Environmental RTDI Programme 2000–2006

ENVIRONMENTAL QUALITY OBJECTIVES

Noise in Quiet Areas

(2000-MS-14-M1)

Synthesis Report

Prepared for the Environmental Protection Agency

by

SWS Environmental Services, SWS Group

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DISCLAIMER

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Landscape, wildlife and the sounds of nature combine to form our natural environment. Tranquil areas are part of our natural resource; they provide places for contemplative recreation, solitude and reflection where one can experience a symphony of sounds and a sense of place.

The natural soundscape is an indicator of environmental quality;
it is part of our heritage and environment, important for wildlife and biodiversity.

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Executive Summary

The European Commission has adopted a Directive relating to the *Assessment and Management of Environmental Noise* (EU, 2002). Member States, including Ireland, are required to implement the Directive and to adopt action plans to meet its objective. The purpose of the directive is to protect the quality of our acoustic environment, control and manage environmental noise in built-up areas, in public parks or other acoustically valued soundscapes (Quiet Areas) in an agglomeration and in Quiet Areas in open country. Establishing the location and determining the quality of Quiet Areas is the first step towards implementation of this directive.

The Environmental Protection Agency (EPA) in association with SWS Environmental Services developed this research project to meet the requirements of this directive[1]. The primary aim of the project is to establish baseline data for Quiet Areas in Ireland.

This task was undertaken through an extensive environmental noise monitoring programme undertaken throughout Ireland over an 18-month period. The project developed criteria for identifying Quiet Areas and delivered reliable, objective and comparable information on the acoustical environment in Ireland. The monitored data provided the basis for developing methodologies for soundscape mapping, assessing the quality of the acoustic environment in Quiet Areas in Ireland and established comprehensive environmental quality objectives (EQOs) and environmental quality standards (EQSs) for Quiet Areas.

The information produced by the project will make a significant contribution to the implementation of the Environmental Noise Directive and will greatly assist Ireland and other Member States in introducing accountable noise abatement development programmes and related monitoring systems for reducing and managing noise pollution. Full details are provided in the Final Report, available from the Environmental Protection Agency.

1. This report was developed as part of the medium-scale project: Environmental Quality Objectives – Noise in Quiet Areas (2000-MS-14-M1). Other deliverables related to this project include a Literature Review and a Final report.

1 Introduction

The European Commission has adopted a Directive relating to the *Assessment and Management of Environmental Noise* (EU, 2002) (the Environmental Noise Directive or END), of which some of the primary objectives are:

- **Monitoring the environmental problem** by requiring competent authorities in Member States to draw up "strategic noise maps" for major roads, railways, airports and agglomerations, using harmonised noise indicators L_{den} (day–evening–night equivalent level) and L_{night} (night equivalent level). These maps will be used to assess the number of people both annoyed and sleep-disturbed throughout Europe.

- **Informing and consulting the public** about noise exposure, its effects, and the measures considered to address noise, in line with the principles of the Aarhus Convention.

- **Addressing local noise issues** by requiring competent authorities to draw up action plans to reduce noise where necessary and maintain environmental noise quality where it is good.

- **Developing a long-term EU strategy**, which includes objectives to reduce the number of people affected by noise in the longer term, and provides a framework for developing the existing Community policy on noise reduction from source.

The Environmental Noise Directive of 2002 is the first attempt to put in place a common approach in Europe to avoid, prevent or reduce the harmful effects of noise in the environment. Member States will be required to introduce harmonised noise indicators and methods of assessment, develop strategic noise maps, and introduce Action Plans where necessary for the reduction of environmental noise and for the preservation of Quiet Areas.

The Environmental Protection Agency (EPA) has a duty to monitor and protect the environment and, in particular, is required under the 1992 EPA Act (Section 65) to make provision for the monitoring of the quality of the ambient environment.

1.1 Project Proposal

Having regard to the possible obligations following from the implementation of the Directive and the above-mentioned requirements of the Act, the EPA and SWS Environmental Services developed a research project to identify and establish baseline data for Quiet Areas in Ireland and to put in place comprehensive environmental quality objectives (EQOs), where such objectives are not already embodied in EU legislation, and to produce additional environmental quality standards (EQSs) which might be necessary for the achievement of the EQOs.

2 Methodology to Evaluate Environmental Noise Levels

The project was executed in the following manner:

- Identify 15 sites in the Irish countryside as reference locations for assessment of the baseline noise environment.
- Develop an extensive database of the soundscape or acoustic quality of the environment in each location through monitoring and noise data analysis.
- Undertake baseline noise mapping for each of the 15 reference sites utilising GIS technology. The noise mapping will provide a visual representation of the noise profile at a given geographical location, which can be used to identify the boundaries of Quiet Areas.
- Evaluate the status of Quiet Areas in Ireland.
- Undertake modelling of anthropogenic noise, based on monitored and/or noise database values, at four of the reference sites representative of different rural conditions in Ireland.
- Integrate the model results with GIS to provide detailed impact maps to demonstrate the technique. This will provide the authorities involved in policy making with the necessary information to assist in the development of policies and plans for noise abatement and control in Quiet Areas locally, regionally and nationally.
- Develop and propose comprehensive EQOs and additional EQSs, where considered necessary for the complete achievement of the proposed EQOs, based on the data gathered during the monitoring and modelling tasks above.

2.1 Description of Work Undertaken

The preliminary identification of potential sites for inclusion in the study was undertaken utilising a combination of GIS and site-specific knowledge based on the experience of the research teams. Acoustical, ecological and socio–cultural criteria were utilised in selecting suitable areas for study. Physical acoustical measurements were undertaken, combined with GIS modelling, to select sites of environmental, historical, cultural and visual (landscape) importance.

In order to undertake a qualitative study on environmental sound levels in Quiet Areas in Ireland, it is important that the principal landscape elements are considered.

Fifteen large area sites were selected around the country spreading across 17 counties. The selected sites were considered representative of the landscape types containing the necessary elements and features that can be found in quiet rural areas throughout Ireland. The combination of landscape elements includes topography, land cover, habitat type, historic landscapes, lake and seashore. Monitoring was conducted at each location on four separate occasions over the project period.

Measurement locations were chosen to provide sound-level data which would be indicative of what may be experienced by persons frequenting the area. The monitoring exercise was undertaken by two monitoring teams adopting the following procedure:

- At each location suitable sites were selected for recording sound levels.
- A control site was identified where one instrument would be erected and left to record continuously undisturbed over a 24-hour period.
- The number of sound-sampling locations within each site varied depending on geographic location, soundscape boundaries and number of sound-level recorders.
- The minimum number of sampling locations within each site was 8, the maximum 20.
- The minimum number of instruments used per site was 3, the maximum 8.
- The minimum recording period for each monitoring location was 15 minutes.

- At each site, overnight undisturbed monitoring was undertaken at a minimum of three locations simultaneously.
- The 24-hour measurement locations (including the integrated wind-measuring sensor) were positioned in the middle of a field in open space and away from reflecting surfaces.
- Monitoring was repeated at each location on four occasions.
- Digital Audio Tape (DAT) recordings of environmental sounds were recorded in the field at four reference sites. These recordings provide actual sound recordings of the soundscape at each site.

3 Identifying and Monitoring Quiet Areas

In a previous report commissioned by the EPA (Dilworth, 2000), certain spatial criteria were suggested that, when considered together, would identify locations that should characterise Quiet Areas.

It was considered that the original criteria specified were not sufficient to ensure that the identified areas would meet the specifications or be characteristic of Quiet Areas in the open countryside.

Consequently, modifications to the original distance criteria were proposed in order to select, with greater precision, areas that should meet the requirements and physical characteristics of Quiet Areas in the open countryside. The primary characteristic of such areas is that they would largely be unaffected or influenced by anthropogenic- or human-induced noise. The revised minimum distance criteria are outlined as follows:

- At least 3 km from urban areas with a population >1,000 people
- At least 10 km from any urban areas with a population of >5,000 people
- At least 15 km from any urban areas with a population >10,000 people
- At least 3 km from any local industry
- At least 10 km from any major industry centre
- At least 5 km from any National Primary Route
- At least 7.5 km from any Motorway or Dual Carriageway (as recommended in EU studies).

In addition to minimum distance criteria, the following environmental, ecological and socio–cultural factors were also taken into account in site selection:

- Low population density
- Low agricultural productivity (away from intensive farming)
- Good network of minor roads/tracks to facilitate accessibility and noise monitoring
- Topography, elevation and land use, including flight paths, wind direction and rural activities
- Inclusion of a selection of sensitive ecological habitats and land uses at varying elevations
- Proximity to and inclusion of areas designated for conservation and places of high amenity value with regard to their natural soundscape
- Transport pressures, in particular traffic flow on National Primary and Regional Routes along the densely populated east coast compared with the low-density population on the western side of the country.

In the context of this study, noise refers to anthropogenic- or human-induced noises. Scientifically, one must also consider that domestic dogs, cows, sheep, and other agricultural animals can also impact on natural soundscapes.

3.1 Landscape Characterisation

The many elements of the natural and cultural heritage that make up our rural landscape include the natural soundscape. The term ‘soundscape’ refers to any acoustic environment, whether it springs from natural, urban, or rural sources (Krause, 2002). It is derived from landscape and can be defined as the auditory environment within which a listener is immersed. Perception of a soundscape is dependent on a person’s experience with their visual impression of an area as well as their impression of the noise sources fitting or not fitting with an area (Fyhri and Klaeboe, 1999).

The perception of noise in a Quiet Area is generally referred to when people feel disturbed or annoyed because of qualities or activities (i.e. tranquillity, solitude, contemplative recreation and reflection) that are interfered with by unexpected noise, not wanted or belonging to that area. Some sounds will be annoying for individuals depending on their lifestyle, socio–cultural backgrounds, and association with an area (i.e. resident, visitor), while for others it may be a sound regarded as belonging to or part of an area.

3.1.1 Natural Soundscapes

Natural soundscapes can be categorised as either biophony or geophony. Biophony is a type of soundscape confined to the sounds that organisms generate in a particular habitat. Geophony is a soundscape of non-living phenomena, for instance the sounds of streams, seashore, wind through trees, or a myriad of other causes.

Environmental sound levels within soundscapes are specific due to their spatio–temporal characteristics and because sound varies according to space and time. As a consequence, the acoustic boundaries within one study area may vary considerably depending on the site characteristics. To characterise or describe a soundscape there is a requirement for quantitative (i.e. sound levels) and qualitative (type of sound: natural–pleasant, anthropogenic–unpleasant) assessment.

Acoustical, visual, ecological and socio–cultural indicators are invariably linked in the process of auditory perception used to characterise the soundscape of an area. The strategy of selecting study areas for this project combined each of these criteria to select reference sites for a representative study of Quiet Areas throughout Ireland.

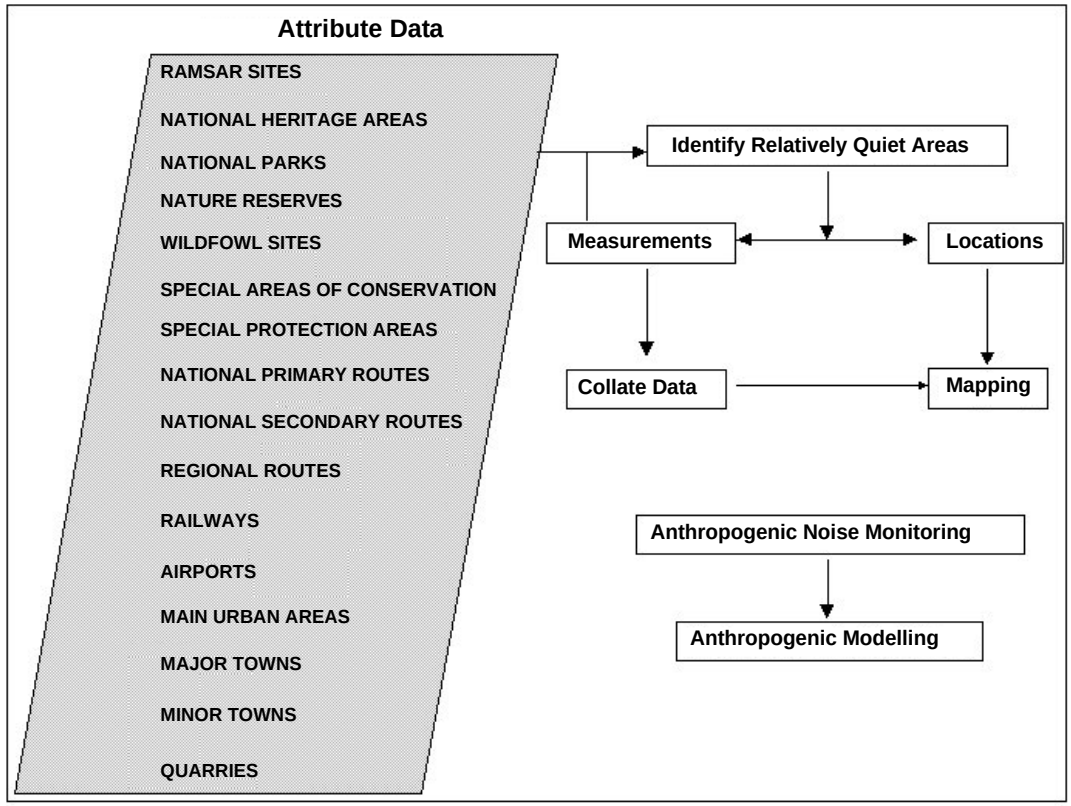
In undertaking this, the following four landscape types were suggested for inclusion in the study:

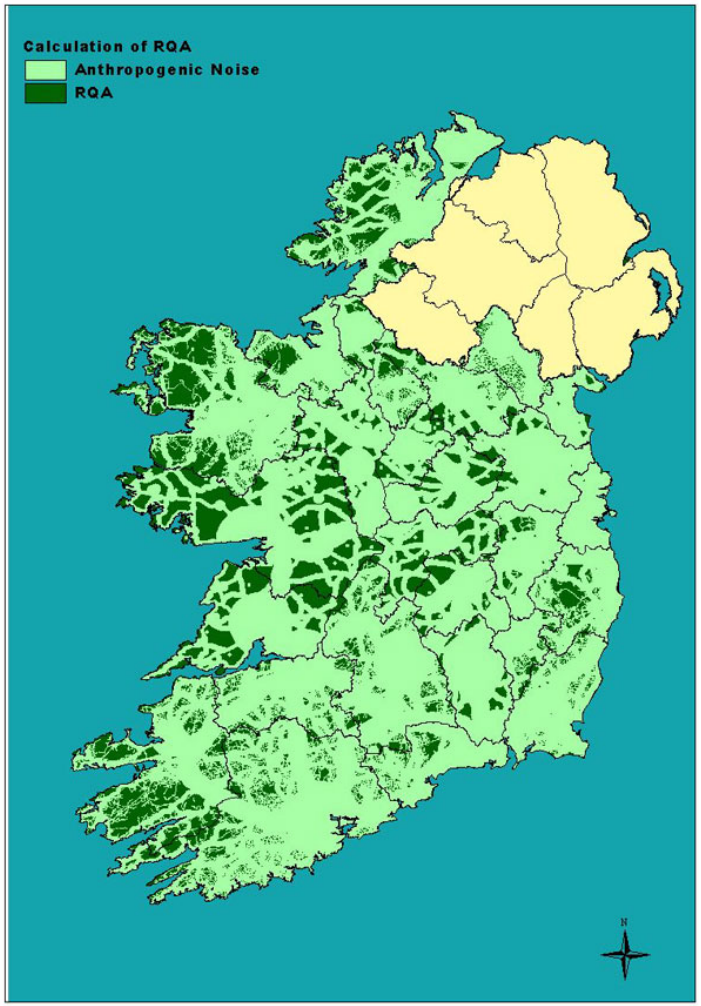
- Mountain, rolling hill and open valley landscapes
- Flat lowland landscapes in the midlands
- Coastal landscapes
- Inland waterway influenced landscapes.

3.2 Site Selection

The preliminary identification of potential sites for inclusion in the study was undertaken utilising a combination of GIS and site-specific knowledge based on the experience of the research teams. Acoustical, ecological and socio–cultural criteria were utilised in selecting suitable areas for study. Monitoring sites included a selection of ecological habitats. Special consideration was given to Natural Heritage Areas (NHAs), Special Protection Areas (SPAs), RAMSAR sites and places of high amenity value with regard to their natural soundscape.

Physical acoustical measurements were undertaken combined with GIS modelling to select sites of environmental, historical, cultural and visual (landscape) importance. Figure 1 outlines the procedure in GIS site selection.





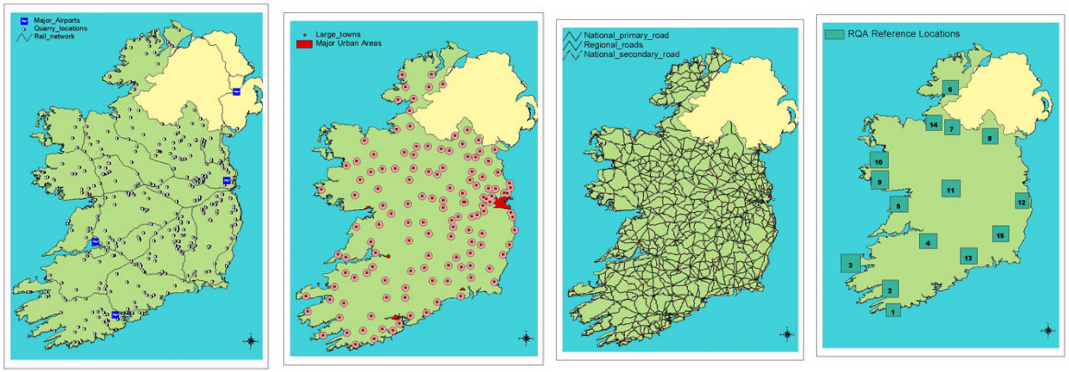


Figure 1. GIS site selection process.

4 Site Investigations

Extensive environmental noise monitoring was undertaken throughout Ireland (Fig. 2). The report for each location in the site survey contained the following:

- Noise description parameters, L_{Aeq}, L_{Amax}, L_{Amin}, L_{A10}, L_{A90} and L_{A95}
- The exact microphone location transposed to a GIS map
- Dates of measurement times, 15-minute interval times
- Description of weather and detailed site-specific 15-minute interval wind data
- A description of the primary noise sources
- Calibration records.

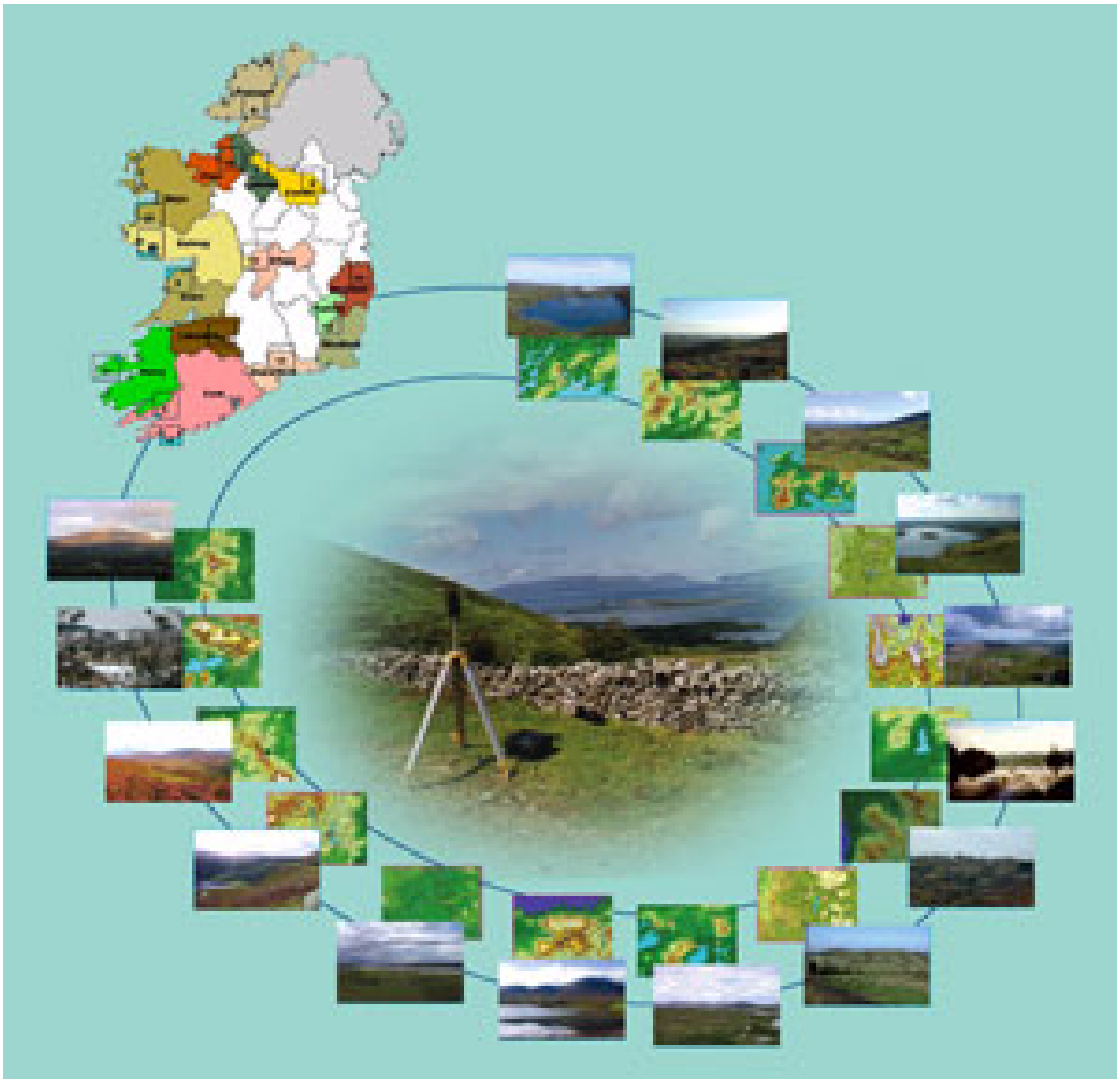


Figure 2. Site locations and landscape types.

In total, monitoring was undertaken in over 300 locations within the 15 reference sites. The resulting environmental database comprises approximately 21,000 individual noise-recording intervals/periods and associated information totalling in excess of 170,000 environmental measurements.

Soundscape mapping was undertaken at four sites and noise modelling was undertaken at representative sites to illustrate how anthropogenic noise can influence Quiet Areas.

The acoustic models were developed and integrated within a Geographic Information System (GIS). The capabilities of developing this system will support the development of strategic environmental assessment for noise and provide an integrated environmental planning methodology for noise control. For the purpose of describing the soundscapes, quantitative criteria are required to characterise the acoustic experience.

Each study site can be broken down into individual geophonic and biophonic soundscapes dependent on geographic locations and habitat type as illustrated in Fig. 3. In this example, within the one study area, monitoring was undertaken at elevated hilltops, lakeside locations, on rough grazing areas, within native woodland, in the vicinity of coniferous forestry and along the seashore.

Qualitative aspects were represented by describing the noise sources and anthropogenic influences within the study area. This information was included in a noise database compiled in Microsoft Excel spreadsheets to document the monitored data.

The noise database compiled for this project provides a unique environmental dataset of environmental sound levels recorded throughout Ireland at the turn of the century combined with digital photography and land-use characteristics that will have inherent value in future years.

Noise data are presented in L_{Aeq}, $L_{Amax,}$ L_{A10}, L_{A90} and L_{A95} values in both graphical and tabular format. The geo-referenced dataset comprises approximately 21,000 individual sound recordings (15-minute intervals) with corresponding wind-speed measurements and site-observation notes.

Daytime, evening and night-time L_{Aeq}, $L_{Amax,}$ and L_{A90} values were calculated for the control location at each study site.

Digital terrain maps were produced using GIS technology for all sample sites, identifying the monitoring location and proximity to known anthropogenic influences such as roads and towns. Figure 4 illustrates the databases developed for each sample.

Figure 3. Geophonic and biophonic variations within study areas.

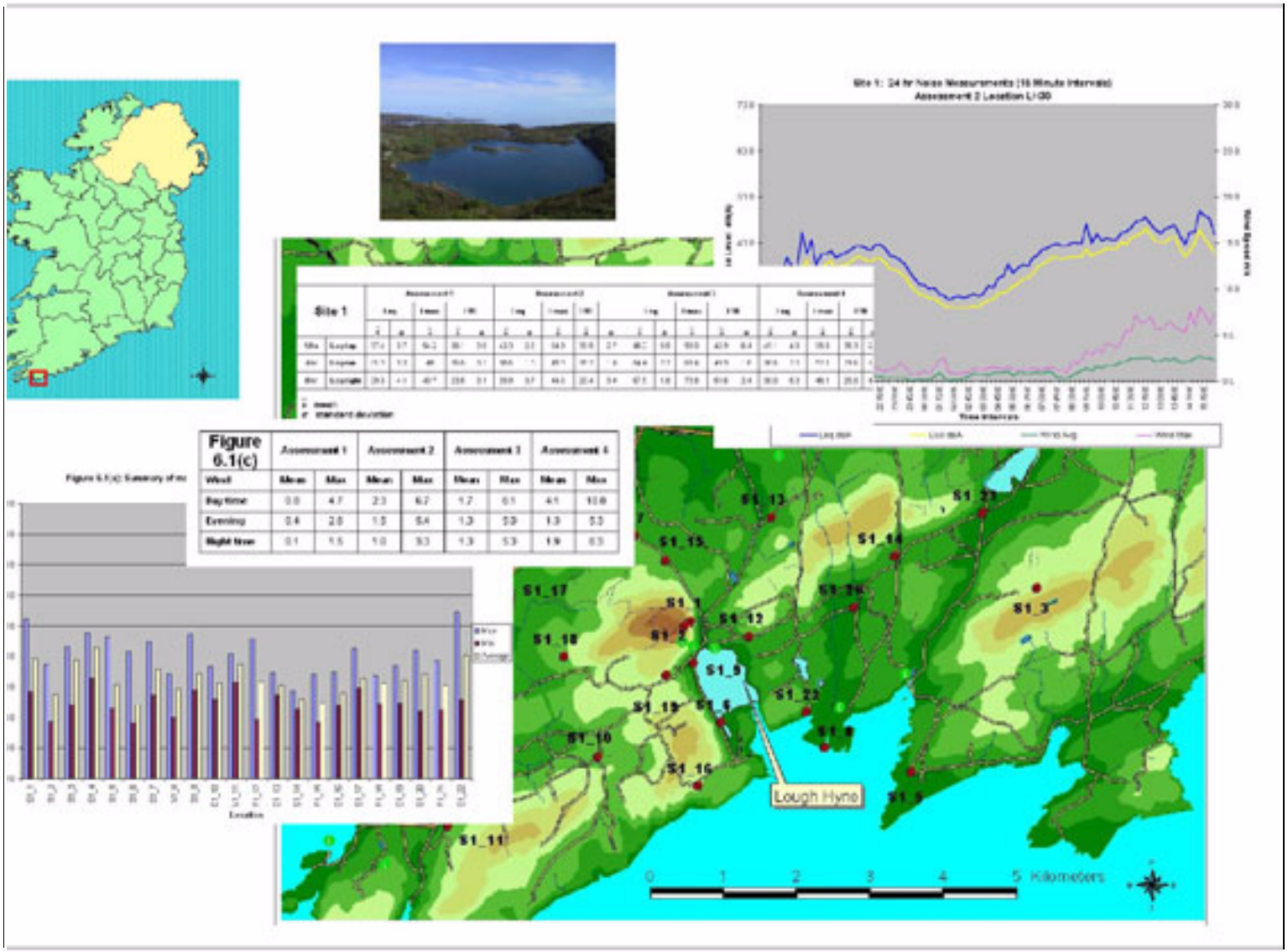


Figure 4. Environmental database information.

5 Review of Monitoring Data

This research provided comprehensive baseline data for Quiet Areas (as defined in the proposed EU Environmental Noise Directive) throughout Ireland.

The research provides excellent examples of biophonic, geophonic and anthropogenic sound sources in addition to examples of how meteorological conditions can influence sound recordings, some of which are discussed below and in detail in the Final Report. Examples of some of the biophonies investigated include lowland and upland bogs, coastal coniferous forests, native woodlands habitats, lakes, bays, riparian zones, inland coniferous forests, inland waterways, enclosed marine environments, shorelines and rough grazing scrub and grasslands.

Each study site can be broken down into individual geophonic and biophonic soundscapes, as discussed previously.

The study also investigated natural habitat sounds that are non-biological in origin. Examples of non-biological sounds or geophonies include wind, rain, streams, rivers and different types of lake, ocean, and inland waterway wave action sounds. The project demonstrates that each study area has its own natural soundscape characteristics. Within a study area, individual soundscape boundaries may exist dependent on geographical location anthropogenic influences and geophonic or biophonic influences.

Anthropogenic sound sources, in particular road traffic noise, follow the natural diurnal patterns, with higher road traffic and associated noise during the morning and evening periods. In certain locations near major population areas, the presence of road traffic noise was a continuous feature of the soundscape.

The project illustrates a marked difference between daytime and night-time sound levels in less densely populated areas, especially at locations where the absence of anthropogenic noise (road traffic) was most notable. The research illustrates how human-induced noise can significantly impair the transmission and reception of natural soundscapes. Certain sites experience longer periods of natural quiet or Noise-Free Intervals (NFIs) (Hempton, 1999). An NFI is defined as a 15-minute period when there is no mechanical or domestic noise present.

The length and duration of NFIs at monitoring sites were significantly different on the east coast compared with those on the west coast. This is largely due to road traffic. This project identifies how pure natural soundscapes, places where no human noise is present, exist only on a temporal level. Within each study area at a limited number of locations, periods of natural quiet were experienced. The periods of natural quiet varied at each location and were dependent on time of day.

Variations in environmental noise levels were observed at all sites. These were largely related to seasonal and other fluctuations resulting from:

- the effects of sound-level variation with changes in wind speed above 3 m/s (sound emissions from wind on vegetation)
- the effects of sound-level variation with wind direction (wind from a source to receiver, e.g. from nearby leaf/branch movement on trees, from a National Primary route, from a river/waterfall flowing down a mountain)
- the effects of temperature and precipitation
- the seasonal effects of agriculture, outdoor recreational activities
- the influence of habitat and associated flora and fauna, i.e. vegetation both with and without leaves
- the effects of insects such as grasshoppers, bees, wasps and other small creatures (increased the background levels from 20/21 to 25/26 dBA)
- the variation in road traffic on tourist routes (localised effects)
- other activity, such as agricultural animals (sheep, cows, etc.) and wildfowl in open areas, will affect the total noise environment.

6 Mapping Soundscapes

The Environmental Noise Directive requires Member States to produce strategic noise maps displaying noise pollution expressed in terms of common noise indicators L_{den}, L_{day}, $L_{evening}$, L_{night} that have also been proposed by the EU (2002).

Current acoustic modelling is done by inputting all pertinent noise sources. As illustrated in this study, given the magnitude of the natural soundscapes under investigation and the associated inherent variables (biophonic, geophonic, anthropogenic noise sources), this task is impossible. The idea, therefore, is to base the acoustic map on a number of representative spatio–temporal sample points within the study area. Based on these sample points, one can approximate the sound levels within the entire study area by means of interpolation methods. In the first phase, using the monitoring dataset computer-based visualisation, sound maps were produced for four reference sites to capture and dynamically interpret all of the data.

In order to generate noise maps from the measured noise levels, the spot measurements together with the mean L_{Aeq} or L_{A90} of each location in each of the four campaigns were introduced in the GIS environment and a coarse (100 × 100 m) surface was calculated using the "topogrid" algorithm in Arc Info, which generates smoothened topographically correct surfaces. These were subsequently contoured as L_{Aeq} or L_{A90} levels. The monitoring location and sound-pressure levels (either as L_{Aeq} or L_{A90}) recorded at each station are shown together with the corresponding contour maps in Figs 5 and 6.

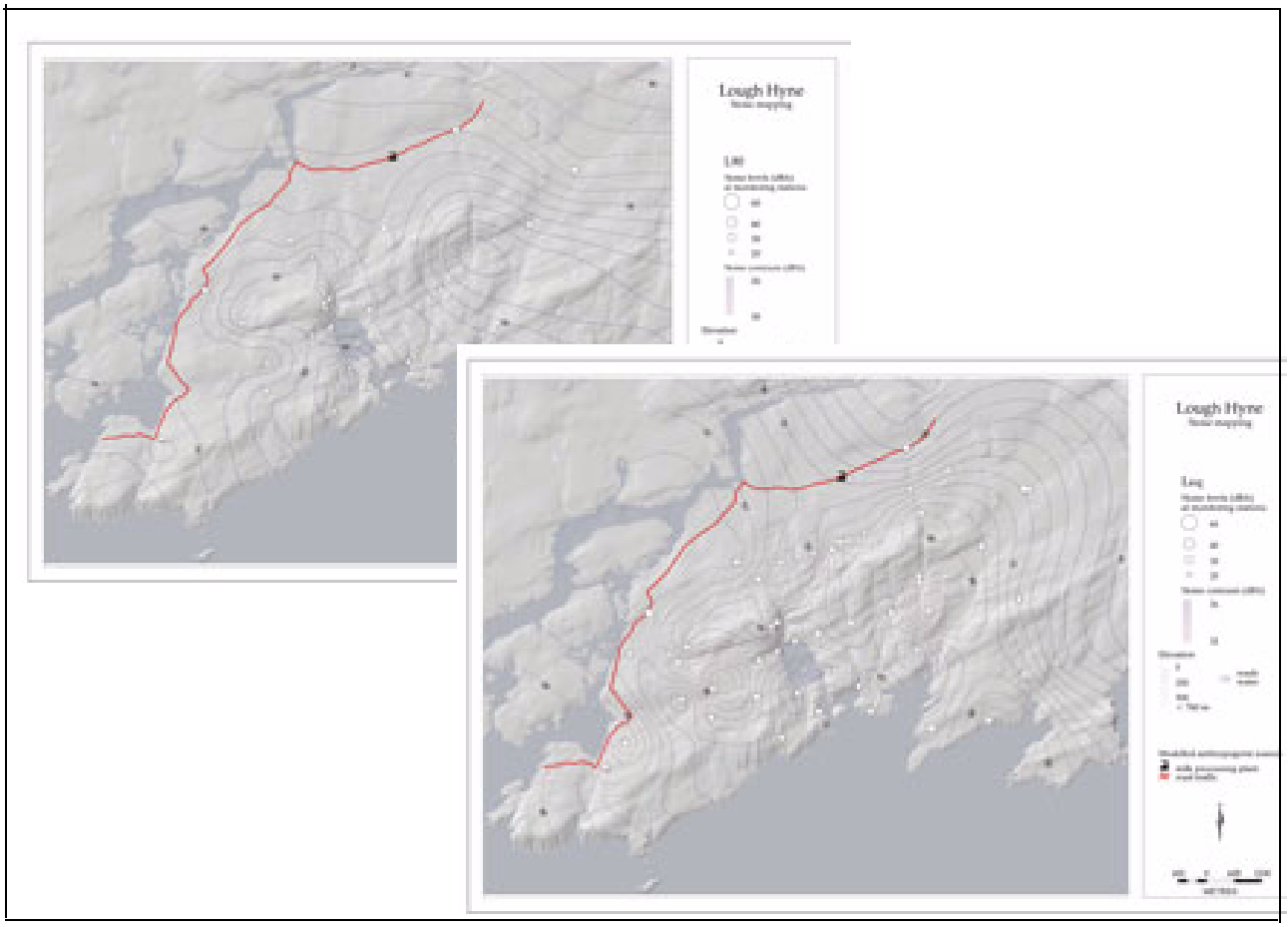


Figure 5. Sound Map Site 1, L_{Aeq} and L_{A90}.

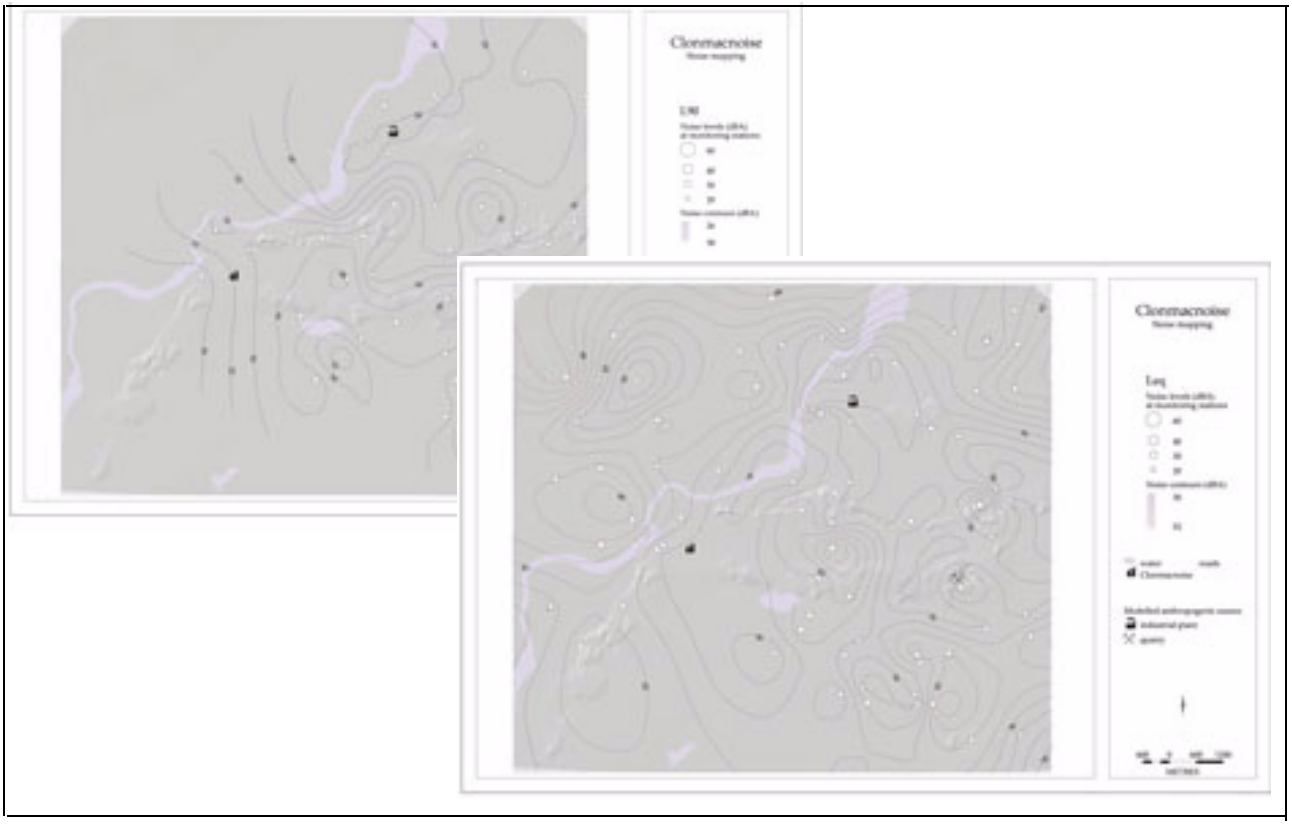


Figure 6. Sound Map Site 11, L_{Aeq} and L_{A90}.

6.1 Anthropogenic Modelling

Anthropogenic noise modelling was conducted to model the impact of the principal sources of anthropogenic noise present in Quiet Areas in rural Ireland. Models were developed in the second phase of the project for each of the following anthropogenic sources:

- Industrial plant
- Milk processing plant
- Tree harvesting
- Quarry or an open pit mine
- Wind farm
- Road traffic.

In the models developed, both the model inputs and outputs were calculated and presented in Arc Info GIS, taking full advantage of the spatial modelling capabilities the system offers. Spatially referenced source and receiver locations and elevations are used as a reference in calculating the input parameters (such as the relative distances, source/receiver heights, barrier location and heights, etc.) in complex terrain prior to noise propagation model implementation.

The ArcView layers provided by the EPA were converted to Arc Info vector coverages, maintaining the attribute table structure for all features. The model domain was divided into two different resolutions: at 100 × 100 m for noise propagation modelling and at 10 × 10 m for direct line of audibility calculations and for the noise map presentations. The 3D elevation models for each site were formed from the elevation contours, spot elevation measurements and significant linear features (coastal and inland water outlines, high-tide water levels, etc.) and utilised to extract locational and elevational attributes for the divided model domain.

6.1.1 Point source modelling

In this example, the sound power level of point or distributed anthropogenic noise sources used in assessing the potential noise impact in the Quiet Areas studied was characterised through an experimental measurement technique.

The sound power level of distributed point sources was represented by an equivalent point source, the Equivalent Acoustic Centre (EAC). The EAC principle was used to define the sound power level of a number of spatially distributed anthropogenic noise sources.

Figure 7 illustrates an example of the noise model produced. The GIS-integrated point source noise modelling procedure implemented in the project involved:

1. Defining the modelling grids
2. Calculating noise attenuation due to geometric spreading
3. Calculating attenuation due to air absorption
4. Calculating attenuation due to ground effects
5. Calculating attenuation due to topographic barrier effects
6. Calculating sound pressure levels (L_p) at each receiver location and combining the contributions from each source at this point to define the noise impact due to the anthropogenic source
7. Combining the anthropogenic noise impacts calculated with the background levels monitored and mapped and presenting a sound map representative of the resultant noise levels due to the anthropogenic sources.

6.1.2 Road traffic modelling

In the case of road traffic noise impacts (line sources), the road traffic noise model was developed based on the UK Department of Transport (Department of Transport Welsh Office, 1988) procedure detailed in "Calculation of Road Traffic Noise" (CRTN). The original CRTN formulation expresses noise levels in terms of the $L_{A10,1h}$ or $L_{A10,18h}$ index.

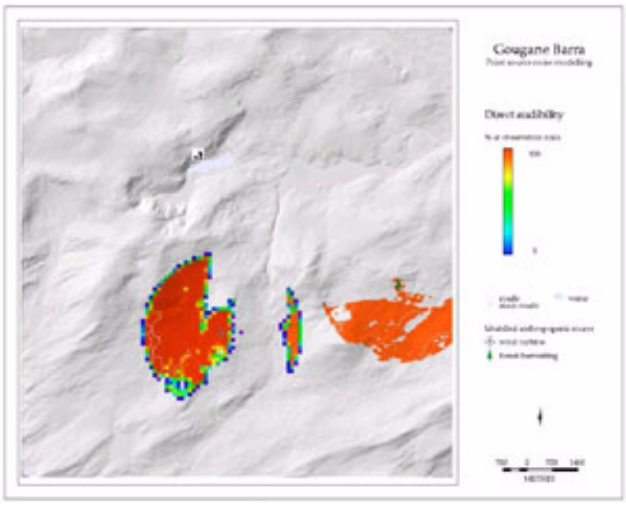
In order to comply with the requirements of the EU Environmental Noise Directive, the basic noise levels ($L_{A10,18h}$) were converted to the EU-recommended common noise indicators (L_{den}, L_{day}, $L_{evening}$, L_{night}) using the relationships proposed by the TRL (Abbot and Nelson, 2002).

The algorithms used in various noise propagation models were analysed and programmed for use in conjunction with the GIS where the inputs for noise attenuation are calculated using the topographic features of the landscape considered.

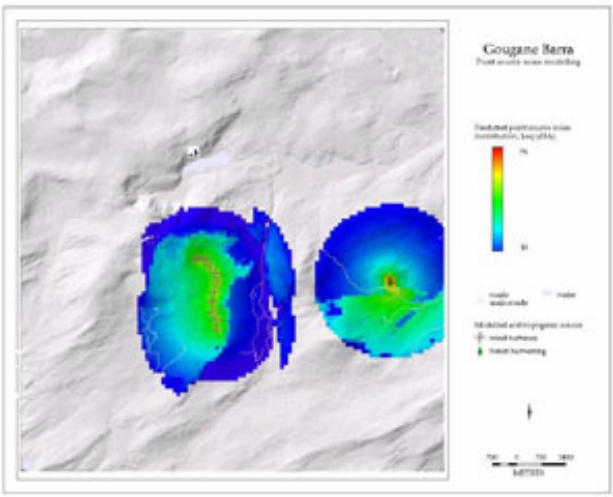
The procedure is similar to that undertaken for point or area source modelling and involves:

1. Defining the modelling grid
2. Defining the road segments
3. Calculating the basic noise level ($L_{A10,18h}$) for each road segment identified by implementing the necessary corrections for the mean traffic speed, percentage heavy vehicles and the road gradient
4. Converting the basic noise levels ($L_{A10,18h}$) determined to the EU-recommended common noise indicators
5. Calculating attenuation due to distance for each road segment–receptor pair
6. Calculating attenuation due to ground absorption for each road segment–receptor pair
7. Calculating attenuation due to topographic barrier effects
8. Defining the noise impact due to road traffic
9. Combining the anthropogenic noise impacts calculated with the background levels monitored and mapped.

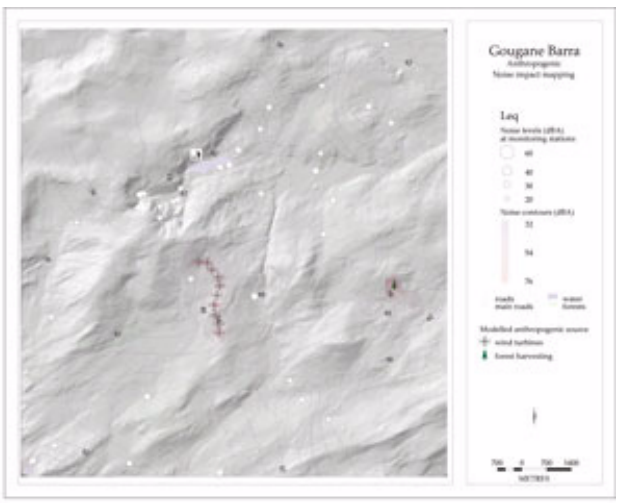
Examples of the road noise modelling outputs are provided in Fig. 8.



(a) Visibility (audibility) indicators calculated.

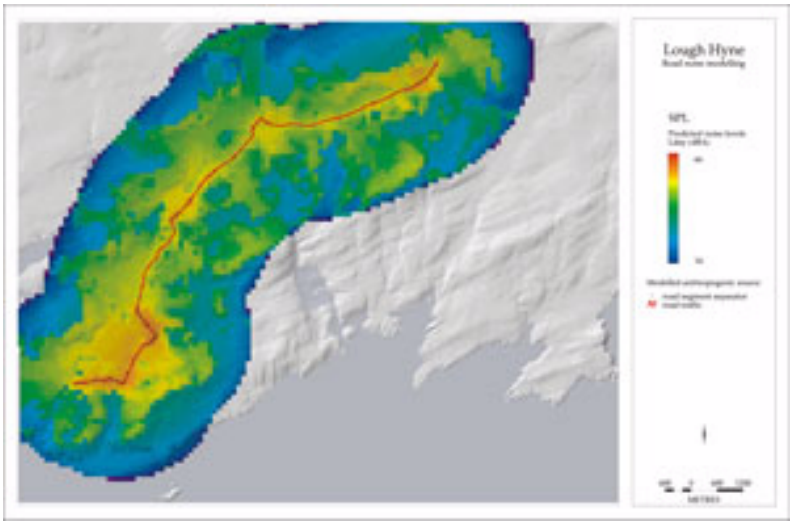


(b) Noise impact due to anthropogenic sources.

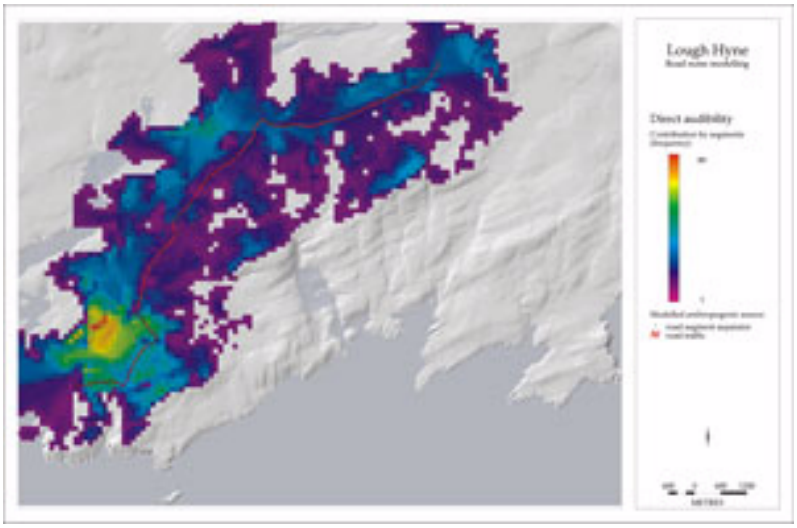


(c) Combined effect of a wind farm and a tree-harvesting site.

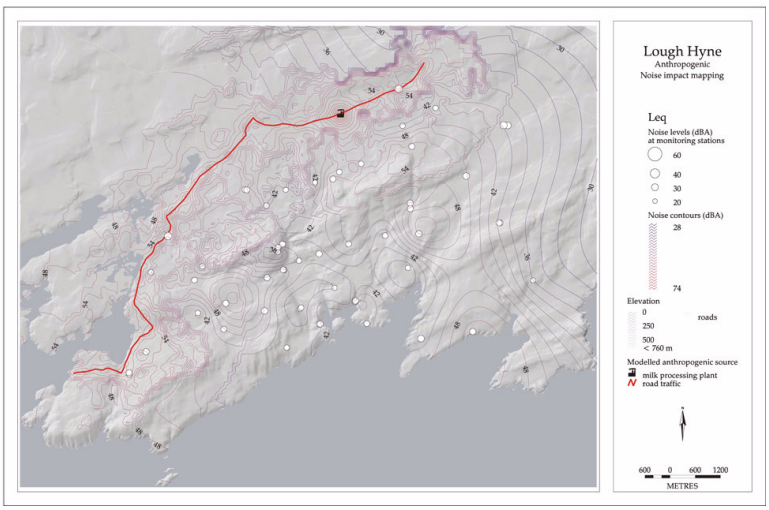
Figure 7. Anthropogenic modelling of point and area sound sources.



(a) Visibility (audibility) indicators calculated.



(b) Noise impact due to anthropogenic sources.



(c) Combined effect of road traffic noise and a milk processing plant.

Figure 8. Road noise anthropogenic modelling.

7 Proposals for Environmental Quality Objectives

The terms Environmental Quality Objective (EQO) and Environmental Quality Standard (EQS) have been used interchangeably in many cases and by a number of different authorities. It is important to make a clear distinction between these terms.

The EPA has defined EQOs as *respective overall levels of quality corresponding to the uses of several compartments of the different environmental media.*

EQOs are descriptive rather than quantifiable and are intended to describe the required degree of quality required. This degree of quality can be achieved by the application of EQSs, which may be presented as precise or wide-ranging limiting values. EQOs are generally wide ranging rather than precise. For example, in 1999, the Swedish government issued a set of 15 EQOs covering the environment.

Examples of Objectives include *Clean air, Flourishing lakes and streams, Sustainable forests* and *Magnificent mountain landscapes.* Within these objectives it may be necessary to set a number of standards in order to achieve the objective. In relation to noise in Quiet Areas, it will be important to set EQOs that describe the overall level of acoustic quality required.

Establishing EQOs requires the consideration of ecology and the quality of the acoustic environment for all species and not just humans. When promoting, protecting or prohibiting certain sounds and soundscapes one must consider the impact of noise in the ecological context while also considering the impact of noise on humans.

The predominant strategy is to maximise the environmental sounds and minimise unwanted or anthropogenic noise within a Quiet Area(s). The most pressing issue surrounding Quiet Areas is that of *quietude, the reduction of unwanted noise in our environment.*

Considering that the Directive defines a Quiet Area in open country as an area that is undisturbed by noise from traffic, industry or recreational activities, it is proposed to define a Quiet Area as *an area in open country, substantially unaffected by anthropogenic noise.*

The overall objective should, therefore, be set in such a way as to prevent the degradation of the acoustic quality by the sources of noise listed.

7.1 Proposed Objectives

In light of the research undertaken, the researchers propose the following environmental quality objectives and suggest strategies to achieve these. The following objectives are proposed:

- The principal quality objective relating to the acoustic environment should be that the acoustic quality of the environment is, and should be maintained as, wholly suitable for the beneficial uses expected.
- Not all areas in the open country substantially unaffected by anthropogenic noise require protection.
- Criteria for selection and identification of Quiet Areas should be linked with sites of national, regional or local importance with regard to landscape, cultural or historical sites, amenity areas or environmentally sensitive areas such as RAMSAR or SPA.
- Implementation of the Environmental Noise Directive and the identification and management of Quiet Areas should be integrated with other relevant EU Directives such as the Habitats and Birds Directives.
- Noise should be included in environmental quality criteria and quality of life indices. A subsidiary EQO will be to protect selected Quiet Areas from the adverse effects of anthropogenic noise.
- Soundscapes in National Parks and other sensitive areas, where the acoustic environment or soundscape are important intrinsic elements of the area, should be protected to support and preserve their biological diversity, how the environment is experienced, as well as for their natural and cultural values.

It is proposed that in order to meet these objectives, a number of strategies will be implemented.

7.2 Proposed Strategies

- The Department of Environment, Heritage and Local Government could introduce a programme to increase public awareness of the effects of noise. Assistance and co-operation could be sought through other Government departments and ENFO in providing educational posters promoting awareness of noise issues and supporting participation in such activities as the International Noise Awareness Day (INAD)[2] and Quiet Lakes[3] initiative.
- Landscape planning proposals could take cognisance of the need to protect natural quiet as a resource to be experienced and enjoyed.
- Guidelines could be developed to support the appropriate classification of Quiet Areas. Classification of Quiet Areas should not be dependent on acoustic measurement alone but should incorporate criteria that define the acoustic space, including amenity use, landscape, ecological aesthetics and cultural and historical associations that may characterise a Quiet Area.
- Measures to support the inclusion of the sonic environment in landscape classification could be put in place.
- Protection of a Quiet Area could be supported by the introduction of a system of monitoring and management by the relevant environmental agencies or planning authorities at selected sites. Low-cost public information notices to raise awareness of natural soundscapes and noise could be developed as part of any management system.
- In designated areas that are protected under the Bird or Habitats Directives, procedures and measures could be developed to prevent unnecessary disturbance due to noise in designated areas, taking into account ecological, cultural and recreational uses.
- Guidelines could be drafted to assist local authorities and other bodies in identifying, monitoring and protecting Quiet Areas in the countryside.
- A review of the EPA Guidance Note for Noise could be undertaken to include some of the key recommendations outlined in this report.

2. INAD is promoted by the League for the Hard of Hearing's Noise Centre (http://www.lhh.org/noise/).
3. The Quiet Lakes initiative is promoted by the Noise Pollution Clearinghouse (http://www.nonoise.org/quietlakes/).

8 Environmental Quality Standards

It is proposed that the EQSs in relation to Quiet Areas could specify the control of actions and activities rather than the application of limiting levels. Nevertheless, for the purposes of clarity, it could be necessary to specify guide levels to give a degree of certainty to enforcers and others as to a suitable standard.

It is recommended that the $L_{A90,1h}$ index be used to define baseline levels in Quiet Areas since L_{den} is intended principally as a descriptor of environmental noise in agglomerations, rather than as a descriptor of quietness.

It is possible that significant short-term noise events could occur in a Quiet Area which might well affect the $L_{A90,1h,}$ but which would be masked by the averaging process used in L_{den}.

8.1 Proposed Environmental Quality Standards

Anthropogenic noise sources may include mobile or stationary sources with both point and vector/line properties on land, at sea and in the air.

Specifying exact spatial boundaries and noise quality standards for Quiet Areas is problematic. Each Quiet Area will have its own unique characteristics and will be subject to varying environmental influences that will shape or influence its acoustic quality.

In considering EQSs for the protection of tranquil areas, one must consider natural quiet as a resource. The relationship between natural quiet and tranquillity is, in general, subjective. The absence of environmental sounds in the natural environment (silence), however, is not representative of a tranquil area. Within Quiet Areas the ability to hear clearly the delicate and quieter intermittent sounds of nature, to experience interludes of extreme quiet for their own sake, and the opportunity to do so for extended periods of time are all important criteria.

While noise levels in Quiet Areas can remain relatively constant, ambient noise levels may demonstrate a degree of variability due to both environmental and anthropogenic noise sources. In measuring background environmental noise levels in Quiet Areas, the L_{A90} indicator is regarded as the most appropriate measurement unit.

Where natural environmental sounds dominate, the L_{A90} is a very good indicator, while the L_{Aeq} is a good indicator when quantifying anthropogenic noise.

The following EQSs are put forward as proposals:

- Approval for any proposed development related to commercial or industrial activity or transportation, within or within such distance of a Quiet Area(s) as would be likely to be audible should be subject to the production of an impact statement of noise within the Quiet Area(s) from the development.
- Where an impact statement of noise is to be produced, noise modelling and prediction of noise levels should be undertaken to illustrate the impact of noise levels within the Quiet Area(s) using appropriate GIS/noise-modelling methodologies.
- Protection of natural quiet should be introduced in National Parks and public amenity areas where the quality of the environment identifies the natural soundscape as an important amenity of the area.
- The use of off-road vehicles and motorised watercraft for leisure purposes should be controlled, restricted or prohibited within Quiet Areas.
- In order for any strategy for protecting Quiet Areas to succeed, noise-control planning, training and education, noise-assessment methodologies and noise reporting, need to be addressed by the relevant environmental and planning authorities.

Whilst this research project significantly progressed the state of knowledge regarding Quiet Areas, it is considered too early to propose formal standards without further research and consultation with the relevant authorities.

In the absence of formal standards, consideration could be given to the following proposed standard:

- The noise from anthropogenic sources should not be clearly audible at any point within Quiet Areas and the noise levels when measured in wind speeds of less than 2 m/s in the absence of significant environmental (geophonic or biophonic) sounds, should not exceed an $L_{A90,1h}$[4] of 30 dB by day or an $L_{A90,1h}$ of 27 dB by night. (The natural baseline sound level is regarded as the $L_{A90,1h}$ in the absence of anthropogenic noise when measured in wind speeds of 2 m/s or less.)

4. In measuring background environmental noise levels in Quiet Area(s), the L_{A90} indicator is regarded as the most appropriate measurement unit.

9 Key Recommendations

As a result of the work carried out in this project, a valuable natural resource has been clearly identified and recorded. The project arose from the Government's concern to protect and enhance environmental quality in Ireland.

The information produced by the project will make a significant contribution to the decision-making process and to the responsibilities of Member States concerning the Environmental Noise Directive's requirements concerning the protection of tranquil or Quiet Areas and environmental noise quality.

At the conclusion of the project a number of key recommendations can be proposed:

- A legislative and administrative framework should be put in place for the identification and control of Quiet Areas.
- Environmental Quality Objectives and Environmental Quality Standards in relation to noise in Quiet Areas should be put in place.
- A programme of further research should be instigated for the purpose of providing effective guidance in relation to the identification and management of Quiet Areas in the countryside.
- Further research is required for the identification and control of environmental noise quality in the urban environment in Ireland similar to the EU Project WG-AEN 005.2003 (Urban and Rural Quiet Areas Report – Symonds Group).
- The outcomes of this and future research should be fed into the EU 'CALM' initiative, *Research for a Quieter Europe.*

10 Conclusions

Ireland has a considerable number of large, open places of astonishing beauty and relative wildness. Each area can have a distinct and powerful aura, fully dependent upon the landscape, natural sounds and natural quiet. As such, these areas afford unique opportunities for undisrupted respite, solitude, contemplative recreation, inspiration, and education. Further, these areas also provide scarce refuges and undisturbed natural habitats for animals.

This project has identified a significant number of Quiet Areas in rural Ireland, still largely unaffected by anthropogenic noise. In these areas, tranquillity can be achieved to the fullest extent in relation to not only sound but also the other senses of the body. The results of this research demonstrate that the quality of the natural soundscape in many areas is excellent; however, monitoring also identified how societal changes and human activity are impacting on Quiet Areas and the extent to which natural tranquillity or quietness can be disturbed by the introduction of man-made noise from transportation, industry and other activities.

As a result of the work carried out in this project, Quiet Areas have been clearly identified and their soundscape captured through monitoring for the first time. Monitoring was undertaken in over 300 locations within 15 reference sites representing the four principal landscape types spread over 17 counties throughout Ireland. The resulting environmental database comprises approximately 21,000 individual noise-recording intervals/periods and associated information totalling in excess of 170,000 environmental measurements.

The information produced by the project will make a significant contribution to the implementation of the Environmental Noise Directive and will greatly assist Ireland and other Member States in introducing accountable noise abatement development programmes and related monitoring systems for reducing and managing noise pollution.

10.1 Further Research

The research conducted in this project has identified Quiet Areas in Ireland and a significant quantity of data on environmental noise levels within those areas has been gathered. This has greatly assisted in the development of criteria for identifying Quiet Areas, and EQOs and EQSs for Quiet Areas. The work done so far will be able to be fed into the EU-funded CALM initiative, *Research for a Quieter Europe*, particularly in the key areas of assessment of environmental noise and action plans in relation to Quiet Areas in open country. However, further work is necessary in order to be able to produce precise criteria for the identification of Quiet Areas. It is proposed that additional research is necessary in the following areas:

- Noise monitoring from major roads, towns and industrial locations in order to ensure that such sources do not substantially affect Quiet Areas.
- Additional monitoring of sound levels from natural sources such as wind effects on vegetation, watercourses, sea water and precipitation, for the purpose of refining the acoustic models developed within this project and for use in a database for further modelling.
- The Environmental Noise Directive includes an objective for the protection of Quiet Areas in urban situations, as well as Quiet Areas in open country. It is proposed that research will be needed, similar to the EU Project WG-AEN 005.2003 (Urban and Rural Quiet Areas Report – Symonds Group), to establish criteria for quiet urban areas and monitoring work will be required to identify such areas.
- Review research to assess noise impacts (including behavioural studies) of developments such as industry, aggregate extraction, roads and other transportation sources or infrastructural developments on wildlife.
- Undertake research studies on the impact of noise on biodiversity.

- Undertake research to provide further information on noise nuisance to outdoor recreational activities, tourism and rural residential communities.
- Undertake research to provide further information on the potential effect of noise-induced disturbances on individual animals and sensitive species within affected areas.
- Establish environmental noise studies in national parks and sites of importance to wildlife and nature conservation.
- Undertake additional[5] qualitative DAT recordings of the sonic environment in sensitive Quiet Areas to represent audio footprints of existing soundscapes.

5. DAT recordings were obtained within four reference Quiet Areas as part of this study.

- The examples illustrated in the Final Report are only representative of a fraction of the extensive monitoring data accumulated over the course of this project. Further research and analysis of the monitored data are required.
- A priority research topic is the development of an accurate Geographic Information System (GIS) digital spatial map of the National territory to illustrate the setback distance criteria from major transport, infrastructural, industrial or anthropogenic noise sources identified in this report.
- Finally, to use the maps developed to refine the available information so as to definitively identify Quiet Areas of National, Regional, or Local importance.

11 Bibliography

Abbott, P.G. and Nelson, P.M., 2002. Converting the UK traffic noise index $L_{A10,18h}$ to EU noise indices for noise mapping. *DEFRA Project Report PR/SE/451/01*. TRL Limited, UK.

Alster, M., 1982. An improved method for determination of radiated sound power and sound transmission from large sources. *Sound and Vibration* **82(2),** 261–274.

Alton, E.F., 1994. *The Masters Handbook of Acoustics*, 3rd ed. Tab Books, New York.

Busnel, R.G. and Fletcher, J. (eds), 1978. *Effects of Noise on Wildlife*. Academic Press, New York.

DEFRA, 2001. *Towards a National Ambient Noise Strategy: A Consultation Paper.* Air and Environmental Quality Division, Department for Environment, Food and Rural Affairs, UK.

Department of Transport Welsh Office, 1988. *Calculation of Road Traffic Noise (CRTN)*. HMSO, London.

Dilworth, C., 2000. *Establishing Rigorous Methods for Identifying and Monitoring of Quiet Areas*. Environmental Protection Agency, Ireland.

Dorrance, M. *et al.*, 1975. Effects of Snowmobiles on White-tailed Deer. *Journal of Wildlife Management* **39(3),** 563–569.

Downing, M., Hobbs, C. and Stusnick, E., 1999. *Measurement of the Natural Soundscapes in South Florida National Parks.* http://www.fican.org/pages/sympos.html [accessed 3 November 03]

Durucan, S., Pathak, K. and Kunimatsu, S., 1998a. Development of a source characterisation model for the prediction of environmental noise near surface mines and quarries. *In: Proceedings of the 27th International Symposium on the Application of Computers and Operations Research in the Mineral Industries*, London, UK, 18–23 April, IMM. pp. 113–123.

Durucan, S., Pathak, K., O'Reilly, B. and Kunimatsu, S., 1998b. Environmental noise near a processing plant: A case study. *In: Proceedings of the 5th International Symposium on Environmental Issues and Waste Management in Energy and Mineral Production*. Ankara, Turkey, May 18–20, Balkema. pp. 179–184.

Environment Agency UK, 2001. *Technical Guidance Note IPPC H3. Draft Horizontal Guidance for Noise Part 2, Noise Assessment and Control.*

Environmental Protection Agency Act, 1992. The Stationery Office, Government Publications, Dublin, Ireland (amended 3rd July 2002).

Environmental Protection Agency NSW, 2002. *Draft Noise Guide for Local Government*. ISBN 073477550 4.

Ernenwein, R., Henry, W.R. and Schmidt, W.B., 1999. *Educating National Park Users on Preserving Natural Soundscapes*. National Park Service. http://www.fican.org/pages/sympos.html [accessed 3 November 03]

EU, 2002. Directive 2002/49/EC of the European Parliament and of the Council of June 25 2002 relating to the assessment and management of environmental noise. *Official Journal of the European Communities*, L189/12–25, 18.7.20

Fleming, G., 1999. *Guidelines for the Measurements and Assessment of Low-Level Ambient Noise*. Acoustics Facility, Volpe Centre. http://www.fican.org/pages/sympos.html [accessed 3 November 03]

Fyhri, A. and Klaeboe, R., 1999. *Exploring the Impact of Visual Aesthetics on the Soundscape.* Internoise 99, Institute of Noise Control Engineering, USA.

Haag, D., 1981. The propagation of noise from petrochemical complexes to neighbouring communities. *Conservation of Clean Air and Water – Europe (Concawe) Report 4/81*.

Hempton, G., 1999. *Acoustic Ecology: Hearing Care and Preserving the Rare Sounds of Silence*. http://www.nonoise.org/news/1999/mar28.htm [accessed 3 November 03]

Henry, W.R., Schmidt, W.B. and Ernenwein, R., 1999. *National Park Service Noise Issues*. National Park Service. http://www.fican.org/pages/sympos.html [accessed 3 November 03]

Institute of Environmental Management and Assessment and Institute of Acoustics, 2002. *Draft Guidelines for Noise Impact Assessment*.

ISO 9613, 1996 (E). *Attenuation of Sound during Propagation Outdoors. Part 1. Calculation of the Absorption of Sound by the Atmosphere. Part 2. General Method of Calculation.*

Kavaler, L., 1975. *Noise: The New Menace*. The John Day Company, New York

Kerkers, A.J., 2000. Lagerwey 750 kW Wind Turbine: Measurement of Sound Emission. *Report No 552aaA0.tk*.

Krause, B., 1993. The Niche Hypothesis. *The Soundscape Newsletter.* June 6, 1993.

Krause, B., 2002. *Wild Soundscapes Discovering the Voice of the Natural World*. Wilderness Press, Berkeley.

Krygier, J.B., 1994. Sound and Geographic Visualization. *In:* MacEachren, A. and Taylor, D.R.F. (eds). *Visualization in Modern Cartography.* Pergamon, New York. pp. 149-166. http://www.owu.edu/~jbkrygie/krygier_html/krysound.html [accessed 3 November 03]

Lamancusa J.S., 2000. *Noise Control Outdoor Noise Propagation.* Penn State University. http://www.me.psu.edu/lamancusa/me458/10_osp.pdf [accessed 3 November 03]

Lee, D., 1994. *Increasing Air Tours Pollute Our National Parks*. p. 25. National Parks Service, Washington.

MacEachren, A. and Taylor, D.R.F. (eds.), 1994. Sound and Geographic Visualization. *In: Visualization in Modern Cartography.* Pergamon, New York. pp. 149–166.

McGregor, I., Crerar, A. and Benyon, D., 2002. Soundfields and soundscapes: reifying auditory communities. *In: Proceedings of the 2002 International Conference on Auditory Display.* Kyoto, Japan. July 2–5, 2002.

McKell, B, Fisher, S., Jones, N., Evans, J. and Stark, B., 2002. Scottish Executive Central Research Unit, 2002. *Monitoring and Mapping of Environmental Noise*. http://www.scotland.gov.uk/cru/kd01/lightgreen/mmen-00.asp [accessed 3 November 03]

Pickering, T., Armstrong, M., Kennedy, S., Whiteley, N. and Madoc-Jones, N., DATE. *The Tranquil Areas Report – What Basis for Defining Wilderness Areas?* http://www.geog.leeds.ac.uk/people/s.carver/student_work/student%20webpages%200001/groupk/3321.html [accessed 3 November 03]

Redström, J., 1998. *Is Acoustic Ecology about Ecology*? University of Oregon Website. http://interact.uoregon.edu/MediaLit/wfae/readings/aeecology.html [accessed 3 November 03]

Schafer, R.M., 1977. *Our Sonic Environment and the Soundscape*. Destiny Books, Vermont.

Schulte-Fortkamp, B. and Nitsch, W., 1999. On Soundscapes and their meaning regarding noise annoyance measurements. *Internoise* 06–08.

Stockwell, C.A., Bateman, G.C. and Berger, J., 1991. Conflict in National Parks: a case study of helicopters and bighorn sheep time budgets at the Grand Canyon. *Biological Conservation* **56(3),** 317–328.

Stoter, J., 1999. Noise prediction models and Geographic Information Systems, a sound combination. *In: Proceedings 11th Annual Colloquium of the Spatial Information Research Centre*. Dunedin, New Zealand, December 12–15.

UK Department for Environment, Food and Rural Affairs, 2001. *Towards a National Ambient Noise Strategy.* A Consultation Paper, Air and Environmental Quality Division.

Wagner, S., Bareiss, R. and Guidati, G., 1996. *Wind Turbine Noise*. Springer, Berlin.