Restoring Habitats of High Conservation Value after Quarrying

Best Practice Manual

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Executive Summary

Purpose and scope

The purpose of this Manual is to provide:

- A background to the principles of ecological restoration and how to use these appropriately in the re-creation of biodiverse habitats
- Practical guidance on plant establishment to promote habitat development.

The Manual is most relevant to hard rock quarries from which it draws its practical examples. However, the ecological principles applied are equally relevant to opencast minesites, gravel or sand pits or any uncontaminated, post-industrial land with a topsoil deficit. The Manual deals with restoration from the viewpoints of both industry and ecologists – it is intended to be equally useful to both disciplines, facilitated by a glossary of technical terms.

The Manual is designed to be used by a wide range of professionals including quarry/minesite managers, quarry vehicle operators, small operators, planning officers, non-government organizations, National Parks managers, environmental consultants, quarry plantsmen, specialist plant nurseries, tertiary students and university researchers.

Information in this Manual is based largely on a slate quarry in Wales; a European perspective is provided by further examples from a slate quarry in Spain and a dolerite quarry in Ireland. Limitations to plant establishment are common to most quarries, regardless of geographic location, particularly low soil fertility and poor water-holding capacity; both stem from a paucity of topsoil. Another common limitation is herbivory. We demonstrate generic principles to overcome these limitations; the main differences between our sites were plant species composition and the target habitat being re-created.

Layout of this Manual

This Manual is in two sections, the first is intended as a reference document to be kept in the office and deals with the framework for restoring biodiverse habitats and covers:

- the **preliminary assessments** to be made – site survey, stakeholder identification and defining target options for restoration
- the **planning** phase which includes how to decide on an appropriate target for the site and if biodiversity conservation is appropriate, how to prioritize conservation objectives; organizations from which funding may be available and project management
- frameworks for **evaluating success** discusses biological, social, economic and statutory indicators.
- Reference and Glossary sections.

The second section of the Manual is a practical guide to plant establishment for habitat creation, the format is an A5 'pocket guide' and it is intended for use in the field and covers:

- Materials handling and storage on site
- Landforming and tipping
- Soil amendments for managing nutrients and water retention
- Seed handling and record keeping
- Seeding and planting techniques for broadleaf woodland, heathland and dehesa habitat establishment
- Methods for setting up and monitoring field trials
- Aftercare management and grazing
- References and Glossary.

Key recommendations

1. A site survey establishes from the outset whether important biological and/or earth science interests exist and therefore need to be incorporated into the restoration design. It also serves to identify the key limiting factors to plant and habitat establishment. Most commonly these limitations are plant nutrient and water availability and grazing.

2. A list of stakeholders with a perceived interest in the site should be drawn up at the earliest opportunity. The list will include experts whose local knowledge can be very valuable.

3. All available options for restoration need to be considered in terms of local conservation plans, community needs, financial constraints and statutory requirements.

4. During the decision-making process, not only should the opinions of stakeholders be sought, but also their active participation in the process. An independent arbitrator may be useful in expediting the process. A cost benefit analysis at the planning stage performs the function of a 'reality check'.

5. Conservation objectives should take account of the existing, naturally established plants on site and wherever possible, these should be left undisturbed. Choices of the habitats to be re-created should favour those that would function by adding size or connectivity to existing (semi-) natural habitats nearby and be in line with local government Biodiversity Action Plans. Some areas of bare substrate or rock that allows for lichen and moss development should be retained, as these primary succession systems contribute to the overall biodiversity of the site.

6. There are a number of funding sources that can potentially assist in restoration. Long-term management of the site must also be costed during the planning phase.

7. Long-term monitoring of a re-created habitat is needed in order to assess if the plant and animal assemblages are developing in the way that was intended. Also, it is important to note the performance of target species, to act on invading noxious species and to check that the end-use is meeting the combined needs of stakeholders.

8. Sufficient land area should be set aside for the separate stockpiling of useful planting substrates and for overburden. Subsoil is very useful as a planting medium, as is finely crushed slate 'sand'; generically such material is referred to as quarry 'fines'. It is important to store fines material separately when there is little or no topsoil available; even without an organic fraction, these fines retain water and enable plant roots to develop.

9. Landforming should be sympathetic to the immediate surroundings. Loose-tipping of material is preferable to spreading and subsequently ripping a prepared area for planting. Loose-tipping creates a range of microhabitats catering for dry and wet-tolerant species and so increases the biodiversity potential.

10. In the early years of vegetation establishment, an external source of plant nutrients must be added to mineral substrates (e.g. quarry fines, subsoil) for healthy plant growth until there is sufficient return of these nutrients from the leaves and roots to the soil. Some habitat types require more nutrient inputs than others do. Fertilizers can be either mineral or organic-based. Organic-based fertilizers have many advantages over mineral fertilizers – they provide a slow release of plant nutrients over a period of years, they

reduce leaching losses and the potential for downstream pollution; they improve soil water retention and promote the rapid reinstatement of the soil microbial biomass that is essential to nutrient cycling in the plant-soil system. Use of an organic fertilizer is less likely to require additional 'top-up' applications of nutrients. Local wastes or by-products can be used to produce a balanced organic fertilizer and can often be obtained at no cost.

11. It is best if seed material used for propagating plants comes from local genetic stock (local provenance); seed collected from within the quarry itself is preferable providing there is sufficient material. For large restoration programmes it is cost-effective to have a dedicated plant nursery on site, with the capacity to treat and store seed according to individual species' requirements, and propagate seedlings in polytunnels for subsequent planting out on site. A large body of site-specific knowledge is then built up over the years, provided that record keeping is strictly adhered to. This leads to improved efficiency.

12. Broadleaf woodland species are best established from one year-old seedlings in temperate climates, and need fertilizer to grow well in mineral substrates. Even species with nitrogen-fixing capability respond to fertilizer addition. Mortality is mainly restricted to the first year and can be greatly reduced by providing a water-retentive rooting medium: glacial till (subsoil at the Welsh site) worked very well. Planting in soil pockets is best for establishing trees on flat benches. On slopes of coarse blocky waste rock, gaps between the rocks must be filled with a fine rooting material to sufficient depth to connect with fines deep within the tip before seedlings can be planted; mortalities are far greater than on flat benches. Tree species palatable to sheep, like holly (*Ilex aquifolium*) , should be avoided.

13. Heathland can be readily established by translocating intact 'turf' (plants with associated peat) from an area designated for disturbance to a recipient site and it is recommended that this be practiced rather than stockpiling peat with vegetation. This method results in a good mix of heathland shrubs, whereas direct seeding tends to favour mostly heather (*Calluna, Erica spp.*). Seeding can be problematic since germination of heather is slow, spasmodic and rather unpredictable when seed become dormant. A nurse crop of a native heath grass is recommended when establishing heather from seed, to protect the small seedlings from erosion and desiccation. A small amount of fertilizer, applied at the time of seeding grass and heather on skeletal substrates of very low fertility, is beneficial.

14. Oak (*Quercus spp.)* in Spanish dehesa is best established from seed; seeds should be sown in December to maximize the time for root development before the onset of the long dry summers.

15. It is recommended that field trials are set-up to determine the best method(s) of accelerating vegetation, if natural establishment appears to be too slow for the desired restoration outcome. This, however, does cost time. Trial design must be able to address the questions that need to be answered. It is recommended that ecologists are consulted unless there is in-house expertise in setting-up trials. The amount of resources required to conduct trials should not be underestimated but in the long run, they can avoid expensive mistakes being made on a large scale. Trials also have the advantage of being a useful demonstration tool for stakeholders to appraise options and progress.

16. Monitoring the progress of trials or indeed the final restoration-planting scheme is essential. During the early years

of restoration, individual plant survival, growth and condition is recorded. In time, as the new species colonize, the monitoring increases in complexity to take account of species richness, a basic indicator of biodiversity, and the abundance of each different species. Monitoring habitat condition considers more than just plant assemblages; environmental site variables, invertebrate and vertebrate species and abundance are also likely to be of interest. However, increasing the scope of monitoring also increases the resources required to do so. Therefore a strategy must be devised that concentrates monitoring to representative areas only and expert advice from an ecologist is recommended.

17. Most sites suffer from herbivory by sheep and rabbits, sometimes deer, goats and hares. Fencing is therefore strongly recommended and preferred to individual tree protectors. Conventional stock fencing can be adapted to also exclude rabbits on flat areas. On steep rocky slopes, electric fencing is feasible for excluding sheep.

18. Fencing against both sheep and rabbits is recommended to protect broadleaf woodland species for at least three to five years. Thereafter, some grazing or coppicing may benefit the biodiversity conservation value of the woodland.

19. Developing heathland also benefits from fencing to exclude sheep and rabbit during the first two to three years. Thereafter, rabbit grazing is beneficial and checks the development of grasses. Grazing by sheep is also beneficial after three or four years, to prevent pioneer woody species such as willow (*Salix spp.*) and birch (*Betula spp.*) from turning heathland into scrub. Periodic burns stimulate new shoot growth to feed red grouse (*Lagopus lagopus*) and reduce the risk of spontaneous fire.

20. Grazing is integral to the management of Spanish dehesa, a landscape of open oak woodland in which animals are grazed on pasture or winter cereals grown under the trees. However, young trees should be protected from grazing until their stem diameter exceeds seven centimetres. The conservation value of this landscape is enriched when some land is allowed to revert to native, legume-dominated scrub, by withdrawing grazing.

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Introduction

Hard-rock quarrying results in disturbed sites with too little topsoil and too much overburden. Such sites can be restored to habitats with high biodiversity by understanding some basic principles and procedures which are described in this manual. The Manual is relevant to non-toxic, hard rock quarries and opencast mine sites, although reference is largely made to slate quarries. We cover planning of restoration and the processes involved if ecological restoration is to be the chosen end-use. We also cover the processes of decision-making, those sectors of the community that should be consulted, and how decisions are reached. We discuss how the end-point is defined in terms of habitat type and what indicates success. Then we describe how to create the right conditions for a chosen habitat to be recreated; we cover landforming, promoting soil formation, collecting and propagating native plant material, planting techniques and grazing management. Finally we deal with monitoring success rate and how to conduct robust trials.

The Manual is the culmination of knowledge and experience gained from the restoration of two European sites, funded by the European Commission ***Life-*** Environment programme. Demonstration trials were designed for quarries in:

- Wales: Penrhyn Quarry, Bethesda operated by Alfred McAlpine Slate Ltd.
- Spain: Pizarras-Villar del Rey, Extremadura operated by Julian Reynolds (slate)

We monitored both sites but the main emphasis has been placed on the Welsh site.

This Manual is the result of experts from industry and restoration ecologists working together, and it is intended to give each discipline a feeling for the 'art' of the other. It is hoped that it will enthuse land managers of hard rock sites to restore sympathetically to conservation end-use knowing that with some foresight, a valuable site will evolve. It is also intended to highlight to scientists the constraints that operators have to deal with whilst practicing ecological restoration on such sites. The Manual cannot hope to inform to sufficient depth about all the specialist aspects of restoration and we make reference to additional reading. In some cases, you are advised to seek expert opinion where a site-specific evaluation is warranted.

One cost-effective approach to realizing a successful restoration strategy with conservation benefit is to appoint within the quarrying and mining industry environmental managers who have come through formal environmental training. These professionals will enable much of the project design and monitoring strategies to be carried out in-house, providing for the all-important aspects of continuity and ownership during the project.

The economic importance of mineral workings was recognized in the 1990 UK Government White Paper '*This Common Inheritance*' although extractive processes are often disruptive to the environment.

Since 1948 all development in the UK, including mineral working, has required planning permission. However, early mineral planning permissions rarely contained effective planning conditions requiring restoration to a beneficial after-use, subsequently defined by statute as use for agriculture, forestry or amenity (Town & Country Planning (Minerals) Act 1981). Early permissions were rarely time-limited. The Act (1981) addressed this omission by applying a 60-year time limit to all mineral planning permissions in force then.

The Planning and Compensation Act 1991 and the Environment Act 1995 addressed the other problems of unconditional mineral planning permissions. These Acts contain provisions intended to allow for the review of old mineral planning permissions through a mechanism requiring the submission of up-to-date schemes of working and schedules of modern planning conditions which are agreed with the Mineral Planning Authority. On approval, these are applied retrospectively and without compensation to mineral working sites (Minerals Review Applications). Both Review applications and planning applications for new mineral working are likely to require environmental impact assessment under the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999. This is also true of re-worked mineral waste for the secondary aggregate market.

This approach of planning for restoration is not practiced by all EU Members States, although where quarrying is planned in designated areas of natural beauty, mitigation may be required. Commonly in Europe there is no condition or obligation for owner-operators to restore after mineral workings have ceased. Where owners make voluntary agreements to restore, there are usually a number of subsidies or grants available to assist them.

There are many examples in the UK of where inappropriate restoration targets that focused on productivity failed. Typically, poor recovery can be expected when there is a failure to match vegetation requirements with substrate characteristics, often very different to the original topsoil at the site. For such 'marginal' land, emphasis has moved from productivity for agriculture or forestry to amenity, which includes restoration for biodiversity, sustainability and leisure.

Ecological restoration is *'the process of assisting the recovery and management of ecological integrity. Ecological integrity includes a critical range of variability in biodiversity, ecological processes and structure, regional and historical context and sustainable cultural practice'* – The Society for Ecological Restoration (1996) definition.

The fundamental mechanism of ecological restoration is to accelerate natural processes of plant colonization and succession, by overcoming the factors that are limiting plant establishment. The objective is to create vegetation which is appropriate for the locality, fulfils the needs of the land users, and does not require expensive maintenance.

The primary function of this Manual is to provide practical guidelines to practitioners for the restoration of self-sustaining, habitats of high conservation value. It gives some background to the subject of ecological restoration and references to sources of information that deal with specific topics in greater detail. A wide variety of best practice manuals already exist, a selection of which is listed in **Table 1**. Some are large volumes covering most aspects of nature conservation practice during restoration, some are based on low cost – low intervention methods, whilst others deal with specific previous industry uses such as landfill sites, metalliferous mines, slate tips and gravel pits. There are publications that are specific for a habitat types, creation of soil-forming materials, biodiversity and planning guidance.

All these manuals have sections that are relevant to either hard rock quarries or habitat creation. No single publication deals adequately with the background and the practicalities of ecological restoration for biodiversity conservation.

Section 1 of this Manual is written for land managers (managing directors, operations managers, quarry/mine managers, small operators and farmers), government minerals planning officers, non-government organizations (NGOs), governmental environmental bodies, National Parks managers, environmental consultants, university graduates and researchers. Section 1 is intended for reference and supplies some theory to the practice of ecological restoration; it also describes the processes to be dealt with primarily in the office or off-site such as planning, consultation, decision-making and frameworks for evaluating success.

Section 2 is written for quarry/mine managers, quarry environmental officers, quarry vehicle operators, small operators and farmers, environmental consultants, university graduates, quarry plantsmen and specialist nurseries producing plants for restoration. Section 2 is intended for use in the field and in plant nurseries. It is formatted as a pocket guide, and will deal with the practicalities of ecological restoration from preparing the ground, collecting local genetic material, through to planting/seeding, designing trials and monitoring.

Table 1. Selected manuals detailing aspects of best practice for land reclamation or restoration.

Publication	Emphasis
Ecoscope (2000) Wildlife management and habitat creation on landfill sites: A manual of best practice. Ecoscope Applied Ecologists. 191 pp.	Techniques for creating a broad range of habitats on landfill sites; operational and engineering constraints, case studies. Size: A4.
J. Mitchley, F Burch, P Buckley & T. A Watt (2000) Habitat restoration monitoring handbook. English Nature Research Report no. 378. English Nature. 26 pp plus appendices.	Implementation of monitoring methods and prescriptions, with check lists. A4.
M.J Oxford (2000) Developing Naturally: A handbook for incorporating the natural environment into planning and development. ALGE. 196 pp.	Relevant Planning Guidance, Codes of Practice and British Standards are listed against activities associated with habitat creation or restoration. A4.
N.A.D Bending, S.G McRae & A.J Moffat. (1999) Soil – forming materials: Their use in land reclamation. DETR. 218 pp.	Preparation of substrates capable of sustaining plant development on land with a range of end-uses. Trial design. Suitability of waste materials. A4.
English Nature, Quarry Products Association & Moulding Sands Association (1999) Biodiversity and minerals – Extracting the benefits for wildlife. Entec UK Ltd. 14 pp.	National and local biodiversity conservation strategies applied to the minerals industry. A4.
Land Use Consultants (1996) Reclamation of damaged land for nature conservation. HMSO. 437 pp.	All-encompassing: strategies for nature conservation, planning, management and case studies for decision-makers; technical fact sheets on establishing a range of habitats for practitioners. A4, 3 volumes.
RML Ltd. (1995) Slate waste tips and workings in Britain. HMSO. 136 pp.	Scale of workings,; assessing potential end-uses for slate workings. Case studies. A4.
D.M. Parker (1995) Habitat creation – A critical guide. English Nature Science Report no. 21. English Nature. 190 pp.	Project management for habitat creation including checklists, techniques for creating a range of habitats, including urban. Based on review of >100 projects. A4.
Welsh Development Agency (1994) Working with nature: Low cost land reclamation techniques. WDA. 60 pp.	Design, plant establishment and management using ecologically based, low intervention principles, case studies. A4.
Land Capability Consultants (1989) Cost effective management of reclaimed derelict sites. HMSO. 90 pp.	Costs and benefits of different end-uses provided by reclaimed land under the Derelict Land Grant Scheme, on-going management and maintenance costs. A4.
Environmental Advisory Unit (1988) Heathland Restoration: A handbook of techniques. British Gas. 160 pp.	Biology of heaths, types of disturbance that degrade heathland, techniques for heathland restoration and aftercare. A4.
B.N.K Davis (1982) Ecology of quarries: the importance of natural vegetation. ITE Symposium no. 11. NERC.	Working with naturally established vegetation on differing quarry substrates.

SECTION 1

The Framework for Ecological Restoration

A **framework** is vital to support projects that aim to re-create a habitat for conservation gain. Many of the best practice principles covered in this Manual are taken from a case study of Penrhyn Quarry, Europe's largest slate quarry, which lies adjacent to Snowdonia National Park in North Wales, and the Glyderau and Cwm Idwal Sites of Special Scientific Interest. The blocky nature of the slate waste tips (slate is extremely resistant to weathering) and the lack of topsoil make the re-vegetation of these waste tips by natural means very slow; one hundred year-old waste tips are only sparsely colonized by trees and woody shrubs. Major constraints to plant establishment are low nutrient availability, low water-holding capacity and grazing pressure from sheep and rabbits. Penrhyn is an active quarry and therefore provides the framework from which guidance on progressive site restoration can be presented although the Manual applies equally well to new, abandoned or closing quarries and mine sites.

1.1 Preliminary assessments

It is important to establish the characteristics of a site before considering what options are available as possible end-uses for that site by gathering existing knowledge and holding discussions with specialists.

1.1.1 Site survey

Maps of the site will be needed, showing characteristics such as landform and altitude, and the locations of buildings and ponds. National mapmaking agencies do not survey quarries in detail until quarrying has ceased, but on active quarries the site engineers should have maps of the landform. Types of information usefully included in maps are shown in Box 1. Paper maps will do for most purposes, but remote sensing and geographical information systems (GIS) can provide many tools for land use managers. Remote sensing includes both traditional aerial photography and satellite imaging. GIS is an extension of digital mapping. Digital mapping enables the manager to update the changing nature of the land, and produce paper maps for desk and field use at a range of scales and complexities.

Box 1 Information to include in site survey maps

Altitude	Indicates suitable vegetation types.
Landform	Steep slopes may be hazardous or inaccessible for planting.
Buildings	Old buildings may be hazards, but may support colonies of bats or birds. They can also have historical or archaeological interest.
Ponds, lakes	Water bodies can be hazardous, but can have significant wildlife or amenity value.
Soil	Soil type(s), horizons and depth of each horizon must be documented to ensure correct replacement
Vegetation	Areas of original vegetation, or vegetation that has colonised naturally, should form the basis of the restoration.
Surface	Is the surface fine, blocky or compacted? Depth of topsoil?
Fences	Where do stock graze on the site?
Earth science assets	Are there geological or geomorphological features of interest to be conserved?
Biological assets	Are there species or habitats of interest to be conserved?

Global Positioning Systems (GPS) are the major recent development in field surveying. Field GPS units currently provide locational accuracies of between 30 metres and 1 cm depending on the system in use and local conditions.

An example of a remotely-sensed image of Penrhyn Quarry is shown in Fig. 1. This image was produced by joining together a number of digital aerial photographs to provide coverage of the quarry and its surrounding area. The composite image was then corrected to fit the Ordnance Survey (O.S.) map base so that map information could be shown as overlays. This image is known as a colour digital orthophoto. Contours (Fig. 2), rivers, buildings etc. can be overlaid for various management purposes, e.g. identifying zones where quarry waste is eroding or sliding towards a significant river. Such images are also useful in identifying where natural re-vegetation is already happening, where soil cover is developing and for ranking the suitability of potential natural regeneration or planting zones.

Fig. 1 Digital composite aerial photograph of Penrhyn Quarry, Wales.

Fig. 2 Contour information from Ordnance Survey can be used as an overlay on digital images.

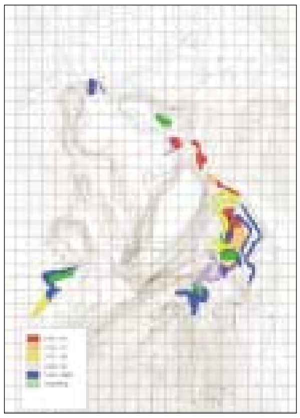


Fig. 3 Progress in tree planting at Penrhyn is added to the site GIS database.

Digital mapping is now the preferred method for maintaining up-to-date records of surface and sub-surface features. Figure 3, for example, shows tree planting trial plots in Penrhyn Quarry for the seasons from 1995-96 to 1999-2000. The areas planted in the last two seasons, 2000-01 and 2001-02, are currently being recorded on paper maps in the field and will be digitized and added to this GIS database. Many surveyors, including the Ordnance Survey, now operate with paperless systems, using GPS to record new features directly into the GIS on a portable computer.

GIS systems have many functions that can be used to produce new and useful management information. The contour data were produced as part of the routine surveys of Penrhyn Quarry and its active, disused and stable zones. The contours were processed in the GIS to produce a digital elevation model (DEM), which is a grid of cells coded for elevation (Fig. 4). DEMs can be rapidly processed to provide new maps of slope (degrees) and aspect (the compass direction which the slope faces). A slope map is shown in Fig. 5 and reclassified into 5- and 10-degree slope classes in Fig. 6. The slope class map could be useful in identifying zones of instability where re-vegetation is likely to be problematic, and where the safety of vehicles and personnel may be a concern.

The aspect maps derived from a DEM can also be useful in re-vegetation work. Much quarry waste is blocky in nature, free draining and consequently a problem for the re-establishment of vegetation. In addition, desiccation on sunny slopes can be dramatic. The aspect map for Penrhyn (Fig. 7) shows slopes facing the eight major points of the compass and flat areas, which can then be rated for likely vegetation heat-stress and desiccation.

Particularly in coastal and mountain areas, wind damage can be significant for trees on poor soils. In the GIS, the prevailing southwesterly Atlantic winds have been modeled impacting on the slopes and surfaces of Penrhyn Quarry. In Fig. 8, the lighter areas are those directly exposed to these prevailing winds and the darker areas are sheltered from them. To quantify this wind effect for management purposes, that map has been reclassified into eight exposure zones ranging from high to low (Fig. 9).

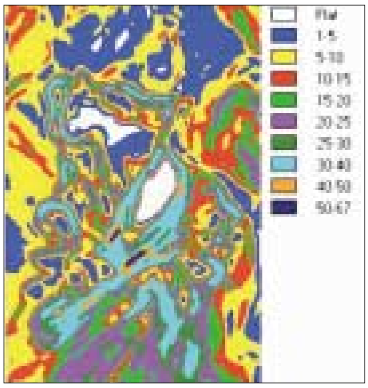


Fig. 6 Slope information can be expanded by defining slope angle into 5- or 10-degree classes

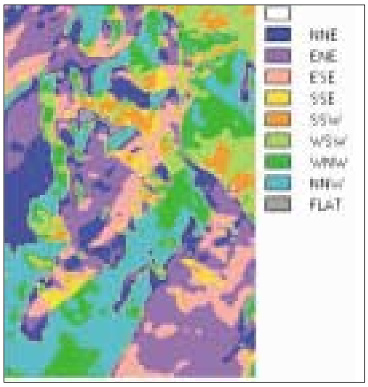


Fig. 7 Aspect map based on the Penrhyn DEM.

Fig. 4 Contour data were coded for elevation to produce this digital elevation model (DEM). The pink colours represent the highest ground in the vicinity of Penrhyn Quarry.

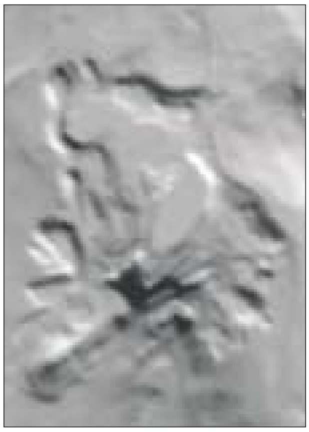


Fig. 8 Map depicting slopes most likely to be impacted by the prevailing south-westerly (SW) wind at Penrhyn.

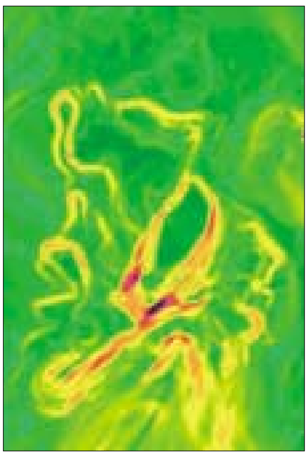


Fig. 5 Map of slope angle based on the Penrhyn DEM: the steepest slopes are red and violet

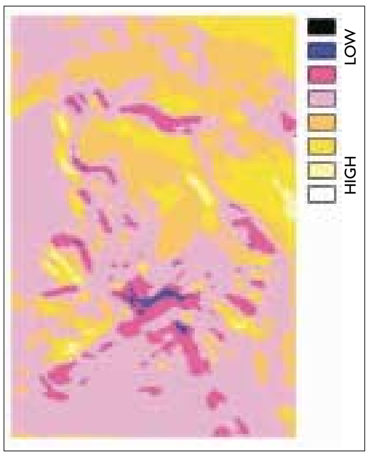


Fig. 9 Map of SW facing slopes further classified to predict degree of exposure to SW winds.

Weather may limit the ability of personnel and machines to achieve certain tasks under prevailing conditions of, for example, snow, fog or wind. It may have Health and Safety implications and limits to safe working may be attached to individual or combined elements of weather. The measurement of weather therefore has an important role on industrial sites. The **climate** of a locality is the synthesis of the day-to-day weather at the locality. Synthesis here implies more than simple averaging: averages, extremes, and frequencies of values and of weather types. The main elements are precipitation (rain), temperature, humidity, sunshine, wind velocity and wind direction; phenomena such as fog, frost, thunder, gales, cloudiness, grass and soil temperatures may also be included. Climatic data are usually expressed in terms of calendar months or seasons and are determined over a period (usually about 30 years) long enough to ensure that representative values for each month or season are obtained. The climate of a locality is mainly governed by the factors of: latitude, position relative to continents and oceans, position relative to large-scale atmospheric circulation patterns (e.g. the Gulf Stream), altitude, and local geographic and topographic features (Lewis, 1991).

It is essential to establish the local climate when planning revegetation work and research. This may be done by seeking climate information, or by inferring climate from an analysis of existing local vegetation. The recording of climate during revegetation work may provide invaluable data that can help to explain the success or failure of species, communities, planting and ground preparation techniques, plant sizes and types, irrigation and watering regimes.

Any large industrial site should consider the installation of at least one high quality, durable, long-term automatic weather station (AWS). Advice on the optimum siting of this AWS should be sought. If revegetation work is being undertaken, it is advisable to install short-term, low-cost AWSs measuring the parameters of fundamental importance to plants. These should be located on sites for planting where conditions are known, or suspected, to be significantly different to the permanent AWS. The World Meteorological Organization, the UK Meteorological Office and the Royal Meteorological Society provide advice on how to process, summarize and record the data.

World Meteorological Organisation,
http://www.wmo.ch

Guide to meteorological instruments and methods of observation. This guide lays down the basic standards of instrument and observing practices.

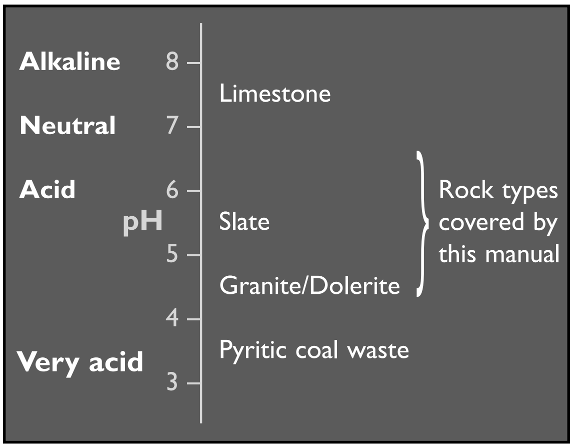
The UK Meteorological Office,
http://www.metoffice.com/

The Royal Meteorological Society,
http://www.royal-met-soc.org.uk/

Baseline surveys are an important part of the information-gathering exercise necessary in order to plan for restoration and methods adopted are similar to those used for Environmental Impact Assessment. It is important to assess the site's history and any remaining archaeological features, its soils, and its existing vegetation and other features of nature conservation value. The **history** of the site is best explored by talking to people who have worked there and local industrial archaeologists. It is helpful to know the types and quantities of material tipped, location and cover area of tips, and particularly whether these vary in pH (measure of degree of acidity or alkalinity), texture or degree of toxicity. Archaeologists should be asked whether there are industrial features, which are worth preserving for their historical interest. Necessary checks should be made to establish whether there are important geological/geomorphological features worthy of conservation and the biological value of the site (or parts of) in terms of rare species or habitat. Expert advice should always be sought; a useful list of contacts appears in section 1.1.2 (Box 7).

Surveys and analyses of **soil** are useful. Most quarries will have little biologically active soil and rather too much inert mineral material. Mineral waste can be very variable, and it is useful to locate areas of finer material where soil can easily form, and areas, which are more coarse and blocky. Chemical analyses can help show up nutrient deficiencies, but it can generally be assumed that raw mineral waste has little or no useful nutrient content. It is however essential to establish how acid (low pH) or alkaline (high pH) the surface layers of the waste are, since this determines which plant species will thrive. In general the hard rock waste covered by this manual does not weather to form alkaline soils, unlike limestone, but there may be areas where old mortar or concrete raise the soil pH (Fig. 10). Variability of substrate texture, drainage, pH and soil nutrient content can be a big advantage where the aim is to create a variety of habitats. This initial assessment of soil or substrate quality by various laboratory analyses can be out-sourced to such commercial organisations such as ADAS, or universities who can also provide interpretation of the results e.g. whether nutrient concentrations are good or poor relative to standardised soil data sets. Analyses follow specific internationally approved protocols.

Fig. 10 Typical pH values for different rock wastes after initial weathering.



The amount of **vegetation** which has developed on tips of different ages shows how severe are the constraints to plant growth. When waste tips are fine enough to retain water and contain some nutrients, growth may be rapid. Restoration of such sites involves assessing whether this natural regeneration is fulfilling the restoration aims, or whether management will be needed to change the vegetation structure or the balance of species, as in the Irish example (Box 2).

Box 2 Dolerite quarry, Ireland: an example of how to decide on intervention approaches

This example refers to a quarry located in a picturesque river valley densely forested with both native broadleaf woodland and conifer plantations. Tourism was important and the quarry visually impacted on region. Planning conditions required that the working quarry waste tips and buildings were screened from the road to protect the amenity value and landscape character of the region, using mixed deciduous and evergreen plantings.

The waste tips were principally of overburden mixed with some clay fines. The surrounding pastures provided a seed source for both gorse (*Ulex*) and grasses. Within two years of forming waste tips, a dense cover of gorse was achieved without intervention. This appeared to delay the natural development of trees so that the desired screening of the site was not achieved and succession to woodland was likely to be slow. Birch (*Betula*) and willow (*Salix*) seedlings were evident but seemed to compete poorly with the gorse. The dominance of gorse, a nitrogen (N)-fixing species, suggested that N might be limiting the growth of the trees, as might be expected with overburden material. It was therefore necessary to test by means of a field trial whether improving N supply would help trees outgrow the gorse or whether planting seedling trees would speed up tree establishment. The two-factorial design of the trial built-in three treatments for planting – none, birch seedlings, willow hardwood cuttings; and two fertilizer treatments – none, controlled-release NPK fertilizer. Two replicate plots were assigned to each of the six treatments. Results of the trial will enable informed decisions to be made on the best intervention approach for promoting tree establishment on the overburden tips and therefore meet planning requirements.

A more detailed survey of the vegetation is essential for planning habitat creation. Often small areas of the original surface vegetation will remain in, or can be found adjacent to, the quarry. The target vegetation will usually be similar to these remnants, which can be important sources of plant seeds, animals and microorganisms for re-colonizing the tips. The most basic vegetation survey is a list of plant species, but it is also useful to know how much there is of each. Using standard survey methods allows the vegetation to be classified (Box 3).

Surveys may reveal rare species that are adapted to the degraded conditions, leading to a redefinition of the restoration objectives. Surveys should also identify species regarded as weeds which may need to be controlled (Boxes 4,5).

Surveys should aim to identify the factors that currently limit development of the target vegetation, so that continuing **limitations** can be brought under control. This is not always easy to do, but careful attention to the plants provides many clues. Are there only a few trees but which grow very well, indicating that dispersal and establishment are the main problems? Are trees stunted with very short new shoots, indicating nutrient shortage? Is the vegetation dominated by nitrogen-fixing species such as gorse (*Ulex*) or clover (*Trifolium*), implying that nitrogen is the main nutrient deficiency? Are plants showing signs of damage by grazing animals? Large dead trees, or trees which have died back severely, indicate drought as a likely problem. Although much can be deduced from naturally established vegetation, it may be necessary to set up field trials in which individual limitations are removed, to identify the main constraints (Section 2.6).

Box 3 Classifying vegetation

Broad types of vegetation are based on the growth form of the main plant components, and are familiar to most people. The following categories are based on the vegetation classification developed for the UK by Joint Nature Conservation Committee (JNCC; 1993).

Woodland	Dominated by trees > 5 m high when mature
Scrub	Dominated by shrubs < 5 m high when mature
Parkland	Scattered trees covering < 30 % of the land
Grassland / Marsh	Dominated by grasses or marsh herbs
Tall herb / fern	Dominated by bracken or other tall herbs
Heathland	Small shrubs (e.g. heather) make up > 25 % of the cover
Mire	Vegetation with the water table at or just below the surface
Swamp	Vegetation frequently or permanently flooded
Cliff	Vegetation on rock sloping at > 60° and > 2 m high
Scree	Vegetation on areas of loose rock fragments

Within these categories different types of woodland, heathland etc are defined on the basis of the species that make them up. To determine the specific vegetation type it is necessary to record all the species within a 2 m x 2 m area (or 5 m x 5 m for woodland) known as a quadrat. Ideally this is repeated for 5 quadrats to find out how constantly each species occurs. In the UK, the National Vegetation Classification (NVC: Rodwell, 1991) contains simple keys based on quadrat data, which can be used to identify the plant community. Many European countries have standardised schemes for classifying their plant communities and for relating their habitats to the EU CORINE and EUNIS classifications e.g. Rivas-Martínez S. (1987) for Spanish vegetation.

Box 4 Invasive, exotic species as primary colonizers: Wales.

One of the most common primary colonizers of slate waste tips around Blaenau Ffestiniog and the Nantlle valley in Wales is an exotic species, *Rhododendron ponticum*. Where there is sufficient soil Rhododendron can grow rapidly and form a dense canopy and a dense litter layer that prevent other plant species from establishing. Once established it can also invade surrounding areas through the dispersal of its seed. It is extremely difficult to eradicate and has been listed as undesirable by the Snowdonia National Park Authority because it is severely damaging a number of important habitats. On slate waste tips that fringe the Park, Rhododendron presents a dilemma: it is a successful colonizer (Photo 1), rapidly produces an organic soil horizon and in Spring provides the waste tips with colour when in flower and its eradication from these sites would be very difficult. A careful appraisal of costs, benefits and risks will be required to decide on the best strategy for its management.

Box 5 Invasive, exotic species as primary colonizers: Spain.

Eucalyptus is a common primary colonizer of bare land in southern Spain. It grows rapidly and therefore is favoured for timber production. However, it has an invasive nature and can exclude native species from colonizing by being better adapted to grow in low-fertility and drought conditions. In Extremadura, the planting of eucalyptus is not permitted on reclaimed land. Here, water is a limiting factor to plant growth and eucalyptus is able to outcompete both annual and perennial native plant species for this resource.

The most severe limitations should be addressed first. However, different limitations interact, and some may be easier to overcome than others. On loose mining waste for example, drought is often the cause of plant death, but increasing the nutrient supply can allow plants to develop deeper root systems and increase their drought tolerance – applying fertilizer to promote deeper rooting is considerably easier than applying soil to improve water supply at the surface.

1.1.2 Stakeholder identification

It is important to identify all the stakeholders early on who have a legitimate interest in a potential restoration scheme. Here, '**stakeholder**' refers to any individual, group or institution that has an actual or perceived interest in the outcome of a restoration scheme. These may be statutory authorities, advisory agencies, businesses, non-governmental or other membership organizations, employees, local residents or those who visit the area. Their interests could range from their legal obligations, economic circumstances, livelihood or simply opinion about environmental quality and landscape.

The identification and involvement of stakeholders needs to be understood as a **process**. There is no set formula for when and how to involve people; these decisions should emerge as the project develops. In practice the involvement of different stakeholders will be appropriate at different stages of the process. The stakeholders who should be involved near the beginning are those who are paying for the restoration, those who are managing it and those who are giving permission.

Statutory authorities such as the **Local Government Minerals Planning Office** will ensure that restoration proposals meet with local as well as national policy, in conjunction with **English Nature, Countryside Council for Wales or Scottish Natural Heritage**, in the UK. Where disturbance is planned in or close to National Parks, Sites of Special Scientific Interest (SSSI) or candidate Special Areas of Conservation (SAC), special restrictions may hold and early discussions with the appropriate authority will be valuable. In areas where local Biodiversity Action Plans are in place, then similar guidance is available from the local government Minerals Planning Office. There are also stakeholder groups that can offer **expert advice** during the planning phase of a restoration scheme on what is important to conserve on site. All those organisations listed in Box 7 are potential stakeholders representing biodiversity, historical and earth science interests: their information will also be useful in the Environmental Impact Assessment (EIA) submission. The list is not intended to be all-inclusive but rather a general guide, and links to other relevant sites can be found at these websites. **Local Wildlife Trusts** may also want to play an important role in aftercare management.

Section 1.2.1.2 deals with methods and levels of consultation; the most successful restoration schemes are those where the public are not only consulted but actively involved with the development of the scheme (Box 6). This is the subject of another ***Life*** - funded programme involving Groundwork UK and the University of Manchester (see www.ecoregen.com for toolkits, including one 'Working with People').

Box 6 Involving stakeholders and building partnerships

Gwynedd Council in partnership with Alfred McAlpine Slate instigated a Community Liaison Group at Penrhyn Quarry, served by Community and County Councillors and quarry staff to address quarry issues within the local community and to involve the community in discussion on aims and goals for restoration, aftercare and enduse. Although many of the residents voice concerns that centre around the nuisance aspects of quarrying such as dust or noise, other issues including the routing of pathways, and the preservation of culturally important heritage features of the quarry have also been discussed and incorporated into operational plans.

Box 7 Stakeholders for advice

British Archaeological Trust
www.rescue-archaeology.freeserve.co.uk

British Geological Survey
www.bgs.ac.uk

Countryside Council for Wales
www.ccw.gov.uk/

English Nature
www.english-nature.org.uk/

Flora Locale
www.naturebureau.co.uk/pages/floraloc/

Forestry Commission
www.forestry.gov.uk/forestry/

Joint Nature Conservation Committee
www.jncc.gov.uk

Local Wildlife Trusts
www.wildlifetrust.org.uk

Quarry Products Association
www.qpa.org.uk/env_pla/

Regionally Important Geological Sites
www.ukrigs.org.uk/rigs/rigswebsite/

Royal Society for the Protection of Birds
www.rspb.org.uk/

Scottish Natural Heritage
www.snh.org.uk/

Soil Survey and Land Research Centre
www.silsoe.cranfield.ac.uk/sslrc/

The Bat Conservation Trust
www.bats.org.uk/

The Butterfly Conservation Trust
www.butterfly-conservation.org

The Game Conservancy Trust
www.game-conservancy.org.uk/

The Herpetological Conservation Trust
www.hcontrst.fg.co.uk

1.1.3 Defining target options

A variety of objectives could be satisfied by quarry restoration (Box 8), and an important part of any restoration project is to decide which of these is or are most important to pursue (Section 1.2.1). In this section we define these objectives.

1.1.3.1 Safety

Safety should always be considered first and throughout a restoration project and provisions in place that are appropriate for the land's target end use. Quarry hazards include landslides and falling stones, steep drops, sharp edges, unstable buildings and structures, voids and deep-water. It must be considered whether areas are safe to access to carry out restoration works by normal means, are additional safety measures required, or if access can be allowed at all i.e. unstable tip.

Landowners have common law responsibilities for the safety of visitors and trespassers as well as responsibilities under the Occupiers Liability Act 1957 and 1984. At the outset of restoration planning, a decision must be made about which, if any, parts of the restored site will be open to public access. Hazards should either be removed or public access restricted where hazards exist. The higher the perceived levels of public after-use, the more comprehensive the work required to remove hazards.

1.1.3.2 Biodiversity conservation

Biodiversity conservation objectives can be either species- or habitat-driven; this is discussed further in Section 1.2.2. An example of a species-driven objective is the provision of heather moorland to encourage red grouse. An example of a habitat-driven objective would be to create native broadleaf woodland.

Photo 1. Slate quarry waste densely colonized by *Rhododendron* in North Wales.

Box 8 Restoration objectives

OBJECTIVE	LIKELY OUTCOME
Safety	Waste tip stabilization, reducing hazards leading to falling and drowning
Biodiversity conservation	Restoring habitats, individual species, genetic resources, useful study sites
Amenity and recreation	Caters for public access, study / interpretation sites
Landscape aesthetics	Improved visual quality of landscape, sympathetic to surroundings, softening outline of man-made structures
Earth science and industrial archaeology	Preserving geological value, cultural heritage
Environmental protection	Filtering pollution, buffering rainfall, carbon sequestration
Productivity (agriculture and forestry)	Land supports pasture, arable, timber, biofuel crops for commercial gain
Development	Reclamation for industry, housing
Recovery of quarry waste	Secondary aggregate uses

Habitats valuable for biodiversity conservation can be created with comparatively little intervention since soil fertility constraints, if they are not too extreme, generally lead to more biodiverse habitats by preventing the dominance of competitive species. Some scientific criteria by which biodiversity value can be assessed are:

Naturalness The “natural habitat” is normally considered to be the one that existed on the site before the impact of humans. However, habitats modified by long-periods of human intervention may also be considered to have important natural characteristics. In some sites, the (semi-) natural habitat of the area may be apparent by surveying land adjacent to the quarry. Where quarries are in more disturbed locations, this may not be so apparent and greater reliance on expert ecological advice may be required. The impact of quarrying itself may create habitats that have much in common with natural habitats in other places, e.g. cliffs. Conservation of these new habitats may also be a high priority.

Diversity This includes the number and range of habitat types within a site, and the number of species and their abundance within each habitat.

Size Larger sized areas of habitat are favoured because they will support a greater number of species (even including rare ones), they will support a larger population size of each species (so more of them will be viable populations able to survive over the long term), and reduce the proportion of the habitat area that is affected by “edge effects” from outside such as nutrient pollution.

Rarity A high conservation value is attached to the presence of rare species because these are the ones whose survival is most at risk. Rare species are more likely to be present in large habitats, and those that contain uncommon natural features. There are different categories of rare species: those whose distribution is confined to a small geographical area and those only found at a low density scattered over a wider geographical area.

Fragility A higher conservation value may be placed on habitats that are fragile: they are easily damaged by external impacts and cannot easily be restored. In some cases quarries may lend themselves to the conservation of fragile habitats e.g. those damaged by trampling, by limiting access.

Typicalness This is based on the assumption that it is possible to define what 'type' a habitat conforms to by using 'standard' habitat data for comparison; such standard habitats have been classified under a framework referred to as the National Vegetation Classification (NVC) (Rodwell, 1991). Generally, habitats that most closely fit an NVC type are considered to be the most valuable. However, the early-colonizing plant communities often encountered on damaged land do not conform to NVC, yet may still be valuable in either scientific or aesthetic terms. Indeed, it is recognized that habitats and their species populations are part of a dynamic process, and that this process also has a value, in providing opportunities to study the way in which plant communities develop with time.

1.1.3.3 Amenity and recreation

Restoring sites for amenity and recreational end-uses requires clear planning of access routes, removal of hazards and attention to legislation governing safety (Section 1.1.3.1), and infrastructure. Diving is a popular use of old quarry pits throughout the UK; pit walls can be developed for rock climbing training. Boardwalks and cycle tracks tend to be well used particularly by the local community. Historic buildings such as quarrymen's hospitals may form part of a guided walk. Amenity schemes can also fulfil an education role when interpretation boards are provided: these may describe the species of animals and plants in the area, how restoration was achieved and the function of industrial relics that remain part of the landscape. The degree of use should be planned for and decisions made on whether car parks and toilets need to be provided. In all cases it is necessary to consult with the local community to ensure the end-use fulfils their needs. Where sites are sufficiently large, it may be possible to combine both amenity and conservation objectives, with a buffer zone separating them.

1.1.3.4 Landscape aesthetics, industrial heritage and earth science

The key **visual impacts** of a quarried area are waste tips with straight outlines, deep voids and stark, unvegetated stony surfaces. There is huge variation amongst people in what landscapes they perceive to be more or less attractive. The cultural importance of landscapes may not correspond with their aesthetic value. Therefore, there is particular importance in wide stakeholder involvement in decisions over target landscapes (Section 1.2.1.2.). Restoring for **aesthetic** reasons often involves the landforming of the site so that it becomes sympathetic with its surroundings. Spoil tips usually undergo 'regrading' to reduce height and improve the landform on a whole-site scale. Voids may be backfilled with quarry waste or allowed to flood. To minimize its visual impact the site would be contoured to coincide with adjacent landforms. After this physical amelioration, establishment of vegetation may also be valuable to soften unnatural outlines and improve the integration of the site into its surroundings. The creation of large flat areas should be avoided since in many landscapes they appear to be unnatural and can hinder plant establishment through exposure to wind and desiccation. Variation in landform in a site can also help meet conservation objectives by providing habitat diversity.

Industrial heritage can be a primary restoration objective at quarries that have a long operating history. Here, buildings and industrial features such as inclines, tramways and water balance lifts (Photo 2) are considered to be part of the history of the community and provide a sense of place (Box 9). Inclines can be preserved by tipping to either side, so avoiding burying the structure itself. It is also important to ensure restoration measures do not affect archaeological or historical features e.g. buildings affected by planted trees. Information on the status of such features can be gained through Cadw (Wales), English Heritage or Historic Scotland; these agencies have the statutory responsibilty for the listing and scheduling of historic buildings. Consultation with local archaeological trusts or museums as well as the community is also encouraged.

Box 9 Aesthetics and heritage in the Welsh landscape – Penrhyn Quarry.

- Galleries hand-carved into rock faces are prized by many in the community and serve as a reminder of the human toil involved in winning slate before the advent of mechanisation. These galleries can also provide nesting sites for rare birds and will be retained as part of the restored landscape (Photo 3).

- The Welsh term 'penclip' (literally *tip head*) is the name given in Welsh slate quarries to the finger-like waste tips faced by hand with slate blocks (Photo 4); facing the sides of the tips in this fashion allowed tramways to be laid and greater amounts of waste to be tipped per unit surface area of land. During consultations in the planning phase of restoration at Penrhyn Quarry, the local community highlighted how important the penclips were to them and were concerned that revegetating these tips would hide this important heritage. Conversely, visitors to the region saw the tips as 'blots on the landscape' that should be concealed. Tips formed by modern tipping methods and not hand-finished were not important to the community, who mostly wanted them regraded and planted.

- This example illustrates that landscape aesthetics can be highly subjective and where opinions differ amongst stakeholders, there is a potential for conflict. The outcome requires sensitive procedures in decision-making (Section 1.2.1.2).

Photo 2. A Victorian water balance lift preserved at Penrhyn Quarry, Wales. The weight of a filled water tank could uphaul a platform carrying slate-laden wagons.

Quarrying may reveal articles of **earth science** interest that are worthy of conserving. For example, limestone quarries frequently reveal fossilized marine shells; animals and whole reef systems that would not normally be visible had quarrying not taken place. Similarly, quarrying may result in rare mineral forms being exposed and/or brought to the surface. Exposed quarry faces can also reveal interesting geological formations like faults, and sequencing of geologically ancient bedrock. Information about the scientific and educational importance of the earth science features of a quarry could be obtained through consultation with specialist societies e.g. the British Geological Survey (Section 1.1.2), universities and museums. Sites that contain designated RIGS (Regionally Important Geological Sites) are under the control of government environmental agencies such as Countryside Council for Wales or English Nature. If such sites are to be considered for their educational value or general access then it may be necessary to buttress unstable rock faces. Accessibility to tall cliffs can be improved by terracing. Many sites offer both earth science and biological value and these two attributes should then not be considered in isolation from each other.

Photo 3. Galleries preserved at Penrhyn Quarry; they served to facilitate the extraction of usable slate and also the rapid removal of rubbish from the working face, often by tram.

Photo 4. 'Penclips' are examples of slate waste tips that were once hand-faced along their advancing head, in the late nineteenth century.

1.1.3.5 Environmental protection

Vegetating a bare area provides not only a visual amelioration and food and shelter for wildlife, but also helps reduce erosion and dust, and improves rainwater infiltration and uptake. Consequently, vegetation indirectly reduces the movement of dissolved pollutants and the sediment loading downstream. Another indirect effect of revegetating quarries is to offset the contribution of atmospheric CO_2 to global warming and the sequestration of global C in soil: this reduces the ecological 'footprint' or impact of quarrying. Improved environmental protection will generally be an indirect effect of creating habitats for conservation or production, although in some cases buffering of pollutant and sediment plumes will be a major objective.

1.1.3.6 Production agriculture or forestry

Restoring rock waste to habitats suitable for production silviculture or agriculture will rarely be cost-effective in the current rural economic climate, since returns would not justify the costs of intervention and management necessary to overcome typically a lack of topsoil and fertility constraints. However, somewhat lower returns e.g. from coppicing re-created woodland or, controlled grazing of heathland and extensive agriculture like that practiced on Spanish dehesa may be feasible and could be offset against management costs.

1.1.3.7 Development and aggregate recovery

In areas where an acute shortage of housing has been identified, development may well be a prime objective for the use of restored land, but it is important to investigate whether this can be achieved whilst also meeting other targets described above. In many development schemes, the reasons for planting may be mainly aesthetic but this can still be consistent with biodiversity objectives, if planned for this purpose at the outset. Aggregate recovery on the other hand means going back to bare land or mineral waste so requiring the whole process of restoration to be revisited. Disturbance is not exclusively detrimental to biodiversity aims however and is one mechanism whereby rare species and ecosystems of mainly early-colonizing species can be expressed. In this context, utilization of secondary aggregates can be used to enhance some biodiversity values.

1.2 Planning for restoration

Once the preliminary information gathering exercise is complete, the next phase is to plan for the restoration project. Informed decisions can now be made about target options for end-use of the site but arriving at a decision that suits the consultees and the site requires the skillful handling of the process of decision-making.

1.2.1 Deciding on target options

This section outlines methods that can be adopted to facilitate decision-making on setting priorities for restoration objectives. Decision-making should follow on from the consultation process and stakeholders should be involved. However, decisions must be made within a statutory context and due care taken to conform to the relevant national guidelines e.g. in England and Wales guidelines of the Health and Safety Executive, as well as those for Strategic and Local Planning. This is best achieved by ensuring local authority planning officers are involved in discussions at the same time as the other stakeholders.

1.2.1.1 Policy context of biodiversity conservation

Regardless of whether biodiversity conservation is a primary restoration objective or not, legislation exists to safeguard the Earth's natural resources at regional, national and international levels. Internationally, there is the UN Convention of Biological Diversity that requires its nations to '*rehabilitate and restore degraded ecosystems*' and the EU Habitats Directive that advises Member States to enhance biodiversity by '*maintaining, managing and where appropriate developing features of the landscape of major importance to wild fauna and flora*'.

It is best at the start of consultation to obtain information from Local Authorities about their regional BAPs (**Biodiversity Action Plans**), as this will serve to highlight threatened species or habitats locally. Also, it is important to ensure that any conditions for restoration, as stipulated in the Planning Permission, are included as part of the site's objectives. These conditions reflect regional planning policies that are consistent with Government policies and commitments relating to international obligations to sustainable development, biodiversity conservation and pollution prevention. National planning policy and guidance is issued by the DTLR (Department of Transport, Local government and the Regions), the Scottish Parliament and the National Assembly for Wales in the form of Planning Policy Guidance Notes (PPGs, England), National Planning Policy Guidance Notes (NPPGs, Scotland) and Planning Guidance: Planning Policy and Technical Advice Notes (TANs, Wales) and Government White Papers (UK-wide). A series of Mineral Planning Guidance Notes (MPGs) exist in England. Current versions of these policies can be accessed and downloaded from the relevant websites (Box 10).

1.2.1.2 Methods for making decisions about restoration objectives

A preceding section (1.1) has already looked at the need to involve stakeholders, to assess opportunities and constraints and to define the targets of restoration. This section illustrates techniques for consultation which help to bring different groups of stakeholders together to reach a common understanding and an agreed set of opportunities, constraints and targets.

These techniques are needed because there may be major differences in the interests of stakeholder groups whose focus is at the local, national and international scale. Even within the local community people will hold a range of opinions about how a quarry site should be managed. In the field of biodiversity conservation there are often considerable differences even amongst technical experts about the objectives for conservation at a particular site. As there is no single way of measuring biodiversity value, the opinion of experts is largely based on their own professional experience. Therefore, a mechanism is needed by which the different perspectives and values of the full range of stakeholders can be integrated, and a mutually agreeable set of objectives is achieved. This increased participation by a wide range of organizations and members of the public can have many benefits in terms of future co-operation and in reducing the risk of subsequent criticism of the restoration of the quarry site.

Whilst these approaches may not always have been followed by practitioners, their use is increasingly recognized as best practice in a commercial context and is becoming standard in many aspects of planning. Evidence for this, and useful web-sites are given in Box 11.

Box 10 Websites with access to legislation relevant to biodiversity conservation

Department of Transport, Local government and the Regions:
www.planning.dtlr.gov.uk/ppg/

National Assembly for Wales:
www.wales.gov.uk/subiplanning/content/tans/
www.wales.gov.uk/subiplanning/content/minerals/

Scottish Parliament:
www.scotland.gov.uk/planning/
www.scotland.gov.uk/library/nppg/

Box 11 Information on, and examples of, best practice that include participatory approaches

1. The Best Value and Best Practice initiative launched by the UK Government Office of the Deputy Prime Minister, features a range of tools and techniques for increasing community involvement and inter-departmental involvement / communication in planning and decision making.

   www.ideas.gov.uk/bestvalue/

2. The International Finance Corporation's report "Doing Better Business Through Effective Public Consultation and Disclosure" is a guide targeted at businesses involved in projects with strong environmental impacts. This strongly advocates the approach to public participation that is promoted in this best practice manual.

   http://www.ifc.org/enviro/Publications/Practice/practice.htm

3. In its report "Participatory Integrated Assessment Methods: an Assessment of their Usefulness to the European Environmental Agency", the European Union states the following.

   The most important recommendation for applications of Participatory Integrated Assessment (PIA) techniques at the Agency is that organisers, in the design of and preparations for any application, should honestly reveal the potentially diverging interests, conflicting views and possible hidden agendas of expected participants. With the arrangements available in all PIA methods and with a skilful moderator, these problems can be managed if they are identified ahead of time and appropriate contingency measures have been taken. The key is to prevent the evolution of hostile attitudes towards the participatory process itself. Meticulous preparations can turn this risk into an opportunity by creating a group dynamics that transform initial tensions into creativity.

   http://reports.eea.eu.int/Technical_report_no_64/en/Technical_Report_64

For those wishing to explore these issues in more depth excellent resources exist at:

- National Center for Environmental Decision-making Research
  www.ncedr.org
- Groundwork/University of Manchester toolkit for community-led regeneration
  www.ecoregen.com

A selection of these well-established professional techniques for participatory decision-making have been tested with key stakeholders involved in the Penrhyn Quarry restoration project. In the following section prominence is given to those techniques that the 'Penrhyn Quarry stakeholders' themselves found most useful, and ones that would have helped overcome some of the weaknesses they identified in the planning and implementation processes that they themselves were involved with.

The participatory decision-making process can be broken down into a number of clear steps. However, those who are unfamiliar with these techniques, may find it best to make use of the skills of a recognized facilitator who already has experience in this field.

Step 1: Design of the consultation process

People are usually sensitive to the process by which a decision is reached as well as the actual decision. If they feel they are included, they are more likely to develop a sense of "ownership" of the restoration scheme, which makes the scheme more likely to be successful. This means:

- those involved should be able to understand the decision-making process
- the process must deal with potential conflicts of interest
- the process must make it easy for people to participate
- the process must follow a logical sequence

Good process design is key to engaging decision-makers, to obtaining information, to developing knowledge, and to building support for restoration. Best practice in process design is about ensuring that the process is acceptable to all the parties. It is important to be sensitive to concerns about who is seen as driving or hosting the decision-making process; and whether there could be a perception of bias. Ensuring that meetings take place at appropriate times, and in neutral venues, can reduce this risk.

Step 2: Identifying stakeholders and their concerns

The key question at this stage is not "what are we going to do", but "who should be involved". The aim is to decide who should be included at each stage of the process and in what role. A good way to start is to determine which groups of people will be affected by the restoration, and whether these effects will be direct or indirect, positive or negative. Likely stakeholder groups are dealt with in Section 1.1.2.

To be feasible, active consultation has to be selective; it may not be realistic to include in the most detailed consultation everyone identified as having an interest. In making this decision, it is helpful to classify stakeholders in an interest / importance matrix (Table 2) as a way to select an appropriate cross section of those who should be included at each stage. However, in a democratic context, such active consultation is best accompanied by publicity in the appropriate media, and through democratic structures, inviting all individuals who positively wish to be involved in the process to participate at an early stage. Care will then need to be taken to ensure that the process does not become dominated by any narrow interest groups. Methods to achieve this openness and balance are outlined in Step 3 below.

Step 3: Defining the scope of the restoration through consultation

A positive attitude of openness and early discussion is likely to lead to collaboration, rather than conflict, in the consultation process. This improves public image and therefore makes future restoration projects or quarry extensions more likely to be approved. By integrating the knowledge of different participants, mistakes and conflicts are avoided and efficient ways of achieving the objectives can quickly be found. An essential component of best practice is to develop effective partnerships and networks that allow consultation and decision-making to take place regularly as the project progresses. Some different ideas for developing such forums are shown in Table 3.

Table 2. Interest / Importance matrix used for evaluating stakeholders

		INTEREST Low	INTEREST High
IMPORTANCE	High	Work to build initiatives to protect the interests of these stakeholders e.g. local business	Work to build good working relationships with these stakeholders to ensure an effective coalition of support for the project e.g. Community Councillors
IMPORTANCE	Low	Unlikely to be the subject of project activities and management e.g. local businesses not directly affected	Their interests may be project targets, but their inclusion risks bias. Need careful management e.g. specialist groups

Table 3. Decision-making and partnership-forming forums

Forum	Includes	Role
Consultative Committee	Representatives nominated by key stakeholder groups identified by the developer.	Meets regularly and at key stages. Advises developer on scope of the restoration and drafts restoration plan.
Issue or Area Forums	Interested parties from the local area, or who have interest in a particular aspect of the design. Attendance may be open, or restricted to a set group.	Meets regularly or on an ad hoc basis. Cross-section of community allows contentious issues to be dealt with as they occur. Care should be taken that particular interest groups do not dominate.
Stakeholder Group and Working Committee	Representatives of key stakeholders, who appoint a Working Committee of technical experts.	Stakeholder group establishes priorities and reviews action plans. Working Committee analyses problems and opportunities and drafts action plans.
Informal or formal cross-institution meetings	Representatives of large organisations such as conservation or environmental agencies.	Ensures strategies and plans are coherent and coordinated between and within organisations.

Good facilitation skills are essential to ensure that meetings:

- maintain the momentum and direction of the work
- maintain a positive atmosphere of collaboration
- reveal the underlying values and perspectives of each stakeholder group

Key rules for effective and sensitive facilitation are:

- Keep the group's goals in mind when giving your own viewpoint
- If you don't understand something being said, seek more information
- Recognize assumptions in what you are saying, and check that they are correct
- When responding try to identify points of commonality rather than difference
- Depersonalize issues: discuss ideas and principles rather than people or groups
- Define issues and stances clearly, using precise and sensitive wording
- Be clear about what you want stakeholders to do

Various techniques have been developed to ease the process of consultation.

Issues mapping is a very useful way of revealing the motivation that lies behind the opinions stated by each stakeholder (Box 12).

Step 4: Collecting and exchanging information and knowledge

Consultation is only meaningful when there is fair and honest disclosure of information by all parties. Generally quarry businesses will need to take the initial step of giving information about their intentions. Some commercially sensitive information will clearly need to be kept confidential. However, if the risks are not too high, disclosure may have important benefits to the business by helping to build trust with other stakeholders leading to longer-term commercial benefits. Once a decision has been taken to disclose information it should be done without delay and in a clearly understandable form.

The ways in which information is exchanged between the participants are therefore critical, and attention must be paid to information management. Meetings should allow exchange and communication rather than one-way information transfer. Another option is to set up a dedicated website on which all documents can be displayed. Alternatives such as making maps, models or photo-montages which can be modified by participants are very useful for people who are not used to technical reports for example, the "Planning For Real" approach – see

http://www.nifonline.org.uk

Box 12 Issues mapping of stakeholder opinions

An issues map is a way of beginning to pin down the stakeholders' underlying interests, values and obligations; results are displayed as they emerge. It has been found to work well for groups of up to 15 people.

1. The purpose of the exercise and its potential benefits are explained. Whilst these kinds of methods are now commonplace in many institutions and organizations, they may still cause concern or scepticism in some stakeholders who are unfamiliar with them. Therefore it is important that facilitators do not assume that all participants are familiar or comfortable with this kind of exercise.

2. Each person is give four cards on which they write down their opinions about issues of concern with the restoration project.

3. All the cards are posted on a wall. Volunteers then group cards together according to the issue presented; all group members must agree on the arrangement.

4. Stakeholders are encouraged to discuss the opinions presented. Participants should clarify the thoughts behind the issues on the cards, thus revealing their concerns and values.

5. A spider diagram or a flow chart is drawn up by the group to summarize the issues and provide a record of the discussion. Relationships between different issues can be represented as links in the diagram.

Step 5: Seeking agreement over the detailed design

At this stage the stakeholders move from a process of consultation to one of negotiation. As with the consultation step, facilitation and conflict management skills are essential (Box 13).

There are many tools that could be used to support the process of negotiation. Most of these tools aim to make explicit the different restoration options that might be considered and then provide ways to balance the views of different groups of people about these different options. Methods such as 'matrix ranking' and 'scoring' explore stakeholder preferences by assigning weights and scores for a range of different features which might include factors such as costs, rarity criteria, water quality criteria, local employment benefits, local access and so on. Examples of the way in which matrix ranking and scoring have been used to negotiate decisions concerning management options can be found at

http://www.uea.ac.uk/dev/publink/analysis.pdf

The final stage is **reality testing**, where the focus moves from finding an option that is agreeable to all, to looking at what is actually feasible. The costs of different restoration options will certainly be central to any decisions regarding feasibility. More formal consideration of the "value for money" represented by different potential restoration schemes is usually carried out through the economic practice of **Cost Benefit Analysis**; an introduction to this approach is given below (Section 1.2.1.3).

Actual costs will vary greatly from site to site depending on the manpower and machinery already available, and costs of access and distance over which material needs to be transported. So it is important not to choose a restoration option for a particular site that is beyond the financial means of the project. All habitats will require some ongoing management costs, and these are likely to be larger for more human-modified habitats. Therefore, habitats that are resilient and stable with minimal intervention will be economically favoured in most cases.

Risk is a hard criterion to include in a formal economic analysis, but it must be taken into consideration if alternative restoration schemes are being compared that differ markedly in the risk that their planned outcomes will not be achieved (Pywell and Putwain, 1996).

Box 13 Conflict management – a suggested procedure

1. Decide on a particular meeting place and time that suits all the parties
2. Clear the air first – this involves starting the meeting by having each individual or stakeholder group describe the disagreement or conflict over the restoration design as they understand it, and identify any feelings they have about it
3. Define the problem – this requires identifying the interests of the stakeholders rather than leaping into a discussion of the potential solutions
4. Analyse the problem – this can involve tracing the history of the problem, looking at the difference between actual and perceived responsibilities, identifying information gaps (which might be legal requirements, or gaps in technical knowledge or expertise), or tracing out differences of opinion about what the priority design principles are. This step does not mean discussing who is 'right' and who is 'wrong', or trying to discuss solutions or alternative design strategies
5. Brainstorm possible solutions or design changes that answer the issues and items identified during the problem analysis
6. Evaluate alternative solutions; using mutually agreed-upon criteria, discuss alternative solutions and select the best approach
7. Decide how the solution will be implemented
8. As a follow-up have each individual write her or his understanding of the issues discussed and agreements made – this can help to uncover areas of misunderstanding that might lead to future challenges.

Step 6: Building practical and responsive monitoring and evaluation systems

Monitoring and evaluation (M&E) is usually the least well-planned part of a restoration programme. Often this stage is left out of the design process, perhaps because of concern about the ongoing costs that might be involved. These costs are however likely to be small in relation to the cost of restoration works, and can prevent the restoration being viewed as a costly failure. If best practice has been followed in the previous stages of project design, there should by this stage be partnerships and networks in place which provide a foundation for M&E systems. NGO's and universities may be familiar with the work involved, but involving the local community can maintain their sense of "ownership" and can provide M&E over the longer term. It is important that post-restoration objectives are clear and outcome-based, if M&E is to be robust.

A growing number of organizations have gained experience that public participation in M&E is an effective way of obtaining reliable results (e.g. the National Biodiversity Network www.nbn.org.uk/). Further tools for setting-up participatory M&E systems are located at www.iucn.org/themes/eval.

1.2.1.3 Cost Benefit Analysis (CBA)

A cost-benefit analysis should be done as part of project planning. No major endeavor should be embarked upon, or money spent, until it is clear that the benefits of spending money will be greater than the costs. Such analysis may be done with qualitative data, but generally CBA compares the monetary costs and the monetary benefits of any project or policy in order to decide whether the benefits outweigh the costs. This is a very well used technique and usually involves the following steps:

Project identification The first step of CBA is to define precisely the project being assessed and where the boundaries of enquiry lie. For example within a restoration project it may be a requirement of a permission for extraction from new areas in a quarry that restoration of a certain amount of degraded land is required. The question here may simply be 'Will the benefits of the new extractions cover the costs of the restoration?' This would be a narrowly defined CBA. A broader boundary may ask the question 'Will the benefits of the restoration (in terms of biodiversity, recreation, landscape etc) be greater than the costs of restoration? This is a much more difficult question to answer than the first, and requires a more complicated CBA.

Classification of impacts After definition, the impacts arising from the project must be identified, and depending on the nature of the project these may include:

- cost of materials such as machinery, fuel, buildings
- staff time and associated costs
- effects on local employment levels, including direct employment and indirect employment generated by increased spending in the local economy
- impacts on the environment.

All the impacts to be included in the CBA must be quantified and then tabulated in terms of *when* they arise, e.g. in year 1, 2 or 20. Having identified the types of impacts, it is necessary to estimate their magnitude and duration. CBA considers only those changes directly attributable to the project and care must be taken not to include changes that would have taken place anyway.

Having completed this task it is necessary to represent the entire project's impacts on a monetary scale. This is relatively easy for simple projects concerned only with marketed goods and staff (as in the question 'Will the benefits of the new extractions cover the costs of the restoration?') but is much more difficult if it is necessary to consider costs and benefits which are not normally bought and sold, such as biodiversity and landscape. Including these so-called 'non-market' goods in a CBA is a complicated business, and expert advice should be sought before embarking on such an analysis (Hanley & Spash 1993, Edwards-Jones *et al.*, 2000).

A very important issue in CBA is concerned with how to value costs and benefits which will occur at some time in the future. For example, imagine the costs of running a piece of machinery may be £1000 per annum now, and you expect that to be about the same in 20 years time (ignoring inflation). But how do you compare a £1000 cost in 20 years time with a £1000 cost tomorrow? This is a complicated issue that requires future costs and benefits to be 'discounted', i.e. expressed in terms of today's money to take account of inflation. This is standard practice in CBA but requires some careful calculation. Further details on this topic can be found in Price (1993) and Layland & Glaister (1994).

Sensitivity Analysis Uncertainties and estimations pervade CBA. By reconsidering the CBA methodology in chronological order, the following major classes of uncertainty become apparent:

- the quantity and quality of physical inputs and outputs to and from the project
- the respective values of these inputs and outputs
- the value of changes in environmental quality
- the appropriate discount rate.

It is wise to consider the influence upon of changing each of these estimations on the final answer. Such analysis may suggest certain areas that may require more effort to obtain more certain costs. It can also allow the comparison of projects for example, the estimated cost/benefit ratio of two projects may be identical but one might be significantly more sensitive to errors in estimation than the other.

1.2.2 Setting biodiversity conservation objectives

Once the decision has been made to include biodiversity conservation objectives into part or indeed the entire restoration programme, then the next stage is to consider what are the chief conservation objectives for a particular site.

Wherever possible, re-created habitats should serve to extend the boundaries of existing habitats, for maximum gain in terms of useful seed rain coming onto the new site and facilitating movement of species across the boundaries (Box 14). However, the decision reached at each site should be based on its individual environment and the views of its stakeholders. In different circumstances it may be decided:

- to try and recreate the original (semi) natural habitat as accurately as possible OR to recreate a rare, or fragile habitat, a habitat typical of a particular type even if it is not the original habitat of the site, or a habitat that supports the population of particular rare or vulnerable species
- to create small patches of a wide range of different habitats OR to maximize the area of one specific habitat (Box 14)
- to use high inputs to create a habitat in its near mature condition OR to use lower inputs and allow "nature to take its course" through natural vegetation dynamics and succession
- to focus efforts on habitat creation OR on particular species (Box 14)

Often, the result of the decision-making process by a range of stakeholders may be to seek a compromise between these choices, but it is important to check that this does not result in none of the objectives being satisfied. Box 15 describes some of the criteria that influenced stakeholder decisions on target habitats at Penrhyn Quarry, Wales.

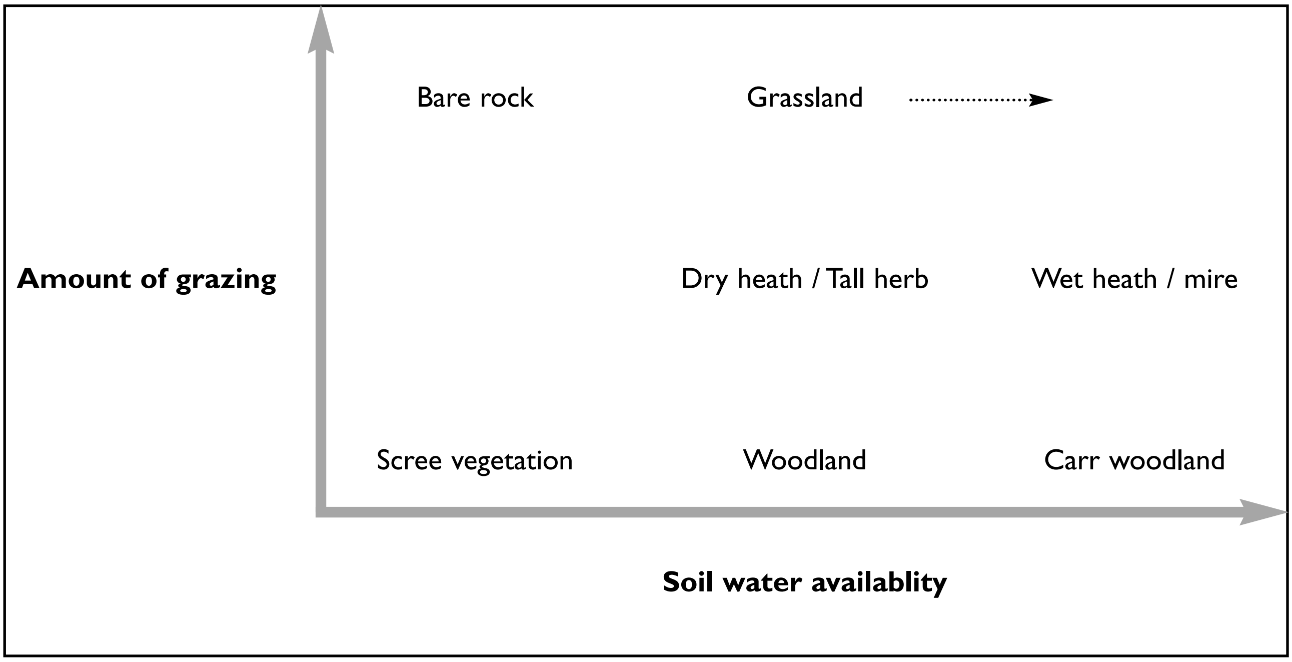
Box 14 Choices for biodiversity conservation objectives

Large blocks of a single habitat vs. smaller 'mosaics' of different habitats? Creating a patchwork of different habitats is likely to increase the total species diversity within a site. However, certain rare species require a large contiguous area of the same habitat. For example, bird diversity is greater in mixed upland heath and woodland than in either of these habitats separately, but many of the species that benefit from the mosaic are relatively common. Large areas of heather moorland are required by red grouse (*Lagopus lagopus*), hen harrier (*Circus cyaneus*) and merlin (*Falco columbarius*). Many wading birds require grassland which is tall enough to provide cover for breeding. However, they may be threatened by the presence of scrub or other tall vegetation which provides cover for their predators. If the management target for areas of heathland or grassland is to prevent the establishment of any tree cover, then it may be necessary to remove even isolated trees, since they provide a seed source which can accelerate succession to woodland.

Choosing between large blocks versus fine scale mosaics should be influenced by the condition of the surrounding landscape. Apart from the decline in total area of valuable habitats, these have been damaged by being fragmented so that species cannot easily move from one patch of that habitat to another. Restoration schemes have the potential to link areas of remaining habitat, providing "corridors" along which wildlife can move. Therefore, it will often be beneficial to create habitats which are similar to valuable habitats on adjacent land so as to extend the area that they cover.

Target species or target habitats? To most people biodiversity conservation means the conservation of rare or threatened species. However, in the long-term these species cannot be conserved without the habitats that they depend on. So most restoration schemes emphasise the creation of target habitats, that are often selected on the basis of which conservation priority species they can support. Then the presence of these species can be used to indicate whether the habitat creation was a success (section 1.3). Occasionally, there may be considerable disagreement amongst stakeholders about which species are the highest priority (e.g. between those that are rare in the locality and those that are rare at an international scale): this demonstrates the critical importance of broad stakeholder involvement before a project begins, rather than reliance on a single "expert".

Fig. 11 Schematic distribution of the major habitat types in lowland UK with grazing intensity and soil water availability.



Box 15 Deciding on high value biodiverse habitats at Penrhyn Quarry, Wales.

Nearby habitats Penrhyn Quarry is a large working slate quarry adjacent to the Snowdonia National Park, and covers some 250 ha. Several threatened habitats are present on land adjacent to the quarry, including wet, dry and montane heathland, deciduous woodland, and a river. The heathlands are of international importance, supporting breeding red grouse *Lagopus lagopus*.

Habitats on site Older tips have sparse scree vegetation with the distinctive Parsley Fern *Cryptogamma crispa*. Patches of deciduous woodland and of dry heath have colonized some areas. Cliffs and buildings provide nesting sites for scarce birds such as the chough *Pyrrhocorax pyrrhocorax*. There are some invasive exotic plant species such as Rhododendron and Buddleja but these are not dominant.

Climate and soil The climate is maritime with rain isohyets of 1800 – 2000 mm p.a. straddling the quarry. Most of the quarry is within an altitude range of 125-350 m. The site is covered with blocky slate waste, with some areas of finer material particularly where the slate has been crushed by traffic. Recent tipping includes large quantities of boulder clay subsoil.

Target habitats On the basis of the above it was decided to attempt to create heathland on the upper, more recently tipped areas of slate waste, and patches of woodland on the lower, older areas. Areas of more developed scree vegetation, and other features such as buildings and a lake, will be retained. Specific habitats to be created are based on NVC community descriptions (Rodwell, 1991a, 1991b). The main or "structural" species to be established are:

Heathland:

(on free-draining slate waste) "**H10** *Calluna vulgaris-Erica cinerea* **heath**"

(on clay or compacted waste) "**H12** *Calluna vulgaris-Vaccinium myrtillus* **heath**"

Woodland: "**W17** Oak-birch-*Dicranum majus* **woodland**":

Sessile oak	*Quercus petraea*	Holly	*Ilex aquifolium*
Downy birch	*Betula pubescens*	Silver birch	*Betula pendula*
Rowan	*Sorbus aucuparia*	Pedunculate oak	*Quercus robur*
Hazel	*Corylus avellana*	Hawthorn	*Crataegus monogyna*
Ash	*Fraxinus excelsior*	Goat willow	*Salix caprea*
Sycamore	*Acer pseudoplatanus*	Juniper	*Juniperus communis*
Beech	*Fagus sylvatica*		

Any of a broad range of habitats could be created on any quarry site, some more easily than others. Each habitat needs a different environment. Environmental factors such as soil water availability and grazing intensity (Fig. 11), soil pH, temperature (strongly linked to altitude) and nutrient availability all have an important bearing on habitat suitability.

The management of quarry substrates for supporting vegetation and grazing management requirements for differing habitats is discussed fully in Section 2 of this Manual.

1.2.3 Funding organizations

- **EU grants** – funding available under differing Objectives (1-4, 5a & 5b) and directed toward the most disadvantaged geographical regions of the EC. Match funding of at least 50% (25% for Objective 1) must be secured from within the Member State and most commonly comes from the Public Sector. ***Life*** (The Financial Instrument for the Environment) funds projects that demonstrate best practice, particularly of environmental enhancement during industrial use, and which is currently on Phase III. ***Life*** funding is directed towards EU Environmental policy uptake. Match funding of at least 50% must be secured from e.g. industry or Public Sector.
- **Central Government funds** – English Partnerships, Welsh Development Agency, Scottish Enterprise.
- **Government Agency grants** – Countryside Agency, Countryside Stewardship Scheme. English Nature, Countryside Council for Wales, Scottish Natural Heritage, Forestry Commission (Woodland Grant scheme for creating or regenerating woods >2.5 ha).
- Other – local authorities, Entrust (Environmental Trust Scheme) which uses monies collected from the Landfill Tax Credit Scheme.

All grant-awarding bodies regularly change their priorities for funding and a visit to their websites early in the planning phase of restoration could save much time (Box 16).

Box 16 Potential sources of funding for restoration projects with conservation objectives

EUROPEAN UNION:

Life programme
//europa.eu.int/comm/life/

EU representation in the UK
www.cec.org.uk

Welsh European Funding Office
www.wefo.wales.gov.uk/newprogs/

CENTRAL GOVERNMENT:

English Partnerships
www. englishpartnerships.co.uk

Welsh Development Agency
www.wda.gov.uk

Scottish Enterprise
www.scottish-enterprise.com

GOVERNMENT AGENCIES:

Countryside Council for Wales
www.ccw.gov.uk/

English Nature
www.english-nature.org.uk/

Scottish Natural Heritage
www.snh.org.uk/

Countryside Agency
www.countryside.gov.uk

Countryside Stewardship Scheme
www.defra.gov.uk/erdp/schemes/css/

Forestry Commission – Woodland Grant
www.forestry.gov.uk/forestry/hcou-4u4j2y

OTHERS:

Entrust
www.entrust.org.uk/

1.2.4 Managing a restoration project

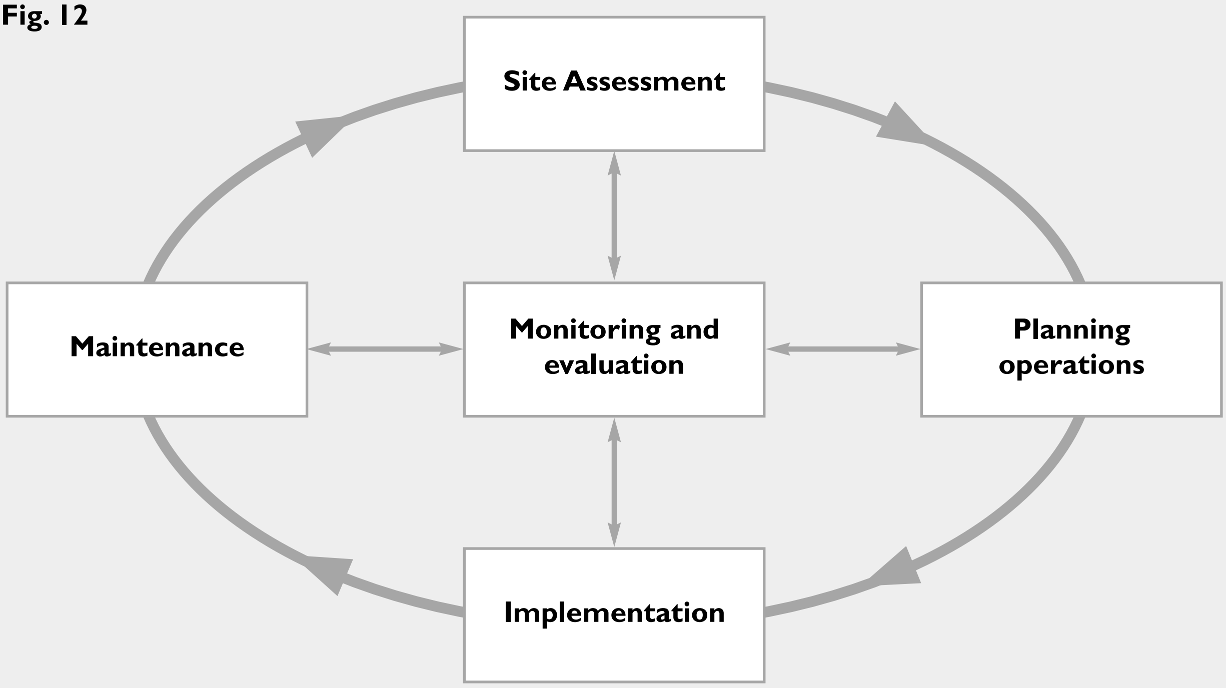
Any restoration project should start with an **assessment** of the problems and potentials of the site, and the wishes of the different stakeholders. For each stakeholder group it is important to identify what role they should play at each stage in the project management process (Fig. 12). When priorities and targets have been established, it will be necessary to **plan** the activities needed to achieve them. Much of the practical work will happen at the **implementation** stage, but it is also important to consider what ongoing **maintenance** will be needed. How maintenance will be funded is an important consideration to plan for, particularly after the five-year statutory aftercare period. Local voluntary groups may be able to do this; alternatively, revenue from e.g. coppicing or light grazing could fund maintenance needs.

Each stage of the project management cycle should be **monitored** and its success **evaluated** (Section 1.2.1.2 – Step 6 deals with the importance of M&E; Section 1.3 looks at frameworks for evaluation) so that methods can be adapted and improved. The decision-making process is presented as a cycle that enables flexibility to be built-in and contingencies to be accommodated – key to a successful restoration project.

In a working quarry that is progressively restored, it is essential to ensure that any negative impact of restoration on profitability is minimized, whilst ensuring that the restoration targets are still met. A critical factor in achieving this efficiency is to integrate the needs for restoration with on-going extraction and civil engineering work of the quarry site. Therefore, the final design of a workable restoration scheme needs to be decided as early as possible. The quarry manager will need to be closely involved to advise on the feasibility of the restoration project with respect to other site operations. Then, once the specific sites for active restoration, and the substrate required for them, have been decided, their establishment can be integrated into the site management plan. Appropriate landforms can be created by ongoing quarrying and tipping operations, soil stripping can be timed so that the soil can be transferred directly to nearby sites where it will be used in restoration.

Fig. 12 The project management process presented as a cycle

Fig. 12



1.3 Frameworks for evaluating the success of habitat creation

It is possible for the 'success' of habitat creation to be evaluated from a number of perspectives e.g.

- Does it meet set biodiversity targets?
- Does it fall within the set financial limits?
- Does it meet with public expectations?
- Does it meet with statutory requirements?

1.3.1. Evaluating success in biological terms

As part of project monitoring, it is important to be able to evaluate how successful schemes have been in biodiversity conservation. A clear definition of targets is essential here (see Section 1.2.2). The criteria used in evaluating success will most likely need to change with time; early on criteria such as the performance of individual plants (e.g. **survival** and **growth rates**) can be used, later on indicators of the state of the established vegetation are more appropriate (e.g. **tree height** or **vegetation cover**). In the longer-term, when the complexity of interactions increases within a created habitat, e.g. plant-plant, animal-plant, then the complexity of the criteria for success also need to increase to take into account these interactions. The practical aspects of undertaking effective monitoring of the criteria discussed in this section are covered fully in Section 2.7.

A simple definition of woodland is a vegetation type dominated by trees more than 5 m tall. This could be used as a measurable indicator of success for woodland creation. Similarly, a simple definition of dwarf shrub heathland is that it has more than 25% cover of ericoid shrubs e.g. heather (*Calluna, Erica*), bilberry (*Vaccinium*) and related plants and / or dwarf gorse (*Ulex*) species. This could be used as a threshold for defining the success of heathland creation.

Such a simple approach can lead to problems, however. Different types of woodland or heathland are defined according to which types of plant make them up, and may have different nature conservation value. If weed species are abundant this may imply that the vegetation is progressing towards a very different endpoint. It is thus valuable to determine the **full list of plant species** present, and the cover of each one.

The aim of many restoration schemes is to encourage biodiversity, i.e. a large number of different types of plant and animal, including scarce and locally distinctive species. However, the total number of plant species is not always a good indicator of biodiversity value. For example, heathlands generally have only a few species of vascular plant. If trees or grasses invade, the number of plant species increases, but the quality of the habitat declines because it becomes less useful to the distinctive heathland invertebrates, reptiles, amphibians and birds. The most accurate indicator of habitat quality may therefore be the presence of target species. Animals are particularly useful for this, since they are generally mobile and can therefore quickly exploit new areas of suitable habitat, or leave areas that are not suitable (Box 17).

Box 17 Birds as indicators of woodland quality

A study of bird distributions in Penrhyn Quarry revealed that woodland edge species such as Great Tit (*Parus major*) and Redstart (*Phoenicurus phoenicurus*) had colonised some areas of taller natural regrowth on the slate waste tips, implying that this habitat fulfils their requirements. However, birds found locally in mature woodland, such as Tree creeper (*Certhia familiaris*), Nuthatch (*Sitta europaea*), Pied Flycatcher (*Ficedula hypoleuca*) and Wood Warbler (*Phylloscopus sibilatrix*), were not found in the quarry regrowth. Woodland edge birds can be seen as **initial target species**; their presence indicates that woodland creation is progressing well. As tree height and canopy closure increase, and more dead wood accumulates and provides new feeding and nesting habitats, it is hoped that birds typical of mature woodland will colonise – these are the **final target species**.

1.3.2 Evaluating success in social terms

Public perceptions of restored habitat quality do not always match the views of conservation experts. Some biodiverse habitats such as scrub, heathland or marsh may be seen as barren or untidy. On the other hand, people with an interest in conservation may focus entirely on woodland creation and the conservation value of open habitats such as scree or grassland may not be appreciated. This illustrates the need for good consultation and communication with and between conservation experts and the general public at the outset, and certainly before the planning phase of a restoration project. Opportunities should be provided for experts to transfer their knowledge of locally important habitats to non-experts in the community in order to foster a better awareness of conservation aims.

Measurable indicators of success in social terms may include how often the public use the site or how opinions may have changed on a site's visual appeal since restoration began. A more formal approach would be to perform contingent valuation based on individuals' 'willingness-to-pay' for the restoration outcome.

1.3.3 Evaluating success in economic terms

Cost benefit analysis was created as a tool for use in project planning (so-called *ex ante* analysis: Section 1.2.1.3), and this is where it has most value. In some circumstances though it may be necessary to weigh up the costs / benefits of a project that is either completed or on-going (so-called *ex post* analysis) for example, to evaluate whether a project was successful and should, therefore, be repeated. When doing such an analysis the same basic principles apply as in *ex ante* analysis, in terms of documenting the costs and benefits accruing in each year of the project, but there are some issues with the discounting that would need to be handled by expert analysts.

1.3.4 Evaluating success in statutory terms

In most instances, there will be statutory requirements laid down in the Planning Permission for extraction regarding the revegetation and aftercare of land in its rehabilitation phase, which extends to a maximum five-year period. There will be an agreed end-use and restoration plan. Mineral Planning Officers must be satisfied that requirements have been met. This is not usually carried out in a prescriptive way, unlike for example in the U.S. where 'stem density' or 'percentage plant cover' are commonly prescribed. Rather, the officers evaluate the fulfilment of a company's obligations through annual site visits and dialogue and judge whether appropriate effort is being channeled into restoration. Measurable indicators of this effort may simply be financial input or, more specifically, may include total area planted, or area prepared to receive plant material.

1.4 References

Bending, N.A.D; McRae, S.G. and Moffat, A.J. (1999) Soil – forming materials: Their use in land reclamation. DETR, London.

Davis, B.N.K. (ed) (1982) Ecology of quarries: the importance of natural vegetation. ITE Symposium no. 11. NERC.

Department of the Environment and Welsh Office (1991) Planning and Compensation Act 1991: Interim Development Order permissions – statutory provisions and procedures. MPG8. HMSO, London.

Department of the Environment and Welsh Office (1995) Environment Act 1995 Review of Mineral Planning Permissions. MPG14. HMSO, London.

Ecoscope Applied Ecologists (2000) Wildlife management and habitat creation on landfill sites: A manual of best practice. Ecoscope. Muker.

Edwards-Jones G, Davies, B. and Hussein, S. (2000) Ecological Economics: an introduction. Blackwell Scientific, Oxford.

English Nature, Quarry Products Association & Moulding Sands Association (1999) Biodiversity and Minerals – Extracting the benefits for wildlife. Entec UK Ltd.

Environmental Advisory Unit (1988) Heathland Restoration: A handbook of techniques. British Gas Southern plc., Southampton.

Hanley, N. and Spash, C. (1993) Cost-benefit analysis and the environment. Edward Elgar, Aldershot.

H.M. Government (1991) This Common Inheritance. HMSO, London.

Joint Nature Conservation Committee (1994) Handbook for Phase 1 habitat survey, a technique for environmental audit. Joint Nature Conservation Committee, Peterborough.

Land Capability Consultants (1989) Cost effective management of reclaimed derelict sites. HMSO, London.

Land Use Consultants and Wardell Armstrong (1996) Reclamation of damaged land for nature conservation. HMSO, London.

Layland, R. and Glaister (eds) (1994) Cost-Benefit Analysis. Cambridge University Press, Cambridge.

Lewis, R.P.W. (1991) Meteorological Glossary, Sixth Edition. The Meteorological Office. HMSO, London.

Mitchley, J; Burch, F; Buckley, P. and Watt, T.A. (2000) Habitat restoration monitoring handbook. English Nature Research Report no. 378. English Nature, Peterborough.

Oxford, M.J. (2000) Developing Naturally: A handbook for incorporating the natural environment into planning and development. Association of Local Government Ecologists. Acanthus Press, Somerset.

Parker, D.M. (1995) Habitat creation – A critical guide. English Nature Science Report no. 21. English Nature, Peterborough.

Price, C. (1993) Time, discounting and value. Blackwell, Oxford. (available electronically from C.Price@bangor.ac.uk)

Pywell, R. and Putwain, P. (1996) Restoration and conservation gain. In: I. Spellerberg (ed) Conservation Biology. Longman, Harlow, Essex. 203-221.

Richards, Moorhead and Laing Ltd. (1995) Slate waste tips and workings in Britain. HMSO, London.

Rivas-Martínez S. (1987) Memoria del mapa de series de vegetación de España. ICONA. Madrid.

Rodwell, J. S. (ed) (1991a) British plant communities. Volume 1. Woodlands and scrub. Cambridge University Press, Cambridge.

Rodwell, J. S. (ed) (1991b) British plant communities. Volume 2. Mires and heaths. Cambridge University Press, Cambridge.

Society for Ecological Restoration (1996) www.ser.org

Welsh Development Agency (1994) Working with nature: Low cost land reclamation techniques. WDA, Cardiff.

1.5 Glossary

(based largely on: Oxford Reference Online, Oxford University Press)

abundance
the total number of each species or, the total amount of all species, present in an area; takes into account the frequency, density and dominance.

aerobic
organisms requiring or utilizing oxygen for metabolic purposes.

aggregate
(in construction) bulk mineral substances, e.g. sand, gravel, crushed rock, tone, graded to size specification used as inert fill in e.g. road construction.

anaerobic
a medium devoid of free oxygen.

backfill
any material used to refill an excavation.

bedrock
solid rock, underlying unconsolidated materials (soil) derived from it through weathering.

bench
(of quarry) level platform cut into rock face (same as terrace).

bioassay
any quantitative procedure in which survival or growth of a given organism is used to estimate the concentration or activity of a test substance.

biodegradable
susceptible to the decomposing action of living organisms.

biodiversity
encompasses all aspects of biological diversity (variety), especially diversity of species, ecosystems and genetic material.

biomass
the total mass of living organic matter.

brashings
woody trimmings e.g. from tree branches.

bryophyte
Bryophyta, a group of plants comprising the liverworts and mosses.

buttress
a structure made of stone or brick which sticks out from and supports a wall/face.

canopy
(of trees) the spread of the upper branches of trees.

carbon sequestration
removal of (usually) gaseous carbon forms into long-term storage in e.g. soil.

carr woodland
found on waterlogged substrates, particularly floodplains

clone
an organism which has the same genes as the original from which it was produced.

community
a group of species characteristically found co-existing because of their similar habitat requirements.

companion species
a plant species grown to improve the performance of a target species.

conservation
a series of measures required to maintain or restore natural habitats and populations of wild flora and fauna.

coppicing
act of thinning woodland by periodic cutting of tree stems.

corridors
strips of a particular habitat type that connect two or more adjacent larger areas of similar habitat.

deciduous
the annual shedding of leaves.

decomposer
an organism that breaks down complex organic substances into simple compounds that can be used by other organisms; essential for nutrient cycling in soil.

dehesa
a Spanish term describing a landscape of large scattered oak trees, in areas of pasture or cereal that are grazed extensively.

dominance
reflects how much of the site a species occupies.

dry heath
free-draining heathland.

ecological restoration
an approach to restoring species or habitats that takes into account the interrelationship of living organisms to each other and their surroundings.

ecology
the study of the interrelationship of living organisms to each other and the physical environment.

ecosystem
an interacting community of independent organisms and the environment they inhabit.

ecotype
a naturally-occuring variant of a species adapted to a specific suite of environmental conditions.

ericoid
belonging to the plant family Ericaceae.

faults
a change in alignment of rock strata

fines
general term for very small particles (sand, silt and clay) often derived from crushed rock in quarries.

gallery
flat area cut into a rock face, used as a passage-way

germination
the beginning of growth of a seed.

glacial till
generally not layered, material deposited directly by glacial ice. Till is poorly sorted (mixed rock particles), with a wide range of grain sizes from clay to boulders.

granite
acidic, igneous hard rock

grass-legume ley
a short-term vegetation cover to promote rapid build-up of organic matter (from grass roots) and nitrogen (from legume).

gullying
the erosion of soil by running water to form clearly defined, narrow channels.

habitat
natural locality in which an organism lives, or the environment of a community.

habitat (re-) creation
creation of habitats of nature conservation value on a site where they do not currently exist.

habitat quality
the levels of environmental variables (e.g. nutrients, climate) that dictate whether an organism can live in its surroundings.

habitat translocation
process of relocating vegetation with associated topsoil and invertebrate species.

heathland
a low-fertility habitat dominated by dwarf woody shrubs, particularly Ericacea family.

horizon
a distinct layer of soil, which differs chemically or physically from layers above or below.

hydroseeding
technique for seeding large areas using water as a propellant.

hyphae
vegetative filaments of fungi; important in binding soil particles and improving soil structure.

indicator
presence of (commonly) a species or other determinant that signifies a certain phase has been reached.

inorganic fertilizer
soluble chemical fertilizers consisting of no living material, principal components are usually nitrogen, phosphorus and potassium.

invertebrate
an animal which lacks a backbone e.g. snail, earthworm, insect.

isohyet
a line drawn through geographical points recording equal amounts of precipitation (rain, snow) during a specific period.

landforming
profiling the shape and form of a site; hard landscaping.

legume
a member of the pea family capable of utilizing atmospheric nitrogen indirectly due to its symbiotic association with specialized bacteria in its roots.

limestone
sedimentary rock that is composed largely of calcium carbonate.

litter
accumulation of discarded plant material on surface of soil.

local provenance
propagative material with a native origin destined to be used in the same local area as it was collected.

mesofauna
organisms between 0.1 to 10 mm, e.g. nematodes, mites and springtails.

microbe
see microorganism

microclimate
climate at the habitat – scale, affected by vegetation cover, soil and topography.

microorganism
organisms less than 0.1 mm e.g. soil bacteria, actinomycetes, fungi, algae and protozoa.

microtopography
physical form of land at the habitat – scale.

mineral
solid inorganic substance of natural occurrence; also a substance obtained by extractive procedures such as quarrying and mining.

mineralization
the conversion of organic nitrogen to inorganic nitrogen (used by plants) by microbes.

morphotypes
a variant within a species population exhibiting a specific morphology (form).

mosaic
a pattern of patches (of plant communities, habitats).

mulch
the term given to various materials applied as a top-dressing to conserve water, suppress weeds, control erosion or reduce soil crusting.

mycorrhiza
a mutually beneficial symbiotic association between plant roots and fungus. The fungus receives nutrients from the roots and in return supplies other nutrients to the plant.

National Vegetation Classification
a system for classifying all natural and semi-natural vegetation communities specific to Britain.

natural habitat
habitat largely unaffected by human intervention.

nature conservation value
a high value is assigned to a species or habitat if they score highly using standardcriteria devised by statutory environmental agencies.

nitrogen-fixing species
(of plants) those able to utilize atmospheric nitrogen through their symbiotic relationship with root-dwelling N-fixing microorganisms.

nurse species
see companion species. May be removed at a later date.

nutrient
a requirement by living organisms to maintain health and vigour

oligotrophic
a system low in nutrients.

organic matter
derived from previously living tissue

overburden
the rocks and/or soil overlying the requisite material for extraction.

pioneer species
species that typically exhibit rapid growth, produce copious amounts of small seed that are easily dispersed and able to germinate and establish on open sites.

porosity
the void volume of a soil that is not occupied by mineral grains.

primary colonizer
a plant that occurs early in a vegetational succession (see pioneer species).

propagule
any seed, fruit, spore or part of a plant or fungus that can produce a new plant.

quadrat
precisely defined area in which a survey takes place

randomization
a process which ensures each unit has the same probability of receiving any given treatment (in experimental design).

reclamation
repairing degraded land for a defined end-use but not its former (semi-) natural state.

restoration
to return a degraded habitat to its former (semi-) natural state.

scarify
to create uneven surface on soil.

scree
an accumulation of coarse rock debris that rests against the base of an inland cliff, produced by the weathering and release of fragments from the cliff face.

scrub
vegetation dominated by small woody shrubs, which typically form an intermediate community between heath and tall woodland.

secondary aggregate
recycled primary aggregate or waste from primary aggregate

seedbank
resevoir of dormant seed within soil.

semi-natural habitat
once a natural habitat but now affected by human activity e.g. grazing, burning.

silviculture
the cultivation of forest trees, or woodland management for timber and other wood products (similar to 'forestry').

skeletal soils
where stony material amounts to more than 35% of the volume of a soil horizon and contain little or no organic matter.

slate
regionally metamorphosed rock, easily split along thin layers of bedding formed during the compression of shales by the overlying rocks.

slumping
the movement of a mass of incoherent sediment down a slope.

species
one or more groups (populations) of individuals that can interbreed.

species richness
the total number of species present in an area or plot.

SSSI
Site of Special Scientific Interest (Wildlife and Country Act, 1981).

subsoil
designates the deeper portion of the soil below the Ap (plough layer) horizon (see topsoil).

substrate
used in this Manual as a general term to describe largely mineral materials used for planting on a site where there is a shortfall in topsoil.

succession
the sequential change in vegetation and associated animals in response to an environmental change or induced by the organisms themselves.

tackifier
functions as an adhesive to ensure seed and mulch stay together after hydroseeding.

target habitat
the preferred habitat type for a habitat creation scheme.

target species
the preferred plants to be established in an area.

terraces
level platforms cut into slopes.

tipping
the dumping of materials on top of each other.

topsoil
uppermost part of the soil, ranges from 7 to 25 cm, known as the plough layer, or Ap horizon.

vascular plants
'higher' plants possessing a developed network of vessels for distributing water and nutrients through the plant body.

vegetative propagation
reproductive process that is asexual i.e. does not involve a recombination of genetic material and involves propagation from roots, stems or leaves.

weathering
natural process by which rocks or soils are by either mechanical (e.g. frost shatter) or chemical (e.g. oxidation) means.

wet heath
not free-draining, with a high water holding capacity.

woodland
a habitat dominated by tall trees.