Environment Agency, Lake District National Park Authority

Environmental Appraisal of Derwentwater Low Water Levels

Volume II: Ecological Appraisal

RKL-Arup *in association with*

Institute of Freshwater Ecology

Environment Agency, Lake District National Park Authority

Derwentwater Low Water Level

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1. INTRODUCTION

RKL-Arup were appointed by the Environment Agency, and the Lake District National Park Authority to undertake a study of Derwentwater Low Water Levels.

The National Park Authority produced a management plan for the lake in 1996. Public consultation for this management plan indicated that the low minimum lake level experienced in 1995 was a cause for concern for the lake users. The Lake District National Park Authority and the Environment Agency therefore commissioned this study to determine if the minimum lake level in Derwentwater was decreasing. The study was also to provide options to manage the minimum lake level and to undertake an environmental appraisal of these options. Studies were undertaken to determine how the ecology, recreational use of the lake, archaeology, agriculture, and landscape would be affected by changes to the minimum lake level. This Environmental Appraisal was undertaken by RKL-Arup working in association with the Institute of Freshwater Ecology and the Smeeden Foreman Partnership.

The study is reported in three volumes.

Volume 1 - Hydrological and Geological Study

Volume 2 - Ecological Appraisal

Volume 3 - Management Options

This report forms Volume 2, the ecological appraisal and is written in conjunction with the Institute of Freshwater Ecology.

The management options listed below are described in more detail in section 6 of this report and Volume 3.

Management Options:

- Do Nothing
- Map and Mark Obstacles
- Dredge Boating Channels
- Permanent Weir
- Temporary Weir
- Maintain at Present Level

1.1 Aims and Objectives

The aim of the appraisal was to assess the relative ecological performance of each management option. In turn, it was intended that options which could lead to an unacceptable deterioration in biological quality were considered carefully in the overall decision-making process, and that mitigation and monitoring measures were formulated to redress adverse effects. This aim was achieved through the following objectives:

- Prepare an inventory of the species and habitats which, both individually and collectively, contribute towards the lake's high nature conservation status
- Define baseline limnology conditions, against which changes in water quality can be assessed
- Define the physico-chemical impacts of each prospective management option upon environmental conditions in and adjacent to the lake

- Evaluate the nature and significance of the physico-chemical impacts upon the species and habitats
- Scope the likely extent of mitigation measures needed to redress ecological impacts, and the monitoring data required to redress current information short-falls.

1.2 Method Statement

This chapter has been prepared through a range of literature review and consultation methods. The evaluation was undertaken by RKL-Arup and the Institute of Freshwater Ecology. Information was obtained through discussions with a variety of statutory and non-statutory consultees, and by reference to published information on ecological surveys in the catchment. Reference was also made to publications in which the broader management of the catchment overlapped with ecological resources, for example, the Lake District National Park's Derwentwater Management Plan. In addition, the Environment Agency and English Nature provided details of relevant surveys which they have commissioned in recent years, and this was supported by citation sheets for statutory designations within the catchment. In summary, the published information consulted during the preparation of this report comprised:

- Summary data from the Derwentwater Macrophyte Survey 1996/97
- Phase 1 Habitat Survey data for the wetland area at the outflow to the River Derwent (Stewart, 1996)
- Derwent and Cumbria Coast Catchment Management Plan - Consultation Report. National Rivers Authority North West Region October 1994
- Derwent and Cumbria Coast Catchment Management Plan - Action Plan. National Rivers Authority North West Region September 1995
- River Derwent and Tributaries SSSI citation sheet
- River Derwent River Corridor Survey data provided by the Environment Agency, dated August 1992.

In addition, personal communications were provided by English Nature, the Lake District National Park Authority, the Environment Agency and Cumbria Wildlife Trust. Their assistance and support in the preparation of this report are gratefully acknowledged. Expert advice on the freshwater biology of Derwentwater was provided by the Institute of Freshwater Ecology's (IFE) specialists and their valuable contribution is also acknowledged.

1.3 Significance Assessment Criteria

The potential ecological effects of a development can be either specific to a particular location, such as habitat loss, or wide ranging such as a fundamental change in water quality. The ecological effects of a scheme may also relate to the construction phase as well as the operational phase. In addition, the effects may be either short-term or long-term, reversible or permanent, and may occur immediately or at some time in the future. Assessing the ecological effects of the scheme has therefore relied upon consultation, concensus-building and professional judgement, with the following questions being posed in arriving at a conclusion:

- Which risk group / biological resource would be affected and in which way?
- Is the effect reversible or irreversible, repairable or non-repairable?
- Do the effects occur over the short-, medium- or long-term?

- Is the effect continuous or temporary, and does it increase or ameliorate through time?
- Are proven mitigation and / or enhancement measures available if required and, if so, how costly are they?

To provide an aid to judging the importance of the different consequences of the proposed options, the above considerations have been employed to define subjective significance assessment criteria. The assessment criteria comprise five ascending levels of importance to the decision-making process, namely:

- None
- Not significant / slight
- Moderate
- Major
- Severe.

Each of the five levels is accompanied by a definition of an assumed relationship to the decision-making process as presented in Table 1.1.

It is important to stress that in the context of the ecological appraisal, the 'do nothing' scenario represents a transient rather than a fixed system, presently characterised by a gradual reduction in absolute minimum water levels.

Table 1.1
Significance Assessment Criteria

Significance Level	Criterion
Severe	These effects are generally, but not exclusively associated with sites and species of national or international importance. Severe effects can be predicted with a high level of certainty. Typically, mitigation measures are either unavailable, or unable to redress fully the losses which might arise. The severe criterion is therefore either long-term or permanent in duration. Severe effects may represent the unrecoverable loss of an individual species, or an impact on a site of national or international importance which compromises the reasons for its designation.
Major	These effects are likely to be important considerations at a regional or district scale. If adverse, they constitute potential concerns to the project which are important factors in the decision-making process. Major effects are either medium- or long-term in duration, and have a medium to high level of probability of occurring. Mitigation measures and detailed design work although available, are unlikely to ameliorate all of the effects upon the receptor habitat or ecological resource.
Moderate	These effects may be important at a district or local scale, but are not likely to be key elements in the decision-making process. Moderate effects, if adverse, are likely to be of short- or medium-term duration. Nevertheless, the cumulative effects of such issues may lead to an increase in the overall impact on a particular resource or material asset. In turn, this may lead to their placement in the category of 'major' effect. They represent issues where effects will certainly be measurable and / or perceptible, but mitigation measures and detailed design work may ameliorate / enhance some of the consequences upon affected communities or resources.
Not significant / slight	Although peripheral to decision-making processes, these effects may be justifiably raised as local issues by interested third parties. They may be of relevance in enhancing the detailed design of a scheme, and in shaping mitigation proposals. These effects, if adverse, are likely to be only of a temporary or short-term nature. Their magnitude, although measurable, will be at the lowest end of the scale relating to magnitude, scope and intensity.
None	No effects, or those which are below levels of perception, within normal bounds of variation, or within the margin of forecasting error. This category also includes effects which are neutral in their influence upon ecological resources, i.e. neither a positive nor negative impact.

1.4 Structure of the Report

This report is arranged into eight sections. Section 2 provides a brief introduction to the site. Section 3 describes and evaluates the aquatic and terrestrial habitats which characterise the lake and its environs. Section 4 provides an insight into the limnology of the lake, to define a baseline against which impacts can be assessed. Section 5 presents the statutory and non-statutory nature conservation designations which have been conferred upon habitats and species. Section 6 summarises the nature of the physico-chemical impacts associated with each option, while Section 7 evaluates the significance of the potential impacts upon the various habitats and species of interest. Section 8 concludes the report with a summary of the key points drawn from the review, and recommendations regarding future work in connection with any future statutory Environmental Assessment.

2. STUDY AREA

Derwentwater is the third largest lake in the Lake District in Cumbria. It is situated south-west of Keswick and is in the Lake District National Park. As shown in Figure 1, Derwentwater is aligned north-south and is approximately 4.5km in length and 1.25km in width. It is centred on National Grid Reference NY260210. In normal conditions, Derwentwater has a surface area of approximately 6.7km². The catchment area of the lake is approximately 85km².

The main river feeder into Derwentwater is the River Derwent. This rises in the Borrowdale Fells and enters at the southern end of the lake. Many smaller becks enter the lake from the east and the west. The catchment is amongst the steepest and wettest in England. The lake discharges at the northern end over a natural sill barrier into a continuation of the River Derwent.

The topography to the south-west falls steeply from Cat Bells at 451mOD to a general shoreline level of 75mOD. To the south-east the topography is again steep, falling from Castlerigg Fell and Bleaberry Fell to the shoreline (Figure 2). To the north and south there are significant 'wash lands' where the River Derwent enters and leaves the lake (Figure 3).

The River Greta enters into the River Derwent 400m downstream of the lake. The River Greta catchment area to its confluence with the River Derwent is approximately 150km², shown on Figure 1, and takes in tributaries from the Blencathra, Matterdale Common and Helvellyn range, together with St Johns Beck from Thirlmere. The River Derwent then flows over the gauging station at Portinscale.

3. LIMNOLOGY OF DERWENTWATER

This section summarises the physical and chemical characteristics (limnology) of Derwentwater. The limnology of the lake is important because it contributes towards creating an unique habitat for aquatic species. In addition, the phytoplankton and invertebrate status of the lake is summarised, and the chemical content of the bottom sediments are described by reference to the work of Rowlatt (1980). The five figures referred to in this section are presented in Appendix A.

3.1 Physical Characteristics

Derwentwater is one of the shallowest lakes in the English Lake District with a mean depth of 5.5 m and a maximum depth of 22 m. The bathymetric profile of the lake makes it susceptible to thermal stratification. The lake typically becomes thermally stratified in late May, with lower depths being cooler. However, the depth of the seasonal thermocline is highly variable and strongly influenced by the speed and direction of the prevailing wind.

The bar-graphs in Figure A1, in Appendix A, show the year-to-year variations in the depth of the mid-Summer thermocline in some of the larger Cumbrian lakes. Most of the lakes are deep and relatively narrow, so their mid-Summer thermoclines are relatively stable. The least stable thermoclines are those recorded in Derwentwater and Bassenthwaite. This is because these lakes are broad and shallow and readily mixed by the action of the waves. The time-series plot in Figure A2 shows the pattern of thermal stratification recorded in Derwentwater in 1995, 1996 and 1997. This is shown by the 20m depth being cooler than the zero depth. No Summer mixing episodes were recorded during this period, but a short period of summer mixing was recorded in 1993 (Jaworski *et al.*, 1994).

In biological terms, Derwentwater is relatively unproductive. However, the accumulation of organic sediments is still sufficient to allow biological de-oxygenation of deeper water in the hypolimnion. The time-series plot in Figure A3 shows the year-to-year variations in the oxygen concentrations measured near the surface and in the deepest water in 1995, 1996 and 1997. The most striking feature is the large year-to-year variations in the duration of the Summer period of deep-water anoxia (reduction in oxygen). The timing of these periods is largely controlled by the frequency and intensity of wind mixing. The magnitude of change can also be influenced, however, by qualitative changes in the composition of the sedimenting phytoplankton.

3.2 Chemical Characteristics

Derwentwater is one of the least productive (i.e. nutrient-poor) lakes in the Lake District. When Pearsall classified the District's lakes in order of increasing productivity earlier this century (Pearsall, 1921) Derwentwater was listed as the sixth in the series (Table 3.1). Since then, most lakes in the area have become more productive (i.e. increased nutrient status). However, Derwentwater is still placed seventh behind Coniston, a lake that has changed little over the last sixty years.

The time-series plot in Figure A4 shows the week-to-week variations in the concentrations of dissolved reactive phosphorus and total phosphorus recorded in Derwentwater in 1995, 1996 and 1997. The Summer concentration of dissolved reactive phosphorus in the lake is frequently very close to the analytical limit of detection (i.e. reactive phosphorus concentrations are very low). Moreover, there has been no consistent increase in the Winter concentrations recorded in recent years. The seasonal fluctuations in the concentration of total phosphorus are, however, very different from those recorded in most Cumbrian lakes. The main factor influencing the concentration of total phosphorus in these lakes is the Summer growth of phytoplankton. The total phosphorus concentrations recorded in Derwentwater are poorly correlated with the measured phytoplankton biomass; rather, they appear to be regulated by the natural episodic re-suspension of the bottom sediment.

Lake	Trophic Status in 1921	Trophic Status in 1997
Wastwater	1	1
Ennerdale	2	2
Buttermere	3	3
Crummock	4	4
Haweswater	5	5
Derwentwater	6	7
Bassenthwaite	7	9
Coniston	8	6
Windermere	9	10
Ullswater	10	8
Esthwaite Water	11	11

Source: Pearsall, 1921 & IFE (1997)

N.B. 1921 rankings relate to chlorophyll content only, 1997 rankings to chlorophyll + phosphorus activity

Table 3.1 Long-Term Change in the Trophic Status of the Large Cumbrian Lakes

3.3 Biological Characteristics

Figure A5 shows the week-to-week variations in the concentration of phytoplankton chlorophyll recorded in Derwentwater between 1995 and 1997. This pattern of variation is very similar to that recorded in earlier years (Jaworski *et al.*, 1994), with the highest concentrations of phytoplankton being recorded in mid Summer. Figure A5 also shows the week-to-week fluctuations in the transparency of the water column as measured by a Secchi disk. In most lakes in the Lake District, the only significant factor influencing the transparency of the water column is the seasonal growth of phytoplankton. Conversely, at Derwentwater many of the recorded fluctuations appear to be related to the re-suspension of the bottom sediment.

The invertebrate populations colonising the shoreline region of Derwentwater have not been studied systematically since the pioneering surveys of Macan (1970). Macan's survey involved collecting invertebrate specimens by sweeping the littoral zone with a long-handled net for a fixed period of time. Five two-minute samples were normally collected at a series of representative stations in the shallow littoral zone.

Table 3.2 summarises these findings qualitatively by comparing the number of species / individuals found in Derwentwater kick samples with those collected from other large Cumbrian lakes. The invertebrate species recorded in Derwentwater are typical of those found in cold, relatively unproductive lakes. Ephemeroptera (mayfly) and Plecoptera (stonefly) are relatively abundant, but there are very few flatworms and leaches. In recent years, several 'immigrant' species of invertebrates have appeared in some Cumbrian lakes. The Antipodean snail *Potamopyrgus jenkinsi* is known to be present in Derwentwater, and the North American amphipod *Crangonyx pseudogracilis* was reported to have reached the lake in 1966 (Macan, 1980).

Lake	Number of Species	Number of Specimens
Wastwater	10	194
Ennerdale	14	515
Buttermere	13	455
Crummock	16	847
Derwentwater	15	1307
Ullswater	15	1696
Windermere (N)	23	2129
Loweswater	17	2739
Coniston	18	1294
Bassenthwaite	19	2508
Windermere (S)	21	2815
Esthwaite Water	16	5987

Source: Macan (1970)

N.B. The numbers are the total number of individuals collected in 100 minutes.

Table 3.2 Invertebrate Species Counts in the Shallow Littoral Zone of Large Cumbrian Lakes

3.4 Lake Sediments

The composition of lake sediments depends on a series of interacting factors such as catchment geology and lake productivity. There have been various studies investigating the chemical composition of Cumbrian lake sediments, but one of the most comprehensive accounts published to date is that of Rowlatt (1980). Table 3.3 compares the elemental composition of the eight Cumbrian lakes studied by Rowlatt (1980). The metals examined in this study were sodium (Na), potassium (K), iron (Fe), manganese (Mn), cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn). The data are presented as *elemental ratios*, where the concentration of each element is compared with the measured concentration of aluminium (A1).

Element:Al ratios provide a convenient means of comparing different lake sediments. The enhancement or depletion of any element may be compared with the 'lattice-held' fraction of other materials, e.g. the material eroded from rocks in the catchment. The baseline 'reference' included in Table 3.3 is the element:Al ratio for glacial clay, i.e. the material transported and deposited under peri-glacial conditions. The element: Al ratios in Table 3.3 can be divided into three, relatively distinct, groups:

- The conservative elements (Na and K).
- The mobile elements (Fe and Mn).
- The enriched elements (Cd, Cu, Pb and Zn).

Table 3.3 illustrates that the Na:Al and K:Al ratios in most lake sediments were very close to those in the reference glacial clay. These elements were therefore clearly derived from the natural erosion of the surrounding catchment. There is some indication that the leaching of K was more pronounced than that of Na, but the analyses presented for the 'reference' clay were also highly variable.

The Mn:Al and Fe:Al ratios in the different lakes were very much higher than those in the glacial clays. The lowest Mn:Al ratios were generally recorded in the lakes where the deepest water becomes anoxic, but the ratio recorded for Derwentwater was comparatively high. Although the Derwentwater Mn concentrations are high, they are still within an acceptable range for a lake system of this nature. The Mn: Al ratio recorded at Derwentwater is not of ecological significance.

The concentration of Cd, Cu, Pb and Zn in the sediments were all very much higher than those recorded in the glacial clay. The element:Al ratios recorded for Derwentwater are, however, very close to the regional average, but two lakes known to have been polluted with heavy metals (Coniston and Ullswater) were excluded from the Rowlatt surveys.

Lake	Na	K	Fe	Mn	Cd	Cu	Pb	Zn
Wastwater	0.13	0.20	0.66	65.6	0.05	0.74	3.14	5.99
Ennerdale	0.11	0.20	0.74	83.2	0.03	0.53	1.73	3.77
Grasmere	0.11	0.23	1.21	26.9	0.15	2.17	7.30	14.3
Rydal	0.13	0.20	1.31	35.3	0.16	1.05	7.00	14.8
Derwentwater	0.10	0.23	1.42	231.5	0.09	0.69	5.23	9.14
Windermere (S)	0.09	0.24	0.81	138.3	0.07	1.32	5.03	11.53
Blelham Tarn	0.10	0.26	0.96	95.0	0.08	0.77	2.80	8.04
Esthwaite Water	0.09	0.25	1.12	27.0	0.09	0.99	4.46	8.33
Glacial Clay	0.13	0.30	0.63	16.5	0.01	0.37	0.29	1.51

Table 3.3 Element : Al Ratios in Seven Cumbrian Lakes

Table 3.4 sets these relative measures in context by comparing the absolute concentrations recorded in Derwentwater with those recorded in one unproductive and two productive Cumbrian lakes. The concentrations of Mn recorded in Derwentwater are comparitively high; but relatively high concentrations were also recorded in the South Basin of Windermere. Table 3.4 also provides figures pertaining to Coniston and Ullswater, to demonstrate the significance of metal contamination in a lake environment.

Lake	Mn	Cd	Cu	Pb	Zn
Wastwater	5,291	4	60	253	483
Derwentwater	16,115	6	48	364	636
Windermere	8,297	4	79	302	692
Esthwaite Water	1,580	5	58	261	487
Ullswater	3,500	ND	70	5,390	1,560
Coniston	12,200	ND	620	210	1,080

N.B. Units = parts per million (ppm)

Source: Wastwater, Derwentwater, Windermere and Esthwaite data – Rowlatt (1980); Coniston and Ullswater data – Tipping *et al.* (1997)

Table 3.4 Metal Concentrations in the Sediments of Six Cumbrian Lakes

Table 3.4 indicates that metal concentrations in the sediments of Coniston and Ullswater are elevated in comparison with the other four lakes. Specifically, Coniston has very high levels of copper and zinc, while Ullswater's sediments contain high levels of lead and zinc. In all cases these elevated metal concentrations are an order of magnitude greater than those in the other lakes. The highest manganese levels were recorded at Derwentwater. In relation to copper, lead and zinc, however, manganese is far less ecotoxic and recorded manganese concentrations of Derwentwater are within normal bounds.

It is possible to explain the high toxic metal content in Coniston's and Ullswater's sediments through an understanding of the district's industrial history. The sediments in Coniston were contaminated with washings from the copper-mine above the lake. At Ullswater, metal contamination occurred in the 1920s following a catastrophic discharge of sediment from a lead workings dam.

There are lead mine spoil tips situated on the shores of Derwentwater at Brandlehow, in the south-west corner of the lake. These spoil tips are much smaller than those at Coniston and Ullswater. Consequently, although there may be some small amount of metals being leached from the tip into the lake, it is considered unlikely that the spoil significantly influences lake geochemistry.

4. HABITATS AND SPECIES

Section 4 describes the habitats and species which, both individually and collectively, contribute to the high nature conservation status of Derwentwater.

4.1 Aquatic Flora

Bryophytes (lower plants such as mosses) dominate the flora of the River Derwent's upper reaches above Derwentwater. Along this reach, the bryophytes can withstand constant wetting and drying. Immediately upstream of Derwentwater, the river channel is characterised by a very unstable substrate comprising cobbles, pebbles and gravel. Here, aquatic plant cover is sparse, comprising alternate water milfoil *Myriophyllum alterniflorum*, shoreweed *Litorella uniflora* and the aquatic mosses *Fontinalis antipyretica* and *F. squamosa*. The reaches of the River Derwent upstream of Derwentwater are most unlikely to be affected in any way by water level fluctuations in the lake downstream. This habitat is therefore considered no further in this environmental appraisal.

As discussed in Section 3.1, Derwentwater is the shallowest and broadest of the major Cumbrian lakes. Its average depth is 5.5 m and its deepest point is only 22 m. The aquatic flora is characteristic of a relatively low level, nutrient-poor (oligotrophic / mesotrophic) lake. Species typical of such physico-chemical conditions include water lobelia *Lobelia dortmanna*, intermediate water-starwort *Callitriche hamulata*, alternate water milfoil, the uncommon awlwort *Subularia aquatica* and quillwort *Isoetes lacustris*. Spiny-spored quillwort *Isoetes echinospora* is also found here in one of its few English localities. Nutrient levels are locally more enriched in the sheltered bays of Derwentwater. At these locations lesser pondweed *Potamogeton pusillus* and white *Nymphaea alba* and yellow *Nuphar lutea* water lillies are recorded. Derwentwater and Bassenthwaite are the only known extant Cumbrian localities for the nationally-scarce floating water plantain *Luronium natans*.

A survey by Stokoe (1983), carried out between February 1975 and September 1980, recorded 55 taxa (refer to Appendix B). Neither maps of species distribution, nor abundance of individual species, were recorded by Stokoe. A more recent survey was undertaken for English Nature in August 1996 and August 1997. This survey gives distribution maps and estimates of abundance in two bays on the western shore and three east-west transects across the lake. This unpublished survey confirmed the presence of two species which are nationally scarce and recorded by Stokoe: *Elatine hexandra* (Lapierre) DC, the six-stamened waterwort and *Isoetes echinospora* Durieu, the spring quillwort.

A third rare species, *Luronium natans* (L.) Raf., the floating water-plantain, which is listed in the EU Habitats and Species Directive, was also recorded during the English Nature survey. The fact that Stokoe failed to record this latter species is probably because it is easily overlooked (Preston & Croft, 1997). A second species that was recorded in 1996 and 1997 but not by Stokoe is *Crassula helmsii* (Kirk) Cockayne, the New Zealand Pigmyweed. This alien was first discovered growing in a pond north of London in 1956; it is now spreading rapidly throughout Britain and is considered to be a threat to the habitat of a number of scarce plants. It is possible that *C. helmsii* arrived in Derwentwater after the work of Stokoe. Both the scarce *L. natans* and the less desirable *C. helmsii* are present in Bassenthwaite Lake.

4.2 Riparian Habitats

Derwentwater supports some of the finest lakeshore habitats within the Derwent catchment, including extensive examples of both soft shore and stony shore hydroseres (Figure 4). There are several sites around some of the lake with soft shorelines and undisturbed transitions from open water to reed swamp and carr woodland. This includes tall herb fen with, for example, marsh woundwort *Stachys palustris*, narrow-leaved buckler fern *Dryopteris carthusiana*, and remote sedge *Carex remota*. Open water transitions have stands of common club-rush *Schoenoplectus lacustris*, bottle sedge *Carex rostrata* and, in places, the local needle spike rush *Eleocharis acicularis*. Some of the stony shorelines support the nationally-scarce thread rush *Juncus filiformis*, while water-pepper *Polygonum minus* is found on Rampsholme Island.

Around the inflow to the lake, and at the outflow close to where the temporary and permanent weir options are proposed, there are flood plain habitats of fen and wet grassland. At the outflow these habitats support outstanding examples of rich fen and sedge or reed swamp. This includes stands of bladder sedge *Carex vesicaria* and tufted sedge *C. elata* along with common reed *Phragmites australis*, marsh cinquefoil *Potentilla palustris*, water horsetail *Equisetum silaifolia* and bogbean *Menyanthes trifoliata*. Narrow-leaved water dropwort *Oenanthe silaifolia* is found here in one of only two known Cumbrian localities.

4.3 Invertebrates

The invertebate fauna of the River Derwent and its tributaries include two nationally-rare species, the leaf beetle *Donacia aquatica* and the snail, *Vertigo lilljeborgi*. *Vertigo lilljeborgi* is found only on undisturbed lake shores in Northern England and Scotland. The Derwent also supports other invertebrate species associated with swift-flowing clean rivers in northern and western Britain. The overall fauna includes ten species of stonefly (Plecoptera), ten species of mayfly (Ephemeroptera) and 17 species of caddisfly (Trichoptera). The riffle beetle *Oulimnius troglodytes* which has a localised distribution is among seven species of aquatic beetle recorded. The aquatic bug *Aphelocheirus aestivalis* is also present. This species has a localised distribution in Britain and is the only representative of the family Aphelocheiridae in the country.

4.4 Fish

4.4.1 Native Fish Community

The native (defined here as pre-1990s) fish community of Derwentwater comprises eel *Anguilla anguilla*, brook lamprey *Lampetra planeri*, minnow *Phoxinus phoxinus*, perch *Perca fluviatilis*, pike *Esox lucius*, brown trout *Salmo trutta* and vendace *Coregonus albula*, with salmon *Salmo salar* and sea trout *Salmo trutta* also passing through the lake on migration. The latter two species are considered below under the heading *migratory salmonids*.

4.4.1.1 Vendace

Of the members of the lake's fish community, the vendace is among the most important due to its high national conservation value. This species requires relatively cool and oxygen-rich water, which it usually obtains from the deep areas of the hypolimnion (lower layer of water in stratified lakes). In addition, it requires access to a clean substratum for spawning between late November and late December, which it finds in shallow (1 to 3 m) areas containing clean gravel and / or macrophytes. The locations of six known vendace spawning grounds are shown in Figure 5. The locations were determined by the inshore capture of adults in the 1997 spawning season. From surveys undertaken by IFE in the 1990s, the population is robust and shows consistent recruitment with no apparent overall trend in abundance. Earlier limited work in the 1980s revealed a similar situation, but there is no other historical information available. A monitoring programme including echo sounding and limited survey gill netting began in 1998.

4.4.1.2 Lampreys

Three species of lamprey are known to occur in the Derwent catchment. Lampreys are important because they are prescribed under both UK and European legislation (refer to Section 5). Relatively little is known about the ecology of lampreys in relation to other native fish species in the catchment. This is because of their complex life cycle and their elusive existence on river beds.

Of the three species in the River Derwent and its tributaries, two migrate to and from the sea during their life cycle, while the third remains in freshwater throughout its life. The sea lamprey (*Petromyzon marinus*) spends the first four or five years as a filter-feeding larval stage (the ammocoete), buried in the sediments of the river. It then undergoes a metamorphosis and migrates out to sea where it feeds as an ectoparasite on other fish before returning to freshwater to spawn and die. The river lamprey (*Lampetra fluviatilis*) has a similar life history, but does not migrate as far out to sea during its parasitic stage before returning to freshwater to spawn. The brook lamprey (*Lampetra planeri*) spends the whole of its life in freshwater and has abandoned the parasitic phase. Thus, the adult stage of the brook lamprey does not feed before spawning and dying.

From a consideration of the behaviour of lampreys in other Cumbrian rivers, it is likely that the sea lamprey and river lamprey do not penetrate the catchment as far as Bassenthwaite Lake. They are most unlikely, therefore, to be found as far upstream as Derwentwater. The brook lamprey, being an exclusively freshwater species, has no such limitations and could well colonise Derwentwater and its tributaries. Indeed, at least one sighting of a brook lamprey has been reported for the lake (I. J. Winfield (1998), pers. comm.).

4.4.1.3 Brown Trout

The brown trout is the most important fish species in angling terms, although all forms of angling on this lake are undertaken at relatively light levels. This species requires relatively cool and oxygen-rich water, although it is less demanding than the vendace and may be found in all parts of the lake. In addition, it requires access to a clean gravel spawning substratum in running water during the Autumn, which it finds in tributaries of the lake. From surveys undertaken by IFE in the 1990s, data indicate that the population is robust and shows consistent recruitment with no apparent overall trend in abundance.

4.4.1.4 Pike

The pike is also subject to some recreational angling, but to a much lower degree than on Bassenthwaite Lake. This species requires relatively warmer water than vendace and brown trout, and is typically found in the inshore areas of the lake. However, it also frequents the deeper areas. In addition, it requires access to macrophytes for use as a spawning substratum during the early Spring, which it finds in inshore areas of the lake. From surveys undertaken by IFE in the 1990s, data indicate that the population is robust and shows consistent recruitment with no apparent overall trend in abundance.

4.4.1.5 Perch

The perch is less frequently fished. This species is tolerant of a range of water temperatures, although it generally prefers warmer temperatures similar to those of pike, and may be found in all parts of the lake. In addition, it requires access to macrophytes for use as a spawning substratum during the spring, which it finds in inshore areas of the lake. From surveys undertaken by IFE in the 1990s, data indicate that the population is robust and shows consistent recruitment with no apparent overall trend in abundance.

4.4.1.6 Eel

The eel is also rarely angled. This species prefers relatively warm water, but may be found in all parts of the lake, although its activity is greatly reduced during the Winter months. Spawning is restricted to the marine environment and so this species requires free access for incoming young (elvers) and outgoing adults (silver eels). Surveys undertaken by IFE in the 1990s were inappropriate for the assessment of eel populations and so little is known of the local status of this species.

4.4.1.7 Minnow

The minnow is not angled, with the potential exception of collection for subsequent use as a live bait. However, the minnow is the main species visible around the lake's shore and so it does have a significant public profile. This species requires relatively warm water and is typically found in the inshore areas of the lake. In addition, it requires access to clean gravels for use as a spawning substratum during the late Spring or early Summer, which it finds in inshore areas of the lake. From surveys undertaken by IFE in the 1990s, data indicate that the population is robust and shows consistent recruitment with no apparent overall trend in abundance.

4.4.2 Introduced Fish Species

Introduced fish species, i.e. not natural, may 'compete' against the existing fish species. In the Derwentwater and Bassenthwaite lake system, concerns have arisen and have been investigated with respect to introductions of roach *Rutilus rutilus*, ruffe *Gymnocephalus cernuus* and dace *Leuciscus leuciscus*. Elsewhere, the roach has been shown to be a potentially dominant competitor for zooplankton; the ruffe has been found to consume large numbers of vendace eggs; and the dace has been shown to consume vendace larvae. In Bassenthwaite Lake, roach, ruffe and dace were first recorded in 1986, 1991 and 1996, respectively, while in Derwentwater roach and dace were first recorded in 1991 and 1997, respectively. Ruffe have yet to be recorded at Derwentwater. However, their arrival from Bassenthwaite Lake by migration along the connecting River Derwent is a possibility. This is despite the ruffe being a small-bodied, bottom-dwelling species which presumably has limited upstream movement capabilities.

These five introductions, like a number involving these species elsewhere in U.K., appear to be the result of accidental or deliberate releases of live bait by anglers fishing for pike. It is possible that ruffe may also be introduced to Derwentwater by this mechanism in the future, independent of the threat from a migration up the River Derwent.

In Bassenthwaite Lake in the late 1990s, the roach has recently declined in abundance, the ruffe has increased and now dominates all areas of the lake, while the dace remains a minor component of the community. Consequently, the threat posed to the vendace by roach has reduced, but there is some concern over the impact of the ruffe through both egg predation and competition for zooplankton. It is too early to draw conclusions about the likely local impact of the dace.

In Derwentwater in the late 1990s, the roach has continued to increase in abundance, while the dace remains a minor component of the community. The latest information available shows that juvenile roach are restricted to the inshore areas of the lake and so show no spatial overlap with juvenile vendace. It is therefore assumed that roach will not compete with vendace even though the diets of both species are dominated by zooplankton. As at Bassenthwaite Lake, it is too early to draw conclusions about the likely local impact of the dace.

4.5 Migratory Salmonids

Both salmon and sea trout migrate through Bassenthwaite Lake and Derwentwater to spawn within some of the catchment's tributaries. It appears that the only scientific information on these fish originates from surveys of young individuals in tributaries, carried out by the Environment Agency. Further information on adults may be available from catch statistics of Castle Fisheries operating on the Derwent downstream of Bassenthwaite Lake, but it is understood that this information is not in the public domain.

Habitat requirements of both salmon and sea trout are somewhat similar, with spawning requiring areas of clean gravel in flowing water during the autumn. Nursery areas are also contained within streams, while the adult foraging ground is at sea. A major environmental requirement of salmon and sea trout is free passage of young from tributaries to the sea and of adults in the reverse direction.

There has in the past been some concern over the effect of poor water quality downstream of Bassenthwaite Lake on the return migration of adult migratory salmonids. However, to the best of our knowledge there are at present no local threats to the status of the populations.

4.6 Wintering Wildfowl and Resident Birds

Derwentwater is acknowledged by both statutory and non-statutory agencies as a site of county importance for wintering wildfowl. The lake provides important feeding areas within the bays and along shallow margins. Appendix C presents a summary of the numbers and breeding status of bird species at Derwentwater. Figure 6 indicates the location of the more significant wildfowl sites.

4.6.1 Trends in the Status of Bird Species

When assessing the potential effects of the water level management options upon bird species and wildfowl, it is worthwhile reviewing bird count data for drought years. This can assist in evaluating the sensitivity of different species to extreme water level changes. In addition, it is helpful to examine seasonal trends in count data, and the susceptibility of species to disturbance, to identify naturally-occurring fluctuations in numbers and to identify potentially sensitive times of year. Data provided by the Lake District National Park Authority are summarised in Table 4.1.

Species	Trends / Sensitivity
Trends	
Mallard	Winter increase
Coot	Winter numbers up
Goldeneye	Winter numbers slight increase
Tufted duck	Numbers steady in Winter
Pochard	Winter increase
Greylag Goose	Increasing breeding population
Canada Goose	Increasing breeding population
Barnacle Goose	Increasing breeding population
Heron	Recent return to breeding on islands
Lesser Black-backed Gull	New breeder
Little Ringed Plover	Attempted breeding on shoreline shingle; rare breeder in Cumbria
Moorhen	Recent return to limited breeding
Yellow Yellow Wagtail	Gone
Reed Warbler	New breeder, but rare in Northern England
Sensitivity	
Common Sandpiper	Usually nests back from the lake edge at Derwentwater, but shingle shore is important for feeding and providing cover for young. Higher water levels can affect nesting success, as shown on Bassenthwaite, which has greatly fluctuating water levels. The Derwenwater and Bassenthwaite populations are an important contribution to the National Park's overall population.
Water rail	Scarce breeder, nest easily flooded
Coot / Moorhen	Fluctuating levels are not helpful to feeding or breeding success of this species
Little ringed plover	One of Cumbria's rarest species, included in Schedule 1. Shoreline shingle nester and feeder; nest easily flooded
Yellow wagtails	If they return to breed, Lodore Marsh flooding could be destructive
Merganser	At times, shoreline nester on islands, etc. Flooding a potential problem
Lesser Black Backed Gull	If water levels were raised so that Scarf rocks were flooded, nesting would be stopped. This however may not be a problem for this particular species because other options are available.

Species	Trends / Sensitivity
Cormorant	The fishing point and day time roost at Scarf rocks may be submerged with higher water levels.
Mute Swan	Nest known to have been flooded in the past at reedbed site.

Table 4.1

Recent Trends in the Status of Wildfowl and Other Species at Derwentwater

It should be borne in mind that there has been a decline in numbers of coot, goldeneye, tufted duck and pochard on Bassenthwaite in recent years. The Derwentwater numbers have on the whole increased and may well have absorbed some of the Bassenthwaite birds. At the present time, this puts a greater emphasis on the welfare of wintering birds than previously. (P. Barron, 1998 pers. comm.)

4.6.2 Summary of Principal Wildfowl Sites

Figure 6 indicates the location of important areas for wintering wildfowl. The figure reveals that both the north and south (Great Bay) ends of the lake are significant areas for wintering wildfowl. In addition, the bays at The Ings and Crow Park represent important locations. Calfclose and Barrow Bays on the east side can be as equally important as those at Otterbield and Derwent on the west. Finally, Kettlewell Bay is regarded as a very important location for wintering wildfowl (P. Barron, 1998 pers. comm.). These areas can be equally important during the Summer, because of food availability.

4.6.3 Disturbance

Disturbance of bird species through construction / maintenance activities is also a relevant concern. For example, Great Bay, Kettlewell and North Bay are crucial for wintering wildfowl. When disturbed, birds at Kettlewell are known to fly to Great Bay, thereby expending energy and losing access to a preferential feeding site. There is much variation in the amount of human recreational disturbance between different wildfowl sites. It is considered likely that locations such as North Bay could support larger numbers in the Summer if there was a decrease in disturbance. However, this may be limited by the territorial behaviour of some species.

The northern end of the lake supports significant numbers of fowl, especially in Winter, and could probably hold larger numbers in the Summer months except for disturbance. The Great Bay voluntary *no boating* zone is very important because it is a significant day time roost site for a variety of species, especially in Summer.

Other sensitive areas for non-wildfowl species include Lodore marsh, Kettlewell reeds, Stable Hills, Ings Wood, Portinscale and the North Bay reed fringe. Shingle areas provide valuable habitat for Sandpiper and Little Ringed Plover. Islands provide refuges for oystercatcher, gulls, sandpipers, mallards, merganser, heron and geese.

5. STATUTORY DESIGNATIONS

The following section summarises the statutory designations which have been conferred upon the study area. The designations relate to both European Union and U.K. nature conservation statutes.

5.1 Special Area for Conservation

The River Derwent, Derwentwater and Bassenthwaite lake constitutes a candidate Special Area for Conservation (SAC) under the European Council's *Habitats and Species Directive* (Directive 92/43/EEC). The proposed designation relates to the oligo-mesotrophic lake habitat (Annex I), and the presence of prescribed Annex II, IV and V species (refer to Section 5.5.2). The proposed boundary of the SAC does not coincide exactly with the SSSI (Section 5.2); the SAC boundary excludes the wetlands listed in the SSSI citation. English Nature's consultations with stakeholders concerning the proposed SAC designation were concluded towards the end of 1997. The system was nominated by the Government as a candidate SAC in May 1998. Responsibility for ratifying the designation rests with the European Council.

5.2 Sites of Special Scientific Interest

Derwentwater falls within the River Derwent and Tributaries SSSI, which was first notified in September 1997. The boundary of the SSSI as it relates to Derwentwater and the tributaries immediately adjacent to the lake is shown in Figure 7.

Parts of the River Derwent and Tributaries SSSI were notified separately as Buttermere SSSI in 1983, and Bassenthwaite Lake SSSI in 1984. The River Derwent SSSI overlaps with, or adjoins, the following existing SSSIs:

- Buttermere Fells
- Honister Crag
- Lodore-Troutdale Woods
- Great Wood
- The Ings
- Bassenthwaite Lake
- Buttermere.

Among these SSSIs, only *The Ings* could potentially interact with Derwentwater's lake levels. This is because part of The Ings SSSI boundary encompasses lakeshore habitat. The observed and anticipated effects of fluctuating water levels upon lakeshore habitats have been considered in Section 4.2.

The River Derwent SSSI citation sheet describes the Derwent-Cocker as the largest oligotrophic river in England that still retains high water quality and a natural channel. There is an abundance of bryophytes on account of the rivers' low nutrient status, and conversely a paucity of species associated with higher nutrient conditions. Both rivers do, however, exhibit a succession of plant communities with increasing distance downstream; this represents minor increases in nutrient levels towards the mouths of the rivers. The Derwent flows through Derwentwater and Bassenthwaite, and these lakes serve to attenuate the rivers' more extreme flow regimes. Derwentwater supports the nationally-rare plant floating water plantain. In places around Derwentwater there is a hydroseral succession from open water to wet woodland, fen and swamp. The hdyroseres on Derwentwater are some of the best examples in the Lake District National Park. Derwentwater also supports the nationally-rare fish vendace (refer to Section 4.4.1.1). Only Bassenthwaite in the same catchment supports this fish species. These are the only remaining native sites for this species in the UK. Two new populations are being established in Scotland using stock from Derwentwater and Bassenthwaite Lake.

5.3 National Nature Reserve

Bassenthwaite lake is a National Nature Reserve (NNR). The NNR is owned by the Lake District National Park Authority and managed under agreement with English Nature.

5.4 Freshwater Fish Directive

Derwentwater is part of a designated Salmonid Water under the EC's Freshwater Fish Directive (78/659/EEC).

5.5 Scheduled Species

5.5.1 Wildlife and Countryside Act 1981, as Amended

The Derwent catchment is understood to contain a breeding population of otters (*Lutra lutra*). This population is believed to be spreading slowly into the middle and upper reaches of the catchment. Otter and vendace (*Coregonus albula*) (refer to Section 4.4.1.1) are protected under Schedule 5 of the Wildlife and Countryside Act 1981, as amended. Floating water plantain (refer to Section 4.1) is protected under Schedule 8 of the Wildlife and Countryside Act, 1981 as amended.

5.5.2 EC Habitats and Species Directive

The River Derwent and Tributaries SSSI includes the following species and habitats listed in the Habitats and Species Directive:

• Atlantic salmon, *Salmo salar*	Annex II, V
• River lamprey, *Lampetra fluviatalis*	Annex II, V
• Brook lamprey, *Lampetra planeri*	Annex II
• Sea lamprey, *Petromyzon marinus*	Annex II
• Otter, *Lutra lutra*	Annex II, IV
• Floating water plantain, *Luronium natans*	Annex II, IV (Derwentwater)
• Meso-oligotrophic lake	Annex I

5.6 Sites of County Nature Conservation Interest

Consultations were held with the Cumbria Wildlife Trust (CWT) to discuss the implications of the water level management options. The Derwentwater Management Plan refers to a series of CWT sites on and around Derwentwater which are considered to be important for nature conservation at a county level. These sites are summarised in Table 5.1 and shown on Figure 8. In practice, the CWT's sites at Derwentwater have not been through the same selection procedure as that used to select county sites outside the National Park boundary. Nevertheless, they are still significant in respect of being an integral part of the Derwent catchment. The Trust has provided initial comments in regard to the proposals, and confirmed without prejudice that there are no immediate concerns posed by any of the options.

Site Number	Location	Interest	Grid Reference
67	Derwentwater south end	B / O	255 188
535	Great Bay	W	257 190
631	Brandelhow Park	W	250 200
632	Fawe Park / Silver Hill	W	252 220
633	North end of Derwentwater	W	254 231
634	St Herberts Island	W	259 212
635	Lords Island	O	266 219
636	Rampsholme Island	O	265 213
638	Falcon Crag	O	272 205
982	Manesty	AW	252 192
987	Hog's Earth, Watendlath	AW	265 185
988	Ashness Woods	AW	270 190
998	Hawes End / Brandelhow	AW	250 213
999	Lingholm / Fawe Park	AW	250 220
1002	Ings	AW	268 221
1003	Castlehead	AW	270 226
1004	Bigwood / Walla Crag / Castlerigg	AW	275 215
1023	Great Wood	E	270 214
1024	Great Wood	E	270 211
1025	Great Wood	E	269 211

Source: Cumbria Wildlife Trust; Derwentwater Management Plan

N.B. Key to 'Interest' coding as follows: B ~ botanical interest; W ~ general wildlife habitat; O ~ ornithological interest; E ~ entomological interest; AW ~ ancient and semi-natural woodland.

Table 5.1 Cumbria Wildlife Trust Sites at Derwentwater

Table 5.1 indicates that of the 20 CWT sites in and around the lake, over 50 % are not related to aquatic or marginal habitats. Such habitats include ancient woodland, woodland supporting entomological interest, and semi-natural parkland of general nature conservation interest. The remainder comprise ornithological sites (considered in greater detail in Section 4.6) and aquatic sites of general wildlife interest such as Great Bay and the north end of the lake. The nature and status of these habitats are considered elsewhere within the report.

5.7 Botanical Interest at North Bay

Options 4 and 5 (permanent and temporary weir respectively) at the outlet of Derwentwater would both require construction and maintenance operations during their design life. In conjunction with the dredging option, this differentiates them from the other management proposals. The suggested locations of the weirs are within 100 m of the point at which the river emerges from the lake at its north end. With the availability of 1992 river corridor survey data from the Environment Agency, it is possible to describe the botanical interest in this area. In turn, this allows for a more detailed evaluation of the biological effects of construction and maintenance operations if a weir option were to be chosen.

In summary, the interest of this part of the Derwent river corridor centres on an area of tall, unimproved neutral grassland and tall herb at the upstream end of the reach. This grassland is botanically rich and and provides good cover for a wide variety of animals. Other points of interest comprise the bankside trees which provide cover for fish and riverine birds, and marginal vegetation and trailing bank vegetation. The latter are important for many aquatic invertebrates, particularly dragonflies and damselflies.

In addition to the river corridor survey, the wetlands at the outflow from Derwentwater have been surveyed by Stewart (1996). The location of the area survey is indicated in Figure 9. This wetland area is under the ownership of the Derwentwater Hotel. The owner takes a pro-active role in introducing the hotel's residents to the site's nature conservation interests.

The central part of the site is low-lying with willow carr and a complex of swamp communities. The most prominent community appears to be forms of *Carex vesicaria* swamp. Changes in community structure appear to be linked with subtle changes in water table height. Fringing the swamp and fen communities on the south and east sides there is an indistinct transition from coarse grassland, to tall herb mire, *Juncus* mire and gradations between these. On the west (landward) side there are transitions from swamp and fen to *Juncus* mire and then into neutral grassland on higher ground. On the south side there is a good hydrosere succession from the open water of the lake to *Carex rostrata*, *Phragmites* beds and a mixed community of *C. elata* and *C. vesicaria*. There are also herbs like *Mentha aquatica*, *Caltha palustris* and *Valeriana officinalis*. Most significantly, this wetland area is one of only two sites in Cumbria which support the rare narrow-leaved water dropwort.

On the eastern side along the river there are stands of *Phalaris arundinacea*, *Filipendula ulmaria*, *Oenanthe crocata*, *Cardamine amara*, *Caltha palustris* and the sedges *Carex rostrata* and *C. vesicaria*. There is a small stand of *Scirpus lacustris* in the river.

6. Nature of Potential Impacts

The technical aspects of the six water level management options are discussed in detail in Volume III Management Options. The following section briefly summarises these options, but in addition seeks to describe their physical effects in an ecological context. In turn, the information presented in this section is carried through to Section 7, which evaluates these impacts against the specific limnological and ecological resources which have been identified previously.

6.1 Option 1: Do Nothing

This in essence entails allowing the sill at the mouth of Derwentwater to continue eroding. In turn, this will cause minimum lake levels to decline through time. However, if trigger incidents reduce, the present significant erosion rate should decline. The present rate may represent a short-term 'peak' within a constantly fluctuating system. In the long term, alterations to local groundwater levels around the lake could occur, although the extent and magitude of this cannot be predicted quantitatively.

Marginal vegetation and riparian habitats would be adversely affected if they are unable to adjust to lower water levels, or if freshly-exposed riparian habitat were unsuitable for colonisation. The biological consequences of a do-nothing scenario are very dependent on the rate of change brought about by declining water levels, and the capacity of flora and fauna to respond to this change. From an ecological management viewpoint, the main concern is that it is difficult if not impossible to predict long-term future changes in the physical environment of the lake brought about by erosion of the glacial sill. In turn, it is not possible to determine the impacts, both positive and negative, that may arise. Conversely, from a positive viewpoint, a do-nothing scenario will lead to no interference in what is a semi-natural aquatic system.

6.2 Option 2: Map and Mark Obstacles

This will allow pleasure craft to avoid unnavigable parts of the lake during low water events. Short-term disturbance of lake sediments will be insignificant in comparison with naturally-occurring processes. Medium- to long-term effects upon ecological resources within and adjacent to the lake are considered to be negligible.

6.3 Option 3: Dredge Boating Channels

Pleasure craft will be able to access those parts of the lake which are inaccessible during low water events. Dredging operations will inevitably give rise to the disturbance and resuspension of sediments from the lake bed. In addition, the dredger will need to gain access to areas of the lake which are significant for wildfowl. In theory, this could cause disturbance to wildfowl if undertaken during inappropriate seasons. However, it is most likely that the timing of dredging activities could be scheduled to minimise disturbance. Dredged sediments would need to be transported and deposited at a suitably licenced facility. Care will need to be taken to ensure that disposal of dredgings does not lead to the inadvertent release of flora and fauna into other water bodies. Dredging will need to be undertaken on a regular basis, and this therefore represents an ongoing, long-term management option.

6.4 Option 4: Permanent Weir

This option would aim to maintain minimum lake levels at a value of 74.61 m above ordnance datum (AOD). This figure is close to the minimum lake level recorded in 1896 (74.65 m AOD). Under ordinary lake levels and flow conditions in the River Derwent, the weir would be submerged. Naturally occurring fluctuations in lake level would remain unchanged, apart from the extent of extreme minimum water levels. In effect, the minimum water level in the lake would be increased by 23 cm when compared to the 1995 level of 74.38 m AOD. This therefore would reduce the range of water level functuation under extreme climatic conditions.

An access point to the weir would be required for both the construction and operation phases of the development. This would require the sensitive location of vehicle access routes to ensure that localised damage to terrestrial and riverine habitats was kept to an absolute minimum.

6.5 Option 5: Temporary Weir

This option would be implemented only when low water level events are predicted. It would be used to maintain the same minimum water level in the lake as the permanent weir. Once low lake level conditions are over, the weir will be removed and stored for the next event. In essence, the ecological effects of the temporary weir are identical to those of the permanent option. This is because both would exert an influence on the physical characteristics of the lake only during periods of unusually low water levels. The naturally-fluctuating conditions along Derwentwater's lakeshore habitats would effectively remain unchanged, although the absolute minimum level would similarly be increased by 23 cm. In ecological terms this is most unlikely to represent any constraints to the status of habitats or individual species. This therefore would reduce the range of water level functuation under extreme climatic conditions.

A temporary weir option would involve a greater degree of attention for the fixing and removal of the weir boards and may be more susceptible to human interference than a permanent weir.

6.6 Option 6: Maintain at Present Level

This option would aim to redress the present situation of falling water levels year on year, thereby 'fixing' present minimum lake levels into the future as the 1995 74.38 m level. The advantages of this option from an ecological management perspective relate primarily to ensuring that the lake's existing physical characteristics, which contribute to its high biological status, are maintained. With future lake levels 'fixed' at a present day minimum level, reasonable confidence could be attached to ensuring the ongoing, long-term biological status of the lake. In addition, water level issues could be eliminated from any future investigations that may be required to investigate changes in the status of a species or habitat.

This option may be achieved by a weir as described in 6.4 or by protecting the existing sill with rock armour.

7. Review of Limnological and Ecological Effects

7.1 Introduction

Having described the nature of the potential impacts in the previous section, Section 7 examines the implications of these potential effects upon the resources and features identified within this chapter. The overall significance of each option's limnological and ecological effects are summarised in an evaluative matrix.

7.2 Limnology

7.2.1 Physical Effects

The seasonal thermocline in Derwentwater is frequently disturbed by the wind, but the concentration of oxygen in the deep water remains naturally very low. Raising the minimum water level by means of a weir option will have no significant effect on the thermal characteristics of the lake. A channel dredging option would inevitably lead to disturbance in sediments on the lake bed. Increased sediment deposition rates on fish spawning grounds could exert an adverse effect during wet summers.

7.2.2 Chemical Effects

Derwentwater has traditionally been and remains one of the least productive lakes in the English Lake District. Raising the water level in the way proposed is most unlikely to have a medium- to long-term effect on the general nutrient status of the lake. In the short-term, more dissolved reactive phosphorus might be mobilised from the newly flooded areas, but these areas are currently inundated during heavy Summer rains.

Dredging operations could have an effect on the internal dynamics of phophorus. Previous research has shown that this could temporarily enhance deoxygenation rates through the resuspension of nutrients within the lower part of the water column. In turn, this could exert a short-term negative effect on fish species associated with the deeper parts of the lake, such as vendace. These effects would almost certainly be minor when compared with the natural process of sediment re-suspension.

7.2.3 Biological Effects

The IFE is not aware of any rare invertebrate species in Derwentwater which would merit special protective measures. It is suspected that the immigrant species noted in 1980 will now have reached other lakes in the area. However, it would be wise to avoid dumping any dredged sediment near another lake to avoid the transfer of non-native invertebrates. Small animals of this kind rapidly colonise any flooded areas, but the final distribution of animals in the enlarged littoral zone will obviously depend on the nature of the substrate.

7.2.4 Lake Sediments

The metal element:Al ratios recorded in Derwentwater are very similar to those recorded in other lakes in the area. There is no evidence of any significant metal contamination, but the concentrations recorded are higher than those recorded in a 'reference' glacial clay. The implications of elevated metal levels upon the waste management of dredgings are considered in Volume III of the report.

7.3 Habitats and Species

7.3.1 Aquatic Flora

Extreme fluctuations of water-level, as occurs in reservoirs, can prevent plants from establishing and flourishing. However, more moderate fluctuations of water level are a natural feature of freshwaters, a feature to which aquatic plants have evolved to survive. In Derwentwater, where the annual fluctuation in level is about 2 m, the high plant diversity indicates that this magnitude of change is not having a detrimental effect. A similar argument applies for *Luronium natans*, the most important species in Derwentwater in terms of national scarcity. In the recent surveys, *Luronium natans* was found in the two bays studied:

- Abbots Bay - growing in shallow water
- Brandlehow-growing at depths between 0.1 and 1.75 m.

The wide depth range over which *L. natans* is present, and its ability to grow submerged in water as well as in air (Preston & Croft, 1997), suggest that naturally-occurring water-level changes will not prevent its continued survival. The nationally scarce *E. hexandra* and the less desirable *C. helmsii* are similarly able to grow submerged at depth and in wet margins around a water body. They are therefore also inherently tolerant of fluctuations in water-level. *I. echinospora* tends to grow in deeper water and so will be less affected by fluctuations in water level than the other three species.

7.3.2 Hydrosere / Lakeshore Habitats

By definition, the lakeshore habitats around Derwentwater are potentially those most at risk from extreme fluctuations in water levels. However, such extreme events are comparatively rare, and the lake's water level regime is characterised by more moderate, naturally-occurring fluctuations throughout the year. The physiological attributes of lakeshore vegetation allow it to respond and survive within this changing environment. The temporary and permanent weirs are the only options which would influence these natural fluctuations in levels. However, as discussed previously, these alterations would entail raising absolute minimum levels in the order of 20 cm. When comparing the shorelines and the 1995 drought level to the proposed weir level the width of the shoreline changes from 0 to 140m (in the Ladore landing area) shown on Figure 10. The magnitude of the impact on the littoral zone would of course vary in response to slope gradient at increasing distances from the lake's high water edge.

7.3.3 Invertebrates

The Derwent catchment undoubtedly supports a diverse and significant aquatic invertebrate fauna. However, it is considered that there are no rare invertebrate species in Derwentwater that would merit any special protective measures. It is suspected that the immigrant species noted in 1980 will by now have reached other lakes in the area. Nevertheless, it would be wise to avoid dumping any dredged sediment near another lake. Aquatic invertebrates are known to rapidly colonise any flooded areas, but their final distribution within an altered littoral zone would obviously depend on the nature of the substrate.

7.3.4 Fish

7.3.4.1 Native Species

The implications of the options upon the ecology of Derwentwater's native fish species have been carefully considered. It is concluded that none of the options would adversely affect any native species. Should Option 3 (channel dredging) be adopted, care would need to be taken regarding the timing of dredging. This would be to ensure that the physical characteristics of the vendace spawning grounds were not compromised.

7.3.4.2 Introduced Fish Species

There will be no negative impact caused by any of the water level management options on the separate issue of introduced fish species impacting on the native community. Indeed, the construction of even a small weir may be beneficial in helping to prevent the upstream migration of ruffe from Bassenthwaite into Derwentwater.

7.3.4.3 Migratory Salmonids

The proposed water level changes are unlikely to have any effect on the ecology of salmon and sea trout in the system as Salmonids tend to move in spate conditions when water is abundant. Similarly, the downstream and upstream movements of young and adult, respectively, salmon and sea trout are unlikely to be impeded by the proposed weir.

7.3.5 Wintering Wildfowl and Resident Birds

Derwentwater is a site of county importance for wintering wildfowl. A review of recent count data has revealed a series of both negative and positive trends among some but not all species. It is evident that water levels in isolation are most unlikely to influence bird counts at Derwentwater; rather, a broad range of environmental variables will come into play. Factors such as human disturbance or habitat loss at other locations will exert an influence on bird counts. It is believed, for example, that upward trends among certain species at Derwentwater could in part be caused by displacement from Bassenthwaite.

Notwithstanding the difficulty in isolating cause and effect in bird count data, it is acknowledged that human disturbance can and does affect adversely affect wildfowl and nesting species. Therefore, those options involving an element of ongoing disturbance, either at sensitive locations or sensitive times of year, may be regarded as unacceptable. Such options would include Option 3, the dredging proposal, if it were to enhance currently limited access at the north bay.

7.4 Statutory Designations

There is a range of statutory designations conferred upon, or proposed for, Derwentwater's lakeshore and oligo-mesotrophic habitats. In addition, certain individual species are protected by law, for example the vendace and the floating water plantain. In a legal context, any planning application for a scheme which potentially compromises the integrity of a statutorily-protected resource constitutes a material consideration in the decision-making process. In extreme cases, planning consent is unlikely to be granted. In the case of any future water level management option, the scheme promoter must be able to demonstrate that the proposal is benign in relation to relevant nature conservation statutes. This will centre on assuring English Nature and The Lake District National Park Authority that the preferred option will not lead to a decline in the quality or status of a prescribed resource.

After careful evaluation of all potential interactions between the six options and the lake's prescribed biological resources, it is considered most unlikely that any option would give rise to an unavoidable or irreversible impact. Certain schemes, for example, Options 3, 4, and 5 (dredge channels, permanent weir, temporary weir) could cause damage if designed, implemented or programmed without careful ecological design. However, advanced awareness of ecological and temporal constraints during the detailed design process will allow for potential impacts to be either avoided completely or maintained within acceptable bounds.

7.5 Significance Assessment

Having described the nature and scope of potential interactions between the six options and the lake's ecology, Table 7.1 summarises the significance of these interactions. The significance assessment criteria presented in Table 1.1 have been used in this evaluation.

Table 7.1 clearly indicates that in general, there are few significant interactions between the water level management options and Derwentwater's biological resources. Those potential interactions which have been identified are highlighted and annotated.

The summary table also reveals that of all the options under consideration, Option 3 (dredge boating channels) would give rise to the broadest range of effects. Individually, each of these effects would not represent a material consideration in the decision-making process. When considered cumulatively, however, the potential effects related to this option take on a greater level of significance. For this reason, the overall biological significance of this option may be regarded as a **moderate adverse** effect, i.e. signficant at a local or district scale.

Biological Resource	Do nothing	Map and Mark obstacles	Dredge boating channels	Permanent Weir	Temporary Weir	Maintain at present level
Limnology						
Physical	None	None	None - Minor Adverse Short-term disturbance of lake bed sediments, but reflects a naturally-occurring phenomenon.	None	None	None
Chemical	None	None	None - Minor Adverse Short-term disturbance of lake bed sediments, but reflects a naturally-occurring phenomenon.	None	None	None
Biological	None	None - Minor Adverse Markers (bouys with chains) could scour macrophytes on lake bed. Mitigation possible through use of non-scouring markers	None	None	None	None
Habitats and Species						
Aquatic Flora	None	None	Minor periodic dredging operations would adversely affect zones occupied by aquatic macrophytes. This could be an irreversible effect if macrophyte communities are unable to recover fully in between dredging activities.	None	None	None
Riparian habitats	None	None	None	None-minor Adverse Potential short-term disturbance at outflow of lake to allow construction access	Minor Adverse Potential long-term but intermittent disturbance at outflow of lake to allow vehicular access	None - Minor Adverse Potential for short-term disturbance to habitat to allow construction access.
Invertebrates	None	None	None	None	None	None
Fish						
Native Fish Community	None	None	None - Minor Adverse Potential for disturbance to spawning grounds if not sensitively scheduled.	None	None	None
Introduced fish species	None	None	None	None	None	None
Migratory salmonids	None	None	None	None	None	None
Birds						
Wintering wildfowl	None	None - Minor Adverse Potential for enhanced access by recreational craft to otherwise inaccessible areas of the lake. Unlikely given high Winter water levels.	None - Minor Adverse Potential for enhanced access by recreational craft to otherwise inaccessible areas of the lake. Unlikely given high Winter water levels.	None	None	None
Breeding and resident species	None	None - Minor Adverse Potential for enhanced access by recreational craft to otherwise inaccessible areas of the lake. Reduce access for walkers.	None - Minor Adverse Potential for enhanced access by recreational craft to otherwise inaccessible areas of the lake	None	None	None
Statutory Designations						

Biological Resource	Do nothing	Map and Mark obstacles	Dredge boating channels	Permanent Weir	Temporary Weir	Maintain at present level
SAC	None	None	None	None	None	None
SSSI	None	None	None	None	None	None
Bassenthwaite Lake, National Nature Reserve	None	None	None	None	None	None
Freshwater Fish Directive	None	None	None	None	None	None
Wildlife & Countryside Act 1981, as amended	None	None	None	None	None	None
EC Habitats and Species Directive	None	None	None	None	None	None
Cumbria Wildlife Trust sites	None	None - Minor Adverse Potential disturbance in sites of ornithological interest	None	None	None	None

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

On the basis of the information gathered in support of the study, the following conclusions concerning the status of Derwentwater can be drawn:

- Derwentwater, its lakeshore habitats, and the species they support collectively represent a site of both regional and international importance for nature conservation.
- Significant nationally-important statutory designations have been conferred on the lake and its flora and fauna by English Nature.
- The River Derwent and Bassenthwaite lake is a candidate Special Area for Conservation under the EC Habitats and Species Directive. Derwentwater shares the same Annex I selection criteria as Bassenthwaite lake, and is therefore likely to be incorporated into the SAC designation when it is ratified.
- The bathymetric and limnological characteristics of Derwentwater play a key role in supporting this ecological interest. Any disruption to these physico-chemical characteristics are highly likely to affect a component of the ecological equilibrium.
- Based on site-specific research and a detailed understanding of many species' ecology, it can be stated with a high level of confidence that most species are sufficiently flexible to respond to a minor alteration in absolute minimum water levels. It is less certain, however, how species will respond in the long term to an ongoing decline in lake levels, should existing conditions continue.
- The biological resources apparently most sensitive to human disturbance and adverse fluctuations in water levels are wintering wildfowl and nesting birds on the shoreline. It is considered most unlikely that any of the proposed options will interfere with the requirements of wintering wildfowl and resident bird populations. The management options are aimed at addressing summertime low water levels. Therefore there is no potential for any option to interact with wintering wildfowl.

  Similarly, species whose lakeside nesting requirements make them susceptible to water level changes, for example, Merganser, Coot, Moorhen and Little Ringed Plover, are most unlikely to be affected. This is because none of the options involves sudden water level rises which have the potential to inundate nesting sites. Rather, the absolute minimum water level will be increased, but will not enhance the flooding potential of the sensitive lakeside nesting habitat.
- Any water level management option which causes ongoing disturbance at sensitive locations, or promotes shoreline flooding events during the nesting season, could lead to a significant adverse impact
- Despite the high value status of Derwentwater, it is concluded that none of the proposed management options would compromise the status of the lake. This applies from an individual species through to a broad habitat level. In many cases, the management options would not cause any discernable effect over and above naturally-occurring fluctuations within the lake and its lakeshore habitats.

8.2 Recommendations

After consultations with the Client team and other nature conservation agencies, it is recommended that the following measures should be taken to keep potential adverse effects to a minimum practicable level:

- For Option 2 and 3 (map and mark obstacles and dredging boat channels), works should be timed to minimise disturbance to wintering wildfowl and to avoid vendace spawning season. The design of markers should make provision for the avoidance of submerged vegetation scouring effects by chains. The practicality and efficiency of deploying non-scouring bouys should be examined.
- For options 4, 5 and 6, (permanent weir, temporary weir and maintain at present levels) construction access should be carefully chosen and agreed with relevant bodies and measures to mitigate the conection impact should be adopted.

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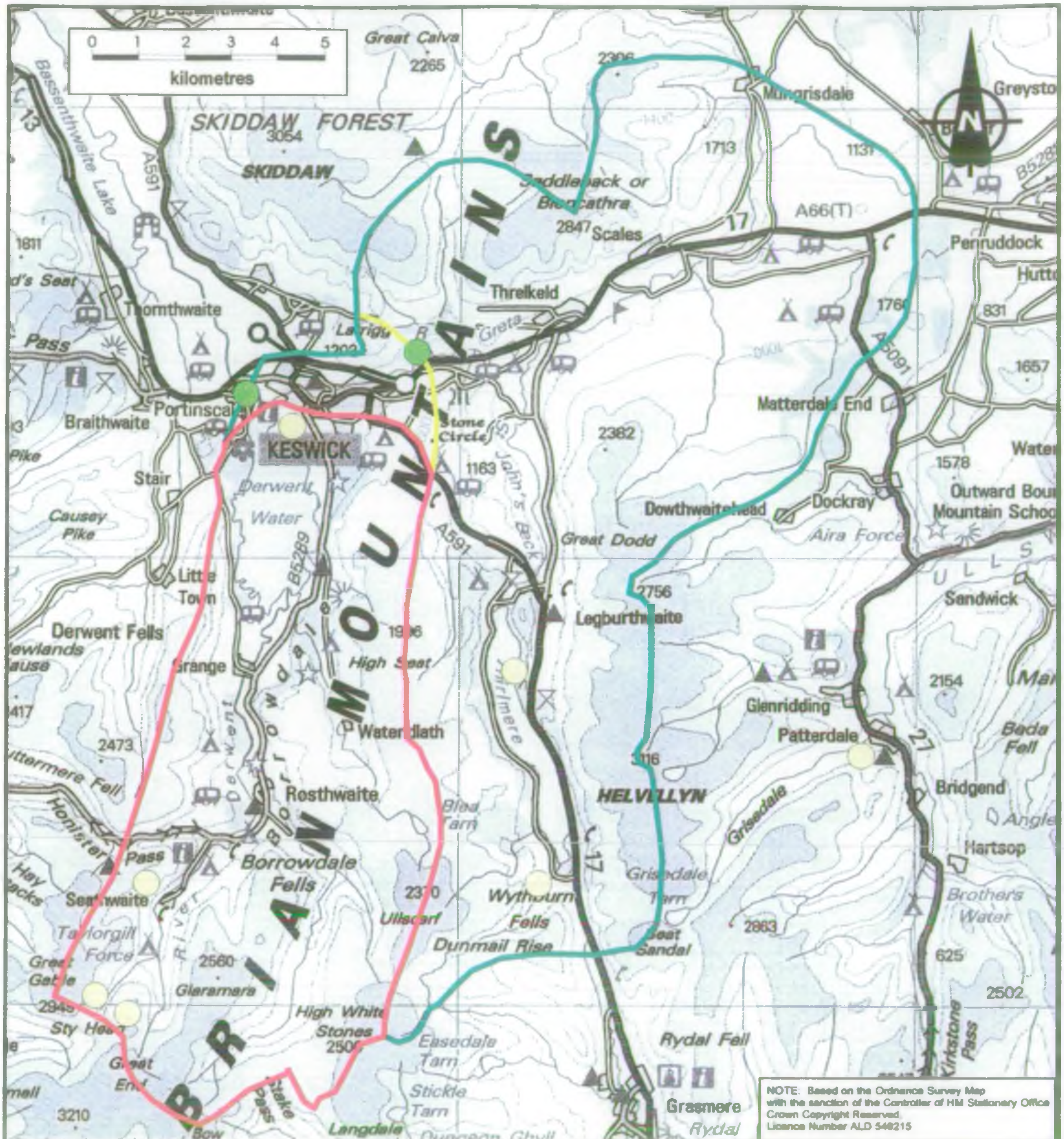
FIGURES



KEY

Catchment to Portinscale	Raingauge
Subcatchment to Low Briery	Flow gauging station
Derwentwater catchment	

RKL-ARUP

Environment Agency
NORTH WEST REGION

Lake District
National Park Authority

Derwentwater
January 1999
Approximate position of catchment boundaries, raingauges and flow gauging stations.
55390
Figure 1

PHOTOGRAPH No 1 - Long distance view from Langtrigg Fell

Derwentwater
January 1999
Landscape Photographs

55390

Figure 2

PHOTOGRAPH No.2 - View over marsh area to southern end of Derwent Water around the inlet

RKL-ARUP smeeden foreman

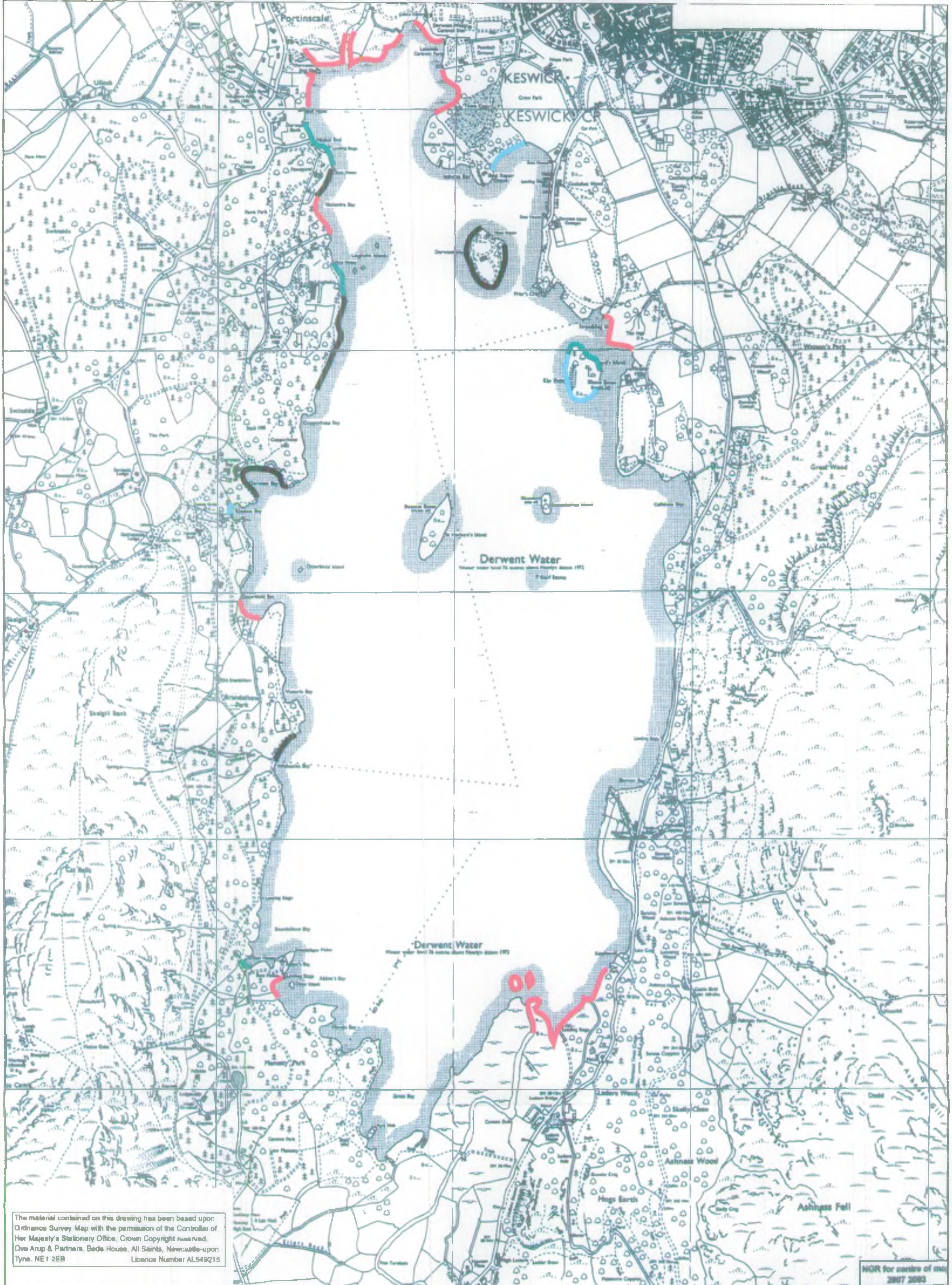
ENVIRONMENT AGENCY
NORTH WEST REGION

Lake District
National Park Authority

Derwentwater
January 1999
Landscape Photographs

55390

Figure 3



RKL-ARUP

Environment Agency

Lake District National Park Authority

LEGEND

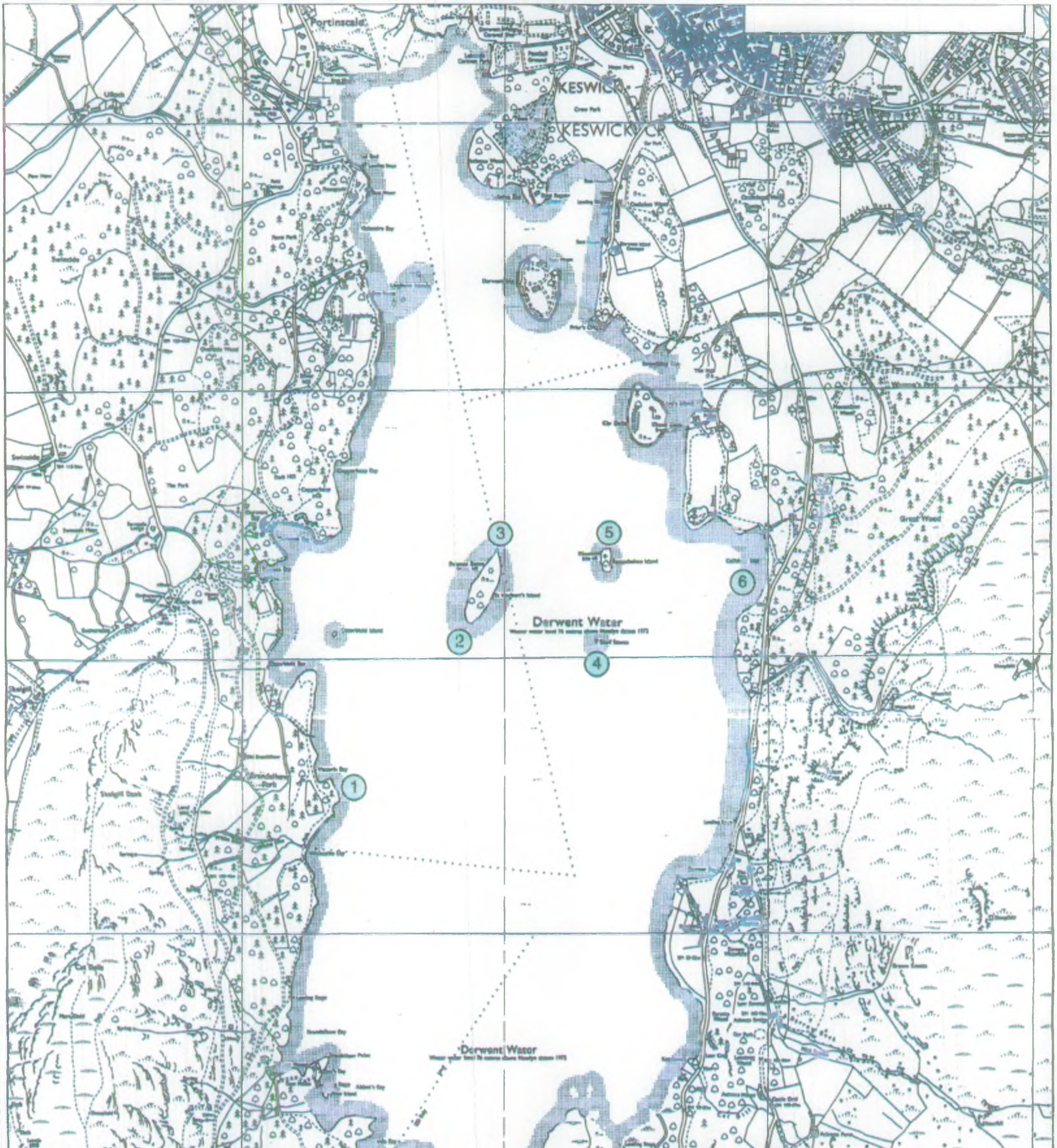
- An extensive/complete example of a stony shore hyrdosere
- An extensive/complete example of a soft shore hydrosere
- A restricted/incomplete example of a stony shore hyrdosere
- A restricted/incomplete example of a soft shore hydrosere

DERWENTWATER

Title: LOCATION OF STONY AND SOFTSHORE HYDROSERE

Date: JANUARY 1999

Figure: 4



RKL-ARUP

Environment Agency

Lake District National Park Authority

LEGEND

(2) Vendace Spawning Grounds

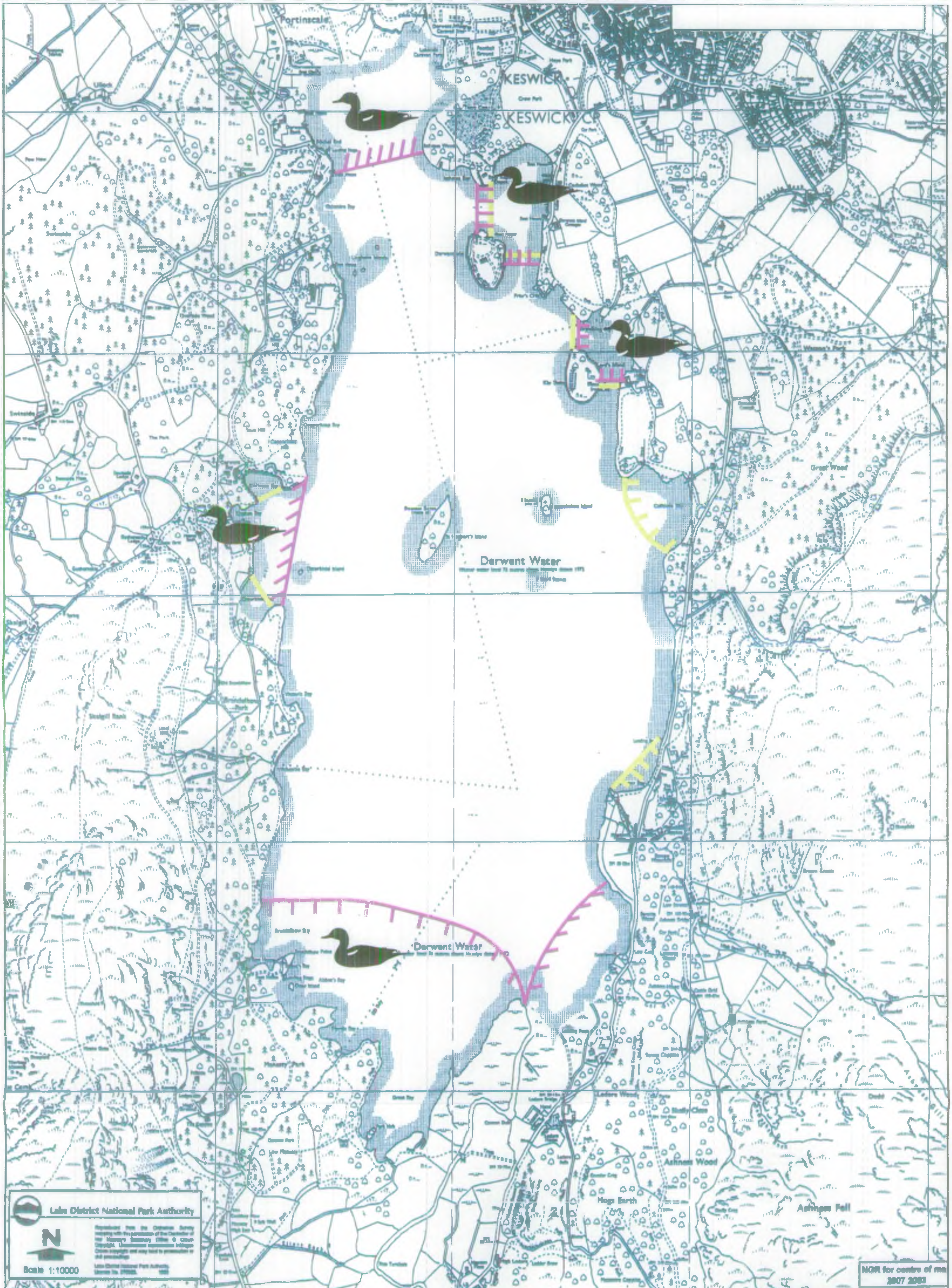
DERWENTWATER

Title: VENDACE SPAWNING GROUNDS

Date: JANUARY 1999

Figure: 5

55390-8500 FIG 5



RKL-ARUP

ENVIRONMENT AGENCY

Lake District National Park Authority

LEGEND

Principal Areas for Wintering Wildfowel

Important Areas for Summer Breeding

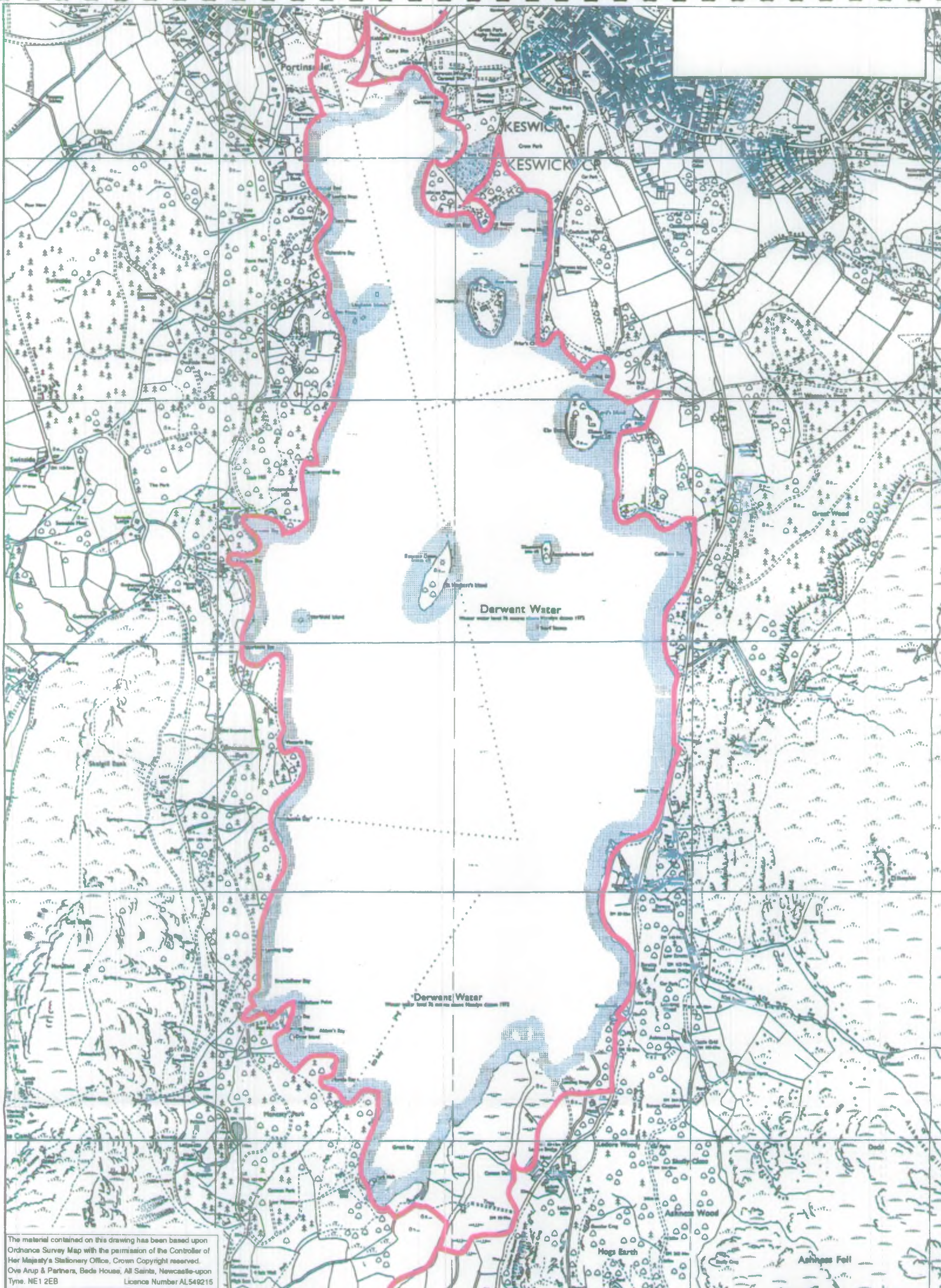
DERWENTWATER

Title: PRINCIPAL AREAS FOR WINTERING WILDFOWEL

Date: JANUARY 1999

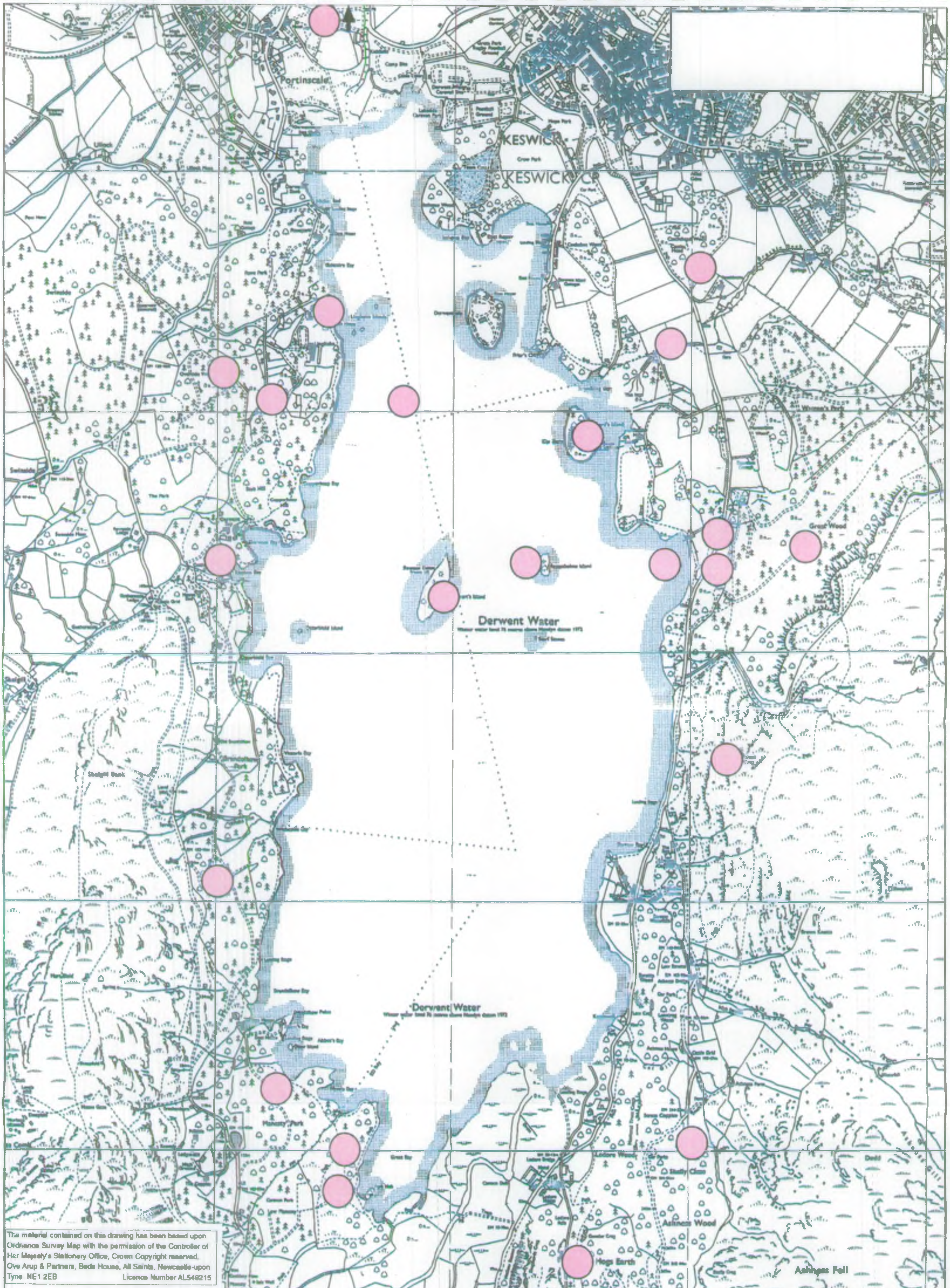
Figure: 6

58390-8500 FIG 6



RKL-ARUP Environment Agency Lake District National Park Authority	LEGEND SSSI Boundary	DERWENTWATER Title: SSSI BOUNDARY Date: JANUARY 1999 Figure: 7

55390-8500 FIG 7



RKL-ARUP

ENVIRONMENT AGENCY

Lake District National Park Authority

LEGEND

Cumbria Wildlife Trust Sites

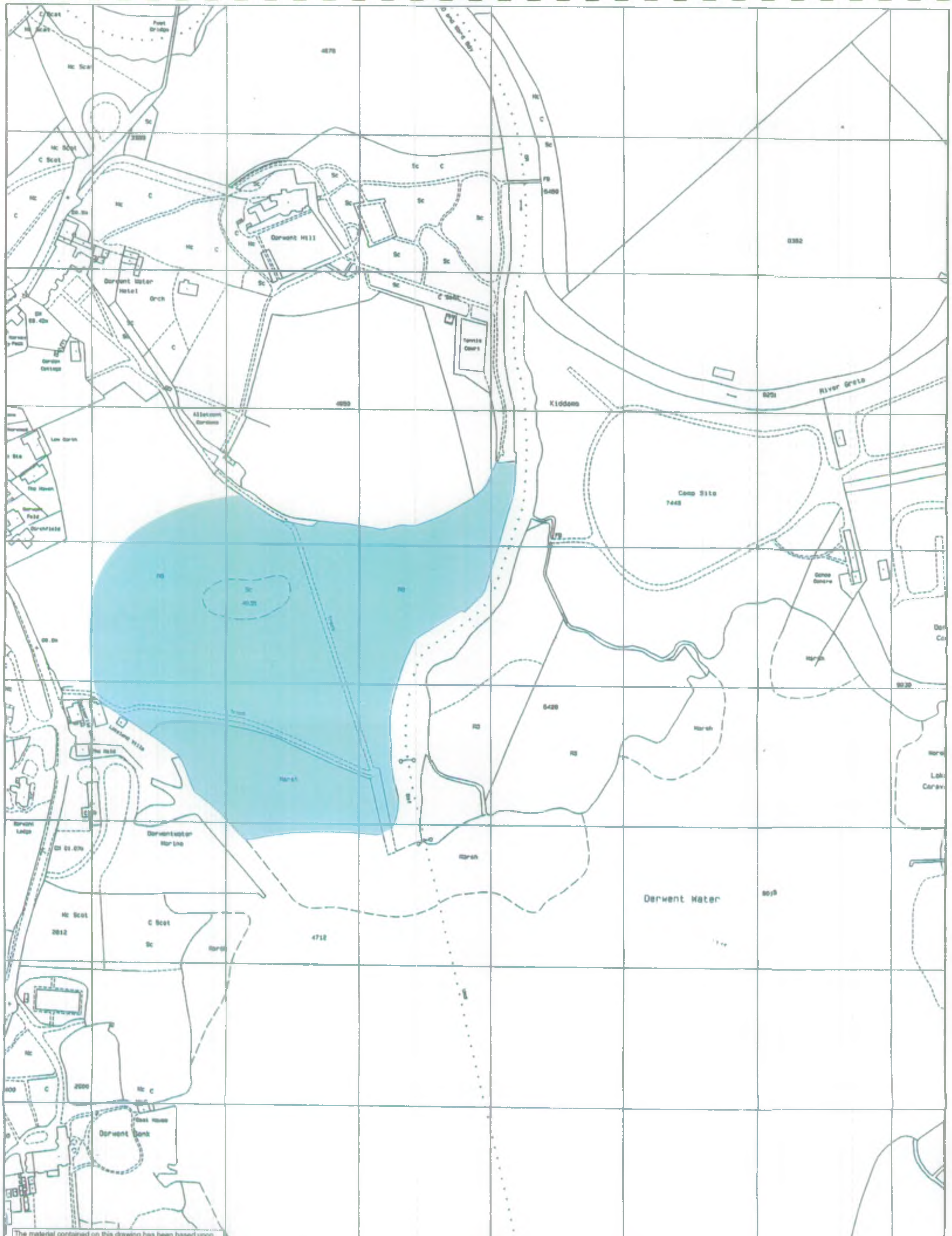
DERWENTWATER

Title: CUMBRIA WILDLIFE TRUST SITES

Date: JANUARY 1999

Figure: 8

55390-8500 FIG 8



RKL-ARUP

Environment Agency

Lake District National Park Authority

LEGEND

Zone of Interest for Weland Flora

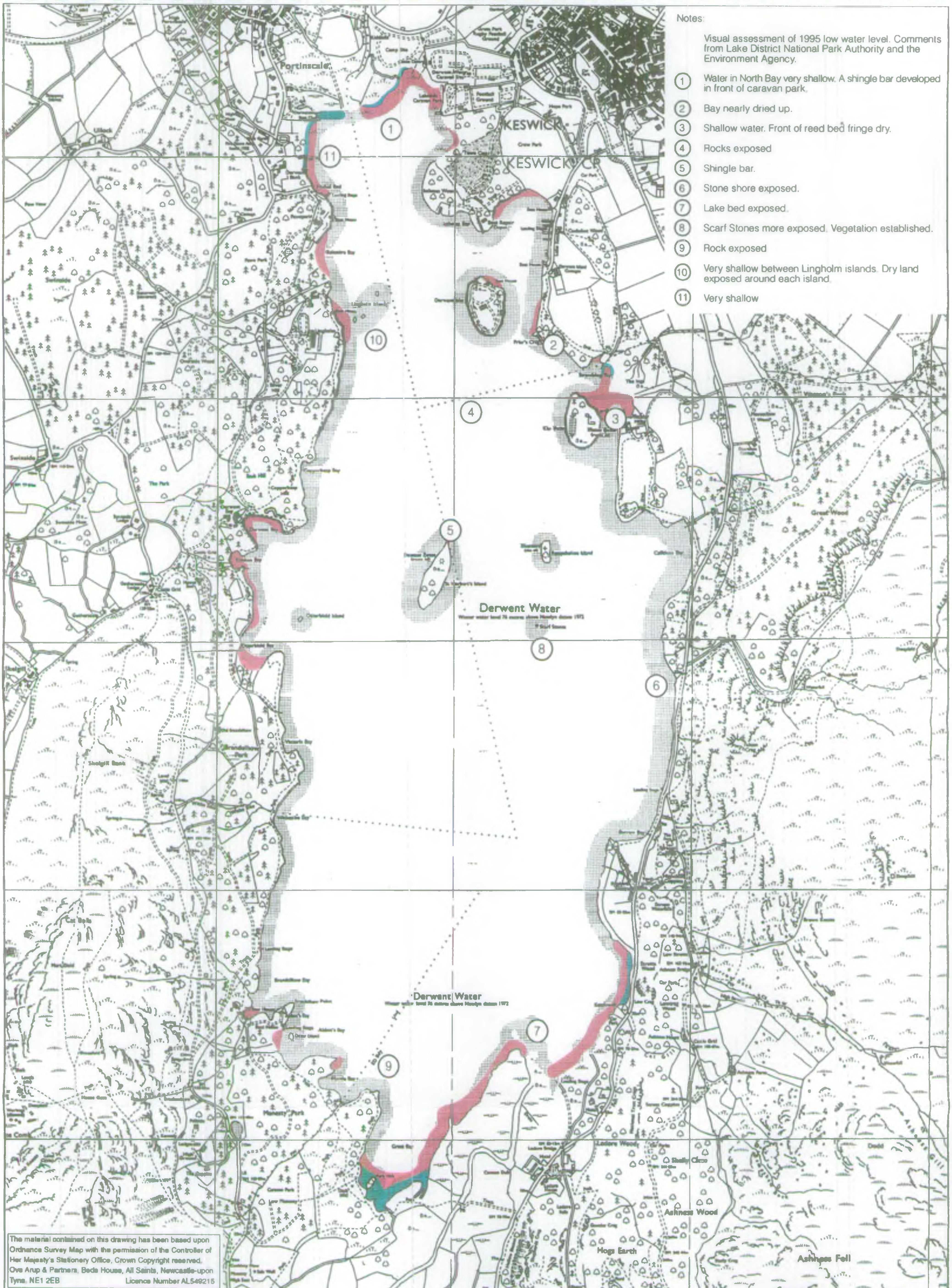
DERWENTWATER

Title: DETAIL OF SSSI AT OUTFLOW FROM LAKE

Date: JANUARY 1999

Figure: 9

55390-8500 FIG 9



Notes:

Visual assessment of 1995 low water level. Comments from Lake District National Park Authority and the Environment Agency.

1. Water in North Bay very shallow. A shingle bar developed in front of caravan park.
2. Bay nearly dried up.
3. Shallow water. Front of reed bed fringe dry.
4. Rocks exposed
5. Shingle bar.
6. Stone shore exposed.
7. Lake bed exposed.
8. Scarf Stones more exposed. Vegetation established.
9. Rock exposed
10. Very shallow between Lingholm islands. Dry land exposed around each island.
11. Very shallow

RKL-ARUP

Environment Agency

Lake District National Park Authority

LEGEND

- Exposed Shore at Water level of 74.61m AOD (proposed minimum lake level)
- Exposed Shore at Water Level of 74.38m AOD (1995 minimum lake level)

Note: Areas estimated from bathymetric survey

DERWENTWATER

Title: EXPOSED SHORE

Date: JANUARY 1999

Figure: 10

Appendix A

Limnology of Derwentwater: Figures A1, A2, A3, A4 & A5

Figure A1. The year-to-year variations is the depth of the mid-summer thermocline in a selected series of Cumbrian lakes.

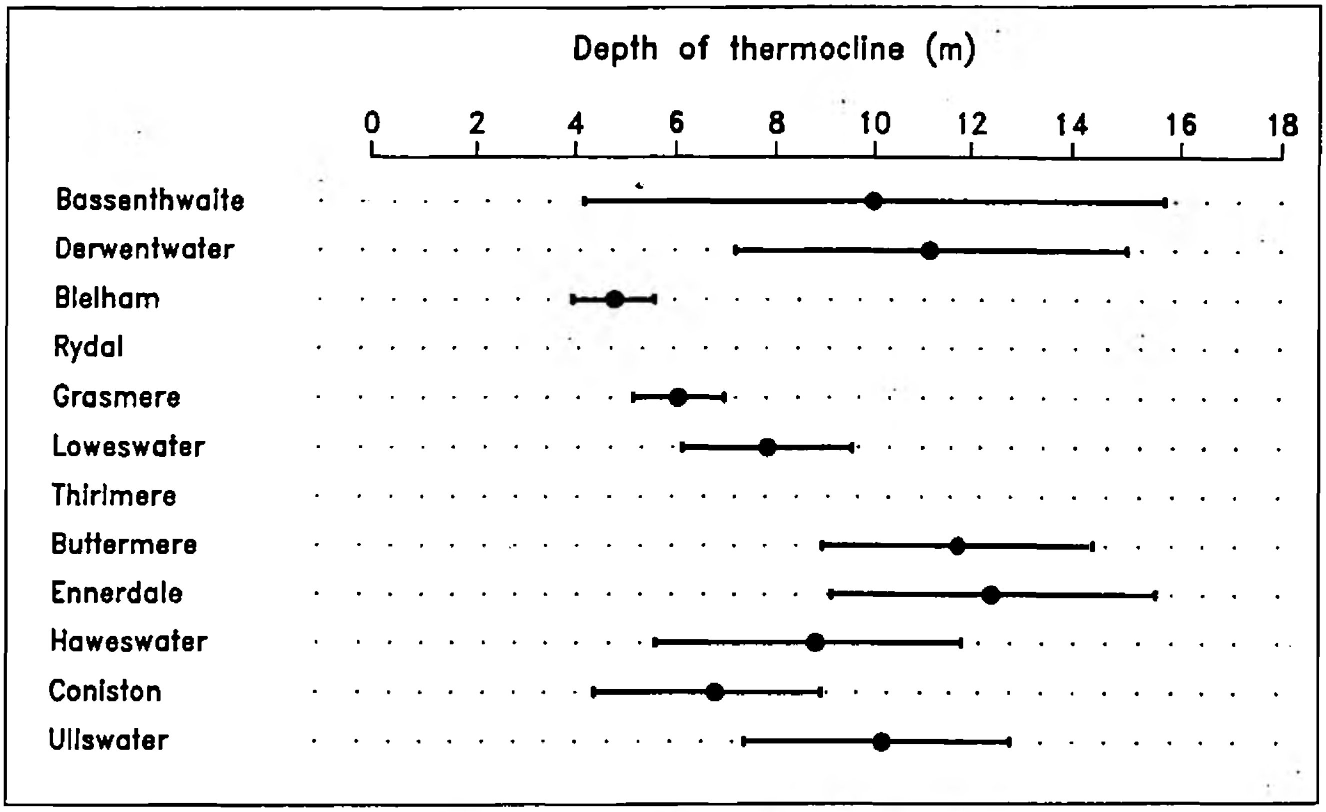


Figure A2. The water temperature measured at depths of 0m and 20m in Derwentwater (1995-1997)

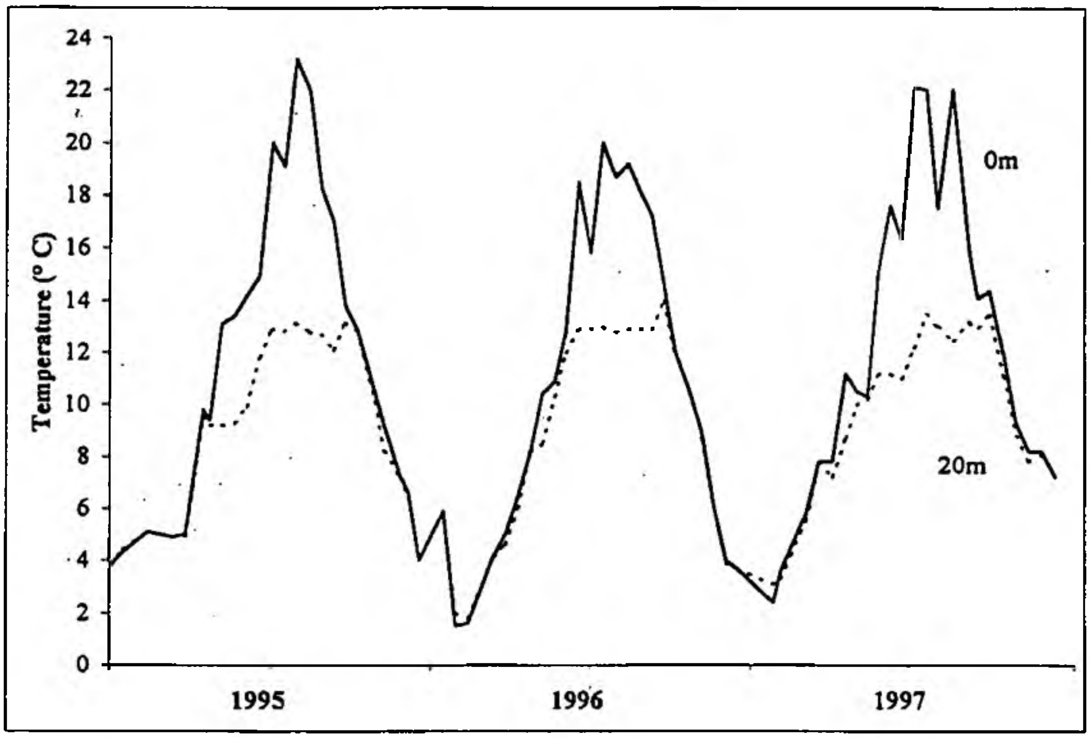


Figure A3. The oxygen concentrations measured at depths of 0m and 20m in Derwentwater (1995-1997).

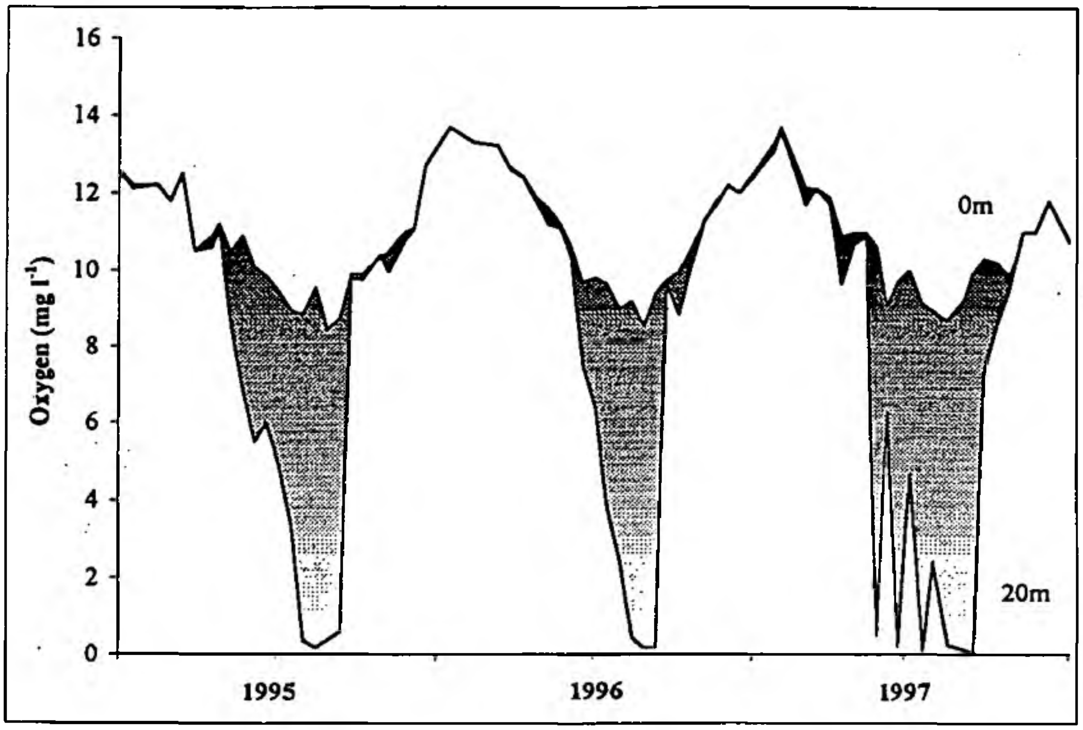


Figure A4. The total phosporus (-) and dissolved reactive phosphorus (….) concentractions measured in Derwentwater (1995-1997).

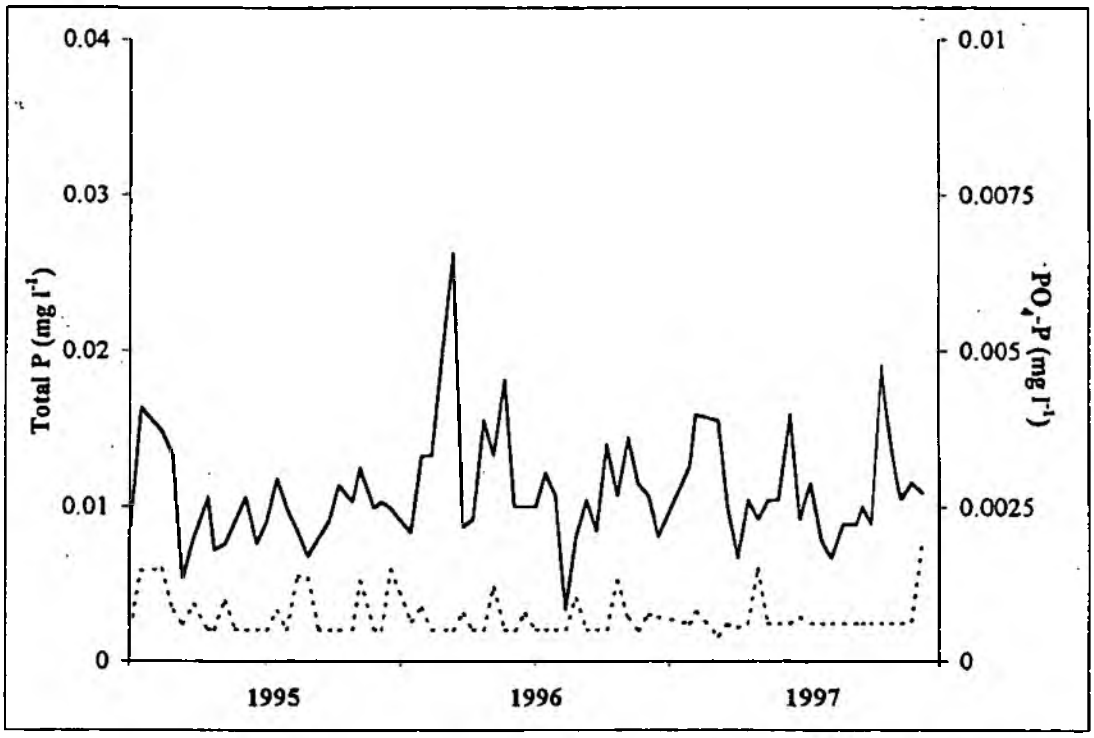
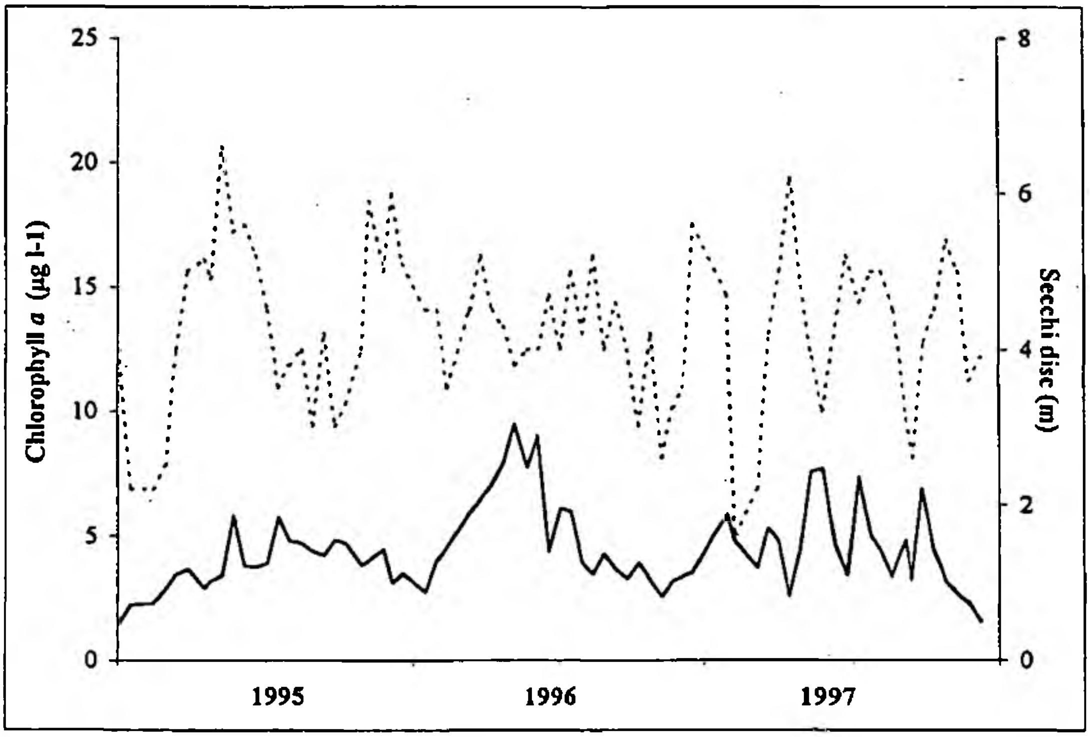


Figure A5. The chlorophyll concentrations (-) and Secchi disc depths (....) recorded in Derwentwater (1995-1997).



Appendix B

Emergent and submerged macrophytes at Derwentwater (after Stokoe, 1983)

- Achillea ptarmica
- Alisma plantago-aquatica
- Apium inundatum
- Aster sp.
- Callitriche hamulata
- Callitriche stagnalis
- Caltha palustris
- Carex rostrata
- Carex vesicaria
- Chara delicatula
- Elatine hexandra
- Eleocharis palustris
- Elodea canadensis
- Elodea nuttallii
- Equisetum fluviatile
- Fontinalis sp.
- Galium palustre
- Glyceria fluitans
- Hydrocotyle vulgaris
- Impatiens sp.
- Iris pseudacorus
- Isoetes echinospora
- Isoetes lacustris
- Juncus acutiflorus
- Juncus articulatus
- Juncus effusus
- Juncus bulbosus
- Littorella uniflora
- Lobelia dortmanna
- Lythrum salicaria
- Myosotis scorpioides
- Myriophyllum alterniflorum
- Nitella flexilis
- Nitella translucens
- Nuphar sp.
- Nymphaea alba
- Oenanthe sp.
- Peplis portula
- Phalaris arundinacea
- Phragmites australis
- Pilularia globulifera
- Polygonum hydropiper
- Potamogeton berchtoldii
- Potamogeton natans
- Potamogeton obtusifolius
- Potamogeton polygonifolius
- Ranunculus flammula
- Ranunculus peltatus
- Scirpus fluitans
- Scirpus lacustris
- Senecio sp.
- Sparganium angustifolium
- Sparganium erectum
- Sparganium minimum
- Utricularia sp.

Appendix C

Wintering Wildfowl and Breeding Birds

Species	Status at Derwentwater
Little Grebe	Probable breeder in very small numbers
Great Crested Grebe	Regular Winter visitor, occasional Summer visitor (nests at Bassenthwaite lake)
Cormorant	c.20 resident, but a roost of over 50 on Rampsholme (birds from Bassenthwaiteroost overnight)
Heron	Three nests each year on islands
Mute Swan	Presently one pair; breeding site unknown in 1998
Whooper swan	Occasional Winter visitor
Pinkfooted Goose	Occasional Winter visitor
Greylag goose	Numbers declined slightly in early 1990s (from maximum of 191 in 1991 to 121 in 1993), but now increasing. Full numbers from the Summer moult period for the last four years have been recorded by the National Park Authority.
Canada Goose	Breeding flock on islands, but do move between lakes. 104 birds recorded during Summer 1998.
Wigeon	Very small numbers in Winter
Teal	Very small numbers in Winter
Pochard	Regular Winter visitor, increasing in numbers (155 in 1998)
Mallard	Resident, nubers increase to c. 350 birds in Winter
Tufted Duck	Resident numbers increase in Winter to usually c.80 - 100 birds; occasional breeder, having bred in 1996
Common scoter	Irregular passage birds (storm-driven?)
Goldeneye	Regular Winter visitor; slight increase to 53 in 1998
Red-breasted Merganser	Breeds in small numbers
Goosander	2 - 3 pairs breed regularly. Lake used as a post-breeding moult site and crèche for young
Ruddy Duck	Occasional; only 1 record for 1998
Osprey	Scarce passage migrant
Water Rail	Scarce, breeds in Ings Wood and Town Cass
Grey Wagtail	Breeding on lake margin; shoreline feeders
Little Ringed Plover	Attempted breeding in 1997; flooded
Moorhen	Breeds campsite area
Coot	Breeds at north end of the lake; Winter numbers increasing to 317 in 1996/97 (Bassenthwaite numbers crashed)
Oystercatcher	2 - 3 pairs nest on shores

Species	Status at Derwentwater
Curlew	Recorded on passage only
Snipe	Breeding resident
Common Sandpiper	Regular Summer visitor; c. 12 breeding pairs; shingle important for feeding
Blackheaded Gull	Resident non-breeding birds
Common Gull	Usually Winter resident
Lesser Black-backed Gull	New breeder on Scarf Rocks
Great Black-backed Gull	1 - 2 most of year, non-breeding, Summer
Yellow Wagtail	Has declined to point at which there are only occasional sightings
Dipper	Present at times usually in Winter
Sedge Warbler	Many breeding locations on riparian fringe and marsh
Rook	Winter roost on Lords Island
Reed Bunting	Recorded around the lake, but a census required for this nationally declining bird

N.B.
It is suggested that geese travel frequently between the lakes in the area and numbers are therefore difficult to quanitfy at any period except Summer moult in June. Records suggest that numbers of geese are fairly constant over the years.