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Analysis Report for AP-070

Analysis of the IMC-461 Sinusoidal Test Conducted From 6/6/16 to 6/9/16

AP-070: Analysis Plan for Hydraulic-Test Interpretations

Task Number 4.4.2.3.1

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1. Introduction

This report discusses the analyses of hydraulic tests performed in the Culebra Dolomite Member (Culebra) of the Rustler Formation (Figure 1) at the Waste Isolation Pilot Plant (WIPP) site at the IMC-461 well pad (Figure 2). These analyses were performed in accordance with the Sandia National Laboratories (SNL) Analysis Plan for Hydraulic-Test Interpretations, AP-070, Revision 2 (Beauheim, 2009). The computer code used for analysis was nSIGHTS (n-dimensional Statistical Inverse Graphical Hydraulic Test Simulator), version 2.50. 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).

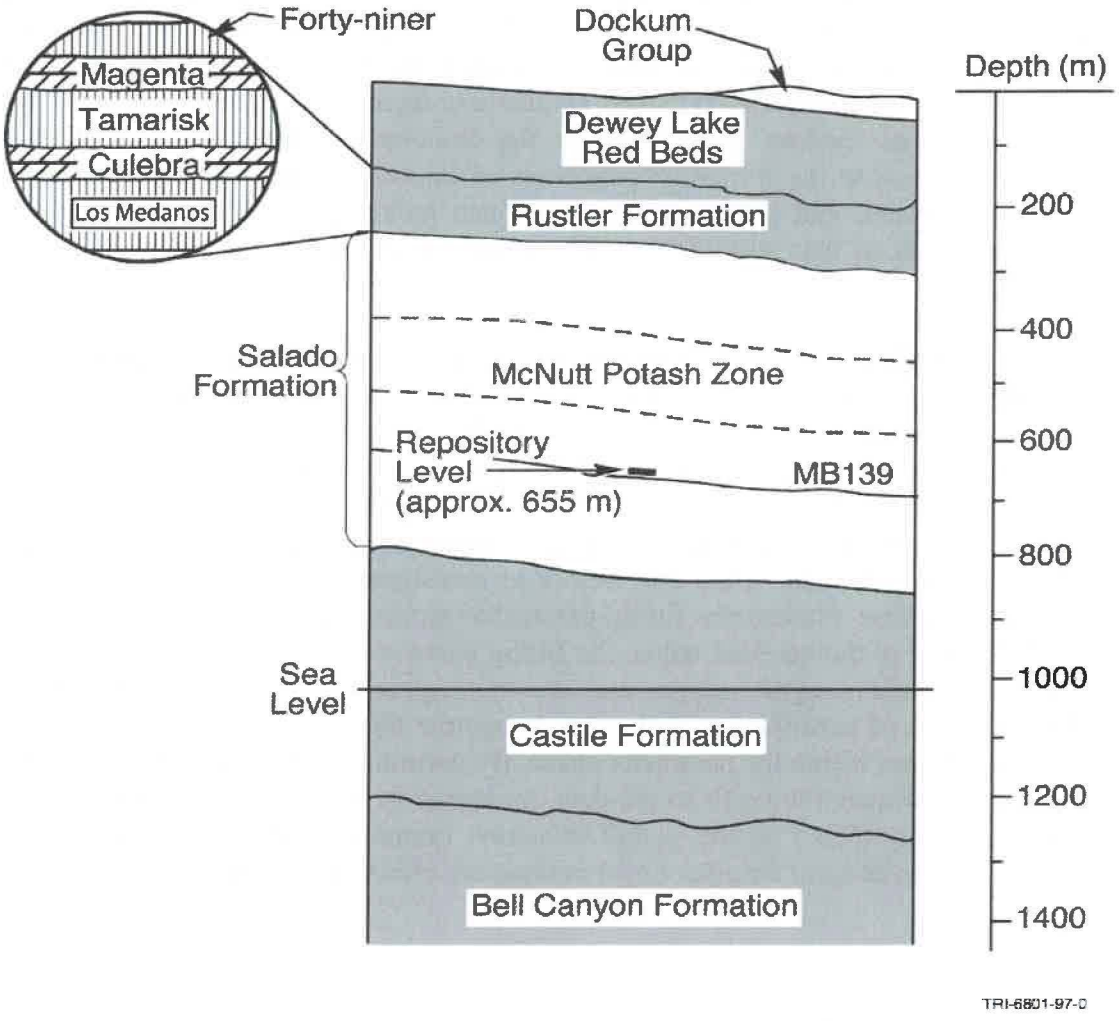


Figure 1. WIPP stratigraphy.

2. Test and Analysis Procedures

Five sinusoidal tests, two constant rate tests, and three slug tests were performed as a suite of pneumatic testing on well IMC-461 between 6/6/16 and 6/9/16. The location of the IMC-461 well pad in the WIPP well network is shown in Figure 2. The well had been tested previously, but it has been acidized and brushed/maintained since those tests were conducted. Pneumatic tests were chosen as the well has a very small (~2") casing diameter making pump installation difficult to impossible. As the tests utilized an air compressor to change pressure in the well, no water was produced during testing.

The main objective of this analysis is to estimate T for subsequent use in T-field generation and WIPP performance assessment calculations, and to reevaluate aquifer parameters against analyses conducted on data from the previous IMC-461 slug tests. Test analysis involved finding the values of the fitting parameters that produced the best-simulated matches to the pressure data collected during the sinusoidal pressure change, constant-rate test/recovery period, and the slug test pressure recovery. All the nSIGHTS test simulations incorporated pre-test pressure records of various durations as "history" periods where the observed pressures were specified in the simulations. In addition to the formation properties of interest (principally transmissivity (T)), static formation pressure and wellbore skin were also included as fitting parameters in the pumping-test analyses so that nSIGHTS could exactly match the amount of wellbore storage observed during the test.

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 unweighted 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

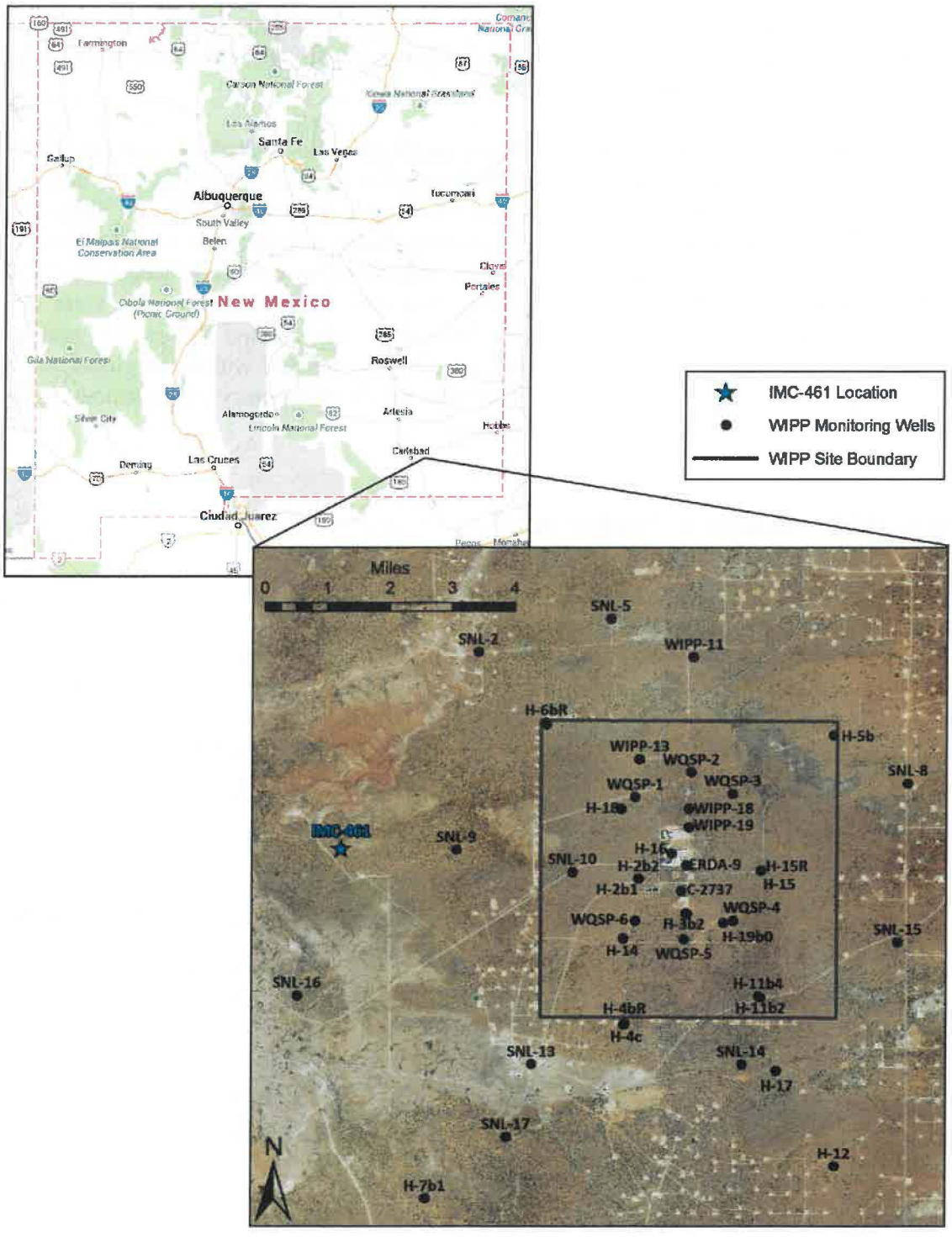


Figure 2. Location of the IMC-461 Culebra well located on the IMC-461 wellpad designated by a blue star.

parameter-space topography that trap the inverse regression algorithm during its attempt to find the global minimum – the smallest unweighted SSE. If multiple data types are included in the match (e.g., if pressures, pressure derivatives, etc., are matched simultaneously), then the weighted SSE values for each component are combined and the overall goodness-of-fit measure is denoted in nSIGHTS as the *fit value*.

Five hundred perturbation/optimization runs were performed for each of the analyses discussed in this report. A visual assessment of parameter-space plots for each fitting variable and a visual assessment of the fits themselves were all used to determine the value of the "fit discriminant". The fit discriminant is used to reduce the perturbations under consideration to only those within the best-fit minimum, and sufficiently close to be subjectively considered "acceptable" fits. All perturbation results for which the fit value was less than the fit discriminant were deemed acceptable solutions and are included in the final range of reported values for each fitting parameter. 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 3 figure captions.

3. IMC-461 Analysis Results

Discussions of IMC-461 and associated test analyses are given below. A summary of the T 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 the sections below and a full listing is contained within the nPost configuration file for each analysis.

Table 1. Culebra Transmissivity and Storativity Estimates.

IMC-461 Testing	Period (min)	Mean S	Geo. Mean T (m^2/s)	Log			Variance $(m^2/s)^2$
				Geo. Mean T (m^2/s)	Min. T (m^2/s)	Max. T (m^2/s)	
6/9, Sine	10	6.17E-05	3.28E-04	-3.48	-3.50	-3.42	5.66E-07
6/6, Sine	20	3.16E-04	1.85E-04	-3.73	-3.85	-3.64	5.01E-12
6/9, Sine	40	2.70E-04	1.99E-04	-3.70	-3.71	-3.70	1.26E-15
6/7, Sine	60	3.64E-04	1.43E-04	-3.85	-3.92	-3.76	2.07E-12
6/8, Sine	120	-	3.56E-05	-4.45	-4.64	-4.29	6.57E-07
6/6, Constant Rate	-	3.53E-04	1.51E-04	-3.82	-3.97	-3.71	3.03E-12
6/7, Constant Rate	-	4.84E-04	1.20E-04	-3.92	-4.02	-3.59	3.37E-12
6/6, Slug	-	2.99E-06	3.56E-04	-3.45	-3.47	-3.43	2.74E-13
6/7, Slug	-	9.57E-10	2.14E-03	-2.67	-5.05	-1.81	2.29E-07
6/8, Slug	-	1.64E-07	3.15E-04	-3.50	-5.52	-2.01	1.41E-08
2005 Slug Test*	-	-	1.92E-04	-3.72	-2.88	-2.82	4.47E-05

*Values from Bowman and Roberts, 2009.

3.1. IMC-461

A physical description of the IMC- 461 well is detailed in Figure 3. The well is a 5.125" bore hole with a 2.375" tubing slotted in the Culebra. The pneumatic testing of the well was made possible using a gauged pressure cap, or kapsoid, on the stick-up portion of the well casing. The kapsoid allowed for contained pressure in the well while being able to measure total pressure (gas and water) and gas pressure. Using a DAS system aboard a testing trailer, pressure was able to be maintained and directed for the sinusoidal and constant rate tests. Slug tests were a result of immediately opening a ball valve connected to the kapsoid after a period of pressure stabilization.

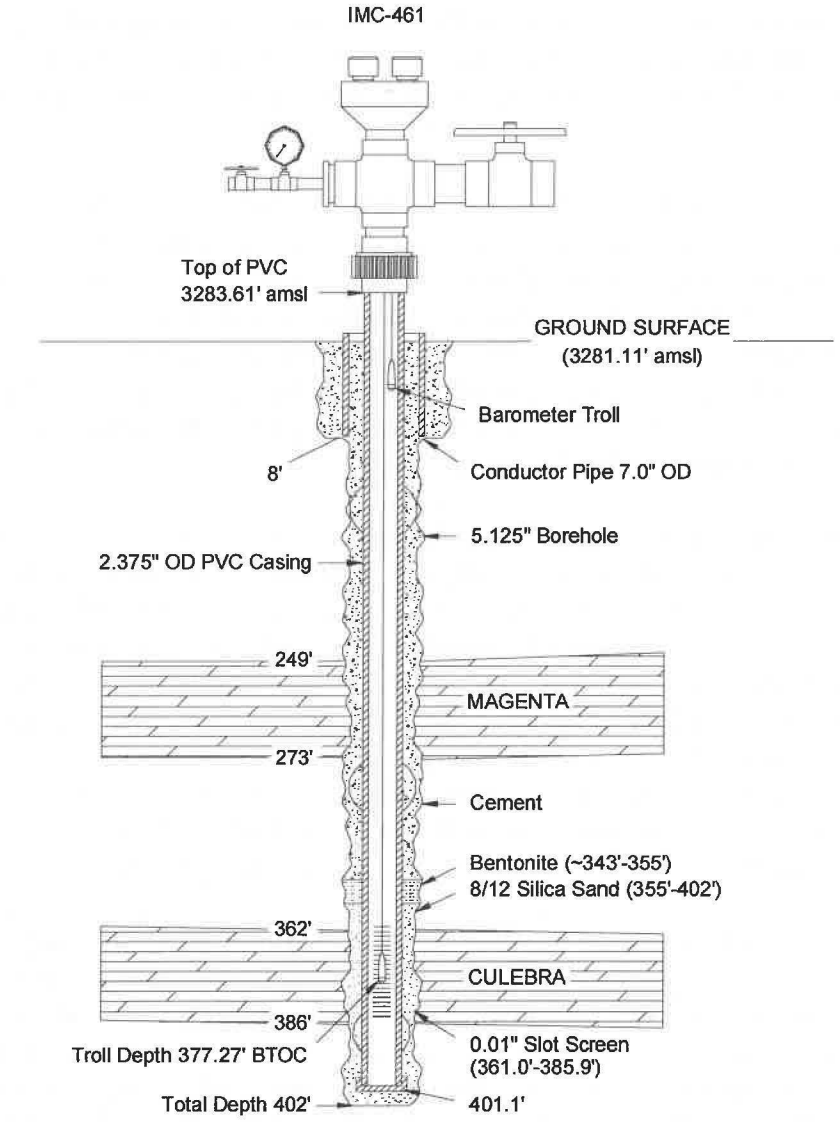
Five slug tests were previously conducted on January 25th-26th, 2005 at the IMC-461 well using pneumatics. The results of their analysis can be found in the analysis report "Analysis of Culebra and Magenta Hydraulic Tests Performed Between January 2005 and August 2008" (Bowman and Roberts 2009). A pressure-manifold system was attached to the IMC-461 wellhead so the 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. The pressure changes of those slug tests varied from approximately 20 psi to 45 psi.

Testing of the IMC-461 aquifer was conducted over four days from 6/6/16 to 6/9/16. The first two days of testing started with a constant-rate test, followed by sinusoidal testing, and concluded with a slug test (Figure 4). The third day consisted of sinusoidal testing followed by a slug test. Only sinusoidal testing was conducted on the fourth day. The first sinusoidal test attempted was excluded from analysis as the amplitude was too high for the short (10 min) period, which led to a deformed sinusoid. Pressure changes were logged by measuring the gas pressure via a transducer above water and total pressure via a pressure transducer below the water surface. For modeling purposes, total pressure is the data that is fit using variable aquifer parameters and flow rate. Flow rate is calculated as the derivative of water pressure (gas pressure subtracted from total pressure) translated to a volume/time through wellbore storage.

The IMC-461 nSIGHTS sinusoidal simulations consisted of a pressure change sequence book-ended by two history sequences; slug simulations consisted of a recovery sequence book-ended by two history sequences; constant-rate simulations consisted of a paired pressure build-up/pressure release sequences book-ended by two history sequences. Typically, pressure diagnostics (e.g., Bourdet derivatives and Ramey plots) are used to better fit and understand the data. However, the low total pressure changes to data noise ratio made these plots unreliable. They were excluded from these tests as a diagnostic tool. The details of each sequence (i.e., start/end time, pressure, etc.) are specified in the IMC-461.nPre files and are listed in Appendix B.1.

The specified IMC-461 conceptual models were chosen because they were the simplest models consistent with the available information that produced an acceptable fit to the data; acceptable by consensus of the modeler and an associate modeler. The models used were infinite-acting, radial systems with a variable T, wellbore storage, and a negative, time-dependent skin with some of these parameters being excluded if it provided a necessary improvement to the model.

A sand pack surrounding the screened portion of the well warranted the inclusion of skin effects into the model. The magnitude of pressure change during testing versus a model that included skin sometimes allowed the skin to become the dominant hydraulic conductivity effect of the model through skin thickness. The occurrences and their meaning will be discussed on a model-by-model basis in the following sections.



NOTE:

1. Depths in feet below ground surface unless otherwise noted.
2. Not to scale.
3. Well info ref. Beauheim (2005)

Figure 3. IMC-461 well configuration during testing.

3.1.1 Pumping Test Analysis and Discussion

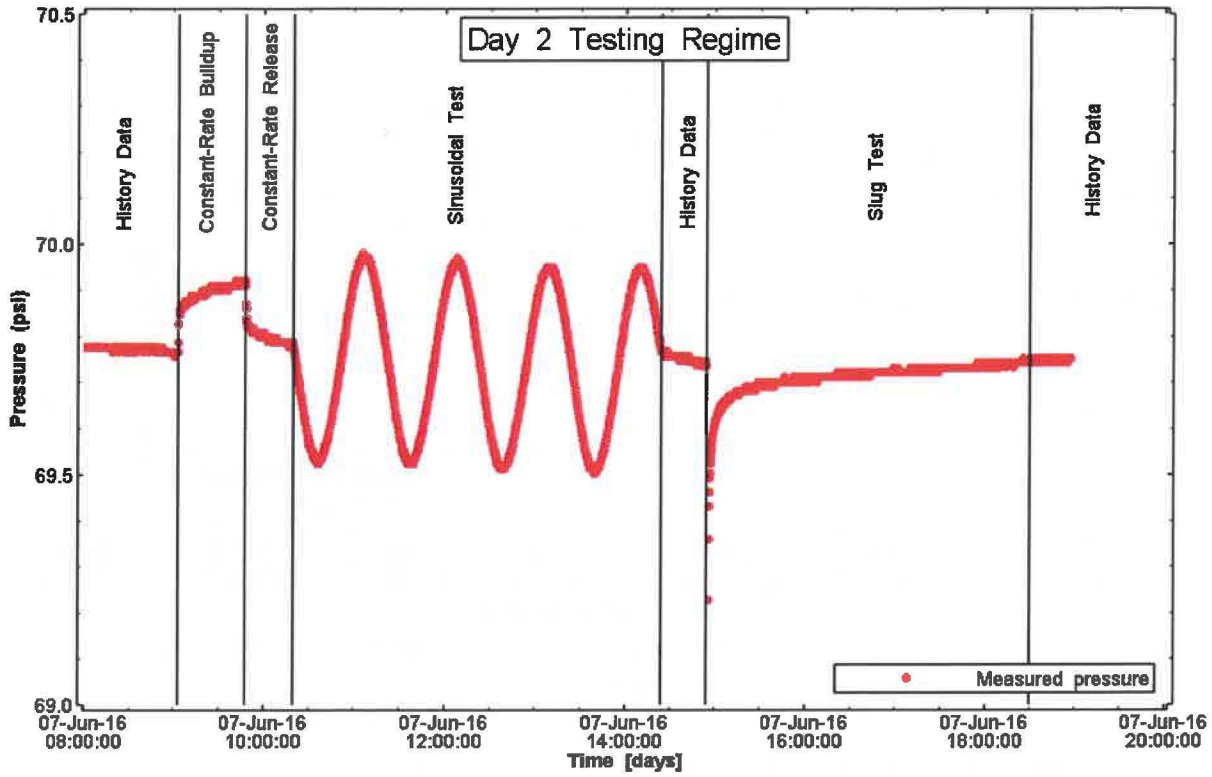


Figure 4. Day 2 Testing Regime for pneumatic testing at IMC-461.

3.1.1a Sinusoidal Test Analysis

The Culebra at IMC-461 was tested with sinusoidal pressure tests of multiple amplitudes (10, 20, 40, 60, 120 min). Differing amplitudes allow for a suite of tests to be analyzed and also deters parameter estimate bias due to background or circumstantial harmonics. Test analysis revealed well constrained *T* estimates but poorly constrained *S* estimates. In the case of the 120 min period sinusoid, S was constrained to a value of 1.0E-5 1/m. In some of the cases, we note that skin conductivity becomes partially dominant over formation conductivity through a large value (~5 m) of skin thickness. In the models where this is the case, K_{skin} was very similar in value to $K_{formation}$. The 120 min sinusoid also had the effect of a seemingly superimposed linear decrease in pressure. As the pressure controls mathematically calculate the sinusoidal response that should exist and it is an enclosed system, barometric/earth tide pressures should not be a contributing factor. The most likely explanation is a slight drift in our pressure transducers. The cumulative pressure change from the effect is ~0.05 psi. The effect warranted a second model because the decrease created bimodal minima (i.e., better fits of different parts of the sinusoid). These tests also had a very well constrained static formation pressure which is an effect that is consistent throughout all tests.

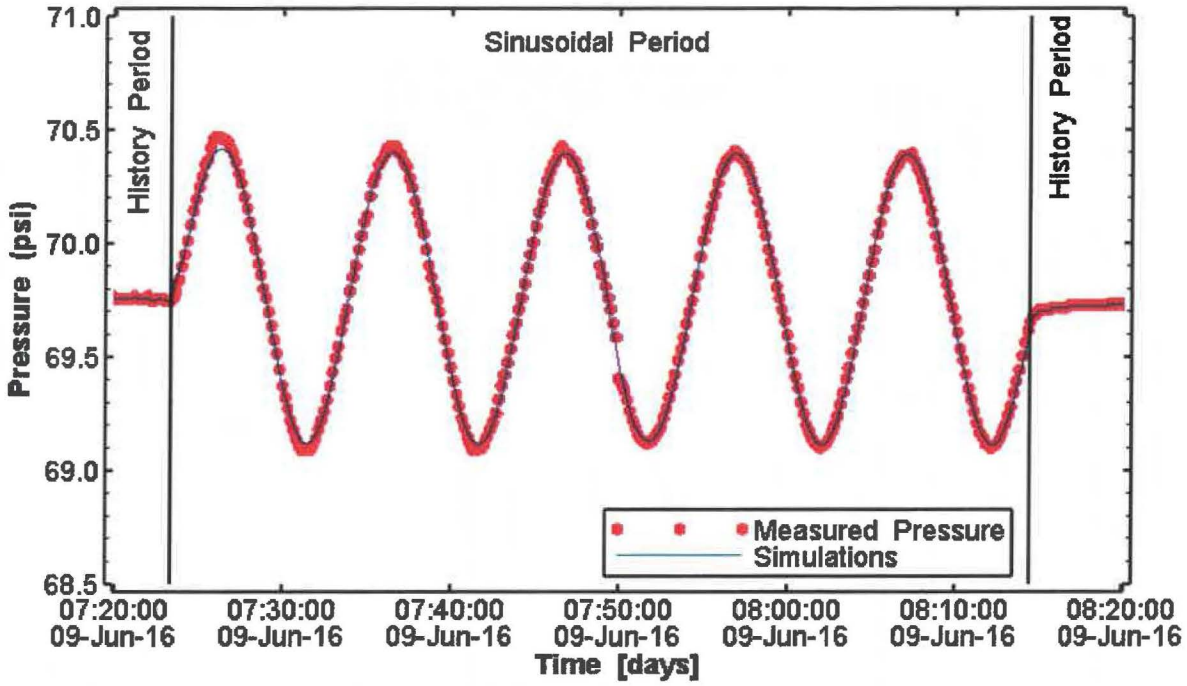


Figure 5. Pressure data and 491 model fits of the 10 min period Culebra sinusoidal test in IMC-461.

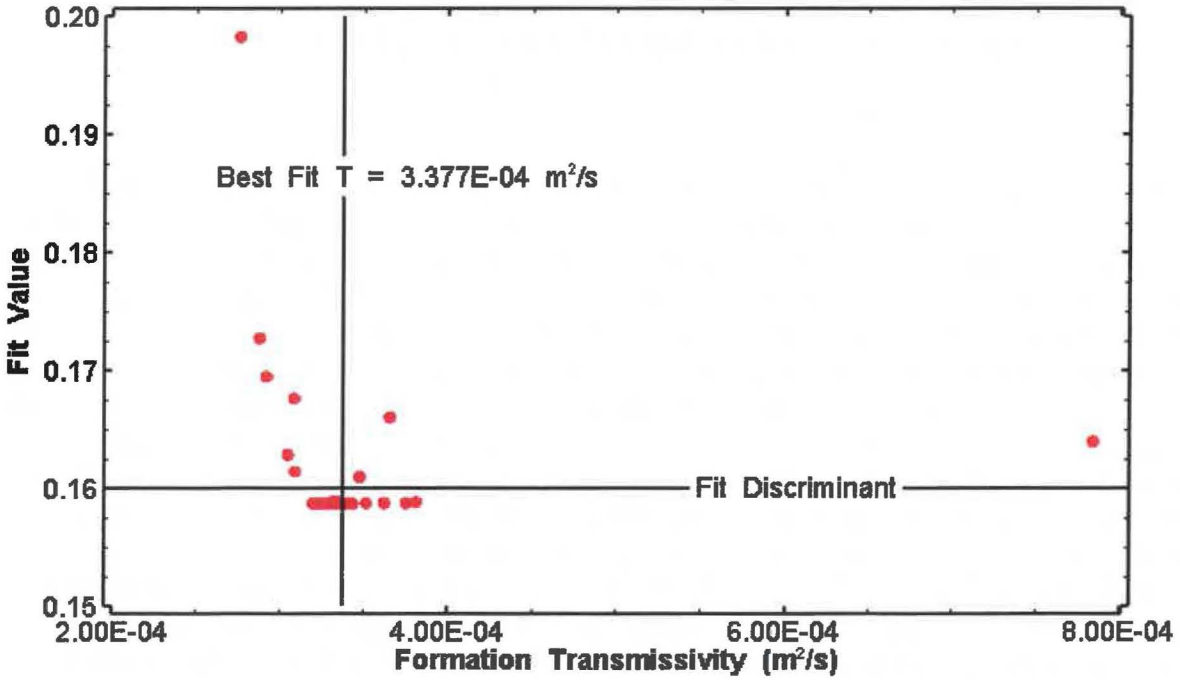


Figure 6. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 10 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.

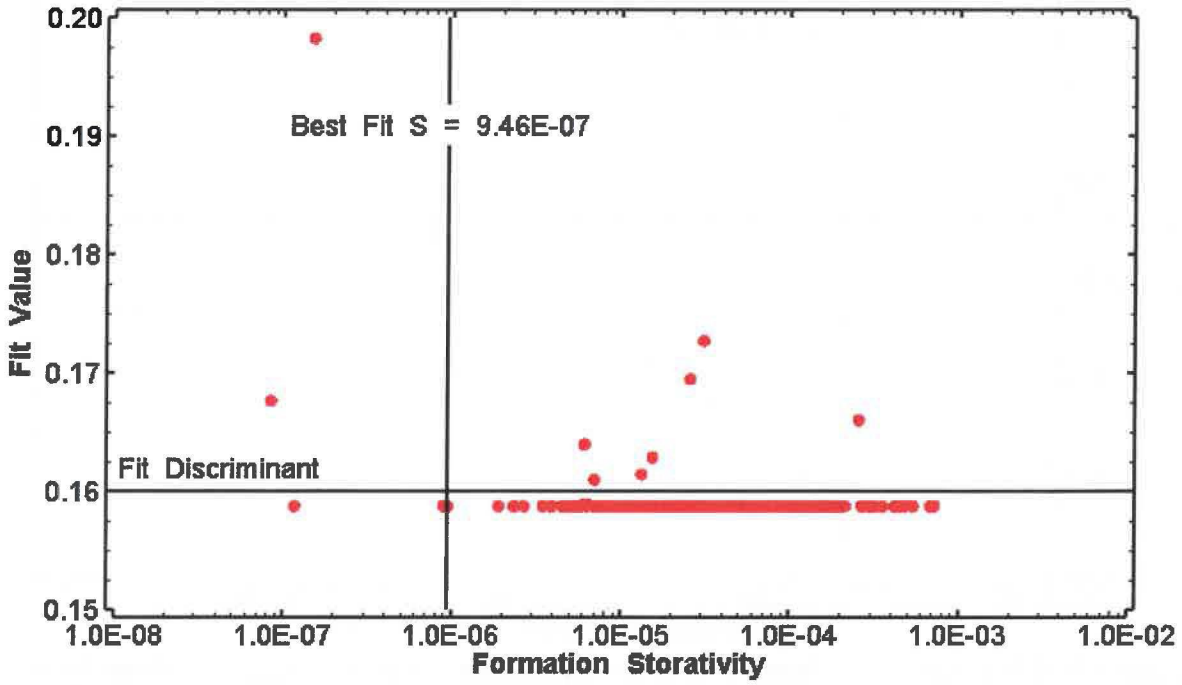


Figure 7. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 10 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.

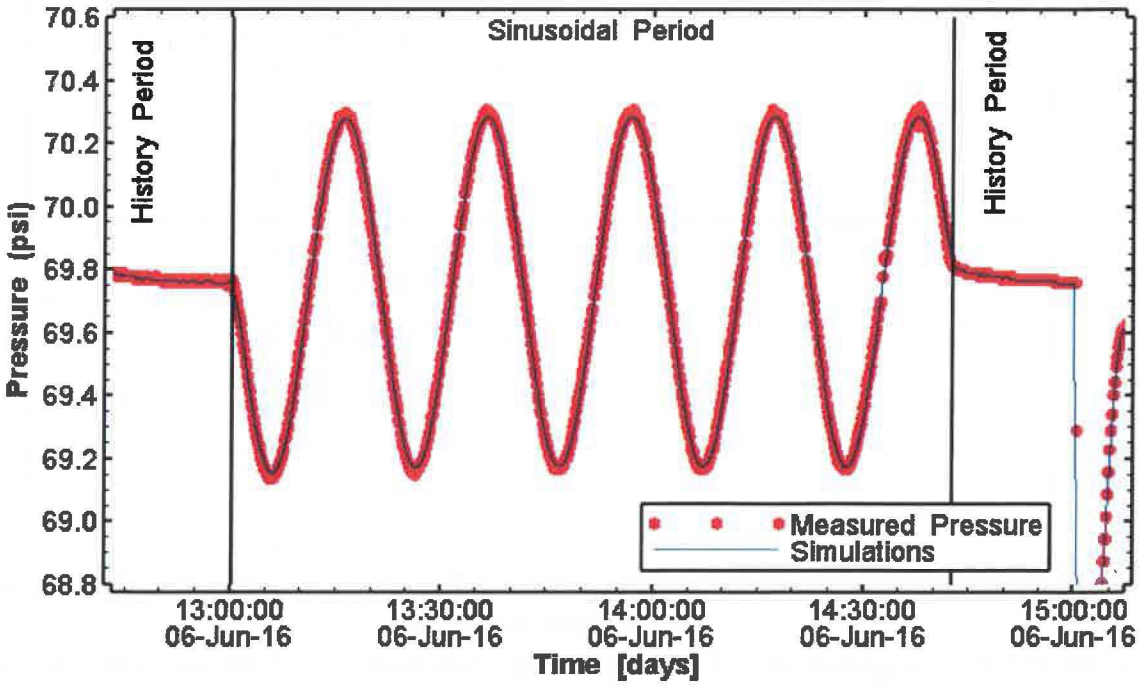


Figure 8. Pressure data and 491 model fits of the 20 min period Culebra sinusoidal test in IMC-461.

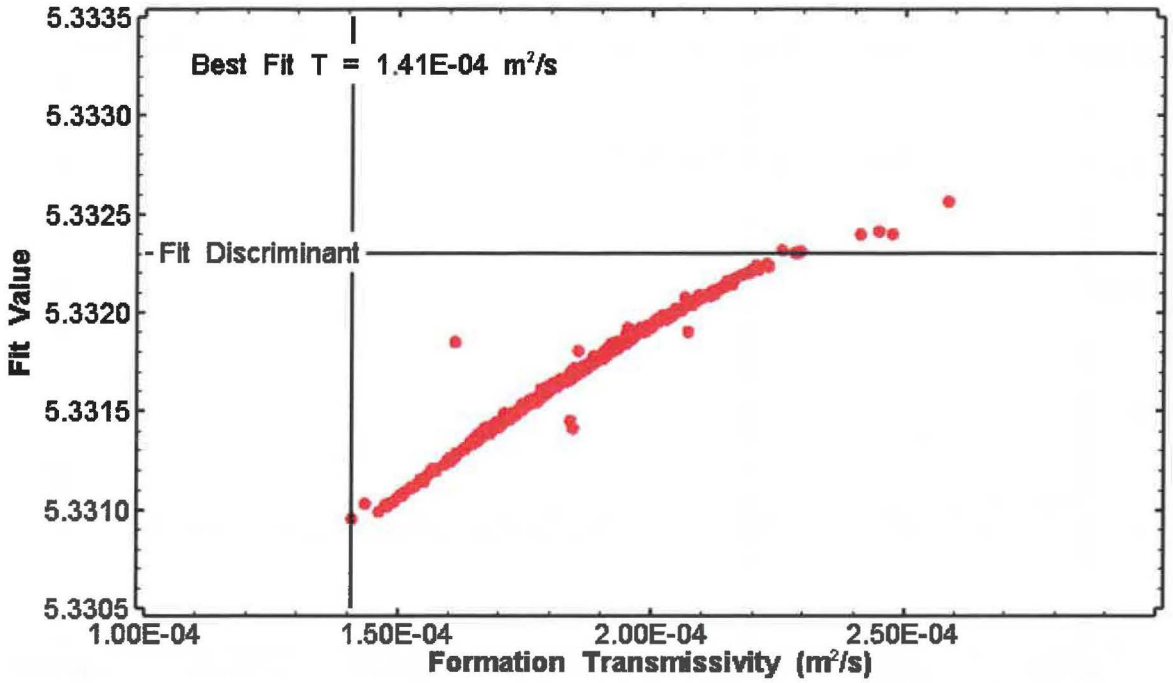


Figure 9. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 20 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.

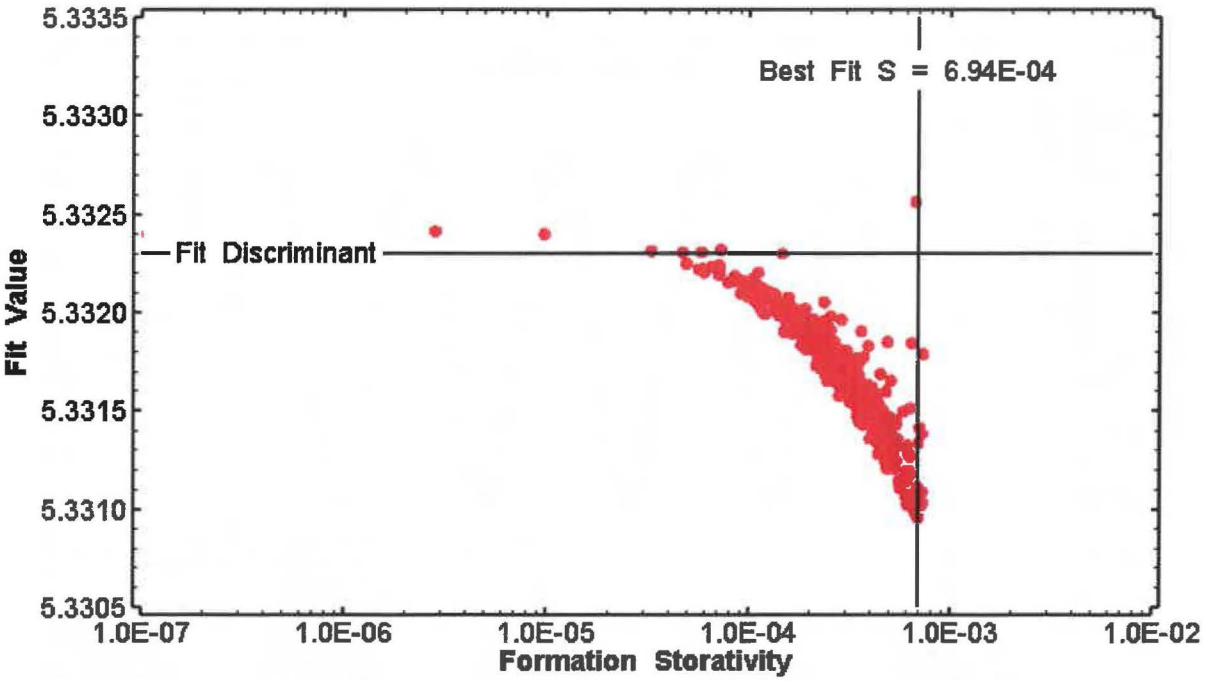


Figure 10. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 20 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.

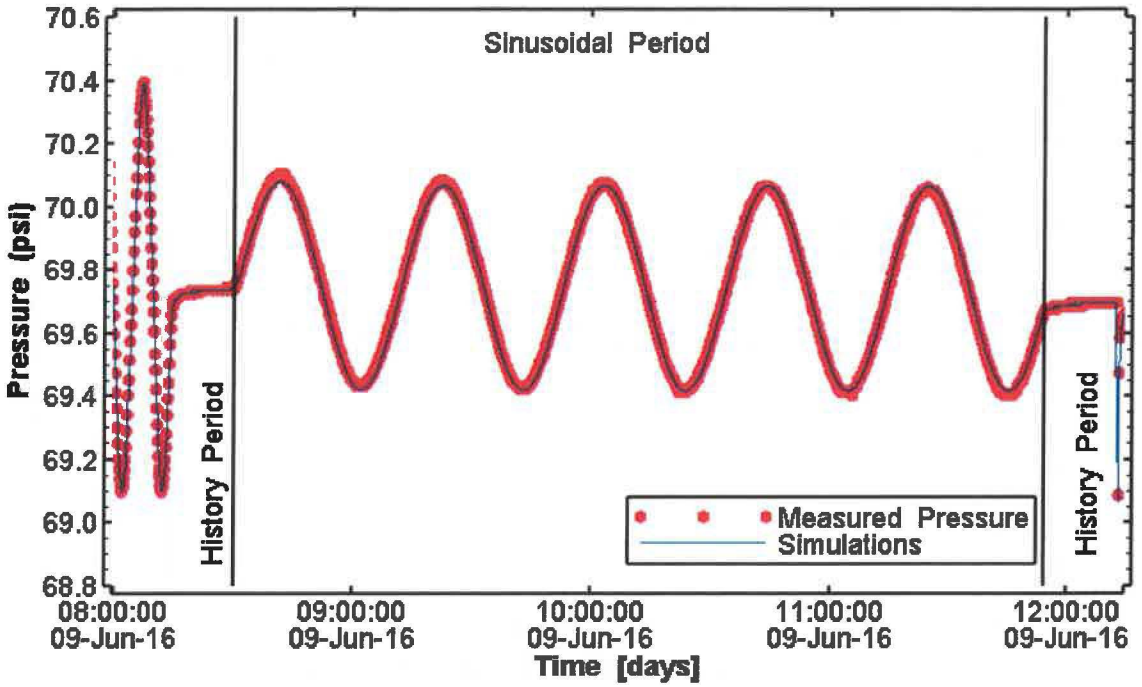


Figure 11. Pressure data and 499 model fits of the 40 min period Culebra sinusoidal test in IMC-461.

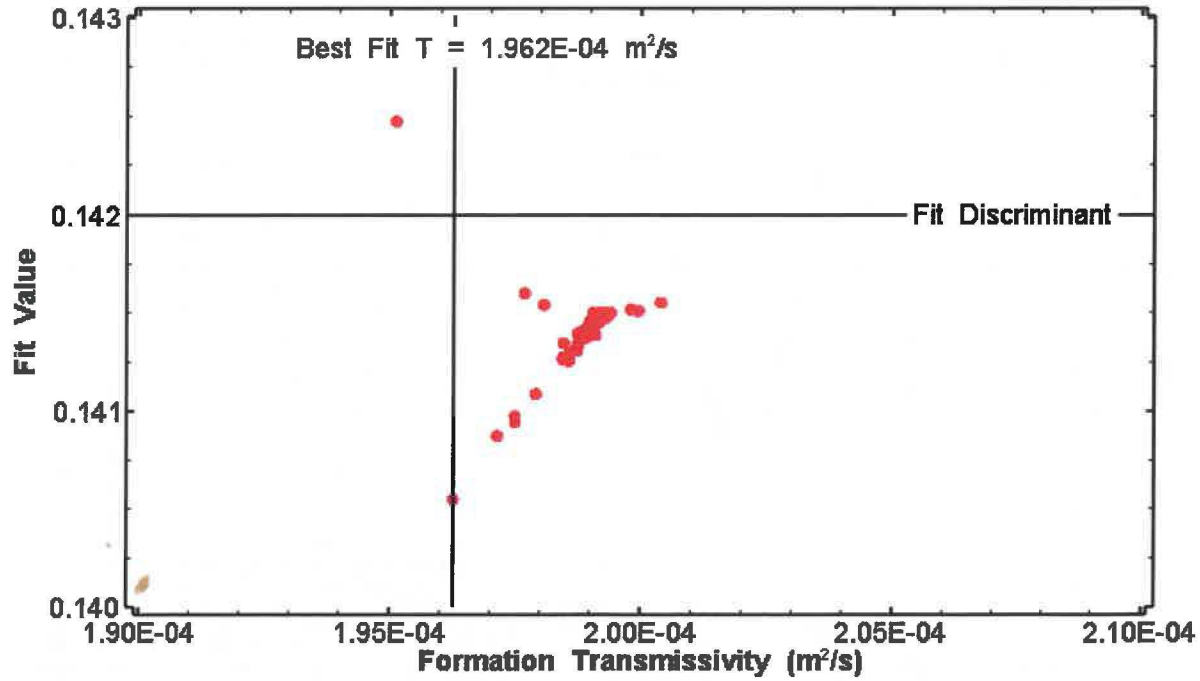


Figure 12. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 40 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.

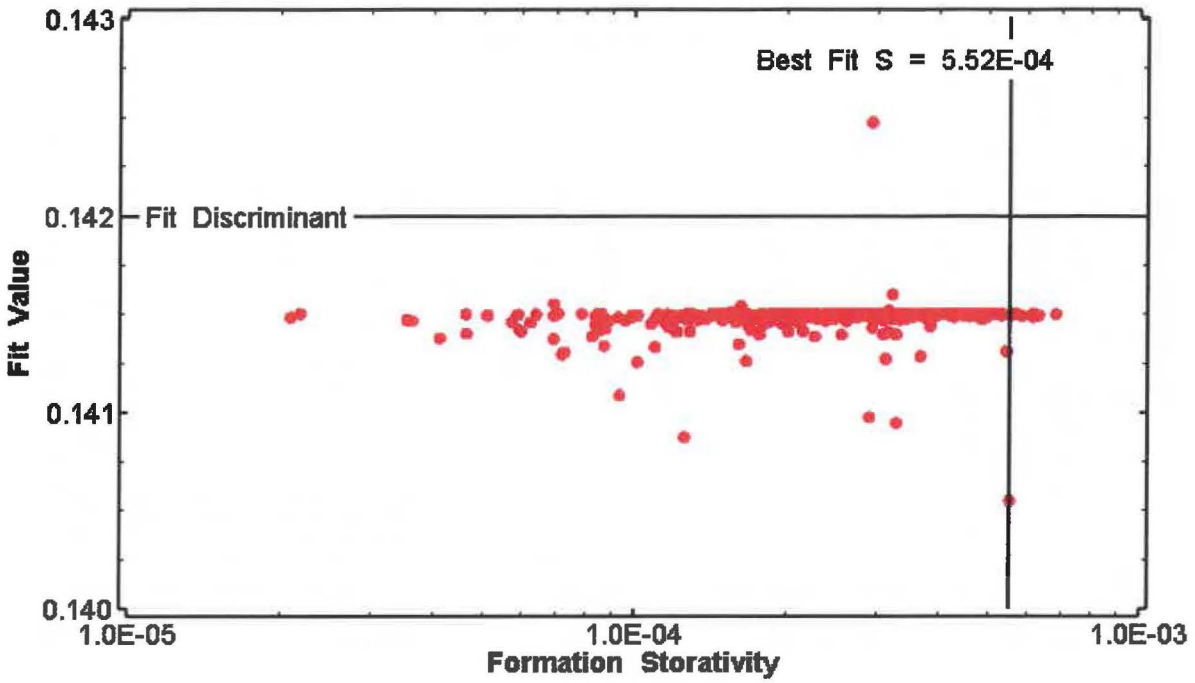


Figure 13. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 40 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.

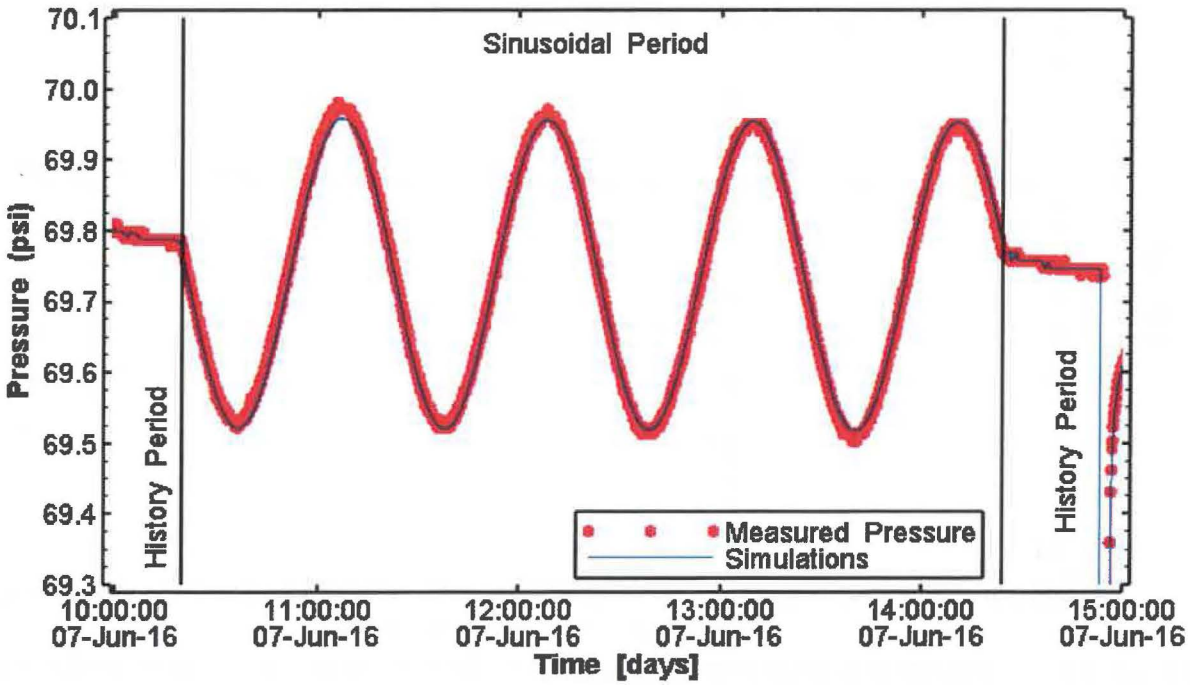


Figure 14. Pressure data and 498 model fits of the 60 min period Culebra sinusoidal test in IMC-461.

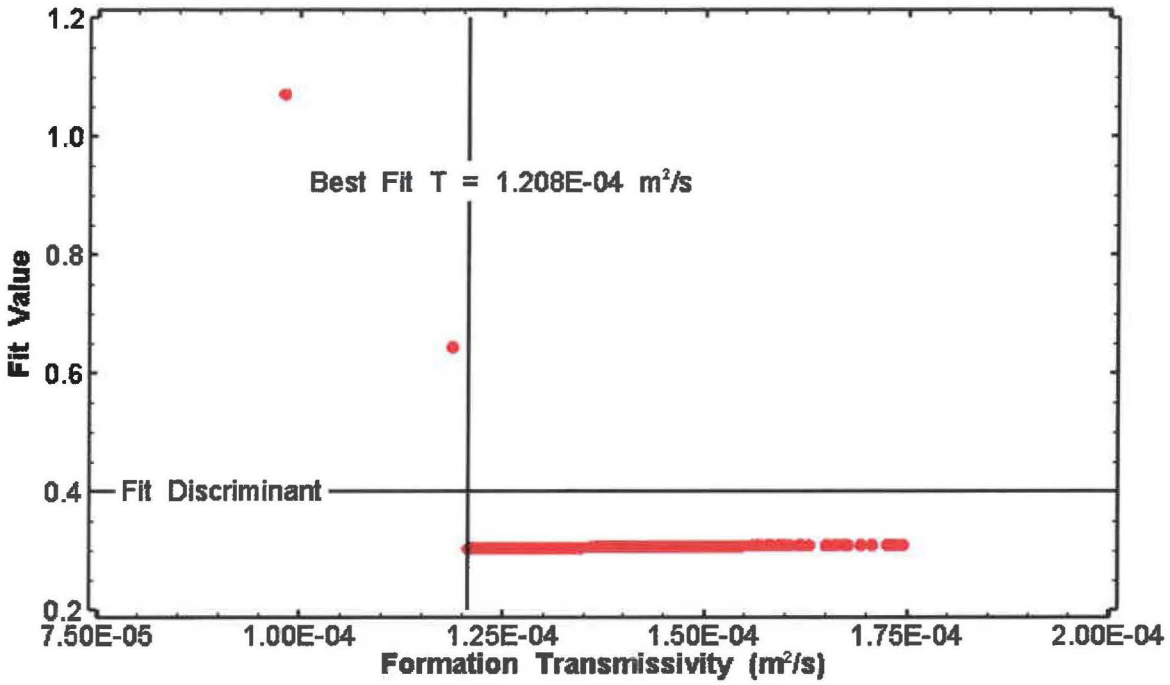


Figure 15. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 60 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.

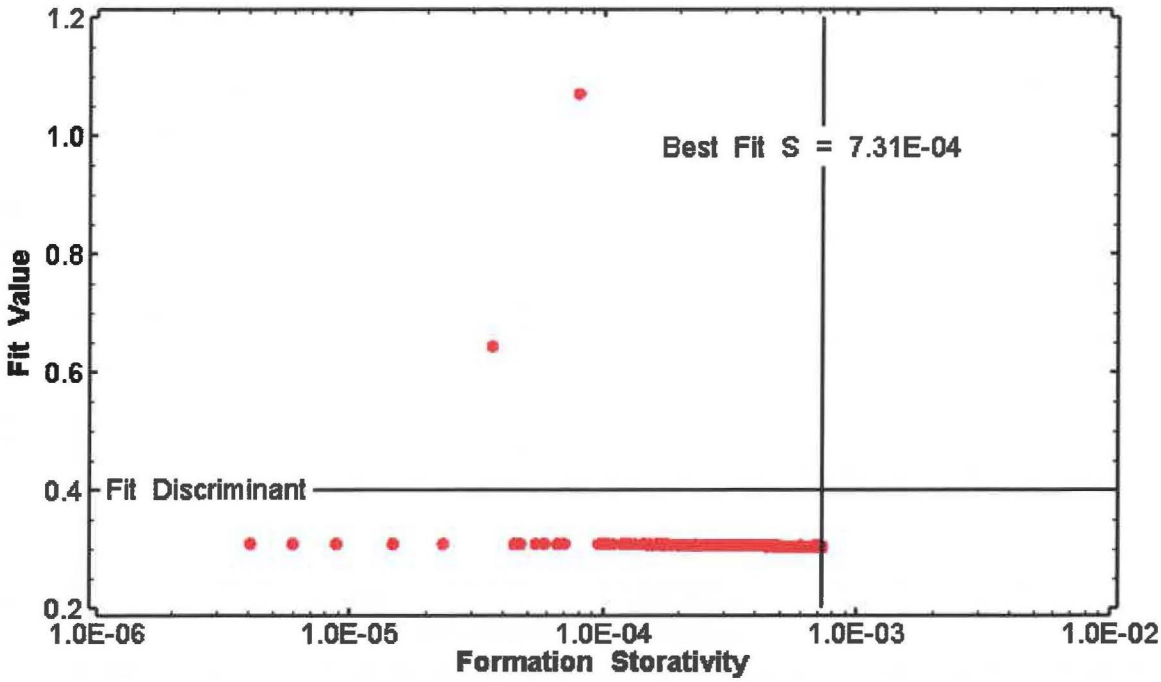


Figure 16. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 60 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.

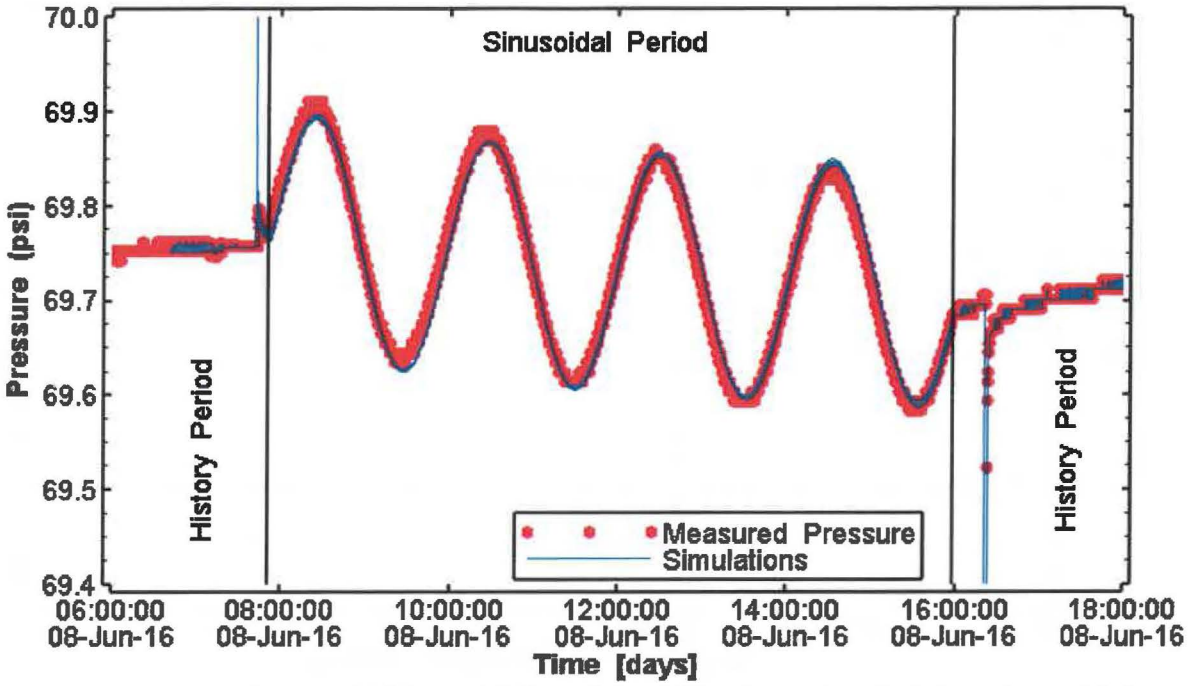


Figure 17. Pressure data and 322 model fits of the 120 min period Culebra sinusoidal test in IMC-461.

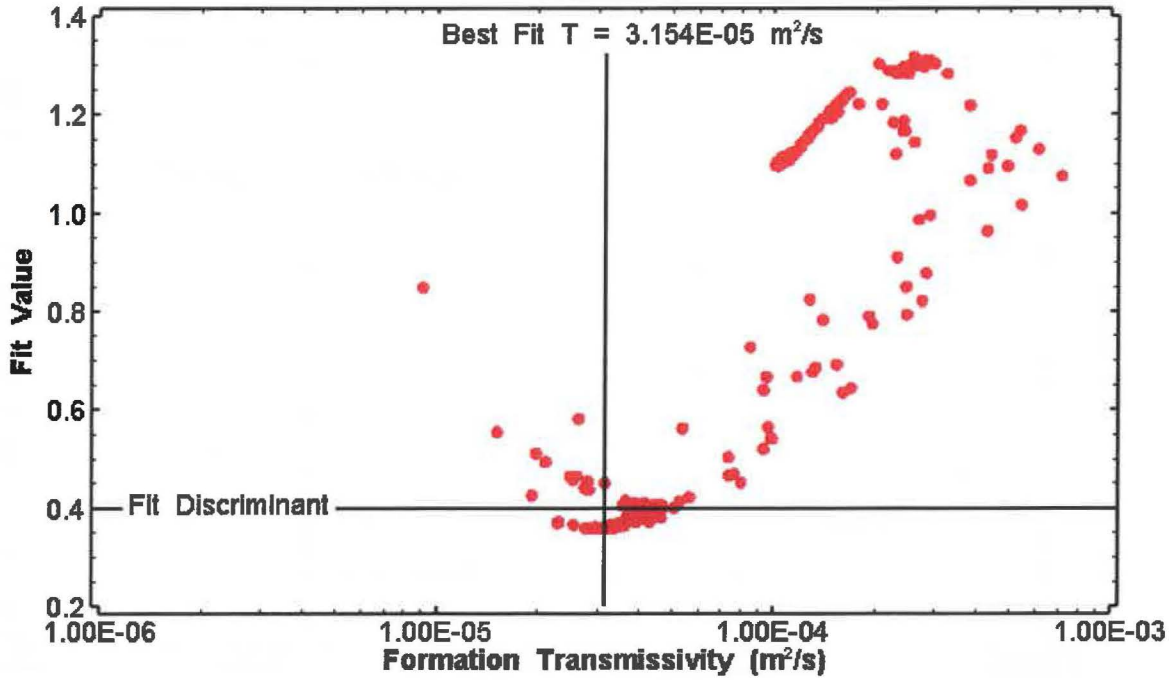


Figure 18. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 120 min period sinusoidal test perturbation analysis with fit discriminant and best fit values.

3.1.1b Constant Rate Test Analysis

The models fit to the constant rate tests performed on IMC-461 had similar results to the sinusoidal tests. They had a well constrained T and static formation pressure. S was, similarly, poorly constrained. Both had extensive skin effects with K_{skin} similar to $K_{formation}$. As stated before, Bourdet diagnostic plots were coarse and relatively unhelpful due to the small pressure changes that accompany these tests.

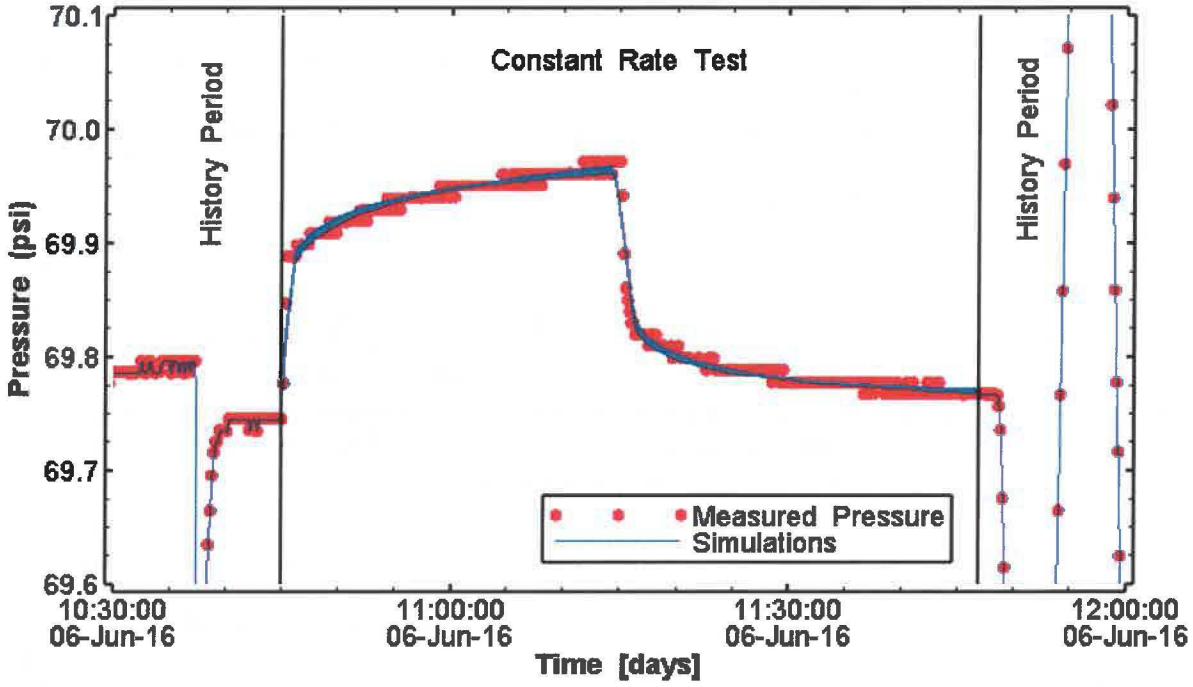


Figure 19. Pressure data and 491 model fits of the 6/6/16 Culebra constant rate test in IMC-461.

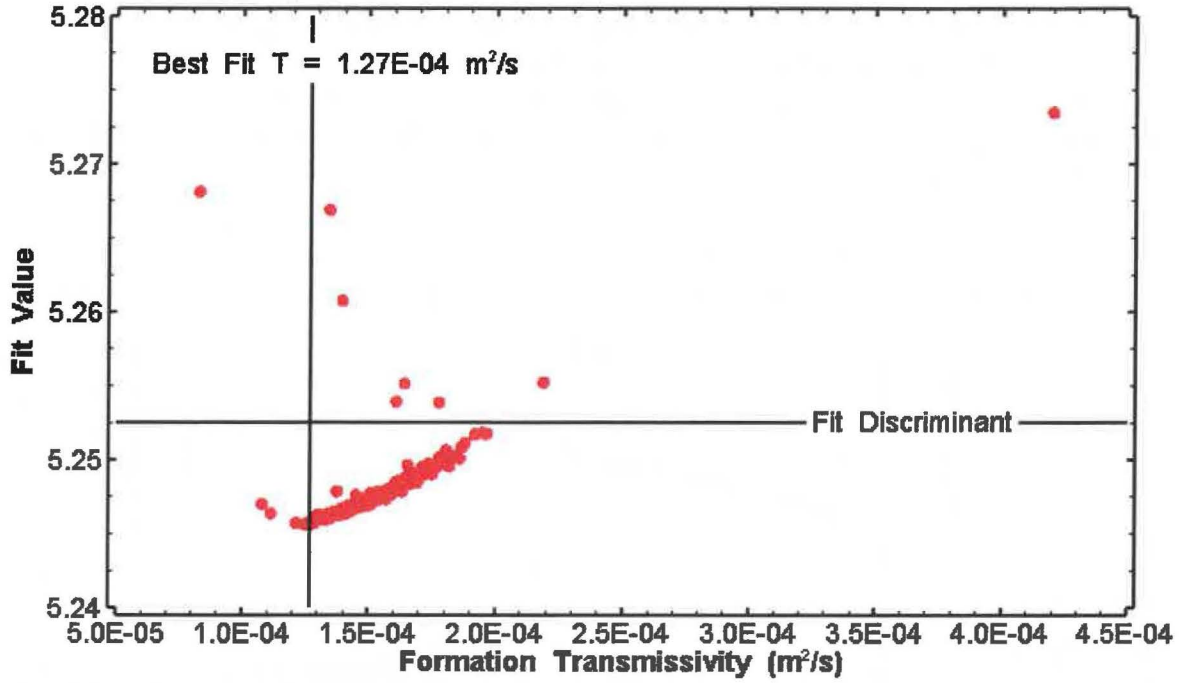


Figure 20. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 6/6/16 Culebra constant rate test perturbation analysis with fit discriminant and best fit values.

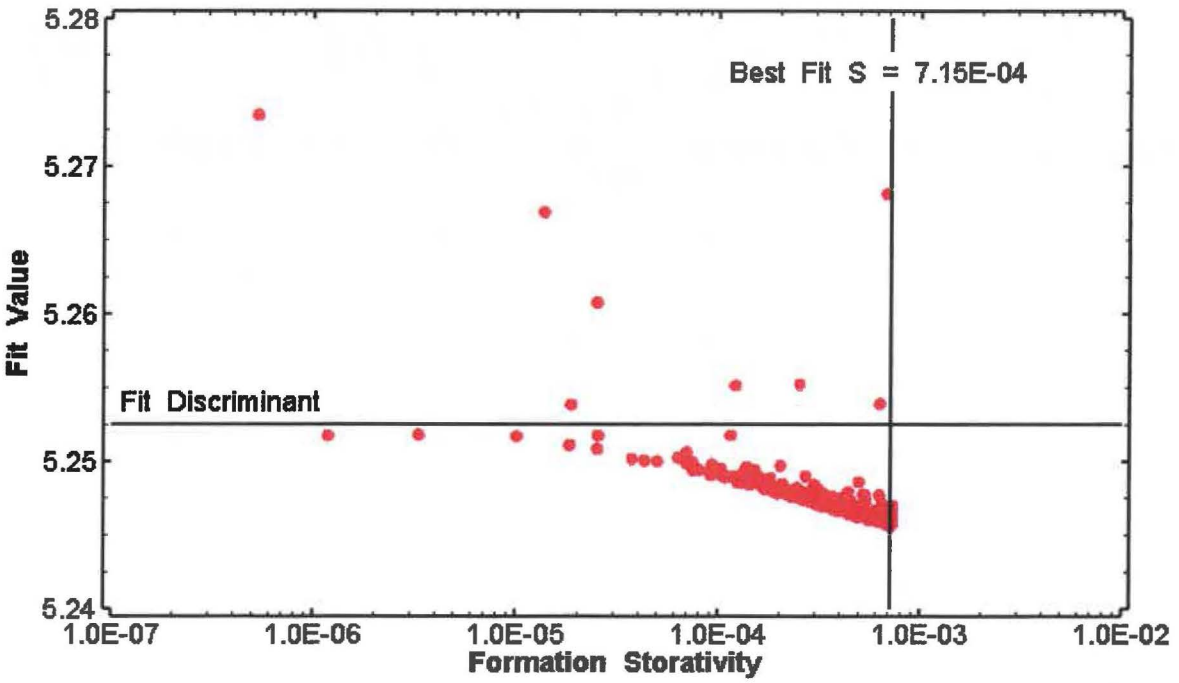


Figure 21. X-Y scatter plot showing the parameter space derived from the IMC-461 6/6/16 Culebra constant rate test perturbation analysis with fit discriminant and best fit values.

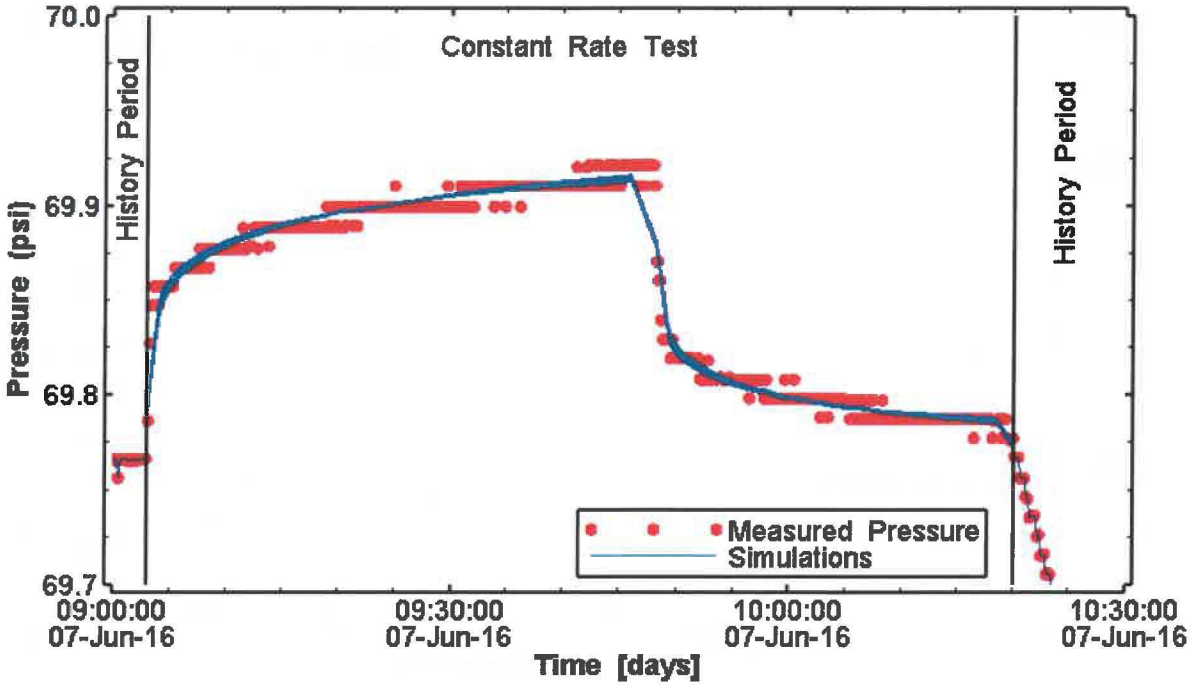


Figure 22. Pressure data and 478 model fits of the 6/7/16 Culebra constant rate test in IMC-461.

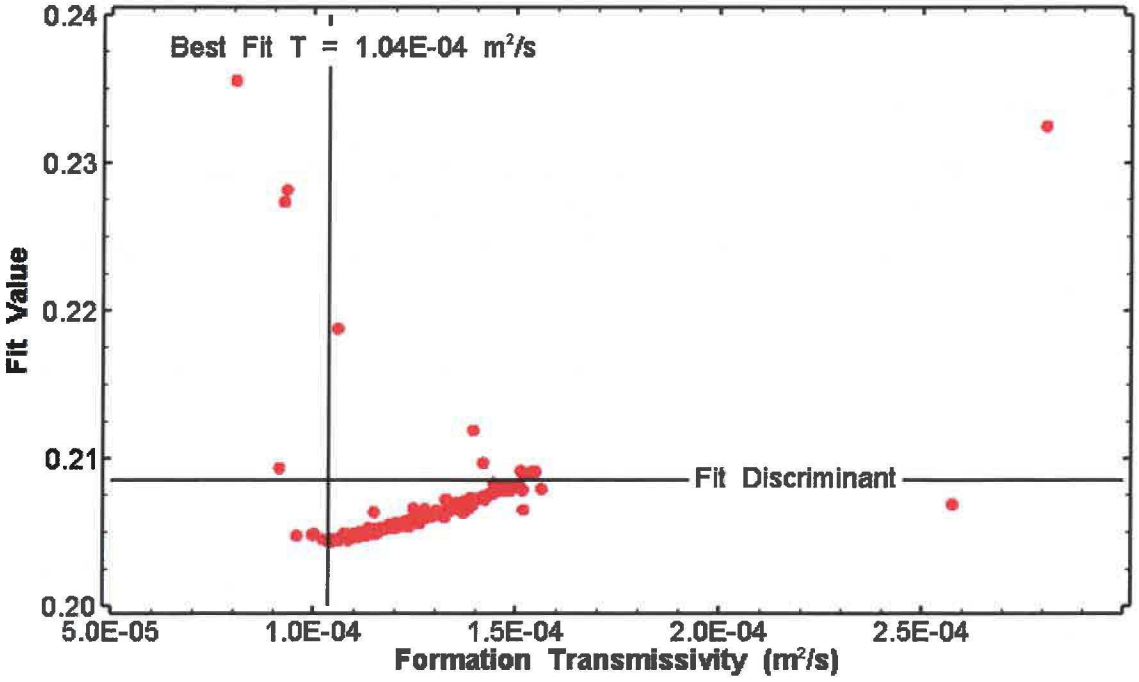


Figure 23. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 6/7/16 Culebra constant rate test perturbation analysis with fit discriminant and best fit values.

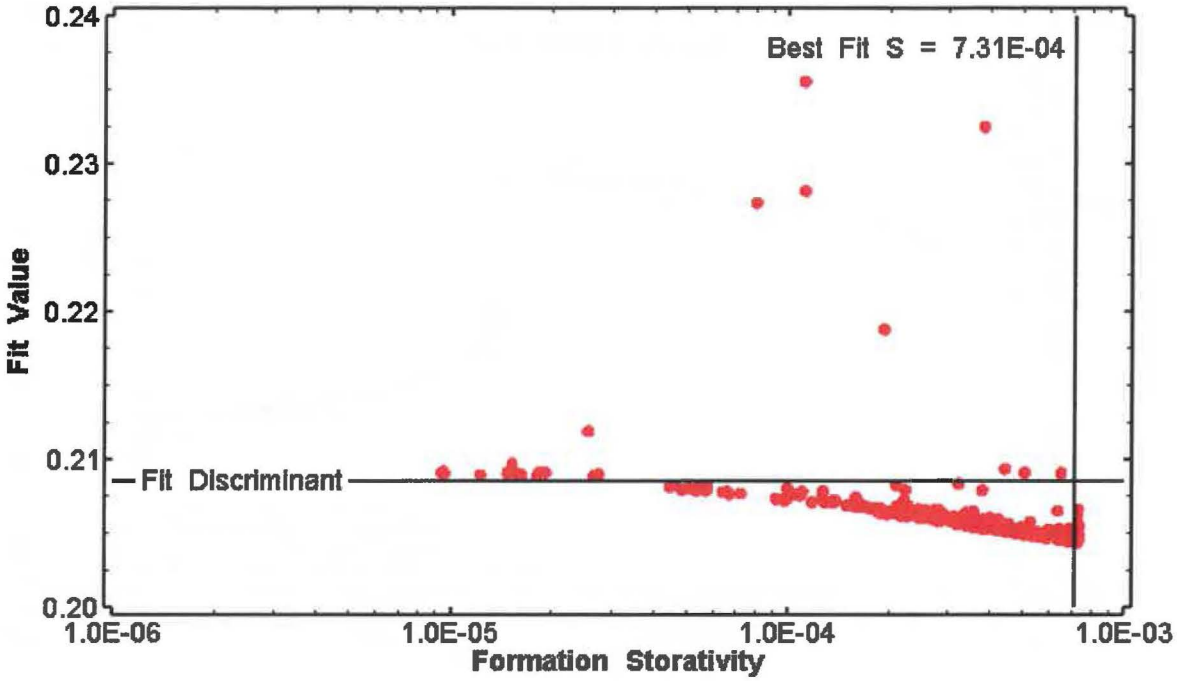


Figure 24. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 6/7/16 Culebra constant rate test perturbation analysis with fit discriminant and best fit values.

3.1.1c Slug Test Analysis

The slug tests at IMC-461 were the most difficult test-type to model due to the relatively low changes in pressure. Static formation pressure was the only parameter that was well constrained in these models. *T*, while not well constrained, did average to a similar value as the other test type results.

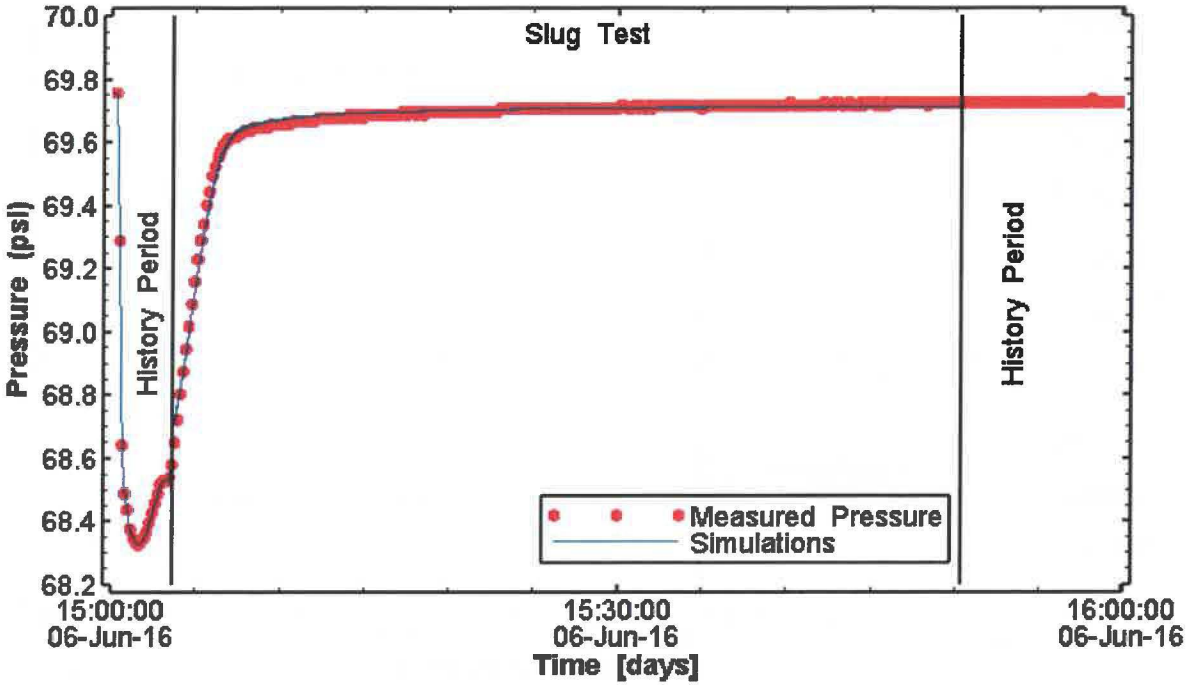


Figure 25. Pressure data and 491 model fits of the 6/6/16 Culebra slug test in IMC-461.

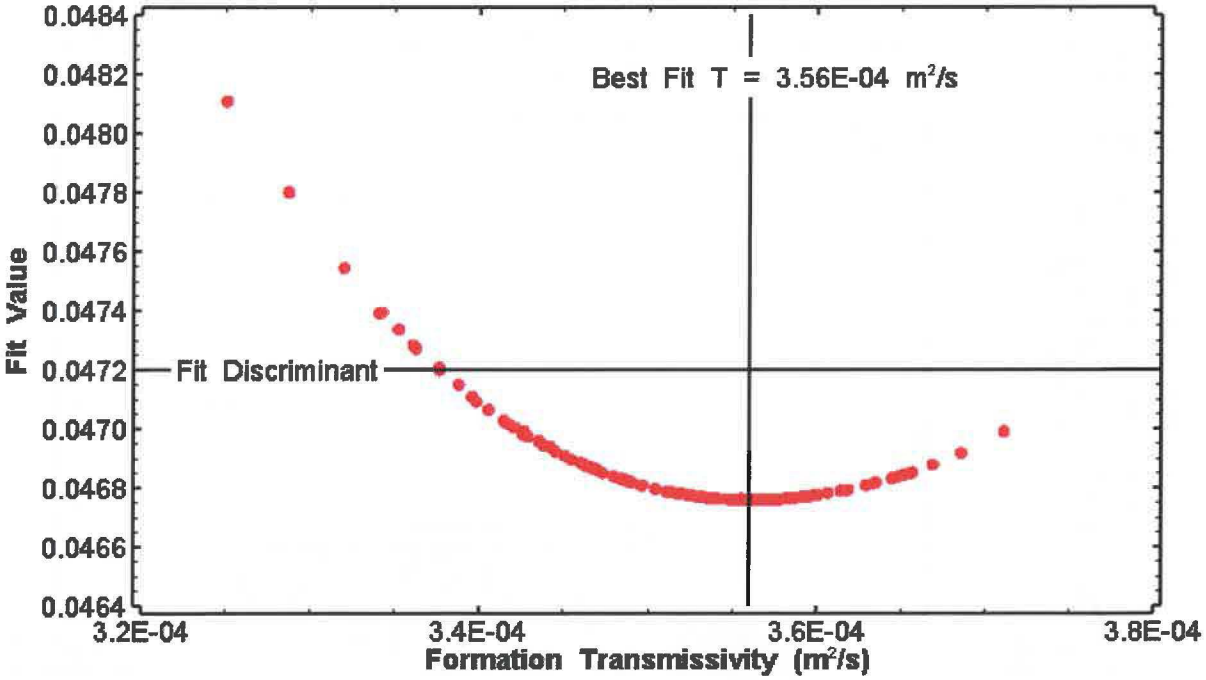


Figure 26. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 6/6/16 slug test perturbation analysis with fit discriminant and best fit values.

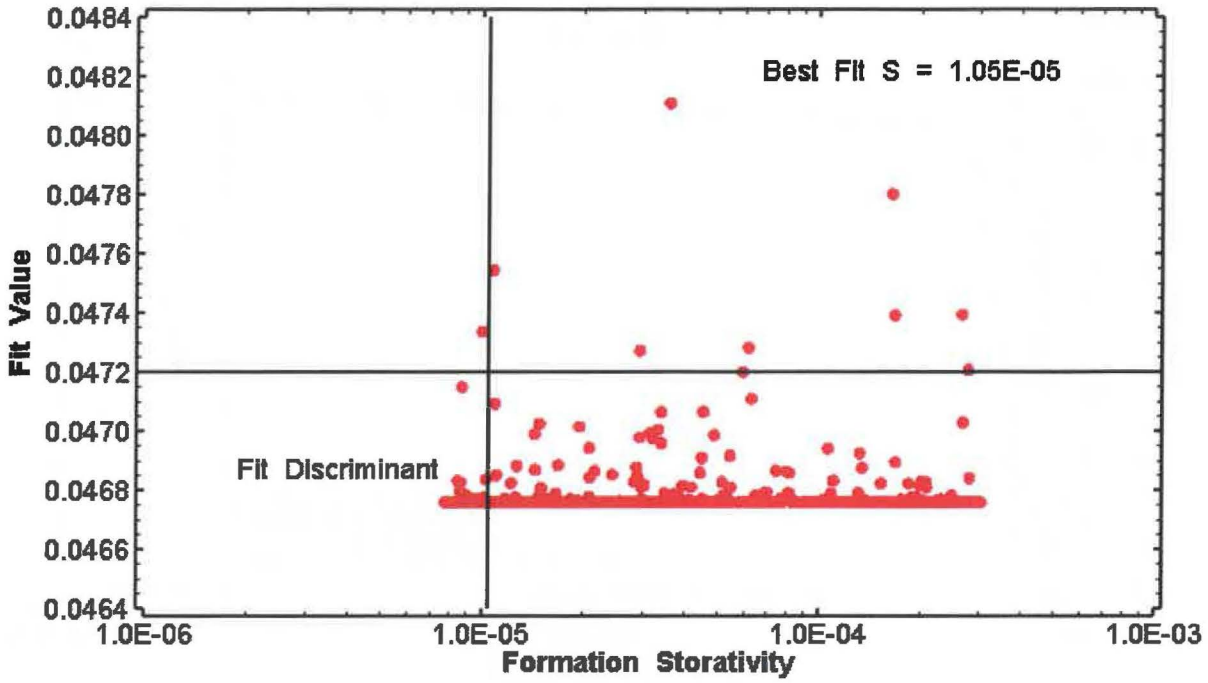


Figure 27. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 6/6/16 slug test perturbation analysis with fit discriminant and best fit values.

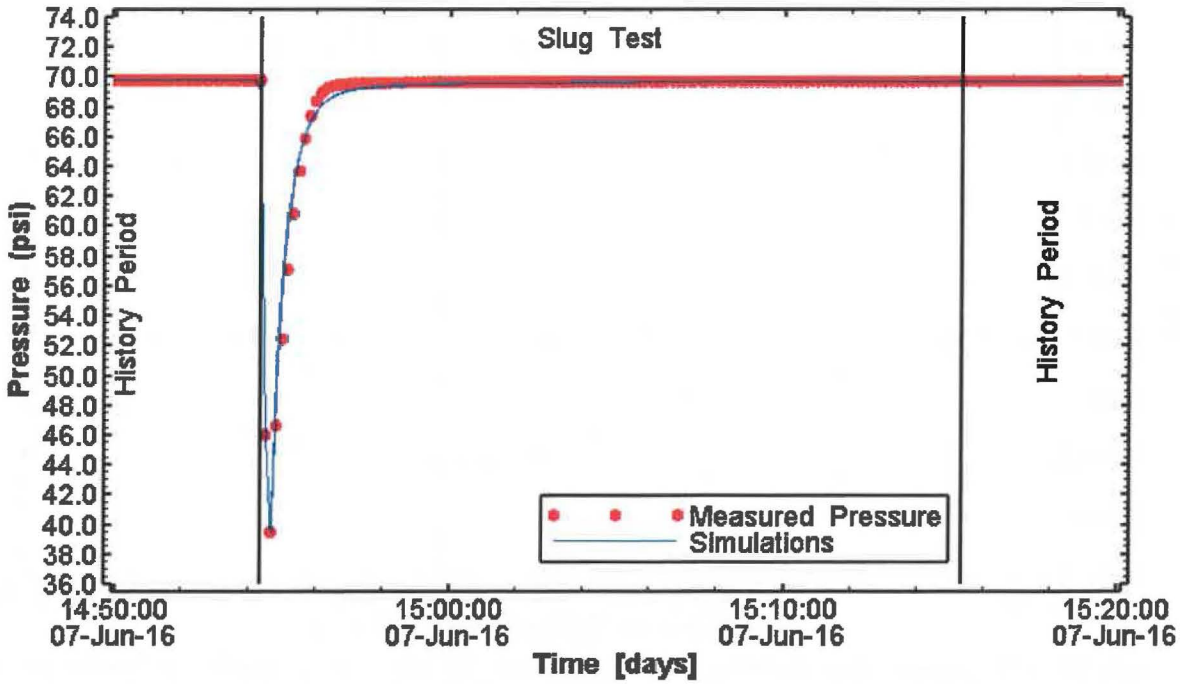


Figure 28. Pressure data and 238 model fits of the 6/7/16 Culebra slug test in IMC-461.

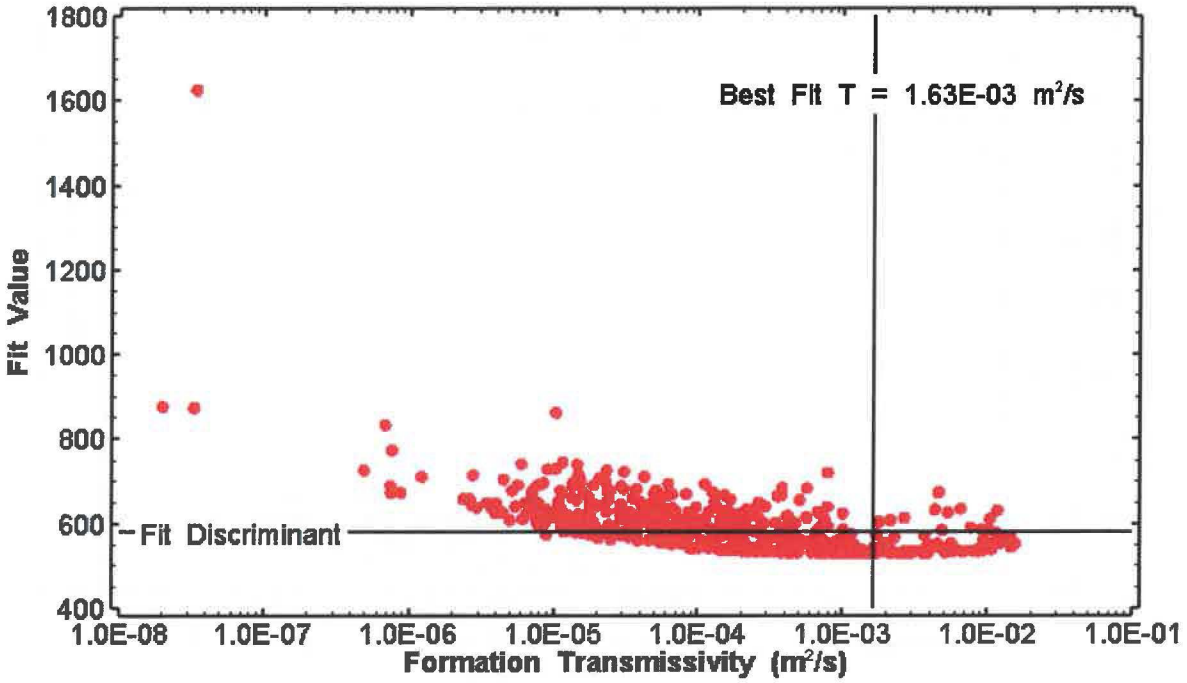


Figure 29. X-Y scatter scatter plot showing the transmissivity parameter space derived from the IMC-461 6/7/16 slug test perturbation analysis with fit discriminant and best fit values.

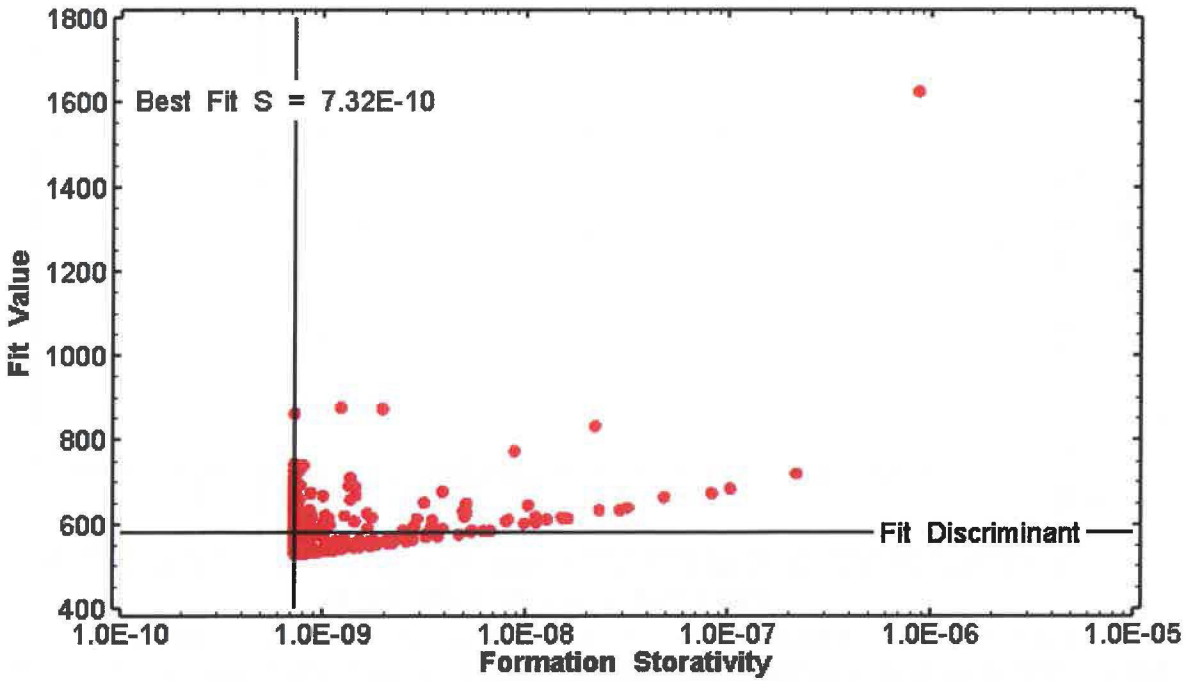


Figure 30. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 6/7/16 slug test perturbation analysis with fit discriminant and best fit values.

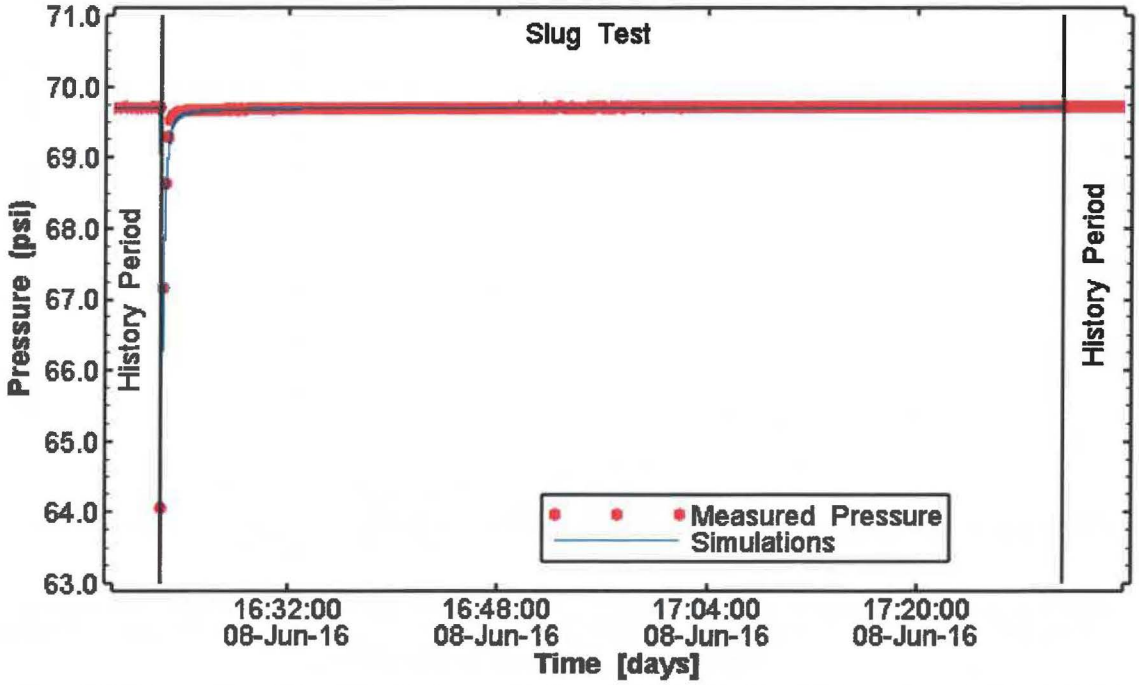


Figure 31. Pressure data and 441 model fits of the 6/8/16 Culebra slug test in IMC-461.

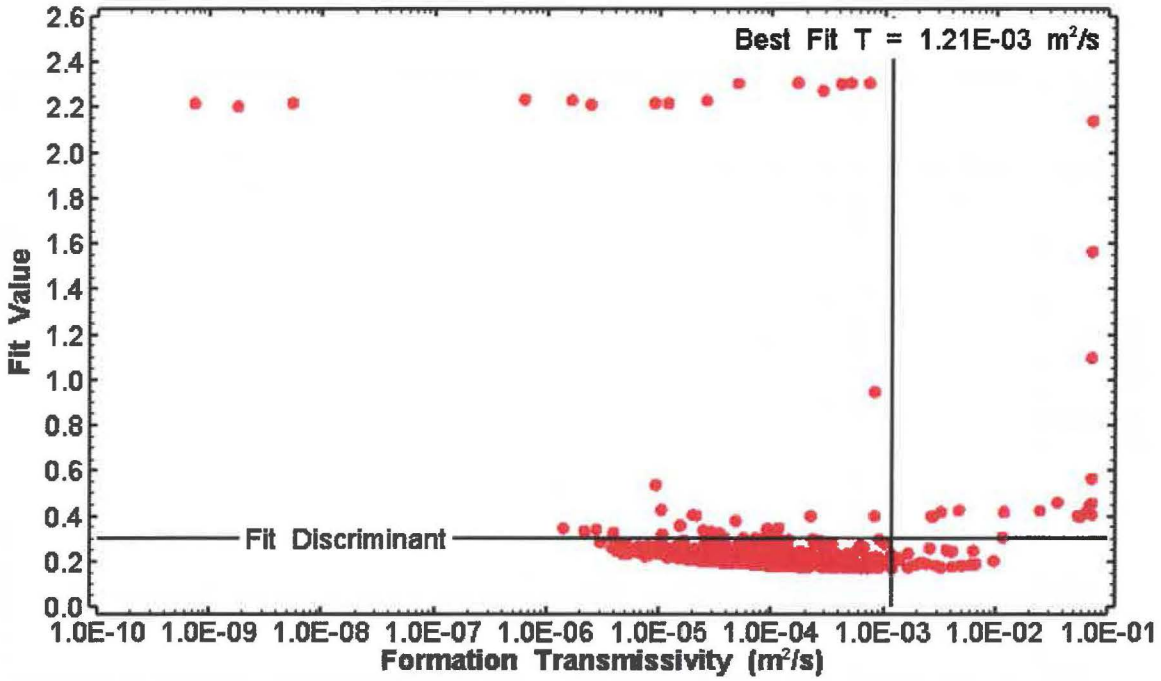


Figure 32. X-Y scatter plot showing the transmissivity parameter space derived from the IMC-461 6/8/16 slug test perturbation analysis with fit discriminant and best fit values.

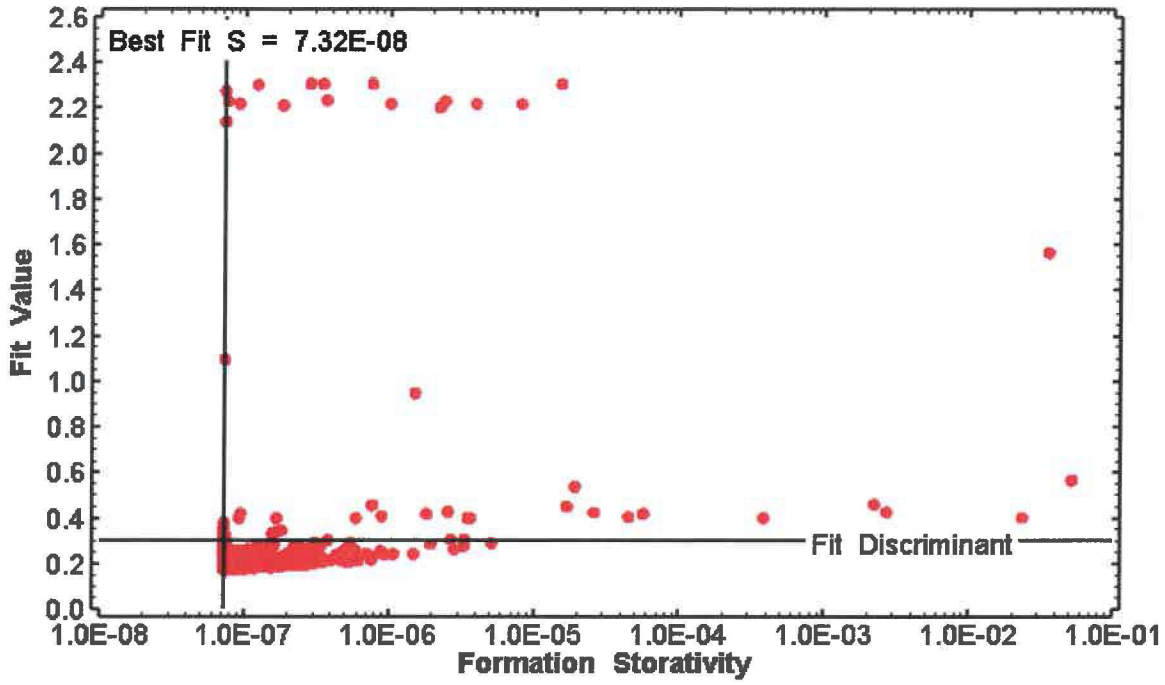


Figure 33. X-Y scatter plot showing the storativity parameter space derived from the IMC-461 6/8/16 slug test perturbation analysis with fit discriminant and best fit values.

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Appendix A – IMC-461 Hydraulic Test – 6/6/16 to 6/9/16

Well	Borehole Diameter (in)	Inside Tubing or Casing Diameter (in)	Culebra Interval (ft bgs)	Fluid Density (g/cm^3)	Data Source Report(s)	Field Notebook
IMC-461	5.125	1.913	362-386	1.008	Letter: IMC-461, 462, and 463(ERMS #541654)	WSWT#5, WTT1-6 Scientific Notebook Supplemental

Date	Start Test Time	Stop Test Time
6/6/2016	10:37	21:07
6/7/2016	9:03	18:57
6/8/2016	7:42	0:00
6/9/2016	7:13	12:19

Appendix B – nSIGHTS Listings

B.1 IMC-461 nSIGHTS Listings

```
************
nPre/64 2.50
************

Version date    25 June 2012
Listing date    01 Aug 2016
QA status       non-QA Open Source
Config file     C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-
461_D4_sine1.nPre
```

Control Settings

Main Settings

Simulation type	Optimization	
Simulation subtype	Normal	
Phase to simulate	Liquid	
Skin zone ?	yes	
External boundary	Fixed Pressure	

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	Optimization	

Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.759	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	4.48965E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Formation spec. storage	Optimization	
Minimum value	1.00000E-08	[1/m]
Maximum value	1.00000E-04	[1/m]
Estimate value	4.89372E-06	[1/m]
Range type	Log	
Sigma	1.00000E+00	

Skin

Radial thickness of skin	Optimization	
Minimum value	0.001	[m]
Maximum value	5.0	[m]
Estimate value	0.0011011	[m]
Range type	Linear	
Sigma	1.00000E+00	
Skin zone conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	8.24331E-07	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Skin zone spec. storage	Optimization	
Minimum value	1.00000E-10	[1/m]
Maximum value	1.00000E-02	[1/m]
Estimate value	8.46114E-07	[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]

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	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-08	[]
Maximum	7.31520E-04	[]
Diffusivity	min/max	
Minimum	1.00000E-06	[m^2/sec]
Maximum	1.00000E+06	[m^2/sec]

Skin Zone

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-10	[]
Maximum	7.31520E-02	[]
Diffusivity	min/max	
Minimum	1.00000E-08	[m^2/sec]
Maximum	1.00000E+08	[m^2/sec]
Skin factor	min/max	
Minimum	-1.52471E-02	[]
Maximum	4.35439E+08	[]

Grid Properties

Grid increment delta	min/max	
Minimum	0.06127	[]
Maximum	0.08308	[]
First grid increment	min/max	
Minimum	3.20053E-01	[m]
Maximum	5.72485E-03	[m]
Skin grid increment delta	min/max	
Minimum	0.00031	[]
Maximum	0.08887	[]
Skin first grid increment	min/max	
Minimum	2.02561E-05	[m]
Maximum	6.04880E-03	[m]
Skin last grid increment	min/max	
Minimum	2.05609E-05	[m]
Maximum	4.30690E-01	[m]
Increment ratio	min/max	
Minimum	7.43118E-01	[]
Maximum	2.78433E+02	[]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42530.262081	[day]
Duration	0.045791	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42530.307872	[day]
Duration	0.035531	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42530.343403	[day]
Duration	0.010764	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42530.354167	[day]
Duration	0.141782	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_04

Sequence type	History	
Start time	42530.495949	[day]
Duration	0.013079	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_05

Sequence type	History	
Start time	42530.509028	[day]
Duration	0.004398	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Test Zone Curves

Curve object to use	P_Curve	
Curve type	Pressure	
Start sequence	H_01	
End sequence	H_05	
Curve time base	Test	
Curve Y data units	[psi]	
Curve Y data is log 10	no	
Curve object to use	Q_Curve	
Curve type	Flow Rate	
Start sequence	H_01	
End sequence	H_05	
Curve time base	Test	
Curve Y data units	[USgpm]	
Curve Y data is log 10	no	

Simulation Results Setup

Output ID	DAT	
Output type	Pressure	
Pressure capture type	Test Zone	
Output units	[psi]	
Output ID	DAT	
Output type	Flow Rate	
Flow rate output type	Well	
Output units	[USgpm]	

OutputFiles

XY Forward Output

Write file ?	no

Optimization Output

Write file ?	no

Optimization Setup

Algorithm	Simplex
Calculate confidence limits ?	yes
Covariance matrix calculations	1st Order
Fixed derivative span ?	no
Fit tolerance	1.0000E-05
Parameter tolerance	not used
# of optimized variables	6
Formation conductivity	OK
Skin zone conductivity	OK
Static formation pressure	OK
Formation spec. storage	OK
Skin zone spec. storage	OK
Radial thickness of skin	OK

Fits to Optimize

CompositeFit	OK

Calculated Parameters Included

# of calculated variables included	0

Suite/Range Setup

# of suite/range variables	0

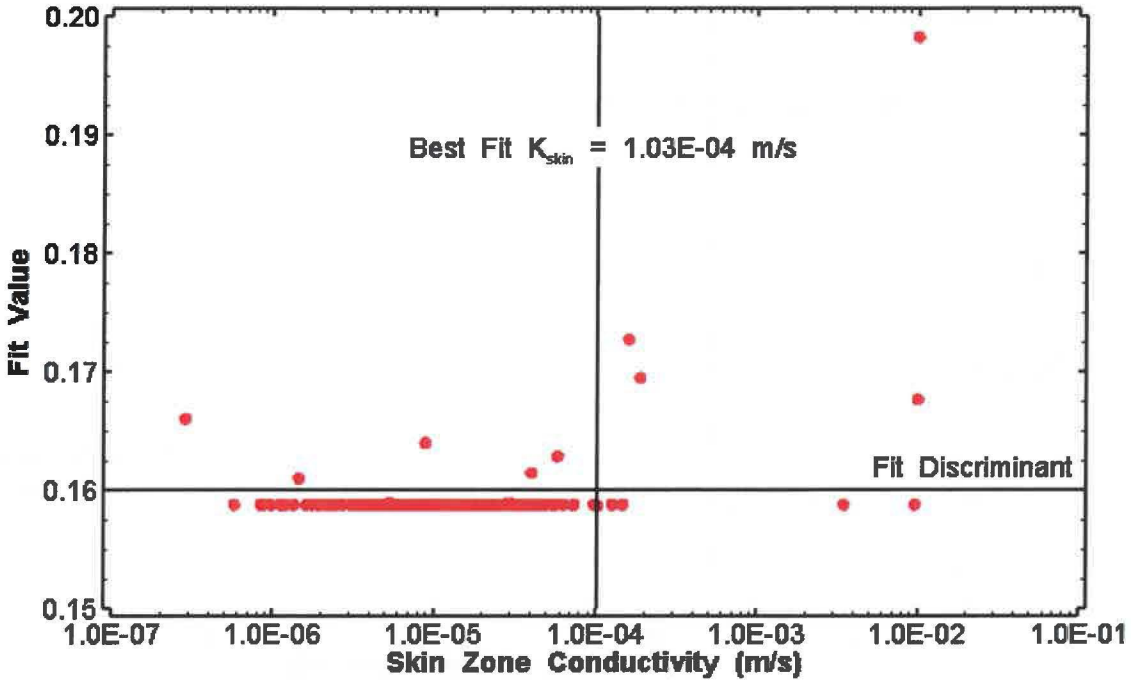


Figure B-1. X-Y scatter plot showing the skin zone conductivity parameter space derived from IMC-461 perturbation analysis for the 10 min period sinusoidal test with the fit discriminant and best fit values.

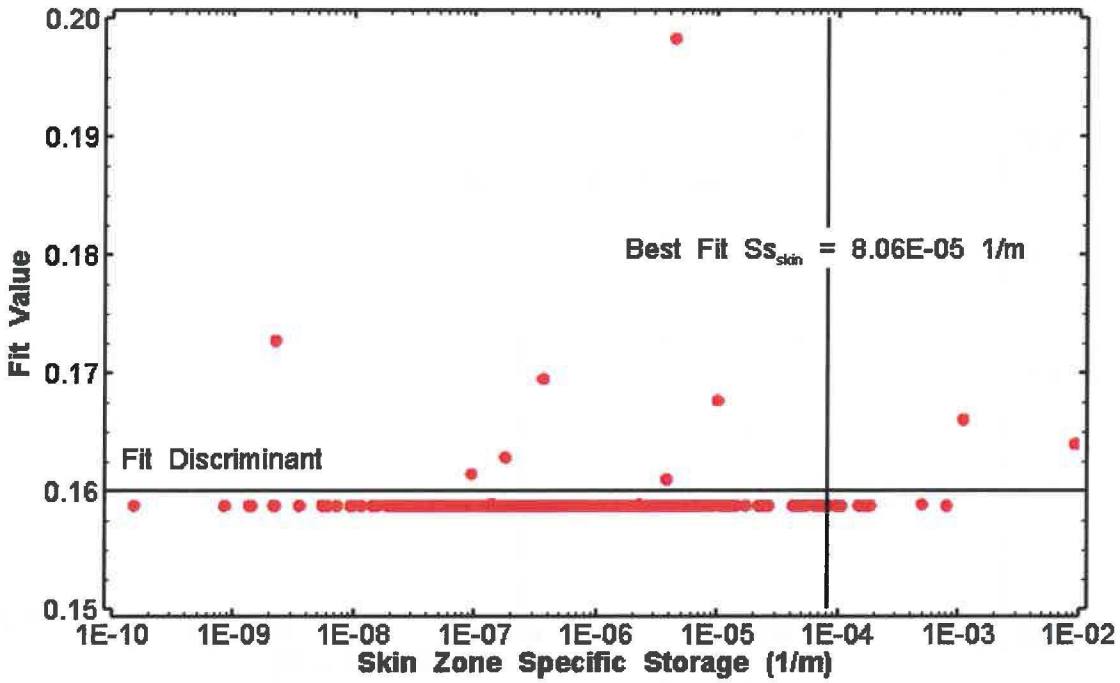


Figure B-2. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for 10 min period sinusoidal test with the fit discriminant and best fit values.

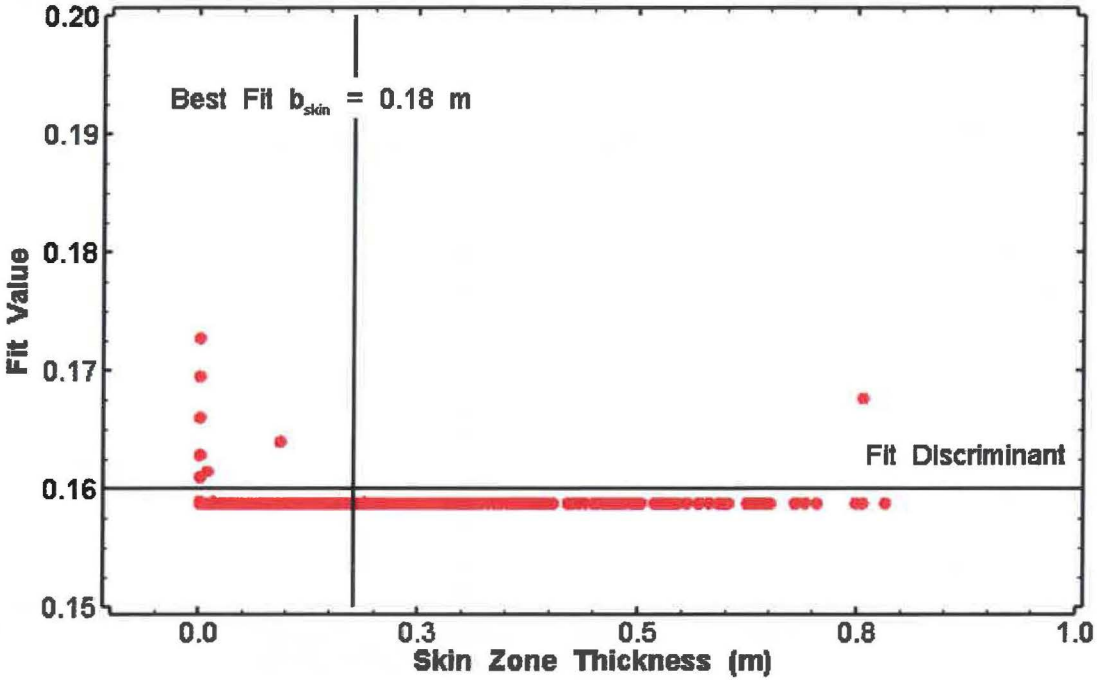


Figure B-3. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the 10 min period sinusoidal test with the fit discriminant and best fit values.

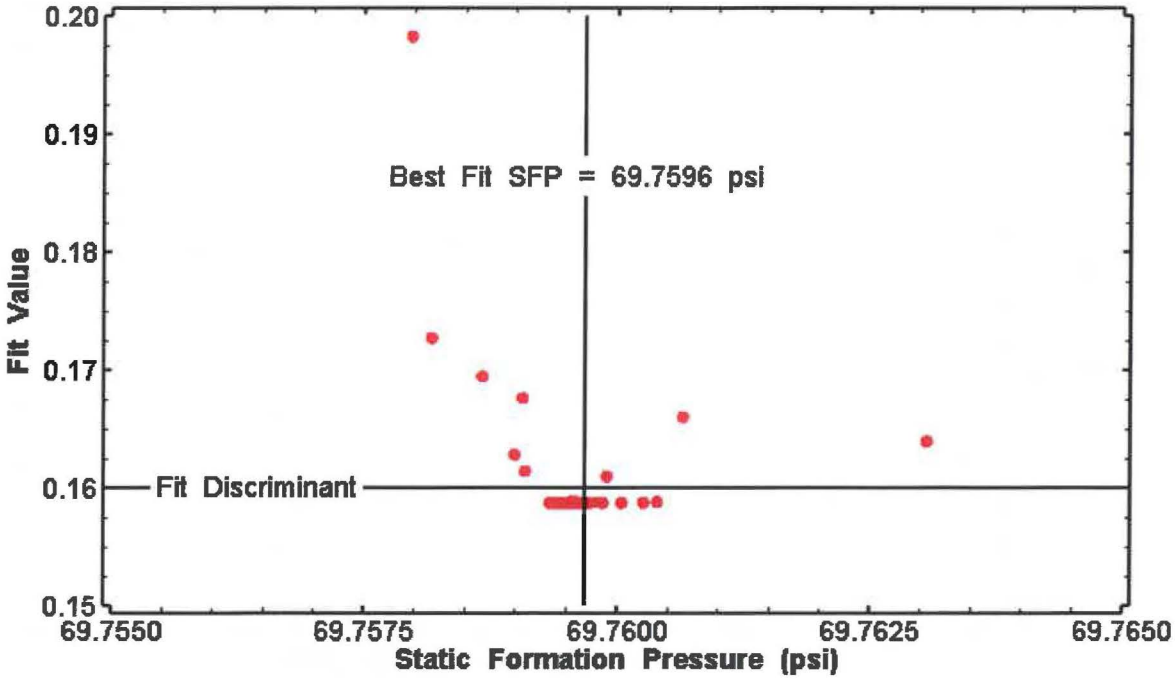


Figure B-4. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the 10 min period sinusoidal test with the fit discriminant and best fit values.

```
************
nPre/64 2.50
************

Version date    25 June 2012
Listing date    01 Aug 2016
QA status       non-QA Open Source
Config file     C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-
461_D1_SINE.nPre
```

Control Settings

Main Settings

Simulation type	Optimization
Simulation subtype	Normal
Phase to simulate	Liquid
Skin zone ?	yes
External boundary	Fixed Pressure

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	Optimization	
Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.734	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]

Estimate value	2.16332E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Formation spec. storage	Optimization	
Minimum value	1.00000E-08	[1/m]
Maximum value	1.00000E-04	[1/m]
Estimate value	7.00372E-05	[1/m]
Range type	Log	
Sigma	1.00000E+00	

Skin

Radial thickness of skin	Optimization	
Minimum value	0.001	[m]
Maximum value	5.0	[m]
Estimate value	4.7814313	[m]
Range type	Linear	
Sigma	1.00000E+00	
Skin zone conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	3.94091E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Skin zone spec. storage	Optimization	
Minimum value	1.00000E-10	[1/m]
Maximum value	1.00000E-02	[1/m]
Estimate value	2.15531E-09	[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]

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	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-08	[]

Maximum	7.31520E-04	[]
Diffusivity	min/max	
Minimum	1.00000E-06	[m^2/sec]
Maximum	1.00000E+06	[m^2/sec]

Skin Zone

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-10	[]
Maximum	7.31520E-02	[]
Diffusivity	min/max	
Minimum	1.00000E-08	[m^2/sec]
Maximum	1.00000E+08	[m^2/sec]
Skin factor	min/max	
Minimum	-1.52471E-02	[]
Maximum	4.35439E+08	[]

Grid Properties

Grid increment delta	min/max	
Minimum	0.06127	[]
Maximum	0.08308	[]
First grid increment	min/max	
Minimum	3.20053E-01	[m]
Maximum	5.72485E-03	[m]
Skin grid increment delta	min/max	
Minimum	0.00031	[]
Maximum	0.08887	[]
Skin first grid increment	min/max	
Minimum	2.02561E-05	[m]
Maximum	6.04880E-03	[m]
Skin last grid increment	min/max	
Minimum	2.05609E-05	[m]
Maximum	4.30690E-01	[m]
Increment ratio	min/max	
Minimum	7.43118E-01	[]
Maximum	2.78433E+02	[]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42527.390046	[day]
Duration	0.057871	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	

Start time	42527.447917	[day]
Duration	0.020833	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42527.468750	[day]
Duration	0.022107	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_04

Sequence type	History	
Start time	42527.490857	[day]
Duration	0.036921	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_05

Sequence type	History	
Start time	42527.527778	[day]
Duration	0.014005	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42527.541782	[day]
Duration	0.071065	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_06

Sequence type	History	
Start time	42527.612847	[day]
Duration	0.014583	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	

Type	Curve	
Wellbore storage	None	

Sequence: H_07

Sequence type	History	
Start time	42527.627431	[day]
Duration	0.251087	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Test Zone Curves

Curve object to use	P_Curve	
Curve type	Pressure	
Start sequence	H_01	
End sequence	H_07	
Curve time base	Test	
Curve Y data units	[psi]	
Curve Y data is log 10	no	
Curve object to use	Q_Curve	
Curve type	Flow Rate	
Start sequence	H_01	
End sequence	H_07	
Curve time base	Test	
Curve Y data units	[USgpm]	
Curve Y data is log 10	no	

Simulation Results Setup

Output ID	DAT	
Output type	Pressure	
Pressure capture type	Test Zone	
Output units	[psi]	
Output ID	DAT	
Output type	Flow Rate	
Flow rate output type	Well	
Output units	[USgpm]	

OutputFiles

XY Forward Output

Write file ?	no

Optimization Output

Write file ?	no

Optimization Setup

Algorithm	Simplex
Calculate confidence limits ?	yes
Covariance matrix calculations	1st Order
Fixed derivative span ?	no
Fit tolerance	1.0000E-05
Parameter tolerance	not used
# of optimized variables	6
Formation conductivity	OK
Skin zone conductivity	OK
Static formation pressure	OK
Formation spec. storage	OK
Skin zone spec. storage	OK
Radial thickness of skin	OK

Fits to Optimize

Cart_DAT_P	OK

Calculated Parameters Included

# of calculated variables included	0

Suite/Range Setup

# of suite/range variables	0

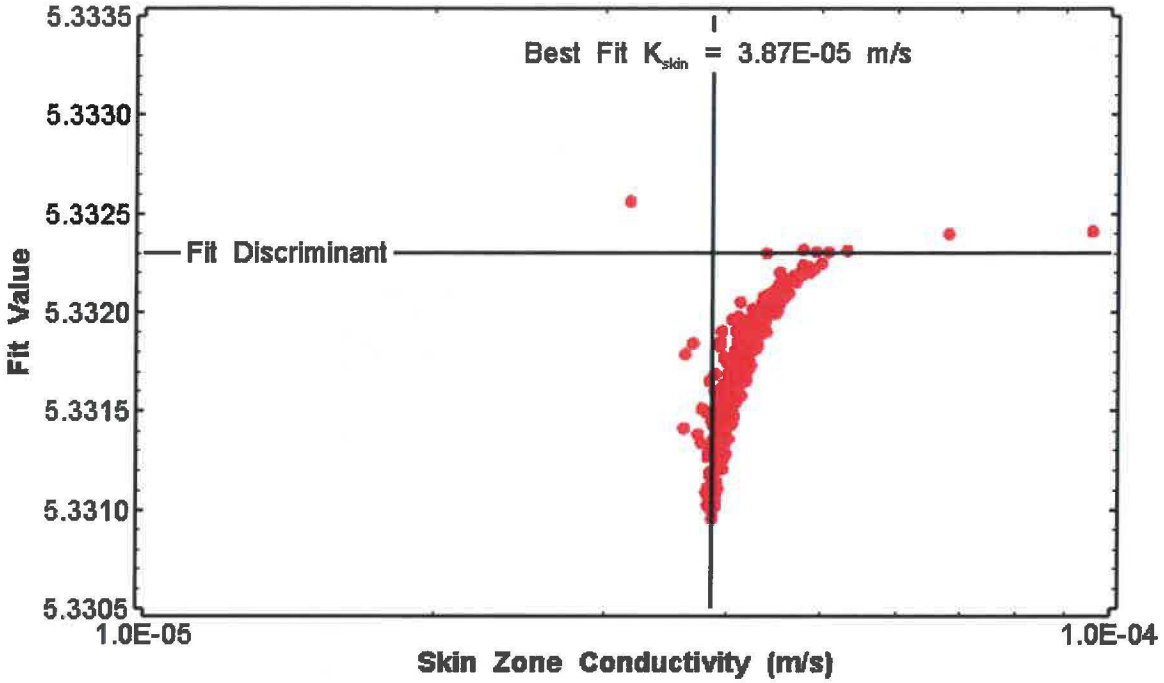


Figure B-5. X-Y scatter plot showing the skin zone conductivity parameter space derived from IMC-461 perturbation analysis for the 20 min period sinusoidal test with the fit discriminant and best fit values.

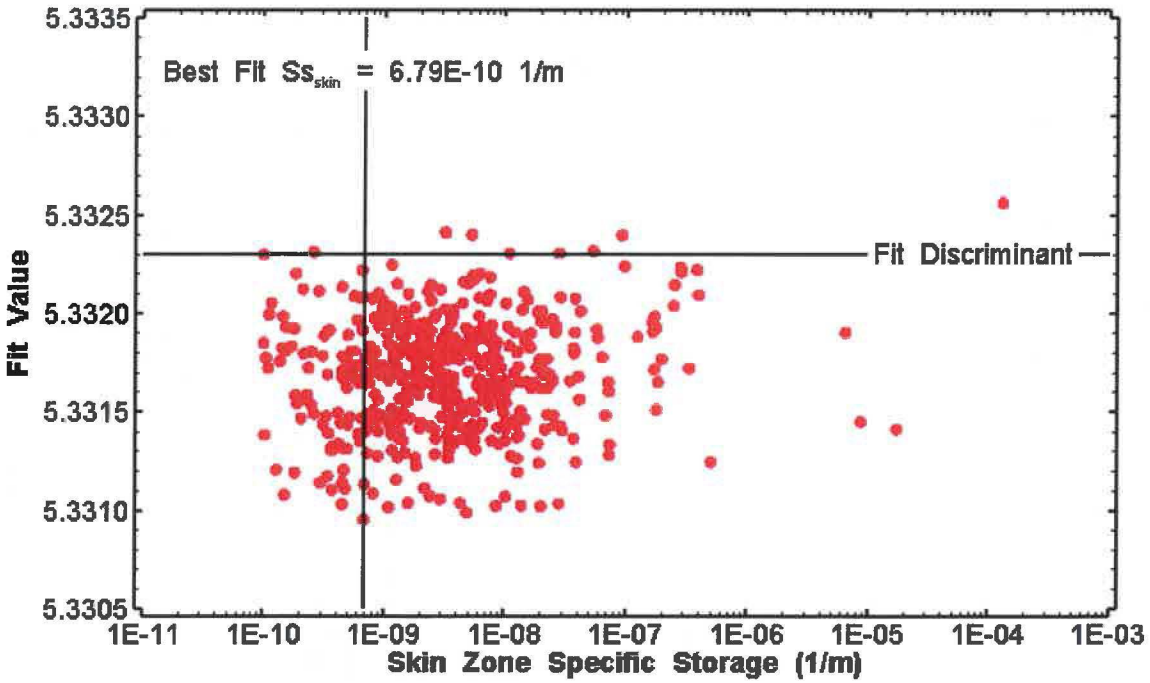


Figure B-6. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for 20 min period sinusoidal test with the fit discriminant and best fit values.

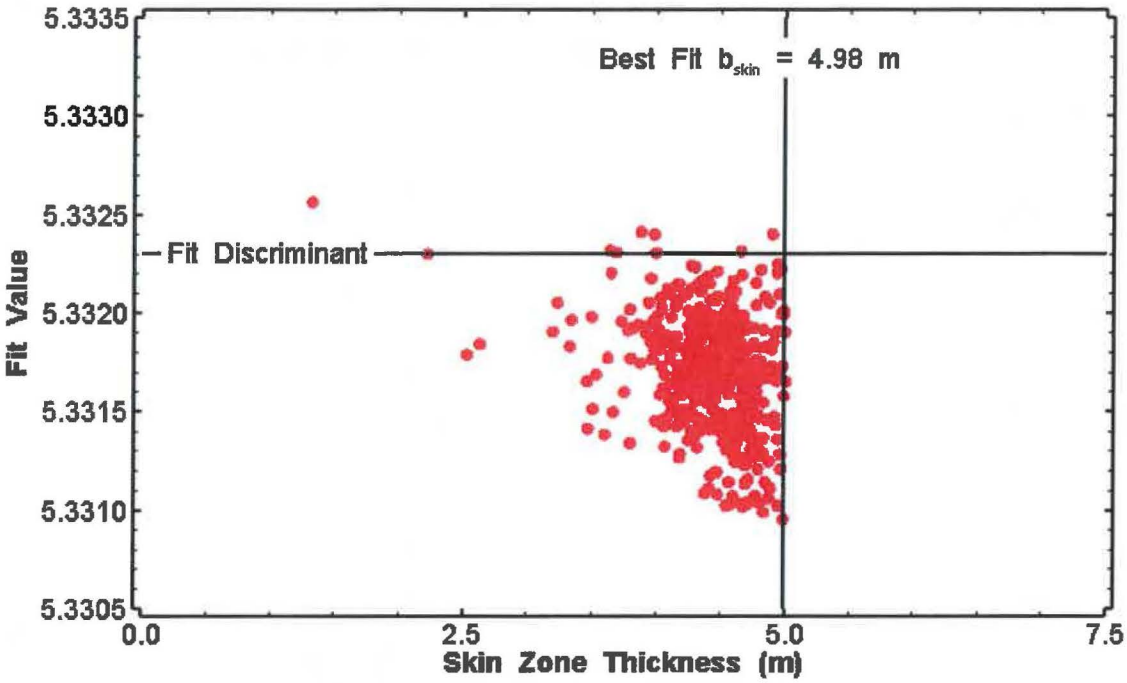


Figure B-7. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the 20 min period sinusoidal test with the fit discriminant and best fit values.

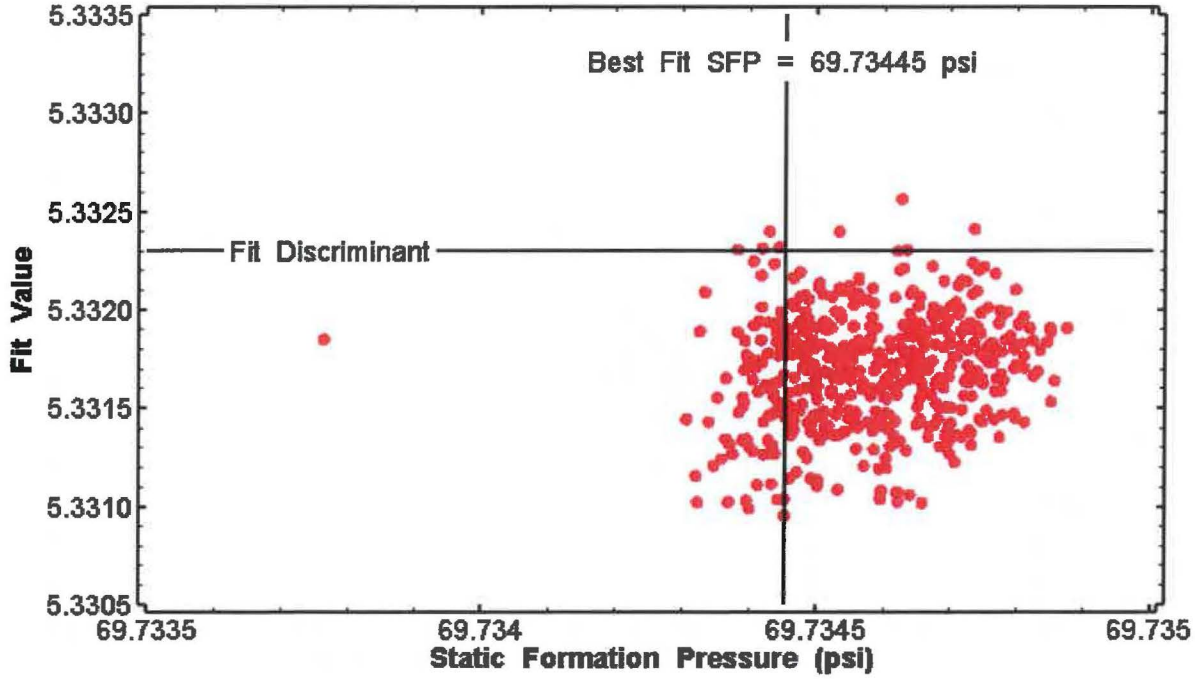


Figure B-8. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the 20 min period sinusoidal test with the fit discriminant and best fit values.

```
************
nPre/64 2.50
************

Version date    25 June 2012
Listing date    01 Aug 2016
QA status       non-QA Open Source
Config file     C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-
461_D4_sine2.nPre
```

Control Settings

Main Settings

Simulation type	Optimization
Simulation subtype	Normal
Phase to simulate	Liquid
Skin zone ?	yes
External boundary	Fixed Pressure

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	Optimization	
Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.742	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	

Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	2.71813E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Formation spec. storage	Optimization	
Minimum value	1.00000E-08	[1/m]
Maximum value	1.00000E-04	[1/m]
Estimate value	5.89304E-05	[1/m]
Range type	Log	
Sigma	1.00000E+00	

Skin

Radial thickness of skin	Optimization	
Minimum value	0.001	[m]
Maximum value	5.0	[m]
Estimate value	0.247773	[m]
Range type	Linear	
Sigma	1.00000E+00	
Skin zone conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	1.78602E-04	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Skin zone spec. storage	Optimization	
Minimum value	1.00000E-10	[1/m]
Maximum value	1.00000E-02	[1/m]
Estimate value	2.95586E-10	[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]

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	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-08	[]
Maximum	7.31520E-04	[]
Diffusivity	min/max	
Minimum	1.00000E-06	[m^2/sec]
Maximum	1.00000E+06	[m^2/sec]

Skin Zone

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-10	[]
Maximum	7.31520E-02	[]
Diffusivity	min/max	
Minimum	1.00000E-08	[m^2/sec]
Maximum	1.00000E+08	[m^2/sec]
Skin factor	min/max	
Minimum	-1.52471E-02	[]
Maximum	4.35439E+08	[]

Grid Properties

Grid increment delta	min/max	
Minimum	0.06127	[]
Maximum	0.08308	[]
First grid increment	min/max	
Minimum	3.20053E-01	[m]
Maximum	5.72485E-03	[m]
Skin grid increment delta	min/max	
Minimum	0.00031	[]
Maximum	0.08887	[]
Skin first grid increment	min/max	
Minimum	2.02561E-05	[m]
Maximum	6.04880E-03	[m]
Skin last grid increment	min/max	
Minimum	2.05609E-05	[m]
Maximum	4.30690E-01	[m]
Increment ratio	min/max	
Minimum	7.43118E-01	[]
Maximum	2.78433E+02	[]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42530.262081	[day]
Duration	0.045791	[day]

Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42530.307872	[day]
Duration	0.035531	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42530.343403	[day]
Duration	0.010764	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42530.354167	[day]
Duration	0.141782	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_04

Sequence type	History	
Start time	42530.495949	[day]
Duration	0.013079	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_05

Sequence type	History	
Start time	42530.509028	[day]
Duration	0.004398	[day]
Time step type	Log	
First log step	1.15741E-07	[day]

# of time steps	250
Type	Curve
Wellbore storage	None

Test Zone Curves

Curve object to use	P_Curve
Curve type	Pressure
Start sequence	H_01
End sequence	H_05
Curve time base	Test
Curve Y data units	[psi]
Curve Y data is log 10	no

Curve object to use	Q_Curve
Curve type	Flow Rate
Start sequence	H_01
End sequence	H_05
Curve time base	Test
Curve Y data units	[USgpm]
Curve Y data is log 10	no

Simulation Results Setup

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

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

OutputFiles

XY Forward Output

Write file ?	no

Optimization Output

Write file ?	no

Optimization Setup

Algorithm	Simplex
Calculate confidence limits ?	yes
Covariance matrix calculations	1st Order

Fixed derivative span ?	no
Fit tolerance	1.0000E-05
Parameter tolerance	not used
# of optimized variables	6
Formation conductivity	OK
Skin zone conductivity	OK
Static formation pressure	OK
Formation spec. storage	OK
Skin zone spec. storage	OK
Radial thickness of skin	OK

Fits to Optimize

CompositeFit	OK

Calculated Parameters Included

# of calculated variables included	0

Suite/Range Setup

# of suite/range variables	0

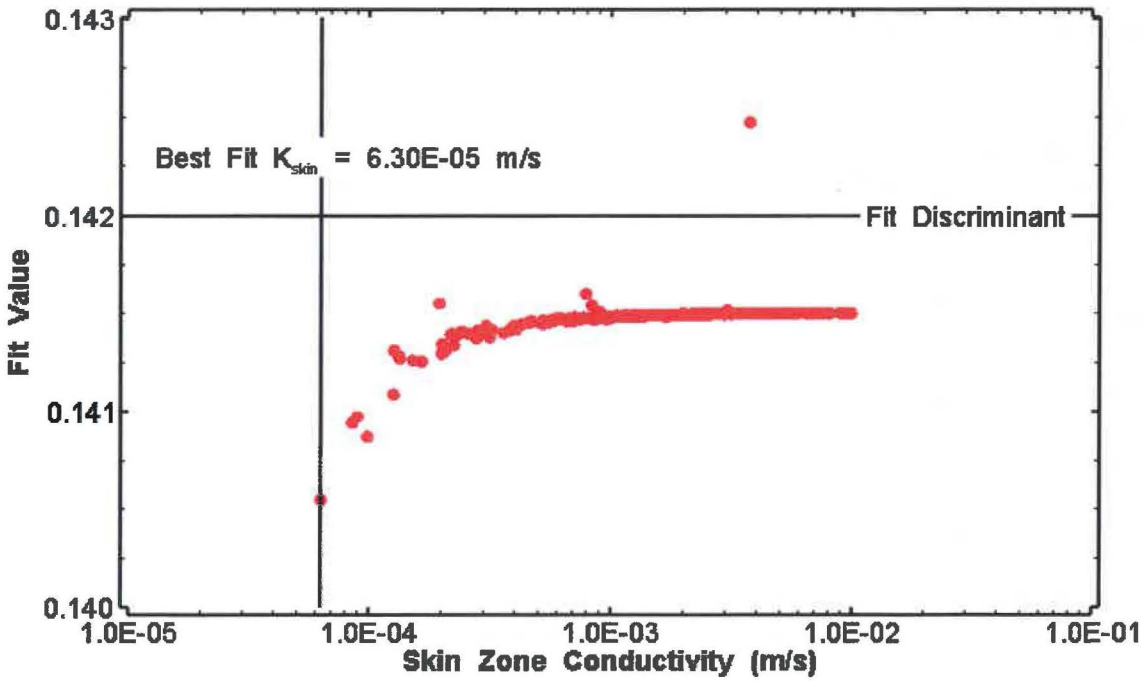


Figure B-9. X-Y scatter plot showing the skin zone conductivity parameter space derived from IMC-461 perturbation analysis for the 40 min period sinusoidal test with the fit discriminant and best fit values.

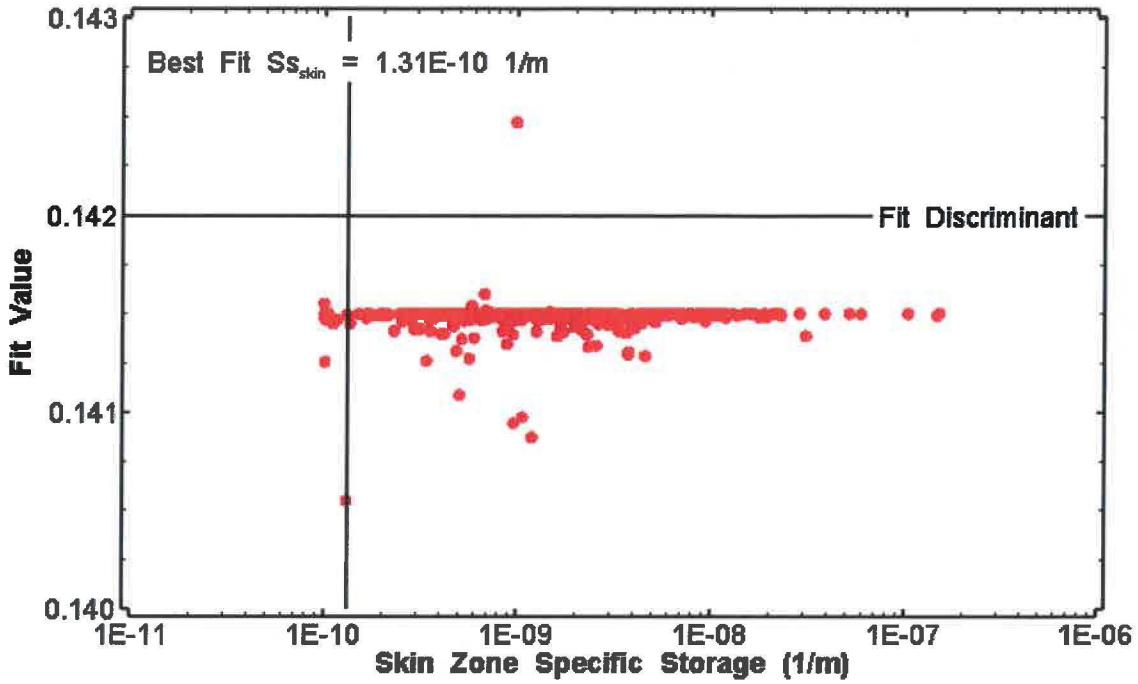


Figure B-10. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for 40 min period sinusoidal test with the fit discriminant and best fit values.

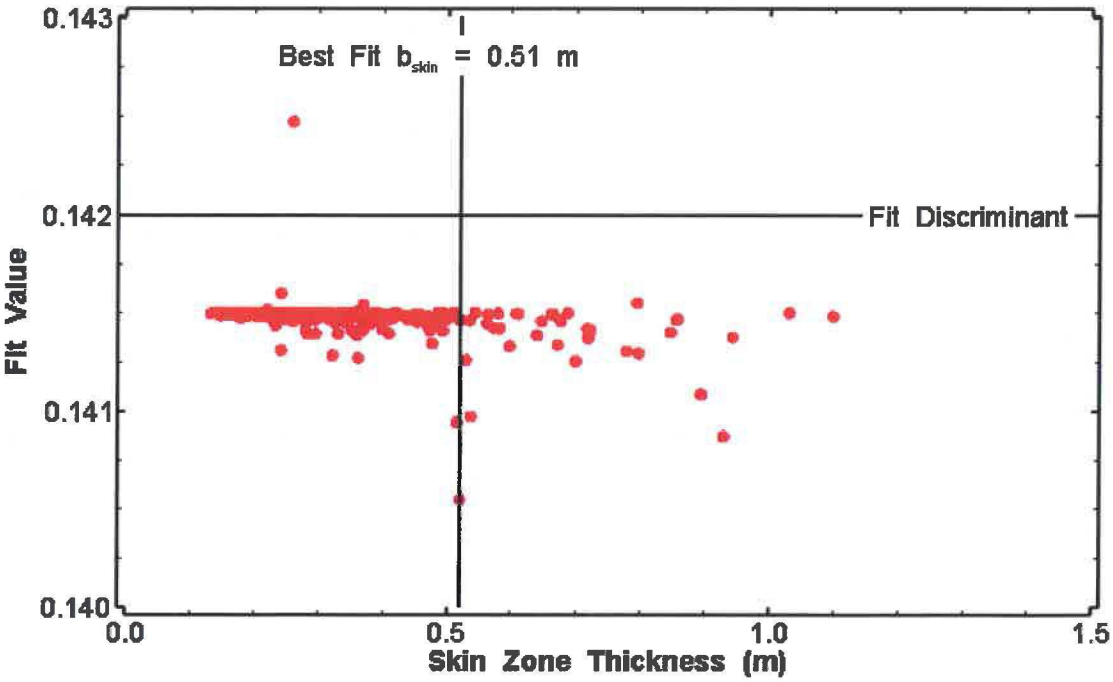


Figure B-11. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the 40 min period sinusoidal test with the fit discriminant and best fit values.

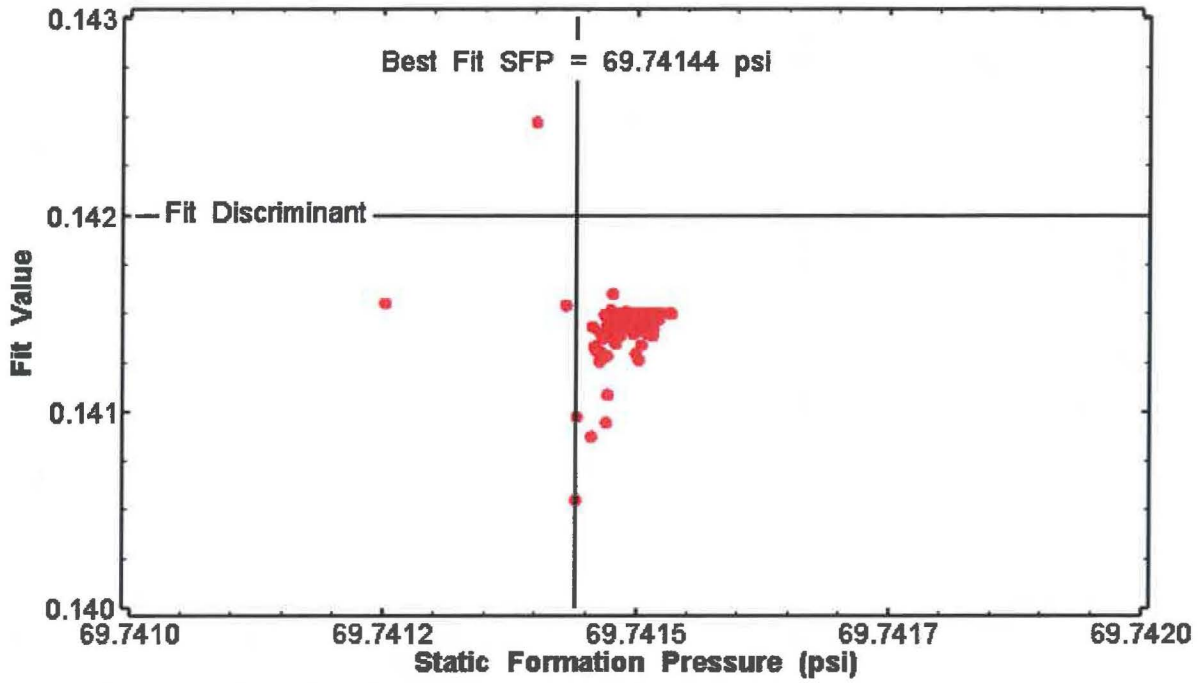


Figure B-12. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the 40 min period sinusoidal test with the fit discriminant and best fit values.

```
************
nPre/64 2.50
************

Version date    25 June 2012
Listing date    01 Aug 2016
QA status       non-QA Open Source
Config file     C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-
461_D2_sine.nPre
```

Control Settings

Main Settings

```
Simulation type                          Optimization
Simulation subtype                             Normal
Phase to simulate                              Liquid
Skin zone ?                                       yes
External boundary                     Fixed Pressure
```

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	Optimization	
Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.731	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	1.67640E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Formation spec. storage	Optimization	
Minimum value	1.00000E-08	[1/m]
Maximum value	1.00000E-04	[1/m]
Estimate value	9.99867E-05	[1/m]
Range type	Log	
Sigma	1.00000E+00	

Skin

Radial thickness of skin	Optimization	
Minimum value	0.001	[m]
Maximum value	5.0	[m]
Estimate value	4.844046	[m]
Range type	Linear	
Sigma	1.00000E+00	
Skin zone conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	4.85565E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	

Skin zone spec. storage	Optimization	
Minimum value	1.00000E-10	[1/m]
Maximum value	1.00000E-02	[1/m]
Estimate value	2.86871E-09	[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]

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	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-08	[]
Maximum	7.31520E-04	[]
Diffusivity	min/max	
Minimum	1.00000E-06	[m^2/sec]
Maximum	1.00000E+06	[m^2/sec]

Skin Zone

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-10	[]
Maximum	7.31520E-02	[]
Diffusivity	min/max	
Minimum	1.00000E-08	[m^2/sec]
Maximum	1.00000E+08	[m^2/sec]
Skin factor	min/max	
Minimum	-1.52471E-02	[]
Maximum	4.35439E+08	[]

Grid Properties

Grid increment delta	min/max	
Minimum	0.06127	[]
Maximum	0.08308	[]
First grid increment	min/max	
Minimum	3.20053E-01	[m]
Maximum	5.72485E-03	[m]
Skin grid increment delta	min/max	
Minimum	0.00031	[]
Maximum	0.08887	[]
Skin first grid increment	min/max	
Minimum	2.02561E-05	[m]
Maximum	6.04880E-03	[m]
Skin last grid increment	min/max	
Minimum	2.05609E-05	[m]
Maximum	4.30690E-01	[m]
Increment ratio	min/max	
Minimum	7.43118E-01	[]
Maximum	2.78433E+02	[]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42528.250694	[day]
Duration	0.126389	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42528.377083	[day]
Duration	0.031366	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42528.408449	[day]
Duration	0.022107	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	

Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42528.430556	[day]
Duration	0.169329	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_04

Sequence type	History	
Start time	42528.599884	[day]
Duration	0.021412	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_05

Sequence type	History	
Start time	42528.621296	[day]
Duration	0.149537	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Test Zone Curves

Curve object to use	P_Curve	
Curve type	Pressure	
Start sequence	H_01	
End sequence	H_05	
Curve time base	Test	
Curve Y data units	[psi]	
Curve Y data is log 10	no	
Curve object to use	Q_Curve	
Curve type	Flow Rate	
Start sequence	H_01	
End sequence	H_05	
Curve time base	Test	
Curve Y data units	[USgpm]	
Curve Y data is log 10	no	

Simulation Results Setup

Output ID	DAT
Output type	Pressure
Pressure capture type	Test Zone
Output units	[psi]
Output ID	DAT
Output type	Flow Rate
Flow rate output type	Well
Output units	[USgpm]

OutputFiles

XY Forward Output

Write file ?	no

Optimization Output

Write file ?	no

Optimization Setup

Algorithm	Simplex
Calculate confidence limits ?	yes
Covariance matrix calculations	1st Order
Fixed derivative span ?	no
Fit tolerance	1.0000E-05
Parameter tolerance	not used
# of optimized variables	6
Formation conductivity	OK
Skin zone conductivity	OK
Static formation pressure	OK
Formation spec. storage	OK
Skin zone spec. storage	OK
Radial thickness of skin	OK

Fits to Optimize

CompositeFit	OK

Calculated Parameters Included

# of calculated variables included	0

Suite/Range Setup

# of suite/range variables	0

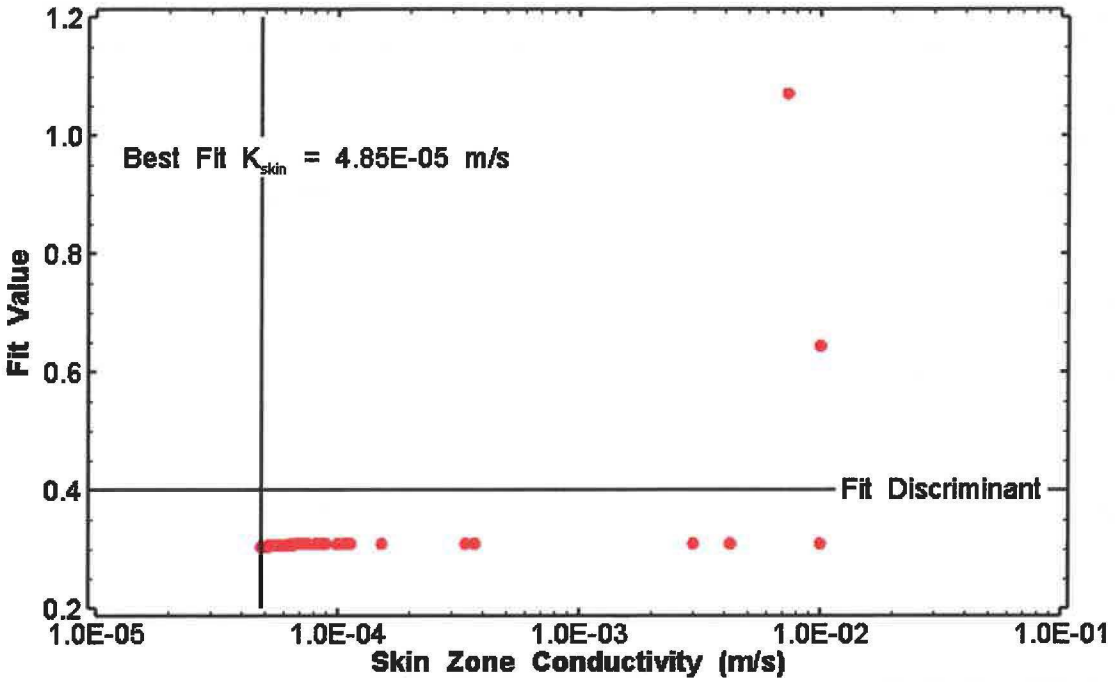


Figure B-13. X-Y scatter plot showing the skin zone conductivity parameter space derived from IMC-461 perturbation analysis for the 60 min period sinusoidal test with the fit discriminant and best fit values.

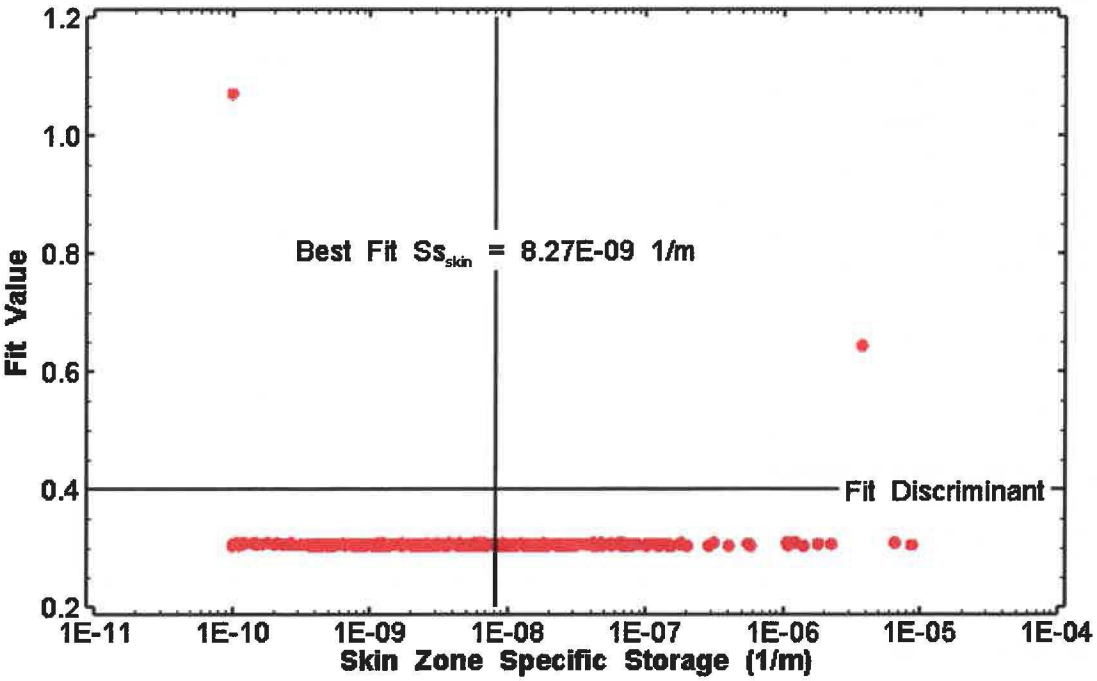


Figure B-14. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for 60 min period sinusoidal test with the fit discriminant and best fit values.

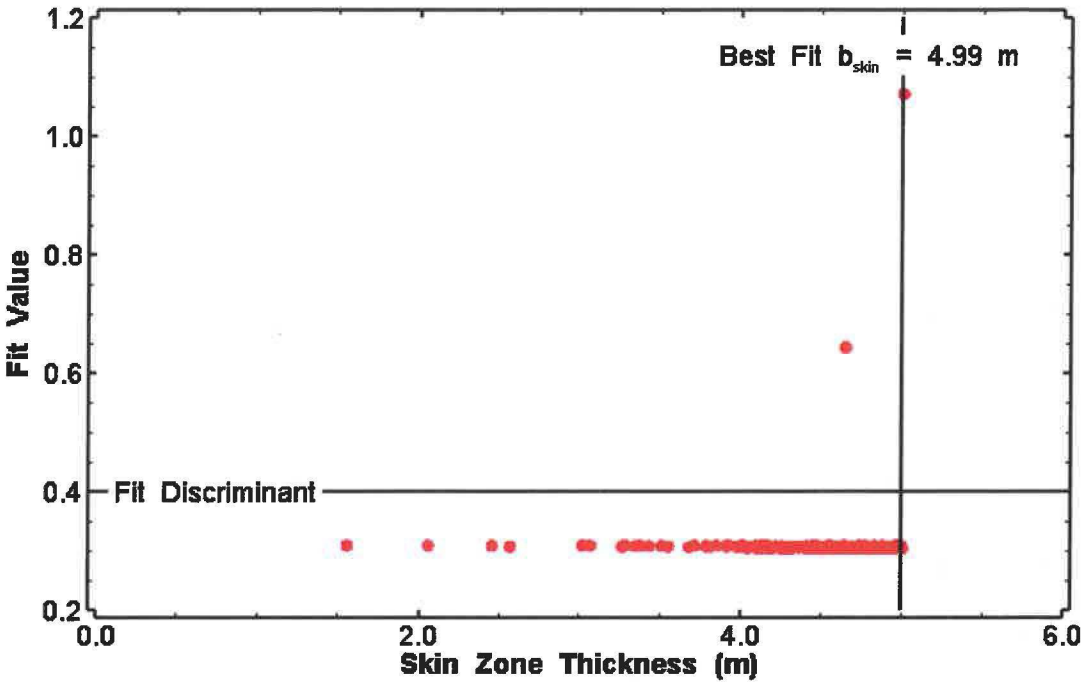


Figure B-15. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the 60 min period sinusoidal test with the fit discriminant and best fit values.

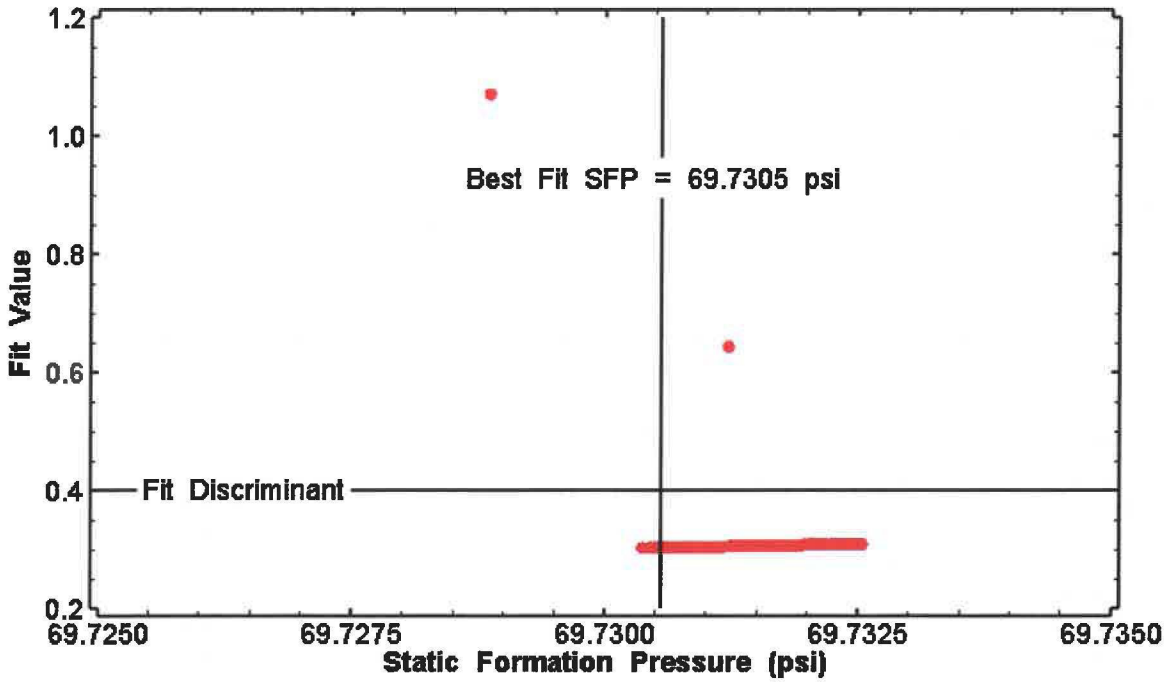


Figure B-16. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the 60 min period sinusoidal test with the fit discriminant and best fit values.

```
************
nPre/64 2.50
************

Version date    25 June 2012
Listing date    01 Aug 2016
QA status       non-QA Open Source
Config file     C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-
461_D3_sine.nPre
```

Control Settings

Main Settings

Simulation type	Optimization
Simulation subtype	Normal
Phase to simulate	Liquid
Skin zone ?	yes
External boundary	Fixed Pressure

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	Optimization	
Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.729	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	

Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	1.53646E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Formation spec. storage	1.00000E-05	[1/m]

Skin

Radial thickness of skin	Optimization	
Minimum value	0.001	[m]
Maximum value	5.0	[m]
Estimate value	3.6191182	[m]
Range type	Linear	
Sigma	1.00000E+00	
Skin zone conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	4.29044E-04	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Skin zone spec. storage	Optimization	
Minimum value	1.00000E-10	[1/m]
Maximum value	1.00000E-02	[1/m]
Estimate value	8.69173E-06	[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]

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	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	7.31520E-05	[]

Diffusivity	min/max	
Minimum	1.00000E-05	[m^2/sec]
Maximum	1.00000E+03	[m^2/sec]

Skin Zone

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-10	[]
Maximum	7.31520E-02	[]
Diffusivity	min/max	
Minimum	1.00000E-08	[m^2/sec]
Maximum	1.00000E+08	[m^2/sec]
Skin factor	min/max	
Minimum	-1.52471E-02	[]
Maximum	4.35439E+08	[]

Grid Properties

Grid increment delta	min/max	
Minimum	0.06127	[]
Maximum	0.08308	[]
First grid increment	min/max	
Minimum	3.20053E-01	[m]
Maximum	5.72485E-03	[m]
Skin grid increment delta	min/max	
Minimum	0.00031	[]
Maximum	0.08887	[]
Skin first grid increment	min/max	
Minimum	2.02561E-05	[m]
Maximum	6.04880E-03	[m]
Skin last grid increment	min/max	
Minimum	2.05609E-05	[m]
Maximum	4.30690E-01	[m]
Increment ratio	min/max	
Minimum	7.43118E-01	[]
Maximum	2.78433E+02	[]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42529.278745	[day]
Duration	0.047958	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42529.326703	[day]
Duration	0.338343	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42529.665046	[day]
Duration	0.017130	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42529.682176	[day]
Duration	0.097890	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Test Zone Curves

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

Curve object to use	Q_Curve
Curve type	Flow Rate
Start sequence	H_01
End sequence	H_03
Curve time base	Test
Curve Y data units	[USgpm]
Curve Y data is log 10	no

Simulation Results Setup

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

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

OutputFiles

XY Forward Output

Write file ?	no

Optimization Output

Write file ?	no

Optimization Setup

Algorithm	Simplex
Calculate confidence limits ?	yes
Covariance matrix calculations	1st Order
Fixed derivative span ?	no
Fit tolerance	1.0000E-05
Parameter tolerance	not used
# of optimized variables	5
Formation conductivity	OK
Skin zone conductivity	OK
Static formation pressure	OK
Skin zone spec. storage	OK
Radial thickness of skin	OK

Fits to Optimize

CompositeFit	OK

Calculated Parameters Included

# of calculated variables included	0

Suite/Range Setup

# of suite/range variables	0

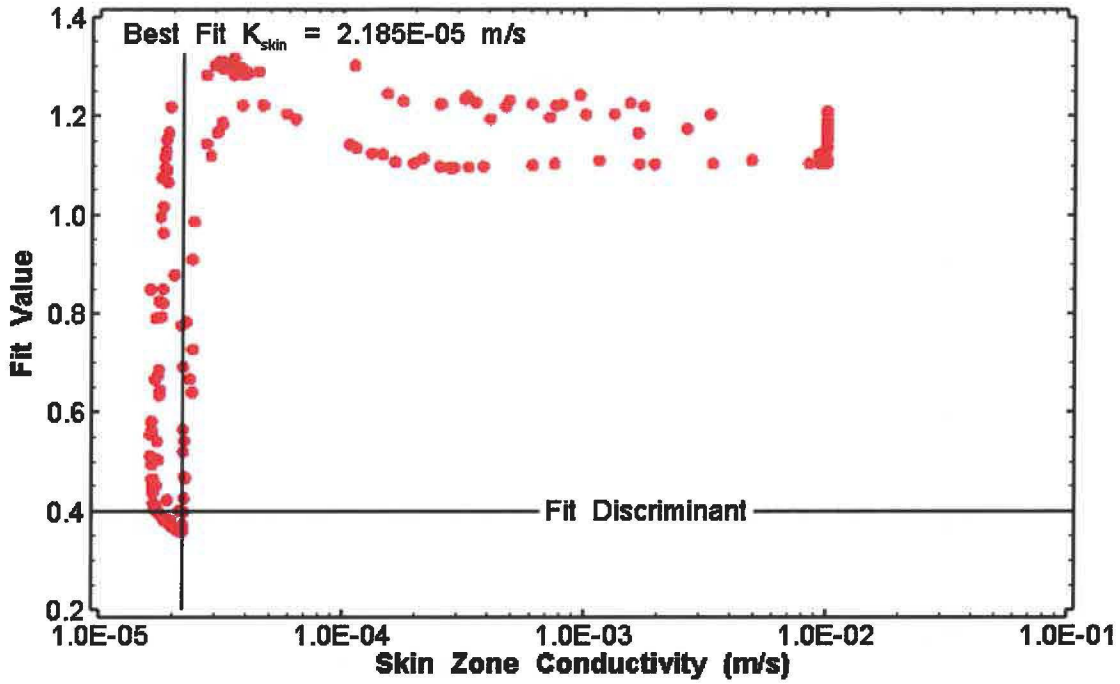


Figure B-17. X-Y scatter plot showing the skin zone conductivity parameter space derived from IMC-461 perturbation analysis for the 120 min period sinusoidal test with the fit discriminant and best fit values.

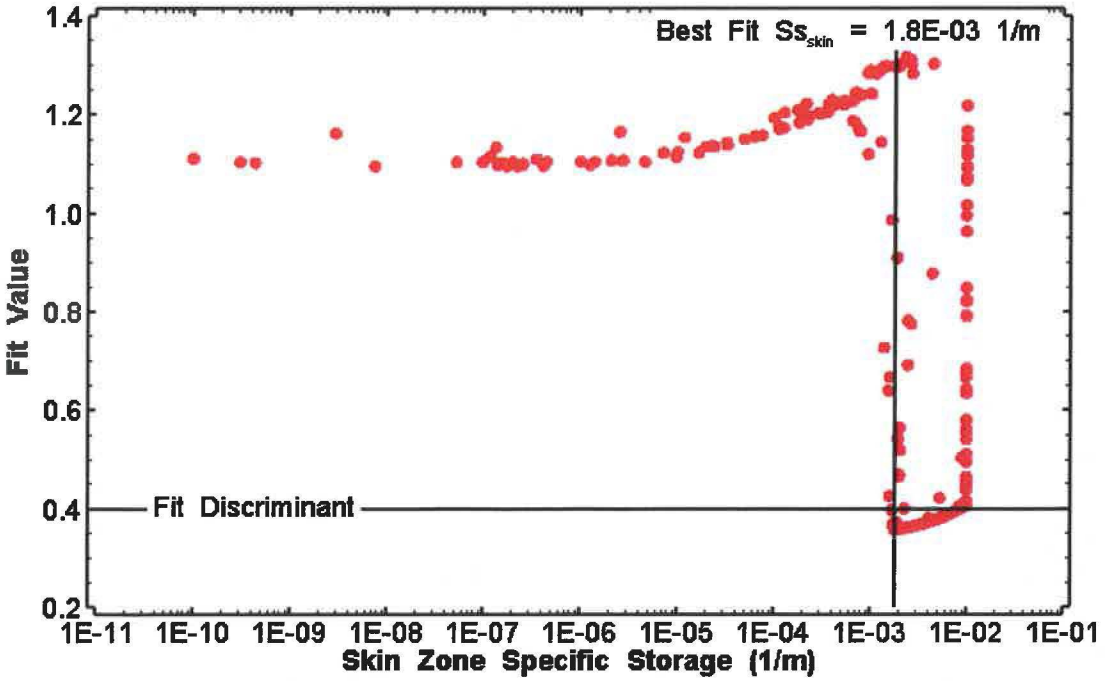


Figure B-18. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for 120 min period sinusoidal test with the fit discriminant and best fit values.

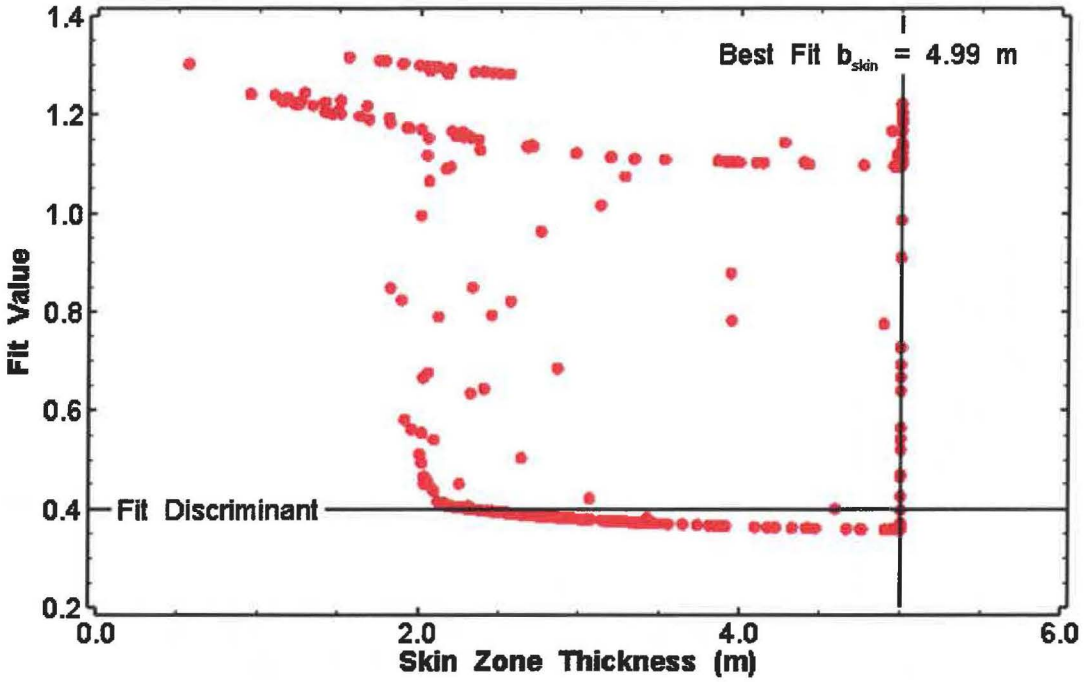


Figure B-19. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the 120 min period sinusoidal test with the fit discriminant and best fit values.

```
************
nPre/64 2.50
************

Version date    25 June 2012
Listing date    01 Aug 2016
QA status       non-QA Open Source
Config file     C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-
461_D1_CR.nPre
```

Control Settings

Main Settings

Simulation type	Forward
Simulation subtype	Normal
Phase to simulate	Liquid
Skin zone ?	yes
External boundary	Fixed Pressure

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	69.748	[psi]
External boundary radius	1000000	[m]
Formation conductivity	1.61609E-05	[m/sec]
Formation spec. storage	9.80494E-05	[1/m]

Skin

Radial thickness of skin	4.9962433	[m]
Skin zone conductivity	4.37856E-05	[m/sec]
Skin zone spec. storage	3.95170E-09	[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]

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	1.18220E-04	[m^2/sec]
Storativity	7.17251E-04	[]
Diffusivity	1.64824E-01	[m^2/sec]

Skin Zone

Transmissivity	3.20300E-04	[m^2/sec]
Storativity	2.89075E-08	[]

Diffusivity	1.10802E+04	[m^2/sec]
Skin factor	-2.74676E+00	[]

Grid Properties

Grid increment delta	0.06128	[]
First grid increment	3.19836E-01	[m]
Skin grid increment delta	0.08885	[]
Skin first grid increment	6.04772E-03	[m]
Skin last grid increment	4.30300E-01	[m]
Increment ratio	7.43286E-01	[]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42527.390046	[day]
Duration	0.057871	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42527.447917	[day]
Duration	0.020833	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: F_02

Sequence type	Flow	
Start time	42527.468750	[day]
Duration	0.022107	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42527.490857	[day]
Duration	0.036921	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42527.527778	[day]
Duration	0.014005	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_04

Sequence type	History	
Start time	42527.541782	[day]
Duration	0.071065	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_05

Sequence type	History	
Start time	42527.612847	[day]
Duration	0.014583	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_06

Sequence type	History	
Start time	42527.627431	[day]
Duration	0.251087	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Test Zone Curves

Curve object to use	P_Curve	
Curve type	Pressure	
Start sequence	H_01	
End sequence	H_06	
Curve time base	Test	
Curve Y data units	[psi]	
Curve Y data is log 10	no	
Curve object to use	Q_Curve	
Curve type	Flow Rate	
Start sequence	H_01	
End sequence	H_06	
Curve time base	Test	

Curve Y data units	[USgpm]
Curve Y data is log 10	no

Simulation Results Setup

Output ID	DAT
Output type	Pressure
Pressure capture type	Test Zone
Output units	[psi]
Output ID	DAT
Output type	Flow Rate
Flow rate output type	Well
Output units	[USgpm]

OutputFiles

XY Forward Output

Write file ?	no

Profile Output

Write file ?	no

Suite/Range Setup

# of suite/range variables	0

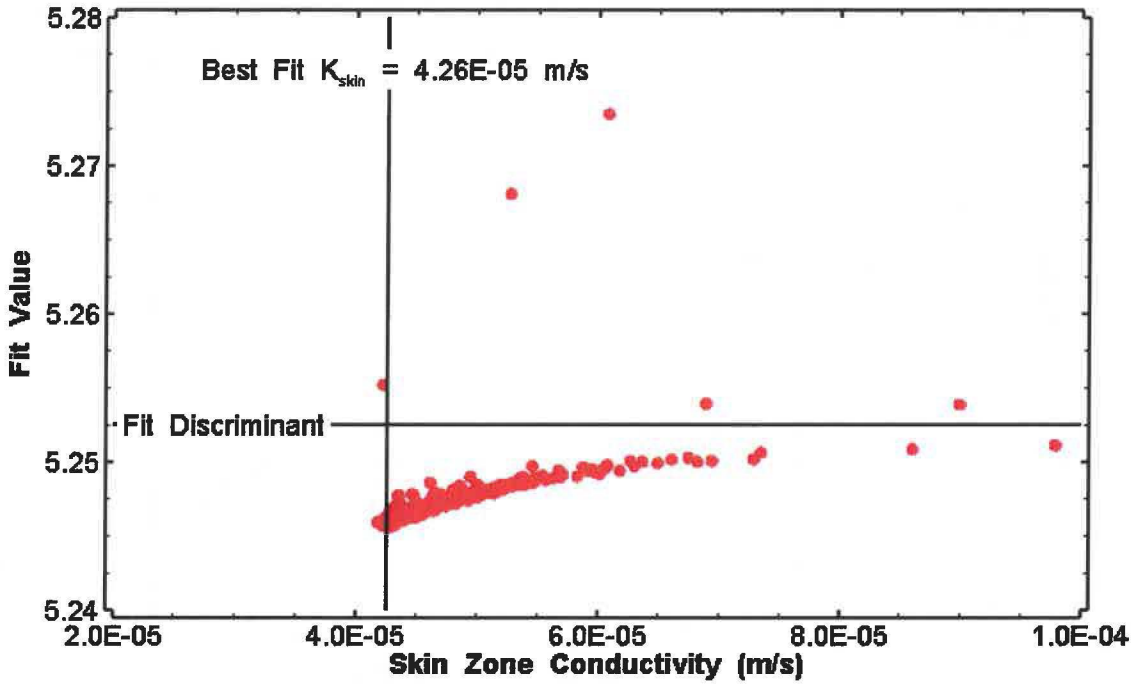


Figure B-20. X-Y scatter plot showing the skin conductivity parameter space for the first constant rate test derived from IMC-461 perturbation analysis with the fit discriminant and best fit values.

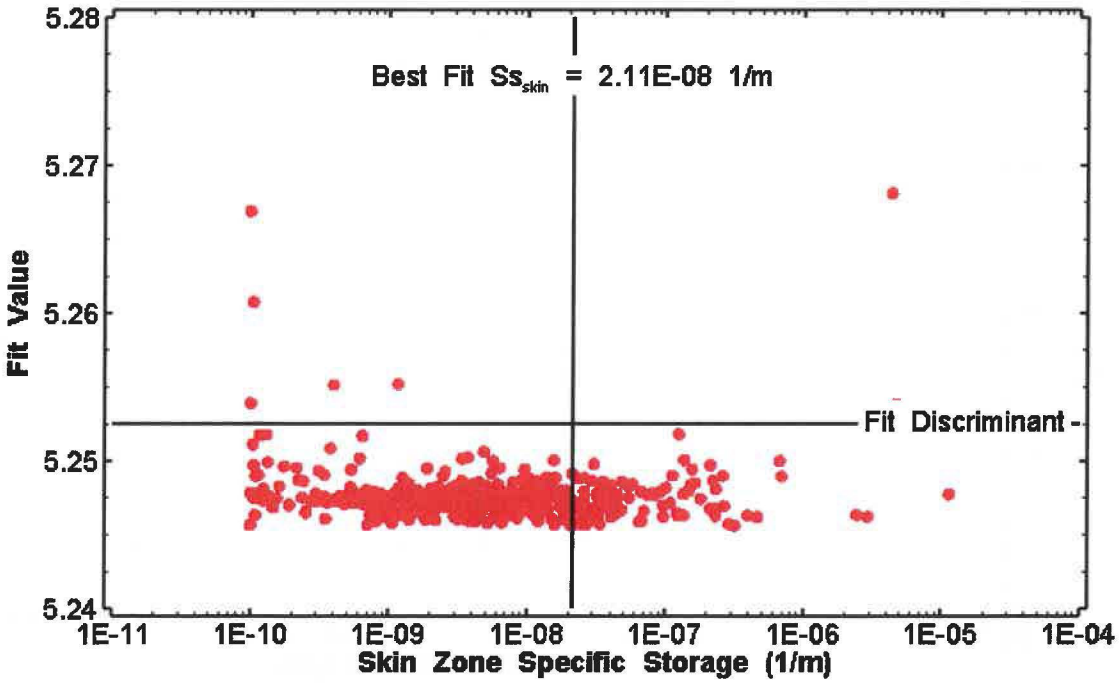


Figure B-21. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for the first constant rate test with the fit discriminant and best fit values.

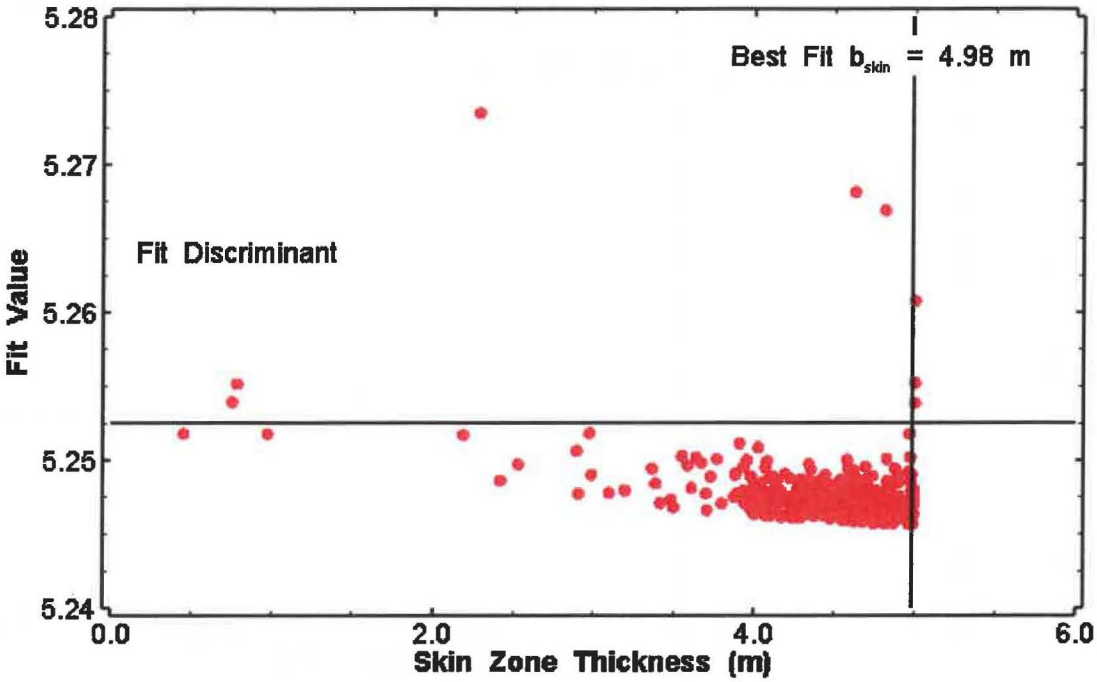


Figure B-22. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the first constant rate test with the fit discriminant and best fit values.

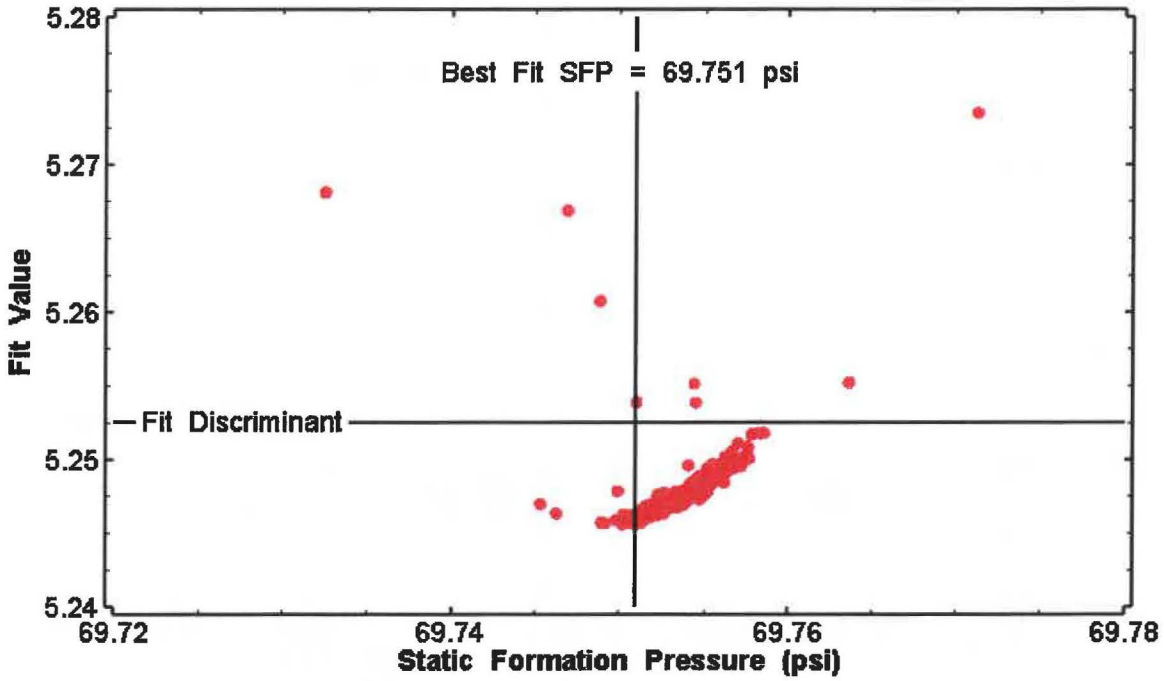


Figure B-23. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the first constant rate test with the fit discriminant and best fit values.

```
************
nPre/64 2.50
************

Version date    25 June 2012
Listing date    01 Aug 2016
QA status       non-QA Open Source
Config file     C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-
461_D2_CR.nPre
```

Control Settings

Main Settings

Simulation type	Optimization
Simulation subtype	Normal
Phase to simulate	Liquid
Skin zone ?	yes
External boundary	Fixed Pressure

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	Optimization	
Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.764	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	

Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	1.42018E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Formation spec. storage	Optimization	
Minimum value	1.00000E-08	[1/m]
Maximum value	1.00000E-04	[1/m]
Estimate value	9.97534E-05	[1/m]
Range type	Log	
Sigma	1.00000E+00	

Skin

Radial thickness of skin	Optimization	
Minimum value	0.001	[m]
Maximum value	5.0	[m]
Estimate value	4.9853544	[m]
Range type	Linear	
Sigma	1.00000E+00	
Skin zone conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	5.18556E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Skin zone spec. storage	Optimization	
Minimum value	1.00000E-10	[1/m]
Maximum value	1.00000E-02	[1/m]
Estimate value	2.39879E-08	[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]

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	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-08	[]
Maximum	7.31520E-04	[]
Diffusivity	min/max	
Minimum	1.00000E-06	[m^2/sec]
Maximum	1.00000E+06	[m^2/sec]

Skin Zone

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-10	[]
Maximum	7.31520E-02	[]
Diffusivity	min/max	
Minimum	1.00000E-08	[m^2/sec]
Maximum	1.00000E+08	[m^2/sec]
Skin factor	min/max	
Minimum	-1.52471E-02	[]
Maximum	4.35439E+08	[]

Grid Properties

Grid increment delta	min/max	
Minimum	0.06127	[]
Maximum	0.08308	[]
First grid increment	min/max	
Minimum	3.20053E-01	[m]
Maximum	5.72485E-03	[m]
Skin grid increment delta	min/max	
Minimum	0.00031	[]
Maximum	0.08887	[]
Skin first grid increment	min/max	
Minimum	2.02561E-05	[m]
Maximum	6.04880E-03	[m]
Skin last grid increment	min/max	
Minimum	2.05609E-05	[m]
Maximum	4.30690E-01	[m]
Increment ratio	min/max	
Minimum	7.43118E-01	[]
Maximum	2.78433E+02	[]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42528.250694	[day]
Duration	0.126389	[day]

Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42528.377083	[day]
Duration	0.031366	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: F_02

Sequence type	Flow	
Start time	42528.408449	[day]
Duration	0.022107	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42528.430556	[day]
Duration	0.169329	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42528.599884	[day]
Duration	0.021412	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_04

Sequence type	History	
Start time	42528.621296	[day]
Duration	0.149537	[day]
Time step type	Static	

Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Test Zone Curves

Curve object to use	P_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
Curve object to use	Q_Curve
Curve type	Flow Rate
Start sequence	H_01
End sequence	H_04
Curve time base	Test
Curve Y data units	[USgpm]
Curve Y data is log 10	no

Simulation Results Setup

Output ID	DAT
Output type	Pressure
Pressure capture type	Test Zone
Output units	[psi]
Output ID	DAT
Output type	Flow Rate
Flow rate output type	Well
Output units	[USgpm]

OutputFiles

XY Forward Output

Write file ?	no

Optimization Output

Write file ?	no

Optimization Setup

Algorithm	Simplex
Calculate confidence limits ?	yes
Covariance matrix calculations	1st Order

Fixed derivative span ?	no
Fit tolerance	1.0000E-05
Parameter tolerance	not used
# of optimized variables	6
Formation conductivity	OK
Skin zone conductivity	OK
Static formation pressure	OK
Formation spec. storage	OK
Skin zone spec. storage	OK
Radial thickness of skin	OK

Fits to Optimize

CompositeFit	OK

Calculated Parameters Included

# of calculated variables included	0

Suite/Range Setup

# of suite/range variables	0

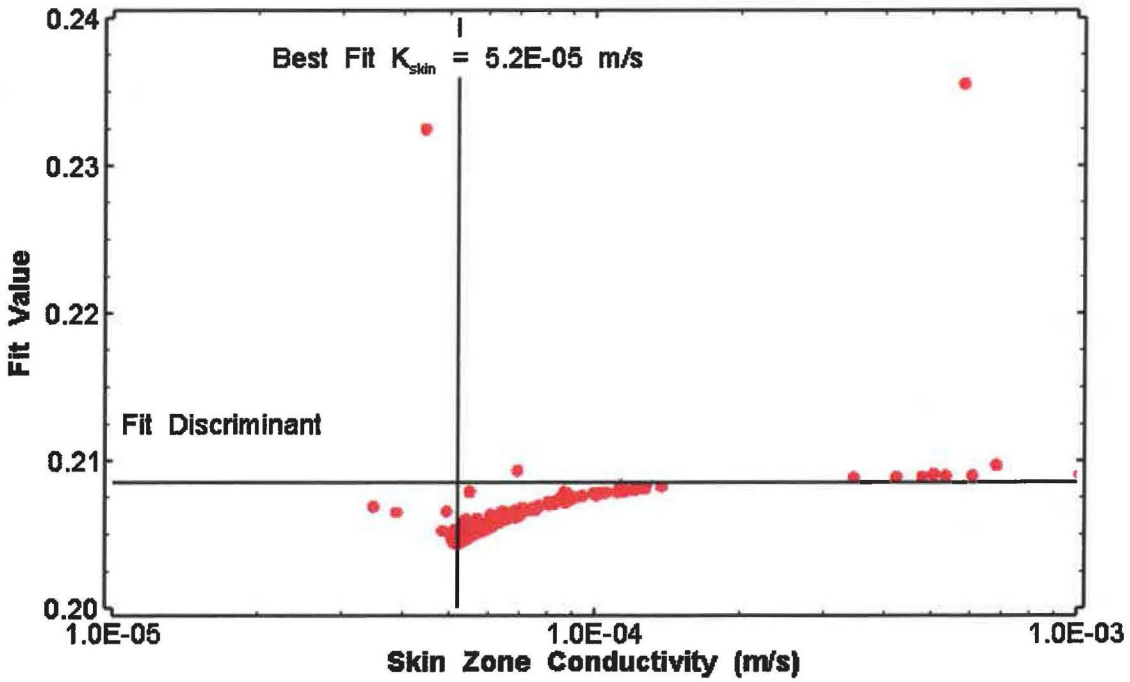


Figure B-24. X-Y scatter plot showing the skin conductivity parameter space for the second constant rate test derived from IMC-461 perturbation analysis with the fit discriminant and best fit values.

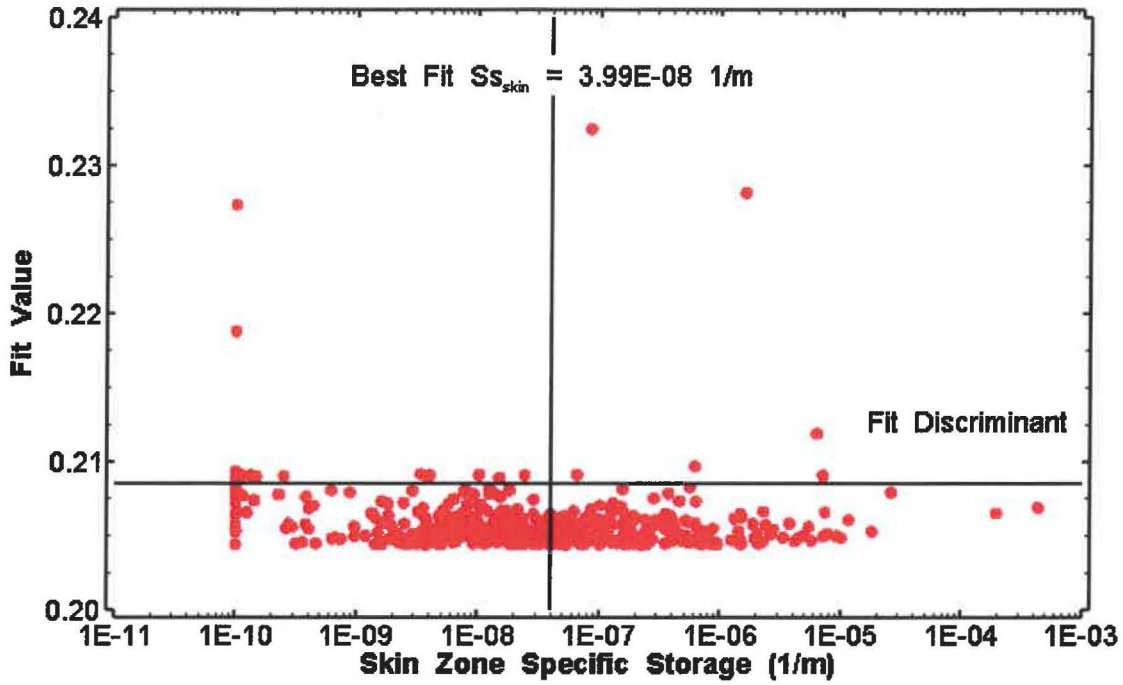


Figure B-25. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for the second constant rate test with the fit discriminant and best fit values.

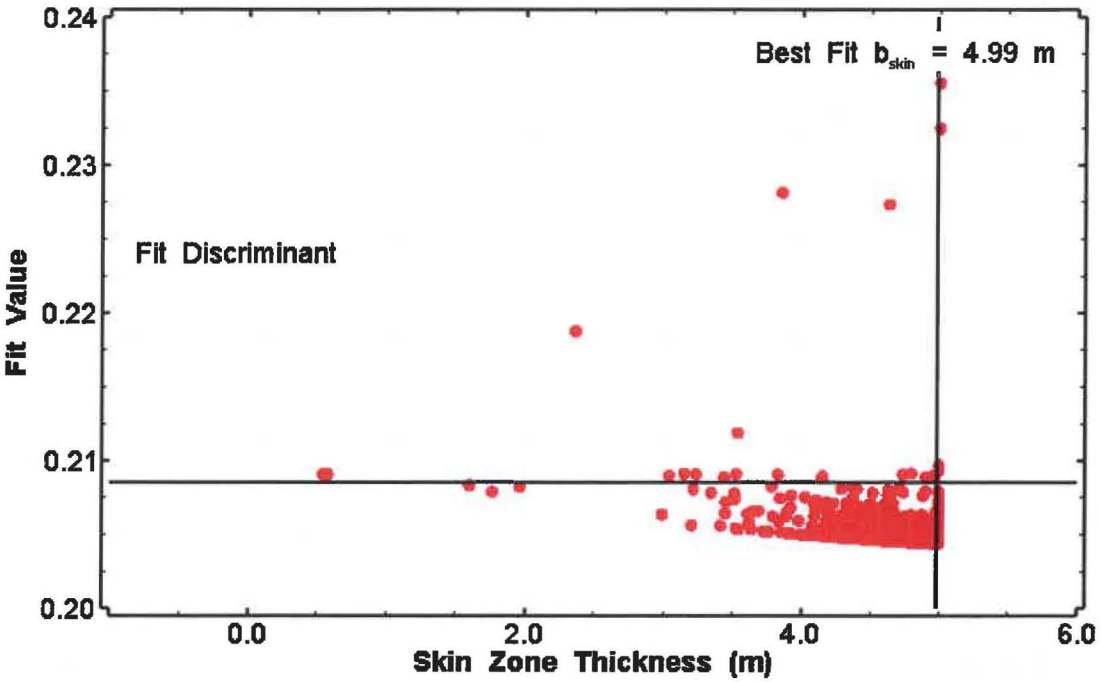


Figure B-26. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the second constant rate test with the fit discriminant and best fit values.

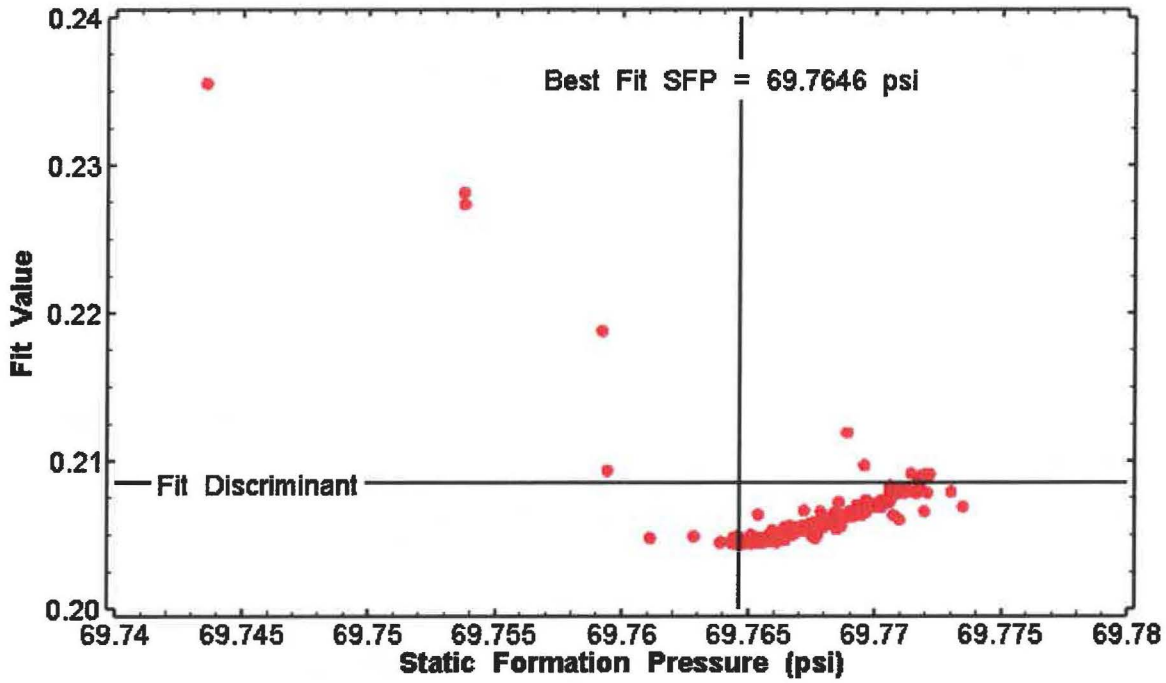


Figure B-27. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the second constant rate test with the fit discriminant and best fit values.

```
************
nPre/64 2.50
************

Version date    25 June 2012
Listing date    01 Aug 2016
QA status       non-QA Open Source
Config file     C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-
461_D1_Slug.nPre
```

Control Settings

Main Settings

```
Simulation type                          Optimization
Simulation subtype                             Normal
Phase to simulate                              Liquid
Skin zone ?                                        no
External boundary                    Fixed Pressure
```

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	Optimization	
Minimum value	67.000	[psi]
Maximum value	71.000	[psi]
Estimate value	69.714	[psi]
Range type	Linear	
Sigma	1.00000E+00	
External boundary radius	1000000	[m]
Formation conductivity	Optimization	
Minimum value	1.00000E-10	[m/sec]
Maximum value	1.00000E-02	[m/sec]
Estimate value	4.86758E-05	[m/sec]
Range type	Log	
Sigma	1.00000E+00	
Formation spec. storage	Optimization	
Minimum value	1.00000E-08	[1/m]
Maximum value	1.00000E-04	[1/m]
Estimate value	3.84190E-07	[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]

Numeric

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

STP flow solution tolerance	1.58503E-11	[USgpm]

Calculated Parameters

Formation

Transmissivity	min/max	
Minimum	7.31520E-10	[m^2/sec]
Maximum	7.31520E-02	[m^2/sec]
Storativity	min/max	
Minimum	7.31520E-08	[]
Maximum	7.31520E-04	[]
Diffusivity	min/max	
Minimum	1.00000E-06	[m^2/sec]
Maximum	1.00000E+06	[m^2/sec]

Grid Properties

Grid increment delta	0.06646	[]
First grid increment	4.47242E-03	[m]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42527.390046	[day]
Duration	0.057871	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42527.447917	[day]
Duration	0.020833	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42527.468750	[day]
Duration	0.022107	[day]
Time step type	Log	
First log step	1.15741E-07	[day]

# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_04

Sequence type	History	
Start time	42527.490857	[day]
Duration	0.036921	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_05

Sequence type	History	
Start time	42527.527778	[day]
Duration	0.014005	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_06

Sequence type	History	
Start time	42527.541782	[day]
Duration	0.071065	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_07

Sequence type	History	
Start time	42527.612847	[day]
Duration	0.014703	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42527.627550	[day]
Duration	0.032450	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	

Type	Curve
Wellbore storage	None

Test Zone Curves

Curve object to use	P_Curve
Curve type	Pressure
Start sequence	H_01
End sequence	F_01
Curve time base	Test
Curve Y data units	[psi]
Curve Y data is log 10	no
Curve object to use	Q_Curve
Curve type	Flow Rate
Start sequence	H_01
End sequence	F_01
Curve time base	Test
Curve Y data units	[USgpm]
Curve Y data is log 10	no

Simulation Results Setup

Output ID	DAT
Output type	Pressure
Pressure capture type	Test Zone
Output units	[psi]
Output ID	DAT
Output type	Flow Rate
Flow rate output type	Well
Output units	[USgpm]

OutputFiles

XY Forward Output

Write file ?	no

Optimization Output

Write file ?	no

Optimization Setup

Algorithm	Simplex
Calculate confidence limits ?	yes
Covariance matrix calculations	1st Order
Fixed derivative span ?	no

Fit tolerance	1.0000E-05
Parameter tolerance	not used
# of optimized variables	3
Formation conductivity	OK
Static formation pressure	OK
Formation spec. storage	OK

Fits to Optimize

CompositeFit	OK

Calculated Parameters Included

# of calculated variables included	0

Suite/Range Setup

# of suite/range variables	0

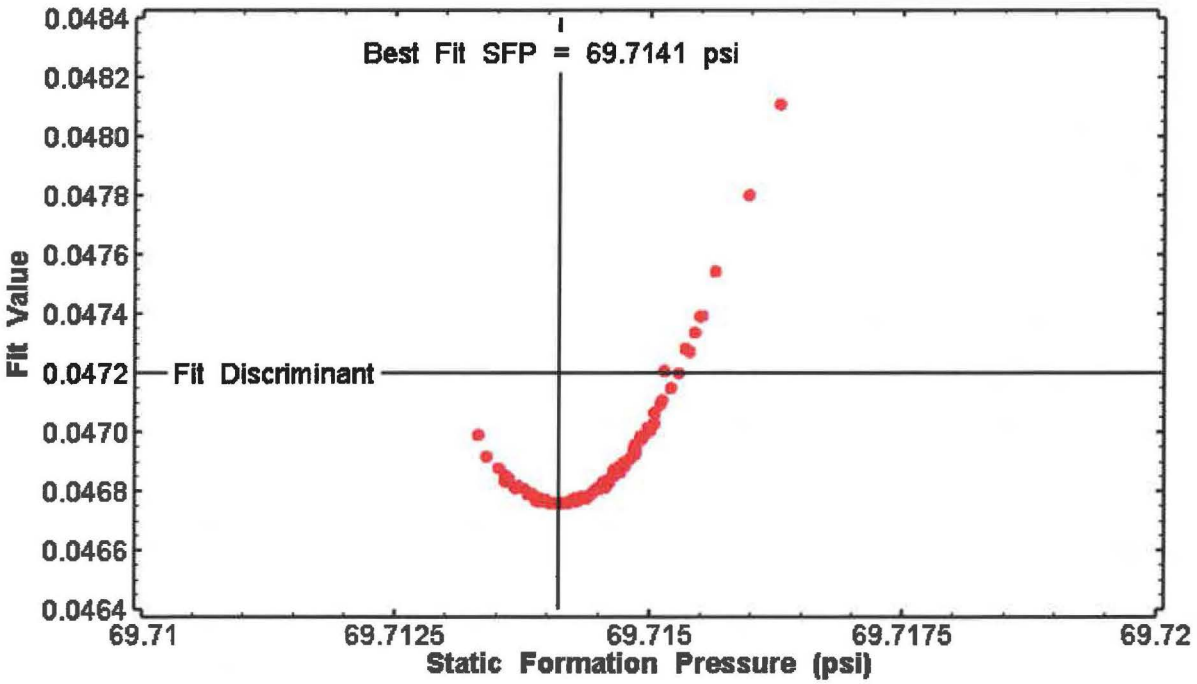


Figure B-28. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the first slug test with the fit discriminant and best fit values.

```
************
nPre/64 2.50
************

Version date    25 June 2012
Listing date    01 Aug 2016
QA status       non-QA Open Source
Config file     C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-
461_D2_slug.nPre
```

Control Settings

Main Settings

Simulation type	Forward
Simulation subtype	Normal
Phase to simulate	Liquid
Skin zone ?	yes
External boundary	Fixed Pressure

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	69.721	[psi]
External boundary radius	1000000	[m]
Formation conductivity	3.30119E-06	[m/sec]
Formation spec. storage	1.00015E-10	[1/m]

Skin

Radial thickness of skin	0.3759119	[m]
Skin zone conductivity	9.93246E-03	[m/sec]
Skin zone spec. storage	7.78883E-05	[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]

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	2.41489E-05	[m^2/sec]
Storativity	7.31630E-10	[]
Diffusivity	3.30069E+04	[m^2/sec]

Skin Zone

Transmissivity	7.26579E-02	[m^2/sec]
Storativity	5.69768E-04	[]
Diffusivity	1.27522E+02	[m^2/sec]
Skin factor	-1.91267E+00	[]

Grid Properties

Grid increment delta	0.07354	[]
First grid increment	3.36528E-02	[m]
Skin grid increment delta	0.03905	[]
Skin first grid increment	2.59175E-03	[m]
Skin last grid increment	1.68879E-02	[m]
Increment ratio	1.99271E+00	[]

Sequences

Sequence: H_01

Sequence type	History

Start time	42528.250694	[day]
Duration	0.126389	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42528.377083	[day]
Duration	0.031366	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42528.408449	[day]
Duration	0.022107	[day]
Time step type	Log	
First log step	1.15741E-07	[day]
# of time steps	250	
Type	Curve	
Wellbore storage	None	

Sequence: H_04

Sequence type	History	
Start time	42528.430555	[day]
Duration	0.169329	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_05

Sequence type	History	
Start time	42528.599884	[day]
Duration	0.021416	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42528.621300	[day]
Duration	0.060180	[day]

Time step type	Static	
Static time step	0.000116	[day]
Type	Fixed	
Fixed value	0.0	[USgpm]
Wellbore storage	None	

Test Zone Curves

Curve object to use	P_Curve
Curve type	Pressure
Start sequence	H_01
End sequence	F_01
Curve time base	Test
Curve Y data units	[psi]
Curve Y data is log 10	no
Curve object to use	Q_Curve
Curve type	Flow Rate
Start sequence	H_01
End sequence	F_01
Curve time base	Test
Curve Y data units	[USgpm]
Curve Y data is log 10	no

Simulation Results Setup

Output ID	DAT
Output type	Pressure
Pressure capture type	Test Zone
Output units	[psi]
Output ID	DAT
Output type	Flow Rate
Flow rate output type	Well
Output units	[USgpm]

OutputFiles

XY Forward Output

Write file ?	no

Profile Output

Write file ?	no

Suite/Range Setup

# of suite/range variables	0

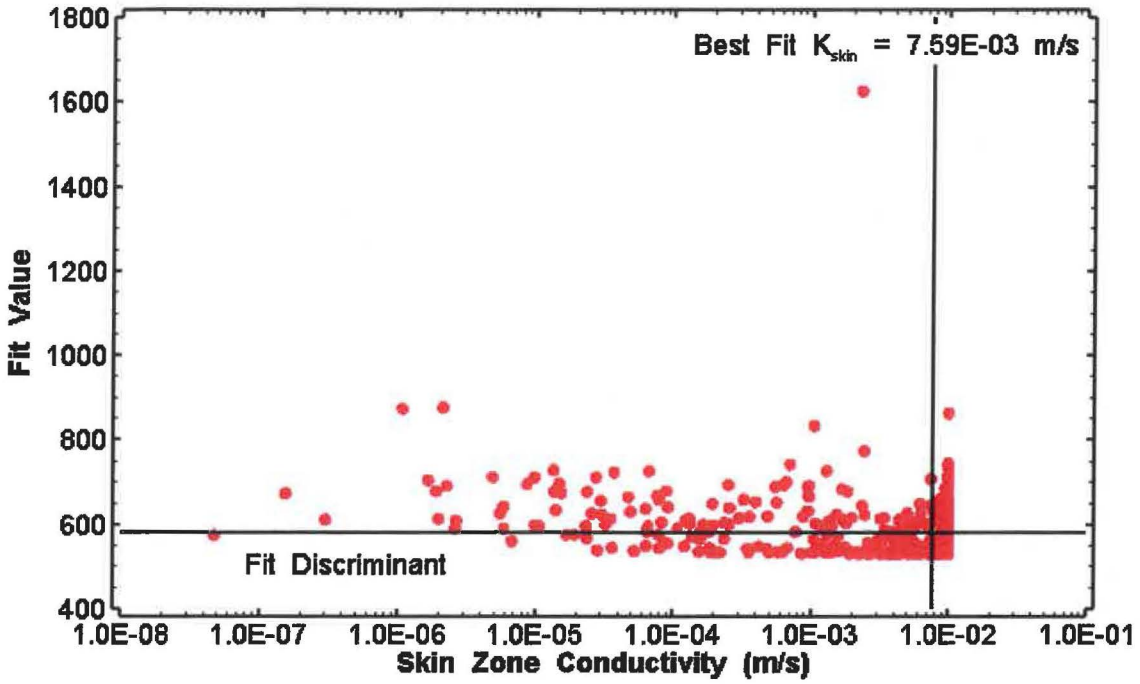


Figure B-29. X-Y scatter plot showing the skin conductivity parameter space for the second slug test derived from IMC-461 perturbation analysis with the fit discriminant and best fit values.

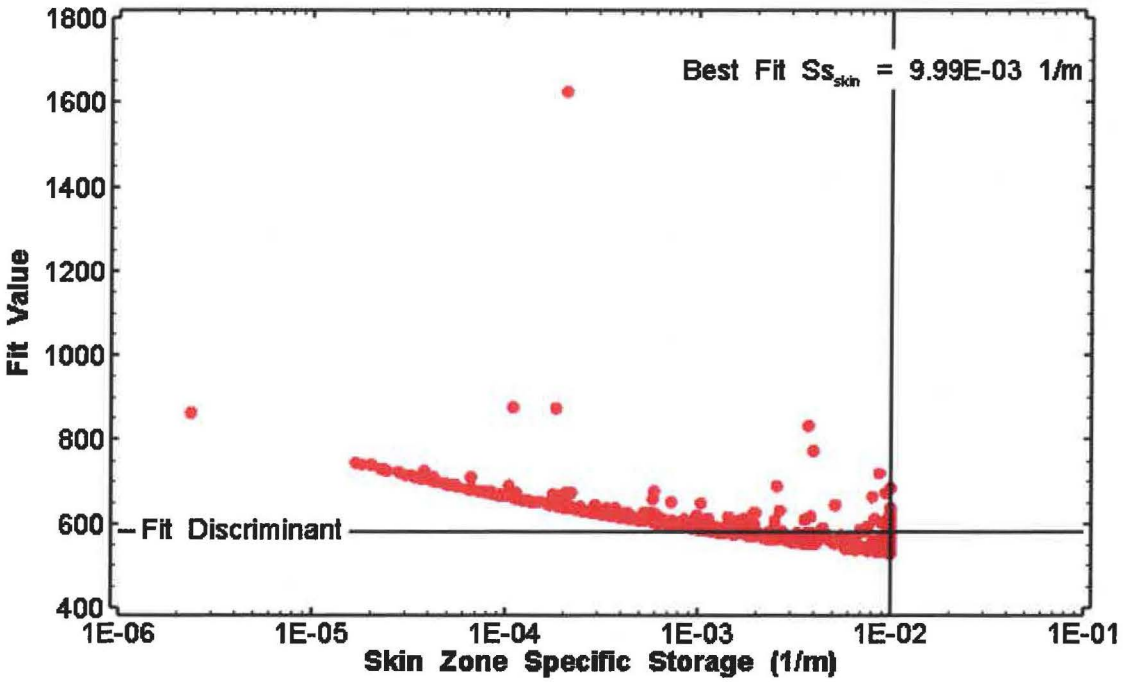


Figure B-30. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for the second slug test with the fit discriminant and best fit values.

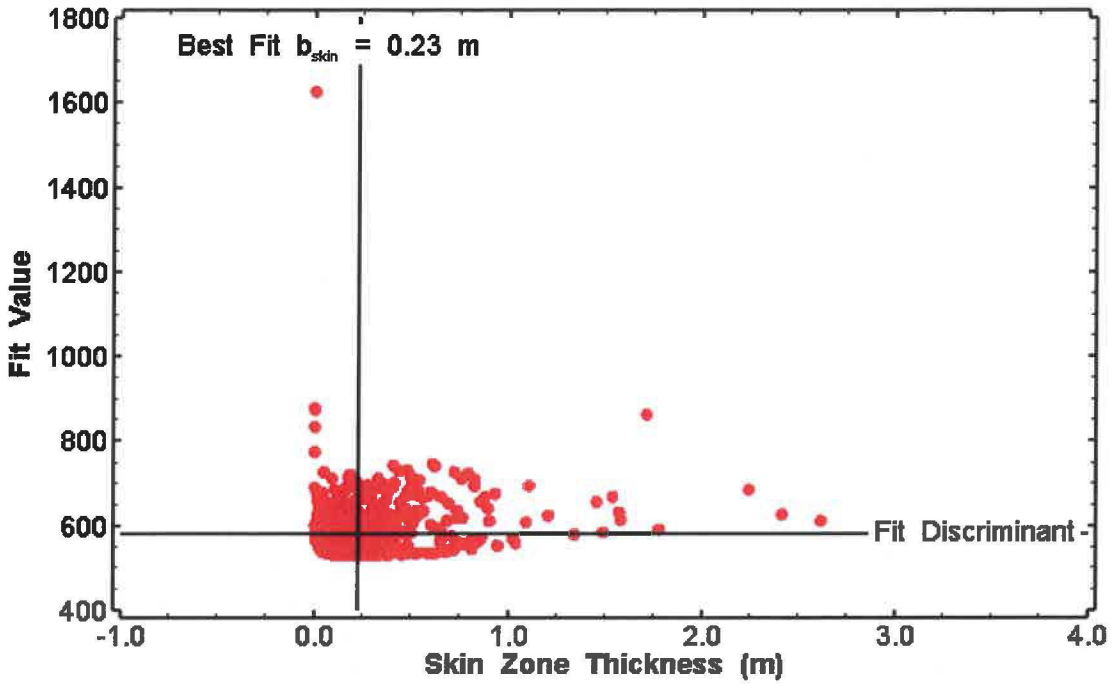


Figure B-31. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the second slug test with the fit discriminant and best fit values.

```
************
nPre/64 2.50
************

Version date    25 June 2012
Listing date    01 Aug 2016
QA status       non-QA Open Source
Config file     C:\SANDIA_PROJECTS\WIPP_wells\Culebra\IMC-461_Sinusoid\IMC-
461_D3_slug.nPre
```

Control Settings

Main Settings

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

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	69.705	[psi]
External boundary radius	1000000	[m]
Formation conductivity	4.97129E-06	[m/sec]
Formation spec. storage	1.28089E-08	[1/m]

Skin

Radial thickness of skin	0.1976759	[m]
Skin zone conductivity	6.90783E-05	[m/sec]
Skin zone spec. storage	2.40869E-04	[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]

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	3.63660E-05	[m^2/sec]
Storativity	9.36999E-08	[]
Diffusivity	3.88111E+02	[m^2/sec]

Skin Zone

Transmissivity	5.05322E-04	[m^2/sec]
Storativity	1.76200E-03	[]
Diffusivity	2.86788E-01	[m^2/sec]
Skin factor	-1.29509E+00	[]

Grid Properties

Grid increment delta	0.07614	[]
First grid increment	2.07884E-02	[m]
Skin grid increment delta	0.02848	[]
Skin first grid increment	1.88034E-03	[m]
Skin last grid increment	7.37795E-03	[m]
Increment ratio	2.81764E+00	[]

Sequences

Sequence: H_01

Sequence type	History	
Start time	42529.278745	[day]
Duration	0.047958	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_02

Sequence type	History	
Start time	42529.326703	[day]
Duration	0.338343	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: H_03

Sequence type	History	
Start time	42529.665046	[day]
Duration	0.017134	[day]
Time step type	Static	
Static time step	0.000116	[day]
Type	Curve	
Wellbore storage	None	

Sequence: F_01

Sequence type	Flow	
Start time	42529.682180	[day]
Duration	0.047820	[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	None	

Test Zone Curves

Curve object to use	P_Curve
Curve type	Pressure
Start sequence	H_01
End sequence	F_01
Curve time base	Test
Curve Y data units	[psi]
Curve Y data is log 10	no
Curve object to use	Q_Curve
Curve type	Flow Rate
Start sequence	H_01
End sequence	F_01
Curve time base	Test
Curve Y data units	[USgpm]
Curve Y data is log 10	no

Simulation Results Setup

Output ID	DAT
Output type	Pressure
Pressure capture type	Test Zone
Output units	[psi]
Output ID	DAT
Output type	Flow Rate
Flow rate output type	Well
Output units	[USgpm]

OutputFiles

XY Forward Output

Write file ?	no

Profile Output

Write file ?	no

Suite/Range Setup

# of suite/range variables	0

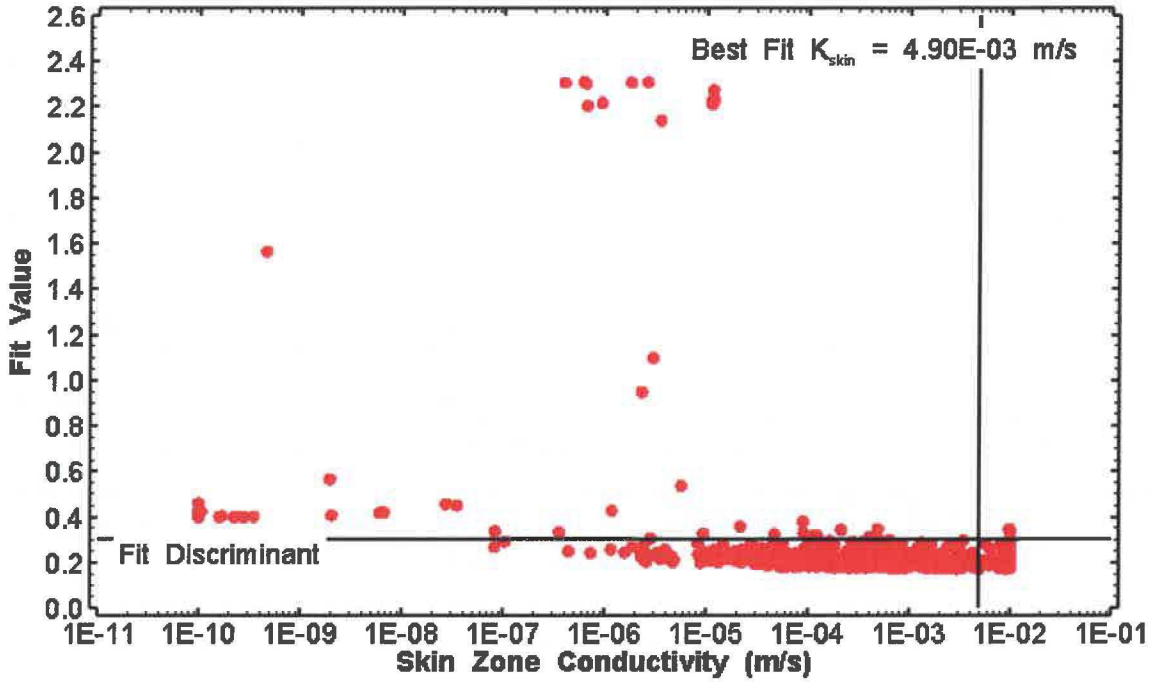


Figure B-32. X-Y scatter plot showing the skin conductivity parameter space for the third slug test derived from IMC-461 perturbation analysis with the fit discriminant and best fit values.

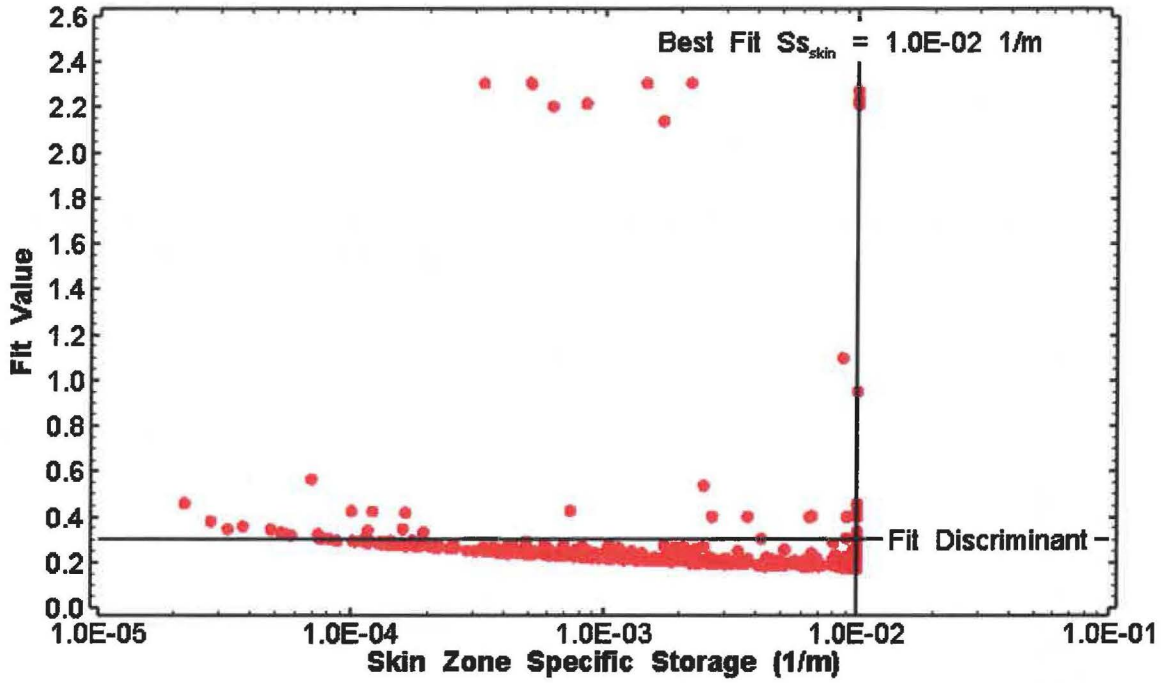


Figure B-33. X-Y scatter plot showing the skin zone specific storage parameter space derived from IMC-461 perturbation analysis for the third slug test with the fit discriminant and best fit values.

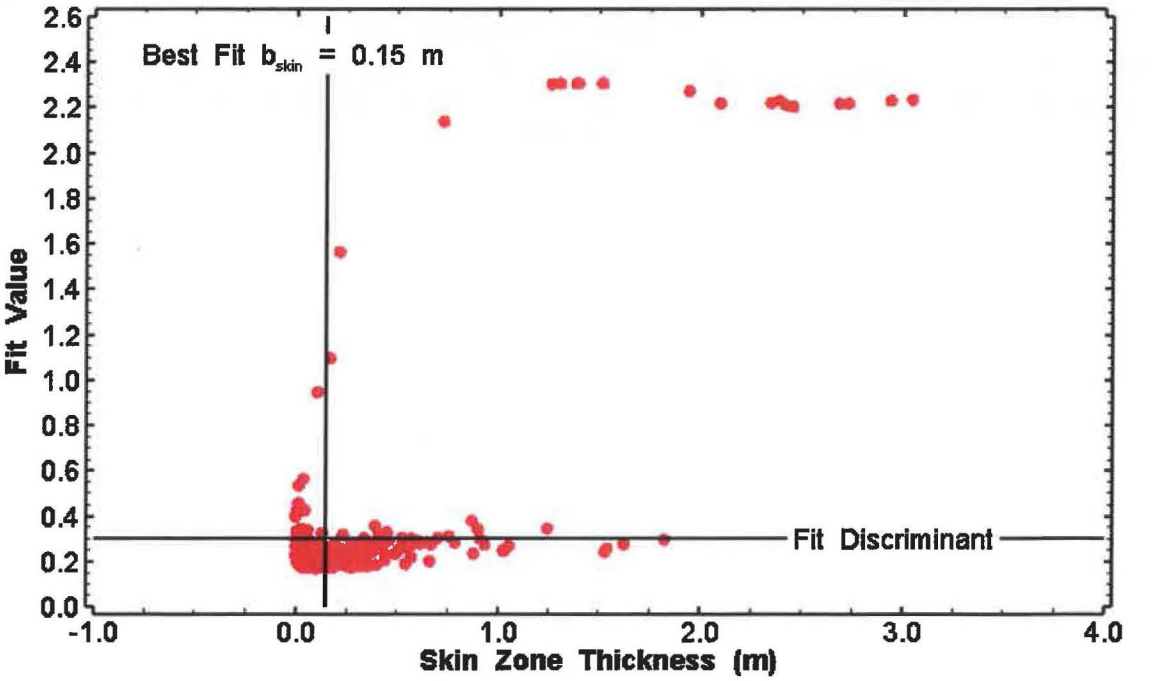


Figure B-34. X-Y scatter plot showing the skin zone thickness parameter space derived from IMC-461 perturbation analysis for the third slug test with the fit discriminant and best fit values.

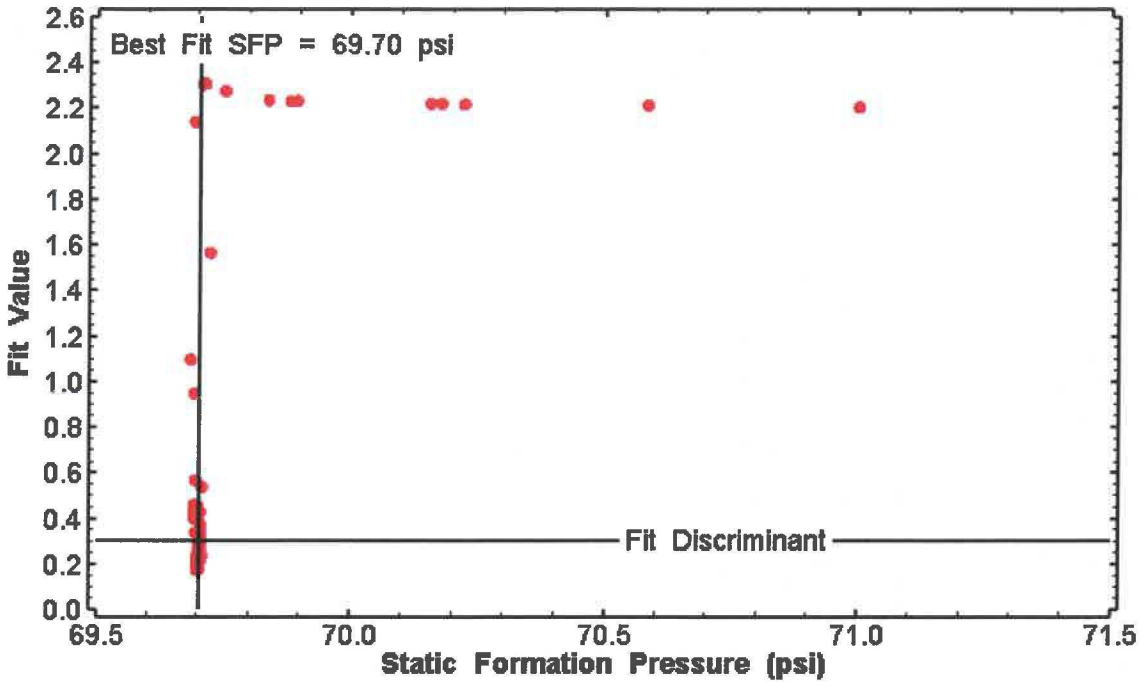


Figure B-35. X-Y scatter plot showing the static formation pressure parameter space derived from IMC-461 perturbation analysis for the third slug test with the fit discriminant and best fit values.

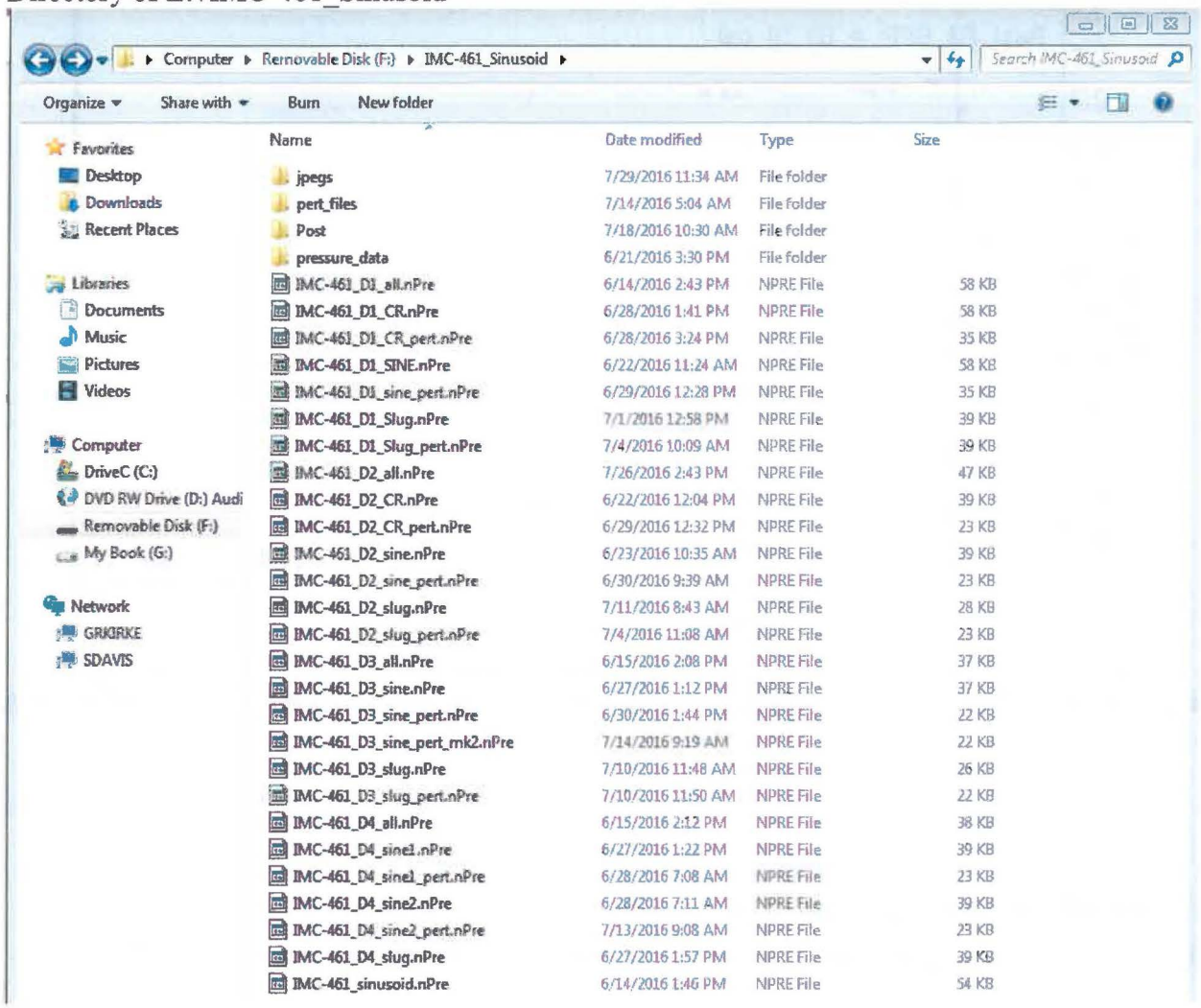
Appendix C – File Directories

These files are located in server file-path: /nfs/data/CVSLIB/WIPP_EXTERNAL/ap070

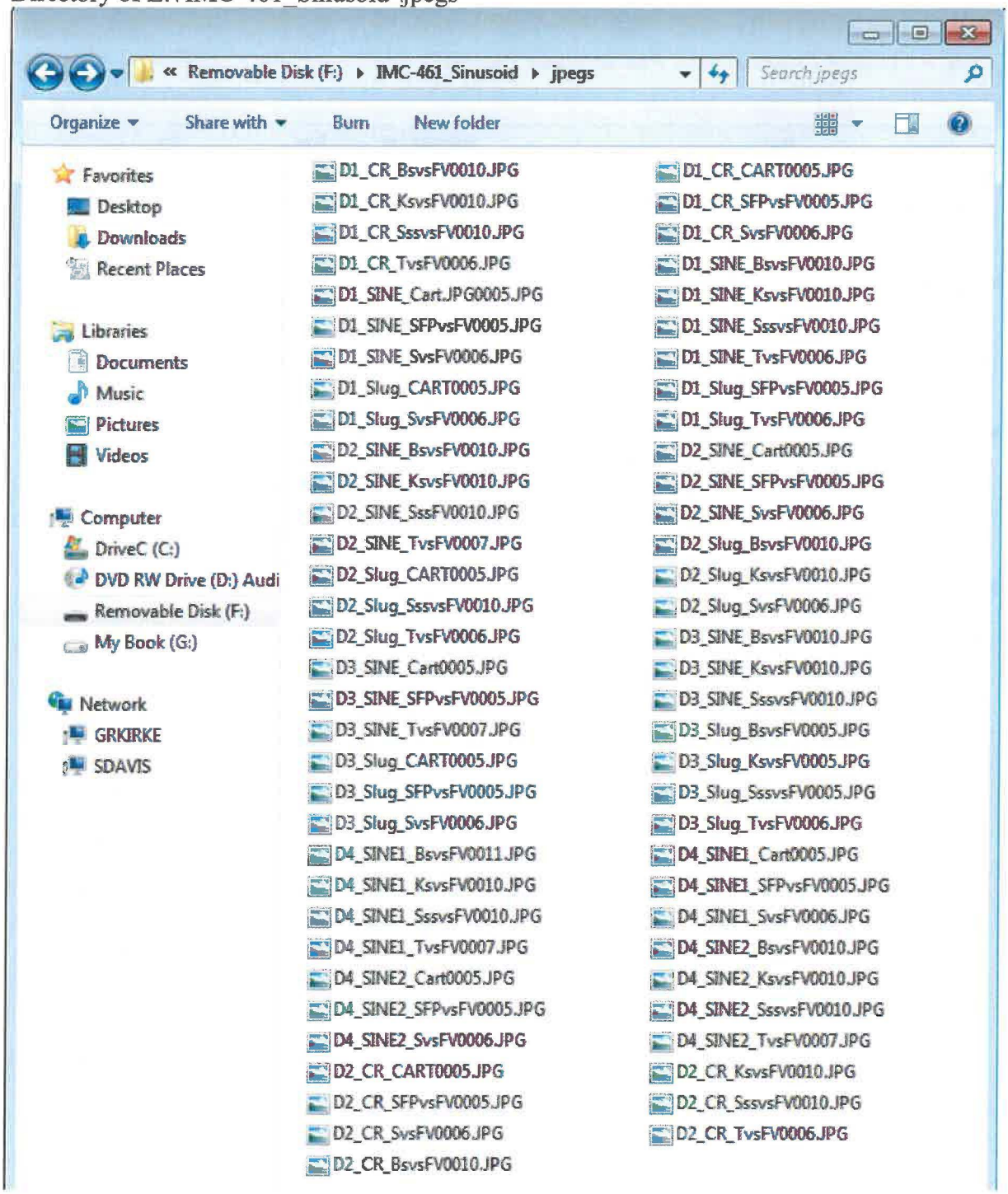
Table C-1. File descriptions.

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

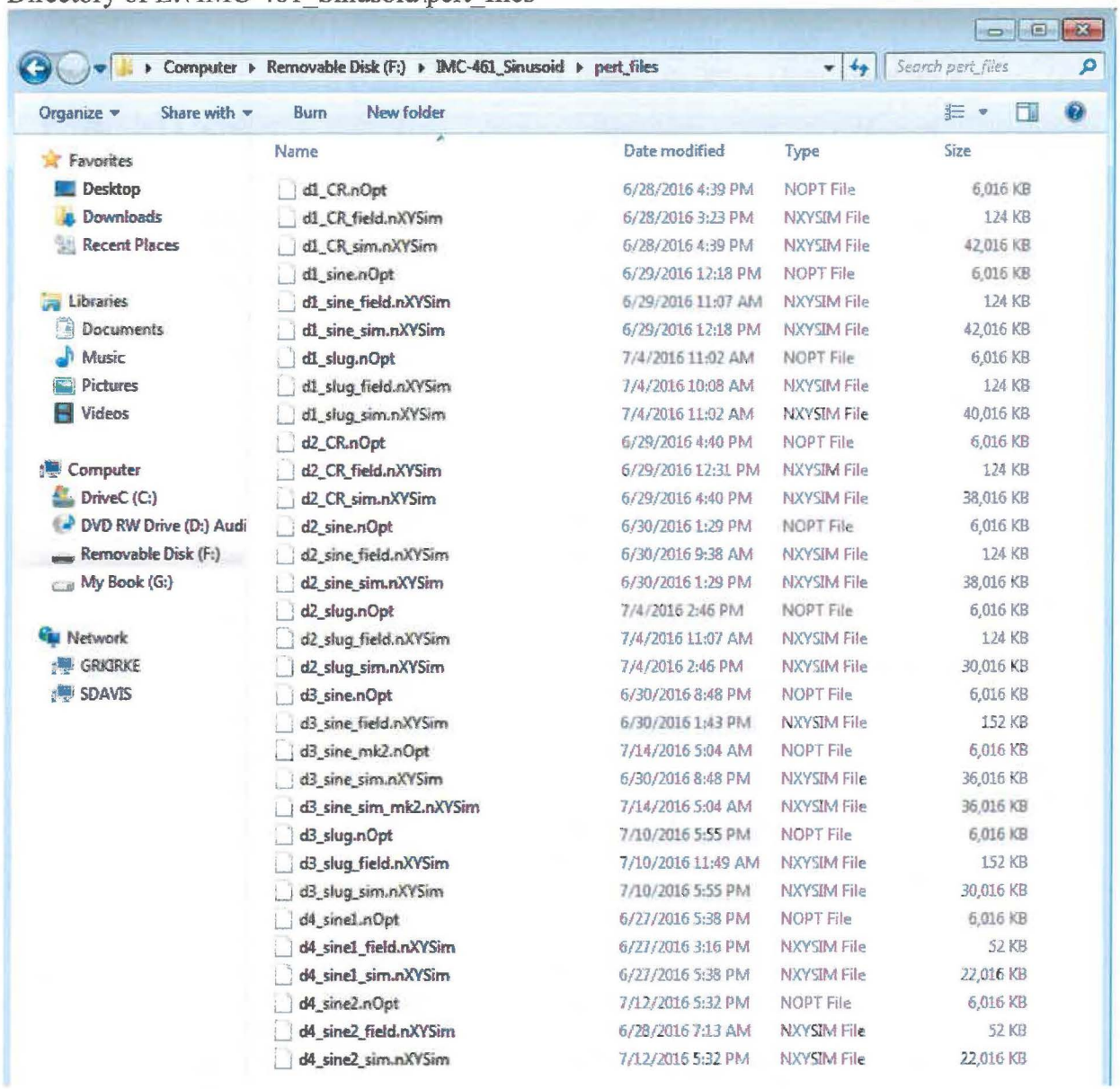
Directory of E:\ IMC-461_Sinusoid



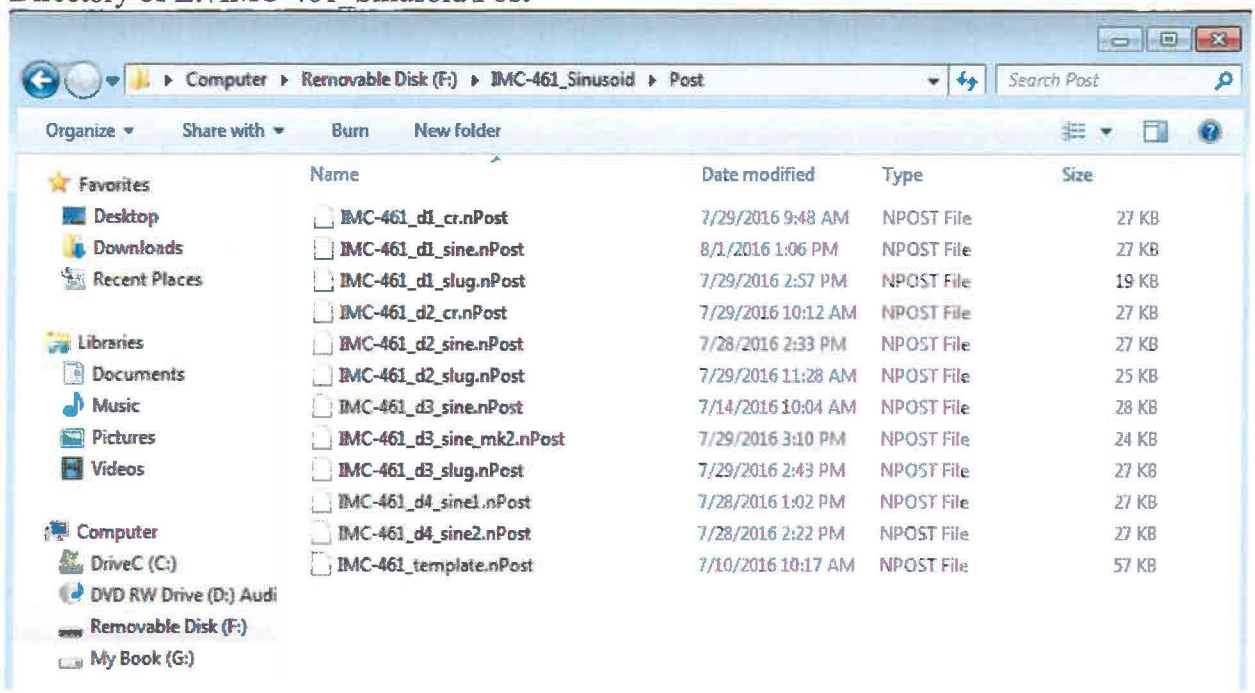
Directory of E:\ IMC-461_Sinusoid \jpegs



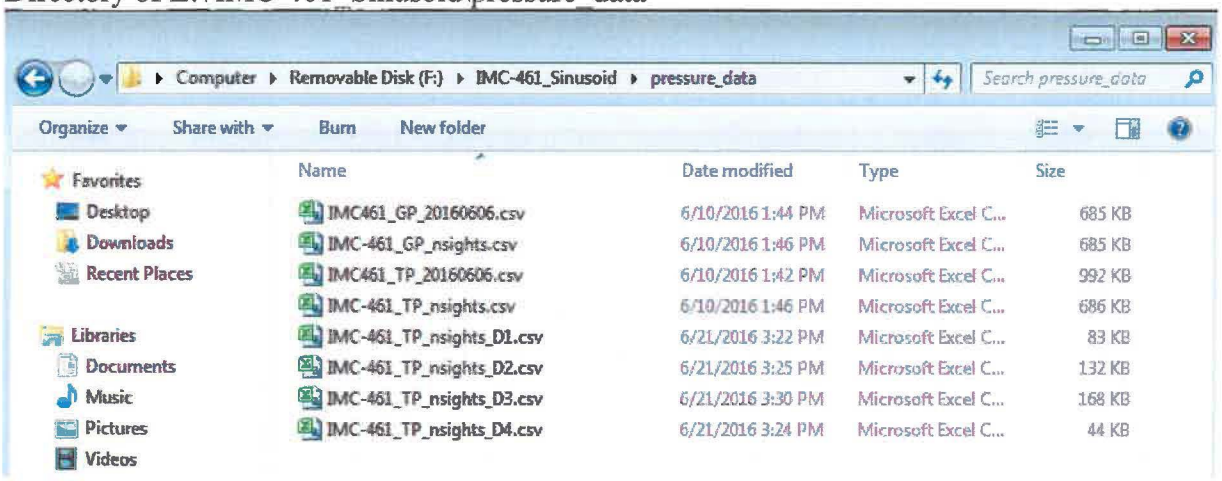
Directory of E:\ IMC-461_Sinusoid\pert_files



Directory of E:\ IMC-461_Sinusoid\Post



Directory of E:\ IMC-461_Sinusoid\pressure_data



Acknowledgements

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