Managing a gas field.

- An application involving the development of algebraic models -

Introduction

There is a great deal of planning involved in running a gas production site such as the one pictured.

Once a site has been chosen and gas wells have been drilled, productivity is monitored by measuring the *rate of flow* of the gas out of each well.

The scenario (a real one)

A gas production site in central Australia contains, potentially, up to six wells. At five of these, wells are already installed and producing gas.

After considering demand levels and production costs the Reservoir Engineer decides that, for the site to be considered viable, the average daily rate of flow from the entire site in any given month must be *at least 5 MMscf/day* (millions of cubic feet per day).

If the average daily rate for a given month falls below this, the sixth well will be installed to increase gas production.

The table below gives the actual average daily flow rate from the site for the months shown. During this period only five wells are installed and producing gas.

Month (end date)	Relative time t (months)	Rate of Gas Flow f (MMscf/d)
5/31/1998		51.717
6/30/1998		47.724
7/31/1998		36.717
8/31/1998		31.755
9/30/1998		28.066
10/31/1998		22.248
11/30/1998		22.199
12/31/1998		19.154
1/31/1999		16.377
2/28/1999		14.611
3/31/1999		13.403
4/30/1999		12.72
5/31/1999		11.285

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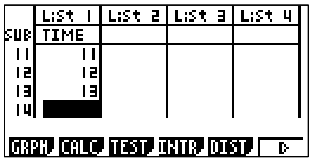
Reservoir Engineers don't wait until the rate falls below the value they have set. They will use the data to predict when the sixth well should be installed.

Activity 1: Viewing the gas flow data.

A. Fill in the *Relative time (months)* column of the table above so that the variable **t** represents the number of months that have passed since the commencement of data collection.

B. Enter the data into STAT mode in a *CASIO 9860G AU* in the following manner

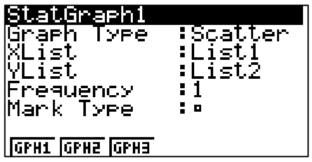
- Move the input bar into the `SUB` row of `List 1`
- Name `List 1` by pressing [SHIFT] then [ALPHA] then typing `TIME`, using the red letters above the keys on the key pad.
- Enter the relative time values in `List 1`, pressing [EXE] after each value.



C. In a similar fashion enter the values for **f**, the monthly rate of gas flow values into an appropriately named `List 2`.

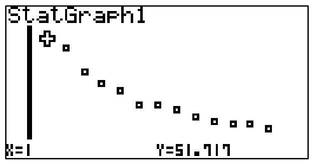
D. To represent this data graphically

- press `GRPH` [F1]
- To set up the graph that you wish to draw press `SET` [F6]
- Once satisfied that `StatGraph 1` is set appropriately press [EXIT][i]
- Now back in the main STAT window press `GPH1` [F1]



E. To have a look at the data represented by the marks on the screen

- Press [SHIFT] then `TRCE` [F1]
- Press ◀ and ▶ to move through your scatter plot, seeing time (X) and flow (Y) values displayed at the bottom of the screen.



1. Describe, in words, what happens to the flow values as time passes.
2. Do *you* think that a sixth well will be required?
3. At what time would you estimate that it will be required?

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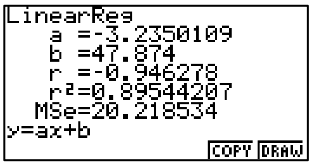
Activity 2: Developing a model for the gas flow data.

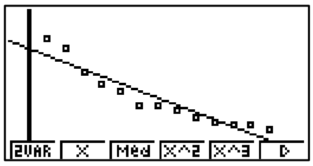
These questions might be more easily answered if we had an *algebraic model* for the relationship between gas flow and time, for the gas field in question.

To develop such an algebraic model,

- Press SHIFT then TRCE F1 again (or EXIT then redraw the graph) to exit TRCE.
- Press CALC F1 to see the types of algebraic models that the *9860G AU* can fit to data. Pressing > F6 shows more options.
- By pressing the F(unction) key beneath your choice of model type, the co-efficients of the best fitting model of that type are calculated.[ii]

Shown here is the *linear* model of best fit





- The right hand screen is obtained by pressing DRAW F6.
- In the left hand screen you also have the option of copying the model into GRAPH mode by pressing COPY F5, selecting a row and pressing EXE.

Clearly a linear model does not accurately represent the relationship between flow and time.

1. Experiment with other types of algebraic models.
   a. Use DRAW to determine the suitability of your selection.
   b. Use COPY to store the equation of your choice of model in GRAPH mode.
2. Use your choice of model to predict in what month the rate of gas flow will drop to below 5 MMscf/day and hence, when the sixth well should be installed to boost gas production.

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Activity 3: Further modelling.

This data covers the next 18 months of gas flows.

Month (end date)	Relative time t (months)	Rate of Gas Flow f (MMscf/d)
6/30/1999		12.992
7/31/1999		9.21
8/31/1999		8.836
9/30/1999		5.874
10/31/1999		4.938
11/30/1999		11.775
12/31/1999		16.709

1/31/2000		15.579
2/29/2000		14.861
3/31/2000		14.067
4/30/2000		26.285
5/31/2000		28.882
6/30/2000		24.963
7/31/2000		23.124
8/31/2000		20.43
9/30/2000		18.963
10/31/2000		17.335
11/30/2000		15.61
12/31/2000		14.516

1. Use this data to suggest the month in which the sixth well was actually installed. Compare this with the prediction you made in the previous activity.

The site that we have been studying only had the potential for six wells. Hence, when the average daily rate of flow falls below 5 MMscf/day after the installation of the sixth well, the site will be closed down. It is very important for companies to be able to forecast when such an event will occur.

2. Use the extra data supplied above to develop a model of the flow of gas from the site in the time after the installation of the sixth well.
3. Use this model to predict when this site will be shut down.

Checkpoint

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[i] Note: In `GRPH SET` it is possible to set up `StatGraph 1`, `2` and `3`, change `Graph Type`, change the list data on which these graphs are based and change `Mark Type`. The default settings are ideal for our current purposes but will need to be changed to generate graphs of different types in different circumstances.

[ii] Also displayed are the r^2 value and MSe.

- The r^2 value– known as the Co-efficient of Determination – represents the percentage of variation in the dependant variable that can explained by variation in the independent variable.
- The MSe value is the sum of the squares of the residuals of the model under consideration, corresponding to the quantity that is minimised when determining the co-efficients of the 'model of best fit'. Hence MSe is the *minimum sum of squared errors*.