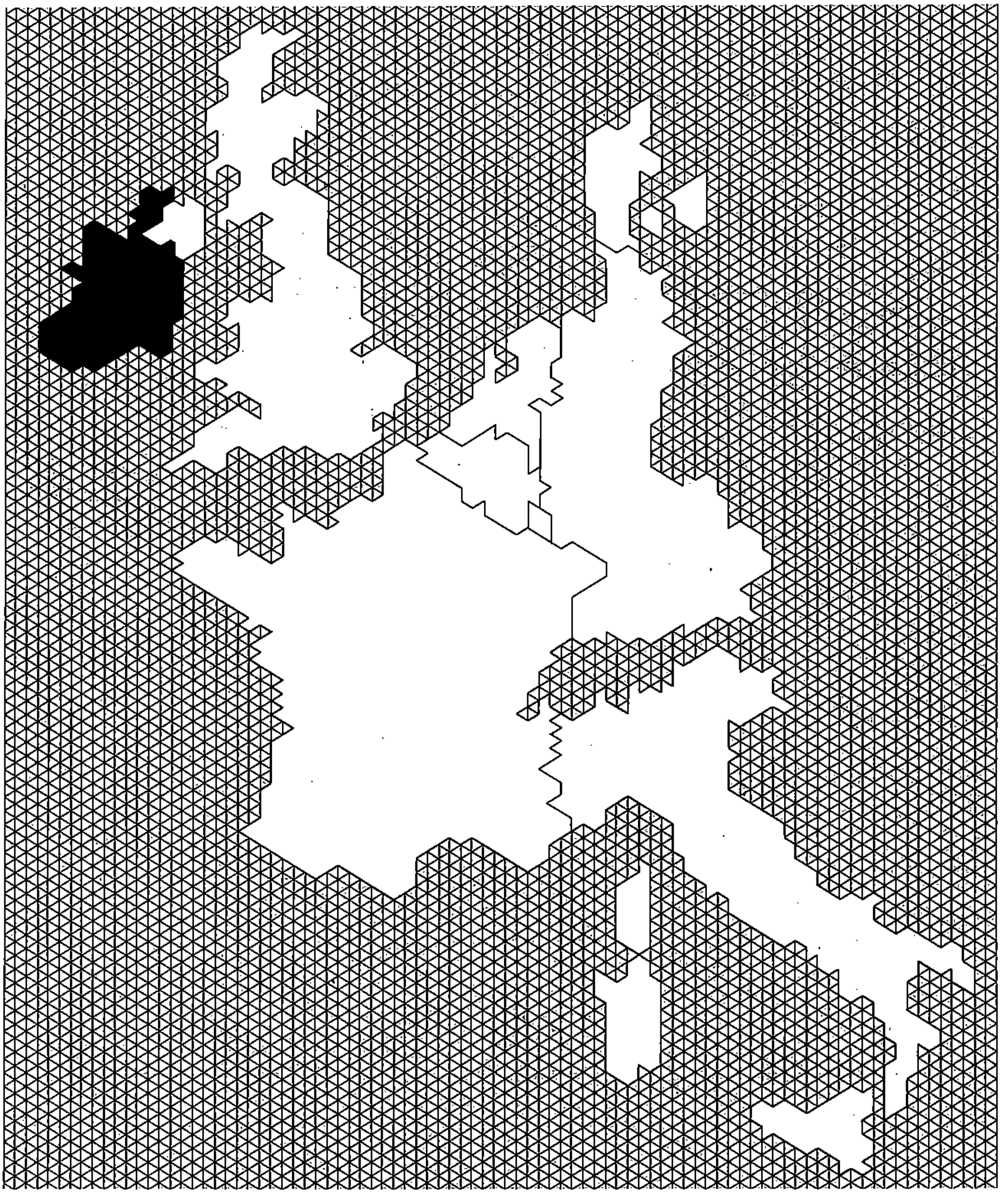
Commission of the European Communities

Groundwater Resources of the Republic of Ireland



Commission of the European Communities

Groundwater Resources of the Republic of Ireland

Directorate-general for the environment,
consumer protection and nuclear safety

Th. Schäfer GmbH · D-3000 Hannover 1

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Introduction

Dr. K.-H. Narjes

Member of the Commission
of the European Communities

responsible for the Environment, Consumer Protection
and Nuclear Safety

The balance of groundwater resources in the Community is an estimate of these resources designed primarily to be of use to water management and planning authorities and, more generally, to national and Community decision-makers. This study has been performed at a scale such as to allow the homogenization of the results and to ensure their consistency as well as meaningful comparisons between Member States. It provides a picture as complete as possible at Community scale of the distribution and availability of groundwater.

One of the first international studies of its kind, it is original on several accounts:

- From the viewpoint of the results, the study provides the necessary elements for national and community groundwater management, especially by collecting and analyzing – in many cases for the first time – data which are usually dispersed; it also identifies gaps which should be filled for rational management of this important resource.
- From the technical viewpoint, the study, by introducing a regionalization both scientific and administrative, has displayed the problems of managing groundwater, within a framework which can also be used for political decision making.
- From the methodological viewpoint, the fact that the study has been carried out by nine teams, one from each Member State, under a project leader has made it possible to compare and harmonize approaches and methods used in the Member States.

The results and methodology should be of widespread interest.

Introduction

A. Andreopoulos
Director-General
Environment, Consumer Protection and Nuclear Safety

The Commission of the European Communities presents the balance of groundwater resources in the Community.

For the first time, a picture as comprehensive as possible at Community scale is given of the aquifers and their availabilities. The study deals with four main themes. Each is illustrated by 38 (1:500000) maps together covering the entire Community (i.e. a total of 152 maps, about 50×80 cm on average) and is explained in detail in 10 reports, one for each Member State and a general survey.

Greece joined the European Community on 1 January 1981, when the studies for the nine other Member States had already been made.

It is for this reason that Greece is not included in this report. Work on Greek underground waters started in 1982 and the information for this Member State will be integrated subsequently into the complete report.

The themes are:

- Inventory of aquifers: location; geometric, lithological and stratigraphical characteristics; type (unconfined or confined); permeability (interstitial of fissures and karst);

- Hydrogeology of aquifers: transmissivities, direction of flow, water exchange between rivers and groundwater, and specific problems such as the intrusion of seawater;

- Groundwater abstraction: abstraction densities, large pumping stations;

- Potential additional groundwater resources: factors such as replenishment, use and water management imperatives are all taken into account in a geographical classification of the areas in which there is a possible surplus, areas in which there is a balance, areas in which resources are now known to be over-used under present abstraction policies and finally areas lacking adequate groundwater resources.

For several Member States this inventory is the first complete cataloging on their own national water resources. The study collates as far as possible all data which would otherwise be dispersed and, in many cases processes them for the first time.

This inventory is not only an essential instrument of Community groundwater management. It will also be extremely useful for the knowledge and management of groundwater resources, thanks to the original evaluation method, which combines both a hydrogeological and administrative regionalization on a network adapted to national administrative units. This makes it very easy to use for management and modelling taking into account administrative and political features.

Special symbology has been devised to ensure uniform mapping of the results throughout the Community. This makes the information more accessible to the layman without sacrificing any of the technical quality of the information.

THE GROUNDWATER RESOURCES OF THE REPUBLIC OF IRELAND

CONTENTS

PREFACE

This report was written in fulfilment of a contract between the Commission of the European Communities, Director of the Environment and Consumer Protection Service, and the Geological Survey of Ireland, dated 13 September, 1978. It is accompanied by a set of twelve maps at a scale of 1:500,000, namely Belfast (Maps 1, 2, 3 and 4), Dublin (Maps 1, 2, 3 and 4) and Cork (Maps 1, 2, 3 and 4) of the series 1404 (Sheets 172-B, 171-D and 172-C respectively).

Chapter VI was written by E.P. Daly, Chapter IX by D. Daly, Chapters I, X and XI by C.R. Aldwell, and the remaining chapters by G.R. Wright, who also edited the report. The assistance of other members of the staff of the Geological Survey, and of members of staff of other Government Agencies, Semi-State Organizations, and Local Authorities, is gratefully acknowledged. The authors are also indebted to the coordinators of the project, Professor J. Fried, Mr. M. Zampetti, and Mme. Beller, for their help and patient guidance.

I. General Description.

The Republic of Ireland has an area of just over 70,000 sq.km. Topographically the country consists of a central lowland, most of which lies between 50m and 130m above sea level, surrounded by mountains and hills with peaks ranging from 500m to 1000m. About 5% of the country stands above 300m and most of this is within 50 km of the sea.

The geological structure is a clear western continuation of Europe and the neighbouring island of Britain. The major part of the country shows a pronounced NE-SW Caledonian trend. In the southern counties of Cork and Kerry, south of the Hercynian Front the structural trend swings markedly to the E-W Armorican line. (See Figure I.1.)

The oldest rocks are the Precambrian schists and quartzites of Donegal, Sligo, Mayo and Galway in the northwest and west, and of Wexford in the southeast. Small areas of Cambrian slates and quartzites occur on the east coast at Howth, Bray and Wexford.

Rocks of Ordovician and Silurian age are more widely distributed, especially in the east. In the southeast they flank the Leinster Granite of the Wicklow and Blackstairs Mountains and extend for some 200 km from Dublin to the south coast. They comprise steeply dipping slates, schists, greywackes and volcanic rocks. The volcanics include tuffs, rhyolites and andesites and are the predominant rocks in east Waterford. To the north of Dublin, Ordovician and Silurian rocks occur widely in Counties Louth, Monaghan and Cavan as slates and sandstones and form country of moderate relief up to 300m. Silurian slates and sandstones are found in the cores of anticlinal inliers in the midlands, forming hills of 500 to 600 metres.

The Devonian strata generally lie unconformably on the older rocks, following the Caledonian orogeny. The Devonian rocks are of continental non-marine facies, ("Old Red Sandstone") and comprise red, purple, and green conglomerates, hard sandstones and slates. They are widespread in the midlands and especially in the south, and owing to their resistance to erosion they often form rugged terrain with ridges and peaks of 600 to 1000m.

The Carboniferous is the most important rock system in Ireland, underlying about half of the country. It occurs over the entire midlands except for a few inliers of older rocks. The rock types include various types of limestone, dolomite, shales, sandstones and a few coal seams. The lower part of the succession is generally of limestones with subordinate shales, while the upper part is of shales with sandstones. Chemical solution of the limestones has taken place to varying degrees, depending on the type of limestone, structural effects and its length of exposure to weathering.

A small outlier of Permo-Triassic rocks occurs near Kingscourt, Co. Cavan. Jurassic, Cretaceous and Tertiary rocks are almost entirely absent. Quaternary deposits are widespread. In the north-east especially they comprise boulder clay. Gravels are common across the midlands, sometimes underlying peat bogs. Accurate knowledge of the thickness of Quaternary deposits is often lacking and they also show complex lateral variation. Along the east and south coasts buried river channels are cut down to 50m below present sea level.

In the drainage pattern the dominant feature is the River Shannon which drains most of the central lowlands before entering its wide estuary into the Atlantic. Other major rivers include the Barrow, Nore, Suir, Lee and Blackwater which drain the south and south east of the country, the Boyne, Liffey and Slaney flowing to the east coast, and the Corrib, Moy, Erne and Foyle in the west and northwest. Much of the midlands is poorly drained peat bog or suffers from winter flooding. Arterial drainage schemes to relieve this problem are important in this region.

The natural vegetation of the country was deciduous forest, but most of this has been removed and the present vegetation is predominantly grassland, with peat bogs and moorland in poorly drained areas and hills over 300m high. Reafforestation, mainly by conifers, is in progress in many upland areas. Land use is primarily for pasture for livestock - dairy cattle on better pastures, beef cattle on poorer land and sheep on upland areas. Tillage is important in some areas, chiefly cereal and fodder crops and sugar beet.

The Irish climate is of the cool temperate oceanic type, being mild, moist, windy and changeable. Rainfall is reliable and fairly evenly distributed through the year, with an average monthly precipitation of at least 50 mm even in the driest period from March to June. Snow is rare at sea level and frost seldom severe near the coast. Summers are usually cool. The mean annual air temperature ranges from 9.5°C to 10.5°C.

Most of Ireland's rainfall comes from Atlantic depressions. As a result the western districts and especially mountainous areas receive most rain. The annual average ranges from 750 mm in the driest areas of the east to 1600 mm in lowland areas of the west. Extremes of over 3000 mm are reported from mountainous parts of the west and south west. Quite large variations from the monthly average rainfall can occur, but seldom a variation of more than 30% from the annual average.

The average relative humidity is about 85%. Cloud and light rain are therefore common. More than 1mm of rain falls on an average of 139 days in the year at the driest station (Dublin) and on 242 days in the year at the wettest (Co. Mayo).

Figures I.2. and I.3. show, respectively, the mean annual rainfall and mean evapotranspiration for Ireland (courtesy of the Meteorological Service.)

FIGURE I.1 Geology

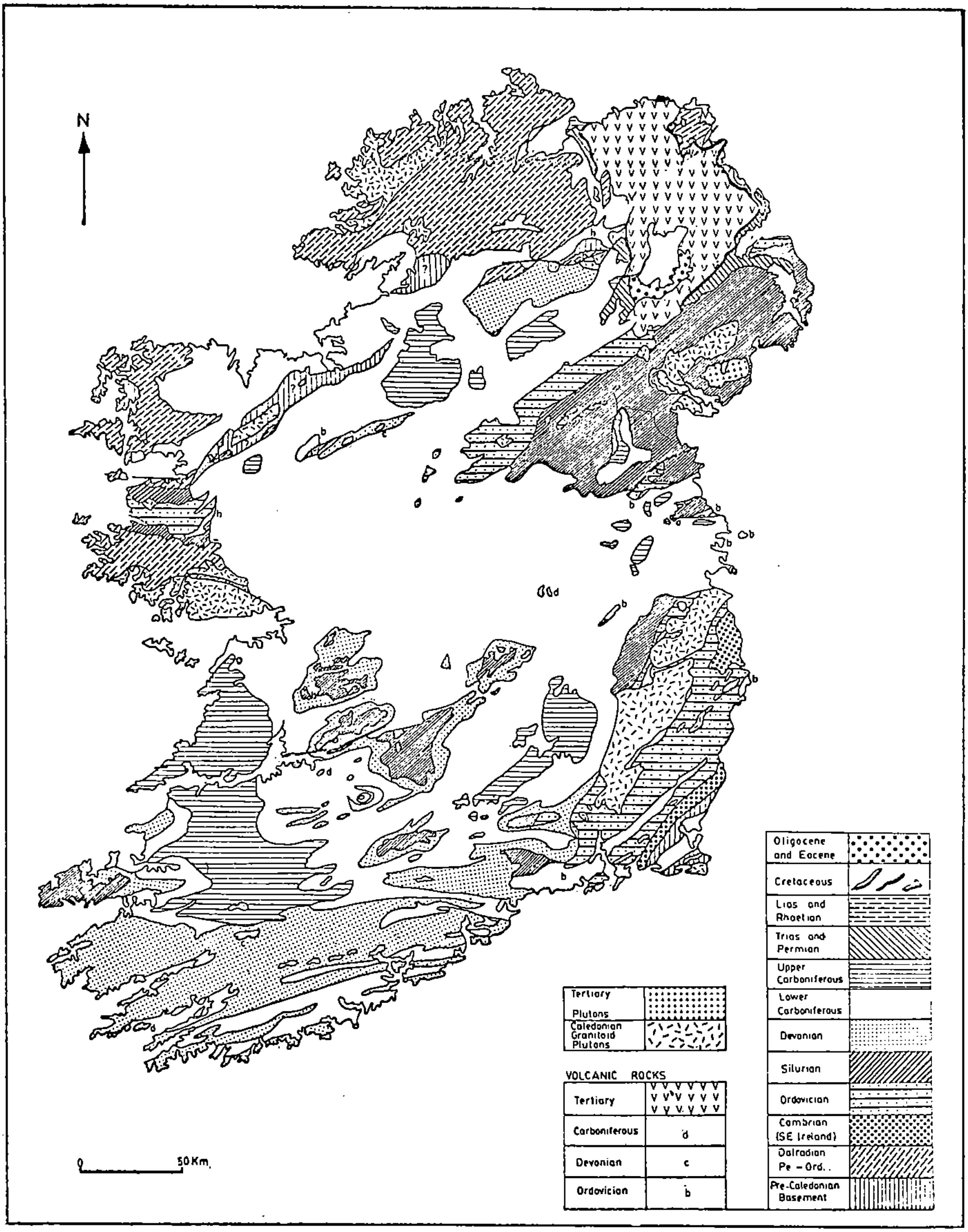
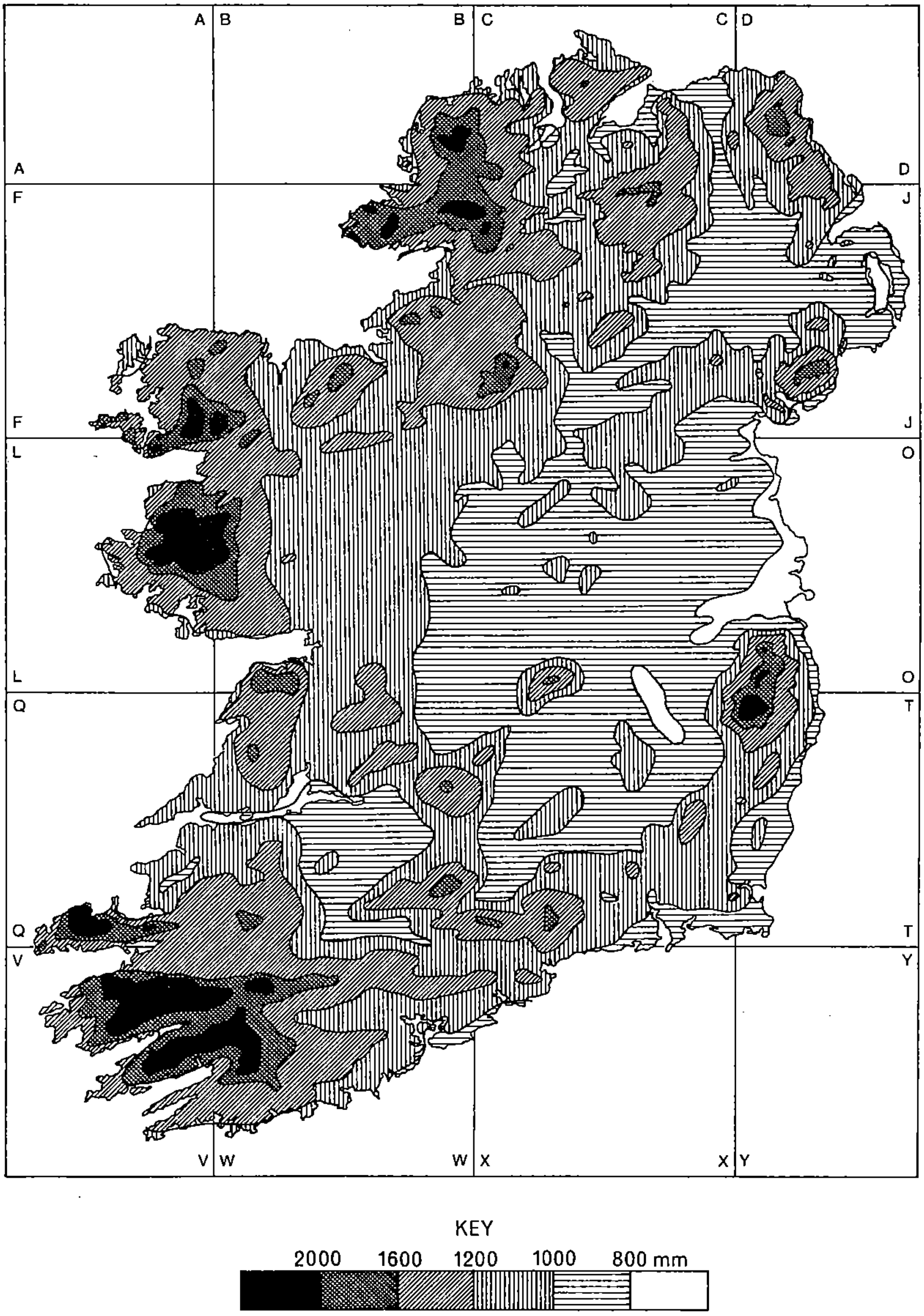
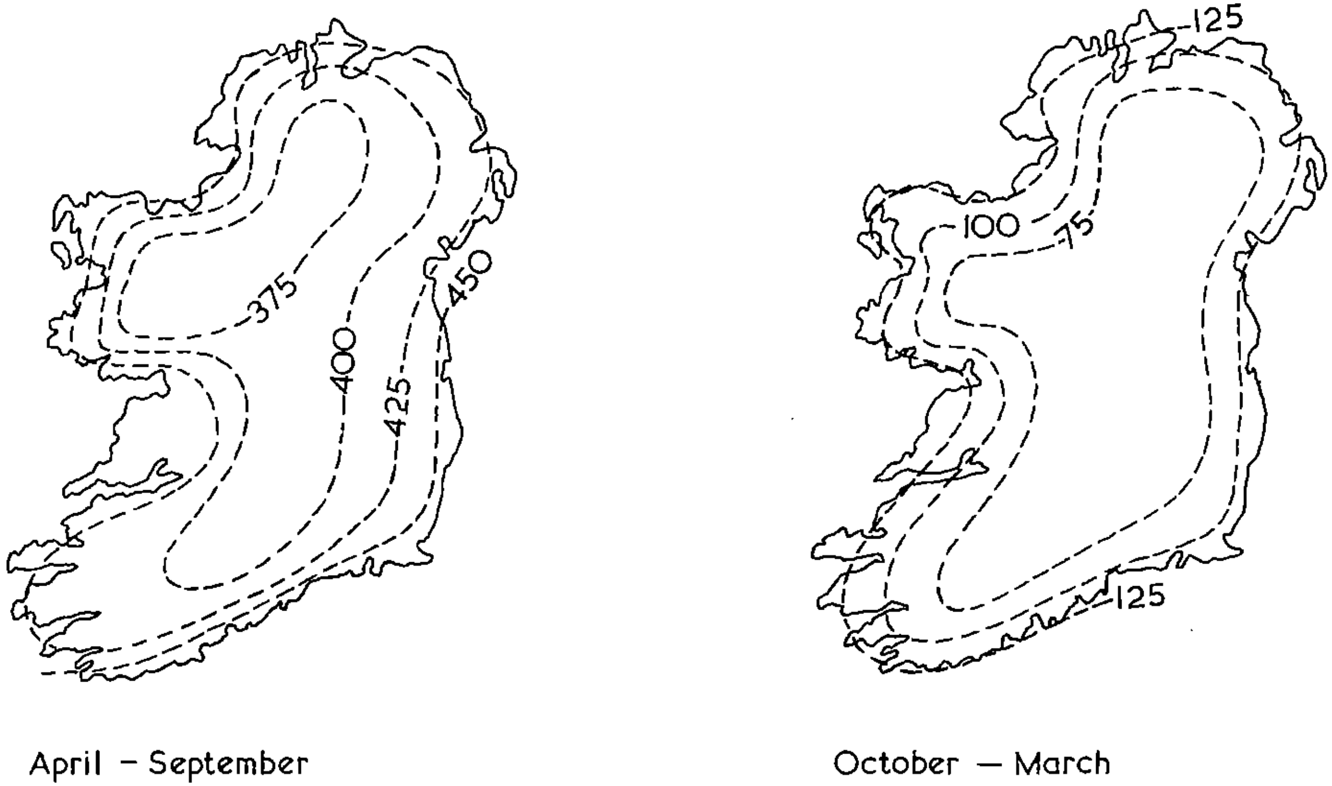


FIGURE I.2 Annual Rainfall



Source: Meteorological Service, Dublin

FIGURE I.3 Mean Potential Evapotranspiration (mm) 1958 - 72



Source : Meteorological Service, Dublin

II. WATER SUPPLY IN THE REPUBLIC OF IRELAND

II.1 The provision of a public water supply in the Republic of Ireland is principally a function of the local authorities, which consist of the County Councils, County Borough Councils and Urban District Councils. These local authorities provide a piped supply to the main urban areas and villages within their boundaries, and sometimes to other adjacent areas (for example Dublin County supplies water to adjacent areas of Counties Kildare, Meath and Wicklow). For the major city supplies, the water source is normally one or more impounding or regulating reservoirs, but for smaller populations supplies are often derived from springs or wells.

Because the population density is low in rural areas, the provision of piped supplies on a regional basis is expensive, and until recently much of the rural population had no public supply except from roadside hand-pumps. In recent years, small rural water supply schemes have increasingly been provided, either by local authorities or by 'Group Schemes' in which groups of residents in a neighbourhood would jointly fund a water supply scheme, assisted by Government grants.

However, the more isolated farms and houses still lack a public supply and must provide their own supply (again aided by Government grants), normally from a well.

Because the public supplies are relatively small, it is often difficult for a local authority to provide a supply from its existing scheme for an industrial concern which uses a lot of water. Consequently, many industries provide their own water supply, often from groundwater. This is especially true of creameries.

II.2 There is at present no requirement for the licensing of water abstractions, and therefore there are no exact figures for water abstraction and usage in the Republic of Ireland. It is, therefore, difficult to estimate the importance of groundwater in the country.

Table II.1 lists the major local authority areas for the country and the estimated water abstraction by source and usage. The total water supply shown on Table II.1 of 1.155 Mcm/d should be a slight underestimate because it ignores small water supplies of less than $5m^3$/day. The total supply inclusive of small supplies is likely to be around 1.2 Mcm/day and because small supplies (for individual houses, farms, etc.) are more often from groundwater than from surface sources, the proportion represented by groundwater is likely to be about 25%.

Trends in groundwater usage

Because of the lack of any system for the licensing of central registration of water usage, there are no accurate figures to indicate the trends of water usage in the country. However, some tendencies can be indicated as taking place in recent years.

(a) Water usage in the country is increasing due to increases in domestic living standards, increasing industrialisation, and intensification of farming methods.

(b) There is an increase in the number of households being provided with a piped water supply, and a consolidation of very small water supply schemes into larger regional schemes.

(c) There is increasing urbanization chiefly in the form of suburban-type development.

(d) Surface water sources are becoming more polluted by domestic, industrial and agricultural effluents (e.g. silage liquor, etc.). This has resulted in the enactment of a Water Pollution Act, in 1977.

It is not clear whether these trends, and other less important factors, are significantly affecting the groundwater use as a proportion of total water use. Much of the present groundwater use is from springs rather than boreholes, and where

TABLE II.1

WATER SUPPLY IN IRELAND (EXCLUDING SMALL SUPPLIES OF LESS THAN $5m^3/d$)

COUNTY	PUBLIC SUPPLY Mm^3/yr		INDUSTRIAL AND PRIVATE SUPPLIES, Mm^3/yr		TOTAL SUPPLY Mm^3/yr	GROUNDWATER AS % OF TOTAL
	SURFACE WATER	GROUND WATER	SURFACE WATER	GROUND WATER	Mm^3/yr	
Carlow	2.206	1.738	(0.365)	1.327	5.637	54.4
Cavan	2.475	0.292	4.275	1.643	8.684	22.3
Clare	3.707	0.713	4.537	0.321	9.279	11.1
Cork (incl. city)	(39.603)	(6.552)	(0.730)	(13.140)	(60.024)	(32.8)
Donegal		(0.164)		-	7.466	(2.2)
Dublin (incl. city)		-		(1.825)	(109.500)	(1.6)
Galway		(3.650)		(0.183)	(16.074)	(23.8)
Kerry	10.990	3.002	0.151	2.115	16.259	31.5
Kildare		(0.548)		(1.095)	5.133	(32.0)
Kilkenny	3.876	5.412	(0.365)	2.306	11.959	64.5
Laois	(0.400)	3.835	(0.365)	0.201	4.800	84.1
Leitrim	0.715	0.904	0.008	0.174	1.800	59.9
Limerick (incl. city)	10.853	3.610	3.003	1.890	19.356	28.4
Longford	2.102	0.707	0.330	0.478	3.619	32.7
Louth	5.497	0.268	0.613	1.221	7.598	19.6
Mayo		(1.825)		(0.183)	(16.425)	(11.1)
Meath	11.408	0.288	0.287	0.726	12.709	8.0
Monaghan	2.770	0.180	1.818	0.846	5.614	18.3
Offaly	2.931	2.337	-	-	5.268	44.4
Roscommon	0.050	9.558	-	-	9.608	99.5
Sligo	3.548	1.129	0.108	0.058	4.842	24.5
Tipperary Nth.	6.691	2.054	0.199	0.855	9.799	29.7
Tipperary Sth.		(3.650)		(1.825)	(10.950)	(50.0)
Waterford (incl. city)	9.678	4.328	2.993	0.455	17.454	27.4
Westmeath	5.355	0.680	0.038	0.018	6.092	11.5
Wexford	9.273	3.573	2.544	0.606	15.996	26.1
Wicklow		(0.365)		-	(5.475)	(6.7)
TOTAL:		61.362		33.489	407.428	23.3

(figures in brackets are rough estimates).

there is still spare capacity in spring sources, these will probably be further developed. However, engineers in Ireland have had little confidence in groundwater sources and normally look for a surface water source (run-of-the-river or impounding reservoir) in preference to a groundwater source. Consequently, the trends of increasing consolidation of small water schemes and increasing urbanization tend to reduce the role of groundwater. The largest urban centres - Dublin, Dun Laoghaire, Cork, Limerick, Waterford, Galway, etc. - rely entirely or largely on surface water sources.

Nevertheless, there is also a good deal of well-drilling still going on in the country, as new homes are built in the rural areas, farms increase their water usage beyond the capacity of their existing wells, and new industries are set up outside country towns. For the last few years, since the introduction of modern down-the-hole hammer drilling rigs largely replaced the older cable-tool rigs, the number of wells drilled each year has been about 5,000, possibly more. About 70 well-drilling firms operate within the country. The average depth of borehole has also increased from around 30-40m before 1970 to (probably) 60m now. Maximum depth in Ireland is normally about 120m. These boreholes are normally of 150mm diameter, sometimes 200mm, and only occasionally wider. Pumps are normally of the 'jet' type (i.e. a hybrid centrifugal + ejector type). For larger abstractions, electric submersible pumps or electrically-driven 'Mono'-type pumps are used. Well-screens are little used, and therefore unconsolidated aquifers are very much underdeveloped, mainly through lack of knowledge and expertise on the part of drillers and engineers, though this is gradually changing for the better.

In summary, it seems reasonable to believe that the groundwater contribution to total water supply will probably remain near its present level for the foreseeable future, but with a tendency to increase gradually in importance as the level of expertise grows and generates confidence.

III PROJECT PROCEDURES

1. Since the science of Hydrogeology is at a very early stage of development in Ireland, the procedures involved in drawing up the maps and the report were concerned with very basic matters, such as the definition of aquifers, the estimation of unrecorded abstractions, and the estimation of recharge in the absence of any detailed knowledge of subsoil conditions. None of this had ever been done before, except for a very few limited areas, so for the most part the project had to start 'from scratch'.

The sections below describe the way in which the country was sub-divided into regions and units for the purpose of this project, and the procedures used in compiling the data and maps .

III.2. Water Resource Regions.

Under the terms of the contract, water resources are to be assessed within regions which correspond to 'decision-making' regions of the country. This presented certain problems:

a) Ireland has a rather centralised system of government, and for many purposes the decision-making unit can be said to be the entire state. For our purposes, however, the state would be too large and too varied an area. In any case, the Government has not yet accepted a responsibility for management of the water resources of the state, although it does now have a responsibility for the control of water pollution (through the Water Pollution Act 1977).

b) Below the central Government, the next tier of government is that of the Local Authorities, i.e. County Councils, County Borough and Urban District Councils, 87 in all. The areas of the counties range from less than 1000 sq. km. (Carlow, Dublin, Louth) to almost 7500 sq. km. (Cork). Local Authorities have statutory responsibility for public water supply, sewerage, and pollution control in their own areas, but no responsibility for water resource management as such. They operate under the general supervision of the Department of the Environment.

It was felt that to assess water resources on a County basis would be inappropriate, because:

i) It would involve an excessive number of chapters, with much duplication of detail.

ii) County boundaries tend not to coincide with hydrological boundaries, so that aquifers and river basins would be divided unnecessarily.

iii) To date, no Local Authority has approached its water resources on a catchment or aquifer basis, preferring to do it on a 'source' basis.

There was, therefore, a need to select a unit larger than any county which would correspond to hydrological realities and yet have some statutory or official recognition. Fortunately, such units already exist in the shape of 'Water Resource Regions', which have been defined by An Foras Forbatha (National Institute for Physical Planning and Construction Research). This body, set up in 1964, is the chief advisory agency to the Department of the Environment. Its Water Resources Division, set up in 1969, is the only National agency whose brief includes all aspects of water resources. The Water Resource Regions, seven in number, were first defined in 1970, and have been used since then in broad assessments of the country's surface water resources(An Foras Forbatha, 1974, 1977).

The seven regions, which are shown in Figure III.1, are:

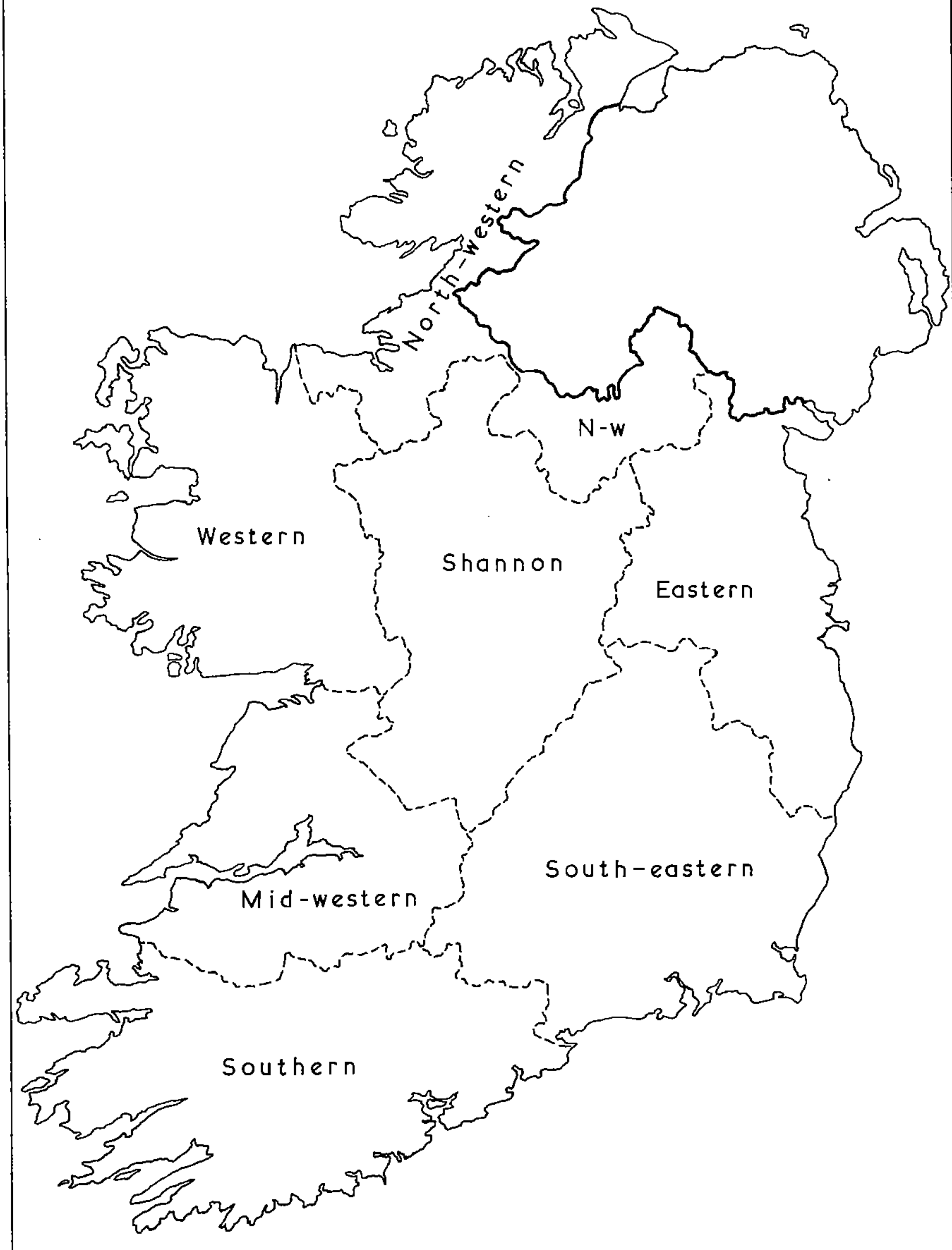
	Area	Est. Popn.(1979)
Eastern	(7,700 sq.km.)	1 375 000
South-eastern	(12,770 sq.km.)	470 000
Southern	(11,700 sq.km.)	480 000
Mid-western	(7,600 sq.km.)	290 000
Shannon	(10,520 sq.km.)	290 000
Western	(9,620 sq.km.)	210 000
North-western	(9,460 sq.km.)	250 000

These Water Resource Regions comprise groups of major river catchments, together with neighbouring smaller catchments and coastal areas. They are "of such a size that all the water requirements of each region can be supplied from the available resources within each region" (An Foras Forbatha, 1974). For the purposes of groundwater resource studies, the regions would be improved by small boundary changes to avoid the problems which occur where a boundary crosses an aquifer and the position of the groundwater divide is not known or may fluctuate. However, for the purposes of the present study the boundaries as defined by An Foras Forbatha have been accepted.

The seven Water Resource Regions correspond approximately in size to the Water Authority areas in England, and they are expected to be the basis for future water resource management in Ireland. The consultants have therefore decided that they meet the essential criteria for this study and the groundwater resources of each region are described in chapters V to XI .

For the purposes of this report each Water Resources Region has been divided into a number of units, the numbers ranging from 10 to 21. The total number of units in the country is 109, giving an average area per unit of about 630 km^2. The boundaries of the units were generally made to conform to surface catchment boundaries, but in a few places this has been varied. It is appreciated that the size of the units is somewhat excessive in that much smaller units would have enabled a better definition of the location of groundwater abstractions and resources, but this would have entailed much more work than was possible in this project.

FIGURE III.1 Water Resource Regions
(after An Foras Forbatha)



3. Definition of Aquifers:

3.1. The aquifers of Ireland have hitherto been identified only very approximately, and on the basis of information of very variable quality. The main reasons for this have been a lack of hydrogeological investigation and an absence of up-to-date geological maps. In order to define the extent of aquifers for this study, an attempt was made, within the constraints of time and manpower available, to draw together as much as possible of the geological mapping and hydrogeological study carried out in Ireland. This entailed reference to University theses, mining company maps, and unpublished work within the Geological Survey, as well as published maps and papers.

Aquifers can be defined on the basis of:

(a) Lithological and/or structural characteristics of geological formations which indicate an ability to store and transmit water.

(b) Hydrological indications of groundwater storage and movement e.g. spring flows, absence of surface drainage, etc.

(c) Information from boreholes suggesting relatively high yields, etc.

Preferably evidence should be available of all three kinds. Unfortunately, over much of the country, evidence of only one or two of the above types is available. Thus in some areas there may be evidence of relatively good well yields without any indication of why the yields are good, making it difficult to even guess at the areal extent of the aquifer.

Again, in places one may suspect that, for instance, a well-jointed sandstone should be a useful aquifer, but without any confirmatory evidence of good well yields (e.g. because the population is sparse) it is difficult to be confident about delineating the sandstone as an aquifer.

Inevitably, compromises have had to be made, and in many areas rather approximate boundaries have had to be drawn. Since different hydrogeologists have worked on different areas, there have inevitably been differing interpretations of the hydrogeology in different areas, and these could not always be completely reconciled. The resulting maps, and the resource estimates, can therefore only be regarded as provisional, and in the future, no doubt considerable modifications will be needed.

3.2. The following notes summarise the reasons for delineation of the aquifers:

(a) Clean, well-bedded limestones from the Visean were classified as fissured aquifers; where karst flow is known or believed to predominate, the map shows accordingly.

(b) Other limestones are shown as aquifers only:

(i) Where good well yields (over 250m^3/d) are known to be common, and/or

(ii) Where strong folding (e.g. in Southern Region) has produced strong joint systems leading to increased permeability.

(c) Quaternary sands and gravels where known from mapping, have been included as porous aquifers.

(d) Where Quaternary deposits are abundant and of significant thickness, and sands and gravels are believed to be quite widespread but not mapped in detail, the Quaternary deposits have been indicated as "complex domain of poor or local aquifers".

(e) The belt of volcanic rocks, interspersed with slates and greywackes, which runs through counties Wicklow, Wexford and Waterford in the southeast Region, has been mapped as an aquifer. Within the belt as mapped, only 40 to 80% of the area is actually underlain by the water-bearing volcanic rocks, the rest being occupied by essentially non-water-bearing rocks.

(f) Coarse, well-bedded and jointed sandstones have been mapped as aquifers where there is at least some corroborative evidence to support the belief. The main sandstones involved are:

Triassic Sandstones

Upper Carboniferous Namurian and Westphalian ('Coal Measures') Sandstones

Lower Carboniferous Basal Sandstones and 'Calp' Sandstones

Devonian 'Old Red Sandstone'

In the case of the Triassic rocks, covering only one small area in the northeast of the country, the rocks have both a primary and a secondary permeability. In the other sandstones, only a secondary permeability can be expected. The 'Coal Measures' sandstones have been studied in some detail, and much information is available as a by-product of exploratory drilling for coal.

Hence all Coal Measure sandstones are classed as aquifers, though their permeability is rather low.

The Namurian Sandstones are little known and normally are covered by impervious shales which greatly restrict infiltration. Consequently they have not generally been included as aquifers.

The Calp Sandstones and Basal Sandstones (in the northeast) have been included as aquifers. The Devonian 'Old Red Sandstone' presents problems - in its main areas of outcrop in the south and southwest of the country it appears to be of very low permeability, but further north, where folding has been less intense, the uppermost portion of the series seems to be a moderate to poor aquifer. Therefore, wherever some corroborative evidence was available nearby, this uppermost part of the series has been mapped as an aquifer.

3.3. Apart from the aquifer boundaries, which are transferred from Map 1, very little information is available to put on Map 2. Major springs were located from information supplied by local authorities or on Geological Survey files, but there are probably several omissions, because few springs have been gauged with any accuracy. Water table contours are drawn for those few areas where they have been mapped - the Nore Basin, South Galway, Clare, and South Wexford. A few transmissivity values are shown where controlled pumping tests have been carried out. Overall, data for this map are very sparse.

4. Groundwater Abstractions:

The main sources of groundwater abstraction data were the County Councils. For a National Survey of Abstractions and Discharges, Local Authorities were requested by An Foras Forbartha in 1977 to collect information on all water abstractions (surface or groundwater) and effluent discharges greater than 5 cu. m. per day. Most Local Authorities have now completed this task. Most local authorities were therefore able to supply details of groundwater abstraction (of over $5m^3/d$) to the Geological Survey, and these data have been used for this study. Abstraction points were then compiled on to maps and totals were calculated for each aquifer unit.

For those few local authority areas for which the details were not available, or were incomplete (mostly areas where groundwater is least important, e.g. Dublin, Wicklow and west Cork), abstractions were estimated more approximately on the basis of personal knowledge of the areas and limited data available on Geological Survey files.

In all cases, an allowance had to be made for the very numerous small abstractions (i.e. less than $5m^3/d$, generally less than $2m^3/d$) from boreholes and dug wells supplying single houses and small farms. It also appears that in some areas, at least, numerous farms which probably abstract more than $5m^3/d$ have nevertheless been omitted from the local authority figures through lack of time and manpower. Since it is very difficult to accurately estimate for each area a figure for small abstractions, a crude allowance has been made over and above the large abstractions. It is felt that this will not lead to major errors in the total estimate of abstractions.

5. Resources Calculations:

Calculation of groundwater resources for the various aquifer units has been carried out, very approximately, on the following basis:

(a) Measurement of areas of aquifer units, by planimeter.

(b) Measurement or estimation of areas of permeable, moderately permeable, poorly permeable, or virtually impermeable cover, allocating respective infiltration factors of 80%, 50%, 20% and 0% to each type of area.

(c) Estimation of annual average rainfall and evapotranspiration for each aquifer unit, using data available from the Meteorological Service and An Foras Taluntais, hence estimating effective rainfall for each aquifer unit.

(d) Special allowances for particular constraints in each area, e.g. presence of karst conditions with quick through-flow; potential seawater intrusion which limits water availability in coastal areas; high run-off from areas of rugged terrain.

(e) Combination of figures from (a) to (d) to produce annual average recharge to the aquifers.

(f) Subtraction of present abstraction figures from recharge figures to derive annual average surplus.

(g) Where possible, i.e. for a few areas, the recharge figure thus computed was compared with a recharge estimate derived from base-flow separations from river hydrographs. Given many assumptions and errors involved, this could not be expected to provide the same answer, but it served as a check that the original estimates were at least reasonably accurate. In general, the exercise suggests that the figures presented in this study tend to be conservative , except for areas of extensive karst.

(h) For Map 4 it was necessary to distinguish between units with a good surplus groundwater resource and units with only locally important resources. This was difficult because of the size of the units and the high effective rainfall in most areas. It was decided to use a 'threshold' value of 25mm of recharge to separate the two classes of unit. For a typical unit with an area of 600 km^2 this would represent a resource of 15 Mm^3 per year, a useful resource in the Irish context. This threshold value seemed to make the most satisfactory division of the units into those with and those without useful groundwater resources. It is recognised that with units of the size chosen it is difficult to highlight the most promising areas.

IV. SUMMARY OF GROUNDWATER RESOURCES

IV.1 Map 1 - Aquifers

1.1 The first requirement of the project was to map the aquifers of the country. The procedure used to define the aquifers in areas where little or nothing was known about the hydrogeology is described in Chapter III. Map 1 is the result. The aquifers of the country are listed in Table IV.1, with an indication of their relative importance, as known at present.

1.2 The characteristics of the aquifers can be summarised:

(a) Fissure permeability predominates. The only widespread aquifers with intergranular permeability only are Quaternary sands and gravels. This is largely explained by the lack of Mesozoic and Tertiary formations in the country.

(b) Irish aquifers are relatively shallow. As far as is known, fissure permeability does not extend appreciably below about 120m (although a few borings have recorded saline water and some degree of fissure flow at much greater depths). In general, it appears that the limestones have not been appreciably opened up by solution below this depth, and fissures in sandstones tend to close up. However, further investigations may locate areas where this does not hold true.

(c) Irish aquifers are generally phreatic rather than confined but local confinement by boulder clay is quite common.

(d) Aquifers are often small in lateral extent, and their shape is complicated by faulting.

(e) Much of the country, especially in the west, is underlain by Karstic aquifers, where flow is largely restricted to conduits, wells are difficult to sink successfully, groundwater storage may be small and the aquifer easily polluted.

1.3 The most important aquifers in the country are the limestones, followed by the Quaternary sands and gravels, and then the various types of sandstone. Each aquifer has its own problems:

(a) The development of the limestones suffers from the lack of detailed geological mapping which is required in order to distinguish the productive from the non-productive strata. Secondly, where the limestones are productive, owing to extensive karstification, they often present great problems to well drillers, owing to caving, dog-legging of boreholes, etc. Pollution of karstified limestones is also a problem. In the karstic areas of the west, in particular, the problems of development are more difficult because well-sinking is often unsuccessful because conduits are widely spaced.

(b) Development of Quaternary deposits is also hampered by lack of detailed mapping, but the problems of well-sinking are much more readily soluble, as the techniques of drilling, screening and developing sand/gravel aquifers are at least well established. The main task here is to disseminate the information to well-drillers and engineers. It is apparent from this map and map 4 that these aquifers hold enormous potential for the country.

(c) The sandstone aquifers of the country are reasonably well mapped geologically, but little known as aquifers, with the exception of the Coal Measures Sandstones. Many of them tend to suffer from restricted recharge owing to the presence of overlying shales.

1.4 Map 1 represents a great advance on previous aquifer maps for the Republic of Ireland, which were at smaller scales and could only be regarded as 'well yield' maps. Much checking and refinement is still needed, especially in the Midlands and West.

IV.2 Map 2 - Groundwater Hydrology

2.1 As mentioned in Chapter III, detailed studies of watertable elevation have been carried out in very few areas - the Nore Basin, S.E. Cork, Galway, Clare, Kildare, South Wexford, and Cavan, Monaghan, Louth. Owing to the small extent of many aquifers, it is difficult to map the watertable at the scale of the project maps.

In general, groundwater movement in the country is closely related to surface water drainage, except for the extensive karst areas.

2.2 Controlled pumping tests are uncommon, and therefore there are few reliable measurements or even estimates of aquifer transmissivity. Those which we have show that transmissivity values are rather low compared with aquifers in some other countries - values of 10^{-3} or 10^{-4} m^2/sec. predominate. This is due in part to the thinness of most aquifers.

2.3 A number of moderately large springs are mapped, particularly in the karst areas of the west, where they are very important in water supply. Most springs seem to be in the 1 - 3 Mm^3/yr range, with a number in the 3 - 10 Mm^3/yr range. Larger springs are not known.

2.4 Saline intrusion is, so far, a problem in very few areas, largely because of low abstraction rates in coastal areas. Problems of mineralized water are encountered in places but could not be mapped on this scale.

IV.3 Map 3 - Groundwater Abstractions

Map 3 has very little information on it. On the three sheets (Dublin, Belfast, Cork) there are only 20 locations with abstractions of more than 1 million cubic metres per day. There are no units, as defined for the project, in which the total groundwater abstraction is more than about 10mm/yr over the unit, hence all units on Map 3 have the same colour.

TABLE IV.1

AQUIFERS IN THE REPUBLIC OF IRELAND

GEOLOGICAL AGE	LITHOLOGY	TYPE OF FLOW	DISTRIBUTION	IMPORTANCE	REMARKS
Quaternary	Alluvium	I	Widespread	*	little known
	Fluvio-glacial sands/gravels	I	Widespread	***	should become more important
Permo-Triassic	Sandstones	I & F	Kingscourt area (E. Region)	**	little developed yet
Carboniferous Westphalian	Sandstones	F	S.E. Region	**	Artesian, low recharge
Namurian	Sandstones	F	S, S.E., M-W. Regions	*	low recharge, little used
Upper Visean	Clean Calcarenites	F	Widespread	****	generally karstified
Visean 'Calp'	Sandstones	F (? + I)	N.W., W., Shannon Regions	**	
Tournaisian	Massive Waulsortian 'reef' limestone	F	Widespread	*** **/*	- S. Region - elsewhere
"	Sandstones	F	N.W. & E. Region	**	'Basal Clastics', have some sulphate problems
Devonian 'Old Red Sandstone'	Sandstones	F	S.E., S., Shannon	**	little known
Ordovician	Tuffs, lavas	F	S.E., E. Region	**	patchy distribution

**** very important *** fairly important ** some importance
* only locally useful

I = Intergranular flow
F = Fissure flow

TABLE IV.2

SUMMARY OF GROUNDWATER RESOURCES BY REGION

WATER RESOURCE REGION	AREA Km^2	AREA OF AQUIFERS Km^2	ESTIMATED ABSTRACTIONS Mm^3/yr	ESTIMATED SURPLUS RESOURCES Mm^3/yr	mm/yr over region
Eastern	7622.5	1392	6.08	197.4	25.9
South-Eastern	12768	4240	20.7	763	59.6
Southern	11406	1474.5	25.15	603.6	52.9
Mid-Western	7508	2942.5	8.43	492.1	65.5
Shannon	10520	3124.9	16.69	471.7	44.8
Western	9615.5	4446	6.23	643.3	67.0
North-Western	9460	1245.5	6.3	202.5	21.4
TOTAL:	68900	18865.4	89.58	3373.6	49.0 over country

V. THE EASTERN WATER RESOURCE REGION

V.1 The Eastern Region includes the catchments of all the rivers draining to the East coast of Ireland from Kilmichael Point in the south to the border with Northern Ireland. It comprises an area of about 7,700 km^2, of which the major catchments of the rivers Boyne (2694 km^2), Liffey (1367 km^2) and Avoca (650 km^2) make up over 60%. The region includes the whole of Counties Louth, Meath, and Dublin, large areas of Counties Wicklow, Kildare and Westmeath, and small parts of Offaly, Cavan and Monaghan.

It includes the largest urban concentration in the country in the greater Dublin area, with a population of over one million. The population of the region is about 1,375,000, around 40% of the total population of the Republic of Ireland.

The region is relatively dry, with average annual rainfall in lowland areas being below 800mm in places, and the region is also relatively sunny.

V.2 Geology

The geology of the region can be summed up as consisting of two large Lower Palaeozoic massifs, the Longford-Down Massif in the north, and the Leinster Massif in the south, with a Carboniferous Limestone lowland occupying the ground inbetween.

The Leinster Massif is a Caledonian fold-belt with a NE-SW trend, consisting of a central core of granite flanked by steeply-dipping Ordovician and Silurian metasedimentary rocks (slates, quartzites, gritstones, greywackes) and some volcanic rocks (in South Wicklow). The entire Lower Palaeozoic sequence (except for the volcanic rocks) is regarded as non-water-bearing.

The Longford-Down Massif is a westerly continuation of a major structure which extends across South Scotland. The lithologies here are similar to those of the Leinster Massif, without the granite core. An inlier of Lower Palaeozoic rocks also occurs to the south along the coast north of Dublin.

The Carboniferous rocks of the lowland area to the north and west of Dublin comprise a variety of limestones of Tournaisian and Visean age, together with sandstones and shales. The limestones are generally gently dipping, predominantly argillaceous or of the Waulsortian type, and not good aquifers on the whole.

Within the Longford-Down Massif lies the Kingscourt-Carrickmacross outlier, bounded by a major fault on its west side and dipping gently westwards, in which a sequence of rocks occurs, from Tournaisian limestone through Visean, Namurian and Westphalian shales & sandstones, to Permo-Triassic sandstones.

Quaternary deposits are very widespread throughout the region, and up to 80m thick. A major morainic belt crosses the region from NE to SW, and smaller morainic deposits surround the Leinster Massif.

V.3 Aquifers

3.1 The Eastern Region is rather poor in aquifers, and few areas have been investigated in any detail, the notable exception being County Louth, at the northern extremity of the region, which is being studied as part of the current North East Regional Development Organization's project.

3.2 Ordovician Volcanics

Outcrops of these rocks occur in South County Wicklow, where they straddle the boundary between the Eastern and South Eastern regions. In this area they are even more discontinuous than in their more southerly outcrops, and they are not exploited to any significant extent. Their inclusion is dependent on their characteristics as known from Counties Waterford and Wexford.

The main water-bearing rocks are believed to be the rhyolites and acid tuffs, with the more basic rocks being less productive and the interbedded slates regarded as aquitards. The outcrops are much faulted, the rocks are steeply dipping and the water sometimes confined by overlying aquitards.

3.3 Carboniferous Limestones

As in most other regions, these are the principal aquifers in the region, and are known in several areas:

(a) In South Dublin, a small outcrop of the Clondalkin Formation has been identified as an aquifer. This consists of about 480m of medium-grained calcarenites and calcisiltites and is reported to be karstified and dolomitised in certain areas. Except for one borehole yielding about $655m^3/d$, it has not been significantly exploited.

(b) Around Edenderry, Co. Offaly, the Edenderry Oolite straddles the boundary with the South Eastern Region. This formation is known to have given moderate yields, but is not regarded as a major aquifer.

(c) In the Boyne valley, from Drogheda (on the coast) upstream to Navan, and also westwards along the margin of the Lower Palaeozoic metasediments, the clean limestones appear to be water-bearing and, at least in places, karstic.

(d) Further north, water-bearing clean limestones occur around the Carrickmacross outlier, though yields are lower than in the Boyne valley.

(e) On the Carlingford peninsula and to the west there are further limestone outcrops where moderate yields have been obtained.

3.4 Carboniferous Sandstones

Basal sandstones around the margin of the Lower Palaeozoic Massif are mapped as 'poor, complex aquifers' to the east of Lough Sheelin. Elsewhere these beds are included in the limestone outcrops which they underlie.

3.5 Permo-Triassic Sandstones

Around Kingscourt occurs the only outcrop within the Republic of Ireland of a Permo-Triassic sandstone. The Kingscourt Sandstone Formation consists of up to 100m of interbedded marls and sandstones overlain by up to 400m of fine-grained red sandstones.

The formation is overlain by deposits of peat, alluvium and boulder clay up to 45m thick, so that infiltration is seriously impeded; artesian conditions prevail in places. The outcrop is only about 22 km^2 in area, is bounded by impermeable rocks, with a major North-South fault along the western boundary. The aquifer is little used, but an artesian supply of $650m^3/d$ is recorded. The aquifer is assumed to have both intergranular and fissure permeability.

3.6 Quaternary Aquifers

Quaternary sand/gravel aquifers are mapped in several parts of the region:

(a) In the north, gravels of the Cooley peninsula are up to 34m thick.

(b) Further south, an area of interbedded sands, gravels and silts stretches southwards from Dundalk to Castlebellingham along the coast, with another deposit between Dunany Point and Clogher Head.

(c) In west County Meath and Northeast Westmeath, sizeable areas of ice-marginal deposits occur. These include eskers, kames, outwash gravels and gravelly moraine. The morainic belt occupies a larger area than that mapped, but in view of the great uncertainty as to the extent of the aquifers within the belt, only limited areas have been put on Map 1.

(d) In County Kildare, the Curragh gravels extend into the Eastern Region around the town of Newbridge. This large outwash plain, of up to 80m thickness of gravelly deposits, is better known and exploited in the S.E. Region (Chapter VI).

(e) Numerous small gravel deposits occur around the margin of the Leinster Massif and those whose topographic position suggests they could be useful local aquifers are shown on Map 1. They are almost entirely unexploited so far, and therefore their properties, thickness, etc. are virtually unknown. Although they are individually of small extent, in total they represent a sizeable potential groundwater resource.

V.4 Abstractions

The abstractions shown for each unit in Table V.1. are very approximate, except for units 1, 2 and 3, where they are more accurate. Groundwater usage within the region is rather small, partly because the region has rather fewer aquifers than most others, but mainly because the population is heavily concentrated in the greater Dublin area, which for many years has been served by a piped water supply derived from surface reservoirs in the Dublin and Wicklow Mountains. The only intensive usage of groundwater is in the Dundalk area, where five major industrial concerns abstract about $3170m^3$/day (1.16 Mm^3/yr). Elsewhere groundwater abstractions are small and widely scattered, and include numbers of small abstractions from aquitards or very local poor aquifers, for household and farm usage or village supplies.

V.5 Recharge

Recharge to the various aquifers is estimated in Table V.1. The Eastern Region is the driest in the country, with mean rainfall in much of the region being below 900mm per year. Effective rainfall is therefore in the range of 230-550mm per year. Much of the area is mantled by glacial till and the infiltration characteristics are largely unknown. The recharge estimates are therefore rather approximate. For the sand and gravel aquifers, allowance has been made for the presence of considerable areas of glacial till aquitards within the areas mapped as 'complex local aquifers'. For the Ordovician volcanic aquifers, an allowance was made for the discontinuity of the water-bearing layers, which in this region generally comprise no more than 40% of the areas shown on Map 1 as 'discontinuous aquifers'.

V.6 Resources

Table V.2, summarises the resources available in the ten groundwater units within the region. The units fall into three groups:

Units 6, 7, and 10 have only small resources (between 0.9 and 14mm over the areas of the units) indicating only locally important resources, in small aquifers.

Units 4, 5, 8 and 9 have only moderate resources (25 to 31mm over the areas of the units), largely in Quaternary sand/gravel aquifers which are as yet little known. In unit 9 these aquifers are also scattered, small deposits, whereas in unit 8 the northern part of the large Quaternary aquifer of the Curragh constitutes a major resource.

Units 1, 2 and 3 have substantial groundwater resources (between 34 and 39mm over the units), chiefly in the Carboniferous limestone aquifers, with significant Quaternary aquifers in addition.

On the whole, the estimates are probably conservative, because the extent of sand and gravel aquifers has probably been very much underestimated, particularly in the broad morainic belt of west County Meath and County Westmeath.

TABLE V.1

SUMMARY OF GROUNDWATER RESOURCES IN THE EASTERN REGION

UNIT NO.	AREA OF UNIT Km^2	AREA UNDERLAIN BY AQUIFER Km^2	ESTIMATED RECHARGE M.cm/yr	ESTIMATED ABSTRACTIONS M.cm/yr	SURPLUS M.cm/yr	SURPLUS mm/yr over unit
1	519	153.65	22.28	2.0	20.28	39
2	847	260	35.97	0.38	35.59	42
3	1005	250	35.16	0.8	34.36	34
4	1690	306.5	47.85	(0.4)	47.45	28
5	379	97.5	12.2	(0.8)	11.4	30
6	334	7	0.8	(0.5)	0.3	0.9
7	860	39	5.1	(0.2)	4.9	5.7
8	757.5	104	23.75	(0.5)	23.25	31
9	555	110	15.93	(0.3)	15.63	28
10	676	64.5	9.86	(0.2)	9.66	14
TOTAL:	7622.5	1392	208.9	(6.08)	202.82	26.5

(Figures in brackets are rough estimates)

TABLE V.2

GROUNDWATER RESOURCES IN THE EASTERN REGION

UNIT NO. & NAME	AREA OF UNIT Km^2	AQUIFERS	AREA OF AQUIFERS Km^2	MEAN RAINFALL mm/yr	MEAN EVAPOTRANSPIRATION mm/yr	EFFECTIVE RAINFALL mm/yr	ESTIMATED RECHARGE Mm^3/yr	TOTAL RECHARGE PER UNIT Mm^3/yr	ESTIMATED ABSTRACTIONS Mm^3/yr	SURPLUS RESOURCES Mm^3/yr
1 N. Louth	519	Quaternary sands and gravels	89.5	900	500	400	11.45	22.28	2.0	20.28
		Carboniferous limestone	64.15	950	500	450	10.83			
2 Glyde & Dee	847	Quaternary sands and gravels	72	900	475	425	8.08	35.97	0.38	35.59
		Permo-Triassic sandstone	22.5	900	475	425	1.91			
		Carboniferous limestone	163	900	475	425	25.98			
3 Boyne-Blackwater	1005	Carboniferous limestone	250	850	475	375	35.16	35.16	0.8	34.36
4 Upper Boyne	1690	Quaternary sands and gravels	190	900	450	450	22.57	47.85	(0.4)	47.45
		Carboniferous	90	850	450	400	18.0			
		limestone	26.5	1000	450	550	7.28			
5 Nanny and Delvin	379	Carboniferous limestone	97.5	800	550	250	12.2	12.2	(0.8)	11.4
6 Broad-meadow	334	Quaternary sands and gravels	7	780	550	230	0.8	0.8	(0.5)	0.3
7 Liffey-Tolka	860	Quaternary sands and gravels	3	800	550	250	0.6	5.1	(0.2)	4.9
		Carboniferous limestone	36	800	550	250	4.5			
8 Upper Liffey	757.5	Quaternary sands and gravels (Curragh)	80	810	470	340	19.72	23.75	(0.5)	23.25
		Do. (West Wicklow)	24	900	480	420	4.03			
9 East Wicklow	555	Quaternary sands and gravels	67	1000	550	450	12.06	15.93	(0.3)	15.63
		Ordovician volcanics	43	1000	550	450	3.87			
10 Avoca	676	Quaternary sands and gravels	28.5	1050	520	530	6.04	9.86	(0.2)	9.66
		Ordovician volcanics	36	1050	520	530	3.82			

(Figures in brackets are rough estimates only)

VI. THE SOUTH-EASTERN WATER RESOURCE REGION

VI.1 This region consists of the Suir (3,610 sq. kms) the Nore (2,530 sq. kms) and the Barrow (3,068 sq. kms) river basins which drain via Waterford Harbour into the Celtic Sea,

the Slaney (1,762 sq. kms) and a number of smaller catchments (1,776 sq. kms).

The area is bounded on the east and south by the Irish and Celtic Seas and in the west and north by the catchment boundaries of the Blackwater, Shannon, Boyne and Liffey rivers.

The region is dominated by the Leinster Massif which runs between the Slaney and Barrow rivers. A number of smaller upland areas are also contained in the region: the Castlecomer Plateau, the Slieve Ardagh Hills, the Slieve na mon, Comeragh and Monavullagh Mountains, while the Slieve Bloom, Devil's Bit, Galty, and Knockmealdown Mountains form the watersheds to the west and south. There are three lowland areas: between Kildare town and Cashel, the area between Goresbridge and Mullinahone and the coastal areas of Wexford and Waterford. Most of the remainder of the region lies between 50m and 150m. In their lower reaches the Barrow, Nore and Suir rivers flow through steep-sided valleys.

The region consists of all of Counties Wexford, Carlow, Kilkenny, most of Laois, over half of Tipperary, Waterford and Kildare and small parts of Offaly, Wicklow and Limerick. The main urban centres in the region are Portlaoise, Kildare, Athy, Carlow, Wexford, New Ross, Waterford, Dungarvan, Clonmel, Tipperary, Thurles and Kilkenny. The population of the region is approximately 470,000.

Detailed groundwater investigations are being carried out in two areas of the region, in the Nore River Basin by the Geological Survey of Ireland and in South Wexford initially by the Geological Survey and now by Wexford County Council.

VI.2 Geology

The geological succession for the region is shown in Table VI.1. There are three structural areas in the region: the eastern area (Ordovician, Cambrian and Precambrian strata and the Leinster Granite) which is characterised by Caledonian folding, the southern area (Silurian, Devonian and Carboniferous strata) which has a series of tight Hercynian folds, and the north central area (Silurian, Devonian, Carboniferous) which has a more complex series of folds. In this third area the Slieveardagh Hills, and the Devil's Bit and Slieve Bloom Mountains have a Caledonian trend, whereas the Castlecomer Plateau has a series of north-south trending folds. The Dinantian strata of the lowlands dip gently to the southeast. There is faulting in all three areas, especially in the Westphalian strata.

VI.3 Aquifers

VI.3.1 Ordovician Volcanics

These volcanics run in a belt from Kilmichael point south of Arklow (in the Eastern region) to Stradbally on the Co. Waterford coast, covering an area of over 800 sq. kms. The Upper Ordovician contains two volcanic formations which are separated by two formations (800 metres) of siltstone and mudstone (Gardiner 1974). The Duncannon formation (320+ metres) at the base of the succession, consists of tuffs, andesites, breccias, and some sediments, and the Campile formation (1,000 metres) consists mainly of rhyolites and some subordinate pyroclastic rocks. The above succession is for southwest Co. Wexford (Gardiner 1974). Gardiner suggests that the volcanic strata thicken from northeast to southwest.

These strata occupy a major syncline, the Campile syncline (Gardiner 1970) and also have undergone considerable faulting.

Permeability is entirely secondary and is probably greatest (transmissivity 4.3×10^{-3} m^2/s) in the northeast Waterford and southwest Wexford area. The rhyolites appear to be the most productive rocks. The outcrop of volcanic rocks does not occupy the entire area shown on Map 1, but varies from 80% in the Tramore (Co. Waterford) area to 60% in the south Wexford area and 40% in the Gorey (north Wexford) area. In its outcrop area the aquifer is overlain by variable thicknesses of superficial deposits, mainly boulder clay, and is generally considered to be unconfined. However downdip the aquifer is confined by the overlying sediments, and also some of the sediments within the volcanic formation.

VI.3.2 UPPER DEVONIAN Sandstones

Although these strata are found throughout the region (Table VI.1), they are only considered to be major aquifers in two areas: on the flanks of the Slieve Bloom and Devil's Bit Mountains (Clonaslee Sandstone), and on the northern flanks of the Slievenamon Mountains (Kiltorcan Sandstone). In the remaining areas it has a very small outcrop area (very steep dip), has been altered by low grade metamorphism, or is only present at considerable depths.

Young (pers. com.) (Clonaslee Sandstones, 150m) and Colthurst(1977)(Kiltorcan Sandstone, 230m) have described the formation as containing white and yellow sandstones with green mudstones. These sandstones are situated on the sides of an anticline and dip under Dinantian shales and argillaceous limestone which confine them. It is considered feasible to exploit the sandstones out to the uppermost boundary of the confining unit (Lower Limestone Shales, 40m thick).

Permeability (transmissivity 4-8 x 10^{-4} m^2/s) is almost entirely secondary, although the Clonaslee Sandstone may contain some primary permeability (Young pers. com.). Drilling in the Clonaslee (Co. Laois) area has shown the Clonaslee Sandstones to be quite friable which has made well completion difficult. Storage coefficient is of the order of 10^{-4}.

The sandstones are overlain in places by the superficial deposits of boulder clay (which confines them) and sands and gravels with which they are in hydraulic continuity.

VI.3.3 DINANTIAN Limestones

The Dinantian in this region consists of various types of limestones, dolomites, and shales in various structural and topographic settings. Permeability is secondary and is a function of lithology, topography, structure, and glacial drainage levels.

Hydrogeologically the area can be divided into three units:

(1) Northern Area.

This area includes all the limestone north of a line from Tipperary Town to New Ross. In this area only the clean, thick, Visean limestones are considered as major aquifers, namely the Crosspatrick Limestone and the Upper Visean limestones;

The Crosspatrick Limestone

This is a long narrow aquifer which stretches from west of Thurles to northeast of Portarlington. It has been described recently by Reeves and Sleeman of the Geological Survey in the Tipperary, Kilkenny and Laois lowlands. It consists of pale grey cherty bioclastic limestone, which appears to fill in depositional hollows in the top of the dolomitised reef (Tournaisian) below it, and is about 70m thick. The dolomitisation of the reef increases progressively towards the top (Sleeman pers. com). Drilling evidence suggests that there is a paleokarst surface at the top of the reef, with the infilling of cavities by dolomite. This upper section of the reef (taken to be about 30m) is also included in the Crosspatrick Limestone as it has very different hydrogeological properties to the remainder of the reef. The distribution of this aquifer on the map is limited to that area mapped by Reeves and Sleeman and to the adjoining areas where it is possible to extrapolate with reasonable accuracy (Map 1). This aquifer may also be present in the lowlands south of Kilkenny city (see minor aquifers) and east of the River Barrow in Co. Kildare.

The aquifer dips gently (less than 15°) to the southeast and is gently folded in the Tipperary (Suir) section of the aquifer. Downdip the aquifer is confined by the Aghamacart peloidal limestone which is an aquitard. Karstification in the Crosspatrick Limestone is unlikely to be extensive 100m below ground level, although the dolomitised reef zone should provide some groundwater to a considerable depth.

The dolomitic zone is friable and quite weathered and proves difficult for well completion. Storage coefficient is of the order of 10^{-3} and transmissivity ranges from $.23 - 1.2 \times 10^{-3}$ m^2/s.

In the outcrop area the aquifer is overlain by varying amounts of boulder clay and sand and gravel which in places are thick enough to affect it hydraulically. Over large parts of the Suir section of the aquifer there is a cover of up to 5m of peat bog (which is mostly saturated), which in turn is underlain by marl, rock or in some places sand and gravel. The effect of this peat should be to confine the aquifer; however this may be counterbalanced by the high percentage of water (greater than 75%) in the peat which may become available by leakage under pumping conditions.

The Upper Visean Limestones

This formation at the top of the Dinantian succession has been described by Reeves and Sleeman in the lowlands of Cos. Tipperary, Kilkenny and Laois (named the Cullahill Limestone in this area), and has been extrapolated by the author over the rest of the area. It covers a large part of the centre of the region.

The Cullahill Limestone is a coarse grained, grey, crinoidal limestone, with chert nodules, thin shale beds and some patches of dolomite. It is jointed both horizontally and vertically and is over 250m thick. This formation is found around the flanks of a large syncline, the Castlecomer Plateau and Slieve Ardagh Hills, the core of which is occupied by Namurian and Westphalian Strata. The limestone is elevated (reaching heights of 300m) in a zone about 5 km wide around the contact with the Namurian.

There are numerous karst features, swallow holes, springs, dry valleys, deep water tables etc., particularly in the upland part of the formation near the boundary with the Namurian.

Fissuring is well developed in the top 20m and decreases with depth. The depth to which fissuring descends is probably related to glacial drainage levels. Fissuring probably does not extend lower than 90m below ground level hence this depth is taken as the effective thickness of the aquifer. Over large areas the aquifer is considered as a karst aquifer and hence cannot be developed in the normal way but it does provide recharge to the non-karst (more productive) areas of the aquifer. This occurs for two reasons (a) in the upland areas where the water table is below the extensively fissured section and (b) in the lowland areas where the fissured section is very thin. The aquifer is not fissured where it is covered by the Namurian strata.

The annual fluctuation of the water table varies from less than 5m in the productive lowland areas to over 20m in the upland karst areas. Transmissivity ranges from .023 to 2.7 x 10^{-2} m^2/s and specific yield is estimated to vary from .1 to 1.5%. This aquifer frequently discharges via large springs (Table VI.2) into the main rivers (Map 2).

The effect of the superficial deposits on the aquifer is similar to that on the Crosspatrick Limestone. Here peat covers most of the aquifer from Ballysloe to Boherlahan northeast of Cashel. The aquifer receives considerable indirect recharge all the year round from streams draining the Namurian Strata and going underground via swallow holes.

(2) The Southern Area

This area includes most of the Dinantian succession south of the line mentioned previously. In this area the limestones and underlying Devonian sandstones have been folded into a series of steeply dipping anticlines (Devonian and Silurian mountains) and synclines (limestone valleys). In this area the whole Dinantian succession is considered to be an aquifer (Wright 1979). The succession outlined by Keeley 1979 in the Carrick syncline is very similar to that described for the northern area mentioned previously. The higher permeability (transmissivity is frequently greater than $2 \cdot 10^{-2}$ m^2/s) in this area is related to more intense structural activity allied to lower glacial drainage levels which allowed deeper karstification to take place. Borehole yields are expected to be higher in the clean limestone formations such as the Upper Visean limestones and the Tournaisian reef. This type of aquifer is dealt with in more detail in the southern region (chapter VII).

The aquifers in the Carrick and South Tipperary synclines are generally unconfined whilst the Dungarvan and Aherlow synclines are in continuity with overlying sands and gravels.

(3) South Wexford Area

In this area the Dinantian succession is quite different from that in the areas previously described. Here dolomitisation is very extensive. The succession consists of a series of interbedded limestones, dolomites, shales, with some thin breccias towards the top of the succession (Cullen 1978). Rocks of both Tournaisian and Visean age are present. The succession dips to the south and has been affected by minor folding and faulting. The southern boundary is marked by a major fault.

Cullen (1978) considers that the whole succession behaves as one aquifer. It would appear from the transmissivity data that the dolomites are less permeable than the micritic limestones. Storage coefficient is of the order of 10^{-4}.

The outlier is confined over a large area by glacial clays and till. In a few places it is in continuity with overlying sands and gravels. Bedrock only comes to the surface in a few places and the bedrock surface is frequently at or below sea level. Recharge is restricted to the areas overlain by sands and gravels and sections of streams which have cut down to bedrock.

VI.3.4 Westphalian Sandstones

These are located in the centre of the Castlecomer Plateau and the Slieveardagh Hills. The succession in both areas consists of two extensive sandstone units interbedded with shales and minor sandstones. The two sandstones are considered as one aquifer in both areas as they have been connected by faults and mining activity. In both areas the strata has been extensively folded and faulted. The Castlecomer Plateau is a large structural basin with subsidiary secondary anticlines and synclines west of Castlecomer. The Slieveardagh Hills consist of a complex series of elongated anticlines and synclines.

In the Castlecomer Plateau the lower formation is the Clay Gall Sandstone (10-15m) a light grey, medium grained, massive sandstone containing shards of shale and coal, whilst the upper formation the Swan Sandstone (5-20m) is a dark grey, fine grained, siliceous laminated sandstone. In the Slieveardagh Hills the lower formation the Glengoole Sandstone (15-20m) is a coarse felspathic sandstone whilst the upper sandstone the Main Rock Sandstone (8-12m) is a fine grey/green friable micaceous sandstone. Permeability is secondary, is due to the presence of joints and is higher in the Slieveardagh Hills. Storage coefficient is of the order of 10^{-4}.

Boreholes in these sandstones frequently produce small artesian flows. In both areas the lower sandstones are more productive but in the centre of the syncline they descend to depths (over 200m) which are beyond the range of even the best drilling contractors in the country.

VI.3.5 Quaternary Sands and Gravels

Fluvioglacial sands and gravels are widely scattered throughout the region. At present only the outwash deposits at Kilmanagh (Co. Kilkenny) and the Nore gravels north of Kilkenny City and the River Barrow gravels at Carlow are considered to be major aquifers. There is very little information on the remaining areas and hence they are considered minor aquifers for the time being.

The outwash deposits are fairly limited in area, are thickest and coarsest in the old preglacial river valleys where conditions were highly charged during the glacial period. Frequently there are eskers, kames and various types of moraines associated with the deposits.

The main bulk of the material is a very coarse (effective size 1mm) and poorly sorted (uniformity coefficient around 20) sand and gravel. Frequently there are small lenses of better sorted material within the main bulk of the deposit. These lenses have resulted from the reworking locally of parts of the **deposits.**
The sands and gravels are often interbedded with boulder clay.

In the Barrow Valley at Carlow the deposit ranges from 10-20m thick and is in continuity with the underlying limestone aquifer. The Nore River Gravels north of Kilkenny City vary in thickness from 15-30m and are probably underlain by a boulder clay.

In the Kilmanagh River Gravels the deposit is about 10m thick, and underlain by a thin boulder clay (2-3m). The gravels are confined in places by a thin boulder clay. The deposits get thinner and finer **where** the valley passes out into the limestone lowlands to the south. The river passing through the aquifer has influent and effluent sections. Transmissivity ranges from .35 to 7 x 10^{-2} m^2/d. Specific yield is of the order of 5-10%.

The Curragh Gravels (Co. Kildare) which straddle the Barrow/Liffey catchment boundary **are** a thick sequence (average 40m, and up to 70m) of outwash gravel probably with associated moraines. The succession consists of thick formations of sand and gravel interbedded with thin boulder clays. The clay content of the upper section of the deposit appears to increase towards the northeast.

VI.3.6 Minor Aquifers

(1) Kilkenny/Carlow Dolomites

In this area the dolomites are particularly cavernous and are considered to be a minor aquifer. They have been developed at **Bagenalstown**(yields of 600-700m cu. per day). This aquifer may be equivalent to the Crosspatrick Limestone west of the Castlecomer Plateau (see Section VI.3.3). The cavernous nature of the rock and its **productivity decrease** to the southwest. The weathering of the dolomite makes well completion difficult. Part of the outcrop area is overlain by sand and gravels with which the aquifer is in contact. The specific yield is of the order of 10^{-3} and transmissivity approximately 1.0 x 10^{-3}.

(2) Edenderry Oolite

A large area of Visean limestones which are covered by bog and till. It is known to have yielded reasonable supplies at Edenderry and also contains a few large springs. The area shown is largely confined and probably also contains a small proportion of aquitards.

(3) Sands and Gravels

Thirteen areas **(Table VI.2)** are underlain either by thick superficial deposits (10-30m) **in which** there is quite a wide variation in lithology (frequently these deposits are moraines) or small areas of sand and gravel, normally less than 10m thick, frequently eskers and narrow valley gravels. Transmissivity can be up to 6.0×10^{-3} m^2/s and specific yield from 5 to 10%. In several places the deposits are in hydraulic continuity with underlying aquifers.

The most important ones are:

(a) The Wexford Coastal gravels:

The deposit here is a complex succession of sands and gravels, tills, and lake and moraine clays. The thickness varies from around 15m in the west **to** over 50m along the coast. Van Putten (1978) considers the area around Screen to have the most potential.

(b) The Southwest Tipperary gravels:

A large morainic complex. There is known to be over 20m of gravel at Limerick Junction.

There are numerous other small areas of sands and gravels, such as the deposits along the River Slaney (Kildavin to Clohamon), those along the Erkina River east of Rathdowney (Co. Loais) and those at Derrygarron northeast of Portlaoise, for which there is insufficient data available.

In the remainder of the region there are very many areas where well sited boreholes will yield 100 cubic metres per day **from aquitards.**

VI.4 Abstractions

There are only three abstractions in the region greater than $1Mm^3/yr$ (Table VI.3). Others worth noting are those at Carlow, Thurles, and Waterford which are in excess of $0.75Mm^3/yr$.

Boreholes have been drilled in both the Upper Visean Limestone (unit 5) and in the various aquifers in County Laois (units 4, 7, 8) to abstract a further $1Mm^3/yr$ from each.

Abstractions are less than 5% of recharge for the individual units (Table VI.5). Groundwater is the main source of supply in this region for agricultural production and processing and for domestic use apart from the larger urban centres i.e. Carlow, Kilkenny, Wexford and Waterford.

VI.5 Surplus Resources available (Table VI.4)

The surplus resources available (Table VI.5) can be grouped into three: those with less than 25mms/yr (3 units), those with between 25-75mms/yr (6 units) and those with greater than 75mms/yr (4 units).

The lowflow from the region at the end of the 1976 drought was of the order of $20m^3/s$, of which $14.8m^3/s$ is estimated to be aquifer flow. Over a full year this aquifer flow would amount to $467Mm^3$. The total recharge for the region of $784Mm^3/yr$ is 1.7 times this aquifer flow. Hence it is considered that the recharge figure of $784Mm^3/yr$ is conservative.

Storage in the aquifers of the region are low although this is probably balanced by the high effective rainfall, the fact that recharge can occur almost throughout the year and indirect recharge from streams crossing the aquifers frequently occurs. Hence there is considerable scope for aquifer management.

Of the total recharge of $784Mm^3/yr$ approximately 55% is for the Dinantian Limestone aquifers. It is not possible to develop these limestones throughout their outcrop area. Development will only be successful in the lowlying areas where fissuring is extensive and deep, e.g. the Barrow Valley; the narrow valleys of the River Nore, and the synclines in the Suir Basin and at Dungarvan.

Problems of saline intrusion are likely to occur in the coastal aquifers or those aquifers along the tidal reaches of the River Suir (to Carrick-on-Suir) and River Slaney (to Enniscorthy) if there is over-abstraction or abstraction points are located too close to saline waters.

TABLE VI.1

GEOLOGICAL SUCCESSION IN THE SOUTHEAST WATER RESOURCE REGION

Period	Lithologies	Distribution	Approximate thickness (m)	Aquifers
Quaternary	Boulder clay, sand and gravel, and peat	Covers most of the region	normally less than 10 but can be up to 60	Sands and gravels
Carboniferous	Westphalian, shales sandstones, coal seams	In the centre of Castlecomer Plateau and Slieve Ardagh Hills	280	Westphalian sandstones
	Namurian, shales and sandstones	On the flanks of the above	450	
	Dinantian, various types of limestones, dolomites and shales	Occupies the two lowland areas west of the Leinster Massif, the southern river valleys, and a small area southwest of Wexford Town	1,200 (in the Kilkenny area) 2,300 (in Carrick Syncline)	certain formations of limestone and dolomite (see Section Ic)
Devonian	Sandstones, shales and the Leinster granite which is of Devonian age	Found in the Slieve Bloom, Devil's Bit, Galty, Knockmealdown, Monavullagh, Comeragh and Slievenamon Mountains. The granite occupies the core of the Leinster Massif.	Slieve Bloom area 300 Ballyragget 50 Nth. Comeraghs 1,500	Upper Sandstone
Silurian	Greywackes, sandstones siltstones and shales	In the cores of the Slieve Bloom, Devil's Bit, Galty, Comeragh and Slievenamon Mountains	Slievenamon area 7,000	none
Ordovician	Volcanics, siltstones sandstones and shales	On the eastern flanks of the Leinster Massif and the Wexford/Waterford lowlands. Also a small area west of the Leinster Massif in southeast county Kildare	2,000 - 3,000	volcanics
Cambrian	Slates and greywackes	Southeast Wexford	1,300 - 2,000	none
Pre-Cambrian	Greywackes, sandstones, gneisses, schists and migmatites	Southeast Wexford		none

TABLE VI.2 DETAILS OF SPRINGS IN THE SOUTHEAST WATER RESOURCE REGION WHOSE AVERAGE FLOW IS CONSIDERED TO BE GREATER THAN 30 l/s (2592 m^3/d)

NAME	LOCATION	LOW FLOW l/s	RATE OF ABSTRACTION l/s
Tobergoolick pool	Paulstown, Co. Kilkenny	26.0 (E)	10.5
Boiling Well	Clomantagh, Co. Kilkenny	30.0	undeveloped
Callan Waterworks	Earls Island, Callan, Co. Kilkenny	12.5 (E)	7.9
Gorteenamuck	Gattabawn, Co. Kilkenny	12.5 (E)	undeveloped
Kyle Springs	Timahoe, Co. Laois	42.0	2.6 at present, will be increased to 31.6
Garrymaddock	Rossmore, Co. Laois	81.0	undeveloped
Darken Well	Derrygarren	18.4	20.0
Aughfeerish Springs	Abbeyleix, Co. Laois		17.6
Kyletilloge	Granston, Co. Laois	19.0	undeveloped
Knockanoran	Durrow, Co. Laois	13.0	undeveloped
Orchard Bridge	Powerstown, Co. Carlow	10.5	5.4
Kiltinin Castle	4km Southeast of Fethard, Co. Tipperary	52.6	undeveloped
Toberadora	3km North of Boherlanan, Co. Tipperary	68.4	plans to take 39.5
Kedrah Springs	3km North of Cahir, Co. Tipperary	120.5	undeveloped
Poulalee and Poulater	4km South of Ardfinnan, Co. Tipperary	126.3	undeveloped
Poulaneigh	3km North of Moycarky, Co. Tipperary	52.6 (E)	undeveloped
Ladyswell	3km Southeast of Thurles, Co. Tipperary		15.1
Toberdaly	4km Southwest of Rhode, Co. Offaly	25.3	6.8
Pollardstown Springs	6km North of Newbridge, Co. Kildare	200	Feeder for Grand Canal(to Dublin)
Castlefarm	4km Northeast of Fontstown, Co. Kildare	12.6	undeveloped
St. Johns Well	Tully, Co. Kildare	12.6	no longer in use
Tobernaloo	3km West of Thurles, Co. Tipperary		11.6
Drinagh Quarry	3km South of Wexford, Co. Wexford	26	undeveloped
	(E) = estimate		

TABLE VI.3 LARGE ABSTRACTIONS IN THE SOUTHEAST REGION

Mm^3/yr

LOCATION	TYPE OF SOURCE	USE	RATE OF ABSTRACTION
Athy, Co. Kildare	Boreholes	Industrial and Public	1.2
Ballyragget, Co. Kilkenny	Boreholes	Industrial	1.7
Dungarvan, Co. Waterford	Boreholes	Public	2.3

TABLE VI.4. contd. SURPLUS RESOURCES AVAILABLE IN EACH UNIT OF THE SOUTHEAST REGION

[Unit No.] Name	Unit Area sq. km.	Aquifers in the unit	Area of each aquifer in the unit sq. km.	Mean Precipitation mm /yr	Mean Potential Evapotranspiration mm /yr	Effective Rainfall mm /yr	Recharge Mm^3/yr	Total Abstraction Mm^3/yr	Available Resources Mm^3/yr	Resources Available for each unit Mm^3/yr
[4] Upper Barrow unit	1458	Upper Devonian sandstone (Clonaslee sandstone)	35.9	1200	467	733	7.22	.02 [3]	7.2	
		Crosspatrick limestone	22.2	875	467	408	2.26	.2	2.2	
		Edenderry Oolite	125.2	830	460	370	8.8	.33	8.5	
		Maryborough Esker	19.2	900	467	433	4.86	.015	4.8	
		Clonaslee sands and gravels	2.0	1200	467	733	1.2	.002	1.2	
		Curragh outwash plain	125.4	810	470	340	31.55	.59	31.0	
		S.W. Wicklow sands & gravels	6	1000	500	500	1·6	·003	1·6	56·5

3. Boreholes have been drilled to abstract an additional 0.6 Mm^3/yr from this aquifer.

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TABLE VI.4. SURPLUS RESOURCES AVAILABLE IN EACH UNIT OF THE SOUTHEAST REGION

[Unit No.] Name	Unit Area sq. km.	Aquifers in the unit	Area of each aquifer in the unit sq. km.	Mean Precipitation mm /yr	Mean Potential Evapotranspiration mm /yr	Effective Rainfall mm /yr	Recharge M m^3/yr	Total Abstraction M m^3/yr	Available Resources M m^3/yr	Resources Available for each unit M m^3/yr
[1] East Wexford coastal unit	535	Ordovician Volcanics	90	975	560	415	7.5	.06	7.4	49.6
		East Wexford coastal sands and gravels	185	950	560	390	42.6	.37	42.2	
[2] River Slaney unit	1762	Ordovician Volcanics	187	1010	550	460	21.5	.6	20.9	30.5
		South west Wicklow Sands & gravels	30	1100	500	600	9.6	.02	9.6	
[3] South Wexford coastal unit	730	Ordovician Volcanics	98	1050	550	500	14.7	.16	14.5	20.3
		South Wexford Limestones	87	975	560	415	6.54	.742	5.8	

1. All the gravel areas in South Wexford are included here as they provide recharge to the underlying limestone. There will be additional indirect recharge from streams passing through the aquifer (Cullen 1978).

2. Boreholes have been drilled to abstract a further 4.4 Mm^3/yr from this aquifer.

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TABLE VI.4. contd. SURPLUS RESOURCES AVAILABLE IN EACH UNIT OF THE SOUTHEAST REGION

[Unit No.] Name	Unit Area sq. km.	Aquifers in the unit	Area of each aquifer in the unit sq. km.	Mean Precipitation mm /yr	Mean Potential Evapotranspiration mm /yr	Effective Rainfall mm /yr	Recharge $M\,m^3/yr$	Total Abstraction $M\,m^3/yr$	Available Resources $M\,m^3/yr$	Resources Available for each unit $M\,m^3/yr$
[5] Middle Barrow unit 4	1088	Upper Visean Limestone	387	900	468	432	53.7	2.69	51.0	64.4
		River Barrow gravels (Carlow)	60.62	875	468	407	9.87	.22	9.75	
		Kilkenny/ Carlow Dolomites	34.8	885	468	417	4.13	.44	3.7	
		Stradbally sands and gravels	4.1	Resources of this aquifer are included in the upper Visean Limestone which underlies it.						
[6] Lower Barrow unit	536	Ordovician Volcanics	40.4	1010	550	460	6.04	.046	6.0	6.0

4. The Westphalian sandstones are considered in unit 8 as groundwater flows into that unit.

5. Only the area not underlain by other aquifers is considered here.

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TABLE VI.4. contd. SURPLUS RESOURCES AVAILABLE IN EACH UNIT OF THE SOUTHEAST REGION

[Unit No.] Name	Unit Area sq. km.	Aquifers in the unit	Area of each aquifer in the unit sq. km.	Mean Precipitation mm /yr	Mean Potential Evapotranspiration mm /yr	Effective Rainfall mm /yr	Recharge Mm^3/yr	Total Abstraction Mm^3/yr	Available Resources Mm^3/yr	Resources Available for each unit Mm^3/yr
[7] Upper Nore unit	581	Upper Devonian sandstone (Clonaslee sandstone)	15.7	990	467	523	21.8	.103	21.7	28.1
		Ballyfin sands and gravels	13.5	980	467	513	3.7	.004	3.7	
		Camross sands and gravels	16.1	990	467	523	2.7	.003	2.7	
[8] Middle Nore unit	1506	Crosspatrick Limestone	39.6	910	468	442	6.55	.17	6.4	
		Upper Visean Limestone (S. Laois & N. Kilkenny)	227	940	468	472	32.05[6]	.69	31.4	

6. Aquifer receives additional indirect recharge.

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TABLE VI.4. contd. SURPLUS RESOURCES AVAILABLE IN EACH UNIT OF THE SOUTHEAST REGION

[Unit No.] Name	Unit Area sq. km.	Aquifers in the unit	Area of each aquifer in the unit sq. km.	Mean Precipitation mm /yr	Mean Potential Evapotranspiration mm /yr	Effective Rainfall mm /yr	Recharge M m^3/yr	Total Abstraction M m^3/yr	Available Resources M m^3/yr	Resources Available for each unit M m^3/yr
[8] iddle Nore ait (contd.)	1506	Upper Visean Limestone (mid-Kilkenny)	129	900	468	432	12.37	.30	12.1	
		Westphalian Sandstone (Castlecomer Plateau)	105	1040	468	572	10.5	.37	10.1	
		Westphalian Sandstone (Sl. Ardagh Hills)	9.0	1000	468	532	1.68	.08	1.6	
		Kilmanagh River gravels (major aquifer)	13.4	1050	468	582	5.8 [7]	.05	5.8	

7. Aquifer receives additional indirect recharge.

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TABLE VI.4. contd. SURPLUS RESOURCES AVAILABLE IN EACH UNIT OF THE SOUTHEAST REGION

[Unit No.] Name	Unit Area sq. km.	Aquifers in the unit	Area of each aquifer in the unit sq. km.	Mean Precipitation mm /yr	Mean Potential Evapotranspiration mm /yr	Effective Rainfall mm /yr	Recharge Mm^3/yr	Total Abstraction Mm^3/yr	Available Resources Mm^3/yr	Resources Available for each unit Mm^3/yr
[8] Middle Nore Unit (contd.)	1506	Nore River gravels at Kilkenny	18.2	880	468	412	5.6	.24	5.4	100.2
		S. Laois N. Kilkenny sands and gravels	48.2	900	468	432	13.54	2.04	11.5	
		Kilmanagh river gravels	22.2	1000	468	532	5.55	.29	5.3	
		Dinin river gravels	23.0	960	468	492	7.36	.22	7.1	
		Kings river sands and gravels	8.1	1000	467	533	3.5		3.5	
[9] Lower Nore Unit	442	Upper Devonian sandstones (Kiltorcan sandstone)	69.0	950	470	480	13.1	.27	12.8	15.6
		Lr. Nore sands and gravels (Thomastown)	10.1	925	470	455	3.0	.17	2.8	

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TABLE VI.4. contd. <u>SURPLUS RESOURCES AVAILABLE IN EACH UNIT OF THE SOUTHEAST REGION</u>

[Unit No.] Name	Unit Area sq. km.	Aquifers in the unit	Area of each aquifer in the unit sq. km.	Mean Precipitation mm /yr	Mean Potential Evapotranspiration mm /yr	Effective Rainfall mm /yr	Recharge Mm^3/yr	Total Abstraction Mm^3/yr	Available Resources Mm^3/yr	Resources Available for each unit Mm^3/yr
[10] Upper Suir Unit	660	Upper Devonian sandstone (Clonaslee sandstone)	69.2	990	467	523	8.13	.12	8.0	
		Crosspatrick Limestone	34.1	950	467	483	6.7	.6	6.1	14.1
[11] Middle Suir Unit	1275	Crosspatrick Limestone	67.1	970	467	503	11.82	.42	11.4	
		Aherlow Lst. Syncline	53.1	1150	467	683	24.6	.12	24.5	
		Up. Visean Lst. Mid. Suir	494	980	467	513	92.67	1.97	90.7	
		Southwest Tipperary sands and gravels	87.0	1090	467	623	23.3	.23	23.1	
		Aherlow Gravels	43.6	1050	467	583	3.4	.02	3.4	153.1

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TABLE VI.4. contd. SURPLUS RESOURCES AVAILABLE IN EACH UNIT OF THE SOUTHEAST REGION

[Unit No.] Name	Unit Area sq. km.	Aquifer in the unit	Area of each aquifer in the unit sq. km.	Mean Precipitation mm /yr	Mean Potential Evapotranspiration mm /yr	Effective Rainfall mm /yr	Recharge M m³/yr	Total Abstraction M m³/yr	Available Resources M m³/yr	Resources Available for each unit M m³/yr
[12] Lower Suir Unit	1640	Ordovician Volcanics	160.0	1000	550	450	25.3	1.54	23.00	175.8
		Lower Suir Limestone Synclines	570	1050	490	560	154	2.0	152	
[13] Waterford coastal unit	555	Ordovician Volcanics	183	1000	560	440	32.2	.22	32.0	48.8
		Dungarvan Limestone Syncline	44.4	1100	560	540	19.2	2.4	16.8	

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TABLE VI.5 SUMMARY OF ABSTRACTIONS AND SURPLUS RESOURCES IN THE UNITS OF THE SOUTHEAST REGION

UNIT NO.	UNIT AREA sq. km.	AREA OF AQUIFER sq. km.	RECHARGE Mm^3/yr	ABSTRACTIONS Mm^3/yr	SURPLUS RESOURCES AVAILABLE Mm^3/yr	SURPLUS RESOURCES AVAILABLE mm/yr over unit
1	535	275	50.1	.5	49.6	93
2	1762	217	31.1	.6	30.5	17
3	730	185	21.2	.9	20.3	28
4	1458	33.6	57.5	1.0	56.5	39
5	1088	487	67.7	3.3	64.4	59
6	536	40	6.0	-	6.0	11
7	581	181	28.2	.1	28.1	48
8	1506	635	104.5	4.3	100.2	67
9	442	79	16.1	.5	15.6	35
10	660	103	14.8	.7	14.1	21
11	1275	745	155.8	2.7	153.1	120
12	1640	730	179.3	3.5	175.8	107
13	555	227	51.4	2.6	48.8	88
TOTALS:	12768	4240	783.7	20.7	763.0	59.6

VII. THE SOUTHERN WATER RESOURCE REGION

VII.1 General Description

The Southern Water Resources Region comprises the drainage basins of all rivers draining to the south and west coasts of Ireland between Dungarvan Bay in the east and Kerry Head in the west. The region encompasses the greater part of counties Cork and Kerry, with small portions of counties Waterford and Limerick and a very small part of Tipperary. It has a total area of some 11,700 sq.km. and a population of around 480,000 (estimated from preliminary figures for 1979 Census). The major urban centre is the city of Cork (population 130,000).

The main river catchments included are those of the Munster Blackwater (3,327 sq. km.), Lee (1,253 sq. km.), Bandon (608 sq. km.), Laune (829 sq. km.) and Maine (399 sq. km.), which together total 6,416 sq. km., or 54% of the total area. The region has a very indented coastline of peninsulas separated by drowned valleys (rias) and some 2,300 sq. km. of the area is regarded as 'coastal' drainage, comprising very small catchments draining directly to the sea.

The region has very strong relief, including Ireland's highest mountains in the MacGillicuddy's Reeks, west of Killarney (up to 1,041 metres elevation), while several other ranges in west Kerry and west Cork lie above 600m, and the Galty Mountains and Knockmealdown Mountains on the eastern boundary of the region also reach heights of well over 600m.

The topography of the region consists of a series of anticlinal ridges and synclinal valleys on a general east-west trend, controlled by the Hercynian fold-movement which dominated the geological structure of the region. Where they meet the sea, the valleys form rias, having been partially submerged in relatively recent times.

The rugged topography and the position of the region in the path of the prevailing south-westerly to westerly winds crossing the Atlantic ensure an abundant rainfall, ranging from over 3,000mm/yr. on the highest peaks to just under 1,000mm/yr. in sheltered valleys in the north and east of the region.

VII.2 Aquifers

VII.2.1 Carboniferous Limestone (fissured aquifer)

The principle aquifer in the southern region is the Carboniferous Limestone, which ranges in age from Tournaisian (Courceyan) to Visean (Chadian-Arundian-Holkerian-Asbian). The thickness of the limestone succession varies up to a maximum of about 1,700m (in north Cork), though it is even thicker outside the region. Within this succession a variety of limestone lithologies is represented. The lowest ones are bedded and argillaceous, with shaly intercalations. These are generally succeeded by a massive sequence of Waulsortian-type limestones, locally referred to (misleadingly) as 'Reef'.

Above the 'Reef' the succession is more variable from place to place, though in many areas it has been largely or completely removed by erosion. It generally consists of bedded limestones, some argillaceous and some clean; in some places a massive sequence (Upper 'Reef') is included.

Although it would be expected, by comparison with limestones elsewhere in the country and abroad, that the best aquifers would be the clean, well-bedded calcarenites found (usually) in the upper part of the succession, in the Southern region it seems that the intense Hercynian folding produced very strong patterns of faulting and jointing, mainly on north-south directions, which have served to integrate the varied succession into one aquifer, including both clean and shaly, both massive and bedded limestones. All seem to have been well jointed and subsequently karstified to a depth well below present sea level. It is probably true that the cleaner and thinner-bedded limestones have higher transmissivities than the others but this has not yet been demonstrated in the field. So for the present, it can be accepted that the limestones are effectively one hydraulically continuous aquifer, and the effective thickness (i.e. the saturated depth of karstification) is of the order of 60-100m.

VII.2.2 Quaternary Sands and Gravels

Fluvioglacial and alluvial sands and gravels form important local aquifers in this region, and can be classified into two groups:

(a) <u>Overlying Limestone</u>:

The limestones occur principally in the synclinal east-west trending valleys, and much of the limestone outcrop is obscured by Quaternary deposits, of which coarse-grained deposits comprise a large part. Mapping of these sand/gravel aquifers is only beginning, so that their full extent and thickness can only be guessed, but it probably extends to at least one third of the area of the limestones. The thickness of the Quaternary is often considerable because the valleys have been cut down and graded to sea levels of perhaps -100m. Thus around Cork Harbour boreholes have proved Quaternary sediments down to -60m O.D. Boreholes penetrating 20m to 30m of Quaternary sediments are common in the synclinal valleys, and much of this thickness is of saturated sands and gravels. The deepest erosion of the bedrock appears to have taken place on the outcrop of the "Lower Limestone Shales", a shaly calcareous sequence immediately below the true limestone succession, so that the gravel aquifers tend to overlap the limestone outcrop.

It seems probable that these Quaternary aquifers are lenticular in shape, and intercalate with boulder clay, silty sands, and peats. Locally they may be hydraulically distinct, but across the limestone outcrop as a whole, they are likely to be substantially in hydraulic continuity with the limestone. If this is so, then these beds, with their inherently high storativity, represent important storage capacity to increase the water resources of the limestone aquifers.

(b) Away from the limestone outcrops, a number of small, but locally important, gravel aquifers are known and exploited. They are especially important, in south and west Cork where the bedrock is the 'Cork Beds', a somewhat calcareous sequence of shales, mudstones and sandstones which is a local facies equivalent in age to the limestone succession further north.

The Cork Beds are not a significant aquifer, though numerous boreholes draw small supplies (normally less than 0.5 lps) from them. In this region, therefore, gravel aquifers are very important. They tend to be rather thin, and occupy narrow stretches alongside the rivers. Examples are shown on the map along the rivers Bandon and Lee, but others are too small to show and yet others probably remain to be found and exploited.

VII.2.3 Minor Aquifers

(a) Coal Measures Sandstone:

A small outcrop of the Coal Measures occurs in west County Limerick; by analogy with other outcrops in counties Kilkenny, Carlow and Tipperary, it is presumed that this will contain one or more sandstone aquifers with a rather low transmissivity. No boreholes are known to substantiate this.

(b) Sandstones in the Upper Carboniferous ('Millstone Grit') succession yield small quantities of water and well yields up to 7.5 lps are recorded from favourable localities. However, the evidence is not yet substantial enough to justify including these rocks as aquifers on the maps.

(c) The upper part of the Devonian ('Old Red Sandstone') succession is known to yield water in moderate amounts in other regions. In this region there are few records of well yields above 1 lps, though there is an exceptional pair of boreholes (100m apart) in north Cork, where each well yielded 31 lps.

VII.3.4 Transmissivities

(a) Limestones:

Transmissivities of fissured and karstified limestones are difficult to estimate because the classical methods of pumping test analysis are of doubtful validity when applied to such cases. However, with reservations, it is possible to arrive at some approximations and the data for this region, while still very poor, are better than for most other regions of the country:-

(i) In the area of Cloyne (southeast Cork) tests on six high-yielding wells have allowed estimates of transmissivity ranging from $200m^2/d$ up to more than $2{,}000m^2/d$ (2.3×10^{-3} to 2.3×10^{-2} $m^2/sec.$). Only two tests had piezometric data. The limestone here is of the massive Waulsortian 'reef' type.

(ii) On Little Island, in Cork Harbour, two industrial boreholes tested in 1974 yielded transmissivity estimates of up to $900m^2/d$. (1×10^{-2} $m^2/sec.$), again in 'reef' limestone.

(iii) At Ringaskiddy, on the east side of Cork Harbour, specific capacity tests on 10 boreholes in the Lower Limestone indicated transmissivities of up to $100m^2/d$ (1.2×10^{-3} $m^2/sec.$) with one exceptional value of $600m^2/d$ (7×10^{-3} $m^2/sec.$) and an average of about $60m^2/d$ (7×10^{-4} $m^2/sec.$).

(iv) Specific capacity tests on three boreholes at scattered locations in north Cork produced apparent transmissivities of about 30-35m^2/d ($3.5 - 4 \times 10^{-4}$ m^2/sec.).

From our knowledge of the limestone aquifers, it is apparent that where drawdowns are relatively high (say over 10m) well losses are often quite large, and transmissivities estimated from specific capacity data by use of a formula such as Logan's:

$$T = Q/s \times 1.22$$

are liable to be in error by a factor of from 2 to 5, perhaps more.

Therefore, it appears that transmissivities in the limestone aquifers of the region probably lie in the general range of 100-2,000m^2/d (1×10^{-3} to 2×10^{-2} m^2/sec.).

(b) Other aquifers:

(i) No useful transmissivity values can be mapped for the Quaternary aquifers, since these are so dependent on the thickness and sorting of each individual deposit.

Values recorded are:

Brinny, south Cork (6m well-screen) 220-350m^2/d (2.5 to 4×10^{-3} m^2/sec.).

Carrigtohill, southeast Cork 30-60m^2/d (8m well-screen) (3.5 to 7×10^{-4} m^2/sec.).

(ii) One transmissivity estimate is available from a specific capacity test on the boreholes in Old Red Sandstone in northeast Cork, of 220m^2/d (2.5 x 10^{-3} m^2/sec.). Well losses probably operate here and the actual transmissivity may be higher, but on the other hand the yield from these two wells was exceptional for this formation.

VII.3.5 River/Groundwater exchange

Though this has not been checked by drawing up watertable maps, it can be generally assumed that most rivers are gaining, i.e. are fed by groundwater (partially or, in summer, wholly).

In certain situations, however, in summer there may be local variations to this norm. Where streams draining upland areas emerge rather abruptly with a change of gradient onto permeable limestone valley areas, there is a possibility of the river losing water to the aquifer locally.

VII.3.6 Particular Problems

(a) Sea water Intrusion:

The limestone aquifers (and some local gravel aquifers) are in many places adjacent to the sea, and in these coastal areas the watertable slopes very gradually down to mean sea level. Therefore, if groundwater abstractions were excessive in such coastal areas there would be a serious risk of seawater intrusion.

As far as is known, no such seawater intrusion has taken place to date. A few boreholes have met with salt water but these were sunk very close to the coast, where a salt water wedge could be expected to occur under natural conditions.

However, in certain areas, e.g. Cork Harbour area, where industrial concerns are relatively concentrated, there could be a risk of over-abstraction in the future which could give rise to serious seawater intrusion.

In any case the proximity of the sea will be the limiting factor on the permissible abstraction in coastal areas of limestone. This has been taken into account when calculating the available water resource in coastal areas.

(b) Mineralized water:

There are no known areas of mineralized water within the region.

(c) Groundwater Seepage areas:

Areas of very high watertable, causing seasonal flooding, are quite common in the limestone valley areas, particularly near the coast. Such areas are generally too small to put on the map.

VII.3.7 Springs

Springs emerging from the limestone aquifers are common, but because the synclinal aquifers tend to be elongate in shape, the catchments of the springs tend to be rather small and consequently the discharges of the springs are only moderate.

There are no accurate records of the flows of springs in Ireland, with only a few exceptions. For the major springs, the local authorities (County Councils) have some data for minimum flows, and we can only guess that the average discharge is some multiple of this.

For the Dower spring in southeast Cork, the minimum flow is around 6,800m^3/d in, say, September, whereas the average flow in say, May, is around 27,000m^3/d or about four times the minimum. For want of better knowledge, this factor of 4 x minimum flow is used for average flow. Using this factor, there are nine known limestone springs in the region which are large enough to put on Map 2.

These springs, with their minimum flows, and estimated average flows, are listed in Table VII.1.

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TABLE VII.1

MAJOR SPRINGS, SOUTHERN WATER RESOURCE REGION

(all from limestone aquifers)

Location	NGR	Minimum Yield lps.	Estimated Average Flow (lps)	Spring Class.
Two Gneeves, Cecilstown, Co. Cork	R 443032	104	400	3
Clogher, Shanballymore Co. Cork	R 665073	93	370	3
Dower, Castlemartyr, Co. Cork	W 979728	78	310	3
Knockduff, Meelin, Co. Cork	R 298124	57	230	2
Inchidaly, Banteer, Co. Cork	W 401987	26	105	2
Ballinvoher, Castletownroche, Co. Cork	R 685036	20	80	1
Claraghatlea, Millstreet, Co. Cork	W 260908	18	75	1
Kilnadrow, Glanworth, Co. Cork	R 761075	17	70	1
Tobermaing, Castleisland, Co. Kerry	R 022097	78	310	3

TABLE VII.2

MAJOR ABSTRACTIONS

SOUTHERN WATER RESOURCE REGION

Use	Location	NGR	Type of Source	Aquifer	Daily Abstraction m^3/d	Annual Abstraction M. cu. m.
Public	Ardfert, Co. Kerry	Q 780214	BH (3)	Quaternary gravel	3,820	1.39
Public	Tobermaing, Co. Kerry	R 022097	Spring	Carboniferous Lst.	3,180	1.16
Industry	Brinny, Co. Cork	W 515595	BH (3)	Quaternary gravel	3,820	1.39
Industry	Ringaskiddy, Co. Cork	W 7665	BH (?10)	Carboniferous Lst.	3,400	1.24
Industry	Carrigtohill, Co. Cork	W 801731	BH (3)	Quaternary gravel	2,700	1.00
Public	Dower, Co. Cork	W 979728	Spring	Carboniferous Lst.	5,000	1.83
Creamery	Mallow, Co. Cork	W 558990	BH (?)	Carboniferous Lst.?	3,182	1.16
Creamery	Mitchelstown, Co. Cork	R 815130	BH (3)	Carboniferous Lst.?	7,273	2.65
Public	Meelin, Co. Cork	R 298124	Spring	Carboniferous Lst.	2,727	1.00

TABLE VII.3

SUMMARY OF GROUNDWATER RESOURCES IN THE SOUTHERN REGION

UNIT NO.	AREA OF UNIT Km^2	AREA UNDERLAIN BY AQUIFER Km^2	ESTIMATED RECHARGE M.cm/yr	ESTIMATED ABSTRACTIONS M.cm/yr	SURPLUS	
					M.cm/yr	mm/yr over unit
1	210	72.5	23.6	1.8	21.8	104
2	530	-	-	-	-	-
3	440	167.5	62.8	1.0	61.8	140
4	1041	166.5	66.0	0.9	65.1	63
5	871.5	-	-	-	-	-
6	248	16	15.35	0.05	15.3	62
7	813	-	-	-	-	-
8	1147	-	-	-	-	-
9	570	24	17.8	1.8	16.0	28
10	290	3	0.8	(0.1)	0.7	2.4
11	168	14	4.2	1.8	2.4	14.2
12	622.5	6	3.5	(0.1)	3.4	5.5
13	795	52.5	26.25	3.4	22.85	28.7
14	538.5	144	41.0	4.9	36.1	67
15	792.5	24	13.95	0.3	13.65	17.2
16	535	145	80.05	1.8	78.25	146
17	375	240	66.0	1.6	64.4	172
18	480	217.5	121.8	4.3	117.5	245
19	522.5	87.5	43.75	0.3	43.45	83
20	437.5	77.5	37.2	0.9	36.3	83
21	250	17	4.7	(0.1)	4.6	18.4
TOTAL:	11700	1474.5	628.75	25.15	603.6	51.6

VIII. The Mid-Western Water Resource Region.

VIII.1.

The Mid-Western Region comprises all the catchments draining into the Shannon Estuary below the weir at Killaloe (the downstream limit of the Shannon Water Resource Region), together with the catchments to the south of Galway Bay and north of Tralee Bay draining westwards to the Atlantic off the Clare and Kerry coasts. The region thus includes almost all of counties Clare and Limerick, with parts of south Galway, north Tipperary, north Cork and north Kerry. It has an area of about 7,500 km^2 and a population of about 290,000 (estimated from the 1979 census) of whom about 60,000 live in Limerick city.

Topographically the region shows similar features on both sides of the Shannon Estuary which bisects it from east to west. West Clare and West Limerick/N.E. Kerry comprise an elevated plateau, up to about 350 m. high. Central Clare and Limerick are occupied by rolling lowlands, while in the east lie ranges of hills (Slieve Aughty, Slieve Bernagh, Slievefelim Hills). The southeastern catchment boundary is formed by the Galty Mountains.

Apart from the Shannon, which enters the region at Killaloe, the main rivers of the area are the Fergus, draining the northern lowland, the Maigue, Deel, and Mulkear, which drain the Limerick side of the estuary, and the Feale, draining westwards to the Kerry coast. There are numerous small lakes in County Clare.

The average annual rainfall over the region is quite heavy ranging from around 1400 mm on western coastal uplands, to around 1000 mm on lowland areas to the east.

VIII.2. Geology

The three broad topographic subdivisions mentioned above correspond to three broad geological divisions. The upland plateaus of West Clare and West Limerick/N. Kerry are formed by gently folded Namurian strata, consisting of alternating shales and sandstones. There is a small outcrop of Westphalian ("Coal Measures") strata in

TABLE VIII.1

GEOLOGICAL SUCCESSION, MID-WESTERN REGION

Quaternary		Glacial till, fluvio-glacial gravels and sands, alluvium, peat
Upper Carboniferous	'Coal Measures'	shales, sandstones, coal seams
	'Millstone Grit'	shales, siltstones, sandstones thin coals
Lower Carboniferous	Upper Limestone	dark bioclastic limestones, well-bedded [Volcanics-agglomerates, ashes, basalts, trachytes.] dark, well-bedded argillaceous limestones.
	Middle Limestone	Pale, massive Waulsortian 'reef' limestones.
	Lower Limestone	Dark, well-bedded argillaceous limestones.
	Lower Limestone Shale	Interbedded sandstones, shales and shaly limestones
Devonian	'Old Red Sandstone'	Conglomerates, sandstones, shales
Silurian		Gritstones and slates

west Limerick, including sandstones and thin coal seams.

The central lowland areas are occupied by gently folded Carboniferous (Tournaisian-Visean) limestones. These have been broadly subdivided into four lithologies as shown in Table VIII.1., with shales at the base. There is a prominent scarp along the eastern edge of the Namurian outcrop where it is underlain by the limestones.

In east Limerick the upper limestones are mixed with a variety of volcanic rocks.

To the east of the limestone lowlands, there are ranges of hills formed predominantly of folded Devonian (Old Red Sandstone facies) and Silurian rocks, much faulted. These rocks also reappear in the Ballyhoura Hills and Galty Mountains to the south.

In North Kerry, to the west of the Namurian plateau, lies a limestone valley which represents the northern extension of the synclinal limestone valleys of the Southern Region (Chapter VII.). Another synclinal limestone valley crosses the regional boundary in north Cork near Rathluirc.

Quaternary deposits are widespread. Boulder clay predominates, and is very thick in part of Limerick (over 50 m.). Drumlins are prominent in central and east Clare. Important gravel deposits are associated with morainic sediments in Limerick and Tipperary.

VIII.3. Aquifers.

3.1. Devonian sandstones

These rocks, of the 'Old Red Sandstone' facies, are little known as aquifers but are tentatively mapped as aquifers in a narrow belt around the hills in the eastern and southern parts of the area. Only the uppermost part of the formation is believed to form the aquifer, and as it dips below the overlying shales it becomes confined.

3.2. Carboniferous limestones

The water-bearing characteristics of the limestones depend on their lithology and degree of structural deformation, and on their history of Karstification.

In Clare, the upper, purer limestones have been karstified and are mapped as karstic aquifers. The Waulsortian and lower limestones are argillaceous and are not considered to be aquifers. In the higher areas of North Clare lies the famous 'Burren', an area of classic karst features - clint pavements, cave systems, underground streams and turloughs. However, in this area, and in the Aran Islands off the coast, it is apparent that karstification extends only a few tens of metres below the elevated ground surface. Consequently, although infiltration is almost total, the water moves very quickly through the ground and storage is very small.

To the south of the Shannon Estuary, in Limerick the lower argillaceous limestones are not considered aquifers, but the Waulsortian type rocks do appear to yield water, perhaps because of a greater degree of fracturing. The best aquifer appears to be, as elsewhere, the upper Visean limestones. These are separated from the Waulsortian by an intervening argillaceous limestone aquitard.

The volcanic rocks of East Limerick are rather problematical, but on the basis of very sparse evidence, the acidic types are included with the upper Visean limestone aquifer, while the basic types are excluded.

3.3. Westphalian sandstones

The Westphalian ('Coal Measures') outlier in West Limerick (Crataloe Coalfield) is mapped as an aquifer, because similar formations elsewhere, in the South Eastern Region, are known to contain thin (10-20 metre thick) sandstone aquifers. This outlier is small (6 km^2) and not yet exploited.

3.4. Quaternary sands and gravels.

Limerick is crossed by a major end-moraine, from Glin on the Shannon Estuary, across to Tipperary town, and some gravel deposits associated with this moraine have been mapped as complex aquifers. Little is known about them, but they have been exploited to some extent near Tipperary town. Similar deposits are found elsewhere in Limerick.

VIII.4. Groundwater hydrology.

The only part of the region which has been studied in any detail is in North Clare and south Galway, where the classic karst areas have been investigated by Williams (1964, etc) and others, resulting in an approximate water table map which has been incorporated in Map 2. Elsewhere almost nothing is known about the groundwater hydrology of the region.

VIII.5. Abstractions.

Abstractions within the region are summarised on Table VIII.2. The concentration of abstractions in the lowlands of Limerick reflects both the greater density of settlement there and the difficulties of obtaining supplies in the karst areas of Clare. There are large abstractions within the region, at Rathluirc, Co. Cork (about 1 Mm^3/yr for a creamery from 5 boreholes) and at Ballyheigue, Co. Kerry (about 1 Mm^3/yr from a spring for public supply). Limerick and Tipperary have excellent pasture and dairying is very important, so that there are numerous creameries in the region, which typically use around 100 m^3/day from boreholes.

VIII.6. Recharge.

Recharge conditions are generally good in the limestones of County Clare, through some areas have fairly thick boulder clay. In Limerick, Tipperary and Kerry, infiltration is impeded. The Devonian sandstones generally have fairly good infiltration. The effective rainfall generally ranges from 475 to 650 mm/yr, with some areas rather higher.

VIII.7. Resources.

Table VIII.3. summarises the groundwater resources of the various units in the region. The resources figures for units 1, 2, 3, and 4,in the range of 60-77 mm/yr. over the units, and for unit 7, must be treated with caution, since these resources are almost entirely in karstic limestones, and very arbitrary allowances have been made for quick through-flow. In these units the actual available resources may be very much lower than indicated. The indicated resources for the remaining units to the south of the estuary can be given with more confidence, as they compare reasonably well with figures derived from hydrograph analysis for a few rivers.

TABLE VIII.2

GROUNDWATER RESOURCES IN THE MID-WEST REGION

UNIT NO. & NAME	AREA OF UNIT Km^2	AQUIFERS	AREA OF AQUIFERS Km^2	MEAN RAINFALL mm/yr	MEAN EVAPOTRANSPIRATION mm/yr	EFFECTIVE RAINFALL mm/yr	ESTIMATED RECHARGE Mm^3/yr	TOTAL RECHARGE PER UNIT Mm^3/yr	ESTIMATED ABSTRACTIONS Mm^3/yr	SURPLUS RESOURCES Mm^3/yr
1 Gort	579	Carboniferous limestone (K)	330	1100	550	550	36.3	44.88	0.28	44.6
		Devonian sandstone	66	1200	550	650	8.58			
2 N.W. Clare	235	Carboniferous limestone (K)	174	1400	575	825	14.35	14.35	0.25	14.1
3 Upper Fergus	468	Carboniferous limestone (K)	305	1100	550	550	29.35	32.95	0.2	32.75
		Devonian sandstone	15	1150	550	600	3.6			
4 W. Clare	470	Carboniferous limestone (K)	4	-	-	-	-	-	-	negligible
5 Lower Fergus	405	Carboniferous limestone (K)	145	1150	550	600	25.95	28.55	0.15	28.4
		Devonian sandstone	10	1200	550	650	2.6			
6 S.W. Clare	655	-	-	-	-	-	-	-	-	-
7 S.E. Clare	365	Carboniferous limestone (K)	45	1050	550	500	6.07	14.47	1.4	13.07
		Devonian sandstone	35	1150	550	600	8.4			
8 Mulkear - Shannon	1035	Quaternary sands and gravels	123	1100	475	625	30.75	75.6	0.1	75.5
		Carboniferous limestone and volcanics	212.5	1000	475	525	34.12			
		Devonian sandstone	79.5	1150	475	675	10.73			
9 Maigue	1180	Quaternary sands and gravels	139.5	1000	475	525	29.3	141.8	2.5	139.3
		Carboniferous limestone and volcanics	578.5	950	475	475	104.2			
		Devonian sandstone	44	950	475	475	8.3			
10 Deel	627	Quaternary sands and gravels	127	1050	475	575	29.2	99.6	1.4	98.2
		Carboniferous limestone	281	1050	475	575	67.8			
		Devonian sandstone	12.5	1000	475	525	2.6			
11 N. Limerick-N. Kerry	229	-	-	-	-	-	-	-	-	-
12 Galey	193	-	-	-	-	-	-	-	-	-
13 N.E. Kerry	441	Quaternary sands and gravels over Carboniferous limestone	210	1030	570	460	48.3	48.3	2.15	46.15
14 Feale	626	Upper Carboniferous sandstone	6	-	-	-	-	-	-	negligible

(X) = Area of Karstic flow.

TABLE VIII .3

SUMMARY OF GROUNDWATER RESOURCES IN THE MID-WESTERN REGION

UNIT NO.	AREA OF UNIT Km^2	AREA UNDERLAIN BY AQUIFER Km^2	ESTIMATED RECHARGE M.cm/yr	ESTIMATED ABSTRACTIONS M.cm/yr	SURPLUS	
					M.cm/yr	mm/yr over unit
1	579	396	44.88	0.28	44.6	77
2	235	174	14.35	0.25	14.1	60
3	468	320	32.95	0.2	32.75	70
4	470	4	-	-	-	-
5	405	155	28.55	0.15	28.4	70
6	655	-	-	-	-	-
7	365	80	14.47	1.4	13.07	36
8	1035	415	75.6	0.1	75.5	73
9	1180	762	141.8	2.5	139.3	118
10	627	420.5	99.6	1.4	98.2	157
11	229	-	-	-	-	-
12	193	-	-	-	-	-
13	441	210	48.3	2.15	46.15	105
14	626	6	-	-	-	-
TOTAL:	7508	2942.5	500.5	8.43	492.07	65.5

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IX. SHANNON WATER RESOURCE REGION

IX.1 Introduction.

The Shannon Region covers the catchment area of the River Shannon upstream of Killaloe. The area is 10,520 km^2 and includes part of twelve counties - Cavan, Leitrim, Roscommon, Sligo, Mayo, Galway, Clare, Longford, Meath, Westmeath, Offaly and Tipperary. The main towns in the region are Athlone, Roscommon, Boyle, Castlerea, Carrick-on-Shannon and Longford. The Shannon rises in the Cuilcagh Mountains in County Cavan and flows southwards through Lough Allen, Lough Ree and Lough Derg, draining the central plain of Ireland. From Lough Derg it flows southwestwards into the Shannon estuary. The area is lowlying and relatively flat, with mountain ridges - Silvermines Slieve Bloom, Cuilcagh Mountains, Curlew Mountains, Slieve Aughty and Arra Mountains - along the catchment divide.

The main tributaries of the Shannon are the Suck, Boyle, Brosna and Inny. The River Suck rises in Lough O'Flynn in northwest Roscommon and flows eastwards to Castlerea and then southeast through Ballinasloe to join the Shannon at Shannon Bridge. The catchment area is 1598 km^2. The Boyle River starts in Lough Gara in County Sligo. The Lung and Breedoge rivers flow into Lough Gara; the Lung River rising east of Kilkelly in Co. Mayo and the Breedoge rising south of Ballanagare in Co. Roscommon. From Lough Gara the Boyle River flows eastwards through Boyle and Lough Key and joins the Shannon upstream of Carrick-on-Shannon. The catchment area is 725 km^2. The River Brosna rises in a lake north of Mullingar in Co. Westmeath. It flows through Mullingar into Lough Ennel and then southwest through Kilbeggan, Clara and Ferbane joining the Shannon north of Banagher. The catchment area is 1248 km^2. The River Inny rises north of Ballyjamesduff in County Cavan. It flows in a southerly direction through Lough Sheelin and Lough Derravarragh and then southwest through Ballymahon to join the Shannon in Lough Ree.

The catchment area is 1191 km^2.

Between Lough Allen and Lough Derg, there is a fall in gradient of only 15.5m (Kilroe, 1907). Consequently drainage is poor throughout much of the area and peat, marshes and lakes are present in the vicinity of the rivers.

IX.2 Geology and Aquifers

2.1. Geology

The solid geology of the Shannon Region consists predominantly of Carboniferous sediments with older sediments and volcanics in the inliers that form the mountain ridges in the area. The dominant lithology is limestone. The area is covered extensively by glacial till, sands and gravels and post glacial peat. In the following paragraphs a brief description is given of the rock types deposited during the Ordovician, Silurian, Devonian, Carboniferous and Quaternary times. (see Table IX.1)

2.1.1. Ordovician and Silurian Lithologies

The Ordovician and Silurian strata of the Shannon Region are present in the cores of inliers, which form the Curlew Mountains, Stokestown inlier, Slieve Aughty Mountains, Arra Mountains, Silvermines Mountains, Slieve Bloom Mountains, and the Ardagh and Longford inliers. The western edge of the Longford-Down massif is also present in the Shannon Region. The lithologies are sedimentary in origin and consist of greywackes, siltstones, shales and slates. They were metamorphosed by the Caledonian orogeny.

2.1.2. Devonian lithologies

The Devonian succession in the Shannon Region consists of sandstones, siltstones and shales, with sandstones predominating. The sediments accumulated in depressions under freshwater and semi arid conditions. They outcrop in the larger anticlines encircling the Ordovician and Silurian metasediments and in five smaller anticlines where only the Devonian sediments are present - Mount Mary, west of Castlerea, north of Dunmore, east of Ferbane and south of Moate.

2.1.3. Carboniferous lithologies.

In Upper Devonian and Lower Tournaisian times deposition of Old Red Sandstone facies rocks occurred south of a line drawn approximately from Galway to Dublin. They rest unconformably on older rocks, and consist of conglomerates, sandstones, siltstones and mudstones, deposited in a mainly fluviatile regime.

During the Lower to Middle Tournaisian, a marine succession was deposited in the southern half of the Shannon Region. In counties Offaly, Tipperary and Galway, silts, calcareous shales, followed by bioclastic limestones were deposited. In Longford, Westmeath and south Roscommon, sandstones and micrites followed by bioclastic limestones were laid down. The Upper Tournaisian in the southern half of the region is characterised by the development of the Waulsortian Reef Limestone. Shelf limestones were formed in the north and west of the region. During the Visean, argillaceous limestones were deposited in the south and east of the region, whereas in the north and west, shelf sandstones, shales, limestones and oolites were deposited.

The Namurian sediments consist of sandstones, and shales which were deposited in a deltaic environment.

2.1.4. Glacial and post-glacial deposits

The Shannon basin was subjected to total glaciation on more than one occasion. Little is known of the earlier glaciations, but in all probability they followed a pattern similar to the latest accumulation of ice, the Midlandian glaciation. A great ice-sheet built up in the midlands of Ireland, with ice streams flowing northwest, and south and southeast, the ice-sheet or divide lying in the Lough Allen area. Glacial sediments have obscured the bedrock topography over much of the area, although they tend to be thin or absent on the higher ground on the northern and southern peripheries. Glacial till is the most common deposit, though the amount of continuous cover and the thickness varies throughout the basin.

North of Lough Ree and west of Lough Derg the till is moulded into the form of drumlins. Those to the north of Lough Ree form part of the large drumlin swarm extending northeast to County Down. Elsewhere, the till mantles the limestone plain with little topographic expression, although a fluted landscape is found in parts of Roscommon, Longford and Westmeath, reflecting the direction of ice movement. The great majority of the tills have a dominant limestone lithology. There is extensive sand and gravel deposition associated with deglaciation. The ice sheet retreated west and north across the basin, decaying finally in the western part between Lough Derg and Lough Ree. Morainic deposits have a limited extent, and fluvioglacial sediments predominate. Significant esker systems aligned east/west, associated with glacial drainage eastwards, are found in Offaly, Westmeath and east Galway. In the same areas, there are more irregular spreads of sands and gravels, forming a kame and kettle topography. This irregular deposition extends over a considerable area. Sand and gravel deposits are largely absent in the north and northeast, i.e. in the drumlin field. Post-glacial sediments have in turn obscured much of the glacial material.

On the poorly drained plains peat bog development is considerable, particularly in Roscommon and Offaly. Blanket bog is common on the hill land. In addition there are thick alluvial sediments along the River Shannon and its tributaries, as well as lacustrine silts and clays around the many lakes in the basin.

TABLE IX. 1

GEOLOGICAL SUCCESSION IN THE SHANNON WATER RESOURCE REGION

PERIOD	LITHOLOGIES	DISTRIBUTION	APPROXIMATE THICKNESS (m)	AQUIFERS
Quaternary	Till, sand and gravel and peat	Covers most of the region	normal less than 10-20	sands and gravels
CARBONIFEROUS NAMURIAN	Sandstones, shales and coalseams	In the mountains surrounding Lough Allen		
CARBONIFEROUS DINANTIAN	Limestones, dolomites, shales and sandstones	They cover most of the Shannon region, and are present in the flat low lying areas		certain of the limestone formations and the sandstones
Devonian	Sandstones, siltstones and shales	Curlew Mountains, Stokestown Inler, Slieve Aughty, Arra Mountains, Silvermines Mountains, Slieve Bloom Mountains, Ardagh and Longford inliers, Mount Mary inliers west of Castlerea, north of Dunmore east of Ferbane and south of Moate	Curlew Mountains 2,250 Slieve Bloom 300	Upper Sandstone
Silurian and Ordovician	greywackes, sandstones, siltstones, shales and slates	In the cores of the Curlew, Slieve Aughty, Arra, Silvermines, Slieve Bloom mountains and in the Stokestown, Ardagh and Longford inliers		None

2.2 Description of Aquifers

Few hydrogeological investigations have been carried out in the Shannon Region and data is sparse. Consequently, definition of the aquifers in the region is difficult and may be subject to large errors.

There are no aquifers among the Ordovician and Silurian lithologies. The coarsest, arenaceous Devonian sandstones are classed as aquifers. The Carboniferous sandstones are aquifers with the exception of the Namurian Sandstone (Millstone Grit). All the sandstones with the exception of the Clonaslee Sandstone are classed as "poor, complex, local aquifers". This reflects the lack of information about them. They have a secondary or fissure permeability. The clean, bedded, arenaceous limestones are usually aquifers, whereas the argillaceous limestones are not. They are frequently karstified, although in most areas the groundwater flow regime is not known in any detail. The lack of geological and hydrogeological data hinders the location of aquifers in the sands and gravels. Usually the depth of saturated sand and gravel is unknown, so in certain parts of the region, especially in east Galway and east Mayo, the area shown as "poor, complex, local" intergranular aquifers is tentative.

2.2.1 Major Aquifers

Clonaslee Sandstone in Slieve Bloom Mountains.

The only Devonian sandstones that are known with certainty to be a major aquifer are the sandstones in the Slieve Bloom Mountains. This aquifer becomes confined beneath the Lower Limestone Shales and the limit of the aquifer is chosen where the depth to the top of the aquifer is 40m. Only the upper sandstones are regarded as an aquifer because the underlying sandstones are argillaceous.

Tullamore Aquifer

This aquifer, which extends from north Tipperary northeastwards into north Offaly, is a pale grey Visean calcarenite. It is covered extensively by peat, till and sand and gravel. The peat reaches a depth of 7m in many areas, whereas the boulder clay and sand and gravel varies from 0 - 30m in thickness.

Lanesborough Aquifer

This aquifer is a pale grey Visean calcarenite which is present along the River Shannon from Lough Forbes to Lough Ree. The eastern boundary is the only one known with certainty. It is a lowlying area covered mainly by glacial till.

Roscrea Aquifer

This is a sand and gravel deposit in the vicinity of Roscrea. The gravels are in the form of eskers, moraines and outwash deposits. They are poorly sorted and range in thickness from 12-60m.

2.2.2 Minor Aquifers

The details of the minor aquifers are given in Table IX.2.

TABLE IX.2 **MINOR AQUIFERS IN SHANNON BASIN**

NAME	LOCATION	AGE AND LITHOLOGY	COMMENTS
Devils Bit	Co. Tipperary	Devonian sandstone	
Toomyvara	Co. Tipperary	Devonian sandstone	
Ferbane	Northeast and southwest of Ferbane, Co. Offaly	Upper Devonian/Lower Carboniferous Sandstones	This aquifer is confined beneath Lower Limestone Shales except for a small area
Moate	west of Moate, Co. Westmeath	Upper Devonian/Lower Tournaisian sandstones with intervening limestones and shales. The lower sandstone is coarse and felspathic whereas the upper sandstone is pale and siliceous	
Ballinacargy	Ballinacargy, Co. Westmeath	This consists of a basal siliceous sandstone, a micrite and a calcareous sandstone. They are Tournaisian in age	The aquifer extends southeastwards beneath a confining bioclastic limestone
Lough Sheelin	North of Lough Sheelin, Co's Cavan and Longford	This comprises two upper Devonian/Lower Tournaisian sandstones with an intervening micrite	
Ardagh	Ardagh, Co. Longford	do.	
Longford	near Longford town, Co. Longford	do.	
Cloon Grange	near Cloon Grange and Drumlish in Co's Leitrim and Longford	Tournaisian sandstone along the boundary of the Longford/Down Massif	
Stokestown	Co's Roscommon and Leitrim	Red - yellow flaggy Tournaisian sandstone, conglomeratic in places	Fault bounded on northwest boundary, whereas it is overlain by bioclastic limestones along the southeast boundary

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TABLE IX.2 contd. MINOR AQUIFERS IN SHANNON BASIN

NAME	LOCATION	AGE AND LITHOLOGY	COMMENTS
Curlew	Co. Roscommon	Devonian sandstone and conglomerate	This is the coarsest formation in the Curlew Mountains
Mount Mary	Co's Galway and Roscommon	Tournaisian sandstone	
Slieve Aughty	Co's Galway and Clare	Devonian sandstone	
Bellstone	Co. Tipperary	Well sorted, pale grey Visean calcarenite	
Borrisokane	Co. Tipperary	Well sorted, pale grey Visean calcarenite	
Curry Rock	Co. Westmeath	Visean calcarenite	Karstified
Leitrim	Co's Roscommon and Leitrim	Cavetown Limestone - Visean, bedded, pale grey, cherty crinoidal limestone	Karstified
Keadew	Co's Sligo, Roscommon and Leitrim	Pale grey Visean calcarenite	Karstified
Lung	North Roscommon	Oakport Limestone - Visean, dark grey argillaceous, bedded limestone at base, and pale calcarenite (Burren type) at top. Nodular chert bands are frequent	Karstified
Cavetown	Co. Roscommon	Cavetown limestone - Visean, bedded, pale grey, cherty crinoidal limestone	Karstified
Athleague	Co's Roscommon and Galway	Pale - medium grey Visean limestone. Burren limestone	Karstified
Lisdaly	near Lisdaly Lough, Co. Roscommon	Cavetown limestone	Karstified

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TABLE IX.2 contd. MINOR AQUIFERS IN SHANNON BASIN

NAME	LOCATION	AGE AND LITHOLOGY	COMMENTS
Ballinasloe	Cos. Roscommon and Galway	Burren limestone	Karstified
Boyle	Co's Mayo, Roscommon and Galway	Boyle sandstone - Visean, hard felspathic and calcareous sandstone. Beds of 5m in thickness	
Bellanagore	Co. Roscommon	Boyle sandstone	
Ballinlough	Co's Mayo and Roscommon	Boyle sandstone	
Dowra	Co's Leitrim and Cavan	Upper Visean sandstone	

Minor Sand and Gravel Deposits

In north Offaly, south Westmeath and south Roscommon, esker deposits and associated gravels are present. In general, the eskers are sinuous, narrow crested, sand and gravel ridges, which rise above the alluvial flats and peat bogs of the midlands. They are usually poorly sorted. It is not known with certainty whether the gravels extend downwards, mirror imaging the topography, and therefore having an adequate saturated zone.

In south Offaly and north Tipperary, eskers sand and gravel moraines and outwash deposits are present. Hydrogeological investigations are needed to define the aquifer area more accurately.

A large expanse of sands and gravels is present in east Galway. The area shown on Map 1 contains bogs, outcrops and till, so the actual area of gravel may be as low as 1/5 of the area shown.

TABLE IX.3 LIST OF SPRINGS WITH MEAN FLOW > 30 l/s ($2590m^3/d$) IN SHANNON WATER RESOURCE REGION

NAME	LOCATION	LOW FLOW (usually minimum recorded flow)	COMMENTS
Edentinny	Ballinamore, Co. Leitrim NGR N113100	7 l/s in 1976	Mean flow 30 l/s
Rockingham	near Boyle, Co. Roscommon NGR M851026	70 l/s ($5782m^3/d$)	
Cloonmagunnane	near Ballaghdereen, Co. Roscommon NGR M683952	8.84 l/s $764m^3/d$	
Silver Island	near Castlerea, Co. Roscommon NGR M685748	54.0 l/s $5542m^3/d$	two springs present
Ballybane	Ballunlough, Co. Roscommon NGR M578748	40.4 l/s $3491m^3/d$	
Rockfield	north of Roscommon town NGR M816677	12.6 l/s $1309m^3/d$	
Cloonslaw	near Stokestown NGR M922795	8.84 l/s $764m^3/d$	
Ballinagard	near Roscommon town NGR M874621	78.9 l/s $6819m^3/d$	
Killeglan	Co. Roscommon NGR M882410	109.6 l/s $9383m^3/d$	
Rohan	Co. Offaly NGR N285282		capacity of 12.63 l/s ($1091m^3/d$)
Lanesboro	Co. Longford NGR N225814	50.5 l/s $4364m^3/d$	
Ballinalee	Co. Longford NGR N225814		
Kilkerrin	Co. Galway NGR M606536	12.7 l/s $1094m^3/d$	

TABLE IX.4. ABSTRACTIONS GREATER THAN $1 Mm^3/yr$ ($2727 m^3/d$) IN THE SHANNON BASIN

NAME	LOCATION	QUANTITY ABSTRACTED	COMMENTS
Cloonmagunnaun spring	near Ballaghadereen, Co. Roscommon NGR M683952	$1.02 Mm^3/yr$ $2791 m^3/d$	
Ballinagard spring	near Roscommon town NGR M874621	$2.5 Mm^3/yr$ $6819 m^3/d$	
Ballybane spring	south of Ballinlough NGR M578748	$1.16 Mm^3/yr$ $3182 m^3/d$	
Killeglan spring	NGR M882410	$5.0 Mm^3/yr$ $13638 m^3/d$	This quantity is not being abstracted at present, but the abstraction will commence in the near future

TABLE IX.5 GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES (EAST OF SHANNON, CO. TIPPERARY) Unit 1

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Roscrea sand and gravel	18.15	940	466.5	7.10×10^6	0.012×10^6	7.088×10^6
Bellstone	76.25	880	466.5	25.22×10^6	0.05×10^6	25.17×10^6
Borrisokane	40	880	466.5	13.23×10^6	0.026×10^6	13.204×10^6
Devonian Sandstone Devils Bit	12.5	950	466.5	4.84×10^6	0.008×10^6	4.832×10^6
Devonian Sandstone Toomyvara	11.0	1,000	466.5	4.69×10^6	0.007×10^6	4.683×10^6
TOTALS:	158.5			55.08×10^6	0.013×10^6	55.067×10^6

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES (EAST OF SHANNON, CO. OFFALY) Unit 2

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Tullamore	25.6	875	466.5	6.00×10^6	0.017×10^6	5.983×10^6
Clonaslee sandstone	20	1,020	466.5	4.43×10^6	-	4.43×10^6
Birr sand and gravel	17.5	890	466.5	2.96×10^6	0.002×10^6	2.958×10^6
Roscrea sand and gravel	10.6	940	466.5	4.0×10^6	0.007×10^6	3.993×10^6
South Offaly sand and gravel	50	920	466.5	9.07×10^6	0.003×10^6	9.037×10^6
TOTALS:	123.7			26.46×10^6	0.059×10^6	26.401×10^6

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES (BROSNA CATCHMENT)

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Tullamore	177.6	859	466.5	25.5 $\times 10^6$	0.69 $\times 10^6$	24.81 $\times 10^6$
Clonaslee sandstone	12.5	1,000	466.5	2.67 $\times 10^6$	-	2.67 $\times 10^6$
Clonaslee sand and gravel	6.25	900	466.5	1.08 $\times 10^6$	0.004 $\times 10^6$	1.076 $\times 10^6$
Clara sand and gravel	6.0	900	466.5	1.07 $\times 10^6$	.004 xx 10^6	1.066 $\times 10^6$
Birr sand and gravel	10.6	875	466.5	1.73 $\times 10^6$	0.007 $\times 10^6$	1.723 $\times 10^6$
Ferbane	2.42	850	466.5	1.1 $\times 10^6$	0.1 $\times 10^6$	1.0 $\times 10^6$
TOTALS:	215.37			33.15 $\times 10^6$	0.805 $\times 10^6$	32.345 $\times 10^6$

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES (EAST OF SHANNON, CO. WESTMEATH AND NORTH OFFALY) Unit 4

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Moate	14.5	921.5	442	3.06×10^6	0.01×10^6	3.05×10^6

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES, (INNY CATCHMENT) Unit 5

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Curry Rock	71.25	975	442	7.69×10^6	0.05×10^6	7.64×10^6
Ballinacargy	7.9	950	442	2.15×10^6	0.005×10^6	2.145×10^6
Lough Sheelin	11.40	990	442	2.0×10^6	0.008×10^6	1.992×10^6
Sand and gravel	2.0	950	442	0.8×10^6	-	0.8×10^6
TOTALS:	92.55			12.64×10^6	0.063×10^6	12.577×10^6

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES

Unit 8

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Dowra	66.9	1350	466.5	11.821×10^6	0.084×10^6	11.737×10^6

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES (WEST OF SHANNON, CO's ROSCOMMON AND SLIGO)

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Keadew	23.75	1170	428	2.55×10^6	0.016×10^6	2.534×10^6
Boyle	8.9	1135	428	2.7×10^6	0.006×10^6	2.694×10^6
Leitrim	4.6	1100	473	0.29×10^6	0.003×10^6	0.287×10^6
TOTALS:	37.25			5.54×10^6	0.025×10^6	5.515×10^6

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES IN BOYLE CATCHMENT

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Lung	153.1	1100	428	17.25×10^6	1.21×10^6	16.04×10^6
Bellanagare	10.0	1110	428	1.94×10^6	0.007×10^6	1.933×10^6
Athleague	23.9	1115	428	3.25×10^6	0.106×10^6	3.144×10^6
Boyle	49.76	1120	428	6.02×10^6	0.033×10^6	5.987×10^6
Curlew	25.8	1200	428	4.6×10^6	0.017×10^6	4.583×10^6
Cavetown	4.56	1115	428	0.67×10^6	0.003×10^6	0.667×10^6
TOTALS:	267.12			33.73×10^6	1.376×10^6	32.354×10^6

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES (WEST OF SHANNON, CO. ROSCOMMON)

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Lanesboro	23.5	970	442	2.6×10^6	0.266×10^6	2.334×10^6
Lisdaly	10.2	1075	428	0.92×10^6	0.007×10^6	0.913×10^6
Strokestown	48.3	1000	428	3.04×10^6	0.057×10^6	2.983×10^6
TOTALS:	82			6.56×10^6	0.33×10^6	6.23×10^6

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES (SUCK CATCHMENT)

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Athleague	986	1025	428	126×10^6	8.50×10^6	117.5×10^6
Mount Mary	38.9	990	428	11.37×10^6	0.026×10^6	11.344×10^6
Ballanagore	9.56	1085	428	1.53×10^6	0.006×10^6	1.524×10^6
Ballinasloe (1)	25.2	960	428	2.08×10^6	0.017×10^6	2.063×10^6
(2)	5.3	960	428	0.39×16^6	0.003×10^6	0.387×10^6
Ballinlough	32.9	1100	428	8.62×10^6	0.022×10^6	8.598×10^6
Sands and gravels	144.3	1025	428	22.74×10^6	1.6×10^6	21.14×10^6
TOTALS:	1242.2			172.73×10^6	10.175×10^6	162.555×10^6

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES, (WEST OF SHANNON, CO. ROSCOMMON)

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Athleague	158.1	990	428	21.9	2.96×10^6	18.94×10^6
Sand and gravel	28.1	975	428	6.45×10^6	0.02×10^6	6.430×10^6
TOTALS:	186.2			28.35×10^6	2.94×10^6	25.41×10^6

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES, (WEST OF SHANNON, CO. GALWAY) Unit 14

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Slieve Aughty	40	1200	466.5	11.736×10^6	-	11.736×10^6
Sand / gravel	302.5	950	466.5	38.61×10^6	0.264×10^6	38.346×10^6
TOTALS:	342.5			50.346×10^6	0.264×10^6	50.082×10^6

GROUNDWATER RESOURCES, ABSTRACTIONS AND SURPLUSES (WEST OF SHANNON, CO. CLARE) Unit 15

AQUIFER	AREA Km^2	MEAN RAINFALL mm	POTENTIAL EVAPOTRANSPIRATION mm	THEORETICAL RESOURCES m^3/yr	ABSTRACTIONS m^3/yr	SURPLUS m^3/yr
Slieve Aughty	35	1200	466.5	10.27×10^6	0.075×10^6	10.195×10^6

TABLE IX.6 SUMMARY OF GROUNDWATER RESOURCES IN SHANNON WATER RESOURCES REGION

UNIT	UNIT AREA Km^2	AREA OF AQUIFERS Km^2	THEORETICAL RESOURCES $m^3/yr \times 10^6$	ABSTRACTIONS $m^3/yr \times 10^6$	SURPLUS RESOURCES $m^3/yr \times 10^6$	SURPLUS RESOURCES mm over unit
1	947.5	158.5	55.08	0.013	55.067	58.1
2	530	123.7	26.46	0.059	26.401	49.8
3	1248	215.40	33.15	0.805	32.345	25.9
4	375	14.5	3.06	0.01	3.05	8.1
5	1191	92.55	12.64	0.063	12.577	10.6
6	880	160.3	26.55	0.332	26.218	29.8
7	445	100.8	12.15	0.142	12.008	27.0
8	332.5	66.9	11.821	0.084	11.737	35.3
9	165	37.25	5.54	0.025	5.515	33.4
10	570	267.12	33.73	1.376	32.354	56.8
11	615	82.0	6.56	0.33	6.23	10.1
12	1508	1242.2	172.73	10.175	162.555	107.8
13	532.5	186.2	28.35	2.94	25.41	47.7
14	762.5	342.5	50.346	0.264	50.082	65.7
15	417.5	35.0	10.27	0.075	10.195	24.4
TOTALS:	10,520	3124.9	488.437	16.693	471.744	44.8 mm over region

X. THE WESTERN WATER RESOURCE REGION

X.1 Introduction

The region includes all of western Ireland draining to the Atlantic coast between the bays of Galway and Killala. The eastern boundary is the watershed of the Shannon. It has a total area of about 9620 km^2 and includes parts of Counties Galway, Mayo and Sligo. Much of the western portion of the region is hilly and mountainous and the Ox Mountains form an important topographic barrier to the northwest. The mountain peaks usually are of between 600 and 900m and high terrain often extends to the indented Atlantic coastline with its numerous islands and headlands. In contrast, the eastern portion is relatively lowlying, forming as it does a part of the Central Lowlands of Ireland. The elevation here typically is between 30 and 100m.

The drainage is dominated by two main river systems, the Corrib and the Moy which together drain over 5200 km^2 on the eastern side of the region. The Corrib discharges southwards into Galway Bay and the Moy northwards into Killala Bay. Three large lakes - Loughs Conn (52 km^2) Corrib (168 km^2) and Mask (83 km^2) are features of the region. The remainder of the area is drained by small rivers or by overland flow directly to the sea, discharging much of the precipitation in a few hours.

Annual rainfall on the area of main drainage averages (1931-1960) 1205mm, producing an average discharge of 186.2m^3/sec. (An Foras Forbartha, 1974).

X.2 Geology

The bulk of the western half of this region is underlain by pre-Devonian crystalline rocks, the most important of which are schists, slates, quartzites, greywackes, gneisses and granites. Devonian rocks occur to the west and northwest of Castlebar. They are of continental Old Red Sandstone facies and comprise coarse conglomerates and sandstones with subordinate siltstones and shales.

They lie unconformably on Dalradian rocks and northwest of Castlebar are more than 300m thick.

Carboniferous rocks are present over more than half the region. Except for a small area of Tournaisian deposits near Loughrea and Namurian strata west of Kiltimagh all the Carboniferous strata here are regarded as Visean. For convenience they may be divided into four areas, as shown in Table X.1

X.3 Aquifers

Groundwater has been very little used in the Western Region to date. The following attempt to define the major aquifers is based on tenuous evidence and unproved assumptions. It should however provide a general guide as to the position.

X.3.1 Major Aquifers

(a) Karst Limestones

Some 3000 km^2 of the Western Region is shown on Map 1 as being formed of karstified limestone. These aquifers are mostly lowlying with water seldom more than 30m below ground surface. Large springs exceeding $5000m^3$/day are present close to the major lakes. Elsewhere springs such as at Clonbern have been gauged at $15000m^3$/day. In some cases it is not clear how much the spring is fed by the limestone and how much by the overlying gravel. The depth to which karstification extends is not known but borehole results suggest at least 30m below present sea level in the lowest parts of the region. An average figure of 50m is suggested for the zone of water-filled karst channels. Many of these are partly blocked with glacial and other debris which makes these aquifers difficult to develop in some districts.

(b) Sands and Gravels

About 2000 km^2 of the Region is covered with sands and gravels of which about 40% overlie karstic limestones. They are mostly fluvioglacial deposits and vary from clean esker gravels to morainic gravels with a sizable admixture of clay.

TABLE X.1

VISEAN SEQUENCE IN THE WESTERN REGION

	Mid Galway Black limestones	Galway-Mayo Shelf-Limestones	Ballina Syncline	Ballymote Syncline
Occurs	Mid and southeast Galway	Nth. and Mid Galway	Mayo Nth. of Ox Mountains	N.W. of Swinford
Base		*Well cemented grey sdsts. and siltstones	*Well cemented *sandstones and conglomerates	*Moy - Boyle sdsts. 30 - 70m
Strata Sequence	Black argillaceous limestones with subordinate shales and chert. Iron pyrite is common	30 - 75m *Medium-dark grey calcarenites with minor shales An argillaceous series near base of lsts. is 45m at Castlebar	W. of Killala 300 + Overlain by argillaceous series 20 - 100m Ballina lst.	Dargan limestone *Oakport limestone 170 - 270m Lisogorman Shales (Includes the * Mullaghmore Sdst. up to 60m) 275-520m *Bricklieve Lst. 335m Roscunnish Shale 120m
Est. Minimum Thickness	500m	700m	700m	1000m

* = Aquifer

Thick Quaternary deposits, exceeding 30m in places, occur widely. They include boulder clays, poorly sorted gravels as well as kames and eskers. Gravels are widespread in east Galway, east and northwest Mayo.

Gravels in west Mayo are overlain by peat for about 75% of their area. They are a mixture of clays, sands and gravels, often poorly sorted. In the vicinity of Crossmolina the gravels are cleaner and kames are present. A thickness of 20-30m appears to be the average. In south Sligo and northeast Mayo there is a mixture of clay and sand with subordinate gravel and a thickness normally ranging between 15 and 30m.

In south Mayo and Galway eskers are numerous and clay is less common. The depth to bedrock is very variable and it is unclear how far below the present ground surface the eskers in fact extend. Marshy flats sometimes with peat often exist between the gravel ridges. In some places the peat is underlain by gravel but in others by marl. A number of large springs occur in the gravels but some of these may derive from the underlying karst limestone. An average saturated thickness of about 10m is considered likely.

X.3.2 Minor Aquifers

(a) The Devonian and Carboniferous Sandstones are classed as minor aquifers because of their limited extent or limited permeability. The main occurrence is in west Mayo where Carboniferous sandstones cover some 500 km^2. Most of this however has a thick drift cover and it is assumed that nearly all the groundwater is in the overlying Quaternary deposits. A public supply well at Killala has yielded some $300m^3$/day but up to the present little serious effort has been made either to explore or exploit these formations.

(b) Other water-bearing rocks

The granite in west Galway has yielded up to $500m^3$/day in a few boreholes at Spiddal. At present this is thought to be due to the existence locally of felsite dykes.

X.4 Groundwater Hydrology

Water movement in the karstic districts of this region is complicated by the loss of river flow to underground cave systems in the limestone. Especially in the catchment of the Corrib the surface drainage network is largely artificial due to the plugging of swallow holes. In much of the Clare catchment, groundwater flow or indeed the level of groundwater has little to do with the river system. At Corofin, for example, in summer the Clare river flows as much as 15m above the watertable in the adjoining limestone.

In the vicinity of Galway Bay the summer watertable in the limestone remains close to sea level for up to 10 km inland and there is a similarly gradual rise to the east of Lough Corrib. The seasonal fluctuation in water level in the karst districts is 6 to 15m. One result of this is the presence of turloughs - shallow seasonal lakes which are a striking feature in karst districts of the west of Ireland. Up to the present few pump tests have been carried out in the region so aquifer coefficients are lacking. Major springs are listed in Table X.2.

X.5 Abstractions

Abstraction estimates for the region are listed in Table X.3. The sparse population of the region (about 210,000) accounts for the low water usage. The region has few urban concentrations, the largest being Galway city (population 37,000). Groundwater usage is largely from springs rather than from boreholes. The karstic nature of most of the aquifers makes borehole sinking a rather risky business. There are no abstractions of more than 1 Mm^3/yr in the region. Usage is primarily for village and farm supplies.

X.6 Recharge

Precipitation ranges from a yearly average of about 1000mm on the lower ground in the eastern sector to over 2600mm at Delphi, west of the Mweelrea Mountains in Co. Mayo. Over the area of main drainage (6692 km^2) the rainfall average (1931-60) was 1205mm.

Evapotranspiration for the region has been estimated for the purpose of this study as 450mm/yr, except on coastal areas, where it is up to 575mm.

The infiltration characteristics of the region vary markedly. In the areas of karstic limestone with thin overburden and in the gravel areas much water infiltrates. Although such areas make up about one third of the region, a part of this water is believed to move through very quickly. About another third of the region is formed by crystalline rocks with almost no infiltration, with the remaining third of the region having moderate to poor infiltration. The effects of the bogs on recharge are not known.

X.7 Resources

The estimated surplus resources for the 16 units in the region are listed in Table X.3, where it is seen that most units have a large surplus. It should be emphasised that the resource estimates for this region carry a larger factor of uncertainty than elsewhere, because of:

(a) The lack of knowledge of the large areas of sand/gravel aquifers mapped, and

(b) The problem of estimating the resources of karstic aquifers in the region.

However, even if the calculated resources of the region prove to be somewhat less than those shown in this report, they are clearly very substantial. This is due particularly to the generally high effective rainfall.

TABLE X.2

MAJOR SPRINGS IN THE WESTERN REGION (LOWFLOWS BELIEVED TO BE 30 lps OR MORE)

NAME	LOCATION	LOWFLOW l/s	ABSTRACTION l/s
	Bohola, Co. Mayo	52.5	4.63
Tobermore	Crossmolina, Co. Mayo	11.35	5.9
	Ballyhaunis, Co. Mayo	52.5	8.31
	Knock, Co. Mayo	19.7	2.1
	Aghamore, Co. Mayo	10.5	
	Kilkelly, Co. Mayo	15.5	2.9
	Crossboyne, Co. Mayo	15.75	4.63
	Swinford, Co. Mayo	8.56	5.29
	Ballindine, Co. Mayo	?	14.4
Gortgarrow spring	2km N. of Clonbern, Co. Galway	158	
Pollaneyster	2km S.E. of Williamstown, Co. Galway	30	
Springfield	1km E. of Williamstown, Co. Galway	130	
Kilshanvy	3km W. of Kilconly,	300	
Ardour	Co. Galway	100	
Kilclooney	8km N. of Tuam, Co. Galway	70	
Lettera	3km W. of Glenamaddy, Co. Galway	400	
Tobernalour	3km N.W. of Tuam, Co. Galway	50	
	Glenamaddy, Co. Galway	1000	
	Tuam, Co. Galway	1000	
Muckloon	2km W. of Ballyforan, Co. Galway		
Cregg	Aucloggeen, Nr. Claregalway, Co. Galway		
Laghtgorge	1km N. of Claregalway, Co. Galway		
Tobernara	5km S.E. of Cloonfad, Co. Galway	150	

TABLE X.3

SUMMARY OF GROUNDWATER RESOURCES IN THE WESTERN REGION

UNIT NO.	AREA OF UNIT Km^2	AREA UNDERLAIN BY AQUIFER Km^2	ESTIMATED RECHARGE M.cm/yr	ESTIMATED ABSTRACTIONS M.cm/yr	SURPLUS	
					M.cm/yr	mm/yr over unit
1	1028	403	58.65	(0.3)	58.35	57
2	* 923	395.5	68.8	(0.4)	68.4	74
3	537	155	17.2	(0.3)	16.9	31
4	438	357.5	53.95	0.7	53.25	122
5	360	215	36.0	0.3	35.7	99
6	463	200.5	29.8	(0.2)	29.6	64
7	321	15	2.7	(0.02)	2.68	8
8	767	5	0.9	(0.01)	0.89	1
9	756	560	90.1	1.2	88.9	118
10	734	664	90.95	1.2	89.75	122
11	* 336	336	58.8	0.3	58.5	174
12	* 261	-	-	-	-	-
13	1006	-	-	-	-	-
14	* 256	92.5	19.65	(0.1)	19.55	76
15	* 542	542	65.5	0.3	65.2	120
16	584.5	505	56.55	0.9	55.65	95
Major lakes	303					
TOTAL:	9615.5	4446	649.55	6.23	643.32	67

* Major lake areas excluded (totalling 303 km^2)

XI. THE NORTHWESTERN WATER RESOURCE REGION

XI.1 Introduction

This is a disjointed region lacking geographical and hydrological continuity. It comprises Co. Donegal, much of Co. Sligo, small parts of Counties Leitrim and Longford north of the Shannon catchment, and the parts of Cavan and Monaghan within the catchment of the Erne. Its area is about 9460 km^2.

The region may be divided into three:

(1) Donegal, which is largely hills, moorland and bog, with peaks of 500-800m. The coastline is much indented and there are many islands.

(2) The plateaus of Sligo and north Leitrim, a terrain of steep cliffs and rugged limestone hills with peaks of 400-700m.

(3) Cavan-Monaghan, which is a region of rolling low hills, numerous drumlins and many small lakes. Altitude here typically is between 50 and 150m with hills rising to 300m.

The main rivers of this part of Ireland are the Erne (4374 km^2) and the Foyle-Mourne (2926 km^2), much of their catchments being in Northern Ireland. The other rivers drain at most a few hundred km^2 and are subject to quick runoff. Main drainage is estimated to make up 7824 km^2, which receives an average rainfall of 1281mm.

XI.2 Geology

Most of Donegal and also the Ox Mountains are composed of ancient crystalline rocks of which schist, granite and quartzite are the most common. In the east, slates and greywackes of Silurian and Ordovician age are present.

The Carboniferous rocks of the Region are widespread and complicated in their geology with both a diachronous base and lateral facies variations. Table XI.1 attempts to summarise the Carboniferous succession in the various parts of the region.

Quaternary deposits are widespread in the region. In Cavan and Monaghan they are mainly drumlins of boulder clay. Some gravel occurs in S. Sligo, N. Monaghan, and locally, usually in river valleys, in Donegal.

TABLE XI.1

CARBONIFEROUS SUCCESSION IN THE NORTHWESTERN REGION

General	Donegal Syncline	Sligo Syncline	Leitrim / Cavan Lough Allen Syncline	Monaghan
Yoredale Shales and Sandstones		Glenade Shales and Sandstones 60m	Shale 30-549m Sandstone 0-457m	
Upper Limestone: Pure massive limestones with abundant chert		Dartry Limestone 350m + (Bricklieve in Ballymote area)	Micrites with minor argillaceous limestones 183-335m	Micrites and argillaceous limestones 419m
Calp: Mainly argillaceous with subordinate sandstones and limestones	Kildoney-Mountcharles Sdst. 71-305m Doorin-Coolmore Shale 75m	Glencar Lst. 180m Benbulben Sh.110m Mullaghmore Sdst. 180m Bundoran Sh. 135m	Shale McNean Sdst. 27-215m Shale (Total) 700m	Shale 122m Sandstone ? thickness
Lower Limestone: Variable rather impervious in west, limestones and shales	South of Syncline Ballyshannon Limestone 700m North of Syncline Arenaceous Facies 600m +	Ballyshannon Lst. 300m +	Shale Lst. Lower Calp Sandstone (Total) 800m	Well bedded brown micrite with shale and chert 540m
Basal Clastics: Mixture of Conglomerates shales, sdsts. and limestones	Sandstones ?	Conglomerates and sandstones 25m	Sandstones 270m +	Shales Sandstones Limestones 100m +

XI.3 Aquifers

All the limestone aquifers are shown on Map 1 as karstified and they cover an area of about 900 km^2. The sandstone aquifers cover an area of about 330 km^2.

Gravels are shown as covering about 100 km^2 with about 50 km^2 of this area underlain by karst limestone. The main gravels are in Sligo and they have clay intermixed with them in a lot of the area. An average saturated thickness of about 10m is assumed.

It was decided to exclude all the limestones north of the Ox Mountains since no large yields have been obtained from them up to the present. In the case of the Dartry Limestone this may be due in part to its usual high elevation. Some of these rocks together with a part of the arenaceous series in the Donegal Syncline may in time prove to be aquifers, but lack of data prevents their inclusion at this time.

There is a problem in some areas of a high sulphate content in the water in the Basal Clastic aquifers, due to the occurrence of gypsum beds in this sequence. Water from the Calp Sandstone sometimes has a high iron content.

XI.4 Groundwater Hydrology

An initial groundwater study has started recently in Counties Cavan and Monaghan. Results are not yet available and groundwater has not been investigated or exploited in Donegal, Leitrim and Sligo except for small local supplies.

Some large springs are present in south Sligo deriving mostly from the karst aquifers. In the Bricklieve Mountains seasonal changes in piezometric levels of at least 30m appear to occur. In the lowland areas of Cavan and Monaghan, annual fluctuation is in the range 1 to 5 metres.

XI.5 Abstractions

Abstractions from aquifers within the various units in the North-West Region are listed in Table XI.3. Groundwater is little used over most of the region, with the exception of units 1, 4 and 8, where there is some more intensive use.

TABLE XI.2

CARBONIFEROUS AQUIFERS AND THEIR LOCATIONS

Aquifer	Nth. Donegal	Sth. Donegal	Nth. Sligo	Sth. Sligo / Leitrim	Cavan	Monaghan
Upper Limestone				x	x	
Calp. Sandstone		x	x			x
Lower Limestone				x	x	x
Basal Clastics	x			x	x	x

The only site of major abstraction, as shown on Map 1 (Belfast), is Killeshandra, Co. Cavan, where a creamery (3 boreholes) and a factory (2 boreholes) abstract 3440 m^3/d (1.25 Mm^3/yr) from the basal clastic beds of the Carboniferous. A few other factories, chiefly of the food-processing type, also abstract substantial quantities. Elsewhere the abstractions are small and scattered, supplying water for villages, farms and single houses. Intensive pig-rearing units and pig-meat processing factories are important in the region, as also are intensive poultry units. These give rise to some pollution problems for both surface water and groundwater.

XI.6 Recharge

Precipitation in Donegal-Sligo averages annually about 1350mm with extremes of 982 and 2717mm. The average in Cavan-Monaghan is about 1050mm with extremes of 931 and 1843mm.

Evapotranspiration inland is estimated at about 450mm/yr, but in coastal areas it is higher, up to 575mm/yr.

Infiltration over much of the Region is seriously impeded by the impervious nature of the ground. Most of the rocks of Donegal are metamorphic and the Quaternary deposits of Cavan, Leitrim and Monaghan are normally heavy boulder-clays which allow very little water to infiltrate.

In the karst areas of Sligo water infiltrates readily and some of the low lying gravels benefit from increased recharge from the neighbouring area's runoff. Estimates of recharge are shown in Table IX.3

XI.7 Groundwater Resources

The available resources in those units with significant areas of aquifer are shown in Table XI.4. In most of those units there is a large surplus above present-day abstraction, and this is shown on Map 4. The remaining units are shown on the map as having only groundwater of local importance, i.e. from very small Quaternary aquifers or from very poorly permeable rocks.

When examining Map 4 and Tables XI.3 and XI.4 it should be remembered that most of the aquifers are little-known and they require further investigation. In particular the characteristics of the Karstic limestones are such that their resources remain problematical. For most purposes, the sandstones probably represent the best aquifers of the region, together with Quaternary aquifers where these can be identified.

TABLE XI.3

GROUNDWATER RESOURCES IN THE NORTH-WESTERN REGION

UNIT NO. & NAME	AREA OF UNIT Km^2	AQUIFERS	AREA OF AQUIFERS Km^2	MEAN RAINFALL mm/yr	MEAN EVAPOTRANSPIRATION mm/yr	EFFECTIVE RAINFALL mm/yr	ESTIMATED RECHARGE Mm^3/yr	TOTAL RECHARGE PER UNIT Mm^3/yr	ESTIMATED ABSTRACTIONS Mm^3/yr	SURPLUS RESOURCES Mm^3/yr
1 Monaghan	530	Carboniferous limestones (K)	107.5	1000	450	550	11.825	40.7	1.1	39.6
		Carboniferous sandstones	105	1000	450	550	28.875			
2	820	Carboniferous limestone (K)	0.5	-	-	-	negligible	-	-	negligible
3	380	-	-	-	-	-	-	-	-	-
4	487.5	Carboniferous limestones (K) and basal clastic series	285	1000	450	550	23.5	23.5	3.6	19.9
5	450	Carboniferous sandstones	25	1300	450	850	5.31	33.47	0.3	33.17
		Carboniferous limestones (K)	132.5	1300	450	850	28.16			
6	108	Carboniferous sandstones	20.5	1300	450	850	6.5	6.5	0.05	6.45
7	292.5	Quaternary sand & gravel	12	1150	575	575	2.76	4.83	(0.05)	4.78
		Carboniferous sandstone	18	1150	575	575	2.07			
8 Ballysadare	645	Quaternary sand & gravel	30	1150	500	650	5.15	53.225	0.7	52.5
		Carboniferous sandstone	3	1150	500	650	0.95			
		Carboniferous limestone (K)	305	1150	500	650	47.125			
9 Sligo	640	Carboniferous sandstones	19	1150	550	600	4.0	15.5	0.2	15.3
		Carboniferous limestone (K)	57.5	1300	500	800	11.5			
10 Bundoran	407.5	Carboniferous sandstones	112	1150	550	600	23.52	26.9	0.2	26.7
		Carboniferous limestones (K)	15	1400	500	900	3.375			
11	155	-	-	-	-	-	-	-	-	-
12 Donegal	467.5	Carboniferous sandstones	20	1325	550	775	3.1	3.1	(0.1)	3.0
13 Ardara	697.5	-	-	-	-	-	-	-	-	-
14 Upper Foyle	852.5	-	-	-	-	-	-	-	-	-
15 Burtonport	582.5	-	-	-	-	-	-	-	-	-
16 Lough Swilly	950	-	-	-	-	-	-	-	-	-
17 Sheep Haven	489.5	-	-	-	-	-	-	-	-	-
18 Inishowen	505	Carboniferous sandstone	8	1200	550	650	1.05	1.05	(0.05)	1.0

(K) = Area of karstic flow

Figures in brackets are rough estimates

TABLE XI.4

SUMMARY OF GROUNDWATER RESOURCES IN THE NORTH-WESTERN REGION

UNIT NO.	AREA OF UNIT	AREA UNDERLAIN BY AQUIFER	ESTIMATED RECHARGE	ESTIMATED ABSTRACTIONS	SURPLUS	
	Km^2	Km^2	M.cm/yr	M.cm/yr	M.cm/yr	mm/yr over
1	530	215.5	40.7	1.1	39.6	75
2	820	0.5	-	-	-	-
3	380	-	-	-	-	-
4	487.5	285	23.5	3.6	19.9	41
5	450	157.5	33.47	0.3	33.17	74
6	108	20.5	6.5	0.05	6.45	59
7	292.5	30.0	4.83	(0.05)	4.78	16
8	645	338	53.25	0.7	52.55	81
9	640	76.5	15.5	0.2	15.3	24
10	407.5	127	26.9	0.2	26.7	65
11	155	-	-	-	-	-
12	467.5	20	3.1	(0.1)	3.0	6
13	697.5	-	-	-	-	-
14	852.5	-	-	-	-	-
15	582.5	-	-	-	-	-
16	950	-	-	-	-	-
17	489.5	-	-	-	-	-
18	505	8	1.05	(0.05)	1.0	2
TOTAL:	9460	1245.5	208.8	6.3	202.5	21.4 (over region)

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