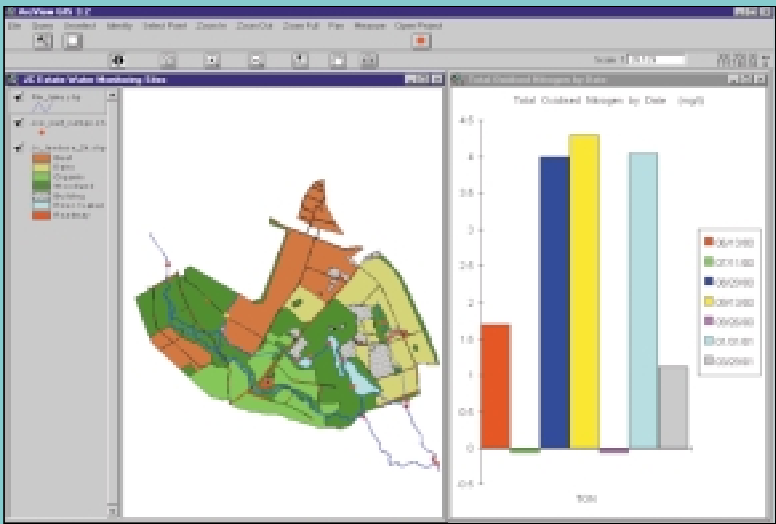
End of Project Report
Project 4480

ENVIRONMENTAL MONITORING ON RESEARCH CENTRES AND LARGE FARMS USING SPATIAL DATA MANAGEMENT TOOLS



Rural Environmental Series No. 28

ENVIRONMENT RESEARCH CENTRE, JOHNSTOWN CASTLE

ENVIRONMENTAL MONITORING ON RESEARCH CENTRES AND LARGE FARMS USING SPATIAL DATA MANAGEMENT TOOLS

END OF PROJECT REPORT

ARMIS 4480

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SUMMARY

The objective of project 4480 was to build an environmental management system by using a visual or map based approach to develop new ways to manage environmental data on a large farm or an estate of several farms. Geographic information system (GIS) techniques are extremely powerful, but they tend to be complex, and often require a high degree of skill and training in order to use them. Using systems analysis, the fundamental environmental management data were identified and a simplified spatial approach was developed to manage these environmental data.

Johnstown Castle Research Centre consists of three farms, ornamental grounds, forests, lakes and streams. A set of database tables was generated to hold farm environmental data on these farms. These included:

1. annual management summary data giving the average number of different types of animals, the amount of organic manure and N, P and K nutrients produced by them, fertiliser purchases, organic and chemical nutrient usage on the farm, achievement of nutrient management planning targets, etc.
2. monthly livestock information recording the numbers of livestock of different types for the three farms, together with management comments on the changes and transfer that take place over the month,
3. detailed land use and nutrient use information for each field or plot on the estate,
4. recent soil analyses information for the experimental plots,
5. analysis results of recent water samples which are taken regularly at sampling points throughout the estate.

The topographical, soil and site features were digitised, in order to collect information on the overall and individual farm boundaries. This included roads, hedges and ditches, streams, rivers and lakes, the buildings and most particularly, the boundaries of all field and experimental plots. When the digitisation was complete, a set of bespoke programs was built, using the GIS system, ArcView. To make the system "user friendly", the menu system was customised by removing complex features; retaining only those buttons and menu options that served a purpose useful to the application. The programs were unified into a PC system called Johnstown Castle Environmental Monitoring System or JCEMS.

For the future, it is envisaged that the maps and spatial techniques will be embodied into an Access database system and developed for use by other research stations and farms.

INTRODUCTION

An environmental management system (EMS) for a large farm or Research Centre must be capable of managing and monitoring the chemical and organic nutrients applied to land, the status of soils and their sensitivity to runoff and the possibility of ground water contamination. It should consider and record the usage of each plot of land, the cropping, whether the land is used for grazing or silage, the soil tests, chemical and organic fertilisers recommended and the amounts actually used. Recording all of these features effectively requires a spatial database system for data recording and management in order that the nutrients supplied to crops and animals may be minimised, and optimum use made of nutrients available as animal manures.

Carton (1998) developed a nutrient management planning system for Johnstown Castle. This was a traditional information system, which used Excel spreadsheet tables to record, store and calculate nutrient requirements, purchases and usage for the farms. This tabular based system can handle summarised soil, crop and environmental information, but management of detailed nutrient data at field scale requires that the relationship between nutrient use and efficiency be related to soil, water and topographical variables and this too requires the use of a GIS approach.

The requirement to create a spatial EMS for a large farm was fulfilled by developing a system to cater for the Research Centre of three farms, lakes, rivers and ornamental grounds at Johnstown Castle. It builds on the techniques found useful in Coulter **et al, (**1998) "Enhancing and visualising data on soils, land use and the environment" and Coulter **et al,** (1998) "Visual Environmental Data on Soils and Landuse". It also builds on the techniques of nutrient management planning as implemented as Teagasc policy for all of its farms. The Code of Good Agricultural Practice (1996) defines the aim of nutrient management -- to prevent water pollution by achieving the correct balance between crop requirements and nutrient application rates from organic and chemical fertilisers, taking account of nutrients available in the soil.

The system is designed to be used for farm management and does not require users to have GIS skills to use it effectively. However, in its present form, it requires the presence of expensive GIS software, and its overall supervision will require annual maintenance of the databases and spatial sources. It is envisaged that the maps and spatial techniques will be translated to a license free visual system and embodied into an Access or some other readily available database system. The aim would be to allow JCEMS to manage the environmental data from other research stations and farm estates that had a similar high level of management information recording. It could also be extended to include visual displays of information for other experimental point, line or polygon data on the estate in question. It would be particularly appropriate for monitoring of point data on river catchments and the system could be extended to interactive internet display of live environmental data.

THE JOHNSTOWN CASTLE ESTATE

Johnstown Castle Research Centre provides national research information on soils and the environment. In addition it is the home of the Teagasc Analytical Services Laboratory for soil, herbage, water and general agricultural materials. The Castle and Estate lies 7 km south west of Wexford at Murntown and is located at national grid reference T 020170.

The grounds of Johnstown Castle consist of an Estate of 450 hectares, and include Johnstown Castle Research Centre, and Teagasc analytical laboratories, the headquarters of the Environmental Protection Agency, a number of sections of the Department of Agriculture and Rural Development and of the Department of Forestry and the Wexford Organisation for Rural Development. In all, there are over 550 personnel working on the Estate in these various organisations.

There are three Teagasc experimental farms in the Estate, 10 ha of lakes and streams, 40 ha of ornamental lawns and woodland and 2.3 ha of formal gardens. In addition, there are 74 ha of woodland, some of it riparian and some commercial conifer forest, an experimental ash plantation and a new, 60 ha plantation of oak and beech species.

Summary Data on the Experimental Farms

Of the 214 ha of farmed area, more than 97% is grassland; the small amount of tillage was planted as part of the organic farming system. In the year 2000, there were 123 ha of grazing land and 84.5 ha of silage.

The three research farms on the estate were designated on the basis of the experimental programme: there is a Dairy Farm of 75 ha, an Organic Dairy Farm of 55 ha and a Beef Farm of 83 ha. These are shown in Fig 1. The two dairy herds are completely experimental while the beef farm is mainly experimental with some fields containing commercial animals.

Table 1: Land use on the Johnstown Castle Research Centre

	Dairy	Organic Dairy	Beef	Total
Grazing	46.9	19.1	56.9	122.9
Silage	28.4	29.6	26.5	84.5
Tillage	-	6.7	-	6.7
Total	**75.3**	**55.4**	**83.4**	**214.1**

A summary of the land usage on the three farms is given in table 1 and the livestock numbers of the farms on January 1, 2000 is given in table 2.

Table 2: Livestock numbers on 1-1-2000

	Dairy	Organic Dairy	Beef	Total
Cows	98	22	4	124
Heifers in Calf	25	22	-	47
Cattle 0 - 1	10	8	42	60
Cattle 1 - 2	14	3	157	174
Heavy Cattle/Bulls	2	1	45	48
Total	**75.3**	**55.4**	**83.4**	**453**

The mean stocking rate for the grassland area was 2.5 LU/ha in 2000. The average milk yield for the year 2000 season was 4,500 l/cow in the organic farm and 5,400 l/cow in the dairy.

Soil Fertility: There are 182 experimental plots and fields among the three farms and these are sampled regularly for lime requirement (LR), phosphorus (P), potassium (K) and magnesium (Mg). In the sampling season September 1999 to April 2000, the mean lime requirement and nutrient levels for the farmed area were LR 4.4 t/ha, P 4.5 mg/l, K 122 and Mg 295.

The average P level of 4.5 mg/l broke down into P index categories of 45% at index 1, 30% at index 2, 19% at index 3 and 7 % at index 4. These low values reflect that samples were largely from P-trial experimental plots rather than land farmed commercially. The corresponding breakdown of K soil test values was 14% at index 1, 29% at index 2, 31% at index 3 and 26% at index 4.

The soil fertility summary of the levels for the three farms in the 1999-2000 season is given in table 3.

Table 3: Soil fertility summary for the Johnstown Castle farms

Farm	LimeRequirement	P	K	Mg
	tonnes/ha		mg/l	
Beef	4.1	7.1	125	356
Dairy	6.1	5.5	134	288
Organic	3.2	2.8	110	276
Overall	**4.4**	**4.5**	**122**	**295**

The distribution of P and K indices for the three farms are given in tables 4 and 5.

Table 4: Distribution of P levels

Phosphorus	Index 1 0 - 3 mg/l	Index 2 3.1 - 6 mg/l	Index 3 6.1 - 10 mg/l	Index 4 > 10 mg/l
Beef	31	15	32	22
Dairy	22	42	30	7
Organic	68	26	5	1
Overall	**45**	**30**	**19**	**7**

These data show that the beef and dairy systems are much more fertile than the organic farming system.

Table 5: Distribution of K levels

Potassium	Index 1 0 - 50 mg/l	Index 2 51 - 100 mg/l	Index 3 101 - 150 mg/l	Index 4 > 150 mg/l
Beef	4	21	47	28
Dairy	1	39	30	30
Organic	27	25	25	23
Overall	**14**	**29**	**31**	**26**

SPATIAL TECHNIQUES FOR MANAGING FARM DATA

The summary data presented for the three farms represent valuable management data and can be used to monitor herd performance, achievement of yield targets, nutrient management planning and so on. However, nutrient management and monitoring on a large farm, and particularly on an experimental farm, requires tools to aid examination of soil fertility measurements and organic and chemical nutrient application data on a field-by-field basis.

The purpose of this project was the development of a management system to facilitate the collection, management, analysis and modelling of detailed fertility and nutrient application data. A spatial database arrangement was deemed to be essential to ensure that the relationships between use of nutrients and fertility of the land could be examined in detail. This should consist of a combination of GIS tools for visualisation and display, with relational database modules to manage, validate, transform and update the farm information in a manner easily accessible to the user. It was essential that the system is designed to be clear and easily operated, so that the user may have access to vital environmental information about the farming system.

The GIS System

The project began by the digitising all topographical features, soil survey maps and site maps for the Research Centre using PC ArcInfo[1]. This spatial data capture process included individual farm boundaries, field and experimental boundaries, roads, rivers, lakes, hedgerows and buildings. The measurable characteristics or attributes of those features relevant to environmental and fertility management were examined and databases were constructed using a simple data structure whenever possible. This was followed by the collection of data on the operation of the Johnstown Castle farming systems, to determine which observable data were relevant to a detailed farm management and monitoring system. When the digitisation was complete, a GIS "project" was built using ArcView[2]. ArcView is a more 'user-friendly' program than the more powerful ArcInfo system. It has the great advantage that, following the minimum of training, staff with little or no experience of GIS systems can use it. To further facilitate this, the menu system can be simplified by removing unnecessary or complex features, retaining only useful buttons and menu options.

The layout of the Research Centre is illustrated in Figure 1, which shows the division into three farms, and the location of the buildings, ornamental grounds, lakes and woodland.

The Structure of Electronic Maps and Spatial Data

Johnstown Castle Environmental Monitoring System (JCEMS) is a desktop PC geographic information system (GIS). The system was built using ArcView.

The information scheme consists of five electronic maps known by the GIS system as "shapefiles" or more simply as e-maps. Each e-map is linked to a spatial database table by the GIS system. Each table forms part of an associated e-map; thus, the spatial database table contains information about the enclosed areas or polygons. Usually however, only unchanging information is kept in the spatial database and user data are kept in linked or related databases. Only these are user-modifiable. This protection is useful because it would be unwise to allow users to edit a spatial database for fear of damage to the integrity of its spatial characteristics.

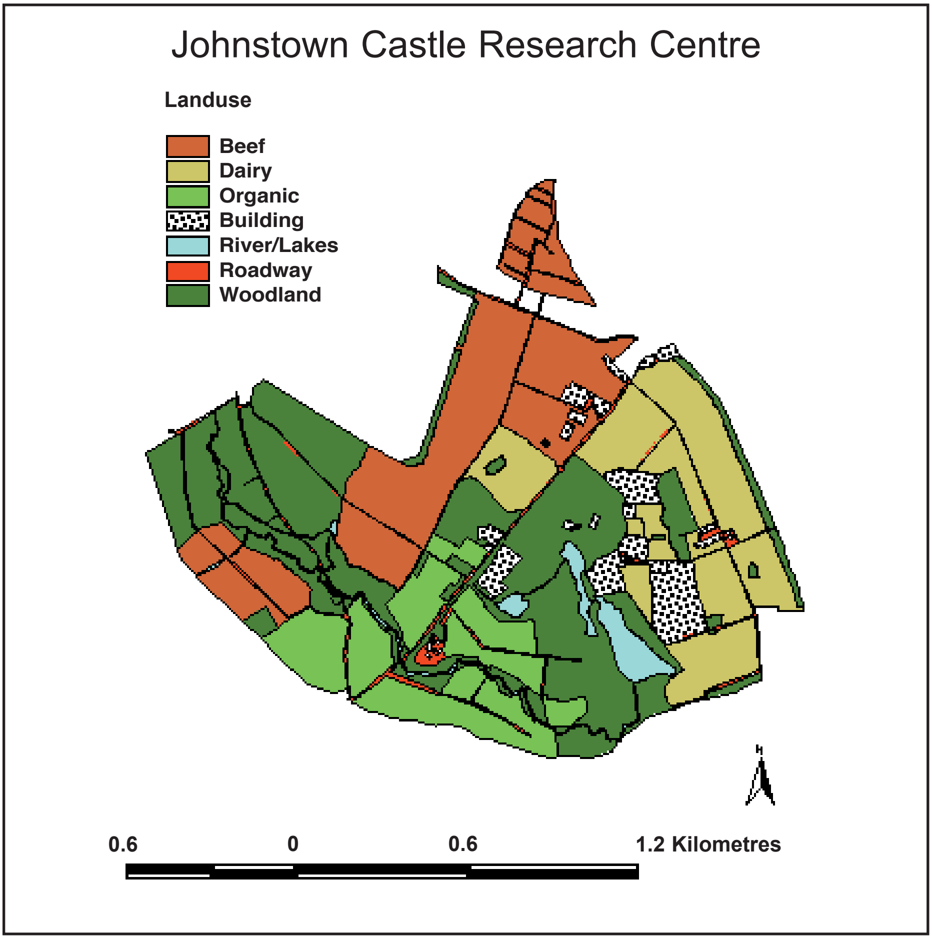

Figure 1. Layout of the Johnstown Castle Research Centre

Three of the e-maps are of central importance to the project. (1) Outline consists of the boundary lines of the Research Centre and the three farms within it; (2) Plots, contains the boundary of each field and bounded area, i.e. the experimental plots, lakes, buildings, major roadways and car parks, the ornamental grounds, gardens and woods and (3) Soil Survey contains both the boundaries of the plots and the boundaries of the soil mapping units on the estate.

1,2 ArcInfo and ArcView are GIS software packages by ESRI. Redlands, CA, USA

These are polygon e-maps because each area within the electronic map has a closed boundary (i.e. a polygon) and is labelled with an identity tag, which is a number that links the polygon to a record in its spatial database table.

There are two line e-maps, Roads for roads and pathways and Rivers for rivers and streams, which originate or pass through the Research Centre. Currently these line features are not internally labelled, though it is planned to extend the line coverages to include infrastructure features such as sewage, electricity, telephone and data pathways and so on.

Finally, there is one point e-map, Waters, which contains the location of sampling points for water quality in the streams and lakes. As with polygon e-maps, these points are labelled internally so that current information on water quality may be displayed or graphed.

The Database Structure

The main information database tables are the Farm Summary table, which is linked to the Outline e-map; and the Nutrients and the Soil Analysis tables, which are linked the Plot e-map. There is also a water sample results table linked to the points in the Waters e-map and a Soil Survey information table linked to the Soil Survey e-map.

The Farm Summary Table

The Farm Summary table contains information or details about the farms and major land divisions within the Research Centre. In this scheme, the land-use classifications within the research centre include beef, dairy and organic farm, ornamental and forestry land, built area, lakes etc. Contained in the details are the overall farmed area, animal, the mean number of livestock of different kinds, the mean dates of animal turnout and housing on each farm, the annual manure production, slurry tank capacity, fertiliser nutrients purchased etc. The database variable names and their meanings are given in table 6.

The Nutrients Table

The nutrients table contains nutrient and other data about each plot, field and bounded area in the Research Centre. For non-farmland, these include lakes, roadways, the buildings, car parks, and site boundaries belonging to Teagasc, EPA and the Department of Agriculture and Rural Development; for these areas, the information is absent or mainly descriptive.

The Animal Table

Table 6: Recorded variables in farm summary table

Item Name	Description
LAND_USER	Used to hold the farm name
DATE_IN	Mean date animals were housed
DATE_OUT	Date turned out
SUM_AREA	Area of farm
SEASON	Farming season
COWS	Number of dairy cows
COWS_CULL	Number of cows culled
COWS_OTHER	Other cows
H_IN_CALF	Heifers in calf
BREED_12	Females for breeding one to two years
BREED_01	Females for breeding less than one year
OTHER_01	Number of other cattle less than 1 year
BULLS	Number of bulls
N_AN	Nitrogen produced by animals
P_AN	Phosphorus produced by animals
K_AN	Potassium produced by animals
N_FERT	Nitrogen fertiliser inorganic
P_FERT	Phosphorus fertiliser inorganic
K_FERT	Potassium fertiliser inorganic
SLURY_TANK	Slurry capacity
SLURY_USED	Slurry spread on land
SLURY_PROD	Slurry produced

For experimental plots and fields on farmland, the nutrient table contains details of its present landuse (e.g. organic farm, forestry); crop (e.g. grazing, silage, feeding barley), nutrient status and so on. A full list of variables is given in table 7.

The animal table consists of the monthly stock count for the different animal types. Table 8 shows the list of database variables.

The Soil Analysis Table

The soil analysis table consists of the most recent soil analytical results for the fields and experimental plots on the farms. Table 9 shows the list of database variables for soil analysis information.

Table 7: Recorded variables in nutrients table

Item Name	Description
PLOT_CODE	Field Identification code
LANDUSE	Farm enterprise
NXCROP	Next crop
PCROP	Previous crop
AN_N_NUT_S	Animal N
AN_P_NUT_S	Animal P
AN_K_NUT_S	Animal K
CHEM_N_NUT	Inorganic N
CHEM_P_NUT	Inorganic P
CHEM_K_NUT	Inorganic K
N_R	Nitrogen required
P_R	Phosphorus required
K_R	Potassium required
DATEREC	Sample date

Table 8: Recorded variables in animals table

Item Name	Description
LANDUSE	Farm enterprise
DATE_STOCK	Stock taking date
COWS	Number of dairy cows
COWS_CULL	Number of cows culled
COWS_OTHER	Number of other cows
H_IN_CALF	Number of heifers in calf
BREED_12	Females for breeding one to two years
BREED_01	Females for breeding less than one year
OTHER_01	Number of other cattle less than 1 year
BULLS	Number of bulls
LU_PRESENT	Present livestock units
N_AN	Nitrogen produced by animals
P_AN	Phosphorus produced by animals
K_AN	Potassium produced by animals
N_FERT	Nitrogen fertiliser inorganic
P_FERT	Phosphorus fertiliser inorganic
K_FERT	Potassium fertiliser inorganic
SLURY_PROD	Slurry produced
SLURY_USED	Slurry spread on land
COMMENT	Farm managers comments re: animal transfers

Table 9: Recorded variables in soil analysis table	
Item Name	**Description**
FIELDNAME	Advisory field identifier
DATE	Sample date
LIME	Lime requirement
P	Phosphorus
K	Potassium
SETCODE	Laboratory identification code
SAML	Advisor Identification Code
SAMN	Advisor sample code

The Water Table

The water table consists of point data that is the results of analysis of water samples at the water sampling points within the estate. The table is used for display and presentation of water purity status and also contains the eight most recent analyses; this is the maximum number of points that can be clearly visualised on graphs at any one time. Table 10 shows the variables recorded in the database.

Table 10: Recorded variables in water information table	
Item Name	**Description**
OIDENT	Sample point identification number
SOURCE	Sample source (Lake/River)
DATE	Sample date
pH	pH levels
P	Phosphorus
TON	Total oxidisable nitrogen
NH_4N	Ammonium N
SC	Salt levels
SETCODE	Laboratory identification code

The Soil Survey Table

The Soil Survey table (Table 11) consists of descriptive data that arising from a detailed soil survey within the estate. The e-map was obtained by digitisation of the soil map of Johnstown Castle (Diamond, 1983) and merging this e-map with the Plots e-map in order that both sets of polygon features would be available for query.

Table 11: Recorded variables in soil survey table	
Item Name	**Description**
NEW_CODE	Farm plot identification code
TEXTURE	Soil texture description
DRAINAGE	Drainage class
SOILGROUP	Soil group category

USING THE SPATIAL SYSTEM

In order to make JCEMS intuitive and easy to use, all of its main functions are separated into separate programs, and each one is started by double clicking the appropriate icon on the desktop (computer screen). There are icons to run the spatial systems to manage the Farm Summary, Nutrients, Soil Fertility and Soil Survey databases. When the user is finished with the program and closes it, changes they have made to the layout, for example by zooming into maps, querying graphs etc., are not saved, so the program always restarts with the optimised arrangement of maps, tables, graphs etc. However, the user is entitled to update or change the numeric databases concerning the above systems and these changes are stored.

Changes to the numeric data may be made by editing the data bases directly or by running a program incorporated for the purpose as a button in the spatial system. For example, the Farm Summary database contains annual average number of animals of different types. These data can be entered by the user but for convenience, there is a pushbutton in Nutrients program which when pressed, requests the starting and finishing date, and will calculate and insert the means directly. These data are used by the program to calculate the annual quantity of animal manure produced on each farm and the quantity of N, P and K contained in it. On the other hand, the annual quantities of chemical nutrients used on each farm must be entered directly by the user.

The Map Controls

There is a map view element with each display produced and when the map element is selected, a number of tool buttons or controls appears above it. The buttons are illustrated in Figure 2. The active button stays depressed until another button is depressed. The Identify button is shown depressed in the figure.

On the top or menu line, only File is active, the remainder are simply headings to describe the functions of the buttons below them. The File menu choices are self-explanatory i.e. Close, Print, Print Setup, Export and Exit. Operation of the Query button is complex and is described in Appendix 1. The Unselect button leaves all elements unselected.

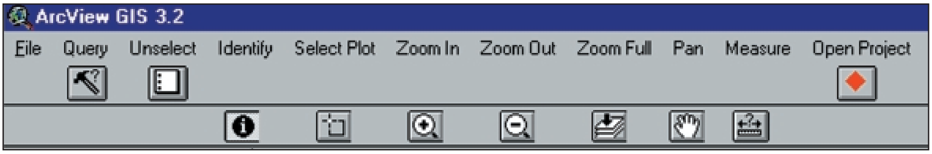

Figure 2. The Map Controls

When a tool button is clicked, the cursor changes, to show which one is being used. The Identify button displays a table of information about any element clicked on the map. An example of its use is given in Figure 10, which shows Soil Survey information. The Select Feature button allows one to pick a feature on the map and its linked database tables. The next button allows one to zoom into or magnify a portion of the map, and the following one to zoom out each time it is clicked on the map. When Zoom Full is clicked on the map, the display returns to maximum extent. The Pan button allows one to move the map sideways to view areas adjacent to the current display. The Measure button allows measurement of the distance in metres between each point clicked on the map. Finally, the Open Project button terminates the current JCEMS program and allows one to change to another program. The program does not allow the user to save any spatial changes, if any, as spatial elements are deliberately set to 'read-only' and cannot be modified by the user.

The Table Controls

When a table is selected rather than a map, the menu system changes to one appropriate for managing tabular data. Figure 3 shows the control buttons.

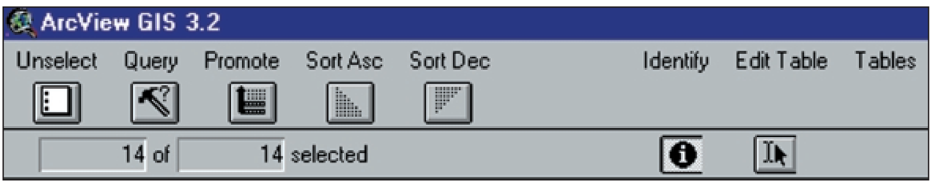

Figure 3. Table controls appear when a table is selected.

The left button unselects any records selected i.e. highlighted in yellow in the chosen table. Operation of the Query button is described in Appendix 1. The Promote button moves selected records together at the top of the table. The Sort buttons operate whichever a field-labels is highlighted in the table. It immediately sorts the whole table according to the values in that field. For example, highlighting Date_stock and then pressing Sort Dec button the records are sorted from the latest to the earliest stocking date.

The Tables menu option is used to modify data in a farm, nutrient or other user modifiable table. It allows records to be added or changed, fields (columns) to be added and so on. The process is complex and should be undertaken only after suitable training. Editing tables is described in Appendix 2.

Farm Summary Data

The whole farm information is obtained from the Farm program. This gives a map of the Estate with tabular data below and to the side if the map. Selecting Dairy (see legend) using the select feature tool button produces a display similar to Figure 4. The selected area is highlighted in yellow, and information related to the Dairy farm also shows as yellow records.

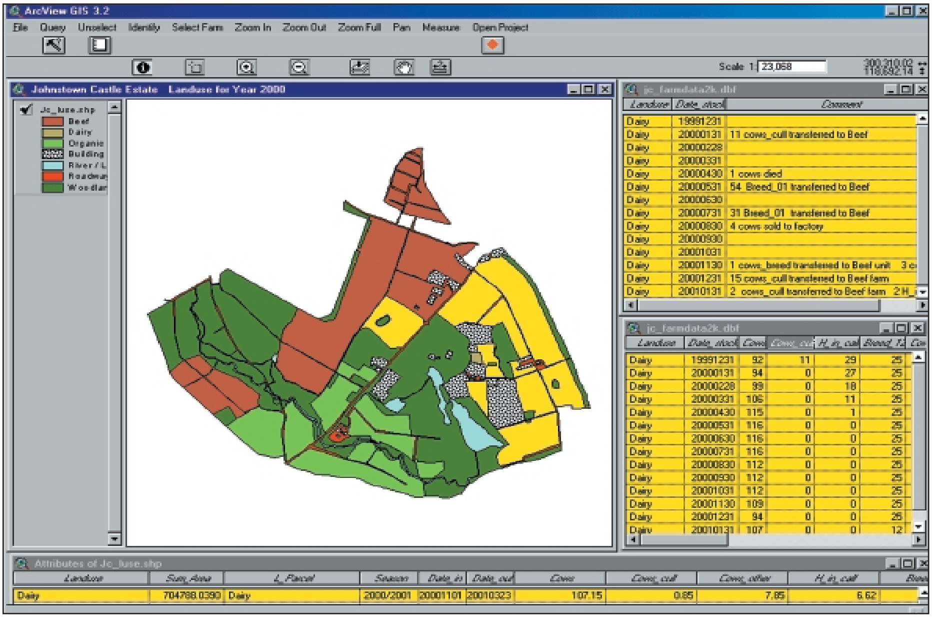

Figure 4. The Farm Data Spatial System with Dairy Information Selected

The table below the map shows summary data about the farm in question. Visible data include the area in m2, the season, date housed, date of turnout to pasture and averages for the year of cows, cull cows, other cows, in calf heifers, breeding stock 1-2 years old, etc. In addition, it shows the total slurry produced in m3 and the calculated N, P and K loadings from animals assuming standard values (Anon, 1996) for manure composition.

The tables to the right of the map shows some samples of the data recorded by the farm manager. The lower table shows detailed stock numbers taken from the monthly animal stocktaking. The upper table shows monthly comments inserted by the farm manager viz the animal transfer or change details from the monthly stocktaking.

Nutrient Management

Nutrient information about individual plots or fields in the current year is obtained by double clicking the Nutrients program icon on the PC desktop. The display format is shown in Figure 5.

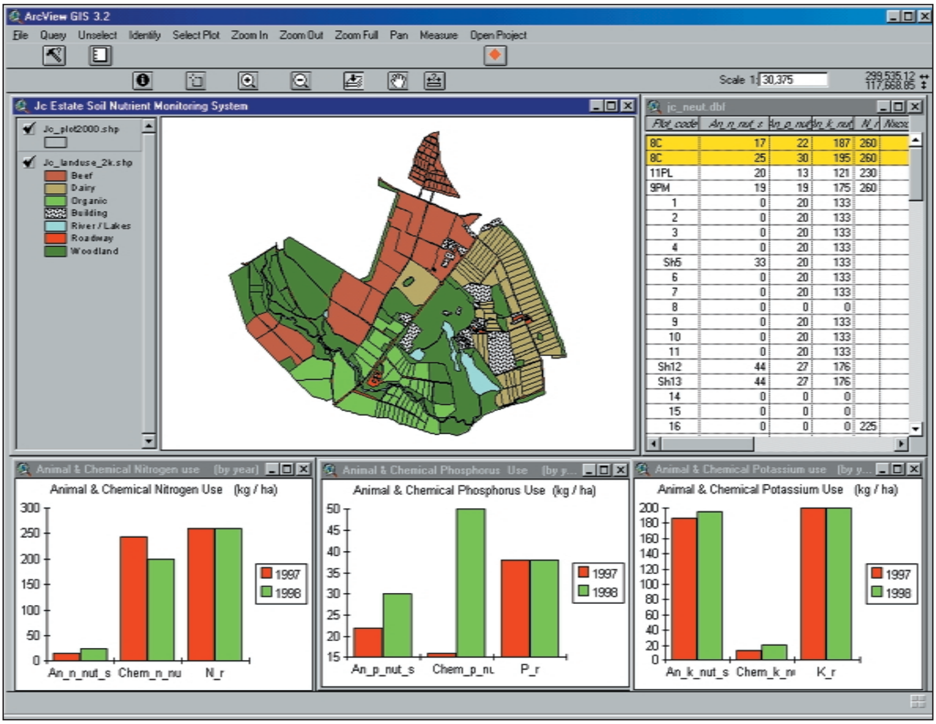

Figure 5. The nutrients management system at plot level.

When a plot or field is selected using the Select Feature button, the three charts at the bottom of the display change to reflect the N, P and K status of the selected plot. Two year's data are shown for the plot in question. The bars on the left of each chart illustrate the animal nutrients applied to the plot. The centre bars refer to the chemical nutrients applied and the right hand bars gives the nutrient advised in the most recent soil test report for that plot. The latest nutrient status information may be imported to the database and chart by clicking on the update button referred to earlier.

A number of plots may be graphed side by side by using the select feature on several plots with the keyboard shift button pressed. It may be necessary to zoom into the area in question before selecting plots because when they are small, clicking on one may result in the selection of several adjacent plots.

Mapping Soil Fertility Levels

The soil fertility levels of individual plots are displayed by clicking the Soil Fertility program icon. The Soil Fertility display screen is illustrated in Figure 6.

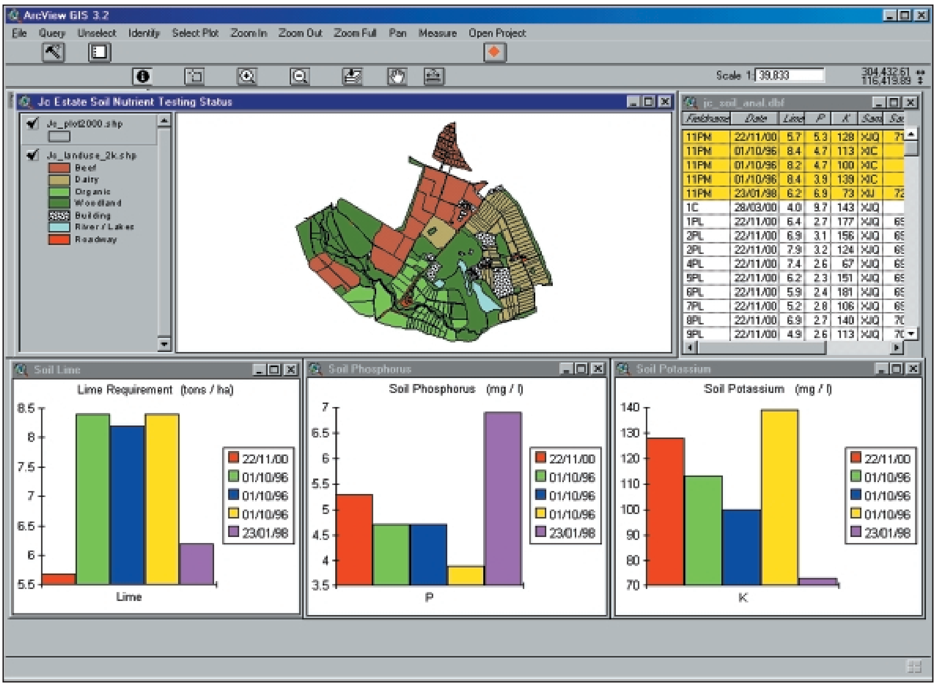

Figure 6. The soil fertility status of plots.

The charts on the bottom of the display show the results of all soil tests recorded by the system in the form of histograms. The table on the right of the display gives the plot code, the date of test and the all the soil test data records for the selected plot. The latest soil analysis data may be imported by clicking on an update button on JCEMS.

If one of the bar charts is selected (using the identify tool), then information may be obtained by clicking on one of the bars. Data about that soil test will pop onto the screen as a small table.

The soil P levels on the farmland at Johnstown Castle are shown in Figure 7 and Figure 8 shows K levels on the farms. The P levels reflect the nature of the experimental programmes on the Dairy, Organic and Beef farms and are not representative of farmland in general. Thus high soil P levels reflect the treatments that have been applied to the plots. A considerable area of the three farms shows high soil K values. These may have been caused by the constraints imposed on manure recycling on experimental land.

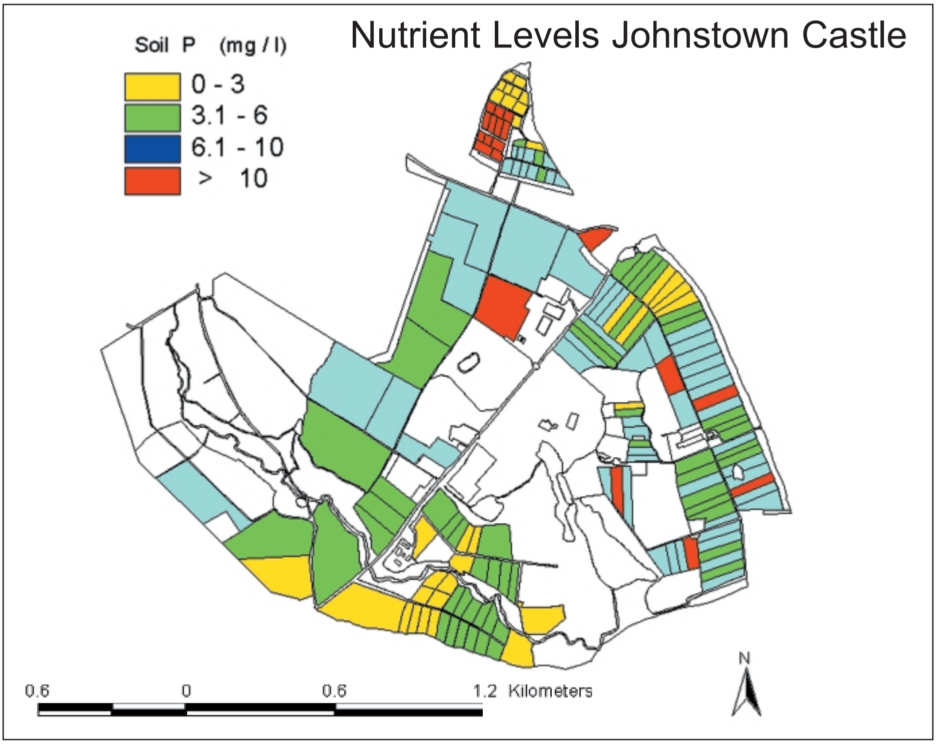

Figure 7. Soil P levels

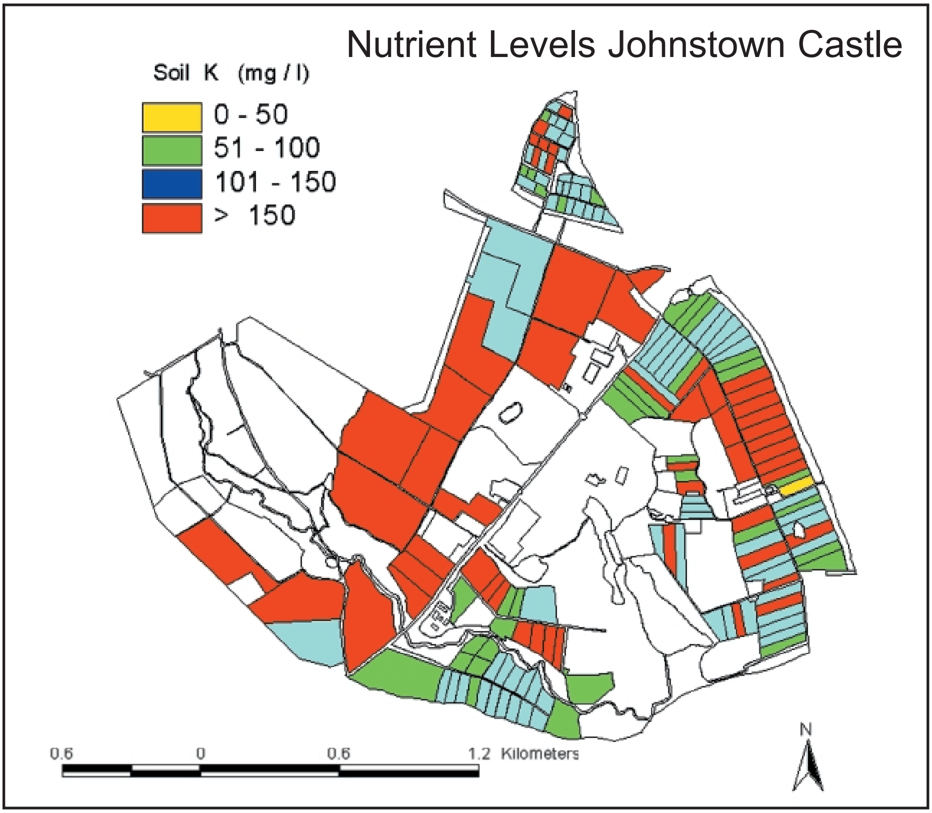

Figure 8. Soil K values

Monitoring Water Purity

The JCEMS includes a system to monitor point data on the purity of water in the lakes and rivers flowing through the Estate. Water samples are taken each month at 18 points within and just outside the Estate boundary. They are analysed for pH, P, TON, NO_3, nitrite NO_2 and NH_4 ions and the results of the analysis are maintained on a database, which is accessible to staff on the local area network.To ensure that the water purity information displayed on the JCEMS is always up-to-date, when Estate water samples are analysed, an update program is run to import the most recent analytical results to the water database by clicking the update button in JCEMS. Figure 9 shows the water Purity systems of JCEMS.

The map of Johnstown Castle shows the three farms, coloured buff, brick and light green and the forests and ornamental grounds are coloured dark green. The rivers are navy blue and the lakes light blue. The 18 sampling points situated along the rivers, streams and lakes are shown as red dots. Figure 9 illustrates the water purity at a point in woodland (dark green) about midway up and to the left of the map. On clicking this point with the select feature button, the sample dot becomes yellow and triggers a display of data in the table on the top right of the screen and graphs along the bottom. The data for the selected point are highlighted in yellow in the spatial database table on the top right.

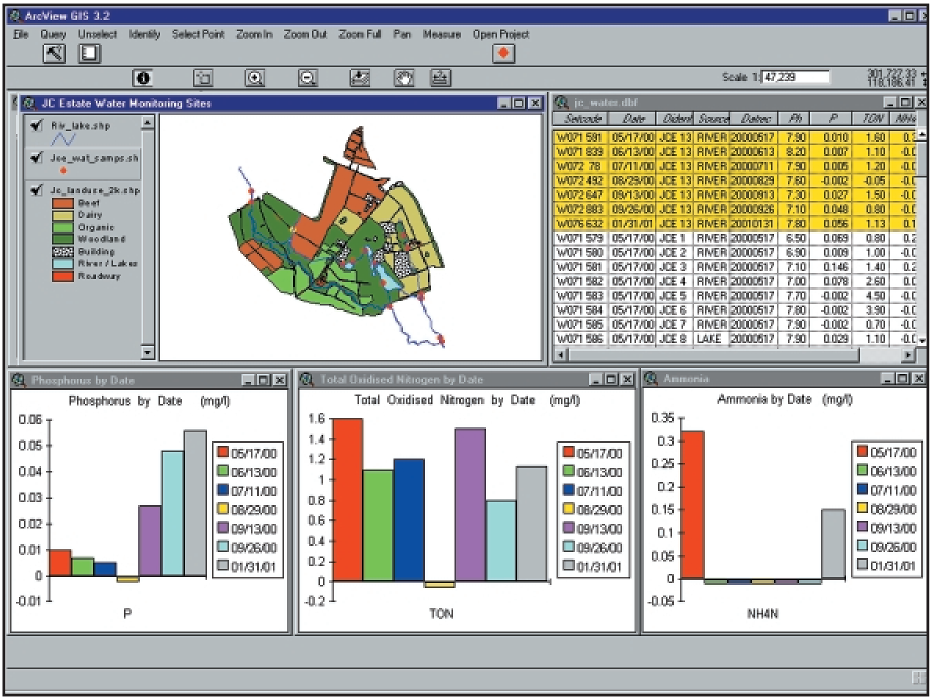

Figure 9. The JCEMS point water sample management system

On the graph, data values below the X-axis indicate that analysis was done but that the results were below the limit of detection of the ion in question. Zero value would indicate that the sample analysis data was not available for the ion.

The Soils of Johnstown Castle

The soil map of Johnstown Castle Research Centre was included in JCEMS as an aid to understanding differences in the behaviour of nutrients in different plots, and to help the choice of land for laying out of new experiments etc. Table 12 gives a brief description of the mapped soil units and the area and percentage area of each one. Approximately 50% of the farmed soils are well drained to moderately drained brown earths and the remainder are gleys with imperfect to poor drainage characteristics. The areas of woodland, lakes, wasteland and the land surroundings buildings are included for completeness.

Table 12: Soil classification of the land area of Johnstown Castle

Map Unit	Soil Group	Drainage	Texture	Area ha	% Total Area
A1	Brown Earth	Well / moderate	Fine loamy	102.5	25.7
A2	Gley	Imperfect	Fine loamy	96.5	24.2
A3	Gley	Poor	Fine loamy	24.4	6.1
B1	Brown Podzolic/ Brown Earth	Well	Sandy	12.1	3
B2	Brown Earth	Moderate	Sandy	5.3	1.3
C1	Brown Earth	Well	Coarse over fine loamy	25.9	6.5
C2	Gley	Moderate / imperfect	Coarse over fine loamy	14.7	3.7
C3	Gley	Poor	Coarse over fine loamy	6.9	1.7
Lakes/Rivers				12.2	3.1
Woodland				78.7	19.8
Building/ Other Land				18.0	4.5

An image of the JCEMS computer screen is shown in Figure 10. This illustrates the soil map and some tools for obtaining information. The display is simpler than the other ones in JCEMS, the tool buttons supplied can be used only for zooming, panning, measuring distances and obtaining information about the soil at different points on the e-map. Thus, as with the other e-maps in JCEMS, the soil information associated with any of the fields or experimental plots may be obtained by clicking on the area in question with the mouse pointer. Figure 10 shows the information window after the results of several queries have popped onto the screen.

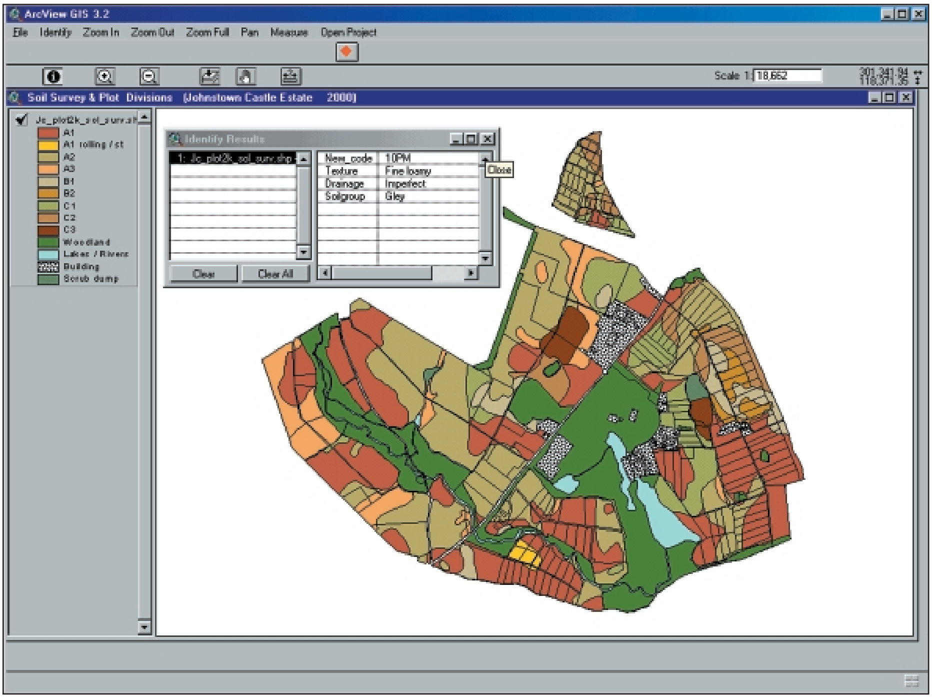

Figure 10. Soils of Johnstown Castle Estate

ACKNOWLEDGMENTS

The project would have been infinitely poorer without the help of many colleagues, particularly John Murphy, Rioch Fox, Alan Cuddihy and Noel Culleton of Johnstown Castle.

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APPENDIX 1

Using the Query Button to Build a Query

Use the query button  to build a query, choose a Field, an Operator, and then a Value. You build a query by double-clicking on these options with the mouse or by typing your query directly into the query text box. By default, the query is contained within parentheses, but the parentheses may not be required, depending on the complexity of your query. If the Update Values choice is on, click once on a field name to list its values in the Values list. Field names are always enclosed in square brackets ([ ]). If the value you want to use in the query is not in the Values list, type it into the query text box.

For example, to select all the houses of more than 1,500 square feet, you could use the query:
([area] > 1500)

Strings such as names are always quoted in queries. Queries on non-indexed fields are case insensitive, so you can select California with:
([state_name] = "california")

Use * as a multiple character wildcard. For example, to select Mississippi you could use the query:
([state_name] = "missi*")

Use ? in a string as a single character wildcard. For example, to find Catherine Smith and Katherine Smith, use:
([owner_name] = "?atherine smith")

To select all the cities with names starting with the letters M to Z, you could use:
([city_name] >= "m")

Values in date fields contain eight digits in the format YYYYMMDD. For example, the 10th of February 1972 would be represented as 19720210. Dates are handled as date objects. So when you are querying a date field you can select all dates before today by using:
([date] < Date.Now)

To select all the dates before a specific date, you could use:
([date] < 19920717.AsDate)

If you double-click a date in the Values list in the Query Builder dialog. AsDate is entered into your expression automatically. It tells ArcView that the eight digit number is to be treated as a date in the expression.

Another way to specify a date in an expression is to give the date as a string and then tell ArcView what format you have given it in, so ArcView can convert it to a eight digit date for you:
([date] > Date.Make("03/15/1993", "MM/dd/yyyy"))

Values in boolean fields are either True or False. So when you are querying a boolean field you can select all the true values by using:
([Wetland] = True)

Complex queries can be built by combining expressions together with the And and Or operators. For example, to select all the houses that have more than 1,500 square feet and a garage for three or more cars, use the query:
([area] > 1500) and ([garage] > 3)

Use the Not operator to exclude. For example, to select all the New England states except Maine, use the query:
([sub_region] = "N Eng") and (not ([state_name] = "Maine"))

Queries can compare the values of two fields. For example to find all the counties with a declining population, use the query:
([pop1990] < [pop1980])

Calculations can be included in queries. For example, to find the counties with a population density of less or equal to 25 people per square mile, you could use the query:
([pop1990] / [area] <= 25)

Dialog box options

Fields: This lists the fields in the theme or table you are querying. If the Update Values choice is on, click once on a field to see all its values listed in the Values list. Double-click on a field to place it into the query text box. If you type in the name of a field instead of clicking in this list, field names are not case sensitive, so typing Area, area or AREA are all allowed.

Fields that have been hidden do not appear in the Field list. If field name aliases have been defined these aliases appear in the Fields list.

Operators: Use these operators to specify relationships between Fields and Values in a query. click or double-click an operator to place it into the query text box. The operators are:

=	equals
>	greater than
<	less than
<>	not equal to
>=	greater than or equal to
<=	less than or equal to
( )	expressions enclosed in parentheses are evaluated first.
and	both expressions are true, e.g. [area] >= 100 and [area] <= 200
or	at least one expression is true, e.g. [rainfall] < 20 or [slope] > 35
not	excludes, e.g. not [name] <= "california"

The mathematical operators + - * / and arbitrary expressions can also be used in queries.

Values: This lists the values for the chosen Field. Only unique values are listed. So for example if 5 features or records in the theme or table you are querying have the same value for the chosen field, this value is only listed once in the Values list. Double-click a value to place it into the query text box. If the value you want to use is not in the list, type it into the query text box. Values cannot be displayed for tables containing more than 32765 records.

Update Values: By default, the Values list updates each time you choose a field. If there are a lot of values, it may take a moment for the values to be updated. Click this choice off if you don't want to update the values. This is particularly helpful if your query compares one field to another and you don't need to see their values, or if want to type specific values into the query text box instead of choosing them from the Values list.

Query text box: This is where your query is displayed as you build it.

Performing a query on a view or a table

If you are using the Query Builder to select features on a view or records in a table, the following options are available for performing your query:

New Set: Makes a new selected set containing the features or records selected in your query. Features or records not in this set are deselected.

Add To Set: Adds the features or records selected in your query to the existing selected set. If there is no existing selected set, the features or records specified in the query become a new set. Use this option to widen your selection.

Select From Set: Selects the features or records in your query from the existing selected set. Only those features or records in this existing set that are selected in your query will remain in the selected set. Use this option to narrow down your selection.

Performing a query to define a feature selection for a theme: If you are using the Query Builder from the Theme Properties dialog box to define a feature selection for a theme you will see OK and Cancel buttons instead of New Set, Add To Set and Select From Set.

OK: Selects the features in your query and makes this query the feature selection definition for the theme. Only those features that meet this definition will be represented in the theme. The query is added to the Theme Properties dialog box.

Cancel: Closes the Query Builder without running the query.

You can copy and paste queries. For example, you might use the Query Builder on a view to query a theme then decide to use this query as the theme's feature selection definition. In this case, you can copy the query, open the Query Builder from the theme's Theme Properties dialog box, and paste the query in. To copy all or part of a query, select what you want to copy and then press CTRL+C. To paste, press CTRL+V. There may be additional keyboard shortcuts on your platform, e.g., in Windows you can also copy with CTRL+INS and paste with SHIFT+INS.

APPENDIX 2

Using the editing features of ArcView

You can edit a database using the Table menu option which is visible when a table is clicked. In order to protect the integrity of JCEMS, only user data, as distinct from spatial data may be edited and saved. The process is started by using the "Start Editing" option from the Table Menu.

Adding a record

When editing is started, the option "Add Records" becomes enabled (from being 'greyed out') in the Edit menu. When this is selected, a blank record (line is added to the bottom of table being edited. To insert data, the fields in this new record must be edited.

Editing a field

Press the Edit button  and thereafter, any field of any record may be edited by clicking on the present contents and retyping.
After completion of editing, use the "Stop Editing" option from the Table Menu. The system will give the option Save Edits? and pressing Yes will make the changes permanent.

To calculate a value for a field:

1. Choose Start Editing from the Table menu.

2. Click on the name of the field you wish to calculate. Note that the names of fields you can calculate appear in a normal font, any that you can't are shown in italics.

3. Click the Calculate button. In the Field Calculator dialog that appears, type the expression for the calculation in the input area of the dialog box. You can use the field and request list items to help you form the expression by double-clicking on field names and requests or you can type the expression yourself.

4. Press OK to perform the calculation. ArcView displays the results in the table.

The calculation applies to the selected set of records. If no records are selected, the calculation applies to all records.

The calculation expression

The expression you type, in its simplest form, can just be a number, a string, a date, or a boolean value. For example, to set the value of a string field named [Zoning] to the string "Industrial", type the string, enclosed in double quotes in the text input area of the dialog box. To set the value of a number field to the number 143, type the number in the text input area of the dialog box.

In addition, an expression may consist of any combination of field names, enclosed in square brackets. The result of the expression must be a single object or value. For example, to calculate the value of a field named [Total Sales] as the product of the number of units, stored in a field named [Units] and the unit price, stored in a field named [Price] and also figure in the sales tax of 8.0%, type ([Units] * [Price]) * 1.08.