the decision on whether, in respect of Schedule 2 projects, impacts are significant and whether EIA should be required. The guidance thus contains "indicative criteria", although area sensitivity and project-specific issues must be taken into account and the decision is still discretionary. The following criteria apply:

- Exclusive criteria

  Under Schedule 2, paragraph 3(h), EIA may be required for installations designed to produce more than 0.5 megawatts of electricity. Under Schedule 2, paragraph 10(h), EIA may be required for inland-waterway construction not included in Schedule 1, canalisation and flood relief works where the area of the works exceeds 1 hectare. In addition, under Schedule 2, paragraph 10(i), EIA may be required for dams and other installations designed to hold water or store it on a long-term basis (unless included in Schedule 1) where the area of the works exceeds 1 hectare.

- Indicative criteria

  Annex A of the Department of the Environment, Transport and the Regions Circular 02/99, *Environmental Impact Assessment*, states that for projects falling under Schedule 2, paragraph 3(h) "in addition to the physical scale of the development, particular regard should be had to the potential wider impacts on hydrology and ecology. EIA is more

likely to be required for new hydroelectric developments which have more than 5 MW of generating capacity". For projects falling under Schedule 2, paragraph 10(h), Annex A states "the impact of flood relief works is especially dependent on the nature of the location and the potential effects on the surrounding ecology and hydrology. Schemes for which the area of the works would exceed five hectares or which are more than 2 km in length would normally require EIA". For projects falling under Schedule 2, paragraph 10(i), Annex A states "particular regard should be had to the potential wider impacts to the hydrology and ecology, as well as to the physical scale of the development. EIA is likely to be required for any major new dam (e.g. where the construction site exceeds 20 hectares)".

Furthermore, EIA may be required for any change to a barrage and may fall under the definition of "land drainage improvement" for which the relevant legislation is the Environmental Impact Assessment (Land Drainage Improvement Works) Regulations 1999 (SI 1999 No 1783). In addition, a change or extension to a barrage may require EIA under the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 (SI 1999 No. 293) if it might have significant adverse effects on the environment. Responsibility for determining whether an EIA is required in this case lies with the local planning authority. Where a barrage constitutes part of the structure of a harbour, then the Harbour Works (Environmental Impact Assessment) Regulations 1999 (SI 1999 No. 3445) need to be consulted.

2.4 Whether or not a formal EIA of proposed barrages is required, the Environment Agency and other statutory consultees and regulators may request environmental information concerning the proposal. An EIA may provide the most appropriate method for a developer to collate the necessary information.

2.5 The Food and Environmental protection Act 1985 Part II (FEPA) requires that a licence be obtained from DEFRA (the licensing authority) to deposit any article or substances in the sea or under the seabed. FEPA licence applications require external consultation which can be implemented through the EIA process.

Other licences, consents and authorisations

2.6 It is recommended that the developer liaise with the Environment Agency during project design and subsequent stages to identify and confirm the consents, licences and authorisations that will be required. Certain prior permissions from the Environment Agency may be required in relation to a barrage project. These may include, for example, impoundment licences, land drainage consents, abstraction licences, and authorisations for borehole drilling, fish stocking, weed cutting, etc. It is recommended that the developer seek independent legal advice and liaise with the Environment Agency during project design and subsequent stages to identify the consents, licences and authorisations that will be required.

3 Potentially significant environmental effects

3.1 The EIA Directive requires the EIA to "identify, describe and assess the direct and indirect effects of a project on the following factors: human beings, fauna and flora; soil, water, air, climate and the landscape; material assets and the cultural heritage; [and] the interaction between the factors." Socio-economic issues, health and safety in the workplace, material assets and cultural heritage are all considered in EU *Guidance on Scoping* (ERM, 2001a) but are not impact categories for which the Environment Agency is the principal competent authority. Advice on these issues is presented in this guidance note without prejudice to the advice of the relevant competent authority, but the relevant competent authority should be consulted for each of these categories in all cases (further advice on the appropriate competent authority to contact is given in the *Scoping Handbook*).

3.2 An EIA of any proposed barrage should determine the potential impacts on the environment of each aspect of the project, including location and management. Careful scoping facilitates this process. This section provides a non-exhaustive description of the environmental issues that might arise during the scoping of such a project. The *Scoping Handbook* provides guidance on how to conduct a scoping exercise.

3.3 Barrages have the potential to affect the environment in many ways. They can differ widely in terms of their mode of operation and location, and key issues are likely to vary from site to site. Therefore, it is recommended that expert advice on detailed technical issues be obtained. The issues arising for all environmental receptors will change over time as the construction proceeds and any impoundment begins or tidal regimes change. Developers and site operators should therefore consider the impacts arising from construction activities and from changes to ecosystems and hydrological processes which occur afterwards.

3.4 Potential impacts are discussed here in broad terms only as their nature and intensity will depend on the physical characteristics of the project and the existing environment to be affected by impoundment or changes in hydrology. An EIA of proposed barrages should take these factors into account in assessing potential impacts on the environment.

3.5 The following paragraphs should be read in conjunction with Table C1. This details the activities involved in the construction and operational phases of barrages and the impacts arising from them.

Water environment

3.6 Surface water hydrology is likely to be affected during all phases of barrage construction and operation. The impounding of water will affect water quality both upstream and downstream of the barrage and can be adverse or beneficial. For estuarine barrages there could be reductions in saline intrusion (depending on the design of the barrage), leading to fundamental water quality and ecological changes. The flushing rate of water is likely to change in the river behind the barrage and downstream which would lead to changes in the levels of dissolved oxygen and suspended solids. Stratification within the impounded water may be expected due to salinity (and temperature) effects.

3.7 Short-term impacts on water quality due to construction activity are likely to be severe and risks of pollutants entering the water must be managed. In particular, suspended solid levels are likely to be very high.

3.8 The impoundment of water leads to the creation of a larger body of standing water that can interact with groundwater and can have major sedimentation impacts with knock-on effects on land drainage, navigation and water quality. Barrages can also lead to higher water tables round the impounded water (with lower saline content) but lower levels elsewhere than were previously the norm. In some cases, potentially polluted groundwater can be flushed, drained or pumped into the impounded water. In order to protect vulnerable groundwater resources it is Environment Agency policy to encourage new developments to locate in areas of low vulnerability to groundwater pollution. However, this policy does not imply an automatic prohibition on barrages within source protection zones.

3.9 Agricultural practices, sewer and industrial discharges upstream of any impoundment could lead to eutrophication of impounded waters with consequent effects on fauna and flora. Designation of the impounded water as a sensitive water under the EC Urban Waste Water Treatment Directive 91/27-1/EEC may have implications on upstream sewage treatment works such as requirements for nutrient stripping. The quality of waters flowing towards the planned barrage need to be examined in order to determine the likely effects that will result. Oxygen demand derived from discharges, from the respiration or decay of algal blooms and from the sediment itself may all be factors affecting oxygen levels within the impoundment. Stratification may be a further important factor determining dissolved oxygen levels. Sewer discharges may affect the bacteriological (and viral) quality of the water body and thereby restrict recreational activity.

Land

3.10 Barrages will have implications for the physical characteristics of the site and are generally perceived to improve the aesthetics of a locality, water bodies being considered to be more attractive than areas of mud. By their nature, such projects have the potential to change the site significantly. Issues to consider include the effect on landscape character of the estuary and, most importantly, the potential for loss of important mudflat and/or gravel habitats. Barrages will almost certainly lead to a reduction in numbers of some species (of both fauna and flora) along with corresponding increases in the numbers of others. Barrages can also have a significant effect on the drainage of adjacent land.

Air and climatic factors

3.11 It is possible that local climate effects will result associated with the change in the hydrology of the area (particularly the appearance of a larger surface area of water). Changes in tidal regimes which can include reduced intrusion of saline water upstream can have localised effects on salt aerosols.

Ecology

3.12 Ecological impacts can be severe and need careful attention. Barrages present a physical obstruction to fish and will cause impacts. Loss of marine fish species is likely, as is loss of fish spawning sites and nurseries. Migratory fish (e.g. salmonids, eels and shad) are likely to be affected by the barrage and considerable attention will need to be paid to the design of appropriate fish pass(es) to accommodate a range of species, some of which are not known to be able to traverse fish passes (e.g. marine fish). The impoundment itself may become colonised by a stable ecology, including (non-migratory) fish populations.

3.13 Mudflat habitats are likely to be lost along with associated changes in saline tolerant flora and fauna. Elsewhere, a change to freshwater conditions can lead to the proliferation of vegetation, which may require harvesting and lead to waste disposal issues. Algal growth may become a problem and may need collecting. Blooms of blue-green algae may necessitate restrictions to activity in and around the impoundment, and the disposal of collected material may also present waste disposal issues. An associated problem of the development of a large impounded water body can be a proliferation of insects (such as midges). Control of such pests can lead to other environmental impacts.

3.14 Changes to bird populations can be expected with decreases likely in wader and shorebird populations, but increases likely in duck and other waterfowl populations utilising the impoundment. Also, the downstream impacts of construction (including dredging) and operation may be significant on estuarine mudflats etc., potentially affecting birds and other wildlife (e.g. through changes to water flow, nutrient and sediment transport). The effects of sewage and other effluents on fauna and flora in an altered hydrological regime need to be considered.

Human environment

3.15 The potential impacts of a barrage on the human environment may take a variety of forms. Barrages can require many staff, and may bring in large numbers of visitors to an area with knock-on economic benefits. So there can be very real economic benefits, but good design is essential to ensure these benefits are positive and not negative. A barrage, for example, may have a detrimental effect on tourism to an area which can counterbalance to some effect the positive economic benefits of the development itself. Any economic benefits must be considered in the light of other effects on the human environment noted below. They are divided here into sections covering socio-economic and health issues; amenity, visual impact and nuisance issues; and culture, heritage and archaeology.

3.16 The potential for socio-economic and health impacts (real and perceived) arising from barrages is not insignificant. Barrages can affect fisheries and tourism and these effects need to be considered carefully. In some cases, there may be direct impacts on farmers and landowners through loss of their land. Navigation may also be affected, and the barrage may need to include locks to permit navigation. If charges for locking are proposed, there may be issues associated with the loss of previously free access rights. The impoundment itself may increase recreational opportunities, particularly those previously lost at lower water levels. Such social issues should be considered when scoping an EIA.

3.17 The identification of which of these issues are significant or are perceived to be significant is an important function of public involvement during the scoping exercise. Understanding likely public concerns is a key issue and reference to experiences from other barrage developments and any public representations to the local planning authority should be made.

3.18 Other issues that commonly need to be addressed are the visual impact of the barrage itself and of the changes to the surrounding environment that result from the barrage (such as impounded water). Amenity restrictions and aesthetic problems may arise from algal blooms, litter and other debris, midges and pests (e.g. rats). Noise and vibration nuisance from traffic during construction of the site (and operation where the barrage also provides for transport access) should also be reviewed; piling during construction may be a particularly noisy activity. The likely quality of any impounded water should be considered carefully as it may be unsuitable for immersion sports – thereby reducing potential amenity value. Any restrictions to access that may arise as a

result of the development should also be considered, as should the creation of nuisances such as noise associated with planned recreational activities and increased traffic flows.

3.19 Impacts on architectural and archaeological heritage can occur due to the direct impact of construction, or due to water impoundment or alterations in erosion regimes. These effects on such archaeological and historical features should be taken into account. The likelihood of there being any unrecorded sites and their potential for discovery or disturbance should also be examined.

Table C1

3.20 The impact identification table highlights:

- sources of impact (development activities);
- potential impacts;
- receptors for these impacts.

3.21 It is recommended that the table is annotated and used during consultations with other interested parties. Reference should also be made to the prompt lists detailing impacts and sources of impacts in the *Scoping Handbook*.

Table C1 Summary of key potential impacts of barrages

Potential receptors of impact		Activities and potential impacts		
		Construction phase	Operational phase	Decommissioning
WATER	Surface water hydrology and channel morphology	**Use of vehicles and machinery** • Increase in surface runoff from soil compaction **Works next to or in watercourses** • Change in flow velocities • Increased erosion and subsequent changes in bed and bank stability • Increased flood risk **Earthworks** • Increased sedimentation of watercourses **Dredging** • Increased flow rates and erosion	**Existence of barrage** • Changes to flushing rates • Changes to erosion patterns • Changes to flow rates • Changes to flow directions • Changes to sedimentation patterns	**Use of vehicles and machinery** • Increase in surface runoff from soil compaction **Works next to or in watercourses** • Change in flow velocities • Increased erosion and subsequent changes in bed and bank stability • Increased flood risk **Removal of barrage** • Changes to sedimentation patterns
	Surface water quality	**Earthworks** • Pollution from suspended material • Disturbance of contaminated soil and subsequent pollution of watercourses **Materials management** • Pollution from spills or leaks of fuel, oil and construction materials **Dredging** • Pollution from suspended material • Mobilisation of contaminants	**Impoundment of water** • Decrease or end of saline intrusion • Eutrophication of impounded water • Change in suspended solids content • Oxygen depletion in impoundment **Dredging** • Increase in suspended solids • Mobilisation of contaminants	**Removal of barrage** • Pollution from suspended material • Disturbance of contaminated soil and subsequent pollution of watercourses **Materials management** • Pollution from spills or leaks of fuel, oil and construction materials

Potential receptors of impact		Activities and potential impacts		
		Construction phase	Operational phase	Decommissioning
WATER *continued*	Groundwater hydrology	**Earthworks** • Change in water table • Changes to groundwater distribution and flow	**Impoundment of water** • Changes in water table • Changes to groundwater distribution flow	**Removal of barrage** • Change in water table • Changes to groundwater distribution and flow
	Groundwater quality	**Earthworks** • Disturbance of contaminated soil and subsequent groundwater pollution **Materials management** • Pollution from spills or leaks of fuel, oil and building materials	**Impoundment of surface water** • Changes in saline concentration of groundwater • Potential for contamination of groundwater, or of impounded water	**Removal of barrage** • Changes to groundwater quality can be expected
LAND	Landscape	**Barrage construction** • Creation of a new landform • Visual impact of construction works	**Physical presence of barrage** • Change in character of landscape • Changed aesthetic appearance	**Barrage removal** • Alteration of landform
	Soils	**Use of vehicles and machinery** • Compaction • Erosion **Earthworks** • Further erosion of exposed soil	**Change in river flow patterns** • Possible increase/decrease in bank erosion of soils • Changes to land drainage patterns for adjacent land • Flood protection can be enhanced	**Use of vehicles and machinery** • Compaction • Erosion **Removal of barrage** • Further erosion of exposed soil
	Geology	**Excavations** • Removal of rock by excavation works		

Potential receptors of impact		Activities and potential impacts		
		Construction phase	Operational phase	Decommissioning
AIR	Local air quality	**Use of vehicles and machinery** • Emissions from construction site traffic • Dust generation	**Increased transport** • Exhaust emissions **Existence of barrage** • Change in saline aerosol loading	**Use of vehicles and machinery** • Emissions from decommissioning site traffic • Dust generation
	Regional/ global air quality		• Electricity generation from barrage may lead to reduced CO_2 or other emissions from other sources	
FLORA AND FAUNA	Aquatic ecology	**Construction works and use of vehicles** • Negative impact on flora and fauna from increased sediment loading of streams • Harm to aquatic flora and fauna from oil, fuel, cement or other substances entering watercourses • Harm to flora and fauna from flow diversions/variations • Noise and disturbance of construction activities (e.g. piling and rock fill) • Restricted opportunity for fish migration in both directions • Changed hydrodynamics may adversely affect fish behaviour (e.g. they may not find their home rivers so easily)	**Water impoundment** • Change in salinity of water and associated loss of flora and fauna • Increase in midges & other insects relying on water bodies for breeding • Increase in algae • Increase in freshwater flora and fauna • Increase in freshwater habitat • Loss of marine flora and fauna **Creation of barrier** • Loss or reduction in numbers of migratory fish • Loss of fish nurseries • Change in invertebrate species • Partial or total loss of marine fish	**Removal of barrier** • Loss of opportunistic species moving in to area after construction • Possible restoration of habitats/species • Change in salinity of water leading to loss of freshwater species • Reduction in algae • Reduction in numbers of insects relying on water bodies for breeding **Decommissioning works and use of vehicles** • Negative impact on flora and fauna from increased sediment loading of streams • Harm to aquatic flora and fauna from oil, fuel, cement or other substances entering watercourses

Potential receptors of impact		Activities and potential impacts		
		Construction phase	**Operational phase**	**Decommissioning**
FLORA AND FAUNA *continued*	Terrestrial ecology	**Earthworks and construction activity** • Habitat removal, fragmentation or severance • Disturbance to, or loss of, species (including rare and sensitive species)	**Water impoundment** • Alteration or loss of wetland habitats and associated changes in bird populations (loss of wader species) • Loss of other terrestrial habitats • Loss of marginal halophillic flora, e.g. saltmarsh **Creation of barrier** • Creation of a barrier for terrestrial species mobility	**Earthworks and decommissioning activity** • Habitat removal, fragmentation or severance • Disturbance to, or loss of, species (including rare and sensitive species)
HUMAN ENVIRONMENT	Socio-economic[1]	**Earthworks and construction activities** • Disruption of services such as electricity, gas, water, or telecommunications due to the presence of underground cables and pipes • Construction-related employment	**Water impoundment** • Opportunities for water-based recreation jobs • Increased tourism possibilities • Energy generation income • Loss of land (e.g. for farming) **Barrage existence** • Possibility of improved transport access • Barrage maintenance jobs • Altered fishery	**Restoration design and after-use** • Public perception of the area may improve following sensitive restoration plans
	Health and safety[1]	**Earthworks and construction activities** • Risk of injury on construction site	**Water impoundment** • Risk of drowning • Risk of immersion in poor quality waters during recreational activities **Barrage existence** • Risk of barrage failure and flooding • Altered flood protection from tidal and fluvial flooding	**Barrage removal work** • Risk of injury on construction site • Risk of barrage failure and flooding

[1] The Agency considers that key impacts to be identified and assessed are likely to include the following, but further advice and guidance should be sought from the relevant competent authority, as indicated in the *Scoping Handbook*.

Potential receptors of impact		Activities and potential impacts		
		Construction phase	Operational phase	Decommissioning
HUMAN ENVIRONMENT *continued*	Amenity	**Earthworks and construction activities** • Reduced recreational activities	**Water impoundment** • Possible alteration of rights of way or reduction in access • Changed visual amenity • Increased recreation opportunities	**Restoration design** • Decrease in amenity/recreational uses
	Nuisance	**Use of vehicles and machinery** • Noise from construction traffic and operations • Mud on roads • Dust generation	**Water impoundment** • Odours from rotting vegetation (due to proliferation of algae/freshwater vegetation) • Increase in numbers of biting insects	**Use of vehicles and machinery** • Noise from construction traffic and operations • Mud on roads **Barrage removal** • Odours from exposed muds • Short-term increase in numbers of biting insects
	Architectural and archaeological heritage[1]	**Construction activities** • Damage to known or unknown features of archaeological or cultural importance	**Water impoundment** • Further damage to archaeological features resulting from expansion of the site and changes in water and ground levels	

[1] The Agency considers that key impacts to be identified and assessed are likely to include the following, but further advice and guidance should be sought from the relevant competent authority, as indicated in the *Scoping Handbook*.

Additional site-specific issues:

4 Mitigation measures

4.1 A monitoring programme should ideally precede any work, gathering data which can subsequently be used to implement mitigation measures (for example, stocking fish). Following the scoping exercise carried out as part of the EIA and the identification of potential environmental effects, mitigation measures should be proposed to avoid or reduce potential negative impacts to air, water, land, ecology and humans, or to introduce positive aspects to the development. For example, such measures could aim to improve flood protection. Guidance has been provided by the Environment Agency to assist developers on a range of relevant subjects in the form of Pollution Prevention Guidelines (see the *Scoping Handbook*). Other relevant publications such as Burt & Watts (1996) provide valuable background information (see Section 5).

4.2 A primary consideration in impact mitigation must be the siting of a barrage, both in strategic terms (whether it should be in the estuary or inland), and in terms of where on the river/estuary the barrage should be sited. Environmental impacts will vary according to both the line of the barrage and the type of barrage (e.g. tidal exclusion, hydropower generating, etc). The development should seek to limit damage to important ecological sites and high-quality landscapes, though it will clearly not be possible to avoid these impacts completely. Also, it is Environment Agency policy to seek the preferential location of developments in areas which are not vulnerable to groundwater pollution (Environment Agency, 1998). It is strongly recommended, therefore, that developers undertake an assessment of alternative sites.

Mitigating the impacts of construction activities

4.3 Construction activities have the potential to affect all environmental receptors. However, the following list summarises the mitigation measures most relevant to barrage developments:

- phasing of construction work (for example, piling) to minimise disturbance to wildlife at sensitive times of year, such as during the breeding season or when young are being raised;
- installation of double glazing in vulnerable properties;
- use of techniques to minimise compaction of soil, such as restricting access during wet conditions and using protective boarding and low ground pressure machinery. If necessary, soil should be carefully removed and stored for subsequent reinstatement;
- use of dust control strategies;
- storage of fuel, equipment and construction materials so as to minimise the risk of soil contamination or water pollution (see Environment Agency, 2000a);
- setting the route and timing of construction traffic so as to avoid residential areas or other sensitive human receptors (e.g. schools, hospitals, nursing homes);
- access roads should avoid riparian zones and should be built using appropriate construction materials.

Mitigating the impacts of the operational phase

4.4 Although sensitive siting and design of a barrage are the primary means for avoiding or reducing its environmental impacts, further measures can be introduced to minimise impacts occurring from the ongoing management of the site. An overall consideration for the proposed development is that its design and operation are in accordance with all other relevant legislation. Developers should seek independent legal advice to ensure that all legal requirements relating to the proposed development are identified and complied with.

4.5 The measures have been arranged according to their primary receptor; however, it should be noted that many of the following mitigation measures are interrelated. For example, speed limits on boats will not only protect the water environment, but will reduce nuisance impacts as well.

Protecting the water environment

4.6 In order to minimise potential impacts on the water environment in the design of barrages, it must be ensured that:

- retention times are kept low to keep suspended solids down, dissolved oxygen levels up, and prevent the build-up of pollution (not too low or small impoundment will result with loss of ecology);
- speed limits can be placed on boats in the vicinity of the barrage;
- sewer, industrial and agricultural discharges should be diverted to outside of barrage if possible or treatment processes should be upgraded (artificial aeration may be required);
- collection and disposal routes should be developed for algae, litter, debris and “nuisance” weeds;
- sustainable drainage systems (SuDS) should be used where appropriate to alleviate flooding, improve water quality and ensure recharge of groundwater base flows;
- potentially polluting activities could be banned, such as immersion sports;
- erosion control measures should be in place where bank or bed scour is likely;
- adequate groundwater investigations are carried out to determine potential for problems (groundwater can be pumped to prevent groundwater rise);
- an emergency plan is formulated and tested through exercises to ensure that procedures to deal with pollution incidents or spillages are in place and operate effectively (some developments may require such plans to be formulated and the Environment Agency should be consulted to identify where this is the case).

Protecting the land environment

4.7 Impacts on soils and landscape may be mitigated by the following:

- appropriate designs of barrage to keep erosion rates as low as possible;
- appropriate screening for visual impacts;
- flood protection may be enhanced by barrage design where, for example, the barrage acts as a barrier to tidal surges and sea level rise (coastal barrages must be able to store river water when in tide-locked situation);
- effective stabilisation of the banks of any impounded water body to keep bank erosion to a minimum.

Protecting the air environment

4.8 Developers should consider the aspects of the development that are likely to lead to emissions to air. Such aspects can include dust generated by vehicle movements during both construction and operational phases.

Protecting ecology

4.9 Measures designed to prevent or reduce impacts to water or land will also help prevent adverse impacts on ecology. The following list identifies further measures to reduce or avoid impacts to terrestrial and aquatic species and their habitats:

- construction of fish passes designed for the species of fish found in those particular waters;
- adequate monitoring should be carried out to gather data which can be used to design better mitigation measures;
- restriction of fishing to certain areas;
- fish restocking programmes may be required and may need monitoring;
- further habitats should be created to compensate for habitat losses and to improve the landscape and ecological potential for the site where possible;
- decommissioning plans should incorporate measures to restore the ecological status of the site.

Protecting the human environment

4.10 Some of the measures noted above can also reduce possible impacts on humans, notably the risk assessment and emergency planning measures. Further mitigation measures more specific to the human environment are listed below:

- adequate compensation payments for landowners losing land area;
- safety concerns should be addressed by such measures as the installation of adequate fencing and other site security to prevent trespass and vandalism;
- odour control strategies should take account of varying wind directions;
- sites of archaeological or cultural interest should be preserved in situ where possible. As relocation is rarely possible, thorough archaeological investigations should be carried out where damage is unavoidable.

5 References and further reading

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