THE USE OF GEOGRAPHIC INFORMATION SYSTEMS AND OTHER COMPUTER AIDED DRAFTING FACILITIES FOR THE PRODUCTION OF GEOHYDROLOGICAL MAPS

by

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Persons interested in procuring the software should contact the Director, Institute for Groundwater Studies, UOFS, PO Box 339, Bloemfontein 9300 Tel 051-401 2394 Fax 051-447 3541, for details on training courses

HydroCom

Geographic Groundwater
Interpretation System

ArcInfo

NGDB

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THE USE OF GEOGRAPHIC INFORMATION SYSTEMS AND OTHER COMPUTER AIDED DRAFTING FACILITIES FOR THE PRODUCTION OF GEOHYDROLOGICAL MAPS

The Steering Committee responsible for this project, consisted of the following persons:

Mr. A.G. Reynders	Water Research Commission (Chairman)
Mr. P. Smit	Water Research Commission (Secretary)
Mr. H.A. Maaren	Water Research Commission
Dr. R.J. Kleywegt	Council for Geological Sciences
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Mr. D.R. McPherson	Department of Water Afairs and Forestry
Prof. J.G.C. Small	Univeristy of the Orange Free State

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Many individuals from within the Institute for Groundwater Studies actively worked on this project. This project would not have been possible without their dedicated commitment.

Frank Hodgson - Project Manager
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Shaun Staats - Advisor
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Carinie le Roux - Financial manager

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1 Introduction and goals

The research documented in this final report was carried out by the Institute for Groundwater Studies for the Water Research Commission. It represents a four-year project which was researched during the years 1991 - 1994.

The report consists of three sections, namely:

- The executive summary.
- The manual, which describes the operation of the software.
- The tutorial, which contains worked examples.

Goals of this research were:

- The establishment of a link between the National Groundwater Data Base, HydroCom and Arc/Info; the latter being the Geographic Information System in use at the Department of Water Affairs and Forestry (DWA&F).
- The establishment of a front end processor to process geohydrological data before it is displayed by means of the Arc/Info System.
- The establishment of user selectable functions which will enable the user to select the type of geohydrological map required, for instance point values, contours or solid shading could be represented.
- A generator to create finite element networks which can be used for modelling groundwater flow in aquifers by interfacing data with the National Groundwater Data Base.

2 Background information

The Institute for Groundwater Studies has been involved in data base programming since 1983. Products that have been developed during this time include the National Groundwater Data Base (NGDB) and HydroCom. These products are currently used nationally in South Africa. Both systems contain point information only.

Geographic Information Systems have been used for data depiction and interpretation by the Department of Water Affairs and Forestry since the late eighties. The DWA&F has standardised on the Arc/Info system.

2.1 The National Groundwater Data Base

The National Groundwater Data Base (NGDB) has been run from a mainframe computer located in Pretoria since its inception in 1986. It only contains groundwater information, the main components of which are illustrated in Figure 1. Its purpose is the storage of all geohydrological data in South Africa. Currently (1994), information on about 130 000 sites has been entered into this data base.

Category	Detail
Basic Information	
Surface Hydrology *	Stage height Discharge/Stream flow
Meteorology*	Rainfall Humidity Pan evaporation Air temperature Solar radiation Wind velocity Direction of wind
Hydrochemistry*	User definable variables and standards
Groundwater	Geology Aquifer Penetration rate Hole construction Hole diameter Casing details Piezometer installation Fill material Equipment Discharge rate Water level Pumping test Borehole geophysics
Instrumentation	
Additional Information	Site selection Name of owner Visits to site Other cases References Comments
User Defined	
Time User Defined	

* Not present in the NGDB

Figure 1. Structures of HydroCom and the NGDB.

2.2 *HydroCom*

HydroCom development began at the Institute for Groundwater Studies in 1986. It is a PC-based hydrological data base, which accepts the entry of data as indicated in Figure 1. The groundwater module was structured along the lines of the NGDB, with the result that most of the NGDB data can be downloaded into HydroCom. HydroCom's purpose is to allow the PC-user to store and process point information in an orderly way, while not connected to the NGDB. Currently (1994), more than 100 HydroCom software packages are in use in South Africa.

2.3 *Arc/Info*

Arc/Info is a commercial Geographic Information System that has been developed in the United States of America. It is workstation- or PC-based. It is predominantly used for map construction but can also be used to analyse spatial data. For example, using the best option analysis facility conditions may be superimposed on data sets so that areas that comply with the set conditions may be selected.

2.4 *NGDB + HydroCom + Arc/Info = GGIS*

In view of the existing facilities for the storage of point information (NGDB and HydroCom) and the availability of Arc/Info software, the next logical step was to link the point information systems with Arc/Info. Two options to achieve this, were possible. These were: the use of existing facilities within Arc/Info to accommodate the point information as coverages; and the development of specialised programs to process point information so that it could be displayed using Arc/Info routines.

At the outset, it was clear that existing facilities within Arc/Info were not sufficient to facilitate the specialised and sometimes complex data manipulations that geohydrologists require. A combination of program development and the use of existing Arc/Info routines was therefore the obvious way to proceed.

The product that was thus created, was named: "Geographic Groundwater Interpretation System" or GGIS for short.

3 Programme structure

GGIS currently runs only on a SUN workstation. It was hoped that during this project, the PC-version of Arc/Info would be able to circumvent the 640 K DOS limitation, but this has not transpired. For the time being therefore, PC-users will not be able to run GGIS.

GGIS does not require a thorough knowledge of the NGDB, HydroCom, Arc/Info or of SUN workstation usage. All programs within GGIS are menu-driven and linkage to the NGDB, HydroCom or Arc/Info is transparent to the user. The manual and tutorial provide ample guidance to get even the uninformed started.

All data processing is done through external programs, linked as object files to Arc/Info. This holds the significant advantage that the routines should be transferable to PC-computers without major revision of the software, when the current DOS limitation is overcome.

4 Principles of processing and presentation of geohydrological data

4.1 Introduction

Processing and presentation of geohydrological data through the use of GGIS are simple matters. A menu system has been devised and by proceeding logically through a number of steps, the user is able to plot and interpret data. A schematic flow diagram of the necessary actions is presented in Figure 2.

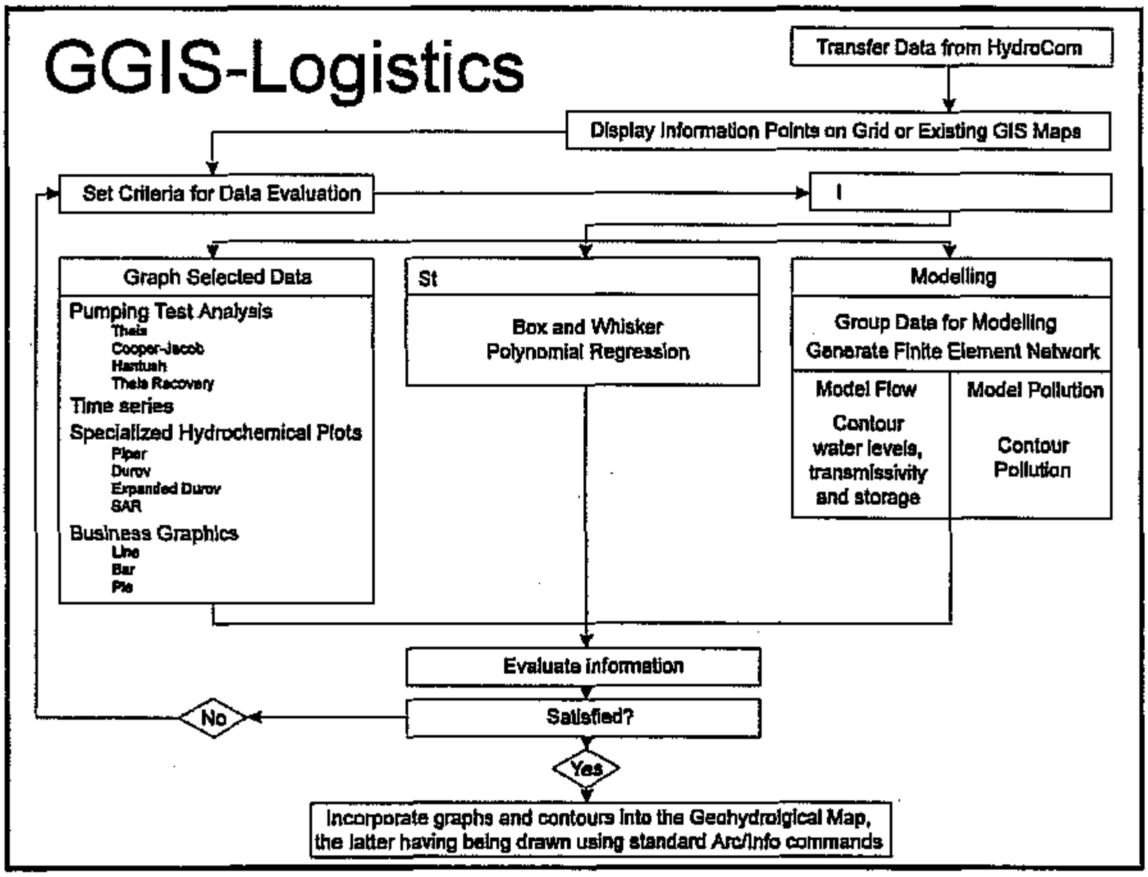


Figure 2. Flow diagram for general GGIS actions.

Processing of this kind is unique to the field of geohydrology and was therefore not available among the more general Arc/Info analysis tools.

Processing and display of data are inseparable and follow logically upon each other. Processing of geohydrological data involves:

- Data collation.
- Data validation.
- Retrieval of data for processing and creation of displays.

Typical use of geohydrological displays within GGIS may include:

- Identification of anomalies and outliers in data series.
- Depiction of trends and patterns.
- Comparison between several geohydrological data sets.
- Interfacing geohydrological data with other data sets.
- Conversion of point data into spatial information.
- Enhancement of reports.

These are a few examples of the many possible techniques that can be used for processing and display of geohydrological data. These techniques and others are described by Lloyd and Heathcote (1985).

Massive data sets and complex display formats can presently be processed, with relative ease, on software that has been developed for personnel and workstation type computers.

4.2 Data types and presentation possibilities in GGIS

A meaningful discussion on the processing and display of geohydrological variables necessitates certain data groupings. These groups have been selected to represent various environments in which geohydrologists operate. Two main groupings are identified in this document, namely: point data versus spatial information.

4.2.1 Point data

Point data are generated at a geographic point. Examples of geohydrology related point data types are:

- Geological data, such as borehole logs.
- Geohydrological data, such as depths of water intersections and well yields.
- Borehole construction data, such as casing, piezometer, development and costs.
- Type of equipment such as pumping equipment and recorders.
- Geophysical data, including surface and borehole measurements.
- Hydraulic properties of the aquifer(s), such as transmissivity and storage.
- Water abstraction and groundwater level records.

- Hydrochemistry.
- Other information, such as topography and surface drainage.

Even though many of these variables have spatial connotations, they refer back to the groundwater abstraction point and are, for that reason, grouped under point data. Examples of variables in the above list with spatial connotations are, for instance, the geological log, which has a vertical dimension and surface geophysics, which has both horizontal and vertical dimensions.

4.2.2 Spatial information

The concept 'spatial information' emphasises two important differences when compared with point data. The term 'spatial' suggests that point data have been processed or displayed in the geographic context, such as on a map. The term 'information' suggests that the point data have been processed to the extent that individual variable values can no longer be recognised.

4.2.3 Presentation possibilities

Tools for the presentation of data and information have been grouped under three main headings in this research. These are:

- Graphs.
- Statistics.
- Maps.

A significant overlap is possible between these categories. Examples are: maps that contain graphs or statistical interpretations as insets and commonly used displays, such as some specialised hydrochemical diagrams, which have a statistical basis. Statistic data displays, as graphs, usually contain processed information together with raw data.

As the discussion of the various displays proceeds, the categories of display that will be supported in this document, will become clear.

4.2.4 Graphic processing and presentation of data

In order to present geohydrological point data as concisely as possible, certain logical groupings are necessary. The following are suggested:

Group 1: Depiction of borehole information.

Geological, geohydrological and construction data; progressive borehole yield during drilling; packer testing results; borehole geophysics.

Group 2: Depiction of hydraulic properties of the aquifer(s)

Hydraulic conductivity, transmissivity, storage and dispersion.

Group 3: Depiction of time-dependent data
Groundwater abstraction, groundwater levels, water quality.

Group 4: Depiction of water chemistries as specialised hydrochemical diagrams for detailed chemical interpretations.

Group 5: Depiction of most data in graphical form, such as bar, scatter and line graphs.

Within these five groups, most point data that are generated during geohydrological investigations, can be accommodated.

Layouts for graphs to depict variables within each of these groups may vary from one presentation to the next. There are, however, three basic rules to be considered when displaying geohydrological data. These are:

- The displays must be clear, concise and legible.
- They should contain only relevant data.
- Displays should be provided with the necessary headings and labels to ensure that they will be meaningful entities on their own.

Keeping these rules in mind, discussions of and recommendations for displays that may be used by the geohydrologist, will now be presented.

4.2.4.1 Borehole information

Vast amounts of valuable data are generated during the drilling of a borehole. Most of these data are of the 'once off' type, in contrast to measurements that may be repeated, such as water levels or water chemistry. Essential 'once off' variables that should be recorded during drilling are:

- Geology.
- Depth of water intersections and yield.
- Penetration rate during drilling.
- Quality measurements of each water strike (electrical conductivity and pH for instance).
- Construction data (hole diameter, depth, casing properties).

Other data that may be recorded after the hole has been completed, are:

- Borehole geophysics.
- Packer testing results.

The latter two variables are not strictly of the 'once off' type, because they may be measured repeatedly, if so desired.

Each of the above variables should be recorded individually for the sake of establishing complete records. Interpretation of the many data sets is, however, very difficult and time-consuming. Ideally, all this information should be summarised onto a single sheet of paper in a format that can easily be included in a report. Because of the amount of information that is contained within such a presentation, it would unnecessarily clutter a geohydrological map. It is therefore suggested that this information should not form part of such a map. HydroCom has the facilities to plot and print the above information.

The variable values within the individual data bases, e.g. geology, aquifer and construction information may, however, be inspected while within GGIS and can assist in the preparation of geohydrological maps.

4.2.4.2 Hydraulic properties of the aquifer

GGIS allows a twofold graphic presentation of hydraulic properties of an aquifer.

Firstly, plots of drawdown versus time for the calculation of aquifer constants may be constructed and embedded into geohydrological maps. Theis, Cooper-Jacob, Hantush, Step and Theis Recovery methods are supported and these techniques are well-documented in literature (for example Kruseman and De Ridder, 1992).

Secondly, the spatial variation of aquifer constants, such as transmissivity and storage, may be grouped or contoured and the results superimposed onto existing maps.

4.2.4.3 Time-dependent data

The geohydrologist measures a variety of time-dependent parameters, such as, water levels, pumping rates, rainfall and water chemistry.

GGIS allows the plotting of all time-dependent data and the superposition of this information onto maps.

4.2.4.4 Specialised hydrochemical diagrams

Many special displays which meaningfully present hydrochemical data have been devised through the years. Of these, four displays stand out in terms of clarity and significance. They are the Piper (Piper, 1944), Durov (Durov, 1948), Expanded Durov (Lloyd, 1965) and SAR (Wilcox, 1955; Bower, Ogata and Tucker, 1968) diagrams. All of these diagrams are so-called multivariate displays, simultaneously taking up to eight variables into consideration, often projecting these variables to a single point on the diagrams.

Advantages of using these diagrams include:

- The plotting of numerous water analyses onto a single diagram.
- The classification of waters according to their chemical characteristics.

- The identification of trends.

Similar evaluation of data may be performed by statistical methods such as factor or principle component analysis. However, statistical evaluations of this kind are usually complex and may only be understood by those familiar with statistical terminology. Specialised chemical diagrams, as map insets, therefore present the data to a wider readership which may be backed by statistical evidence in reports, if necessary.

4.2.4.5 Other graphics

Various possibilities exist to depict water chemistries for individual water samples. Presentations which have been used are the line (including Schoeller), scatter, bar, vector, radial, star, pie and polygon (including Stiff) diagrams (Lloyd and Heathcote, 1985) and Chernoff faces. In GGIS, only bar, scatter and line graphs are supported. It is important to note that in most specialised diagrams the units used are meq/l, thus reflecting the true reactive ratios of the constituents. However, in the case of line, scatter and bar diagrams, the units may also be in mg/l. Results of chemical analyses are usually reported by laboratories as mg/l. This unit is often preferred by planners and managers.

Business graphics such as line, scatter and bar plots are often used to depict geohydrological data. These diagrams allow clear and concise presentations of a variety of aspects. By changing the y-axis of the plot from a linear scale to a logarithmic scale, the range of values that may be depicted becomes almost unlimited.

4.2.5 Statistical processing and presentation of data

Only two statistical interpretations are allowed within GGIS. These are:

- Box and Whisker plots.
- Polynomial trends.

It was felt that these two presentation techniques cater for the majority of parameters that may have to be summarised on a map.

4.2.6 Spatial Information systems

4.2.6.1 Introduction

Geographic information systems (GIS), as used for water supply data, have undergone significant development during the past five years (Fulton, 1992; Haefner, 1992; Juracek, 1992). GIS, in its simplest form, constitutes two essential components, namely a map drafting facility and a related data base.

All elements, such as points, lines, arcs and text that are drafted, are recorded as spatial entities within the data base.

All information in a GIS is structured according to certain definable conditions. A basic requirement is usually that variables of the same type are stored together, to allow ease of data retrieval. Each storage unit is usually referred to as a coverage. Geohydrological data and information such as water levels, positions of boreholes and distribution networks may therefore constitute separate coverages as part of a GIS data base.

One of the main advantages of standardising on GIS is that geohydrological information may be combined with other information sets. Typical information sets that are useful to the geohydrologist are topography, soils, geology, meteorology, urban development, waste disposal, mining and industrial development. This information is generally available from institutions involved in other geographic disciplines where GIS has been used for some time. It therefore does not need to be entered by the geohydrologist.

The advantage of having complementary information sets available at the start of a geohydrological investigation, is enormous. It allows, among other things, the identification of target areas where geohydrological investigations would be meaningful. The only constraints are:

- The availability of information sets.
- The quality of the information.

4.2.6.2 Entry of spatial information

Entry of information into GIS is complex and time-consuming. Point data may be imported electronically from existing data bases, such as the NGDB and HydroCom (even without the aid of GGIS). Existing maps, however, either have to be digitised or scanned for entry into the GIS. Digitising involves the physical tracing of all lines, points and text into GIS coverages. Electronic scanning of existing maps may be much faster but provides a raster image which may be used as a coverage in the GIS. Raster images are not true GIS images and no intelligence can be attached to them. Raster images consist of millions of dots, with each dot representing a single scanned pixel. Such images occupy vast storage space on computer disks. In view of these limitations, it is almost always necessary to convert raster images to vector images.

Vector images may be obtained from raster images by activating suitable computer software. This software is capable of recognising patterns and converting them into lines, text, symbols and shadings. Vectorisation of raster images is a major task due to the poor quality of raster image obtainable from most printed maps. It may, for instance, take more than a month to vectorise a single topographic map. Nevertheless, scanning and vectorising is the preferred technique for capturing information into a GIS.

Organisations in South Africa, such as the Department of Water Affairs and Forestry and the Council for Geological Sciences are involved in capturing geographical information as GIS coverages. Catalogues of the available coverages may be obtained from them.

4.2.6.3 Conversion of point data

The conversion of point geohydrological data into spatial information is the next logical step in GIS application. This is most commonly achieved by contouring point values. Examples of geohydrological variables that may be contoured are transmissivities, storage coefficients, hydrochemical data and water levels.

GGIS provides a contouring package that is based on the work of Buys *et al.* (1992). Other contouring packages may also be used. They are, however, not linked to the menu system of GGIS.

A recent development in Arc/Info is the transformation of spatial information into grid images. In these applications, the grid images should be coarse, typically consisting only of a 40 x 30 matrix. The purpose of such transformations is to convert spatial information into averaged grids, whereafter averaged grids may again be analysed by using standard Arc/Info tools. A typical application would be the transformation of water-level and topographic information into two raster images of identical dimensions. Thereafter, the interrelationship between these two variables may be studied. Grid procedures are particularly useful for comparison of complex information sets.

The combination of GIS technology with geohydrological tools such as specialised interpretations and modelling, has been under development for a number of years in other countries. Examples are the NWIS-II (USGS, 1991) and REGIS (TNO, 1993) software. All three software packages (including GGIS) have the capability of converting point data to spatial data, integrating data sets with GIS and executing flow and mass transport models from within the GIS environment.

4.2.6.4 Geohydrological maps and the UNESCO legend

Geohydrological maps to depict groundwater related information have been available for many years. Numerous examples of such maps are given in publication by UNESCO (1983). Standardised geohydrological codes and maps were suggested by UNESCO in 1963 and revised in 1983. The publications relating to these suggestions were well-received and many maps have been produced using the suggested legend or variations thereof.

The Geohydrological Map of England and Wales (1977) is one of the many examples where the UNESCO code has been used. Many other geohydrological maps of Europe and other parts of the world have been published. The UNESCO code of 1983 lists numerous geohydrological maps world-wide. The latest in this series is the Geohydrological Map of Lesotho (Arduino *et al.*, 1994).

From these examples, it is noticed that the tendency for geohydrological maps is to have a large central base map showing the major geohydrological variables. Surrounding this map are smaller map inserts showing other variables of geohydrological interest. In the case of the Lesotho Map, for instance, information on the following topics have been included:

- Geohydrological legend.
- Summary of geohydrology for Lesotho in text format.
- Climatic information, including rainfall time series, contours and wind directions.
- Base flow and run-off information.
- Water quality information tabled and plotted onto Piper diagrams.
- Geological and geohydrological cross-sections.
- Groundwater contours and flow nets.
- Tables showing individual and interesting characteristics that relate to the geohydrology at specific localities on the map.

GGIS is ideally suited to construct the map insets, while the Arc/Info software may be used for drafting the main map.

Standardisation of colours and codes are recommended bearing in mind the great number of geohydrological maps that are being produced world-wide. It is recommended that the UNESCO legends of 1963 and 1983 should be followed as closely as possible.

The DWA&F in conjunction with the Water Research Commission is currently investigating standard geohydrological legends for use in South Africa. Once these become available, their use on geohydrological maps is recommended. South African geohydrological maps that have appeared during 1995 are the Pietersburg and Cape Town Sheets on a scale of 1:500 000 and the Groundwater Resources of the Republic of South Africa (2 sheets) on a scale of 1:2 500 000. It is the intention of the DWA&F to publish geohydrological maps for the whole of the country. The use of the GGIS for data evaluation during the compilation stages of these maps will significantly assist in drawing meaningful conclusions.

4.2.7 Conclusions

In terms of hydrological data processing and presentation, the only limit is the imagination of the individual who is analysing the data. In this document, an attempt has been made to present those techniques that are available in GGIS. Many other, more sophisticated, techniques are available - these may require significant experience and computing power. When searching for a specific processing and presentation technique, the following criteria should be considered:

- The level of expertise of the individual.
- The quality of the data.
- The available computer power.
- The level of expertise of the individuals to whom the information is to be presented.

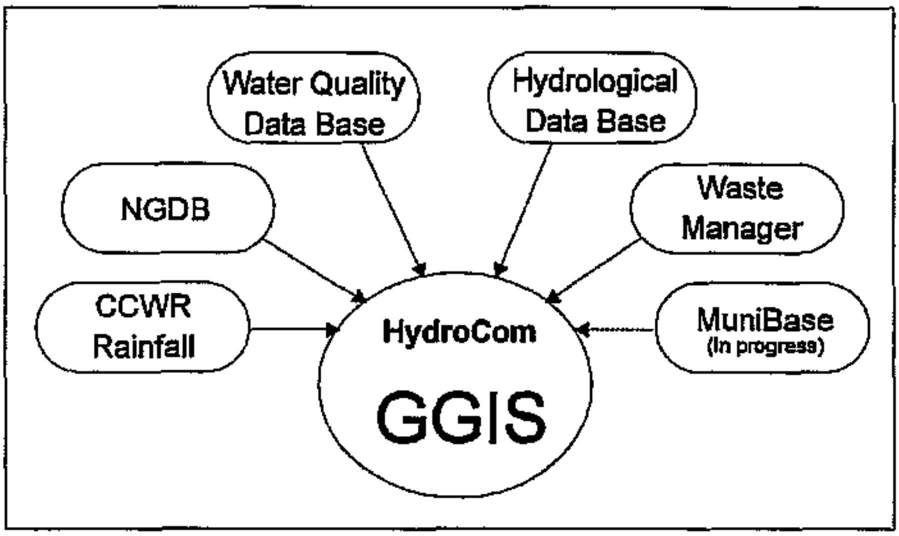
5 Conclusions

The success of this project may be evaluated in terms of the original goals and the degree to which these have been achieved:

Goal 1: *The establishment of a link between the National Groundwater Data Base, HydroCom and Arc/Info; the latter being the Geographic Information System in use at the Department of Water Affairs and Forestry.*

This link was established and the procedure is as follows:

- Select and download NGDB data to HydroCom.
- Edit data within HydroCom and ensure that it is of sufficient quality to be processed within GGIS.
- Transfer this data to directories on the SUN workstation as described in the manual and tutorial and process the data through the GGIS menus.
- The result is a system that not only can accept and process data from the NGDB, and also from other existing data bases through HydroCom, as indicated below:



Goal 2: *The establishment of a front end processor to process geohydrological data before it is displayed by means of the Arc/Info System.*

This was accomplished and a large number of computing routines were established as part of the GGIS system to process data on all levels, such as graphs, statistics and modelling.

Goal 3: *The establishment of user selectable functions which will enable the user to select the type of geohydrological map required, for instance point values, contours or solid shading.*

This was accomplished through the menu system within GGIS and the user may process data, plot the information on maps or contour the information. The resultant plots may be repositioned as inlays on a main map. The geohydrological legend which is currently under development, should be implemented by the DWA&F under Arc/Info, thus making it available to GGIS.

Goal 4: *The creation of a finite element network generator which can be used for modelling groundwater flow in aquifers by interfacing data with the National Groundwater Data Base.*

The finite element generator has been created and is available within GGIS. It provides input into either the flow or mass transport models. These models have also been incorporated into the GGIS package and can be run through the menu system within GGIS.

The overall conclusion is drawn that GGIS is unique, a valuable asset and that it should serve South African geohydrologists well in the years to come. As in the case of any computer software, adaptations will continuously be made to ensure that GGIS meets the requirements of improved hardware, software and that of the geohydrological community. Without these adaptations, the software will soon become redundant.

6 Recommendations

The development of a software package, such as GGIS, should be followed by continued enhancement of the software, as the need arises. Needs could be process driven or hardware driven. In this respect, it is important to anticipate and pro-actively provide for additional software development. Needs which have already been identified and which should be addressed in the near future, are the following:

- Training of individuals in the use of the GGIS software is essential and should be an on-going process. Individuals interested in using this software should contact the Director, Institute for Groundwater Studies, UOFS, P.O. Box 339, Bloemfontein 9300 Tel 051 401 2394 Fax 051 447 3541.

- Establishment of direct access of NGDB data from GGIS, without having to transfer NGDB data through HydroCom to the GGIS environment will greatly expedite processing of large data sets.

- Implementation of GGIS under NT-Windows is recommended. This will allow PC-users to make use of GGIS.

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1. Introduction

GGIS can be used to give a new dimension to HydroCom data. GGIS uses the power of Arc/Info and custom applications to produce a powerful and flexible method of analysing and viewing HydroCom and other GIS data.

This report has been written in the format of a manual which describes the use of the GGIS software. It assumes that the user is familiar with the Arc/Info software package.

1.1 Description of project GGIS

This project consists of the creation of a link between HydroCom data and Arc/Info, the provision of tools to analyse and process that data and the presentation of the results in combination with other GIS data in the form of a geohydrological map.

1.2 Outline of operation of GGIS

The following points are the essential steps in the production of the above-mentioned geohydrological map:

1.2.1 Data preparation

The HydroCom data to be used by GGIS may be entered by hand into the appropriate HydroCom data files, or they may be downloaded from the National Groundwater Data Base into HydroCom data files. As these data files are DOS based and GGIS is UNIX based, the data must then be made available to GGIS for further processing.

1.2.2 Data analysis

GGIS provides an extensive set of tools to analyse and process the HydroCom data and presents the results in a graphical format for further interpretation or presentation. These tools include plotting of data points, identification and selection of certain points or groups of points based on user definable criteria, interactive data editing facilities, hydrogeological and hydrochemical analysis of borehole data, statistical analysis of data, modelling of HydroCom data and processed GIS data and contouring of various sets of data and results.

1.2.3 Additional operations

Full access is provided to all built-in functions and commands of Arc/Info to facilitate the addition of GIS data to the HydroCom data in order to enhance the display and/or processing of the HydroCom data. This includes, but is not limited to, the addition of coverages obtained from other data sources and the processing of these additional coverages in combination with the HydroCom data to produce new views of the data.

1.2.4 Producing output

GGIS provides an easy-to-use option to produce output from Arc/Info, using the built-in Arc/Info commands and functions. This can be used to simplify the production of geohydrological maps.

2. Getting started

This chapter describes how to start GGIS, the GGIS menu structure, how to select commands from the menu, how to define options on a dialog, how to view the About dialog and how to close GGIS.

Also contained in this chapter are concepts that explain basic features of GGIS.

2.1 The GGIS directory structure

While HydroBase can only access one subdirectory or HydroBase project at a time, GGIS can handle all subdirectories simultaneously. Every project consisting of one or more HydroBase directory starts with a project directory. The project directory consists of all coverages, grids, etc. There must be one directory with the name "_hbase". The _hbase directory can be compared with the _hbase directory on a PC which contains all data subdirectories. During start up of GGIS, the program will look for the _hbase directory. If not found, the program will terminate.

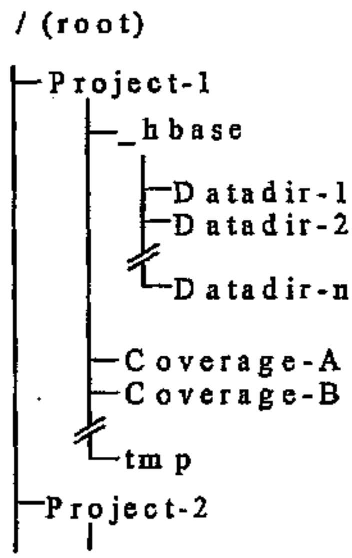

Figure 1. The GGIS directory structure.

2.2 Transferring data to the SUN Workstation

When starting a new project using GGIS, the first requirement is to create the following directory structure on the SUN: a project directory, under the project directory, a directory with the name "_hbase", under the _hbase directory, at least one data subdirectory must be created and as many data subdirectories as necessary may be created. The recommended procedure is to establish an electronic link between the PC and the SUN; relevant files from the PC's HBASE subdirectories are copied to the _hbase subdirectories of the SUN.

Only files with the DBF and DBT extensions need to be copied. The normal copy command may be used if the connection is via PC-NFS and access to the mounted SUN disks is available; otherwise FTP must be used. Help from the system administrator is recommended if uncertainty exists.

If transfer by electronic means is not possible, files can be transferred using a floppy disk.

2.3 Starting GGIS

Before you start GGIS, ensure that the system complies with the requirements as set out in Section 2.1.

To start GGIS:

1. On the Sun workstation, change directory to the workspace from where the HydroCom data can be accessed.
2. Start Arc/Info and ArcPlot.
3. Start GGIS by entering the "&r ggis" command.

After you have started GGIS, you will see the GGIS window, which displays a drawing area, a menu bar and a title bar. The title bar will contain information about the data sets that are currently being accessed.

☞ **Note**

Arrange the command window from which you started GGIS in such a way that it is always visible. Important information is displayed in this window as well as prompts to which you must respond.

2.4 The GGIS menu structure

GGIS is largely menu driven, resulting in an easy-to-use and powerful program. The following options may be found on the menu system of GGIS:

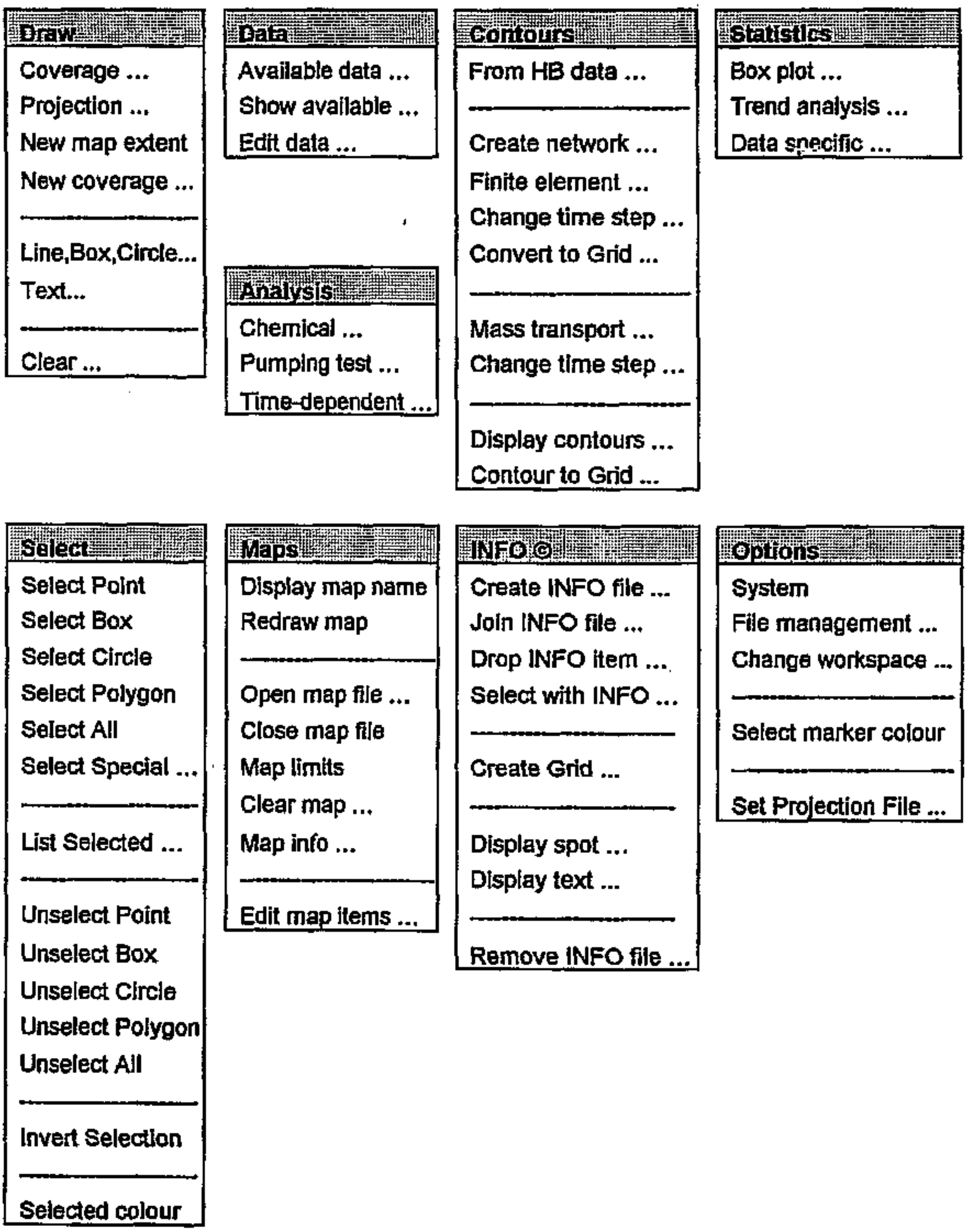

Figure 2. The GGIS menu system.

2.5 Selecting commands from the menu

GGIS is controlled by selecting commands from the menu. Those options on the menu bar which are followed by a ▼ symbol, have associated pulldown menus. Commands on the pulldown menus, followed by an ellipsis (...), will activate a dialog, when selected. Commands on the pulldown menus, which are not followed by an ellipsis, will execute the command when selected.

To choose a command from a pulldown menu:

1. Move the mouse pointer to an option on the menu bar and press the Menu button. The menu remains open until you choose a command or click outside the menu.
2. Point to a command and press the Menu button.

2.6 Using a dialog

When GGIS needs more information or has a message, a dialog opens. You choose options in the dialog and enter values, and then choose the ☑ button (OK) to process your choices. Choose the ☒ button (CANCEL) to return to the program with no change. Some dialogs have a ➡ button (NEXT). Choosing this button is the same as choosing the ☒ button and then selecting the command on the menu following the command which opened the dialog.

2.6.1 Choosing options

Options in a dialog have square check boxes or option buttons. In a group of options with square check boxes, you can select several options at the same time. In a group of option buttons, you can select only one option at a time.

2.6.2 Text entry fields

Some dialogs have text entry fields in which information may be typed. Highlighted text in a text entry field disappears when you begin to enter new information. To edit the highlighted text, first move the text cursor to remove the highlighting.

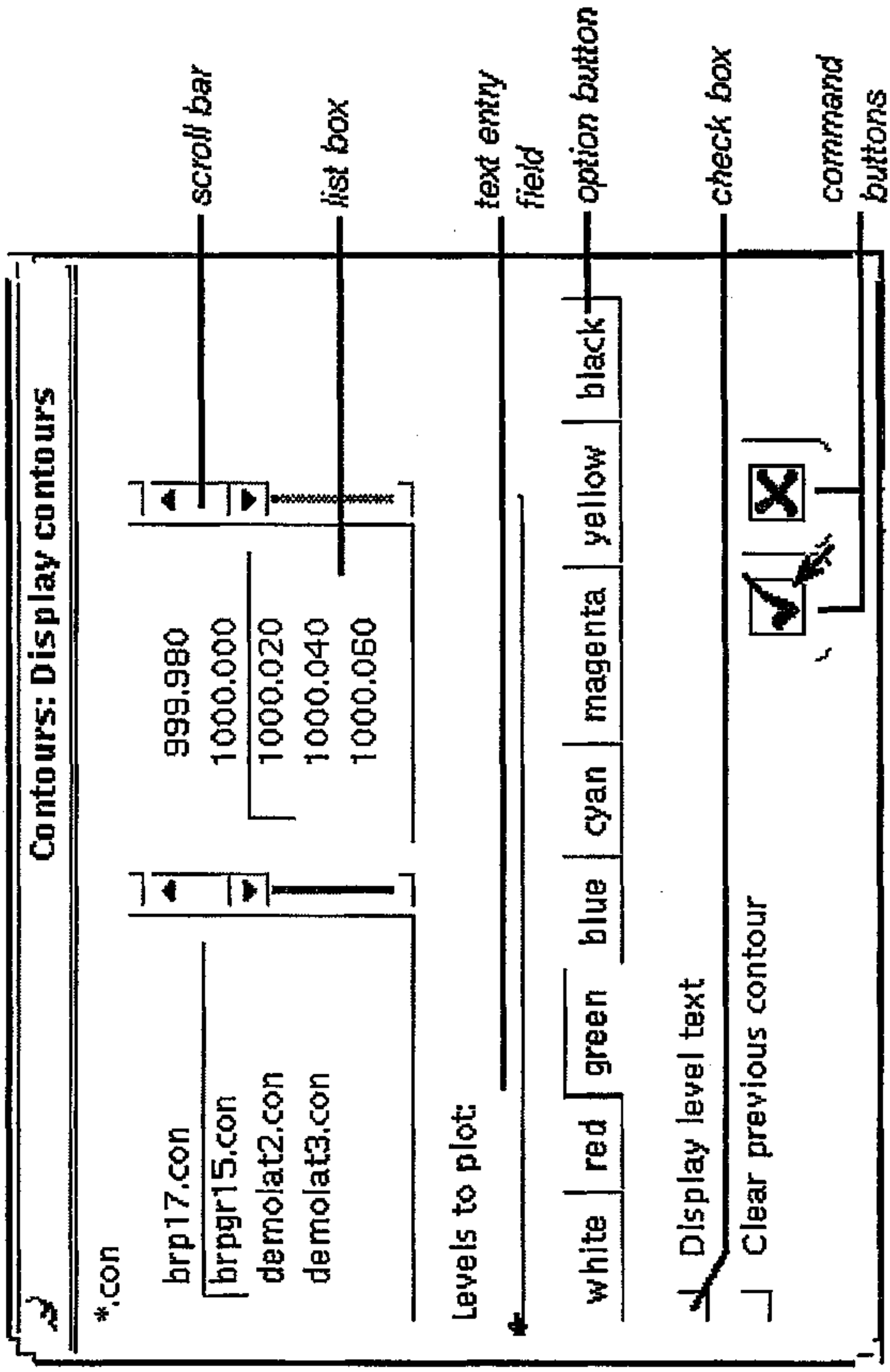

Figure 3. A dialog box.

2.6.3 List boxes

Some dialogs have a list box which contains file names, point numbers, etc., which may be selected. To select an item in a list box, point to the item and press the Select button. If the list of items is longer than the available display space, click on the scroll bar to the right of the list to bring additional items into view for selection.

2.6.4 Command buttons

Command buttons are the final options you must choose from to complete the dialog. These buttons are displayed at the bottom of the dialog and are normally one or more of the following: ☑, ☒ and ➨. Other buttons may also be found here. Choosing a command button closes the dialog and processes your choices according to the function of the command button.

2.7 The About command

The About command is on the main menu. It displays a dialog with the GGIS version number, version date and copyright information. The authors provide technical support. If you need help, please have your GGIS version number and version date at hand when you call for technical support. This helps us expedite your call.

2.8 Closing GGIS

Selecting the Quit command from the menu is the only safe way of closing down GGIS. The closing down process involves, amongst others, the deletion of temporary files. If GGIS is not closed down using the Quit command, these temporary files may remain on disk, and in this way consume valuable disk space.

☞ **Note**

If you have exited GGIS by some other route than the Quit command, GGIS will leave files in the tmp directory in your workspace. You are allowed to delete all the files in this directory and remove the directory itself. Before you do, leave GGIS and make sure you are the only user of this workspace.

3. Preparing the data

GGIS makes use of HydroCom data in its native format - no conversion process is necessary. If the data are to be accessed for the first time by GGIS, it will automatically be prepared for use by GGIS. In the _hbase directory, two files, *control.dbf* and *control.ntx*, will be created. These two files are the controlling data base and index files; they contain all the information needed to access point data and to link it to the other data bases in the data subdirectories. Two coverages will be created; one with a grid large enough to display all HydroBase data in geographical co-ordinates and another for the points contained in the controlling data base. This makes all available HydroCom data for the selected data base accessible for further processing by GGIS. A directory named *tmp* will be created to store all temporary files.

The following procedure describes the minimum steps for drawing a coverage from HydroCom data:

1. Select the option *Draw | Coverage* from the menu. The dialog in Figure 4 will appear.

2. Under `Coverage`, select `hb_grid`.

3. Under `Feature`, select `Arcs`.

4. Select `Set map extent`.

5. Under `Color`, select the desired colour for the grid (we suggest white). You can select the colour in three different ways:
   - Using a predefined colour.
   - Using the three sliders to "mix" a custom colour.
   - Typing the CMY colour code.

6. Choose the ☑ button.

The grid will be drawn on the screen in the selected colour.

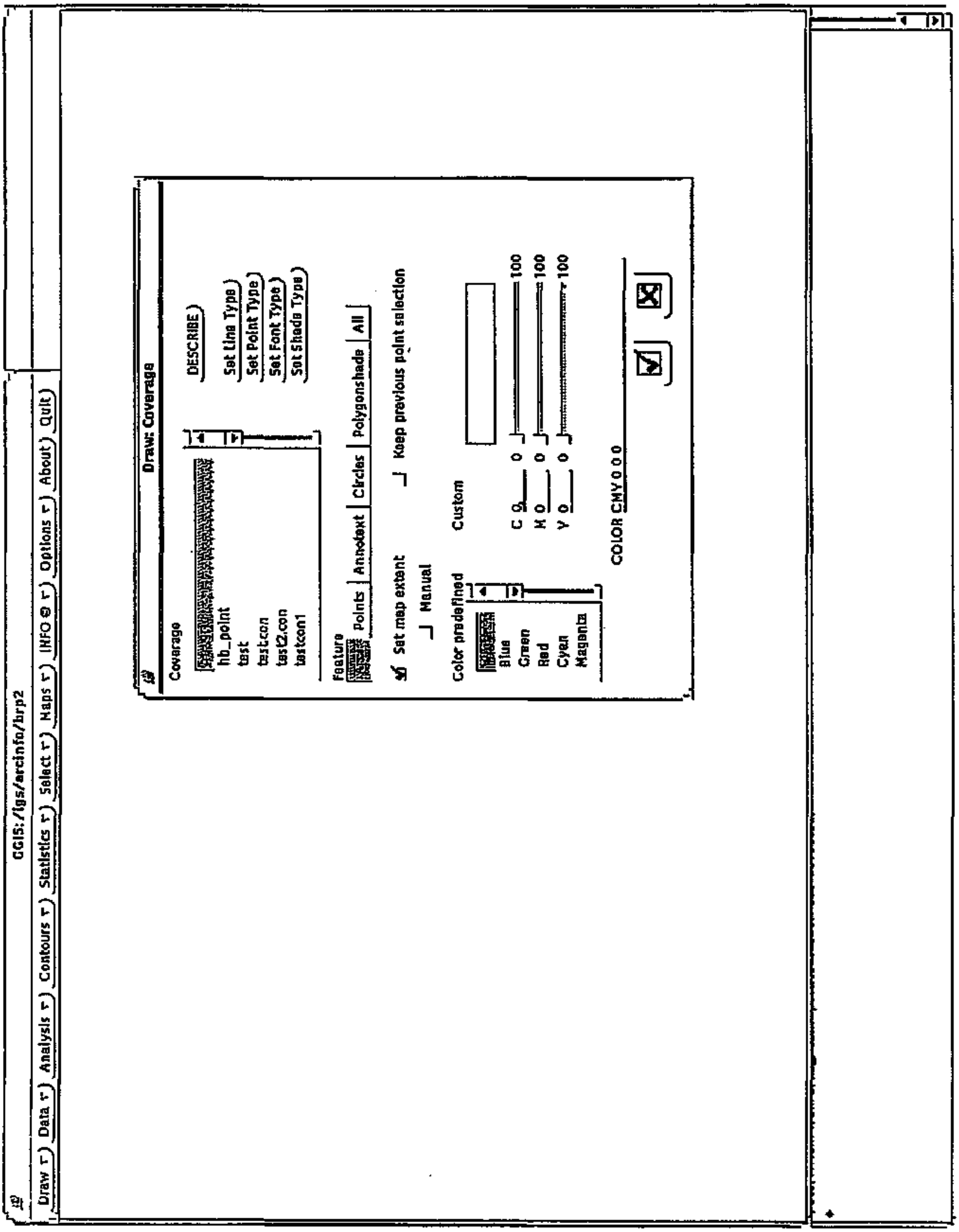

Figure 4. Dialog - Draw coverage.

To display the points available in the HydroCom data, do the following:

1. Under `Coverage`, select `hb_point`.
2. Under `Feature`, select `Points`.
3. Deselect `Set map extent`.
4. Under `Color`, select the desired colour for the points (we suggest yellow).
5. Choose the ☑ button.

The points representing all site id's will be drawn on the screen in the selected colour. When this has been completed, choose the ☒ button to close the dialog.

By default, GGIS will always use a projection file with the name *gg.proj* to select projection parameters. This file is located in the *ggis* directory and will be copied to workspace, unless it exists when GGIS is started.
(See also 5.1.1 Projection - p. 52.)

A sample of what the screen may look like with the points displayed is shown in Figure 5.

Additional coverages, such as topographic information, boundaries, etc., from other sources may be added to the display at this stage. Select the particular coverage under `Coverage`, the required feature under `Feature`, the desired colour under `Color` and choose the ☑ button.

The *Draw | Coverage* dialog has a number of options with which you may set various default values for Arc and with which you can display additional information from the available coverage(s). The options are the buttons `Set Line Type`, `Set Point Type` and `Set Shade Type`, which execute standard Arc AML's, and the button `DESCRIBE` which executes the Arc command of the same name.

The options `Annotext`, `Circles` and `Polygonshade` under `Feature`, will display these features for the selected coverage if they are in the selected coverage.

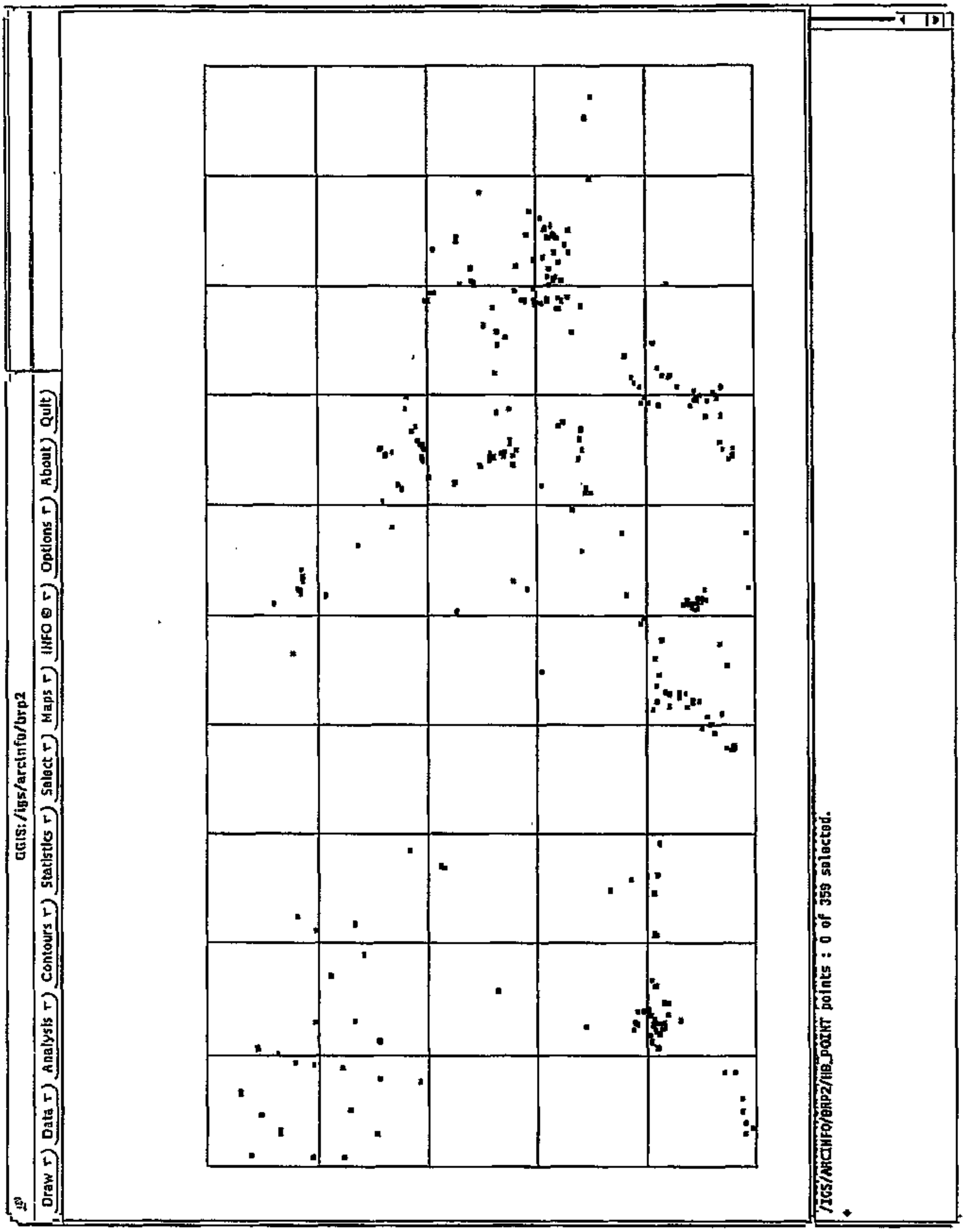

Figure 5. Sample of a coverage displayed.

The option, `Set map extent`, will set the map extent to that of the selected coverage. By default, it will be on if no extent has been set, otherwise it will be off, by default. You may override the default setting, with the result as expected. If you select the sub-option `Manual`, a dialog will appear containing the co-ordinates `X-min`, `X-max`, `Y-min` and `Y-max`. You may edit these values to those required to show the desired extent of the map.

The option, `Keep previous point selection`, will display only those points selected previously in the current Arc session, with any of the available point selection methods, when the coverage is drawn again.

4. Analysing the data

The HydroCom data may be analysed in a number of ways to provide you with an answer to virtually any question that can be generated about the available data. The questions are put to the GGIS system through dialogs and the answers are presented in the form of a modified display of the original data.

4.1 Selecting points for analysis

Before you can analyse the data, you have to select one or more points on which to operate. This selection can be done by various means; the most powerful and flexible options being those under the *Select* option on the menu. Other options may also be used to select points directly or indirectly as a result of the action performed by the option. Other options which allow you to select points are *Data | Available data, Data | Show available* and *Data | Edit data.*

Irrespective of the method by which a selection is made, the selected point(s) will be displayed in a colour different from the unselected points.

The options shown in Table 1, are available under the *Select* option on the menu by which you may select points:

Option	Action/Result
Select Point	Indicate a single point with the mouse which to select
Select Box	Indicate two opposite corners of a rectangular area within which all points will be selected
Select Circle	Indicate the centre and radius of a circular area within which all points will be selected
Select Polygon	Draw polygon, within which all points will be selected, by pressing the Select button and end drawing by pressing the Menu button
Select All	All points are selected
Select Special	Opens a dialog with which a complex selection can be done (see Using Select Special below for more detail)
List Selected	Opens a dialog listing all selected point, from which the selection can be changed (see Using List Selected below)
Unselect Point	Indicate a single point with the mouse which to unselect
Unselect Box	Indicate two opposite corners of a rectangular area within which all points will be unselected
Unselect Circle	Indicate the centre and radius of a circular area within which all points will be unselected
Unselect Polygon	Draw polygon, within which all points will be unselected, by pressing the Select button and end drawing by pressing the Menu button
Unselect All	All points are unselected
Invert Selection	All selected points become selected and vice versa.

Table 1: Options for select.

4.2 Using Select Special

The most powerful and flexible way to select one or more points is to use the option *Select | Select Special* from the menu. Selecting this option presents you with a dialog as shown in Figure 6.

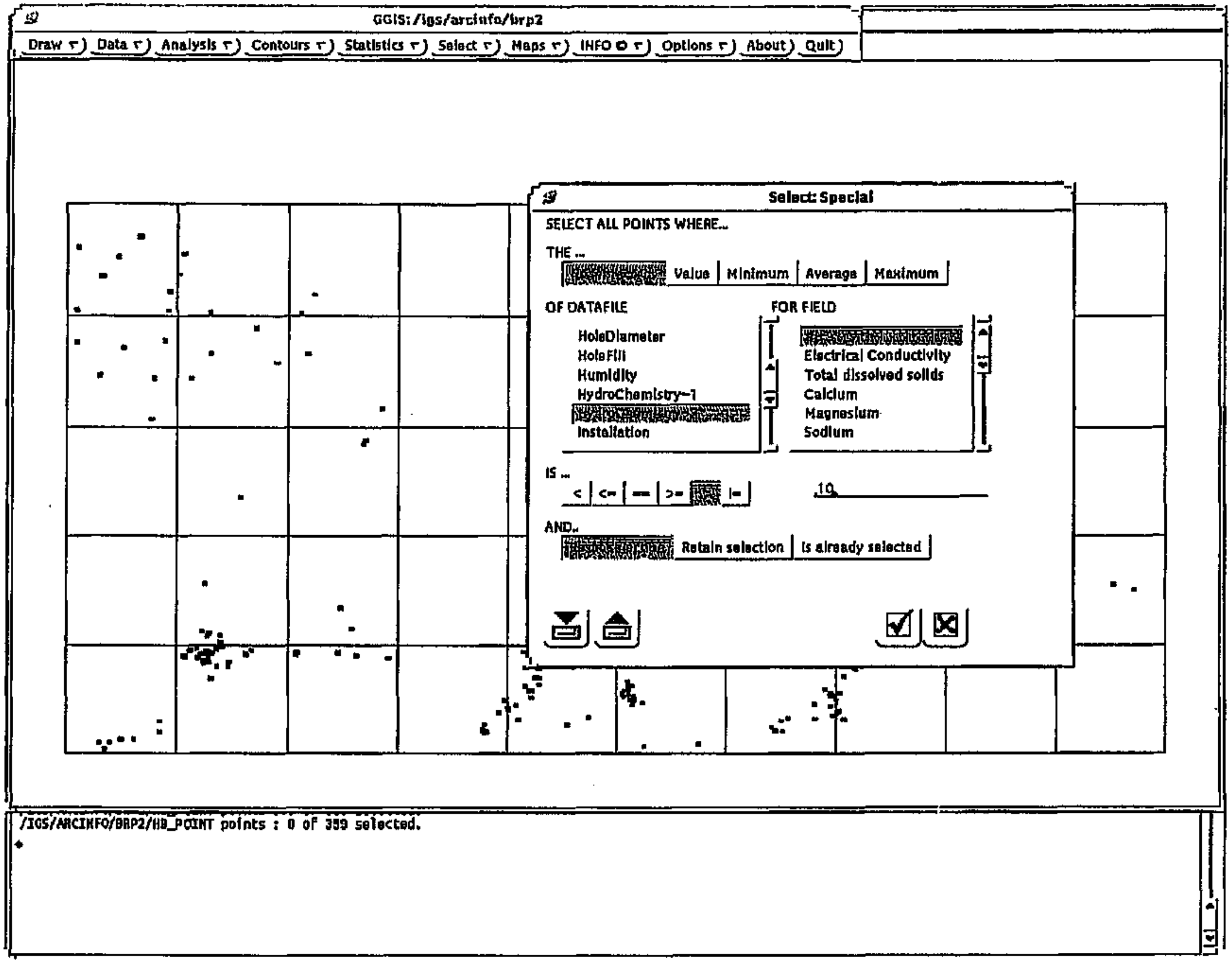

Figure 6. Dialog - Select special.

The dialog displays the names of all the available HydroCom tables, the fields of the currently selected table, various options that can be applied to create a selection, as well as various command buttons to manage the selection process.

The following is an example of selecting one or more points:

1. Under `THE...`, select the appropriate option.

2. Under `OF DATAFILE`, select the HydroCom table on which the selection must be based. After you have selected a name, the fields for the selected table will be displayed under `FOR FIELD`.

3. Under `FOR FIELD`, select the field on which you want to apply the option selected under `THE...`. If you have selected `No. of records` under `THE...`, it is still necessary to select a field.

4. Under `IS...`, select the operator which you want to apply to the preceding selection and enter an appropriate value. Text or numbers may be entered.

☞ **Note**

You must press Enter after typing the text or numbers, or else the value will not be accepted.

---

5. Under `AND...`, select the appropriate option according to the following table.

The option...	*will...*
Reset selection	unselect all selected points before selecting points meeting the current specification.
Retain selection	add points meeting the current specification to those points already selected by a previous selection.
Is already selected	select points meeting the current specification from those points already selected by a previous selection. Points selected by a previous selection but which do not meet the current selection specification, will be unselected.

Table 2: Options for AND ...

6. Choose the ☑ button.

The data will now be scanned for points meeting the specification and the points found will be selected. After all valid points have been selected, the dialog will remain on screen to enable you to define another selection.

You may save the current selection of points which will enable you to load the selection again, if you want to operate on the same selection of points.

To save the current selection:

1. Choose the button.
2. You will be prompted for a file name. Enter the file name, without extension, and press Enter.
3. Choose the ☑ button to save the selection and close the dialog.

To reload a selection, later, when you want to operate on a previous selection of points, do the following:

1. Choose the button.
2. You will be prompted for a file name. Enter the file name, without extension, and press Enter.
3. Choose the ☑ button to load the selection and close the dialog.

To close the *Select | Select Special* dialog, choose the ☒ button. The selected points, if any, will remain selected until another operation deselects them.

4.3 Using List Selected

Once you have selected one or more points by any of the methods available for selecting points, you may wish to review which points were selected and optionally change the selection. The option *Select | List Selected* provides you with a list of the HydroCom Site Id Numbers for all selected points, from which you may change the selection to include only those points you select from the list presented. When you select the option *Select | List Selected*, a dialog as in Figure 7 will appear.

Under `SITE IDs`, a list of Site Id Numbers of the points selected by a previous selection process will appear.

To change the selection:

1. Under `SITE IDs`, select one or more Site Id Numbers. As you select a point, the Site Id Number is inserted into the `Selected sites` text entry field, separated by a space from the previous Site Id Number. You may also add other Site Id Numbers in the `Selected sites` text entry field by typing them in from the keyboard.

2. When you have selected all the points you want to, choose the ☑ button to process your choices and close the dialog.

3. To abandon your choices, choose the ☒ button.

Irrespective of the method used, when you have selected one or more points, you may analyse the data for the selected points in a number of ways. Ways of analysing the data are presented in the next section.

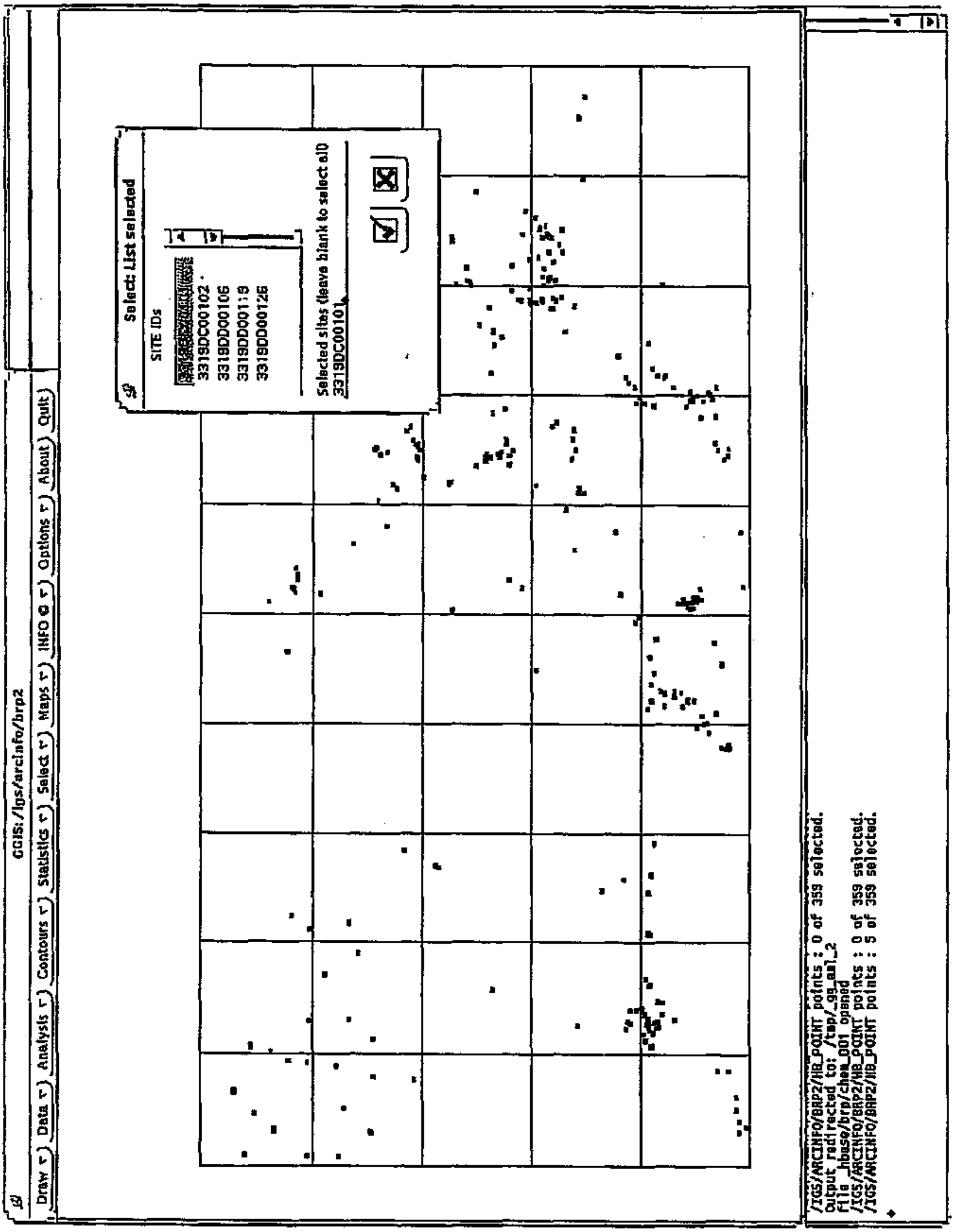

Figure 7. Dialog - List selected.

4.4 Maps

Maps form the basis of the HydroCom data display. Various options can be applied to the available data which will affect the display.

4.4.1 Data evaluation - Point information

GGIS can provide detailed information regarding any point displayed on the coverage. This information includes the Site Id Number of the selected point, the names of all available HydroBase tables and the number of rows in each table for the selected point.

To display this information, select the option *Data | Available data* from the menu. The selected point will be displayed in a different colour and the dialog will appear (see Figure 8).

Choosing the ◀ and ▶ button will display the data for the previous and next point respectively. The previous and next point are determined by the indexed order in which the Site Id Number of the points appears in the HydroCom Basic Information table. Choosing one of the =>> buttons will display all data available of the selected type for the selected point as shown above.

Determining what data are available for the points, can be done easily with the *Data | Show available data* option. When you select this option from the menu, the dialog shown in Figure 9 will appear.

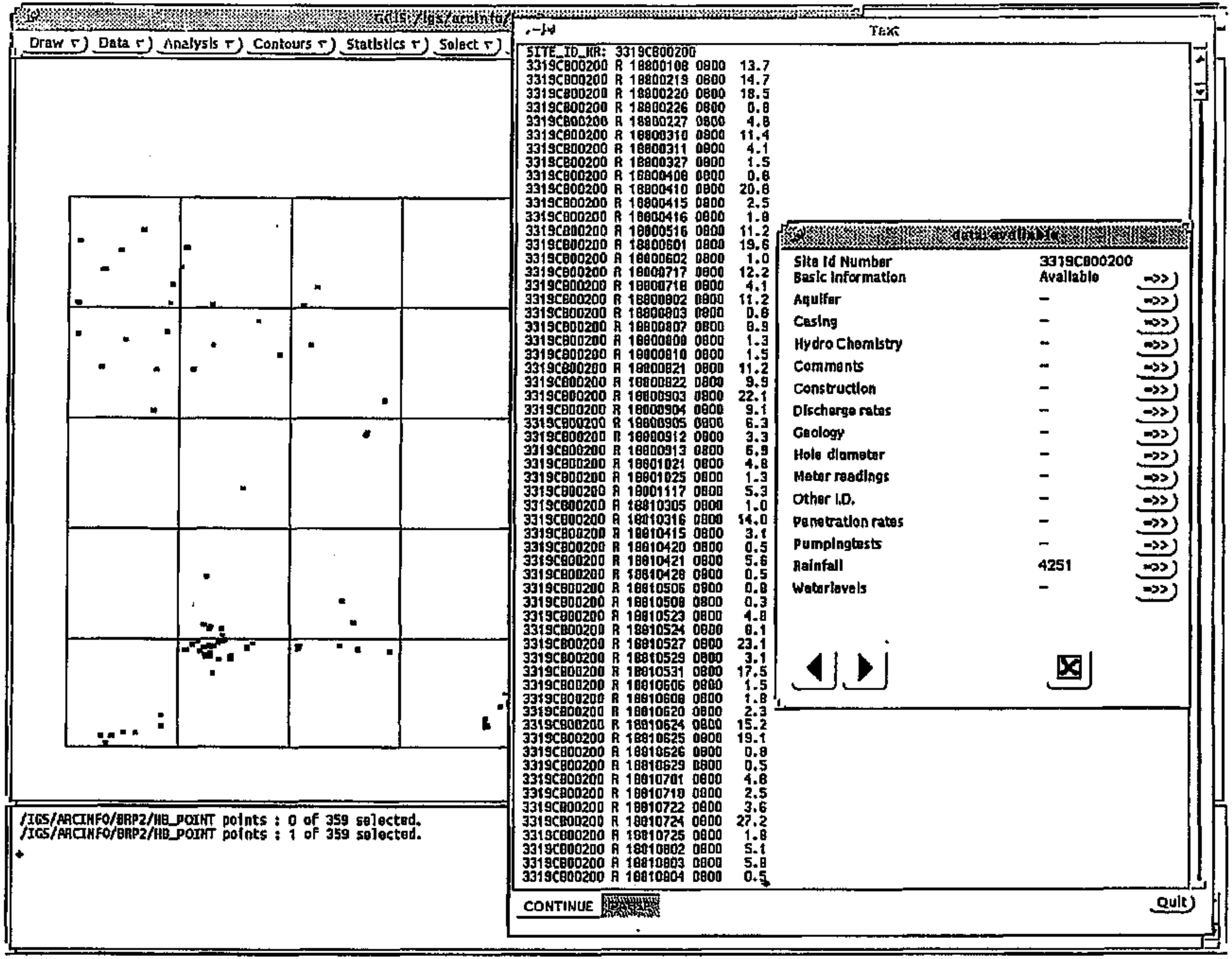

Figure 8. Dialog - Available data.

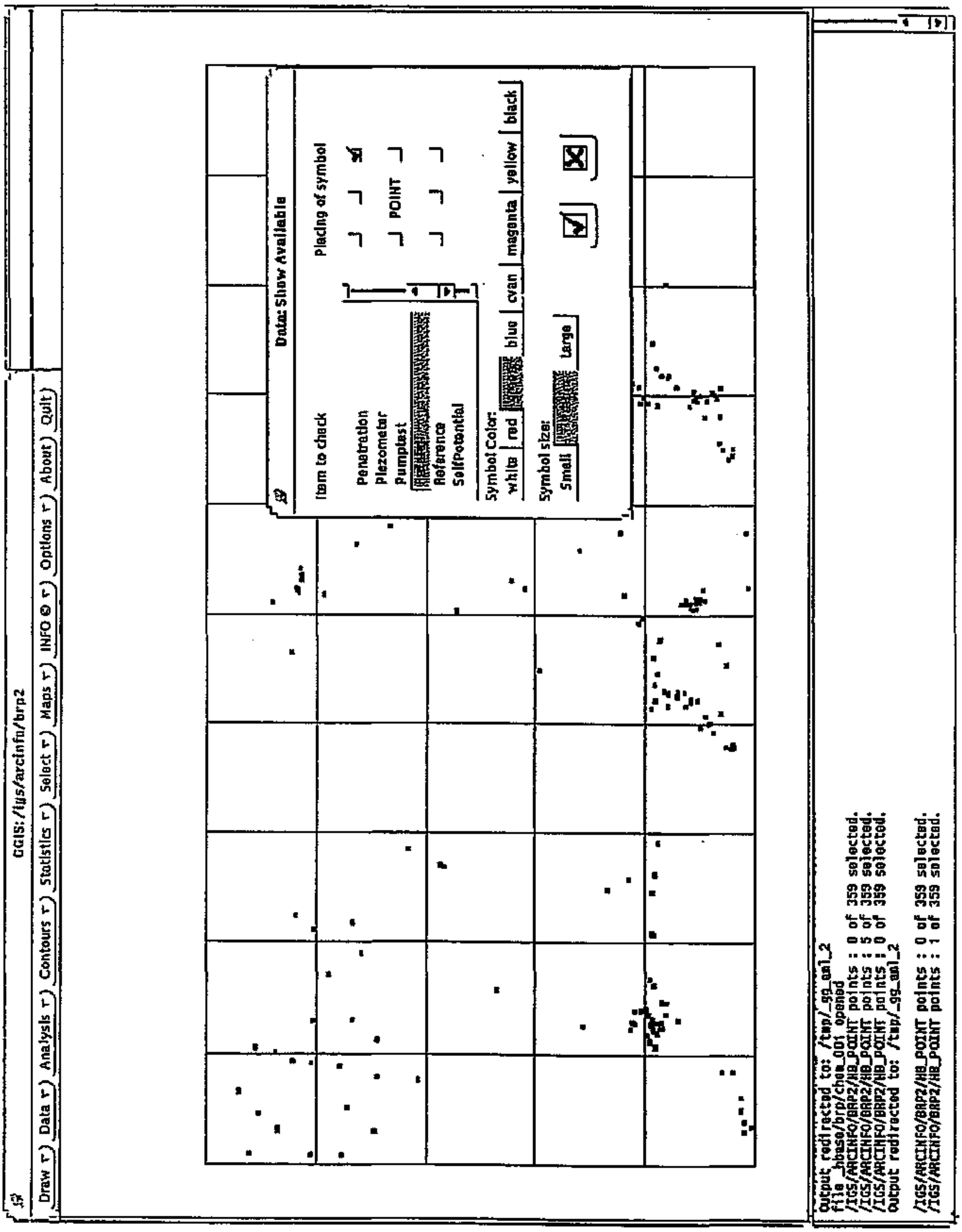

Figure 9. Dialog - Show data.

To determine which points have data of a specified type, do the following:

1. Under `Item to check`, select the data type.

2. Under `Placing of symbol`, select the position of the marker relative to the position of the point.

3. Under `Symbol color`, select the colour for the marker.

3. Under `Symbol size`, select the marker size (we suggest `Small`, but bigger markers may be used if the points are fewer and further apart).

4. Choose the ☑ button.

The selected type of data will now be scanned for available data. For each point for which there are data of the selected type, a predefined marker will be placed near the point in the selected position relative to the point, and the point will become selected. The dialog will remain on screen to enable you to mark points according to another condition. When you have completed all your selections, choose the ☒ button to close the dialog.

GGIS also provides you with a facility to edit the HydroCom data directly. This enables you to make adjustments to the data where obvious problems are identified by graphical or other analyses. To edit the data of the currently selected point, select the option *Data | Edit data* from the menu. You will then be presented with a list of all available data types from which you may select one. The data of the selected type for the selected point will then be displayed in a dialog similar to the one in Figure 10.

The example displays the selected data for the selected point in a dialog that permits you to edit the data. The data may be edited by moving the insertion point to the desired field and typing the new value(s). The buttons at the bottom of the dialog control the movement through the data and have the functions shown in Table 3:

Choose this...	to do this...
	display data of the first record for the selected point
	display data of the 5th previous record for the selected point
	display data of the previous record
	display data of the next record
	display data of the 5th next record for the selected point
	display data of the last record for the selected point
	save changes made to the data currently displayed
	exit the data editor

Table 3: Options for Data | Edit data.

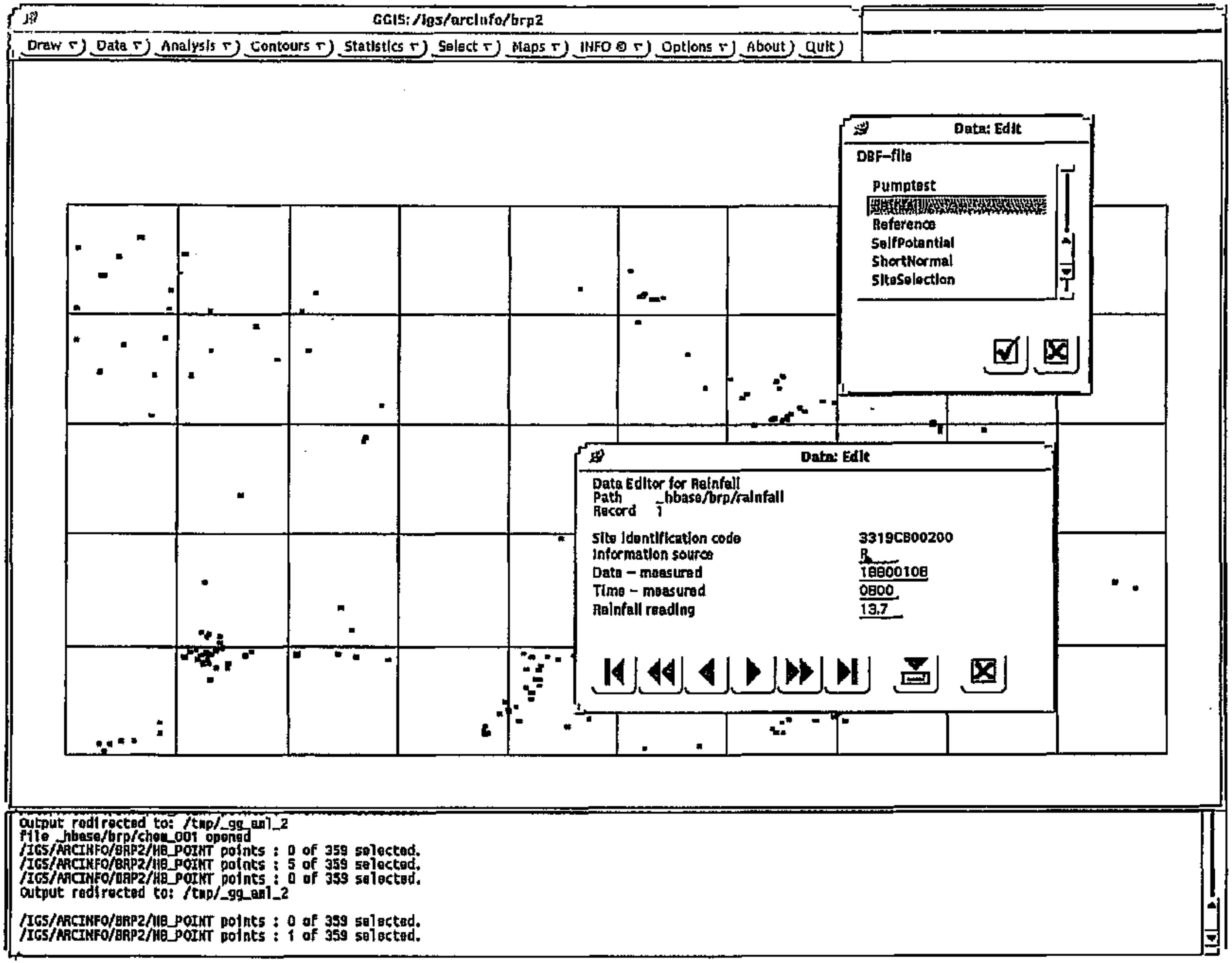

Figure 10. Dialog - Data edit.

4.4.2 Contours - Regional information

GGIS provides facilities to generate and display contours for the following parameters:

- All numerical parameters from HydroBase, such as Water levels, Hydrochemistry, Geology, Aquifer, Geophysics, Meteorology, etc.
- Groundwater modelling.
- Water pollution modelling.

The facilities to generate and display contours are available under the *Contours* menu option.

When you select the option *Contours* | *From HB data* from the menu, you will be presented with a dialog (see Figure 11).

To generate contours for any of the HydroBase numerical parameters:

1. Under `Data file`, select the data file from which you want to generate contours. The `Parameter` list will be updated to display all numerical parameters available from the selected data file.

2. Under `Parameter`, select a parameter for which you want to generate contours.

3. Under `Statistical operation`, select the appropriate value or calculated value.

4. Under `Relate to`, select an option to which you want to relate the parameter for the statistical operation, e.g. to calculate the water level above mean sea level, select the parameter water levels and the option `Elevation`. The option `Thickness` can be used with lithology, while the option `Selected sites` limits the calculations to points selected previously by a point selection operation.

5. Under `Constant expression`, enter the name of a parameter and a value to which it must be equal. This will limit the data processed for the selected statistical operation to that which is valid according to the expression.

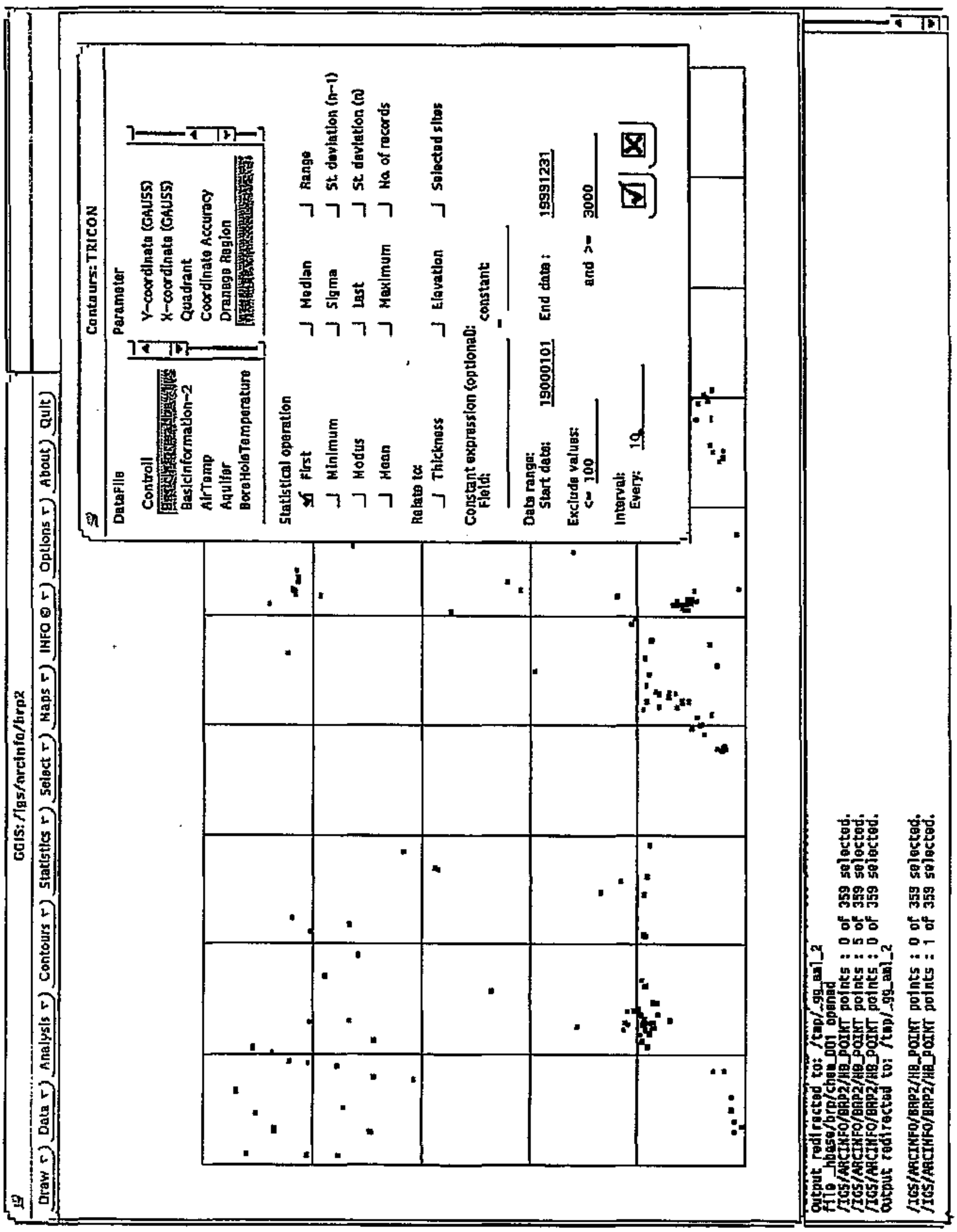

Figure 11. Dialog - Tricon contours.

6. Under `Date range`, enter new values for `Start date` and/or `End date`, if so desired and if the selected data parameter is a time-dependent data type. This will limit the data processed for the selected statistical operation to that which is within the date range.

7. Under `Exclude values`, enter new values for <= and /or >=, if so desired. Results from the statistical operation which fall outside the values specified, will be discarded.

8. Under `Interval: Every`, enter the desired contour interval.

9. Choose the ☑ button to process the selections, after which the TRICON dialog will be displayed (see Figure 12).

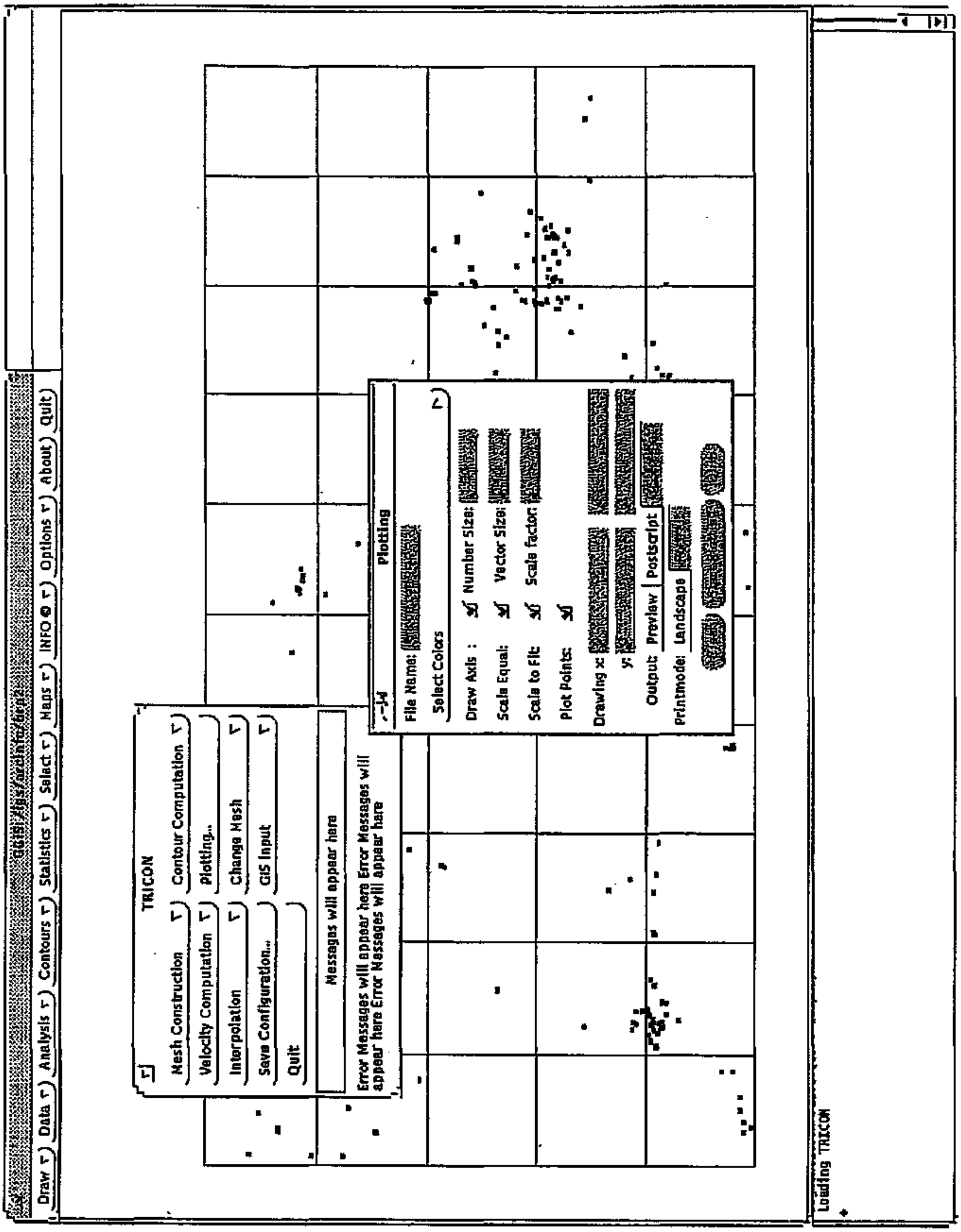

Figure 12. The TRICON dialog.

To process the data extracted by the previous operation, the following steps are required:

1. Select `GIS Input`. From the resulting dialog, select `Create TRICON files`. This will convert the data extracted by the previous operation into TRICON format. TRICON is able to generate two types of contours:
   - TIN Contours - These contours are exactly as they are calculated. No interpolation is done.
   - GRID Contours - These contours are interpolated to a regularly spaced grid.

2. Select `Mesh construction`. From the resulting dialog, select `Start mesh construction`. TRICON will create a triangular irregular network between the given set of scattered data points.

3. Select `Contour computation`. From the resulting dialog, select `Start contour computation`. Contour lines will be computed by means of a linear interpolation along the diagonals of the triangles in the network.

4. Select `Plotting`.... From the resulting dialog, select `GIS format` under `Output`. Then select `Start plotting`. This will produce a graphic representation of the triangulation, the contour map and levels of data points. Then select `Quit` to close the dialog.

5. Select `Quit` to exit TRICON.

6. You will now be prompted for a file name for the coverage to be generated. Enter the name, including a `.con` extension, press Enter and select the ☑ button. A message indicating the status of the process will be displayed while the coverage is generated.

To display contours generated as described above, select the option *Contours | Display contours ...* from the menu. You will then be presented with the following dialog:

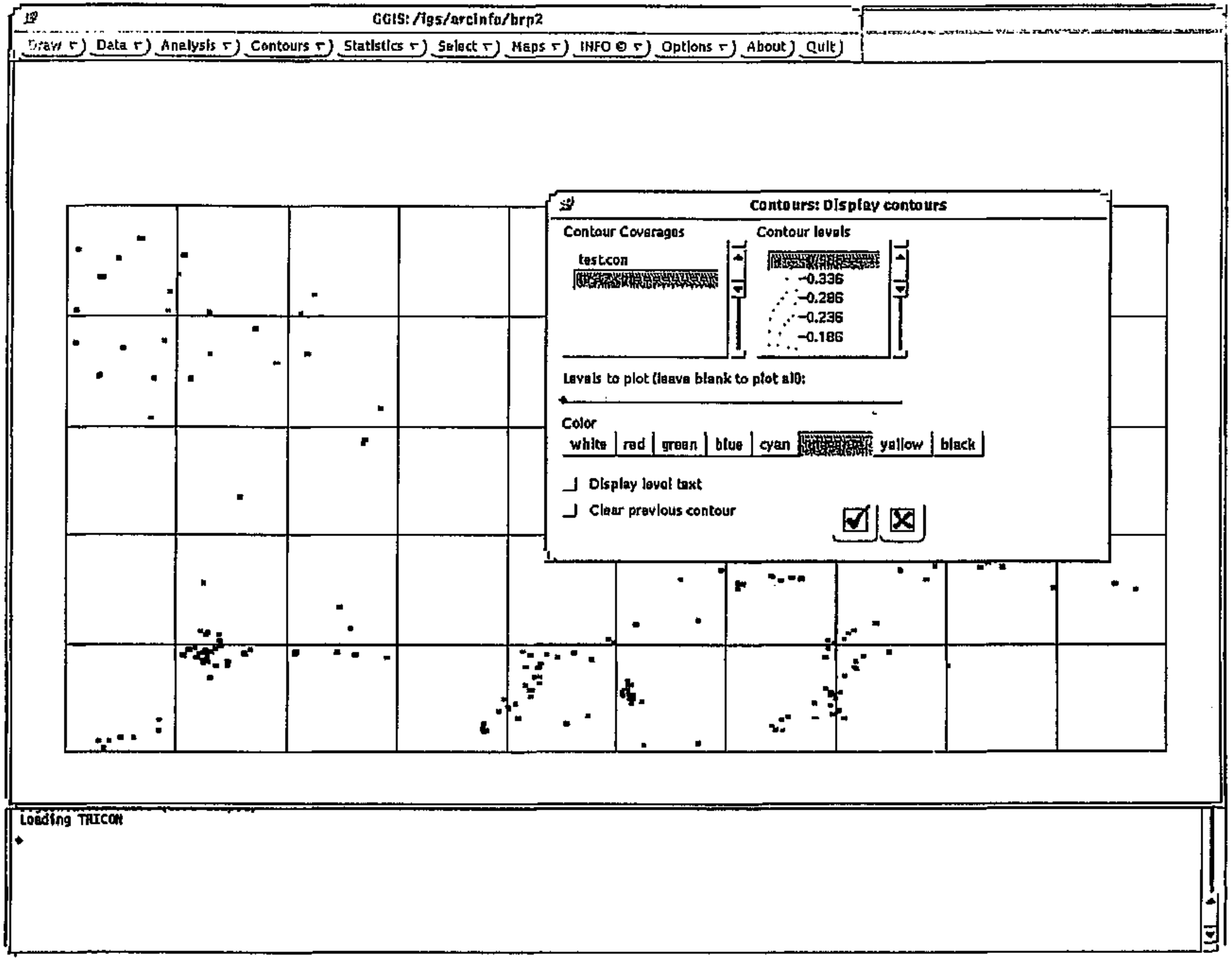

Figure 13. Dialog - Display contours.

To display the contours generated previously:

1. Under `Contour coverage`, select the coverage for which you want to display contours. The list of available `Contour levels` will be updated to reflect the levels available in the coverage.

2. Under `Levels to plot`, enter the values for the levels you wish to plot and separate them with a space, or select them from the list under `Contour levels`. If you wish to plot all levels, which is the default, leave this field blank.

3. Under `Color`, select the colour in which all selected levels must be plotted.

4. Selecting `Display level text`, will print the contour level values on the map for each contour level plotted.

5. Selecting `Clear previous contour`, will remove the previous contours before plotting the contours according to the current specifications.

6. Choose the ☑ button to display the contours.

7. Choose the ☒ button to close the dialog.

To generate a network for groundwater modelling, select the option *Contours | Create network* from the menu. The create network dialog will appear (see Figure 14).

To create a network:

1. Under `Network file`, enter a name for the network file and press Enter. Entering the name of an existing file, loads that network set-up.

2. Under `Point properties`, enter the values for the `Transmissivity`, `Storativity`, `Discharge`, `Initial head` and select whether it is a `Constant head`. These properties will apply to all subsequent points to be added or changed.

3. Under `Mass transport concentrations`, enter values for `Initial` and `Pumped water`. These values will apply to all subsequent points to be added or changed, as selected under `Mode`.

4. Under By, select Point or Polygon. If you select Point, you will be able to apply any option selected under Mode to any of the available points. If you select Polygon, and you select the option Add under Mode, you may add points to the network. In this case, enter values for the fields Polygon nx and Polygon ny under By. A rectangular grid of points of the dimension specified will be scanned and all points falling within the specified polygon, will be added to the network. You may also apply the options Change and Delete under Mode to all points within the specified polygon.

   The options Move and Show under Mode are not available when Polygon is selected under By.

5. Under Mode, select the option according to the following table:

The option...	*will...*
Add	add a node or nodes in a polygon to the network with properties as defined.
Change	change the properties of the selected node(s) to that as defined.
Delete	delete the selected node(s) from the network.
Move	move the indicated node from its current position to the new position indicated.
Show	display the point properties of the indicated node.

Table 4: Options for Mode.

Whichever option you choose, if you are indicating By Point, you will be prompted to indicate a point. The cursor in the map display will change to a cross hair cursor, indicating that you are in point mode and can indicate the node to which you want to apply the operation as selected above. When you have finished, click the Menu button to terminate point mode.

You may then change any of the options and/or values in the dialog and continue to Add, Change, Delete or Move nodes.

If you are indicating By Polygon, you will be prompted to indicate the first and subsequent points of the polygon. To end the definition of the polygon and close it, press the Menu button.

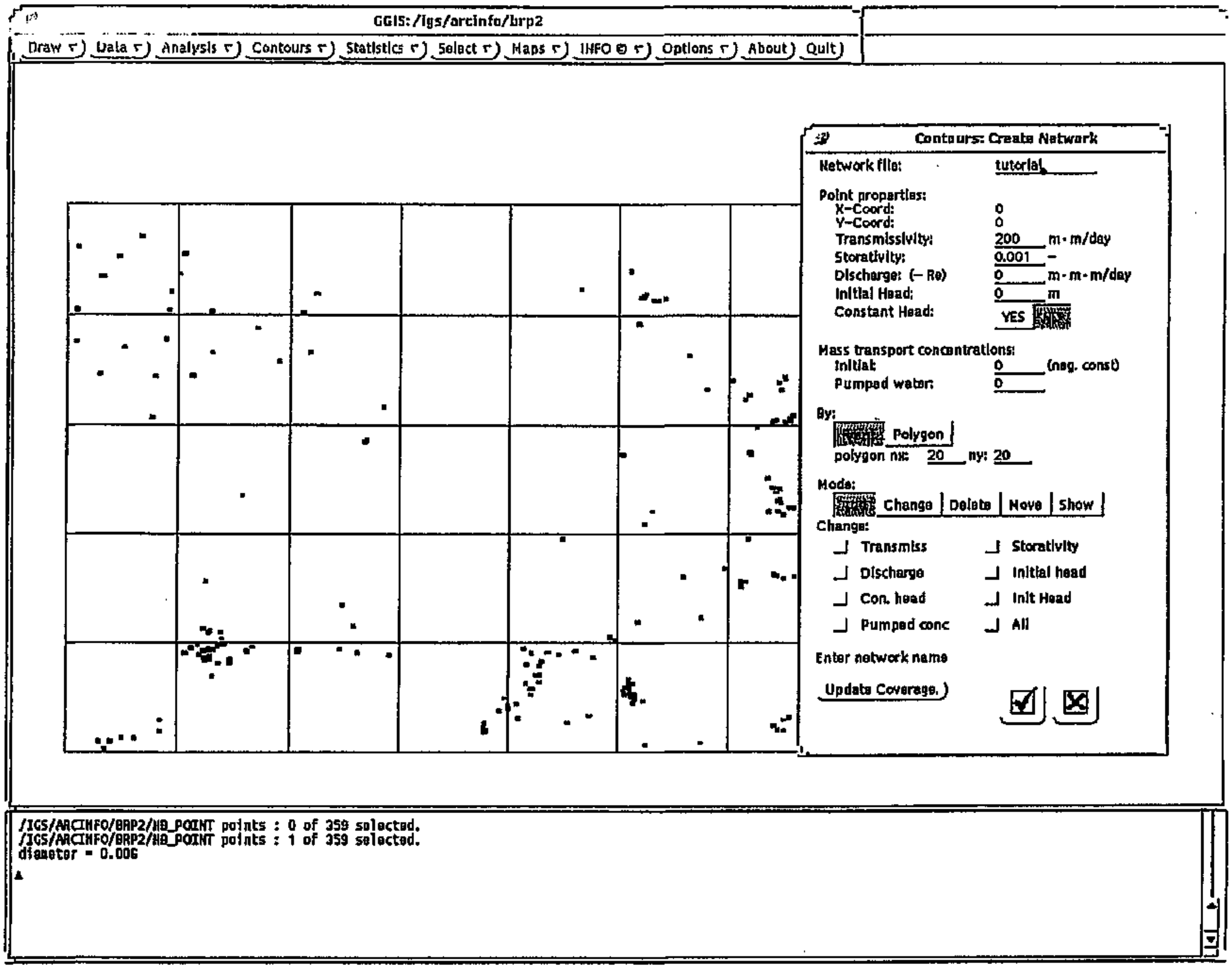

Figure 14. Dialog - Create network.

6. Under `Change`, select one or more properties which must be changed with the next `Change` operation as described above.

7. When the network is set up to your specifications, choose `Update coverage` to add the network point data to the coverage. Then select the ☑ button to close the dialog.

The network set-up information will now be processed.

When the Modelling dialog appears on the screen, do the following:

8. Under `Modelling parameters`, enter a value for `Number of timesteps`, `Initial timestep`, and `Step increment`.

9. Choose the ☑ button to close the dialog and do the modelling.

The input will now be processed after which a list of time steps will be displayed. After selecting a time step, TRICON will be activated. Follow the same procedure as described before to create the contours.

You will then be prompted for a file name for the coverage to be generated. Enter the name, press Enter and select the ☑ button. A message indicating the status of the process will be displayed while the coverage is generated.

To display contours generated as described above, select the option *Contours | Display contours ...* from the menu. Follow the same procedure as described before to display the contours.

The result may then appear as in Figure 15.

To do water pollution modelling, you must have a network set-up for this purpose. If you have not yet set up a network, you must do so with the option *Contours | Create network ...* and specify the `Mass transport concentrations`. Select the option *Contours | Mass transport ...* from the menu.

You will then be presented with a dialog box (see Figure 16).

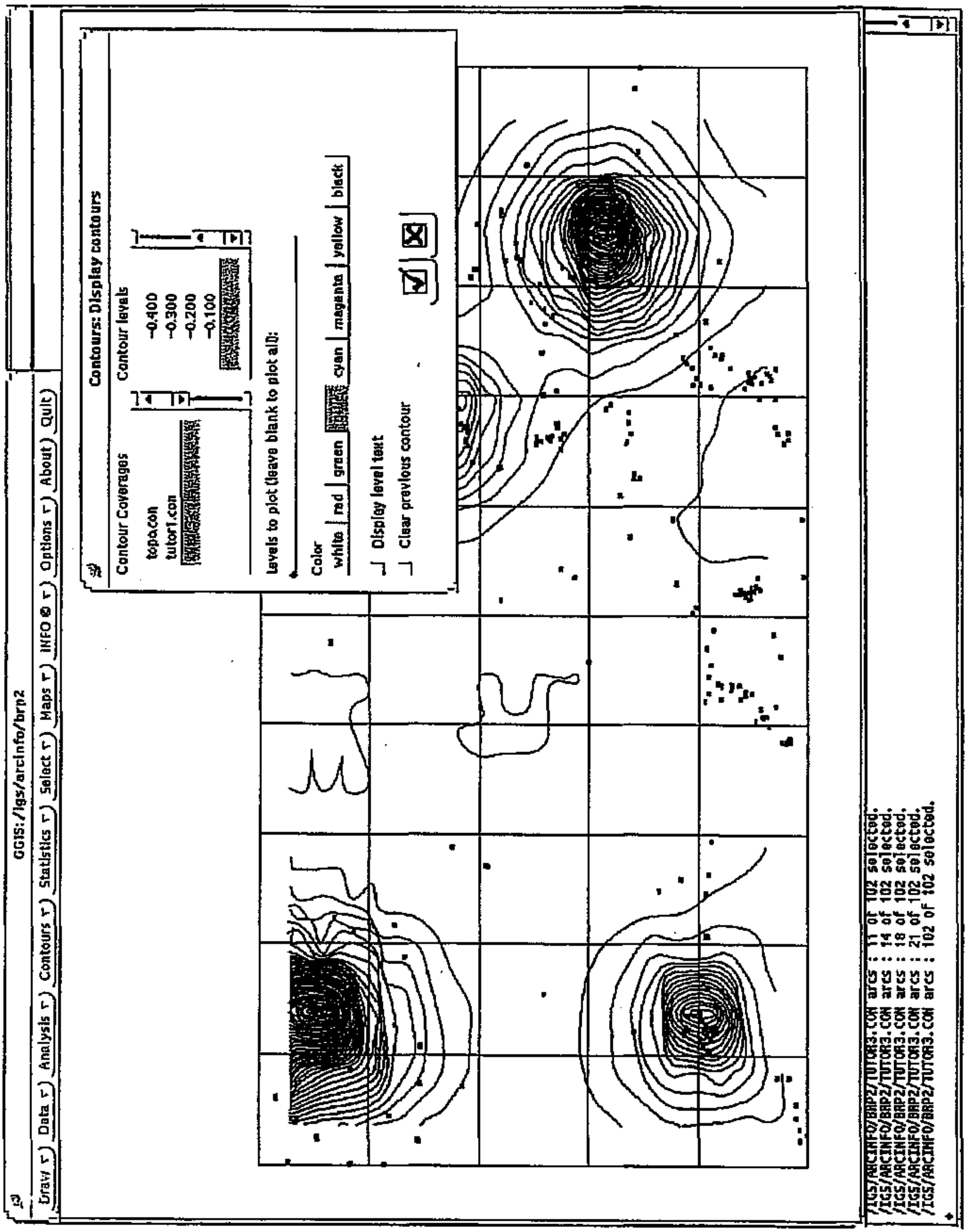

Figure 15. Contours displayed.

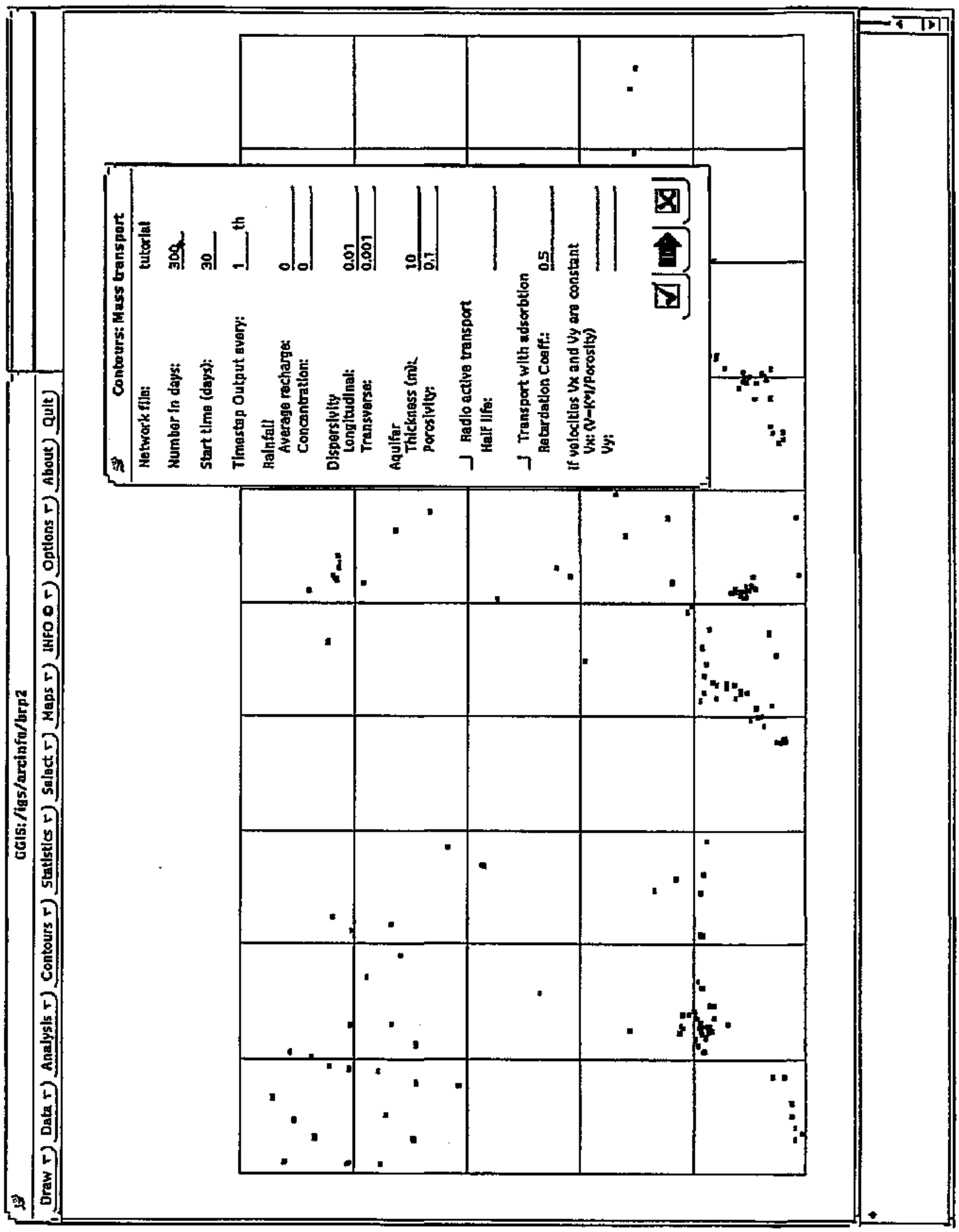

Figure 16. Dialog - Mass transport.

To do the modelling:

1. Enter values for all parameters.

2. Select the ☑ button to close the dialog.

The input will now be processed after which a list of time steps will be displayed. After selecting a time step, TRICON will be activated. Follow the same procedure as described before to create the contours.

You will then be prompted for a file name for the coverage to be generated. Enter the name, press Enter and select the OK button. A message indicating the status of the process will be displayed while the coverage is generated.

To display contours generated as described above, select the option *Contours | Display contours ...* from the menu. Follow the same procedure as described before to display the contours.

4.5 Graphs

4.5.1 Time - Bar, Scatter, Line

Time-dependent plots permit visual presentation of all parameters measured against time, and which have previously been entered into HydroCom. Time-dependent plots may, for instance, be stage height recorded in streams, meteorological parameters, hydrochemistry and discharge rate from boreholes.

Figure 17 is an example of a time-dependent graph of rainfall.

To produce this graph, or any of the other time-dependent graphs, select the option *Analysis* | *Time-dependent* from the menu. The dialog shown in Figure 17 will appear on the screen.

To produce graphs, do the following:

1. Under `DATAFILE`, select the data file from which you want to generate a graph. The field(s) containing data that may be used to produce a graph will be listed under `FIELD`.
2. Under `FIELD`, select the field containing the data to graph.
3. Under `Graph type`, select the graph type you want.
4. Under `Data type`, select the type of data to be displayed in the graph.
5. Under `Graph color`, select a colour for the graph frame and text.
6. Under `Data color`, select a colour in which the data must be displayed.
7. Under `Date range`, enter new values for `Start date` and/or `End date`, if so desired.
8. Choose the ☑ button.

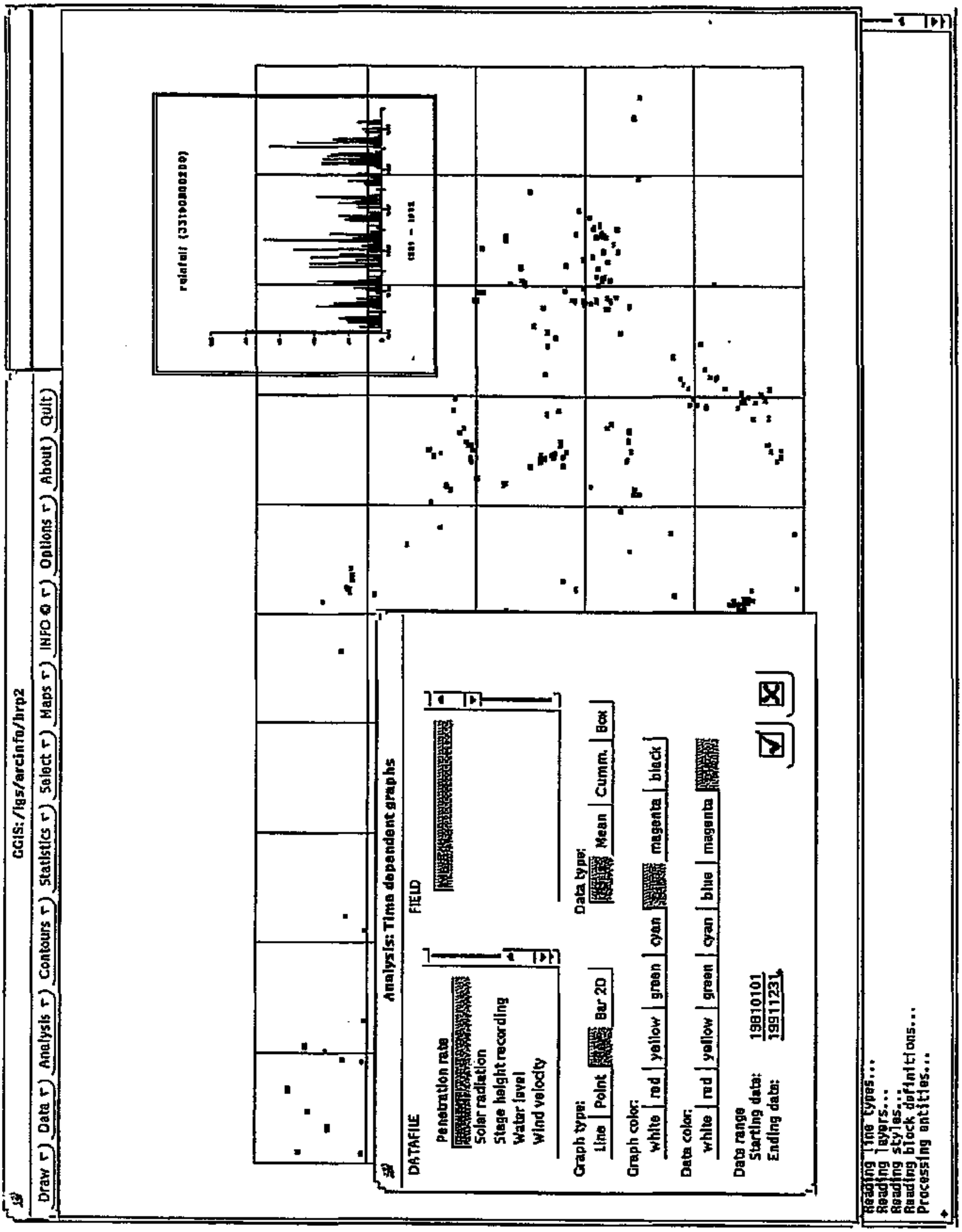

Figure 17. Dialog -Analysis:Time-dependent graphs

You will be prompted to `Define the box` area in which the graph must be displayed. The graph will then be displayed and will include the specified data for the selected point, limited to the data available in the specified date range.

The dialog will remain on the screen to allow you to produce any additional graphs. When you have finished, choose the ☒ button to close the dialog.

4.5.2 Chemistry - Piper, Durov, Expanded Durov, S.A.R.

Four specialised hydrochemical plot facilities have been included; these allow visual presentation of water chemistry and related data. The four diagrams provided are Piper, Durov, Expanded Durov and Sodium Adsorption Ratio diagrams.

The Piper, Durov and Expanded Durov diagrams are used to compare and distinguish between waters of different chemistries, for the purpose of classification and grouping, or to understand evolutionary processes which the water has undergone. The Sodium Adsorption Ratio diagram is used to classify water for irrigation use. Detailed explanation on the use and purpose of these diagrams is available in literature. Figure 18 is an example of a Piper diagram.

To produce this diagram or any of the other specialised hydrochemical diagrams, select the option *Analysis | Chemical* from the menu. The dialog shown in the lower right corner of the screen shown in Figure 18, will appear on the screen.

To produce any of these diagrams, do the following:

1. Under `Diagram`, choose the button of the desired diagram.
2. Under `Graph color`, select a colour for the graph frame and text.
3. Under `Data color`, select a colour in which the data must be displayed.
4. Under `Date range`, enter new values for `Start date` and/or `End date`, if so desired.
5. Choose the ☑ button.

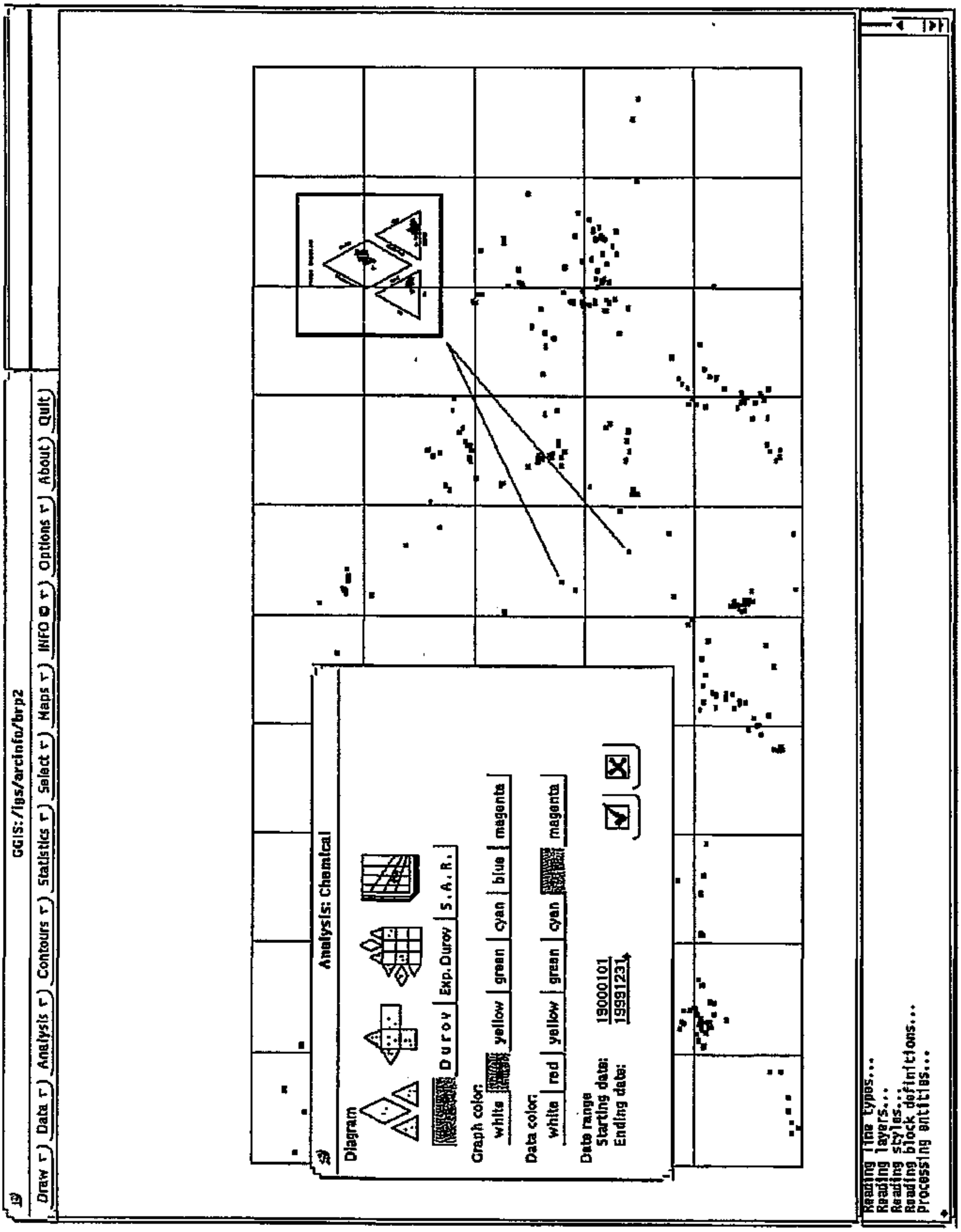

Figure 18. Dialog - Chemical analysis.

You will be prompted to `Define the box` area in which the diagram must be displayed. The diagram will then be displayed and will include data of all the selected points, limited to the data available in the specified date range.

The dialog will remain on screen to allow you to produce any additional diagrams. When you have finished, choose the ☒ button to close the dialog.

4.5.3 Aquifer - Theis, Cooper-Jacob, Hantush, Step, Recovery

Pumping test plots allow visual presentation of pumping test data and calculation of hydraulic values. The analysis provided are Theis, Cooper-Jacob, Theis recovery, Hantush and Step draw-down.

Pumping test analysis is a specialised task and evaluation by unskilled personnel may lead to incorrect interpretation. It is assumed that those who use this facility are familiar with the various options and constraints for the analysis of pumping test results. Figure 19 is an example of a Theis analysis.

To produce this analysis or any of the other pumping test analyses, select the option *Analysis | Pumping test* from the menu. The dialog shown in the lower right corner of the screen above, will appear on the screen.

To produce any of these analyses, do the following:

1. Under `Point`, select the point for which you wish to do the analysis. The available pumping tests for the selected point, if any, will then be displayed under `Pumping test`.
2. Under `Pumping test`, select the pumping test you want to analyse.
3. Under `Analysis`, choose the button of the desired analysis.
4. Under `Graph color`, select a colour for the graph frame and text.
5. Under `Data color`, select a colour in which the data must be displayed.
6. Choose the ☑ button.

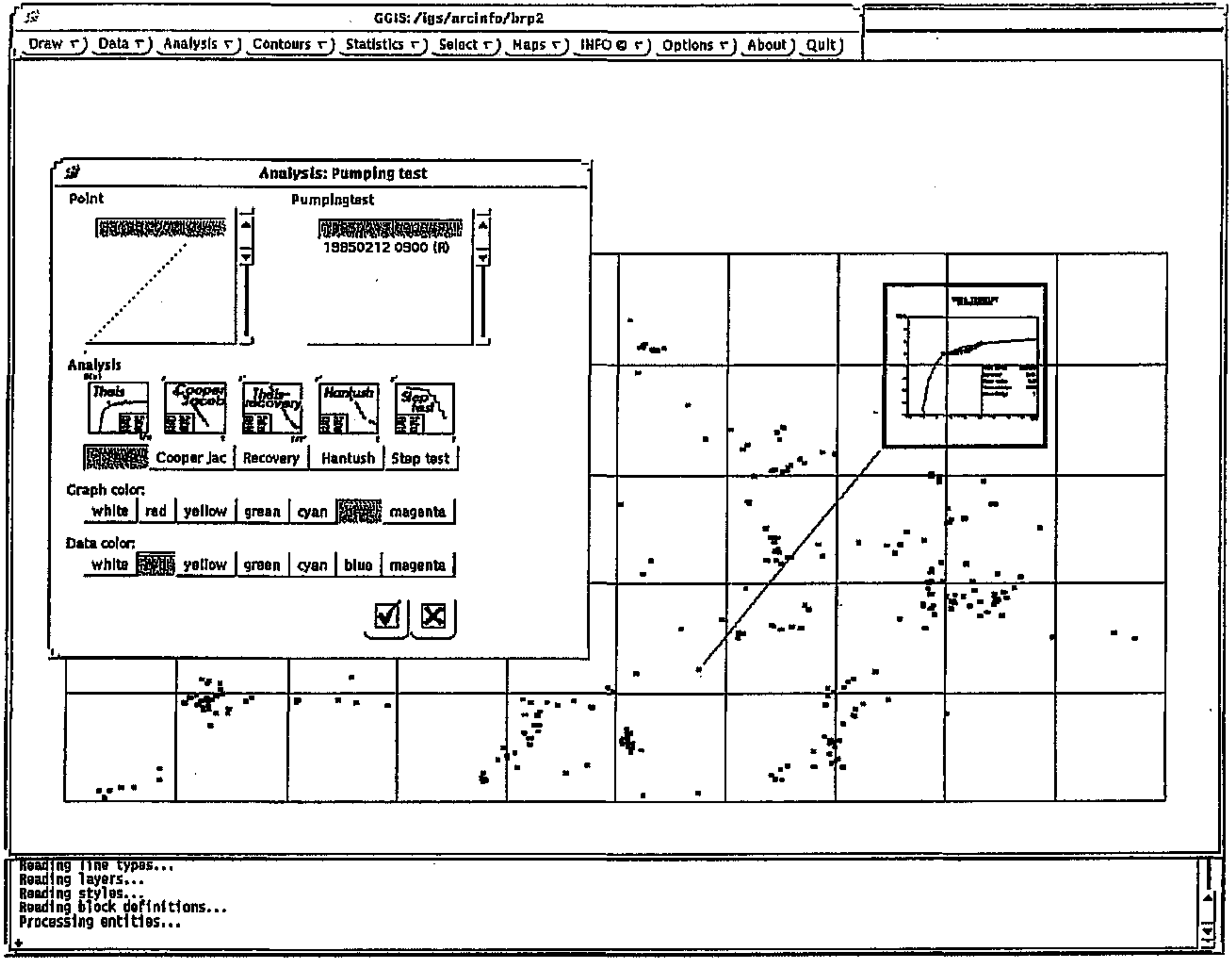

Figure 19. Dialog - Pumping test analysis.

You will be prompted to `Define the box` area in which the analysis must be displayed. The analysis will then be displayed and will only include data of the selected point.

The dialog will remain on screen to allow you to produce any additional diagrams. When you have finished, choose the ☒ button to close the dialog.

4.5.4 Statistics - Box plot, Trend analysis, Data specific

The box plot represents five statistical parameters determined for a selected data set. The parameters are minimum and maximum values, the standard deviation and the mean.

When you select the option *Statistics | Box plot* from the menu, a dialog will appear on the screen (see Figure 20).

To do the statistical operation and create the graph, do the following:

1. Under `Data file`, select the HydroCom table from which the data must be extracted. The table's fields will be listed under `Parameter`.
2. Under `Parameter`, select the field on which to do the statistical operation.
3. Under `Sites`, select a number of sites. As you select them from the list, they will appear in the `Site ids` field.
4. Under `Title 1` and `Title 2`, enter a title and subtitle for the graph.
5. Choose the `Next batch` button for as many times as you want to add batches of data to the graph, each time selecting different sites for each batch.
6. Choose the ☑ button. The statistical calculations will now be done. You will be prompted in the command window to `Define the box` area in which the graph must be displayed. After indicating the size and position of the box on the screen, the graph will be displayed in that area.

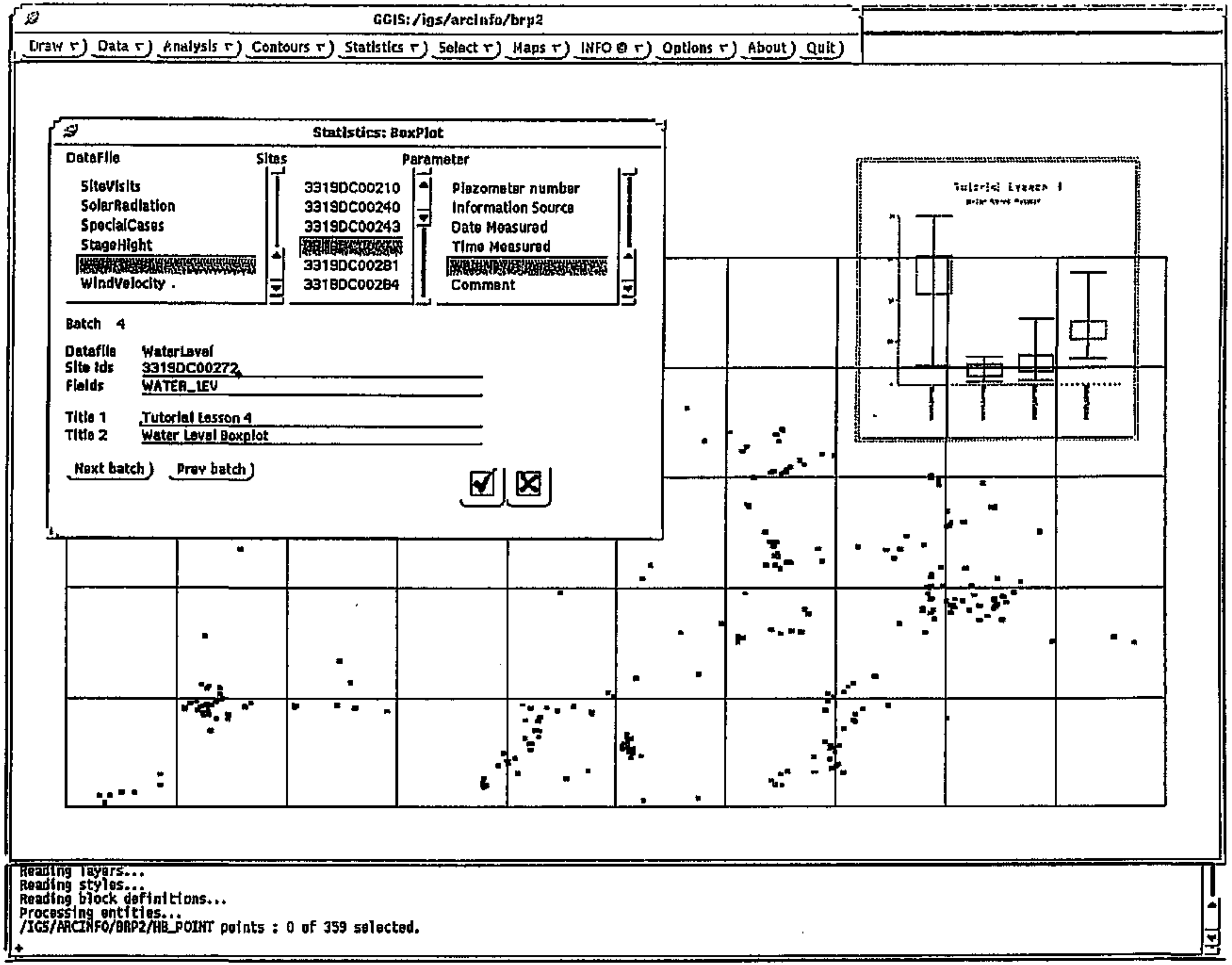

Figure 20. Dialog - Box and whisker plot

When you select the option *Statistics | Trend Analysis* from the menu, the dialog in Figure 21 will appear on the screen.

To do the Trend Analysis operation and create the graph, do the following:

1. Under `Data file`, select the HydroCom table from which the data must be extracted. The table's fields will be listed under `Parameter`.
2. Under `Parameter`, select the field on which to do the trend analysis.
3. Under `Polynomial degree`, select the degree.
4. Select the graph, data and statistics colour for the graph.
5. Under `Graph Title`, enter the title.
6. Choose the ☑ button. The statistical calculations will now be performed. You will be prompted in the command window to `Define the box` area in which the graph must be displayed. After indicating the size and position of the box on the screen, the graph will be displayed in that area.

When you select the option *Statistics | Data specific* from the menu, the dialog in Figure 22 will appear on the screen. *To do the Data specific Analysis operation, do the following:*

1. Select the HydroCom table from which the data must be extracted.
2. Choose the ☑ button. The statistical calculations will be done. Another dialog box will be displayed with the calculated properties.

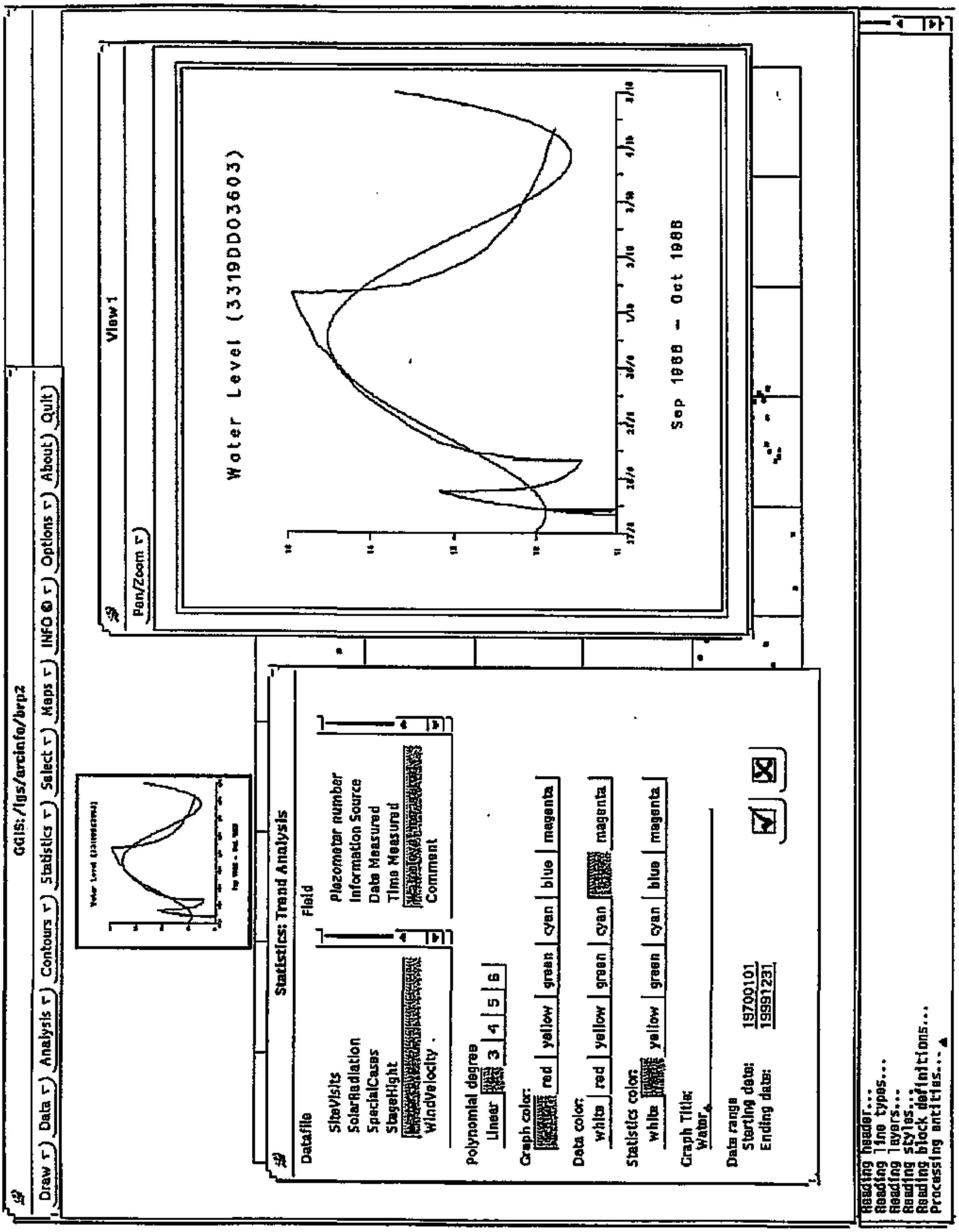

Figure 21. Dialog - Trend analysis.

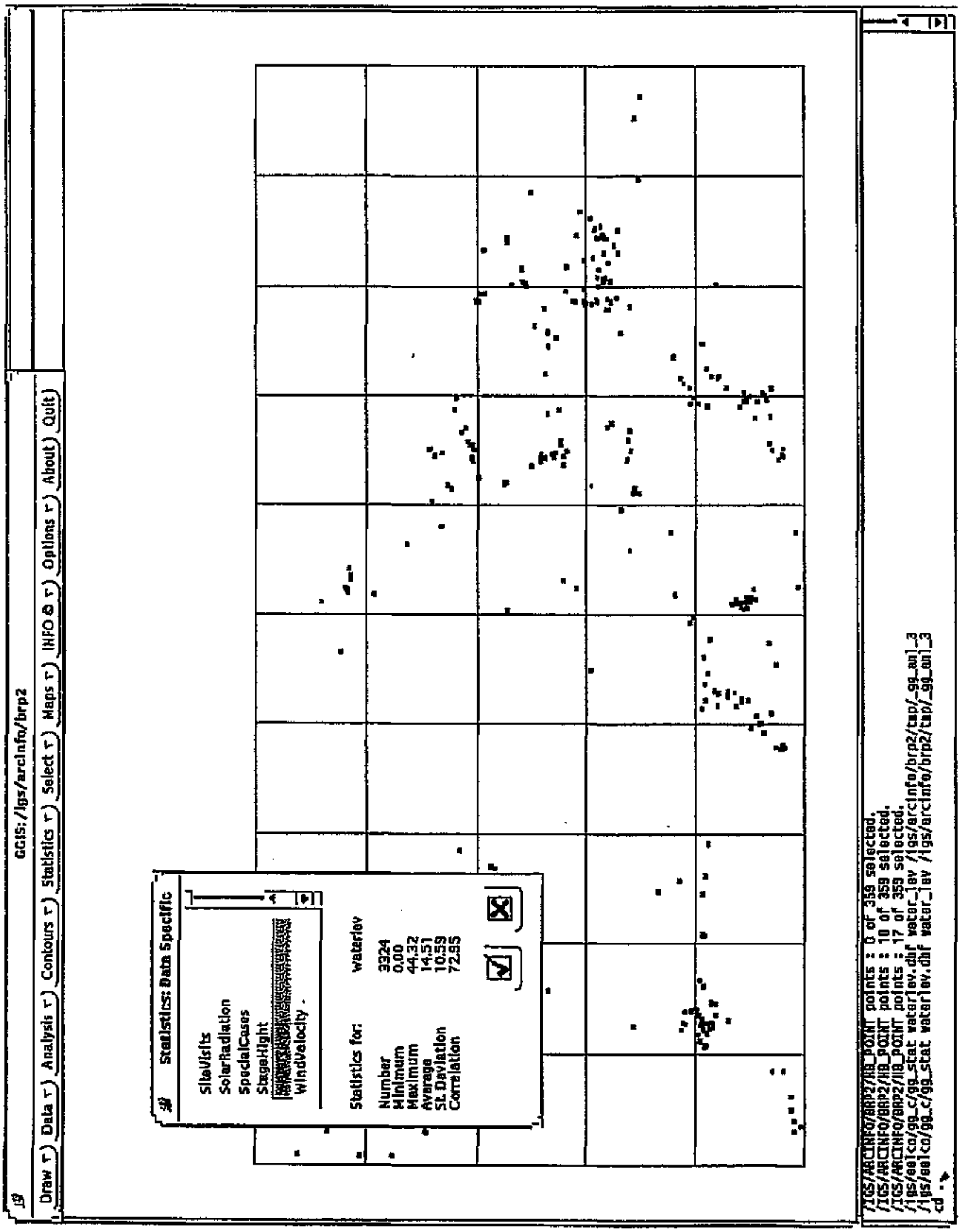

Figure 22. Dialog - Data statistics.

5. Additional operations

In addition to the features described previously, there are other features available via the menu options of GGIS. The following is a description of all these menu options available from the GGIS menu system.

5.1 Draw menu

5.1.1 Projection

Select this option to project your coverage according to your specifications. The coverages created by GGIS will always be projected using the projection file specified with *Options | Set Projection File.* The default is gg.proj.
(See also: 5.4.4 Set Projection file - p. 69.)
Select the coverage to be projected and the projection file to be used and press the ☑ button.

5.1.2 New map extent

Select this option to change the current map extent to a new one. After selecting the option, a prompt will appear in the command window to `Define the box`. With the mouse, indicate the bottom-left corner of the box and then the upper-right corner, depicting the new map extent.

5.1.3 New coverage

If, at some stage during the processing of the data, you wish to create a new coverage based on a section of the displayed data, you may do so by using this option. The new coverage will consist of a point and a polygon defined by you and will not contain data from other coverages. This option can be particularly useful if you want to define an area based on processed data, which can later be displayed as a shaded area describing the result of the previous data processed.

Selecting the *Draw | New coverage* option from the menu presents you with the dialog in Figure 23.

To define the new coverage:

1. Under `Coverage name`, enter the name of the new coverage.

2. Under `Polygon ID`, enter the ID of the polygon which will be used to define the area of the new coverage, e.g. `1`.

3. Choose the `Add` button. On the dialog, the prompt `Indicate centre of polygon` will appear. After indicating the centre of the polygon with the mouse, you will be prompted to `Indicate point`. After indicating a point, the same prompt will appear, until you press the Menu button, at which time the polygon will be closed.

   You may choose the `Add` button again to define additional polygons to be included in the new coverage. The value under `Polygon ID` will be automatically incremented.

4. Choose the ☑ button to create the new coverage.

The dialog will remain on screen to allow you to create additional coverages. When you have finished, choose the ☒ button to close the dialog.

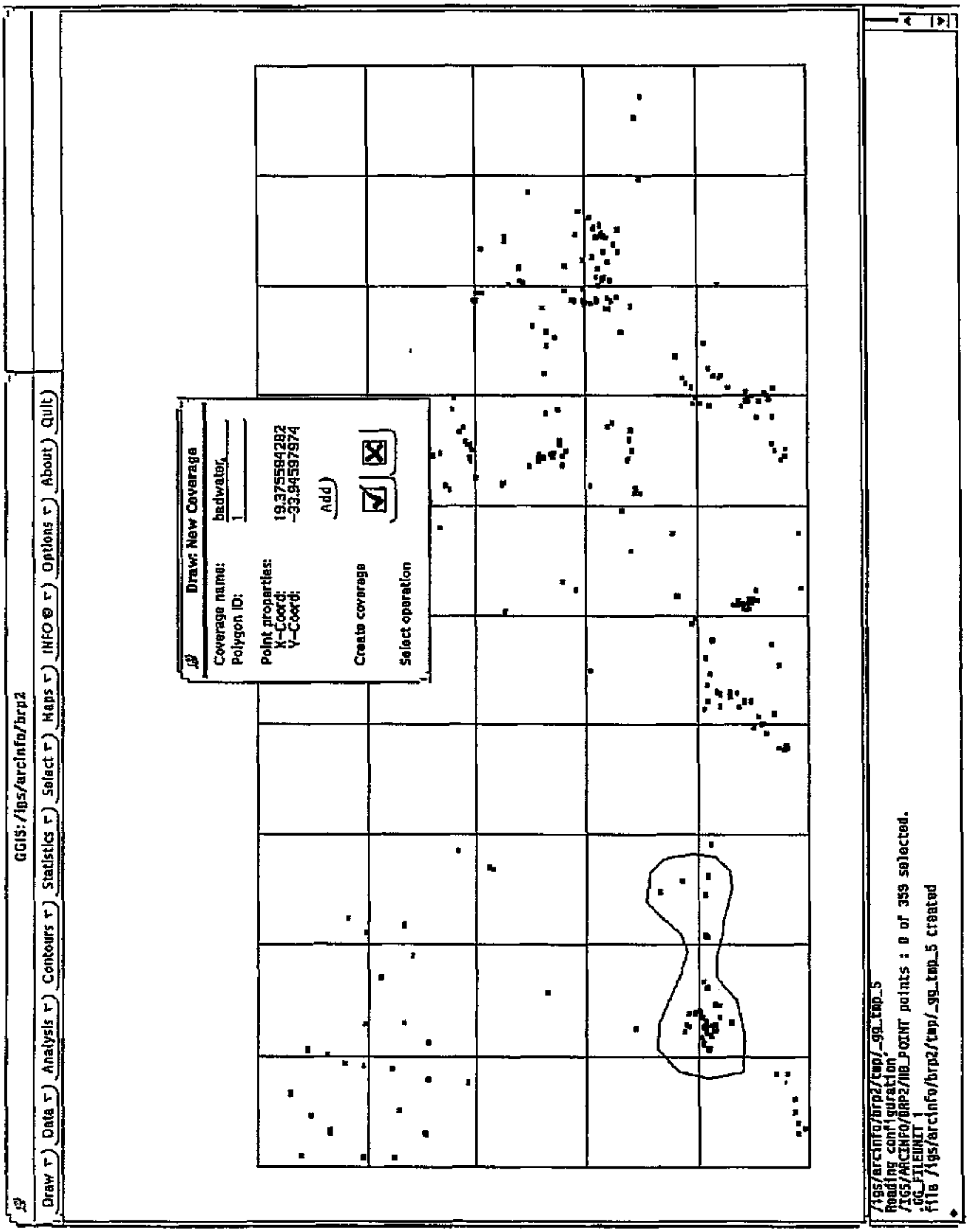

Figure 23. Dialog - Draw new coverage.

5.1.4 Grid

With GGIS you can not only use contours to display spatially distributed values, but the Grid option can also be used to display areas of related values. If you have created a grid or you received one from somebody else, you can use GGIS to display it, using the Grid option. If you select this option, you are presented with the dialog box shown in Figure 24.

After choosing the grid file you want to display, the following options must be defined in the dialog.
The display may be chosen as the main view or in a separate window.
The maximum and minimum contour values must be chosen.
The contour interval must be selected; this will control the number of shaded areas that will appear.
The highest and lowest colours are chosen and GGIS creates a colour ramp between those colours based on the number of intervals it calculates.

The grid area is drawn, showing areas of related values by colour coding.

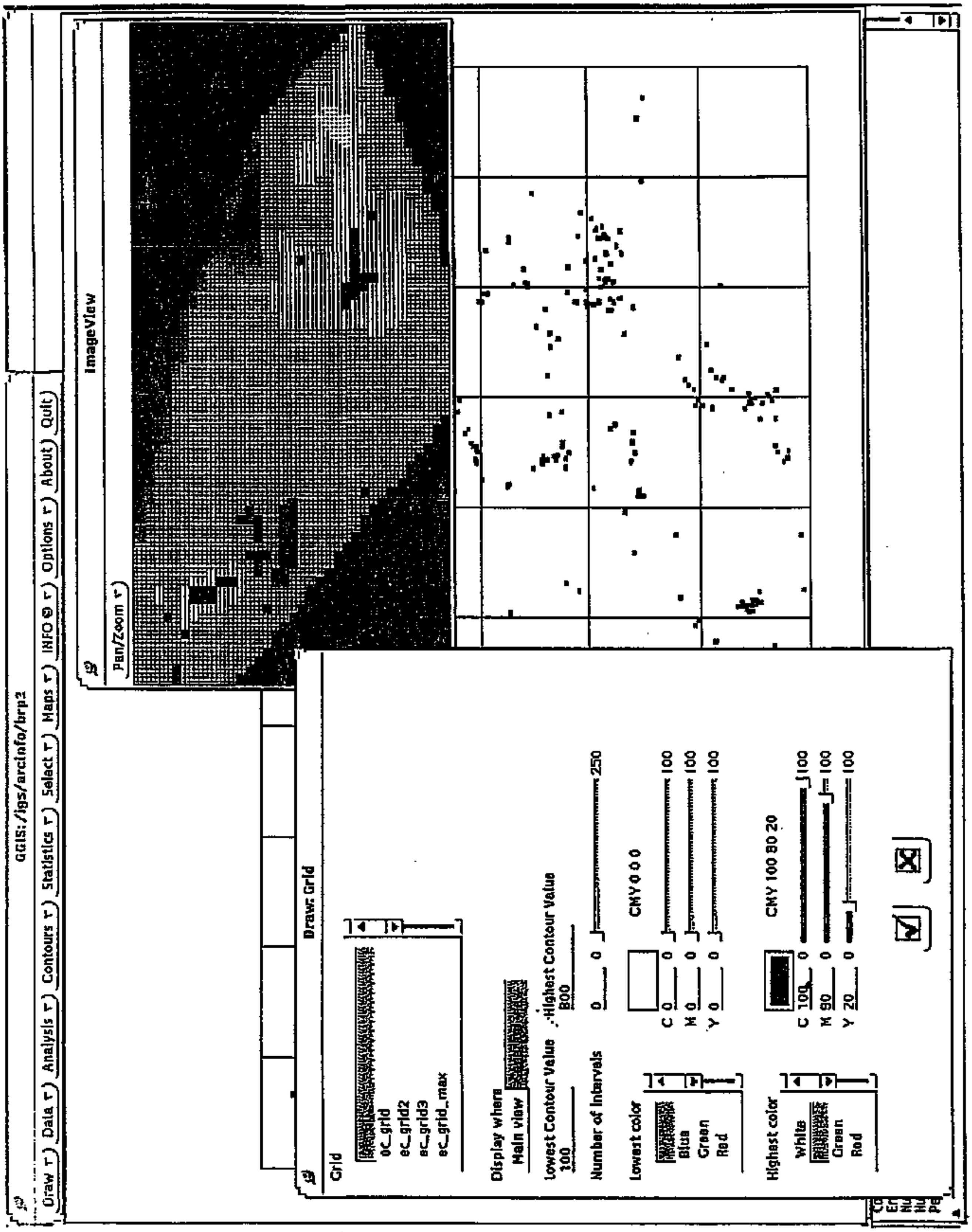

Figure 24. Dialog - Grid.

5.1.5 Line, Box and Circle

You may draw additional lines, boxes and/or circles on the display in the selected colour of the selected type by selecting this option from the menu. The dialog in Figure 25 will be presented.

To draw one or more lines, boxes and/or circles:

1. Under `Draw`, select the object you want to draw.
2. Under `Line type`, select the line type for the new object from the list, then choose the `Set Line Type` button.
3. Under `Line color`, select the colour for the new object.
4. Choose the ☑ button to start drawing the object. When drawing lines, press the Menu button to terminate line drawing.

The dialog will remain on screen to allow you to draw additional objects. When you have finished, choose the ☒ button to close the dialog.

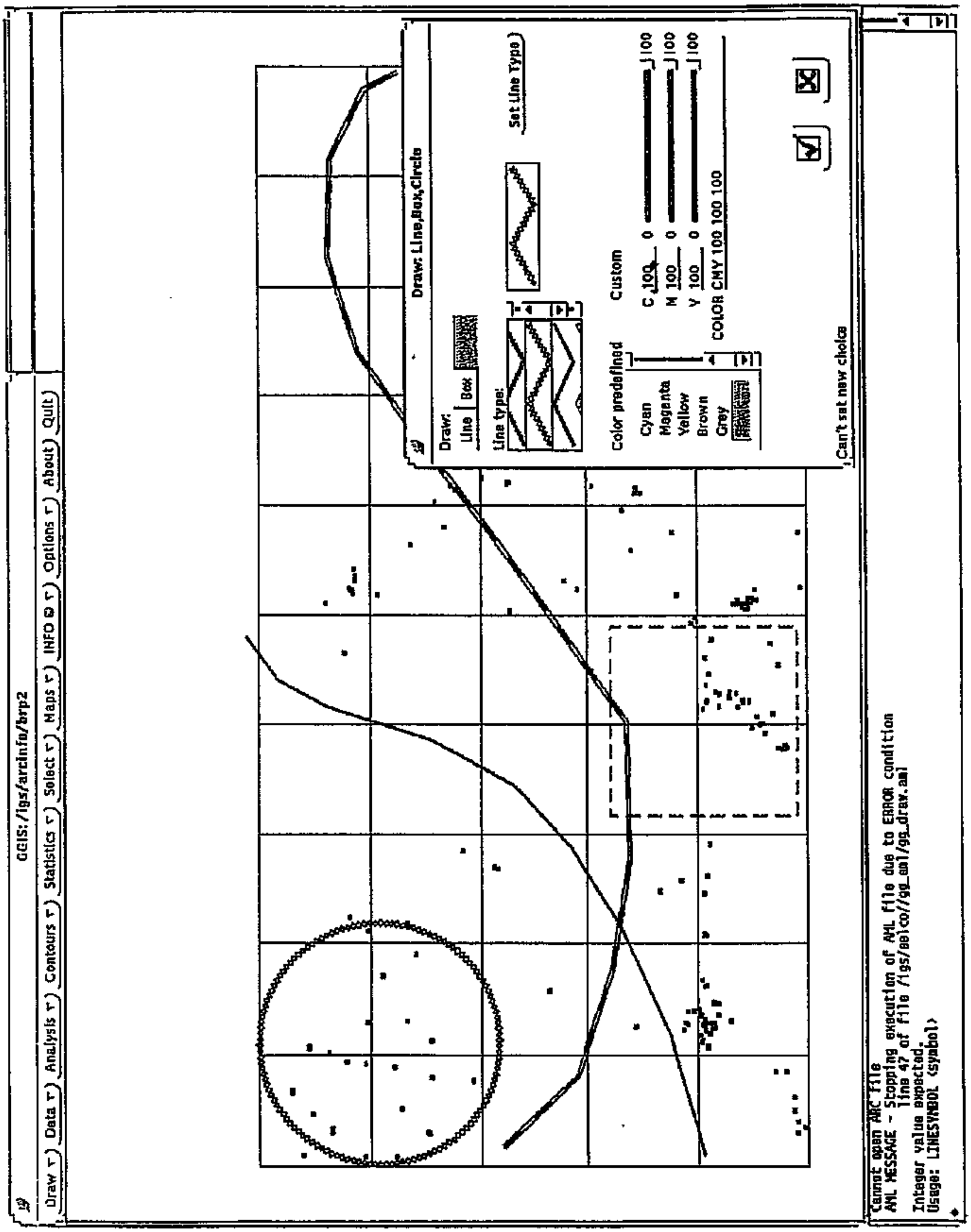

Figure 25. Dialog - Draw line.

5.1.6 Text

Text in the specified colour and size may be added to the display by selecting this option. When you select this option, you will be presented with the dialog in Figure 26.

To add text to the display:

1. Under `Text to insert`, enter the text you want to add.
2. Under `Placing of text`, select the alignment of the text with respect to the point to be indicated.
3. Under `Font type`, select the font for the text.
4. Under `Text color`, select the colour for the text.
5. Under `Text size`, select the size for the text.
6. Choose the ☑ button to place the text. In the command window, you will be prompted to `Enter point`, at which stage you must indicate the point where the text must be placed.

The dialog will remain on screen to allow you to add additional text. When you have finished, choose the ☒ button to close the dialog.

5.1.7 Clear

If, at some stage, you wish to clear the display, select this option. You will be asked for confirmation before the display is cleared.

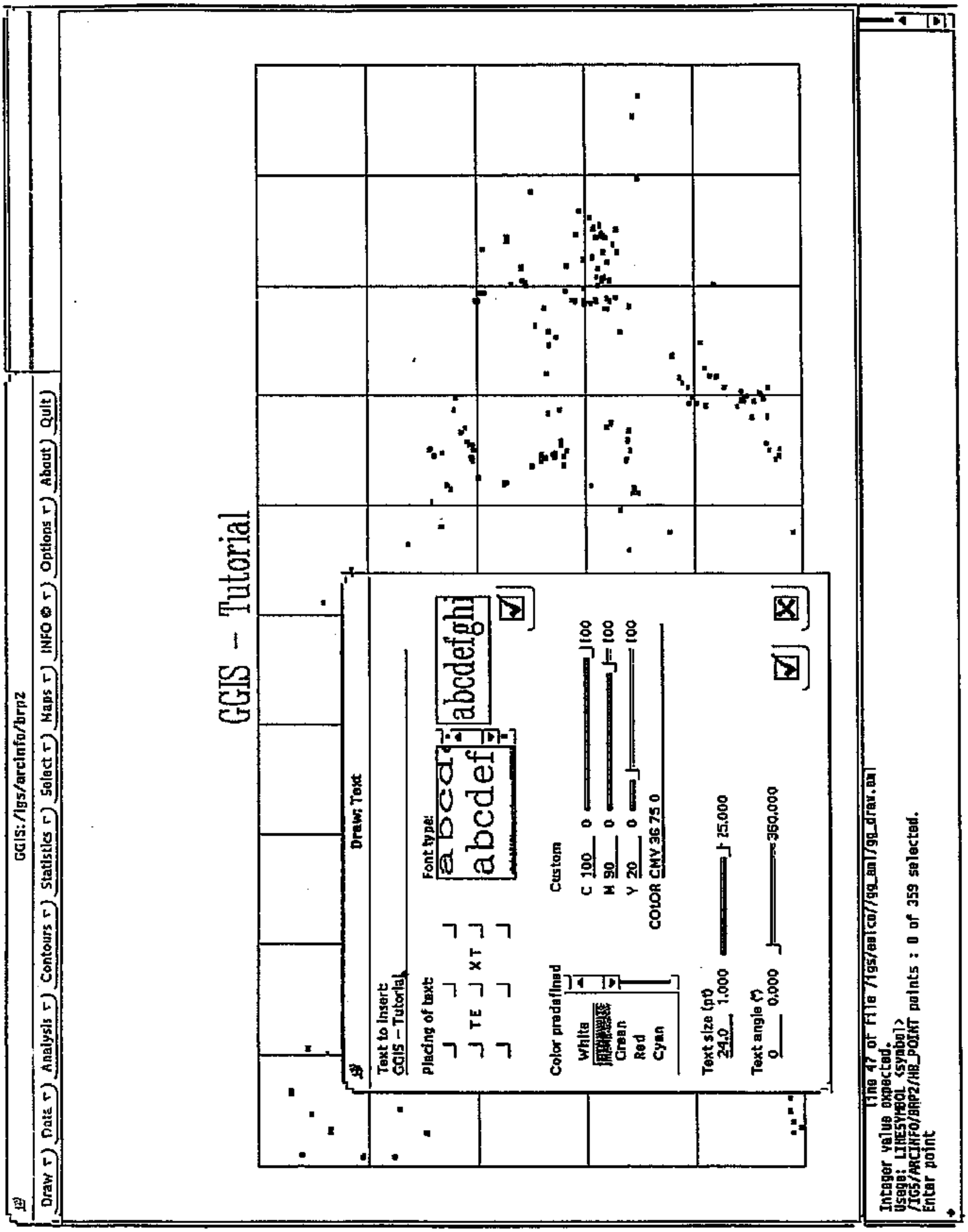

Figure 26. Dialog - Draw text.

5.2 Maps menu

The options on this menu provide an interface to the map facilities of Arc in a convenient and easy-to-use selection of commands.

5.2.1 Display map name

This option will display the name of the active map file, if one has been opened.

5.2.2 Redraw map

Select this option to redraw all entities in a map file.

5.2.3 Open map file

This option is the first to select when you want to create a map file of subsequent work in the Arc session. When you select this option, you will be prompted for a name for the map file. After entering the name, choose the OK button to close the dialog. All drawing actions will from then on be saved in this file.

5.2.4 Close map file

Select this option when you want to stop capturing drawing actions to the map file.

5.2.5 Map limits

By default, all drawing actions will be captured to the map file. To limit this to only a certain section of the display, select this option from the menu. The prompt `Define the box` will appear in the command window, after which you can use the mouse to indicate the new area for the map limits.

5.2.6 Clear map

Select this option to clear the current active map file of all drawing entities. You will be asked for confirmation before this action is performed.

5.2.7 Map info

Select this option to see a scrollable list of all entities currently in the map file. Choose the `QUIT` button to close the list.

5.2.8 Edit map items

The drawing entities in the map file may be moved, resized and deleted, which provides you with a convenient method for arranging the drawing. When you select this option, a dialog with buttons for Move, Resize and Delete appears.

To move a drawing entity:

1. Choose the `Move` button. The prompt `1=Select, 2=Next, 3=Who, 4=Abort, 5=Box, 9=Quit` will appear in the command window.
2. Select an entity with the mouse. The entity will then be redrawn and the prompt `1=Select, 2=Next, 3=Who, 4=Abort, 5=Box, 9=Quit` will again appear in the command window.
3. Enter 9, to quit the selection. The prompts `Enter the position to move from` and `Enter point` will appear in the command window.
4. Indicate a point with the mouse. The prompts `1=show box. Use any other key to mark the position` and `Enter point` will appear in the command window.
5. Indicate the new position of the point and press the Menu button on the mouse. The selected entity will then be moved to the new position.

To delete a drawing entity:

1. Choose the `Delete` button. The prompt `1=Select, 2=Next, 3=Who, 4=Abort, 5=Box, 9=Quit` will appear in the command window.

2. Select an entity with the mouse. The entity will be redrawn and the prompt `1=Select, 2=Next, 3=Who, 4=Abort, 5=Box, 9=Quit` will again appear in the command window.

3. Enter `9`, to quit the selection. The selected entity will be deleted.

To resize a drawing entity:

1. Choose the `Resize` button. The prompt `1=Select, 2=Next, 3=Who, 4=Abort, 5=Box, 9=Quit` will appear in the command window.

2. Select an entity with the mouse. The entity will be redrawn and the prompt `1=Select, 2=Next, 3=Who, 4=Abort, 5=Box, 9=Quit` will again appear in the command window.

3. Enter `9`, to quit the selection. The prompt `Define the box` will appear in the command window, after which you can use the mouse to indicate the new size and position of the selected entity. The selected entity will then be deleted and redrawn in the new position in the indicated size.

After you have completed all editing, select the DONE button to close the dialog.

5.3 INFO menu

In cases where you want to insert symbols with different sizes depending on the value of a certain item, it is easier to do such a operation using an INFO file.

5.3.1 Create INFO file

An INFO file, containing any numerical parameter stored in HydroBase, must be created before the INFO operations can be run.

Firstly, the data file and the parameter(s) to be associated with the INFO file must be selected from HydroBase. The selected data in HydroBase can be evaluated using INFO's elementary statistics or data manipulation capabilities. The results of such evaluations are written into the INFO file. For example, the first (oldest) or last (youngest) measurements in a range can be identified, as could the maximum and minimum values, the average or the sum of the range. INFO can also be used to select points so that these could be highlighted in a display.

The selected data are transferred to an INFO data base, and must be identified by a header. For this reason, GGIS will require that a prefix be defined; for example, WL for water levels or EC for electrical conductivity. GGIS will automatically assign header names, to fields that are created by INFO, based on the prefix. For example, if you selected WL as a prefix for your data, and used INFO to calculate the minimum, maximum and mean, header names for the results fields written in the INFO file will automatically be called: WL_min, WL_max and WL_mean.

The Relate to option gives you control over how GGIS calculates the values. *Relate to Elevation* will give you values where the values measured are deducted from the borehole elevation. *Relate to Thickness* will give you values where values: Depth_to_top and Depth_to_bottom are taken into consideration.

You may also specify a date range or a value range to filter out unwanted or incorrect values.

5.3.2 Join INFO file

After you have created the INFO file, the file must be "joined" to give GGIS access to the file. To do this: Select this option, select the INFO file you have just created and press the ☑ button.

5.3.3 Drop INFO file

When you have finished using the previously created join, you may remove the item using the Drop INFO item option. This option automatically removes the last join. If there was no last join, it will ask you what item to drop. Dropping items keep your INFO file(s) small and fast.

5.3.4 Select with INFO

We have seen that points could be selected directly from the HydroBase data using *Select* as described in Chapter 4. An alternative method makes use of INFO files. Choose *INFO | Select with INFO...* from the menu, a dialog will appear on your screen which differs from the *Select | Select special* dialog, in that the two list boxes, data file and field are replaced by a single list box displaying INFO fields. (See: 4.2 Using Select Special p. 16.)

5.3.5 Create Grid

A grid may be used to quickly display spatial variables over an area. GGIS creates a grid from values stored in an INFO file.
Select the item and field to be displayed and supply a grid name. While creating the grid, the program will ask you for a cell size (square cell), whether the entire coverage should be converted and how missing values should be determined.
After the grid has been created, you can display it using: *Draw | Grid.*
(See: 5.1.4 Grid p.55.)

5.3.6 Display spot

It may be useful in a presentation to display spots with the marker-size scaled according to the value of the point. This can be achieved using *INFO | display spot* option.

Select the INFO file and the field for which the marker is to be displayed. Select a colour for the marker and the desired shape, for example, a circle or square. Set the marker size for the minimum and maximum values in the data set. GGIS scales the marker sizes for all values in between the minimum and maximum. Finally, press the ☑ button to complete the operation (see Figure 27).

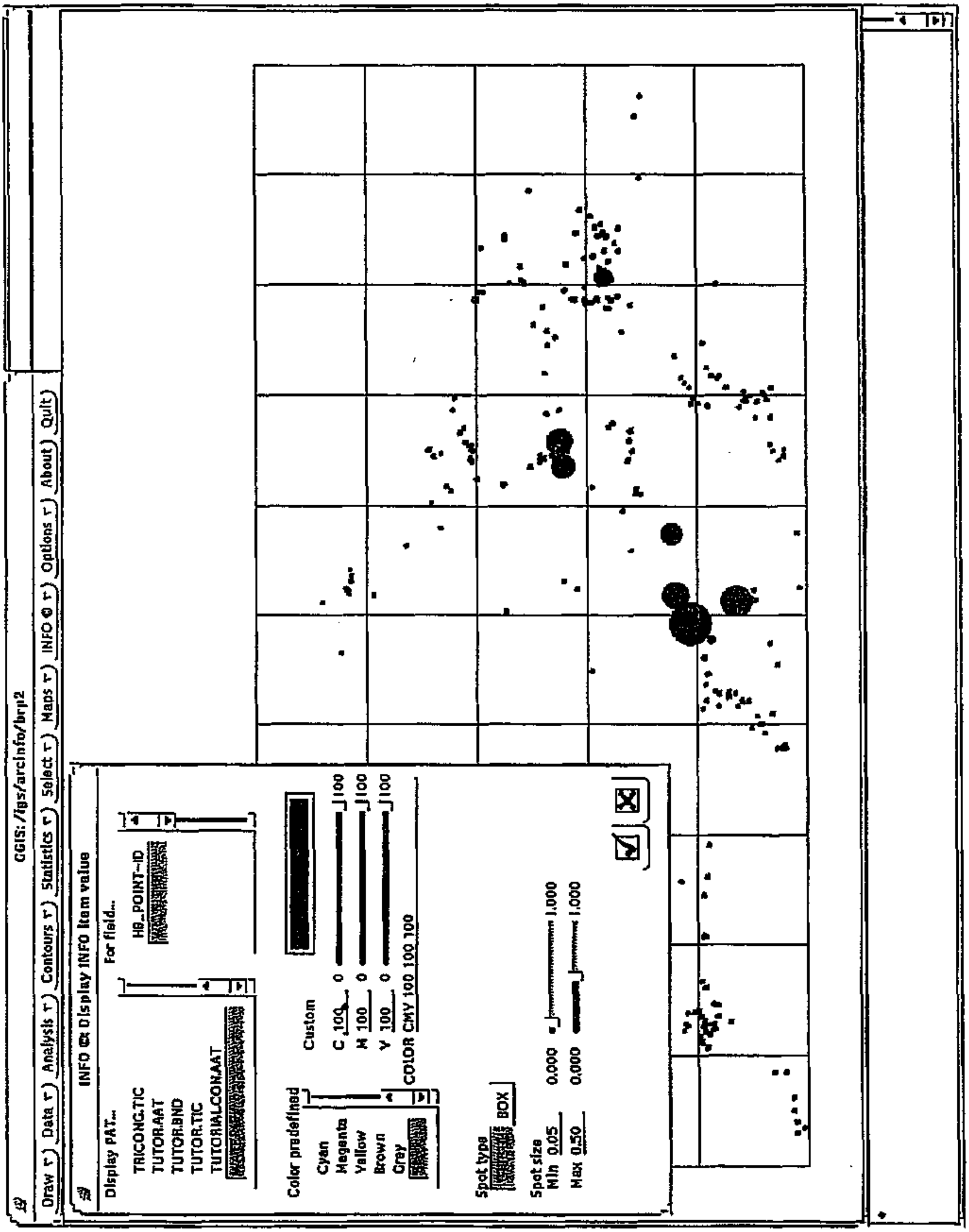

Figure 27. Spots displayed.

5.3.7 Display text

This option controls the position, angle and attributes of text that is associated with a selected point.

Select the Point Attribute file (PAT) and the required field. Options appear which allow you to define where the text should be placed relative to the point, the angle of the text string, as well as text attributes such as, font, colour and size.
Press the ☑ button to commence plotting.

5.3.8 Remove INFO file

After you have finished all the manipulations on a data set, it is advisable to delete the INFO file. This is because the INFO file is not updated when HydroBase data are changed, thus correlation between the INFO file and your points in the hb_point coverage cannot be guaranteed.

5.4 Options menu

The options on this menu provide access to additional facilities to enable you to manage the GGIS work session more easily.

5.4.1 File management

This option provides you with a function to delete unwanted files of various types. When you select this option, a dialog will appear, allowing you to delete files.

To delete one or more files:

1. Under `File type`, select the type of file you want to list.

2. From the list of files, select the file you want to delete. Its name will appear under `File name`.

3. Choose the `Delete` button. The file will be deleted.

4. When you have finished deleting files, choose the ☑ button to close the dialog.

5.4.2 Change workspace

You may change the workspace at any stage during your GGIS session, while still retaining the current display. To do so, select this option from the menu. A dialog will appear, stating the name of the current workspace and prompting you for the name of the new workspace. After entering the name of the new workspace, choose the ☑ button.

GGIS will access the new workspace and check that the HydroBase data are in the correct format. That data and any other Arc data in the workspace will become available to you.

5.4.3 Select marker colour

Markers are used to show the position of the boreholes in the HydroBase data. The colour in which the markers appear for both selected and normal markers can be set with this option. When you select this option, a dialog will appear, allowing you to change the colour.

To change the colour of the markers:

1. Under `Predefined`, select the colour you want, or under `Custom`, use the sliders to adjust the values for Cyan, Magenta and Yellow or enter the values for `C`, `M` and `Y`, or under `Color`, enter the colour values in the format
   CMY <Cyan_Value> <Magenta_Value> <Yellow_Value>.
2. Choose the button `APPLY (Normal markers)` to set the colour for normal markers to the colour specified or choose the button `APPLY (Selected markers)` to set the colour for selected markers to the colour specified.
3. Choose the ☑ button to close the dialog.

5.4.4 Set Projection file

Although GGIS by default uses geographic projection information stored in the file gg.proj, any other geographic projections can be used.
To use a custom projection, you make your own projection file as explained in the Arc/Info manual. This file must be copied to your current workspace.
Select *Options* | *Set Projection File* and select the required projection file.
Once a new projection file has been chosen, the projection information contained in it becomes the default projection for all map drawing, until another projection file is selected.

THE USE OF GEOGRAPHIC INFORMATION SYSTEMS AND OTHER COMPUTER AIDED DRAFTING FACILITIES FOR THE PRODUCTION OF GEOHYDROLOGICAL MAPS

by

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Report to the Water Research Commission

Annexure B
Tutorial

WRC Report No. 377/1/95 **March 1995**
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Contents

List of Figures

Introduction

This tutorial will give you a hands-on introduction to the main features of GGIS. The tutorial contains the following lessons:

- Lesson 1: Generating a rainfall graph. You will use the *Data | Show available* option to find the data for the graph, visually check the data with the *Data | Available* option and then create the graph using the *Analysis | Time-dependent* option.
- Lesson 2: Generating a Piper diagram. You will use the powerful *Select | Select special* option to find the data, view the data, possibly edit it using *Data | Available* and then create the graph using the *Analysis | Chemical* option.
- Lesson 3: Generating a Theis-recovery graph. You will find the data for the analysis using the *Select Special* feature of GGIS, check the data on-screen, edit it to correct an error made during data entry, complete the analysis using the corrected data and display the graph on screen.
- Lesson 4: Generating a box plot. You will use *Select Special* to find the data for the analysis and generate the graph on the screen from the selected data.
- Lesson 5: Generating contours from HydroCom data. You will find the data for the contours using *Select Special*, generate the contours from the selected data and display the contours on the screen together with the grid and site id points.
- Lesson 6: Generating contours from aquifer modelling. You will create the network, simulate water-level responses and display the contours on the screen.

If you don't want to go through the entire tutorial from beginning to end, you can start the beginning of any lesson, provided that you have started GGIS and loaded the data, as described below. Each lesson is divided into sections; beginning with an overview of concepts, terms and procedures related to the lesson, followed by a practice session with step-by-step instructions for accomplishing the task. By working through the practice sessions, you will familiarize yourself with the features of GGIS, enabling you to produce the same results from your own data.

Getting started

The procedure described here should be followed each time you want to work with the GGIS system. From the command tool window, enter `cd /ggis/demo` to log into the directory which holds the data that will be used for this tutorial.

Starting GGIS

Start Arc by entering `arc` at the prompt, and then start ArcPlot at the Arc prompt by entering `ap`. To start GGIS, enter the command `&r /ggis/ggis` at the ArcPlot prompt. This will activate the ArcPlot window and the GGIS menu will appear. Arrange the windows to resemble the layout shown in Figure 1.

The last few lines of the command tool window from which GGIS was started, should be visible, as important messages appear there. This is also the place where you would enter any commands or responses to prompts when required by the system.

Loading the data

As a minimum requirement, the coverages named **hb_grid** and **hb_point** should be loaded. To accomplish this, select the option *Draw | Coverage* from the menu.

To display the grid which represents the area of the data used for this tutorial, do the following:

1. Under `Coverage`, select `hb_grid`.
2. Under `Feature`, select `Arcs`.
3. Select `Set map extent`.
4. Under `Color`, select the colour for the grid (we suggest white).
5. Choose the ☑ button.

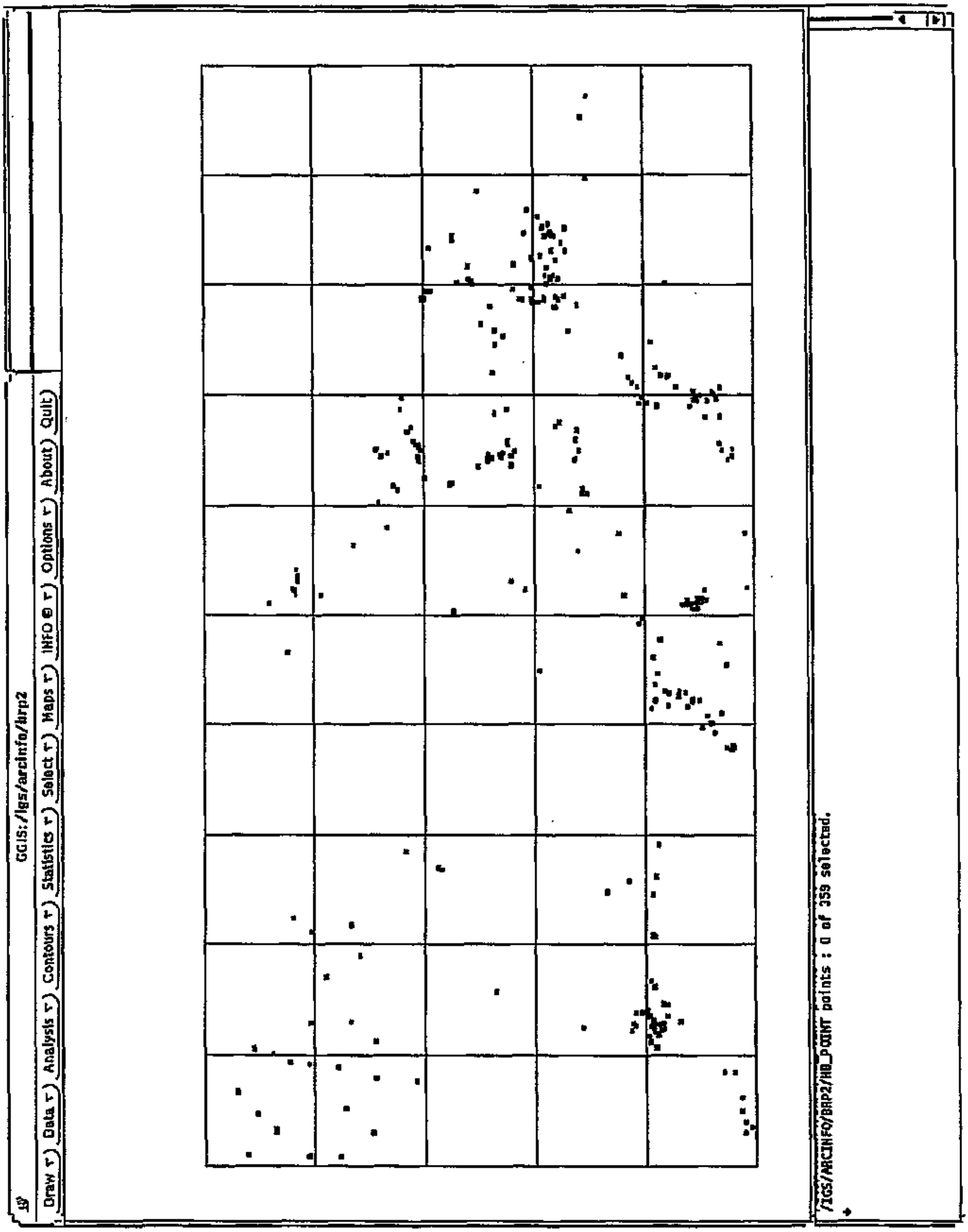

Figure 1. A displayed coverage.

The grid will be drawn on the screen in the selected colour.

To display the points available in the HydroCom data, do the following:

1. Under `Coverage`, select `hb_point`.
2. Under `Feature`, select `Points`.
3. Ensure that `Set map extent` is not selected.
4. Under `Color`, select the desired colour for the points (we suggest green.
5. Choose the ☑ button.

The points representing all site id's will be drawn on the screen in the selected colour.

Any additional data may be drawn on the screen in a similar way, keeping in mind that the map extent should not be reset. When this has been completed, choose the ☒ button to close the dialog. The system is now ready to be used for the lessons which follow.

Lesson 1: Generating a rainfall graph

In this lesson, you will produce a graph of the rainfall measured at a certain site by doing the following:

- Find the data for the graph using features of GGIS
- Check the data on-screen to determine whether it is what you want to use for the graph
- Create the graph using the selected data and display it on the screen

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☞ **Note**

You must follow the instructions at the beginning of this tutorial under the Getting started *section before starting with this lesson.*

Finding the data

Taking into account the vast quantities of data that can be available to you, it is important that the correct data for your specific purpose can be located quickly, efficiently and easily. GGIS has various ways of helping you to accomplish this objective.

The method you will use to find the data for this graph can be found under the option *Data | Show available* on the menu. This method scans the data for points which have data of the required type. A marker is placed next to all points displayed on the screen which have data of the required type. The points are also selected, making them available for further processing.

To determine which points have rainfall data, do the following:

1. Under `Item to check`, select `Rainfall`.
2. Under `Placing of symbol`, select the position of the marker relative to the position of the point.

3. Under `Symbol color`, select the colour in which you want the marker to be displayed.

4. Under `Symbol size`, select the marker size (we suggest `Medium`, but bigger markers may be used if there are only a few widely spaced points).

5. Choose the ☑ button. The rainfall data will now be scanned for available data. For each point for which there is rainfall data, a predefined marker will be placed near the point in the selected position relative to the point, and the point will become selected.

6. Choose the ☒ button to close the dialog.

A message in the command window will indicate how many sites were found that do have rainfall data. Since you require only one for the purpose of this lesson, you must select the one to use. For this, select the option *Select | List selected* from the menu (see Figure 2).

To select the site to be used for this lesson, do the following:

1. Under `SITE IDs`, select `3319CB00200`. The site id will appear in the field `Selected sites`.

2. Choose the ☑ button. All the previously selected sites will be deselected except this one site, which will remain selected.

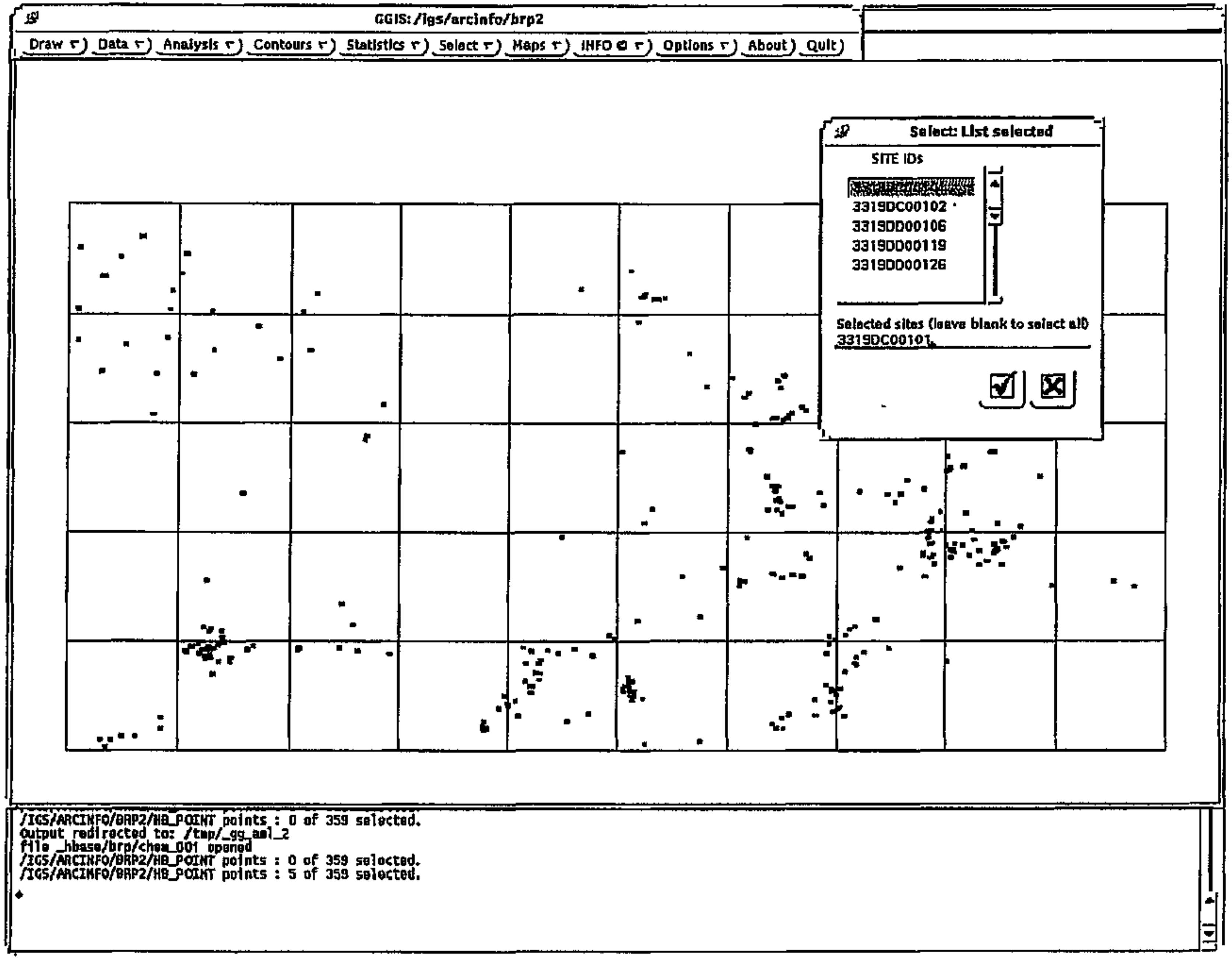

Figure 2. The list selected dialog box.

Checking the data

Now that you have found data that can possibly be used for the graph, it is time to review the data values. To accomplish this, you will use the method found under the option *Data | Available data* on the menu. This method displays a list of data types which could be available, as well as the number of records of each data type available for the selected point. You may view any of the available data types pertaining to the selected point. You could equally do this for any other point.

To display this information, select the option *Data | Available data* from the menu. The summary of available data will be displayed for the first selected point. Opposite Rainfall, choose the =>> button. This will display the data in a new window, which will appear as shown in Figure 3.

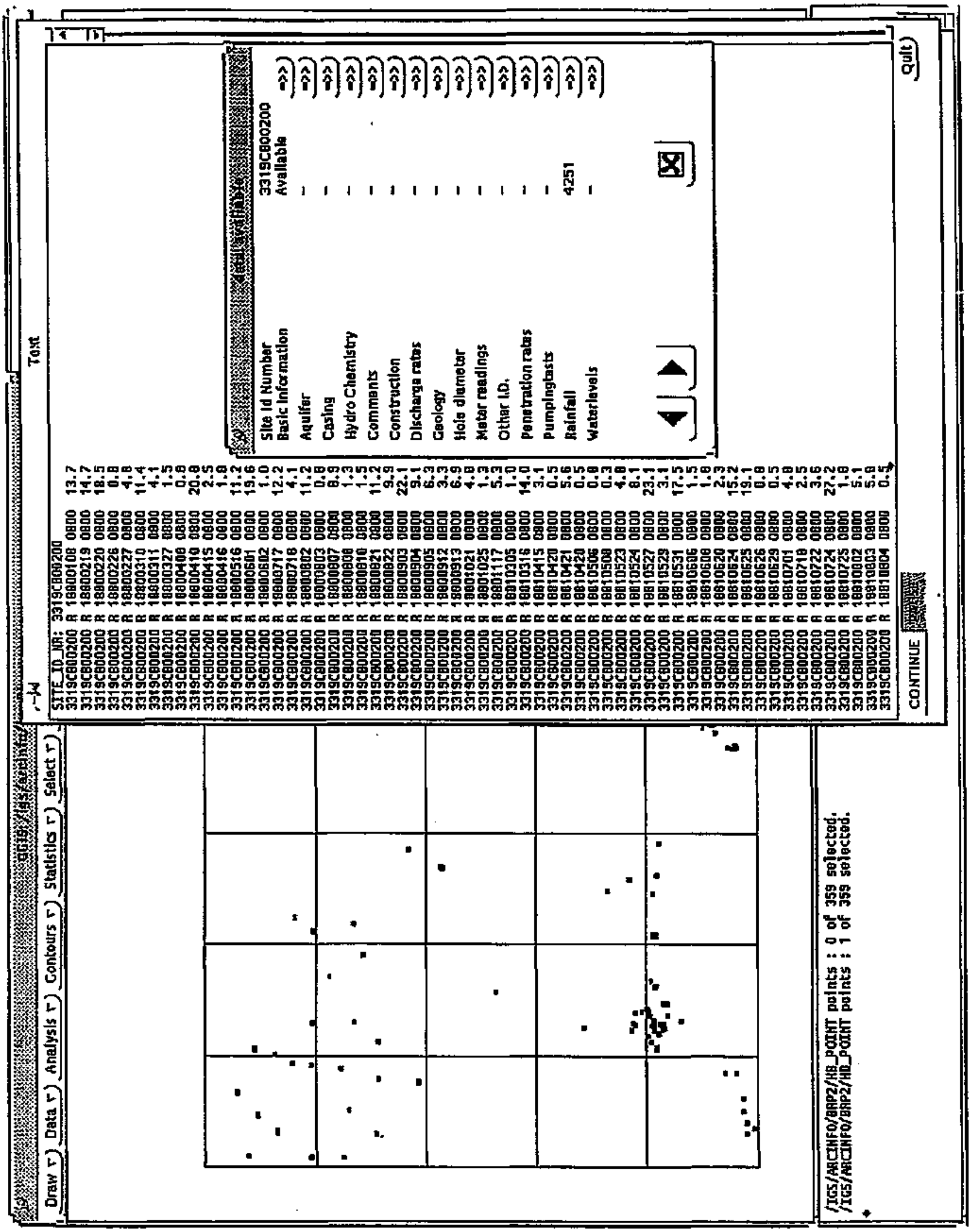

Figure 3. Summary of available data.

To see what rainfall data are available for the selected point, do the following:

1. Select the `CONTINUE` option at the bottom of the window. The data will start to scroll, showing the new data. To stop the scrolling, select the `PAUSE` option.

2. Choose the `Quit` button to close the data window.

3. Choose the ☒ button to close the `Data: Available data` dialog.

Creating the graph

Rainfall data are classified by GGIS as "time-dependent", because they are usually measured against time, and will consequently be displayed in a time-dependent graph, as found under the option *Analysis* | *Time-dependent* on the menu.

☞ **Note**

Any other time-dependent data, such as Water levels, Discharge rates, Evaporation, etc., can be displayed in this type of graph.

To create the rainfall graph, do the following:

1. Select the option *Analysis* | *Time-dependent* from the menu.

2. Under `DATAFILE`, select `Rainfall`. The field(s) containing data that may be used to produce a graph will be listed under `FIELD`.

3. Under `FIELD`, select the field `Reading`.

4. Under `Graph type`, select the option `Bar`.

5. Under `Data type`, select option `As is`.

6. Under `Graph color`, select a colour for the graph frame and text.

7. Under `Data color`, select a colour for the data.

8. Under `Date range`, enter the value `19810101` for `Start date` and `19911231` for `End date`.

9. Choose the ☑ button. You will be prompted in the command window to `Define the box` area in which the graph must be displayed. After indicating the size and position of the box on the screen, the graph will be displayed in that area.

10. Choose the ☒ button to close the dialog.

See Figure 4 for a sample of a time-dependent graph.

☞ **Note**

For more information on topics covered in this lesson, see the following sections in the GGIS Reference Manual:

- *4.1.2 Using List selected*
- *4.2.1 Maps | Data evaluation - Point information*
- *4.3.1 Graphs | Time - Bar, Scatter, Line*

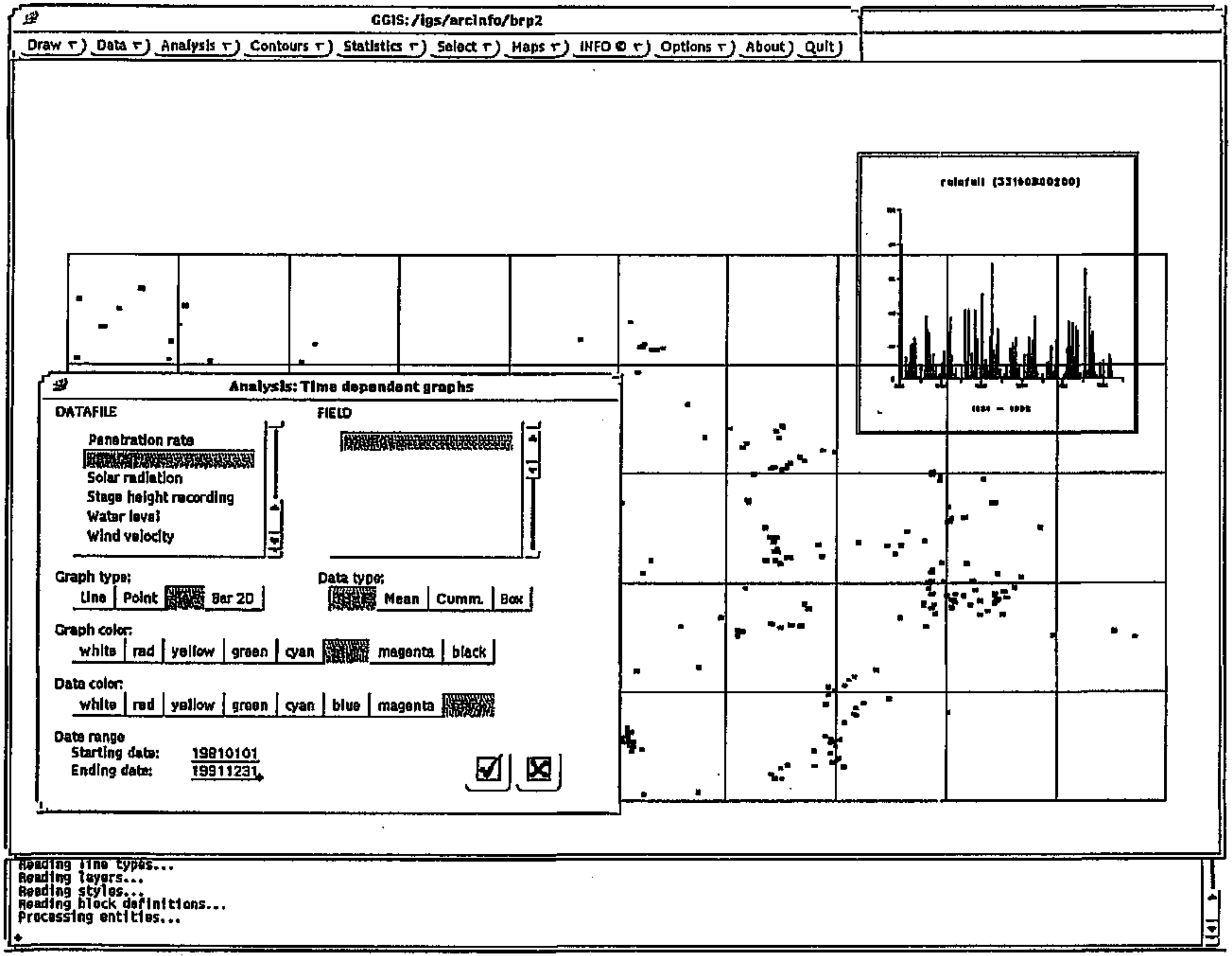

Figure 4. Sample of a time-dependent graph.

Lesson 2: Generating a Piper diagram

In this lesson, you will create a Piper diagram using groundwater chemical analysis results from a certain site, by doing the following:

- Find the data for the diagram using the *Select Special* feature of GGIS
- Check the data on-screen, and possibly edit it, to determine whether it is suitable for the diagram
- Create the diagram using the selected data and display it on the screen

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☞ **Note**

You must follow the instructions at the beginning of this tutorial under the Getting started *section before starting with this lesson.*

Finding the data

GGIS has a number of options with which you can select the data you want to use, of which *Select | Select Special* is the most powerful. This is the method you will use to find the data you need for this diagram.

This method scans the data at the field level, evaluating the data values according to your specifications. This is done to determine whether a point should be selected or not. You have further control over the selection by limiting the selection process to points previously selected, adding newly selected points to an existing selection, or deselecting any selected points before starting the new selection process.

When you select the *Select | Select special* option from the menu, the dialog shown in Figure 5 will appear on the screen.

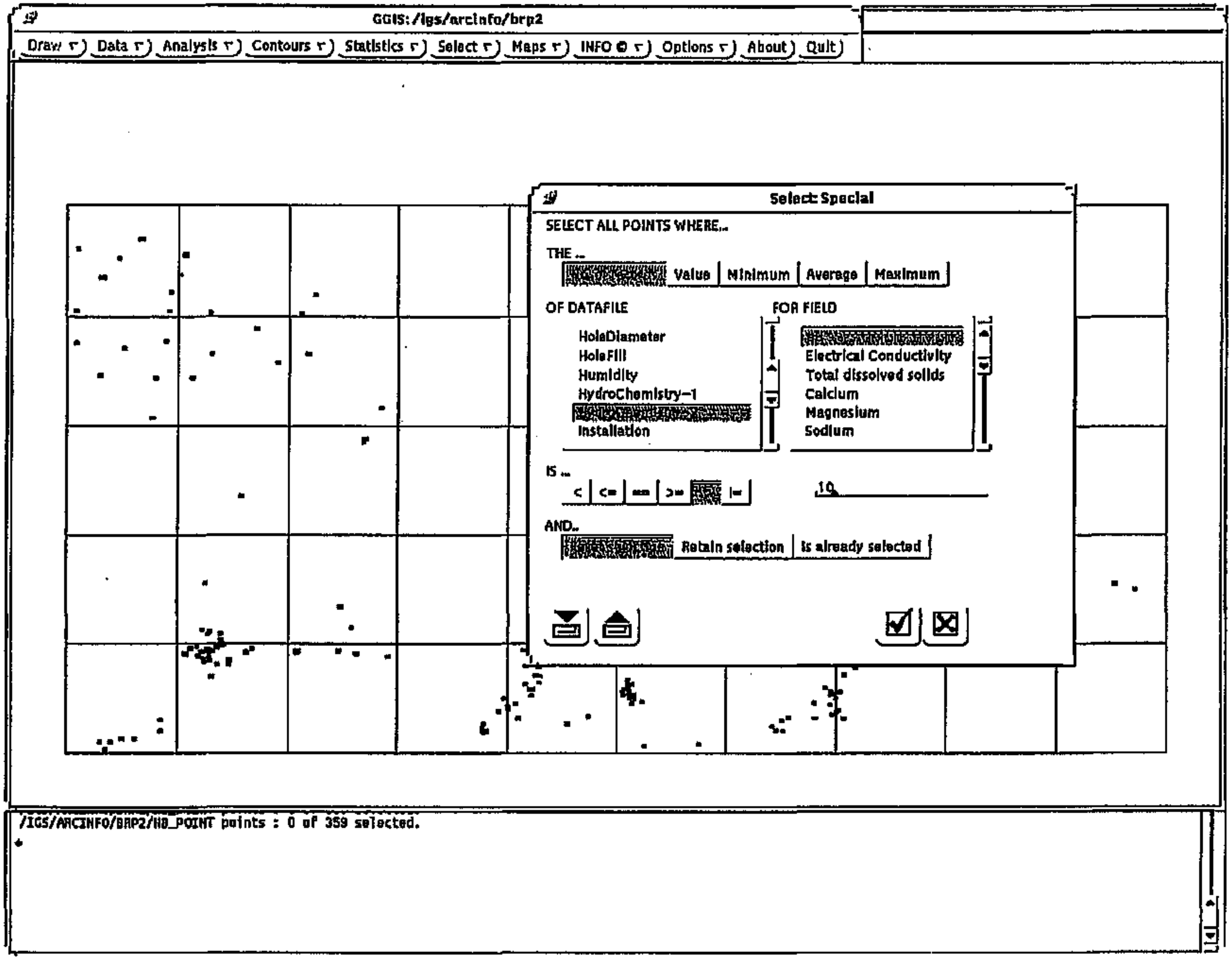

Figure 5. The select special dialog box.

To determine which point to use for the diagram, do the following:

1. Under `THE...`, select `No. of records`.
2. Under `OF DATAFILE`, select `HydroChemistry`. The fields for the HydroChemistry table will be displayed under `FOR FIELD`.
3. Under `FOR FIELD`, select any field following the numbered fields in the list, e.g. `Aluminium`.
4. Under `IS...`, select the greater-than operator (>) and enter the value `10`. You must press Enter after typing the numbers, or else the value will not be accepted.
5. Under `AND...`, select `Reset selection`.
6. Choose the ☑ button. The data will now be scanned and all points having more than 10 records of hydrochemistry data will be selected.
7. Choose the ☒ button to close the dialog.

Checking the data

The selected data can be viewed to determine its suitability for the analysis. To view the selected data, select the option *Data | Available data* from the menu. From the resulting dialog, choose the =>> button opposite HydroChemistry. You can scroll through the data as described in the previous lesson. When you have finished viewing the data, choose the Quit button to close the data window and then choose the ☒ button to close the *Data:Available* dialog.

Creating the graph

The Piper diagram is used to compare and distinguish between waters of different chemistries, for the purpose of understanding the evolutionary processes which the water has undergone. This is done for all samples in the specified date range for all the selected points (see Figure 6).

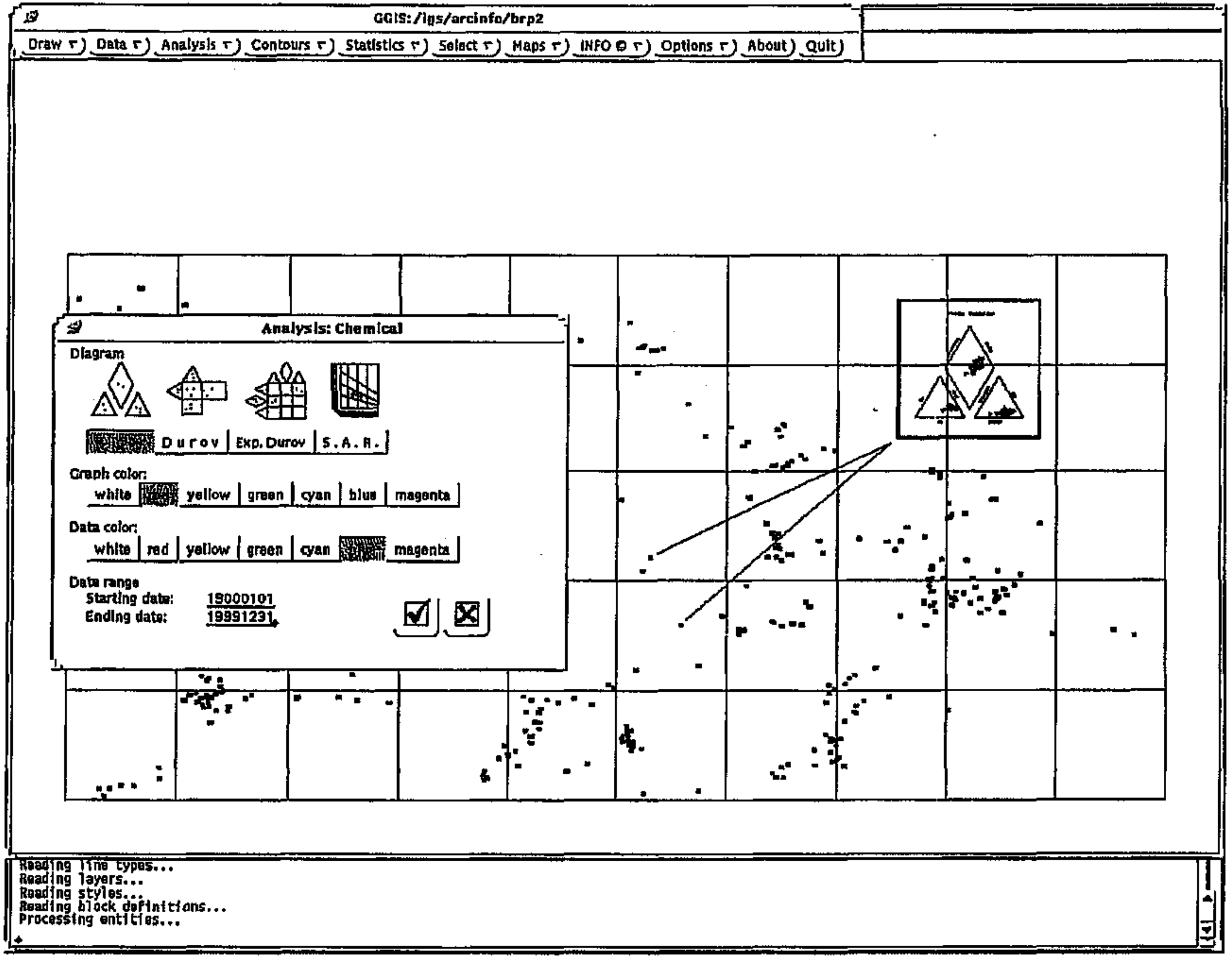

Figure 6. The chemical analysis dialog box.

To create the Piper diagram for the selected data, select the option *Analysis* | *Chemical* from the menu: The dialog shown in Figure 6 will appear on the screen.

To create the Piper diagram, do the following:

1. Under `Diagram`, select `Piper`.
2. Under `Graph color`, select a colour for the graph frame and text.
3. Under `Data color`, select a colour in which the data must be displayed.
4. Under `Date range`, enter the value `19890601` for `Start date` and `19900630` for `End date`.
5. Choose the ☑ button. You will then be prompted in the command window to `Define the box` area in which the diagram must be displayed. After indicating the size and position of the box on the screen, the diagram will be displayed in that area.
6. Choose the ☒ button to close the dialog.

☞ **Note**

For more information on topics covered in this lesson, see the following sections in the GGIS Reference Manual:

- *4.1.1 Using Select Special*
- *4.3.2 Graphs | Piper, Durov, Expanded Durov, S.A.R.*

Lesson 3: Generating a Theis-recovery graph

In this lesson, you will analyse water-level recovery data from a certain site using the Theis-recovery method:

- Find the data for the analysis using the *Select Special* feature of GGIS
- Check the data on-screen and edit it to correct an error made during data entry
- Perform the analysis using the corrected data and display the graph on the screen

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☞ ***Note***

You must follow the instructions at the beginning of this tutorial under the Getting started *section before starting with this lesson.*

Finding the data

Data for a pumping test are located in three separate tables, namely Pumping tests, Water levels and Discharge rates. The controlling data for any specific test are located in Pumping tests. To find the data, select the option *Select* | *Select special* from the menu.

To determine which point to use for the diagram, do the following:

1. Under `THE...`, select `No. of records`.

2. Under `OF DATAFILE`, select `Pumping tests`. The fields for the Pumping tests table will be displayed under `FOR FIELD`.

3. Under `FOR FIELD`, select any field in the list.

4. Under `IS...`, select the greater-than operator (>) and enter the value `1`. You must press Enter after typing the numbers, or else the value will not be accepted.

5. Under AND..., select Reset selection.
6. Choose the ☑ button. The data will be scanned and all points having more than one record of pumping test data will be selected.

To further limit the selection to points which have recovery type pumping tests, do the following:

7. Under THE..., select Value.
8. Under OF DATAFILE, select Pumping tests. The fields for the Pumping tests table will be displayed under FOR FIELD.
9. Under FOR FIELD, select Method tested.
10. Under IS..., select the equals operator (==) and enter the value R. You must press Enter after typing the text, or else the value will not be accepted.
11. Under AND..., select Is already selected.
12. Choose the ☑ button. The data of the selected points will be scanned and all points having an attribute R in the "Method tested" field will be selected; all the other selected points will be deselected.
13. Choose the ☒ button to close the dialog.

Editing the data

During data entry, an error was made which you will correct. The data will be edited with the *Data | Edit data* option of GGIS. The method found under this option displays a list of data types which could be available for the selected point, from which you select one. You may view and edit each value in the selected data type field.

To edit the data, select the option *Data | Edit data* from the menu. A list of data types will be displayed.

To view and edit the data for the selected point, do the following:

1. Under `DBF-file`, select `Water levels` (see Figure 7).
2. Choose the ☑ button. The `Data: Edit` window will appear, showing the first record for the selected point (see Figure 7).

Creating the graph

Pumping test graphs are visual presentations of pumping test data and calculations of hydraulic values. These analyses are specialised and it is therefore assumed that you are familiar with the various options and constraints used in the analysis of pumping test results.

Apart from the above, GGIS requires little input to produce a graph of a pumping test analysis. To do the analysis and create the graph, select the option *Analysis | Pump test* from the menu (see Figure 8).

To do the recovery analysis and create the graph, do the following:

1. Under `Point`, select `3319DC00210`. The pumping tests available for this point will be listed under `Pumping test`.
2. Under `Pumping test`, select `19850212 0900 (R)`.
3. Under `Analysis`, select `Recovery`.
4. Under `Graph color`, select a colour for the graph frame and text.
5. Under `Data color`, select a colour in which the data must be displayed.
6. Choose the ☑ button. In the command window, you will be asked the question `Is the aquifer confined? (y/n)`. Press N, then Enter. You will then be prompted in the command window to `Define the box` area in which the graph must be displayed. After indicating the size and position of the box on the screen, the graph will be displayed in that area.
7. Choose the ☒ button to close the dialog.

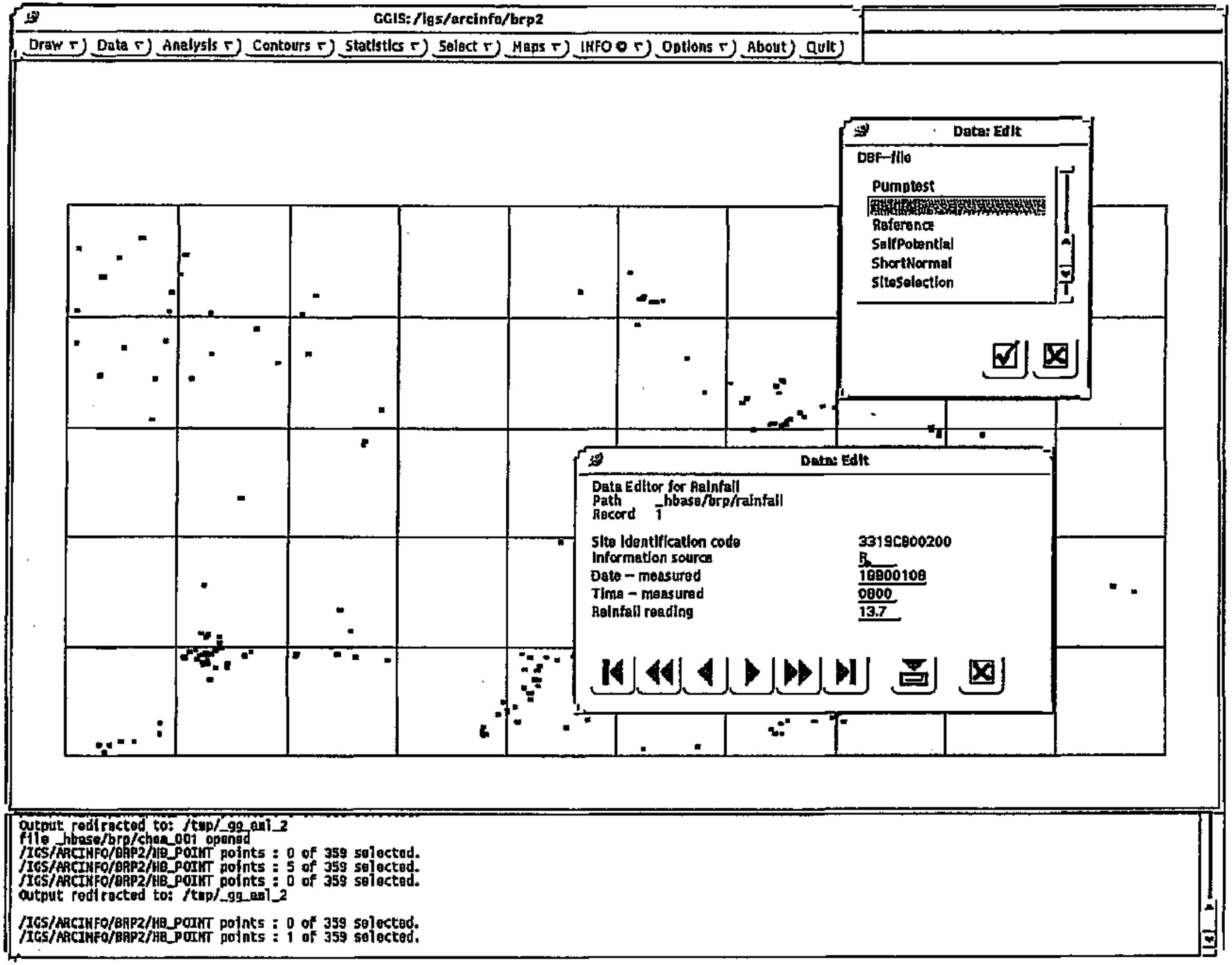

Figure 7. The data-edit dialog.

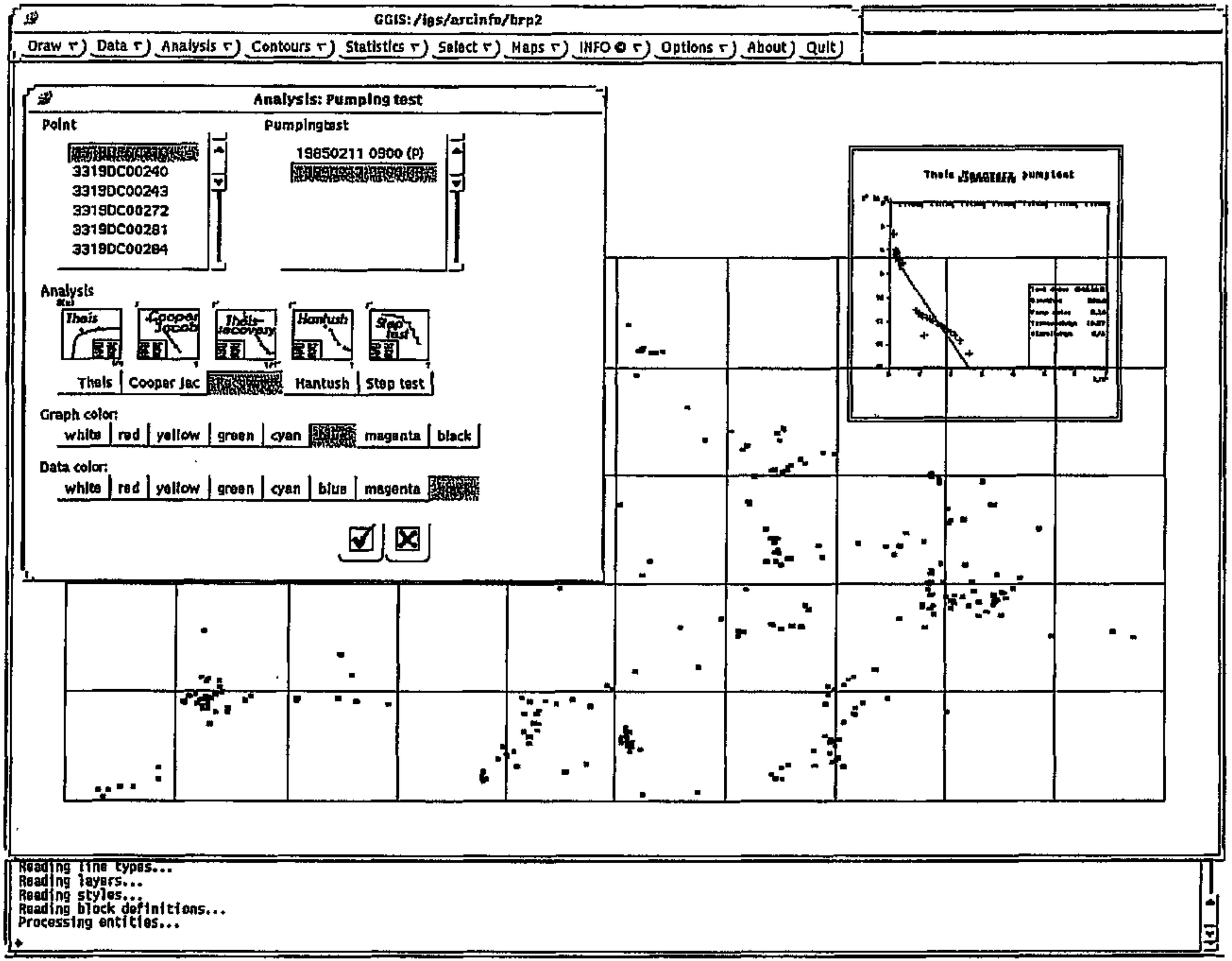

Figure 8. The pumping test dialog box.

☞ **Note**

For more information on topics covered in this lesson, see the following sections in the GGIS Reference Manual:

- *4.1.1 Using Select Special*
- *4.2.1 Maps | Data evaluation - Point information*
- *4.3.3 Graphs | Aquifer - Theis, Cooper-Jacob, Hantush, Step, Recovery*

Lesson 4: Generating a box plot

In this lesson, you will generate a box plot of water-level data from a selection of boreholes by doing the following:

- Find the data for the analysis using the *Select Special* feature of GGIS
- Generate the graph on the screen from the selected data

☞ **Note**

You must follow the instructions at the beginning of this tutorial under the Getting started *section before starting with this lesson.*

Finding the data

To find the water-level data that will be used for this lesson, select the option *Select | Select special* from the menu.

To determine which points to use for the graph, do the following:

1. Under `THE...`, select `No. of records`.
2. Under `OF DATAFILE`, select `Water levels`. The fields for the water-levels table will be displayed under `FOR FIELD`.
3. Under `FOR FIELD`, select the field `Water level measured`.
4. Under `IS...`, select the greater-than operator (>) and enter the value `10`. You must press Enter after typing the numbers, or else the value will not be accepted.
5. Under `AND...`, select `Reset selection`.
6. Choose the ☑ button. The data will be scanned and all points having more than 10 records of water-level data will be selected.
7. Choose the ☒ button to close the dialog

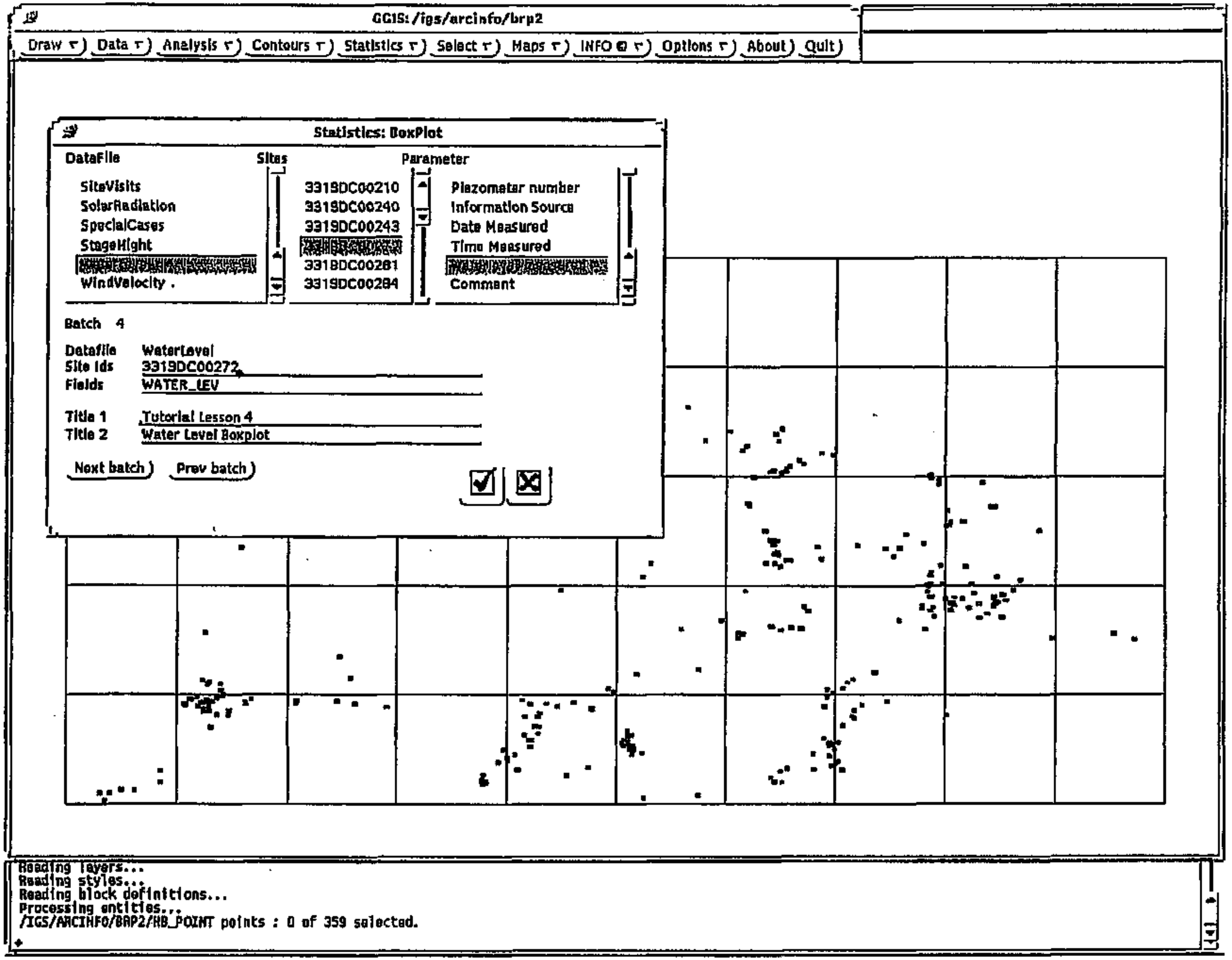

Figure 9. The boxplot dialog box.

Creating the graph

The box plot is a representation of a number of statistical operations done on the selected data sets, which are minimum and maximum values of the data set, mean value and the fourth-spread.

To do the statistical operation and create the graph, do the following (see Figure 9):

1. Under `Data file`, select `Water levels`. The water-level fields will now be listed under `Parameter`.
2. Under `Parameter`, select `Water level measured`.
3. Under `Sites`, select the first three sites. As you select them from the list, they will appear in the `Site ids` field.
4. Under `Title 1` and `Title 2`, enter a title and subtitle for the graph.
5. Choose the `Next batch` button.
6. Select all text in the `Site ids` field and delete it.
7. Under `Sites`, select three more sites. As you select them from the list, they will appear in the `Site ids` field.
8. Repeat steps 5, 6 and 7 once more.
9. Choose the ☑ button. The statistical calculations will be performed. You will be prompted in the command window to `Define the box` area in which the graph must be displayed. After indicating the size and position of the box on the screen, the graph will be displayed.

The diagram could appear on the screen as shown in Figure 10.

☞ **Note**

For more information on topics covered in this lesson, see the following sections in the GGIS Reference Manual:

- *4.1.1 Using Select Special*
- *4.3.3 Graphs | Statistics - Box plot, Trend analysis, Data specific*

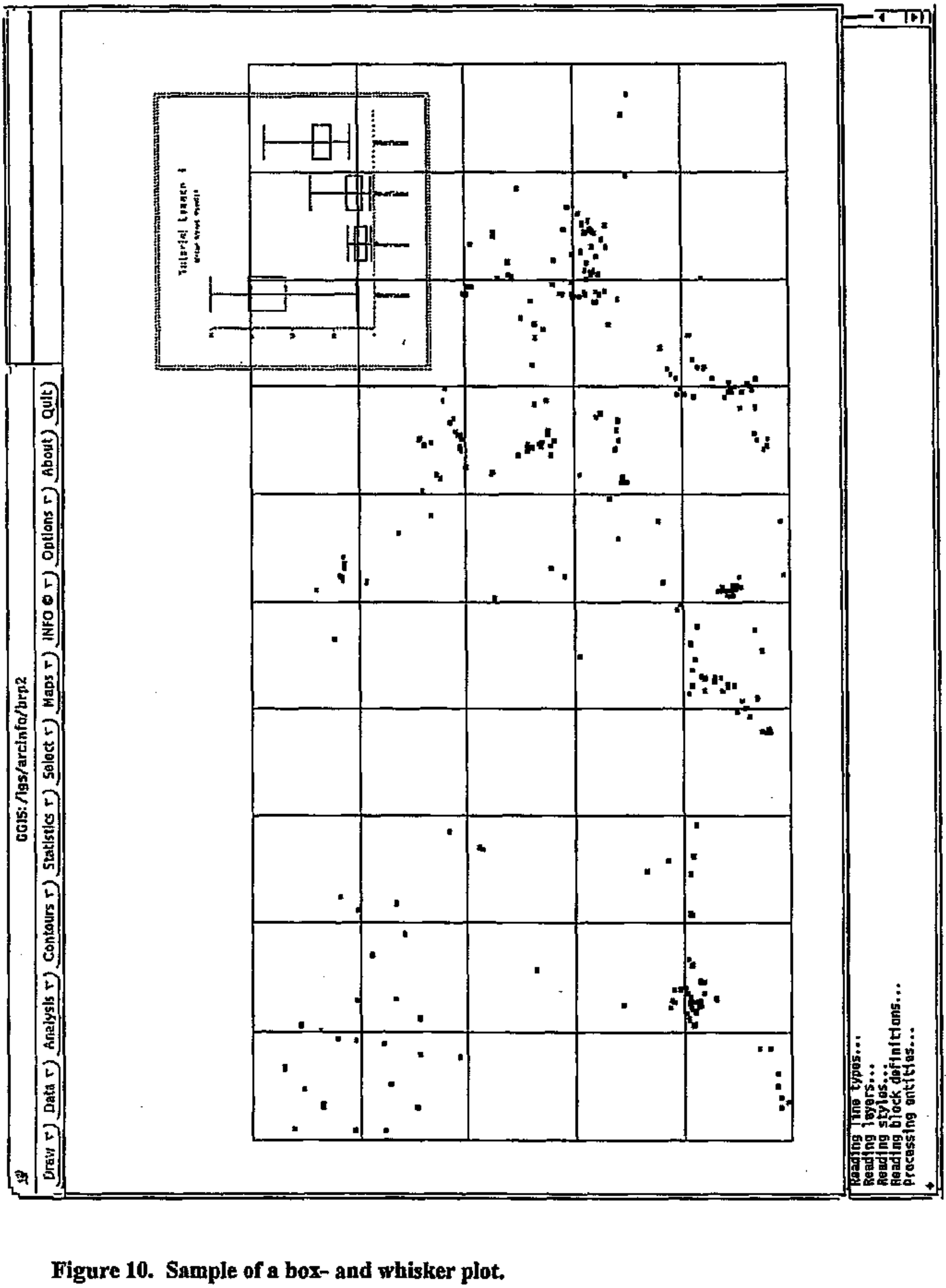

Figure 10. Sample of a box- and whisker plot.

Lesson 5: Generating contours from HydroCom data

In this lesson, you will use HydroBase data to generate contours of the borehole elevations by doing the following:

- Find the data for the contours using the *Select Special* feature of GGIS
- Generate the contours from the selected data
- Display the contours on the screen together with the grid and site id points

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☞ **Note**

You must follow the instructions at the beginning of this tutorial under the Getting started *section before starting with this lesson.*

Selecting the data

Contours can be generated from any numerical data in HydroBase, providing you with a powerful tool for analysis and presentation. For this tutorial, you will not look at specific data values, but you will determine which points to include in the contour map.

As some of the data do not have complete enough records for contour generation, you need to select valid points. To achieve this, select the option *Select | Select special* from the menu.

To determine which points will be included, do the following:

1. Under `THE...`, select `Value`.
2. Under `OF DATAFILE`, select `Basic Information`. The fields for the Basic Information table will be displayed under `FOR FIELD`.
3. Under `FOR FIELD`, select the field `Ground elevation` in the list.

4. Under `IS...`, select the greater-than-or-equal-to operator (>=) and enter the value `150`. You must press Enter after typing the numbers, or else the value will not be accepted.

5. Under `AND...`, select `Reset selection`.

6. Choose the ☑ button. The data will now be scanned and all points having a ground elevation greater than 150 will be selected.

To further limit the selection to points with valid ground elevations, do the following:

7. Under `IS...`, select the less-than-or-equal-to operator (<=) and enter the value `750`. You must press Enter after typing the numbers, or else the value will not be accepted.

8. Under `AND...`, select `Is already selected`.

9. Choose the ☑ button. The data of the selected points will now be scanned and all points having a value less than 750 for the Ground Elevation field will be selected, and all other selected points will be deselected.

10. Choose the ☒ button to close the dialog.

The selected points to be contoured will be highlighted.

Generating the contours

Generating contours involves two steps, namely assembling the data needed for the contour generation and generating the contours. During the assembly of the data, a number of statistical and other calculations can be performed on the selected data. When the data have been selected and before the contours are calculated, a number of parameters that will affect the contour calculations and results, may be changed.

For this lesson, the topography will be the subject of the contour calculations. To assemble the data, select the option *Contours | From HB data* from the menu (see dialog in Figure 11).

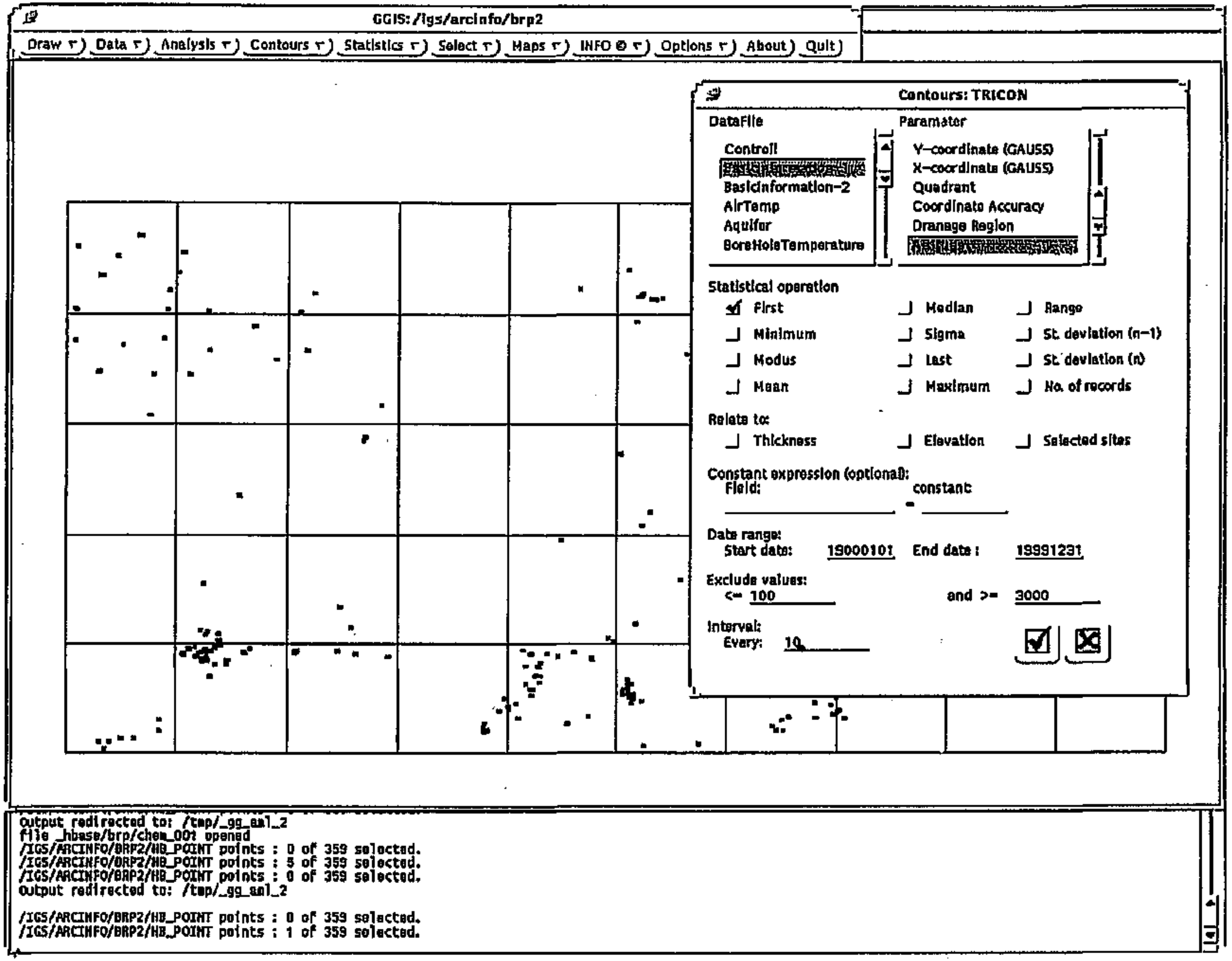

Figure 11. Create contours with HydroBase data.

To assemble and prepare the data for the contours, do the following:

1. Under `Data file`, select `Basic Information`. The fields for the Basic Information table will be displayed under `FOR FIELD`.
2. Under `FOR FIELD`, select the field `Ground elevation` in the list.
3. Under `Statistical operation`, select `First`.
4. Under `Relate to`, do **not** select anything.
5. Under `Constant expression`, do **not** enter anything.
6. Under `Date range`, leave the default dates of `19000101` and `19991231`.
7. Under `Exclude values`, enter `150` for <=, and enter `750` for >=.
8. Under `Interval`, enter `25`.
9. Choose the ☑ button. The ground elevations of all points in the specified range will now be extracted and prepared for further processing by TRICON, the contour generator.

TRICON will be activated automatically and will appear on screen as follows:

To generate the contours from the selected data, do the following:

1. Choose the `GIS_Input` button. From the resulting dialog, choose the `Create TRICON files` button. When this process has been completed, the dialog will be closed.
2. Choose the `Mesh_Construction` button. From the resulting dialog, choose the `Start mesh construction` button. When this process has been completed, the dialog will be closed.
3. Choose the `Contour_Computation` button. From the resulting dialog, choose the `Start contour computation` button. When this process has been completed, the dialog will be closed.
4. Choose the `Plotting...` button. From the resulting dialog, choose `GIS format` under `Output`, and then choose `Start plotting`. When this process has been completed, choose the `Quit` button to close the dialog.
5. Choose the `Quit` button to close the TRICON dialog.

(See Figure 12.)

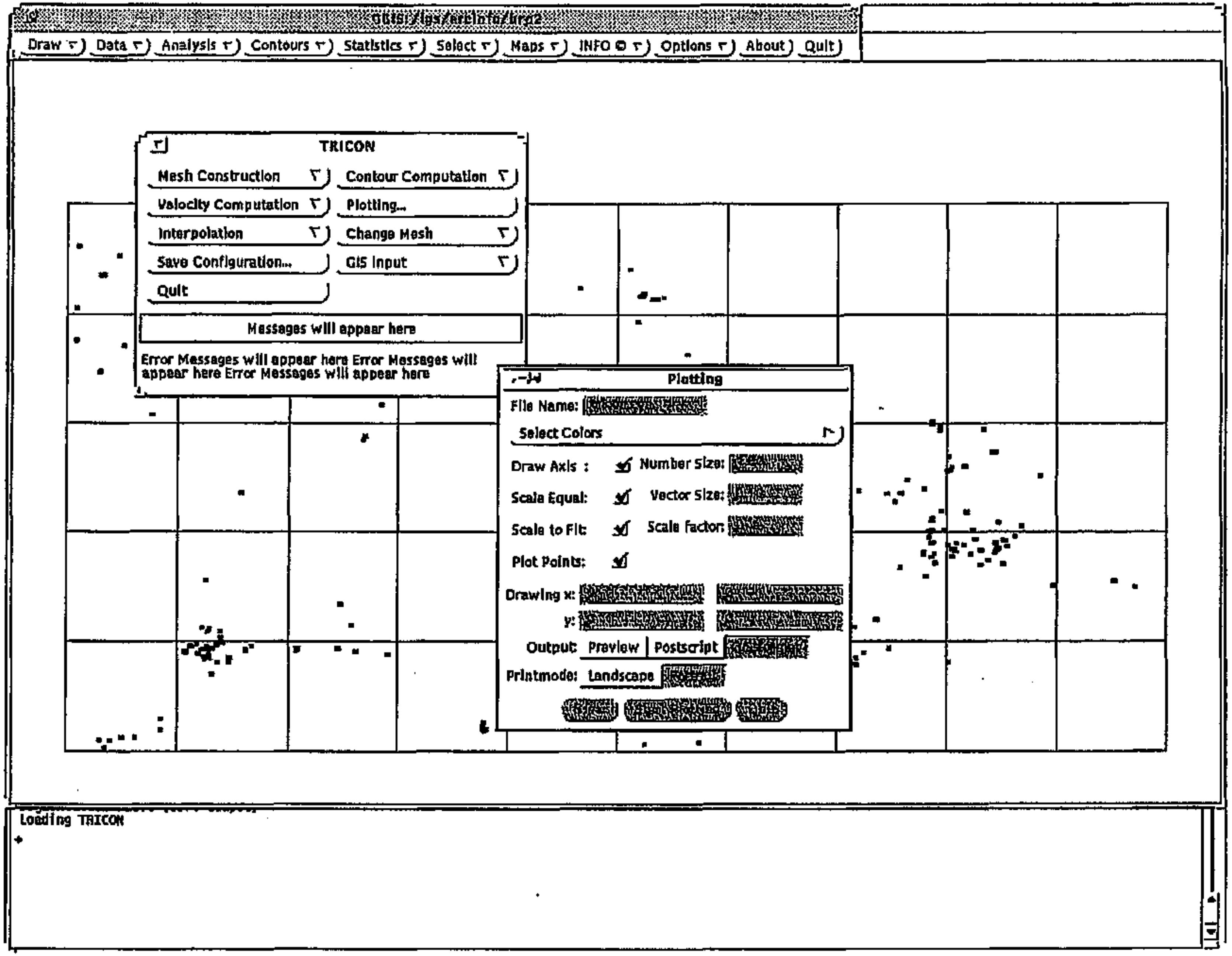

Figure 12. Tricon dialog.

You will be prompted to enter a contour coverage name. Enter the name `topo.con` and press Enter. Then select the ☑ button to start the contour generation process. A message will be displayed, indicating that GGIS is busy importing the TRICON data.

Displaying the results

In order to display the contours you have created, you need to select the coverage in which the contours were stored, in this case `topo.con`, and then select the contours you wish to display. For contrast, you may select an individual contour or groups of contours to display in different colours.. Text may also be added to the display to indicate the level (value) of the contour lines.

Select the option *Contours | Display contours* from the menu and a dialog will appear on the screen (see Figure 13).

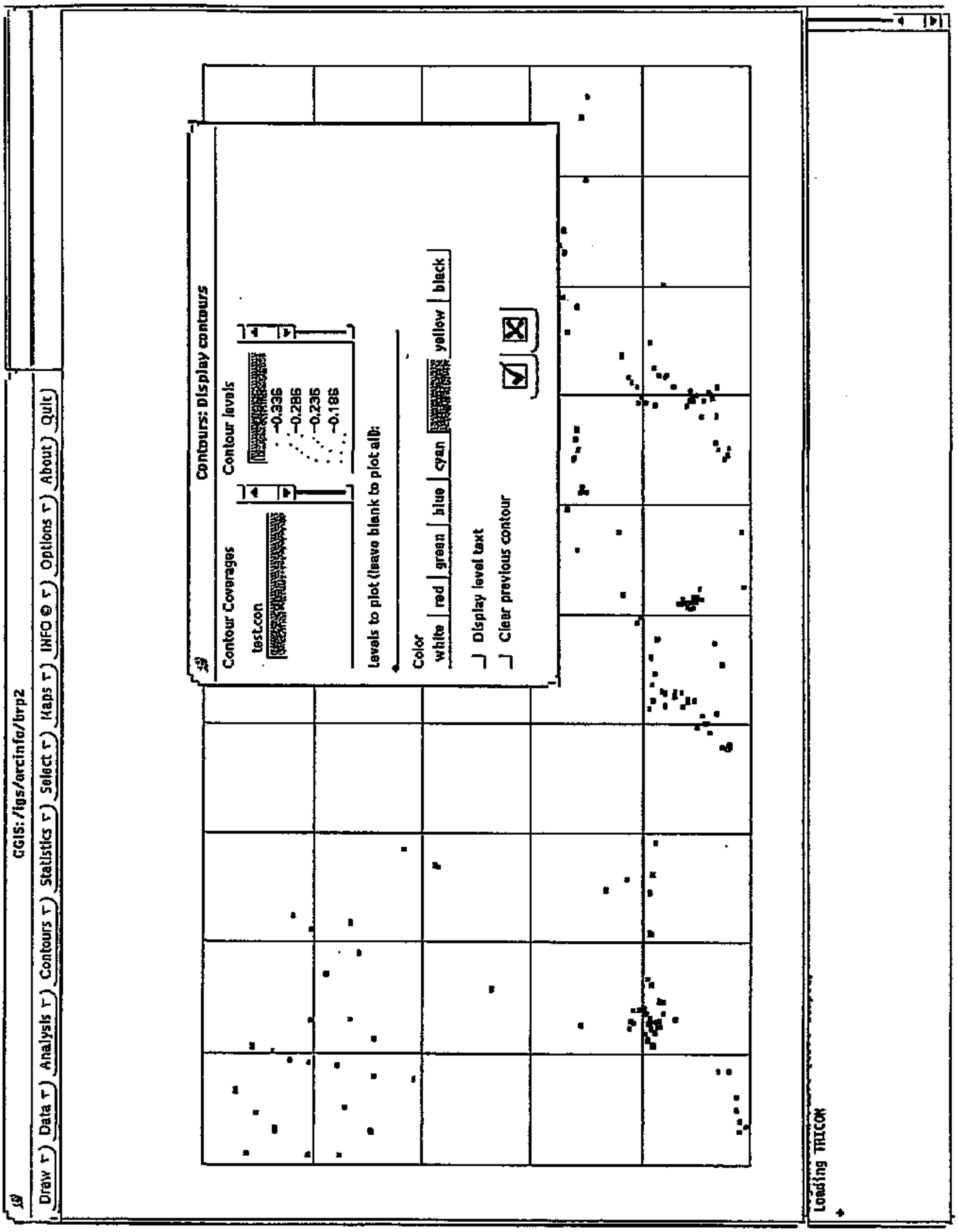

Figure 13. Display contours dialog.

To display the contours generated previously, do the following:

1. Under `Contour coverages`, select the `topo.con` coverage. The available contour levels will be displayed under `Contour levels`.
2. Under `Contour levels`, do **not** select any levels. This will have the effect that all levels will be displayed.
3. Under `Color`, select `Magenta`. This is the colour in which all the contours will be displayed.
4. Do **not** select `Display level text` or `Clear previous contour`.
5. Choose the ☑ button to display the contours. The dialog will remain on screen for further selection after the contours have been displayed.

To display the hundreds levels in a different colour, do the following:

6. Under `Contour levels`, select all the hundreds levels, e.g. `200`, `300`, `400`, etc. The values of the selected levels will appear under `Levels to plot`. You may, of course, also enter these values from the keyboard under `Levels to plot`.
7. Under `Color`, select `Yellow`. This is the colour in which all the selected contours will be displayed.
8. Select `Display level text`, but **not** `Clear previous contour`.
9. Choose the ☑ button to display the selected contours.
10. When that has been completed, choose the ☒ button to close the dialog.

The display could then appear as in Figure 14.

☞ **Note**

For more information on topics covered in this lesson, see the following sections in the GGIS Reference Manual:

- *4.1.1 Using Select Special*
- *4.2.2 Maps | Contours - Regional information*

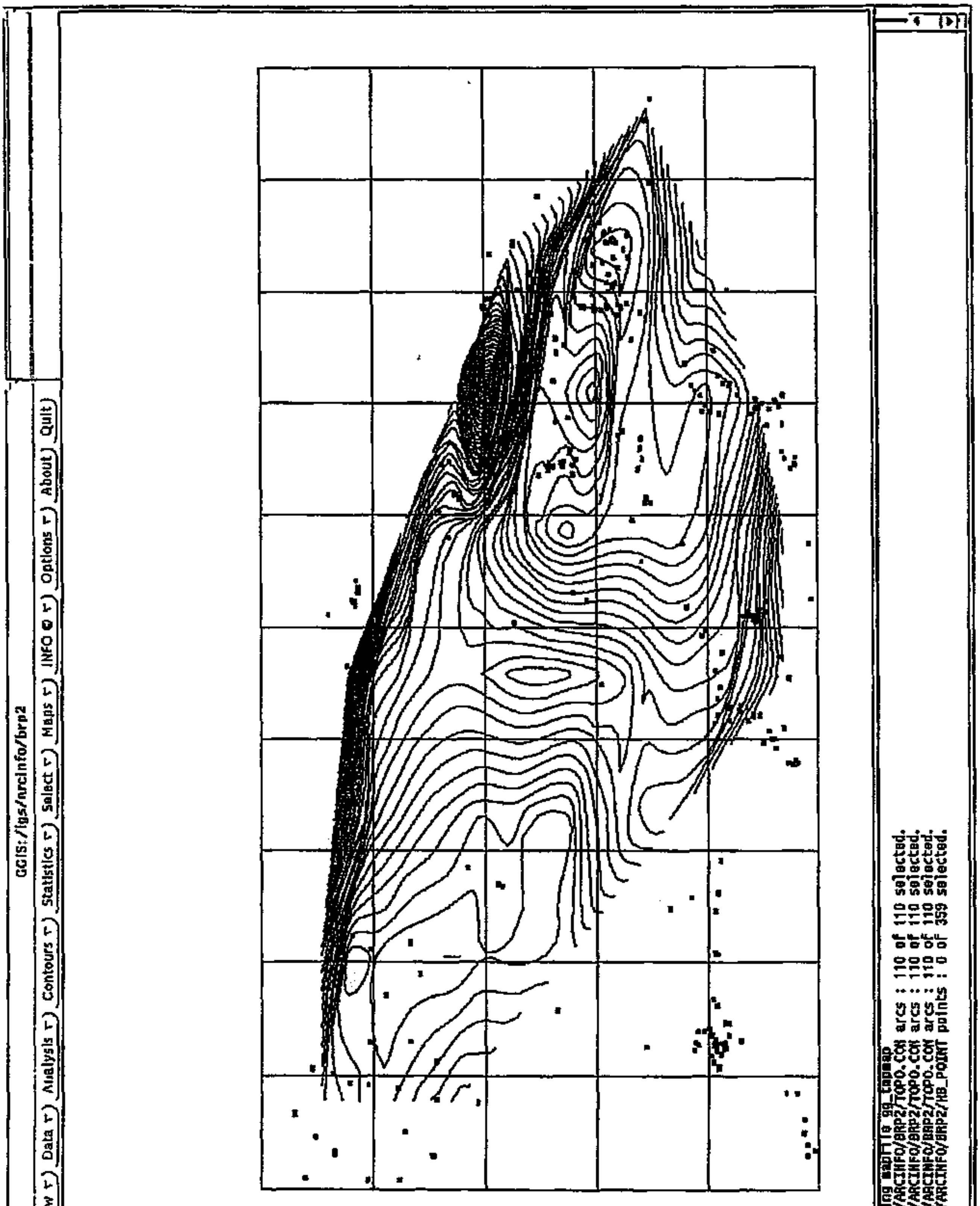

Figure 14. Sample of contours.

Lesson 6: Generating contours from aquifer modelling

In this lesson, you will set up a network for groundwater modelling and generate contours of the results by doing the following:

- Set up the network for modelling
- Generate the contours from the resulting data
- Display the contours on the screen together with the grid and site id points as well as the network nodes

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☞ ***Note***

You must follow the instructions at the beginning of this tutorial under the Getting started *section before starting with this lesson.*

Creating the network

GGIS provides you with a flexible and powerful method for setting up a network to your exact specifications. You may use point mode and/or polygon mode to specify the nodes and their hydraulic variables. After you have set up the network, GGIS will do the modelling with values you supply for the time step parameters.

Select the option *Contours* | *Create network* from the menu. The dialog shown in Figure 15 will appear on the screen.

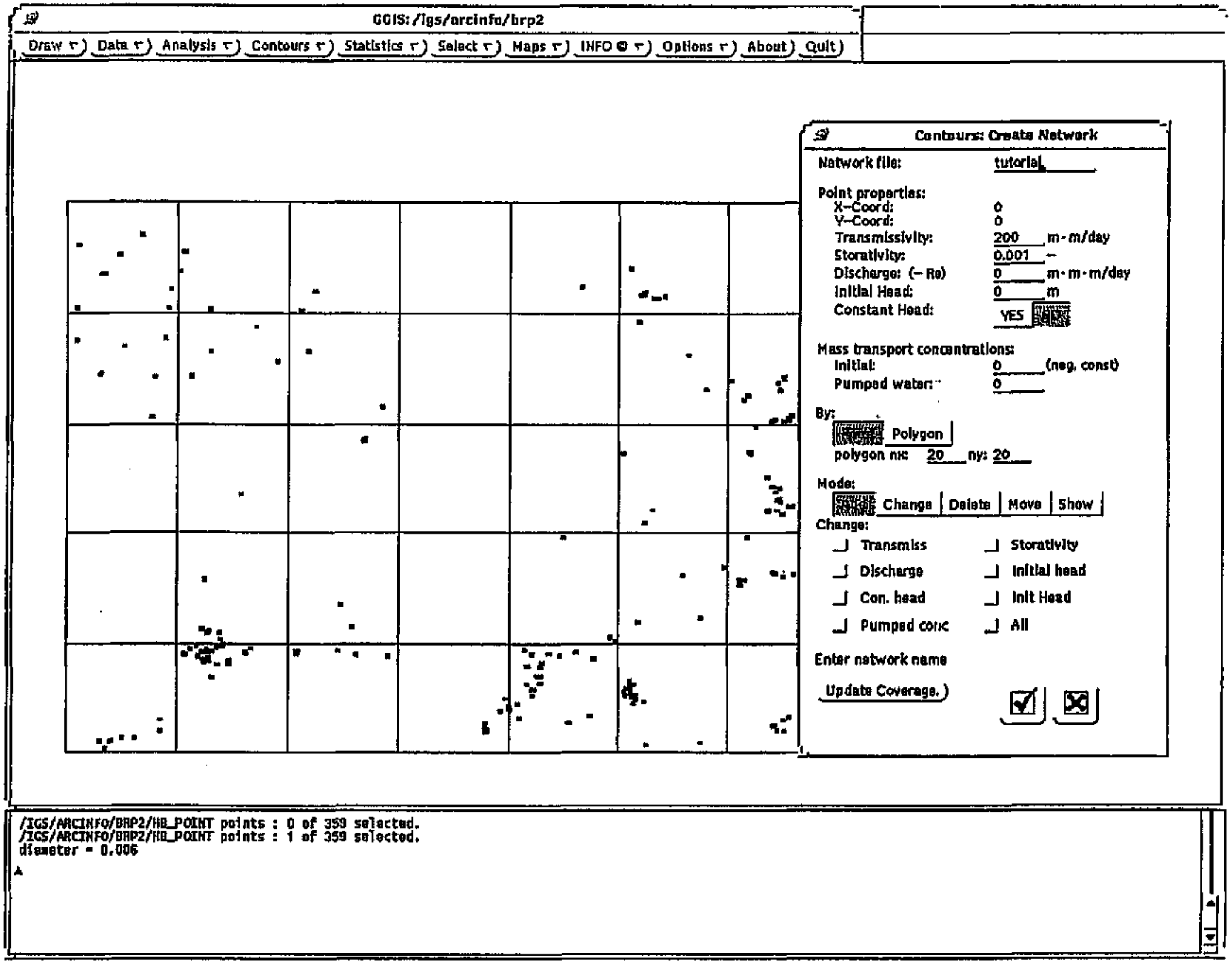

Figure 15. The create network dialog.

To set up and create the network, do the following:

1. Under `Network file`, enter the name `tutorial` and press Enter.

2. Under `Point properties`, enter the value `200` for `Transmissivity`, `0.001` for `Storativity`, `0` for `Discharge`, `0` for `Initial head` and select `NO` for `Constant head`.

3. Under `Mass transport concentrations`, enter `0` for `Initial` and `0` for `Pumped water`.

4. Under `By`, select `Polygon`, and enter `20` for both `polygon nx` and `polygon ny`. This is the maximum number of nodes for the polygon.

5. Under `Mode`, select `Add`. In the dialog, you will be prompted to `Indicate first point`. Indicate the bottom-left corner of the grid as the first point. You will then be prompted to `Indicate next point (MENU to close)`. Moving the cursor clockwise, draw the left, top and right sides of a rectangle which encloses all points. After indicating the endpoint of the right side, press the Menu button to close the rectangle.

6. Under `Point properties`, enter `2000` for `Discharge`.

7. Under `By`, select `Point`.

8. Under `Mode`, select `Add`. In the dialog, you will be prompted to `Indicate point`. Indicate a point in the upper-left quadrant of the area and another in the bottom-right quadrant, then press the Menu button.

9. Under `Point properties`, enter `1000` for `Discharge`.

10. Under `Mode`, select `Add`. In the dialog, you will be prompted to `Indicate point`. Indicate a point in the upper-right quadrant of the area and another in the bottom-left quadrant, then press the Menu button.

11. Choose the `Update coverage` button to add the nodes to the network coverage.

12. Choose the ☑ button to save the network set-up and close the dialog.

When the Modelling dialog appears on the screen, do the following:

13. Under `Modelling parameters`, enter `10` for `Number of time steps`, `1` for `Initial time step` and `1.2` for `Step increment`.

14. Choose the ☑ button to close the dialog and complete the modelling.

Generating the contours

After the modelling has been completed, a list of time steps will be displayed. Select the last one in the list. This data set will be passed to TRICON to be used for the calculation of the contours.

To generate the contours with TRICON, do the following:

1. Choose the `GIS_Input` button. On the resulting dialog, set the `Interval distance` to `0.1`, then choose the `Create TRICON files` button. When this process has been completed, the dialog will be closed.

2. Choose the `Mesh_Construction` button. From the resulting dialog, choose the `Start mesh construction` button. When this process has been completed, the dialog will be closed.

3. Choose the `Contour_Computation` button. From the resulting dialog, choose the `Start contour computation` button. When this process has been completed, the dialog will be closed.

4. Choose the `Plotting...` button. From the resulting dialog, choose `GIS format` under `Output`, and then choose `Start plotting`. When this process has been completed, choose the `Quit` button to close the dialog.

5. Choose the `Quit` button to close the TRICON dialog.

You will be prompted to enter a contour coverage name. Enter `modelling.con` and press Enter. Then select the ☑ button to start the contour generation process. A message will be displayed, indicating that GGIS is busy importing the TRICON data.

Displaying the results

To display the contours, select the option *Contours | Display contours* from the menu.

To display the contours generated previously, do the following:

1. Under `Contour coverages`, select the `modelling.con` coverage. The available contour levels will be displayed under `Contour levels`.
2. Under `Contour levels`, do **not** select any levels. This will have the effect that all levels will be displayed.
3. Under `Color`, select `Cyan`. This is the colour in which all the contours will be displayed.
4. Do **not** select `Display level text` or `Clear previous contour`.
5. Choose the ☑ button to display the contours. The dialog will remain on screen for further selection after the contours have been displayed.
6. Choose the ☒ button to close the dialog.

The display could then appear as in Figure 16.

☞ **Note**

For more information on topics covered in this lesson, see the following section in the GGIS Reference Manual:

- *4.2.2 Maps | Contours - Regional information*

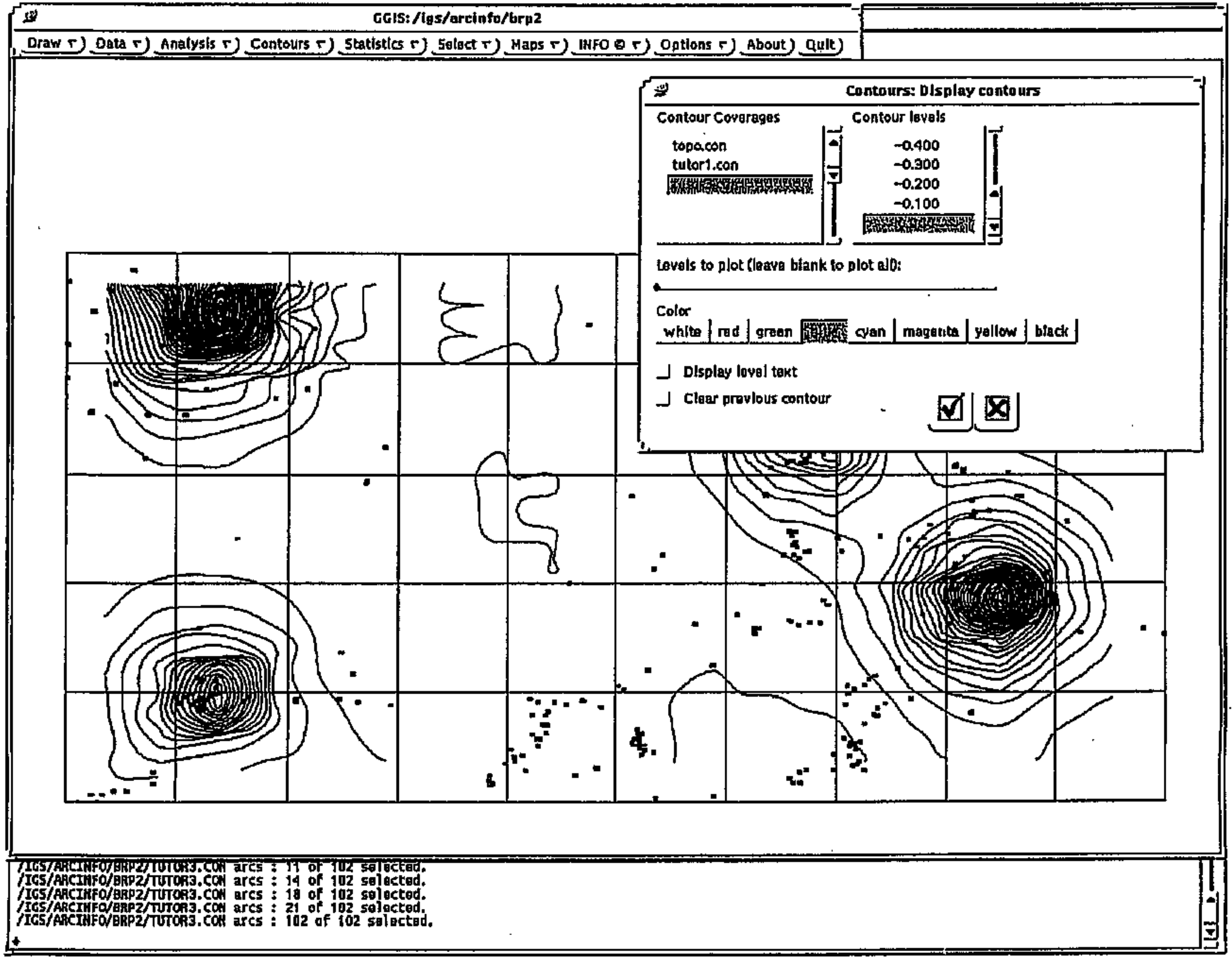

Figure 16. Contours displayed.