INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS (IRISH GROUP)

FIFTH ANNUAL SEMINAR ON GROUNDWATER DEVELOPMENT

"IRISH GROUNDWATER HAS COME OF AGE"

KILLESHIN HOTEL, PORTLAOISE - MONDAY & TUESDAY 22ND & 23RD APRIL, 1985

P R O G R A M M E

	Item	Speaker
MONDAY 22ND APRIL		
10.30 a.m.	Registration and Coffee	
11.00 a.m.	Welcome and Introduction	Dr. D. Burdon
11.15 a.m.	E.E.C. Guidelines For Potable Water	Mr. D. O'Hegarty
12.00 Noon	Groundwater Treatment	Mr. A. Bowen
12.30 p.m.	Discussion	
1.00 p.m.	Lunch	
2.30 p.m.	Groundwater Development at Portlaoise	Mr. E. Creed
3.00 p.m.	Hydrogeology of Portlaoise Limestone Aquifer	Mr. K. T. Cullen
3.45 p.m.	Discussion	
4.00 p.m.	Coffee	
4.15 p.m.	Portlaoise Well Drilling and Test Pumping Programme	Mr. K. O'Dwyer
5.00 p.m.	Discussion	
5.15 p.m.	Exhibits	
TUESDAY 23RD APRIL		
9.30 a.m.	Lagan Valley Groundwater Development Project	Mr. J. Finlay
10.15 a.m.	Geology of Lagan Valley	Mr. P. Bennett
10.30 a.m.	Discussion	
11.00 a.m.	Coffee	
11.30 a.m.	Geology of The Clonaslee Sandstone Aquifer	Mr. E. Daly
11.45 a.m.	Groundwater Development - An Engineer's View	Mr. M. Hand
12.15 p.m.	Discussion	
12.45 p.m.	Close and Lunch	Ms. M. Naughton

International Association of Hydrogeologists - Irish

Groundwater Development in Ireland - 1985

List of Delegates

Mr. Robert Aldwell	Hydrogeologist Geological Survey of Ireland
Mr. Des Barry	Consulting Engineer J.B.Barry & Partners
Mr. Peter Bennett	Hydrogeologist Geological Survey of Ireland
Mr. Alec Bowen	Mahon McPhillips
Dr. David Burdon	Hydrogeologist Minerex Ltd.
Mr. Frank Burke	Snr. Executive Engineer Meath County Council
Mr. Seamus Byrne	Wexford County Council
Mr. Philip Callery	Carlow County Council
Mr. Alan Chapple	Consulting Engineer Kirk, McClure & Morton
Dr. Colman Concannon	Chemist Dublin County Council
Mr. Brian Connor	Hydrogeologist Geoex Ltd.
Ms. Catherine Coxin	Trinity College
Mr. Edward Creed	Consulting Engineer N.O'Dwyer & Partners
Ms. Margaret Cross	Drilling Contractor
Mr. Tom Cross	Drilling Contractor
Mr. Patrick Crowe	Tipperary County Council
Mr. Kevin Cullen	Hydrogeologist K.T. Cullen Dublin 14
Mr. Donal Daly	Hydrogeologist Geological Survey of Ireland
Mr. Eugene Daly	Hydrogeologist Geological Survey of Ireland
Mr. Joe Diver	Celtic Engineering Co. Dublin 1
Mr. Michael Dooley	Executive Engineer Roscommon County Council
Mr. Dan Duggan	Snr. Executive Engineer Wexford County Council
Mr. John Dunne	Drilling Contractor Mallow Co. Cork
Mr. Paddy Dunne	Drilling Contractor Drumskin Co. Louth
Mr. Ronnie Dunne	Department of the Environment
Mr. Malcom Edgar	Consulting Engineer Jennings & O'Donovan
Ms. Katherine Farrell	Johnson Well Screens
Mr. Jim Finlay	Consulting Engineer Kirk, McClure & Morton Belfast

Mr. Dan Fogarty	Drilling Contractor Kilkenny
Dr. Richard Foley	Chemist Institute of Industrial Research & Standards
Mr. Gerry Forde	Executive Engineer Wexford County Council
Mr. Paul Foster	Mono Pumps Ltd. Dublin 11
Mr. Tom Geraghty	Department of the Environment
Mr. Michael Hand	Consulting Engineer P.H.McCarthy Son & Partners
Mr. Dermot Hughes	Consulting Engineer N.O'Dwyer & Partners
Mr. William Johnson	Office of Public Works
Mr. Larry Kelly	An Foras Forbartha
Mr. John Kilgallen	Snr.Executive Engineer Longford County Council
Mr. Michael Looby	Snr.Executive Engineer Offaly County Council
Mr. Gerry McLoughlin	Department of the Environment
Mr. William Moynihan	Avonmore Electrical Ltd. Co. Cork
Mr. John Mulholland	Kilkenny County Council
Ms. Margaret Naughton	Hydrogeologist An Foras Forbartha
Mr. Danny O'Connor	Snr. Executive Engineer Dublin County Council
Mr. Denis O'Donohue	Drilling Contractor Hollyfort Co. Weford
Mr. Kieran O'Dwyer	Groundwater Engineer K.T.Cullen Dublin 14
Mr. Denis O'Leary	Department of the Environment
Mr. Diarmuid O'Hegarty	Department of the Environment
Mr. John O'Donoghue	Celtic Engineering Dublin 1
Mr. Stephen Peel	Hydrogeologist Minerex Ltd.
Mr. Victor Reilly	Snr.Executive Engineer Mayo County Council
Mr. Pat Rouse	Snr. Executive Engineer Tullamore U.D.C.
Mr. William Smyth	Geological Survey of Northern Ireland
Mr. Liam Thornton	Office of Public Works
Mr. Denis Tierney	Tipperary County Council North Riding
Mr. Geoff Warke	Geological Survey of Northern Ireland
Mr. Geoff Wright	Hydrogeologist Geological Survey of Ireland

This SEMINAR has been organised by the Committee of the IRISH GROUP of the INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS:

MR. PETER BENNETT, PRESIDENT.
MS. BREDA NAUGHTON, SECRETARY.
MR. KEVIN CULLEN, TREASURER.

The organisers wish to thank all the Speakers and their organisations for their presentations, and the Management and Staff of the Killeshin Hotel.

INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS - IRISH GROUP

FIFTH ANNUAL SEMINAR ON GROUNDWATER DEVELOPMENT

Monday, 22 April, 1985

WELCOME AND INTRODUCTION

Dr. David J. Burdon

On behalf of the President, the officers and the members of the Irish Group of the International Association of Hydrogeologists, I welcome you all to our fifth annual seminar on Groundwater Development. Mr. Peter Bennett, our president, would normally welcome you; but as he is presenting a paper on the Lagan Valley tomorrow, he thought it better that someone else should make the address of welcome and introduce the work of the seminar.

This year, we are celebrating the fact that we consider that groundwater has come of age in Ireland. Our statesmen have lowered the official time of coming of age from 21 to 18; as better scientists controlling time, we have no difficulty in lowering much more groundwater´s coming of age. Our abundant surface waters have mitigated against a realization in Ireland that all waters, including groundwater, are a major natural asset; the tendancy was to drain and get rid of water rather than to conserve and use it. To those who have worked in arid and semi-arid regions of the world, the value of water is clear. And this fact is slowly but surely being realised in Ireland today. The large number of papers being presented for discussion here by many eminent and learned workers in the field of groundwater, and the much larger number who are attending this fifth annual seminar bear testomy to the fact that groundwater has indeed come of age in Ireland.

I particularily welcome Mr. D. O´Hegarty, who will speak on the rather complex "E.E.C. Guidelines for Potable Water". These seem very stringent, and only rain-water would readily reach the standards they seem to set. I hope Mr. O´Hegarty will tell us how they are to be applied in Ireland so that we are not left thirsty for a drink of water. And how do they affect Guinness and the Middleton distilleries ? Possibly, Mr. Bowen´s paper on "Groundwater Treatment" will indicate how such water can be brought close to or within the EEC´s limits set for potable water.

The excellent development and use of groundwater from the limestone aquifers of Laoise will be treated in three fine papers by Mr. E. Creed, Mr. K.T. Cullen and Mr. K. O´Dwyer. This has proved a very successful operation, and the first speaker, Mr. Creed, is an engineer who has a wide knowledge and appreciation of the use of groundwater; he could be called an honourary hydrogeologist.

On the second day, our President and Mr. J. Finlay will give us some detailed information on the investigations and development of groundwater in the Lagan Valley. On the week-end of 22-24 February, the Irish Group of the IAH had a most instructive tour of groundwater sites in Northern Ireland, in particular to the developed gravel aquifers of Garryford and Armoy, both in Co. Antrim. The tour was conducted by Mr. Peter Bennett, and it was a visit which filled us all with admiration for the hydrogeological work being carried out in Northern Ireland. Probably, the papers from Mr. Finlay and Mr.P.Bennett to be presented here will be of the same high standard, and all of us in the south can learn from the approach to groundwater accepted and used in the north.

The last two papers to be presented are by Mr. Eugene Daly on the "Clonaslee Sandstone Aquifer" and by Mr. M. Hand on the "Engineer's View of Groundwater Development". While we have many unconsolidated sand and gravel aquifers, sandstone aquifers are rare in Ireland; however, Mr. Daly's studies and investigation on the Castlecomber Plateau have given him a deep knowledge of sandstone aquifers, and his paper should be of much interest to us all. Finally. Mr. Hand's paper will open up a subject of great importance to hydrogeologists; how can they best locate and study aquifers so that their drilling, test-pumping and development provide water which is acceptable in quantity, quality and cost to the engineer in charge of the over-all project.

Ample time has been left in the programme for discussion. The papers are virtually useless unless they are thoroughly discussed. The preparation of a paper is of major use and benefit only to the author unless it is discussed. A paper which is not discussed would be better presented for printing in some suitable scientific magazine or technical journal. So, I hope there will be much discussion at this meeting. There are always more than one aspect to a hydrogeological subject, and authors need a widening of their views and concepts, if not of their basic facts, by contributions by others. So, if in your opinion an author is wrong, do not hesitate to say so, and provoke a lively discussion which will benefit all.

The papers and discussions end with a small closing speech by our hard-working and efficient secretary; to her, to Mr. Peter Bennett and to Mr. Kevin Cullen the success of this meeting will be largely due.

Finally, allow me on behalf of our President and members of the Irish Group of the International Association of Hydrogeologists to thank all the non-hydrogeologists who are attending this, our fifth seminar at Port Laoise. We welcome the engineers from many counties, we welcome the consulting engineers, we welcome the drillers and staff who are here, as well as those who supply equipment and material required for the efficient development of this no longer underestimated valuable resource of our land, our groundwater.

GROUNDWATER DEVELOPMENT AT PORTLAOISE

E.J. CREED, BE, CENG, MIEI, MIWES,

ASSOCIATE

NICHOLAS O'DWYER & PARTNERS

CONSULTING ENGINEERS

1. INTRODUCTION

1.1 This paper deals with the Engineering approach to the development of Portlaoise Limestone Aquifer in the light of the water requirements of Portlaoise Town and Environs, together with consideration of the requirements of the wider area of North-East County Laois.

1.2 In this necessarily brief summary previous measures taken to provide supplies of potable water are outlined and details of the proposals for the initial development of the Limestone Aquifer are set out.

2. HISTORICAL BACKGROUND

2.1 The existing sources of water for Portlaoise are shown on Fig. 1. The growth of demand over a long period of time led to the piecemeal addition of new sources on an ad hoc basis, rather than as a composite planned entity.

2.2 The source first utilised for a piped water supply to Portlaoise was that located at Knocks, near Ballyfin, where water from surface springs is collected into a concrete tank and treated by slow sand filtration. The water was delivered through 2 No. 5" C.I. mains to Pallas at the west end of Portlaoise Town where a Service Reservoir was constructed. The yield of the Knocks source is 225 m3 per day in normal weather conditions but this falls to 45 m3 per day in drought conditions. This source is no longer used for Portlaoise and is now utilised to supply Ballyfin and the adjoining area between Ballyfin and Mountrath.

2.3 Growth of demand in Portlaoise led to the construction of the Catholes scheme in the early 1930s. The source is the Owenass River, a tributary of the River Barrow and it is located on the eastern flank of the Slieve Bloom mountains 8 kms west of Portlaoise near the village of Rosenallis. The water is treated by slow sand filtration before delivery to Portlaoise through an 8" C.I. main. This source also supplies Mountmellick through two 5" mains. The normal yield of the Catholes is 1,700 m3 per day of which 1,050 m3 is supplied to Portlaoise and 650 m3 to Mountmellick. As the catchment is entirely mountainous the yield is very low in drought conditions and the source failed completely in 1984. Quality problems are encountered because the slow sand filters provide little colour reduction and the water is usually of a peaty brown colour. In rainy conditions the filters are rapidly covered with a layer of silt and require frequent cleaning.

2.4 Further growth in demand required the development of new sources in the late 1960s and early 1970s. A small surface spring at Meelick, on the southern outskirts of Portlaoise Town was developed for an output of 410 m3 per day, which is pumped directly to the distribution system. This system was commissioned in 1967.

2.5 In 1974 a surface spring at Darkin Well, near Straboe, some 4 km north east of Portlaoise, was brought into service to provide the first major addition to the Portlaoise suppy since the 1930s. The safe dry weather yield of the well is 1400 m3 per day and the water is of excellent quality requiring no treatment, except sterilisation, before being delivered to service.

2.6 At the Darkin Well duplicate centrifugal pumps were installed to deliver water through a 9" A.C. rising main to a new Service Reservoir at Kilminchy 3 km east of Portlaoise on the main Dublin Road. From Kilminchy an 18" A.C. pipe was laid to the Town centre and various improvements were carried out to the distribution system. These works were completed in 1975 and resulted in the provision of a good quality water supply for more than half of Portlaoise Town, but the areas served from Pallas Reservoir continued to receive water of poor quality.

3. INVESTIGATION OF FURTHER SOURCES

3.1 In a Report submitted to Laois County Council in April 1971, Nicholas o'Dwyer & Partners proposed that groundwater sources to the east of Portlaoise should be developed to supply the future water demand of the town. The first stage development proposed was the utilisation of the Darkin Well and the construction of Kilminchy Reservoir and, as noted above, this stage was completed in 1975.

3.2 In 1976 the Consulting Engineers commenced examination of the sources to be used for further augmentation of Portlaoise Water Supply. Feasibility studies were carried out on the provision of the long-term requirements from either the River Nore or the River Barrow. Either of these river abstraction schemes would be technically feasible but substantial investment would be required in treatment facilities and a trunk distribution system.

3.3 At the same time gaugings were carried out on surface wells at Morette, near the Heath, 7 km east of Portlaoise and at Kyle Springs, near Timahoe, some 10 km south east of Portlaoise.

The Morette source was considered unsuitable as the development and operating costs would be large for a relatively small yield of 2,300 m3 per day. In view of the distance of the Kyle Springs from Portlaoise it was decided that more economical use could be made of this source for the South-East Laois Regional Water Supply Scheme.

3.4 On the map of North-East Laois shown on Fig. 2 it will be noted that no tributary of any substance enters the River Barrow from the right bank between the Triogue and Morette Rivers, a distance of over 25 km. It was postulated that the runoff from this area of circa 90 km2 was likely to be reaching the River Barrow through a sub-surface system where substantial aquifers could be located. The consistently high dry weather flow from the Darkin Well suggested that it was situated in an area of large sub-surface storage capacity, whilst its proximity to Portlaoise and the high ground at Kilminchy rendered the area attractive for groundwater exploration.

3.5 In mid-1976 the Consulting Engineers prepared a brief for a Hydrogeological Survey of areas adjacent to the Darkin Well and Kilminchy on the east side of the town, and at Knockmay, near Pallas Reservoir, on the west side. The latter site was not selected for any particular geological reasons, but because it had been designated as an industrial estate and a water supply, even of relatively small quantity, would have been of substantial short term benefit. In October 1976 the Council accepted proposals for the Hydrogeological work put forward by Dr. David Burdon of Minerex Limited. The survey was carried out in November-December 1976 and a comprehensive report was submitted to the Consulting Engineers by Dr. Burdon in January 1977. This Report contained recommendations for the siting of exploratory boreholes in areas of low resistivity.

3.6 Tenders were invited for drilling of these exploratory boreholes but, due to problems of obtaining access from landowners, work did not commence until August 1979 and was completed in November 1979. The results of this work were sufficiently encouraging to obtain the Council's approval to a second drilling programme which was completed between September and November 1980. The details and results of this exploratory work are covered in Mr. K.T. Cullen's paper, and it is sufficient to note herein that the location of the Limestone Aquifer was established at Derrygarron and the indications were that the yield would be adequate, at the least, for the immediate and medium term requirements of Portlaoise and environs.

3.7 A major difficulty confronting a Local Authority in carrying out extensive groundwater investigations arises from the financing of such work. In the case of surface water abstraction schemes the capacity of the source is known in advance and the Council can submit a full Preliminary Report to the Government and obtain approval for financing of the work through the Local Loans Fund. In groundwater exploration the extent and yield of the source must be ascertained before firm proposals for the extent of the work can be submitted, with the result that exploratory work may have to be undertaken in piecemeal fashion as finance becomes available.

4. PROPOSALS FOR IMMEDIATE DEVELOPMENT OF THE PORTLAOISE LIMESTONE AQUIFER

4.1 Consequent on the location of the aquifer at Derrygarron and the preliminary yield assessment, Laois County Council instructed Nicholas O'Dwyer & Partners in May 1980 to prepare a Preliminary Report for the augmentation of Portlaoise Water Supply Scheme from the aquifer. The Report was submitted to the Council in March 1981, and examined the further exploratory work required on the aquifer as well as making proposals for the necessary augmentation works.

4.2 At this time Nicholas O'Dwyer & Partners had also been retained by the Council to examine and report on the water supplies to Mountmellick and Portarlington, the other major towns of the County, both of which are situated in the Barrow catchment in North-East Laois. The Consulting Engineers carried out an assessment of the long-term water demand in north-east Laois and determined that the total requirements of the area would amount to 25,000 m3 per day by the year 2025.

4.3 The long term water demands are set out in Table 1.

TABLE 1

AREA	DEMAND M3/DAY
Portlaoise & Environs	11,000
Portarlington & Environs	5,000
Mountmellick & Environs	4,000
Rural & Agriculture	5,000
TOTAL	25,000

The total quantities available from existing sources and proven new sources are set out in Table 2.

TABLE 2

SOURCE	SAFE YIELD M3/DAY
Darkin Well	1,400
Derrygarron Aquifer	5,600
Portarlington Treatment Works	7,000
Minor Sources	1,000
TOTAL	15,000

Thus there was a deficit of 10,000 m3/day in the quantity available in the long term, and whilst the short term requirements of 5,500 m3 per day for Portlaoise could be readily met from available sources there would be a long term deficit of 4000 m3 per day in this area. Furthermore, it would be necessary for the Council to retain the unsatisfactory source at the Catholes and the equally unsatisfactory borehole source at Derryguile in order to supply Mountmellick.

4.4 In the March 1981 Report, the Consulting Engineers proposed that further Hydrogeological investigation and exploratory drilling should be carried out in the Derrygarron area and other contiguous areas, with not less than 8 No. exploratory boreholes being drilled and tested. Incorporated in the same drilling contract would be the provision of four borehole production wells, with their associated observation wells. Details of the investigation, well-drilling and well construction will be dealt with by Mr. K.T. Cullen and Mr. K. O'Dwyer in subsequent papers.

4.5 A map of the Derrygarron/Kilminchy area is shown in Fig. 3. The Consulting Engineers proposals for the first stage abstraction from the Portlaoise Limestone Aquifer are:

4.5.1 Installation of 4 No. electric submersible borehole pumps each with a capacity of 108 m3 per hour, giving an output of 4,500 m3 per day for 2 No. pumps, which, together with the 1,400 m3 per day from the Darkin Well, will provide for the 5500 m3 per day Stage 1 water demand for Portlaoise Town and Environs. 2 No. pumps will run in normal operation, so that 100% standby is available, allowing pumps and wells to be maintained during normal working hours without emergency measures being required in the event of breakdown.

4.5.2 Construction of a central control building at Derrygarron which will house chlorination and fluoridation plants, and the central controls for the telemetry system. A building at each well head will house the local pump controls and will be connected to the Derrygarron Centre by communication cable.

4.5.3 Laying of rising mains from each well head to the Derrygarron centre and laying of a 350/450 mm rising main from Derrygarron to Kilminchy. The layout of the wellfield is such that the rising mains can be conveniently routed to Derrygarron for central metering and chemical dosing after the branch mains join in the combined rising main. Whilst a detailed discussion of the system hydraulics would take too long to expound here, it can be noted that the design of the pipework is such that the pipe sizes and pump characteristics have been matched in such a way that a fourfold increase in flow through the combined rising main can be accommodated whilst still remaining within the optimum operating range of the pumps, but, nevertheless, no throttling of pumps is required at the lower flow rates.

4.5.4 Construction of a second reinforced concrete service reservoir at Kilminchy with a capacity of 3,700 m3, which together with the existing reservoir of 2700 m3 capacity, will provide 1.16 days storage for the Stage 1 demand of 5,500 m3 per day. Adequate space is available on the Kilminchy site for the provision of further reservoir capacity when required.

4.5.5 Provision of duplicate booster pumps at Pallas Reservoir on the western outskirts of Portlaoise, which will allow the reservoir to fill at night and make the storage available to serve the high western areas of the town during periods of maximum demand.

4.5.6 Provision of a computer based telemetry system which will:

(a) Control the operation of the pumps in the Derrygarron wellfield and at Darkin Well so as to provide the most economic operation conditions.

(b) Monitor and store pump operating data for maintenance purposes.

(c) Monitor and store reservoir levels, meter readings, pressures and similar control data.

(d) Monitor and store selected aquifer parameters such as levels in pumping and observation wells, temperature, pH, rainfall etc. to allow long term examination of aquifer performance and potential.

(e) Control the chlorination and fluoridation plants and store residual chlorine levels.

(f) Display the system status and performance on a mimic diagram incorporating indicators for the various instruments.

A V.D.U. will be provided at the Derrygarron Control Centre to enable the operator to display information relative to any part of the system, and a hardcopy of the information display on the screen can be produced by a printer. Provision is also included for a V.D.U. at the Council's offices to allow the supervising Engineer to ascertain the status of the system and obtain access to information stored in the computer.

4.6 Following approval of the Consulting Engineers' proposals by the Council and the Minister for the Environment, the exploratory and well-drilling contract was completed in 1984. Tenders have been received and reported on for the Civil Works, Pumping Plant, and Telemetry System and it is anticipated that work should commence at an early date.

4.7 The results of the 1984 investigation indicate that the potential of the aquifer is far in excess of the amount of 5,600 m3 per day estimated in 1980, and that it can supply the long term requirements of Portlaoise Town and environs with substantial spare capacity available for such other areas as the Council may decide. The full potential can be assessed over a period of years after abstraction has commenced and drawdown and recharge have been studied.

6. ACKNOWLEDGEMENTS

The author wishes to thank Mr. Dermot O'Riordan, County Engineer, Laois County Council, for his permission to allow presentation of the three papers on the Portlaoise Limestone Aquifer. He also wishes to thank Mr. Dermot Hughes, the Partner in charge of the project, and the other Directors of Nicholas O'Dwyer & Partners for their permission to prepare this paper.

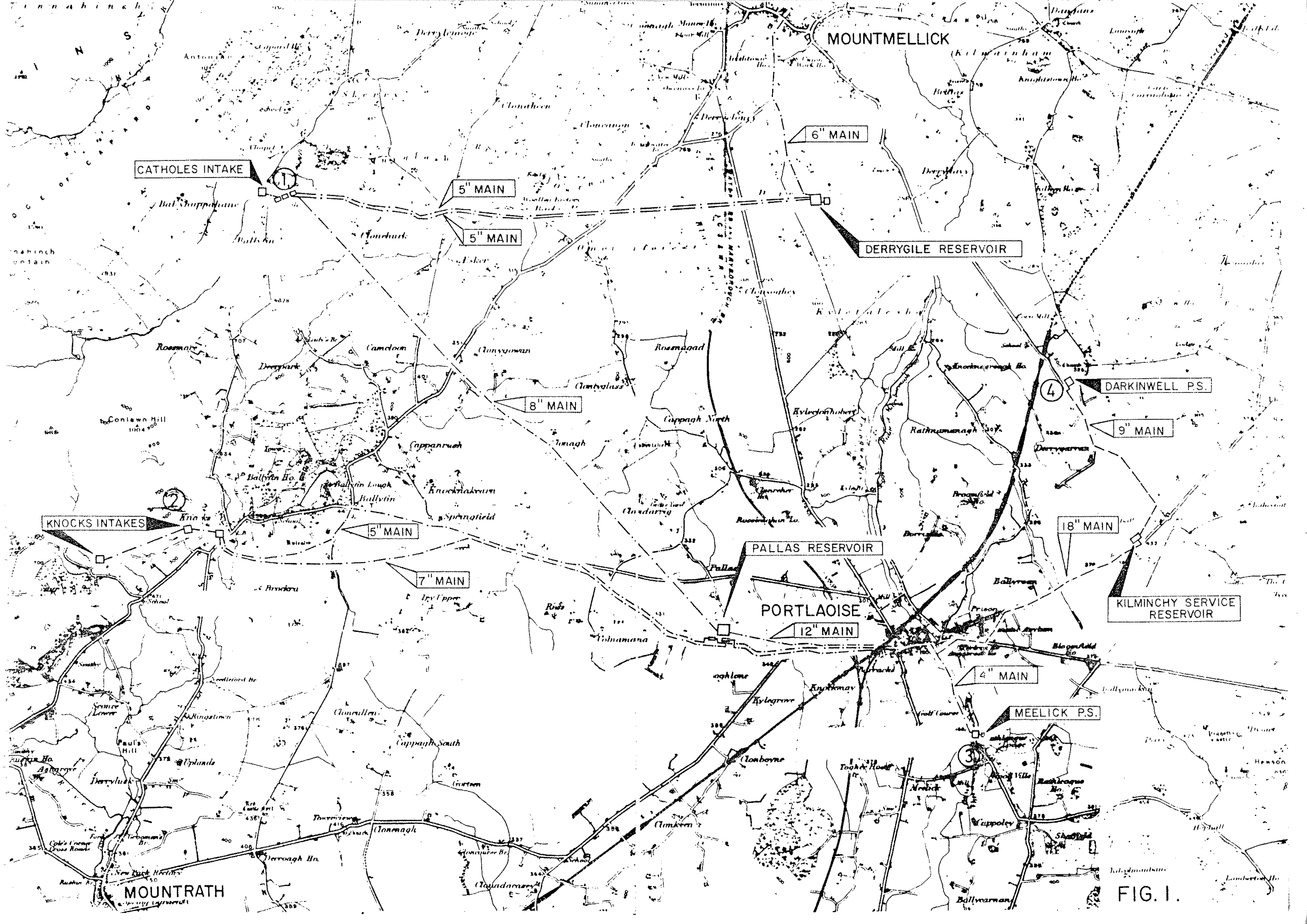
MOUNTMELLICK
6" MAIN
CATHOLES INTAKE
1
5" MAIN
5" MAIN
DERRYGILE RESERVOIR
8" MAIN
4
DARKINWELL P.S.
9" MAIN
2
KNOCKS INTAKES
5" MAIN
18" MAIN
PALLAS RESERVOIR
7" MAIN
KILMINCHY SERVICE RESERVOIR
PORTLAOISE
12" MAIN
4" MAIN
MEELICK P.S.
3
MOUNTRATH

FIG. I.

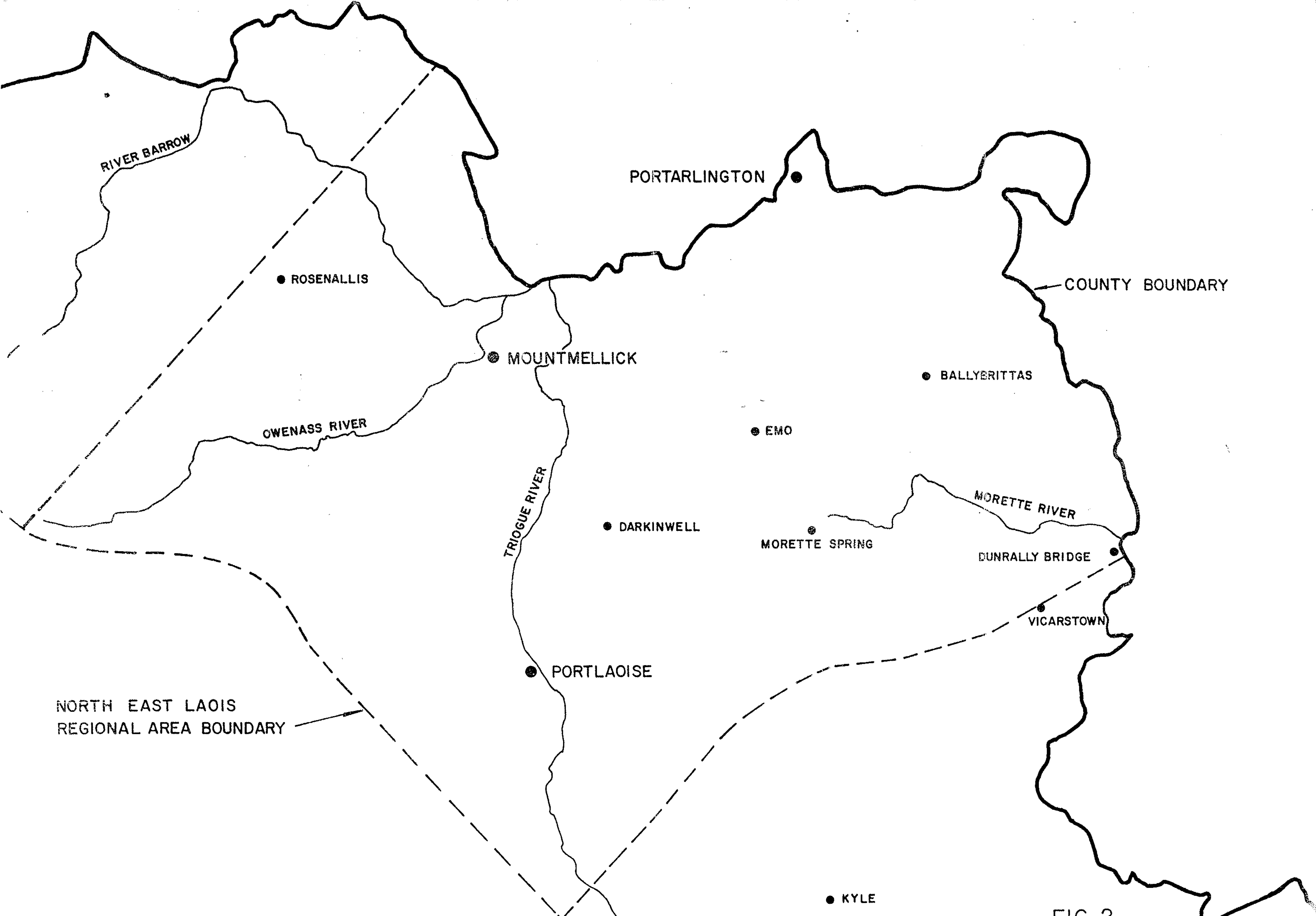
RIVER BARROW
PORTARLINGTON
ROSENALLIS
COUNTY BOUNDARY
MOUNTMELLICK
BALLYBRITTAS
OWENASS RIVER
EMO
TRIOGUE RIVER
MORETTE RIVER
DARKINWELL
MORETTE SPRING
DUNRALLY BRIDGE
VICARSTOWN
PORTLAOISE
NORTH EAST LAOIS
REGIONAL AREA BOUNDARY
KYLE

FIG. 2.

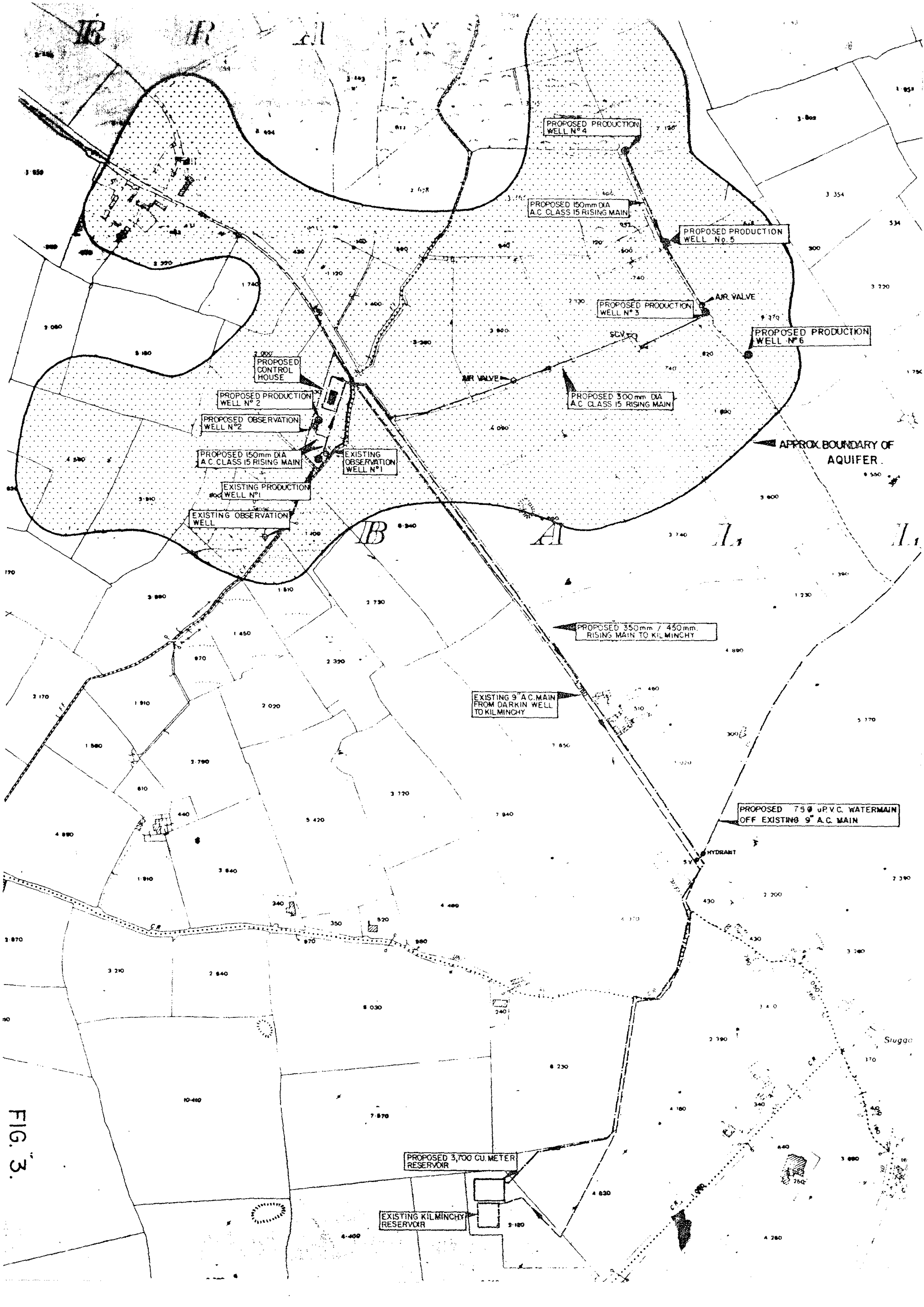
PROPOSED PRODUCTION WELL Nº 4
PROPOSED 150mm DIA A.C. CLASS 15 RISING MAIN
PROPOSED PRODUCTION WELL No. 5
AIR VALVE
PROPOSED PRODUCTION WELL Nº 3
PROPOSED PRODUCTION WELL Nº 6
SCV
PROPOSED CONTROL HOUSE
PROPOSED PRODUCTION WELL Nº 2
AIR VALVE
PROPOSED 300mm DIA A.C. CLASS 15 RISING MAIN
PROPOSED OBSERVATION WELL Nº 2
PROPOSED 150mm DIA A.C. CLASS 15 RISING MAIN
EXISTING OBSERVATION WELL Nº 1
APPROX. BOUNDARY OF AQUIFER.
EXISTING PRODUCTION WELL Nº 1
EXISTING OBSERVATION WELL
PROPOSED 350mm / 450mm. RISING MAIN TO KILMINCHY
EXISTING 9" A.C. MAIN FROM DARKIN WELL TO KILMINCHY
PROPOSED 75Ø uP.V.C. WATERMAIN OFF EXISTING 9" A.C. MAIN
HYDRANT
PROPOSED 3,700 CU. METER RESERVOIR
EXISTING KILMINCHY RESERVOIR
Sluggo

FIG. 3.

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HYDROGEOLOGY OF THE PORTLAOISE LIMESTONE AQUIFER

Presented to the Fifth Annual I.A.H. (Irish Group) Seminar on groundwater development, held at the Killeshin Hotel, Portlaoise on 22nd and 23rd April, 1985.

S U M M A R Y

1. INTRODUCTION:

The recently completed groundwater development project carried out just north-east of Portlaoise has identified a major limestone aquifer that should be capable of meeting the fresh water demand in this region for the foreseeable future. The results of this project together with similar ones already completed elsewhere in Ireland confirmed that, as in other European countries, groundwater can be developed here in quantities that compare with surface water abstractions.

Although groundwater can be developed in Ireland to meet part of the apparently ever increasing demand for fresh water, this island's very varied geological structure imposes many difficulties on groundwater development projects and the successful outcome of a well drilling programme is dependent on a full understanding of the hydrogeological conditions existing in the area. The Portlaoise groundwater development project included both direct (drilling) and indirect (geophysical) methods of investigation and exploration which have been found to be applicable to the Irish geological environment and the programme of studies carried out at Portlaoise has now become the blueprint for most similar projects in Ireland.

My talk today will attempt to describe the methodology of the various hydrogeological studies carried out at Portlaoise and how the results of these studies have contributed to an understanding of the hydrogeology and potential of this important limestone aquifer.

II. GEOLOGICAL SETTING:

Portlaoise lies on the western limb of the major Lower Carboniferous synclinal structure that lies between the sandstone mountains of the Slieve Bloom and Devil's Bit ranges and the granite peaks of the Wicklow Mountains. On a more local scale, Portlaoise is underlain by a south easterly dipping succession of limestone that overlie the older Devonian sandstones of the Slieve Bloom Mountains and are themselves overlain by the younger Coal Measures of the Castlecomer Plateau.

The bedrock geology is nearly everywhere covered by a thick blanket of glacial deposits from the last ice sheet to cover this region and which finally retreated some 10-15,000 years ago. The landforms that make up the local topography are therefore the preserved bed over which the last ice sheet moved, except where they result from glacial outwash deposits released by meltwater flowing from the retreating ice sheet.

The ultimate groundwater potential of any Irish limestone aquifer will be a function of the degree of structural disruption of the aquifer caused by faulting and folding and also the extent of karstification within the limestone mass resulting from enhanced solution of limestone by sub-glacial meltwaters. Unfortunately, however, the degree to which either of these two features are present in a limestone unit is usually completely hidden by the extensive glacial cover, thus necessitating the use of indirect methods of investigation prior to trial well drilling programmes.

III. GROUNDWATER INVESTIGATIONS:

The siting of the original trial well at Portlaoise in 1977 by Dr. David Burdon of Minerex Limited was based primarily on the results of a very limited resistivity survey carried out over an area which Dr. Burdon considered had some groundwater potential. The resistivity survey, consisting of three profile lines and a series of soundings, located a deep hollow in the bedrock surface which was infilled with glacial deposits. The trial well completed at Rathnamanagh encountered a thick sequence of clays and sand/gravel layers in excess of 76 m. in thickness and was subsequently test pumped at a rate of 982 m^3/day (216,000 g.p.d.).

The successful outcome of this first drilling programme encouraged Laois County Council to further investigate the area between the successful trial well at Rathnamanagh and the main service reservoir for the area at Kilminchy. This investigation consisted mainly of a resistivity survey as this method of exploration had proven very successful in locating the initial trial well site.

This extensive geophysical survey identified an area of "low" resistivity in Derrygarran to the north of the Kilminchy Reservoir and which was interpreted as reflecting an area of deeply weathered (karstified) limestone bedrock. The resulting trial well confirmed this interpretation and encountered broken and weathered limestone bedrock to the bottom of the well at 61 m. with major inflows of groundwater occurring over the complete depth of the well. A subsequent pumping test showed that the Derrygarren trial well was capable of a sustained yield of some 2,356 m^3/day (0.52 m.g.d.).

The successful outcome of the Derrygarran drilling programme satisfied Laois County Council that the immediate freshwater demand for Portlaoise could be supplied from production wells located in this limestone aquifer. Further resistivity surveys were carried out by Minerex Limited and the Author to delineate areas of intense karstification and the 1984 drilling and well testing programme was undertaken to provide both the immediate and future water supplies for Portlaoise and its environs. These objectives were met by the 1984 programme when three production wells in the Derrygarran-Ballydavis well field were pumped continuously for 14 days at a combined rate of some 9,100 m^3/day (2 m.g.d.).

IV. HYDROGEOLOGY:

The results of all the works and studies carried out to date at Portlaoise can be compiled together to provide an understanding of the hydrogeological structure of this major limestone aquifer which will assist in the development of this renewable resource.

The Portlaoise limestone aquifer should be considered as an extensive block of limestone some 100 m. thick which is covered by a relatively thin cover of glacial deposits. This block or slab of limestone has undergone varying degrees of karstification which was probably caused by sub-glacial meltwaters with the degree of weathering varying both laterally and vertically. Also, this block of limestone has deep channels cut into its surface by subglacial streams which are now infilled with glacial clays and sand/gravel layers. This extensive network of cavities and fissures appear to be fully interconnected as does the gravel infill with the enclosing limestone walls.

The degree of karstification varies vertically with deep electrical soundings suggesting a maximum depth of some 90-100 m. Wells located in areas of intense karstification give high yields of the order of some 0.75 m.g.d. while wells in areas with less intense weathering return yields of 150,000 - 300,000 g.p.d.

V. ACKNOWLEDGEMENTS:

The Author wishes to thank Laois County Council for permission to present this paper and to describe the results of the recent groundwater development project at Portlaoise.

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PORTLAOISE GROUNDWATER DEVELOPMENT PROJECT

WATER WELL DRILLING AND TESTING PROGRAMME

by Mr. Kieran O'Dwyer, B.E.

A paper presented to the Fifth Annual I.A.H. (Irish Group) Seminar on groundwater development at the Killeshin Hotel, Portlaoise on 22nd & 23rd April, 1985.

SUMMARY

I. INTRODUCTION:

The 1984 Portlaoise groundwater development project included the drilling and testing of a series of production, observation and exploratory wells which were designed to develop and investigate the Portlaoise limestone aquifer. This paper describes the various drilling conditions encountered during this major undertaking and how these conditions affected the design and construction of the different types of water wells. The paper also describes the results of the pumping tests that were carried out on a number of the wells completed during the project to provide both well performance data and aquifer response information.

The drilling contract at Portlaoise was awarded to Dunnes Well Drilling of Mallow and consisted of the construction of 4 production, 3 observation and 7 exploratory wells. The well testing programme at Portlaoise was sub-contracted to Avonmore

Electrical Limited and consisted of a series of step-tests, 72 hour production tests and a 14 day well field test.

II. WELL CONSTRUCTION DETAILS:

The drilling specifications required that the internal diameter of the production wells should not be less than 225 m.m. in diameter and that the finished well should be lined over their full length with thermoplastic well casing and screen with a target depth of some 60 - 90 m. In order to provide for the installation of such long lengths of well casing and screen it was necessary to complete the upper part of each production well at a much greater diameter than the planned finished diameter of 225 m.m. to accommodate extra casing strings to support collapsing or unstable well walls. Also, the drilling contract required that a steel casing be cement grouted into the bedrock to prevent pollution of the wells by surface waters.

The construction of the production wells consisted of the following stages:

(i) the setting of temporary 450 m.m. steel casing to bedrock.

(ii) the deepening of the well by 3 m. into the bedrock at 450 m.m. diameter.

(iii) installing and centering the permanent 375 m.m. steel casing in the well.

(iv) pressure grouting the annular space between the permanent casing and the well walls while withdrawing the temporary 450 m.m. steel casing.

(v) allowing the cement grout to set for not less than 72 hours.

Note: Stages I-V were accomplished with the cable-tool drilling system.

(vi) the well was then deepened at a diameter of 375 m.m. to depths where unstable ground conditions necessitated the use of steel casing to support the well walls.

(vii) the installation of 311 m.m. steel casing.

(viii) the deepending of the well to its finished depth at a diameter of 311 m.m.

(ix) the installation of 225 m.m. thermoplastic well casing and screen.

(x) well development using compressed air.

Note: Stages VI - X were accomplished with an air-flush rotary drilling system.

(xi) alignment tests.

Drilling conditions varied tremendously from site to site which is a feature that characterises groundwater development in karstic limestone terrain. The variability in ground conditions necessitated on site changes and alterations in the drilling and final design of each production well and this flexibility played an important part in the successful outcome of the drilling project.

The construction of the observation and exploratory wells followed on the same general lines as the production wells except that the drilling diameters were reduced to provide smaller finished diameters.

III. DRILLING TECHNIQUES:

Different drilling techniques were adopted during the Portlaoise drilling project to suit the varying ground conditions. Three drilling techniques were used;

(a) Cable-tool system or percussion method.

(b) Down-the-hole hammer.

(c) Rotary rock-roller bit.

The cable-tool system was mainly used in the overburden while the two air flush systems were used to drill the bedrock depending on the degree of fracturing and weathering. The down-the-hole hammer system proved useful where the limestone bedrock was competent but quite useless where the limestone was extensively weathered. The rock-roller bit succeeded in the poorest of ground conditions though drilling progress was reduced when compared with the rapid drilling rates provided by the down-the-hole hammer system. Each of the drilling techniques used at Portlaoise proved useful in the varied overburden and rock conditions encountered here and the ability to change drilling systems to suit the varying conditions was an significant advantage.

Compressed Air was the primary flushing medium for the large rotary drilling rig. Bio-degradable foam was added to the compressed air stream to assist in the lifting of the drill cuttings and hole cleaning.

IV. PUMPING TESTS:

A series of pumping tests were carried out on the production and some of the exploratory wells to provide information on individual well performance and on aquifer response. Short duration step-tests were carried out on each of the production wells to determine the relationship between drawdown and discharge rates. The results from the step-tests are shown graphically on the attached diagram which allows a comparison of the capacity of the three production wells in the Derrygarran-Ballydavis well field and shows how the output from the three wells compares with Trial Well No.8.

3 day yield tests were carried out on 9 of the wells completed at Portlaoise and the results of these tests are tabulated in the attached table. These tests were designed to determine the maximum sustainable yield of the wells and to provide information on the aquifer characteristics and structure. These yield tests confirmed that the production wells completed during the project were capable of discharge rates in excess of 2272 m^3/day (0.5 m.g.d.) and that the aquifer was of considerable extent. No barrier conditions were observed in any of the tests and an analysis of the observation well data gave transmissivity values for the limestone aquifer in the range 500 m^2/day and storage coefficients of between 1 - 5 x 10^{-4}.

A combined 3 day test was carried out at Production Well Site No.5 in the Straboe well field where the production well and the original exploratory well on this site were pumped simultaneously to determine the potential output of the site. The combined abstraction from the two wells at the end of the test was some 5,000 m^3/day (1.1 m.g.d.) and while steady state conditions had not set in by the end of the test this result is sufficient to indicate the potential of the limestone aquifer at Straboe. The other trial well developed in the Straboe well field, Trial Well No.2, yielded 3,747 m^3/day (0.8 m.g.d.) in a 72 hour test, confirming the capacity of this part of the aquifer.

A 14 day well field test was carried out in the Derrygarran-Ballydavis well field at the end of the project to determine how the limestone aquifer would respond to all three production wells operating simultaneously. The combined output from the three production well sites at the end of the test was 9,312 m^3/day (2 m.g.d.) and while the yield characteristics of each production well were different from the individual 72 hour tests carried out earlier in the project the successful outcome of the 14 day test confirmed that the Portlaoise limestone aquifer was capable of meeting the water demand for Portlaoise and its environs.

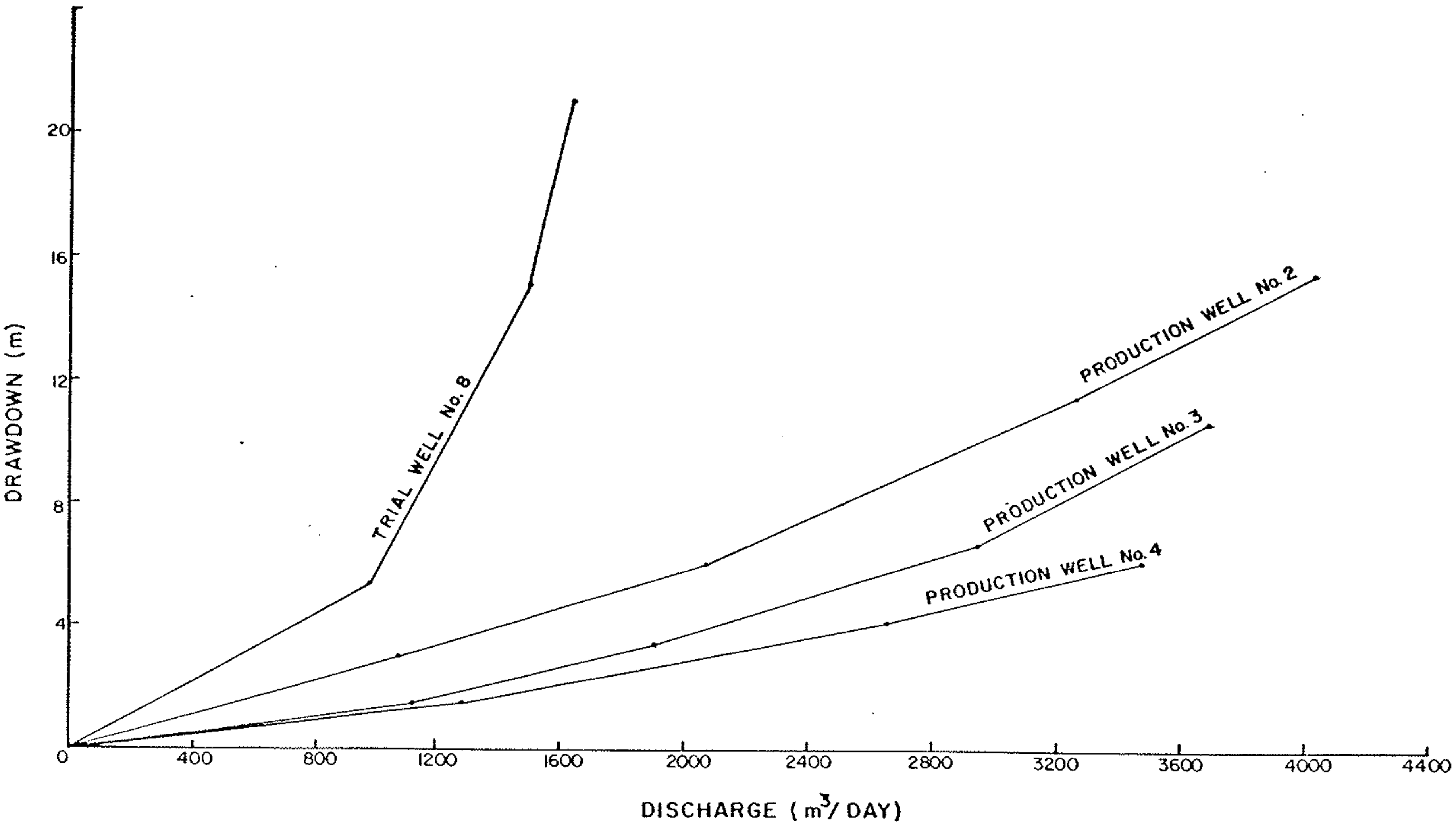
V. ACKNOWLEDGEMENTS:

The Author wishes to thank Laois County Council for permission to present this paper and to describe the results of the recent groundwater development project at Portlaoise.

WELL NO.	TEST DURATION DAYS	FINAL PUMPING RATE m^3/day	WATER LEVEL (m)	DRAWDOWN (m)	SPECIFIC CAPACITY m^3/day/m
PW 1	3	2,356 *	10.50	9.09	259
PW 2	3	4,418	18.63	17.43	254
PW 2	14	2,348	12.92	9.92	237 **
PW 3	3	3,414	20.65	16.30	209
PW 3	14	3,788	31.06	24.46	155 **
PW 4	3	4,418	18.62	15.45	286
PW 4	14	3,176	35.55	29.99	106 **
T 1	3	3,747	25.08	23.70	158
T 5	3	737	47.41	45.10	16
T 8	3	1,505	17.7	14.86	101
T 2	3	1,604	23.20	21.92	73 **
PW 5	3	3,475	24.49	23.39	149 **

<u>Pumping-test results from wells completed in the Portlaoise Limestone Aquifer</u>

* 1980
** Interference from other pumping wells.



DISCHARGE v DRAWDOWN FOR PRODUCTION WELLS Nos. 2, 3, 4 AND TRIAL WELL No. 8.

K.T. CULLEN

GEOLOGY OF THE LAGAN VALLEY

by

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Sandstones of Triassic (Sherwood Sandstone) and possibly Permian age comprise aquifers in the Lagan Valley southwest of Belfast (Fig.1). They are, however, interbedded with mudstone and siltstone formations which do not produce water (Fig.2), and all the rock strata are generally concealed by thick glacial tills, fluvioglacial sands and gravels, and river alluvium. The sandstone aquifers are confined by the tills and alluvium, except along the northwest side of the valley where most of the recharge takes place.

The basic geology of the area was known from sporadic water well drilling over the years (Fig.3) but the extent and productivity of the 'Permian' sandstone along the southeast side of the valley were very uncertain. Recent drilling at more than thirty sites, including four cored boreholes located in an attempt to provide complete coverage of the strata and supplemented by geophysical logging, has demonstrated that the boundaries between the sandstones and other formations are very gradational. Also, rapid lateral facies changes in the formations, particularly the 'Permian', produce great variations in aquifer properties. When these problems are combined with the presence of Tertiary dykes, vertical sheets of basaltic material which impede groundwater flow, it is not surprising that the yields of boreholes tend to be very variable. Despite the intensive drilling of recent years knowledge of the geology is still incomplete but a revised geological map has been prepared (Fig.4) by A. Smith of GSNI. The southeast margin of the Permo-Triassic appears to be much less sinuous than previously thought, despite the fact that the basement surface only dips at an angle of about 15° (Fig.5). This is based on the evidence of several boreholes which drilled through the 'Permian' strata into greywackes. Cross-valley faulting may be more common than shown, and although strike faulting has not been identified it is probably an added complication.

There is no obvious association between high yields and particular horizons of the sandstones. Fissure flow appears to be dominant over intergranular flow, by a ratio of about 10:1, but the core from a borehole at the highest yielding site (Glenburn) did not show any unusual development of jointing. However, a down-hole television survey of the same hole revealed several open bedding plane fissures, and it is presumed that they must have considerable areal extent. Television has only been used in two other unlined holes in the area and bedding plane fissures were not recognised in either, so there is still insufficient evidence to say that they are not widespread.

Fig. 1 Location map & regional geology

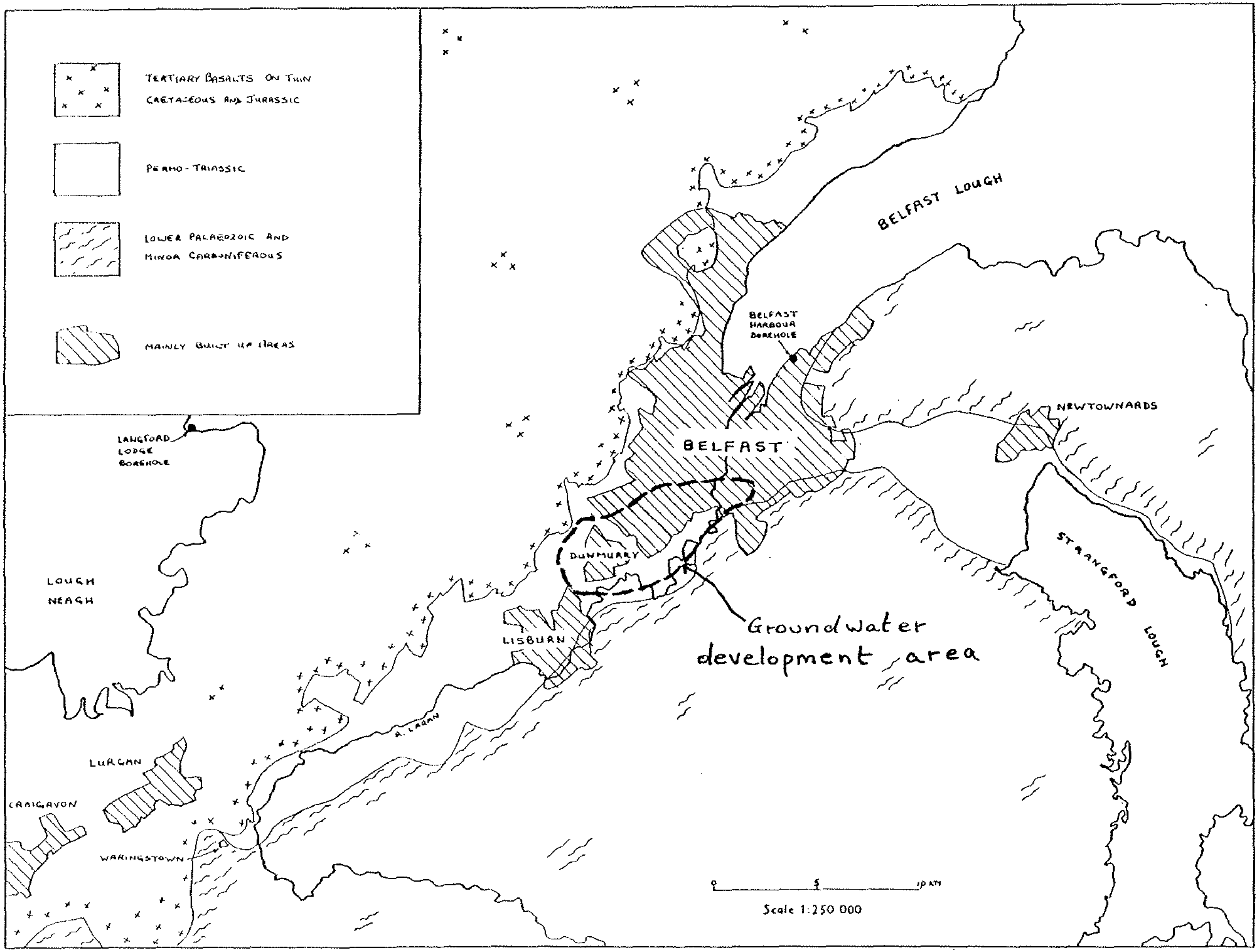


Fig. 2 Idealised vertical section through the Permo-Triassic in the Lagan Valley

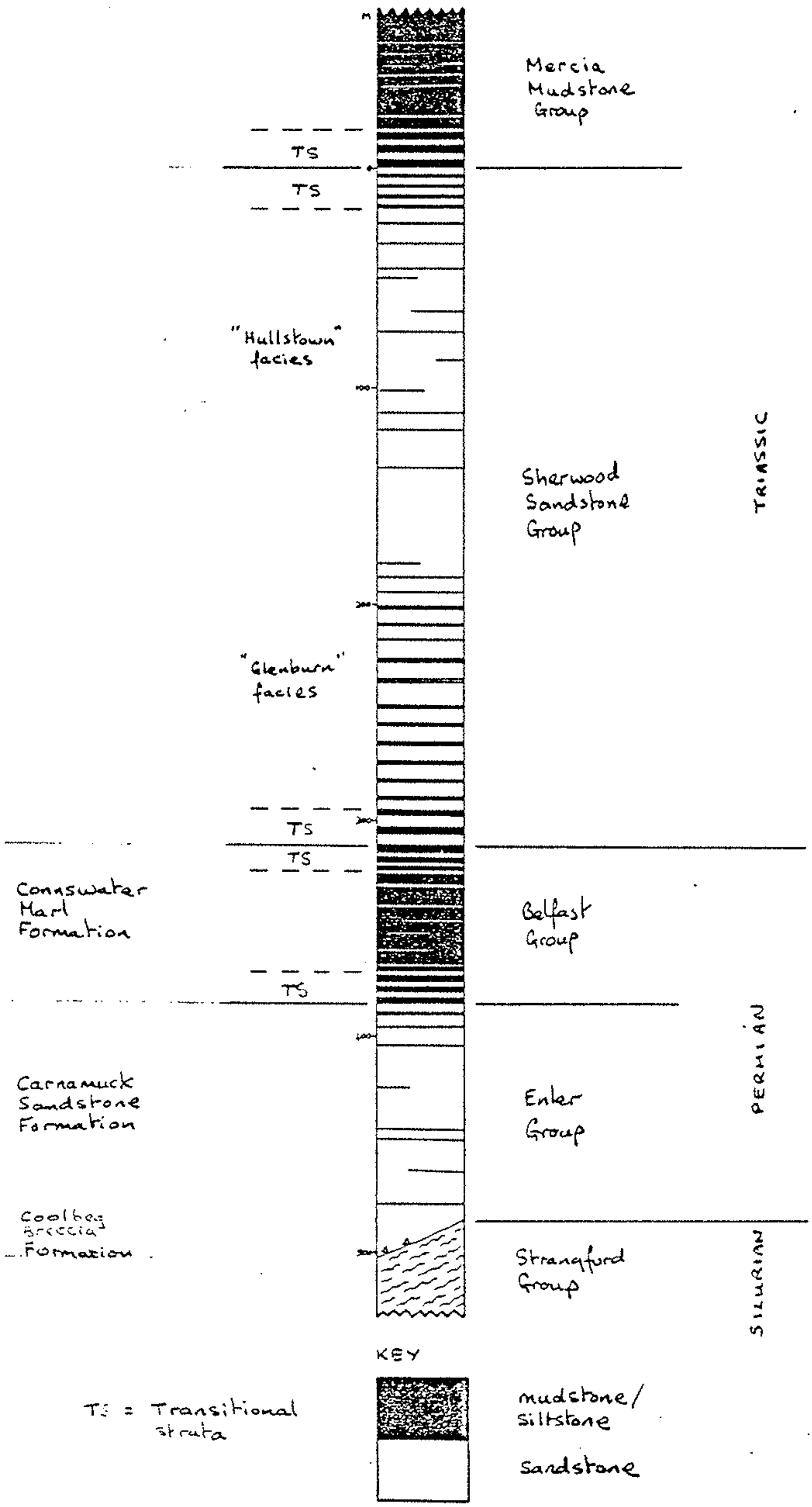


Fig. 3 Geological map (prior to drilling) + new sites

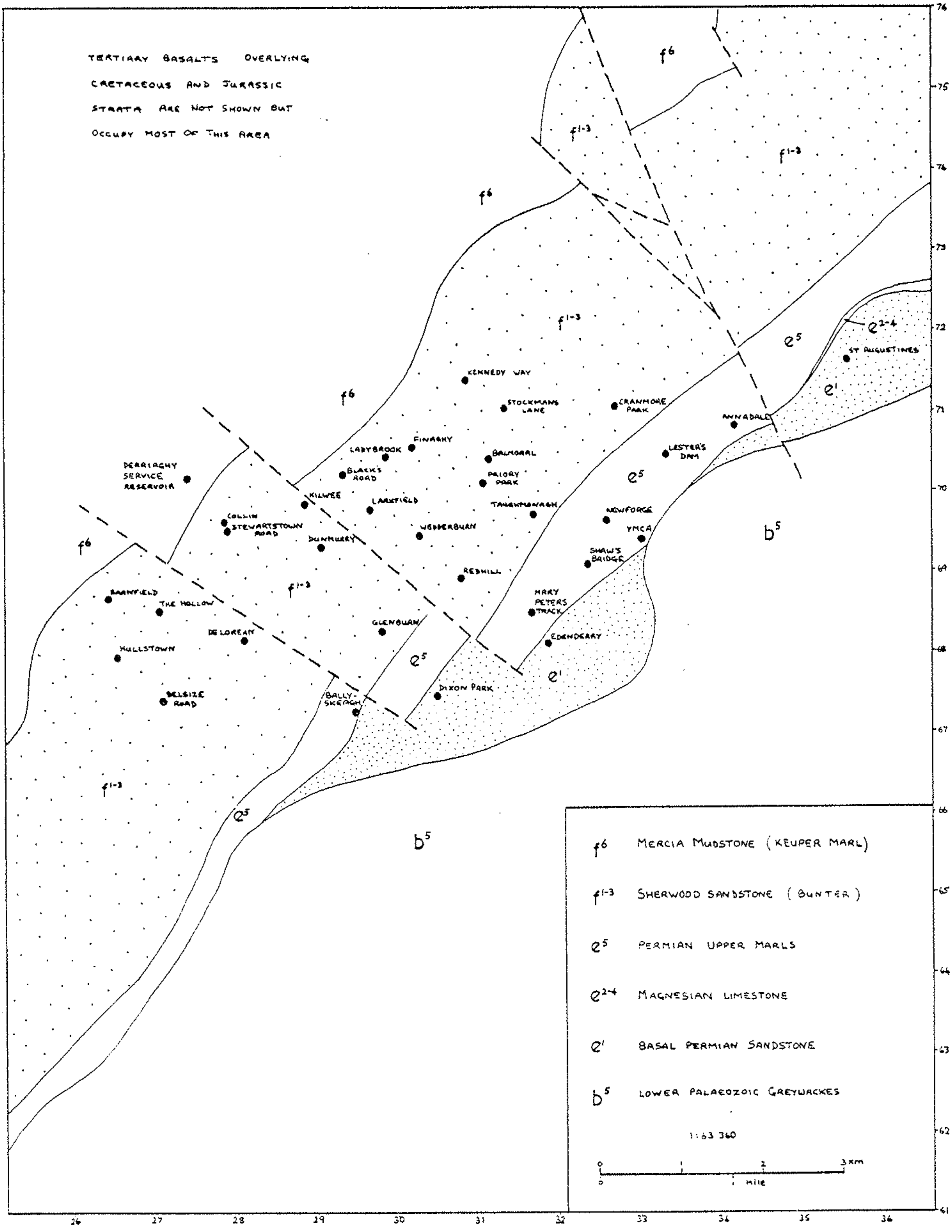


Fig. 4 Updated geological map

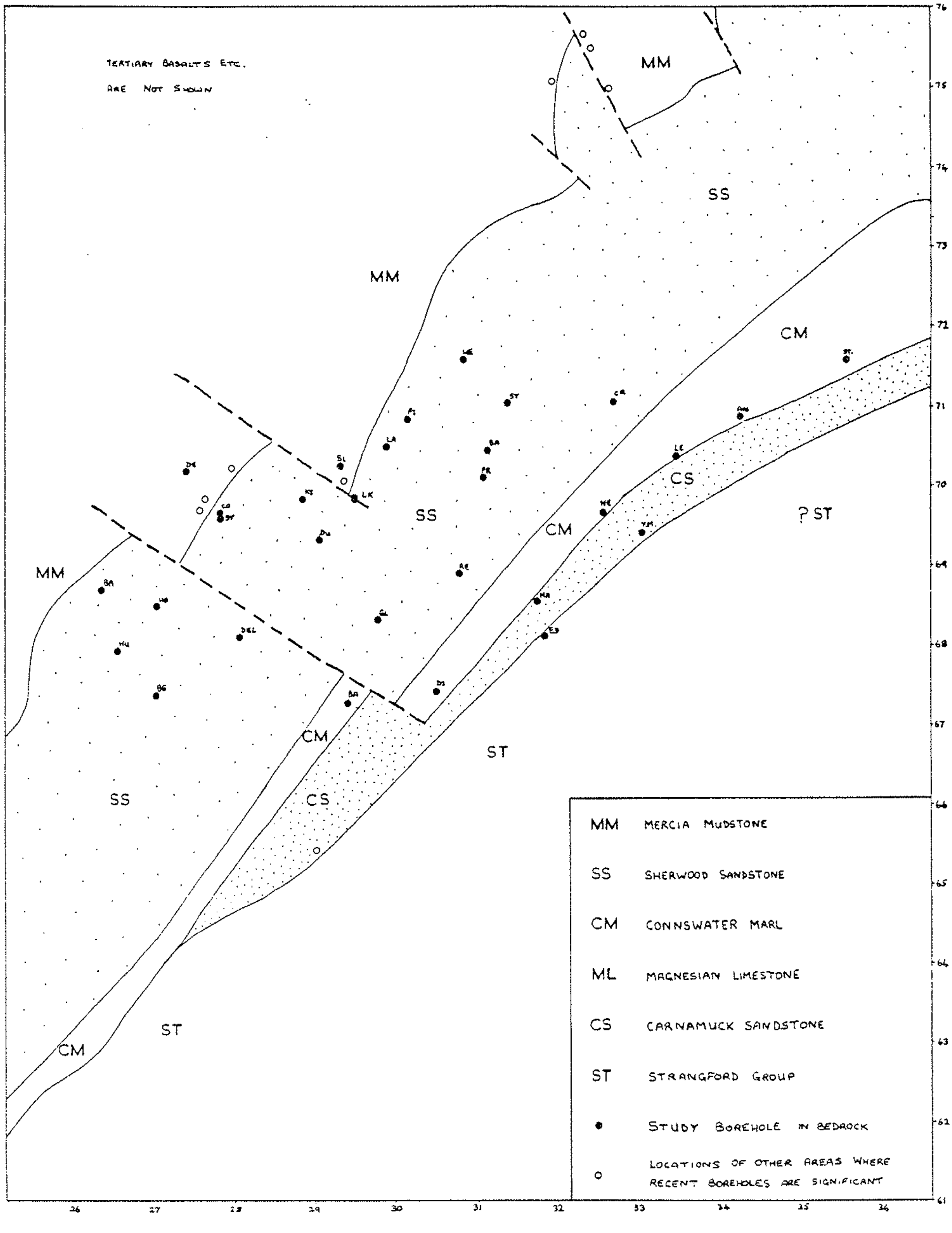


Fig. 5 Generalised geological section

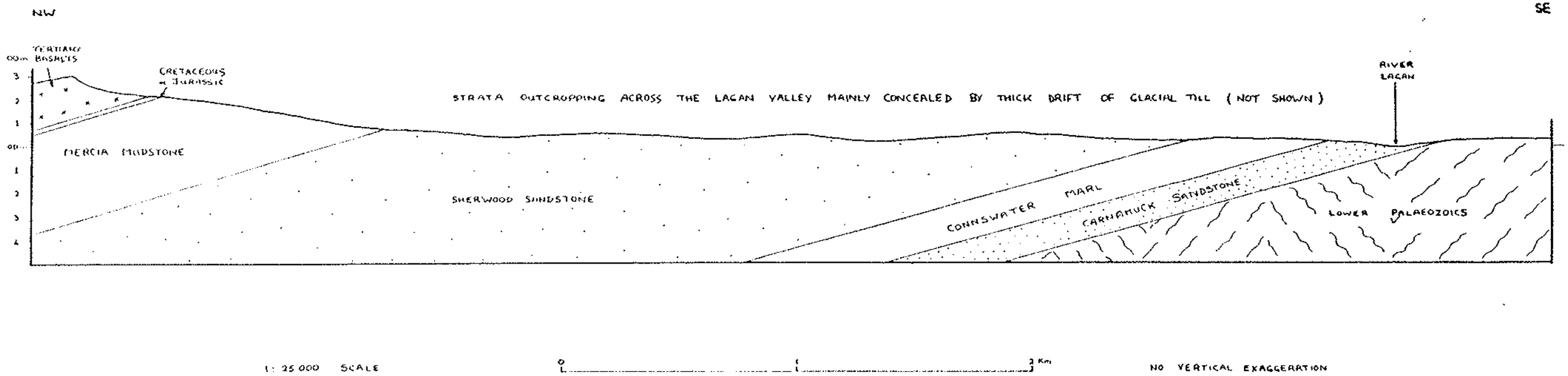
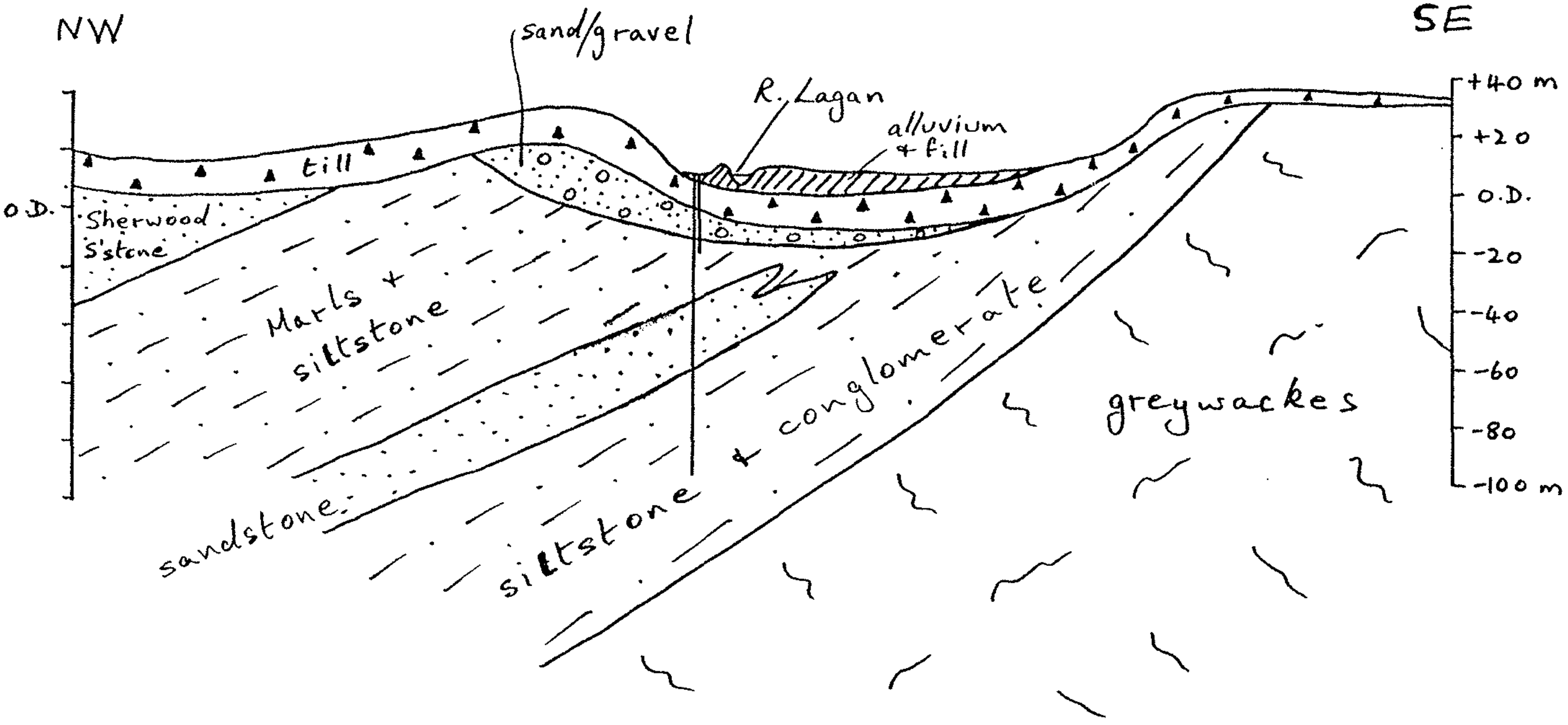


Fig. 6 Diagrammatic section though Newforge site



LAGAN VALLEY BOREHOLE DEVELOPMENT

by

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1. Introduction

This paper covers recent work initiated by The Department of the Environment for Northern Ireland, Water Service, in the search for and development of new production borehole sources from the sandstones of the Lagan Valley between Belfast and Lisburn.

The subject matter is dealt with under four broad headings covering several aspects of the Development, namely:

(a) Historical Background.
(b) The Search for Water.
(c) Findings.
(d) Implementation and Feasibility

HISTORICAL BACKGROUND

2. History of Boreholes

The story of Lagan Valley Borehole water as a public supply dates back to 1935 when the former Lisburn Urban District Council guided by their Engineer, Mr R.E.L. Clarke, commissioned the Barbour Well at Duncans Road in Lisburn. Three more boreholes were drilled in the mid-forties - two of which were also successfully developed.

As a result of a major report on Lisburn Water in 1972 Kirk, McClure & Morton, Belfast were asked (amongst other things) to refurbish firstly the Barbour Well in 1973 and then No.3 and No.4 boreholes - the latter having been abandoned for obscure reasons several years earlier. A fourth borehole - No.2 - was the only unsuccessful borehole out of four drilled.

The boreholes themselves were found to be still in excellent condition but the same could not be said of the installations generally which it would have to be said were in extremely poor condition.

All three boreholes were extensively refurbished both structurally and mechanically and they continue to make a significant contribution to the water supply of Lisburn some fifty years after the commissioning of the Barbour Well.

3. Lagan Valley Hydrogeological Study (L.V.H.S.)

In 1971 the Ministry of Development commissioned the G.S.N.I. and I.G.S. to undertake a hydrogeological study of the Lagan Valley to evaluate the groundwater potential of the underlying sandstone aquifer for public water supply and possible river augmentation.

In the early stages this was supervised from I.G.S. in London with the result that progress was inevitably slow. In 1974, however, Peter Bennett who was with I.G.S. in London at that time returned to the Province and was entrusted with the completion of the study - which was achieved in May 1976.

Peter Bennett, in an extremely comprehensive document, strongly recommended:

(a) Exploitation of groundwater resources between Belfast and Lisburn (Estimated yield 24 Ml/d (5 m.g.d.)).

(b) Limitation of the existing boreholes in Lisburn.

The main recommendations were accepted and in 1977 a start was made on the implementation of the recommendations when my firm was commissioned to develop the Derriaghy site as a production borehole. This borehole had been drilled as part of the L.V.H.S. itself.

4. Derriaghy Borehole

This borehole yielding some 0.5 m.g.d. was commissioned in 1977 pumping, after chlorination, direct into the Derriaghy supply area - a mixed domestic and industrial area. This operated very successfully for eleven months but its life was to be shortlived when one John Z. DeLorean got to hear of it and decided that the borehole would have to go as the particular green field site was just right for the building of his dream sports car.

In September 1978 we were instructed to abandon and demolish the new source and construct a new one near the perimeter of the site under consideration. The replacement Derriaghy borehole was re-commissioned in 1980 after overcoming a number of problems both contractural and technical and is still in full production, which is more than can be said for J.Z. DeLorean's sports car.

This Contract brought home some of the unforseen problems of drilling and provided an invaluable crash course in parts of Murphy's Law unknown to us at the time.

THE SEARCH FOR WATER

5. Phase 1

In February 1978 it was decided to initiate Phase 1 of Peter Bennett's study recommendation - a search for underground water in the Finaghy/Dunmurry area. In the months that followed we soon learnt to respect his expertise in what for us was a new science, while he, I believe, learned to appreciate the compromise often necessary on Engineering grounds (planning, access, services, etc.) bearing in mind that each site had to be thought of as an operational outstation.

A preliminary site investigation contract to establish potential production borehole sites quickly laid to rest the myth that the Bunter Sandstone was a large sponge full of water and all one had to do was sink a borehole into it and you had water. Some 10 exploratory holes were sunk in a total of four search areas before we were satisfied we had three potential Production boreholes. This success rate - 30%, which disappointed us at the time, was to prove to be the pattern over the future years.

Apart from the usual difficulties of finding water in sufficient quantities we even had difficulties finding the sandstone in certain locations.

A subsequent Contract for the drilling and test pumping of the three potential sites confirmed the anticipated yields and a scheme linking the boreholes by means of a common pumping main from Larkfield (Black's Road) via Kilwee (upper Dunmurry Lane) and Stewartstown Road to the Poleglass Service Reservoir was conceived and later implemented.

6. Phase 2 Contract

Our early drilling experiences had brought home to us the somewhat limited resources and experience of local water drilling Contractors. As a result we advised the Employer that further drilling should be included in one major drilling contract covering the full extent of the search area. This, it was felt, would attract more widespread interest throughout the U.K. and E.E.C. Countries.

This change in policy was accepted and following Selective Tendering procedure, tenders were sought and a Contract was subsequently awarded in December 1981 to Water Utility Company of Mallow, Co. Cork, working in conjunction with Ulster Foundations and Drilling and Geoservices.

The Contract was later extended (because of low success rate) to embrace some 25 sites scattered across the search area - some 70 km^2 - in the Lagan Valley between Belfast and Lisburn (see map attached).

7. Specification

Drilling holes into the ground can be 'boring' work, particularly if you immediately fill them with concrete, but drilling for and proving water demand careful specification writing followed by competent precision drilling in accordance with the Specification and all of this not just on one site but on 25 separate sites.

The exercise demands a concentrated team effort from all involved from the rig operator to Geologists, Hydrogeologists and Engineers alike. In addition to the professional expertise required it demands skill, ingenuity, trust, teamwork and above all infinite patience and determination. It is all to easy to get despondent when you are spending someone's money and producing little water in return.

It is worth commenting briefly on aspects of drilling procedure and specification which helped to streamline operations and produce a responsible approach from the parties to the Contract.

(a) Site Selection

Learning from previous experience all drilling work was considered to be investigatory and so no land was acquired beforehand. Until a site had been successfully test pumped there was no point in acquiring land that might be useless. This may seem like stating the obvious but I can assure you it was not always so in the past.

All drilling was undertaken, following excellent spade work by the D.O.E. Lands Section Officials who undertook prior negotiations with landowners.

(b) Drilling Procedure

On each site two pilot holes were drilled some 100 metres apart using a 600 mm temporary casing to bed rock and continuing down to 100 m at 150 mm.

Each pilot hole was then test pumped to decide potential yields before electronic logging was undertaken to determine verticality and straightness (comment later) and useful geological data.

The preferred pilot hole was then permanently cased and grouted into bedrock before proceeding to enlarge the remainder of the borehole to 450 mm. After cleaning, the borehole was then test pumped for some three weeks in order to establish the reliable yield. A further verticality survey was undertaken. The second pilot hole was permanently lined, grouted to rockhead and capped for use as an observation borehole. It was made clear that any borehole not up to specification on vertically would be re-drilled at the Contractor's expense.

(c) Vertical Drilling

A specification need not be complicated or indeed lengthy. In this case the method of drilling was not specified only the relevant diameters, depths, casing and liners.

The verticality and straightness of a completed production borehole as indicated by electronic log survey had to be such that a 260 mm pump and motor on a 150 mm rising main would not touch the borehole sides at any point. Non compliance carried the risk of non acceptance with potential cost penalty.

8. Drilling Methods

The Contractor's response on site was to ensure that he utilised the right equipment and used it correctly. Three drilling methods were used during the course of the Contract:-

(a) Overburden Drilling

The overburden was drilled using conventional shell and auger techniques within a 600 mm temporary steel casing which was retained in place until completion of the pilot hole stage.

(b) Rotary Drilling

Rotary drilling was undertaken using a Hydreq Gryphon multi purpose hydraulically operated rig mounted on a four wheel drive tractor powered by 6 cylinder 120 B.H.P. diesel engine. The rig incorporated a two circuit hydraulic system to provide independent flows for rotation and pull down.

(c) Percussion Drilling

In two instances (Newforge and Lesters Dam) unstable conditions in the Permian sandstone which halted rotary drilling were overcome by utilising a cable tool percussion drill brought to site for a short period.

Rotary drilling utilised tri-cone bits directly coupled to two heavy collars immediately behind the bit using only the combined self weight of the drill string to dictate progress through the sandstone. Too many drilling operators working a bonus system push from the top with disasterous results. It might be all right for piling but not for boreholes. We have had one instance (not in the Phase 2 Contract) of finishing up with two boreholes for the price of one!

In truth, vertical boreholes are a Utopian idea but useable straight almost vertical boreholes are obtainable in a good year! The Engineer must be the final arbitrator.

9. Test Pumping

The decision to proceed beyond the two pilot hole phase was dependant on the success of a 12 hour air-lift test pump during which water levels were carefully monitored both during pumping and the subsequent recovery period. Leaning heavily on Peter Bennett's advice the decision to proceed further would be taken. These were important decisions as the subsequent completion of a potential production borehole represents some 60% of the site development costs.

The 21 day pumping test undertaken upon completion of the Potential Production B.H. utilised an appropriately rated submersible pump supplied from one of two mobile generators (one stand-by). Our fears about noise levels (earlier contract) did not materialise due to the success of improved sound proofing methods and good public relations work.

The drawdowns obtained at Production boreholes varied between 35 m and 62 m with Glenburn by far and away the most successful of the Contract and (I am reliably informed the best in the Province) only falling some 44 m when yielding some 5 Ml/d, 1.1 m.g.d.

During test pumping log time graphs of water levels were plotted until equilibrium conditions were achived. In most instances flows were increased in stages in order to 'home' in on the safe reliable yield.

10. Electronic Logging

The advent of modern techniques for the electronic logging of boreholes has allowed the Engineer and Geologist to build up a comprehensive picture of the geometry of the borehole, the material of the borehole and the fluid column. The information logged and recorded on site was as follows:

(a) Deviation from vertical

(b) The axial co-ordinates of the deviation

(c) The polar co-ordinates of the deviation

(d) Diameter

(e) Gamma log

(f) Density log

The last two were of particular interest to Peter Bennett in strata correlation and bulk density determination.

In certain instances logging was followed up by visual inspection using a specially adapted submersible C.C.T.V. Camera which was lowered into the borehole. This was utilised for example at Glenburn to observe and understand suspected fracturing of the sandstone. The camera, linked to a V.D.U. located at the well head, was capable of providing both 360° rotated view of the borehole wall and down hole view which were recorded with on the spot editing for future re-use.

Two different specialist logging contractors using similar electronic apparatus have been used successfully. These men are highly mobile experts who bring their sophisticated apparatus with them in suitably adapted vehicles as and when required.

In one instance a short fall in computerised print out of results was overcome by the hasty preparation of an appropriate programme within the confines of the Consultant's Office.

I am convinced that logging of boreholes is an essential requirement in any water drilling Contract with the expence - some £500/borehole being good value for money.

11. <u>Hazards</u>

When I was preparing for this evening someone suggested that I should not underplay the problems and hazards of working on the fringe of and indeed within an urban area, albeit South and West Belfast.

We have probably experienced most things:-

(a) We have had the usual difficulties with landowners (and their dogs);

(b) Para-military groups in the Finaghy area and at Derriaghy;

(c) Heavy vandalism - Rotary rig driven into ditch (Ladybrook), slashing of excavator hydraulics;

(d) Obstructions dropped into boreholes - from crow bars to beer cans;

(e) Severe damage to borehole casing - subsequently written off and re-drilled;

(f) Golfers who slice and Glue sniffers who also deviate from the straight.

The prospect of visiting such a large number of sites with their individual problems could have been awful but somehow there was always somewhere else to try while things were sorted. Once the team got 'into' the job and demonstrated it meant business progress rarely suffered. Local knowledge and the close proximity of sites made things easier which was some compensation for not having a telephone on site (never on one site long enough). The Contractor, Water Utility Company, aided and abetted by Ulster Foundations were both willing and able - a real find for a most important contract. It was a pleasure to work with them.

FINDINGS

12. Geological

During the course of the Contract normal drilling logs and samples were augmented by continuous cores at four sites selected by G.S.N.I. to provide optimum geological information.

The geology of the Lagan Valley turned out to be much more complex than expected particularly in the Finaghy area where the existence of a deep glacial channel made drilling difficult. The Permian sandstones on which geological information was lacking have been recorded in the series of boreholes along the valley in a South-Westerly direction from Ravenhill to Ballyskeagh.

The known prepondance of dykes was not a serious problem. Preliminary magnetometer surveys undertaken by G.S.N.I. successfully located the presence of dykes in open space areas. In more urban areas however it was not practical to utilise this form of survey because of the presence of iron metals, overhead lines, etc., and so avoidance was reduced to the old fashioned "hit or miss". At the end of the day dykes were only encountered in about five boreholes (all urban) out of a total of 43, i.e. just over 10%.

Both the Bunter and Permian sandstones varied considerably in hardness with the latter being particularly unstable. As a result all boreholes, with the exception of Dixon Park and Kennedy Way, have been lined with 300 mm slotted P.V.C. screen surrounded by gravel pack.

The Permian Sandstones which are less well cemented generally produced better yields per metre than those of the Bunter.

The existence of a network of observation boreholes in the Valley will permit careful monitoring of piezometric levels and preliminary work on these has already improved our knowledge of ground water flows on the area. These show more variation than was thought and emphatically confirm a concentration of water in the Glenburn area of Dunmurry where the highest yield was found.

Permanent recorders will be installed at four sites (Dixon Park, Ballyskeagh, Priory Park and Dunmurry Lane).

In several isolated instances artesian flow conditions prevailed (Priory Park, Stockmans Lane, Newforge) and in one case - Newforge a sustained flow from a gravel layer - has now been metered at some 0.22 ml/d for some months without fall off.

13. Aquifer Yield

Following the completion of the test pumping programme it has been recommended that eight sites be developed as Production boreholes.

Details of these are as follows:

SITE NAME	CONTRACT REFERENCE NO.	YIELD (Ml/d)	YIELD (mgd)	BOREHOLES (NO.)
Kennedy Way	1	0.68	0.15	1
Glenburn	4	5.00	1.10	2
Lesters Dam	10	2.27	0.50	2
The Hollow	15	1.59	0.35	2
Newforge	17	1.05	0.23	1
Stewartstown 2	22	1.95	0.43	1
Hullstown	23	0.96	0.21	1
Balmoral	25	2.18	0.48	1
TOTAL		15.68	3.45	

This together with those Production boreholes already in operation should produce a yield of 25.59 Ml/d (5.63 m.g.d.) made up as follows:-

BOREHOLES	YIELD	
	(Ml/d)	(mgd)
Phase 1	3.55	0.78
Phase 2 (8 sites)	15.68	3.45
Derryaghy	2.27	0.50
Belsize Road	4.09	0.90
TOTAL YIELD	25.59	5.63

A few interesting statistics emerge from Phase 2

	Ml/d	m.g.d.	% Average
Minimum Yield	0.68	0.15	34.8 %
Maximum Yield	5.00	1.10	255.8 %
Average Yield	1.96	0.43	100 %

Note:-

1) This average yield is some 50% greater than the previous N.I. average figure of 0.29 m.g.d. quoted on a recent paper by Mr D. Logan.

2) The total yield figure of 25.59 Ml/d (5.63 m.g.d.) compares favourably with Peter Bennett's 1976 production of 24 Ml/d (5 m.g.d.).

14. Water Quality

During the course of the Phase 2 Contract over 100 samples of water were taken for analysis in the Divisional Laboratory at Oldpark.

Water quality is good and generally conforms with EEC requirements. In certain cases however hardness and manganese levels are slightly above preferred levels for an isolated source but with appropriate blending with other source water their acceptance should not present any lasting problem. As with most things in Northern Ireland, the public is not always amenable to change and even U.K. Standards of hardness can become unacceptable to local "Softies".

17. Future Development

Following the submission of a Feasibility Report it seems probable that the eight production boreholes will be developed on a programmed basis:

(a) Two sites (The Hollow, Hullstown) will be connected individuality to the Stoneyford Aqueduct.

(b) One site (Stewartstown No.2) will be connected to the existing Phase 1.

(c) One site (Kennedy Way) on the factory estate at Kennedy Way would appear to be attractive for Industry.

(d) Four sites (Glenburn, Balmoral, Newforge and Lesters Dam) which together make up 41% of the whole Lagan Valley yield will be connected to Breda S.R. where it will be adequately blended with the soft waters of the Silent Valley.

18. Costs

The costs of the completed scheme will be some £2,630 K which represents some £240 K per outstation or £467 K/m.g. Given that the development will require neither storage facilities nor treatment plant this must be seen as fairly good value for money.

The disadvantage is that electricity costs for pumping will compare unfavourably with upland water however given that there is already extensive pumping of water into the Belfast area from Lough Neagh (Dunore and Castor Bay).

I am confident that the Lagan Valley Boreholes will provide Eastern Division with an attractive local source water at an acceptable cost per m^3.

19. Final Thoughts

Given the original success of Mr R.E.L. Clarke in 1935 with the Barbour Well and subsequent boreholes it is not easy to understand why it has taken almost 50 years to contemplate further development of Lagan Valley water.

It is a sobering thought, however, to calculate in this year of drought, that the additional yield now proven and hopefully sustainable in the future represents:

in 1 year - 66 % of the capacity of the Silent Valley
and
in 50 years - 34 fillings of the Silent Valley.

Let us hope before long the full potential of the Lagan Valley Sandstones will be utilised.

Thanks are due to:

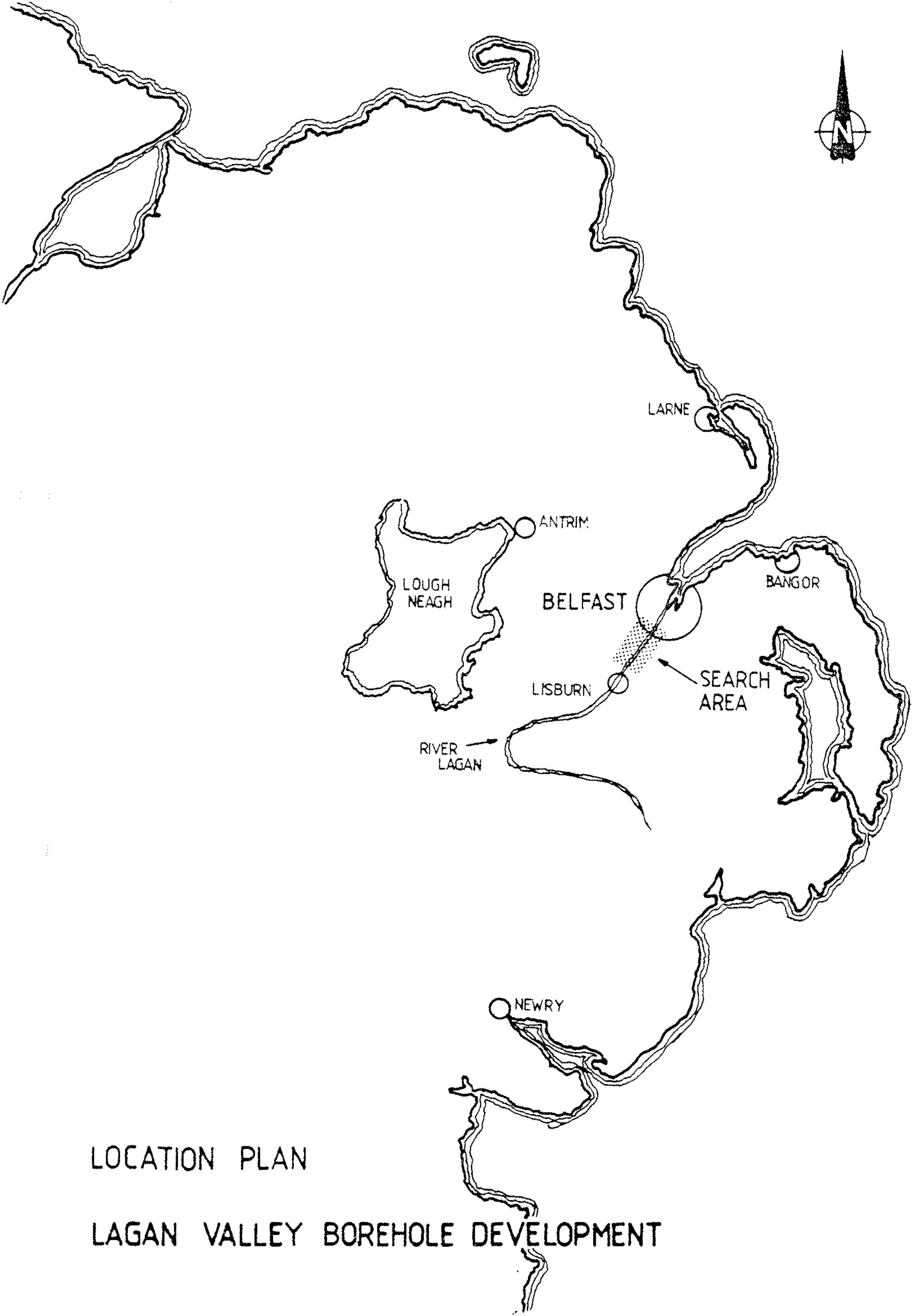
1. The Chief Engineer, The Department of the Environment for Northern Ireland, Water Service, for permission to present this paper.

2. G.S.N.I. and in particular Mr P. Bennett.

3. The Engineers and Scientists of the Water Service Central Design Unit and Eastern Division for the help and co-operation throughout the scheme.

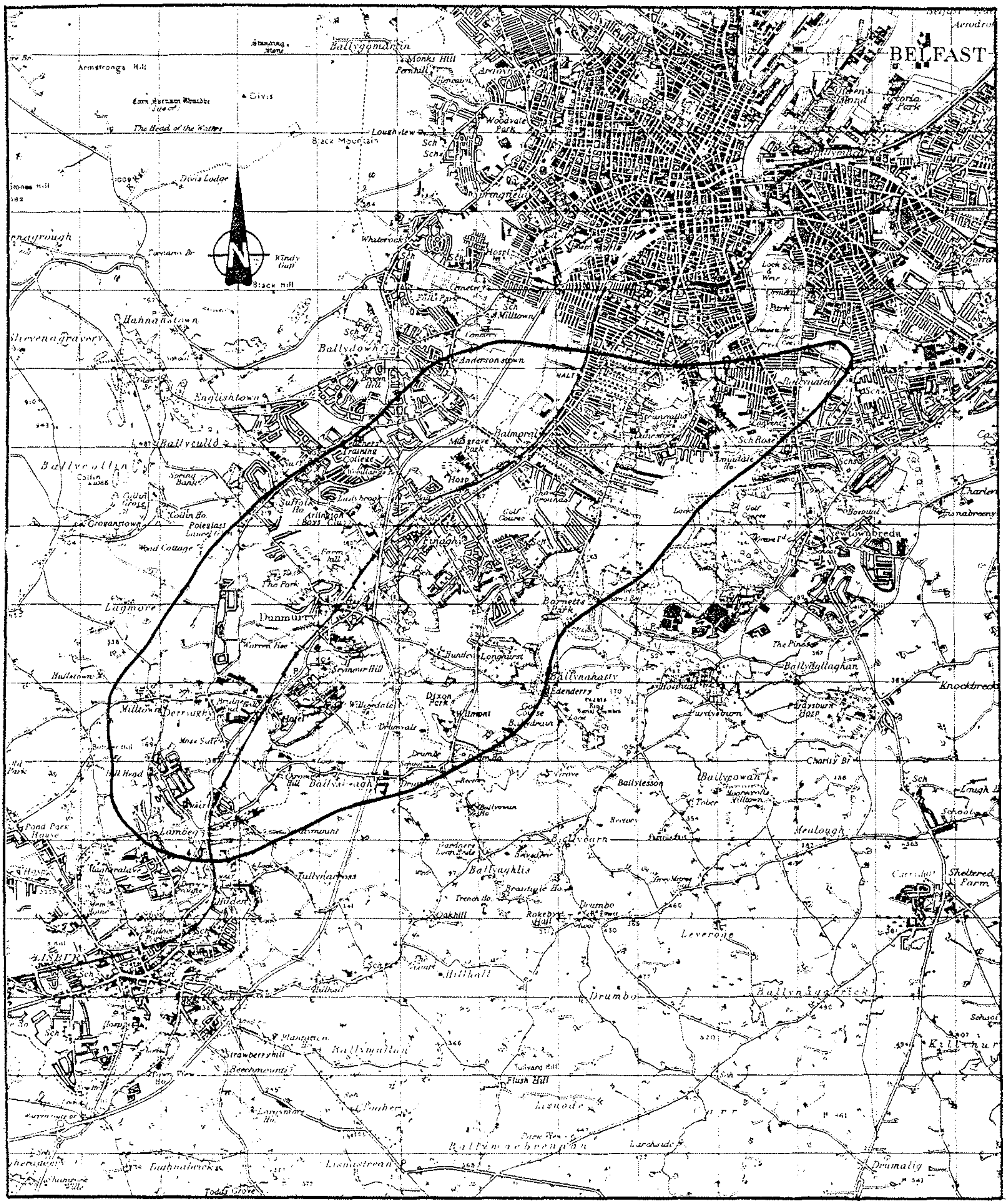
4. The staff of Kirk, McClure & Morton for their interest, support and enthusiasm.

5. The Contractor involved, particularly Water Utility Company.



LOCATION PLAN

LAGAN VALLEY BOREHOLE DEVELOPMENT



THE SEARCH AREA

INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS (IRISH GROUP)

FIFTH ANNUAL SEMINAR ON GROUNDWATER DEVELOPMENT

"IRISH GROUNDWATER HAS COME OF AGE"

KILLESHIN HOTEL, PORTLAOISE - MONDAY & TUESDAY 22ND & 23RD APRIL, 1985

GROUNDWATER DEVELOPMENT - AN ENGINEER'S VIEW

BY

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1. Introduction

The object of this paper is to discuss, in somewhat broader terms, groundwater exploration and its harnessing for use as potable water supply. What follows is an Engineer's perspective. As my own experiences with groundwater have been in public supply and as many of the audience are also involved in public supply, I will endeavour to present practical problems in the local authorities use of groundwater.

As an example of a groundwater exploration and development project I will first of all discuss a scheme to provide 2545 m^3/d of potable water to Tullamore town. This will also serve as background material to the previous paper.

Engineers have until recently tended to neglect groundwater as a source for public supply. In the next section I will postulate reasons for this and give my views on the obstacles still encountered by Engineers and possible strategies for overcoming them.

Finally I will endeavour to put the surface water versus groundwater argument in perspective by presenting some cost comparisons.

It should be noted that for the purposes of this paper all reference to groundwater are to sunk wells and boreholes only and do not include springs.

2. Ground Water Development for Tullamore

2.1 Background

Tullamore is located in the heart of the midlands with no major river or stream nearby. Traditionally its water supply came from surface water sources near the Slieve Bloom Mts. Treatment consisted of slow sand filtration at Clonaslee, Co. Laois with water flowing by gravity to Tullamore, some 9 miles away (Fig. 1). In 1965 P.H. McCarthy Son & Partners prepared a report outlining proposals for the provision of 2270 m^3/d of treated water for Tullamore. These proposals provided for the abstraction of water from the Clodiagh & Gorragh Rivers, coagulation, filtration, sterilisation and fluoridation at Clonaslee and delivery to Tullamore by gravity. This scheme was completed in 1971 when the demand was about 1820 m^3/d. However demand quickly increased (Table 1) and by 1973 active consideration was being given to duplication of the treatment works by harnessing the Glenlahan and Glenbarrow Rivers. Gauging of these Rivers in the dry summer of 1975 showed them to be inadequate for the proposed abstraction. It was at this stage, with the prospect of a 450 m^3/d wet industry establishing in the town, that groundwater was first muted.

TABLE 1 : Water Demand Growth for Tullamore

YEAR	ESTIMATED POPULATION	DEMAND (m^3/d)
1965	7100	1730
1973	7800	2730
1977	8400	3320
1980	8700	3640*
1984	9200	3410*
1985	9300	3640*

* Includes 450 m^3/d to Laois and Offaly County Councils

2.2 Preliminary Investigations

Initial enquiries were made as to the success of drilling by farmers and industry in the Tullamore and Clonaslee areas. Also the Geological Survey of Ireland was consulted and three sites were selected for trial holes (Fig. 1). Site No. 1 was located in Spollenstown industrial estate in the town itself. Site No. 2 was located 2 miles North of Tullamore adjacent to the Silver River. Site No. 3 was located adjacent to Rathcoffey Bridge, 1½ miles East of Clonaslee. All sites were chosen because of their likely potential as gravel aquifers.

2.3 Trial Borehole Drilling and Testing

The three holes were drilled and tested during 1976. Separate contracts were let for drilling and testing. Drilling was carried out using rotary rig with air and water flush while testing employed mono pumps driven by tractor. Table 2 gives the trial hole data. It is evident that only shallow depths of gravel were encountered with little water. The gravel/overburden was sealed off with steel liner and drilling continued into rock. Major water quantities were encountered in the Silver River borehole. Also the Rathcoffey borehole results were encouraging. The Spollenstown site however yielded only a small quantity of poor quality water and further exploration in this area was abandoned.

TABLE 2 : Trial Borehole Data

Trial Hole No.	1	2	3
Location	Spollenstown	Silver River	Rathcoffey
Drilled dia.	200 mm	200 mm	200 mm
Depth to Rock	5 m	6.0 m	13 m
Total Depth	46 m	27.5 m	76 m
Rock Formation	Bioclastic Lst.	Bioclastic Lst.	Sandstone/Shale
Drillers Yield Est.	2.5 - 4 l/s	19 l/s	6 l/s
Tested Capacity	2 l/s	3.4 l/s	5.7 l/s
Drawdown	32 m	6 m	64 m
Water Quality	Poor	Hardness 300 mg/l Iron 0.5 mg/l	Good

The trial drilling and testing had indicated the presence of water quantities in excess of 2270 m^3/d in the Silver River aquifer. This would be sufficient to satisfy immediate demand with some slack for the future. Duty and standby production boreholes were duly drilled and mains laid to supply 32 l/s to the adjacent reservoir. The minimum treatment of chlorination and fluoridation was provided.

The Rathcoffey borehole had indicated groundwater potential in the Clonaslee area also. It was decided that the true potential of this aquifer be assessed with a view to providing an additional 2270 m^3/d when warranted by the ever increasing demand in the town.

2.4 Detailed Investigation

While drilling the trial holes we were acquainted with the services of hydro-geologists Messrs Geox Ltd. They were duly commissioned to interpret the results to date and report on the full development of the Clonaslee aquifer. These investigations included:

* A study of existing topographical and geological maps
* Discussions with prospecting companies possessing licences in the area
* A detailed inventory of existing wells and boreholes
* Collection of available meteorological and hydrological data

This information coupled with the Rathcoffey test hole findings facilitated estimation of the yield of the aquifer for the recharge available. Six sites were thus recommended for production holes with a view to providing 2270 m^3/d. The further development of the aquifer is limited by the carrying capacity of the trunk main from Clonaslee to Tullamore.

2.5 Production Boreholes at Clonaslee

The production boreholes were drilled in the summer of 1978. Of the six sites recommended by Geox Ltd., one could not be purchased and the other five were drilled. One additional site was also chosen during the drilling. Six holes were therefore drilled. One was not completed as the driller lost his bit. Another produced negligible yield as it intersected black shale. The other four were usable holes.

The boreholes were generally drilled to bedrock using a percussion rig. A rotary rig with air and water flush then completed the holes. The successions encountered were sandstones and shales generally as in the Rathcoffey trial hole. Other borehole details are shown in Table 3.

TABLE 3 : Clonaslee Production Borehole Data

Borehole	A	B	C	D	F	G
Drilled diameter	250 mm	250 mm	250 mm	250 mm	200 mm	250 mm
Depth to Rock	12 m	5.8 m		6.7 m	14.6 m	7.9 m
Total Depth	76 m	76 m	20 m	76 m	72 m	76 m
Rock Formation	Shale/ Sandst.	Shale/ Sandst.	-	Shale/ Sandst.	Black Shale	Shale/ Sandst.
Capacity	10.7 l/s	4.7 l/s	-	2.2 l/s	-	6.6 l/s
Drawdown	30 m	30 m	-	30 m	-	30 m
Remarks	Source	Source	Abandoned	Source	Observation Well	Source

Detailed logging of the holes was completed by the G.S.I. and Mr. E. Daly has already discussed the geology of the aquifer in detail.

As the sandstone tended to be very fractured, consideration was given to lining the boreholes to prevent collapse during subsequent pumping. An effort to install slotted 200 mm P.V.C. liner in the holes failed as the loose rock tended to jam the liner. Consequently no more than 15 m of liner could be installed in the holes. Last year, however 190 mm I.D. thermoplastic liner was installed in boreholes B and F. It is intended to install similar liner in borehole A before pump installation.

Testing of the boreholes was carried out in autumn 1978 and 1979. The test programme of 1978 was abandoned with only one borehole tested, after three weeks of breakdown and equipment failure. The remaining three boreholes were tested in two weeks in 1979. All boreholes were tested using mono pumps driven by a tractor. Each borehole was tested for four days and one day for step tests followed by three days continuous pumping at expected capacity.

The quality of water from the tested boreholes was good. Iron was present in the early stages of pumping but not to an alarming degree. Hardness was also at acceptable levels. A selection of test results for the four successful boreholes and the original Rathcoffey trial holes are shown in Table 4.

TABLE 4 : CHEMICAL AND BACTERIOLOGICAL ANALYSES OF WATER SAMPLES

TAKEN DURING TEST PUMPING OF CLONASLEE BOREHOLES

PRODUCTION BOREHOLE		A	B	C	D	Rathcoff
SAMPLING DATE		24/9/79	29/11/78	24/9/79	19/9/79	31/3/76
Appearance	2 ft tube	clear	clear	clear	clear	clear
Colour	Hazen Units	5	5	5	5	5
Turbidity	Formazin Units	15	0	12	0	0.7
Odour		none	none	none	none	none
Dissolved Solids	mg/l	270	325	305	350	-
Suspended Solids	mg/l	4.8	13.3	4.2	9.2	slight
pH (at 15°C)		7.8	7.7	7.5	7.4	7.75
Chloride	mg Cl^-/l	10.5	29.4	13.4	12.4	20
Sulphate	mg S/l	0.0	3.9	0.0	0.0	5.0
Free Ammonia	mg N/l	0.01	0.07	0.01	0.02	0.043
Albuminoid Ammonia	mg N/l	0.05	0.08	0.04	0.06	0.073
Nitrite	mg N/l	0.001	0.001	0.001	0.001	0.001
Nitrate	mg N/l	1.05	1.30	1.30	1.49	0.2
Permanganate Value 4 hr at 27°C	mg O/l	0.00	0.20	0.00	0.04	0.03
Total Alkalinity	mg $CaCO_3$/l	236	240	242	256	229
Total Hardness	mg $CaCO_3$/l	254	252	276	278	200
Permanent Hardness	mg $CaCO_3$/l	72	101	41	39	-
Calcium Hardness	mg $CaCO_3$/l	194	134	244	246	-
Total Iron	mg Fe/l	0.03	0.54	0.08	0.03	0.16
Total Coliforms	No./100 ml	none	48	none	none	none
Faecal Coliforms	No./100 ml	none	none	none	none	1

2.6 Developing the Clonaslee Well Field

The Clonaslee aquifer has not as yet been harnessed. This is because the Silver River source could adequately supply the town when combined with the Clonaslee surface sources. However because of problems at Silver River the development of the Clonaslee scheme has advanced to tender stage. The scheme provides for the pumping of a maximum 2545 m^3/d from boreholes A, B, D and G and the Rathcoffey trial hole.

In a scheme such as this with scattered borehole sites the collection and control system require much thought. As shown in Fig. 2 we have opted for providing individual rising mains to central collection points which deliver by gravity to the existing treatment works. We have therefore provided for laying pipes in common trenches where convenient. Submersible pumps will be used to deliver the water from the boreholes and chlorination and fluoridation will be provided at the existing treatment works.

A telemetry and remote control system will be provided for data gathering, monitoring and direct control of each pumping unit from the treatment works. Signals will be transmitted through private signal cables in ducts laid with pipeline runs. Data will be assimilated and supervised by a microprocessor based control station at Clonaslee. Peripheral equipment such as printer, tape deck, VDU and keyboard will allow data to be printed or stored and facilitate control automatically or by UDC personnel. Typical data will include borehole water levels, pumping rates and reservoir levels.

The already mentioned borehole F which failed to produce sufficient quantities for development, will be used as an aquifer level monitoring borehole and an automatic recorder will be fitted on the borehole for this purpose.

2.7 Summary

The town of Tullamore and its environs are expected to grow to a population of 11,500 by the turn of the century. With the continued expansion on commercial and industrial fronts the demand for water is projected at 6800 m^3/d. This quantity will be available to the town by 1987. However some 60% of the supply will be groundwater whereas pre 1976 the town relied totally on surface water sources.

3. Aspects of Groundwater Development

3.1 The Groundwater Decision

Traditionally Engineers have tended to rely on surface water sources, particularly for larger schemes. The reasons for this are many and varied but can be summarised as follows:

* Surface waters can be seen and measured. Both quantity and quality were easily determined
* There was poor data on groundwater resources
* There was a general lack of knowledge and expertise in underground drilling and groundwater development among Engineers
* Many Engineers had bad experiences with boreholes particularly with regard to pumps and general maintenance
* A poor drilling service meant relatively low yields from boreholes
* Well fields as we now know them were not considered because of collection system control limitations
* The hardness of groundwater was considered excessive for its use in domestic supply
* By dint of their training Engineers are risk averse
* The DOE were sceptical of groundwater

In the last decade many of these barriers have been lowered or removed. For example:

* The Engineer now has easy access to good preliminary information from the C.S.I.
* The services of hydrogeologists are available to the Engineer. As well as his all round expertise in the area the hydrogeologist can access geological maps, aerial photographs, mining company records etc., which may not be readily available to the Engineer
* Resistivity studies are now available for detailed field investigation
* Drilling and testing standards have improved and large boreholes in difficult strata are now possible
* Pumping plant continues to improve in reliability
* Modern technology and the advances in computerisation have facilitated control of remote borehole installations
* The marketing of groundwater as a source of public supply has meant better acceptability among Engineers

At the same time the cost of development of surface water sources has continued to increase due to the scarcity of suitable abstraction points, the deterioration in quality of our lakes and rivers and the increasing cost of chemicals. The decision to go for groundwater is therefore being made easier for the Engineer. The likely capital and running cost savings further strengthen his argument. Yet, there are many potential areas of frustration for the Engineer. Some of these are discussed hereunder.

3.2 Planning and Financing Groundwater Schemes

Many of our past groundwater schemes have tended to be completed piecemeal as low budget projects. This has inevitably led to high maintenance costs during operation. Also, in many cases the full development potential of an aquifer or an individual borehole has not been achieved. For major groundwater schemes proper planning is essential. However, the nature of groundwater development does not lend itself directly to the existing procedures for local authority public works schemes. A preliminary report is generally a desk and field study of available options, with a recommendation and costing of the favoured option. If groundwater is an option then a realistic appraisal cannot be made without recourse to hydrogeological investigations and test drilling. This will entail a much greater expenditure by the local authority at this stage than would be required for an equivalent surface source investigation. Therefore, finance is required up front to complete investigations but the loans cannot be made available from Central Government without preliminary report sanction. A 'Catch 22' situation exists unless the local authority can divert monies from revenue sources. This may not be possible in the present period of financial stringency and so groundwater is overlooked for the wrong reasons. In this regard it is significant that many major groundwater developments have evolved as replacements for approved surface water schemes.

It is regrettable that this situation should continue to exist. A desk study of available data indicating a reasonable chance of groundwater potential should be sufficient to allow the advancement of finance for comprehensive investigations to be carried out. This would involve the DOE in closer control to ensure that these monies were effectively and efficiently spent.

3.3 Trial Boreholes

Detailed study of the geology, previous drillings, etc., only serve to indicate the most likely location of a successful borehole. The only sure way to find out is to drill and test the aquifer. However, each scrap of information will serve to increase the odds in favour of a successful strike. Once a borehole has been drilled, sampled, logged and tested all this information can be used to up date information previously collected and recorded thus increasing the odds in favour of a further success. To this end it can be said that there is no such thing as an unsuccessful borehole. Therefore a degree of 'failure' must be acceptable by the Engineer in the exploration process. Every borehole must be regarded as an investment. To get maximum return on this investment every reasonable step must be taken to record information. A detailed borehole log should be compiled. This can be done using a combination of drilling records, chipping samples and geophysical logging. The information will prove an invaluable asset not alone in aquifèr development but also in solving aquifer problems which may arise after prolonged pumping.

3.4 Drilling Site Acquisition

In the normal run of events the acquisition of a site can be a long drawn out affair depending on the personalities involved. The most common approach in Ireland is to drill a trial borehole in the particular site and if adequate quantities of water are found to drill larger production holes. Should the trial hole be inadequate it tends to be abandoned. In our dealings with land-owners therefore an agreement needs to be flexible to allow for both outcomes. Consequently an agreement is made to pay the landowner a certain sum for permission to drill with a condition that the local authority can acquire the site for a greater sum should adequate quantities of water be found. In theory this is a reasonable and fast approach to permitting drilling operations to begin. In practice, however I have found that landowners tend to change their perception of the agreement once water is found. Frequently, therefore, the agreement is challenged as the landowner tries to sell the water as well as the land. In these situations local authorities are slow to exert their apparent right to acquire the site as per the agreement and I have experience of two local authorities who have shied away from court proceedings to exert their right following legal advice. The agreements were renegotiated in an obvious blackmail situation and inflated prices extracted for the sites.

In the interest of the public good it is desirable that borehole site acquisition be regularised. Land purchase agreements should be bolstered up by statute to ensure that agreements signed in advance are binding. An important consideration in this regard is the vexed question of ownership of underground water which also needs the attention of the legislators. From the Engineer's point of view similar powers to those conferred on local authorities by the Public Health (Ireland) Act 1878 with regard to wayleave acquisition are desirable. The serving of a notice of intention to enter the lands to drill would suffice to advance exploration and allow forward planning. The legal acquisition of the site could proceed during the detailed planning stage with landowner compensation being determined by negotiation or arbitration.

The question of borehole site size is of major concern to the Engineer. He must ensure adequate space for siting boreholes and associated buildings and also allow for access to the boreholes for maintenance or rehabilitation purposes. On the other hand he should keep the site to a reasonable minimum so as to lessen acquisition and development costs as well as site maintenance costs. My own experience would indicate that a 400 m^2 site will suffice in most situations particularly if it has road frontage. Where special treatment of the borehole water is envisaged a larger site should be considered.

The ideal site is of course on an existing treatment works, reservoir site or a road layby already in the local authorities ownership. A convenient three phase E.S.B. supply is an added bonus. However, Murphys law decrees that the optimum sites are remote from public roads, devoid of power supplies and owned by the least co-operative farmer in the neighbourhood. It is the Engineer's lot to overcome these difficulties.

3.5 Water Supplies Act, 1942

The 1942 Water Supplies Act deals with the abstraction of water for public use by sanitary authorities. Under the Act the expression "source of water" means any lake, river, stream, well or spring. A well is defined elsewhere as "a shaft or borehole sunk in the ground to obtain water". Clearly, therefore, groundwater is covered under the Act.

The Act stipulates a procedure to be followed by a sanitary authority prior to abstracting water abbreviated as follows:

* Ascertain the persons to whom damage may be caused by the taking of water
* Prepare a book of reference of these persons
* Issue written notice to each such person outlining the proposal and advising them on how to make objections
* Publish similar notice in a locally circulating newspaper advising persons aggrieved by the proposal on how to make objections

The Act puts the onus on the individual to object to the proposal within a stated time period. These objections will be considered by the Minister before making an abstraction order. However, aggrieved persons are entitled to compensation for loss if they follow specified procedures. Compensation may be determined by negotiation or arbitration.

To my knowledge the procedures under this Act have never been followed for a proposed groundwater abstraction. It would appear therefore that local authorities are not protected under the Act and are open to claims or injunctions from other users or potential users of groundwater. With the increasing use of groundwater as a source and the increasing cost of water to the consumer it is to be expected that local authorities will be challenged where large abstractions lower aquifer water tables. It is essential therefore that aquifer data be adequately documented for use as evidence in hearings or to dispel bogus claims.

To date local authorities have tended to compensate existing private borehole owners who could prove loss of supply due to abstraction for public supply. In some instances existing boreholes have been deepened while in others free or special rate connections have been provided from public mains. Consequently, the rights of either party have never been determined in the Courts.

These views are but a layman's thoughts but I consider that local authorities should at least have legal opinion as to their rights with regard to existing and proposed groundwater abstractions. Clearly, this area revolves around the groundwater ownership issue already mentioned and as such could also benefit from statute.

3.6 Borehole Design and Specification

Major groundwater strikes tend to be located in difficult strata. Gravel aquifers tend to be shallow and are drilled by percussion or shell and auger rigs. The well design incorporating well screens and gravel pack, and the development procedures have been discussed at previous I.A.H. Seminars and I do not propose to discuss them further here.

Good rock aquifers tend to be broken in nature making for different drilling situations. Rock drills tend to be rotary or down the hole hammer utilising air or water flush. Occasionally, mud and foam are used as flushing media.

Trial holes need only be big enough to facilitate penetration of the strata to the required depth and test pumping. A 150 mm diameter open hole is normally adequate in rock. The finished diameter of the production hole is determined by the anticipated yield and pump size. Gradual siltation and collapse have in the past been recurring problems with high output boreholes. Proprietary screwed thermoplastic liner and complementary screen can be used to protect the borehole and the pump. These add up to 50% in direct and indirect costs to borehole drilling but are now essential in production borehole design.

Drillers should be asked to tender on the basis of a detailed specification which should include clauses on:

* Finished depth and diameter requirements
* Well casing and drive shoes
* Sampling and record keeping
* Borehole verticality
* Disinfection of borehole on completion
* Abandoned holes
* Capping of Wells

For production holes the logs of adjacent trial holes should be given as a guide.

Despite the existence of tender rates careful consideration must be given to the rig and the method of borehole construction. Under many borehole contracts drillers fail to reach the design depth because of plant limitations but still get paid under the terms of the contract. In my view a better approach is to get prices on the basis of a performance specification with a proviso that only boreholes completed to the required depth and diameter will be considered for payment.

3.7 Administration of Drilling and Testing Contracts

Drilling and testing contracts are generally let separately to individual specialists. The testing contractor is sought after drilling is complete and an estimate of borehole yield is available. This procedure can be wasteful of time and resources and consideration should be given to letting one contract to include both drilling and testing. This approach is feasible where the likely yield of the borehole is known and it has the following advantages:

* The local authority only needs to go to tender once with consequent savings in time and administration costs

* Well drilling contractors are now offering package deals with drilling, testing and full 24 hour supervision of the testing at cost effective rates

* Site supervision costs savings can be effected

* The boreholes can be made available in the fastest possible time after land acquisition so that detailed plans for the overall scheme can be approved

* Single point responsibility is achieved as one contractor is responsible for all the work. Thus deficiencies in drilling which manifest themselves in testing cannot be blamed on another party. Also tendering the testing plant will not require the diversion of local authority personnel from other works. Here too breakdowns due to dirty fuel, overheating of motors etc., cannot be attributed to negligence on the part of client personnel

* V.A.T. is payable at 10% on drilling contracts and 23% on testing contracts. On a combined contract the 10% rate applies

Where a number of boreholes are to be completed under one contract this approach allows pump data from earlier boreholes to be used in the accurate siting of later ones.

3.8 Site Supervision

Competent site personnel are an essential ingredient in good drilling and testing records. While the contractor may have the onus under the contract to provide these records the Engineer should ensure that the information is accurate. The Resident Engineer has also the important function of making on the spot decisions so that expensive standing time does not arise.

I consider that a Resident Engineer should be present or near at hand during all drilling operations. He should have sufficient presence at the well-head to be in a position to verify all driller information. My experience has been that an exchange of views between the drill rig operator and the Resident Engineer can only be of benefit to the completed product. As drilling is a lonely occupation operators are only too glad of the company.

With regard to testing, a Resident Engineer should be present during all step testing and until stabilised drawdown is achieved in continuous pumping tests. After this, periodic checks should suffice to verify the continuity of pumping at the exact rate.

Consideration should be given to the provision of mobile site accommodation for site personnel during drilling and testing operations. This is particulary relevant during winter months. The marginal investment in supervisory personnel and their welfare on site will give good return in usable information.

3.9 Water Quality

As this topic has already been extensively discussed I will confine myself to a few brief observations.

Public water supply should conform at all times to the E.E.C. Guidelines for Potable water. To this end sufficient sampling and testing should be completed during test pumping to indicate deviations from these guidelines. These tests facilitate estimation of the treatment costs required which then become a function in the overall cost equation.

Groundwaters are always hard - sometimes up to 350 mg/l as $CaCO_3$. Carbonate hardness causes problems for consumers particularly with boilers and laundering. However modern detergents have eliminated the latter problem while the use of indirect hot water systems has lessened the boiler problems. Dual immersion heating of water still presents problems. To my knowledge there is no onus on Local Authorities to provide soft water to consumers, and the EEC Guidelines do not stipulate a hardness figure. Nonetheless the consumer does not like to be told to install his own softener though this is common practice for industrial consumers. The softening of water on a large scale is an expensive operation requiring high capital and operational costs. However the mixing of surface water with hard groundwater serves to provide a more acceptable water as was the case with Tullamore.

Great care should be taken in examining for Iron and Manganese. Iron particularly tends to precipitate when in contact with oxygen. Every effort should be made therefore to exclude air from sample containers so that an accurate Iron level is recorded in the laboratory. It is important to observe trends in Iron and Manganese levels over the duration of pumping tests and indeed during longterm production. While the levels tend to stabilise I have experienced one borehole where a forefold increase has occurred over a number of years pumping.

The presence of Hydrogen Sulphide (H_2S) in water gives an objectionable "rotten egg" smell and taste. However as it rapidly disappears on exposure to the atmosphere it can go undetected at test pumping stage. On one occasion I was alerted to its presence by a passerby who commented on the smell which "hung in air" in the vicinity of the borehole. A special sampling kit is needed to stabilise the gas pending measurement in the laboratory. The problem can be easily cured by simple aeration and a cascade aerator was installed on top of the reservoir in this instance.

Other specific parameters to watch for are the nitrate and nitrite levels which should be compared to coliform counts to determine pollution levels. The overall balance of the water is of prime importance when considering corrosiveness and with this regard the Langelier Index should be determined although many analysts tend to omit this test today.

3.10 Borehole Collection System Considerations

The minimum treatment required for borehole water is chlorination and fluoridation Sometimes iron and mangenese removal may be necessary. Depending on the number of boreholes to be collected and their geographical location, consideration must be given to central treatment as opposed to self contained treatment units at each well-head. The advantages of central treatment lie chiefly in economies of scale, chemical cost savings and day to day control aspects. Against these must be pitted the risk of deposit formation on the raw water collection mains. A cost benefit analysis is required in each individual situation.

Ideally potable water should be fed to supply from a service reservoir. Treated water will be delivered by rising main to this reservoir in the case of collective treatment of water from a number of boreholes. Where self contained treatment units are employed, or indeed for raw water collection systems, a choice must be made between individual or common rising mains. Individual rising mains are more expensive but will give greater flexibility and control in the event of a leak or burst. When using common collection mains a non-return valve must be provided at each well-head to prevent back flow when the borehole is not in use. Great care is required in pump selection. The pump should be capable of delivering a realistic yield at maximum anticipated drawdown against the maximum anticipated head loss i.e. when all boreholes are in operation. At the other end of its curve the pump should not overpump the borheole at minimum head loss conditions i.e. when all other boreholes are resting.

Modern telemetry and control systems have a particular application in borehole systems where a number of installations are involved. As well as information gathering and storage as outlined for the Clonaslee scheme a system can offer the following control functions:

* On/off control of pumps
* Cut-in and Cut-out of selected borehole pumps at preset levels in reservoirs
* Rotation of pump duty to ensure resting of pumps as required and to keep all pumps in running order.
* Borehole pump duty can be selected on minimum pumping cost criteria.
* Borehole pump shut down in the event of excessive drawdown or overpumping due to a burst on the rising main.

Many of these functions have heretofore been manual operations. The modern systems facilitate more efficient management of water systems generally with great savings in personnel and transport costs. However a word of warning is required regarding these systems. Engineers must take a personal interest in the efficient running of schemes if maximum advantage is to be taken of the installed system. A caretaker must be given sufficient training and direction. Further he must be motivated to use it to cut water production costs and this motivation, be it stick or carrot, must come from the Engineer.

3.11 Maintenance

The image of groundwater has been frequently tarnished in the Engineer's mind because of recurring maintenance problems. Many of these problems emanated from the "hole in the ground" era of groundwater exploration where boreholes were not designed with long term performance in mind but more as cheap low quality holes. Dog-legs, loss of verticality, damaged overburden casings, changes in diameter, siltation and collapse made pump installation and retrieval a nightmare. Maintenance costs included borehole rehabilitation, redrilling and loss of pumps. If drilling is completed to a sufficient diameter and the borehole constructed to detailed design and specification these costs can be eliminated.

Records of borehole levels and output should be reviewed for early warning signals of borehole or pump deterioration. In this way maintenance measures can be planned so as to avoid disruption of supply. Fall off in output with high borehole water level would indicate pump deterioration. Rapid drawdown would indicate aquifer failure. In the former case pump examination and overhaul will be required while in the latter, acid or chlorine treatment may restore yield. Clearly a local authority needs to have personnel trained and equipped to tackle these problems. Relying on outside specialists is not cost effective nor does it lend itself to speedy solutions. Also emergency repair work, which is inevitable with mechanical and electrical equipment, can best be carried out by local authorities themselves. A derrick for lifting pumping units is an essential piece of equipment where boreholes are being used. Engineers and other supervisory staff should have easy access to a dip meter.

Where one borehole supplies a region then 100% standby in terms of borehole and pumping plant should be provided. If a borehole field exists then one standby for a number of boreholes should suffice. Care should be taken however to rotate pump duty to ensure that the standby is in perfect working order. If these precautions are taken then routine preventative maintenance and emergency work can be carried out with some degree of comfort and security.

4. Groundwater Economics

4.1 Capital Costs

It is incorrect to say that groundwater development is cheaper than the development of surface sources. However it can be said that the scarcity of surface sources due to their exploitation in the past makes them expensive. Groundwater development on the other hand is still young and throughout the country aquifers continue to be found which can be developed more economically than the available surface sources. The capital comparison must be made between the cost of the completed boreholes, collection system and treatment plant if required, as opposed to the intake works, flocculation, settlement and filtration requirements of the surface source.

If we consider the Tullamore situation as already outlined the capital cost estimate of the proposed borehole development compares well with an estimate of the capital cost of developing the existing local rivers. However, as stated earlier these rivers were incapable of supplying the required volume and consequently this comparison can only be of academic interest.

Hidden savings are present with groundwater development which are unlikely to accrue under surface water developments. For example groundwater schemes lend themselves easily to staged development. This gives great flexibility to local authorities and in this regard it is significant that many groundwater schemes are being completed by annual small expenditures under the D.O.E.'s Small Schemes Programme.

On the other hand hidden costs may arise in the form of hardness, iron and manganese removal. Also land acquisition and the provision of power to remote sites can prove costly. So too can the provision of compensation water for landowners adversely affected by the abstractions.

4.2 Running Costs

While the predominant running cost with surface water schemes is chemicals, that of groundwater schemes is electricity. The cost of water from the surface sources at Clonaslee worked out at 2.3p per m^3 (10.5p per 1000 gallons) in 1984 exclusive of caretaking and maintenance. An equivalent estimate of cost of the new borehole sources at full production and at 1984 prices was 2.5p per m^3 (11.4p per 1000 gallons). However the Clonaslee surface water source must be seen as exceptional since water flows by gravity through the treatment process to supply in Tullamore with consequent low production costs. In general terms a significant running cost saving would be expected when using groundwater sources.

We have recently designed a scheme for the supply of 230 l/sec from 18 borehole sources. The scheme envisages double pumping to centralised treatment of the water for removal of up to 0.8 mg/l of Iron and 1.2 mg/l of Manganese to M.A.C. levels. The estimated running costs for this scheme, again excluding caretaking and maintenance, was 5p per m^3 (23p per 1000 gallons). While this cost is twice the expected Clonaslee water cost it still compares well with the running cost of the surface water alternative.

With regard to everyday monitoring and caretaking groundwater schemes can prove costly if a suitable monitoring and control system as already discussed is not installed. Other costs include routine sampling of individual sources while general maintenance should not vary significantly from that of surface water systems provided always that adequate design and supervision has gone into the boreholes and system generally.

It must be noted that running costs cannot be assessed in isolation from capital costs. High capital expenditure can be used to minimise running costs. When making comparisons between groundwater and surface water options therefore it is necessary to capitalise future estimated running costs to present day prices using a suitable discount rate. The most economical option can only be demonstrated by using this method to compare like with like.

5. Conclusions

In concluding I must return to the theme of this Seminar ie. that "Irish Groundwater has come of Age". For Tullamore Water Supply groundwater has indeed come of age and this is also true for the various schemes discussed at this and other I.A.H. seminars. However, if grounwater is to reach maturity it needs to shrug off hang-ups of its neglected youth. Its continued development, however, depends on factors outside the Engineer's control. These include the legal ownership of groundwater, abstraction procedure and drillsite acquisition powers. We must continue to seek leglislation in these areas.

There are also factors within the Engineer's direct control which delay the maturity of groundwater. These include:

* The acceptance of a level of trial hole 'failure'
* A culture change with regard to planning and financing
* Ensuring that detailed and accurate hydrogeological, drilling and testing information is secured and recorded for future use
* Striving for the highest standard of borehole design and construction
* Seeking and implementing strategies for overcoming quality problems
* Ensuring adequate design of collection systems and making use of modern technology for monitoring and control
* Gearing up for and implementing preventative maintenance programmes

The Engineers who come to grips with these relics of the last decade will benefit most from continued groundwater development. I feel that the industry will not be found wanting and I am confident of a bright future for Irish groundwater.

6. Acknowledgement

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As the title suggests,the opinions expressed are entirely personal and not necessarily those of either organisation.

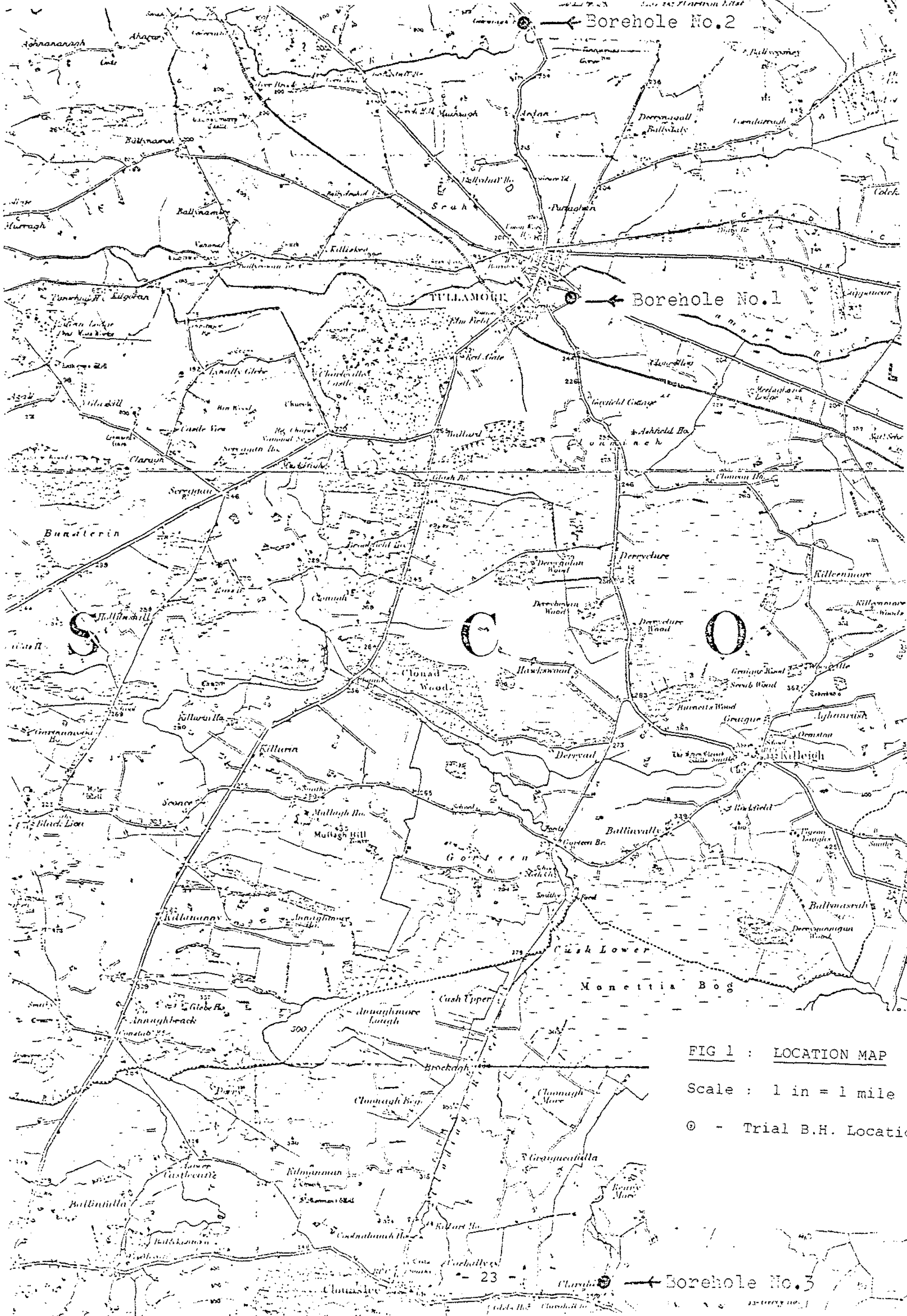
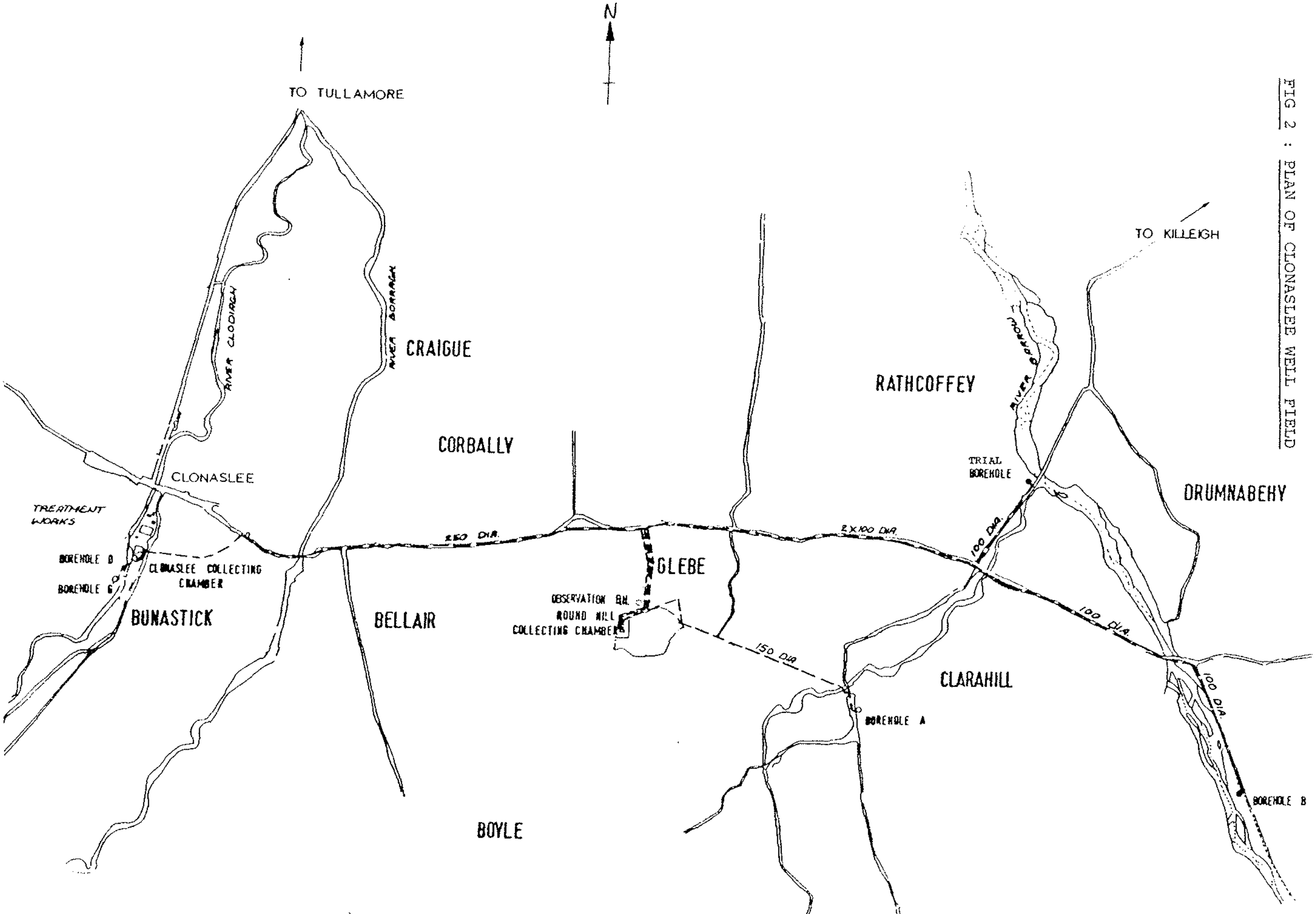


FIG 1 : LOCATION MAP

Scale : 1 in = 1 mile

⊙ - Trial B.H. Locatio



Scale: 3 ins. = 1 mile

FIG 2 : PLAN OF CLONASLEE WELL FIELD