AN INTEGRATED STEADY-STATE WELBORE SIMULATION AND ANALYSIS PACKAGE

CALUM GUNN and DEREK FREESTON

Geothermal Energy New Zealand Ltd, Auckland, New Zealand
Geothermal Institute, University of Auckland, New Zealand

SUMMARY. An integrated wellbore simulation and analysis package is presented. The package differs from usual steady-state geothermal wellbore simulators in that it also includes a number of modules that provide additional analytical tools for the reservoir engineer. These comprise: an automatic output curve prediction facility; a matching analysis module for comparison of simulated versus measured downhole pressure and temperature profiles; a module for assessing the consistency of measured downhole profile data (termed 'lower bound analysis'); and, a preprocessor module to the steady-state Simulator to ensure that the wellhead or 'deepest feed' conditions entered into the package, such as fluid composition and enthalpy, are consistent with respect to each other. The input and output parameters are all stored in a relational database, and presentation of the results can be in a technical format. The package is applied to a case study of an optimal wellbore casing and liner size problem, and the potential benefits of its application are demonstrated.

INTRODUCTION

The main function of a wellbore simulator is to determine wellhead conditions at underground geothermal reservoir conditions at the interface with wellbore, to estimate how those conditions change with depth down (or up) the wellbore when it is discharging fluid. Results in the form of pressures, temperatures, and other fluid properties are produced by the simulator at discrete depths down the wellbore. Where the wellhead conditions are the specified input conditions the simulator calculates from the top of the well down to the 'deepest feed' from the reservoir. This is termed a wellhead/down simulation. Alternatively, where deepest feed zone conditions are specified, the simulator performs a deepest feed/up simulation. A steady-state simulator assumes that the simulated conditions do not significantly vary with respect to time, and thus the discharge is considered to be 'stable'.

Wellbore simulators can be used as tools for predicting the behaviour of geothermal wellbore flow by allowing the user to vary parameters associated with the well's design, fluid properties and mass flowrates, and feed zone characteristics. Running a series of simulations over a range of discharging mass flowrates can also allow the prediction of a well's characteristic output or production curve (the plot of mass flowrate against wellhead pressure). However, this requires a knowledge of the drawndown relationships for the fluid well which express mass flowrate as a function of the undisturbed reservoir pressures and pressures within the wellbore at each feed zone.

Gunn and Freeston (1991) have discussed that the validity of the predicted well output curve is dependent on three important considerations:

- the accuracy of the wellbore simulator itself;
- the accuracy of the parameters entered as input data into the simulator;
- and, the applicability of the chosen drawndown relationships.

The accuracy of the wellbore simulator depends on the validity of the correlations coded into the program. These correlations typically include expressions for:

- fluid properties in the presence of non-condensable gases and dissolved solids;
- flow regimes transition boundaries;
- void fraction (vapour volume fraction in two-phase fluid); and
- friction factor.

The accuracy of the input parameters entered into such a steady-state simulator is dependent on:

- the amount of data available to accurately build a conceptual model of the well (for example, the correct location of feed zones and the fluid parameters at those feeds);
- the accuracy of any available measured data (for example, the ranges of measurement error for any wellhead or deepest feed pressures, temperatures, enthalpies, fluid impurity concentrations, and mass flowrates), and,
- whether the well had reached a stable flow when the measurements were taken; and,
- the accuracy of any estimated data (for example, casing and liner roughness, and in some cases diameter which may have been reduced by scaling).

The greater the amount of accurate measured data that is available, the better is the model of the well that can be entered into the simulator. Such models are often verified through matching analysis, the comparison of simulated downhole pressure and temperature profiles against measured profiles taken during an actual discharge of the well. Various input parameters may require calibrating in the simulator before simulated behaviour may match observed data. For example, often non-condensable gases and dissolved solids content are represented by an equivalent CO₂ and NaCl content respectively. This means that a measured value of either CO₂ or NaCl might not be the appropriate input value for those parameters to adequately match the observed conditions. These parameters may require calibration until a suitable value is found.

Another example would be in calibrating well Casing and liner diameters where the amount of scaling is unknown, but other parameters are available with a high degree of accuracy. However, as discussed in Gunn et al. (Submitted), there is little point matching simulated data against measured data to calibrate such parameters when there are notable errors in the measured data.

This paper presents a computer package that integrates a steady-state wellbore simulator with a number of other analysis tools. These tools are designed to:

- aid the user in evaluating the suitability of measured data for matching analysis;
- allow the user to actually perform matching analysis for calibration purposes; and
- to automate the process of predicting wellbore output curves, and in relation to this procedure to estimate unknown parameters of the deepest feed zone's drawdown relationship where necessary.
Although the package cannot in itself address concerns about the applicability of particular drawdown relationships, it provides the user with a choice of such relationships to apply.

The preparation of this package is part of an ongoing study into wellbore simulation, and it is intended to extend the scope of the package to include the modelling of transient effects.

SIMULATION AND ANALYSIS MODULES

The package includes five main simulation and analysis modules, which are as follows.

Discharge Test Simulation

This is the core module of the package. It allows the simulation of steady-state flow in a discharging well at a single mass flowrate. The features, assumptions and correlations built into this module are discussed in more detail in later sections of this paper.

Preprocessing Fluid Composition and Properties

The input parameters for a discharge test include fluid properties and fluid composition, some of which may be available from actual wellhead or other measurements. These values will not necessarily be consistent with respect to each other, and in some cases various parameters will be unknown. Inconsistencies can be due to measurement error, but typically measured enthalpy values may not be adequately due to the presence of gases or dissolved solids. Inconsistencies may also result from related measurements having been observed at different times. Wellhead and deepest feed conditions entered into the simulation module are initially preprocessed to ensure that a consistent and complete set of input parameters is used in the discharge test simulation. A simulation is not allowed to proceed without such a step having first been performed.

Output Test Simulation

In the real world a number of actual discharge tests on a geothermal well can be performed to produce the well's characteristic output or production curve. However, this is an expensive operation. The package includes a module for automatically performing such a series of discharge test simulations to produce an estimate of the output curve. Such a procedure is termed an output test simulation. As part of the simulation the package may be requested to calculate suitable downhole parameters at the desired feed conditions, which can be presented graphically as well as in a text format. An example of this procedure is given in the case study in the final section of this paper.

Matching Analysis

As discussed above, matching analysis is a tool that can be used to calibrate the input parameters to the simulator. Measured downhole pressure and temperature profiles can be entered into the package to allow their subsequent comparison against simulated results. The profiles can be compared graphically, to allow "by-eye" matching, or a simple statistical matching analysis report can be produced.

Lower Bound Analysis

As noted above, observed downhole profiles in discharging wells can be subject to significant measurement error. Lower bound analysis is a method for estimating the suitability of measured data for application to matching analysis. The method works by simply analysing the consistency of measured pairs of two-phase pressure and temperature measurements taken at intervals down the wellbore. The analysis estimates the minimum CO₂ or NaCl content required for each pair to satisfy saturation condition. If these minimum values, or lower bounds, have considerable variation down the wellbore then the data can be considered to be of little use for calibrating wellbore or field parameters. In some cases such analysis can aid the identification or verification of feed zone locations, and also suggest calibrated NaCl or CO₂ content values to be entered into the simulator. The resultant lower bound profiles can be displayed graphically if required. Lower bound analysis is described in detail in Gunn et al. (submitted).

STEADY-STATE SIMULATION FEATURES

The core module of the package is the steady-state simulation module itself. It includes the following features:

- Models liquid, two-phase, and superheated steam flow
- Incorporates dissolved solid content by an equivalent weight percent of NaCl
- Incorporates non-condensable gas content by an equivalent weight percent of CO₂
- Estimates the effect of both NaCl and CO₂ on fluid liquid phase properties
- Estimates the effect of CO₂ on fluid vapour phase properties and on superheated steam properties
- Allows wellhead/down or deepest feed pressure calculation
- Models second, and, third, zones, and calculates fluid composition at secondary feeds.
- Allows linear, quadratic, or superheated steam type downhole relationships to be specified at each feed for calculating mass flowrate.
- Allows multiple changes of casing and liner diameter, and roughness to be specified. (A library of standard casing and liner sizes is included).
- Models the effect of deviations in the wellbore from vertical on the pressure gradient.
- Models heat transfer with the surrounding rock formation and well casing.
- Provides simulated results at each depth of interest for: pressure; temperature; enthalpy; dryness; weight percent of NaCl in the liquid phase; partial pressure of CO₂; mass flowrate; flow regime or fluid type; and, frictional, accelerational and gravitational pressure gradient.
- Provides graphical plots of simulated downhole pressure and temperature profiles.

SIMULATION ASSUMPTIONS AND CORRELATIONS

The steady-state simulation module of the package has been developed by combining and subsequently modifying the two programs described in Hadgu and Freeston (1990), and by adding in provision for modelling superheated steam flow. Like these programs it has been assumed that:

- Flow is steady and one-dimensional
- Phases are in thermodynamic equilibrium
- Fluid properties remain constant within a depth increment, and dissolved solids and non-condensable gases can be represented by an equivalent NaCl content and equivalent CO₂ content respectively.

The simulator solves the mass, momentum, and energy equations up or down the well for a user-specified discharge test (defined below), which includes the calculation depth increment (or step). This user-specified increment is adjusted automatically by the program about changes of geometry, at secondary feed zones, and at the calculated flash point depth.

Fluid Properties

The formulae for evaluating fluid properties are those outlined in Hadgu (1989). CO₂ is considered to affect:

- overall fluid pressure, and the partial pressure of CO₂ is determined from the relationship by Sutton (1976) and from Henry's Law (the reason for using Sutton's relationship as against that found from applying Dalton's Law is discussed in Gun and Freeston (prep.));
- density of the vapour phase only (from Pritchett et al., 1981);
- enthalpy of both liquid and vapour phases (from Hadgu, 1989); and
- viscosity of the vapour phase only (from Pritchett et al., 1981).

NaCl is considered to affect:

- saturation pressure (from Haas, 1976);
Flow Regimes

The two-phase flow regime transition criteria outlined in Hadgu and Freeston (1990) have been used (i.e., bubble, slug, churn and annular) with the addition of an extra flow regime. It was found that the specified flow regime transition boundaries could allow slug flow to be predicted at low mass flowrates where flow is nearly saturated vapour. Physically it would not be possible for a slug to form from the small amount of liquid present, and so for this reason a mist flow regime was added. Unlike the other flow regimes, which are dependent on the superficial velocities of the liquid and vapour phases, the mist flow regime is considered to occur when the dryness (vapour phase mass fraction) is higher than 85%.

The effect of wellbore deviations on flow regime transition boundaries is not assessed.

**Void Fraction, Friction Factor and Pressure Gradient Calculations**

The correlations for void fraction, friction factor, and the pressure gradient calculations have generally been taken from Hadgu (1989). However, the gravitational, frictional and accelerational components of the pressure drop are calculated for all flow regimes.

**DATA STRUCTURE**

The package is centred around a relational database that allows the user to build up conceptual models of a geological wellbore as data comes to hand, and to assign a series of alternative geometry configurations (i.e., casing and liner sizes and depths) and feed zone configurations for any well. This allows the user to associate any desired geometry and feed zone configuration with a particular discharge test simulation. The user can also enter any measured downhole pressure and temperature profiles from both shut-in and discharging well tests into the database. The first set of measured data can be used to incorporate the effects of heat transfer with the surrounding rock formation into the simulation. The second set, involving measured discharge profiles, can be used in the matching analysis module.

The various input data types are described below.

**Well Descriptions**

The database can contain an "unlimited" number of wells and their associated descriptions. No other data types may exist in the database without being assigned to an already specified well.

**Geometry Configurations**

Each well can have a series of alternative casing and liner configurations assigned to it. For example, the user could have one configuration describing the existing geometry, and have another reflect a proposed workover configuration. Geometries could be assigned to allow the user to estimate the effects of drilling subsequent wells in a field with a variety of larger diameters in order to optimize wellbore fluid production. The user can select from a standard range of casing and liner sizes, and thus need not be concerned with specifying diameters directly. However, these values can be changed to reflect the effects of scaling for instance. Wellbore deviations and roughnesses can also be specified.

**Feed Zone Configurations**

Because the calibration of feed zone parameters does not have a unique solution (Bjornsson and Bodvarsson, 1987) the user can assign a series of feed zone configurations to aid in the determination of a suitable model of the well where more than one feed is considered to be significant. (Each configuration can be associated with a different discharge test simulation in order to find which one best reproduces any observed behaviour). Mass flowrate and enthalpy, or alternatively, enthalpy, reservoir pressure, and an appropriate drawdown relationship need to be specified at each feed. Feeds can be specified to produce or accept fluid, although flow in the wellbore itself must be upward. The drawdown relationship options are as follows.

**Linear:**  \[ p_r - p_t = aW \]  
**Quadratic:**  \[ p_r - p_t = aW + bW^2 \]  
**Steam:**  \[ W = a(p_r^2 - p_t) \]

Where:
- \( p_r \) = reservoir pressure (bar a)
- \( p_t \) = wellbore pressure at feed depth (bar a)
- \( W \) = mass flowrate (kg/s)
- \( a \) = linear (first order) drawdown factor, or steam relationship coefficient
- \( b \) = quadratic (second order) drawdown factor
- \( n \) = steam relationship drawdown exponent

**Discharge Tests**

This data type is at the core of any simulation run. It contains either the wellhead or deepest feed zone parameters used as the starting conditions for a simulation, depending on whether the calculation is to be wellhead/down, or deepest feed up. These conditions include fluid composition and properties (i.e., fluid type, pressure, temperature, enthalpy, \( CO_2 \) content and NaCl content), and the mass flowrate. The discharge test data also specifies which of the geometry and feed zone configurations assigned to the well are to be associated with the simulation. If only a primary feed is present then no feed zone configurations need to be specified (as such configurations describe additional feeds only). A series of discharge tests involving different geometry or feed configurations, and differences in other parameters such as mass flowrate, can be assigned to a well.

**Output Tests**

An output test comprises a set of discharge tests over a range of mass flowrates; and, the drawdown relationship that relates these flowrates to the pressure drop between the reservoir and the wellbore entrance. Output tests can be described with or without all drawdown parameters specified at the deepest feed zone, and a linear, quadratic, or steam drawdown relationship can be used (i.e., those shown in equations (1) - (3) above). The undisturbed reservoir pressure at the deepest feed zone must be specified in all cases. This data structure results in the following two output curve prediction methods.

**Fully Specified Drawdown Relationship**

If a drawdown relationship and its parameters are known then the user specifies one discharge test describing deepest feed parameters that is already assigned to the current well, as the basis for a set of new program-generated discharge tests over a user specified range of mass flowrates.

**Unknown Drawdown Parameters**

If the drawdown parameter(s) are not known then the user can require the program to calculate them. In this case the user specifies one or two discharge tests describing wellhead parameters to act as the basis of the drawdown parameter calculation. The program performs a wellhead/down simulation on each of these discharge tests and uses the pressures calculated at the deepest feed zone depth to calculate the unknown drawdown parameters. Only one wellhead/down discharge test simulation is required to fully specify a linear or steam drawdown relationship as this involves calculating only a single unknown parameter (the "a" in equations (1) and (3)). Two wellhead/down simulations are required if a quadratic drawdown relationship is requested.
as this involves calculating two unknown drawdown parameters (the "a" and "b" parameters in equation (2)).

Measured Static Temperature Profiles

A single static downhole temperature profile, taken from shut-in measurements, can be assigned to any well. This data can be used to take account of heat transfer in a discharge test simulation if the user so requires. Apart from the downhole pairs of depths and temperatures, the static temperature profile data type also includes heat transfer parameters such as: rock thermal diffusivity; rock and, casing thermal conductivity; discharge period; and, the estimated distance to the "undisturbed" rock formation temperature.

Measured Discharge Profiles

Measured downhole pressure and temperature profiles at different discharging mass flows rates, from measurements taken during an actual discharge test, can be assigned to any well. This data can be used for matching analysis against simulated profiles to calibrate discharge test, feed zone, or geometry configuration parameters.

SIMULATION METHODOLOGY

Wellbore simulators are like any other computer program that attempts to simulate some sort of complex physical behaviour. In simulating the required behaviour there are a number of assumptions that have to be built into the program itself such as the correlations discussed above, and a number of assumptions that need to be made in selecting the appropriate input parameters. The current package provides the user with tools for assessing whether the simulator is appropriate to the well being modelled, and also whether the input parameters are likely to be appropriate. Matching analysis can enable the user to verify the package's predictions and to calibrate input parameters. If "good", measured data is available for a particular well then it could be used to assess the simulator's performance. The "goodness" of such measured data firstly should be verified through the package's lower bound analysis facility however.

In many cases, measured pressure and temperature profiles under discharge conditions may not yet be available. The simulator might even be applied to a field where no wells have yet been discharged. In such a case, the package could be used to estimate initial discharge conditions based on shut-in measurements, and to assess the relative benefits say in increasing the diameters of subsequently drilled wells. However, as more more measurements become available, these can be used to build up and/or calibrate the model of the well and its associated parameters as entered into the package. For example, secondary feed zone conditions may become more evident, as may a characteristic drawdown expression for the primary feed.

When no measured data is available for corroboration of the package's predictions it is important to realise that the power of the simulator then lies in the differences between the "what-if" scenarios that are being investigated rather than in the actual magnitude of those predictions. This is because each scenario will be based on the same set of underlying assumptions.

For example, a fictitious representative well can be easily modelled for a field for instance. "What-if" studies on such a representative well can aid decisions as to optimal casing and liner sizes amongst other considerations. In such a case there can of course be no substantiating data to assess the simulator's performance. However, the package can still be used to predict the relative difference between a number of scenarios (as illustrated in the case study at the end of this paper).

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These applications are generally relevant to investigating well behaviour where a reasonable amount of corroboration measured data is available, particularly actual downhole discharge profiles. This data could be used for calibrating such unknown parameters as secondary feed conditions or drawdown parameters, and involve matching analysis. The resultant well model could then be used to examine the existing performance of the well. A typical reason for modelling an existing system would be to determine the flash point depth. This is important for setting the appropriate depth for chemical injection to reduce scaling, which occurs at the flashpoint depth. The flashpoint depth is highly dependent on the fluid composition. The sensitivity of this depth to various levels of NaCl and/or CO₂ can be examined.

Modelling Changes to Existing Systems

These applications generally investigate changes to a system where the meter rates have been satisfactorily calibrated, in an attempt to predict the effects of a physical change in any of those parameters. This could involve performing output test simulations to predict increases or decreases in production due to variations in a number of different factors, for example casing and liner diameter reductions resulting from a workover, or changes due to reservoir "degassing". This latter case can occur in reservoirs which initially have a high non-condensable gas content. This content may decrease rapidly after the well is discharged for the first time, and the simulator could estimate the subsequent change in behaviour through an appropriate sensitivity analysis of feed input parameters relating to fluid composition.

Modelling Representative Systems

As mentioned above, a "fictitious" well, representative of all or part of a field's reservoir conditions, (depending on reservoir homogeneity) can be modelled in the simulator. Sensitivity analyses can then be performed to determine which input parameters are the significant factors to any predicted variations in well output. Such a procedure is demonstrated in the following case study of a representative well.

CASE STUDY - APPLICATION TO ESTIMATING OPTIMAL CASING AND LINER SIZES

This case study examines the application of the current simulator to "optimizing" casing and liner sizes for a representative well. The study does not attempt to actually optimize the wellbore fluid production, but serves to demonstrate how a wellbore simulator can be a useful part of the overall optimization process. The application of simulators to predicting the effect of wellbore diameter on output curves has been examined by a number of authors including Hadgu and Freeston (1986), and Barnett (1989).

Representative Well Input Parameters

The raw data is taken from the example in the Tutorial Manual of the current package (GENZL and Auckland University, 1991). The well used is representative of a near dry steam well. Wellhead conditions are given below.

| Mass Flowrate: | 22kg/s | Pressure: | 12bar |
| Dryness: | ~ 98% | Gas Content: | 1% CO₂ by weight of total fluid |
| NaCl Content: | None |

The actual well casing and liner configuration associated with the above wellhead conditions is as follows:

- 0 - 620m: Casing 9 5/8" 40b/ft (vertical)
- 620 - 1145m: Casing 9 5/8" 40b/ft (30° from vertical)
- 1145 - 1280m: Liner 7 7/8 29b/ft (30° from vertical)

Because the wellhead conditions are almost-dry, a steam drawdown relationship is assumed for the major feed at the
well bottom (i.e., equation (3)), above). The undisturbed reservoir pressure at this depth (i.e., 1200 m) is assumed to be 36.5 bara.

Two larger casing and liner configurations are suggested for the purpose of improving production from similar wells to be drilled in the field. These are as follows.

- **0 - 620 m**: Casing 13"¹/₈ 68 lb/ft (vertical)
- **620 - 1145 m**: Casing 13"¹/₈ 68 lb/ft (30° from vertical)
- **1145 - 1280 m**: Liner 10 ³/₄" 51 lb/ft (30° from vertical)

and

- **0 - 400 m**: Casing 18"²/₈ 87.5 lb/ft (vertical)
- **400 - 620 m**: Casing 13"¹/₈ 68 lb/ft (vertical)
- **620 - 1145 m**: Casing 13"¹/₈ 68 lb/ft (30° from vertical)
- **1145 - 1280 m**: Liner 13"¹/₈ 51 lb/ft (30° from vertical)

**Output Curve Prediction for the Actual Casing and Liner Diameters**

The overall analysis procedure for the actual casing and liner diameters involves fully specifying the characteristic drawdown relationship for the major feed zone at 1200 m. In a standard well test simulation, this would normally be achieved by performing a top-down discharge test simulation based on the above wellhead conditions and the associated casing and liner configuration. The resultant calculated drawdown pressure in the wellbore at the depth of the primary feed could then be used to determine the unknown drawdown factor "p". The drawdown exponent "n" is typically assumed to be a representative value. For example, Hagedo (1989) used a value of 0.75, as is used here. In a real study, it would be wise to perform sensitivity analysis on this parameter and utilize the most conservative results when drawing any subsequent conclusions.

At this point, with the drawdown relationship fully specified, a set of feed zone pressure and mass flow rates could be used to perform the discharge test calculation. The resulting calculated drawdown pressure in the wellbore could then be used to determine the drawdown factor "p". The drawdown exponent "n" is typically assumed to be a representative value. For example, Hagedo (1989) used a value of 0.75, as is used here. In a real study, it would be wise to perform sensitivity analysis on this parameter and utilize the most conservative results when drawing any subsequent conclusions.

The current simulation package integrates all these steps and then performs them automatically. The major steps occur at the input data stage rather than at the simulation stage. These steps are as follows:

1. Enter the well description data.
2. Assign the initial casing and liner configuration to the well geometry configuration, selecting the appropriate diameters, and reference the initial geometry configuration.
3. Preprocess the wellhead conditions to determine unknown parameters such as enthalpy and temperature. (This step is performed automatically by the package when the discharge test is saved to the database.
4. Assign an output test to the well. This data type comprises: the appropriate drawdown relationship (i.e., steam); the undisturbed reservoir pressure at the deepest feed; the range of mass flow rates of interest; the number of discrete points required on the output curve; and, if desired, the discharge test assigned to the well in the previous step.
5. Perform the output test simulation. (This is done simply by entering the appropriate function key from the output test data entry screen).

The package then performs the initial wellhead discharge test simulation, and uses the results to determine the missing drawdown parameter. The package continues the simulation by automatically creating a new discharge test of the deepest feed conditions for each of the discrete feed mass flow rates specified as part of the output test simulation data. Each of these new discharge tests is individually processed to ensure the consistency of the feed conditions.

The package includes a user interface for performing the following tasks:

- Specify the geometry configuration for the feed zone.
- Assign the feed zone pressure and mass flow rates to the feed zone.
- Assign the drawdown relationship to the feed zone.
- Assign the output test to the well.
- Perform the output test simulation.
- Analyze the results of the output test simulation.

**Results for the Representative Well**

The first output test simulation for the representative well using the original small casing and liner sizes was performed over a range of mass flow rates from 10 to 25 kg/s, and seven discrete points on the output curve were requested. The two output test simulations using the larger sizes were both performed over a mass flow rate range of 10 to 40 kg/s, and seven discrete points on the output curve were requested.

The package allows the results of a number of output test simulations to be plotted and compared against each other on the same graph. The mass flow rate versus feed zone pressure (i.e., the drawdown relationship) is also plotted along with the output test curves. The results as produced by the package are shown in Figure 1. The flow choked in each case at 40 kg/s.

**Interpretation of the Results**

The improvement in production between the original casing and liner configuration and the first set of suggested new sizes is readily apparent. At a typical wellhead pressure of around 1500 psia, the increase in mass flow rate is close to 50%. By contrast, the production increase between the first set of new sizes and the largest sizes is only an additional 5% or so. Should these results be associated with an analysis of drilling and well costs, then it could be shown whether this small increase in production is worth the additional expense.

The package's presentation of the mass flow rate against feed zone pressure on the same graph as the output curve is a useful indicator as to the possible gains in production. Where the pressure difference between the output curve and feed zone is relatively small, the more data available, the more certain the conclusion that the two suggested new sizes are the best. In this case, there cannot be a large increase in pressure. The feed zone pressure curve provides an upper bound to the output curve.
This case study demonstrates the potential use of the package to highlight where an additional increase in wellbore diameter has only a marginal effect on the production. As noted above, the important features for such a representative well study is to look at the relative production increases rather than the magnitudes. Although only two sets of geometry configurations have been considered in this example, the number of alternatives that the package can examine is not limited.

CONCLUSION

A new computer package has been developed, designed to incorporate a steady-state simulator with various analysis tools to aid the user in assessing the simulator's performance and in assessing the consistency of any measured data entered into the program. Three major application areas for the package have been identified in terms of, modelling existing systems, modelling changes to existing systems, and modelling fictitious or representative systems. The facility of automatic output curve prediction has been illustrated for an application of the latter type, and the package has been shown to be a potentially powerful aid for "what-if" scenarios concerning wellbore parameters.

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REFERENCES


Figure 1: Comparison of the representative well's drawdown relationship against output curves for various geometry configurations (Graph from WELLSIM Version 1.0)