Reservoir Engineering for Geologists
Part I – Overview

by Ray Mireault and Lisa Dean

Welcome to the first article in a series intended to introduce geologists to reservoir engineering concepts and their application in the areas of Corporate Reserve Evaluation, Production, Development, and Exploration.

Topics covered in the series are:
Article 1: Overview
Article 2: COGEH Reserve Classifications
Article 3: Volumetric Estimation
Article 4: Decline Analysis
Article 5: Material Balance Estimates
Article 6: Well Test Interp./Pressure Transient Analysis
Article 7: Rate Transient Analysis
Article 8: Monte Carlo Simulation
Article 9: Reservoir Simulation
Article 10: Coalbed Methane Fundamentals
Article 11: Tight Gas and Shale Gas
Article 12: Oil Recovery

The format for each article will generally be to introduce the concept(s), discuss the theory, and illustrate its application with an example.

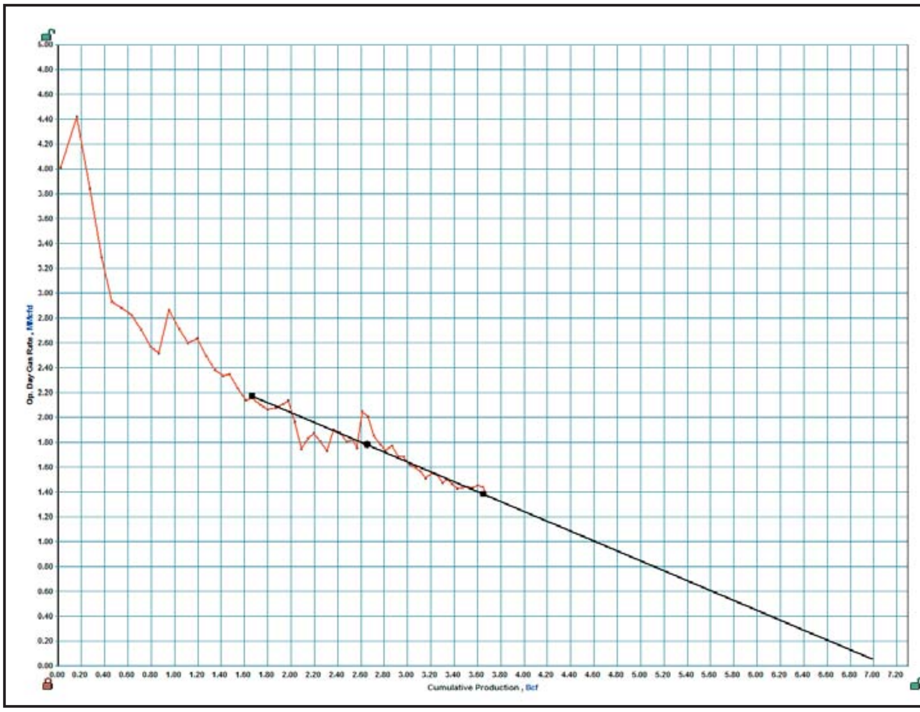


Figure 1. Traditional decline analysis – Rate vs. Cum. Prod.

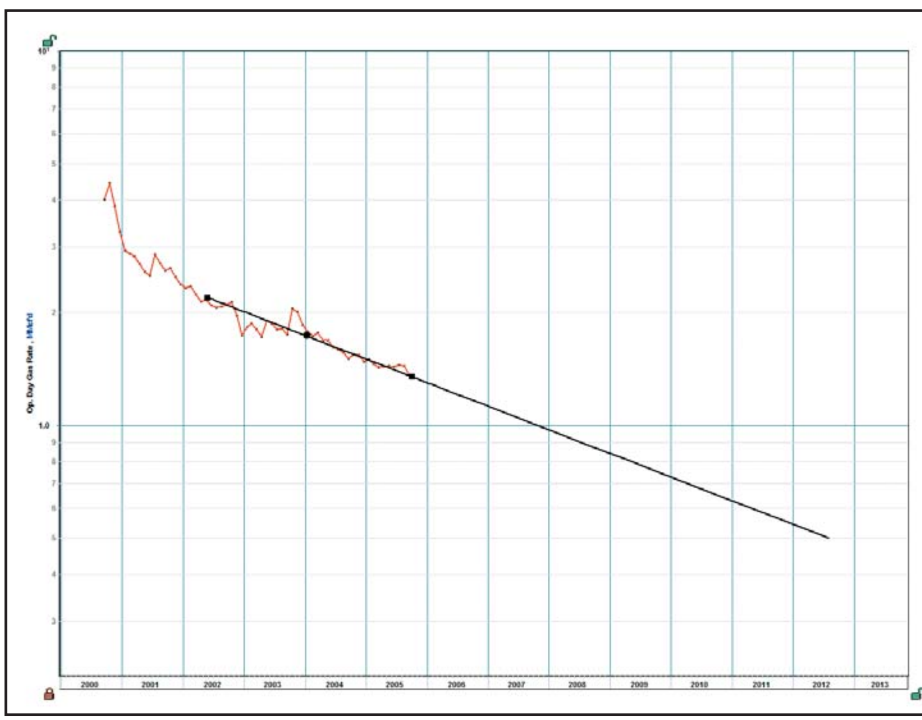


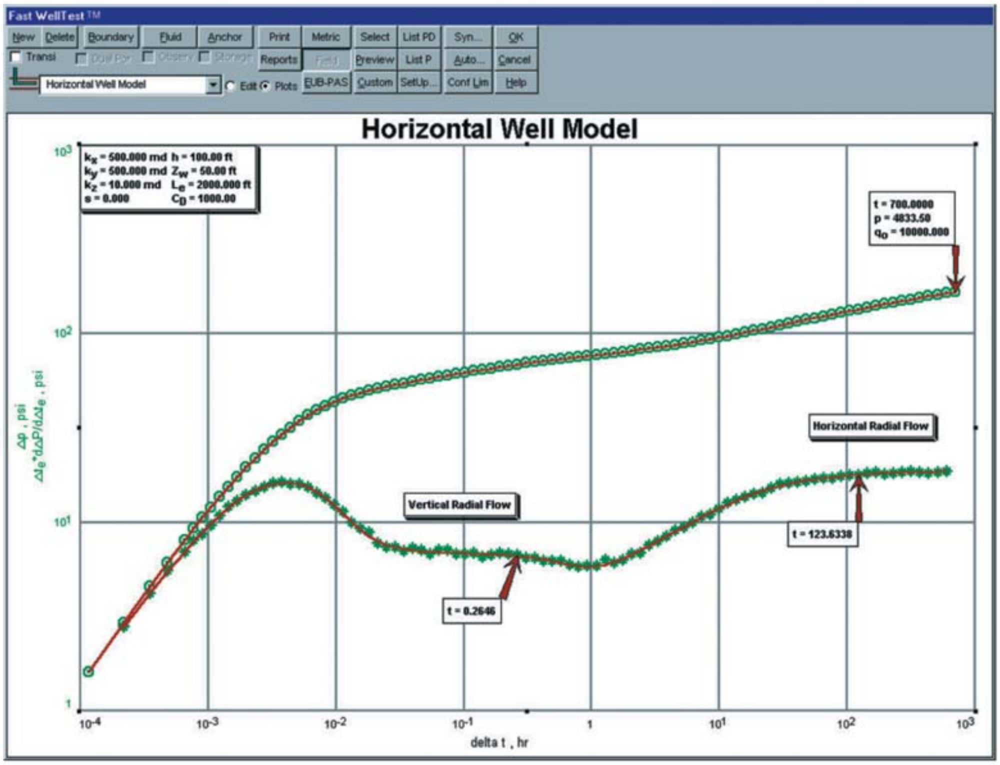
Figure 2. Traditional decline analysis – Rate vs. Time.

ARTICLE DEFINITIONS AND USES

COGEH, the Canadian Oil and Gas Evaluation Handbook, Reserve Classifications provide a Canadian standard reference methodology for estimating reserve volumes according to reserve and resource category. There have been many recent changes in an attempt to achieve a "global standard" in order to ensure the public release of accurate, understandable reserve and resource estimations and classifications.

Volumetric Techniques are used to indirectly estimate Hydrocarbons in Place (OOIP and OGIP) from estimates of area, thickness, porosity, water saturation, and hydrocarbon fluid properties. Analogue or theoretical estimates for hydrocarbon recovery are then applied to estimate recoverable hydrocarbons. These techniques are utilized prior to the acquisition of sufficient production data to allow a more rigorous determination of reserves and resource estimates. These methods are therefore primarily used for evaluating new, non-producing pools and the evaluation of new petroleum basins.

Decline analysis techniques extrapolate the historical performance trend to an economic production limit or cutoff to forecast the expected ultimate recovery



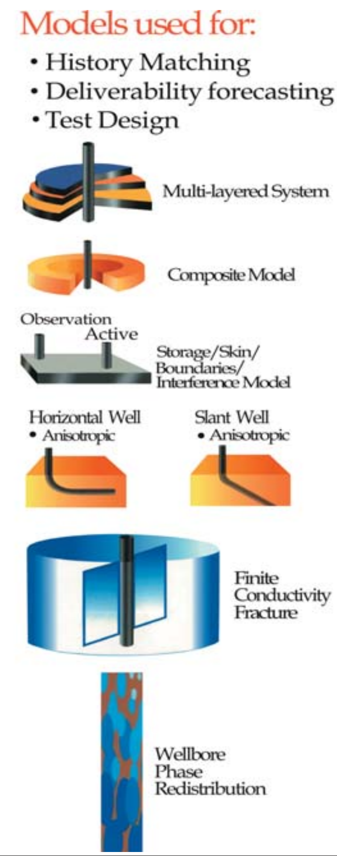


Figure 3. Horizontal well model.

(EUR). The method plots the production rate through the production history (time) and records the production rate decline as cumulative production increases (Figures 1 and 2). In theory it is only applicable to individual wells, but in practice extrapolations of group production trends often provide acceptable approximations for EUR. Two key assumptions are that past trends represent the full capability of the producing entity and that the trends and operating practices continue into the future. Deviations from theoretical performance can help identify wells and areas that are underperforming. Well workovers to resolve mechanical problems or changes in operating practices can enhance performance and increase recovery. The presence of pressure maintenance by an aquifer may make this method inappropriate to use. This technique is also more reliable than volumetric methods when sufficient data is available to establish a reliable trend line.

Material balance techniques are used to estimate hydrocarbons in place (OOIP and OGIP) from measurements of fluid production and the resultant change in reservoir pressure caused by that production. The technique requires accurate estimates of fluid properties, production volumes, and reservoir pressure. Estimates for hydrocarbon recovery, based on fluid properties and analogue producing pools/formations, are then applied to estimate

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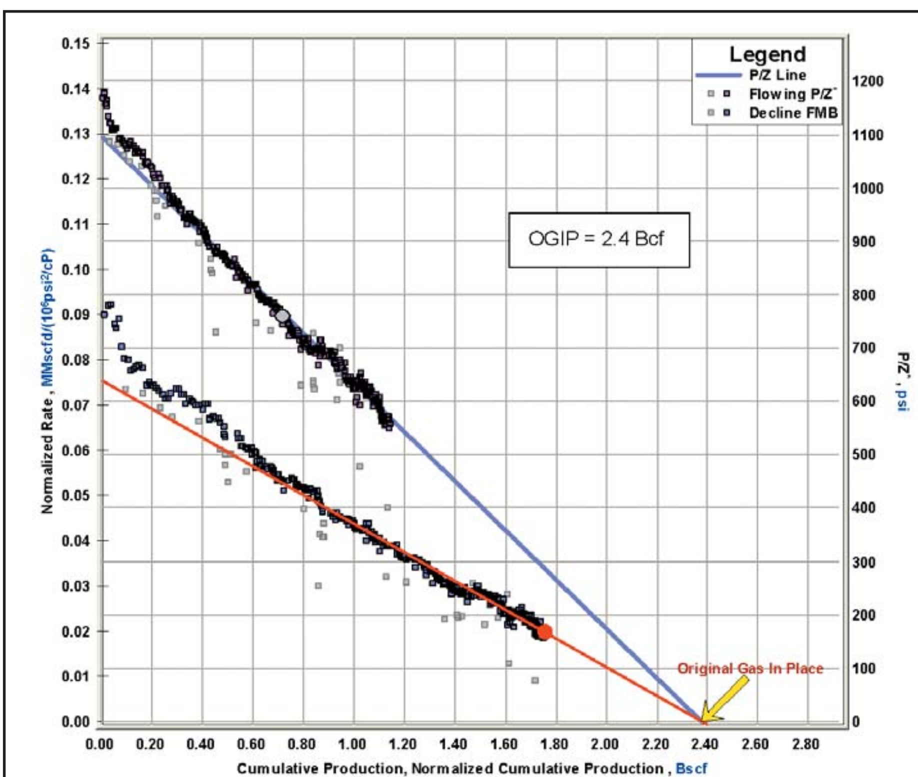

Figure 4 – Flowing material balance.

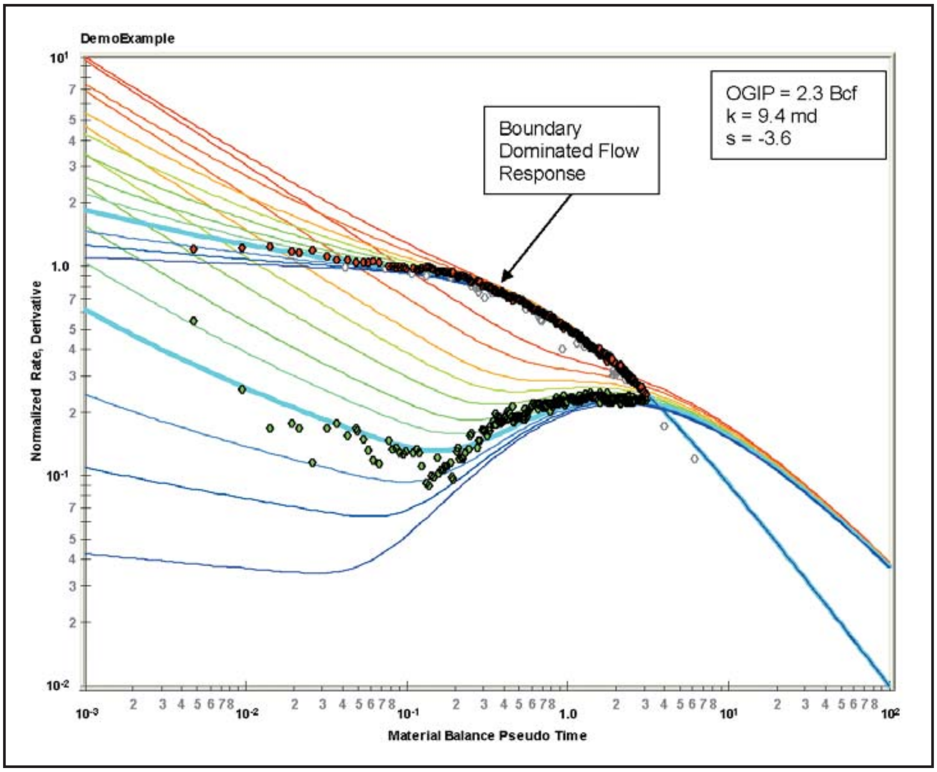

Figure 5. Blasingame typecurve analysis.

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recoverable hydrocarbons. These methods are more reliable than volumetric methods as long as there is sufficient data to establish the relationship.

Well tests and the subsequent pressure transient analyses are used to determine fluids present in the reservoir, estimate well productivity, current reservoir pressure, permeability, and wellbore conditions from mathematical flow equations and dynamic pressure buildup measurements. The technique requires that a well be produced for a period of time and then shut-in for an appropriate length of time. Analysis inputs include fluid viscosity, rock properties, net pay thickness of the producing interval, and the mechanical configuration of the wellbore. An adequate buildup provides information on the reservoir flow pattern near the wellbore, identifies restricted reservoirs, and can sometimes infer the geometric shape of the well's drainage area (see Figure 3).

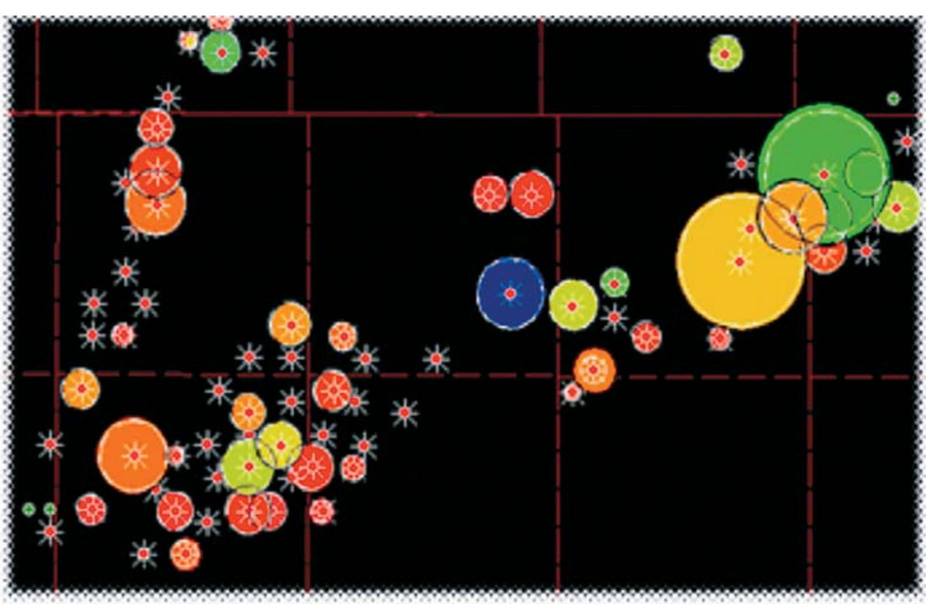

Figure 6. Visualization of results.

Rate transient analysis (RTA), also know as advanced decline analysis is a relatively recent development that uses well flowing pressures to characterize well and reservoir properties and estimate in-place volumes. This technique has been made available by the introduction of SCADA (Supervisory Control and Data Acquisition) data capture systems that generally provide the frequency of flow and pressure information required for real-life application (flowing material balance and type curve analysis – see Figures 4 and 5). Since pressure information can be captured without shutting the well in and without the loss of cash flow, the frequency of "testing" can be significantly increased and changes in operating performance identified more quickly than is practical with conventional testing.

Monte Carlo simulation is used to deal with the uncertainty in every input parameter value in the volumetric equation. Instead of a single number, it allows the geologist to provide a value range for areal extent, pay thickness, porosity, water saturation, reservoir pressure, temperature, fluid properties, and recovery factor. Multiple (typically 10,000) iterations are run to generate a probable range of values for in-place and recoverable hydrocarbons (Figure 6). The simulation is especially applicable to play and resource assessments.

Numerical reservoir simulation uses material balance and fluid flow theory to predict fluid movement through three-dimensional space. The inputs of geometric shape of the deposit, the rock, and fluid properties must be determined from other methods to deal with the non-uniqueness of the forecasts. However, it has the ability to visually integrate the geological and geophysical interpretation with the analytical approach to reservoir analysis (Figure 7).

Although different techniques are used in different situations, a major purpose of reservoir engineering is to estimate recoverable oil or gas volumes and forecast production rates through time. Forecasts of production rate and cumulative volumes are a key input for the following:

- Exploration play assessment,
- Development drilling locations,

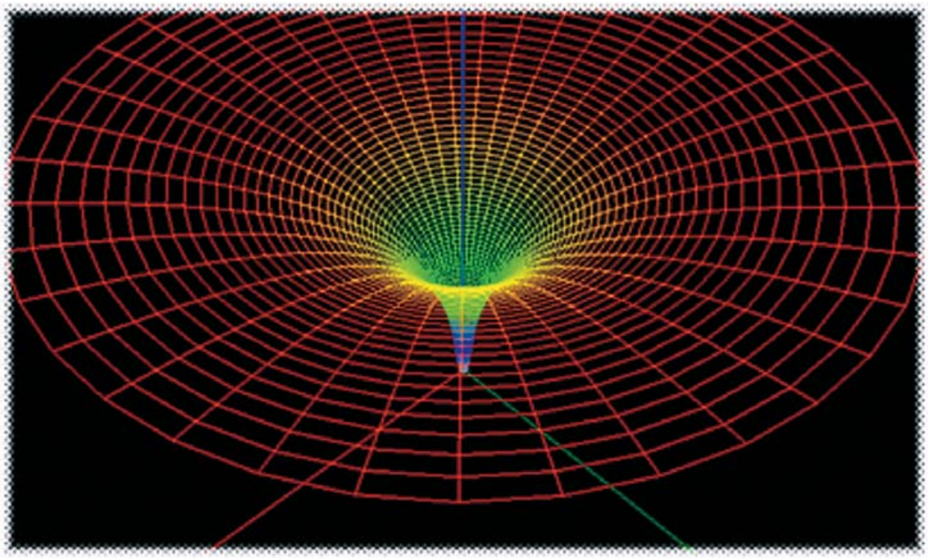

Figure 7. Pressure profile from numerical model.

- Accelerated production from a producing pool,
- Rank and budgeting of potential exploration and development expenditures,
- Corporate reserve evaluations.

The different techniques also have different applications at different times in the life of a field or prospect. For example, the initial stages of exploration may require volumetric estimates based upon analogue data due to the lack of existing well information and estimating volumes with Monte Carlo simulation. Volumetric estimates based upon actual well data may be the next step after exploration drilling and testing has proven successful. As development and production commence, SCADA frequency production and pressure measurements can be obtained for RTA analysis. Monthly production volumes provide the data for material balance and decline analysis techniques.

As production continues, the accuracy and reliability of the estimates obtained from RTA, material balance, and decline analysis increases. Integrating all the techniques provides more reliable answers than relying solely on any one method. In addition, integrating the techniques can lead to additional hydrocarbon discoveries and/or increased recovery from known accumulations.

Articles two through nine address the main topics of reservoir engineering. The remaining articles will focus on play types that are presently of interest to the industry. Included in this group of plays are coalbed methane concepts and interpretation (Figures 8 and 9), tight gas, shale gas, and an overview of secondary and tertiary oil recovery methods.

Look for our next article on the COGEH Reserve Classifications in next month's Reservoir.

This article was contributed by Fekete Associates, Inc. For more information, contact Lisa Dean at Fekete Associates, Inc.

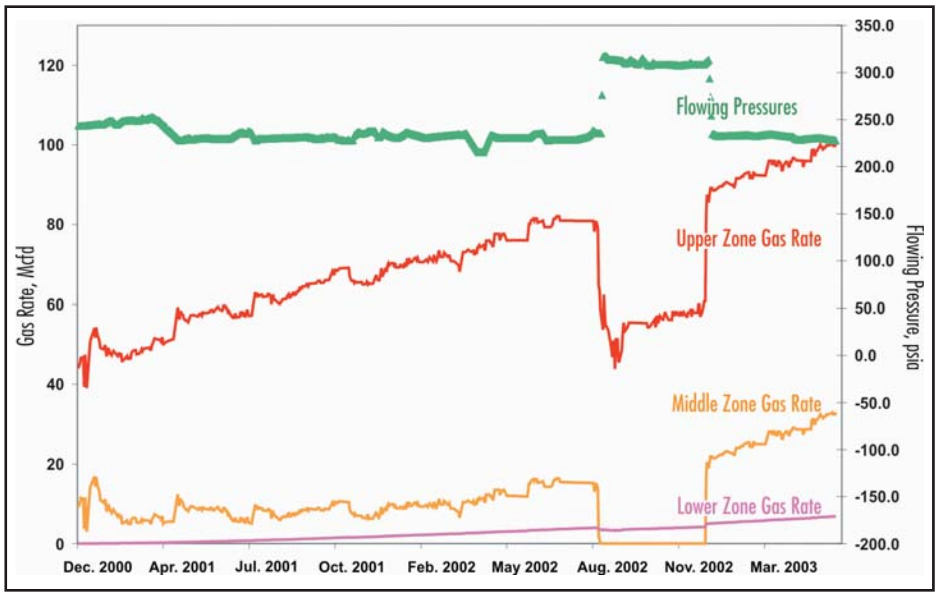

Figure 8. Historical rates vs. time.

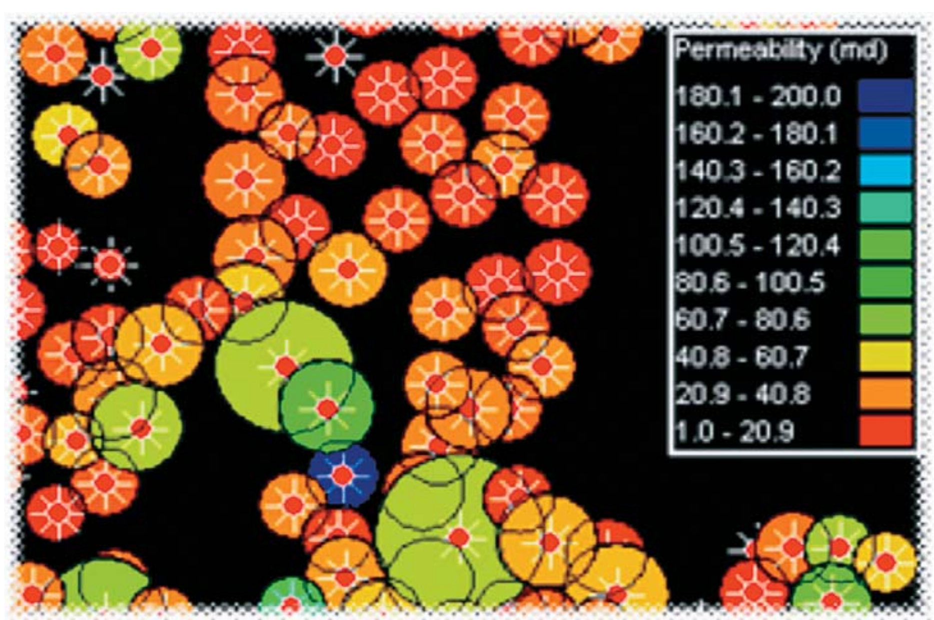

Figure 9. Drainage area and permeability.