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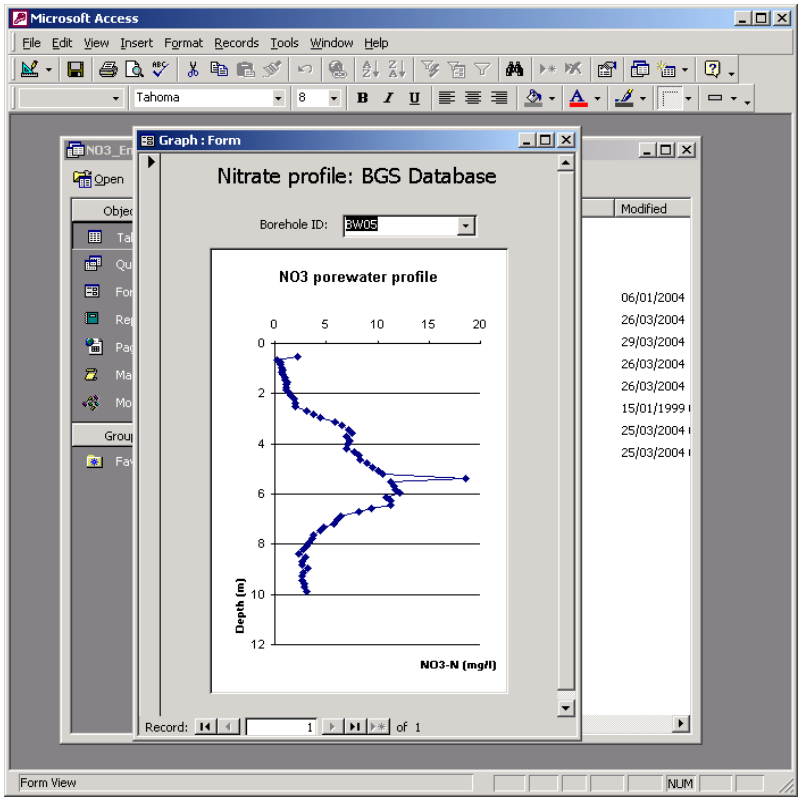
Databasing of nitrate porewater profiles and timeseries data

Groundwater Systems and Water Quality Programme

Internal Report IR/04/072R



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/04/072R

Databasing of nitrate porewater profiles and timeseries data

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Report; nitrate; unsaturated zone; time-series; database.

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Foreword

This report is the first published product of a study by the British Geological Survey (BGS) aimed at gaining an improved understanding of the 3-dimensional distribution of nitrate in groundwater and developing models of nitrate transport.

The authors are grateful to those of their colleagues who have made data available from their project archives.

Acknowledgements

In addition to the BGS staff acknowledged in the Foreword, a number of individuals in the water industry have contributed indirectly to the production of this report by supplying data to BGS.

A particular contribution was made by Chris Young of the WRc, who kindly made the WRc archive of porewater profiles available to the project.

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Summary

This report describes the results from the first task within the BGS research project "3-D understanding and models of nitrate transport". The objectives were to collate and database the considerable body of data on nitrate concentrations in groundwater held by BGS, collected over a long period from a diverse range of science budget and commercial projects. This data needs to be drawn together to allow it to advance our understanding of the movement of nitrate and other solutes in groundwater.

The construction and access of two databases is described. These are:

- porewater profiles of nitrate and other solute concentrations in the unsaturated zone containing all important data collected at BGS Wallingford since 1977 and also the WRc porewater profile archive;
- time-series records for nitrate in mainly public abstraction boreholes collected by BGS for science budget and commercial projects.

1 Introduction

1.1 BACKGROUND

Elevated nitrate concentrations in groundwater are a major problem currently facing the water supply industry, and because there can be a considerable time lag between leaching from the soil to arrival at a water supply borehole, nitrate will remain a concern for many years to come. Predicting nitrate concentrations arriving at the water table requires quantification of nitrate leaching from the soil and an understanding of solute movement in the unsaturated zone of the aquifer. The Water Framework Directive requires the reversal of increasing trends of nitrate (and other solutes) in groundwater bodies where there is a risk of concentrations exceeding the standard or where groundwater users or receptors will be affected.

BGS currently holds a considerable body of data on nitrate concentrations in groundwater, collected over a long period from a diverse range of science budget and commercial projects. This is a valuable dataset that needs to be collated with other data (landuse, rocks properties and other solutes) for easy access and which may help future research studies.

1.2 OBJECTIVES

The work described here forms the first task within the project "3D understanding and models of nitrate transport". The objectives are to collate and database existing datasets:

- historical nitrate porewater profiles from cored boreholes collected by various BGS projects and ancillary information including agricultural records (mainly from collation in Coleby et al., 1998);
- historical nitrate porewater profiles collected by WRc as part of their research on nitrate in the 1970s;
- recent porewater profiles from LOCAR and other BGS projects;
- time-series data collected for UKWIR (Chilton et al, 2003) and from commissioned work for water companies.

This data will then be available in a consistent format and indexed for future use in nitrate related projects. It is intended these databases will continue to be populated and updated.

This report describes the sources of information used, the construction of the databases and the present content.

2 Profiles database

2.1 STRUCTURE

The nitrate profile database contains chemical analyses of porewater chemistry in the unsaturated zone. This data is currently stored as an Access file, accessible on a shared drive in W:/Data/Hydrochemical/Nitrate Databases.

There are two separate Access databases (NO_3_Jersey and NO_3_England). The Jersey and England data have been separated because their georeferencial system is different. Both databases contain the following relational tables linked by Borehole ID number:

- **Borehole ID** which contains information about the location of the borehole from which the analysed core porewater was extracted and the date of the profile (borehole ID number, co-ordinates, date of sampling when known);
- **Site Details** which contains the site information for each borehole such as the site name, the borehole ID number, the drilled depth of borehole, the penetrated aquifer, the drilled date, information about soils and agricultural and fertilizer record (potential source/pathways of nitrate;
- **Value** which contains the actual chemical data for each borehole for a specific depth;
- **Species** which lists all the determinands that are present within the values table.

A number of queries have been built-in to facilitate the extraction of information from the database, such as extracting only the nitrate data, or only the information for a single borehole. It also includes a profile viewer from which plots can be printed (Figure 2.1).

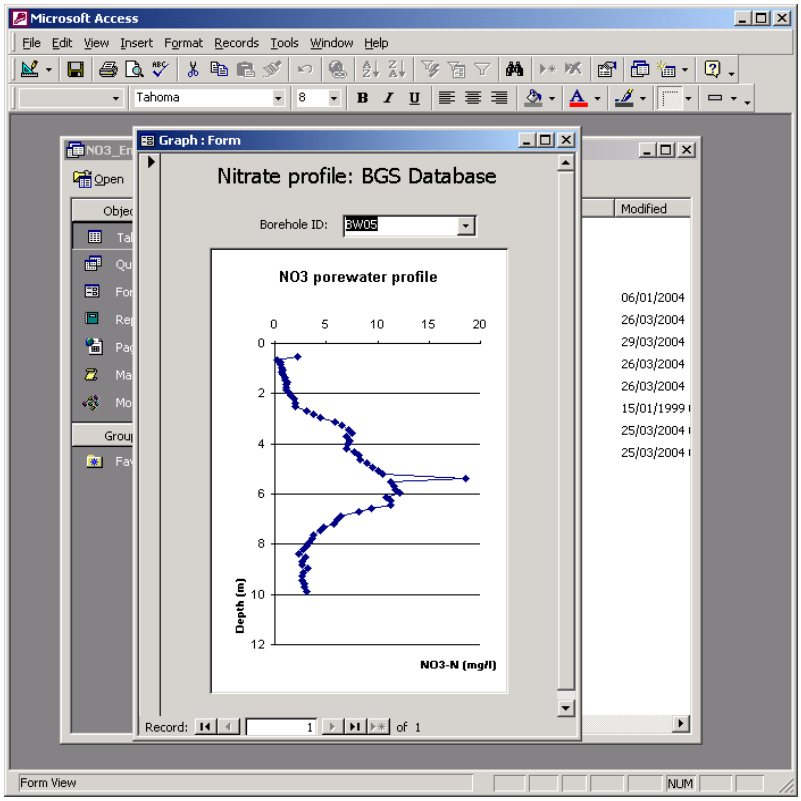


Figure 2.1 Profile preview from the NO_3_England database

2.1.1 The NO_3_England database:

The NO_3_England database consists of the following specific tables:

1. **Borehole ID all**: this contains the borehole identification code –borehole ID- (PROJECT2 field), easting, northing, day, month and year of sampling (DAYSAMP, MONSAMP, YEARSAMP). This table contain 374 entries, of which some fields are blanks. The primary key of this table is the borehole ID. This table is linked via the PROJECT2 field with the site details information, as illustrated in Figure 2.2.

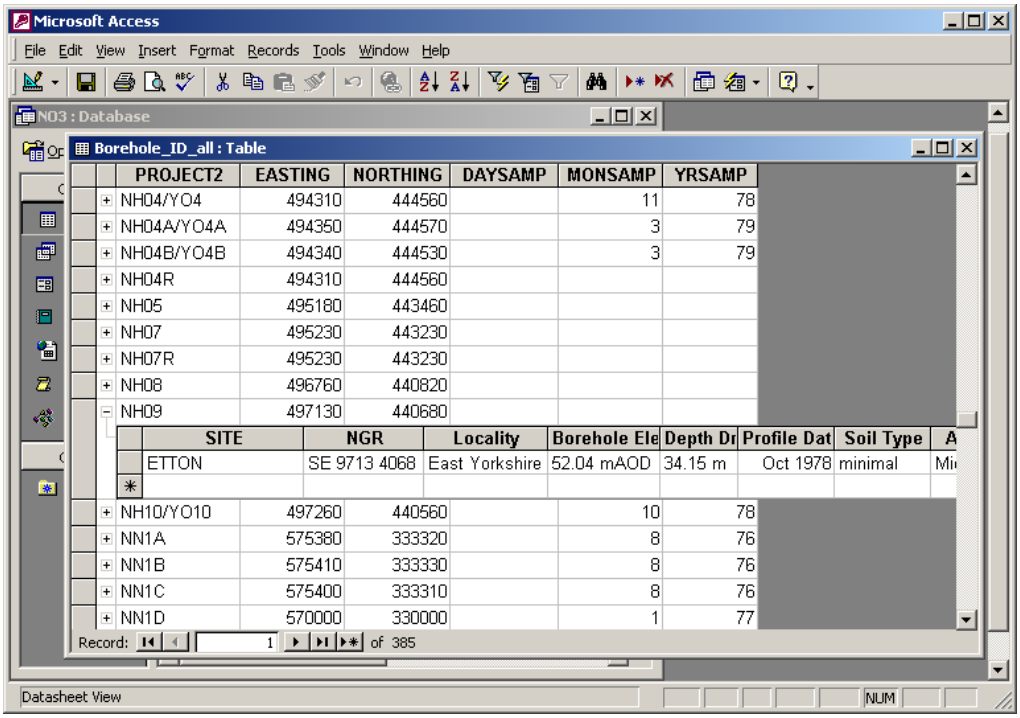


Figure 2.2 View of the Borehole ID_all table and the link with the site details

2. **Borehole ID where values**: this contains the same fields as the above table but only for the sites for which there are some data in the Values table. The primary key of this table is the borehole ID. Each record is then linked with the corresponding chemical analyses from the Values table as illustrated in Figure 2.3. This table hold 236 records.

3. **Data Source**: this file is a copy of the summary of data holdings in profiles database compiled in this report. It records for each site, the number of nitrate profile available, the aquifer, the maximum profile depth, the list of chemical parameters for which there are value in the database for this site, the availability of a tritium profile, agricultural information and other paper information held in BGS, including reports. The primary key to this table is the site name and the origin of the data (Gleadthorpe profiles were available from both BGS and WRc data).

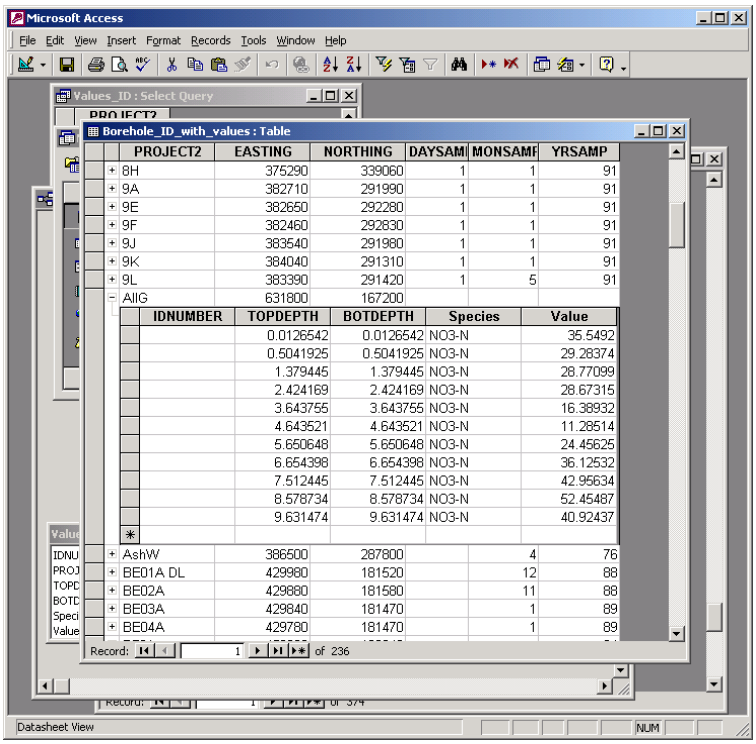


Figure 2.3 View of the Borehole_ID_where_values table and its links

4. **Site Details_all**: this table contains the following information: site name (SITE), the borehole ID (PROJECT2), the grid reference (NGR), the locality, borehole elevation, depth drilled, soil type, aquifer, soil drift thickness, depth to water level, cored sample porosity, mean annual rainfall, estimated effective rainfall, land use history, mean nitrate fertiliser, reference. Most of these fields are incomplete (except the site names and the borehole ID), as data was not available digitally. The primary key of this table is the borehole ID and it contains 386 entries.

5. **Site Details_where_values:** this is the same table as the previous one, but showing only sites for which there are chemical analyses data (in the "Values" table). This table hold 236 records; it is linked with the " Borehole_ID_where_values" and the "Values" tables. Therefore for each record, it is possible to get the information of the borehole and to display the chemical analyses as illustrated in Figure 2.4. The primary key of this table is the borehole ID.

6. **Species:** this table listing the determinands that have been analysed for within the "Values" table, it is linked with this table, i.e. for each species it is possible to display all the analyses for this determinand. The primary key of this table is the species (determinand description).

7. **Values** this table contains the chemical analyses data; its headings are IDNUMBER (arbitrary number where existing), the borehole ID (PROJECT2), the top and bottom depth in metres (TOPDEPTH, BOTDEPTH), the determinand (SPECIES) that was analysed and the corresponding measured value. There is no primary key on this table.

Queries:

The following queries are provided:

1. **Append Values**: appends new values to the values table;
2. **NO_3 db**: displays only the nitrate values from the Value database;

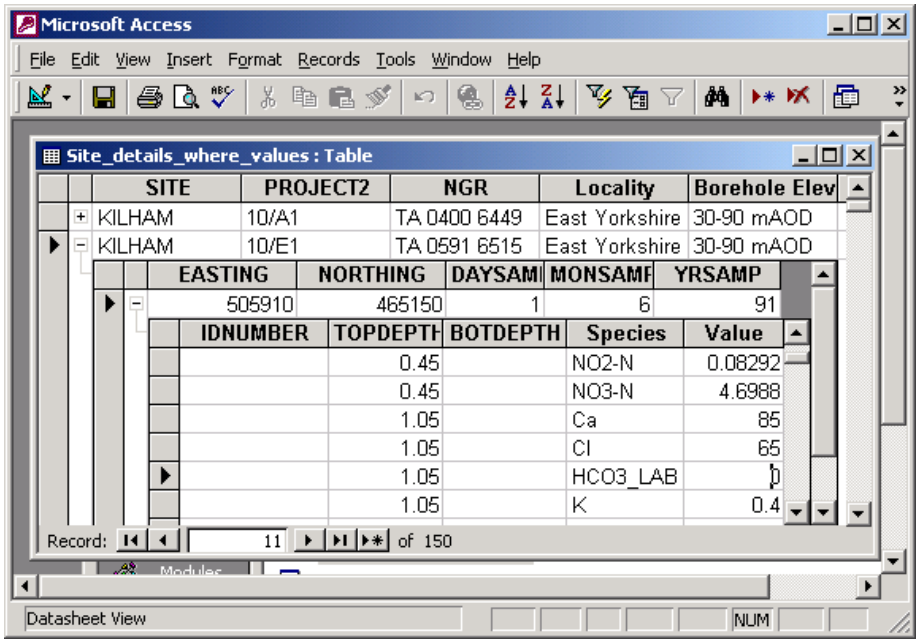


Figure 2.4 View of the Site_Details_where_Values table and its links

3. **Qry nitrate DB**: selects the nitrate data available for a given borehole ID. This query is used within the plotting form;
4. **Summary Table**: returns a summary table with for each site: the number of profiles available, the aquifer, and the maximum top and bottom depth of the profiles;
5. **Value_ID**: returns the list of borehole number for which there are some entries in the "Values" table;
6. **Value_Crosstab**: displays the data in the "Values" table as a series of columns with the corresponding chemical analyses for each borehole and depth (top and bottom) (Figure 2.5).

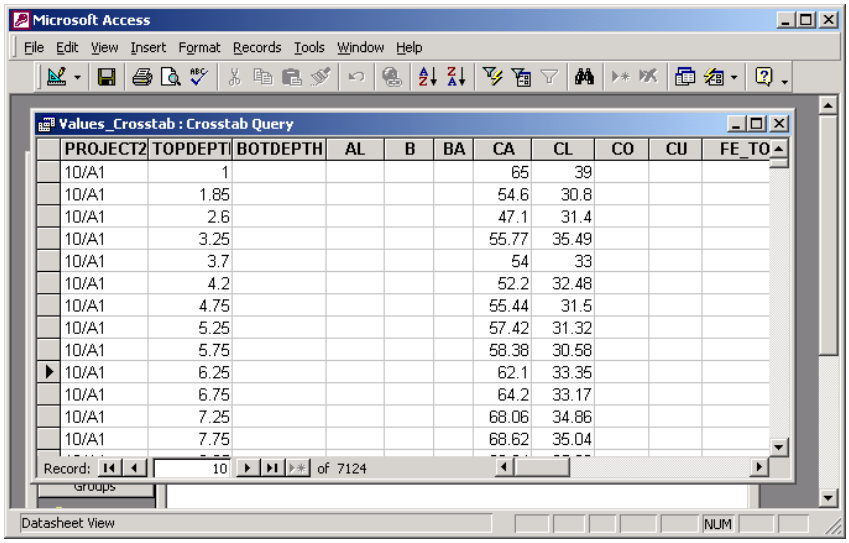


Figure 2.5 View of the Value_Crosstab query

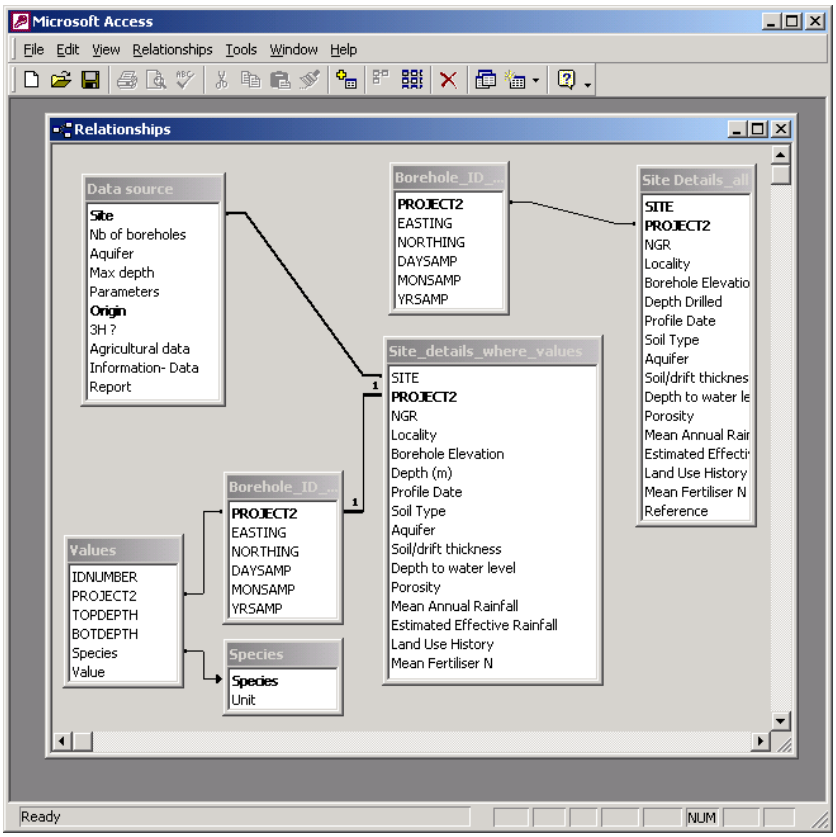


Figure 2.6 View of the NO_3_England database relationships

Forms:

Graph: plots the nitrate profile for a selected borehole. There is a scrolling menu to choose from in the form (Figure 2.1).

Relationships within the tables:

Most tables are linked with an undefined relationship using “Borehole ID” (PROJECT” field). However, the “Borehole_ID_where_value” and the “Site_details_where values” tables are linked together so that each borehole ID, corresponds to only one site. The table of relationships is illustrated in Figure 2.6.

2.1.2 The NO_3_Jersey database

Tables:

1. **Borehole ID** contains borehole number (PROJECT2 field), easting, northing, day, month and year of sampling (DAYSAMP, MONSAMP, YEARSAMP). This table contains 14 records, the primary key is the borehole ID, and it is linked with the site details table.
2. **Site Details** comprises: site name (SITE), the borehole number (PROJECT2), the grid reference (NGR), the locality, the borehole elevation, depth drilled, soil type, aquifer, soil drift thickness, depth to water level, porosity, mean annual rainfall, estimated effective rainfall, land use history, mean fertiliser N, reference. Most of these fields are blanks. This table contains 14 records, the primary key is the borehole ID.
3. **Species** is a table listing the chemical analyses determinants in the Value table.

4. **NO3** contains only the nitrate analyses data from the Value table: its headings are IDNUMBER (arbitrary number where existing) field, the borehole number (PROJECT2), the top and bottom depth in metres (TOPDEPTH, BOTDEPTH), the species that was analysed and the corresponding measured value.
5. **Value** is a table containing chemical analyses data; its headings are IDNUMBER (arbitrary number where existing) field, the borehole number (PROJECT2), the top and bottom depth in metres (TOPDEPTH, BOTDEPTH), the species that was analysed and the corresponding measured value.

Queries:

1. **NO_3 db**: displays only the Nitrate values from the Value database.
2. **Query Nitrate datab:** selects the nitrate data available for a given borehole ID. This query is used within the plotting form.
3. **Value_Crosstab**: display the data in the Values table in a cross-tabulated shape i.e. for each borehole and depth (top and bottom) a series of columns with the corresponding chemical analyses.

Form:

JN plots the nitrate profile for a selected borehole. There is a scrolling menu to choose from in the form.

Relationships:

There are two one-to-many relationships between the site details, borehole_ID and the values tables. The borehole ID (PROJECT2 field) is the key sorting field. Figure 2.7 illustrates the relationships in the NO_3 Jersey database.

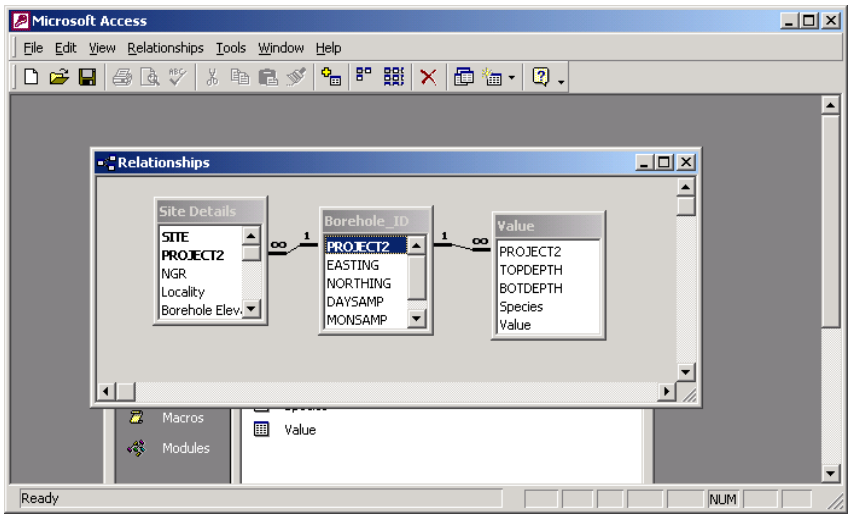


Figure 2.7 View of the NO_3_Jersey database relationships

2.2 DATA SOURCES

The database contains nitrate unsaturated zone profiles from the following BGS studies:

- Project commissioned by MAFF looking at nitrate attenuation within the unsaturated zone in the major aquifers of England and Wales (Kinniburgh et al., 1999; Coleby et al., 1998). This collated data from some 19 sites studied by BGS since 1977 from: Chilton et al. 1991; Chilton et al.,1997; Foster et al. 1977; Foster et al., 1986; Geake and Foster, 1989; Kinniburgh and Trafford, 1996; Parker and Bridge, 1987; Parker and Perkins, 1988; Parker et al., 1989; Parker et al., 1991;
- Study of nitrate in groundwater in Jersey (Chilton and Bird, 1994),
- Recharge through the Drift (Marks et al., 2004)
- Transport and fate of pesticides in the unsaturated and saturated zones (Chilton et al., 1993; BGS and IH, 1995, 1996). Nitrate profiles from five sites on the Hampshire Chalk were collected as part of this pesticides study.
- Data gathered in 2002-2003 during the Lowlands Catchment Research Programme (LOCAR) from the Frome-Piddle, and Pang-Lambourn catchments on the Chalk and the Triassic sandstone Tern catchment.

Historical data from the Water Research Centre (WRc) was also included. This important dataset was provided to BGS in paper form and was digitised as part of this project, either manually from tables of data or directly from plots using the Un-Scan-It software.

2.3 CONTENT

Table 2.1 Summary of data holdings in profiles database

Digital Information						Additional paper information			
Site	**No of boreholes**	**Aquifer**	**Max depth (m)**	**Parameters**	**Origin**	**^3H ?**	**Agricultural data**	**Information- Data**	**Report/Project**
Alland Grange	1	Upper Chalk	9.6	NO_3-N	WRc		yes	Borehole record, NO_3 graph	Thanet
Anmer	5	Middle/Upper Chalk	29.0	Ca Cl K Mg Na NO_3-N SO_4	BGS		yes		Coleby et al. 1998
Ashwood	1	Triassic SST	152.0	NO_3-N	WRc	yes		Map, borehole record, NO3 and NO2 analyses (table and graph for NO2 only), aquifer props data, Tritium data and graph, lithological log	
Bircham	25	Middle/Upper Chalk	61.0	Ca Cl K Mg Na NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Black Wood	21	Upper Chalk	30.0	Ca Cl HCO_3_LAB K MC Mg Na NH_4-N NO_2-N NO_3-N PH_LAB SO_3	BGS		yes		Coleby et al., 1998
Bougthon	6	Sherwood Sandstone	10.0	Ca Cl HCO_3_LAB K Mg Na NH_4-N NO_2-N NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Boxford	1	Chalk	73.9	NH_4-N NO_2-N NO_3-N TON	BGS			Completion details	LOCAR
Boyton End	1	Drift/Chalk	20.8	NO_3-N	BGS				Marks et al., 2004
Bricketts Wood	3	Chalk	27.1	NO_3-N	WRc			Site map, report, analyses, chemical cross-sections, site location map, borehole record+geophysical log+analyses+graphs (Bh 1+2+3), depth sample analyses.	
Bridgets Farm	2	Chalk	32.5	Cl NH_4-N NO_2-N NO_3-N SO_4 TOC	BGS		yes		Coleby et al., 1998
Broadfield Cottages	1	Chalk	90.2	NH4-N NO_2-N NO_3-N TON	BGS			Completion details	LOCAR

Digital Information						Additional paper information			
Site	**No of boreholes**	**Aquifer**	**Max depth (m)**	**Parameters**	**Origin**	**^3H ?**	**Agricultural data**	**Information- Data**	**Report/Project**
Camp Farm	2	Triassic SST	14.5	NO_3-N	WRc			Site map, borehole records (bh 1+2+3), chemical analysis, some NO3- graphs, geophysical log (bh 3)	
Chateauneuf Grouville	5	Jersey Shale Formation	4.7	Al, B, Ba, Ca, Cl, Co, Cu, Fe tot, HCO_3, K, Li, Mg, Mn, Na, NH4-N, Ni, NO_2-N, NO_3-N, P tot, pH, SEC, Si, SO_4, Sr, V, Y, Zn	BGS		yes		Chilton and Bird, 1994
Checkhill Farm	3	Triassic SST	90.0	NO_3-N	WRc	yes		Site map, geological, geophysical and completion infos, borehole records (bh 1+2+3) and associated chemical analysis and graphs, Tritium	
Cheesemans Farm	1	Upper Chalk	34.9	NO_3-N	WRc	yes	yes	Borehole record, NO3 and NO2 analyses (table and graphs), aquifer props data, Tritium data and graph	Thanet
Compton	4	Lower Chalk	5	NO_3-N, Atrazine, Moisture	BGS		yes		Chilton et al., 1993
Cornish Farm	4	Upper Chalk	79.3	NO_3-N	WRc	yes	yes	Borehole records (bh 1+2+3), Eastbourne chalk file, data bh 3 (R) Tritium bh 4	Eastbourne chalk
Deep Dean	28	Middle Chalk	29.5	NO_3-N	WRc		yes	Borehole record (bh 1 to 10), chemical analysis and graphs (bh 1 to 28), data (bh 34 to 38) General info, weather Station reports, Eastbourne chalk study file	Eastbourne chalk
Down Farm	2	Chalk	102.5	NH_4-N NO_2-N NO_3-N TON	BGS			Completion details	LOCAR
Etton	3	Middle Chalk	45.9	Cl NH_4-N NO_2-N NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Fleam Dyke	12	Middle Chalk	23.0	Cl NO_3-N SO_4 Cl	BGS		yes		Coleby et al., 1998
Fonthill	11	Chalk	33.0	Cl NO_3-N SO_4	BGS		yes		Coleby et al., 1998

Digital Information						Additional paper information			
Site	**No of boreholes**	**Aquifer**	**Max depth (m)**	**Parameters**	**Origin**	**^3H ?**	**Agricultural data**	**Information- Data**	**Report/Project**
Fordington Down	1	Chalk	80.0	NH_4-N NO_2-N NO_3-N TON	BGS			Completion details	LOCAR
Frilsham Meadow	7	Chalk	60.4	NH_4-N NO_2-N NO_3-N TON	BGS			Completion details	LOCAR
Frome Whitfield	2	Chalk	29.8	NH_4-N NO_2-N NO_3-N TON	BGS			Completion details	LOCAR
Gleadthorpe	2	Sherwood Sandstone	17.7	Cl NH_4-N NO_2-N NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Gleadthorpe	2	Sherwood Sandstone	27.5	NO_3-N	WRc		yes	Borehole record (bh 1+2+3+5+6)	
Gothersley Farm	1		14.5	NO_3-N	WRc			Borehole record, landuse info, chemical analysis, Ortho-P and NO2 graphs	
Higher Came Farm	1	Chalk	60.0	NH_4-N NO_2-N NO_3-N TON	BGS			Completion details	LOCAR
Hurley	3	Upper Chalk	100.1	NO_3-N	WRc			Boreholes records (bh 1+2+3+5+6+7), NO3 profiles	
Kilham	5	Upper Chalk	9.8	Ca Cl HCO_3_LAB K Mg Na NH_4-N NO_2-N NO_3-N SO_4	BGS		yes		Coleby et al., 1998
La Francheville Grouville	6	Jersey Shale Formation	7.1	Al, B, Ba, Ca, Cl, Co, Cu, Fe tot, HCO_3, K, Li, Mg, Mn, Na, NH_4-N, Ni, NO_2-N, NO_3-N, P tot, pH, SEC, Si, SO_4, Sr, V, Y, Zn	BGS		yes		Chilton and Bird, 1994
La Retraite Five Oaks	2	Jersey Shale Formation	4.5	Al, B, Ba, Ca, Cl, Co, Cu, Fe tot, HCO_3, K, Li, Mg, Mn, Na, NH_4-N, Ni, NO_2-N, NO_3-N, P tot, pH, SEC, Si, SO_4, Sr, V, Y, Zn	BGS		yes		Chilton and Bird, 1994
Lambourn	4	Middle Chalk	24.0	Ca Cl K Mg Na NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Leckford	2	Upper Chalk		NO_3-N, TOC, Moisture	BGS		yes		Chilton et al., 1993

Digital Information						Additional paper information			
Site	**No of boreholes**	**Aquifer**	**Max depth (m)**	**Parameters**	**Origin**	**^3H ?**	**Agricultural data**	**Information- Data**	**Report/Project**
Manston	2		27.2	NO_3-N	WRc			NO3 data and graph 11+12 (R)	Thanet
Massingham	4	Middle/Upper Chalk	48.0	Ca Cl K Mg Na NH_4-N NO_2-N NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Mid Coal Brook	1		55.9	NH4-N NO_2-N TON	BGS				
Netherhale Farm	1	Upper Chalk	22.5	NO_3-N	WRc			Borehole record, plot	Thanet
North Dean	6	Middle Chalk with Upper Chalk cap in places	24.0	Ca Cl K Mg Na NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Ogbourne	5	Lower Chalk	31.4	Ca Cl HCO_3_LAB K Mg Na NO_2-N NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Quex Park	4		8.4	N--N	WRc			NO3 data and graph 13+14+15+16 (R)	Thanet
Rothamsted Experimental Station	7	Chalk	46.2	NO_3-N	WRc		yes	Site map, geological, geophysical (bh 5+6+7) infos, borehole records (bh 1+2+3+4+5+6+7) and associated chemical analysis and graphs	
Sparrow Castle	2	Upper Chalk	19.8	NO_3-N	WRc		yes	Borehole records (bh 1+2), plot (1+2)	Thanet
Sprattling Court Farm	4	Upper Chalk	41.7	NO_3-N	WRc	yes	yes	Borehole records (bh 1+2+3), Tritium profiles (2+3+4 R)	Thanet
Sutton Manor	2	Upper Chalk		NO_3-N, TOC, Moisture, Atrazine	BGS		yes		Chilton et al., 1993
St Michaels School Pl Fd	1	Jersey Shale Formation	4.0	Al, B, Ba, Ca, Cl, Co, Cu, Fe tot, HCO_3, K, Li, Mg, Mn, Na, NH_4-N, Ni, NO_2-N, NO_3-N, P tot, pH, SEC,	BGS		yes		Chilton and Bird, 1994

Digital Information						Additional paper information			
Site	**No of boreholes**	**Aquifer**	**Max depth (m)**	**Parameters**	**Origin**	**^3H ?**	**Agricultural data**	**Information- Data**	**Report/Project**
				Si, SO_4, Sr, V, Y, Zn					
Stoke on Tern	2	Sherwood Sandstone	26.0	NH_4-N NO_2-N TON	BGS			Completion details	LOCAR
Stonor	4	Middle Chalk	21.5	Ca Cl K Mg Na NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Tom Hill	6	Sherwood Sandstone	11.9	Ca Cl K Mg Na NO_2-N NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Trumpletts Farm	1	Chalk	99.9	NH_4-N NO_2-N NO_3-N TON	BGS			Completion details	LOCAR
Wellings	5	Sherwood Sandstone	15.0	Ca Cl K Mg Na NO_2-N NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Westbury	1	Chalk	19.4	NO_3-N	WRc			Borehole records (bh 1) and NO3 graph, map	Eastbourne chalk
Western Court	2	Upper Chalk		NO_3-N, Atrazine, Moisture, TOC	BGS		yes		Chilton et al., 1993
Wigden's Bottom	13	Chalk	29.8	NO_3-N	WRc	yes	yes	Tritium profiles bh 6Eastbourne chalk study file	Eastbourne chalk
Wildmoor	4	Sherwood Sandstone	11.2	Ca Cl K Mg Na NO_2-N NO_3-N SO_4	BGS		yes		Coleby et al., 1998
Wonston	5	Chalk	9.8	NO_3-N	BGS				Chilton et al., 1993; BGS & IH, 1996

(R) indicates the desired information is only available in the Report file

Total number of profiles: 262.

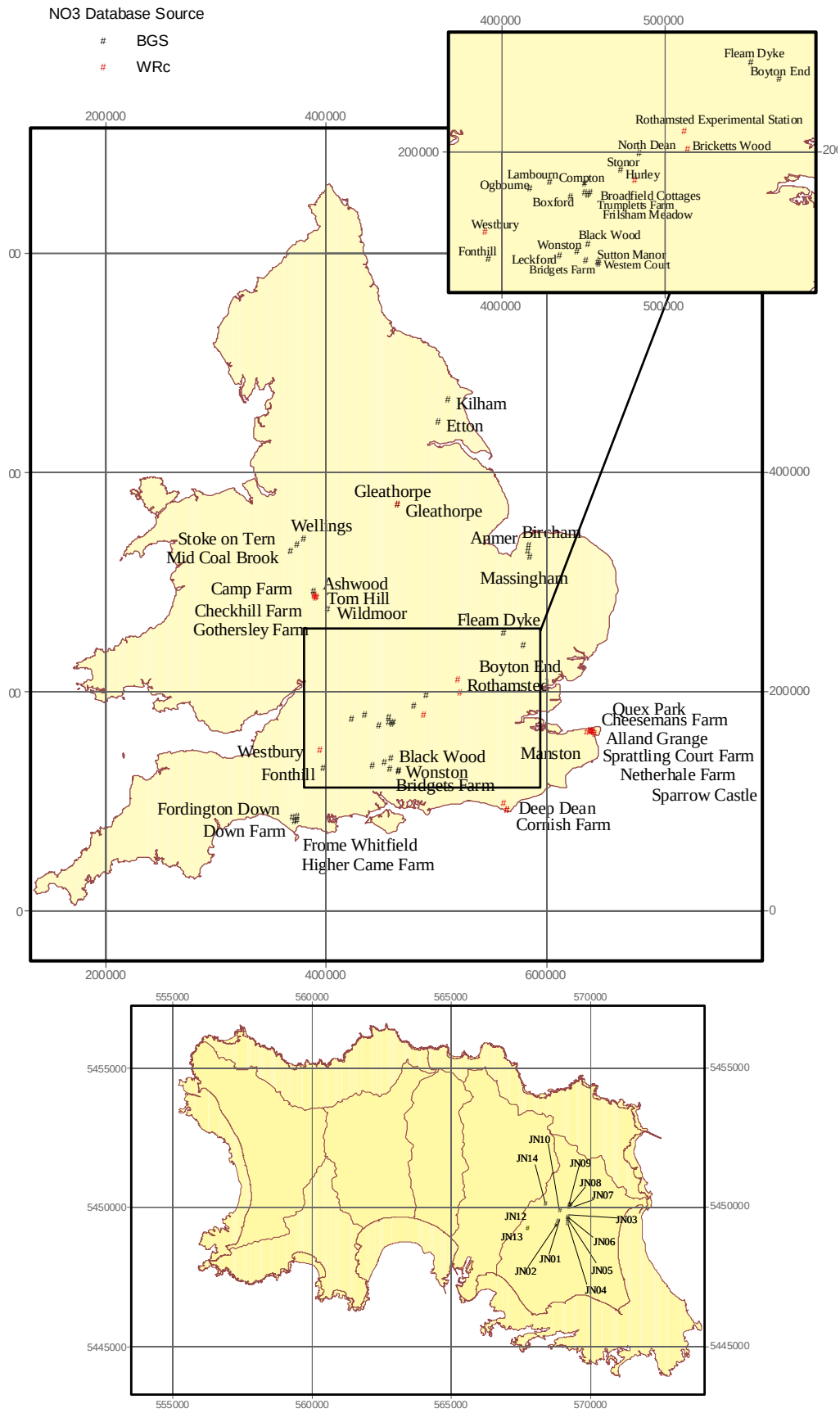


Figure 2.8 Location map of sites with profiles a) England data; b) Jersey data

2.4 EXAMPLES

The following plots illustrate the data in term of depth of analysis and sampling intervals. Values are shown using mid-point depth where both top and bottom depth are known, otherwise either top or bottom depth is used. Depth assignment is consistent within each profile.

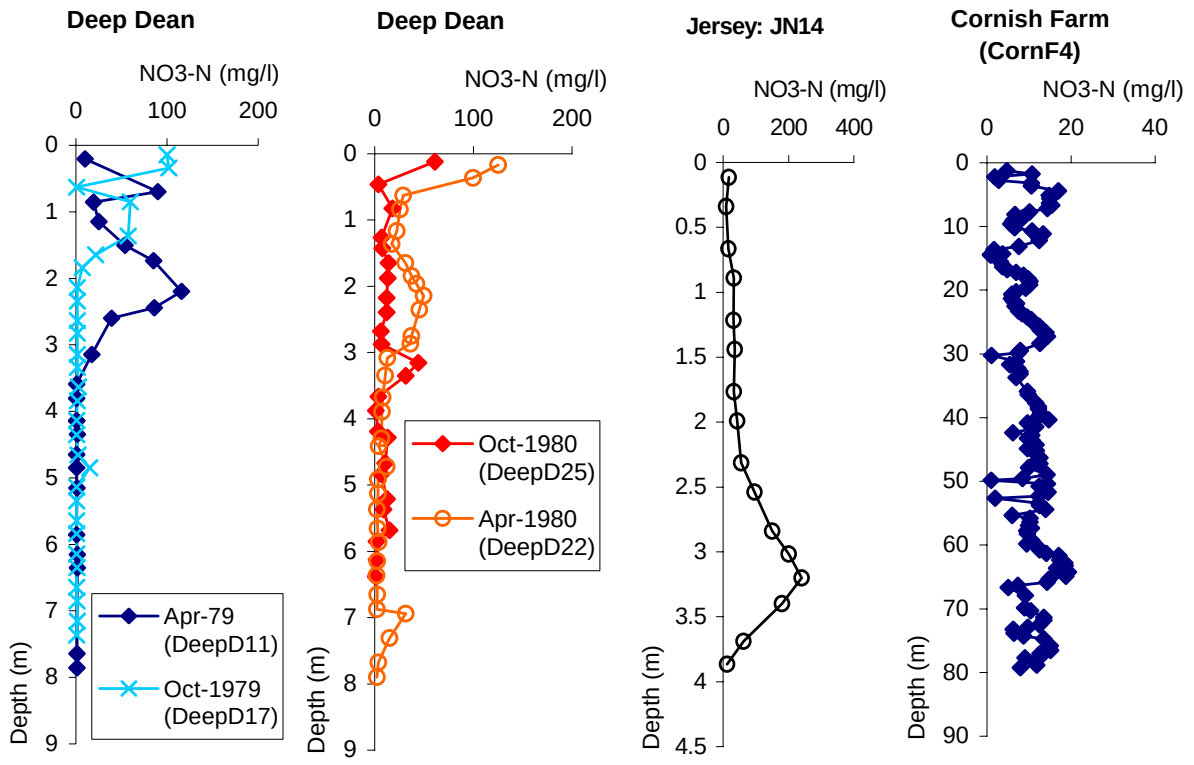


Figure 2.9 Examples of nitrate plots from the databases

3 Time-series database

The time-series database contains all of the nitrate-project related time-series data that are currently held by BGS Wallingford. At present it contains 477 source entries, with a source being either a borehole or a spring. This includes one bromate time-series and 476 sources with nitrate-species time-series data, of these 476 entries one is for simazine and one is for atrazine.

3.1 STRUCTURE

The database comprises a collection of Excel spreadsheets that are located in folders according to the project for which the data were initially collated. A metadata catalogue exists that holds all the available data for each time-series at the time of print. Due to ambiguity over the definition of a 'time-series' it has been decided to incorporate a simple three-stage selection procedure that requires some alterations to basic "IF-THEN-OTHERWISE' formulae in. Excel. The Excel spreadsheet is linked to Access, which allows the results of the Excel decision statements to be used to select the time-series of interest. The results of a pre-defined, but easily altered query in Access may then be exported and used to search the collection of spreadsheets containing the time-series data. This effectively ensures that no data is lost as a result of defining a 'time-series', and allows the user to select time-series based on their own requirements.

Below is a view of the time-series database which is stored in W:Data/Hydrochemical/Nitrate Databases/Time-series (Figure 3.1). Within this folder are the folders that contain the time-series data listed by the project for which the data was initially acquired. Below the project folders are the applications that may be used to select and search for the required time-series.

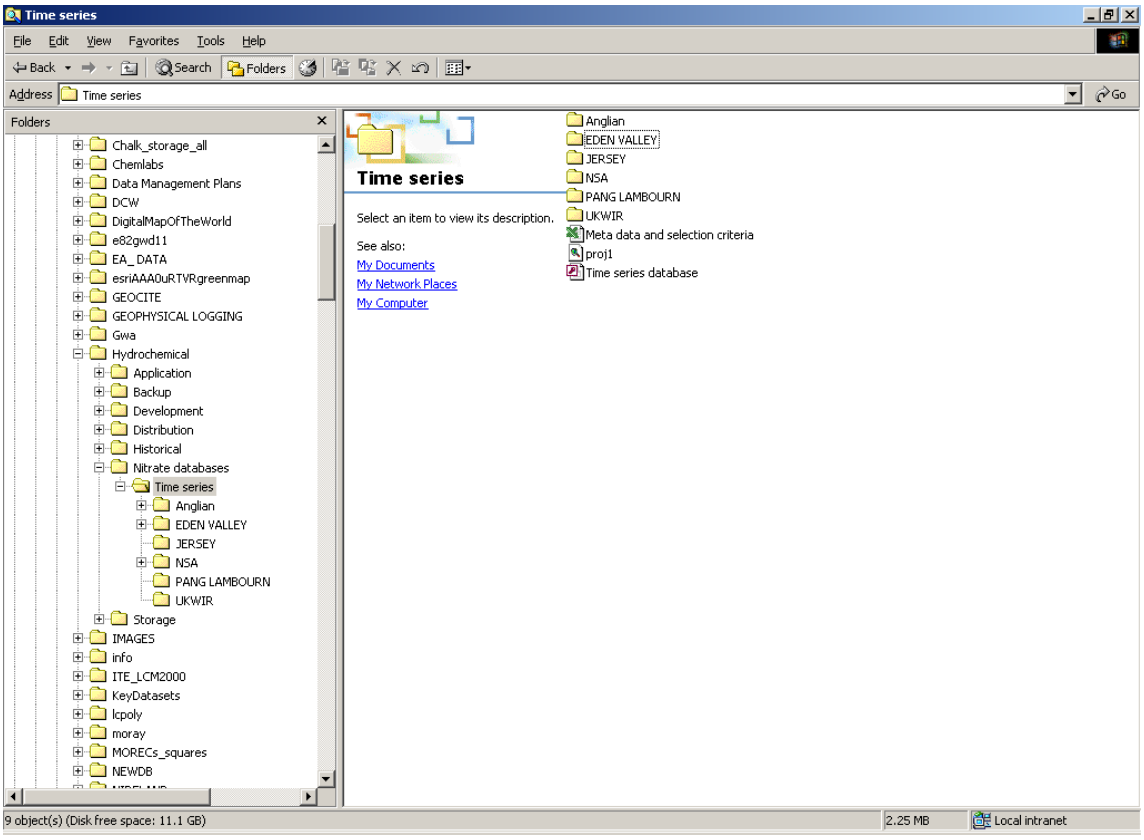


Figure 3.1 The time-series data base

The selection procedure provides a method of interrogating the database that could with time be made user-friendlier. However there are a number of other ways of choosing time-series data, these are listed below in order of decreasing technical effort:

- the location of each data source is plotted by aquifer on a geological map of the UK in Arc View 3.0. Information on each location may be retrieved by selecting the 'identify' tool symbol (first symbol from the left on the second row of symbols), and then selecting the point of interest. Alternatively by selecting the 'select feature' symbol (fourth tool symbol from the left on the second row of symbols), a number of points may be selected at once by dragging a box over the area of interest. By holding the shift key down it is possible to select a number of areas using the select feature. NB the theme of interest must be 'active' (i.e. selected so that it appears raised) before any theme data can be selected;
- the meta-data table in the Data Catalogue folder contains a summary of the data associated with each source. Viewing this and using the filter function in Excel allows for a degree of selection;
- alternatively the area or aquifer of interest may be broadly deduced by the title of the project folders in which the time-series data are kept.

The flow chart in Figure 3.2 illustrates the potential data selection pathways discussed above.

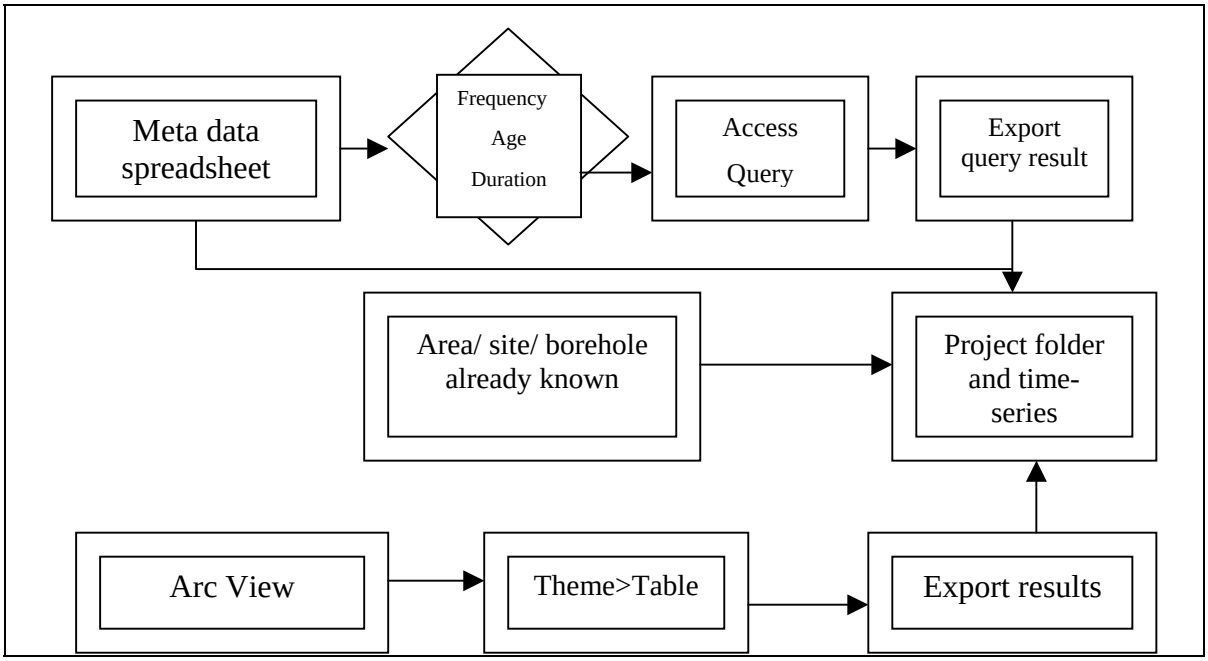


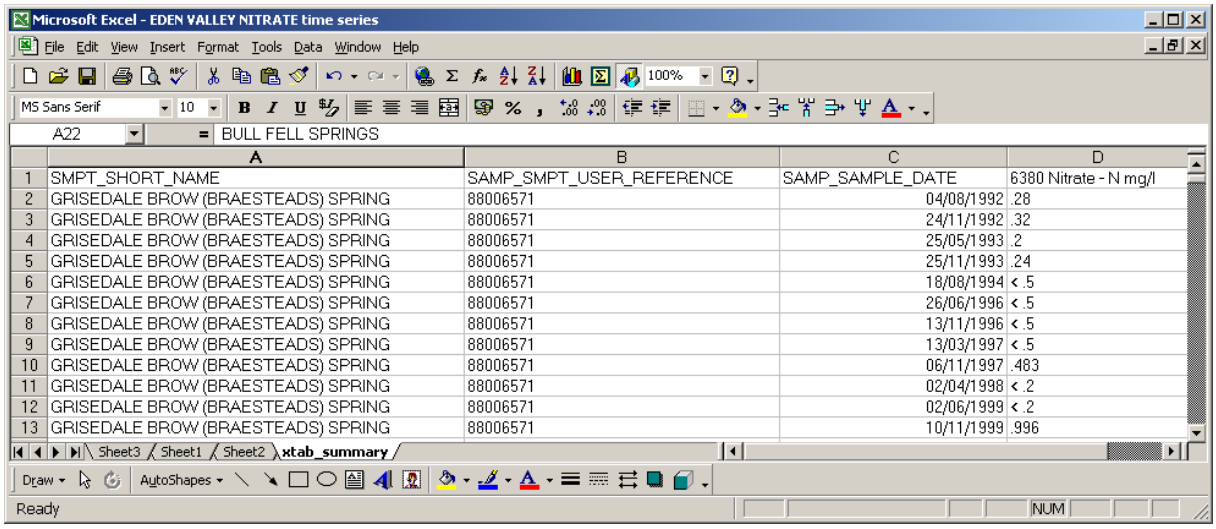
Figure 3.2 Time-series selection pathways

3.1.1 Data files

With the exception of the Eden Valley project data and some files from Anglian Water Services where both Total Oxidised Nitrate (TON) and nitrate (NO_3) are required for a complete series, time-series data are kept in two column Excel files, with a file for each time-series. The one file per series and two columns per file format (i.e. date in the left hand and concentration in the right hand column) is the 'ideal', and the majority of time-series are so organised, however time constraints have meant that all Eden valley time-series are unformatted and appear as received in one spreadsheet that is four columns abreast. Anglian

Water Services data are held in one Excel file with each series located in a separate sheet in the two-column format

An example of the Eden Valley data appears below. The disadvantage is that data in this format may be less easily plotted than those series that are in separate Excel files or sheets with Excel files.



	A	B	C	D
1	SMPT_SHORT_NAME	SAMP_SMPT_USER_REFERENCE	SAMP_SAMPLE_DATE	6380 Nitrate - N mg/l
2	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	04/08/1992	.28
3	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	24/11/1992	.32
4	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	25/05/1993	.2
5	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	25/11/1993	.24
6	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	18/08/1994	< .5
7	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	26/06/1996	< .5
8	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	13/11/1996	< .5
9	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	13/03/1997	< .5
10	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	06/11/1997	.483
11	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	02/04/1998	< .2
12	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	02/06/1999	< .2
13	GRISEDALE BROW (BRAESTEADS) SPRING	88006571	10/11/1999	.996

Figure 3.3 A view of the Eden Valley time-series spreadsheet

3.1.2 Meta data and selection criteria

It has been decided that rather than exclude any data from the time-series database three simple ‘logical test’ formula in Excel would be used to parameterize selection if required. This simple formula returns a ‘1’ or ‘0’ for a true or false answer respectively. The ‘1’ or ‘0’ can then be recognised by Access to select the required time-series

An example of the formula box appears in figure 3-4 below, it is created in Excel when “If()” is entered in the formula line at the top of the spreadsheet.

The logical test may be as simple as “<10” which has been used initially in the ‘Age’ decision formula, i.e. return ‘1’ if the last entry in the time-series is less than 10 years ago (true), or ‘0’if not (false).

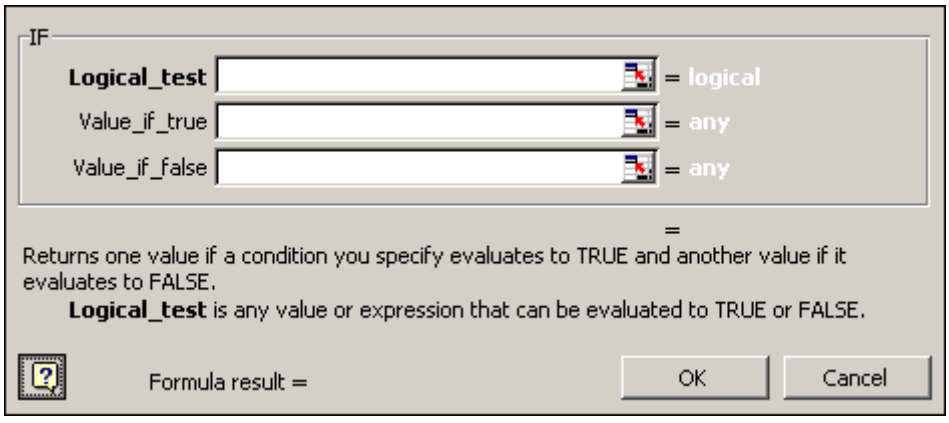


Figure 3.4 The logical test used to select time-series

Selection criteria based on the 'Frequency', 'Age' and 'Duration' of a time-series are located at the extreme right of the 'meta data and selection criteria' Excel file of the database. The criteria are initially set up so as to select time-series that span more than 10 years, are less than ten years old and contain, on average, more than two data entries per year.

Frequency: The formula returns a proxy frequency result based on whether there are more than two data points per year in the time-series. It must be noted that this result is an indication of, and not an absolute frequency.

Age: The formula returns a result base on whether the last entry in the time-series was greater than 10 years old on the 1st January 2004.

Duration: The formula returns a result based on whether the series is greater than 10 years long or not.

Part of the 'meta data table with decision formula' Excel file is shown below in figure 3-5. The formula highlighted is that of the frequency logical test, and is as follows:

$$IF((L2/((K2-J2)/365.25))<2,0,1)$$

The bracketed term is the logical test, i.e. the number of data points (L2), divided by the duration of the time-series ((K2-J2)/365.25)), less than 2, a '0' is returned if the answer is positive otherwise a result of '1' is returned.

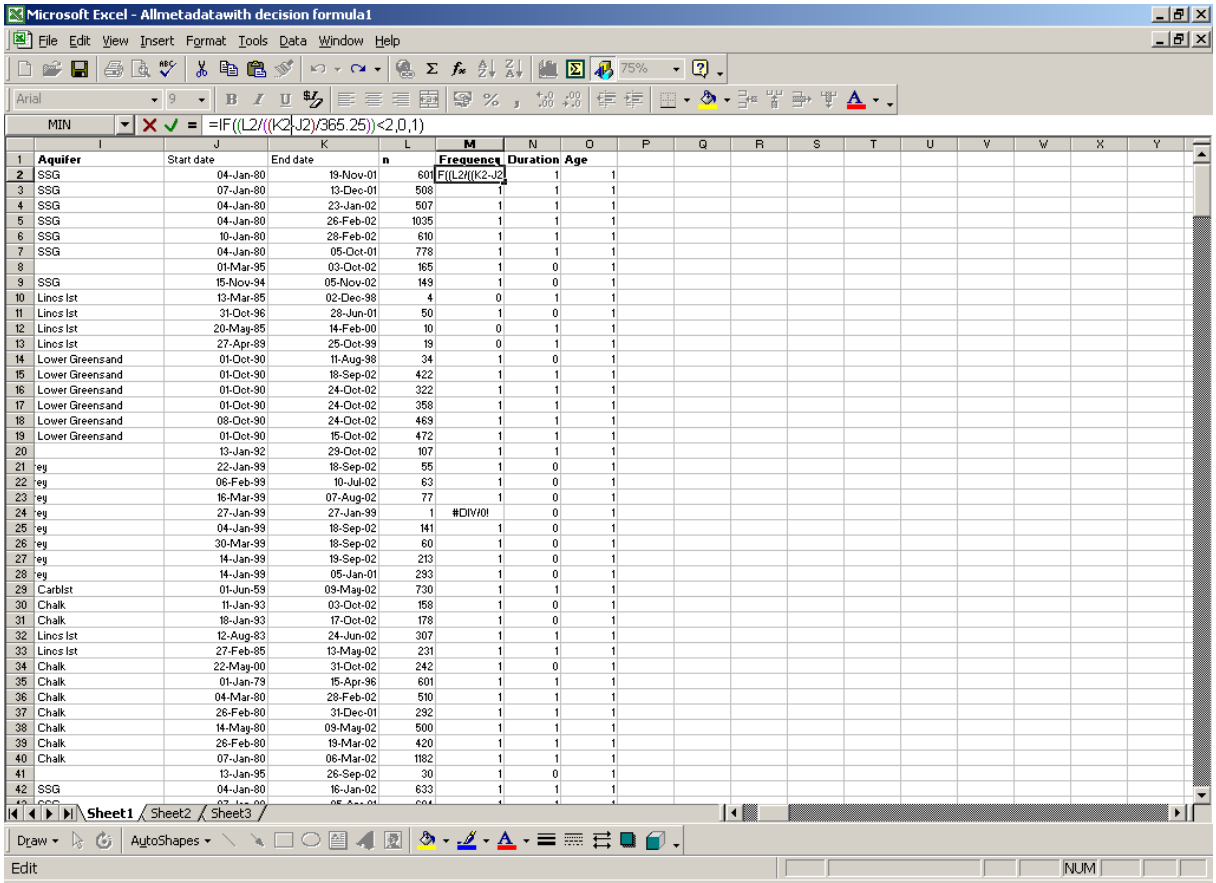


Figure 3.5 Part of the metadata table with decision formula highlighted

3.1.3 Access

The metadata table is linked to Access. “Like” commands are used in Access to select the time-series required. Hence the results of the Excel formula can be used along with other criteria such as Aquifer to select the time-series of interest. Figure 3.6 below shows the present layout of the query in Access. Query design may be entered by highlighting the query title (Query 1) and then clicking on the design symbol. Simply delete or add “Like ‘x’” commands, where ‘x’ represents the field entry of interest, to select on a given attribute of the time-series. Figure 3.7 below shows the result of a query based on the criteria selected in the query shown in Figure 3.6. This gives the time-series from sampling locations in the Sherwood Sandstone Group that are greater than 10 years in length, less than 10 years old and contain, on average greater than 2 analyses per year. To run the Access query double click on the query title or press the ‘run’ symbol (red exclamation mark) while in design view.

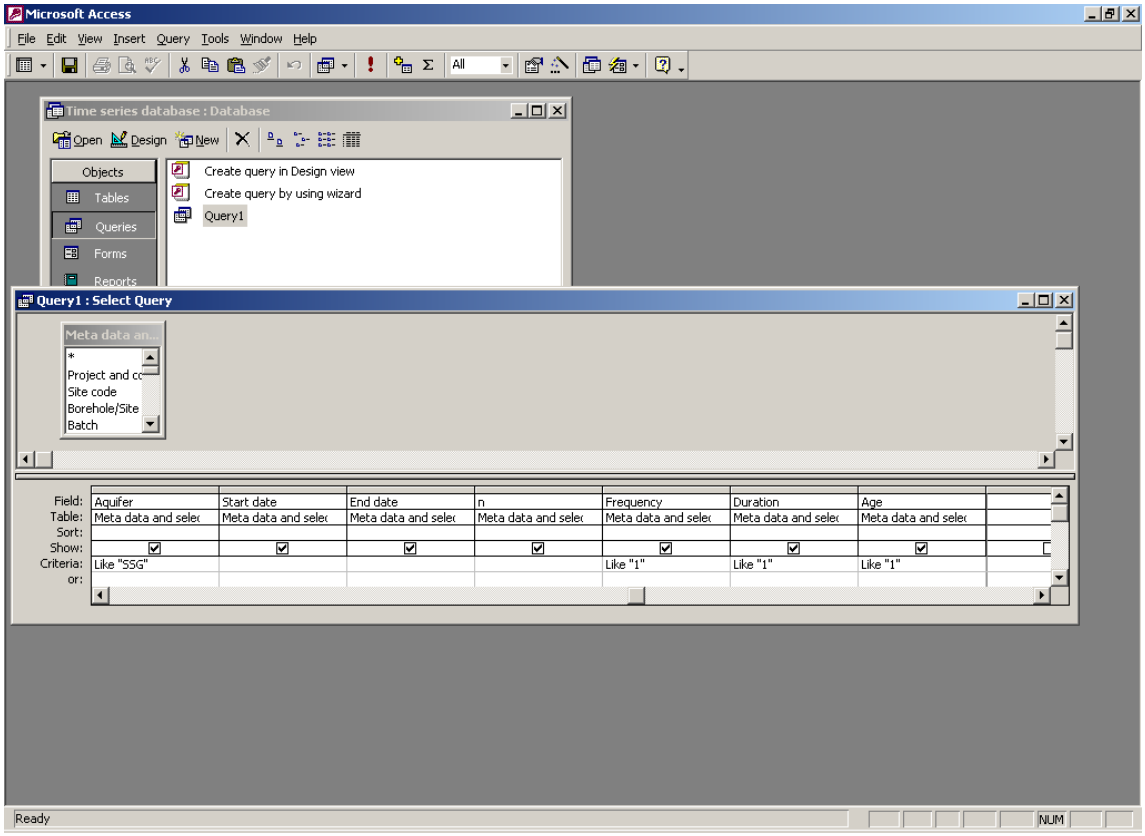


Figure 3.6 Query design in Access

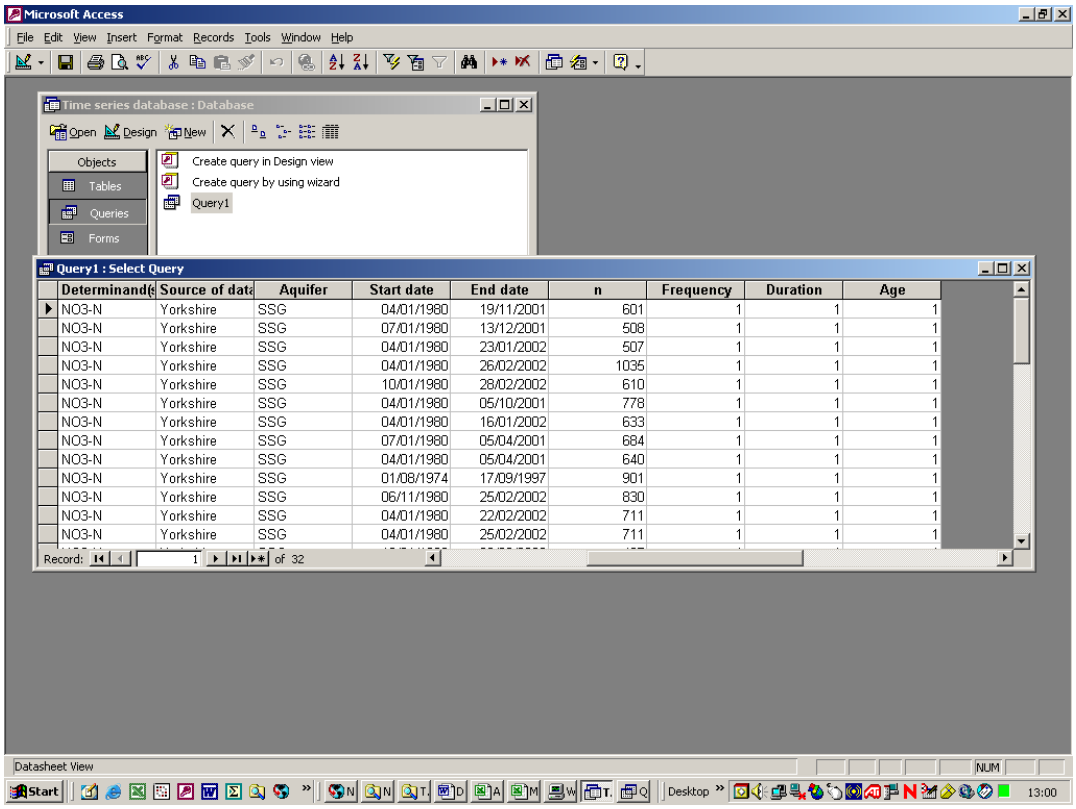


Figure 3.7 Results from query shown in Figure 3.6

3.1.4 Arc View

If the user has Arc View ESRI software then time-series data may be selected using this Geographical Information System (GIS) package.

The location of each data source is plotted by aquifer on a geological map of the UK in Arc View 3.0. Information on each location may be retrieved by selecting the ‘identify’ tool symbol (first symbol from the left on the second row of symbols), and then selecting the point of interest. Alternatively by selecting the ‘select feature’ symbol (fourth tool symbol from the left on the second row of symbols), a number of points may be selected at once by dragging a box over the area of interest. By holding the shift key down it is possible to select a number of areas using the select feature. NB the theme of interest must be ‘active’ (i.e. selected so that it appears raised) before any theme data can be selected. More proficient users of Arc View 3.0 would be able to build queries and select time-series according to their properties. However it is intended that Microsoft Access be used primarily to select time-series of interest.

In Figure 3.8 the ‘select feature’ tool has been used to drag a rectangle over the desired points, note that only the time-series from the Carboniferous Limestone aquifer are highlighted. Once the points of interest are selected, select ‘Theme’ menu and then table as in Figure 3.9. To export the selection click on the ‘File’ menu and ‘Export’, the selected points may then be exported in a convenient format.

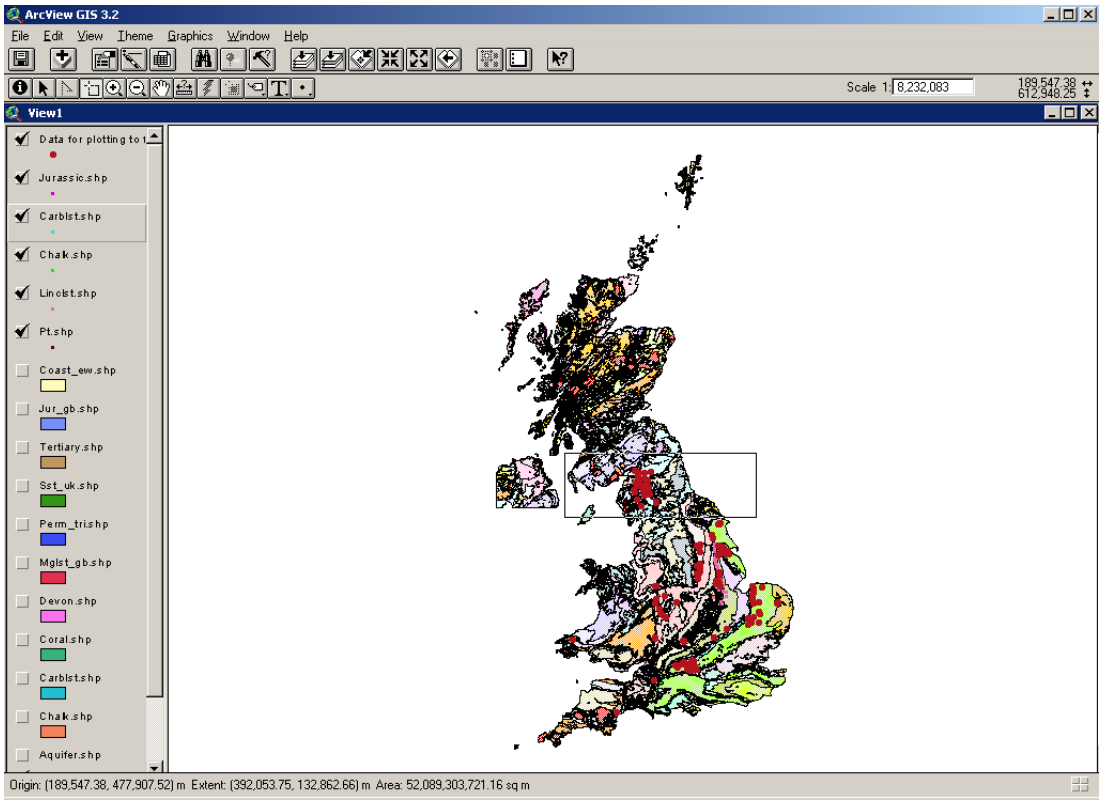


Figure 3.8 Arc View display of nitrate time-series profile locations.

Figure 3.9 Select Theme then Table to display selected points in a table that may then be exported.

3.2 EXAMPLES

The time-series data sets held in the database includes some with as few as 3 entries and others with several hundred. The longest series date back to the 1960's. A selection of nitrate trend plots from Chilton et al (2003) is presented below. Note the difference between trends in two boreholes at the same site (Figures 3.10 and 3.11), the seasonality of nitrate concentration in some abstracted groundwater (Figure 3.12) and the occurrence of large gaps in data (Figure 3-13).

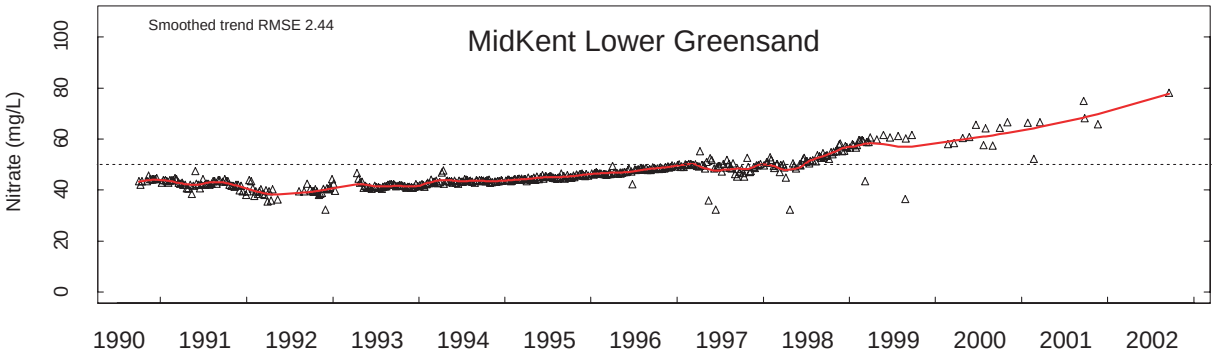


Figure 3.10 Charing 2 showing dramatically rising nitrate concentrations and no seasonal fluctuation.

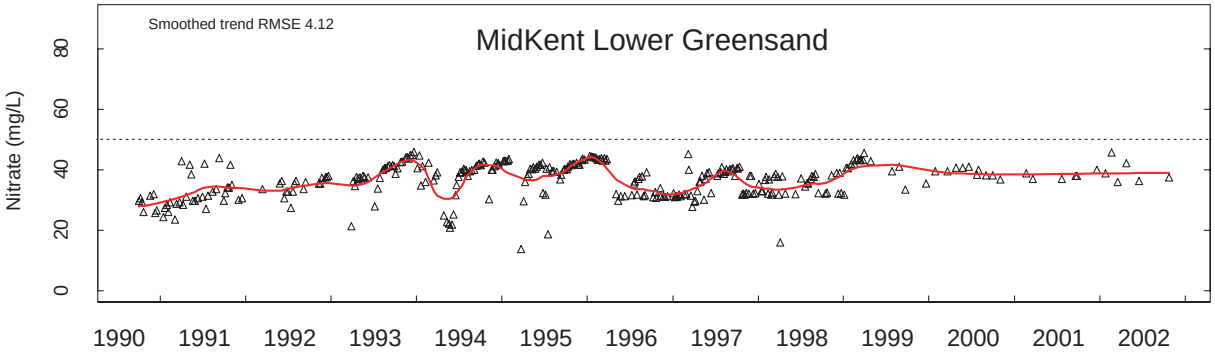


Figure 3.11 Charing 3 showing a less dramatic increase in nitrate concentrations than Charing 2 and occasional seasonality

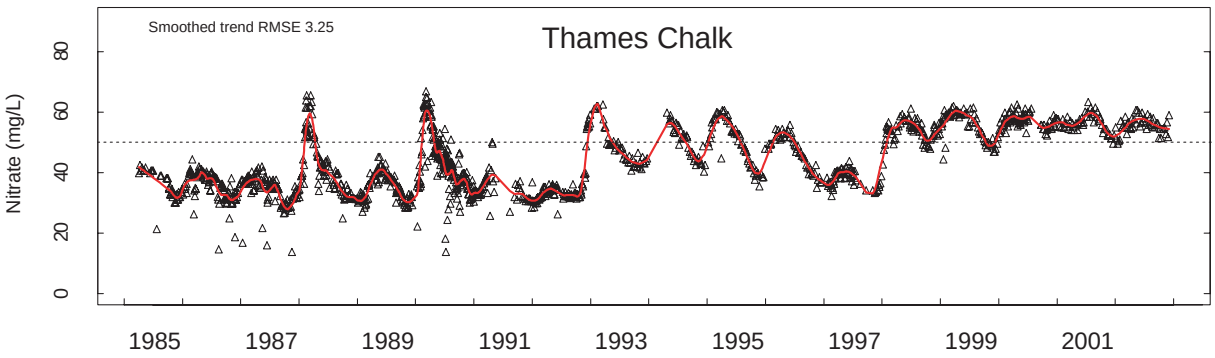


Figure 3.12 Ogbourne 5 shows pronounced seasonal variation as well as occasional large and sustained increases in nitrate concentrations

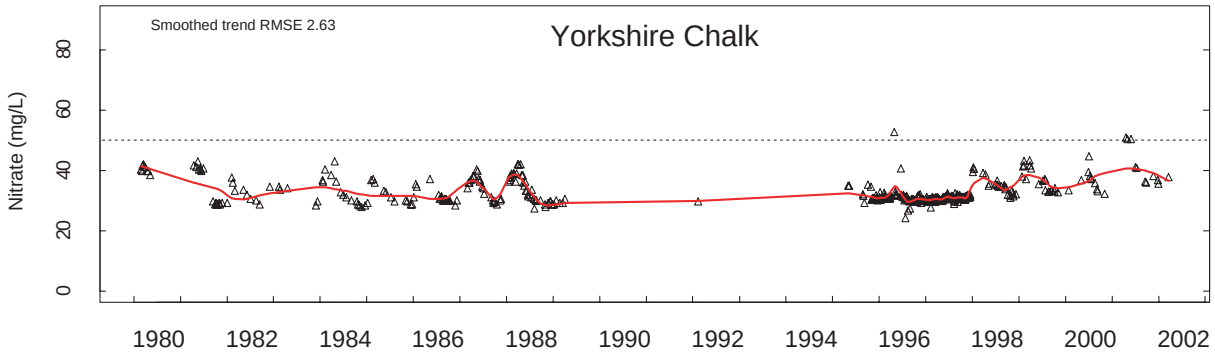


Figure 3.13 Etton 1 illustrates the relatively common occurrence of data gaps

It must be noted that due to the non-exclusivity of the database the 'time-series' are varied, with some comprising only a few entries. The examples above are from sites where more intensive monitoring has been carried out.

3.3 DATA SOURCES

The database contains time-series data from a number of different BGS projects:

- Nitrate Sensitive Areas (NSAs) were established in response to EC initiatives in 1990, the scheme ran until 2001. Data collected from the EA and water companies by Anne Williams are included in the database and are interpreted in Silgram et al.(2003);
- Anglian Water Services; many nitrate time-series have been compiled during several years work by BGS in East Anglia. Hughes et al. (2003) produced a summary of this work and discuss many of the time-series contained within the database;
- Eden Valley; Environment Agency (North West Region) groundwater quality monitoring data has been acquired for, and used in BGS project work investigating rising nitrate concentrations in the Eden Valley (Butcher et al., 2003)
- Jersey; the BGS first produced a review of the groundwater resources of Jersey in 1989. In 1991 Robins and Smedley published the 'Hydrogeological and hydrogeochemical survey of Jersey', the BGS has been producing annual reports on the state of Jersey's groundwater resources and quality ever since. Most of the time-series data included in the database has been collected as part of the ongoing work in Jersey and reference to it may be found in the annual reports, the latest being Robins and Bird (2002).
- LOCAR (LOwland CAtchment Research); Environment Agency (Thames Region) groundwater quality monitoring data was acquired during conceptual modelling of the hydrogeology of the Pang and Lambourn river catchments of the Berkshire Downs (Gallagher et al *on going work*).
- U.K. Water Industries Research (UKWIR); a body of time-series data was collected as part of phase 2 of this ongoing project on the impact of changing water quality on water resources and the water industry. A graphical compilation of much of this set of data is presented and interpreted within Chilton et al (2003).

3.4 CONTENT

The distribution of the time-series data, which comprises 477 entries, is shown below in figures 3-14 and 3-15.

All the time-series water quality data, except one series of bromate concentrations, are of N-species compounds. Owing to different sources of data, some boreholes and sites have duplicate entries. The duplicates have been included in the database, as they either cover different time periods, or contain data collected on different dates. Effort has been made to include all of the data available at the time of compilation. There are however, instances where the aquifer type, and rarely, the grid reference or site name are missing. A summary of the time-series database may be found in the appendices.

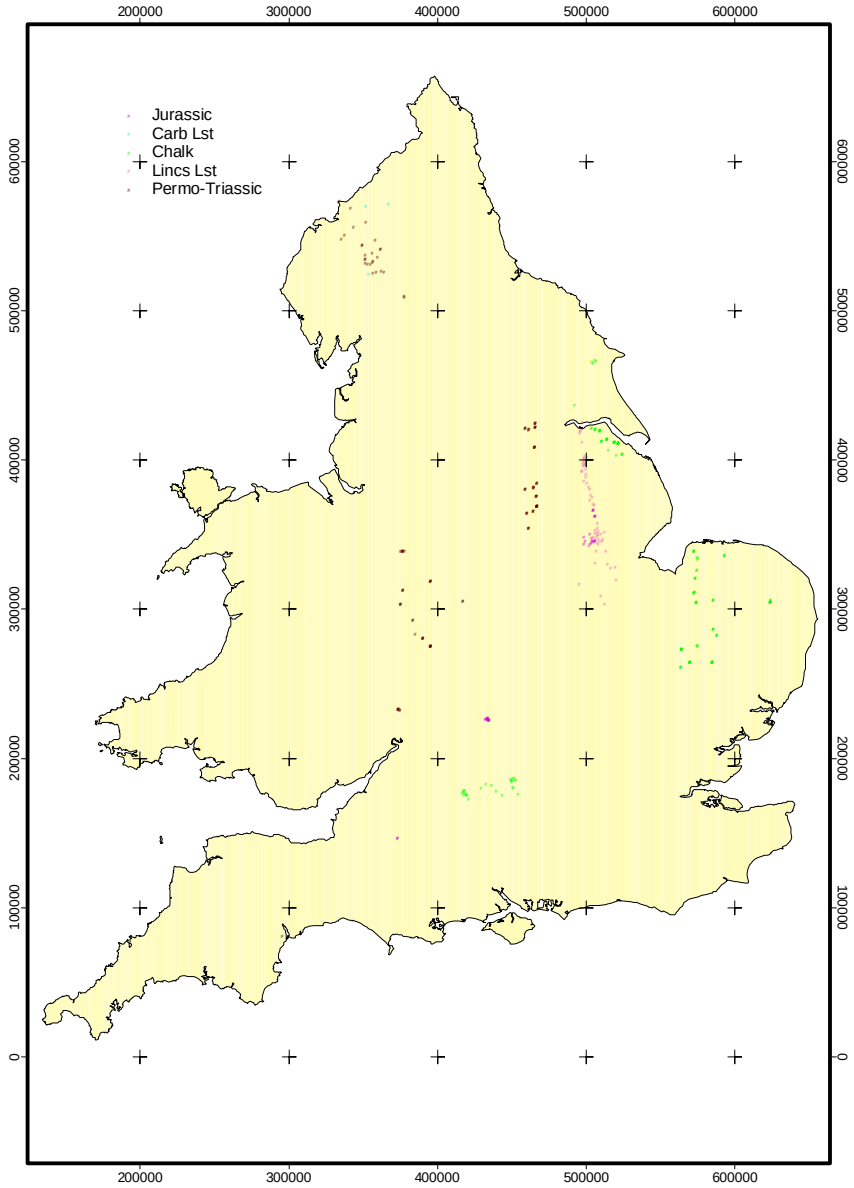


Figure 3.14 Location map of sites with time-series in England

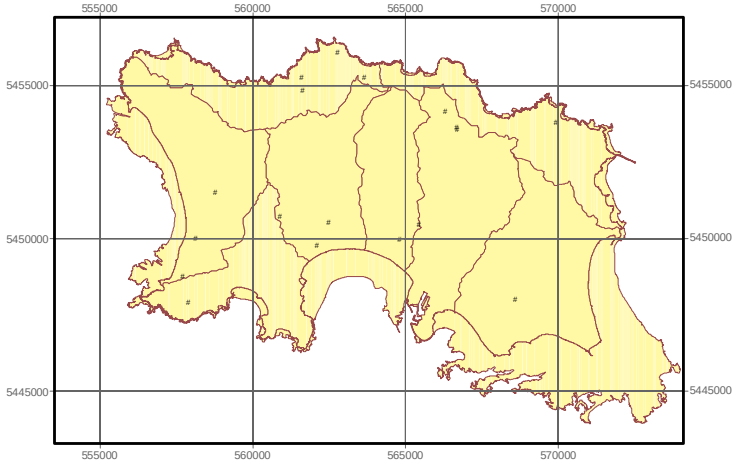


Figure 3.15 Location map of sites with time-series in Jersey .

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Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

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4 Appendix 1 Summary of time-series database

Site	Number of sources	Aquifer	First record	Last record	Determinand(s)	Project and contact
Amen Corner	3	Permotrias (Undiff)	18/03/1976	27/06/2001	NO3	NSA/AW
Amthorpe	3	Sherwood Sandstone Group	04/01/1980	23/01/2002	NO3-N	UKWIR/AJG,DJK
Arc	1	Permotrias (Undiff)	22/02/1991	04/11/1997	NO3	NSA/AW
Aswarby	2		13/03/1985	23/05/2001	NO3	NSA/AW
Atlantic Hotel	1	Sand and Granite	03/05/1990	29/10/2002	NO3-N	Jersey/MJB
Austerfield	3	Sherwood Sandstone Group	04/01/1980	28/02/2002	NO3-N	UKWIR/AJG,DJK
Barbary Plains	1	Permotrias (Undiff)	09/09/1993	10/09/2002	NO3, NO2	EDEN VALLEY/ASB
Barnby Moor	3	Permotrias (Undiff)	02/06/1986	31/07/2001	NO3,TON	NSA/AW
Barnoldby	3	Chalk	25/03/1981	03/07/2002	NO3	ANGLIAN/AH
Barrow Upon Humber	4	Chalk	02/03/1981	12/06/2002	NO3	ANGLIAN/AH
Barton Upon Humber	3	Chalk	27/03/1980	15/06/2002	NO3	ANGLIAN/AH
Bartondale	1	Chalk	09/10/1990	20/05/1999	NO3	NSA/AW
Beachamwell	4	Chalk	04/02/1985	26/06/2002	NO3	ANGLIAN/AH
Beacon Edge	1	Permotrias (Undiff)	01/11/1988	10/09/2002	NO3, NO2	EDEN VALLEY/ASB
Bednall	4	Permotrias (Undiff)	23/06/1987	12/07/2001	TON, NO3, NO2	NSA/AW
Bellozane	1		01/12/1994	16/05/2002	NO3-N	Jersey/MJB
Benham	1	Chalk	14/04/1992	02/01/2002	TON,NO3, NO2	LOCAR/AJG
Besco Laudry	1	Sand and Shale	11/05/1990	29/10/2002	NO3-N	Jersey/MJB
Bircham	2	Chalk	18/02/1985	15/05/2002	NO3	ANGLIAN/AH
Birchmoor	21	Lower Greensand	14/04/1981	01/07/2002	NO3	NSA/AW
Birling Farm	1		01/03/1995	03/10/2002	NO3-N	UKWIR/AJG,DJK

Site	Number of sources	Aquifer	First record	Last record	Determinand(s)	Project and contact
Blewbury	2	Chalk	09/03/1990	17/04/2002	TON,NO3, NO2	LOCAR/AJG
Boiling Wells Spring	2	Jurassic (Undiff)	10/04/1985	23/09/1998	NO3	NSA/AW
Boughton	8	Permotrias (Undiff)	03/04/1975	03/09/2001	NO3	NSA/AW
Bowscar	2	Sherwood Sandstone Group	01/09/1973	10/09/2002	NO3,NO2	EDEN VALLEY/ASB
Bowscar	1	Sherwood Sandstone Group	15/11/1994	05/11/2002	NO3-N	UKWIR/AJG,DJK,
Branston Booths	1	Lincs lst	24/10/1984	14/02/2000	NO3	NSA/AW
Branston Booths	4	Lincs lst	13/03/1985	28/06/2001	NO3-N,	UKWIR/AJG,DJK
Bromsberrow	5	Permotrias (Undiff)	07/01/1975	13/08/2001	NO3	NSA/AW
Bucklebury	1	Chalk	03/11/1992	07/08/2001	TON,NO3, NO2	LOCAR/AJG
Bull Fell Springs	1	Ordovician (Sedimentary)	04/08/1992	12/02/2002	NO3, NO2	EDEN VALLEY/ASB
Caistor St Edmunds	6	Chalk	06/04/1981	03/07/2002	NO3	ANGLIAN/AH
Carlton	4	Permotrias (Undiff)	19/03/1981	28/03/1996	NO3	NSA/AW
Caythorpe	1	Jurassic (Undiff)	21/03/1990	27/02/1996	NO3	NSA/AW
Century Plantation	1	Jurassic (Undiff)	22/11/1990	29/09/1998	NO3	NSA/AW
Charing	6	Lower Greensand	01/10/1990	24/10/2002	NO3-N	UKWIR/AJG,DJK
Chartridge	1		13/01/1992	29/10/2002	NO3-N	UKWIR/AJG,DJK
Chateau le Chaire	1	Conglomerate	15/06/1990	11/09/2001	NO3-N	Jersey/MJB
Cheam	8		04/01/1999	19/09/2002	NO3-N	UKWIR/AJG,DJK
Chelvey	1	Carblst	01/06/1959	09/05/2002	NO3-N	UKWIR/AJG,DJK
Chequer House	4	Permotrias (Undiff)	05/05/1975	07/09/2001	NO3	NSA/AW
Chilton	3	Chalk	13/02/1990	17/04/2002	TON,NO3, NO2	LOCAR/AJG
Clayhill	1	Jurassic (Undiff)	08/12/1980	29/04/2002	NO3	NSA/AW
Cliburn	1	Permotrias (Undiff)	27/10/1969	13/02/2002	NO3, NO2	EDEN VALLEY/ASB

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Clipstone	3	Permotrias (Undiff)	18/03/1976	27/06/2001	NO3	NSA/AW
Cobblers Spring	1		26/03/1991	12/08/1998	NO3	NSA/AW
Compton	2	Chalk	30/08/1990	11/03/1998	TON,NO3, NO2	LOCAR/AJG
Congham	2	Chalk	08/04/1981	19/05/1997	NO3	ANGLIAN/AH
Cornish	1	Chalk	11/01/1993	03/10/2002	NO3-N	UKWIR/AJG,DJK
Cowick	3	Permotrias (Undiff)	03/01/1978	26/07/2001	NO3	NSA/AW
Cowick Wood	1		05/02/1990	12/09/1997	NO3	NSA/AW
Cranwell	1	Jurassic (Undiff)	27/02/1991	27/05/1999	NO3	NSA/AW
Cranwell Plantation	1	Jurassic (Undiff)	21/11/1990	27/05/1999	NO3	NSA/AW
Craycrop	1	Carblst	04/02/1997	04/09/2002	NO3, NO2	EDEN VALLEY/ASB
Croft Farm	1		11/02/1997	04/09/2002	NO3, NO2	EDEN VALLEY/ASB
Crossfell House Farm	1		14/02/1997	06/09/2002	NO3, NO2	EDEN VALLEY/ASB
Cunning Garth	1	Permotrias (Undiff)	11/03/1997	24/01/2002	NO3, NO2	EDEN VALLEY/ASB
Dale Spring	1		31/07/1992	11/09/2002	NO3, NO2	EDEN VALLEY/ASB
Deep Dean	1	Chalk	18/01/1993	17/10/2002	NO3-N	UKWIR/AJG,DJK
Drove	2	Lincs lst	12/08/1983	24/06/2002	NO3-N	UKWIR/AJG,DJK
Duckaller	1	Permotrias (Undiff)	25/03/1975	27/12/1996	NO3	NSA/AW
Eden Lacy	1	Permotrias (Undiff)	10/02/1997	05/09/2002	NO3, NO2	EDEN VALLEY/ASB
Edenbridge	1	Permotrias (Undiff)	30/05/1985	10/09/2002	NO3, NO2	EDEN VALLEY/ASB
Edenford	1	Permotrias (Undiff)	10/02/1997	04/09/2002	NO3, NO2	EDEN VALLEY/ASB
Edenhall	2	Permotrias (Undiff)	19/09/1972	13/02/2002	NO3, NO2	EDEN VALLEY/ASB
Edgeford	1		14/03/1990	28/01/2002	TON-N	NSA/AW
Elkesley	4	Chalk	09/02/1981	23/10/2001	NO3	ANGLIAN/AH

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English Town Farm	1	Permotrias (Undiff)	04/02/1997	04/09/2002	NO3, NO2	EDEN VALLEY/ASB
Essendon	1	Chalk	22/05/2000	31/10/2002	Bromate	UKWIR/AJG,DJK
Etton	6	Chalk	01/01/1979	09/05/2002	NO3-N	UKWIR/AJG,DJK
Everton	3	Lower Greensand	10/12/1980	04/07/2002	NO3	ANGLIAN/AH
Far Baulker	3	Permotrias (Undiff)	01/06/1971	29/06/2001	NO3	NSA/AW
Farihill	1		30/07/1992	02/04/1998	NO3, NO2	EDEN VALLEY/ASB
Filching	1		13/01/1995	26/09/2002	NO3-N	UKWIR/AJG,DJK
Finningley	4	Sherwood Sandstone Group	04/01/1980	06/11/2002	NO3-N	UKWIR/AJG,DJK
Fognam Down	1	Chalk	09/04/1992	11/09/2000	TON,NO3, NO2	LOCAR/AJG
Fosters Bridge	1		13/03/1985	28/08/2002	NO3	NSA/AW
Fring	1	Chalk	18/02/1985	20/06/2001	NO3	ANGLIAN/AH
Friston	1	Chalk	28/01/1994	26/09/2002	NO3-N	UKWIR/AJG,DJK
Gaitsgill	1		11/02/1997	05/09/2002	NO3, NO2	EDEN VALLEY/ASB
Gamblesby	2	Permotrias (Undiff)	01/11/1988	11/09/2002	NO3, NO2	EDEN VALLEY/ASB
Gayton	3	Chalk	18/02/1985	01/07/2002	NO3	ANGLIAN/AH
Geltsbridge Farm	1	Permotrias (Undiff)	04/02/1997	02/09/2002	NO3, NO2	EDEN VALLEY/ASB
Geltsdale Springs	1		03/08/1992	04/09/2002	NO3, NO2	EDEN VALLEY/ASB
Geranium Farm	1	Granite	07/05/1990	29/10/2002	NO3-N	Jersey/MJB
Goat	1		27/02/2002	19/09/2002	NO3-N	UKWIR/AJG,DJK
Gore	1		11/01/1995	05/11/2002	NO3-N	UKWIR/AJG,DJK
Goxhill	5	Chalk	10/06/1981	26/06/2002	NO3	ANGLIAN/AH
Great Heck	1	Sherwood Sandstone Group	01/08/1974	17/09/1997	NO3-N	UKWIR/AJG,DJK
Great Heck	3	Sherwood Sandstone Group	09/01/1978	26/07/2001	NO3	NSA/AW

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Great Shefford	1	Chalk	08/10/1997	23/09/2002	TON,NO3, NO2	LOCAR/AJG
Grindle Forge	2	Permotrias (Undiff)	19/08/1980	26/06/2001	NO3	NSA/AW
Grisdale Brow	1	Ordovician (Volcanic)	04/08/1992	10/09/2002	NO3, NO2	EDEN VALLEY/ASB
Grouville Spring	1	Granite	12/06/1990	21/10/2002	NO3-N	Jersey/MJB
Guildhall Spring	1	Jurassic (Undiff)	26/03/1991	12/08/1998	NO3	NSA/AW
Habrough	6	Chalk	25/02/1981	03/07/2002	NO3	ANGLIAN/AH
Hack	1		16/03/1999	10/09/2002	NO3-N	UKWIR/AJG,DJK
Hagley	4	Permotrias (Undiff)	02/07/1959	04/01/1999	NO3	NSA/AW
Hallburn Farm	1		05/02/1997	04/09/2002	NO3, NO2	EDEN VALLEY/ASB
Hamsptead Norreys	1	Chalk	06/03/1997	23/09/2002	TON,NO3, NO2	LOCAR/AJG
Hatfield	5	Sherwood Sandstone Group	18/12/1975	01/07/2001	NO3	NSA/AW
Hatfield	4	Sherwood Sandstone Group	04/01/1980	25/02/2002	NO3-N	UKWIR/AJG,DJK
Hatfield Woodhouse	3	Sherwood Sandstone Group	04/01/1980	25/02/2002	NO3-N	UKWIR/AJG,DJK
Haywood Oaks	1		19/08/1992	14/11/1997	NO3	NSA/AW
Hazells	1	Chalk	11/01/1995	04/11/2002	NO3-N	UKWIR/AJG,DJK
Healing	10	Chalk	08/01/1980	05/07/2002	NO3	ANGLIAN/AH
Henpit	1	Chalk	07/03/1990	20/05/1999	NO3	NSA/AW
Highfield Hotel	1	Volcanic	25/05/1990	31/10/2002	NO3-N	Jersey/MJB
Highfield Lane	3	Sherwood Sandstone Group	04/01/1980	20/02/2002	NO3-N	UKWIR/AJG,DJK
Hillington	2	Chalk	15/01/1992	14/06/2002	NO3	ANGLIAN/AH
Hopwas	2	Permotrias (Undiff)	02/07/1964	09/12/1996	NO3	NSA/AW
Houghton	3	Chalk	20/05/1985	16/05/2002	NO3	ANGLIAN/AH
Hunger	1	Permotrias (Undiff)	22/02/1991	04/11/1997	NO3	NSA/AW

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Isleham	7	Chalk	12/02/1985	01/07/2002	NO3	ANGLIAN/AH
Ivegill	1		10/02/1997	05/09/2002	NO3, NO2	EDEN VALLEY/ASB
Jerriestown Farm	1		04/02/1997	02/09/2002	NO3, NO2	EDEN VALLEY/ASB
Kentmere	1		06/08/1992	09/09/2002	NO3, NO2	EDEN VALLEY/ASB
Kilham	1	Chalk	07/03/1990	20/05/1999	NO3	NSA/AW
Kilham	1	Chalk	23/04/1979	16/04/1996	NO3-N	UKWIR/AJG,DJK
Kings Rd Bury	3	Chalk	02/04/1981	02/07/2002	NO3	ANGLIAN/AH
Kintbury	1	Chalk	05/08/1992	29/05/2002	TON,NO3, NO2	LOCAR/AJG
Kinver	1	Permotrias (Undiff)	17/06/1976	23/12/1996	NO3	NSA/AW
La Mare Vineyards	1	Granite	30/05/1990	28/10/2002	NO3-N	Jersey/MJB
Ladywell	1		23/03/1987	07/02/2002	TON-N	NSA/AW
Lambourn	1	Chalk	11/03/1997	02/07/2002	TON,NO3, NO2	LOCAR/AJG
Langley	1		25/02/1999	14/08/2002	NO3-N	UKWIR/AJG,DJK
L'Auberge du Nord	1	Granite	22/05/1990	28/10/2002	NO3-N	Jersey/MJB
Leckhampstead	1	Chalk	16/06/1993	06/06/2002	TON,NO3, NO2	LOCAR/AJG
Limber Grange	1		23/05/1990	30/10/1992	NO3	NSA/AW
Lintridge	2	Permotrias (Undiff)	01/01/1974	04/11/1997	NO3	NSA/AW
Little London	7	Chalk	02/12/1981	05/07/2002	NO3	ANGLIAN/AH
Littleworth	2	Sherwood Sandstone Group	05/04/1983	20/02/2002	NO3-N	UKWIR/AJG,DJK
Low Moor Farm	1	Carblst	07/02/1997	06/09/2002	NO3, NO2	EDEN VALLEY/ASB
Lower Links	3	Chalk	28/03/1990	02/07/2002	NO3	ANGLIAN/AH
Lyng Forge	3	Chalk	05/01/1995	05/07/2002	NO3	ANGLIAN/AH
Marham	10	Chalk	06/04/1981	02/07/2002	NO3	ANGLIAN/AH

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Marlston	1	Chalk	02/07/1992	03/08/1999	TON,NO3, NO2	LOCAR/AJG
Middledale	1	Chalk	07/03/1990	20/05/1999	NO3	NSA/AW
Mildenhall	1	Chalk	06/11/1992	29/05/2002	TON,NO3, NO2	LOCAR/AJG
Moulton	6	Chalk	07/04/1981	03/07/2002	NO3	ANGLIAN/AH
N0123	1	Permotrias (Undiff)	02/03/1976	06/11/2000	NO3	NSA/AW
Nestles Dalston	1	Permotrias (Undiff)	09/07/1980	02/09/2002	NO3, NO2	EDEN VALLEY/ASB
Newbury	1	Chalk	06/07/1992	11/12/2000	TON,NO3, NO2	LOCAR/AJG
Nonsuch	1		22/01/1999	18/09/2002	NO3-N	UKWIR/AJG,DJK
Nord Vue	2		16/01/1968	11/09/2002	NO3, NO2	EDEN VALLEY/ASB
North Newbald	5	Chalk	23/04/1981	11/04/1996	NO3-N	'UKWIR/AJG,DJK
North Newbald	1	Chalk	04/04/1979	29/04/1997	NO3	'NSA/AW
North Pickenham	3	Chalk	06/04/1981	27/06/2002	NO3	ANGLIAN/AH
Nunnery Lodge	3	Chalk	25/04/1991	01/07/2002	NO3	ANGLIAN/AH
Nutwell	3	Sherwood Sandstone Group	10/04/1980	23/01/2002	NO3-N	UKWIR/AJG,DJK
Oakeley	1	Ordovician (Sedimentary)	10/11/1989	28/12/1991	NO3	NSA/AW
Oaks	3		29/01/1999	18/09/2002	NO3-N	UKWIR/AJG,DJK
Odessa Beelsby	1	Chalk	22/02/1990	30/07/1993	NO3	NSA/AW
Offley Bottom	1		23/08/1994	29/10/2002	NO3-N	UKWIR/AJG,DJK
Ogbourne	1	Chalk	19/09/1986	10/05/2000	NO3-N	UKWIR/AJG,DJK
Ogbourne St George	9	Chalk	19/09/1986	10/01/2002	NO3	NSA/AW
Old Chalford	12	Jurassic (Undiff)	12/11/1976	03/01/2002	NO3	NSA/AW
Ousby Moor	1	Permotrias (Undiff)	27/08/1976	05/09/2002	NO3, NO2	EDEN VALLEY/ASB
PCV	1		01/01/1996	28/04/2001	NO3-N	UKWIR/AJG,DJK

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Phillips	1		16/03/1999	04/09/2002	NO3-N	UKWIR/AJG,DJK
Pollington	3	Sherwood Sandstone Group	03/01/1978	26/07/2001	NO3-N	NSA/AW
Pollington	1	Sherwood Sandstone Group	03/01/1978	26/07/2001	NO3-N	UKWIR/AJG,DJK
Potterhanworth	1	Permotrias (Undiff)	01/03/1991	27/05/1999	NO3	NSA/AW
Priory Inn	1	Granite	09/05/1990	28/10/2002	NO3-N	Jersey/MJB
Rauceby Station	1	Jurassic (Undiff)	30/04/1987	19/05/1998	NO3	NSA/AW
Ronez Quarry	1	Granite	25/05/1990	28/10/2002	NO3-N	Jersey/MJB
Rossington	2	Sherwood Sandstone Group	04/01/1980	10/05/2001	NO3-N	UKWIR/AJG,DJK
Rotheryhaugh Farm	1	Carblst	06/02/1997	04/09/2002	NO3, NO2	EDEN VALLEY/ASB
Roughton Gill	1	Ordovician (Volcanic)	05/08/1992	03/09/2002	NO3, NO2	EDEN VALLEY/ASB
Secombe	1		20/01/1999	18/09/2002	NO3-N	UKWIR/AJG,DJK
Sedgeford	4	Chalk	08/04/1981	25/07/2001	NO3	NSA/AW
Sedgeford	1	Chalk	21/04/1989	22/04/1998	NO3	ANGLIAN/AH
Sedgeford	1	Chalk	08/04/1981	24/04/2002	NO3-N	UKWIR/AJG,DJK
Sheriff Hales	3	Permotrias (Undiff)	02/03/1976	16/05/2001	NO3	NSA/AW
Sidway	1	Permotrias (Undiff)	22/02/1991	04/11/1997	NO3	NSA/AW
Slipend	1		14/06/1993	21/10/2002	NO3-N	UKWIR/AJG,DJK
South Fawley	1	Chalk	22/06/1992	11/12/2000	TON,NO3, NO2	LOCAR/AJG
Southfield house	1	Jurassic (Undiff)	22/02/1993	09/01/1996	NO3	NSA/AW
Speen	1	Chalk	30/08/1990	21/07/1998	TON,NO3, NO2	LOCAR/AJG
Spittals Farm	1		14/02/1997	06/09/2002	NO3, NO2	EDEN VALLEY/ASB
Spring Close	1		08/01/1999	22/05/2002	NO3-N	UKWIR/AJG,DJK
Spring Well	1	Jurassic (Undiff)	04/04/1979	27/04/2001	NO3	NSA/AW

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St Heliers Nursery	1	Volcanic	15/05/1990	25/10/2002	NO3-N	Jersey/MJB
St Ouen's Bay	1	Sand	01/05/1990	31/10/2002	NO3-N	Jersey/MJB
St Peters Nursery	1	Shale	07/05/1990	29/10/2002	NO3-N	Jersey/MJB
States Farm	2	Volcanic	29/05/1990	31/10/2002	NO3-N	Jersey/MJB
Sunnyside	3	Permotrias (Undiff)	06/12/1989	24/08/2001	NO3	NSA/AW
Sutcourt	1		18/01/1999	05/06/2002	NO3-N	UKWIR/AJG,DJK
Sutton	4		21/01/1999	18/09/2002	NO3-N	UKWIR/AJG,DJK
Swynnerton	3	Sherwood Sandstone Group	16/05/1977	13/11/2001	NO3-N	UKWIR/AJG,DJK
Tancredpit	1	Chalk	09/10/1990	20/05/1999	NO3	NSA/AW
Tesson Mill	1	Shale	05/06/1990	31/10/2002	NO3-N	Jersey/MJB
Thames	2	Jurassic (Undiff)	02/04/1985	23/09/2002	NO3-N	UKWIR/AJG,DJK
Thames	4	Chalk	18/05/1981	16/10/2002	NO3-N	UKWIR/AJG,DJK
The Bogs	1	Permotrias (Undiff)	22/02/1991	04/11/1997	NO3	NSA/AW
The Wellings	2	Permotrias (Undiff)	18/10/1972	26/06/1992	NO3	NSA/AW
Thornham	3	Sherwood Sandstone Group	04/01/1980	23/01/2002	NO3-N	UKWIR/AJG,DJK
Thornton	3	Chalk	10/06/1981	03/07/2002	NO3-N	UKWIR/AJG,DJK
Tom Hill	2	Permotrias (Undiff)	03/01/1978	06/08/2001	NO3	NSA/AW
Trowse Newton	2	Chalk	19/09/1996	23/05/2002	NO3	ANGLIAN/AH
Twelve Acre Wood	3	Chalk	12/02/1985	04/07/2002	NO3	ANGLIAN/AH
Two Mile Bottom	3	Chalk	09/07/1996	05/07/2002	NO3	ANGLIAN/AH
Twyford	1	Chalk	07/12/1990	05/11/2002	NO3-N	UKWIR/AJG,DJK
Ulceby	3	Chalk	07/11/1989	28/06/2002	NO3	ANGLIAN/AH
Upton	3	Chalk	13/02/1990	17/04/2002	TON,NO3, NO2	LOCAR/AJG

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Val de la Mare	1	Shale	01/05/1990	31/10/2002	NO3-N	Jersey/MJB
Waneham Bridge	3	Chalk	02/01/1985	02/07/2002	NO3	ANGLIAN/AH
Warren Farm	1	Jurassic (Undiff)	15/11/1990	30/04/1996	NO3	NSA/AW
Waterworks Road	1		04/01/1993	10/10/2002	NO3-N	UKWIR/AJG,DJK
Wellings Farm	1	Permotrias (Undiff)	22/02/1991	04/11/1997	NO3	NSA/AW
West Brownrigg	1		14/02/1997	24/01/2002	NO3, NO2	EDEN VALLEY/ASB
Westwood	2		21/01/1998	13/05/2002	Atrazine,Simazine	UKWIR/AJG,DJK
Wheelbarrow Hall	1	Permotrias (Undiff)	04/02/1997	02/09/2002	NO3, NO2	EDEN VALLEY/ASB
Wildmoor	7	Permotrias (Undiff)	08/06/1990	08/08/2001	NO3	NSA/AW
Winterbourne	1	Chalk	06/03/1997	23/09/2002	TON,NO3, NO2	LOCAR/AJG
Woodcote	1		21/01/1999	18/09/2002	NO3-N	UKWIR/AJG,DJK
Woodhouse Farm	1		20/02/1997	06/09/2002	NO3, NO2	EDEN VALLEY/ASB