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SERIES OF ECOLOGICAL ASSESSMENTS ON ARTERIAL DRAINAGE MAINTENANCE No 2

Ecological Impact Assessment (EcIA) of the Effects of Statutory Arterial Drainage Maintenance Activities on Raised Bogs & Associated Habitats

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Foreword

This Ecological Impact Assessment follows on from the strategic approach outlined in "**Series of Ecological Assessment on Arterial Drainage Maintenance No. 1: Screening of NATURA 2000 Sites for Impacts of Arterial Drainage Maintenance Operations."**

It examines the impacts of statutory arterial drainage maintenance activities on raised bogs and associated habitats, outlines measures to mitigate any negative impacts, and possible enhancement opportunities.

Environment Section

ECOLOGICAL ASSESSMENT OF THE EFFECTS OF STATUTORY ARTERIAL DRAINAGE MAINTENANCE ACTIVITIES ON CERTAIN HABITATS WITHIN SPECIAL AREAS OF CONSERVATION

Habitats assessed

- Active raised bog (EU code 7110, priority habitat)
- Raised bog still capable of regeneration (EU code 7120)
- Depressions on peat substrates of *Rhynchosporion* (EU code 7150)
- Bog woodland (EU code 9110, priority habitat)

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Note: A number of maps and photographs included in this report are not available in pdf copy and can be obtained directly from Environment Section.

Summary

The Office of Public Works (OPW) is statutorily obligated to maintain arterial drainage channels under the 1945 Arterial Drainage Act. Arterial Drainage Maintenance acts solely to retain the arterial drainage scheme design capacity i.e. the hydrological regime of the channel generated at scheme works stage. No excavation of virgin ground is required. Hence there is no sudden change in water levels. Special Areas of Conservation (SACs) are given legal protection under Irish and European law within Article 6.1 of the EU Habitats Directive. SACs include the EU Annex I habitats of active raised bog (code 7110), degraded raised bog (7120), *Rhynchosporion* depressions (7150) and bog woodland (9110). SACs are required to be maintained is a manner that maintains a favourable ecological status for the relevant Annex I habitat(s) (and/or Annex II species).

This report serves to assist the OPW in ensuring compliance of Arterial Drainage Maintenance operations with the EU Habitats Regulations, 1997. The purpose of this study is to determine the ecological impacts associated with maintenance operations, that could have detrimental impacts on raised bog and associated habitats designated as SACs. Having determined potential impacts, measures are then proposed to mitigate such impacts. This report does not deal with the ecological impact of the original drainage channels, which have been constructed prior to SAC designation. It is the maintenance of these channels that is reviewed.

Raised bogs are domed shaped masses of peat occupying former lakes or shallow depressions. Peat, which is the compacted remains of undecomposed, dead plant material, occurs in waterlogged, anaerobic conditions. Over the past centuries most of Europe's peatland have been drained and used as a source for fuel and/or reclaimed for agriculture and forestry. Excluding Scandinavia, Ireland still has 50% of the remaining area of uncut raised bogs in NW Europe. Ireland's raised bogs are classified as oceanic raised bogs or ridge-raised bogs, which has a very restricted distribution on the Atlantic fringe of NW Europe. They may be as much as 15 m deep, characterised by several species of *Sphagna* moss and dwarf ericoid shrubs, as well as other plant species such as Deer-grass, Bog Rosemary, Sundew, Bog Asphodel, Cranberry, White-beaked Sedge, Cottongrass, Bogbean and *Cladonia* lichens. Because of the nutrient-poor, acidic, exposed and fluctuating wet conditions of bogs, faunal species diversity and density is poor. Species likely to occur include Frog, Irish Hare, Otter, Skylark, Meadow Pipit, Curlew, Irish Red Grouse, Snipe, Merlin and occasionally Greenland White-fronted Goose. Invertebrates are the most abundant animals present, but few species are exclusive to bogs.

Raised bogs have a characteristic microtopography of mounds on the bog surface, termed hummocks, and depressions where water collects, called hollows. Where the water table remains above the surface level all year round, pools occur. Sometimes on flat areas, one species will dominate to form a lawn. Natural internal drainage systems sometimes develop, resulting in soaks and flushes with increased nutrient content. Other EU Annex I habitats also occur on raised bog sites namely, degraded raised bog still capable of regeneration, *Rhynchosporion* depressions on peat substrates, and bog woodland.

The hydrology of bogs is extremely complex, but is fundamental to their ecology and understanding the impact of developments, and site management. The most important characteristics typical of raised bogs that distinguish them, in a hydrological sense, from mineral soils are, a relatively large storage coefficient and the discharge regulating properties of the surface layer. Hydrologically, raised bogs can be considered as two-layered systems, comprising an uppermost layer or acrotelm, which includes the surface of live vegetation, and the entire peat body below termed the catotelm. The characteristics of these two layers are important with respect to bog hydrology. To a major extent, the hydrology of a bog is determined by the properties of the acrotelm. This layer has a high hydraulic conductivity near the surface, but becomes less permeable with depth. One important feature of an intact acrotelm is its regulating function in the lateral discharge from the bog. Undisturbed raised bogs usually have a domed surface. Because of its high water content and flexible matrix, peat shrinks when it loses water. The result of shrinkage is subsidence of the bog surface. The condition of a raised bog site can also be assessed by the presence of a well developed Central Ecotope (i.e. a typical grouping of community complexes closely related to the original vegetation of the bog expanse). Information on specific raised bogs can be obtained from the NPWS database, including detailed assessment of raised bogs in the early 1990s (Kelly *et al.*, 1995) and more recent monitoring (Valverde *et al.*, 2005). Research and restoration work on bog ecosystems has concentrated on two bogs, namely Raheenmore Bog and Clara Bog.

Construction of the original Arterial Drainage Schemes required major hard engineering e.g. widening and deepening of existing channels, and sometimes opening new channel reaches. This would typically have resulted in a drop of circa 1 m in the water table, but this could vary depending on local conditions. The channel capacity will gradually reduce over time, as both silt and vegetation levels increase and other obstructions develop. This necessitates maintenance, so as to return the channel capacity to its original design conditions. This is achieved by the removal of excess silt and vegetation, repairing bank damage or slippage and the removal of obstructions. This is undertaken with suitable rigged hydraulic excavators designed for the appropriate site conditions. As part of this report, arterial drains within, or adjacent to, a number of raised bog SACs were surveyed in a number of locations spread across the country, namely Addergoole Bog, Co. Galway, Moanveanlagh Bog, Co. Kerry and Garriskil Bog, Co. Westmeath.

The impacts of Arterial Drainage Maintenance on the ecology of a raised bog can be divided into direct and indirect impacts. The direct impacts of Arterial Drainage Maintenance are confined to a narrow corridor along the drain. In many instances, such impacts will have little, if any, impact on the ecology of the raised bog. Such impacts are not deemed ecologically significant, (especially if ecologically sensitive working practices are employed) because:
(i) These drains are artificial habitats in the first instance, and require maintenance to continue to act as a drain.
(ii) Drainage maintenance does not entail deepening of channels.
(iii) Arterial drains are generally at the periphery of, or beyond the SAC boundary, where habitats are of less ecological value.

However, Arterial Drainage Maintenance can indirectly affect the ecological status of a raised bog, due to the impact of the drain on the hydrology of the bog. If the

drainage channel is causing a continual decline in the ecological quality of the bog, then drainage maintenance is perpetuating this situation. Also, the lowering of the locality's water table, associated with arterial drainage, can benefit and encourage peat cutting. Removal of peat from a bog has a devastating effect on the bog's ecosystem, by removal of surface vegetation, drying out of uppermost peat, increasing temperature, oxygen levels, and hence decomposition rates, within surface peat. Subsidence of a raised bog can also occur due to drainage and peat cutting, which can cause an on-going deterioration of the bog. Changes in the hydrology of the bog is mirrored by changes in the flora and fauna present. Case studies in Clara and Raheenmore bogs indicate that drainage (albeit not necessarily arterial drains), and associated peat cutting, have had dramatic impacts on the ecology of these bogs.

The cause(s) of a continued decline in the ecological quality of a raised bog is a very complex issue. Drainage and associated peat cutting definitely cause a reduction in the ecological status of any raised bog. Whether one or both of these factors are causing a continued decline, is often not fully understood. However, if arterial drainage is in close proximity to a raised bog, then it possibly is one of the factors causing such decline. To determine this requires further hydrological and ecological studies. Each raised bog is different, and therefore, studies specific to the raised bog in question will need to be undertaken, to determine the causes of on-going ecological decline.

Arterial drains are, by their nature, relatively deep. Their potential to impact on a raised bog and associated habitats is dictated by two principal factors:

- How close is the drain to the bog.
- How close is the mineral soil to the drain.

With regard to the above, deep drains in the following locations would have a decreasing impact on a raised bog (all things being equal):
(i) On the high bog.
(ii) At the edge of the bog.
(iii) Within 100 m of the current peat face.
(iv) Over 100 m from the peat face on free-flowing, mineral soil.
(v) Over 100 m from the peat face on peat
However, upstream drains can also be having a detrimental impact on the bog's ecology. Depending on the hydrology of the region, this impact could be as detrimental as a drain c. 100 m from the peat face.

Four areas of policy, recently adopted by the OPW, serve to mitigate many of the direct ecological impacts of maintenance works. The Environmental Drainage Maintenance Programme (in conjunction with the Fisheries Boards), has resulted in 10 alterations to work practices, ranging from leaving banks untouched, managing vegetation and the tossing of spawning gravel. An Annual Works Programme is drawn up with the Fisheries Boards, to accommodate the timing of works in spawning channels. Fisheries Boards also liaise with OPW operational staff to co-ordinate operations on the ground, for the benefit of fish stocks. Finally, the excavator fleet has recently (1999) been upgraded, and this working fleet is to be maintained at less than 7 years old.

The more complex, and potentially more damaging, effect of indirect hydrological impacts on raised bogs will be primarily be mitigated by liaison with relevant statutory bodies, notably the NPWS. This will be substantially facilitated by a dedicated Environment Section established in 2003 within the OPW Drainage Division. Special attention will be paid to arterial drains within 100 m of a raised bog SAC facebank and drains beyond 100 m on free-draining mineral soil. Liaison will occur between the OPW and NPWS with respect to instigating studies on specific raised bogs, where there has been a deterioration in the ecological status, and where arterial drains may be a contributing factor. In this regard studies such as the *Raised bog monitoring project* (Valverde *et al*., 2005) will be referenced.

If it is discovered that an arterial drain is a contributory factor in the ecological decline of a raised bog, then a decision will be required as to conflicting issues of:

- Maintaining arterial drainage within the locality, benefiting the productivity of agricultural land and possibly the viability of property.
- The negative ecological impact of the continued presence of such drains on the ecology of the raised bog SAC.

Both these issues have legal, social, political and cost implications. In essence, it is a managerial call to decide upon the outcome of such scenarios.

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1. INTRODUCTION

1.1 Objective and scope of this study

1.1.1 Introduction

This report stems from the Office of Public Works' (OPW) Screening Report recommendations to carry out an assessment of raised bogs and associated habitats (Gilligan, 2005). This Screening Report has reviewed all the EU sites of ecological interest in Ireland (i.e. SACs, SPAs). It sets out a strategic approach to managing the various conservation aspects of these sites. The majority of the information supplied in this chapter, as well as within chapter 3, has been sourced from this document. This Screening Report is a framework document, where more thorough information is supplied on the subjects dealt with in these chapters. While the Screening Report is currently in draft form, it is at an advanced consultation stage, with an expected completion date of early 2006 (N. Gilligan, pers. comm.)

This current report will serve to assist the OPW in ensuring compliance of Arterial Drainage Maintenance operations with the EU Habitats Regulations, 1997. In accordance with Section 31 of these regulations (refer 1.7.2), an appropriate assessment should be carried out. The operation, or activity, should only be undertaken when it is ascertained that it will not adversely affect the integrity of the site and then, to take on board conclusions from the assessment.

The purpose of this study is to determine the ecological impacts associated with OPW drainage maintenance operations that could have a detrimental impact on:

- Active raised bog (EU code 7110, priority habitat)
- Raised bog still capable of regeneration (EU code 7120)
- Depressions on peat substrates of *Rhynchosporion* (EU code 7150)
- Bog woodland (EU code 9110, priority habitat)

Having determined any such potential impacts, then mitigation measures are proposed so as to minimise same.

1.1.2 Assessment of maintenance operations only

It should be noted that this report only deals with the ecological impacts of maintenance operations, which serve to keep arterial drainage channels functioning to their design standard. It is not the purpose of this report to determine the ecological impacts of the actual drainage channels on the habitats concerned.

The national programme of Arterial Drainage Schemes commenced in 1948 and finished in 1995 (refer 1.3). Hence, some of these channels have been in place for over 50 years. They have been a determining factor in the fabric of the countryside for some time now. Survey (commenced 1992), and designation (commenced mid-1990s), of all Special Areas of Conservation (SACs - refer 1.7.1) has occurred with these channels in place. Accordingly, all SAC designations are related to conservation aspects present in a post Arterial Drainage Scheme environment, i.e. the

ecological status of relevant designated habitats was deemed to be of sufficient quality to warrant SAC status with arterial drains already in place.

The fact that the ecological status of some SACs could be improved by blocking some of these drains is not relevant. Firstly, the OPW is statutorily obligated to maintain these. Secondly, it is unrealistic to determine the ecological impacts of past activities on SACs - virtually every piece of land has the potential for enhanced ecological significance, if certain land management practices are discontinued and / or altered.

1.1.3 Environmental Impact Assessment / Ecological Assessment

The scope of an Environmental Impact Assessment (EIA) encompasses a detailed evaluation across a broad range of environmental aspects, from heritage through to air emissions. However, maintenance works do not involve any widening or deepening of the original water channel, but only re-establishes the water level / channel flow relationship to the original Arterial Drainage Scheme design. In acknowledgement that maintenance works are of such a small scale, as compared to developments described in the 1st Schedule of the 1989 - 2000 EIA Regulations (ref. 1.7.2), it is not foreseen that maintenance operations would require an EIA for specific works. In addition, The Natural Habitats Regulations specifically require an assessment of potential impacts on the site's conservation aspects. Hence, it is reasonable that a practicable approach would be to utilise a more focused type of assessment. This approach will have a narrower scope than the typical broad EIA approach and will study the specific relevant conservation aspects only.

Ecological Assessment (EcA) is the term used to describe this type of study. The objective of each study will be to assess the impact of Arterial Drainage Maintenance operations on that particular aspect, to identify mitigating measures if applicable, and ascertain practical enhancement opportunities, if relevant.

1.2 Legal and policy context for river drainage and flood relief

The Office of Public Works (OPW) is the body through which Central Government exercises its statutory responsibilities in respect of river drainage and flood relief. It derives its statutory authority in relation to arterial drainage and flood relief from the 1925 Arterial Drainage Act, 1945 Arterial Drainage Act and the Arterial Drainage Amendment Act, 1995. The National Flood Policy Review published in 2004 and adopted by the Government, has given the OPW the lead role in Flood Policy.

Maintenance works are carried out in fulfilment of the statutory requirement under the 1945 Arterial Drainage Act. This requires that:

- Scheme channels are maintained in "proper repair and effective condition", i.e. in a condition that protects benefiting land from an appropriate risk of flooding, and provides adequate outfall for land drainage (e.g. from agricultural lands, urban areas, bog developments, forestry and amenities).
- The maintenance of channels an coastal embankments in a condition that protects benefiting land from an appropriate risk of flooding.

- The maintenance, repair and/or replacement of all structures, including accommodation bridges, weirs, sluice barrages, sluices, pumping stations and tidal flap gates.

The Arterial Drainage Amendment Act, 1995 empowered the Commissioners to execute drainage schemes to alleviate localised flooding problems.

On completion of schemes, the Commissioners have a statutory responsibility for the maintenance of these schemes. Failure by the Minister to comply with the obligations of the 1945 Drainage Act, could lead to compensatory claims for damage to the benefiting lands.

1.3 Historical background

The Commissioners of Public Works was the body charged with responsibility for flood relief under the 1842 Arterial Drainage Act. Work consisted of preparing plans and carrying out flood relief schemes on localised areas of river catchments.

Between 1945 and 1995, the OPW completed 34 Arterial Drainage Schemes on river catchments, (together with 5 Estuarine Embankment Drainage schemes). The schemes carried out under the 1945 Act differed from previous schemes, in that they dealt with the total river catchment, rather than a localised piecemeal approach.

The 1945 Act was amended in 1995, in response to serious urban flooding problems. Since the 1995 Amendment Act, the OPW has embarked on a programme of urban flood alleviation schemes, which while not catchment based, regard has to be taken of the downstream effect.

1.4 Functions of statutory arterial drainage

Arterial Drainage Schemes normally included the widening and deepening of an existing channel, with some localised re-alignment, and in a few cases, the opening of a new channel. Typically, the water table would have dropped by c. 1 m, although this would vary depending on local conditions (e.g soil, geology etc.). Regular maintenance works are necessary, in fulfilment of the statutory requirement under the 1945 Drainage Act, to maintain the drainage works in "proper repair and effective condition".

The primary purpose of all these schemes is to provide agricultural land with flood alleviation and outfall for land drainage. Scheme designs altered the channels to provide flood capacity for a minimum of a three year flood event, in addition to creating an outfall for drainage of adjoining lands. In the case of modern urban flood relief schemes, flood protection for a 100 - 200 year flood event would be the design objective.

To date, over 260,000 hectares of land has benefited from the 1945 Arterial Drainage Act schemes. An independent report on the cost effectiveness of maintaining these drainage schemes was commissioned by the Dept. of Finance and carried out (Price,

et al., 1999). This report concluded that the current maintenance service offers a cost benefit ratio of 13:1. Hence, it is a highly cost effective service for the State.

1.5 Arterial Drainage Maintenance operations

Arterial Drainage Maintenance acts solely to retain the scheme design capacity. Following the arterial scheme works, the channel capacity will gradually reduce, as silt and vegetation levels increase over the intervening years. This necessitates maintenance to return the channel capacity to its design condition. This is an on-going process and ensures that the level of drainage provided to the riparian lands, and the flood protection originally provided, is retained. These maintenance works serve to retain the hydrological regime of the channel as that generated at scheme works stage. No excavations of virgin ground is necessary. A drop in water level may occur, but this would only be in the range of 50 - 300 mm, back to the original scheme design water datum.

1.6 Extent of maintenance operations

There are 34 completed schemes now maintained under statutory obligation. The OPW are responsible for the maintenance of 11,500 km of channel, 730 km of embankments, some 18,500 bridges and 750 ancillary structures such as sluice gates, tidal barrages and pumping stations. Annually, about 2000 km of channels are maintained, with circa 200 structures repaired / replaced.

Three OPW Drainage Maintenance Regions manage this programme of works i.e.

- West Region, Headford, Co. Galway.
- East Region, Trim Co. Meath.
- South-West Region, Mungret, Co. Limerick

Figure 1 shows the catchments maintained by the OPW.

Drainage maintenance operations are geographically spread across the country and encompass a range of habitats. Some of these habitats area protected under EU law and are termed Natura 2000 sites, including Special Areas of Conservation (SACs). As such, there is a need to take account of the environmental legislation relating to these legally protected areas of ecological interest.

1.7 Drainage operations and environmental legislation

1.7.1 Special Areas of Conservation (SACs)

European Sites, under the Habitats Directive, consist of both SAC and Special Protected Area (SPA) designations. SACs are to be managed in a manner that maintains a favourable ecological status for the relevant Annex I habitats and/or Annex II species. All European sites (Natura 2000 network) have a prescribed list of specific conservation aspects.

The SAC status gives legal protection under Irish and European law as determined by Article 6.1 of the EU Habitats Directive:

"Member States shall establish the necessary conservation measures involving, if need be, appropriate management plans specifically designed for the sites or integrated into other development plans, and appropriate statutory, administrative and contractual measures which correspond to the ecological requirements of the natural habitat types in Annex I and the species in Annex II present on the sites".

The Habitats Directive, was adopted in 1992 by the Council of the European Communities on the conservation of natural and semi-natural habitats and species of flora and fauna. The Directive seeks to establish "Natura 2000", a network of protected areas throughout the European Community. It is the responsibility of each member state to designate Special Areas of Conservation (SACs) to protect habitats and species, which, together with the Special Protection Areas (SPAs) designated under the 1979 Birds Directive, form Natura 2000.

In the Habitats Directive, there is a list of habitats requiring conservation measures. The list, which is called Annex I, includes priority habitats, which require particular attention. Priority Irish habitats include raised bogs, bog woodland and active blanket bogs. Other Annex I habitats include heaths, lakes and woodlands among others.

The Habitats Directive was transposed into national legislation by the European Union (Natural Habitats) Regulations, 1997. Under Irish law:

- The Minister must prepare lists of "Notifiable Actions" for different habitats, which should be sent to known landowners and users. Any actions in the lists can be carried out only with prior agreement of the Minister. Relevant "Notifiable Actions" are detailed in appendix 1. Relevant "Notifiable Actions" include:

- drainage works on the bog or within the local water catchment area,
- alteration of the banks, bed or flow of watercourses. (It should be noted that works under the 1945 Arterial Drainage Act are deemed to be *Government Functions* (Regulations; Section 31). Accordingly, drainage maintenance operations are exempt from complying with *Notifiable Actions*.)

- A person who illegally damages a site may be prosecuted or required to repair damage.

A number of SACs encompass raised bog (EU priority habitat) and associated habitats e.g. bog woodland, depressions on peat substrate of *Rhynchosporion* and, raised bog

still capable of regeneration. Sometimes, OPW arterial drainage channels intersect, or come in close proximity to, these habitats.

Figure 2 shows the geographical extent of drained catchments and SACs containing active raised bog and associated habitats. Appendix 2 gives a list of SACs containing raised bog and associated habitats, which have intersecting OPW arterial drainage channels.

1.7.2 Environmental Impact Assessment (EIA)

Two components of legislation are relevant to the concept of Environmental Impact Assessments (EIA) for Drainage works. Firstly, the primary national legislation Environmental Impact Regulations 1989 - 2000 stipulates the classes of development that would require an EIA. The second component of relevant legislation is the Natural Habitats Regulations, 1997. Section 31 stipulates that where an operation or activity is likely to have a significant effect on a European Site (i.e. an SAC or SPA), than an assessment should be carried out on the implications for that site in view of the site's conservation objectives. An EIA is deemed to be an appropriate form of assessment for the purposes of these regulations. However, a more focussed approach termed an Ecological Assessment, is deemed more appropriate for this study (ref. 1.1.3).

1.7.3 National Parks and Wildlife Service

The National Parks and Wildlife Service (NPWS), Department of the Environment, Heritage and Local Government, is responsible for the implementation of the various legislation in respect of ecologically protected areas. In addition they also implement the Wildlife Acts 1976 / 2000 which serve to protect Ireland's flora and fauna.

2. RAISED BOGS AND ASSOCIATED HABITATS

2.1 Introduction

Once large parts of Europe were covered with peat. In past centuries, most of these peatlands have been drained and used as a source of fuel, and/or reclaimed for agriculture and forestry. Ireland still has 50% of the remaining area of uncut raised bogs in north-western Europe (excluding Scandinavia), despite the fact that 94% already has been exploited for fuel and garden peat production. In Ireland, Cross (1990) estimated that 23,000 ha, or 7.4% of the original area of raised bog, remained with an intact surface, with only 3.8% of the high scientific interest. This figure, in all likelihood, can be reduced further for present day statistics.

Raised bogs in north-western Europe are primarily (but not exclusively) lowland peatlands, which can occupy the bottoms of broad, flat valleys, the heads of estuaries or shallow basins. The peat may be over 10 m deep. Their development requires a sufficiently high rate of precipitation input (800 – 1000 mm per year in the Irish Midlands), not restricted to a single season, i.e. divided reasonably evenly over the year. These conditions are required to permit peat to accumulate above the level of the mineral ground or the influence of telluric water (Van der Schaaf, 2002).

2.2 Classification and extent

Ireland's raised bogs are classified as oceanic raised bogs or ridge-raised bogs (Moore and Bellamy, 1974). This bog type has a very restricted distribution on the Atlantic fringe of north-west Europe, and given the destruction which has occurred in other countries, Ireland is now probably the world headquarters for the type.

Irish raised bogs occur mostly in the midland counties of east Galway, Kildare, Laois, Longford, east Mayo, Offaly, Roscommon, Tipperary and Westmeath and in the Bann, Valley in Northern Ireland. They can be classified into two types: Western raised bogs and True Midland raised bogs, with the boundary between the two being taken as the 1,000 isohyet. Figure 3 shows the major distribution of raised bogs in Ireland.

The type division for raised bogs is based on a combination of floristic and morphological characteristics. The Western raised bogs are typified by the presence of the moss *Campylopus atrovirens* and the liverwort *Pleurozia purpurea*, a greater abundance of Carnation Sedge (*Carex panicea*), and a greater tendency to extend beyond the confines of their original basin (Hammond, 1979; Schouten, 1984). However, in effect, there is a continuum across the country from the relatively dry east to the hyperoceanic west.

2.3 Development of raised bogs

Raised bogs are dome shaped masses of peat occupying former lakes or shallow depressions. Peat is composed of the compacted remains of undecomposed, dead plant material. It will occur in waterlogged conditions where, due to a lack of oxygen, decomposition of plant material cannot occur.

At the end of the last glaciation, some 10,000 years ago, glaciers in Ireland retreated northwards and the permafrost disappeared. In central Ireland, ridges up to about 100 m wide and 20 m high in a west-east direction were formed, commonly known as eskers. On top of the limestone bedrock, ground moraine (till) was formed. Between the eskers and till mounds, lakes and lake systems formed. Surface sediments were easily washed into the lake basins. These sediments, with a low hydraulic conductivity, contained clay with fine sand and pebbles, know as glacio-lacustrine clay. In some areas, lake marl was deposited on top of the clay. Lake marl is a deposit with a high content of calcium carbonate (Schouten, 2002).

Some 8,000 years ago, peat started to develop in depressions occupied by small lakes, in which anaerobic (i.e. oxygen starved) conditions occurred. Initially, the lakes became completely filled with peat, and the open water was replaced by species-rich plant communities, washed by nutrient-rich groundwater. This is known as a fen. Fen peat is mainly composed of layers of reed, various sedge species and (birch or alder) trees (eutrophic species). As the lakes were overgrown in time, the influence of nutrient-rich water gradually declined and a mesotrophic environment (transitional stage) developed. As a result, plants which were able to grow in a mineral poor habitat, invaded. In time, the plants became solely dependent on the nutrient-poor precipitation i.e. rain water (ombrotrophic stage), and plants typical of raised bogs, such as *Sphagnum* moss and heather developed on the bog. If the climate is wet enough, these species will expand across the fen surface, and a spongy peat develops, above the influence of the ground water. As this occurs, species which can survive in poor, acidic conditions dominate, thus commencing the development of a raised bog. Some 7,000 years ago, the climate in Ireland became suitable for peat growth (Cross, 1989).

By their nature, raised bogs form as a peat deposit above the regional groundwater level in their immediate surroundings, underlying fen peat and mineral deposits. In their most distinctive development, raised bogs form shallow domes of ombrogenous peat, delimited by mineral ground, fen or water courses (Wheeler and Shaw, 1995). Accumulation is greatest in the centre and least around the margins, where decay is somewhat faster, leading to a dome shaped mass of peat, or a raised bog. This process occurs over 100s or even 1000s of years. This process is shown in figure 4.

2.4 Profile of peat

Raised bogs may be as much as 15 m deep, and have well defined strata of different peat types, overlying the mineral soils, which consist of sands, loams, clays and marl (Carey and Hammond, 1970). The peat becomes more humified, darker and denser with depth, while the surface peats of actively growing bog are light in colour, fibrous and permeable. Remains of trees are found at the interface between fen peat and bog

peat, representing a relatively brief period of fen woodland, and an additional layer of tree remains is often encountered within the bog peat itself, representing relatively warmer climatic periods, when the bog surface dried out (McNally and Doyle, 1984).

2.5 Flora of raised bogs

A typical raised bog is characterised by the dominance of several species of *Sphagna* and dwarf ericoid shrubs. There may be as many as a dozen different species of *Sphagna*, although usually only 4 or 5 are common. Some form hummocks, which may be up to 1 m high, capped by heathers and different mosses. Other mosses are found in hollows and pools, which occur between the hummocks.

Ling Heather (*Calluna vulgaris*), Cross-leaved Heath (*Erica tetralix*) and Deer-grass (*Scirpus caespitosus*) are abundant, while Bog Rosemary (*Andromeda polifolia*) and Round-leaved Sundew (*Drosera rotundifolia*) also occur with a high constancy, but low cover value. If the bog has been unburnt for some time *Cladonia* lichen (e.g. *C. ciliata, C. portentosa*) will also co-dominate. On flats, Bog Asphodel (*Narthecium ossifragum*) is abundant, sometimes with Cranberry (*Vaccinium oxycoccus*) creeping through the *Sphagnum* moss carpets, if there is slight flushing (i.e. nutrient input). In permanently water-logged hollows, White-beaked Sedge (*Rhynchospora alba*), Great Sundew (*Drosera anglica*) and Common Cottongrass (*Eriophorum angustifolium*) are evident, while Bogbean (*Menyanthes trifoliata*) occurs in pools. Areas of nutrient enrichment occur on most bogs. Where these are well developed, they are known as soaks or flushes. They are typified by the occurrence of fen vegetation, often with stands of Birch. Drainage is much better on the steep margins of raised bogs, which are rather dry and largely covered in Ling Heather. Most bog margins have been cut for peat, causing the peat to dry out and shrink.

2.6 Fauna of raised bogs

Raised bogs are extremely nutrient-poor, acidic, wet, exposed and with fluctuating water levels. Consequently, they are relatively poor in terms of faunal species diversity and population densities. Frog (*Rana temporaria*) is probably the only permanent inhabitant, since birds and the Irish Hare (*Lepus timidus hibernicus*) are able to feed elsewhere. Otter (*Lutra lutra*) frequent pools.

The most obvious vertebrates are birds, with species such as Skylark (*Alauda arvensis*), Meadow Pipit (*Anthus pratensis*), Curlew (*Numenius arquata*), Irish Red Grouse (*Lagopus lagopus hibernicus*) and Snipe (*Gallinago gallinago*) being frequently present. Merlin (*Falco columbarius*) hunt over bogs. A particularly important species is the Greenland White-fronted Goose (*Anser albifrons flavirostris*), which traditionally fed and roosted on callows and bogs during the winter months.

Invertebrates are, by far, the most abundant animals on bogs and certain groups are well represented (e.g. Collembola, Lepidoptera and Spiders). As with vertebrates, few species are exclusive to bogs, with the Small Copper Butterfly (*Lycaena phlaeus*), Large Heath Butterfly (*Coenonympha tullia*) and Large Marsh Grasshopper (*Stethophyma grossum*) being exceptions.

2.7 Characteristics of raised bogs

2.7.1 Introduction

The most important producers of organic matter in a raised bog are *Sphagnum* species. The *Sphagnum* species help to create the characteristically low pH environment of bogs and they can store a large volume of water (Wheeler and Shaw, 1995). The wet conditions of bogs are caused by accumulation of precipitation. Therefore, the chemical composition of the bog water is nutrient poor, and is influenced by processes within the peat (Wheeler and Shaw, 1995).

2.7.2 Hummocks and hollows (microtopography)

Healthy bogs show a microtopographical structure, in which *hummocks* and *hollows* can be recognised. *Sphagnum* moss is the principal species found therein. The *Sphagnum* species that form the hollows differ from those forming the hummocks (Kelly and Schouten, 2002). The surface of a raised bog is typically waterlogged, and the highest part of the bog is often the wettest, and shows the most developed pattern in hollows and hummocks.

The shallow depressions in the bog surface where water collects, or where the water table reaches ground level or lies above ground level (depending on the seasonal fluctuations), are called hollows. Marginal hollows tend to be elongated, as they are focus points for surface water run-off. They are often dominated by Bog Asphodel (Gore, 1983).

Hummocks are mounds on the bog surface that can range from a few centimetres to more than a metre in height. They are usually composed mainly of *Sphagnum* moss, such as *S. magellanicum, S. capillifolium S. imbricatum* and *S. fuscum*, but other bryophyte species such as *Hypnum jutlandicum* and *Leucobryum glaucum* are also important, especially as the hummock grows taller and becomes drier (Gore, 1983). Ling Heather is another important element, as it flourishes where the water table in not at surface level.

2.7.3 Pools (Gore, 1983).

Pools are depressions in the bogs surface, where the water table remains above the surface level all year round, or below surface levels for only very short periods of time. They are characterised by the presence of aquatic plant species such as the mosses *Sphagnum cuspidatum* and *Cladopodiella fluitans*.

2.7.4 Lawns and flats (Gore, 1983).

Lawns are shallow hollows or flat areas, where one species dominates to form a lawn. This is frequently a *Sphagnum* moss, such as *S. magellanicum*, which can completely fill a hollow to form a small lawn. Flats are more or less flat areas which are intermediate between hollow and hummock communities. They tend to be drier than lawns.

2.7.5 Soaks and flushes

On larger bogs (> 260 ha), internal drainage systems may develop, perhaps as a response to differential growth of the bog, resulting in formation of depressions or valleys. Surface water becomes concentrated here, initially as diffuse flushes or pools, which then develop down the slope into definite streams. The increased flow probably elevates both oxygen and nutrient flux, leading to the formation of linear poor-fen communities. They may also be a response to artesian water upwelling through the peat, bringing nutrients from the underlying mineral substrate. Gore (1983), defined a soak as a strip of fen with seepage of moving water, crossing bogs, or separating bog areas from each other. For the Irish context, soaks have been described as areas of mesotrophic or minerotrophic vegetation, occurring on otherwise ombrotrophic bogs, and are usually associated with internal drainage However, as a result of peat exploitation, almost all Irish soak systems have been lost (Schouten *et al*., 2002). Today, only three raised bogs with large open water soak systems remain, namely Clara Bog (Co. Offaly), Addergoole Bog (Co. Galway) and Shanville Bog (Co. Roscommon) (Cross, 1990).

2.7.6 Lagg zone

The lagg is the marginal drainage channel which circumscribes the bog and receives water draining off the bog. It also receives water from the adjacent mineral soil, and hence is richer in nutrients, thus enabling fen vegetation to persist. Because of drainage and peat cutting, there is little remaining of lagg zones on Irish raised bogs, although vestiges are present on Redwood Bog, Co. Tipperary.

2.7.7 Underground streams / lakes

On some bogs underground streams occur. There may be little surface indication of their existence, although their course may be traced by the presence of Purple Moorgrass.

Lakes are associated with some bogs. Usually they form part of the bog margin, and are separated from the bog by a narrow band of fen.

2.7.8 Summary of raised bog characteristics

Some of the characteristics typical of raised bogs are summarised below.

Soil pH	3.5 (acid)
Annual rainfall	800 - 1,200 mm
Peat depth	Up to 15 m
Common plants	*Sphagnum* mosses, Bog Cottons, Ling Heather, Cross-leaved Heath, Bog Rosemary, Cranberry, Bog Asphodel, Beak Sedge, Deergrass, Sundew, *Cladonia* lichens
Common animals	Cranefly, Damselfly, Dragonfly, Emperor Moth, Black Slug, Pond Skater Common Frog, Irish Hare.
Common Birds	Red Grouse, Curlew, Snipe, Meadow Pipit, Skylark, Kestrel, Hooded Crow
Rare and protected plants	Bog Orchid
Protected Birds	Greenland White-fronted Goose

2.8 Associated habitats

There are other EU Annex I (Habitats Directive) habitats associated with raised bogs. They are generally inextricably linked with the ecology and hydrology of the bog. As such, any assessment of raised bogs can be applied to these habitats also.

2.8.1 Degraded raised bog still capable of natural regeneration (codes 7120; 51.2)

Romao (1996) describes degraded raised bogs thus: These are raised bogs where there has been disruption to the natural hydrology of the peat body. This leads to surface desiccation and / or species change or loss. Vegetation on these sites usually contains species typical of active raised bog as the main component, but the relative abundance of individual species is different. Sites judged to be still capable of natural regeneration will include those areas where the hydrology can be repaired and where, with appropriate rehabilitation management, there is a reasonably expectation of re-establishing vegetation with peat-forming capability within 30 years. Sites unlikely to qualify as SACs are those that consist largely of bare peat, that area dominated by agricultural grasses or other crops, or where components of bog vegetation have been eradicated by closed canopy woodland.

2.8.2 *Rhynchosporion* depressions on peat substrates (codes 7150; 54.6)

Romao (1996) describes *Rhynchosporion* depressions thus: These are highly constant pioneer communities of humid exposed peat, or sometimes sand, with White Beak-sedge (*Rhynchospora alba*), Brown Beak-sedge (*R. fusca*), Sundew (*Drosera intermedia, D. rotundifolia*) and Marsh Clubmoss (*Lycopodiella inundata*). This vegetation can form on stripped areas of raised bogs or blanket bogs, but also can occur naturally on seep- or frost-eroded areas of wet heaths and bogs, in flushes and in the fluctuation zone of nutrient-poor pools with sandy, slightly peaty substratum.

These communities are similar, and closely related to those of shallow bog hollows (code 51.122) and of transition mires (code 54.57).

2.8.3 **Bog woodland** (codes 91D0; 44A1 - 44A4)

Romao describes bog woodland thus: Coniferous and broad-leaved forests on a humid to wet peaty substrate, with the water level permanently high and even higher than the surrounding water table. The water is always very poor in nutrients (raised bogs and acid fens). These communities are generally dominated by Downy Birch, Alder Buckthorn (*Frangula alnus*) and Scots Pine, with species specific to bogland or, more generally to nutrient-poor environments, such as *Vaccinium* spp., *Sphagnum* spp. and *Carex* spp.

2.9 Hydrology

2.9.1 Introduction

According to Ivanov (1981), the volume of water in undisturbed peat varies in the range 88 - 97%. Apart from a negligible content of mineral material, the rest is organic matter, being the remains of vegetation, accumulated in the course of time. Raised bogs have groundwater levels above those of their close surroundings. This makes them solely dependent on precipitation for their water supply. Although bogs are areas that do not receive groundwater, but lose it to their surroundings, they are wet environments, in the sense that groundwater levels are normally close to the surface.

The hydrology of bogs is extremely complex, but it is fundamental to, their ecology, an understanding of the impact of developments, and site management. The process of raised bog formation has already been described, in which a dome-shaped body rises above the influence of ground water, which is then dependent solely on atmospheric precipitation. Once formed, the bog is to some extent self-perpetuating, because as it continues to expand horizontally and vertically, it causes deterioration of the drainage in the surrounding land. An idealised raised bog will form a dome, from which water drains radially into the marginal lagg. However, such symmetry is rarely encountered (although Raheenmore Bog, Co. Offaly closely approaches it), because the original basins were either irregular in outline, or subsequent development has distorted the original shape.

The most important characteristics typical of raised bogs that distinguish them in a hydrological sense from mineral soils are (Van der Schaaf, 2002):
- A relatively large storage coefficient caused by, the high porosity and high proportion of large pores in young *Sphagnum* material in the surface layer; and the unevenness of the bog surface, together with the frequent presence of groundwater at, or near, the surface
- The discharge regulating properties of the surface laye,r caused by the strong decrease of hydraulic conductivity with depth. This causes the outflow to increase rapidly with a rising water table when the water can flow through the highly permeable upper layer, but in times of lowering of the water table, the opposite occurs.

- Vertical oscillation of the surface, related to wet and dry seasons (usually only a few cm), as a result of the flexible peat matrix and water table fluctuation. The lowest levels occur at the end of the summer and the highest level at the end of the winter.

2.9.2 The concept of diplotelmy

As peat accumulates, the lower layers become completely anaerobic and waterlogged, and only the very thin surface layers receive oxygen. Hydrologically, raised bogs can be considered as two-layered (diplotelmic) systems, comprising an uppermost layer or acrotelm, and a catotelm which comprises the entire peat body below the acrotelm (Ivanov, 1981; Ingram, 1983). The acrotelm is the thin top layer of the bog peat, and the catotelm usually comprises the bulk of the peat in a raised bog (Van der Schaaf, 1999). The catotelm is the body of colloidal, compressed peat that remains permanently waterlogged and gives the bog its overall shape. The acrotelm, which overlies this and protects the catotelm, is shallow, and includes the surface of live vegetation, in which most of the biological activity occurs. It comprises the fluctuating water table, and is the functional horizon for plant growth. The acrotelm is composed of living vegetation cover at the top, with underlying recently produced dead plant material and fresh peat. It is usually thin (< 50 cm), because the peat gradually decays and eventually gets incorporated into the catotelm.

The characteristics of these two layers are important with respect to bog hydrology and are given in table 2.

2.9.3 Hydrological regulation

The hydrology of the bog is to a major extent determined by the properties of the upper peat layer (acrotelm). The acrotelm can be regarded as an integrated combination of plants (especially *Sphagnum* species), peat and water. Plant growth contributes to the formation of a microtopographical structure, which has a capacity for regulating water movement and discharge, and which helps to maintain the growth of, and survival conditions for, the plants (Wheeler and Shaw, 1995; Van der Schaaf, 2002). As such, the acrotelm has a high hydraulic conductivity near the surface, but becomes less permeable with depth, as the peat becomes more consolidated and decomposed or humified, (resulting in a decrease of the average pore size). An intact acrotelm shows a gradient of decreasing hydraulic conductivity with increasing depth, with the deeper peat layers (catotelm) having a low hydraulic conductivity. Thus, the acrotelm is not only the aquifer of a raised bog, but also the layer, which largely regulates the bog's hydrological system.

One of the important features of an intact acrotelm is its regulating function in the lateral discharge from the bog. Water balance studies show that vertical seepage accounts for only a very small part of the liquid discharge from the bog; most of the excess precipitation is discharged laterally over and through the acrotelm layer. As a result, lateral discharge is large in periods of high precipitation, but in drier periods, when the water table starts to drop, it decreases rapidly. In this way, high and relatively constant water tables are maintained, on which the typical plant communities of bogs depend.

The catotelm usually comprises the bulk of the peat in a raised bog. It is built up of former acrotelm peat. The catotelm peat is to some extent consolidated and moderately to strongly humified. It has a much lower hydraulic conductivity than the acrotelm and correspondingly slower rates of water movement within it. In case of an undamaged bog, the catotelm is the water-saturated anaerobic base to the acrotelm (Wheeler and Shaw, 1995) and the aquitard underlying the acrotelm aquifer.

Table 2: Characteristics of catotelm and acrotelm of raised bogs (Lindsay et al, 1988)

Catotelm	Acrotelm
A constant or little changing water content	An intensive exchange of moisture with the atmosphere and the surrounding area
A very slow exchange of water with the subjacent mineral strata and the area surrounding it	Frequent fluctuations in the level of the water table and a changing content of moisture
Very low hydraulic conductivity in comparison with the acrotelm (a difference of 3 - 5 orders of magnitude)	High hydraulic conductivity and water yield and a rapid decline of these with depth.
Waterlogged conditions imply no oxygen present.	Periodic access of air to interstitial spaces during period of lowered water table.
No aerobic microorganisms and a reduced quantity of other kinds in comparison with the acrotelm.	A relatively large quantity of anaerobic bacteria and microorganisms, facilitating the rapid decomposition and transformation into peat of each year's dying vegetation.
No living plants	The presence of a living plant cover, which constitutes the top layer of the acrotelm, and which binds the whole surface together into a 'skin', preventing the water-saturated catotelm from starting to flow, even after heavy rains.

2.9.4 Acrotelm capacity

Research shows that the transmissivity and depth of the acrotelm at a given location in the bog are connected to the local surface slope, the flow pattern and the length of the flow path leading to that location (Schouten, 2002). On this basis the concept of acrotelm capacity was introduced, which is the acrotelm transmissivity per specific discharge. A distinction was made between the actual and the potential acrotelm capacity. The potential acrotelm capacity is calculated from local surface slope, flow pattern and flow path length. In an undisturbed situation, the potential and actual acrotelm capacity are assumed to be equal, In disturbed situations, the actual acrotelm capacity is smaller than the potential value.

2.10 Surface subsidence after drainage

Undisturbed raised bogs usually have a domed surface. Because of its high content of water and flexible matrix, peat shrinks when it loses water. The result of shrinkage is subsidence of the bog surface. Usually loss of water is caused by drainage. Shallow drains may have apparantly little effect, but deeper drains (c. 1m) have a more severe effect (Uhden, 1960). Peat cutting along a bog margin, often associated with drainage, causes a local lowering of the groundwater table and thus an increased drainage of the remaining peat along the newly formed margin (the face bank).

Subsidence is largest at the newly formed margin. Initially, the slope of the bog surface begins to increase in a narrow zone along the margin. In a bog, an increased surface slope means an increased hydraulic gradient, and this results in a quicker discharge of water from the bog and consequently, an intensified drainage of more inward parts of the bog, which in turn begin the subside, and so on. In this way, the man-induced subsidence caused by turf cutting, and associated drainage, gradually expands into the bog. More rapid and extensive drying out is caused by drainage of underlying permeable soils under the bog. This causes water to be lost from the base of the bog, which can cause very rapid subsidence (ten Heggeler *et al*, 2004). This has happened at Clara bog between 1990 - 2002.

2.11 Ecotopes

Plant communities appear to occur in regular configurations representing community complexes. Hydrological differences are of primary importance between community complexes. The classic hummock-hollow system is an example of such a complex. Community complexes can be grouped on a higher level into ecotopes: that is areas covered with closely related community complexes and showing a relative uniformity in (abiotic) habitat conditions, such as water table fluctuations and certain hydrological characteristics. The main ecotopes identified have been called Central, Sub-central, Sub-marginal, Marginal and Face-bank. They basically represent concentric zones from the bog centre to the bog margin. This distinction between main bog ecotypes is applicable to most of the Irish raised bog systems today (Kelly *et al*, 1995: Derwin and MacGowan, 2000). The presence and extent of each of the different ecotopes appears to be strongly related to the degree of human impact.

Apart from the main bog ecotopes, a number of soak and lagg ecotopes have also been identified.

The Central Ecotope is thought to be the most closely related to the original vegetation of the bog expanse. The work by Kelly *et al*, (1995) showed that it has become the rarest of the characteristic bog ecotopes in the remaining raised bogs in Ireland. The presence of a Central Ecotope usually means that the full range of bog plant communities is contained within the site. Where the Central Ecotope is represented, the Sub-central Ecotope occurs in most cases in association with it. This resulting high diversity of plant communities also ensures a good representation of plant and animal species characteristic of a bog system. Furthermore, the presence and extent of the Central Ecotope also indicates that the site's acrotelm functions are still intact to a considerable degree, as research showed that this ecotope has the largest acrotelm depths (Schouten, 2002). Sub-marginal and Marginal Ecotopes are present in almost all remaining Irish bog sites.

The presence of a well developed Central Ecotope can be considered the primary criterion by which to judge the condition of a site. The assessment of the hydrological condition of a site can be based on the relative proportions of the Central plus Sub-central Ecotopes to the other bog ecotopes, or to put it in another way, the proportion of active to moribund acrotelm on the site.

2.12 Research and restoration

In the last decades of the 20th century, awareness grew that conservation and restoration of bogs was important from several points of view, such as uniqueness, preservation of biodiversity, the global carbon cycle, national heritage, etc.
The research work on bog ecosystems in Ireland has concentrated on two raised bogs in the Irish Midlands, Clara Bog and Raheenmore Bog (positions shown in Figure 5). Clara Bog, bisected into a western and eastern part by a road, was chosen for its valuable soak systems, for example Shanley's Lough on the western half and Lough Roe on the eastern half. Raheenmore Bog, a typical Irish Midland dome-shaped bog, suffered from marginal turf cutting and damage from drainage; however, it was deemed to be only moderately disturbed.

Research has indicated that between 1990–2002, Clara Bog West has subsided due to drainage of underlying mineral soil (ten Heggeler *et al*, 2004). In contrast, restoration measures (the blocking of surface drains) on Raheenmore Bog and Clara Bog East, have resulted in a positive development of the acrotelm.. This is documented in more detail later under Chapter 4 (Ecological Impacts of Drainage Maintenance).

2.13 Special Areas of Conservation (SACs)

The status of SACs have already been discussed (1.7.1). The best and most representative examples of Ireland's raised bogs and associated habitats have been designated as SACs. Virtually all of the raised bog SACs have a conservation plan of some format completed. These sites would also have a site synopsis detailing, in summary, the importance of the SAC. There is also a map of the site showing exact boundaries for the area of conservation interest. These are all available from the

National Parks and Wildlife Service, Dublin. Also, many of the raised bogs have more detailed reports (Kelly *et al*., 1995). Site synopses for raised bogs relevant to this study are given in appendix 3.

Monitoring of raised bogs has recently commenced. These studies will aid in determining the on-going ecological quality of the bog i.e. whether the ecological quality is improving, remaining the same or, disimproving. The first set of reports on this have just been completed (Valverde *et al*., 2005). These indicate that an overall, significant deterioration is occurring, with approximately 20 - 30% of the active raised bog being lost from the samples of bogs examined.

3. DESCRIPTION OF ARTERIAL DRAINAGE MAINTENANCE OPERATIONS CARRIED OUT BY THE OPW

The majority of the information supplied in this chapter has been sourced from the OPW's Screening Report (Gilligan, 2005).

3.1 Original arterial drainage scheme works

Construction of the original Arterial Drainage Schemes required major hard engineering. Typically, it involved widening and deepening the existing channel, with some localised re-alignment, and in a few cases, the opening of a new channel reach. Using Draglines, work entailed excavation of all soil types such as peat, clays and gravel, while rock was normally blasted. The channel cross section was excavated to a trapezoidal form, channel width was standardised, longitudinal gradients were made more uniform, and cross sectional beds were made even. All in-stream and riparian vegetation and soils were removed, and access for construction plant was made along the channel banks. In schemes prior to c. 1973, excavated material was stockpiled in spoil heaps setback parallel to the channel. Post 1973, the spoil was levelled out on riparian lands, with damaged lands topsoiled and reseeded.

Scheme designs altered the channels to provide flood capacity for a minimum of the 3 year flood and to provide an outfall for drainage of adjoining lands. In many cases, the creation of an outfall dictated the design bed levels.

3.2 Hydrological change due to arterial drainage schemes

Typically, the riparian water table would have been dropped by circa 1 metre. However, this value would vary widely depending on a number of characteristics such as soils, geology, topography, catchment hydrology and critical design factors. Arterially drained channels differ from more natural channels, in that the waterway has significantly more uniform flow velocities, more constant depth/width ratios, a reduction in connectivity to floodplains, and more in-stream storage capacity.

3.3 Maintenance works

3.3.1 General

Following the scheme works, the channel capacity will gradually reduce over time, as both silt and vegetation levels increase and other obstructions develop. This necessitates maintenance, so as to return the channel capacity to its original design condition. The purpose of Arterial Drainage Maintenance is simply to retain the scheme channels design capacity to convey water in an effective manner. The OPW maintain arterial drainage channels on a regular basis (c. every 5 years). This is necessary, so as to return the channel capacities to their original design conditions, in fulfilment of the statutory maintenance obligation under the 1945 Drainage Act (and 1995 Amendment Act).

Channel maintenance is achieved by the removal of excessive silt and vegetation, repairing bank damage or slippage, and the removal of obstructions such as fallen or encroaching trees. Otherwise, poor drainage and water logging of riparian land will ensue. Effective maintenance returns the channel to its design capacity, with, in most cases, no alterations to the bank or bed, except where severe erosion has occurred. The bed of the channel is not deepened below original design level. Often, there is no necessity to impinge on the channel bed. Excavation of virgin ground is not required, and generally the majority of the riparian vegetation is left intact.

Some channels are steep and fast flowing, which are subject to flash floods, bank erosion and rapid movement of bed gravel. However, 60 - 70% of OPW scheme channels are of very gentle longitudinal gradient, with rapid deposition of silt, especially those which are subject to prolific growth of in-stream vegetation. The steeper sections of channel normally require relatively little maintenance work. The majority of maintenance works are on smaller, lower lying channels, with 90% of works in channels with a base width of less than 3 metres. The average channel requires maintenance every 4 - 6 years. Channels with prolific weed growth require maintenance annually, particularly where downstream urban bridges are at risk of being blocked, due to a flow of decaying vegetation, in Autumn. Conversely, some channels may only require maintenance every 20 years, due to the self cleaning characteristics of the channel.

3.3.2 Particulars of maintenance works

Channel maintenance operations normally involves removing the build-up of foreign or natural material that impedes the free flow of water. Predominantly, this consists of the removal of water-entrained silt and associated vegetation from the bed of the channel, by suitably rigged hydraulic excavators. Restrictions in channels, due to bank slippage or damage, would be re-graded to the original profile. Channel breaches, caused by bank erosion, would be resolved by re-profiling the bank in-situ, or, in some cases, by importing protection material, such as rock armour or log poles. In addition, other larger vegetation such as trees, which impinge on channel capacity, are either removed in whole, or by selective removal of lower branches. This may also occur for the purposes of machines access to the channel for maintenance purposes.

The material removed in the maintenance operations is normally spread along the bank, or on top of existing spoil heaps, where present. In most cases, no alterations to the bank are required, and in some cases, the channel is not disturbed at all, if there is no build-up of material.

Maintenance works are executed by OPW direct labour staff, using a fleet of approximately 70 hydraulic excavators nation-wide. 17% of the excavator fleet consist of long reach machines, which normally work on channels in excess of 4 metre base width, or have high banks. Works on the majority of channels are carried out using standard reach 15 ton hydraulic excavators. Plant are designed for the appropriate site conditions. Hence, low ground pressure excavators are employed on soft ground, with standard ground pressure excavators utilised on more firm land. In addition, for works on very weak ground, a system of timber mats is used, to reduce the excavator’s ground pressure even further.

Other operations include weedcutting. A number of channels have an annual prolific growth of aquatic plants, but are too wide, or the bank conditions too unstable, to allow maintenance by way of excavators, even those designed for low ground pressure and long reach. Weed cutting boats are engaged in these cases, or where a particular channel requires to be cleared of aquatic vegetation growth, but it is not deemed necessary to remove silt or other heavy material. In all, approximately 90 km of channel are cleaned annually by four weed cutting boats, operating on a seasonal basis, with the majority of the works concentrated in the West of Ireland.

A new from of weed cutting excavator bucket has recently been introduced into maintenance operations. This equipment allows the excavator to remove in-stream vegetation without disturbance to the channel bed. This is proving very useful, particularly where spawning channels suffer from prolific weed growth.

3.3.3 Particulars of works other than channel maintenance

Embankments are also maintained by the OPW. Nearly all embankment schemes are tidal in nature. The frequency of maintenance for embankments tends to be less uniform than that for channels. Embankments are scheduled for works when it is deemed that the structure is in need of repair to maintain an effective condition. Repair works normally takes a form of structural strengthening, by importing soil / rock or utilising in-situ material. The latter normally entails the excavation of estuarine silt or soil, generally taken from the front berm, and placing and shaping this on the existing embankment, thus restoring the embankment to its original Design Level. In this regard, strips of land parallel to the existing embankment, normally within 20 - 30 m riverside of the embankment are excavated for maintenance work. In other cases, structural strengthening is achieved by importing rock / soil material.

Included within the 18,500 bridges maintained are structures ranging from concrete pipe culverts, timber bog access ramparts through to concrete or masonry abutments, either with a similar decking material, or steel girders with concrete or timber decking. Maintenance works repairs approximately seventy structures per annum, which is restricted to the most critical ones. Repair works are normally carried out with a similar material as that of the structure in question, with the exception of the wooden structures, that tend to be substantially deteriorated and are replaced by concrete structures.

Ancillary structures such as sluice gates, tidal barrages and pumping stations are repaired or replaced as necessary, to maintain their respective operating function.

3.4 CASE STUDIES

3.4.1 Addergoole Bog, Lough Corrib (SAC code 297)

This site was visited on the 26th July, 2005 (with Nathy Gilligan and Charlie O' Sullivan of the OPW). Drains F604, F604/1 & C4/2 will be maintained this year.

Drains F604 & F604/1 occur within old cutover bog, now being invaded by scrub. The following flora occurs within the drains - Yellow Water Lily (*Nuphar lutea*), Common Reed (*Phragmites australis*) and Pondweed (*Potamogeton* sp. - occasional). On the banks, Common Valerian (*Valeriana officinalis*), Knapeed (*Centaurea nigra*), Meadowsweet (*Filipendula ulmaria*), Purple Loosestrife (*Lythrum salicaria*), Bog Myrtle (*Myrica gale*) and occasional Hawthorn (*Crataegus monogyna*) occur.

Some segments only require the removal of in-stream vegetation. In these instances, a weedcutting bucket will be used, thus minimising disturbance of the channel bed. The normal excavator bucket for the removal of silt material will be used on the remaining reaches. Figure 6 shows the SAC and drains in question.

3.4.2 Moanveanlagh Bog, Co. Kerry (SAC 2351)

This site was visited 18/8/05 with Mark Noonan (OPW staff member). The relevant OPW drain is C1/18/17. Tracks run to the drain and there is a grassy track running adjacent to the drain, between it and the cutover bog.

Vegetation present within channel includes Himalayan Balsam (*Impatiens glandulifera*), Hogweed (*Heracleum sphondylium*) and Bur-reed (*Sparganium* sp.). On the channel banks and adjacent land, Bracken (*Pteridium aquilinum*), Nettle (*Urtica dioica*), Bindweed (*Convolvulus arvensis*), Bramble (*Rubus fruticosus*), Bittersweet (*Solanum dulcamara*), Cleavers (*Galium aparine*), Wild Angelica (*Angelica sylvestris*), Clover (*Trifolium* sp.), Ragwort (*Senecio* sp.), Hogweed, Common Cat's-ear (*Hypochoeris radicata*), Meadowsweet (*Filipendula ulmaria*), Willow (*Salix aurita, S. viminalis*), Hawthorn (*Crataegus monogyna* - occasional), Thistle (*Cirsium arvensis*), Purple Loosestrife (*Lythrum salicaria*), Willowherb (*Epilobium* sp.), Goldenrod (*Solidago virgaurea*), Buttercup (*Ranunculus repens*), Yarrow (*Achillea millefolia*), Knapweed (*Centaurea nigra*) and Silverweed (*Potentilla anserina*) were recorded.

The high bog itself is soft underfoot, well vegetated and good *Sphagnum* cover. Hummocks are present and the dome is still reasonably intact. The vegetation present includes Ling Heather (*Calluna vulgaris*), Bog Cotton (*Eriophorum* spp.), Bog Myrtle (*Myrica gale*), Cross-leaved Heath (*Erica tetralix*), Carnation Sedge (*Carex panicea*), *Cladonia* (spp.) lichens, Deer-grass (*Scrirpus caespitosus*) and Bog Asphodel (*Narthecium ossifragum*). Between drain and high bog, there is 100 - 200 m of cutover bog.

Figure 7 and photographs 1 - 4 show this SAC and the relevant OPW drains.

During maintenance work, 1 inch of spoil, at the very maximum, would be taken from base of maintained drain. However, for the most part, little if any would be taken. By utilising a weedcutting bucket, only weeds will be removed for the most part, and virtually no spoil would be removed. Build-up of spoil would only be removed from drain, when necessary i.e. if it was affecting flow.

3.4.3 Garriskil Bog, Co Westmeath (SAC code 679)

This site was visited on 6th September, 2005. The raised bog itself was surveyed at the north-western edge. Here, it was dominated by Deergrass (*Scripus caespitosus*), with Ling Heather (*Calluna vulgaris*), Bog Cottons (*Eriophorum* spp.), Bog Asphodel (*Narthecium ossifragum*), Cross-leaved Heath (*Erica tetralix*) and *Sphagnum* moss. Bare ground was quite evident. Grazing did not appear to be an issue, and the bare ground didn't seem to occur due to peat cutting. It was, therefore, concluded that this is likely to be the result of recent burning.

The arterial drain at the north-western boundary of the site (C331/1/1) was observed to have not been maintained recently. It is estimated that it was possibly over 10 years since maintenance occurred. Vegetation present include Fool's Watercress (*Apium nodiflorum*), Common Reed (*Phragmites australis*), Willowherb (*Epilobium* spp.), Soft Rush (*Juncus effusus*), Floating Sweet-grass (*Glyceria fluitans*), Watercress (*Nasturtium officinale*), Hogweed (*Heracleum sphondylium*), Creeping Buttercup (*Ranunculus repens*), Flag Iris (*Iris pseudacorus*) and Wild Angelica (*Angelica sylvestris*). On the bank, Nettle (*Uritca dioica*), Ragwort (*Senecio jacobaea*), Wild Angelica, Meadowsweet (*Filipendula ulmaria*), Yarrow (*Achillia millefolia*), Woundwort (*Stachys palustris*) and Hawthorn (*Crataegus monogyna*) occur.

The arterial drain within coniferous woodland at the southern tip of the SAC was also viewed (C33). This was observed to be vegetated with *Chara* spp. and some Common Reed. On the bank, Willow (*Salix* sp.) and Bramble (*Rubus fruticosus*) scrub was common. Also noted were Woundwort, Iris, Willowherb and Bindweed (*Convolvulus arvensis*). To the east of this drain, the land adjacent to the SAC is predominantly wet grassland grazed by cattle. The Inny River, which forms the eastern boundary of the SAC has large spoil heaps - the result of past river dredging in the mid 1960s.

Figure 8 shows the SAC in question along with OPW drains and locations of photographs taken.

4. ECOLOGICAL IMPACTS OF ARTERIAL DRAINAGE MAINTENANCE

4.1 Introduction

4.1.1 Direct impacts

Drainage channels contain aquatic species and some bankside vegetation. Drainage maintenance results in direct ecological impacts. This can take the form of the removal and/or alteration of the plant and invertebrate communities associated with the watercourse. Dredging impacts on communities within the watercourse, while the removal of bankside vegetation obviously alters this riparian habitat. The dumping of spoil adjacent to the channel also serves to radically alter bankside habitat. Machine access to channels can impact on habitats along the route chosen.

These impacts may be short-term, but regular maintenance means there shall be a continual occurrence. Some plants, invertebrates and other animals will not survive or thrive with continual disturbance. However, direct impacts are restricted to a narrow corridor along the channel, as well as to a lesser degree, a narrow corridor along which machines gain access to the drain. Also, arterial drains are man-made habitats. Without maintenance, they will not continue to be drains, (which in itself, could result in a loss of some aquatic species). The necessary works required to maintain drains ensures that they are periodically disturbed habitats. The abundance of drains locally and regionally, means that any short-term loss of aquatic species, due to drainage maintenance, is not ecologically significant. Similarly, the loss of bankside vegetation is not regarded as ecologically significant. Also, these direct impacts can be mitigated by ecologically sensitive working practices, as discussed in chapter 5.

As far as raised bog and associated habitats are concerned, the direct ecological impact of Arterial Drainage Maintenance is negligible, unless the drain is within current high bog. It should also be stated that the vast majority of arterial drains are outside, or at the margins of, raised bog SACs. Here, the ecological quality of the bogland habitat is normally compromised, and / or the habitat is of less ecological significance.

4.1.2 Indirect impacts

With respect to raised bogs and their associated habitats, drainage maintenance has more potential for indirect impacts than direct impacts discussed above. It can impact on the hydrological integrity of the bog. The quality of a raised bog is very much dependent on factors affecting bog hydrology e.g. drainage and turf cutting. The higher the level of activities leading to drainage of the bog, the drier the bog will be. This will result in a reduced ecological value, with the possible loss of pools and some specialised bog plants (and invertebrates). A drier bog is generally a more uniform habitat. Therefore, drainage maintenance within the catchment of a raised bog may impact on the hydrological and ecological quality of the bog. The main purpose of this study is to assess such impacts, and to determine methods of minimising any potential impacts.

4.2 Hydrological impacts due to the original arterial drainage schemes

Arterial drainage, while mainly directed at improving agricultural land, it was also carried out to provide outfalls for turf cutting drains. In the latter case these drains will obviously have an impact on the associated bog. However, peatlands can also be affected due to arterial drainage directed at improving farmland. Cross (1990) states that arterial drainage directed at improving agricultural land, can also have an impact on raised bog habitat. Indeed, activities such as maintenance on rivers (i.e. deepening and widening), or drainage on the surrounding agricultural land, can have a significant impact on the high bog hydrology. These activities are occurring periodically around the high bog in some of the raised bogs. This impact may partially explain the unfavourable conservation status of some raised bogs, where there are no other obvious impacts.

As previously stated, the original drainage scheme would have increased channel capacity to cater for the 3 year flood event. Typically, the water table would have dropped by c. 1 m. This obviously has had an impact on the hydrology of the area. If a raised bog is within the catchment of an affected water table, then this will have been affected hydrologically and, in all likelihood, ecologically. In some instances, e.g. Raheenmore, the marginal drains which represent the original lagg, have been deepened, thus directly affecting the water table of the bog (Cross, 1990). In other cases, there is no direct effect, but the water table of the entire region may be lowered. The catotelm may therefore lose water, but as the peat is colloidal, it does not necessarily dry out, but may just shrink to a new, lower level. It is significant that several of the remaining wetter raised bogs lie on watersheds where the impact of arterial drainage is least e.g. L. Lurgeen Bog, Co. Galway.

Appendix 4 details the land expected to "benefit" (from a drainage perspective), as a result of arterial drainage schemes in the vicinity of raised bog SACs. These maps indicate that the majority of the raised bogs under review have been hydrologically compromised by the relevant arterial drainage scheme. However, as already stated, the ecological quality of all raised bog SACs have been assessed after the completion of the arterial drainage schemes. In other words, the ecological quality of the SAC was good enough at the time to warrant SAC status, with the arterial drain in place. If the ecological quality of the raised bog is being maintained in a post drainage scheme environment, then, in all likelihood, the arterial drain is not compromising the designated ecological quality of the SAC. However, if there has been an ecological decline in the status of the raised bog since designation, then the continued presence of the arterial drain *may* be a contributory factor in this.

4.3 Hydrological impacts due to Arterial Drainage Maintenance

On average, every four to five years, maintenance removes the build up of material to reinstate the channel capacity. Maintenance works continuously to re-establish the hydrological regime of the channel, to that generated at scheme works stage. As a rule, medium to high gradient channels have limited build-up of silt, and maintenance works consist of removing obstructions, repairing banks damaged and removal of dense in-stream vegetation. Typically, the low water level of the channel would not have appreciably increased above the original design datum, but the maintenance works would reinstate the flood capacity of the channel, hence reinstating the high

flow design datum. In practical terms, this would mean that the water body would flow at a certain level for a particular rainfall event, this level would commence to rise slightly over the years due to capacity reduction, and then the maintenance works re-establishes the original water level/channel flow relationship. Low gradient channels requiring maintenance would normally have an average low water level of 50 - 300 mm above the scheme design level, which has built up over the intervening years. Maintenance then returns the low water level back to the post scheme datum, and again reinstates the high flow datum, due to the return of the channel's flood capacity. This in an on-going process, and ensures that the level of drainage provided to the riparian lands, and the flood protection originally provided, is retained. Accordingly, the hydrological regime surrounding medium to high gradient channels would have a stable low flow datum, with some increase in the high flow datum building up over a few years. The maintenance returns this to the original design high flow datum.

In light of the fact that these operations do not involve any widening or deepening of the original drained channel, it is envisaged that maintenance of arterial drains would not be have significant effects on the hydrological regime of the channel. Accordingly, there is expected to be no significant effect on surrounding water levels. Since the arterial drains have all been in place prior to designation of raised bog SACs, it would be expected that the maintenance of these drains would have no significant impact on the ecological quality of the raised bog, or associated, habitats and/or dependent species. However, it is not that simple. Drainage can lead to a continual deterioration of a raised bog ecosystem over time. Therefore, some time after SAC designation, the ecological quality of a raised bog could have reduced, due to the continued presence of drains. In other words, the maintenance of a drain that continues to negatively impact on a raised bog, has the effect of continuing the ecological decline of the SAC in question.

The Raised Bog Monitoring Project (Valverde *et al*., 2005) has indicated that the extent of active raised bog has decreased by 25 - 37% (c. 581 ha) within the bogs surveyed. Appendix 5 details tables of bogs where a deterioration of ecological quality was registered. These include raised bogs where arterial drains are present nearby. However, it should be again stated that it is not necessarily the arterial drain that is causing this continued decline, but it may be a contributory factor. Further studies are required to determine this.

4.4 Hydrological impacts due peat cutting

Arterial drainage can directly, or indirectly, benefit peat cutting on a bog by reducing water levels, notably by providing a suitable outfall for drainage associated with turf cutting. Removal of peat from a bog has a devastating effect on the bog ecosystem. Once the surface vegetation has been removed, the bog can be considered to have been destroyed, and to be no more than a deposit of peat, which is exploited by open-cast mining. Not only are the plant and animal communities lost, so also is the irreplaceable sub-fossil record.

The principal effect of cutting and associated drainage, is to reduce the height of the water table. This leads to the desiccation of the peat in the acrotelm, an increase in temperature and oxygen levels within the peat, and hence an increase in biological

activity, causing decomposition. With the destruction of the acrotelm, the catotelm is exposed to the atmosphere and the bog ecosystem is degraded to heathland. This is an extreme event, but even small areas of cutting and isolated drains can have pronounced effects on raised bogs (Tubridy, 1984; Lindsay *et al*, 1988). A drain will speed up the loss of water from the bog, causing localised lowering of the water table. Even a shallow drain, such as occurs along townland boundaries, can have a pronounced effect over a period of time, leading to wastage of peat on either side and producing a shallow valley in the bog. Such a drain can also lead to pool systems drying out, either by directly draining the pools, or by a general lowering of the water table.

Deep peripheral drains, such as arterial drains or those excavated when a bog is being prepared for mechanical peat harvesting, and marginal cutting by hand, have a major impact on the bog. Not only is the lagg destroyed, but the activity cuts deep into the catotelm, which therefore dries out and oxidises. The net effect is to reduce the height of the water table in the adjacent intact bog, which consequently sinks. Another response of the bog to drying out as a result of cutting, is the development of vertical cracks parallel to the cut margins. The net effect is that the bog shrinks from the edge inwards.

4.5 Bog subsidence

The acrotelm capacity decreases when surface slopes increase, and or flow path lengths decrease. Such changes are usually connected to the process of peat subsidence. Hydrological and ecological studies indicate that the process of subsidence/acrotelm deterioration, that is initiated through disturbance of the bog margin by drainage or/and peat cutting, may slowly encroach towards the interior of the bog. This means that it is possible that in sites whose acrotelm has largely remained intact, but which have suffered marginal drainage, gradual acrotelm deterioration is likely to occur in the future. Where permeable subsoils are drained, the subsidence occurs much more rapidly and extensively. Drainage at the edge of Clara Bog has caused subsidence of over 1 m, extending up to 600 m into the bog, within a 10 year period (Schouten, 2002).

4.6 Impact on vegetation

The main impact of drainage is to cause a gradual loss of hygrophilous (water loving) species. Initially, the changes may be very subtle and be detectable only by detailed monitoring. The bryophytes, especially the *Sphagna*, are the first species to respond, with a decline in the pool and carpet species such as *S. cuspidatum* and *S. pulchrum,* and an increase in those species tolerant of drier conditions e.g. *S. capillifolium*. The drop in water table need not be great to have a profound effect, as *Sphagna* moss have very narrow ranges of tolerance to water stress. For example, *Sphagnum papillosum* is incapable of survival after 16 days of drought, and a drain may in effect extend a drought period on the bog surface (Clymo and Hayward, 1982).

Simultaneously, but more slowly, higher plants such as White-beaked Sedge (*Rhynchospora alba*) and Bogbean (*Menyanthes trifoliata*) will also decline, while

Deergrass (*Scirpus caespitosus*), Ling Heather and Bell Heather gradually increase in abundance, and trees such as Downy Birch (*Betula pubescens*) and Scots Pine (*Pinus sylvatica*) may invade the bog surface. Such changes may occur when the average water table is lowered by only 4 - 5 cm (Ivanov, 1981).

Drying out of the bog surface will obviously have a major impact on soaks and flushes. Open pools infill with vegetation to form a scragh, but as desiccation proceeds, this is replaced progressively by drier types of communities, with Purple Moorgrass and Bog Myrtle (*Myrica gale)* often becoming dominant. With increased aeration of the surface peat, Birch and Scots Pine may invade the bog, further speeding up the drying process. The net effect is a reduction of the variety of habitats, communities and species, and the loss of the subtle nutrient and hydrological gradients which exist around the pools, streams and soaks.

Drying out as a result of drainage is invariably accompanied by burning, which undoubtedly accelerates the changes.

The vegetation of Lough Roe soak (Clara Bog) which is unique in Ireland has changed substantially since the early 1990s due to drainage (Schouten, 2002).

4.7 Impact on fauna

The direct impacts of maintaining a drainage channel will, in turn, impact on aquatic fauna and other animals (e.g. Otters) which may utilise the watercourses. However, similar to the reasoning outlined in section 4.1, this impact is not deemed ecologically significant.

The indirect impacts of drainage via the changes exerted on the hydrology and thus the vegetation of a bog, can have consequences for fauna. The principal effects will be a decline in the communities associated with aquatic habitats and *Sphagnum* lawns and carpets. Work on Mongan Bog (Tubridy, 1988) indicates that the flowing water of drains cutting into raw peat has little to offer aquatic invertebrates, with only Pond Skaters (*Gerris* sp.) able to exploit the habitat. The gradual drying out of the bog will increase the depth to which detritivores can penetrate, so speeding up the process of peat wastage. Lumbricids may also move in, as soil conditions ameliorate. The unique faunal assemblages of soak systems will be lost, as they slowly dry out.

4.8 Case studies - Clara and Raheenmore bogs (Schouten, 2002)

4.8.1 Clara Bog West (Co. Offaly)

Clara Bog has suffered severe damage during the last two centuries. About one third of its original size has been lost. The bog subsided extensively over the past 150-200 years, mainly due to the bog road and its associated drains, not only those immediately alongside the road, but also the double and triple drains on the bog, parallel to the bog road. The double and triple drains were blocked around 1995. In the early 1990s, peat extraction increased at the southern and south-western bog margin outside the nature reserve. In 1995/96 the drains within the southern cutover zone were deepened well into the mineral subsoil and some new ones were made. This resulted in a lowering of the groundwater table to a level below the bottom of the peat.

Between 1991-2002, severe subsidence occurred in the southern and south-eastern part of Clara Bog West. Also two small lakes and some pools formed. A comparison of bog surface levels measured in 1991 and 2002, showed subsidence values of up to a little over 1 m in the southern part of the bog, decreasing northwards, but still measurable at distances up to 600 m from the southern margin. This suggested that drainage of the bog had intensified. The subsidence was unequal, which changed the surface slopes on Clara Bog West. This resulted in a changed flow pattern on the bog. The changed flow pattern caused lakes, waterlogged areas and drier areas. Owing to a different flow pattern on Clara Bog West, the behaviour of the surface outflow has changed, resulting in shorter residence times of the water in the surface layer. In time, this may lead to subsidence in the top layer of the bog, and increased drainage and/or a decreasing water supply to both the Western soak and the soak system of Shanley's Lough. The subsidence also partly destroyed the acrotelm. Partial destruction of the acrotelm has, and will continue to affect, the ecology of the bog.

The subsidence was attributed to a decrease in pore water pressure (and resultant shrinkage) in the lower peat layers, resulting from the propagation of the lowering of the groundwater level in the cutover zone *via* the underlying mineral soil (till). An increase in the volume fraction of organic matter also resulted. The effect has most likely been enhanced by the continued expansion of the cutover zone into the bog in recent times, as a result of turf cutting.

Because subsidence is a delayed response to the changes that cause it, it is unlikely that the present process has already come to an end. In addition, it may eventually cause indirect additional subsidence, resulting from damage to the acrotelm and subsequent loss of regulating properties. Hence, the subsidence may have a long-term impact on the ecological conditions on Clara Bog West. The cause of this reduction in ecological quality of Clara Bog West can be attributed to drainage and increased peat extraction at the southern edge of Clara Bog West, in the period 1991-2003. This ecological impact extends about 600 m into the bog.

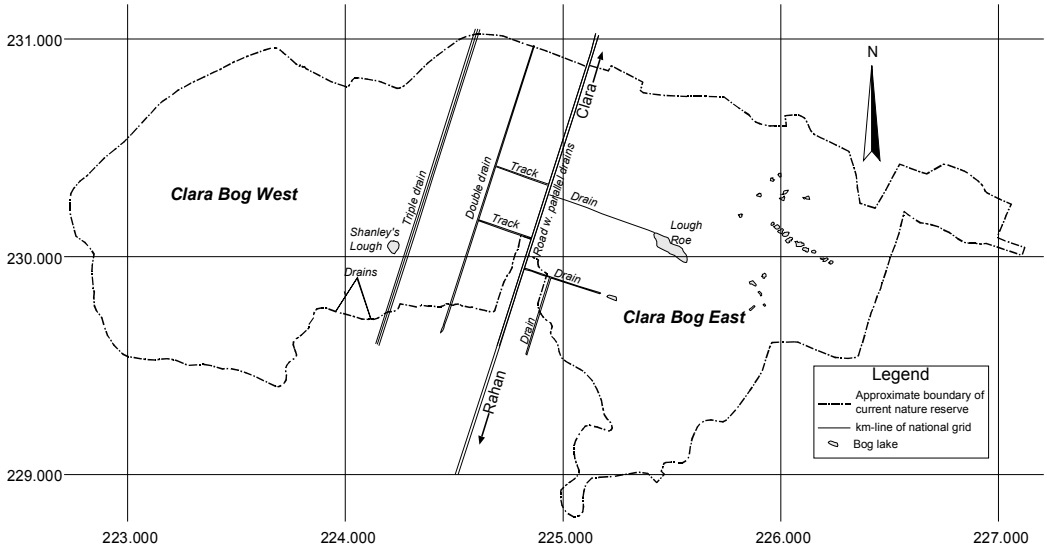

Figure 9: Outline of Clara Bog in 1991 with national grid co-ordinates (Van der Schaaf, 1999).

4.8.2 Clara Bog East

In 1983/84, Bord na Móna had cut a dense network of surface drains, about 0.6 m deep and spaced 18 to 20 m, to prepare the bog for industrial peat extraction. Also, smaller cutting activities were undertaken at the often privately owned bog margins. During a survey in 1992/93, it was found that Clara Bog East had suffered severely from the internal drainage installed in the early 1980's. The drainage had caused much damage to the acrotelm. Acrotelm transmissivity measurements in 1992 showed that the actual transmissivity was on average only one fifth of the theoretical value, which indicated a severe degradation of the acrotelm (Van der Schaaf, 1999).

In 1987-1989, the drains were blocked provisionally, and more effectively in 1996, and already at the end of the growing season of 1997, *Sphagnum* species showed a large expansion in many areas. The values measured in 2003 showed a considerable improvement over those of 1992, and the acrotelm of Clara Bog East is recovering from damage inflicted in the 1980's, albeit with restrictions in areas with a relatively steep slope and/or a short flow path length. This means that the restoration measures carried out on Clara Bog East have been effective, and that the original loss of ecological value can be attributed to drainage.

4.8.3 Raheenmore Bog

Raheenmore Bog suffered from marginal turf cutting and surface drainage in the north-eastern part of the bog. As a result of a drainage system, which is probably over 100 years old and has now partly terrestrialised, this part of the bog has subsided gradually, causing the highest point to shift towards the south-west. This has affected the flow pattern on the bog. The south-western part became drier as a result of shorter flow paths, whereas the flow path lengths north-east of the highest point have increased, causing more water to discharge at the north-eastern margin. In 1990/91, an acrotelm survey on Raheenmore Bog showed that the hydrological functioning of the acrotelm was below that expected. A survey of acrotelm depth and transmissivity compared with the potential situation, indicated a rather poor condition of the acrotelm (Van 't Hullenaar & ten Kate, 1991; Van der Schaaf, 1999).

In 1995, the drains were blocked in an attempt to stimulate acrotelm growth. Some old face banks near a northern dam were re-graded. To investigate how the acrotelm had developed since, a new acrotelm survey was carried out. This indicated that the hydrological regulatory function of the acrotelm had improved. The overall acrotelm thickness has increased since 1990/1991, not only in the centre of Raheenmore Bog, but also towards the margins. Also, the acrotelm is still developing, with spatially alternating well-developed and less developed patches.

Therefore, it can be concluded that the acrotelm of Raheenmore Bog has developed positively during the last decade. Again, it can be deduced that drainage was the cause of the original deterioration of the ecological quality of Raheenmore Bog.

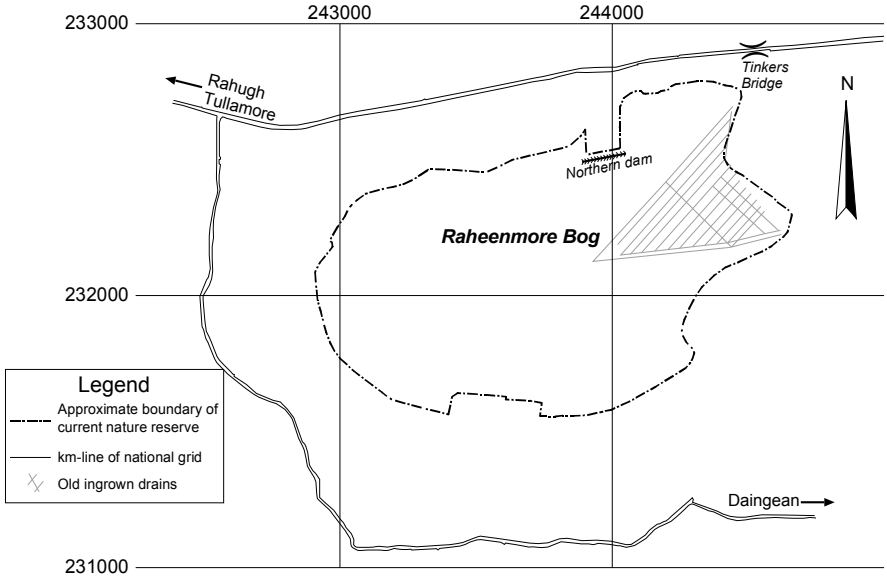

Figure 10: Outline of Raheenmore Bog with co-ordinates of the national grid in 1991 (Van der Schaaf, 1999). Position of northern dam (constructed after 1993) added.

4.8.4 Final remarks on acrotelm recovery and decay

The example of Raheenmore Bog shows that acrotelm recovery is a process that may take several decades to complete. At measuring sites installed around 1990, the *Sphagnum* surface had become 10-15 cm higher, and at the benchmarks installed in the same time for levelling purposes, the *Sphagnum* was about 10 cm or more higher than in 1991 (Van der Schaaf, 1996). The same was found on Clara Bog East. The development of the acrotelm on Clara Bog East, in terms of depth per time, was visibly faster than on Raheenmore Bog, although this was not uniformly so on this bog. The speed of acrotelm recovery is limited by the speed of growth of peat forming vegetation, mainly *Sphagnum* species. Acrotelm decay is a much faster process. It may take no more than a few years, as was shown in a comparison of acrotelm depth in relation to surface slope between Clara Bog West and East (Van der Schaaf, 1996).

The difference in recovery speed between Clara Bog East and Raheenmore Bog shows that the sooner restoration measures are taken after a calamity on a bog, the more effective they are likely to be. This not only refers to acrotelm decay, but also to irreversible effects of subsidence, resulting from a destroyed acrotelm (Van der Schaaf, 2000), which may alter the hydrological conditions on a bog.

Geological and geohydrological studies at the macro-scale level show that the bog system is relatively independent of regional hydrology in the short to medium term (Schouten, 2002). However, there is concern that, in the medium to long term, adverse impacts on the topography of the bog may occur due to compaction of the basal peat layers, if the regional ground-water levels drop significantly.
Acrotelm functions can be disturbed by (Schouten, 2002):
- damage to the peat-forming *Sphagnum*-dominated vegetation by fires or surface drainage or,
- changes in surface slopes and flow path lengths, usually as a result of peat subsidence following drainage.

4.9 Conclusion

The direct impacts of Arterial Drainage Maintenance are confined to a narrow corridor along the drain. Such impacts are not deemed ecologically significant, (especially if ecologically sensitive working practices are employed) because:
(i) These drains are artificial habitats in the first instance, and require maintenance to continue to act as a drain.
(ii) Drainage maintenance does not entail deepening of channels, or disturbing the bed of the drain.
(iii) Arterial drains are generally at the periphery of, or beyond the SAC boundary, where habitats are of less ecological value.

However, Arterial Drainage Maintenance can indirectly affect the ecological status of a raised bog, due to the impact of the drain on the hydrology of the bog. If the drainage channel is causing a continual decline in the ecological quality of the bog, then drainage maintenance is perpetuating this situation. Also, the lowering of the locality's water table, associated with arterial drainage, can benefit and encourage peat cutting. Removal of peat from a bog has a devastating effect on the bog's ecosystem, by removal of surface vegetation, drying out of uppermost peat, increasing temperature, oxygen levels, and hence decomposition rates, within surface peat. Subsidence of a raised bog can also occur due to drainage and peat cutting, which can cause an on-going deterioration of the bog. Changes in the hydrology of the bog is mirrored by changes in the flora and fauna present. Case studies in Clara and Raheenmore bogs indicate that drainage (albeit not necessarily arterial drains), and associated peat cutting, have had dramatic impacts on the ecology of these bogs.

The cause(s) of a continued decline in the ecological quality of a raised bog is a very complex issue. Drainage and associated peat cutting definitely cause a reduction in the ecological status of any raised bog. Whether one or both of these factors are causing a continued decline, is often not fully understood. However, if arterial drainage is in close proximity to a raised bog, then it possibly is one of the factors causing such decline. To determine this requires further hydrological and ecological studies. Each raised bog is different, and therefore, studies specific to the raised bog in question will need to be undertaken, to determine the causes of on-going ecological decline.

Arterial drains are, by their nature, relatively deep. Their potential to impact on a raised bog and associated habitats is dictated by two principal factors:

- How close is the drain to the bog.
- How close is the mineral soil to the drain.

With regard to the above, deep drains in the following locations would have a decreasing impact on a raised bog (all things being equal):
(i) On the high bog.
(ii) At the edge of the bog.
(iii) Within 100 m of the current peat face.
(iv) Over 100 m from the peat face on free-flowing, mineral soil.
(v) Over 100 m from the peat face on peat
However, upstream drains can also be having a detrimental impact on the bog's ecology. Depending on the hydrology of the region, this impact could be as detrimental as a drain c. 100 m from the peat face.

5. MITIGATION MEASURES

5.1 Introduction

The original arterial drainage schemes within the catchment of a raised bog, will likely have had some detrimental impact on the ecology of the bog. The land expected to benefit from arterial drainage schemes have been mapped (refer appendix 4). If this included raised bog SAC, then most likely the drainage scheme resulted in a deterioration of the raised bog. However, all raised bog SACs have been designated post completion of arterial drainage schemes. Therefore, their ecological quality was adequate to designate as an SAC with the arterial drains in place. Special Areas of Conservation are not designated on their potential value. Even though the removal of an arterial drain may improve the ecological quality of the bog, this is not a requirement with regards to SACs. Virtually all land has potential for ecological improvement, if certain measures are taken. The purpose of SAC designation is to maintain (and possibly enhance) the site's ecological quality.

The purpose of this report is to assess the potential impact of on-going maintenance of these drains. As has already been discussed (section 4.3), maintenance of arterial drains has little impact on altering the post arterial drainage scheme hydrology of an area. The direct impacts of Arterial Drainage Maintenance is mostly restricted to localised impacts within the narrow corridor of the drain and adjacent land. However, the presence of an arterial drain can have a long-term impact on a raised bog and associated habitats. In other words, the detrimental impact of the arterial drain on the bog's ecology may not have stopped. If this is the case, then the ecological status of the raised bog will continue to deteriorate. In such instances, drainage maintenance ensures the arterial drain continues to function properly and, as consequently, results in a continued deterioration of the SAC. Therefore, it is important to determine if the presence of arterial drains are resulting in a continual decline in the raised bog's ecological status.

5.2 Mitigation of direct impacts

The Screening Report (Gilligan, 2005) has identified four areas of policy, recently adopted by the OPW, which serve to mitigate many of the direct ecological impacts of maintenance works i.e.

(i) Environmental Drainage Maintenance Programme
(ii) Annual Works Programme to accommodate spawning
(iii) Fishery habitat enhancement
(iv) Upgraded excavator fleet

All of the above policies help mitigate the ecological impacts of maintenance operations on the aquatic environment within the drain. Only the Environmental Drainage Maintenance Programme and upgraded excavator fleet have the potential to mitigate ecological impacts on raised bog habitats. As previously stated (ref. 4.1.1), the Arterial Drainage Maintenance operations are likely to have little direct impact on the ecology of raised bog habitats.

5.2.1 Environmental Drainage Maintenance Programme

The OPW Drainage Division, in partnership with the Regional and Central Fisheries Boards (CFB), have established an Environmental Drainage Maintenance (EDM) programme. Emanating from this, ten environmentally sensitive alterations to work practices have been adopted. These range from leaving banks untouched, managing trees and vegetation and the timely tossing of spawning gravel. The simple measure of leaving one bank untouched during maintenance can have pronounced positive ecological benefits, in the direct locality of the drain. These methods have been published on a double sided laminated sheet as guidance notes for operational staff and are now been incorporated in routine maintenance operations (refer appendix 6).

The next phase of this programme is to continue auditing and promoting the implementation of the new work practises, continue to assess impacts on target aquatic species through studies with the Central and Regional Fisheries Boards, and instigate consultations with the NPWS to commence developing further environmentally sensitive work practises, with a view to publishing of, and training on, a second wave of EDM guidance notes.

5.2.2 Annual works programme to accommodate spawning

The OPW Drainage Regions and relevant Fisheries Boards discuss and revise the annual works programme to accommodate the timing of works in spawning drainage channels. Over the last few years, the typical annual work programme has changed substantially to reflect this requirement.

5.2.3 Fishery habitat enhancement

The Fisheries Boards liaise with OPW operational staff to co-ordinate operations on the ground, to the benefit of fish stocks. This could involve the timely construction of in-channel fishery improvements or, the removal of existing stocks by electro-fishing, where works could impact on the same.

5.2.4 Upgraded excavator fleet

Traditional maintenance utilised Dragline excavators which had a number of environmentally related disadvantages as follows:

- High ground pressure, which caused damage to surrounding ground and banks.
- Unwieldy to manoeuvre around bank side vegetation and resultant damage of the same.
- Cumbersome for drivers to control the excavation bucket, and hence difficult to execute the selective removal of channel material, or control the depths of excavation.
- Slow progress that forced relatively long intervals between successive maintenance operations on the same channel.

The introduction of a hydraulic excavator fleet began in the mid 1990's and was completed in 1999. These excavators replaced the draglines and reversed many of the above disadvantages. Furthermore, it is now policy that the working fleet is to be maintained at less than seven years old, which sets the average machine age of three

and half years, and accordingly, excavators are in excellent working order. All excavators use long life biodegradable engine oil and hydraulic oil. In addition, due to the good mechanical condition, there is effectively no loss of fluids, such as hydraulic oil, and no on site breakdowns, with resultant bank side mechanical maintenance. The excavators are appropriate for the ground conditions, and offer a high level of control to the drivers. Hence, a more selective approach to material removal can be implemented, including the ability to alter the channel profile, if desirable.

5.3 Liaison with statutory bodies

In light of the fact that drainage works are predominately within inland waters, the OPW Screening Report (Gilligan, 2005) has identified two main stakeholders i.e. the Fisheries Boards and the National Parks & Wildlife Service (NPWS).

Over past years, working relationships have been established with the Central and Regional Fisheries Boards throughout the country at all staff levels. OPW operational staff engage in open informal on-site communications, while in more sensitive catchments, regular meetings are held.

In more recent times, the OPW are building up consultations with staff of the NPWS. Regional management now have the opportunity to review the annual works programme, and over the next few years it is envisaged that Drainage operational staff will develop open on-site communications with many of the Conservation Rangers and District Conservation Officers. This will integrate a deeper understanding of practical environmental protection within maintenance works.

In 2004, a framework for communicating with these stakeholders was agreed and consists of the following:

- As soon as practical at the start of the year, Drainage Regions are to forward the relevant sections of the Annual Maintenance Programme with a copy of appropriate scheme maps, to the NPWS Regional Managers and the Regional Fisheries CEO.
- As a follow up, the Drainage Regions will offer the opportunity of a meeting with the stakeholders to discuss and refine the programme of works.
- For works that fall within SACs, SPAs or NHAs, these are to be flagged on the works programme and prior to commencement, and at least three weeks notice will be given to the NPWS.
- Forward a copy of the entire Annual Works Programme to the CFB whom review the same for appropriate EDM research sites and will revert to Drainage Regional Offices with their requirements.

Observations or comments on practical measures to either mitigate possible environmental impacts, or exploit enhancement opportunities, are integrated into the maintenance works. While the current communication framework offers adequate positive interaction, it is intended to continuously develop improved consultation protocols at all staff levels with both the Fisheries Boards and the NPWS.

5.4 Environmental management

A dedicated Environment Section was established within the Drainage Maintenance Service in 2003. The environmental section will provide assistance to the Drainage Maintenance Service in managing the many environmental issues that will arise in this sector over the coming years.

GIS systems are foreseen as a significant tool to manage both the existing and future environmental information and to this effect; the Drainage Maintenance Service has recently digitised the original drainage scheme maps. This will be of benefit to all stakeholders and will aid the rapid and accurate transfer of geographical environmental data. Ultimately, it is hoped to contain all maintenance work programmes, fishery information (such as spawning reaches), environmentally designated areas (e.g. SACs), other sensitive sites (such as habitats of protected species), and general habitat information, in this format.

5.5 Proximity to raised bog SAC

As already discussed (section 4.9), whether an arterial drain is causing a continual deterioration of a raised bog and its associated habitats, is mostly dependent on proximity of the drain to the bog, and to the underlying mineral soil. Therefore:

- The OPW will liaise with the NPWS with regard to arterial drains within 100 m of a raised bog facebank.
- Arterial drains beyond 100 m, but on free-draining mineral soil will also be referred to the NPWS.

As discussed in section 5.3, the NPWS are consulted on Arterial Drainage Maintenance within designated sites, which would include SAC sites designated for raised bog and associated habitats. When the OPW present the works programme in GIS format, it will facilitate visually identifying channels within 100 m of a raised bog SAC.

5.6 Further studies

The *Raised bog monitoring project* (Valverde *et al*,, 2005) has detailed raised bogs where there has been a decline in ecological quality (appendix 5). The deterioration noted may not be caused by arterial drainage. However, where an ecological decline has been noted, the cause of such should be investigated, with respect to the continued presence of arterial drains.

In this regard, liaison between the OPW and the NPWS will occur, with respect to instigating studies on specific raised bogs, where there has been a deterioration in the ecological status, and where arterial drains may be a contributing factor. The following are of relevance to this:

- Ecological monitoring of raised bog SACs can indicate whether the ecological status of the raised bog is being maintained. The

presence of a well developed "central ecotope" is the primary criteria by which to judge a site.

- Conductivity measurements can be utilised to indicate whether an arterial drain is likely to be causing a continual deterioration of a raised bog and associated habitats. Conductivity can be used as an indicator of groundwater influence. If there is groundwater influence within a drain, this implies the drain is likely to be impacting not just locally, but over a larger area. If this is the case, the drain is more likely to detrimentally impact on a raised bog's hydrology, and subsequently its ecology. Generally, as one moves away from a bog, the conductivity will increase. However, if a drain shows a dramatic increase in conductivity, then this is likely to indicate groundwater influence, and an increased chance that this drain is causing a continued deterioration in the bog's ecology. It should be noted that conductivity measurements can only give an indication of possible groundwater influence. It cannot be used in a definitive way and further studies would always be required to confirm any potential conclusions from conductivity measurements.

The leading role with respect to researching the inter-relationships between Arterial Drainage Maintenance and the ecological status of designated raised bogs, is the responsibility of the NPWS. This is the organisation with detailed background knowledge of raised bog sites and the expertise for assessing current information and future research. The NPWS is also the body legally responsible for the maintenance of the ecological status of designated raised bog SACs. The OPW is fully willing to liaise with the NPWS regarding future studies, which could determine if relevant arterial drainage schemes are having a detrimental impact on raised bog sites. If it can be shown that any particular drainage scheme is contributing to ecological decline, then again the OPW will actively engage with the NPWS to determine the most appropriate course of action.

If it is discovered that the presence and funcitoning of an arterial drain is a contributory factor in the ecological decline of a raised bog, then a decision will be required as to conflicting issues of:

- Maintaining arterial drainage within the locality, benefiting the productivity of agricultural land and possibly the viability of property.
- The negative ecological impact of the continued presence of such drains on the ecology of the raised bog SAC.

Both these issues have legal, social, political and cost implications. In essence it is a managerial call to decide upon the outcome of such scenarios, and beyond the remit of this report.

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Appendix 1: Notifiable Actions for raised bog, cutover bog and bog woodland

NOTICE OF NOTIFIABLE ACTIONS

Under STATUTORY INSTRUMENT 94 of 1997, made under the EUROPEAN COMMUNITIES ACT 1972 and in accordance with the obligations inherent in the COUNCIL DIRECTIVE 92/43/EEC of 21 May 1992 (the Habitats Directive) on the conservation of the natural habitats and species of wild fauna and flora, all persons must obtain the written consent of the Minister for the Environment, Heritage and Local Government, Heritage and Local Government before performing any of the operations listed below on, or affecting, the habitat of *raised bog, cutaway bog and bog woodland,* **where it occurs on these lands / water areas**

Where a landowner has a current approved plan under the Rural Environmental Protection Scheme or any scheme which the Minister considers to be equivalent s/he need only notify the Minister of activities not covered in the plan.

The activities which should not be undertaken before consent are;

- grazing of livestock
- grazing by livestock treated within the previous week with a pesticide which leaves persistent residues in the dung
- adding lime
- adding fertiliser of any sort
- creation of new tracks or paths
- burning areas of vegetation
- reclamation, infilling, or ploughing
- reseeding, planting of trees or any other species
- cutting trees or removing timber
- drainage works on the bog or within the local water catchment area
- cutting turf or peat moss extraction
- use of any pesticide or herbicide, including sheep dip
- dumping, burning or storing any materials
- alteration of the banks, bed or flow of watercourses
- operation of commercial recreation facilities (e.g. botanical tours)
- introduction (or re-introduction) into the wild of plants or animals of species not currently found in the area
- any other activity of which notice may be given by the Minister from time to time

Please note that the activities listed below may require a licence or consent from another statutory authority (e.g. the local planning authority, the Minister of the Environment, or the Minister for Agriculture, Food and Forestry). ***The activities listed below must be notified to the Minister for Environment when they are not regulated by another statutory authority***

- developing leisure facilities including golf courses, sports pitches, caravan or camping facilities.
- removal of soil, mud, gravel, sand or minerals
- developing roads or car parks
- construction of fences, buildings or embankments
- afforestation
- erecting or operating a windfarm

EXPLANATORY NOTE

The Minister for the Environment, Heritage and Local Government, Heritage and Local Government has the responsibility under these Regulations to implement the European Union Directive on the protection of Habitats. This Directive sets out a procedure for ensuring that the farming and other management within a designated site (Special Area of Conservation) is done in a way which will not damage the environment. The legal mechanism to achieve this objective is to serve on landowners and occupiers a notice stating that they must consult with the Minister before doing certain things.

In most cases the Minister's objective of sustainable farming will be met by a continuation of the current agricultural practices and after the consultation period, the farmer will continue to farm as s/he always has. In some cases an intensification of agriculture (e.g. an increase in stock numbers) will not be environmentally sustainable and will not be acceptable to the Minister. In these cases the activity must be discontinued and a compensation system will be invoked. There are legal penalties for persons who ignore this procedure.

The restrictions apply to "habitats" such as "sand dunes" or "blanket bog" or to certain populations of species (such as lampreys at spawning beds). The Minister's staff in the National Parks and Wildlife Service will assist anyone who is in doubt about where the habitat or species is on their land.

Appendix 2: ***SACs containing Raised Bog Active (EU code 7110) and associated habitats (codes 7120,7150 & 9110) and intersecting OPW Channels***

Channels

Sitecode	Site Name	Scheme Name	Type ID
6	KILLYCONNY BOG	Boyne	C1/8/23/2
6		Boyne	X2/C1/8/23/2
6		Boyne	C1/8/18

Sitecode	Site Name	Scheme Name	Type ID
231	BARROUGHTER BOG	Killimore Carrigahorig	unnamed
231		Killimore Carrigahorig	C1
231		Killimore Carrigahorig	C1/1/1

Sitecode	Site Name	Scheme Name	Type ID
296	LISNAGEERAGH BOG AND BALLINASTACK TURLOUGH	Corrib Clare	SG 18/2

Sitecode	Site Name	Scheme Name	Type ID
297	LOUGH CORRIB	Corrib Clare	C4
297	(Addergoole Bog)	Corrib Clare	C4/1
297	(Addergoole Bog)	Corrib Clare	C4/6
297	(Addergoole Bog)	Corrib Clare	F604
297	(Addergoole Bog)	Corrib Clare	F604/1
297	(Addergoole Bog)	Corrib Clare	F75
	Sixty other channels overlap with the Lough Corrib SAC but not in areas of relevance to Raised Bog habitat.		

Sitecode	Site Name	Scheme Name	Type ID
301	LOUGH LURGEEN BOG/GLENAMADDY	Corrib Clare	SG.18/4
301	TURLOUGH	Corrib Clare	SG.18/4/1
301		Corrib Clare	SG.18/4/1/1
301		Corrib Clare	SG.18/4/2
301		Corrib Clare	SG.18/4/2/1
301		Corrib Clare	SG.18/4/3

Sitecode	Site Name	Scheme Name	Type ID
440	LOUGH REE	Ballyglass	C1
440		Inny	C1
440		Inny	C1/1
440		Inny	C1/2
440		Inny	C2
440		Inny	C2
440		Inny	C3
440		Inny	C3A/1
440		Inny	C4
440		Inny	C5
440		Inny	C5A
440		Inny	C6/2
440		Inny	C6 outfall
e: As of 2005, no arterial drains intersect with raised bog sites within L. Ree SAC			

Sitecode	Site Name	Scheme Name	Type ID
572	CLARA BOG	Brosna	C9(4)

Sitecode	Site Name	Scheme Name	Type ID
582	RAHEENMORE BOG	Boyne	C1/64/22/2
582		Boyne	C1/64/25

Sitecode	Site Name	Scheme Name	Type ID
595	CALLOW BOG	Boyle	C1
595		Boyle	C1/1
595		Boyle	C1/3/1
595		Boyle	C2
595		Boyle	C2/1
595		Boyle	C20
595		Boyle	C3

Sitecode	Site Name	Scheme Name	Type ID
604	DERRINEA BOG	Boyle	C1/24

Sitecode	Site Name	Scheme Name	Type ID
614	CLOONSHANVILLE BOG	Boyle	C6
614		Boyle	C6/5
614		Boyle	C6/7/1/2/1/1

Sitecode	Site Name	Scheme Name	Type ID
647	KILCARREN-FIRVILLE BOG	Carrigohorig	C1/2/1
647		Carrigohorig	C1/2/2

Sitecode	Site Name	Scheme Name	Type ID
679	GARRISKIL BOG	Inny	C1
679	GARRISKIL BOG	Inny	C33
679	GARRISKIL BOG	Inny	C33/1
679	GARRISKIL BOG	Inny	C33/1/1
679	GARRISKIL BOG	Inny	C34

Sitecode	Site Name	Scheme Name	Type ID
2298	RIVER MOY		
2298	(Gowlaun Bog & Cloongoonagh Bog)	Moy	C1/48
2298	(Gowlaun Bog complex)	Moy	C1/48/5
2298	(Gowlaun Bog complex)	Moy	C1/48/6
2298	(Gowlaun Bog complex)	Moy	C1/47
2298	(Gowlaun Bog complex)	Moy	C1/47/1
	Two hundred other channels overlap with the River Moy SAC but not in areas of relevance to Raised Bog habitat.		

Sitecode	Site Name	Scheme Name	Type ID
2340	MONEYBEG & CLAREISLAND BOG	Inny	C1
2340		Inny	C59
2340		Inny	C60
2340		Inny	C60/1
2340		Inny	XC60/1

Sitecode	Site Name	Scheme Name	Type ID
2342	MOUNT HEVEY BOG	Boyne	C1/37/2/2
2342		Boyne	C1/37/2/3
2342		Boyne	C1/37/7/3
2342		Boyne	C1/37/7/3/1
2342		Boyne	C1/44/10
2342		Boyne	C1/44/11
2342		Boyne	XC1/44/11
2342		Boyne	C1/44/11/1

Sitecode	Site Name	Scheme Name	Type ID
2351	MOANVEANLAGH BOG	Feale	C1/18/17

Sitecode	Site Name	Scheme Name	Type ID
2352	MONIVEA BOG	Corrib Clare	C3/8/14

Sitecode	Site Name	Scheme Name	Type ID
2354	TULLAGHANROCK BOG	Boyle	C1
2354		Boyle	C1/2
2354		Boyle	C1/3

APPENDIX 3:

Site synopses for raised bog SACs with intersecting OPW arterial drainage channels.

SITE NAME: KILLYCONNY BOG (CLOGHBALLY)
SITE CODE: 000006

Killyconny Bog is situated approximately half way between Virginia and Kells on the Cavan/Meath border and some 8km from each. It is underlain by Lower Palaeozoic shales and consists of two small basins which have coalesced over a low drumlin ridge.

There are few raised bog in the area and Killyconny Bog seems to be one of the best developed. Though some marginal drainage and cutting has taken place the central part of the bog is relatively intact.

Much of the bog is very wet and there are many areas of pool and hummock formation. The pools support the moss *Sphagnum cuspidatum*, and a good growth of algae in summer. Wet areas about the pools support other *Sphagnum* mosses such as *S. magellanicum*, while *S. papillosum, S. fuscum, S. capillifolium* and *Hypnum cupressiforme* are important components of hummocks. Vascular plants are also found on the bog: Bog Cotton (*Eriophorum angustifolium* and *E. vaginatum*), the heathers (*Calluna vulgaris* and *Erica tetralix*), Bog Asphodel (*Narthecium ossifragum*) and White Beak-sedge (*Rhynchospora alba*). Also occurring on the site is Bog Rosemary (*Andromeda polifolia*) which is found almost exclusively on raised bogs and which is rare in N.E. Ireland.

While the surface of the bog is generally homogeneous some higher areas with dense tussocks of Bog Cotton (*Eriophorum vaginatum*) are found; these provide shelter for Hares. There are also lines of water movement, shown by the occurrence of Common Sedge (*Carex nigra*) and Soft Rush (*Juncus effusus*). Bird species found on the bog include Meadow Pipit and Curlew, and sometimes also Kestrel and Long-eared Owl which hunt over it for beetles, Pygmy Shrews and Frogs.

8.1.1997

SITE NAME : BARROUGHTER BOG
SITE CODE : 000231

Barroughter Bog is a relatively small raised bog, situated on the shores of Lough Derg, a few kilometres east of Woodford, and bounded in the north by the Cappagh River. The bog has a good dome, which is slightly hollowed towards the eastern side. The north-eastern corner (cut off by an old drain and track), and a narrow area in the south-east, are fairly dry due to drainage and burning.

A large area (about 34 hectares) in the centre shows an outstanding raised bog habitat with small and large pools containing Bog Mosses (*Sphagnum* spp.), including *Sphagnum pulchrum* - a very scarce plant in Ireland. Extensive flat lawns of a range of Bog Mosses (*Sphagnum* spp.) and low hummocks occur between the pools, and the whole area is quaking. Despite frequent burning, regeneration of Bog Mosses around this central area is good and the ground is wet and spongy.

A small flushed area occurs in the centre and towards the edge of the quaking area. This flush adds diversity to the bog, with a few small Birch (*Betula pubescens*) trees, Bilberry (*Vaccinium myrtillus*), Crowberry (*Empetrum nigrum*) and Cranberry (*Vaccinium oxycoccus*) in abundance, and a range of moss species.

The site also includes some wet grassland along the Cappagh River and an area of rocky grassland in the north.

A threat to the extent and quality of the central and most interesting habitat is present in the form of active "hopper" turf extraction around 90% of the bog's perimeter. This is especially serious along the south-west facing edge, where the quaking area lies quite close to the perimeter. Burning has caused some drying out of the bog surface. The area of outstanding habitat (i.e. the very wet, quaking area) in the centre of the bog could be extended if burning was prevented, especially towards the south-west.

Barroughter Bog is a raised bog of considerable conservation value. Given its relatively small size, the area of outstanding quaking habitat is remarkably large. Its proximity to the shores of Lough Derg, with its succession from open water through extensive reed beds and marginal scrub, to raised bog, adds to its importance. It is also the only raised bog on the shores of Lough Derg.

13.1.1997

SITE NAME : LISNAGEERAGH BOG AND BALLINASTACK TURLOUGH
SITE CODE : 000296

This site comprises a large raised bog and a small turlough, situated about 3 km north-east of Glenamaddy in County Galway.

The bog has a largely intact dome, approximately 50% of which is high quality raised-bog habitat. This includes a small but active hummock/pool system in an isolated portion of the bog, in the south-west. Although fire has damaged this area a little, some large hummocks which occur as islands in the bogpools have escaped any damage. Three separate areas of long, winding pools occur, the best being in the centre of the bog. In these pool complexes, Bog Mosses (*Sphagnum* spp.) are colonising the open water and are forming lawns between the pools. Brown Beak-sedge (*Rhynchospora fusca*), a plant which is scarce in Ireland, is abundant in the pool complexes. An unusual plant community, comprising Carnation Sedge (*Carex panicea*) and Bog Mosses, occurs also. The presence of a number of flushes, some of which are dominated by Purple Moor-grass (*Molinia caerulea*), adds habitat diversity.

In the north of the site is Ballinastack Turlough, whose floodwaters abut the raised bog. Peat deposits are associated with the turlough - an unusual feature for a turlough which is supplied with mineral-rich ground water. Vegetation dominated by Common Sedge (*Carex nigra*) occurs on the peaty substrate.

Associated with the bog, and to the north-east, is an area of wet grassland on heavy clay soil which grades into abandoned and regenerating cut-away, which is wet and rich in Bog Mosses. There is also an extensive area of cut-away bog in the south-west, comprising a mixture of dry banks dominated by Ling Heather (*Calluna vulgaris*), and wet pools.

The turlough attracts wintering waterfowl, which move between this site and other turloughs in the Glenamaddy area according to water levels and disturbance. Three species which are listed on Annex I of the EU Birds Directive occur - Greenland White-fronted Goose (60-80 average), Whooper Swan (up to 70 in recent winters) and Golden Plover (500-1000+). Wigeon is also regular in winter (up to 500), along with smaller numbers of other waterfowl species (above figures are based on counts carried out in the mid-1990s). Lisnageeragh Bog provides habitat for Red Grouse.

Raised Bogs are a rare habitat in Europe, and in Ireland they continue to be threatened by peat harvesting, drainage, afforestation and burning.

The occurrence of a high proportion of good quality raised bog, a habitat listed on Annex I of the EU Habitats Directive, with actively-growing Bog Moss communities makes this site of considerable ecological interest. The close association of a turlough, also listed on Annex I of the EU Habitats Directive, which is in itself a valuable natural habitat and is important for waterfowl, enhances the diversity of the site.

SITE NAME : ADDERGOOLE BOG, LOUGH CORRIB
SITE CODE : 000297

Lough Corrib is situated to the north of Galway city and is the second largest lake in Ireland with an area of approximately 18,240 ha (the entire site is 20,556 ha). The lake can be divided into two parts: a relatively shallow basin, underlain by Carboniferous limestone, in the south and a larger, deeper basin, underlain by more acidic granite, schists, shales and sandstones, to the north. The surrounding lands are mostly pastoral farmland, to the south and east, and bog and heath, to the west and north. In addition to the lake basin, adjoining areas of conservation interest, including woodland, grassland and limestone pavement, have been incorporated into the site.

This site is of major conservation importance and includes twelve habitats listed on Annex I of the EU Habitats Directive. Six of these are priority habitats - petrifying springs, Cladium fen, active raised bog, limestone pavement, bog woodland and orchid-rich calcareous grassland. The other annexed habitats present include hard water lakes, lowland oligotrophic lakes, floating river vegetation, alkaline fens, Molinia meadows and old Oak woodlands.

Active raised bog occurs at Addergoole, on the south-east shore of the lake 5 km north of Galway city, between the Clare and Cregg rivers. This is one of the most westerly intact raised bogs in the country and has well developed surface features including as bog pools dominated by *Sphagnum cuspidatum*. The bog also supports a stand of bog woodland, dominated by Downy Birch (*Betula pubescens*), which has developed in a soak system. Soaks are now a very rare feature of Irish raised bogs.

Otter and Irish Hare have been recorded regularly within this site. Both of these species are listed in the Red Data Book and are legally protected by the Wildlife Act 1976.

Peat cutting threatens Addergoole Bog and already a substantial area of it has been cut away.

Despite this ongoing interference however, Lough Corrib is one the best examples of a large lacustrine system in Ireland, with a range of habitats and species still well represented. The lake itself is internationally important for birds and is designated as a Special Protection Area.

27.09.02

SITE NAME : LOUGH LURGEEN BOG/GLENAMADDY TURLOUGH
SITE CODE : 000301

Lough Lurgeen Bog/Glenamaddy Turlough covers almost 1,200 ha and is situated east of the town of Glenamaddy. It consists of a very large turlough, over 170 ha in area, and a vast expanse of over 1,000 ha of typical intact western raised bog. A small lake occurs on top of the bog.

The Lake, Bog and Turlough are in close association. Water from the bog feeds the lake which in turn is linked to the turlough. This leads to quite a unique ecosystem which is of high conservation value.

On the bog, there are a number of interesting features, pool-hummock systems, a lake, a large fen and a number of flushes, dominated by Purple Moor-grass (*Molinia caerulea*). The lake is a traditional goose site and the turlough is now used by Greenland White-fronted Goose (74). Other birds reported for the site during 2 seasons between 1984 and 1987 (3 counts were made) are Bewick's Swan 14, Whooper Swan 8, Wigeon 472, Teal 73, Mallard 229, Shoveler 15, Pochard 20, Golden Plover 23, Lapwing 62, Snipe 20, Curlew 39, Redshank 15.

A very large turlough of high conservation value in such close proximity to a vast expanse of raised bog is quite unique. The whole ecosystem is therefore of high conservation value.

24.5.2005

SITE NAME: CLARA BOG
SITE CODE: 000572

Clara Bog is situated some 2 km south of Clara village. Much of it is state-owned and designated a statutory Nature Reserve.

Clara Bog has long been regarded as one of the most important lowland raised bogs in the country, being the largest remaining example of the true Midland sub-type. It has well developed hummock and hollow complexes and one of the few remaining soak systems. The bog vegetation has been much studied and is well known. Variations in the proportions of Bog moss (*Sphagnum* spp.), Heather (*Calluna vulgaris*) and Cottongrass (*Eriophorum* spp.) has been related to ecological features such as pools, soaks and ridges.

Several rare invertebrate species are associated with the soak, including the midge, *Lasiodiamesa sphagnicola*, for which Clara Bog is its only known Irish site, a click beetle, *Ampedus pomorum* and another midge, *Parhelophilus consimilis*. The bog is also important for the rare moss, *Tetraplodon angustatus*, at its only known Irish station here.

Clara Bog supports breeding Merlin (1-2 pairs), a scarce species in Ireland and one that is listed on Annex I of the EU Birds Directive. Red Grouse also breeds, along with other common bogland species such as Meadow Pipit and Skylark.

To the east the transition into calcarous woodland, and to the north the transition to the esker ridge have been retained and some excellent examples of esker grassland occur in the site. Some peripheral reclaimed farmland is also included in the site, because management undertaken in these areas can have a profound effect upon the rest of the bog.

The site has been divided into a western and an eastern section by a road. The eastern part of the site has been damaged by previous drainage attempts, however, restoration work is in progress. Continuing peat extraction from the southern margins is also damaging and has potential effect upon much of the internal bog, including the soak system. Ideally the whole bog should be managed as a hydrological unit.

Active raised bogs, once characteristic of central Ireland, are now rare and vulnerable, and have been recognised by the European Union as a habitat of international importance. Ireland has a special responsibility to conserve the best of its remaining bogs. Further drainage, peat extraction, burning or attempted land reclamation is not consistent with this responsibility.

25.2.1999

SITE NAME: RAHEENMORE BOG
SITE CODE: 000582

This raised bog developed in a small basin in the catchment of two major river systems i.e. the Brosna and the Boyne. It is situated about 5 km from Daingean. The peat is very deep, being up to 15 m in places. The bog has a well-developed hummock and hollow system.

The hummocks are often colonised by the mosses *Sphagnum imbricatum* and *S. fuscum*. Pool areas support Great Sundew (*Drosera anglica*), the moss *Sphagnum cuspidatum* and the liverwort (*Cladopodiella fluitans*). In places, moss lawns of *Sphagnum magellanicum* have infilled the pools. Overall, the cover of *Sphagnum* moss on the bog is very good. Away from the dome summit, Bog Asphodel (*Narthecium ossifragum*) flats dominate the peat surface.

Some sections of old cutaway bog has narrow strips of Downy Birch (*Betula pubescens*) woodland developing. Much of the rest of the cutaway is now un-improved pasture and wet grassland, rich in Rushes (*Juncus* spp.) and Purple Moor-grass (*Molinia caerulea*). Valerian (*Valeriana officinalis*), Meadowsweet (*Filipendula ulmaria*) and Brown Sedge (*Carex disticha*) can also be found in fields at

the bog margins. In 1959, the very rare Rannock Rush (*Scheuchzeria palustris*), found only in its only Irish Station in a nearby bog, was transplanted to Raheenmore Bog. However, it has not been recorded recently and may be now extinct.

Raheenmore Bog is within the breeding territory of a pair of Merlin, a scarce species in Ireland and one that is listed on Annex I of the EU Birds Directive. Other typical bogland birds which breed include Red Grouse and Snipe.

The margins of the bog have been arterially drained in connection with the previous Boyne Drainage Scheme. This could result in desiccation of the bog. However, the majority of the bog dome is undrained and peat extraction has substantially discontinued. On the western side, mineral springs feeding the lagg zone still survive. (The lagg zone is the natural marginal drainage channel circumscribing the bog and receiving water from the bog and adjacent mineral soil). Although the north-eastern section suffered from burning in the past, the majority of the site is relatively unaffected by this practice at present.

Raheenmore Bog is a classical example of a Midland Raised Bog and the deepest remaining in Ireland. This habitat is increasingly under threat in this country and worldwide. The site is remarkably intact and is one of the few raised bogs where restoration of the lagg zone is feasible.

10.1.1997

SITE NAME: CALLOW BOG
SITE CODE: 000595

Callow Bog is located approximately 7 km north-west of Frenchpark, Co. Roscommon in the townlands of Callow or Runnawillin, Cloonmagunnaun, Keelbanada, Creggan and Ratra. It is situated on the south-western shore of Lough Gara and is underlain by Carboniferous limestone.

The site is a candidate Special Area of Conservation selected for active raised bog, degraded raised bog and *Rhynchosporion*, habitats that are listed on Annex I of the E.U. Habitats Directive. Active raised bog comprises areas of high bog that are wet and actively peat-forming, where the percentage cover of bog mosses (*Sphagnum* spp.) is high, and where some or all of the following features occur: hummocks, pools, wet flats, *Sphagnum* lawns, flushes and soaks. Degraded raised bog corresponds to those areas of high bog whose hydrology has been adversely affected by peat cutting, drainage and other land use activities, but which are capable of regeneration. The *Rhynchosporion* habitat occurs in wet depressions, pool edges and erosion channels where the vegetation includes White Beak-sedge (*Rhynchospora alba*) and/or Brown Beak-sedge (*R. fusca*), and at least some of the following associated species, Bog Asphodel (*Narthecium ossifragum*), Sundews (*Drosera* spp.), Deergrass (*Scirpus cespitosus*), Carnation Sedge (*Carex panicea*).

The raised bog habitat includes both areas of high bog and cutover. The high bog consists of five lobes dissected by roads and a stream. Overall the high bog is relatively flat with slight slopes north to Lough Gara. Two wet areas with pools occur, and there are a number of tear pools to the north. The high bog also supports a very large central flush. The River Lung flows near the north-western boundary of the site and there is a low relief drumlin to the north west of the bog. To the south the raised bog is surrounded by agricultural land.

The high bog has vegetation typical of a Western Midland raised bog, consisting of Ling Heather (*Calluna vulgaris*), Cottongrasses (*Eriophorum* spp.) Carnation sedge and Deergrass. Bog Asphodel is abundant throughout the high bog. Other species present include Bog-rosemary (*Andromeda polifolia*), Cranberry (*Vaccinium oxycoccos*), the moss, *Racomitrium languinosum*, Lousewort (*Pedicularis sylvatica*) and Bilberry (*Vaccinium myrtillus*). Bog Moss (*Sphagnum* spp.) cover is typically quite low with few hummocks, however, *Sphagnum capillifolium*, and *S. papillosum* occur in places. The scarce bog mosses *Sphagnum imbricatum* and *S. fuscum* are found on the site, though are limited in occurrence. *Sphagnum auriculatum* occurs in pools along with Great Sundew (*Drosera anglica*), Bogbean (*Menyanthes trifoliata*) and White Beak-sedge. Bog Myrtle (*Myrica gale*) is found in

association with bog pools. Lichen (*Cladonia portentosa*) cover is good on the high bog where no recent burning has occurred. Tear pools occur to the north of the main lobe and support some *Sphagnum cuspidatum*. To the south, abundant *Campylopus atrovirens* and *Sphagnum magellanicum* are found along pool edges. Two flushes dominated by Purple Moor-grass (*Molinia caerulea*) occur, the larger one found in the centre of the main lobe and the smaller one a linear feature with swallow holes to the north-east. The main flush has good bog moss oss cover and also supports Cross-leaved Heath (*Erica tetralix*), Devil's-bit Scabious (*Succisia pratensis*) and Tormentil (*Potentilla erecta*). The rare Red Data Book species, Alder Buckthorn (*Frangula alnus*), has been recorded from this central flush area. At the north-west corner of the site some Birch (*Betula* sp.), Gorse (*Ulex europaeus*) and Bog Myrtle are encroaching onto the high bog.

The vegetation of the cutover is dominated by Ling Heather on old peat banks, with stagnant pools in places and some regenerating peat to the south. To the south-east there is much Common Reed (*Phragmites australis*), Purple Moor-grass and Bulrush (*Typha latifolia*) on cutover. Scattered Gorse and Willow (*Salix* sp.) occur in small amounts. To the north of the high bog the vegetation is dominated by White Beak-sedge, reflecting the disturbance from peat cutting in this area. Here also there is much bare peat. In places towards the centre of the site there are old tracks quite close to the high bog which support calcicole species and which are lined with Bracken (*Pteridium aquilinium*), willows (*Salix* sp.), Gorse and Purple Moor-grass along with some Bilberry (*Vaccinium myrtillus*).

Current landuse on the site consists of peat-cutting along much of the bog margins, apart from the north-east where the presence of Lough Gara has curtailed access and the bog margins are relatively intact. Afforestation has occurred on the high bog to the north of the site. Damaging activities associated with this landuse include drainage and burning. Fire damage was recorded in the 1980s when most of the bog was badly damaged. More recently, the large central flush area has been burnt and there is evidence of regular burning throughout the area. Apart from a few small areas of high bog to the north-west and south, most of the high bog has suffered burning in the recent past. These are all activities that have resulted in loss of habitat and damage to the hydrological status of the site, and that pose a continuing threat to its viability.

Callow Bog is of considerable conservation significance comprising as it does a raised bog, a rare habitat in the E.U. and one that is becoming increasingly scarce and under threat in Ireland. Its semi-natural lake margins and its northerly location add to its overall conservation value. Active raised bog is listed as a priority habitat on Annex I of the E.U. Habitats Directive. Priority status is given to habitats and species that are threatened throughout the E.U. Ireland has a high proportion of the total E.U. resource of this habitat type (over 60%) and so has a special responsibility for its conservation at an international level.

31.10.2002

SITE NAME: DERRINEA BOG
SITE CODE: 000604

Derrinea Bog is a small raised bog site situated on the northern margin of Cloonagh Lough, just east of the Mayo/Roscommon border and approximately 10 km north-west of Ballyhaunis. A river emanating from Cloonagh Lough forms the eastern and northern boundary of the site, which features an extensive area of pools, quaking flats and well-developed hummocks.

The pools are colonized by Bogbean (*Menyanthes trifoliata*), carpets of Bog-sedge (*Carex limosa*) and Crowberry (*Empetrum nigrum*). Surrounding these areas, quaking flats have good Bog Moss (*Sphagnum* spp.) cover, with White Beak-sedge (*Rhynchospora alba*), the moss *Campylopus atrovirens* and Great Sundew (*Drosera anglica*) also present. The hummock-forming Bog Moss (*Sphagnum imbricatum*) is found around the pools. The scarce Bog Moss (*Sphagnum recurvum* var. *tenue*) has been recorded from the site.

A small hillock at the southern end of the bog has an almost complete cover of Heather (*Calluna vulgaris*), with occasional Sessile Oak (*Quercus petraea*).

Despite drainage and turf cutting in the western part of the site, the more easterly areas are remarkably wet and display an extensive mosaic of bog habitats which contribute to the value of the site.

13.1.1997

SITE NAME: CLOONSHANVILLE BOG
SITE CODE: 000614

Cloonshanville Bog is located approximately 2 km east of Frenchpark. The eastern boundary of the site is the Breedoge River, the southern the Frenchpark/Elphin road. It is underlain by low-permeability, clayey limestones. The bog developed in a shallow basin in a groundwater discharge zone. The regional watertable has been lowered, but evidence of groundwater inputs are seen on and around the high bog.

Cloonshanville Bog is a large raised bog, a priority habitat listed on Annex I of the EU Habitat Directive. The bog is largely dominated by Heather (*Calluna vulgaris*), with Deergrass (*Scirpus cespitosus*) and Common Cottongrass (*Eriophorum angustifolium*) occurring frequently. Cranberry (*Vaccinium oxycoccos*) is found in some sections of the bog. In the wettest areas hummock/pool systems have developed. The cover of lichens and Bog Mosses (*Sphagnum* spp.) is generally good and the scarce species, *S. imbricatum, S. fuscum* and *S. pulchrum* occur.

A large flush area occurs in the centre of the bog dome. The main body of the flush supports an extensive area of bog woodland. This habitat is also listed as a priority Annex I habitat under the EU Habitats Directive and is an extremely rare Irish woodland type. The woodland is well-developed structurally and contains a diverse range of plant species. It is dominated by Birch (*Betula* sp.) with some Willow (*Salix* sp.) occurring, and with an understorey of tussocky Purple Moor-grass (*Molinia caerulea*). Bog Myrtle (*Myrica gale*) occurs in places. Three areas of coniferous plantation have been included within the site for hydrological reasons.

The Breedoge River, which marks the eastern boundary of the site, adds habitat diversity and is important for wildfowl, including Mallard and Snipe.

23.1.1997

SITE NAME: GARRISKIL BOG
SITE CODE: 000679

This raised bog site lies 3 km west of Lough Derravaragh and 3 km east of Rathowen. It is bounded to the southeast and southwest by the rivers Inny and Riffey.

The site has a well developed system of pools and hummocks occupying 25% of the dome. Here, the Bog mosses *Sphagnum imbricatum, S. fuscum* and the moss *Leucobryum glaucum* are important components of the hummocks, frequently crowned by the moss *Racomitrium lanuginosum* and sometimes colonised by Bilberry (*Vaccinium myrtillus*). In the pools *Sphagnum* mosses (*S. auriculatum* var. *auriculatum, S. cuspidatum*), Great Sundew (*Drosera anglica*), White Beak-sedge (*Rhynchospora alba*) and the liverwort *Cladopodiella fluitans* occur. In between the pools and hummocks "quaking" *Sphagnum* moss carpets support Bog Asphodel (*Narthecium ossifragum*). The area of bog away from this system is drier and more uniformly sedge-rich. In the northwest corner of the site, there is a small wet and quaking area dominated by the moss *Sphagnum cuspidatum* and Common Cottongrass (*Eriophorum angustifolium*) with Soft Rush (*Juncus effusus*), Bog Asphodel and Bottle Sedge (*Carex rostrata*) also present. Along the northeast margin a narrow band of fen-grassland occurs.

Old cutaway bog provides an additional habitat where Purple Moor-grass (*Molinia caerulea*) and Heather (*Calluna vulgaris*) dominate, along with Cottongrasses (*Eriophorum angustifolium* and *E. vaginatum*) while in some parts Downy Birch (*Betula pubescens*) woodland is developing.

On and around the hummocks a rich lichen flora, featuring an abundance of the scarce *Cladonia rangiferina*, has developed. Garriskil Bog is, on occasion, used as a refuge by the Greenland White-fronted Goose flock which winters on the large Co. Westmeath lakes. The site is within a breeding territory of a pair of Merlin. Both of these species are of high conservation importance and are listed on Annex I of the EU Birds Directive. Other birds breeding on the site include Snipe, Curlew and Redshank.

In general, human landuse within the site is low, with much of the previous cutaway areas reverting to semi-natural wilderness. Burning in the past has caused damage, with some bare peat exposure evident in places. This is always a very real threat to a bogland habitat. Past drainage of the bog has unfavourably impacted on the site, although many of these drains have now been infilled and blocked. However, a more serious threat is the arterial drainage of the R. Inny. This could result in major and irreversible damage to the hydrological integrity of this raised bog habitat.

Garriskil bog is a very good example of a relatively intact true Midland raised bog characterised by its typical flora. This habitat is increasingly under threat in Ireland. A remarkable and impressive feature of this site is an extensive and well-developed system of pools and hummocks. Garriskil Bog has one of the best developed pool systems of any remaining raised bog in the country and the site is of unique conservation value.

14.1.1997

SITE NAME: RIVER MOY - RAISED BOG SITES
SITE CODE: 002298

This site comprises almost the entire freshwater element of the Moy and its tributaries including both Loughs Conn and Cullin. The system drains a catchment area of 805 sq. km. Most of the site is in Co. Mayo though parts are in west Sligo and north Roscommon. Apart from the Moy itself, other rivers included within the site are the Deel, Bar Deela, Castlehill, Addergoole, Clydagh and Manulla on the west side and the Glenree, Yellow, Strade, Gweestion, Trimogue, Sonnagh, Mullaghanoe, Owengarve, Eighnagh and Owenaher on the east side. The underlying geology is Carboniferous Limestone for the most part though Carboniferous Sandstone is present at the extreme west of the site with Dalradian Quartzites and schists at the south west. Some of the tributaries at the east, the south of Lough Conn and all Lough Cullin are underlain by granite. There are many towns adjacent to but not within the site. These include Ballina, Crossmolina, Foxford, Swinford, Kiltimagh and Charlestown.

The site is a candidate SAC selected for alluvial wet woodlands and raised bog, both priority habitats on Annex I of the E.U. Habitats Directive. The site is also a candidate SAC selected for old oak woodlands, degraded raised bog and *Rhynchosporion*, all habitats listed on Annex I of the E.U. Habitats Directive. The site is also selected for the following species listed on Annex II of the same directive – Atlantic Salmon, Otter, Sea and Brook Lamprey and White-clawed Crayfish.

On higher ground adjacent to the woodlands is blanket bog with scattered shrubs and trees on the drier areas. The rocky knolls often bear Juniper (*Juniperus communis*) or Gorse (*Ulex europaeus*), with some unusual rare herb species such as Intermediate Wintergreen (*Pyrola media*) and Lesser Twayblade (*Listera cordata*).

Within the site are a number of raised bogs including those at Kilgarriff, Gowlaun, Derrynabrock, Tawnaghbeg and Cloongoonagh. These are examples of raised bogs at the north-western edge of the spectrum and possesses many of the species typical of such in Ireland, including an abundance of Bog Asphodel (*Narthecium ossifragum*), Carnation Sedge (*Carex panicea*) and the moss *Campylopus*

atrovirens. Some of the bogs include significant areas of active raised bog habitat. Well developed pool and hummock systems with quaking mats of bog mosses (*Sphagnum* spp.), Bog Asphodel (*Narthecium ossifragum*) and White Beaked-sedge (*Rhynchospora alba*) are present. Many of the pools contain a diversity of plant species, including Bogbean (*Menyanthes trifoliata*), the bog moss *Sphagnum cuspidatum*, *Campylopus atrovirens*, Common Cottongrass (*Eriophorum angustifolium*), Great Sundew (*Drosera anglica*) and occasional Lesser Bladderwort (*Utricularia minor*). Several of the hummock-forming mosses (*Sphagnum fuscum* and *S. imbricatum*) which occur here are quite rare in this region and add to the scientific interest of the bogs within the overall site.

Depressions on the bogs, pool edges and erosion channels, where the vegetation is dominated by White Beaked-sedge (*Rhynchospora alba*) comprise the habitat *Rhynchosporion*. Associated species in this habitat at the site include Bog Asphodel, Sundews, Deergrass (*Scirpus cespitosus*) and Carnation Sedge.

Degraded raised bog is present where the hydrology of the uncut bogs, has been affected by peat cutting and other land use activities in the surrounding area such as afforestation and associated drainage and also by the Moy arterial drainage. Species typical of the active raised bog habitat are still present but the relative abundance of them is different. A typical example of the degraded habitat, where drying has occurred at the edge of the high bog, contains an abundance and more uniform cover of Ling Heather (*Calluna vulgaris*), Carnation Sedge, Deergrass and sometimes Bog-myrtle (*Myrica gale*). Occurring in association with the uncut high bog are areas of wet regenerating cutover bog with species such as Common Cottongrass, bog mosses and Sundew, while on the drier areas, the vegetation is mostly dominated by Purple Moor-grass (*Molinia caerulea*). Natural regeneration with peat-forming capability will be possible over time with some restorative measures.

Drainage of the Moy in the 60s lowered the level of the lakes, exposing wide areas of stony shoreline and wet grassland, which are liable to flooding in winter. This increased the habitat diversity of the shoreline and created a number of marginal wetlands, including fens and marshes. Plant species of note in the lake-margin include Heath Cudweed (*Omalotheca sylvatica*), Great Burnet (*Sanguisorba officinalis*) and Irish Lady's-tresses (*Spiranthes romanzoffiana*). These three species are listed on the Irish Red Data list and are protected under the Flora Protection Order 1999.

Other habitats present within the site include wet grassland dominated by Rushes (*Juncus* spp.) grading into species-rich marsh in which sedges are common. Among the other species found in this habitat are Yellow Iris (*Iris pseudacorus*), Water Mint (*Mentha aquatica*), Purple Loosestrife (*Lythrum salicaria*) and Soft Rush (*Juncus effusus*).

Grey Willow (*Salix cinerea*) scrub and pockets of wet woodland dominated by Alder (*Alnus glutinosa*) have become established in places throughout the site. Ash (*Fraxinus excelsior*) and Birch (*Betula pubescens*) are common in the latter and the ground flora is typical of wet woodland with Meadowsweet (*Filipendula ulmaria*), Angelica (*Angelica sylvestris*), Yellow Iris, Horsetail (*Equisetum* spp.) and occasional tussocks of Greater Tussock-sedge (*Carex paniculata*).

The Moy system is one of Ireland's premier salmon waters and it also encompasses two of Ireland's best lake trout fisheries in Loughs Conn and Cullin. Although the Atlantic Salmon (*Salmo salar*) is still fished commercially in Ireland, it is considered to be endangered or locally threatened elsewhere in Europe and is listed on Annex II of the Habitats Directive. The Moy is a most productive catchment in salmon terms and this can be attributed to its being a fingered system with a multiplicity of 1^{st} to 5^{th} order tributaries which are large enough to support salmonids < 2 years of age while at the same time being too small to support significant adult trout numbers and are therefore highly productive in salmonid nursery terms.

The Moy has been arterially dredged in the 60s. Water levels have been reduced since that time. This is particularly evident along the shores of Loughs Conn and Cullin and in the canal-like appearance of some river stretches. Ongoing maintenance dredging is carried out along stretches of the river system where the gradient is low. This is extremely destructive to salmonid habitat in the area.

The site supports populations of several species listed on Annex II of the EU Habitats Directive, and habitats listed on Annex I of this directive, as well as examples of other important habitats. The

presence of a fine example of broad-leaved woodland in this part of the country increases the overall habitat diversity and adds to the ecological value of the site as does the presence of the range of nationally rare and Red Data Book plant and animal species.

16.05.2005

SITE NAME: MOUNT HEVEY BOG
SITE CODE: 002342

Mount Hevey Bog is situated approximately 4 km north-east of Kinnegad, in the townlands of Cloncrave, White Island, Aghamore, Kilwarden and Kilnagalliagh. The Meath-Westmeath county boundary runs through the centre of the bog. The site comprises a raised bog that includes both areas of high bog and cutover bog. The Dublin-Sligo railway runs through the northern part of the bog isolating two northern lobes. The northern lobes are adjacent to the Royal Canal.

The site is a candidate Special Area of Conservation selected for active raised bog, degraded raised bog and Rhynchosporion, habitats that are listed on Annex I of the E.U. Habitats Directive. Active raised bog comprises areas of high bog that are wet and actively peat-forming, where the percentage cover of bog mosses (*Sphagnum* spp.) is high, and where some or all of the following features occur: hummocks, pools, wet flats, *Sphagnum* lawns, flushes and soaks. Degraded raised bog corresponds to those areas of high bog whose hydrology has been adversely affected by peat cutting, drainage and other land use activities, but which are capable of regeneration. The Rhynchosporion habitat occurs in wet depressions, pool edges and erosion channels where the vegetation includes White Beak-sedge (*Rhynchospora alba*) and/or Brown Beak-sedge (*R. fusca*), and at least some of the following associated species, Bog Asphodel (*Narthecium ossifragum*), Sundews (*Drosera* spp.), Deergrass (*Scirpus cespitosus*), Carnation Sedge (*Carex panicea*).

The site consists of a long narrow bog separated into four sub-sections; the larger eastern section supports a wet quaking area with hummock/hollows and pool complex. Hummock/hollow complex also occurs in the south-west lobe and the north-west lobe of the site. An infilled lake is now a soak system. Forestry occurs on the most easterly section of the site. There is abandoned cutover all around this bog and particularly on the western section. There is some wet and actively regenerating areas of the cutover along the southern margins of the western lobe and along the railway.

Much of the high bog has vegetation typical of the Midlands Raised Bog type. The vegetation consists of Ling Heather (*Calluna vulgaris*), Cottongrass (*Eriophorum angustifolium* and *E. vaginatum*), Bog Asphodel, White Beak-sedge and midland indicator species Bog-rosemary (*Andromeda polifolia*) and the bog moss *Sphagnum magellanicum*. The wet quaking area in the eastern section of the bog has pools that support the bog moss *Sphagnum cuspidatum* with White Beak-sedge, Cottongrass and Ling Heather at the edges. The hummock/hollow complex supports a range of hummock-forming bog mosses, including *Sphagnum imbricatum* and *S. fuscum*, as well as other species such as *S. capillifolium, S. magellanicum and S. papillosum*. Other plants found in the hummock/hollow complexes are Bog-rosemary, Cross-leaved Heath (*Erica tetralix*), Bog Asphodel and Deergrass.

The infilled lake is wet and quaking and the vegetation is dominated by Purple Moor-grass (*Molinia caerulea*), Bog-myrtle (*Myrica gale*) and Downy Birch (*Betula pubescens*) with bog mosses *Sphagnum palustre* and *S. papillosum*. The birch trees appear to be between 20 and 30 years old and the Bog Myrtle is over 150 cm high. The edge of the former lake is clearly marked by robust plants of Ling Heather. Some areas of old abandoned cutover bog on the site are very wet and regenerating well, with a good cover of bog mosses, including such species as *Sphagnum cuspidatum, S. papillosum*, *S. capillifolium*, *S. auriculatum* and *S. subnitens.*

Current landuse on the site consists of limited mechanised peat-cutting, mostly on the eastern end of the high bog. There are areas of old peat cuttings all around the site with some very old abandoned regenerating cutover along the edge of the railway. The area to the east of the site has been afforested. Areas of cutover have been reclaimed for agricultural purposes. Damaging activities associated with these landuses include drainage throughout the site (both old and recent) and burning of the high bog.

These are all activities that have resulted in loss of habitat and damage to the hydrological status of the site, and pose a continuing threat to its viability.

Mount Hevey Bog is a site of considerable conservation significance comprising as it does a raised bog, a rare habitat in the E.U. and one that is becoming increasingly scarce and under threat in Ireland. The site supports a good diversity of raised bog microhabitats, including hummock/hollow complexes, pools, flushes and regenerating cutover, as well as a number of scarce plant species. Active raised bog is listed as a priority habitat on Annex I of the E.U. Habitats Directive. Priority status is given to habitats and species that are threatened throughout the E.U. Ireland has a high proportion of the total E.U. resource of this habitat type (over 60%) and so has a special responsibility for its conservation at an international level.

31.10.2002

SITE NAME: MOANVEANLAGH BOG
SITE CODE: 002351

Moanveanlagh Bog is situated in Co. Kerry approximately 6 km east of Listowel, mainly within the townlands of Carhooeara and Bunagarha. The site comprises a raised bog that includes both areas of high bog and cutover bog.

The site is a candidate Special Area of Conservation selected for active raised bog, degraded raised bog and Rhynchosporion, habitats that are listed on Annex I of the E.U. Habitats Directive. Active raised bog comprises areas of high bog that are wet and actively peat-forming, where the percentage cover of bog mosses (*Sphagnum* spp.) is high, and where some or all of the following features occur: hummocks, pools, wet flats, *Sphagnum* lawns, flushes and soaks. Degraded raised bog corresponds to those areas of high bog whose hydrology has been adversely affected by peat cutting, drainage and other land use activities, but which are capable of regeneration. The Rhynchosporion habitat occurs in wet depressions, pool edges and erosion channels where the vegetation includes White Beak-sedge (*Rhynchospora alba*) and/or Brown Beak-sedge (*R. fusca*), and at least some of the following associated species, Bog Asphodel (*Narthecium ossifragum*), Sundews (*Drosera* spp.), Deergrass (*Scirpus cespitosus*), Carnation Sedge (*Carex panicea*).

This is a relatively flat site with some marginal areas that slope relatively steeply towards the cutover. There are a few large hummocks but over much of the site the micro-topography is very uniform. A flush area extends along the north and north-east of the site. In the south-west a bog burst has occurred and concentrically arranged tear pools can be seen, some of which are up to 12 m long. A swallow hole occurs near the middle of the site. Cutover bog occurs around the south-west, south and south-eastern margins of the high bog.

Much of the high bog has vegetation typical of a Western Raised Bog. The vegetation of the high bog is dominated by Bog Asphodel, White Beak-sedge, Cross-leaved Heath (*Erica tetralix*) and Carnation Sedge. Small patches of the moss *Racomitrium lanuginosum* and Common Lousewort (*Pedicularis sylvatica*) occur at the site. Purple Moor-grass (*Molinia caerulea*) is very common in the flush areas. The tear pools are mostly bare of vegetation but some of these do support Bladderwort (*Utricularia* sp.) and the bog mosses *S. cuspidatum* and *S. auriculatum*, with *S. papillosum* and the moss *Campylopus atrovirens* occurring at the pool edges. Towards the margins of the bog Bog-myrtle (*Myrica gale*) is frequent.

Current landuses on the site consist of a small area of peat-cutting at the margins and a low level of grazing by cattle in the north-east section of the high bog. Peat-cutting has significantly declined since the 1970s. Other damaging operations include extensive fire damage, which is still occurring and the dumping of household refuse and cars around the high bog. These are all activities that have resulted in the loss of habitat and damage to the hydrological status of the site, and pose a continuing threat to its viability. This site also suffers from invasive species with Rhododendron (*Rhododendron ponticum*) recorded on the western edge of the site and Pitcher Plant (*Sarracenia purpurea*) forming a large colony.

Moanveanlagh Bog is significant in terms of its geographical location as it is at the extreme south-western range of raised bogs in Ireland. Moanveanlagh Bog is a site of considerable conservation significance comprising as it does a raised bog, a rare habitat in the E.U. and one that is becoming increasingly scarce and under threat in Ireland. This site supports a good diversity of raised bog microhabitats, including flushes. Active raised bog is listed as a priority habitat on Annex I of the E.U. Habitats Directive. Priority status is given to habitats and species that are threatened throughout the E.U. Ireland has a high proportion of the total E.U. resource of this habitat type (over 60%) and so has a special responsibility for its conservation at an international level.

31.10.2002

SITE NAME: MONIVEA BOG
SITE CODE: 002352

Monivea Bog is situated approximately 5 km north-east of Athenry, Co. Galway. It is located in the townlands of Corrantarrmud, Newcastle, Glenaslat and Lenamor. To the east lies the Killaclogher River and to the north a large coniferous plantation. It is located in an area of Karstic limestone.

The site is a candidate Special Area of Conservation selected for active raised bog, degraded raised bog and Rhynchosporion, habitats that are listed on Annex I of the E.U. Habitats Directive. Active raised bog comprises areas of high bog that are wet and actively peat-forming, where the percentage cover of bog mosses (*Sphagnum* spp.) is high, and where some or all of the following features occur: hummocks, pools, wet flats, *Sphagnum* lawns, flushes and soaks. Degraded raised bog corresponds to those areas of high bog whose hydrology has been adversely affected by peat cutting, drainage and other land use activities, but which are capable of regeneration. The Rhynchosporion habitat occurs in wet depressions, pool edges and erosion channels where the vegetation includes White Beak-sedge (*Rhynchospora alba*) and/or Brown Beak-sedge (*R. fusca*), and at least some of the following associated species, Bog Asphodel (*Narthecium ossifragum*), Sundews (*Drosera* spp.), Deergrass (*Scirpus cespitosus*), Carnation Sedge (*Carex panicea*).

The site consists of two higher areas to the north and south with a central depression associated with an extensive flush system. The dome of the bog features a pool/hummock complex including wet, quaking areas. There is also a lake and swallow holes located in the north-west flush and soak system. Cutover is found all around the margins of the high bog and is extensive on the north and eastern margins. Tracks are found on the high bog to allow access for peat-cutting.

The high bog has vegetation typical of the Western Raised Bog type consisting of Carnation Sedge, Ling Heather (*Calluna vulgaris*), Bog Asphodel, Deergrass, the lichen *Cladonia portentosa* and the moss *Racomitrium lanuginosum*. Overall, Deergrass dominates the drier part of the high bog. In the pool/hummock complex on quaking bog, the cover of bog mosses (*Sphagnum* spp.) reaches 75%, consisting mainly of lawns of *Sphagnum cuspidatum*. Elsewhere, *Sphagnum* cover is typically low, ranging from 5-20%. Some pools are algae-dominated, but healthier pools have Hare's-tail Cottongrass (*Eriophorum vaginatum*) and bog mosses (*S. cuspidatum* and *S. auriculatum*). Hummocks consist of the bog mosses *S. fuscum, S. capillifolium* and *S. imbricatum,* with the mosses *Campylopus introflexus* and *Leucobryum glaucum*. Ling Heather and lichens are also found on the hummocks. The bog features a large soak-system in the north-west which originates at the lake. The open water is colonised by Bottle Sedge (*Carex rostrata*), Bogbean (*Menyanthes trifoliata*), Soft Rush (*Juncus effusus*) and Marsh Cinquefoil (*Potentilla palustris*), associated with quaking bog moss lawns. To the south-east of the lake there is a pool surrounded by scraw vegetation, this consists of a quaking mat of mosses (i.e. *Sphagnum cuspidatum, S. recurvum, S. palustre* and *Aulacomnium palustre*), Cranberry (*Vaccinium oxycoccos*), Purple Moor-grass (*Molinia caerulea*) and Bog-sedge (*Carex limosa*). Swallow holes are vegetated by willows (*Salix* spp.), Downy Birch (*Betula pubescens*), Broad Buckler-fern (*Dryopteris dilatata*), Tormentil (*Potentilla erecta*), Honeysuckle (*Lonicera periclymenum*) and Devil's-bit Scabious (*Succisa pratensis*). A number of small flushes with Purple Moor-grass, Bog-myrtle (*Myrica gale*) and bog mosses (*S. imbricatum, S. palustre* and *S. fuscum*) occur around the site. The cutover areas are sparsely vegetated in the north, east and south, and where vegetation occurs it is

dominated by Common Cottongrass (*Eriophorum angustifolium*). The tracks in and around the bog are lined mainly with Gorse (*Ulex europeaus*) and willows with some Birch (*Betula* sp.) and Bracken (*Pteridium aquilinum*). Gorse encroaches onto the high bog at the mid-west of the site.

There is extensive mechanical peat cutting to the north, east and south of the site, and some hand-cutting in the south-west. In places the facebank reaches 3 m in height with associated cracking and slumping. Some of the present high bog drains are new and others have been deepened. Burning events have occurred on the bog in the past and in places the peat remains unvegetated. These are all activities that have resulted in loss of habitat and damage to the hydrological status of the site, and pose a continuing threat to its viability.

Monivea Bog is a site of considerable conservation significance comprising as it does a raised bog, a rare habitat in the E.U. and one that is becoming increasingly scarce and under threat in Ireland. The site supports a diversity of raised bog microhabitats including hummock/hollow complexes, pools, flushes, soak system and open water. Active raised bog is listed as a priority habitat on Annex I of the E.U. Habitats Directive. Priority status is given to habitats and species that are threatened throughout the E.U. Ireland has a high proportion of the E.U. resource of this habitat type (over 60%) and so has a special responsibility for its conservation at an international level.

31.10.2002

SITE NAME: TULLAGHANROCK BOG
SITE CODE: 002354

Tullaghanrock Bog is situated approximately 5 km east of Ballaghaderreen and is located in the townlands of Tullaghan Rock and Creggan, Co. Roscommon. The site comprises a raised bog that includes both areas of high bog and cutover. The southern and eastern margins are bounded by the River Lung and the old Ballaghaderreen railway line adjoins the north-west margin.

The site is a candidate Special Area of Conservation selected for active raised bog, degraded raised bog and Rhynchosporion, habitats that are listed on Annex I of the E.U. Habitats Directive. Active raised bog comprises areas of high bog that are wet and actively peat-forming, where the percentage cover of bog mosses (*Sphagnum* spp.) is high, and where some or all of the following features occur: hummocks, pools, wet flats, *Sphagnum* lawns, flushes and soaks. Degraded raised bog corresponds to those areas of high bog whose hydrology has been adversely affected by peat cutting, drainage and other land use activities, but which are capable of regeneration. The Rhynchosporion habitat occurs in wet depressions, pool edges and erosion channels where the vegetation includes White Beak-sedge (*Rhynchospora alba*) and/or Brown Beak-sedge (*R. fusca*), and at least some of the following associated species, Bog Asphodel (*Narthecium ossifragum*), Sundews (*Drosera* spp.), Deergrass (*Scirpus cespitosus*), Carnation Sedge (*Carex panicea*).

The bog has developed between a ridge and a river and has a domed surface with an undulating pattern of hummocks and pools. There is a small plantation to the south-east of the high bog. To the south and east there is a semi-natural margin between the high bog and the River Lung. Cutover bog occurs around the remaining margins of the high bog in particular on the northern margin where it grades into agricultural land.

Much of the high bog has vegetation typical of the Western Raised Bog type, consisting of Ling Heather (*Calluna vulgaris*), Common Cottongrass (*Eriophorum angustifolium*), Deergrass, Carnation Sedge and the bog moss *Sphagnum magellanicum*. The pools contain the bog mosses *Sphagnum cuspidatum* and *S. auriculatum*) with White Beak-sedge, Bogbean (*Menyanthes trifoliata*) and Great Sundew (*Drosera anglica*). The hummocks are formed by bog mosses such as *S. magellanicum, S. papillosum* and *S. capillifolium*), Ling Heather, Cross-leaved Heath (*Erica tetralix*) and Deergrass. The hummocks also contain support Crowberry (*Empetrum nigrum*), Cranberry (*Vaccinium oxycoccos*) and Round-leaved Sundew (*Drosera rotundifolia*). Where the Lung River forms a natural southern boundary to Tullaghanrock Bog, a strip of wet grassland habitat runs between the bog and the river. Common species found here include Tufted Hair-grass (*Deschampsia cespitosa*), Creeping Bent-grass

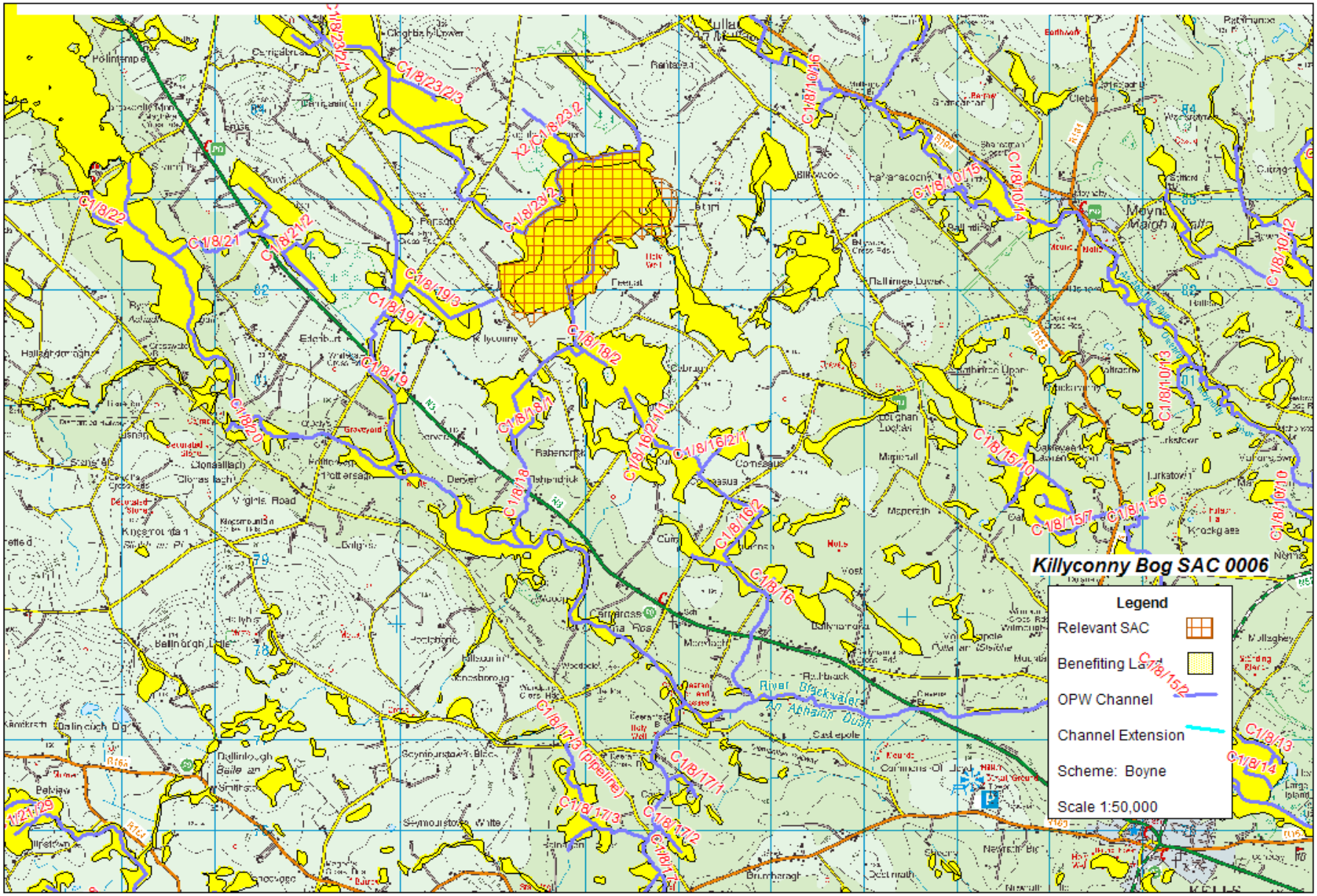
(*Agrostis stolonifera*), Meadow Fox-tail (*Alopecurus pratensis*), Meadowsweet (*Filipendula ulmaria*) and Wild Angelica (*Angelica sylvestris*). In the south-west there is active regeneration of cutover, with extensive patches of the bog moss *Sphagnum cuspidatum* and Common Cottongrass occurring here. Other areas of old cutover bog now support Purple Moor-grass (*Molinia caerulea*) and Gorse (*Ulex europaeus*).

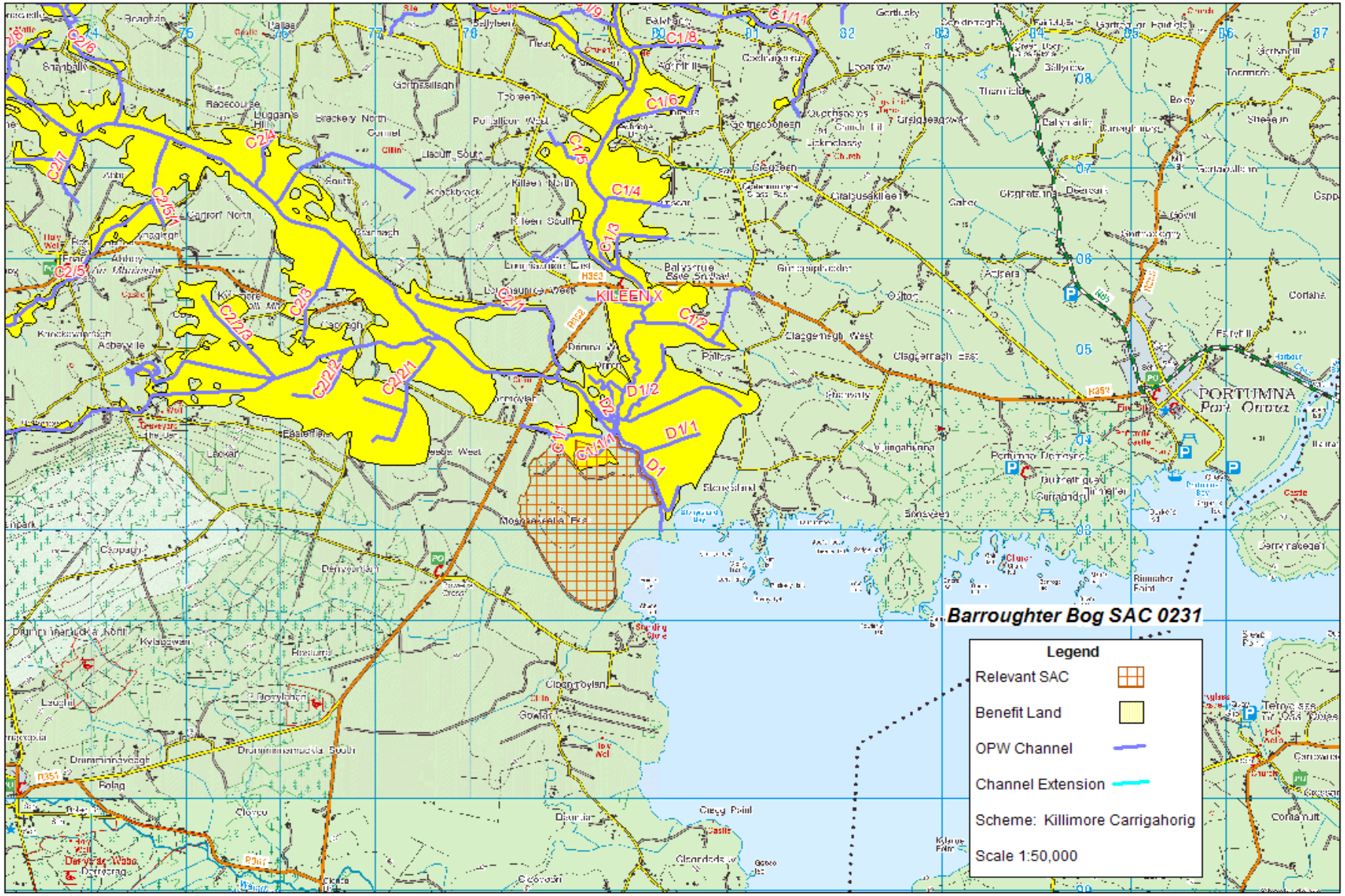
Current landuse on the site consists of a small forestry plantation on the south-eastern high bog and another on the western margin. Areas of cutover have been reclaimed for agricultural grassland on the west and north-west margins and agricultural grazing occurs on the southern boundary. Peat-cutting no longer occurs on this site. While most of the drains are old and infilling, there are new deep drains around the forestry.

Tullaghanrock Bog is a site of considerable conservation significance comprising as it does a raised bog, a rare habitat in the E.U. and one that is becoming increasingly scarce and under threat in Ireland. This site supports a good diversity of raised bog microhabitats, including hummock/hollow complexes, pools, flushes and regenerating cutover. Active raised bog is listed as a priority habitat on Annex I of the E.U. Habitats Directive. Priority status is given to habitats and species that are threatened throughout the E.U. Ireland has a high proportion of the total E.U. resource of this habitat type (over 60%) and so has a special responsibility for its conservation at an international level.

31.10.2002

<u>Appendix 4</u>: "Benefitting" land due to arterial drainage schemes with respect to raised bogs SACs and associated habitats. (OPW database)


Killyconny Bog SAC 0006
Legend
Relevant SAC
Benefiting La
OPW Channel
Channel Extension
Scheme: Boyne
Scale 1:50,000
C1/8/22
C1/8/21
C1/8/21/2
C1/8/23/2/3
C1/8/23/2
C1/8/19/3
C1/8/19/1
C1/8/19
C1/8/20
C1/8/18/2
C1/8/18/1
C1/8/18
C1/8/16/2/1/1
C1/8/16/2/1
C1/8/16/2
C1/8/16
C1/8/16/1
C1/8/17/3 (pipeline)
C1/8/17/1
C1/8/17/2
C1/8/17/3
C1/8/10/16
C1/8/10/15
C1/8/10/14
C1/8/10/12
C1/8/10/13
C1/8/15/10
C1/8/15/7
C1/8/15/6
C1/8/10/10
C1/8/15/2
C1/8/13
C1/8/14
River Blackwater
An Abhainn Dubh


Barroughter Bog SAC 0231
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Killimore Carrigahorig
Scale 1:50,000
KILLEEN X
PORTUMNA
Port Omna
C1/1
C1/2
C1/3
C1/4
C1/5
C1/6
C1/7
C1/8
C1/9
C1/10
C1/11
C2/1
C2/2
C2/2/1
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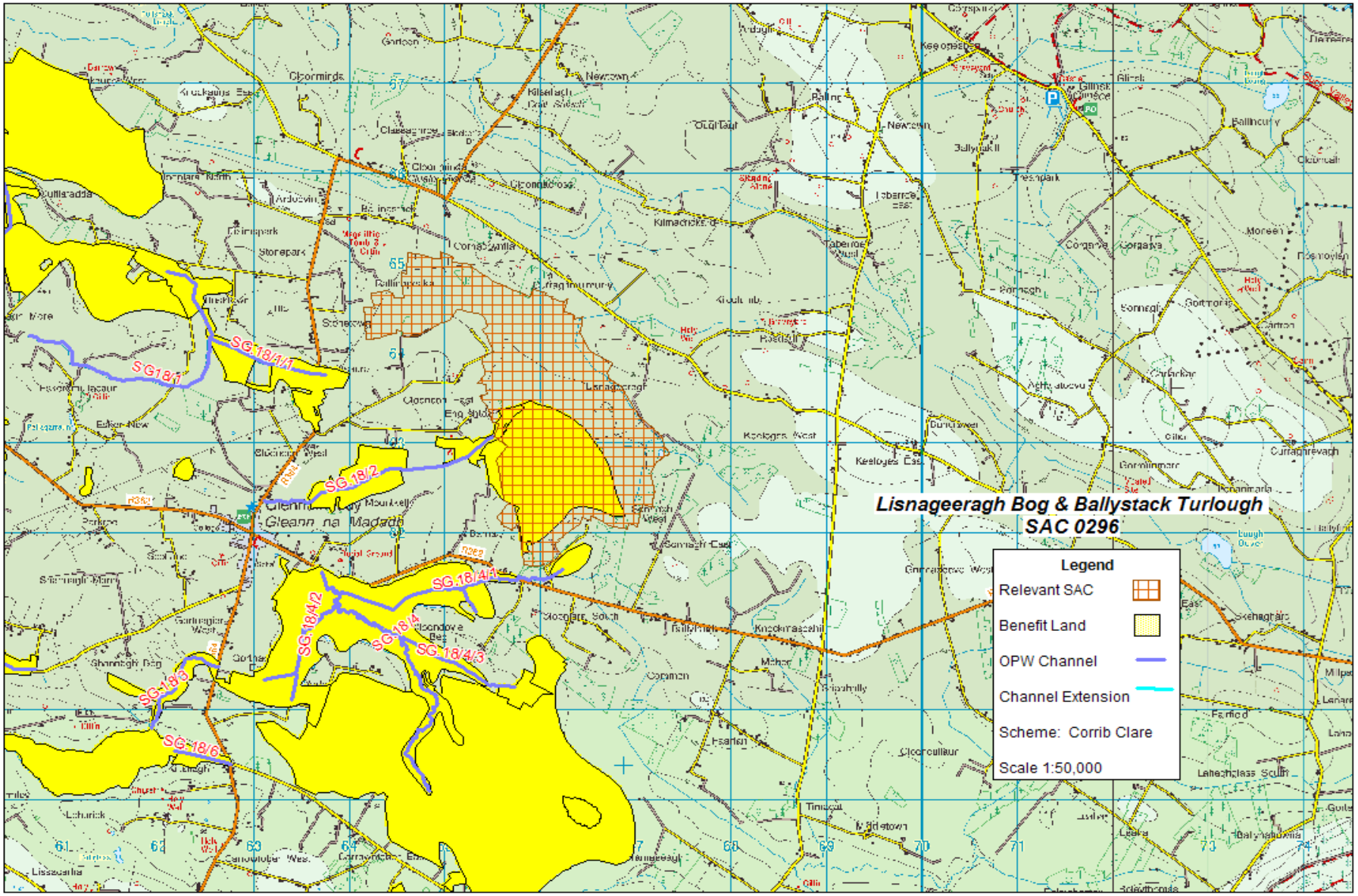
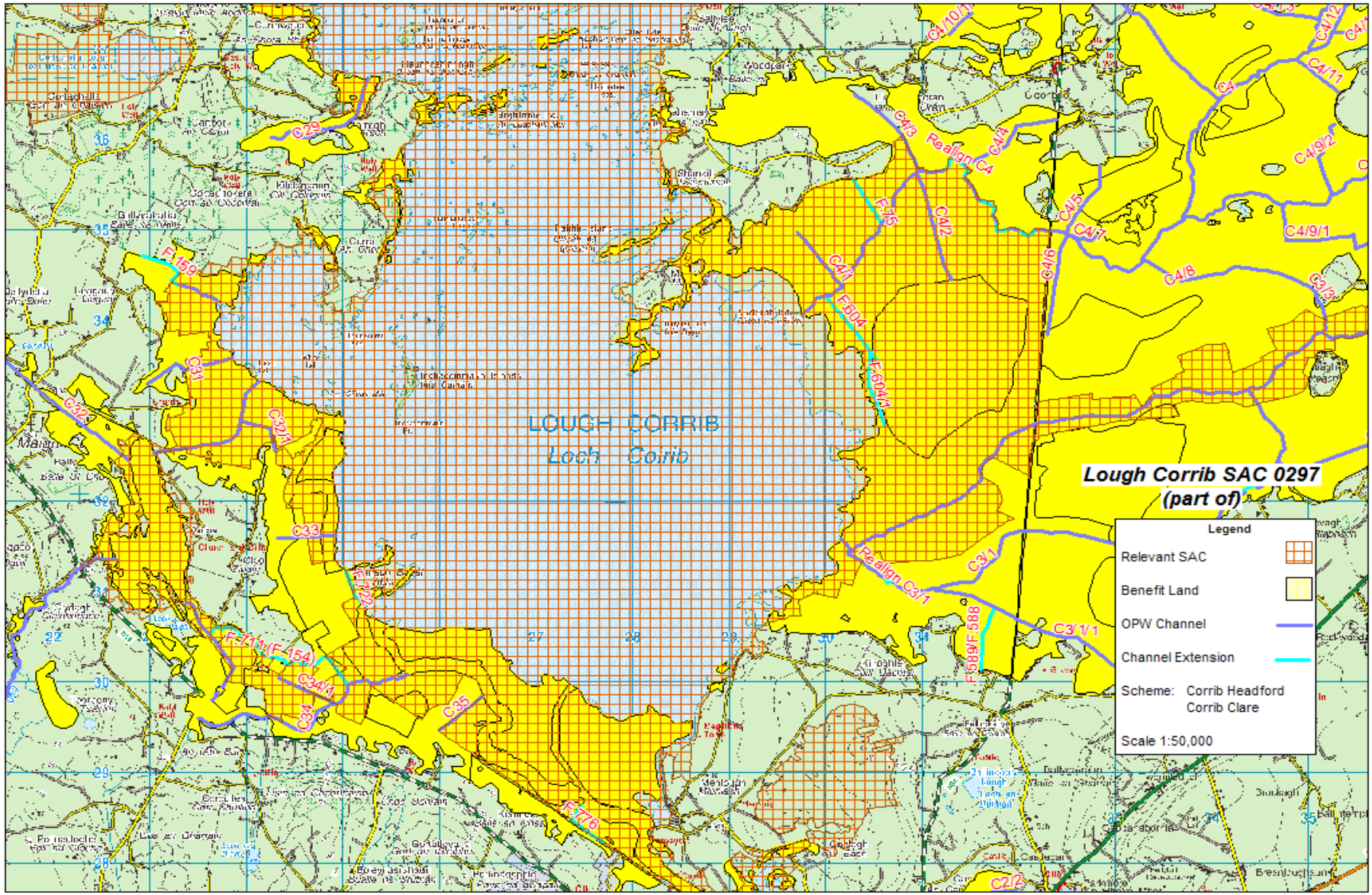
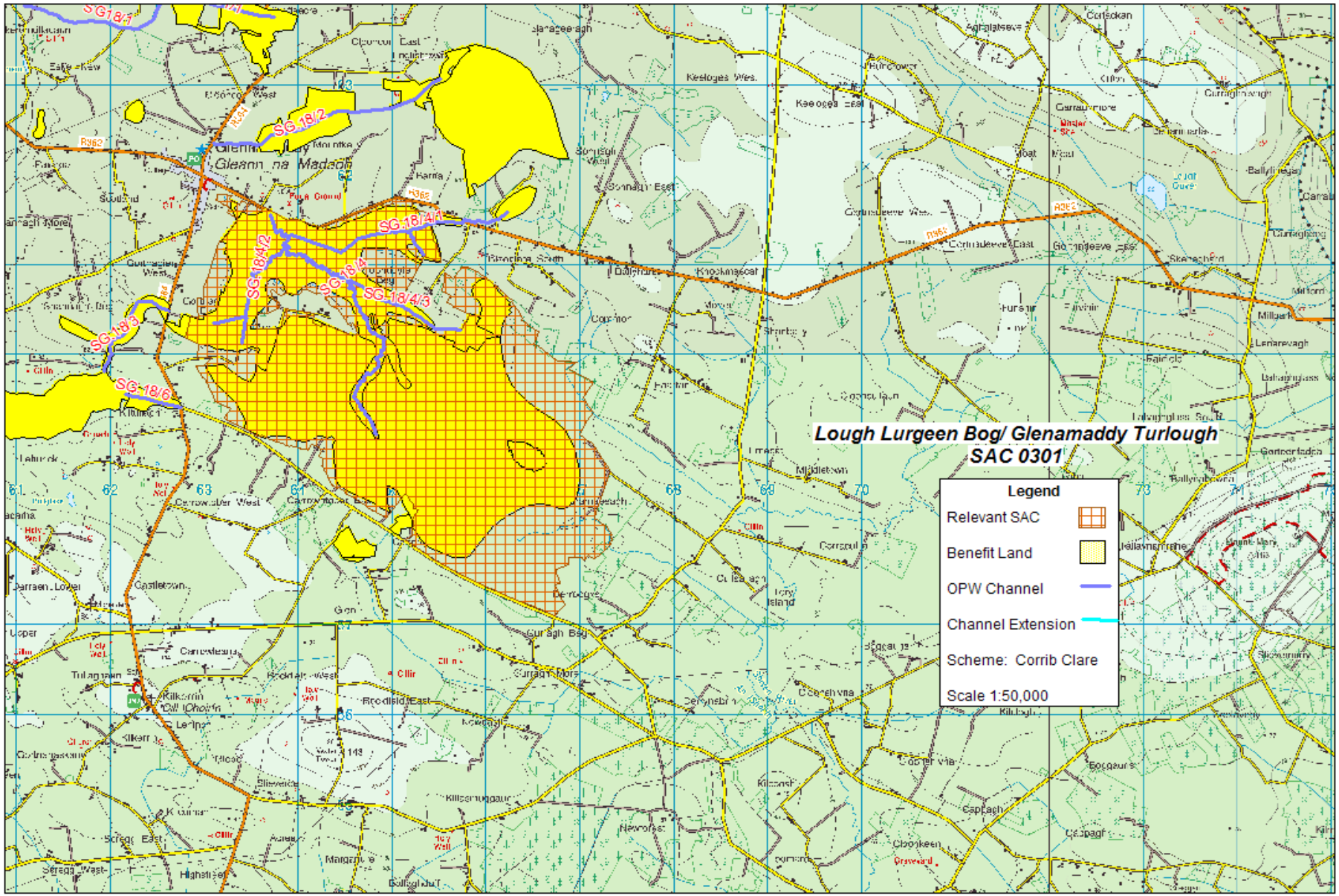
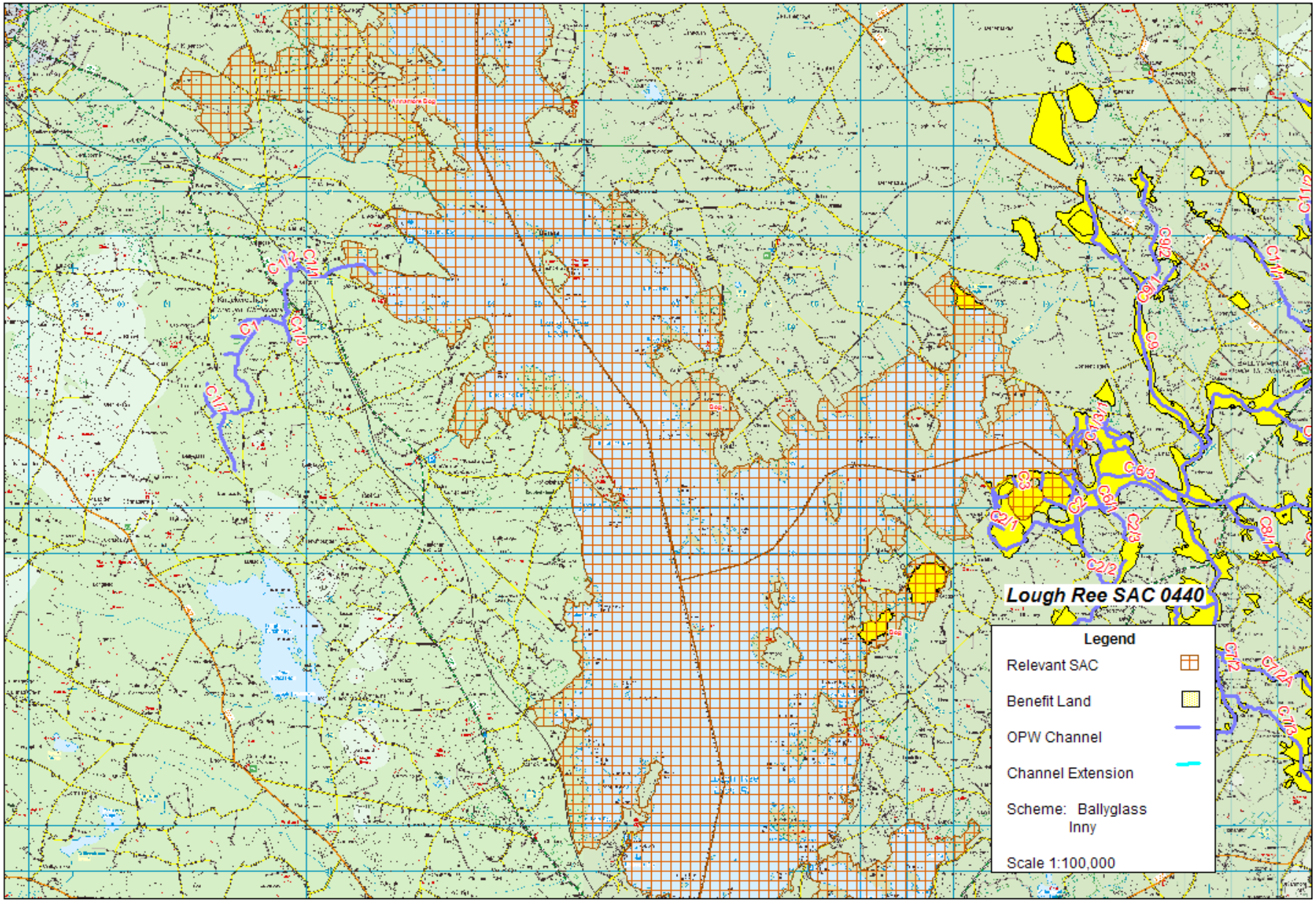
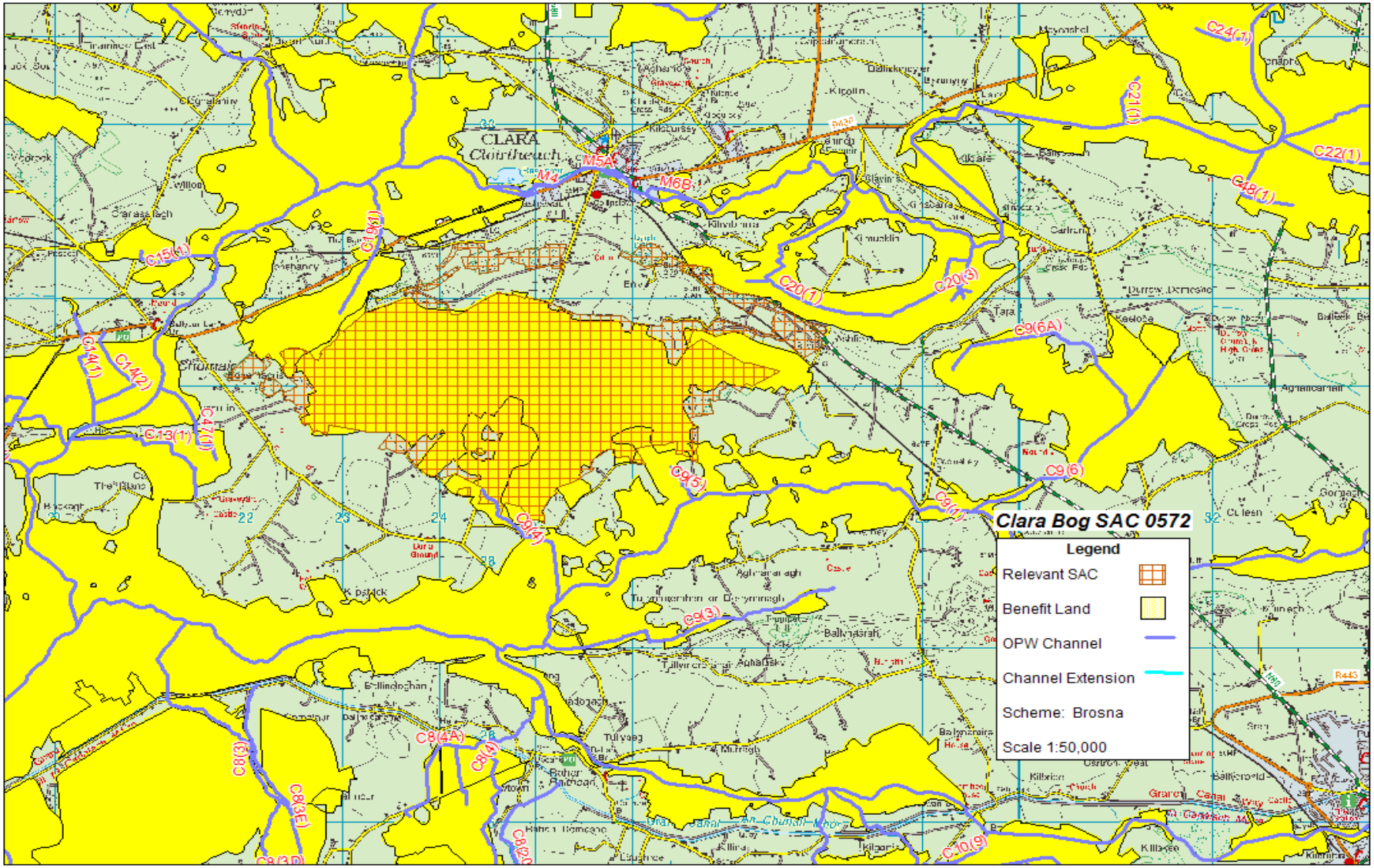
C2/6
C2/7
D1
D1/1
D1/2

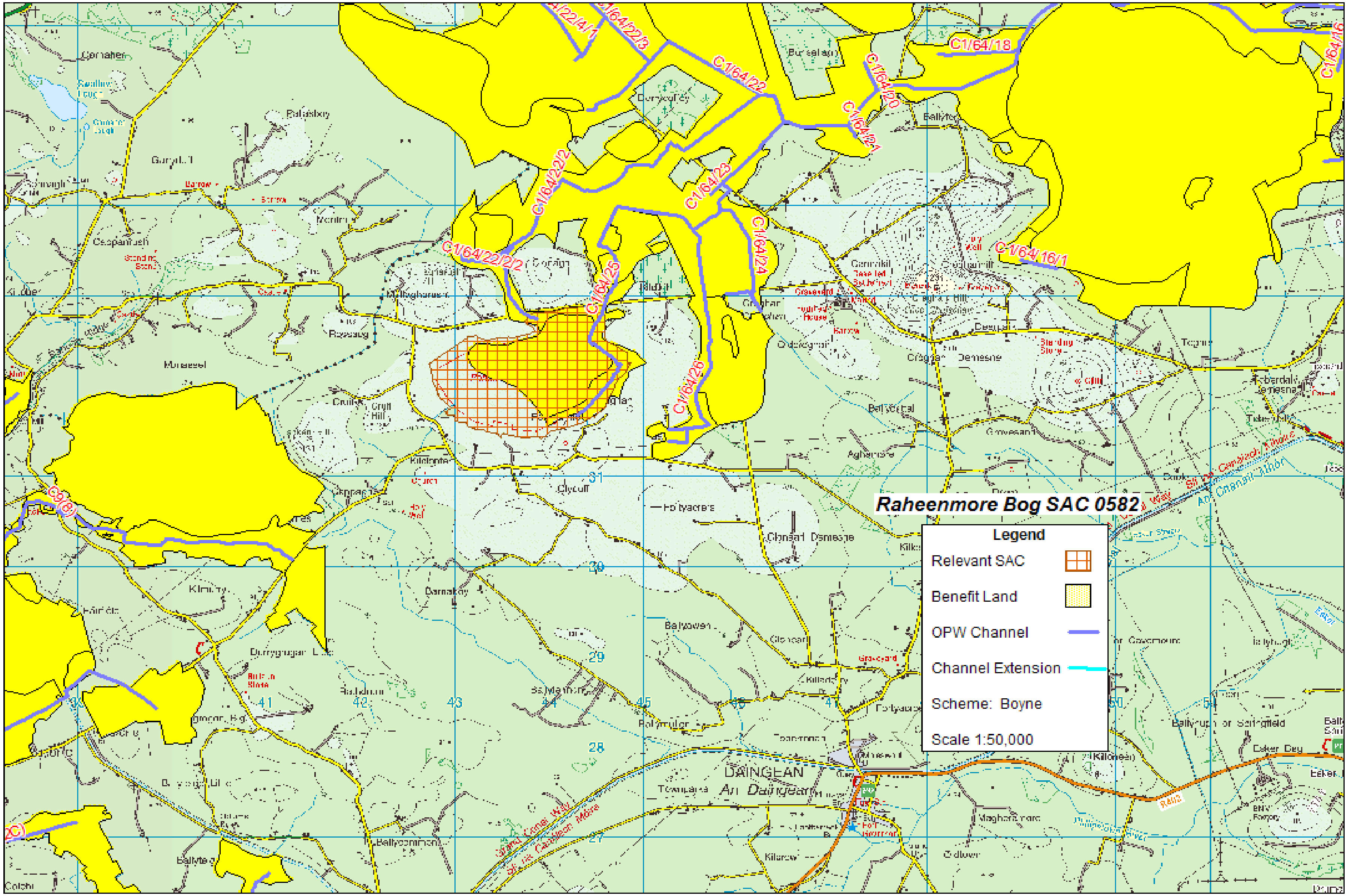

Lisnageeragh Bog & Ballystack Turlough
SAC 0296
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Corrib Clare
Scale 1:50,000
SG18/1
SG18/4/1
SG18/2
SG18/4/1
SG18/4/2
SG18/4
SG18/4/3
SG18/3
SG18/6


LOUGH CORRIB
Loch Coirib
Lough Corrib SAC 0297
(part of)
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Corrib Headford
Corrib Clare
Scale 1:50,000
C29
C31
C32
C32/1
C33
C34
C34/1
C35
C4/10/1
C4/12
C4/11
C4
C4/9/2
C4/9/1
C4/8
C4/3
Realign C4
C4/4
C4/5
C4/7
C4/6
C4/2
C4/1
F.75
F.604
F.604/1
F.159
F.171 (F.454)
F.178
C3/1
Realign C3/1
C3/1/1
F.589/F.588
C212

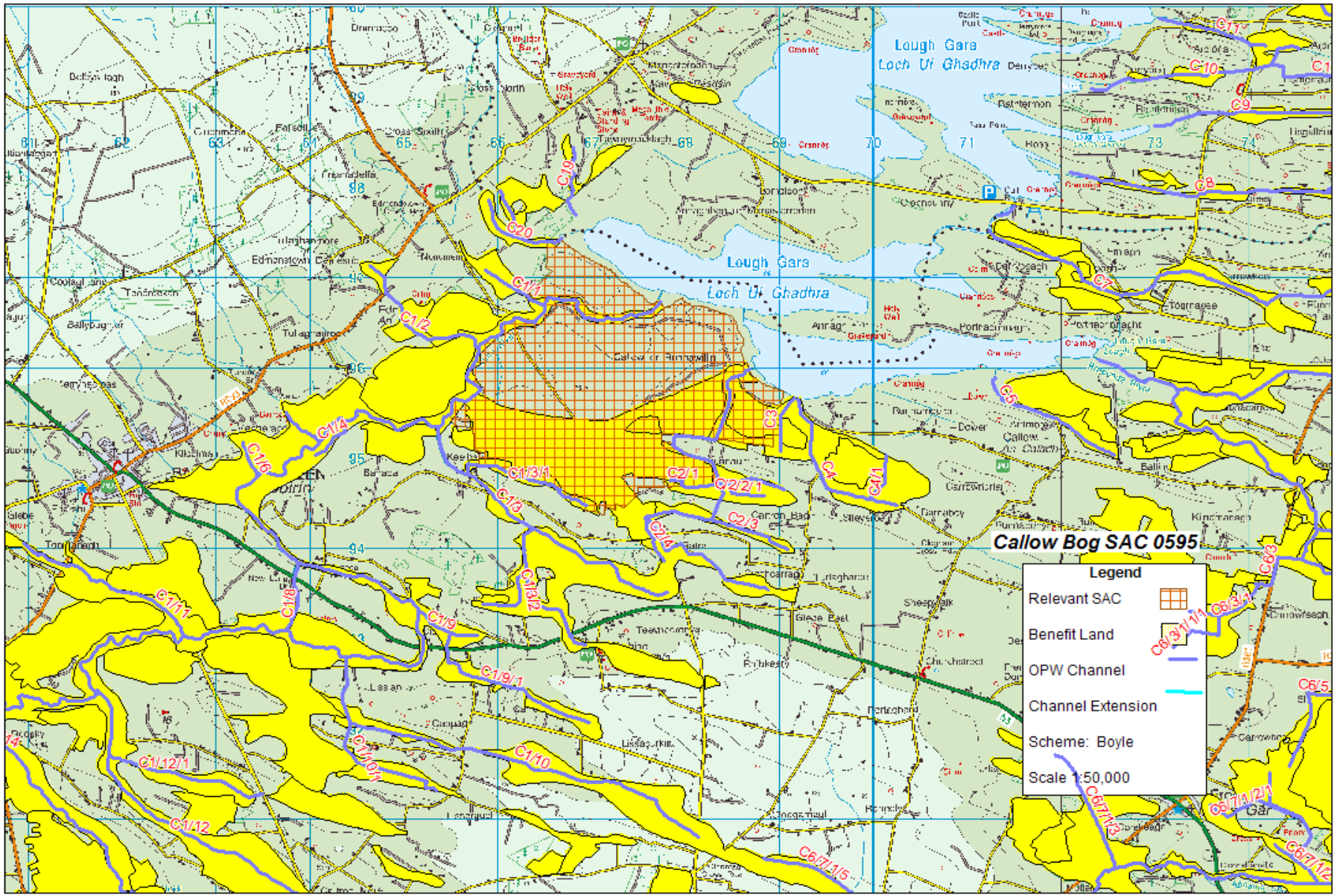

SG 18/1
SG 18/2
SG 18/3
SG 18/4
SG 18/4/1
SG 18/4/2
SG 18/4/3
SG 18/6
Lough Lurgeen Bog/ Glenamaddy Turlough
SAC 0301
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Corrib Clare
Scale 1:50,000

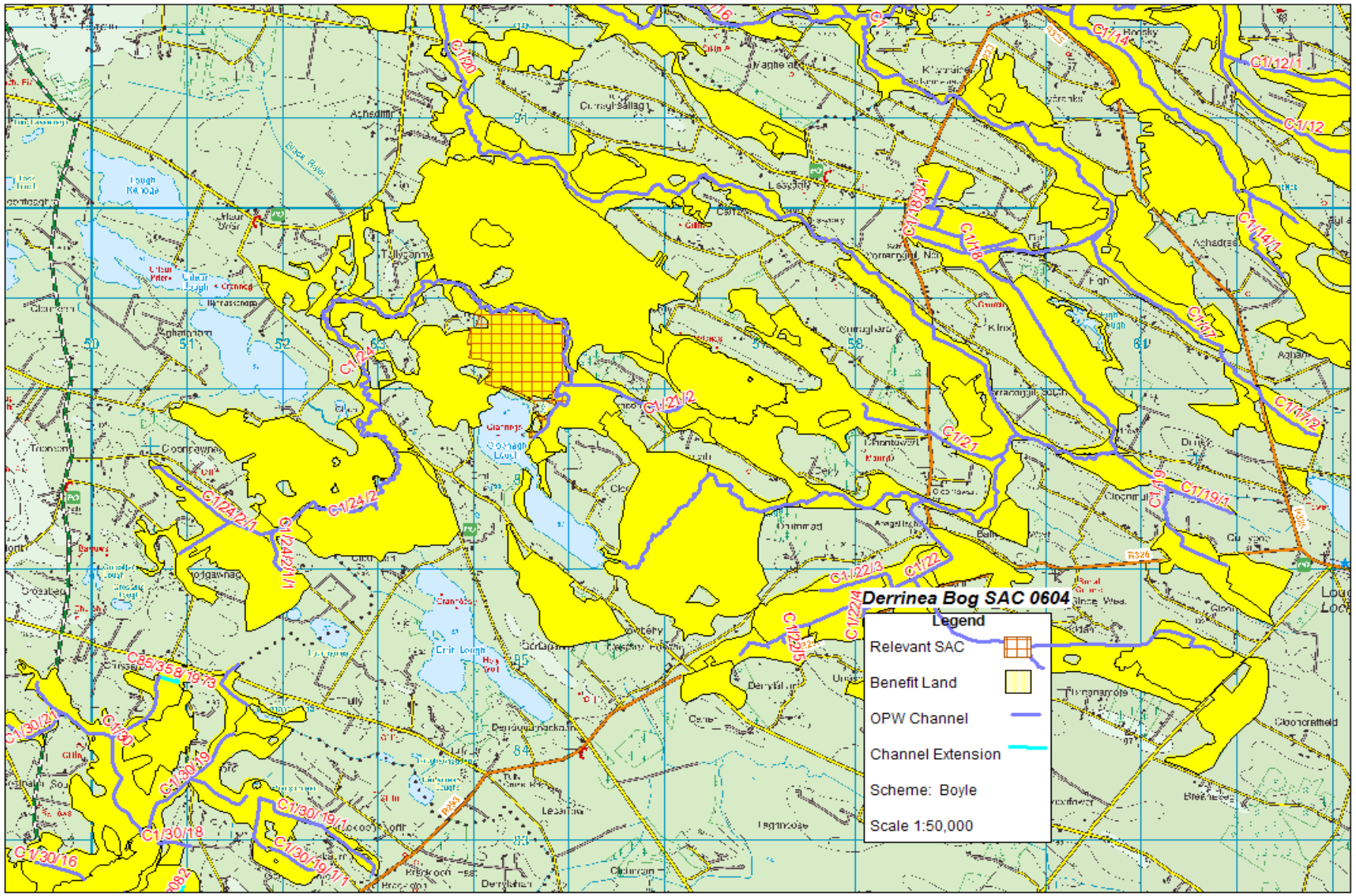

Lough Ree SAC 0440
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Ballyglass
Inny
Scale 1:100,000

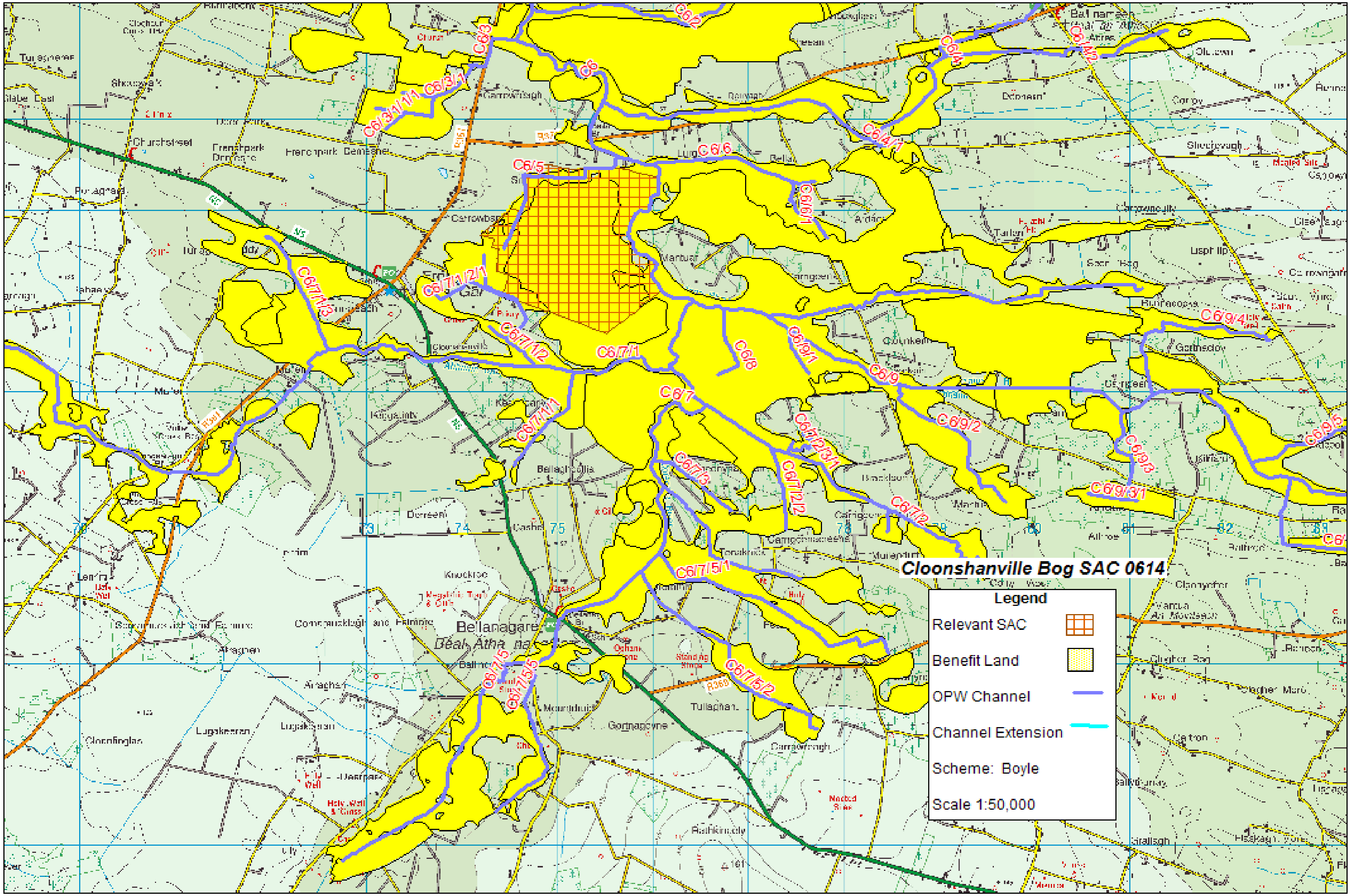

Clara Bog SAC 0572
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Brosna
Scale 1:50,000
CLARA
Clár Iúchair
M4
M5A
M6B
C24(1)
C21(1)
C22(1)
C48(1)
C20(3)
C20(1)
C9(6A)
C9(6)
C9(5)
C9(4)
C9(3)
C9(1)
C19(1)
C15(1)
C14(1)
C14(2)
C13(1)
C47(1)
C8(4A)
C8(4)
C8(3E)
C8(3D)
C10(9)

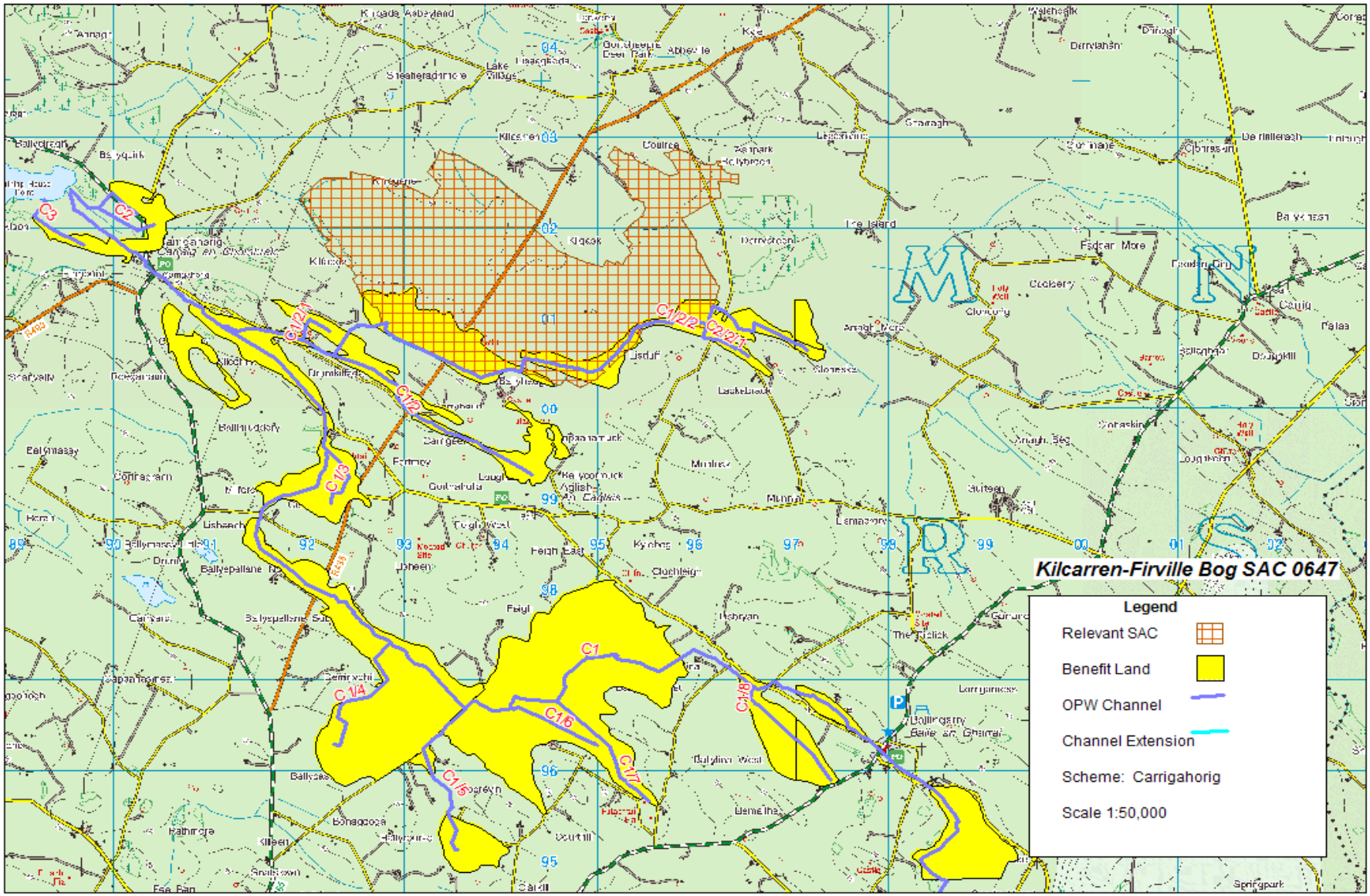


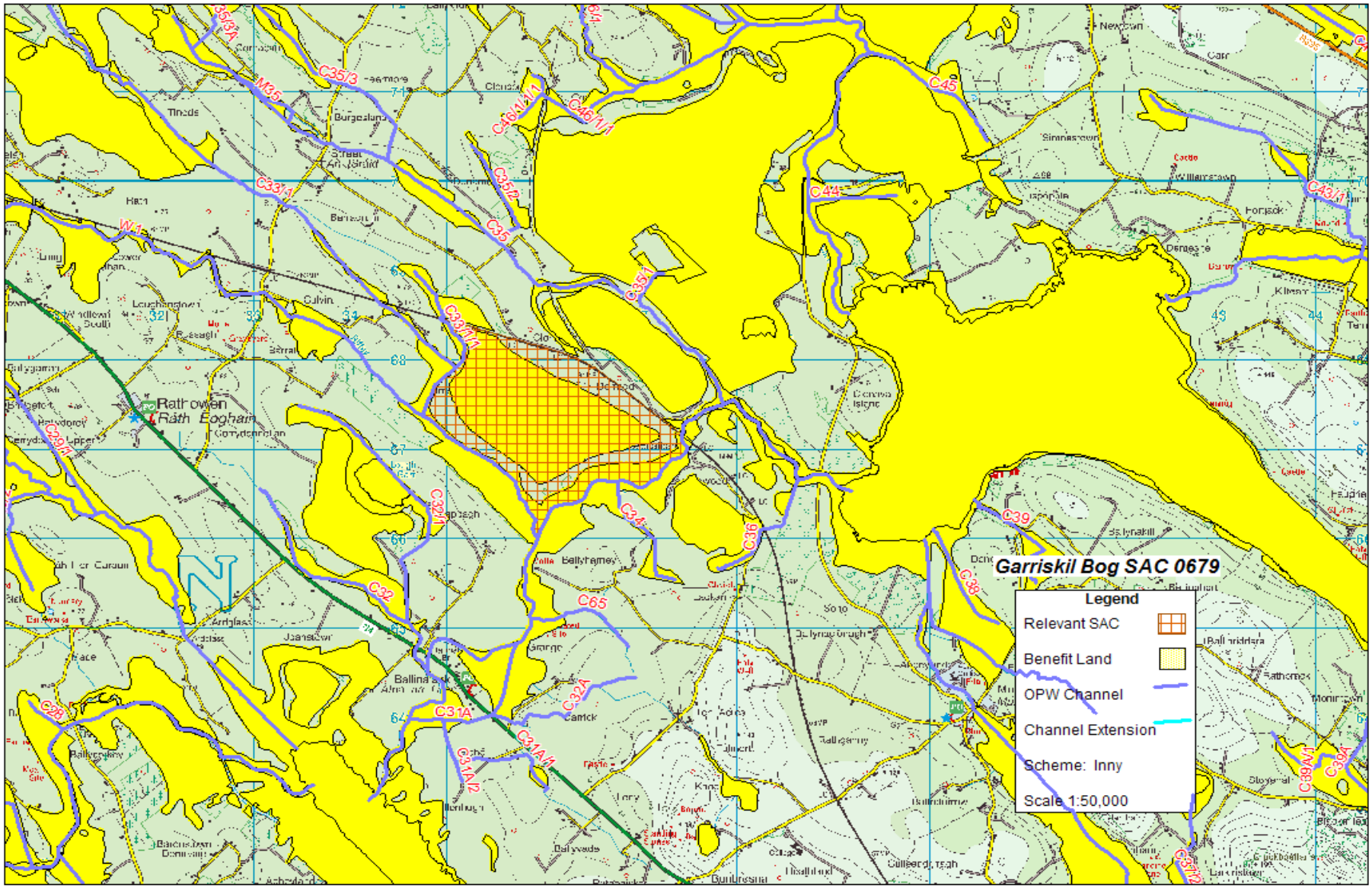
Raheenmore Bog SAC 0582
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Boyne
Scale 1:50,000
C1/64/18
C1/64/20
C1/64/21
C1/64/22
C1/64/23
C1/64/24
C1/64/25
C1/64/26
C1/64/16/1
C1/64/22/2
C1/64/22/2/2
C9(8)
DAINGEAN
An Daingean

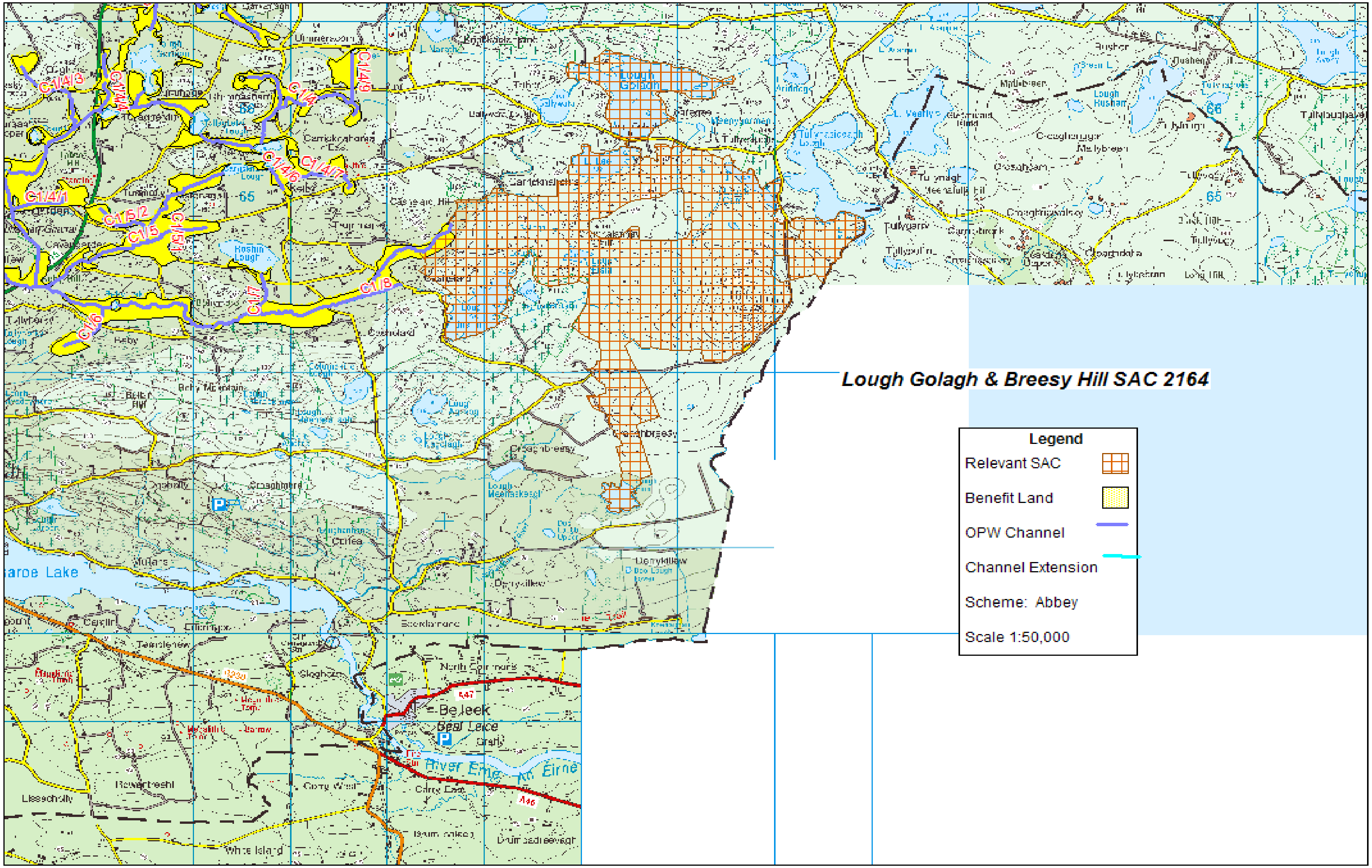

Lough Gara
Loch Uí Ghadhra
Lough Gara
Loch Uí Ghadhra
Callow Bog SAC 0595
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Boyle
Scale 1:50,000

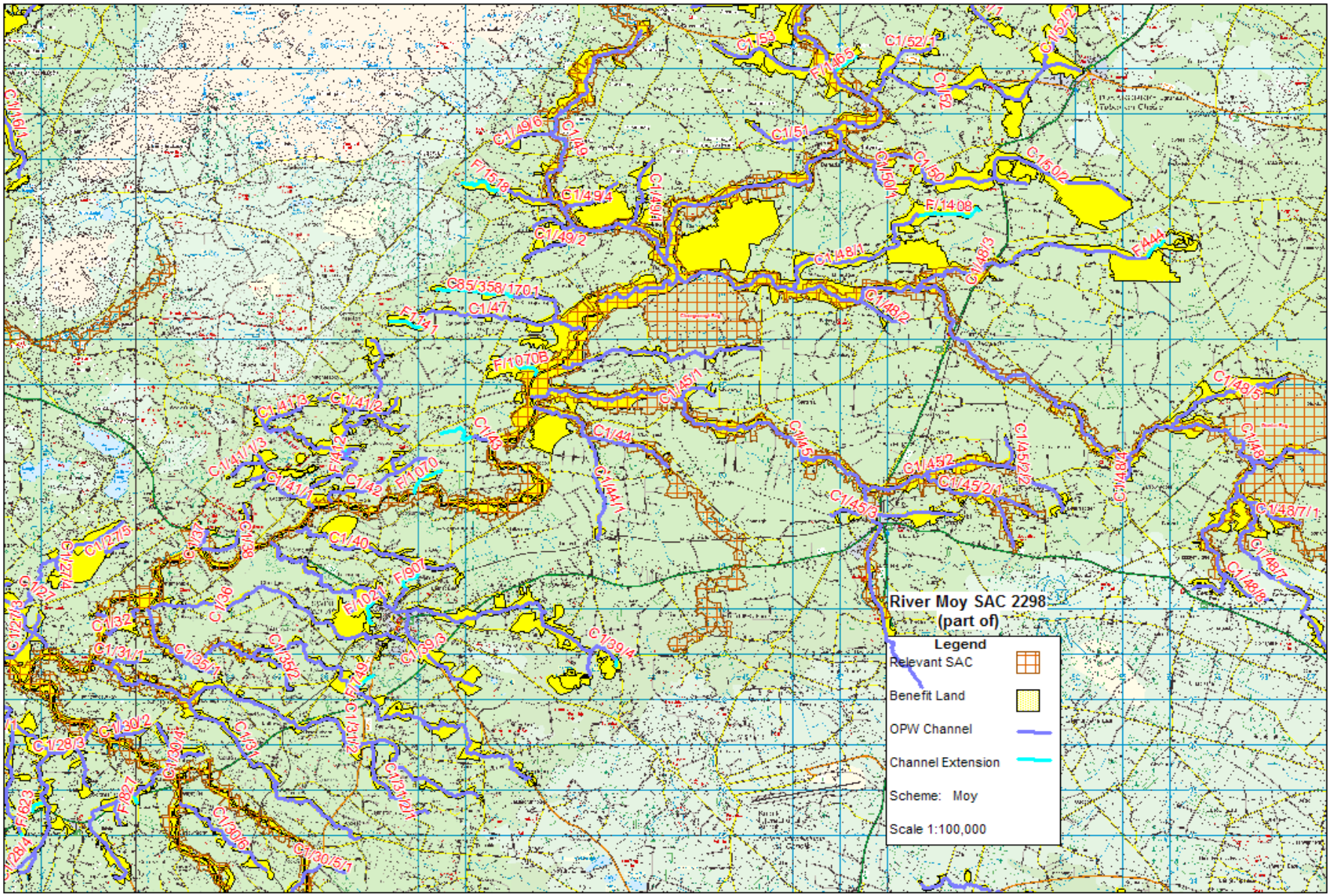

Derrinea Bog SAC 0604
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Boyle
Scale 1:50,000

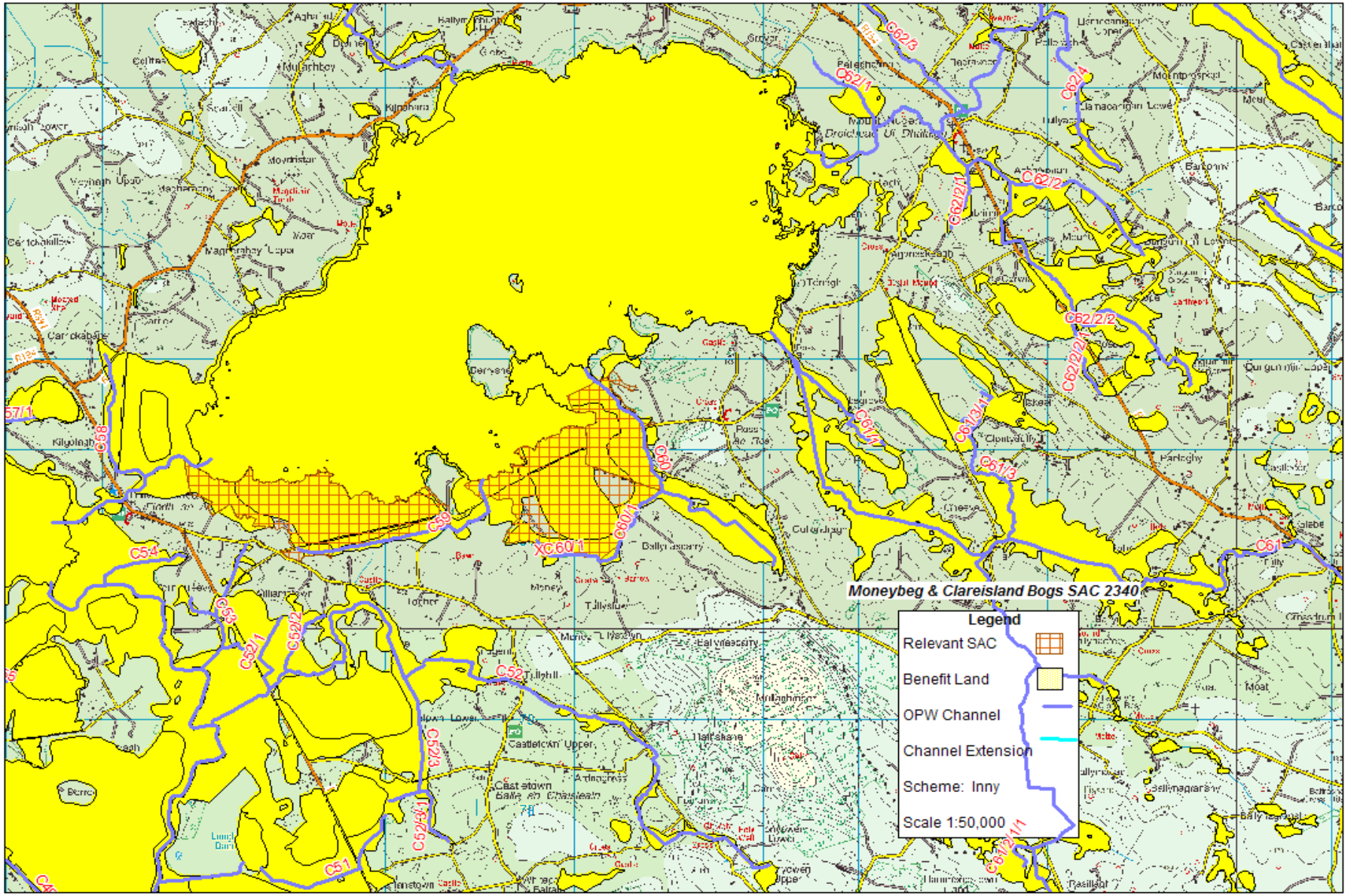

Cloonshanville Bog SAC 0614
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Boyle
Scale 1:50,000
C6/3
C6/3/1
C6/3/1/1/1
C6
C6/2
C6/4
C6/4/2
C6/4/1
C6/5
C6/6
C6/6/1
C6/7
C6/7/1
C6/7/1/1
C6/7/1/2
C6/7/1/2/1
C6/7/1/3
C6/7/2
C6/7/2/2
C6/7/2/3/1
C6/7/3
C6/7/5
C6/7/5/1
C6/7/5/2
C6/7/5/5
C6/8
C6/9
C6/9/1
C6/9/2
C6/9/3
C6/9/3/1
C6/9/4
C6/9/5
Bellanagare
Béal Átha na

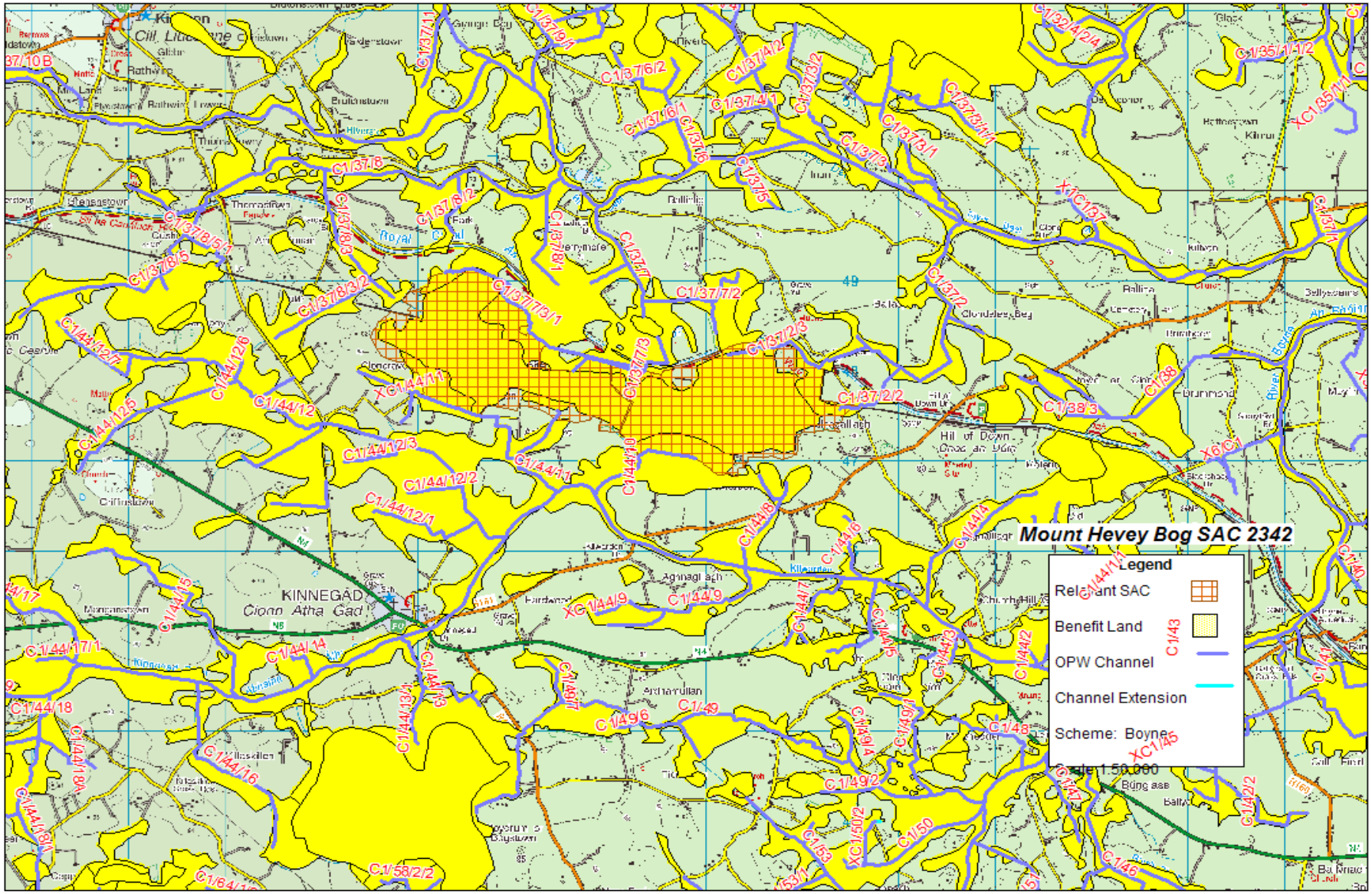

Kilcarren-Firville Bog SAC 0647
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Carrigahorig
Scale 1:50,000
C1
C1/1
C1/2
C1/2/1
C1/2/2
C1/3
C1/4
C1/5
C1/6
C1/7
C2
C2/1
C3

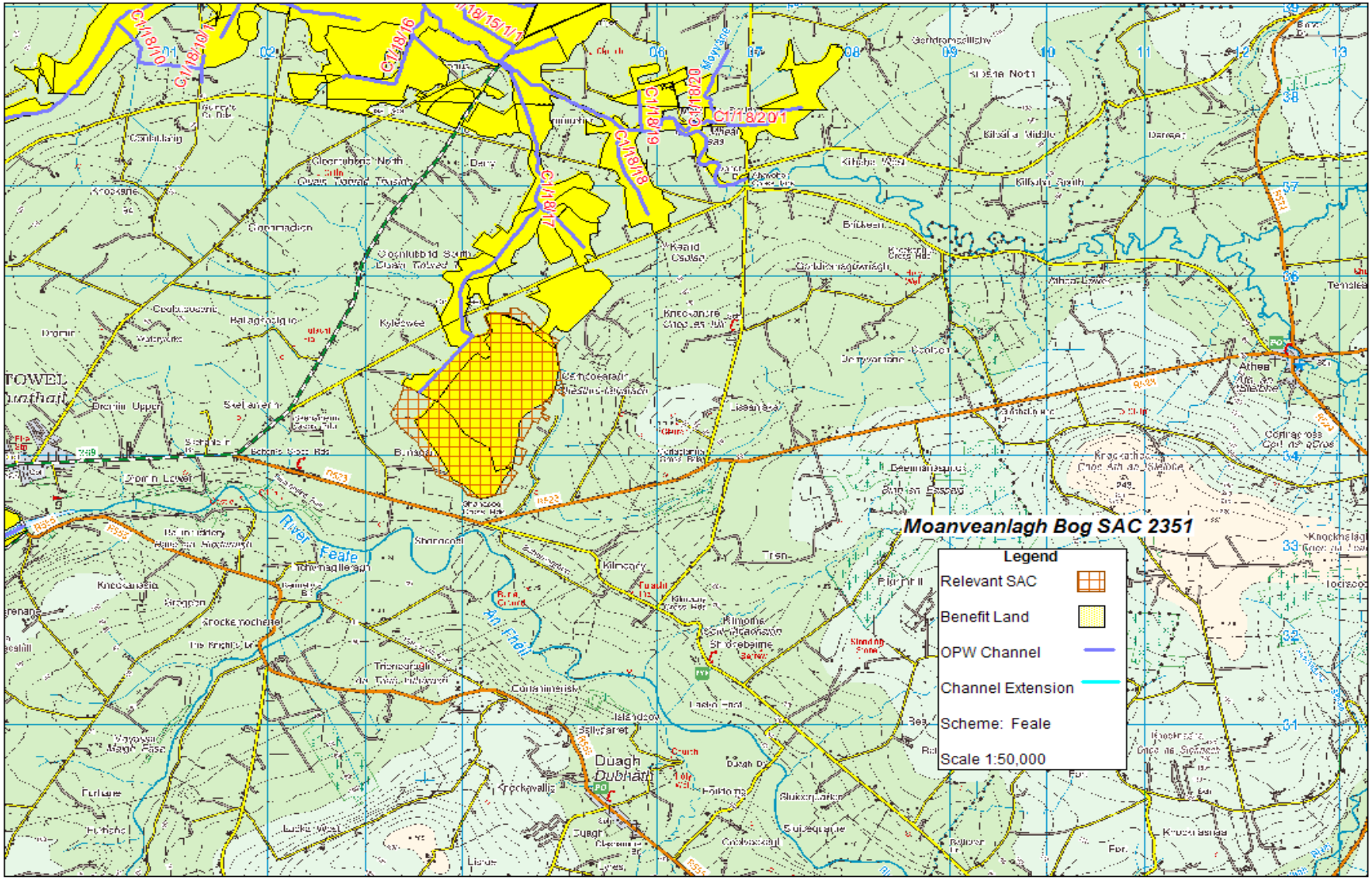

Garriskil Bog SAC 0679
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Inny
Scale 1:50,000
Rathowen
Ráth Eoghain

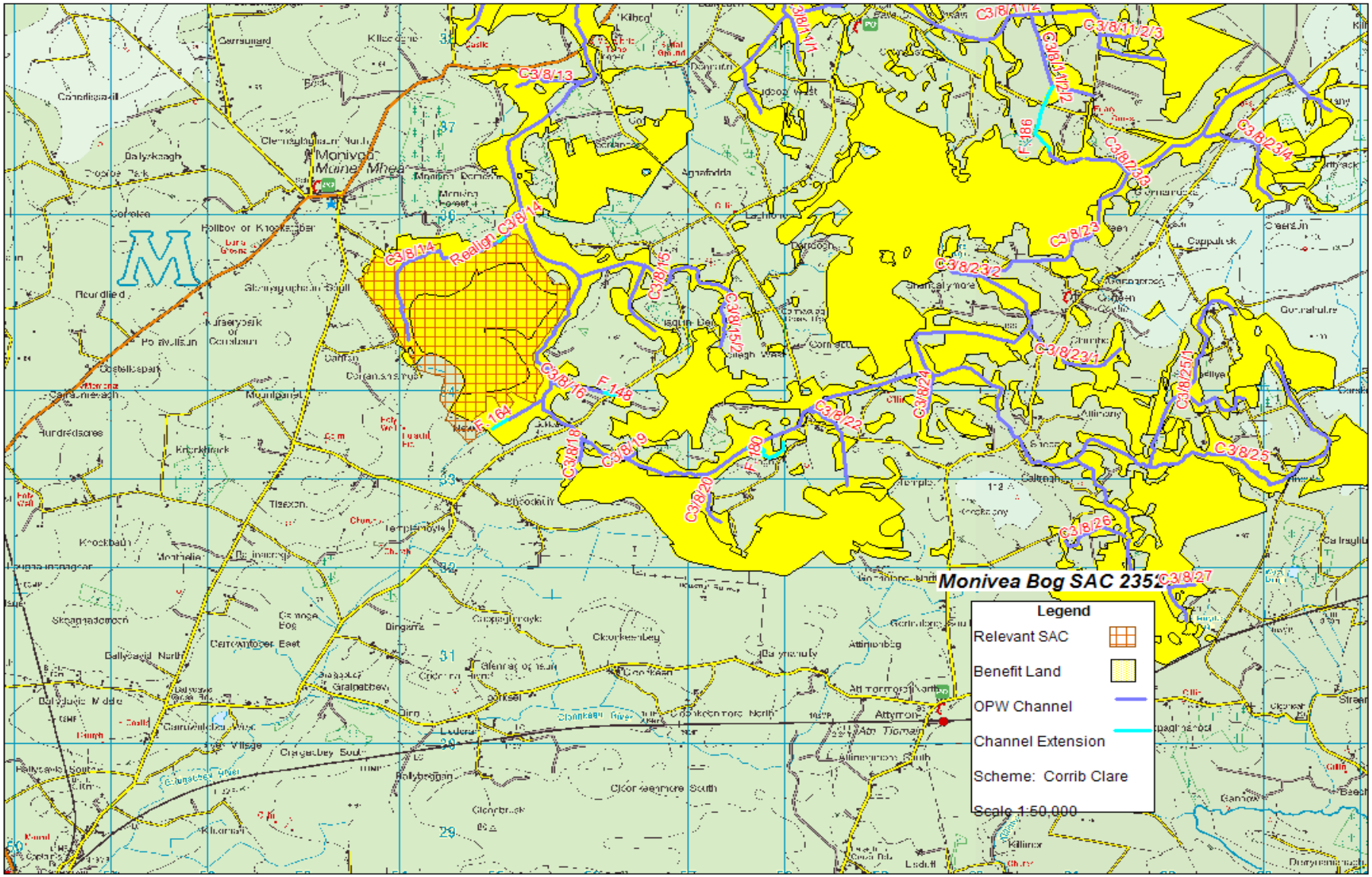

Lough Golagh & Breesy Hill SAC 2164
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Abbey
Scale 1:50,000
C1/4/3
C1/4/4
C1/4
C1/4/9
C1/4/6
C1/4/7
C1/4/1
C1/5/2
C1/5
C1/5/1
C1/7
C1/8
C1/6
Lough Golagh
Belleek
River Erne
Assaroe Lake

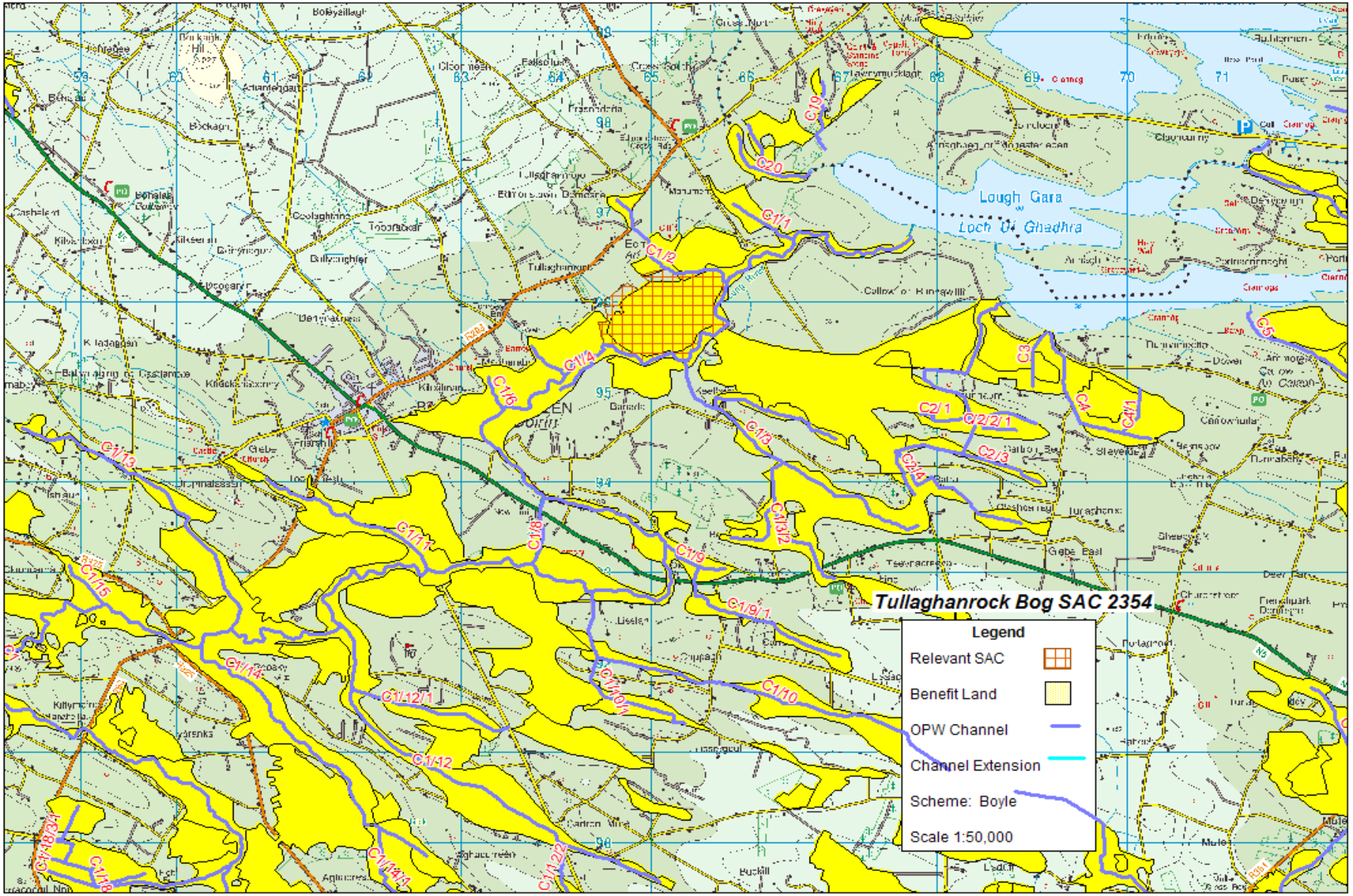

River Moy SAC 2298
(part of)
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Moy
Scale 1:100,000


Moneybeg & Clareisland Bogs SAC 2340
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Inny
Scale 1:50,000


Mount Hevey Bog SAC 2342
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Boyne
Scale 1:50,000
KINNEGAD
Cloonn Atha Gad


Moanveanlagh Bog SAC 2351
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Feale
Scale 1:50,000
River Feale
Duagh
Dubhach
C/118/20
C/118/201
C/118/19
C/118/18
C/118/17
C/118/16
C/118/15/1/1
C/118/10
C/118/11


Monivea Bog SAC 2352
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Corrib Clare
Scale 1:50,000
C3/8/13
C3/8/14
C3/8/15
C3/8/16
C3/8/19
C3/8/20
C3/8/22
C3/8/23
C3/8/24
C3/8/25
C3/8/26
C3/8/27
F.148
F.164
F.180
F.186
Realign
Monivea
Moinéar Mhéa


Tullaghanrock Bog SAC 2354
Legend
Relevant SAC
Benefit Land
OPW Channel
Channel Extension
Scheme: Boyle
Scale 1:50,000
Lough Gara
Loch Ui Ghadhra
C1/1
C1/2
C1/3
C1/4
C1/5
C1/6
C1/7
C1/8
C1/9
C1/9/1
C1/10
C1/10/1
C1/11
C1/11/1
C1/11/2
C1/12
C1/12/1
C1/13
C1/14
C1/14/1
C1/15
C1/16
C1/17
C1/18
C1/18/1
C1/3/2
C19
C20
C2/1
C2/2/1
C2/3
C2/4
C3
C4
C4/1
C5

<u>Appendix 5</u>: Summary of Raised Bog Monitoring Project 2004 - '05.
(Valverde *et al*., 2005)

Available on hard copies only from Environment Section.

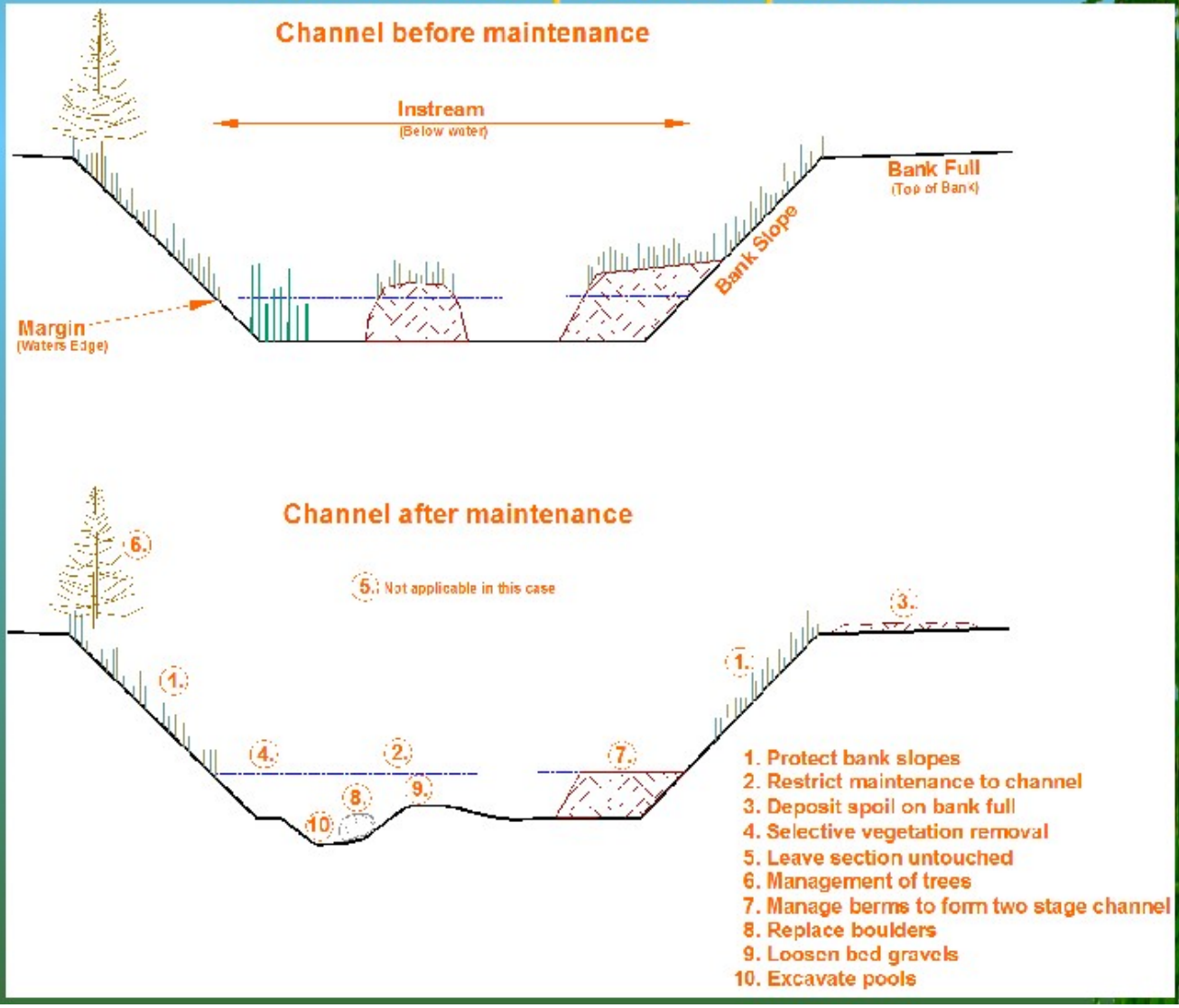
<u>Appendix 6</u>: Environmental Drainage Maintenance guidance notes - 10 steps to environmentally friendly maintenance.

Environmental Drainage Maintenance

Guidance Notes

10 Steps to Environmentally Friendly Maintenance

Sketch with examples of EDM practices



Steps to be carried out as standard procedure

1. **Protect bank slopes**
   - Retain vegetation on non-working bank
   - Minimise scraping of bank slope on working bank
2. **Restrict maintenance to channel**
   - Remove instream material only
   - Retain marginal vegetation
3. **Deposit spoil on bank full**
   - Maximise spoil deposition on bank full or spoil heaps
   - Minimise spoil deposition on bank slopes
4. **Selective vegetation removal**
   - Retain Canary and other marginal grasses
   - Remove Bulrush, Bur-reed and Water celery type vegetation

Steps to be carried out in consultation with Foreman/Technician

1. **Leave sections untouched**
   - If channel capacity is not effected, then leave intact
   - Only maintain if environmental works required
2. **Management of trees**
   - Leave intact if no reduction in channel capacity caused
   - Remove overhanging branches to flood level
   - Use saw or secateurs for removal, not excavator
3. **Manage berms to form two stage channel**
   - Remove top of berms to low flow levels
   - Remove vegetation and soil from gravel berms
   - Replace sod to the berm where feasible
4. **Replace boulders**
   - Reinstate boulders and gravels as removed by maintenance operations
   - Reinstate boulders into channel from spoil heaps
   - Boulders placed below low flow level and staggered

Steps to be carried out in consultation with Fisheries

1. **Loosen bed gravels**
   - Loosen or toss bed gravels to wash out fines
   - Only considered between 1st July and 30th September
2. **Excavate pools**
   - Excavate pools staggered along channel centre and sides
   - Excavated material placed to form adjacent riffles
   - Completed only if channel bed of suitable material

July 2003

Protected Species

Lamprey

Crayfish

Freshwater Pearl Mussel