Lough Melvin Catchment Management Plan

The Programme is funded by the EU INTERREG IIIA Programme for Ireland/Northern Ireland and the project partners: Northern Regional Fisheries Board; Agri-Food and Biosciences Institute (AFBI) Northern Ireland; Queen’s University Belfast and Teagasc.

June 2008

Edited by:
Emer Campbell and Bob Foy
Lough Melvin
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Editors:
Emer Campbell, Lough Melvin Nutrient Reduction Programme Manager & Bob Foy, Project Principal.

Authors (in alphabetical order):
Barry, Chris (QUB/AFBI), Byrne, Paul (Teagasc), Campbell, Danny (QUB), Campbell, Emer (NRFB), Cockerill, Claire (QUB), Doody, Donnacha (Teagasc & AFBI), Foy, Bob (AFBI), Hutchinson, George (QUB), Laing, David (NRFB), O’Kane, Colm (NRFB), Schulte, Rogier (Teagasc), Quinn, Michael (NRFB).

All maps produced and GIS work undertaken by Colm O’Kane (NRFB)

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Special mention goes to those community members whose passion, interest and pride in Lough Melvin is an inspiration. We hope that the Catchment Management Plan serves as a vehicle for that passion and provides the foundation for a well-managed and sustainable Lough Melvin into the future.

Northern Regional Fisheries Board
Bord Iascaigh Réigiúnach an Tuaisceart

Northern Regional Fisheries Board
Station Road
Ballyshannon
County Donegal
Ireland
www.nrfb.ie

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Foreword

Lough Melvin is one of the few natural post-glacial salmonid lakes in northwestern Europe that remains in a relatively pristine and undisturbed state. It is internationally recognised for its diverse assemblage of plants and animals, in particular the salmonid fish community including Atlantic salmon, the rare Arctic (Melvin) char, and three distinct strains of trout – the indigenous sonaghan, gillaroo and ferox. However, the long-term future of this ecosystem is uncertain as increasing nutrient inputs from the surrounding catchment threaten its viability and integrity.

The Lough Melvin Catchment Management Plan encompasses the cross-border nature of the catchment. It has been developed with the vision to halt and reverse the decline in water quality so as to protect the lake’s unique values. The Plan describes the fragility of the ecosystem and highlights the many threats to its sustainability. It provides a framework for the protection of Lough Melvin by identifying actions that will reduce these threats and making recommendations on how the lake can be managed by the responsible authorities in a more integrated and sustainable way.

The Plan has been developed utilising a facilitated collaborative and inclusive approach. We would like to extend our gratitude to the Catchment Management Group, the Steering Committee and the many organisations and stakeholders for engaging in this process, which bodes well for the future of the lake.

We also thank the Programme Manager, Emer Campbell for her wholehearted endeavours in bringing the Lough Melvin Nutrient Reduction Programme to fruition and in successfully overseeing the delivery of a Catchment Management Plan of this scope, in what has been a very tight timescale. In addition, we would like to congratulate all of the Programme staff whose contribution and dedication has made the delivery possible.

Finally, we thank the EU INTERREG IIIA Programme for Ireland/Northern Ireland and the Programme Partners: Northern Regional Fisheries Board, Teagasc, Queen’s University Belfast and the Agri-Food and Biosciences Institute, Belfast, for funding this work.

Catchment management requires long-term commitments and this Lough Melvin Catchment Management Plan only marks the beginning of the process. Successful implementation of the Plan requires the coordination of efforts of both public and private bodies, those with direct interests in the water environment and those whose activities impact on the potential to maintain the “good ecological status” as required by the Water Framework Directive. It is only with cooperation and action in the short-term that the long-term future of this unique and internationally significant lake will be secured.

Dr. Bob Foy  
Project Principal  
Chair of Management Group  
Agri-Food and Biosciences Institute

Mr. Harry Lloyd  
Project Principal  
Chair of Steering Committee  
Northern Regional Fisheries Board
Mapped Information Sources:
Information contained in or utilised to produce the GIS maps within this document was sourced from the following organisations:

- Agri-Food and Biosciences Institute (AFBI)
- Centre for Ecology and Hydrology (CEH)
- Coillte Teoranta
- Department of Agriculture, Fisheries and Food (DAFF), Forest Service
- Department of Agriculture and Rural Development (DARD), Forest Service
- Environment and Heritage Service Northern Ireland (EHSNI)
- Environmental Protection Agency (EPA)
- Gamma Ltd.
- GeoDirectory
- Geological Survey Ireland (GSI)
- Leitrim County Council
- National Parks and Wildlife Service
- Northern Ireland Statistics and Research Agency (NISRA)
- Northern Regional Fisheries Board (NRFB)
- Office of Public Works (OPW)
- Ordnance Survey Ireland (OSI)
- Ordnance Survey of Northern Ireland (OSNI)
- Teagasc, Environment Research Centre, Johnstown Castle
- Ulster Wildlife Trust

Abbreviations and Acronyms:
AONB . . . Area of Outstanding Natural Beauty
AES . . . . Agri-Environmental Scheme
AFBI . . . . Agri-Food and Biosciences Institute
ASSI . . . . Area of Special Scientific Interest
BOD . . . . Biological Oxygen Demand
CAP . . . . Common Agricultural Policy
CMP . . . . Catchment Management Plan
CMS . . . . Countryside Management Scheme
CSA . . . . Critical Source Area
DAF . . . . Department of Agriculture and Food
DARD . . . . Department of Agriculture and Rural Development
DoE . . . . Department of the Environment
DRP . . . . Dissolved Reactive Phosphorus
EC . . . . . European Community
EHS . . . . Environment and Heritage Service
EPA . . . . Environmental Protection Agency
ESA . . . . Environmentally Sensitive Area
EU . . . . . European Union
FYM . . . . Farmyard Manure
GIS . . . . . Geographical Information System
ha . . . . . Hectare
IUCN . . . . International Union for Conservation of Nature
L . . . . . Liter
m . . . . . Metre
ml . . . . . Millilitre
mg . . . . . Milligram
mPRS . . . modified Phosphorus Ranking Scheme
N . . . . . Nitrogen
NHA . . . . Natural Heritage Area
NI . . . . . Northern Ireland
NMP . . . . Nutrient Management Planning
NPWS . . National Parks and Wildlife Service
NRFB . . . Northern Regional Fisheries Board
O . . . . . Oxygen
P . . . . . Phosphorus
p.e. . . . Population Equivalent
PI . . . . . Phosphorus Index
PP . . . . . Particulate Phosphorus
REPS . . . Rural Environmental Protection Scheme
RoI . . . . Republic of Ireland
SAC . . . . Special Area of Conservation
STP . . . . Soil Test Phosphorus
TDP . . . . Total Dissolved Phosphorus
TP . . . . . Total Phosphorus
TSS . . . . Total Suspended Solids
µg . . . . . Microgram
WFD . . . . Water Framework Directive
WWTP . . . Waste Water Treatment Plant
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Ode to Lough Melvin by Brigid Rose Connolly

As by your tranquil shore I strayed
as the golden sun sank in the west,
I watched your peaceful flowing tide
your little ripplet beat the crest.
There, sailing on your waters blue,
the snow white swan with dripping wings
Adds beauty to your magic shore,
enchantment to your lovely scenes.
Around your balmy, sun kissed shore.
The little birds sang forth in song,
And from the trees across the lake
re-echo notes in chanting throng.
The Dartry mountains, high above,
as if to guard your onward glide
With shadows long and wide,
Embrace the splendour of the Melvin side.
There lofty trees, as phantoms lone,
Within your bosom gently grow
to form islands that allure
Your lovely peaceful water-flow,
Where ruins of Rosclogher bring
Tradition onwards to our view
to tell a tale of former days,
United with Lough Melvin blue,
Oh beauteous lake, beyond compare,
The angler hails thee nature’s queen,
from far-off lands they come to fish
And view your tranquil shore serene
as down below, endearing all,
You onward flow in brilliant hue,
surpassing scenes of nature’s gifts
In peace reposes Melvin blue
Executive Summary
Executive Summary

Ireland's waterways, lakes and wetlands are a significant part of our natural heritage and their management and maintenance is our responsibility, as the current generation of environmental caretakers. One of these, Lough Melvin is a unique and internationally significant lake located in the counties of Leitrim and Fermanagh. Described as “one of the few remaining natural post-glacial salmonid lakes in northwestern Europe”, the lake covers an area of 2206 ha and is renowned for its early “run” of Atlantic salmon, unique assemblage of fish species and diversity of flora and fauna. In relatively pristine condition, the lake and surrounding catchment area are highly valued for their recreational, heritage and environmental qualities by anglers, tourists, scientists and the local community.

Due to the importance of Lough Melvin as an oligo-mesotrophic (low-medium nutrient) lake that supports a diversity of habitats and species, it has been designated as a Special Area of Conservation (SAC) under the EU Habitats Directive. However, the health and status of Lough Melvin is particularly vulnerable to human activities, with the most significant threat being an increase in phosphorus loadings from housing, forestry and agriculture within the surrounding catchment. Currently phosphorus concentrations in the lake have increased by over 40% in little more than a decade and monitoring of the catchment rivers indicates that phosphorus loadings are continuing to increase.

To protect the water quality and ultimate health of Lough Melvin, the sources of nutrients from the surrounding catchment need to be managed and methods for their control developed and implemented. It is imperative that this action is taken now to ensure the survival of this rare natural resource otherwise irreversible damage may be done to the system. Linking activities within the surrounding catchment to environmental impacts on the lake and managing the lake at a catchment scale, is the only way that management actions can be prioritised and targeted for the most effective and beneficial environmental outcomes. The Lough Melvin Catchment Management Plan aims to provide a basis for the conservation of Lough Melvin into the future in an effective and holistic way.
Executive Summary

1 The Lough Melvin Nutrient Reduction Programme

The Lough Melvin Nutrient Reduction Programme was funded by the EU Interreg IIIA Programme for Ireland/Northern Ireland and the Project Partners. The aim was to develop a Catchment Management Plan (CMP) for the lake that would promote good ecological status and address the primary catchment threats of which, nutrient enrichment is the most critical. The overall goal derived for the Lough Melvin CMP is to:

“Protect the health and unique environmental values of Lough Melvin and its catchment”

Much of the CMP focuses on nutrient enrichment, as this is a key threat to ecological health, but it also covers other potential threats. It incorporates outputs from four Project Strands. The Project Partners were responsible for individual strands with the Northern Regional Fisheries Board (Strand 1) providing overall coordination of the Programme. An outline of the strands is provided below.

Strand 1 Programme Coordination

Project Partner: Northern Regional Fisheries Board. Harry Lloyd- Project Principal. Dr. Milton Matthews. Emer Campbell- Programme Manager, Angela Kilalea- Administrative Assistant, Colm O’Kane- GIS Technician, David Laing- Forest Project Officer, Michael Quinn- Wastewater Project Officer. This strand aimed to produce a catchment management plan for Lough Melvin that would promote “good ecological status” (as required by the Water Framework Directive) and could form the basis of a Biodiversity Action Plan (as may be required by the Habitats Directive). It also undertook to raise awareness and promote improved environmental management. Within Strand 1 targeted assessments of the impacts on Lough Melvin from forestry and waste water treatment facilities in the catchment were also undertaken.

Strand 2 Agri-Environmental

Project Partner: Teagasc Research. Dr. Owen Carton & Dr. Donnacha Doody (to April 2007); Dr. Rogier Schulte & Dr. Paul Byrne- Agri-Environmental Manager. The strand developed an agri-environmental suite of measures to safeguard and improve the status of mesotrophic lakes such as Lough Melvin.

Strand 3 Economic Assessment

Project Partner: Institute of Agri-Food and Land Use, Queen’s University Belfast. Prof. George Hutchinson, Dr. Danny Campbell- Research Assistant & Dr. Claire Cockerill- Research Assistant. The aim of this strand was to conduct an economic assessment of costs and benefits of the proposed programme of agri-environmental measures and to investigate the use of “nutrient trading” a tool for delivering lower nutrient input to the lake. This strand also provided an economic valuation for the conservation of the fish assemblage in Lough Melvin.

Strand 4 Water Quality and Carbon Isotope Analysis

Project Partner: Agri-Food and Biosciences Institute (AFBI), Belfast and Queen’s University Belfast. Dr. Bob Foy- Project Principal and Chris Barry- Research Assistant. The aim of this strand was to complete a water quality analysis programme for Lough Melvin and its inflowing river network with specific emphasis on nutrients and their sources.
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2 Catchment Management Plan Development

The Lough Melvin CMP was developed in consultation with three main stakeholder groups. These were the: Lough Melvin Catchment Management Group; Lough Melvin Steering Committee and; wider community and specific interest groups. The Lough Melvin Catchment Management Group consisted of representatives of cross-border government, semi-state bodies and research organisations, which have a role in the long-term and sustainable management of the lake. The Steering Committee was also a cross-border group with the majority of members having specific, assigned, and formal responsibilities in the development of the CMP.

In addition, stakeholders were consulted individually or brought together to provide advice and expertise for particular topics, investigations or parts of the Plan. The Forestry Working Group was established to oversee the work undertaken for the forestry component of the Programme and comprised of members representing private and public forestry management organisations. The wider community and specific interest groups were engaged directly or were provided with the opportunity to become involved and have input to the Programme through a variety of means including information evenings, one-on-one and group meetings/presentations, feedback forms, surveys etc.

Two public consultation events were held for the Programme. The first, in June 2007, was to promote the unique values of Lough Melvin and highlight the potential threats to the lake. The second held in February 2008 presented results from the various investigations and get feedback from the local community. Both information evenings were publicised via local newspapers, community information notes, posters in local shops, libraries etc., on the Programme website and by direct invitation.

3 Lough Melvin’s Significance

Lough Melvin is an exceptional example of a naturally oligo-mesotrophic lake with low to medium nutrient levels and supporting a diverse range of plants and associated animal life. Lakes of this type are of significant environmental and conservation importance having become increasingly rare in Ireland and the UK due to widespread human induced changes within their catchments.

Lough Melvin is best known for its unique and internationally important assemblage of fish species, most of which are indigenous to the lake, some of which represent the only remaining populations of their type. The lake supports Atlantic salmon, rare Arctic (Melvin) char, indigenous sonaghan, gillaroo and ferox trout. The salmonid fish community in Lough Melvin originates from the end of the last Ice Age and its continuation is an indication of the lake’s relatively pristine and undisturbed state. Within the catchment, nationally and internationally significant habitat types (and species) such as peat bogs, nutrient poor and species rich grasslands, hay meadows, oak woodlands and natural scrubland are found.

Lough Melvin’s ecological assets and values provide for a wealth of “spin-off” tangible and intangible environmental, social and economic benefits e.g. tourism, drinking water supply, and ecological interest. The lake is a very important recreational and heritage area for anglers, tourists, scientists and the local community. In turn, the economic and social benefits depend on and consequently will impact on, the ecological integrity and health of the system.

There are many pressures acting on the environment of Lough Melvin, which can adversely affect and alter the quality of the habitat that the lake and surrounding catchment provides. The health of Lough Melvin and its ecological communities is particularly vulnerable to catchment pressures and landscape uses. The biological integrity of the lake is at risk from a number of key threats, which include the introduction of pest plants and animals, water abstraction, climate change, fish stocking, land clearance and disturbance, recreational pressures and drainage/dredging of tributaries. However, the most significant threat is nutrient enrichment (from housing, forestry and agriculture) which inevitably lowers biodiversity.
4 A High Risk Catchment

Phosphorus is transported from land to water in decreasing order of importance via surface runoff, subsurface flow and leaching to groundwater. The export rates of phosphorus can vary considerably with catchments depending on soil type, hydrology, slope and climatic conditions.

Rainfall and runoff are high within the Lough Melvin catchment and the soils are naturally nutrient poor and inefficient at binding and holding onto phosphorus. Soils are poorly drained so that surface runoff is commonplace. This, in association with high slopes and an extensive hydrological network makes the catchment particularly effective at rapidly transferring phosphorus from land to the lake. Areas in the catchment that may be particularly prone to the loss of nutrients were defined using three catchment characteristics for specific risk factors for phosphorus loss. These were: distance from watercourses or hydrological connectivity; slope and; soil desorption risk.

This analysis, shown in Figure B, demonstrated that high risk factors predominated and for management purposes, provides justification that effectively the whole of the catchment is potentially at high risk for phosphorus transport. Overall, less than 4% of the catchment area fell into the lowest risk classes for phosphorus desorption, hydrological connectivity and slope. Some 36% fell into the highest risk class for each of these three categories. The soil phosphorus desorption map also shows very limited areas (3%) that could be considered to have low or medium risk of desorption of P from any soils in the catchment that are enriched with phosphorus. For hydrological connectivity, over 60% of land is within 200m of a stream. This measure of connectivity is based on the river and stream network shown in the 1:50000 Ordnance Survey map and so ignores connectivity provided by the multiplicity of small open field drains that occur throughout the catchment. Only for slope was a majority of the catchment area not in the highest risk class.

Figure B: Soils Desorption risk, slope risk and distances from watercourses maps (left to right).
Executive Summary

It is recommended that the whole of the Lough Melvin catchment be considered to have a high overall risk of phosphorus loss from diffuse pollution.

5 Lough Melvin’s Water Quality Status

5.1 Overview

Prior to the investigations on Lough Melvin during 2006 and 2007 that are reported in this section, the only integrated monitoring programmes on the lake and its inflowing river network were from 1990 and 2001/02. These studies combined physical-chemical and biological monitoring. Additional surveys of lake nutrients and chlorophyll a were available from 1995 and from 2002 to 2004. The main finding from these investigations was that total phosphorus (TP) concentrations in the lake increased after 1995. Freshwater eutrophication is closely linked to increased availability of phosphorus as this nutrient usually limits primary production. As TP is used as a key parameter for defining the trophic status of lakes and rivers, the increase was and is a cause for concern in the management of the lake. During 1990 and 1995/96, mean TP concentrations in Lough Melvin were quite stable at close to 19 µg L\(^{-1}\), which is typical of a mesotrophic lake. By 2001/02, TP was over 50% higher to 30 µg L\(^{-1}\) which was approaching the lower limit of 35 µg L\(^{-1}\) used to define eutrophic lakes. In addition, significantly higher TP concentrations were observed in inflowing stream waters in 2001/02 compared to 1990 linking the increase to greater external inputs of phosphorus from the catchment.

However, the increase in TP loadings to the lake observed in 2001/02 was smaller than the increase in lake TP concentration, so that the higher losses of TP from the catchment recorded in 2001/2 alone could not account for all the rise in lake TP concentration. It was suggested by Girvan & Foy (2006) that this discrepancy reflected an unusual or one-off perturbation of the catchment in the late 1990s and/or 2000, which caused a pulse of phosphorus to enter the lake, contributing to the elevated lake TP observed in 2001. A potential candidate for this perturbation was increased clearfelling in the catchment as a severe storm in December 1998 left extensive areas of fallen coniferous trees and was followed by timber recovery and accelerated rates of clearfelling. Clearfelling of conifers on peat soils in Ireland has been found to increase phosphorus concentrations in drainage water. It therefore was judged likely that increased forestry activities were responsible for the rapid increase in lake TP between 1995 and 2001.

A number of other observations from the lake and catchment were consistent with a sudden forest related perturbation around 1999/2000. For example, between August 2002 and the end of 2004 lake TP concentrations declined to an average of 24.5 µg L\(^{-1}\), suggesting a measure of recovery. Additionally, water clarity had decreased in Lough Melvin by 2001/02, which was consistent with another observed impact of clearfelling on peat soils, namely increased dissolved organic carbon losses, which give the waters of Lough Melvin their characteristic peat stain.

Although TP measured in 2004 had declined from the concentrations observed in 2001/02, the mean concentration remained some 25% above values recorded in the 1990s. The limited monitoring record could not determine whether this was due to a long-term increase in lake TP or a legacy effect of the perturbation that occurred around 2000. If the lake was undergoing a long-term increase in P, then the increase observed between 1995 and 2004 was such that if continued unabated, enrichment would shift lake TP from its desired mesotrophic class to a eutrophic status by around 2030.
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Accordingly, and to provide up to date information on water quality and loadings of nutrients to the lake an integrated programme of water quality monitoring was commissioned as part of the Lough Melvin Nutrient Reduction Programme. With respect to TP and chlorophyll a the data obtained for all monitoring is summarised in Figure C below.

5.2 Results

![Graph showing TP and chlorophyll a concentrations](image)

Figure C: Mean annual total phosphorus, mean annual chlorophyll a and maximum chlorophyll a concentrations. Upper and lower limits are shown for mesotrophic status based upon the OECD (1982) classification scheme.

Monitoring of the lake in 2006-7 found no evidence for a continued decline of lake TP that was observed from 2001 to 2004, but rather TP increased to 27 µg L⁻¹ or 50% above what are considered to be base levels observed in 1990 and 1995.

Despite considerable phosphorus enrichment, algal abundances in Lough Melvin have remained at low levels indicative of oligo-mesotrophic status. Clearly, factors other than phosphorus availability must also limit algal production. Sufficient light for photosynthesis and growth by algae only reaches to (no more than) five metres depth in Lough Melvin due to rapid attenuation by the peat stained water. As a result, algae spend the majority of time in darkness and receive insufficient light to exploit the abundance of phosphorus. Peat staining has therefore exerted a stabilising effect in Lough Melvin by counteracting the algal response to phosphorus enrichment.

Nevertheless, phosphorus-enhanced algal growth still presents a significant threat. The frequency and severity of blue-green algal blooms, that are unsightly and potentially toxic to humans, pets and livestock, is far greater under conditions of high phosphorus availability. Sheltered bays and backwaters, which possess a high recreational and aesthetic value, are particularly prone to prolonged blue-green algal blooms. The littoral zones of the lake may also be subject to increasing pressure on the basis that algae attached to the substrate and aquatic plants are not limited by light and will exploit increases in phosphorus availability. Fast growing filamentous species of algae tend to become dominant under conditions of nutrient enrichment and these have the potential to displace natural floras and alter community structure. This is of particular significance in Lough Melvin where the littoral macrophyte community is a primary reason for its designation as a Special Area of Conservation (SAC) under the Habitats Directive.
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Widespread increases in phosphorus export intensity have occurred in the catchment. The south-east area of the catchment, largely devoted to agriculture, has consistently shown the greatest increases. Accumulation of soil phosphorus, poor septic tank functioning and a number of agricultural practices are highlighted as potential causes. Additional monitoring in 2006-07 showed that forested areas have among the highest phosphorus export rates in the catchment but some of the lowest nitrate export rates, while agricultural areas displayed both high phosphorus and nitrate export rates. Discharges of effluent from the three wastewater treatment plants within the catchment presently play only a small role in the enrichment of the lake. However, there are numerous new developments and as their associated human populations expand they have the potential to increase phosphorus inputs to the lake.

The gradual increase in phosphorus loading from diffuse sources is currently the most significant long-term cause of enrichment of Lough Melvin. However, the rapid increase of phosphorus export following clearfelling, although relatively short lived, has highlighted the need for an integrated approach to forest management for the Lough Melvin catchment as a whole. For example, annual limits of the areas subjected to clearfelling should be managed on a catchment basis so as not to jeopardise the status of the lake.

The annual cycles of temperatures and dissolved oxygen concentrations has been relatively consistent since 1990, and remain favourable for aquatic biota. Periods of stratification were observed in 2007 during which dissolved oxygen became depleted in the deeper waters, however these were of sufficiently short duration to allow dissolved oxygen to remain sufficiently high so as not to warrant immediate concern.

The zooplankton and phytoplankton communities in Lough Melvin have not displayed any major shifts over time although the abundances of species that can utilise terrestrial organic matter washed into the lake have significantly increased, suggesting that such exports have increased.

The low algal abundances observed in 2006/2007 may simply reflect a natural fluctuation. However, there is evidence to suggest that due to the greater organic matter loading, attenuation by dissolved terrestrially derived compounds may have increased the degree of light limitation and thus decreased primary production. Additionally, they may reflect increased predation by zooplankton on phytoplankton, with the zooplankton populations stimulated by increased organic matter loadings from the catchment. The potential for a decrease in the overall productivity of the lake due to higher catchment inputs of organic carbon exists and may be of significance in regard to the long-term quality of the lake as a recreational fishery.

Lough Melvin currently fulfils the criteria required to justify designation as a mesotrophic lake. Nevertheless, the clear upward trend in phosphorus loading and lake concentration demonstrates that action must be taken to avoid further deterioration of the habitat and a breach of the lower eutrophic threshold.

6 Concentration and Load Targets

To maintain the ecological, social and economic values that Lough Melvin supports, the concentration of phosphorus in the lake must be maintained at a sustainable level. Current nutrient loads to Lough Melvin are approximately 13 tonnes of P per year with the concentration in the lake now averaging 27 µg L⁻¹. This is a 50% increase on what are considered to be base levels in 1990 of 19 µg L⁻¹.

A TP concentration of between 19 and 25 µg L⁻¹ equates to an average nutrient loading of less than 10 tonnes to 12 tonnes per annum. Therefore, a reduction in loads of approximately 3 tonnes (23%) would be required to reduce the concentration in Lough Melvin to baseline levels.
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7 Agriculture

In Ireland, eutrophication of rivers and lakes has been identified as one of the major causes of impaired water quality. Eutrophication of rivers and lakes due to P losses has been identified as the most important impact of Irish agriculture on water quality. The increased agricultural contribution to the phosphorus loading of surface waters in recent decades has coincided with the departure from traditional extensive farming practices comprising grazing, haymaking and out-wintering of cattle towards a more intensive form of agriculture.

Nutrient losses from agriculture may have point or diffuse origins. Point sources, those which have a discrete point of origin, may include runoff from yard areas, defective tanks and leaks. Diffuse sources are derived from accumulated soil nutrients which are then lost in runoff from the land. To achieve a satisfactory level of productivity farmers apply fertilisers, but increasing the nutrient supply to land over and above agronomically optimum levels also increases the relative risk of nutrient loss to water. Soils have a finite capacity to absorb phosphorus and soil P levels that exceed this capacity may result in increased P-concentrations in soil water. Whilst this phosphorus loss can be agronomically insignificant, it can have significant limnological implications with concomitant environmental and economic costs. Such phosphorus losses are not evenly distributed within agricultural land but show a pronounced spatial variation according to hydrology, agronomic management and soil type. While the physical landscape characteristics and climate play a fundamental role in determining the potential for phosphorus loss in any given area (i.e. govern the potential for transport), the main source of P is determined by Soil P Test levels as a function of historic and current nutrient inputs and land management practices.

Agriculture has been identified as one of several sources of phosphorus to Lough Melvin. Previous reports (Girvan & Foy, 2003) on water quality in the catchment demonstrated that agriculture was the largest single contributor to the phosphorus loadings to the lake. The sensitivity of Lough Melvin is such that further increases in loads are undesirable and thus there is an urgent need to develop and implement mitigation strategies for P-loss from agriculture.

Agriculture in the Lough Melvin catchment is considered extensive. Stocking rates are generally low and largely reflect the limited carrying capacity of the land. Soils in the catchment are dominated by gleys and peats, which cover 47% and 40% of the catchment area, respectively. The former are characterised by poor drainage characteristics and weak structure. This limits their landuse and carrying capacity, and leaves them vulnerable to poaching damage by grazing stock, which may increase the risk of overland flow and associated P loss. The farming landuse on these soils is therefore mostly confined to suckler and sheep enterprises. Traditionally, initiatives to improve nutrient management on farms have tended to focus on the needs of intensive farming and operate within a framework that will ensure optimum production, and are not necessarily aligned with the geo-environmental context of catchments where stocking rates and soil phosphorus levels are relatively low.

Currently, there are both regulatory and voluntary controls on agriculture to protect water quality. The implementation of the Nitrates Directive and the Water Framework Directive (WFD) has posed challenges to agriculture to modify nutrient management practices so that the “good ecological status” requirement of the WFD can be achieved by 2015. Voluntary agri-environmental schemes (AESs) established under Regulation 2078/92 of the 1992 Common Agricultural Policy (CAP) reward farmers for farming in an environmentally responsible manner. Regulation 2078/92 stipulated that “measures must contribute towards other specific environmental goals set out in Community legislation”. In this respect, agri-environment measures may be used to meet commitments under the Nitrates Directive and Water Framework Directive and may necessitate customised streams within them requiring more targeted management regimes to protect the more sensitive waters.
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The aim of Strand 2 was to identify the specific risks of nutrient loss to water quality posed by agriculture in the Lough Melvin catchment (with wet soils and a mesotrophic waterbody) and, in order to reduce P losses to water, determine appropriate agri-environmental measures to address these risks. These measures could then be promoted for uptake voluntarily, via the AESs either by incorporating the measures identified into them, or alternatively implementing them via a stand-alone scheme for the catchment.

7.1 Methods

Existing datasets were collated to assess landscape conditions and agricultural activities in the catchment. Farm stakeholders were contacted to identify their perception of the main environmental issues in the catchment, risk assessments were undertaken for individual farms, and mitigation measures were identified and evaluated. Therefore, the methodology comprised two distinct aspects: (i) identification of risks and (ii) identification and evaluation of measures. The identification of risks comprised five components, namely farm selection, farm systems survey, farmyard survey, field-by-field survey, and estimation of stock carrying capacity. Identification of measures to address these risks involved literature reviews and consultation with researchers and other relevant stakeholders. The identified measures were subsequently evaluated by researchers, policy-makers, practitioners, and farmer stakeholders through survey questionnaires and workshops. The participation of farmers in these processes was considered central to the successful identification of measures that the farmers would be willing to implement. The final stage in evaluating the measures was determining the effectiveness of the measures and costing them so that a cost-effectiveness analysis could be completed. This was to achieve a balance by realising the need for a trade-off between measures popular with farmers and equally important, the desire for policy-makers to mitigate P loss at least cost.

7.2 Results

Many of the risks associated with agriculture are intensified in the Lough Melvin catchment due to its bio-physical environment - high rainfall levels, high runoff risk, high drainage density and high desorption risk (due to the preponderance of peat and gley soils), - all of which create conditions that potentially exacerbate phosphorus loss to water. The field-by-field surveys found that 31% of the surveyed area presented a geo-environment with high risk for phosphorus loss to water owing to the coincidence of source and transport P-loss factors. A further 30% had a medium risk and 39% presented a low risk for phosphorus loss.

Specifically, outside of risks associated with the landscape, the following risks from agriculture were observed:

The farms surveys demonstrated that there is significant scope for improvement in nutrient management planning (NMP) on many farms. This was primarily attributed to the lack of specific information on soil test P levels of individual fields (with specific reference to the lack of identification of Index 4 fields), a lack of knowledge on NMP or lack of alignment of NMP to the Soil Test P of individual fields, or to difficulties with slurry management due to landscape conditions. P inputs in excess of agronomic requirements were commonly observed, which over time have resulted in a build-up of soil P levels – 22% of the surveyed area within the catchment was in Index 4. Having soils at Index 4 STP levels produces no agronomic benefit whilst presenting a potential threat to water quality. This build-up of P was found to be localised within farms and resulted from slurry applications being concentrated on a limited number of fields. This practice reflects the limited spread areas available on the ground which is primarily a consequence of soil conditions or topography affecting accessibility and trafficability. The high P inputs to certain individual fields may also reflect the tendency to maximise output (in order to maintain stocking rates) on those fields where possible to compensate for the lower productive potential of other fields.
As well as the application rates, the application timing also presents a risk to water quality. These applications, at inopportune times (on poor soil conditions in early spring), in a landscape where the potential for incidental losses is high are often necessitated by inadequate storage facilities that are legally compliant but not always adequate, particularly in “wet” springs. These difficulties highlight the problem associated with slurry management in such a landscape and warrant further research and development on sustainable farm management strategies.

7.3 Recommendations

A management prescription for agriculture in the catchment to reduce P loss has been proposed based on the measures identified from the literature, the results of the evaluation of these measures by the various relevant stakeholders (including local farmers), and the cost effectiveness analysis of the measures. The recommended management prescription for agriculture in the catchment is based on the following four pillars:

Pillar 1 involves provision of nutrient and agri-environmental advisory programme that includes soil testing and a Nutrient Management Plan (NMP), free of charge to the farmer. This will involve adoption of the most cost-effective and popular source reduction measures. It is considered pivotal in facilitating knowledge transfer and implementation of Best Management Practices, in order to reduce P loss in the long-term by addressing sources or pressures. Elements of this NMP should include the following category A measures:

1. Identification of Index 4 soils and peaty soils, by soil sampling of all fields within the catchment.
2. Reduce slurry/fertiliser application rates to agronomically optimum levels: this represents a direct win-win situation in which both direct costs to the farmer and potential for P-loss to water are reduced simultaneously.
3. Feeding low P concentrates. Though this measure will be cost-effective, its total impact will be small in light of the relatively small of P entering the catchment in the form of concentrates.
4. Removing P in silage and not replacing the P off-take on Index 4 soils. This measure will be restricted in its application as it will only be applicable to a limited number of fields and subject to the availability of alternative and suitable spreading areas.

Pillar 2 involves reducing P loss in the short-term by addressing pathways. This will be effective in improving water quality in the short to medium term by intercepting P that is being lost in runoff. This will involve adoption of the most cost-effective and popular interception measures. These measures include:

1. Sediment barriers or sedimentation ponds in drainage ditches.
2. Grass buffer zones of 2.5m width adjacent to water courses.
3. Hedgerows aligned to the relief profile; perpendicular to overland flow.

The latter two measures are currently optional under existing AESs and could be encouraged for uptake in the Lough Melvin catchment.

Together, implementation of Pillars 1 and 2 are estimated to have the potential to reduce P-loss to water by c. 50% of theoretically maximum potential reduction at 6% of theoretically maximum potential costs.
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**Pillar 3** In the event that the implementation of measures in Pillars 1 and 2 should not lead to sufficient reductions in P-loss from water, implementation of reserve measures (i.e. measures that were ranked to be medium cost-effective and/or “second choice” with farmers) for source reduction or pathway interception could be considered. These include:

1. Provision of compensation for reductions in overall stocking rate.
2. Provision of compensation for reductions in stock by selling calves in autumn.

Together, implementation of Pillars 1 and 2 and 3 are estimated to have the potential to reduce P-loss to water by c. 80% of theoretically maximum potential reduction at 16% of theoretically maximum potential costs.

**Pillar 4** involves a review of concerns not addressed by these measures. Further considerations, which relate to the current instruments regulating agriculture in the catchment may also need to be evaluated and enhanced if required:

1. The main challenge in the catchment is the limited slurry spreading area available. This results in slurry applications being concentrated on those fields where accessibility is possible. A manifestation of this is that 22% of the surveyed area is in STP Index 4. This is currently only partly addressed by the Action Plan for the Nitrates Directive, i.e. there may be sufficient forage area or ‘net farm area’ to suggest that there is < 170 kg ha⁻¹ but in reality, much of this organic N may be concentrated on a limited number of fields. In the event that implementation of Pillars 1, 2 and 3 does not result in adequate reductions in P-loss to water, withholding slurry applications on Index 4 soils may be required. At the same time, this should not be allowed to lead to situations where slurry is consistently and singularly re-routed to Index 3 soils with high connectivity to water.

2. In the current Action Plan for the Nitrates Directive in the Republic of Ireland (RoI) states that an Index 3 can be assumed where a soil test is not available. This facilitates continued P inputs to fields that are at Index 4 where these remain unidentified. By contrast, under the Northern Ireland (NI) regulations P from fertiliser may only be applied if soil analysis shows that there is a requirement for it and this is potentially an approach that would have merits across the entire catchment.

3. A concern raised by various stakeholders has been the building of housing and slurry storage facilities under the Department of Agriculture grant schemes in the RoI. These concerns have included the facilitation of intensifying agriculture by allowing more livestock to be kept, facilitating animal B&B arrangements, and finding suitable spread area for the additional slurry produced. There is anecdotal evidence that some farmers graze cattle outside of the catchment, bring these cattle back to the catchment for winter housing and also spread the slurry in the catchment. These practices may inadvertently be encouraged by current grant schemes.

4. In the recent past (last 12 months) the value of nutrients in slurry has increased sharply, following the sudden rise in fertiliser prices. Indeed it may now be economically feasible or even advantageous for farmers to export excess slurry to areas outside the catchment. In particular, this would address concerns identified above where availability of suitable spreadlands is limited to Index 4 soils, or where nutrients are imported into the catchment through animal B&B arrangements.
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5. A significant proportion (perhaps 50%) of farmers in the catchment are currently outside of AESs; an increased participation rate in such schemes should benefit water quality. It is envisaged that participation in REPS may increase in the advent of increased payments under REPS 4. However, uptake may be accelerated with a concerted local promotion of the schemes by the relevant agencies. In the event that not all farmers participate it may be worth considering a stand-alone scheme for implementing specific measures to protect water quality. Such schemes may not require farmers to put all the farm under the scheme but only those high risk areas. One means of facilitating such a scheme would be via auction processes as discussed by Strand 3 project partners.

8 Forestry

Well-managed forests and woodlands provide social, economic and environmental benefits including recreational areas, rural employment and a range of ecological habitats. With respect to climate change, forestry offers a means of storing carbon dioxide and is a potential source of renewable energy. As a rule, the nutrient exports from forestry are lower than those recorded from agricultural land. Thus, a switch from agricultural land to forestry would be expected to lower inputs to water of phosphorus and nitrogen compounds.

Unfortunately, forestry activities also have the potential to negatively impact on the aquatic environment and some of these are the precise reverse of the benefits listed above. While nutrient exports from forests are lower than from lowland agricultural land, in the uplands, exports of phosphorus from forestry are often higher than upland areas of rough grazing. Thus, forestry has been a source of eutrophication of upland lakes. It has also been implicated in acidification, bank erosion and sedimentation.

The potential for heavily afforested coniferous catchments to act as a diffuse source of nutrients has been well documented within northern Europe and is particularly relevant for a sensitive catchment such as Lough Melvin. The potential for forestry to result in erosion, sedimentation and alter catchment hydrology are also of concern to the extent that they adversely impact on salmonid survival. The majority of phosphorus entering Lough Melvin originates from diffuse sources within the surrounding catchment and although established forests contribute or lose only relatively small amounts of phosphorus, losses can increase substantially during the establishment, fertilisation and deforestation phases particularly on peat soils.

8.1 Lough Melvin Study

As part of the Lough Melvin Nutrient Reduction Programme, the objective of the Forestry Component was to assess the potential risk that forestry poses to the nutrient status of Lough Melvin. This involved determining the characteristics of forestry within the Lough Melvin catchment; identification of areas and activities considered to be of high risk of causing eutrophication and, where possible, quantification of the potential impacts. Where sufficient information was available, mitigation measures have been proposed. The information collation and review stage was greatly aided by members of the Forestry Working Group (Forest Service NI, Forest Service RoI, private foresters and Coillte).

Compared to the island of Ireland where forest cover is only 10% of the land area, forestry is a much more significant land cover in the Lough Melvin catchment as it accounts for over 25% of the catchment area (Figure D).
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Figure D: Distribution of Forestry in the Lough Melvin Catchment

The most prevalent commercial species planted throughout the catchment are Sitka spruce (Picea sitchensis) and Lodgepole pine (Pinus contorta) which are particularly suitable for the Irish climate and soil conditions. In total, 45% of forestry within the Lough Melvin catchment is grown on peat soils and 42% on gleys, which have a low adsorption capacity for phosphorus. In addition, peat soils are relatively infertile and so require fertilisation.

8.2 Risk factors

Many of the risks associated with forestry are increased in the Lough Melvin catchment due to the sensitive catchment characteristics such as high runoff risk, high slopes, proximity to watercourses, high P-desorption risk and high precipitation rates. The following points highlight the key forestry related pressures within the Lough Melvin catchment.

- The low binding capacity of organic blanket peat for phosphorus. 45% of all forestry is grown on blanket peats and 42% grown on gleys.
- Nutrient deficient stands within the Lough Melvin catchment may require future applications of phosphate fertilisers.
- Low yield classes in the catchment may lead to future applications of fertiliser at the reforestation stage.
- 61% of Coillte and Forest Service NI forestry was planted before the introduction of the Forestry and Water Guidelines and the introduction of forest certification. Buffer zones are absent in many of these older sites.
- The catchment has a high run-off risk and a high connectivity due to its high density drainage network. The Roogagh and County rivers drain heavily forested sub-catchments.
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• 49% of the forestry in the catchment is planted on areas classified as having high risk for soil desorption, slope and proximity to watercourses.

• Windthrow sites are common throughout forested areas of the catchment leading to increases in clearfell activities.

• Clearfell activities pose a risk of elevated phosphorus loss due to the breakdown of brash especially on blanket peat sites.

• Currently 419 ha are identified for clearfell in the catchment in 2015 but there is insufficient cross-border consultation between the forest management organisations regarding how the total yearly area of clearfell and fertiliser application in the catchment may impact on nutrient losses to Lough Melvin.

8.3 Future Nutrient Loads from Forestry

Clearfelling is identified as the forestry activity that has the greatest potential to cause the release of nutrients. Therefore, this section focuses on future clearfelling activity within the catchment to highlight the future loads expected from forestry over the next 7-8 years. Locations of proposed clearfelling within the Lough Melvin catchment between 2007 and 2015 are largely within the heavily forested Roogagh catchment although an area on the north-eastern shore of Lough Melvin near Muckenagh Bridge is identified for clearfelling in 2011 that could directly impact on the lake. The most notable feature is that there are 419 ha projected for clearfelling in 2015, which is almost 15 times the area clearfelled in 2007.

Table A: Forest areas projected for clearfelling in the Lough Melvin catchment 2007-2015.

<table>
<thead>
<tr>
<th>Year of Clearfell</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>28 Ha</td>
</tr>
<tr>
<td>2008</td>
<td>32 Ha</td>
</tr>
<tr>
<td>2009</td>
<td>88 Ha</td>
</tr>
<tr>
<td>2010</td>
<td>72 Ha</td>
</tr>
<tr>
<td>2011</td>
<td>115 Ha</td>
</tr>
<tr>
<td>2012</td>
<td>75 Ha</td>
</tr>
<tr>
<td>2013</td>
<td>20 Ha</td>
</tr>
<tr>
<td>2014</td>
<td>131 Ha</td>
</tr>
<tr>
<td>2015</td>
<td>419 Ha</td>
</tr>
</tbody>
</table>

To quantify the total phosphorus loads from future clearfelling operations within the Lough Melvin catchment, a phosphorus loss model was developed that assessed the impact of clearfelling using phosphorus exports rates from forest land. The model shows significant increases in phosphorus loss from increased clearfelling activities within the catchment between 2007 and 2015, but most particularly in 2015 with loads projected to increase from 625 kg P in 2007 to 3530 kg P in 2015 (Figure E). Note that these loads are for clearfelling only and do not include nutrient loads from other forestry activities for e.g. fertilisation. These loads can be compared with the current loading of phosphorus to Lough Melvin, which is estimated to be approximately 13 tonne P per year but with a target of 10 tonne P per year. Thus, the projected loading for 2015 from clearfelling alone of 3.5 tonnes P is 27% of current loading, which is considered undesirably high. Based on current knowledge it would be expected that lake concentration of total phosphorus would increase in proportion to the increase in catchment loading.
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**Figure E: Forecast Phosphorus loads from clearfelling operations (only) in the period 2007-2015.**

If these activities progress with no intervention or mitigation, and assuming that there are no other increases in phosphorus from other forestry activities or other land use activities within the catchment, then the concentration in Lough Melvin would be expected to increase to between 32 µg L⁻¹ and 34 µg L⁻¹.

**8.4 Recommendations**

It was widely acknowledged by stakeholders including members of the Forestry Working Group, that the Lough Melvin catchment is highly sensitive and that forestry organisations have an obligation to reduce the potential risk forestry activities pose to the ecological status of the lake. The forestry industry over the past 20 years has made significant changes to forestry practices and developed new environmental guidelines in line with scientific research, to minimise the impact on the environment. However, the sensitivity of the Lough Melvin catchment to nutrient loss and the sensitivity of the lake to nutrient enrichment must be stressed, reiterated and accounted for. The interaction between forestry and water is complex and risks of phosphorus loss are increased under particular catchment characteristics.

In light of the increase in nutrient loads from clearfelling activities alone within the catchment in the short to medium term, it is imperative that measures are put in place to reduce or eliminate the impacts on Lough Melvin. Consequently, a total of 57 forestry measures were developed from literature and in consultation with technical experts, to reduce the impacts of forestry on the water quality of Lough Melvin. The measures aimed at building on existing protective measures incorporated in the Forestry and Water Guidelines and were targeted specifically to the Lough Melvin catchment. The measures were ranked and prioritised and then assessed at a Forestry Workshop.

The following top 8 measures were identified:

1. Buffer zones should be created beside watercourses in line with best management practices where windthrow is not a risk factor. This measure would require operational change for existing sites.

2. Coillte and the Forest Service NI should develop progressive felling plans on a whole catchment basis. This requires annual consultation between the two organisations.
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3. Aerial fertilisation proposals from RoI and NI should be combined prior to consultation with the regulatory authorities at a cross border level i.e. The Fisheries Board, River Agency and E.H.S. This measure requires only operational changes and could be done with an annual assessment and agreement between Coillte and Forest Service NI.

4. Brash should be removed as far back from watercourses as possible. This measure will require operational changes and environmental side effects would need to be considered.

5. On clearfell sites, strategically position ochre at the end of collector drains (Pilot Study to be undertaken by COFORD).

6. The poorest nutrient deficient sites should be identified and allocated for areas of open space as part of forest redesign plans. This most appropriate delivery route for this measure is considered to be the Indicative Forest Strategy and Forest Design Plans. It was considered a measure that could easily be accommodated in the NI portion of the catchment.

7. On reforestation sites, no fertiliser should be applied until vegetation has re-established.

8. In areas of high risk, silt traps should be installed either prior to ground preparation or harvesting. This is already standard practice.

Other recommendations from the Forestry Working Group:

- Sensitive areas (such as spawning grounds) in the catchment should be better identified and forestry operators made aware.
- Difficult forestry sites posing single event risks should be identified and managed through correct environmental planning.
- Where sensitive sites and difficult forestry sites combine, consultation between appropriate agencies on protective measures is needed.
- The planting of broadleaf woodland should be undertaken in areas of high run-off risk, areas prone to over grazing and poaching from intensive stocking.
- The current study did not have a monitoring programme that was targeted to specific land uses and it was recommended by the Forestry Working Group that an independent, targeted monitoring programme be established immediately for the Lough Melvin catchment to identify the benefits and impacts of forestry on water quality.

8.5 Summary

The agreement by the forestry organisations on a set of measures is a first step towards managing the increased nutrient loads expected from forestry in the future. However, it is only a first step. It is essential that consultation and cooperation is enhanced between the forestry organisations operating in the catchment and that the recommendations presented in this study are developed further and ultimately implemented. Work must continue to deliver action on the ground, before any environmental benefits can be realised.
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9 Housing-Wastewater

In the past decade, the human population within the Lough Melvin catchment has increased dramatically in line with the growth in housing experienced around the country. The population of Kinlough, which has perhaps seen the greatest increase in number of dwellings in County Leitrim, doubled between the censuses in 2002 and 2006, from over 300 to nearly 700. Currently, there are approximately 3000 people resident within the catchment with approximately 40% (1161) resident in three villages; Kinlough and Kiltyclogher in County Leitrim and Garrison in County Fermanagh (Figure F). In addition, Rossinver in County Leitrim is a small hamlet located on the Ballagh River.

Figure F: Urban centres and rural residential properties in the Lough Melvin catchment

The impacts of increased development and housing within the catchment include land disturbance that causes erosion and sedimentation in nearby waterways and organic pollution of water. For lakes, the dominant impact is eutrophication from wastewater generated by occupied dwellings. Wastewater contains significant amounts of phosphorus primarily from sewage and the use of household detergents. Currently, for housing in the Lough Melvin catchment most of this phosphorus will reach the lake, contributing to the lake’s nutrient loading.

The main purpose of wastewater treatment processes, either through a Wastewater Treatment Plant (WWTP) or on-site wastewater treatment system is to remove organic matter and pollutants such as ammonia. However, these systems are not necessarily designed or effective at removing nutrients, especially phosphorus, and this is particularly the case for septic tanks within the Lough Melvin catchment.

A short desktop study and septic tank survey was undertaken to identify and highlight the potential issues associated with wastewater and housing within the Lough Melvin catchment. The outputs are summarised below.
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9.1 WWTP

In the Lough Melvin catchment, the villages of Kinlough, Kiltyclogher, and Garrison are serviced by WWTPs. These plants treat the wastewater of 38% of the catchment population.

The effluent from Kinlough WWTP enters Lough Melvin via the Kinlough River at the south-western end of the lake. In 2006, Leitrim County Council installed phosphorus removal facilities (ferric dosers) with the aim of reducing effluent TP levels to < 2 mg P L⁻¹. However, there have been fluctuations in the quality of effluent being discharged from the WWTP. These reflect population expansion in Kinlough, which has limited the capacity of the WWTP to deal with peak loads. A new WWTP to be completed by 2009 will have a p.e. of 2100 and is considered to have significant capacity to cope with the further expansion of Kinlough. The effluent will be required to meet a stringent TP standard of 0.8 mg P L⁻¹ which has been set by Leitrim County Council. This standard reflects the sensitivity of Lough Melvin to enrichment. Other standards to be met by the new WWTP are BOD <11 mg L⁻¹ and total suspended solids <15 mg L⁻¹.

The Garrison WWTP, which provides primary and secondary treatment, discharges directly to Lough Melvin via a pipe that runs under the walkway at the Garrison Pier. Environment and Heritage Service have issued a Water Order Consent specifying the effluent annual average standard as 40 mg L⁻¹ BOD, 60 mg L⁻¹ suspended solids and 2 mg P L⁻¹ total phosphorus. However, these levels are higher than those that have been set by Leitrim County Council for Kinlough WWTP. Monitoring results from 2006 and 2007 suggest that there is great variability in the quality of the effluent from the WWTP. Phosphorus removal facilities have recently been installed which should reduce the nutrient loading and an upgrade is planned to allow phosphorus removal, largely in recognition of the need to maintain the condition of the lake under the Habitats Directive.

Kiltyclogher WWTP is much smaller than those at Garrison and Kinlough as it services a population of approximately 170. It discharges via a drain into the County River. Treatment is considered to be poor, barely achieving secondary treatment standards and there is no facility for phosphorus removal. Kiltyclogher has also received funding for a new WWTP to be built on the same site with a capacity of 500 p.e. Work on the new plant was due to start in mid 2008 and be completed by the end of 2009. Standards to be met by the new WWTP are BOD <25 mg L⁻¹, total suspended solids <35 mg L⁻¹ and total phosphorus <2 mg P L⁻¹.

Summary and Recommendations

- Modelling based on nutrient load per population equivalent estimates show that the three WWTPs in the Lough Melvin catchment potentially contribute 890 kg of TP to the lake per year. Kinlough contributes 480 kg P yr⁻¹ (without P removal), Kiltyclogher 130 kg P yr⁻¹ and Garrison 279 kg P yr⁻¹ (without P removal). The total contribution from WWTPs is equivalent to approximately 7% of the annual loading of phosphorus to the lake.

- This contribution has been lowered through the installation of P removal and will be further reduced significantly when full operation of P removal facilities takes place. The new WWTP at Kinlough in particular will operate to a very high standard of phosphorus removal and has capacity to accommodate future expansion of the village.

- The populations that these three WWTPs serve are much smaller than the mandatory size required for the installation of phosphorus removal under the Urban Waste Water Treatment Directive. The operators of the WWTPs have taken the initiative in installing or planning for P removal and the presence of phosphorus removal at such small population centres is therefore a mark of their commitment to improving water quality in the lake.
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- If an 80% removal efficiency, equivalent to removing 700 kg P yr\(^{-1}\) is achieved then the contribution these WWTPs to the total phosphorus loading to Lough Melvin would be in the region of only 1%. Lowering loading by 700 kg P yr\(^{-1}\) is quite small in terms of the current lake loading but it represents approximately 25% of the loading reduction of around 3 tonnes P yr\(^{-1}\) that is recommended for the lake. On this basis, it is important that the new and upgraded WWTPs are completed as soon as possible.
- There are continued concerns about the performance of the old plant in Kinlough while the new plant is being built in the same location, considering the small size of the site. This should be closely monitored and concerns should be addressed through timely communication with the local community.
- Given the development in the village of Garrison and the probable localised adverse ecological impacts of the existing discharge that are evident in the lake, plans to increase the capacity of the WWTP and install phosphorus removal should be put in place in the near future. In addition, the variability in the sampling results from the WWTP should be investigated.

9.2 On-site wastewater treatment systems (OSWTS)

In rural areas with low-density housing, sewer systems are not a viable option and on-site treatment systems are utilised. The most common of these is the septic tank, although Proprietary Effluent Treatment Plants are becoming more common.

The majority of single dwellings in Ireland are serviced by septic tank systems and within the Lough Melvin catchment, 62% of the population (nearly 2000 people) rely on an on-site wastewater treatment system to treat household wastewater. Due to the type of landscape and water logged soils within the catchment, it is considered unlikely that septic tanks in the Lough Melvin catchment are working to a satisfactory level. The impracticality of monitoring septic systems means that their contribution in terms of phosphorus loading to Lough Melvin is uncertain. However, it is commonly observed both in the Lough Melvin catchment and elsewhere that most septic systems discharge directly to surface waters, so that rural population per capita values for phosphorus from septic tanks cannot be very different from the per capita phosphorus loadings from WWTPs. It is estimated that septic tanks could contribute 1.12 tonnes P yr\(^{-1}\) or close to 10% of the total input of phosphorus to Lough Melvin.

In order to classify the specific issues and risks posed to water quality by septic tanks within the Lough Melvin catchment, a septic tank survey was undertaken in January and February of 2008.

A summary of some of the information collated is provided below.

- Two chamber septic tanks with percolation trenches or soak pits accounted for 72% of treatment systems in the survey.
- 46% of the systems were over 20yrs old. Older systems are likely to comply only with standards at the time of building, which would now be considered inadequate (e.g. having soak pits rather than properly designed percolation areas).
- 66% of septic tank effluent was discharged to a drain and 8% discharged to a stream. This means that the majority of septic tank effluent has a direct pathway to a nearby waterway.
- 38% of the households surveyed had their septic tank desludged, but the frequency was inadequate, with only 24% desludging in the last 5yrs. Only 12% had desludged in the last 12 months. Over half of the respondents stated that they had never maintained the tank and/or were unaware when it had last been maintained.
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- In severe cases there were:
  > No percolation systems and effluent discharged straight to stream or drain
  > No stones in soak pit
  > Badly designed percolation areas
  > Tanks sited on very steep slopes (14% on gradients greater than 1:5).

Note: the term “soak pit” is used to describe a hole in the ground filled with stones through which septic tank effluent is directed. Soak pits are no longer considered suitable as a part of the treatment system and have been replaced by properly designed percolation areas. However, they were historically utilised and are found throughout the catchment.

Wastewater treatment system surveys undertaken on 80 dwellings in the Ballagh River catchment in 2003 indicated similar problems with systems, with over half of owners having never maintained their septic tanks. In addition, this survey identified a communal Bord na Mona Puraflow system servicing five council houses in Rossinver that is less than 10m from the Ballagh River in an area subject to regular inundation.

Summary and Recommendations

Septic tank systems in the catchment pose a significant risk to the water quality of the catchment’s waterways and Lough Melvin due to their location, age and maintenance regime of systems and the catchment’s characteristic poor soils, high water tables and high slopes. A safe generalisation based on these factors and on site surveys within the catchment, is that the majority of septic tank systems are not operating effectively and any phosphorus removal is extremely limited. Recommendations (not exclusive) on how the risk to water quality can be addressed are presented below:

- An education and awareness programme should be developed and implemented by the relevant authorities as a high priority in the short term. Many community members are unaware of the maintenance requirements for their wastewater treatment systems or issues with contamination of nearby waterways. This is considered to be a relatively low cost and effective option for reducing the pollution risk from septic tanks.

- Enforcement authorities in some cases do not have sufficient resources to undertake adequate inspections of treatment systems within the catchment. Resources should continue to be sought for additional enforcement capacity and the catchment should be prioritised as a target catchment for proactive monitoring and enforcement.

- Alternative and more effective methods of treating household wastewater should be investigated for sensitive and high risk catchments such as Lough Melvin. This could include the investigation of the use of constructed wetlands and willow beds on sites where treatment of effluent is insufficient.

- Householders should be required to update their wastewater treatment systems to meet required standards. This should be grant aided and considered a high priority as it is very probable that there are a significant number of antiquated systems within the catchment.

- Consideration should be given to the introduction of bye-laws for the control of pollution from septic tanks.

- Further investigation on the communal wastewater system servicing the 5 council houses in Rossinver and less than 10m from the Ballagh River needs to be undertaken and a new system installed if flooding of the system is evident or its location is deemed high risk.

- The location and suitability of the Lough Melvin catchment for one-off housing should be critically considered by the relevant authorities. This should be done with a “whole of catchment” perspective.
Executive Summary

because it is the cumulative impacts of housing and wastewater within the catchment that is the major issue. One off housing should not be permitted or at the very least severely restricted outside sewered areas or locations where proprietary treatment systems with P removal facilities are not practicable.

10 Nutrient Trading and Auctions

Agri-environmental schemes are a well established approach to nutrient management within catchments. However, research suggests the success of these schemes can be limited, for example, by engaging farms already managed to minimise nutrient runoff, resulting in overcompensation of compliance costs and a relatively low level of additional environmental benefits. As a more cost efficient alternative, Market Based Instruments in particular Nutrient Trading and Land Management Auctions, which create incentives for behaviour changes through market signals, were investigated.

Nutrient trading typically takes the form of a ‘cap and trade’ system where an absolute limit on emissions is set. ‘Permits’, allowing a specified level of emissions, are allocated, before a market for trading is created. Those who exceed emission reduction can sell excess permits to those who find it more costly. Where insufficient permits are held to cover discharge levels, either additional permits must be purchased or discharges must be reduced through abatement or increased efficiency, otherwise a fine will be issued.

Benefits associated with trading schemes are cost efficiency, they facilitate economic growth, incentivise innovation to reduce pollution, can result in indirect environmental benefits, they are flexible and facilitate stakeholder engagement. Challenges include difficulty in monitoring diffuse sources of pollution, difficulty in ensuring trades have an equivalent impact on water quality, high levels of risk and uncertainty, difficulty in identifying a suitable regulatory agency and potentially high costs. Examples of water quality trading schemes that involve a high level of trades and have been operating for any considerable length of time are scarce. This may indicate the limited potential for application of a trading scheme in this context.

However, case studies highlight that successful schemes tend to have low costs, local management initiatives, have a relatively simple design and stakeholder collectives to spread risks.

Auctions for land use management are used to select landholders that will be allocated payment for implementing management practices that reduce pollution output. Typically, farmers submit ‘bids’ to the regulator outlining compensation required for implementation of approved agri-environmental measures. Bids are scored using a weighting index to reflect benefits that are most highly valued by the agency. Those bids which offer most environmental benefit for least cost are awarded short term contracts. Through the competitive bidding process, true costs of participation are revealed resulting in more cost efficient allocation of funding. For this reason, they are considered to be less subjective. Auctions are more suitable where nonpoint sources occur, they are flexible and transparent. Challenges include the potential for high administrative and transaction costs along with difficulty in identifying a suitable regulatory agency. The need to design the auction to suit the specific circumstances is essential to ensure success. Application of such schemes highlight the potential for considerable cost savings. Successful auction schemes tend to involve stakeholders from an early stage, provide support to assist landholders in constructing bids and reduce the cost of bid preparation and finally, adopt an auction design that is well developed through pilot and trials.
Executive Summary

Based on available information, the report suggests that nutrient trading is not a viable nutrient management approach for implementation in the Lough Melvin Catchment. Significant problems arise from the small number of point sources which contribute a relatively low proportion of phosphorus to the lake. Given the difficulties with trading between nonpoint sources, arising from the costs incurred from monitoring diffuse pollution sources, it is likely that the costs of operating such a scheme would significantly outweigh benefits. Furthermore, additional legislation would be required to impose a more stringent ‘cap’ on nutrient levels, which is likely to face opposition.

However, conditions in the Lough Melvin catchment appear to accommodate application of an auction approach, for example, in terms of numbers of potential participants, the range of nutrient reduction measures that could be implemented along with the ability to assess bids easily according to phosphorus contribution and finally, the potential for heterogeneous costs associated with implementation of proposed measures.

Any auction approach should be consistent with existing legislation and run parallel to existing land management schemes. Ultimate government involvement will be required to ensure such adherence, to agree terms of the auction mechanism, to award contracts and handle funds. Whilst complicated by the cross border location, this could be achieved through establishing a Melvin Catchment Management Board with representatives from RoI and NI government bodies. The auctions should be managed at local level, to provide technical assistance, monitor and ensure compliance.

The next step towards successful implementation would involve economic field experiments with potential farmer participants to test and refine design, engage and involve stakeholders and provide training. The potential to engage point sources through a trading mechanism combined with an auction for nonpoint sources could be investigated.

11 Governance Framework

An understanding of controls and governance arrangements that are relevant to management of Lough Melvin is a key part of the catchment management process. A study was undertaken as part of the Lough Melvin Nutrient Reduction Programme to identify the most significant governance issues relevant to the catchment in both NI and the RoI. Gaps, barriers and constraints to the effective implementation of controls and governance were also identified, and recommendations for solutions or mitigation presented. The following provides a summary of the outputs of this study.

11.1 Key Governance Drivers

The most important drivers of management within the Lough Melvin catchment are EU Directives relating to water quality and biodiversity, and in particular:

Habitats Directive

Lough Melvin has been classified as a Special Area of Conservation (SAC) in NI and is a candidate SAC (cSAC) in RoI under the 1992 EU Habitats Directive (92/43/EEC). The SAC forms the heart of the catchment both in geographical/physical terms and in the context of governance and regulation. The Habitats Directive requires the key features of the SAC to be maintained at a favourable conservation status.

Water Framework Directive

The Water Framework Directive (2000/60/EC) is already having a considerable influence on governance within the catchment. It has provided a statutory basis for standardisation of water quality standards and
Executive Summary

monitoring across jurisdictions and a catchment-based approach to water management. It requires the waters of Lough Melvin to be at least of good ecological status by 2015. Basic measures relevant to the catchment will form part of the wider Draft North Western River Basin Management Plan, to be published for public consultation in December 2008. It is anticipated that these basic measures will include some of the measures identified in the Lough Melvin CMP. Such measures should be consistent with and contribute to the water quality (and other) objectives set under the Habitats Directive.

Nitrates Directive

Agriculture is an important land-use within the catchment, and the Nitrates Directive (91/676/EEC) is a key driver in regulating diffuse pollution from agricultural sources. The Directive does not require any specific targets for the catchment, but its measures assist both governments to meet their obligations under both the Habitats and Water Framework Directives.

11.2 Priority Governance Issues

Governance issues were identified for seven main categories: water management; agriculture; nature conservation; land-use planning; fisheries; forestry and general governance issues. Prioritisation was then undertaken via: a consultation process with 32 key stakeholders representing 17 different organisations; comments on draft reports provided by the Catchment Management Group, organisational stakeholders and the Steering Committee and; a stakeholder workshop. Twelve priority governance issues that impact most on the sustainable and integrated approach to management of Lough Melvin are outlined below:

1. Common Water Quality standards and monitoring should be agreed across the catchment. Enforcement capacity in the catchment is affected by resource constraints.
2. Agri-environment schemes have a key role in management of the catchment. Such schemes need to be enhanced to maximise their effect.
3. Transposition and implementation of the Habitats Directive within the catchment is often weak and generally variable across jurisdictions.
4. Two separate Conservation Plans exist for Lough Melvin SAC. Their status and level of detail differ significantly.
5. The quality of policy protection for Lough Melvin SAC differs significantly between jurisdictions.
6. There are differences in the transposition and implementation of the EIA Directive between jurisdictions.
7. Land use planning is a key catchment issue (e.g. in restricting one-off housing in sensitive parts of the catchment)
8. The existing regulations covering the introduction of zebra mussels, pike and other alien species are inadequate.
9. The role of other stakeholders (e.g. Angling clubs) in preventing their introduction to Lough Melvin is significant.
10. There is significant variation in the scope for EIA of forestry operations between NI and RoI.
11. Clearfelling within the catchment could have significant implications on water quality.
12. Stakeholders must ensure that the Lough Melvin Catchment Management Plan will be implemented.
11.3 Summary and Recommendations

Recommendations to address the twelve priority governance issues were developed and are presented below according to the timescales in which they could be implemented.

Recommendations which could be implemented in the short term are identified as follows:

- Training on the application of Article 6 of the Habitats Directive should be provided to all relevant authorities in both jurisdictions, including the planning authorities, forestry agencies, water services authorities, and fisheries authorities.

- Cross border agreement should be reached on what is required to fulfil an Appropriate Assessment under Article 6 of the Habitats Directive.

- An education programme for landowners whose activities could have an impact on the Lough Melvin SAC should be undertaken in both jurisdictions.

- Service Level Agreements may be required to formalise consultation between organisations on the need for Appropriate Assessment screening under the Habitats Directive.

- A single Conservation Plan should be prepared for Lough Melvin SAC, or at least a common approach taken to separate plans. This should include detailed favourable condition tables for all selection features.

- The review of Leitrim CDP 2003-2009 should include a robust policy, which accurately reflects the requirements of Article 6 of the Habitats Directive.

- Increased application of sub-threshold EIA should be considered by the planning authorities, particularly in RoI.

- Training and guidance on the interpretation of “significant effects on the environment” and other key issues, should be considered for appropriate authorities.

- Every effort should be made to involve planning authorities in the catchment management plan process.

- PPS14 policies should continue to be applied in the Lough Melvin catchment.

- Leitrim CDP 2009-2015 should include policies restricting one-off housing in sensitive parts of the catchment.

- In both jurisdictions, planning conditions should be used to require tertiary effluent treatment where necessary.

- Government agencies should support angling clubs and other stakeholders to take a proactive approach in alien species initiatives.

- A cross border contingency plan should be put into place to deal with the event of alien species introduction, including appropriate contacts and procedures.

- Initiatives should take account of the fact that some species alien to the catchment, such as pike, could have a particularly devastating impact on the wildlife interest of Lough Melvin.

- The application of discretionary EIA for sub-threshold projects should be expanded.
Executive Summary

- All major forestry operations in the catchment that may have a significant effect on Lough Melvin should be screened for appropriate assessment under Article 6 of the Habitats Directive.
- Agricultural agencies should establish a forum with the objective of agreeing a package of common agri-environment measures which can be targeted at the Lough Melvin catchment. Any agricultural forum for the catchment should also include the regulatory bodies such as Leitrim County Council and EHS.
- There should be active management of all forestry riparian buffer zones to reduce the potential impact of clearfelling, including machinery exclusion zones.
- An Implementation Group of key stakeholders should be established to co-ordinate the implementation of key measures identified in the Catchment Management Plan.
- Representatives of any Catchment Management Plan group should be at a sufficiently high level in their organisations to facilitate implementation measures.
- A lead agency should be established for the Catchment Management Plan – possibly a Local Authority.

Recommendations that derive from issues that are considered important and urgent, but with feasibility restricted by various factors, are listed below. It is suggested that early addressing of these issues should provide results in the medium term.

- Agreement over water quality definitions for both chemical and ecological parameters is needed covering both jurisdictions.
- An agreed target for the total phosphorus concentration in Lough Melvin between all relevant agencies is required.
- A more precise and/or extensive monitoring regime for the catchment is required, including greater liaison between water quality and fisheries agencies.
- Agencies in both jurisdictions should reach agreement on a monitoring specification which meets both WFD and Habitats Directive requirements without duplication.
- An appropriate enforcement capacity should be sought, informed by the outcomes of existing studies and ongoing water quality monitoring, and taking account of the sensitive nature of the catchment. This should be pursued at a high level through the national budgeting and Programme for Government process. In the meantime, Lough Melvin should be prioritised as a target catchment for proactive monitoring and enforcement.
- Unified agri-environment measures are required across the catchment. Research by the appropriate agencies suggests that this is best served by a catchment-specific scheme, available to all farmers in the catchment.
- There should be an increased level of inspection of participating farms in the catchment.
- Compliance with the Birds and Habitats Directives could be achieved by the introduction of National Planning Guidance on this issue.
Executive Summary

- PPS2 in NI is currently under review and should be amended to reflect the requirement for AA of Area Plans.
- A Thematic Local Area Plan for the Lough Melvin catchment should be explored in County Leitrim. Scope for a parallel or integrated approach with NI Planning policy to include the County Fermanagh portion of the catchment should be considered.
- Future forestry planning needs to take account of the potential impact of clearfelling and this should be reflected in buffer zones, open spaces, species composition and coupe sizes.
- Co-ordination to achieve a total annual clearfell limit for the catchment should be explored.

**Longer term** recommendations that derive from issues that are considered important and urgent are listed below.

- The EC (Natural Habitats) Regulations require further amendment to ensure compliance with the Habitats Directive, notably with respect to addressing strategic plans in RoI.
- Legislation relating to alien species introductions in both jurisdictions should be amended and harmonised.
- Statutory requirement for re-planting of clearfelled areas under RoI Forestry Acts needs to be amended with respect to unsuitable areas.

11.4 Conclusion

This assessment, based on research and consultation with stakeholders, has culminated in significant consensus over the key governance issues in the catchment. In this context, the recommendations provided can be considered as "toolkit" for addressing the priority governance issues relating to water quality in the catchment.

12 Adaptive Management

Natural resource management relies on assessments and designs that in turn are based on various assumptions, and it is often difficult to predict precisely how the natural environment will respond to any intervention. Creating feedback mechanisms within an adaptive management framework ensures that catchment management is responsive to changing conditions both in the lake and the catchment. An outline of the adaptive management process is given in Figure G. Currently the Assess problem and Design stages have been completed by the Lough Melvin Programme but the adaptive management cycle requires that not only the management measures designed to address the problem be implemented but that the effectiveness of these measures be reviewed, evaluated and adjusted as necessary, as new information becomes available. The monitoring and evaluation steps and their associated reporting, can also be important when they provide stakeholders and the community with information on the status of Lough Melvin and the progress and results of implementation of the CMP.
**Executive Summary**

![Figure G: Adaptive Management Process](image)

It is recommended that a holistic monitoring system is developed for Lough Melvin that integrates and links ecological values and objectives with implementation of actions. In addition, the establishment of a long term monitoring strategy for Lough Melvin, involving the use of remote sensing technology that is linked to a global database such as the Global Lake Ecological Observatory Network GLEON is recommended.

It is also recommended that evaluation against the recommendations outlined in the CMP is undertaken on a yearly basis by a cross-border Lough Melvin Management Group or Stakeholder Forum, with a more holistic and detailed review of the actual CMP to be undertaken on a five yearly basis. This review should be considered and adjusted accordingly in light of the development and implementation of the Water Framework Directive River Basin Management Plans.
Introduction
Introduction

Ireland’s waterways, lakes and wetlands are a significant part of our natural heritage and their management and maintenance is our responsibility, as the current generation of environmental caretakers.

In recent years, with unprecedented economic growth, Ireland’s natural resources have come under increasing pressure. Systems that were once untouched and in pristine condition are beginning to show evidence of decline (EPA, 2007b). It is essential that our water resources, on which we depend on for so much, are conserved. Once systems are damaged, it is a costly and much more difficult task to restore them to health.

Lough Melvin is a unique and internationally significant lake located in the north-west of Ireland within the counties of Leitrim and Fermanagh. Described as “one of the few remaining natural post-glacial salmonid lakes in northwestern Europe”, Lough Melvin covers an area of 2206 ha and is renowned for its early “run” of Atlantic salmon, unique assemblage of fish species and diversity of flora and fauna. In relatively pristine condition, the lake and surrounding catchment area are highly valued for their recreational, heritage and environmental qualities by anglers, tourists, scientists and the local community.

Due to the importance of Lough Melvin as an oligo-mesotrophic (low-medium nutrient) lake that supports a diversity of habitats and species, it has been designated as a Special Area of Conservation (SAC) under the EU Habitats Directive. However, the health of Lough Melvin and its unique environmental values are particularly vulnerable to human activities in the surrounding catchment, with the most significant threat being an increase in nutrients from housing, forestry and agriculture. The greater nutrient loads from the surrounding catchment have resulted in nutrient concentrations within the lake increasing by over 50% in less than a decade and these catchment loadings are continuing to climb.

It is imperative that action is taken now to protect this rare natural resource before irreversible damage is done to the system. To protect the water quality and ultimate health of Lough Melvin, the sources of nutrients from the surrounding catchment need to be managed and methods for their control implemented. The development of the Lough Melvin Catchment Management Plan provides a basis for the conservation of Lough Melvin into the future in an effective and holistic way. Linking activities within the surrounding catchment to environmental impacts on the lake and managing the lake at a catchment scale, is the only way that management actions can be prioritised and targeted for the most effective and beneficial environmental outcomes.
1.1 Lough Melvin Nutrient Reduction Programme

The Lough Melvin Nutrient Reduction Programme was funded by the EU Interreg IIIA Programme for Ireland/Northern Ireland and the Project Partners. Its aim was to develop a Catchment Management Plan (CMP) for Lough Melvin that would promote good ecological status and address the primary catchment threats (nutrient enrichment).

The overall goal of the Lough Melvin Catchment Management Plan is to:

“Protect the health and unique environmental values of Lough Melvin and its catchment”

More specific objectives for the Programme included:

- Improving the definition of the relative contributions to nutrient transfer in agricultural river basin catchments;
- Improving the definition of the impact of certain mitigation measures;
- Improved co-operation between multiple authorities to collaborate on the management of International River Basin Districts.

The CMP focuses on nutrient enrichment as the key threat to ecological health, but also makes reference to other potential threats. It incorporates outputs from four Project Strands. Project Partners were responsible for individual strands with the Northern Regional Fisheries Board (Strand 1) being responsible for overall coordination of the Programme. An outline of the strands is provided below.

1.1.1 Strand 1 Programme Coordination

**Project Partner:** Northern Regional Fisheries Board. Harry Lloyd- Project Principal. Dr. Milton Matthews. Emer Campbell- Programme Manager, Angela Killalea- Administrative Assistant, Colm O’Kane- GIS Technician, David Laing- Forest Project Officer, Michael Quinn- Wastewater Project Officer.

**Aim**

To produce a catchment management plan for Lough Melvin and its catchment that will promote “good ecological status” (as required by the Water Framework Directive) and could form the basis of a Biodiversity Action Plan (as may be required by the Habitats Directive) and; to raise awareness and promote environmental controls, management, and improve environmental behaviour.

**Activities**

- Convene and provide technical support to the Lough Melvin Catchment Management Group.
- Link with project partners to ensure that information and data is collected and provided on a consistent basis.
- Develop the existing Geographical Information System (GIS) for Lough Melvin.
- Collate and incorporate existing data into a catchment management information system.
- Investigate the potential impacts of forestry and housing (wastewater) on Lough Melvin.
- Provide a focal point for contacts with farms and residents in the catchment.
- Financial management.
Introduction

1.1.2 Strand 2 Agri-Environmental

**Project Partner:** Teagasc. Dr. Owen Carton & Dr. Donnacha Doody (to April 2007); Dr. Rogier Schulte & Dr. Paul Byrne- Agri-Environmental Manager.

**Aim**
To develop and provide an agri-environmental suite of measures to safeguard and improve the environment of the Lough Melvin catchment.

**Activity**
Conduct up to 240 farm visits within the catchment to define and cost a programme of measures appropriate to extensive farming in order to reduce nutrient releases to Lough Melvin.

1.1.3 Strand 3 Economic Assessment

**Project Partner:** Institute of Agri-Food and Land Use (IAFLU), Queen’s University Belfast. Prof. George Hutchinson, Dr. Danny Campbell- Research Assistant & Dr. Claire Cockerill- Research Assistant.

**Aim**
Conduct an economic assessment of costs and benefits of the proposed programme of agri-environmental measures. Investigate the use of “nutrient trading”.

**Activities**
- Conduct a questionnaire survey of 1,000 households on the Lough Melvin catchment to determine Willingness to Pay (WTP) for the preservation of the trout and char populations of Lough Melvin.
- Assess the relative costs and benefits of each of the options offered by Strand 2 using the data obtained from farm surveys.
- Examine the possibility of nutrient trading by reviewing best practice elsewhere, the information base required to operate and evaluate the scheme, and the legislative framework required for application in a cross-border catchment.

1.1.4 Strand 4 Water Quality and Carbon Isotope Analysis

**Project Partner:** Agri-Food and Biosciences Institute (AFBI), Belfast and Queen’s University Belfast. Dr. Bob Foy- Project Principal and Chris Barry- Research Assistant.

**Aim**
To complete a water quality analysis programme for Lough Melvin and its inflowing river network with specific emphasis on nutrients and their sources.

**Activities:**
- Conduct a water quality monitoring programme of the lake and inflowing rivers (covering nutrients, algal abundance and oxygen status).
- Conduct stable isotope analysis of biota in lake to determine the relative importance of external and internal nutrient sources to Lough Melvin food webs. Determine sources of carbon to Lough Melvin and their influence on productivity.
1.2 Catchment Management

Rivers, lakes and wetlands do not exist in isolation. They are a dynamic part of catchment-based processes that are intrinsically linked to operations and activities within the catchment. Therefore, to ensure the future and health of Lough Melvin, sustainable and strategic management of the catchment is essential.

A catchment is defined as an area of land that drains to a single point (lake, river confluence etc.) and is comprised of resources: soil, water, air and vegetation. Changes to one resource within a catchment will ultimately affect one or more of the other components and the catchment therefore provides a logical basis for the management of water resources. Studies using a catchment management approach to water resource management generally provide a better understanding of the advantages and disadvantages of various land management options, and of the most appropriate actions to implement (Ellis, 2003; Cummings, 1999).

The aim of a Catchment Management Plan is to balance the utilisation of the resource (lake) with its conservation, thus enabling the resource to be protected and enhanced. At the core of the catchment management planning process is the recognition that the health of a waterbody depends on the actions and decisions made by all those using and managing the land, water and other environmental resources within the catchment.

Consultation is therefore a key element of the planning and implementation of catchment management, and engagement with a diversity of interested stakeholders optimises the effectiveness and ultimate success of the catchment management plan. The diversity of interests needs to be recognised to establish and maintain an integrated and holistic framework necessary for success.

“Success” itself is not measured by the production of the plan but by the resulting actions and cooperation that lead to changes that benefit the water, environment and its users/stakeholders, in the long term. The aim therefore of catchment management is to improve land and water management by recognising and balancing the many interdependencies (land, water, environmental and social resources) operating at the catchment scale (Baker, Borghesi & Campbell, 2000).

The EU Water Framework Directive 2000/60/EC (WFD) focuses on the concept of integrated catchment management. Its aim is to “preserve waters currently in high and good status” and “to protect, enhance and restore” other inland surface waters to good ecological status by 2015, via a coordinated and integrated water management approach. Consequently, the principles of catchment management are becoming core to the management of water resources in Ireland and Europe. The River Basin Management Plans that will be produced initially as part of the implementation of the WFD will focus on river basin districts rather than an individual catchment such as Lough Melvin, which is the focus of this document.

In preparing this Catchment Management Plan (CMP) consultation and engagement has been undertaken with a diversity of stakeholders to gain an insight into the social and economic aspects influencing management of the lake and the surrounding catchment. In addition, the CMP provides an understanding of the biophysical components of the catchment and how they may interact.
1.3 Plan Development

The Lough Melvin CMP is the product and culmination of the investigation results produced as part of Strands 1 to 4. In developing a CMP, a number of steps are required (Figure 1). Development of the Lough Melvin CMP followed this process and a more detailed outline is presented in Figure 2.

Figure 1: Catchment Management Plan Development process
Introduction

Figure 2: Lough Melvin Catchment Management Plan Development Process

- Information Collation
  - Catchment characteristics
  - Ecological Assets/Threats
  - Legislation and Policy
  - Monitoring

- Investigations
  - Agriculture
  - Wastewater
  - Forestry

- Target Setting
  - Overall Goals & Objectives
  - Ecological Objectives

- Development of Measures
  - Agriculture e.g. buffer strips
  - Forestry e.g. timing of felling
  - Wastewater e.g. upgrades WWTP's

- Costing
  - Estimated costs for implementation of measures

- Actions and Recommendations
  - Information Gaps
  - Prioritised Actions (measures)
  - Methodologies for Implementation

- Catchment Management Plan

Implementation
**1.3.1 Consultative Process**

The main components of the stakeholder engagement process for the Lough Melvin Programme are shown in the Engagement Framework (Figure 3). The Lough Melvin CMP was developed in consultation with three main stakeholder groups. These were the; Lough Melvin Catchment Management Group; Lough Melvin Steering Committee and; the wider community and specific interest groups.

![Figure 3: Engagement Framework for Lough Melvin Catchment Management Plan](image)

**CONSULTATION**
- **Principles**
  - Provide a framework for ongoing communications and engagement
  - Identify key stakeholders and methods for engagement

**TARGETTED STAKEHOLDER GROUPS**
- **Working Groups**
  - Provide specific input to key components
  - Workshop options and alternatives
  - Provide information that will increase the accuracy and applicability of CMP
  - Liaise with other Community Groups

- **E.g. Forestry Working Group**
  - Lough Melvin Forest Project Officer
  - Forest Service (NI and RoI)
  - Coillte
  - NIFB
  - Private Forestry Representatives

**STRAEGIC DIRECTION AND OVERSIGHT**
- **MG Principles**
  - Advise the Programme Manager on issues relating to management of Lough Melvin
  - Promote and disseminate information
  - Review the CMP

**SC Principles**
- Responsible for key programme deliverables
- Ensure outputs are scientifically rigorous, applicable, contribute to long-term sustainability and completed within time limits
- Share information and monitor progress

**TECHNICAL**
- **SC Core Membership**
  - Northern Regional Fisheries Board
  - Environment and Heritage Service DOE NI
  - Teagasc
  - Agri-Food and Biosciences Institute
  - Institute of Agri-Food and Land Use (QUI)
  - Leitrim County Council

**PROGRAMME STRUCTURE**
- **Strand 1: NRFB**
  - Coordination
  - Financial Management
  - Stakeholder Engagement
  - GIS and Information Management
  - Forestry Assessment
  - Wastewater Assessment
  - Catchment Management Plan

- **Strand 2: TEAGASC**
  - Development of agri-environmental suite of measures
  - Consultation

- **Strand 3: QUB**
  - Economic assessment of costs and benefits
  - Trading, WTP

- **Strand 4: AFBI**
  - Water Quality analysis
  - Stable isotope analysis

The membership of the Lough Melvin Catchment Management Group (CMG) consisted of representatives from cross-border government, semi-state bodies and research organisations with a role in the long-term and sustainable management of Lough Melvin. The purpose of the Group was to ensure that the project in general, and hence the CMP, was consistent with and contributed to the overall broader strategic goals of government in the catchment with respect to water quality and conservation. The role of the Group was to: provide strategic and policy advice; ensure information is disseminated throughout respective organisations, government departments and the local community and; to avail of opportunities to promote and improve the outcomes of the Lough Melvin Programme. The CMG included members of the Steering Committee.
The Lough Melvin Steering Committee was a cross-border group with the majority of members having specific, assigned, and formal responsibilities in the development of the CMP. Its purpose was to coordinate the scientific work programme and to ensure that the programme outputs were scientifically rigorous, applicable, and provided a basis for the long-term sustainable management of Lough Melvin. Its roles included: providing scientific input; monitoring progress and ensuring that deliverables were completed within the established time limits and; controlling project expenditure.

Membership of both groups is provided in Table 1.

**Table 1: Membership of Catchment Management Group**

<table>
<thead>
<tr>
<th>Nominee</th>
<th>Role</th>
<th>Organisation</th>
</tr>
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<tbody>
<tr>
<td>Adrian Hurst</td>
<td>Lough Erne Liaison Officer</td>
<td>Fermanagh County Council</td>
</tr>
<tr>
<td>Dave Duggan</td>
<td>Regional Manager</td>
<td>National Parks and Wildlife Service</td>
</tr>
<tr>
<td>Francis Gaffney (to Sept 2007) and Brian Kenny (from Oct 2007)</td>
<td>Senior Engineer</td>
<td>Leitrim County Council</td>
</tr>
<tr>
<td>Frank Macken</td>
<td>Agriculture Inspector</td>
<td>Department of Agriculture and Food (RoI)</td>
</tr>
<tr>
<td>Ian Irwin</td>
<td>Divisional Forest Officer</td>
<td>Forest Service Northern Ireland, Department of Agriculture and Rural Development (NI)</td>
</tr>
<tr>
<td>John Kane</td>
<td>Senior Fisheries Officer</td>
<td>Department of Culture, Arts and Leisure (NI)</td>
</tr>
<tr>
<td>Martin McGarigle</td>
<td>Regional Inspectorate</td>
<td>EPA (RoI)</td>
</tr>
<tr>
<td>Noel Foley</td>
<td>Divisional Inspector</td>
<td>Forest Service Department of Agriculture &amp; Food (RoI)</td>
</tr>
<tr>
<td>Patrick McGurn</td>
<td>Conservation Advisor</td>
<td>Countryside Management Division Department of Agriculture and Rural Development (NI)</td>
</tr>
<tr>
<td>Tim Morris/John Sadlier</td>
<td>Assistant Principal Officer/Principal Officer Water Quality</td>
<td>Department of Environment, Heritage and Local Government (RoI)</td>
</tr>
<tr>
<td>Tony McNally</td>
<td>North South Share Programme Coordinator</td>
<td>Donegal County Council</td>
</tr>
<tr>
<td>Trevor Champ</td>
<td>Senior Research Officer</td>
<td>Central Fisheries Board (RoI)</td>
</tr>
</tbody>
</table>

**And Steering Committee Members**

<table>
<thead>
<tr>
<th>Nominee</th>
<th>Implementing Body</th>
<th>Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angus McRobert/Yvonne McElarney (to April 2007) and Cate Murphy (from April 2007)</td>
<td>Environment &amp; Heritage Service Northern Ireland</td>
<td></td>
</tr>
<tr>
<td>Bob Foy</td>
<td>Project Principal Strand 4- Water Quality Project Leader</td>
<td>Agri-Food and Biosciences Institute, Belfast</td>
</tr>
<tr>
<td>Brendan Maguire</td>
<td>Senior Fisheries Environmental Officer</td>
<td>Northern Regional Fisheries Board (NRFB)</td>
</tr>
<tr>
<td>Emer Campbell</td>
<td>Programme Manager</td>
<td>NRFB</td>
</tr>
<tr>
<td>Harry Lloyd</td>
<td>Project Principal CEO- NRFB</td>
<td>NRFB</td>
</tr>
<tr>
<td>George Hutchinson</td>
<td>Strand 3- Economic Assessment Project Leader</td>
<td>Queen’s University Belfast</td>
</tr>
<tr>
<td>Milton Matthews</td>
<td>Assistant CEO</td>
<td>NRFB</td>
</tr>
<tr>
<td>Owen Carton/ Rogier Schulte (to April 2007)</td>
<td>Strand 2- Agri-Environmental Project Leader</td>
<td>Teagasc</td>
</tr>
</tbody>
</table>
Introduction

In addition to the two main groups, stakeholders were consulted individually or brought together to provide advice and expertise for particular topics, investigations or parts of the Plan. The Forestry Working Group was established to oversee the work undertaken for the forestry assessment component of the Programme and comprised of members representing private and public forestry management organisations.

The wider community and specific interest groups were engaged directly or were provided with the opportunity to become involved and have input to the Programme through a variety of means including information evenings, one-on-one and group meetings/presentations, feedback forms, surveys etc.

Communication tools and processes used included the development and maintenance of the Programme website (www.loughmelvinprogramme.com), production and distribution of brochures and programme overviews, presentations at various workshops, meetings and conferences and the hosting of catchment tours.

Two public consultation events were held for the Programme. The first was held in June 2007 to promote the unique values of Lough Melvin and highlight the potential threats to the lake. The second was held in February 2008 to present the results of the various investigations and get feedback from the local community. Both information evenings were publicised via local newspapers, community information notes, posters in local shops, libraries etc., on the Programme website and by direct invitation.
Background

2.1 Lough Melvin and its Catchment

Lough Melvin is situated in the north-west of Ireland approximately 5km from the Atlantic Ocean, in the counties of Leitrim and Fermanagh. The lake occupies an area of 2206 ha and is the 10th largest lake in Ireland, draining a catchment area of 22,463 ha. The lake and catchment traverse the border between Northern Ireland and the Republic of Ireland with 47% of the catchment being located in County Fermanagh and 53% in County Leitrim.

![Lough Melvin Catchment Map]

Running south-east to north-west, Lough Melvin lies within a glaciated valley and is approximately 12km long with a maximum width of less than 3km and an average depth of 10.9m (see Figure 6). The deepest part of the lake (45m) is found at the centre of a basin near its southeastern edge (towards Rossinver). A large proportion of the lake (46%) is less than 5m deep with extensive shallow areas around the lake’s islands and shores (Girvan & Foy, 2003).

Lough Melvin is a mesotrophic (low to medium nutrient status) lake that is characterised by diverse plant and animal communities. It is considered to be in a relatively pristine state and is fringed by emergent swamp and fen habitat.

A number of wooded and semi-wooded islands are located on Lough Melvin. These are: Inisheher, Inishmean, Inishtemple, and Inishkeen in County Leitrim and Gorminish, Sally, Greagh and Bilberry islands in County Fermanagh. Rosskit Island on the northeastern shore of the lake is actually connected to the mainland via a narrow stretch of land.

The outflowing River Drowes at Lareen Bay in the north-west of the lake drains a small part of County Donegal meandering for approximately 7km, before discharging into Donegal bay north of Tullaghan in County Leitrim. The Lough Melvin catchment is part of the Drowes catchment but as the focus of this study is the lake itself only the Lough Melvin catchment (and not the Drowes catchment) has been included.
2.1.1 Climate

The climate of Ireland is influenced strongly by its proximity to the Atlantic Ocean and the warming effects of the Gulf Stream. The country experiences a temperate climate with mild wet winters and cool wet summers. Highest temperatures occur in the summer months of July and August with rainfall generally greatest in the cooler months of December and January.

The regional climate of the northwest is characterised by high rainfall and frequent high winds. Lough Melvin’s local climate is influenced by its proximity to the coast and the Atlantic Ocean (within 5km) and its location between two major mountain ranges, the Ben Bulben range, County Sligo and the Blue Stack Mountains, County Donegal (Dúchas, 2002).

Average annual rainfall for the region between 1990 and 2006, was 1200mm. Areas with higher elevation and greater exposure are prone to higher rainfall and may receive between 1400mm and 1600mm per year (Gardner, 1986). The sunniest months occur from May to July. The year 2007 had the highest average sunshine hours since 1990, with a daily average in May of 8.4 hours.

Temperatures around the lake rarely fall below freezing due to its proximity to the coast (Gardner, 1986). Similarly, higher temperatures are modified by the prevailing winds, with maximum “air” temperatures averaging at 14°C.

Lough Melvin is particularly windswept and exposed (Girvan & Foy, 2003). Wind speeds tend to be highest over the winter period (November to March) with prevailing winds blowing from a southwesterly direction (Gardner, 1986).
Background

Note: Rainfall, temperature and sunshine data are based on information from the Ballyshannon climatological and synoptic station.

2.1.2 Geology

The geology of the Lough Melvin catchment is dominated by Middle Carboniferous Limestone, with portions of Upper Avonian Shales & Sandstones and Lower Carboniferous Limestone. The Dartry Limestone formation underlies over 26% of the catchment area, predominately in the south and eastern parts of the catchment (see Figure 7). The Glenade Sandstone formation in the upper eastern reaches of the catchment underlies 23% of the catchment and the Mullaghmore sandstone formation dominates the northern and western shores.

Figure 7: Bedrock Geology

The geology of the catchment has a significant effect on the water chemistry of the waterways and rivers draining those areas. Limestone rock erodes more easily and will increase the pH and conductivity of the water, tending to increase its productivity (Crowley, 2003). Rivers draining large areas of limestone include the Glenaniff and Ballagh Rivers.
2.1.3 Soils

The soils within the Lough Melvin catchment are dominated by gleys, peats and peaty gleys (see Table 2 and Figure 8.

Table 2: Area and % cover of soil types

<table>
<thead>
<tr>
<th>Soil Types</th>
<th>Hectares</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gley</td>
<td>10553</td>
<td>47</td>
</tr>
<tr>
<td>Peat</td>
<td>8951</td>
<td>40</td>
</tr>
<tr>
<td>Complex</td>
<td>1181</td>
<td>5</td>
</tr>
<tr>
<td>Ranker</td>
<td>1040</td>
<td>5</td>
</tr>
<tr>
<td>Water</td>
<td>206</td>
<td>1</td>
</tr>
<tr>
<td>Brown Podzolic</td>
<td>199</td>
<td>1</td>
</tr>
<tr>
<td>Brown Earth</td>
<td>160</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Alluvium</td>
<td>148</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
<td>&lt;1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22463 ha</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Notes:

- “Other” constitutes urban (Garrison), disturbed (e.g. dumps) and soils that were not surveyed
- Complex soils are a combinations of different soil types e.g. in the catchment this is usually a combination of Peats and Gleys.
- Rankers are Soils that have a depth of less than 40cm usually on top of bedrock.

![Figure 8: Distribution of soil types in the Lough Melvin catchment](Image)
Background

Gleys and peats account for nearly 90% of the soils within the catchment. Gleyed soils are dominant occupying nearly half (10,553 ha) of the area and develop under waterlogging conditions with poor drainage and weak physical structure. They become sticky when wet and so are difficult to cultivate due to their poor drainage and particularly susceptible to poaching (Cruickshank, 1997).

The second most common soil type is peat, covering an area of nearly 9000 ha. Peat soils have high organic matter content and occur as either blanket peat or basin peat. Raised bog peat (Allen Series) is found at the eastern end of the Lough Melvin catchment and may exceed 10m in depth in places, unless it has been harvested for turf. Blanket peat is generally only 1-2m deep and is common in the higher regions of the catchment on the Arroo and Dough/Thur Mountains.

The shoreline areas of Lough Melvin comprise sandy materials (mainly medium to coarse grained sediments), muddy (common in eastern end of lake), rocky (loose rock and bedrock) and peaty substrates primarily at the eastern end of the lake (Dúchas, 2002).

Further information on the catchment soil types and their impact on the productivity of the land is provided in Soil suitability for agriculture Section 7.3.2.

2.1.4 Hydrology

Flow monitoring of the outflow from Lough Melvin at Lareen has been undertaken by the Office of Public Works since 1975. While there are some gaps in the data, notably for 1993 and currently for 2003 and 2004, the record is sufficiently long to draw general conclusions on the throughput of water in the lake. Using the hydrological year, which by convention begins in October, the mean annual flow since October 1975 to September 2007 was $248 \times 10^6$ m$^3$ yr$^{-1}$. The time series shows that inter-annual variation between years is relatively small so that the annual flow in the driest year (1976/77) was only 27% below the average while the wettest year (1992/93) was 28% above the average runoff (Figure 9). Given that the quantity of water leaving the lake in an average year of $248 \times 10^6$m$^3$ is very close to the computed volume of water in the lake of $245 \times 10^6$m$^3$, the water retention time is almost exactly 1 year (0.99 years).

![Figure 9: Time series of annual flows leaving Lough Melvin at Lareen. Flows are plotted on the basis of hydrological year record that begins in October 1975.](image-url)
The combined area of the catchment plus lake is 247 km², or $247 \times 10^6$ m², so, given the mean volume of water leaving the lake is $248 \times 10^6$ m³ yr⁻¹, average runoff is almost identical to a value of unity, or 1 m yr⁻¹. This rate of runoff is high, reflecting the high rainfall of the area, and is approximately 70% higher than the more inland catchments of Lough Erne and Lough Neagh. Flow from Lough Melvin follows a distinct annual cycle, with July having the lowest average flow of 2.6 m³ sec⁻¹ and January the highest 13 m³ sec⁻¹ (Figure 10). The plot of the annual flow cycle includes the ranges of maximum and minimum flows for each month and shows that the summer months are by no means reliable in terms of low runoff as even during mid-summer it was possible to encounter monthly flows which were greater than the average flow rate for the year as a whole (78 m³ sec⁻¹).

![Figure 10: Annual cycle of mean monthly flows leaving Lough Melvin at Lareen. The errors denote the highest and lowest flows for the period 2005 to 2007.](image)

The hydrology of the Lough Melvin catchment is a product of its specific climate, geology and soils. There are over 30 streams that enter Lough Melvin from the surrounding catchment in Leitrim and Fermanagh (see Figure 11). The southern part of the catchment drains mountains within the Darty Mountain range (Arroo and Dough/Thur mountains) and is characterised by steep slopes with many small flashy streams draining small sub-catchments. The two main tributaries in this area of the catchment are the Ballagh River and the Glenaniff River. Fowley’s Falls, a series of cascades on Glenaniff River are a well known feature. The southeastern and northeastern parts of the Lough Melvin catchment are less steep and dotted with small lakes that feed into large river systems. The two main tributaries in this area are the County River, which forms the Leitrim/Fermanagh border, and the Roogagh River.

There are 48 lakes within the Lough Melvin catchment ranging in size from over 30 ha (Lattone Lough) to 0.02 ha. The total combined area of lakes (excluding Lough Melvin) equates to 121 ha or less than 1% of the catchment, with Lough Melvin accounting for approximately 9%. 
Background

Figure 11: Main river systems within the Lough Melvin catchment

Plate 2: Lake in Big Dog Forest in the Roogagh River catchment

Plate 3: Glenaniff River

Legend

- Blue: Lakes
- Black: Rivers
- Green: Melvin Sub-catchments

Disclaimer
This information product has been derived from the best quality data available at the time of its development. The NRFB accepts no responsibility for the accuracy of this product.
Details of the main tributaries flowing into Lough Melvin are presented in Table 3. The four largest rivers (Roogagh, County, Glenaniff and Ballagh Rivers) drain 70% of the total catchment area. The remaining 30% of the catchment consists of smaller streams with 18% being either directly drained or drained via unnamed streams.

Table 3: Subcatchments and areas in the Lough Melvin catchment

<table>
<thead>
<tr>
<th>Sub-Catchment</th>
<th>Area (ha)</th>
<th>% of total catchment area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roogagh River</td>
<td>6016</td>
<td>27</td>
</tr>
<tr>
<td>County River</td>
<td>5523</td>
<td>25</td>
</tr>
<tr>
<td>Glenaniff River</td>
<td>2724</td>
<td>12</td>
</tr>
<tr>
<td>Ballagh River</td>
<td>1380</td>
<td>6</td>
</tr>
<tr>
<td>Tullymore River</td>
<td>905</td>
<td>4</td>
</tr>
<tr>
<td>Clancy’s River</td>
<td>773</td>
<td>3</td>
</tr>
<tr>
<td>Kinlough River</td>
<td>400</td>
<td>2</td>
</tr>
<tr>
<td>Derrynaseer River</td>
<td>390</td>
<td>2</td>
</tr>
<tr>
<td>Haran’s River</td>
<td>211</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>4143</td>
<td>18</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22463</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Until 2002, there was no hydrometric monitoring on any of the inflowing rivers to Lough Melvin. Since then, the Rivers Agency of the Department of Agriculture and Rural Development (DARD) installed level recorders on the two largest rivers (Roogagh and County) while, in 2006, Leitrim County Council initiated flow monitoring on the Glenaniff, Ballagh and Clancy’s Rivers. Thus, flow records are now available for 70% of the drainage area to Lough Melvin. The flow records from the inflowing rivers are compared in Table 4 for the hydrometric year October 2006 to September 2007. In terms of the long-term record of flows leaving the lake presented in Figure 9, flows over this hydrometric year were 15% above average.

Table 4: Hydrological characteristics of the Roogagh, County, Ballagh, Glenaniff and Clancy’s Rivers for the hydrological year October 2006 to September 2007.

<table>
<thead>
<tr>
<th>River</th>
<th>Roogagh</th>
<th>County</th>
<th>Ballagh</th>
<th>Glenaniff</th>
<th>Clancy’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (km²)</td>
<td>60.0</td>
<td>55.3</td>
<td>13.8</td>
<td>27.2</td>
<td>77</td>
</tr>
<tr>
<td>Annual runoff (mm yr⁻¹)</td>
<td>1142</td>
<td>1192</td>
<td>1345</td>
<td>1575</td>
<td>1268</td>
</tr>
<tr>
<td>Mean flow (m³ sec⁻¹)</td>
<td>2.17</td>
<td>2.09</td>
<td>0.59</td>
<td>1.36</td>
<td>0.31</td>
</tr>
<tr>
<td>Q₉₅ Low flow (m³ sec⁻¹ km⁻²)</td>
<td>0.002</td>
<td>0.003</td>
<td>0.003</td>
<td>0.007</td>
<td>0.005</td>
</tr>
<tr>
<td>Q₅ High flow (m³ sec⁻¹ km⁻²)</td>
<td>0.137</td>
<td>0.121</td>
<td>0.145</td>
<td>0.159</td>
<td>0.158</td>
</tr>
<tr>
<td>Q₉₅/Q₅ ratio</td>
<td>66</td>
<td>46</td>
<td>43</td>
<td>24</td>
<td>32</td>
</tr>
</tbody>
</table>

Note: The Q₉₅ and Q₅ statistics are indices of low and high flows respectively. The Q₉₅ is the flow that is exceeded for 95% of the time record while the Q₅ is exceeded for 5% of the time. The distribution was undertaken using daily flows over the period October 2006 to September 2007.
Background

There is an obvious gradient of higher runoff rates from three streams to the south-west of the catchment (Ballagh, Glenaniff and Clancy’s Rivers) in comparison to runoff from the Roogagh and County Rivers, which drain the east portion of the catchment. However, annual runoff rates for all of the rivers were high (>1100 mm yr⁻¹) and the range between four of the rivers was less than 200 mm yr⁻¹. Runoff from the remaining river, the Glenaniff River was 1575 mm yr⁻¹ which, when evapo-transpiration of at least 300 mm yr⁻¹ is allowed for, suggests an annual rainfall in this catchment of close to 2000 mm over the period of measurement.

When normalised to catchment area, high flows as estimated by the $Q_{5}$ flow statistic were remarkably similar between rivers. Low flows as estimated by the $Q_{95}$ statistic varied rather more between streams. This statistic gives an indication of groundwater contribution to flows and the normalised rate was highest for the Glenaniff River. Thus, although this river drained approximately 50% of the area, in comparison to the two largest rivers, Roogagh and County, it had the highest non-normalised $Q_{95}$ flow (0.18 m³ sec⁻¹ vs 0.15 m³ sec⁻¹ and 0.12 m³ sec⁻¹ for the County and Roogagh Rivers respectively). The $Q_{95}:Q_{5}$ ratio is an indicator of flashiness and the ratios for the Roogagh, County and Ballagh Rivers of over 40 are exceptionally high (Wilcox, 1997). None of the rivers had, what could be considered a low $Q_{95}:Q_{5}$ ratios of less than 10, indicating that seasonal groundwater transfers are unimportant in determining flows over the year. Rather their similarity in terms of high $Q_{5}$ rates indicate that in all catchments rainfall is rapidly and efficiently transferred into runoff and hence flow. This in turn is consistent with the water logged nature of most soils and their inherently low infiltration rates. Such soils are therefore exceptionally prone to runoff and the associated losses of nutrients applied to the soil surface either in manures or chemical fertilisers.

The hydrological characteristics of the Lough Melvin catchment (high rainfall and runoff potential, extensiveness of the drainage network and steep slopes) make it particularly prone to high export rates. This means that mobile nutrients and pollutants can be transported rapidly and effectively to Lough Melvin when for example manure or chemical fertiliser applications are shortly followed by sufficient rainfall to cause runoff.
2.1.5 Catchment Land Cover Type

The CORINE (Co-Ordination of INformation on the Environment) Land Cover provides standardised inventory of land cover types within the Lough Melvin catchment. CORINE is derived from satellite imagery and uses a common methodology throughout Europe to give a pan-European inventory of land cover. It consists of 44 classes with a minimum mapping unit of 25 ha, at the 1:100,000 scale. This size limit leads to some generalisation of land cover types as any small pockets of non-dominant land cover types within each 25 ha square will be excluded.

As shown in Figure 12, the predominant land cover type in the catchment is pasture, occupying 19% of the area or 4647 ha, followed by agricultural land, peat bogs and natural grassland (each occupying 16%). Peat bogs are common in upland areas; with pasture and woodland scrub dominating areas of the lakeshore.

Table 5: Areas of Land Cover

<table>
<thead>
<tr>
<th>Land Cover Type</th>
<th>Hectares</th>
<th>Percentage %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pastures</td>
<td>4647</td>
<td>19</td>
</tr>
<tr>
<td>Land principally occupied by agriculture with areas of natural vegetation</td>
<td>3868</td>
<td>16</td>
</tr>
<tr>
<td>Peat bogs</td>
<td>3953</td>
<td>16</td>
</tr>
<tr>
<td>Natural grassland</td>
<td>3843</td>
<td>16</td>
</tr>
<tr>
<td>Coniferous forest</td>
<td>3315</td>
<td>13</td>
</tr>
<tr>
<td>Water bodies (includes Lough Melvin)</td>
<td>2299</td>
<td>9</td>
</tr>
<tr>
<td>Transitional woodland Scrub</td>
<td>1397</td>
<td>6</td>
</tr>
<tr>
<td>Moors and heaths</td>
<td>1268</td>
<td>5</td>
</tr>
<tr>
<td>Broad Leaved forest</td>
<td>50</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Discontinuous urban fabric</td>
<td>30</td>
<td>&lt;1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>24670</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
Background

Land use in the Lough Melvin Catchment

The usage of land within the Lough Melvin catchment is related (indirectly and directly) to the type of land cover. The three primary landuses that are relevant for this study (in terms of the eutrophication of Lough Melvin) are agriculture, forestry and housing. The types and extent of these activities (in particular forestry and agriculture) are directly influenced by the climate, relief, hydrology and soils of the area. Soil type is particularly influential as soils are typically poorly draining and infertile.

Agriculture

Agricultural activity within the Lough Melvin catchment tends to be extensive and restricted to the grazing of beef cows and sheep, with mountainous areas only supporting extensive sheep grazing. Historically, with EU agricultural subsidies paid per head of livestock, overgrazing was widespread on commonage areas. Peat soils in these upland areas are particularly prone to erosion as particles are easily washed away during high rainfall events. This may be contributing excessively to the peat stain colour of the lake water. The impacts of overgrazing (landslip and soil erosion) are evident in the upland areas of the catchment, particularly on Arroo Mountain (Crowley, 2003).

The short growing season and the vulnerability of the gley soils to poaching mean that it is common practice for cattle to be housed for up to 7 months over the winter period with grass silage used as primary winter forage. The environmental impacts relating to these and other farming practices within the catchment are discussed in Section 7, Agriculture.
**Forestry**

Land that is owned either privately or publicly and managed for forestry, or by forestry organisations such as Coillte or the Forest Service NI, occupies 25% (5657 ha) of the area within the Lough Melvin catchment. State forestry is particularly important in NI, where it represents 30% (3118 ha) of the total area of land within the County Fermanagh portion of the catchment, compared to the 13% (1590 ha) owned by Coillte in the County Leitrim portion of the catchment.

Private forestry in County Leitrim accounts for 428 ha while in County Fermanagh it covers an area of 293 ha. With the decline of farming in the region and incentives for diversification, including woodland schemes, the importance of private forestry is likely to increase (Mellon & Woodrow, 2008).

Much of the planting within the Lough Melvin catchment was undertaken in the 1960s and 1970s in upland areas, particularly in the County and Roogagh River sub-catchments. Most forests are coniferous plantations, primarily consisting of Sitka spruce (*Picea sitchensis*) and Lodgepole pine (*Pinus contorta*). However, farm diversification schemes may focus more on planting broadleaf trees or potentially short-rotation coppice as a source of renewable energy.

Forestry and its potential impacts on water quality are discussed in detail in Forestry Section 8.

**Housing**

There are only three villages within the catchment; Kinlough and Kiltyclogher in County Leitrim and Garrison on the shore of Lough Melvin, in County Fermanagh. Up to the 1990s, populations in the area were in general decline (Gardner, 1986). Traditionally considered one of the poorer regions in the west of Ireland, the surrounding catchment area experienced chronic unemployment and emigration, leading eventually to land abandonment.

Over the past decade, this downward trend has been reversed. House builds within the catchment have increased significantly in line with the housing boom throughout the county. Kinlough in particular has seen a large increase in housing developments with over a doubling in population between 2002 and 2006. This is most likely directly related to the areas Section 23 status (tax designations) which was introduced to encourage building in depopulated regions. In addition to the housing developments within urban areas, construction of single houses has occurred along the foreshore of Lough Melvin and along its tributaries particularly in the County Leitrim part of the catchment. The impacts of housing on the ecology of the lake (in terms of wastewater) are discussed further in Section 9, Housing-Wastewater.
2 Background
Lough Melvin’s Significance
Lough Melvin’s Significance

3.1 Assets and Values

Natural features such as rivers, lakes and ecosystems are valued as assets when they provide tangible or intangible benefits. Tangible benefits may include the use of the resource as a drinking water supply and a fishery, while intangible benefits may be a natural resource’s aesthetic properties, ecological value or scientific interest. A water resource can have a high ecological or environmental value for a variety of reasons including the presence of a rare plant or animal or the provision of an uncommon habitat that enables breeding and feeding of an assemblage of species.

Broad criteria on which the ecological value of a resource can be assessed include:

- Rarity - having rare and threatened species or rare genetic strains of species
- Naturalness - how close the resource is to its natural state
- Diversity - supports highly diverse plant and animal communities
- Importance to other systems - providing breeding or feeding areas for rare species.

Source: Department of Natural Resources and Environment (2002).

As shown below, all of the above criteria are applicable to Lough Melvin and its catchment, demonstrating, if in a somewhat simplistic way, the ecological value and significance of the area.

**Rarity:** Lough Melvin is naturally oligo-mesotrophic with low to medium nutrient levels supporting a diverse range of plants and associated animal life. Lakes of this type are considered of significant environmental and conservation importance having become increasingly rare in Ireland and the UK due to widespread human induced changes within their catchments.

**Naturalness:** Lough Melvin is one of the few remaining examples of a natural post-glacial salmonid lake in northwestern Europe (Ferguson, 1986).

**Diversity:** Lough Melvin supports a rich diversity of plant and animal species (salmon, char, trout, otter and aquatic plants).

**Importance to other systems:** Lough Melvin supports the rare Arctic (Melvin) char, indigenous sonaghan, gillaroo, ferox trout and the otter. The catchment is also an important spring salmon habitat.

These ecological assets and values provide for a wealth of “spin-off” tangible and intangible environmental, social and economic benefits e.g. tourism, drinking water supply and ecological interest. In turn, the economic and social benefits depend on and consequently will impact on, the ecological integrity and health of the system.
3.2 Formal Recognition of Value

Identifying and protecting sites of environmental value is one way that the ecological value of natural resources such as Lough Melvin can be recognised. Some sites, representing the best examples of natural and semi-natural ecosystems, are of such significance that they merit formal designation under national and EU legislation and require additional protection and management. In this regard, Lough Melvin and areas within its catchment are formally recognised for their environmental values under a number of different designations. These are described below and shown in Figure 13.

Figure 13: Designated Areas of Environmental Significance

3.2.1 Special Areas of Conservation

Three areas within the Lough Melvin catchment have been designated as Special Areas of Conservation (or candidate SACs). These are: the West Fermanagh Scarplands (UK0030300); Arroo Mountain (IE001403) and; Lough Melvin itself (NI and RoI). Special Areas of Conservation (SACs) are designated under the 1992 EU Habitats Directive (92/43/EEC) and are considered to be of European importance in terms of their habitat and/or plant or animal species. Those habitats and species designated as SACs are required to be protected under EU law, as part of a global biodiversity network called Natura 2000.

Lough Melvin was selected for designation as a Special Area of Conservation primarily based on its status as a mesotrophic water body and the presence of Molinia meadows (NI designation only). It is considered to be an “outstanding example” in a European context of an “oligotrophic to...
Lough Melvin’s Significance

mesotrophic standing water(s) with vegetation of the *Littorelletea uniflorae* and/or of the *Isoetanojuncetea* and of a site representing *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (Annex 1 Habitats- EU Habitats Directive). Other qualifying features include the presence of old sessile oak woodlands (NI designation only), otter (RoI only) and Atlantic salmon.

The cSAC site (000428) in RoI covers an area of approximately 1840 ha and includes the lake, the River Drowes and its floodplain, and lands generally within 50m of the lake. In some areas, marginal habitats that are considered to have their own ecological interest such as wet grasslands and semi-natural woodlands, were included e.g. area around Gubanumbera Point. The County, Glenaniff and Ballagh Rivers and lands within 30m of the river banks, are also part of the cSAC because of their importance as spawning areas.

The NI SAC (UK0030047) site includes the lake/open water, the islands and adjacent semi-natural habitats such as woodland, species rich grassland and natural transition vegetation such as scrub and heath. It covers an area of just over 516 ha which comprises approximately 410 ha of open water, 26 ha of *Molinia* meadows and 28 ha of oak woods.

Arroo Mountain, part of the Ben Bulben range on the southeastern border of the catchment, has been designated as a candidate SAC for the priority habitats of active blanket bog, and petrifying springs with Tufa formation (*Cratoneurion*), and other habitats: Northern Atlantic wet heaths with *Erica Tetralix* and; calcareous rocky slopes with chasmophytic vegetation (NPWS, pers. comm., 2008). The mountain habitat consisting of blanket bog, heathland, upland grassland with wooded ravines and limestone gorges, supports rich and rare alpine and arctic alpine plant species. Species present include the: Mossy Saxifrage (*Saxifraga hypnoides*) which is occasional in the north and west but very rare elsewhere; Rue-leaved Saxifrage (*Saxifraga tridactylites*), frequent in the south and west but local elsewhere; Mountain Avens (*Diyas octopetala*), locally abundant in the north and west but very rare in mountains of the north; and Mountain Sorrel (*Oxyria digyna*). Benbulben Mountain to the south and Arroo Mountain are considered to be the most botanically rich mountains in Ireland (Minogue, 2002; Dúchas, 1999; Gardner, 1986). Part of Arroo Mountain is also designated as a Special Protection Area (SPA) for the Red-billed Chough (Fiona Farrell, NPWS, pers. comm., 2008).

The Western Fermanagh Scarplands on the eastern edge of the catchment was designated as a candidate SAC because it is one of most extensive areas of blue moor-grass (*Sesleria albicans*) grassland in NI and is also one of only two sites representing *Molinia* meadows in NI (the other being the Lough Melvin SAC). Other priority features include the; *Tilio-Acerion* forests of slopes, screes and ravines and; limestone pavements. Qualifying features but not primary reasons for designation include the: presence of natural eutrophic lakes; Northern Atlantic wet heaths; blanket bogs; petrifying springs with tufa formation (*Cratoneurion*) and alkaline fens (source: www.ehsni.gov.uk).

### 3.2.2 Salmonid Waters- Protected Area

Lough Melvin was designated in NI as a salmonid water under the Freshwater Fish Directive (FFD) in 2003, giving it Protected Area status and requiring it to meet certain water quality and parameter standards. The designation enforces its registration under the Water Framework Directive and the implementation of a stricter monitoring regime. The WFD will essentially supersede the FFD in 2013 (Mellon & Woodrow, 2008). The County and Roogagh Rivers were also designated as salmonid rivers under the FFD.
3.2.3 Areas of Special Scientific Interest

Areas of Special Scientific Interest (ASSI) are applicable only to the NI portion of the catchment and are areas of land that have been identified as being of the highest degree of conservation value.

Lough Melvin was designated as an Area of Special Scientific Interest (ASSI) in 1997 prior to its designation as a candidate SAC in 2005 (EHS, 2007b). The ASSI includes the open waters as well as associated habitats including swamp communities, boulder and rock shore, fen, woodland and species-rich grassland. Primary selection features included its unique post-glacial fish community, five rare and notable plant species and species rich grassland.

Other areas designated as ASSI's within the catchment are Glennasheevar, Lough Aleater and Tullysranadeega. Lough Aleater (designated in 2005) is an oligotrophic upland lake that provides a range of habitats for a diversity of flora and fauna. It has a significantly diverse macrophyte flora (EHS, 2007b). Its unique aquatic flora and fauna are dependent on the low levels of nutrients.

Tullysranadeega ASSI represents one of the largest areas of traditionally managed fields in NI and hosts a diversity of grassland types. In addition, it is the only known site for the nationally rare Melancholy Thistle (*Cirsium heterophyllum*) in Ireland.

Glennasheevar ASSI is a large area of intact oceanic blanket bog with associated habitats of wet and dry heath communities. Notable species include: the oblong-leaved sundew (*Drosera intermedia*); the hummock-forming *Sphagnum fuscum* and; species of Lepidoptera (source: www.ehsni.gov.uk).

3.2.4 Nature Reserve

Nature reserves are areas reserved and managed for conservation because of their importance for flora and fauna, or features of geological or other special interest. Lough Naman Bog in the northeastern part of the catchment has been designated as a nature reserve in NI due to its relatively undisturbed state. Golden Plover, dunlin and red grouse used to breed in this site but have disappeared, probably as a result of changing land use (source: www.ehsni.gov.uk).

3.2.5 Natural Heritage Areas

Natural Heritage Areas (NHA) are areas nationally designated for the protection of wildlife under the Wildlife Acts 1976 & 2000 (RoI). NHAs are considered important for the habitats present or for the species of plants and animals that they support.

Lough Melvin, Anroo Mountain (001403), Aghavoghil Bog (002430) and Kinlough Wood (001415) are proposed for designation as Natural Heritage Area’s (NHA). Dough and Thur Mountains (002384) have been designated as an NHA. The Lough Melvin and Anroo Mountain designations overlap with SAC designation (which takes precedence).

The Dough/Thur Mountains NHA and Aghavogil Bog NHA represent areas of upland blanket bog, which has becoming increasingly scarce in Ireland and Europe. These areas support a diversity of butterfly, bird, and animal and plant species. Kinlough Wood is a wet woodland of planted origin with species of Alder (*Alnus glutinosa*), Ash (*Fraxinus excelsior*), Birch (*Betula pubescens*), Willow (*Salix sp*) and Hazel (*Corylus avellana*) (NPWS, 2004; NPWS, 2003).
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3.2.6 Other

The north shore of Lough Melvin within County Leitrim and the southern part of the catchment around the Arroo Mountain area are classed as Area’s of Outstanding Natural Beauty (AONB). These areas are considered to be representative of the highest quality landscapes within County Leitrim. Leitrim County Council has committed to their protection and limits development in these areas (Leitrim County Council, 2002).

Lough Melvin, the Glenaniff River and environs and the Dough and Thur are classified as Areas of High Visual Amenity. These areas although less sensitive than AONB’s are highly scenic and again development is controlled. In addition, a number of areas around Lough Melvin are named as areas with Protected Views and Prospects. These include views from Aghavogil Bog towards Lough Melvin and the view of Lough Melvin from Loughross Bar, near Rossinver (Leitrim County Council, 2002).

3.3 Fauna

Lough Melvin and its catchment support a rich diversity of animal species, some of which are indigenous, others are remnant populations of their type and no longer survive elsewhere. The unique assemblages of fish species are perhaps the most well known and are discussed in Section 3.4.

The European otter *Lutra lutra* can be found in riparian and coastal habitats and the island of Ireland supports one of the most important otter populations remaining in Western Europe (Whilde, 1993). The presence of otter is an indication of a healthy river system with unpolluted waters, good fish stocks and bankside vegetation. The main prey of the species is aquatic or semi-aquatic and includes frogs, eels and salmonids (Bailey & Rochford, 2006).

The otter is listed as an Annex II species under the EU Habitats Directive, requiring strict protection as a species of European interest. Species Action Plans have been produced for the conservation of the species (EHS, 2007c and NPWS, 2008). The otter is listed in the Irish Red Data Book as vulnerable and fully protected under the Wildlife Acts 1976 and 2000 (Rol) and the (Northern Ireland) Order 1985 and the Conservation Regulations (Northern Ireland) 1995. The distribution of otter in Europe has been significantly reduced and the population in Ireland has declined by nearly 20% since 1982. The country however, still retains a relatively dense population (NPWS, 2008; Magee & McLaughlin, 2007; EHS, 2007c; Bailey & Rochford, 2006).

Otter was one of the qualifying features for Lough Melvin’s designation as an SAC (Rol only). The species has been recorded from the River Drowes and the main inflowing rivers, and are considered likely to be widespread throughout the Lough Melvin catchment (Bailey & Rochford, 2006 in 2004-2005 survey).
Lough Melvin’s Significance

The main threats to the otter are: development along waterways, water pollution, acidification, land drainage, dredging, agricultural intensification and, habitat fragmentation and loss of riparian habitat.

Pine Marten, a listed species under the Berne Convention, Annex V of the EU Habitats Directive, and the Irish Red Data Book, was recorded in recent years on the southern shores of Lough Melvin adjacent to semi-natural woodland (Dúchas, 2002).

Due to the open nature of Lough Melvin, it is not considered a prime habitat for waterbirds. However, moderate numbers do occur and the Greenland White-fronted Goose (*Anser albirostris flavirostris*), a species listed in Annex I of the E.U. Birds Directive, the Berne Convention and Bonn convention, and considered to be internationally important, has occasionally been reported on the lake’s islands (NPWS, 2005; Whilde, 1993). Whooper Swans (*Cygnus cygnus*) also an Annex I species, overwinters on the lake every year and can be found within the River Drowes floodplain and in sheltered bays and inlets (NPWS, 2005). In addition, Dipper (*Cinclus cinclus*), Pochard (*Aythya farina*) and Common scooter (*Melanitta nigra*), all Irish Red Data Book species, have been recorded (Dúchas, 2002).

Daubenton’s Bat (*Myotis daubentonii*) an internationally important species listed in the Irish Red Data Book, and Whiskered Bat (*Myotis mystacinus*) listed as threatened, are also found within the Lough Melvin area (Dúchas, 2002). These bats utilise the open water as well as adjacent woodland and scrubland (Whilde, 1993).

Additional information on the faunal records and species can be found in the Conservation Plan (draft) for the Lough Melvin cSAC (Dúchas, 2002) or on the NPWS or EHS websites (www.npws.ie; www.ehsni.gov.uk and; www.jncc.gov.uk ). However, it is worth noting that there is a general lack of (in particular geographically referenced) flora and fauna records, which has been a limiting factor in preparing information for the CMP. It is important that accurate records of species are kept for the catchment and that these are made available in suitable formats (i.e. location data recorded for GIS) for the management of the lake and catchment into the future.
3.4 Fish

Lough Melvin is perhaps best known for its unique and internationally important assemblage of fish species, most of which are indigenous to the lake, some of which represent the only remaining populations of their type. The salmonid fish community in Lough Melvin originates from the end of the last Ice Age and its continuation is an indication of the lake’s relatively pristine and undisturbed state (Ferguson, 2004; Ferguson, 1986).

Lough Melvin supports a high diversity of fish species including Arctic char (Salvelinus alpinus), Atlantic salmon (Salmo salar) and three distinct sub-species of trout: gillaroo (Salmo stomachius), sonaghan (Salmo nigrinennis), and ferox (Salmo ferox). In addition, three-spined stickleback (Gasterosteus aculeatus), eel (Anguilla anguilla) and nine-spined stickleback (Pungitius pungitius) are present and three non-native species: perch (Perca fluviatilis), rudd (Scardinius erythrophthalmus) and minnow (Phoxinus phoxinus) also occur (Kelly & Connor, 2007; Ferguson & Taggart, 1991).

3.4.1 Arctic Char

Arctic char (Salvelinus alpinus) are the most northerly distributed of freshwater fish and are considered likely to have been the first to recolonise Ireland after the last Ice Age over 13,000 years ago (Igoe et al., 2003). Having adapted to the climatic extremes of the Arctic, char are near the southern end of their range in Ireland and are most commonly found in deep, cold, glacial lakes. In Ireland, they are the most sensitive of the salmonids being particularly susceptible to changes in water quality, flourishing only in lakes with pristine waters. Once quite widespread in Ireland, with over seventy populations, approximately one third (24) of these have become extinct (Igoe et al., 2003).

In NI, char became extinct in Lough Neagh around 1844 and in Lough Erne in the early twentieth century. Currently, char are confined to isolated populations in freshwater lakes that provide suitable conditions (oxygenated water, gravel shores and depth, where other salmonids are present) (Igoe & Hammar, 2004). They are listed as vulnerable in the Irish Red Data Book.

The Arctic char of Lough Melvin were originally designated as a distinct species (Salvelinus grayi) or subspecies of Salvelinus alpinus (S. a. grayi) and there is still debate over whether it qualifies for separate species status. In the Handbook of European Freshwater Fishes, Kottelat & Frehoff (2007) list the char population within Lough Melvin as a separate species known as Melvin char. Further genetic study is considered to be required to determine its distinctiveness from other European populations. The population in Lough Melvin is identified under the Provisional Red List Assessments as critically endangered- at extremely high risk of extinction in the wild due the fact that it only occurs in one location and the “low numbers of mature individuals” (Kottelat & Frehoff, 2007). In 2004, a revised list of priority species for NI was published that included Arctic char (EHS, 2007a). The catchment of Lough Melvin supports the only two remaining populations of Arctic char in NI. In 2005, a previously unknown population was discovered in Lough Formal, which is a small upland lake in the Roogagh River catchment of Lough Melvin, and it is possible that other populations exist in unpolluted small lakes within the catchment.

The population of Arctic char in Lough Melvin are typically confined to the deeper parts of the lake. They feed predominately in the pelagic zone on zooplankton Daphnia spp, Leptodora kindti, Chaoborus sp. and various chironomid life stages particularly during the summer period. Less is known about their feeding habits in the colder months, however evidence suggests that benthic feeding is dominant (Igoe & Hammar, 2004). Ferguson (1986) noted that the char’s diet in Lough Melvin overlapped considerably with that of the indigenous sonaghan population. Displacement of
char to the pelagic zone in lakes occupied by trout has also been noted by Igoe & Hammar (2004). Spawning occurs from late October to late November in shallow water (>1 m) on clean, walnut sized gravels mixed with larger stones, near the shore where aeration is high and wave action prevents deposition of fine materials on the gravel beds (Whilde, 1993). During the breeding season, the males develop brightly coloured red bellies.

Plate 7: Arctic Char

The introduction of non-native fish can have major impacts on char populations through competition and predation (EHS, 2007a; Igoe et al., 2003). The extinction of the species in some western lakes has been attributed to the introduction of pike. Char are also particularly vulnerable to eutrophication and may be adversely affected by the introduction of the Zebra mussel, which colonise shallow gravel areas normally utilised by the fish for spawning (EHS, 2007).

Having evolved in cold conditions, increasing temperatures due to climate change could have serious impacts on the population of Arctic char in Lough Melvin (EHS, 2007a). Angling of Arctic char is not considered to be a significant threat as they are difficult to catch and angling for the species is rarely undertaken (Igoe et al., 2003).

The population in Lough Melvin was considered of healthy status in 2001 (Igoe & Hammar, 2004; Igoe et al., 2003). However, as set out in Section 3.4.4, surveys since 2000 have either failed to locate any fish or caught only small numbers.

The main threats to the Arctic char in Lough Melvin are: the introduction of non-native fish, eutrophication, acidification and increasing temperatures that may arise from climate change.
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3.4.2 Melvin Trout

The brown trout *Salmo trutta* is a well known fish in Ireland that is associated with clean, fast flowing rivers and mesotrophic to oligotrophic lakes and reservoirs. Brown trout colonised Ireland at the end of the last Ice Age some 14,000 years ago and have readily adapted to local conditions. Although the brown trout is considered to be a single species, there is a large degree of genetic diversity, which may warrant separate designations (Ferguson, 2004).

In Lough Melvin, there are three genetically distinct types of brown trout: gillaroo; sonaghan and; ferox, which differ in colour, feeding, spawning and behaviour (see Table 6). Kottelat & Frehof (2007) in the *Handbook of European Freshwater Fishes* document the brown trout in Lough Melvin as 3 separate species, and a significant body of work on genetic differentiation has been undertaken by scientists (in particular Professor Andy Ferguson) that has defined the degree of genetic difference between the Melvin trout types.

The differences in the appearance (morphology) of the three Melvin trout are quite marked. Gillaroo (meaning red fellow) are a golden colour with red spots, sonaghan tend to be silvery or light brown with black spots while the ferox (meaning ferocious) is most distinguishable by its angular head, which enables it to eat larger prey.

The coexistence of the three Brown trout (sub) species in Lough Melvin is highly unusual in a European context (McKeown, Prodöhl & Ferguson, 2003). In addition, the most populous of the Melvin trout, the sonaghan, is indigenous to the lake. The genetic distinctiveness of each of the trout species is maintained by their reproductive isolation and separate spawning grounds (shown in Figure 14 and in Table 6). Sonaghan spawn in a number of the small inflowing streams whilst gillaroo and ferox spawn only in the Drowes (and Lareen Bay) and Glenaniff rivers respectively (Ferguson, 2004; Ferguson & Taggart, 1991). Spawning occurs on gravel within fast flowing water from October to March, peaking in the winter months of November, December and January. Adult trout “home” back to the stream where they were born and this natal homing instinct maintains the genetic distinctness of populations, even when they feed as adults in the same lake. Of interest, the gillaroo juveniles move upstream from the River Drowes and Lareen Bay to Lough Melvin after spawning unlike most young trout, which travel downstream (Ferguson & Taggart, 1991).
Figure 14: Spawning grounds of the Lough Melvin Trout

Different habitat characteristics are required for the spawning, juvenile and adult stages of the trout’s lifecycle and well-vegetated banks along rivers are very important (Environment Agency & The River Restoration Centre, 2006). River systems of particular importance for the spawning of trout are shown in Figure 14.

The Glenaniff River supports a high density of salmon and trout spawning, providing the only spawning grounds for the ferox trout, which utilise the deeper, lower part of the river. Sonaghan spawn in the upper sections of the Glenaniff River as well as in a number of tributaries that feed into Lough Melvin. The Ballagh and Glenaniff rivers have been found to have a higher density of trout and salmon than the County, Roogagh and Clancy’s tributaries, which emphasised the importance of these tributaries for trout and salmon recruitment within the system (Crowley, 2003). The spawning grounds of the gillaroo are restricted to the outflowing Drowes River and Lareen Bay.

Table 6: Characteristics of the Lough Melvin Trout

<table>
<thead>
<tr>
<th>Trout</th>
<th>Prey</th>
<th>Spawning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sonaghan</td>
<td>Mid water: Daphnia, Cladocera, chironomid pupae, chaoborus</td>
<td>Smaller inflowing rivers eg. Tullymore, Breffni, Clancy’s Rivers</td>
</tr>
<tr>
<td>Gillaroo</td>
<td>Bottom: Molluscs, snails, shrimp</td>
<td>Outflowing Drowes River and Lareen Bay</td>
</tr>
<tr>
<td>Ferox</td>
<td>&gt;3yrs- fish - perch, char, trout</td>
<td>Glenaniff River (deeper section)</td>
</tr>
</tbody>
</table>

Source: Ferguson, 1986
Lough Melvin’s Significance

The presence of brown trout is a good indicator of a healthy lake and river system as they require clean, cold and well-oxygenated waters. Although brown trout are common and widespread in unpolluted rivers and lakes throughout Ireland, the genetically differentiated types within Lough Melvin mean that Melvin populations are unique, but also very susceptible to changing environmental conditions. Although brown trout as a generic species has no conservation listing under the IUCN (International Union for Conservation of Nature) the trout within Melvin are provisionally listed as vulnerable (sonaghan and gillaroo) and data deficient (ferox). Vulnerable species are those that are considered to be facing a high risk of extinction in the wild (Kottelat & Freyhof, 2007).

Having restricted spawning areas, the trout within Lough Melvin are in a delicate balance and very susceptible to environmental change (Ferguson & Taggart, 1991).

The main threats to the trout populations within Lough Melvin are: the introduction of non-native fish and invertebrates (e.g. pike and zebra mussel), eutrophication and the destruction of spawning habitat through land clearance, vegetation removal along riverbanks, and sedimentation of spawning gravels.

3.4.3 Atlantic salmon

Atlantic salmon (Salmo salar) are still relatively abundant in Ireland though commercial exploitation and habitat destruction is believed to have severely impacted on populations. Atlantic salmon (freshwater populations) are considered to be threatened internationally, are listed in Annex II of the EU Habitats Directive and were one of the qualifying features for the designation of Lough Melvin as an SAC.

Salmon require specific conditions within the river environment for spawning. In particular, the presence of small stones and gravel in fast-flowing shallow water is important. These gravels provide protection for the eggs and the newly hatched fish. During the juvenile stages, salmon feed primarily on aquatic insect larvae until they migrate to sea at between one and three years old. They then spend one to four years at sea before returning to the river to spawn (SEPA, 2005).

Lough Melvin and its tributaries support a viable population of salmon and the outflowing River Drowes provides excellent spawning and nursery habitat. It is one of Ireland’s top spring and summer salmon fisheries and is one of few salmon fisheries that remained open for 2008. The spring salmon element is especially important, as the numbers of this multi-sea winter stock have declined greatly throughout Ireland. Adult salmon return to Lough Melvin from the Atlantic Ocean from January when there is a good run of spring salmon through to April/May with some summer and autumn fish. The main grilse run starts around the middle of July peaking around August.

The main threats to the Atlantic salmon population in Lough Melvin are similar to those impacting on the other salmonid species i.e. the introduction of non-native species, eutrophication and the destruction of spawning habitat through land clearance, vegetation removal along river banks, and sedimentation of spawning gravels.
3.4.4 Status of fish populations

The fish stocks and/or fish species within Lough Melvin have been surveyed on a number of occasions (e.g. 1986 (O’Grady), 1993 (CFB), 2001 (CFB) and 2005 (CFB)).

Lough Melvin recorded the highest mean biomass of trout in lakes surveyed in the northern region in 2005 and also was shown to have high growth rates. Seven species of fish were recorded, five of which were native, the others being rudd, rudd-roach hybrid and perch (Kelly & Connor, 2007).

In 2001, twelve char were caught during a survey of Lough Melvin. In 2003 and 2004, the Department of Culture, Arts and Leisure attempted to catch mature char from Lough Melvin to produce juvenile stock as an angling initiative but were unsuccessful (J Kane, DCAL, pers. comm., 2007). However, in June 2005, three Arctic char were caught. In 2007, the NRFB attempted to net char but were unsuccessful.

Further information on the status of fish populations can be found in “A Survey of the Fish Populations in 46 lakes in the Northern Regional Fisheries Board, June to September 2005 and 2006” undertaken by the Central Fisheries Board (as part of the NS Share Fish in Lakes project) which is currently awaiting finalisation.

3.5 Habitats and Flora

Mesotrophic lakes such as Lough Melvin have potentially the highest macrophyte diversity of any lake type and contain a higher proportion of nationally scarce and rare aquatic plants. They have become increasingly rare in Western Europe because of nutrient inputs from anthropogenic sources and landuse changes within catchments.

Lough Melvin is considered to be the least disturbed of the large lakes within NI, supporting macrophyte flora typical of mesotrophic lakes with excellent water quality (Joint Nature Conservation Committee JNCC, 2007). Species include quillwort (Isoetes lacustris), shoreweed (Littorella uniflora), water lobelia (Lobelia dortmanna), alternate water-milfoil (Myriophyllum alterniflorum) and a variety of pondweeds, including various-leaved pondweed (Potamogeton gramineus), perfoliate pondweed (P. perfoliatus) and bright-leaved pondweed (P. x nitens) (NPWS, 2005). Slender-leaved pondweed (Potamogeton filiformis) also occurs in Lough Melvin and has a restricted distribution within the UK (Magee & McLaughlin, 2007). Swamp vegetation is sparse, generally only occurring in the sheltered bay areas. Species include Reeds (Phragmites australis), Common Spike-rush (Eleocharis palustris) and Common Club-rush (Scirpus lacustris) (NPWS, 2005).

Apart from the aquatic freshwater environment of the lake and tributaries, there are a number of terrestrial habitats within the Lough Melvin catchment that support nationally and internationally significant habitat types (and species) such as peat bogs, nutrient poor and species rich grasslands, hay meadows, oak woodlands and natural scrubland.

The Lough Melvin SAC (which incorporates Garvos ASSI and Lough Melvin ASSI) and West Fermanagh Scarplands SAC are the only representative sites of Molinia meadow (Annex 1 listed habitat) remaining in NI and are considered to be the best representations of this habitat type within the UK. Diverse examples of (purple moor-grass) Molinia caerulea – Cirsium dissectum- fen meadows, ranging from Molinia-dominated swards with black bog-rush (Schoenus nigricans) to very herb-rich swards managed as hay meadows, are described. Molinia meadows are located primarily on moist, base rich peat and peaty gley soils with fluctuating water tables. Often forming mosaics with dry grassland, heath and scrub, the habitat is known for being species rich with purple moor-grass
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and a variety of rushes, sedges and tall herbs (Magee & McLaughlin, 2007). Blue-eyed grass (Sisyrinchium bermudiana) is associated with this habitat type. In RoI, seventeen SAC’s contain the habitat Molinia meadows (Patrick McGurn, DARD, pers. comm., 2007).

The Tullysranadeega ASSI within the catchment represents one of the most extensive concentrations of traditionally managed fields in NI with a range of species rich grassland types present. The pastures are dominated by sharp-flowered rush, carnation sedge and sweet vernal grass with a wide variety of associated species. The nationally rare melancholy thistle (Cirsium heterophyllum) occurs in this habitat type.

Old sessile oak woodlands are located on the northern shores of the lake and in particular on and near Rosskit Island. These oak woodlands with holly (Ilex) and hard ferns (Blechnum) are restricted in Europe to the UK and Ireland and were a qualifying feature in the NI SAC designation. Although there are considerable variations within the habitat type, sessile oak woodlands tend to support a rich bryophyte community with rare species, such as Campylopus setifolius, Sematophyllum demissum, Adelanthus decipiens, Leptoscyphus cuneifolius and Plagiochila atlantica (JNCC, 2007).

Notable plant species associated with the habitat types found in the Lough Melvin catchment include the Irish Red Data Book listed Globeflower (Trollius europaeus), Marsh helleborine (Epipactis palustris), Blue-eyed grass (Sisyrinchium bermudiana) and Tea-leaved willow (Salix phylicifolia). Melancholy thistle (Cirsium heterophyllum), a hay meadow species, was located on Roogagh River in 1949 and is believed to be still present today. The species is rare, having only been recorded in NI (Magee & McLaughlin, 2007).

The Globeflower is protected under the Flora Protection Order (1999) and is listed as a NI scheduled species. It is considered endangered, only occurring in Leitrim, Donegal and Fermanagh (on Lough Melvin) (NPWS, 2005; Dúchas, 2002).

The Blue-eyed grass is found on lakeshores and in wet pastures as far south as County Cork but it is restricted in NI to the areas around Lough Melvin and Lough Erne (Magee & McLaughlin, 2007).
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The main threats to the terrestrial habitats and flora of Lough Melvin and its catchment are: eutrophication of terrestrial habitats, land clearance for housing or farming activities, drainage, changing farming practices including the addition of fertilisers, ploughing, over or undergrazing and change from haymaking to silage.

3.6 Riverine Habitat

The viability of the trout and salmon populations in Lough Melvin is entirely dependent on the availability of suitable spawning areas in the inflowing and outflowing streams within the catchment. Therefore, it is vital that the riverine systems within the catchment are maintained in a healthy condition.

Rivers are continuously changing and are subject to natural geomorphological and hydrological processes as well as human induced changes (Environment Agency et al., 2006). The riparian zone is an important component with trees and shrubs along the riverbank providing shade and protecting the banks from erosion. Woody debris, which overhangs or falls into streams, provides a diversity of habitats for macroinvertebrates, fish, birds and mammals. In natural systems, an uneven age structure will provide a diversity of habitat niches for a variety of plants and animals (Environment Agency et al., 2006). It is therefore important that streams within the catchment are given adequate protection.

The main threats to the riverine habitat within the Lough Melvin catchment are: land clearance, removal of bankside/riparian vegetation, stock access, sedimentation, eutrophication and dredging.

3.7 Economic and Social Values

In addition to (and because of) the variety of habitats and species within the Lough Melvin catchment, the lake and surrounding area provide a host of direct and indirect economic and social benefits. The provision of drinking water is a direct economic benefit provided by Lough Melvin, which supplies the towns of Ballyshannon and Bundoran in County Donegal. The sustainability of this water supply is directly dependant on the health of the lake. Other economic and social values are discussed in brief below.

3.7.1 Historical Values

Lough Melvin and the surrounding catchment have a rich history and archaeological heritage. A number of national monuments are located in the area including the remains of Rosclogher castle, crannogs, church sites and various mass rocks. At Ross Friary, near Kinlough, four Franciscan friars led by Micheál Ó Cléirigh wrote much of the Annála Ríoghachta Éireann (Annals of the Kingdom of Ireland), a history of Ireland from the earliest times to the seventeenth century that is often referred to the Annals of the Four Masters. A memorial to them was unveiled in 1975 by Cearbhail O’Dalaigh the late President of Ireland, at Mullinaleck Bridge on the River Drowes, which is close to the Friary.
Lough Melvin’s Significance

The ruins of Rosclogher Castle, residence of the MacClancy clan stands on an island off the southern shore of Lough Melvin (ruins shown in Plate 11 above) and an old abbey is located about 250 yards away. MacClancy was a powerful sub-chiefain of Darty whose territory stretched from Glack on the east to Bunduff on the west, and north to south from Mullinameek to Aghanlish. Legend says that MacClancy had the castle built in order to protect his only daughter from small pox, which was rampant in Darty. Captain Francisco de Cuellar wrote an account of the castle in 1588. De Cuellar was a Spanish soldier on one of several vessels of the Spanish Armada, which were shipwrecked at Streedagh Strand, County Sligo. After making his way to Dromahaire Castle, he found refuge in Rosclogher Castle, where he joined ten other shipwreck survivors under the protection of Tadhg Óg MacClancy. When news came of a large English force searching for them, De Cuellar offered to defend the castle to the death. The castle was besieged by the English for 18 days without any effect after which snow forced their retreat. De Cuellar eventually escaped to Scotland and from there to the Spanish Netherlands where he wrote of his experiences in Ireland.

In their accounts, neither Brother Ó Cléirigh nor Captain de Cuellar concerned themselves much with water quality. However, de Cuellar may have come close to truth with his description of those who lived in the vicinity of Lough Melvin in 1588 when he wrote: “They drink sour milk, for they have no other drink; they don’t drink water, although it is the best in the world.” (References: Allingham H. and Crawford R. (ed. and transl.) 1988. Captain Cuellar’s adventures in Connacht and Ulster: a picture of the times drawn from contemporary sources, reprinted to commemorate the 400th anniversary of the wrecking of three vessels on Streedagh Strand (Sligo). See also http://homepage.eircom.net/~fmasters/chieftains.html and ftp://ftp.ucc.ie/pub/celt/texts/S108200.txt)

3.7.2 Tourism

The main attraction for tourists in the Lough Melvin area is the quality of the angling. The unique fish species present in the lake and the relatively unspoilt natural setting draws tourists from all over the world. Angling for trout is common on the lake, while the River Drowes is regarded as one of the premier salmon fisheries in the country and frequently produces the first salmon of the season on opening day on January 1st. The salmon season runs to 30th September and the brown trout season is from 15th February to 30th September.
Lough Melvin’s Significance

There are three angling fisheries on Lough Melvin. The southeastern quarter of the lake, Rossinver Bay and the Roosky shore constitute the Rossinver fishery. Most of the salmon having migrated into the lake congregate in this area, prior to ascending the spawning rivers, in December. The north-east corner of the lake in NI is leased from the Ily estate and anglers are required to purchase permits from the Garrison & Lough Melvin Anglers Association. An open fishing competition is held every year over two days by the Association, attracting visitors from all over the world. The remainder of the lake is classified as an “open fishery”.

Lough Melvin and surrounds are also highly valued for their scenic quality. Common recreational activities include sightseeing, hiking and cycling with various trails dotted throughout the catchment, including the Ulster Way. Economic benefits arise from tourism directly, through the use of accommodation, eating and other facilities provided by local businesses.

3.7.3 Residential

Due to the relatively unspoilt rural nature of the catchment, it is highly valued as a residential area. A number of one-off houses have been constructed in recent years and sites with views of the lake and along scenic routes are especially sought after. The value of land will also be expected to increase as affordable, rural, unspoilt residential sites with access to coastal resorts and towns, become increasingly rare. However, the primary reasons why people wish to live in the area (unspoilt and rural) are dependant on the healthy status of the lake and catchment. Eutrophication, blue-green algal blooms and damaged, polluted river systems would severely reduce the quality of living for residents and the attractiveness of the area for potential residents, investors and tourists.

3.8 Economic Value of Fish Species

As part of the Lough Melvin Programme, an investigation into the valuation of fish species present in the lake was undertaken. The overall objective of this component was to provide information on the relative economic values that the general public (in NI and ROI) attach to the fish species within the Lough Melvin catchment namely: Arctic char, Atlantic salmon, ferox, gillaroo, and sonaghan. An outline of this study is provided in the following sections.

3.8.1 Introduction

Environmental resources and services, such as clean air and water, and healthy fish and wildlife populations, are typically not traded in conventional markets. Therefore, their economic value is not revealed by market prices. The only option for assigning monetary values to them is to rely on non-market valuation methods. The rationale for attempting to estimate individuals’ preferences for non-market goods and services in monetary terms is to enable environmental impacts generated by human activities to be accounted for in decision making. Valuing changes in the quantity and quality of environmental assets brought about by economic activity allows environmental costs and benefits to be made commensurate with, and placed in the same political dialogue as, conventional economic costs and benefits.

While many people benefit directly from preservation of fish species through angling, there may also be a sizable proportion of the population who derive little or no benefit but possess strong existence values because they believe in the preservation of the asset for current or future generations. Non-use or existence benefits to the public must not be omitted as this would understate the total resource value of the fish species, and may lead to under provision of protection or less support for
provision than is socially warranted. A non-market valuation technique known as discrete choice experiments is used for this purpose as it captures both use and non-use values. The method is used reliably to provide estimates, in monetary terms, of the value to the public of preserving a number of rare and endangered fish species within the Lough Melvin Catchment.

Methods are discussed in Section 3.8.2 and the results are presented in Section 3.8.3. For a more detailed discussion on the discrete choice experiment methodology, refer to the Strand 3 Technical Report; Fish Valuation.

3.8.2 Methods

In discrete choice experiments, respondents are asked to choose their preferred alternative among several hypothetical alternatives in a choice set. The alternatives are defined in terms of a number of attributes and each attribute is denoted with two or more levels. By asking respondents to complete a sequence of choice sets, it is possible to infer their willingness to give up some amount of one attribute in order to achieve more of another attribute. Discrete choice experiments are based on the idea that individuals derive benefits-defined here as utility-from the different characteristics, or attributes, that a good possesses, rather than directly from the good per se. Accordingly, a change in one of the attributes (such as price) can cause a respondent to switch their decision from one alternative to another that provides a superior combination of attributes. Thus, respondents choose the alternative that provides them with the highest utility. Based on this, the probability of choosing a specific alternative is a function that the utility associated with that alternative is greater than the utility associated with the remaining alternatives. Discrete choice experiments are the preferred approach for valuing complex and multi-dimensional scenarios, especially to:

- capture both use and non-use values;
- identify the attributes the general public value;
- determine the implicit ranking of these attributes; and
- estimate the value of changing more than one of the attributes at once.

In this application, the basic idea behind the discrete choice experiment technique is to quantify a respondent’s willingness to pay (WTP) in order to conserve rare and endangered fish species within the Lough Melvin Catchment. The fish species—or attributes-focused on here are: the Arctic char; the Atlantic salmon; the ferox; the gillaroo and; the sonaghan.

As part of the discrete choice experiment respondents were firstly informed that the above fish species are under threat and will become extinct if there is no intervention. Images of the fish species were shown to respondents and a brief description of each species—in terms of their uniqueness and angling potential—was read to respondents. Respondents were then made aware that a number of options are available to respond to the threats to the fish species. Subsequently, respondents were shown examples of the outcomes that could be achieved. An example of a typical set of outcomes—or choice set—which was presented to respondents in the course of the interview is presented in Figure 15 overleaf.
Figure 15: Example choice set presented to respondents

Each choice set outlined three possible outcomes. The first two outcomes—labelled as Option A and Option B—described the conservation status of each of the fish species after the implementation of two different conservation schemes. At the end of these policies, the fish species would either be: conserved; or, extinct. While a particular policy described under either Option A or Option B may have been unable to prevent some of the fish species from becoming extinct, they both ensured that all fish species would not become extinct. The final outcome—labelled as Do Nothing—showed the outcome if nothing was done to protect the fish species. In this case, the respondents were informed that all of the fish species would become extinct. When choosing their preferred outcome—either Option A, Option B or Do Nothing—respondents were explicitly asked to bear in mind the value that they personally would have to pay per year—through a one-off increase in their Income Tax and/or Value Added Tax contributions. As part of the interview, respondents were asked to identify their preferred outcome from 16 such choice sets.

The population of interest was the adult population of NI and RoI. A stratified random sample of 1,186 respondents was selected for this study to reflect the geographic distribution of the adult population; the approximate rural/urban split; the approximate socio-economic status of the regional population; and the approximate gender and age profile of the regional population.
3.8.3 Results

Overall, the survey was administered by experienced interviewers to a stratified random sample of 1,186 respondents drawn from the adult population in NI and RoI. Of these, 754 respondents agreed to participate. Thus, the overall response rate was 64 percent. In NI, a response rate of 55 percent was achieved, which was somewhat lower to the response rate of 71 percent achieved in RoI.

As may be seen from the breakdown of respondents who participated in the survey according to gender and age in Table 7, below, the samples in NI and RoI are fairly representative of the population.

Table 7: Profile of survey sample and population (percent)

<table>
<thead>
<tr>
<th></th>
<th>Northern Ireland</th>
<th>Republic of Ireland</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample (N=303)</td>
<td>Population(^{a}) (N=1,369,334)</td>
<td>Sample (N=451)</td>
</tr>
<tr>
<td>Male</td>
<td>50.83</td>
<td>48.35</td>
<td>50.78</td>
</tr>
<tr>
<td>Female</td>
<td>49.17</td>
<td>51.65</td>
<td>49.22</td>
</tr>
<tr>
<td>Aged between 15 and 24 years</td>
<td>14.85</td>
<td>18.49</td>
<td>18.85</td>
</tr>
<tr>
<td>Aged between 35 and 44 years</td>
<td>15.84</td>
<td>18.80</td>
<td>19.51</td>
</tr>
<tr>
<td>Aged between 45 and 54 years</td>
<td>17.82</td>
<td>15.63</td>
<td>16.63</td>
</tr>
<tr>
<td>Aged between 55 and 64 years</td>
<td>15.18</td>
<td>13.17</td>
<td>13.08</td>
</tr>
<tr>
<td>Aged between 65 years and over</td>
<td>20.13</td>
<td>17.25</td>
<td>11.31</td>
</tr>
</tbody>
</table>

\(^{a}\) NI population includes only persons aged 15 years and over. Obtained from the Northern Ireland Statistics and Research Agency (NISRA). See www.nisra.gov.uk.

\(^{b}\) RoI population includes only persons aged 15 years and over. Obtained from the Central Statistics Office (CSO). See www.cso.ie.

\(^{c}\) Total population obtained by aggregating NI population and RoI population.

Using the choices made by respondents in the choice experiment, it is possible to estimate how much money respondents are willing to sacrifice-or, in other words, willing to pay-in order to prevent any, or all, of the fish species from becoming extinct. The main results of this are summarised in Table 8, below. Median WTP estimates per person per year are reported for preserving each of the fish species (i.e. the ceteris paribus values) and preserving all fish species. The implicit rankings of the fish species are also reported.
Table 8: Median willingness to pay (WTP) to avoid the fish species becoming extinct from the Lough Melvin Catchment (€/year)

<table>
<thead>
<tr>
<th>Fish Species</th>
<th>Northern Ireland</th>
<th>Republic of Ireland</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WTP</td>
<td>Rank</td>
<td>WTP</td>
</tr>
<tr>
<td>Arctic char</td>
<td>15.62 (12.39–18.56)</td>
<td>4</td>
<td>10.36 (8.18–11.86)</td>
</tr>
<tr>
<td>Atlantic salmon</td>
<td>28.80 (21.10–32.80)</td>
<td>1</td>
<td>28.96 (23.11–31.73)</td>
</tr>
<tr>
<td>Ferox</td>
<td>10.87 (8.12–12.31)</td>
<td>5</td>
<td>12.45 (10.37–14.72)</td>
</tr>
<tr>
<td>Gillaroo</td>
<td>20.34 (17.20–23.50)</td>
<td>3</td>
<td>13.26 (11.75–15.99)</td>
</tr>
<tr>
<td>Sonaghan</td>
<td>27.47 (22.49–31.07)</td>
<td>2</td>
<td>21.98 (18.28–25.34)</td>
</tr>
<tr>
<td>All fish</td>
<td>34.58 (29.93–38.93)</td>
<td>–</td>
<td>33.13 (28.29–37.64)</td>
</tr>
</tbody>
</table>

WTP estimates are generalised, or aggregated to the NI and RoI populations as a whole to indicate the median total economic value for preserving each of the fish species (i.e. the ceteris paribus values) and preserving all fish species.

As may be seen the public place highest value on preserving Atlantic salmon. Subsequently, sonaghan and gillaroo respectively are found to be the next highly valued fish species. Whereas ferox is found to be the least valued fish species in NI, in RoI it is found to be Arctic char. As indicated by the non-overlapping confidence intervals, the public in NI have statistically significantly higher WTP for Arctic char and gillaroo. For the other fish species, WTP estimates are found to be statistically equivalent for the two jurisdictions. For both jurisdictions, the median WTP per year for preserving Atlantic salmon and sonaghan is estimated to be €29.12 and €26.28 respectively. The equivalent figures for gillaroo, Arctic char and ferox are €15.51, €12.49 and €11.52 respectively.

To preserve all five species of fish, the median WTP per year is estimated to be €34.58 and €33.13 for NI and RoI respectively.

Table 9: Aggregate median willingness to pay (WTP) to avoid the fish species becoming extinct from the Lough Melvin Catchment (million €/year)

<table>
<thead>
<tr>
<th>Fish Species</th>
<th>Northern Ireland</th>
<th>Republic of Ireland</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferox</td>
<td>14.884 (11.122–16.852)</td>
<td>42.026 (34.989–49.699)</td>
<td>54.664 (49.478–59.964)</td>
</tr>
<tr>
<td>Gillaroo</td>
<td>27858 (23.409–32.178)</td>
<td>44.767 (39.644–53.963)</td>
<td>73.662 (66.436–81.035)</td>
</tr>
<tr>
<td>Sonaghan</td>
<td>37622 (30.795–42.548)</td>
<td>74.194 (61.706–85.519)</td>
<td>124.686 (109.841–135.258)</td>
</tr>
<tr>
<td>All fish</td>
<td>47346 (40.980–53.304)</td>
<td>111.837 (95.504–127.047)</td>
<td>166.682 (145.246–191.156)</td>
</tr>
</tbody>
</table>

a 95 percent confidence interval in parenthesis.
Inspection of the aggregated median WTP estimates, shows that the total economic value of the fish species is estimated to be almost €50 million in NI and over €110 million in RoI.

3.8.4 Conclusion

The results indicate that the public places high values on preserving the rare and endangered fish species within the Lough Melvin Catchment. Highest aggregate median WTP values are found for preserving Atlantic salmon (€138 million per year), lowest for preserving ferox (€55 million per year), with preserving sonaghan (€167 million per year), gillaroo (€74 million per year) and Arctic char (€59 million per year) ranking in between. To preserve all fish species the total aggregate median WTP is found to be €167 million.

There are clear uses for these value estimates. They illustrate the general public’s high demand for policy instruments which ensure the preservation of rare and endangered fish species within the Lough Melvin Catchment. The results should also be used to inform decisions concerning the prioritisation of resources within such policy instruments.

3.9 Ecological Objectives and Targets

The overall vision for Lough Melvin is to:

“Maintain the unique and internationally significant diversity of species and habitats that Lough Melvin supports, in a manner that ensures the sustainability of its assets and values into the future.”

Ecological objectives provide the next tier of objectives and represent the desired ecological outcomes for Lough Melvin. Defining ecological objectives and setting resource condition targets enable management options to be assessed and prioritised into the future. The Lough Melvin SAC objectives as specified in the respective conservation plans are presented in the Appendix. The NI plan was updated in 2007 and includes detailed favourable condition tables for SAC designation features and for ASSI features. The RoI plan developed by the NPWS (Draft 2002) includes broad objectives for each feature but no favourable condition tables. These Plans have been utilised as base information for the ecological objectives set out below.

Objectives were identified for the broad assets (fish, habitats etc.) in terms of the desired condition of species and/or biota (biodiversity objectives), biological processes (process objectives) and physical conditions (habitat objectives). Objectives can be expressed as one of four main targets, which are related to the present condition of assets. These are: reinstate, restore, maintain and reduce. Due to the paucity of information on the current condition of individual ecological assets, only broad ecological objectives have been developed. As information becomes available from monitoring programmes and species/habitat surveys, the ecological objectives should be further refined and expanded so they can be effectively monitored.
Lough Melvin’s Significance

Ecological Objectives

**General:**
- Restore average annual concentration of TP in Lough Melvin to 20 µg L\(^{-1}\).
- Maintain mesotrophic status of Lough Melvin (which will support many of the objectives outlined below).
- Maintain and where applicable restore water quality in tributary river systems.

**Fauna**
- Maintain viable populations of European otter.
- Maintain habitat areas for Daubenton’s Bat and Whiskered Bat, areas of woodland and scrubland.

**Fish**
- Maintain self-sustaining populations of the unique diversity of trout types (ferox, sonaghan, gillaroo).
- Maintain/restore self-sustaining population of Arctic char.
- Maintain self-sustaining populations of Atlantic salmon.

**Habitats & Flora**
- Maintain diverse healthy macrophyte communities.
- Maintain the extent and habitat quality of *Molinia* meadows.
- Restore extent and habitat quality of native woodlands (sessile oak) where possible.
- Maintain and restore riparian habitats.
Lough Melvin’s Significance
There are many pressures acting on the environment of Lough Melvin, which can adversely impact and alter the quality of the habitat that the lake and surrounding catchment provides. Threats are activities or factors that have the potential to affect the quality of the asset or cause it to decline, whereas impacts are defined as the effect that the threat has on the receiving environment or asset. Actions and recommendations can be developed and prioritised by taking into account the risk of the threat occurring and the severity of the impact, if it does occur.

The biological integrity, diversity and sustainability of Lough Melvin are at risk from a number of key threats. These include the introduction of pest plants and animals, water abstraction, climate change, fish stocking, land clearance and disturbance, recreational pressures, drainage/dredging of tributaries and eutrophication. The focus of the CMP is on Lough Melvin itself and on eutrophication as the key threat. However, other threats and their impacts are discussed below to provide an overall picture of the risk to the health of Lough Melvin in a catchment management context. Eutrophication as the key threat is discussed in Section 5.3.

### 4.1 Pest Plants and Animals

Introduced, non-native plant and animal species pose a major threat to freshwater ecosystems, altering the quality of habitat and diversity of indigenous species. Non-native species that become invasive are considered to be the second most significant threat to biodiversity in freshwater ecosystems, after land use change. The impacts of invasive species are varied and include competition for resources, predation, alteration of habitats, introduction of parasites and pathogens and dilution of native gene pools (Stokes, O’Neill & McDonald, 2006; Maguire & Sykes, 2004).

Invasive species can be introduced either deliberately or accidentally to freshwater systems via numerous routes or pathways. The greatest risks of introductions arise from pet and aquaria trade, angling, boating, tourism and horticulture and landscaping. In Ireland, recreational boating and angling are key routes through which invasive species are introduced to lakes and rivers (C. Maguire, QUB, pers. comm., 2007).

Risk assessments have been carried out by the “Invasive Species in Ireland” project for 385 established invaders and 171 potential invaders and of those, 30 established and 35 potential were classified as high risk. Freshwater species dominated the high risk potential group. The freshwater species that are considered high impact or high risk in Ireland are shown in Table 10 and Table 11:

#### Table 10: High impact invasive species

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Species</th>
<th>Type of Organism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zebra mussel</td>
<td>Dreissena polymorpha</td>
<td>Invertebrate</td>
</tr>
<tr>
<td>Canadian waterweed</td>
<td>Elodea canadensis</td>
<td>Aquatic Plant</td>
</tr>
<tr>
<td>Nuttall’s waterweed</td>
<td>Elodea nuttallii</td>
<td>Aquatic Plant</td>
</tr>
<tr>
<td>Floating pennywort</td>
<td>Hydrocotyle ranunculoides</td>
<td>Aquatic Plant</td>
</tr>
<tr>
<td>Australian swamp stonecrop</td>
<td>Cassula helmsii</td>
<td>Aquatic Plant</td>
</tr>
<tr>
<td>Brazilian Elodea</td>
<td>Egeria densa</td>
<td>Aquatic Plant</td>
</tr>
<tr>
<td>Parrot’s Feather</td>
<td>Myriophyllum aquaticum</td>
<td>Aquatic Plant</td>
</tr>
<tr>
<td>Brown Bullhead catfish</td>
<td>Ameiurus nebulosus</td>
<td>Aquatic Plant</td>
</tr>
<tr>
<td>Dace</td>
<td>Leuciscus leuciscus</td>
<td>Aquatic Plant</td>
</tr>
<tr>
<td>Water fern</td>
<td>Azolla filiculoides</td>
<td>Aquatic Plant</td>
</tr>
<tr>
<td>Chub</td>
<td>Leuciscus cephalus</td>
<td>Aquatic Plant</td>
</tr>
<tr>
<td>Curly leaved waterweed</td>
<td>Lagaerisphon major</td>
<td>Aquatic Plant</td>
</tr>
</tbody>
</table>
Table 11: High risk potential invaders

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Species</th>
<th>Type of Organism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Primrose</td>
<td>Ludwigia grandiflora</td>
<td>Aquatic plant</td>
</tr>
<tr>
<td>Noble crayfish and Turkish Crayfish</td>
<td>Astacus astacus &amp; A. eptodenys</td>
<td>Crustacean</td>
</tr>
<tr>
<td>Signal crayfish</td>
<td>Pacificastus leniusculus</td>
<td>Crustacean</td>
</tr>
<tr>
<td>Spiny-cheeked/striped crayfish</td>
<td>Oconectes limosus</td>
<td>Crustacean</td>
</tr>
<tr>
<td>Asian Clam</td>
<td>Corbicula fluminea</td>
<td>Invertebrate</td>
</tr>
<tr>
<td>Ruffe</td>
<td>Astidichthys nobilis</td>
<td>Fish</td>
</tr>
<tr>
<td>Goldfish</td>
<td>Gymnocephalus cemuus</td>
<td>Fish</td>
</tr>
<tr>
<td>Ponto-Caspian Mysid</td>
<td>Carassis auratus</td>
<td>Fish</td>
</tr>
<tr>
<td>Zander</td>
<td>Hemimysis anomala</td>
<td>Crustacea</td>
</tr>
<tr>
<td>Red swamp crayfish</td>
<td>Stizostedon lucoperca</td>
<td>Fish</td>
</tr>
<tr>
<td>Silver Carp</td>
<td>Procambarus clarkii</td>
<td>Crustacean</td>
</tr>
<tr>
<td></td>
<td>Gyrodactylus salaris</td>
<td>Invertebrate</td>
</tr>
<tr>
<td></td>
<td>Hypophthalmichthys molitrix</td>
<td>Fish</td>
</tr>
</tbody>
</table>

The more commonly occurring or high risk species are discussed in brief in the following sections.

### 4.1.1 Zebra Mussel

The zebra mussel (*Dreissena polymorpha*) is probably the most serious invasive species threat to Lough Melvin. It is a fresh water bivalve mollusc, native to the Black and Caspian Seas and Aral drainage basins of Eastern Europe and Western Asia, which has spread across Europe over the last 200 years. The first sighting of the zebra mussel in Ireland was in 1994, in the lower regions of the Shannon system. It has since spread to over 55 water bodies in Ireland throughout the Shannon system and connecting navigation system. In recent years, it has been spreading into unconnected waterways and lakes and was confirmed in Lough Corrib in September 2007. Lough Erne, which is adjacent to Lough Melvin, has had zebra mussels since the mid 1990s (Hynes, 2007; Maguire & Sykes, 2004; Rosell, Maguire & McCarthy, 1999). The widespread colonisation of zebra mussel throughout Ireland indicates the suitability of the freshwater habitat for this species.

There are many impacts from the invasion of zebra mussels. They attach to solid surfaces and in large quantities are capable of blocking water abstraction pipes, damaging boat engines and sinking navigational buoys. Environmental impacts can also be severe as the species colonise spawning grounds of salmonids, in particular Arctic char and compete for food (EHS, 2007).

Zebra mussels feed by filtering up to 1 litre of water per individual and it is estimated that in Lough Erne, the population can filter the entire lake every 2 weeks (Maguire & Sykes, 2004). Therefore, they have the ability to significantly alter the abundance of phytoplankton and zooplankton, thus directly altering food resources for indigenous fish populations. As the suspended planktonic matter is removed, the transparency and clarity of the water increases creating favourable conditions for benthic algae, macrophytes and predatory fish.

In many waters, the most apparent change has been the new occurrence of blue-green algae blooms. One theory suggests that zebra mussels select the more desirable algae species and reject less palatable blue-green algae (Lucey, Sullivan & Minchin, 2005). It is important to note that zebra mussels do not cause a net loss of nutrients from the system but rather they alter the way the system cycles nutrients, shifting energy from the pelagic to the benthic zone (EHS, 2007b).
Lough Melvin is considered to be the second most vulnerable lake in NI for a successful invasion of zebra mussels. Water bodies were prioritised based on a number of parameters:

- Water chemistry: pH, calcium concentration;
- Physical: lake size, lake area, proximity of infested water bodies, connectivity of water bodies, recreational usage, the occurrence of angling competitions, the presence of boat clubs on the lake, licensed fishing and the number of access points;
- Conservation designation.

Lough Melvin provides suitable conditions for the invasion of the zebra mussel and its susceptibility is of serious concern. If the zebra mussel spreads to the lake it is probable that the there will be an increase in water clarity, decreases in phytoplankton and zooplankton abundance and an increase in macrophyte growth. The most serious impacts are considered to be the fouling of spawning beds for the Arctic char and the reduction in food species, in particular for the indigenous sonaghan (Ferguson, 2004).

A number of signs have been erected around Lough Melvin highlighting the dangers of zebra mussel introduction. In addition, education and awareness programmes have targeted anglers to encourage steam cleaning of boats. However, there is evidence to suggest from elsewhere in Ireland, that voluntary guidelines are not sufficient to prevent the introduction of aquatic invasive species (Hynes, 2007). Currently there is no viable method for enforcing controls on the movement of boats from Lough Erne to Lough Melvin and the risk of introduction remains high. Ferguson (2004) considers that introduction of the zebra mussel to Lough Melvin by way of boats and other gear is almost a forgone conclusion, unless much more serious controls are put in place.

### 4.1.2 Pike

The pike (Esox lucius) is native through large areas or northern Europe, Asia and North America. They can grow quickly in Ireland reaching up to 20 kg and are valued for angling in particular by sport anglers. However although abundant in many small and large lakes, slow flowing rivers and canals, they are non-native to Ireland having been introduced in the 13th century. Within Ireland, their range is still expanding, most probably via illegal introductions. However, these introductions have serious ecological impacts particularly with respect to native salmon populations. Over recent years pike have appeared in lakes in south Donegal and where this has occurred the resident trout populations have collapsed.

Pike are highly predatory opportunistic feeders, preying mainly on other fish but also feeding on amphibians, invertebrates, and vertebrates including mice and waterbirds. Pike are known to consume large quantities of juvenile salmonids and significantly reduce the diversity and numbers of native salmonid populations. They are considered to have had a major impact on Arctic char populations due to predation during the spawning season (Igoe et al., 2003).
Pike are not present within Lough Melvin but their introduction would cause obvious and dramatic detrimental environmental impacts. Lough Melvin is valued for its indigenous fish populations and for the quality of its trout and salmon fishing. If pike became established in the lake, it is highly probable that they would displace ferox as the top predator thus altering the natural food chain (Ferguson, 2004). Predation on other fish would reduce the numbers and diversity of the indigenous trout and salmon populations, and could result in the extinction of the resident Arctic char population. While they have never been recorded in Lough Melvin, the current status of the catchment as being free from pike is unclear for a single specimen was found among fish netted in Lough Lattone during a survey by the Central Fisheries Board in 2006 (Kelly & Connor, 2007). However, further and more extensive surveys in the summer of 2007 and spring of 2008 did not capture any specimens. The confirmed existence of pike within the catchment would be of serious concern.

4.1.3 Roach

Roach (Rutilus rutilus) were initially introduced to Ireland from England in 1889, when specimens used for bait escaped into the Blackwater River, in County Cork. Intentional introductions in other parts of the country have occurred to provide a food source for pike (Stokes et al., 2004).

Roach have severe impacts on the ecosystem balance within lakes as they feed heavily on zooplankton, which reduces the predation on phytoplankton and consequently exacerbates algal blooms (Stokes et al., 2004). Roach also compete for zooplankton with Arctic char and other salmonid populations (Igoe et al., 2003). The Irish Red Data Book (Whilde, 1993) notes that the illegal introduction of roach to many waters in Ireland over the past few decades has had significant impacts on the resident fish communities and care should be taken particularly in waters that have fish communities of conservation significance e.g. Lough Melvin. Roach have not been recorded from Lough Melvin, but a roach-rudd hybrid was recorded from a fish survey in the lake. In 2006, a single specimen was found in Lough Lattone, although as for pike no further specimens have been discovered despite intensive netting of this lake.

4.1.4 Rudd

Rudd (Scardinius erythrophthalmus) is a freshwater fish that is very similar to roach in appearance. While it is not considered native to Ireland, by the mid 20th century rudd were widespread in many lowland lakes. Since then it has collapsed in abundance due to being out-competed by the newly introduced roach, with which it has similar dietary preferences. It is now found and is locally abundant in Lough Melvin, although it is unclear when and how it arrived in the lake. Rudd feed on aquatic plants and may be a threat to the aquatic plant communities within Lough Melvin. The increase in the numbers of rudd in the lake, and recent reports of the occurrence of roach/rudd hybrids are likely to have a serious impact on the ecosystem balance (M. O’Grady, EPA, pers. comm., 2006).
4.1.5 **Canadian waterweed**

Canadian pondweed or waterweed (*Elodea canadensis*) is native to North and South America where it occurs in lakes, ponds, canals and slow flowing water. It was introduced to Ireland in 1836 as a fragment on an imported log from Canada, and rapidly spread to Europe. It can form dense stands and reproduces vegetatively competing for nutrients and outgrowing many native aquatic plants. Canadian pondweed is one of only a few exotic plant species that have been recorded in Lough Melvin, but it is currently not considered to be having a notable impact (EHS, 2007b).

4.2 **Stocked Fish**

Stocking with hatchery-reared brown trout has been carried out since the late nineteenth century and is widely practiced to supplement natural stocks, primarily for angling (Ferguson 2004). However, stocking of alien salmonid species or populations for recreational and commercial purposes is considered to be one of the most important issues in salmonid conservation (Kottelat & Freyhof, 2007). Potential adverse impacts include the competitive exclusion of native fish and/or interbreeding, resulting in the dilution or loss of unique gene combinations (Environment Agency et al., 2006).

Stocking is not undertaken currently in Lough Melvin (though native stocking has occurred historically in some tributaries) but it is a particularly relevant concern for the Lough Melvin trout. Stocking of brown trout of hatchery origin into Lough Melvin could bring about a breakdown in the reproductive isolation between the three trout types. Hatchery-reared trout have no spawning area to home to and therefore they could spawn at random causing widespread interbreeding and a breakdown in the reproductive isolation among the three types (Ferguson, 2004).

**Recommendation:**

In recognition of the threat to the genetic integrity of the salmonid populations, and also due to fact that trout are abundant in the lake, stocking of fish in Lough Melvin does not occur. However, it is recommended that stocking of fish is not permitted at all within the Lough Melvin catchment as the potential impacts on the native trout species are too severe.

4.3 **Land Clearance and Housing**

As previously noted, the Lough Melvin catchment has experienced a significant increase in the number of single houses and housing developments over the past decade.
The environmental impacts associated with this increase in housing are varied and include land disturbance and clearing, loss of habitat for rare and/or listed species (e.g. otter), and the increased risk of sediments and pollutants reaching the lake e.g. disturbed soils, urban runoff, and nutrients from wastewater.

The impacts of wastewater from housing in relation to nutrient enrichment of the lake are discussed in Section 9.

### 4.4 Water Abstraction

Lough Melvin provides a potable water source for the towns of Bundoran, part of Ballyshannon (since 1991) and a number of private water schemes in County Donegal. Water is abstracted from the lake via a pumping station close to the Derynaseer Pier, on the northern shore. The water extracted from Lough Melvin is treated on site with alum, which is recycled through the plant, and the sludge by-product from the treatment process is exported off site.

In the summer months, Donegal can experience short periods of drought in line with a surge in the tourist populations. This puts particular pressure on limited water supplies and in 2001, a study was conducted by Donegal County Council to investigate additional abstraction options for the county. Lough Melvin was investigated as one of three possible options but was discarded due to the nature of the lake and its significant ecological importance.

In 2006, an average of 4060 cubic metres of water per day was extracted from Lough Melvin or almost 1.5*10 m³ for the year (Hugh Kerr, Donegal County Council, pers. comm., 2008). This rate of abstraction is less than 1% of the volume of water leaving the lake. The current extraction of water from Lough Melvin is not licensed but is required to be within the catchment safe yield, though this figure was not available from the EPA hydrometric section.

The water levels within Lough Melvin determine the area, extent and biodiversity of the lake’s littoral zones (interface between land and water). The littoral zones are particularly productive areas supporting the largest diversity of invertebrates due to the range of habitats e.g. woody debris, soft and hard sediments and gravel. They also provide spawning grounds for salmonid species such as the Arctic char. Extracting significant amounts of water from Lough Melvin will reduce water levels and expose littoral zones. Spawning gravels around the lake and in the out-flowing River Drowes could also become desiccated, reducing the breeding success for salmonid species. It is particularly important that water levels in the outflowing River Drowes are maintained as the river (and nearby Lareen bay) provide the only breeding grounds for the gillaroo trout and support significant salmon spawning grounds.
4 Threats and Impacts

**Recommendation:**

While currently there is no plan for further extraction of water from the Lough Melvin catchment, it is recommended that future abstractions should be consistent with maintaining the ecological integrity of the lake, particularly during times of low flows.

4.5 **Recreation**

Lough Melvin and its surrounds are relatively popular as a recreational area with facilities provided in Garrison, Rossinver and Kinlough. The lake is considered to be the most important salmon and trout fishery in the northwest of Ireland attracting anglers from all over the world.

Although disturbance to date from recreation is considered to be minimal, its popularity for angling, camping and boating holidays needs to be managed to ensure that there are no future adverse impacts on the lake.

Public areas particularly on the outskirts of Kinlough need to be better maintained. Some areas suffer from excessive dumping of litter, which should be monitored by the local county council.

**Recommendation:**

Plans in place to expand on the tourism facilities around Lough Melvin if implemented, need to be undertaken in a sustainable manner, and demonstrate no negative impact on the health of Lough Melvin.
4.6 Drainage/Dredging

Drainage of land and dredging of waterways or drainage ditches involves the removal of sediments, vegetation, low level trees and other material that are considered to be causing an obstruction, to increase the flow capacity of the waterway. Increasing the rate of flow increases the “flashiness” of streams and rivers, particularly in upland catchments, and this can have serious deleterious impacts on river habitat and water quality. The disturbance of the banks and bed of the river increases the sediment load, which can deposit onto spawning grounds downstream, smothering salmonid eggs. Dredging also removes valuable spawning substrates and reduces the connectivity of the riverine system with its floodplain by increasing the steepness of the banks (Environment Agency et al., 2006). Increased nutrient loads through the mobilisation of sediment, can cause nutrient enrichment of the river and downstream water bodies.

The Office of Public Works (OPW) is responsible for maintenance of the drainage network in RoI. The County River and its tributaries from County Leitrim are part of the Kilcoo drainage scheme and are maintained every 5-10 years with the main Country River channel being cleared every 10 years (Terry McMorrow, OPW, pers. comm., 2008). There were two tributaries (C4 and C6) which were cleared between May and June 2007 as part of the arterial drainage maintenance operations.

In County Fermanagh, the Rivers Agency (as part of the Department of Agriculture and Rural Development) are responsible for drainage maintenance. The Lower Roogagh near Garrison is maintained every year, which involves bush and vegetation removal only (flow impacts only). The Upper Roogagh is inspected every 6 years and was last maintained approximately 10 years ago. Maintenance on this river involves some removal of gravel and Fisheries Officers are contacted prior to any work being undertaken. It is considered unlikely that the river would have any maintenance work carried out within the next 10 years (Alan Goodwill, Rivers Agency, pers. comm., 2008).

The potential for dredging to increase nutrient loads in waterways is discussed further in Section 7.

Action:

The potential adverse impacts of the drainage maintenance on sediment and nutrient loads in the inflowing tributaries to Lough Melvin need to be identified through pre-maintenance assessment and monitoring and the drainage practices revised if required.

4.7 Climate Change

In NI, annual temperatures are predicted to increase by 1.2°C by 2020 and 2.8°C by 2080 due to climate change (Harrison, Berry, Viles, Austin, Hosell, & Rehfsch, 2001). The impacts of these increases in temperature and other climate changes on river and lake systems are largely unquantified (Environment Agency et al., 2006). In the west of Ireland, changes to the extent and intensity of rainfall could alter significantly the current transport rates of nutrients or other pollutants from the catchment. In addition, increased temperatures will impact on aquatic environments which would make conditions less favourable for salmonid species, in particular for Arctic char (EHS, 2007a).
4 Threats and Impacts
Nutrients and Water Quality
5.1 Nutrients

Nutrients occur naturally and widely in the environment in plants, animals, rocks, soils and waste products. They are essential to life and are cycled through water, sediments and plants and animals (NCCMA, 2003). Nitrogen and phosphorus are key growth limiting nutrients and in agriculture are used extensively in fertilisers to encourage plant growth (EPA, 2004; NCCMA, 2003).

In lakes and rivers, phosphorus is regarded as the primary nutrient limiting the growth of algae and plants. It occurs as either inorganic or organic phosphorus compounds and, in turn, these can be present in soluble or insoluble, i.e. particulate, fractions. Soluble inorganic phosphate is highly bio-available for plant growth but in water or soil solution, the phosphate ion is chemically active and concentrations in freshwater can reflect equilibrium relationships with particulate phosphorus. Thus, while plants and algae can only directly utilise soluble phosphorus, as they deplete phosphate concentrations in water or the soil, this can lead to desorption of inorganic phosphate that is bound to particulate matter. Thus while immediately not bio-available, particulate phosphorus can be an important long-term source of bio-available phosphorus. Organic phosphorus compounds are generally of low bioavailability for plant growth but phosphatase enzymes released by plant roots, algae and bacteria potentially can interact with organic phosphorus so as to release soluble inorganic phosphates that are bio-available.

In terms of practical implications, given limited resources, it is advisable to control sources of phosphorus that have high bio-availability. But equally, as particulate and soluble organic compounds have some potential as bio-available sources of phosphorus for algal growth, they should not be ignored in any programme to lower phosphorus inputs to a lake or river.

Soluble inorganic phosphate is present typically only at very low concentrations in unpolluted waters but it occurs in large quantities in partially treated and untreated sewage and in land runoff contaminated by recent applications of manures or chemical fertilisers. It is the dominant phosphorus fraction in sewage that has been subjected to secondary treatment and polyphosphates, which are a component of some household fabric detergents, are readily hydrolysed to soluble inorganic phosphate during sewage treatment. In natural waters, organic phosphorus often arises from the decay of plant material and the dominant class, insitol phosphates, have low bio-availability. Particulate phosphorus arises from sediment erosion. Its significance is therefore twofold: firstly from the damaging effects of sediment on habitats such as those used for spawning salmonids and secondly reflecting the degree to which phosphate in the sediment can be desorbed for plant growth.

Human activities such as agriculture, plantation forestry and housing, all can potentially increase phosphorus inputs to water significantly. Phosphorus in domestic sewage, farmyard runoff, animal slurries, milk washings, silage effluent, artificial fertilisers and many industrial wastewaters can enter lakes and rivers via point sources such as direct discharges from wastewater treatment plants, farmyard runoff and septic tanks or from diffuse sources such as excessive or the ill timed application of natural and artificial fertilisers.

The total quantity of nutrients entering a water body in a year is its nutrient load, which is dependant on losses from the catchment minus the phosphorus that is retained within the drainage network (Jennings, Mills, Jordan, Jensen, Sondergaard, Barr, Glasgow & Irvine, 2003). Activities within the catchment affect the nutrient loads significantly and not all areas will contribute equal amounts. Factors affecting phosphorus transport within the catchment are soil, climate, proximity to waterways, extensiveness of the drainage network and risk conditions e.g. phosphorus soil saturation, fertiliser use and slurry spreading.
5.2 Water Quality

A lake’s water quality is commonly assessed in reference to its trophic status which describes the productivity of the system and provides a means of classification. The main factors that regulate the trophic state of lakes are the rate of nutrient supply, lake hydrology and morphometry. There are three commonly used categories of trophic status: oligotrophic, mesotrophic and eutrophic. Exports of nutrients from unmodified catchments with infertile soils are generally low and waterways and lakes draining these types of catchments tend to be oligotrophic (nutrient poor) or only moderately enriched with nutrients (mesotrophic). Eutrophic lakes are those that are highly productive and enriched. Ultra oligotrophic and hypertrophic denote extreme conditions of oligotrophy and eutrophy respectively.

The trophic status of lakes is commonly assessed by three key parameters: chlorophyll a, total phosphorus and transparency. The classification scheme proposed by the Organisation for Economic Co-Operation and Development (OECD) is widely used (Table 12). In Ireland however, the system requires some modification, as many lakes are sufficiently peat stained as to lower water transparency so that it falls within the range shown for eutrophic lakes even though chlorophyll concentrations are low.

Table 12: OECD Lake Trophic classification scheme

<table>
<thead>
<tr>
<th>Lake Category</th>
<th>Total Phosphorus $\mu$g L$^{-1}$</th>
<th>Chlorophyll a $\mu$g L$^{-1}$</th>
<th>Transparency m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra-Oligotrophic</td>
<td>&lt;4</td>
<td>&lt;1.0 &lt;2.5</td>
<td>&gt;12 &gt;6</td>
</tr>
<tr>
<td>Oligotrophic</td>
<td>&lt;10</td>
<td>&lt;2.5 &lt;8.0</td>
<td>&gt;6 &gt;3</td>
</tr>
<tr>
<td>Mesotrophic</td>
<td>10-35</td>
<td>2.5-8 8-25</td>
<td>6-3 3-1.5</td>
</tr>
<tr>
<td>Eutrophic</td>
<td>35-100</td>
<td>8-25 25-75</td>
<td>3-1.5 1.5-0.7</td>
</tr>
<tr>
<td>Hypertrophic</td>
<td>&gt;100</td>
<td>&gt;25 &gt;75</td>
<td>&lt;1.5 &lt;0.7</td>
</tr>
</tbody>
</table>

5.3 Eutrophication

Eutrophication refers to the process of nutrient enrichment and is a form of organic pollution causing increased production of plants and algae in lakes and rivers. It alters the natural ecological balance of freshwaters and has a number of direct and indirect impacts including oxygen depletion, pH changes, shifts in species composition, food chain effects, decrease in biodiversity, increases in toxic algal blooms and the collapse of sensitive fish species populations (EPA, 2005; EPA, 2004; Jennings et al., 2003). It is the primary threat to water quality in Ireland (EPA, 2006a; EHS, n.d.). Excessive inputs of nutrients either directly or from inflowing rivers will gradually alter the trophic status of a waterbody from oligotrophic to eutrophic. In some parts of the world, lakes can be naturally eutrophic due to geological, soil and climatic factors, but commonly in Ireland, the natural status of lakes is to be at the lower end of the mesotrophic scale of lake productivity. In 1990 when first surveyed, total phosphorus concentrations of 19$\mu$g L$^{-1}$ in Lough Melvin was typical of a mildly mesotrophic lake and this is considered to be its natural or historic status (EPA, 2004; Girvan & Foy, 2003). The mean TP concentrations in the lake have increased from 19$\mu$g L$^{-1}$ in 1990 to 30$\mu$g L$^{-1}$ in 2001/02 to 27$\mu$g L$^{-1}$ in 2006/07. There are clear indications that the lake is experiencing nutrient enrichment.
The influx of additional nutrients to a waterbody increases primary production. The increase in plankton mass in the water column reduces light penetration, increasing turbidity and decreasing visibility for fish species searching for prey. As the algal cells die and sink to the bottom they are broken down by bacteria, which utilise oxygen in the water. The decreasing dissolved oxygen concentrations can severely impact on salmonid species as well as cause further releases of phosphorus from the lake sediments which fuels the growth of algae, continuing the cycle (EPA, 2005; EPA, 2004). Provided there is sufficient light penetration, benthic algae can grow on the surface of rocks and stones (epilithic forms), on submerged plants (epiphytic forms) or on the bottom sediments (epipelic forms, or the benthos) of lakes.

Excess algae can clog water abstraction points and cause taste and odour problems in the treatment process. In addition, reaction between chlorine and increased organic matter can produce carcinogenic by-products. Controlling these effects adds significant costs to treating water for drinking.

Algal blooms formed by excessive concentrations of algae (in particular cyanobacteria) are not only aesthetically unappealing but can also be extremely toxic. Depending on the level and type of exposure, health effects range from skin irritations to liver damage, to death. Cyanobacteria are photosynthetic bacteria rather than plants but they are commonly referred to as blue-green algae. In Irish lakes, they mostly occur as colonies or filaments of cells and often possess gas vacuoles, which enable them to regulate their position in the water column to optimise light harvesting and avoid losses through sedimentation. However, especially when calm weather follows windy weather, cell buoyancy can be sufficiently positive so that the cells float to the surface where they form a surface bloom or scum. Factors that exacerbate algal growth, such as excess nutrients and high temperatures, will increase the size of the blooms, which can persist for several days. Reports from the local community suggest that blue-green algal blooms on Lough Melvin have become more frequent in recent years.

Mesotrophic water bodies are in a delicate balance and the high diversity of species present in these systems is directly related to their low to moderate nutrient status. Thus in a mesotrophic lake such as Lough Melvin, the ecological impacts of eutrophication will be the decline and loss of species that have adapted to the specific water quality conditions and natural nutrient status (see www.water-research.net). The salmonid fauna and macrophyte flora of Lough Melvin are particularly sensitive to the various impacts of eutrophication (e.g. decreased oxygen levels and water clarity). For example the loss of Arctic char in another naturally mesotrophic lake, Lough Conn, has been attributed to the effects of enrichment and specifically the excess growth of benthic algae in littoral margins of the lake that were utilised for spawning by char (source: www.charr.org)

It is likely that if nutrient loads from the catchment continue to rise and lake concentrations of phosphorus continue to increase, there will be significant and catastrophic loss of biodiversity within the system.
5.4 Nutrient Load Estimates using Landcover types

Nutrient models are particularly useful in enabling the prediction, estimation and control of diffuse sources of nutrients (Shepherd, Harper & Millington, 1999). Modelling catchment processes to estimate nutrient transport can be used to estimate the impacts of changed land use practices on the export of nutrients from the catchment.

Export coefficient models can be used to estimate nutrient loads from catchments using simple algebra (Jennings et al., 2003). Export coefficients (per ha) are applied to land uses within the catchment e.g. agriculture, forestry and multiplied by the area to give an estimate of the total nutrient load from that area of land. The output or nutrient load to a water body on an annual basis is then calculated by summing all of the respective loads from the various land use types.

The Lough Melvin nutrient model was developed to cross-reference data from the water quality monitoring results presented in Section 6 and to estimate the nutrient loads contributed to the lake from housing (wastewater) and specific landcover types in the catchment. The predictive aspects of models can be used to determine the effects of management activities and should be developed further for Lough Melvin.

5.4.1 Development Methodology

The Coordination of Information on the Environment (CORINE) was used to calculate areas of specific land vegetation within the catchment. The CORINE Land Cover project provides a common, European land cover database in ArcInfo format derived from satellite imagery and the database used in this project was derived from 2000 LANDSAT Thematic Mapper images of Ireland at a scale of 1:100,000 and the minimum area classified is 25 ha (Smith, Jordan & Annett, 2004). Using ArcGIS 9.2 software the area was calculated in hectares for each CORINE land cover class present within the Lough Melvin Catchment.

The P export coefficients used in the Lough Melvin nutrient model are based on those given by Smith et al. (2004). These were developed through measured nutrient losses from experimental sub-catchments in NI that were representative of land cover. For the land cover classes not represented in these catchments, published export coefficients from PLUARG (1978) and Ferrier et al. (1996) were used. Precipitation also contributes to phosphorus inputs to water bodies, therefore rainfall that falls directly onto Lough Melvin was also taken into account and calculated in kg total P ha⁻¹ yr⁻¹.

Total P loads for each land cover class was calculated by multiplying the land cover area by the export coefficient (P Load = Land cover area X P coefficient), where P load is in kg P yr⁻¹, land cover area is in ha and P coefficient is in kg ha⁻¹ yr⁻¹. The annual P load from the sewered population of the Lough Melvin Catchment was calculated in kg total P person⁻¹ yr⁻¹ and export coefficients were based on Gray (1984) and Storey (1990). The annual P load from the unsewered (rural) population of the Lough Melvin Catchment was calculated in kg total P person⁻¹ yr⁻¹ and the export coefficient was based on Smith (1977). By employing the export coefficients for the different land use types and calculating the human contribution to P loads it was possible to predict the annual loads of total P for the Lough Melvin catchment and its sub-catchments.
### 5.4.2 Results

The results of the modelling are presented in Table 13. Note that in some cases the export coefficients under or overestimate loadings. For example, the export coefficient for forestry is for a standing crop only and does not take into account increased nutrient export due to fertilisation or clearfelling (refer to Section 8.8 Future Nutrient Loads from Forestry).

**Table 13: Results of modelling showing estimated nutrient load contributions from land cover types within the Lough Melvin catchment.**

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Hectares</th>
<th>CoEff: kg ha$^{-1}$ yr$^{-1}$</th>
<th>TP kg yr$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discontinuous urban fabric</td>
<td>30</td>
<td>1.20</td>
<td>36</td>
</tr>
<tr>
<td>Pastures</td>
<td>4643</td>
<td>0.75</td>
<td>3482</td>
</tr>
<tr>
<td>Land principally occupied by agriculture with areas of natural vegetation</td>
<td>3823</td>
<td>0.49</td>
<td>1873</td>
</tr>
<tr>
<td>Broad Leaved Forest</td>
<td>50</td>
<td>0.26</td>
<td>13</td>
</tr>
<tr>
<td>Coniferous Forest</td>
<td>3315</td>
<td>0.36</td>
<td>1193</td>
</tr>
<tr>
<td>Natural Grassland</td>
<td>3843</td>
<td>0.65</td>
<td>2498</td>
</tr>
<tr>
<td>Moors and heaths</td>
<td>1267</td>
<td>0.13</td>
<td>165</td>
</tr>
<tr>
<td>Transitional Woodland Scrub</td>
<td>1381</td>
<td>0.26</td>
<td>359</td>
</tr>
<tr>
<td>Peat Bogs</td>
<td>3953</td>
<td>0.23</td>
<td>909</td>
</tr>
<tr>
<td>Waterbodies</td>
<td>2364</td>
<td>0.20</td>
<td>473</td>
</tr>
<tr>
<td><strong>POPULATION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sewered Population</td>
<td>1161</td>
<td>0.766</td>
<td>889</td>
</tr>
<tr>
<td>Rural Unsewered Population</td>
<td>1919</td>
<td>0.44</td>
<td>844</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>12735</strong></td>
</tr>
</tbody>
</table>

The total nutrient load estimated based on current land cover types is 12,735 kg or just under 13 tonnes of TP per year.

### 5.5 Specific Risk Factors in the Lough Melvin catchment

In catchments, phosphorus is transported via surface runoff, subsurface flow and leaching to groundwater. The export and utilisation of phosphorus within a catchment varies considerably with catchment characteristics including soil type, hydrology, slope and climatic conditions (Jennings et al., 2003).

High slopes for example are associated with higher runoff and higher phosphorus losses. Hydrology directly affects the rate of phosphorus transport as pollutants have less distance to travel and can therefore be transported quickly and easily. Artificial drainage within a catchment will significantly increase the rapid transport of phosphorus from the field to receiving waters. The intensity of rainfall is particularly important as it mobilises and increases transport rates especially if it occurs after a prolonged dry period. In fact, high intensity rainfall has been found to be the most important driving variable for phosphorus transport at the local and catchment scale (Jennings et al., 2003). Given the relatively high rates of annual runoff and peak runoff that occur in all the inflowing rivers to
Lough Melvin, it is apparent that both rainfall and runoff are sufficiently high to justify a high risk classification for the catchment.

Other catchment characteristics of Lough Melvin also make it particularly susceptible to the loss of nutrients. Soils within the catchment are naturally nutrient poor and are inefficient at binding and holding onto phosphorus. In addition, high slopes combined with an extensive hydrological network make the catchment particularly effective at rapidly transferring phosphorus from land to the lake. To identify specific areas in the catchment which are particularly prone to the loss of nutrients and therefore to provide a means of defining problem areas for nutrient losses, three catchment characteristics that can influence phosphorus transfer were mapped. These were: distance from watercourses or hydrological connectivity; slope and; soil desorption risk.

5.5.1 Hydrological connectivity

The proximity of land within the catchment to a waterway influences the rate and efficiency of phosphorus transfer. Buffers were created at distances of 0–200m considered high risk; 200–500m considered moderate risk and; > 500m considered low risk. The lakes and rivers shape files were sourced from the EPA and EHSNI.

The “distance from surface water” risk categorisation is based on the principle that the closer a source of phosphorus is to a waterway, the greater the risk of phosphorus transport to the waterway from that area (Magette et al., 2006). The distances from surface waters were based on the methodology used in “Eutrophication from Agricultural Sources: Field by Field Risk Assessment” (Magette et al., 2006).

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**Figure 16: Risk classes for distances from watercourses**
When buffers are created at intervals of 0-200m, 200-500m and > 500m and classified into the three risk categories already mentioned; 60% of the catchment is within 200m of a watercourse (high risk category); 32% is between 200-500m of a watercourse (Moderate Risk Category) and 8% of the catchment is greater than 500m from a watercourse (Low Risk Category). 92% of the catchment is within 500m of a watercourse and this is indicative of the high density drainage network in the catchment.

5.5.2 Slope

High slopes increase rainfall runoff and the rate of phosphorus transfer from the landscape to nearby waterways. Threshold classifications were applied as follows: 0-3° - low risk; 3-7° - Medium Risk and > 7° - significant risk. These ranges have previously been used in agricultural land quality classifications and in the assessment of erosion risk potential (Jordan et al., 2007; MAFF, 1999).

Slope values were calculated across 50m grids for the Lough Melvin Catchment using GIS (Geographic Information System) and a merged Digital Elevation Model (DEM) sourced from OSI and OSNI.

Figure 17: Slope Risk Map

Under these three risk categories 0-3°, 3-7° and > 7°; 24% of the catchment is considered low risk (0-3°); 40% of the catchment is at moderate risk (3-7°) and 36% of the catchment is high risk (> 7°). As 76% of the catchment is moderate or high risk due to slope this will lead to increased levels of runoff and increase the risk of phosphorus transport to the lake.
5.5.3 Soils Desorption Risk

Peat and gley soils account for almost 87% of the Lough Melvin catchment. These soils, due to their chemistry and hydrological characteristics are particularly susceptible to losing phosphorus to water (desorption) (Daly, Coulter & Mills, 2000). Peat and gley soils are at a higher risk compared with Brown-Earths or Podzolic soils if they have moderate to high phosphorus content or if phosphorus is applied, because they are prone to surface runoff, which dissolves and transports any applied phosphorus and weakly-bound soil phosphorus (David Styles, Trinity College Dublin, pers. comm., 2007).

Soils types depicted on the ‘County Leitrim Resource Survey’ (Anon, 1973) and ‘The soils of Northern Ireland at a survey scale of 1:50,000’ (Jordan & Higgins, 2007), were classified in terms of “high risk”, “moderate risk” and “low risk” based on the current knowledge of phosphorus desorption characteristics of soils.

**Soils Desorption Risk**

- High
- Medium
- Low

**Figure 18: Potential Desorption Risk Map for Phosphorus from Soils**

When soils were categorised into areas of high, medium and low risk for desorption; 97% of the Lough Melvin catchment was found to be high risk; 1% was medium risk and 2% is considered at low risk from desorption. The catchment is almost completely categorised as being at high risk from desorption due to the predominance of peats and gleys. With the high rainfall in the catchment (approximately 1200mm per year), the desorption risk is elevated further.
### 5.6 Compound Risk

As noted above the catchment of Lough Melvin is prone to high runoff, indicating a high potential risk for phosphorus loss. The analysis presented in this section for specific risk factors associated with phosphorus desorption, hydrological connectivity and slope also show that high risk factors tend to predominate and for management purposes provide justification that effectively the whole of the catchment is potentially at high risk for phosphorus transport. Overall, less than 4% of catchment area fell into the lowest risk classes for phosphorus desorption, hydrological connectivity and slope. Some 36% fell into the highest risk class for each of these three categories. The soil phosphorus desorption map also shows very limited areas (3%) that could be considered to have low or medium risk of desorption of P from any soils in the catchment that are enriched with phosphorus. For hydrological connectivity over 60% of land is within 200m of a stream. This measure of connectivity is based on the river and stream network shown in the 1:50000 Ordnance Survey map and so ignores connectivity provided by the multiplicity of small open field drains that occur throughout the catchment. Only for slope was a majority of the catchment area not in the highest risk class.

It is recommended that the whole of the Lough Melvin catchment be considered to have a high overall risk of phosphorus loss from diffuse pollution.
6.1 Phosphorus increases and trophic status

Prior to the investigations on Lough Melvin during 2006 and 2007 that are reported in this chapter, the only integrated monitoring programmes on the lake and its inflowing river network were in 1990 and 2001/02. These studies combined physical-chemical and biological monitoring. Additional surveys of lake nutrients and chlorophyll a were available from 1995 and from 2002 to 2004. The main finding from these investigations was that total phosphorus (TP) concentrations in the lake increased after 1995.

As phosphorus is the nutrient that usually limits the growth of algae in freshwaters and TP is a key parameter for defining the trophic status of water bodies, the increase was and is a cause for concern in the management of the lake (OECD, 1982). During 1990 and 1995/96 mean TP concentrations in Lough Melvin were quite stable at 19.1 and 18.4 µg L⁻¹ respectively, but by 2001/02, TP had increased by approximately 50% to 29.5 µg L⁻¹, so approaching the lower limit of 35 µg L⁻¹ that defines the eutrophic status of lakes (Girvan & Foy, 2006). In addition, significantly higher TP concentrations were observed in inflowing stream waters in 2001/02 compared to 1990 linking the increase to greater external inputs of phosphorus from the catchment.

However, the increase in TP loadings to the lake observed in 2001/02 was smaller than the increase in lake TP concentration, so that the higher losses of TP from the catchment recorded in 2001/02 alone could not account for the rise in lake TP concentration. It was suggested by Girvan & Foy (2006) that this discrepancy reflected an unusual or one-off perturbation of the catchment in the late 1990s and/or 2000, which caused a pulse of phosphorus to enter the lake, contributing to the elevated lake TP observed in 2001. A potential candidate for this perturbation was increased clear felling in the catchment as a severe storm in December 1998 left extensive areas of fallen coniferous trees and was followed by timber recovery and accelerated rates of clear felling. Clear felling of conifers on peat soils in Ireland has been found to increase phosphorus concentrations in drainage water (Cummins & Farrell, 2003a). It therefore was judged likely that increased forestry activities were responsible for the rapid increase in lake TP between 1995 and 2001.

A number of other observations from the lake and catchment were consistent with a sudden forest related perturbation around 1999/2000. For example between August 2002 and the end of 2004 lake TP concentrations declined to an average of 24.5 µg L⁻¹, suggesting a measure of recovery. Additionally water clarity had decreased in Lough Melvin by 2001/02, which was consistent with another observed impact of clear felling on peat soils, namely increased dissolved organic carbon losses, which give the waters of Lough Melvin their characteristic peat stain.

Although TP measured in 2004 had declined from the concentrations observed in 2001/02, the mean concentration remained some 25% above values recorded in the 1990s. The limited monitoring record could not determine whether this was due to a long-term increase or a legacy effect of the perturbation that occurred prior to 2001. The question of whether phosphorus concentrations would have continued to decline remained unanswered, as did the alternative, that there was a gradual rise in both lake TP and exports of phosphorus from the catchment. If the latter is the case, then the trend increase up to 2004 is such that if continued unabated, enrichment by phosphorus would shift lake TP from its desired mesotrophic class to a eutrophic status by around 2030.

Accordingly and to provide up to date information on water quality and loadings of nutrients to the lake an integrated programme of water quality monitoring was commissioned as part of the Lough Melvin Nutrient Reduction Programme (LMNRP). This section summarises both the outputs of this monitoring and how the results obtained compared with previous monitoring exercises.
6.1.1 Effects of elevated phosphorus concentrations: 1990-2004

As phosphorus usually limits algal production in freshwaters, increases in TP would be expected to result in greater primary productivity. However, chlorophyll concentrations taken from the open water of Lough Melvin, which is widely used as a proxy for algal abundance, were similar throughout the period 1990–2004. Since nitrate concentrations in Lough Melvin were considered sufficiently high so as not to limit algal productivity, then factors other than the availability of nutrients were controlling algal growth (Girvan & Foy, 2006).

Light limitation of primary production is a relatively common occurrence in Ireland where many lakes receive high inputs of coloured humic material (lewson & Taylor, 1978). These catchment-derived compounds significantly reduce the depth to which photosynthetically available radiation penetrates in lakes. In relatively deep, polymictic, humic stained lakes such as Lough Melvin the low optical depth and the large mixing depth negatively interact to depress primary productivity as the action of the wind ensures that circulating algal cells spend the majority of time in darkness. In neighbouring Lough Erne for example, where TP concentrations are indicative of eutrophic conditions, light reduction by humic compounds limit the algal response to levels that merit mesotrophic classification (Foy, McGlynn & Gibson, 1993). Terrestrially derived organic compounds can therefore exert an optical control upon algal production, providing a degree of ‘trophic stability’ to the system (Girvan & Foy, 2006).

6.1.2 Possible effects of continued nutrient enrichment

In alkaline, humic, polymictic lakes such as Lough Erne and Lough Melvin the phytoplankton community is dominated by cyanobacteria or blue-green algae. Many cyanobacteria possess gas vacuoles that confer positive buoyancy, allowing them to float into the illuminated surface waters during calm conditions and increase their light dose relative to other species. An unfortunate consequence is that unsightly and potentially hazardous cyanobacterial surface scums or blooms can result. Such algal blooms do not always reflect high algal abundance for in Lough Melvin they occur when relatively low concentrations of algae that are distributed over a great depth of water become concentrated at the surface and then are blown so as to accumulate along the shoreline. Given the historic records that show blue-green algae have dominated the phytoplankton in Lough Melvin since the 1950s, algal blooms have probably been a natural characteristic of the lake since before the onset of anthropogenic eutrophication. However, it can be argued that the increased nutrient status of the lake will increase the severity of these blooms given that nutrient limitation is now less likely to occur in the lake.
In contrast to the pelagic zone, which is the open water part of the lake system, where lack of light has limited responses to phosphorus enrichment, the littoral zone of the lake may be more sensitive. Filamentous algae often become dominant in areas subject to nutrient enrichment, displacing vascular aquatic plants, which are a primary reason for Lough Melvin’s designation as an SAC under the Habitats Directive. Filamentous algae can also impede water movement and cause the accumulation of silt and organic matter; factors that have been linked with the loss of high quality macrophyte communities. Littoral invertebrate communities also suffer through loss of suitable habitat with subsequent effects upon the consumer species that depend upon them. Additionally, pebble and gravel beds used for spawning by char will become unsuitable with excessive growths of algae. An example of this littoral response to nutrient enrichment can already be seen in Lough Melvin where the Garrison Wastewater Treatment Plant discharges directly into the lake. At this location, dense epilithic carpets of the filamentous green alga, *Cladophora glomerata* grow on the surfaces of rocks along a significant stretch of the littoral zone. At present, this species appears to be confined to this area of the lake.

### 6.1.3 Summary

Despite a period of significant nutrient enrichment the pelagic productivity of Lough Melvin remained largely unchanged between 1990 and 2004. If nutrient concentrations continue to rise the effects may be more varied and subtle than the typical phytoplankton response but no less serious in the potential for degradation of the ecosystem as a whole.

### 6.2 Methods

The sampling and analytical practices employed for monitoring Lough Melvin have been consistent during each period of sampling, so providing comparable results and an outline of these is given below. More detail is provided in the Strand 4 Technical Report.

#### 6.2.1 Lake sampling

Lough Melvin was sampled fortnightly between September 2006 and October 2007. A mooring buoy deployed over the deepest point (45m) maintained a constant sampling location. Discrete water samples were taken from the surface, 20, 30 and 40m depth using a Kemmerer water sampler (Wildco, USA). An integrated or composite sample from 0 m to 10 m was taken using an epilimnetic tube sampler (Lund & Talling, 1957). Zooplankton was sampled by vertical hauls over the depth of the water column using a 53µm mesh plankton net. Water transparency was measured using a Secchi disk. Depth profiles of dissolved oxygen (DO) and temperature were taken at 5m intervals using a YSI model 59 dissolved oxygen and temperature meter. In 2007, a YSI model 6600 sonde was deployed unattended over the deepest point of the lake at 38m depth between the 2nd May and 16th August to examine the impacts of stratification events on DO. The sonde recorded dissolved oxygen, temperature, conductivity and pH at ten-minute intervals for the duration of deployment.
6.2.2 Laboratory analyses

Analyses were carried out at the Agri-Food & Biosciences Institute (AFBI) according to well-established protocols that are subject to internal quality control and quality assurance schemes (ISO9001;2000). The dissolved fraction for analysis was defined by filtration at 0.45 µm. Total phosphorus (TP), total soluble phosphorus (TSP), soluble reactive phosphorus (SRP), total oxidised nitrogen (TON), nitrite (NO₂), ammonium (NH₄) and soluble silica (SiO₂) were determined using standard methods according to Gibson et al. (1980) and Jordan (1997). The soluble organic phosphorus (SOP) fraction was determined by subtraction of SRP from TSP concentrations and the particulate phosphorus (PP) fraction was determined by subtraction of TSP from TP concentrations. Nitrate was determined as nitrite (NO₂) subtracted from total oxidised nitrogen (TON). Samples for TON, NO₂, NH₄ and major ions were frozen prior to analysis. pH and conductivity were measured on unfiltered samples. Alkalinity was measured on filtered samples by Gran titration. Filtered samples were analysed for calcium, magnesium, potassium and sodium using a Perkin-Elmer atomic absorption spectrophotometer. Soluble chloride and sulphate were measured by ion chromatography. Chlorophyll a was determined by extraction into hot methanol (Talling & Driver, 1963). Phytoplankton samples were preserved with acidified Lugol’s iodine and enumerated from composite samples using an inverted microscope according to the Utermohl-Lund sedimentation technique (Lund et al., 1958). Zooplankton were preserved using 4% formaldehyde or 90% ethanol and enumerated using a Sedgewick-Rafter slide according to Wetzel & Likens (1979).

6.2.3 River Sampling

Figure 19: Water Sampling points in Lough Melvin catchment

ID Sample Points
0 Roogagh
1 Roogagh (Glen Bridge)
2 Roogagh (Glen East)
3 Roogagh (Barr of Drumgormly)
4 Muskenagh/Tullymore
5 Dawnexe
6 Kinlough
7 Clancy’s
8 Glesceff
9 Ballagh
10 County
11 County (Lattone Trb.)
12 County (Grafferty/Kiltyclogher)
13 County (from Dean’s & Lattone Lough)
14 Derrynesser
15 Breffni

Disclaimer
This information product has been derived from the best quality data available at the time of its development. The NRFB accepts no responsibility for the accuracy of this product.
Lough Melvin’s Water Quality

Rivers were sampled on the same day that lake monitoring took place and water samples analysed for pH, conductivity, alkalinity, major ions, phosphorus, nitrogen and soluble silica following the same protocols as for lake samples. The five largest rivers, accounting in total for 77% of the catchment, were monitored in all surveys with additional streams increasing coverage to >80% of the area (Table 14). In 2001/02 and 2006/07, the small stream at the village of Kinlough which receives effluent from a sewage treatment works was monitored in addition to the lake outflow (River Drowes). During 2001/02 and 2006/07, inflowing streams and rivers were sampled from the most downstream bridge or ford; these were all within a kilometre of the lake. In 1990 road closures around the lake made vehicle access problematic and rivers lying wholly within the Rol were accessed by boat where they entered the lake.

Table 14: Grid references of river sampling points and periods of sampling.

<table>
<thead>
<tr>
<th>River/Stream</th>
<th>Irish Grid reference</th>
<th>Catchment area (km²)</th>
<th>Year(s) sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muckenagh</td>
<td>G 918 543</td>
<td>10.4</td>
<td>1990, 2001/02, 2006/07</td>
</tr>
<tr>
<td>Roogagh</td>
<td>G 939 520</td>
<td>59.2</td>
<td>1990, 2001/02, 2006/07</td>
</tr>
<tr>
<td>County</td>
<td>G 937 507</td>
<td>56.1</td>
<td>1990, 2001/02, 2006/07</td>
</tr>
<tr>
<td>Ballagh</td>
<td>G 925 495</td>
<td>14.1</td>
<td>1990, 2001/02, 2006/07</td>
</tr>
<tr>
<td>Glenaniff</td>
<td>G 921 497</td>
<td>224</td>
<td>1990, 2001/02, 2006/07</td>
</tr>
<tr>
<td>Derrynaseer</td>
<td>G 889 559</td>
<td>2.4</td>
<td>2001/02</td>
</tr>
<tr>
<td>Breffni</td>
<td>G 876 531</td>
<td>1.95</td>
<td>2001/02</td>
</tr>
<tr>
<td>Kinlough</td>
<td>G 815 558</td>
<td>3.4</td>
<td>2001/02, 2006/07</td>
</tr>
<tr>
<td>Clancy’s</td>
<td>G 860 543</td>
<td>7.5</td>
<td>1990, 2006/07</td>
</tr>
<tr>
<td>Glen</td>
<td>G 938 515</td>
<td>2.1</td>
<td>1990</td>
</tr>
<tr>
<td>Drowes (outflow)</td>
<td>G 832 567</td>
<td>240.2*</td>
<td>2001/02</td>
</tr>
<tr>
<td>Drumgormly</td>
<td>H 020 485</td>
<td>737</td>
<td>2006/07</td>
</tr>
<tr>
<td>Glen East</td>
<td>G 994 517</td>
<td>10.60</td>
<td>2006/07</td>
</tr>
<tr>
<td>Glen Bridge</td>
<td>G 993 521</td>
<td>5.66</td>
<td>2006/07</td>
</tr>
<tr>
<td>Lattone</td>
<td>G 947 469</td>
<td>9.25</td>
<td>2006/07</td>
</tr>
<tr>
<td>Deans</td>
<td>G 978 454</td>
<td>2.17</td>
<td>2006/07</td>
</tr>
<tr>
<td>Sraduffy</td>
<td>G 973 453</td>
<td>10.99</td>
<td>2006/07</td>
</tr>
</tbody>
</table>

Note: * tributaries of the Roogagh River, † tributaries of the County River. * includes lake area of 22.7 km²

The Office of Public Works (OPW) operates a level recorder on the Lough at Lareen Bay and a hydrological station on the River Drowes just downstream of the Lough (G 832 567). In July 2001, the Rivers Agency of the Department of Agriculture and Rural Development installed level recorders on the County and Roogagh Rivers close to where they enter Lough Melvin. In October 2006, the Environmental Protection Agency (RoI) installed data loggers on the Glenaniff, Ballagh, Clancy’s, Breffni, and Kinlough Rivers.
6.2.4 Roogagh and County sub-catchment tributaries

To examine the effects of land use in greater detail three tributaries of the Roogagh and County Rivers were also monitored in 2006/07. These are the two largest rivers and account for approximately 50% of the phosphorus and nitrogen entering the lake. Additionally they drain extensive areas of coniferous forestry. To ensure a homogenous land use type, tributary sampling points were selected in the headwaters but some compromises were required between sampling a desired land use and the logistic constraints imposed by accessibility. On the Roogagh River the sampling point at Drumgormly principally drains the Big Dog and Tullyloughan Forests; that located at Glen East drains Little Dog and Conagher Upper Forests, while the Glen Bridge sampling point mostly drains unimproved natural grassland with some forest and peat land around Meenacloyabane and Tullyloughdaugh. On the County River, the Lattone tributary drains areas of forestry, peat land and steep scrub below Saddle Hill (this stream should not be confused with another that drains into Lattone Lough). The Sraduffy tributary, sampled at the village of Kiltyclogher, drains a variety of land uses from Dough Mountain down to the village, and Dean's tributary drains from Dean's Lough, an 8 ha lake that in turn drains areas of agricultural pasture and unimproved grassland from Scribbagh to Aghavanney.

6.2.5 Nutrient Loading and Export Estimation: Methodology for comparison between monitoring periods

To compare nutrient loadings and exports between monitoring periods a similar methodology was employed in 2006/07 to that used previously in 1990 and 2001/02 when catchment monthly flows were estimated from the monthly total runoff from the OPW flow recorder on the outflow and scaled for each catchment area assuming uniform runoff across the catchment. These were combined with monthly mean concentrations to give annual loadings to the lake. The contribution of small streams that were not monitored was estimated by calculating mean catchment nutrient export rates and scaling these up by the unmonitored area of the catchment.

At the time of preparing this report, flows from the outflow for 2006/07 were unavailable, but as five major rivers were gauged, their flow records were used to calculate mean monthly catchment runoff rates (m$^3$ month$^{-1}$). These were applied to data using the same monthly flow times monthly concentration methodology that was employed in 1990 and 2001/02. (Note the Strand 4 Technical Report provides a comparison of nutrient loading and export estimation methodologies. Alternative methods, such as deriving flow-weighted concentrations by linking sample concentration to instantaneous flows did not produce appreciably different outcomes compared to the method used in this section of combining mean monthly concentrations with mean monthly flows). GIS delineation of catchment boundaries was revised in 2006/07 to better reflect true boundaries. The total loading of each nutrient to the lake was calculated by summing the loadings from three contributing components:

\[ L' = (\sum L) + L_{UM} + L_{PS} \]  

Where:  
- \( L' \) = total nutrient load (tonnes)  
- \( L^c \) = annual catchment nutrient load (tonnes)  
- \( L_{PS} \) = loading from point source direct discharges (tonnes)  
- \( L_{UM} \) = loading from un-monitored catchment areas (tonnes)
Nutrient loads from each monitored catchment \((L)\) were then estimated by calculating a flow weighted mean concentration:

\[
FWMC = \frac{\sum (C_i Q_i)}{\sum Q_i} \quad \text{equation 2}
\]

Where:
- \(FWMC\) = flow weighted mean concentration (g m\(^{-3}\))
- \(C_i\) = concentration on day of sampling (g m\(^{-3}\))
- \(Q_i\) = mean daily flow on day of sampling (m\(^3\) sec\(^{-1}\), mean daily flow)

Catchment export rates are then:

\[
M^{\text{EXPORT}} = 10^3 \times L^C / A^C \quad \text{equation 3}
\]

Where:
- \(M^{\text{EXPORT}}\) = catchment export rate (kg ha\(^{-1}\) yr\(^{-1}\))
- \(A^C\) = catchment area (ha)

Loadings from un-monitored areas of the catchment \((L^{UM})\) were estimated using nutrient export rates from monitored catchments that were considered to be most representative in terms of land use. On this basis the un-monitored area of the catchment was divided into 7 discrete sections and loadings were calculated as the product of the area of each un-monitored area and the assigned nutrient export rate. Loadings from direct point source discharges \((L^{PS})\) which could not be directly monitored, in this case the Garrison wastewater treatment plant which discharges directly into the lake, were calculated by applying annual per capita nutrient contributions to the population of the village. This assumes that, on an annual basis, each person produces 0.76 kg TP, 0.64 kg TSP, 0.56 kg SRP and 2.4 kg of nitrogen as nitrate + ammonia.

### 6.2.6 Nutrient loading and export estimation within the Roogagh and County catchments

Sampling three tributaries within the Roogagh and County Rivers combined with the samples at their point of inflow to Lough Melvin divided these catchments into four discrete areas. Flow data for these rivers was recorded at the inflow at 15-minute intervals allowing the use of instantaneous flow data. The methodology used for the rivers was employed with the mean daily flow on the day of sampling substituted for the flow to the closest 15 minutes. Flows within each tributary catchment were then estimated as the proportion of the flow at inflow by area assuming uniform precipitation over each catchment. To calculate loadings and exports for the downstream area of the catchment between the inflow and the tributary sampling points, the loading and flows from the tributary catchments were summed and subtracted from the total loading and flow for the entire river at the downstream sample point.
6.3 Results

6.3.1 Lake and catchment hydrology

Between 1975 and 2002 runoff from the lake and catchment averaged 1100 mm year\(^{-1}\) but during the 1990, 2001/02 and 2006/07 monitoring periods runoff was above average at 1402 mm, 1277 mm and 1314 mm respectively so that water retention times were below average at 0.81, 0.89 and 0.87 years for each of these periods respectively. Based on flows measured in 2006/07, the distribution of effective precipitation (rainfall less evaporation) across the catchment shows an altitudinal effect with those rivers draining land on the high southern shore receiving a greater proportion of the rainfall (Table 15).

Table 15: Annual precipitation in 2006/07 for five major river catchments.

<table>
<thead>
<tr>
<th>River catchment</th>
<th>Annual Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glenaniff</td>
<td>1580</td>
</tr>
<tr>
<td>Ballagh</td>
<td>1349</td>
</tr>
<tr>
<td>Clancy’s</td>
<td>1331</td>
</tr>
<tr>
<td>County</td>
<td>1112</td>
</tr>
<tr>
<td>Roogagh</td>
<td>1112</td>
</tr>
</tbody>
</table>

6.3.2 Temperature & dissolved oxygen

During all monitoring periods the water column of Lough Melvin failed to develop a well defined, summer long thermal stratification, although short term temperature differences between the surface and bottom temperature were observed and have persisted for up to six weeks before poor weather allowed the lake surface to cool sufficiently to allow wind induced mixing. These cooling and mixing events were caused by frontal cooling associated with low pressure systems moving in from the Atlantic. The high frequency of water column mixing events is characteristic of the polymictic nature of the lake. Dissolved oxygen (DO) levels were high during each monitoring survey, typically > 90% the air saturated level and the frequent mixing of the entire water column prevented serious depletion of DO in the deeper waters. Continuous monitoring of temperature and DO in the deep water basin using an unattended sonde between May and August 2007 allowed some estimates to be made of the rate of DO depletion that could occur between mixing events (Figure 20).
The record from the sonde revealed two distinct periods of appreciable DO depletion when thermal stratification effectively isolated the deeper waters from the mixed, oxygenated surface waters. The first was between late May and early July and the second from early July to early August. Over these periods, respiratory consumption of DO in the deep waters was relatively constant and resulted in steady decreases in DO. The first period of stratification lasted 39 days and the second 26 days during which respiratory oxygen consumption occurred at a rate of 0.058 and 0.094 mg O₂ L⁻¹ day⁻¹ respectively. The reasons for the higher respiration rate observed during the second stratification period are unknown but may have simply reflected the increase in temperature that followed lake mixing in July combined with the high inputs of organic carbon from the catchment that resulted from the usually high summer rain and flows that accompanied the weather systems that led to the lake mixing. If the lake had not mixed in July 2007, when DO increased by approximately 1.5 mg L⁻¹, then an uninterrupted stratification to early August would have resulted in a minimum DO approaching the 6 mg L⁻¹ limit for salmonids. Alternatively, the first stratification period would have had to have continued for 83 days respectively for DO concentrations to fall to 6 mg O₂ L⁻¹.
6.3.3 Secchi Depth

The OECD trophic classification of lakes by Secchi depth is accurate where lake water has limited peat stain. However, in peat rich lakes sometimes referred to as dystrophic lakes, the severe light attenuation by humic compounds modifies the relationship between water clarity, measured by the Secchi depth and chlorophyll a. Thus for Lough Melvin, mean Secchi disk depths have been within the OECD eutrophic category despite chlorophyll being no higher than the lower end of the mesotrophic scale for lakes. No correlation between chlorophyll concentration and Secchi depth has been observed in Lough Melvin, demonstrating that algae do not contribute significantly to light attenuation.

Figure 21: Annual Secchi depth cycles at site 1 for 1990, 2001/02 and 2006/07.

Minimum Secchi depths are observed in early spring following peak runoff during the winter months that delivers greater amounts of dissolved and particulate material to the lake (Figure 21). Compared to 1990, a distinct decline in water clarity was observed in 2001/02 suggesting that loadings to the lake of light-attenuating organic matter from the catchment had increased. In the same way that clear felling on peat soils has been shown to increase phosphorus concentrations in drainage water, it has also been shown to increase exports of organic matter (Cummins & Farrell, 2003a, 2003b). The decline in water clarity observed in 2001/02 in conjunction with elevated lake phosphorus concentrations further reinforces the view that accelerated forestry operations following storm damage in 1999 was responsible for the increase in lake TP beyond the pattern indicated by measured TP loadings from the catchment.

Somewhat deeper Secchi depths, that imply an increased clarity of the lake, were observed in 2006/07 and are consistent with a degree of catchment recovery although they remain significantly shallower than observed in 1990, suggesting that organic matter exports are increasing over time.
6.4 Major Ion Chemistry, pH and conductivity

No appreciable change in the major ion chemistry of Lough Melvin has been observed during the course of the three monitoring surveys. Humic or dystrophic lakes can be acidic due to the influence of drainage water originating from peat lands but Lough Melvin and other humic stained lakes in the region are alkaline due to the high proportion of carboniferous rock in the catchment, and for this reason are relatively unique in the global context.

Table 16: Mean pH (-log [H+]), conductivity (µS cm⁻¹) and concentrations of major ions (mg L⁻¹)

<table>
<thead>
<tr>
<th>Ion</th>
<th>1990</th>
<th>2001/02</th>
<th>2006/07</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca²⁺</td>
<td></td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Mg²⁺</td>
<td></td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>Na⁺</td>
<td></td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td>K⁺</td>
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<td></td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td></td>
<td>15.2</td>
<td></td>
</tr>
<tr>
<td>Cl⁻</td>
<td></td>
<td>6.1</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>7.85</td>
<td></td>
</tr>
<tr>
<td>Conductivity</td>
<td></td>
<td>785</td>
<td>177</td>
</tr>
</tbody>
</table>

6.5 Nutrients and trophic status

Mean total phosphorus concentrations in Lough Melvin are currently within the limits for mesotrophic lakes (Table 17 and Figure 22). Mean and maximum chlorophyll values have consistently indicated mesotrophic status except in 2006/07 when concentrations were in the oligotrophic class for lakes. In Table 17 statistically significant differences between years are denoted in red for the comparison between 1990 vs 2001/02, blue for 1990 vs 2006/07, and black for 2001/02 vs 2006/07. Concentrations of TP, total soluble phosphorus and soluble reactive phosphorus were significantly lower in 1990 compared to either 2001/02 or 2006/07. No difference was observed for the phosphorus fractions measured in 2001/02 and 2006/07. Neither nitrate nor ammonium showed any difference between years. Concentrations of soluble silica were low in 1990 relative to the other years.

Table 17: Mean annual phosphorus, nitrogen and silica concentration for 1990, 2001/02 and 2006/07. NS = no significant difference at the p<0.05 level using paired t-test of monthly values.

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>2001/02</th>
<th>2006/07</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total phosphorus (µg P L⁻¹)</td>
<td>19</td>
<td>30</td>
<td>27</td>
<td>p&lt;0.005, p&lt;0.05, NS</td>
</tr>
<tr>
<td>Total soluble phosphorus (µg P L⁻¹)</td>
<td>13</td>
<td>21</td>
<td>18</td>
<td>p&lt;0.005, p&lt;0.005, NS</td>
</tr>
<tr>
<td>Soluble reactive phosphorus (µg P L⁻¹)</td>
<td>7</td>
<td>11</td>
<td>10</td>
<td>p&lt;0.01, p&lt;0.025, NS</td>
</tr>
<tr>
<td>Nitrate (mg N L⁻¹)</td>
<td>0.17</td>
<td>0.19</td>
<td>0.16</td>
<td>NS, NS, NS</td>
</tr>
<tr>
<td>Ammonia (mg N L⁻¹)</td>
<td>15</td>
<td>20</td>
<td>20</td>
<td>NS, NS, NS</td>
</tr>
<tr>
<td>Soluble silica (mg SiO₂, L⁻¹)</td>
<td>0.84</td>
<td>1.70</td>
<td>1.48</td>
<td>p&lt;0.001, p&lt;0.001, NS</td>
</tr>
</tbody>
</table>
6.6 Nutrient Budget

6.6.1 Nutrient Loadings: Comparisons between monitoring periods

Table 18 summarises annual nutrient loadings from the monitored catchments. The County River receives nutrients from the wastewater treatment plant (WWTP) at Kiltyclogher and these are included in the values presented. The WWTP at Garrison discharges directly into the lake but the discharge from the WWTP that serves the village of Kinlough is included in the loading of the Kinlough stream. At the whole catchment scale SOP loss decreased between 2001/02 and 2006/07 while PP and SRP loss increased, raising phosphorus loss (TP) overall (Figure 24). Loss intensities of all phosphorus fractions from each catchment area were greater in 2006/07 than observed in 1990. Although loadings are dependent upon flows, the values presented are comparable due to the similar amounts of precipitation observed during each period. In contrast nitrate plus ammonium inputs to the lake declined.

Table 18 (overleaf): Annual loading (tonnes) of soluble reactive phosphorus (SRP), total soluble phosphorus (TSP), total phosphorus (TP), particulate phosphorus (PP), soluble organic phosphorus (SOP), nitrate (NO3-N) and Ammonia (NH4-N) to Lough Melvin from river catchments in 1990, 2001/02 and 2006/07.
### Lough Melvin’s Water Quality

#### Figure 23: Major catchments areas and lake inflow (only) sampling points

<table>
<thead>
<tr>
<th>River/Stream</th>
<th>Year</th>
<th>SRP</th>
<th>TSP</th>
<th>TP</th>
<th>PP</th>
<th>SOP</th>
<th>NH₃-N</th>
<th>NO₃-N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roogagh</td>
<td>1990</td>
<td>1.24</td>
<td>2.19</td>
<td>2.67</td>
<td>0.48</td>
<td>0.95</td>
<td>2.13</td>
<td>10.37</td>
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<tr>
<td></td>
<td>2001/02</td>
<td>1.35</td>
<td>2.34</td>
<td>2.98</td>
<td>0.64</td>
<td>0.99</td>
<td>5.03</td>
<td>13.86</td>
</tr>
<tr>
<td></td>
<td>2006/07</td>
<td>1.39</td>
<td>2.44</td>
<td>3.13</td>
<td>0.69</td>
<td>1.05</td>
<td>2.84</td>
<td>10.08</td>
</tr>
<tr>
<td>County</td>
<td>1990</td>
<td>1.35</td>
<td>2.24</td>
<td>3.20</td>
<td>0.96</td>
<td>0.89</td>
<td>3.42</td>
<td>22.14</td>
</tr>
<tr>
<td></td>
<td>2001/02</td>
<td>1.13</td>
<td>2.24</td>
<td>2.95</td>
<td>0.71</td>
<td>1.11</td>
<td>1.40</td>
<td>18.07</td>
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<tr>
<td></td>
<td>2006/07</td>
<td>1.49</td>
<td>2.39</td>
<td>3.63</td>
<td>1.24</td>
<td>0.90</td>
<td>1.65</td>
<td>12.54</td>
</tr>
<tr>
<td>Glenaniff</td>
<td>1990</td>
<td>0.38</td>
<td>0.47</td>
<td>0.71</td>
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<td>0.68</td>
<td>9.82</td>
</tr>
<tr>
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<td>0.74</td>
<td>1.06</td>
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<td>0.33</td>
<td>0.68</td>
<td>9.78</td>
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<tr>
<td></td>
<td>2006/07</td>
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<td>0.96</td>
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<td>0.31</td>
<td>0.15</td>
<td>0.80</td>
<td>7.70</td>
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<tr>
<td>Ballagh</td>
<td>1990</td>
<td>0.18</td>
<td>0.28</td>
<td>0.42</td>
<td>0.14</td>
<td>0.10</td>
<td>0.38</td>
<td>6.43</td>
</tr>
<tr>
<td></td>
<td>2001/02</td>
<td>0.22</td>
<td>0.41</td>
<td>0.52</td>
<td>0.11</td>
<td>0.19</td>
<td>0.49</td>
<td>5.44</td>
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<tr>
<td></td>
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<td>0.53</td>
<td>0.70</td>
<td>0.17</td>
<td>0.19</td>
<td>0.58</td>
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<tr>
<td>Clancy’s</td>
<td>1990</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
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<td>0.01</td>
<td>0.03</td>
<td>0.61</td>
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<tr>
<td></td>
<td>2001/02</td>
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<td>0.09</td>
<td>0.06</td>
<td>0.16</td>
<td>1.48</td>
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<tr>
<td></td>
<td>2006/07</td>
<td>0.10</td>
<td>0.16</td>
<td>0.24</td>
<td>0.09</td>
<td>0.06</td>
<td>0.16</td>
<td>1.48</td>
</tr>
<tr>
<td>Muckenagh</td>
<td>1990</td>
<td>0.26</td>
<td>0.45</td>
<td>0.60</td>
<td>0.15</td>
<td>0.19</td>
<td>0.16</td>
<td>3.90</td>
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<tr>
<td></td>
<td>2001/02</td>
<td>0.26</td>
<td>0.48</td>
<td>0.62</td>
<td>0.14</td>
<td>0.21</td>
<td>0.33</td>
<td>2.71</td>
</tr>
<tr>
<td></td>
<td>2006/07</td>
<td>0.25</td>
<td>0.45</td>
<td>0.63</td>
<td>0.18</td>
<td>0.20</td>
<td>0.28</td>
<td>1.62</td>
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<tr>
<td>Glen</td>
<td>1990</td>
<td>0.32</td>
<td>0.49</td>
<td>0.64</td>
<td>0.15</td>
<td>0.17</td>
<td>0.43</td>
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<tr>
<td>Breffni</td>
<td>2001</td>
<td>0.02</td>
<td>0.03</td>
<td>0.08</td>
<td>0.05</td>
<td>0.01</td>
<td>0.03</td>
<td>0.42</td>
</tr>
<tr>
<td>Derrynaseer</td>
<td>2001/02</td>
<td>0.06</td>
<td>0.12</td>
<td>0.15</td>
<td>0.03</td>
<td>0.06</td>
<td>0.07</td>
<td>0.81</td>
</tr>
<tr>
<td>Kinlough</td>
<td>2001/02</td>
<td>0.18</td>
<td>0.31</td>
<td>0.42</td>
<td>0.11</td>
<td>0.13</td>
<td>1.92*</td>
<td>2.46*</td>
</tr>
<tr>
<td></td>
<td>2006/07</td>
<td>0.20</td>
<td>0.27</td>
<td>0.40</td>
<td>0.13</td>
<td>0.07</td>
<td>1.46*</td>
<td>1.46*</td>
</tr>
</tbody>
</table>

* denotes NO₃-N + NH₄-N

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**Disclaimer:**

This information product has been derived from the best quality data available at the time of its development. The NRFB accepts no responsibility for the accuracy of this product.
Figure 24: Annual total phosphorus loading to Lough Melvin from inflowing rivers

Figure 25: Annual nitrogen (NO₃ + NH₄) loading to Lough Melvin from inflowing rivers

6.6.2 Changes in the intensity of phosphorus loss: 2001/02 - 2006/07

Within the Roogagh River catchment, which is the most heavily forested of the inflowing rivers to Lough Melvin, the intensity of SRP, SOP and PP losses was unchanged. The intensity of SOP loss decreased in all other monitored river catchments. The intensity of PP loss increased from all catchments except from the Ballagh, which was unchanged. Startling increases in the loss intensity of SRP from the Glenaniff and Ballagh catchments were observed. The flow-weighted mean SRP concentration in these catchments increased by 88% and 47% respectively between 2001/02 and 2006/07 and 28% and 40% between 1990 and 2001/02. Within the Glenaniff catchment the increase of TP loss intensity was entirely due to greater loss of SRP. For the Ballagh River, increases in the intensity of SRP and PP losses accounted for 70% and 30% of the increase in TP loss respectively. The intensity of SRP loss from the Muckenagh catchment decreased to a similar level to that observed in 1990 and, coupled with lower SOP loss intensity and a slight increase in PP loss intensity, this was the only catchment to show a reduction in the intensity of TP loss since 2001/02. Loss intensities of SRP and PP from the County River, which were similar in 1990 and 2001/02, increased markedly by 25% and 65% respectively.
6.6.3 Principal sources of increasing phosphorus loss: 1990 – 2006/07

Percentage increases in nutrient loadings can be used to examine how individual subcatchments contributed to the overall increase in TP loading, highlighting areas of the Lough Melvin catchment where phosphorus export intensity has risen (Figure 26). Since 2001/02, the intensity of phosphorus loss from the Roogagh River has remained quite static with a 10% contribution to the increase in TP loading due to greater flows during this period. Between 1990 and 2001 TP export intensity rose within this catchment and as 43% of the land area of this river catchment is occupied by coniferous forestry this provides support for the hypothesis that accelerated clearfelling forestry in 1999 resulted in a pulse of phosphorus to the lake. On this basis, between 2001/02 and 2006/07, export rates of phosphorus would have been expected to decline as the catchment recovered from the forestry related perturbation. However, there was no discernible change in phosphorus loss intensity between these periods. This need not be inconsistent with a forestry related pulse, for any decrease could be countered by increases in agriculture related diffuse losses of phosphorus. In this respect, of the larger catchments the Roogagh, which is the most heavily forested, was unusual in showing no marked increase in phosphorus loss between 2001/02 and 2006/07. The minimal forested areas of the Ballagh and Glenaniff catchments, combined with an absence of urban settlements, indicate that the increases in phosphorus loss are more likely to be related in some way to agricultural land use management.

The substantial contribution to increased particulate phosphorus loading from the County River is a serious cause for concern. Future measures aimed at curbing and reducing P inputs to the lake could therefore be most effective by targeting this sub-catchment together with the Ballagh and Glenaniff catchments.

![Pie chart of river contributions to the increase in total phosphorus loading between 1990 - 2001/02 and 2001/02 - 2006/07](image)

Whilst increases in SRP export rate were observed from all river catchments, the most substantial increases were observed in the exports from the southern area of the catchment via the adjacent Glenaniff, Ballagh and County Rivers (Figure 27). The increase in particulate P loading was largely restricted to the County River catchment. The increase indicated for the small streams component of the PP loss is likely an overestimate as this is based upon average catchment export rates and
thus reflects a strong contribution from the County River, which by area accounts for approximately a quarter of the catchment. For comparative purposes, the area of the small streams component represents approximately 18% of the catchment.

![Pie chart showing the river contributions to the increase in SRP and PP loading observed between 2001/02 and 2006/07.](image)

**Figure 27:** Pie charts showing the river contributions to the increase in SRP and PP loading observed between 2001/02 and 2006/07.

### 6.6.4 Kinlough WWTP 2001/02 & 2006/07

The small stream into which the Kinlough WWTP discharges effluent was monitored in 2001/02 and 2006/07 (Table 19). The census of 2001/02 recorded a population in the village of 300 persons, but by 2006/07 this had more than doubled to 626 persons. Loadings from the WWTP can be estimated by multiplying the population by the per capita loadings for each of the phosphorus fractions. These values can then be compared with exports of phosphorus from the stream that are based on the water samples taken. Given that the phosphorus export from the stream would include phosphorus from, for example, agricultural land and septic tanks, it would be expected that the measured stream export of phosphorus should be larger than the estimated export of phosphorus from the WWTP discharge. Such a difference was observed in 2001/2 when the WWTP contributed only 55% of the measured TP export from the stream. However, despite the increased population of Kinlough by 2006, the measured annual TP export from the stream declined slightly from 0.42 to 0.40 tonnes in 2006/07. The most probable explanation for the failure of the stream loading to respond to the increased population of Kinlough was the implementation by Leitrim County Council of phosphorus removal at the Kinlough WWTP in 2006. That the reduction in stream loading was not larger as a result of phosphorus removal is likely to be a reflection of the fact that the WWTP remains overloaded (refer to Section 9).

| Table 19: Loading (tonnes year\(^{-1}\)) of phosphorus fractions to Lough Melvin from the Kinlough stream in 2001/02 and 2006/07 according to observed concentrations and calculations by per capita contribution. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| **Year**        | **2001/02**     | **2006/07**     |
|                 | **per capita**  | **Stream load** | **per capita**  | **Stream load** |
|                 |                 | **observed**    |                 | **observed**    |
| SRP             | 0.168           | 0.18            | 0.35            | 0.2             |
| TSP             | 0.192           | 0.31            | 0.4             | 0.23            |
| TP              | 0.23            | 0.42            | 0.48            | 0.4             |
6.7 Phosphorus loading model

The Vollenweider (1976) loading relationship, from which the OECD (1982) general equation is derived, correlates lake TP concentration with the mean inflow TP concentration weighted by the water retention time. Foy (1992), in a study of 10 Northern Irish lakes, found that this general equation underestimated TP concentration in lakes in NI and derived a relationship that more closely fitted observed concentrations. This equation has been used here to provide estimates of TP in Lough Melvin based on the measured loadings of TP to the lake. These predictions of lake TP in Lough Melvin agree well with the observed mean lake concentrations except for 2001/02 where the measured lake TP is appreciably higher than predicted by the concurrent catchment loading of TP.

As noted earlier, this discrepancy is taken as evidence for a pulse of TP delivered to the lake in 1999/2000. The decline in lake TP observed between 2002 and 2004 supports this hypothesis as the decline is consistent with a temporary input of TP to the lake being flushed from Lough Melvin.

The lake TP observed in 2006/07 is consistent with the TP exports for that period, demonstrating that phosphorus export intensity in the catchment has gradually increased over that recorded in 1990. Lake TP concentrations were consistent between 1990 and 1995/96 suggesting that increases of catchment export began to occur at some point after this. Figure 28 shows the rise in lake TP from this point to the most recent data. The 2001/02 data are excluded from this relationship as this year did not fit with the observed pattern of loadings to the lake from the catchments.

Figure 28: Observed lake TP and lake TP concentration predicted from contemporary TP loadings to the lake. Trend lines plotted from 2008 show predicted lake TP concentrations.

Notes
(a) Trend lines exclude the observed 2001/02 outlier, (b) The near identical lake TP concentrations observed in 1990 and 1995/96 suggest that similar inputs of TP to the lake for these periods so that the predicted lake TP based on loadings measured in 1990 is shown for 1995/96.
6.7.1 Nutrient sources within the Roogagh and County River catchments 2006/07

The six additional monitoring points in the catchments of the Roogagh and County Rivers enabled an assessment to be made of the spatial variation in nutrient losses within each catchment and relate this to the respective land use (Figure 37). Within the Roogagh River catchment each of the monitored tributaries and the remaining downstream portion of the catchment exported TP approximately in accordance with their respective areas (Figure 30). Rates of soluble reactive phosphorus export were also relatively uniform. The non-forested but upland Glen Bridge tributary had the lowest nutrient export rates of all phosphorus and nitrogen fractions. The highest export was from the upland but forested Drumgormly catchment. The second highest loss was from the forested Glen East tributary. In both the Drumgormly and Glen East catchments the higher TP export rates were largely due to greater exports of particulate phosphorus. The downstream ‘remainder’ section is devoted to agriculture and this portion of the Roogagh catchment had significantly higher export rates of SOP and nitrate than any of the tributaries. Overall, the extent to which land use determines phosphorus and nitrate export intensity can be seen by comparing low export rates from the unimproved Glen Bridge tributary catchment with the remaining sub-catchments dominated by either agriculture or forestry.

Figure 29: Percentage land use for tributary catchments of the Roogagh and County River sub-catchments (CORINE, 2000).

Note: Proportions indicated for ‘Agricultural use’ are the sum of the CORINE categories ‘Land principally occupied by agriculture with areas of natural vegetation’ and ‘Pastures’. 
Lough Melvin’s Water Quality

Figure 30: Pie charts showing: left) the proportions by area of the Roogagh River occupied by each monitored sub-catchment tributary and the remainder of the catchment and right) their contribution to the total phosphorus load.

Figure 31: Export rates from sub-catchments of the Roogagh River for total phosphorus (TP), particulate phosphorus (PP), soluble organic phosphorus (SOP), soluble reactive phosphorus (SRP) and ammonia (NH4) and nitrate (NO3) .
Between 2001/02 and 2006/07, the County River was responsible for 28% of the increases in SRP loading, 51% of the increased PP loading and 40% of the increased TP loading to Lough Melvin, highlighting the need for greater resolution in relation to nutrient sources within this catchment. Based on per capita loadings, the urban contribution of nutrients from the Kiltyclogher WWTP accounted for a small proportion of the overall nutrient load at: 7% of the SRP load, 2% of the PP load, 2% of the SOP load, 4% of the TP load and 4% of the nitrogen load ($\text{NO}_3+\text{NH}_4$). The estimated population increase of 16 people in Kiltyclogher between 2001/02 and 2006/07 could therefore only account for a negligible fraction of the greater exports observed over time from the County River catchment. The additional monitoring of the County River allowed nutrient exports to be defined for four sections of the catchment. Nutrients from Kiltyclogher WWTP discharge into the lower reaches of the river and are included in the ‘remainder’ section of the sub-catchment. Data for this section is presented in Figure 32 and Figure 33 have been corrected for this input and therefore are for rural sources of nutrients.

As for the Roogagh River, the agriculturally dominated downstream portion of the County River exported nitrate per unit area at rates three times greater than the upstream sections of the catchment. This downstream portion of the catchment also exported disproportionately more TP but this was principally in the particulate phosphorus fraction (Figure 33). The tributaries export rates of the other phosphorus fractions were relatively uniform although SRP exports increased with increasing proportions of coniferous forestry.

![Figure 32: Pie charts left) the proportions by area of the County River occupied by each monitored tributary and the remainder of the catchment and right) their contribution to the total phosphorus load from the County River.](image-url)
6.7.2 Nutrient export intensities in 2006/07

The measured export rates of TP, nitrate and ammonium normalised on a per unit area basis are summarised in Figure 34 and Figure 35 and include river catchment export rates where they enter Lough Melvin as well as rates from the sub-catchments of the County and Roogagh Rivers. Of those streams that enter Lough Melvin, the Kinlough stream, which receives effluent from the Kinlough WWTP showed the highest nutrient loss intensities. The highest individual TP loss rate was the downstream section of the County River which as has been discussed reflected a high loss of particulate phosphorus. Otherwise catchments with large proportions of agricultural land and/or coniferous forestry displayed the greatest loss rates of TP. Nitrate loss intensities, with the exception of the Muckenagh catchment, were higher in catchments dominated by agricultural land use. Although the Ballagh and Glenaniff catchments have been highlighted for their increased losses of phosphorus observed over time, the phosphorus export rates per unit area from these catchments were among the lowest in 2006/07.
Figure 34: Ranked total phosphorus export rates for catchments in 2006/07.

Figure 35: Ranked nitrate (NO$_3$-N) and ammonia (NH$_4$-N) export rates for catchments in 2006/07.
6.8 Biological Limnology

Marked changes in the zooplankton community and more subtle changes within the phytoplankton community were observed between 1990 and 2007 and suggest that inputs of terrestrially derived matter may have increased, stimulating components of the plankton either directly or via the microbial loop.

6.8.1 Phytoplankton

The abundance of dinophytes and cryptophytes in the phytoplankton was significantly greater in 2007 than in previous years and two additional species were recorded for the first time. Many species of the dinophyta and cryptophyta have the capacity for mixotrophic nutrition; that is they can supplement photosynthetic production by the assimilation of dissolved and/or particulate organic compounds and thus possess a competitive advantage in light limited conditions.

Humic stained lakes such as Lough Melvin receive large amounts of terrestrial organic matter derived from the catchment, which can serve as significant food supplements for mixotrophic algae & ciliates. Increases in the abundance of mixotrophic algae therefore suggest that the supply of terrestrial organic compounds may have increased.

![Diagram](image)

Figure 36: Simplified diagram describing potential pathways of terrestrial support of components of a pelagic food web.

6.8.2 Zooplankton

Higher abundances of the dominant rotifer species were observed in 2001/02 and 2006/07 compared to 1990. Additionally the rotifer, Conochilus unicornis was recorded for the first time in 2001/02. Rotifers depend to a large extent upon bacterial grazing to gain nutrition and can therefore be expected to benefit from increased bacterial production resulting from conditions of increased organic matter loading that provides a greater abundance of bacterial substrates. Peak abundances of C. unicornis were consistently observed during the late autumn, when algal abundances are low suggesting utilisation of other dietary sources. In fact colonies were sufficiently abundant in 2006 to allow carbon and nitrogen stable isotope analysis on three consecutive fortnightly occasions, the results of which were consistent with a diet composed almost exclusively of terrestrially derived organic matter.
The cyclopoid copepod, *Cyclops strenuus abyssorum* showed significantly greater abundances in each successive monitoring period. This species is omnivorous and feeds raptorially with rotifers and ciliates constituting a large part of its diet. Greater production of these prey items in response to increased organic matter loading and subsequent bacterial production may therefore be stimulating greater production by *Cyclops*.

Bacteria, ciliates, protozoa and mixotrophic algae that can utilise terrestrially derived organic matter represent potential trophic pathways to zooplankton, which can then be consumed by fishes such as Arctic char and sonaghan. Although zooplankton will select the most energetically optimal food source where possible, in this case algae, periods of low algal productivity will increase dietary reliance upon sources of nutrition derived from terrestrial organic matter. If loadings of terrestrial organic matter to the lake were to increase, light attenuation would increase simultaneously resulting in a greater degree of light limitation upon algae and the system will be expected to shift to a greater reliance upon terrestrial organic matter. The lower nutritional quality of catchment derived organic matter relative to primary production by algae can therefore be expected to result in lower overall biomass production, particularly for species that rely upon the pelagic food web such as Arctic char and sonaghan.

### 6.9 Discussion

#### 6.9.1 Temperature and dissolved oxygen status

Temperature and dissolved oxygen (DO) are key factors driving the distribution of aquatic species. They are inherently linked in lentic freshwaters by a negative solubility relationship and the potential for thermal stratification leading to hypolimnetic deoxygenation. Lough Melvin’s designation as a Special Area of Conservation stems, in part, from its unique salmonid community and these require cool, well-oxygenated water. Their long-term survival in Lough Melvin relies upon the persistence of these conditions throughout the year.

Lethal temperatures for Arctic char have been experimentally measured at between 18.7 – 26.6°C depending on the life history stage (alevins, fry or parr) and temperature acclimation history (Baroudy & Elliott, 1996). Therefore a cool, well-oxygenated deep-water zone that persists throughout the year is of paramount importance to the survival of Arctic char in Lough Melvin as this species is the most temperature sensitive salmonid in the lake. The mean annual temperatures at 45m in Lough Melvin have risen in each successive monitoring period, significantly so between 1990 and 2006-7 (paired t-test, t = 4.08, p < 0.005). The increase in temperature in the Lough over the monitoring period was 1.29 ºC (0.59 – 1.98; 95% CL) and therefore is greater than the global temperature increase of approximately 0.15ºC over the same period (Brohan et al., 2006). Local weather variations in response to changes in the North Atlantic oscillation appear to exert a large effect on Lough Melvin’s temperature regime (Figure 37). However, maximum bottom temperatures in Lough Melvin have yet to exceed 17ºC and indicate that the habitat is currently favourable for salmonids in this respect.
Despite two distinct periods of deoxygenation in the deep water basin during stratification events in 2007, DO concentrations did not drop to the threshold value of 6 mg O₂ L⁻¹ specified for salmonid waters under the EU Fish Directive. Had the two periods of stratification not been separated by a short period of poor weather, DO concentrations by the second turnover event would only have decreased to an estimated 7 mg O₂ L⁻¹.

Currently the likelihood of continuous calm weather occurring for a period in excess of 2 months on Lough Melvin appears to be low. Lake morphometry, local catchment topography and a coastally exposed location ensure that winds are sufficient to prevent strong persistent stratification from developing. Stratification observed to date in Lough Melvin can be considered weak compared to lakes that permanently stratify. Without changes in climate and/or significant increases in productivity and/or external organic matter loading, DO concentrations are likely to remain favourable for salmonids. However, this conclusion must be tentative as the climate is moving towards previously uncharted territory and the interactions between the local climate and the thermal stability of the lake merits further study.

### 6.9.2 Trophic Status and the Catchment

The low algal abundances recorded during the spring and summer of 2007 are difficult to explain in view of similar nutrient concentrations (N, P, SiO₂). Secchi depths indicated a similar light climate to those observed during previous monitoring surveys where algal abundances were significantly higher. The associated studies carried out as part of the Lough Melvin Nutrient Reduction Programme have shown that for much of the year the higher trophic levels in Lough Melvin are dependent on inputs of carbon from the catchment rather than algal production within the lake. It is known that dissolved organic matter loading from the catchment will reduce the light climate and so depress...
photosynthesis and algal production within the lake. Additionally, the trophic studies have shown that the zooplankton in Lough Melvin are subsidised by organic carbon from the catchment which, in turn, may enable the zooplankton higher populations which then depress (through enhanced grazing pressure) algal abundances in the lake.

Lough Melvin continues to fall within the OECD (1982) mesotrophic category based upon mean annual total phosphorus concentration. There is evidence of some decline in concentrations since the peak observed in 2001-02. Lower silica concentrations and deeper Secchi disk depths observed in 2006-07 are consistent with the idea that the catchment may be recovering from a perturbation. Nevertheless, there was no statistically significant difference between monthly total phosphorus concentrations in 2001-02 and 2006-07 and total phosphorus remains a serious cause for concern. While the impacts of a potential catchment perturbation may be relatively short lived, increases in loading from diffuse sources are contributing to rising levels.

Both mean and maximum chlorophyll values recorded since the 1990s have consistently shown oligo-mesotrophic characteristics. In concert with the annual wind-induced mixing regime a threshold level of nutrients exists in humic stained lakes beyond which light limits phytoplankton productivity rather than nutrients. Under such circumstances, the use of chlorophyll concentrations for trophic classification becomes inadequate in much the same way as Secchi disk depths fail to reflect algal abundance. The development of additional parameters for the trophic classification of humic stained lakes would be beneficial both for individual lake assessment and for examining lake responses over longer timescales (White & Irvine, 2003; McCarthy et al., 1999).

The results of three annual monitoring surveys have shown the absence of a phytoplankton response to phosphorus enrichment. On the basis of the 1990 results phosphorus limitation could be expected to occur at some point below a mean annual concentration of 19 µg L$^{-1}$. At the whole lake scale these results are unlikely to provoke calls for urgent action. However, the higher phosphorus concentrations observed in recent years relative to 1990 can be expected to result in a greater frequency and severity of algal blooms. Many areas used for recreational purposes are situated in relatively quiet backwaters where unsightly and in some cases hazardous cyanobacterial surface scums form most rapidly, posing a serious threat to the amenity value of the lake.

Widespread increases in phosphorus export intensity have occurred in the catchment. The south-east area of the catchment, largely devoted to agriculture, has consistently shown the greatest increases. Accumulation of soil phosphorus, poor septic tank functioning and a number of agricultural practices are highlighted as potential causes. Forested areas show among the highest phosphorus export rates but some of the lowest nitrate export rates, while agricultural areas displayed both high phosphorus and nitrate export rates. Discharges of effluent from the three waste water treatment plants within the catchment presently play only a small role in the enrichment of the lake. However there are numerous new developments and as their associated human populations expand they have the potential to increase phosphorus inputs to the lake.

The gradual increase in phosphorus loading from diffuse sources is currently the most significant long term cause of enrichment of Lough Melvin. However the rapid increase of phosphorus export following clear felling, although relatively short lived, has highlighted the need for an integrated approach to forest management for the Lough Melvin catchment as a whole. For example annual limits of the areas subjected to clear felling should be managed on a catchment basis so as not to jeopardise the status of the lake.
Lough Melvin’s Water Quality

6.9.3 Summary

Widespread increases in phosphorus export intensity have occurred in the catchment. The south-east area of the catchment, largely devoted to agriculture, has consistently shown the greatest increases. Phosphorus loading from diffuse sources is the most significant cause of the recent enrichment of Lough Melvin. Accumulation of soil phosphorus, poor septic tank functioning and a number of agricultural practices are highlighted in this report as potential causes.

Rapid increases of phosphorus export following clear felling events, although relatively short lived, have highlighted the need for a measured approach and suggest that an annual limit should be set (refer 6.10).

Discharges of effluent from the three waste water treatment plants within the catchment presently play a negligible role in the enrichment of the lake. However, there are numerous new developments and the per capita nutrient burden upon the lake is expected to rise considerably in the future.

The annual cycles of temperature and dissolved oxygen concentrations have been relatively consistent since 1990 and remain favourable for aquatic biota. Periods of stratification were observed in 2007 during which dissolved oxygen became depleted in the deeper waters, however these were of sufficiently short duration to allow dissolved oxygen to remain sufficiently high so as not to warrant concern.

The principal components of the zooplankton and phytoplankton communities have not displayed any marked shifts over time. However, the abundances of species with the capacity to utilise terrestrial organic matter have significantly increased, suggesting that such exports have increased.

The low algal abundances observed in 2006/07 may simply reflect a natural fluctuation. However, there is evidence to suggest that due to the greater organic matter loading, attenuation by dissolved terrestrially derived compounds may have increased the degree of light limitation and thus decreased primary production. Additionally they may reflect increased predation by zooplankton on phytoplankton, with the zooplankton populations stimulated by increased organic matter loadings from the catchment. The potential for a decrease in the overall productivity of the lake due to higher catchment inputs of organic carbon exists and may be of significance in regard to the long term quality of the lake as a recreational fishery.

Lough Melvin currently fulfils the criteria required to justify designation as a mesotrophic lake. Nevertheless, the clear upward trend in phosphorus loading and lake concentration demonstrates that action must be taken to avoid further deterioration of the habitat and a breach of the lower eutrophic threshold.

6.10 Concentration and Load Targets

To maintain the ecological, social and economic values that Lough Melvin supports, the concentration of phosphorus in the lake must be maintained at a sustainable level. Current nutrient loads to Lough Melvin are approximately 13 tonnes of P per year with the concentration in the lake now averaging 27µg L⁻¹. This is a 50% increase on what are considered to be base levels in 1990 of 19µg L⁻¹.

Draft conservation objectives developed for the Lough Melvin NI SAC identify an upper limit of 25µg L⁻¹ of phosphorus for Lough Melvin (EHS, 2007b). This figure aligns with the policy of setting a maximum increase of 20% on baseline values as outlined in the Total Phosphorus Water Quality Standards for Scottish Freshwater Lochs Policy No. 16 (SEPA, 2002).

A TP concentration of between 19 and 25µg L⁻¹ equates to an average nutrient loading of less than 10 tonnes to 12 tonnes per annum. Therefore, a reduction in loads of approximately 3 tonnes (23%) would be required to reduce the concentration in Lough Melvin to baseline levels.
Agriculture
7.1 Agriculture and water quality

7.1.1 Introduction

In the advent of the Common Agricultural Policy (CAP) and associated Government policies, there has been a departure from traditional extensive farming practices comprising grazing, haymaking and out-wintering of cattle towards a more intensive form of agriculture in the Lough Melvin catchment. This has included increased fertilisation, silage making, and winter housing of cattle (with associated manure storage and disposal management), and has had the overall effect of increasing the agricultural contribution of phosphorus (P) loading to surface waters (McGarrigle & Champ, 1999).

Agriculture has been identified as one of several sources of P to Lough Melvin. Previous reports (Girvan & Foy, 2003) on water quality in the catchment demonstrated that agriculture was the largest single contributor to the P loadings.

The overall aim of this study was to employ an integrated approach involving the collation of quantitative and qualitative information that could be used to identify the threats posed by agriculture to the water quality and ecological status of Lough Melvin and to develop and cost a suite of agri-environmental measures to address these risks. Specifically this involved collation of existing datasets to assess landscape conditions and agricultural activities in the catchment, issue identification with stakeholders, risk assessments for individual farms, and development of mitigation measures that would be (i) environmentally effective, (ii) implementable and cost effective, (iii) practical and attractive for uptake by the farmer. We considered it essential that the suite of agri-environmental measures would achieve a high degree of acceptance by the stakeholder (i.e. farmer) community, with a view to maximising participation, implementation and success. To this end, we developed a participatory approach in this study, in which we consistently and formally integrated farmers’ participation, opinion and knowledge into each module of our research.

7.1.2 Phosphorus use in agriculture

Agronomically, P is essential for crop growth. P advice for grassland is based on an index system, which depends on the level of plant available P in the soil and is measured using Morgan’s extractant in RoI (Coulter, 2004) and Olsen P in NI. The P indices and corresponding STP ranges are summarised in Table 20 and Table 21. For Morgan’s P, soils in Index 1 are deficient in P and may require a build-up in P reserves depending on their landuse. For grazing systems (intensive and extensive) an Index 3 is recommended. Soils in Index 4 have elevated P reserves and are unlikely to respond to additional P applications (Schulte & Herlihy, 2007). Phosphorus is applied to grasslands in NI based on the Olsen P Index. Indices range from 0 (deficient) to 9 (very large), with the majority of fields having an index of 1-4 (Table 21). The target index for grassland is Index 2, which ranges from 16-25mg P L⁻¹. There is an increased risk of P loss to water at and above index 4. At Index 3, it is advised that care is taken to ensure that the total input of P from fertiliser and organic manure does not exceed the total amount of P removed by the crop.

<table>
<thead>
<tr>
<th>Soil P Index</th>
<th>Morgan P range (mg L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0-3.0</td>
</tr>
<tr>
<td>2</td>
<td>3.1-5.0</td>
</tr>
<tr>
<td>3</td>
<td>5.1-8.0</td>
</tr>
<tr>
<td>4</td>
<td>&gt;8.0</td>
</tr>
</tbody>
</table>
Table 21: Olsen Soil P index

<table>
<thead>
<tr>
<th>Soil P Index</th>
<th>Olsen P range (mg L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0-9</td>
</tr>
<tr>
<td>1</td>
<td>10-15</td>
</tr>
<tr>
<td>2</td>
<td>16-25</td>
</tr>
<tr>
<td>3</td>
<td>26-45</td>
</tr>
<tr>
<td>4</td>
<td>46-70</td>
</tr>
<tr>
<td>5</td>
<td>71-100</td>
</tr>
<tr>
<td>6</td>
<td>101-140</td>
</tr>
<tr>
<td>7</td>
<td>141-200</td>
</tr>
<tr>
<td>8</td>
<td>201-280</td>
</tr>
<tr>
<td>9</td>
<td>&gt;280</td>
</tr>
</tbody>
</table>

Maintenance of satisfactory level of productivity requires the application of nutrients in the form of fertilisers or manures, but increasing the nutrient supply to land also increases the relative risk of nutrient loss to water. Soil has been shown to have a finite capacity to hold P and when this limit is reached the concentration in soil water increases (Nash & Halliwell, 1999). A number of studies have demonstrated a positive relationship between the STP level and P loss to water (McDowell et al., 2001; Tunney et al., 2000; Pote et al., 1999; Sharpley et al., 1996). Whilst this P loss can be agronomically insignificant, it can have significant limnological implications in the form of eutrophication with concomitant environmental and economic costs.

### 7.1.3 Phosphorus and the environment

Throughout Europe eutrophication has become a pervasive problem and the diffuse P losses from agriculture are contributing to it (Ulen & Jakobsson, 2005). According to the European Environment Agency (2005), the contribution of agriculture to the annual P loads to EU waters ranges from 25-75%. The Environmental Protection Agency (EPA) has cited eutrophication of rivers and lakes due to P losses from agriculture as the most critical impact of Irish agriculture on water quality, accounting for over 70 per cent of the P load reaching inland waters (EPA, 2004; EPA, 2006b). Most recent results of lake water quality surveys indicate that measures, primarily aimed at reducing diffuse source pollution, are required to improve the water quality of those lakes (EPA, 2006b). The Nitrates Directive (91/676/EEC) and the Water Framework Directive (WFD) (2000/60/EC) are aimed to address these concerns and to modify nutrient management practices so that the good ecological status requirement of the WFD can be achieved by 2015.

Nutrient losses from agriculture may have point or diffuse origins. Diffuse P losses are not evenly distributed within agricultural land but show a wide spatial variation according to hydrology, agronomic management and soil type (Sonneveld et al., 2006). Schulte et al. (2006) found that the risk for P loss is highest in the western and northern parts of the RoI because of the prevalence of poorly draining soils and high net rainfall levels resulting in water surpluses and pathways for P loss for a large proportion of the year, and that this would be particularly problematic where P sources were allowed to build up. While the physical landscape characteristics and climate play a fundamental role in determining the potential for P loss in any given area, historic and current nutrient inputs and land management practices can exacerbate it (Withers & Lord, 2002).

In Ireland studies on agricultural catchments with similar soil test phosphorus (STP) levels have found annual P loss rates ranging from 0.23kg P ha⁻¹ to 3.13kg P ha⁻¹ depending on their soil chemistry and hydrological response (Jordan et al., 2005), demonstrating that P loss at catchment scale depends on the capacity of the soil to deliver P and on the hydrology to remove it. In many studies most P was found to be lost during low frequency high intensity rainfall events. For example,
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Tunney et al., (2000) found that 40% of the annual DRP exported from field plots occurred during a period of four days. Jordan et al. (2007), using a continuous bank-side analyser to characterise P transfers in a rural catchment found that acute, storm-dependent transfers accounted for 92% of the P load measured over the study period.

The dominant form of runoff in Ireland is saturation excess overland flow from variable source areas which expand and contract seasonally as well as during storm events (Daly et al., 2000). Where the VSA occurs in association with high STP levels, critical source areas (CSAs) for P develop, which are the main source of P exported from a catchment (Gburek & Sharpley, 1998; Pionke et al., 2000). Other pathways for P loss include subsurface pathways (groundwater flowpaths or by field drains), roadways, ditches and streams/rivers.

Phosphorus may be lost in dissolved or particulate form. In arable land, where erosion/detachment is the dominant mobilisation process occurring, particulate P (PP) is the main form of P exported, while in grasslands, where solubilisation is the dominant mobilisation process, dissolved P (DP) is the main form of P exported. However, the form of P exported will vary between catchments as demonstrated in a study by Douglas et al. (2007) which found high (>50%) PP transfers in a grassland catchment in NI. In addition, the direct removal of freshly applied slurry and fertiliser during rainfall events, known as an ‘incidental’ loss (Sonneveld et al., 2006) contribute high loads of both PP and DP to watercourses. The presence of livestock also results in the uneven re-distribution of nutrients within grazed land (due to dung-pats, concentration of livestock at feeding and drinking areas, or near gates), which may generate areas of greater risk to water (Tunney et al., 2007).

7.1.4 Risk identification

Rather than implementing general strategies over a wide area, areas that pose the greatest risk for P loss should be identified so as to target mitigation strategies most efficiently, (Hughes et al., 2005). The P Index (PI) system (not to be confused with the STP indices in the previous section which are agronomic based) was developed by Lemunyon & Gilbert (1993) to aid in the identification of high risk areas of P loss. It is a qualitative predictor used to determine the relative risk of P loss to water at field-scale. It accounts for and ranks both source and transport factors controlling P loss with the resulting dimensionless PI values indicating the relative risk of P loss from the field (Buczko & Kuchenbuch, 2007; Heathwaite et al., 2003). The PI is seen as a valid means on which to base P management recommendations in the USA by both the scientific community and policy makers and is also being positively viewed in Europe (Heathwaite et al., 2003). A PI was developed for grassland systems in Ireland by Magette et al. (2006) (referred to as the modified phosphorus ranking scheme or mPRS). The mPRS is used to categorise fields into low, medium and high risk for P loss depending on P source and transport factors. In order for any particular field to pose a high risk for P loss to water it must have both a high potential to supply P (source factors) and a high transport potential (transport factors) because the most critical areas for P loss are where hydrologically active areas intersect high soil P areas. Details on the development and testing of the mPRS can be found in Magette et al. (2006).
7.2 Agriculture and environmental protection

7.2.1 Voluntary controls - agri-environmental schemes

The 1992 Common Agricultural Policy (CAP) included a requirement (the EU Agri-Environment Regulation 2078/92) that Member States establish agri-environmental schemes (AESs). The Regulation permits Member States to reward farmers for farming in an environmentally responsible manner.

In the RoI the Regulation was implemented through the introduction of the voluntary Rural Environment Protection Scheme (REPS). REPS comprises a 5 year contract, administered by the Department of Agriculture and Food (DAF), specific to the individual farm in which the farmer is required to comply with a set of 11 compulsory measures and additional supplementary measures. (DAF, 2007) The Core measures cover;

- Nutrient Management Planning;
- Grassland and Soil Management;
- Protection and Maintenance of Watercourses;
- Retention of Wildlife Habitats;
- Maintenance of Farm and Field Boundaries;
- Restricted Use of Pesticides and Fertilisers;
- Buffer strip around Archaeological Features;
- The Visual Appearance of the Farm;
- Tillage Crop Production;
- Training;
- Farm Records.

Further Information on REPS can be found at: http://www.agriculture.gov.ie/index.jsp?file=schemes/reps.xml

The corresponding schemes administered by the Department of Agriculture and Rural Development (DARD) in NI are the Environmentally Sensitive Areas Scheme (ESAS) and the Countryside Management Scheme (CMS). The ESAS is geographically targeted and applies to land inside one of the five designated ESA areas in NI while the CMS is aimed at the wider countryside outside of ESA areas. The schemes require the following:

- Follow general environmental requirements;
- Follow good farming practice;
- Attend agri-environment workshops;
- Manage all field boundaries on the farm;
- Produce and implement a farm waste management plan;
- Follow the management requirements for all farm habitats and features; where there are no farm habitats at least one optional habitat must be undertaken (DARD, 2006a).

Further information on the ESA and CMS schemes can be found at: http://www.ruralni.gov.uk/index/environment/countryside_management_main/schemes.htm

Regulation 2078/92 stipulated that “measures must contribute towards other specific environmental goals set out in Community legislation” (EC, 1992). In this respect, agri-environment measures may
be used to meet commitments under the Nitrates Directive and Water Framework Directive and this philosophy now appears to be more strongly incorporated into REPS 4, which includes a supplementary measure for Western lake catchments. It is recognised that there are limitations to the current approach to agri-environmental schemes as it merely involves following prescribed activities and monitoring for their compliance. This limits the range of actions and flexibility of the schemes in responding to changing information or circumstances. For example, the nature of the contracts may limit the incentives and opportunities for co-operation between landholders as might be required in the coordination for catchment management (Hodge, 2001).

7.2.2 Regulatory controls on agriculture and water quality

The two primary pieces of legislation governing nutrient losses from agriculture to water in the RoI and NI are the EU Nitrates Directive (91/676/EEC) and the EU Water Framework Directive (2000/60/EC). The WFD requires the introduction of co-ordinated programmes of measures to achieve “good status” in all waters. Since the reduction of P loss to waters is necessary to achieve good ecological condition, measures to control P loss, particularly those of diffuse origin, will be central to this objective (Kronvang et al., 2005). The WFD also requires an analysis of the cost-effectiveness of the measures. The Nitrates Directive has introduced mandatory measures to reduce nutrient losses to water from agriculture, through improved farming practices. This has been implemented through the European Communities Good Agricultural Practice for Protection of Waters Regulations (S.I. No. 378 of 2006) in the RoI which became effective on August 1st 2006, and through The Nitrates Action Programme Regulations (Northern Ireland) 2006 (NAP Regulations) and the Phosphorus (Use in Agriculture) (Northern Ireland) Regulations 2006 (Phosphorus Regulations) which came into effect on January 1st 2007. These Regulations specify key measures that farmers are required to follow, including:

- Stocking rate limits;
- Prohibited spreading periods for application of organic manures and chemical fertiliser;
- Livestock manure storage requirements;
- Farmyard management;
- Land application restrictions for organic and chemical fertilisers (soil conditions, proximity to waterbodies, application rates and spreading methods);
- Application of nitrogen and phosphorus to crop requirement only;
- Definition of suitable soil and weather conditions for spreading organic manures and chemical fertilisers;
- A reduction in the phosphorus balance on farms where it is high;
- Record keeping to show compliance with the above (DARD, 2006b; DAF, 2006).

The Nitrates Regulations set a limit of 170 kg N ha\(^{-1}\) for livestock manure spread on land including that deposited by the animals themselves, but farmers may apply for a derogation to allow up to 250 kg N ha\(^{-1}\). Under the Nitrates Directive the implementation of action programmes in relation to the whole territory of the Member State or to areas identified by the Member State as vulnerable zones is required. Both the RoI and NI have adopted the former approach. Under the Regulations, Local Authorities have a number of responsibilities including the monitoring of surface waters and groundwaters and to carry out inspections of farm holdings.
Agriculture in the Lough Melvin catchment

Agricultural enterprises and practices

Farming is an important industry in the Lough Melvin catchment, and most rural dwellers practice some form of agriculture. Land use in the catchment is predominantly grassland agriculture with suckler cattle and sheep stock. Agricultural census data were obtained from the Central Statistics Office (CSO) in the RoI and from DARD in NI.

Table 22: Livestock summary data

<table>
<thead>
<tr>
<th>Livestock category</th>
<th>Total RoI</th>
<th>Total NI</th>
<th>Catchment total</th>
<th>Total LU equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>3891</td>
<td>3635</td>
<td>7526</td>
<td>5074</td>
</tr>
<tr>
<td>Sheep</td>
<td>12199</td>
<td>1342</td>
<td>13541</td>
<td>1896</td>
</tr>
<tr>
<td>Catchment average stocking rate (LU/ha)</td>
<td></td>
<td></td>
<td></td>
<td>0.5</td>
</tr>
</tbody>
</table>

Based on the figures in Table 22 there are approximately 7,500 cattle and 13,500 sheep in the catchment, giving a stocking rate well below 1LU ha⁻¹, and in the national context would be considered extensive farming. These census data would suggest that the stocking rates were rather similar on both sides of the border at that time. However, if we compare the overall number of stock with the respective utilisable agricultural areas on each side of the border from CORINE, we find that the stocking rates are 0.66LU ha⁻¹ and 0.45LU ha⁻¹ in the RoI and NI parts of the catchment, respectively. The stocking rates in terms of livestock units per ha (area of DED or Census Ward) were compared for the year 2000 in the RoI and NI and are presented in Figure 38.

Crowley (2003) compared livestock numbers from the RoI 2000 census with that of the previous census in 1991 (total livestock numbers for the whole DED in all cases) and the results indicated that during this period total cattle numbers increased by 23% and sheep by a very substantial 83%. This is likely to have been accompanied by a significant increase in grazing pressure and intensification in land management through fertiliser and manure applications. For the County Fermanagh part of the catchment data from the census ward level from the DARD Agricultural and Horticultural census 1997-2007, demonstrates that although numbers fluctuated between years, the overall trend was downwards. The 2007 cattle numbers represent 69% of the 1997 numbers, while the 2007 sheep numbers represent 58% of the 1997 numbers. However, these decreases are from historically high livestock numbers for the county, which began a significant upward trend in the 1980s as can be observed in Figure 39.
7.3.2 Soil suitability for agriculture

Soil type and climatic conditions are the two most important factors influencing production from grassland because of their influence on trafficability for both animals and machinery, and the high annual rainfall levels combined with heavy clay soils make trafficability a significant problem in the West of Ireland (Shaloo et al., 2004). The Lough Melvin catchment is no exception. The soils in the catchment are dominated by gleys and peats, which cover 47% and 40% of the catchment area, respectively.

Gleys are soils which have developed under permanent or intermittent water-logging conditions and are characterised by poor drainage characteristics and weak structure. This limits their landuse and leaves them vulnerable to poaching damage by grazing stock, which restricts the length of the grazing season and the proportion of fodder utilised. Grazing and trafficking on wet soils like these
with the resultant soil compaction impacts may diminish herbage nutrient uptake and increase the risk of overland flow thus intensifying the risk of P loss (Schulte et al., 2006). These soils, with their inherently poor drainage characteristics, have limited landuse, which is mostly confined to suckler, sheep and forestry enterprises. In addition to the adverse soil conditions, grazing capacity is also limited by the topography. The poor drainage conditions also retard growth in the spring thereby shortening the grazing season further (Anon, 1973). These conditions result in a long in-wintering period of 5 to 6 months and necessitates large quantities of silage or other winter feed and manure storage capacities. The shorter growing season also increases the chance of P loss because P uptake occurs for only a shorter part of the year leaving it more susceptible to loss in runoff. To alleviate poor drainage these soils are often found drained via subsurface drainage pipes or peripheral drainage ditches to make them agriculturally more useful and versatile.

Lee & Walsh (1973) estimated the potential grazing capacity of the soils in the area (assuming drainage of wet mineral soils, fertiliser inputs of 48kg N ha⁻¹ or 230kg N ha⁻¹ with adequate P and K, and grazing potential extrapolated from experimental sites elsewhere) to range from approximately 0.5 LU ha⁻¹ to 2.6 LU ha⁻¹ depending on soil type and N input. The soils would appear best suited to grazing by light stock and, having high yield classes, may also be suitable for forestry where environmental requirements are met. In conclusion, productive agriculture is difficult in the catchment due to these soil constraints and is further exacerbated by the nature of the topography (high slopes).

7.4 Summary

Agriculture in the catchment is constrained by soil and topographical conditions, yet these same conditions facilitate P loss to water and may be exacerbated with agricultural intensification. The methodology employed in this study will assess these risks and develop mitigation strategies to address them.

7.5 Methodology

7.5.1 Methodology introduction

The aims of this strand of the project were twofold:

- From a practical perspective to contribute to the catchment management plan (CMP) by addressing the risks posed by agriculture to the water quality and ecological status of Lough Melvin;
- From a research perspective to develop and cost a suite of agri-environmental measures to safeguard and improve water quality in mesotrophic lake catchments.

In order to achieve these aims, the methodology employed involved a number of individual tasks including:

- Collating background information on catchment physical characteristics and agricultural practices;
- An assessment of the current AESs with the farmers to ascertain they attitudes to the existing schemes, and the types of measures farmers would be willing to adopt;
- To conduct a detailed, site-specific, field-by-field risk assessment using the mPRS;
- Developing targeted and effective agri-environmental measures;
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- Evaluation of the proposed measures with the farmers and other key stakeholders;
- Liaising with Strand 3 project partners to undertake a cost-effectiveness analysis of the measures.

A key aspect of the study was stakeholder participation, particularly by the farmers, which took place to ensure the measures were (i) targeted at identified risks, (ii) environmentally effective, (iii) implementable and cost effective, (iv) practical and attractive for uptake by the farmer. These methodologies are summarised in Figure 40.

![Figure 40: Methodology components](image)

7.5.2 Evaluation of current agri-environmental schemes

The participation of farmers in the development of the agri-environmental measures was considered essential to ensure that they would be suitable, practical, and have a high uptake. To facilitate this consultation process a questionnaire was developed to gain their input. Although a number of formats were considered for the questionnaire, a simple format was chosen whereby the participants would rank in order of preference the options that followed each question. Key issues for agri-environmental schemes and farming in the Lough Melvin catchment were identified and the twelve questions in the questionnaire focused on these issues.
7.5.3 Farm surveys

The farm survey included farm selection, farm systems survey, a farmyard survey and a field-by-field survey. The concept of CSAs, discussed in Section 7.1.3, was used to identify risks for P loss within the catchment. The mPRS developed by Magette (2006) was utilised for this risk assessment (Table 23). The justifications for use of these factors are fully described in Magette (2006) and are not further elaborated on here, except to point out that some factors have a greater impact ("weight") on P loss than others and that depending on the magnitude of each factor a numerical risk level or "score" is assigned. Soil sampling is required as part of this methodology. The Morgan P test was used as Magette et al. (2000) uses it in the mPRS and it is the standard test used by Strand 2 partners Teagasc.

Other data required for the mPRS were collected directly from the farmer during the survey or from existing datasets, knowledge of the literature and professional experience.

Table 23: Field-by-field survey data requirements for the mPRS (Magette et al., 2006)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
<th>Weighting</th>
<th>Low Risk (1)</th>
<th>Medium Risk (2)</th>
<th>High Risk (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>P Usage Rate</td>
<td>1</td>
<td>0-5 kg P ha⁻¹</td>
<td>5-10 kg P ha⁻¹</td>
<td>&gt;10 kg P ha⁻¹</td>
</tr>
<tr>
<td></td>
<td>P Application Timing</td>
<td>0.9</td>
<td>Based on soil type &amp; timing</td>
<td>Based on soil type &amp; timing</td>
<td>Based on soil type &amp; timing</td>
</tr>
<tr>
<td>S2</td>
<td>Soil P</td>
<td>0.8</td>
<td>0-5 mg P L⁻¹</td>
<td>5.1-8 mg P L⁻¹</td>
<td>&gt;8 mg P L⁻¹</td>
</tr>
<tr>
<td></td>
<td>Desorption Risk</td>
<td>1</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>S3</td>
<td>Farmyard Risk</td>
<td>0.8</td>
<td>Good</td>
<td>Moderate</td>
<td>Poor</td>
</tr>
<tr>
<td>T1</td>
<td>Transport Distance</td>
<td>0.75</td>
<td>&gt;500m</td>
<td>200 – 500m</td>
<td>0 – 200m</td>
</tr>
<tr>
<td>T2</td>
<td>Connectivity</td>
<td>0.75</td>
<td>Low risk due to absence of subsurface drains and surface field drains</td>
<td>Moderate risk due to subsurface drains, or surface field drains with link to water.</td>
<td>High risk due to subsurface drains, and surface field drains with link to water.</td>
</tr>
</tbody>
</table>

In the mPRS, the risk of P loss due to applications of P is the product of the usage and timing factor (S1). The risk of P loss due to soil P concentrations is the product of soil P and desorption risk (S2). The sum of these (S1 + S2 + S3) gives the source sub-score (where S3 is the risk associated with the farmyard). The transport sub-score is the product of the distance factor (T1) and the connectivity factor (T2). The product of the source sub-score and transport sub-score gives the overall risk score for the field. Each field was classified as low, medium or high risk for P loss based on the overall site score.
7.5.4 Identification of risks and development of measures

Using the results of the mPRS and observations in the field a number of risks were identified. Based on the literature review and expert knowledge measures were developed for each of the risks identified. These range in complexity from something as simple as nutrient management planning to the installation of constructed wetlands and are described in later sections.

While the effectiveness and cost are important evaluation criteria for the mitigation measures, acceptability of the measures by the stakeholders (farmers, policy makers) is also important. Therefore, the robustness of the measures and their practicality for implementation were assessed by:

- holding a workshop with researchers, policy-maker and practitioner stakeholders. Attendees were divided into three groups to evaluate and rank the measures. Each group presented their top 10 measures, which were then discussed;
- an evaluation survey form was presented to the farmers listing the risks and the mitigation measures. These were explained to the farmer and the farmer was asked to rank them, in order of preference with their practicality and likelihood for uptake in mind;
- personnel from the Department of Agriculture and Rural Development (DARD) in NI could not attend the workshop and a consultation was held with them separately.

7.5.5 Effectiveness and costing of the measures

The final stage in the methodology was determining the effectiveness of the measures and costing them so that a cost-effectiveness analysis could be completed by Strand 3 project partners. The cost, and in particular the cost effectiveness, of the measures was seen to be an important evaluation criterion of the measures and is presented in section 7.6.4.

7.6 Results

7.6.1 Introduction

It is difficult to apportion the incidence of P loss to specific source areas due to the spatial complexity of P contributing areas, however this is somewhat overcome with the use of the Phosphorus Index. This study has demonstrated the applicability of the mPRS in identifying areas of risk, and in developing targeted mitigation measures. Due to variations in the sources and pathways involved with site conditions, the potential effectiveness, practicality and costs of these measures are tentative and as such the figures used in this report should be viewed as indicative rather than absolute.

7.6.2 Risk assessment results

The spatial distribution of the risk assessment results are not presented here for confidentiality purposes. However a breakdown of the collective data is presented in Table 24. It is evident from this that a significant proportion (31%) of the area surveyed had a high potential for P loss. This was due to the coincidence of source and transport factors associated with P loss.
Table 24: Risk class of surveyed area within the catchment

<table>
<thead>
<tr>
<th>Risk Class</th>
<th>% of surveyed area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>39</td>
</tr>
<tr>
<td>Medium</td>
<td>30</td>
</tr>
<tr>
<td>High</td>
<td>31</td>
</tr>
</tbody>
</table>

**P input rates and soil P levels**

The farms surveys demonstrated that there is significant scope for improvement in nutrient management planning (NMP) on many farms. Inputs in excess of agronomic requirements were commonly observed, which over time has resulted in a buildup of soil P levels. Of the total area surveyed within the catchment, 22% was in Index 4 (>8mg L⁻¹) and does not require additional P inputs. This build up of P was found to be localised within farms and resulted from slurry applications being concentrated on a limited number of fields. This may be a consequence of soil conditions or topography affecting accessibility and trafficability. It may also be a result of slurry being applied mostly to lands in close proximity to farmyard in order to reduce costs associated with the transport of slurry. The variance between the apparent spread area available and the actual spread areas used may require further study so that suitable spread areas can be identified, be reconciled with the amount of manure/slurry produced on the farm. With regard to P input rates, 42% of surveyed fields were found to be at high risk, 14% at medium risk and the remaining 44% at low risk. Based on soil STP levels 22% of the surveyed area was found to be at high risk, 25% at medium risk and the remainder (53%) at low risk.

The high P inputs to certain individual fields may reflect the tendency to maximise output from those fields where possible to compensate for the lower productive potential of other fields on the farm due to their soil condition and/or topography. This is not a sustainable strategy and needs to be reviewed so that the stocking rates on farms match their carrying capacity and ability to safely assimilate the waste produced. These elevated soil P levels form a reservoir for P loss to water into the future. It is important to consider that such input rates and STP levels are unnecessary for optimum productivity. Research by Teagasc has demonstrated that maximum beef production can occur with a Morgan’s STP level of 6mg L⁻¹ and that there is no difference in output between sites with application rates of 15kg P ha⁻¹ and 30kg P ha⁻¹ (Culleton *et al.*, 2000). An additional concern raised during consultations with both farmers and other stakeholders was the grant-aided construction of housing and slurry storage facilities in the catchment. There was general agreement that this would have more negative than positive impacts as it would facilitate agricultural intensification and the slurry produced consequently would ultimately end up on land where it cannot be adequately assimilated and where the risk of loss to water is high.
Therefore, the first and most crucial measure is to address nutrient management by developing, implementing and reviewing NMPs to ensure that nutrients are applied at appropriate rates taking into account the carrying capacity of the land and its assimilative capacity. Whilst NMP is an integral part of REPS, it is not a strong feature of the ESA or CMS schemes. AESs are currently offered on a voluntary basis, with farmers using their own personal judgement to assess the advantages and disadvantages of participation to ascertain if the scheme would benefit them (Strauss et al., 2007). It may be necessary in sensitive catchments for more widespread implementation of NMPs through encouraging uptake of these schemes. NMP within the AESs could be further enhanced by tailoring NMP strategies for the type of soil and landscape conditions found in these sensitive catchments. In addition, consideration needs to be given to matching the stocking density to the production capacity of the soil. In terms of nutrient management the mPRS could function to move manure applications away from high risk sites to those of lower risk. Each farm NMP should include:

- farm and field maps showing land area, soil type, landuse, presence of waterbodies;
- an indication of expected yields to assess the P off-take and maintenance requirements;
- a detailed analysis of the nutrients available to the farmer including the nutrient status of the soils based on soil analysis results (soils should be tested every 4-5 years; the cost of this will be approximately €1.25 ha yr⁻¹), nutrients available in organic form and any supplementary chemical fertiliser requirements;
- an identification of environmental hazards on a field-by-field basis (e.g. using the mPRS);
- an identification of the most appropriate methods and timings for application for the individual farm having considered the soil conditions, topography, any targets at risk and so on (a decision support system may be required);
- a calibration protocol for application equipment to ensure that application targets are achieved and not exceeded;
- an education programme on NMP. This may also involve calibration exercises and demonstrations for both farmers and contractors.
Within the NMP for each farm the following measures may be used to mitigate the risks associated with high P input rates and high soil P levels:

- Phyto-remediation or vegetative mining – removal of P from the soil by removal of crop biomass (e.g. removing silage) and not replacing the P off-take. A first cut of silage will contain, on average, six tonnes of dry matter per hectare, of which 0.3% (18kg) is P. In general 40 kg P ha\(^{-1}\) will change the STP level of the soil by one unit. Therefore at least two first cut silage off-takes would be required to reduce the STP level by one unit (for example from 8.5 to 75 mg L\(^{-1}\)). It should be appreciated that these figures are approximations only as the quantity of P removal required to reduce the STP levels by one unit will vary spatially.

- Use P-free fertiliser on farms;

- Reduce stocking rates on farms; There is not a lot of information available on the effects of stocking density of P loss, however SNIFFER (2004) cite a study that demonstrated 40% less P loss from pastures when no grazing occurred, compared with when they were stocked.

- Reduce P application rates.

- Do not apply P fertilisers/slurry to high P index soils. Research by Teagasc has demonstrated that soils with a STP level above 8mg L\(^{-1}\) have a higher risk of P loss to water indicating that P applications on such soils should be avoided.

- Plough and reseed pastures to redistribute P so that P-rich surface layers susceptible to entrainment in runoff are below the effective depth of interaction (i.e. reduce stratification of P in the soil). Tunney \textit{et al.} (2007) suggest that research is required to assess if the ploughing down of the P-enriched surface layer may be useful in the medium term to reduce P loss to water from high P soils;

- Add P immobilizing amendments to manures or to the soil (gypsum, calcium carbonate, iron or aluminium). In many respects this is treating the problem rather than preventing it and there are arguments against it on the grounds of costs, the fear of negative environmental impacts, and animal welfare (Kronvang \textit{et al.}, 2005);

- Reduce rate of application and improve distribution of manure/slurry. Research (Withers & Bailey, 2003), suggests that splitting manure applications will reduce potential for P losses.

\textbf{Timing of slurry and fertiliser applications}

Land-spreading of slurries is a cost-efficient and effective means of fertilisation but also presents a pollution risk when spread close to waterways, on waterlogged land, or when spread in wet weather (EPA, 2006a). The majority of the catchment was classified as high risk for runoff and therefore the timing of slurry applications is a significant issue. The poor soil conditions, topography and precipitation levels act synergistically to increase the likelihood of incidental losses when slurry applications occur, particularly if they are at rates in excess of crop requirements at inopportune times. Applications in the growing season between May and September are preferable and at lowest risk of transfer whereas application at times outside of this on high risk soils for runoff increases the risk for loss significantly (Magette \textit{et al.}, 2006). It was observed that most farmers (75%) spread manure/fertiliser in early spring when there is a greater risk of loss. Losses at this time will be influenced by the type of manure, the rate and method of application, the antecedent soil moisture conditions, the topography of the site in question, and the incidence of rainfall events after the application. Some farmers indicated that this was often necessitated by inadequate storage facilities but that improvements were being made. Poor soil conditions also increase the susceptibility to poaching which can exacerbate incidental P losses.
Agriculture

Based on current knowledge and the literature, these risks could be addressed using the following:

- Extend the closed spreading period- improve storage facilities to provide farmers with greater flexibility in terms of when manure must be landspread. However, the potential positive effects of such infrastructural improvements would be negated if it encouraged farmers to hold additional livestock over the winter and would therefore need to have conditions attached to the funding of such schemes;
- Loosen compacted soil layers to improve infiltration (Cuttle et al., 2006);
- Reduce soil compaction (and thereby reducing the potential for generation of runoff) by lowering the air pressure in machinery tyres, by using larger tyres or dual wheels (Ulen & Jakobsson, 2005), or low ground-pressure farm machinery (Shaloo, 2004);
- Reduce the length of the grazing season to reduce poaching damage (Cuttle et al., 2006);
- Reduce stocking rates and therefore generate less slurry;
- Only keep cows over the winter and sell calves, thus reducing slurry generation;
- Adopt a summer grazing farming system and destock for the winter, and avoid slurry production completely;
- Place slurry into/onto soil (Cuttle et al., 2006) (alternative equipment such as trailing shoe);
- Change from liquid to solid manure systems (P. McGurn, DARD, pers. comm., 2007).

Topography

- Long uninterrupted slopes have been identified as being important for P transport due to the generation of runoff and the erosive and dissolution transfer associated with this. This is accentuated where the waterbody is located immediately downslope. Hydrological engineering approaches to flowpath manipulation have been investigated by Heathwaite et al. (2005) and included changes to landuse and/or land management practices that can disconnect, store and buffer the transport of nutrients along the dominant flow route. This risk could be addressed by employing the following:
  - Establish new hedges to break hydrological connectivity. Slope lengths can be reduced by introducing vegetative barriers across slopes (Owens et al., 1997; Cuttle et al., 2006; Owens et al., 2007);
  - Establish riparian buffer strips at base of slopes;
  - Add immobilising amendments to riparian zones;
  - Establish and maintain constructed wetlands at base of slopes;
  - Establish/maintain ditches uphill of high P fields to intercept run-on onto these fields, or use ditches to intercept runoff and associated P load before they reach free water. The concept here is that ditches would be established parallel to watercourses or perpendicular to the flow of surface runoff for interception purposes. Such ditches may require periodic maintenance (SNIFER, 2004);
  - Establish willow coppice at base of slopes.
Proximity and connectivity to watercourses

Connectivity refers to the movement of P from soil to water via preferential pathways such as underground field drains, field edge drainage ditches and roadways. In the Lough Melvin catchment where soil drainage is impeded, storm runoff is dominated by overland flow which is augmented by these field drains and ditches and these therefore play an important role in the transport of P. The hydrology of the catchment, which is very flashy due to the prevalence of these impermeable soils and drainage ditches. Of the fields surveyed, 55% occurred within 0-200m of a watercourse, 14% within 200-500m and 31% within 500m. Only 11% of fields had a high connectivity risk due to the presence of field drains and drainage ditches with a direct link to water, 70% had a medium connectivity risk and 19% had a low connectivity risk.

Because of the poor soil conditions, traversing the land with machinery and animals is particularly difficult during the winter and thus roadways have been built by many farmers. In many instances these act as a direct conduit for the transfer of sediment and P which is often exacerbated by the topography of the area. Roadways along with ditches may speed delivery of P to watercourses but the former are limited spatially and their contributions may need to be quantified in future research. In the long term, risks associated with high hydrological connectivity will probably be best mitigated using source controls but transport controls will also have a role.

Possible measures to target proximity and connectivity risks include:

- Do not apply fertilisers to fields/areas which have a high hydrological connectivity to watercourses – fields with open drains, waterlogged areas draining to nearby watercourses, riparian areas;
- Reduce grazing intensity in fields with watercourses (Rhodes et al., 2007);
- Allow field drainage systems to deteriorate;
- Ulen and Jakobsson (2005) suggest the use of limed surface runoff inlets and backfills in drains to encourage the chemical precipitation of SRP;
- Block drains to increase the water retention time;
- Whilst the ditch network may act to reduce water retention time and thereby facilitate P routing to watercourses, the ditch network may also be used to attenuate P through use of ochre and wetland systems within them. Research at Teagasc has shown ochre has good potential for phosphorus retention (4g kg\(^{-1}\)) and could be strategically placed in drainage ditches to remove P from drainage waters;
- Barriers could be installed in drainage ditches to slow flow and create temporary storage zones to promote sedimentation to trap sediment and the associated P (Heathwaite et al., 2005). The placement of these would need to be optimised to reduce the impact on the operation of field drains and to prevent excessive backing up of the ditches.
- Vegetated buffer strips are unlikely to be effective in landscapes with field drains as these will bypass the strips. In such instances, it may be better to discharge the drain waters into constructed wetlands in riparian areas.
- For roadways channelised flow could be routed to sediment traps/impoundments.
**Farmyard risk**

While it is recognised that the farmyard risk cannot be strictly considered a field level factor it was included as part of the field-by-field risk assessment because several studies have shown farmyards make significant contributions to reduced water quality in catchments dominated by grassland agriculture (Magette *et al.*, 2006). Farmyards were categorised into low, medium and high risk based on their manure/slurry storage capacity and facilities, dirty water storage capacity, silage effluent storage capacity, dirty areas, management of the farmyard and whether or not there was any evidence of an imminent pollution threat. Previous studies (Girvan & Foy, 2003) found that point source pollution from farmyards was not significant in the catchment and the results of these surveys corroborate this. No farmyard was classified as high risk, 6 were classified as medium risk and the remaining majority as low risk.

**Other farm activities and practices**

Particular farm activities or practices may present risks to water quality. These include:

- **Storage of silage bales near ditches and streams** - this is a particular issue when these are stored immediately upslope of the ditch/watercourse. Where the quality of the silage is poor and there is leakage of effluent the risk for transfer is high due to the proximity of the watercourse.

- **Storage of FYM close to streams** - there was only one instance of this observed in the catchment and again water quality benefits would result if this was ceased.

- **Poor siting of feed and water troughs (in hydrologically active areas)** - the risk here is associated with the concentration of animal excreta and soil damage generating contaminated runoff, which if coinciding with a hydrologically active area linked to a watercourse will result in contamination of that watercourse. Although this activity may be localised the increased erosion can represent significant sources of the total P load (Johnes & Hodgkinson, 1998).

  This could be addressed by:
  
  - Moving feed and water troughs regularly to avoid excessive poaching and the concentration of excreta;
  - Improving the ground condition around existing water troughs through use of hardcore and/or woodchip;
  - Re-siting water and feed troughs away from high risk areas.

- **Animal access to streams/lake for drinking** - Stream bank erosion can be a significant source of P to water. Grazing and trampling of bank-side vegetation can destabilise the bank increasing erosional losses while access to the channel can result in direct contamination with excreta.

  This could be addressed by:
  
  - Fencing off rivers/streams/lake from livestock and ensuring the new water source (animal operated drinkers that siphon water from the stream) is sited away from vulnerable areas;
  - Constructing bridges for livestock and machinery to cross watercourses.
Gateways near streams or at base of slope – increased activity around the gateway results in rutting, soil damage and compaction, which reduces infiltration capacity. The congregating of animals around the gateway will also result in the concentration of excreta. The potential for ponding and generation of runoff coinciding with a supply of P presents a risk to water if gateways are in close proximity to the watercourse.

These risks could be addressed by:
- Improving the ground conditions around gateways using hardcore;
- Moving gateways from high risk areas to lower risk areas upslope.

Out-wintering of livestock – out-wintering on sacrifice paddocks is practiced by some farmers and is a potential source of nutrient and sediment loss to water depending on the proximity and connectivity to watercourses. The impact of the use of such paddocks merits further research and in the meantime, farmers should endeavour to ensure that these are located away from high risk areas.

Importing of feedstuff - The additional P brought into the system that is not utilised by the animal is excreted thereby increasing the amount of P recycled in livestock manures. Concentrates have higher concentrations of P than herbage. Also, the switch from hay to silage (which has higher concentrations of P on a dry matter basis) means that over time both the intake and excretion of P from individual cattle have increased. This is exacerbated by the fact that there is also evidence that the proportion of P in soluble form in manures increases disproportionately as the P content of the diet increases. This could be addressed by:
- Reducing P intake into farm systems by reducing use of imported feeds;
- Phase feeding of livestock – grouping of livestock on the basis of their feed requirements;
- Feed low P concentrates;
- Substitute purchased concentrates with home grown or local cereals and/or better fodder quality;
- Manipulation of feed composition.
- Imported P in feedstuffs and its contribution to the P content of manures needs to be assessed in terms of nutrient budgets within the catchment and the current stocking rates which require this.

Drainage operations

Drainage maintenance works involves the removal of silt, vegetation and other obstructions, and the repair of damaged banks, all of which may impair the channel from its full hydraulic conveyance capacity. The dredged material is then usually placed along the bank (OPW, 2007a). From a water quality perspective the generation of suspended solids during the excavation processes in the channel will have many adverse impacts as suspended sediment reduces light penetration, clogs aquatic vegetation and fish spawning gravels, and is an important vector for the transport of nutrients (Russell et al., 2001).

Drainage works are undertaken by the OPW in the County (Kilcoo) river. However, the impacts of these activities have not been monitored and therefore their potential impact on P dynamics is unknown. Given the findings of monitoring elsewhere (Byrne, 2005) which found exceptionally high increases in P levels during such events (for example at one site TP concentrations jumped from 33µg L⁻¹ to 610µgL⁻¹ (of which 97% was PP)) it may be prudent to establish a monitoring programme.
when drainage maintenance is scheduled again in order to evaluate the magnitude of its impact on P dynamics as well as the other possible adverse effects resulting from the process.

The drainage works may also impact on the incidence of overbank flooding, which has been shown to be an important sink for sediment and associated nutrients (Kronvang et al., 2005). Kronvang et al., (2005) showed that between 1.18gP m\(^{-2}\) and 6.5gP m\(^{-2}\) could be retained during short overbank flooding periods.

Measures to address the risks posed by drainage maintenance include:

- removing sediment and biomass from ditches and moving it away from the channel or off-site;
- preventing erosion of disturbed beds and banks (e.g. by establishing riparian buffer zones or restricting access to the river);
- reducing or phasing out of drainage activities to allow the restoration of floodplain and riparian wetlands that would act as sinks for sediment and P during flood events.

**Lack of information**

Encouraging farmers to alter their farming practices is a challenge and requires good communication to improve understanding. One-to-one advice may be the most effective means of achieving this. There is evidence to suggest that education can have positive outcomes. A two year study carried out on thirty deer farms in New Zealand, (Rhodes et al., 2007), demonstrated that farmers who had received information packs and consequently voluntarily adopted BMPs such as excluding livestock from streams or limiting grazing intensity in fields containing waterways improved stream health on their farms compared to those who did not receive information or adopt BMPs. Problems arising from nutrient management practices are often the result of inadequate awareness and difficulties in accessing suitable advice. Increasing awareness could be addressed by:

- Improving accessibility to advice or an advisory service for catchment farmers;
- Attending courses formulated specifically for Western lake catchments;
- Providing a free intensive advisory service for two years on a pilot basis for farmers in the catchment;
- Certifying farmer competency in nutrient management.

The dissemination of information to farmers may be carried out using a number means, such as:

- One to one contact;
- One to group – farm walks, seminars etc.;
- Farmer clubs or networks – this can foster cooperation and knowledge transfer through an interchange of farm experiences;
- Press – e.g. Farmers Journal;
- Shows/events – e.g. local shows could be used to raise awareness;
- Establishment of demonstration farms – these would allow farmers to see at first hand the effort involved in implementing and the effectiveness of a range of mitigation options;
- Website – an established website with information targeted and tailored to nutrient best management practices for the environmental and agronomic conditions found around Lough Melvin.
7.6.3 Evaluation of measures

The variation in the effectiveness of mitigation options can be large and could not be specifically quantified because field experiments are lacking, a point also noted by Ulen & Jakobsson, 2005. The timescale of effectiveness of the measures is also something with uncertainty and has important implications for the future establishment of the schemes. The lifespan of the measures is also important if one considers sink-source dynamics. Other factors such as acceptance by the stakeholders (farmers, policy makers), and ease of implementation are also important to consider. Therefore, the robustness of the measures and their practicality for implementation were assessed with the relevant stakeholders as detailed in section 7.5 and the output from these consultations is presented in the sections anon.

In general, farmers tended to prefer options that were practical and easy to implement. For example, making improvements to existing infrastructure like feed/water areas and gateways were preferred more than moving them. Development of wetlands was unpopular. Measures requiring changes to fertiliser/manure practices were popular as they could be implemented without impacting on productivity whilst also resulting in cost savings. Interestingly, reducing stock numbers (particularly reductions over the winter) was also popular provided that adequate compensation was available. This may reflect current concerns over beef prices and the increasing cost of feed.

7.6.4 The effectiveness and costs of the measures

Taking into consideration the complex, heterogeneous and variable nature of P export from agricultural land a wide range of measures is necessary. The cost effectiveness figures developed here are based on the best information available at present. While they are tentative due to the lack of specific research in this area, they do provide some exploratory indications of the relative cost effectiveness of the various measures as they can differ by orders of magnitude. Therefore, we have categorised the cost effectiveness (€/kg P) of each potential measure, as well as its total impact (potential reduction in P-loss), its total cost of implementation across the catchment (€) and its relative popularity ranking into four categories (Table 25):

<table>
<thead>
<tr>
<th>Cost effectiveness (€/kg P)</th>
<th>Total costs (€)</th>
<th>Total impact (kg P)</th>
<th>Relative popularity (farmers’ preference)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt; 10</td>
<td>&lt; 10,000</td>
<td>&gt; 1,000</td>
</tr>
<tr>
<td>B</td>
<td>10 – 100</td>
<td>10,000 – 100,000</td>
<td>100 – 1,000</td>
</tr>
<tr>
<td>C</td>
<td>100 – 1,000</td>
<td>100,000 – 1,000,000</td>
<td>10 – 100</td>
</tr>
<tr>
<td>D</td>
<td>&gt; 1,000</td>
<td>&gt; 1,000,000</td>
<td>&lt; 10</td>
</tr>
</tbody>
</table>

The results are summarised in Table 26 and Figure 42. Cost effectiveness is reported in € per kg P removed from the system (source reduction) or € per kg P intercepted (runoff interception).
Table 26: Cost effectiveness, total impact, total costs and popularity of the P loss mitigation measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Cost effectiveness</th>
<th>Total cost</th>
<th>Total impact</th>
<th>Popularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed low P concentrates</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Not replacing P on Index 4 silage area</td>
<td>A</td>
<td>A</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>Free advisory service and NMP</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Reduce overall stocking rate (sheep)</td>
<td>B</td>
<td>B</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Sedimentation barriers in drainage ditches</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Reduce overall stocking rate (suckler cows)</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Run-off / run-on interception ditches</td>
<td>C</td>
<td>B</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>Grass buffer strip (2.5m)</td>
<td>B/C</td>
<td>C</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Reduce stock by selling calves in autumn</td>
<td>C</td>
<td>C</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Willow/alder buffer strip (5.0m)</td>
<td>C</td>
<td>C</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Grass buffer strip (1.5m)</td>
<td>C</td>
<td>C</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Plough and reseed Index 4 soils</td>
<td>C</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Re-route runoff from roads to sediment traps</td>
<td>C</td>
<td>C</td>
<td>B</td>
<td>N/A</td>
</tr>
<tr>
<td>Wetlands at base of slopes</td>
<td>C</td>
<td>D</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>Hedgerows across slopes</td>
<td>D</td>
<td>A</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>Gravel hardcore around troughs</td>
<td>D</td>
<td>B</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>Move troughs away from high risk areas</td>
<td>D</td>
<td>B</td>
<td>D</td>
<td>B</td>
</tr>
<tr>
<td>Gravel hardcore around gateways near streams</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Move gateways from high risk areas</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Fence off water courses</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>N/A</td>
</tr>
<tr>
<td>Fence off water courses with 1.5m buffer strip</td>
<td>D</td>
<td>D</td>
<td>B</td>
<td>N/A</td>
</tr>
<tr>
<td>Move troughs regularly</td>
<td>B</td>
<td>N/A</td>
<td>N/A</td>
<td>C</td>
</tr>
<tr>
<td>Reduce Target Index to Index 2</td>
<td>D</td>
<td>N/A</td>
<td>N/A</td>
<td>C</td>
</tr>
<tr>
<td>Linear wetlands within drainage ditches</td>
<td>D</td>
<td>N/A</td>
<td>N/A</td>
<td>C</td>
</tr>
<tr>
<td>Only buy fodder produced within the catchment</td>
<td>D</td>
<td>N/A</td>
<td>N/A</td>
<td>C</td>
</tr>
</tbody>
</table>

In Table 26, measures were ranked primarily by cost effectiveness, secondarily by total costs, and tertiarily by total impact. Figure 42 plots the cumulative costs of the measures against their cumulative impact in this ranking (both relative to total costs and total impact); it suggests that implementation of the first 5 measures have the potential to account for 50% of maximum reduction P-loss, at less then 5% of total potential costs.
Further and on-the-ground research will be required to verify both effectiveness and cost figures in different site situations before such measures can be rolled out on a large scale. However, these preliminary figures and the feedback from the farmers allow the following observations to be made:

- Source reduction will be the most effective long term strategy, but using such a strategy it may take a number of years before improvements in water quality are observed. It is clear from Figure 42 that measures to reduce P at source are also among the most cost effective.

- In contrast, transport controls are less cost effective but may bring about improvements in water quality more rapidly. Interestingly, most of the measures popular with farmers are also those that are the most cost effective. In terms of developing a management prescription for agricultural P loss in the Lough Melvin catchment a mix of these source and transport control measures may be required.

- Based on both the farmer evaluation and the cost effectiveness analysis a number of measures can be prioritised and a number dropped. The following measures are unlikely to be successful due to their unlikelihood for uptake by farmers:
  - Ploughing and reseeding Index 4 fields (due to lack of farmer interest as only a limited area of land in the catchment is suitable for ploughing);
  - Reducing the Target Index to Index 2 (due to its low popularity with farmers because of the nutrient input restrictions required);
  - Only buying fodder produced within the catchment (because of its low popularity with the farmers due to (i) concern if sufficient fodder would be available; (ii) concern over the quality of the fodder in the catchment, and (iii) concern over the potential to distort local fodder prices).

- Measures with a cost-effectiveness in the D-category are the least cost-effective and could also be dropped on the basis that they offer poor value for money. Alternatively, they may be used as reserve measures where other more cost effective measures have not brought about improvements or are unsuited to addressing the specific risk.

**Figure 42: Relationship between cumulative impact and cumulative costs (relative to total impact and total cost)**

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7.7 Recommendations

Based on these observations, we recommend that the management prescription for agriculture in the catchment be based on the following four pillars:

**Pillar 1** involves provision of nutrient and agri-environmental advisory programme that includes soil testing and a Nutrient Management Plan (NMP), free of charge to the farmer. This will involve adoption of the most cost-effective and popular source reduction measures. It is considered pivotal in facilitating knowledge transfer and implementation of Best Management Practices, in order to reduce P loss in the long-term by addressing sources or pressures. Elements of this NMP should include the following category A measures:

- Identification of Index 4 soils and peaty soils
- Reduce slurry/fertiliser application rates to agronomically optimum levels
- Feeding low P concentrates
- Removing P in silage and not replacing the P off-take on Index 4 soils. This measure will be restricted in its application as it will only be applicable to a limited number of fields and subject to the availability of alternative and suitable spreading areas.

**Pillar 2** involves reducing P loss in the short-term by addressing pathways. This will be effective in improving water quality in the short to medium term by intercepting P that is being lost in runoff. This will involve adoption of the most cost-effective and popular interception measures, which are primarily Category B, C, or D measures, the latter not being very cost effective but popular with farmers in some instances. These measures include:

- Barriers or sedimentation ponds in drainage ditches (Effectiveness Category B, relatively popular)
- Grass buffer zones of 2.5m width (Effectiveness Category B/C, relatively popular)
- Hedgerows (Effectiveness Category D, relatively popular)

The latter two measures, while not as cost effective as Category A and B measures are popular with farmers and therefore likely to be taken up. These measures are currently optional under existing AESs and could be encouraged for uptake in the Lough Melvin catchment.

Together, implementation of Pillars 1 and 2 are estimated to have the potential to reduce P-loss to water by c. 50% of theoretically maximum potential reduction at 6% of theoretically maximum potential costs.

**Pillar 3** Where insufficient progress is made with the above, implementation of reserve measures (the remaining less cost effective and/or less popular measures with farmers) for source reduction or pathway interception would be required. These could include:

- Provision of compensation for reductions in overall stocking rate (effectiveness category B, relatively popular)
- Provision of compensation for reductions in stock by selling calves in autumn (effectiveness category C, relatively popular)

Together, implementation of Pillars 1 and 2 and 3 are estimated to have the potential to reduce P-loss to water by c. 80% of theoretically maximum potential reduction at 16% of theoretically maximum potential costs.

Category D measures should be of lowest priority given their cost effectiveness values.
Pillar 4 involves a review of concerns not addressed by these measures. Further considerations, which relate to the current instruments regulating agriculture in the catchment may also need to be evaluated and enhanced if required:

> The main challenge in the catchment is the limited slurry spreading area available. This results in slurry applications being concentrated on those fields where accessibility is possible. A manifestation of this is that 22% of the surveyed area is in STP Index 4. This is currently only partly addressed by the Action Plan for the Nitrates Directive, i.e. there may be sufficient forage area or ‘net farm area’ to suggest that there is < 170kg/ha but in reality much of this organic N may be concentrated on a limited number of fields. A provision within the Action Plan is that once manure/slurry is spread to meet crop requirements on Index 1, 2, and 3 soils the remaining slurry/manure can be spread on Index 4 soils, provided the 170kg limit is not exceeded. Again this may require further investigation in the Melvin context, given the bio-physical environment which presents conditions that facilitate P loss. In the event that implementation of Pillars 1, 2 and 3 does not result in adequate reductions in P-loss to water, withholding slurry applications on Index 4 soils may be required. At the same time, this should not be allowed to lead to situations where slurry is re-routed to index 3 soils with high connectivity to water.

> In the current Action Plan for the Nitrates Directive in the RoI states that an Index 3 can be assumed where a soil test is not available. This may facilitate continued P inputs to fields that are at Index 4 where these remain unidentified. By contrast, under the NI regulations P from fertiliser may only be applied if soil analysis shows that there is a requirement for it and this is potentially an approach that would have merits across the entire catchment.

> A concern raised by various stakeholders has been the building of housing and slurry storage facilities under the Department of Agriculture grant schemes in the RoI. These concerns have included the facilitation of intensifying agriculture by allowing more livestock to be kept, facilitating animal B&B arrangements, and finding suitable spread area for the additional slurry produced. There is anecdotal evidence that some farmers graze cattle outside of the catchment, bring these cattle back to the catchment for winter housing and also spread the slurry in the catchment. These practices may inadvertently be encouraged by current grant schemes.

> In the recent past (last 12 months) the value of nutrients in slurry has increased sharply, following the sudden rise in fertiliser prices. Indeed it may now be economically feasible or even advantageous for farmers to export excess slurry to areas outside the catchment. In particular, this would address concerns identified above where availability of suitable spreadlands is limited to Index 4 soils, or where nutrients are imported into the catchment through animal B&B arrangements.

A significant proportion (perhaps 50%) of farmers in the catchment are currently outside of AESs; an increased participation rate in such schemes should benefit water quality. It is envisaged that participation in REPS may increase in the advent of increased payments under REPS 4. However, uptake may be accelerated with a concerted local promotion of the schemes by the relevant agencies. In the event that not all farmers participate it may be worth considering a stand-alone scheme for implementing specific measures to protect water quality. Such schemes may not require farmers to put all the farm under the scheme but only those high risk areas. One means of facilitating such a scheme would be via auction processes as discussed by Strand 3 project partners.
7.8 Discussion

An important concept in the project was the participation of stakeholders and particularly that of farmers. Farmers participated in the risk assessment, and in the development of the measures. Information on a field-by-field basis directly from farmers provided invaluable insights into farming practices and the risks presented at individual field level. Input from the farmers in evaluating the measures was also important as without consultation the measures proposed could be potentially inappropriate to the farm systems, could impose unacceptable constraints on farming activities, or could be unacceptable to a majority of farmers.

7.8.1 Nutrient Management Planning

This study has found that there is significant scope to improve landuse management in the Lough Melvin catchment. Indeed, many of the risk areas identified in this study related to NMP. Implementing NMP to avoid P surpluses is regarded as the most effective diffuse P transfer mitigation option (Tilman et al., 2002). In general, P is not likely to pose any environmental threats when application rates of manure and fertilisers are based on soil test recommendations, rates do not exceed crop removal, and good agronomic management practices are employed. To date, REPS has focused more on nutrient management based on STP thresholds and stocking limits. Of greater concern is that AESs in NI do not require farm NMPs. To achieve water quality standards, consideration of both source and transport factors is likely to bring about the greatest benefit in reducing P loss. The mPRS considers both these factors to indicate the potential for P transfer to surface water, is therefore preferable to the use of threshold P levels only, and may be a means of progressing NMP within the catchment to enhance water quality protection. However, such an approach may not be readily implementable as it would require additional budgeting for the necessary training and human resources. Therefore, it may only be possible (and indeed only necessary) in a limited capacity and in such circumstances it would need to be targeted at the most sensitive catchments where water quality is a concern.

7.8.2 Management of animal manures

Opportunities for safe slurry spreading in the Lough Melvin catchment are limited. This is a result of the high proportion of soils with impeded drainage on sloping land under high rainfall, which increases the risk of runoff generation and subsequent diffuse and incidental losses. The farm surveys identified the uneven distribution of P applications on the farms with applications concentrated on a small number of fields. This practice has lead to an elevation in soil P levels and often occurs on fields designated as “high risk” for P loss due to other source or transport factors. Water from high risk fields may to some degree be diluted by nutrient poor water originating from the less intensively farmed areas. This includes the runoff from rough pastures, heaths and blanket bog areas.

Adequate storage capacity for manures is essential in controlling when slurry is spread. Anecdotal evidence suggests that, historically, this has been problematic in the Lough Melvin catchment and has resulted in the spreading of slurry at inappropriate times. In such situations, applications were concentrated on fields along roadways as these were the only fields accessible under the poor soil conditions. In some instances however, there has been no alternative but to go onto land to spread manures despite the trafficability and pollution risks presented on these wet poorly drained soils. Ideally, the timing of manure applications should coincide with periods of vigorous crop growth (spring-early summer for grassland) rather than later in the year (Carton & Magette, 1999). However,
because soil conditions in the Lough Melvin catchment are usually unsatisfactory in spring it may be better to leave applications until the summer when conditions improve, even though the nitrogen fertiliser replacement value of the slurry will be lower at this time. Regular low rates of slurry application may be a more prudent strategy than infrequent high rate applications with sufficient time between applications to avoid surface sealing and allow sufficient time for nutrient uptake. A useful facility for farmers in the catchment would be a decision support system to aid with the timing of manure spreading based on soils and weather conditions. Indeed, such a tool is currently being developed by Teagasc, UCD and Met Eireann (Holden, Schulte & Walsh, 2007).

7.8.3 Carrying capacity

Another issue in relation to manure management that arose during this study was that sometimes land unsuitable and unused for the purposes of spreading slurry was included for the purposes of calculating the “spread area” available to the farmer with the result that in farm global terms the apparent spreading rates may seem quite low. Similarly, actual stocking densities may be higher on the ground due to the concentration of grazing on certain fields because other outlying ground is less used or unused due to its condition. Therefore, while in the national context the stocking rates are relatively low on a purely areal basis, in terms of the utilisable area and carrying capacity of the land they can be relatively high. It may be prudent to undertake research so that the sustainable carrying capacity of the land can be determined and appropriate stocking rates can be set for different areas within the catchment. Efforts to improve water quality could be further enhanced if soil testing was mandatory on all fields. The proportion of fields in Index 4 was unexpectedly high. In the absence of a soil test an Index 3 would be assumed for these fields for the purposes of the Nitrates Directive (in the RoI only).

7.8.4 Connectivity

Risks not related to NMP but more to specific farming practices or site conditions (feed and water trough positioning, gateway positioning, high connectivity etc) can on the whole be addressed by common sense and practical approaches. Fencing off stock from water may not be practicable in open hill land or where the river bank is known to flood, and where provision of an alternative water supply is required this is not a cost-effective measure. One negative aspect of fencing stock out of water margins is likely to be problems of excessive vegetation growth impeding access by walkers and anglers.

Overall, in the Lough Melvin catchment, the low permeability soils combined with the subsurface and edge of field drainage systems and topography result in a high, often channelised, runoff regime and where high soil P areas coincide with this regime critical source areas for P loss result. Such a hydrological regime has important implications for siting and design of mitigation measures. Sharples et al., (1999) suggest that P mitigation measures be targeted at the hydrologically controlled critical P source areas in the surface runoff-producing areas near streams to be most effective. While conventional BMPs include buffer strips adjacent to receiving streams, consideration should be given to manipulating the vast drainage ditch network in the catchment as a means of reducing P transfer. While these ditches are responsible for increasing connectivity, and are necessary to maintain the land drainage status, they may also, through various macrophyte assemblages within them function to remove P from the water column. These vegetative communities could provide mitigation similar to riparian corridors by offering a spatial buffer for non-point agricultural runoff (Moore et al., 2000). The vegetative characteristics of these ditches may be optimized for the treatment of runoff related contaminants such as P, whilst at the same time also preserve valuable...
agricultural land that might otherwise be dedicated to wetland treatment (Bouldin et al., 2004). Ditches may be modified in several ways to improve phosphorus retention. This may include varying the slope, width and depth of the ditch or establishment of vegetation or dams to promote sedimentation. One relatively simple means of implementing this measure would be to widen ditches at field corners to form a basin for sedimentation (Hauge, 2005). While this research is at an early stage, these modifications appear to be very cost effective and popular with farmers as they do not significantly impact on the adjacent land.

### 7.8.5 Implementation of measures

In terms of implementing all these mitigation measures in the future it should be appreciated that there are uncertainties on the effectiveness of measures due to the number of variables that may influence P loss. Not least among these are inter-annual variations in climate, which can have a significant impact on its mobilisation (Kronvang et al., 2005). Other factors include the timescale to effectiveness, and timescale of effectiveness of the measures which will depend on several factors such as soil P status and P saturation, the by-passing of dissolved P and P fractions associated with colloidal materials, and the longevity of the measures (sink-source dynamics). Overall, there may be a significant time lag (several years) between implementation of measures and observed improvements in water quality. This is compounded by the potential for P traps such as wetlands or buffer zones to become net sources of P to water over time. There is a serious lack of data on the effectiveness of various mitigation options and there is an urgent need for this to be addressed and for practical design criteria to be produced. These measures may not be all universally applicable to all farms and situations. Due to the complex and heterogeneous nature of P loss measures may only be required on some farms in certain circumstances, or on certain areas of land in certain locations.

From a national perspective and in the context of the WFD it may be prudent to look at tailored AESs for sensitive catchments where both the risk and consequence of P loss is higher. In these areas where slope, soil type, climate, hydrology and farming practices combine to elevate risk it may be necessary to encourage AES uptake by all farmers on a voluntary basis by increasing the financial incentives or on a compulsory basis through legislation. Both the range of measures and the scale of implementation (a larger proportion of farms with measures in place) may need to be greater in such catchments and this may need to be reflected in the compensation. Tackling the problem of eutrophication in cooperation with farmers, as opposed to within a compulsory regulatory framework, will be the most preferable and probably most effective way forward.

Farmers must work within the landscape at their disposal and in doing so a balance must be struck between operating an economically viable enterprise and safeguarding the environment. With this in mind, it is important that boundaries of acceptable and unacceptable field management be set taking account of the intrinsic vulnerability of the landscape, a point also argued by Withers & Lord (2002). In doing so, it is important that the social and economic aspects are also considered so that farmers are compensated for the production sacrificed and that land abandonment is avoided.

This project has taken a participatory approach to the development of agri-environmental measures and demonstrated that the integration of farmers into agri-environmental research will facilitate a broader acceptance of recommendations arising from such work. Combining this approach with a cost effectiveness analysis will allow the effective targeting of resources on measures that will not only be effective at mitigating P loss, but which will also have a high uptake by farmers.
8.1 Introduction

Well managed forests and woodlands provide social, economic and environmental benefits including recreational areas, rural employment and a range of ecological habitats. With respect to climate change, forestry offers a means of storing carbon dioxide and is a potential source of renewable energy. As a rule the nutrient exports from forestry are lower than those recorded from agricultural land. Thus, a switch from agricultural land to forestry would be expected to lower inputs to water of phosphorus and nitrogen compounds. Strategically positioned woodland potentially benefits the aquatic environment in a number of ways. Riparian woodlands can effectively intercept runoff from agricultural land, retain nutrients, and so limit eutrophication.

They provide a means of controlling bank erosion and slowing floodwaters. Over-hanging deciduous trees provide dappled shade that allows some primary production in the streams while regulating water temperature, which is critical for providing spawning and nursery conditions for fish. Leaf litter from riparian woodland is a food source and provides habitat for aquatic macroinvertebrates that are an important food resource for salmonids.

Unfortunately, forestry activities also have the potential to negatively impact on the aquatic environment and some of these are the precise reverse of the benefits listed in the previous paragraph. While nutrient exports from forests are lower than from lowland agricultural land, in the uplands, exports of phosphorus from forestry are often higher than upland areas of rough grazing. Thus, forestry has been a source of eutrophication of upland lakes. It has also been implicated in acidification, bank erosion and sedimentation (Cummins & Farrel, 2003a; Cummins & Farrel, 2003b; Giller et al., 2002; Giller et al. 1997; Leeks & Robert, 1987). Where the dense canopy of conifers overhangs a stream it severely depresses primary production, while the needles of conifers are of lower nutritional value to macroinvertebrates than the leaf litter of deciduous trees. Rather than slowing floods, the provision of open field drains before planting enhances peak flood flows. Acidification impacts are often reported from acid-sensitive catchments that are already impacted by acid rain. In Ireland, the bulk of adverse effects have been attributed to coniferous plantations, in particular, where these have been established in the uplands on blanket peats or on steeply sloping terrain.
8.2 Purpose of Lough Melvin Study

The potential for heavily afforested coniferous catchments to act as a diffuse source of nutrients has been well documented within northern Europe and is particularly relevant for a sensitive catchment such as Lough Melvin. The potential for forestry to result in erosion, sedimentation and alter catchment hydrology are also of concern to the extent that they adversely impact on salmonid survival. The majority of phosphorus entering Lough Melvin originates from diffuse sources within the surrounding catchment and although established forests contribute or lose only relatively small amounts of phosphorus, losses can increase substantially during the establishment, fertilisation and deforestation phases particularly on peat soils.

As part of the Lough Melvin Nutrient Reduction Programme, the objective of the Forestry Component was to assess the potential risk that forestry poses to the nutrient status of Lough Melvin. This involved determining the characteristics of forestry within the Lough Melvin catchment; identification of areas and activities considered to be of high risk of causing eutrophication and, where possible, quantification of the potential impacts. Where sufficient information was available, mitigation measures have been proposed. Five key tasks were undertaken to achieve the objectives of the study:

1. Stakeholder Engagement including a Forestry Working Group
2. Information Collation and Review
3. Quantification of Loads
4. Determination of Impact
5. Mitigation Options & Recommendations

Task 2 drew extensively on information on current forestry practices in the catchment that was given freely by professional forest staff in the Forest Service Northern Ireland (Ian Irwin, Ian Thompson and Findan Cox), Forest Service of the Department of Agriculture, Fisheries and Food (Noel Foley and Senan Kelly) and Coillte (Mick O’Donovan, Martin Joyce, Michael Delaney and Eugene Griffin). The outputs of these tasks are presented in the sections below.

8.3 Forestry in the Lough Melvin Catchment

Compared to the island of Ireland where forest cover is only 10% of the land area, forestry is a much more significant land cover in the Lough Melvin catchment as it accounts for over 25% of the catchment area. The bulk of this forest estate dates from the 1960s and, as was the case elsewhere in Ireland, a significant proportion of the newly afforested land was established on upland areas of blanket peat. The expansion of forestry in the 1970s is reflected in the age classes of forestry within the Lough Melvin catchment, with a peak of planting in the decade 1970 to 1980 (Figure 43). Over 10 km² of land was planted during this period. Since 2000, the majority of planting has involved the restocking of clearfelled sites rather than the afforestation of previously unplanted areas.
Forestry

**Figure 43: Distribution of Forestry in the Lough Melvin Catchment**

**Figure 44: Most heavily forested sub-catchments**
The largest areas of forestry occur in the Roogagh and County Rivers which together account for 77% of the forested area within the Lough Melvin catchment (Table 27). In the Roogagh catchment, forestry accounts for 50% of the catchment area.

### Table 27: Area of Forestry in the Main Lough Melvin River Catchments

<table>
<thead>
<tr>
<th>River</th>
<th>Catchment Area (ha)</th>
<th>Forestry Area (ha)</th>
<th>Forestry as % of Catchment Area</th>
<th>% of Total Forest Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roogagh River</td>
<td>6015</td>
<td>2995</td>
<td>50</td>
<td>53</td>
</tr>
<tr>
<td>County River</td>
<td>5523</td>
<td>1357</td>
<td>25</td>
<td>24</td>
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<tr>
<td>Other Catchments</td>
<td>4142</td>
<td>570</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>Glenaniff River</td>
<td>2724</td>
<td>80</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Ballagh River</td>
<td>1380</td>
<td>128</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Tullymore River</td>
<td>905</td>
<td>116</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Derrynaseer River</td>
<td>390</td>
<td>93</td>
<td>24</td>
<td>2</td>
</tr>
<tr>
<td>Kinlough River</td>
<td>400</td>
<td>78</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>Haran’s River</td>
<td>211</td>
<td>75</td>
<td>36</td>
<td>1</td>
</tr>
</tbody>
</table>

Approximately 7% of the forest cover is classified as broadleaf forestry occupying 388 ha, 17% is either heather, grass, unplanted, dead, felled, or tracks (979 ha) with the remaining 76% classified as either conifer or mixed plantation forestry or unplanted (4290 ha). (Note: For NI “areas classified as mixed forestry contain a minimum of 7% broadleaf” (F. Cox, Forest Service NI, pers. comm., 2006). The most prevalent commercial species planted throughout the catchment are Sitka spruce (Picea sitchensis) and Lodgepole pine (Pinus contorta). These species are typically grown in Ireland because they are particularly suitable for the Irish climate and soil conditions.

### 8.3.1 Broadleaf Woodland

Broadleaf woodland is located in scattered pockets within the Lough Melvin catchment. Plantations of broadleaf species grown under the private grant schemes include Common Alder (Alnus glutinosa), Silver Birch (Betula pendula) and Pedunculate Oak (Quercus robur). In addition to the recently planted broadleaf plantations, there are significant areas of semi-natural woodland within the catchment. In 2005 and 2006, the Woodland Trust (N.I) undertook a comprehensive survey to identify areas of ancient woodland in the northern part of the Lough Melvin catchment. The Woodland Trust identified areas possibly of ancient woodland on Rosskit Island, Gorminish Island, Carron and the lower reaches of the Roogagh River. The largest area of intact broadleaf woodland (11 ha) is located on Rosskit Island. It has a good age structure of sessile oak, ash and downy birch. Gorminish Island falls within the ASSI and consists of mature oak plantation but of poor age structure. Areas along the Roogagh River are dominated by ash with some sessile oak and birch. In recent years, semi-natural woodland has been under threat from land clearance from agriculture and housing development.
8.3.2 Productivity of Forestry

Soil type influences forestry growth rates and the overall productivity of a forest stand. Forestry within the Lough Melvin catchment is grown on blanket peat and gley soils in roughly similar proportions: in the County Leitrim portion of the catchment, 47% of coniferous forestry is on peats and 47% on gleys. In the County Fermanagh portion, the proportions are 54% on peat soils and 36% on gley soils. In total, 45% of forestry within the Lough Melvin catchment is grown on peat soils and 42% on gley soils, which have a low adsorption capacity for phosphorus. In addition, peat soils are relatively infertile and so require fertilisation. This is reflected in the average duration of the rotation cycles for the Lough Melvin catchment where a Sitka Spruce rotation can take up to 60 years where trees are grown on marginal peat soils (Source: Forest Service NI and Coillte Inventory data). Forestry planted on gley soils has a shorter rotation of 40-45 years. In contrast, on fertile soils such as brown earths, the normal duration is 35-40 years. Forestry in the Lough Melvin catchment can produce a yield class of 14-20.
8.4 Management of Forestry

Detailed information on the legislation, policy and controls governing forestry is provided in the “Evaluation of the controls and governance arrangements pertaining to the management of Lough Melvin” Task 1 report. An overview of the responsible organisations and their roles in management of forestry within the catchment is provided below.

The responsibility for development and management of the forest sector in Ireland rests with the Forest Service of the Department of Agriculture, Fisheries and Food (DAFF) and the Forest Service Northern Ireland of the Department of Agriculture and Rural Development (DARD). (In the subsequent text Forest Service Northern Ireland is referred to as Forest Service NI). Forest Service NI is an Executive Agency within DARD and its aim is “to contribute to the economic development of the entire forestry sector in NI, whilst at the same time promoting the sustainable management of forests for multiple uses and conserving and enhancing the rural environment”. Within the Lough Melvin catchment, the Forest Service NI manages 3118 ha or 55% of the total forest area. It is responsible for managing forests on a sustainable basis and is subject to independent audit and certification against the UK Woodland Assurance Standard (Forest Service NI, 2006).

The Forest Service of DAFF is Ireland’s national forest authority and is responsible for forest policy, promotion of the forest sector, administration of forestry grant schemes, forest protection, control of felling and the promotion and support of forest research. The Forest Service promotes Sustainable Forest Management as a central principle of Irish forest policy. Through this, “forests are managed
to provide economic, social and environmental benefits on a sustainable basis for both current and future generations." The Forest Service is responsible for "ensuring the development of forestry within Ireland in a manner and to a scale that maximises its contribution to national socio-economic well-being on a sustainable basis that is compatible with the protection of the environment" (DAFF, 2008).

Coillte Teoranta is a state owned commercial company established in 1989 when it acquired ownership of the State’s forests and expanded its operations from forest management to land-based businesses and added-value processing operations. Approximately 70% of the national forest estate is owned by Coillte (Coillte Teoranta, 2007). Currently, Coillte has an estate of 1590 ha within the Lough Melvin catchment. Coillte forests are managed in accordance with the criteria for sustainable forestry management set down by the Forest Stewardship Council. Coillte’s plantations in the Lough Melvin catchment are in Coillte management district N2. There are 26 individual forests in this District and each has a five-year management plan from 2006 to 2010. There is also a District Strategic Plan for the same period, which outlines the various policies including environmental issues.

Private forestry occupies just over 9% (293 ha) of the total afforested area in the County Fermanagh area of the catchment and 19% (428 ha) of the total afforested area in the County Leitrim area of the catchment. Private forestry companies mainly manage the private forestry in the catchment.
The EU Common Agricultural Policy’s Afforestation Scheme and now the Irish state aid grant schemes support the development of private forestry as an alternative land use to agriculture. The grant system under the Afforestation Scheme aids the landowner with the costs of establishment of forestry on private land. Grants are available for both broadleaf and coniferous plantations though grant rates are higher for planting of broadleaves. In NI, grant schemes for woodland are administered by Forest Service NI and Countryside Management Branch of DARD and in the RoI the Forest Service has the responsibility for the administration of forestry schemes. All newly grant aided private forestry must incorporate at least 10% broadleaf species.

The Forestry Environmental Protection Scheme (RoI) was introduced in 2007 for farmers that are already members of the Rural Environmental Protection Scheme (REPs). The main objective of the scheme is to develop “high nature value” forestry. The scheme is currently being implemented as a pilot and will help to meet commitment under the Rural Development Plan (development of forestry section). The Forest Service is responsible for the promotion and implementation of the FEPS.

The Native Woodland Scheme encourages the expansion and protection of Ireland’s native woodlands. The scheme supports the planting of indigenous tree species. Sites located within SAC’s, SPA’s and NHA’s may be eligible for development under the scheme (Teagasc, 2007). There are similar schemes available in NI.

The Forest Service is in the process of producing the Indicative Forest Strategy (IFS). The main aim of the IFS is to provide guidance in relation to the suitability of land for the development of forestry. The IFS takes a wide range of environmental constraints into consideration including fishery sensitive areas and soil productivity. The IFS identifies areas in the Co. Leitrim portion of the catchment that are suitable and unsuitable for afforestation based on environmental conditions (refer Table 28). Note that this assessment does not take into account whether the land is already planted or not and there are significant areas within the catchment that are currently forested, which under current guidelines are considered unplantable.

**Table 28: Suitability of land within the Lough Melvin catchment for forestry development (RoI only)**

<table>
<thead>
<tr>
<th>Categories</th>
<th>Sum (ha)</th>
<th>% of total Catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suitable for a wide range of woodlands</td>
<td>1351</td>
<td>11%</td>
</tr>
<tr>
<td>Potential for woodland development</td>
<td>2730</td>
<td>23%</td>
</tr>
<tr>
<td>Limited potential for woodland development</td>
<td>5081</td>
<td>43%</td>
</tr>
<tr>
<td>Unproductive or unplantable</td>
<td>2730</td>
<td>23%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11892</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Source: Forest Service RoI (in press)
8.5 Forestry and Nutrients

Management activities associated with forestry plantations, including ground preparation (cultivation/drainage), fertilisation, the construction of roads and clearfelling, have the potential to negatively impact on the freshwater environment (Cummins & Farrell, 2003a; Altiainen & Luttunen, 1999; Moore, 1999; Steven et al., 1995; Titus & Malcolm, 1992; Leek & Roberts, 1987; Swift, 1987). The degree of interaction between forestry and water quality within catchments is complex and varies according to the soil type, topography, geology, climate and vegetative cover. To evaluate the sources of diffuse nutrients and consequent risks to the water quality and long-term sustainability of Lough Melvin, it is necessary to identify and recognise how forestry activities can potentially increase the supply of nutrients to receiving waters within the catchment. The following section provides an overview of the forestry cycle and the respective activities that could have impacts on water quality.

Figure 48: Forest Model - Nutrient movement from source to receptor

8.5.1 Forestry Guidelines

It is important to note prior to discussing the impacts of forestry that significant areas in the west of Ireland were planted with exotic tree species in the 1950s and 60s when economic, social and environmental factors were different from those today (Kennedy, 2005). Indeed an awareness of the environmental pressures associated with upland forestry in particular, has built up only gradually since the 1960s. Equally, the development of mitigation measures has been a process of incremental advances. Currently, forestry in Ireland is subject to a series of environmental guidelines and operates within the concept of Sustainable Forest Management (SFM). These guidelines were
codified in NI when the Forestry Commission published the “Forestry and Water Guidelines” (1st edition) in 1988. In Ireland, the Forest Service released the “Forestry and Fisheries Guidelines” in 1991. Thus, over 60% of forestry was established in the Lough Melvin catchment before these guidelines were published. Figure 49 shows the distribution of forestry before and after the introduction of the Guidelines.

Figure 49: Pre and Post Guideline forestry in the Lough Melvin catchment

Much of the forestry within the Lough Melvin catchment is grown on marginal blanket peat and humic rich gley soils, which have a low phosphorus binding capacity (Cummins & Farrell, 2003a; Renou & Cummins, 2002), and this is the primary environmental or water quality concern associated with forestry in the catchment.

Plate 26: Pre and Post Guideline plantations in the Lough Melvin catchment. Left photo shows planting to edge of watercourse. Right photo shows well established buffer strip.
Forest management practices have changed in recent decades since the introduction of the Guidelines and planting on mineral poor sites is now avoided. Moreover, afforestation on land previously used for agriculture with more fertile soils has become a more common practice (McCabe et al., 2004). Many ex-agricultural sites are located at lower altitudes on mineral soils and on such sites, the fertilisation requirements are greatly reduced thus decreasing the risks of nutrient runoff. Since 1990, in the Lough Melvin catchment, 425 ha have been converted to forestry from land previously used for agriculture under the private grants and premiums schemes administered by the Forest Service, Forest Service NI and the Countryside Management Board.

8.6 The Forestry Cycle

A commercial forest cycle within the Lough Melvin catchment (Figure 50) typically involves enclosure of the land to limit access by grazing animals, ground preparation (cultivation and drainage), planting, fertilisation (manual or aerial), road construction, thinning, clearfell and replanting where applicable. Although there is a presumption towards replanting the areas that have been harvested for timber, not all land will be replanted in order to comply with current forestry guidelines.

8.6.1 Cultivation and Drainage

On poorly draining afforestation and reforestation sites, cultivation and drainage is undertaken to encourage adequate tree development. Mechanical mounding is the primary method of cultivation used within the Lough Melvin catchment though some ripping is undertaken by the Forest Service NI. Mound drains are from 8 to 10 m apart and are dug to a depth of 0.2 to 0.4 m cm, depending on the subsoil layer and are approximately 0.6 m in width (M. O’Donovan, Coillte and I. Thompson, Forest Service NI, pers. comm., 2007). Mechanical mounding can result in 30% overall site disturbance (Worrell, 1996). Ripping involves the breaking up of the iron pan by a tractor drawn plough and improves the aeration of the soil (I. Thompson, Forest Service NI, pers. comm., 2007). However, soils with a distinct iron pan are uncommon in the catchment.
Throughout the cultivation process and for a short time after drainage, there are increased risks of erosion and sediment runoff due to the site disturbance. Risks are particularly high on sites with steep slopes of >30% and erodible soils, and following periods of sustained rainfall (Nisbet, 2001). Moffat (1988) found that sediment concentrations in adjacent streams could be increased by over two orders of magnitude during the cultivation of low nutrient peat soils.

The main objective of the forestry organisations within the catchment is to cause minimal site disturbance to reduce the mobilisation of sediment to water (I. Thompson, Forest Service NI & M. O’Donovan, Coillte, pers. comm., 2007). A Cultivation Plan, which identifies potential vulnerable areas on-site such as watercourses and important habitats, is developed prior to commencement of any cultivation work. Silt traps are installed before drainage reaches waterways and, in steeply sloping areas, rock armour may be used to protect against erosion. Nisbet (2001) also notes that buffer strips are useful in retaining mobilised sediment on site. It is important to note that many of the drains in forested areas of the Lough Melvin catchment are dry in the summer months and may only have flows in periods of sustained rainfall.

Further information in relation to best management practices for ground preparation is available in the Forest Service “Forest and Water Quality Guidelines 2000” and the Forestry Commission “Forest and Water Guidelines 2003”.

8.6.2 Forest Fertilisation

Inorganic fertilisers are applied to forestry plantations to aid the establishment of the forest crop and to increase the growth rate of trees, thereby increasing the overall yield. Species type and the site conditions are significant determinants in the type and application rate of fertilisers (Forest Service Guidelines 2000). The first application of rock phosphate (pellets) is applied to the crop for the initial stages of growth. Second applications may also be applied if trees are grown on mineral poor soils e.g. peat and are experiencing nutrient deficiencies (identified by yellow foliage and foliar chemical analysis) (Teagasc, 2007).

In the Lough Melvin catchment, depending on the growth rate and soil type, no more than 1-2 applications of fertiliser over the life of the crop are considered necessary to sustain growth (I. Irwin, Forest Service NI and M. O Donovan, Coillte, pers. comm. October 2007). Applications of fertiliser are site specific and commonly required only on sites with low soil fertility and are carried out during the growing months between April and August. On reforestation sites, Coillte and the Forest Service NI apply no fertiliser where the harvested trees have produced a crop of Yield Class >16 (M. O’Donovan and M. Joyce, Coillte & I. Thompson, Forest Service NI, pers. comm., 2007). This would cover a large proportion of trees grown on mineral soils in the catchment. The trend of recent years has been for lower fertiliser applications. In all their forests, Coillte have reduced annual applications from 703 tonnes in 1996 to 132 tonnes in 2006 (M. Delaney, Coillte, pers. comm. 2007).
Where fertilisers are applied, slow release phosphorus fertilisers, most commonly rock phosphate, are used. Nitrogen and potassium fertilisers tend to be used on a remedial basis. Depending on the particular site requirements, application rates on initial afforestation sites range from 250 kg ha⁻¹ to 500 kg ha⁻¹ (equivalent to 35 kg ha⁻¹ – 70 kg ha⁻¹ of elemental phosphorus) (M. O’Donovan, Coillte, pers. comm., & I. Thompson, Forest Service NI, pers. comm., 2007). The Forest Service (RoI) has revised its recommendations for the maximum rate of application at the establishment of forest sites from 420 kg ha⁻¹ (of rock phosphate) to 350 kg ha⁻¹ (S. Kelly, Forest Service, pers. comm., 2007).

The application of phosphate in fertilisers is an additional source of phosphorus that can potentially reach watercourses. There is therefore an increased risk of nutrient runoff from these fertilised sites, which can cause elevated levels of nutrients in nearby water bodies, altering the water chemistry and encouraging excessive algal growth (Miller et al., 1996; Binkley & Brown, 1993; Swift, 1990; Swift 1987). Losses of nutrients from fertilised sites tend to be greatest during the first 6-month period when direct washout into drains and watercourses occurs (Nisbet, 2001). Research suggests that P loss from fertilised sites can occur for up to 5 years after application (Miller et al., 1996; Swift 1990). Studies have shown that P leaching can amount to 0.5 – 2 kg ha⁻¹ yr⁻¹ after the application of fertiliser on mineral poor soils such as peat (Miller et al., 1996; Swift 1987; Harriman, 1978).

Aerial applications of rock phosphate and urea fertiliser are the primary concern within the UK (Nisbet, 2001). Aerial rather than manual application is usually undertaken where sites are difficult to access and manual applications are impractical. Since 2006, aerial fertilisation in the RoI has been controlled by license under the Minister for Agriculture and Food. The primary reason for this is to restrict aerial applications and reduce the risks posed to the freshwater environment (Kavanagh, 2007). In NI, there are no formal licensing controls. However, sites are assessed on an individual basis and no applications take place without prior consultation with water regulatory authorities as well as other interested bodies (I. Irwin, Forest Service NI, pers. comm., 2007).

In the Lough Melvin catchment, aerial fertilisation is only undertaken where other methods of fertilisation are not feasible. The last Forest Service NI record of aerial fertilisation was in 2003 at a reforestation site within the “Big Dog” forest where 250 kg ha⁻¹ of rock phosphate was applied over an area of 26 ha. No sites within the catchment are targeted for fertiliser application within the next five years (I. Irwin, Forest Service NI, pers. comm., 2007). There are no records of aerial fertilisation in the County Leitrim area of the catchment (M. O’ Donovan, Coillte and B. Maguire, NRFB, pers. comm., 2007).
The most recent application of fertiliser in the County Leitrim area of the catchment occurred at “Tullintaggart” reforestation site in 2001 where 250 kg ha\(^{-1}\) of rock phosphate was applied over a 7 ha area. In 2005, 27 ha of private forestry plantations received fertiliser (Ratheelin 7 ha, Lattone 8 ha, Gorteendarragh 12 ha). On reforestation sites, Coillte and the Forest Service NI do not spread fertiliser on ground that has previously produced a crop of Yield Class >16 (M. O’Donovan and M. Joyce Coillte & I. Thompson Forest Service NI, pers. comm., 2007). However, one of the main concerns in relation to setting a threshold of Yield Class >16, is the fact that a Yield Class of >16 is often not reached where forestry is grown on blanket peats. Therefore, within the Lough Melvin catchment it is likely that fertilisation on reforestation sites will be required. An increase in fertilisation activity may occur in the future due to the forecasted clearfelling of 952 ha between 2008 and 2015.

In terms of water quality, the decreasing trend in the application of phosphate fertilisers in forestry is positive, however, there are still significant risks from fertiliser application that are exacerbated by the catchment’s specific conditions: the low fertility of peat soils, poor capacity to absorb phosphorus combined with high slopes and the high annual rainfall.

**8.6.3 Thinning**

Thinning of forestry stands is undertaken to reduce competition between trees and increase the growth and volume of the remaining crop. However, thinning can lead to areas of wind throw that, in turn, require clearfelling. A wind throw model developed by Ní Dhubháin et al. (2001) suggests that large blocks of forestry located in areas of the Roogagh and County sub-catchment have a high probability of wind throw (>0.9). The model is based on top height, soil type and altitude, wind zones and thinned or un-thinned areas. Because of the risk of wind throw, thinning is not commonly practiced in County Fermanagh plantations by Forest Service NI (I. Irwin, Forest Service NI, pers. comm., 2007).

In County Leitrim, first thinning of the crop occurs after approximately 22 years with second thinning occurring at approximately 25 years (M. O’Donovan, Coillte, pers. comm., 2007). In areas planted before the introduction of the Forestry and Water Guidelines, Coillte’s policy is to create buffer zones when first thinning is being carried out, where feasible.

The immediate environmental risks associated with thinning operations are considered to be relatively low as there is minimal site disturbance and any release of nutrients is primarily absorbed by the remaining standing crop.
8.6.4 Road Construction

The construction of forest roads causes disturbance to the soil surface and has the potential to increase sedimentation and nutrient runoff. Johnson & Brondson (1995) monitored sediment yields from road surfaces within a Scottish forest and found that sediment yields from heavily trafficked roads were two to ten times higher than from an infrequently used old road. In addition, the introduction of aggregate for road construction from outside the forest site may cause considerable changes to the chemical composition of the soil and water.

Road construction is undertaken to provide operators with safe access in and out of forest coupes and is an integral part of forestry operations. Forest roads are designed to carry legal haulage loads including the heavy loads carried by harvesters, forwarders and trucks, and usually include loading bays and turntables. The Forest Service (RoI) provides grant aid for forest road construction and although roads do not require planning permission, those servicing areas exceeding 20 ha in size must be surveyed by a professional engineer or surveyor.

The Forestry Commission “Forestry and Water Guidelines” 2003 (4th edn.) provides guidance on road construction and maintenance and states that forest road works requires meticulous planning and execution if damage to streams is to be avoided. Ryan et al. (2004) has published the “Forest Road Manual” guidelines for the design, construction and management of forest roads. To reduce the risks of soil disturbance and erosion, the forest owners usually undertake road construction activities during the summer months when conditions are dry.

In preparation for thinning, Coillte constructs roads or lay-bys two years prior to the thinning process to ensure adequate time for road materials to bind (M. O’Donovan, Coillte, pers. comm., 2007). Coillte have identified 7 forest coupes for roading within the next 5 years – (Kiltyclogher, Gubmanus, Conray, Lugasnaughta, Gubacreeny 2008; Tullyskehenny, 2009; Gortnader rany, 2010) and these sites will be thinned approximately two years after the roads are constructed (M. O’Donovan, Coillte, pers. comm., 2007).

The construction of forest roads within the County Fermanagh area of the catchment was carried out mainly in the 1970s and 1980s and the existing road network is considered adequate to perform everyday forestry operations. Therefore, there are no areas identified for road construction within the next 5 years (I. Irwin, Forest Service NI, pers. comm., 2007).
8.6.5 Clearfell

Clearfell and harvesting of the crop is the final stage of the forest cycle. Forestry stands are selected for clearfell when they have reached a suitable size for market sale. Shortwood systems are the main type of clearfell operation employed within the Lough Melvin catchment. Problems associated with vulnerability to wind throw have tended to shorten the forest cycle so advancing the dates of clearfelling in the County Fermanagh portion of the catchment.

Clearfell is considered to be the most disruptive phase of the forest cycle and has received the greatest attention in terms of its potential impacts on water quality (Nisbet, 2001; Leeks & Roberts, 1987). The impacts identified include acidification, increases in nutrients, sedimentation and siltation (Neal et al., 2004b; Reynolds 2004; Cummins & Farrell 2003a; Johnston et al., 2000; Cunningham, Farrell & Collins, 1999; Steven et al., 1995; Binkley & Brown, 1993; Titus & Malcolm, 1992; Leeks & Roberts 1987).

The use of heavy machinery for harvesting and site preparation activities causes soil compaction, reducing the ability of the soil to retain water and increasing runoff (Moore, 1999). Most damage is caused by operations on poorly draining soils including surface-water gleys, shallow peats overlying poorly drained clay soils, and deep peats (Carling et al., 2001). In forest harvesting operations, there is a current trend to increase the size, power and loads of logging machines, with weights amounting to 12-16 tonnes unloaded (Ampoorter et al., 2007). New machinery has incorporated improved environmental protection capabilities such as wider tyres and reduction in the ground pressure of machines. Harvesting activities, if conducted to the edge of streams, can result in significant sediment loading of water bodies (Moore, 1999). The removal of vegetation on sites also reduces the evaporation and interception of rainfall, which increases annual runoff and sharpens the peak runoff in spring and summer (Rankinen & Kenttamies, 2005; Cunningham et al., 1999).

The main environmental concerns with clearfelling of forestry are the risk of sediment loss and nutrient release from the breakdown of organic matter (lop and top). A recent monitoring study undertaken in the Owenriff catchment in County Galway showed an average export of phosphorus of 7.2 kg P ha⁻¹ yr⁻¹ in the first year following clearfell on a peat site. This export coefficient was expected to halve by the second year and halve again by the third year. After the third year, it was projected that there would be no export from the site (Sweeney, 2007). However, studies by Cummins & Farrell (2003a) and Titus & Malcolm (1992) show sustained levels of P loss (1.4 kg P ha⁻¹ yr⁻¹) for 7 years after felling. By comparison, the phosphorus export coefficient from forest land (mature forest stands) is 0.36 kg P ha⁻¹ yr⁻¹.
It is the practice of Coillte and the Forest Service NI to go through a detailed planning process with widespread and focused consultation prior to clearfell activities being undertaken. If the site is identified as medium or high risk then relevant mitigation measures are put in place (E. Griffin, Coillte & I. Irwin, Forest Service NI, pers. comm., 2008). Within the Lough Melvin catchment, a detailed harvesting plan is produced for each specific site. In recognition of these potential impacts, clearfelled operations now include a number of measures that are specifically designed to minimise water pollution risk. Harvesting site plans now mitigate against the potential for soil damage and erosion largely through the use of brash mats. The strategic positioning of brash mats away from watercourses can reduce the availability of nutrients coming in contact with watercourses.

The Forest Service “Forest Harvesting and Environmental Guidelines” 2000 and the Forest Service NI “Environmental Guidelines for Timber Harvesting” 2006 provide best management practices for harvesting operations, to reduce environmental impacts. Good management can reduce sediment loss and minimise site damage with on site discipline and attention to detail considered key elements to good harvesting (Nisbet, 2001). The guidelines recommend that sizes of felling coupes should be reduced in sensitive areas. Phased felling of plots between 10 and 20 ha has been found to reduce the impacts of clearfelling on water quality (Neal et al., 2004a; Carling et al., 2001). Coillte and the Forest Service NI aim to limit the size of felling coupes to no more than 20 ha. This maximum felling size promotes diversification and limits the total amount of nutrients available after clearfell (Forest Service, 2000). Under certain conditions, the threshold of 20 ha may be exceeded i.e. if wind throw is a risk and for redesign plans. The Forest Service sets a maximum felling limit of 25 ha when granting a felling licence for all forest owners. In highly sensitive catchments such as Lough Melvin, there may be a case for reducing this felling limit further (i.e. to 10 ha).

The setting of a maximum felling limit aids in managing the risk to water quality posed by clearfelling activities. However, the Lough Melvin catchment drains a large area that traverses two forest management authorities’ jurisdictions and there are currently no restrictions on the total amount of clearfelling that can be undertaken within the catchment at any one time. This is a significant risk in the management of the lake and highlights the importance of managing the landscape at a catchment scale rather than at an individual site or coupe scale.

There is no information available on areas to be replanted within the Lough Melvin catchment. Historically, all areas that were clearfelled were reforested, but since the introduction of requirements under the Sustainable Forestry Management (Forest Stewardship Council), this obligation for replanting may be eased.

### 8.6.6 Brash Mats

Following clearfell operations, there are large quantities of low value woody debris consisting of branches, bark, needles and twigs left on site. These residuals are known as “lop and top” and their management is now integral to both limiting the potential for damage to water quality and the success of re-establishing the second crop of trees. In particular, brash mats consisting of tree tops and branches are the primary means used during harvesting operations to protect the soil and limit mechanical damage from heavy machinery (L. Irwin, Forest Service NI & M. O’Donovan Coillte, pers. comm., 2007). They are generally a good soil protection measure, enabling the extraction of timber from wet sites where the soil has low bearing strength, while protecting the underlying soil from rutting and liquefaction (Moffat et al., 2006; Wood, Carling & Moffatt, 2003; Hutchings, Moffat & French, 2002). Protection can be enhanced by their strategic positioning away from watercourses.
After timber removal brash mats are left on site following clearfelling to provide nutrients for the new crop (M. O’Donovan, Coillte and I. Irwin, Forest Service NI, pers. comm., 2007). Thus the elimination of or the lower rates phosphate fertilisers now used in reforestation takes into account the nutrient supplied from the brash mat. To facilitate replanting brash mats may be concentrated into windrows after harvesting operations are completed as these assist replanting through provision of shelter as well as a source of nutrients for the new crop (I. Thompson, Forest Service NI, pers. comm., 2007).

Although brash mats protect the soil structure and protect against soil compaction and erosion their role in eutrophication is more problematic. Nutrients that are not taken up by the new crop can become mobile during wet weather and cause excessive nutrient input to receiving watercourses. As documented by Moffat et al. (2006) brash may contain approximately half the amount of phosphorus and potassium recommended in fertiliser, and double the normal nitrogen application rate. Titus & Malcolm (1992) carried out a study monitoring the trends in nutrient concentrations in leachate from beneath clear strips and brash swathes after clearfelling upland Sitka spruce on peaty gley soils. Felling of three different sites with similar characteristics was undertaken and these were monitored for nutrient losses over a seven year period. The study found that potassium losses were highest in the first two years following clearfelling. The potassium loss was 54% - 43 kg ha\(^{-1}\) in the first year. Titus & Malcolm (1992) also found that phosphorus loss was constant over the 7 year period with an average of 1.4 kg P ha\(^{-1}\) yr\(^{-1}\).

Removal of brash from sites post clearfelling can reduce nitrogen and phosphorus leaching (Moffat et al., 2006; Stevens et al., 1995). However, this is problematic as it is not only costly but there is a strong possibly that the loss of nutrients would require additional applications of chemical fertilisers to sustain timber production. Moreover, as most of the plant available nutrients are in the leaves of the brash, the material would have to be removed quickly, i.e. before leaf fall from the cut branches occurred. Because of its value as a nutrient source and use in pollution mitigation, brash has never been removed from clearfell sites within the Lough Melvin catchment (I. Irwin, Forest Service NI & M. O’Donovan, Coillte, pers. comm., 2007). Recently the Balcas Timber Ltd. Enniskillen commenced a pilot project to assess the economic viability of the brash collected from clearfelled sites being used as an alternative energy source. In this instance, it is envisaged that leaf fall before the brash is removed will leave sufficient reserve of nutrients for the new crop of trees.
8.7 Forestry Pressures in the Lough Melvin catchment

Many of the risks associated with forestry are increased in the Lough Melvin catchment due to sensitive catchment characteristics such as high runoff risk, high slopes, proximity to watercourses, high P - desorption risk and high precipitation rates, which were described in section 5.5. A simple assessment of the spatial distribution of their combined risk was undertaken by combining each risk factor to give three overall levels of risk, namely high, moderate and low. Each risk associated with slope, soils desorption and the distances from watercourse was assigned a value of 1, 2 or 3 representing low to high risk. The compound risk map combined multiplicatively so that high risk scored 24-27, medium 10-20 and low less than 10. Using the GIS these values were converted to rasters from vector format using the spatial analyst extension with ESRI ArcView 9.2. Similar to the slope risk map these were calculated using a 50m grid so combining the three rasters would be possible.

Areas of forestry have been overlain on high risk areas within the Lough Melvin catchment (Figure 51). In total, 49% of forestry in the catchment is located on areas classed as having high overall risk. Only 3% was classed as low risk. These proportions are comparable to the distribution of risk for the whole of the Lough Melvin catchment, where 45% of the area was classed as high risk and 4% as low risk.

Plate 35: Forestry on steep slopes- example of a potentially high risk area
Figure 51: Forestry on high risk areas within the Lough Melvin catchment. High risk is defined as areas showing high risk relating to both soil desorption, slope and distance from water courses.

The following points highlight the key forestry related pressures within the Lough Melvin catchment.

- The low binding capacity of organic blanket peat for phosphorus. 45% of all forestry is grown on blanket peats and 42% grown on gleys.
- Nutrient deficient stands within the Lough Melvin catchment may require future applications of phosphate fertilisers.
- Low yield classes in the catchment may lead to future applications of fertiliser at the reforestation stage.
- 61% of Coillte and Forest Service NI forestry was planted before the introduction of the *Forestry and Water Guidelines* and the introduction of forest certification. Buffer zones are absent in many of these older sites.
- The catchment has a high run-off risk and a high connectivity due to its high density drainage network. The Roogagh and County rivers drain heavily forested sub-catchments.
- 49% of the forestry in the catchment is planted on areas classified as having high risk for soil desorption, slope and proximity to watercourses (See Section 5.5).
- Windthrow sites are common throughout forested areas of the catchment leading to increases in clearfell activities.
- Clearfell activities pose a risk of elevated phosphorus loss due to the breakdown of brash especially on blanket peat sites.
Currently 419 ha are identified for clearfell in the catchment in 2015 but there is insufficient cross-border consultation between the forest management organisations regarding how the total yearly area of clearfell and fertiliser application in the catchment may impact on nutrient losses to Lough Melvin.

### 8.8 Future Nutrient Loads from Forestry

Clearfelling is identified as the forestry activity that has the greatest potential to cause the release of nutrients. Therefore, the remainder of this section focuses on future clearfelling activity within the catchment to highlight the future loads expected from forestry over the next 7-8 years.

Figure 52 shows locations of proposed clearfelling within the Lough Melvin catchment between 2007 and 2015. These are largely within the heavily forested Roogagh catchment although an area on the north-eastern shore of Lough Melvin near Muckenagh Bridge is identified for clearfelling in 2011 that could directly impact on the lake. Areas identified for clearfelling per year within the Lough Melvin catchment up to 2015 were sourced from Forest Service NI and Coillte clearfell plans (and data). The most notable feature is that there are 419 ha projected for clearfelling in 2015, which is almost 15 times the area clearfelled in 2007 (Table 29).

**Figure 52: Distribution of forestry identified for clearfelling 2007-2015.**
Table 29: Forest areas projected for clearfelling in the Lough Melvin catchment 2007-2015.

<table>
<thead>
<tr>
<th>Year of Clearfell</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>28 Ha</td>
</tr>
<tr>
<td>2008</td>
<td>32 Ha</td>
</tr>
<tr>
<td>2009</td>
<td>88 Ha</td>
</tr>
<tr>
<td>2010</td>
<td>72 Ha</td>
</tr>
<tr>
<td>2011</td>
<td>115 Ha</td>
</tr>
<tr>
<td>2012</td>
<td>75 Ha</td>
</tr>
<tr>
<td>2013</td>
<td>20 Ha</td>
</tr>
<tr>
<td>2014</td>
<td>131 Ha</td>
</tr>
<tr>
<td>2015</td>
<td>419 Ha</td>
</tr>
</tbody>
</table>

8.8.1 Phosphorus Loss Model

To quantify the total phosphorus loads from future clearfell operations within the Lough Melvin catchment, a phosphorus loss model was developed for the Lough Melvin catchment. This model was developed to aid in the planning and preparation for the increased risks posed by forestry (increased clearfelling areas) over the next 7-8 years. The model assessed the impact of clearfelling through the use of phosphorus exports from forest land. The phosphorus export coefficient from mature forest stands was taken to be 0.36 kg P ha⁻¹ yr⁻¹ (Smith et al. 2004). For areas which have been clearfelled, the export coefficients developed from the Owenriff catchment in County Galway were utilised (Owenriff Working Group Rapporteur’s Report, 2007). To various degrees the Owenriff and Melvin catchments have similar characteristics such as soil type, proximity to water, high runoff risk and the historic forest management use of phosphate fertilisers.

The Lough Melvin forestry phosphorus loss model was based on the following coefficients:

1. Clearfelled coniferous stand phosphorus export coefficients (from the Owenriff)
   
   > 7.2 kg P ha⁻¹ yr⁻¹ for Year 1
   > 3.6 kg P ha⁻¹ yr⁻¹ for Year 2
   > 1.8 kg P ha⁻¹ yr⁻¹ for Year 3

2. Standing crop export coefficient of 0.36 kg P ha⁻¹ yr⁻¹ after last three years (Smith et al. 2004).

These clearfelling phosphorus export coefficients from the Owenriff are conservative in that they are high but their adoption was considered a more prudent approach than adopting lower values. This was partly because there is no precise basis for disregarding the results as unrepresentative or exceptional at present. In addition, their adoption was considered prudent or precautionary given the rare and fragile ecological status of Lough Melvin and the large areas of forestry planted before the introduction of the Forestry and Water Guidelines.
Forestry

The Forestry Table in Appendix 1 gives the breakdown of load contributions from clearfell for the years 2007-2015 based on Coillte and Forest Service NI clearfell projections. The phosphorus model shows significant increases in phosphorus loss from increased clearfelling activities within the catchment between 2007 and 2015, but most particularly in 2015 with loads projected to increase from 625 kg P in 2007 to 3530 kg P in 2015 (Figure 53). Note that these loads are for clearfelling only and do not include nutrient loads from other forestry activities for e.g. fertilisation. These loads can be measured against the current loading of phosphorus to Lough Melvin that are set out in Section 6.10, where the current loading is estimated to be approximately 13 tonne P per year but with a target of 10 tonne P year. Thus, the projected loading for 2015 from clearfelling alone of 3.5 tonnes P is 27% of current loading, which is considered undesirably high. Based on current knowledge it would be expected that lake concentration of total phosphorus would increase in proportion to the increase in catchment loading.

![Total Phosphorus Load from Clearfell](image)

Figure 53: Forecast Phosphorus loads from clearfelling operations (only) in the period 2007-2015.

If these activities progress with no intervention or mitigation, and assuming that there are no other increases in phosphorus from other forestry activities or other land use activities within the catchment, then the concentration in Lough Melvin would be expected to increase to between 32 µg L\(^{-1}\) and 34 µg L\(^{-1}\).

8.9 Forestry Measures/Actions

In light of the increase in nutrient loads from clearfelling activities alone within the catchment in the short to medium term, it is imperative that measures are put in place to reduce or eliminate the impacts on Lough Melvin. Consequently, a total of 57 forestry measures were developed from literature and in consultation with technical experts, to reduce the impacts of forestry on the water quality of Lough Melvin. The measures aimed at building on existing protective measures incorporated in the Forestry and Water Guidelines and were targeted specifically to the Lough Melvin catchment.
The Forestry Working Group (comprising of representatives from forestry organisations within the catchment and the NRFB) scored each of the measures (-5 most negative and +5 most positive) based on the following criteria:

- Uptake by Forestry Agencies
- Ease for Administration
- Scientific Soundness
- Environmental Effectiveness
- Productivity Side-Effects
- Environmental Side-Effects

The highest ranked measures (21) were identified and then assessed at a Forestry Workshop. The aims of the Workshop were:

- To present to forestry operators and agencies in the catchment, a number of measures that could be implemented by the forestry sector to help maintain and enhance water quality in the catchment;
- To identify a small number of high priority robust measures from within those presented;
- To discuss issues related to the priority measures and identify potential opportunity/requirements for their implementation.

The following top 8 measures were identified:

1. Buffer zones should be created beside watercourses in line with best management practices where windthrow is not a risk factor. This measure would require operational change for existing sites.
2. Coillte and the Forest Service NI should develop progressive felling plans on a whole catchment basis. This requires annual consultation between the two organisations.
3. Aerial fertilisation proposals from RoI and NI should be combined prior to consultation with the regulatory authorities at a cross border level i.e. The Fisheries Board, River Agency and E.H.S. This measure requires only operational changes and could be done with an annual assessment and agreement between Coillte and Forest Service NI.
4. Brash should be removed as far back from watercourses as possible. This measure will require operational changes and environmental side effects would need to be considered.
5. On clearfell sites, strategically position ochre at the end of collector drains (Pilot Study to be undertaken by COFORD).
6. The poorest nutrient deficient sites should be identified and allocated for areas of open space as part of forest redesign plans. This most appropriate delivery route for this measure is considered to be the Indicative Forest Strategy and Forest Design Plans. It was considered a measure that could easily be accommodated in the NI portion of the catchment.
7. On reforestation sites, no fertiliser should be applied until vegetation has re-established.
8. In areas of high risk, silt traps should be installed either prior to ground preparation or harvesting. This is already standard practice.
Other recommendations from the Forestry Working Group

- Sensitive areas (such as spawning grounds) in the catchment should be better identified and forestry operators made aware.
- Difficult forestry sites posing single event risks should be identified and managed through correct environmental planning.
- Where sensitive sites and difficult forestry sites combine, consultation between appropriate agencies on protective measures is needed.
- The planting of broadleaf woodland should be undertaken in areas of high run-off risk, areas prone to over grazing and poaching from intensive stocking.
- The current study did not have a monitoring programme that was targeted to specific land uses and it was recommended by the Forestry Working Group that an independent, targeted monitoring programme be established immediately for the Lough Melvin catchment to identify the benefits and impacts of forestry on water quality.

8.10 Conclusion

The use of additional measures to those recommended in the Forestry and Water Guidelines follows a “precautionary approach”. It has been widely acknowledged by stakeholders including members of the Forestry Working Group, that the Lough Melvin catchment is highly sensitive and that forestry organisations have an obligation to reduce the potential risk forestry activities pose to the ecological status of the lake. The forestry industry over the past 20 years has made significant changes to forestry practices and developed new environmental guidelines in line with scientific research, to minimise the impact on the environment.

Figure 54: The redesign of a forest in the Roogagh sub-catchment
Figure 54 provides an example of the redesign of forestry within the Roogagh sub-catchment. In this forest, all the riparian zones of streams and lakes are either left unplanted or else planted with broadleaved mixed woodland species. These newly afforested and reforestation sites managed by Forest Service NI and Coillte (for afforestation sites only) incorporate 15% broadleaf species and 10% open spaces (on a district basis only). Accumulating evidence from scientific research (Machava, McCabe, O’Dea, Cabral, & Farrell, 2007; Strive Report, 2007; Nisbet et al. 2002) has shown the Forestry and Water Guidelines to be generally effective in both Ireland and the UK.

However, the sensitivity of the Lough Melvin catchment to nutrient loss and the sensitivity of the lake to nutrient enrichment must be stressed, reiterated and accounted for. The interaction between forestry and water is complex and risks of phosphorus loss are increased under particular catchment characteristics (Sweeney, 2007; Cummins & Farrell, 2003a). Evaluation of the catchment using the parameters specified in the Forest Service’s Indicative Forest Strategy, indicates that large areas of the Lough Melvin catchment are considered unsuitable for afforestation. Consideration should be given to the cessation/withdrawal of forestry activities in these areas under the pending programme of measures for ecological protection (T. Champ, CFB, pers. comm., 2008).

The agreement by the forestry organisations on a set of measures is a first step towards managing the increased nutrient loads expected from forestry in the future. However, it is only a first step. It is essential that consultation and cooperation is enhanced between the forestry organisations operating in the catchment and that the recommendations presented in this study are developed further and ultimately implemented. Work must continue to deliver action on the ground, before any environmental benefits can be realised.
Housing- Wastewater
In the past decade, the human population within the Lough Melvin catchment has increased dramatically in line with the growth in housing experienced around the country. The population of Kinlough, which has perhaps seen the greatest increase in number of dwellings in County Leitrim, doubled between the censuses in 2002 and 2006, from over 300 to nearly 700. There are approximately 3000 people resident within the catchment with approximately 40% (1161) resident in three villages; Kinlough and Kiltyclogher in County Leitrim and Garrison in County Fermanagh. In addition, Rossinver in County Leitrim is a small hamlet located on the Ballagh River. The distribution of residential properties within the catchment is shown in Figure 55.

The impacts of increased development and housing within the catchment include land disturbance that causes erosion and sedimentation in nearby waterways and organic pollution of water. For lakes, their dominant impact is their contribution to the eutrophication from wastewater generated by occupied dwellings. This contains significant amounts of phosphorus primarily from sewage and the use of household detergents. Currently, for housing in the Lough Melvin catchment most of this phosphorus will reach the lake, contributing to the lake’s nutrient loading. The main purpose of wastewater treatment processes, either through a Wastewater Treatment Plant (WWTP) or on-site wastewater treatment system is to remove organic matter and pollutants such as ammonia. However, these systems are not necessarily designed or effective at removing nutrients, especially phosphorus, and this is particularly the case for septic tanks within the Lough Melvin catchment.

Decisions relating to housing developments and individual houses impact directly on the health of the catchment and Lough Melvin, and should be considered very carefully. It is possible that one major housing, industrial or agricultural development could threaten the lake’s unique ecology (Mellon & Woodrow, 2008).
9.1 Purpose of Lough Melvin Study

A short desktop study and septic tank survey was undertaken to identify and highlight the potential issues associated with wastewater and housing within the Lough Melvin catchment. The study was not part of the original Lough Melvin Programme deliverables or outputs and as such is additional work undertaken to provide a more holistic view of nutrient sources within the catchment. The outputs of this study are presented in the following sections entitled Wastewater Treatment Plants and Onsite Wastewater Treatment Systems.

9.2 Wastewater Treatment Plants

In urban areas where there is a density of population, creation of sewered areas and WWTPs is a viable treatment option. In the Lough Melvin catchment, the villages of Kinlough, Kiltyclogher, and Garrison are serviced by WWTPs. These plants treat the wastewater of 38% of the catchment population. There are four main stages in wastewater treatment: preliminary, primary, secondary (biological) and tertiary, which produce an increasing quality of effluent. Not all WWTPs operate all treatment processes and therefore the quality of effluent can vary considerably. A generalised overview of the various stages is provided below.

Preliminary treatment screens out large items such as paper, wood and plastic. Primary treatment involves the settlement of heavier organic matter with the majority of suspended solids removed at this stage. The secondary treatment process involves the oxidation of the remaining organic material, including dissolved fractions by bacteria. This stage of treatment should remove 90% of all solids and organic materials and lower the initial Biological Oxygen Demand (BOD) of untreated sewage of over 200 mg O L⁻¹ to values of 20 mg O L⁻¹ or lower.

Typically, municipal wastewaters contain high amounts of total phosphorus, between 5 and 20 mg L⁻¹, of which 1-5 mg L⁻¹ is organic and the rest is inorganic. Normally, secondary treatment only removes 1-2 mg L⁻¹, so large amounts of phosphorus can be discharged in the final effluent, causing eutrophication in surface waters (Lenntech, 2008). The third and final stage of the treatment process is tertiary treatment. Chemical precipitation, involving the addition of salts of calcium, aluminium or iron, is used to remove phosphorus from the effluent. Alternatively, natural systems such as ponds or wetlands have been used to remove phosphorus and nitrogen compounds, sometimes referred to as effluent polishing; the aim is often to achieve very low nutrient concentrations in the effluent.

The Urban Waste Water Treatment Directive requires phosphorus removal from effluent discharging into waters that are vulnerable to eutrophication. The standard of removal is either to achieve an 80% removal of the influent total phosphorus or to meet a final effluent standard of 2 mg P L⁻¹. However, this requirement is only mandatory where the population equivalent (p.e.) exceeds 10,000 persons. There are no urban areas within the Lough Melvin catchment that approach this population and in addition, the lake is not designated as a “sensitive area” under the Directive. Nevertheless, the relevant stakeholders do recognise the sensitivity of Lough Melvin to eutrophication and the responsibility to reduce nutrient loadings from wastewater.
9.3 Lough Melvin WWTPs

Three WWTPs are located in the Lough Melvin catchment at Kinlough and Kiltyclogher in County Leitrim and Garrison in County Fermanagh.

9.3.1 Kinlough WWTP

The discharge from Kinlough WWTP enters Lough Melvin via the Kinlough River at the south-western end of the lake. In 2006 Leitrim County Council installed phosphorus removal facilities (using ferric dosers) with the aim of reducing effluent TP levels to < 2 mg P L⁻¹. Monitoring of effluent is undertaken under the Urban Wastewater Regulations and the 2 mg P L⁻¹ figure was exceeded on one of the six sampling occasions in 2007 (June) due to operational problems with the ferric dosers. The issue with the dosers has since been resolved. However, as is evident from monitoring undertaken on the Kinlough River referred to in Section 6, there have been fluctuations in the quality of effluent being discharged from the WWTP. These reflect population expansion in Kinlough which has limited the capacity of the WWTP to deal with peak loads.

There is recognition by stakeholders and the wider community that the Kinlough WWTP is inadequate for the current size of the village. Using funding provided by the Leitrim Towns and Villages Sewerage Scheme, a contract to design, build and operate the new WWTP for the next 20 years has been awarded to a private company. Work on the new plant, which will be built on the existing site, is proposed to start in June/July 2008 and be fully completed by 2009 (Leitrim County Council pers. comm., 2008). Work on improving the sewer network was undertaken in Kinlough in 2007, which includes an extension to the existing network and the separation of foul water and storm water. The new WWTP will have a p.e. of 2100 and is considered to have significant capacity to cope with the further expansion of Kinlough. The effluent will be required to meet a stringent TP standard of 0.8 mg P L⁻¹ which has been set by Leitrim County Council. This standard reflects the sensitivity of Lough Melvin to enrichment. Other standards to be met by the new WWTP are BOD <11 mg L⁻¹; total suspended solids <15 mg L⁻¹.

9.3.2 Kiltyclogher WWTP

Kiltyclogher WWTP is much smaller than those at Garrison and Kinlough as it services a population of approximately 170. It discharges via a drain into the County River. Treatment is considered to be poor, barely achieving secondary treatment standards and there is no facility for phosphorus removal. Kiltyclogher WWTP was sampled three times in 2007 with TP on one occasion exceeding 5 mg P L⁻¹. Under the Leitrim Towns and Villages Sewerage Scheme, Kiltyclogher has also received funding for a new WWTP to be built on the same site with a capacity of 500 p.e. Work on the new plant was due to start in mid 2008 and be completed by the end of 2009. Standards to be met by the new WWTP are BOD <25 mg L⁻¹, total suspended solids <35 mg L⁻¹ and total phosphorus <2 mg P L⁻¹.

9.3.3 Garrison WWTP

The Garrison WWTP which provides primary and secondary treatment discharges directly to Lough Melvin via a pipe that runs under the walkway at the Garrison Pier. Although the overall contribution to the total loading of phosphorus to Lough Melvin is small, the phosphorus in the discharge is the likely cause of algal mats that are often washed onto the shore of the adjacent north-eastern beach (Girvan & Foy, 2003). The Garrison WWTP services the population of Garrison of around 360 people.
The nominal p.e. of the plant is given as 550 suggesting that it is not overloaded. Environment and Heritage Service have issued a Water Order Consent specifying the effluent annual average standard as 40 mg L\(^{-1}\) BOD, 60 mg L\(^{-1}\) suspended solids and 2 mg P L\(^{-1}\) total phosphorus. However, these levels are higher than those that have been set by Leitrim County Council for Kinlough WWTP.

Monitoring results from 2006 and 2007 suggest that there is great variability in the quality of the effluent from the WWTP with TP ranging from 0.26 mg P L\(^{-1}\) in August 2001 to 14 mg P L\(^{-1}\) in September 2001 and 5.1 mg P L\(^{-1}\) in June 2007. This variability strongly suggests dilution of the effluent by storm water entering the sewer system and/or the ingress of ground water into the systems. The latter being a problem in areas of water logged soils. Therefore, although the TP in the effluent can be low this does not mean that the loading is also low as the low concentrations most probably reflect effluent dilution rather than retention of nutrients within the WWTP. In this case, a clearer assessment of the impact of the WWTP on Lough Melvin requires the quantification of effluent flows as well as effluent concentrations.

Phosphorus removal facilities have recently been installed which should reduce the nutrient loading and an upgrade is planned to allow phosphorus removal, largely in recognition of the need to maintain the condition of the lake under the Habitats Directive. At present, there is no time schedule set for the new Garrison WWTP (NI Water, pers. comm., 2008).

**9.3.4 Rossinver**

There is no sewer network for the small hamlet of Rossinver and all residents have septic tank systems with probable eventual discharge of nutrients to Lough Melvin, nor is there any plan to install a WWTP in the near future (Leitrim County Council pers. comm., 2008). The Organic Centre at Rossinver has the only license to discharge effluent in the County Leitrim portion of the catchment. Treatment is achieved using a reed bed system and willow plantation to deal with effluent from the premises and there has been good compliance with the conditions of the licence (Leitrim County Council pers. comm., 2008).

**9.3.5 Conclusions and Recommendations**

- Modelling based on nutrient load per population equivalent estimates show that the three WWTPs in the Lough Melvin catchment potentially contribute 890 kg of TP to the lake per annum. Kinlough contributes 480 kg P yr\(^{-1}\) (without P removal), Kiltyclogher 130 kg P yr\(^{-1}\) and Garrison 279 kg P yr\(^{-1}\) (without P removal). The total contribution from WWTPs is equivalent to approximately 7% of the annual loading of phosphorus to the lake.

- This contribution has been lowered through the installation of P removal and will be further reduced significantly when full operation of P removal facilities takes place. The new WWTP at Kinlough in particular will operate to a very high standard of phosphorus removal and has capacity to accommodate future expansion of the village.

- The populations that these three WWTPs serve are much smaller than the mandatory size required for the installation of phosphorus removal under the Urban Waste Water Treatment Directive. The operators of the WWTPs have taken the initiative in installing or planning for P removal and the presence of phosphorus removal at such small population centres is therefore a mark of their commitment to improving water quality in the lake.
If an 80% removal efficiency, equivalent to removing 700 kg P yr\(^{-1}\), is achieved then the contribution these WWTPs to the total phosphorus loading to Lough Melvin would be in the region of only 1%. Lowering loading by 700 kg P yr\(^{-1}\) is quite small in terms of the current lake loading but it represents approximately 25% of the loading reduction of around 3 tonnes P yr\(^{-1}\) that was recommended for the lake in section 6. On this basis it is important that the new and upgraded WWTPs are completed as soon as possible.

There are continued concerns about the performance of the old plant in Kinlough while the new plant is being built in the same location, considering the small size of the site. This should be closely monitored and concerns should be addressed through timely communication with the local community.

The variability in the sampling results from the Garrison WWTP should be investigated.

The development in the village of Garrison and the probable localised adverse ecological impacts of the existing discharge that are evident in the lake, plans to increase the capacity of the WWTP and install phosphorus removal should be put in place in the near future.

### 9.4 On site wastewater treatment systems

In rural areas with low density housing, sewer systems are not a viable option and on-site treatment systems are used. A large rural population in Ireland means that these systems are particularly prevalent, with approximately 500,000 properties currently without public sewerage, representing over 1.6 million people (a quarter of the island’s population), and generating around 300 million litres of wastewater a day (NS Share, 2007). A number of types of systems can be used to deal with wastewater arising from single (or small groups of) domestic dwellings that are not connected to mains sewer systems. The most common of these is the septic tank, although Proprietary Effluent Treatment Plants are becoming more common.

In Ireland, septic tanks remove solids by primary settlement and some biological removal of organic matter is achieved by the bacteria that can tolerate the anoxic or septic conditions in the tank. Heavy solids sink to form a sludge layer at the bottom of the tank which is overlain by water with a scum layer on top. This effluent drains out of the tank into a soakaway, soak pit or percolation area. The phosphorus removal is limited and is only achieved by tinkering solids from the tank. The effluent from septic tanks typically has concentrations of TP of 9 mg P L\(^{-1}\) (CFB, n.d.). This value is somewhat higher than found in the effluent from WWTPs not because the rural population generates more phosphorus but because the effluent discharge to septic tanks is less diluted by storm water runoff.

Proprietary treatment systems are designed to treat raw sewage or septic tank effluent to a higher standard. In many respects, they resemble miniature WWTPs. Thus they do not operate passively in the way a septic may, but have moving parts that require maintenance and require electricity for their operation. Although these systems provide high quality effluent, phosphorus removal is limited with typical concentrations of between 5 and 8 mg P L\(^{-1}\) expected (CFB, n.d.).

Additional treatment to effluent produced by a treatment plant or septic tank can be achieved by filtration for example through a soil percolation area with graded sand or peat. Under ideal conditions a properly designed percolation bed can remove virtually all phosphorus from the effluent as the soil through which the effluent passes has a large capacity to absorb phosphorus. This ideal is rarely
achieved in areas such as Lough Melvin as the soils have impeded drainage and are usually water logged. In this situation, the high water table means that no soil percolation takes place. To avoid the septic tank overflowing, the percolation bed usually has a direct discharge to a drain or stream, which will discharge when soils are water logged. An alternative is to construct a constructed wetland or reed bed through which the effluent is discharged. A number of designs have been proposed. The capacity of reed beds to remove phosphorus is variable. Removal depends on the degree of biological processes, which will be slow during the winter. Thus phosphorus removal is commonly low when water residence times are short but can be high (>75%) under long residence times of 100 days or more.

There are many potential problems associated with the use of septic tanks in treating wastewater. These include the presence of older systems, which may not comply with current standards, systems that discharge directly to watercourses, those on unsuitable sites on poorly drained soils with high water tables and poor maintenance (lack of desludging in particular).

### 9.4.1 Lough Melvin

The majority of single dwellings in Ireland are serviced by septic tank systems and within the Lough Melvin catchment, 62% of the population (nearly 2000 people) rely on an on-site wastewater treatment system to treat household wastewater.

McGarrigle & Champ (1999) noted that domestic septic tanks can cause significant problems to surface waters, particularly in areas with waterlogged soils. Within the Lough Melvin catchment peat and gley soils account for almost 87% of soils. Figure 56 shows the location of residential properties in relation to soil type in the Lough Melvin catchment. Due to the chemistry and hydrological characteristics of peats and gleys they are particularly susceptible to desorption of P (Daly et al., 2000) and are therefore ineffective at retaining phosphorus from septic tank effluent.

![Figure 56: Residential properties on different soil types in the Lough Melvin catchment](image-url)
In addition, nearly half of the Lough Melvin catchment have moderate to high slopes, which increase the risk of the wastewater bypassing treatment systems and also increase movement of water over and through the soils. High water tables and occasional flooding within the catchment reduces the filtration capacity of percolation areas resulting in inadequate treatment of septic tank effluent. The high drainage density network is an additional risk because septic tanks will be close to watercourses and therefore any phosphorus will be more easily transported.

Due to the type of landscape and water logged soils within the catchment, it is considered unlikely that septic tanks in the Lough Melvin catchment are working to a satisfactory level. The impracticality of monitoring septic systems means that their contribution in terms of phosphorus loading to Lough Melvin is uncertain. However it is commonly observed both in the Lough Melvin catchment and elsewhere that most septic systems discharge directly to surface waters, so that rural population per capita values for phosphorus from septic tanks can not be very different from the per capita phosphorus loadings from WWTPs. For the Lough Neagh catchment a rural population per capita of 0.44 kg P person⁻¹ has been used which is 57% of the urban per capita of 0.77 kg P person⁻¹ yr⁻¹ (see section 6.2.6). On this basis the rural population in the Lough Melvin catchment would contribute a phosphorus input of 844 kg P yr⁻¹ to the Lough or 7% of the lake loading of total phosphorus. This value is perhaps conservatively low, as the survey of septic systems that is reported in this section suggests that connectivity of septic tanks with waters is well above 57% and may be closer to 80%. Basing the rural per capita on 80% of the sewered per capita or 0.61 kg P person⁻¹ yr⁻¹ gives a lake phosphorus loading from septic tanks of 1.12 tonnes P yr⁻¹ or close to 10% of the total input of phosphorus to Lough Melvin.

9.4.2 Septic Tank Surveys

In order to classify the specific issues and risks posed to water quality by septic tanks within the Lough Melvin catchment, a septic tank survey was undertaken in January and February of 2008. Figure 57 shows the distribution of surveys (nearly 50) that were undertaken during this period.

A summary of some of the information collated is provided below.

- Two chamber septic tanks with percolation trenches or soak pits accounted for 72% of treatment systems in the survey.
- 46% of the systems were over 20yrs old. Older systems are likely to comply only with standards at the time of building, which would now be considered inadequate (e.g. having soak pits rather than properly designed percolation areas).
- 66% of septic tank effluent was discharged to a drain and 8% discharged to a stream. This means that the majority of septic tank effluent has a direct pathway to a nearby waterway.
- 38% of the households surveyed had their septic tank desludged, but the frequency was inadequate, with only 24% desludging in the last 5yrs. Only 12% had desludged in the last 12 months. Over half of the respondents stated that they had never maintained the tank and/or were unaware when it had last been maintained.
- In severe cases there were:
  > No percolation systems and effluent discharged straight to stream or drain
  > No stones in soak pit
  > Badly designed percolation areas
  > Tanks sited on very steep slopes (14% on gradients greater than 1:5).
Note: the term “soak pit” is used to describe a hole in the ground filled with stones through which septic tank effluent is directed. Soak pits are no longer considered suitable as a part of the treatment system and have been replaced by properly designed percolation areas. However, they were historically utilised and are found throughout the catchment.

Wastewater treatment system surveys undertaken on 80 dwellings in the Ballagh River catchment in 2003 indicated similar problems with systems, with over half of owners having never maintained their septic tanks. In addition, this survey identified a communal Bord na Mona Puraflow system servicing five council houses in Rossinver that is less than 10m from the Ballagh River in an area subject to regular inundation.

Desludging

Septic tanks require desludging on a regular basis to remain effective. In County Leitrim, desludging of tanks is often undertaken by local farmers using slurry tankers who subsequently spread the sludge on the land. Movement of sludge requires a permit from Mayo County Council but disposal does not. Sustainable and environmentally friendly disposal of septic tank sludge is a requirement under WFD and Leitrim County Council is currently investigating options for its management (Leitrim County Council, pers. comm., 2008). In County Fermanagh, NI Water offers a discretionary service for the desludging of septic tanks. The typical cost is between £70 and £80 but is built into annual property rates (NI Water, pers. comm., 2008). Therefore, householders are actually already paying for the service even if they do not avail of it.

Figure 57: Septic tank surveys in the Lough Melvin catchment January/February 2008
9.4.3 Conclusions and Recommendations

Modelling undertaken as part of the Lough Melvin Programme based on nutrient load per population equivalent estimates that the unsewered population in the Lough Melvin catchment contributes 844 kg of TP to the lake per annum. This is equivalent to just under 7% of the total annual loading.

Septic tank systems in the catchment pose a significant risk to the water quality of the catchment’s waterways and Lough Melvin. This risk is due to a number of factors that include: the location, age and maintenance regime of systems and the catchment’s characteristic poor soils, high water tables and high slopes. A safe generalisation based on these factors and on site surveys within the catchment, is that the majority of septic tank systems are not operating effectively and any phosphorus removal is extremely limited. Recommendations (not exclusive) on how the risk to water quality can be addressed are presented below:

- An education and awareness programme should be developed and implemented by the relevant authorities as a high priority in the short term. Many community members are unaware of the maintenance requirements for their wastewater treatment systems or issues with contamination of nearby waterways. This is considered to be a relatively low cost and effective option for reducing the pollution risk from septic tanks.

- Enforcement authorities in some cases do not have sufficient resources to undertake adequate inspections of treatment systems within the catchment. Resources should continue to be sought for additional enforcement capacity and the catchment should be prioritised as a target catchment for proactive monitoring and enforcement.

- Alternative and more effective methods of treating household wastewater should be investigated for sensitive and high risk catchments such as Lough Melvin. This could include the investigation of the use of constructed wetlands and willow beds on sites where treatment of effluent is insufficient.

- Householders should be required to update their wastewater treatment systems to meet required standards. This should be grant aided and considered a high priority as it is very probable that there are a significant number of antiquated systems within the catchment.

- Consideration should be given to the introduction of bye-laws for the control of pollution from septic tanks.

- Further investigation on the communal wastewater system servicing the 5 council houses in Rossinver and less than 10m from the Ballagh River needs to be undertaken and a new system installed if flooding of the system is evident or its location is deemed high risk.

- The location and suitability of the Lough Melvin catchment for one-off housing should be critically considered by the relevant authorities. This should be done with a “whole of catchment” perspective because it is the cumulative impacts of housing and wastewater within the catchment that is the major issue. One off housing should not be permitted or at the very least severely restricted outside sewered areas or locations where proprietary treatment systems with P removal facilities are not practicable.
Nutrient Trading

10.1 Introduction

In order to manage the nutrient levels in Lough Melvin, a holistic and integrated approach is necessary to address the various sources of nutrient exchange into the lake. Sources of pollution in the catchment vary and include both point sources i.e. two sewage treatment works and septic tanks, and non-point (or diffuse) sources, i.e. agriculture and forestry.

In terms of management of nutrient output from agricultural land, Agri-Environment schemes are commonly used and offer a single fixed payment for compliance with a pre-determined set of management prescriptions. Agri-Environment schemes currently run in both NI (e.g. Countryside Management Scheme, Organic Farming Scheme, Environmentally Sensitive Area Scheme) and the RoI (Rural Environment Protection Scheme). Whilst the Agri-Environment Schemes are a widely used policy tool, Latacz-Lohmann & Schilizzi (2005) list several problems, which commonly limit their success:

- Farmers who already manage their farms in a way that minimises nutrient runoff (e.g. maintaining a low stock density, spreading slurry to comply with carrying capacity of fields) will have a greater incentive to participate in such a scheme, resulting in overcompensation of compliance costs and a relatively lower level of additional environmental benefits.
- Lack of adequate monitoring provides an incentive to farmers to renege on their agreed course of action. This incentive will be affected by factors such as the probability of detection, the level of fine, the payment method and level of flexibility relating to the agri-environment contract.
- There is a lack of incentive for farmers to devise alternative, innovative or joint solutions to reducing nutrient runoff.
- It is difficult to prevent farmers returning to their ‘old ways’ as soon as the contract is completed, obliterating any improvements which may aggravate the public who have essentially funded the scheme.
- Transaction costs associated with delivering such an agri-environment scheme may be unknown and administrative costs could potentially restrict the funds available to pay for implementation of agri-environmental policies.

A further difficulty associated with the Lough Melvin case study particularly arises from the cross border location of the lake. This may make it more difficult to co-ordinate an agri-environment scheme that is equivalent under the frameworks set by agencies in NI and RoI.

Given these problems, there is strong justification for investigating the possibility of adopting more cost efficient alternative policy approaches to engage landholders in a program to reduce nutrient levels in Lough Melvin.

One such alternative is the ‘command and control’ approach where environmental legislation is “implemented via regulatory instruments coupled with systems of monitoring and sanctioning of non-compliance” (Pearce & Turner, 1990). One of the major disadvantages with this approach is that it fails to account for the costs of control, which are likely to differ across polluters and be unknown to the regulatory agency. As a result, the system limits flexibility, offers no incentive to go beyond control targets and does not account for economic growth (Ribaudo, 1997). Empirical simulations have also suggested that regulation costs associated with command and control policies are higher than incentive based instruments (Atkinson & Lewis, 1974; Roach et al., 1981; Hahn & Noll, 1982; Seskin, Anderson & Reid, 1983) as a result of their inability to address the disparities in the costs of pollution control across landholders.
10.2 Market Based Instruments

Another alternative approach to environmental regulation that has gained popularity in recent years is the use of Market Based Instruments (MBIs). MBIs are defined by Stavins (2000) as,

“regulations that encourage behaviour through market signals rather than through explicit directives regarding pollution control levels or methods”.

The advantage of market based instruments over command and control policies are that they provide the incentive for those that can achieve reductions at least cost to do so. Therefore, it is a more cost effective approach because it maximises the environmental benefit per pound/Euro spent. In addition, by operating through a market, it is not necessary for the regulator to know each firms’ costs to achieve the least cost outcome because costs are based on individual costs and benefits.

In order to meet their objectives, which include ‘halting the loss of biodiversity’ and ‘preserving natural resources that are under pressure’, the European Commission are increasingly favouring Market Based Instruments because they ‘provide flexible and cost effective means for reaching given policy objectives’. Such policy tools are advocated in the European Union’s 6th Environment Action Programme, the Sustainable Development Strategy and the Lisbon Strategy. Furthermore, the EU specifically encourage the use of MBIs to help manage natural resources in order to comply with the Water Framework Directive.

Grafton (2005) sets out elements which are necessary for successful implementation of any Market Based Instrument. The first step is to gain ‘an understanding of the cause and effect of conservation actions and environmental outcomes’. Secondly, this information is utilised to design the policy instrument appropriately. The next step is to test the mechanism in order to ensure that it has been ‘suitably adapted and tailored to the specific scenario’. This can be achieved through a series of economic experiments initially conducted within a laboratory setting and then with a number of landholders in what is termed a field experiment. Finally, pilot tests are also advisable to refine the design of the scheme. Such testing is favourable to ensure that any adjustments can be made before the mechanism is fully implemented.

There are a variety of Market Based Instruments including offsets, tradable permits (which encapsulate both ‘cap and trade’ and credit programs) and auctions.

Offsets describe the situation where landholders are permitted to, ‘undertake developments that may be damaging on the condition that they fund offsetting conservation practices that more than compensate for the damage they cause’. (Grafton, 2005)

Offsetting conservation practices can occur either on-site or off-site. The former aims to restore natural resources at the actual site where damages have occurred. Off-site projects aim to improve conditions at a different location providing comparable resources to those damaged at the actual site. Given the aim of the Lough Melvin Catchment Management Plan is to preserve the mesotrophic status of the lake and the unique species it supports, such offsets would have to consist of on-site (rather than off-site) conservation practices. This option would have the potential to allow for
building development within the lake catchment, for example, without increasing the overall level of nutrients in the Lough.

A number of problems commonly associated with offsets, reduce their attractiveness. These include: difficulties in identifying suitable offsetting projects; potential for project failure due to lack of compliance or unanticipated detrimental externalities; and, difficulty in proving ‘additionality’ ie. that offset projects are additional to what would otherwise have occurred. In addition, there is uncertainty regarding the operation costs associated with this particular approach. The lack of application of offsets within a catchment scenario makes it difficult to be confident of their successful implementation as a viable policy tool to achieving nutrient reduction in Lough Melvin.

The remaining examples of Market Based Instruments mentioned above are increasingly utilised as effective tools for managing land and will be further explored in the next sections.

**10.3 Tradable permits**

**10.3.1 Definition**

 Tradable permits are a form of Market Based Instrument applied to help achieve the goals set out by environmental policies by allowing the market to reveal those firms that can obtain environmental improvements at lowest cost (Stoneham & Chaudhri, 2000). Tradable permits operate either as credit trading or ‘cap and trade’ systems³.

The credit program assigns credits when a source reduces pollution below a baseline level. These credits can be transferred to help another firm comply with the targets. Therefore, transferred credits represent the right to pollute a set amount that is established by the regulatory agency and will be identical for all market participants, i.e. landholders. This approach is reliant upon an ability to measure and enforce discharge targets. As this approach awards credits when reductions are made beyond a baseline level, there is no restriction on the total amount of pollution.

‘Cap and trade’ systems, which have been more commonly adopted, impose an absolute limit on total emissions. This usually takes the form of a mandatory ‘cap’, for example on the total quantity of nutrients entering the water. This is often referred to as a Safe Minimum Standard (SMS)⁴. This cap will prevent the total load of pollutants increasing to a level that exceeds what society deems is acceptable (Stoneham & Chaudhri, 2000).

Once a cap has been set, it is specified as ‘legal partial property rights’. These will be held by individual firms and will define their allocation of the cap. These permits represent a tradable right to emit pollution by engaging in a polluting activity and therefore represent the benefit of polluting. Permits will be allocated to each individual firm either by ‘grandfathering’ (i.e. freely distributed) or through sale e.g. auctions. The last step in the process is to set up the necessary market infrastructure to facilitate trade of permits between landholders (Grafton, 2005).

Firms that exceed reduction can sell their permits to firms which find it more costly to do so. Permits will be held where the incremental or ‘marginal’ cost of pollution equals the marginal

³ Ellerman (2005) also identifies ‘averaging’ as a third type of trading which operates as a specific type of credit trading without certification by the regulator that reductions are beyond that which would have occurred naturally.

⁴ According to the NutrientNet group, the goal could be a percentage reduction goal that is pursued through a voluntary, open program.
profit gained from an additional unit of the polluting activity. In equilibrium, the marginal cost of reducing pollution will equal the price of the permits as no firm will abate where permits can be purchased at a relatively less cost (assuming that transaction costs were zero). Incentive payments can be introduced as an additional enticement to encourage trading where payment is made if the mandatory reduction is achieved.

In both cases, firms which do not hold sufficient permits to cover their discharge levels can: buy additional permits; control their discharge of nutrients through installing abatement technology or increasing efficiency; or both. Firms which fail to hold permits or credits that equate to their level of discharge will face a financial penalty.

The success of a cap and trade system is dependent upon a number of factors outlined by Grafton (2005):

- The costs of reducing pollution must differ between sources in order to achieve gains from trade
- Monitoring and enforcement must be effective in order to ensure compliance with the environmental targets
- Links between sources and discharge should be clearly identifiable
- Trading markets must be competitive so that the permit price reflects marginal abatement costs
- Trading costs are not so high as to deter market participation.

### 10.3.2 Point-Nonpoint Trading

One of the major difficulties associated with trading in a water catchment is that pollution is typically discharged by a combination of both point and nonpoint sources. As described above, a key feature of the successful implementation of a trading programme that achieves cost efficient pollution reduction is effective monitoring and enforcement. For nonpoint sources, effective monitoring and enforcement is complicated by the uncertainty concerning the transport of discharges from nonpoint sources.

In order to address this issue, biophysical modelling techniques can be used to gain a better understanding of the relationship between land use and management and discharges from nonpoint sources (Horan & Shortle, 2005). This will help to estimate discharge loadings from individual nonpoint sources and to monitor the anticipated impacts of any pollution reduction management actions.

Such modelling can be expensive as it requires detailed information about land characteristics and land management practices. Obtaining this information can be time consuming and may be difficult, particularly in the case of private land. Even with monitoring, uncertainty will still remain in relation to nonpoint source control and its impact on water quality.

To take this into consideration, regulatory agencies can incorporate a ‘trading ratio’ within the rules of trading for point and nonpoint sources. This ratio defines the number of nonpoint source permits that will trade for one point source permit (Horan, 2001). A trading ratio in excess of 1:1 allows for an error of margin where point and nonpoint source pollution reduction does not have equivalent impact on water quality. Allowing for the uncertainty in this way, increases the chance the environmental standards will be attained.
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If the trading ratio is set unnecessarily high, this will limit trade since point sources will be forced to purchase a large number of nonpoint source permits in exchange for a single unit of their pollution (Malik, Larson & Ribaudo, 1994). Conversely, if a ratio is set too low, this increases the likelihood of failing to meet the environmental targets due to trading of disparate pollution reduction permits.

Typically, ratios of two or three to one are utilised to compensate for the uncertainty regarding the impact of reducing nonpoint source discharges. Horan & Shortle (2005) investigate if this practice is optimal. They find that because the number of permits is not determined by the local regulatory agency but more typically at a national scale, larger ratios such as are commonly applied in the US, help to mitigate for the inefficiently high level of permits specified.

Horan & Shortle (2005) outline that “For economic efficiency, the trading ratio should reflect the relative expected marginal environmental (damage) impacts from each source, the relative uncertainty (risk) created by each source and the relative marginal transactions costs associated with trade.”

Estimation of the trading ratio is usually informed by models of the effectiveness of the management action adopted to reduce pollution that take into consideration hydrological and topographical characteristics. Accuracy will be dependent on uncertainty caused by unpredictable weather conditions and in regard to the effectiveness of the nonpoint source pollution controls.

Monitoring of nonpoint source effectiveness would reduce this uncertainty and the need for a cautiously high ratio. However, monitoring nonpoint sources can be technically difficult and expensive. Generally, monitoring and enforcement requires clear and comprehensible incentives that are consistent with group goals and penalties and rewards that are considered to be fair eg. penalise only offending parties rather than groups. Such costs can erode the cost efficiency benefits associated with trading. This emphasises the need to balance the costs of effective monitoring of nonpoint source controls with setting a high ratio that accounts for uncertainty.

Whilst enforceable restrictions on point sources that require a permit to be held for each unit of discharged pollution can be imposed, nonpoint dischargers such as agricultural sources are generally considered as having a right to pollute at historical levels. Therefore, any efforts to engage agriculture in such a scheme tend to be on a voluntary basis.

Despite the practical difficulties arising from trade between point and nonpoint sources, the potential gains to trade provide a strong incentive to consider implementing trading schemes in practice. Further discussion of these potential benefits is considered below.

10.4 Benefits

The use of a trading scheme as a policy tool for water quality improvement is recommended by the US EPA (2004). They identify a number of potential benefits based on previous experiences of trading programs that incorporate economic, environmental and social benefits, summarised below:

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5 For further information on setting point-nonpoint source trading ratios see Malik et al. (1994), Horan (2001), Johansson (2002), Horan & Shortle (2005)
10.4.1 Economics Benefits

Firstly, as outlined previously, the trading process can reduce the societal cost of water quality management allowing water quality targets to be achieved at a reduced price. These cost savings arise through allowing those with low abatement costs to carry out the required pollution reduction. This provides the opportunity to take advantage of economies of scale and efficiencies that exist.

Linked to this, trading circumvents the problem of asymmetric information i.e. when landholders know more about the costs associated with abating discharge and the profits gained if allowed to pollute, whilst the agency knows more about the benefits of reducing pollution. Therefore, unlike the command and control system, it is not necessary for the agency to know the costs of each individual polluter as this would be revealed through the market system.

In addition, economic growth can be facilitated in such a scheme, where expanding or new land users can choose to control pollution output themselves, offset an equivalent level of pollution through purchase of permits or both.

10.4.2 Environmental Benefits

In terms of environmental benefits, targets can be reached more quickly by those who have the means to achieve such reduction. This has the potential to include nonpoint sources of pollution, if practical issues can be overcome through the use of trading ratios.

Incentives for ‘overcontrol’ and innovation approaches to achieving control are created.

Indirect environmental benefits are likely to result from this more rapid response and incentives to reduce pollution beyond target levels. These benefits could include improvements to habitats and protection of ecosystems which in turn could provide economic benefits, such as increased tourism.

10.4.3 Social Benefits

The trading approach provides a more flexible means of achieving nutrient reduction than command and control policies. Where participants have greater control over how they comply, it is likely to be a more sustainable approach.

It is thought that the trading process also facilitates dialogues and cooperation between stakeholders eg. farmers, environmental groups and local officials that is important for a sustainable management approach. Furthermore, such an approach engages a range of types of dischargers, unlike agri-environment schemes which focus on agricultural landholders.

10.4.4 Challenges

Whilst there are many potential gains to water quality trading programs from economic, environmental and social perspectives, a number of practical difficulties threaten to reduce the attractiveness of this scheme as a viable policy tool. The main potential difficulties are outlined below.

Firstly, Boyd et al. (2003) stress that technical challenges, such as modelling water pollution transportation in the catchment can be problematic, time consuming and expensive. This is a very real challenge particularly where nonpoint sources form part of the potential market. In this case, there is no certainty regarding measurement of pollution reduction or how monitoring and
enforcement can be achieved. Definition of environmentally equivalent trades will be more difficult to identify, hence reducing the political and scientific defensibility of the trading approach.

Randall and Taylor (2000) suggest that high levels of risk aversion and high levels of uncertainty associated with trading can reduce the incentive to participate. High transaction costs can also eliminate potential market participants. Where the size and/or activity of the trading market is restricted, competition for the right to discharge, necessary to ensure efficient permit pricing, will be eroded. This reduces the financial viability of the trading mechanism.

The lack of a suitable regulatory authority may be another problem (Boyd et al., 2003). The role of the authority can be significant to ensure trade is facilitated, for example: through defining the rules of trade; identifying and connecting potential trading partners; checking and approving trades; monitoring and enforcing compliance; and, communicating outcomes to government, stakeholders and the public. Where the costs incurred by the authority in order to conduct these duties are prohibitive, the gains to the trading scheme will be eroded. Furthermore, skill and experience of operating such a system will be required and may be difficult to encounter.

In addition to these challenges, the characteristics of a specific catchment, when factored together, must be amenable to water quality trading. These characteristics will include the form of the pollutant, hydrological and topographical characteristics, the number, type and location of pollution sources and their costs of controlling pollution. In other words, stringent criteria must be met to render water quality trading a feasible policy tool.

The tradable permit system presents a potentially very effective tool for achieving cost efficient water quality improvement. However, as presented in this section, implementation is not straightforward. Success will very much depend on a range of factors both known and unknown and will rely heavily on the integration of key information sources and expertise. It appears that many of the complications arise when nonpoint sources form part of the equation. The report continues to investigate another potential Market Based Instrument.

### 10.5 Auctions for Land Use Management

#### 10.5.1 Definition

Auctions for land use management are used by the regulatory agency to select the landholders that will be allocated payment for implementing management practices that reduce pollution output.

Auctions are closely allied to trading as a form of Market Based Instrument. Tradable permit schemes have had proven success in cutting the costs of point source emissions. However, this type of scheme may not be feasible where environmental problems result from both point and nonpoint sources (Stoneham & Chaudhri, 2000). Transaction costs (i.e. costs arising from identification of the source, administration, monitoring and enforcement) associated with a point-nonpoint source tradable permit schemes are likely to be prohibitive.

Whilst auctions have been successfully applied to a range of markets, including the mobile phone market, they have more recently been applied to address natural resource problems. More specifically, Latacz-Lohmann and Van der Hamsvoort (1997) have demonstrated that auctions are “an efficient mechanism for achieving land-use change for environmental goals”. For example, the Conservation Reserve Program (CRP), operated by the USDA (Riechelderfer & Boggess, 1988), adopts an auction mechanism to distribute land management contracts through a competitive
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bidding process. Stoneham, Chaudhri & Strappazzon (2003) reports that the auction mechanism has many potential applications in Australia where changes in land use are necessary to achieve environmental improvements, including nutrient control, salinity control and conservation of remnant vegetation. As a result, the majority of published literature that evaluates the implementation of auctions for conservation contracts is based on Australian pilot programs such as the Catchment Care Scheme for the Onkaparinga River Catchment in South Australia (Bryan et al., 2005).

10.5.2 The Auction Process

The process of conducting an auction for conservation contracts firstly requires a budget to be set. The budget represents the amount of funding that the government will allocate to achieve the environmental target. Following this, a range of management actions, which could be feasibly implemented to achieve environmental targets, should be identified by the regulatory agency. Once the budget is set and management actions are identified, the regulatory agency must adopt a bid selection approach that will assist in fulfilling the objectives of the auction.

The next step in the process is for landholders to construct their ‘bids’ which provide details of the proposed management actions and the compensation cost required. Landholders can be assisted by regulatory authorities in the construction of their bids through the development of individual management agreements. These plans identify the required changes from each participating landholder. The payment or compensation demanded to carry out these changes will be dependent on the land characteristics, productivity of the landholder, the level of environmental awareness, income, size of landholding, etc. This information will help the landholder to determine the compensation they would expect to receive from the generation of pollution credits (e.g. reduced nutrients), the return they would expect from the generation of ordinary goods and services (e.g. timber, wood pulp) and the environmental benefits signalled by the agency. Where these benefits occur as a result of one land-use change, landholders could place very competitive bids (Stoneham & Chaudhri, 2000).

When the regulatory agency receives all bids from landholders, they will assess the bids according to cost efficiency. The agency will assign relative weights to individual benefit variables to reflect those benefits that are most highly valued. Management actions proposed in individual bids will be scored accordingly. Bids will then be ranked in terms of environmental benefit per unit of cost.

Contracts will be awarded to the landholders who have submitted bids that offer most environmental benefit per unit cost, up to the point where the budget is exhausted. The landholders will then implement the management activities outlined in their bids, in return for the agreed payment.

Chan, Lepagne & Appels (2003) identify key features for an efficient auction. These include:

- “Selected landholders should be productive and cost efficient in carrying out their management actions
- Selected conservation activities are effective in generating outcomes to meet the agency’s conservation goals
- Selected conservation activities should have low opportunity costs
- Selected landholders receive the smallest payments that are required to retain their participation in the program.”
10.5.3 Auction Design

The successful implementation of any auction depends considerably on how the design corresponds with the specific circumstances. Auctions for conservation contracts are more complex than standard auctions, for example, because they involve procurement of multi-unit, heterogeneous items. Therefore, it is essential to test and pilot auction design prior to implementation. Readers are referred to the Strand 3 technical report for a more detailed discussion of Auction design.

10.5.4 Advantages of Auctions

One of the main reasons for implementing auctions arises from problems with obtaining detailed information about the characteristics of nonpoint sources for alternative market based instruments, such as tradable permits. As previously discussed, such technical and practical difficulties associated with point-nonpoint source trading, can result in costs that make such an approach infeasible. Auctions can offer a more suitable alternative for nonpoint source land use management.

Bryan et al. (2005) identify four key reasons that explain why auctions are a preferred policy tool for generating land use change: allocative efficiency, objectivity, transparency, and flexibility.

Allocative efficiency occurs when “the auction is won by the highest bidder and when the value of the highest bidder reflects the true social value of the resource”. In the context of conservation contracts, landholders who can achieve land use change at lowest cost and/or who value the environment highly, will offer very competitively priced conservation projects. Under conditions of perfect competition, where there are many sellers and many buyers in the market who have access to full information, auctions are likely to maximise allocative efficiency. Because auctions involve participants in a competitive bidding process, environmental targets can be reached at least cost (Stoneham & Chaudhri, 2000).

Due to the nature of the auction process, where price is determined through the market mechanism rather than being set by government, auctions can be less subjective than other policy mechanisms. Objectivity arises because bidders compose their individual bids, which are accepted or rejected relative to other submitted bids.

The auction process also tends to be more transparent as the rules associated with evaluating and selecting contracts will be revealed prior to the auction commencing (Chan et al., 2003). Interested landholders will typically be given information packs which describe the process and design of the auction and allocation of contracts. This instils greater confidence in the policy tool, encouraging participation.

Finally, auctions are flexible. They do not compromise policy objectives because conditions can be attached. Conditional stipulations help to manage risks incurred by the regulatory agency.
**10.6 Challenges**

Whilst there are significant advantages in adopting an auction scheme to manage land use changes for the purpose of environmental improvement, prior experience has identified a number of key challenges that threaten to erode these potential benefits.

Latacz-Lohmann & Schilizzi (2005) present findings from the Scottish Executive pilot schemes, which suggest that high administration costs and high transaction costs borne by the landholders reduce the potential gains from participation in the auction scheme. Furthermore, unsuccessful bidders reported high costs associated with preparing the bids in the face of uncertainty. This problem is likely to reduce the number of bidders participating in future schemes.

The need for a suitable regulatory infrastructure can present difficulties similar to those identified for trading mechanisms. The role of the agency will be significant, for example: designing the auction mechanism; issuing a call for bids and providing information about the procedure and rules associated with the auction; assisting landholders to develop their individual management plans and providing information on costs to encourage realistic and feasible bids; bid evaluation, assessment and selection; administration; monitoring and enforcing. It is possible that significant costs will be incurred in meeting these requirements. If the costs are too high, the gains from the auction mechanism may be eroded.

Bryan et al. (2005) identify several factors that may reduce the efficient allocation of contracts at auction. “Whilst auctions have the potential to achieve efficient outcomes, they may also perform poorly depending on market conditions, bidder behaviour and auction design”.

To a certain extent, thoughtful design of the auction mechanism can help to avoid some of these difficulties.

**10.7 Review of Best Practice**

In considering the implementation of alternative nutrient management schemes, it is useful to review case studies that are relevant and from which lessons can be learned. Readers are referred to the Strand 3 Technical Report where a selection of the most relevant and informative trading and auction schemes are reviewed.

In considering these examples, a number of issues regarding the successful implementation of such schemes have been identified and are indicated below.

With regards to water quality trading, successfully functioning schemes appear to meet environmental objectives set with little evidence of the occurrence of hotspots. Successful schemes tend to have low transaction costs (EFTEC, 2005), are relatively simple in design and involve low levels of liability. As evident from the examples discussed, the formation of collectives can help to share the risk of individual liability and provide assistance with calculating credit values, for example.

Regulation and management of trading schemes varies but tends to involve local management initiatives which can more easily take local conditions and circumstances into account. This local control comes in the form of local authorities, independent collaborative groups or sources themselves eg. government authorities, either at state or local level. These entities tend to set targets, monitor and enforce compliance though more active involvement in running the schemes...
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can also occur. US schemes are well set up to introduce trading schemes given that TMDL targets have already been put in place.

As reported by ADAS (2007), trading between nonpoint sources is unlikely to be viable primarily due to a lack of variation in the costs of reducing pollution. Point-nonpoint trading tends to result in greater cost savings because the cost abatement differentials are greater. However, complications can arise from difficulties of monitoring nonpoint sources. The reliance on proxies may not be accurate which increases the risk of liability. Furthermore, the complexities of many of the trading schemes suggest high levels of administration and lack of support from potential participants. Kraemer (2003) notes that a range of potential barriers to trade exist including lack of available information, uncertainty regarding the impact of existing regulations and a lack of understanding amongst the general public.

As highlighted above, it is difficult to find concrete examples of water quality trading schemes which involve a high level of trades and have been operating for any considerable length of time. This indicates the limited potential for application of a trading scheme in this context, a result also found in ADAS (2007). In addition, a lack of examples limits the information base that can be used to inform an assessment of the feasibility of implementing such a scheme within the Lough Melvin Catchment.

The auctions reviewed appear to have been successful in achieving their environmental objectives, without any significant issues arising from noncompliance or broken contracts. They are reported to be a more cost efficient approach than alternative or existing schemes.

Interviews with participants of the Scottish Challenge funds (which offered incentives for planting trees) were not satisfied with the tendering scheme and disliked the uncertainty of discriminatory price principle which they felt was unfair (CJC Consulting, 2004). This suggests that investment in educating participants and involvement of stakeholders is likely to be an important factor in bringing participants on board.

Field trials also provide an opportunity to train participants and reduce uncertainty. They present an important opportunity to gain information about auction design and application prior to full scale policy implementation. However, learning can reduce the efficiency of the auction. This can potentially be overcome by altering the auction rules to prevent landholders predicting outcomes from previous results.

The administrative and cost burden associated with preparing bid submissions can be another deterring feature, particularly where applicants are unsuccessful in their contract application. Participants can be helped to prepare bids by provision of information or assistance provided by field officers, as in the Onkaparinga Catchment Care Programme (Bryan et al., 2005). Administrative costs are likely to diminish with experience.

Stoneham & Chaudhri (2000) have proposed linking tradable emission markets with auctions for conservation contracts to involve both point and non-point sources in one ‘environment economy’. Point sources would operate in the market through trading permits whilst nonpoint sources engage through auctions which generate credits. The auctions would be carried out as previously described with bids ranked using an environmental benefits index and contracts awarded to those which offer most value for money. These banked credits could then be ‘traded’ as permits to point sources. Point sources also have the option of trading with other point sources. Transactions are represented in the diagram below.
The potential advantages of such an approach would be the reduced funding burden on the government, the involvement of both point and nonpoint sources, the ability for the government to exercise control, reduced risk for participants arising from noncompliance, flexibility to incorporate new entrants or development. No examples of such an approach exist in reality. The potential to merge both policy instruments will firstly depend on the success of the auction.
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10.8 Economic Instruments for Nutrient Management in the Lough Melvin Catchment

In order to consider which type of market based instrument would achieve a cost effective reduction in nutrient loadings, it is necessary to consider the catchment characteristics. As outlined in the US EPA Water Quality Trading Assessment Handbook, the information base required to evaluate the viability of nutrient trading schemes is quite detailed. Firstly, pollutant suitability has to be determined. This includes identifying sources of pollution and collecting information on the source location, pollution transportation, time pollution occurs, type, form and quantity of pollution discharged and required reduction in pollution levels. This information is used to ensure potential trades between sources result in equivalent impact on water quality. Where differences in source pollution characteristics occur, it may be possible to apply ‘translation or trading ratios’ to ensure equivalent trades. The information is also used to check that trading will adequately meet the targets set for the water catchment.

The second stage involves assessment of the financial attractiveness to consider if trading will result in sufficient economic returns to make such a scheme viable and worthwhile. To achieve this, detailed information on required reductions and abatement costs from major polluters will be required. Trade will be viable between sources with high cost differentials.

The final step is to identify an appropriate market infrastructure required to implement the trading process and to facilitate achievement of water quality targets.

Whilst this level of information is not currently available for the Melvin catchment, provisional assessment of the viability of a trading scheme can be conducted based on available information and lessons learned from best practice examples. The necessity for water quality improvement has been identified by previous research (Girvan & Foy, 2006). Within the Lough Melvin Catchment, point sources which have been identified as contributing to P loadings in the lake include three (relatively small) sewage treatment works (STWs) which constitute around 7% of total P loadings (Girvan & Foy, 2003) and rural housing septic tanks which are thought to contribute a further 10% of total P loadings. If standards (ie. a cap) were imposed in the Lough Melvin Catchment, which required these point sources to reduce their P loadings, in a trading scheme, they could theoretically trade with nonpoint sources, if nonpoint sources could abate P relatively less expensively creating incentives for trade.

A number of complications arise in reality. Firstly, a cap would have to be set and load allocations would have to be assigned. Whilst the existence of TMDLs in the US facilitates this element of implementing a trading system, no such standard is available for the Melvin catchment. In addition, given that water quality in the Lough meets existing legislative requirements, additional legislation would be required to uphold this more stringent standard which may be opposed by affected parties.

Secondly, potential difficulties arise from the small number of point sources. The two major sewage treatment facilities in Melvin are currently introducing more stringent treatment procedures which will reduce their nutrient loadings in the lake. Therefore, these sources are likely to comply with reduction targets set as part of a nutrient trading scheme. The remaining point sources contribute a relatively small proportion of the P concentration in the Lough. If the cap were imposed on point sources, as is typically the case, trading would achieve only a small P reduction. Trading ratios could be used but this increases the marginal cost of reducing pollution for the nonpoint sources, which reduces the incentive to participate in such a trade. Furthermore, the small number of trades are unlikely to justify the operation costs of a nutrient trading scheme.
If the aim were to maintain existing level of nutrients as opposed to reducing current levels, the cap could be used to control additional sources of P, for example, arising from development in the area. New sources could be required to trade with nonpoint sources. Again, consideration would have to be given to the level of trading that is likely to occur that will be dependent on the level of additional pollutant loading arising from development projects to ensure that the operational costs of a trading scheme are justified.

However, in both these cases, the costs of facilitating trade are likely to outweigh the benefits. Transaction costs incurred from participating in the trade which would include the administrative costs of bargaining and setting up a trade, data collection costs to determine outcomes of trade, the cost of monitoring to ensure compliance, and the cost of developing and implementing abatement measures. “Trading will be inefficient if too few, or too small, sources are involved in the trades” (Jarvis & Solomon, 1998). Furthermore, the costs involved in potential trading with many nonpoint sources can be “difficult to arrange and enforce. The cost of educating and financing many small nonpoint BMPs is larger and requires more monitoring than one large nonpoint source” (Jarvis & Solomon, 1998).

Finally, as discussed previously, the viability of trading between nonpoint sources is unlikely to be feasible given lack of variation in costs of abatement. This is particularly likely to be the case within the Lough Melvin catchment, where most farms are beef and/or sheep farms. This lack of variation in farm types and hence cost differentials, is likely to restrict the gains from trade. Given these restrictions, the costs involved with gathering the level of information required to evaluate a trading scheme for Melvin, outlined by the EPA Water Quality Handbook, is likely to be inefficient.

As an alternative, auctions are potentially a cost-effective approach where nonpoint sources exist. It is not necessary to set a ‘cap’ on water quality to design the auction. As illustrated in the examples of auctions for conservation contracts described previously, the ultimate level of pollution reduction can be determined by the amount of available funding and the bid proposals submitted by landholders.

The auction approach creates incentives for voluntary participation amongst farmers without the need to develop new legislation to enforce additional targets. This voluntary approach is more likely to foster support from potential participants. However, Latacz-Lohmann & Schillizzi (2005) highlight the potential difficulties with implementation of auctions to award conservation contracts:

“Bidding schemes yield the highest benefits when the conservation agency has little information about landholders’ compliance costs, the number of potential participants is large, the contracts offered are homogeneous and farms are heterogeneous in their compliance costs. The fewer of these conditions apply, the less well an auction will perform relative to a fixed-rate payment scheme.”

Finally, in Melvin, the number of potential nonpoint source bidders should be sufficient and is comparable to reviewed schemes in the US and Australia. Secondly, costs of compliance in terms of the costs of implementing nutrient reduction measures, will be largely known and relatively homogeneous. However, it is possible that opportunity costs that also inform a landholders’ bid could differ. These opportunity costs will depend on the actual value of the land to the landholder and on personal circumstances. Finally, contracts will be heterogeneous which may create additional administrative costs arising from the assessment of benefits associated with bids. On this point, it is important to note the differences between the Melvin and Scottish contexts. In Scotland, the Land Management Contract Scheme aims to provide whole farm support in order to reward widespread...
Nutrient Trading

economic, environmental and social benefits. Latacz-Lohmann & Schilizzi report that designing an appropriate benefit index to rank bids would generate high transaction costs and a risk of complaints and appeals. By limiting the benefit assessment to phosphorus or nutrient reduction, as in the Australian schemes, the benefits index for assessing conservation contracts for Melvin, are likely to be more straightforward, transparent and less costly.

A further advantage to this nutrient management approach is that some of the information required for auction design will have been collated already within this Interreg Project. This includes the identification of additional best management agricultural measures that can feasibly be adopted by individual landholders to reduce the level of nutrient loadings; the costs of implementing these measures; the effectiveness in terms of average P reduction for each measure; identification of farm characteristics, including information on land characteristics, that could be used to inform assessments of land that could feed into the environmental benefits index used to assess bids. In addition, the involvement of stakeholders will have established links necessary to gain support and acceptance of an auction scheme.

If an auction approach were found to be a viable and cost efficient approach for Melvin, consideration could be given to expanding the scheme to include point sources through trading credits generated by nonpoint sources, as suggested by Stoneham & Chaudhri (2000). A land management auction held with the Lough Melvin non-point source emitters would result in a reduction in the amount of nutrients in the Lough. In addition to this, there was a further by-product, such as a reduction in water quality improvement that benefited the general community within the Melvin catchment. If a tradable permit system were held with the point source emitters alongside the land management auction, the improved water quality produced by the farmers and/or foresters would be valuable to the point source emitters. Then the farmers could sell their land management improvements to the agency. These mitigation credits could then be traded by the agency with the point source emitters. So in addition to having permits to pollute, they could alternatively have credits to pollute. Credits would be sought if they were less expensive than permits or than abating the pollution.

The absence of relevant theory, limited number of real-life examples and complex nature of conservation auctions demand caution for their implementation. Latacz-Lohmann & Schilizzi suggest that experimental testing provides an opportunity to “make at low cost all the serious and potentially expensive mistakes both in the financial and in the political sense”. This approach is also recommended by Cason & Gangadharan (2005) and has been adopted in Australia. Latacz-Lohmann & Schilizzi advise comprehensive investigations prior to introduction of a full scale scheme, which would include:

- Devising a theoretical model of bidding behaviour and potential outcomes
- Simulating bidder behaviour via computer based techniques
- Conventional Laboratory experiments typically with student subjects
- Artefactual Field experiments with landholders
- Natural Field experiments or small scale trials

Such prior testing will reveal information about suitability of design, opportunity costs faced by landholders, levels of participation and associated transaction costs. It also provides the opportunity to engage and involve stakeholders that is necessary to generate support and acceptance of a new scheme. Finally, the field experiments and trials provide training to potential participants in order to familiarise landholders with the processes encourage participation levels and ensure mutually beneficial outcomes.
10.9 Legislation

10.9.1 Consistency with Existing Policies

Trades must take place within the context of existing regulations and enforcement requirements. Nonpoint source measures must be additional to those included within existing land and/or agri-environmental management schemes.

The two most important existing policies for reducing phosphorus from agricultural diffuse sources in NI are the Nitrates Directive (Nitrates Action Programme Regulations (NI) 2006) and the Phosphorus Directive (Phosphorus (Use in Agriculture) Regulations (NI) 2006) both of which were implemented in January 2007. Similarly, the Nitrates Directive (91/676/EEC) implemented in Ireland since 1991 (which addresses eutrophic waters where phosphorus is the main contributor) along with The Water Pollution Acts of 1977 and 1990. These regulations will contribute to reducing eutrophication in NI water bodies as part of their efforts to implement the Water Framework Directive and their impact will be monitored. They primarily focus on actions relating to the application of fertiliser and storage of manure. However, the impacts on water quality to water bodies such as Lough Melvin, will not be known for years.

Any policy tool would have to be consistent with the above (and other) regulations and run alongside Nitrogen Vulnerable Zones and relevant agri-environment schemes such as REPS in RoI and the Environmentally Sensitive Area and Countryside Management Scheme in NI. There is the potential that an additional auction scheme would introduce a heavier administrative burden to farmers which would diminish the efficiency advantage of such schemes.

In the US, water quality standards include an ‘antidegradation policy’ through a three level approach to protect water quality. “Tier 1” maintains water quality to protect existing usage of the water body. “Tier 2” protects higher quality water bodies where quality is better than that required to facilitate “fishable/swimmable” uses. “Tier 3” protects resource waters of ‘outstanding’ quality, including waters of “exceptional ecological significance”. Such an approach would facilitate protection of Lough Melvin, however, does not appear to exist for either Ireland or UK (USEPA, 2007).

10.9.2 Legislative Framework

Schemes such as Auctions for Conservation Contracts require ultimate government involvement. In the Conservation Reserve Program, the US Department of Agriculture relies on three of its component agencies to run the auction program. The Natural Resources Conservation Service provides the technical assistance to farmers and ensures quality of compliance. The Farm Service Agency administers the contracts, sets compliance determinations and serves as the lead agency to ensure compliance with existing legislation and policies. They are responsible for consulting with other organisations and departments to determine potential impacts of action. Finally, the Commodity Credit Corporation overseas matters of financial delivery.

In Australia, the BushTender and Catchment Care programs are governed at state level by the Department of Sustainability and Environment but are managed at regional level by a Catchment Management Authorities or a Catchment Water Management Board respectively.

The potential situation for Lough Melvin is complicated by the cross border location and shared responsibility from both governments in NI and the RoI. In this case, it may be prudent to establish a Lough Melvin Catchment Water Management Board with representatives from RoI and NI.
government bodies including Department of Agricultural and Rural Development, Department of Agriculture, Fisheries and Food, Department of the Environment, and the Department of the Environment, Heritage and Local Government and other relevant experts. The remit of this Board would be to ensure that existing regulations on both sides are adhered to, to agree terms and conditions of the auction mechanism, to award contracts and handle funds made available by both governments. The need to manage the auctions at local level, including provision of technical assistance, monitoring and compliance could be operated through an organisation such as the Environmental Protection Agency in Ireland or the Regional Fisheries Board, who would report to the Catchment Management Board.

The management infrastructure may be affected by the call for NI to review the status of environmental governance. This review was submitted in June 2007 and calls for a more integrated approach to environmental governance, including the enhancement of an ‘all-island approach to environmental governance at policy and operational levels’. One of the recommendations of the review is for an Independent Environmental Protection Agency to take responsibility for environmental regulation. If an EPA for NI were to be established, this could create a mechanism for necessary cooperation.

### 10.10 Gaps in Knowledge

A number of uncertainties exist regarding the appropriateness of the auction mechanism. As previously stated, such prior testing will reveal information about suitability of auction design, opportunity costs faced by landholders, levels of participation, associated transaction costs, the opportunity to engage and involve stakeholders and to provide training to potential participants.

There is the need to establish an appropriate Environmental Benefits Index that would account for the desired benefits from nutrient reduction actions. This would require input from a range of experts. The index could be modelled on the formula adopted for the Australian programs, such as the Onkaparinga Catchment Care Program (Bryan et. al., 2005).

In order to inform the design of an appropriate auction mechanism and the Environmental Benefits Index, it would be necessary to collate research gathered from the results in this Report.

### 10.11 Recommendations

The aim of this section of the report was to: “Examine the possibility of nutrient trading by reviewing best practice elsewhere, the information base required to operate and evaluate scheme, and the legislative framework required for application in a cross-border catchment”. This review of theoretical and empirical studies suggests that water quality trading between point and non point sources is not currently feasible as a stand alone method for nutrient management in the Lough Melvin catchment. The key points identified are summarised below.

There are few point sources. Firstly, the two major WWTPs in the catchment have opted to reduce their nutrient output through the introduction of more stringent pollution abatement processes. Remaining point sources contribute a relatively small proportion of P loading. The costs of conducting a nutrient trading program in these circumstances are likely to outweigh the benefits.

The viability of trade occurring between nonpoint sources has been investigated elsewhere (EFTEC, 2005; ADAS, 2007) and is unlikely to offer sufficient gains to trade for farmers due to lack of differential in compliance costs.
Reducing uncertainty would require very detailed level of information and tight monitoring which would increase the transaction and administrative costs of operating the trading scheme. This would in turn reduce the cost efficiency advantages that such a scheme offers over alternative approaches.

Auctions for conservation contracts appear to offer a potentially viable alternative to engage agricultural (and potentially forest) landholders in a voluntary capacity, who are the major contributors to phosphorus input in Melvin. Auctions would provide a mechanism to reveal the opportunity costs held by landholders within the catchment to provide a cost efficient nutrient management scheme. The potential gains to trade should provide an incentive to participate in the scheme. Furthermore, information required to further develop an auction for Melvin catchment has been generated in this study, therefore, an information base and expertise on which to draw will exist.

Conservation auctions are complex mechanisms and success is heavily dependent on application context and appropriate scheme design. A lack of applicable theory and limited number of practical examples means there is little to guide auction design for specific purposes. Therefore, the next step should be to conduct experiments which will reveal potential and unforeseen problems, provide information on suitability of design, opportunity costs faced by landholders, levels of participation and associated transaction costs and to provide training to potential participants in order to familiarise landholders with the processes encourage participation levels and ensure mutually beneficial outcomes. This will provide vital information about the costs of running the scheme and indicators of success prior to implementation of a full scale land management auction.

Finally, programmes must be a collaborative project involving stakeholders and those with local knowledge with government agencies. The involvement of these groups in this development process is necessary to inform the approach, gain local support and facilitate acceptability of the mechanism.
Governance Framework
Governance Framework

11.1 Introduction

An understanding of controls and governance arrangements that are relevant to management of Lough Melvin is a key part of the catchment management process. This section of the CMP summarises the outputs of a project entitled “Evaluation of the controls and governance arrangements pertaining to the management of Lough Melvin” which aimed to identify, assess and analyse relevant legislation, policies and governance issues relevant to the catchment, and make recommendations on how gaps, constraints and other governance issues could be addressed. More detail is provided in the Task 1, Task 2 and Final Reports which can be accessed from the Northern Regional Fisheries Board or on the Lough Melvin Programme CD.

11.2 Key Governance Drivers

The most important drivers of management within the catchment are EU Directives relating to water quality and biodiversity, and in particular:

- Habitats Directive
- Water Framework Directive
- Nitrates Directive

11.2.1 Habitats Directive

Lough Melvin has been classified as a Special Area of Conservation (SAC) in NI and is a candidate SAC (cSAC) in RoI under the 1992 EU Habitats Directive (92/43/EEC). The SAC forms the heart of the catchment both in geographical/physical terms and in the context of governance and regulation. The Habitats Directive requires the key features of the SAC to be maintained at a favourable conservation status. Some of these features relate directly to water quality, and the Directive requires favourable condition to be measured against clear scientific parameters. For Lough Melvin this means the setting of clear objectives for the maintenance of the lake’s mesotrophic status. The site’s scientific and regulatory needs under the Habitats Directive are therefore likely to be more stringent than the more general water quality standards required by the Water Framework Directive.

In this context, the targets and objectives set by the SAC Conservation Plans in each jurisdiction should provide the template for management of the catchment. Key governance issues within the catchment include:

- The status and role of SAC Conservation Plans in both jurisdictions;
- The application of Article 6 of the Habitats Directive and use of “appropriate assessment” for both plans and projects.

11.2.2 Water Framework Directive

The Water Framework Directive (2000/60/EC) is already having a considerable influence on governance within the catchment. It has provided a statutory basis for standardisation of water quality standards and monitoring across jurisdictions and a catchment-based approach to water management. It requires the waters of Lough Melvin to be at least of good ecological status by 2015. Basic measures relevant to the catchment will form part of the wider Draft North Western River Basin Management Plan, to be published for public consultation in December 2008. It is anticipated that these basic measures will include some of the measures identified in the Lough Melvin CMP. Such measures should be consistent with and contribute to the water quality (and other) objectives set under the Habitats Directive.
11.2.3 Nitrates Directive

Agriculture is an important land-use within the catchment, and the Nitrates Directive (91/676/EEC) is a key driver in regulating diffuse pollution from agricultural sources. The Directive does not require any specific targets for the catchment, but its measures assist both governments to meet their obligations under both the Habitats and Water Framework Directives.

11.2.4 Additional governance context

Four key governance issues provide a backdrop which is relevant both to the Lough Melvin catchment and in a wider context. These are:

i) The variation in responsibilities and functions between local authorities in each jurisdiction, and the role of elected councillors in policy and decision-making in RoI;

ii) The regulatory role of an independent Environmental Protection Agency (EPA) in the RoI and the retention of regulation by central government in NI;

iii) The existence of an ongoing Review of Public Administration (RPA) in NI and a parallel Review of Environmental Governance;

iv) The absence of any statutory cross-border body within the catchment, such as Waterways Ireland or the Loughs Agency.

All of these issues have relevance in determining how the Lough Melvin catchment is managed.

The project identified that governance issues can be classified under four main headings:

i) Transposition of EU Directives at a national (NI or RoI) level;

ii) Implementation of legislation or policy (at both national and catchment level);

iii) Enforcement capacity of regulating bodies;

iv) Operational issues, such as cross border or inter-departmental co-operation.

11.3 Stakeholders’ roles and governance issues

In evaluating the efficacy of various governance measures and controls, it is necessary to identify all the key statutory stakeholders with a role in management of the catchment in both jurisdictions. It is also essential to have a detailed understanding of key catchment management issues, such as those which are described in detail elsewhere in the CMP.

This section summarises those issues within seven distinct categories, although it is acknowledged that these are arbitrary and that there is considerable overlap between them. The organisations responsible for governance and management within each category are also identified.

11.3.1 Water Management

Water quality legislation represents one of the most significant drivers for management within the Lough Melvin catchment. While statutory obligations on nature conservation and fisheries are also key drivers, many fishery and biodiversity objectives also depend on meeting specific water quality targets.
Key issues affecting the total phosphorus (TP) concentrations of Lough Melvin include:

- Agricultural practices such as stocking levels, spreading of livestock manures and the use of chemical fertilisers and other organic manures other than livestock manure;
- Forestry activity including establishment of new plantations and clearfelling;
- Point source discharges from Waste Water Treatment Plants and septic tanks from single dwellings.

### Table 30: Organisations involved in Water Management

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Organisation</th>
<th>Role in the catchment</th>
</tr>
</thead>
</table>
| NI           | EHS Water Management Unit | Basic functions set out in the Water (NI) Order 1999. Its key activities in the catchment include:  
• Monitoring water quality;  
• Controlling effluent discharges;  
• Taking action to combat or minimise the effects of pollution; and  
• Supporting environmental research. |
| NI           | NI Water          | A government-owned company (GoCo) established by statute in 2007 and responsible for water supply and sewerage services in NI.                       |
| RoI          | Leitrim County Council | Functions set out in the Local Government (Water Pollution) Acts, 1977 and 1990, include:  
• enforcement of water pollution legislation;  
• attach appropriate pollution control conditions in the licensing of effluent discharges from industry, etc., made to waters or to sewers;  
• issue notices (“section 12 notices”) to farmers, etc., specifying measures to be taken within a prescribed period to prevent water pollution; |
| RoI          | EPA               | An independent public body established under the Environmental Protection Agency Act 1992. It has responsibilities for a wide range of licensing, enforcement, monitoring and assessment activities associated with environmental protection. |

The most significant governance issues on water quality in the catchment were identified as:

- An urgent need for common water quality standards and targets across both jurisdictions;
- Existing legislation and regulatory powers are generally adequate in both jurisdictions;
- There is a potential shortfall in aspects of enforcement capacity, particularly in relation to septic tank compliance;
- Cross-border co-ordination is good at a technical level, but lacking at a more practical level within the catchment;
- Water quality monitoring programmes require greater liaison both within and across jurisdictions to ensure common standards and avoid duplication.
11.3.2 Agriculture

Farming is an important land use within the Lough Melvin catchment. However, the dominant soil types (peat and gley) and the upland topography are not suitable for intensive agriculture. The majority of agriculture is permanent grassland with extensive grazing by beef cows, the raising of store cattle and sheep grazing at higher altitude.

Despite the extensive nature of agriculture within the catchment, it is still a significant source of phosphorus (P) loss from diffuse sources. The main factors resulting in P loss are:

- Limited availability of suitable spread lands for slurry;
- Stocking levels in relation to the carrying capacity of the land;
- Relatively high incidence of high soil P.

Table 31: Organisations involved in Agriculture

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Organisation</th>
<th>Role in the catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI</td>
<td>Dept. of Agriculture and Rural Development (DARD)</td>
<td>Responsible for the promotion, regulation and administration of agriculture in NI. It manages agri-environment schemes operating in the catchment.</td>
</tr>
<tr>
<td>NI</td>
<td>EHS Water Management Unit</td>
<td>Responsible for the regulation of water quality regulations which relate to agricultural activities eg Nitrates Directive regulations. It is also responsible for monitoring compliance of farm businesses with 5 Statutory Management requirements (SMRs) based on the EC Birds, Habitats, Groundwater, Nitrates and Sewage Sludge Directives.</td>
</tr>
<tr>
<td>RoI</td>
<td>Dept. of Agriculture and Food (DAFF)</td>
<td>Responsible for the promotion, regulation and administration of agriculture in Ireland. It ensures cross compliance through the application of Statutory Management Requirements (SMRs).</td>
</tr>
<tr>
<td>RoI</td>
<td>Teagasc</td>
<td>Provides integrated research, advisory and training services to the agriculture and food industry and rural communities. This includes management of the REPS scheme.</td>
</tr>
<tr>
<td>RoI</td>
<td>Leitrim County Council</td>
<td>Local Authorities have a regulatory role in respect of certain agricultural regulations.</td>
</tr>
</tbody>
</table>

The most significant governance issues on agriculture in the catchment were identified as:

- Potential impacts of the Nitrates Directive – both positive and potentially negative;
- The importance of agri-environment schemes as incentives to benefit water quality and biodiversity;
- The need for agri-environment schemes to contain a standardised suite of relevant measures. One approach may be a catchment-specific scheme, available to all farmers in the catchment.
- The importance of farmers as stakeholders, and the need for their participation in catchment management.
11.3.3 Nature Conservation

Lough Melvin is a site of European importance for its nature conservation interests. In NI it is a designated Special Area for Conservation (SAC) under the Habitats Directive and Area of Special Scientific Interest (ASSI), while in Ireland it is a candidate SAC and Natural Heritage Area (NHA). The features for which it was classified as an SAC are listed in Section 3.2.1.

Despite its importance for biodiversity and fisheries, Lough Melvin has not been designated as a Ramsar site in either jurisdiction.

Table 32: Organisations involved in Nature Conservation

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Organisation</th>
<th>Role in the catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI</td>
<td>EHS Natural Heritage</td>
<td>The designation, protection and management of key wildlife sites. This includes responsibility for ensuring that Lough Melvin SAC is maintained in favourable condition.</td>
</tr>
<tr>
<td>RoI</td>
<td>National Parks and Wildlife Service (NPWS)</td>
<td>This section of DOEHLG is responsible for designation, protection and management of key wildlife sites. This includes responsibility for ensuring that Lough Melvin cSAC is maintained in favourable condition.</td>
</tr>
<tr>
<td>RoI</td>
<td>Leitrim County Council</td>
<td>Key role in protecting biodiversity through planning process, meeting water quality objectives etc.</td>
</tr>
</tbody>
</table>

The most significant governance issues on nature conservation in the catchment were identified as:

- Effective implementation of the Habitats Directive is critical for the ecological future of the catchment;
- Implementation of the Habitats Directive is variable, especially the use and application of “appropriate assessment” under Article 6.
- A more co-ordinated approach to management of Lough Melvin SAC is desirable.
11.3.4 Land-use planning

Land-use planning is a key determinant of environmental quality within the Lough Melvin catchment. Planning policies, zonations and individual decisions can all have direct or indirect impacts on water quality, habitat loss and other ecological factors. In particular, decisions relating to housing developments and even individual houses have the potential to affect the water quality of Lough Melvin.

Table 33: Organisations involved in Land-use planning

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Organisation</th>
<th>Role in the catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI</td>
<td>DOE Planning Service</td>
<td>Planning Service is responsible for the production of Planning Policy Statements, Area Plans as well as development control issues and enforcement. Lough Melvin is covered by the Fermanagh Area Plan 2007. There is currently no timetable for the plan’s review.</td>
</tr>
<tr>
<td>NI</td>
<td>Planning Appeals Commission</td>
<td>The appellate body for NI but with no power to hear third party appeals. Interpretation of planning policy can affect development control in the catchment.</td>
</tr>
<tr>
<td>RoI</td>
<td>Leitrim County Council</td>
<td>The Local Authority is responsible for both strategic planning and development control in the catchment. The area is covered by the Leitrim County Development Plan, and a new plan is currently being drafted.</td>
</tr>
<tr>
<td>RoI</td>
<td>Border Regional Authority</td>
<td>Its role includes ensuring co-ordination, consistency and compatibility in plans, policies, etc. at a regional level.</td>
</tr>
<tr>
<td>RoI</td>
<td>An Bord Pleanala</td>
<td>Appellate body with statutory power to hear third party appeals.</td>
</tr>
</tbody>
</table>

The most significant governance issues on planning in the catchment were identified as:

- The protection of Lough Melvin SAC from inappropriate development through the application of Article 6 of the Habitats Directive (see Nature Conservation also);
- The transposition and implementation of the EIA Directive is variable across jurisdictions;
- Planning policies for the protection of Natura 2000 sites are extremely variable;
- The planning system has a key role in addressing issues such as septic tanks and one-off housing;
- The expansion of settlements such as Garrison and Kinlough;
- The need for planning authorities to be more closely involved in catchment management issues.
11.3.5 Fisheries

Lough Melvin supports a unique post-glacial salmonid fish population including Atlantic salmon, Arctic char and three races of trout, which are considered by some to be separate species – ferox, sonaghan and gillaroo. In addition to being of considerable ecological importance, the fish assemblage also represents an important fishery resource for anglers.

Table 34: Organisations involved in Fisheries

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Organisation</th>
<th>Role in the catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI</td>
<td>Dept. of Culture, Arts and Leisure (DCAL)</td>
<td>DCAL has overall policy responsibility for the supervision and protection of inland fisheries, and for the establishment and development of fisheries. Role in preventing introduction of certain fish species (e.g. pike) into the system.</td>
</tr>
<tr>
<td>NI</td>
<td>Fisheries Conservancy Board (FCB)</td>
<td>Established under the Fisheries Act (NI) 1966. The sponsor body is the Department of Culture, Arts and Leisure, and operates as water bailiff on its behalf. Will be disbanded under the Review of Public Administration.</td>
</tr>
<tr>
<td>NI</td>
<td>Garrison and Melvin Angling Association</td>
<td>Club bailiffs have power to enforce Fisheries Act regulations.</td>
</tr>
<tr>
<td>NI</td>
<td>EHS</td>
<td>Has a role in preventing the spread of zebra mussels into the catchment through enforcement of legislation and introduction of codes of practice etc.</td>
</tr>
<tr>
<td>RoI</td>
<td>Northern Regional Fisheries Board (NRFB)</td>
<td>The NRFB is the statutory body responsible for the conservation, protection, development, management, promotion and marketing of inland fisheries in Ireland’s northern fisheries region.</td>
</tr>
<tr>
<td>RoI</td>
<td>Leitrim County Council</td>
<td>The Local Authorities has a role in protecting fisheries indirectly by ensuring water quality and the integrity of rivers and spawning beds and by avoiding contamination of waters by alien species such as zebra mussels.</td>
</tr>
</tbody>
</table>

The most significant governance issues relating to fisheries in the catchment were identified as:

- The need to protect the lake from pollution and decreased water quality, especially from diffuse pollution;
- The importance of preventing the introduction of alien species such as zebra mussels and pike;
- The need for harmonisation of regulation across the border;
- Future pressure for water abstraction.
11.3.6 Forestry

The management of commercial conifer plantations gives rise to a number of environmental issues of relevance to the Lough Melvin catchment. These include:

- Drainage of land in preparation for planting, increasing erosion and sediment runoff to water courses;
- Use of fertilisers in establishing new plantations, and periodic application during early growth stages;
- Harvesting beside water courses can lead to sedimentation, while needles of felled conifers can contribute to leaching of P or alter the pH of the water course.

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Organisation</th>
<th>Role in the catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI</td>
<td>DARD Forest Service</td>
<td>Regulation of private forestry and management of State forests in NI.</td>
</tr>
<tr>
<td>RoI</td>
<td>DAFF Forest Service</td>
<td>Responsible for development of forestry in Ireland. It is responsible for felling licences, grant aid for private forestry as well as the development of the Forest Environment Protection Scheme (FEPS).</td>
</tr>
<tr>
<td>RoI</td>
<td>Coillte</td>
<td>Coillte is a State owned company operating primarily in forestry, and has responsibility for a large part of Ireland’s forested area</td>
</tr>
</tbody>
</table>

The most significant governance issues relating to forestry in the catchment were identified as:

- The use of appropriate assessment (under Habitats Directive) in relation to major forestry operations such as clearfelling;
- Disparity in EIA regulations;
- The potential impact of clearfelling on water quality;
- Harmonisation of forestry management practices.
11.3.7 General governance issues

A number of general governance issues within the catchment do not fit within any of the foregoing categories.

**Profile of the Lough Melvin Catchment**

It is suggested that the profile of Lough Melvin is low among some government bodies and their staff. This may result from a lack of information about the area and the international significance of Lough Melvin in a nature conservation and fisheries context. Management of the catchment would also benefit by raising the profile of Lough Melvin (and the issues affecting it) at a high level in both Governments. Involvement in the Catchment Management Group by high-level representatives from key organisations would assist in this, but this should not be to the exclusion of representatives who have local knowledge.

**Non-government stakeholder participation in Lough Melvin**

Involvement of non-government stakeholders is an essential ingredient in management of the Lough Melvin catchment. It is therefore important that other stakeholders are as involved as possible in the catchment management process. This is particularly important where governance and regulation is insufficient to address key issues such as:

- preventing the introduction of zebra mussels and pike into the system or
- involvement in agri-environment and other schemes.

There is currently no mechanism for the co-ordinated involvement of stakeholders across the whole catchment. The Erne/Melvin Catchment Group established by EHS in NI, has up to now focussed on the larger Erne system, and there is concern that the wider range of issues affecting the Erne system may continue to constrain the group’s involvement in Lough Melvin.

**Role of local authorities in RoI**

Local Authorities in RoI have a very important role in the governance of the catchment, not least through the development of land use policies for decision making in the County Development Plan and Area Plans. However, such plans and policies need to be agreed with elected members before they can be adopted. Some policies may be perceived by elected representatives as restrictive of development, which may lead to opposition.
11.4 Priority governance issues for Lough Melvin

The previous section summarises the issues according to seven main topics. However, prioritisation at a catchment scale for management is necessary and was undertaken based on three main parameters:

1. The importance of the issues in the context of the three key governance drivers (Habitats, Water Framework and Nitrates Directives);
2. The urgency of addressing shortcomings in governance approaches, and;
3. The feasibility of addressing these issues in the short term.

Prioritisation was undertaken via a consultation process with 32 key stakeholders representing 17 different organisations; comments on draft reports provided by the Catchment Management Group, organisational stakeholders and the Steering Committee and; a stakeholder workshop.

There was generally a strong correlation between the priority issues agreed at the stakeholder workshop and those considered to be the most important. However, there were also some notable differences such as the role of EIA and appropriate planning policies in the protection of Lough Melvin.

The 12 top priority governance issues for Lough Melvin are summarised in Table 36 along with recommendations on how they should be dealt with and notes on the urgency and timescale for action.

<table>
<thead>
<tr>
<th>Priority Issue</th>
<th>Recommendations</th>
<th>Notes</th>
<th>Timescale for Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Common Water Quality standards and monitoring should be agreed across the catchment.</td>
<td>Agreement over water quality definitions for both chemical and ecological parameters. Agreeed target for the total phosphorus concentration in Lough Melvin between all relevant agencies (20µg L⁻¹). A more precise and/or extensive monitoring regime for the catchment is required, including greater liaison between water quality and fisheries agencies. Agencies in both jurisdictions should reach agreement on a monitoring specification which meets both WFD and Habitats Directive requirements without duplication. Monitoring protocols should be subject to service level agreements between agencies in the same jurisdiction. These should be based on factors including the results of inter-calibration exercises.</td>
<td>Common and agreed water quality standards are fundamental to the execution of any controls, policies or regulations that seek to protect water quality.</td>
<td>This issue is considered to be both important and urgent. The number of initiatives that require common standards and the number of agencies involved in monitoring for different purposes, however, means that resolution of the issue may not be feasible in the short term. It is considered that the issue needs to be addressed in the short term in order to find a resolution in the short to medium term.</td>
</tr>
</tbody>
</table>
## Governance Framework

<table>
<thead>
<tr>
<th>Priority Issue</th>
<th>Recommendations</th>
<th>Notes</th>
<th>Timescale for Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Enforcement capacity in the catchment is affected by resource constraints</td>
<td>An appropriate enforcement capacity should be sought, informed by the outcomes of existing studies and ongoing water quality monitoring, and taking account of the sensitive nature of the catchment. In the meantime, Lough Melvin should be prioritised as a target catchment for proactive monitoring and enforcement given the significant water quality issues within the catchment.</td>
<td>Enforcement of existing regulations and legislation is seen as an issue in many areas and often is the major barrier to resolving issues. Resources tend to be the limiting factor in enforcement. Improving enforcement is likely to be one of the most cost-effective ways of ensuring maintenance of water quality in the catchment. In NI a study is currently being undertaken on the impact of dispersed population on water quality. The outcomes will advise future policy. Ideally the outcomes should be used to identify appropriate enforcement needs for sensitive catchments such as Lough Melvin.</td>
<td>The issue is considered to be both important and urgent. It is acknowledged that the unlocking of resources needs to be done at a national level and can be difficult. This issue needs to be addressed in the short term.</td>
</tr>
<tr>
<td>3 Agri-environment schemes have a key role in management of the catchment. Such schemes need to be enhanced to maximise their effect.</td>
<td>A suite of unified agri-environment measures should be available to all farmers in the Lough Melvin catchment; These should include measures and appropriate incentives for water quality. Increased rates for these measures in the catchment should be explored. There should be an increased level of inspection of participating farms in the catchment.</td>
<td>The role of tailored agri-environment measures in the catchment is of extremely high importance because of the potential improvements in water quality that can result from practical measures. They are also important, however, because of their role in bringing landowners into the process from a positive perspective. It is unclear as to how feasible some issues are relating to a unified agri-environment scheme for the catchment, including: The potential for enhanced payments on a catchment basis to improve take-up Parity of measures in both jurisdictions Potential for a scheme that, in providing for the needs of the catchment, is likely to be different from national schemes.</td>
<td>The issue is considered to be both important and urgent. Feasibility of different recommendations varies. Recommendations for this issue should be addressed in the short to medium term.</td>
</tr>
</tbody>
</table>
### Priority Issue

<table>
<thead>
<tr>
<th>Priority Issue</th>
<th>Recommendations</th>
<th>Notes</th>
<th>Timescale for Action</th>
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</thead>
<tbody>
<tr>
<td>4 Transposition and implementation of the Habitats Directive within the catchment is often weak and generally variable across jurisdictions.</td>
<td>Training on the application of Article 6 should be provided to all relevant authorities in both jurisdictions, including the planning authorities, forestry agencies, water services authorities, and fisheries authorities. An education programme for landowners whose activities could have an impact on the SAC should be undertaken in both jurisdictions. Service Level Agreements may be required to formalise consultation between organisations on the need for appropriate assessment screening. The EC (Natural Habitats) Regulations require further amendment to ensure compliance with the Habitats Directive.</td>
<td>The Habitats Directive and its full application is an important tool in protecting the requirements of the designated interest of Lough Melvin, including water quality. While there is a need for some legislative change to align national regulations with the EU Habitats Directive, a considerable improvement in application could be achieved by operational changes in each jurisdiction and cross-border agreements. The potential of full application of the Directive in reducing deterioration in water quality is high.</td>
<td>Recommendations not requiring legislative change should be carried out in the short term. It is recognised that, while urgent and important, legislative change is likely to be in the medium term or longer.</td>
</tr>
<tr>
<td>5 Two separate Conservation plans exist for Lough Melvin SAC. Their status and level of detail differ significantly.</td>
<td>A single Conservation Plan should be prepared for the Lough Melvin SAC, or at least a common approach taken to separate plans. This should include detailed favourable condition tables for all selection features.</td>
<td>A Conservation Plan for Lough Melvin SAC sets out standards for favourable condition. These can include total phosphorus levels for the lake and form the basis of assessment of plans or projects that may have an effect on the site. An agreed and adopted approach to favourable condition and other management aspects is important to lay the basis for effective protection of the status of the site.</td>
<td>It is considered that this issue is both important and urgent. It is also considered that the recommendations are achievable in the short term. These recommendations should be carried out in the short term.</td>
</tr>
<tr>
<td>6 The quality of policy protection for Lough Melvin SAC differs significantly between jurisdictions.</td>
<td>The review of Leitrim CDP 2003-2009 should include a robust policy which accurately reflects the requirements of Article 6. PPS2 in NI is currently under review and should be amended to reflect the requirement for AA of Area Plans. Compliance with the Birds and Habitats Directives could be achieved by the introduction of National Planning Guidance on this issue.</td>
<td>The importance of the Habitats Directive in protecting the water quality of Lough Melvin has been discussed earlier. In order to be fully enforced, the requirements of the Habitats Directive need to be appropriately reflected in strategic planning documents.</td>
<td>This issue is considered to be both important and urgent. While the need for National Planning Guidance is clearly a national issue, appropriate policy protection through the Leitrim County Development Plan and PPS2 is considered highly feasible. Recommendations for this issue should be addressed in the short term where the opportunity is there (i.e. where appropriate policy and strategic documents are under review).</td>
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</table>
## Governance Framework

<table>
<thead>
<tr>
<th>Priority Issue</th>
<th>Recommendations</th>
<th>Notes</th>
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<tbody>
<tr>
<td>7</td>
<td>Increased application of sub-threshold EIA should be considered by the planning authorities, particularly in Rol. Training and guidance on the interpretation of “significant effects on the environment” and other key issues, should be considered.</td>
<td>Because of the nature of catchments and, specifically, the position of Lough Melvin at the foot of the catchment, there is a high potential for its water quality to be affected by actions a considerable distance away. A more stringent interpretation of what constitutes “significant impacts on the environment” could bring EIA requirements to bear on various projects that currently fall outside the system. Some projects, such as peat extraction of less than 10 ha in Rol would still fall outside the system without legislative change.</td>
<td>This issue is considered to be both important and urgent. Although changes to implementation of the EIA Directive would be considered limited in feasibility, the recommendations given here are highly feasible operational issues. Recommendations for this issue should be addressed in the short term.</td>
</tr>
<tr>
<td>8</td>
<td>Every effort should be made to involve planning authorities in the catchment management plan process. A Thematic Local Area Plan for the Lough Melvin catchment should be explored in County Leitrim. Consider scope for parallel or integrated approach with NI Planning policy to include the Fermanagh part of the catchment. PPS14 policies should continue to be applied in the Lough Melvin catchment. Leitrim CDP 2009-2015 should include policies restricting one-off housing in sensitive parts of the catchment. In both jurisdictions, planning conditions should be used to require tertiary treatment etc. where necessary.</td>
<td>The strategic and regulatory nature of land use planning, plus the fact that many of the issues that affect water quality in the catchment are within the control of the planning system, means that it is of extremely high importance in this context. Certain opportunities exist to deal with issues in the short term, such as the current review of the Leitrim County Development Plan.</td>
<td>It is considered that this issue is both important and urgent. It is also considered that the majority of recommendations are achievable and should be applied in the short term. It is considered that exploration of a thematic Local Area Plan in Leitrim and an integrated approach in NI should be considered in the short term, although the execution is likely to be in the medium or long term.</td>
</tr>
<tr>
<td>9</td>
<td>Legislation relating to alien species introductions in both jurisdictions should be amended and harmonised. Government agencies should support angling clubs and other stakeholders to take a proactive approach in alien species initiatives. A cross border contingency plan should be put into place, including appropriate contacts and procedures. Initiatives should take account of the fact that some species alien to the catchment, such as pike, could have a particularly devastating impact on the wildlife interest of Lough Melvin.</td>
<td>While there are many governance issues that need to be addressed to ensure the future water quality of Lough Melvin, there is concern that the impact of some alien species could have on the catchment could be devastating to the species for which water quality is being maintained.</td>
<td>It is considered that this issue is both important and urgent. It is also considered that, because inadvertent or deliberate introductions could happen at any time, recommendations must be applied in the short term. Measures would also need to be continually applied.</td>
</tr>
</tbody>
</table>
## Priority Issue Recommendations Notes Timescale for Action

### 10 There is significant variation in the scope for EIA of forestry operations between NI and RoI.

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Notes</th>
<th>Timescale for Action</th>
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</thead>
<tbody>
<tr>
<td>The application of discretionary EIA for sub-threshold projects should be expanded.</td>
<td>While there are considerable variations between the two jurisdictions on the size of forestry operation (afforestation or deforestation) that would either require screening for an EIA or a mandatory EIA, there is provision in both for discretionary EIA for projects likely to have significant effects on the environment.</td>
<td>It is considered that the issue and recommendation is important. Urgency is medium but would be likely to increase in response to any increase in private forestry applications. The recommendation should be applied in the short to medium term.</td>
</tr>
</tbody>
</table>

### 11 Clearfelling within the catchment could have significant implications for water quality

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Notes</th>
<th>Timescale for Action</th>
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<tbody>
<tr>
<td>All major forestry operations in the catchment that may have a significant effect on Lough Melvin should be screened for appropriate assessment under Article 6 of the Habitats Directive. There should be active management of all riparian buffer zones to reduce the potential impact of clearfelling, including machinery exclusion zones. Future forestry planning needs to take account of the potential impact of clearfelling and this should be reflected in buffer zones, open spaces, species composition and coupe sizes. Co-ordination to achieve a total annual clear-fell limit for the catchment should be explored. Amend statutory requirement for re-planting of clear-felled areas under ROL Forestry Acts.</td>
<td>Clearfelling has the potential for large-scale mobilisation of nutrients in the catchment and can cause quick and considerable peaks in P levels. Resolving the issue will require a complex combination of measures that include practical measures, strategic planning and cross-border agreements.</td>
<td>The issue is considered to be high in terms of importance. Indications are that there is relatively little clearfelling planned for the next 6 or 7 years in the catchment (though this increases substantially in 2015). However, the complexities involved in resolving the issue suggest that there is also a high level of urgency in starting to deal with it now. It is considered that the issue needs to be addressed in the short term in order to find a resolution in the medium term.</td>
</tr>
</tbody>
</table>

### 12 Stakeholders must ensure that the Lough Melvin Catchment Management Plan will be implemented

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Notes</th>
<th>Timescale for Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>An Implementation Group of key stakeholders should be established to co-ordinate the implementation of key measures identified in the Catchment Management Plan. Representatives should be at a sufficiently high level in their organisations to facilitate implementation measures. A lead agency should be established – possibly a Local Authority</td>
<td>The value of a Catchment Management Plan is that it is both integrated and highly targeted. Any strategic plan, however, is only as good as its application, and one that relies on input from any different agencies and individuals needs to be driven from a central point that has sufficient influence to ensure compliance from all parties.</td>
<td>The issue is considered to be both important and urgent. Feasibility of addressing the issue is highly dependent on the readiness of an appropriate agency to take the lead role.</td>
</tr>
</tbody>
</table>
11.5 Analysis of issues and recommendations and timescales for action

Table 36 presents the issues and recommendations based on their importance and urgency and the potential timescales for addressing these.

Some recommendations, such as amendments to legislation, are unlikely to be achievable in the short term. Others however, relate more to processes and interactions which are more feasible in terms of delivery.

Recommendations which could be implemented in the short term are identified as follows:

- Training on the application of Article 6 of the Habitats Directive should be provided to all relevant authorities in both jurisdictions, including the planning authorities, forestry agencies, water services authorities, and fisheries authorities.
- Cross border agreement should be reached on what is required to fulfil an Appropriate Assessment under Article 6 of the Habitats Directive.
- An education programme for landowners whose activities could have an impact on the Lough Melvin SAC should be undertaken in both jurisdictions.
- Service Level Agreements may be required to formalise consultation between organisations on the need for Appropriate Assessment screening under the Habitats Directive.
- A single Conservation Plan should be prepared for Lough Melvin SAC, or at least a common approach taken to separate plans. This should include detailed favourable condition tables for all selection features.
- The review of Leitrim CDP 2003-2009 should include a robust policy which accurately reflects the requirements of Article 6 of the Habitats Directive.
- Increased application of sub-threshold EIA should be considered by the planning authorities, particularly in RoI.
- Training and guidance on the interpretation of “significant effects on the environment” and other key issues, should be considered for appropriate authorities.
- Every effort should be made to involve planning authorities in the catchment management plan process.
- PPS14 policies should continue to be applied in the Melvin catchment.
- Leitrim CDP 2009-2015 should include policies restricting one-off housing in sensitive parts of the catchment.
- In both jurisdictions, planning conditions should be used to require tertiary effluent treatment where necessary.
- Government agencies should support angling clubs and other stakeholders to take a proactive approach in alien species initiatives.
- A cross border contingency plan should be put into place to deal with the event of alien species introduction, including appropriate contacts and procedures.
- Initiatives should take account of the fact that some species alien to the catchment, such as pike, could have a particularly devastating impact on the wildlife interest of Lough Melvin.
- The application of discretionary EIA for sub-threshold projects should be expanded.
Governance Framework

- All major forestry operations in the catchment that may have a significant effect on Lough Melvin should be screened for appropriate assessment under Article 6 of the Habitats Directive.
- Agricultural agencies should establish a forum with the objective of agreeing a package of common agri-environment measures which can be targeted at the Melvin catchment. Any agricultural forum for the catchment should also include the regulatory bodies such as Leitrim County Council and EHS.
- There should be active management of all forestry riparian buffer zones to reduce the potential impact of clearfelling, including machinery exclusion zones.
- An Implementation Group of key stakeholders should be established to co-ordinate the implementation of key measures identified in the Catchment Management Plan.
- Representatives of any Catchment Management Plan group should be at a sufficiently high level in their organisations to facilitate implementation measures.
- A lead agency should be established for the Catchment Management Plan – possibly a Local Authority.

Recommendations that derive from issues that are considered important and urgent, but with feasibility restricted by various factors, are listed below. It is suggested that early addressing of these issues should provide results in the medium term.

- Agreement over water quality definitions for both chemical and ecological parameters is needed covering both jurisdictions.
- An agreed target for the total phosphorus concentration in Lough Melvin between all relevant agencies is required.
- A more precise and/or extensive monitoring regime for the catchment is required, including greater liaison between water quality and fisheries agencies.
- Agencies in both jurisdictions should reach agreement on a monitoring specification which meets both WFD and Habitats Directive requirements without duplication.
- An appropriate enforcement capacity should be sought, informed by the outcomes of existing studies and ongoing water quality monitoring, and taking account of the sensitive nature of the catchment. This should be pursued at a high level through the national budgeting and Programme for Government process. In the meantime, Lough Melvin should be prioritised as a target catchment for proactive monitoring and enforcement.
- Unified agri-environment measures are required across the catchment. Research by the appropriate agencies suggests that this is best served by a catchment-specific scheme, available to all farmers in the catchment.
- There should be an increased level of inspection of participating farms in the catchment.
- Compliance with the Birds and Habitats Directives could be achieved by the introduction of National Planning Guidance on this issue.
- PPS2 in NI is currently under review and should be amended to reflect the requirement for AA of Area Plans.
- A Thematic Local Area Plan for the Lough Melvin catchment should be explored in
County Leitrim. Scope for a parallel or integrated approach with NI Planning policy to include the County Fermanagh portion of the catchment should be considered.

- Future forestry planning needs to take account of the potential impact of clearfelling and this should be reflected in buffer zones, open spaces, species composition and coupe sizes.
- Co-ordination to achieve a total annual clear-fell limit for the catchment should be explored.

**Longer term** recommendations that derive from issues that are considered important and urgent are listed below.

- The EC (Natural Habitats) Regulations require further amendment to ensure compliance with the Habitats Directive, notably with respect to addressing strategic plans in RoI.
- Legislation relating to alien species introductions in both jurisdictions should be amended and harmonized.
- Statutory requirement for re-planting of clearfelled areas under RoI Forestry Acts needs to be amended with respect to unsuitable areas.

### 11.6 Conclusion

This section has identified the key governance drivers relating to water quality in the Lough Melvin catchment. It has also set out to identify the principal governance issues and has prioritised those considered to be the most important and urgent, making recommendations as to how they should be addressed. Further analysis has determined those issues and recommendations that can most easily be addressed within a short time frame.

This assessment, based on research and consultation with stakeholders, has culminated in significant consensus over the key governance issues in the catchment. In this context, the recommendations provided can be considered as “toolkit” for addressing the priority governance issues relating to water quality in the catchment.
Landuse Management Actions and Recommendations

This section summarises in table format the priority actions or measures from the agriculture, forestry and housing/wastewater sections. Actions or measures are aimed at directly reducing the nutrient loads entering Lough Melvin and are thus threat based. Actions from the governance section have not been reiterated here as they are found in summarised format already within Section 11.

**Table 37: Lough Melvin Management Actions and Recommendations**

<table>
<thead>
<tr>
<th>Actions/Measures</th>
<th>Responsible Agency</th>
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</thead>
<tbody>
<tr>
<td><strong>Agriculture</strong></td>
<td></td>
</tr>
<tr>
<td>Provision of nutrient and agri-environmental advisory programme that includes soil testing and a Nutrient Management Plan (NMP), free of charge to the farmer. To include:</td>
<td></td>
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<tr>
<td>• identification of Index 4 soils and peaty soils</td>
<td>Teagasc and DARD</td>
</tr>
<tr>
<td>• Reduce slurry/fertiliser application rates to agronomically optimum levels</td>
<td></td>
</tr>
<tr>
<td>• Feeding low P concentrates</td>
<td></td>
</tr>
<tr>
<td>• Removing P in silage and not replacing the P off-take on Index 4 soils. This measure will be restricted in its application as it will only be applicable to a limited number of fields and subject to the availability of alternative and suitable spreading areas.</td>
<td></td>
</tr>
<tr>
<td>Implement/encourage uptake of interception measures:</td>
<td></td>
</tr>
<tr>
<td>• Barriers or sedimentation ponds in drainage ditches</td>
<td>Teagasc and DARD</td>
</tr>
<tr>
<td>• Grass buffer zones of 2.5m width</td>
<td></td>
</tr>
<tr>
<td>• Hedgerows</td>
<td></td>
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<tr>
<td>Where insufficient progress is made with the above, implementation of reserve measures (the remaining less cost effective and/or less popular measures with farmers) for source reduction or pathway interception would be required. These could include:</td>
<td></td>
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<tr>
<td>• Provision of compensation for reductions in overall stocking rate</td>
<td>Teagasc, DAFF, DARD</td>
</tr>
<tr>
<td>• Provision of compensation for reductions in stock by selling calves in autumn</td>
<td></td>
</tr>
<tr>
<td><strong>Forestry</strong></td>
<td></td>
</tr>
<tr>
<td>Buffer zones should be created beside watercourses in line with best management practices where windthrow is not a risk factor.</td>
<td>Coillte, Forest Service NI and forestry owners</td>
</tr>
<tr>
<td>Coillte and the Forest Service N.I. should develop progressive felling plans on a whole catchment basis.</td>
<td>Coillte &amp; Forest Service NI</td>
</tr>
<tr>
<td>Aerial fertilisation proposals from R.o.I and N.I. should be combined prior to consultation with the regulatory authorities at a cross border level i.e. The Fisheries Board, River Agency and E.H.S.</td>
<td>Coillte &amp; Forest Service NI</td>
</tr>
<tr>
<td>Brash should be removed as far back from watercourses as possible</td>
<td>Coillte &amp; Forest Service NI</td>
</tr>
<tr>
<td>On clearfell sites, strategically position ochre at the end of collector drains (Pilot Study)</td>
<td>TBA</td>
</tr>
<tr>
<td>The poorest nutrient deficient sites should be identified and allocated for areas of open space in redesign plans.</td>
<td>Coillte &amp; Forest Service NI and RoI</td>
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</tbody>
</table>
### Landuse Management Actions and Recommendations

<table>
<thead>
<tr>
<th>Actions/Measures</th>
<th>Responsible Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>On reafforestation sites, no fertiliser should be applied until vegetation has re-established</td>
<td>Coillte, Forest Service NI &amp; forestry owners</td>
</tr>
<tr>
<td>In areas of high risk, silt traps should be installed either prior to ground preparation or harvesting.</td>
<td>Coillte &amp; Forest Service NI</td>
</tr>
<tr>
<td>Sensitive areas (such as spawning grounds) in the catchment should be identified and forestry operators made aware.</td>
<td>Fisheries Board, DCAL and forestry owners</td>
</tr>
<tr>
<td>Difficult forestry sites posing single event risks should be identified and managed through correct environmental planning.</td>
<td>Coillte &amp; Forest Service NI</td>
</tr>
<tr>
<td>Where sensitive sites and difficult forestry sites combine, consultation between appropriate agencies on protective measures may be needed.</td>
<td>Coillte &amp; Forest Service NI and relevant stakeholders</td>
</tr>
<tr>
<td>The planting of broadleaf woodland should be undertaken in areas of high run-off risk, areas prone to over grazing and poaching from intensive stocking.</td>
<td>Coillte &amp; Forest Service NI &amp; Forest Service RoI</td>
</tr>
</tbody>
</table>

### Housing/Wastewater

<table>
<thead>
<tr>
<th>Actions/Measures</th>
<th>Responsible Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>An education and awareness programme should be developed and implemented by the relevant authorities as a high priority in the short term.</td>
<td>EHS and Leitrim County Council</td>
</tr>
<tr>
<td>Resources should continue to be sought for additional enforcement capacity and the catchment should be prioritised as a target catchment for proactive monitoring and enforcement.</td>
<td>Leitrim County Council</td>
</tr>
<tr>
<td>Alternative and more effective methods of treating household wastewater should be investigated for sensitive and high risk catchments such as Lough Melvin.</td>
<td>EHS and Leitrim County Council</td>
</tr>
<tr>
<td>Householders should be required to update their wastewater treatment systems to meet required standards. This should be grant aided and considered a high priority as it is very probable that there are a significant number of antiquated systems within the catchment.</td>
<td>EHS and Leitrim County Council</td>
</tr>
<tr>
<td>Consideration should be given to the introduction of bye-laws for the control of pollution from septic tanks.</td>
<td>Leitrim County Council</td>
</tr>
<tr>
<td>Further investigation on the communal wastewater system servicing the 5 council houses in Rossinver and less than 10m from the Ballagh River needs to be undertaken and a new system installed if flooding of the system is evident or its location is deemed high risk.</td>
<td>Leitrim County Council</td>
</tr>
<tr>
<td>The location and suitability of the Lough Melvin catchment for one-off housing should be critically considered by the relevant authorities on a “whole of catchment” basis. One off housing should not be permitted or at the very least severely restricted outside sewered areas or locations where proprietary treatment systems with P removal facilities are not practicable.</td>
<td>Planning Service NI and Leitrim County Council</td>
</tr>
</tbody>
</table>
Landuse Management Actions and Recommendations
Adaptive Management Framework
Adaptive Management Framework

Adaptive management is a systematic process for continual improvement and is often portrayed as a six step continuous cycle involving assessing, designing, implementing, monitoring, evaluating and adjusting (see Figure 58). Adaptive management is important especially in natural resource management as many assessments and designs are based on a number of assumptions, and it is extremely difficult to predict how the natural environment will respond to any intervention. Creating feedback mechanisms within the adaptive management framework ensures that the Lough Melvin CMP is responsive to changing conditions. In addition, monitoring and evaluation, and the associated reporting that is required, are important for providing stakeholders and the community with information on the status of Lough Melvin and the progress and results of implementation of the CMP.

The assess and design stages have been completed by the Lough Melvin Programme but the adaptive management cycle will ensure that the outputs of these stages will be reviewed and adjusted as necessary, as new information becomes available and as the monitoring and evaluation stages provide feedback.

Figure 58: Adaptive Management Process
13.1 Monitoring

It is recommended that a holistic monitoring system is developed for Lough Melvin that integrates and links ecological values and objectives with implementation of actions. It is also recommended that data on species and habitats within the catchment be collated into the GIS for the catchment to form an ecological map. It is impractical to aim to preserve species and habitats within the catchment without an understanding of their current status and location.

In terms of water quality monitoring, a long-term strategy recommendation is outlined below.

**Water Quality Monitoring**

Three year long monitoring programmes, in addition to specific monitoring of the lake between each, have demonstrated that Lough Melvin is under increasing pressure from phosphorus enrichment and that lake concentrations are expected to rise in the future. While stakeholders have demonstrated a strong willingness to remedy the situation through a number of measures and agri-environmental schemes, there is no framework for assessing how effective these measures will be or if they will be sufficient to curb the recent rises in phosphorus export intensity. The Lough Melvin Programme has shown that cross border cooperation is crucial for the successful management of Lough Melvin as a sustainable resource, but it has highlighted the fact that there is no consensus as to who is willing or responsible for monitoring the lake in the future.

There are strong grounds for monitoring Lough Melvin, not only to assess its changing status and the efficacy of management strategies, but also as a means to examine lake-catchment dynamics at the regional scale. The basis for this argument is that while we may be able to mitigate against the direct pressures exerted upon freshwaters through agri-environmental and socio-economic management practices, changes in climate related biogeochemical cycling are largely beyond the reach of management at the catchment scale.

The Global Lake Ecological Observatory Network (GLEON) is an organisation that links limnological data from lakes distributed across the world. Monitoring is carried out largely by the use of remote sensing instruments and the database forms a powerful tool for examining climate related impacts upon freshwaters. Currently there is one GLEON site in the RoI; however, this is of a very different lake type to Lough Melvin, which is representative of the majority of lakes in the region.

The establishment of a long term monitoring strategy for Lough Melvin, involving the use of remote sensing technology that is linked to a global database such as GLEON is recommended.

13.2 Evaluation and Review

It is recommended that evaluation against the recommendations outlined in the CMP is undertaken on a yearly basis by a cross-border Lough Melvin Management Group or Stakeholder Forum, with a more holistic and detailed review of the actual CMP to be undertaken on a five yearly basis. This review should be considered and adjusted accordingly in light of the development and implementation of the River Basin Management Plans.
Appendices
### Appendix 1: Forestry Data

#### Table 1: Modelled phosphorus loads from forestry in the Lough Melvin catchment

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (Ha)</th>
<th>Export Coefficient kg P ha⁻¹ yr⁻¹</th>
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<th>TP including Clearfell (kg)</th>
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**Column A:** Total P loads from clearfell activities only.

**Column B:** Total P loads from catchment, based on CORINE 2000 and the human contribution, accounting for increased P export from clearfelling activities.

**Column C:** Total P loads from catchment based on CORINE 2000 and the human contribution (not accounting for increased P export from clearfelling activities- export based on standing crop only).
Appendix 2: SAC Objectives

Republic of Ireland (only environmental objectives extracted)  
(National Parks & Wildlife Service)

**Objective 1:** To maintain and enhance the ecological value of the annexed habitat on the site-oligo-mesotrophic lake.

**Objective 2:** To maintain and enhance the ecological value of other natural and semi-natural habitats.

**Objective 3:** To maintain and where possible, increase the populations of species listed in Annex II of the Habitats Directive for which the site was selected.

**Objective 4:** To maintain and enhance the populations of other notable plant and animal species that are found on the site.

Northern Ireland SAC Objectives (Environment & Heritage Service)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Grade</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligotrophic to mesotrophic standing water with vegetation belonging to Littorelletea uniflorae and/or Isoeto-Nanojuncetea</td>
<td>A</td>
<td>Open water area to remain stable and water level regime to follow a natural cycle.</td>
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<tr>
<td></td>
<td></td>
<td>The lake water to remain poor in plant nutrients and not to fluctuate outside normal limits.</td>
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<td>The lake water alkalinity not to fluctuate outside normal limits.</td>
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<td></td>
<td>The degree of peat staining of the lake water to remain at low levels.</td>
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<td></td>
<td>Characteristic aquatic vegetation to remain present, including zones of isoeetid vegetation.</td>
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<tr>
<td></td>
<td></td>
<td>Hard basin substrate not to become buried below soft sediments. Inflows not to carry an abnormal sediment load.</td>
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<tr>
<td></td>
<td></td>
<td>Minimal negative impacts from artificial structures.</td>
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<tr>
<td></td>
<td></td>
<td>Minimal negative impacts from recreation.</td>
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<tr>
<td></td>
<td></td>
<td>Co-ordinate monitoring efforts north and south of the border, and correlate the results</td>
</tr>
<tr>
<td>Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinia caerulea)</td>
<td>B</td>
<td>Maintain and expand the extent of existing fen meadow but not at the expense of other SAC (ABC) features. (There are area of degraded heath, scrub, and damp grassland which have the potential to develop into fen meadow)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maintain and enhance fen meadow species diversity including the presence of notable or rare species.</td>
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<tr>
<td></td>
<td></td>
<td>Maintain the diversity and quality of habitats associated with the fen meadow, e.g. wet grasslands, wet heath, wet woodland and scrub, especially where these exhibit natural transition to fen meadow.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seek nature conservation management over suitable areas immediately outside the SAC where there may be potential for restoring fen meadow.</td>
</tr>
</tbody>
</table>
### Appendices

#### Feature Grade Objective

<table>
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<tr>
<th>Feature</th>
<th>Grade</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
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<td>Old sessile oak woods with Ilex and Blechnum in the British Isles</td>
<td>C</td>
<td>Maintain and expand the extent of existing oak woodland but not at the expense of other SAC (ABC) features. (There are area of degraded heath, wetland and damp grassland which have the potential to develop into oak woodland)</td>
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<td>Maintain and enhance Oak woodland species diversity including the presence of notable or rare species.</td>
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<td></td>
<td></td>
<td>Maintain and enhance Oak woodland structure</td>
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<tr>
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<td></td>
<td>Maintain the diversity and quality of habitats associated with the Oak woodland, e.g. fen meadow, grasslands, wet heath wet woodland and scrub, especially where these exhibit natural transition to Oak woodland</td>
</tr>
<tr>
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<td></td>
<td>Seek nature conservation management over adjacent forested areas outside the SAC where there may be potential for woodland rehabilitation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seek nature conservation management over suitable areas immediately outside the SAC where there may be potential for woodland expansion.</td>
</tr>
<tr>
<td>Salmon Salmo salar</td>
<td>C</td>
<td>Maintain and if possible, expand existing population numbers and distribution</td>
</tr>
<tr>
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<td></td>
<td>Maintain and where possible, enhance the extent and quality of suitable Salmon habitat, in particular the chemical and biological quality of the water</td>
</tr>
</tbody>
</table>

#### Additional ASSI selection feature objectives

<table>
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<th>Feature</th>
<th>Component Objective</th>
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<tbody>
<tr>
<td>Freshwater Fish</td>
<td>Maintain and if possible, expand population numbers and distribution of unique post glacial fish community- (Sonaghen Salmo nigrininis, gillaroo S. stomachius, ferox S. ferox, and Arctic Charr Salvelinus alpinus)</td>
</tr>
<tr>
<td></td>
<td>Maintain and where possible, enhance the extent and quality of suitable habitat, in particular the chemical and biological quality of the water</td>
</tr>
<tr>
<td>Higher Plant Assemblage</td>
<td>Maintain abundance and distribution and if feasible, enhance population of five individual rare and notable plant species.</td>
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<tr>
<td></td>
<td>Establish the status of these species and if appropriate draw up further conservation priorities for these species.</td>
</tr>
<tr>
<td>Purple Moor-grass and rush pastures (not Molinia meadows)</td>
<td>Maintain and expand the extent of Purple Moor-grass and rush pastures (i.e. inundation and flushed species-rich grassland types along the foreshore), but not at the expense of other SAC (ABC) or ASSI features. (There are area of scrub which have the potential to develop into these species rich grasslands)</td>
</tr>
<tr>
<td></td>
<td>Maintain and enhance species and community diversity including the presence of notable species.</td>
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</table>
References


