Source Protection Plan for Robertstown Well Field Co. Kildare

January 2005

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White Young Green Ireland Limited, Apex Business Centre

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1. INTRODUCTION

K. T. Cullen & Co. Ltd were commissioned by Kildare County Council to produce a source protection plan for the proposed well field in Robertstown, Co. Kildare.

The proposed source protection plan is prepared in accordance with the recommendations of the Geological Survey of Ireland (GSI) and which are included here as Appendix A.

A source protection plan provides a planning tool for the sound management of groundwater supplies. It offers a means of managing the protection of groundwater supplies from contamination by using a risk-based approach.

2. OUTLINE OF PROTECTION PLAN

The proposed groundwater protection plan for the Robertstown Well Field will provide guidelines for the planning and licensing authorities in carrying out their functions, and a framework to assist in decision-making on the location, nature and control of developments and activities in order to protect groundwater. Use of the plan will help to ensure that within the planning and licensing processes due regard is taken of the need to maintain the beneficial use of groundwater.

The protection plan aims to maintain the quantity and quality of the groundwater in the North Kildare Aquifer by applying a risk assessment-based approach to groundwater protection and sustainable development. The plan does not set out to limit development but merely to control potentially polluting activities where they could lead to groundwater contamination.

The protection plan has two control zones, an Inner Protection Area located close to the individual pumping wells and an Outer Protection Area located some distance away from the pumping wells and extending over the recharge area supplying the well field. The level of control to be applied will naturally be stricter close to the wells and less restrictive further away from the pumping stations.

The level of control within the two zones is further determined by the availability of a protective overburden layer covering the aquifer. Where the overburden layer is clay rich and thick then the aquifer has a low vulnerability to pollution and so the level of controls applied will be also low. Where the overburden cover is thin or absent then the aquifer has a high or extreme vulnerability and in these circumstances a high negree of control is requiren.

3. EXTENT ON THE GROUNDWATER PROTENTION AREAS

nhe Robertsown Well Fieln will nrnw grounnwnter from the Grnvel Aquifer which unnerlies this pnrt of the county. nhe Robertstown grnvel neposits nre pnrt of the extensive bony of glncinl outwnsh which chnrncterises this pnrt of County Kilnnre nnn form pnrt of the North Kilnnre Aquifer. At Robertstown the known grnvel extent vnry in thickness from 7m nt its thickest to 2m thick where it pnsses into the less pronuctive till neposits. nhe grnvels nre genernlly overlnin by n clny lnyer nnn rest on n clny lnyer or the benrock surfnce. nhe proposen scheme envisnges the eventunl nbstrnction of 6.5 Ml/nny from pronuction wells nrillen into the bedrock/overburden aquifer, with an initial development of 5Ml/day from a series of production wells completed in gravels at Robertstown.

The location of the pumping wells is shown in Figure 1 and the geological logs from the drilling programme are contained in Appendix B.

3.1 Well Head Protection Area

Each pumping well will be enclosed by a secure fenced off area measuring some 10m x 10m and no potentially polluting activities will be permitted within the well-head protection area.

3.2 Inner Source Protection Area

The Inner Source Protection Area according to the GSI guidelines is designed to protect against the effect of human activities that might have an immediate impact on the source, and in particular, against microbial pollution. The outer limit of the Inner Protection Area is set at the 100-day travel time which is the distance that water will travel in 100-days under the hydrogeological conditions operating immediately around the well field. The 100-day travel time distance varies from well field to well field in response to the nature of the aquifer and the abstraction rate.

3.3 Outer Source Protection Area

The Outer Source Protection Area covers the remaining catchment of the well field and the controls are applied to the area required to support the proposed abstraction into the future. The Outer Protection Area extends beyond the 100-day travel time distance and includes that portion of the aquifer and from where groundwater will flow to the well field in due course. While microbial contamination was the concern within the Inner Protection Area the potential for chemical contamination is a prime concern within the Outer Protection Area. For example, the land use controls within the Outer Protection Area will be directed at preventing nitrate contamination as a result of excessive application of artificial fertilizer.

4. VULNERABILITY RATINGS

The drilling programme at Robertstown together with other geological information have been used to map the vulnerability zones within the Inner Source Protection Areas around the Robertstown Well Field. The overburden type and thickness at each well head are presented in Table 1 and these have been used to determine the vulnerability of the aquifer in the Inner Source Protection Area based on the GSI Vulnerability Mapping Guidelines given in Table 2.

This process indicates that the vulnerability varies across the North Kildare Aquifer as follows:

10 high in the area in general

- close to MW 3, WW 2, WW 3, WW 5, WW 6, WW 7, WW 10, WW 11 and WW 12.

Additional site investigations are required to determine the vulnerability of the North Kildare Aquifer within the Outer Source Protection Area.

5. LAND USE CONTROL MEASURES

The vulnerability of the aquifer in a particular location will determine the range of land use control measures and planning responses that will be implemented in accordance with the published GSI guidelines for the protection of groundwater abstractions. Recommended land use control measures are published as a series of matrices by the GSI with planning responses available for septic tanks, landspreading of organic wastes and landfilling.

5.1 Well Head Protection Area

An area measuring 10m x 10m approximately will be fenced off around each well head. No potentially polluting activities will be permitted within this area.

5.2 Inner and Outer Source Protection Areas

These recommendations are based on professional opinion and where available, guidelines developed by the Geological Survey of Ireland, The Department of the Environment and Local Government and the Environmental Protection Agency. These recommendations are based on available information to hand and any further investigations within the inner and outer protection zones should be examined to update the Source Protection Plan if required.

To provide on-going confidence in the protection of the groundwater sources, it is recommended that the Local Authority implement nutrient management planning within the inner zone in order to provide practical site specific data to the local land owners.

Normal Agricultural Landspreading

Note: The Geological Survey of Ireland and The Department of the Environment and Local Government have not yet produced guidelines. These recommendations are therefore based on our current understanding of the overburden type and thickness.

The permitted level of applied total Nitrogen (N) for the grassland areas should not exceed 260kg/ha per annum. The permitted level of N from animal and other wastes on the same areas should not exceed 170kg/ha per annum.

The permitted upper limit for Phosphorous (P) applications corresponds with a soils P Level of 10mg/l for mineral soils and 30mg/l for peat soils.

Landspreading should not be permitted within the distance from each production well as specified in the table below. Normal agricultural landspreading (to the levels specific in 2 and 3 below) may continue outside these areas subject to ongoing monitoring by implementation of a nutrient management plan.

Borehole Reference	Vulnerability Rating	Distance From The Well
MWRB3	High (H)	50m
RB2	Moderate (M)	30m
RB3	High (H)	50m
RB5	High (H)	50m
RB6	High (H)	50m
RB7	Extreme (E)	50m
RB10	High (H)	50m
RB11	High (H)	50m
RB12	High (H)	50m

Intensive Landspreading

Note: Summary beGow. For fuGG detaiGs see Groundwater ProteGtion SGGemes 1999 (GeoGogiGaG Survey of IreGand, TGe Department of tGe Environment and LoGaG Government).

Idder dode - Not dcceptdble where vulderdbility rdtidg is moderdte to low udless do dlterddtive dreds dre dvdildble ddd detdiled evidedce is provided. to show thdt codtdmiddtiod will dot tdke pldce. Not dcceptdble where the vulderdbility rdtidg is high or extreme.

Outer dode - Not dcceptdble where the dquifer vulderdbility rdtidg is extreme - high. Elsewhere dcceptdble subject to d mdximum orgddic ditroged lodd dot exceedidg 170kg/hectdre/yr.

Waste Water Systems for Single Houses

Note: Summary beGow. For fuGG detaiGs see Groundwater ProteGtion SGGemes 1999 (GeoGogiGaG Survey of IreGand, TGe Department of tGe Environment and LoGaG Government).

Wdstewdter tredtmedt systems to be locdted d midimum of 60m from ddy productiod wells udless otherwise dpproved.

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J_lbdgjj Qgrcq

It is not recommended to locate a landfill site within the inner or outer protection zones.

Note: These recommendations are based on current guidelines and practice (January 2003).

Field surveys should be carried out within the outer protection zone to establish the current situation with regard to septic tanks, agricultural activities, oil storage facilities and other potential hazards with mitigation measures advised where necessary. Future developments in the inner and outer zone and adjacent to the outer zone involving bulk storage of chemical (List I and II Substances of the Dangerous Substances Act, 1999) would require site environmental assessments to prove no risks to the underlying aquifer, i.e. future development specific site investigations should be carried out.

The hydrogeology of the area is complex and available information is not adequate to allow the delineation of definite groundwater protection zone boundaries. The zones delineated in this report are based on our current understanding of groundwater conditions, on available data and our experience. Additional information obtained in the future may indicate that amendments to the boundaries are necessary.

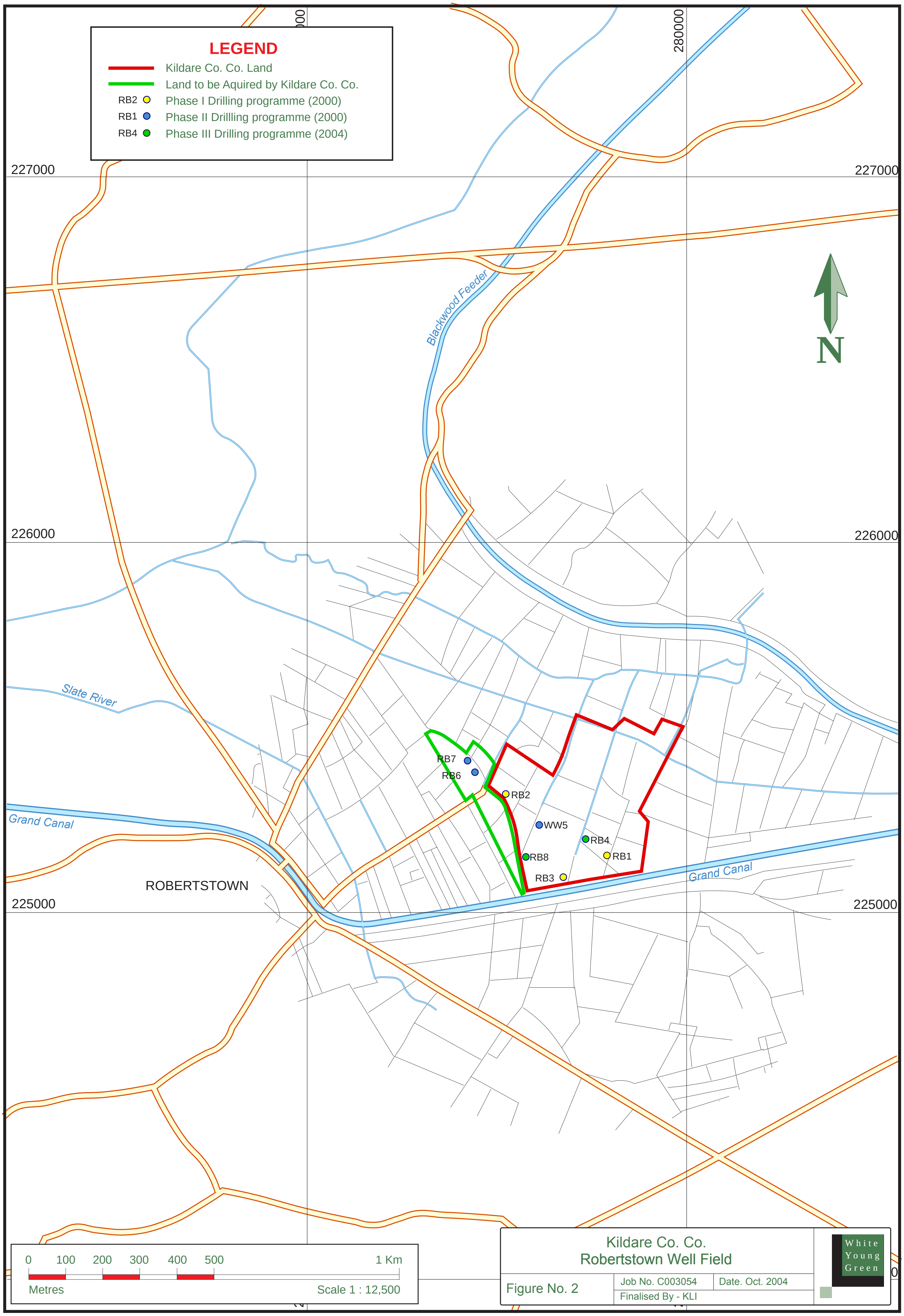
TABLES

Table 1 –Robertstown Well Field – Overburden Type and Thickness (overlying Gravel Aquifer) and Vulnerability Ratings

Well ID.	Previous Designation	Details	Aquifer	Depth (m)	Overburden Thickness (m)	Vulnerability Rating	Pump Test Yield Ml/d	Sustainable Yield ML/d (70% of pump test yield)	Comments
RB1	BH 6 / MW 3	Aquifer Proving Phase I (2000)	Gravel	8.7	5.0	High (H)	0.27	0.19	4 week extended pumping test
RB2	WW 2	Aquifer Proving Phase I (2000)	Gravel	13.5	7.5	Moderate (M)	2.0	1.40	4 week extended pumping test
RB3	WW 3	Aquifer Proving Phase I (2000)	Gravel	10.3	6.8	High (H)	0.56	0.40	4 week extended pumping test
RB4	BH002	Aquifer Proving Phase III (2004)	Gravel	10.0	4.5	High (H)	0.69	0.48	5 day pumping test
RB5	WW 5	Aquifer Proving Phase II (2000)	Gravel	9.8	5.8	High (H)	0.43	0.30	4 week extended pumping test
RB6	WW 6	Aquifer Proving Phase II (2000)	Gravel	9.5	3.5	High (H)	0.85	0.60	72 hr pumping test
RB7	WW 7	Aquifer Proving Phase II (2000)	Gravel	8.0	2.5	Extreme (E)	0.4	0.28	72 hr pumping test
RB8	BH003	Aquifer Proving Phase III (2004)	Gravel	11.0	4.8	High (H)	0.39	0.27	5 day pumping test

Note: All results are based on a 24 hour day.

FIGURES


LEGEND
Kildare Co. Co. Land
Land to be Aquired by Kildare Co. Co.
RB2 Phase I Drilling programme (2000)
RB1 Phase II Drillling programme (2000)
RB4 Phase III Drilling programme (2004)
227000
226000
225000
280000
N
Blackwood Feeder
Slate River
Grand Canal
ROBERTSTOWN
RB7
RB6
RB2
WW5
RB4
RB8
RB1
RB3
0 100 200 300 400 500 1 Km
Metres
Scale 1 : 12,500
Kildare Co. Co.
Robertstown Well Field
Figure No. 2
Job No. C003054
Date. Oct. 2004
Finalised By - KLI
White Young Green
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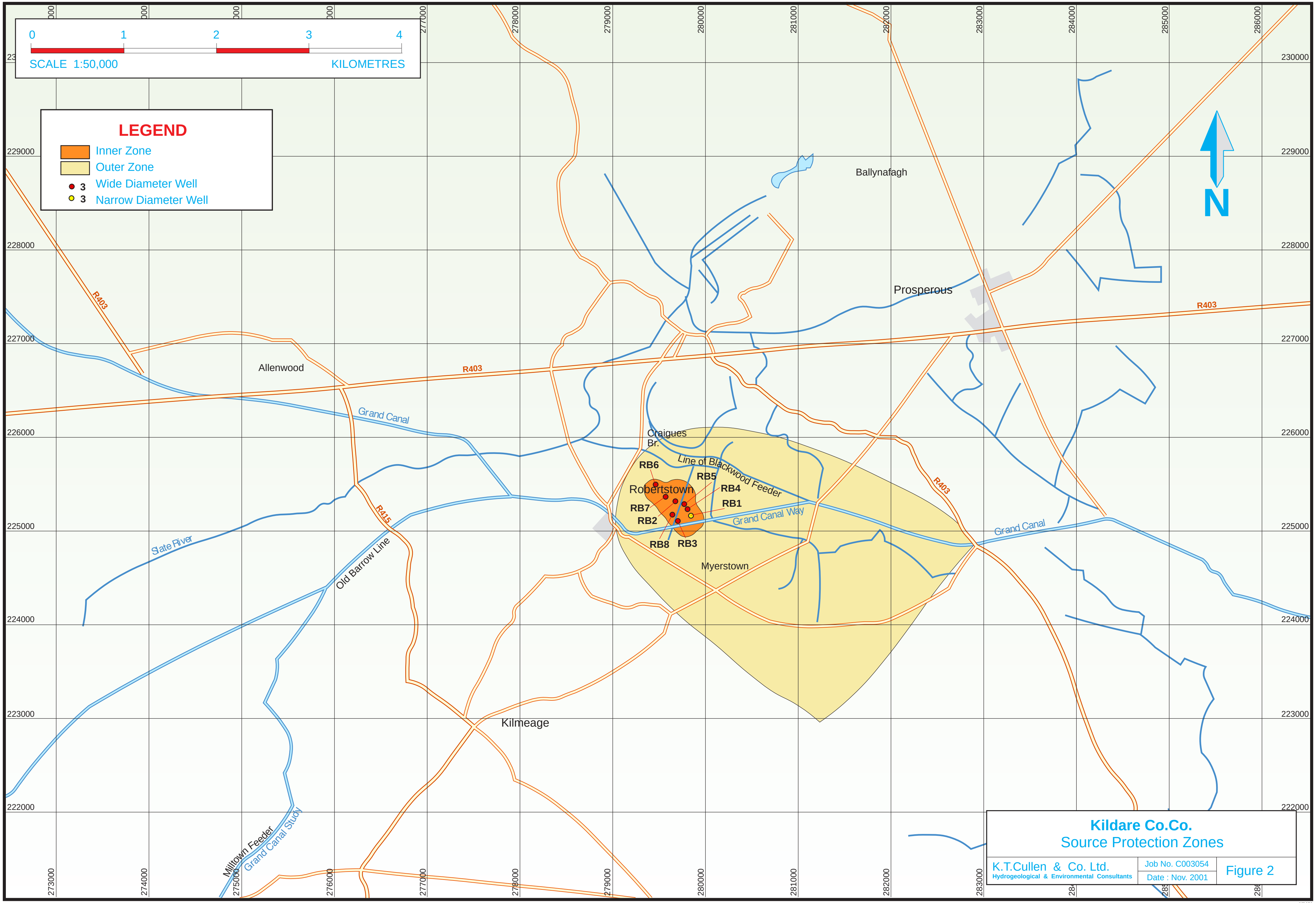

0 1 2 3 4
SCALE 1:50,000
KILOMETRES
LEGEND
Inner Zone
Outer Zone
3 Wide Diameter Well
3 Narrow Diameter Well
N
Ballynafagh
Prosperous
Allenwood
R403
Grand Canal
Craigues Br.
Line of Blackwood Feeder
RB6
RB5
RB4
RB1
RB7
RB2
RB8
RB3
Robertstown
Grand Canal Way
Myerstown
R415
Slate River
Old Barrow Line
Kilmeage
Milltown Feeder
Grand Canal Study
230000
229000
228000
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226000
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223000
222000
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Kildare Co.Co.
Source Protection Zones
K.T.Cullen & Co. Ltd.
Hydrogeological & Environmental Consultants
Job No. C003054
Date : Nov. 2001
Figure 2
JF(8)

Appendix I Extract taken from Groundwater Protection Schemes (DELG, EPA, GSI, 1999)

The following text is taken from **Groundwater Protection Schemes**, which was jointly published in 1999 by the Department of Environment and Local Government (DELG), Environmental Protection Agency (EPA) and Geological Survey of Ireland (GSI). This Appendix gives details on the two main components of Groundwater Protection Schemes – land surface zoning and groundwater protection responses. It is included here so that this can be a stand alone report for the reader. However, it is recommended that for a full overview of the groundwater protection methodology, the publications **Groundwater Protection Responses for On-Site Systems for Single Houses ('septic tanks')**, **Groundwater Protection Responses for Landfills** and **Groundwater Protection Responses for Landspreading of Organic Wastes** should be consulted. These publications are available from the GSI, EPA and Government Publications Office.

Land Surface Zoning

Vulnerability Categories

Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities.

The vulnerability of groundwater depends on: (i) the time of travel of infiltrating water (and contaminants); (ii) the relative quantity of contaminants that can reach the groundwater; and (iii) the contaminant attenuation capacity of the geological materials through which the water and contaminants infiltrate. As all groundwater is hydrologically connected to the land surface, it is the effectiveness of this connection that determines the relative vulnerability to contamination. Groundwater that readily and quickly receives water (and contaminants) from the land surface is considered to be more vulnerable than groundwater that receives water (and contaminants) more slowly and in lower quantities. The travel time, attenuation capacity and quantity of contaminants are a function of the following natural geological and hydrogeological attributes of any area:

(i) the subsoils that overlie the groundwater;
(ii) the type of recharge - whether point or diffuse; and
(iii) the thickness of the unsaturated zone through which the contaminant moves.

In general, little attenuation of contaminants occurs in the bedrock in Ireland because flow is almost wholly via fissures. Consequently, the subsoils (sands, gravels, glacial tills (or boulder clays), peat, lake and alluvial silts and clays), are the single most important natural feature influencing groundwater vulnerability and groundwater contamination prevention. Groundwater is most at risk where the subsoils are absent or thin and, in areas of karstic limestone, where surface streams sink underground at swallow holes.

The geological and hydrogeological characteristics can be examined and mapped, thereby providing a groundwater vulnerability assessment for any area or site. Four groundwater vulnerability categories are used in the scheme – **extreme (E)**, **high (H**), **moderate (M**) and **low (L**). The hydrogeological basis for these categories is summarised in Table A.1 and further details can be obtained from the GSI. The ratings are based on pragmatic judgements, experience and available technical and scientific information. However, provided the limitations are appreciated, vulnerability assessments are essential when considering the location of potentially polluting activities. As groundwater is considered to be present everywhere in Ireland, the vulnerability concept is applied to the entire land surface. The ranking of vulnerability does not take into consideration the biologically-active soil zone, as contaminants from point sources are usually discharged below this zone, often at depths of at least 1 m. However, the groundwater protection responses take account of the point of discharge for each activity.

Vulnerability maps are an important part of Groundwater Protection Schemes and are an essential element in the decision-making on the location of potentially polluting activities. Firstly, the vulnerability rating for an area indicates, and is a measure of, the likelihood of contamination. Secondly, the vulnerability map helps to ensure that a Groundwater Protection Scheme is not unnecessarily restrictive on human economic activity. Thirdly, the vulnerability map helps in the choice of preventative measures and enables developments, which have a significant potential to contaminate, to be located in areas of lower vulnerability.

In summary, the entire land surface is divided into four vulnerability categories – extreme (**E**), high (**H**), moderate (**M**) and low (**L**) – based on the geological and hydrogeological factors described above. This subdivision is shown on a groundwater vulnerability map. The map shows the vulnerability of the first groundwater encountered (in either sand/gravel aquifers or in bedrock) to contaminants released at depths of 1–2 m below the ground surface. Where contaminants are released at significantly different depths, there will be a need to determine groundwater vulnerability using site-specific data. The characteristics of individual contaminants are not taken into account.

Table A.1 Vulnerability Mapping Guidelines

Vulnerability Rating	**Hydrogeological Conditions**				
	Subsoil Permeability (Type) and Thickness			**Unsaturated Zone**	**Karst Features**
	high permeability (*sand/gravel*)	moderate permeability (e.g. *sandy subsoil*)	low permeability (e.g. *clayey subsoil, clay, peat*)	(*sand/gravel* aquifers only)	(<30 m radius)
Extreme (E)	0–3.0 m	0–3.0 m	0–3.0 m	0–3.0 m	–
High (H)	>3.0 m	3.0–10.0 m	3.0–5.0 m	>3.0 m	N/A
Moderate (M)	N/A	>10.0 m	5.0–10.0	N/A	N/A
Low (L)	N/A	N/A	>10.0 m	N/A	N/A

Notes: i) N/A = not applicable.
ii) Precise permeability values cannot be given at present.
iii) Release point of contaminants is assumed to be 1-2 m below ground surface.

Source Protection Zones

Groundwater sources, particularly public, group scheme and industrial supplies, are of critical importance in many regions. Consequently, the objective of source protection zones is to provide protection by placing tighter controls on activities within all or part of the zone of contribution (ZOC) of the source.

There are two main elements to source protection land surface zoning:
Areas surrounding individual groundwater sources; these are termed source protection areas (SPAs).
Division of the SPAs on the basis of the vulnerability of the underlying groundwater to contamination.

These elements are integrated to give the source protection zones.

Delineation of Source Protection Areas

Two source protection areas are recommended for delineation:
Inner Protection Area (SI);
Outer Protection Area (SO), encompassing the remainder of the source catchment area or ZOC.

In delineating the inner (SI) and outer (SO) protection areas, there are two broad approaches: first, using arbitrary fixed radii, which do not incorporate hydrogeological considerations; and secondly, a scientific approach using hydrogeological information and analysis, in particular the hydrogeological characteristics of the aquifer, the direction of groundwater flow, the pumping rate and the recharge.

Where the hydrogeological information is poor and/or where time and resources are limited, the simple zonation approach using the arbitrary fixed radius method is a good first step that requires little technical expertise. However, it can both over- and under-protect. It usually over-protects on the downgradient side of the source and may under-protect on the upgradient side, particularly in karst areas. It is particularly inappropriate in the case of springs where there is no part of the downgradient side in the ZOC. Also, the lack of a scientific basis reduces its defensibility as a method.

There are several hydrogeological methods for delineating SPAs. They vary in complexity, cost and the level of data and hydrogeological analysis required. Four methods, in order of increasing technical sophistication, are used by the GSI:
(i) calculated fixed radius;
(ii) analytical methods;
(iii) hydrogeological mapping; and
(iv) numerical modelling.

Each method has limitations. Even with relatively good hydrogeological data, the heterogeneity of Irish aquifers will generally prevent the delineation of definitive SPA boundaries. Consequently, the boundaries must be seen as a guide for decision-making, which can be re-appraised in the light of new knowledge or changed circumstances.

Inner Protection Area (SI)

This area is designed to protect against the effects of human activities that might have an immediate effect on the source and, in particular, against microbial pollution. The area is defined by a 100-day time of travel (ToT) from any point below the water table to the source. (The ToT varies significantly between regulatory agencies in different countries. The 100-day limit is chosen for Ireland as a relatively conservative limit to allow for the heterogeneous nature of Irish aquifers and to reduce the risk of pollution from bacteria and viruses, which in some circumstances can live longer than 50 days in groundwater.) In karst areas, it will not usually be feasible to delineate 100-day ToT boundaries, as there are large variations in permeability, high flow velocities and a low level of predictability. In these areas, the total catchment area of the source will frequently be classed as SI.

If it is necessary to use the arbitrary fixed radius method, a distance of 300 m is normally used. A semi-circular area is used for springs. The distance may be increased for sources in karst aquifers and reduced in granular aquifers and around low yielding sources.

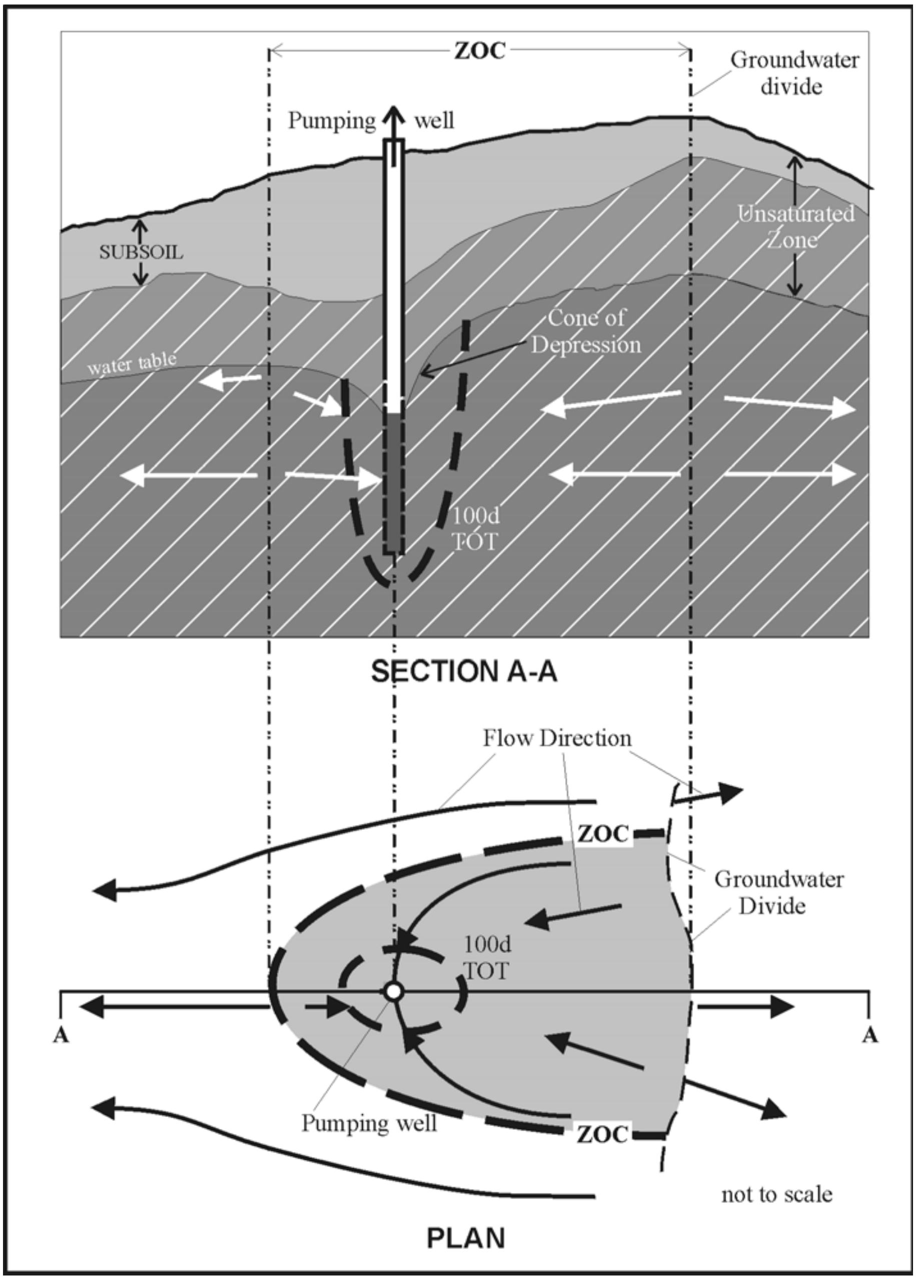
Outer Protection Area (SO)

This area covers the remainder of the ZOC (or complete catchment area) of the groundwater source. It is defined as the area needed to support an abstraction from long-term groundwater recharge i.e. the proportion of effective rainfall that infiltrates to the water table. The abstraction rate used in delineating the zone will depend on the views and recommendations of the source owner. A factor of safety can be taken into account whereby the maximum daily abstraction rate is increased (typically by 50%) to allow for possible future increases in abstraction and for expansion of the ZOC in dry periods. In order to take account of the heterogeneity of many Irish aquifers and possible errors in estimating the groundwater flow direction, a variation in the flow direction (typically ±10–20°) is frequently included as a safety margin in delineating the ZOC.

A conceptual model of the ZOC and the 100-day ToT boundary is given in Fig. A.1.

If the arbitrary fixed radius method is used, a distance of 1000 m is recommended with, in some instances, variations in karst aquifers and around springs and low-yielding wells.

The boundaries of the SPAs are based on the horizontal flow of water to the source and, in the case particularly of the Inner Protection Area, on the time of travel in the aquifer. Consequently, the vertical movement of a water particle or contaminant from the land surface to the water table is not taken into account. This vertical movement is a critical factor in contaminant attenuation, contaminant flow velocities and in dictating the likelihood of contamination. It can be taken into account by mapping the groundwater vulnerability to contamination.



Delineation of Source Protection Zones

The matrix in Table A.2 gives the result of integrating the two elements of land surface zoning (SPAs and vulnerability categories) – a possible total of eight source protection zones. In practice, the source protection zones are obtained by superimposing the vulnerability map on the source protection area map. Each zone is represented by a code e.g. SO/H, which represents an Outer Source Protection area where the groundwater is highly vulnerable to contamination. The recommended map scale is 1:10,560 (or 1:10,000 if available), though a smaller scale may be appropriate for large springs.

All of the hydrogeological settings represented by the zones may not be present around each groundwater source. The integration of the SPAs and the vulnerability ratings is illustrated in Fig. A.2.

Table A.2 Matrix of Source Protection Zones

VULNERABILITY RATING	**SOURCE PROTECTION**	
	Inner (SI)	***Outer (SO)***
Extreme (E)	SI/E	SO/E
High (H)	SI/H	SO/H
Moderate (M)	SI/M	SO/M
Low (L)	SI/L	SO/L

Resource Protection Zones

For any region, the area outside the SPAs can be subdivided, based on the value of the resource and the hydrogeological characteristics, into eight aquifer categories:

Regionally Important (R) Aquifers

(i) Karstified aquifers (**Rk**)
(ii) Fissured bedrock aquifers (**Rf**)
(iii) Extensive sand/gravel aquifers (**Rg**)

Locally Important (L) Aquifers

(i) Sand/gravel (**Lg**)
(ii) Bedrock which is Generally Moderately Productive (**Lm**)

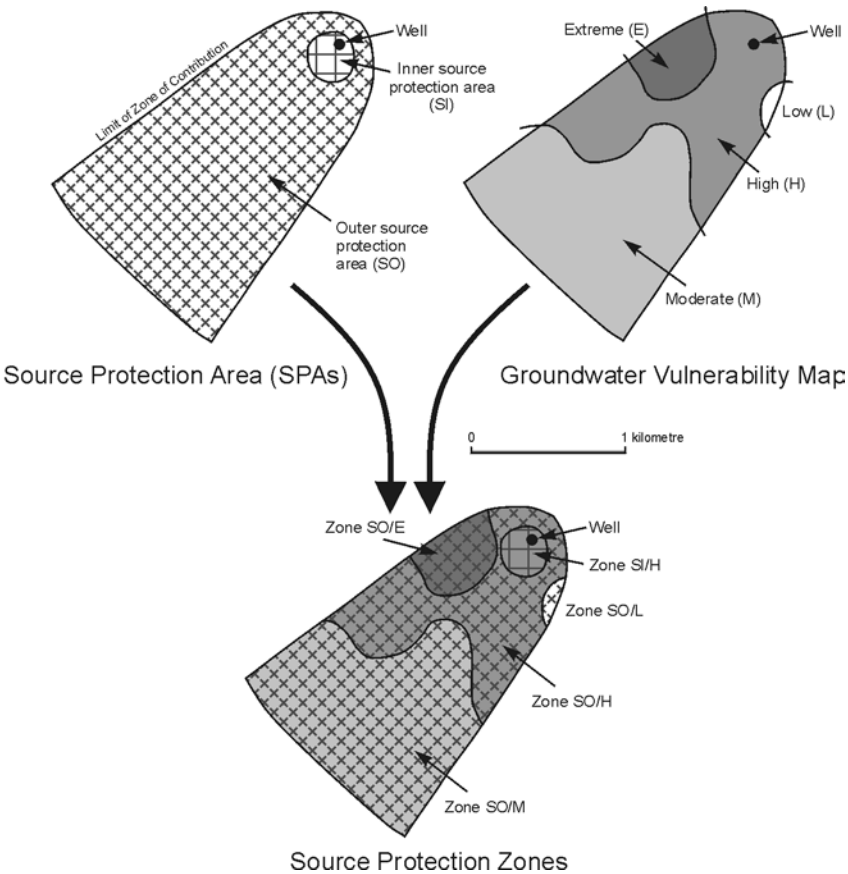


Fig. A.2 Delineation of Source Protection Zones Around a Public Supply Well from the Integration of the Source Protection Area Map and the Vulnerability Map

(iii) Bedrock which is Moderately Productive only in Local Zones (**Ll**)

Poor (P) Aquifers
(i) Bedrock which is Generally Unproductive except for Local Zones (**Pl**)
(ii) Bedrock which is Generally Unproductive (**Pu**)

These aquifer categories are shown on an aquifer map, which can be used not only as an element of a Groundwater Protection Scheme but also for groundwater development purposes.

The matrix in Table A.3 gives the result of integrating the two regional elements of land surface zoning (vulnerability categories and resource protection areas) – a possible total of 24 resource protection zones. In practice this is achieved by superimposing the vulnerability map on the aquifer map. Each zone is represented by a code e.g. **Rf/M**, which represents areas of regionally important fissured aquifers where the groundwater is moderately vulnerable to contamination. In land surface zoning for groundwater protection purposes, regionally important sand/gravel (**Rg**) and fissured aquifers (**Rf**) are zoned together, as are locally important sand/gravel (**Lg**) and bedrock which is moderately productive (**Lm**). All of the hydrogeological settings represented by the zones may not be present in each local authority area.

Flexibility, Limitations and Uncertainty
The land surface zoning is only as good as the information which is used in its compilation (geological mapping, hydrogeological assessment, etc.) and these are subject to revision as new information is produced. Therefore a scheme must be flexible and allow for regular revision.

Uncertainty is an inherent element in drawing geological boundaries and there is a degree of generalisation because of the map scales used. Therefore the scheme is not intended to give sufficient information for site-specific decisions. Also, where site specific data received by a regulatory body in the future are at variance with the maps, this does not undermine a scheme, but rather provides an opportunity to improve it.

Groundwater Protection Responses

Introduction
The location and management of potentially polluting activities in each groundwater protection zone is by means of a **groundwater protection response matrix** for each activity or group of activities. The level of response depends on the different elements of risk: the vulnerability, the value of the groundwater (with sources being more valuable than resources and regionally important aquifers more valuable than locally important and so on) and the contaminant loading. By consulting a **Response Matrix**, it can be seen: (a) whether such a development is likely to be acceptable on that site; (b) what kind of further investigations may be necessary to reach a final decision; and (c) what planning or licensing conditions may be necessary for that development. The groundwater protection responses are a means of ensuring that good environmental practices are followed.

Table A.3 Matrix of Groundwater Resource Protection Zones

VULNERABILITY RATING	**RESOURCE PROTECTION ZONES**					
	Regionally Important Aquifers (R)		**Locally Important Aquifers (L)**		**Poor Aquifers (P)**	
	Rk	**Rf/Rg**	**Lm/Lg**	**Ll**	**Pl**	**Pu**
Extreme (E)	Rk/E	Rf/E	Lm/E	Ll/E	Pl/E	Pu/E
High (H)	Rk/H	Rf/H	Lm/H	Ll/H	Pl/H	Pu/H
Moderate (M)	Rk/M	Rf/M	Lm/M	Ll/M	Pl/M	Pu/M
Low (L)	Rk/L	Rf/L	Lm/L	Ll/L	Pl/L	Pu/L

Four levels of response (**R**) to the risk of a potentially polluting activity are proposed:

R1 Acceptable subject to normal good practice.

R2[a,b,c,...] Acceptable in principle, subject to conditions in note a,b,c, etc. (The number and content of the notes may vary depending on the zone and the activity).

R3[m,n,o,...] Not acceptable in principle; some exceptions may be allowed subject to the conditions in note m,n,o, etc.

R4 Not acceptable.

Integration of Groundwater Protection Zones and Response

The integration of the groundwater protection zones and the groundwater protection responses is the final stage in the production of a Groundwater Protection Scheme. The approach is illustrated for a hypothetical potentially polluting activity in the matrix in Table A.4.

The matrix encompasses both the geological/hydrogeological and the contaminant loading aspects of risk assessment. In general, the arrows (→↓) indicate directions of decreasing risk, with ↓ showing the decreasing likelihood of contamination and → showing the direction of decreasing consequence. The contaminant loading aspect of risk is indicated by the activity type in the table title.

The response to the risk of groundwater contamination is given by the response category allocated to each zone and by the site investigations and/or controls and/or protective measures described in notes a, b, c, d, m, n and o.

It is advisable to map existing hazards in the higher risk areas, particularly in zones of contribution of significant water supply sources. This would involve conducting a survey of the area and preparing an inventory of hazards. This may be followed by further site inspections, monitoring and a requirement for operational modifications, mitigation measures and perhaps even closure, as deemed necessary. New potential sources of contamination can be controlled at the planning or licensing stage, with monitoring required in some instances. In all cases the control measures and response category depend on the potential contaminant loading, the groundwater vulnerability and the groundwater value.

In considering a scheme, it is essential to remember that: (a) a scheme is intended to provide guidelines to assist decision-making on the location and nature of developments and activities with a view to ensuring the protection of groundwater; and (b) delineation of the groundwater protection zones is dependent on the data available and site specific data may be required to clarify requirements in some instances. It is intended that the statutory authorities should apply a scheme in decision-making on the basis that the best available data are being used. The onus is then on a developer to provide new information which would enable the zonation to be altered and improved and, in certain circumstances, the planning or regulatory response to be changed.

Table A.4 Groundwater Protection Response Matrix for a Hypothetical Activity

VULNERABILITY RATING	SOURCE PROTECTION		RESOURCE PROTECTION						
			Regionally Imp.		Locally Imp.		Poor Aquifers		
	Inner	*Outer*	*Rk*	*Rf/Rg*	*Lm/Lg*	*Ll*	*Pl*	*Pu*	
Extreme (E)	R4	R4	R4	R4	R3[m]	R2[d]	R2[c]	R2[b]	↓
High (H)	R4	R4	R4	R3[m]	R3[n]	R2[c]	R2[b]	R2[a]	↓
Moderate (M)	R4	R3[m]	R3[m]	R2[d]	R2[c]	R2[b]	R2[a]	R1	↓
Low (L)	R3[m]	R3[o]	R2[d]	R2[c]	R2[b]	R2[a]	R1	R1	↓
	→	→	→	→	→	→	→	→	→

(Arrows (→ ↓) indicate directions of decreasing risk)

Use of a Scheme

The use of a scheme is dependent on the availability of the groundwater protection responses for different activities. Currently, responses have been developed for three potentially polluting activities: IPC-licensable landspreading of organic wastes (primarily piggeries and poultry waste), domestic wastewater treatment systems, and landfills. Additional responses for other potentially polluting activities will be developed in the future.

Summary of Permeability Data and Analyses for Subsoils Mapped as Till, and Overlain by Fontstown Series Soils

Description of unit location:	Undulating to flat. Mostly in the southern half of the county. Strong correlation between fontstown soil type and tillage areas.
Why is this a single K unit?	Occupies 22% of county, largely southern and western parts.

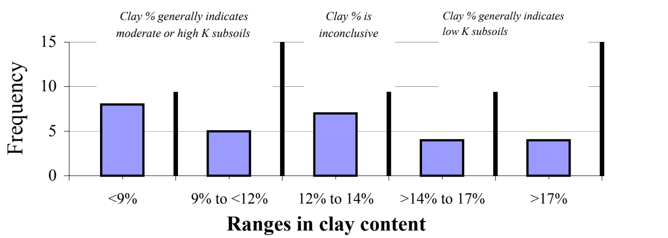
1. General Permeability Indicators and Region Characteristics

Rock type	Limestone
Depth to bedrock	Generally >3m
Subsoil type	Till
Soil type	Fontstown is the main type. Mylerstown, Mortartstown and Kilpatrick groundwater gley series are included where they are mapped in low-lying Fontstown areas. 28 samples
Vegetation and land use	Pasture and tillage
Artificial drainage density	Few drains
Natural drainage density	Low
Topography and altitude	Undulating-flat topography. 60-150m OD.
Ave. effective rainfall (mm)	The mean ppt is 750-875mm per annum

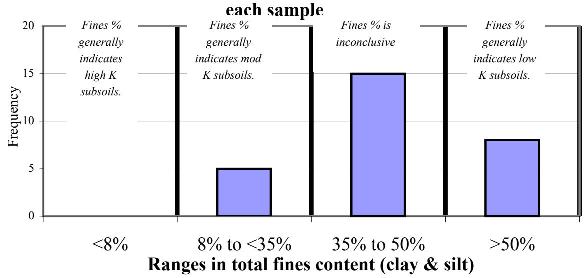
2. Summary of Particle Size Analysis and Field Descriptions of Subsoil Samples.

NB Particle distributions adjusted to discount particles greater than 20mm. Graphs only depict samples taken from 1) a known depth exceeding 1.5m in boreholes or 1m in exposures, AND 2) locations not at permeability boundaries.

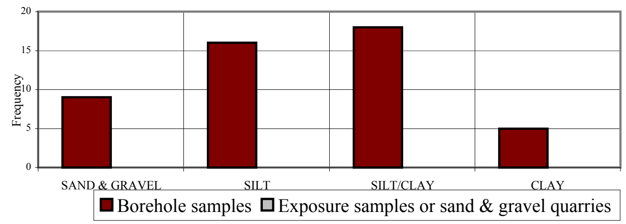
Summary of particle size data: proportion of clay fraction in each sample



Summary of particle size data: proportion of total fines fraction in each sample



Field description of samples: range in principal subsoil types described using BS5930:1999



3. Data from Permeability Tests.

T' tests: min/25mm	# Results	# Tests T<1	# Tests T>50	Variable head tests (m/sec):	# Results	Range Values	Typical value	Pump tests (m/sec):	# Results	Range Values	Typical value	Lab tests (m/sec):	# Results	Range Values	Typical value

4. Summary and Analysis

Criteria	Comments		Implications of each criterion for assessment of subsoil permeability
Quaternary / subsoil origin	Limestone Till	>>>	M-L
Particle size data	Wide variation	>>>	M-L
Field description data	Generally silty subsoils	>>>	M
Soil type	Well - excessively drained soil	>>>	M
Artificial drainage density	Generally very low density, but higher desnity occurs in localised areas.	>>>	M
Natural drainage density	Generally low	>>>	M
Permeability test data	-	>>>	-
Rock type	Limestone (occasionally shaley limestone)	>>>	L-M
Land use	Tillage & Pasture	>>>	M
	Overall conclusion	>>>	**Moderate**

5. COMMENTS: Subsoil permeability indicators are variable, but the soil maps indicate that the area is generally excessively well drained, and field descriptions were mainly silty or sandy subsoils, on balance, a moderate permeability has been assigned. It is likely that the very frequency sand and gravel units mapped on the margins of this unit, are in fact interspersed within it. This would help to increase the overall subsoil permeability.

Summary of Permeability Data and Analyses for Subsoils Mapped as Till, and Overlain by Elton Series Soils

Description of unit location:	Undulating-flat. Mostly east & north of county. 25% of county.
Why is this a single K unit?	Occupies 25% of the county & largely eastern and northern parts of county.

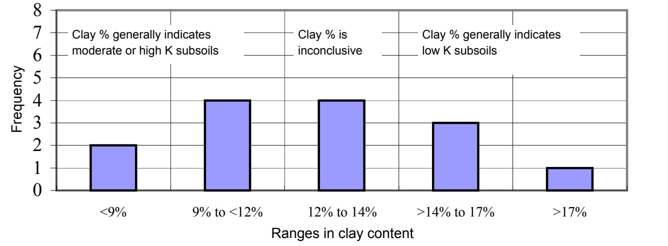
1. General Permeability Indicators and Region Characteristics

Rock type	Carrighill, Ballysteen and Calp Formations.
Depth to bedrock	Wide variety of depth to bedrock
Subsoil type	Limestone till, some admixture of shale/granites closer to the wicklow border. Undifferentiated till in the north.
Soil type	Dominantly Elton series. Dunnstown (groundwater gley) is included as the Elton and Dunnstown are associated, with Dunnstown occupying the lower-lying areas. A small pocket of the mortarstwon series is also included as it occurs within the Elton series. Fourteen samples were used for Particle Size Analysis.
Vegetation and land use	Pasture/stud farms are found on this soil type.
Artificial drainage density	Low on the elton, some artificial drainage on the dunnstown, particularly around Martinstown.
Natural drainage density	Low
Topography and altitude	Undulating - flat; normally <150m
Ave. effective rainfall (mm)	Precipitation is variable (750-<1000mm)

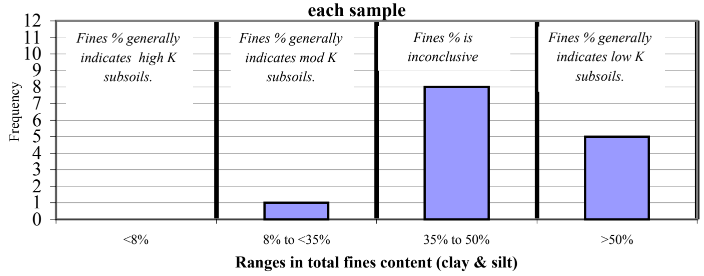
2. Summary of Particle Size Analysis and Field Descriptions of Subsoil Samples.

NB Particle distributions adjusted to discount particles greater than 20mm. Graphs only depict samples taken from 1) a known depth exceeding 1.5m in boreholes or 1m in exposures, AND 2) locations not at permeability boundaries.

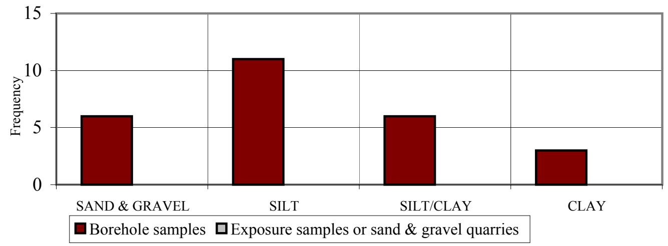
Summary of particle size data: proportion of clay fraction in each sample



Summary of particle size data: proportion of total fines fraction in each sample



Field description of samples: range in principal subsoil types described using BS5930:1999



3. Data from Permeability Tests.

T' tests: min/25mm # Results	# Tests T<1	# Tests T>50	**Variable head tests (m/sec):** # Results	Range Values	Typical value	**Pump tests (m/sec):** # Results	Range Values	Typical value	**Lab tests (m/sec):** # Results	Range Values	Typical value

4. Summary and Analysis

Criteria	**Comments**		**Implications of each criterion for assessment of subsoil permeability**
Quaternary / subsoil origin	Limestone till	>>>	M-L
Particle size data	A wide variation	>>>	M
Field description data	Generally silty subsoils	>>>	M
Soil type	Well - excessively drained soil	>>>	M-L
Artificial drainage density	Generally very low density, but higher desnity occurs in localised areas.	>>>	M
Natural drainage density	Generally low	>>>	M
Permeability test data	-	>>>	-
Rock type	Generally muddy limestones	>>>	L-M
Land use	Tillage and pasture	>>>	M
	Overall conclusion	>>>	M

5. COMMENTS: Subsoil permeability indicators are variable, but the soil maps indicate that the area is generally excessively well drained, and field descriptions were mainly silty or sandy subsoils, on balance, a moderate permeability has been assigned. It is likely that the very frequency sand and gravel units mapped on the margins of this unit, are in fact interspersed within it. This would help to increase the overall subsoil permeability.

Summary of Permeability Data and Analyses for Subsoils Mapped as Till, and Overlain by Kennycourt Series Soils

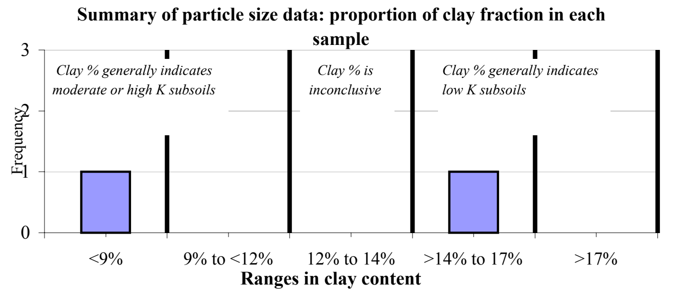
Description of unit location:	Rolling. 4% of county, eastern part bordering wicklow and dublin.
Why is this a single K unit?	Occupies the lower slopes of the Wicklow mountains.

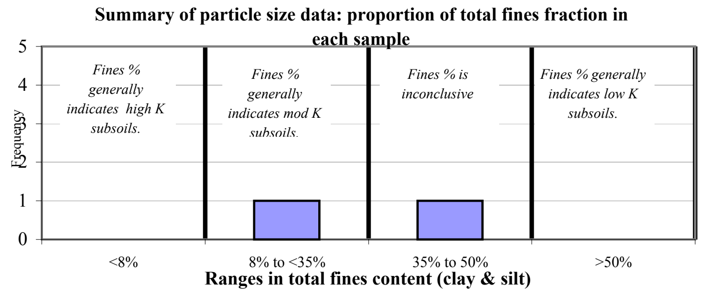
1. General Permeability Indicators and Region Characteristics

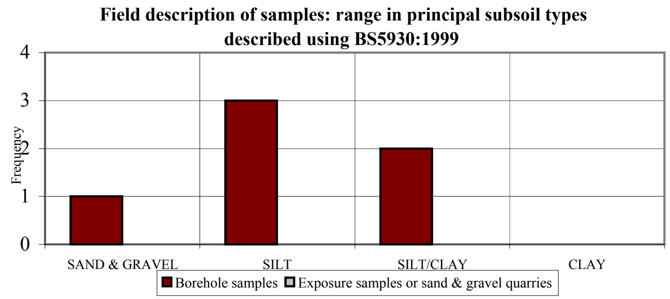
Rock type	Greywackes & shales
Depth to bedrock	Generally 3-5m
Subsoil type	Limestone till
Soil type	Kennycourt - stony loam, well drained. Six samples.
Vegetation and land use	Pasture
Artificial drainage density	low
Natural drainage density	low
Topography and altitude	150-240 m OD, rolling, 4 degree slopes.
Ave. effective rainfall (mm)	875-1000mm ppt.

2. Summary of Particle Size Analysis and Field Descriptions of Subsoil Samples.

NB Particle distributions adjusted to discount particles greater than 20mm. Graphs only depict samples taken from 1) a known depth exceeding 1.5m in boreholes or 1m in exposures, AND 2) locations not at permeability boundaries.







3. Data from Permeability Tests.

T' tests: min/25mm	# Results	# Tests T<1	# Tests T>50	Variable head tests (m/sec):	# Results	Range Values	Typical value	Pump tests (m/sec):	# Results	Range Values	Typical value	Lab tests (m/sec):	# Results	Range Values	Typical value

4. Summary and Analysis

Criteria	Comments		Implications of each criterion for assessment of subsoil permeability
Quaternary / subsoil origin	Limestone Till	>>>	M-L
Particle size data	Two samples of variable clay fraction.	>>>	H-M
Field description data	Generally silty subsoils	>>>	H-M
Soil type	Well-excessively well drained	>>>	M
Artificial drainage density	No artifical drainage	>>>	M
Natural drainage density	Low	>>>	M
Permeability test data	-	>>>	-
Rock type	Shales	>>>	L-M
Land use	Pasture	>>>	M
	Overall conclusion	>>>	M

5. COMMENTS: Subsoil permeability indicators are variable, but the soil maps indicate that the area is generally well well drained, and field descriptions were mainly silty subsoils, on balance, a moderate permeability has been assigned. It is likely that the very frequency sand and gravel units mapped on the margins of this unit, are in fact interspersed within it. This would help to increase the overall subsoil permeability.

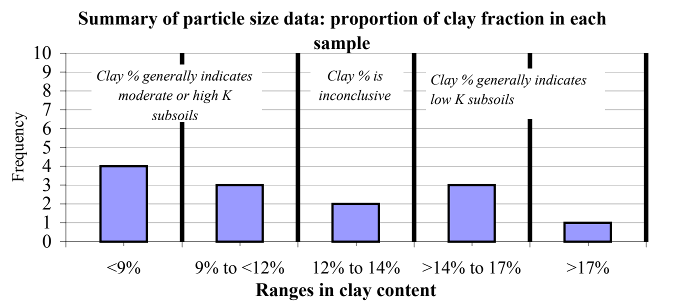
Description of unit location:	Flat - undulating, occupying large areas of North Kildare.
Why is this a single K unit?	Occupies 13% of the county largely north Kildare

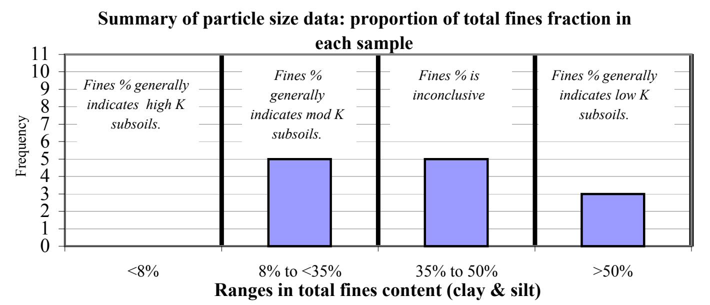
1. General Permeability Indicators and Region Characteristics

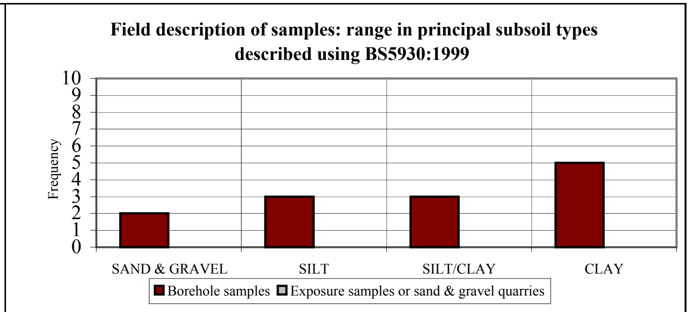
Rock type	Calp limestone
Depth to bedrock	Generally 3-5 & 5-10m
Subsoil type	Undifferentiated till
Soil type	Straffan complex comprises 6 soil series mostly gley soils. Thirteen samples were used in the analysis.
Vegetation and land use	Generally pasture, some tillage and some rushy areas.
Artificial drainage density	Considerable areas have undergone artificial drainage, comprising deepening of water courses and installing of closed field drains.
Natural drainage density	High
Topography and altitude	Flat - undulating; 60-90m OD
Ave. effective rainfall (mm)	precipitation is approximately 750mm

2. Summary of Particle Size Analysis and Field Descriptions of Subsoil Samples.

NB Particle distributions adjusted to discount particles greater than 20mm. Graphs only depict samples taken from 1) a known depth exceeding 1.5m in boreholes or 1m in exposures, AND 2) locations not at permeability boundaries.







3. Data from Permeability Tests.

T' tests: min/25mm	# Results	# Tests T<1	# Tests T>50	Variable head tests (m/sec):	# Results	Range Values	Typical value	Pump tests (m/sec):	# Results	Range Values	Typical value	Lab tests (m/sec):	# Results	Range Values	Typical value

4. Summary and Analysis

Criteria	Comments		Implications of each criterion for assessment of subsoil permeability
Quaternary / subsoil origin	Undifferentiated till	>>>	L-M
Particle size data	Wide variation	>>>	L-M
Field description data	Generally clayey subsoils	>>>	L
		>>>	
Soil type	Mostly gleys, clay loams comprises 70% of complex	>>>	L
Artificial drainage density	High	>>>	L-M
Natural drainage density	High	>>>	L-M
Permeability test data		>>>	
Rock type	Muddy Limestone (Calp Limestone)	>>>	L-M
Land use	Generally pasture	>>>	M
	Overall conclusion	>>>	**L**

5. COMMENTS: Subsoil permeability indicators are variable, but the soil maps indicate that the area is generally poorly drained and field descriptions were mainly clayey subsoils, on balance, a Low permeability has been assigned.

Summary of Permeability Data and Analyses for Subsoils Mapped as Till, and Overlain by Allenwood Complex

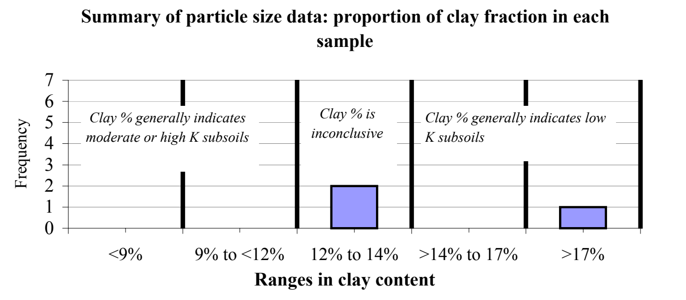
Description of unit location:	The allenwood complex occupies the margins of the peat/bogs (allen + banagher (reclaimed peat)) in the northern part of the county. It comprises the mylerstown gw gley and peaty gleys. Occupies 1% of county.
Why is this a single K unit?	Occupying the areas between the Fontstown/Elton soil series and the Banagher/Allen peat series.

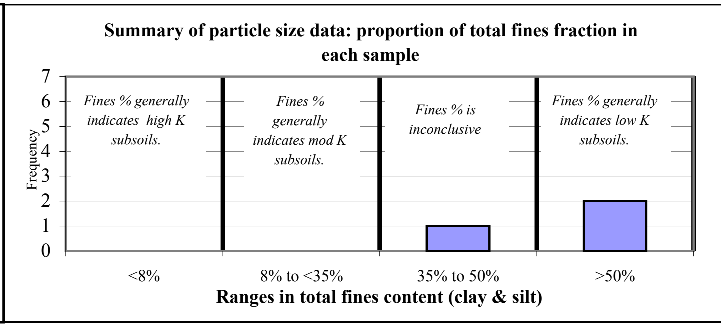
1. General Permeability Indicators and Region Characteristics

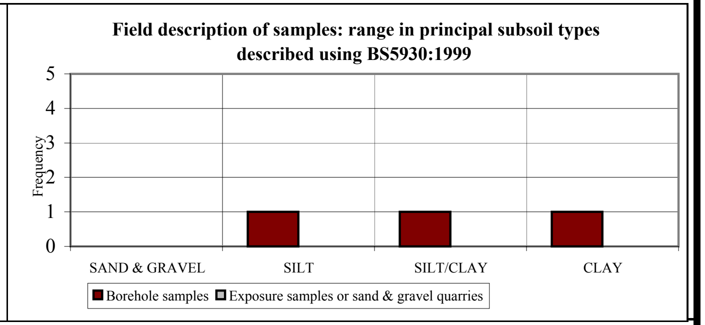
Rock type	BN boston hill fmn - nodular muddy lst&shale
Depth to bedrock	Generally greater than 10m
Subsoil type	Undifferentiated till (clayey gravel/gravelly clay)
Soil type	Allenwood complex comprises the mylerstown groundwater gley & peaty gleys, thus a mixture of peaty soils and grey-brown podzolics. Three samples analysed.
Vegetation and land use	Rushes where it is not managed and pasture where it has undergone drainage.
Artificial drainage density	High
Natural drainage density	High
Topography and altitude	Flat.
Ave. effective rainfall (mm)	750-875mm of precipitation.

2. Summary of Particle Size Analysis and Field Descriptions of Subsoil Samples.

NB Particle distributions adjusted to discount particles greater than 20mm. Graphs only depict samples taken from 1) a known depth exceeding 1.5m in boreholes or 1m in exposures, AND 2) locations not at permeability boundaries.







3. Data from Permeability Tests.

T' tests: min/25mm	# Results	# Tests T<1	# Tests T>50	Variable head tests (m/sec):	# Results	Range Values	Typical value	Pump tests (m/sec):	# Results	Range Values	Typical value	Lab tests (m/sec):	# Results	Range Values	Typical value

4. Summary and Analysis

Criteria	Comments	Implications of each criterion for assessment of subsoil permeability	
Quaternary / subsoil origin	Undifferentiated till	>>>	L-M
Particle size data	A variation from silty to clayey soils.	>>>	L-M
Field description data	A variation from silty to clayey subsoils.	>>>	L-M
Soil type	Loam-peaty loam-Peat	>>>	L-M
Artificial drainage density	High water table, big deep drains along perimeters and internal closed field drains	>>>	L-M
Natural drainage density	High water table, margins of peat bogs.	>>>	L-M
Permeability test data	-	>>>	none
Rock type	Muddy limestone	>>>	L-M
Land use	Where it has been drained there is rough pasture used for sheep grazing.	>>>	L-M
	Overall conclusion	>>>	M

5. COMMENTS: Subsoil permeability indicators are inconclusive, on balance in order to be conservative it is given a moderate permeability.

Summary of Permeability Data and Analyses for Subsoils Mapped as Till, and Overlain by Liffey regosol

Description of unit location:	Occupies the flood plain alongside the River Liffey.
Why is this a single K unit?	Occupies the flood plain alongside the River Liffey.

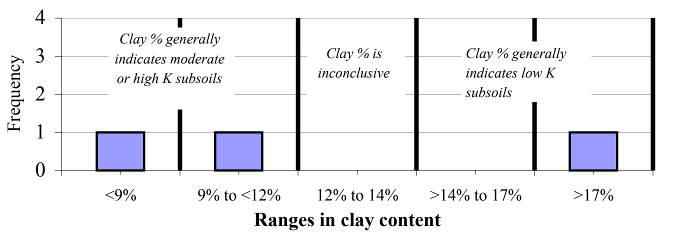
1. General Permeability Indicators and Region Characteristics

Rock type	Predominantly Limestone.
Depth to bedrock	Generally greater than 10m
Subsoil type	Limestone and undifferentiated till.
Soil type	Liffey regosol - alluvium - loam-silty-clay loam. Three samples
Vegetation and land use	Predominantly pasture
Artificial drainage density	Low
Natural drainage density	Low
Topography and altitude	Generally 60m OD.
Ave. effective rainfall (mm)	750-875 precipitation.

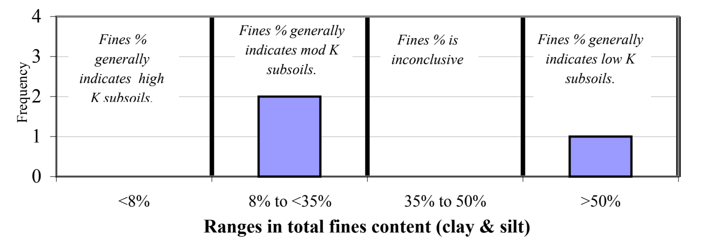
2. Summary of Particle Size Analysis and Field Descriptions of Subsoil Samples.

NB Particle distributions adjusted to discount particles greater than 20mm. Graphs only depict samples taken from 1) a known depth exceeding 1.5m in boreholes or 1m in exposures, AND 2) locations not at permeability boundaries.

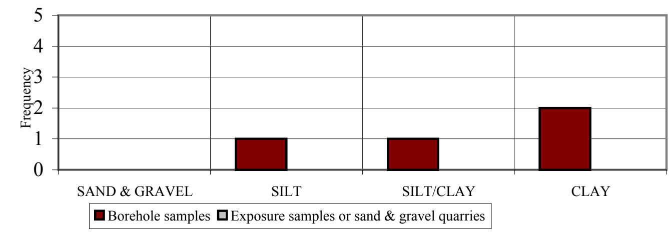
Summary of particle size data: proportion of clay fraction in each sample



Summary of particle size data: proportion of total fines fraction in each sample



Field description of samples: range in principal subsoil types described using BS5930:1999



3. Data from Permeability Tests.

T' tests: min/25mm	# Results	# Tests T<1	# Tests T>50	Variable head tests (m/sec):	# Results	Range Values	Typical value	Pump tests (m/sec):	# Results	Range Values	Typical value	Lab tests (m/sec):	# Results	Range Values	Typical value

4. Summary and Analysis

Criteria	Comments		Implications of each criterion for assessment of subsoil permeability
Quaternary / subsoil origin	Alluvium	>>>	M
Particle size data	Indicates moderate or high permeability subsoils	>>>	L
Field description data	Variation in the field description.	>>>	L-M
Soil type	Alluvium - well drained - loam	>>>	M
Artificial drainage density	Low	>>>	M
Natural drainage density	Low	>>>	M
Permeability test data	-	>>>	-
Rock type	Limestone	>>>	
Land use	Pasture	>>>	M
	Overall conclusion	>>>	M

5. COMMENTS: On balance subsoil indicators suggest that the alluvium alongside the River Liffey is moderately permeable.

Summary of Permeability Data and Analyses for Subsoils Mapped as Till, and Overlain by the Finnery Complex

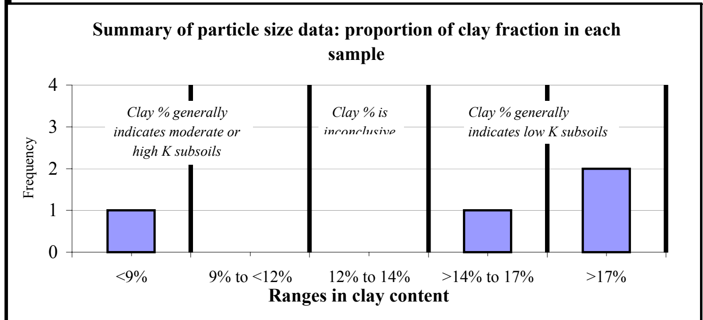
Description of unit location:	Occupying portions of the river valleys in the west of the county. Associated with a high water table all yr. Round. Mapped in Laois as Alluvium (subtypes Po & K), mapped in Limerick as the Camogue series
Why is this a single K unit?	Occupying the flood plains in the western part of Kildare, approximately 2.5% of the county.

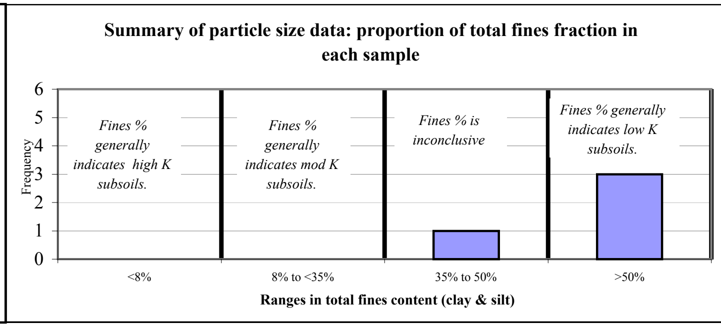
1. General Permeability Indicators and Region Characteristics

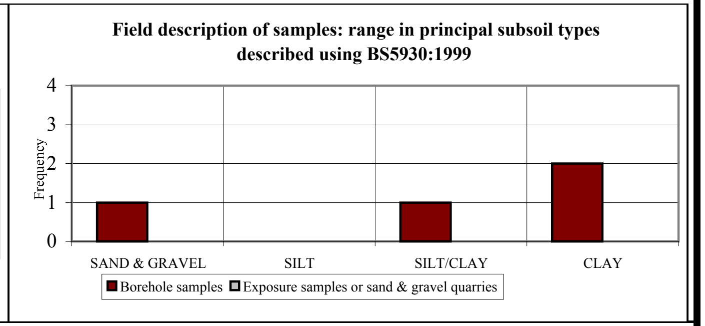
Rock type	Largely clean shelf limestones.
Depth to bedrock	Generally 5-10 and greater than 10m.
Subsoil type	Alluvium.
Soil type	Finnery complex comprises organic & mineral materials. Four samples were analysed.
Vegetation and land use	Largely restricted to rought summer grazing.
Artificial drainage density	Large open drains and closed field drains are common.
Natural drainage density	High
Topography and altitude	Flat and low-lying.
Ave. effective rainfall (mm)	Approximately 750mm of precipitation.

2. Summary of Particle Size Analysis and Field Descriptions of Subsoil Samples.

NB Particle distributions adjusted to discount particles greater than 20mm. Graphs only depict samples taken from 1) a known depth exceeding 1.5m in boreholes or 1m in exposures, AND 2) locations not at permeability boundaries.







3. Data from Permeability Tests.

T' tests: min/25mm	# Results	# Tests T<1	# Tests T>50	**Variable head tests (m/sec):**	# Results	Range Values	Typical value	**Pump tests (m/sec):**	# Results	Range Values	Typical value	**Lab tests (m/sec):**	# Results	Range Values	Typical value

4. Summary and Analysis

Criteria	**Comments**		**Implications of each criterion for assessment of subsoil permeability**
Quaternary / subsoil origin	Generally alluvium or till.	>>>	L-M
Particle size data	Variable with a tendency toward the low permeability end.	>>>	L-M
Field description data	Variable, a mixture of sandy and clayey subsoils.	>>>	L-M
Soil type	Alluvium and peat	>>>	M-L
Artificial drainage density	High	>>>	L
Natural drainage density	High	>>>	L
Permeability test data		>>>	-
Rock type	Limestones.	>>>	M-L
Land use	Pasture.	>>>	L-M
	Overall conclusion	>>>	M

5. COMMENTS: On balance subsoil indicators are not conclusive, to be conservative the complex is given a moderate permeability rating. This is a similar rating to that used in Laois for similar deposits.

Summary of Permeability Data and Analyses for Subsoils Mapped as Till, and Overlain by the Garristown Soil Series.

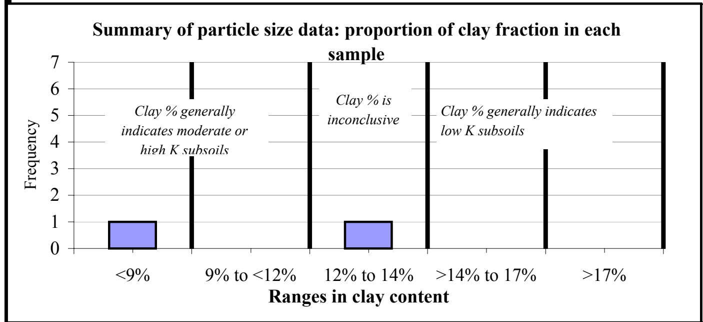
Description of unit location:	Occupy a small area in the very north of kildare adjacent to meath
Why is this a single K unit?	A surface water gley occupying a distinct area in North Kildare.

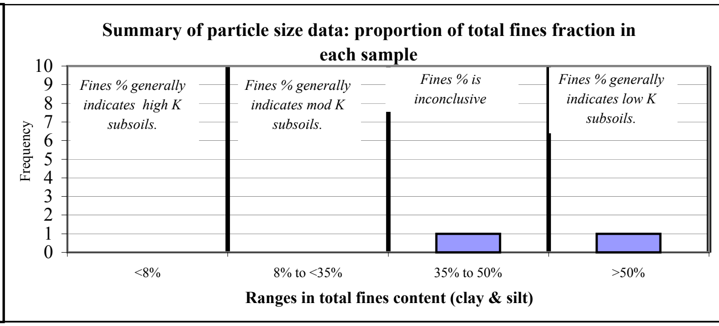
1. General Permeability Indicators and Region Characteristics

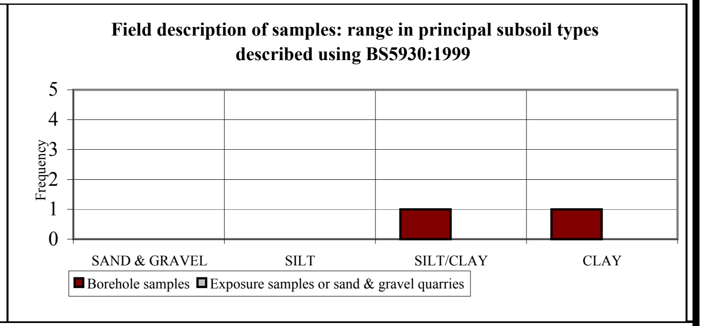
Rock type	Namurian shales NAM
Depth to bedrock	0-3;3-5m
Subsoil type	Undifferentiated till
Soil type	The Garristown soil series is aheavy textured clay loam of poor structure, and is a surface water gley. Two samples analysed.
Vegetation and land use	Pasture, rushes where there is no artificial drainage.
Artificial drainage density	Drained using closed field drains.
Natural drainage density	Several streams.
Topography and altitude	Rolling
Ave. effective rainfall (mm)	750-875mm of precipitation.

2. Summary of Particle Size Analysis and Field Descriptions of Subsoil Samples.

NB Particle distributions adjusted to discount particles greater than 20mm. Graphs only depict samples taken from 1) a known depth exceeding 1.5m in boreholes or 1m in exposures, AND 2) locations not at permeability boundaries.







3. Data from Permeability Tests.

T' tests: min/25mm	# Results	# Tests T<1	# Tests T>50	Variable head tests (m/sec):	# Results	Range Values	Typical value	Pump tests (m/sec):	# Results	Range Values	Typical value	Lab tests (m/sec):	# Results	Range Values	Typical value

4. Summary and Analysis

Criteria	Comments		Implications of each criterion for assessment of subsoil permeability
Quaternary / subsoil origin	Dense impermeable undifferentiated till	>>>	L-M
Particle size data	Variable and possibly not representative as there are patches of higher permeability material within the series	>>>	M-L
Field description data	Largely clayey subsoils.	>>>	M-L
Soil type	Clay Loam	>>>	L
Artificial drainage density	Closed field drains on sloping ground	>>>	L
Natural drainage density	High	>>>	L
Permeability test data	-	>>>	-
Rock type	Namurian shales (elsewhere in the country are typically associated with low permeability subsoils)	>>>	L
Land use	Pasture with rushy slopes where no field drains.	>>>	L
	Overall conclusion	>>>	L

5. Comments Subsoil permeability indicators suggest low permeability and the soil maps indicate that the area is poorly or imperfectly drained, and field descriptions were mainly clayey subsoils, on balance, a Low permeability has been assigned.

Summary of Permeability Data and Analyses for Subsoils Mapped as Till, and Overlain by Kellistown and Newtown soil series

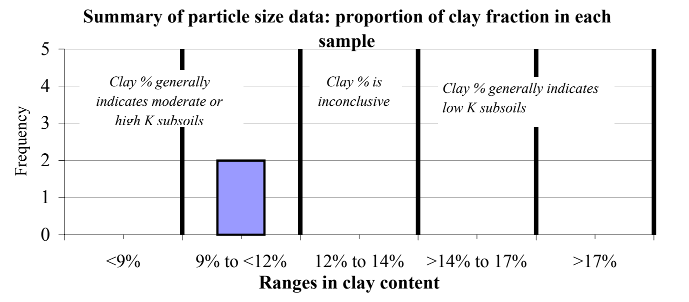
Description of unit location:	Mapped at the southern tip of kildare, intermingled with the Athy cpx and Newtown groundwater gley
Why is this a single K unit?	Occupies 1.6% of the county, confined to the southern tip of the county.

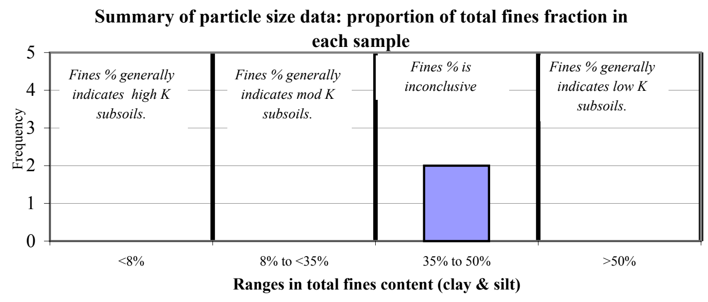
1. General Permeability Indicators and Region Characteristics

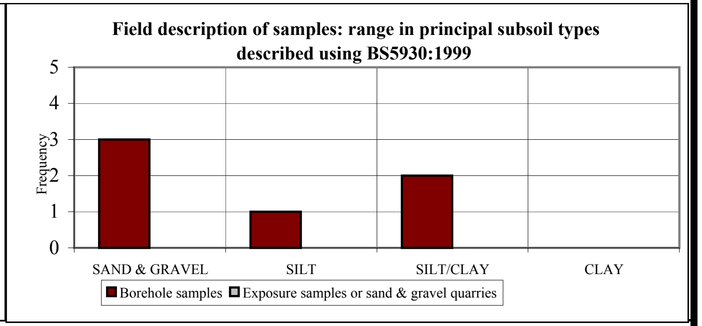
Rock type	Granite
Depth to bedrock	Largely 5-10m
Subsoil type	Limestone till
Soil type	The KELLISTOWN soil series, a sandy loam which is well drained. Six samples were used in the analysis.
Vegetation and land use	Largely tillage and pasture.
Artificial drainage density	Low
Natural drainage density	Low
Topography and altitude	Undulating to rolling; 60-120m OD
Ave. effective rainfall (mm)	750-875mm of precipitation.

2. Summary of Particle Size Analysis and Field Descriptions of Subsoil Samples.

NB Particle distributions adjusted to discount particles greater than 20mm. Graphs only depict samples taken from 1) a known depth exceeding 1.5m in boreholes or 1m in exposures, AND 2) locations not at permeability boundaries.







3. Data from Permeability Tests.

T' tests: min/25mm	# Results	# Tests T<1	# Tests T>50	Variable head tests (m/sec):	# Results	Range Values	Typical value	Pump tests (m/sec):	# Results	Range Values	Typical value	Lab tests (m/sec):	# Results	Range Values	Typical value

4. Summary and Analysis

Criteria	Comments		Implications of each criterion for assessment of subsoil permeability
Quaternary / subsoil origin	Limestone tills with less than 20% granite/shale admixture.	>>>	M
Particle size data	Suggests moderate or high permeability subsoil.	>>>	M-H
Field description data	Generally sandy or silty subsoils.	>>>	M
Soil type	Generally a well drained sandy loam.	>>>	M
Artificial drainage density	Low	>>>	M-H
Natural drainage density	Low	>>>	M-H
Permeability test data	-	>>>	-
Rock type	Granite	>>>	M
Land use	Tillage and pasture	>>>	M
	Overall conclusion	>>>	**M**

5. Comments: Subsoil permeability indicators suggest moderate-high permeability and the soil maps indicate that the area is generally excessively well drained, on balance, a moderate permeability has been assigned. It is likely that the very frequency sand and gravel units mapped on the margins of this unit, are in fact interspersed within it. This would help to increase the overall subsoil permeability.

Summary of Permeability Data and Analyses for Subsoils Mapped as Till, and Overlain by Grange Series Soils

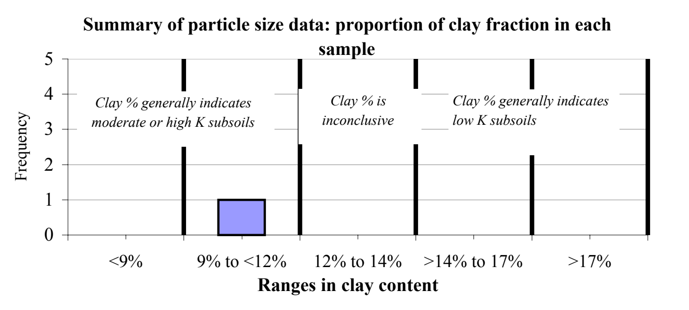
Description of unit location:	Extreme north east of kildare occupying 0.33% of the county.
Why is this a single K unit?	A unique soil type to Kildare, occupying a small area of the county.

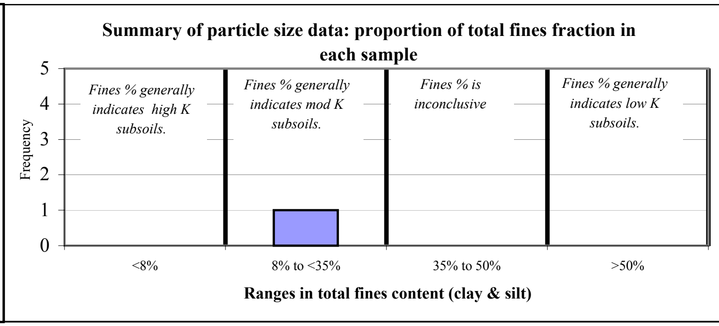
1. General Permeability Indicators and Region Characteristics

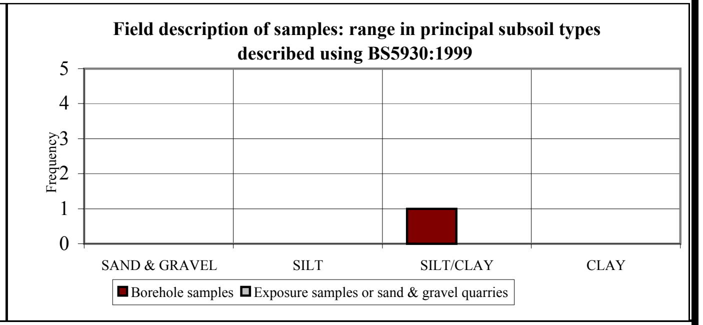
Rock type	Calp lst (CD)
Depth to bedrock	generally <5m and <3m in parts with outcrop
Subsoil type	Limestone till
Soil type	Grange soil series - The 'C' horizon is a gritty to sandy loam with some gravel pockets. One sample taken.
Vegetation and land use	Pasture
Artificial drainage density	Low
Natural drainage density	Low
Topography and altitude	undulating (3-4degs), 70mOD
Ave. effective rainfall (mm)	precipitation approximately 750mm/yr

2. Summary of Particle Size Analysis and Field Descriptions of Subsoil Samples.

NB Particle distributions adjusted to discount particles greater than 20mm. Graphs only depict samples taken from 1) a known depth exceeding 1.5m in boreholes or 1m in exposures, AND 2) locations not at permeability boundaries.







3. Data from Permeability Tests.

T' tests: min/25mm			Variable head tests (m/sec):			Pump tests (m/sec):			Lab tests (m/sec):		
# Results	# Tests T<1	# Tests T>50	# Results	Range Values	Typical value	# Results	Range Values	Typical value	# Results	Range Values	Typical value

4. Summary and Analysis

Criteria	Comments	Implications of each criterion for assessment of subsoil permeability	
Quaternary / subsoil origin	Limestone Till	>>>	L-M
Particle size data	The one sample suggests moderate or high permeability	>>>	M
Field description data	The one sample suggests a silty to clayey subsoil.	>>>	L-M
Soil type	Well drained gritty sandy loam	>>>	M
Artificial drainage density	Low	>>>	M
Natural drainage density	Low	>>>	M
Permeability test data		>>>	
Rock type	Muddy limestone	>>>	L-M
Land use	Pasture	>>>	M
	Overall conclusion	>>>	**M**

5. Comments: Subsoil permeability indicators suggest moderate-high permeability and the soil maps indicate that the area is generally excessively well drained, on balance, a moderate permeability has been assigned.

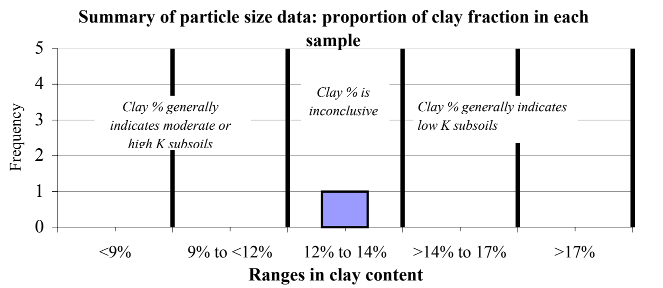
Description of unit location:	Extreme north east of kildare occupying 0.35% of the county.
Why is this a single K unit?	A unique soil type to Kildare, occupying a small area of the county.

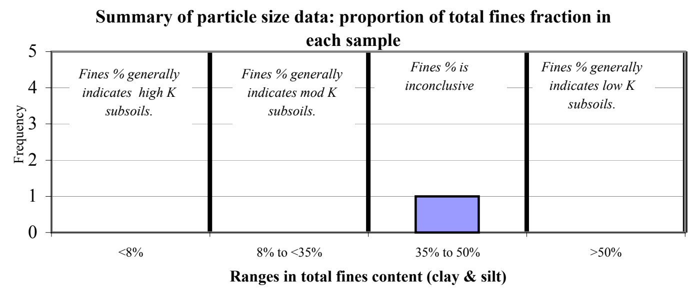
1. General Permeability Indicators and Region Characteristics

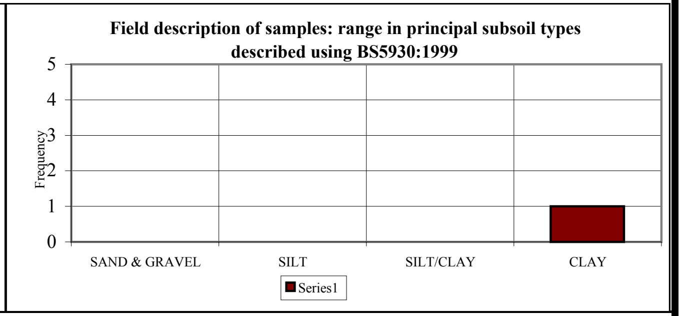
Rock type	Calp (muddy) limestone
Depth to bedrock	generally <5m and <3m in parts with outcrop
Subsoil type	Limestone till
Soil type	Donaghcrumper Series - grey brown podzolic, moderately well drained loam-clay loam. One sample.
Vegetation and land use	Generally pasture
Artificial drainage density	Low
Natural drainage density	Low
Topography and altitude	Flattish to undulating; 61m OD
Ave. effective rainfall (mm)	750mm precipitation approximately

2. Summary of Particle Size Analysis and Field Descriptions of Subsoil Samples.

NB Particle distributions adjusted to discount particles greater than 20mm. Graphs only depict samples taken from 1) a known depth exceeding 1.5m in boreholes or 1m in exposures, AND 2) locations not at permeability boundaries.







3. Data from Permeability Tests.

T' tests: min/25mm	# Results	# Tests T<1	# Tests T>50	Variable head tests (m/sec):	# Results	Range Values	Typical value	Pump tests (m/sec):	# Results	Range Values	Typical value	Lab tests (m/sec):	# Results	Range Values	Typical value

4. Summary and Analysis

Criteria	Comments	Implications of each criterion for assessment of subsoil permeability
Quaternary / subsoil origin	Limestone Till	>>> L-M
Particle size data	Only one sample - inconclusive	>>> L-M
Field description data	Only one sample that suggests clayey subsoil.	>>> L-M
Soil type	Grey brown podzolic; loam to clay loam that is moderately well drained.	>>> M
Artificial drainage density	Low	>>> M
Natural drainage density	Low	>>> M
Permeability test data	-	>>>
Rock type	Muddy limestone	>>> L-M
Land use	Pasture	>>> L-M
	Overall conclusion	>>> **M**

5. Comments: Subsoil permeability indicators suggest moderate-low permeability and the soil maps indicate that the area is generally well drained, on balance, a moderate permeability has been assigned.

Appendix IV: Discussion Of the Key Indicators of Domestic and Agricultural Contamination of Groundwater

A.1 Introduction

This appendix is adapted from Daly, 1996.

There has been a tendency in analysing groundwater samples to test for a limited number of constituents. A "full" or "complete" analysis, which includes all the major anions and cations, is generally recommended for routine monitoring and for assessing pollution incidents. This enables (i) a check on the reliability of the analysis (by doing an ionic balance), (ii) a proper assessment of the water chemistry and quality and (iii) a possible indication of the source of contamination. A listing of recommended and optional parameters are given in Table A1. It is also important that the water samples taken for analysis have not been chlorinated - this is a difficulty in some local authority areas where water take-off points prior to chlorination have not been installed.

The following parameters are good contamination indicators: E.coli, nitrate, ammonia, potassium, chloride, iron, manganese and trace organics.

TABLE A1

Recommended Parameters		
Appearance	Calcium (Ca)	Nitrate ($N0_3$)*
Sediment	Magnesium (Mg)	Ammonia ($NH_4$and NH_3)*
pH (lab)	Sodium (Na)	Iron (Fe)*
Electrical Conductivity (EC)*	Potassium (K)*	Manganese (Mn)*
Total Hardness	Chloride Cl)*	
General coliform	Sulphate ($S0_4$)*	
E. coli *	Alkalinity	
Optional Parameters (depending on local circumstances or reasons for sampling)		
Fluoride (F)	Fatty acids *	Zinc (Zn)
Orthophosphate	Trace organics *	Copper (Cu)
Nitrite ($N0_2$)*	TOC *	Lead (Pb)
B.O.D.*	Boron (B) *	Other metals
Dissolved Oxygen *	Cadmium (Cd)	
*** good indicators of contamination**		

A.2 Faecal Bacteria and Viruses

E. coli is the parameter tested as an indicator of the presence of faecal bacteria and perhaps viruses; constituents which pose a significant risk to human health. The most common health problem arising from the presence of faecal bacteria in groundwater is diarrhoea, but typhoid fever, infectious hepatitis and gastrointestinal infections can also occur. Although E. coli bacteria are an excellent indicator of pollution, they can come from different sources - septic tank effluent, farmyard waste, landfill sites, birds. The faecal coliform : faecal streptococci ratio has been suggested as a tentative indicator to distinguish between animal and human waste sources (Henry *et al*., 1987). However, researchers in Virginia Tech (Reneau, 1996) cautioned against the use of this technique.

Viruses are a particular cause for concern as they survive longer in groundwater than indicator bacteria (Gerba and Bitton, 1984).

The published data on elimination of bacteria and viruses in groundwater has been compiled by Pekdeger and Matthess (1983), who show that in different investigations 99.9% elimination of *E. coli* occurred after 10-15 days. The mean of the evaluated investigations was 25 days. They show that 99.9% elimination of various viruses occurred after 16-120 days, with a mean of 35 days for Polio-, Hepatitis, and Enteroviruses. According to Armon and Kott (1994), pathogenic bacteria can survive for more than ten days under adverse conditions and up to 100 days under favourable conditions; entertoviruses can survive from about 25 days up to 170 days in soils.

Bacteria can move considerable distances in the subsurface, given the right conditions. In a sand and gravel aquifer, coliform bacteria were isolated 100 ft from the source 35 hours after the sewage was introduced (as reported in Hagedorn et al., 1981). They can travel several kilometres in karstic aquifers. In Ireland, research at Sligo RTC involved examining in detail the impact of septic tank systems at three locations with different site conditions (Henry, 1990; summarised in Daly, Thorn and Henry, 1993). Piezometers were installed down-gradient; the distances of the furthest piezometers were 8 m,10 m and 9.5 m, respectively. Unsurprisingly, high faecal bacteria counts were obtained in the piezometers at the two sites with soakage pits, one with limestone bedrock at a shallow depth where the highest count (max. 14 000 cfu's per 1000 ml) and the second where sand/gravel over limestone was present (max 3 000 cfu's per 100 ml). At the third site, a percolation area was installed at 1.0 m b.g.l; the subsoils between the percolation pipes and the fractured bedrock consisted of 1.5 m sandy loam over 3.5 m of poorly sorted gravel; the water table was 3.5 b.g.l. (So this site would satisfy the water table and depth to rock requirements of S.R.6:1991, and most likely the percolation test requirement.) Yet, the maximum faecal coliform bacteria count was 300 cfus per 100 ml. Faecal streptocci were present in all three piezometers. It is highly likely that wells located 30 m down gradient of the drainage fields would be polluted by faecal bacteria.

As viruses are smaller than bacteria, they are not readily filtered out as effluent moves through the ground. The main means of attenuation is by adsorption on clay particles. Viruses can travel considerable distances underground, depths as great as 67 m and horizontal migrations as far as 400 m have been reported (as reported in US EPA, 1987). The possible presence of viruses in groundwater as a result of pollution by septic tank systems is a matter of concern because of their mobility and the fact that indicator bacteria such faecal coliforms have been found not to correlate with the presence of viruses in groundwater samples (US EPA, 1987).

The natural environment, in particular the soils and subsoils, can be effective in removing bacteria and viruses by predation, filtration and absorption. There are two high risk situations: (i) where permeable sands and gravels with a shallow water table are present; and (ii) where fractured rock, particularly limestone, is present close to the ground surface. The presence of clayey gravels, tills, and peat will, in many instances, hinder the vertical migration of microbes, although preferential flow paths, such as cracks in clayey materials, can allow rapid movement and bypassing of the subsoil.

A.3 Nitrate

Nitrate is one of the most common contaminants identified in groundwater and increasing concentrations have been recorded in many developed countries. The consumption of nitrate rich water by young children may give rise to a condition known as methaemoglobinaemia (blue baby syndrome). The formation of carcinogenic nitrosamines is also a possible health hazard and epidemiological studies have indicated a positive correlation between nitrate consumption in drinking water and the incidence of gastric cancer. However, the correlation is not proven according to some experts (Wild and Cameron, 1980). The EC MAC for drinking water is 50mg/l.

The nitrate ion is not adsorbed on clay or organic matter. It is highly mobile and under wet conditions is easily leached out of the rooting zone and through soil and permeable subsoil. As the normal concentrations in uncontaminated groundwater is low (less than 5 mg/l), nitrate can be a good indicator of contamination by fertilisers and waste organic matter.

In the past there has been a tendency in Ireland to assume that the presence of high nitrates in well water indicated an impact by inorganic fertilisers. This assumption has frequently been wrong, as examination of other constituents in the water showed that organic wastes - usually farmyard waste, probably soiled water - were the source. The nitrate concentrations in wells with a low abstraction rate - domestic and farm wells - can readily be influenced by soiled water seeping underground in the vicinity of the farmyard or from the spraying of soiled water on adjoining land. Even septic tank effluent can raise the nitrate levels; if a septic tank system is in the zone of contribution of a well, a four-fold dilution of the nitrogen in the effluent is needed to bring the concentration of nitrate below the EU MAC (as the EU limit is 50 mg/l as NO_3 or 11.3 mg/l as N and assuming that the N concentration in septic tank effluent is 45 mg/l).

The recently produced draft county reports by the EPA on nitrate in groundwater show high levels of nitrate in a significant number of public and group scheme supplies, particularly in south and southern counties and in counties with intensive agriculture, such as Carlow and Louth. This suggest that diffuse sources – landspreading of fertilisers – is having an impact on groundwater.

In assessing regional groundwater quality and, in particular the nitrate levels in groundwater, it is important that:

(i) conclusions should not be drawn using data only from private wells, which are frequently located near potential point pollution sources and from which only a small quantity of groundwater is abstracted;

(ii) account should be taken of the complete chemistry of the sample and not just nitrate, as well as the presence of *E. coli.*;

(iii) account should be taken of not only the land-use in the area but also the location of point pollution sources;

(iv) account should be taken of the regional hydrogeology and the relationship of this to the well itself. For instance, shallow wells generally show higher nitrate concentrations than deeper wells, low permeability sediments can cause denitrification, knowledge on the groundwater flow direction is needed to assess the influence of land-use.

A.4 Ammonia

Ammonia has a low mobility in soil and subsoil and its presence at concentrations greater than 0.1 mg/l in groundwater indicates a nearby waste source and/or vulnerable conditions. The EU MAC is 0.3 mg/l.

A.5 Potassium

Potassium (K) is relatively immobile in soil and subsoil. Consequently the spreading of manure, slurry and inorganic fertilisers is unlikely to significantly increase the potassium concentrations in groundwater. In most areas in Ireland, the background potassium levels in groundwater are less than 3.0 mg/l. Higher concentrations are found occasionally where the rock contains potassium e.g. certain granites and sandstones. The background potassium:sodium ratio in most Irish groundwaters is less than 0.4 and often 0.3. The K:Na ratio of soiled water and other wastes derived from plant organic matter is considerably greater than 0.4, whereas the ratio in septic tank effluent is less than 0.2. Consequently a K:Na ratio greater than 0.4 can be used to indicate contamination by plant organic matter - usually in farmyards, occasionally landfill sites (from the breakdown of paper). However, a K:Na ratio lower than 0.4 does not indicate that farmyard wastes are **not** the source of contamination (or that a septic tank is the cause), as K is less mobile than Na. (Phosphorus is increasingly a significant pollutant and cause of eutrophication in surface water. It is not a problem in groundwater as it usually is not mobile in soil and subsoil).

A.6 Chloride

The principle source of chloride in uncontaminated groundwater is rainfall and so in any region, depending on the distance from the sea and evapotranspiration, chloride levels in groundwater will be fairly constant. Chloride, like nitrate, is a mobile cation. Also, it is a constituent of organic wastes. Consequently, levels appreciably above background levels (12-15 mg/l in Co. Offaly, for instance) have been taken to indicate contamination by organic wastes such as septic tank systems. While this is probably broadly correct, Sherwood (1991) has pointed out that chloride can also be derived from potassium fertilisers.

A.7 Iron and manganese

Although they are present under natural conditions in groundwater in some areas, they can also be good indicators of contamination by organic wastes. Effluent from the wastes cause deoxygenation in the ground which results in dissolution of iron (Fe) and manganese (Mn) from the soil, subsoil and bedrock into groundwater. With reoxygenation in the well or water supply system the Fe and Mn precipitate. High Mn concentrations can be a good indicator of pollution by silage effluent. However, it can also be caused by other high BOD wastes such as milk, landfill leachate and perhaps soiled water and septic tank effluent.

Box A1 Warning/trigger Levels for Certain Contaminants		
As human activities have had some impact on a high proportion of the groundwater in Ireland, there are few areas where the groundwater is in a pristine, completely natural condition. Consequently, most groundwater is contaminated to some degree although it is usually not polluted. In the view of the GSI, assessments of the degree of contamination of groundwater can be beneficial as an addition to examining whether the water is polluted or not. This type of assessment can indicate where appreciable impacts are occurring. It can act as a warning that either the situation could worsen and so needs regular monitoring and careful land-use planning, or that there may be periods when the source is polluted and poses a risk to human health and as a consequence needs regular monitoring. Consequently, thresholds for certain parameters can be used to help indicate situations where additional monitoring and/or source protection studies and/or hazard surveys may be appropriate to identify or prevent more significant water quality problems.		
Parameter	**Threshold** mg/l	**EU MAC** mg/l
Nitrate	25	50
Potassium	4	12
Chloride	30 (except near sea)	250
Ammonia	0.15	0.3
K/Na ratio	0.3-0.4	
Faecal bacteria	0	0

Box A2 Summary : Assessing a Problem Area

Let us assume that you are examining an area with potential groundwater contamination problems and that you have taken samples in nearby wells. How can the analyses be assessed?

E. coli present ⇨ organic waste source nearby (except in karst areas), usually either a septic tank system or farmyard.
E. coli absent ⇨ either not polluted by organic waste or bacteria have not survived due to attenuation or time of travel to well greater than 100 days.
Nitrate > 25 mg/l ⇨ either inorganic fertiliser or organic waste source; check other parameters.
Ammonia > 0.15 mg/l ⇨ source is nearby organic waste; fertiliser is not an issue.
Potassium (K) > 5.0 mg/l ⇨ source is probably organic waste.
K/Na ratio > 0.4 (0.3, in many areas) ⇨ Farmyard waste rather than septic tank effluent is the source. If < 0.3, no conclusion is possible.
Chloride > 30 mg/l ⇨ organic waste source. However this does not apply in the vicinity of the coast (within 20 km at least).

In conclusion, faecal bacteria, nitrate, ammonia, high K/Na ratio and chloride indicate contamination by organic waste. However, only the high K/Na helps distinguish between septic tank effluent and farmyard wastes. So in many instances, while the analyses can show potential problems, other information is needed to complete the assessment.

A.8 References

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location	County	Plot_no	location	Scheme	details	NGR	Easting	Northing	type	LAB	LAB_REF	date	pH	pH_field	Temp(O c)	Temp_Field (O c	Dslvd oxgen %sat	DO_field (mg/l)	DO_field (%sat)	BOD(mg/l O2)	Conduct (us/cm)	conduct_field_u	Ammonia (mg/l N)	O-Phosphate (mg)	TON (mg/l N)
Castledermot WS	KID	6	Castledermot WS	Castledermot @ Plunketstown		S805860	280527	186017	Bore	DUB	3718	11/21/95	7.29		nda		nda			nda	718		<0.005	0.015	6.704
Castledermot WS	KID	6	Castledermot WS	Castledermot @ Plunketstown		S805860	280527	186017	Bore	DUB	2988	08/21/96	7.12		nda		nda			nda	683		<0.01	0.012	7.621
Castledermot WS	KID	6	Castledermot WS	Castledermot @ Plunketstown		S805860	280527	186017	Bore	DUB	4095	11/20/96	7.36		nda		nda			nda	712		<0.01	0.0215	8.609
Castledermot WS	KID	6	Castledermot WS	Castledermot @ Plunketstown		S805860	280527	186017	Bore	DUB	4342	11/05/97	7.24		nda		nda			nda	652		0.018	0.018	8.107
Castledermot WS	KID	6	Castledermot WS	Castledermot @ Plunketstown		S805860	280527	186017	Bore	DUB	666	02/11/98	7.32		nda		nda			nda	583		<0.01	0.00929	8.195
Castledermot WS	KID	6	Castledermot WS	Castledermot @ Plunketstown		S805860	280527	186017	Bore	DUB	3184	09/10/98	7.51		nda		nda			nda	599		2.589	0.0901	9.329
Castledermot WS	KID	6	Castledermot WS			S805860	280527	186017	Bore	DUB	116	01/14/99	7.4	nda	9.3	9.3	nda	9.48	85.3	nda	609	nda	<0.01	0.01127	9.49
Castledermot WS	KID	6	Castledermot WS			S805860	280527	186017	Bore	DUB	3211	10/12/99	7.89	nda	10.1	10.1	nda	nda		nda	356	430	0.016	1.32639	2.74
Kilberry Area WS	KID	9	Kilberry Area WS			N662000	266200	200000	Bore	DUB	3014	08/22/96	7.39		nda		nda			nda	799		<0.01	0.009	10.559
Kilberry Area WS	KID	9	Kilberry Area WS			N662000	266200	200000	Bore	DUB	4079	11/19/96	7.54		nda		nda			nda	820		<0.01	0.009	9.934
Kilberry Area WS	KID	9	Kilberry Area WS			N662000	266200	200000	Bore	DUB	4329	11/04/97	7.21		nda		nda			nda	700		<0.01	0.008	10.756
Kilberry Area WS	KID	9	Kilberry Area WS			N662000	266200	200000	Bore	DUB	695	02/12/98	7.25		nda		nda			nda	750		<0.01	0.007	14.407
Kilberry Area WS	KID	9	Kilberry Area WS			N662000	266200	200000	Bore	DUB	3152	09/08/98	7.12		nda		nda			nda	742		<0.01	0.0096	10.84
Kilberry Area WS	KID	9	Kilberry Area WS			N662000	266200	200000	Bore	DUB	57	01/12/99	7.29	nda	10.9	10.9	nda	6.97	64	nda	742	nda	<0.01	0.009	12.294
Kilberry Area WS	KID	9	Kilberry Area WS			N662000	266200	200000	Bore	DUB	2775	09/20/99	7.13	nda	12.4	12.4	nda	6.1		nda	749	936	<0.01	0.006	9.174
Kilberry area WS	KID	9	Kilberry area WS			N662000	266200	200000	Bore	DUB	726	02/09/00	7.25	nda	10.4	10.4	nda	8.45		nda	751	849	<0.01	0.01	9.44
Kilberry area WS	KID	9	Kilberry area WS			N662000	266200	200000	Bore	DUB	5809	11/21/00	7.443	nda	11.7	11.7	6.24	6.24		nda	833	862	0.02	0.005558	6.745
Kilberry area WS	KID	9	Kilberry area WS			N662000	266200	200000	Bore	DUB	1467	04/04/01	7.161	nda	9	9	7.11	7.11		nda	856	893	<0.01	0.023987	10.801
Monasterevin WS(spring@Hybla)	KID	14	Monasterevin WS(spring@Hybla)			N642125	264230	212502	Spring	DUB	3167	09/09/98	7.38		nda		nda			nda	611		<0.01	0.009	3.247
Monasterevin WS(spring@Hybla)	KID	14	Monasterevin WS(spring@Hybla)			N642125	264230	212502	Spring	DUB	92	01/13/99	7.54	nda	9.5	11.2	nda	2.42	23	nda	597	nda	<0.01	0.011	3.134
Monasterevin WS(spring@Hybla)	KID	14	Monasterevin WS(spring@Hybla)			N642125	264230	212502	Spring	DUB	3202	10/11/99	7.45	nda	11.2	11.2	nda	nda		nda	614	758	<0.01	0.006	3.42
Monasterevin WS(spring@Hybla)	KID	14	Monasterevin WS(spring@Hybla)			N642125	264230	212502	Spring	DUB	724	02/09/00	7.36	nda	9.9	9.9	nda	5.35		nda	651	728	<0.01	<0.005	3.11
Monasterevin WS(spring@Hybla)	KID	14	Monasterevin WS(spring@Hybla)			N642125	264230	212502	Spring	DUB	5811	11/21/00	7.467	nda	9.9	9.9	4.15	4.15		nda	693	717	<0.01	<0.005	2.226
Monasterevin WS(spring@Hybla)	KID	14	Monasterevin WS(spring@Hybla)			N642125	264230	212502	Spring	DUB	1469	04/04/01	7.33	nda	9.3	9.3	4.92	4.92		nda	695	723	0.04	0.018274	3.27
Monastrevin WS (BH No.1(Ballykelly))	KID	15	Monastrevin WS (BH No.1(Ballykelly))	Ballykelly		N642125	264354	203229	Bore	DUB	3716	11/21/95	7.25		nda		nda			nda	804		<0.005	0.009	6.012
Monastrevin WS (BH No.1(Ballykelly))	KID	15	Monastrevin WS (BH No.1(Ballykelly))	Ballykelly		N642125	264230	212502	Bore	DUB	3012	08/22/96	7.2		nda		nda			nda	837		<0.01	0.006	8.175
Monastrevin WS (BH No.1(Ballykelly))	KID	15	Monastrevin WS (BH No.1(Ballykelly))	Ballykelly		N642125	264230	212502	Bore	DUB	4081	11/19/96	7.2		nda		nda			nda	857		<0.01	0.007	8.154
Monastrevin WS (BH No.1(Ballykelly))	KID	15	Monastrevin WS (BH No.1(Ballykelly))	Ballykelly		S642125	264230	212502	Bore	DUB	3166	09/09/98	7.19		nda		nda			nda	759		<0.01	0.009	8.437
Monastrevin WS (BH No.1(Ballykelly))	KID	15	Monastrevin WS (BH No.1(Ballykelly))	Ballykelly		S642125	264230	212502	Bore	DUB	91	01/13/99	7.28	nda	11.2	10.8	nda	7.28	67.7	nda	753	nda	<0.01	0.009	7.779
Monastrevin WS (BH No.1(Ballykelly))	KID	15	Monastrevin WS (BH No.1(Ballykelly))	Ballykelly		S642125	264230	212502	Bore	DUB	5812	11/21/00	7.319	nda	10.8	10.8	nda	nda		nda	880	911	0.059	<0.005	4.077
Monastrevin WS (BH No.1(Ballykelly))	KID	15	Monastrevin WS (BH No.1(Ballykelly))	Ballykelly		S642125	264230	212502	Bore	DUB	1470	04/04/01	7.202	nda	10.7	10.7	5.36	5.36		nda	871	911	<0.01	0.014014	6.722
Churchtown WS	KID	18	Churchtown WS	Churchtown		S640955	264000	195500	Bore	DUB	3015	08/22/96	7.3		nda		nda			nda	728		<0.01	0.016	12.548
Churchtown WS	KID	18	Churchtown WS	Churchtown		S640955	264000	195500	Bore	DUB	4078	11/19/96	7.34		nda		nda			nda	696		<0.01	0.014	9.784
Churchtown WS	KID	18	Churchtown WS	Churchtown		S640955	264000	195500	Bore	DUB	4328	11/04/97	7.32		nda		nda			nda	647		<0.01	0.016	12.147
Churchtown WS	KID	18	Churchtown WS	Churchtown		S640955	264000	195500	Bore	DUB	4714	12/09/97	7.46		nda		nda			nda	666		0.014	0.016	12.76
Churchtown WS	KID	18	Churchtown WS	Churchtown		S640955	264000	195500	Bore	DUB	696	02/12/98	7.37		nda		nda			nda	607		<0.01	0.013	13.136
Churchtown WS	KID	18	Churchtown WS	Churchtown		S640955	264000	195500	Bore	DUB	3153	09/08/98	7.44		nda		nda			nda	667		<0.01	0.0143	13.008
Churchtown WS	KID	18	Churchtown WS	Churchtown		S640955	264000	195500	Bore	DUB	58	01/12/99	7.36	nda	10.4	10.4	nda	8.73	80.6	nda	637	nda	<0.01	0.014	10.982
Churchtown WS	KID	18	Churchtown WS	Churchtown		S640955	264000	195500	Bore	DUB	2774	09/20/99	7.25	nda	10.8	10.6	nda	7.8		nda	637	767	<0.01	0.013	10
Churchtown WS	KID	18	Churchtown WS	Churchtown		S640955	264000	195500	Bore	DUB	727	02/09/00	7.33	nda	10.8	10.8	nda	8.85		nda	693	775	<0.01	0.011	9.99
Churchtown WS	KID	18	Churchtown WS	Churchtown		S640955	264000	195500	Bore	DUB	5808	11/21/00	7.395	nda	10	10	8.1	8.1		nda	735	759	<0.01	0.006101	10.554
Churchtown WS	KID	18	Churchtown WS	Churchtown		S640955	264000	195500	Bore	DUB	1466	04/04/01	7.242	nda	10.8	10.8	8.63	8.63		nda	734	753	<0.01	0.026112	10.057
Monasterevin WS (Lughill)	KID	20	Monasterevin WS (Lughill)			N635064	263507	206482	3 No. Springs	DUB	3717	11/21/95	7.27		nda		nda			nda	725		<0.005	0.016	6.243
Monasterevin WS (Lughill)	KID	20	Monasterevin WS (Lughill)			N635064	263507	206482	3 No. Springs	DUB	3013	08/22/96	7.18		nda		nda			nda	732		<0.01	0.01	7.736
Monasterevin WS (Lughill)	KID	20	Monasterevin WS (Lughill)			N635064	263507	206482	3 No. Springs	DUB	4080	11/19/96	7.18		nda		nda			nda	747		<0.01	0.009	8.132
Monasterevin WS (Lughill)	KID	20	Monasterevin WS (Lughill)			N635064	263507	206482	3 No. Springs	DUB	4330	11/04/97	7.17		nda		nda			nda	665		<0.01	0.009	7.72
Monasterevin WS (Lughill)	KID	20	Monasterevin WS (Lughill)			N635064	263507	206482	3 No. Springs	DUB	652	02/11/98	7.21		nda		nda			nda	653		<0.01	0.009	8.327
Monasterevin WS (Lughill)	KID	20	Monasterevin WS (Lughill)			N635064	263507	206482	3 No. Springs	DUB	3165	09/09/98	7.23		nda		nda			nda	644		<0.01	0.011	8.332
Monasterevin WS (Lughill)	KID	20	Monasterevin WS (Lughill)			N635064	263507	206482	3 No. Springs	DUB	90	01/13/99	7.17		10.8		nda			nda	663		<0.01	0.011	9.154
Monasterevin WS (Lughill)	KID	20	Monasterevin WS (Lughill)			N635064	263507	206482	3 No. Springs	DUB	2794	09/21/99	7.19	nda	11.2	11.2	nda	5.6		nda	659	804	<0.01	0.007	7.696
Monasterevin WS (Lughill)	KID	20	Monasterevin WS (Lughill)			N635064	263507	206482	3 No. Springs	DUB	725	02/09/00	7.22	nda	10.9	10.9	nda	6.83		nda	701	789	<0.01	0.007	7.41
Monasterevin WS (Lughill)	KID	20	Monasterevin WS (Lughill)			N635064	263507	206482	3 No. Springs	DUB	5810	11/21/00	7.262	nda	10.7	10.7	6.36	6.36		nda	773	800	0.018	<0.005	8.45
Monasterevin WS (Lughill)	KID	20	Monasterevin WS (Lughill)			N635064	263507	206482	3 No. Springs	DUB	1468	04/04/01	7.075	nda	10.8	10.8	6.56	6.56		nda	753	785	0.02	0.016167	8.159
Newtown / Kilcock WS	KID	22	Newtown / Kilcock WS			N818394	281850	239447	Bore	DUB	3715	11/21/95	7.31		nda		nda			nda	574		0.14	0.013	0.06
Newtown / Kilcock WS	KID	22	Newtown / Kilcock WS			N818394	281850	239447	Bore	DUB	2954	08/20/96	7.16		nda		nda			nda	624		0.078	0.009	0.084
Newtown / Kilcock WS	KID	22	Newtown / Kilcock WS			N818394	281850	239447	Bore	DUB	4101	11/21/96	7.26		nda		nda			nda	576		0.137	0.015	0.062
Newtown / Kilcock WS	KID	22	Newtown / Kilcock WS			N818394	281850	239447	Bore	DUB	4710	12/09/97	7.23		nda		nda			nda	557		0.134	0.012	0.1
Newtown / Kilcock WS	KID	22	Newtown / Kilcock WS			N818394	281850	239447	Bore	DUB	649	02/11/98	7.24		nda		nda			nda	539		0.163	0.013	0.027
Newtown / Kilcock WS	KID	22	Newtown / Kilcock WS			N818394	281850	239447	Bore	DUB	3169	09/09/98	7.25		nda		nda			nda	542		0.197	0.017	<0.01
Newtown / Kilcock WS	KID	22	Newtown / Kilcock WS			N818394	281850	239447	Bore	DUB	94	01/13/99	7.3	nda	11.8	9.5	nda	7.2	64.5	nda	543	nda	0.17	0.015	0.021
Newtown / Kilcock WS	KID	22	Newtown / Kilcock WS			N818394	281850	239447	Bore	DUB	2792	09/21/99	7.3	nda	13.9	13.9	nda	3		nda	535	648	0.068	0.011	0.127
Newtown / Kilcock WS	KID	22	Newtown / Kilcock WS			N818394	281850	239447	Bore	DUB	692	02/07/00	7.19	nda	11.3	11.3	nda	3.52		nda	589	633	0.14	0.015	0.07
Newtown / Kilcock WS	KID	22	Newtown / Kilcock WS			N818394	281850	239447	Bore	DUB	5793	11/20/00	7.16	nda	12.7	12.7	0.41	0.41		nda	611	624	0.172	0.103611	0.042
Newtown / Kilcock WS	KID	22	Newtown / Kilcock WS			N818394	281850	239447	Bore	DUB	1377	04/03/01	7.183	nda	12.7	12.7	3.63	3.63		nda	622	645	0.08	0.007104	0.142
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	3714	11/21/95	7.34		nda		nda			nda	672		<0.005	0.012	2.84
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	2957	08/20/96	7.24		nda		nda			nda	679		<0.01	0.011	2.933
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	4105	11/21/96	7.3		nda		nda			nda	681		<0.01	0.004	2.932
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	4332	11/04/97	7.28		nda		nda			nda	595		<0.01	0.01	2.87
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	692	02/12/98	7.36		nda		nda			nda	597		<0.01	0.007	2.855
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	3151	09/08/98	7.33		nda		nda			nda	602		<0.01	0.0109	3.095
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	3151	09/08/98	7.33		nda		nda			nda	602		<0.01	0.011	3.1
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	89	01/13/99	7.33	nda	9.6	9.6	nda	6.17	56	nda	568	nda	<0.01	0.014	2.846
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	2795	09/21/99	7.43	nda	11.3	11.3	nda	7.3		nda	607	723	<0.01	0.011	2.963
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	722	02/09/00	7.42	nda	9.9	9.9	nda	8.72		nda	632	710	<0.01	0.007	2.85
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	5796	11/20/00	7.198	nda	9.9	9.9	3.68	3.68		nda	681	697	<0.01	0.075726	2.757
Pollardstown Fen	KID	23	Pollardstown Fen	Pollardstown Fen		N773154	277282	215459	Spring	DUB	1380	04/03/01	7.319	nda	10.2	10.2	7.25	7.25		nda	677	703	<0.01	0.005654	2.974
Clogherinkoe WS	KID	40	Clogherinkoe WS			N658387	265500	239000	Bore	DUB	2955	08/20/96	7.36		nda		nda			nda	608		<0.01	0.059	1.333
Clogherinkoe WS	KID	40	Clogherinkoe WS		Clogherinicoe	N658387	265500	239000	Bore	DUB	4102	11/21/96	7.38		nda		nda			nda	615		<0.01	0.047	2.302
Clogherinkoe WS	KID	40	Clogherinkoe WS			N658387	265500	239000	Bore	DUB	4367	11/06/97	7.41		nda		nda			nda	524		0.012	0.048	2.133
Clogherinkoe WS	KID	40	Clogherinkoe WS			N658387	265500	239000	Bore	DUB	4711	12/09/97	7.4		nda		nda			nda	552		0.028	0.047	2.483
Clogherinkoe WS	KID	40	Clogherinkoe WS			N658387	265500	239000	Bore	DUB	650	02/11/98	7.37		nda		nda			nda	534		<0.01	0.05268	2.306
Clogherinkoe WS	KID	40	Clogherinkoe WS			N658387	265500	239000	Bore	DUB	3168	09/09/98	7.37		nda		nda			nda	541		<0.01	0.049	2.1
Clogherinkoe WS	KID	40	Clogherinkoe WS			N658387	265500	239000	Bore	DUB	93	01/13/99	7.39		10.8		nda			nda	547		<0.01	0.045	3.592
Clogherinkoe WS	KID	40	Clogherinkoe WS			N658387	265500	239000	Bore	DUB	2793	09/21/99	7.29	nda	11	11	nda	3.8		nda	548	663	<0.01	0.058	1.939
Clogherinkoe WS	KID	40	Clogherinkoe WS			N658387	265500	239000	Bore	DUB	693	02/07/00	7.28	nda	10.8	10.8	nda	6.41		nda	580	653	0.02	0.049	2.43
Clogherinkoe WS	KID	40	Clogherinkoe WS			N658387	265500	239000	Bore	DUB	5794	11/20/00	7.426	nda	10.4	10.4	nda	3.91		nda	620	637	0.01	0.119055	2.185

Clogherinkoe WS	KID	40	Clogherinkoe WS		N658387	265500	239000	Bore	DUB	1378	04/03/01	7.292	nda	10.8	10.8	2.97	2.97		nda	619	646	<0.01	0.046382	2.235
Hare Park (Curragh Camp)	KID	42	Hare Park (Curragh Camp)		N770115	277011	211522	Bore	DUB	3046	08/27/96	6.92		nda		nda			nda	788		<0.01	0.018	4.461
Hare Park (Curragh Camp)	KID	42	Hare Park (Curragh Camp)	HarePark,Currag	N770115	277011	211522	Bore	DUB	4103	11/21/96	7.24		nda		nda			nda	790		<0.01	0.01	4.327
Hare Park (Curragh Camp)	KID	42	Hare Park (Curragh Camp)		N770115	277011	211522	Bore	DUB	4369	11/06/97	7.25		nda		nda			nda	694		<0.01	0.008	3.972
Hare Park (Curragh Camp)	KID	42	Hare Park (Curragh Camp)		N770115	277011	211522	Bore	DUB	694	02/12/98	7.25		nda		nda			nda	719		<0.01	0.01	4.298
Hare Park (Curragh Camp)	KID	42	Hare Park (Curragh Camp)		N770115	277011	211522	Bore	DUB	3164	09/09/98	7.21		nda		nda			nda	707		<0.01	0.022	5.693
Hare Park (Curragh Camp)	KID	42	Hare Park (Curragh Camp)		N770115	277011	211522	Bore	DUB	55	01/12/99	7.375	nda	10.4	10.4	nda	8.33	76.7	nda	675	nda	<0.01	0.018115	4.404
Hare Park (Curragh Camp)	KID	42	Hare Park (Curragh Camp)		N770115	277011	211522	Bore	DUB	2772	09/20/99	7.14	nda	11.1	11.1	nda	8.7		nda	708	876	<0.01	0.015	4.918
Hare Park (Curragh Camp)	KID	42	Hare Park (Curragh Camp)		N770115	277011	211522	Bore	DUB	694	02/07/00	7.21	nda	10.6	10.6	nda	8.9		nda	736	831	<0.01	0.005	4.43
Hare Park (Curragh Camp)	KID	42	Hare Park (Curragh Camp)		N770115	277011	211522	Bore	DUB	1471	04/04/01	7.266	nda	10.7	10.7	9.26	9.26		nda	838	876	0.02	0.011823	5.085
McDonagh(Curragh Camp)	KID	50	McDonagh(Curragh Camp)	McDonagh Pump Stn	N788117	278814	211736	Bore	DUB	3047	08/27/96	7.16		nda		nda			nda	744		<0.01	0.127	5.638
McDonagh(Curragh Camp)	KID	50	McDonagh(Curragh Camp)	McDonagh Pump Stn	N788117	278814	211736	Bore	DUB	4104	11/21/96	7.84		nda		nda			nda	687		<0.01	0.282	4.835
McDonagh(Curragh Camp)	KID	50	McDonagh(Curragh Camp)	McDonagh Pump Stn	N788117	278814	211736	Bore	DUB	4712	12/09/97	7.83		nda		nda			nda	595		0.015	0.012	4.597
McDonagh(Curragh Camp)	KID	50	McDonagh(Curragh Camp)	McDonagh Pump Stn	N788117	278814	211736	Bore	DUB	693	02/12/98	7.76		nda		nda			nda	601		<0.01	0.012	4.596
McDonagh(Curragh Camp)	KID	50	McDonagh(Curragh Camp)	McDonagh Pump Stn	N788117	278814	211736	Bore	DUB	3150	09/08/98	7.69		nda		nda			nda	624		<0.01	0.0133	5.218
McDonagh(Curragh Camp)	KID	50	McDonagh(Curragh Camp)	McDonagh Pump Stn	N788117	278814	211736	Bore	DUB	56	01/12/99	7.87	nda	9.8	9.8	nda	12.31	113	nda	597	nda	<0.01	0.011822	4.825
McDonagh(Curragh Camp)	KID	50	McDonagh(Curragh Camp)	McDonagh Pump Stn	N788117	278814	211736	Bore	DUB	2773	09/20/99	7.61	nda	10.6	10.6	nda	11.8		nda	621	730	<0.01	0.011	5.248
McDonagh(Curragh Camp)	KID	50	McDonagh(Curragh Camp)	McDonagh Pump Stn	N788117	278814	211736	Bore	DUB	695	02/07/00	7.76	nda	10.4	0.4	nda	12.1		nda	640	720	<0.01	0.01	4.84
McDonagh(Curragh Camp)	KID	50	McDonagh(Curragh Camp)	McDonagh Pump Stn	N788117	278814	211736	Bore	DUB	5795	11/20/00	7.785	nda	9.9	9.9	nda	11.98		nda	688	707	<0.01	0.08722	4.875
McDonagh(Curragh Camp)	KID	50	McDonagh(Curragh Camp)	McDonagh Pump Stn	N788117	278814	211736	Bore	DUB	1379	04/03/01	7.695	nda	10.4	10.4	12.22	12.22		nda	687	717	0.02	0.011522	5.369
Martinstown	KID	72	Martinstown		N773064	277283	206406		DUB	4713	12/09/97	7.24		nda		nda			nda	730		0.023	0.018	10.528
Osborne Lodge	KID	74	Osborne Lodge		N756147	275579	214671		DUB	2956	08/20/96	7.15		nda		nda			nda	641		<0.01	0.007	1.412
Monasterevin WS BH No.1 & Spring)	KID	80	Monasterevin WS BH No.1 & Spring)	Ballykelly	N641126	264100	212600		DUB	4331	11/04/97	7.28		nda		nda			nda	707		<0.01	0.007	5.845
Monasterevin WS BH No.1 & Spring)	KID	80	Monasterevin WS BH No.1 & Spring)	Ballykelly	N641126	264100	212600		DUB	651	02/11/98	7.29		nda		nda			nda	689		<0.01	<0.005	5.979
Monasterevin WS(sprng+Bore1+2)	KID	80	Monasterevin WS(sprng+Bore1+2)		S642125	264230	212502		DUB	3201	10/11/99	7.22	nda	11.2	11.2	nda	nda		nda	740	954	<0.01	0.006	8.05
Monasterevin WS(sprng+Bore1+2)	KID	80	Monasterevin WS(sprng+Bore1+2)		S642125	264230	212502		DUB	723	02/09/00	7.19	nda	10.9	10.9	nda	5.11		nda	878	986	<0.01	0.007	7.23

Nitrate (mg/l N	Nitrate (mg/l NO)	Nitrite (mg/l N	alkalinity(mg/l	Chloride (mg/lCl)	Flouride (mg/lF)	TOTL_HARD(mg/l)	Ca_hardness	Faecal_ Coliform	Sulphate (mg/l S)	Sulphide (mg/l S)	Sodium (mg/l Na)	Potassium (mg/l)	Magnesium (mg/l)	Copper (mg/l Cu)
7.34	32.50152	nda	318	17.38	nda	nda	nda	nda	16.2	nda	7.67	1.93	13.84	nda
nda	33.74*	nda	302	17.87	nda	nda	nda	nda	12.7	nda	8.04	1.68	13.1	nda
nda	38.13*	nda	316	18.1	nda	nda	nda	nda	14.12	nda	7.09	2.17	9.2	nda
nda	35.91*	nda	314	18.429	nda	nda	nda	nda	16.089	nda	7.739	0.496	14.016	nda
nda	36.31*	nda	289	17	nda	nda	nda	nda	11.9	nda	9.5	1.4	15.2	nda
nda	41.31*	nda	273	18.9	nda	nda	nda	nda	13.2	nda	10.4	11.7	13.8	nda
nda	42.02*	nda	296	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda
nda	12.13*	nda	156	13.8	nda	nda	nda	nda	10.18	nda	13.67	2.81	6.39	nda
nda	46.76*	nda	308	38.63	nda	nda	nda	nda	38.28	nda	12.19	1.61	12.23	nda
nda	43.97*	nda	310	35.86	nda	nda	nda	nda	40.56	nda	12.37	2.51	9.72	nda
nda	47.64*	nda	294	54.646	nda	nda	nda	nda	42.341	nda	20.458	3.92	15.154	nda
nda	63.81*	nda	308	42.8	nda	nda	nda	nda	30.7	nda	13.1	1.7	14.7	nda
nda	48.0*	nda	311	35.1	nda	nda	nda	nda	33.8	nda	14.8	1.8	14.7	nda
nda	54.42*	nda	303	54.8	nda	nda	nda	nda	37.5	nda	15.8	2.3	16.8	nda
nda	40.60*	nda	314	35	nda	nda	nda	nda	37.1	nda	15.4	2.07	15.03	nda
nda	41.80*	nda	276	33.6	nda	nda	nda	nda	30.4	nda	14.62	1.61	14.24	nda
nda	29.87*	nda	241	34.4	nda	nda	nda	<1	31.7	nda	11.6	<1	14.5	nda
nda	47.83*	nda	305	43.1	nda	nda	nda	<1	31	nda	14.87	0.55	13.86	nda
nda	14.38*	nda	303	13.4	nda	nda	nda	nda	18.7	nda	8.9	1.3	26.4	nda
nda	13.88*	nda	315	18.3	nda	nda	nda	nda	25.3	nda	10.2	1.4	31.2	nda
nda	15.14*	nda	334	16.34	nda	nda	nda	nda	19.7	nda	8.47	1.19	27.6	nda
nda	13.77*	nda	299	17.4	nda	nda	nda	nda	20.5	nda	8.84	1.18	26.8	nda
nda	9.86*	nda	240	13.9	nda	nda	nda	<1	19.5	nda	6.9	<1	26.2	nda
nda	14.48*	nda	310	11.08	nda	nda	nda	<1	20.2	nda	9.3	0.2	28.8	nda
6.27	27.76356	nda	320	19.52	nda	nda	nda	nda	57.66	nda	9.36	2.14	31.88	nda
nda	36.22*	nda	348	21.28	nda	nda	nda	nda	61.05	nda	7.88	1.71	30.18	nda
nda	36.09*	nda	356	21.24	nda	nda	nda	nda	64.18	nda	8.59	1.96	32.55	nda
nda	37.37*	nda	341	20.9	nda	nda	nda	nda	61.7	nda	10.4	2.3	31.3	nda
nda	34.45*	nda	337	24.8	nda	nda	nda	nda	77.6	nda	11.4	2.9	35.8	nda
nda	18.05*	nda	257	19.2	nda	nda	nda	<1	74.3	nda	8.2	1.4	31.4	nda
nda	29.77*	nda	350	14.12	nda	nda	nda	<1	59.9	nda	10.03	1.86	33.9	nda
nda	55.57*	nda	276	33.22	nda	nda	nda	nda	24.2	nda	10.55	1.95	12.4	nda
nda	43.31*	nda	288	29.13	nda	nda	nda	nda	21.55	nda	10.57	1.32	13.04	nda
nda	53.80*	nda	272	37.466	nda	nda	nda	nda	21.072	nda	11.4	0.731	13.834	nda
nda	56.50*	nda	274	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda
nda	58.18*	nda	268	33	nda	nda	nda	nda	21.6	nda	11.3	1.6	13.3	nda
nda	57.61*	nda	262	31.9	nda	nda	nda	nda	22.8	nda	14.6	2	14.5	nda
nda	48.62*	nda	267	37.2	nda	nda	nda	nda	26	nda	14.3	2.1	16.1	nda
nda	44.28*	nda	270	29	nda	nda	nda	nda	20.9	nda	11.79	1.53	16.87	nda
nda	44.24*	nda	325	28.4	nda	nda	nda	nda	21.4	nda	12.7	1.69	14.6	nda
nda	46.73*	nda	263	30.6	nda	nda	nda	<1	21.4	nda	10.5	<1	15.5	nda
nda	44.53*	nda	275	20.83	nda	nda	nda	<1	24.9	nda	13.49	1.78	14.18	nda
6.67	29.53476	nda	273.798	23.45	nda	nda	nda	nda	25.94	nda	11.45	1.89	14.66	nda
nda	34.27*	nda	316	25.85	nda	nda	nda	nda	25.73	nda	10.44	1.83	12.94	nda
nda	36.0*	nda	318	25.8	nda	nda	nda	nda	25.35	nda	10.57	1.86	9.17	nda
nda	34.18*	nda	318	25.731	nda	nda	nda	nda	20.232	nda	10.109	0.775	11.337	nda
nda	36.89*	nda	318	32.523	nda	nda	nda	nda	22.805	nda	10.965	1.812	12.085	nda
nda	36.89*	nda	302	23.4	nda	nda	nda	nda	23.5	nda	13.9	1.7	14.3	nda
nda	40.52*	nda	308	24.8	nda	nda	nda	nda	21.8	nda	12.7	2.3	12.2	nda
nda	34.10*	nda	291	24.7	nda	nda	nda	nda	25.4	nda	12.72	1.63	15.42	nda

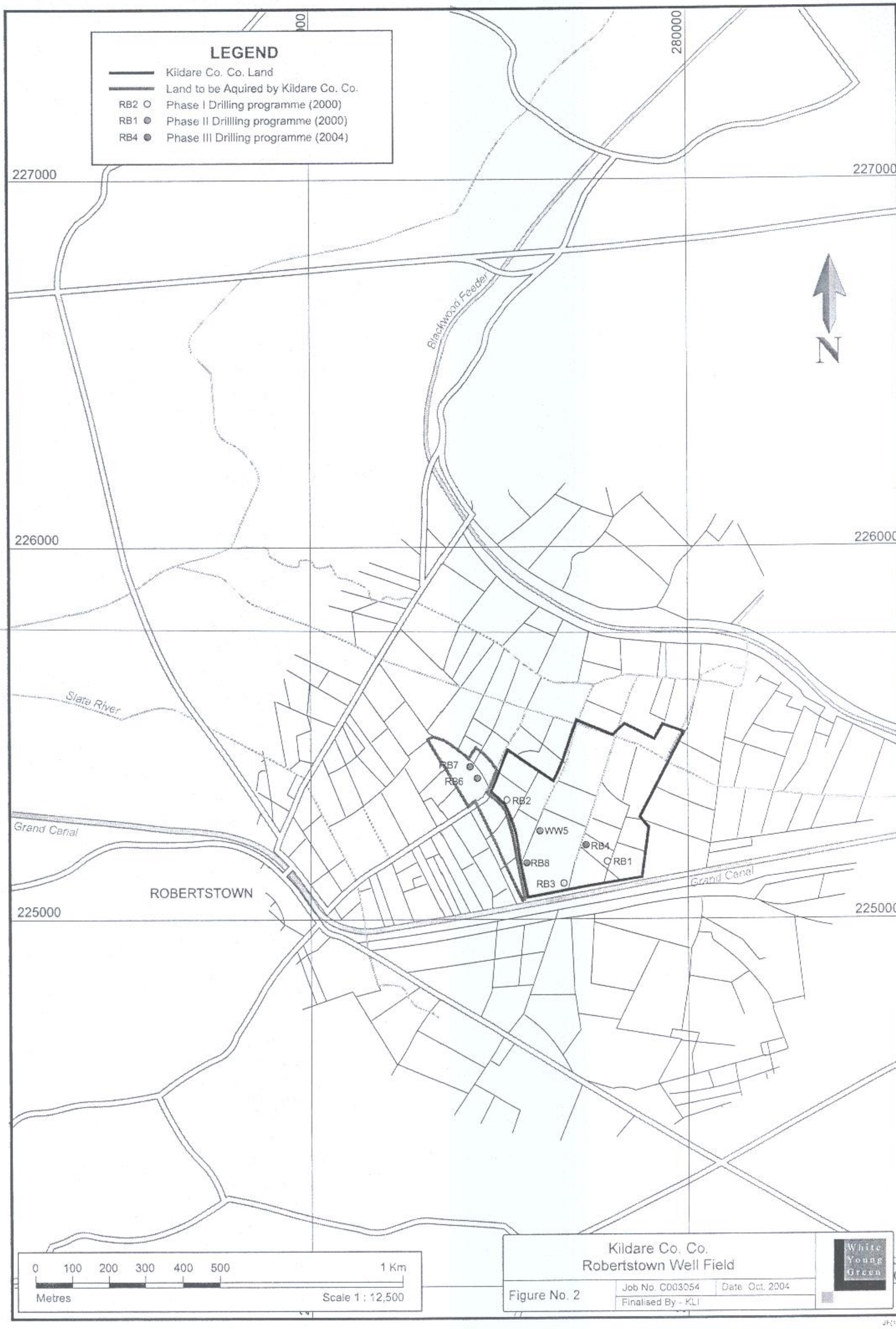
nda	32.81*	nda	287	21	nda	nda	nda	nda	20	nda	12.03	1.84	13.07	nda
nda	37.42*	nda	279	23.1	nda	nda	nda	<1	20.7	nda	9.3	<1	12	nda
nda	36.13*	nda	300	15.96	nda	nda	nda	<1	23.1	nda	11.88	0.84	12.08	nda
0.13	0.57564	nda	210.665	13.69	nda	nda	nda	nda	41.3	nda	7.5	2.51	6.05	nda
nda	0.35*	nda	248	14.4	nda	nda	nda	nda	70	nda	7.28	2.74	5.91	nda
nda	0.27*	nda	252	10.51	nda	nda	nda	nda	41.38	nda	8.31	2.41	2.09	nda
nda	0.44*	nda	254	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda
nda	0.13*	nda	322	16.772	nda	nda	nda	nda	100.161	nda	7.226	2.209	6.794	nda
nda	<0.04*	nda	220	11.8	nda	nda	nda	nda	61.7	nda	9.1	2.8	6.6	nda
nda	0.9*	nda	258	14.8	nda	nda	nda	nda	75	nda	8.3	2.5	7.5	nda
nda	0.56*	nda	245	13.77	nda	nda	nda	nda	50.6	nda	7.67	2.22	6.58	nda
nda	0.31*	nda	252	13.45	nda	nda	nda	nda	73.6	nda	7.82	2.26	6.57	nda
nda	0.19*	nda	244	11.5	nda	nda	nda	<1	52.4	nda	6.6	1.3	6.6	nda
nda	0.63*	nda	238	9.92	nda	nda	nda	<1	70	nda	8.07	1.17	5.94	nda
2.92	12.92976	nda	302.489	13.69	nda	nda	nda	nda	18.97	nda	10.01	1.45	19.08	nda
nda	12.97*	nda	338	14.7	nda	nda	nda	nda	18.6	nda	11.59	1.51	19.07	nda
nda	12.97*	nda	318	12.84	nda	nda	nda	nda	17.9	nda	10.14	0.52	18.5	nda
nda	12.71*	nda	330	12.511	nda	nda	nda	nda	16.687	nda	8.762	<0.01	18.875	nda
nda	12.66*	nda	322	13.8	nda	nda	nda	nda	18.3	nda	10.8	0.7	19.6	nda
nda	13.73*	nda	319	12.8	nda	nda	nda	nda	18	nda	11.6	0.7	19.6	nda
nda	13.73*	nda	319	12.8	nda	nda	nda	nda	18	nda	11.6	0.7	19.6	nda
nda	12.62*	nda	302	16.4	nda	nda	nda	nda	20.8	nda	11.8	0.9	21.4	nda
nda	13.12*	nda	290	15.85	nda	nda	nda	nda	19.78	nda	11.19	0.66	19.95	nda
nda	12.62*	nda	257	15.9	nda	nda	nda	nda	19.4	nda	10.92	0.63	19.69	nda
nda	12.21*	nda	290	12.5	nda	nda	nda	23	17.8	nda	6.9	<1	14.4	nda
nda	13.17*	nda	318	10.89	nda	nda	nda	10	20.05	nda	10.36	<1	17.65	nda
nda	5.89*	nda	300	11.4	nda	nda	nda	nda	20.7	nda	8.71	0.93	12.6	nda
nda	10.18*	nda	298	10.55	nda	nda	nda	nda	24.49	nda	10.24	2.14	8.25	nda
nda	9.43*	nda	282	17.708	nda	nda	nda	nda	25.367	nda	14.3	1.097	12.757	nda
nda	10.98*	nda	298	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda
nda	10.23*	nda	340	13.384	nda	nda	nda	nda	24.659	nda	9.45	0.67	12.625	nda
nda	9.30*	nda	269	10.3	nda	nda	nda	nda	22.9	nda	12.8	2	13.1	nda
nda	15.90*	nda	291	12.8	nda	nda	nda	nda	28.6	nda	11.9	1.1	14	nda
nda	8.59*	nda	288	11.85	nda	nda	nda	nda	22.6	nda	10.7	0.82	13.44	nda
nda	10.76*	nda	265	11.96	nda	nda	nda	nda	23.8	nda	10.53	0.75	12.44	nda
nda	9.68*	nda	285	9.6	nda	nda	nda	<1	21.6	nda	9.5	<1	11.6	nda
nda	9.90*	nda	272	9.13	nda	nda	nda	<1	24.35	nda	10.3	<1	11.6	nda
nda	19.75*	nda	322	26.24	nda	nda	nda	nda	3.58	nda	33.92	2.21	13.49	nda
nda	19.17*	nda	352	20.33	nda	nda	nda	nda	42.67	nda	17.39	2.51	11.92	nda
nda	17.58*	nda	352	23.415	nda	nda	nda	nda	34.382	nda	17.501	1.389	14.61	nda
nda	19.04*	nda	338	33	nda	nda	nda	nda	27.7	nda	23.3	2.1	13.6	nda
nda	25.20*	nda	325	27.1	nda	nda	nda	nda	28.5	nda	22.6	2.2	12.7	nda
nda	19.48*	nda	322	40.6	nda	nda	nda	nda	29.3	nda	26.6	2.5	13.7	nda
nda	21.78*	nda	325	27.5	nda	nda	nda	nda	24.8	nda	20.1	2.08	13.47	nda
nda	19.62*	nda	341	30.73	nda	nda	nda	nda	23.7	nda	21.53	2.09	12.59	nda
nda	22.52*	nda	330	36.5	nda	nda	nda	<1	30.2	nda	23.6	0.82	15.65	nda
nda	24.97*	nda	293	18.31	nda	nda	nda	nda	5.27	nda	21.32	1.66	12.96	nda
nda	21.43*	nda	332	11.5	nda	nda	nda	nda	19.43	nda	11.82	0.78	12.7	nda
nda	20.37*	nda	332	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda
nda	20.37*	nda	320	11.1	nda	nda	nda	nda	18.9	nda	8.2	0.5	15.9	nda
nda	23.11*	nda	344	11	nda	nda	nda	nda	19.2	nda	9.1	1	16	nda

nda	21.39*	nda	310	14.7	nda	nda	nda	nda	22	nda	9.8	0.8	16.9	nda
nda	23.24*	nda	289	14.14	nda	nda	nda	nda	19.3	nda	8.28	0.58	15.88	nda
nda	21.43*	nda	322	13.37	nda	nda	nda	nda	19.78	nda	8.34	0.58	15.67	nda
nda	21.59*	nda	313	10.9	nda	nda	nda	<1	19.6	nda	7.4	0.5	14.7	nda
nda	23.77*	nda	320	9.72	nda	nda	nda	<1	18.7	nda	8.56	<1	14.85	nda
nda	46.63*	nda	352	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda	nda
nda	6.25*	nda	338	9	nda	nda	nda	nda	9.3	nda	6.24	0.71	9.8	nda
nda	25.90*	nda	330	18.378	nda	nda	nda	nda	46.514	nda	8.133	0.664	28.372	nda
nda	26.48*	nda	328	23.975	nda	nda	nda	nda	52.301	nda	8.576	1.671	28.33	nda
nda	35.65*	nda	332	21.9	nda	nda	nda	nda	75.4	nda	10.36	2.81	32.5	nda
nda	32.01*	nda	308	20.4	nda	nda	nda	nda	83.6	nda	11.07	3.63	30	nda

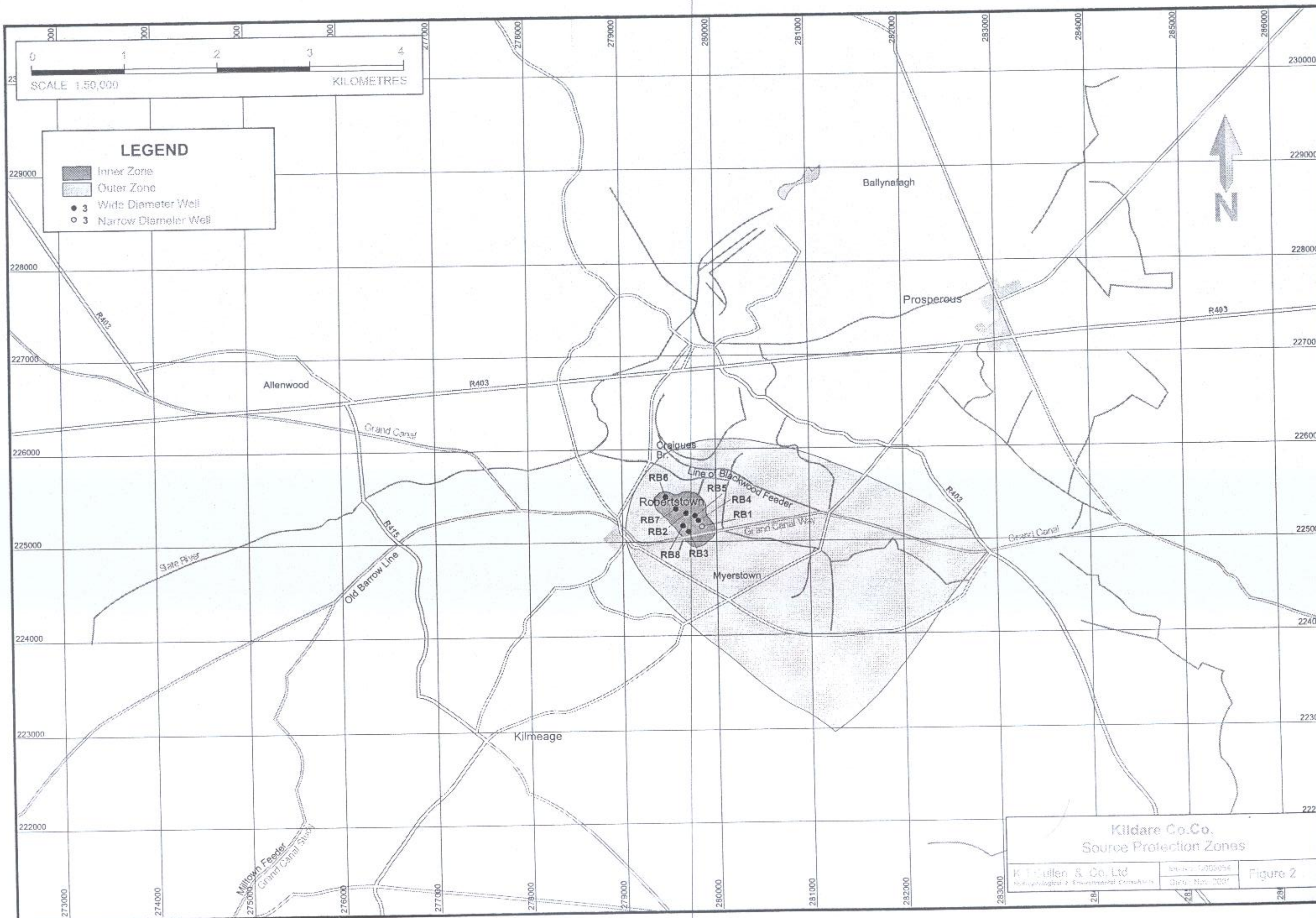
Calcium (mg/l Ca)	Iron (mg/l Fe)	Manganese (mg/l
110.53	0.0113	0.0025
113.54	0.236	<0.0005
120.6	0.0633	0.002
127.451	0.067	0.007
117	0.0165	<0.0005
101.8	0.0513	0.009
nda	0.0281	<0.0005
62.6	0.0535	0.0105
135.54	0.128	0.0058
147	0.182	0.0058
146.189	<0.001	0.0028
148.1	0.0067	0.0014
140.4	<0.01	0.0021
171.2	0.0115	0.0025
144.1	0.0081	0.0037
140.4	<0.02	0.0042
126.5	<0.05	0.0024
136.6	<0.05	0.0024
103.3	0.0149	<0.0005
131.4	0.0458	0.0025
111.2	0.0097	0.0025
109.8	0.0201	0.0032
96.5	<0.05	0.0046
103.1	0.0698	0.0019
109.29	0.0066	0.0494
127.13	0.0926	0.0149
143.8	0.0081	0.0143
130.1	0.0142	0.0173
162	0.0063	0.0225
130.2	<0.05	0.0629
126	<0.05	0.0231
118.36	0.287	<0.0005
116	0.185	<0.0005
124.626	0.021	<0.0005
nda	0.015	0.0017
127.1	0.003	<0.0005
119.1	<0.01	<0.0005
144.7	<0.0005	0.0006
115.8	<0.02	<0.0005
126.2	<0.02	<0.0005
112.6	<0.05	<0.001
107	<0.05	<0.001
108.28	0.0389	0.0051
123.76	0.5	0.0051
134.9	0.0194	<0.0005
136.664	0.076	0.0006
132.3	0.0248	<0.0005
123.3	0.0526	0.0031
161.7	<0.0005	0.001
128.3	0.0022	<0.0005

133.8	<0.02	<0.0005
126.3	<0.05	<0.001
127.2	0.1549	0.0034
95.96	1.952	0.113
124.9	5.046	0.398
94.41	1.468	0.135
nda	4.585	0.144
124.6	4.072	0.157
114.7	2.134	0.147
140.6	3.065	0.211
108.5	1.135	0.1041
121.8	1.0674	0.1286
107.4	1.6531	0.1539
104.85	1.0454	0.2133
98.48	0.144	0.0152
119.2	0.239	0.0197
129.7	0.0223	0.0047
112.923	0.194	0.0138
112.7	0.223	0.006
109.2	0.1	0.0097
109.2	0.1	0.0097
130	0.111	0.0077
111.7	0.0998	0.0153
116.8	<0.02	0.0014
95.1	<0.05	0.0272
98.85	<0.05	0.0032
111	0.201	0.0736
119.1	0.0186	0.0256
110.966	<0.001	0.017
nda	0.024	0.0185
106.1	0.0083	0.0134
106.6	<0.01	0.0153
131.8	0.0097	0.0141
108.1	0.1462	0.1351
110.2	0.0316	0.0414
95.5	<0.05	0.0095
94.75	<0.05	0.0387
145.62	0.293	0.0015
161.2	0.0315	<0.0005
137.181	0.05	0.0011
136.3	0.012	<0.0005
133	0.0371	0.0069
150.3	0.0088	0.001
133.8	<0.02	<0.0005
133.33	<0.02	<0.0005
130	<0.05	<0.001
147.09	0.146	0.0015
138.8	0.155	0.001
nda	0.011	0.0018
121.2	0.0015	<0.0005
117.5	<0.01	<0.0005

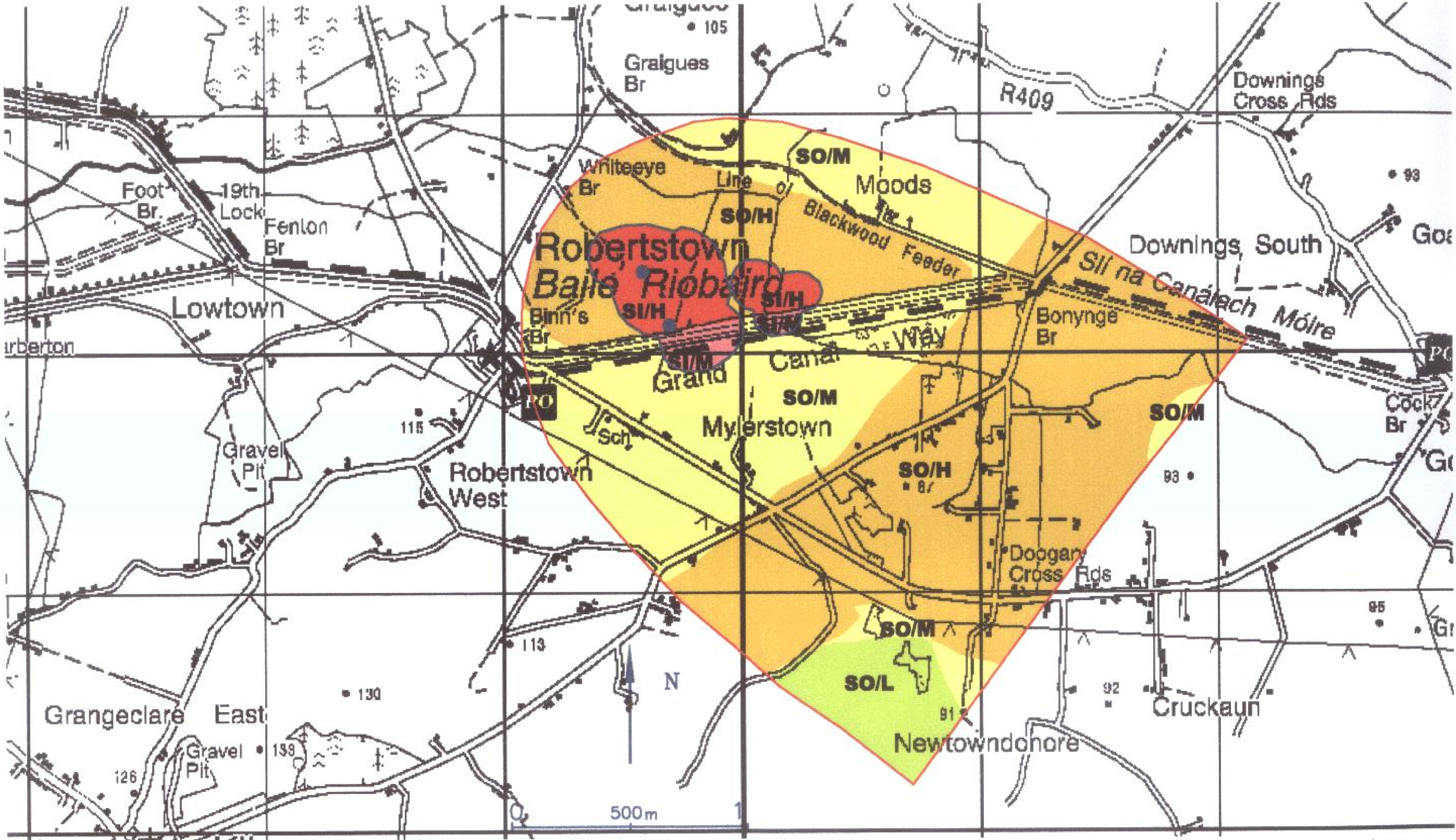
140.8	0.0125	0.0006
118.4	<0.02	<0.0005
118.8	<0.02	<0.0005
96	<0.05	<0.001
102.35	<0.05	<0.001
nda	0.028	0.0029
128.6	0.939	0.0209
125.432	<0.001	0.0111
121	0.0413	0.0099
150.6	<0.02	0.0156
151.4	<0.02	0.0146



LEGEND
Kildare Co. Co. Land
Land to be Aquired by Kildare Co. Co.
RB2 Phase I Drilling programme (2000)
RB1 Phase II Drillling programme (2000)
RB4 Phase III Drilling programme (2004)
280000
227000
226000
225000
Blackwood Feeder
N
Slate River
Grand Canal
ROBERTSTOWN
RB7
RB6
RB2
WW5
RB4
RB1
RB8
RB3
Grand Canal
0 100 200 300 400 500 1 Km
Metres
Scale 1 : 12,500
Kildare Co. Co.
Robertstown Well Field
Figure No. 2
Job No. C003054
Date: Oct. 2004
Finalised By - KLI
White Young Green



0 1 2 3 4
SCALE 1:50,000
KILOMETRES
LEGEND
Inner Zone
Outer Zone
3 Wide Diameter Well
3 Narrow Diameter Well
N
Ballynafagh
Prosperous
R403
R403
R403
R403
Allenwood
Grand Canal
Grand Canal
Craigues Br.
Line of Blackwood Feeder
RB6
RB5
RB4
RB1
Robertstown
RB7
RB2
RB8
RB3
Grand Canal Way
Myerstown
R415
Slate River
Old Barrow Line
Kilmeage
Milltown Feeder
Grand Canal Stub
Kildare Co.Co.
Source Protection Zones
K.T. Cullen & Co. Ltd
Hydrogeological & Environmental Consultants
Figure 2



Graigues Br
105
R409
Downings Cross Rds
93
Gos
Whiteeye Br
Line of Blackwood Feeder
Moods
SO/M
SO/H
Foot Br.
19th Lock
Fenlon Br
Robertstown
Baile Ríobaird
SI/H
SI/H
SI/M
SI/M
Downings South
Síl na Canálech Móire
Bonynge Br
Lowtown
Binn's Br
Grand Canal Way
SO/M
SO/M
Cock Br
PO
115
Sch
Mylerstown
Gravel Pit
Robertstown West
SO/H
93
Doogan Cross Rds
113
SO/M
SO/L
95
N
130
92
Cruckaun
91
Grangeclare East
Gravel Pit
138
126
Newtowndonore
0
500m
1