Analysis Report for AP-070

Analysis of Culebra and Magenta Hydraulic Tests Performed
Between January 2005 and August 2008

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

Task Number 1.4.2.3

Authors:
Dale O. Bowman, IL, 6712
Repository Performance Department

Randall M. Roberts
HydroResolutions LLC

Technical Review:
Richard L. Beauheim
Repository Performance Department

QA Review:
Shelly Johnson, 6710
Carlsbad Programs Group

Management Review:
Christi Leigh, 6712
Manager, Repository Performance Department

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Contents

1. Introduction .....................................................................................................................................6
2. nSIGHTS Overview ........................................................................................................................7
3. Test and Analysis Procedures .........................................................................................................9
4. Culebra Analysis Results .............................................................................................................11
   4.1 SNL-6 .................................................................................................................................. 11
   4.2 IMC-461 .............................................................................................................................. 16
5. Magenta Analysis Results .............................................................................................................25
   5.1 C-2737 ................................................................................................................................. 25
   5.2 H-11b2 ................................................................................................................................. 32
   5.3 H-15 ..................................................................................................................................... 36
6. References .......................................................................................................................................42

Appendix A – Culebra and Magenta Hydraulic Tests – January 2005 to August 2008 ..................43
Appendix B – nSIGHTS Listings .....................................................................................................45
Appendix C – File Directories .........................................................................................................101

Tables

Table 1. Culebra Transmissivity Estimates ......................................................................................... 11
Table 2. Parameter Estimates Per Slug Test Derived from the IMC-461 Perturbation Analysis ........19
Table 3. Magenta Transmissivity Estimates ....................................................................................... 25

Figures

Figure 1. WIPP stratigraphy .............................................................................................................6
Figure 2. Directory structure for Culebra nSIGHTS analyses .............................................................7
Figure 3. Data folder containing the pressure and flow-rate files for nPre input .................................8
Figure 4. Post folder containing simulation output and post-processed data ..................................8
Figure 5. Locations of tested wells ..................................................................................................9
Figure 6. SNL-6 well configuration during testing .........................................................................12
Figure 7. Pressure data from Culebra in SNL-6 ...........................................................................13
Figure 8. Simulated pressure-history for SNL-6 from well completion records .........................14
Figure 9. X-Y scatter plot showing 497 estimates of transmissivity derived from the SNL-6 perturbation analysis ..................................................15
Figure 10. X-Y scatter plot showing 497 estimates of transmissivity derived from the SNL-6 perturbation analysis ..................................................15
Figure 11. Linear plot showing 497 simulations of the SNL-6 pressure response .........................16
Figure 12. IMC-461 well configuration during testing .................................................................17
Figure 13. Pressure data from slug tests of the Culebra in IMC-461 ...............................................18
Figure 14. Formation transmissivity comparison from IMC-461 slug tests ..................................19
Figure 15. Semilog Ramey A plot showing 187 simulations of the IMC-461 response for slug test 1 ...........................................................................20
Figure 16. Log-log Ramey B plot showing 187 simulations of the IMC-461 response for slug test 1 ...........................................................................20
Figure 17. Semilog Ramey A plot showing 242 simulations of the IMC-461 response for slug test 2 .................................................................21
Figure 18. Log-log Ramey B plot showing 242 simulations of the IMC-461 response for slug test 2 .................................................................21
Figure 19. Semilog Ramey A plot showing 96 simulations of the IMC-461 response for slug test 3 .................................................................22
Figure 20. Log-log Ramey B plot showing 96 simulations of the IMC-461 response for slug test 3 .................................................................22
Figure 21. Semilog Ramey A plot showing 203 simulations of the IMC-461 response for slug test 4 .................................................................23
Figure 22. Log-log Ramey B plot showing 203 simulations of the IMC-461 response for slug test 4 .................................................................23
Figure 23. Semilog Ramey A plot showing 211 simulations of the IMC-461 response for slug test 5 .................................................................24
Figure 24. Log-log Ramey B plot showing 211 simulations of the IMC-461 response for slug test 5 .................................................................24
Figure 25. Configuration of well C-2737 during testing .........................................................................................................................26
Figure 26. Pressure data from slug tests of the Magenta in C-2737 ...........................................................................................................27
Figure 27. XY-scatter plot showing 43 estimates of transmissivity derived from the C-2737 slug-withdrawal test perturbation analysis........28
Figure 28. Linear plot showing 43 simulations of the C-2737 slug-withdrawal test .........................28
Figure 29. Semilog plot showing 43 simulations of the C-2737 slug-withdrawal test Ramey A and derivative response ........................................29
Figure 30. Log-log plot showing 43 simulations of the C-2737 slug-withdrawal test Ramey B and derivative response ........................................29
Figure 31. XY-scatter plot showing 59 estimates of transmissivity derived from the C-2737 slug-injection test perturbation analysis..............30
Figure 32. Linear plot showing 59 simulations of the C-2737 slug-injection test response .................30
Figure 33. Log-log plot showing 59 simulations of the C-2737 slug-injection test Ramey A and derivative response ........................................31
Figure 34. Log-log plot showing 59 simulations of the C-2737 slug-injection test Ramey B and derivative response ........................................31
Figure 35. Configuration of well H-11b2 during testing .........................................................................................................................33
Figure 36. Pressure data from the Magenta pumping test in H-11b2 ..................................................................................................34
Figure 37. Flow-rate data from the Magenta pumping test in H-11b2 ..........................................................................................34
Figure 38. XY-scatter plot showing 97 estimates of transmissivity derived from the H-11b2 perturbation analysis ........................................35
Figure 39. Linear plot showing 97 simulations of the H-11b2 pressure response ..............................35
Figure 40. Log-log plot showing 97 simulations of pressure change and derivative during the H-11b2 pressure-buildup test .........................................36
Figure 41. Configuration of well H-15 during testing ..................................................................................37
Figure 42. Pressure data from the Magenta pumping test in H-15 ..................................................................................................38
Figure 43. Flow-rate data from the Magenta pumping test in H-15 ..........................................................................................38
Figure 44. Log-log diagnostic plot of the H-15 pressure-buildup test ....................................................39
Figure 45. XY-scatter plot showing 96 estimates of transmissivity derived from the H-15 perturbation analysis ..............................................39
Figure 46. Linear plot showing 96 simulations of the H-15 pressure response .....................................40
Figure 47. Log-log plot showing 96 simulations of pressure change and derivative during the H-15 pressure-drawdown test. .................................................................40
Figure 48. Log-log plot showing 96 simulations of pressure change and derivative during the H-15 pressure-buildup test. .................................................................41

Appendix B Figures

Figure B-1. Estimates of static formation pressure and transmissivity derived from the SNL-6 perturbation analysis. .................................................................49
Figure B-2. X-Y scatter plot showing 497 estimates of specific storage derived from the SNL-6 perturbation analysis .................................................................50
Figure B-3. A comparison of skin conductivity estimates for the five IMC-461 slug test perturbation analyses. .................................................................75
Figure B-4. Estimates of formation transmissivity and static formation pressure derived from the C-2737 perturbation analysis .........................................................86
Figure B-5. Estimates of skin zone conductivity and skin zone thickness derived from the C-2737 perturbation analysis .................................................................86
Figure B-6. XY-scatter plot showing 43 estimates of specific storage derived from the C-2737 slug-withdrawal test perturbation analysis .....................................................87
Figure B-7. XY-scatter plot showing 59 estimates of specific storage derived from the C-2737 slug-injection test perturbation analysis.........................................................87
Figure B-8. Estimates of formation transmissivity and static formation pressure derived from the H-11b2 perturbation analysis .................................................................93
Figure B-9. Estimates of skin zone conductivity and skin zone thickness derived from the H-11b2 perturbation analysis .................................................................93
Figure B-10. Estimates of skin hydraulic conductivity and formation transmissivity derived from the H-15 perturbation analysis .........................................................99
Figure B-11. XY-scatter plot showing 96 estimates of specific storage derived from the H-15 perturbation analysis .................................................................99
1. Introduction

This report discusses the analyses of hydraulic tests performed in the Culebra Dolomite and Magenta Members of the Rustler Formation (Figure 1) at the Waste Isolation Pilot Plant (WIPP) site between January 2005 and August 2008. These analyses were performed 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 2.41. 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-6, IMC-461, C-2737, H-11b2, and H-15.

Figure 1. WIPP stratigraphy.
2. nSIGHTS Overview

The nSIGHTS code consists of two independent applications: nPre.exe and nPost.exe. The preprocessor 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 postprocessor, nPost, 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 \texttt{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 \texttt{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 \texttt{nOpt} extension. The corresponding transient pressure simulations are stored in an nPre output file with an \texttt{nXYsim} extension. Both the \texttt{nOpt} and \texttt{nXYsim} files are read by nPost and all of the post-processing results are stored in a configuration file with an \texttt{nPost} extension.

The nSIGHTS input and output files for each tested well are stored in a directory structure like that shown in Figure 2.

![Figure 2. Directory structure for Culebra nSIGHTS analyses.](image)
The nPre configuration file is stored in the folder named for the tested well in a directory named for the strata tested (Figure 2). Transient pressure and flow-rate files are stored in the Data folder (Figure 3) and all nPre output files as well as the nPost configuration file are stored in the Post folder (Figure 4).

Figure 3. Data folder containing the pressure and flow-rate files for nPre input.

Figure 4. Post folder containing simulation output and post-processed data.
3. Test and Analysis Procedures

Slug tests were performed in wells SNL-6, IMC-461, and C-2737 (Figure 5). The SNL-6 slug test of the Culebra was superimposed on the ongoing slow recovery from drilling and completion of the well. The well was bailed for approximately 137 minutes to remove a slug of water, after which a Level TROLL® was installed for monitoring. Five slug tests were conducted on the Culebra in well IMC-461 using compressed nitrogen to depress water levels. After all pressures had stabilized, the pressurized nitrogen was released to initiate each slug test. The C-2737 slug tests of the Magenta used a straddle-packer tool with a downhole shut-in valve. The tool was lowered down hole with empty tubing and then the shut-in valve was opened to perform a slug-withdrawal test. After equilibration, water was added to perform a slug-injection test.

Pumping tests were performed on the Magenta in wells H-11b2 and H-15 (Figure 5). In H-11b2, the Magenta was pumped at a constant rate of approximately 0.2 gallons per minute (gpm) for 2.9 days. In H-15, the Magenta was pumped at a rate of approximately 1.0 gpm for 2.1 days, and then at approximately 1.5 gpm for an additional 0.2 days. Pressure recoveries were monitored in the two wells for periods of 27 and 12 days, respectively.

Figure 5. Locations of tested wells.
All the nSIGHTS test simulations incorporated pre-test pressure records of various durations as “history” periods where the associated pressures were simply specified in the simulations.

Test analysis involved finding the values of the fitting parameters that produced the best simulated matches to the pressure data collected during the slug or constant-rate test and subsequent recovery period. In addition to the formation properties of interest (principally transmissivity \( T \)), tubing string radius was also included as a fitting parameter in the pumping-test analyses 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, however, is relatively small, so any correlation between \( T \) and other fitting parameters is not of concern.

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 sample the parameter space adequately 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 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. The final number of satisfactory perturbation results for each test is reported in the Section 4 and 5 figure captions.
4. Culebra Analysis Results

Discussions of the Culebra test analyses for SNL-6 and IMC-461 are given below. A summary of the transmissivity estimates obtained from perturbation analysis of each test is shown in Table 1. The full range of \( T \) values from which the statistics in Table 1 are derived is presented as a scatter plot in each section below and a full listing is contained within the nPost configuration file for each analysis.

**Table 1. Culebra Transmissivity Estimates.**

<table>
<thead>
<tr>
<th>Culebra Wells</th>
<th>Geometric Mean (m²/s)</th>
<th>Log Geometric Mean (m²/s)</th>
<th>Log Minimum (m²/s)</th>
<th>Log Maximum (m²/s)</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNL-6</td>
<td>8.72E-12</td>
<td>-11.059</td>
<td>-11.064</td>
<td>-11.048</td>
<td>9.77E-7</td>
</tr>
<tr>
<td>IMC-461*</td>
<td>1.92E-4</td>
<td>-3.72</td>
<td>-3.74</td>
<td>-3.68</td>
<td>4.47E-5</td>
</tr>
</tbody>
</table>

*Values are the geometric means of multiple tests described in Table 2.

4.1 SNL-6

The Culebra interval of well SNL-6 was drilled on September 7, 2005, using compressed air with soap mist to remove cuttings (Powers, 2009). The well was completed on September 10, 2005, using 2.88-inch (7.32-cm) outside diameter (OD), 2.48-inch (6.30-cm) inside diameter (ID) fiberglass casing with a 26-ft (7.92-m) section of screen across the Culebra interval (Figure 6). All water was evacuated from the hole or well casing using compressed air on September 8, 10, 13, and 14, 2005.

The Culebra contains halite cements at SNL-6 (Powers et al., 2006), leading to an expectation of very low transmissivity. This expectation was supported by the very slow stabilization of the water level in the well observed since monitoring began with a Level TROLL® on November 18, 2005 (Figure 7). Because of this slow recovery, testing was planned to be superimposed on the existing trend rather than delayed until complete stabilization had occurred. On January 16, 2008, approximately 18 gallons (69 L) of water were bailed from the well over a period of approximately 137 minutes, amounting to an approximately 73-ft (22-m) slug removal. The Level TROLL® was reinstalled approximately 66 minutes later to monitor water-level (or pressure-head) recovery.
NOTE:
1. Depths in feet below ground surface unless otherwise noted.
2. Not to scale.

Figure 6. SNL-6 well configuration during testing.
The nSIGHTS simulation of the SNL-6 test consisted of four sequences that included the entire history of the well from the time the Culebra was drilled on September 7, 2005 through August 27, 2008. A pressure-history sequence was constructed for the period between September 7 and November 18, 2005 from well-completion records (Powers, 2009) and is shown in Figure 8. The Culebra pressure response measured from November 18, 2005 to January 16, 2008 was simulated as a slug-type sequence. The period of slug removal on January 16, 2008 was treated as a pressure-history sequence, and the pressure recovery measured since the Level TROLL® was reinstalled was treated as a slug sequence. The details of each sequence, i.e., start/end time, pressure, etc., are specified in the SNL-6.nPre file and are listed in Appendix B.1. All of the data shown in Figure 7 were used in the SNL-6 regression analysis, i.e., both the initial pressure recovery following drilling and the 2008 slug-test response were simulated.
The SNL-6 data were not suitable for creating a diagnostic plot to help determine the appropriate conceptual model, so the simplest model that was consistent with the geologic observations and produced a satisfactory fit to the data ("satisfactory" as determined by the analyst) was used: an infinite-acting radial system with wellbore storage. The objectives of the analysis included obtaining an estimate of the static formation pressure ($P_f$) of the Culebra at SNL-6 in addition to obtaining an estimate of transmissivity ($T$). The ranges of $T$ and $P_f$ values obtained from perturbation analysis are shown in Figures 9 and 10, respectively. The geometric mean $T$ estimate derived from this analysis was 8.72E-12 m$^2$/s and the geometric mean $P_f$ estimate was 591 psia (relative to the depth of the Level TROLL®). This $P_f$ estimate corresponds to a freshwater head approximately 22 m above ground surface, or an elevation of approximately 1133 m above mean sea level (msl). The simulated SNL-6 Cartesian responses corresponding to the 497 $T$ and $P_f$ values shown in Figures 9 and 10 are shown in Figure 11.
Figure 9. X-Y scatter plot showing 497 estimates of transmissivity derived from the SNL-6 perturbation analysis.

Figure 10. X-Y scatter plot showing 497 estimates of transmissivity derived from the SNL-6 perturbation analysis.
Figure 11. Linear plot showing 497 simulations of the SNL-6 pressure response.

4.2 IMC-461

The configuration of well IMC-461 is shown in Figure 12. A pressure-manifold system was attached to the IMC-461 wellhead on January 25, 2005. With this system, the 2-inch PVC well casing could be pressurized with compressed nitrogen to depress the water level in the well. After the water level was lowered to the desired depth and all pressures had stabilized, the nitrogen was rapidly vented from the well to initiate a slug test. Three such slug tests were performed on January 25, 2005, and two were conducted on January 26, 2005. The slug magnitudes for the first three tests were nominally 40 psi, 40 psi, and 20 psi. The slug magnitudes for the last two tests were nominally 30 and 50 psi.

Figure 13 shows the pressure records from the IMC-461 tests used in this analysis. Pressures prior to and between the slug tests on each day were included in the nSIGHTS simulations as pressure histories; the data from January 25 were not included as histories for the tests conducted on January 26. Each slug test was fit separately using the same model. The details of each sequence, i.e., start/end time, etc., are specified in the IMC-461.nPre files and are listed in Appendix B.2.
Figure 12. IMC-461 well configuration during testing.

NOTE:
1. Depths in feet below ground surface unless otherwise noted.
2. Not to scale.
The IMC-461 conceptual model was an infinite-acting, homogeneous, radial system with wellbore storage and a pressure-dependent skin. The pressure-dependent skin was applied allowing for three zones based on pressure points of 40, 56, and 63 psi to influence skin hydraulic conductivity. This approach was adopted because the small slots in the IMC-461 well screen were believed to be restricting the flow of water at high pressure gradients/velocities. The geometric mean skin hydraulic conductivity ($K_s$) estimates at each pressure point are given in Table 2 for each slug test. Linear interpolation was used to estimate $K_s$ values between the three pressure points. The model provided satisfactory fits to each slug test, but required slightly different parameter values for each, as listed in Table 2.

Table 2 also lists how many of the 500 perturbation runs for each test had low SSE values near the global minimum and produced acceptable fits. The $T$ value for each of those fits is plotted against SSE in Figure 14. The geometric mean $T$ calculated for each test from those fits is given in Table 2. The geometric mean $T$ of the mean $T$ values from each test is 1.92E-4 m²/s. The semilog Ramey A (Ramey et al., 1975) and log-log Ramey B simulations corresponding to the $T$ values shown in Figure 14 are shown in Figures 15 through 24.
Table 2. Parameter Estimates Per Slug Test Derived from the IMC-461 Perturbation Analysis.

<table>
<thead>
<tr>
<th>IMC-461 Slug Test Estimates</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
<th>Test 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin Pressure Zone mean K (m/s) @40 psi</td>
<td>4.05E-7</td>
<td>5.29E-7</td>
<td>1.06E-7</td>
<td>4.58E-7</td>
<td>3.57E-7</td>
</tr>
<tr>
<td>Skin Pressure Zone mean K (m/s) @56 psi</td>
<td>4.72E-7</td>
<td>1.01E-6</td>
<td>1.20E-6</td>
<td>1.21E-6</td>
<td>6.76E-7</td>
</tr>
<tr>
<td>Skin Pressure Zone mean K (m/s) @63 psi</td>
<td>3.74E-6</td>
<td>1.44E-5</td>
<td>9.04E-6</td>
<td>8.43E-6</td>
<td>4.94E-6</td>
</tr>
<tr>
<td>Mean Formation K Estimate (m/s)</td>
<td>2.41E-5</td>
<td>2.11E-5</td>
<td>2.64E-5</td>
<td>2.99E-5</td>
<td>3.06E-5</td>
</tr>
<tr>
<td>Mean Formation T Estimate (m²/s)</td>
<td>1.76E-4</td>
<td>1.55E-4</td>
<td>1.93E-4</td>
<td>2.19E-4</td>
<td>2.24E-4</td>
</tr>
<tr>
<td>Log Mean T (m²/s)</td>
<td>-3.753</td>
<td>-3.81</td>
<td>-3.71</td>
<td>-3.660</td>
<td>-3.65</td>
</tr>
<tr>
<td>Log Minimum T (m²/s)</td>
<td>-3.824</td>
<td>-3.85</td>
<td>-3.73</td>
<td>-3.672</td>
<td>-3.70</td>
</tr>
<tr>
<td>Log Maximum T (m²/s)</td>
<td>-3.748</td>
<td>-3.80</td>
<td>-3.70</td>
<td>-3.656</td>
<td>-3.54</td>
</tr>
<tr>
<td>T Variance</td>
<td>1.20E-4</td>
<td>4.56E-5</td>
<td>1.23E-4</td>
<td>3.76E-6</td>
<td>7.06E-5</td>
</tr>
</tbody>
</table>

Perturbation Runs Accepted 187 242 96 203 211

Figure 14. Formation transmissivity comparison from IMC-461 slug tests.
Figure 15. Semilog Ramey A plot showing 187 simulations of the IMC-461 response for slug test 1.

Figure 16. Log-log Ramey B plot showing 187 simulations of the IMC-461 response for slug test 1.
Figure 17. Semilog Ramey A plot showing 242 simulations of the IMC-461 response for slug test 2.

Figure 18. Log-log Ramey B plot showing 242 simulations of the IMC-461 response for slug test 2.
Figure 19.  Semilog Ramey A plot showing 96 simulations of the IMC-461 response for slug test 3.

Figure 20.  Log-log Ramey B plot showing 96 simulations of the IMC-461 response for slug test 3.
Figure 21. Semilog Ramey A plot showing 203 simulations of the IMC-461 response for slug test 4.

Figure 22. Log-log Ramey B plot showing 203 simulations of the IMC-461 response for slug test 4.
Figure 23. Semilog Ramey A plot showing 211 simulations of the IMC-461 response for slug test 5.

Figure 24. Log-log Ramey B plot showing 211 simulations of the IMC-461 response for slug test 5.
5. Magenta Analysis Results

Discussions of the Magenta test analyses for C-2737 (withdrawal – W and injection – I), H-11b2, and H-15 are given below. A summary of the transmissivity estimates obtained from perturbation analysis of each test is shown in Table 3. The full range of $T$ values from which the statistics in Table 3 are derived is presented as a scatter plot in each section below and a full listing is contained within the nPost configuration file for each analysis.

<table>
<thead>
<tr>
<th>Magenta Wells</th>
<th>Geometric Mean $(m^2/s)$</th>
<th>Log Geometric Mean $(m^2/s)$</th>
<th>Log Minimum $(m^2/s)$</th>
<th>Log Maximum $(m^2/s)$</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-2737 – W</td>
<td>1.11E-7</td>
<td>-6.96</td>
<td>-7.12</td>
<td>-6.91</td>
<td>1.88E-3</td>
</tr>
<tr>
<td>C-2737 – I</td>
<td>1.99E-7</td>
<td>-6.70</td>
<td>-6.71</td>
<td>-6.69</td>
<td>5.35E-6</td>
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<tr>
<td>H-11b2</td>
<td>1.56E-7</td>
<td>-6.81</td>
<td>-6.82</td>
<td>-6.80</td>
<td>6.40E-6</td>
</tr>
<tr>
<td>H-15</td>
<td>9.50E-7</td>
<td>-6.0222</td>
<td>-6.0223</td>
<td>-6.0219</td>
<td>3.62E-9</td>
</tr>
</tbody>
</table>

5.1 C-2737

Hydraulic testing of the Magenta Member of the Rustler Formation in C-2737 occurred between January 10 and 17, 2007, and consisted of a slug-withdrawal test followed by a slug-injection test. All testing was performed using a straddle-packer tool set across the Magenta (Figure 25). The straddle-packer tool was equipped with a downhole shut-in valve configured to be in a closed position except when power was applied to it.

The straddle-packer tool string was installed into C-2737 on January 9, 2007 with the tubing empty of water. On January 10, 2007, the shut-in valve was opened to initiate the slug-withdrawal test. The test proceeded normally until it was terminated on January 15, 2007 by closing the shut-in valve. Approximately 15 gallons (57 L) of fresh water were then added to the tubing above the valve, after which the valve was opened to initiate a slug-injection test. This test continued until January 16, 2007.

Figure 26 shows the pressure record from C-2737 used in this analysis. The pressures measured prior to opening of the shut-in valve on January 10, 2007, were included in a pressure-history period for simulation of the slug-withdrawal test. For simulation of the slug-injection test, all pressures measured prior to opening the shut-in valve on January 15, 2007 (including the slug-withdrawal test), were included in a pressure-history period. The details of each sequence, i.e., start/end time, etc., are specified in the C-2737_first.nPre and C-2737_second.nPre files and are listed in Appendix B.3.
Figure 25. Configuration of well C-2737 during testing.

NOTE:
1. Depths in feet below ground surface unless otherwise noted.
2. Not to scale.

Analysis Report
AP-070
Page 26 of 108
Figure 26. Pressure data from slug tests of the Magenta in C-2737.

The specified C-2737 conceptual model was an infinite-acting, homogeneous, radial system with wellbore storage and skin. Due to an inability to fit the slug-withdrawal and slug-injection tests with identical parameters, each test was fitted with separate simulations. Of the 500 perturbation/optimization runs performed for the slug-withdrawal test, 43 provided satisfactory fits to the data. The range of transmissivity \( T \) values estimated from these 43 runs is shown in Figure 27. The geometric mean \( T \) value was 1.11E-7 m\(^2\)/s. The Cartesian (linear), semilog Ramey A, and log-log Ramey B simulations corresponding to the 43 \( T \) values are shown in Figures 28, 29, and 30, respectively. Of the 500 perturbation/optimization runs performed for the slug-injection test, only 59 provided satisfactory fits to the data. The range of transmissivity \( T \) values estimated from these 59 runs is shown in Figure 31. The geometric mean \( T \) value was 1.99E-7 m\(^2\)/s. The Cartesian (linear), semilog Ramey A, and log-log Ramey B simulations corresponding to the 59 \( T \) values are shown in Figures 32, 33, and 34, respectively.
Figure 27. XY-scatter plot showing 43 estimates of transmissivity derived from the C-2737 slug-withdrawal test perturbation analysis.

Figure 28. Linear plot showing 43 simulations of the C-2737 slug-withdrawal test.
Figure 29. Semilog plot showing 43 simulations of the C-2737 slug-withdrawal test Ramey A and derivative response.

Figure 30. Log-log plot showing 43 simulations of the C-2737 slug-withdrawal test Ramey B and derivative response.
Figure 31. XY-scatter plot showing 59 estimates of transmissivity derived from the C-2737 slug-injection test perturbation analysis.

Figure 32. Linear plot showing 59 simulations of the C-2737 slug-injection test response.
Figure 33. Log-log plot showing 59 simulations of the C-2737 slug-injection test Ramey A and derivative response.

Figure 34. Log-log plot showing 59 simulations of the C-2737 slug-injection test Ramey B and derivative response.
5.2 H-11b2

A pumping test was conducted in well H-11b2 to evaluate the hydraulic properties of the Magenta. The configuration of H-11b2 during the test is shown in Figure 35. Pumping was initiated on April 21, 2008, and continued for approximately 3 days at a nominal rate of 0.2 gpm (1.3E-2 L/s). Pressure recovery was then monitored for the next 27 days. Figure 36 shows the pressure record from H-11b2 used in this analysis, and Figure 37 shows the flow-rate record. The pressures shown in Figure 36 were separated into four nSIGHTS sequences for this analysis. The first 8 hours and final 24 hours of the pumping period were included in the nSIGHTS simulation as pressure-history sequences due to minor irregularities in the pumping rate. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the H-11b2.nPre file and are listed in Appendix B.4.

The specified H-11b2 conceptual model, based on the characteristics of the buildup-period diagnostic plot, was an infinite-acting, homogeneous, radial system with wellbore storage and skin. Of the 500 perturbation/optimization runs performed, 97 provided satisfactory fits to the data. The range of Magenta $T$ values estimated from these 97 runs is shown in Figure 38. The geometric mean $T$ value was 1.56E-7 m$^2$/s. The Cartesian and log-log pressure-buildup diagnostic simulations corresponding to these 97 $T$ values are shown in Figures 39 and 40, respectively.
Figure 35. Configuration of well H-11b2 during testing.

NOTE:
1. Depths in feet below ground surface unless otherwise noted.
2. Not to scale.
Figure 36. Pressure data from the Magenta pumping test in H-11b2.

Figure 37. Flow-rate data from the Magenta pumping test in H-11b2.
Figure 38. XY-scatter plot showing 97 estimates of transmissivity derived from the H-11b2 perturbation analysis.

Figure 39. Linear plot showing 97 simulations of the H-11b2 pressure response.
5.3 H-15

A dual-rate (6.3E-2 and 9.5E-2 L/s [1.0 and 1.5 gpm]) pumping test was initiated in the Magenta in H-15 on March 17, 2008 and continued for approximately 2.3 days, followed by a ~12-day recovery period. The configuration of the well during the test is shown in Figure 41. Figure 42 shows the pressure record from H-15 used in this analysis, and Figure 43 shows the flow-rate record. The pressures shown in Figure 42 were separated into four nSIGHTS sequences for this analysis. The pre-test pressures beginning on March 17, 2008 were included in the nSIGHTS simulation as a pressure history. The pressures measured at the brief transition between the two pumping rates were also included in the nSIGHTS simulation as a pressure history to account for the stabilization of the second pumping rate. The details of each sequence, i.e., start/end time, flow rate, etc., are specified in the H-15(M).nPre file and are listed in Appendix B.5.

The specified H-15 conceptual model, based on the characteristics of the Bourdet diagnostic plot (Bourdet et al., 1989) of the recovery period shown in Figure 44, was an infinite-acting, homogeneous, radial system with wellbore storage and skin. The pressure derivative begins to stabilize around an elapsed time of 7 days (Figure 44). Of the 500 perturbation/optimization runs performed, the 96 with the lowest SSE values were selected as providing the best fits to the data. Figure 45 shows that these 96 runs encompassed a very small range of $T$ values. The geometric mean $T$ value was 9.50E-7 m$^2$/s. The Cartesian, log-log pressure-drawdown, and log-log pressure-buildup diagnostic simulations corresponding to these 96 $T$ values are shown in Figures 46, 47, and 48, respectively.

Figure 40. Log-log plot showing 97 simulations of pressure change and derivative during the H-11b2 pressure-buildup test.
NOTE:
1. Depths in feet below ground surface unless otherwise noted.
2. Not to scale.

Figure 41. Configuration of well H-15 during testing.
Figure 42. Pressure data from the Magenta pumping test in H-15.

Figure 43. Flow-rate data from the Magenta pumping test in H-15.
Figure 44. Log-log diagnostic plot of the H-15 pressure-buildup test.

Figure 45. XY-scatter plot showing 96 estimates of transmissivity derived from the H-15 perturbation analysis.
Figure 46. Linear plot showing 96 simulations of the H-15 pressure response.

Figure 47. Log-log plot showing 96 simulations of pressure change and derivative during the H-15 pressure-drawdown test.
Figure 48. Log-log plot showing 96 simulations of pressure change and derivative during the H-15 pressure-buildup test.
6. References


## Appendix A – Culebra and Magenta Hydraulic Tests – January 2005 to August 2008

<table>
<thead>
<tr>
<th>Well</th>
<th>Date and Time Start DAS</th>
<th>Date and Time Stop DAS</th>
<th>Date and Time Start</th>
<th>Date and Time Stop</th>
<th>Borehole Diameter (in)</th>
<th>Inside Casing Diameter (in)</th>
<th>Interval (ft)</th>
<th>Specific Gravity (g/cm³)</th>
<th>TROLL Filenames</th>
<th>DAS Filenames (ERMS#)</th>
<th>Field Notebook (ERMS#)</th>
<th>Reports</th>
</tr>
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<tbody>
<tr>
<td>SNL-6</td>
<td>9/10/2007 11:00</td>
<td>1/16/2008 10:00</td>
<td>1/16/2008 ~11:05</td>
<td>1/16/2008 ~11:30</td>
<td>7.875</td>
<td>2.48</td>
<td>Culebra 1324-1346.5</td>
<td>1.244</td>
<td>SNL-6 (C3)</td>
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<td>WSWT#12</td>
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Notes:
- WSWT = WIPP Site Well Testing Scientific Notebook
- Magenta = Magenta Hydrology Scientific Notebook
- Bolded Date and Time Start DAS and Stop DAS are actually TROLL file start and stop date and time.
- IMC-461 and C-2737 Date and Time Start and Stop are date and time the slug test was initiated and date and time monitoring of response ended.
- SNL-6 Date and Time Start and Stop are date and time the bailing started and ended.
- H-11b2 and H-15 Date and Time Start and Stop refer to pump.
- Specific gravity for H-11b2 is the last specific gravity of the pumping test.
Appendix B – nSIGHTS Listings

B.1 SNL-6 nSIGHTS Listings

**************
nPre/32 2.41Q
**************

Version date  1 Mar 2007
Listing date   06 Nov 2008
QA status      QA: Q
Config file    C:\SANDIA_PROJECTS\WIPP_wells\Culebra\SNL_6\SNL 6.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 22.500 [ft]
Flow dimension 2.0 []
Static formation pressure 591.613 [psi]
External boundary radius 1000000 [m]
Formation conductivity 1.26760E-12 [m/sec]
Formation spec. storage 1.01082E-05 [1/m]
### Fluid

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<thead>
<tr>
<th>Property</th>
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</thead>
<tbody>
<tr>
<td>Fluid density</td>
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<td>kg/m^3</td>
</tr>
<tr>
<td>Fluid thermal exp. coeff.</td>
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<td>1/C</td>
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</table>

### Test-Zone

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<tr>
<th>Property</th>
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<tbody>
<tr>
<td>Well radius</td>
<td>3.938</td>
<td>in</td>
</tr>
<tr>
<td>Tubing string radius</td>
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### Numeric

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<td># of radial nodes</td>
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</tr>
<tr>
<td>Pressure solution tolerance</td>
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<td>psi</td>
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<tr>
<td>STP flow solution tolerance</td>
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<td>m^3/sec</td>
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### Calculated Parameters

#### Formation

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</thead>
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<td>m^2/sec</td>
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<tr>
<td>Storativity</td>
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</tr>
<tr>
<td>Diffusivity</td>
<td>1.25403E-07</td>
<td>m^2/sec</td>
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</tbody>
</table>

#### Test Zone

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<th>Units</th>
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</thead>
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<td>Open hole well-bore storage</td>
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<td>m^3/Pa</td>
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#### Grid Properties

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<tr>
<td>First grid increment</td>
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### Sequences

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<td>day</td>
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<tr>
<td>Duration</td>
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<td>day</td>
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<td>Time step type</td>
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<tr>
<td>Static time step</td>
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<td>day</td>
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<td>Type</td>
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#### Sequence: S_01

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<td>Sequence type</td>
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<tr>
<td>Start time</td>
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<td>day</td>
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<tr>
<td>Duration</td>
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<td>day</td>
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<tr>
<td>Time step type</td>
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<tr>
<td>First log step</td>
<td>1.15741E-07</td>
<td>day</td>
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<tr>
<td># of time steps</td>
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<td></td>
</tr>
<tr>
<td>Initial pressure type</td>
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<tr>
<td>Initial pressure</td>
<td>60.000</td>
<td>psi</td>
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**Sequence: H_02**

Sequence type: History
Start time: 39463.333337 [day]
Duration: 0.375000 [day]
Time step type: Static
Static time step: 0.000116 [day]
Type: Curve
Wellbore storage: Open

**Sequence: S_02**

Sequence type: Slug
Start time: 39463.708337 [day]
Duration: 223.791663 [day]
Time step type: Log
First log step: 1.15741E-07 [day]
# of time steps: 250
Initial pressure type: Absolute
Initial pressure: 212.100 [psi]

**Test Zone Curves**

Curve object to use: History 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

Curve object to use: Pressure Curve
Curve type: Pressure
Start sequence: H_02
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: [m^3/sec]
SNL-6 Optimization Settings

*************
nPre/32 2.41Q
*************

Version date 1 Mar 2007
Listing date 06 Nov 2008
QA status QA: Q
Config file C:\SANDIA_PROJECTS\WIPP_wells\Culebra\SNL_6\SNL 6.nPre

Control Settings

**Main Settings**
- Simulation type: Optimization
- 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: 22.500 [ft]
- Flow dimension: 2.0
- Static formation pressure Optimization
  - Minimum value: 150.000 [psi]
  - Maximum value: 2000.000 [psi]
  - Estimate value: 591.613 [psi]
  - Range type: Linear
  - Sigma: 1.00000E+00
- External boundary radius: 1000000 [m]
- Formation conductivity Optimization
  - Minimum value: 1.00000E-14 [m/sec]
Maximum value                            1.00000E-07     [m/sec]
Estimate value                           1.26760E-12     [m/sec]
Range type                               Log
Sigma                                    1.00000E+00
Formation spec. storage                    Optimization
Minimum value                            1.00000E-10     [1/m]
Maximum value                            1.00000E-03     [1/m]
Estimate value                           1.01082E-05     [1/m]
Range type                               Log
Sigma                                    1.00000E+00

**Fluid**

Fluid density                                   1244.00     [kg/m^3]
Fluid thermal exp. coeff.                   0.00000E+00     [1/C]

**Test-Zone**

Well radius                                       3.938     [in]
Tubing string radius                               1.24     [in]

**Numeric**

# of radial nodes                                   250     []
Pressure solution tolerance                 1.45038E-11     [psi]
STP flow solution tolerance                 1.00000E-15     [m^3/sec]

Figure B-1. Estimates of static formation pressure and transmissivity derived from the SNL-6 perturbation analysis.
Figure B-2. X-Y scatter plot showing 497 estimates of specific storage derived from the SNL-6 perturbation analysis.
B.2 IMC-461 nSIGHTS Listings

**************
nPre/32 2.41Q
**************

Version date  1 Mar 2007
Listing date   26 Nov 2008
QA status      QA: Q
Config file    C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC_461\IMC_461_firstpulse.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                              24.000     [ft]
Flow dimension                                      2.0     []
Static formation pressure                         60.305     [psi]
External boundary radius                          1000000     [m]
Formation conductivity                      2.43870E-05     [m/sec]
Formation spec. storage                     1.00000E-06     [1/m]

Skin
Radial thickness of skin                         0.0138115     [m]
Skin zone conductivity $f(P)$ point
Skin zone spec. storage $6.36987E-03$ [1/m]

**Fluid**

Fluid density $1008.00$ [kg/m$^3$]
Fluid thermal exp. coeff. $0.00000E+00$ [1/C]

**Test-Zone**

Well radius $2.5625$ [in]
Tubing string radius $0.957$ [in]

**Numeric**

- # of radial nodes $250$ []
- # of skin nodes $50$ []
- Pressure solution tolerance $1.45038E-11$ [psi]
- STP flow solution tolerance $1.00000E-15$ [m$^3$/sec]

**f(x) Points Parameters**

**Skin zone conductivity**

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<th>$Y$ value</th>
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<td>[psi]</td>
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<td>Y value#2</td>
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<td>Pressure #3</td>
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<td>[psi]</td>
<td>$9.03432E-07$ [m/sec]</td>
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Parameter curve type Linear

**Calculated Parameters**

**Formation**

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<tbody>
<tr>
<td>Storativity</td>
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<td>Diffusivity</td>
<td>$2.43870E+01$</td>
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**Skin Zone**

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<td>Diffusivity</td>
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<tr>
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<td>$f(P)$</td>
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**Test Zone**

Open hole well-bore storage $1.87793E-07$ [m$^3$/Pa]

**Grid Properties**

Grid increment delta $0.08219$ []
First grid increment                        6.75834E-03     [m]
Skin grid increment delta                       0.00393     []
Skin first grid increment                   2.56118E-04     [m]
Skin last grid increment                    3.09249E-04     [m]
Increment ratio                             2.18541E+01     []

Sequences

Sequence: H_01
Sequence type                                History
Start time                               38377.430740     [day]
Duration                                     0.026320     [day]
Time step type                                 Static
Static time step                             0.000010     [day]
Type                                            Curve
Wellbore storage                                 None

Sequence: S_01
Sequence type                                 Slug
Start time                               38377.457060     [day]
Duration                                     0.011880     [day]
Time step type                                 Static
Static time step                             0.000010     [day]
Initial pressure type                        Absolute
Initial pressure                               22.119     [psi]

Sequence: H_02
Sequence type                                History
Start time                               38377.468940     [day]
Duration                                     0.203680     [day]
Time step type                                 Static
Static time step                             0.010000     [day]
Type                                            Curve
Wellbore storage                                 None

Test Zone Curves
Curve object to use                        Create 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]
IMC-461 nSIGHTS Optimization Settings – First Pulse

*************
nPre/32 2.41Q
*************

Version date   1 Mar 2007
Listing date   26 Nov 2008
QA status      QA: Q
Config file
C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC_461\IMC_461_firstpulse.nPre

Control Settings

Main Settings
Simulation type                            Optimization
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                              24.000     [ft]
Flow dimension                                   2.0     []
Static formation pressure                       60.305     [psi]
<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>External boundary radius</td>
<td>1000000</td>
<td>[m]</td>
</tr>
<tr>
<td>Formation conductivity</td>
<td>Optimization</td>
<td></td>
</tr>
<tr>
<td>Minimum value</td>
<td>1.00000E-10</td>
<td>[m/sec]</td>
</tr>
<tr>
<td>Maximum value</td>
<td>1.00000E-02</td>
<td>[m/sec]</td>
</tr>
<tr>
<td>Estimate value</td>
<td>2.43870E-05</td>
<td>[m/sec]</td>
</tr>
<tr>
<td>Sigma</td>
<td>1.00000E+00</td>
<td></td>
</tr>
<tr>
<td>Formation spec. storage</td>
<td>1.00000E-06</td>
<td>[1/m]</td>
</tr>
<tr>
<td>Skin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radial thickness of skin</td>
<td>Optimization</td>
<td></td>
</tr>
<tr>
<td>Minimum value</td>
<td>0.001</td>
<td>[m]</td>
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<td>[m]</td>
</tr>
<tr>
<td>Estimate value</td>
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<td>[m]</td>
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<tr>
<td>Sigma</td>
<td>1.00000E+00</td>
<td></td>
</tr>
<tr>
<td>Skin zone conductivity</td>
<td>f(P) point</td>
<td></td>
</tr>
<tr>
<td>Skin zone spec. storage</td>
<td>Optimization</td>
<td></td>
</tr>
<tr>
<td>Minimum value</td>
<td>1.00000E-08</td>
<td>[1/m]</td>
</tr>
<tr>
<td>Maximum value</td>
<td>1.00000E-02</td>
<td>[1/m]</td>
</tr>
<tr>
<td>Estimate value</td>
<td>6.36987E-03</td>
<td>[1/m]</td>
</tr>
<tr>
<td>Sigma</td>
<td>1.00000E+00</td>
<td></td>
</tr>
<tr>
<td>Fluid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluid density</td>
<td>1008.00</td>
<td>[kg/m^3]</td>
</tr>
<tr>
<td>Fluid thermal exp. coeff.</td>
<td>0.00000E+00</td>
<td>[1/C]</td>
</tr>
<tr>
<td>Test-Zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well radius</td>
<td>2.5625</td>
<td>[in]</td>
</tr>
<tr>
<td>Tubing string radius</td>
<td>0.957</td>
<td>[in]</td>
</tr>
<tr>
<td>Numeric</td>
<td></td>
<td></td>
</tr>
<tr>
<td># of radial nodes</td>
<td>250</td>
<td>[]</td>
</tr>
<tr>
<td># of skin nodes</td>
<td>50</td>
<td>[]</td>
</tr>
<tr>
<td>Pressure solution tolerance</td>
<td>1.45038E-11</td>
<td>[psi]</td>
</tr>
<tr>
<td>STP flow solution tolerance</td>
<td>1.00000E-15</td>
<td>[m^3/sec]</td>
</tr>
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</table>

*************
nPre/32 2.41Q
*************

Version date   1 Mar 2007
Listing date   26 Nov 2008
QA status       QA: Q
Config file     C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC_461\IMC_461_secondpulse.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: 24.000 [ft]
- Flow dimension: 2.0
- Static formation pressure: 60.316 [psi]
- External boundary radius: 1000000 [m]
- Formation conductivity: 2.14858E-05 [m/sec]
- Formation spec. storage: 1.00000E-06 [1/m]

**Skin**

- Radial thickness of skin: 0.0244083 [m]
- Skin zone conductivity: f(P) point
- Skin zone spec. storage: 8.63857E-03 [1/m]

**Fluid**

- Fluid density: 1008.00 [kg/m^3]
- Fluid thermal exp. coeff.: 0.00000E+00 [1/C]

**Test-Zone**

- Well radius: 2.5625 [in]
- Tubing string radius: 0.957 [in]
# of radial nodes                                   250     
# of skin nodes                                      50     
Pressure solution tolerance                 1.45038E-11     [psi]  
STP flow solution tolerance                 1.00000E-15     [m^3/sec]  

f(x) Points Parameters

Skin zone conductivity

<table>
<thead>
<tr>
<th>Points type</th>
<th>f(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure #1</td>
<td>275.790     [psi]</td>
</tr>
<tr>
<td>Y value#1</td>
<td>2.04531E-07     [m/sec]</td>
</tr>
<tr>
<td>Pressure #2</td>
<td>386.106     [psi]</td>
</tr>
<tr>
<td>Y value#2</td>
<td>4.32436E-07     [m/sec]</td>
</tr>
<tr>
<td>Pressure #3</td>
<td>434.370     [psi]</td>
</tr>
<tr>
<td>Y value#3</td>
<td>3.44048E-06     [m/sec]</td>
</tr>
</tbody>
</table>

Parameter curve type       Linear

Calculated Parameters

Formation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmissivity</td>
<td>1.57173E-04     [m^2/sec]</td>
</tr>
<tr>
<td>Storativity</td>
<td>7.31520E-06     []</td>
</tr>
<tr>
<td>Diffusivity</td>
<td>2.14858E+01     [m^2/sec]</td>
</tr>
</tbody>
</table>

Skin Zone

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmissivity</td>
<td>f(P)</td>
</tr>
<tr>
<td>Storativity</td>
<td>6.31928E-02     []</td>
</tr>
<tr>
<td>Diffusivity</td>
<td>f(P)</td>
</tr>
<tr>
<td>Skin factor</td>
<td>f(P)</td>
</tr>
</tbody>
</table>

Test Zone

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open hole well-bore storage</td>
<td>1.87793E-07     [m^3/Pa]</td>
</tr>
</tbody>
</table>

Grid Properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid increment delta</td>
<td>0.08155     []</td>
</tr>
<tr>
<td>First grid increment</td>
<td>7.60454E-03     [m]</td>
</tr>
<tr>
<td>Skin grid increment delta</td>
<td>0.00650     []</td>
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<tr>
<td>Skin first grid increment</td>
<td>4.24393E-04     [m]</td>
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<tr>
<td>Skin last grid increment</td>
<td>5.79763E-04     [m]</td>
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<tr>
<td>Increment ratio</td>
<td>1.31166E+01     []</td>
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</tbody>
</table>

Sequences

Sequence: H_01

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence type</td>
<td>History</td>
</tr>
<tr>
<td>Start time</td>
<td>38377.430740     [day]</td>
</tr>
</tbody>
</table>
### Duration

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time step type</td>
<td>Static</td>
</tr>
<tr>
<td>Static time step</td>
<td>0.000010 [day]</td>
</tr>
<tr>
<td>Type</td>
<td>Curve</td>
</tr>
<tr>
<td>Wellbore storage</td>
<td>None</td>
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</table>

### Sequence: S_01

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Sequence type</td>
<td>Slug</td>
</tr>
<tr>
<td>Start time</td>
<td>38377.500350 [day]</td>
</tr>
<tr>
<td>Duration</td>
<td>0.012200 [day]</td>
</tr>
<tr>
<td>Time step type</td>
<td>Static</td>
</tr>
<tr>
<td>Static time step</td>
<td>0.000010 [day]</td>
</tr>
<tr>
<td>Initial pressure type</td>
<td>Absolute</td>
</tr>
<tr>
<td>Initial pressure</td>
<td>22.132 [psi]</td>
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### Sequence: H_02

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<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Sequence type</td>
<td>History</td>
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<tr>
<td>Start time</td>
<td>38377.512550 [day]</td>
</tr>
<tr>
<td>Duration</td>
<td>0.160070 [day]</td>
</tr>
<tr>
<td>Time step type</td>
<td>Log</td>
</tr>
<tr>
<td>First log step</td>
<td>1.15741E-07 [day]</td>
</tr>
<tr>
<td># of time steps</td>
<td>250</td>
</tr>
<tr>
<td>Type</td>
<td>Curve</td>
</tr>
<tr>
<td>Wellbore storage</td>
<td>None</td>
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</table>

### Test Zone Curves

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve object to use</td>
<td>Create Curve</td>
</tr>
<tr>
<td>Curve type</td>
<td>Pressure</td>
</tr>
<tr>
<td>Start sequence</td>
<td>H_01</td>
</tr>
<tr>
<td>End sequence</td>
<td>H_02</td>
</tr>
<tr>
<td>Curve time base</td>
<td>Test</td>
</tr>
<tr>
<td>Curve Y data units</td>
<td>[psi]</td>
</tr>
<tr>
<td>Curve Y data is log 10</td>
<td>no</td>
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</table>

### Simulation Results Setup

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Output ID</td>
<td>DAT</td>
</tr>
<tr>
<td>Output type</td>
<td>Pressure</td>
</tr>
<tr>
<td>Pressure capture type</td>
<td>Test Zone</td>
</tr>
<tr>
<td>Output units</td>
<td>[psi]</td>
</tr>
<tr>
<td>Output ID</td>
<td>DAT</td>
</tr>
<tr>
<td>Output type</td>
<td>Flow Rate</td>
</tr>
<tr>
<td>Flow rate output type</td>
<td>Well</td>
</tr>
<tr>
<td>Output units</td>
<td>[m^3/sec]</td>
</tr>
</tbody>
</table>

### IMC-461 nSIGHTS Optimization Settings – Second Pulse

```
*************
nPre/32 2.41Q
*************
```
Control Settings

Main Settings
Simulation type: Optimization
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: 24.000 [ft]
Flow dimension: 2.0 [ ]
Static formation pressure: 60.316 [psi]
External boundary radius: 1000000 [m]
Formation conductivity: Optimization
  Minimum value: 1.00000E-10 [m/sec]
  Maximum value: 1.00000E-02 [m/sec]
  Estimate value: 2.14858E-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: 0.001 [m]
### Analysis Report

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum value</td>
<td>1.0</td>
<td>[m]</td>
</tr>
<tr>
<td>Estimate value</td>
<td>0.0244083</td>
<td>[m]</td>
</tr>
<tr>
<td>Range type</td>
<td>Linear</td>
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</tr>
<tr>
<td>Sigma</td>
<td>1.00000E+00</td>
<td></td>
</tr>
<tr>
<td>Skin zone conductivity</td>
<td>f(P) point</td>
<td></td>
</tr>
<tr>
<td>Skin zone spec. storage</td>
<td>Optimization</td>
<td></td>
</tr>
<tr>
<td>Minimum value</td>
<td>1.00000E-08</td>
<td>[1/m]</td>
</tr>
<tr>
<td>Maximum value</td>
<td>1.00000E-02</td>
<td>[1/m]</td>
</tr>
<tr>
<td>Estimate value</td>
<td>8.63857E-03</td>
<td>[1/m]</td>
</tr>
<tr>
<td>Range type</td>
<td>Log</td>
<td></td>
</tr>
<tr>
<td>Sigma</td>
<td>1.00000E+00</td>
<td></td>
</tr>
</tbody>
</table>

**Fluid**

- **Fluid density**: 1008.00 [kg/m^3]
- **Fluid thermal exp. coeff.**: 0.00000E+00 [1/C]

**Test-Zone**

- **Well radius**: 2.5625 [in]
- **Tubing string radius**: 0.957 [in]

**Numeric**

- **# of radial nodes**: 250
- **# of skin nodes**: 50
- **Pressure solution tolerance**: 1.45038E-11 [psi]
- **STP flow solution tolerance**: 1.00000E-15 [m^3/sec]

---

*************
nPre/32 2.4.1Q
*************

Version date   1 Mar 2007
Listing date   26 Nov 2008
QA status      QA: Q
Config file    C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC_461\IMC_461_thirdpulse.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  24.000 [ft]
- Flow dimension  2.0 []
- Static formation pressure  60.347 [psi]
- External boundary radius  1000000 [m]
- Formation conductivity  1.77677E-05 [m/sec]
- Formation spec. storage  1.00000E-06 [1/m]

**Skin**
- Radial thickness of skin  0.0389451 [m]
- Skin zone conductivity  f(P) point
- Skin zone spec. storage  6.47239E-03 [1/m]

**Fluid**
- Fluid density  1008.00 [kg/m^3]
- Fluid thermal exp. coeff.  0.00000E+00 [1/°C]

**Test-Zone**
- Well radius  2.5625 [in]
- Tubing string radius  0.957 [in]

**Numeric**
- # of radial nodes  250 []
- # of skin nodes  50 []
- Pressure solution tolerance  1.45038E-11 [psi]
- STP flow solution tolerance  1.00000E-15 [m^3/sec]

**f(x) Points Parameters**

**Skin zone conductivity**
- Points type  f(P)
- Pressure #1  275.790 [psi]
- Y value#1  1.00001E-08 [m/sec]
- Pressure #2  386.106 [psi]
- Y value#2  8.20325E-07 [m/sec]
Pressure #3                                    434.370     [psi]
Y value#3                                  4.84304E-06     [m/sec]

Parameter curve type                              Linear

Calculated Parameters

Formation
Transmissivity                              1.29974E-04     [m^2/sec]
Storativity                                 7.31520E-06     []
Diffusivity                                 1.77677E+01     [m^2/sec]

Skin Zone
Transmissivity                                     f(P)
Storativity                                 4.73469E-02     []
Diffusivity                                        f(P)
Skin factor                                        f(P)

Test Zone
Open hole well-bore storage                 1.87793E-07     [m^3/Pa]

Grid Properties
Grid increment delta                            0.08080     []
First grid increment                        8.75440E-03     [m]
Skin grid increment delta                       0.00957     []
Skin first grid increment                   6.25933E-04     [m]
Skin last grid increment                    9.90931E-04     [m]
Increment ratio                             8.83452E+00     []

Sequences

Sequence: H_01
Sequence type                                 History
Start time                               38377.430740     [day]
Duration                                        0.165630     [day]
Time step type                                 Static
Static time step                             0.000100     [day]
Type                                            Curve
Wellbore storage                                  None

Sequence: S_01
Sequence type                                 Slug
Start time                               38377.596370     [day]
Duration                                        0.010620     [day]
Time step type                                 Static
Static time step                             0.000010     [day]
Initial pressure type                        Absolute
Initial pressure                               40.922     [psi]
**Sequence: H_02**

<table>
<thead>
<tr>
<th>Sequence type</th>
<th>History</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start time</td>
<td>38377.606990 [day]</td>
</tr>
<tr>
<td>Duration</td>
<td>0.065630 [day]</td>
</tr>
<tr>
<td>Time step type</td>
<td>Log</td>
</tr>
<tr>
<td>First log step</td>
<td>1.15741E-07 [day]</td>
</tr>
<tr>
<td># of time steps</td>
<td>250</td>
</tr>
<tr>
<td>Type</td>
<td>Curve</td>
</tr>
<tr>
<td>Wellbore storage</td>
<td>None</td>
</tr>
</tbody>
</table>

**Test Zone Curves**

- Curve object to use: Create 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: [m^3/sec]

**IMC-461 nSIGHTS Optimization Settings – Third Pulse**

*************
nPre/32 2.41Q
*************

Version date: 1 Mar 2007
Listing date: 26 Nov 2008
QA status: QA: Q
Config file: C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC_461\IMC_461_thirdpulse.nPre

**Control Settings**

**Main Settings**

<table>
<thead>
<tr>
<th>Simulation type</th>
<th>Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation subtype</td>
<td>Normal</td>
</tr>
<tr>
<td>Phase to simulate</td>
<td>Liquid</td>
</tr>
<tr>
<td>Skin zone ?</td>
<td>yes</td>
</tr>
</tbody>
</table>
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                              24.000     [ft]  
Flow dimension                                      2.0     []  
Static formation pressure                        60.347     [psi]  
External boundary radius                        1000000     [m]  
Formation conductivity                     Optimization  
Minimum value                            1.00000E-10     [m/sec]  
Maximum value                                    1.00000E-02     [m/sec]  
Estimate value                           1.77677E-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                                0.001     [m]  
Maximum value                                1.0     [m]  
Estimate value                             0.0389451     [m]  
Range type                                    Linear  
Sigma                                    1.00000E+00  
Skin zone conductivity                   f(P) point  
Skin zone spec. storage                    Optimization  
Minimum value                             1.00000E-08     [1/m]  
Maximum value                             1.00000E-02     [1/m]  
Estimate value                            6.47239E-03     [1/m]  
Range type                                    Log  
Sigma                                    1.00000E+00  

**Fluid**

Fluid density                                   1008.00     [kg/m^3]  
Fluid thermal exp. coeff.                   0.00000E+00     [1/C]  

Information Only
**Test-Zone**

Well radius                                      2.5625     [in]
Tubing string radius                              0.957     [in]

**Numeric**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td># of radial nodes</td>
<td>250</td>
</tr>
<tr>
<td># of skin nodes</td>
<td>50</td>
</tr>
<tr>
<td>Pressure solution tolerance</td>
<td>1.45038E-11    [psi]</td>
</tr>
<tr>
<td>STP flow solution tolerance</td>
<td>1.00000E-15    [m^3/sec]</td>
</tr>
</tbody>
</table>

*************
nPre/32 2.41Q
*************

Version date   1 Mar 2007
Listing date   05 Jan 2009
QA status      QA: Q
Config file    C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC_461\IMC_461_fourthpulse.nPre

**Control Settings**

**Main Settings**

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation type</td>
<td>Forward</td>
</tr>
<tr>
<td>Simulation subtype</td>
<td>Normal</td>
</tr>
<tr>
<td>Phase to simulate</td>
<td>Liquid</td>
</tr>
<tr>
<td>Skin zone ?</td>
<td>yes</td>
</tr>
<tr>
<td>External boundary</td>
<td>Fixed Pressure</td>
</tr>
<tr>
<td>Curve data source</td>
<td>Objects</td>
</tr>
</tbody>
</table>

**Liquid Phase Settings**

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquifer type</td>
<td>Confined</td>
</tr>
<tr>
<td>Aquifer horizontal permeability</td>
<td>Isotropic</td>
</tr>
<tr>
<td>System porosity</td>
<td>Single</td>
</tr>
<tr>
<td>Compensate flow dimension geometry</td>
<td>yes</td>
</tr>
<tr>
<td>Leakage</td>
<td>None</td>
</tr>
</tbody>
</table>

**Test Zone Settings**

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test zone volume can vary</td>
<td>no</td>
</tr>
<tr>
<td>Test zone compressibility can vary</td>
<td>no</td>
</tr>
<tr>
<td>Test zone temperature can vary</td>
<td>no</td>
</tr>
<tr>
<td>Default test-zone temperature</td>
<td>20.00 [C]</td>
</tr>
<tr>
<td>Solution variable</td>
<td>Pressure</td>
</tr>
<tr>
<td>Allow negative head/pressure</td>
<td>yes</td>
</tr>
</tbody>
</table>

**Parameters**

**Formation**

Information Only
### Formation
- **Formation thickness**: 24.000 ft
- **Flow dimension**: 2.0
- **Static formation pressure**: 60.266 psi
- **External boundary radius**: 1000000 m
- **Formation conductivity**: 2.99933E-05 m/sec
- **Formation spec. storage**: 1.00000E-06 1/m

### Skin
- **Radial thickness of skin**: 0.0665191 m
- **Skin zone conductivity**: f(P) point
- **Skin zone spec. storage**: 1.53930E-03 1/m

### Fluid
- **Fluid density**: 1008.00 kg/m³
- **Fluid thermal exp. coeff.**: 0.00000E+00 1/C

### Test-Zone
- **Well radius**: 2.5625 in
- **Tubing string radius**: 0.957 in

### Numeric
- **# of radial nodes**: 250
- **# of skin nodes**: 50
- **Pressure solution tolerance**: 1.45038E-11 psi
- **STP flow solution tolerance**: 1.00000E-15 m³/sec

### f(x) Points Parameters
#### Skin zone conductivity
<table>
<thead>
<tr>
<th>Points type</th>
<th>Pressure #1</th>
<th>Y value#1</th>
<th>Pressure #2</th>
<th>Y value#2</th>
<th>Pressure #3</th>
<th>Y value#3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>275.790</td>
<td>4.35066E-07</td>
<td>386.106</td>
<td>7.75374E-07</td>
<td>434.370</td>
<td>3.20684E-06</td>
</tr>
</tbody>
</table>

Parameter curve type: Linear

### Calculated Parameters
#### Formation
- **Transmissivity**: 2.19407E-04 m²/sec
- **Storativity**: 7.31520E-06
- **Diffusivity**: 2.99933E+01 m²/sec

#### Skin Zone
- **Transmissivity**: f(P)
Storativity  \[ 1.12603\times 10^{-02} \]  
Diffusivity  \[ f(P) \]  
Skin factor  \[ f(P) \]

**Test Zone**

Open hole well-bore storage  \[ 1.87793\times 10^{-07} \text{m}^3/\text{Pa} \]

**Grid Properties**

Grid increment delta  \[ 0.07962 \]  
First grid increment  \[ 1.09063\times 10^{-02} \text{m} \]  
Skin grid increment delta  \[ 0.01437 \]  
Skin first grid increment  \[ 9.41999\times 10^{-04} \text{m} \]  
Skin last grid increment  \[ 1.87754\times 10^{-03} \text{m} \]  
Increment ratio  \[ 5.80881\times 10^{00} \]

**Sequences**

**Sequence: H_01**

Sequence type  \[ History \]  
Start time  \[ 38378.367041 \text{day} \]  
Duration  \[ 0.042030 \text{day} \]  
Time step type  \[ Static \]  
Static time step  \[ 0.000100 \text{day} \]  
Type  \[ Curve \]  
Wellbore storage  \[ None \]

**Sequence: S_01**

Sequence type  \[ Slug \]  
Start time  \[ 38378.409071 \text{day} \]  
Duration  \[ 0.006930 \text{day} \]  
Time step type  \[ Static \]  
Static time step  \[ 0.000010 \text{day} \]  
Initial pressure type  \[ Absolute \]  
Initial pressure  \[ 31.384 \text{psi} \]

**Sequence: H_02**

Sequence type  \[ History \]  
Start time  \[ 38378.416001 \text{day} \]  
Duration  \[ 0.159370 \text{day} \]  
Time step type  \[ Static \]  
Static time step  \[ 0.000100 \text{day} \]  
Type  \[ Curve \]  
Wellbore storage  \[ None \]

**Test Zone Curves**

Curve object to use  \[ Create Curve \]  
Curve type  \[ Pressure \]  
Start sequence  \[ H_01 \]  
End sequence  \[ H_02 \]  
Curve time base  \[ Test \]  
Curve Y data units  \[ \text{psi} \]
Curve Y data is log 10

Simulation Results Setup

<table>
<thead>
<tr>
<th>Output ID</th>
<th>DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output type</td>
<td>Pressure</td>
</tr>
<tr>
<td>Pressure capture type</td>
<td>Test Zone</td>
</tr>
<tr>
<td>Output units</td>
<td>[psi]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Output ID</th>
<th>DAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output type</td>
<td>Flow Rate</td>
</tr>
<tr>
<td>Flow rate output type</td>
<td>Well</td>
</tr>
<tr>
<td>Output units</td>
<td>[m^3/sec]</td>
</tr>
</tbody>
</table>

IMC-461 nSIGHTS Optimization Settings – Fourth Pulse

*************
nPre/32 2.41Q
*************

Version date   1 Mar 2007
Listing date   05 Jan 2009
QA status      QA: Q
Config file    C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC_461\IMC_461_fourthpulse.nPre

Control Settings

Main Settings
Simulation type     Optimization
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**: 24.000 [ft]
- **Flow dimension**: 2.0 [
- **Static formation pressure**: 60.266 [psi]
- **External boundary radius**: 1000000 [m]
- **Formation conductivity**
  - Minimum value: 1.00000E-10 [m/sec]
  - Maximum value: 1.00000E-02 [m/sec]
  - Estimate value: 2.99933E-05 [m/sec]
- **Range type**: Log
- **Sigma**: 1.00000E+00
- **Formation spec. storage**: 1.00000E-06 [1/m]

### Skin
- **Radial thickness of skin**
  - Minimum value: 0.001 [m]
  - Maximum value: 1.0 [m]
  - Estimate value: 0.0665191 [m]
  - Range type: Linear
  - Sigma: 1.00000E+00
- **Skin zone conductivity**
  - f(P) point
- **Skin zone spec. storage**
  - Minimum value: 1.00000E-08 [1/m]
  - Maximum value: 1.00000E-02 [1/m]
  - Estimate value: 1.53930E-03 [1/m]
  - Range type: Log
  - Sigma: 1.00000E+00

### Fluid
- **Fluid density**: 1008.00 [kg/m^3]
- **Fluid thermal exp. coeff.**: 0.00000E+00 [1/C]

### Test-Zone
- **Well radius**: 2.5625 [in]
- **Tubing string radius**: 0.957 [in]

### Numeric
- **# of radial nodes**: 250 []
- **# of skin nodes**: 50 []
- **Pressure solution tolerance**: 1.45038E-11 [psi]
- **STP flow solution tolerance**: 1.00000E-15 [m^3/sec]

*************
nPre/32 2.41Q
*************

Version date 1 Mar 2007
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: 24.000 [ft]
Flow dimension: 2.0 []
Static formation pressure: 60.266 [psi]
External boundary radius: 1000000 [m]
Formation conductivity: 3.06077E-05 [m/sec]
Formation spec. storage: 1.00000E-06 [1/m]

Skin
Radial thickness of skin: 0.0279449 [m]
Skin zone conductivity: f(P) point
Skin zone spec. storage: 9.99159E-03 [1/m]

Fluid
Fluid density: 1008.00 [kg/m^3]
Fluid thermal exp. coeff.: 0.00000E+00 [1/C]
**Test-Zone**

Well radius                                      2.5625     [in]  
Tubing string radius                              0.957     [in]

**Numeric**

# of radial nodes                                   250     []  
# of skin nodes                                      50     []  
Pressure solution tolerance                 1.45038E-11     [psi]  
STP flow solution tolerance                 1.00000E-15     [m^3/sec]

---

**f(x) Points Parameters**

**Skin zone conductivity**

<table>
<thead>
<tr>
<th>Points type</th>
<th>f(P)</th>
<th>Pressure #1</th>
<th>275.790     [psi]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y value#1</td>
<td>2.02988E-07     [m/sec]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure #2</td>
<td>386.106     [psi]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y value#2</td>
<td>4.45711E-07     [m/sec]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure #3</td>
<td>434.370     [psi]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y value#3</td>
<td>1.93963E-06     [m/sec]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Parameter curve type  Linear

---

**Calculated Parameters**

**Formation**

Transmissivity                              2.23901E-04     [m^2/sec]  
Storativity                                 7.31520E-06     []  
Diffusivity                                 3.06077E+01     [m^2/sec]

**Skin Zone**

Transmissivity                              f(P)  
Storativity                                 7.30905E-02     []  
Diffusivity                                 f(P)  
Skin factor                                 f(P)  

**Test Zone**

Open hole well-bore storage                 1.87793E-07     [m^3/Pa]

**Grid Properties**

Grid increment delta                         0.08136     []  
First grid increment                        7.88538E-03     [m]  
Skin grid increment delta                   0.00729     []  
Skin first grid increment                   4.76228E-04     [m]  
Skin last grid increment                    6.75749E-04     [m]  
Increment ratio                             1.16691E+01     []
Sequences

**Sequence: H_01**

- **Sequence type**: History
- **Start time**: 38378.367041 [day]
- **Duration**: 0.138749 [day]
- **Time step type**: Static
- **Static time step**: 0.000100 [day]
- **Type**: Curve
- **Wellbore storage**: None

**Sequence: S_01**

- **Sequence type**: Slug
- **Start time**: 38378.505790 [day]
- **Duration**: 0.009160 [day]
- **Time step type**: Static
- **Static time step**: 0.000010 [day]
- **Initial pressure type**: Absolute
- **Initial pressure**: 13.810 [psi]

**Sequence: H_02**

- **Sequence type**: History
- **Start time**: 38378.514950 [day]
- **Duration**: 0.060420 [day]
- **Time step type**: Static
- **Static time step**: 0.000100 [day]
- **Type**: Curve
- **Wellbore storage**: None

Test Zone Curves

- **Curve object to use**: Create 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**: [m^3/sec]
IMC-461 nSIGHTS Optimization Settings – Fifth Pulse

*************
nPre/32 2.41Q
*************

Version date   1 Mar 2007
Listing date   26 Nov 2008
QA status       QA: Q
Config file
C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC_461\IMC_461_fifthpulse.nPre

Control Settings

Main Settings
Simulation type                            Optimization
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                              24.000     [ft]
Flow dimension                                    2.0     []
Static formation pressure                        60.266     [psi]
External boundary radius                        1000000     [m]
Formation conductivity                     Optimization
Minimum value                            1.00000E-10     [m/sec]
Maximum value                            1.00000E-02     [m/sec]
Estimate value                           3.06077E-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 0.001 [m]
Maximum value 1.0 [m]
Estimate value 0.0279449 [m]
Range type Linear
Sigma 1.00000E+00
Skin zone conductivity f(P) point
Skin zone spec. storage Optimization
Minimum value 1.00000E-08 [1/m]
Maximum value 1.00000E-02 [1/m]
Estimate value 9.99159E-03 [1/m]
Range type Log
Sigma 1.00000E+00

Fluid
Fluid density 1008.00 [kg/m^3]
Fluid thermal exp. coeff. 0.00000E+00 [1/C]

Test-Zone
Well radius 2.5625 [in]
Tubing string radius 0.957 [in]

Numeric
# of radial nodes 250 []
# of skin nodes 50 []
Pressure solution tolerance 1.45038E-11 [psi]
STP flow solution tolerance 1.00000E-15 [m^3/sec]
Figure B-3. A comparison of skin conductivity estimates for the five IMC-461 slug test perturbation analyses.
B.3  C-2737 nSIGHTS Listings

**************
nPre/32 2.41Q  
**************

Version date   1 Mar 2007  
Listing date   07 Jan 2009  
QA status      QA: Q  
Config file    C:\SANDIA_PROJECTS\WIPP_wells\Magenta\CopyofC2737\C-2737_first.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 23.300 [ft]
Flow dimension 2.0 []
Static formation pressure 150.683 [psi]
External boundary radius 1000000 [m]
Formation conductivity 2.09942E-08 [m/sec]
Formation spec. storage 8.77373E-06 [l/m]

Skin
Radial thickness of skin 2.9999972 [m]
Skin zone conductivity                      3.36784E-08     [m/sec]
Skin zone spec. storage                     1.00000E-07     [1/m]

Fluid
Fluid density                                   1012.00     [kg/m^3]
Fluid thermal exp. coeff.                   0.00000E+00     [1/C]

Test-Zone
Well radius                                       6.125     [in]
Tubing string radius                              0.995     [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]

Calculated Parameters

Formation
Transmissivity                              1.49097E-07     [m^2/sec]
Storativity                                 6.23096E-05     []
Diffusivity                                 2.39284E-03     [m^2/sec]

Skin Zone
Transmissivity                              2.39179E-07     [m^2/sec]
Storativity                                 7.10185E-07     []
Diffusivity                                 3.36784E-01     [m^2/sec]
Skin factor                                -1.13358E+00     []

Test Zone
Open hole well-bore storage                 2.02200E-07     [m^3/Pa]

Grid Properties
Grid increment delta                         0.06365     []
First grid increment                        2.07382E-01     [m]
Skin grid increment delta                   0.06142     []
Skin first grid increment                  9.85570E-03     [m]
Skin last grid increment                   1.87996E-01     [m]
Increment ratio                             1.10312E+00     []

Sequences

Sequence: H_01
Sequence type                                     History
Start time                                 39091.739900     [day]
Duration                                    0.639270     [day]
Time step type                                Log
First log step: 1.15741E-07 [day]
# of time steps: 250
Type: Curve
Wellbore storage: Open

**Sequence: H_02**

Sequence type: History
Start time: 39092.379170 [day]
Duration: 0.003590 [day]
Time step type: Log
First log step: 1.15741E-07 [day]
# of time steps: 250
Type: Curve
Wellbore storage: Open

**Sequence: S_01**

Sequence type: Slug
Start time: 39092.382760 [day]
Duration: 1.125573 [day]
Time step type: Log
First log step: 1.15741E-03 [day]
# of time steps: 250
Initial pressure type: Absolute
Initial pressure: 51.362 [psi]

**Sequence: H_03**

Sequence type: History
Start time: 39093.508333 [day]
Duration: 4.094447 [day]
Time step type: Log
First log step: 1.15741E-07 [day]
# of time steps: 250
Type: Curve
Wellbore storage: Open

**Sequence: H_04**

Sequence type: History
Start time: 39097.602780 [day]
Duration: 2.518054 [day]
Time step type: Log
First log step: 1.15741E-07 [day]
# of time steps: 250
Type: Curve
Wellbore storage: Open

**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 Slug-Withdrawal Optimization Settings

*************
nPre/32 2.41Q
*************

Version date   1 Mar 2007
Listing date   07 Jan 2009
QA status      QA: Q
Config file    C:\SANDIA_PROJECTS\WIPP_wells\Magenta\CopyofC2737\C-2737_first.nPre

Control Settings

Main Settings
Simulation type                            Optimization
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**: 23.300 [ft]
- **Flow dimension**: 2.0 []
- **Static formation pressure**: Optimization
  - Minimum value: 140.000 [psi]
  - Maximum value: 165.000 [psi]
  - Estimate value: 150.683 [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: 2.09942E-08 [m/sec]
  - Range type: Log
  - Sigma: 1.00000E+00
- **Formation spec. storage**: Optimization
  - Minimum value: 1.00000E-07 [1/m]
  - Maximum value: 1.00000E-04 [1/m]
  - Estimate value: 8.77373E-06 [1/m]
  - Range type: Log
  - Sigma: 1.00000E+00

**Skin**

- **Radial thickness of skin**: Optimization
  - Minimum value: 0.0001 [m]
  - Maximum value: 3.0 [m]
  - Estimate value: 2.9999972 [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: 3.36784E-08 [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: 1.00000E-07 [1/m]
  - Range type: Log
  - Sigma: 1.00000E+00

**Fluid**

- **Fluid density**: 1012.00 [kg/m^3]
- **Fluid thermal exp. coeff.**: 0.00000E+00 [1/C]

**Test-Zone**

- **Well radius**: 6.125 [in]
- **Tubing string radius**: 0.995 [in]
### Numeric

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td># of radial nodes</td>
<td>250</td>
</tr>
<tr>
<td># of skin nodes</td>
<td>50</td>
</tr>
<tr>
<td>Pressure solution tolerance</td>
<td>1.45038E-11 [psi]</td>
</tr>
<tr>
<td>STP flow solution tolerance</td>
<td>1.58503E-11 [USgpm]</td>
</tr>
</tbody>
</table>

*************
nPre/32 2.41Q
*************

Version date   1 Mar 2007  
Listing date   07 Jan 2009  
QA status      QA: Q  
Config file    C:\SANDIA_PROJECTS\WIPP_wells\Magenta\CopyofC2737\C-2737_second.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**: 23.300 [ft]  
- **Flow dimension**: 2.0 []  
- **Static formation pressure**: 151.358 [psi]
External boundary radius                        1000000     [m]
Formation conductivity                      2.94316E-08     [m/sec]
Formation spec. storage                     6.84488E-06     [1/m]

**Skin**
Radial thickness of skin                      0.1188325     [m]
Skin zone conductivity                      2.42957E-08     [m/sec]
Skin zone spec. storage                     6.15783E-06     [1/m]

**Fluid**
Fluid density                                   1000.00     [kg/m^3]
Fluid thermal exp. coeff.                   0.00000E+00     [1/C]

**Test-Zone**
Well radius                                       6.125     [in]
Tubing string radius                              0.995     [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]

**Calculated Parameters**

**Formation**
Transmissivity                              2.09019E-07     [m^2/sec]
Storativity                                 4.86113E-05     []
Diffusivity                                 4.29980E-03     [m^2/sec]

**Skin Zone**
Transmissivity                              1.72544E-07     [m^2/sec]
Storativity                                 4.37319E-05     []
Diffusivity                                 3.94550E-03     [m^2/sec]
Skin factor                                 1.19962E-01     []

**Test Zone**
Open hole well-bore storage                 2.04627E-07     [m^3/Pa]

**Grid Properties**
Grid increment delta                          0.07592     []
First grid increment                         2.16451E-02     [m]
Skin grid increment delta                     0.01158     []
Skin first grid increment                    1.81224E-03     [m]
Skin last grid increment                     3.15968E-03     [m]
Increment ratio                              6.85041E+00     []
## Sequences

### Sequence: H_01

<table>
<thead>
<tr>
<th>Sequence type</th>
<th>History</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start time</td>
<td>39091.739900 [day]</td>
</tr>
<tr>
<td>Duration</td>
<td>0.639270 [day]</td>
</tr>
<tr>
<td>Time step type</td>
<td>Log</td>
</tr>
<tr>
<td>First log step</td>
<td>1.15741E-07 [day]</td>
</tr>
<tr>
<td># of time steps</td>
<td>250</td>
</tr>
<tr>
<td>Type</td>
<td>Curve</td>
</tr>
<tr>
<td>Wellbore storage</td>
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<th>History</th>
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</thead>
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<tr>
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</tr>
<tr>
<td>Duration</td>
<td>0.003590 [day]</td>
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<tr>
<td>Time step type</td>
<td>Log</td>
</tr>
<tr>
<td>First log step</td>
<td>1.15741E-07 [day]</td>
</tr>
<tr>
<td># of time steps</td>
<td>250</td>
</tr>
<tr>
<td>Type</td>
<td>Curve</td>
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<tr>
<td>Wellbore storage</td>
<td>Open</td>
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### Sequence: H_03

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<td>Log</td>
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<tr>
<td>First log step</td>
<td>1.15741E-07 [day]</td>
</tr>
<tr>
<td># of time steps</td>
<td>250</td>
</tr>
<tr>
<td>Type</td>
<td>Curve</td>
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<td>Wellbore storage</td>
<td>Open</td>
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### Sequence: H_04

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<td>Duration</td>
<td>0.004170 [day]</td>
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<tr>
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<td>Log</td>
</tr>
<tr>
<td>First log step</td>
<td>1.15741E-07 [day]</td>
</tr>
<tr>
<td># of time steps</td>
<td>250</td>
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<tr>
<td>Type</td>
<td>Curve</td>
</tr>
<tr>
<td>Wellbore storage</td>
<td>Open</td>
</tr>
</tbody>
</table>

### Sequence: S_01

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<tr>
<td>Duration</td>
<td>1.397220 [day]</td>
</tr>
<tr>
<td>Time step type</td>
<td>Log</td>
</tr>
<tr>
<td>First log step</td>
<td>1.15741E-07 [day]</td>
</tr>
<tr>
<td># of time steps</td>
<td>250</td>
</tr>
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<td>Initial pressure type</td>
<td>Absolute</td>
</tr>
<tr>
<td>Initial pressure</td>
<td>182.669 [psi]</td>
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Test Zone Curves

Curve object to use                Create Curve
Curve type                        Pressure
Start sequence                    H_01
End sequence                      S_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]

C-2737 Slug-Injection Optimization Settings

*************
nPre/32 2.41Q
*************

Version date 1 Mar 2007
Listing date 07 Jan 2009
QA status QA: Q
Config file C:\SANDIA_PROJECTS\WIPP_wells\Magenta\CopyofC2737\C-2737_second.nPre

Control Settings

Main Settings

Simulation type                  Optimization
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**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Test zone volume can vary</td>
<td>no</td>
</tr>
<tr>
<td>Test zone compressibility can vary</td>
<td>no</td>
</tr>
<tr>
<td>Test zone temperature can vary</td>
<td>no</td>
</tr>
<tr>
<td>Default test-zone temperature</td>
<td>20.00 [C]</td>
</tr>
<tr>
<td>Solution variable</td>
<td>Pressure</td>
</tr>
<tr>
<td>Allow negative head/pressure</td>
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</table>

**Parameters**

**Formation**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formation thickness</td>
<td>23.300 [ft]</td>
</tr>
<tr>
<td>Flow dimension</td>
<td>2.0[]</td>
</tr>
<tr>
<td>Static formation pressure</td>
<td>Optimization</td>
</tr>
<tr>
<td>Minimum value</td>
<td>140.000 [psi]</td>
</tr>
<tr>
<td>Maximum value</td>
<td>165.000 [psi]</td>
</tr>
<tr>
<td>Estimate value</td>
<td>151.358 [psi]</td>
</tr>
<tr>
<td>Range type</td>
<td>Linear</td>
</tr>
<tr>
<td>Sigma</td>
<td>1.000000E+00</td>
</tr>
<tr>
<td>External boundary radius</td>
<td>1000000 [m]</td>
</tr>
<tr>
<td>Formation conductivity</td>
<td>Optimization</td>
</tr>
<tr>
<td>Minimum value</td>
<td>1.000000E-09 [m/sec]</td>
</tr>
<tr>
<td>Maximum value</td>
<td>1.000000E-05 [m/sec]</td>
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<tr>
<td>Estimate value</td>
<td>2.94316E-08 [m/sec]</td>
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<tr>
<td>Range type</td>
<td>Log</td>
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<tr>
<td>Sigma</td>
<td>1.000000E+00</td>
</tr>
<tr>
<td>Formation spec. storage</td>
<td>Optimization</td>
</tr>
<tr>
<td>Minimum value</td>
<td>1.000000E-07 [1/m]</td>
</tr>
<tr>
<td>Maximum value</td>
<td>1.000000E-04 [1/m]</td>
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<tr>
<td>Estimate value</td>
<td>6.84488E-06 [1/m]</td>
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<td>Range type</td>
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<tr>
<td>Sigma</td>
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**Skin**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Radial thickness of skin</td>
<td>0.1188325 [m]</td>
</tr>
<tr>
<td>Skin zone conductivity</td>
<td>2.42957E-08 [m/sec]</td>
</tr>
<tr>
<td>Skin zone spec. storage</td>
<td>6.15783E-06 [1/m]</td>
</tr>
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</table>

**Fluid**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Fluid density</td>
<td>1000.00 [kg/m^3]</td>
</tr>
<tr>
<td>Fluid thermal exp. coeff.</td>
<td>0.000000E+00 [1/C]</td>
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</table>

**Test-Zone**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Well radius</td>
<td>6.125 [in]</td>
</tr>
<tr>
<td>Tubing string radius</td>
<td>0.995 [in]</td>
</tr>
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</table>

**Numeric**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td># of radial nodes</td>
<td>250[]</td>
</tr>
<tr>
<td># of skin nodes</td>
<td>50[]</td>
</tr>
<tr>
<td>Pressure solution tolerance</td>
<td>1.45038E-11 [psi]</td>
</tr>
<tr>
<td>STP flow solution tolerance</td>
<td>1.58503E-11 [USgpm]</td>
</tr>
</tbody>
</table>
Figure B-4. Estimates of formation transmissivity and static formation pressure derived from the C-2737 perturbation analysis.

Figure B-5. Estimates of skin zone conductivity and skin zone thickness derived from the C-2737 perturbation analysis.
Figure B-6. XY-scatter plot showing 43 estimates of specific storage derived from the C-2737 slug-withdrawal test perturbation analysis.

Figure B-7. XY-scatter plot showing 59 estimates of specific storage derived from the C-2737 slug-injection test perturbation analysis.
B.4  H-11b2 nSIGHTS Listings

***************
nPre/32 2.41Q
***************

Version date   1 Mar 2007
Listing date   14 Jan 2009
QA status      QA: Q
Config file    C:\SANDIA_PROJECTS\WIPP_wells\Magenta\H-11b2\h-11b2 (m).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                              26.000     [ft]
Flow dimension                                      2.0     []
Static formation pressure                       171.942     [psi]
External boundary radius                        1000000     [m]
Formation conductivity                      1.97204E-08     [m/sec]
Formation spec. storage                     1.00000E-08     [1/m]

Skin
Radial thickness of skin                      0.1068659     [m]
Skin zone conductivity                        1.94818E-03     [m/sec]
### Skin zone spec. storage

9.92250E-03 [1/m]

### Fluid

<table>
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<th>Property</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Fluid density</td>
<td>1041.00</td>
<td>kg/m^3</td>
</tr>
<tr>
<td>Fluid thermal exp. coeff.</td>
<td>0.00000E+00</td>
<td>1/C</td>
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</table>

### Test-Zone

<table>
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<tr>
<th>Property</th>
<th>Value</th>
<th>Unit</th>
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<tr>
<td>Well radius</td>
<td>3.9375</td>
<td>in</td>
</tr>
<tr>
<td>Tubing string radius</td>
<td>0.795</td>
<td>in</td>
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### Numeric

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
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<td>250</td>
<td>[]</td>
</tr>
<tr>
<td># of skin nodes</td>
<td>50</td>
<td>[]</td>
</tr>
<tr>
<td>Pressure solution tolerance</td>
<td>1.45038E-11</td>
<td>psi</td>
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<tr>
<td>STP flow solution tolerance</td>
<td>1.58503E-11</td>
<td>USgpm</td>
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### Calculated Parameters

#### Formation

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<tr>
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<tbody>
<tr>
<td>Transmissivity</td>
<td>1.56280E-07</td>
<td>m^2/sec</td>
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<tr>
<td>Storativity</td>
<td>7.92480E-08</td>
<td>[]</td>
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<tr>
<td>Diffusivity</td>
<td>1.97204E+00</td>
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#### Skin Zone

<table>
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<tr>
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<th>Unit</th>
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<tr>
<td>Transmissivity</td>
<td>1.54389E-02</td>
<td>m^2/sec</td>
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<tr>
<td>Storativity</td>
<td>7.86338E-02</td>
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<tr>
<td>Diffusivity</td>
<td>1.96340E-01</td>
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#### Test Zone

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<tbody>
<tr>
<td>Open hole well-bore storage</td>
<td>1.25487E-07</td>
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#### Grid Properties

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<td>First grid increment</td>
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<td>[m]</td>
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<td>Skin grid increment delta</td>
<td>0.01483</td>
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<tr>
<td>Skin first grid increment</td>
<td>1.49458E-03</td>
<td>[m]</td>
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<tr>
<td>Skin last grid increment</td>
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### Sequences

#### Sequence: H_01

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<th>Value</th>
<th>Unit</th>
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<td>Sequence type</td>
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<td>History</td>
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<td>Start time</td>
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<td>[day]</td>
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<tr>
<td>Duration</td>
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<td>[day]</td>
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<td>Time step type</td>
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</tr>
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<td>Static time step</td>
<td>0.000116</td>
<td>[day]</td>
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Type                                         Curve
Wellbore storage                             None

**Sequence: H_02**

Sequence type: History
Start time: 39559.611110 [day]
Duration: 0.346400 [day]
Time step type: Log
First log step: 1.15741E-07 [day]
# of time steps: 250
Type: Curve
Wellbore storage: Open

**Sequence: F_01**

Sequence type: Flow
Start time: 39559.957510 [day]
Duration: 1.734160 [day]
Time step type: Log
First log step: 1.15741E-07 [day]
# of time steps: 250
Type: Fixed
Fixed value: -0.2 [USgpm]
Wellbore storage: Open

**Sequence: H_03**

Sequence type: History
Start time: 39561.691670 [day]
Duration: 0.904860 [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: 39562.596530 [day]
Duration: 27.111803 [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: Create Curve
Curve type: Pressure
Start sequence: H_01
End sequence: F_02
Curve time base: Test
Curve Y data units: [psi]
Curve Y data is log 10: no
Simulation Results Setup

Parameters:
- **Output ID**
- **Output type**
- **Pressure capture type**
- **Output units**

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<tr>
<th>Output ID</th>
<th>DAT</th>
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<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

H-11b2 nSIGHTS Optimization Settings

- **Version date**: 1 Mar 2007
- **Listing date**: 14 Jan 2009
- **QA status**: QA: Q
- **Config file**: C:\SANDIA_PROJECTS\WIPP_wells\Magenta\H-11b2\h-11b2 (m).nPre

Control Settings

**Main Settings**

- **Simulation type**: Optimization
- **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**

<table>
<thead>
<tr>
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<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Test zone volume can vary</td>
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</tr>
<tr>
<td>Test zone compressibility can vary</td>
<td>no</td>
</tr>
<tr>
<td>Test zone temperature can vary</td>
<td>no</td>
</tr>
<tr>
<td>Default test-zone temperature</td>
<td>20.00 [C]</td>
</tr>
<tr>
<td>Solution variable</td>
<td>Pressure</td>
</tr>
<tr>
<td>Allow negative head/pressure</td>
<td>yes</td>
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</table>
## Parameters

### Formation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formation thickness</td>
<td>26.000</td>
<td>ft</td>
</tr>
<tr>
<td>Flow dimension</td>
<td>2.0</td>
<td></td>
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<tr>
<td>Static formation pressure</td>
<td>Optimization</td>
<td></td>
</tr>
<tr>
<td>Minimum value</td>
<td>165.000</td>
<td>psi</td>
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<tr>
<td>Maximum value</td>
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<td>psi</td>
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<td>m/sec</td>
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</tr>
<tr>
<td>Sigma</td>
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</tr>
<tr>
<td>Formation spec. storage</td>
<td>1.00000E-08</td>
<td>1/m</td>
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</tbody>
</table>

### Skin

<table>
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</tr>
</thead>
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<tr>
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<td>Optimization</td>
<td></td>
</tr>
<tr>
<td>Minimum value</td>
<td>0.001</td>
<td>m</td>
</tr>
<tr>
<td>Maximum value</td>
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<td>Sigma</td>
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<tr>
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<tr>
<td>Minimum value</td>
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<td>m/sec</td>
</tr>
<tr>
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<td>m/sec</td>
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<td>Sigma</td>
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<tr>
<td>Minimum value</td>
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<tr>
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### Fluid

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<tr>
<td>Fluid density</td>
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<td>kg/m^3</td>
</tr>
<tr>
<td>Fluid thermal exp. coeff.</td>
<td>0.00000E+00</td>
<td>1/C</td>
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### Test-Zone

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well radius</td>
<td>3.9375</td>
<td>in</td>
</tr>
<tr>
<td>Tubing string radius</td>
<td>0.795</td>
<td>in</td>
</tr>
</tbody>
</table>

### Numeric

<table>
<thead>
<tr>
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<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td># of radial nodes</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td># of skin nodes</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Pressure solution tolerance</td>
<td>1.45038E-11</td>
<td>psi</td>
</tr>
<tr>
<td>STP flow solution tolerance</td>
<td>1.58503E-11</td>
<td>USgpm</td>
</tr>
</tbody>
</table>
Figure B-8. Estimates of formation transmissivity and static formation pressure derived from the H-11b2 perturbation analysis.

Figure B-9. Estimates of skin zone conductivity and skin zone thickness derived from the H-11b2 perturbation analysis.
B.5 H-15 nSIGHTS Listings

*************
nPre/32 2.41Q
*************

Version date   1 Mar 2007
Listing date   25 Nov 2008
QA status      QA: Q
Config file    C:\SANDIA_PROJECTS\WIPP_wells\Magenta\H-15\H-15(m).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                       185.750     [psi]
External boundary radius                        1000000     [m]
Formation conductivity                      1.24693E-07     [m/sec]
Formation spec. storage                     1.50767E-07     [1/m]

Skin
Radial thickness of skin                      0.4105964     [m]
Skin zone conductivity                       8.73378E-03     [m/sec]

Information Only
Skin zone spec. storage 1.50815E-03 [1/m]

**Fluid**

Fluid density 1073.00 [kg/m^3]
Fluid thermal exp. coeff. 0.00000E+00 [1/C]

**Test-Zone**

Well radius 3.9375 [in]
Tubing string radius 0.795 [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]

**Calculated Parameters**

**Formation**

Transmissivity 9.50160E-07 [m^2/sec]
Storativity 1.14884E-06 []
Diffusivity 8.27059E-01 [m^2/sec]

**Skin Zone**

Transmissivity 6.65514E-02 [m^2/sec]
Storativity 1.14921E-02 []
Diffusivity 5.79106E+00 [m^2/sec]
Skin factor -1.63029E+00 []

**Test Zone**

Open hole well-bore storage 1.21745E-07 [m^3/Pa]

**Grid Properties**

Grid increment delta 0.07280 []
First grid increment 3.85601E-02 [m]
Skin grid increment delta 0.03327 []
Skin first grid increment 3.38355E-03 [m]
Skin last grid increment 1.67093E-02 [m]
Increment ratio 2.30771E+00 []

**Sequences**

**Sequence: H_01**

Sequence type History
Start time 39524.530000 [day]
Duration 0.088700 [day]
Time step type Static
Static time step 0.000116 [day]

Information Only
Sequence: F_01

Type: Flow
Start time: 39524.618700 [day]
Duration: 2.079200 [day]
Time step type: Log
First log step: 1.15741E-07 [day]
# of time steps: 250
Type: Fixed
Fixed value: -1.0 [USgpm]
Wellbore storage: Open

Sequence: H_02

Sequence type: History
Start time: 39526.697900 [day]
Duration: 0.001420 [day]
Time step type: Static
Static time step: 0.000010 [day]
Type: Curve
Wellbore storage: Open

Sequence: F_02

Sequence type: Flow
Start time: 39526.699320 [day]
Duration: 0.209280 [day]
Time step type: Log
First log step: 1.15741E-07 [day]
# of time steps: 250
Type: Fixed
Fixed value: -1.5 [USgpm]
Wellbore storage: Open

Sequence: F_03

Sequence type: Flow
Start time: 39526.908600 [day]
Duration: 11.802700 [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: Create Curve
Curve type: Pressure
Start sequence: H_01
End sequence: F_03
Curve time base: Test
Curve Y data units: [psi]
Curve Y data is log 10: no
Simulation Results Setup

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<tr>
<th>Output ID</th>
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<tr>
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<td>Pressure capture type</td>
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<tr>
<td>Output units</td>
<td>[psi]</td>
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<table>
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H-15 Optimization Settings

*************
nPre/32 2.41Q
*************

Version date 1 Mar 2007
Listing date 25 Nov 2008
QA status QA: Q
Config file C:\SANDIA_PROJECTS\WIPP_wells\Magenta\H-15\H-15(m).nPre

Control Settings

Main Settings

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<td>Simulation subtype</td>
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<td>Phase to simulate</td>
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<tr>
<td>Skin zone ?</td>
<td>yes</td>
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<tr>
<td>External boundary</td>
<td>Fixed Pressure</td>
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<td>Curve data source</td>
<td>Objects</td>
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Liquid Phase Settings

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<td>System porosity</td>
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<tr>
<td>Compensate flow dimension geometry</td>
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<td>Leakage</td>
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Test Zone Settings

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<td>Test zone compressibility can vary</td>
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<tr>
<td>Test zone temperature can vary</td>
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# Parameters

## Formation

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<td>Static formation pressure</td>
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<tr>
<td>Formation conductivity</td>
<td>Optimization</td>
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<td>Minimum value</td>
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<tr>
<td>Maximum value</td>
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<td>m/sec</td>
</tr>
<tr>
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</tr>
<tr>
<td>Sigma</td>
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<td></td>
</tr>
<tr>
<td>Formation spec. storage</td>
<td>Optimization</td>
<td></td>
</tr>
<tr>
<td>Minimum value</td>
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<td>1/m</td>
</tr>
<tr>
<td>Maximum value</td>
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<td>1/m</td>
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<tr>
<td>Estimate value</td>
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<td>1/m</td>
</tr>
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<td>Range type</td>
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## Skin

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</tr>
<tr>
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<td>m</td>
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<tr>
<td>Maximum value</td>
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<td>m</td>
</tr>
<tr>
<td>Estimate value</td>
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<tr>
<td>Sigma</td>
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</tr>
<tr>
<td>Skin zone conductivity</td>
<td>Optimization</td>
<td></td>
</tr>
<tr>
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<td>m/sec</td>
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## Fluid

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<tbody>
<tr>
<td>Fluid density</td>
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</tr>
<tr>
<td>Fluid thermal exp. coeff.</td>
<td>0.00000E+00</td>
<td>1/C</td>
</tr>
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## Test-Zone

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Well radius</td>
<td>3.9375</td>
<td>in</td>
</tr>
<tr>
<td>Tubing string radius</td>
<td>0.795</td>
<td>in</td>
</tr>
</tbody>
</table>

## Numeric

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td># of radial nodes</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td># of skin nodes</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Pressure solution tolerance</td>
<td>1.45038E-11</td>
<td>psi</td>
</tr>
<tr>
<td>STP flow solution tolerance</td>
<td>1.58503E-11</td>
<td>USgpm</td>
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</table>
Figure B-10. Estimates of skin hydraulic conductivity and formation transmissivity derived from the H-15 perturbation analysis.

Figure B-11. XY-scatter plot showing 96 estimates of specific storage derived from the H-15 perturbation analysis.
# Appendix C – File Directories

## Table C-1. File descriptions.

<table>
<thead>
<tr>
<th>File Extension</th>
<th>Function/Use</th>
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<tbody>
<tr>
<td>&lt;filename&gt;.nPre</td>
<td>Files used for initial well test analysis.</td>
</tr>
<tr>
<td>&lt;filename&gt;X.nPre</td>
<td>Files used to generate perturbation analysis of .nPre results.</td>
</tr>
<tr>
<td>.nPost</td>
<td>Post-processing files used to visualize .nPre and perturbation analysis.</td>
</tr>
<tr>
<td>.nOpt</td>
<td>Optimization data used for post processing in .nPost files.</td>
</tr>
<tr>
<td>&lt;filename&gt;.nXYSim</td>
<td>Simulation data used for post processing in .nPost files.</td>
</tr>
<tr>
<td>&lt;filename&gt;FieldData.nXYSim</td>
<td>Field data used for post processing in .nPost files.</td>
</tr>
<tr>
<td>.jpg</td>
<td>Graphic output from .nPost files.</td>
</tr>
<tr>
<td>.csv, .xls, .dat</td>
<td>Data files used as input for .nPre files.</td>
</tr>
</tbody>
</table>

D:\>dir/s  
Volume in drive D is AP-070_AnalysisRpt_2-09_Disk1  
Volume Serial Number is 4999-834C  

Directory of AP-070_AnalysisRpt_2-09_disk1\  
02/16/2009 03:19 PM <DIR> Culebra  
02/16/2009 03:16 PM <DIR> Magenta  
0 File(s) 0 bytes  

Directory of AP-070_AnalysisRpt_2-09_disk1\Culebra  
02/16/2009 03:19 PM <DIR> ..  
02/25/2041 03:44 PM <DIR> ..  
02/16/2009 03:19 PM <DIR> SNL_6  
0 File(s) 0 bytes  

Directory of AP-070_AnalysisRpt_2-09_disk1\Culebra\SNL_6  
02/16/2009 03:19 PM <DIR> ..  
02/25/2041 03:44 PM <DIR> ..  
02/16/2009 03:20 PM <DIR> Data  
02/16/2009 03:20 PM <DIR> Figures  
02/16/2009 03:19 PM <DIR> Post  
11/06/2008 09:35 AM 33,089 SNL_6.nPre  
11/05/2008 03:14 PM 20,075 SNL_6X.nPre  
2 File(s) 53,164 bytes  

Directory of AP-070_AnalysisRpt_2-09_disk1\Culebra\SNL_6\Data  
02/16/2009 03:20 PM <DIR> ..  

Information Only
Directory of AP-070_AnalysisRpt_2-09_Disk1\Magenta\C2737\Data

02/16/2009 03:19 PM <DIR>  Data
02/16/2009 03:19 PM <DIR>  Figures
02/16/2009 03:18 PM <DIR>  Post
4 File(s)  93,636 bytes

Directory of AP-070_AnalysisRpt_2-09_Disk1\Magenta\C2737\Figures

02/16/2009 03:19 PM <DIR>  .
02/25/2041 03:44 PM <DIR>  ..
10/06/2008 08:50 AM 82,066 C-2737 Cartesian Horsetail_01.JPG
10/06/2008 08:51 AM 88,224 C-2737 Cartesian Horsetail_02.JPG
10/01/2008 02:27 PM 84,156 C-2737 Cartesian.JPG
01/07/2009 09:56 AM 137,508 C-2737 Ramey A Slug 1 Horsetail.JPG
01/07/2009 09:58 AM 137,017 C-2737 Ramey A Slug 2 Horsetail.JPG
01/07/2009 09:57 AM 125,411 C-2737 Ramey B Slug 1 Horsetail.JPG
01/07/2009 09:58 AM 139,015 C-2737 Ramey B Slug 2 Horsetail.JPG
01/06/2009 09:44 AM 66,208 C-2737 Ss vs SSE_01.JPG
01/06/2009 09:43 AM 55,682 C-2737 Ss vs SSE_02.JPG
01/07/2009 11:47 AM 53,155 C-2737 Ss vs SSE_1.JPG0009.JPG
01/07/2009 11:47 AM 60,133 C-2737 Ss vs SSE_2.JPG0009.JPG
01/07/2009 09:55 AM 60,309 C-2737 SSE_01.JPG
01/07/2009 09:55 AM 68,362 C-2737 SSE_02.JPG
01/07/2009 10:00 AM 103,253 Kskin vs Lskin.JPG
01/07/2009 10:00 AM 75,163 T vs Pf.JPG
15 File(s)  1,335,662 bytes

Directory of AP-070_AnalysisRpt_2-09_Disk1\Magenta\C2737\Post

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02/25/2041 03:44 PM <DIR>  ..
01/06/2009 12:53 PM 6,160,384 C-2737_first.nOpt
01/06/2009 12:53 PM 28,688,384 C-2737_first.nXYSim
01/06/2009 02:13 PM 237,568 C-2737_first_Field Data.nXYSim
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02/16/2009  03:16 PM  <DIR>          .
02/25/2041  03:44 PM  <DIR>          ..
11/04/2008  02:16 PM  1,101,824 H-15(m)_Field Data.nXYSim
11/06/2008  10:24 PM  6,160,384 H-15(m)_Perturb.nOpt
11/06/2008  10:24 PM  86,032,384 H-15(m)_Perturb.nXYSim
01/14/2009  02:26 PM  19,935 H-15.nPost

  4 File(s)   93,314,527 bytes

Total Files Listed:
  85 File(s)  319,240,931 bytes
  54 Dir(s)   276,731,904 bytes free

Volume in drive D is AP_070_AnalysisRpt_2-09_Disk2
Volume Serial Number is 4999-8A74

Directory of AP_070_AnalysisRpt_2-09_Disk2\Culebra

02/16/2009  03:48 PM  <DIR>          IMC_461
0 File(s)              0 bytes

Directory of AP_070_AnalysisRpt_2-09_Disk2\Culebra\IMC_461

11/17/2008  03:45 PM  25,765 IMC_461_fifthpulse.nPre
11/17/2008  03:47 PM  18,143 IMC_461_fifthpulseX.nPre
11/07/2008  10:32 AM  25,701 IMC_461_firstpulse.nPre
11/07/2008  10:33 AM  18,147 IMC_461_firstpulseX.nPre
01/05/2009  02:07 PM  25,764 IMC_461_fourthpulse.nPre
01/05/2009  09:49 AM  18,145 IMC_461_fourthpulseX.nPre
11/19/2008  02:59 PM  25,701 IMC_461_secondpulse.nPre
11/19/2008  02:59 PM  18,149 IMC_461_secondpulseX.nPre
11/18/2008  04:21 PM  25,700 IMC_461_thirdpulse.nPre
11/18/2008  04:21 PM  18,146 IMC_461_thirdpulseX.nPre