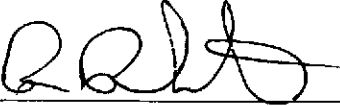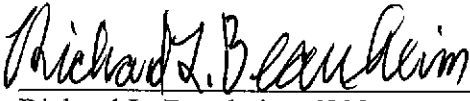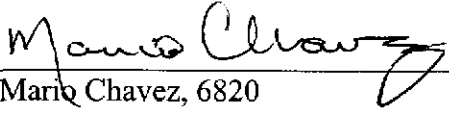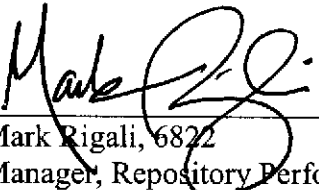543901

Analysis Report for AP-070

Analysis of Culebra Pumping Tests Performed
Between December 2003 and August 2005

(AP-070: Analysis Plan for Non-Salado Hydraulic-Test Interpretations

Task Number 1.4.2.3

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Contents

Table

Figures

1. Introduction

This report discusses the analyses of pumping tests performed in the Culebra Dolomite Member of the Rustler Formation at the Waste Isolation Pilot Plant (WIPP) site between December 2003 and August 2005. These analyses were performed between August 2005 and May 2006 in accordance with the Sandia National Laboratories (SNL) Analysis Plan for Non-Salado Hydraulic-Test Interpretations, AP-070, Revision 1 (Beauheim, 2004). The computer code used for analysis was nSIGHTS (n-dimensional Statistical Inverse Graphical Hydraulic Test Simulator), version 2.30. A detailed description of the approach followed in these analyses can be found in Beauheim et al. (1993, Appendix B) and Roberts et al. (1999, Chapter 6). The data analyzed for this report were collected at the following wells: SNL-1, SNL-2, SNL-3, SNL-5, SNL-9, SNL-12, SNL-13, SNL-14, WIPP-11, WIPP-25, and C-2737. Both barometric and earth-tide effects were removed from the data sets prior to analysis.

2. nSIGHTS Overview

The nSIGHTS code consists of two independent applications: nPre.exe and nPost.exe. The pre-processor and simulator, nPre, is used to process the field data prior to analysis, set up the mathematical model, and then run the model in inverse mode to estimate the hydraulic parameters of interest, e.g., transmissivity (T), flow dimension (n), etc. It also generates the data used to quantify the uncertainty associated with those hydraulic-parameter estimates. The post-processor, nPost, post-processes the results stored in the nPre output files, allowing graphical and statistical analysis of the simulation results.

All field data used in each analysis are entered or read into nPre and stored in a configuration file with an *nPre* extension. The field data include well radius, tubing-string radius, formation thickness, fluid density, and the transient pressure and flow-rate data. All input field data, including the reference ERMS numbers and field notebooks for each well, are listed in Appendix A.

The conceptual model chosen based on the characteristics of the test response determines the fitting parameters that will be estimated for each analysis. The model fitting parameters for each analysis are specified in the *nPre* configuration files named for each of the wells. Five hundred (500) sets of optimized fitting parameters were generated for each analysis in this report as part of the fitting-parameter uncertainty calculation. These 500 optimized parameter sets are stored in the nPre output file with an *nOpt* extension. The corresponding transient pressure simulations are stored in an nPre output file with an *nXYsim* extension. Both the *nOpt* and *nXYsim* files are read by nPost and all of the post-processing results are stored in a configuration file with an *nPost* extension.

The nSIGHTS input and output files for each tested well are stored in a directory structure like that shown in Figure 1.
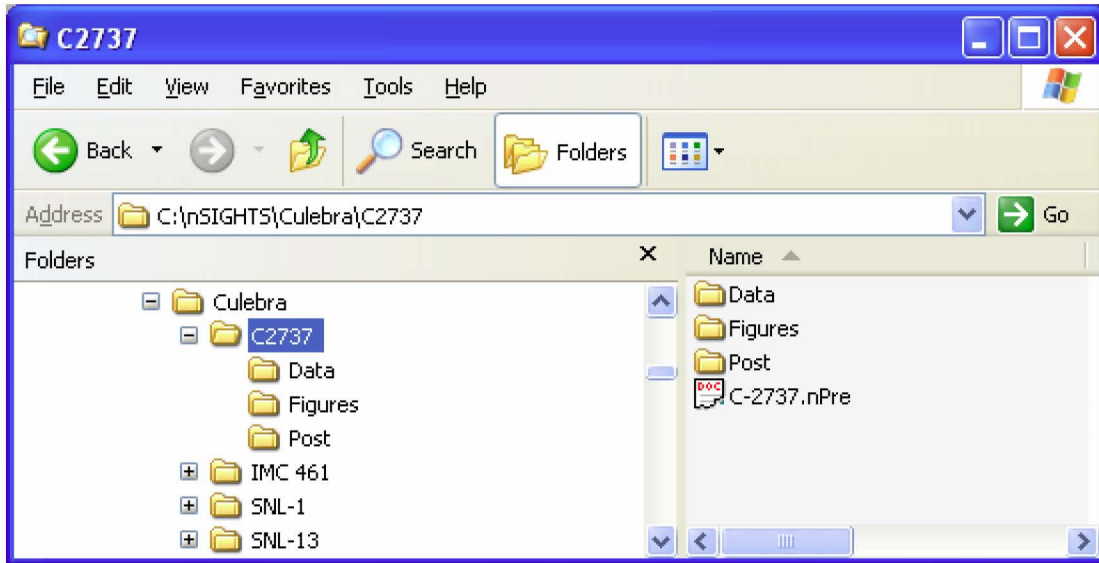
Figure 1. Directory structure for Culebra nSIGHTS analyses.

The nPre configuration file is stored in the folder named for the tested well (Figure 1). Transient pressure and flow-rate files are stored in the Data folder (Figure 2) and all nPre output files as well as the nPost configuration file are stored in the Post folder (Figure 3).
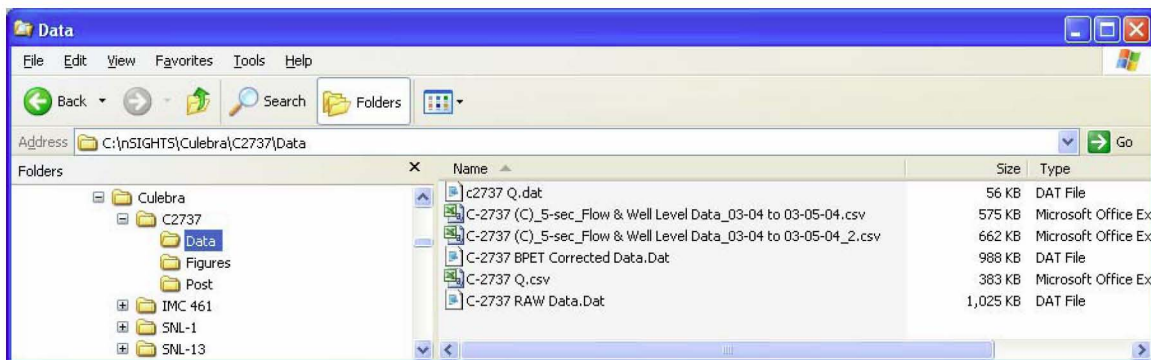
Figure 2. *Data* folder containing the pressure and flow-rate files for nPre input.
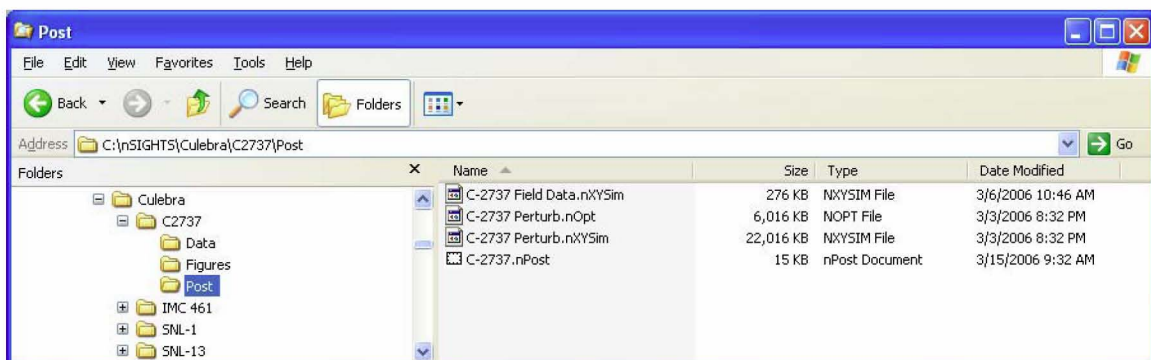
Figure 3. *Post* folder containing simulation output and post-processed data.

8

3. Test and Analysis Procedures

At some of the tested wells discussed in this report (e.g., SNL-1, SNL-2, SNL-12, C-2737), long-term pressure records were available leading up to the tests. When helpful, these pressure records were used to specify pre-test history sequences for the nSIGHTS test simulations.

The testing sequence at most of the wells discussed in this report consisted of a series of pumping events at more or less constant rates. Typically, a pump would be installed in the well and then turned on only long enough to bring water to ground surface. The day before the actual test was to begin, the pump would be operated just long enough to establish the rate the pump could sustain over the intended duration of the test and to set all control valves and the pump motor speed appropriate to that rate. The well would then be allowed to recover overnight before beginning the constant-rate test. In some instances (e.g., SNL-2), installing the pump and setting the rate were accomplished in the same day. In other instances (e.g., WIPP-11), the final constant-rate test was begun after only a few hours of recovery from the rate-setting event.

For analysis, these pre-test pumping events were treated in one of two ways. For SNL-1, SNL-12, and WIPP-11, the pre-test pumping events were simulated in the same way as the constant-rate test, but less weight was given to the pre-test pumping events in the parameter optimization process. For SNL-2, SNL-3, SNL-5, SNL-9, SNL-14, C-2737, and WIPP-25, the pre-test pumping events were treated as "history" periods and the associated pressures were simply specified in the simulations. All pressure recoveries were simulated.

Test analysis involved finding the values of the fitting parameters that produced the best simulated matches to the pressure data collected during the constant-rate test and subsequent recovery period. In addition to the formation properties of interest (principally transmissivity and flow dimension), tubing string radius was also included as a fitting parameter so that nSIGHTS could exactly match the amount of wellbore storage observed during the test. The main objective of these analyses was to estimate T in the vicinity of each well for subsequent use in T-field generation and WIPP performance assessment calculations. Correlation between estimated T values and the other fitting parameters reported in Appendix B would be of interest if these correlations resulted in large uncertainty in the estimated T values. The uncertainty in the estimated T values shown in Table 1, however, is seen to be relatively small, so any correlation between T and other fitting parameters is not of interest.

The uncertainty quantification method applied to the analyses in this report is a process referred to as *perturbation analysis*. In this process, preliminary analyses are performed in which a reasonable fit is obtained to the specified constraints defined in the nPre configuration file. The resulting values of the fitting parameters are the *baseline solution* set – a single value for each fitting parameter that provides a satisfactory fit to the data (*satisfactory* being a judgment call on the part of the analyst). Perturbation analysis begins by assigning a plus/minus range corresponding to the parameter space one wishes to investigate to each of the baseline fitting-parameter values. These plus/minus fitting-parameter ranges for each analysis are listed in Appendix B. Starting at the baseline value, the fitting parameters are randomly perturbed to fall somewhere within their assigned ranges and are then optimized from these random starting points. The objective of perturbation analysis is to adequately sample the parameter space and locate all of the minima within the parameter space. By definition, the parameter-space

minimum that provides the best quantitative fit to the data, measured in terms of the smallest sum of squared errors (SSE), is the *global minimum* (assumed true solution), and the other minima are referred to as *local minima*. Local minima are effectively localized depressions in the parameter-space topography that trap the inverse regression algorithm during its attempt to find the global minimum – the smallest SSE.

Five hundred (500) perturbation/optimization runs were performed for each of the analyses discussed in this report. From these perturbation results, only those solutions that provided a satisfactory fit (as determined by the analyst) to the data are presented in this report – effectively those solutions that fall within the global minimum. In some cases, the original baseline solution may not fall within the global minimum defined through perturbation analysis.

4.   Analysis Results

Discussions of the individual test analyses are given below. A summary of the transmissivity estimates obtained from perturbation analysis of each test is shown in Table 1.

Table 1. Transmissivity Estimates.

Well	Geometric Mean (m^2/s)	Minimum (m^2/s)	Maximum (m^2/s)	Variance
SNL-1	6.24E-04	5.97E-04	6.51E-04	2.95E-05
SNL-2	1.07E-04	1.03E-04	1.12E-04	2.32E-05
SNL-3	9.88E-04	4.32E-04	4.53E-03	7.84E-02
SNL-5	4.86E-06	2.20E-06	8.56E-06	4.31E-02
SNL-9	3.86E-05	3.56E-05	3.96E-05	5.90E-06
SNL-12	4.97E-04	4.89E-04	5.09E-04	1.01E-05
SNL-14	4.92E-05	4.81E-05	4.91E-05	2.00E-06
WIPP-11	4.27E-04	8.34E-05	2.42E-03	4.59E-01
WIPP-25	2.51E-04	2.21E-04	3.13E-04	2.50E-04
C-2737	6.62E-07	6.57E-07	6.63E-07	2.66E-08

4.1   SNL-1

On March 3, 2005, the Culebra interval in SNL-1 was acidized by injecting 48 barrels (7.63 m^3) of a 15% hydrochloric acid (HCl) solution followed by 48 barrels (7.63 m^3) of fresh water into the well. A pump was installed in the well after the acidization on March 3, 2005, and an evaluation of potential pumping rates was performed on March 4, 2005. Testing activities in SNL-1 were initiated on March 7, 2005. Three preliminary pumping episodes lasting between 19.5 minutes and 17.7 hours occurred before the final 40.46-hr test at 35 gpm. Figure 4 shows the pressure record from SNL-1 used in this analysis. The pressures measured prior to the start of the testing activities on March 7, 2005, were included in the nSIGHTS simulation as a pressure history. The pressures shown in Figure 4 were separated into 11 nSIGHTS sequences

for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-1.nPre file and are listed in Appendix B.1.
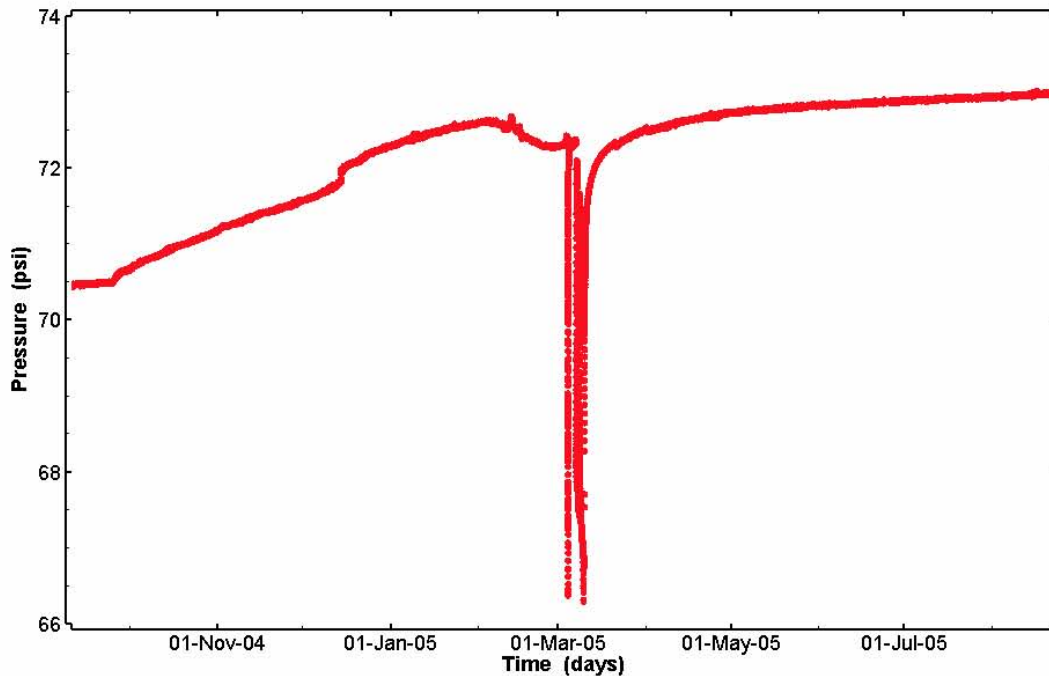
Figure 4. Pressure data from SNL-1.

The specified SNL-1 conceptual model, based on the characteristics of the final buildup period diagnostic plot shown in Figure 5, was a composite-geometry (*n*) system with wellbore storage and skin. The pressure derivative indicated radial flow (*n* = 2) until about 500 minutes elapsed time (Figure 5).   After that time, the upward sloping late-time derivative indicates far-field sub-radial flow (*n* < 2), which could be indicative of a decrease in transmissivity with distance. The range of transmissivity (*T*) values estimated from the SNL-1 analysis for the radial-flow period (?) is shown in Figure 6. The SNL-1 geometric mean *T* value was 6.24E-4 m^2/s. The Cartesian, detailed Cartesian, and log-log pressure-buildup diagnostic simulations corresponding to the *T* values in Figure 6 are shown in Figures 7, 8, and 9, respectively.

11

Figure 5. Log-log diagnostic plot of the final SNL-1 pressure-buildup test.
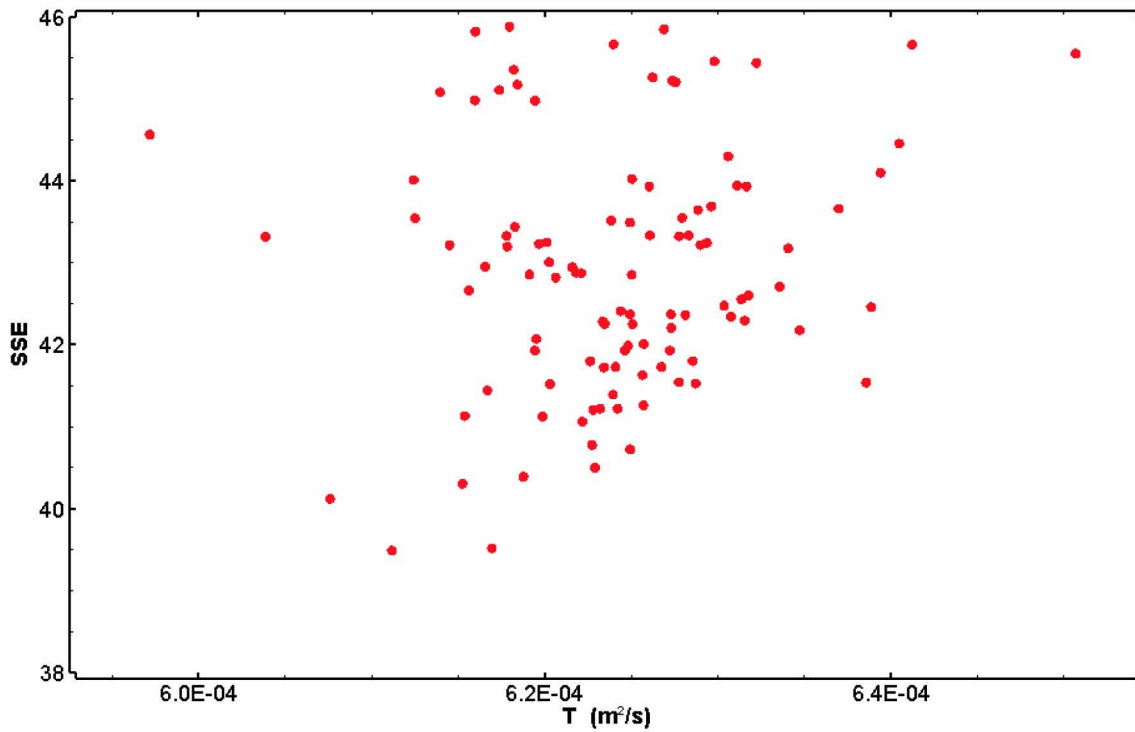
Figure 6. Estimates of transmissivity derived from the SNL-1 perturbation analysis.
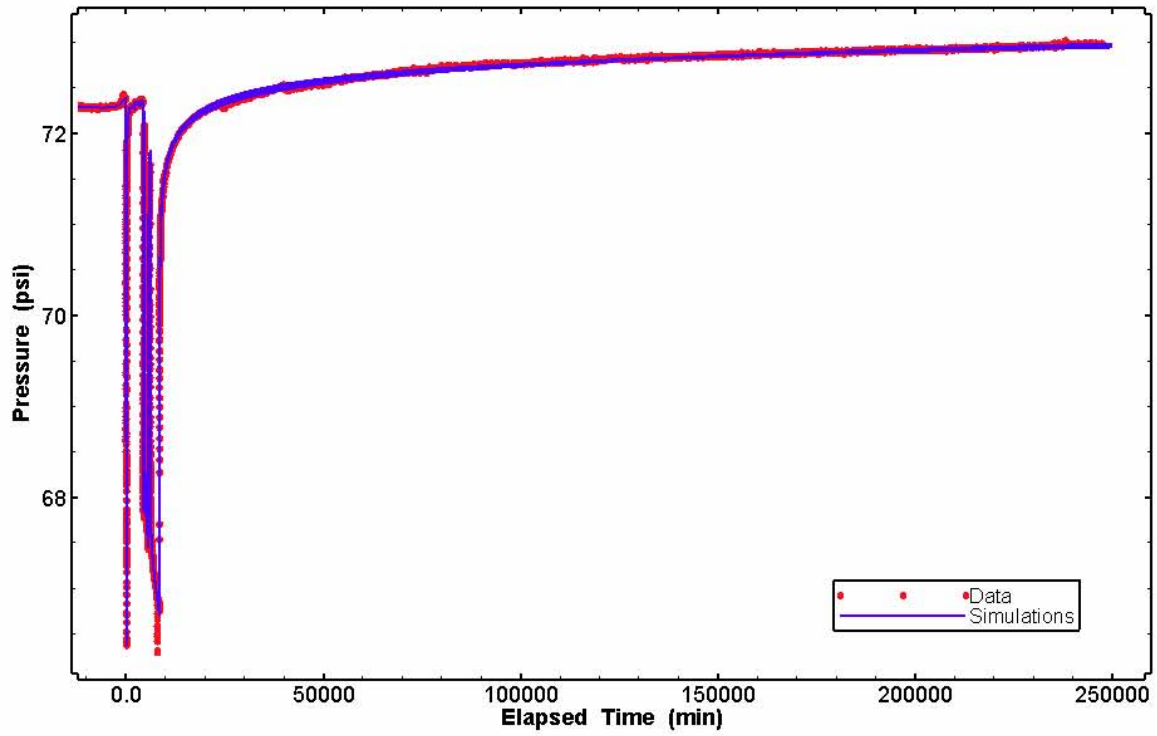
Figure 7. Simulations of the SNL-1 pressure response.

Figure 8. Detail of simulations of the SNL-1 pressure response.
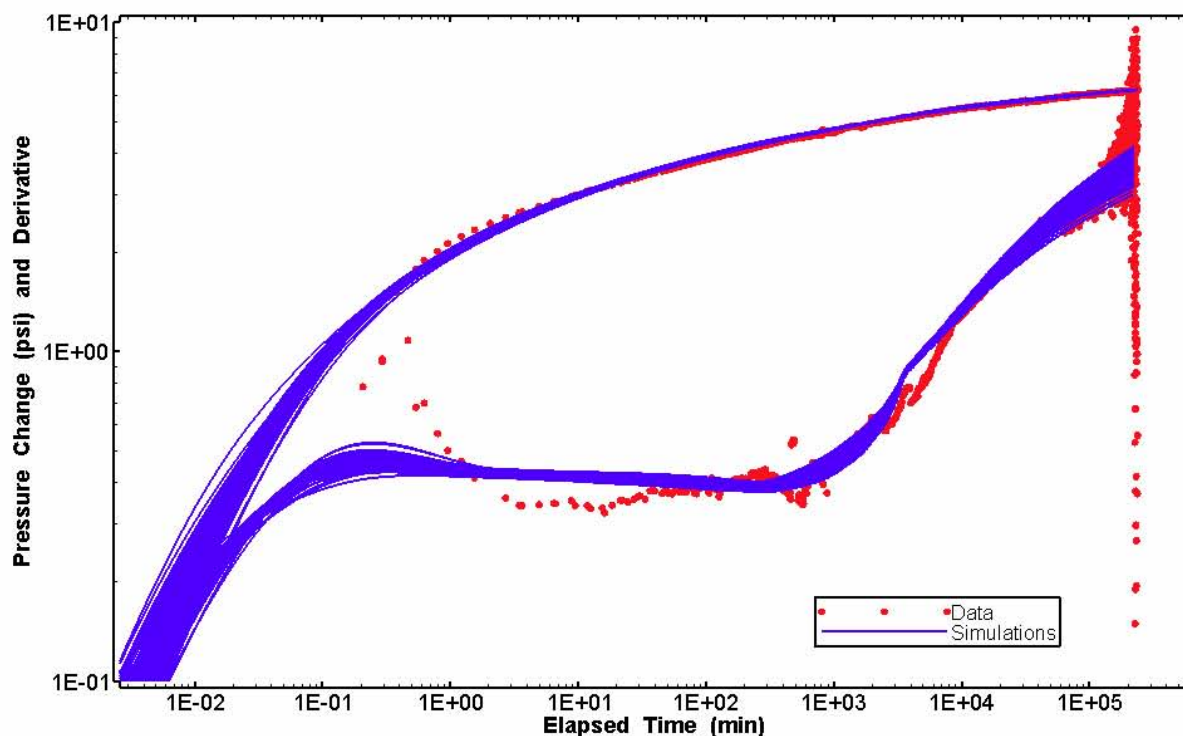
Figure 9. Simulations of pressure change and derivative during the final SNL-1 pressure-buildup test.

4.2 SNL-2

The Culebra interval in SNL-2 was acidized on January 19, 2005, by injecting 48 barrels (7.63 m^3) of a 15% HCl solution followed by 48 barrels (7.63 m^3) of fresh water into the well. A pump was installed in the well after the acidization on January 19, 2005, and an evaluation of potential pumping rates was performed that evening. A constant-rate (12 gpm) pumping test was initiated in SNL-2 on January 20, 2005, and continued for approximately 96.4 hours. The first 79 hours of pressure buildup following the end of pumping were also included in the analysis. About 79 hours after the pressure buildup began, the SNL-2 pressure response began to exhibit pressure changes not associated with SNL testing activities, precluding its usefulness for analysis. Figure 10 shows the pressure record from SNL-2 used in this analysis. The pressures measured prior to the start of the pumping test on January 19, 2005 were included in the nSIGHTS simulation as a pressure history. The pressures shown in Figure 10 were separated into four nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-2.nPre file and are listed in Appendix B.2.
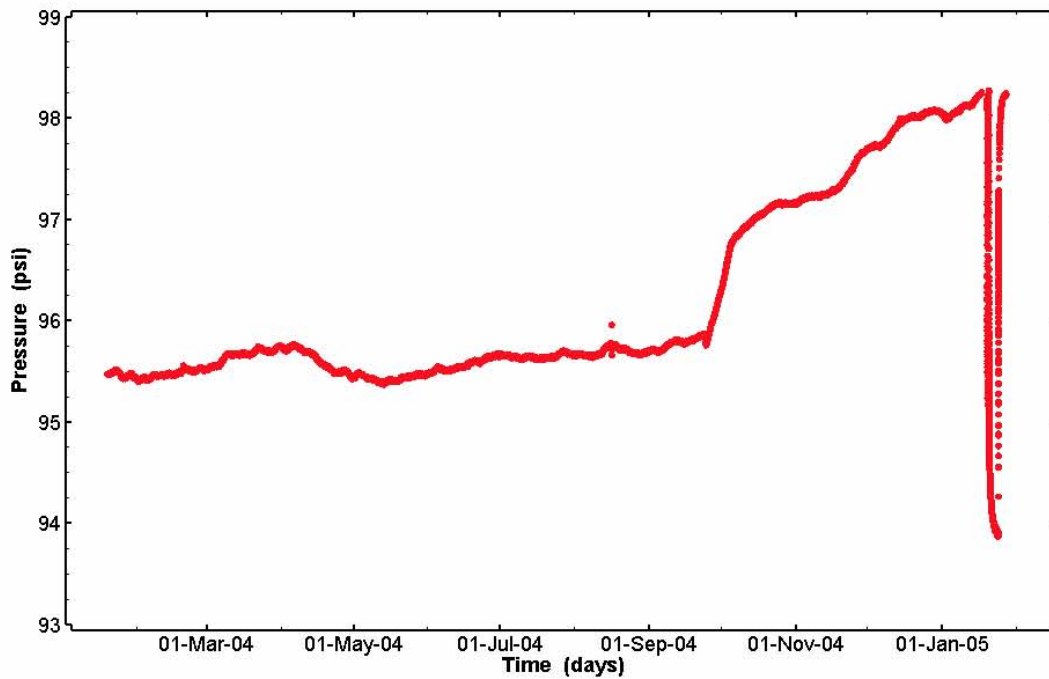
Figure 10. Pressure data from SNL-2.

The specified SNL-2 conceptual model, based on the characteristics of the buildup-period diagnostic plot shown in Figure 11, was a composite-T system with wellbore storage. The pressure derivative exhibits a radial stabilization between 1 and 10 minutes elapsed time (Figure 11) and then rises until approximately 100 minutes elapsed time, indicating a decrease in T. After that time, the downturn in the derivative probably results from the complex pre-test pressure history whose pressure changes are not associated with SNL testing activities. The range of T values estimated from the SNL-2 analysis corresponding to the first derivative stabilization is shown in Figure 12. The geometric mean T value was 1.07E-4 m^2/s. The Cartesian and log-log pressure-buildup diagnostic simulations corresponding to these T values are shown in Figures 13 and 14, respectively.

15
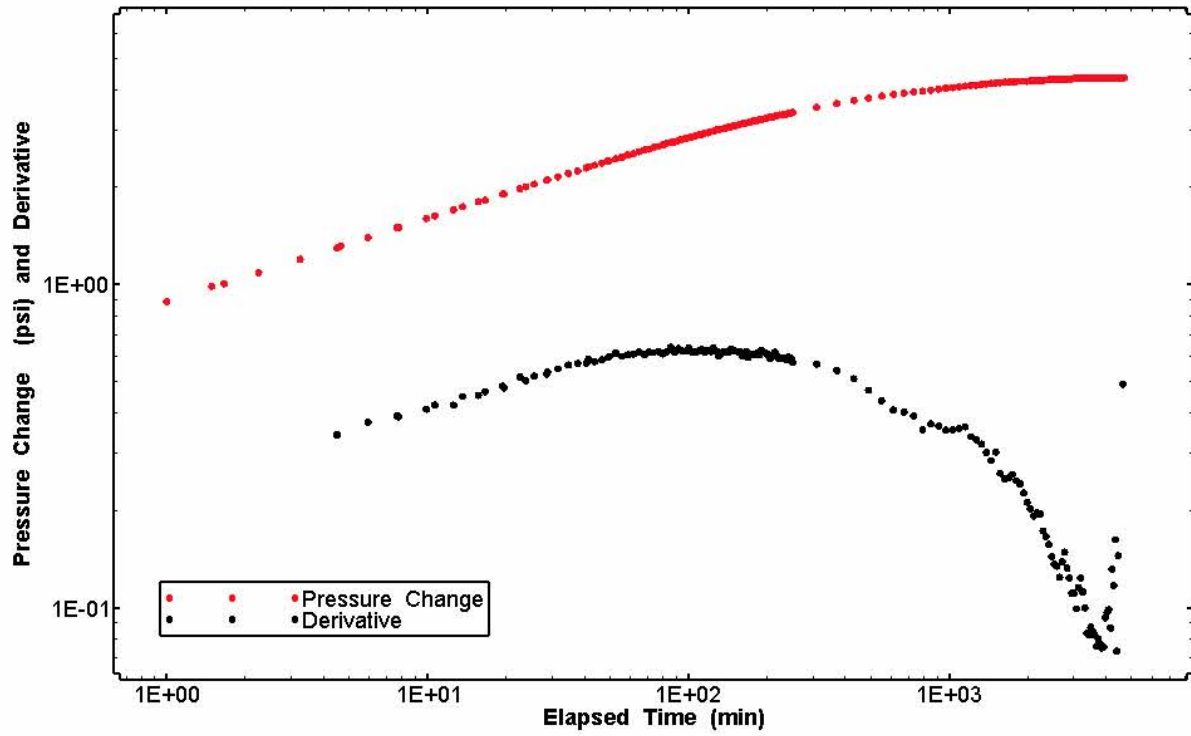
Figure 11. Log-log diagnostic plot of the final SNL-2 pressure-buildup test.
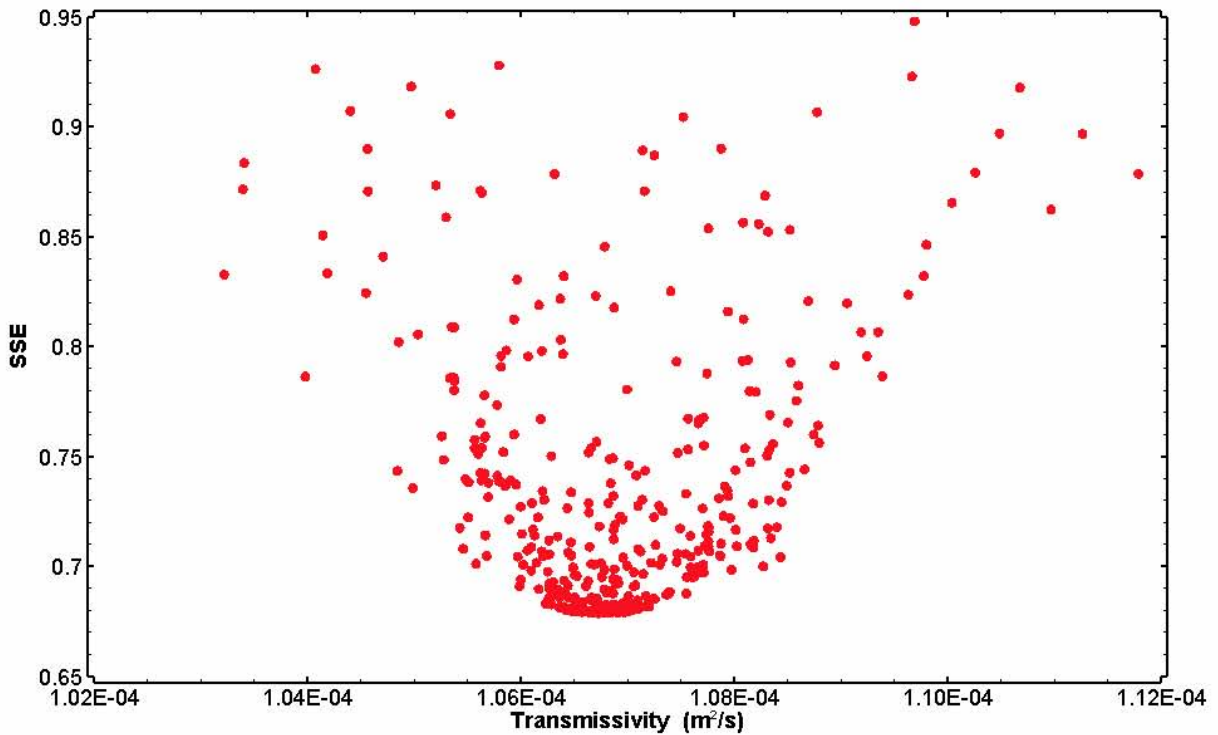
Figure 12. Estimates of transmissivity derived from the SNL-2 perturbation analysis.
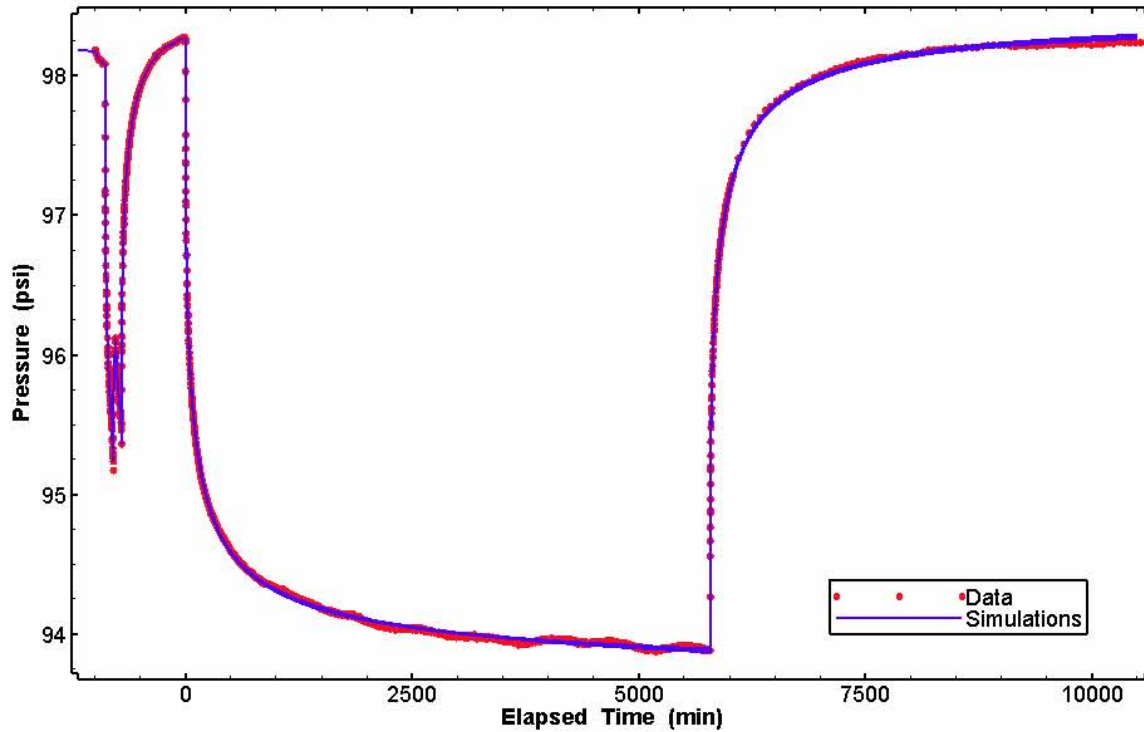
Figure 13. Simulations of the SNL-2 pressure response.
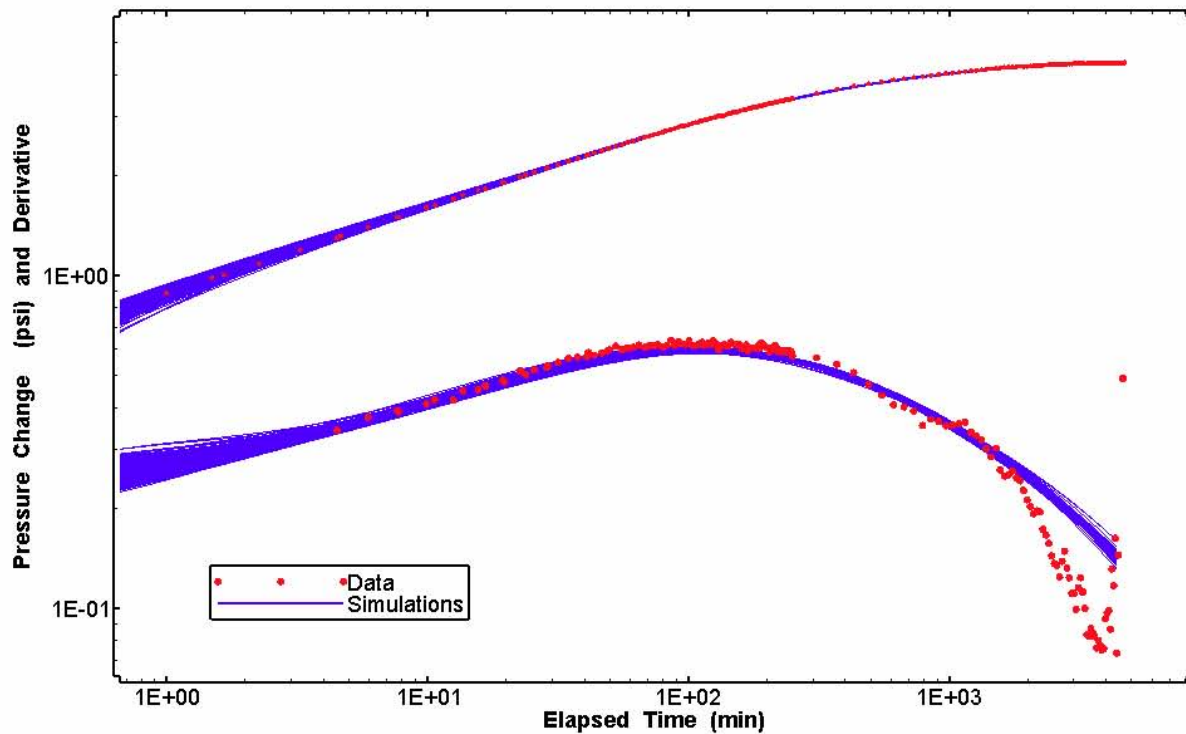
Figure 14. Simulations of pressure change and derivative during the final SNL-2 pressure-buildup test.

4.3   SNL-3

A constant-rate (10 gpm) pumping test was initiated in SNL-3 on April 14, 2004, and continued for approximately 2.2 days. The subsequent 10.4 days of pressure buildup were also included in this analysis. Figure 15 shows the pressure record from SNL-3 used in this analysis. The pressures shown in Figure 15 were separated into three nSIGHTS sequences; details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-3.nPre file and are listed in Appendix B.3.
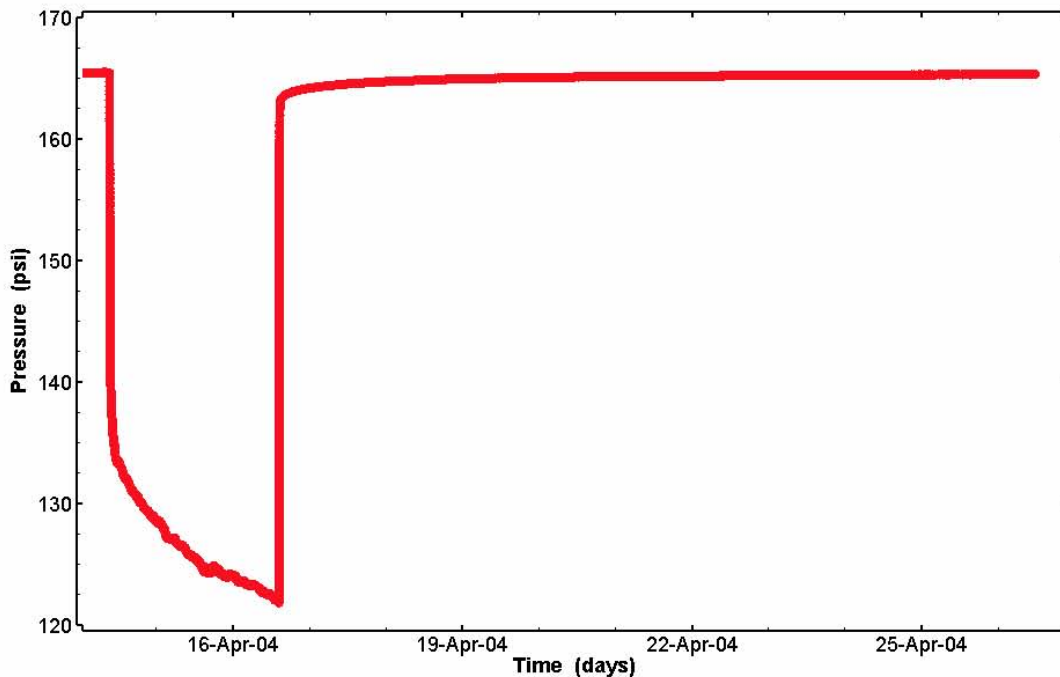
Figure 15. Pressure data from SNL-3.

The specified SNL-3 conceptual model, based on the characteristics of the pressure-buildup diagnostic plot shown in Figure 16, was a composite-T system with wellbore storage and a time-dependent skin. The observed linear upward trend in the derivative beginning at approximately 0.04 days (Figure 16) is indicative of constantly decreasing T in a radial flow system. The range of T values estimated from the SNL-3 analysis that affect the early-time fit to the linear part of the derivative is shown in Figure 17. The geometric mean of these T values is 9.88E-4 m^2/s. The simulated SNL-3 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the T values shown in Figure 17 are shown in Figures 18 and 19, respectively.

18
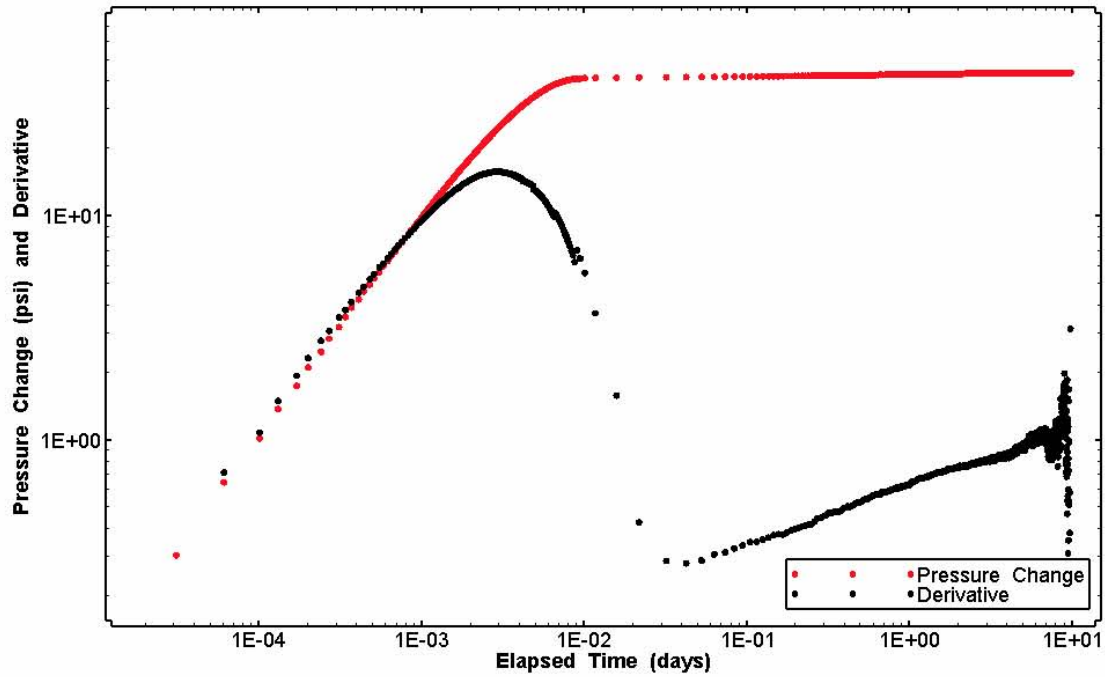
Figure 16. Log-log diagnostic plot of the SNL-3 pressure-buildup test.
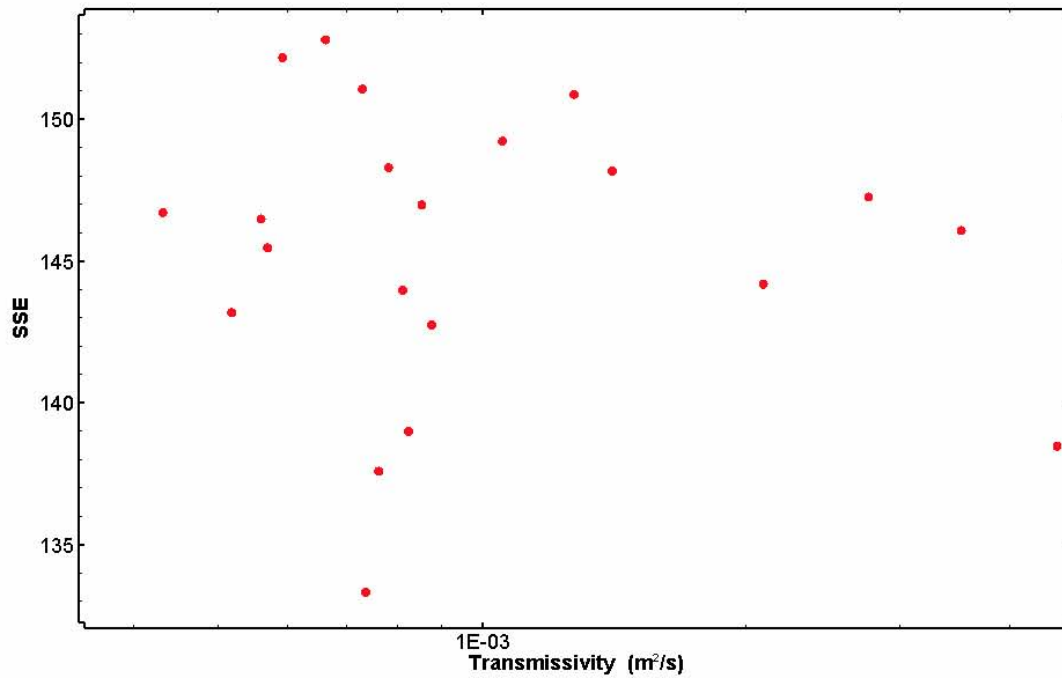
Figure 17. Estimates of transmissivity derived from the SNL-3 perturbation analysis.

19
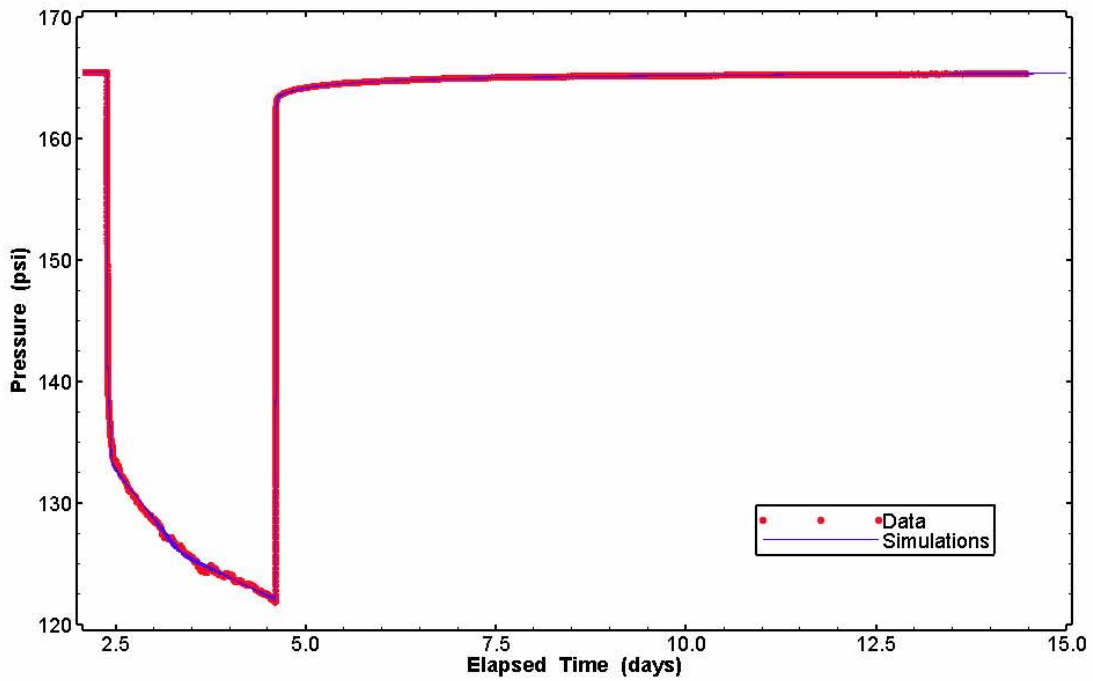
Figure 18. Simulations of the SNL-3 pressure response.
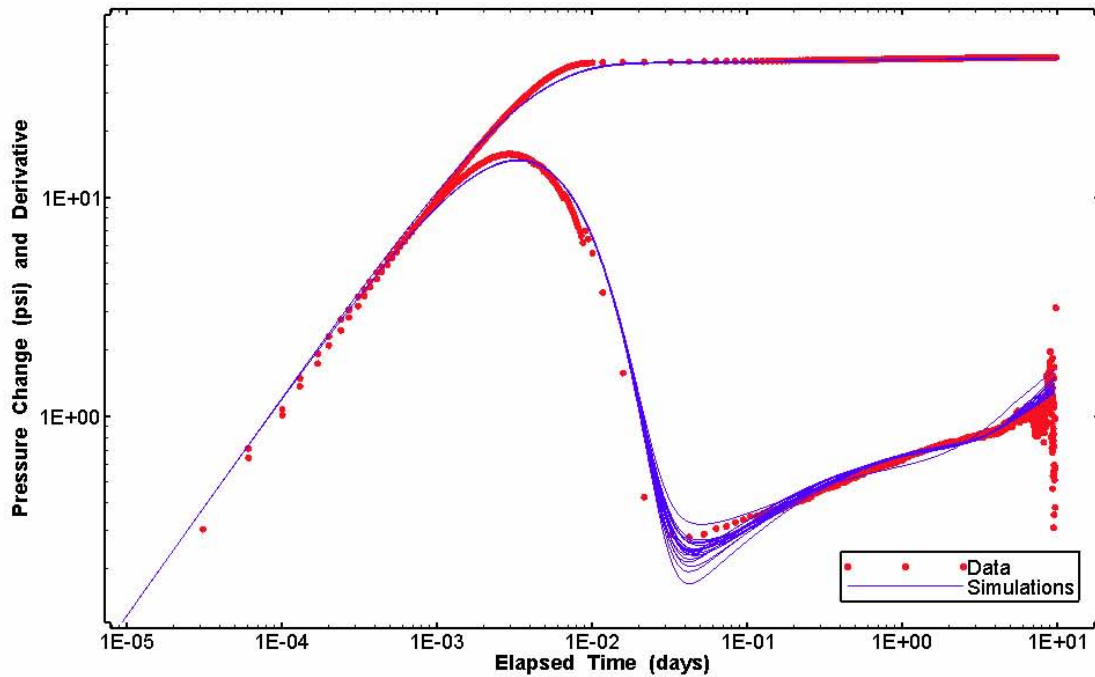
Figure 19. Simulations of pressure change and derivative during the SNL-3 pressure-buildup test.

4.4   SNL-5

Various pumping rates were evaluated in well SNL-5 over a 3.5-hr period on July 19, 2004. The actual pumping test began on July 20, 2004, had an average rate of 3.5 gpm, and lasted approximately 94.1 hr. The pressure response from July 19 – August 18, 2004 (Figure 20) was included in this analysis. The pressures shown in Figure 20 were separated into five nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-5.nPre file and are listed in Appendix B.4.
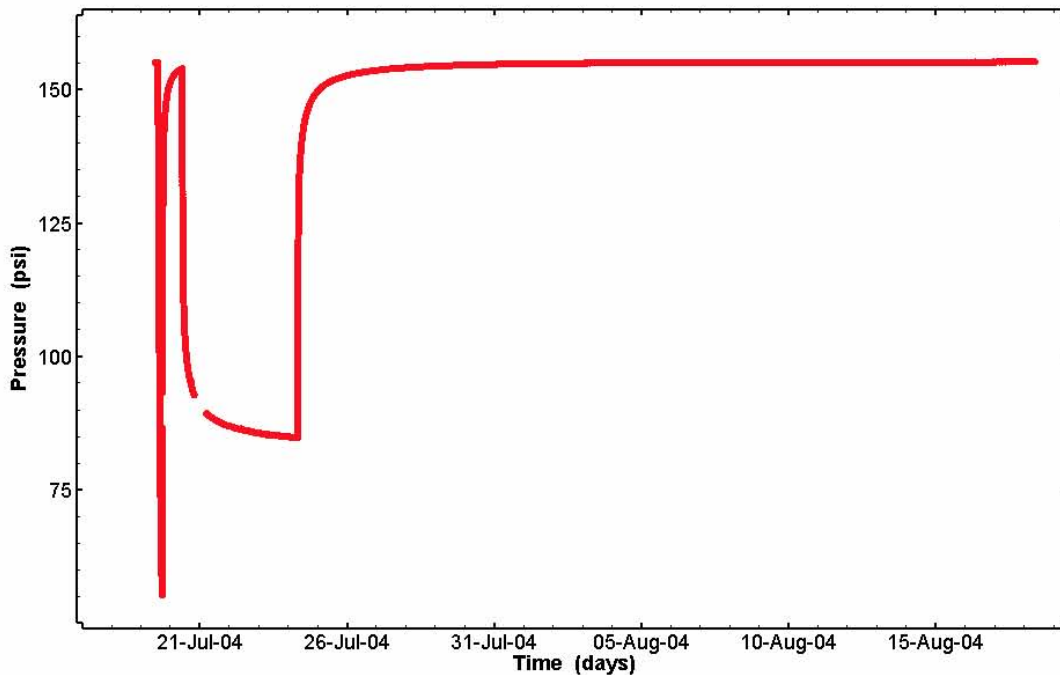
Figure 20. Pressure data from SNL-5.

The specified SNL-5 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 21, was a composite-T system with wellbore storage. The pressure derivative appears to stabilize between approximately 90 and 300 minutes (Figure 21) and then begins to trend downward, indicating an increase in T. The range of T values estimated from the SNL-5 analysis is shown in Figure 22. Variations in T were estimated by optimizing both the value of T and the distance (r) at which that value occurred at three discrete points (indicated by three colors in Figure 22) in the model. Values of T between those three points were linearly interpolated by the code. For each simulation, the value of T in the model varied continuously. The match to the stabilized portion of the derivative was affected by T values that were changing linearly with distance between the first two populations (red and black) shown in Figure 22. The geometric mean T value of 4.86E-6 m^2/s was therefore calculated from these combined populations. The simulated SNL-5 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the T values shown in Figure 22 are shown in Figures 23 and 24, respectively.

21
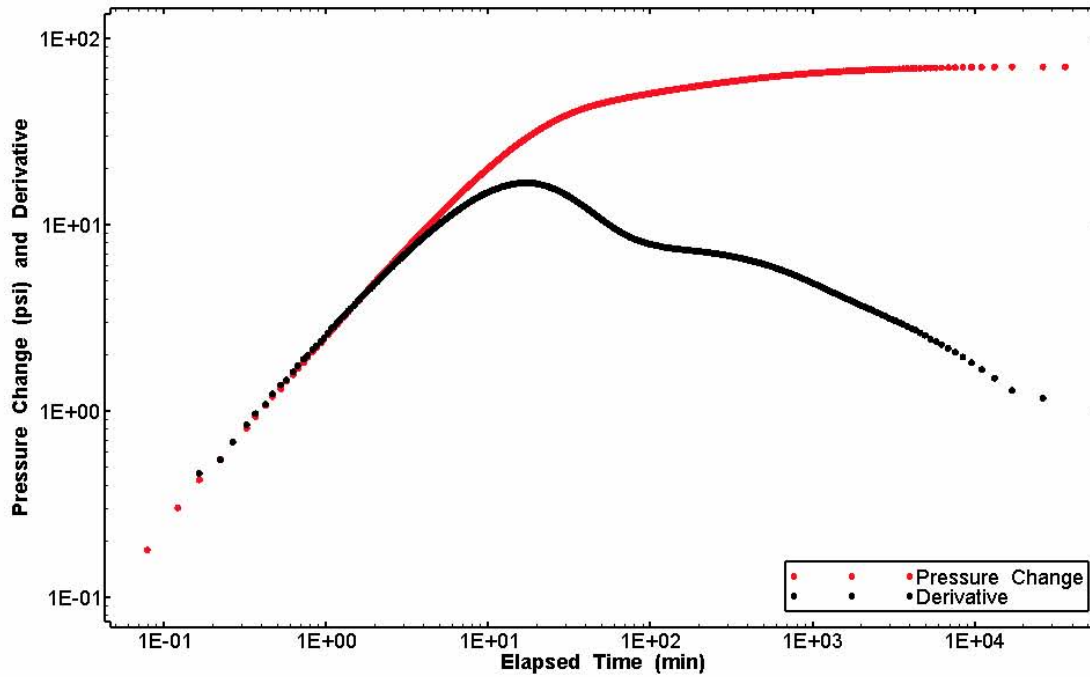
Figure 21. Log-log diagnostic plot of the final SNL-5 pressure-buildup test.
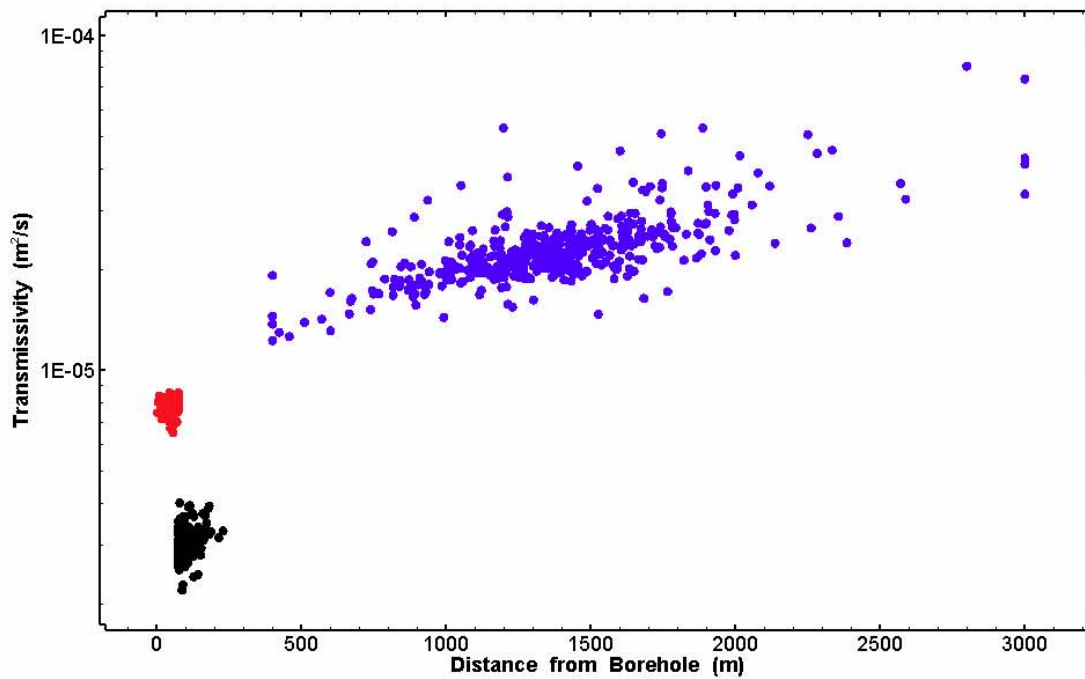
Figure 22. Estimates of transmissivity derived from the SNL-5 perturbation analysis.
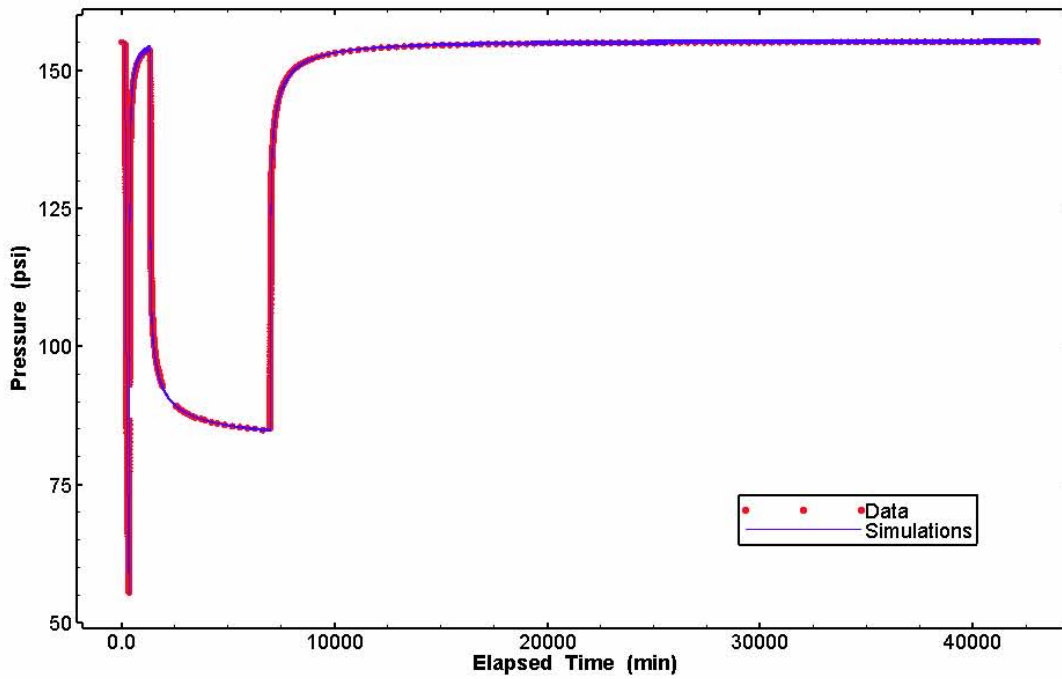
Figure 23. Simulations of the SNL-5 pressure response.
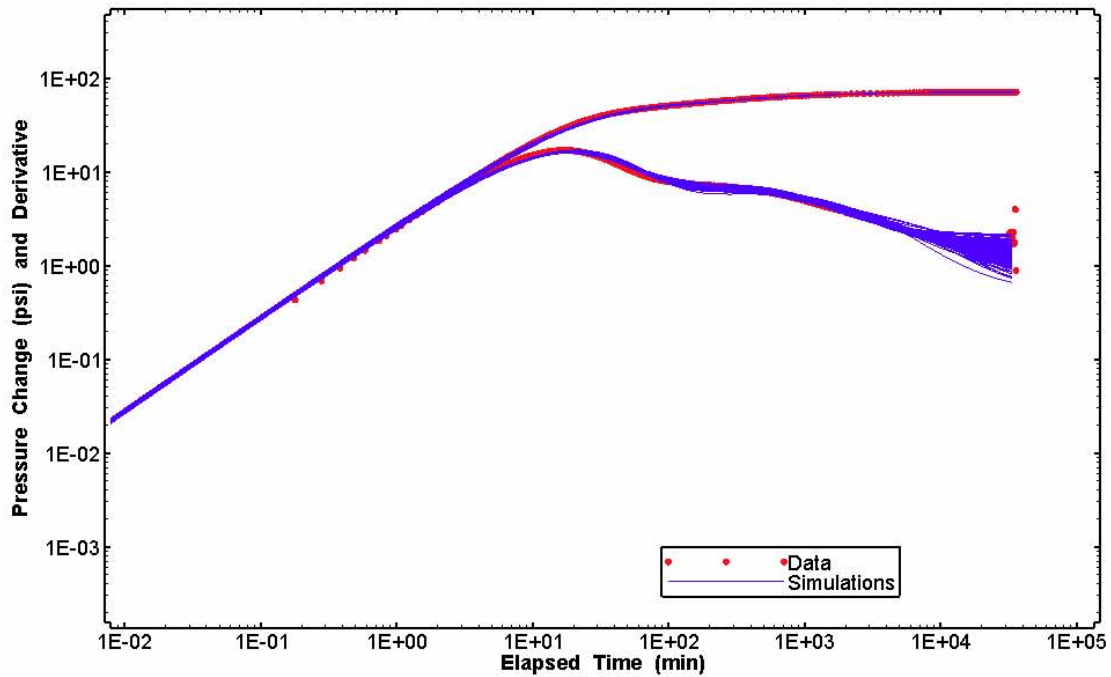
Figure 24. Simulations of pressure change and derivative during the final SNL-5 pressure-buildup test.

4.5   SNL-9

A constant-rate pumping test at 12.5 gpm was initiated in SNL-9 on December 2, 2003, and lasted approximately 90.6 hr. The pressure response from December 2, 2003 – March 17, 2004 (Figure 25) was included in this analysis. The pressures shown in Figure 25 were separated into three nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-9.nPre file and are listed in Appendix B.5.
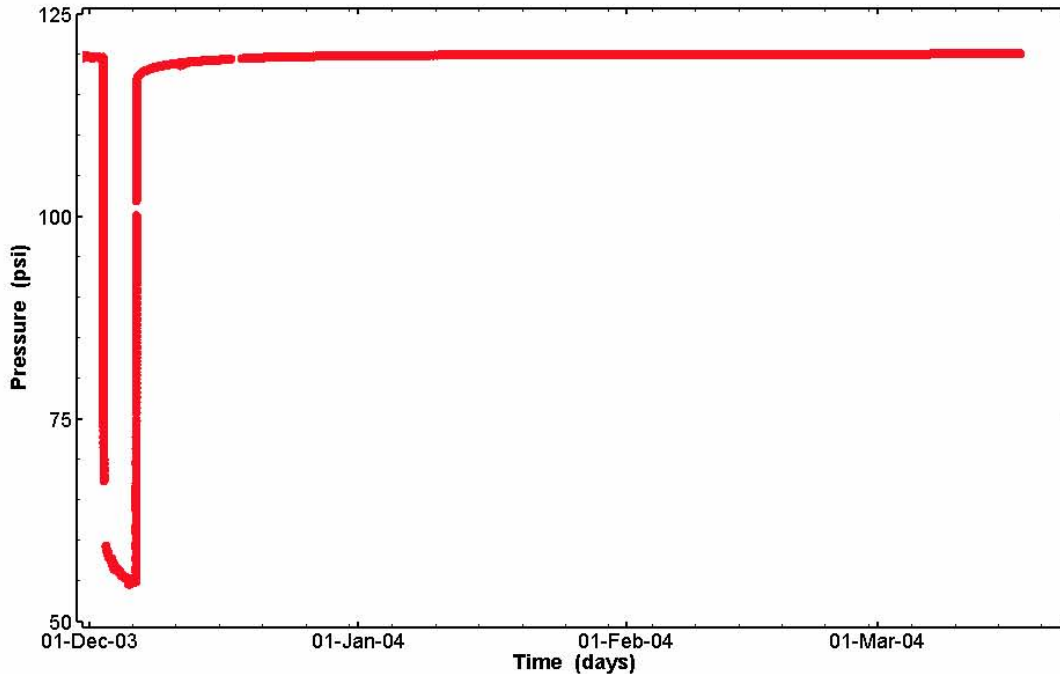
Figure 25. Pressure data from SNL-9.

The specified SNL-9 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 26, was a dual-porosity system with wellbore storage and skin. The range of fracture T values (Figure 27) estimated from this analysis corresponds to a stabilized derivative beginning at approximately 2.0E4 minutes in Figure 26. The geometric mean T estimate was 3.86E-5 m^2/s. The simulated SNL-9 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the T values shown in Figure 27 are shown in Figures 28 and 29, respectively.

24
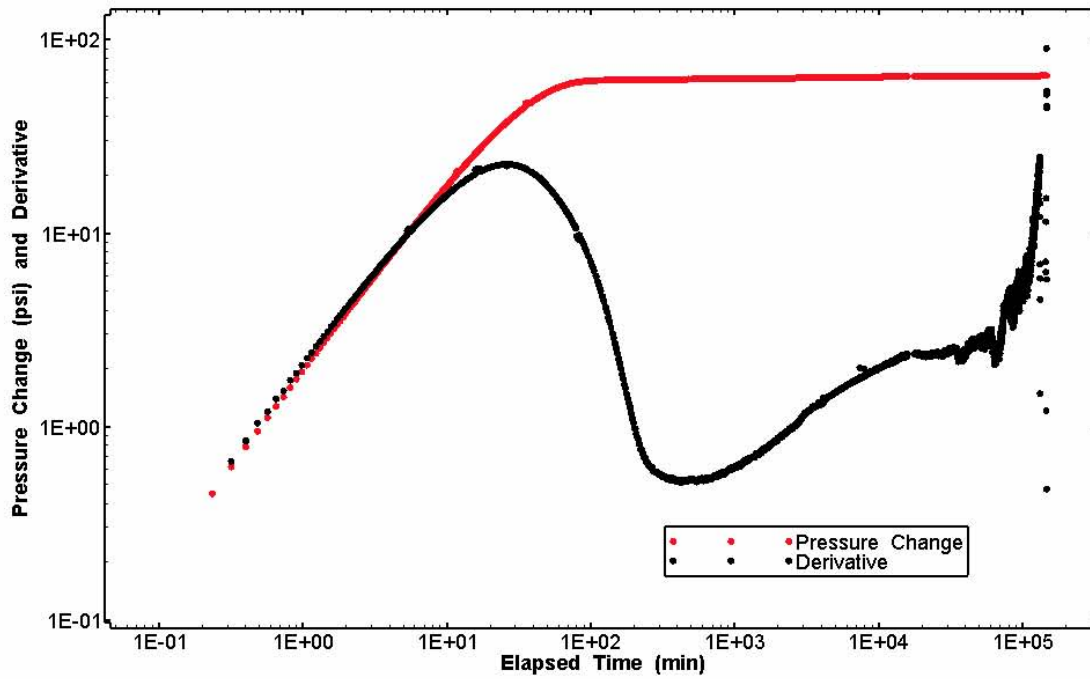
Figure 26. Log-log diagnostic plot of the SNL-9 pressure-buildup test.
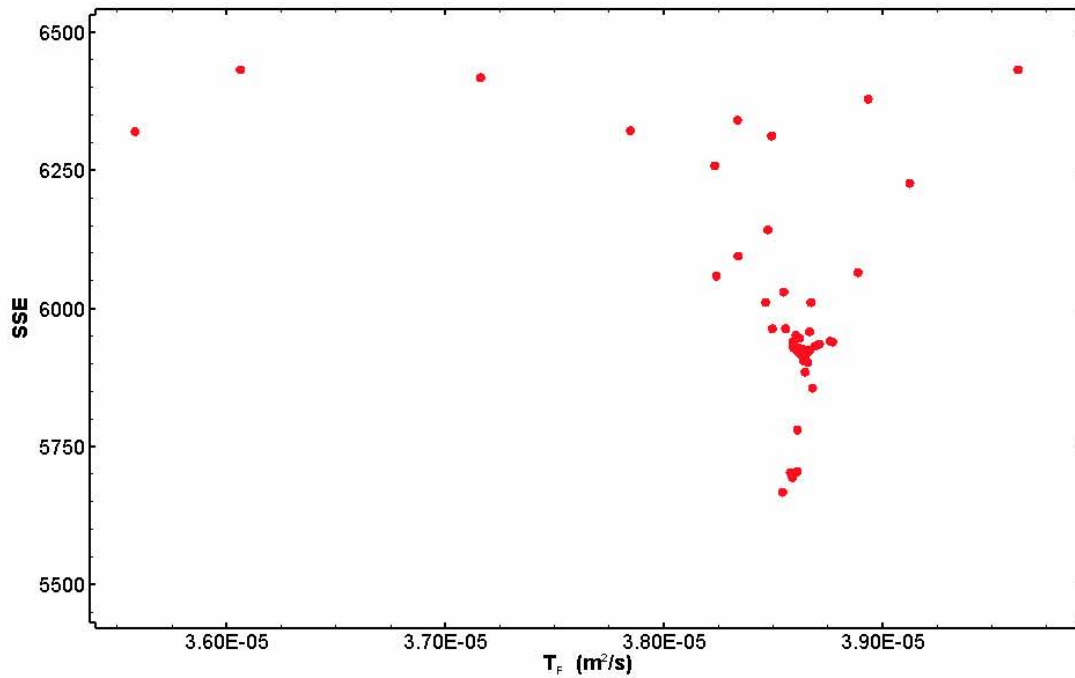
Figure 27. Estimates of transmissivity derived from the SNL-9 perturbation analysis.
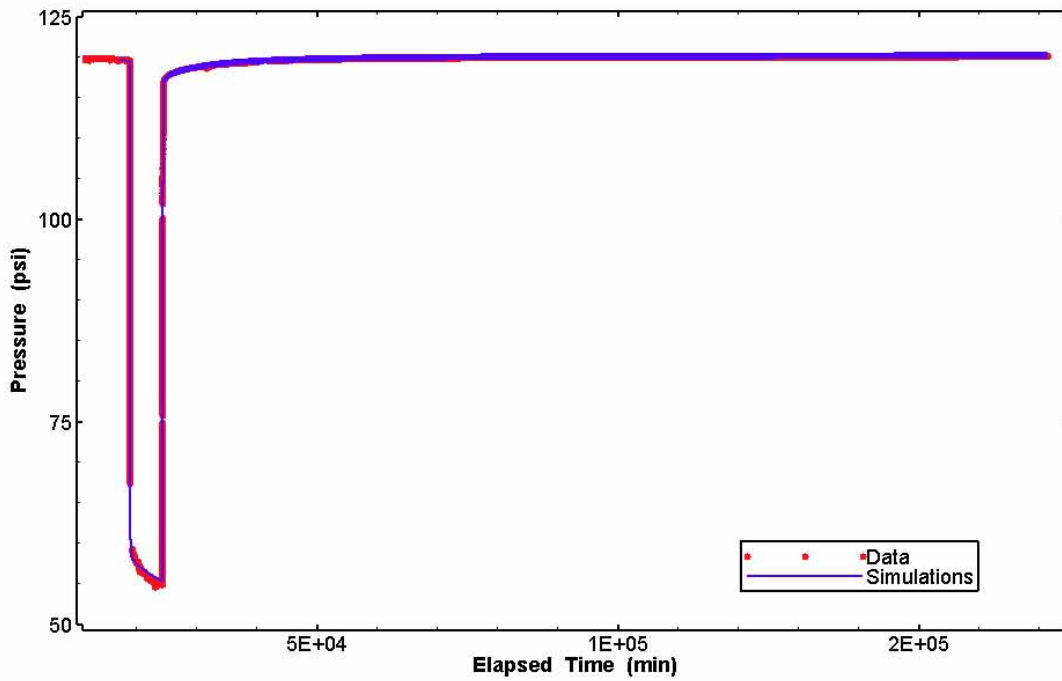
Figure 28. Simulations of the SNL-9 pressure response.
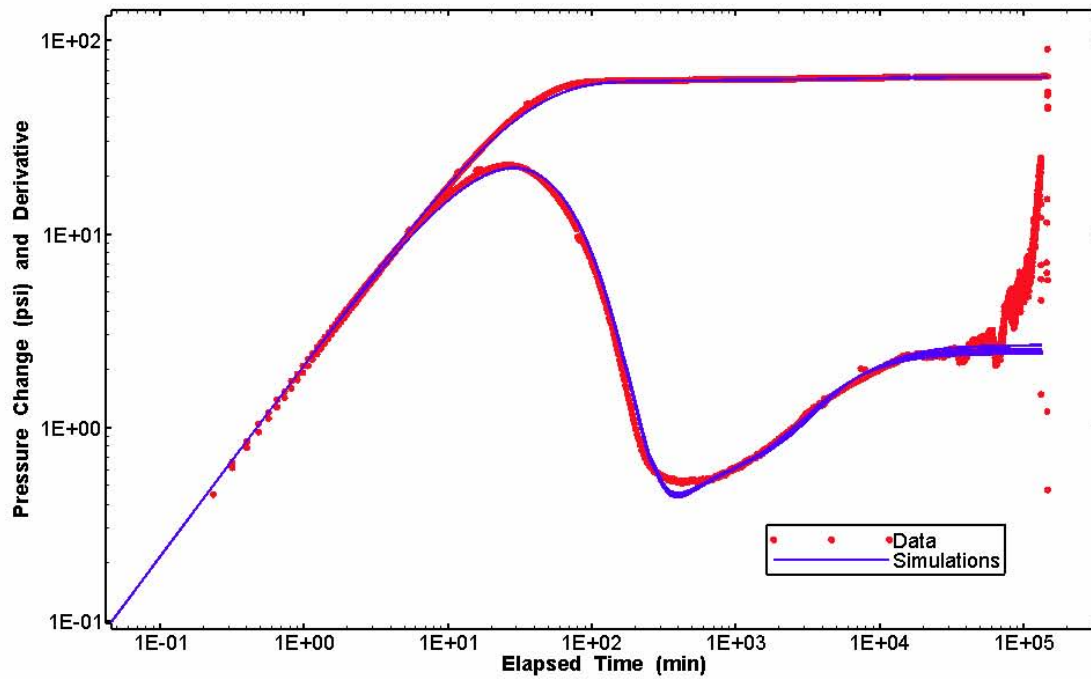
Figure 29. Simulations of pressure change and derivative during the SNL-9 pressure-buildup test.

4.6 SNL-12

Various pumping rates were evaluated in well SNL-12 over a 2.7-hr period on August 9, 2004. The actual pumping test began on August 10, 2004, had an average rate of 20 gpm, and lasted approximately 95.7 hr. The pressure response from April 12 – September 14, 2004 (Figure 30) was included in this analysis. Pressures from April 12 – August 9, 2004 were included as a pressure history in the nSIGHTS simulations. The pressures shown in Figure 30 were separated into six nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-12.nPre file and are listed in Appendix B.6.
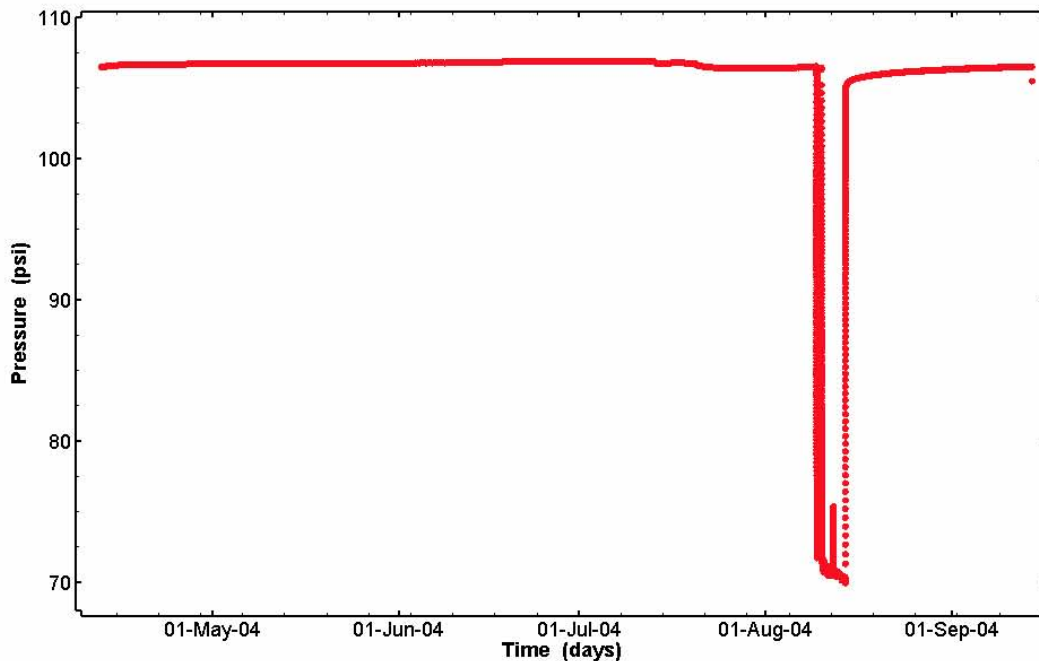
Figure 30. Pressure data from SNL-12.

The specified SNL-12 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 31, was a dual-porosity and composite-*n* system with wellbore storage and a time-dependent skin. The near-field *n* was specified to be radial. The range of *T* values (Figure 32) estimated from this analysis corresponds to the derivative stabilization between approximately 1000 and 2000 minutes in Figure 31. The geometric mean *T* value was 4.97E-4 m^2/s. The simulated SNL-12 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the *T* values shown in Figure 32 are shown in Figures 33 and 34, respectively.

27
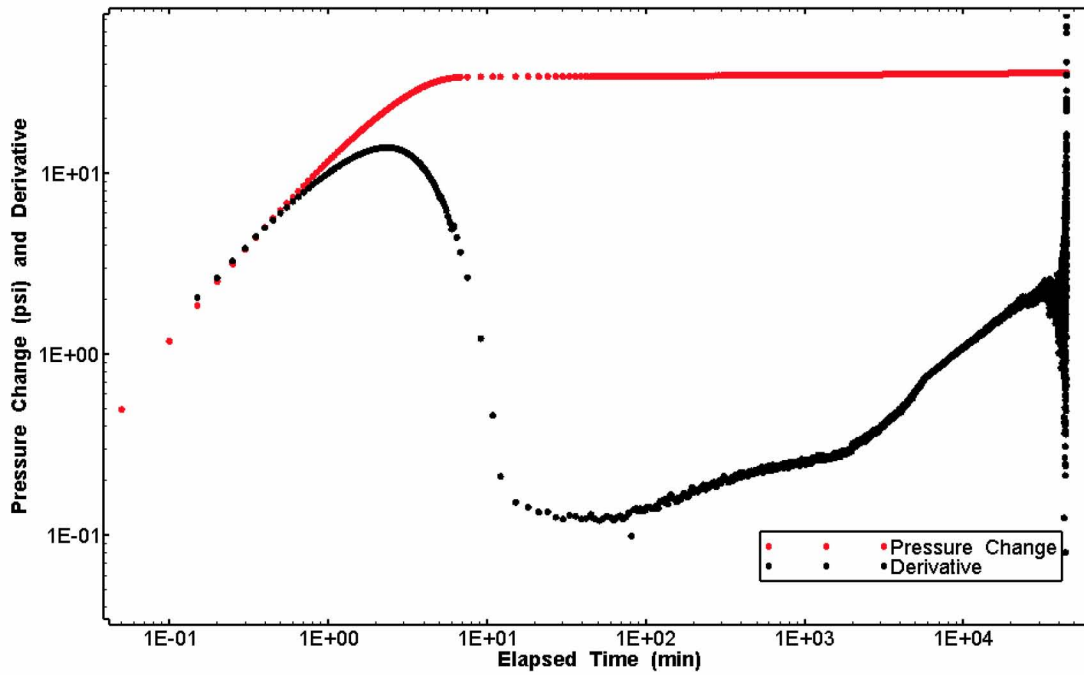
Figure 31. Log-log diagnostic plot of the final SNL-12 pressure-buildup test.
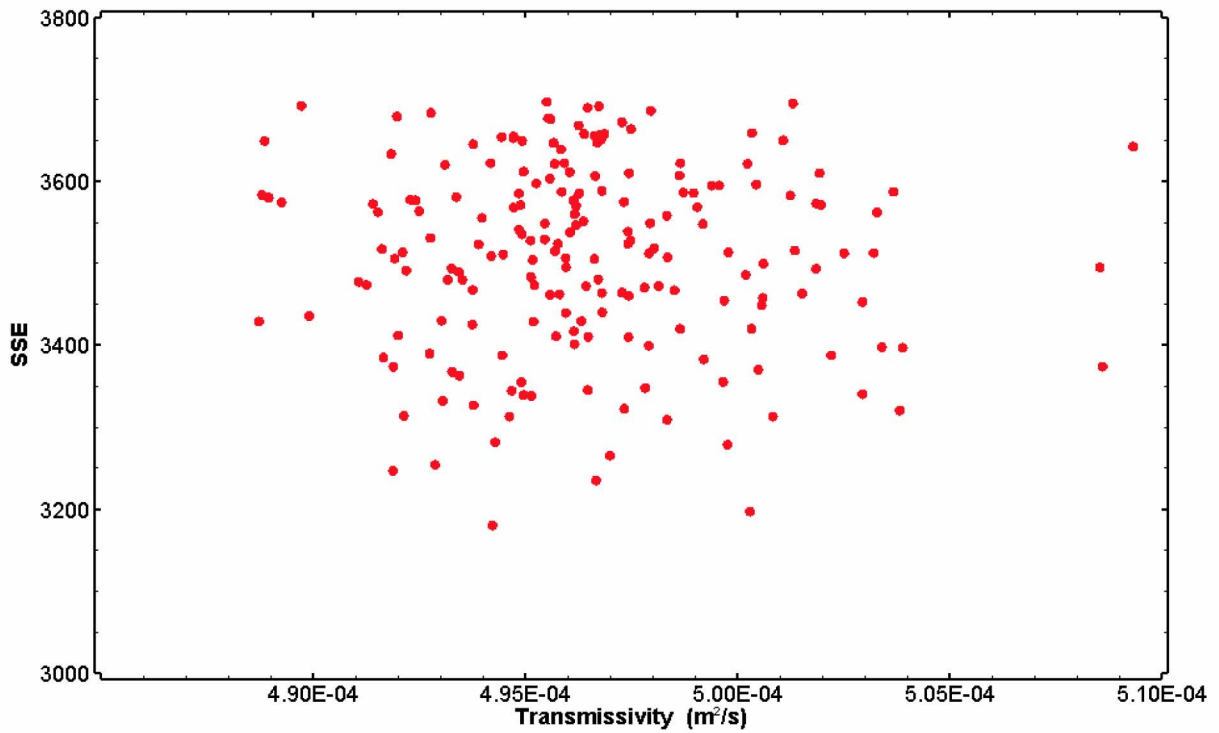
Figure 32. Estimates of transmissivity derived from the SNL-12 perturbation analysis.
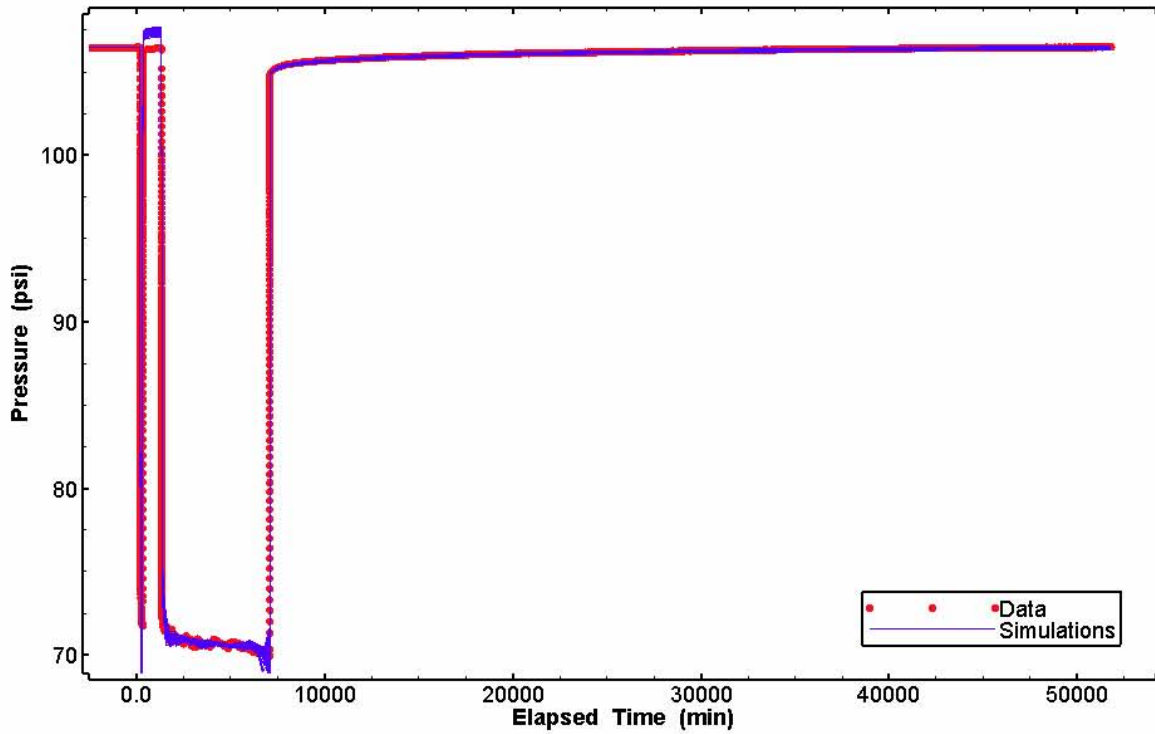
Figure 33. Simulations of the SNL-12 pressure response.
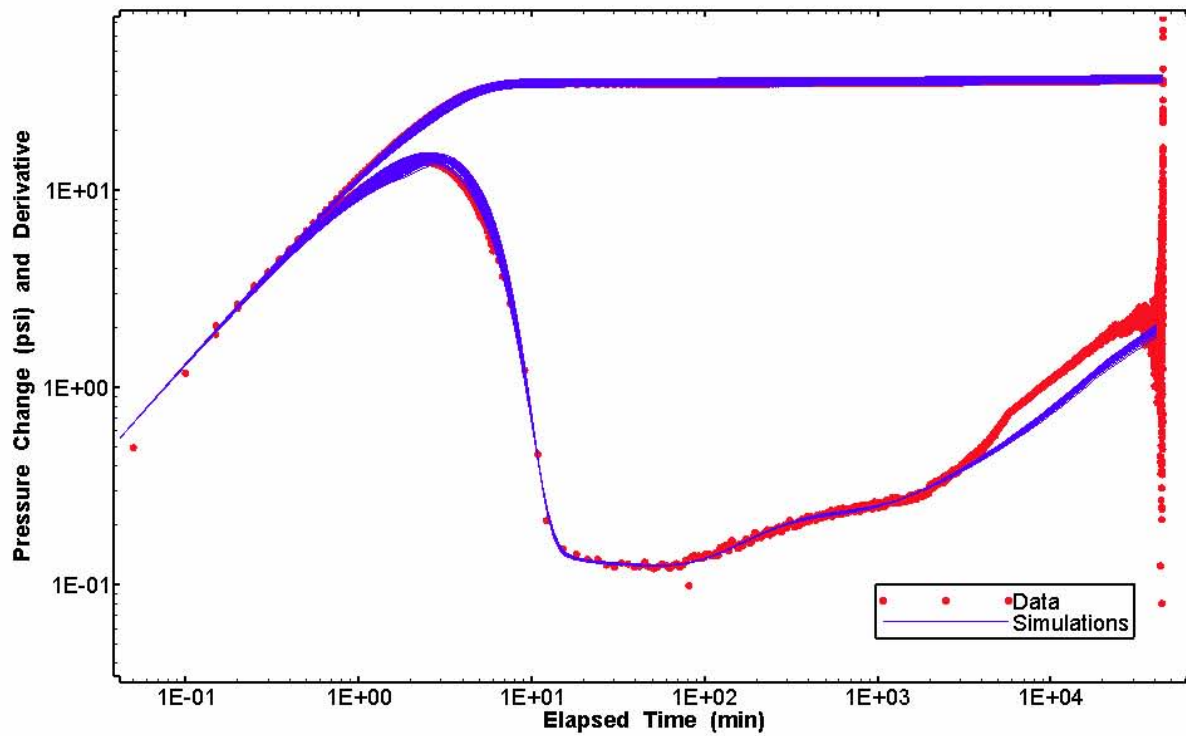
Figure 34. Simulations of pressure change and derivative during the SNL-12 pressure-buildup test.

4.7   SNL-14

Various pumping rates were evaluated in well SNL-14 over a 4.6-hr period on July 20, 2005. A constant-rate (30 gpm) pumping test was initiated in SNL-14 on August 4, 2005. Pumping ended on August 26, 2005, and the subsequent pressure buildup through January 3, 2006 was included in this analysis (Figure 35). The pressures shown in Figure 35 were separated into eight nSIGHTS sequences for this analysis. SNL-14 pressures from June 14 – August 4, 2005 were included in the nSIGHTS simulations as a pressure history. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the SNL-14.nPre file and are listed in Appendix B.7.
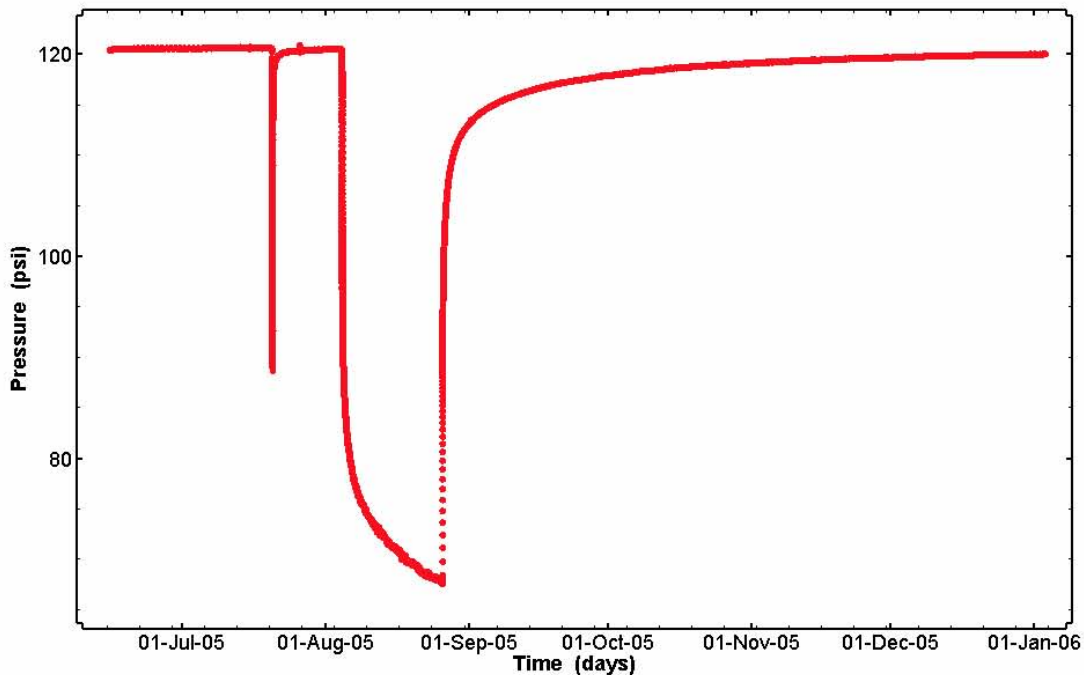
Figure 35. Pressure data from SNL-14.

The specified SNL-14 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 36, was a dual-porosity system with wellbore storage, a time-dependent skin, and a linear no-flow boundary. The range of fracture T values (Figure 37) estimated from this analysis corresponds to the derivative stabilization that begins at approximately 3 days in Figure 36. The assumed effect of the no-flow boundary then begins to dominate the response after about 8 days (Figure 36). The fracture T estimates are shown in Figure 37. The geometric mean fracture T estimate derived from this analysis was 4.9E-5 m^2/s.

The simulated SNL-14 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the *T* values shown in Figure 37 are shown in Figures 38 and 39, respectively.
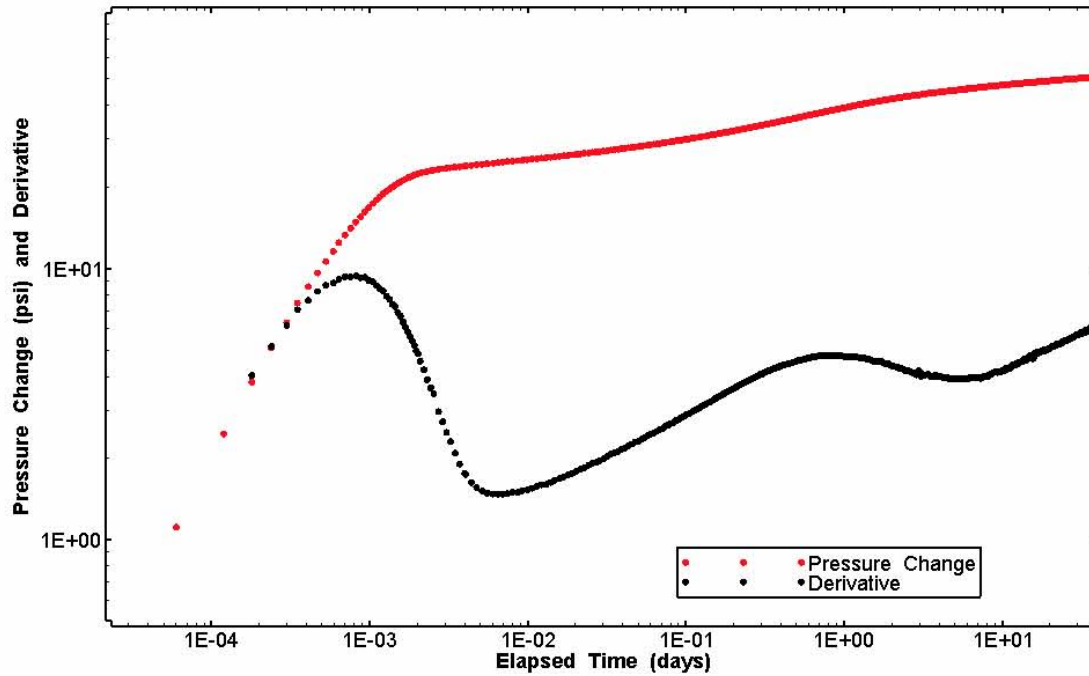
Figure 36. Log-log diagnostic plot of the final SNL-14 pressure-buildup test.
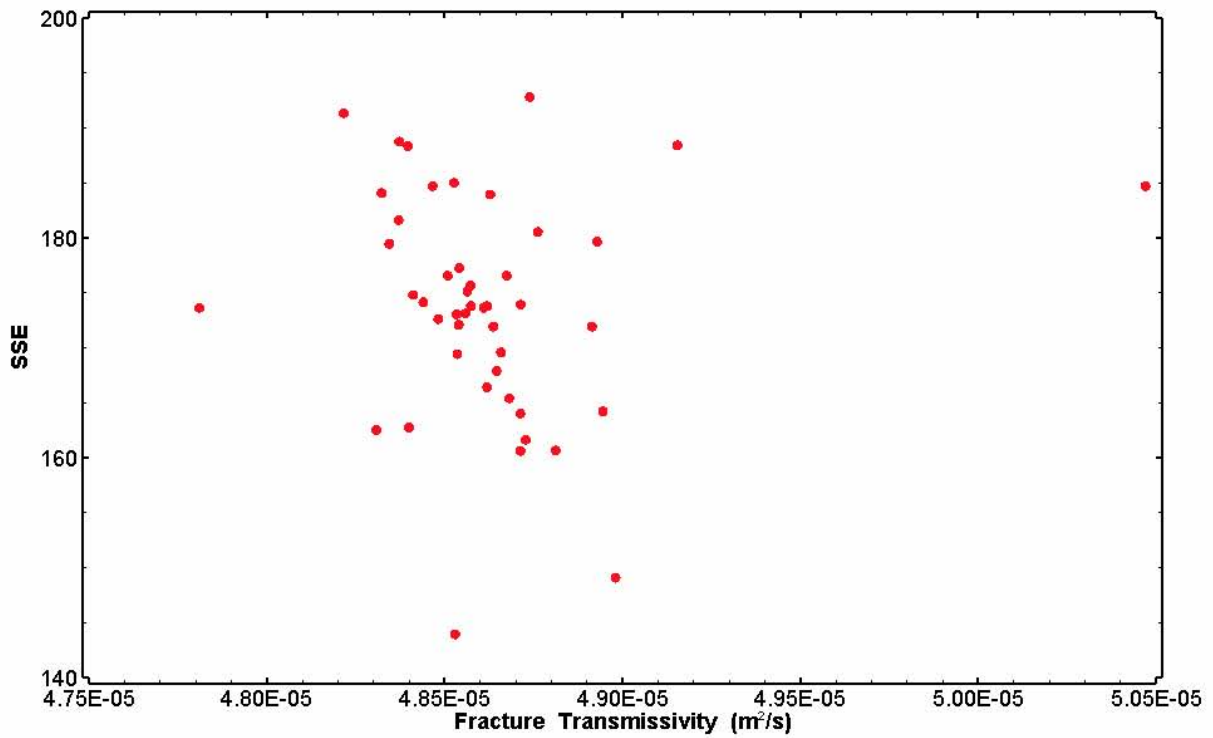
Figure 37. Estimates of transmissivity derived from the SNL-14 perturbation analysis.
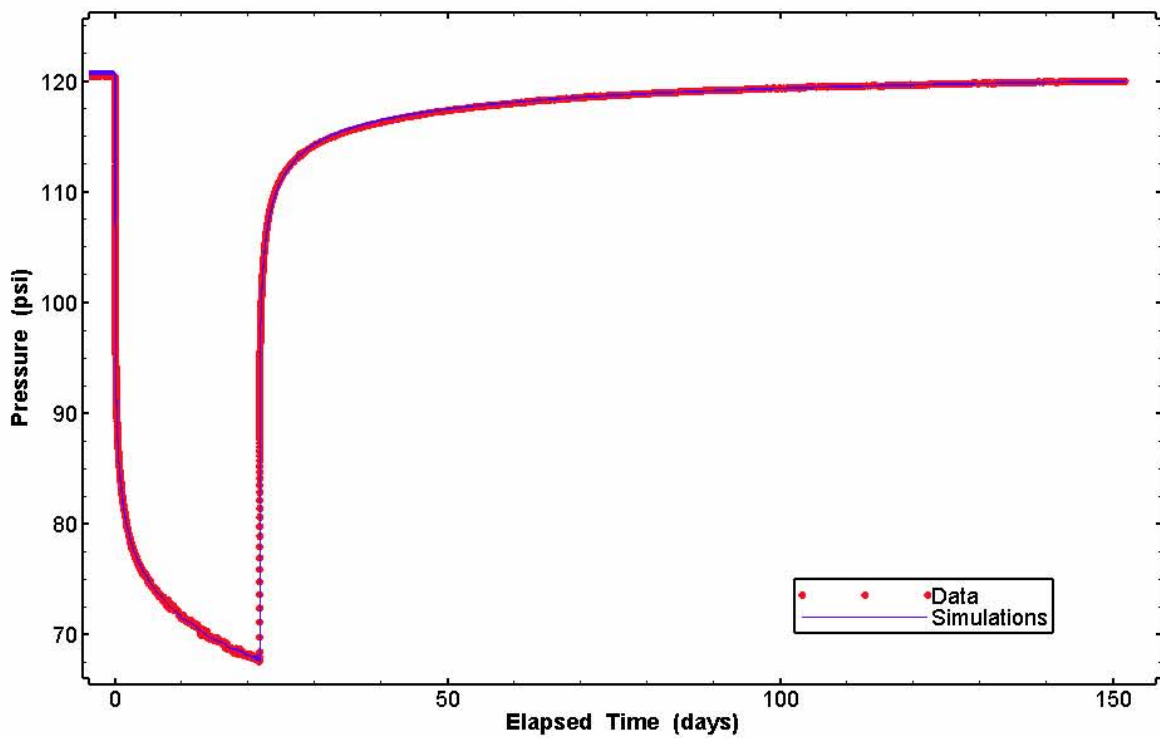
Figure 38. Simulations of the SNL-14 pressure response.
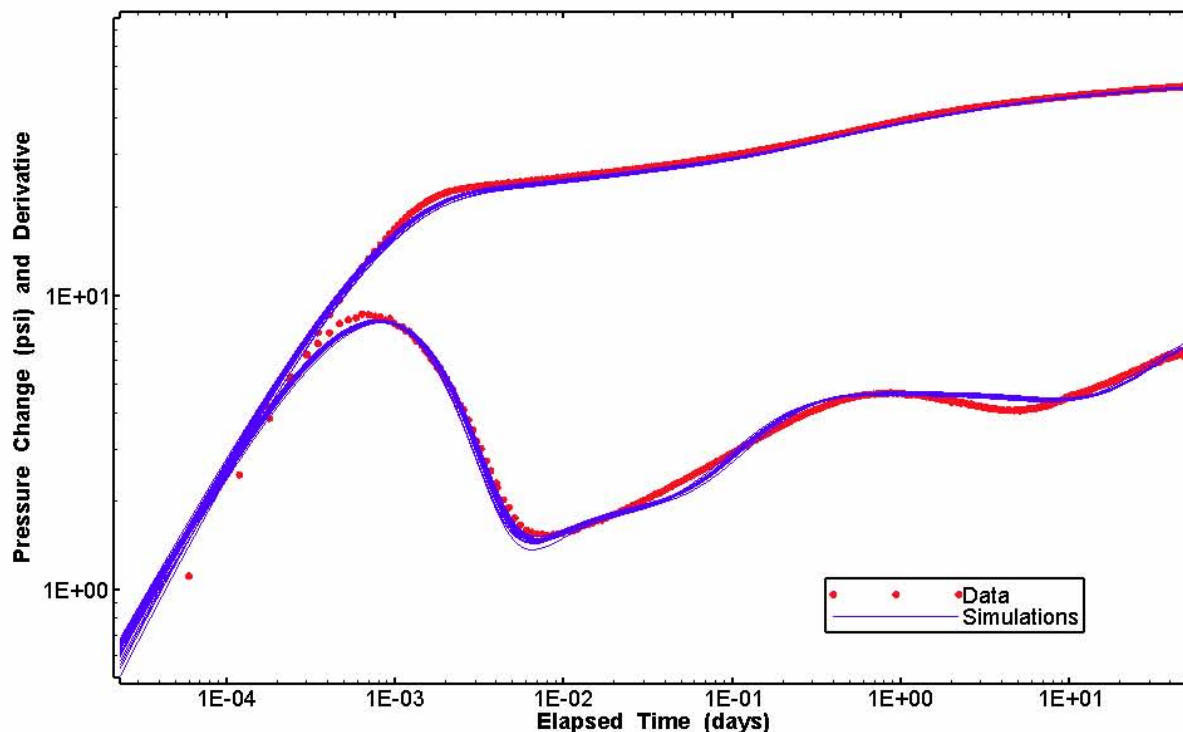
Figure 39. Simulations of pressure change and derivative during the final SNL-14 pressure-buildup test.

4.8   WIPP-11

The Culebra interval in WIPP-11 was acidized on January 5, 2005, by injecting 43 barrels (6.84 m^3) of a 15% HCl solution charged with liquid nitrogen followed by 58 barrels (9.22 m^3) of fresh water into the well. An evaluation of potential pumping rates was performed over a 3.5-hr period on January 31, 2005. The pumping test began on February 1, 2005 and continued until February 20, 2005 at a rate of 35 gpm. The pumping-test data and the subsequent pressure buildup through April 4, 2005 were included in this analysis (Figure 40). The pressures shown in Figure 40 were separated into eight nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the WIPP-11.nPre file and are listed in Appendix B.8.
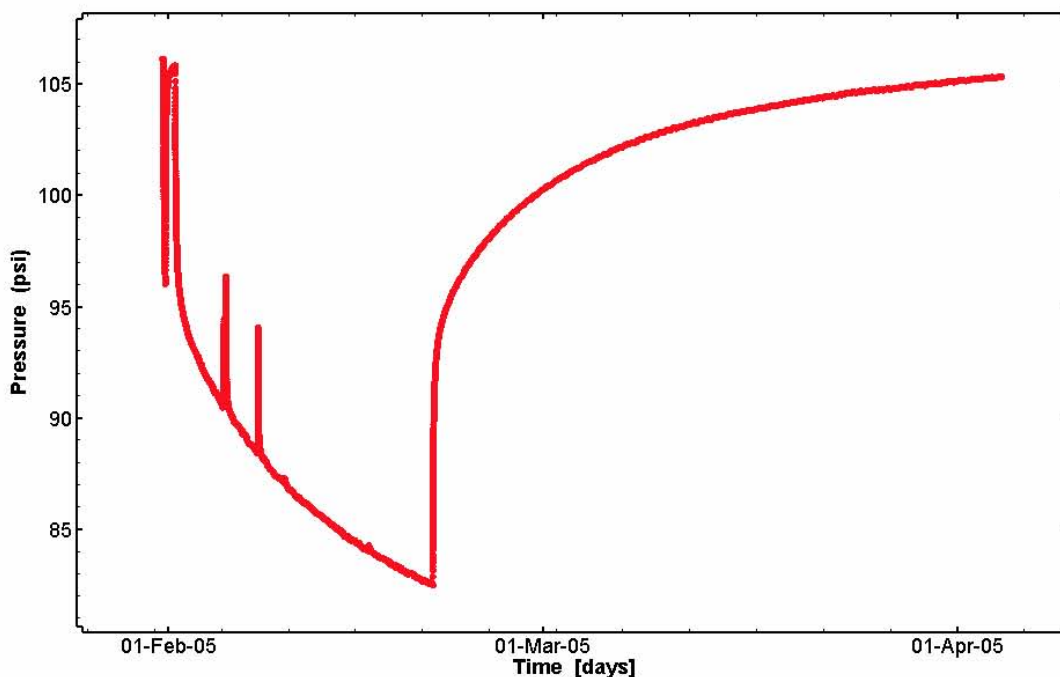
Figure 40. Pressure data from WIPP-11.

The specified WIPP-11 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 41, was a composite-T system with wellbore storage. Relatively high T variability was indicated by the constantly changing slope of the derivative in Figure 41. This T variability was simulated by optimizing a $T(r)$ function in the WIPP-11 model. Both the value of T and the distance from the borehole to that value were optimized using six discrete points. The value of T in the model was linearly interpolated between the six discrete points. An example of a single $T(r)$ solution is shown in Figure 42. Note that the relationship between T and distance in the model depends on the value of specific storage (S_s) in the model, which was fixed at 1.0E-6 m^{-1} in this analysis. The range of estimated T and radius (r) values for the complete $T(r)$ function is shown in Figure 43. Those T values that correspond to the derivative stabilization that begins at approximately 7.0E-4 days in Figure 41, i.e., the near-field T values, are those values that are interpolated between the first two sets of points shown in Figure 43. The geometric mean estimate of T derived from these first two sets of points was 4.27E-4 m^2/s. The simulated WIPP-11 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the T values shown in Figure 43 are shown in Figures 44 and 45, respectively.
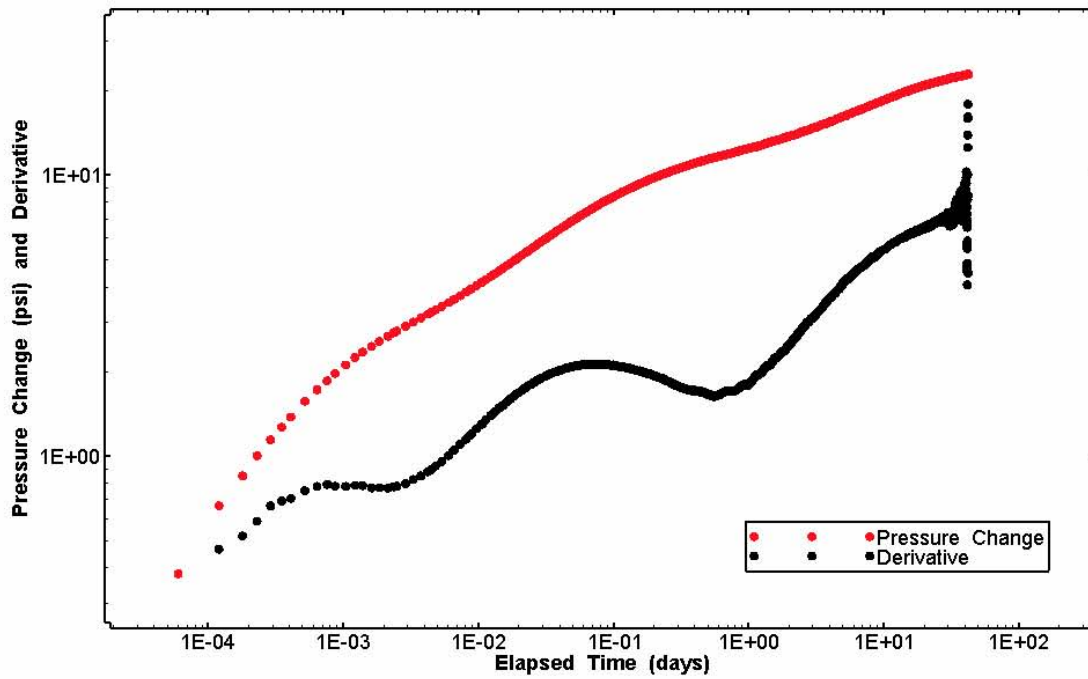
Figure 41. Log-log diagnostic plot of the final WIPP-11 pressure-buildup test.
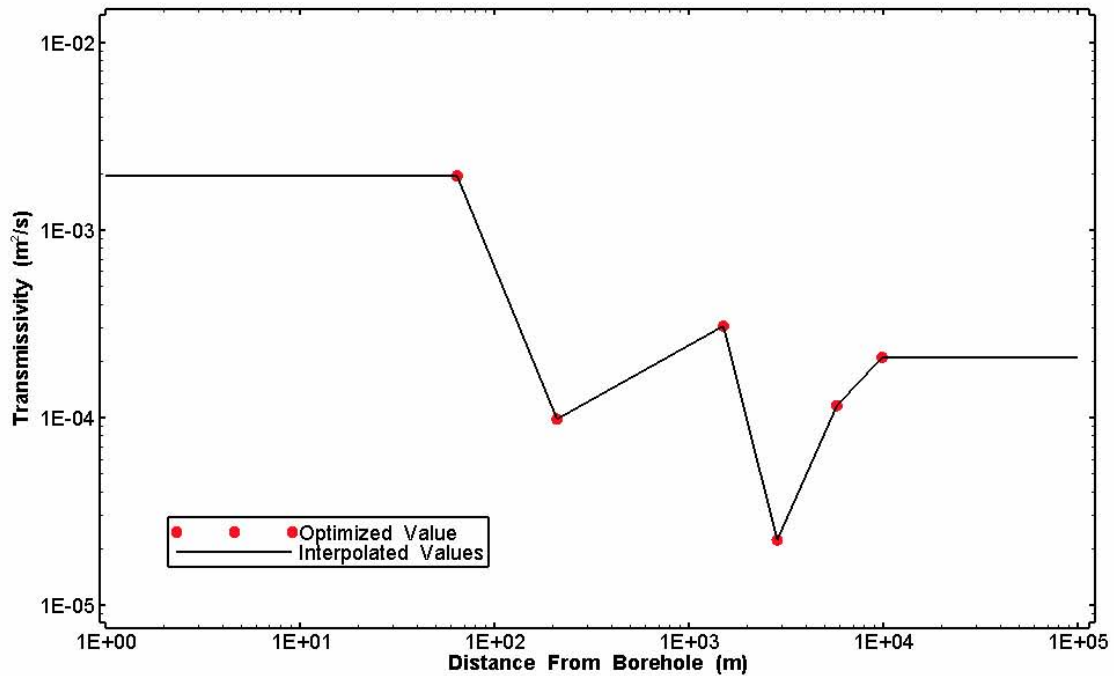
Figure 42. A single radially varying transmissivity estimate obtained from the WIPP-11 perturbation analysis.
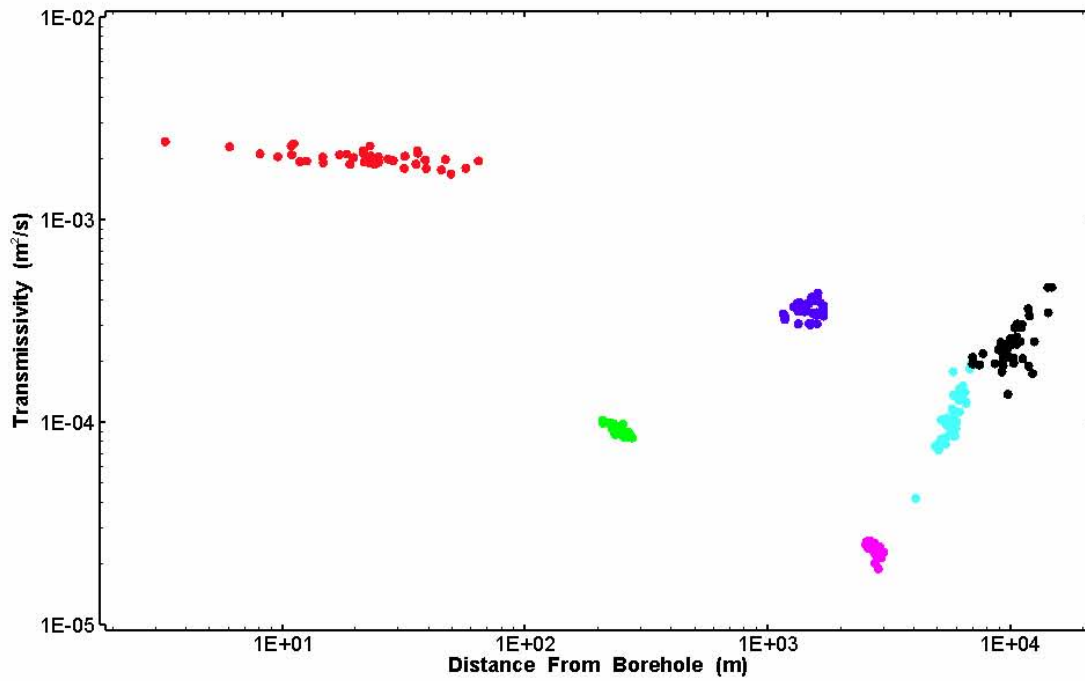
Figure 43. Estimates of radially varying transmissivity derived from the WIPP-11 perturbation analysis.
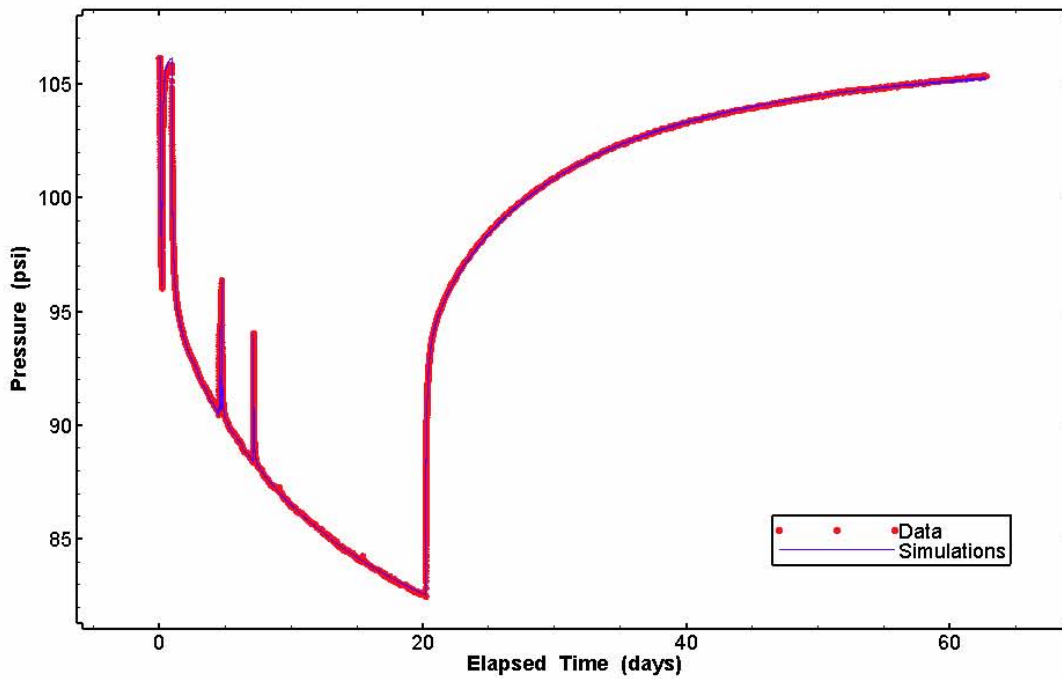
Figure 44. Simulations of the WIPP-11 pressure response.
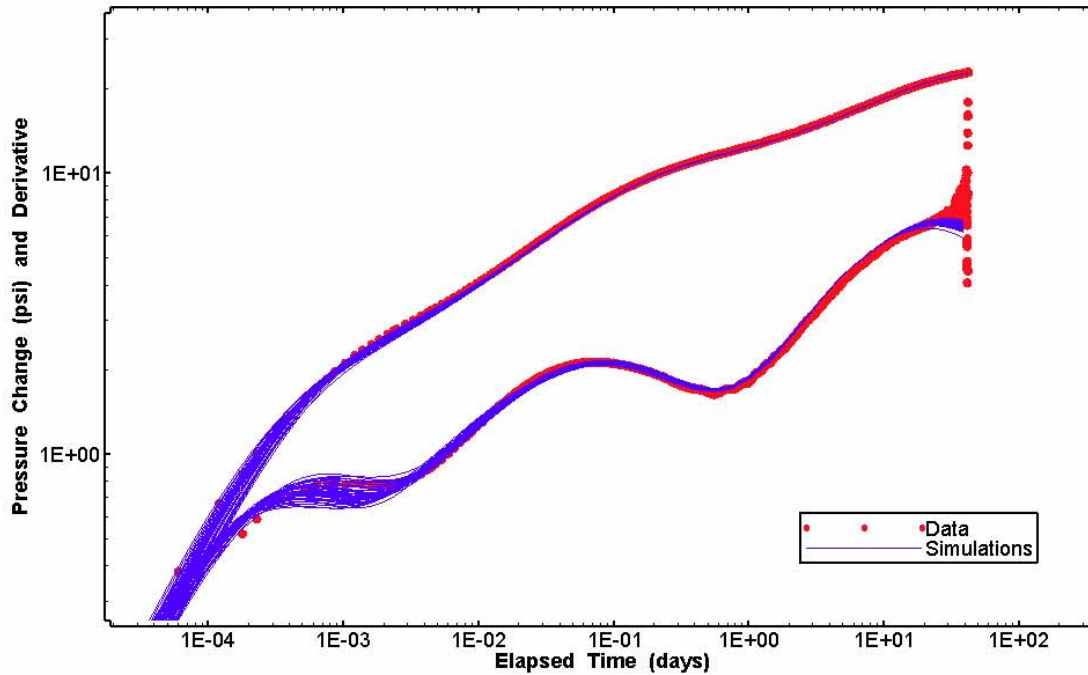
Figure 45. Simulations of pressure change and derivative during the final WIPP-11 pressure-buildup test.

4.9   WIPP-25

A constant-rate pumping test was initiated in well WIPP-25 on September 22, 2004, at a rate of 30 gpm. Pumping was interrupted for about three minutes approximately five hours after the test was started. Pumping ended on September 23, 2004, and the subsequent pressure buildup through September 29, 2004 (Figure 46), was included in this analysis. The pressures shown in Figure 46 were separated into six nSIGHTS sequences for this analysis. WIPP-25 pressures from September 20 – 22, 2004, were included in the nSIGHTS simulations as a pressure history. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the WIPP-25.nPre file and are listed in Appendix B.9.
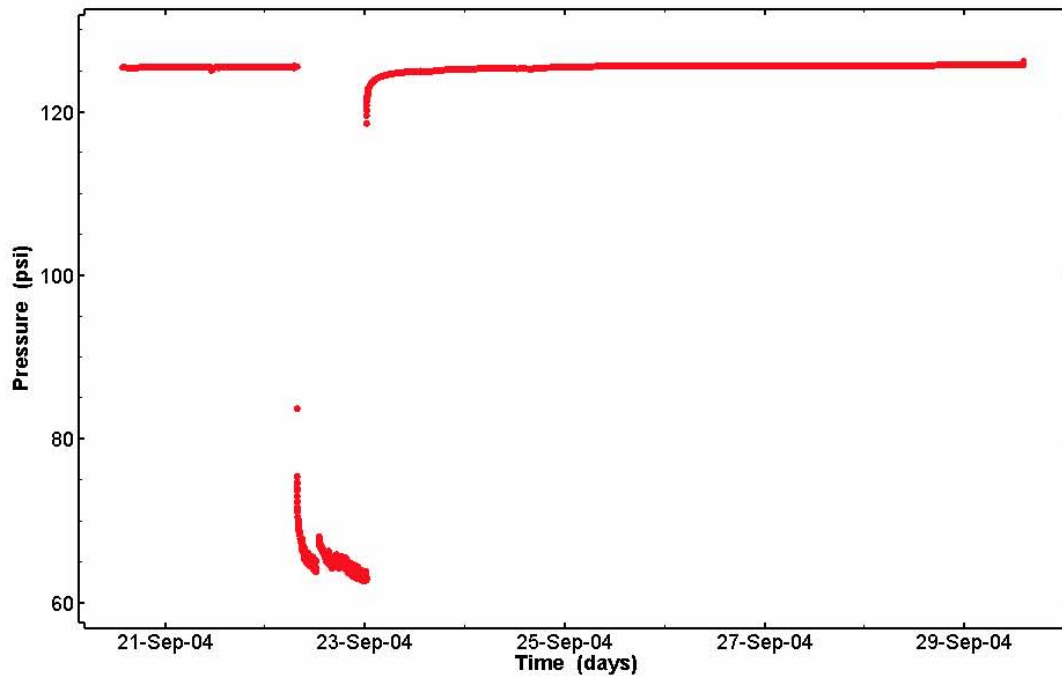
Figure 46. Pressure data from WIPP-25.

The specified WIPP-25 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 47, was an infinite-acting radial system with wellbore storage and a time-dependent skin. The range of T values estimated from this analysis is shown in Figure 48. The geometric mean estimate of T derived from this analysis was 2.51E-4 m^2/s. The simulated WIPP-25 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the T values shown in Figure 48 are shown in Figures 49 and 50, respectively.
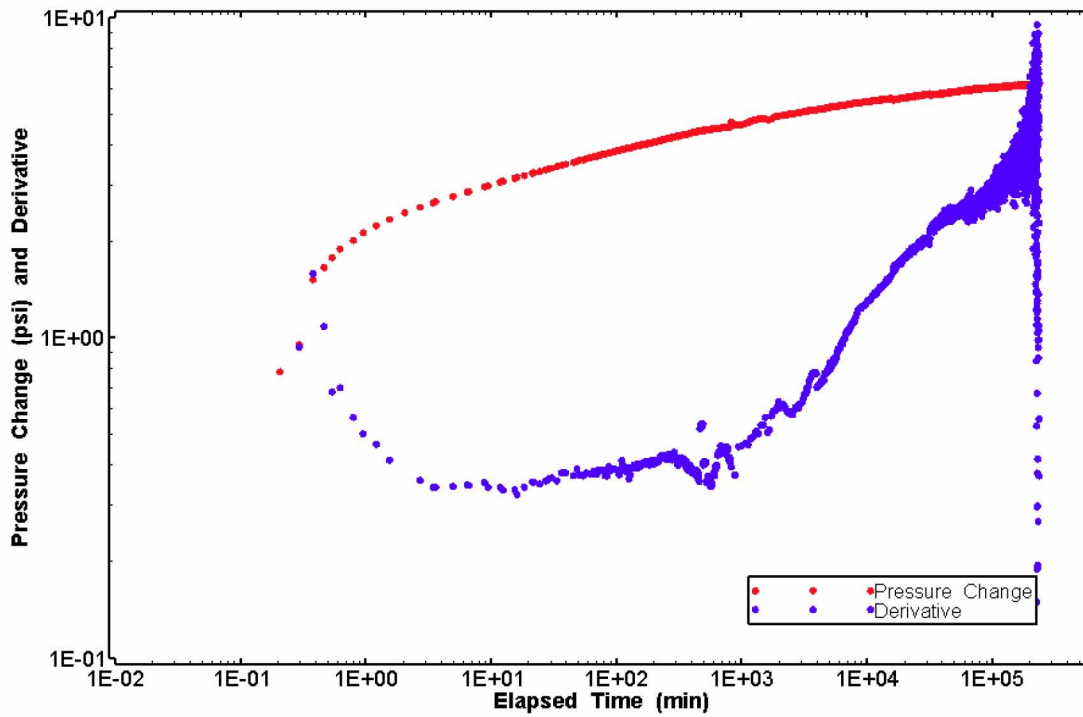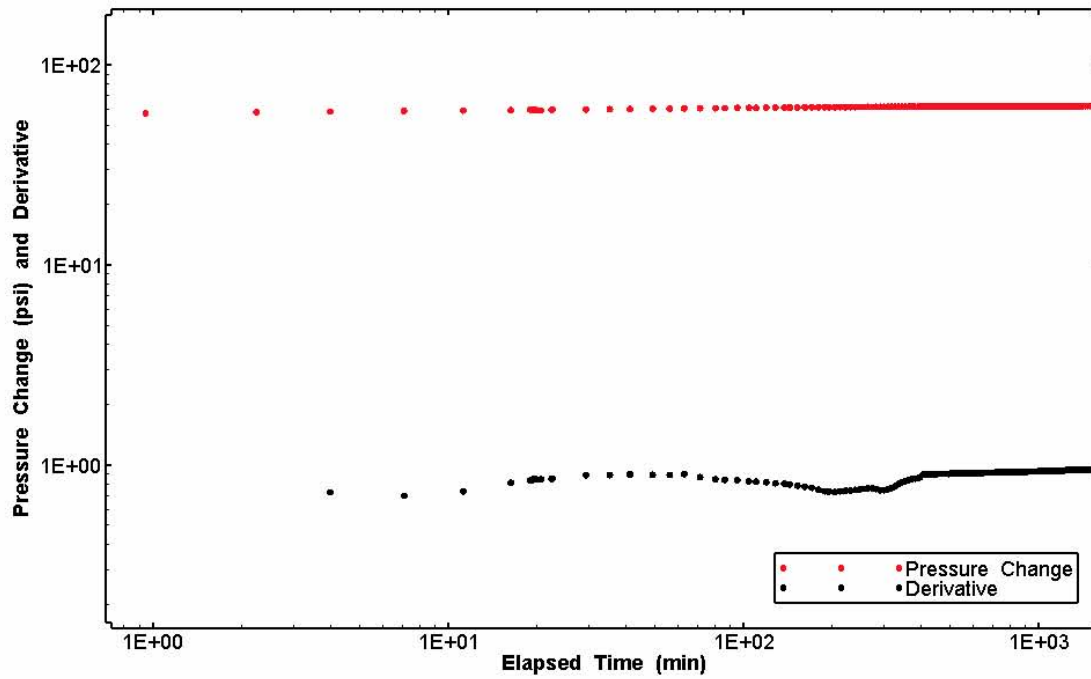
**Figure 47. Log-log diagnostic plot of the final WIPP-25 pressure-buildup test.**
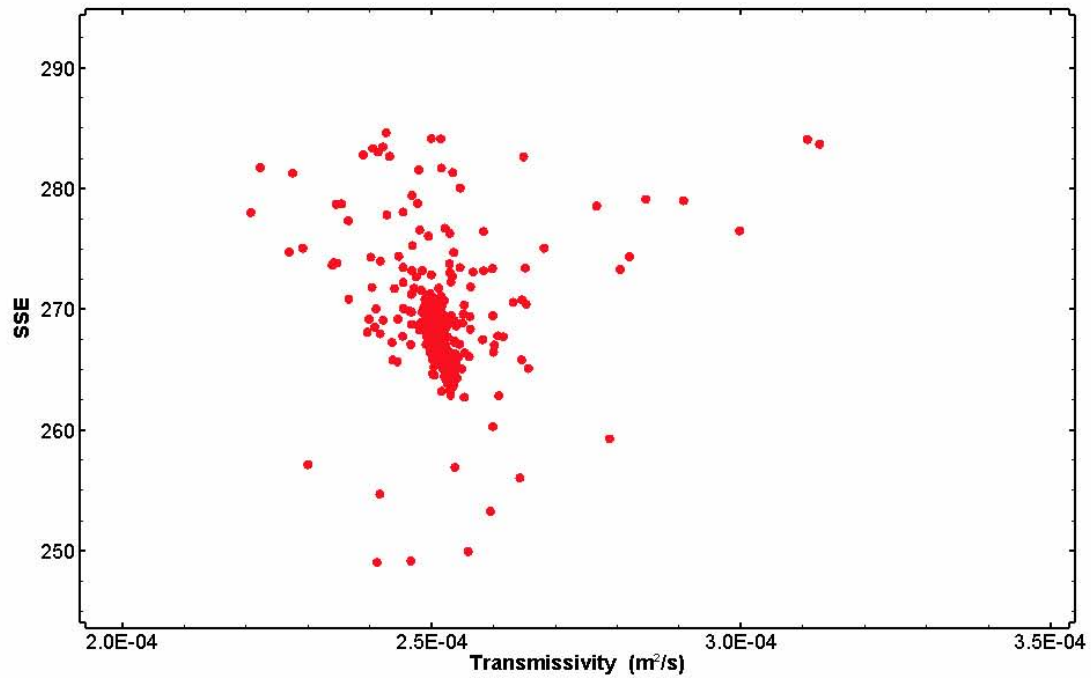
**Figure 48. Estimates of transmissivity derived from the WIPP-25 perturbation analysis.**
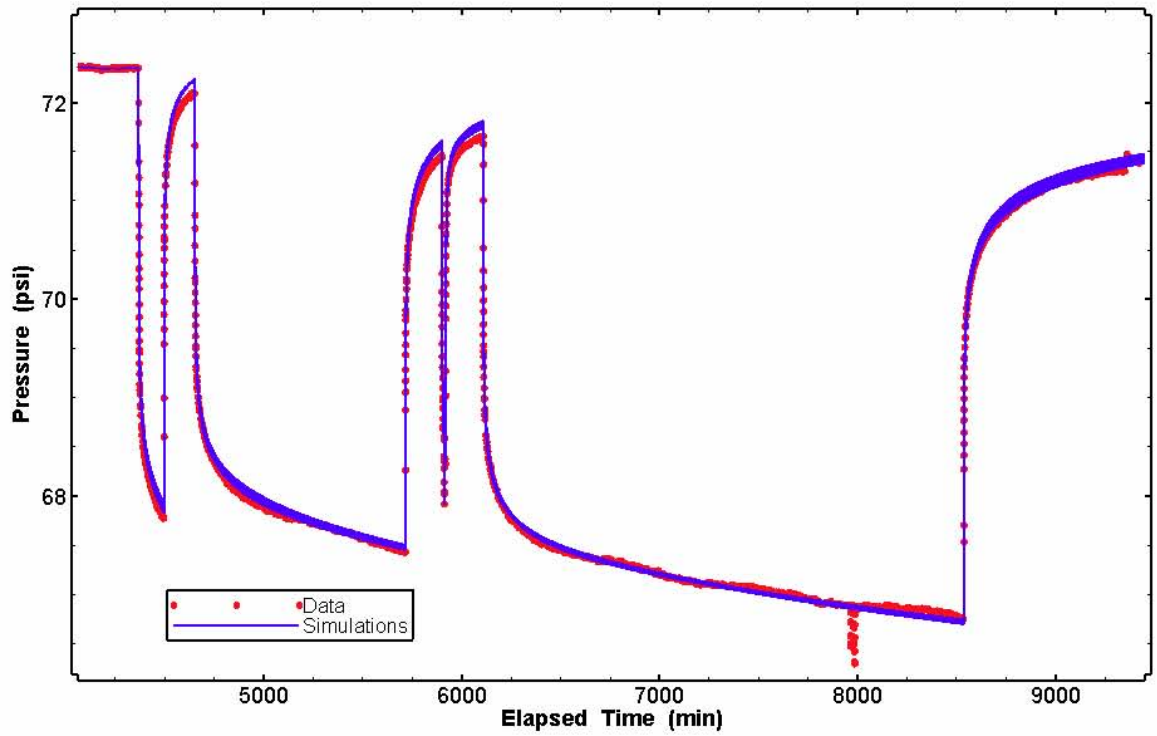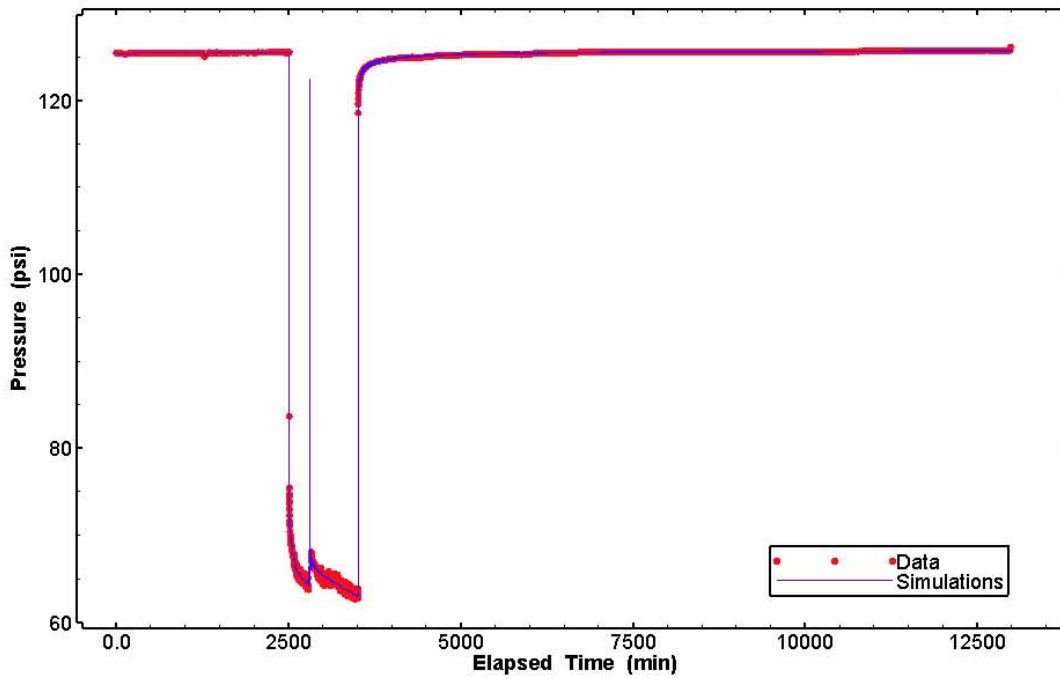
Figure 49. Simulations of the WIPP-25 pressure response.
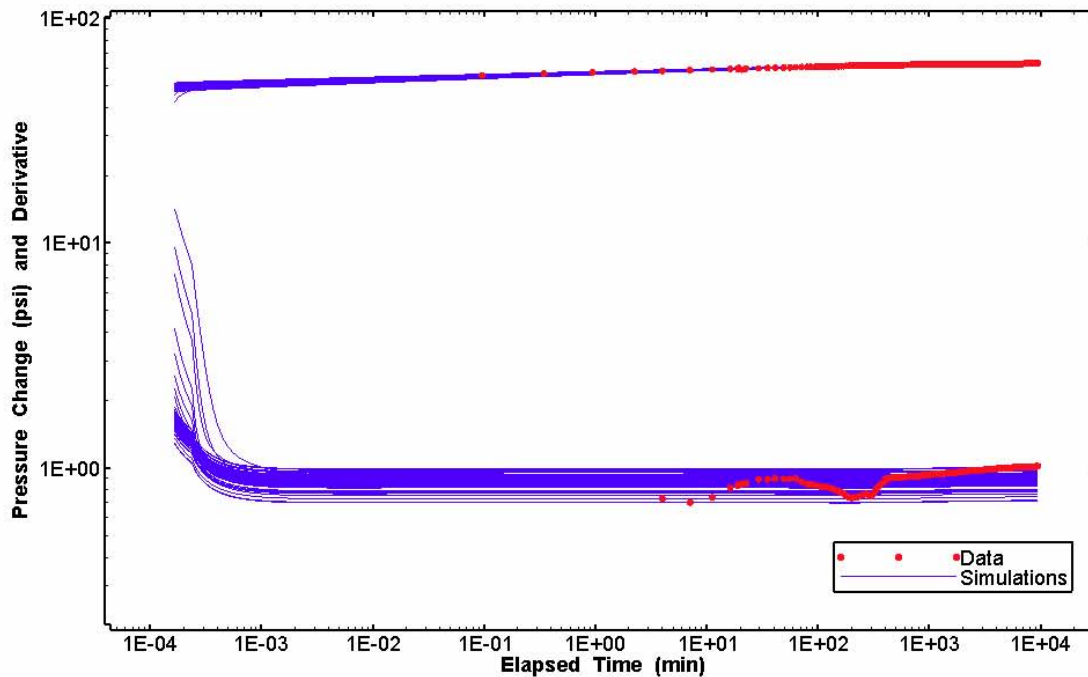
**Figure 50. Simulations of pressure change and derivative during the final WIPP-25
pressure-buildup test.**

4.10 C-2737

A constant-rate pumping test was initiated in well C-2737 on March 4, 2004. Pumping ended on March 5, 2004, after 10.4 hours of pumping at 0.3 gpm, and the subsequent pressure buildup through March 18, 2004, was included in this analysis (Figure 51). C-2737 pressures from January 1 – March 4, 2004, which included a series of pumping exercises in late January 2004, were included in the nSIGHTS simulations as a pressure history. The pressures shown in Figure 51 were separated into six nSIGHTS sequences for this analysis. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the C-2737.nPre file and are listed in Appendix B.10.
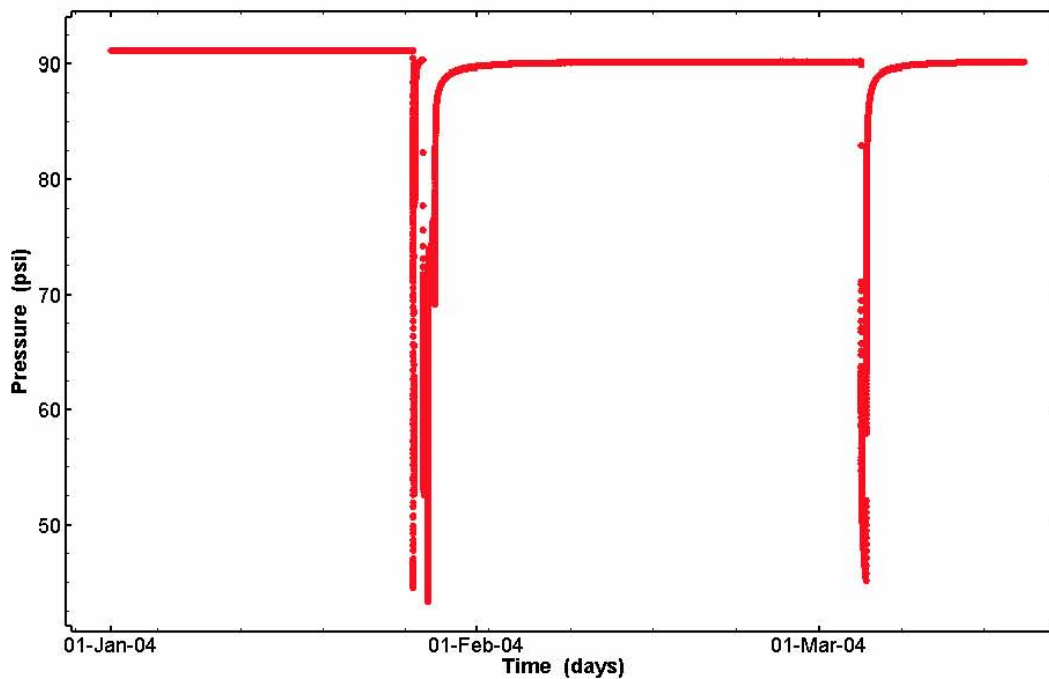
Figure 51. Pressure data from C-2737.

The specified C-2737 conceptual model, based on the characteristics of the final pressure-buildup diagnostic plot shown in Figure 52, was an infinite-acting radial system with wellbore storage and skin. The range of *T* values estimated from this analysis is shown in Figure 53. The mean estimate of *T* derived from this analysis was 6.62E-7 m^2/s. The simulated C-2737 Cartesian and log-log pressure-buildup diagnostic responses corresponding to the *T* values shown in Figure 53 are shown in Figures 54 and 55, respectively.

41
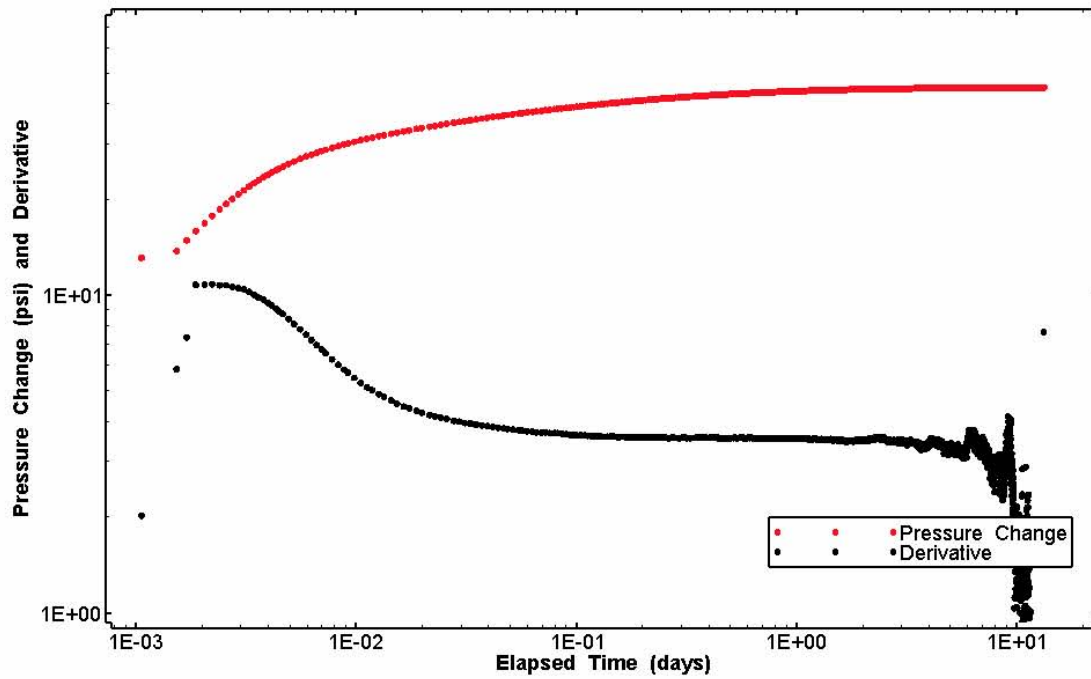
Figure 52. Log-log diagnostic plot of the final C-2737 pressure-buildup test.
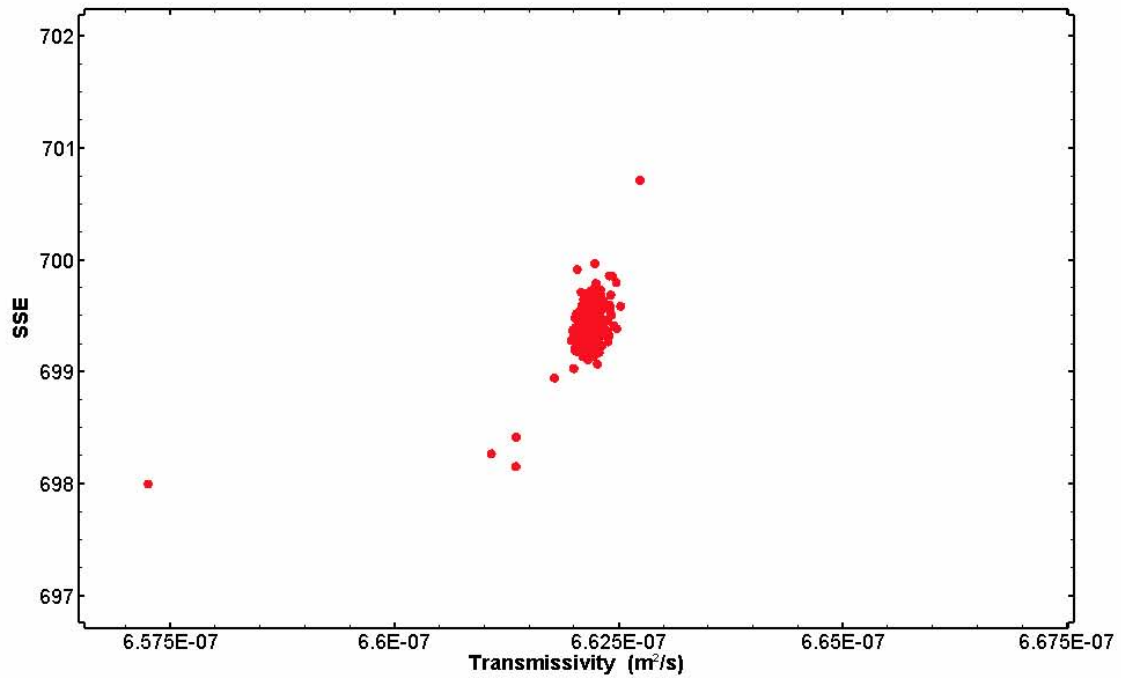
Figure 53. Estimates of transmissivity derived from the C-2737 perturbation analysis.
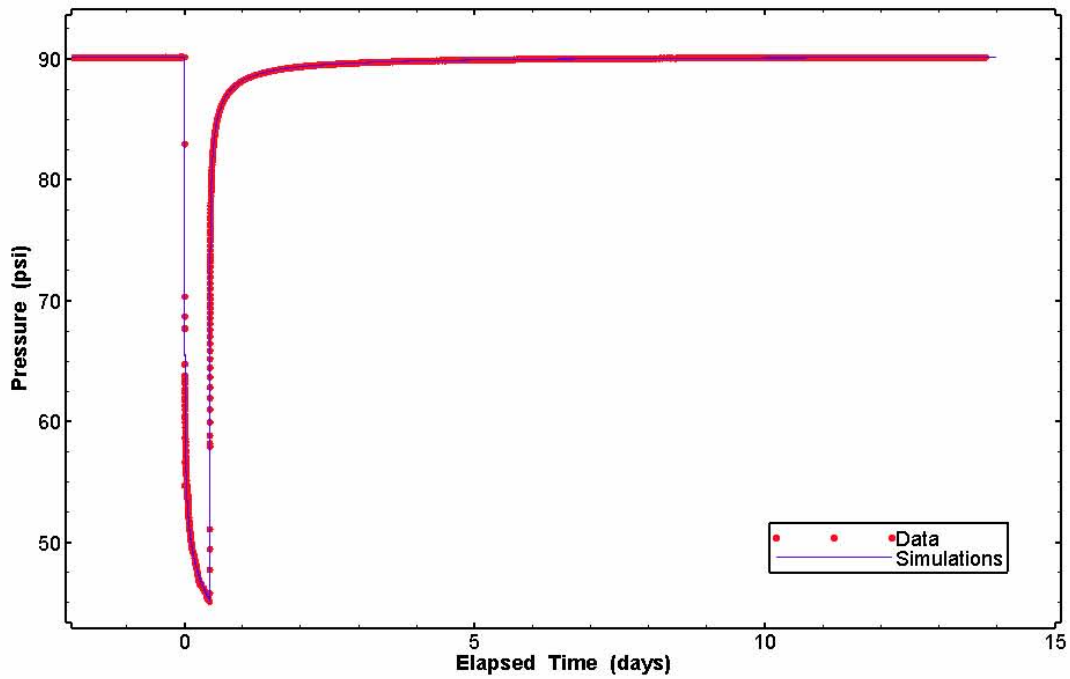
Figure 54. Simulations of the C-2737 pressure response.
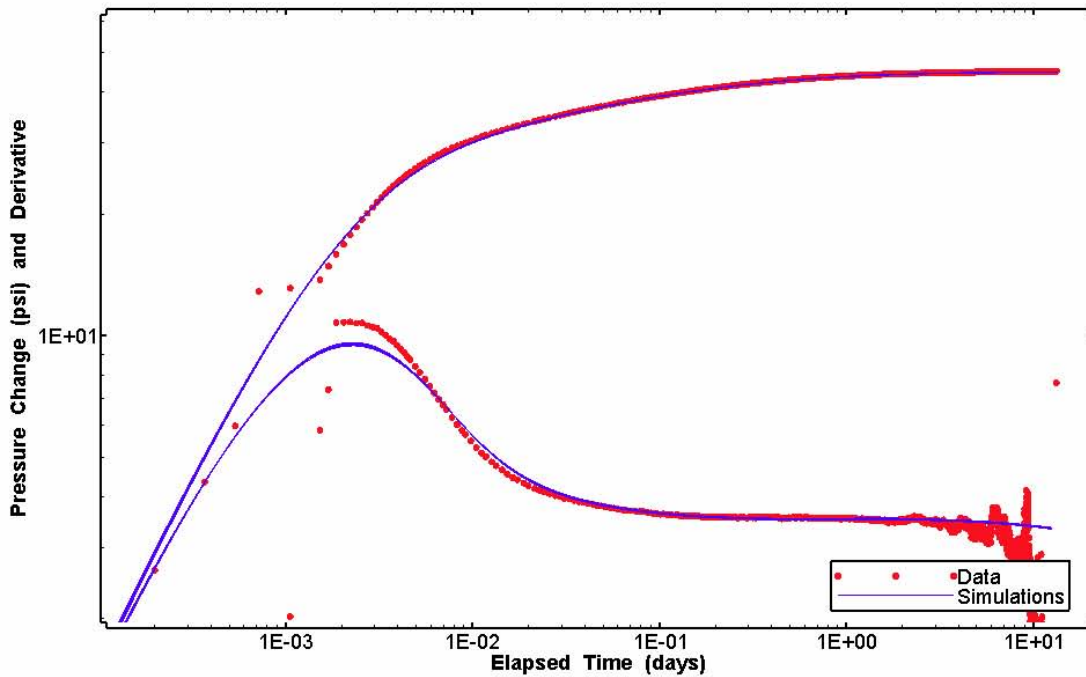
Figure 55. Simulations of pressure change and derivative during the C-2737 pressure-buildup test.

References

Beauheim, R.L. 2004. Analysis Plan for Non-Salado Hydraulic-Test Interpretations, AP-070, Revision 1. ERMS# 537479. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Beauheim R.L., R.M. Roberts, T.F. Dale, M.D. Fort, and W.A. Stensrud. 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report*. SAND92-0533. Albuquerque, NM: Sandia National Laboratories.

Roberts R.M., R.L. Beauheim, and P.S. Domski. 1999. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Final Report*. SAND98-2537. Albuquerque, NM: Sandia National Laboratories.

Appendix A -- Culebra Pumping Tests – December 2003 to August 2005

Well	Date and Time Start DAS	Date and Time Stop DAS	Date and Time Start Pump	Date and Time Stop Pump	Borehole Diameter (in)	Inside Casing Diameter (in)	Culebra Interval (ft)	Specific Gravity (g/cm^3)	Troll Filenames (ERMS# 539221)	DAS Filenames (ERMS# 543540)	Field Notebook (ERMS# 540244)
C-2737	3/4/2004 12:40	3/5/2004 11:19	3/4/2004 14:10	3/5/2004 0:32	12.25	6.241	675-698	1.0642	C-2737 C-2737_WLBPET_11-1-2003_to_4-1-2004 corrected.xls	C-2737 (C)_5-sec_Flow & Well Level Data_03-04 to 03-05-04.csv	WIPP Notebook #2
SNL-1	3/7/2005 12:19	3/10/2005 11:53	3/7/2005 12:50	3/10/2005 10:20	11	4.33	596-624	1.0278	SNL-1 SNL-1 Final Corrected Pressure.xls	SNL-1 (C)_5-sec_Flow & Well Level Data_03-07 to 03-10-2005.csv	WIPP Notebook #6
SNL-2	1/19/2005 18:37	1/24/2005 11:51	1/19/2005 19:11	1/24/2005 10:25	12.25	4.33	456-481	1.009	SNL-2 SNL-2(C9-C14 compilation)WLBPET corrected.xls	SNL-2 (C)_5-sec_Data_01-20 to 01-24-05.csv	WIPP Notebook #5
SNL-3	4/13/2004 11:54	4/17/2004 8:23	4/13/2004 13:11	4/16/2004 14:32	12.25	4.33	755-775	1.035	SN11028 2004-04-13 105407 SNL-3(C-pump2)-F.xls	SNL-3 (C)_5-sec_Flow & Well Level Data_04-13 to 4-15-2004reviewed.xls SNL-3 (C)_5-sec_Flow & Well Level Data_04-15 to 4-17-2004reviewed.xls	WIPP Notebook #2 & 3
SNL-5	7/19/2004 13:05	7/24/04 9:19 (1)	7/19/2004 13:52	7/23/2004 7:50	11	4.33	637-660	1.011	SN13475 2004-07-19 112609 SNL-5(C-Pump1)-F.xls	SNL-5 (C)_5-sec_Flow & Well Level Data_07-2004_Part 1.csv SNL-5 (C)_5-sec_Flow & Well Level Data_07-2004_Part 2.csv	WIPP Notebook #3 &4
SNL-9	12/2/2003 14:16	12/6/2003 10:07	12/2/2003 14:38	12/6/2003 9:16	15.75	8.42	550-573	1.022	SN13590 2003-11-19 120134 SNL9(C2)-F.xls SN13590 2003-12-18 134604 snl 9 (c-3)-F.xls	SNL-9 (C)_5-sec_Data_12-02 to 12-04-03 reviewed.xls SNL-9 (C)_5-sec_Data_12-04 to 12-06-03 reviewed.xls	WIPP Notebook #2
SNL-12	8/9/2004 12:39	8/14/2004 10:00	8/9/2004 13:17	8/14/2004 8:28	12.25	4.33	547-587	1.0044	SN11358 2004-08-09 101349 SNL-12(C3-pump)-F.xls	SNL-12 (C)_5-sec_Flow & Well Level Data 083104 combined final table.xls	WIPP Notebook #4
SNL-14	8/4/2005 13:15	8/26/2005 9:35	8/4/2005 13:59	8/26/2005 7:51	11	4.85	650-677	1.060	SNL-14 SNL-14 August 2005 20-Day test Corrected PHEAD.xls	SNL14 5 Minute flow start 8-4-05 1000.xls	WIPP 30 Day Pumping Test #03
WIPP-11	1/31/2005 12:29	2/20/2005 19:06	1/31/2005 13:45	2/20/2005 18:53	12.25	8.921	844-867	1.038	SN17339 2005-01-31 132623 WIPP-11 (Cpump1BU1).xls	WIPP-11 (C)_5-sec_Flow & Well Level Data_01-31 to 02-03-	WIPP 30 Day Pumping Test #02

Well	Date and Time Start DAS	Date and Time Stop DAS	Date and Time Start Pump	Date and Time Stop Pump	Borehole Diameter (in)	Inside Casing Diameter (in)	Culebra Interval (ft)	Specific Gravity (g/cm³)	Troll Filenames (ERMS# 539221)	DAS Filenames (ERMS# 543540)	Field Notebook (ERMS# 540244)
										05.xls	
										WIPP-11 (C)_5-sec_Flow & Well Level Data_02-03 to 02-06-05.xls	
										WIPP-11 (C)_5-sec_Flow & Well Level Data_02-06 to 02-07-05rev.xls	
										WIPP-11 (C)_5-sec_Flow & Well Level Data_02-07 to 02-07-05rev.xls	
										WIPP-11 (C)_5-sec_Flow & Well Level Data_02-07 to 02-10-05rev.xls	
										WIPP-11 (C)_5-sec_Flow & Well Level Data_02-10 to 02-14-05rev.xls	
										WIPP-11 (C)_5-sec_Flow & Well Level Data_02-14 to 02-17-05rev.xls	
										WIPP-11 (C)_5-sec_Flow & Well Level Data_02-17 to 02-20-05rev.xls	
WIPP-25	9/10/2004 9:55	9/23/2004 9:00	9/10/2004 11:39	9/23/2004 0:25	7.875	4.95	447-472	1.022	SN16771 2004-09-20 135045 WIPP-25(C5Pump1)-F2.xls	WIPP-25 (C)_5-sec_Flow & Well Level Data_09-16 to 9-23-2004comments.xls	WIPP Notebook #4

Appendix B – nSIGHTS Listings

B.1 SNL-1 nSIGHTS Listings

```
**********
nPre 2.30Q
**********

Version date    22 July 2005
Listing date    23 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL-1\SNL-1.nPre
```

Control Settings

Main Settings

```
Simulation type                           Forward
Simulation subtype                         Normal
Phase to simulate                          Liquid
Skin zone ?                                   yes
External boundary                  Fixed Pressure
Curve data source                         Objects
```

Liquid Phase Settings

```
Aquifer type                             Confined
Aquifer horizontal permeability         Isotropic
System porosity                            Single
Compensate flow dimension geometry            yes
Leakage                                      None
```

Test Zone Settings

```
Test zone volume can vary                      no
Test zone compressibility can vary             no
Test zone temperature can vary                 no
Default test-zone temperature       20.00    [C]
Solution variable                        Pressure
Allow negative head/pressure                  yes
```

Parameters

Formation

```
Formation thickness                 28.000      [ft]
Flow dimension                    f(r) point
Static formation pressure           73.767      [psi]
External boundary radius            1000000     [m]
Formation conductivity              7.24422E-05 [m/sec]
Formation spec. storage             1.00000E-06 [1/m]
```

Skin

```
Radial thickness of skin              9.439796     [m]
Skin zone conductivity                7.78386E-03  [m/sec]
Skin zone spec. storage               1.00000E-07  [1/m]
```

Fluid

```
Fluid density                         1027.80      [kg/m^3]
Fluid thermal exp. coeff.             0.00000E+00  [1/C]
```

Test-Zone

```
Well radius                           2.165        [in]
Tubing string radius                  1.5001279    [in]
```

Numeric

```
# of radial nodes                     250          []
# of skin nodes                       50           []
Pressure solution tolerance           1.45038E-11  [psi]
STP flow solution tolerance           1.58503E-11  [USgpm]
```

f(x) Points Parameters

Flow dimension

```
Points type                           f(r)
 Radius #1                            0.0          [m]
 Y value#1                            2.0          []
 Radius #2                            2445.3687063 [m]
 Y value#2                            1.017654     []

Parameter curve type                  Step Full
```

Calculated Parameters

Formation

```
Transmissivity                        6.18250E-04  [m^2/sec]
Storativity                           8.53440E-06  []
Diffusivity                           7.24422E+01  [m^2/sec]
```

Skin Zone

```
Transmissivity                        6.64305E-02  [m^2/sec]
Storativity                           8.53440E-07  []
Diffusivity                           7.78386E+04  [m^2/sec]
Skin factor                          -5.10339E+00  []
```

Test Zone

```
Open hole well-bore storage           4.52547E-07  [m^3/Pa]
```

Grid Properties

```
Grid increment delta                          0.05811      []
First grid increment                     5.68132E-01       [m]
Skin grid increment delta                     0.10513      []
Skin first grid increment                6.09598E-03       [m]
Skin last grid increment                 9.47501E-01       [m]
Increment ratio                          5.99611E-01       []
```

Sequences

Sequence: H_01

```
Sequence type                               History
Start time                              -250970.960       [min]
Duration                                 250979.962       [min]
Time step type                               Static
Static time step                            1.000000       [day]
Type                                          Curve
Wellbore storage                              None
```

Sequence: H_02

```
Sequence type                               History
Start time                                    9.002       [min]
Duration                                   4203.000       [min]
Time step type                               Static
Static time step                              2.000       [min]
Type                                          Curve
Wellbore storage                              Open
```

Sequence: H_03

```
Sequence type                               History
Start time                                 4212.002       [min]
Duration                                    155.728       [min]
Time step type                               Static
Static time step                              0.500       [min]
Type                                          Curve
Wellbore storage                              Open
```

Sequence: F_01

```
Sequence type                                  Flow
Start time                                 4367.730       [min]
Duration                                    127.400       [min]
Time step type                                  Log
First log step                           1.66667E-04       [min]
# of time steps                                 250
Type                                          Fixed
Fixed value                                   -40.0       [USgpm]
Wellbore storage                              Open
```

Sequence: F_02

```
Sequence type                                  Flow
```

```
Start time                              4495.130    [min]
Duration                                 157.160    [min]
Time step type                               Log
First log step                       1.66667E-04    [min]
# of time steps                              250
Type                                       Fixed
Fixed value                                  0.0    [USgpm]
Wellbore storage                            Open
```

Sequence: F_03

```
Sequence type                               Flow
Start time                              4652.290    [min]
Duration                                1064.064    [min]
Time step type                               Log
First log step                       1.66667E-04    [min]
# of time steps                              250
Type                                       Fixed
Fixed value                                -35.0    [USgpm]
Wellbore storage                            Open
```

Sequence: F_04

```
Sequence type                               Flow
Start time                              5716.354    [min]
Duration                                 184.646    [min]
Time step type                               Log
First log step                       1.66667E-04    [min]
# of time steps                              250
Type                                       Fixed
Fixed value                                  0.0    [USgpm]
Wellbore storage                            Open
```

Sequence: H_04

```
Sequence type                            History
Start time                              5901.000    [min]
Duration                                  19.500    [min]
Time step type                            Static
Static time step                           0.250    [min]
Type                                       Curve
Wellbore storage                            None
```

Sequence: F_05

```
Sequence type                               Flow
Start time                              5920.500    [min]
Duration                                 189.250    [min]
Time step type                               Log
First log step                       1.66667E-04    [min]
# of time steps                              250
Type                                       Fixed
Fixed value                                  0.0    [USgpm]
Wellbore storage                            Open
```

Sequence: F_06

```
Sequence type                               Flow
```

```
Start time                                   6109.750      [min]
Duration                                     2427.790      [min]
Time step type                                    Log
First log step                            1.66667E-04      [min]
# of time steps                                   250
Type                                            Fixed
Fixed value                                     -35.0      [USgpm]
Wellbore storage                                 Open
```

Sequence: F_07

```
Sequence type                                    Flow
Start time                                   8537.540      [min]
Duration                                   241462.460      [min]
Time step type                                    Log
First log step                            1.66667E-04      [min]
# of time steps                                   250
Type                                            Fixed
Fixed value                                       0.0      [USgpm]
Wellbore storage                                 Open
```

Test Zone Curves

```
Curve object to use                    Pressure Curve
Curve type                                   Pressure
Start sequence                                   H_01
End sequence                                     H_04
Curve time base                                  Test
Curve Y data units                              [psi]
Curve Y data is log 10                             no
```

Simulation Results Setup

```
Output ID                                         DAT
  Output type                                Pressure
  Pressure capture type                     Test Zone
  Output units                                 [psi]

Output ID                                         DAT
  Output type                               Flow Rate
  Flow rate output type                          Well
  Output units                               [USgpm]
```

SNL-1 nSIGHTS Optimization Settings

```
**********
nPre 2.30Q
**********


Version date    22 July 2005
Listing date    23 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL-1\SNL-1.nPre
```

Parameters

Formation

```
Formation thickness                              28.000      [ft]
Flow dimension                               f(r) point
Static formation pressure                    Optimization
   Minimum value                                65.000      [psi]
   Maximum value                                80.000      [psi]
   Estimate value                               73.767      [psi]
   Range type                                    Linear
   Sigma                                    1.00000E+00
External boundary radius                        1000000      [m]
Formation conductivity                       Optimization
   Minimum value                            1.00000E-08      [m/sec]
   Maximum value                            1.00000E-01      [m/sec]
   Estimate value                           7.24422E-05      [m/sec]
   Range type                                       Log
   Sigma                                    1.00000E+00
Formation spec. storage                      1.00000E-06      [1/m]
```

Skin

```
Radial thickness of skin                     Optimization
   Minimum value                                0.0001      [m]
   Maximum value                                  10.0      [m]
   Estimate value                             9.439796      [m]
   Range type                                       Log
   Sigma                                    1.00000E+00
Skin zone conductivity                       Optimization
   Minimum value                            1.00000E-05      [m/sec]
   Maximum value                            1.00000E-01      [m/sec]
   Estimate value                           7.78386E-03      [m/sec]
   Range type                                       Log
   Sigma                                    1.00000E+00
Skin zone spec. storage                      1.00000E-07      [1/m]
```

Fluid

```
Fluid density                                 1027.80      [kg/m^3]
Fluid thermal exp. coeff.                  0.00000E+00      [1/C]
```

Test-Zone

```
Well radius                                     2.165      [in]
Tubing string radius                         Optimization
   Minimum value                                   1.0      [in]
   Maximum value                                 2.165      [in]
   Estimate value                            1.5001279      [in]
   Range type                                    Linear
   Sigma                                    1.00000E+00
```

Numeric

```
# of radial nodes                                 250      []
# of skin nodes                                    50      []
Pressure solution tolerance                1.45038E-11      [psi]
```

```
STP flow solution tolerance                    1.58503E-11      [USgpm]
```

SNL-1 Fitting-Parameter Estimates
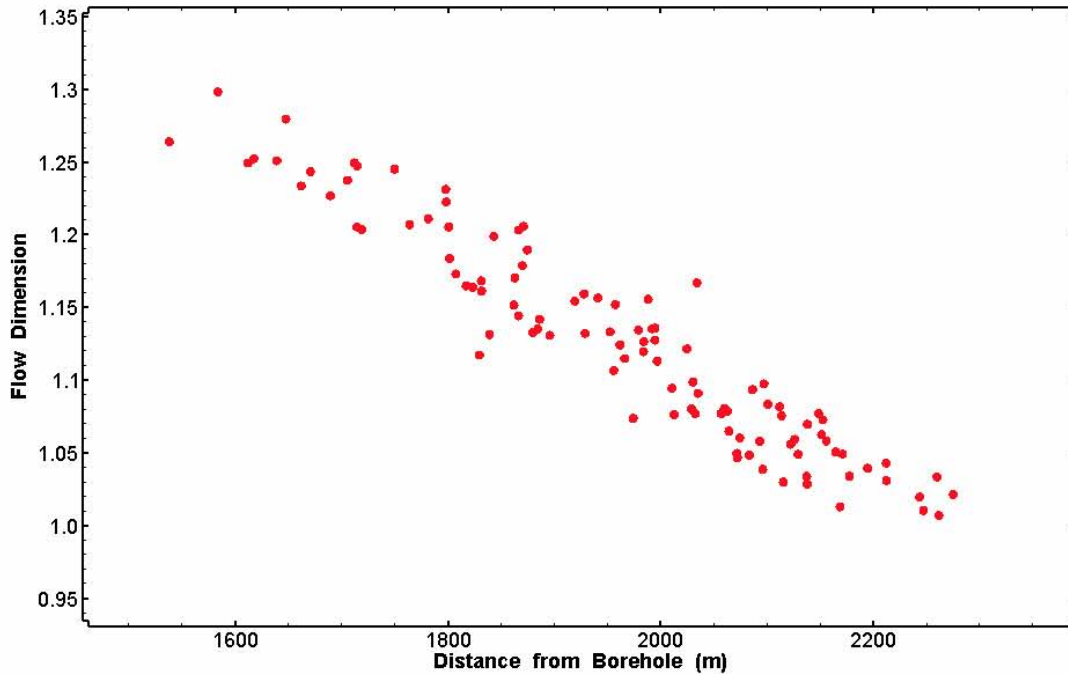
Figure B-1. Estimates of flow dimension derived from the SNL-1 perturbation analysis.
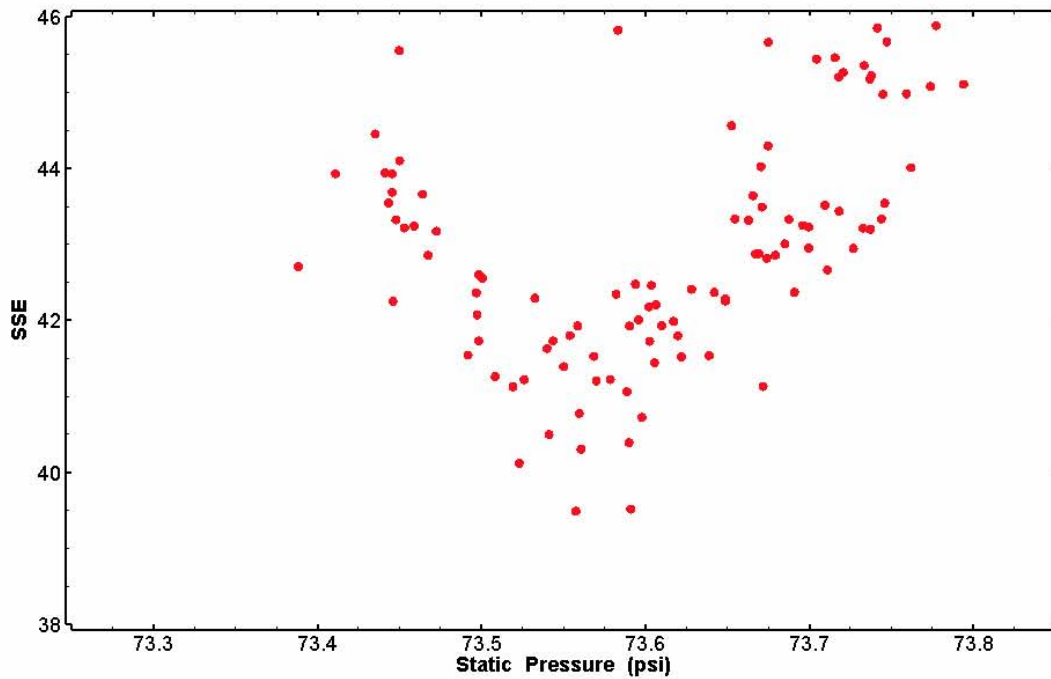
Figure B-2. Estimates of static formation pressure derived from the SNL-1 perturbation analysis.
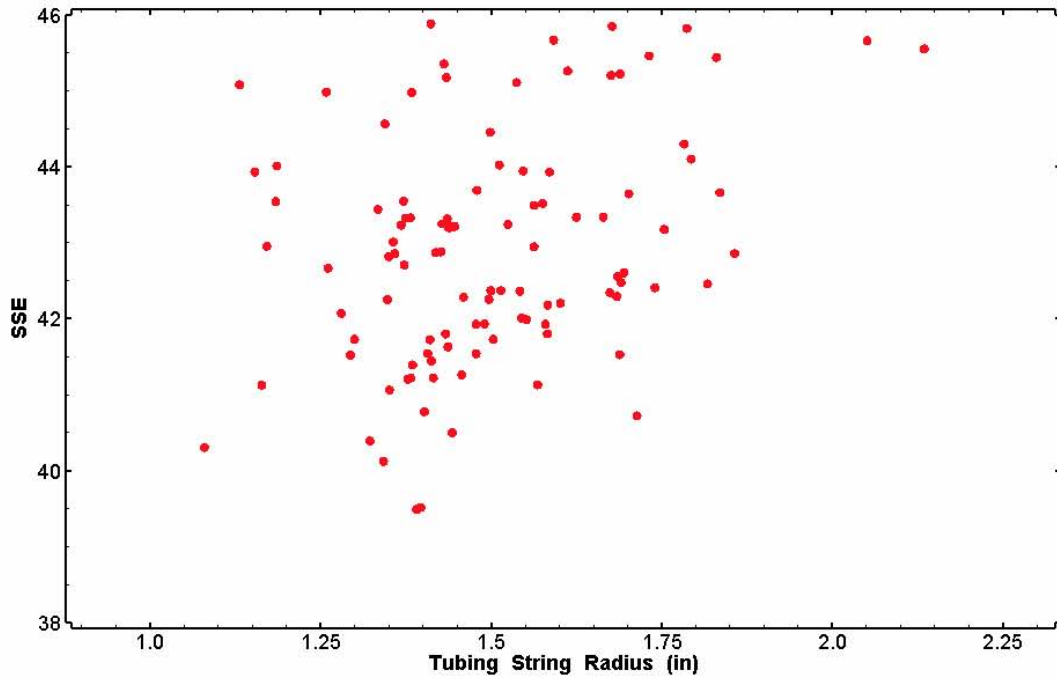
Figure B-3. Estimates of tubing string radius derived from the SNL-1 perturbation analysis.
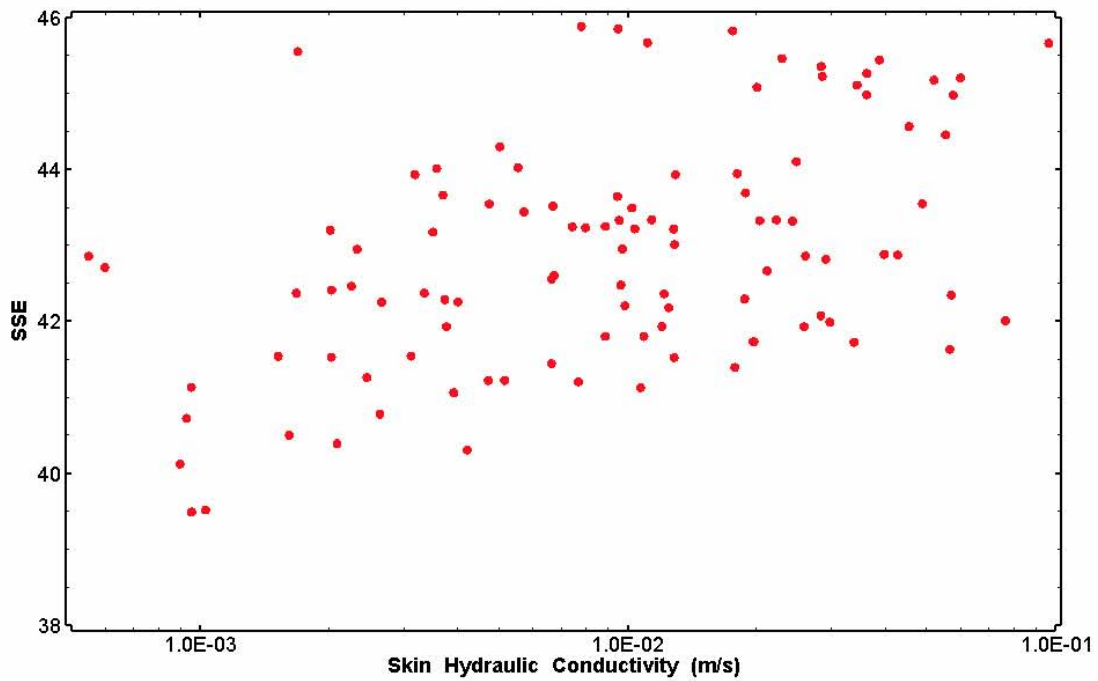
Figure B-4. Estimates of skin hydraulic conductivity derived from the SNL-1 perturbation analysis.
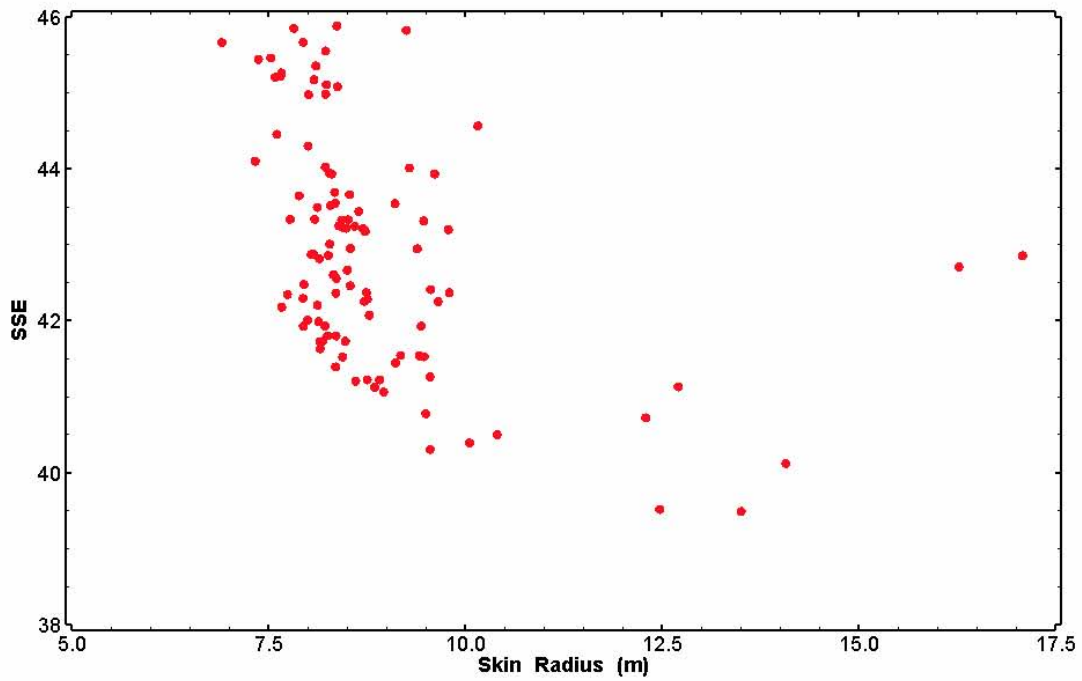
Figure B-5. Estimates of skin radius derived from the SNL-1 perturbation analysis.
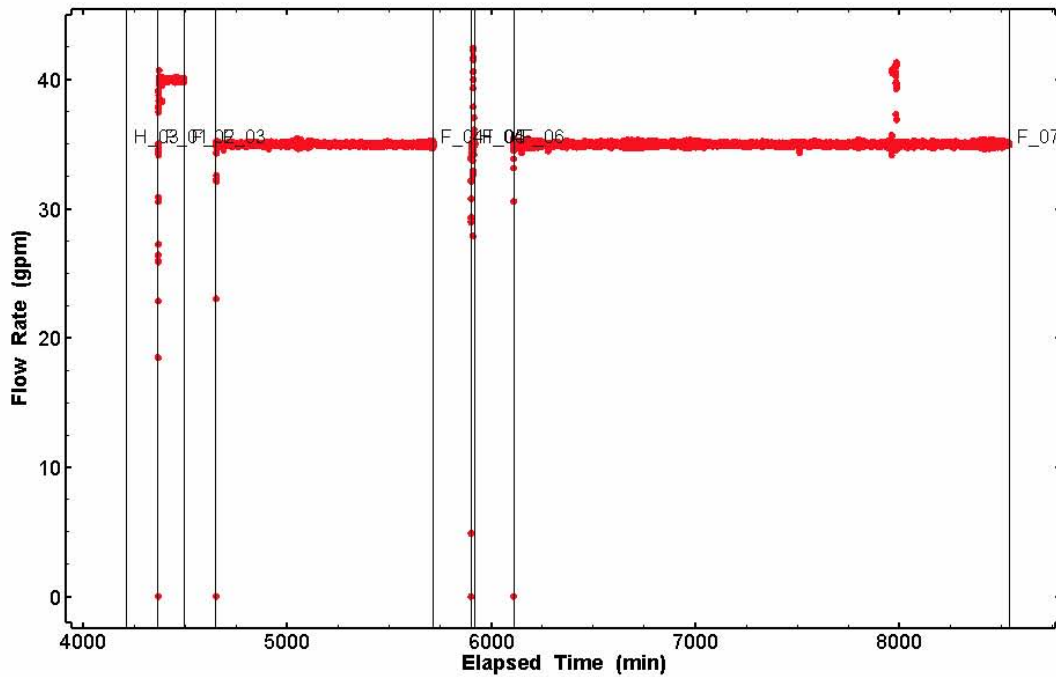
Figure B-6. Flow rates measured during the SNL-1 testing.

B.2   SNL-2 nSIGHTS Listings

```
**********
nPre 2.30Q
**********


Version date    22 July 2005
Listing date    23 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL 2\SNL-2.nPre
```

Control Settings

Main Settings

```
Simulation type                                Forward
Simulation subtype                              Normal
Phase to simulate                               Liquid
Skin zone ?                                          no
External boundary                       Fixed Pressure
Curve data source                               Objects
```

Liquid Phase Settings

```
Aquifer type                                  Confined
Aquifer horizontal permeability              Isotropic
System porosity                                 Single
Compensate flow dimension geometry                 yes
Leakage                                           None
```

Test Zone Settings

```
Test zone volume can vary                           no
Test zone compressibility can vary                  no
Test zone temperature can vary                      no
Default test-zone temperature            20.00      [C]
Solution variable                             Pressure
Allow negative head/pressure                       yes
```

Parameters

Formation

```
Formation thickness                      25.000     [ft]
Flow dimension                              2.0      []
Static formation pressure                98.376     [psi]
External boundary radius                1000000     [m]
Formation conductivity              f(r) point
Formation spec. storage          1.00000E-06        [1/m]
```

Fluid

```
Fluid density                            1009.00    [kg/m^3]
Fluid thermal exp. coeff.         0.00000E+00       [1/C]
```

Test-Zone

```
Well radius                                  2.165      [in]
Tubing string radius                     1.5000144      [in]
```

Numeric

```
# of radial nodes                              250      []
Pressure solution tolerance            1.45038E-11      [psi]
STP flow solution tolerance            1.58503E-11      [USgpm]
```

f(x) Points Parameters

Formation conductivity

```
Points type                                   f(r)
 Radius #1                                    0.001      [m]
 Y value#1                              1.47460E-02      [m/sec]
 Radius #2                              742.6866088      [m]
 Y value#2                              1.31862E-05      [m/sec]
 Radius #3                              5782.035865      [m]
 Y value#3                              3.23096E-04      [m/sec]

Parameter curve type                        Linear
```

Calculated Parameters

Formation

```
Transmissivity                                f(r)
Storativity                            7.62000E-06      []
Diffusivity                                   f(r)
```

Test Zone

```
Open hole well-bore storage            4.60910E-07      [m^3/Pa]
```

Grid Properties

```
Grid increment delta                       0.06713      []
First grid increment                   3.81844E-03      [m]
```

Sequences

Sequence: H_01

```
  Sequence type                            History
  Start time                           -527196.135      [min]
  Duration                              526196.135      [min]
  Time step type                            Static
  Static time step                         500.000      [min]
  Type                                       Curve
  Wellbore storage                            None
```

57

Sequence: H_02

```
Sequence type                               History
Start time                          -1000.000      [min]
Duration                             1002.082      [min]
Time step type                                Static
Static time step                        1.000      [min]
Type                                          Curve
Wellbore storage                               None
```

Sequence: F_01

```
Sequence type                                  Flow
Start time                              2.082      [min]
Duration                             5786.254      [min]
Time step type                                  Log
First log step                    1.66667E-04      [min]
# of time steps                           250
Type                                          Fixed
Fixed value                             -12.0      [USgpm]
Wellbore storage                               Open
```

Sequence: F_02

```
Sequence type                                  Flow
Start time                           5788.336      [min]
Duration                             4711.664      [min]
Time step type                                  Log
First log step                    1.66667E-04      [min]
# of time steps                           250
Type                                          Fixed
Fixed value                               0.0      [USgpm]
Wellbore storage                               Open
```

Test Zone Curves

```
Curve object to use                         P Curve
Curve type                                 Pressure
Start sequence                                 H_01
End sequence                                   H_02
Curve time base                                Test
Curve Y data units                            [psi]
Curve Y data is log 10                           no
```

Simulation Results Setup

```
Output ID                                       DAT
  Output type                              Pressure
  Pressure capture type             Superposition
   DAT[1] operation                    + Pressure
    Type                                 Constant
    Fixed radius                          0.0001      [m]
  Output units                            [psi]

Output ID                                       DAT
  Output type                            Flow Rate
  Flow rate output type                      Well
```

58

```
   Output units                                [USgpm]
```

SNL-2 Optimization Settings

```
**********
nPre 2.30Q
**********


Version date    22 July 2005
Listing date    23 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL 2\SNL-2.nPre
```

Parameters

Formation

```
Formation thickness                   25.000     [ft]
Flow dimension                           2.0     []
Static formation pressure         Optimization
   Minimum value                      86.000     [psi]
   Maximum value                     110.000     [psi]
   Estimate value                     98.376     [psi]
   Range type                          Linear
   Sigma                          1.00000E+00
External boundary radius             1000000     [m]
Formation conductivity             f(r) point
Formation spec. storage          1.00000E-06     [1/m]
```

Fluid

```
Fluid density                        1009.00     [kg/m^3]
Fluid thermal exp. coeff.        0.00000E+00     [1/C]
```

Test-Zone

```
Well radius                            2.165     [in]
Tubing string radius              Optimization
   Minimum value                         1.5     [in]
   Maximum value                         4.0     [in]
   Estimate value                   1.5000144    [in]
   Range type                          Linear
   Sigma                          1.00000E+00
```

Numeric

```
# of radial nodes                        250     []
Pressure solution tolerance      1.45038E-11     [psi]
STP flow solution tolerance      1.58503E-11     [USgpm]
```

SNL-2 Fitting Parameter Estimates
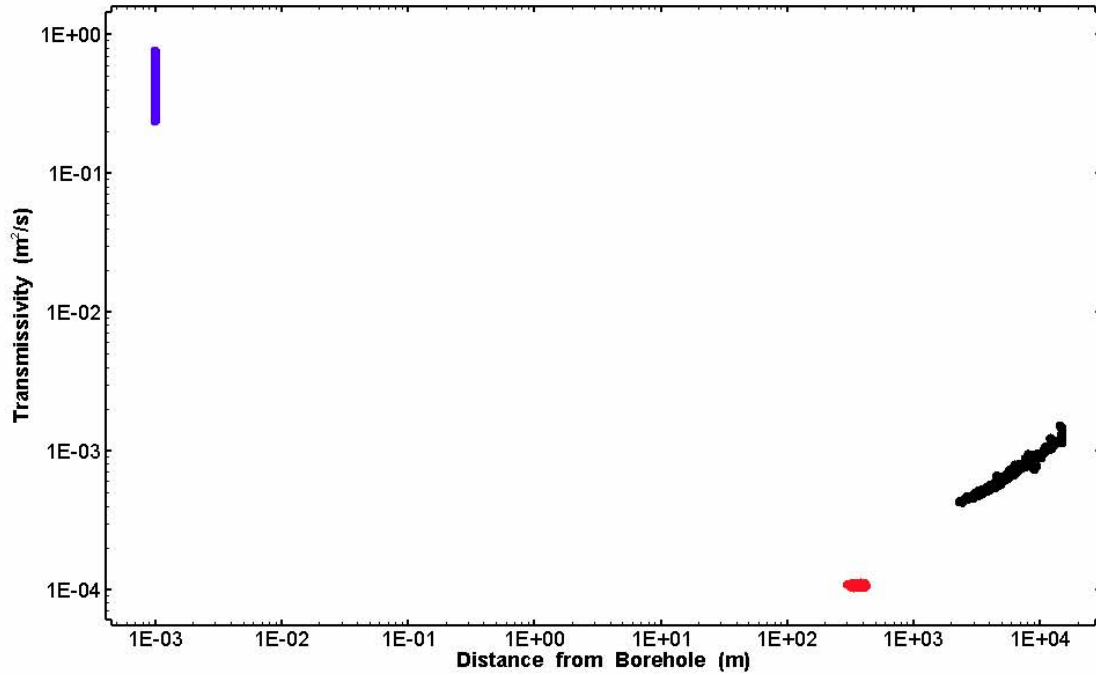
Figure B-7. Estimates of radially varying transmissivity derived from the SNL-2 perturbation analysis.
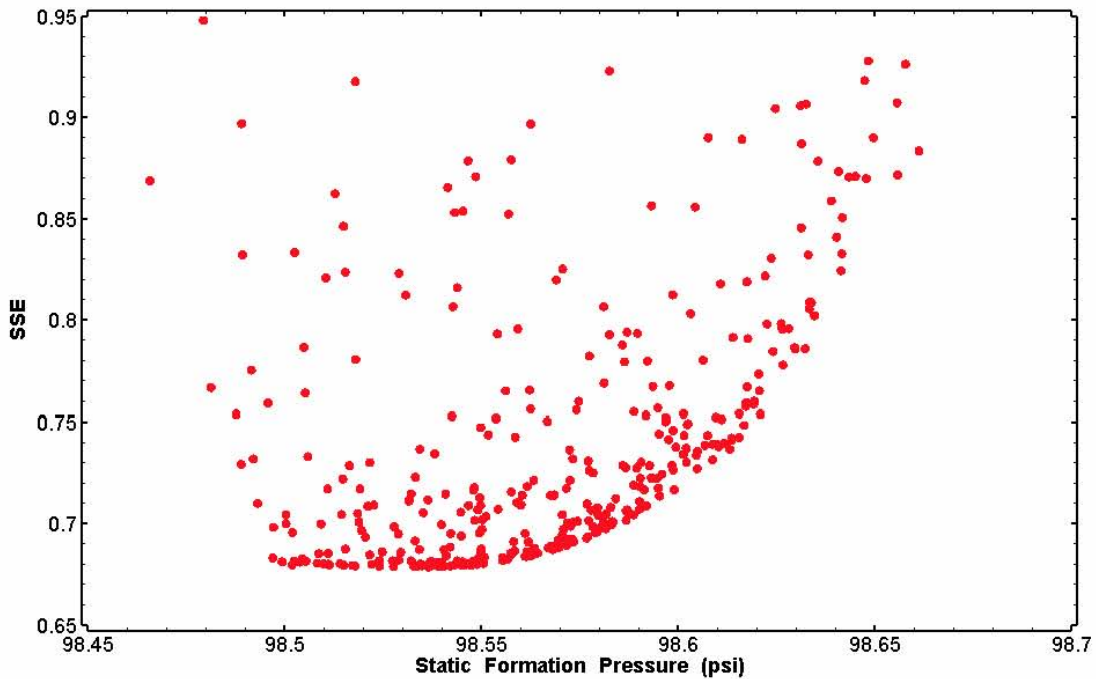
Figure B-8. Estimates of static formation pressure derived from the SNL-2 perturbation analysis.
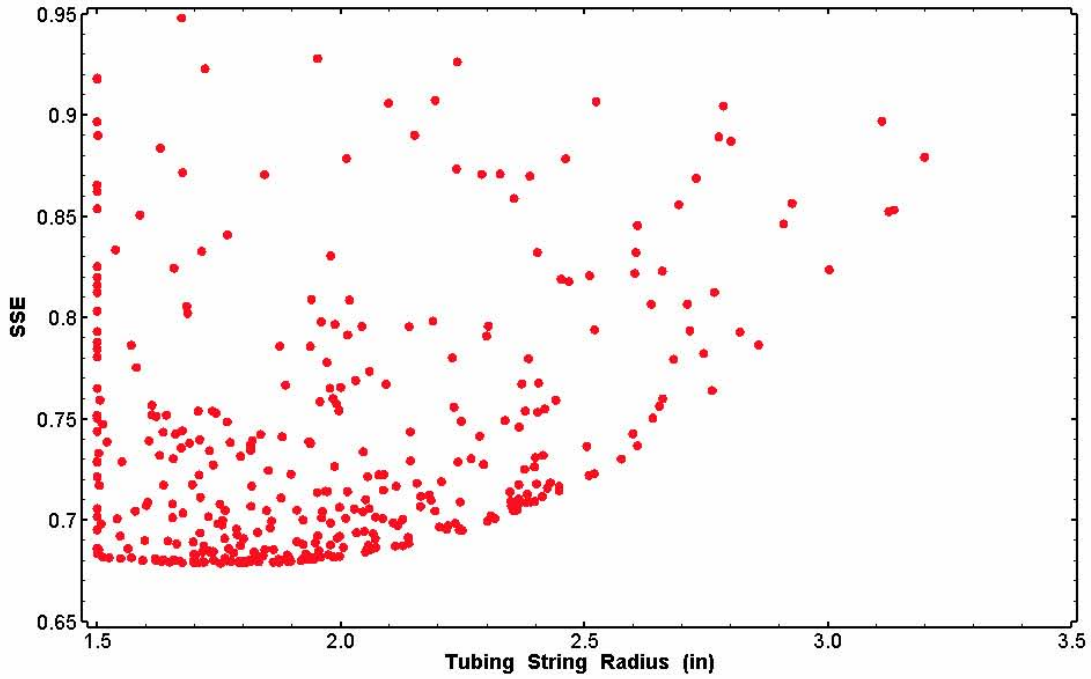
Figure B-9. Estimates of tubing string radius derived from the SNL-2 perturbation analysis.
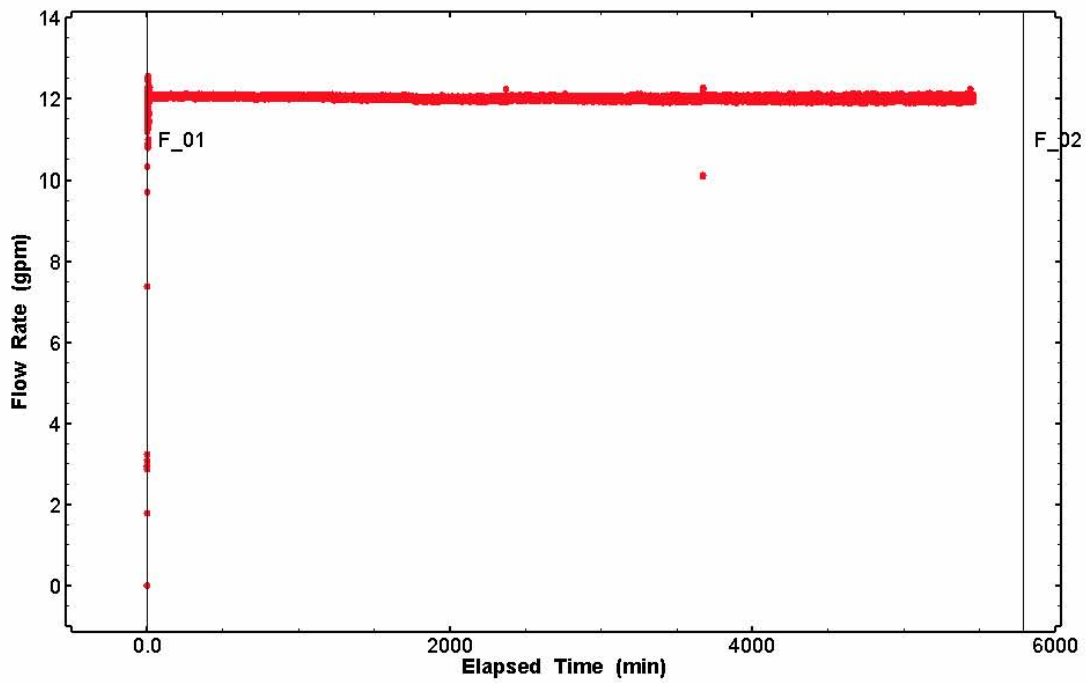
Figure B-10. Flow rates measured during the SNL-2 testing.

B.3   SNL-3 nSIGHTS Listings

```
**********
nPre 2.30Q
**********


Version date    22 July 2005
Listing date    27 Apr 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL 3\SNL-3.nPre
```

Control Settings

Test Description

Main Settings

```
Simulation type                          Forward
Simulation subtype                        Normal
Phase to simulate                         Liquid
Skin zone ?                                  yes
External boundary                 Fixed Pressure
Curve data source                        Objects
```

Liquid Phase Settings

```
Aquifer type                            Confined
Aquifer horizontal permeability        Isotropic
System porosity                           Single
Compensate flow dimension geometry           yes
Leakage                                     None
```

Test Zone Settings

```
Test zone volume can vary                     no
Test zone compressibility can vary            no
Test zone temperature can vary                no
Default test-zone temperature             20.00     [C]
Solution variable                       Pressure
Allow negative head/pressure                 yes
```

Parameters

Formation

```
Formation thickness                       20.000     [ft]
Flow dimension                               2.0     []
Static formation pressure                165.540     [psi]
External boundary radius                 1000000     [m]
Formation conductivity               f(r) point
Formation spec. storage              1.00000E-06     [1/m]
```

Skin

```
Radial thickness of skin                 0.0000173     [m]
Skin zone conductivity                   f(t) point
Skin zone spec. storage                  1.00000E-06   [1/m]
```

Fluid

```
Fluid density                            1035.00       [kg/m^3]
Fluid thermal exp. coeff.                0.00000E+00   [1/C]
```

Test-Zone

```
Well radius                              2.165         [in]
Tubing string radius                     1.8           [in]
```

Numeric

```
# of radial nodes                        250           []
# of skin nodes                          50            []
Pressure solution tolerance              1.45038E-11   [psi]
STP flow solution tolerance              1.58503E-11   [USgpm]
```

f(x) Points Parameters

Formation conductivity

```
Points type                              f(r)
 Radius #1                               6.0299749     [m]
 Y value#1                               1.53552E-04   [m/sec]
 Radius #2                               763.3368394   [m]
 Y value#2                               1.74206E-05   [m/sec]
 Radius #3                               2588.6872667  [m]
 Y value#3                               9.99827E-06   [m/sec]

Parameter curve type                     Linear
```

Skin zone conductivity

```
Points type                              f(t)
 Time #1                                 206444.160000 [day]
 Y value#1                               6.83458E-10   [m/sec]
 Time #2                                 207131.761160 [day]
 Y value#2                               3.20516E-10   [m/sec]
 Time #3                                 211592.768300 [day]
 Y value#3                               2.50530E-10   [m/sec]
 Time #4                                 289669.414910 [day]
 Y value#4                               2.08608E-10   [m/sec]
 Time #5                                 403870.639170 [day]
 Y value#5                               1.91428E-10   [m/sec]

Parameter curve type                     Linear
```

63

Calculated Parameters

Formation

```
Transmissivity                                   f(r)
Storativity                          6.09600E-06       []
Diffusivity                                      f(r)
```

Skin Zone

```
Transmissivity                                   f(t)
Storativity                          6.09600E-06       []
Diffusivity                                      f(t)
Skin factor                                      f(r)
```

Test Zone

```
Open hole well-bore storage          6.47025E-07       [m^3/Pa]
```

Grid Properties

```
Grid increment delta                     0.08400       []
First grid increment                 4.82025E-03       [m]
Skin grid increment delta                0.00001       []
Skin first grid increment            3.53484E-07       [m]
Skin last grid increment             3.53593E-07       [m]
Increment ratio                      1.36322E+04       []
```

Sequences

Sequence: H_01

```
  Sequence type                         History
  Start time                           1.454250       [day]
  Duration                             0.935190       [day]
  Time step type                         Static
  Static time step                     0.050000       [day]
  Type                                    Fixed
  Fixed value                           165.444       [psi]
  Wellbore storage                         Open
```

Sequence: F_01

```
  Sequence type                            Flow
  Start time                           2.389440       [day]
  Duration                             2.216029       [day]
  Time step type                            Log
  First log step                     1.15741E-07       [day]
  # of time steps                           250
  Type                                    Fixed
  Fixed value                             -10.0       [USgpm]
  Wellbore storage                         Open
```

Sequence: F_02

```
  Sequence type                            Flow
```

64

```
Start time                                4.605469      [day]
Duration                                 10.394531      [day]
Time step type                                 Log
First log step                        1.15741E-07      [day]
# of time steps                                250
Type                                         Fixed
Fixed value                                    0.0      [USgpm]
Wellbore storage                              Open
```

Simulation Results Setup

```
Output ID                                      DAT
  Output type                             Pressure
  Pressure capture type                  Test Zone
  Output units                               [psi]

Output ID                                      DAT
  Output type                            Flow Rate
  Flow rate output type                       Well
  Output units                             [USgpm]
```

SNL-3 Optimization Settings

```
**********
nPre 2.30Q
**********


Version date    22 July 2005
Listing date    27 Apr 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL 3\SNL-3.nPre
```

Parameters

Formation

```
Formation thickness                         20.000      [ft]
Flow dimension                                 2.0      []
Static formation pressure              Optimization
  Minimum value                            140.000      [psi]
  Maximum value                            180.000      [psi]
  Estimate value                           165.540      [psi]
  Range type                                Linear
  Sigma                                1.00000E+00
External boundary radius                   1000000      [m]
Formation conductivity                    f(r) point
Formation spec. storage              1.00000E-06      [1/m]
```

Skin

```
Radial thickness of skin               Optimization
  Minimum value                            1.0E-05      [m]
  Maximum value                                1.0      [m]
  Estimate value                         0.0000173      [m]
```

```
    Range type                                   Log
    Sigma                             1.00000E+00
Skin zone conductivity                 f(t) point
Skin zone spec. storage           1.00000E-06       [1/m]
```

Fluid

```
Fluid density                        1035.00       [kg/m^3]
Fluid thermal exp. coeff.         0.00000E+00       [1/C]
```

Test-Zone

```
Well radius                             2.165       [in]
Tubing string radius                      1.8       [in]
```

Numeric

```
# of radial nodes                         250       []
# of skin nodes                            50       []
Pressure solution tolerance       1.45038E-11       [psi]
STP flow solution tolerance       1.58503E-11       [USgpm]
```

SNL-3 Fitting Parameter Estimates
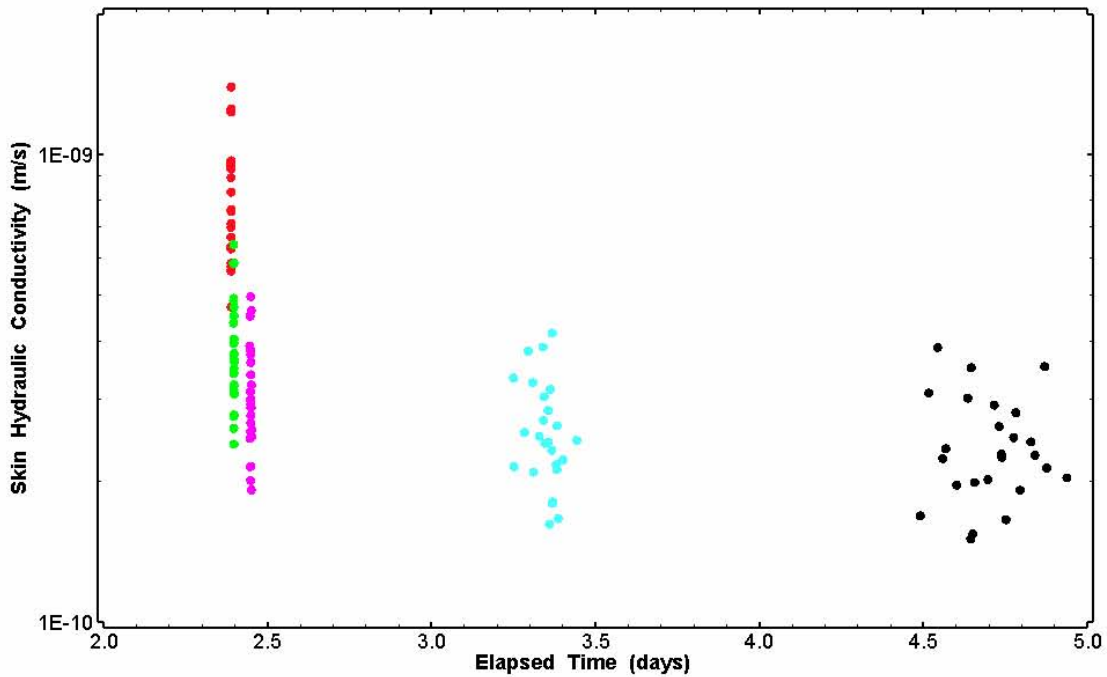
Figure B-11. Estimates of time-varying skin hydraulic conductivity derived from the SNL-3 perturbation analysis.

66
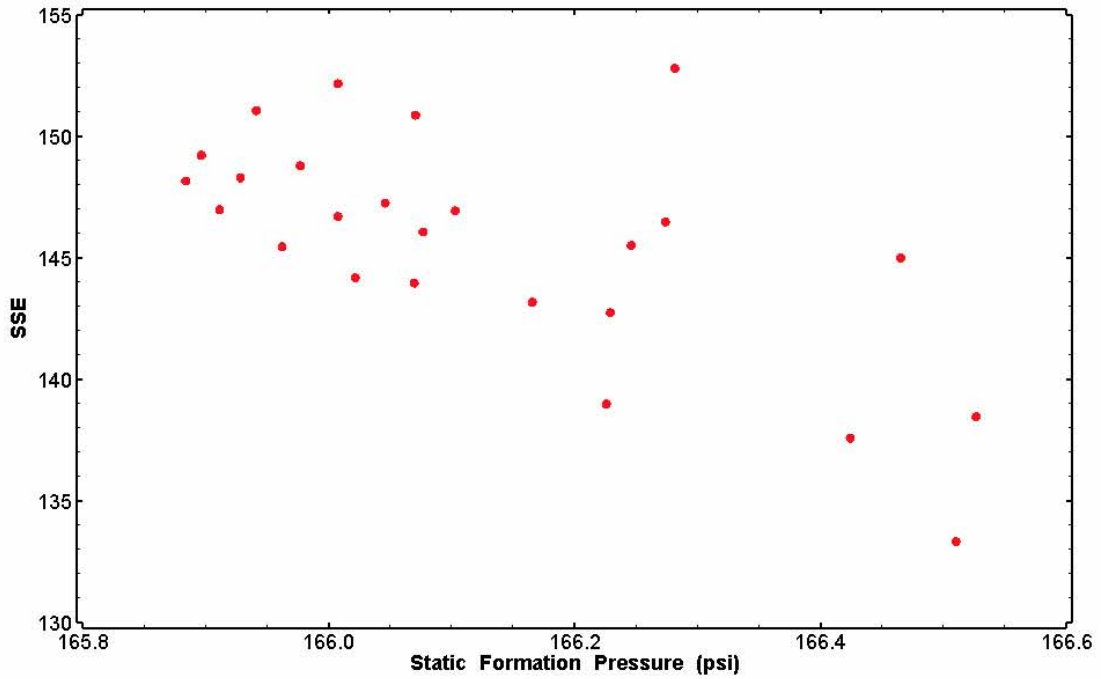
Figure B-12. Estimates of static formation pressure derived from the SNL-3 perturbation analysis.
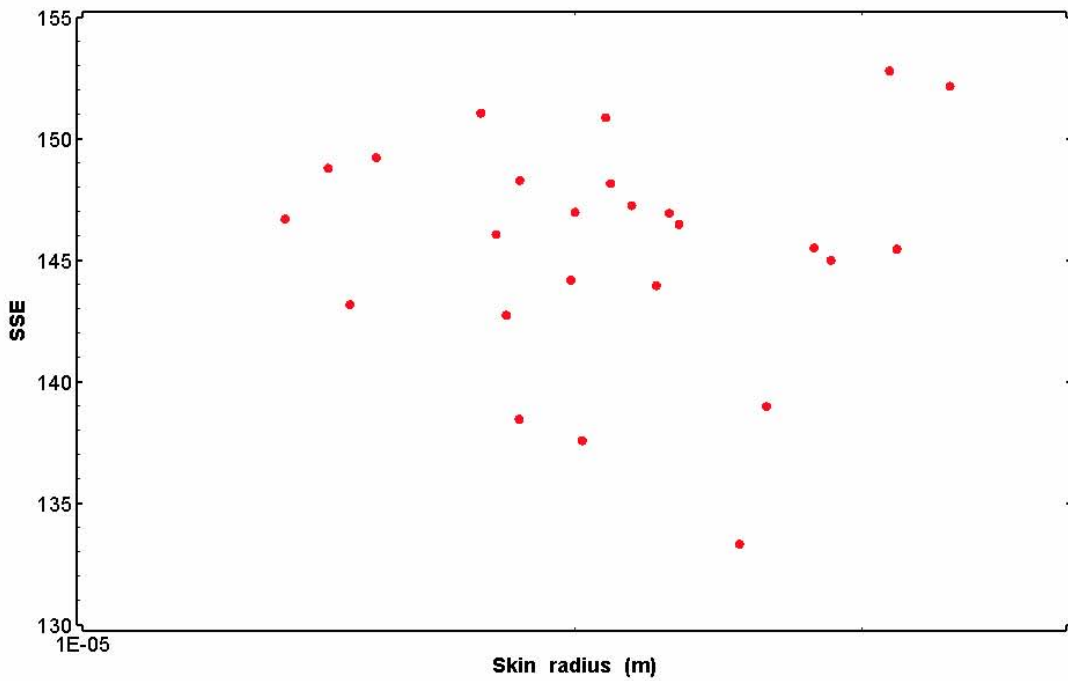
Figure B-13. Estimates of skin radius derived from the SNL-3 perturbation analysis.
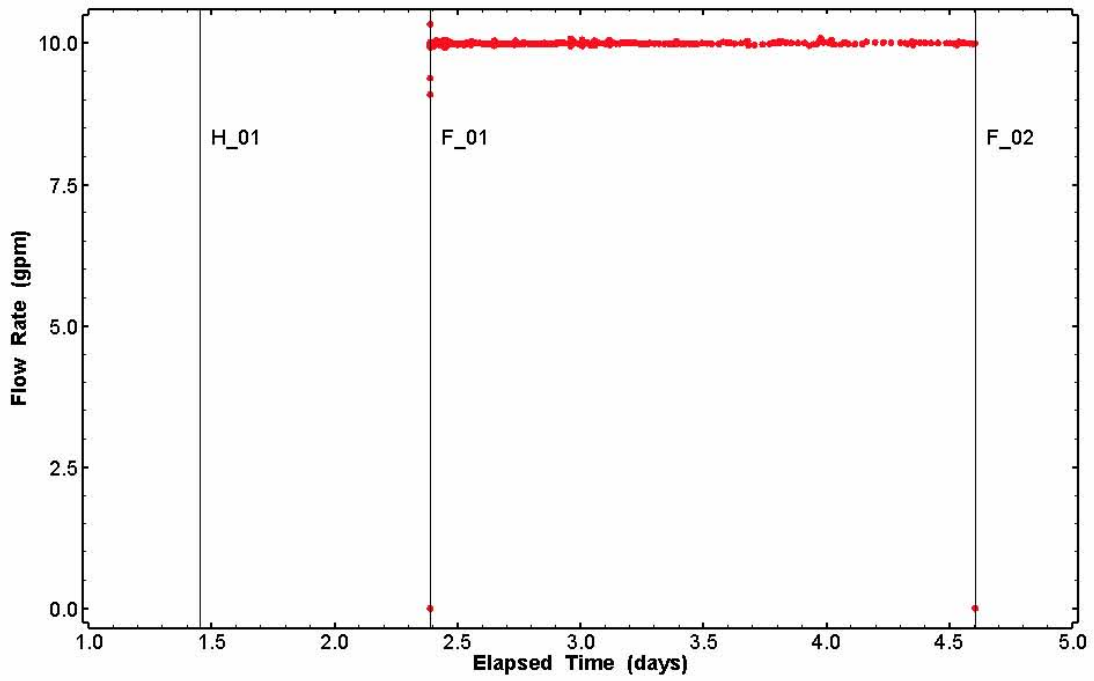
Figure B-14. Flow rates measured during the SNL-3 testing.

B.4   SNL-5 nSIGHTS Listings

```
nPre 2.30Q
*********

Version date     22 July 2005
Listing date     27 Apr 2006
QA status        QA:Q
Config file      C:\nSIGHTS\Culebra\SNL 5\SNL-5.nPre
```

Control Settings

Main Settings

```
Simulation type                          Forward
Simulation subtype                        Normal
Phase to simulate                         Liquid
Skin zone ?                                   no
External boundary                 Fixed Pressure
Curve data source                        Objects
```

Liquid Phase Settings

```
Aquifer type                            Confined
Aquifer horizontal permeability        Isotropic
System porosity                           Single
Compensate flow dimension geometry           yes
Leakage                                     None
```

Test Zone Settings

```
Test zone volume can vary                     no
Test zone compressibility can vary            no
Test zone temperature can vary                no
Default test-zone temperature        20.00      [C]
Solution variable                       Pressure
Allow negative head/pressure                 yes
```

Parameters

Formation

```
Formation thickness                  7.0104     [m]
Flow dimension                          2.0     []
Static formation pressure           155.335     [psi]
External boundary radius            1000000     [m]
Formation conductivity            f(r) point
Formation spec. storage          9.48085E-07    [1/m]
```

Fluid

```
Fluid density                       1011.00     [kg/m^3]
Fluid thermal exp. coeff.        0.00000E+00    [1/C]
```

Test-Zone

```
Well radius                                    2.165      [in]
Tubing string radius                       1.8175729      [in]
```

Numeric

```
# of radial nodes                                250      []
Pressure solution tolerance              1.45038E-11      [psi]
STP flow solution tolerance              1.58503E-11      [USgpm]
```

f(x) Points Parameters

Formation conductivity

```
Points type                                     f(r)
 Radius #1                                  50.369803      [m]
 Y value#1                                1.09028E-06      [m/sec]
 Radius #2                                  82.8396426     [m]
 Y value#2                                4.21197E-07      [m/sec]
 Radius #3                                1248.930036      [m]
 Y value#3                                3.24706E-06      [m/sec]

Parameter curve type                          Linear
```

Calculated Parameters

Formation

```
Transmissivity                                  f(r)
Storativity                              6.64645E-06      []
Diffusivity                                     f(r)
```

Test Zone

```
Open hole well-bore storage              6.75381E-07      [m^3/Pa]
```

Grid Properties

```
Grid increment delta                         0.06713      []
First grid increment                     3.81844E-03      [m]
```

Sequences

Sequence: H_01

```
  Sequence type                              History
  Start time                                   0.000      [min]
  Duration                                   145.114      [min]
  Time step type                              Static
  Static time step                             1.000      [min]
  Type                                         Curve
  Wellbore storage                              Open
```

70

Sequence: H_02

```
Sequence type                              History
Start time                                 145.114      [min]
Duration                                   206.947      [min]
Time step type                             Static
Static time step                           0.167        [min]
Type                                       Curve
Wellbore storage                           Open
```

Sequence: F_01

```
Sequence type                              Flow
Start time                                 352.061      [min]
Duration                                   983.687      [min]
Time step type                             Log
First log step                             1.66667E-04  [min]
# of time steps                            250
Type                                       Fixed
Fixed value                                0.0          [USgpm]
Wellbore storage                           Open
```

Sequence: F_02

```
Sequence type                              Flow
Start time                                 1335.748     [min]
Duration                                   5647.770     [min]
Time step type                             Log
First log step                             1.66667E-04  [min]
# of time steps                            250
Type                                       Fixed
Fixed value                                -3.5         [USgpm]
Wellbore storage                           Open
```

Sequence: F_03

```
Sequence type                              Flow
Start time                                 6983.518     [min]
Duration                                   36116.482    [min]
Time step type                             Log
First log step                             1.66667E-04  [min]
# of time steps                            250
Type                                       Fixed
Fixed value                                0.0          [USgpm]
Wellbore storage                           Open
```

Test Zone Curves

```
Curve object to use                        P Curve
Curve type                                 Pressure
Start sequence                             H_01
End sequence                               H_02
Curve time base                            Test
Curve Y data units                         [psi]
Curve Y data is log 10                     no
```

71

Simulation Results Setup

```
Output ID                                          DAT
  Output type                                  Pressure
  Pressure capture type                       Test Zone
  Output units                                    [psi]

Output ID                                          DAT
  Output type                                 Flow Rate
  Flow rate output type                            Well
  Output units                                  [USgpm]

Output ID                                        P_S_01
  Output type                                  Pressure
  Pressure capture type                   Superposition
   P_S_01[1] operation                      + Pressure
    Type                                      Constant
     Fixed radius                          0.001      [m]
  Output units                                    [psi]
```

SNL-5 Optimization Settings

```
**********
nPre 2.30Q
**********


Version date    22 July 2005
Listing date    27 Apr 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL 5\SNL-5.nPre
```

Parameters

Formation

```
Formation thickness                    7.0104      [m]
Flow dimension                            2.0      []
Static formation pressure         Optimization
   Minimum value                     140.000      [psi]
   Maximum value                     175.000      [psi]
   Estimate value                    155.335      [psi]
   Range type                          Linear
   Sigma                          1.00000E+00
External boundary radius             1000000      [m]
Formation conductivity              f(r) point
Formation spec. storage           Optimization
   Minimum value                 1.00000E-08      [1/m]
   Maximum value                 1.00000E-04      [1/m]
   Estimate value                9.48085E-07      [1/m]
   Range type                             Log
   Sigma                          1.00000E+00
```

Fluid

```
Fluid density                            1011.00      [kg/m^3]
Fluid thermal exp. coeff.            0.00000E+00      [1/C]
```

Test-Zone

```
Well radius                                2.165      [in]
Tubing string radius                  Optimization
   Minimum value                           1.2        [in]
   Maximum value                           2.166      [in]
   Estimate value                      1.8175729      [in]
   Range type                             Linear
   Sigma                             1.00000E+00
```

Numeric

```
# of radial nodes                           250       []
Pressure solution tolerance          1.45038E-11      [psi]
STP flow solution tolerance          1.58503E-11      [USgpm]
```

SNL-5 Fitting Parameter Estimates
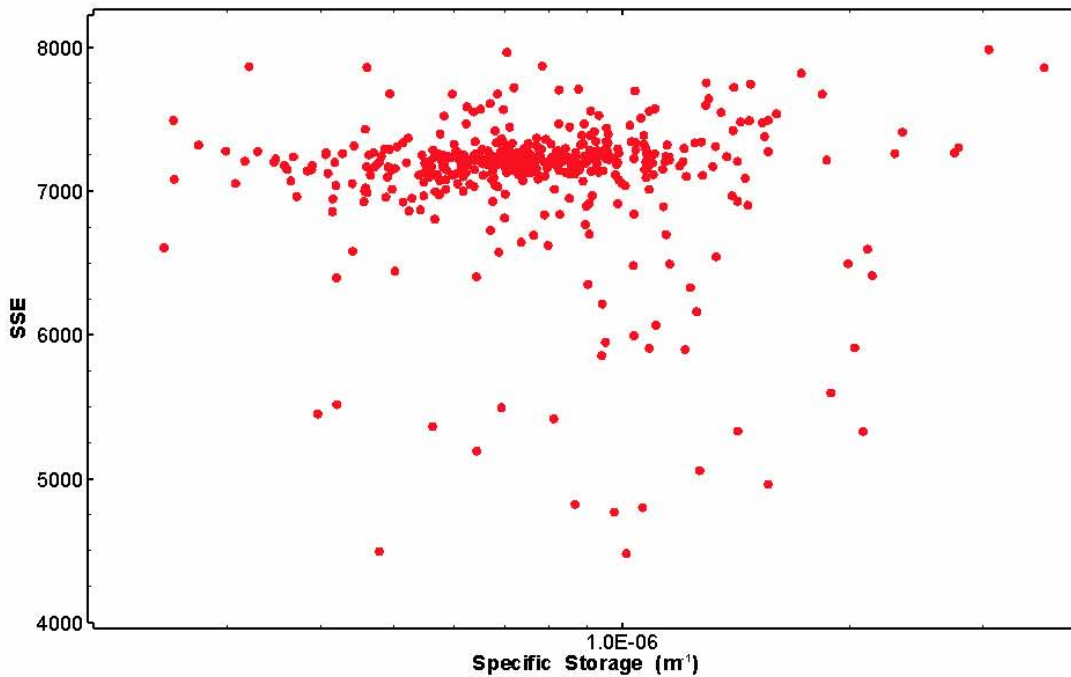
Figure B-15. Estimates of specific storage derived from the SNL-5 perturbation analysis.

73
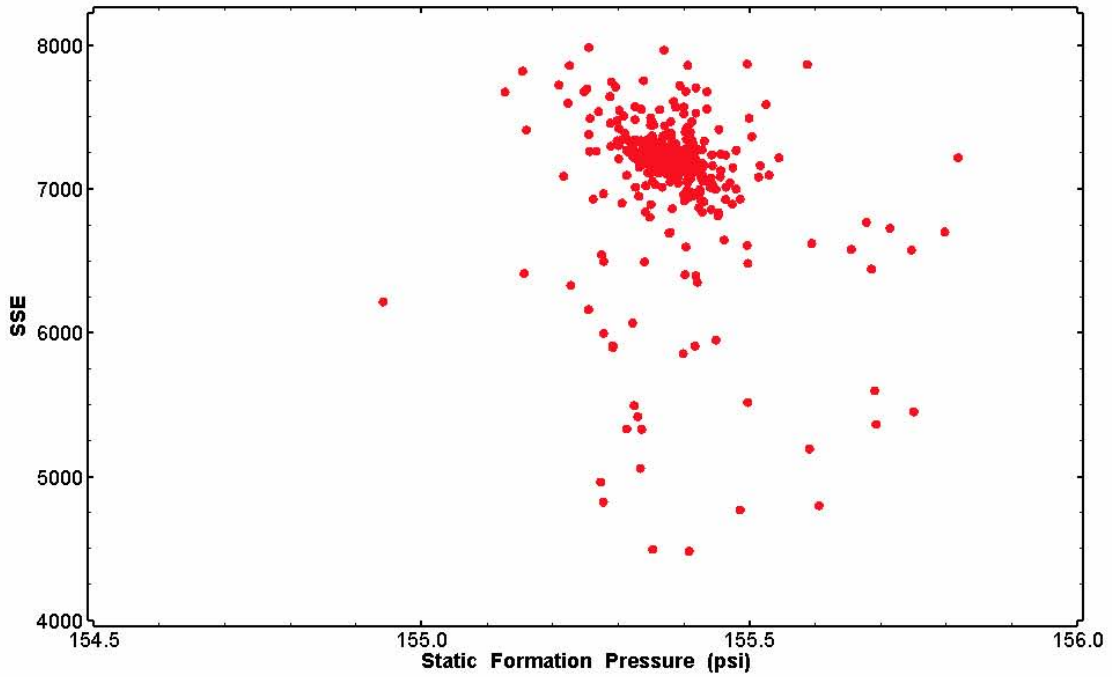
Figure B-16. Estimates of static formation pressure derived from the SNL-5 perturbation analysis.
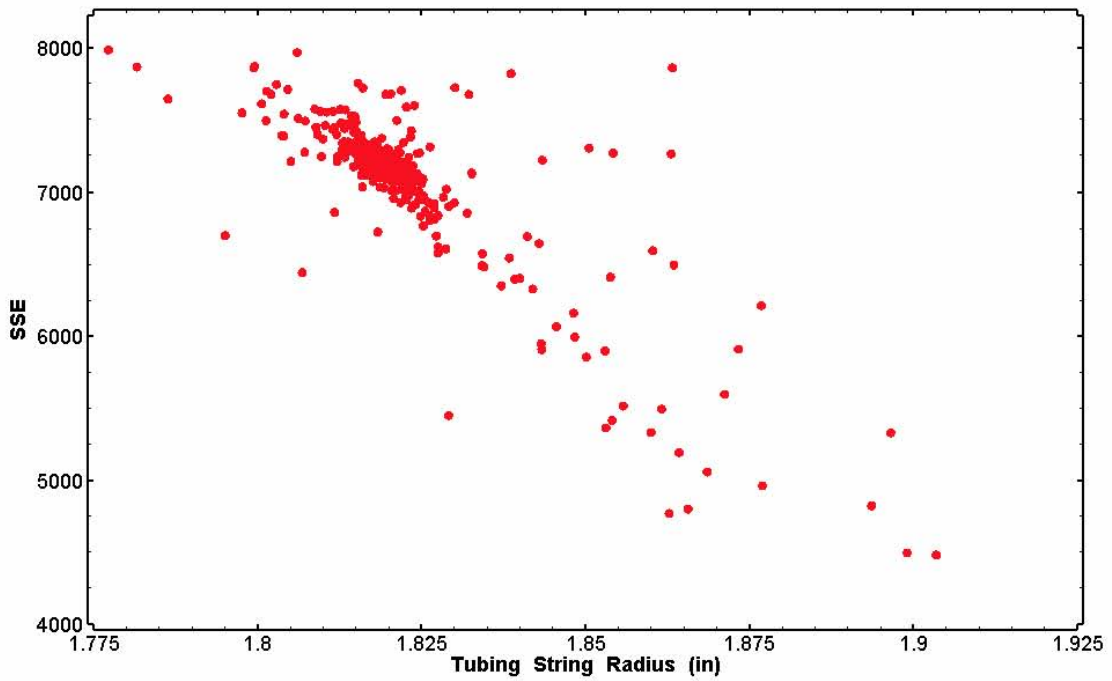
Figure B-17. Estimates of tubing string radius derived from the SNL-5 perturbation analysis.
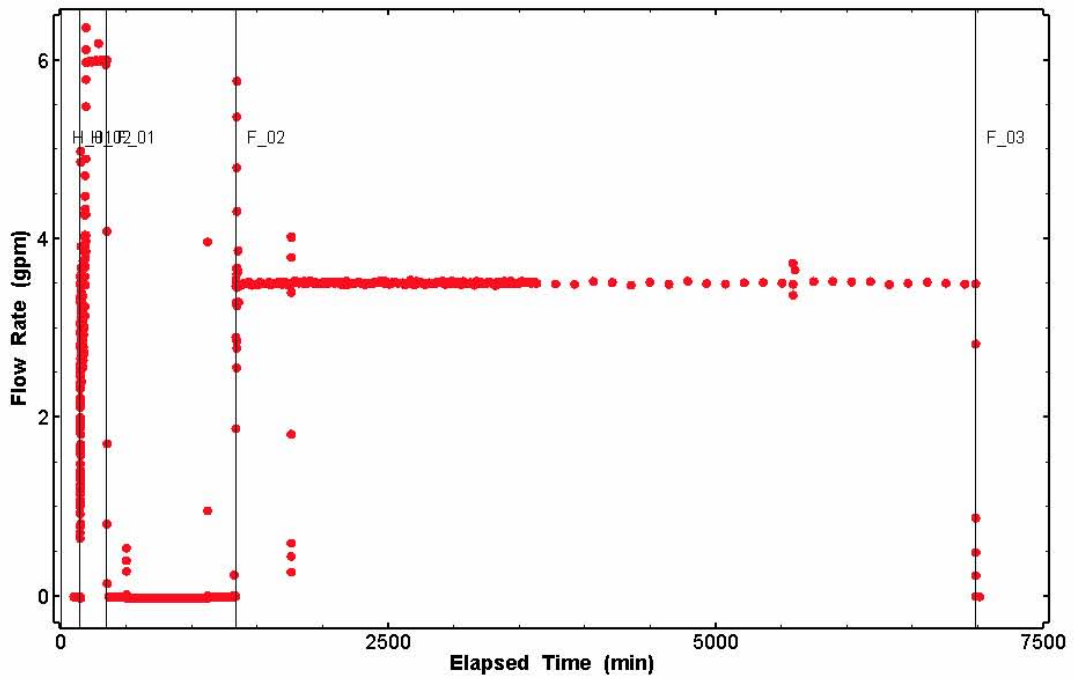
Figure B-18. Flow rates measured during the SNL-5 testing.

B.5 SNL-9 nSIGHTS Listings

```
**********
nPre 2.30Q
**********
```

```
Version date    22 July 2005
Listing date    28 Apr 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL 9\SNL-9.nPre
```

Control Settings

Main Settings

```
Simulation type                             Forward
Simulation subtype                          Normal
Phase to simulate                            Liquid
Skin zone ?                                      yes
External boundary                     Fixed Pressure
Curve data source                            Objects
```

Liquid Phase Settings

```
Aquifer type                                Confined
Aquifer horizontal permeability            Isotropic
System porosity                                 Dual
Matrix block type                          Prismatic
Compensate flow dimension geometry               yes
Leakage                                         None
```

Test Zone Settings

```
Test zone volume can vary                         no
Test zone compressibility can vary                no
Test zone temperature can vary                    no
Default test-zone temperature         20.00      [C]
Solution variable                           Pressure
Allow negative head/pressure                     yes
```

Parameters

Formation

```
Formation thickness                   23.000     [ft]
Flow dimension                           2.0     []
Static formation pressure            120.303     [psi]
External boundary radius             1000000     [m]
```

Fracture

```
Fracture conductivity            5.39328E-04     [m/sec]
Fracture spec. storage           2.61158E-08     [1/m]
```

Matrix

```
Matrix volume factor                    0.990000     [decimal]
Geometry factor (Alpha)                     1200     [1/m^2]
Matrix conductivity                  1.01579E-12     [m/sec]
Matrix spec. storage                 3.59532E-04     [1/m]
```

Skin

```
Radial thickness of skin               0.0904817     [m]
Skin zone conductivity               4.44686E-05     [m/sec]
Skin zone spec. storage              6.94574E-07     [1/m]
```

Fluid

```
Fluid density                            1022.00     [kg/m^3]
Fluid thermal exp. coeff.            0.00000E+00     [1/C]
```

Test-Zone

```
Well radius                                 4.21     [in]
Tubing string radius                         4.0     [in]
```

Numeric

```
# of radial nodes                            250     []
# of skin nodes                               50     []
# of matrix nodes                              1     []
```

Calculated Parameters

Dual Porosity

```
Fracture thickness                      0.070104     [m]
Matrix thickness                        6.940296     [m]
Lambda - interporosity flow          2.58442E-06     []
Omega - storativity ratio            7.33720E-07     []
Beta - transient parameter           3.52236E+00     []
```

Skin Zone

```
Transmissivity                       3.11743E-04     [m^2/sec]
Storativity                          4.86924E-06     []
Diffusivity                          6.40228E+01     [m^2/sec]
Skin factor                          6.82275E+00     []
```

Test Zone

```
Open hole well-bore storage          3.23900E-06     [m^3/Pa]
```

Grid Properties

```
Grid increment delta                     0.07758     []
First grid increment                 1.59248E-02     [m]
Skin grid increment delta                0.01251     []
Skin first grid increment            1.34639E-03     [m]
Skin last grid increment             2.45472E-03     [m]
```

```
Increment ratio                              6.48740E+00      []
Number of nodes                                       249      []
```

Sequences

Sequence: H_01

```
Sequence type                                   History
Start time                                    17000.000      [min]
Duration                                       1876.000      [min]
Time step type                                   Static
Static time step                                100.000      [min]
Type                                              Curve
Wellbore storage                                   None
```

Sequence: F_01

```
Sequence type                                      Flow
Start time                                    18876.000      [min]
Duration                                       5438.598      [min]
Time step type                                   Static
Static time step                                  1.000      [min]
Type                                              Fixed
Fixed value                                       -12.5      [USgpm]
Wellbore storage                                   Open
```

Sequence: F_02

```
Sequence type                                      Flow
Start time                                    24314.598      [min]
Duration                                     147090.402      [min]
Time step type                                      Log
First log step                               1.66667E-04      [min]
# of time steps                                     250
Type                                              Fixed
Fixed value                                         0.0      [USgpm]
Wellbore storage                                   Open
```

Test Zone Curves

```
Curve object to use                        Pressure Curve
Curve type                                       Pressure
Start sequence                                       H_01
End sequence                                         H_01
Curve time base                                      Test
Curve Y data units                                  [psi]
Curve Y data is log 10                                 no
```

Simulation Results Setup

```
Output ID                                             DAT
  Output type                                     Pressure
  Pressure capture type                          Test Zone
  Output units                                       [psi]
```

```
Output ID                                          DAT
  Output type                                 Flow Rate
  Flow rate output type                            Well
  Output units                                 [USgpm]
```

SNL-9 Optimization Settings

```
**********
nPre 2.30Q
**********

Version date    22 July 2005
Listing date    28 Apr 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL 9\SNL-9.nPre
```

Parameters

Formation

```
Formation thickness                    23.000      [ft]
Flow dimension                             2.0      []
Static formation pressure              120.303     [psi]
External boundary radius               1000000     [m]
```

Fracture

```
Fracture conductivity              5.39328E-04     [m/sec]
Fracture spec. storage             2.61158E-08     [1/m]
```

Matrix

```
Matrix volume factor               0.990000     [decimal]
Geometry factor (Alpha)                1200      [1/m^2]
Matrix conductivity                1.01579E-12   [m/sec]
Matrix spec. storage               3.59532E-04   [1/m]
```

Skin

```
Radial thickness of skin           0.0904817     [m]
Skin zone conductivity             4.44686E-05   [m/sec]
Skin zone spec. storage            6.94574E-07   [1/m]
```

Fluid

```
Fluid density                         1021.00    [kg/m^3]
Fluid thermal exp. coeff.          0.00000E+00   [1/C]
```

Test-Zone

```
Well radius                            4.21      [in]
Tubing string radius                   4.0       [in]
```

Numeric

```
# of radial nodes                                     250      []
# of skin nodes                                        50      []
# of matrix nodes                                       1      []
```

SNL-9 Fitting Parameter Estimates

Figure B-19. Estimates of lambda and omega derived from the SNL-9 perturbation analysis.

Figure B-20. Estimates of fracture and matrix specific storage derived from the SNL-9 perturbation analysis.

Figure B-21. Estimates of fracture transmissivity and matrix hydraulic conductivity derived from the SNL-9 perturbation analysis.

Figure B-22. Estimates of static formation pressure derived from the SNL-9 perturbation analysis.
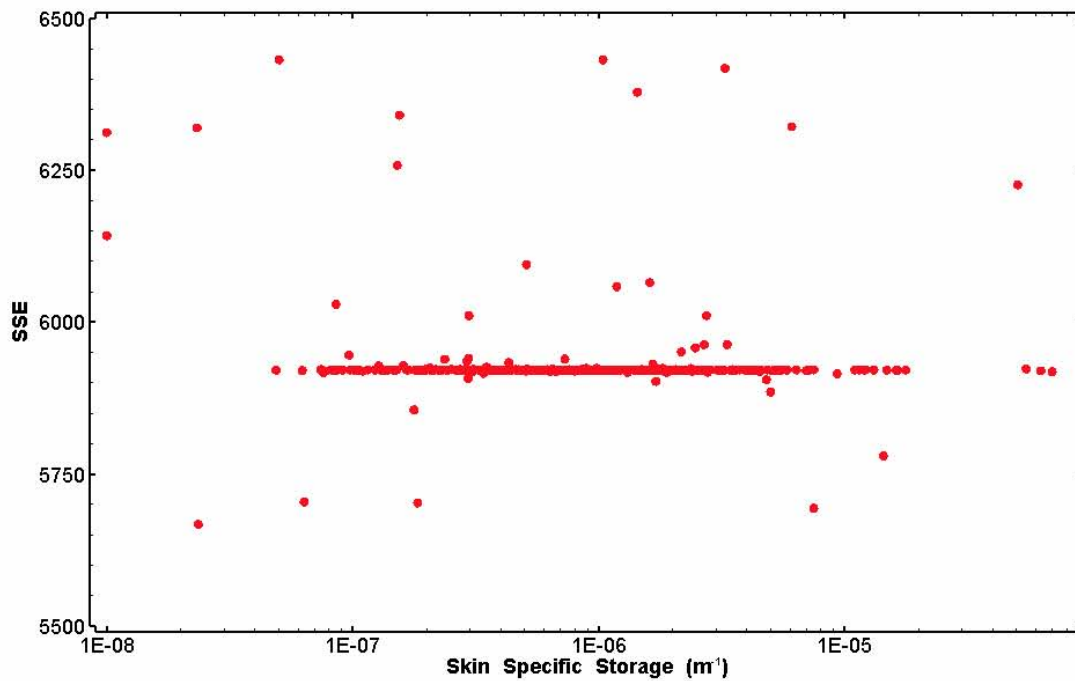
Figure B-23. Estimates of skin specific storage derived from the SNL-9 perturbation analysis.
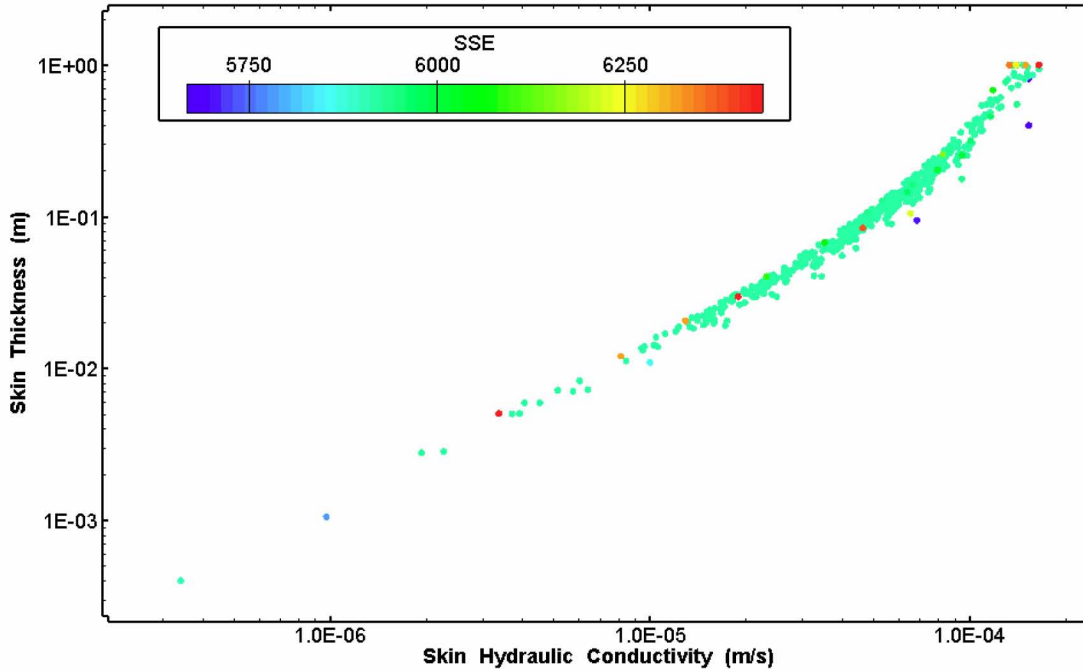
Figure B-24. Estimates of skin hydraulic conductivity and radius derived from the SNL-9 perturbation analysis.
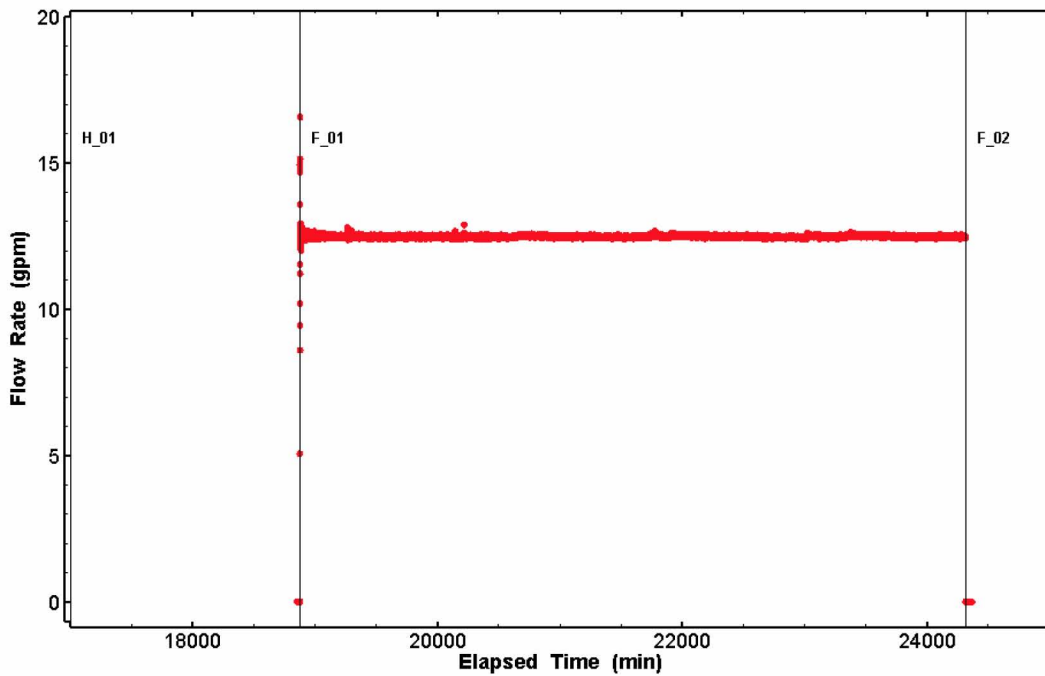
Figure B-25. Flow rates measured during the SNL-9 testing.

B.6   SNL-12 nSIGHTS Listings

```
**********
nPre 2.30Q
**********
```

```
Version date    22 July 2005
Listing date    22 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL 12\SNL-12.nPre
```

Control Settings

Main Settings

```
Simulation type                             Forward
Simulation subtype                          Normal
Phase to simulate                           Liquid
Skin zone ?                                     yes
External boundary                   Fixed Pressure
Curve data source                           Objects
```

Liquid Phase Settings

```
Aquifer type                               Confined
Aquifer horizontal permeability           Isotropic
System porosity                                Dual
Matrix block type                         Prismatic
Compensate flow dimension geometry              yes
Leakage                                        None
```

Test Zone Settings

```
Test zone volume can vary                        no
Test zone compressibility can vary               no
Test zone temperature can vary                   no
Default test-zone temperature         20.00      [C]
Solution variable                          Pressure
Allow negative head/pressure                    yes
```

Parameters

Formation

```
Formation thickness                   40.000     [ft]
Flow dimension                     f(r) point
Static formation pressure            112.680     [psi]
External boundary radius            1000000      [m]
```

Fracture

```
Fracture conductivity            4.15134E-03     [m/sec]
Fracture spec. storage           2.28474E-10     [1/m]
```

84

Matrix

```
Matrix volume factor                           0.990000    [decimal]
Geometry factor (Alpha)                            1200    [1/m^2]
Matrix conductivity                        5.66514E-12     [m/sec]
Matrix spec. storage                       1.24864E-04     [1/m]
```

Skin

```
Radial thickness of skin                      0.0005369    [m]
Skin zone conductivity                       f(t) point
Skin zone spec. storage                    1.91614E-07     [1/m]
```

Fluid

```
Fluid density                                  1004.40     [kg/m^3]
Fluid thermal exp. coeff.                  0.00000E+00     [1/C]
```

Test-Zone

```
Well radius                                      2.165     [in]
Tubing string radius                               2.0     [in]
```

Numeric

```
# of radial nodes                                  250     []
# of skin nodes                                     50     []
# of matrix nodes                                    6     []
```

f(x) Points Parameters

Flow dimension

```
Points type                                       f(r)
 Radius #1                                      0.3592     [m]
 Y value#1                                         2.0     []
 Radius #2                                 135.1541817     [m]
 Y value#2                                  -0.0525097     []

Parameter curve type                         Step Full
```

Skin zone conductivity

```
Points type                                       f(t)
 Time #1                                      9060.179     [min]
 Y value#1                                  2.03363E-06     [m/sec]
 Time #2                                     16558.731     [min]
 Y value#2                                  6.32041E-07     [m/sec]
 Time #3                                     25671.391     [min]
 Y value#3                                  9.71358E-07     [m/sec]
 Time #4                                     74202.915     [min]
 Y value#4                                  9.22399E-07     [m/sec]
 Time #5                                     90410.819     [min]
 Y value#5                                  7.20814E-07     [m/sec]
 Time #6                                    219981.144     [min]
 Y value#6                                  7.27608E-07     [m/sec]
```

```
Time #7                                  420613.154      [min]
Y value#7                                7.51564E-07     [m/sec]
Time #8                                  425649.101      [min]
Y value#8                                6.52393E-07     [m/sec]
Time #9                                  426283.773      [min]
Y value#9                                3.34698E-06     [m/sec]


Parameter curve type                         Linear
```

Calculated Parameters

Dual Porosity

```
Fracture thickness                          0.12192      [m]
Matrix thickness                           12.07008      [m]
Lambda - interporosity flow             4.95207E-07      []
Omega - storativity ratio               1.84827E-08      []
Beta - transient parameter              2.67930E+01      []
```

Skin Zone

```
Transmissivity                                 f(t)
Storativity                             2.33616E-06      []
Diffusivity                                    f(t)
Skin factor                                    f(t)
```

Test Zone

```
Open hole well-bore storage             3.56965E-02      [STB/psi]
```

Grid Properties

```
Grid increment delta                        0.08395      []
First grid increment                    4.86293E-03      [m]
Skin grid increment delta                   0.00020      []
Skin first grid increment               1.09048E-05      [m]
Skin last grid increment                1.10091E-05      [m]
Increment ratio                         4.41718E+02      []
Number of nodes                                1244      []
```

Sequences

Sequence: H_01

```
  Sequence type                             History
  Start time                           -171261.852      [min]
  Duration                              171436.852      [min]
  Time step type                             Static
  Static time step                          200.000      [min]
  Type                                        Curve
  Wellbore storage                             None
```

Sequence: H_02

```
  Sequence type                             History
```

```
Start time                              175.000     [min]
Duration                                 11.050     [min]
Time step type                           Static
Static time step                          0.100     [min]
Type                                      Curve
Wellbore storage                          None
```

Sequence: F_01

```
Sequence type                            Flow
Start time                              186.050     [min]
Duration                                162.350     [min]
Time step type                           Static
Static time step                          0.167     [min]
Type                                      Curve
Wellbore storage                          Open
```

Sequence: F_02

```
Sequence type                            Flow
Start time                              348.400     [min]
Duration                               1004.400     [min]
Time step type                           Log
First log step                      1.66667E-04     [min]
# of time steps                           250
Type                                      Fixed
Fixed value                               0.0       [USgpm]
Wellbore storage                          Open
```

Sequence: F_03

```
Sequence type                            Flow
Start time                             1352.800     [min]
Duration                               5742.050     [min]
Time step type                           Log
First log step                      1.66667E-04     [min]
# of time steps                           250
Type                                      Curve
Wellbore storage                          Open
```

Sequence: F_04

```
Sequence type                            Flow
Start time                             7094.850     [min]
Duration                              44709.150     [min]
Time step type                           Log
First log step                      1.66667E-04     [min]
# of time steps                           250
Type                                      Fixed
Fixed value                               0.0       [USgpm]
Wellbore storage                          Open
```

Test Zone Curves

```
Curve object to use                  Create Curve
Curve type                           Flow Rate
Start sequence                            F_01
End sequence                              F_04
```

```
Curve time base                                 Test
Curve Y data units                              [USgpm]
Curve Y data is log 10                          no


Curve object to use                             P Curve
Curve type                                      Pressure
Start sequence                                  H_01
End sequence                                    H_02
Curve time base                                 Test
Curve Y data units                              [psi]
Curve Y data is log 10                          no
```

Simulation Results Setup

```
Output ID                                       DAT
  Output type                                   Pressure
  Pressure capture type                         Test Zone
  Output units                                  [psi]


Output ID                                       DAT
  Output type                                   Flow Rate
  Flow rate output type                         Well
  Output units                                  [USgpm]


Output ID                                       BOUND
  Output type                                   Pressure
  Pressure capture type                         Superposition
   BOUND[1] operation                           + Pressure
    Type                                        Constant
    Fixed radius                                0.0001    [m]
  Output units                                  [psi]
```

SNL-12 nSIGHTS Optimization Settings

```
**********
nPre 2.30Q
**********


Version date    22 July 2005
Listing date    22 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL 12\SNL-12 - dbl poro - sans
Bourdet.nPre
```

Parameters

Formation

```
Formation thickness                             40.000    [ft]
Flow dimension                          f(r) point
Static formation pressure               Optimization
   Minimum value                                103.000   [psi]
```

```
    Maximum value                                   115.000      [psi]
    Estimate value                                  112.680      [psi]
    Range type                                       Linear
    Sigma                                        1.00000E+00
External boundary radius                            1000000      [m]
```

Fracture

```
Fracture conductivity                          Optimization
    Minimum value                               1.00000E-06      [m/sec]
    Maximum value                               1.00000E-01      [m/sec]
    Estimate value                              4.15134E-03      [m/sec]
    Range type                                          Log
    Sigma                                       1.00000E+00
Fracture spec. storage                         Optimization
    Minimum value                               1.00000E-11      [1/m]
    Maximum value                               1.00000E-05      [1/m]
    Estimate value                              2.28474E-10      [1/m]
    Range type                                          Log
    Sigma                                       1.00000E+00
```

Matrix

```
Matrix volume factor                           0.990000      [decimal]
Geometry factor (Alpha)                            1200      [1/m^2]
Matrix conductivity                        Optimization
    Minimum value                           1.00000E-14      [m/sec]
    Maximum value                           1.00000E-07      [m/sec]
    Estimate value                          5.66514E-12      [m/sec]
    Range type                                      Log
    Sigma                                   1.00000E+00
Matrix spec. storage                       Optimization
    Minimum value                           1.00000E-07      [1/m]
    Maximum value                           1.00000E-02      [1/m]
    Estimate value                          1.24864E-04      [1/m]
    Range type                                      Log
    Sigma                                   1.00000E+00
```

Skin

```
Radial thickness of skin                   Optimization
    Minimum value                               1.0E-05      [m]
    Maximum value                                  10.0      [m]
    Estimate value                             0.0005369      [m]
    Range type                                      Log
    Sigma                                   1.00000E+00
Skin zone conductivity                       f(t) point
Skin zone spec. storage                    Optimization
    Minimum value                           1.00000E-07      [1/m]
    Maximum value                           1.00000E-02      [1/m]
    Estimate value                          1.91614E-07      [1/m]
    Range type                                      Log
    Sigma                                   1.00000E+00
```

Fluid

```
Fluid density                                  1004.40      [kg/m^3]
```

```
Fluid thermal exp. coeff.                      0.00000E+00    [1/C]
```

Test-Zone

```
Well radius                                          2.165    [in]
Tubing string radius                                   2.0    [in]
```

Numeric

```
# of radial nodes                                      250    []
# of skin nodes                                         50    []
# of matrix nodes                                        6    []
```

SNL-12 Fitting Parameter Estimates
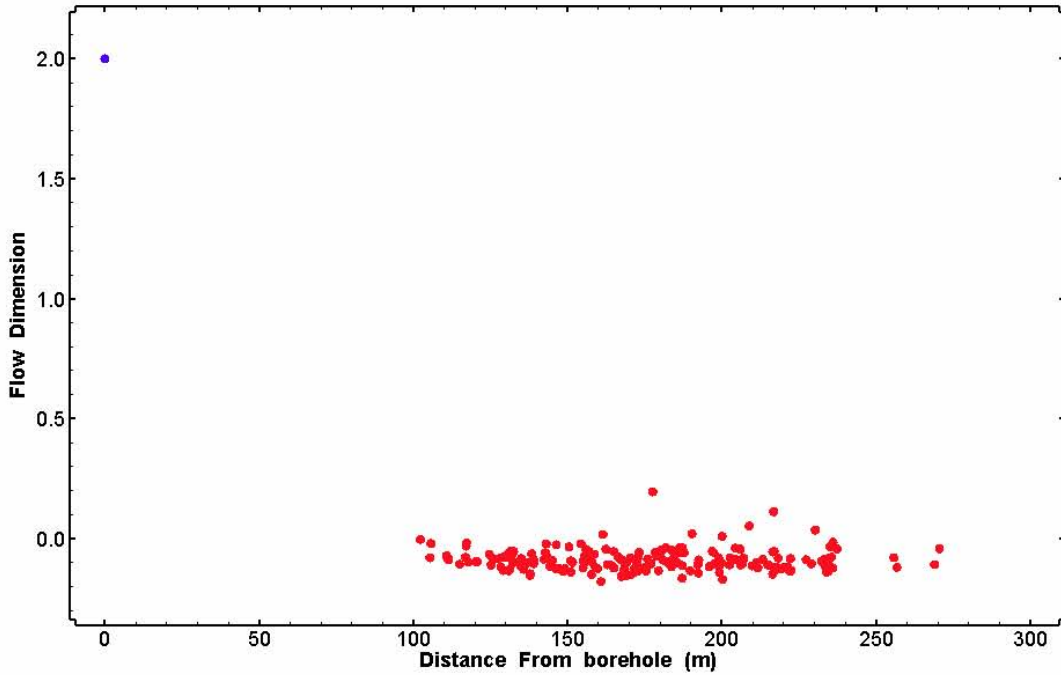
Figure B-26. Estimates of radially varying flow dimension derived from the SNL-12 perturbation analysis.
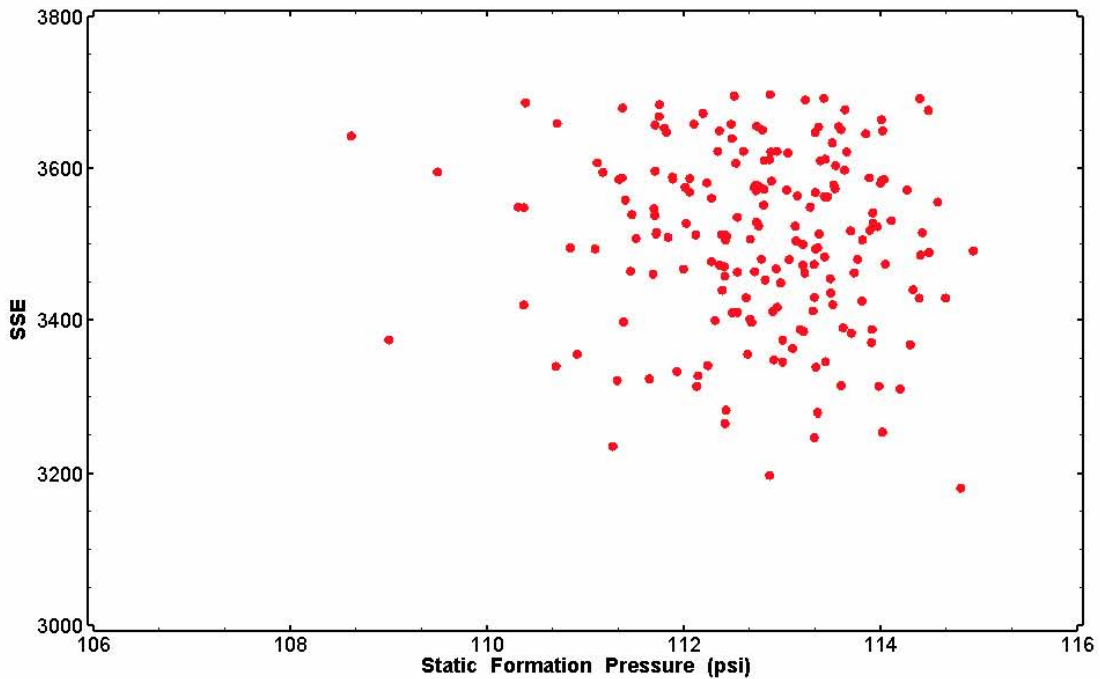
Figure B-27. Estimates of static formation pressure derived from the SNL-12 perturbation analysis.

Figure B-28. Estimates of time-varying skin hydraulic conductivity derived from the SNL-12 perturbation analysis.
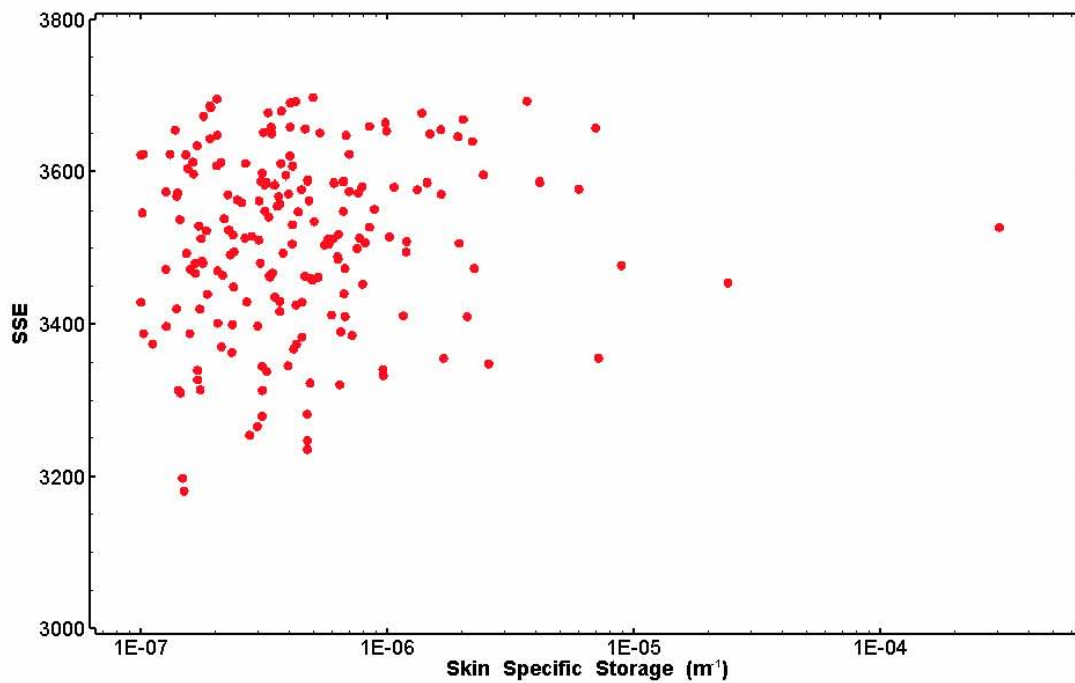
Figure B-29. Estimates of skin specific storage derived from the SNL-12 perturbation analysis.
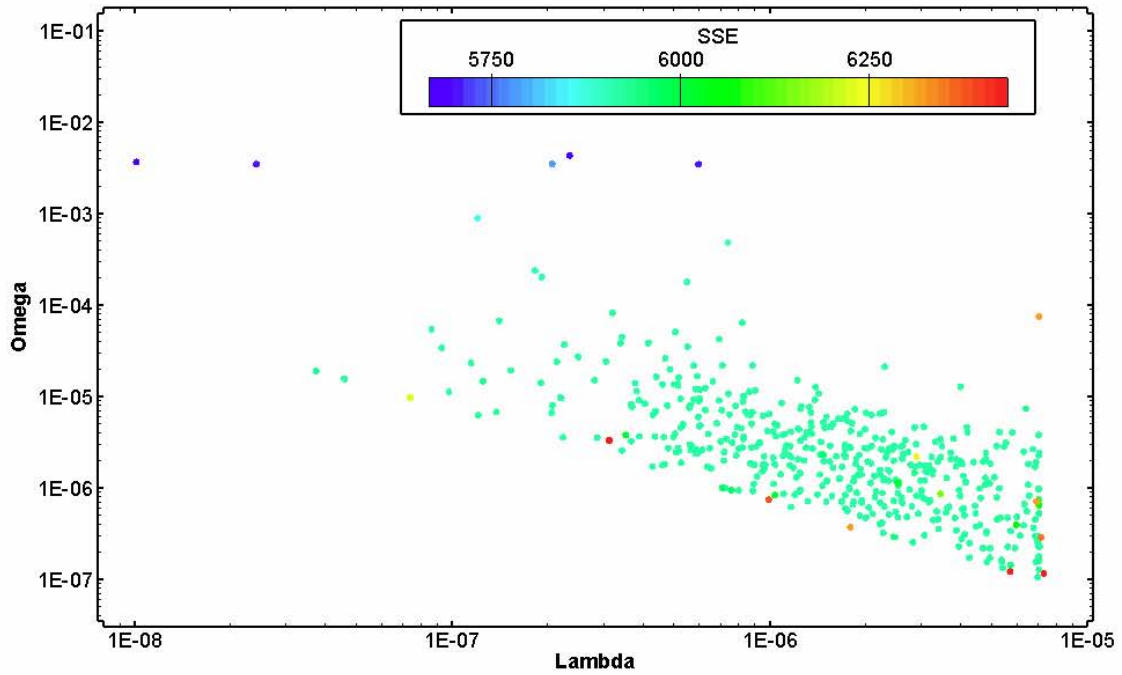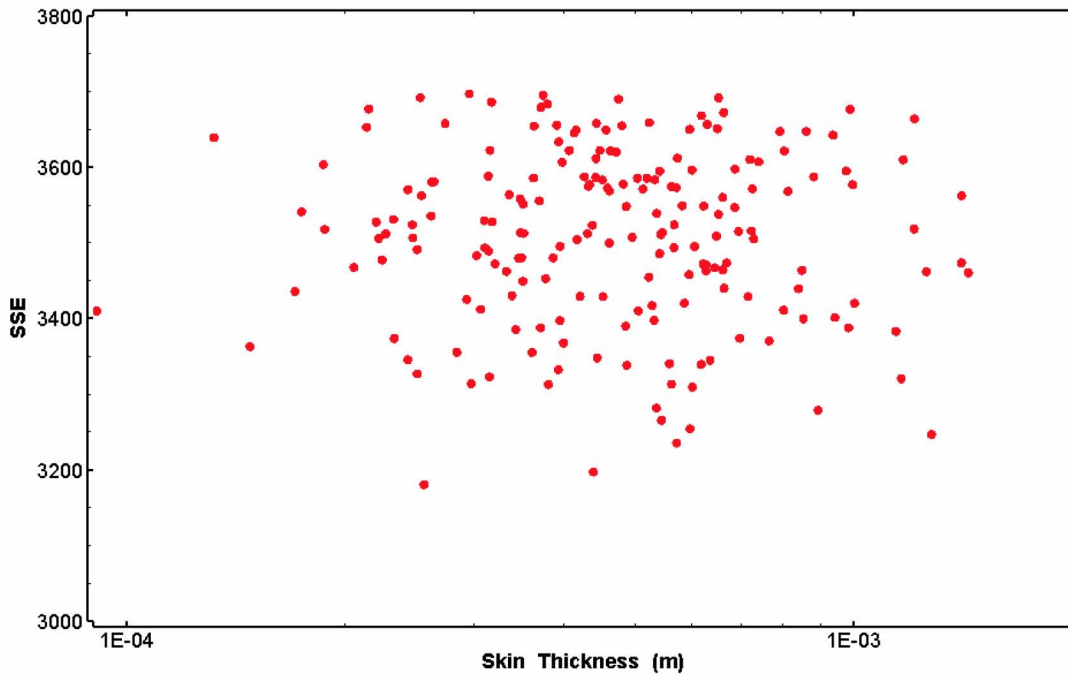
Figure B-30. Estimates of skin radius derived from the SNL-12 perturbation analysis.
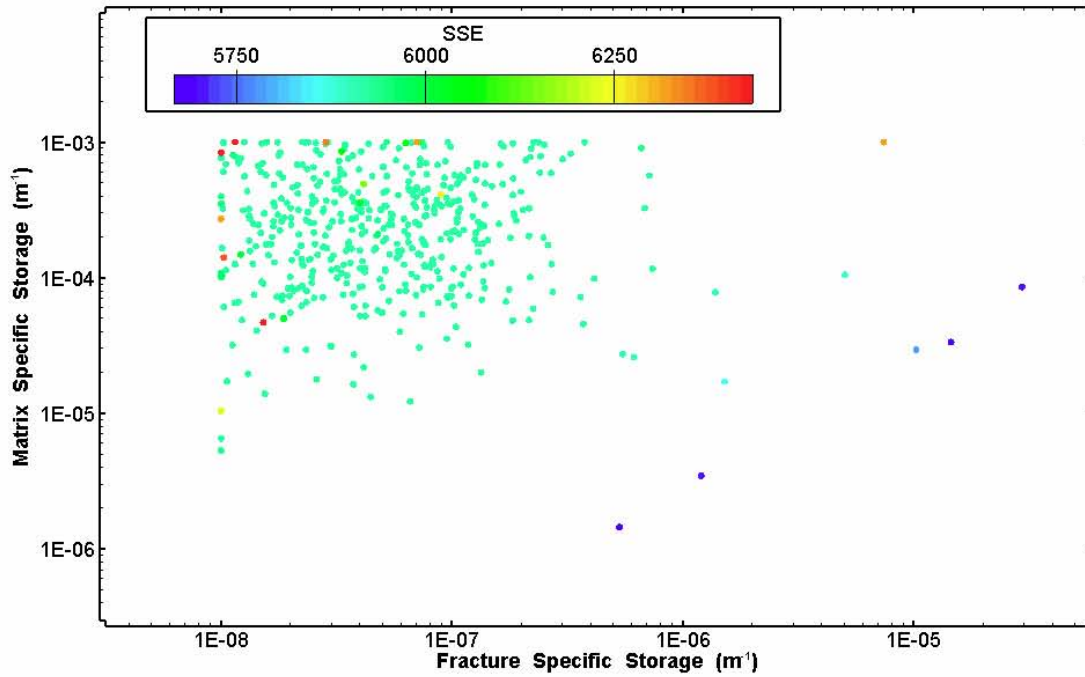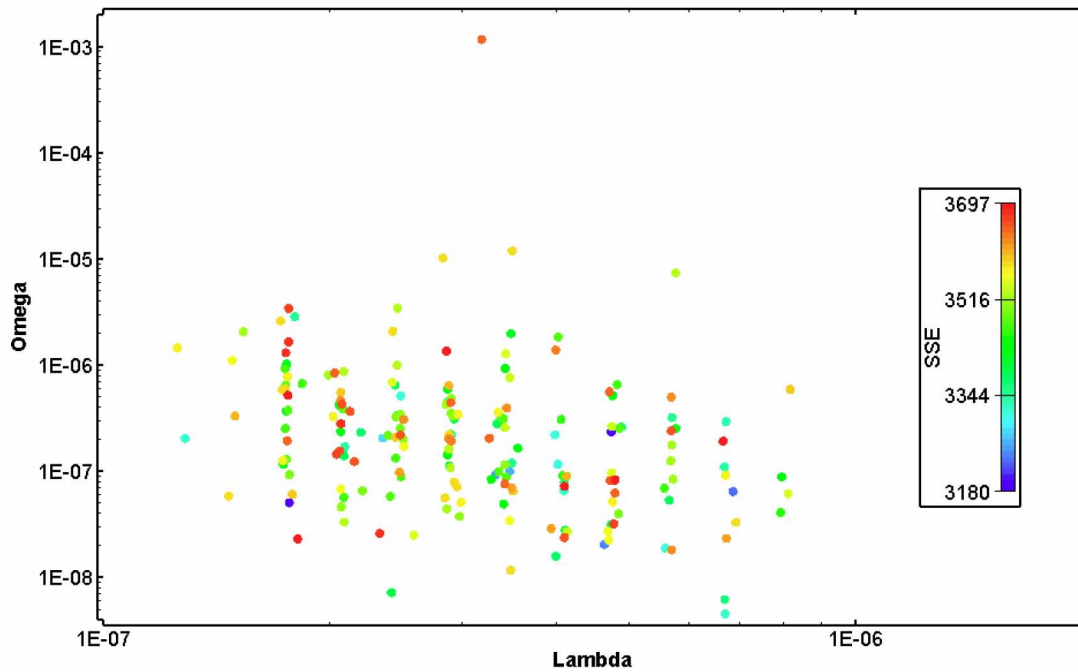

Figure B-31. Estimates of fracture and matrix specific storage derived from the SNL-12 perturbation analysis.
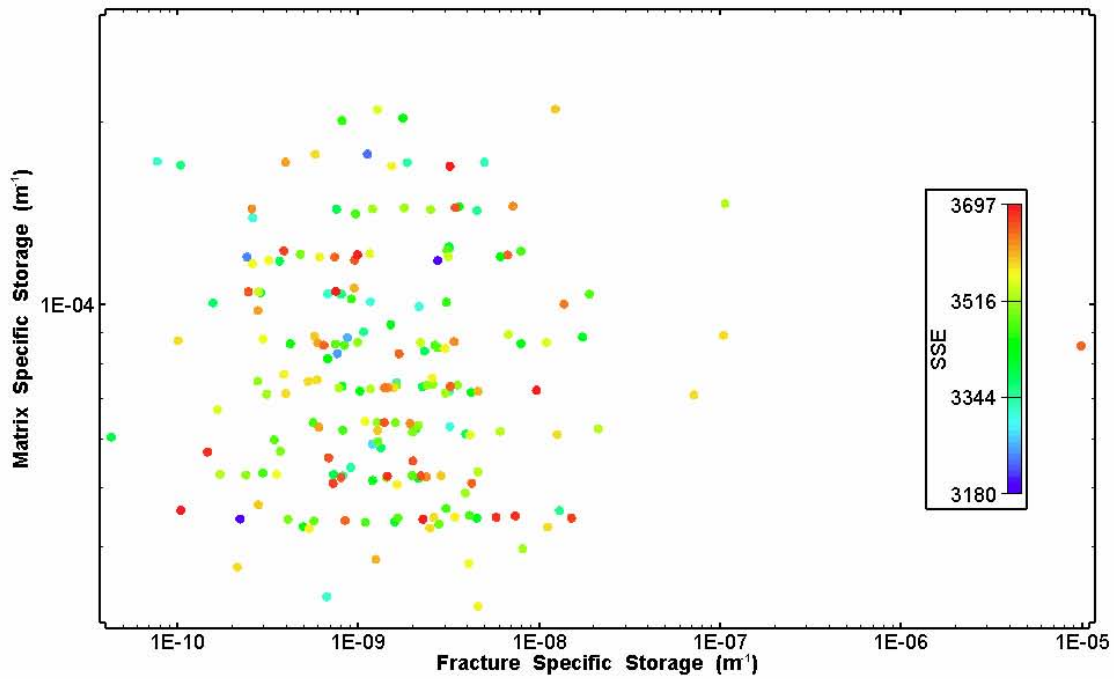
Figure B-32. Estimates of fracture and matrix specific storage derived from the SNL-12 perturbation analysis.
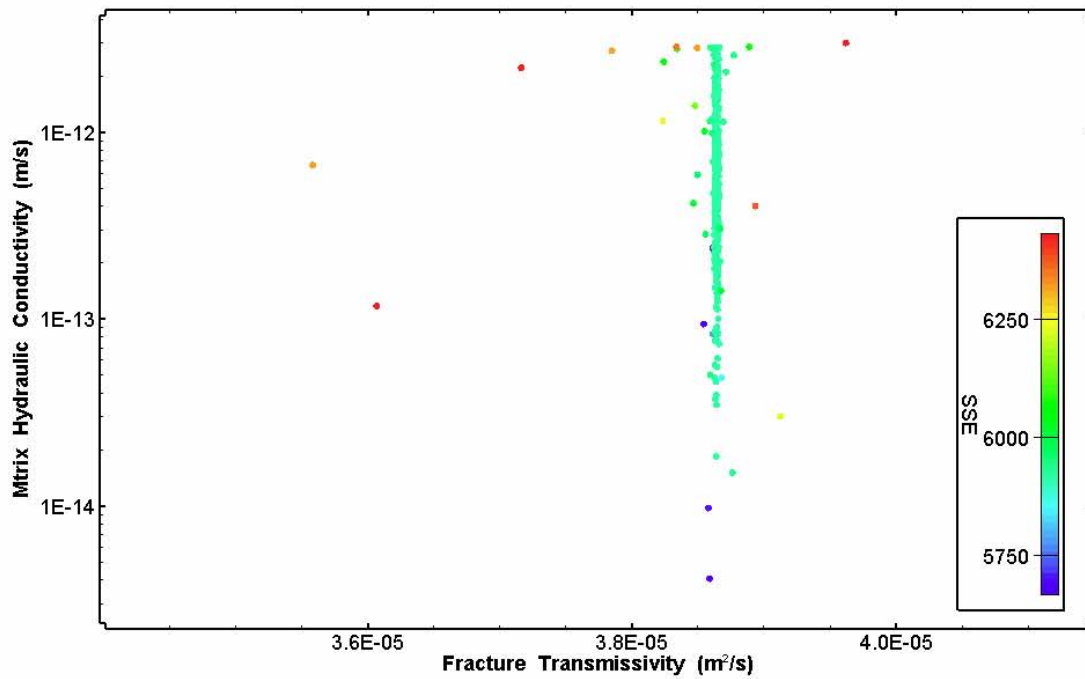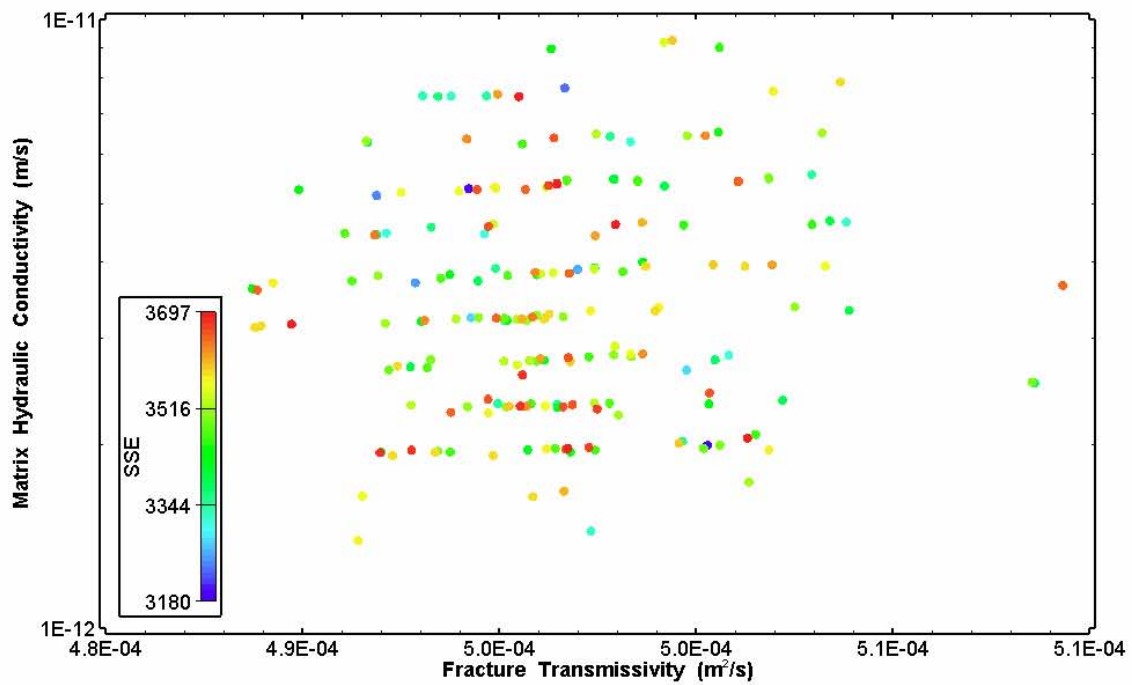

Figure B-33. Estimates of fracture transmissivity and matrix hydraulic conductivity derived from the SNL-12 perturbation analysis.
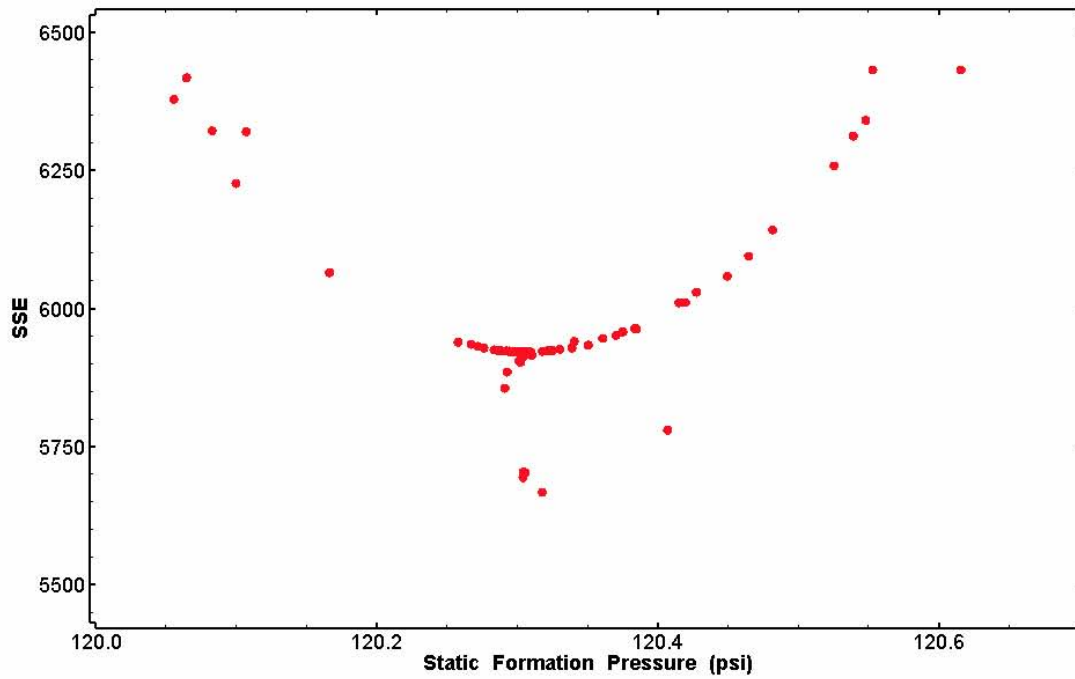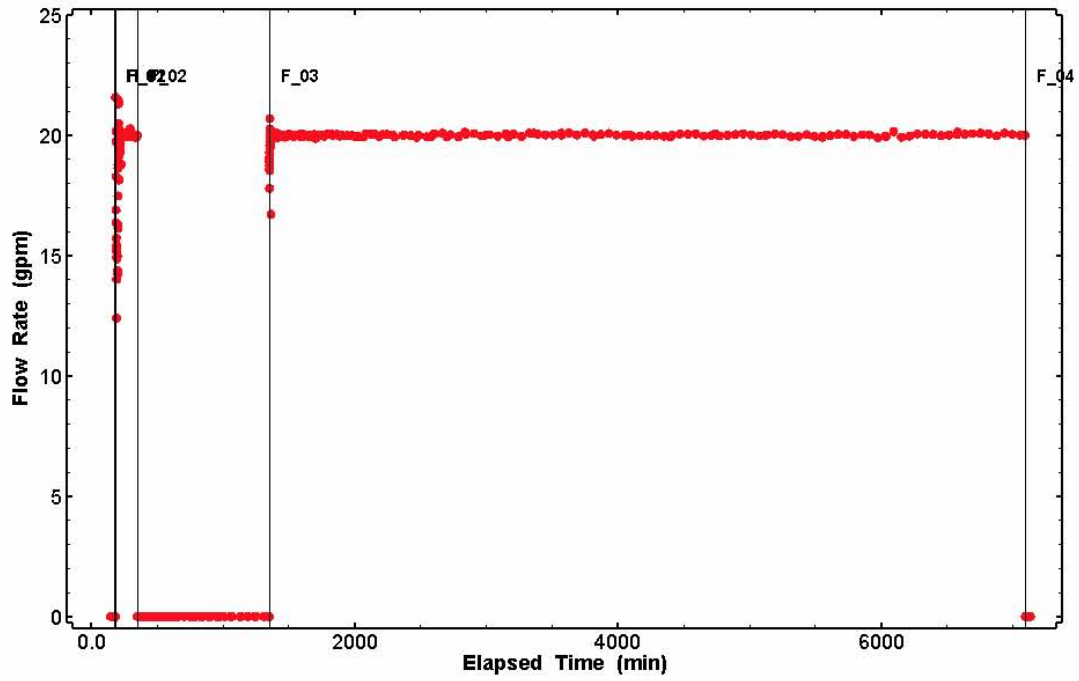
Figure B-34. Flow rates measured during the SNL-12 testing.

B.7   SNL-14 nSIGHTS Listings

```
**********
nPre 2.30Q
**********


Version date    22 July 2005
Listing date    23 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\SNL 14\SNL-14.nPre
```

Control Settings

Main Settings

```
Simulation type                             Forward
Simulation subtype                           Normal
Phase to simulate                            Liquid
Skin zone ?                                     yes
External boundary                    Fixed Pressure
Curve data source                           Objects
```

Liquid Phase Settings

```
Aquifer type                               Confined
Aquifer horizontal permeability           Isotropic
System porosity                                Dual
Matrix block type                         Prismatic
Compensate flow dimension geometry              yes
Leakage                                        None
```

Test Zone Settings

```
Test zone volume can vary                        no
Test zone compressibility can vary               no
Test zone temperature can vary                   no
Default test-zone temperature              20.00      [C]
Solution variable                          Pressure
Allow negative head/pressure                    yes
```

Parameters

Formation

```
Formation thickness                        27.000     [ft]
Flow dimension                                2.0      []
Static formation pressure                 121.316     [psi]
External boundary radius                  1000000     [m]
```

Fracture

```
Fracture conductivity                  6.08099E-04     [m/sec]
Fracture spec. storage                 3.79982E-07     [1/m]
```

Matrix

```
Matrix volume factor                          0.990000      [decimal]
Geometry factor (Alpha)                           1200      [1/m^2]
Matrix conductivity                         2.96239E-12      [m/sec]
Matrix spec. storage                        4.22988E-05      [1/m]
```

Skin

```
Radial thickness of skin                     5.5191819      [m]
Skin zone conductivity                        f(t) point
Skin zone spec. storage                     1.00000E-06      [1/m]
```

Fluid

```
Fluid density                                1060.00       [kg/m^3]
Fluid thermal exp. coeff.                   0.00000E+00     [1/C]
```

Test-Zone

```
Well radius                                     2.425      [in]
Tubing string radius                        1.7229424      [in]
```

Numeric

```
# of radial nodes                                 250      []
# of skin nodes                                    50      []
# of matrix nodes                                   4      []
```

f(x) Points Parameters

Skin zone conductivity

```
Points type                                      f(t)
 Time #1                                     0.000000      [day]
 Y value#1                                 1.37594E-03      [m/sec]
 Time #2                              175807.917390        [day]
 Y value#2                                 1.17065E-03      [m/sec]
 Time #3                             1874850.258500        [day]
 Y value#3                                 1.12243E-03      [m/sec]
 Time #4                             2399873.998100        [day]
 Y value#4                                 3.11687E-02      [m/sec]

Parameter curve type                           Linear
```

Calculated Parameters

Dual Porosity

```
Fracture thickness                           0.082296      [m]
Matrix thickness                             8.147304      [m]
Lambda - interporosity flow                2.21789E-06      []
Omega - storativity ratio                  9.07320E-05      []
Beta - transient parameter                 2.44445E-02      []
```

Skin Zone

```
Transmissivity                              f(t)
Storativity                  8.22960E-06    []
Diffusivity                                 f(t)
Skin factor                                 f(t)
```

Test Zone

```
Open hole well-bore storage  5.78831E-07    [m^3/Pa]
```

Grid Properties

```
Grid increment delta             0.06078    []
First grid increment         3.49749E-01    [m]
Skin grid increment delta        0.09197    []
Skin first grid increment    5.93353E-03    [m]
Skin last grid increment     4.90366E-01    [m]
Increment ratio              7.13240E-01    []
Number of nodes                      846    []
```

Sequences

Sequence: H_01

```
Sequence type                   History
Start time                   -50.010420    [day]
Duration                      34.960420    [day]
Time step type                   Static
Static time step               0.100000    [day]
Type                              Curve
Wellbore storage                   None
```

Sequence: H_02

```
Sequence type                   History
Start time                   -15.050000    [day]
Duration                       0.020000    [day]
Time step type                   Static
Static time step               0.000100    [day]
Type                              Curve
Wellbore storage                   None
```

Sequence: H_03

```
Sequence type                   History
Start time                   -15.030000    [day]
Duration                       0.033890    [day]
Time step type                   Static
Static time step               0.000500    [day]
Type                              Curve
Wellbore storage                   None
```

Sequence: H_04

```
Sequence type                   History
```

```
Start time                              -14.996110     [day]
Duration                                  0.013550     [day]
Time step type                              Static
Static time step                          0.000116     [day]
Type                                         Curve
Wellbore storage                             None
```

Sequence: H_05

```
Sequence type                              History
Start time                              -14.982560     [day]
Duration                                 14.982560     [day]
Time step type                              Static
Static time step                          0.005000     [day]
Type                                         Curve
Wellbore storage                             None
```

Sequence: H_06

```
Sequence type                              History
Start time                                0.000000     [day]
Duration                                  0.166450     [day]
Time step type                              Static
Static time step                          0.001157     [day]
Type                                         Curve
Wellbore storage                             None
```

Sequence: F_01

```
Sequence type                                 Flow
Start time                                0.166450     [day]
Duration                                 21.650400     [day]
Time step type                                 Log
First log step                        1.15741E-07     [day]
# of time steps                                250
Type                                         Curve
Wellbore storage                             Open
```

Sequence: F_02

```
Sequence type                                 Flow
Start time                               21.816850     [day]
Duration                                130.183150     [day]
Time step type                                 Log
First log step                        1.15741E-07     [day]
# of time steps                                250
Type                                         Fixed
Fixed value                                    0.0     [USgpm]
Wellbore storage                             Open
```

Test Zone Curves

```
Curve object to use                        P Curve
Curve type                                Pressure
Start sequence                                H_01
End sequence                                  H_06
Curve time base                               Test
Curve Y data units                           [psi]
```

99

```
Curve Y data is log 10                              no

Curve object to use                            Q Curve
Curve type                                    Flow Rate
Start sequence                                     F_01
End sequence                                       F_01
Curve time base                                    Test
Curve Y data units                              [USgpm]
Curve Y data is log 10                               no
```

Simulation Results Setup

```
Output ID                                           DAT
  Output type                                   Pressure
  Pressure capture type                    Superposition
   DAT[1] operation                           + Pressure
     Type                                       Constant
       Fixed radius                         1.0      [m]
   DAT[2] operation                            - Delta P
     Type                                       Constant
       Fixed radius                  1220.866283     [m]
  Output units                                    [psi]

Output ID                                           DAT
  Output type                                   Flow Rate
  Flow rate output type                             Well
  Output units                                   [USgpm]
```

SNL-14 Optimization Settings

```
**********
nPre 2.30Q
**********


Version date   22 July 2005
Listing date   23 May 2006
QA status      QA:Q
Config file    C:\nSIGHTS\Culebra\SNL 14\SNL-14.nPre
```

f(x) Points Parameters

Skin zone conductivity

```
Points type                                        f(t)
 Time #1                               0.000000    [day]
  Y value#1                                    Optimized
 Time #2                                       Optimized
   Minimum                         86400.000000    [day]
   Estimat                        175807.917390    [day]
   Maximum                        734400.000000    [day]
  Y value#2                                    Optimized
 Time #3                                       Optimized
   Minimum                        735264.000000    [day]
```

```
     Estimat                              1874850.258500      [day]
     Maximum                              1944000.000000      [day]
  Y value#3                                    Optimized
  Time #4                                      Optimized
     Minimum                              1944864.000000      [day]
     Estimat                              2399873.998100      [day]
     Maximum                              3456000.000000      [day]
  Y value#4                                    Optimized

X opt range type                                Linear
X opt sigma                               1.00000E+00

Y opt minimum value                       1.00000E-06       [m/sec]
Y opt maximum value                       1.00000E-01       [m/sec]
Y opt range type                                   Log
Y opt sigma                               1.00000E+00

Parameter curve type                            Linear
```

SNL-14 Fitting Parameter Estimates
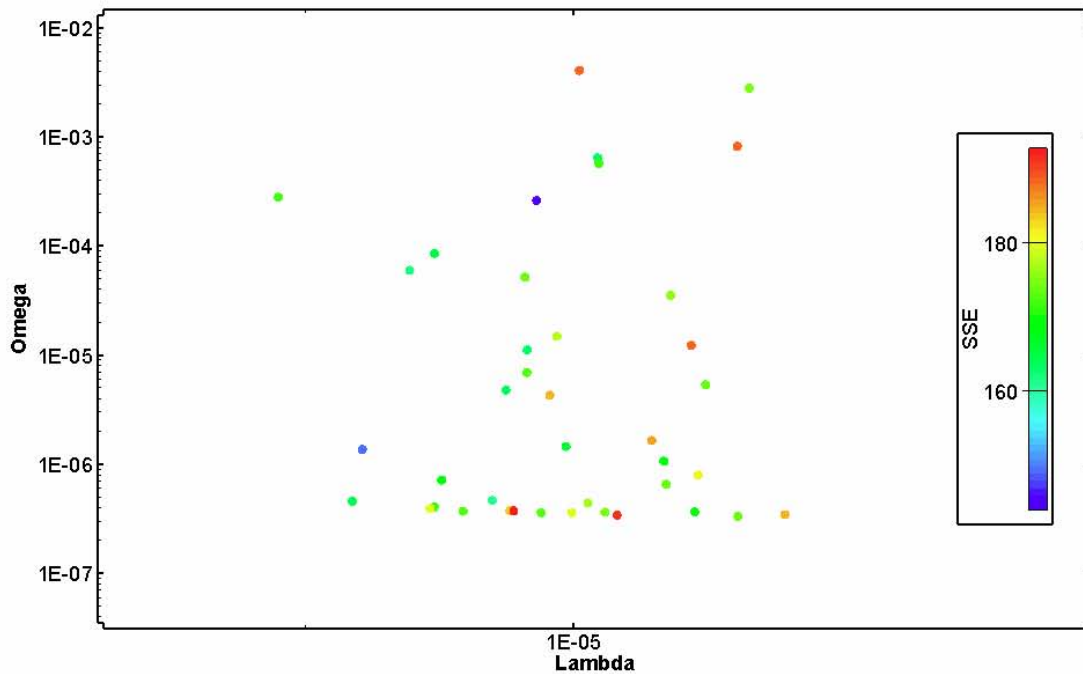
Figure B-35. Estimates of Lambda and Omega derived from the SNL-14 perturbation analysis.

101
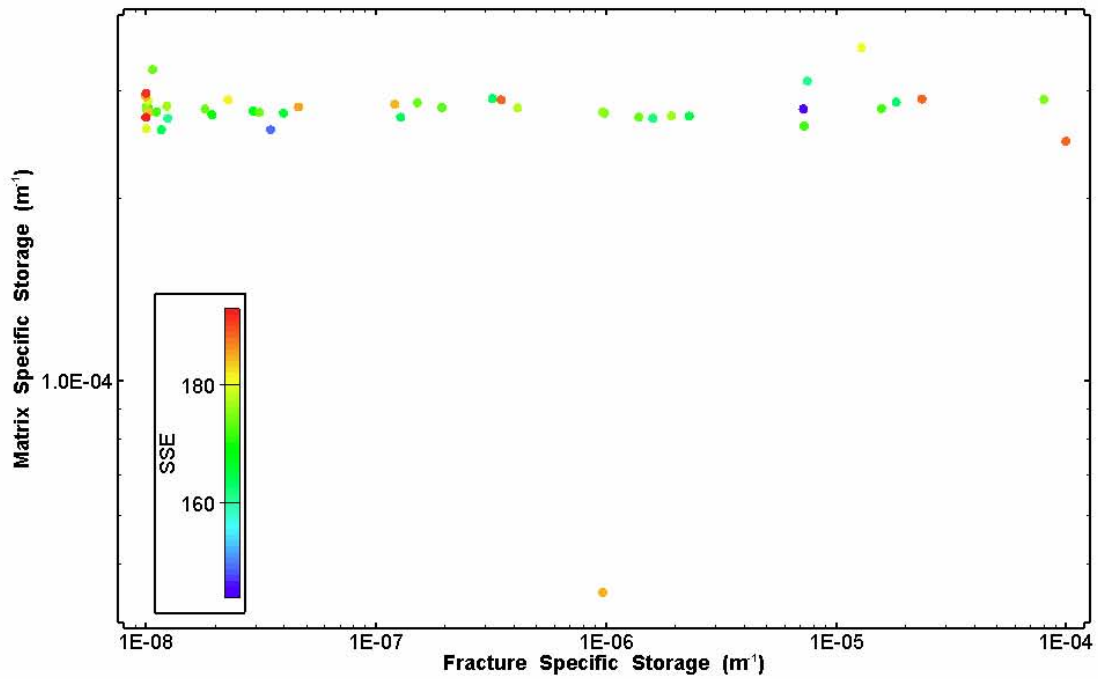
Figure B-36. Estimates of fracture and matrix specific storage derived from the SNL-14 perturbation analysis.
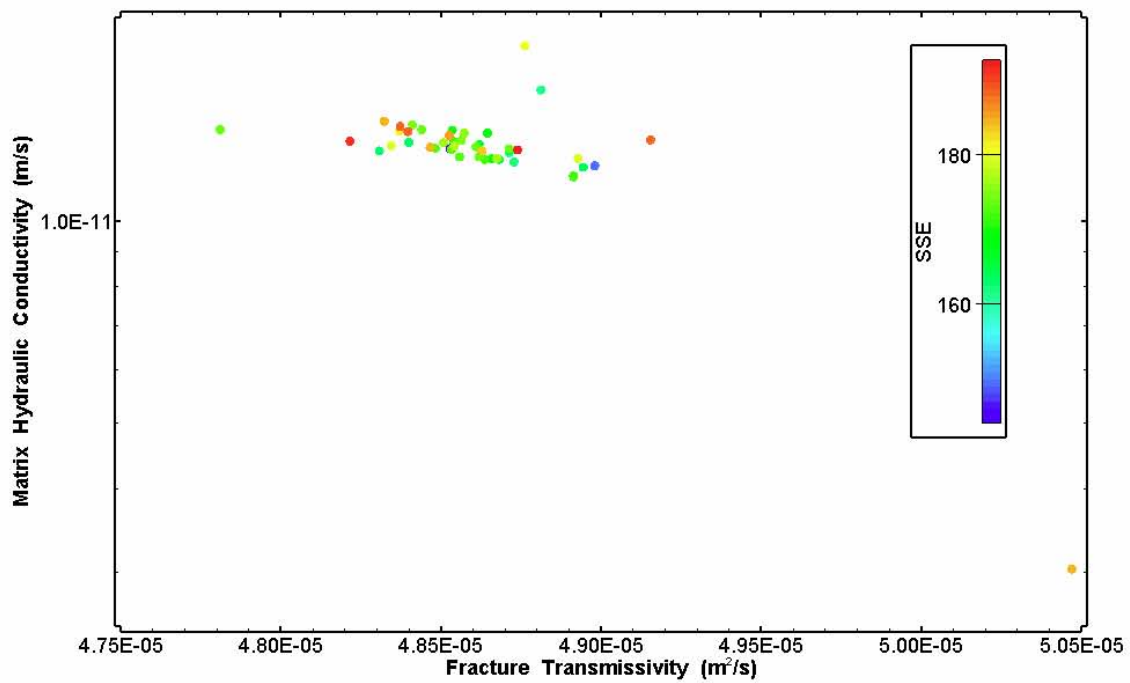
Figure B-37. Estimates of fracture transmissivity and matrix hydraulic conductivity derived from the SNL-14 perturbation analysis.
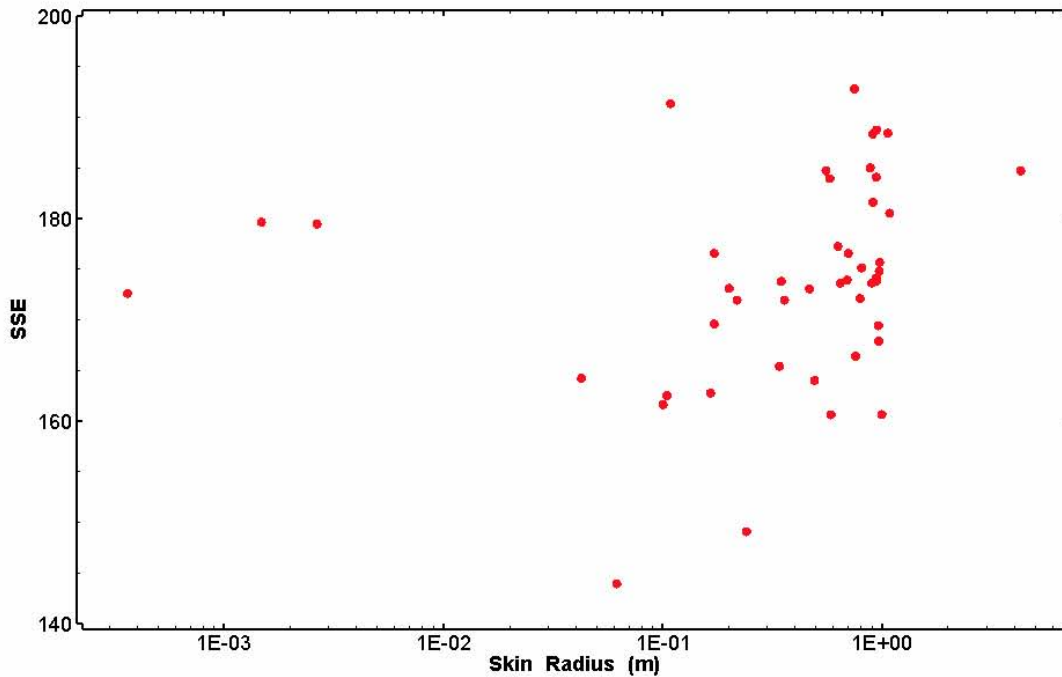
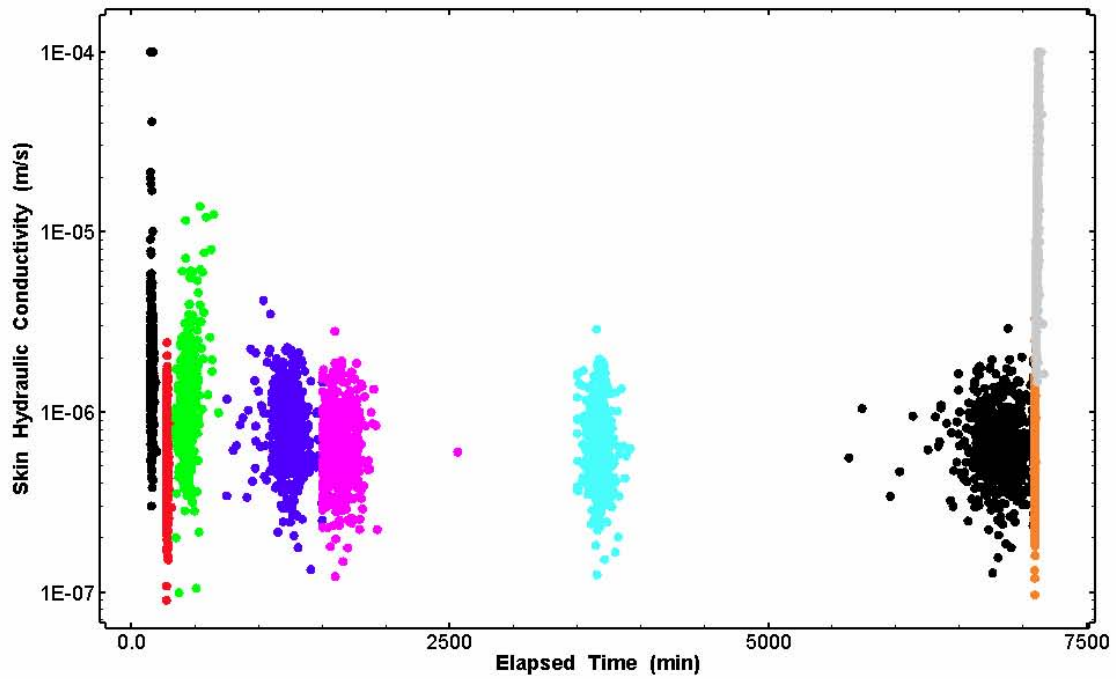**Figure B-38. Estimates of skin radius derived from the SNL-14 perturbation analysis.**
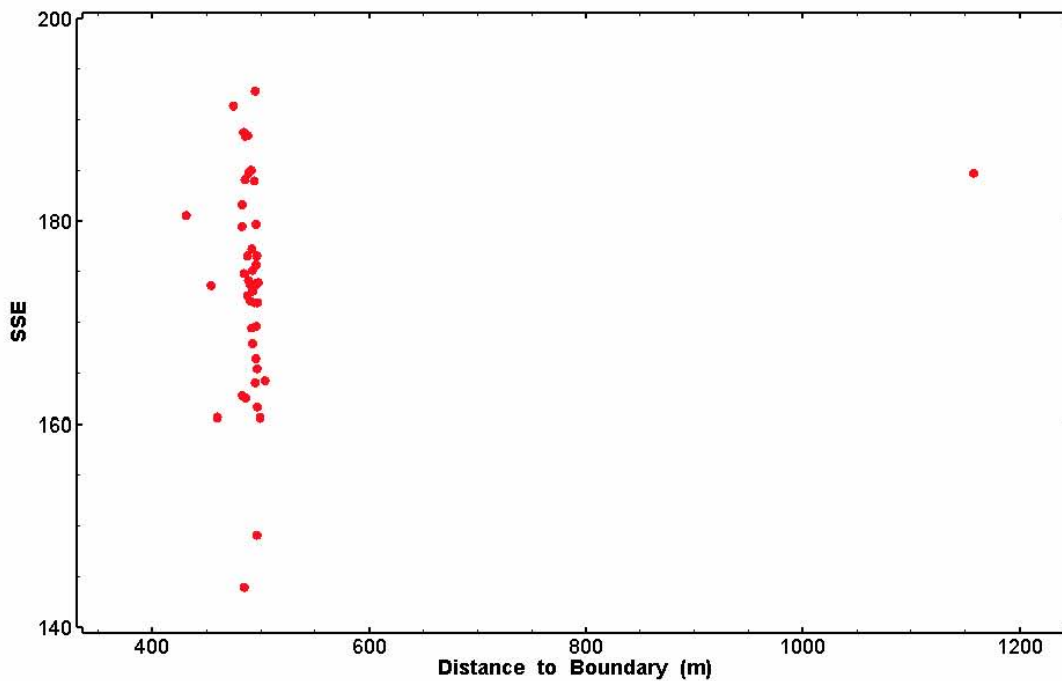
**Figure B-39. Estimates of distance to linear no-flow boundary derived from the SNL-14 perturbation analysis.**
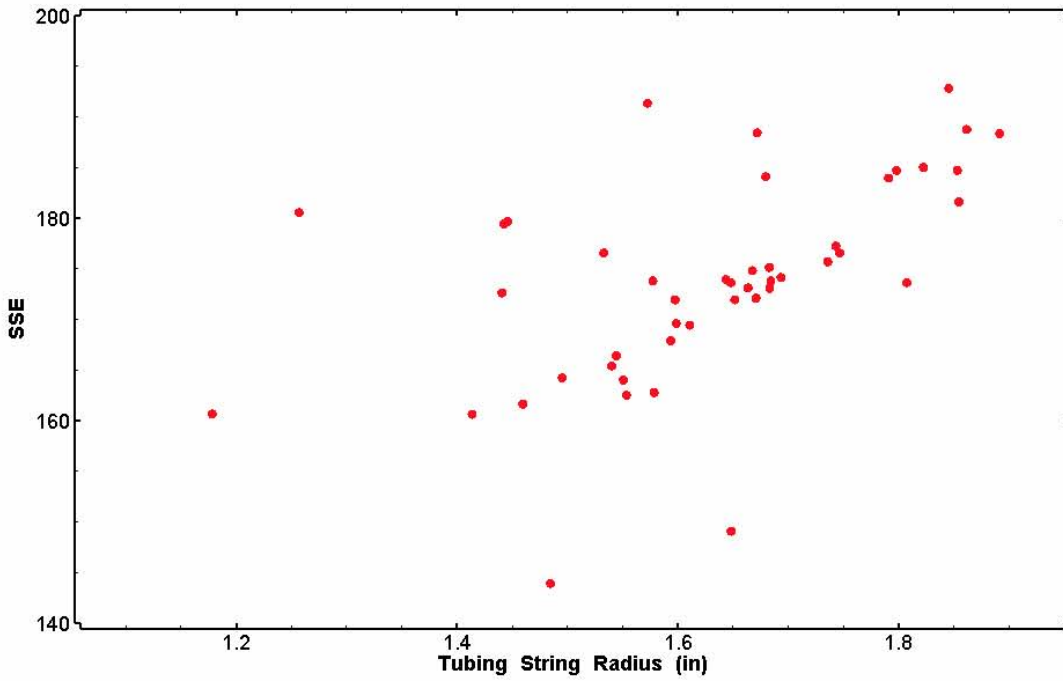
Figure B-40. Estimates of tubing string radius derived from the SNL-14 perturbation analysis.
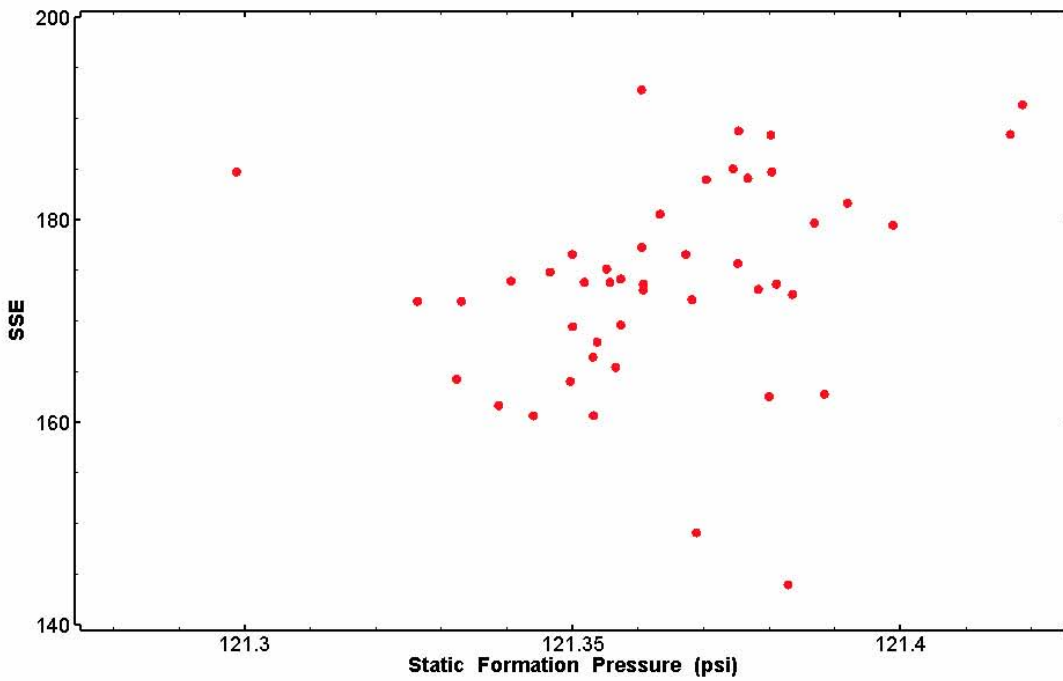
Figure B-41. Estimates of static formation pressure derived from the SNL-14 perturbation analysis.
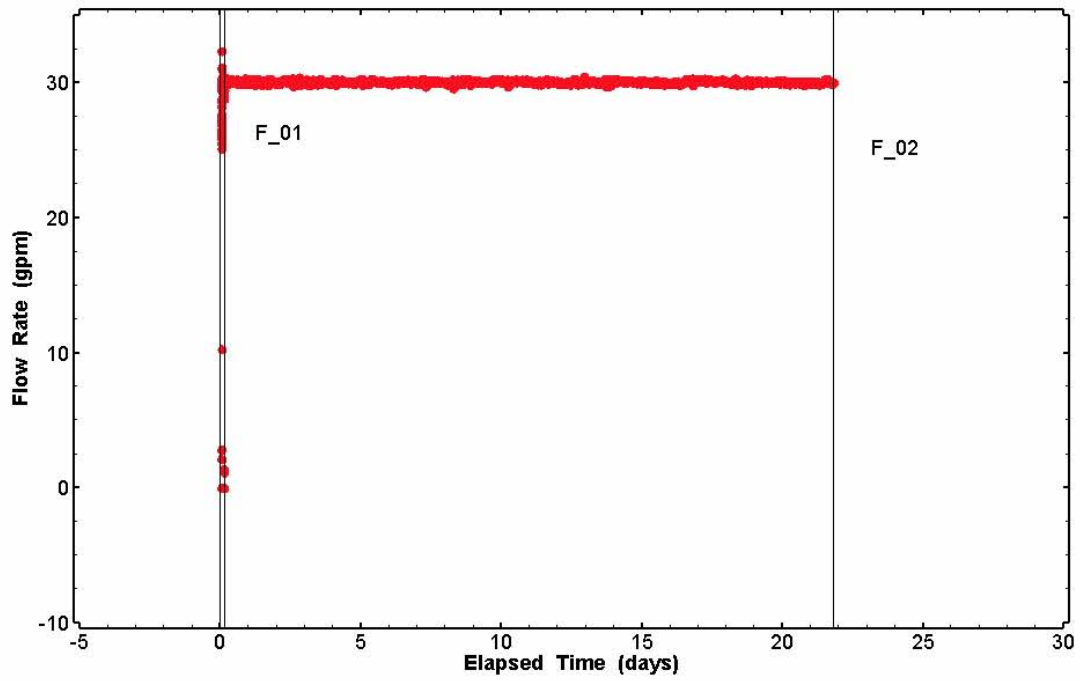
Figure B-42. Flow rates measured during the SNL-14 testing.

B.8   WIPP-11 nSIGHTS Listings

```
**********
nPre 2.30Q
**********


Version date     22 July 2005
Listing date     02 May 2006
QA status        QA:Q
Config file      C:\nSIGHTS\Culebra\WIPP 11\WIPP 11 - new Ss.nPre
```

Control Settings

Main Settings

```
Simulation type                              Forward
Simulation subtype                            Normal
Phase to simulate                             Liquid
Skin zone ?                                      yes
External boundary                     Fixed Pressure
Curve data source                            Objects
```

Liquid Phase Settings

```
Aquifer type                                Confined
Aquifer horizontal permeability            Isotropic
System porosity                               Single
Compensate flow dimension geometry               yes
Leakage                                         None
```

Test Zone Settings

```
Test zone volume can vary                         no
Test zone compressibility can vary                no
Test zone temperature can vary                    no
Default test-zone temperature              20.00      [C]
Solution variable                           Pressure
Allow negative head/pressure                     yes
```

Parameters

Formation

```
Formation thickness                        23.000     [ft]
Flow dimension                                2.0     []
Static formation pressure                 106.497     [psi]
External boundary radius                  1000000     [m]
Formation conductivity                  f(r) point
Formation spec. storage               1.00000E-06     [1/m]
```

Skin

```
Radial thickness of skin                0.0047474     [m]
Skin zone conductivity                6.61728E-04     [m/sec]
```

```
Skin zone spec. storage                         1.00000E-04       [1/m]
```

Fluid

```
Fluid density                                     1038.00         [kg/m^3]
Fluid thermal exp. coeff.                       0.00000E+00       [1/C]
```

Test-Zone

```
Well radius                                       4.4605          [in]
Tubing string radius                              0.405           [ft]
```

Numeric

```
# of radial nodes                                   250           []
# of skin nodes                                      50           []
Pressure solution tolerance                     1.45038E-11       [psi]
STP flow solution tolerance                     1.58503E-11       [USgpm]
```

f(x) Points Parameters

Formation conductivity

```
Points type                                        f(r)
 Radius #1                                       28.16815         [m]
 Y value#1                                       2.43671E-04      [m/sec]
 Radius #2                                       277.5993399      [m]
 Y value#2                                       1.02754E-05      [m/sec]
 Radius #3                                       1300.4607014     [m]
 Y value#3                                       6.22036E-05      [m/sec]
 Radius #4                                       2540.1901332     [m]
 Y value#4                                       3.63627E-06      [m/sec]
 Radius #5                                       5805.4107287     [m]
 Y value#5                                       1.03456E-05      [m/sec]
 Radius #6                                       9934.8825796     [m]
 Y value#6                                       4.00114E-05      [m/sec]

Parameter curve type                               Linear
```

Calculated Parameters

Formation

```
Transmissivity                                     f(r)
Storativity                                     7.01040E-06       []
Diffusivity                                        f(r)
```

Skin Zone

```
Transmissivity                                  4.63898E-03       [m^2/sec]
Storativity                                     7.01040E-04       []
Diffusivity                                     6.61728E+00       [m^2/sec]
Skin factor                                        f(r)
```

Test Zone

```
Open hole well-bore storage                      4.69662E-06      [m^3/Pa]
```

Grid Properties

```
Grid increment delta                                0.08016       []
First grid increment                             9.85224E-03      [m]
Skin grid increment delta                           0.00084       []
Skin first grid increment                        9.49505E-05      [m]
Skin last grid increment                         9.88463E-05      [m]
Increment ratio                                  9.96724E+01       []
```

Sequences

Sequence: H_01

```
  Sequence type                                    History
  Start time                                      0.000000       [day]
  Duration                                        0.074990       [day]
  Time step type                                    Static
  Static time step                                0.000100       [day]
  Type                                              Curve
  Wellbore storage                                   None
```

Sequence: F_01

```
  Sequence type                                      Flow
  Start time                                      0.074990       [day]
  Duration                                        0.147470       [day]
  Time step type                                     Log
  First log step                               1.15741E-07       [day]
  # of time steps                                    250
  Type                                              Curve
  Wellbore storage                                   Open
```

Sequence: F_02

```
  Sequence type                                      Flow
  Start time                                      0.222460       [day]
  Duration                                        0.742120       [day]
  Time step type                                     Log
  First log step                               1.15741E-07       [day]
  # of time steps                                    250
  Type                                              Fixed
  Fixed value                                        0.0         [USgpm]
  Wellbore storage                                   Open
```

Sequence: H_02

```
  Sequence type                                    History
  Start time                                      0.964580       [day]
  Duration                                        0.010410       [day]
  Time step type                                    Static
  Static time step                                0.001000       [day]
  Type                                              Curve
```

108

```
Wellbore storage                                    None
```

Sequence: F_03

```
Sequence type                                       Flow
Start time                              0.974990     [day]
Duration                                3.525010     [day]
Time step type                                      Log
First log step                          1.15741E-07  [day]
# of time steps                               250
Type                                                Curve
Wellbore storage                                    Open
```

Sequence: H_03

```
Sequence type                                       History
Start time                              4.500000     [day]
Duration                                2.658910     [day]
Time step type                                      Static
Static time step                        0.001000     [day]
Type                                                Curve
Wellbore storage                                    Open
```

Sequence: F_04

```
Sequence type                                       Flow
Start time                              7.158910     [day]
Duration                                13.067870    [day]
Time step type                                      Log
First log step                          1.15741E-07  [day]
# of time steps                               250
Type                                                Fixed
Fixed value                             -35.0        [USgpm]
Wellbore storage                                    Open
```

Sequence: F_05

```
Sequence type                                       Flow
Start time                              20.226780    [day]
Duration                                42.573220    [day]
Time step type                                      Log
First log step                          1.15741E-07  [day]
# of time steps                               250
Type                                                Fixed
Fixed value                             0.0          [USgpm]
Wellbore storage                                    Open
```

Test Zone Curves

```
Curve object to use                                 Pressure
Curve type                                          Pressure
Start sequence                                      H_01
End sequence                                        H_03
Curve time base                                     Test
Curve Y data units                                  [psi]
Curve Y data is log 10                              no


Curve object to use                                 Q Curve
```

```
Curve type                                      Flow Rate
Start sequence                                       F_01
End sequence                                         F_03
Curve time base                                      Test
Curve Y data units                               [USgpm]
Curve Y data is log 10                                 no
```

Simulation Results Setup

```
Output ID                                             DAT
   Output type                                   Pressure
   Pressure capture type                        Test Zone
   Output units                                     [psi]

Output ID                                             DAT
   Output type                                  Flow Rate
   Flow rate output type                             Well
   Output units                                   [USgpm]
```

OutputFiles

XY Forward Output

```
Write file ?                                          yes
File nameC:\nSIGHTS\Culebra\WIPP 11\Post\WIPP-11.nXYSim
Run ID                                            Perturb
If file exists                                  Overwrite
Output data                                   AutoSimData
```

WIPP-11 Optimization Settings

```
**********
nPre 2.30Q
**********


Version date    22 July 2005
Listing date    02 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\WIPP 11\WIPP 11 - new Ss.nPre
```

Parameters

Formation

```
Formation thickness                          23.000     [ft]
Flow dimension                                  2.0     []
Static formation pressure           Optimization
   Minimum value                           100.000     [psi]
   Maximum value                           120.000     [psi]
   Estimate value                          106.497     [psi]
   Range type                              Linear
   Sigma                               1.00000E+00
```

110

```
External boundary radius                      1000000      [m]
Formation conductivity                      f(r) point
Formation spec. storage                     1.00000E-06    [1/m]
```

Skin

```
Radial thickness of skin                    Optimization
   Minimum value                            1.0E-05        [m]
   Maximum value                            10.0           [m]
   Estimate value                           0.0047474      [m]
   Range type                                      Log
   Sigma                                    1.00000E+00
Skin zone conductivity                      Optimization
   Minimum value                            1.00000E-08    [m/sec]
   Maximum value                            1.00000E-03    [m/sec]
   Estimate value                           6.61728E-04    [m/sec]
   Range type                                      Log
   Sigma                                    1.00000E+00
Skin zone spec. storage                     1.00000E-04    [1/m]
```

Fluid

```
Fluid density                               1038.00        [kg/m^3]
Fluid thermal exp. coeff.                   0.00000E+00    [1/C]
```

Test-Zone

```
Well radius                                 4.4605         [in]
Tubing string radius                        Optimization
   Minimum value                            0.200          [ft]
   Maximum value                            1.000          [ft]
   Estimate value                           0.405          [ft]
   Range type                                    Linear
   Sigma                                    1.00000E+00
```

Numeric

```
# of radial nodes                           250            []
# of skin nodes                             50             []
Pressure solution tolerance                 1.45038E-11    [psi]
STP flow solution tolerance                 1.58503E-11    [USgpm]
```

WIPP-11 Fitting Parameter Estimates
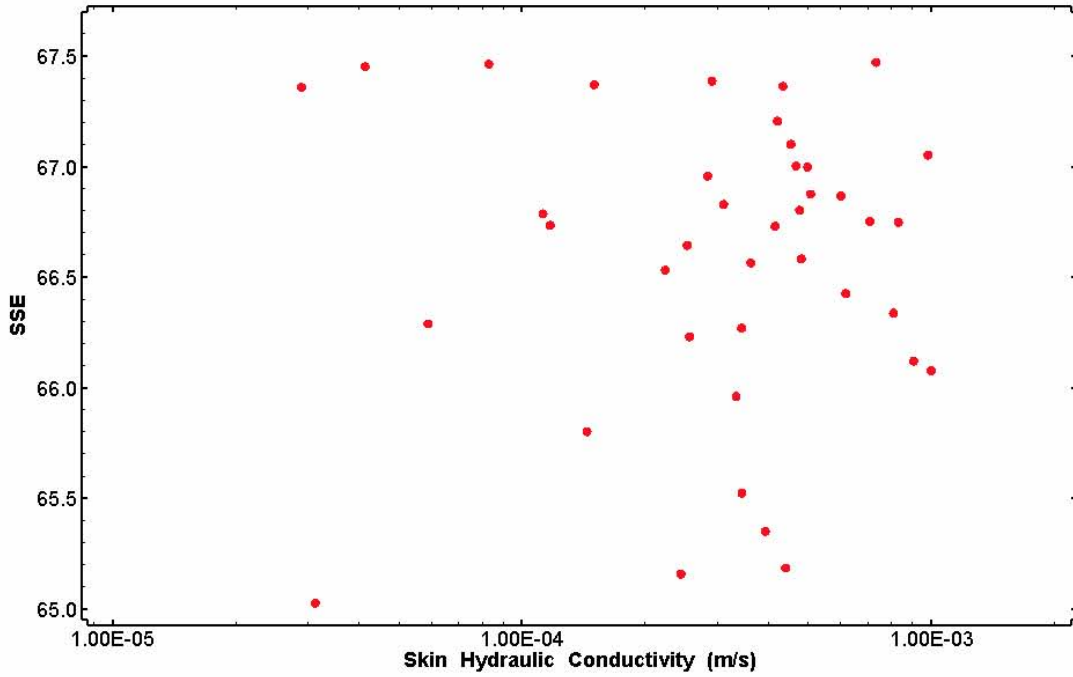
Figure B-43. Estimates of skin hydraulic conductivity derived from the WIPP-11 perturbation analysis.
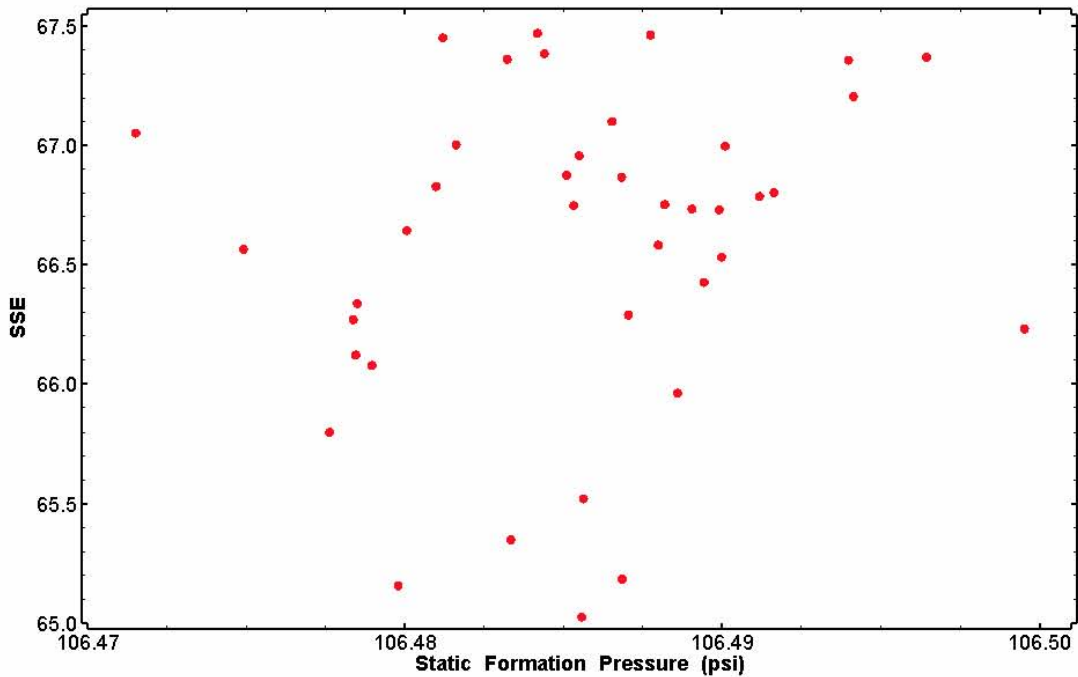
Figure B-44. Estimates of static formation pressure derived from the WIPP-11 perturbation analysis.
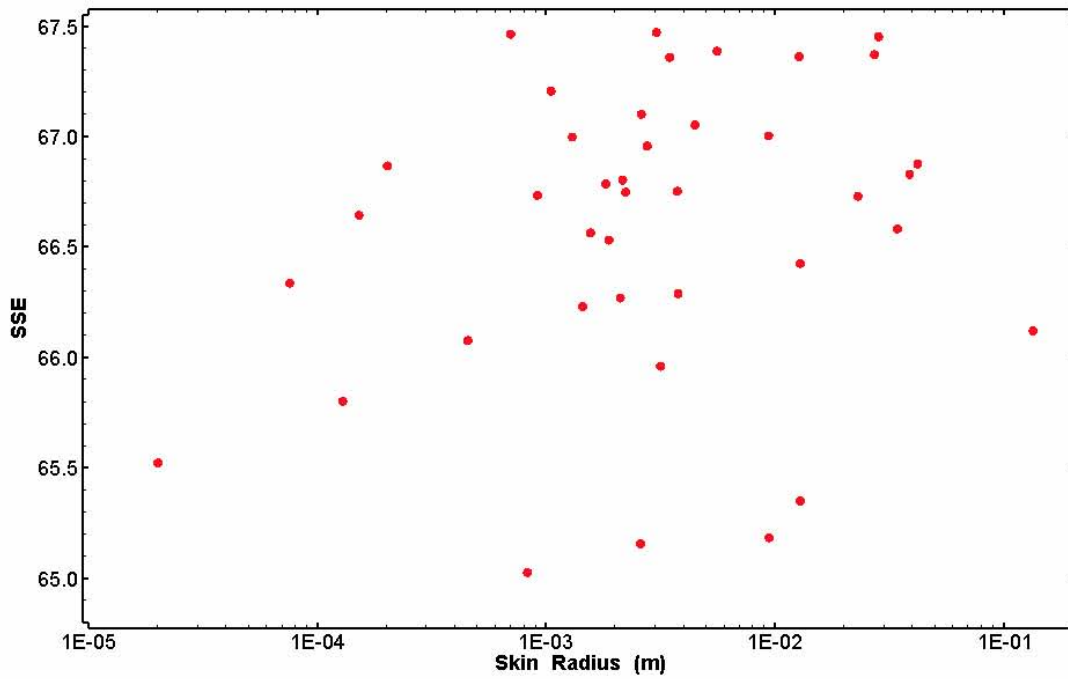
Figure B-45. Estimates of skin radius derived from the WIPP-11 perturbation analysis.
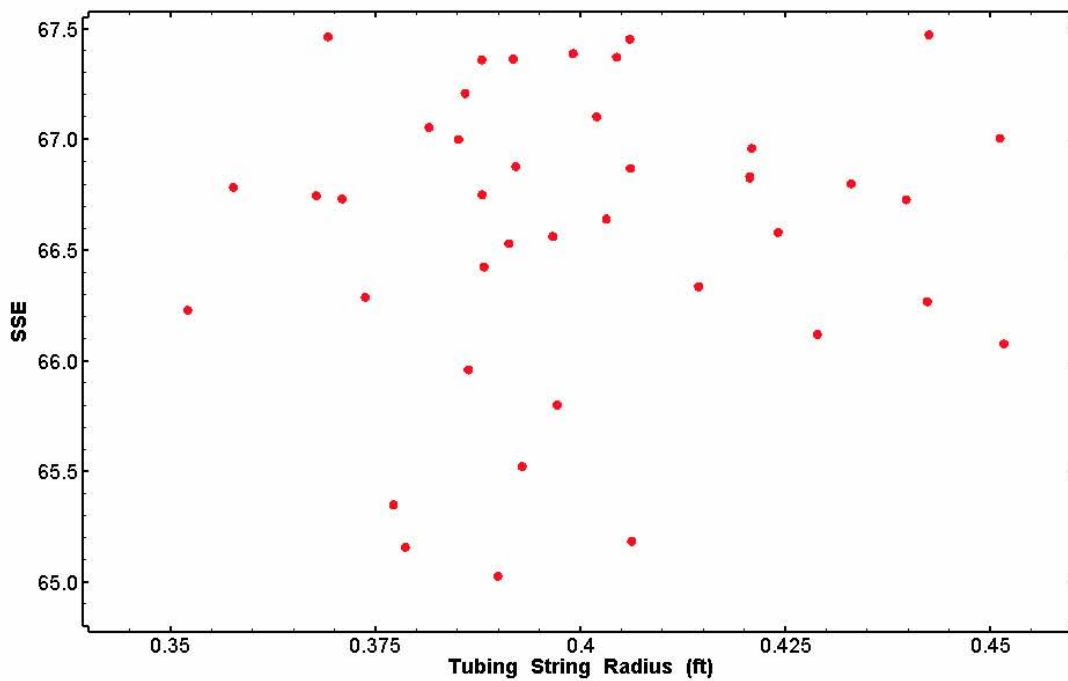
Figure B-46. Estimates of tubing string radius derived from the WIPP-11 perturbation analysis.

113
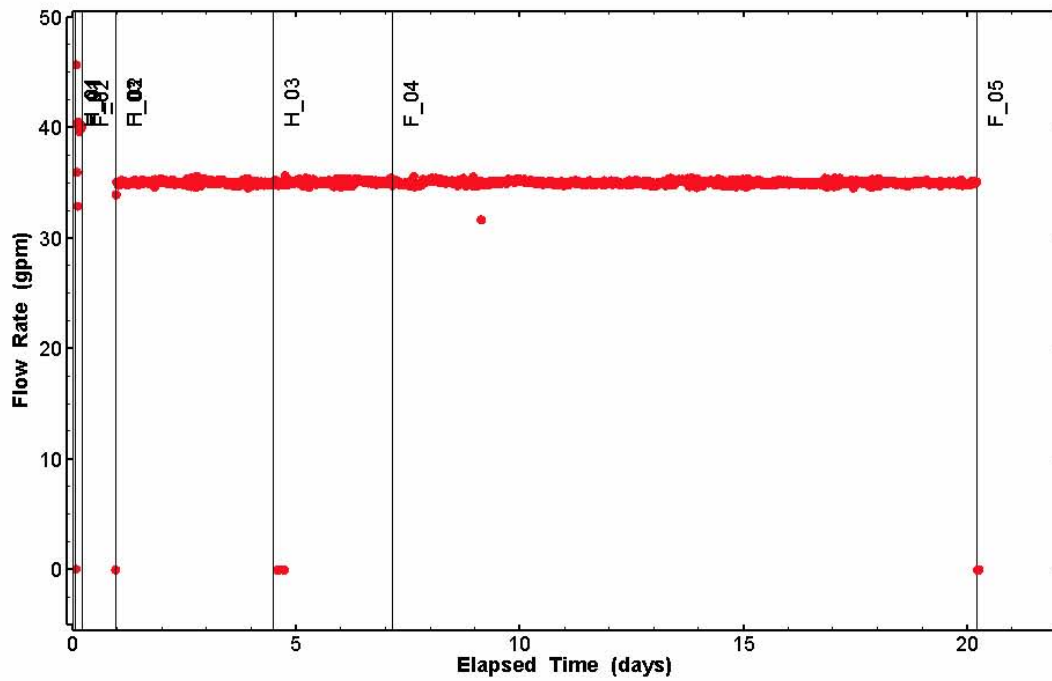
Figure B-47. Flow rates measured during the WIPP-11 testing.

B.9   WIPP-25 nSIGHTS Listings

```
**********
nPre 2.30Q
**********
```

```
Version date    22 July 2005
Listing date    02 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\WIPP 25\WIPP-25.nPre
```

Control Settings

Main Settings

```
Simulation type                             Forward
Simulation subtype                           Normal
Phase to simulate                            Liquid
Skin zone ?                                     yes
External boundary                   Fixed Pressure
Curve data source                           Objects
```

Liquid Phase Settings

```
Aquifer type                               Confined
Aquifer horizontal permeability           Isotropic
System porosity                              Single
Compensate flow dimension geometry              yes
Leakage                                        None
```

Test Zone Settings

```
Test zone volume can vary                        no
Test zone compressibility can vary               no
Test zone temperature can vary                   no
Default test-zone temperature              20.00      [C]
Solution variable                          Pressure
Allow negative head/pressure                    yes
```

Parameters

Formation

```
Formation thickness                        25.000      [ft]
Flow dimension                                2.0      []
Static formation pressure                 125.722      [psi]
External boundary radius                  1000000      [m]
Formation conductivity                3.39004E-05      [m/sec]
Formation spec. storage               1.00000E-06      [1/m]
```

Skin

```
Radial thickness of skin                0.0086243      [m]
Skin zone conductivity                   f(t) point
```

115

```
Skin zone spec. storage                          1.88034E-08      [1/m]
```

Fluid

```
Fluid density                                       1022.00      [kg/m^3]
Fluid thermal exp. coeff.                        0.00000E+00      [1/C]
```

Test-Zone

```
Well radius                                            2.475     [in]
Volume change from normal                               0.45     [m^3]
Test-zone compressibility                        1.55482E-08     [1/Pa]
```

Numeric

```
# of radial nodes                                        250     []
# of skin nodes                                           50     []
Pressure solution tolerance                      1.45038E-11     [psi]
STP flow solution tolerance                      1.58503E-11     [USgpm]
```

f(x) Points Parameters

Skin zone conductivity

```
Points type                                            f(t)
 Time #1                                          150650.393     [min]
 Y value#1                                        1.80134E-07     [m/sec]
 Time #2                                          156107.611     [min]
 Y value#2                                        1.67710E-07     [m/sec]
 Time #3                                          167920.057     [min]
 Y value#3                                        1.63584E-07     [m/sec]
 Time #4                                          169548.382     [min]
 Y value#4                                        1.72878E-07     [m/sec]
 Time #5                                          190423.149     [min]
 Y value#5                                        1.67647E-07     [m/sec]
 Time #6                                          239999.335     [min]
 Y value#6                                        1.56946E-07     [m/sec]

Parameter curve type                                 Linear
```

Calculated Parameters

Formation

```
Transmissivity                                   2.40239E+02     [ft^2/day]
Storativity                                      7.62000E-06     []
Diffusivity                                      3.15275E+07     [ft^2/day]
```

Skin Zone

```
Transmissivity                                         f(t)
Storativity                                      1.43282E-07     []
Diffusivity                                            f(t)
Skin factor                                            f(t)
```

116

Test Zone

```
Test-zone volume                        0.5446069     [m^3]
Isolated well-bore storage              8.46767E-09   [m^3/Pa]
```

Grid Properties

```
Grid increment delta                    0.08268       []
First grid increment                    6.16212E-03   [m]
Skin grid increment delta               0.00262       []
Skin first grid increment               1.65152E-04   [m]
Skin last grid increment                1.87317E-04   [m]
Increment ratio                         3.28967E+01   []
```

Sequences

Sequence: H_01

```
Sequence type                           History
Start time                              0.000         [min]
Duration                                2510.000      [min]
Time step type                          Static
Static time step                        30.000        [min]
Type                                    Curve
Wellbore storage                        None
```

Sequence: H_02

```
Sequence type                           History
Start time                              2510.000      [min]
Duration                                3.200         [min]
Time step type                          Static
Static time step                        0.167         [min]
Type                                    Curve
Wellbore storage                        None
```

Sequence: F_01

```
Sequence type                           Flow
Start time                              2513.200      [min]
Duration                                302.016       [min]
Time step type                          Log
First log step                          1.66667E-04   [min]
# of time steps                         250
Type                                    Fixed
Fixed value                             -30.0         [USgpm]
Wellbore storage                        Isolated
```

Sequence: F_02

```
Sequence type                           Flow
Start time                              2815.216      [min]
Duration                                3.336         [min]
Time step type                          Log
First log step                          1.66667E-04   [min]
# of time steps                         250
```

```
Type                                          Fixed
Fixed value                                     0.0      [USgpm]
Wellbore storage                           Isolated
```

Sequence: F_03

```
Sequence type                                  Flow
Start time                                 2818.552      [min]
Duration                                    695.202      [min]
Time step type                                  Log
First log step                          1.66667E-04      [min]
# of time steps                                 250
Type                                          Fixed
Fixed value                                   -30.0      [USgpm]
Wellbore storage                           Isolated
```

Sequence: F_04

```
Sequence type                                  Flow
Start time                                 3513.754      [min]
Duration                                   9486.246      [min]
Time step type                                  Log
First log step                          1.66667E-04      [min]
# of time steps                                 250
Type                                          Fixed
Fixed value                                     0.0      [USgpm]
Wellbore storage                               None
```

Test Zone Curves

```
Curve object to use                         P Curve
Curve type                                 Pressure
Start sequence                                 H_01
End sequence                                   H_02
Curve time base                                Test
Curve Y data units                            [psi]
Curve Y data is log 10                           no
```

Simulation Results Setup

```
Output ID                                       DAT
  Output type                              Pressure
  Pressure capture type                  Test Zone
  Output units                               [psi]

Output ID                                       DAT
  Output type                             Flow Rate
  Flow rate output type                        Well
  Output units                            [USgpm]
```

WIPP-25 Optimization Settings

```
**********
nPre 2.30Q
```

118

```
*********
```

```
Version date    22 July 2005
Listing date    02 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\WIPP 25\WIPP-25.nPre
```

Parameters

Formation

```
Formation thickness                         25.000      [ft]
Flow dimension                              2.0         []
Static formation pressure         Optimization
    Minimum value                           120.000     [psi]
    Maximum value                           130.000     [psi]
    Estimate value                          125.722     [psi]
    Range type                              Linear
    Sigma                         1.00000E+00
External boundary radius                    1000000     [m]
Formation conductivity            Optimization
    Minimum value                           1.00000E-08 [m/sec]
    Maximum value                           1.00000E-04 [m/sec]
    Estimate value                          3.39004E-05 [m/sec]
    Range type                              Log
    Sigma                         1.00000E+00
Formation spec. storage                     1.00000E-06 [1/m]
```

Skin

```
Radial thickness of skin          Optimization
    Minimum value                           0.0001      [m]
    Maximum value                           10.0        [m]
    Estimate value                          0.0086243   [m]
    Range type                              Log
    Sigma                         1.00000E+00
Skin zone conductivity            f(t) point
Skin zone spec. storage           Optimization
    Minimum value                           1.00000E-08 [1/m]
    Maximum value                           1.00000E-04 [1/m]
    Estimate value                          1.88034E-08 [1/m]
    Range type                              Log
    Sigma                         1.00000E+00
```

Fluid

```
Fluid density                               1022.00     [kg/m^3]
Fluid thermal exp. coeff.                   0.00000E+00 [1/C]
```

Test-Zone

```
Well radius                                 2.475       [in]
Volume change from normal                   0.45        [m^3]
Test-zone compressibility         Optimization
    Minimum value                           4.00000E-10 [1/Pa]
    Maximum value                           1.00000E-05 [1/Pa]
```

```
Estimate value                              1.55482E-08     [1/Pa]
Range type                                          Log
Sigma                                       1.00000E+00
```

Numeric

```
# of radial nodes                                   250     []
# of skin nodes                                      50     []
Pressure solution tolerance                 1.45038E-11     [psi]
STP flow solution tolerance                 1.58503E-11     [USgpm]
```

WIPP-25 Fitting Parameter Estimates
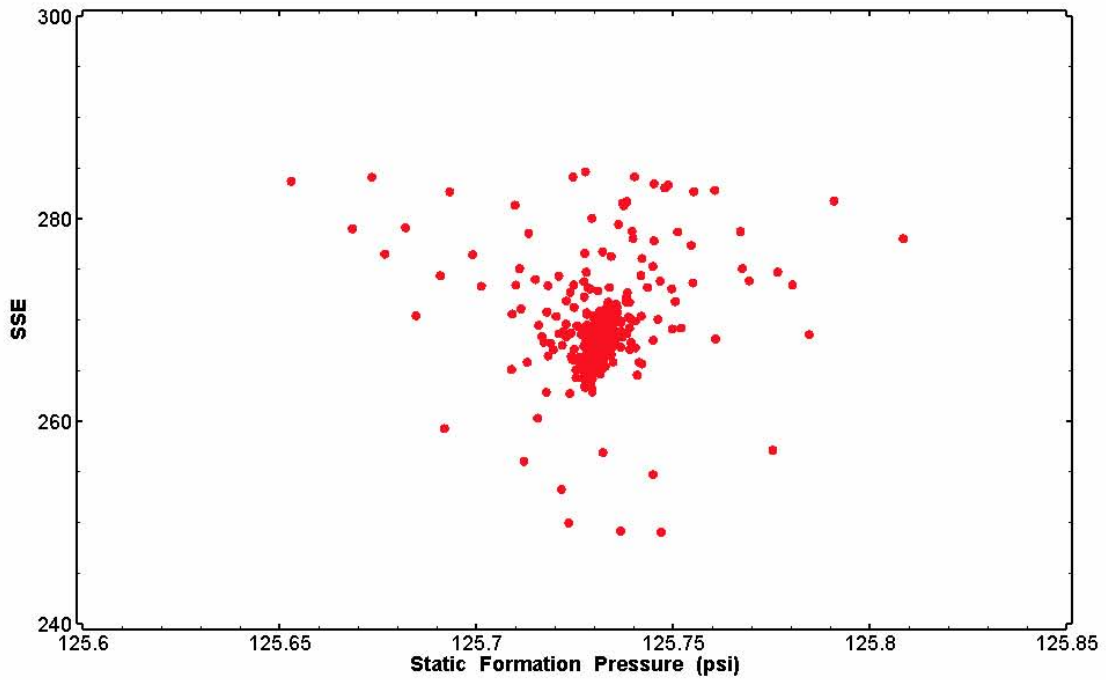
Figure B-48. Estimates of static formation pressure derived from the WIPP-25 perturbation analysis.
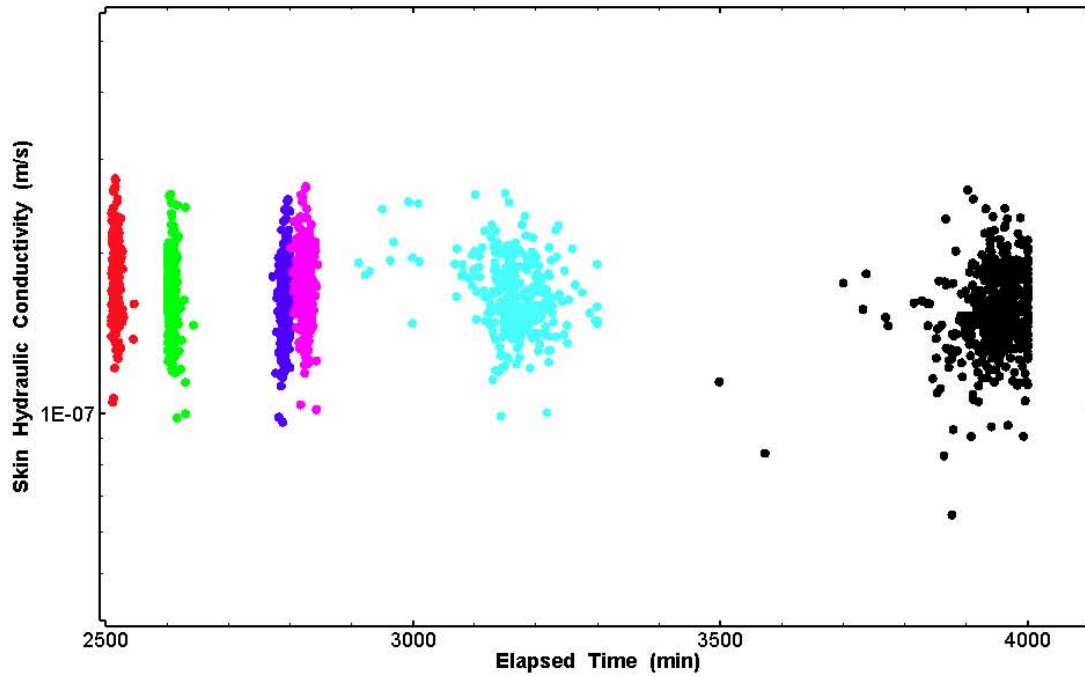
Figure B-49. Estimates of time-varying skin hydraulic conductivity derived from the WIPP-25 perturbation analysis.

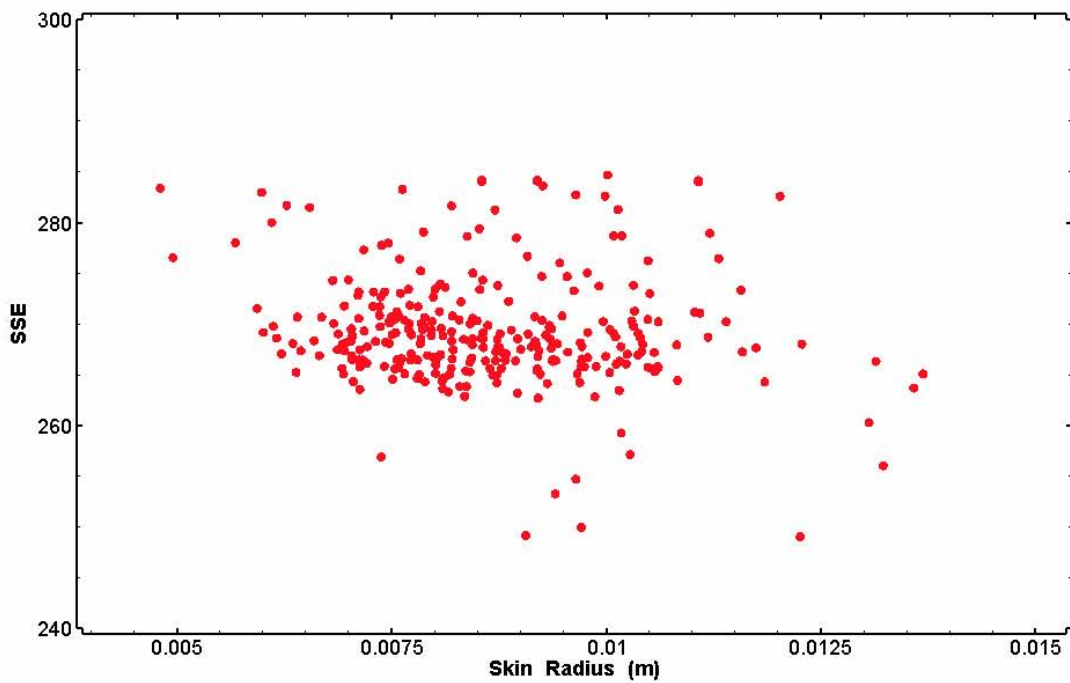**Figure B-50. Estimates of skin radius derived from the WIPP-25 perturbation analysis.**
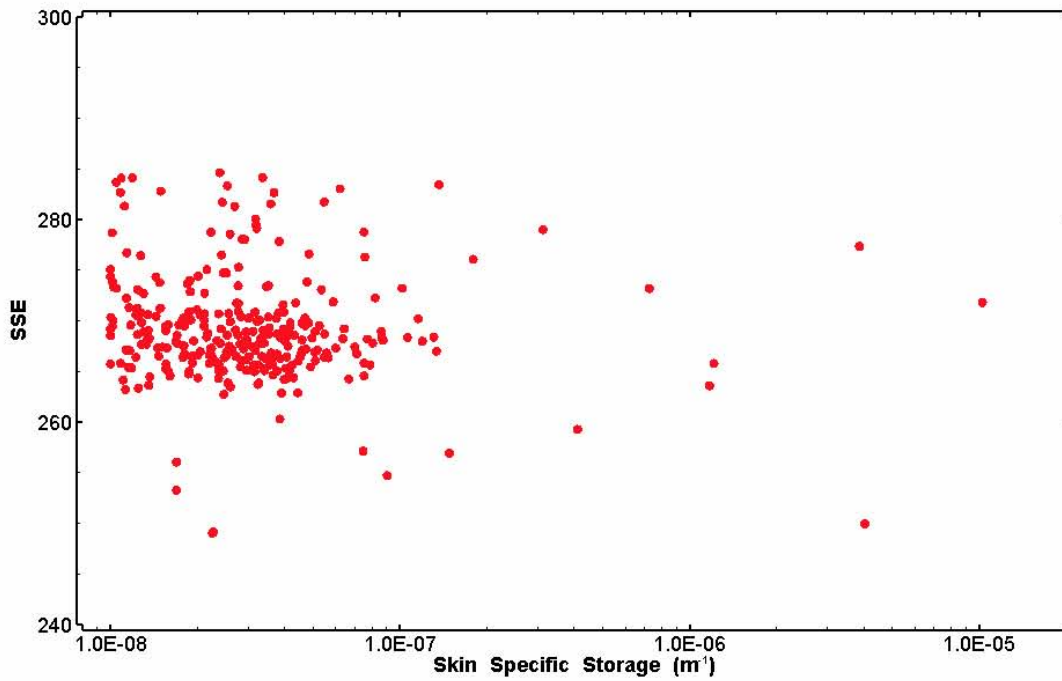
Figure B-51. Estimates of skin specific storage derived from the WIPP-25 perturbation analysis.
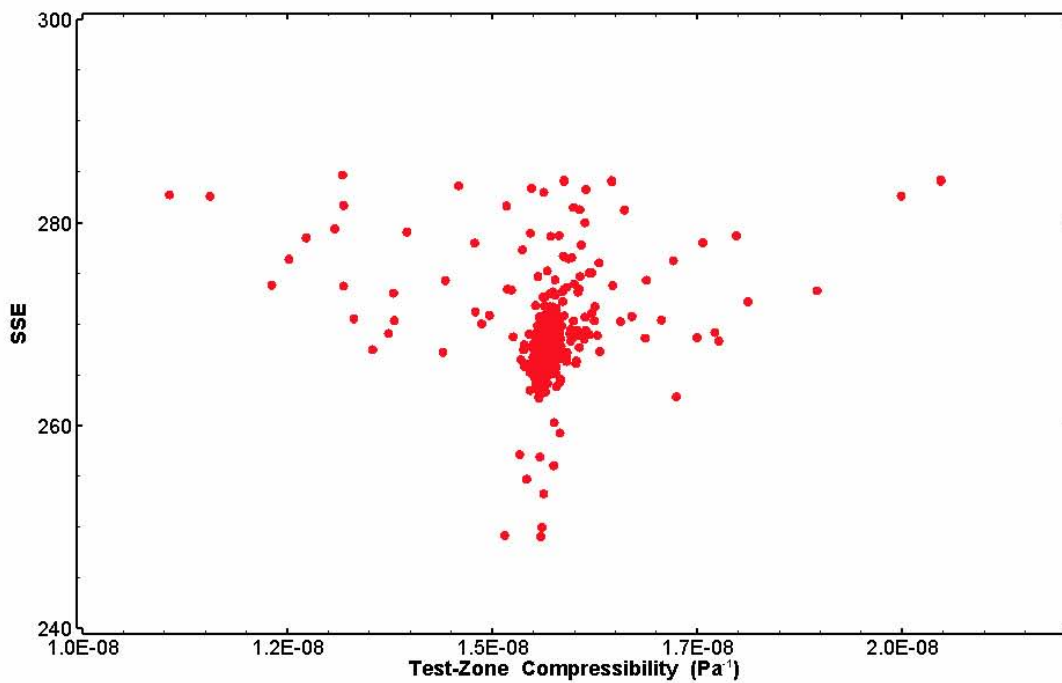
Figure B-52. Estimates of test-zone compressibility derived from the WIPP-25 perturbation analysis.
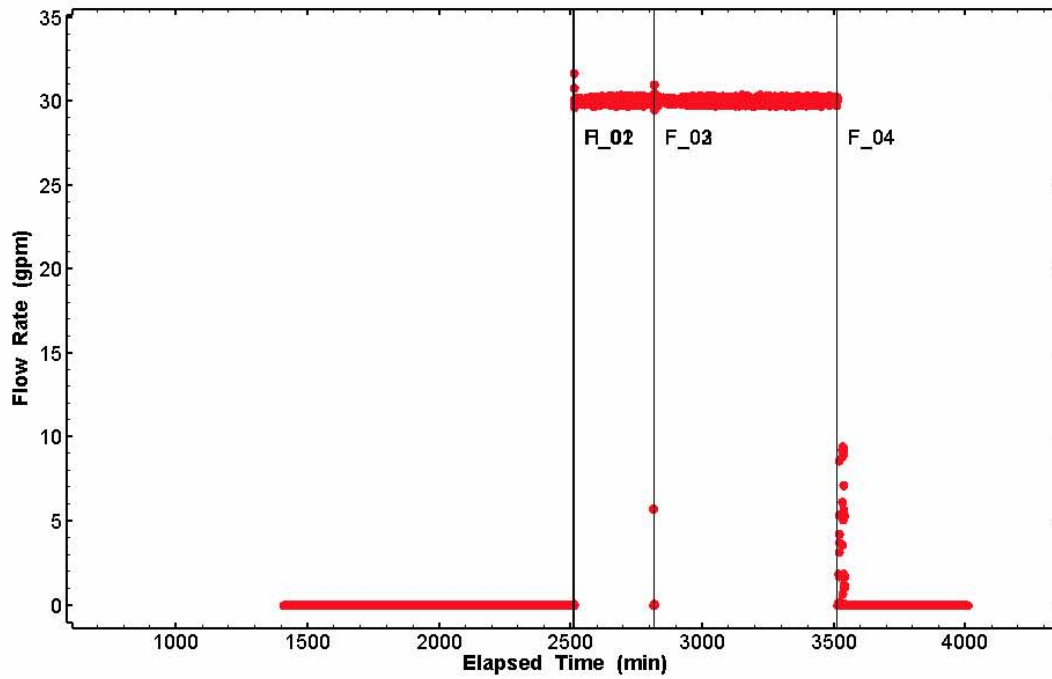
Figure B-53. Flow rates measured during the WIPP-25 testing.

B.10   C-2737 nSIGHTS Listings

```
**********
nPre 2.30Q
**********
```

```
Version date    22 July 2005
Listing date    02 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\C2737\C-2737.nPre
```

Control Settings

Main Settings

```
Simulation type                            Forward
Simulation subtype                          Normal
Phase to simulate                           Liquid
Skin zone ?                                    yes
External boundary                   Fixed Pressure
Curve data source                           Objects
```

Liquid Phase Settings

```
Aquifer type                               Confined
Aquifer horizontal permeability           Isotropic
System porosity                              Single
Compensate flow dimension geometry             yes
Leakage                                        None
```

Test Zone Settings

```
Test zone volume can vary                       no
Test zone compressibility can vary              no
Test zone temperature can vary                  no
Default test-zone temperature         20.00      [C]
Solution variable                          Pressure
Allow negative head/pressure                   yes
```

Parameters

Formation

```
Formation thickness                   23.000     [ft]
Flow dimension                           2.0     []
Static formation pressure             90.241     [psi]
External boundary radius             1000000     [m]
Formation conductivity            9.91966E-08     [m/sec]
Formation spec. storage           5.47899E-07     [1/m]
```

Skin

```
Radial thickness of skin             0.093313    [m]
Skin zone conductivity            2.75487E-07     [m/sec]
```

```
Skin zone spec. storage                    1.86613E-06      [1/m]
```

Fluid

```
Fluid density                                1064.20        [kg/m^3]
Fluid thermal exp. coeff.                  0.00000E+00      [1/C]
```

Test-Zone

```
Well radius                                    3.1205       [in]
Volume change from normal                         0.0       [m^3]
Test-zone compressibility                  1.09951E-07      [1/Pa]
```

Numeric

```
# of radial nodes                                 250       []
# of skin nodes                                    50       []
Pressure solution tolerance                1.45038E-11      [psi]
STP flow solution tolerance                1.58503E-11      [USgpm]
```

Calculated Parameters

Formation

```
Transmissivity                             6.95408E-07      [m^2/sec]
Storativity                                3.84099E-06      []
Diffusivity                                1.81049E-01      [m^2/sec]
```

Skin Zone

```
Transmissivity                             1.93128E-06      [m^2/sec]
Storativity                                1.30823E-05      []
Diffusivity                                1.47625E-01      [m^2/sec]
Skin factor                               -4.97913E-01      []
```

Test Zone

```
Test-zone volume                             0.1383593      [m^3]
Isolated well-bore storage                 1.52128E-08      [m^3/Pa]
```

Grid Properties

```
Grid increment delta                           0.07825      []
First grid increment                       1.40469E-02      [m]
Skin grid increment delta                      0.01588      []
Skin first grid increment                  1.26864E-03      [m]
Skin last grid increment                   2.71870E-03      [m]
Increment ratio                            5.16679E+00      []
```

Sequences

Sequence: H_01

```
  Sequence type                               History
  Start time                               -63.533180       [day]
```

125

```
Duration                              25.573060    [day]
Time step type                           Static
Static time step                       0.500000    [day]
Type                                      Curve
Wellbore storage                        Isolated
```

Sequence: H_02

```
Sequence type                           History
Start time                           -37.960120    [day]
Duration                               0.827080    [day]
Time step type                           Static
Static time step                       0.003000    [day]
Type                                      Curve
Wellbore storage                        Isolated
```

Sequence: H_03

```
Sequence type                           History
Start time                           -37.133040    [day]
Duration                               1.133040    [day]
Time step type                           Static
Static time step                       0.003000    [day]
Type                                      Curve
Wellbore storage                        Isolated
```

Sequence: H_04

```
Sequence type                           History
Start time                           -36.000000    [day]
Duration                              36.004460    [day]
Time step type                           Static
Static time step                       0.100000    [day]
Type                                      Curve
Wellbore storage                        Isolated
```

Sequence: F_01

```
Sequence type                              Flow
Start time                             0.004460    [day]
Duration                               0.434640    [day]
Time step type                             Log
First log step                      1.15741E-07    [day]
# of time steps                             250
Type                                      Fixed
Fixed value                                -0.3    [USgpm]
Wellbore storage                        Isolated
```

Sequence: F_02

```
Sequence type                              Flow
Start time                             0.439100    [day]
Duration                              13.560900    [day]
Time step type                             Log
First log step                      1.15741E-07    [day]
# of time steps                             250
Type                                      Fixed
Fixed value                                 0.0    [USgpm]
```

126

```
Wellbore storage                              Isolated
```

Test Zone Curves

```
Curve object to use                       Create Curve
Curve type                                    Pressure
Start sequence                                    H_01
End sequence                                      H_04
Curve time base                                   Test
Curve Y data units                               [psi]
Curve Y data is log 10                              no
```

Simulation Results Setup

```
Output ID                                          DAT
   Output type                               Pressure
   Pressure capture type                    Test Zone
   Output units                                 [psi]


Output ID                                          DAT
   Output type                              Flow Rate
   Flow rate output type                         Well
   Output units                              [USgpm]
```

C-2737 Optimization Settings

```
**********
nPre 2.30Q
**********


Version date    22 July 2005
Listing date    02 May 2006
QA status       QA:Q
Config file     C:\nSIGHTS\Culebra\C2737\C-2737.nPre
```

Parameters

Formation

```
Formation thickness                      23.000    [ft]
Flow dimension                              2.0     []
Static formation pressure            Optimization
   Minimum value                         85.000    [psi]
   Maximum value                         95.000    [psi]
   Estimate value                        90.241    [psi]
   Range type                             Linear
   Sigma                             1.00000E+00
External boundary radius                1000000    [m]
Formation conductivity               Optimization
   Minimum value                     1.00000E-09    [m/sec]
   Maximum value                     1.00000E-05    [m/sec]
   Estimate value                    9.91966E-08    [m/sec]
   Range type                                Log
   Sigma                             1.00000E+00
```

127

```
Formation spec. storage                Optimization
    Minimum value                       1.00000E-07      [1/m]
    Maximum value                       1.00000E-05      [1/m]
    Estimate value                      5.47899E-07      [1/m]
    Range type                                   Log
    Sigma                               1.00000E+00
```

Skin

```
Radial thickness of skin               Optimization
    Minimum value                           0.0001      [m]
    Maximum value                             10.0      [m]
    Estimate value                        0.093313      [m]
    Range type                                   Log
    Sigma                               1.00000E+00
Skin zone conductivity                 Optimization
    Minimum value                       1.00000E-10      [m/sec]
    Maximum value                       1.00000E-04      [m/sec]
    Estimate value                      2.75487E-07      [m/sec]
    Range type                                   Log
    Sigma                               1.00000E+00
Skin zone spec. storage                Optimization
    Minimum value                       1.00000E-07      [1/m]
    Maximum value                       1.00000E-05      [1/m]
    Estimate value                      1.86613E-06      [1/m]
    Range type                                   Log
    Sigma                               1.00000E+00
```

Fluid

```
Fluid density                            1064.20      [kg/m^3]
Fluid thermal exp. coeff.              0.00000E+00      [1/C]
```

Test-Zone

```
Well radius                              3.1205      [in]
Volume change from normal                   0.0      [m^3]
Test-zone compressibility              Optimization
    Minimum value                       1.00000E-08      [1/Pa]
    Maximum value                       1.00000E-05      [1/Pa]
    Estimate value                      1.09951E-07      [1/Pa]
    Range type                                   Log
    Sigma                               1.00000E+00
```

Numeric

```
# of radial nodes                           250      []
# of skin nodes                              50      []
Pressure solution tolerance            1.45038E-11      [psi]
STP flow solution tolerance            1.58503E-11      [USgpm]
```
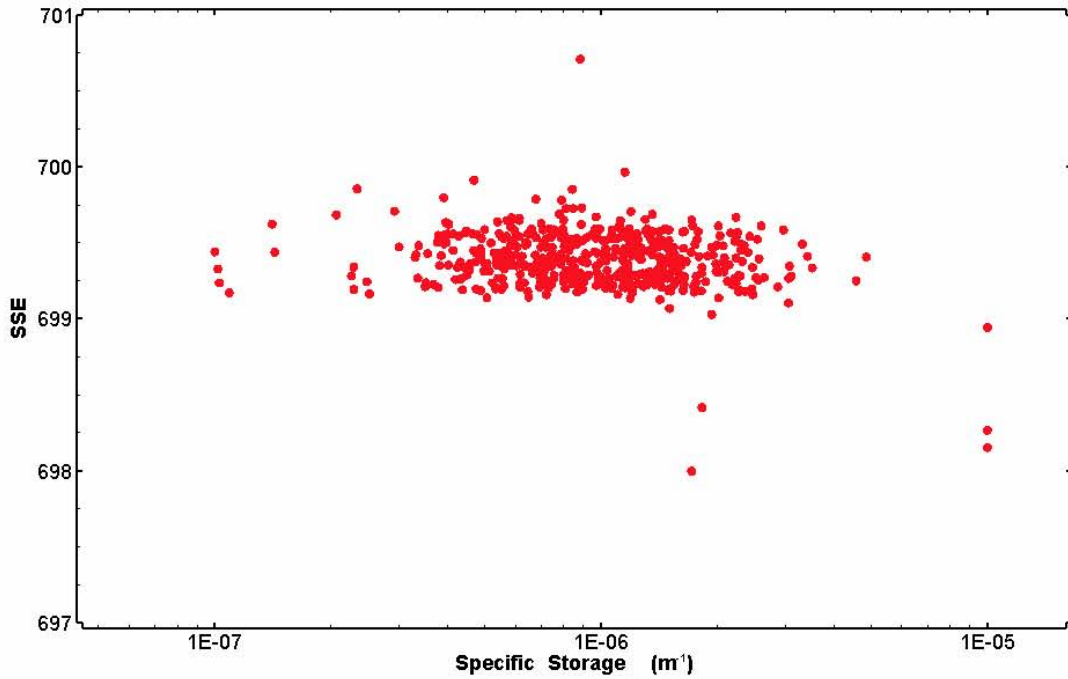
C-2737 Fitting Parameter Estimates

Figure B-54. Estimates of specific storage derived from the C-2737 perturbation analysis.
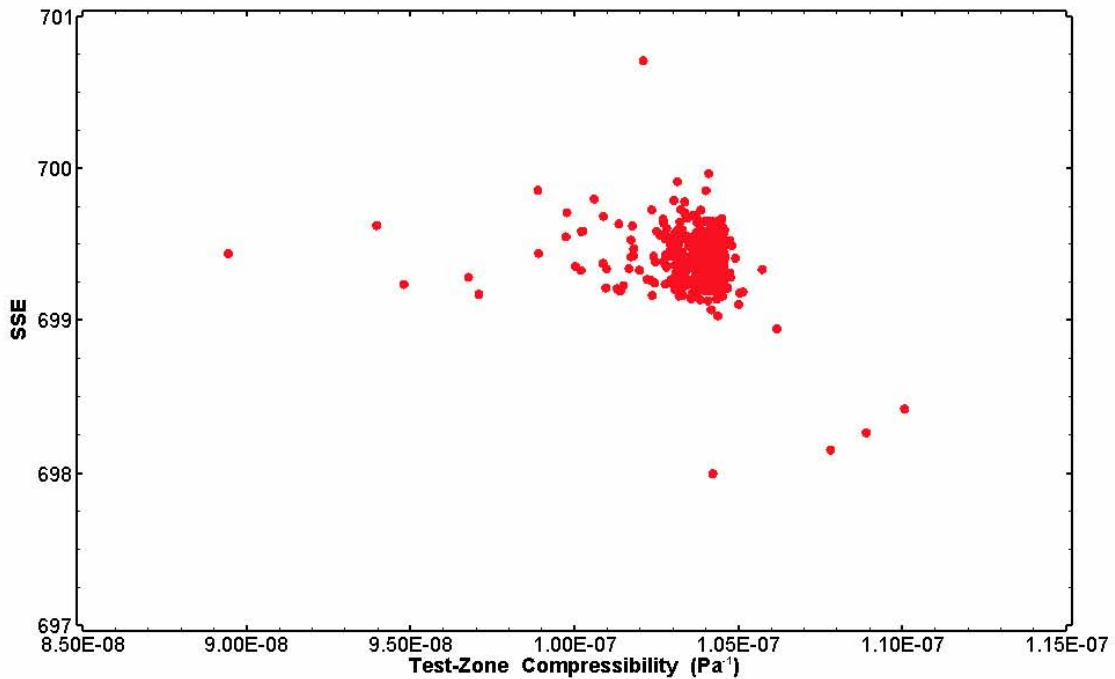

Figure B-55. Estimates of test-zone compressibility derived from the C-2737 perturbation analysis.
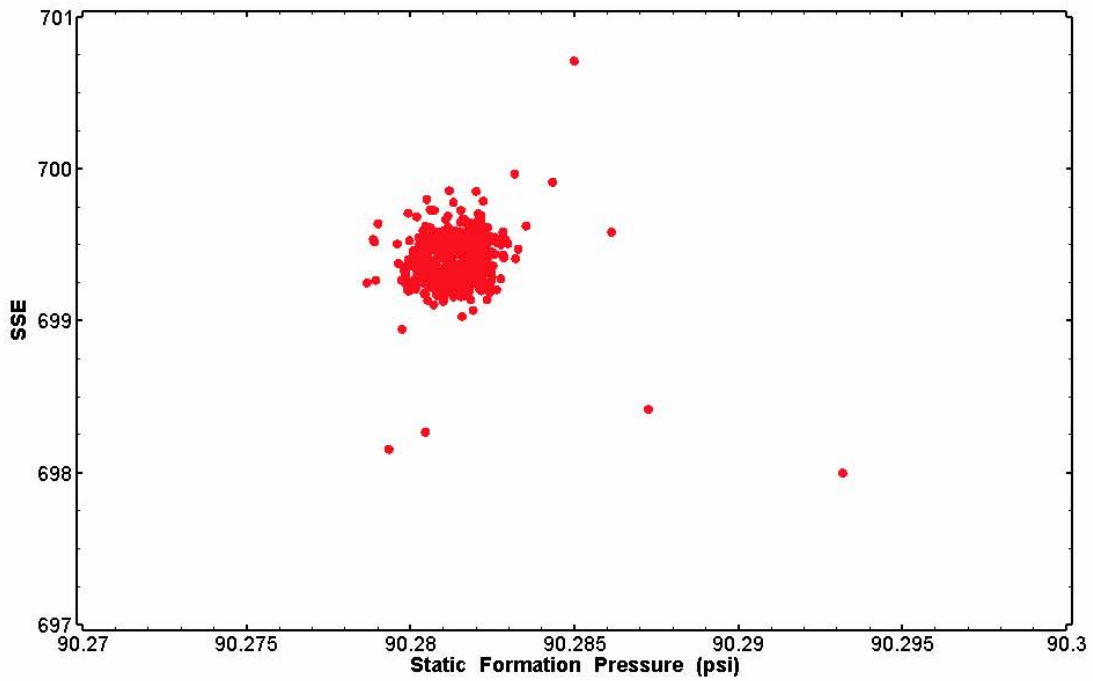
Figure B-56. Estimates of static formation pressure derived from the C-2737 perturbation analysis.
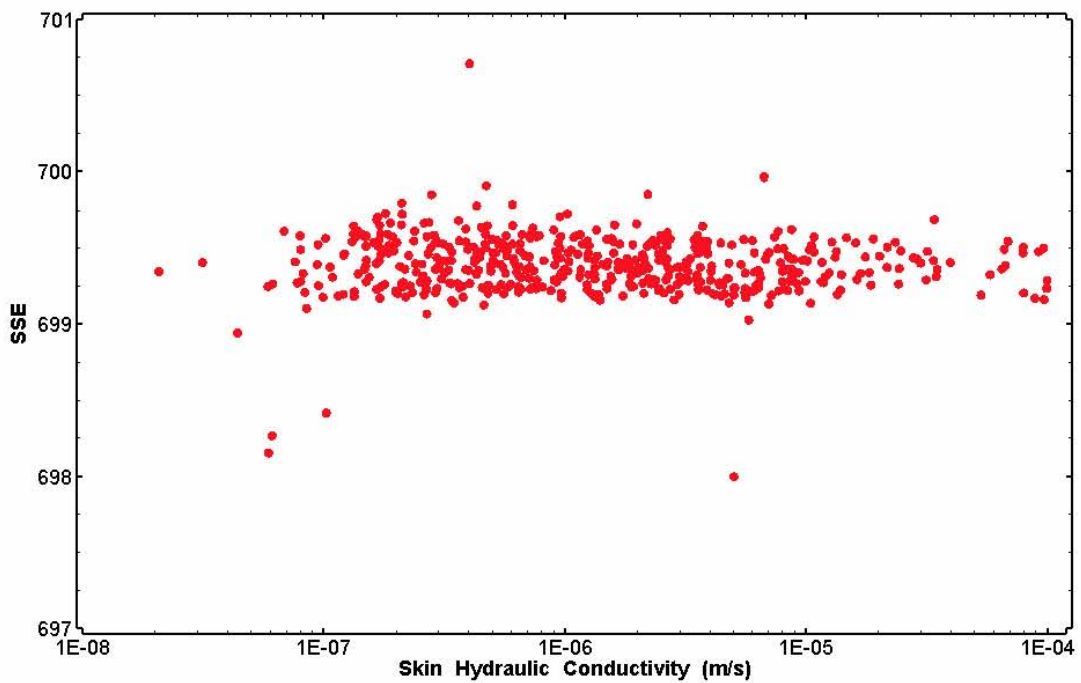

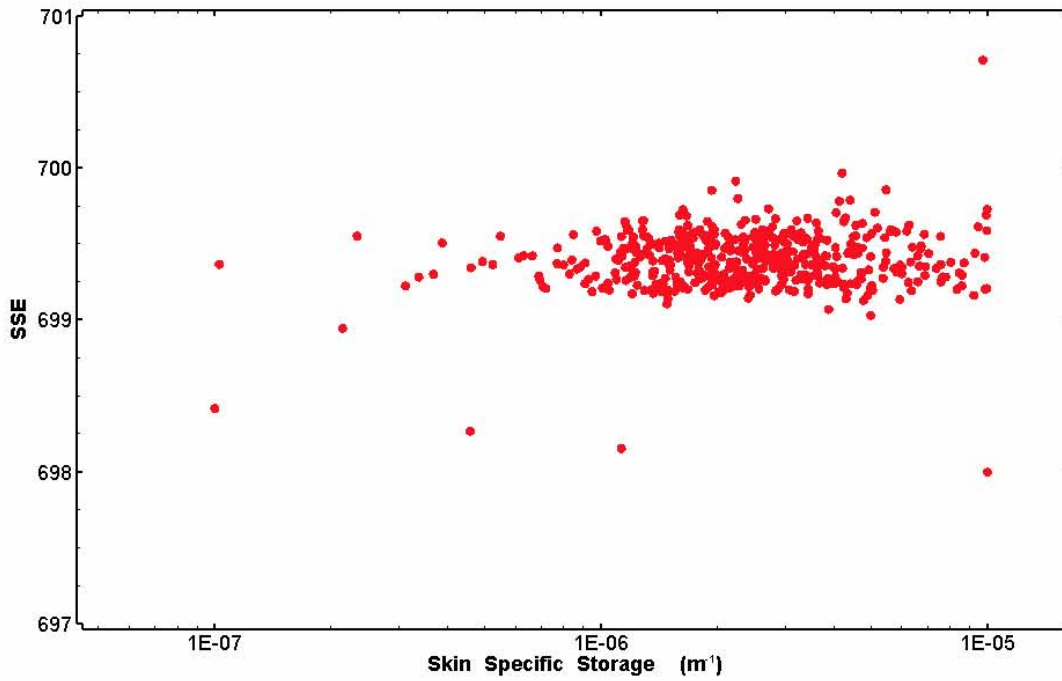**Figure B-57. Estimates of skin hydraulic conductivity derived from the C-2737 perturbation analysis.**

Figure B-58. Estimates of skin specific storage derived from the C-2737 perturbation analysis.
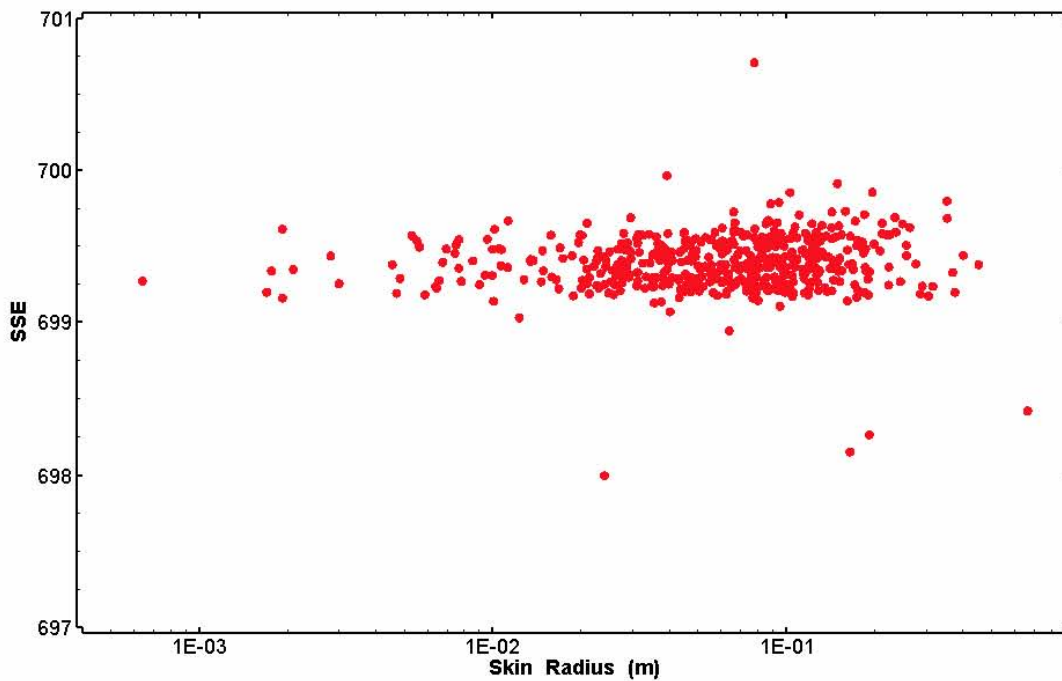

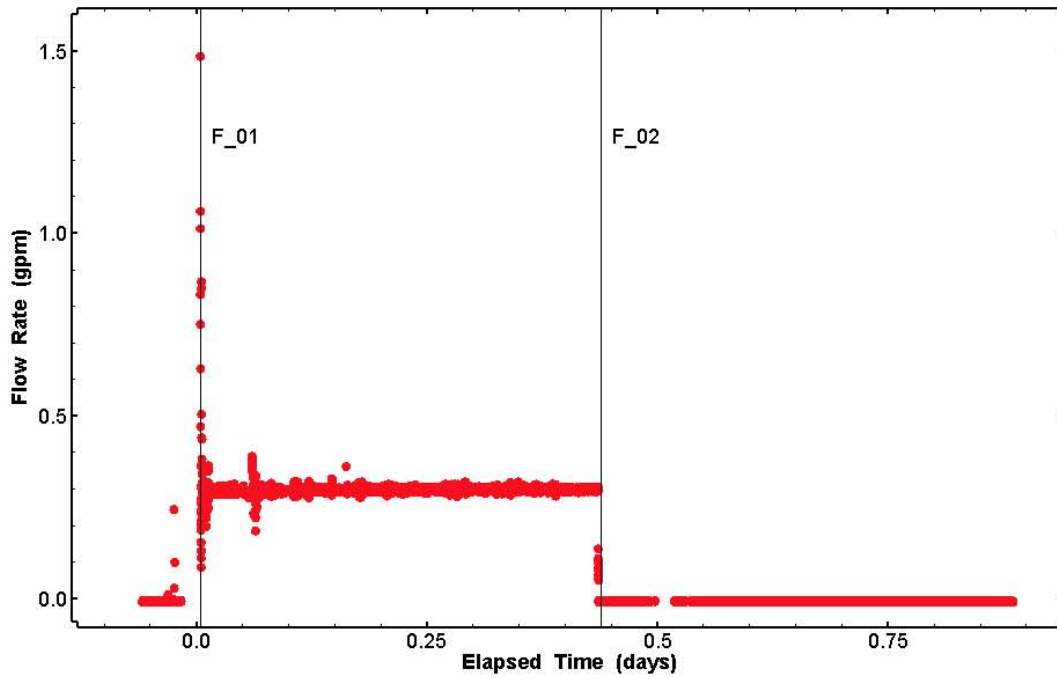**Figure B-59. Estimates of skin radius derived from the C-2737 perturbation analysis.**

131

Figure B-60. Flow rates measured during the C-2737 testing.