AGSO

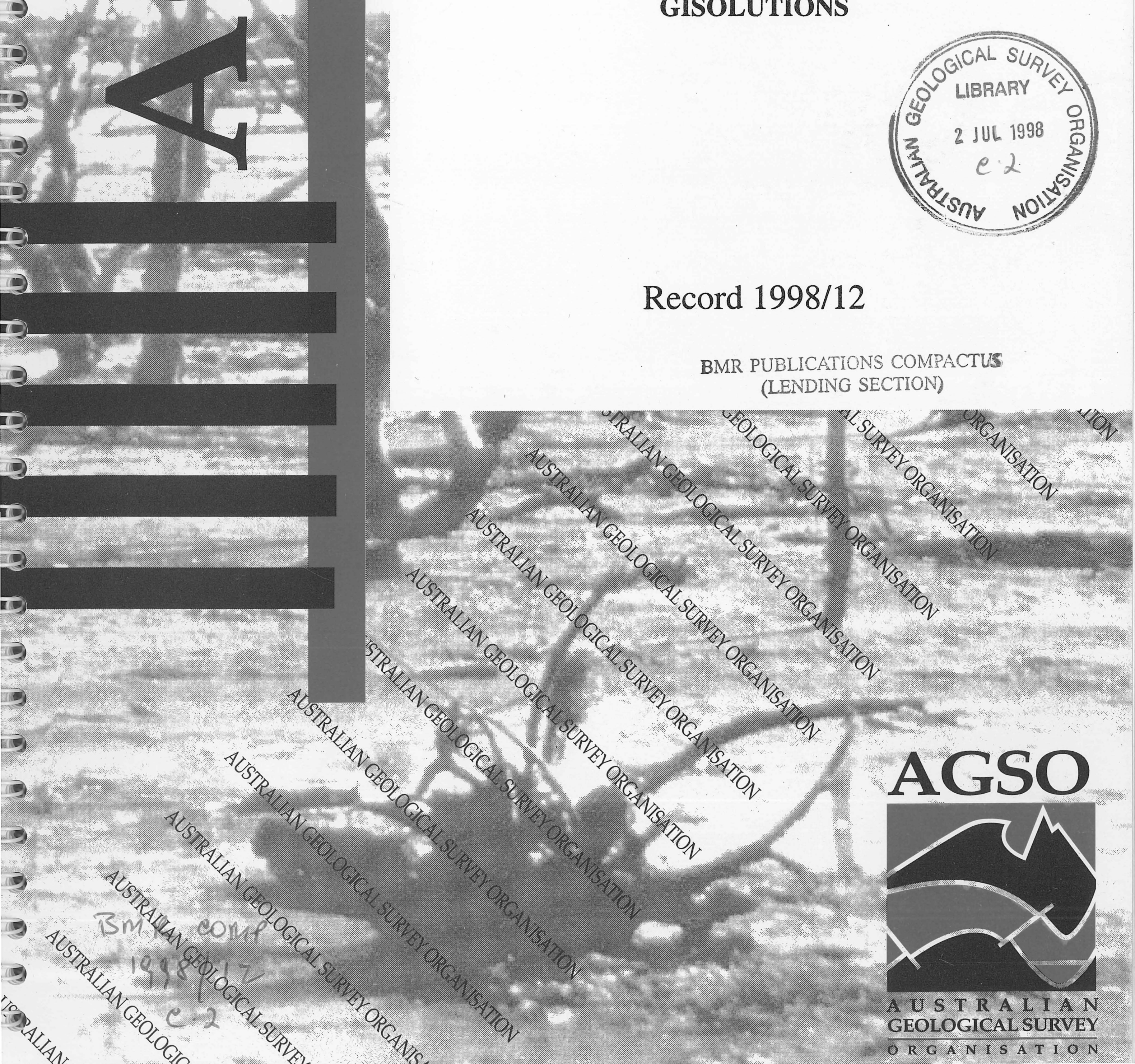
A NEW GIS EXTENSION FOR VISUALISING WATER BORE DATA AND OTHER TABULAR GEOLOGICAL DATA

by

Robyn Gallagher

GISOLUTIONS

Record 1998/12



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CONTENTS

ABSTRACT

A consultancy for AGSO has led to an extension being written for the GIS system ArcView3 which allows users to visualise and analyse water bore data, and also potentially other complex borehole data. It updates a previous extension for ArcView2 and includes new tools implemented via Avenue script. The borehole data model is a series of tables attached to points locating the bores, in the traditional 'one-to-many' situation. ArcView is able to use that data model, and some analysis tools implemented in Avenue script. The package is relevant in many geological situations, such as drillholes and field sampling programmes, where many pieces of information need to be associated with each point on the ground.

INTRODUCTION

In a consultancy for AGSO, an ArcView3 extension for visualising water bore data has been written by Robyn Gallagher in September, 1997. It updates a previous extension for ArcView2 (Gallagher, 1996) and includes new tools implemented via Avenue script. The consultancy was undertaken for the Western Water Study.

The Western Water Study (*Wiluraratja Kapi*) is attempting to improve water supply to Aboriginal lands in the arid zone of central Australia. It is a cooperative project between AGSO, the Northern Territory Department of Lands, Planning & Environment (DLPA), and the Central Land Council (CLC). A major task of the project is to link the information systems of the three organisations in an Arc/Info geographic information system for the pilot study area, the southwest NT, and to view the data using the simpler ArcView3 system (Wischusen et al., 1997).

The NT DLPA's newly-commissioned database of waterbore information HYDSYS is the source of stratigraphic and groundwater information for the Western Water Study. The data is accessible as dBase tables. This borehole data shares characteristics associated with many other geological data sets such as mineral deposits, drillholes, and field sample sites. The spatial data are represented as points on (or below) the ground, with other tables containing additional descriptive information linked to the points by some identifying field such as a sample or hole number. This linked information is measured many times for the same point either over depth intervals, over time, or for many different elements/commodities: a situation referred to in database theory as a **one-to-many** relationship.

Because one-to-many relationships are so common in geology, this extension implements a method for storing and using such data in ArcView3.

The software developed may be obtained on request from the project leader for the Western Water Study, Gerry Jacobson, at the Australian Geological Survey Organisation.

The Data Model

The borehole **spatial data** must be stored as points in a form recognised by ArcView (an Arc/Info coverage, an event theme or a shapefile) then loaded into an ArcView view as a theme with an appropriate name (I use *bores* in my ArcView demonstration and in this report). The points must have at least two attributes: the identifier used to link the points to the relevant information in other tables; and an elevation value. These attributes will be visible in a table which ArcView names Attributes of theme (eg *Attributes of bores*).

The **other tables** should be in a format useable by ArcView: dBase4 is the most convenient format since that is ArcView's native format; INFO is a possibility; CSV text has some reduced functionality in ArcView; Access, Oracle etc are possible, but the user must make them visible to ArcView. The tables should be added to an ArcView project, and given meaningful names (eg *borehole geology, borehole stratigraphy, borehole water quality*). Each of these tables must contain a field, such as a hole identifier, which links records in the table back to the borehole points: it may have a different name in each table, and a different name to the field in the point attribute table.

Setting up the Data Model in ArcView

Information about the theme and its tables is communicated to ArcView via **a text file**, which can be created using any editor. The file contains a very simple description of the data model, and ArcView stores the information it contains for use in all of the new tools which work on one-to-many data.
The text file contains one line for the theme, and one line for each of the linked tables. The information it stores is the following:

view name, theme name, link field, elevation field, SWL field
table name1, table type 1, link field1, from field1, to field1, label field1
table name2, table type 2, link field2, from field2, to field2, label field2
.
.
table name n, table type n, link field n, from field n, to field n, label field n

where
view name is the name of the view containing the theme
theme name is the name of the theme
link field is the field used to link the point to information in other tables
elevation field is the field containing the elevation of the point
SWL field is the field containing standing water level (or "none")

table name is the name of a linked (one-to-many) table
table type is a code for the type of the table:
1 the table contains information which is measured over depth
2 the table contains information which is measured over time
link field is the field in that table containing an identifier which corresponds to the link field of the point
from field is the name of the field in the linked table containing the starting depth or the date of measurement
to field is the name of the field in the linked table containing the end depth or the time of measurement
label field is any field in the linked table to be used for labelling intervals in some of the tools

The following is an example of such a text file:

```
View1,bores,rego_no,elev_ahd,bed_swl
borehole geology,1,reg_no,from,to,rock_type
borehole stratigraphy,1,reg_no,from,to,symbol
borehole drillers log,1,rego_no,lith_from,lith_to,lith_desc
borehole water quality,2,station,date,time,date
borehole drill,1,rego_no,drl_from,drl_to,drl_type
borehole casing,1,rego_no,cas_from,cas_to,cas_type
borehole screens,1,rego_no,scr_from,scr_to,scr_type
borehole water cuts,1,rego_no,bed_from,bed_to,bed_ph
```

An Avenue script, called *WWS.GenericSetupLinks,* is used to read the data model file and store its contents as a list of lists within the project. It is not attached to a button, as the script only needs to be used when the data model is created or modified.

The One-to-Many Tools

Once a data model has been stored in a project's Object Tag, it is available via a number of utilities. Six of these utilities are in the *WWS Utilities* Menu, and four are in the Tool Bar. Following ArcView convention the utilities in the Tool Bar require some user interaction with the theme in the view, whereas the utilities in the Menu operate on the currently selected set of features, or all features if none are selected.

Most of the utilities require the user to pick which linked table is to be used for the current operation of the tool. A list of tables, extracted from the data model, is presented when a tool button is selected with the mouse, so that the user can choose a table. The tool continues to operate on that table until a tool button is clicked again to allow the user to choose a different table. Some tools may optionally operate on the attribute table of the theme instead of on a one-to-many table.

Menu Utilities

Cross-section Shapefile

This tool creates a polygon shape file representing a cross-section for a line of bores. It is not a true cross-section in that the intervals are not joined between bores. The intervals down each hole are represented as rectangular boxes.

The tool operates on the current selected set of bores. If there are no bores selected, nothing happens. Bores may be selected using any of the standard ArcView tools: spatially with the mouse; using the query builder; or by pointing at required bore identifiers in the bore attribute table.

As with all tools, the user must pick which linked table is to be represented. He must also pick the bore which marks the start of the cross-section line, and the bore which marks its end, by selecting bore identifiers from a list. In the first case, the bore identifiers are presented so that the default will be the one furthest to the west; in the second case the default will be the one furthest to the east.

When the user has picked the end bores, the cross-section is along a line between them, with all other bore positions projected onto this line. A vertical exaggeration, greater than 1, may be supplied by the user.

Each interval down each hole is represented in the shapefile as a rectangular polygon, with all the interval attributes from the linked table joined to it.
This means the shapefile can be loaded as a theme in a view, then coloured using the Legend Editor or labelled using ArcView's labelling tools.

Water Beds Shapefile

This tool creates a polyline shape file representing water cuts for a line of bores. It is designed to create a data set to be used with the cross-section shape files from the *Cross-section Shapefile* tool.

The tool operates on the current selected set of bores. If there are no bores selected, nothing happens. Bores may be selected using any of the standard ArcView tools: spatially with the mouse; using the query builder; or by pointing at required bore identifiers in the bore attribute table.

The user must pick which linked table contains the water beds. He must also pick the bore which marks the start of the cross-section line, and the bore which marks its end, by selecting bore identifiers from a list. In the first case, the bore identifiers are presented so that the default will be the one furthest to the west; in the second case the default will be the one furthest to the east.

When the user has picked the end bores, the water beds cross-section is along a line between them, with all other bore positions projected onto this line. A vertical exaggeration, greater than 1, may be supplied by the user.

If this data set is to be used with a cross-section shape file, the user must create it with exactly the same bores and vertical exaggeration!!

For each hole, a line is created to mark the SWL in the main theme table, if it exists and is non-zero. That line only has one non-empty attribute - the bore identifier. Also, any water cuts for a hole are represented as horizontal lines at the appropriate depths. Those lines have all of the attributes copied from the entry in the water beds table.

The shapefile can be loaded as a theme in a view, then coloured using the Legend Editor or labelled using ArcView's labelling tools.

Add Rulers

This utility draws horizontal and vertical rulers as graphics on a view. It is designed mainly for putting measurements on cross-section views.
It uses the extent of the first active theme to determine the extent of the rulers, but prompts the user for the spacing of tics in the x and y directions as well as the vertical exaggeration. That vertical exaggeration must correspond to the one used to make the cross-section, if it is not 1.

A vertical ruler is drawn down the left side of the view and a horizontal ruler is drawn along the bottom, with divisions and labels as specified by the user.

Four graphic objects are created: the vertical axis, the labels on the vertical axis, the horizontal axis and the labels on the horizontal axis. The position or size of the labels may not be satisfactory, but the user can select the group and re-size or re-position it easily.

Calculate Reduced

This utility calculates a value for each selected feature, or for all features if none are selected, by reducing the depth of some chosen feature (eg SWL or the bottom of Cainozoic stratigraphy) by the bore elevation. The values are stored in a new table which has one record for each feature, and may be joined back to the bore theme table using the link field specified in the model.

The table used for this calculation may be any of the linked tables, or the main bore attribute table. A selection must be made from the list of available tables.

If the main bore attribute table is picked, the user must simply choose a numeric field in that table (eg *bed_swl*) for use in the calculation. If a one-to-many linked table is chosen, the user must construct a query which defines the records in that table which are to be used (eg *era = "CAINOZOIC"*). The tool finds the greatest value of the "to field" (ie the bottom of the deepest interval) for each selected bore, where a record satisfies the query, and calculates its reduced value.

Calculate Thickness

This utility is similar in operation to the preceding one in that it also calculates a value for each selected feature, or for all features if none are selected. The numeric value calculated is the depth or thickness of some chosen feature (eg depth of SWL or the thickness of Cainozoic stratigraphy). The values are stored in a new table which has one record for each feature, and may be joined back to the bore theme table using the link field specified in the model.
The table used for this calculation may be any of the linked tables, or the main bore attribute table. A selection must be made from the list of available tables.

If the main bore attribute table is picked, the user must simply choose a numeric field in that table (eg *bed_swl*) whose value is plotted. If a one-to-many linked table is chosen, the user must construct a query which defines the records in that table which are to be used (eg *era = "CAINOZOIC"*). The tool finds the difference between the greatest value of the "to field" and the smallest value of the "from field" for each selected bore, where a record satisfies the query, and plots that thickness.

Calculate Most Recent

This utility only operates on linked tables with a date and time field (type 2). It calculates a value for each selected feature, or for all features if none are selected, which is taken from the record in the linked table with the most recent date. If more than one record at any point has the same date, the time field determines 'most recent'.

The user must select a table from a list of all tables containing a date field.

The calculated values are stored in a new table which has one record for each feature, and may be joined back to the bore theme table using the link field specified in the model.

Main Aquifer

This utility derives a one-to-one table of 'main aquifers' for selected bores. Because it is quite slow, it only operates if there is a selected set imposed on the theme (that selected set may be all the bores, but the user must explicitly select them).

The main aquifer of a bore is defined as the stratigraphic unit (ie the record of the stratigraphy table) which is intersected by the water bed with the lowest (non-zero) ec value.

The user is presented with a list of all linked tables, so that he can select the table of water beds, then with a list of the numeric fields of that table so that he can select the field containing the ec value.

A second picklist of tables is presented for the user to select the stratigraphy table.

Finally, the user must nominate the name of the (dBase) table which will be created to hold the main aquifers. By default it will be called *aquifers.dbf*. The table has fields containing the bore identifier, the "from field" and "ec field" of the water beds table, and all fields from the stratigraphy table.

For each selected bore, the entry in the water beds table with the lowest (non-zero) ec value is found: the starting depth of the interval (or the end depth if the starting depth is zero) is recorded. Then the interval in the stratigraphy table which contains that depth is found, and this record is the main aquifer.

Whenever a bore has such an entry in the stratigraphy table, a main aquifer entry is created for it in the output table.

Tools

Information

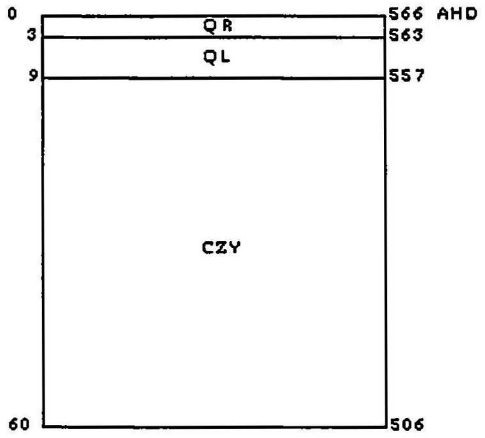
This tool is just like the existing ArcView Information Tool, except that it also displays records from a linked table. When a user points to a theme feature with the mouse, the visible fields in the theme attribute table, and all entries in the linked table for that point, appear in an expanded Information window. The main entry appears first in the lefthand side of the window, followed by an entry for each "many" record, titled with its "link field" and "from field" entry. The user can pick any of these entries, to see it in full in the righthand window.

Draw Information

This tool draws a picture of the Information for a feature, instead of listing fields from its tables. If there is no information in a linked table for a given feature, nothing is drawn.

For tables of type 1 (those containing depth intervals), this results in a simple downhole log, drawn in a temporary pop-up graphics window. The contents of the log depend on the linked table selected by the user when the tool is invoked. When a user points to a theme feature with the mouse, the data model information is used to find the "from field" and "to field" of the linked table for drawing downhole intervals, as well as the "label field" for labelling them. The drawings are temporary - when a window's pin is pulled it is deleted.

Here is an example of a drawing:



For tables of type 2 (those containing date and time), a time series graph is drawn in a temporary pop-up graphics window. The contents of the graph are determined when the user picks an additional numeric field to be graphed. When a user points to a theme feature with the mouse, the data model information is used to find the "date" and "time" fields of the linked table.

The time series picture is a simple bar graph showing the value of the nominated field for each different value of date+time. The drawings are temporary - when a window's pin is pulled it is deleted. If the time series can be created just for "date", **Charts** create much more useful documents than this simple drawing.

Select Many

This tool is almost identical to the standard ArcView Spatial Selection Tool, which already makes use of any linked tables. This version of the tool simply ensures that the linked table is open, with its selected records promoted to the top.

Super Bore Picture

This tool draws all available information for a bore. The picture and text are drawn in a temporary pop-up graphics window, which is deleted when the window's pin is pulled.

The information about the bore is accessed by finding the link and depth fields for each table from the data model stored in the project's Object Tag. If a bore has no information in any of the linked tables, the space for that information is empty in the bore picture.

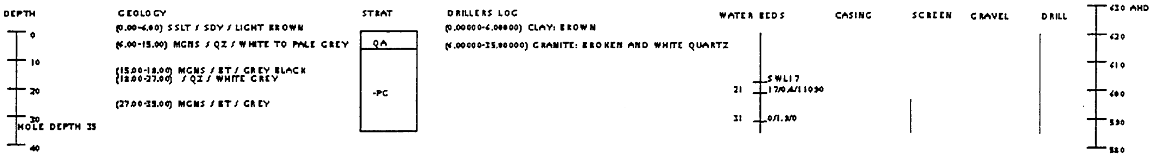
From the lefthand side of the picture the following information is presented for each depth interval where it is available:
* a 'ruler' measuring depth downhole, with a marker for hole depth
* text information about rock type, description and colour from the geology table
* a block diagram of units from the stratigraphy table
* text information about lithology from the driller's log
* a marker for SWL from the main bore table, and swl/yield/ec values for points down the hole from the water beds table
* casing intervals and diameters, colour-coded for casing type
* screen intervals, colour-coded for screen type
* gravel intervals, colour-coded for gravel type
* drill intervals, colour-coded for drill type
* a 'ruler' marking reduced AHD downhole.

Colour-coding for casing, screen, gravel and drill types is:

type:	colour:	type:	colour:
0	black	1	red
2	green	3	blue
4	yellow	5	cyan
6	magenta		

This tool makes no effort to resolve situations where pieces of information overlap on the drawing. To make a better cartographic product graphic text and objects may be selected, moved or re-sized.

Here is an example of a super bore picture:


DEPTH
0
10
20
30
HOLE DEPTH 35
40
GEOLOGY
(0.00-6.00) SSLT / SDY / LIGHT BROWN
(6.00-15.00) MGNS / QZ / WHITE TO PALE GREY
(15.00-18.00) MGNS / BT / GREY BLACK
(18.00-27.00) / QZ / WHITE GREY
(27.00-35.00) MGNS / BT / GREY
STRAT
QA
-PC
DRILLERS LOG
(0.00000-6.00000) CLAY: BROWN
(6.00000-35.00000) GRANITE: BROKEN AND WHITE QUARTZ
WATER BEDS
SWL17
21
17/04/11030
31
0/1.3/0
CASING
SCREEN
GRAVEL
DRILL
630 AHD
620
610
600
590
580

General Utilities

Create a Color Palette (an option in the Window menu)

This tool really has two parts: an Arc/Info AML which writes the RGB components of a shadeset to an ASCII file; and an ArcView utility which reads that ASCII file and creates a color palette. However the ArcView utility will read any ASCII file of the correct format, no matter how it was created.

By default, ArcView reads Arc/Info shadesets as fill palettes, not color palettes, hence the need for this utility.

The AML utility is very simple. It must be run from Arcplot:
&run write_shades <shadeset> <no_symbols> {filename}
The arguments are the name of the shadeset (e.g. *agso94*), the number of symbols to be considered (max 999), and optionally the name of the ASCII file. If that name is omitted, the file will be named from the shadeset, with *.txt* extension.

This utility ONLY works for shadesets defined via RGB or CMYK, NOT those like *colornames* which vary from device to device, and for which Arcplot is unable to return the colour components.

The ASCII file it creates contains one record per shade symbol, where that record contains 3 values representing the Red, Green and Blue components of the symbol, each separated by a blank character.

The ArcView utility prompts the user for the name of the ASCII file described above (which must have a *.txt* extension) and the name of the output palette, which receives a *.avp* extension. It creates an ODB file which is available for the user to load into ArcView via the Palette Manager, just like other available palettes. The utility does NOT load the palette.

Colour theme with LUT

This tool mimics Arc/Info's ability to symbolise a data set using a lookup table (LUT) which maps field values to symbol numbers. It is intended for colouring themes such as geology, when large amounts of time have been invested creating Arc/Info LUT's.

The tool uses the **current color palette**: the user must have already loaded the correct palette.

The utility expects the View to have one active theme, on which it operates. The user is prompted for the field in the theme table on which the legend is to be based (e.g. *map_symbol, polylabel, igds-text*), then the name of the lookup table. The LUT must contain a field with the same name as that just specified in the theme table. The user must pick an integer field in the LUT which contains the symbol number (e.g. *symbol*). Optionally, it is possible to pick a field in the LUT to be used for the legend labels (Cancel = label with the field on which the legend is based) and a field in the LUT to be used to sort the legend (e.g. *age*, Cancel = don't sort).

The theme is classified uniquely on the field picked for the legend, then the LUT is used to set the colour of each different feature by finding the symbol corresponding to each classification.

NOTE this utility assumes a symbol numbering from 1 (just like ArcInfo), because we assume a transparent symbol in the first Color Palette location in ArcView (symbol no 0). Watch out ... you might be one colour out !!

Delete themes and theme tables

This utility is a modified version of the View-Edit-Delete Themes menu item. For each theme to be deleted from the View, it looks for all table documents called "Attributes of ..." (ie the theme tables) and deletes them from the project as well.

The Extension

The extension is called *wws.avx* (Western Water Study). It is created using a project called *make_wws_extn.apr*, which contains the Avenue code for all of the utilities, as well as a script which creates the extension file. All of the Avenue scripts begin with the name *WWS*.

The Scripts

WWS.SetupLinks

This script is used whenever a new one-to-many data model must be added to a project, or if a data model is changed.

It presents the user with a browser for choosing the name of the text file containing the data model, and reads that file. Each record (line) in the file is stored as a list of strings, for example the first line of the file described above becomes {"View1","bores","rego_no","elev_ahd","bed_swl"}.

All of those lists are put into another list. This list of lists is stored in the Object Tag of the Project GUI. This is done because Object Tags are persistent, ie are saved with the project, so are available whenever the project is opened. It avoids having to read the text file each time the project is used.

The script also clears and resets all links between the theme and the related one-to-many tables. Links are persistent in a project so this process only needs to be carried out when the data model is created or altered.

While reading the text file, the script checks for the existence of the tables and fields referred to in the file. If any object does not exist in the project, the script stops with an error message.

WWS.BoreSelectTable

This script is attached to a Click event for the three utilities in the ToolBar. It allows the user to pick which linked table is to be used for the tool. It is also run from many of the Menu utilities.
The script retrieves the data model from where it is stored as a list of lists in the Object Tag of the Project GUI. From this information it constructs a list of available linked tables which can be presented to the user in a MsgBox window.

When the user has picked a table, a pointer to it is made available to the tool scripts via a global variable called *_codeno.*

WWS.BoreSelectTable2

This script allows a user to pick which linked table of type 2 is to be used for a tool. It is used for utilities like Calculate Most Recent, which operate only on tables containing a date field.

The script functions similarly to *WWS.BoreSelectTable*, except that it constructs a list containing only type 2 tables.

WWS.IdMany

This script is derived from the View.Identify script provided with ArcView. It is the Apply script for the new Information Tool.

The script enlarges the Identify window to allow easier viewing of the listed information.

It retrieves data model information for the relevant linked table from the ObjectTag of the project, using global variable _codeno.

The tool reports on all bores within a circle of one pixel radius around the location pointed to by the mouse. The information in the bore's attribute table is posted in the Identify window, then all entries in the linked table for that bore are found and listed, differentiated by the value in the "from field".

This script uses some temporary table selections, so on conclusion all the table selections are reset to their status on entry to the script.

WWS.DrawInformation

This is the Apply script for the Draw Information Tool.

It retrieves data model information for the relevant linked table from the Object Tag of the project, using global variable _codeno.

The tool draws pictures of all bores within a circle of one pixel radius around the location pointed to by the mouse. Each picture is created in the graphics layer of a new temporary View named from the linked table, the bore "link field" and the "label field". These views have a RemoveDoc(SELF) shutdown script so that each is deleted when its pin is pulled.

The contents of the picture depend on the type of the table: type1 tables contain depth information so a downhole picture is created; type2 tables contain information measured over time, so a time series graph is created.

To draw a downhole picture, the script extracts the elevation of the bore from its attribute table, then finds all entries in the linked table for the bore. Depth labels are constructed using the "from field" and the "to field" of each record, and the value of the "label field" is placed as the interval label. Each downhole interval is represented as a rectangle with a label at its centre; depth labels are placed to the left of the column; elevation AHD is placed to the right..

The time series picture requires the user to nominate an additional numeric field to be graphed. All entries for the bore in the linked table are graphed, even those with zero values of the variable. A simple bar graph is created, each data marker being labelled with the date ("from field") and time ("to field") corresponding to the reading.

This script uses some temporary table selections, so on conclusion all the table selections are reset to their status on entry to the script.

WWS.SelMany

This script is derived from the View.SelectPoint script provided with ArcView. It is the Apply script for the new Select Many Tool.

It retrieves data model information for the relevant linked table from the Object Tag in the project GUI, using global variable _codeno.

Selection is done by pointing at a single feature with the mouse, or by drawing a box. If the shift key is held down, the selected features are added to the current selection set.

ArcView automatically selects records in linked tables, so the script only needs to ensure that the window for the linked table is open and that the selected records are promoted to the top of the table.

WWS.CrossSection_shp

This is the Click script on the *Cross-section Shapefile* Menu item. It runs the *WWS.BoreSelectTable* script directly, so that the user can pick a linked table for creating the shape file.

The script retrieves data model information for the linked table from the Object Tag in the project GUI, using global variable _codeno.

This utility operates only on a selected set of features. If there are no points selected in the bore theme, the script exits. The utility is able to deal with the special case of one selected borehole.

The cross-section is created in a shape file of class Polygon. The user is prompted for the name of the shape file in a FileDialog.Put, with *xsect.shp* the default name.

The polygons receive a clone of all the fields in the linked table, with Alias replacing Name if any fields are aliased.

The user must pick which boreholes define the endpoints of the cross-section line. The coordinates of the bores are placed in a list and sorted in ascending order, along with their link field values.

The sorted link values are presented in a MsgBox, so that the user can pick the hole which starts the line. The point with the smallest easting will be the default, being first in the list.

The list is then sorted in descending order, and those sorted link field values presented for the user to pick the hole which ends the line. The point with the largest easting will be the default, being first in the list.

A vertical exaggeration factor must be supplied in a MsgBox.Choice. The default is 1.

Each hole is represented as a sequence of rectangular shapes, one polygon for each interval down the hole. The width of a rectangle is calculated as 1/100 of the length of the cross-section line, or 400 m for a single hole.

The script loops over the selected points in the bore theme, projecting their position perpendicularly onto the cross-section line A rectangular shape is constructed for each interval, centred on the distance of the bore from the start of the line, and the field values for that interval transferred to the shape VTab.

WWS.WaterBeds_shp

This is the Click script on the *Water Beds Shapefile* Menu item. It runs the *WWS.BoreSelectTable* script directly, so that the user can pick a linked table containing the water beds.

The script retrieves data model information for the linked table from the Object Tag in the project GUI, using global variable _codeno.

This utility operates only on a selected set of features. If there are no points selected in the bore theme, the script exits. The utility is able to deal with the special case of one selected borehole.

The water beds cross-section is created in a shape file of class Polyline. The user is prompted for the name of the shape file in a FileDialog.Put, with *wbedsect.shp* the default name.

The polylines receive a clone of all the fields in the linked table, with Alias replacing Name if any fields are aliased, except for the SWL line, which only receives a clone of the link field.

The user must pick which boreholes define the endpoints of the cross-section line. The coordinates of the bores are placed in a list and sorted in ascending order, along with their link field values.

The sorted link values are presented in a MsgBox, so that the user can pick the hole which starts the line. The point with the smallest easting will be the default, being first in the list.

The list is then sorted in descending order, and those sorted link field values presented for the user to pick the hole which ends the line. The point with the largest easting will be the default, being first in the list.

A vertical exaggeration factor must be supplied in a MsgBox.Choice. The default is 1.

Each water cut is represented as horizontal line at the appropriate depth. The extent of the line is calculated as 1.5/100 of the length of the cross-section line, or 600 m for a single hole. There is also one line for each hole which has a value of SWL in the theme table.

The script loops over the selected points in the bore theme, projecting their position perpendicularly onto the cross-section line A horizontal polyline shape is constructed for each water bed, and its field values transferred to the shape VTab. The 'from value' of the water cut us used as the depth of the line if it is present, otherwise the 'to value'.

WWS.Ruler

This is the Click script on the *Add Rulers* menu item.

It finds the extent of the first active theme to determine the length of the rulers.

These rulers are graphic objects, so some text and line symbols are made for drawing.

The user is prompted with a msgbox.MultiInput for the x- and y- spacing of ruler tics and the vertical exaggeration.

The vertical ruler is a line with small horizontal tics drawn across it. Labels are drawn to the left of the tics. The lines receive an ObjecTag "yruler", the labels an ObjectTag "ylabel", so that they can be selected and grouped into two graphics objects.

The horizontal ruler is a line with small vertical tics drawn across it. Labels are drawn below the tics. The lines receive an ObjecTag "xruler", the labels an ObjectTag "xlabel", so that they can be selected and grouped into two graphics objects.

WWS.LabelReduced

This is the Click script on the *Calculate reduced* menu item.

It does not make use of the *WWS.BoreSelectTable* script, since the user may wish to use the main bore attribute table rather than a linked table. Therefore the script retrieves data model information from the ObjectTag in the project GUI, and constructs its own picklist of available tables which includes the bore attribute table. The user selects a table from that extended list.

If some bores are selected, only they are used for the calculation. Otherwise all points are used. The reduced values are calculated and stored in a new dBase table, named by the user.

The action of the script depends on whether the user picks the bore attribute table for calculating reduced values, or one of the linked tables.

In the first case, a list of all numeric fields in the bore attribute table is created and presented in a MsgBox. The user must pick a field from that list. Then
the reduced value = bore elevation (AHD) - field value.

If a linked table is to be used, a standard ArcView query window is presented, so that the user can create a logical expression. This query defines the records in the linked table which cover a depth interval of interest. For example, the query *[desc] = "CAINOZOIC"* would select all records covering the Cainozoic era in the linked stratigraphy table. For each bore, the record with the largest "to field" value (ie the deepest interval) is found, and the reduced value = bore elevation - to field.

This script uses some temporary table selections, so on conclusion all the table selections are reset to their status on entry to the script.

WWs.LabelThickness

This is the Click script on the *Calculate thickness* menu item. It is almost identical to *WWS.LabelReduced.*

It does not make use of the *WWS.BoreSelectTable* script, since the user may wish to use the main bore attribute table rather than a linked table. Therefore the script retrieves data model information from the ObjectTag in the project GUI, and constructs its own picklist of available tables which includes the bore attribute table. The user selects a table from that extended list.

If some bores are selected, only they are used in the calculation. Otherwise all points are used. The thickness values are stored in a new dBase table, named by the user.

The action of the script depends on whether the user picks the bore attribute table for calculating thickness values, or one of the linked tables.

In the first case, a list of all numeric fields in the bore attribute table is created and presented in a MsgBox. The user must pick a field from that list. Then the value of that field is returned in the table.

If a linked table is to be used, a standard ArcView query window is presented, so that the user can create a logical expression. This query defines the records in the linked table which cover a depth interval of interest. For example, the query *[desc] = "CAINOZOIC"* would select all records covering the Cainozoic era in the linked stratigraphy table. For each bore, the records with the smallest "from field" and the largest "to field" value are found, and the thickness value = to field - from field

This script uses some temporary table selections, so on conclusion all the table selections are reset to their status on entry to the script.

WWS.LabelMostRecent

This is the Click script on the *Most recent* menu item. It calculates the most recent value of a field, based on fields containing date and time.

It makes use of the *Bore.SelectTable2* script, which retrieves data model information from the ObjectTag of the project and constructs a picklist of available tables which have type = 2. The user selects a table from that list.

If some bores are selected only they are used in the calculations, otherwise all points are used. The field values are calculated and stored in a new dBase table, named by the user.

For each point, the record in the linked table with the greatest value of the date field is found. If two identical date values exist, the record with the largest value of the time field is considered the most recent.

Note: Currently, the date and time fields are considered to be integer numbers. Date is in the North American format, eg 19890327.

This script uses some temporary table selections, so on conclusion all the table selections are reset to their status on entry to the script.

WWS.RGBPalette

This script is activated from the pull-down *Windows* menu in the View GUI.

It initiates a dialogue whereby the user supplies the name of a .txt file containing the RGB definition of a Color Palette, and a second dialogue to supply the name of the .avl file which will contain the new color palette,

The script simply reads the ASCII file, extracting Red, Green and Blue values (0 to 255) from each record. These values define a colour. The colours are added to a list, from which an ODB file is made. The first colour in the palette is the transparent colour.

WWS.ColorLegendWithLUT

This script is the Click script on the *Colour theme with LUT* menu item.

It checks there is exactly one active theme, then uses MsgBoxes to prompt the user for the theme field to colour on, the name of the lookup table, the name of the field in the lookup table that is to be used for labelling the legend, the name of a field to be used to sort the legend, and the field in the lookup table which contains the symbol number in the colour palette.
The lookup table must contain a field with the same name (or alias) as the colouring field in the theme.

A unique classification is created for the theme, using the colouring field. In a query over each of the legend classifications, the Query request is used on the LUT to find the mapping of the classification field to a symbol number in the color palette. There is an extra complication in building the query if the colouring field is a character string. The script looks for the ? character in that field (very often used in geological unit names), and re-writes the query so that the ? is not used by ArcView as a wild card.

The legend for the classification is set to the specified colour. If no entry is found in the LUT, the colour is set to black. If a label field was supplied, its value in the LUT is assigned to the classification.

If the user requested sorting, the classes are cloned into a list which is sorted. That list is used to sort the legend, since legends cannot be sorted directly.

WWS.MainAquifer

This script is the click script of the *Main aquifer* menu item. It must compare several tables and is quite slow, therefore it only works if the theme has a selected set.

After retrieving data model information from the ObjectTag of the project, the script builds a list of all available linked tables so that the user can pick the table which contains stratigraphy and the table of water beds. For the water beds table, a list of numeric fields is built up, from which the user must pick the field representing the ec values.

Since a new dBase table of 'main aquifers' is created, the file dialogue menu provides a browser for naming and storing that table on disk. The new table contains fields from the water beds table (the bore identifier, the from field, and the ec field) as well as all fields from the stratigraphy table.

A preliminary selection is placed on the water beds table, to reduce it to all records containing either a non-zero "from field" or "to field". This causes incomplete data to be ignored.

For all selected points in the theme, records from the water beds table with a non-zero value of the ec field are found, and the smallest value of ec determined. If that record has a non-zero "from field" its depth is used to find an interval in the stratigraphy table; otherwise the "to field" depth is used. The record for the bore in the stratigraphy table which has a depth interval containing the water bed depth is selected as the main aquifer. Its record, along with the relevant fields of the water beds record are added to the new table.

A single record is added to the main aquifer table for every selected bore which has an entry in the water beds table and a corresponding interval in the stratigraphy table.

WWS.SuperBorePicture

This script is the Apply script of the tool which draws the 'super bore picture'. It uses information from most of the linked tables.

Note: The names of the tables used to retrieve the bore information are explicitly stored in the script:
borehole stratigraphy
borehole geology
borehole drillers log
borehole water cuts
borehole casing
borehole screens
borehole gravel
borehole drill
These names were those decided on at AGSO: if the table names are changed in the project, the script must be modified.

Using the hardcoded table names, the remaining link information from the theme to the tables is read from the data model stored in the project's Object Tag. If any table name is not found in the data model lists, the script stops with an error message.

The tool draws pictures of all bores within a circle of one pixel radius around the location pointed to by the mouse. Each picture is created in the graphics layer of a new temporary View named with "Bore Picture" concatenated to the bore "link field" and the "label field". These views have a RemoveDoc(SELF) shutdown script so that each is deleted when its pin is pulled.

Any entries for the current bore are found in each of the linked tables containing stratigraphy, geology, drillers log, water beds, casing, screens, gravel, and drill. This is a straightforward, repetitive process. For any table, if information is present, it is added to the picture at the depth given by the "from field" or for the interval from the "from field" to the "to field". The information is drawn approximately in columns, arranged across the view from left to right, with an appropriate heading

STRAT is represented as boxes containing text from the nominated "label field".

GEOLOGY information is text from the fields *rock_type, rock_desc* and *color*, written at the "from" location of the interval..

DRILLERS LOG text is from the *lith_desc* field, again written at the "from" location of the depth interval.

The WATER BEDS column consists of labels on a vertical line extending to the bottom of the hole. The SWL is marked if there is a non-zero value in the "swl field" of the main bore attribute table. If there are entries in the linked water beds table, each of these is marked and labelled on the right of the vertical line with a string made up of the fields bed_swl/bed_yield/bed_ec. If any of these fields is null, its value is represented as "-", eg 25.6/-/2. This label is matched on the left of the vertical line with the value of the "from field", or if that is missing the "to field" .
The CASING is drawn as a series of vertical lines for each interval over which casing data is present, with a label for the casing diameter. The colour of the vertical line and the label represents the casing type *(cas_type)*, which is used as a colour code as described below.

SCREEN, GRAVEL and DRILL are all drawn as vertical lines for each interval over which data is available. The colour of the vertical line segments represents the code from the given table (*scr_type, gvl_type, drl_type*), which is used as a colour code as described below.

The colour coding of lines and labels is set in a pre-determined colour list at the start of the script: code 0 is black; code 1 is red; code 2 is green; code 3 is blue; code 4 is yellow; code 5 is cyan; code 6 is magenta. More codes will require extra colours.

A vertical line with horizontal tics is drawn at each end of the picture. The ruler at the left represents intervals marking downhole distances, measured from 0 at the top of the hole. The ruler at the right is labelled with AHD values.

WWS.AddWQAliases

This script is not attached to any button or menu. It simply provides an easy way of adding aliases to fields in the water quality table from a lookup table. It can be run whenever necessary by the data administrator.

The script has the table names inline: *borehole water quality* and the lookup table *wqvarlup.dbf.* If table or field names are changed, the script must be altered and recompiled.

The script creates a list of the fields in the water quality table, and loops over them searching for those names in the *variable* field of the lookup table. Then an alias for that field is created from the value in the *shortname* field of the lookup table.

WWS.DeleteThemeAndTable

This script is the Click script on the *Delete themes and theme tables* Menu item.

It is copied from the system script *View.DeleteThemes*, and has modifications in two places. These occur when a theme is deleted from the View: the script searches for any tables called '*Attributes of* the theme name', and removes them from the Project.

CONCLUSIONS

Because one-to-many relationships are so common in geology, the methodology developed for this project should find much wider use in many other GIS applications. The one-to-many tools which have been written in Avenue script can be modified or extended to help answer other questions we may pose of data of this type.

REFERENCES

Gallagher, R., 1996. Visualising waterbore data with ArcView2. Australian Geological Survey Organisation Record 1996/18, 17 pp.

Wischusen, J., Jamieson, M., Rose, B., Bierwirth, P., Woodcock, L., Lau, J.E., Soilleux, M., & Jacobson, G., 1997. The Western Water Study GIS, an aid to groundwater assessment and prospecting on Aboriginal land in central Australia. Third National Forum on GIS in the Geosciences, 19-20 March 1997. Australian Geological Survey Organisation Record 1997/36