THREE DIMENSIONAL VISUALISATION OF GEOTHERMAL FIELDS USING CAD SOFTWARE

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SUMMARY – In this paper the use of CAD software for the Visualisation of geothermal field features in three dimensions has been investigated. A 3D drawing of the Kawerau field has been developed. Drawing methods and technique are explained. The usefulness of the Visualisations for the management of the field is discussed.

1. INTRODUCTION

Geothermal fields consist of many features; geology, fluid temperatures and pressures, wells etc, which are all located in three dimensional (3D) space. These features are measured and conjectured by engineers and scientists and then reported to peers and clients.

A quick survey of recent papers presented to this workshop and reports in the author's work place found that the above features were rarely represented as 3D figures or drawings. 2D cross sections and contour plots in plan or section are common. 3D is used where the application inherently uses 3D software, e.g. reservoir modelling.

The reasons 3D is not used more often may be.

- Expense of suitable software
- Software is too difficult to use
- Representations in 2D are more understandable.
- Not worth the effort.

This paper investigates the use of common CAD software to visualise field features and measurements.

2. KAWERAU GEOTHERMAL FIELD

The Kawerau Geothermal field has been used as an example for this paper (Figs 1, 2 and 3). The field has a good spread of well locations and therefore measured data. The contents of this paper should not be considered an indication of actual Kawerau data. Some 'artistic license' has been used and the data is from various dates over the 40 year operating history of the field. Fictional well names have been used.

3. CAD SOFTWARE

Basic 3D CAD software is not expensive, even freeware programs will produce most of the drawings given in this paper. Often engineering companies in the geothermal industry will have CAD installed for other uses.

The drawings produced in this paper actually do not require a lot of general CAD skills as the actual drawing elements are generated with software. Some patience is required to learn the commands for generating 3D views.

CAD drawings are produced in widely accepted formats (.dwg, .dxf) which allows files to be distributed to, and views explored by, different users of the information.

CAD software has high resolution. This enables images to be generated from absolute map co-ordinates and over a wide range of scales.

CAD drawings can have a large number elements spread over many layers. Turning layers on and off and saving defined views allows one drawing to show many different images of the field features.

AutoCAD LT and IntelliCAD were used for this paper. In generating the images in this paper extensive use was made of layers, attached files and 3D view options.

There is specialised software available that will generate the type of visualisations discussed in this paper. Software used for geographic information systems (GIS), earth sciences and petroleum exploration will produce more than adequate visualisations, but are more expensive than the CAD software used here. The cost of this software ranges from $US4000 for GIS packages to $US85,000+ for software used for petroleum exploration.

4. GENERATION OF CONTORS AND SURFACES

Many features and measurements of a geothermal field can be graphically represented by contours e.g temperature or surfaces and/or solids e.g geological formations.

some CAD programs are able to generate contours and surfaces from numeric data but this is not usually a feature of low cost programs. For this paper a shareware program, QuikGrid (John

Coulhard, Perspective Edge Software), was used. QuikGrid creates 3D contours and surface grids from text files containing point locations and data values. The contours and grids can be exported as .DXF files and imported in to *CAD* drawings.

5. PRELIMINARY PLANING

Data used for drawing in this paper came fiom a number of sources. It was important to ensure that the data uses a common map grid and units of measurement. This will save having to scale and move drawing element as they are imported into the main drawing.

For this paper external reference files were attached to the main drawing. This kept the main drawing size low and allowed the reference files to be altered separately. If the drawing file was to be distributed then the attached files may need to be included (bound) to the drawing.

6. COLOUR

Appropriate use of colour for data display allows interrelationships and patterns within data to be easily observed. Colour schemes developed for cartography (Brewer, 1994) will provide a guideline. There are colour schemes for qualitative, diverging and sequential data and combinations.

Temperature contours, which are sequential data, can be shown with small changes in hue between contours. eg. pink to red.

Place objects of the same type and colour on separate layers and colour by layer. This will allow object colours to be changed easily.

7. GENERATION OF DRAWING FEATURES AND ELEMENTS .

1.1 Surface Features

Useful surface features that can be included in the drawing:

- Ground level contours and/or grid
- Roads, Rivers etc
- Pipelines and power plant.

For the Kawerau example the ground level surface grid was generated fiom the location and levels of subsidence survey marks and topographical maps. Pipelines, roads etc were imported directly fiom engineering drawings.

The wells at Kawerau are drilled to 1500m. The ground levels around the field vary only by 30m which is small compared to the depth of sub-surface features. Including Putauaki (Mt Edgecumbe), 800m high, to the south of the field in the surface grid added a good surface reference point.

12 Wells

Wells provide the best reference point within the drawing. They all start at the surface, so define ground level, and are completed within the depths of the reservoir. As the wells are mostly vertical they are a reference for the orientation of the visualisation.

For this paper the wells have been drawn as tubes. The casing is drawn 6m in diameter and the open hole slightly smaller (3m), for distant views they could have been much larger. Giving the wells a thickness that can be distinguished in a distant view helps depth perception when perspective views are used.

1.3 Geology

Geology can be drawn as surfaces at the boundaries between formations. Drilling logs show the depth of these boundaries. Therefore well location and boundary depth can be used to generate surface contours and grids. Conjectured or known faulting will require additional data points for the surface generation or direct draughting.

1.4 Two Dimensional Data

Two Dimensional Data (2D data) is data that has a location at the surface and a value but does not originate at any particular depth. For example, total mass flow from a well or chloride concentration in the well fluid.

2D data can be viewed in two dimensions. This could be a contour plot over a plan view of the surface features. But showing this data in 3D views will give some clues to the possible source at depth. Figure 1 shows a 3D view of total mass flow fkom wells. The mass flow rate is represented by a cone. The size of the cone is proportional to the flow rate. Perspective has not been used so the size of the cones remains relative. Each cone is block object. This makes placement and scaling simple.

1.5 Three Dimensional Data

3D data has a location, depth and a value. This can be down hole temperature and pressure, chemistry, resistivity etc.

For this paper ways of showing down hole temperature have been investigated.

Temperature measurement is often shown in 2D plan view as isotherms (contours) at a nominated depth.

In 3D, temperatures can also be shown as surfaces of constant temperature. See Figure 1. Gathering the data for these surfaces is based on well log

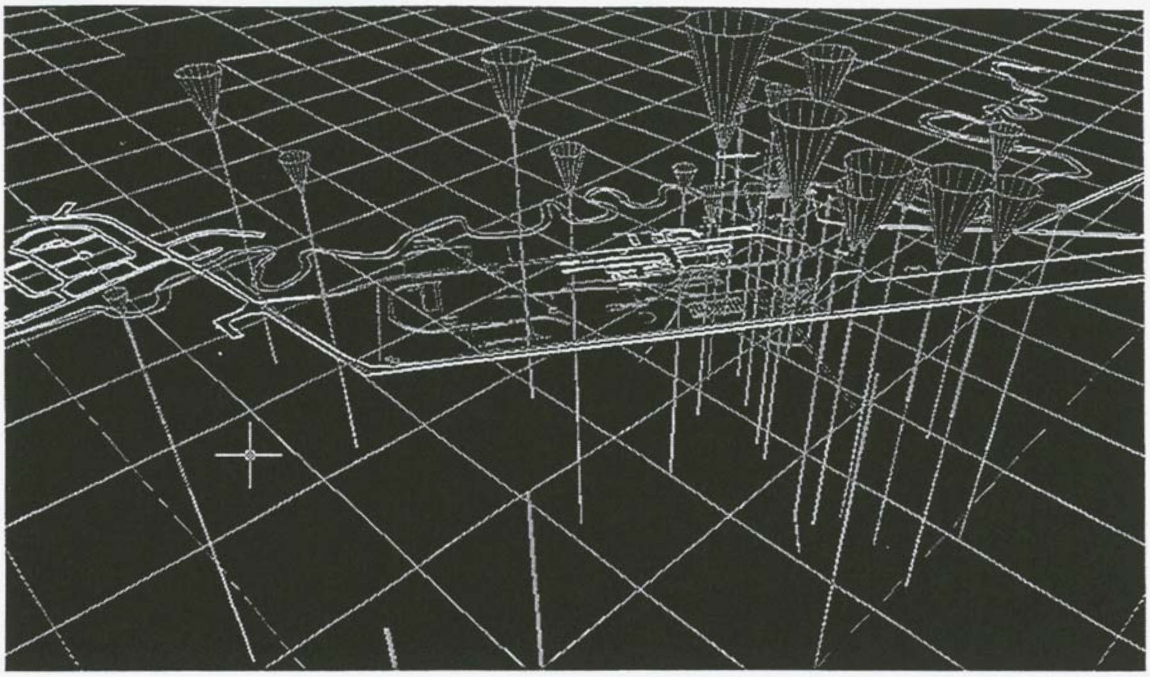

Figure 1 Perspective view of Kawerau **from** the southeast. Cones on each well indicate the relative flow fiom the well. This graphic is a screen shot with hidden lines removed.

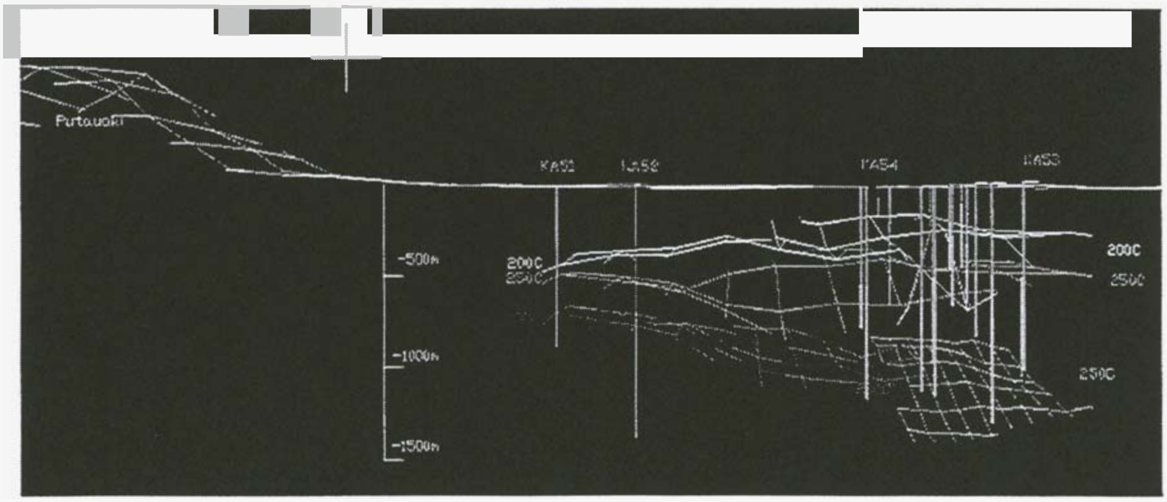

Figure 2. Cross section (800m wide) fiom the summit of Putauaki to the northwest part of the field. The surfaces of the 200°, 250°, 280°C represent the isotherms. The outflow tongue to the **north** is indicated by the top and bottom 250°C surfaces. **This** cross section is produced by using the DVeiw and CLip functions in AutoCAD. The grid *sizes* on each surface **are** not the same.

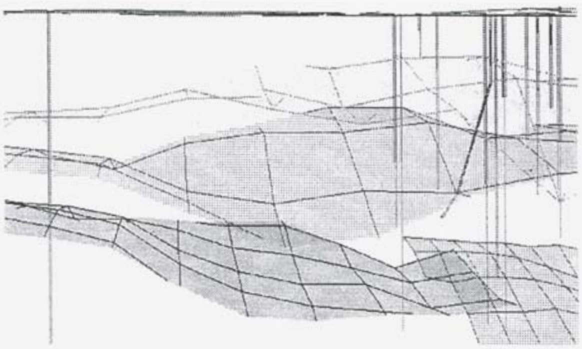

Figure 3. Section of Fig. 2 that **has** been exported to a vector drawing package and transparent fill added to the temperature surfaces.

data. Where wells have a temperature inversion then separate surfaces for the second and sequential occurrence of the given temperatures can be generated.

8. SPOT MEASUREMENTS

Some measurements (eg well feed zones) may be specific to the well or cannot be projected between wells. In theses cases the data needs to be visualised only at the point of measurement.

For example scaled flattened spheres located at the point of measurement can be used to show the relative size of well feed zones.

9. PRESENTATION

Views of the 3D drawing are generated using the AutoCAD DVIEW command. View target, camera position and perspective (lens) set to best show the feature/s concerned. Cross sections can be generated using the CLIP function in DVIEW.

Hidden line removal of small solid features can be used. Solid filling of surfaces has limitations as often underlying surfaces will be covered. Using advanced rendering or colouring a wire frame surface with a transparent fill (Figure 3) will allow the underlying feature to show. Only wire frame images have been presented in this paper. Shading and rendering of surfaces was investigated. In some cases this added more clarity to the final images but with added cost (more expensive CAD software and time to draw).

For this paper the figures shown are views that have been copied and pasted as vector graphics or from bitmap screen prints. The original figures are in colour so some clarity is lost when printed in grey scale.

Text and legends can be added after a drawing file has been exported or on the drawing itself. A user co-ordinate system (UCS) can be defined on the view so text drawn in the UCS will appear orientated flat to the observer and not orientated to the field objects.

Although it is not a feature of the Cad software used here, 'fly throughs' can be an effective way of presenting 3D data to an audience

10. DISCUSSION

As can be seen, fiom the examples here, 3D visualisations can be generated using inexpensive CAD software. Only a limited number of CAD skills are required but these will take some time to explore and become skilled at.

It is easy to show too much information at once or use views that do not clearly indicate location of features. The clipped cross sections like Figure 2 give the correct location and limit the information presented. Using cross sections may seem to defeat the purpose of having a 3D drawing but the 3D drawing will allow an infinite number of cross sections to be produced.

For the Kawerau example, plotting isothermal surfaces showed the general temperature sweep more clearly than a series of flat temperature contours shown in plan. The temperature surfaces also showed how the cold down flows in some of the older wells puts a 'dent' in the temperature surface.

The most asked question for the management of the Kawerau field is locations for new production wells. Since well production is related to faulting, the geology would need to be added to the 3D drawing to help with answers to this question.

11. ACKNOWLEDGMENTS

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12. REFERENCES

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