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OVERVIEW REPORT

AN OVERVIEW OF DESIGN & MANAGEMENT APPROACHES TO REDUCING THE ENVIRONMENTAL FOOTPRINT OF THE SUPPLY CHAIN FOR LAND-WON AGGREGATES

Research funded through Defra's Aggregates Levy Sustainability Fund

GWP consultants | University of Leeds | miro Mineral Industry Research Organisation | defra Department for Environment Food and Rural Affairs | English Heritage

Sustainable Aggregates An overview of design and management approaches to reducing the environmental footprint of the supply chain for land-won aggregates

SUSTAINABLE AGGREGATES

Sustainable Aggregates:
Aggregate resources produced from sand and gravel deposits, crushed rock or dredged from the sea contribute to the economic and social well being of the UK. Their production and supply has environmental effects.

The Aggregate Levy Sustainability Fund (ALSF) has provided funding to undertake work to minimise and mitigate these effects. This report is part of a portfolio of work that reviews ALSF and other work undertaken between 2002-2007 on 'promoting environmentally-friendly extraction and transport' of land-won aggregates to provide a state of knowledge account and to highlight the gaps in our understanding and practices.

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Sustainable Aggregates An overview of design and management approaches to reducing the environmental footprint of the supply chain for land-won aggregates

1 BACKGROUND & INTRODUCTION

This report is about the supply of land-won primary aggregates. It provides an overview of the contribution that the Aggregates Levy Sustainability Fund (ALSF) has made, through research, development, review and dissemination projects, to promoting and supporting sustainable development through reduction of the environmental footprint (Figure 1) associated with every stage of the supply chain for land-won aggregates, upstream of the market (Figure 2).

"Like all forms of development, quarrying, processing and the transportation of aggregates to the marketplace has the potential to both positively and negatively affect the environment, which in turn can have social as well as economic effects. Understanding these effects and how the negative ones may be controlled or alleviated are important concerns in the planning policy and decision-making processes….".

Planning4Minerals, Chapter 5

In this report, the concept of 'environmental footprint' is used to characterise the positive and negative effects of quarrying, processing and transportation of land-won aggregates, using the following key environmental subject areas as a framework:

- Water environment
- Dust, noise and vibration
- Transport
- Archaeology/heritage
- Biodiversity
- Geodiversity
- Visual amenity and landscape character
- Sustainable use of energy, carbon footprint
- Sustainable use of quarry wastes and by-products

Figure 1: Environmental footprint for land-won aggregates

The overview presented in this report is based on a review exercise of the land-won research and development parts of the ALSF programme commissioned by the Department of the Environment, Food and Rural Affairs (DEFRA) both through programmes managed by MIRO (MIST and SAMP[1]) and English Heritage. The broad themes within which this review has taken place are:

- Theme 1: Reducing the environmental effect
- Theme 2: Sustainable provision of aggregates
- Theme 3: Creating environmental improvements
- Theme 4: Heritage

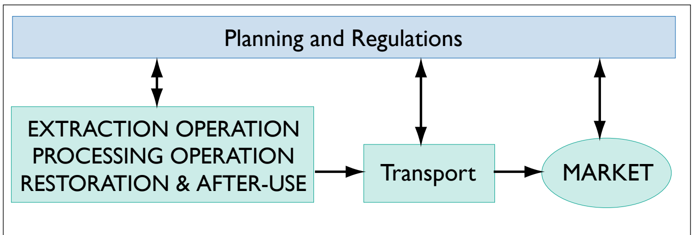

Figure 2: Supply chain for land-won aggregates

Within this structure, sub-themes were identified, and detailed subject-based review and state of knowledge reports have been completed as illustrated schematically in Figure 3.

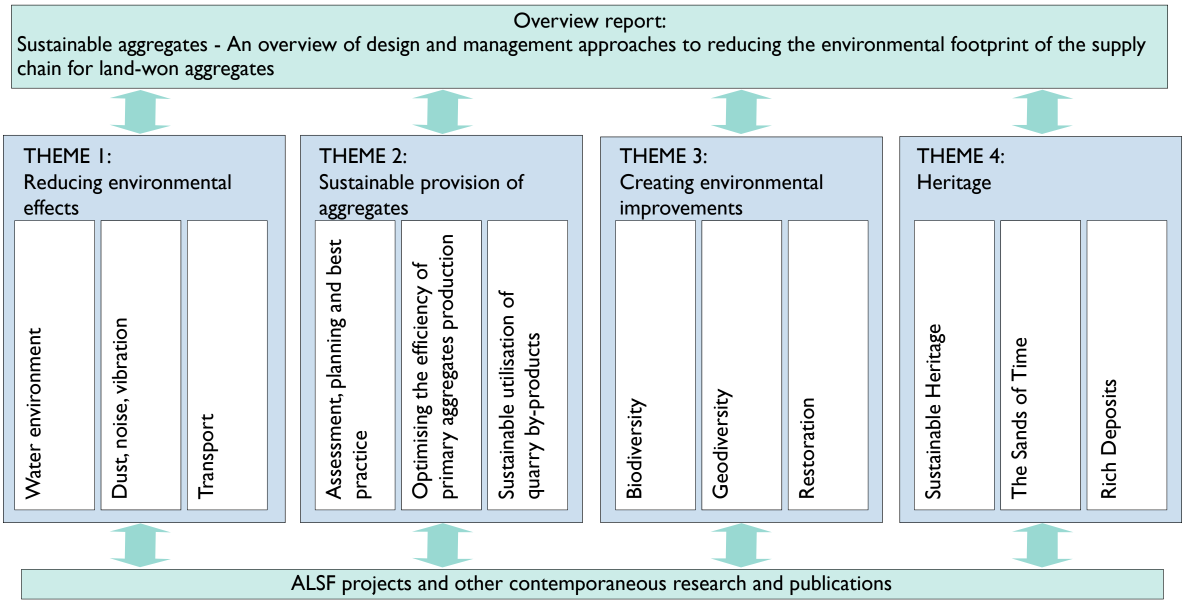

Figure 3:Structure of the MIRO/EH ALSF thematic review

OBJECTIVES

The objectives of this report have been devised with a wide readership in mind, ranging from a reader requiring a broad introduction to the subject of sustainable land-won aggregates to a reader interested in accessing the research itself and requiring guidance as to what is available and how to obtain it. They are:

- To provide a brief introduction to the subject of characterising, managing and reducing the environmental footprint of the supply chain for land-won aggregates, within a logical framework and with reference to the completed ALSF research and other resources (summarised and evaluated in the thematic review reports);
- To highlight the findings of the themed reviews as they relate to characterisation of the environmental footprint of the supply chain for land-won aggregates; and
- To provide a direct portal to themed reviews of ALSF and other contemporary research and other projects undertaken in this area and, through these themed reviews, to provide 'signposts' to the ALSF research relating to land-won aggregates and project reports and other outputs.

Structure and scope of the report

This report presented in three chapters following this introductory section:

- Chapter 2: Characterising the environmental footprint
- Chapter 3: Managing and mitigating the environmental footprint throughout the supply chain and quarry life-cycle

The report is supported by a searchable bibliography of all ALSF reports and other literature upon which the thematic reviews and this overview report are based. This bibliography will be available electronically on CD from MIRO. It is also expected to be available through the website that contains the full versions of all the ALSF review reports, www.sustainableaggregates.com.

Characterising the environmental footprint (Chapter 2)

Following an introduction, Chapter 2 comprises eleven sections, each covering one of the elements relevant to characterising 'environmental footprint', listed in Figure 1[2].

Each of these sections is deliberately concise and is structured identically as follows:

- A non-technical description of the environmental footprint element, identifying specific environmental effects and how they are avoided, mitigated or incorporated in the delivery of long, medium and short term environmental benefits.
- A descriptive summary of the ALSF research relevant to the 'footprint element'.
- Sources of further information (primarily the relevant thematic review or reviews if appropriate).

In most cases, the individual sections of Chapter 2 draw directly on the 12 thematic review reports that have been produced (see Table 1). However, where there is no review sub-theme that provides source information on that subject directly, other ALSF outputs, (or combinations of sub-theme reviews) have been used as sources for these appendices.

Managing and mitigating the environmental footprint throughout the supply chain and quarry life-cycle (Chapter 3)

The first five sections of Chapter 3 consider, in turn, the environmental footprint associated with each individual supply chain stage (see Figure 2). Two further sections consider the importance of health and safety and stakeholder engagement to achieving effective management and mitigation of the environmental footprint throughout the quarry life-cycle and supply chain.

Characterising the environmental footprint at any stage of the supply chain for land-won aggregates supply requires different approaches at different phases in the life-cycle of a quarry (planning and design phase, operational phase, and post-closure phase), and the ranking of and emphasis on individual footprint elements also varies. The progression of emphasis throughout the life-cycle is reflected in the individual sections of Chapter 3.

Each of the sections of Chapter 3 is deliberately concise and is structured identically as follows:

- A table summarising the various activities relevant at the supply chain stage under consideration, and listing context and considerations associated with those activities.
- A table and accompanying text describing the relevance of each of the environmental footprint elements to the subject supply chain element throughout the quarry life-cycle.
- Sources of further information (primarily the relevant thematic review or reviews if appropriate).

As in Chapter 2, explicit reference is made to the thematic reviews and other ALSF projects upon which the material in this chapter is based and which provide sources of further information.

The important topics of health and safety management and stakeholders are considered at the end of Chapter 3. Both of these topics cut across and are relevant to the entire ALSF land-won aggregate research and development programme. Whilst there are some projects dealing specifically with these issues, several of the projects covered in the thematic review reports consider health and safety implications of management and mitigation approaches to reducing environmental footprint and most highlight stakeholder engagement as a key issue.

These final two sections in Chapter 3 are similar in structure to the 5 supply chain sections that precede them, providing a concise summary and guide to sources of further information.
One of the aims of the themed reports was to identify current gaps in knowledge in key areas and to make recommendations for future research priorities. This will help to inform the future allocation of funding and the management of the ALSF programme. Appendix 1 to this overview reports provides necessarily brief summaries of these gaps and recommendations which are listed in full in the themed reports.

Source material

The principal source materials for this report and its accompanying bibliography have been the 12 themed review reports indicated in Figure 3. The titles and authors of these reports are listed in the bibliography, and also at the end of sections of this report that draw on them. All of the references cited and the reports reviewed by the authors of the themed review reports are included in the bibliography. The bibliography may be searched based on the themed review report (or reports) that cite individual references and also by reference to the concepts discussed in this report. Table 1 illustrates the way in which the themed review reports relate to the chapters and sections of this report.

In addition to the review reports, the following more general overview or dissemination materials produced by the ALSF land-won programmes have been used as direct sources for this report:

- www.goodquarry.com
- A Quarry Design Handbook, GWP Consultants LLP and David Jarvis Associates Ltd, 2007 (SAMP2.E3)
- www.planning4minerals.org.uk and the associated publication Planning4Minerals: A Guide on Aggregates, Quarry Products Association, British Marine Aggregates Producers Association, the British Geological Survey and Entec UK Ltd, 2006.

These and other sources of further information are included throughout this report where relevant.

Themed review report	Relevance to Chapter 2 sections[1]		Relevance to Chapter 3 sections[1]	
Theme 1: Reducing Environmental Effects				
Reducing the Environmental Effect of Aggregate Quarrying on the Water Environment	2.1	**Water**	3.1 3.7	Planning and regulation Stakeholders
Reducing the Environmental Effect of Aggregate Quarrying: Dust, Noise and Vibration	2.2 2.3 2.4	**Dust** **Noise** **Vibration from blasting**	3.1 3.2 3.3 3.5 3.6 3.7	Planning and regulation Extraction operation Processing operation Transport of quarry products Health and safety Stakeholders
Reducing the Environmental Effect of Transporting Aggregate	2.5	**Transport**	3.1 3.5 3.6 3.7	Planning and regulation **Transport of quarry products** Health and safety Stakeholders
Theme 2: Sustainable Provision of Aggregates				
Sustainable Provision of Aggregates: Assessment and Planning			3.1 3.7	**Planning and regulation** Stakeholders
Optimising the Efficiency of Primary Aggregate Production	2.11	Sustainable use of quarry wastes	3.1 3.2 3.3	Planning and regulation **Extraction operation** **Processing operation**
Sustainable Utilisation of Quarry by-Products	2.11	**Sustainable use of quarry wastes**	3.1 3.2 3.3	Planning and regulation Extraction operation Processing operation
Theme 3: Creating Environmental Improvements				
Creating Environmental Improvements through Biodiversity	2.7	**Biodiversity**	3.1 3.2 3.4 3.7	Planning and regulation Extraction operation Quarry restoration and after-use Stakeholders
Creating Environmental Improvements through Geodiversity; A "state of knowledge" review of research and applications.	2.8	**Geodiversity**	3.1 3.2 3.4 3.7	Planning and regulation Extraction operation Quarry restoration and after-use Stakeholders
Creating Environmental Improvements through Restoration	2.1 2.7 2.8 2.9	Water Biodiversity Geodiversity Visual amenity and landscape character	3.1 3.2 3.4 3.7	Planning and regulation Extraction operation **Quarry restoration and after-use** Stakeholders
Theme 4: Heritage				
Rich deposits – Aggregates extraction, research and the knowledge pool Sustainable heritage – aggregates extraction and management of the historic environment 'The Sands of Time' – aggregates extraction, heritage and the public	2.6	**Archaeology/ Heritage**	3.1 3.2 3.4 3.5 3.6 3.7	Planning and regulation Extraction operation Quarry restoration and after-use Transport of quarry products Health and safety Stakeholders

Table 1. Relationship between the themed review reports and the overview report

[1] The sections listed in bold type are those that are directly based on the thematic review report against which they are listed or most directly relevant to that subject.

2 CHARACTERISING THE ENVIRONMENTAL FOOTPRINT

The report uses the concept of environmental footprint to characterise the positive and negative environmental effects of quarrying, processing and transportation of land-won aggregates.

The elements of environmental footprint listed in Figure 1 are either aspects of the environment (receptors) that are affected (positively or negatively) by the quarrying, processing and transportation of land-won aggregates, or are sources of adverse or beneficial impact on the environment from these activities. Some of the elements of 'environmental footprint' can fall into either or both categories. The table below distinguishes them in this way.

Receptors of environmental effects of quarrying	Sources of environmental effects of quarrying
Potential for temporary or permanent adverse environmental effects of aggregate quarrying that must be mitigated	
■ Water environment	■ Dust, noise and vibration
■ Archaeology/historic environment	■ Transport
■ Biodiversity	■ Use of energy, carbon footprint
■ Geodiversity	■ Use of quarry wastes and by-products
■ Visual amenity/landscape character	
Potential for temporary or permanent beneficial environmental effects	
■ Water environment	■ Use of quarry wastes and by-products
■ Archaeology/historic environment	■ Biodiversity
■ Biodiversity	■ Geodiversity
■ Geodiversity	
■ Visual amenity/landscape character	

Table 2: Classification of sources and receptors of environmental effects associated with quarrying, processing and transportation of land-won aggregates.

All those elements of environmental footprint that are classified as receptors of environmental effects associated with quarrying, processing and transportation of land-won aggregates have potential to be positively as well as negatively affected. For example, surface water has the potential to be adversely impacted through increased storm flows giving rise to increased flooding downstream and reduction in water quality due to discharge of suspended solids, whereas carefully designed and managed surface water management systems at a quarry can give rise to a reduction in flood risk downstream and an improvement in water quality through effective settlement of suspended solids. Similarly, effective screening can significantly mitigate temporary adverse effects of quarry excavations on visual amenity and landscape character, but design of completed excavations that are geomorphologically sympathetic with surrounding landforms can give rise to permanent environmental benefits in these areas.

In addition to being receptors of adverse or beneficial environmental effects, biodiversity and geodiversity also have the potential to be sources of environmental benefit. For example, a beneficial effect on biodiversity may be realised through the incorporation of new or replacement habitats as part of a restoration scheme. Similarly, environmental benefits may be delivered through development of new rock exposures or public access arrangements to enhance geodiversity value at a particular site during the operational or post closure phases (or both). Quarry wastes and by-products are sources of environmental effects, which may be adverse or beneficial. The sensitive and well planned incorporation of these materials in quarry restoration can provide suitable landforms for the delivery of environmental benefits any or all of the receptors listed (with the possible exception of archaeology/historic environment). For example, placement of quarry wastes in the base and up the sides of a completed quarry excavation can provide slopes and landforms suitable for habitat establishment, access to geodiversity interest, safe and ecologically sound water bodies and improved visual amenity and landscape character. Conversely, quarry waste and by products that are left in unsightly tips within or outside a quarry excavation after it is completed can give rise to significant adverse environmental effects on a temporary (i.e. during the operation phase) or permanent basis. Maximising sales of these materials may compromise the degree to which beneficial permanent restoration schemes can be delivered; it is essential that design takes into account these potential tensions and aims to achieve an optimum solution.

Dust, noise, vibration, transport and use of energy/carbon footprint are all sources of environmental effects, which have the potential to have adverse environmental effects on a range of receptors (including, and especially, people living or working in close proximity to the supply chain activities). Minimising these effects requires minimisation and mitigation techniques at source (e.g. implementation of dust and noise minimisation measures, effective screening of noisy activities, careful design of quarry blasting to reduce vibration and other effects, careful design of access arrangements to sites, establishment of a safe and efficient driving culture, and continual monitoring and management of energy use and carbon footprint).

Characterisation of environmental footprint is an exercise in assessing the overall balance of negative and positive environmental effects. An objective to 'minimise environmental footprint' is an objective to reduce to a minimum the overall negative effects either by mitigating those effects directly or by balancing them with other positive effects, or both.

Characterising the environmental footprint associated with any stage of the supply chain for land-won aggregates supply (Figure 2) requires different approaches at different phases in the life-cycle of a quarry: planning and design phase, operational phase, and post closure phase. The activities that are relevant in relation to the characterisation of the environmental footprint at each of these phases, and the outcomes and objectives of this process, are summarised in Figure 4 (the essentially iterative nature of the activities relevant at each stage is indicated by the use of double headed arrows in the figure).

Where there are likely to be significant environmental effects, a quarry application will normally be accompanied by an Environmental Statement (ES). An ES results from the formal process known as Environmental Impact Assessment (EIA), by which information on all potential impacts is collated, evaluated and presented in a form that provides a basis for consultation, and enables decision makers to take account of these effects when determining whether or not a project should proceed. This is a process whereby the existing 'environmental footprint' (Figure 1, Table 2) of a site is characterised (baseline studies) and the temporary and permanent environmental footprint of operating the quarry are predicted as is the permanent environmental footprint of the restored site post-closure. EIA is central to the quarry design process in order to meet the key environmental objectives of the planning and design phase of the quarry life-cycle: minimum anticipated temporary and permanent environmental footprint.

Figure 4 is taken from A Quarry Design Handbook and illustrates the importance of mitigating environmental footprint as well as the essential balance that must be achieved between this and the other primary objectives of successful quarry design.

In the operational and post-closure phases of the quarry life-cycle, the emphasis shifts from prediction of environmental effects (and design of management and mitigation approaches to limit adverse effects) to monitoring and management of effects within a legal and planning framework.

Throughout the quarry lifecycle, effective stakeholder engagement is critical to the success of quarry projects, to reduce or avoid conflict and take advantage of a range of perspectives and opinions in developing and implementing schemes (see also Chapter 3, section 3.7). The success of stakeholder engagement is, in large part, dependent upon availability of accessible information. This chapter of the overview aims to provide accessible introductory information on the key elements of environmental footprint for land-won aggregates production and to guide the reader to more detailed information in the thematic review reports upon which it draws and, through them to the body of research and other materials upon which they are based.
In each of the following sections, three aspects are summarised for each of the subjects defined as making up the environmental footprint: the nature of the issues; the possible solutions and opportunities; and the contribution that ALSF projects (and some other contemporaneous research and review material) have made to improving environmental awareness and practice.

Each section of Chapter 2 also makes reference to the main review or reviews on which it is based (see Table 1), together with other relevant sources of information.

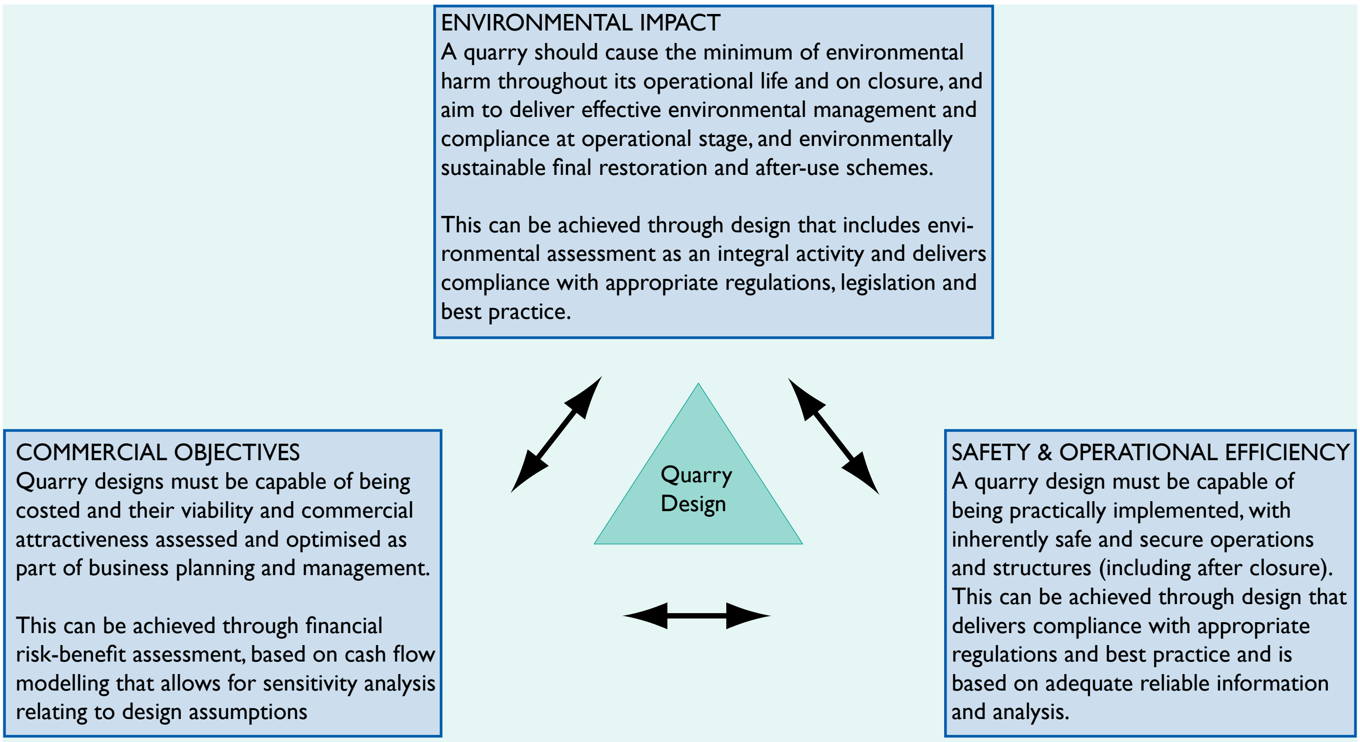

Figure 4: The essential balance to be achieved through quarry design

2.1 WATER

Surface mineral extraction on any scale will change the surface water regime in and around the site. The local groundwater regime may also be affected, particularly if excavation occurs below the water table. Aspects of quarrying and associated activities that can affect surface water and groundwater bodies include initial ground investigation works, excavation, dewatering of workings that operate below the water table and restoration.

Specific impacts that may be relevant to Environmental Impact Assessment may include:

- creation of potential pathways for groundwater and contamination flow between aquifers by drilling exploration boreholes;
- disturbance or removal of surface water features;
- removal of the unsaturated (above water table) zone, causing an increased risk of aquifer contamination;
- a decrease in local groundwater levels and changes in groundwater flow rates through dewatering, resulting in a change in the amount and quality of groundwater received by local water bodies and at abstraction points;
- subsidence;
- modification of drainage, surface water run-off, groundwater levels and water quality following restoration using (lower permeability) overburden or imported fill.

Groundwater may also impact the quarry, by constraining the final base of working and the method of working.

At an early stage in the quarry planning process, a conceptual hydrogeological model should be constructed so that potential adverse impacts can be identified and initial mitigation measures can be proposed and incorporated into quarry designs. During the operational and post-closure phases, continual monitoring and review of the conceptual model is vital to enable greater understanding of the local water environment, and to support any modifications to the design or incorporate additional mitigation measures.

In certain situations, the presence of a quarry can be beneficial to the water environment rather than detrimental. A carefully designed restoration scheme can improve the quality of groundwater and surface water, create new wetland environments and increase local biodiversity in line with Water Framework Directive objectives to protect and improve the water environment.

Specific Government guidelines relating to impact on the water environment of surface mineral workings will be provided by Annex 3 (in draft form) of the current Minerals Policy Statement (MPS2). The statutory powers of the Environment Agency (EA) and the Scottish Environment Protection Agency with respect to controlling impacts on the water environment are relatively limited, but there are two important exceptions to this. When water is taken from an existing natural source and used in quarry processing and related industrial applications, then an abstraction licence is required from the EA. Similarly, when water is released from the quarry back into the environment, then an EA discharge consent is required.

Abstractions for the purpose of quarry dewatering have been exempt from such licensing and controlled only by planning conditions, but those exemptions are soon to be lifted. In order to help with this change, protocols have been drafted (through the ALSF) for use by operators, the EA, MPA and Planning Inspectors to combine both the planning and abstraction licensing systems once the exemption is lifted.

ALSF projects have also produced technical advice on the design of drainage systems, settlement lagoons and attenuation ponds, together with case studies to demonstrate their application. A comprehensive description of the technical issues and remediation methods for the restoration of quarries to water bodies also now exists. This should assist all interested parties (technical and non-technical) to identify quarry operation and restoration strategies that may be relevant to a specific site.

ALSF review reports

- ALSF research, development, review and dissemination projects on water have been reviewed by Capita Symonds Ltd in 2007: Reducing the Environmental Effect of Aggregate Quarrying on the Water Environment.
- Water is also a key consideration in restoration. ALSF research, development, review and dissemination projects on restoration have been reviewed by David Jarvis and colleagues at David Jarvis Associates Ltd and John Cripps and colleagues at the University of Sheffield in 2007: Creating Environmental Improvements through Restoration.
- All ALSF review reports are available atwww.sustainableaggregates.com

Other sources of information

www.goodquarry.com and www.bgs.ac.uk/planning4minerals contain useful information on the water environment, potential effects of quarrying on the water environment and recommended good practice. www.netregs.gov.uk provides information on UK water legislation.

2.2 DUST

Dust associated with quarry operations can be a cause of complaint, because of the nuisance and visual impact that it causes to local residents.

The definition of dust can vary, but it is usually considered as particulate matter between 1 and 75 μm (micron, 1 micron is 0.001 mm) diameter. It is produced wherever there are abrasive forces acting on materials. Recent ALSF projects have helped to clarify and model the sources and relative importance of site derived dust, which are ranked in approximate order of decreasing importance.

- Drill & blast.
- Rock processing.
- Stockpiles.
- Conveyors.
- Initial handling.
- Overburden handling.
- Vehicles on unmade roads.

Dust is carried by moving air when there is sufficient energy in the air-stream (wind speed and turbulence), and is deposited through gravitational settling (sedimentation), washout (such as during rainfall or by wetting) and through impaction on surfaces. Settled dust can be re-suspended where conditions allow, either by wind blow from bare surfaces or by disturbance such as vehicle movement. Various computational models to help predict the likely dust issues have been assessed by ALSF projects. However, the key factor is that complaints about dust are usually associated with periods of dry and windy weather.

It is generally recognised that the smallest particles (up to 10 μm, called PM_{10}) can have health effects, so the UK has introduced National Air Quality Standards (NAQS) to control these. Some diesel emissions would fit into this category, but quarry machinery is now subject to very strict emissions limits. This, together with the fact that background PM_{10} values are usually very low due to the rural setting of most quarries, means that the NAQS limits are unlikely to be exceeded.

The main issue is usually nuisance dust, and the greatest problems will be experienced near to the significant dust sources. This is generally within 100 m, but dust can still be an issue up to 1 km away. Incorporation of larger standoffs (e.g. to mitigate noise or visual impacts) may therefore not provide effective mitigation; emphasis should be on the reduction of dust emissions at source.

At present there are no official standards for nuisance dust. Planning conditions applied to quarries specify various methods of assessing dust emissions, but the measurements from different methods are generally not interchangeable. At any given location, dust will either be carried through or deposited. It is therefore important to measure both elements, and this can be done using directional and depositional gauges respectively. The actual monitoring regime should be planned carefully and should incorporate a weather monitoring station, to ensure the dust results can be interpreted correctly. ALSF projects have assessed the accuracy and comparability of different monitoring methods, including a new system that uses sticky pads which are then digitally scanned and measured.

ALSF projects have also suggested ways in which the creation of dust can be minimised during the processing operation. This may assist the standard mitigation measures, which usually involve wetting susceptible areas with water to prevent the dust getting airborne. Site haulage roads can be watered with a bowser (a truck spraying water from a tank), or a semi-permanent hose/sprinkler system. Dusty benches and faces may need to be sprayed with a water jet before blasting takes place, and stockpiles and loading/transfer points can benefit from having a fine mist sprayed over them.

If dust is a problem at a particular location, then it may be necessary to consider the screening of operations from winds that could blow towards residential properties.

ALSF review reports

- ALSF research, development, review and dissemination projects on dust have been reviewed by Bill Birch and colleagues at the University of Leeds and Ian Lowndes of Nottingham University in 2007 (in the report that also considers vibration and noise): Reducing the Environmental Effect of Aggregate Quarrying: Dust, Noise and Vibration.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

www.goodquarry.com contains a useful section that defines and describes some of the terms around dust, and together with www.bgs.ac.uk/planning4minerals, outlines some good practices.

2.3 NOISE

Quarries are almost always situated in rural communities which, away from major roads, tend to be quiet. The introduction of large machinery for excavation, transportation and processing is often seen as intrusive, and must be properly managed. The use of such machinery generates different types and levels of noise, which is often described as "unwanted sound". This can represent a health risk for operators within the site and is subject to normal Health & Safety legislation. However, the concern here is with what can be called environmental noise or noise pollution.

The noise emanating from a quarry is usually complex in nature, as it changes with time and is affected by the in-situ changing meteorological conditions. It will eventually affect the ambient noise environment of the immediate neighbourhood and can give rise to complaint from local residents.

In order to protect the local population from excessive noise, the Government has issued guidance (Annex 2 of MPS2) on the maximum levels of noise that should arise from quarry operations over and above existing local noise levels. These background noise levels should be monitored prior to the start of an operation. The regulation of noise from a site is achieved through the enforcement of planning conditions set by the MPA. An agreed noise monitoring programme usually involves regular monitoring at specified locations, and should take into account changes in the location of noise sources throughout the life of a quarry operation.

An understanding of the source (which can be static or mobile), the path and the receiver is needed to define outdoor noise propagation. The source will emit sound power that can be measured in the vicinity of the source. Noise levels then naturally diminish with:

- distance from source
- ground reflections interfering with the direct noise
- atmospheric absorption
- the presence of natural barriers and heavily wooded areas

Finally, the sound levels from all sources combine at the receiver. However, a vertical change in wind or temperature can refract (bend) the noise path up or down, causing noise shadow zones which may modify the effectiveness of any barriers.

Wherever possible, the objective should be to control the generation of noise (e.g. through the use of effective silencers and isolating vibrating machinery), rather than trying to affect its propagation. A good example is the recent development of "white noise" reversing alarms which are less intrusive than single tone models.

Once the noise is emitted, propagation of noise to a receptor can be reduced by a barrier of some description. The best solution is usually to design the operation such that the source is "hidden" from the receptor by an existing feature of the quarry (e.g. the quarry highwall). For a static noise source, it may be possible to enclose it and use acoustic cladding, but with trucks and mobile plant, this is not practicable. Construction of an earth mound or baffle to obscure the noise sources is another common approach, which often doubles as a soil storage facility. Other measures, such as erecting an acoustic barrier (wall or fence), are likely to be costly but may be necessary.

There are a number of noise prediction models available, which can be used to assess the effectiveness of different site designs in controlling noise. These models require the sound levels of the different noise sources to be known. DEFRA has recently published an updated noise database for quarries, which should enable more accurate modelling and predictions.

There are a range of types of wall or screen design, which have particular benefits. The effectiveness of vegetation belts is currently not understood very well.

ALSF review reports

- Although no noise mitigation studies have been funded by ALSF to date, a review of the current state of knowledge for quarries and noise was included with the report produced by Bill Birch and colleagues at the University of Leeds and Ian Lowndes of Nottingham University in 2007 (in the report that also considers vibration and dust): Reducing the Environmental Effect of Aggregate Quarrying: Dust, Noise and Vibration.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

www.goodquarry.com contains a useful section that defines and describes the terms used in noise, and together with www.bgs.ac.uk/Planning4Minerals outlines some good practices.
Other sources of information can be found in the bibliography accompanying this overview report.

2.4 VIBRATION FROM BLASTING

Aggregates can be excavated from sand and gravel quarries by simply digging the fairly loose material, but material from hard rock quarries usually needs to be blasted to produce a pile of broken rock that can be excavated. Where blasting does take place, it gives rise to vibration, which is often perceived as a nuisance and may give rise to fears of structural damage.

The reality of quarry blasts is far less dramatic than film images of blasting depicting huge explosions with lots of flying rock, dust clouds and vibrations. Quarry blasts are designed to use the correct amount of explosive to produce the required product without excessive flying rock or vibrations. Blasts are usually multi-hole events with small time delays between each hole. Control of flyrock requires an understanding of the location of the blastholes and explosive charge in relation to the geometry of the blasting area. This is achieved through accurate surveying and profiling the face(s) of the bench, which must be undertaken by law.

Controlling vibration levels from quarry blasting is more complex than control of fly rock and is based on understanding the effects of the amplitude (measured as Peak Particle Velocity or PPV), and frequency of vibrations and their duration. Ground vibration levels generally reduce with distance, so properties distant from the blast are unlikely to feel anything. Structures that are close to the site will often be protected by a vibration limit set by the MPA, so consideration must be given to the maximum amount of explosive detonated at any instant in time in order to minimise vibration levels and comply with limits. This amount of explosive is known as the Maximum Instantaneous Charge Weight or MIC.

The allowable MIC is calculated from previously recorded blast data, but this requires a comprehensive monitoring regime that gathers blast parameters and recorded vibration data (PPV). Recent ALSF projects have shown how important it is to keep this dataset up to date, and have produced a well structured database to ensure that observations can be used to improve blast design and implementation to reduce environmental effects to a minimum. The greater control which is now possible benefits both operator and local resident.

International and UK research has led to general agreement on the levels of vibration likely to lead to different degrees of damage (cosmetic, minor and major or structural). However, the limits imposed on quarries by the MPAs are usually well below any of these thresholds, and so the main issue with blasting is the nuisance factor. This can often be reduced with good communications between the operator and local residents. Prior announcement of blasting times will help reduce the startling nature of blasts.
The small time delay between each blasthole improves the fragmentation, but just as importantly, it reduces the MIC and therefore reduces the vibration levels. Where local residents or sensitive structures are close to the site boundary, it may be necessary to reduce the MIC further using techniques such as "decking", where the explosive charge in each blasthole is divided into two or more separate columns, and detonated on different time delays.

In recent years, the most commonly used form of delay detonator in the UK has been the non-electric type, but electronic detonators are increasingly used for applications where vibration control within strict limits is essential. Some ALSF projects have developed and applied this in UK quarries, with considerable success. The timing of these detonators is much more accurate than the non-electric type and allows a far greater degree of control. They allow the blasting engineer to select the optimal delays to minimise the vibrations.
Recent work has shown that not all the disturbance caused by blasting is due to ground vibrations. Air pressure waves emanating from the blast (referred to as air-overpressure) can also cause buildings to shake and windows to rattle. A recent ALSF project has successfully developed and tested equipment designed to assess this impact, thus enabling better understanding and control of this effect.

ALSF review reports

- ALSF research, development, review and dissemination projects on ground vibrations and air-overpressure have been reviewed by Bill Birch and colleagues at the University of Leeds and Ian Lowndes of Nottingham University in 2007 (in the report that also considers dust and noise): Reducing the Environmental Effect of Aggregate Quarrying: Dust, Noise and Vibration.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

www.bgs.ac.uk/Planning4Minerals gives a useful introduction to blasting issues, while www.goodquarry.com has a very detailed section which describes the technical terms and outlines the techniques used to control the effects of blasting.

2.5 TRANSPORT

The transport of aggregate from the quarry or other source to the point of use is essential, but does extend the environmental footprint by affecting communities in the vicinity of transport routes and infrastructure. It also affects the global environment as transport accounts for between 20% and 40% of the total carbon dioxide emissions generated by the aggregate industry as a whole.

Alternatives to road transport are limited (rail: 7.1%, marine dredging: 6.9%, ship: 2.9%, inland waterways: <0.5% of aggregates sold) and even where these are used, the aggregates are probably still moved by road for part of their journey. The alternative modes of transport will, of course, have their own environmental implications.

The effects of quarry traffic on local communities give rise to a range of concerns and complaints such as:

- ‘intimidation’ by large vehicles;
- use of roads unsuitable for the size of vehicle;
- dust;
- mud from wheels and the vehicle body;
- vibration;
- congestion.
- danger;
- damage to verges;
- spillages;
- exhaust pollutants;
- noise, including vehicle movements early or late in the day as well as the additional noise associated with empty vehicles which travel faster and the “body-slap” when travelling over potholes;

A Transportation Assessment should be carried out as part of the planning application, and should address all the potential issues identified above. A number of mitigation measures are possible.

The location of the site access point is critical and it is sometimes possible to construct a substantial haul road within the site boundary which acts as a “by-pass” to keep vehicles out of small villages etc. It may be necessary to change the road layout at the site access point, to maintain traffic flow and improve safety through increased visibility. Occasionally, an agreement may be reached for the quarry company to pay for a new roundabout or section of road, if it is required.

Agreed haulage routes are likely to be defined in the planning consent and it is vital that these are complied with. This is often more difficult where contract hauliers are used, but should still be enforced. Drivers should also be encouraged to drive in a safe and considerate manner at all times.

Every attempt should be made to ensure there is minimum debris deposited by trucks on the public roads. This means that all loads should be sheeted and will usually require a well designed wheel wash.

Traffic vibration is usually less of a problem than noise, which can be considerable if an empty vehicle is travelling on a poorly maintained road. Bumps and pot-holes in the road can exacerbate suspension noise, impact noise from movement of tipper bodies and various rattles. However, all of these can be reduced relatively easily. Engine and exhaust noise should be reduced by ensuring the vehicle is well maintained.
In an attempt to reduce the environmental footprint of aggregates transport, ALSF transport funding has been used for activities in the following areas.

- Business advisors have been funded to help aggregate transport operators review their business and identify an action plan to improve the efficiency of their operation.
- The 'Safe and Fuel Efficient Driving' (SAFED) scheme has been run for the aggregates industry, funding the training of driving instructors and drivers to develop their skills.
- Rail and water freight grants have been offered to help operators transport aggregates by rail or water instead of road where the environmental benefits justify doing so.

A research project is currently in progress, which is considering emissions at all stages of the aggregates life cycle, including transport.

ALSF review reports

- ALSF research, development, review and dissemination projects on transporting aggregate have been reviewed by Chris Fry of AEA and Matthew Wayman (C4S) in 2007: Reducing the Environmental Effect of Transporting Aggregate.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

Information on the Safe and Fuel Efficient Driving programme can be found at www.safedaggregates.org.uk. www.bgs.ac.uk/Planning4Minerals gives a useful introduction to the transport issues, and www.goodquarry.com describes a number of mitigation measures which will help to reduce the impact of transport on the local environment.

2.6 ARCHAEOLOGY/HERITAGE

Evidence for human activity in England goes back for half-a-million years. The manner in which our ancestors have shaped the landscape across this vast time has left us with an incredibly rich, fascinating historic environment encompassing a remarkable and diverse range of monuments, features, artefacts and landscapes. They are encountered on land and under the sea; some are immediately visible, others deeply buried or submerged. A significant proportion of these emerge from discoveries made in advance of, or during, aggregates extraction. All share the single characteristic that they are irreplaceable. Once they are gone, they are gone for ever, so they should be managed very carefully.

A steady supply of aggregates is essential to maintain the infrastructure of our country, without aggregates the construction of houses, hospitals, schools and roads would not be possible. A major challenge facing those involved in aggregates extraction and the management of the historic environment is striking the right balance between conservation and development. Although primary extraction frequently comes with a cost to our archaeological heritage, it can also provide us with significant opportunities to advance our understanding of our past. Carefully planned extraction can also provide historic environment professionals with outreach and educational opportunities and offer extraction companies positive publicity.

The planning system already includes guidance on minerals development in the form National Minerals Policy Guidance (MPG) and Minerals Policy Statements (MPS), and guidance on archaeology and the historic environment in the form of Planning Policy Guidance Notes 15 and 16. Further national guidance (funded though the ALSF) is also being developed by the recently established Minerals and Historic Environment Forum, which includes senior representatives from the minerals industry, planning, and the historic environment. The aim of this additional guidance is to ensure that informed decisions can be made regarding the level of archaeological knowledge that is necessary at each stage of the planning process. It also aims to ensure that the full range of appropriate investigative techniques is considered, and to promote greater consistency in planning authority responses.

The planning system relies on archaeological curators providing input into the historic environment aspects of the Local Development Framework (LDF) and all subsequent stages in the planning process. LDFs should give clear guidance to developers about where development may and may not be acceptable. Developers should consider local archaeological curators as the primary contact for guidance on areas that have historic environment potential and the right approaches for assessing this potential.

Historic environment resources are not all equal in significance. Some are of national or international importance, for example our World Heritage Sites and Scheduled Monuments; others are less significant. It is important that this is recognised by all those involvement in the safeguarding and management of the historic environment, since guidance for all planning conditions state that they should be necessary, relevant, enforceable, precise and reasonable in all other respects.

Early identification of historic environment issues is crucial in planning extraction operations and reduces risk. Pre-application discussions are strongly recommended. An archaeological assessment should be incorporated within the Environmental Impact Assessment (EIA) which accompanies some planning applications; this may lead to a request for additional information. If planning permission is granted, mitigation measures required by conditions or in separate legal agreements could range from no further work to a requirement for preservation of a site in situ. Alternatively the requirement could be limited to recording of features, for example through archaeological excavation in advance of excavation work proceeding. It may be possible to achieve some mitigation through appropriate design of the extraction site and its subsequent restoration.

The ALSF projects commissioned through English Heritage have supported a significant number of strategic marine and terrestrial research projects which aim to enhance the baseline information necessary for effective future management.

Evaluation and recording of the historic environment is an incremental process. A range of techniques, too numerous to consider in detail here, are available to evaluate and record the historic environment. Some focus on site detection (e.g. aerial photography, field-walking, geophysics), others on recording structures and deposits (e.g. surveying and excavation). Investigative work normally requires that a range of approaches be adopted as no two sites are the same. However, all evaluation and recording work should have clear research goals linked, wherever possible, to local, regional and national research agendas. The advent of the ALSF has enabled significant methodological and technical advances to predictive, evaluation and mitigation tools, which will advance information gain and cost effectiveness. This, in turn, will benefit both the aggregates industry and the historic environment. It has also enabled the development of research agendas and management and conservation strategies for aggregates producing areas through the analysis, synthesis, and dissemination of important data from work undertaken in response to aggregate extraction; and local education, interpretation, outreach and community involvement.

ALSF review reports

- ALSF research, development, review and dissemination projects on aggregate extraction, heritage and the public have been reviewed by Atkins Heritage with Gill Andrews (Archaeological Consultant) and Professor John Barrett (Sheffield University): Rich Deposits – Aggregates extraction, research and the knowledge pool.
- ALSF research, development, review and dissemination projects on sustainable heritage have been reviewed by J, Flatman, J. Short, J. Doeser, and E. Lee (Centre for Applied Archaeology of the Institute of Archaeology, University College London): Sustainable Heritage – Aggregates extraction and management of the historic environment.

- ALSF research, development, review and dissemination projects on aggregate extraction, heritage and the public have been reviewed by Julian Richards (Consultant): The Sands of Time – Aggregates extraction, heritage and the public.
- All ALSF review reports are available at www.sustainableaggregates.com.
- Information concerning all ALSF funded projects relating to the historic environment can be found at www.english-heritage.org.uk/ALSF and http://ads.ahds.ac.uk/catalogue/projArch/alsf/.

Other sources of information

www.algao.org.uk the Association of Local Government Archaeological Officers UK (ALGAO: UK) website gives information on a wide range of issues and concerns relating to the historic environment, strategically at UK level and in more detail at national level.

www.helm.org.uk the Historic Environment Local Management web site holds best practice, case studies and policy statements produced by English Heritage, as well as range of guidance produced by English Heritage, HELM partners, Local Authorities, regional agencies and other key organisations.

www.archaeologists.net/ the Institute of Field Archaeologists (IFA) website contains a range of codes, guidance and standards documents for archaeologists and those interested in the historic environment.

2.7 BIODIVERSITY

Biodiversity is the term used to describe biological diversity, which is recognised as being crucial to the sustainability of our planet. It is used to describe the variety (and variability) of all living things and the relationship between them. Quarries often have the opportunity to practically contribute to the conservation of biodiversity, but they can also have a damaging effect.

Around 700 SSSIs were once quarries or land owned by mineral operators. Most proposed sites will require an Environmental Impact Assessment, which will include ecological surveys and baseline assessments. Habitats and species covered by a statutory designation (such as Sites of Special Scientific Interest and Special Areas of Conservation) and others covered by law (such as hedgerows and badgers) are heavily protected. Natural England or the Countryside Council of Wales must give their approval before a planning authority can grant permission to work in such an area. Even if a habitat isn't designated it may still be of local importance and therefore in need of protection.

A large number of biodiversity related projects have been funded by the ALSF, through both MIRO (where the main focus has been on research and review) and Natural England (where the emphasis has been on practical projects).

The relationship between biodiversity and quarries can logically be divided up into the different lifecycle phases of the site (see Figure 5).

At the planning and design phase, where potential sites are being identified and designs are being developed, the priority should be to choose sites and design options that maximise benefits and minimise damage. This will always require the earliest possible monitoring of baseline levels, and the agreement of habitat end-uses. The habitats being developed in restoration design should ideally fit in to local and national Biodiversity Action Plans (BAPs). Damage to existing protected or important habitats should be avoided, and care should be taken with less obvious wildlife such as invertebrates.

During the operational phase, there will be considerable change inside and possibly adjacent to the site. ALSF projects have highlighted the changes in surface and ground water that can affect certain habitats, and that therefore need to be managed or mitigated to minimise damage and maximise opportunities for benefit. A number of organisations produce briefing sheets that give guidelines for accommodating different species of plants, invertebrates, etc. in operational areas. However, it is important to remain flexible to deal with the unpredictable.

ALSF projects have shown that the restoration of quarry sites provides the greatest opportunity to benefit biodiversity, and that the minerals industry can make a significant contribution to UK BAP targets. Habitat creation should always follow best practice, with site investigations and on-site trials, soil nutrition, and natural regeneration (where possible) and local seed sourcing all being important. Restorations schemes should not be ecologically too ambitious, sometimes benefiting from having fewer habitats but over larger areas. Public access needs to be designed in from the very beginning of a scheme, and consideration should be given to the potential for bird strikes in areas around airfields.

The long-term management and funding of any restoration scheme that incorporates a biodiversity element is crucial to its success. ALSF projects have confirmed the importance of stakeholder partnerships which are involved in extended monitoring and management. These often involve a mixture of councils, statutory bodies (such as Natural England) NGOs (such as RSPB and Wildlife Trusts) and voluntary groups. The on-going commitment of the operating company beyond its statutory duties may be required for some schemes to succeed.

Some of the most successful schemes are where there has been an imaginative integration of a number of different end-uses. Biodiversity can often be enhanced alongside geodiversity, education, recreation or flood-alleviation schemes.

ALSF projects have highlighted the importance of the regional and national context. Schemes for enhancing biodiversity should not just be considered at the specific site level, but should consider the wider landscape benefits and biodiversity objectives.

ALSF review reports

- ALSF research, development, review and dissemination projects on biodiversity have been reviewed by Jaqui Wier and Alice Davies of RSPB in 2007: Creating Environmental Improvements through Biodiversity.
- Biodiversity is a key consideration in restoration. ALSF research, development, review and dissemination projects on restoration have been reviewed by David Jarvis and colleagues at David Jarvis Associates Ltd and John Cripps and colleagues at the University of Sheffield in 2007: Creating Environmental Improvements through Restoration.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

The Nature After Minerals partnership between RSPB and Natural England has produced a website (www.afterminerals.com) that contains excellent case studies and habitat guides. The Post-Mining Alliance (hosted by the Eden Project) also seeks to pool resources and case studies on aspects of post mining regeneration, including biodiversity (www.postmining.org).

Further background information is available from www.mineralsandnature.org.uk, www.goodquarry.com and www.bgs.ac.uk/Planning4Minerals .

2.8 GEODIVERSITY

Geodiversity refers to the variety of rocks, their associated geological features and processes within nature, and includes land-shaping processes and soils as well as bedrock geology. It underpins the extremely varied landscapes that exist in the UK, together with the biodiversity that thrives on them, and it has a major influence on local culture and heritage. It can be considered to include the following.

- All rocks and recent unconsolidated surface sediments.
- Structural and tectonic features at all scales.
- Fossils and palaeoecology.
- Minerals and mineralisation.
- Stratigraphical relations and unconformities.
- Geomorphology including landscape and active processes.
- Fossil landscapes.
- Weathered rocks and soils and soil forming processes.
- Mineral resources, mines and quarries.
- Engineering geology (slopes, rockfalls, landslides, waste tips and lagoons).
- Hydrogeology.
- Environmental geology, including mining wastes and other contaminated land.
- Built environment (e.g. local building stone, dry stone walls).

Around 700 Sites of Special Scientific Interest (SSSI), many of which are designated and therefore protected on the basis of their geology or geomorphology. Other non-statutory sites such as Regionally Important Geological and Geomorphological Sites (RIGGS) are considered during the quarry application process. Government gives guidance on how important sites should be considered through Planning Policy Statement 9: Biodiversity and Geological Conservation.

The decision as to whether exposures need to be conserved (or preserved) will depend on a wide variety of factors. Their aesthetic, scientific/research/educational, recreational, social/historical, 'sense of place' and spiritual/religious values are usually assessed using terms that are qualitative and subjective, such as world, national, state, regional, local significance, and high, medium and low. An ALSF project has developed a system for producing a standard Geodiversity Profile to assess the value of a geological site, particularly in quarries.

It is clear that quarrying and mineral extraction is going to have a strong relationship with geodiversity, as they are both concerned with material in the ground. It might appear that quarrying would have an entirely negative impact, but this is certainly not the case. Excavation through the earth reveals strata and features that would not otherwise be visible, and provides many opportunities for research, education and recreation.

At each stage of a quarry's life (planning, operation, post-closure) the objectives must be to minimise damage to important features of geodiversity, and to maximise the benefits. The importance of planning for geodiversity (together with other potential impacts) at the earliest stage of design cannot be overemphasised. One ALSF project has created a procedure for producing a Company Geodiversity Action Plan (cGAP), which should ensure that operating companies are aware of the issues and opportunities throughout the life-cycle of a site.

Geoconservation (the policies, procedures and practical enhancement of geodiversity) does not always mean preserving things intact. In an operational quarry, geological exposures can often be recorded and replaced by features of equivalent interest as the excavation progresses, or even recreated by special excavation in a different location. This is not the case in disused or abandoned quarries where new exposures are not likely to be created and preservation may need to be considered.

A significant number of ALSF projects have aimed to directly benefit the environment through geodiversity and geoconservation acitivites, many of which have had a strong educational element. These include the practical restoration of quarries, rescuing important features, creating quarry viewing areas, improving safety and accessibility, establishing Geodiversity trails and the production of high quality interpretation panels, guided walk booklets, education packs and DVDs.

Other projects have had more of a research and development focus. These include surveys of geodiversity at local sites and the production of geodiversity audits, the creation of local geodiversity action plans, and the development of the cGAPS mentioned previously. The principal aim of an audit should be to provide the framework necessary for informing the sustainable management, planning, conservation and interpretation of all aspects of the geodiversity of the area concerned. The audit should precede the development and implementation of the Local Geodiversity Action Plan (LGAP), which should include well defined objectives and a route to achieving them.

ALSF review reports

- ALSF research, development, review and dissemination projects on geodiversity have been reviewed by Peter Scott, David Roche, and Clive Nicholas (David Roche Consulting) and David Lawrence and Keith Ambrose (BGS) in 2007: Creating Environmental Improvements through Geodiversity.
- Geodiversity is a key consideration in restoration. ALSF research, development, review and dissemination projects on restoration have been reviewed by David Jarvis and colleagues at David Jarvis Associates Ltd and John Cripps and colleagues at the University of Sheffield in 2007: Creating Environmental Improvements through Restoration.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

Natural England's website has a section on geological conservation at www.naturalengland.org.uk/conservation/geology/default.htm and a number of the ALSF projects have produced websites. Natural England have also produced two very helpful documents on geodiversity (Natural Foundations: Geodiversity for people, places and nature) and geoconservation (Geological Conservation: A guide to good practice) which are both available as free downloads from their website.

Detailed background information is available fromwww.goodquarry.com and other sources of information can be found in the bibliography accompanying this overview report.

2.9 VISUAL AMENITY AND LANDSCAPE CHARACTER

Aggregate quarries (active, dormant or restored) are part of the landscape. They sit within the wider landscape contributing to or detracting from it. Landscape is considerably more than just the visual perception of a combination of landform, vegetation and land uses. It also embodies history, culture, geology, wildlife etc and is, moreover, dynamic.

The potential effects during mineral extraction include visual intrusion and changes to landscape character due to the introduction of discordant features into the landscape, and loss of landscape features or vegetation due to excavation and associated workings. Post restoration, the issues involve the introduction of new landscape features, the creation of landscape with different character to that which existed prior to mineral working, and changes in character of views associated with different landscape character.
The landscape architect is one of the key professionals whose input is therefore required from the beginning of a quarry project. Such input may include:

- landscape and visual assessments;
- site selection on a national, regional, county or local scale;
- definition of quarry boundaries, internal configurations and directions of working;
- soil, overburden and quarry waste handling and placement;
- location and design of plant, structures and access/haul roads;
- protection/avoidance of retained landscape features;
- phasing;
- mitigation measures;
- progressive restoration;
- afteruse;
- aftercare maintenance/management.

Active quarries are dynamic features in the landscape. In order to minimise or avoid landscape and visual impacts it is essential to give close consideration to several key factors. The positioning of the final quarry rim or boundary will, in part, determine the visual impact and have an important effect on the ease with which the completed quarry fits into the surrounding landform. Similarly, the locations of plant, accesses, haul roads, utilities, stockpiles, silt lagoons, etc need to be decided to minimise impacts. However, it is in the selection of directions of working that visual impact may be substantially increased or decreased. The same quarry in the same location but worked in an opposite direction may be either invisible to nearby receptors or may reveal a new stark face every day as the quarry moves away from the receptors.

If landscape and visual impacts cannot be planned or designed out, mitigation measures need to be incorporated. Wherever possible, these measures should be integrated into the overall restoration scheme rather than included as temporary features. Flowing, screening landforms are better than linear, triangular cross-sectioned mounds.

It is often possible for restoration to be achieved progressively throughout the life of the quarry, particularly in sand and gravel operations but sometimes in hard rock quarries. Apart from the early return of land to some other beneficial use, such progressive restoration reduces the need for double handling of materials which minimises deterioration of soils and saves money.

Quarries are a temporary use of land, which may continue for 3-5 years for a small sand and gravel quarry to several tens of years for a major hard rock operation. Their restoration to a beneficial after-use is a pre-requisite before a modern planning permission is granted. However, the needs of society evolve and scope exists to cater for a wide range of after-uses beyond the more typical agriculture, forestry, amenity or nature conservation. Some built after-use, for example, may serve a local need as well as fund the installation and maintenance of bioconservation, geoconservation or education facilities. A collaborative approach between operators, local authorities, NGOs and special interest groups is often effective. However, care must be taken that restoration schemes are achievable and not too ambitious, and the impact on landscape and visual amenity must always be considered.

The ALSF projects relating to landscape and visual matters provide guidance on subjects ranging from screening bunds to stakeholder consultation. An integrated approach will hopefully avoid the need for mitigation in the first place. Where mitigation is unavoidable it should be equally integrated into the landscape or after-use rather than being intrusive in its own right.

ALSF review reports

- A review specifically on landscape and visual amenity was not carried out as part of the ALSF review process, as this did not form a separate theme within the MIST/SAMP funding. However, several aspects of this subject were included in a number of projects under the Restoration theme and within other ALSF funding streams.
- Visual amenity and landscape character are key considerations in restoration. ALSF research, development, review and dissemination projects on restoration have been reviewed by David Jarvis and colleagues at David Jarvis Associates Ltd and John Cripps and colleagues at the University of Sheffield in 2007: Creating Environmental Improvements through Restoration.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

www.bgs.ac.uk/Planning4Minerals gives a useful introduction to the landscape and visual issues, and www.goodquarry.com describes a number of mitigation measures which help to reduce the impact.
Other sources of information can be found in the bibliography accompanying this overview report.

2.10 SUSTAINABLE USE OF ENERGY, CARBON FOOTPRINT

Energy use represents a significant cost to the quarry industry, but it should also be considered in terms of the levels of CO_2 produced. CO_2 is a prime polluter of the environment and contributor to global warming. Among other ways, it is created whenever fossil fuels are burned on-site (in vehicles, generators, boilers, furnaces, etc) or when electricity is consumed that has been generated by fossil fuel.

The Quarry Products Association (QPA), whose member companies account for 70% of UK aggregate production, has reported the energy consumption figures for quarries across Great Britain since 2004. Usage of electricity, natural gas, gas oil, diesel, heavy fuel oil and recovered fuel oil have all been measured to give total on-site energy use for production of aggregates, asphalt and ready-mix concrete. This can then be converted into CO_2 emissions.

The QPA acknowledges that because of the scale of the industry, with over 1,800 locations covered, the quality and quantity of data still needs to be improved. This explains why the existing data is rather inconsistent. The reported reduction from 9.98 kg of CO_2 per tonne of aggregate in 2004 to 7.71kg in 2006 is a very significant fall. It may not be reliable, but the trend appears to be in the right direction.

The total CO_2 emitted from aggregate production constitutes between 0.5 and 0.6 % of the total UK carbon emissions. However, this does not include delivery which is mostly by road and significantly increases the emissions. This issue led to an ALSF project funded through the Department for Transport. The Safe and Fuel Efficient Driving programme trained over 5,400 drivers and resulted in a 10% fuel saving.

The QPA has issued a Statement of Intent (reproduced below) to show its commitment to the government's draft Climate Change Bill, which is likely to require a 25% reduction in emissions by 2020.

The Quarry Products Association will:

- Ensure members understand the data, the terminology and the objectives relating to carbon.
- Improve our Understanding of our carbon footprint, and the impact of all our activities.
- Identify and prioritise key areas for industry action.
- Seek to make the best use of all available resources – for example we believe the Aggregates Levy Sustainability Fund should have a key role in supporting future carbon reduction in the sector.
- Work with our stakeholders to identify potential for joint action on carbon reduction. This may well highlight policy conflicts and difficult issues which we will need to confront and work through.
- Use our sustainable development strategy and reporting to update on progress.

The QPA has also produced a card giving "Useful Action for Business", with the following advice.

- Measure, monitor and review all energy use to understand energy demands.
- Introduce a carbon reduction plan engaging management and staff at all levels.
- Focus on high energy use activities as a priority, eg asphalt plants.
- Implement general energy efficiencies, carry out site energy reviews.
- Ensure regular maintenance of plant, vehicles and equipment, and that controls are working and set correctly.
- Evaluate installing more efficient plant/motors.
- Look for logistics efficiencies, ensure drivers are trained to drive safely and efficiently.
- Consider carbon implications down the supply chain.
- Consult QPA website carbon zone www.qpa.org for further information.
- See other websites, eg www.carbontrust.co.uk, www.est.org.uk

A Good Practice Guide (No. 315: Energy and Resource Management, Fuel Power and Water, A guide for managers in the minerals industry) is available from the Carbon Trust with further practical guidance and advice on energy conservation.

An important Waste and Resources Action Programme (WRAP) funded research project is currently undertaking a Life Cycle Analysis of aggregates, which should lead to a better understanding of the sources and amounts of CO_2 at each stage of a quarry's operation. The measured impacts will include;

- carbon dioxide (CO_2);
- particulate matter less than 10 microns (PM10) and Total Suspended Particulates;
- nitrogen monoxide (NO), carbon monoxide (CO), etc from engines and blasting;
- surface solid waste volume.

ALSF review reports

- No carbon reduction studies have been funded through the MIST/SAMP programmes to date, so there has been no ALSF review report produced on this subject. The ALSF review on transport considers a number of ALSF projects funded through the Department for Transport, including the Safe and Fuel Efficient Driving programme, which can be found at www.safedaggregates.org.uk.

Other sources of information

Further information can be obtained from the QPA website carbon zone www.qpa.org, and at www.carbontrust.co.uk and www.est.org.uk.

2.11 SUSTAINABLE USE OF QUARRY WASTES

Quarry wastes and by-products arise from the stripping of overburden/interburden materials; from washing of sand and gravel to remove fines; and from scalpings, crushing and dry screening. Temporary (sometimes long-term) space is required for storage of these materials until they can be sold as secondary aggregate or general fill off-site or incorporated into restoration. Such storage can give rise to adverse environmental effects (e.g. visual impact and generation of dust) and may have a detrimental impact on the efficient operation of the quarry because of the space required to accommodate tips or stockpiles of these materials. Quarry wastes and by-products are a largely unavoidable by-product of the extraction and processing of aggregates. Such materials are defined as wastes in a quarry setting when no market currently exists for them. However, unlike many other wastes, they are generally inert and non-hazardous. Most wastes arising from the excavation and processing operations (as compared to stripping of superficial materials or removal of intercalated layers of clay) comprise material that is too fine for the required quarry products. The term quarry fines is often used, but it can have a variety of meanings, and not all quarry fines are waste.

They can be considered to have a secondary environmental footprint in the sense that the unwanted material that cannot be utilised directly in progressive quarry restoration will usually have to be stockpiled or removed, with the attendant problems of dust, visual impact, transport and energy issues from re-handling. However, quarry waste also represents a significant amount of wasted energy (unnecessary breakage by blast or crusher) and an untapped resource which both have implications for sustainability. The minimisation of quarry fines is perceived as essential in order to achieve resource efficiency, environmental protection and optimisation of the quarrying process.

The amount of waste is governed by the geology, nature of the rock, product specifications, extraction and production processes, and to some extent its location with respect to potential markets and market economics. It can comprise up to 15 to 20% of the excavated rock; and at some sites it may exceed 50% of the excavated rock following downstream processing.

A number of ALSF projects aimed to address the key issues, seen as:

- improving aggregate reserve definition to better match the raw materials with the desired product;
- assessing extraction and processing methods that seek to maximise the production of primary aggregate products and minimise non-saleable products (including silt, fines and clays) and energy consumption;
- considering ways of making economic use of material that is currently considered waste.

The utilisation of quarry fines is seen as a way to minimise the accumulation of unwanted material and at the same time to maximise resource use and efficiency. Utilisation opportunities for quarry fines are identified by the end user, when fit-for-purpose criteria become available that allows their use.

A common limiting factor on the utilisation of fines is the distance from the source to the potential use. Also, the exact quantities and characteristics of fines are often unclear and the application of the Aggregates Levy to quarry fines is another disincentive to further usage.

However, there are many current and potential uses for quarry fines, including unbound applications (e.g. compost, artificial soils, remediation, site restoration, landscaping, road pavements, embankment construction, landfill capping, filler applications, manufactured sand, cement making, green roofs, straw and clay blocks) and bound applications (e.g. concrete, hydraulically bound mixtures, manufactured aggregates, ceramic products, asphalt pavement, bituminous blocks, synthetic rock, kerbs, fibre reinforced pre-cast units and grout products).

ALSF review reports

There are two review reports of ALSF research, development, review and dissemination projects which cover this subject area.

- The report Sustainable Utilisation of Quarry by-Products, by Evaggelia Petavratzi (Scott Wilson), has summarised recent projects that have investigated the application of novel or existing processes to enhance the use and value of the potentially non-saleable product streams.
- The other, Optimising the Efficiency of Primary Aggregate Production (by Ian Lowndes of Nottingham University and Kip Jeffrey of the University of Leicester) reviews the projects and research which have considered the challenge of reducing quarry waste, principally quarry fines.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

www.goodquarry.com contains a major section, which is the output of one of the ALSF projects concerning minimising waste, which includes a helpful overview of the issues.

Other sources of information can be found in the bibliography accompanying this overview report.

3 MANAGEMENT & MITIGATION OF THE ENVIRONMENTAL FOOTPRINT OF THE SUPPLY CHAIN FOR LAND-WON AGGREGATES

Chapter 3 comprises seven sections. In sections 3.1 to 3.5, the elements of the supply chain (illustrated in Figure 2) for land-won aggregates are described in turn and the way in which environmental footprint can be characterised, managed and mitigated are described, having regard to differences of emphasis at successive quarry life-cycle phases. Section 3.6 reviews ALSF projects and project elements dealing with the management of health and safety and the relationship of this to management of the environmental footprint of the supply chain. Section 3.7 examines the importance of stakeholder engagement to managing and mitigating the environmental footprint of the supply chain for land-won aggregates. The general structure of and framework for this chapter is illustrated schematically in Figure 5 below.

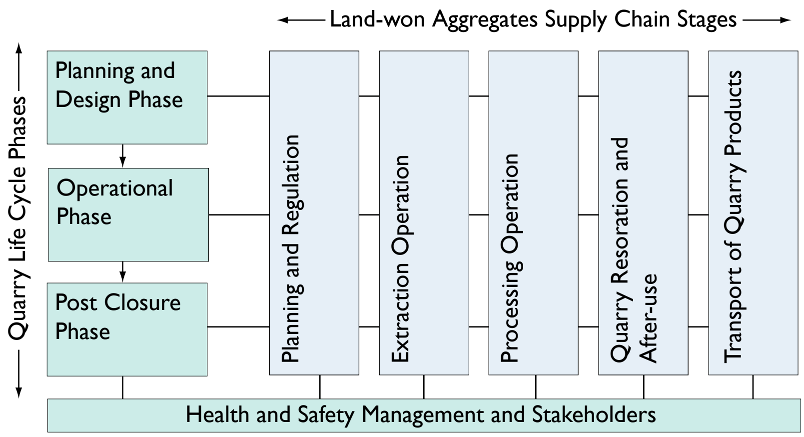

Figure 5 Framework for considering the environmental footprint of the supply chain and key considerations

Characterising the environmental footprint (Figure 1) associated with any element of the supply chain for land-won aggregates supply (Figure 2) requires different approaches at different phases in the life-cycle of a quarry: planning and design phase, operational phase, and post closure phase. The activities that are relevant in relation to the characterisation of the environmental footprint at each of these phases, and the outcomes and objectives of this process, are summarised in Figure 6 (the essentially iterative nature of the activities relevant at each stage is indicated by the use of double headed arrows in the figure).

Where there are likely to be significant environmental effects, a quarry application will normally be accompanied by an Environmental Statement (ES). An ES results from the formal process known as Environmental Impact Assessment (EIA), by which information on all potential environmental effects is collated, evaluated and presented. An ES provides a basis for consultation, and enables decision makers to weigh up whether adverse environmental effects can be mitigated sufficiently to justify the working of the site. This is a process whereby the existing 'environmental footprint' of a site is characterised (baseline studies) and the temporary and permanent environmental footprints of operating the quarry are predicted. EIA is central to the quarry design process in order to meet the key environmental objectives of the planning and design phase of the quarry life-cycle: i.e. minimum anticipated temporary and permanent adverse environmental effects. In the operational and post-closure phases of the quarry life-cycle, the emphasis shifts from prediction of environmental effects (and design of management and mitigation approaches to limit adverse effects) to monitoring and management of effects within a legal and planning framework.

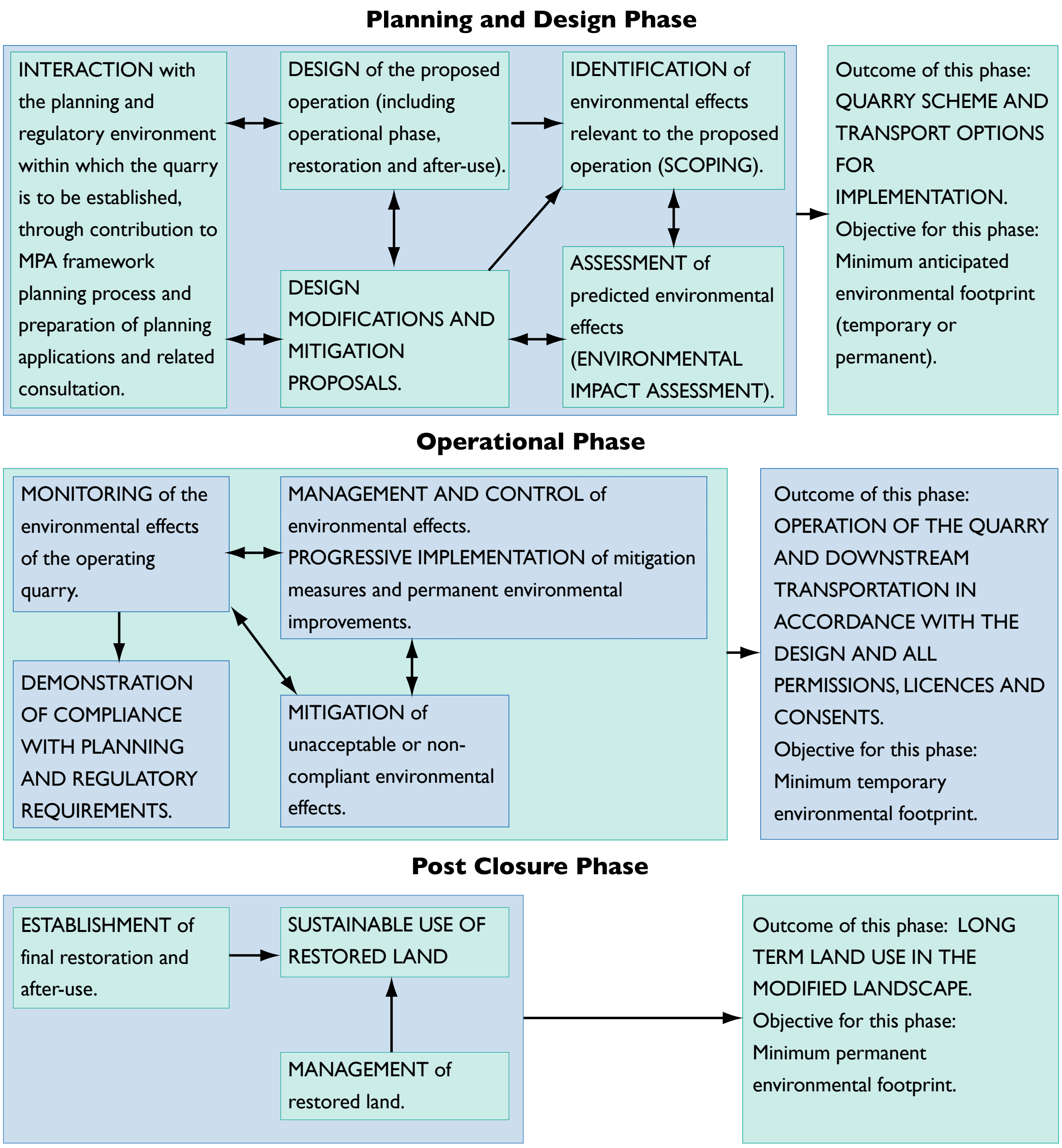

Figure 6: Lifecycle phases relevant to the characterisation and management of environmental footprint

3.1 PLANNING AND REGULATION

Table 3.1 summarises the various activities relevant to planning and regulation that affect the environmental footprint for this element of the quarry supply chain.

Supply Chain Element	Relevant Activites	Context and Considerations
PLANNING + REGULATION	Obtaining planning permission for aggregate quarries	■ Wider planning context and site selection ■ National policy ■ Regional Aggregate Working Parties (RAWPS) and land-bank requirements ■ County/regional policy and site allocations ■ Mineral safeguarding ■ Identification of preferred sites in minerals local plan ■ Site specific matters ■ Quarry design and associated design risk assessment ■ Environmental Impact Assessment ■ Licence and permit applications (abstraction, discharge, waste management/PPC) ■ Legal agreements (section 106) ■ Stakeholder consultations (pre and post application)
	Compliance with regulatory framework and best practice	■ Health & Safety (especially Quarries Regulations 1999, regulations relevant to transport safety) ■ Environmental regulations and law (control of pollution, environmental health) ■ Building codes and demand for responsible sourcing of primary and secondary land-won aggregates (influence on market) ■ Audits and strategies for reducing carbon footprint of aggregate production and transport

Table 3.1 Activities/issues relevant to management and mitigation of environmental footprint through planning and regulation

The planning and regulation of quarries during and after operations is paramount; such planning and regulation aims to ensure that quarries are controlled, safe, defined, time-limited, socially and environmentally responsible and restored to a positive after-use. They ensure that quarries are located in appropriate places and that valuable natural resources are not squandered or sterilised.

Planning is controlled by national policy. Regional and local government applies such policy by way of Frameworks and Documents (which are replacing Structure, Local and Mineral and Waste Plans). National policy also imposes the requirement (beyond certain thresholds) for formal Environmental Assessment (EA) of quarries and extensions. Such EA provides the social and environmental baseline data and predicted impacts by which the environmental footprint of quarries, product processing and transport may be reduced. Quarry planning, assessment and design allows for the activities and issues in Table 1 to be undertaken or addressed so that social and environmental impacts are minimised, opportunities for social and environmental gain are maximised and the whole process from inception to restoration management is safe, efficient and part of an applied holistic approach.

Planning and regulation also affect the transport of quarry products and the markets for aggregates through building codes and aggregate specifications. These aspects are beyond the scope of the ALSF review process of which this report is an overview.

Table 3.2 and the text that follows it describes the relevance of each of the environmental footprint elements to planning and regulation throughout the quarry life-cycle.

	PLANNING AND DESIGN PHASE	OPERATIONAL PHASE	POST CLOSURE PHASE
Water	H	H	M
Dust, noise and vibration	H	H	N
Transport	H	H	N
Archaeology	H	H	N
Biodiversity	H	H	M
Geodiversity	H	H	M
Visual & landscape character	H	M	M
Sustainable use of energy, carbon footprint	H	M	L
Sustainable use of quarry wastes and by-products	H	M	L

H Highly relevant at this phase of the quarry life-cycle – a major focus or driver for design/modelling, compliance monitoring or implementation.

M Of medium relevance at this phase of the quarry life-cycle –part of a planned and managed system based on a whole life-cycle design.

L Of low relevance at this phase of the quarry life-cycle.

N Not relevant at this phase of the quarry life-cycle.

Table 3.2 Relevance of environmental footprint elements to planning and regulation throughout the quarry lifecycle.

During the planning and design phase of the quarry life-cycle, the environmental footprint elements are all highly relevant both in the site specific activity of designing an operation (and its associated environmental, safety and economic impact and risk assessments) and in regional spatial planning, which gives rise to preferred and 'no go' areas for extraction, largely influenced by environmental issues.

Once planning permission has been granted, the focus during the operational phase shifts to compliance with the conditions attached to the planning permission and a range of licences and regulations, and the meeting of obligations under any legal agreements.

During the post closure phase of the quarry life-cycle, there may be remaining obligations under legal (usually Section 106 agreements) which are likely to relate to of the restored site including management of the site and access arrangements.

ALSF review reports

- ALSF research, development, review and dissemination projects concerned with planning and regulation have been reviewed by E. Steadman, T. Coleman and A.G. Gunn (BGS), C. Fry of AEA, and R. Greenwood (TRL) in 2007: Sustainable Provision of Aggregates: Assessment and Planning.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

www.bgs.ac.uk/Planning4Minerals contains useful background information on the planning system in the UK and www.goodquarry.com contains descriptions and links to all the relevant government policy statements and guidance.

3.2 EXTRACTION OPERATION

Table 3.3 summarises the various activities and elements relevant to the extraction operation that affect the environmental footprint of this stage of the quarry supply chain.

Supply Chain Element	Relevant Activities	Context and Considerations
Extraction Operation	Assess and prove reserves	■ Site selection ■ Resource evaluation (including safety and economic evaluations) ■ Reserve definition (measured, inferred, proven) ■ Planning approval
	Excavation and associated temporary storage of quarry waste and by-products	■ Excavation geometry (e.g. depth, working limits, advancing and final face and bench geometry and stability) ■ Tip and lagoon geometry (e.g. location, height, slopes ■ Primary breakage requirements (blasting/ripping) ■ Quality control (e.g. selective quarrying, phasing, blending, homogenising) ■ Compliance with health and safety regulation and legislation ■ Advance works (e.g. soil stripping and storage, archaeology, habitat protection, translocation of protected species) ■ Progressive restoration ■ Monitoring of environmental effects and compliance monitoring (e.g. noise, dust, vibration, water quality, quantity and effect on nearby abstractions) ■ Stakeholder engagement (e.g. neighbours, liaison groups, planners, regulators, special interest groups, workforce)
	On-site haulage	■ Methods (e.g. trucks, conveyors) ■ Routes (designed to balance efficient operation, safety and minimum environmental effects) ■ Safety (safe use of mobile plant and safe design and use of haul routes) ■ Monitoring of environmental effects and compliance monitoring

Table 3.3 Elements and activities/issues relevant to management and mitigation of environmental footprint of the extraction operation

As described in A Quarry Design Handbook (SAMP3.E2), quarry design is the context for ensuring that an essential balance is achieved in quarry operations throughout their life-cycle between limiting environmental impact, ensuring safety and operational efficiency and meeting the operator's commercial objectives (see also Figure 4 and the introduction to Chapter 2). A successful quarry design is one that is based on reliable investigation, assessment and analysis and plans an operation to achieve this balance throughout the quarry life-cycle, from site selection to closure and after-use. A further measure of success is that the design leads to implementation that does not require major amendment to overcome 'unforeseen' geological, environmental or operational difficulties and is sufficiently flexible to adapt to market and other commercial pressures.

Table 3.4 and the text that follows it describe the relevance of each of the environmental footprint elements to the extraction operation throughout the quarry life-cycle.

	PLANNING AND DESIGN PHASE	OPERATIONAL PHASE	POST CLOSURE PHASE
Water	H	M	M/H
Dust, noise and vibration	H	M	N
Transport	H	M	N
Archaeology	H	M	M/H
Biodiversity	H	M	M/H
Geodiversity	H	M	M/H
Visual & landscape character	H	M	M/H
Sustainable use of energy, carbon footprint	H	H	L/M/H
Sustainable use of quarry wastes and by-products	H	H	L/M/H

H Highly relevant to the extraction operation at this phase of the quarry life-cycle – a major focus or driver for design/modelling, compliance monitoring or implementation.

M Of medium relevance to the extraction operation at this phase of the quarry life-cycle –part of a planned and managed system based on a whole life-cycle design.

L Of low relevance to the extraction operation at this phase of the quarry life-cycle.

N Not relevant to the extraction operation at this phase of the quarry life-cycle.

Table 3.4 Relevance of environmental footprint elements to the extraction operation throughout the quarry lifecycle.

The principal activity relating to the extraction operation at the planning and design phase is the design of the operation itself. The objective of this design effort is normally on getting planning permission and all the environmental footprint elements are highly relevant within the frameworks of environmental impact assessment, safe and efficient working, and demonstrating sustainability.

During the operational phase, the focus shifts to monitoring and management of environmental footprint elements. With the exception of sustainable use of energy and quarry wastes and by-products, these have been ascribed 'medium relevance' in Table 4. This is because the quarry design process should have given rise to schemes and procedures that can be implemented with predictable environmental effects that can be monitored and compliance demonstrated. Therefore, providing the design process has been successful, there should be no need for ongoing investigation, design and implementation of remedial or mitigation measures relating to the first seven footprint elements. The two 'sustainability elements', however, give rise to ongoing opportunities for improvement throughout the operational phase (always bearing in mind that an increase in beneficial use of by-products as secondary aggregates could have a detrimental effect on permitted quarry restoration, which may be dependent on such materials).

During the post closure phase it is obvious that those elements of environmental footprint that relate directly to the extraction operation itself (i.e. dust, noise, vibration and transport) will have no relevance. In relation to any application for a non 'green field' development at the site, the impact of the development on water resources, heritage, biodiversity, and geodiversity of the restored site and its associated post-closure development will be of high relevance. For a site restored to agricultural use (or left as a site of biodiversity or geodiversity interest), these would still be important but would have medium relevance assuming that the design and environmental assessment had anticipated the post-closure environmental footprint of these 'passive' after-uses. The relevance of the sustainability elements will depend on the post-closure proposals for the site. If the landform is to be left untouched, for example, sustainable use of quarry wastes and by-products remaining at the site as restoration materials will have no relevance given that these materials will not be 'used'. If a post-closure development proposal includes earthworks to modify a restored quarry site, then clearly this aspect of environmental footprint becomes relevant again. Similarly, sustainable use of energy and carbon footprint will be strongly dependent on the use to which the site is to be put post-closure.

ALSF review reports

- ALSF research, development, review and dissemination projects concerned with the extraction operation have been reviewed by Ian Lowndes (Nottingham University) and Kip Jeffrey and (University of Leicester) in 2007: Optimising the Efficiency of Primary Aggregate Production. This report also reviews ALSF projects relevant to the processing operation.
- In addition, the sections of the review Creating Environmental Improvements through Restoration that deal with progressive restoration and the need for the extraction operation to be designed and implemented with final restoration objectives firmly in view at all times is relevant.

Further sources of information

The Quarry Design Handbook (SAMP3.E2) describes a staged and iterative approach to designing extraction operations. Extensive information www.goodquarry.com includes a range of sections describing individual elements of the extraction operation. www.goodquarry.com which was used to disseminate the output of some of the projects covered by the review report on optimising the efficiency of primary aggregate production.

3.3 PROCESSING OPERATION

Table 3.5 summarises the various activities and elements relevant to the processing operation that affect the environmental footprint of this stage of the quarry supply chain.

Supply Chain Element	Relevant Activities	Context and Considerations
Processing Operation	Crushing and screening	■ Type ■ Mobile/fixed ■ Location (out of pit, in pit, combinations)
	Washing	■ Water source (e.g. groundwater or surface water, abstraction licence requirements) ■ Method ■ Silt disposal ■ Water disposal ■ Monitoring of environmental effects and compliance monitoring
	Homogenising/ blending	■ Method (selective excavation, stockpiles etc) ■ Timing (before/after processing)
	Product storage	■ Stockpiles ■ Hoppers/silos
	Non-saleable materials	■ Storage ■ Disposal ■ Use as restoration materials in accordance with quarry design and planning permission

Table 3.5 Elements and activities/issues relevant to management and mitigation of environmental footprint of the processing operation

In common with the extraction operation, the design, implementation and management of the processing operation and its environmental effects are intimately related to the overall quarry design process. The processing methods selected at any quarry will be influenced by a range of considerations relating to the properties of the mineral and the requirements of the market. For crushed rock, selection of crushing and screening plant is a critical determining factor in the resulting product mix and sometimes the quality of the products (e.g. in terms of particle shape and grading). The proportion of crushed and/or screened material that may fall into the category 'quarry waste or by-products' (and the properties of that material) is strongly influenced by the type of crusher and/or screening circuit employed (with or without washing). Different processing solutions can give rise to widely differing environmental effects arising from:

- The number and specification of crushers and screens;
- The location of crushers, screens and washing facilities within the quarry site;
- Whether plant is fixed, mobile or a combination of the two;
- The amount of short and long term stockpiling required of quarry products, quarry by-products and quarry waste;
- Whether the product will be washed and, if so, the source of water; and
- Abstraction, storage and discharge arrangements for water and silt arising from processing operations.

There can be a tension between optimising the commercial attractiveness of the product mix through an optimal processing solution and selecting processing and associated facilities that will minimise the environmental footprint of aggregate processing.

Table 3.6 and the text that follows it describe the relevance of each of the environmental footprint elements to the processing operation throughout the quarry life-cycle.

	PLANNING AND DESIGN PHASE	OPERATIONAL PHASE	POST CLOSURE PHASE
Water	H	M/H	M
Dust, noise and vibration	H	M/H	N
Transport	H	M/H	N
Archaeology	H	M	N
Biodiversity	H	M	M
Geodiversity	H	M	M
Visual & landscape character	H	M	M
Sustainable use of energy, carbon footprint	H	H	M
Sustainable use of quarry wastes and by-products	H	H	L/M/H

H Highly relevant to the processing operation at this phase of the quarry life-cycle – a major focus or driver for design/modelling, compliance monitoring or implementation.

M Of medium relevance to the processing operation at this phase of the quarry life-cycle –part of a planned and managed system based on a whole life-cycle design.

L Of low relevance to the processing operation at this phase of the quarry life-cycle.

N Not relevant to the processing operation at this phase of the quarry life-cycle.

Table 3.6 Relevance of environmental footprint elements to the processing operation throughout the quarry lifecycle.

At the planning and design phase of the quarry life-cycle, all environmental footprint elements are highly relevant to overall quarry design. Given the wide variation in processing solutions and the environmental effects to which they give rise (including their effect on overall site layouts and the excavation operation) it is essential that planning and design relating to the processing operation is completely integrated with the overall design of the operation.

At the operational phase most of the environmental footprint elements become part of a planned and managed system based on a whole life-cycle design, hence they are generally of 'medium relevance' during this phase. However, water, dust, noise, vibration, off-site transport, and visual and landscape character may need some further attention in the light of modifications that may be made to processing facilities to improve an operational or environmental aspect. For example, addition of a tertiary crusher to convert material that would otherwise be waste quarry fines (requiring storage on site before being incorporated into quarry restoration) to input raw material for concrete blocks. This will have a knock on consequences for environmental effects as well as sustainable use of quarry wastes and by-products. There could also be effects on the restoration scheme, given the change in the balance of quarry arisings that will remain on site. Even without major modifications for commercial and/or environmental improvement, there are ongoing opportunities in relation to sustainable use of energy and quarry wastes through implementation of changes to the processing facilities at a quarry.

At the post-closure phase of the quarry life-cycle, the only potentially highly relevant environmental footprint element is 'sustainable use of quarry wastes and by-products' and that is only relevant if the after-use involves the re-excavation of quarry wastes and by-products used in restoration (or construction using these materials as foundations). Elements that could relate to the restoration or after-use of sites used for the processing operation are generally of medium relevance on the basis that the restoration scheme will have been part of the whole life-cycle design for the quarry.

ALSF review reports

There are two reviews of ALSF research, development, review and dissemination projects which cover this subject area.

- The report Sustainable Utilisation of Quarry by-Products (by Evaggelia Petavratzi of Scott Wilson) has summarised recent projects that have investigated the application of novel or existing processes to enhance the use and value of the potentially non-saleable product streams.
- The other, Optimising the Efficiency of Primary Aggregate Production (by Ian Lowndes of Nottingham University and Kip Jeffrey of the University of Leicester) reviews the projects and research which have considered the challenge of reducing quarry waste, principally quarry fines both through excavation and processing.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

Extensive information is available on www.goodquarry.com, which was used to disseminate the output of some of the projects covered by the review reports relevant to processing.

3.4 QUARRY RESTORATION AND AFTER-USE

Table 3.7 summarises the various activities and elements relevant to quarry restoration and after-use that affect the environmental footprint of this stage of the quarry supply chain.

Supply Chain Stage	Elements	Activities/Issues
Quarry restoration and After-Use	Landform	■ Context (i.e. geological, geomorphological and social setting) ■ Materials (i.e. stability of final excavated and fill slopes, suitability of materials in foundations) ■ Methods (e.g. landform replication, restoration of pre-existing ground levels, restoration to water, hidden or disguised landforms) ■ Timing (progressive/on completion)
	Land cover	■ Context (i.e. geodiversity, biodiversity and landscape character appropriate to the site in its surrounding area) ■ Materials (i.e. suitability and availability of materials to support vegetation cover and other after-uses for which the landform is appropriate) ■ Methods ■ Timing (progressive/on completion)
	Land-use	■ Context (i.e. geological, geomorphological, biological and social setting) ■ Options (based on context and regional spatial planning)

Table 3.7 Elements and activities/issues relevant to management and mitigation of environmental footprint of quarry restoration and after-use

Quarrying inevitably involves the temporary disturbance of and permanent change to land. Minimising land-take, even for short periods, can reduce the environmental footprint. However, in many cases, well-considered use of an expanded footprint can allow for the better integration of extraction (and related processing), restored landforms, mitigation measures and after-uses. Ill-considered planning, assessment, design, construction and management of restoration can lead to damage or waste of energy, resources and opportunities. Successful designs for quarries and related facilities will, as part of the design solution, incorporate mitigation measures to reduce to a minimum the potential for negative environmental effects throughout the life-cycle of the quarry and maximise the opportunities for environmental benefits (ideally realised progressively). These mitigation measures should be seen as part of the progressive and final restoration. Whilst quarries are required to have approved restoration schemes from commencement, it is important that final restoration uses and solutions are re-visited regularly throughout the life-cycle to reflect the changing needs of society, and the knock-on effects of changes to the extraction and/or processing operation (e.g. to address sustainability or environmental footprint issues) that may influence the exact amounts of available restoration materials or the geometry of the site. Restoration to any after-use or mixed after-uses should not be seen as a final act, but a progressive objective which returns land to a positive use as soon as possible. All restoration schemes and after-uses require on-going monitoring and management to fulfil the long-term objectives.

For some quarries (notably hard-rock operation where the quarry will be progressively deepened within its maximum excavation limits throughout its operational life) this may be restricted to restoration of site perimeters, through establishment of permanent screening measures, or establishment of final landforms and reinstated vegetation at access points, out-of pit spoil mounds etc. For sites where the final excavated landform (with or without backfilling) can be achieved progressively (e.g. sand and gravel sites or hard-rock sites worked in a number of phases each at full depth), final restoration of the quarry excavation area and establishment of some after-uses can be achieved progressively.

Table 3.8 and the text that follows it describes the relevance of each of the environmental footprint elements to quarry restoration and after-use throughout the quarry life-cycle.

	PLANNING AND DESIGN PHASE	OPERATIONAL PHASE	POST CLOSURE PHASE
Water	H	M	H
Dust, noise and vibration	H	M	N
Transport	H	M	N
Archaeology	H	M	L/M/H
Biodiversity	H	M	H
Geodiversity	H	M	H
Visual & landscape character	H	M	H
Sustainable use of energy, carbon footprint	H	L/M	L/M/H
Sustainable use of quarry wastes and by-products	H	L/M/H	L/M/H

H Highly relevant to quarry restoration and after-use at this phase of the quarry life-cycle – a major focus or driver for design/ modelling, compliance monitoring or implementation.

M Of medium relevance to quarry restoration and after-use at this phase of the quarry life-cycle –part of a planned and managed system based on a whole life-cycle design.

L Of low relevance to quarry restoration and after-use at this phase of the quarry life-cycle.

N Not relevant to quarry restoration and after-use at this phase of the quarry life-cycle.

Table 3.8 Relevance of environmental footprint elements to the quarry restoration and after-use throughout the quarry lifecycle.

During the planning and design phase, all environmental footprint elements are highly relevant, being essential considerations for the design process, which includes the design of restoration and after-use. Restoration schemes always include permanent elements that are achieved progressively during the operational phase of the quarry life-cycle, as described above. Restoration schemes often also include temporary elements (especially screening) to mitigate the environmental effects of the excavation and processing activities. Ideally both permanent and temporary restoration elements during the operational phase of the quarry life-cycle will be implemented according to a plan established through the quarry design process – they are therefore ascribed 'medium relevance' above. The exception to this is sustainable use of quarry wastes and by-products which be of higher relevance if changes are made to processing or excavation which influence the availability of restoration materials.

During the post-closure phase, final restoration of the site is achieved and the permanent after-use of the site is established. If built development or recreational use is part of the after-use, then additional permissions will be required and, with the exception of dust, noise, vibration and transport of quarry products, environmental footprint elements become relevant once again in limiting the permanent environmental footprint of the quarry site.

ALSF review reports

- ALSF research, development, review and dissemination projects concerned with restoration and after-use have been reviewed by David Jarvis and colleagues at David Jarvis Associates Ltd and John Cripps and colleagues at the University of Sheffield in 2007: Creating Environmental Improvements through Restoration.
- Also relevant to restoration and after-use are the review reports concerned with biodiversity and geodiversity, both of which are important elements of restoration design.

Other sources of information

Restoration

Further background information is available from www.mineralsandnature.org.uk and www.bgs.ac.uk/

Planning4Minerals. The website www.goodquarry.com has an extensive section on restoration, with many examples and links to a variety of successful schemes.

Biodiversity

The After Minerals website (www.afterminerals.com) contains excellent case studies and advice on creating a range of habitats, as well as information on the habitat potential of every active mineral site in England. The Post-Mining Alliance (hosted by the Eden Project) also seeks to pool resources and case studies on aspects of post mining regeneration, including biodiversity (www.postmining.org).
Further background information is available from www.mineralsandnature.org.uk, www.goodquarry.com and www.bgs.ac.uk/Planning4Minerals.

Geodiversity

Natural England's website has a section on geological conservation at www.naturalengland.org.uk/conservation/geology/default.htm and a number of the ALSF projects have produced websites. Natural England has also produced two very helpful documents on geodiversity (Natural Foundations: Geodiversity for people, places and nature) and geoconservation (Geological Conservation: A guide to good practice) which are both available as free downloads from their website.

Detailed background information is also available from www.goodquarry.com.

3.5 TRANSPORT OF QUARRY PRODUCTS

Table 3.9 summarises the various activities and elements relevant to the transport of quarry products that affect the environmental footprint of this stage of the quarry supply chain.

Supply Chain Stage	Elements	Activities/Issues
TRANSPORT OF QUARRY PRODUCTS	Method	■ Type (train, truck, boat) ■ Routes ■ Distances
	Despatch arrangements	■ Loading ■ Site access

Table 3.9 Elements and activities/issues relevant to management and mitigation of environmental footprint of transport of quarry products

There is a general description on the environmental effects of the transport of quarry products in Chapter 2 of this overview report (2.5).

Table 3.10 and the text that follows it describes the relevance of each of the environmental footprint elements to transport of quarry products throughout the quarry life-cycle.

	PLANNING AND DESIGN PHASE	OPERATIONAL PHASE	POST CLOSURE PHASE
Water	M	M	N
Dust, noise and vibration	H	M	N
Transport	H	M	N
Archaeology/Heritage	H	M	N
Biodiversity	M	M	N
Geodiversity	N	M	N
Visual & landscape character	M	M	N
Sustainable use of energy, carbon footprint	H	H	N
Sustainable use of quarry wastes and by-products	M	H	N

H Highly relevant to transport of quarry products at this phase of the quarry life-cycle – a major focus or driver for design/modelling, compliance monitoring or implementation.

M Of medium relevance to transport of quarry products at this phase of the quarry life-cycle –part of a planned and managed system based on a whole life-cycle design.

L Of low relevance to transport of quarry products at this phase of the quarry life-cycle.

N Not relevant to transport of quarry products at this phase of the quarry life-cycle.

Table 3.10 Relevance of environmental footprint elements to the transport of quarry products throughout the quarry lifecycle.

During the planning and design phase of the quarry life-cycle, the focus is on demonstrating that the transport options (especially lorry traffic on local roads) associated with quarry proposals can be implemented without unacceptable environmental effects. This is achieved through Environmental Assessment and all associated stakeholder engagement, and within the framework of regional and local transport policies.

During the operational phase, all but the last two of the levels of relevance are shown as 'medium' given that, in common with other aspects of the supply chain, quarry transport issues should be part of a planned and managed system during this phase. The sustainability footprint elements, however, are likely to have much higher relevance during this phase, given initiatives to improve sustainable use of energy (including reduction of carbon footprint) as well as the expected general increase in the proportion of quarry wastes and by-products that can be taken off-site as secondary aggregates or for other beneficial uses.

There is no relevance of transport of quarry products to the environmental footprint in the post-closure phase since, by definition, the production of aggregates and other quarry products would, by then, have ceased.

ALSF review reports

- ALSF research, development, review and dissemination projects on transporting aggregate have been reviewed by Chris Fry of AEA and Matthew Wayman of C4S in 2007: Reducing the Environmental Effect of Transporting Aggregate.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

Information on the Safe and Fuel Efficient Driving programme can be found at www.safedaggregates.org.uk. www.bgs.ac.uk/Planning4Minerals gives a useful introduction to the transport issues, and www.goodquarry.com describes a number of mitigation measures which will help to reduce the impact of transport on the local environment.

3.6 HEALTH AND SAFETY MANAGEMENT THROUGHOUT THE SUPPLY CHAIN

Table 3.11 summarises the important health and safety issues relevant to the supply chain for land won aggregates and their relevance to management and mitigation of the environmental footprint throughout the quarry life-cycle.

Health & Safety Issue	Relevance to Management & Mitigation of Environmental Footprint
PLANNING AND DESIGN PHASE Design of the extraction and processing operations, meeting the requirements of the Quarries Regulations 1999. Securing a planning permission based on the quarry design and obtaining all necessary regulatory permits and licences. Design of a restoration scheme that ensures the safety of people and structures involved in its after-use. Design of interim faces, final faces, tip slopes and a restoration scheme ensuring support for third party land throughout the quarry life-cycle. Planning the transport operation incorporating a safe driving culture, choosing routes that minimise danger to other road users, and selecting vehicles that ensure the health and safety of drivers.	Quarry designs that meet all safety and efficiency criteria relevant to excavation, processing and restoration (throughout the quarry life-cycle) it may not necessarily reduce to minimum possible environmental footprint. ■ Emissions of noise, dust, vibration, and CO_2 are likely to be significantly mitigated through design of safe, efficient and secure quarry operations. ■ Minimising anticipated environmental effects of quarry transport through planning and design will normally be entirely compatible with ensuring that the transport operation is inherently safe. ■ Reducing to a minimum adverse effects on, and maximising potential benefits to, the water environment, biodiversity, geodiversity, archaeology & heritage, visual amenity, and landscape character may require several iterations of a quarry design (within the context of EIA). For each of these iterations, design risk assessment should highlight any conflicts, which need to be resolved to minimise environmental footprint whilst maintaining safe and secure operations. ■ Anticipation of the amount of quarry waste that will be generated by the operations is an important element of characterising the environmental footprint because it affects the size and nature of temporary storage arrangements (including screening structures) that are needed, as well as restoration landforms that can be created and their environmental effects. This is another area where an iterative approach is essential, considering the environmental footprint arising from the temporary and permanent placement of these materials alongside its stability and security.
OPERATIONAL PHASE Compliance with the Quarries Regulations 1999 so as to ensure safe working environments in the extraction and processing operations at all times Monitoring and management of all excavated slopes, accumulations of quarry waste (in tips, screening structures or placed progressively in restoration), soils and stockpiles of products or by-products to ensure their stability. Compliance with planning conditions and regulatory licences and permits that have implications for safe levels of emission of dust, noise, vibration or water. Operation and management of the transport operation incorporating a safe driving culture, choosing routes that minimise danger to other road users, and selecting vehicles that ensure the health and safety of drivers.	During the operational phase of a quarry, the permitted scheme developed during the planning and design phase (based substantially on EIA and compliant with the Quarries Regulations 1999) will be implemented. All aspects of environmental footprint need to be monitored at this stage and new mitigation measures or changes to operational details may be required to address any unforeseen adverse environmental effects, or to improve environmental performance. Any such changes should be subject to a robust design risk assessment approach to ensure that safety and efficiency are not compromised.
POST CLOSURE PHASE Creation of final restoration landform (especially final slopes or faces) that is secure in relation to the intended after-use and management plan.	The key environmental issues relating to the post-closure phase of a quarry are: visual impact, landscape character, long term effects on the water environment, biodiversity and geodiversity. Effective quarry design anticipates the overall environmental footprint of the restored quarry and its after-use, but is necessarily based on assumptions made at the planning and design phase. Changes to final excavated slope geometry may arise during the operational phase. Similarly, there may be reductions in the amount of restoration materials available arising through sales of by-products that were not anticipated at the planning and design phase or increases arising from off-site disposal or sale being greater than anticipated. Such changes can give rise to significant differences in the final restoration scheme from the original design, especially in quarries that have been operational for many years. As the operational phase continues, a process of ongoing design and operational risk assessment should allow amendments to the restoration scheme that balance long term environmental footprint against long term security and safety of the restoration slopes and landforms.

Table 3.11 Health and safety issues relevant to the management of environmental footprint

ALSF review reports

A review specifically on health and safety projects was not carried out as part of the ALSF review process, as this did not form a separate theme within the MIST/SAMP funding. However, several aspects of this subject were included in a number of projects, some of which were covered in the thematic reviews.

Other sources of information

The following ALSF projects specifically relate to health and safety:
CSM, University of Exeter, MA/4/4/006:- Improving the standards of health & safety management in the quarrying sector. Also see website www.quarrysafe.co.uk
QPA, MA/5/2/009:- Cutting work-related accidents, dangerous occurrences and occupational ill health, by sharing best practice. Also see website: www.safequarry.com
CSM, University of Exeter, MA/6/2/002:- Improving the Safety of Lone Workers in Quarrying Operations through Behavioural Safety Interventions
QPA, MA/6/2/015:- Extending effective communication and sharing of knowledge to enhance the health and safety of quarry workers, visitors and the public. An extension project for the www.safequarry.com free web facility requested by quarry operators

In addition A quarry design handbook (SAMP2.E3) has a major section (Part II) dealing with achieving the essential balance through quarry design between safety, environmental footprint and commercial objectives through iterative approaches and operational, commercial and environmental risk assessment. Secure and sustainable final slopes for SME aggregate quarries (SAMP1.020) describes the need for, and evaluates a wide range of methods of obtaining, secure and sustainable final slopes in quarries. This highlights the need for the design of engineering and restoration approaches to be advanced alongside assessment of landscape and visual effects.

www.goodquarry.com includes a large amount of information relevant to safety aspects of quarry design and management.

Health and Safety Commission, 1999. Health and safety at quarries: Quarries Regulations 1999 - Approved Code of Practice (HSE Books, HMSO 1999) provides practical guidance with respect to the requirements of the Quarries Regulations 1999.

3.7 STAKEHOLDER ENGAGEMENT AND THE ENVIRONMENTAL FOOTPRINT THROUGHOUT THE SUPPLY CHAIN

Table 3.12 (overleaf) summarises the various stakeholder groups that may be concerned and involved throughout the supply chain for land-won aggregates and indicates the range of ways in which they may be engaged so as to contribute to management and reduction of the environmental footprint.

Supply Chain Element	Stakeholder Group	Stakeholder Engagement Approaches
Planning and Regulation	Mineral Planning Authority Local Authorities (Parish to Region) Non-statutory Consultees Public Employees Landowners/neighbours	■ Public meetings ■ Public exhibitions ■ Charrette/workshops ■ Newspapers/radio/TV/ Internet ■ Leaflets
Extraction Operation	Mineral Planning Authority Local Authorities (Parish to Region) Non-statutory Consultees Public Employees Landowners/neighbours	■ Liaison groups ■ Quarry visits ■ Public exhibitions ■ Media
Processing Operation	Mineral Planning Authority Local Authorities (Parish to Region) Non-statutory Consultees Public Employees Landowners/neighbours	■ Liaison groups ■ Quarry visits ■ Public exhibitions ■ Media
Restoration and After-use	Mineral Planning Authority Local Authorities (Parish to Region) Non-statutory Consultees Public Employees Landowners/neighbours	■ Public meetings ■ Public exhibitions ■ Charrette/workshops ■ Newspapers/radio/TV/Internet ■ Leaflets ■ Liaison groups ■ Quarry visits
Transport of Quarry Products	Mineral Planning Authority Local Authorities (Parish to Region) Non-statutory Consultees Public Employees Landowners/neighbours	■ Liaison groups ■ Quarry visits ■ Public exhibitions ■ Media

Table 3.12 Stakeholder groups and approaches to engagement to reduce actual and perceived environmental footprints

Good communications between all relevant parties maximises the potential for an efficient quarry operation and restoration with minimal negative environmental effects. In addition, good communications can avoid misapprehension and conflict. Stakeholder consultation is high on the Government's agenda and is a legal requirement placed upon Local Authorities. Such consultation should be tailored to fit the stage within the process, the parties involved and the scale/nature of the operations. The quarry owner/operator and/or any consultants commonly use meetings and site visits. The quarry owner/operator and/or any consultants normally use public exhibitions, meetings, charrettes/workshops, the media, leaflet drops and quarry visits for interactive communication and consultation with the public and specific local stakeholders and groups. Once operational, such early Local Authority/public consultation may evolve into a Quarry Liaison Group which meets on a regular basis throughout the life of the quarry. Such Groups can continue the two-way flow of information, complaints and suggestions. Within stakeholder consultation, enormous scope exists for the education and dissemination of information to the public and quarrying, restoration and after-use, particularly to schoolchildren. Site visits, viewing platforms, Open Days, school projects etc involve the local community and educate the next generation in the value of quarrying and its associated problems and solutions.

Table 3.13 and the text that follows it describes the relevance of each of the environmental footprint elements to stakeholder engagement throughout the quarry life-cycle.

	PLANNING AND DESIGN PHASE	OPERATIONAL PHASE	POST CLOSURE PHASE
Water	H	H	H
Dust, noise and vibration	H	H	N
Transport	H	H	N
Archaeology	H	M	L/M/H
Biodiversity	H	H	H
Geodiversity	H	M	H
Visual & landscape character	H	M	H
Sustainable use of energy, carbon footprint	M	M	L
Sustainable use of quarry wastes and by-products	M	M	L/M/H

H Highly relevant to stakeholder engagement at this phase of the quarry life-cycle – a major focus or driver for design/modelling, compliance monitoring or implementation.

M Of medium relevance to stakeholder engagement at this phase of the quarry life-cycle –part of a planned and managed system based on a whole life-cycle design.

L Of low relevance to stakeholder engagement at this phase of the quarry life-cycle.

N Not relevant to stakeholder engagement at this phase of the quarry life-cycle.

Table 3.13 Relevance of environmental footprint elements to stakeholder engagement throughout the quarry lifecycle.

During the planning and design phase stakeholder engagement is directed towards communicating proposals to all stakeholder groups, taking into account their feedback (ranging from statutory consultations to expressions of public concern or opposition) and submitting a planning application. The input of a wide range of stakeholders is an important and increasingly valuable process in developing aggregate production proposals that reduce to a minimum the environmental footprint.

During the operational phase, the emphasis shifts to communication of monitoring results (to those stakeholders with a formal regulatory function) and liaison and general 'good neighbour' engagement with the public. Those who monitor environmental effects of quarrying need to be engaged in a positive way so that mitigation or corrective action can be implemented in the event of non-compliance. Even more important is engagement of those directly affected by the environmental effects of quarrying and liaison, community mediation and sensitive complaints handling procedures are all ways of achieving this and routes for feedback giving rise to environmental improvements.

The post-closure phase can also be an important time for stakeholder engagement in terms of community access or development of plans for commercial and recreational uses (with or without built development).

ALSF review reports

- A review specifically on stakeholder engagement was not carried out as part of the ALSF review process, although many of the projects reviewed include important sections on the importance of stakeholder engagement and ways in which this can best be achieved.
- All ALSF review reports are available at www.sustainableaggregates.com.

Other sources of information

Chapter 7 of A Quarry Design Handbook concerns engagement with and involvement of stakeholders. The project Charrettes – stakeholder consultation for the mineral industry (David Jarvis Associates, MA/5/3/005) is directly relevant to this topic.

www.goodquarry.com includes a wide range of information providing accessible introductions to many aspects of quarry operations and their environmental effects. This can be a helpful starting for members of the public who wish to understand quarrying operations.

(Footnotes)

[1] MIST = Mineral Industry Sustainable Technology Programme. SAMP = Sustainable Land-Won & Marine Dredged Aggregate Minerals Programme.

[2] noise, dust and vibration are covered in separate sections, even though they have been reviewed in a single report

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