スウェーデンハードロック研究所および超深地層研究所計画における亀裂性岩盤を対象とした水理解析

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吉添 誠* William Dershowitz**

要旨

本報告書は、三菱商事株式会社が平成14年度に実施した、瑞浪超深地層研究所(MIU)計画、並びにスウェーデンのHRL(Hard Rock Laboratory)国際共同研究である、エスポTRUE Block Scale Continuation プロジェクトに関わる解析作業を取り纏めたものである。

TRUE Block Scale Continuation(以下、TRUE-BS) プロジェクトに関わる平成14年度の主要な業務は、TRUE-BS の調査対象領域の岩体における亀裂の連続性に関する評価であった。実施した解析作業の主なものは、水理試験に基づく地下水流動解析、最新の微小構造モデルの作成、及び移行経路の同定である。

・水理構造解析：TRUE-BS 岩体内の亀裂の連続性を水理的干渉試験における非整数次元解析を利用して検討を行なった。当該解析により、亀裂ネットワーク内の移行経路の幾何学的性状に関する重要な情報が得られた。

・物質移行のモデル化： TRUE-BS 岩体を構成する亀裂の詳細な微小構造のモデル化とモデル化手法の開発を行なった。本モデルにおいては、角礫岩、断層粘土、カタクラサイト、マイロナイト、変質花崗岩から成る各不動帯の個別の特性が考慮された。今年度は、主要な TRUE-BS における物質移行試験を最新の微小構造モデルを用いてシュミレートし、その結果を改良後の平成12年度微小構造モデルを利用して得られた結果と比較した。

・水理干渉試験のモデル化：可能性のある潜在的な移行経路の特性を特定決定するため、個別の水理試験の評価を行なった。シミュレーションは破過時間を評価するためにこれらの移行経路に基づいて行なった。

また、MIU 計画に関する作業として、正馬様用地の水理モデルを作成した。具体的には、水理試験解析コード FlowDim を用いて MIU-4 試験結果の非整数次元解析を実施した。また、MIU の水理構造学的な統合化の一環としての長期揚水試験の解析とともに、研究所用地の初期的な FracMan による亀裂ネットワーク・モデルの構築を支援するために、DH-2 号孔の水理試験の解析を実施した。

本報告書は、三菱商事（株）が核燃料サイクル開発機構の委託により実施した業務に関するものである。

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ABSTRACT

During Heisei-14, Golder Associates provided support for JNC Tono at the MIU Underground Rock Laboratory and the Äspö Block Scale Continuation Project.

Major activities for the Block Scale Continuation project during H-14 included evaluation of the connectivity of the TRUE-BS rock block. Major analyses were carried out to analyze flow dimension based on hydraulic tests, to evaluate the updated microstructural model, and to understand transport pathways.

- ***Hydrostructural Analysis***: During H-14, Golder Associates carried out extensive analysis of the fracture connectivity within the TRUE-BS rock block, using fractional dimension analysis with hydraulic interference measurements. These analyses provided crucial insights into the geometry of transport pathways within fracture networks.

- ***Transport Modeling***: Golder developed and implemented a detailed microstructural model for fractures which make up the TRUE rock block. This model considers the individual properties of each immobile zone, including breccia, gouge, cataclasite, mylonite, and altered granite. During H-14, simulations were carried out for each of the major TRUE-BS transport experiments, using the updated microstructural model. Results were compared against those obtained using the calibrated micro-structural model of H-12.

- ***Hydraulic Interference Modeling***: Each of hydraulic experiments was studied in detail to determine possible transport pathway properties. Simulations were carried out based on these pathways to assess possible breakthrough times.

Major activities for the MIU Laboratory concentrated on development of hydrostructural models for the MIU and Shin-MIU sites. The FlowDim fractional dimension hydraulic test interpretation system was used to carry out a unified analysis of the MIU-4 experiment. In addition to the long term pumping test analysis as the MIU hydrostructural synthesis, Golder carried out analyses of hydraulic tests in borehole DH-2 to support development of preliminary FracMan discrete fracture network models for the Shi-Yu-u Chi site.

概要

平成14年度は、瑞浪超深地層研究所（MIU）計画、並びにJNCが参加するスウェーデンのHRL(Hard Rock Laboratory)の国際共同研究である、エスポTRUE Block Scale Continuation(以下、TRUE-BS）プロジェクトに関わる作業を実施した。

同プロジェクトに関わる平成14年度の主要な業務は、TRUE-BS岩体の連続性に関する評価であった。TRUE-BSプロジェクトの報告書の作成も実施された。実施した解析作業の主なものは、水理試験に基づく地下水流動解析、最新の微小構造モデルの作成、及び移行経路の同定であった。

水理構造解析： TRUE-BS岩体内の亀裂の連続性を水理的干渉試験における非整数次元解析を利用して検討を行なった。当該解析により、亀裂ネットワーク内の移行経路の幾何学的性状に関する重要な情報が得られた。

物質移行のモデル化： TRUE-BS岩体を構成する亀裂の詳細な微小構造のモデル化とモデル化手法の開発を行なった。本モデルにおいては、角礫岩、断層粘土、カタクラサイト、マイロナイト、変質花崗岩から成る各不動帯の個別の特性が考慮された。今年度は、主要なTRUE-BSにおける物質移行試験を最新の微小構造モデルを用いてシュミレートし、その結果を改良後の平成12年度微小構造モデルを利用して得られた結果と比較した。

水理干渉試験のモデル化：TRUE-BSプロジェクトで考慮された付加的な移行経路の特性を水理的干渉試験に基づいて明らかにした。また、可能性のある移行経路を明らかにするためにFracManを用いて水理的干渉試験の評価を行なった。

また、市有地サイトを含むMIU計画に関する作業として、水理モデルが作成された。

MIU-4試験の解釈：水理試験解析コードFlowDimを用いてMIU-4試験結果の非整数次元解析を実施した。各試験毎に、流れの次元、透水量係数T、貯留係数S及び水頭拡散率ηが算出された。

MIU水理構造学的統合化：長期揚水試験を解析することによって、正馬様用地における亀裂と断層の幾何学及び特性に関する理解の改良がはかられた。

研究所用地における初期モデル作成：研究所用地の初期的なFracManによる亀裂ネットワーク・モデルの構築を支援するため、DH-2号孔の水理試験の解析を実施した。

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1. INTRODUCTION

During fiscal year H-14, Golder Associates assisted JNC Tono with hydrogeologic analyses and simulations for the MIU Underground Rock Laboratory and the Äspö Block Scale Continuation experiments. Support for the MIU Underground Rock Laboratory focused on data analysis and hydrostructural model synthesis for the MIU and Shi Yu-u Chi sites. Äspö Block Scale Continuation efforts focused on understanding of geometry and properties of transport pathways.

H-14 tasks are summarized in Table 1-1. H-14 Deliverables are summarized in

Table 1-2. Deliverables provided as Appendices to this report are indicated with the corresponding Appendix number.

Table 1-1. Heisei-14 Task Summary

Task	Title
1	Äspö Block Scale Continuation Support
2	MIU AND Shi Yu-u Chi Site Characterization Support

Table 1-2. Heisei-14 Deliverables

Task		Date	Appendix
1.1	Hydrostructural Analysis	Sept 30, 2002	A
1.2	Transport Modeling	Oct 30, 2002	B
1.3	Hydraulic Interference Modeling	Oct 30, 2002	C
2.1	MIU-4 Test Interpretation Support	Sept 30, 2002	D
2.2	MIU Hydrostructural Synthesis	Oct 30, 2002	E
2.3	Shi Yu-u Chi Initial Model Support	Oct 30, 2002	F

2. ÄSPÖ BLOCK SCALE CONTINUATION SUPPORT

During H-14, Golder Associates supported JNC/Tono participation in the Äspö Block Scale Continuation Project. The purpose of the Block Scale Continuation Project is to enhance understanding of flow and transport processes in fractured rock at the 50 to 200 m scale, the key scale for repository safety assessment within the JNC Heisei-12 framework. JNC has participated in the TRUE Block Scale since 1998, and has played a key role in hydrostructural model development, experimental design, test interpretation, and numerical modeling. During H-14, Golder Associates carried out the following three tasks for the TRUE Block Scale project:

- Task 1.1: Hydrostructural Analysis
- Task 1.2: Transport Modeling
- Task 1.3: Hydraulic Interference Modeling

2.1 Task 1.1: Hydrostructural Analysis

Within the TRUE Block Scale Project (1997-2001), Golder Associates assisted JNC in developing much of the hydrostructural model which provided the framework for understanding of the rock block studied in the project. During H-14, Golder Associates assisted JNC in carrying out additional hydrostructural analyses as needed to apply the hydrostructural model for TRUE Continuation project experiments.

The question of flow geometry has important implications for the movement of tracers in the TRUE Block Scale volume. How many pathways participate in transport and how much surface area do those pathways provide for fracture-rock interaction? Is the flow along pipe-like channels that would produce geometrically linear flow in hydraulic tests? Is the flow confined to two-dimensional planar features, such as the major features of the TRUE Block hydrostructural model? Is there a three-dimensional network of fractures providing the major portion of flow along the pathways of the tracer testing?

The flow geometry question can be answered in part by careful attention to the geometric information that can be derived from the pressure data produced during the testing. So far in the TRUE Block Scale project, the well test analysis has focused on methods that assume two-dimensional flow, as in the build-up tests for the KI0025F02 borehole (e.g. Adams, et al, 1999).

The hydrostructural model development (Hermanson and Doe, 2000) looked at geometry mainly from the pseudo-steady drawdowns at the end of the tests and interference data during drilling and did not use geometric information in the transient data.

A comprehensive look at transient data from the standpoint of flow dimension has not previously been undertaken for the longer-term pumping data that were obtained during the tracer phase of the TRUE Block Scale project. During H-14, Golder evaluated a sufficient portion of these data to define the flow geometries of the major conductors that were important for the tracer testing, specifically Structure #20 and connecting features, such as Structures #21, #13, and #22. In addition to these analyses, Golder carried out transient type curve analysis of the buildup data from KI0025F02 (Adams, et al, 1999). These tests are short-term (30-minute) tests that do not provide the same distance of coverage as the later tracer tests, but they do give some information on other important structures that in the TRUE Block Scale volume that were not part of the tracer testing, such Structures #19, #6, #7, and #10.

Details of this analysis are provided in Appendix A. An example fractional dimension analysis is illustrated in Figure 2-1.

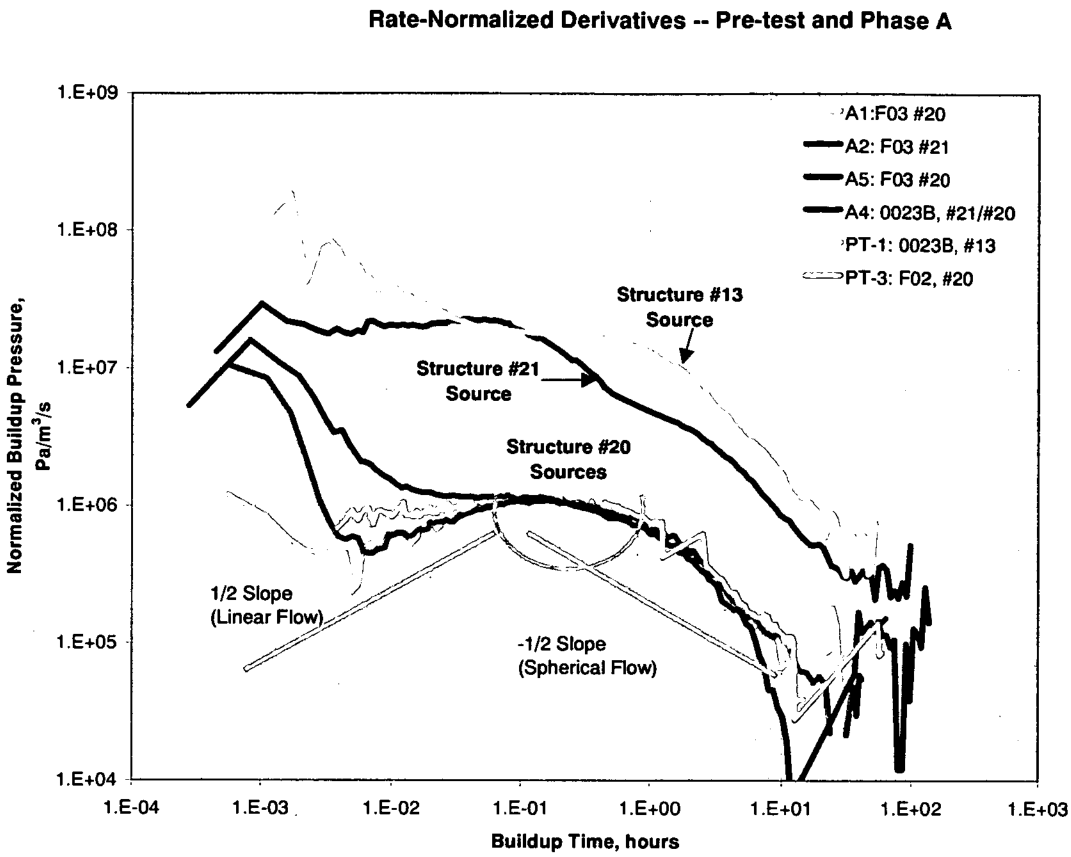

Figure 2-1. Rate Normalized Derivatives for Selected Source Zones From TRUE-BS Tracer Testing Phase

Conclusions from this analysis were as follows:

1. All of the intervals ultimately see constant pressure boundaries or higher dimension flow regions indicating that all of the structures have connection to the larger flow systems of the laboratory.
2. For Structure #20 the distance to these boundaries is between 100-m and 250-m, the uncertainty being dictated by the range of diffusivity values.
3. The region of Structure #20 around KI0025F03 and adjacent holes has a lower diffusivity than more distance regions of the structure around KI0025F and KA2563. This lower diffusivity may indicate a higher porosity region Structure #20 in the core experiment area.

4. The region of most interest for tracer testing lies within a portion of Structure #20 that is characterized by Dimension 2 flow or lower.
5. Spherical flow may appear in the later portions of tests for Structures #6, #7, and #10.
6. Geometric analyses using pressure derivatives are a useful tool for corroborating the hydrostructural models

Based on these analyses, the following recommendations were made:

1. As part of future work on the TRUE Block Scale volume, additional long pumping tests should be performed using other structures as sources, particularly if those structures might be the focus of future tracer testing.
2. Modeling work to include matching of transient well-test data would provide an additional check of the numerical models, particularly with respect to the boundary connections, as the boundary connections my be a key part of the observed pressure derivatives.
3. Pressure derivative data analysis with a view to the hydrostructural model should be an on-going activity in the iterative characterization of block-scale volumes.

2.2 Task 1.2 Transport Modeling

JNC is responsible for discrete fracture network and channel network transport simulation during the Block Scale Continuation Project. During H-14, Golder developed and implemented a detailed microstructural model for fractures which make up the TRUE rock block. This model considers the individual properties of each immobile zone, including breccia, gouge, cataclasite, mylonite, and altered granite. During H-14, simulations were carried out for each of the major TRUE-BS transport experiments, using the updated microstructural model. Results were compared against those obtained using the calibrated micro-structural model of H-12.

In the TRUE-BS rock block, transport pathways are defined by fractures, faults, and fracture intersections. The key transport processes are:

- advection,

- sorption on mineral surfaces,
- diffusion/sorption in geological materials,
- diffusion into stagnant pore volumes, and
- immobilization due to precipitation and incorporation in mineral lattices.

These processes are of different importance in experiments and in safety assessment. Although advection and sorption on mineral surfaces are primary processes in experiments, matrix sorption and matrix diffusion are the primary processes of concern for repository performance assessment.

The updated microstructural model for the fractures of the TRUE-BS rock block are described in Figure 2-2, and Tables 2-1 through 2-3.

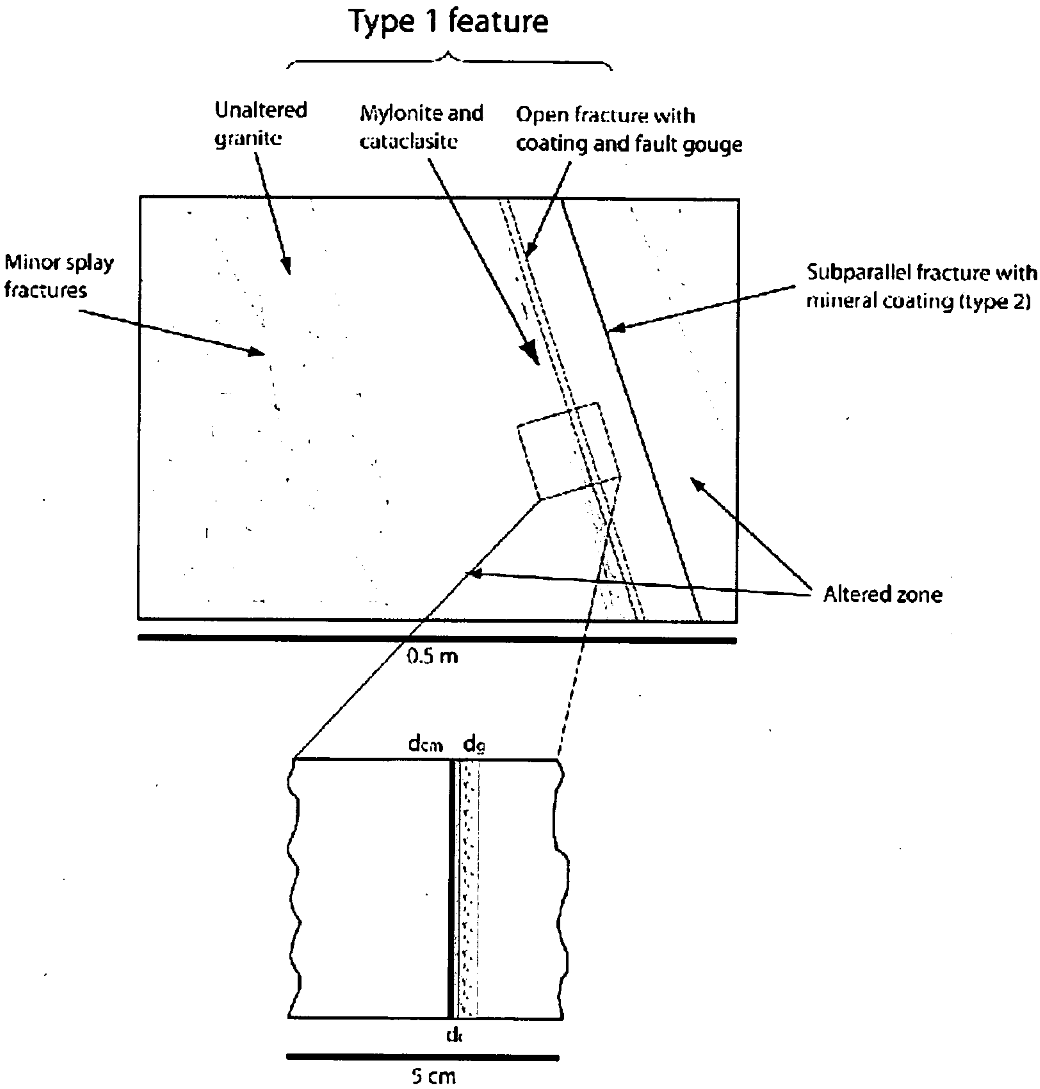

Figure 2-2. Updated Microstructural Model

Table 2-1. Properties of 100-m Scale Geological Structure Type 1 (Fault)

Rock type	Extent (cm)	Porosity (%)	Formation factor (-)
Intact wall rock	-	0.3	7.3E-5
Altered zone	20	0.6	2.2E-4
Cataclasite/Mylonite d_{cm}	2	1	4.9E-4
Fault gouge d_g	0.5	20	5.6E-2
Fracture coating d_c	0.05	5	6.2E-3

Table 2-2. Properties of 100-m Scale Geological Structure Type 2 (Non-fault)

Rock type	Extent (cm)	Porosity (%)	Formation factor (-)
Intact wall rock	-	0.3	7.3E-5
Altered zone	10	0.6	2.2E-4
Fracture coating d_c	0.05	5	6.2E-3

Table 2-3. Calculated Kd For the Different Materials in Contact With the Different Types of Groundwater

TRUE Block Scale groundwater:

	C (mg/l)	C (M)	K_c	Fracture Coating CEC=30 μeq/g K_d (m³/kg)	Fault Gouge CEC=90 μeq/g K_d (m³/kg)	Cataclasite CEC=8.5 μeq/g K_d (m³/kg)	Altered Zone CEC=11 μeq/g K_d (m³/kg)	Intact wall rock CEC=5.7 μeq/g K_d (m³/kg)
Na^+	2065	9.0E-2	0.1^A	3.7E-5	1.1E-4	1.1E-5	1.4E-5	7.1E-6
Mg^{2+}	42	1.7E-3	11^B	2.5E-3	7.8E-3	7.4E-4	9.7E-4	4.9E-4
K^+	8	2.1E-4	66^B	9.4E-4	2.9E-3	2.7E-4	3.6E-4	1.8E-4
Ca^{2+}	1485	3.7E-2	1	2.3E-4	7.1E-4	6.7E-5	8.8E-5	4.4E-5
Rb^+	0.03	3.5E-7	2.00E+03^A	5.2E-3	1.6E-2	1.5E-3	2.0E-3	1.0E-3
Sr^{2+}	24	2.7E-4	1^A	2.3E-4	7.1E-4	6.7E-5	8.8E-5	4.4E-5
Cs^+	0.002	1.8E-8	2.00E+05^A	5.2E-2	1.6E-1	1.5E-2	2.0E-2	1.0E-2
Ba^{2+}	0.06	4.3E-7	20^A	4.6E-3	1.4E-2	1.3E-3	1.8E-3	8.8E-4

Fresh groundwater:

	C (mg/l)	C (M)	K_c	Fracture Coating CEC=30 μeq/g K_d (m³/kg)	Fault Gouge CEC=90 μeq/g K_d (m³/kg)	Cataclasite CEC=8.5 μeq/g K_d (m³/kg)	Altered Zone CEC=11 μeq/g K_d (m³/kg)	Intact wall rock CEC=5.7 μeq/g K_d (m³/kg)
Na^+	21.1	9.2E-4	0.1^A	1.9E-4	5.9E-4	5.6E-5	7.3E-5	3.7E-5
Mg^{2+}	3.2	1.3E-4	11^B	6.9E-2	2.1E-1	2.0E-2	2.6E-2	1.3E-2
K^+	1.7	4.4E-5	66^B	4.9E-3	1.5E-2	1.4E-3	1.9E-3	9.5E-4
Ca^{2+}	34.5	8.6E-4	1	6.2E-3	1.9E-2	1.8E-3	2.4E-3	1.2E-3
Rb^+	0.03	3.4E-7	2.00E+03^A	2.7E-2	8.4E-2	7.9E-3	1.0E-2	5.2E-3
Sr^{2+}	0.6	6.4E-6	1^A	6.2E-3	1.9E-2	1.8E-3	2.4E-3	1.2E-3
Cs^+	0.002	1.8E-8	2.00E+05^A	2.7E-1	8.4E-1	7.9E-2	1.0E-1	5.2E-2
Ba^{2+}	0.06	4.3E-7	20^A	1.2E-1	3.8E-1	3.6E-2	4.8E-2	2.4E-2

Brine groundwater:

	C (mg/l)	C (M)	K_c	Fracture Coating CEC=30 μeq/g K_d (m³/kg)	Fault Gouge CEC=90 μeq/g K_d (m³/kg)	Cataclasite CEC=8.5 μeq/g K_d (m³/kg)	Altered Zone CEC=11 μeq/g K_d (m³/kg)	Intact wall rock CEC=5.7 μeq/g K_d (m³/kg)
Na^+	8500	3.6E-1	0.1^A	1.2E-5	3.8E-5	3.5E-6	4.7E-6	2.3E-6
Mg^{2+}	2.1	8.7E-5	11^B	2.8E-4	8.6E-4	8.1E-5	1.1E-4	5.3E-5
K^+	46	1.2E-3	66^B	3.1E-4	9.7E-4	9.1E-5	1.2E-4	6.0E-5
Ca^{2+}	19300	4.8E-1	1	2.5E-5	7.8E-5	7.3E-6	9.7E-6	4.8E-6
Rb^+	0.03	3.4E-7	2.00E+03^A	1.7E-3	5.3E-3	5.0E-4	6.6E-4	3.3E-4
Sr^{2+}	313	3.6E-3	1^A	2.5E-5	7.8E-5	7.3E-6	9.7E-6	4.8E-6
Cs^+	0.002	1.8E-8	2.00E+05^A	1.7E-2	5.3E-2	5.0E-3	6.6E-3	3.3E-3
Ba^{2+}	0.06	4.3E-7	20^A	5.0E-4	1.6E-3	1.5E-4	1.9E-4	9.7E-5

A Value from TRUE-1 investigation of altered Äspö diorite, sampled at KXTT2 15.1m (Byegård et al. 1998)
B Value from investigation of Finnsjön granodiorite (Byegård et al. 1995)

Most transport simulations for the TRUE-BS project were carried out using calibrated transport properties. While this was useful for deriving effective transport properties for the fractures tested, it did not demonstrate understanding of the transport pathways.

Simulations carried out during H14 were true predictive simulations. The transport properties used were taken directly from the microstructural model of Dershowitz et al. (2003). No conditioning or calibration of transport properties was carried out.

Three sets of transport experiments were simulated, representing the TRUE-Block Scale Phase C experiments C1, C2, and C3. Test C-3 was a radially converging tracer test since the induced flow rate in the injection section was significantly higher than the pressure of essential passive tracer injection. Tests C-1 and C-2 were unequal strength dipole tracer tests, since a slight excess pressure was applied at the injection locations. Example simulation results from tests C-1, C-2, and C-3 using the updated microstructural model are provided in Figure 2-3, Figure 2-4, and Figure 2-5.

Conclusions from these simulations are as follows:

1. The geologically based micro-structural model makes a significant improvement in the ability to predict both sorbing and non-sorbing tracers
2. While calibrated immobile zone parameters are able to produce better matches than those obtained by direct application of the microstructural model, the microstructural model provides improved understanding of the underlying mechanisms of solute retention
3. In general, the microstructural model provides greater retention than was observed experimentally. This is in stark contrast to the need to increase retention parameters in the calibrated models.

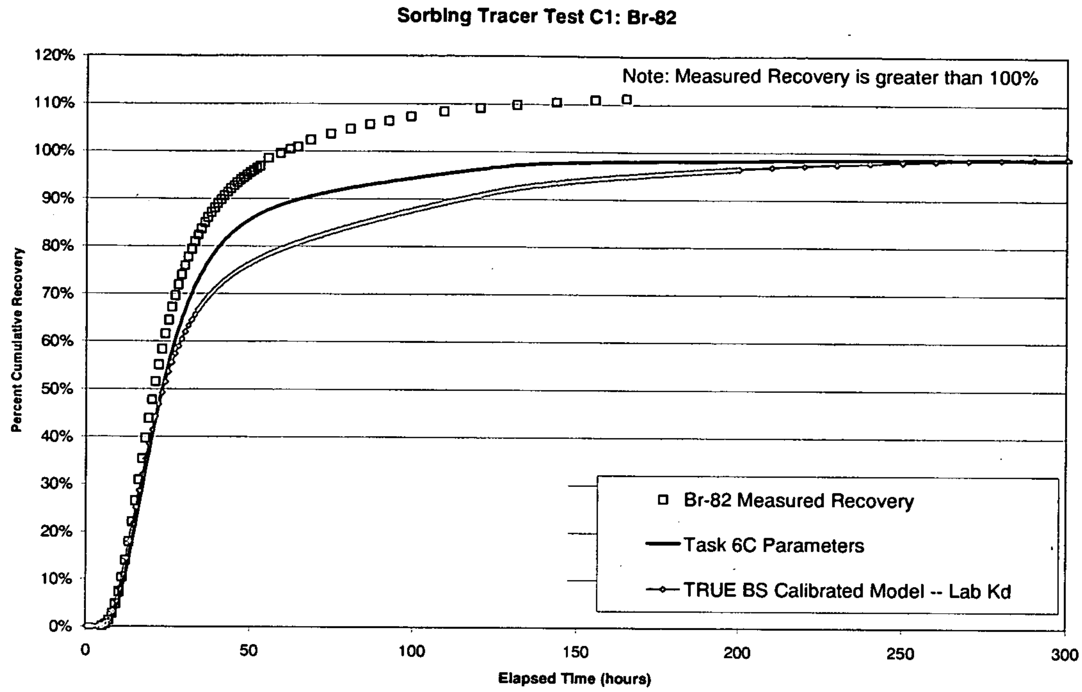

Figure 2-3. Predictive Simulation, Tracer Test C-1

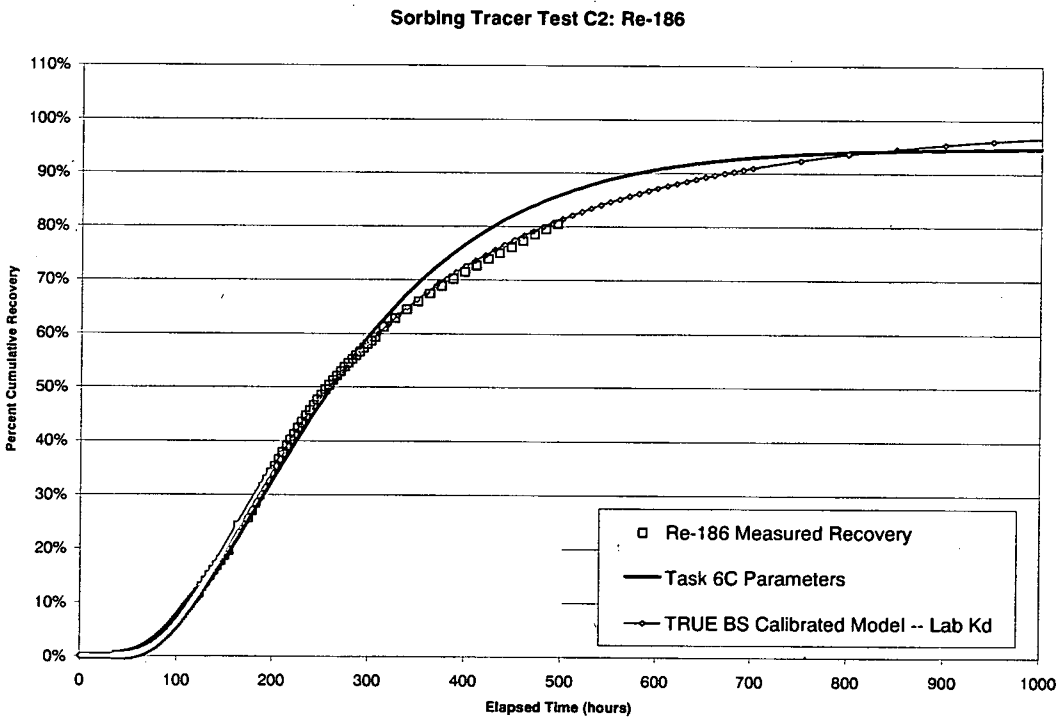

Figure 2-4. Predictive Simulation, Tracer Test C-2

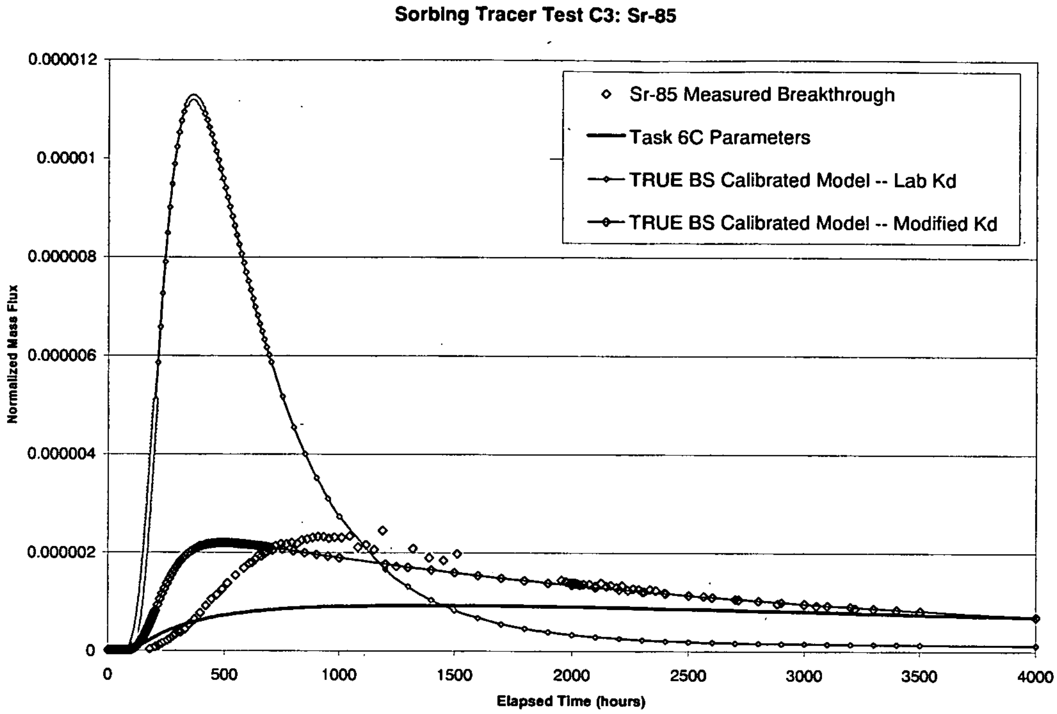

Figure 2-5. Predictive Simulation, Tracer Test C-3

2.3 Task 1.3: Hydraulic Interference Modeling

The TRUE-BS Continuation project intends to carry out tracer tests within the TRUE-BS rock mass to evaluate:

- the transport properties of longer pathways,
- the properties of smaller "background" fractures on transport
- hydraulic connectivity or compartmentalisation of the rock mass.

During H-14, Golder Associates carried out simulations of hydraulic interference to evaluate the properties and potential suitability of different transport pathways for this testing. In particular, the simulations were carried out to evaluate the implications of problems with the current TRUE-BS instrumentation, and potentials for improvement to that instrumentation. The TRUE-BS borehole array is illustrated in Figure 2-6.

All major tracer tests carried out so far have utilized borehole KI0023B. In particular, the is the borehole used for the Phase C tracer tests C1, C2, and C3 simulated in the current study.

KI0023B is used as a sink because the current packer installation includes a short-circuit between structures #6 and #20 in section P7 of the borehole. The flow between structures #20 and #6 within packer interval P7 is 0.2 l/min, as measured by tracer dilution technique. This is one of the largest flows measured on the site, and indicates that P7 is serving as a significant conductor.

As a result of the presence of this conductor provided by packer interval KI0023B:P7 a number of alternative sinks in boreholes KI0025F, -F02, -F03, KA2563A and KI0025F risk losing tracer mass to this artificial sink. It is also impossible to use structure #20 in KI0023B as a source (injection section).

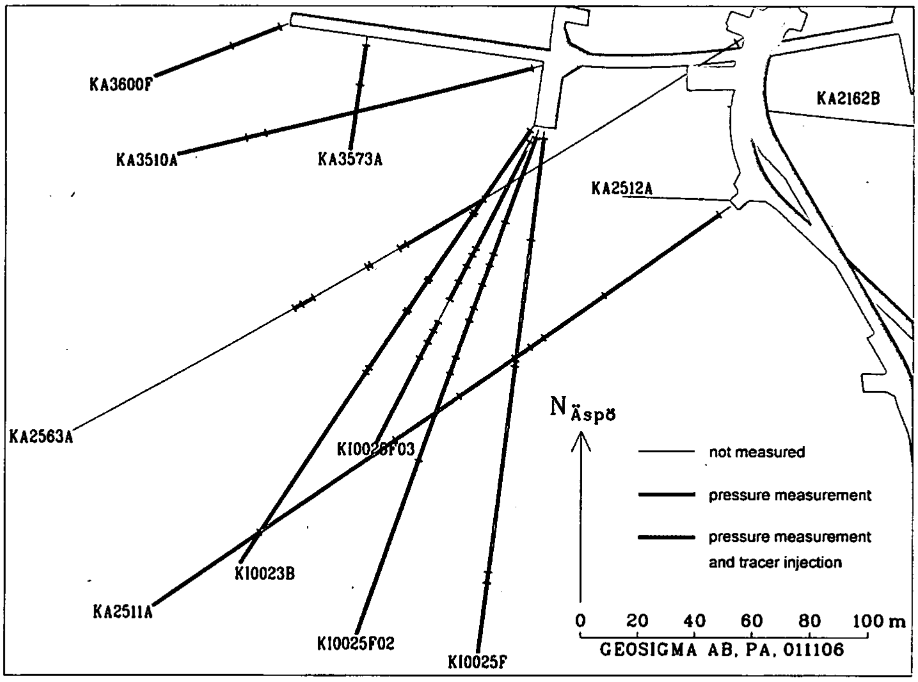

Figure 2-6. Borehole and Instrumentation Geometry at the TRUE Block Scale Site

The packer interval KI0023B:P6 works as a sink despite the short circuit in KI0023B:P7 because pumping from P6 provides an even lower head than that seen in P7. As a result, P6 has been tested extensively already, and is not very interesting as a sink for future tracer testing.

Golder Associates, together with GeoSigma and Conterra AB have evaluated the potential sink and source intervals for future testing. The intervals simulated during H-14 are listed in Table 2-4. The notation used for Table 2-4 is as follows. "f" indicates tests carried out to evaluate longer network pathways. "b" indicates simulations carried out to evaluate background fracture effects. Where simulations are designated "R", simulations were carried out using both the current and the remediated borehole configurations. The proposed remediated packer geometry is specified in Table 2-5. An example distance drawdown plot from these simulations is provided in Figure 2-7.

Table 2-4. Simulations of Hydraulic Interference for Potential TRUE-BSC Pathways

Sim.	Sink	Struct #	Source	Struct #	Cartesian Length (m)	Objective
f4	KI0023B:P6 Q=2.0 l/min	20/21	KI0025F:R2	19	110	Long distance, network
f5 f5R	KI0025F:R2 Q=3.5 l/min	19	*KA2563A:S1*	*19*	*115*	*Long distance, single structure*
f10 f10R	KI0025F02:P5 Q=2.5 l/min	20	*KA2563A:S1*	*19*	*51*	*Long distance, network*
f11	KI0025F02:P5 Q=2.5 l/min	20	KI0025F:R2	19	96	Long distance, network
f15 f15R	KI0025F03:P5 Q=2.6 l/min	20	*KA2563A:S1*	*19*	*50*	*Long distance, network*
b2 b2R	KI0023B:P4 Q=0.5 l/min	13	*KI0025F03:P4*	*21*	*17*	*Background fracture network??*
b4 b4R	KI0023B:P6 Q=2.0 l/min	20/21	KI0025F03:?			Background fractures or network
b8 b8R	KI0025F03:P5 Q=2.6 l/min	20	*KI0023B:P4*	*21*	*18*	*Background fracture network??*
b13	KI0025F03:P6 Q=0.8 l/min		KI0025F02:P7	23	10	Background fracture network??
b18	KI0025F02:P5 Q=2.5 l/min	20	KI0025F03:P3	13	20	Background fracture network??
b23 b23R	KI0025F02:P5 Q=2.5 l/min		*KI0023B:P5*	*?*	*20*	*Background fracture network??*

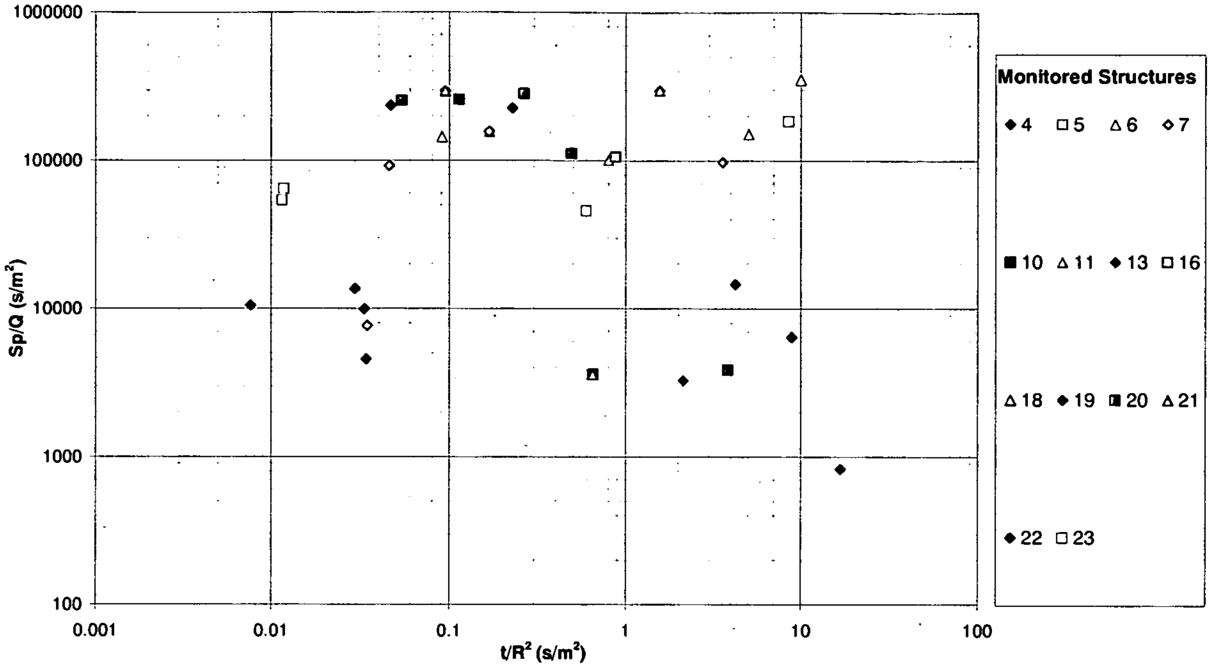

Figure 2-7. Example Hydraulic Interference Simulation, Sink in KI0023B:P6

Table 2-5. Proposed Remediation of KI0023B (after Andersson, 2003)

Old Sec.	Interval (m)	Struct	Bh length (m)	Flow* (l/min)	New Sec	Interval (m)
P1	113.7-200.7	#10	169-171	16.00	R1	113.7-200.7
		#?	141-146	2.00		
P2	111.3-112.7	#19	112	2.85	R2	111.3-200.7
P3	87.2-110.3	#?	87-88	0.02	R3	87.2-110.3
P4	84.8-86.2	#13	85.6	0.80	R4	77.0-86.0
P5	73.0-83.8	#?	75-76	0.02	R5	73.0-76.0
		#?	72-75	0.30		
P6	71.0-72.0	#21	71.1	2.00	R6	71.0-72.0
P7	43.5-70.0	#20	69.8	2.00	R7	66.0-70.0
		#?	51-56	0.07		56.0-65.0 Blind
		#?	46-50	0.64	R8	46.0-55.0
		#6	44.2	1.00		
P8	41.5-42.5	#7	42.2	40		
P9	4.5-40.5	#?	31-32	2.00	R9	4.5-45.0
		#5	8	5.00		

3. TASK 2: MIU AND SHI YU-U CHI SITE CHARACTERISATION SUPPORT

During H-14, Golder assisted JNC in interpretation of hydraulic experiments at the MIU and Shi Yu-u Chi Sites. The following three subtasks were carried out:

- Task 2.1: MIU-4 Test Interpretation Support
- Task 2.2: MIU Hydrostructural Synthesis
- Task 2.3: Shi Yu-u Chi Initial Model Support

3.1 Task 2.1: MIU-4 Test Interpretation Support

Golder Associates carried out extensive FlowDim fractional dimension analysis to evaluate the results of the MIU-4 hydraulic tests and borehole characterization.

The FlowDim hydrogeologic analyses were carried out to derive reliable estimates for the transmissivity and freshwater head using an appropriate flow model. In addition to providing recommended parameter values, the analyses generally aim to determine confidence limits for derived parameters as an indication of the degree of uncertainty.

Prior to the start of the analyses, the borehole history and the starting input parameters were defined for each of the MIU boreholes, including the duration of the borehole history. For intervals that have no evidence for heterogeneity, the borehole history was assumed to start at the time when the contractor drilling through the midpoint of the interval. If there is evidence for a water-conducting feature within the interval, the borehole history was assumed to start at the time of drilling through this feature. The next step was to discretize the history period in accordance with the documented activities.

The geometrical and fluid properties were fixed in all FlowDim analyses. The handling of the other parameters varies between analysis method. Table 3-1 summarizes the treatment of storativity, skin, wellbore storage, and flow dimension in the MIU-4 FlowDim analyses. Interpretation of the data with the different techniques allows for cross checking of input parameters against matched parameters.

Table 3-1. FlowDim Analysis for MIU Hydraulic Tests

Parameter	FLOWDIM Analytical Analysis
Storativity	Matched parameter but reliability depends on accuracy of assumed skin (0[1)])
Skin	Assumed Parameter (0[1)])
Wellbore storage	Input parameter
Flow dimension[1)]	Radial Cylindrical [2)]

Comments:

1) Typically assumed to be 0 unless the early time data is relatively free of noise and then this parameter is determined from type curves

The flow geometry is assumed to be radial cylindrical unless otherwise suggested by examination of the pressure derivative data

The relevant test phases were examined on normalized plots to check for consistency of formation response throughout the test. In cases where near-wellbore properties have changed, a single set of parameters does not provide a good match to the entire test sequence. In these cases, certain parameters are allowed to change between phases when simulating the entire test sequence. In addition, injection phases can reduce the near wellbore properties with the injection of particles into the formation. If the normalized plots confirm this response, the injection phase analysis is deemphasized.

After review of the normalized plots, the individual phases of testing were evaluated in log-log and semi-log coordinates. Viewing the parameters derived in the individual phase to the entire test sequence provided a confirmation for parameter reliability.

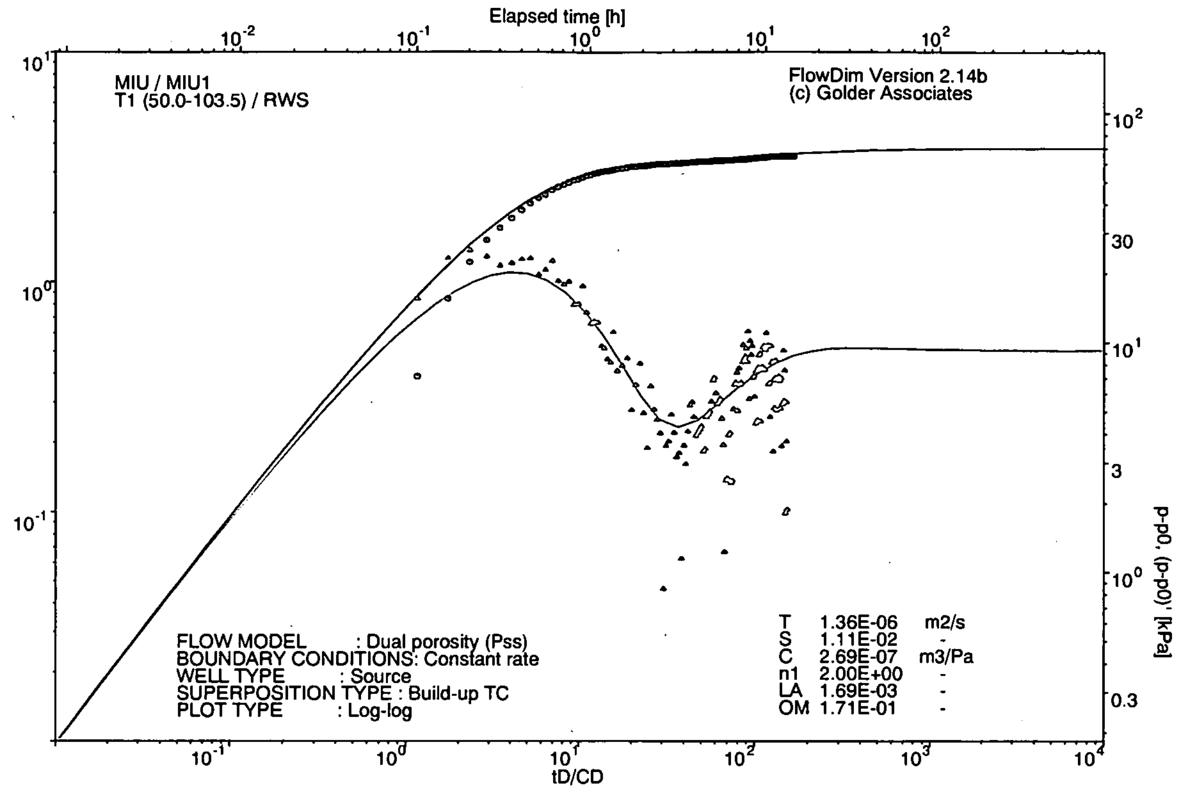

Figure 3-1. Example of FlowDim Analysis

Figure 3-2 presents a summary plot of the pressure derivative curves for the eleven MIU-4 tests. The derivatives are normalized with respect to pumping rate to allow direct comparison of the results. The pressure scale also has been recalculated to provide transmissivity values. The combined rate normalization and transmissivity calculation involves the following relationship: $T = Q / (4\pi \, t\,dp/dt)$. The common plotting of a number of test records allows a ready comparison of transmissivity values. Furthermore, similarities of derivative shape can indicate whether different tests are affecting the same or different conducting features.

For each MIU-4 test, there were several flow and pumping phases. The FlowDim analyses reported in Appendix D primarily study the rws or sws (recovery from pumping or slug) phases. These phases have the longest records and the highest quality, being least disturbed by pumping rate variations.

Table 3-2 summarizes the results of the FlowDim analyses for these pumping periods. Analyses used composite type curves assuming inner and outer regions with different properties. Table 3-2 gives both the inner and outer zone transmissivities and flow dimensions. The dimensionless radius appears in the table as well, but it is very unreliable value because it depends on storativity, which cannot be separated from skin effects for sources zone tests.

The pressure derivative curves for the MIU-4 tests fall into several groups which are as follows:

1. Tests 1 (Mizunami Group, 60-68m), 2 (Mizunami Group, 72-74m), and 9 (Tsukiyoshi Fault Core, 670-677m) are lower transmissivity intervals with dimensions of 2 or less.
2. Tests 3 (Weathered Granite, 83-117m), 4 (WCF in Toki Granite, 314-316m), 7 (Upper Highly Fractured Domain, 183-254m), 8 (Hangingwall, More Fractured Zone754-790m), 10 (Hangingwall, Sparsely Fractured, 690-753m), 11 (Lower Sparsely Fractured Domain, 500-562m), and 12 (Lower Sparsely Fractured Domain, 361-424m). These tests all have a dimension of two or slightly greater. They appear to have local regions with low transmissivity and connect with higher transmissivity regions within the first minute of test. The records indicate stabilization into features with transmissivities between 2×10^{-6} and 3×10^{-5} m^2/s.
3. Test 6 (Hanging wall, 584-647) has an anomalously high apparent transmissivity which decreases with distance to about the same level as the group 2 tests.

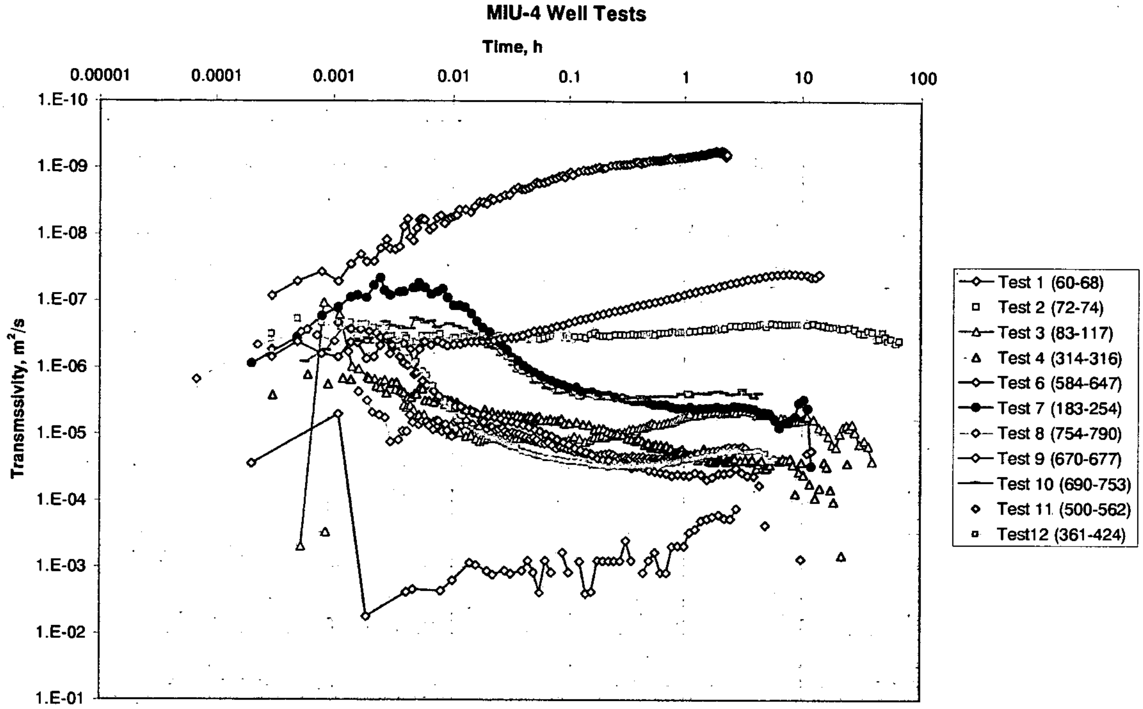

Figure 3-2. MIU-4 Analysis Summary

Table 3-2. Hydraulic Properties From FlowDim Analyses of MIU-4 Tests (rws only; sws if no rws)

Test	top	bottom	phase	T1	n1	mobility ratio	Dimensionless Composite Boundary	T2	n2
	m	m		m^2/s				m^2/s	
1	60	68	sws	2.8E-09	2	3.3	25	8.5E-10	2
2	72	77	rws	3.4E-07	2	1.5	115	2.3E-07	2
3	83	118	rws	1.3E-05	2	2.7	1.30E+12	4.8E-06	2
4	183	254	rws	1.0E-07	2	0.5	8.6	2.0E-07	2
6	315	317	rws	6.3E-06	2	0.3	5000	2.1E-05	2
7	362	434	rws	3.4E-07	2	1.9	6.5	1.8E-07	3
8	500	563	rws	3.8E-07	2	5.6	19	6.8E-08	3
9	584	647	rws	1.3E-05	2	0.01	20	1.3E-03	2
10	670	677	sws	5.7E-07	2	0.017	25	3.4E-05	1
11	691	753	sws	5.9E-07	2	0.1	57	5.9E-06	1.9
12	755	790	rws	8.5E-07	2	0.9	35	9.4E-07	2.4

3.2 Task 2.2: MIU Hydrostructural Synthesis

During H-14, Golder Associates assisted JNC in synthesizing hydraulic, geochemical, geophysical, and geological information to support the MIU site hydrostructural model. This analysis focused on interpretation of transient hydraulic responses (and lack of responses) during the LPT experiments. The long term pumping test at the MIU was performed at the end of 2001 and early in 2002. The test used two source zones, one in the hanging wall of the Tsukiyoshi Fault and one in the foot wall.

The interpretation of the source zone data is complicated by pressure history effects that arise from cross flow in MIU-2, the source hole, when the MP monitoring casing was being replaced by packers for testing. The foot wall of the Tsukiyoshi fault has considerably higher heads than the hanging wall, and connecting the two hydro-stratigraphic units through MIU-2 results in significant cross flow between the two units. The pressure effects of this cross flow are not dissipated before the LPT testing. Furthermore, additional cross flow period occurred when the packers were moved for the second, hanging wall, test. The drawdowns and pressure build-ups due to cross flow exceed those that could be achieved by the pumping test.

The analysis of the LPT data required filtering out of the background effects. This was done by the testing contractor, but the results were not consistent among the separately analyzed phases of the tests. Based on a review of the LPT data in Tono during October, 2002, Golder Associates proposed to reconciling the discrepancies between the results of separate phases by analyzing the test as single phase with multiple steps. Interpret II, a standard petroleum analysis package, has this capability. The effective pumping rate between the hanging wall and the hangingwall is not known precisely, but it can be estimated from flow logs that were run while the packers were removed from the hole. Also, the rate during packer removal can be treated as a variable and determined from an optimized match to the data.

3.2.1 Long-Term Pumping Test — Observation wells

JNC-Tono supplied Golder Associates with the pressure interference data for the LPT experiments. The data cover four observation sections in MIU-1 for the hanging wall test and four sections in MIU-3 for the hangingwall test. As discussed above, the data have superposed trends from the cross flow during packer removal in MIU-2. The contractor-supplied data from JNC include data corrected for the background trend. Golder Associates analyzed these corrected data using FlowDim. The FlowDim analysis results are summarized in Table 3-2 and Figures 3-3 and 3-4.

Hanging wall tests (Figure 3-3) are best fit using dimension-2 type curves. The transmissivity values range from 1.0×10^{-5} m^2/s to 1.8×10^{-5} m^2/s. Storativity values range from 5.9×10^{-5} to 1.2×10^{-4}. These values define diffusivity as having a range from 0.14 to 0.31 m^2/s. The diffusivity values are relatively low for major conducting zones, when compared with similar conductors in the Äspö TRUE Block Scale Experiment (which are in a range from 4 to 38 m^2/s). Given the high transmissivity of the fault hanging wall, the low diffusivity would appear to be the result of very high storage, hence one might expect that the fault zone has a large porosity as compared with other typical fracture zones.

The foot wall tests (Figure 3-4) differ from the hanging wall tests in both dimension and diffusivity. The dimension of the responses in the foot wall are 1.25 with one observation (MIU 3-6) having a dimension of 1.6. These data suggest that conductive features in the foot wall has a linear geometry with some leakage. In contrast, the hanging wall behaves as a generally two dimensional (planer) feature. The diffusivity value for MIU 3-6 is similar to that of the hanging wall (0.24 m^2/s), while the other observation zones see diffusivities ranging from 1.3 to 2.8 m^2/s. Transmissivity and storativity values from the foot wall test (Table 3-2) are generally about 2-3 orders of magnitude larger than the values for the hanging wall. It should be noted, however, that for a given magnitude of pumping, the transmissivity is larger for a smaller dimension match.

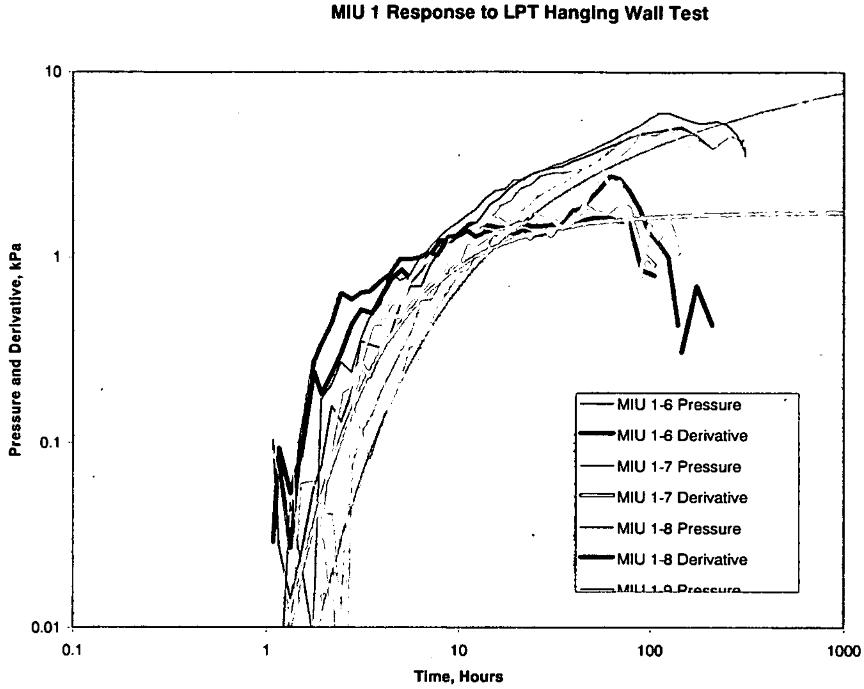

Figure 3-3. Pressure Interference in the Hanging Wall of the Tsukiyoshi Fault From the LPT Experiment

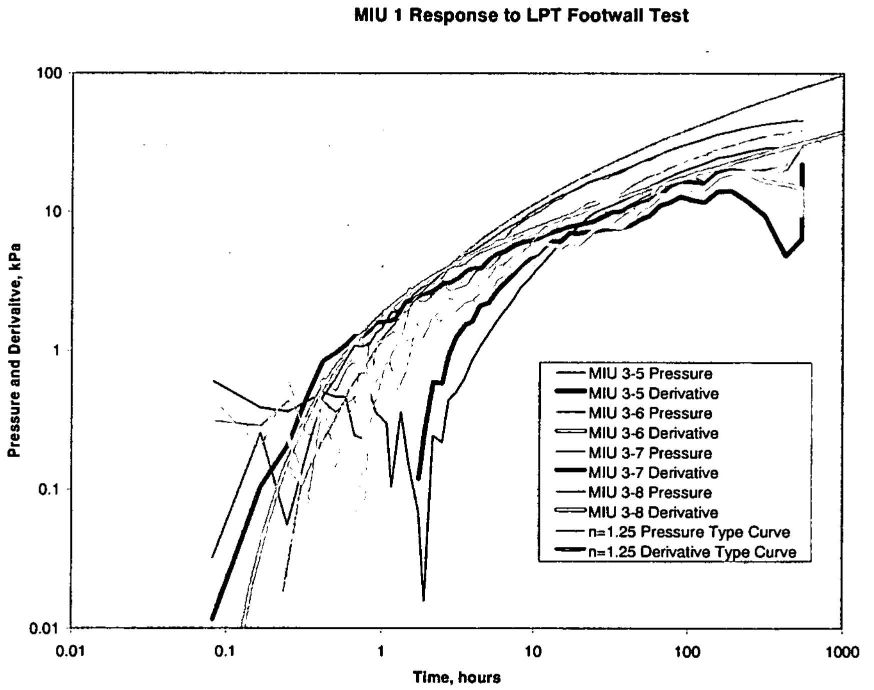

Figure 3-4. Pressure Interference in the Foot Wall of the Tsukiyoshi Fault From the LPT Experiment

Table 3-3. Hydraulic Properties and Flow Dimensions for LPT Interference Tests

Source	Observation	T, m^2/s	S, -	η, Diffusivity, m^2/s	Dimension n
MIU-2 Foot Wall	MIU3-5	1.10E-03	4.60E-03	0.24	1.6
	MIU3-6	7.20E-02	2.70E-02	2.67	1.25
	MIU3-7	7.22E-02	2.60E-02	2.78	1.25
	MIU3-8	6.90E-02	5.20E-02	1.33	1.25
MIU-2 Hanging Wall	MIU1-6	1.70E-05	7.90E-05	0.22	2
	MIU1-7	1.40E-05	1.00E-04	0.14	2
	MIU1-8	1.80E-05	5.90E-05	0.31	2
	MIU1-9	1.50E-05	1.20E-04	0.13	2

3.3 Task 2.3: Shi Yu-u Chi Initial Model Support

During H-14, Golder assisted JNC in development of an initial discrete fracture network (DFN) model localized to the Shi Yu-u Chi site. Golder's support focused on analysis of DH-2, which is the key to hydrostructural analysis in the Shi Yu-u Chi area.

The DH-2 borehole testing is the primary source for data to understand the hydrostructural framework for the Shi Yu-u Chi Site. DH-2 has produced some results that are inconsistent with normal hydrologic testing concepts. The two major anomalies are (1) periods of pressure recovery during constant-rate pumping tests, and (2) major discrepancies between production and recovery behaviors. The cause of pressure recoveries may be related to increased conductivity during the test. Increase in conductivity can be the result of changes to skin, possibly from erosion of fracture-filling materials. Another rock-based cause for recovery is ex-solution of gas, as gas-bearing water has a lower viscosity than single-phase water, resulting in a higher hydraulic conductivity due to reduced viscosity. A third possible cause of recovery during the test can be some equipment leakage (i.e., the permeability of equipment goes up).

The second discrepancy results from the virtually instant recovery from the tests. Despite pumping drawdowns that develop gradually, the recovery is almost instantaneous. Part of this rapid recovery can be caused by the shutting-in of the test interval during recovery. However, this only removes that portion of recovery that comes from well-bore storage and skin effects. The instant recovery almost suggests that the aquifer or fractures were not drawn down at all, and the production was coming from equipment leakage.

The data from the testing of borehole DH-2 exhibit two severe well testing anomalies. These are:

- Partial recovery of the pressure during the pumping period
- Very rapid recovery at the end of the test

During most of the well tests in DH-2, the pressure began to recover during the pumping phase of the test. Most often, such a pressure recovery is caused by decreases in the flow rate. The main remedy involves using an analysis approach that incorporates the variable flow rates.

In the DH-2 tests, however, rate controls were in place such that the flow rate should have been constant, and the tests exhibited partial recovery anyway. The only cause for such partial recoveries is a change in the mobility, that is the conductivity, of the tested materials during the test. Such changes may be increases in the hydraulic conductivity of the rock, development of leaks in the equipment, or development of leaks along the borehole wall. The rapid recovery of the major part of the DH-2 well tests indicates that the permeabilities were changing during the test.

Figure 3-5 shows and example of this behavior. Thirteen of the nineteen intervals showed some partial recovery, and most the remaining intervals showed a leveling of the pressure drawdown before resuming an increased drawdown rate. Table 1 summarizes the effect in terms of the time at which the recovery begins to occur and the amount of recover expressed as a percent of the pressure drawdown at the time the recovery began.

A qualitative examination of the data indicate that the onset of recovery is an inverse function of the transmissivity of the interval, since the recovery begins earlier in more transmissive zones. The amount of recovery varies from none to 15% with most recoveries in the range of a few percent.

FlowDim type curve derivative analysis is particularly useful for understanding flow geometrics. The results of FlowDim analysis of the DH-2 tests are summarized in Table 3-4. Figure 3-6 provides the derivative curves for all the DH-2 tests.

Analysis of FlowDim results indicates the following:

1. All tests show evidence of a constant pressure-boundary.
2. Assuming a storage of 1×10^{-5}, the boundary lies at a radius of a few tens of meters for all tests.
3. No tests show stabilization to two-dimensional flow, though some tests can be matched using type curves with skin and storage.
4. Most tests can be matched with linear flow.
5. The boundary effects appear at a range of times between 0.1 and 2.5 hours. This is significantly earlier than the onset of the partial recoveries.
6. The time of the onset of boundary effects is a clear function of the transmissivity.

Table 3-4. Summary of DH-2 Analyses

	Recovery During Pumping		Boundary Analysis				Properties
Test	Onset Time, h	Percent	Onset Time, h	Dimension	Derivative kPa/(l/m)	Distance, m (S=1E-5)	T, m^2/s
DH2-1	none		0.18	1	1.4	15.5	9.3E-06
DH2-2	3.9	2%	0.88	1	40	20.3	3.2E-07
DH2-3	1.9	0.14%	0.14	1	2.7	31.2	4.8E-06
DH2-4	2	0.4%	0.18	1	2.0	40.5	6.5E-06
DH2-5a	3.2	3%	0.18	1	8.8	19.6	1.5E-06
DH2-5b	1.5	15%					
DH2-6	10	2%	1.0	1.0	72	16.1	1.8E-07
DH2-7	unclear		0.125	1	0.56	64.6	2.3E-05
DH2-8	step test		0.097	2	0.74	49.5	1.8E-05
DH2-9	2	1%	0.10	1 or 2	2.0	30.6	6.5E-06
DH2-10	4.5	1%	0.8	1 or 2	2.5	77.4	5.2E-06
DH2-11	2	1%	0.13	1	3.2	27.6	4.1E-06
DH2-12	4	0.32%	1.2	1	36	25.0	3.6E-07
DH2-13	11	3%	2.5	1	110	20.6	1.2E-07
DH2-15	none		0.056	2?	0.26	63.5	5.0E-05
DH2-16	1.5	3%	0.044	1	0.26	56.3	5.0E-05
DH2-17	none		0.044	1.5	0.26	56.3	5.0E-05
DH2-18	none		0.12	1.5	2.8	28.3	4.6E-06
DH2-19	6	1%	0.17	1 or 2	42	8.7	3.1E-07

Note: Transmissivity based on cylindrical flow conversion of derivative. Linear flow values will be larger.

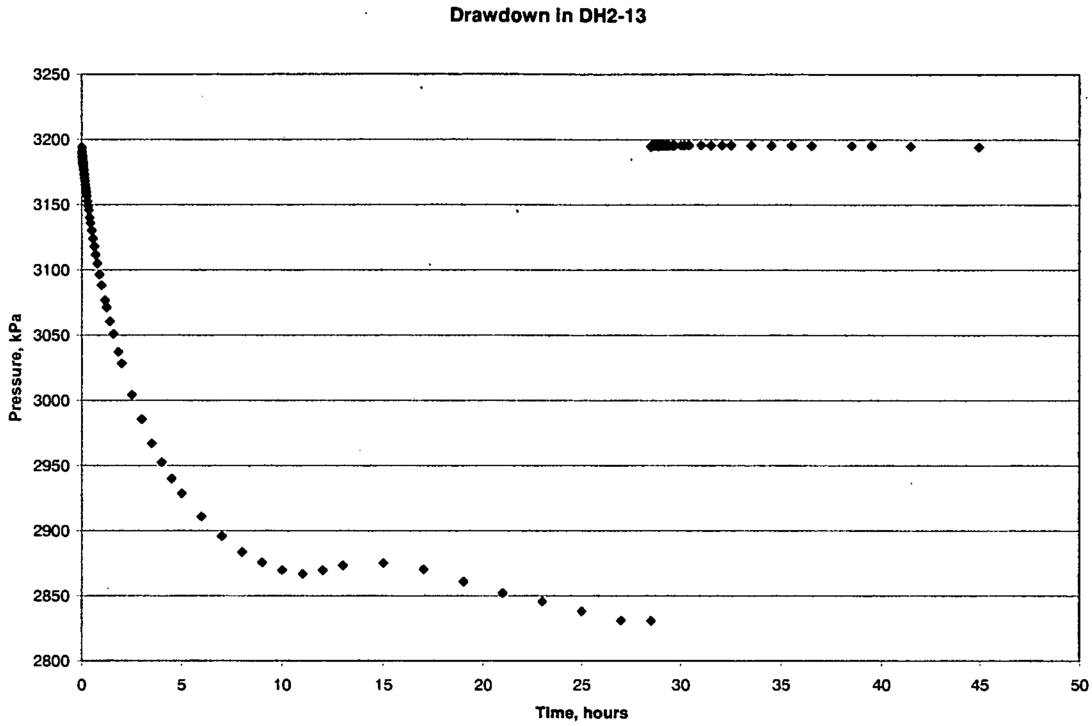

Figure 3-5. Example of Partial Pressure Recovery

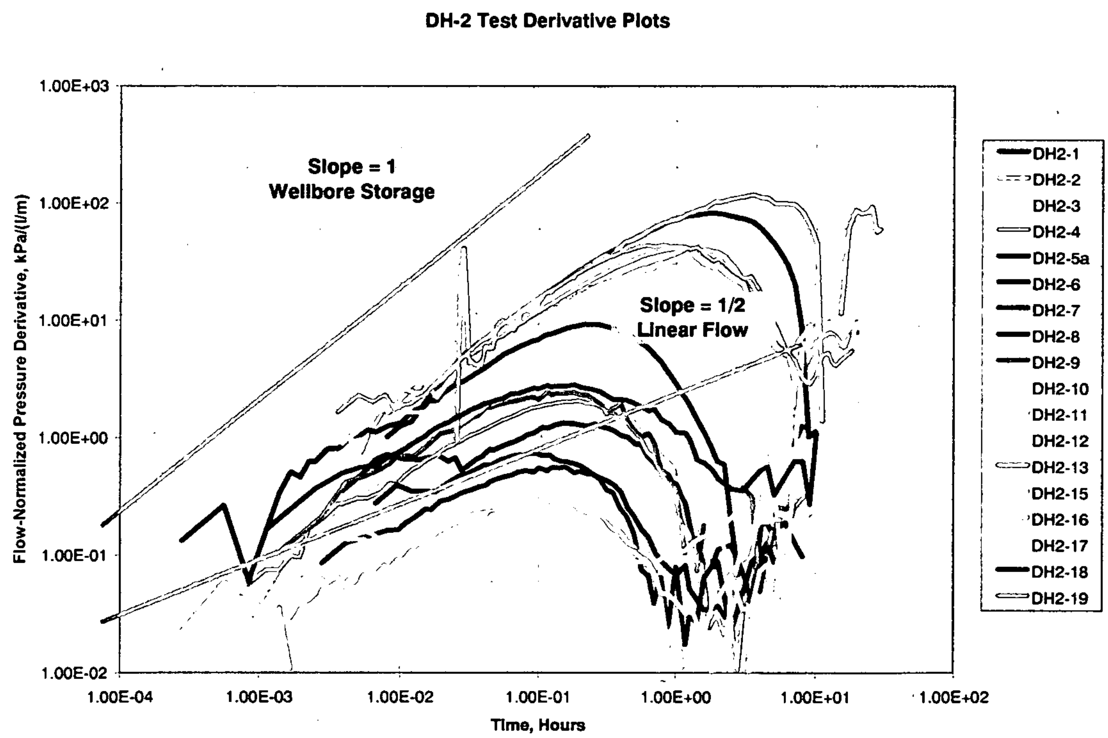

Figure 3-6. Derivative plots for DH-2 well tests

Analysis of DH-2 has provided significant insights into the hydrologic behavior of the Shi Yu-u Chi site. The analysis presented in this report raises the following issues:

1. Has the later time pressure recovery during pumping been understood yet? That recovery happens later in the test than these derivatives show, but it still needs an explanation. Before publishing it would be good to make sure that whatever is causing the pressure recovery is not affecting the earlier time data that appear in the derivative plots.
2. The linear flow can be caused by fracture intersection zones (FIZ), but it can also be caused by lots of other things. We have analysed similar well tests from granitic reservoirs in southeast Asia. Our analysis of these tests indicated that many different geometries could create this behavior.
3. The key thing is to use knowledge of geology to decide which of the many possibilities are reasonable. One interesting geological hypotheses is that these tests are all seeing a major subvertical conductor at a distance of 50-100m from the borehole. Does this idea make any geological sense?
4. Some additional information on storage is very important to get the diffusivities. Knowledge of diffusivity will make it possible to more definitively estimate the length scales for the boundary effects. Diffusivity also facilitates derivation of permeability from the testing. Keep in mind that the linear flow equations are different from cylindrical flow, and the log-log 1/2 slope lines give the product of K and Ss. 2-D flow solutions provide transmissivity (m^2/s).

4. CONCLUSIONS

During Heisei-14, Golder Associates developed and documented substantial advances in radioactive waste management technology for JNC. The major accomplishments of H-14 include:

- Analysis of flow and transport pathways and processes at the Äspö TRUE-BS rock block.
- Assistance in interpretation of Large Scale Pumping Test LPT-1, and hydraulic test MIU-4
- Support for development of the hydrostructural model for the Shi Yu-u Chi area based on DH-2 hydraulic test interpretations.

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APPENDIX A

TRUE BLOCK SCALE HYDROSTRUCTURAL ANALYSIS

APPENDIX B

TRUE-BLOCK TRANSPORT MODELLING

APPENDIX C

TRUE BLOCK SCALE HYDRAULIC INTERFERENCE ANALYSIS

APPENDIX D

MIU-4 FLOW DIMENSION ANALYSIS

APPENDIX E

LONG TERM PUMP TEST ANALYSIS

APPENDIX F

SHI YU-U CHI ANALYSIS

APPENDIX A

GENERALIZED DIMENSION ANALYSIS OF BUILD-UP TESTS USING PRESSURE RESULTS FROM TRACER TESTS

ÄSPÖ HARD ROCK LABORATORY

TECHNICAL NOTE

TRUE BLOCK SCALE EXPERIMENT

GENERALIZED DIMENSION ANALYSIS OF BUILD-UP TESTS USING PRESSURE RESULTS FROM TRACER TESTS

THOMAS DOE

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1. INTRODUCTION

This report presents analysis of well tests in the TRUE Block Scale volume. The main purpose of these interpretations is to provide information on the geometry of the conducting features intersected by the borehole. The analyses focus on the longer term tests that were performed as part of the tracer testing program including the pre-tests and the A series tests.

The question of flow geometry has important implications for the movement of tracers in the TRUE Block Scale volume. How many pathways participate in transport and how much surface area do those pathways provide for fracture-rock interaction? Is the flow along pipe-like channels that would produce geometrically linear flow in hydraulic tests? Is the flow confined to two-dimensional planar features, such as the major features of the TRUE Block hydrostructural model? Is there a three-dimensional network of fractures providing the major portion of flow along the pathways of the tracer testing?

The flow geometry question can be answered in part by careful attention to the geometric information that can be derived from the pressure data produced during the testing. So far in the TRUE Block Scale project, the well test analysis has focused on methods that assume two-dimensional flow, as in the build-up tests for the KI0025F02 borehole (e.g. Adams, et al, 1999). The hydrostructural model development (Hermanson and Doe, 2000) looked at geometry mainly from the pseudo-steady drawdowns at the end of the tests and interference data during drilling and did not use geometric information in the transient data.

A comprehensive look at transient data from the standpoint of flow dimension has not previously been undertaken for the longer-term pumping data that were obtained during the tracer phase of the TRUE Block Scale project. The work presented in this report looks at a sufficient portion of these data to define the flow geometries of the major conductors that were important for the tracer testing, specifically Structure #20 and connecting features, such as Structures #21, #13, and #22. In addition to these analyses, this report also presents a new plotting of the buildup data from KI0025F02 (Adams, et al, 1999). These tests are short-term (30-minute) tests that do not provide the same distance of coverage as the later tracer tests, but they do give some information on other important structures that in the TRUE Block Scale volume that were not part of the tracer testing, such Structures #19, #6, #7, and #10.

1.1 Flow Dimension

The classic two-dimensional approach assumes that the conducting feature is a tabular-shaped conductor oriented perpendicular the wellbore axis. The interpretations presented here use a generalized dimension approach (Barker, 1988), which makes no assumptions of the conductor geometry. Thus the interpretations provide information on the geometry of the conducting feature as well as its conducting properties.

Barker (1988) introduced the generalized radial flow approach to the hydrologic literature. Essentially it defined the dimension of a conductor as the power at which the conducting area grows with radial distance from the pumping well, assuming homogeneous hydraulic properties. If the properties are not homogeneous, the dimension reflects the power growth of the product of area and hydraulic conductivity or conductance. The fractional dimension approach is described in detail in Doe and Geier (1991) and is summarized here.

The dimension, n, is one plus the exponent of area growth. For classical two-dimensional aquifers the conducing area grows with the first power of radius. Linear flow geometries, such as a vertical hydraulic fracture or a channel have areas that do not grow with distance, i.e., the power exponent is zero. Spherical flow occurs when the area grows at power of radius squared. Fractional dimensions arise when the area grows by a non-integer power. Such as case may arise from a variety of geometries, but a general explanation involves conducting geometries that are not space-filling or involve leakage. Consider, for example, a two-dimensional planar conductor. If the space is uniformly conductive or if a heterogeneous pattern uniformly fills the two-dimensional space, the conductor will have a dimension of 2. If the conductive pattern does not fill the space, the conductor may have a dimension somewhat less than 2. Indeed dimensions of 1.7-1.8 are common for planar features. Leakage over the conductor surface may lead to a dimension somewhat greater than 2.

The dimension of the conductor is readily recognizable from the shape of the well test curve. For constant rate tests, the slope of the build-up or drawdown curve in logarithmic plots will be equal to $1-n/2$ for dimensions less than 2. Thus a linear flow conductor will have a characteristic ½ slope. A conductor with a dimension of 1.5 will yield a curve with a slope of ¼.

1.2 Pressure Derivative Analysis

The pressure derivative curves provide even clearer indications of dimension. Bourdet originally proposed the derivative curve as a means of identifying the time at which the semi-log approximation of the Theis or Exponential Integral curve becomes valid. Recognizing that $n=2$ flow has this semi-log relationship, Bourdet reasoned that a log plot of pressure change versus log time should have a zero slope, and this zero slope would be more diagnostic than a semilog straight line. This pressure derivative plot has advantages in dealing with generalized or fractional dimension flow, because a pressure derivative curve will approach a slope of $1-n/2$ for all dimensions including those between 2 and 3. Thus the combination of log plots and derivative plots provides a strong basis for diagnosing dimension.

2. APPROACH

2.1 Data Sources and Preparation

The report describes generalized dimension analysis of:

- Source zones in KI0025F02 using short buildup tests, and
- Source zones in and near Structure #20 that were run as part of the tracer testing program.

The KI0025F02 short-term build-up tests (Adams, et. al., 1999) provide a derivative plot for each of the major conducting structures in the TRUE Block-Scale volume. These test were relatively short (about half an hour), and they were conducting with the entire hole open except for the packer-isolated flow interval. By contrast the tracer Pre-tests, which were run to select tracer injection and collection locations, ran for up to several months, and provide a deeper look into hydraulic property variations with distance from the source borehole.

In addition to the source hole data, a selection of observation hole results from the Phase A tracer tests were also analyzed. The selection came from the A-5 tests which used KI0025F03:P5 as a source in Structure #20. Observation results characterize connectivity between sources and observation points. Particularly important is the use of observation responses to calculate hydraulic diffusivity, η, which controls the speed of propagation of pressure disturbances in the flow system. Diffusivity, which is the ratio of transmissivity (or hydraulic conductivity) to storativity (or specific storage), is essential to defining the scale of investigation for the well test data.

The pressure data were extracted from the Äspö data base, and imported into FlowDim, a well-test analysis code described in further detail below. FlowDim provides type-curve matching analyses and also outputs pressure and derivative curves that are adjusted for buildup superposition effects, initial time and pressure uncertainty, and noise in the derivative data. The exported data were normalized with respect to rate using an Excel spreadsheet. The resulting pressure derivative data were converted to equivalent two-dimensional transmissivity and plotted with respect to time and distance from the pumping source.

The conversion of the pressure scale takes advantage of the use of the pressure derivative's relationship to transmissivity. Transmissivity is commonly calculated using the semi-log slope of the pressure data versus time. The pressure derivative is identically the semi-log slope, and one therefore estimate transmissivity as,

$$T = \frac{\rho g}{4 p t \, {}^{dp}\!/_{dt}}$$

where $t \, {}^{dp}\!/_{dt}$ defines the pressure derivative, and pressure and time in compatible units for the transmissivity.

The rescaling of time uses the equation for radius of investigation (Streltsova, 1988) which relates the distance of pressure propagation to the diffusivity, η, and time , or $r = 2\sqrt{\eta t}$. This scaling requires a knowledge of the diffusivity of pressure propagation, which is estimated from observation well responses. Typical diffusivity in major conductors ranges from about 1 to 20 m^2/s. As diffusivity is the ratio of transmissivity to storativity, high diffusivity values can result from either high conducting properties or low storative properties. Conversely, a highly conductive feature can have a lower diffusivity if it is also associated with a relatively large amount of porosity. Note also that this porosity need only to be connected to the flow path and therefore may not be entirely within the conductive flow path.

Because of the lack of constant-rate conditions, we focused on pressure recovery data for the current analysis.

2.2 Type Curve Matching Using FlowDim

Well test records provide information on the both the geometry and the hydraulic properties of the test interval. The analyses involve comparing the pressure or flow data to idealized dimensionless pressure against dimensionless time type curves.

FlowDim is a Golder Associates code for analyzing well tests. The code include both single hole and cross hole capabilities, as well as the ability to match cylindrical and generalized dimensional flow. The user may specify constant pressure, constant rate, or pressure recovery conditions. The code can also match composite dimension systems, that is, systems where the dimension changes with radial distance. FlowDim analyzes pressure recovery data by calculating type curves based on the superposition of a simplified pressure and flow history. For the current analysis, we assumed constant rate for the withdrawal. Uraiet (1980) showed that this was acceptable assumption for analyzing the pressure recovery from constant pressure tests.

FlowDim can be set for either hydrologic or petroleum units, however, the code calculates storage properties rather than skin. Hydrologic well test approaches generally ignore skin and calculate storativity from the time offset of the data, while petroleum approaches assume storage properties based on the porosity and fluid compressibilities and calculate the borehole skin.

Borehole skin is usually viewed as a drilling damage effect, where positive skin indicate permeability reduction by processes like mud invasion and negative skin indicates permeability enhancements by such processes as acidization. Skin may also arise from the natural heterogeneities of the conducting feature. A positive skin, for example, can reflect a low permeability zone immediately around the borehole, while a negative skin may indicate locally high permeability. Skin is therefore a useful concept for separating the average hydraulic properties from the local conditions near the borehole.

It is not possible to simultaneously calculate the storativity and the skin effect from a single-hole test. To obtain one property one must assume the other. For the analyses in this report we calculated skin (assuming storativity) and storativity (assuming no skin effect). We report storativity values based on an assumption of zero skin. Extremely low storage values often indicate the presence of a strong positive skin effect, while extremely high storage values may indicate the opposite. For the purpose of estimating skin we assumed that the hydraulic diffusivity was equal to 1, that is, the transmissivity and storativity are equal. Based on this assumption we then calculate a skin effect using the formula below.

The type curve match fits the pressure or flow data by translating the data along both the pressure (or flow) axis and the time axis. The transmissivity comes from the pressure axis match. The time axis match provides measures of skin, storativity, and well bore storage. Figure 1 shows a set of constant rate type curves. The well bore storage is indicated by the logarithmic unit slope portion of the beginning of the type curve. The well bore storage reflects the total compressibility of the borehole, the water in the borehole, and the test equipment. Well bore storage can also be calculated independently from the arithmetic slope and beginning of the well test. The family of type curves provides either storativity matches or skin matches according to the formulae below.

The dimension of the well test, as mentioned above, influences the logarithmic slope of the late time portion of a test in a pressure-time plot (for dimensions less than two) and in the derivative plot (for all dimensions). For source wells, FlowDim generates a separate family of type curves for each desired dimension. For observation wells, FlowDim calculates a single family of type curves that covers all dimensions.

Figure 1 shows a set of FlowDim type curves. The curves in Figure 1 are for dimension two flow, and a similar set of curves can be created for any other dimension. These type curves are similar to the familiar Theis type curves with the addition of wellbore storage and skin effects. The curves also plot the type curve using the ratio of dimensionless time and dimensionless wellbore storage rather than dimensionless time on the x-axis. Each curve represents a different value of dimensionless wellbore storage and skin, $C_D e^{2s}$, where e is the base of natural logarithm, s is the skin factor, C is the wellbore storage, and C_D is defined as:

$$C_D = C / 2\pi S r_w^2$$

where S is the storativity and r_w is the wellbore radius. The values of $C_D e^{2s}$ shown in Figure 1 are .03, 0.1, 0.3, 3, 10, 100, 10^3, 10^4, 10^6, 2×10^8, 10^{10}, 10^{15}, 10^{20}, and 10^{30}.

FlowDim determines wellbore storage from the time match. Given this value and assuming the skin is zero, the storativity is calculated directly from the $C_D e^{2s}$ parameter of the best-matching curve and the definition of dimensionless wellbore storage.

The $C_D e^{2s}$ curve-match value also allows us to calculate skin if we assume storativity. In this case skin is

$$s = 0.5 \ln[(C_D e^{2s})_{Match} / C_D]$$

where $C_De^{2s}{}_{Match}$ comes from the parameter of the best-fitting type curve, and C_D is calculated either from the time match or using a C value calculated from the straight-line, early data in an arithmetic plot of the pressure build-up.

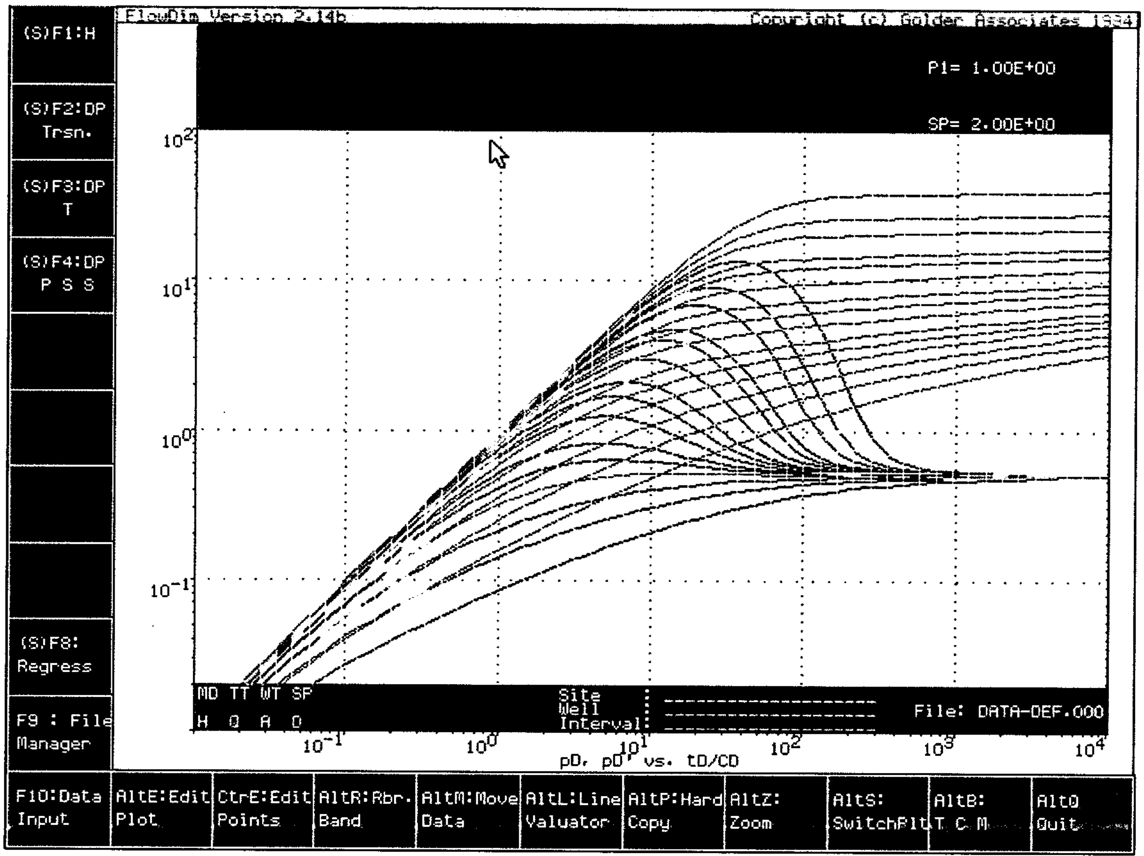

Figure 1. FlowDim Type Curves for Dimension-2 Flow

3. ANALYSES

3.1 Pumping Sources During the Tracer Test Phase

The best data for flow geometry analysis was obtained during the tracer testing phase as this phase of field work produced the longest pumping durations and hence provides information over the largest distance scales of any hydraulic testing in the block. Many tests were repeated on the same intervals during the Phase A, Phase B, and Phase C tests. For example, the Phase B and C tests only used the KI0023B:P6 sink, which had been tested previously during the Pre-tests (PT tests) and the Phase A tests. Although hydraulic properties can change with pumping, most of these changes are negligible or occur very close to the well, hence this study focused on only one longer term test for each pumping interval.

The source zone analyses look at a two basic plots — rate normalized derivative plots and transmissivity-distance plots.

Rate-normalized plots provide derivative data for all the selected source zones in a common plot. Pressure and derivative data are normalized to the rates to allow a direct comparison. The rate normalized plot allows a comparison of several tests. Similar behaviors can indicate that different tests are influencing the same feature. Conversely, different or inconsistent behaviors between tests can suggest that the tests are influencing separate conducting features.

The transmissivity-distance plot converts the derivative to an equivalent two-dimensional transmissivity on one axis and converts the time to distance using the radius of investigation formula discussed in Section 2. There are several words of caution with regards to this plot. First, composite behaviors, that is systems where the properties or geometries change with distance, influence the derivative behavior. For example, consider a composite system with a step change in transmissivity at some radius. If both shells of the composite are two-dimensional, i.e. cylindrical flow, this system will produce a pressure derivative with two flat portions, earlier for the inner shell and later for the outer shell, each portion having its own constant derivative value reflecting that shell's transmissivity. Separating these two flat portions is a transition period that reflects the composite boundary, and this transition period can last for a log cycle of time or longer depending on the transmissivity contrast. The transition period appears to be a change in property over some distance in the transmissivity-distance plot, however, it may in reality reflect a step change in values. Hence, it is best to treat the transition portions of the plot qualitatively and reserve quantitative interpretation for the time-distance periods where the derivative is stabilized to a particular shell's properties.

Figure 2 shows the normalized derivative curves for the source zones. The results come from the following tests:

KI0025F02:P5	Structure #20	Pre-Test 3
KI0023B:P4	Structure #13	Pre-Test 1
KI0025F03:P5	Structure #20	Test A-1 and A-5
KI0025F03:P4	Structure #21	Test A-2
KI0023B:P6	Structure #21	Test A-4

Derivative plots can be analysed by understanding that the transmissivity varies inversely with the derivative value, such that tests with higher derivative values have lower transmissivities. Changes in the derivative to higher or lower values indicate property changes to lower and higher transmissivities respectively.

Figure 2 clearly shows similarity of the derivative curves for Structure #20 zones. After a early drop in the derivative reflecting skin effects, each Structure #20 zone has a derivative that indicates a flow dimension between 1.5 and 2. The plot also shows that the important source zone, KI0023B:P6, that is usually assumed to be a Structure #21 intersection, clearly behaves as though it is part of Structure #20. After about 10 minutes, the derivative values steady fall indicating an increase in conductance. This falling derivative does not reach a stable slope — a negative half slope would indicate spherical flow. Rather, the concave downward form of the derivative suggests a constant pressure boundary or a transition to a higher conductivity region. After about ten hours, this transition region appears to stabilize, however, the derivative in this region is noisy and the tests do not run long enough to clearly show that dimension of the ultimate system that Structure #20 appears to connect with.

Figure 2 also shows derivative curves for Structure #13 and Structure #21 source zones. These zones have lower transmissivity than the Structure #20 zones. The two zones have very similar derivatives, both having a flat derivative at a value of about 2×10^{7} Pa-s/m^{3}, which relates to a transmissivity of about 5×10^{-8} m^2/s. Both derivatives have the same drop with time indicating transitions to regions that are more conducting. The curves are similar but offset in time suggesting that KI0025F03:P4 intersects the two-dimensional flow region and sees the higher conductance region before KI0023B:P4. This indicates that KI0025F03:P4 is closer to the higher conductivity region. In short, these two intervals appear to be seeing the same conductive geometry but from different points in the system. Curiously, the derivative values in these two intervals do not drop to the same level as those in the Structure #20 zones. If there was an ultimate connection of the Structure #13 and #21 zones to the same high conductivity region as the Structure #20 zones, the derivative values would be expected to converge.

The second plot for the source zones is shown in Figure 3. This is the transmissivity-distance plot. It is also in log-log coordinates, and is essentially a mirror image of the derivative plots. The plots give distance assuming a constant diffusivity of 5 m^2/s, which is an approximate value derived from the interference responses from KI0025F03 to KI0023B and KI025F02. The diffusivity values to more distance points, KI0025F and KA2563A are larger, as discussed below, hence the distance values are likely to be underestimates. The uncertainty in diffusivity is not as severe as one might initially think, because distance scales as the square root of diffusivity. Hence, for example, a factor of nine uncertainty in diffusivity translates into a factor of three uncertainty in distance.

The transmissivity distance plot shows that the transition period from the local transmissivity of Structure #20 to the feature or system that is acting as a constant pressure boundary occurs at about 100 meters. If we use a higher diffusivity, such as that derived from the more distance interference tests (about 30 m^2/s) the distance to the boundary increase to about 250 meters. One way to assess the appropriate distance is to look for geologic features lying between 100 and 300 meters, and see if there are good candidates for this boundary.

The source zone tests do not indicate a clear spherical flow since there is no clear stabilization to a particular derivative slope. However, the derivative behavior, after about 10 minutes, does indicate possible higher dimension flow albeit with spatially varying properties. Nonetheless, a very important point in this analysis is that the tracer injection points, and hence the tracer pathways are all less than 100-m in length, hence *the flow dimension that is relevant to tracer test interpretation is a dimension of two or less.*

3.2 Pressure Interference Results

Pressure interference data were analyzed for the A5 tracer test. The focus was primarily on Structure #20 zones, but nearby pathways were also included. The pressure responses are plotted in Figure 4.

There are a few key features to the interference responses. First, the Structure #20 intervals, including KI0023B:P6 show an obvious similarity of behavior. This indicates that these are potentially part of a common flow feature. By comparison, other nearby zones that are plotted clearly have different and delayed responses, and appear to parts of different, though possibly connected, conductors. *If the fracture network were one single spherical flow system, all interference responses should be similar with distance regardless of structure and should have slopes appropriate to spherical behavior.* The structures are clearly having a dominating effect on the interference responses.

Another key point is the variation of diffusivity within Structure #20. The diffusivity values for the interference responses are given below.

Observation Zone	Diffusivity, η, m^2/s
KI0025F	34.8
KI0025F02	4.7
KA2563A	38.6
KI0023B:P6	1.6
0025F02-6	12.5
0025F02-3	1.5
0023B:P4	2.7

Of key note is the relative lower diffusivity values for the closest interference points (KI0025F02 and KI0023B) of 4.7 and 1.5 m^2/s respectively and the higher diffusivity values for KI0025F and KA2563 (35 and 39 m^2/s respectively). There could be a decrease in transmissivity between the source and the further observation points, but one does not see this in the form of the derivative. Rather, the lower diffusivity values could reflect higher storage and higher porosity near the core of the TRUE Block Scale tracer activities. This also indicates that Structure #20 has lower porosity further away. This suggestion could be corroborated by reviewing the geologic descriptions of these intervals and comparing the degree of alteration and damage.

3.3 Flow Dimension Behaviors in Other Structures

Long term transient tests have only been performed for the design and execution of tracer tests. Hence the selection of source zones has emphasized Structure #20 and nearby structures. There are no longer term tests on other Structures, such as Structures #5, #6, #7, #19, or #10. These data are not critical to the tracer testing, however, they are of interest to the overall hydrostructural model or to any future work in the TRUE Block Scale volume that would use these structures.

The buildup testing in KI0025F02 (Adams, et al, 1999) provides a look at these other structures. The tests are not ideal for this purpose as the durations are relatively short and KI0025F02 was open during the testing except for the pumping interval, such that there is a possibility that the borehole itself was acting as a constant pressure boundary.

Figure 5 shows the normalized derivative plots for KI0025F02 hydraulic testing. For this plot the derivative is given as equivalent two-dimensional transmissivity for direct reading of hydraulic properties.

Figure 5 shows a breakthrough to higher conductance regions in all tests. The transmissivity of the higher conductance region is not the same for each test. It is therefore unclear whether they are all connecting to the same ultimate boundary.

The later time behavior may be interpretable as spherical flow for some tests. Structures #6, #7, and #10 clearly have later time behaviors with the distinctive negative half-slope of spherical flow. For Structures #6 and #7, the proximity to the Structure #5 and other related structures might be a hypothesis worth considering for the spherical flow effect. In this case, Structure #5 may be part of a thick high conductivity zone, and spherical flow may be a partial penetration effect of the conductors connecting Structures #6 and #7 to that region.

Conspicuous in the derivative is also the lack of closed boundary behaviors. All of the pressure derivatives ultimately see constant pressure boundaries or possibly higher-dimension, spherical flow. There is no evidence in the data that there are closed compartments, however, there may be a degree of isolation of the structures from one another.

Structures #19 and #20 have clear two-dimensional flow regions, as do Structure #23 and possibly #22. Again, the plotting of these derivatives as transmissivity provides a quantification of their flow properties.

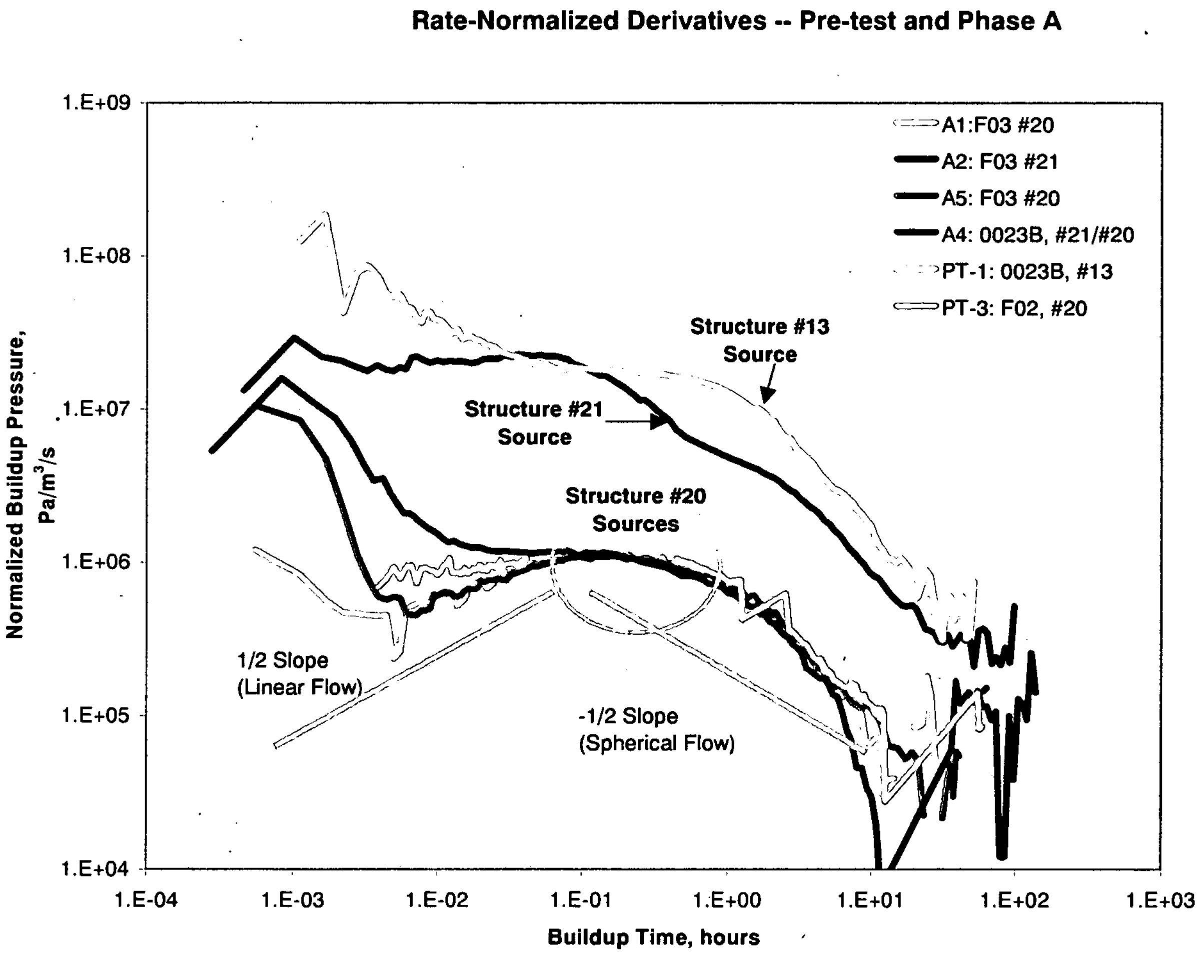

Figure 2. Rate Normalized Derivatives For Selected Source Zones From the Tracer Testing Phase

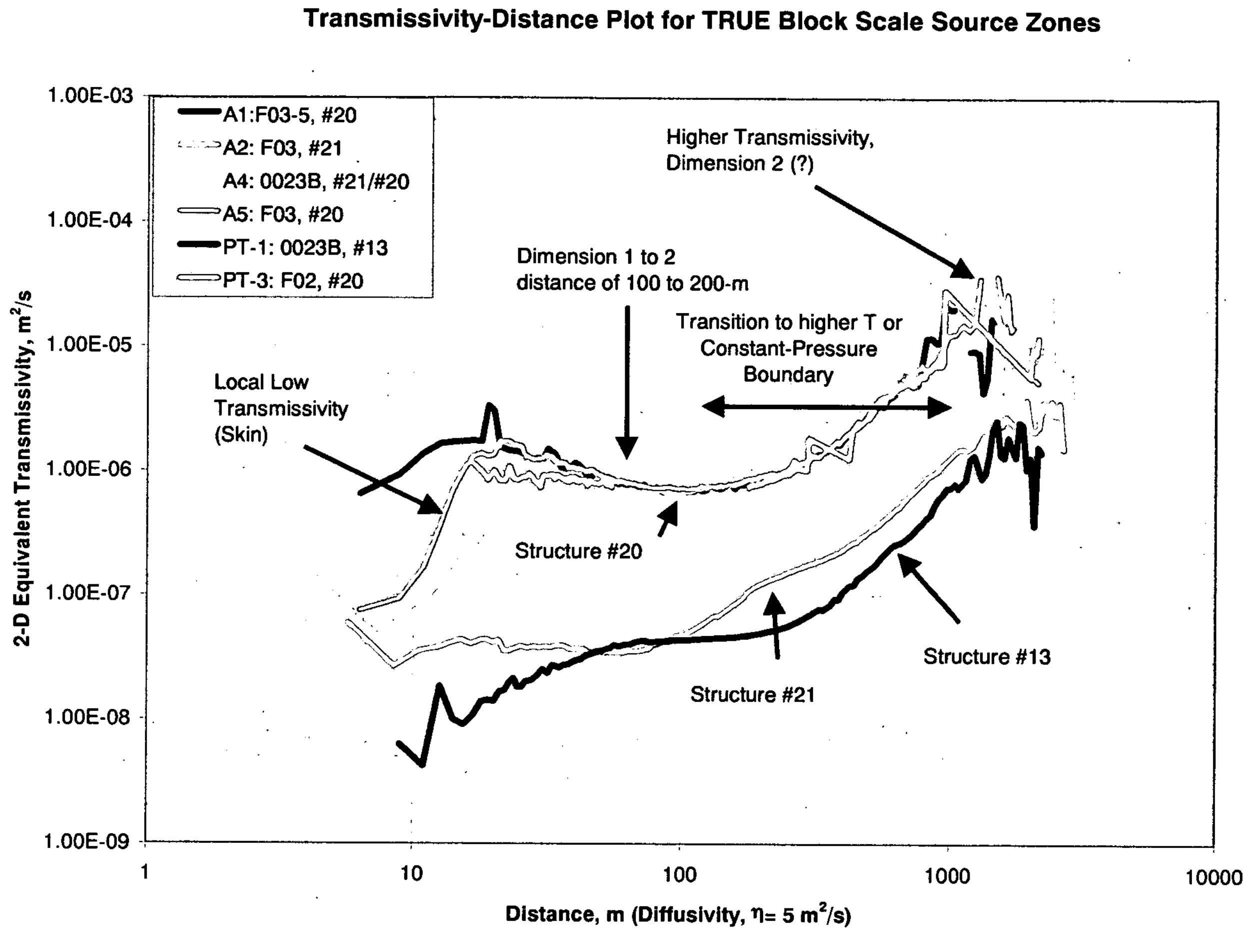

Figure 3. Transmissivity Versus Distance For Pressure Derivatives From Selected Tracer Phase Source Zones

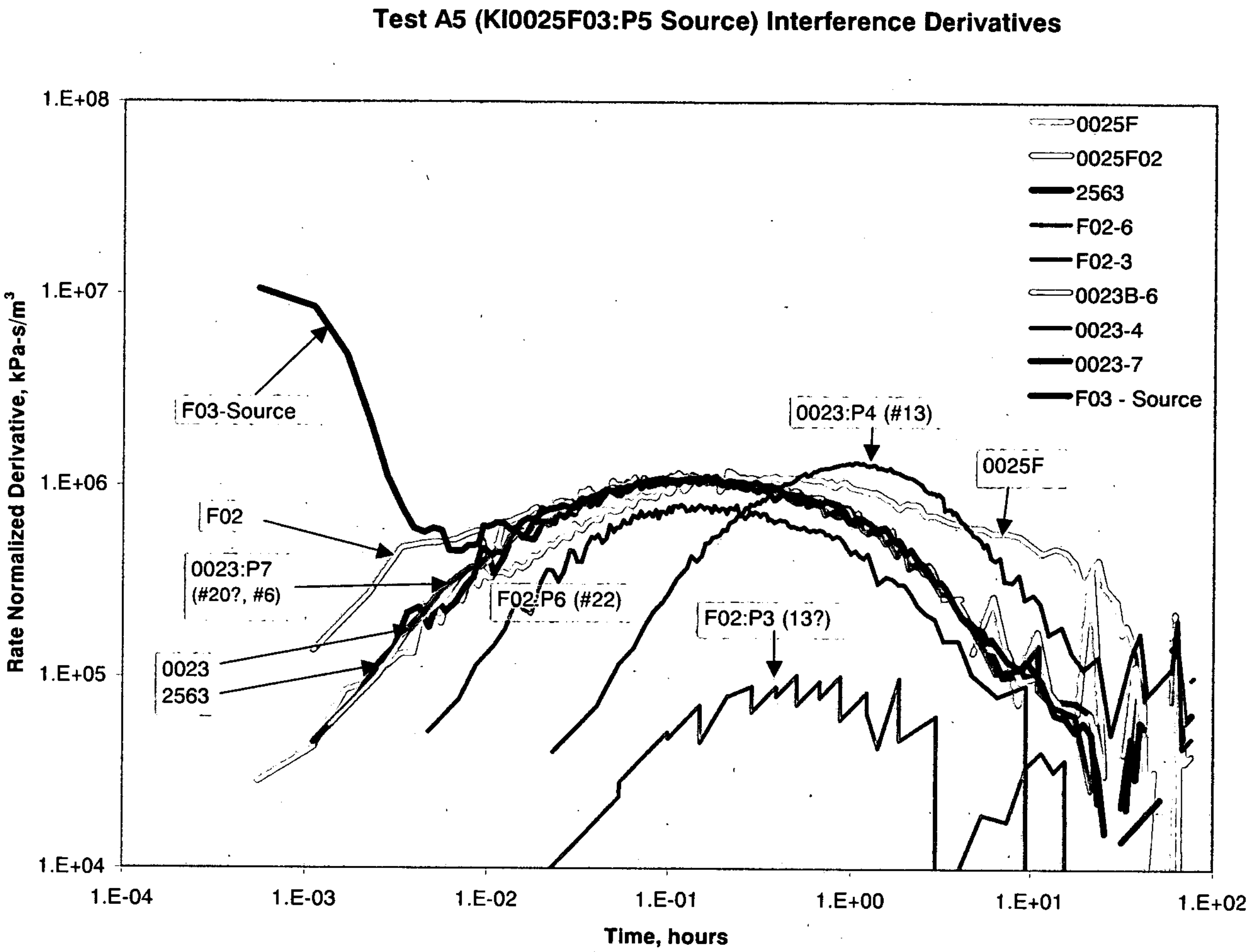

Figure 4. Derivative Plots of Selected Pressure Interferences From the Phase A Tracer Test

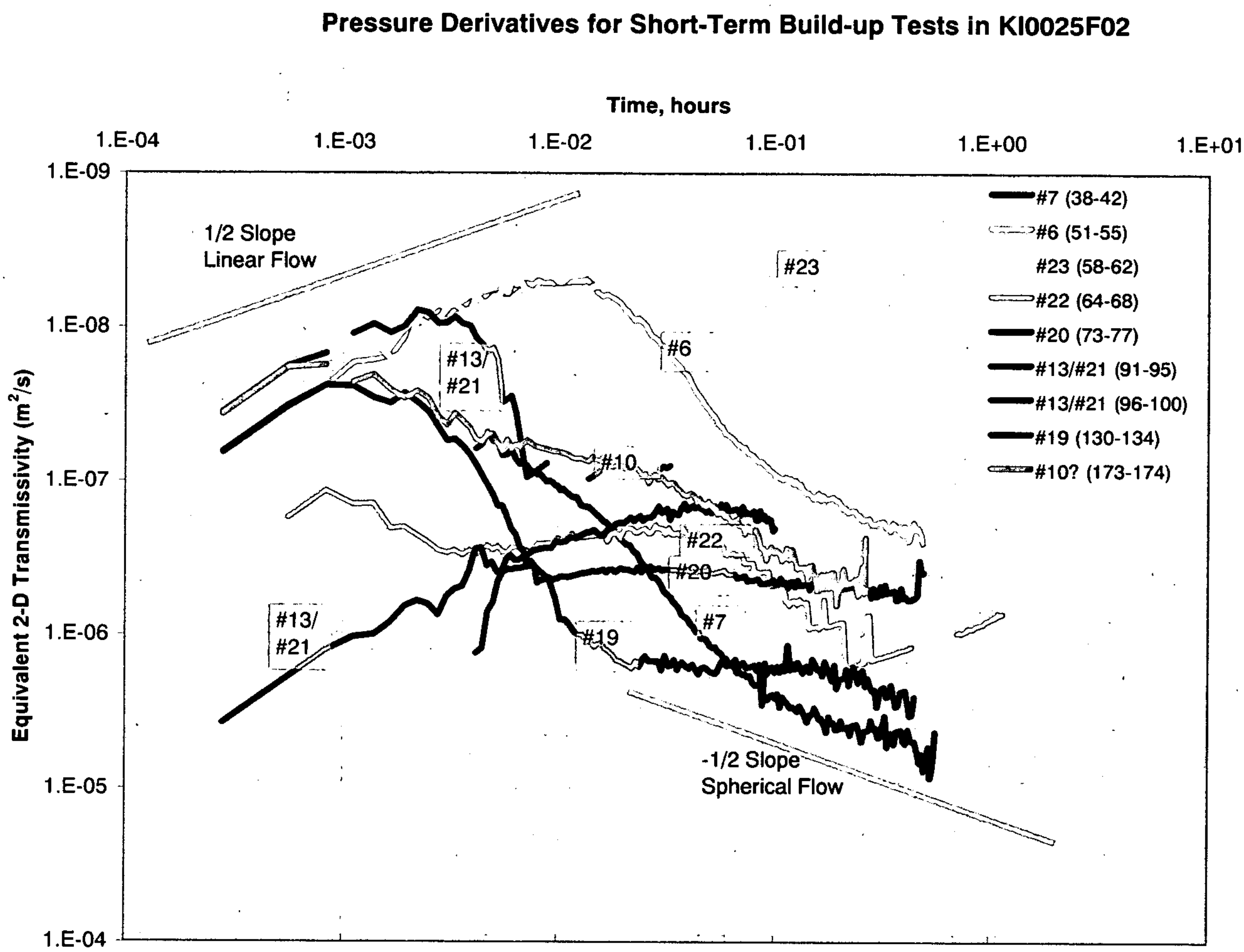

Figure 5. Pressure Derivatives For Short Build-Up Tests From KI0025F02

4. SUMMARY AND CONCLUSIONS

This report has presented generalized dimension analyses of pressure derivative plots for hydraulic tests in the TRUE Block Scale volume. These plots allows the following conclusions:

- All of the intervals ultimately see constant pressure boundaries or higher dimension flow regions indicating that all of the structures have connection to the larger flow systems of the laboratory.
- For Structure #20 the distance to these boundaries is between 100-m and 250-m, the uncertainty being dictated by the range of diffusivity values.
- The region of Structure #20 around KI0025F03 and adjacent holes has a lower diffusivity than more distance regions of the structure around KI0025F and KA2563. This lower diffusivity may indicate a higher porosity region Structure #20 in the core experiment area.
- The region of most interest for tracer testing lies within a portion of Structure #20 that is characterized by Dimension 2 flow or lower.
- Spherical flow may appear in the later portions of tests for Structures #6, #7, and #10.
- Geometric analyses using pressure derivatives are a useful tool for corroborating the hydrostructural models

Based on these analyses, we can make the following recommendations.

- As part of future work on the TRUE Block Scale volume, additional long pumping tests should be performed using other structures as sources, particularly if those structures might be the focus of future tracer testing.
- Modeling work to include matching of transient well-test data would provide an additional check of the numerical models, particularly with respect to the boundary connections, as the boundary connections may strongly influence the observed pressure derivatives.
- Pressure derivative data analysis with a view to the hydrostructural model should be an on-going activity in the iterative characterization of block-scale volumes.

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APPNEIX B

TRANSPORT MODELING USING UPDATED MICROSTRUCTURAL MODELS

ÄSPÖ HARD ROCK LABORATORY

TECHNICAL NOTE

TRUE BLOCK SCALE EXPERIMENT

TRANSPORT MODELING USING UPDATED MICROSTRUCTURAL MODELS

Ver 1.0

WILLIAM DERSHOWITZ
KATE KLISE

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1. INTRODUCTION

JNC is responsible for discrete fracture network and channel network transport simulation within the Block Scale Continuation Project. During H-14, Golder implemented a detailed microstructural model for fractures which make up the TRUE-BS rock block. This model considers the individual properties of each immobile zone, including breccia, gouge, cataclasite, mylonite, and altered granite. During H-14, Golder carried out simulations for the major TRUE-BS transport experiments, using the updated microstructural model. Results were compared against those obtained using the calibrated micro-structural model of H-12.

In the TRUE-BS rock block, transport pathways are defined by fractures, faults, and fracture intersections. The key transport processes are:

- advection
- sorption on mineral surfaces,
- diffusion/sorption in geological materials,
- diffusion into stagnant pore volumes and
- immobilization due to precipitation and incorporation in mineral lattices.

These processes are of different importance in experiments and in safety assessment. Although advection and sorption on mineral surfaces are primary processes in experiments, matrix sorption and matrix diffusion are the primary processes of concern for repository performance assessment.

2. MICROSTRUCTURAL AND HYDROSTRUCTURAL MODELS

The updated microstructural model for the fractures of the TRUE-BS rock block was developed by Dershowitz et al. (2002). The model is illustrated in Figure 2-1 and Figure 2-2, and Tables 2-1 through 2-3.

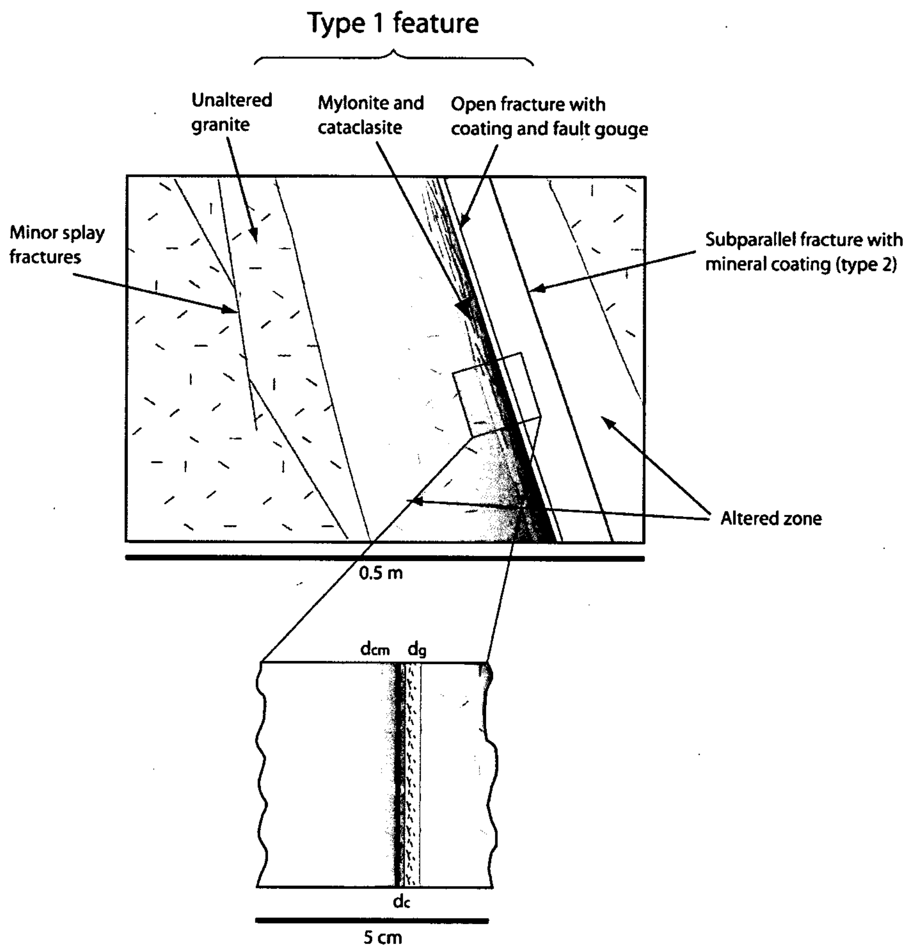

Figure 2-1. Updated Microstructural Model, Shear Fracture (after Dershowitz et al., 2003)

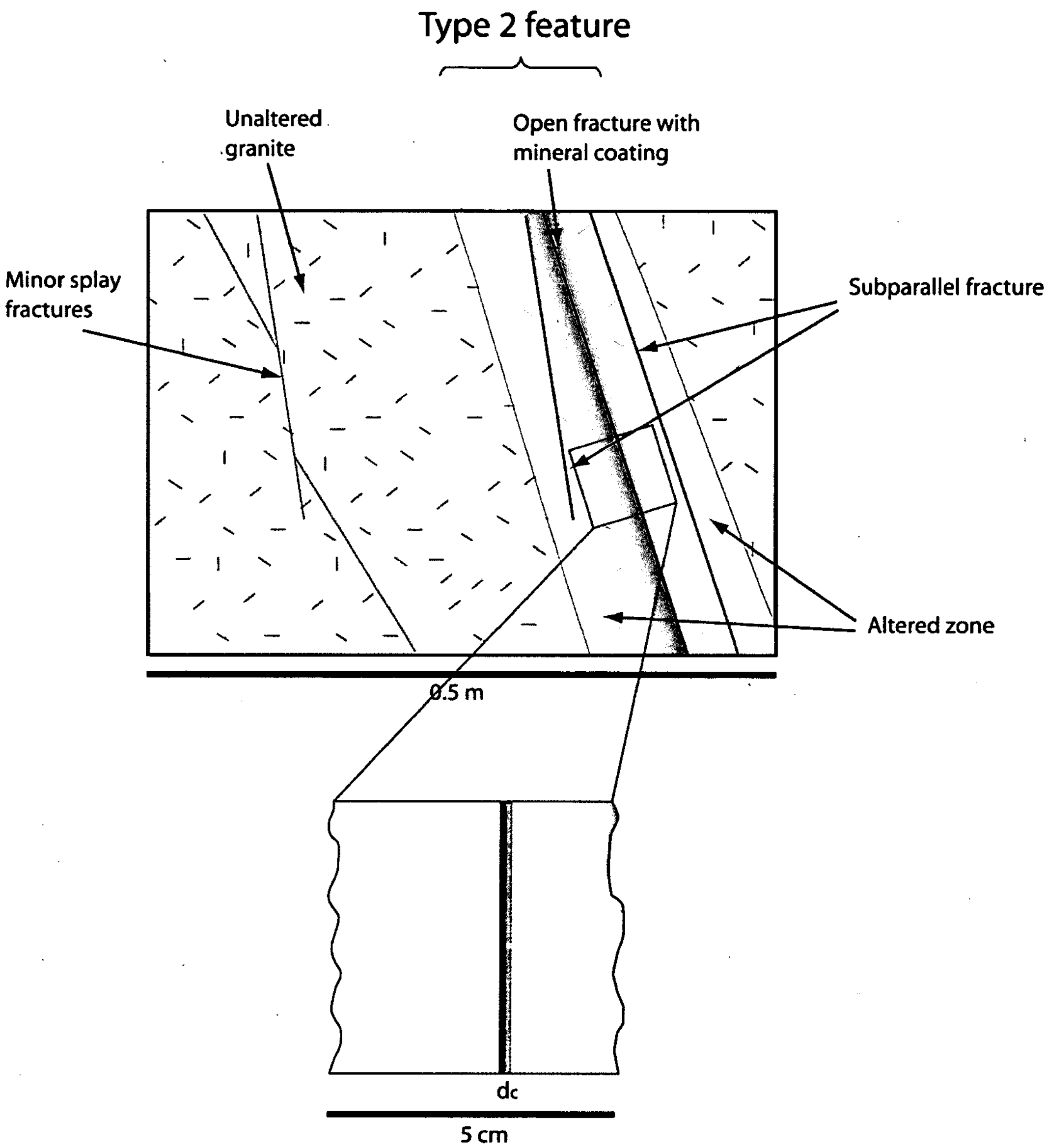

Figure 2-2. Updated Microstructural Model, Non-Shear Fracture (after Dershowitz et al., 2003)

Table 2-1. Properties of 100-m Scale Geological Structure Type 1 (Fault)

Rock type	Extent (cm)	Porosity (%)	Formation factor (-)
Intact wall rock	-	0.3	7.3E-5
Altered zone	20	0.6	2.2E-4
Cataclasite/Mylonite d_{cm}	2	1	4.9E-4
Fault gouge d_g	0.5	20	5.6E-2
Fracture coating d_c	0.05	5	6.2E-3

Table 2-2. Properties of 100-m Scale Geological Structure Type 2 (Non-fault)

Rock type	Extent (cm)	Porosity (%)	Formation factor (-)
Intact wall rock	-	0.3	7.3E-5
Altered zone	10	0.6	2.2E-4
Fracture coating d_c	0.05	5	6.2E-3

Table 2-3. Kd for the different materials in contact with the different types of groundwater

TRUE Block Scale groundwater:

	C (mg/l)	C (M)	K_c	Fracture Coating CEC=30 μeq/g K_d (m³/kg)	Fault Gouge CEC=90 μeq/g K_d (m³/kg)	Cataclasite CEC=8.5 μeq/g K_d (m³/kg)	Altered Zone CEC=11 μeq/g K_d (m³/kg)	Intact wall rock CEC=5.7 μeq/g K_d (m³/kg)
Na^+	2065	9.0E-2	0.1[A]	3.7E-5	1.1E-4	1.1E-5	1.4E-5	7.1E-6
Mg^{2+}	42	1.7E-3	11[B]	2.5E-3	7.8E-3	7.4E-4	9.7E-4	4.9E-4
K^+	8	2.1E-4	66[B]	9.4E-4	2.9E-3	2.7E-4	3.6E-4	1.8E-4
Ca^{2+}	1485	3.7E-2	1	2.3E-4	7.1E-4	6.7E-5	8.8E-5	4.4E-5
Rb^+	0.03	3.5E-7	2.00E+03[A]	5.2E-3	1.6E-2	1.5E-3	2.0E-3	1.0E-3
Sr^{2+}	24	2.7E-4	1[A]	2.3E-4	7.1E-4	6.7E-5	8.8E-5	4.4E-5
Cs^+	0.002	1.8E-8	2.00E+05[A]	5.2E-2	1.6E-1	1.5E-2	2.0E-2	1.0E-2
Ba^{2+}	0.06	4.3E-7	20[A]	4.6E-3	1.4E-2	1.3E-3	1.8E-3	8.8E-4

Fresh groundwater:

	C (mg/l)	C (M)	K_c	Fracture Coating CEC=30 μeq/g K_d (m³/kg)	Fault Gouge CEC=90 μeq/g K_d (m³/kg)	Cataclasite CEC=8.5 □eq/g K_d (m³/kg)	Altered Zone CEC=11 μeq/g K_d (m³/kg)	Intact wall rock CEC=5.7 μeq/g K_d (m³/kg)
Na^+	21.1	9.2E-4	0.1[A]	1.9E-4	5.9E-4	5.6E-5	7.3E-5	3.7E-5
Mg^{2+}	3.2	1.3E-4	11[B]	6.9E-2	2.1E-1	2.0E-2	2.6E-2	1.3E-2
K^+	1.7	4.4E-5	66[B]	4.9E-3	1.5E-2	1.4E-3	1.9E-3	9.5E-4
Ca^{2+}	34.5	8.6E-4	1	6.2E-3	1.9E-2	1.8E-3	2.4E-3	1.2E-3
Rb^+	0.03	3.4E-7	2.00E+03[A]	2.7E-2	8.4E-2	7.9E-3	1.0E-2	5.2E-3
Sr^{2+}	0.6	6.4E-6	1[A]	6.2E-3	1.9E-2	1.8E-3	2.4E-3	1.2E-3
Cs^+	0.002	1.8E-8	2.00E+05[A]	2.7E-1	8.4E-1	7.9E-2	1.0E-1	5.2E-2
Ba^{2+}	0.06	4.3E-7	20[A]	1.2E-1	3.8E-1	3.6E-2	4.8E-2	2.4E-2

Brine groundwater:

	C (mg/l)	C (M)	K_c	Fracture Coating CEC=30 μeq/g K_d (m³/kg)	Fault Gouge CEC=90 μeq/g K_d (m³/kg)	Cataclasite CEC=8.5 μeq/g K_d (m³/kg)	Altered Zone CEC=11 μeq/g K_d (m³/kg)	Intact wall rock CEC=5.7 μeq/g K_d (m³/kg)
Na^+	8500	3.6E-1	0.1[A]	1.2E-5	3.8E-5	3.5E-6	4.7E-6	2.3E-6
Mg^{2+}	2.1	8.7E-5	11[B]	2.8E-4	8.6E-4	8.1E-5	1.1E-4	5.3E-5
K^+	46	1.2E-3	66[B]	3.1E-4	9.7E-4	9.1E-5	1.2E-4	6.0E-5
Ca^{2+}	19300	4.8E-1	1	2.5E-5	7.8E-5	7.3E-6	9.7E-6	4.8E-6
Rb^+	0.03	3.4E-7	2.00E+03[A]	1.7E-3	5.3E-3	5.0E-4	6.6E-4	3.3E-4
Sr^{2+}	313	3.6E-3	1[A]	2.5E-5	7.8E-5	7.3E-6	9.7E-6	4.8E-6
Cs^+	0.002	1.8E-8	2.00E+05[A]	1.7E-2	5.3E-2	5.0E-3	6.6E-3	3.3E-3
Ba^{2+}	0.06	4.3E-7	20[A]	5.0E-4	1.6E-3	1.5E-4	1.9E-4	9.7E-5

A: Value from TRUE-1 investigation of altered Äspö diorite, sampled at KXTT2 15.1m (Byegård et al. 1998)
B: Value from investigation of Finnsjön granodiorite (Byegård et al. 1995)

The deterministic structures of the TRUE-BS hydrostructural model are illustrated in Figure 2-3. The hydraulic parameters of those structures are provided in Table 2-4.

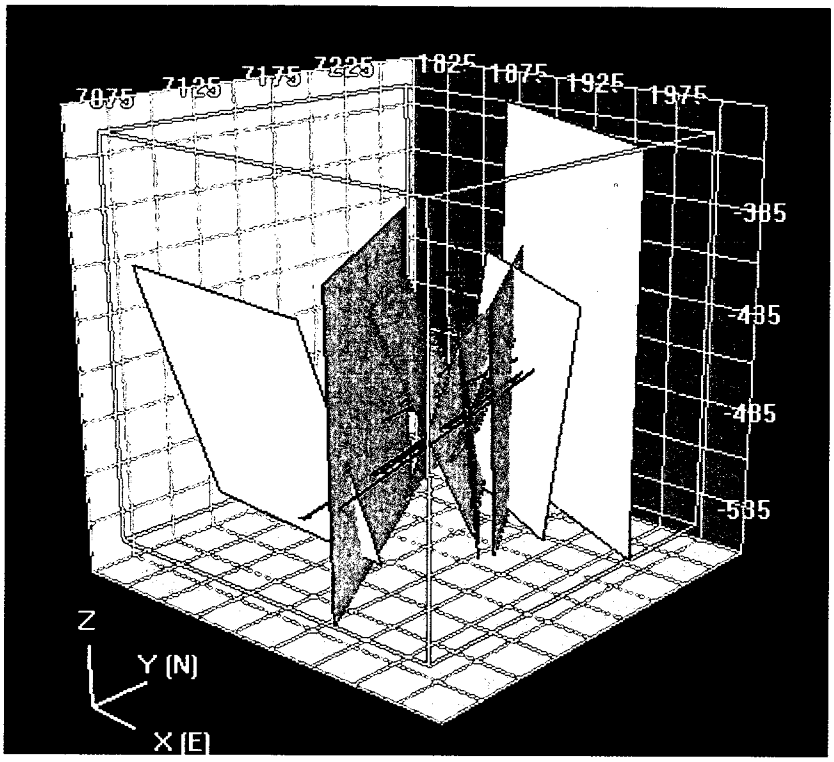

Figure 2-3. TRUE-BS Hydrostructural Framework, Deterministic Structures (after Dershowitz et al., 2003)

Table 2-4. Deterministic Structures, TRUE-BS Hydrostructural Model

Structure ID	Transmissivity (m2/s)	Storativity	Transport Aperture (m)	Geologic Structure Type
5	4.020E-07	3.170E-04	2.917E-04	1
6	1.910E-07	2.185E-04	2.010E-04	2
7	9.760E-08	1.562E-04	1.437E-04	2
10	2.980E-08	8.631E-05	7.941E-05	1
13	1.380E-08	5.874E-05	5.404E-05	1
19	1.020E-07	1.597E-04	1.469E-04	1
20	1.430E-07	1.891E-04	1.740E-04	1
21	6.020E-08	1.227E-04	1.129E-04	2
22	2.190E-08	7.399E-05	6.807E-05	2
23	1.660E-07	2.037E-04	1.874E-04	2
24	8.510E-08	1.459E-04	1.342E-04	2

3. TRANSPORT SIMULATIONS

Most transport simulations for the TRUE-BS project were carried out using calibrated transport properties. While this was useful for deriving effective transport properties for the fractures tested, it did not demonstrate understanding of the transport pathways.

Simulations carried out during H-14 were true predictive simulations. The transport properties used were taken directly from the microstructural model of Dershowitz et al. (2003). No conditioning or calibration of transport properties was carried out.

Three sets of transport experiments were simulated, representing the TRUE-Block Scale Phase C experiments C1, C2, and C3.

3.1 Tracer Tests

Tracer tests performed at the TRUE Block Scale site are summarized in Tables 3-1 through 3-4, based on Andersson et al. (2002). Phase C tracer tests included injections of radioactive sorbing tracers in three different source locations (Andersson et al, 2001c).

Test C-3 was a radially converging tracer test since the induced flow rate in the injection section was significantly higher than the pressure of essential passive tracer injection. Tests C-1 and C-2 were unequal strength dipole tracer tests, since a slight excess pressure was applied at the injection locations.

Table 3-1. Tracer Test Geometry (after Andersson et al., 2002)

Test #	Flow path	Structures	Flow geometry	Inj. flow (ml/min)	Pump flow (ml/min)	Tracer	Distance
C-1	KI0025F03:P5 – KI0023B:P6	20, 21	Forced injection	45	1950	$^{82}Br^-$, $^{24}Na^+$, $^{42}K^+$, $^{47}Ca^{2+}$, $^{86}Rb^+$, $^{134}Cs^+$, Uranine	14 (16)
C-2	KI0025F03:P7 – KI0023B:P6	23, 20, 21	Forced injection	10	1950	$^{186}ReO_4^-$, $^{47}Ca^{2+}$, $^{131}Ba^{2+}$, $^{137}Cs^+$ Naphtionate	17 (97)
C-3	KI0025F02:P3 – KI0023B:P6	21	Passive injection	1.8	1950	HTO, $^{22}Na^+$, $^{85}Sr^{2+}$, $^{83}Rb^+$, $^{133}Ba^{2+}$	33 (33)
C-4	KI0025F03:P5 – KI0023B:P6	20, 21	Forced injection	45	1950	$^{82}Br^-$, $^{131}I^-$, $^{47}Ca^{2+}$, $^{131}Ba^{2+}$, $^{54}Mn^{2+}$, $^{57}Co^{2+}$, $^{65}Zn^{2+}$	14 (16)

Table 3-2. Tracer Injection Data For Test C-1 (after Andersson et al., 2002)

Borehole section	Section Volume (ml)	Inj. rate flow meter (ml/min)	Inj. rate dil.curve (ml/min)	Tracer	$t_{1/2}$	Max inj. conc. (Bq/kg)	Total Inj. amount (MBq)
KI00F03: P5	7214	45	25	$^{82}Br^-$	35.3 h	$1.82 \cdot 10^7$	138
				$^{24}Na^+$	15.0 h	$2.14 \cdot 10^6$	15.6
				$^{42}K^+$	12.4 h	$2.79 \cdot 10^7$	229
				$^{47}Ca^{2+}$	4.5 d	$1.64 \cdot 10^6$	10.7
				$^{86}Rb^+$	18.7 d	$2.12 \cdot 10^6$	13.3
				$^{134}Cs^+$	2.1 y	$6.21 \cdot 10^5$	7.79

Table 3-3. Tracer Injection Data For Test C-2 (after Andersson et al., 2002)

Borehole section	Section Volume (ml)	Inj. rate flow meter (ml/min)	Inj. rate dil.curve (ml/min)	Tracer	$t_{1/2}$ (d)	Max inj. conc. (Bq/kg)	Total Inj. amount (MBq)
KI00F03:P7	4978	10	8.5	$^{186}ReO_4^-$	3.8 d	$3.80 \cdot 10^7$	171
				$^{47}Ca^{2+}$	4.5 d	$1.45 \cdot 10^7$	56.4
				$^{131}Ba^{2+}$	11.5 d	$5.74 \cdot 10^6$	25.7
				$^{137}Cs^+$	30.2 y	$4.46 \cdot 10^6$	23.5

Table 3-4. Tracer Injection Data For Test C-3 (after Andersson et al., 2002)

Borehole section	Section Volume (ml)	Inj. rate flow meter (ml/min)	Inj. rate dil.curve (ml/min)	Tracer	$t_{1/2}$ (d)	Max inj. conc. (Bq/kg)	Total Inj. amount (MBq)
KI00F02:P3	8424	-	1.8	HTO	12.3 y	$2.12 \cdot 10^7$	244
				$^{22}Na^+$	2.6 y	$2.68 \cdot 10^6$	21.6
				$^{85}Sr^{2+}$	64.9 d	$2.74 \cdot 10^6$	22.1
				$^{83}Rb^+$	86.2 d	$5.12 \cdot 10^6$	45.9
				$^{133}Ba^{2+}$	10.5 y	$2.61 \cdot 10^4$	0.55

3.2 Simulations

Simulations of tracer tests C-1, C-2, and C-3 were carried out using FracMan/PAWorks (Dershowitz et al., 2002), with the Laplace Transform Galerkin transport solution. This solution discretized the fractures as pipes, and directly applied all of the immobile zone transport properties based on the microstructural model as described in Chapter 2 above.

The parameters used in the simulations are summarized in Tables 3-5, 3-6, and 3-7.

Simulation results are provided in Figures 3-1 through 3-30. In general, the simulations carried out with the updated microstructural model indicate greater retention than was observed in the measured breakthrough curves. However, the results as predictive simulations are surprisingly good. This provides initial indications of the usefulness of the microstructural model.

Table 3-5. Parameters for C-1 Tracer Simulations

C1	Calibration Parameters	Task 6C Parameters	reference	
Fracture on Structure 20	Transmissivity	1.43E-07	Task 6C report	
	Fracture Aperture (m)	1.89E-04	Task 6C report	
	Transpot Aperture (m)	2.36E-05	Task 6C report	2.36E-03
	Pipe Width (m) -- MAX	0.1	max 10cm	0.1
	Pipe Area (m^2)	2.36E-06	e_t*width	2.36E-04
	Advective velocity (m/yr)	6816.3	phaseCrep	
	Advective velocity as calculated freom 1/5000 of the pumping rate (m/yr)	91596.75		15000
	Path Length (m)	17.9	from geometry	
	Dispersion (m)	1.79	max 10%	
Fracture Coating	Thickness (m)	0.0005	Task 6C report	
	Porosity (%)	5.0%	Task 6C report	
	Pipe Area	0.179	V_{void}/thickness	
Fault Gouge-Cataclasite/Mylonite (immobile zone)	Thickness (m)	0.025	Task 6C report	
	Porosity (%)	4.8%	Task 6C report	
	Pipe Area	0.17184	V_{void}/thickness	
	Tortuosity	0.09526	Task 6C report	
Altered Rock	Thickness (m)	0.2	Task 6C report	
	Porosity (%)	1.0%	Task 6C report	
	Pipe Area	0.0358	V_{void}/thickness	
Intact Rock	Thickness (m)	10		
	Porosity (%)	0.3%	Task 6C report	
	Pipe Area	0.01074	V_{void}/thickness	
Retardation Factor	*R = 1+Kd*(density/n)*	Br	Kd, Task 6C report	
	Fracture Coating	1	0	
	Fault Gouge/Cataclasite	1	0	
	Altered Zone	1	0	
	Intact wall rock	1	0	
		Na^+	Kd, Task 6C report	
	Fracture Coating	3.0	3.70E-05	
	Fault Gouge/Cataclasite	2.8	3.08E-05	
	Altered Zone	4.9	1.40E-05	
	Intact wall rock	7.5	7.10E-06	
		K^+	Kd, Task 6C report	
	Fracture Coating	52.8	9.40E-04	
	Fault Gouge/Cataclasite	46.7	7.96E-04	
	Altered Zone	100.2	3.60E-04	
	Intact wall rock	166.3	1.80E-04	
		Ca^{2+}	Kd, Task 6C report	
	Fracture Coating	13.7	2.30E-04	
	Fault Gouge/Cataclasite	12.2	1.96E-04	
	Altered Zone	25.2	8.80E-05	
	Intact wall rock	41.4	4.40E-05	
		Rb^+	Kd, Task 6C report	
	Fracture Coating	287.5	5.20E-03	
	Fault Gouge/Cataclasite	253.5	4.40E-03	
	Altered Zone	552.0	2.00E-03	
	Intact wall rock	919.3	1.00E-03	
		Cs^+	Kd, Task 6C report	
	Fracture Coating	2866.2	5.20E-02	
	Fault Gouge/Cataclasite	2526.4	4.40E-02	
	Altered Zone	5511.0	2.00E-02	
	Intact wall rock	9184.3	1.00E-02	

	Calibration Parameters	Process Discrimination Parameters	reference	
	Transmissivity	9.60E-07	true bs DFN	
	Fracture Aperture (m)	1.96E-03	true bs DFN	
	Transpot Aperture (m)	5.88E-04	DFN calibration	
	Pipe Width (m) -- MAX	0.1	max 10cm	
	Pipe Area (m^2)	5.88E-05	e_t*width	
	Advective velocity (m/yr)	18000	calibraiton to initial breakthrou	
	Path Length (m)	17.9	from geometry	
	Dispersion (m)	1.5	max 10%	8.4%
Breccia	Thickness (m)	0.003	0.003m to 0.0001m	
	Porosity (%)	5.50%	40% - 5%	
	Pipe Area	0.1969	V_{void}/thickness	
Altered Rock	Thickness (m)	0.02	0.02m to 0.005m	
	Porosity (%)	2%	2% - 0.5%	
	Pipe Area	0.0716	V_{void}/thickness	
Intact Rock	Thickness (m)	10		
	Porosity (%)	0.10%	<0.5%	
	Pipe Area	0.00358	V_{void}/thickness	
	R = 1+Kd(density/n)*	Br	Kd, Process Discrimination St	
	Breccia	1	0	
	Altered Zone	1	0	
	Intact wall rock	1	0	
		Na^+	Kd, Process Dis	Lab Kd
	Breccia	2.2	2.38E-05	1.40E-06
	Altered Zone	4.3	2.38E-05	
	Intact wall rock	66.6	2.38E-05	
#REF!				
		K^+	Kd, Process Dis	Lab Kd
	Breccia	23.0	4.40E-04	2.00E-04
	Altered Zone	61.6	4.40E-04	
	Intact wall rock	1213.2	4.40E-04	
#REF!		Ca^{2+}	Kd, Process Dis	Lab Kd
	Breccia	8.8	1.56E-04	5.20E-06
	Altered Zone	22.5	1.56E-04	
	Intact wall rock	430.8	1.56E-04	
		Rb^+	Kd, Task 6C rep	Lab Kd
	Breccia	121.2	2.40E-03	4.00E-04
	Altered Zone	331.6	2.40E-03	
	Intact wall rock	6613.0	2.40E-03	
		Cs^+	Kd, Task 6C rep	Lab Kd
	Breccia	141.3	2.80E-03	8.00E-04
	Altered Zone	386.7	2.80E-03	
	Intact wall rock	7715.0	2.80E-03	

Table 3-6. Parameters for C-2 Tracer Simulations

C2	Calibration Parameters	Task 6C Parameters	reference			Calibration Parameters	Process Discrimination Parameters	reference	
Fracture on Structure 23	Transmissivity	1.66E-07	Task 6C report			Transmissivity	6.78E-09	true bs DFN	
	Fracture Aperture (m)	2.04E-04	Task 6C report			Fracture Aperture (m)	1.65E-04	true bs DFN	
	Transpot Aperture (m)	2.55E-05	Task 6C report	2.55E-04		Transpot Aperture (m)	4.94E-05	DFN calibration	
	Pipe Width (m) -- MAX	0.1	max 10cm	0.1		Pipe Width (m) -- MAX	0.19	max 10cm	
	Pipe Area (m^2)	2.54644E-06	e_t*width	2.54644E-05		Pipe Area (m^2)	9.39E-06	e_t*width	
	Advective velocity (m/yr)		phaseCrep			Advective velocity (m/yr)	28000.0	calibraiton to initial breakthro	
	Advective velocity as calculated freom 1/5000 of the pumping rate (m/yr)	85014.70		14878					
	Path Length (m)	6.1	from geometry			Path Length (m)	6.1	from geometry	
	Total Path Length	68.6	from geometry			Total Path Length	68.6	from geometry	
	Dispersion (m)	5.9	use process disc. value			Dispersion (m)	5.9	max 10%	8.6%
Fracture Coating	Thickness (m)	0.0005	Task 6C report						
	Porosity (%)	5.0%	Task 6C report						
	Pipe Area	0.0613	V_{void}/thickness						
Fault Gouge-Cataclasite/Mylonite (immobile zone)	Thickness (m)	0.025	Task 6C report		**Breccia**	Thickness (m)	0.003	0.003m to 0.0001m	
	Porosity (%)	4.8%	Task 6C report			Porosity (%)	5.50%	40% - 5%	
	Pipe Area	0.058848	V_{void}/thickness			Pipe Area	0.128117	V_{void}/thickness	
	Tortuosity	0.09526							
Altered Rock	Thickness (m)	0.2	Task 6C report		**Altered Rock**	Thickness (m)	0.02	0.02m to 0.005m	
	Porosity (%)	1.0%	Task 6C report			Porosity (%)	0.5%	2% - 0.5%	
	Pipe Area	0.01226	V_{void}/thickness			Pipe Area	0.011647	V_{void}/thickness	
Intact Rock	Thickness (m)	10	Task 6C report		**Intact Rock**	Thickness (m)	10		
	Porosity (%)	0.3%	Task 6C report			Porosity (%)	0.01%	<0.5%	
	Pipe Area	0.003678	V_{void}/thickness			Pipe Area	0.00023294	V_{void}/thickness	
Fracture on Structure 22	Transmissivity	2.19E-08	Task 6C report			Transmissivity	6.78E-09	true bs DFN	
	Fracture Aperture (m)	7.40E-05	Task 6C report			Fracture Aperture (m)	1.65E-04	true bs DFN	
	Transpot Aperture (m)	9.25E-06	Task 6C report	9.25E-05		Transpot Aperture (m)	4.94E-05	DFN calibration	
	Pipe Width (m) -- MAX	0.1	max 10cm	0.1		Pipe Width (m) -- MAX	0.1	max 10cm	
	Pipe Area (m^2)	9.24916E-07	e_t*width	9.24916E-06		Pipe Area (m^2)	4.94E-06	e_t*width	
	Advective velocity (m/yr)		phaseCrep			Advective velocity (m/yr)	28000.0	calibraiton to initial breakthrc	
	Advective velocity as calculated freom 1/5000 of the pumping rate (m/yr)	234059.36		40960					
	Path Length (m)	29.2	from geometry			Path Length (m)	29.2	from geometry	
	Dispersion (m)	5.9	use process disc. value			Dispersion (m)	5.9	max 10%	
Fracture Coating	Thickness (m)	0.0005	Task 6C report						
	Porosity (%)	5.0%	Task 6C report						
	Pipe Area	0.2923	V_{void}/thickness						
Fault Gouge- (immobile zone)	Thickness (m)	0.025	Task 6C report		**Breccia**	Thickness (m)	0.003	0.003m to 0.0001m	
	Porosity (%)	4.8%	Task 6C report			Porosity (%)	5.50%	40% - 5%	
	Pipe Area	0.058848	V_{void}/thickness			Pipe Area	0.128117	V_{void}/thickness	
	Tortuosity	0.09526	Task 6C report						
Altered Rock	Thickness (m)	0.2	Task 6C report		**Altered Rock**	Thickness (m)	0.02	0.02m to 0.005m	
	Porosity (%)	1.0%	Task 6C report			Porosity (%)	0.5%	2% - 0.5%	
	Pipe Area	0.05846	V_{void}/thickness			Pipe Area	0.011647	V_{void}/thickness	
Intact Rock	Thickness (m)	10	Task 6C report		**Intact Rock**	Thickness (m)	10		
	Porosity (%)	0.3%	Task 6C report			Porosity (%)	0.01%	<0.5%	
	Pipe Area	0.017538	V_{void}/thickness			Pipe Area	0.00023294	V_{void}/thickness	
Fracture on Structure 20	Transmissivity	1.43E-07	Task 6C report						
	Fracture Aperture (m)	1.89E-04	Task 6C report						
	Transpot Aperture (m)	2.36E-05	Task 6C report	2.36E-04					
	Pipe Width (m) -- MAX	0.1	max 10cm	0.1					
	Pipe Area (m^2)	2.36346E-06	e_t*width	2.36346E-05					
	Advective velocity (m/yr)		phaseCrep						

Table 3-7. Parameters for C-3 Tracer Simulations

C3	Calibration Parameters	Task 6C Parameters	reference	
Fracture on Structure 21	Transmissivity	6.02E-08	Task 6C report	
	Fracture Aperture (m)	1.23E-04	Task 6C report	
	Transpot Aperture (m)	1.53E-05	Task 6C report	8.53E-04
	Pipe Width (m) -- MAX	0.1	max 10cm	0.1
	Pipe Area (m^2)	1.53E-06	e_t*width	8.53E-05
	Advective velocity (m/yr)		phaseCrep	
	Advective velocity as calculated freom 1/5000 of the pumping rate (m/yr)	137056.59		2600
	Path Length (m)	32.9	from geometry	
	Dispersion (m)	3	max 10%	
Fracture Coating	Thickness (m)	0.0005	Task 6C report	
	Porosity (%)	5.0%	Task 6C report	
	Pipe Area	0.329	V_{void}/thickness	
Fault Gouge-Cataclasite/Mylonite (immobile zone)	Thickness (m)	0.025	Task 6C report	
	Porosity (%)	4.8%	Task 6C report	
	Pipe Area	0.31584	V_{void}/thickness	
		0.09526	Task 6C report	
Altered Rock	Thickness (m)	0.2	Task 6C report	
	Porosity (%)	1.0%	Task 6C report	
	Pipe Area	0.0658	V_{void}/thickness	
Intact Rock	Thickness (m)	10	Task 6C report	
	Porosity (%)	0.3%	Task 6C report	
	Pipe Area	0.01974	V_{void}/thickness	
Retardation Factor	*R = 1+Kd*(density/n)*	Br	Kd, Task 6C report	
	Fracture Coating	1	0	
	Fault Gouge/Cataclasite	1	0	
	Altered Zone	1	0	
	Intact wall rock	1	0	
		Na^+	Kd, Task 6C report	
	Fracture Coating	3.0	3.70E-05	
	Fault Gouge/Cataclasite	2.8	3.08E-05	
	Altered Zone	4.9	1.40E-05	
	Intact wall rock	7.5	7.10E-06	
		Sr^{2+}	Kd, Task 6C report	
	Fracture Coating	13.7	2.30E-04	
	Fault Gouge/Cataclasite	12.2	1.96E-04	
	Altered Zone	25.2	8.80E-05	
	Intact wall rock	41.4	4.40E-05	
		Rb^+	Kd, Task 6C report	
	Fracture Coating	287.5	5.20E-03	
	Fault Gouge/Cataclasite	253.5	4.40E-03	
	Altered Zone	552.0	2.00E-03	
	Intact wall rock	919.3	1.00E-03	
		Cs^+	Kd, Task 6C report	
	Fracture Coating	254.5	4.60E-03	
	Fault Gouge/Cataclasite	221.4	3.84E-03	
	Altered Zone	496.9	1.80E-03	
	Intact wall rock	809.1	8.80E-04	

	Calibration Parameters	Process Discrimination Parameters	reference		
	Transmissivity	8.10E-07	true bs DFN		
	Fracture Aperture (m)	1.80E-03	true bs DFN		
	Transpot Aperture (m)	5.40E-04	DFN calibration		
	Pipe Width (m) -- MAX	0.1	max 10cm		
	Pipe Area (m^2)	5.40E-05	e_t*width		
	Advective velocity (m/yr)	1385	calibralton to initial breakthrough time		
	Path Length (m)	32.9	from geometry		
	Dispersion (m)	2	max 10%	6.1%	
Breccia	Thickness (m)	0.003	0.003m to 0.0001m		
	Porosity (%)	17.00%	40% - 5%		
	Pipe Area	1.1186	V_{void}/thickness		
Altered Rock	Thickness (m)	0.02	0.02m to 0.005m		
	Porosity (%)	0.20%	2% - 0.5%		
	Pipe Area	0.01316	V_{void}/thickness		
Intact Rock	Thickness (m)	10			
	Porosity (%)	0.08%	<0.5%		
	Pipe Area	0.005264	V_{void}/thickness		
	R = 1+Kd(density/n)*	HTO	Kd, Process Discrimination Study Calibr		
	Breccia	1	0		
	Altered Zone	1	0		
	Intact wall rock	1	0		
		Na^+	Kd, Process [	Lab Kd	Kd Multiplie
	Breccia	2.2	7.14E-05	1.40E-06	51
	Altered Zone	99.4	7.14E-05		
	Intact wall rock	246.9	7.14E-05		
		Sr^{2+}	Kd, Process [	Lab Kd	Kd Multiplie
	Breccia	1.7	4.70E-04	4.70E-06	100
	Altered Zone	#VALUE!	4.70E-04		
	Intact wall rock	17908.5	4.70E-04		
		Rb^+	Kd, Process [	Lab Kd	Kd Multiplie
	Breccia	1.0	2.40E-02	4.00E-04	60
	Altered Zone	6337.5	2.40E-02		
	Intact wall rock	13225.0	2.40E-02		
		Ba^{2+}	Kd, Process [	Lab Kd	Kd Multiplie
	Breccia	1.0	3.00E-03	2.00E-04	15
	Altered Zone	1.0	3.00E-03		
	Intact wall rock	1.0	3.00E-03		

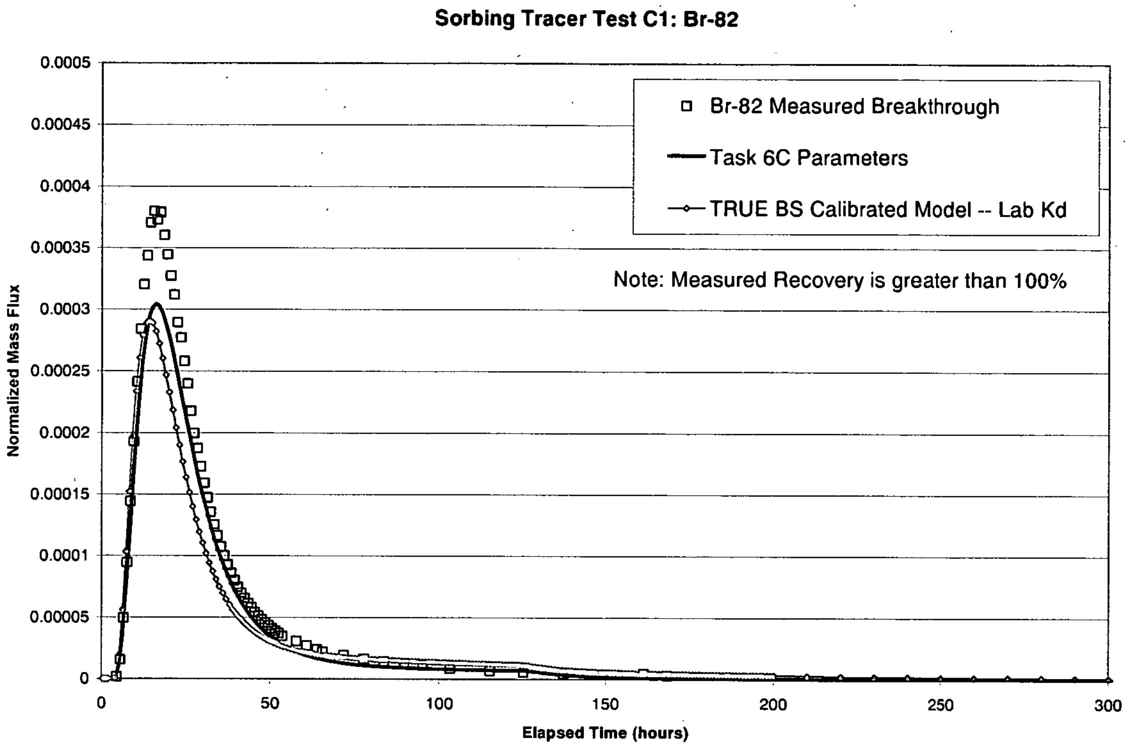

Figure 3-1. Test C1, Breakthrough of Br-82

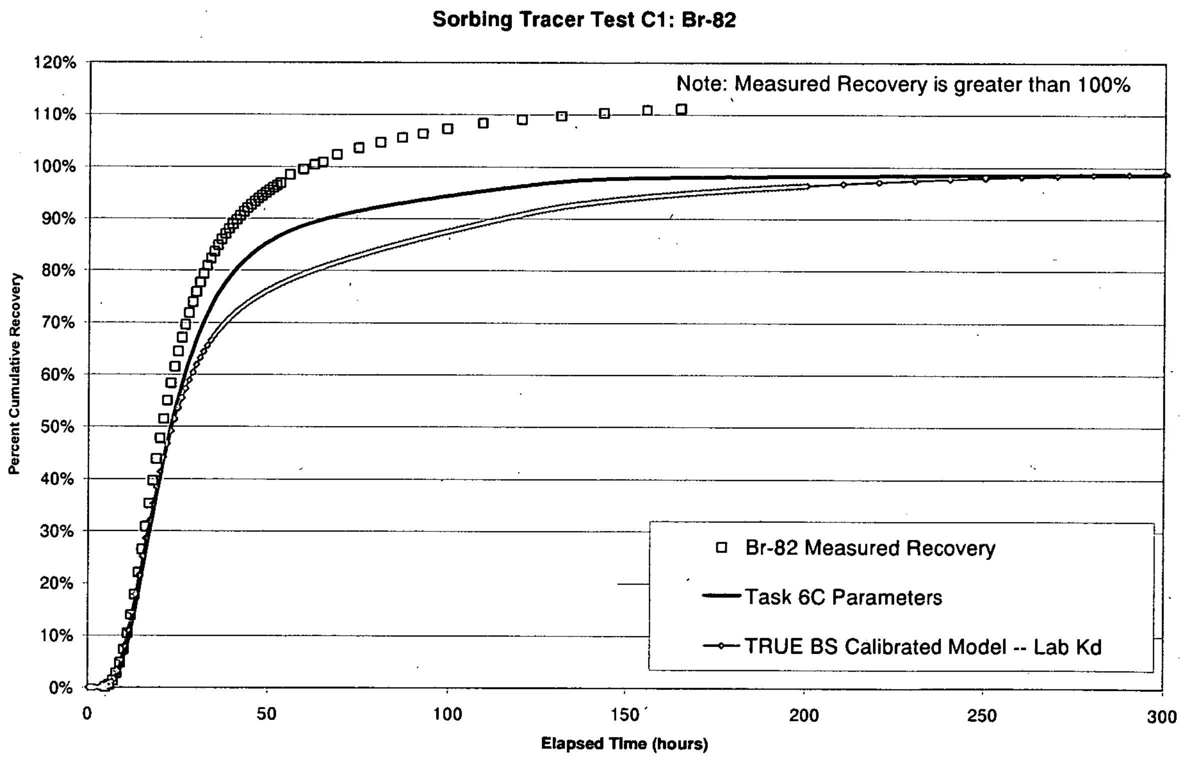

Figure 3-2. Test C1, Cumulative Recovery of Br-82

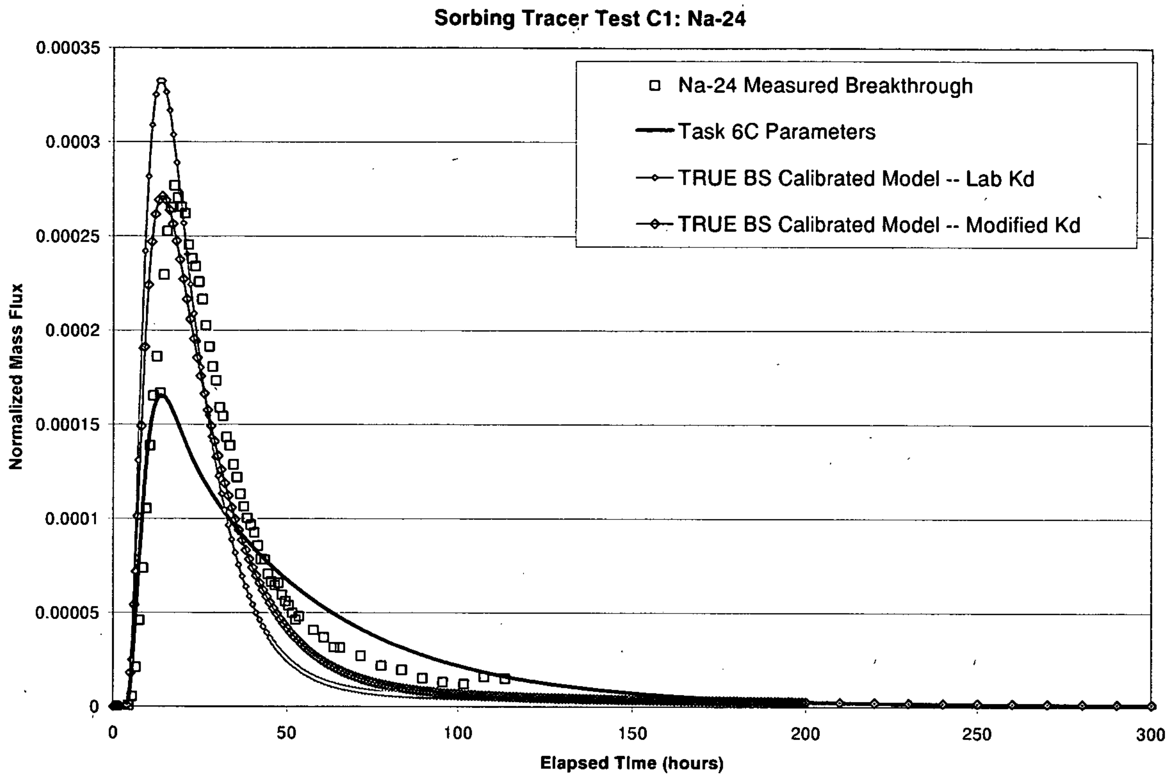

Figure 3-3. Test C1, Breakthrough of Na-24

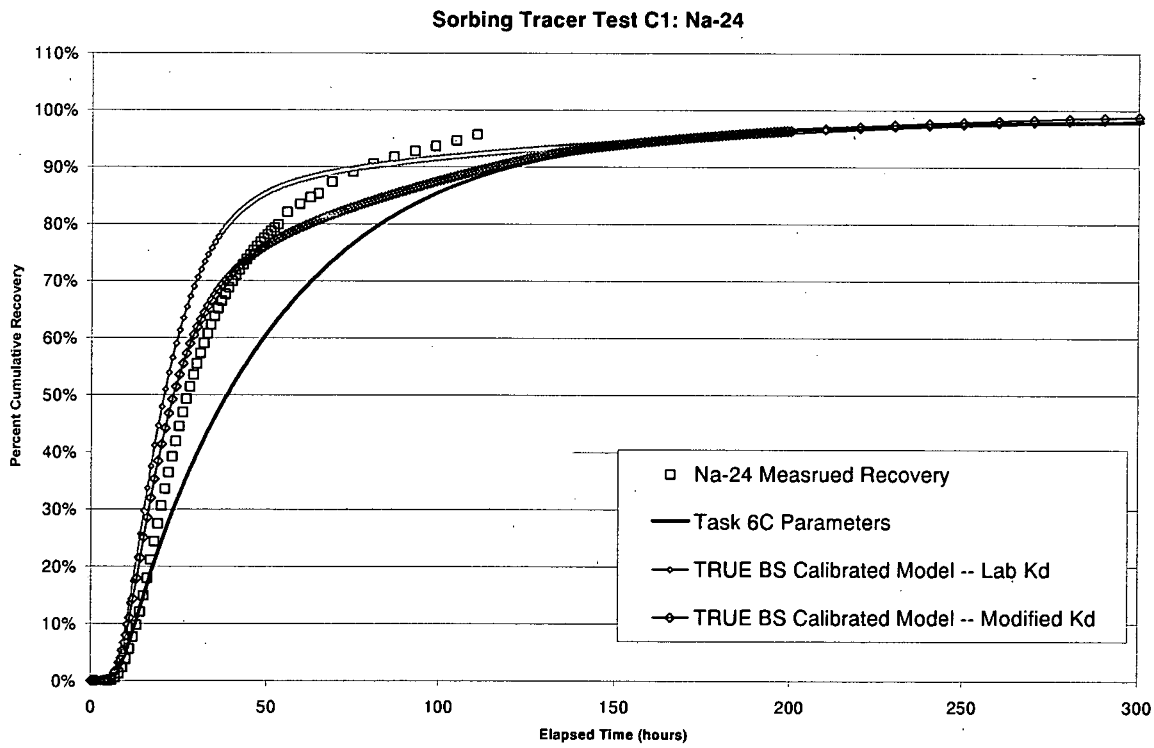

Figure 3-4. Test C1, Cumulative Recovery of Na-24

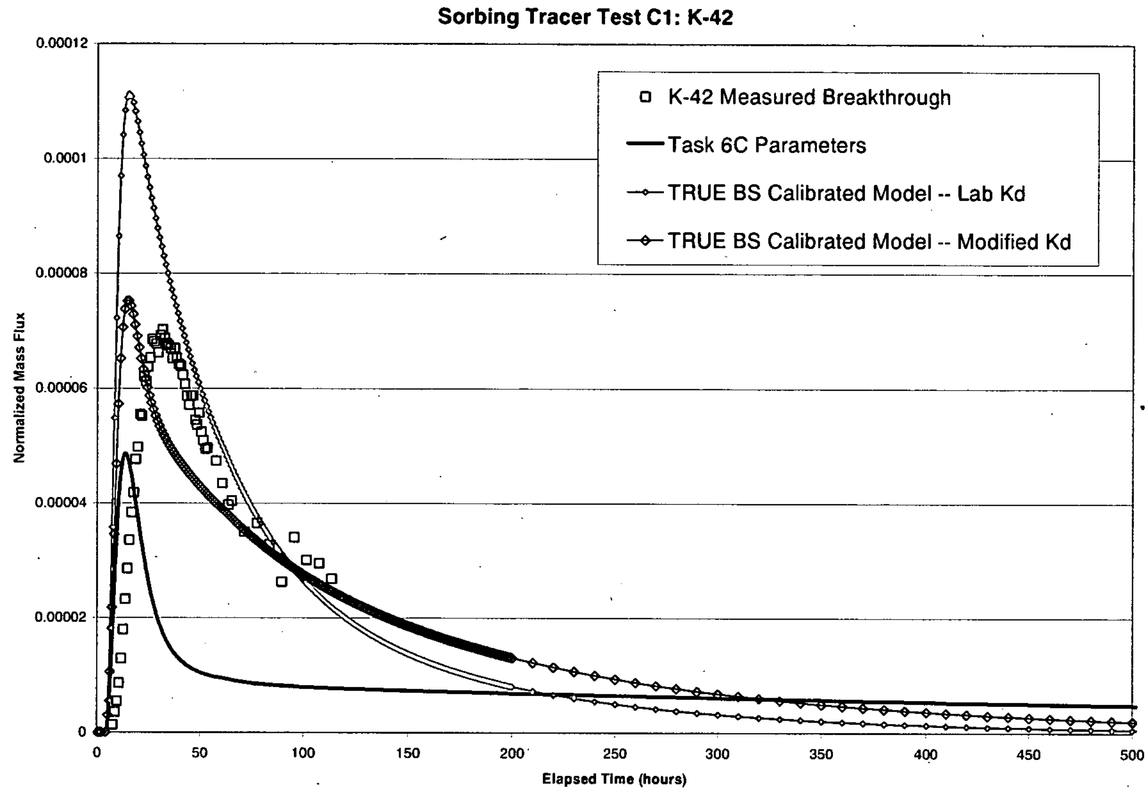

Figure 3-5. Test C1, Breakthrough of K-42

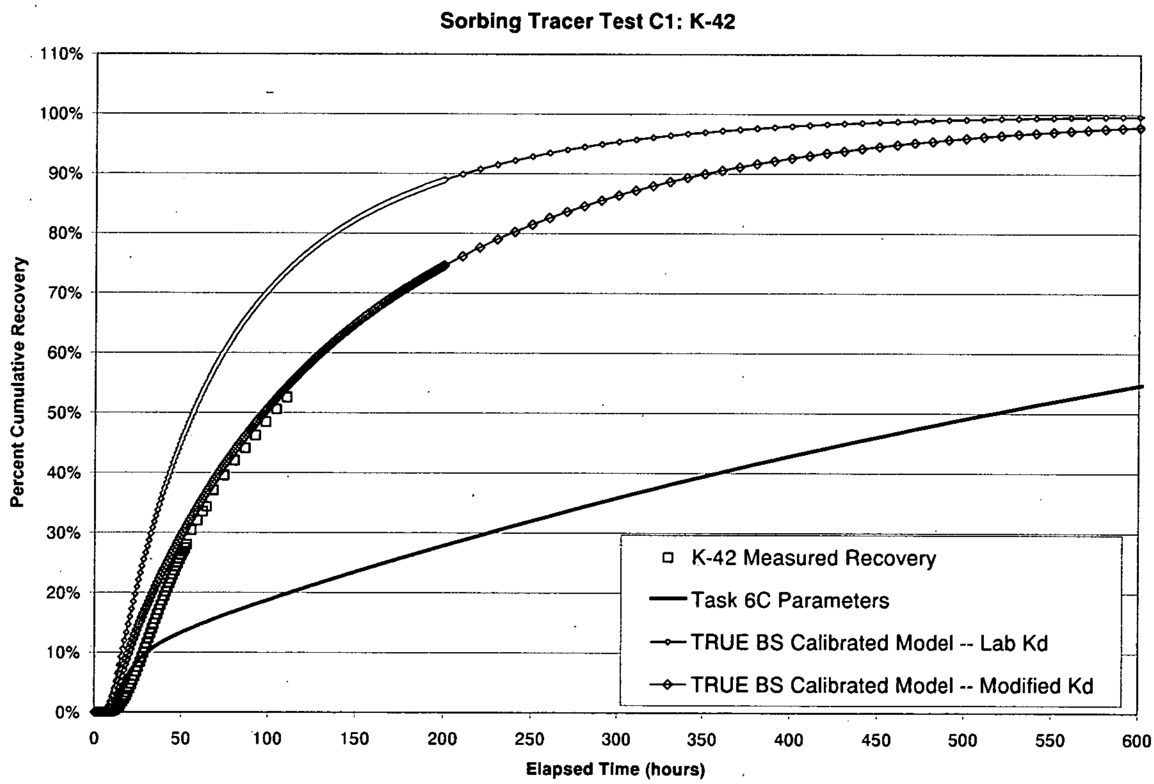

Figure 3-6. Test C1, Cumulative Recovery of K-42

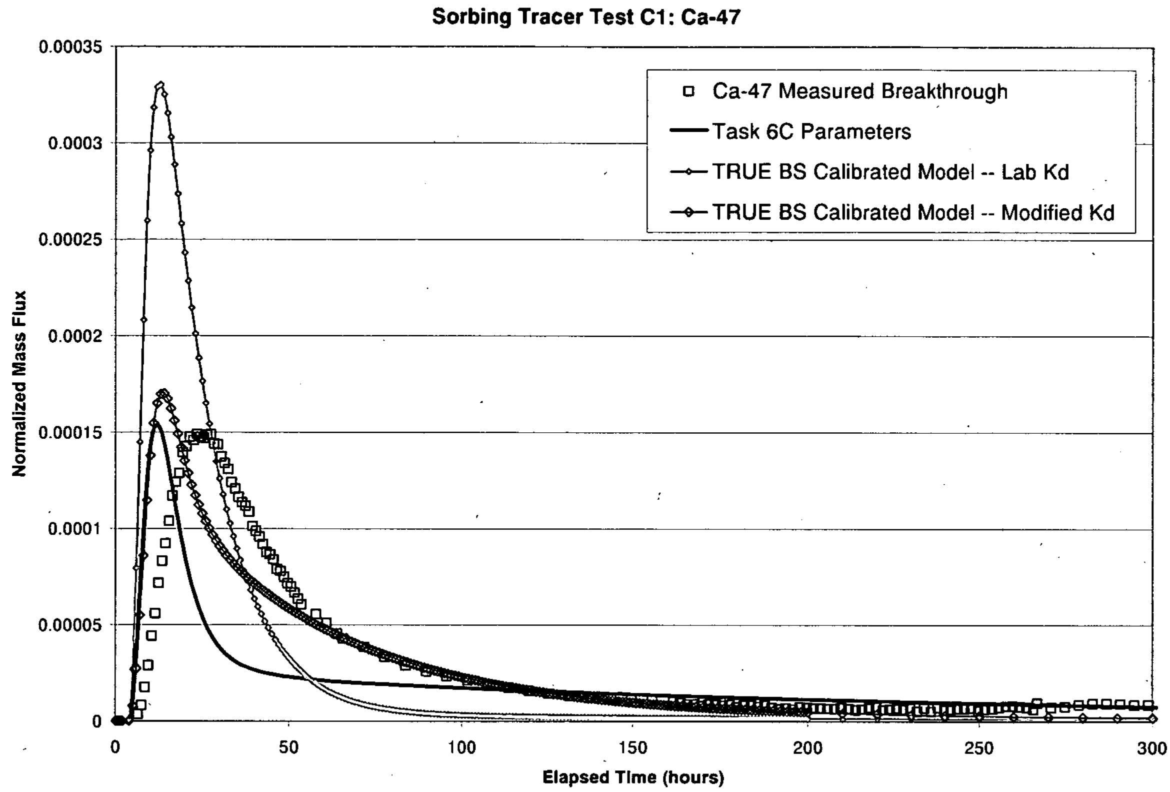

Figure 3-7. Test C1, Breakthrough of Ca-47

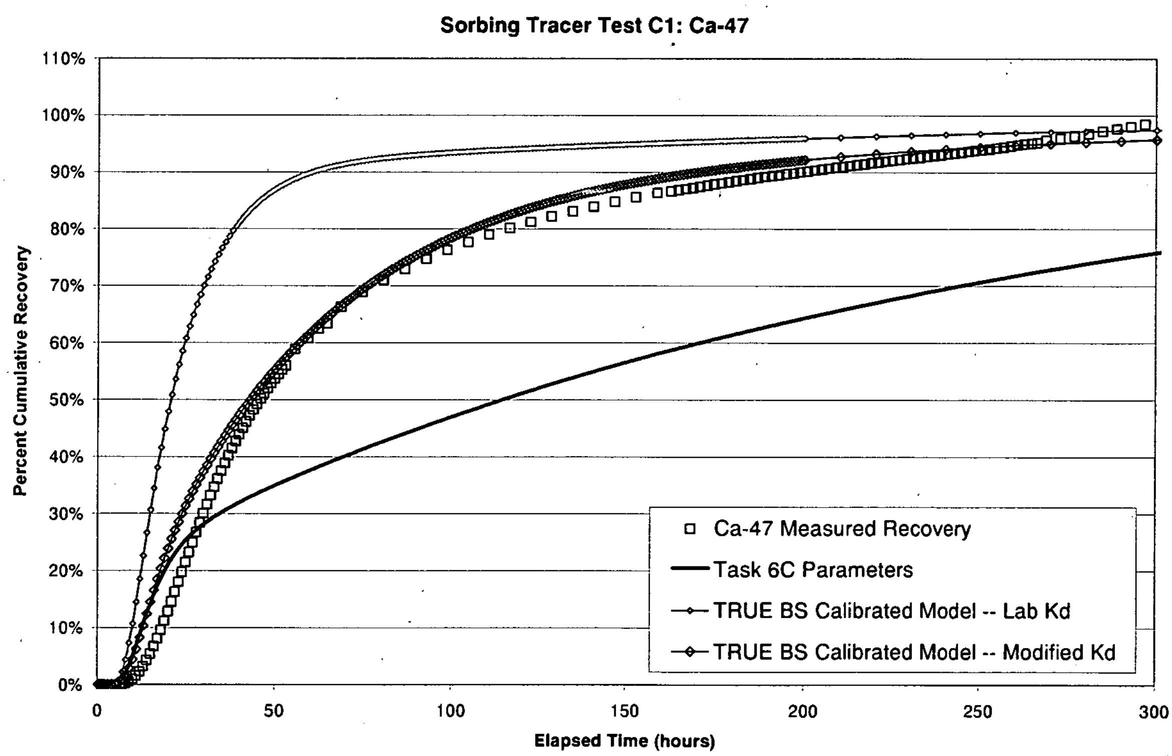

Figure 3-8. Test C1, Cumulative Recovery of Ca-47

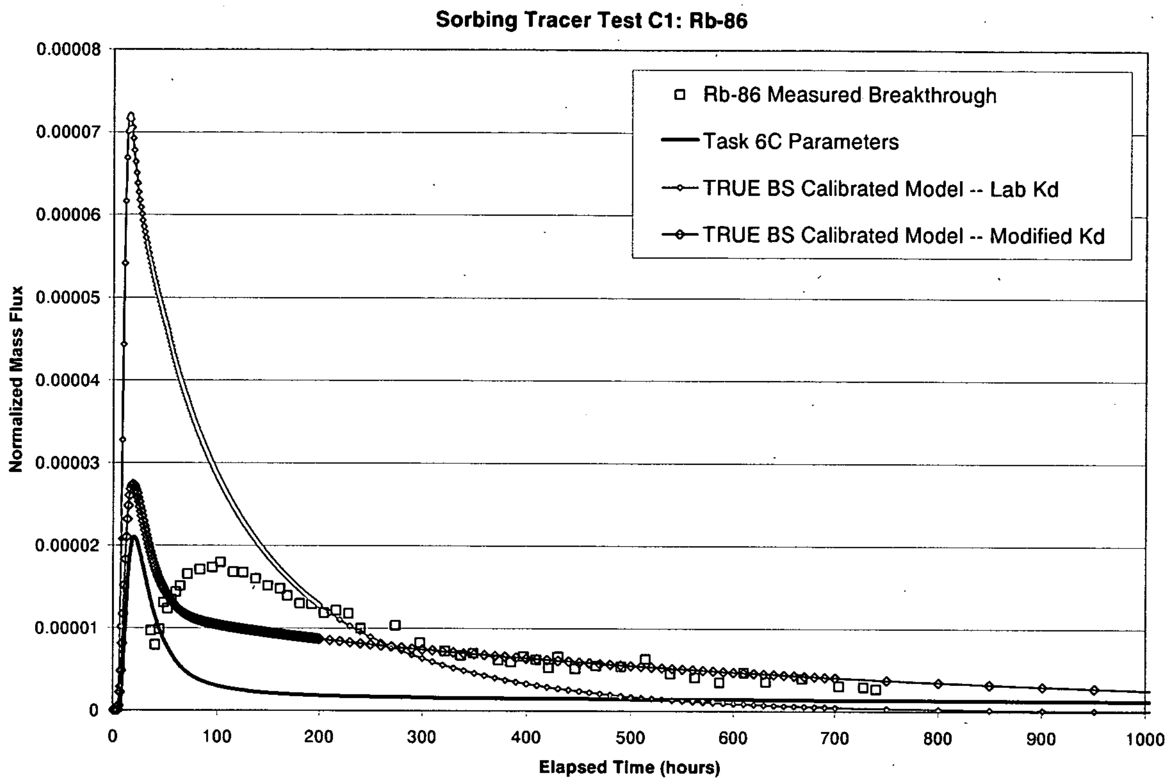

Figure 3-9. Test C1, Breakthrough of Rb-86

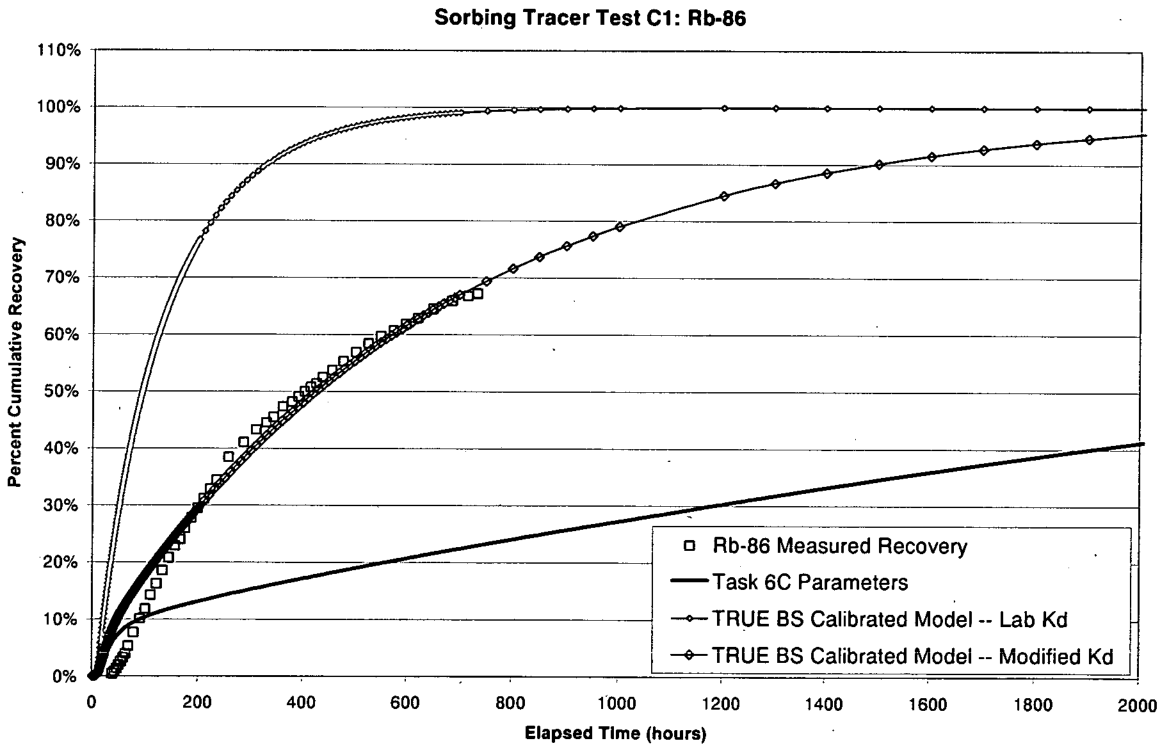

Figure 3-10. Test C1, Cumulative Recovery of Rb-86

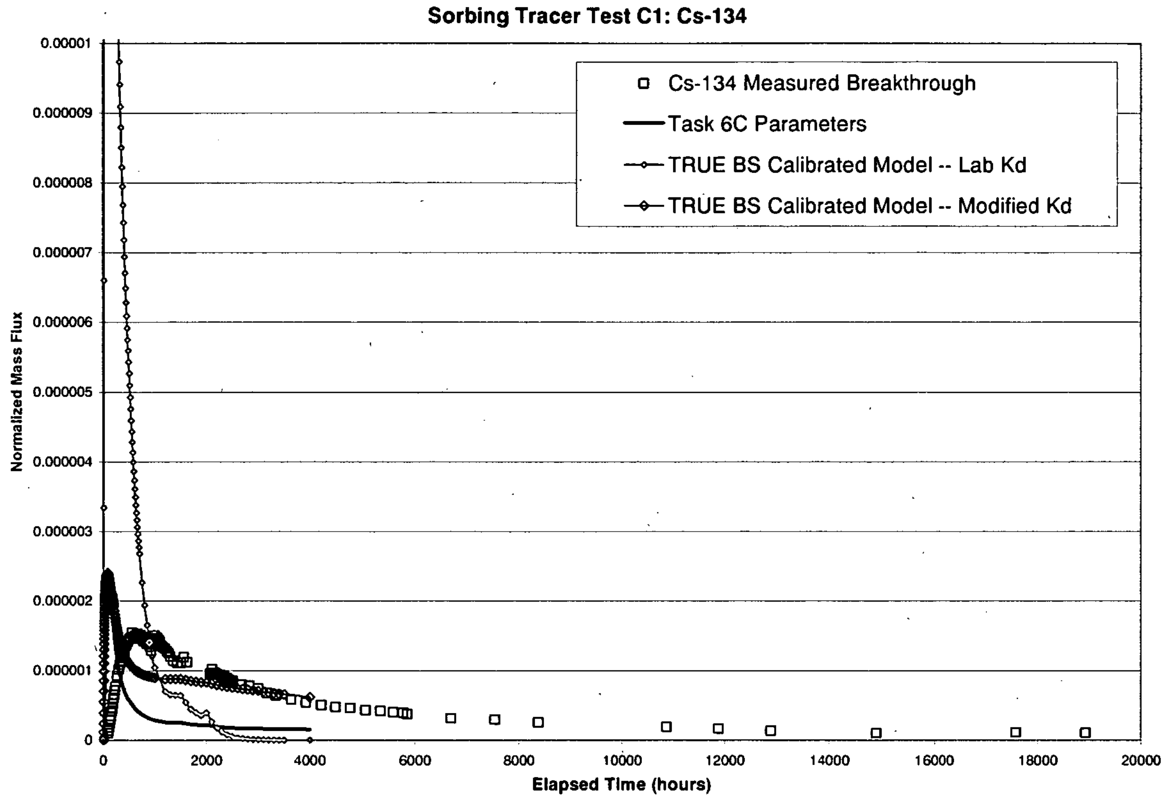

Figure 3-11. Test C1, Breakthrough of Cs-134

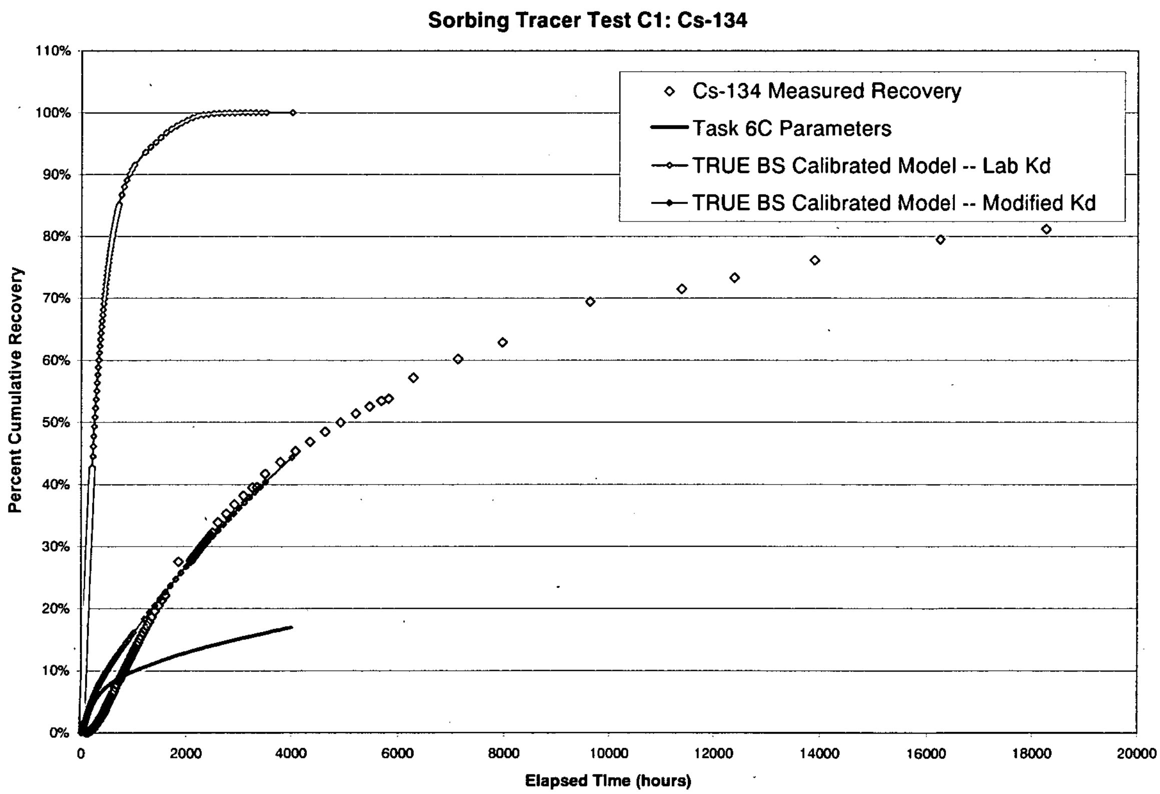

Figure 3-12. Test C1, Cumulative Recovery of Cs-134

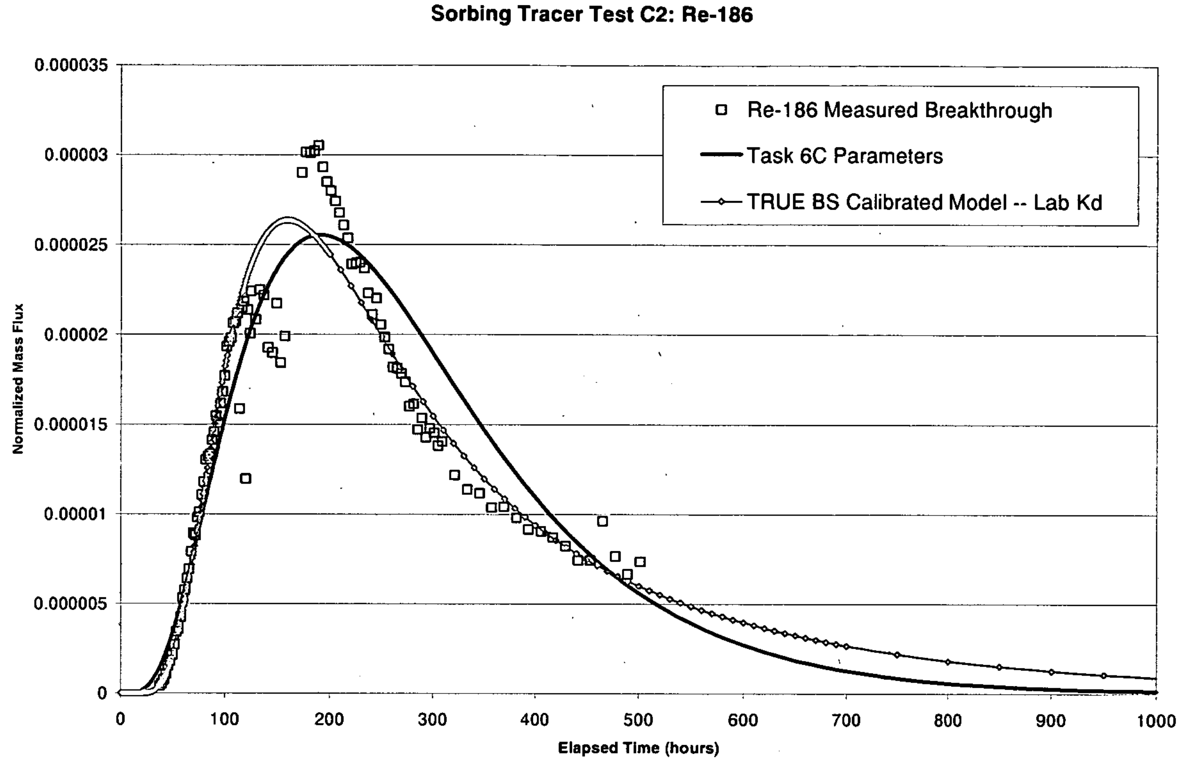

Figure 3-13. Test C2, Breakthrough of Re-186

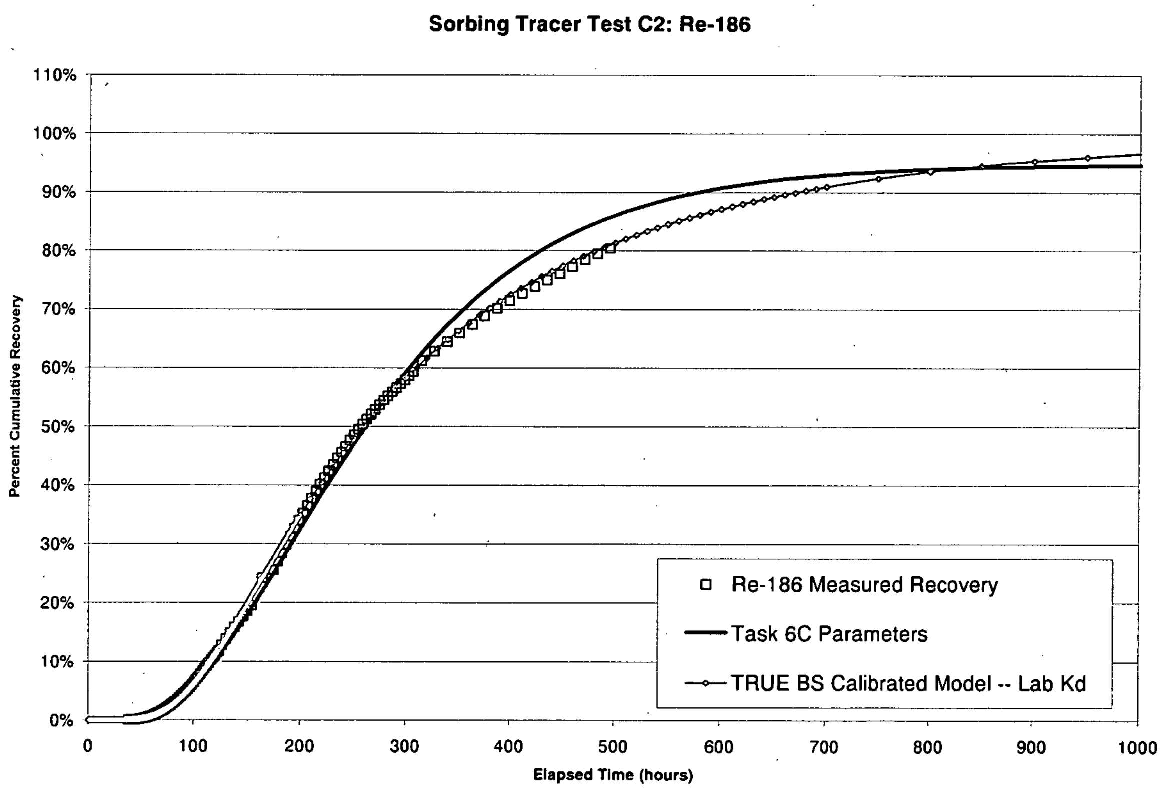

Figure 3-14. Test C2, Cumulative Recovery of Re-186

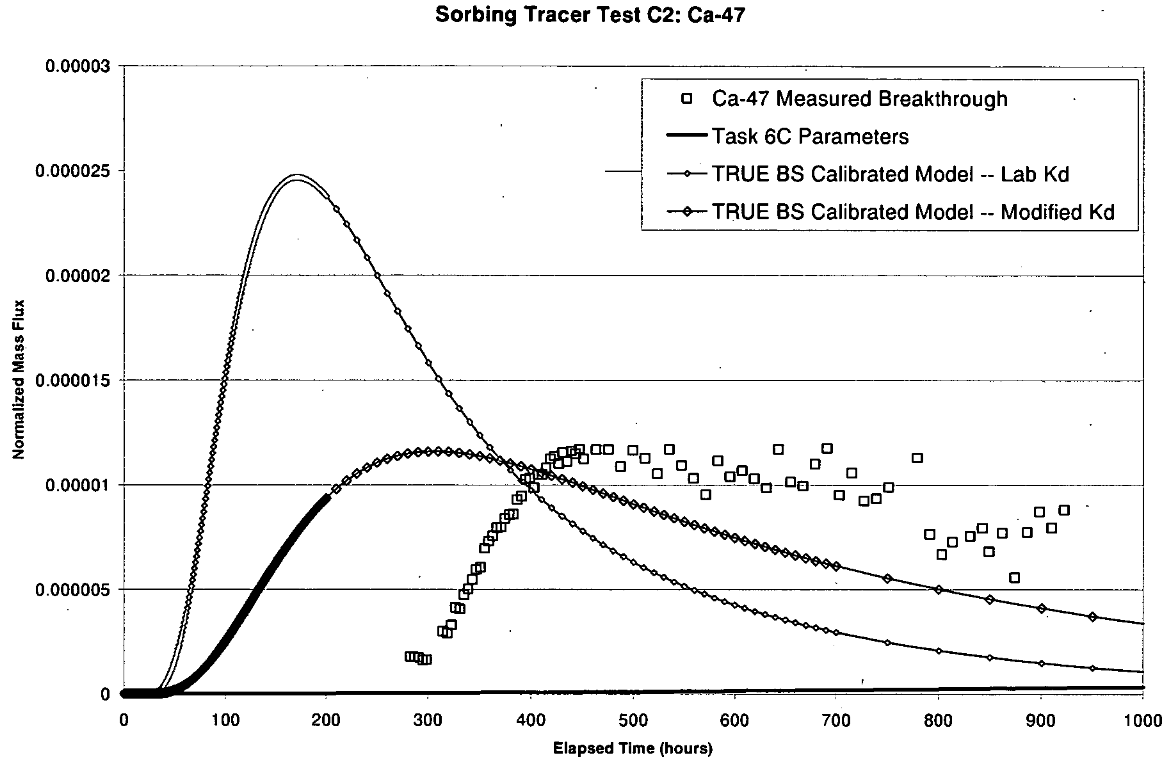

Figure 3-15. Test C2, Breakthrough of Ca-47

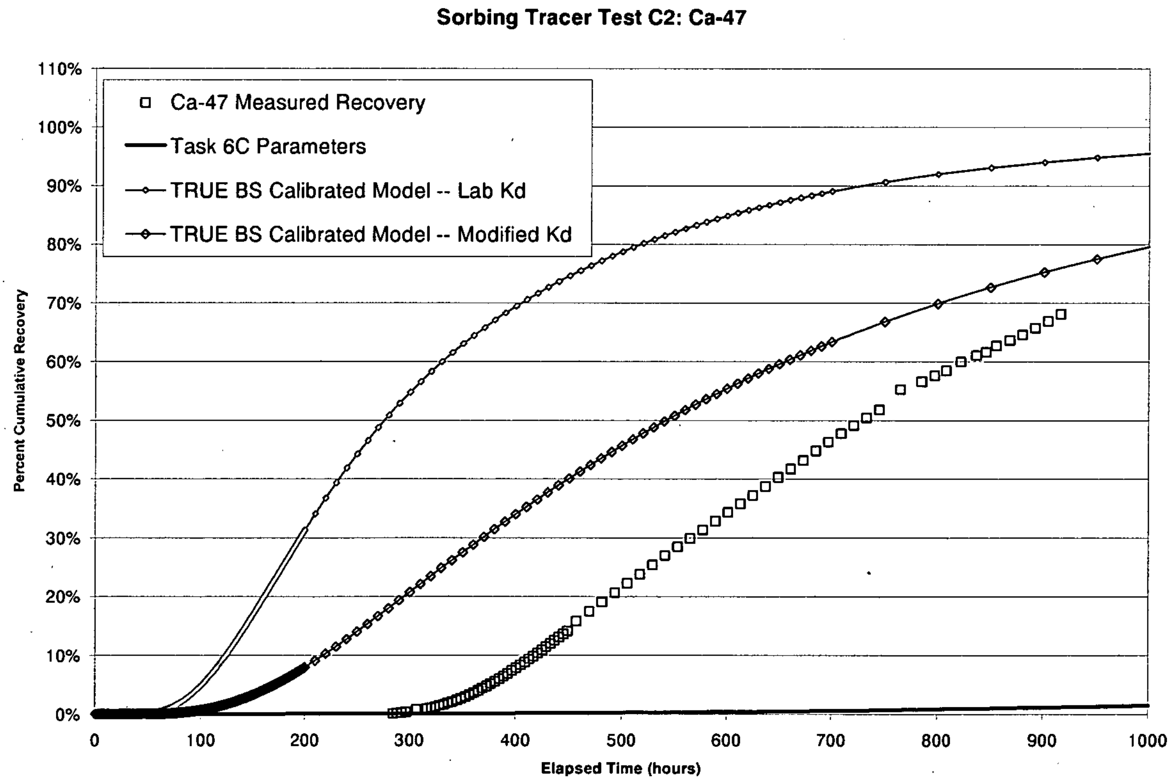

Figure 3-16. Test C2, Cumulative Recovery of Ca-47

Sorbing Tracer Test C2: Ba-131

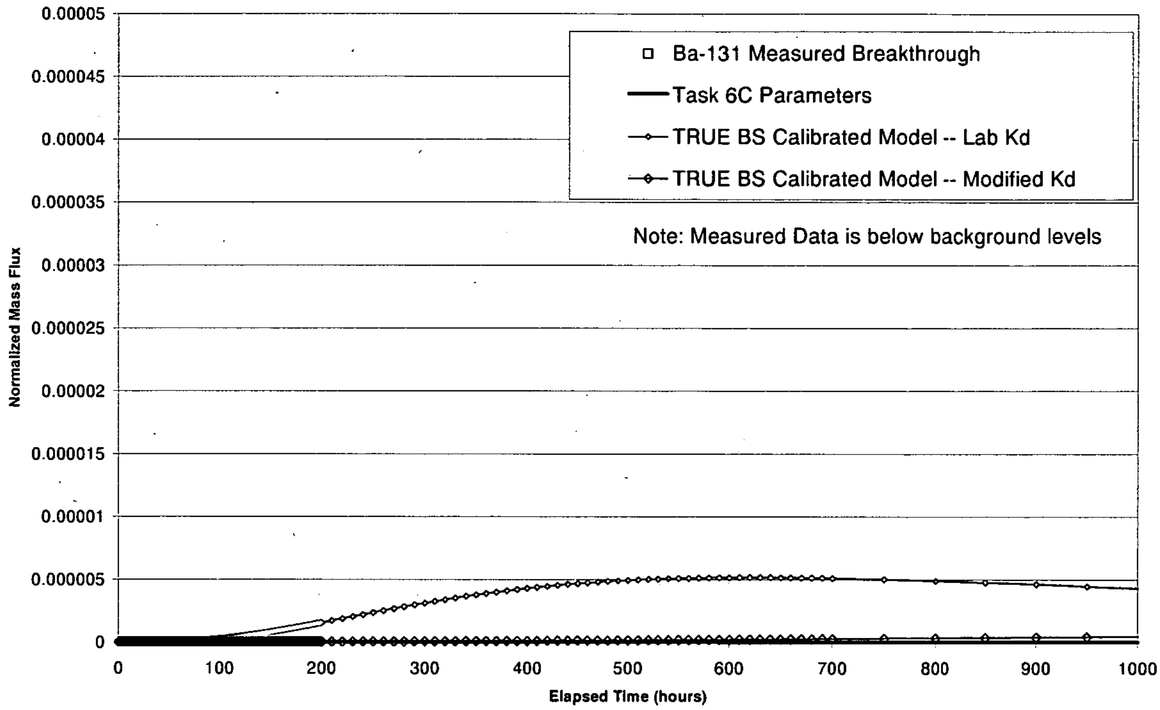

Figure 3-17. Test C2, Breakthrough of Ba-131

Sorbing Tracer Test C2: Ba-131

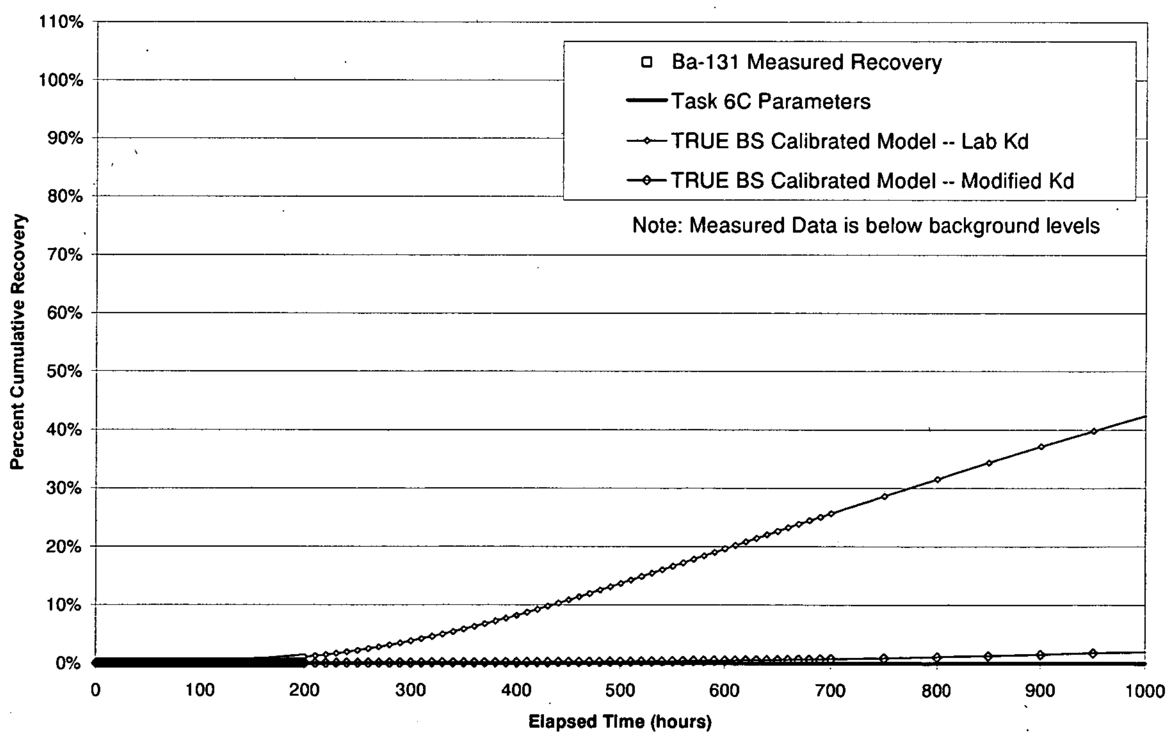

Figure 3-18. Test C2, Cumulative Recovery of Ba-131

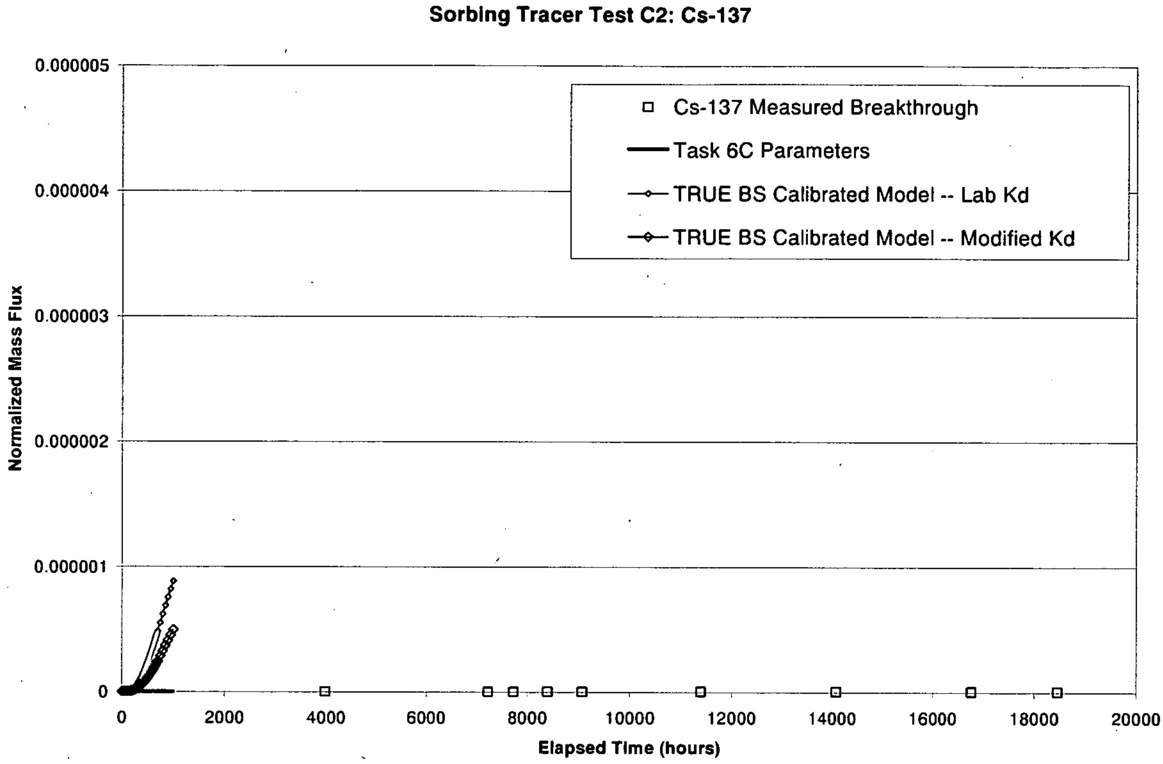

Figure 3-19. Test C2, Breakthrough of Cs-137

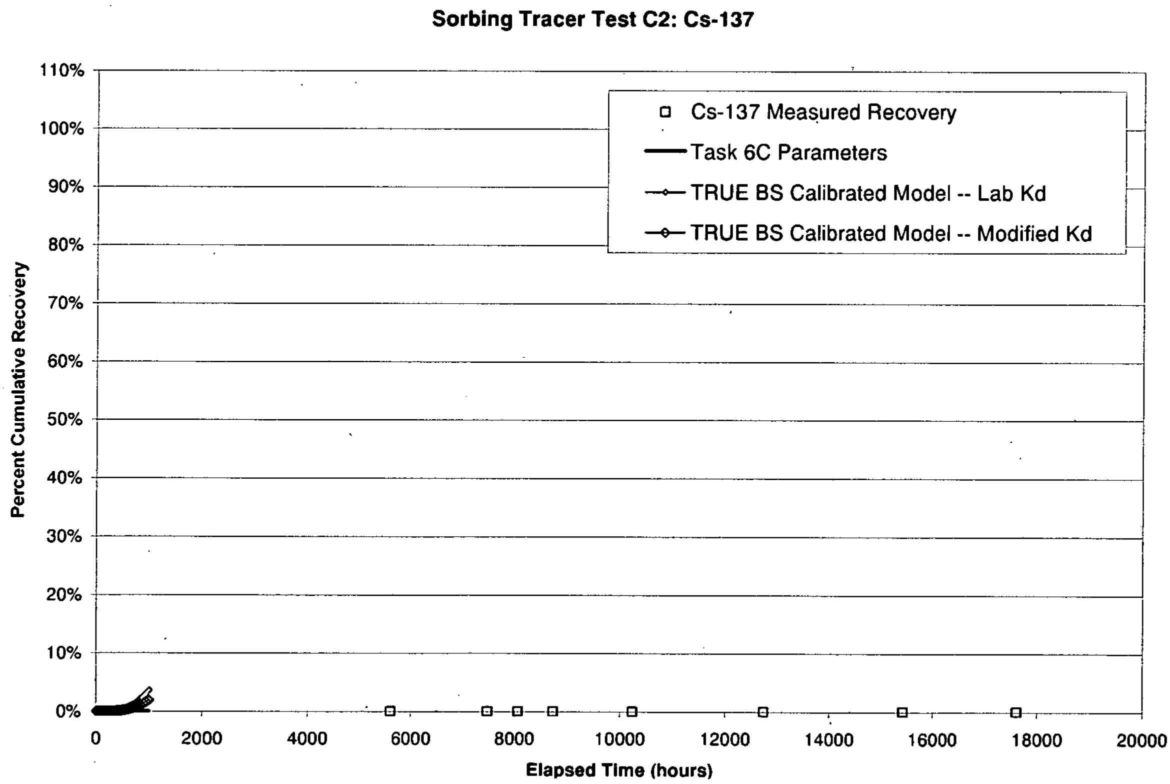

Figure 3-20. Test C2, Cumulative Recovery of Cs-137

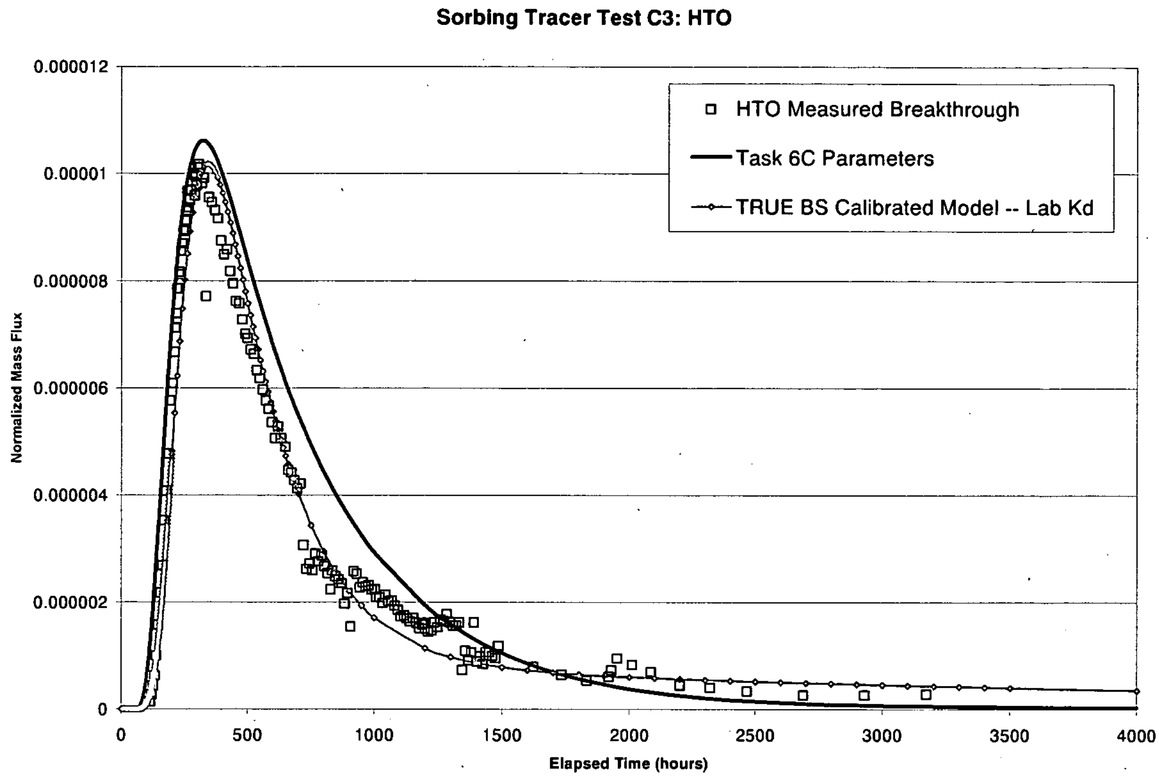

Figure 3-21. Test C3, Breakthrough of HTO

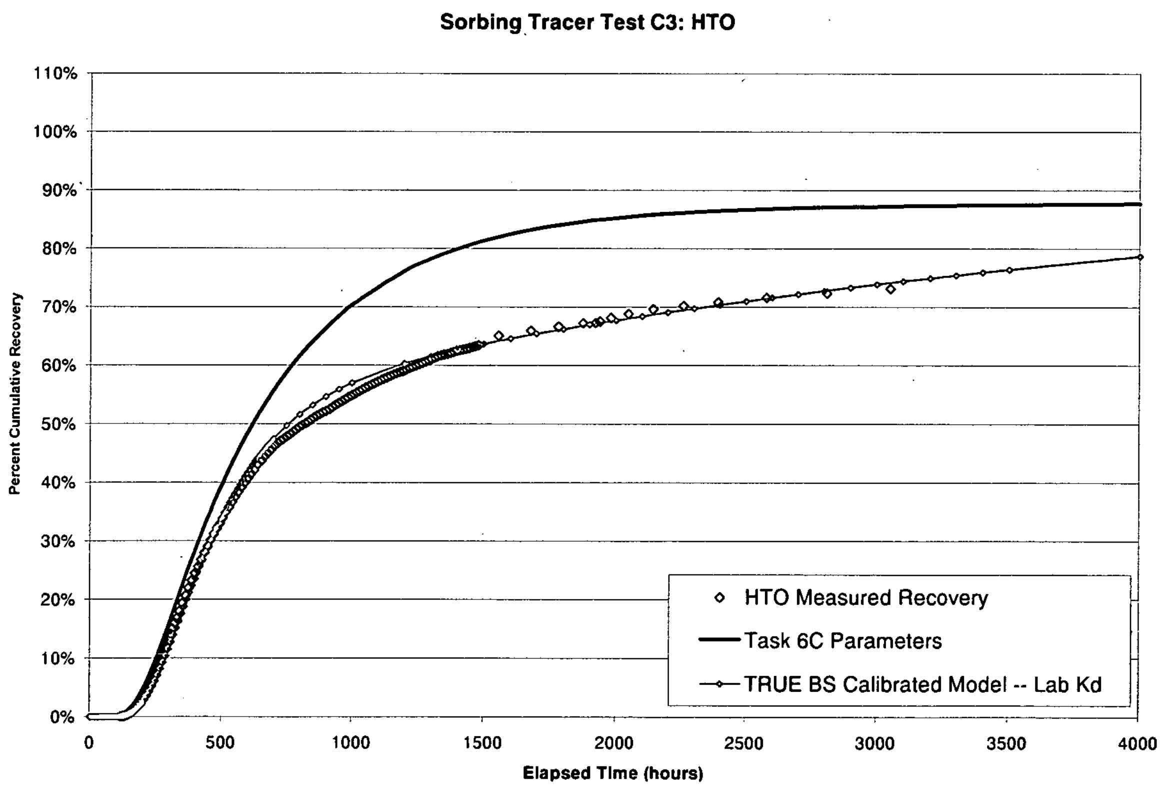

Figure 3-22. Test C3, Cumulative Recovery of HTO

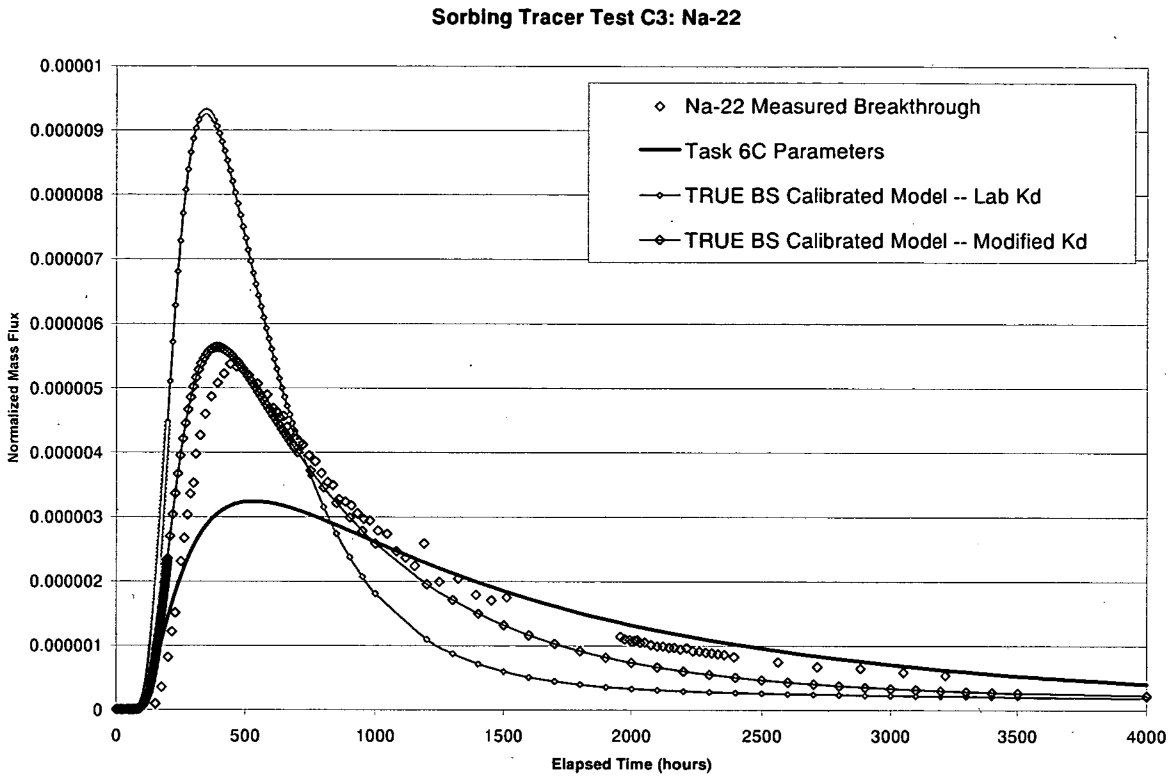

Figure 3-23. Test C3, Breakthrough of Na-22

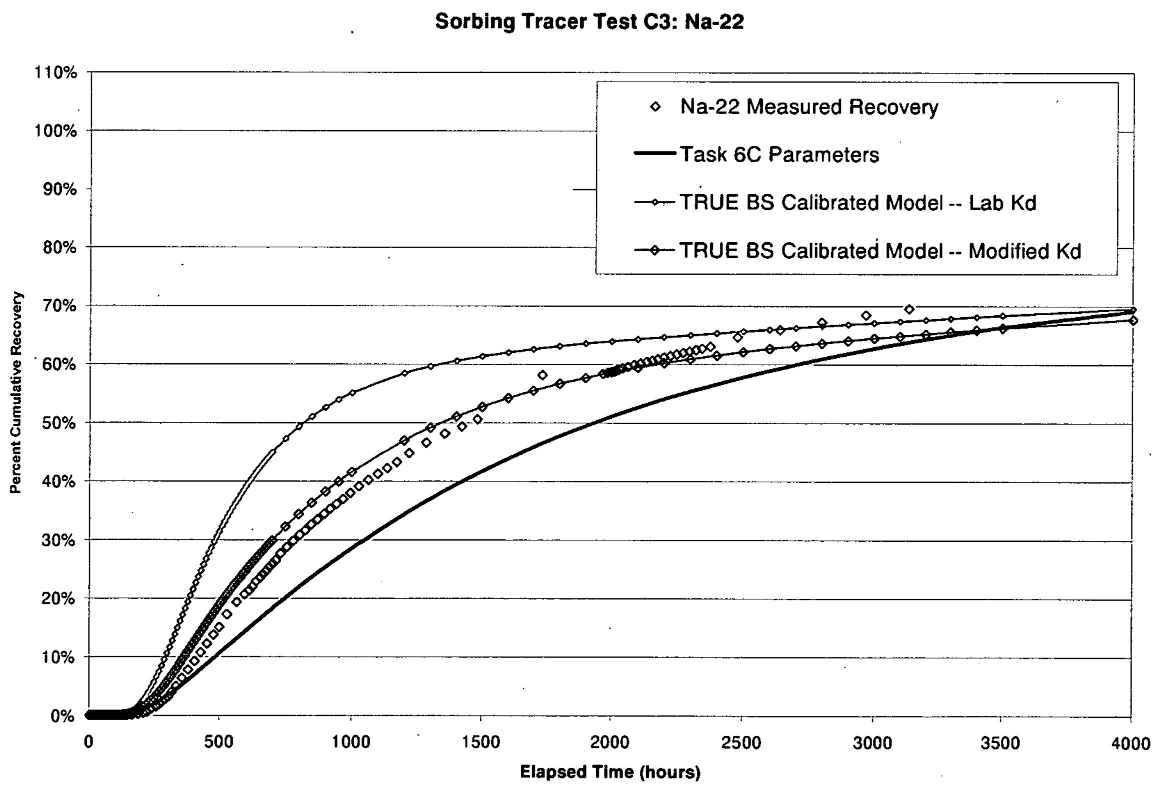

Figure 3-24. Test C3, Cumulative Recovery of Na-22

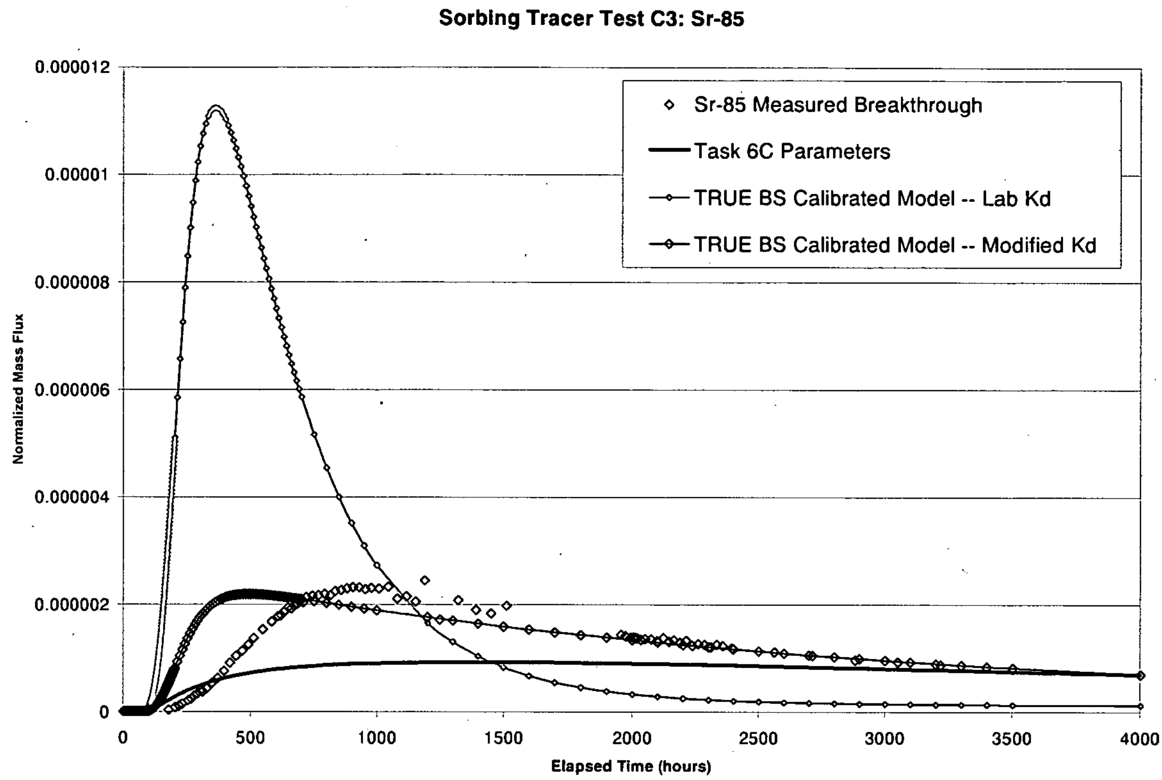

Figure 3-25. Test C3, Breakthrough of Sr-85

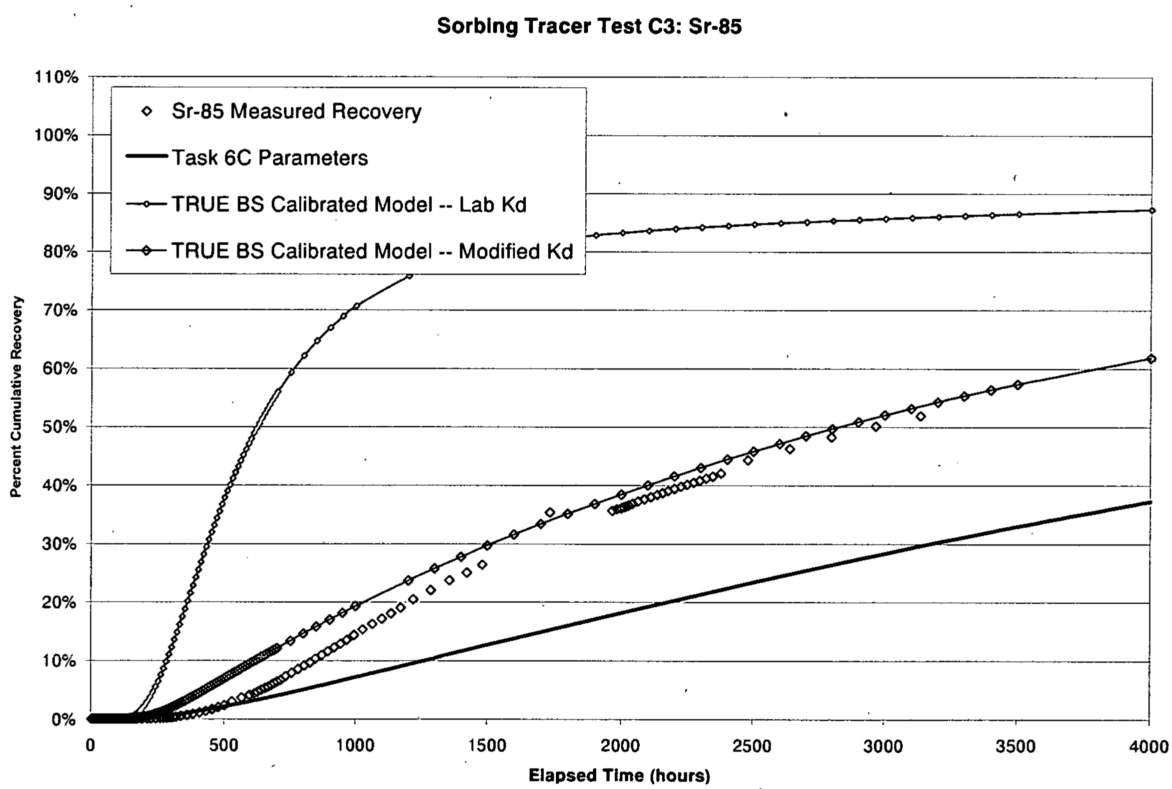

Figure 3-26. Test C3, Cumulative Recovery of Sr-85

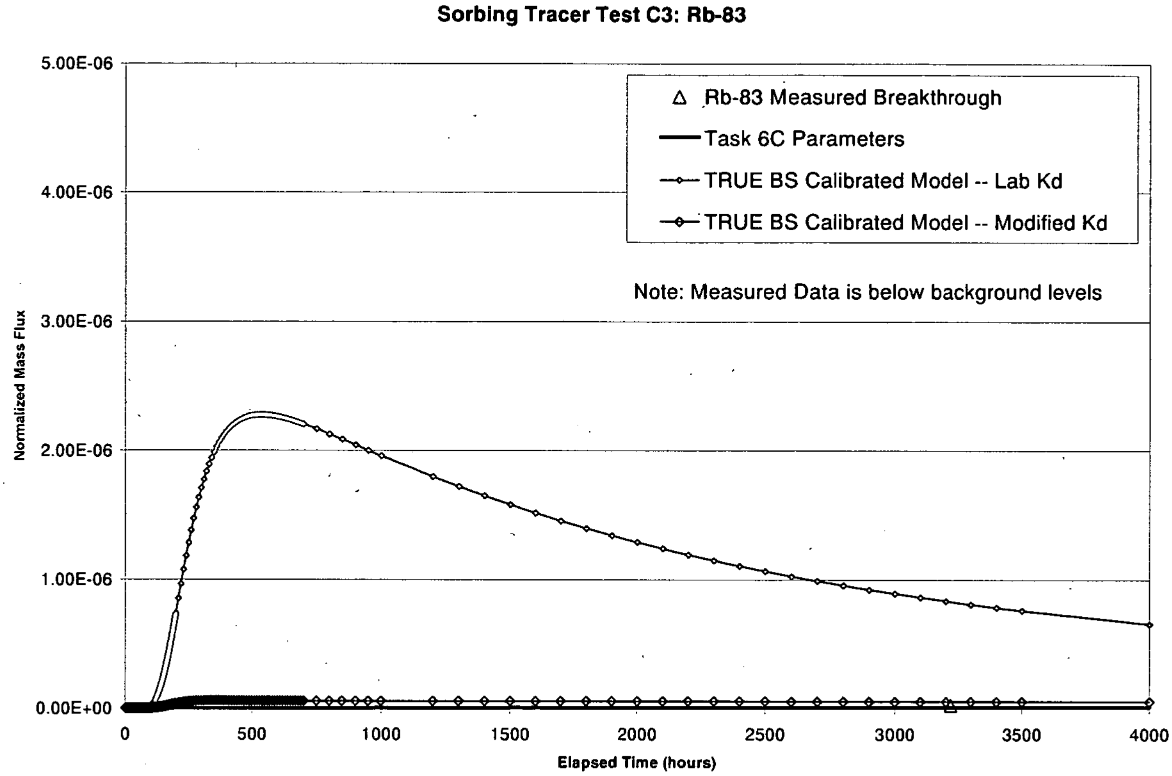

Figure 3-27. Test C3, Breakthrough of Rb-83

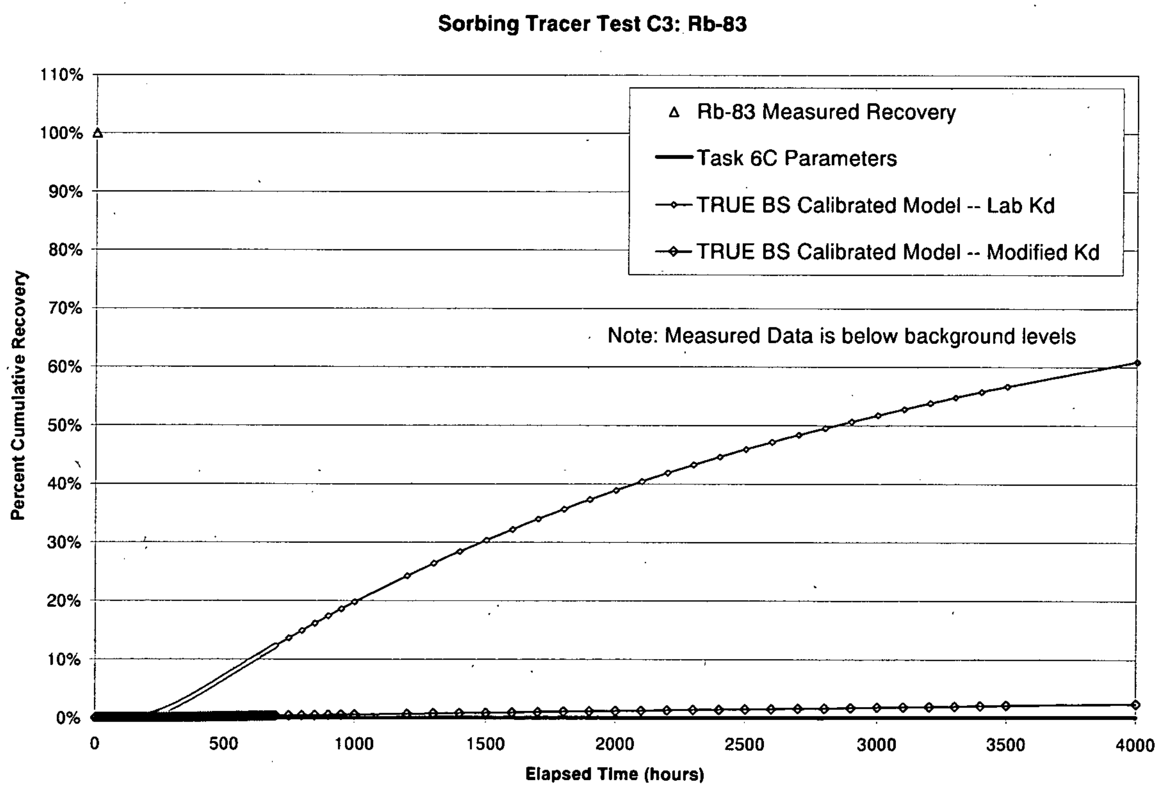

Figure 3-28. Test C3, Cumulative Recovery of Rb-83

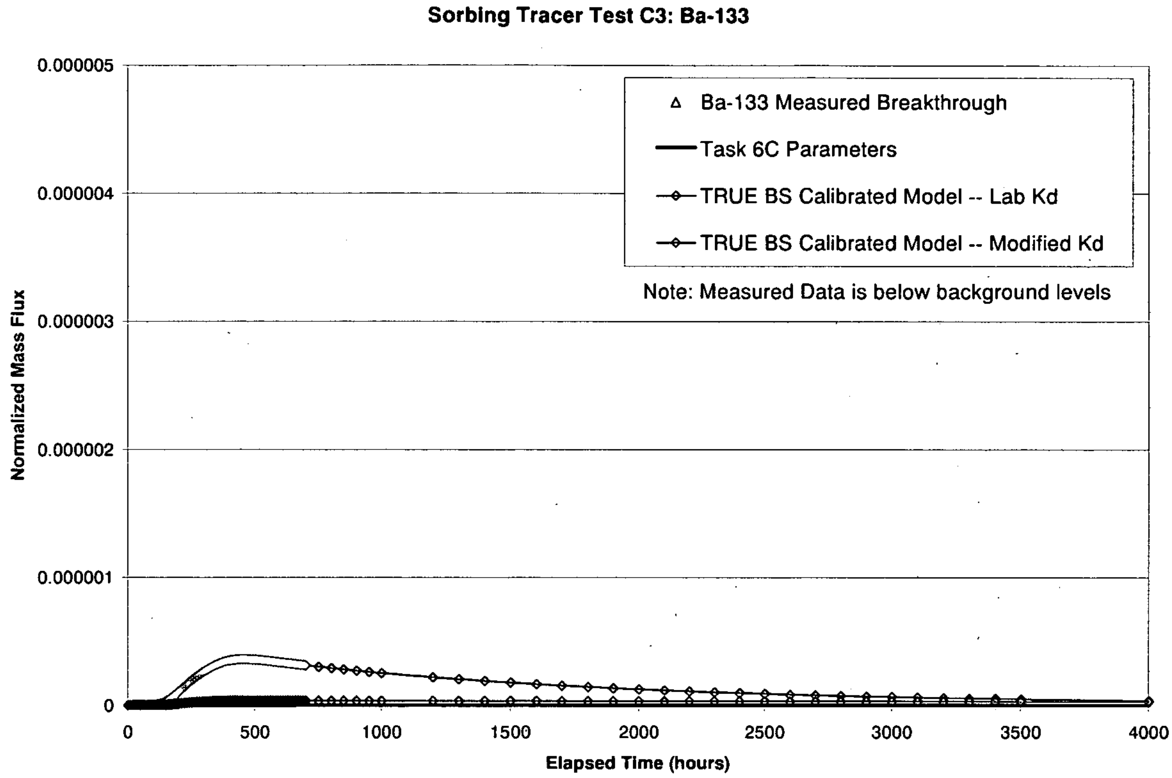

Figure 3-29. Test C3, Breakthrough of Ba-133

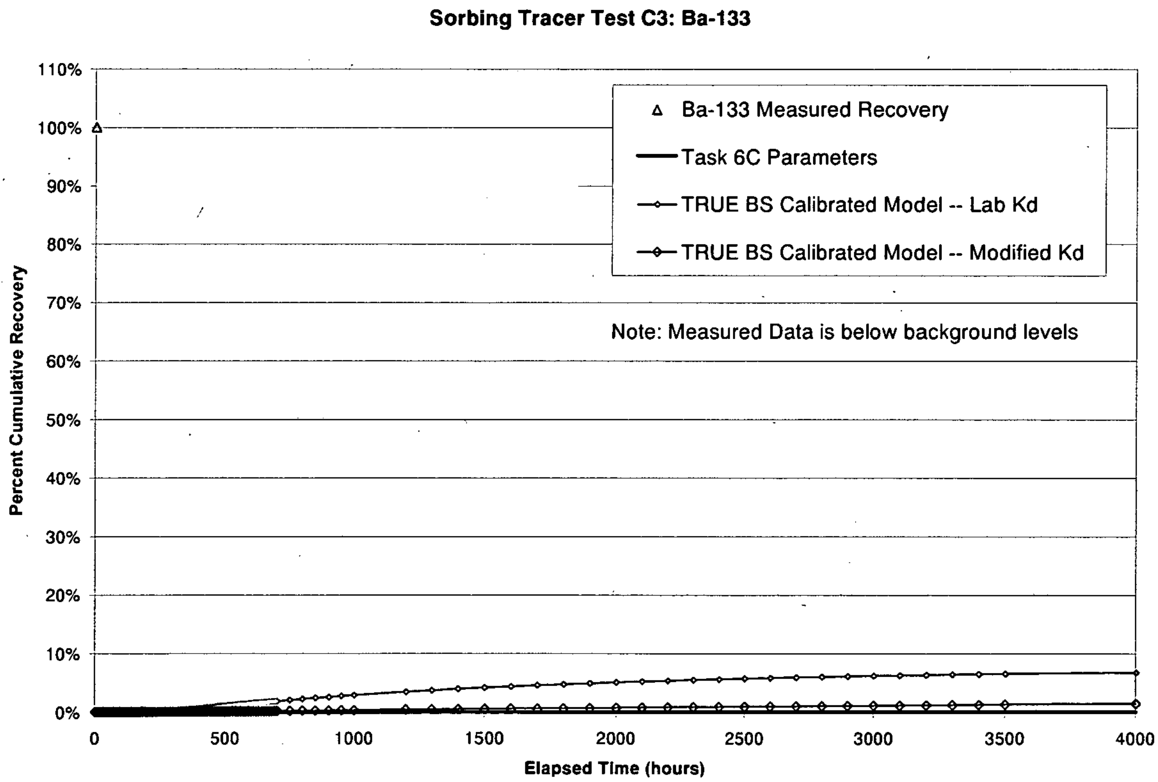

Figure 3-30. Test C3, Cumulative Recovery of Ba-133

4. CONCLUSIONS

During H-14, simulations were carried out for the major TRUE-BS transport experiments C-1, C-2, and C-3 using an updated microstructural model. Results were compared against those obtained using the calibrated model of H-12. The updated microstructural model generally predicted somewhat greater retention than was observed in situ. However, the magnitude of retention was comparable to that obtained through the calibrated transport simulations of H-12. This indicates that detailed microstructural model analysis does have the potential to support predictive transport analysis in fractured rock.

5. REFERENCES

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Byegård, J., G. Skarnemark, and M. Skålberg, 1995. "The use of some ion-exchange sorbing tracer cations in in-situ experiments in high saline groundwaters. Mat. Res. Soc. Symp. Proc., Vol 353, pp 1077-1084.

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Dershowitz, W., A. Winberg, J. Hermanson, J. Byegård, E.L. Tullborg, P. Andersson, and M. Mazurek, 2003. A Semi-synthetic Model of Block Scale Conductive Structures at the Äspö Hard Rock Laboratory. SKB, Stockholm.

APPENDIX C

TRANSPORT PATHWAY ANALYSIS USING HYDRAULIC INTERFERENCE DATA

ÄSPÖ HARD ROCK LABORATORY

TECHNICAL NOTE

TRUE BLOCK SCALE EXPERIMENT

TRANSPORT PATHWAY ANALYSIS USING HYDRAULIC INTERFERENCE DATA

WILLIAM DERSHOWITZ
KATE KLISE

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1. INTRODUCTION

This report describes DFN flow simulations and analyses carried out by Golder Associates during H-14 to support the TRUE-BS Continuation project. The TRUE-BS Continuation project is currently planning the H-15 experimental program to address longer fracture network pathways and background fractures. The simulations and analyses described in this report support evaluation of the feasibility of specific experimental configurations, considering the connectivity of the rock mass. Connectivity considerations include the hydrostructural model, channeling, and compartmentalization.

The simulations described in this report provide insight for the pathways being considered for additional tracer testing during the TRUE BS Continuation project. Simulations were carried out based on these pathways to assess hydraulic connectivity.

2. HYDROSTRUCTURAL MODEL

This chapter describes the updated TRUE-BS hydrostructural model used for the hydraulic interference simulations. The model is described in detail in Dershowitz et al. (2003). The model is based primarily on the TRUE-Block Scale hydrostructural model (Andersson et al., 2002). The model combines generally north-west trending deterministic structures with background fractures. Background fractures included in this model are defined according to a radius distribution based on a lognormal distribution with mean 2 m and standard deviation 2 m. This is smaller than that assumed in previous analyses (Dershowitz et al., 2002) in order to represent the lack of hydraulic continuity (compartmentalization) in the rock mass indicated by groundwater geochemistry measurements.

Figure 2-1 provides a visualization for the deterministic 100 m scale structures in the updated TRUE-BS hydrostructural model, colored by transmissivity. Figure 2-2 presents a horizontal slice through the model at the –450 masl.

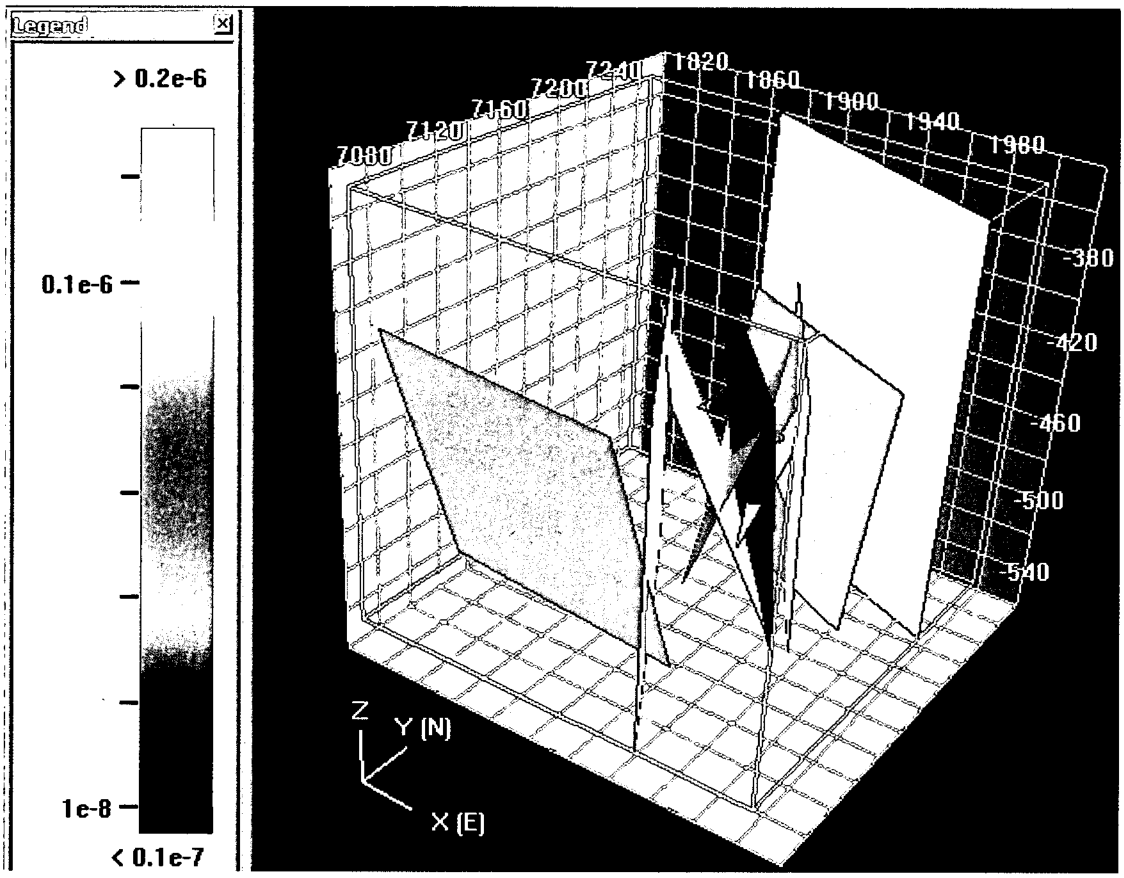

Figure 2-1. Deterministic 100 M Scale Structures Coloured According to Transmissivity

Figure 2-3 and Figure 2-4 provide visualisations of the background fractures coloured by set and transmissivity, respectively.

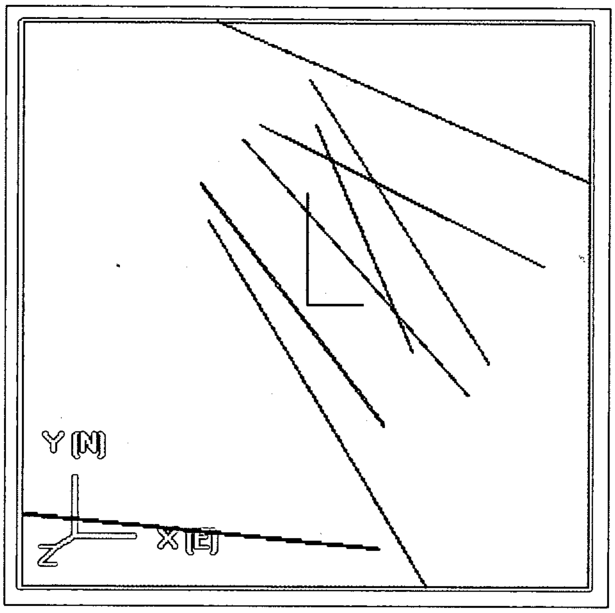

Figure 2-2. Horizontal Section (Trace Map) Through the Deterministic 100 M Structures of the 200 M Model At Z= –450 Masl

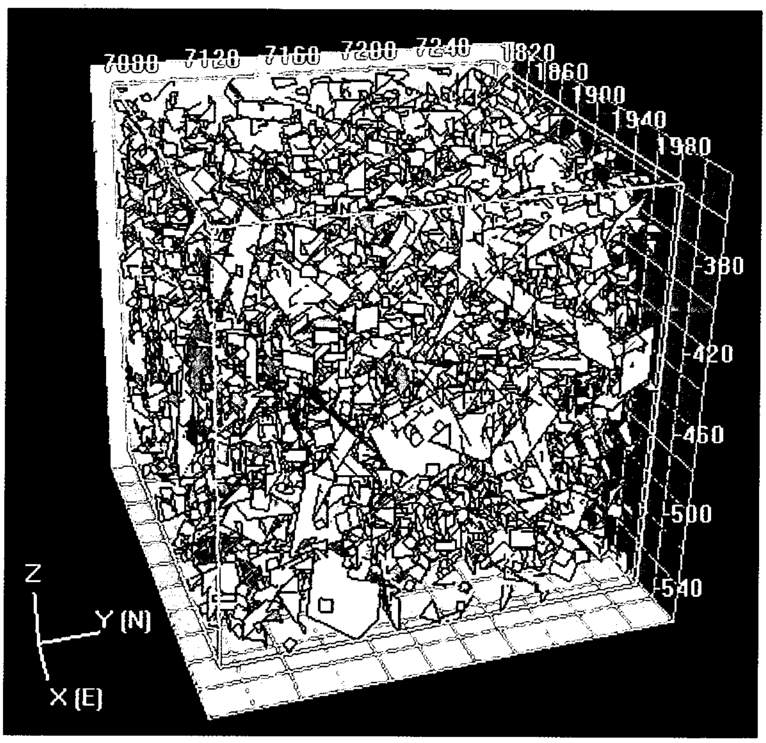

Figure 2-3. Background Fractures Coloured By Set, Shallow Set (Blue), NNW (Yellow)

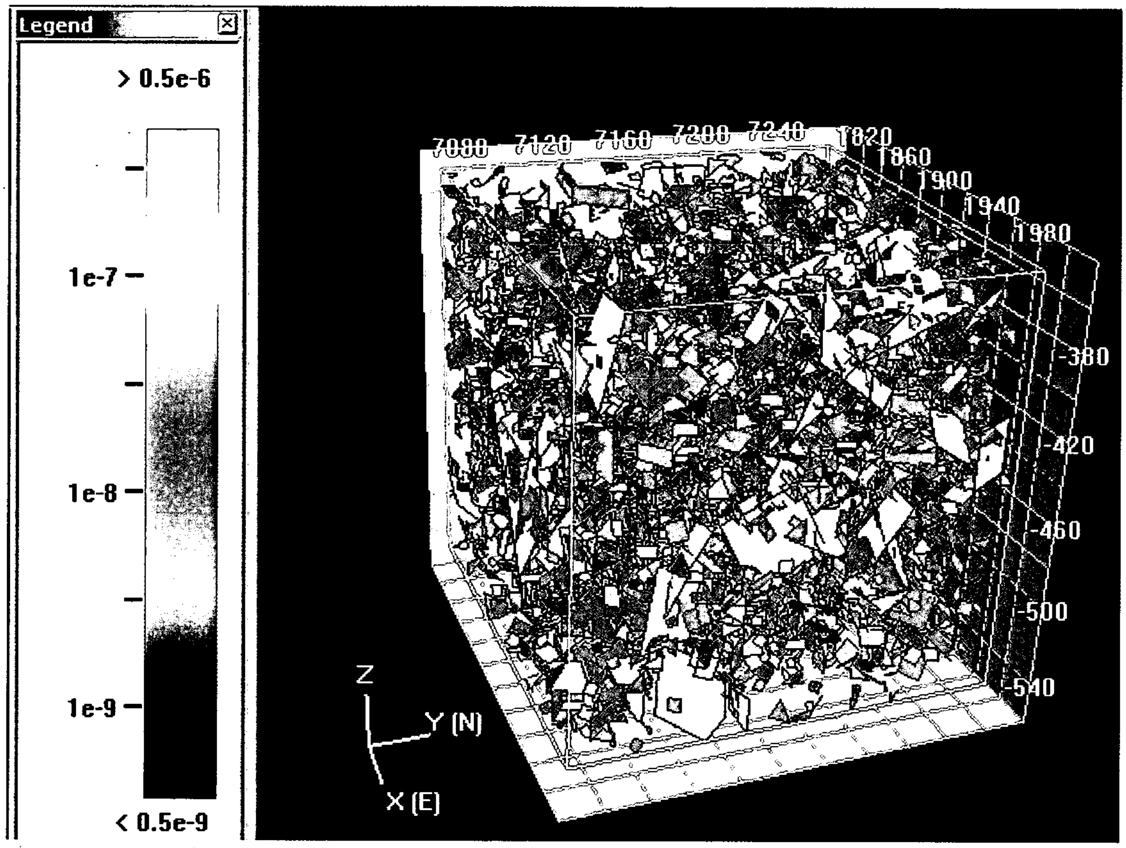

Figure 2-4. Background Fractures Coloured By Transmissivity (Log Scale)

3. HYDRAULIC INTERFERENCE ANALYSIS

The TRUE-BS Continuation project intends to carry out tracer tests within the TRUE-BS rock mass to evaluate:

- transport properties of longer pathways,
- properties of smaller "background" fractures on transport
- hydraulic connectivity or compartmentalization of the rock mass.

Golder Associates simulations of hydraulic interference were carried out to evaluate the properties and potential suitability of different transport pathways for this testing. In particular, the simulations were carried out to evaluate the implications of problems with the current TRUE-BS instrumentation, and potentials for improvement to that instrumentation. The TRUE-BS borehole array is illustrated in Figure 3-1

All major tracer tests carried out in the TRUE-BS rock mass so far have utilized borehole KI0023B. In particular, this is the borehole used for the Phase C tracer tests C1, C2, and C3. KI0023B is used as a sink because the current packer installation includes a short-circuit between structures #6 and #20 in section P7 of the borehole. The flow between structures #20 and #6 within packer interval P7 is 0.2 l/min, as measured by tracer dilution technique. This is one of the largest flows measured on the site, and indicates that P7 is serving as a significant conductor.

As a result of the presence of the conductor provided by packer interval KI0023B:P7 a number of alternative sinks in boreholes KI0025F, -F02, -F03, KA2563A and KI0025F risk losing tracer mass to this artificial sink. It is also not possible to use structure #20 in KI0023B as a source due to the flow in KI0023B:P7.

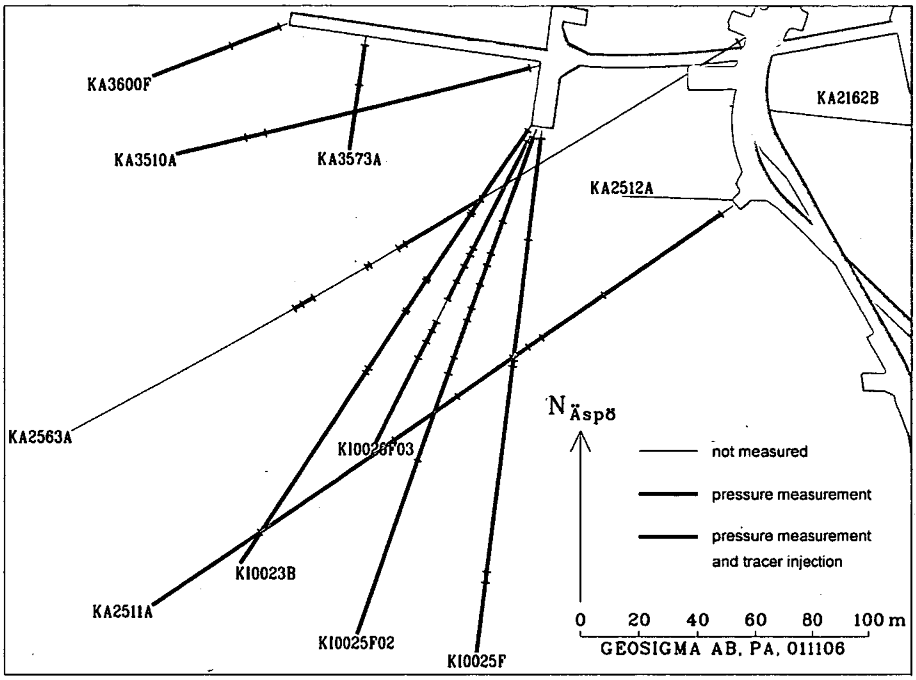

Figure 3-1. Borehole And Instrumentation Geometry at the TRUE Block Scale Site

The packer interval KI0023B:P6 works as a sink despite the short circuit in KI0023B:P7 because pumping from P6 provides an even lower head than that seen in P7. As a result, P6 has been tested extensively already, and is not very interesting as a sink for future tracer testing.

Golder Associates, together with GeoSigma and Conterra AB evaluated potential sink and source intervals for future testing. Table 3-1 and Table 3-2 list these possible source and sink intervals.

The intervals highlighted in green or blue are those for which FracMan interference and transport simulations have been carried out. In Table 3-1 and Table 3-2, italics indicate tests that are analysed both with and without remediation of KI0023B:P7, since the short circuit is expected to influence the testing.

Six of the sinks listed in Table 3-1 could also be used for testing background fracture transport pathways, and therefore also appear in Table 3-2. Table 3-3 describes the possible re-instrumentation of KI0023B used in the simulations for alternative sink instrumentation.

Table 3-1. Possible Sinks for Longer Distance Transport Pathways

	Sink	Struct #	Source	Struct #	Length (m)	Objective	Comment
f1	KA2563A:S4 Q=1.8 l/min	20	*KI0025F:R4*	*20*	*57*	*Long distance, single structure*	
f2	KI0023B:P2 (Q=2.0 l/min??)	19	*KI0025F:R2*	*19*	*84*	*Long distance, single structure*	*Need re-instrumentation of KI0023B, flow lines blocked?*
f3			*KI0025F:R1*	*Z*	*97*	*Long distance, network*	*Need re-instrumentation of KI0025F and KI0023B*
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
f5	KI0025F:R2 Q=3.5 l/min	19					
f6			*KA2563A:S3*	*13*	*119*	*Long distance, network*	
f7			*KI0023B:P2*	*19*	*84*	*Long distance, single structure*	*KI0023B should be optimized (shorter section), flow lines blocked*
f8			*KI0023B:P1*	*10*	*75*	*Long distance, network*	*Need re-instrumentation of KI0023B*
f9			KI0025F03:P1	19		Long distance, single structure	Need re-instrumentation of KI0025F03
f10	KI0025F02:P5 Q=2.5 l/min	20					
[redacted]			[redacted]	[redacted]	[redacted]	[redacted]	
f12			KI0025F03:P1	19	52	Long distance, single structure	Need re-instrumentation of KI0025F03
f13	KI0025F02:P6 Q=2.5 l/min	22	See comments				Same source sections as for KI0025F02:P5
f14	KI0025F03:P4 Q=1.2 l/min	21	*KA2563A:S1*	*19*	*50*	*Long distance, network*	
f15	KI0025F03:P5 Q=2.6 l/min	20					

Table 3-2. Possible Sinks for Background Fracture Transport Pathways

	Sink	Struct #	Source	Struct #	Length (m)	Objective	Comment
b1	KA2563A:S4 Q=1.8 l/min	20	*KI0023B:?*	*?*	*15-20*	*Background fractures or network*	*Optimization of KI0023B needed*
b2	KI0023B:P4 Q=0.5 l/min	13					
b3			*KI0025F03:P3*	*13*		*Background fracture?*	
b4	KI0023B:P6 Q=2.0 l/min	20/21	KI0025F03:?			Background fractures or network	Optimization of KI0025F03 needed
b5	KI0025F03:P4 Q=1.2 l/min	21	*KI0023B:P4*	*21*	*17*	*Background fracture network??*	
b6			*KI0023B:P5*	*?*	*17-20*	*Background fracture network??*	*Optimization of KI0023B needed*
b7			*KI0025F02:P3*	*13,21*	*16*	*Background fracture network??*	
b8	KI0025F03:P5 Q=2.6 l/min	20					
b9			*KI0023B:P5*	*?*	*15-20*	*Background fracture network??*	*Optimization of KI0023B needed*
b10			KI0025F02:P6	22	12	Background fracture network??	
b11			KI0025F02:P7	23	17	Background fracture network??	
b12	KI0025F03:P6 Q=0.8 l/min	22	KI0025F02:P6	22	10	Background fracture	Section progressively clogged during Phases A and B
[redacted]			[redacted]	[redacted]	[redacted]	[redacted]	
b14			*KI0023B:?*	*?*	*12-15*	*Background fracture network??*	*Optimization of KI0023B needed*
b14	KI0025F03:P7	23	KI0025F02:P7	23	9	Background fracture	
b15			KI0025F02:P6	22	8	Background fracture network??	
b17			*KI0023B:?*	*?*	*10-15*	*Background fracture network??*	*Optimization of KI0023B needed*
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
b19			KI0025F03:P4	21	17	Background fracture network??	
b20			KI0025F03:P6	22	17	Background fracture network??	
b21			KI0025F03:P7	23	21	Background fracture network??	
b22			*KI0023B:P4*	*13*	*22*	*Background fracture network??*	
b23							
b24	KI0025F02:P6 Q=2.5 l/min	22	KI0025F03:P6	22	10	Background fracture ?	
b25			KI0025F03:P7	23	15	Background fracture network??	
b26			*KI0023B:?*	*?*	*18-22*	*Background fracture network??*	*Optimization of KI0023B needed*

Table 3-3. Old and Tentative New Instrumentation of Borehole KI0023B

Old Sec.	Interval (m)	Struct	Bh length (m)	Flow* (l/min)	New Sec	Interval (m)
P1	113.7-200.7	#10 #?	169-171 141-146	16.00 2.00	R1	113.7-200.7
P2	111.3-112.7	#19	112	2.85	R2	111.3-200.7
P3	87.2-110.3	#?	87-88	0.02	R3	87.2-110.3
P4	84.8-86.2	#13	85.6	0.80	R4	77.0-86.0
P5	73.0-83.8	#? #?	75-76 72-75	0.02 0.30	R5	73.0-76.0
P6	71.0-72.0	#21	71.1	2.00	R6	71.0-72.0
P7	43.5-70.0	#20 #? #? #6	69.8 51-56 46-50 44.2	2.00 0.07 0.64 1.00	R7 R8	66.0-70.0 56.0-65.0 Blind 46.0-55.0
P8	41.5-42.5	#7	42.2	40		
P9	4.5-40.5	#? #5	31-32 8	2.00 5.00	R9	4.5-45.0

*Flow from open borehole (drawdown 4000 kPa) from double packer flow log (5 m sections) combined with hydraulic tests and measurements during drilling.

Simulations were carried out for all of the sink intervals indicated in green and blue in Table 3-1 and Table 3-2. For tests indicated in blue, the current packer configuration of KI0023B:P7 and the installation described in Table 3-3 was used. An example of the simulation results is provided in Figure 3-2.

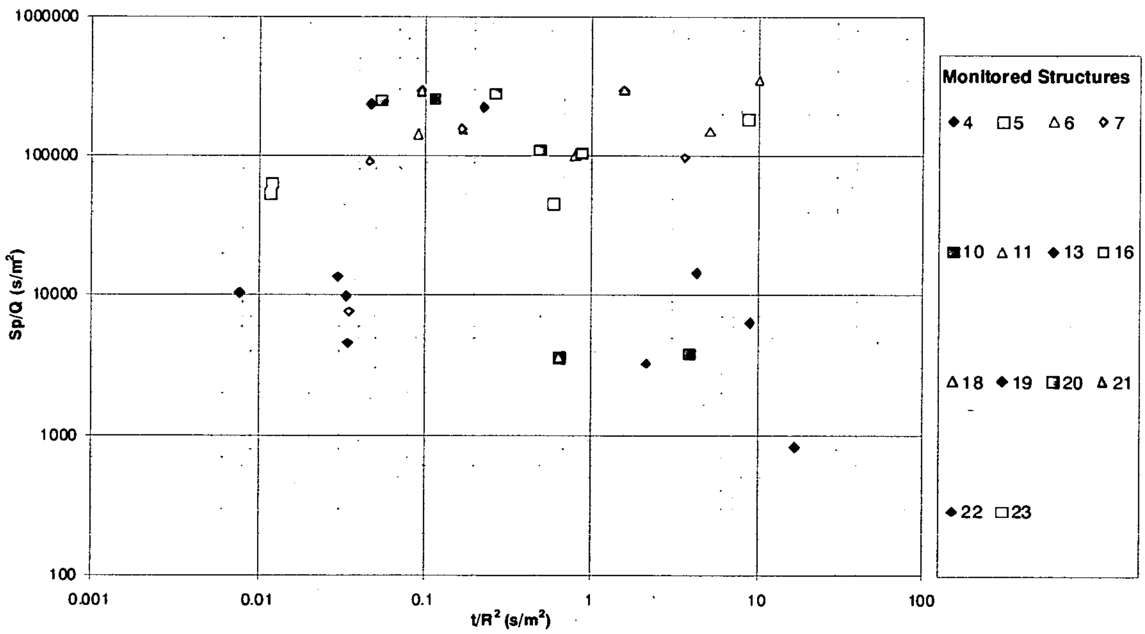

Figure 3-2. Simulation of Hydraulic Interference, KI0023B:P6 Sink, Not Remediated

4. SUMMARY

The analyses presenting in this report demonstrate that:

- There are a number of attractive pumping sections for both longer distance tracer testing, and tracer testing involving background fractures
- Many of these intervals require re-instrumentation of KI0023B, in order to eliminate the short circuit in interval P7.

5. REFERENCES

Andersson, P., J. Byegård, T. Doe, J. Hermanson, P. Meier, E.-L. Tullborg, and A. Winberg, 2002. "TRUE Block Scale Project Final Report – 1. Characterisation and model development", Swedish Nuclear Fuel and Waste Management Company (SKB), Technical Report TR-02-13. SKB, Stockholm

Dershowitz, W., A. Winberg, J. Hermanson, J. Byegård, E.L. Tullborg, P. Andersson, and M. Mazurek, 2003. A Semi-synthetic Model of Block Scale Conductive Structures at the Äspö Hard Rock Laboratory. SKB, Stockholm.

Dershowitz, W., M. Uchida, and K. Klise, 2002. Predictive Simulation and Evaluation, TRUE Block Scale Project. SKB, Stockholm.

APPENDIX D

GENERALIZED DIMENSION ANALYSIS
OF MIU-4 HYDRAULIC TESTS

MIU

UNDERGROUND ROCK LABORATORY

TECHNICAL NOTE

GENERALIZED DIMENSION ANALYSIS OF MIU-4 HYDRAULIC TESTS

Version 1.0

THOMAS DOE

CRISTIAN ENACHESCU

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1. INTRODUCTION

As part of the H-14 activities Golder Associates carried out FlowDim type curve analysis of eleven single hole tests from the MIU-4 borehole. The data sheets for the FlowDim analyses are provided as Appendices to this report.

2. TYPE CURVE ANALYSIS

FlowDim analysis results are provided in Table 2-1. Type curve analysis was carried out to match both time and derivative data. Figure 2-1 presents a summary of the pressure derivative curves. The derivatives are normalized with respect to pumping rate to allow direct comparison of the results. The pressure scale also has been recalculated to provide transmissivity values. The combined rate normalization and transmissivity calculation involves the following relationship: $T = Q / (4\pi \, t\mathrm{d}p / \mathrm{d}t)$. The common plotting of a number of test records allows a ready comparison of transmissivity values. Furthermore, similarities of derivative shape can indicate if different tests are affecting the same or different conducting features.

For each MIU-4 test, there were several flow and pumping phases. FlowDim analysis plots for all phases are provided as appendices. The rws or sws (recovery from pumping or slug) phases were selected as the most representative. These phases have the longest records and the highest quality, being least disturbed by pumping rate variations.

The selected rws and sws results are summarized in Table 2-2. Where the test analyses used composite type curves (inner and outer regions with different properties), Table 2-2 gives both the inner and outer zone transmissivities and flow dimensions. The dimensionless radius appears in the table as well, but it is unreliable because it depends on storativity, which cannot be separated from skin effects for source zone tests.

The pressure derivative curves for the MIU-4 tests fall into several groups which are as follows:

1. Tests 1 (Mizunami Group, 60-68m), 2 (Mizunami Group, 72-74m), and 9 (Tsukiyoshi Fault Core, 670-677m) are lower transmissivity intervals with dimensions of 2 or less.
2. Tests 3 (Weathered Granite, 83-117m), 4 (WCF in Toki Granite, 314-316m), 7 (Upper Highly Fractured Domain, 183-254m), 8 (Footwall, More Fractured Zone754-790m), 10 (Footwall, Sparsely Fractured, 690-753m), 11 (Lower Sparsely Fractured Domain, 500-562m), and 12 (Lower Sparsely Fractured Domain, 361-424m). These tests all have a dimension of two or slightly greater. They appear to have local regions with low transmissivity and connect with higher transmissivity regions within the first minute of

test. The records indicate stabilization into features with transmissivities between 2×10^{-6} and 3×10^{-5} m^2/s.

3. Test 6 (Hanging wall, 584-647) has an anomalously high apparent transmissivity which decreases with distance to about the same level as the group 2 tests.

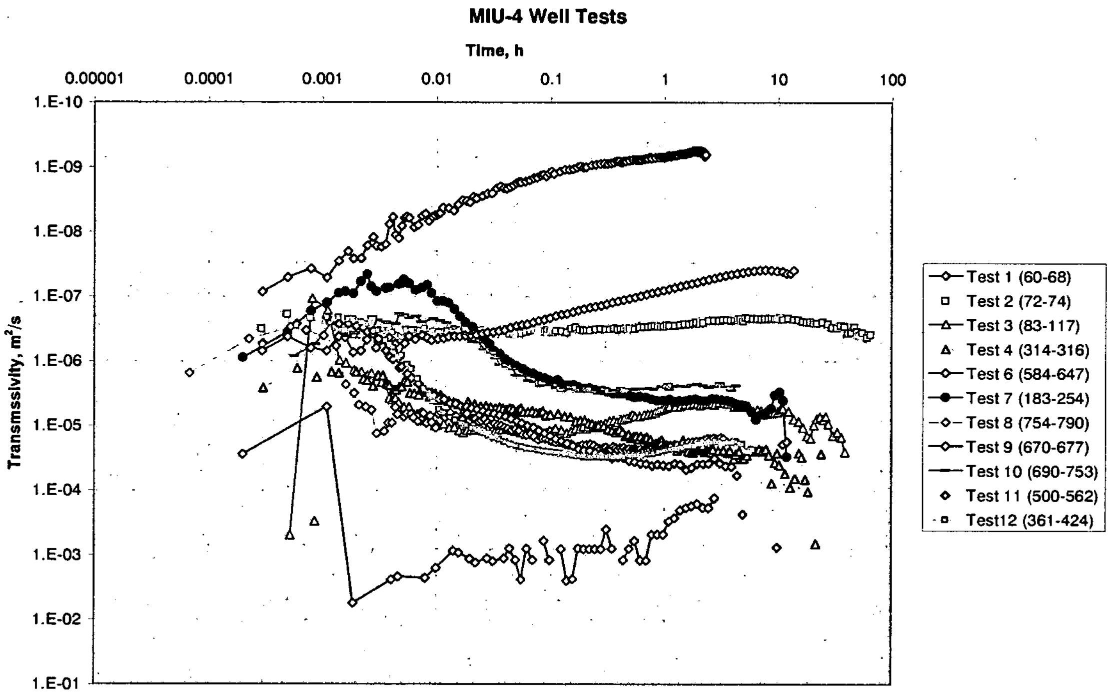

Figure 2-1. Pressure Derivative Analysis, MIU-4

Table 2-1. FlowDim Analysis of MIU-4

test no	top mabh	bottom mabh	phase	T1	n1	mob ratio	rd1	T2	n2	Notes
1	**68.45**	**78.02**	pw1	4.40E-09	2	10	6.8	4.40E-10	2	
Mizunami Group			pw2	5.30E-09	2	5.7	4.9	9.30E-10	2	
			pw3	3.40E-09	2	7	2.9	4.86E-10	2	
			sws	2.80E-09	2	3.3	25	8.48E-10	2	Also matches with perfect n=1.5
2	**82.5**	**88.6**	sw1	4.40E-07	2	2	10	2.20E-07	2	
Mizunami Group			sws1	6.60E-07	2	2.1	43	3.14E-07	2	
			sw2	7.30E-07	2	1.8	140	4.06E-07	2	
			sws2	9.70E-07	2	1.7	36	5.71E-07	2	
			rw	2.20E-07	2	1.6	98	1.38E-07	2	
			rws	3.40E-07	2	1.5	115	2.27E-07	2	good -2d
3	**95.02**	**134.47**	sw1	1.20E-06	2					
Weathered Granite			sws1	2.30E-06	2					S=1.7e-23; Good 2d with big skin
			sw2	9.00E-07	2					
			sws2	8.20E-06	2					
			rw	1.70E-06	2					
			rws	1.30E-05	2	2.7	1.30E+12	4.81E-06	2	
7	**183.2**	**254.2**	pw	1.10E-06	2	0.2	5.10E+01	5.50E-06	2	
Upper Highly Frac Domain			rw1	4.70E-07	2					
			rw2	9.10E-07	2					
			rws	1.00E-07	2	0.5	8.6	2.00E-07	2	n>2?
4	**315**	**317**	sw1	5.80E-06	2					
WCF in Sparse Frac Domain			sw2	1.30E-05	2					
			sws2	3.40E-05	2					
			pw	7.50E-07	2	24.3	100	3.09E-08	2	
			rw	5.20E-06	2	0.3	860	1.73E-05	2	
			rws	6.30E-06	2	0.3	5000	2.10E-05	2	3D flow? or 2, 2-D steps?
12	**361.6**	**424.1**	pw	1.50E-05	2	100	450	1.50E-07	2	
Lower Sparsely Frac Domain			sw	3.10E-07	2	0.1	10	3.10E-06	2	
			sws	3.10E-07	2.5	0.03	3600	1.03E-05	2	
			rw	9.90E-07	2	0.24	494	4.13E-06	2	
			rws	3.40E-07	2	1.9	6.5	1.79E-07	3	Best cirve
11	**500.3**	**562.8**	pw1	1.80E-05	2	7	516	2.57E-06	2	
Lower Sparsely Frac Domain			pw2	1.40E-05	2	25	180	5.60E-07	2	
			sw	3.00E-07	2	0.1	5	3.00E-06	2	
			sws	7.00E-07	2	5.6	86	1.25E-07	3	
			rw1	2.80E-06	2					
			rw2	6.10E-06	2					
			rw3	3.30E-06	2					
			rws	3.80E-07	2	5.6	19	6.79E-08	3	Best curve
6	**584**	**647.1**	sw2	5.50E-06	2	0.1	154	5.50E-05	2	
Hanging Wall			sws2	4.80E-06	2	0.01	20	4.80E-04	2	Big skin
			sw3	2.40E-05	2					
			rw	5.60E-05	2					
			rws	1.30E-05	2	0.01	20	1.30E-03	2	
	669.5	**677**	pw	9.30E-07	2	0.8	33	1.16E-06	2	
Tsukiyoshi Fault Core			pw2	4.50E-07	2	1.5	11.2	3.00E-07	2	
			sw	2.40E-07	2	5.2	22	4.62E-08	2	
			sws	5.70E-07	2	0.017	25	3.35E-05	[illegible]	
	690.5	**753**	pw1	7.80E-07	2	16	81	4.88E-08	2	
Footwall: Sparsely Fractured			pw2	7.00E-07	2	7.1	117	9.86E-08	[illegible]	
			sw	1.30E-07	2	2.6	4.3	5.00E-08	[illegible]	More like big skin
			sws	5.90E-07	2	0.1	57	5.90E-06	3	Best curve
	754.5	**790.1**	pw	1.17E-05	2	10	50	1.17E-06	2	
Footwall more fractured			rw	1.38E-05	2					
			rws	8.50E-07	2	0.9	35	9.44E-07	[illegible]	

Table 2-2. Summary Hydraulic Properties From FlowDim Analyses of MIU-4 Tests (rws only; sws if no rws)

Test	top	bottom	phase	T1	n1	mobility ratio	Dimensionless Composite Boundary	T2	n2
	m	m		m^2/s				m^2/s	
1	60	68	sws	2.8E-09	2	3.3	25	8.5E-10	2
2	72	77	rws	3.4E-07	2	1.5	115	2.3E-07	2
3	83	118	rws	1.3E-05	2	2.7	1.30E+12	4.8E-06	2
4	183	254	rws	1.0E-07	2	0.5	8.6	2.0E-07	2
6	315	317	rws	6.3E-06	2	0.3	5000	2.1E-05	2
7	362	434	rws	3.4E-07	2	1.9	6.5	1.8E-07	3
8	500	563	rws	3.8E-07	2	5.6	19	6.8E-08	3
9	584	647	rws	1.3E-05	2	0.01	20	1.3E-03	2
10	670	677	sws	5.7E-07	2	0.017	25	3.4E-05	1
11	691	753	sws	5.9E-07	2	0.1	57	5.9E-06	1.9
12	755	790	rws	8.5E-07	2	0.9	35	9.4E-07	2.4

3. CONCLUSIONS

Analysis of the MIU-4 test has provided insight concerning the hydraulic properties of the various formations at the MIU site. These analysis have supported development of the MIU hydrogeologic DFN model.

Appendix A: Flow Dim Analysis Report MIU4-01

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T1 (59.70 - 68.25)
Event name			:	PW1
Date			:	
Input file name			:	pw1.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	1.90E-03
Interval length	(h)	[m]	:	8.55E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	2.99E+02
Static formation pressure	(pi)	[kPa]	:	4.10E+02
Test duration	(tt)	[h]	:	1.98E+01
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	5.87E-16
Transmissivity	(Th)	[m2/s]	:	4.43E-09
Storage	(S)	[m/Pa]	:	1.44E-07
Storativity	(Sh)	[-]	:	1.41E-03
Skin	(s)	[-]	:	0.00E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	6.78E+00
Mobility ratio	(sg)	[-]	:	1.00E+01
Time match	(TM)	[1/h]	:	3.14E+00
Pressure match	(PM)	[1/kPa]	:	8.84E+00

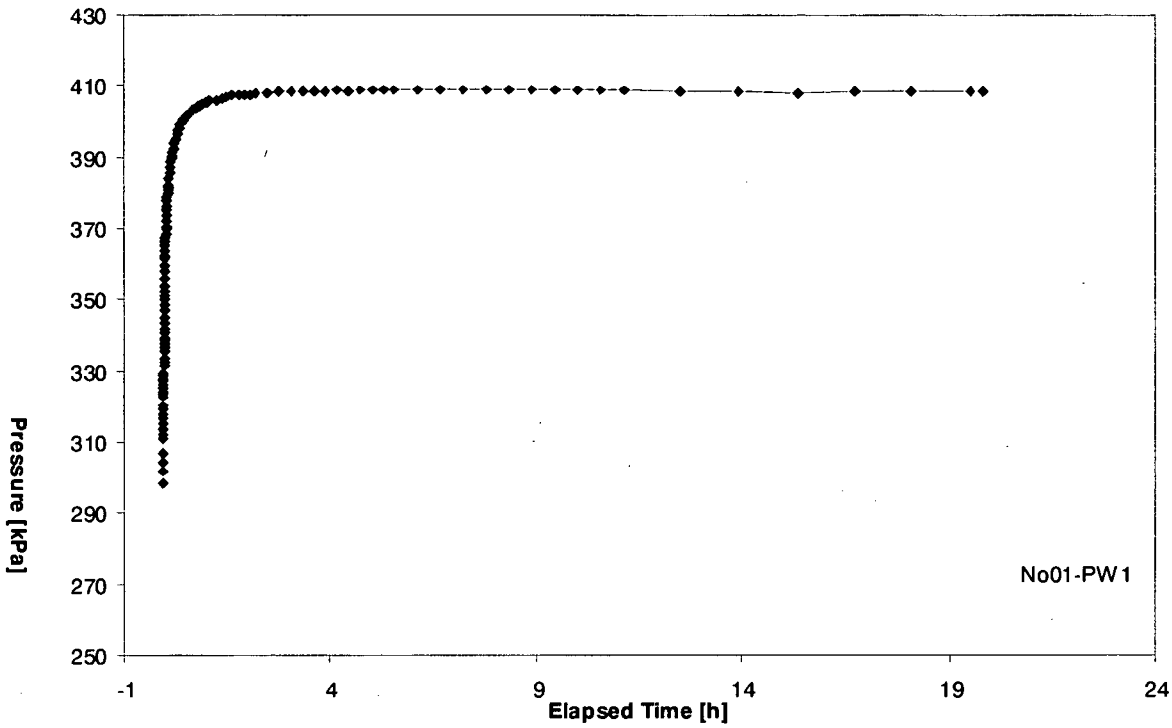

Fig. 1: CARTESIAN plot

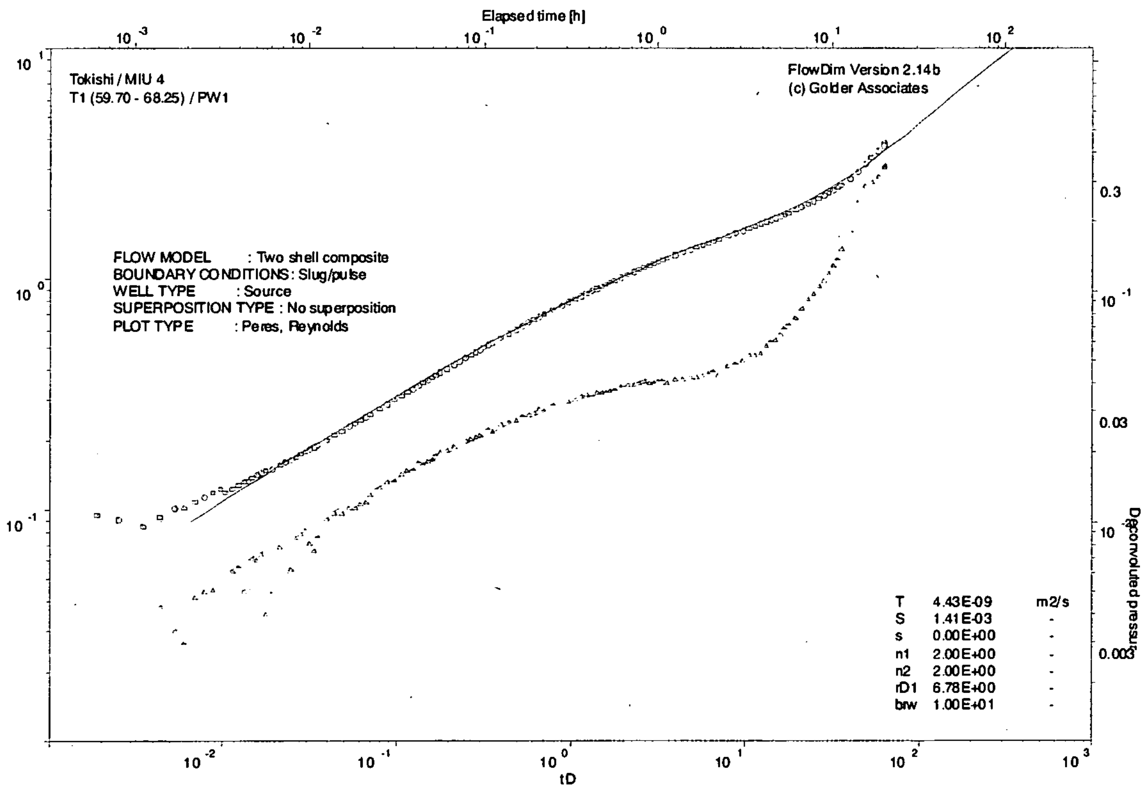

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T1 (59.70 - 68.25)
Event name			:	PW2
Date			:	
Input file name			:	pw2.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	4.80E-02
Tubing radius	(ru)	[m]	:	1.90E-03
Interval length	(h)	[m]	:	8.55E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	3.11E+02
Static formation pressure	(pi)	[kPa]	:	4.07E+02
Test duration	(tt)	[h]	:	9.40E+00
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	6.95E-16
Transmissivity	(Th)	[m2/s]	:	5.25E-09
Storage	(S)	[m/Pa]	:	7.99E-08
Storativity	(Sh)	[-]	:	7.83E-04
Skin	(s)	[-]	:	0.00E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	4.90E+00
Mobility ratio	(sg)	[-]	:	5.67E+00
Time match	(TM)	[1/h]	:	1.05E+01
Pressure match	(PM)	[1/kPa]	:	1.05E+01

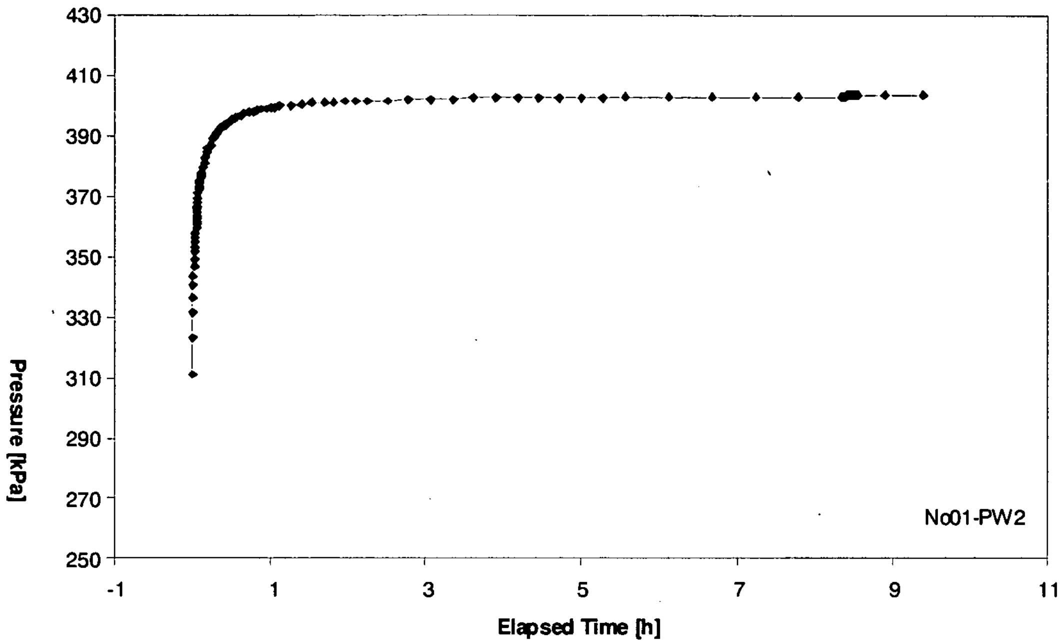

Fig. 1: CARTESIAN plot

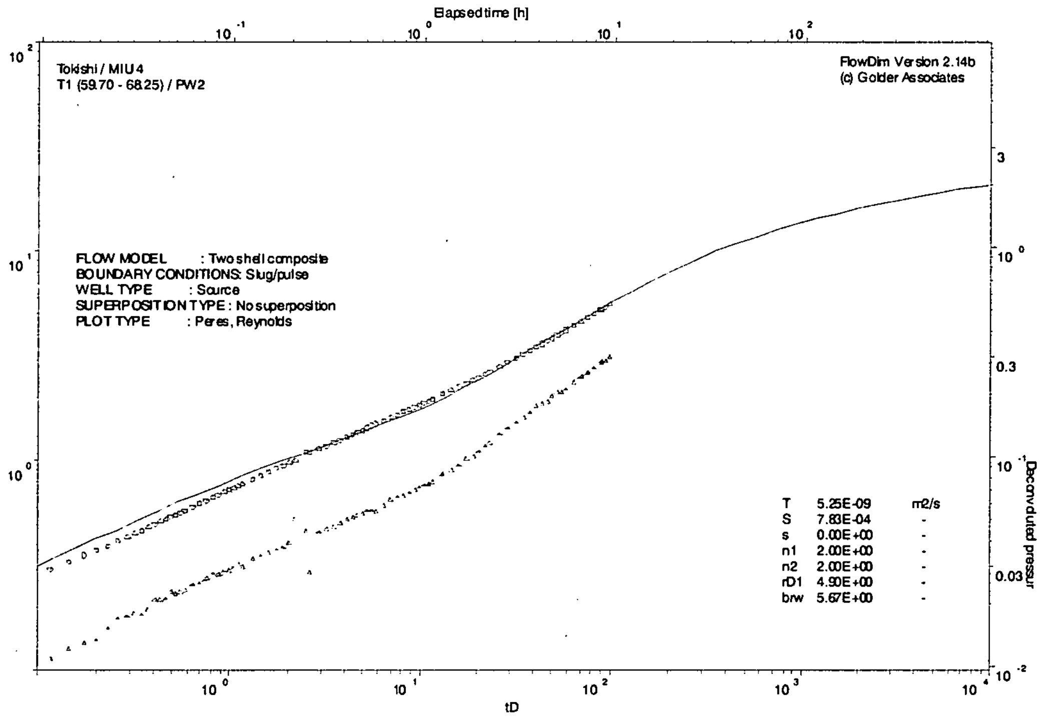

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T1 (59.70 - 68.25)
Event name			:	PW3
Date			:	
Input file name			:	pw3.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	1.90E-03
Interval length	(h)	[m]	:	8.55E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	3.05E+02
Static formation pressure	(pi)	[kPa]	:	4.07E+02
Test duration	(tt)	[h]	:	1.67E+01
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	5.10E-16
Transmissivity	(Th)	[m2/s]	:	3.85E-09
Storage	(S)	[m/Pa]	:	2.66E-07
Storativity	(Sh)	[-]	:	2.61E-03
Skin	(s)	[-]	:	0.00E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	2.88E+00
Mobility ratio	(sg)	[-]	:	6.97E+00
Time match	(TM)	[1/h]	:	1.47E+00
Pressure match	(PM)	[1/kPa]	:	7.67E+00

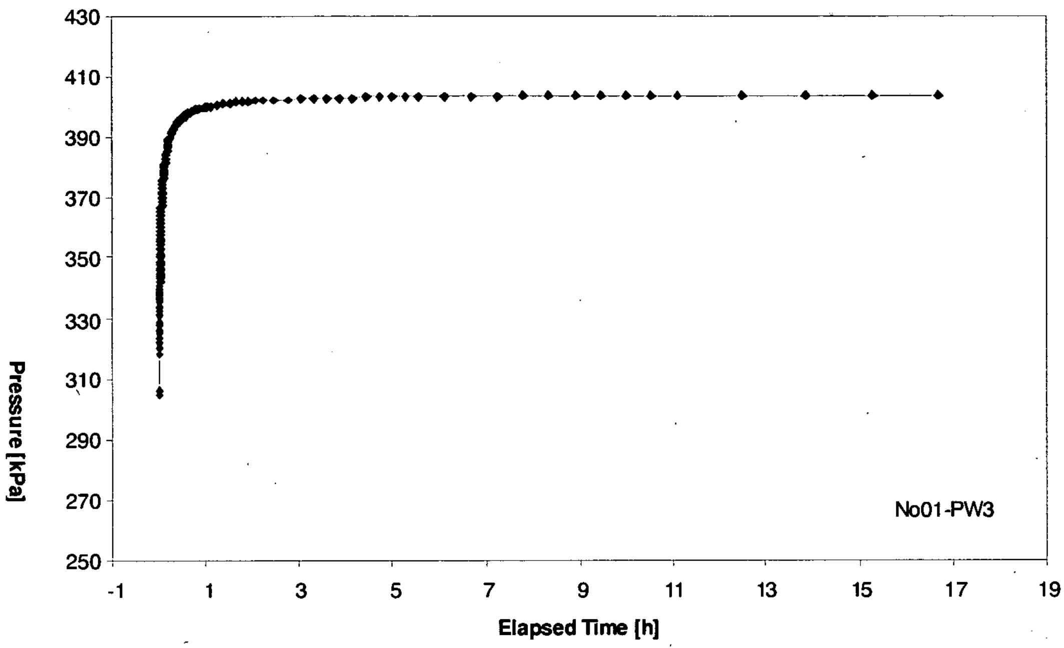

Fig. 1: CARTESIAN plot

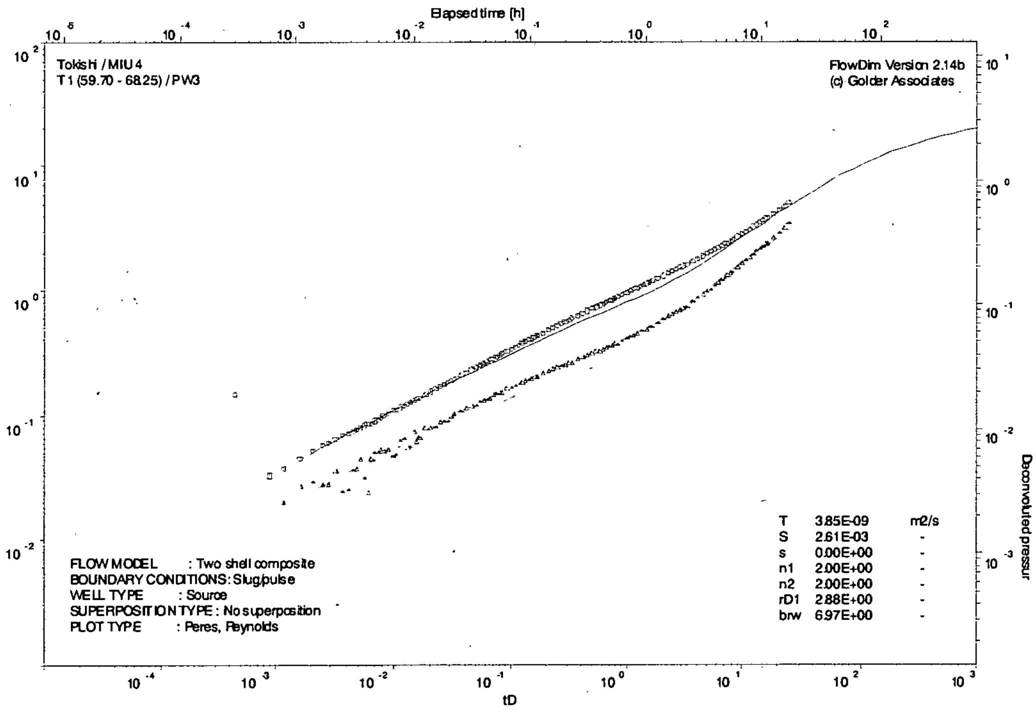

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T1 (59.70 - 68.25)
Event name			:	SWS
Date			:	
Input file name			:	sws.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	4.80E-02
Interval length	(h)	[m]	:	8.55E+00
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	2.47E+00
Flow rate	(q)	[l/min]	:	1.49E-03
Test duration	(tt)	[h]	:	2.30E+00
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Agarwal
TEST RESULTS				
Transmissibility	(T)	[m3]	:	3.64E-16
Transmissivity	(Th)	[m2/s]	:	2.74E-09
Storage	(S)	[m/Pa]	:	1.45E-10
Storativity	(Sh)	[-]	:	1.43E-06
Wellbore storage coefficient	(C)	[m3/Pa]	:	2.10E-10
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	2.52E+01
Mobility ratio	(sg)	[-]	:	3.25E+00
Time match	(TM)	[1/h]	:	3.00E+01
Pressure match	(PM)	[1/kPa]	:	7.07E-02

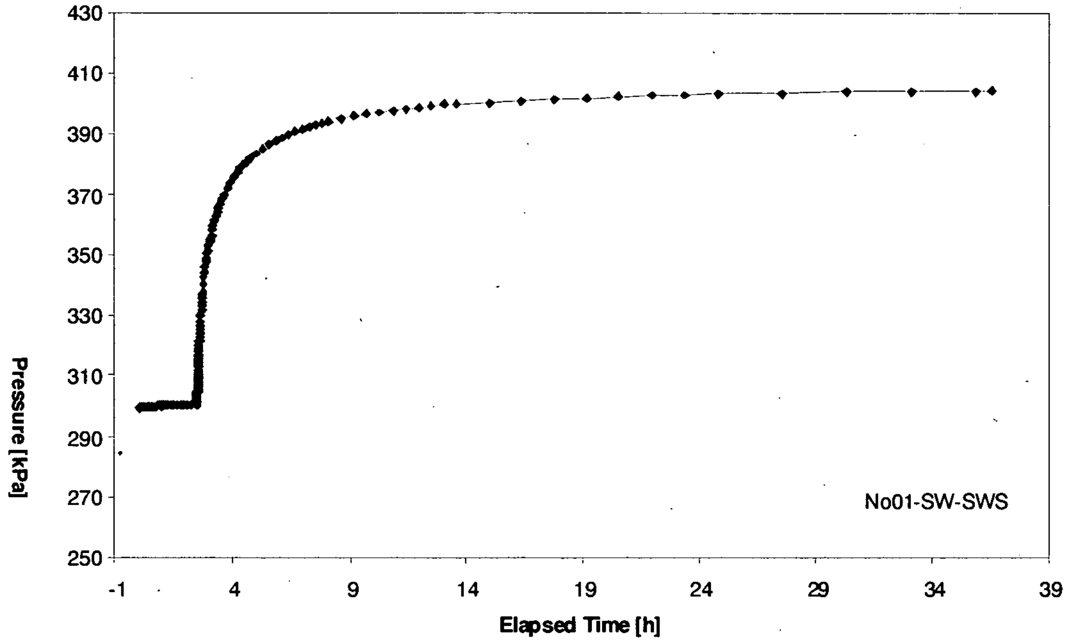

Fig. 1: CARTESIAN plot

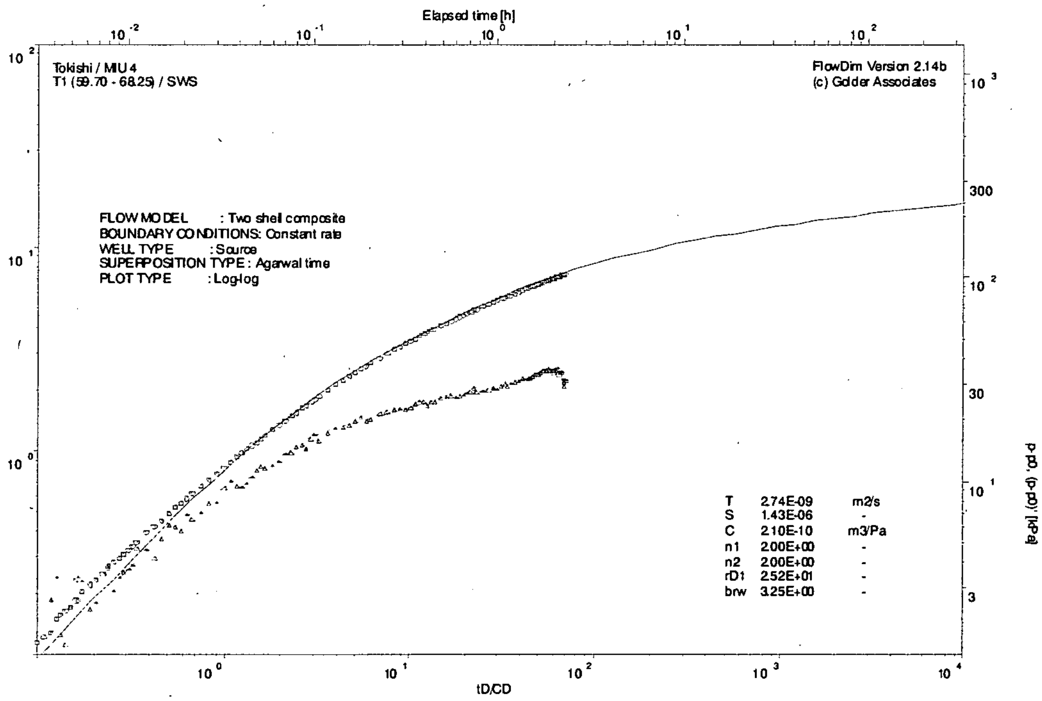

Fig. 2: Log-Log plot

Appendix B: Flow Dim Analysis Report MIU4-02

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T2 (72.00 - 77.44)
Event name			:	SW1
Date			:	
Input file name			:	sw1.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	3.92E-02
Interval length	(h)	[m]	:	5.44E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	4.28E+02
Static formation pressure	(pi)	[kPa]	:	4.93E+02
Test duration	(tt)	[h]	:	2.78E+00
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(認)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	5.77E-14
Transmissivity	(Th)	[m2/s]	:	4.35E-07
Storage	(S)	[m/Pa]	:	4.50E-07
Storativity	(Sh)	[-]	:	4.41E-03
Skin	(s)	[-]	:	3.00E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	1.00E+01
Mobility ratio	(sg)	[-]	:	2.00E+00
Time match	(TM)	[1/h]	:	9.86E+01
Pressure match	(PM)	[1/kPa]	:	2.04E+00

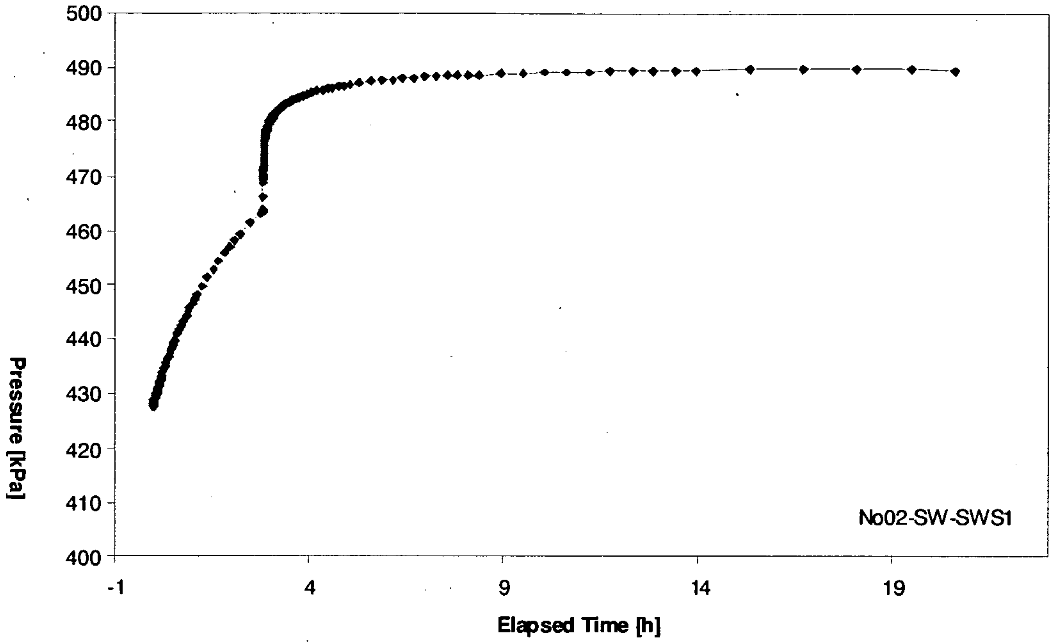

Fig. 1: CARTESIAN plot

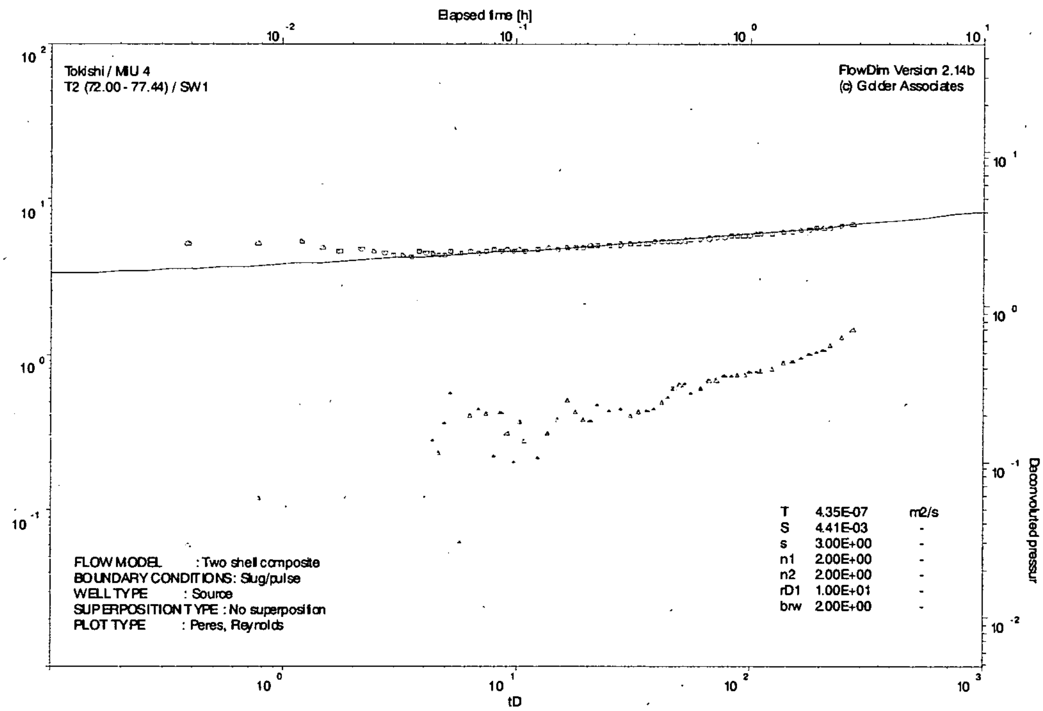

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T2 (72.00 - 77.44)
Event name			:	SWS1
Date			:	
Input file name			:	sws1.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	5.44E+00
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	2.82E+00
Flow rate	(q)	[l/min]	:	1.05E-01
Test duration	(tt)	[h]	:	2.35E+00
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Agarwal
TEST RESULTS				
Transmissibility	(T)	[m3]	:	8.79E-14
Transmissivity	(Th)	[m2/s]	:	6.64E-07
Storage	(S)	[m/Pa]	:	9.72E-09
Storativity	(Sh)	[-]	:	9.54E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	2.20E-10
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	4.25E+01
Mobility ratio	(sg)	[-]	:	2.07E+00
Time match	(TM)	[1/h]	:	6.96E+03
Pressure match	(PM)	[1/kPa]	:	2.44E-01

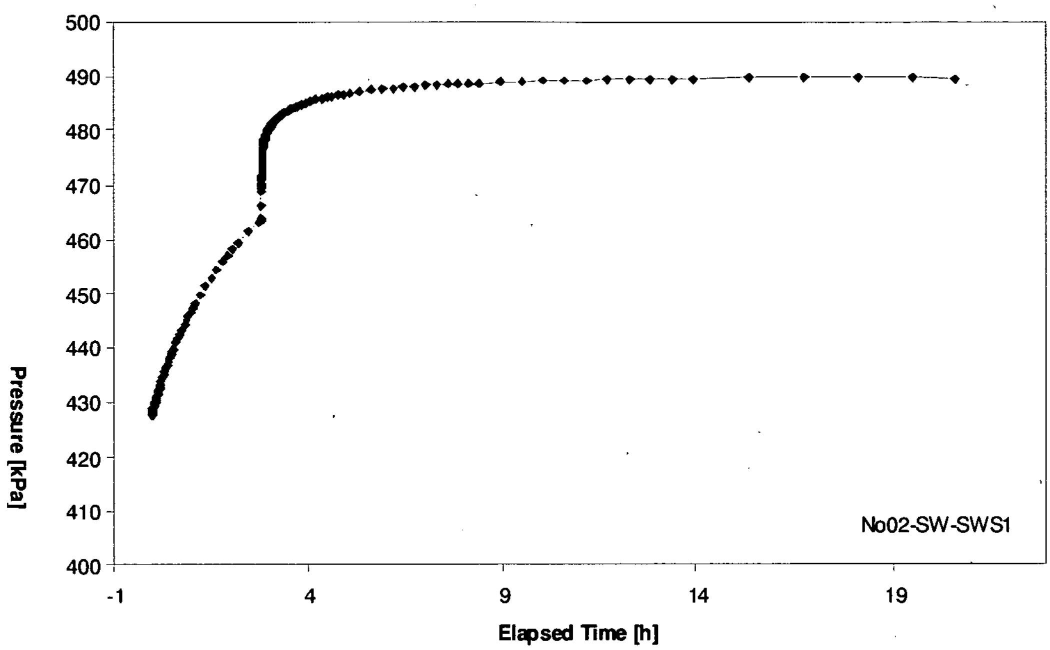

Fig. 1: CARTESIAN plot

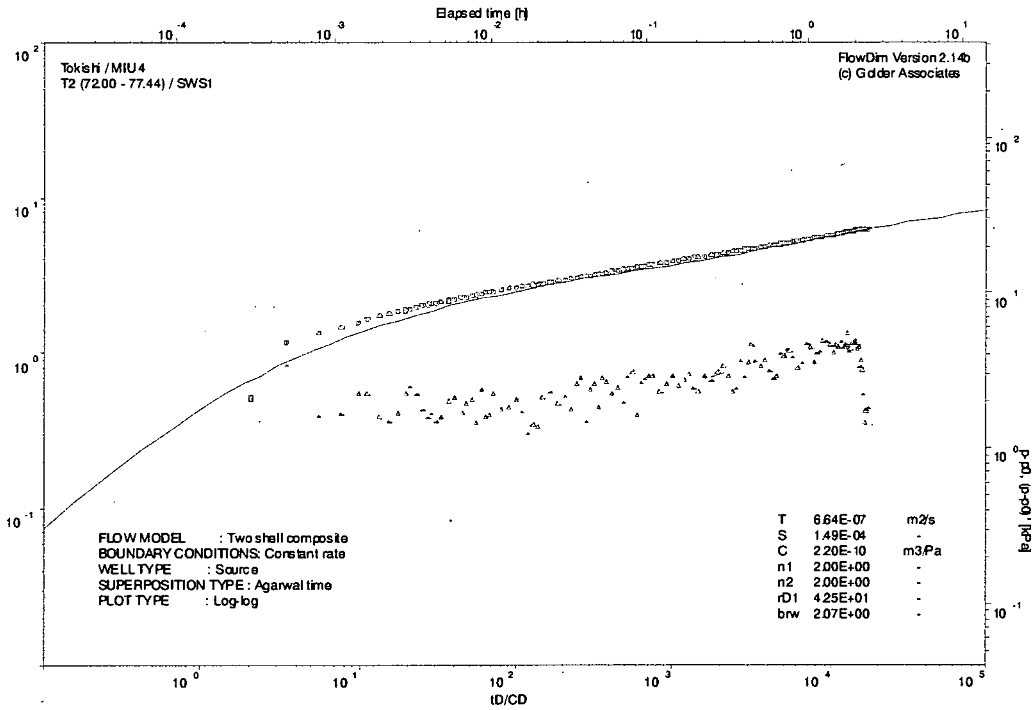

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T2 (72.00 - 77.44)
Event name			:	SW2
Date			:	
Input file name			:	sw2.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	3.92E-02
Interval length	(h)	[m]	:	5.44E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	2.91E+02
Static formation pressure	(pi)	[kPa]	:	4.85E+02
Test duration	(tt)	[h]	:	1.33E+00
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	9.65E-14
Transmissivity	(Th)	[m2/s]	:	7.28E-07
Storage	(S)	[m/Pa]	:	4.37E-09
Storativity	(Sh)	[-]	:	4.28E-05
Skin	(s)	[-]	:	5.00E-01
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	1.42E+02
Mobility ratio	(sg)	[-]	:	1.80E+00
Time match	(TM)	[1/h]	:	2.66E+04
Pressure match	(PM)	[1/kPa]	:	3.41E+00

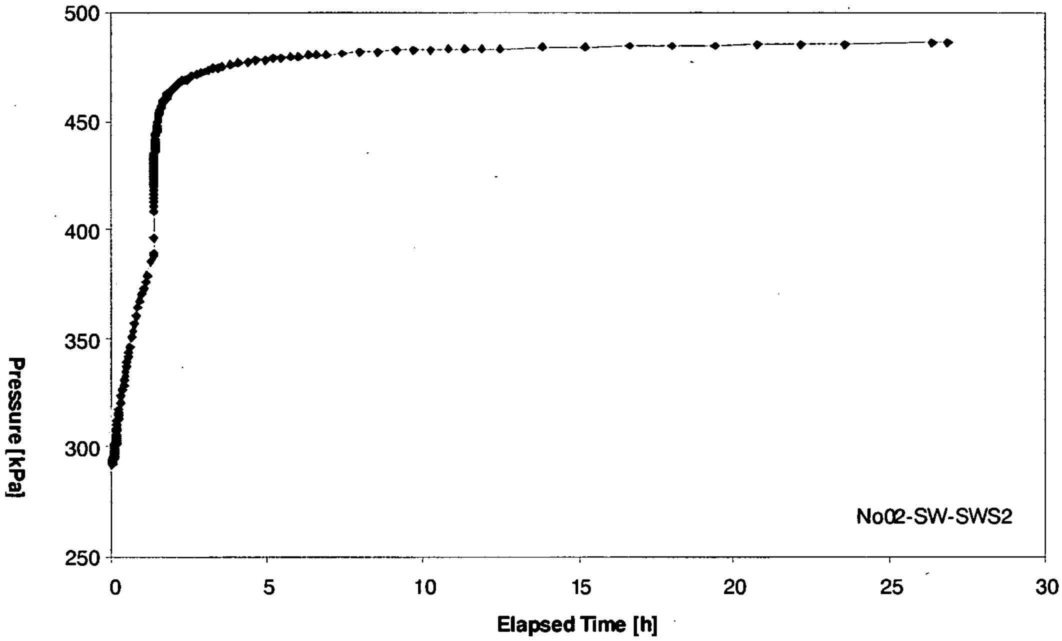

Fig. 1: CARTESIAN plot

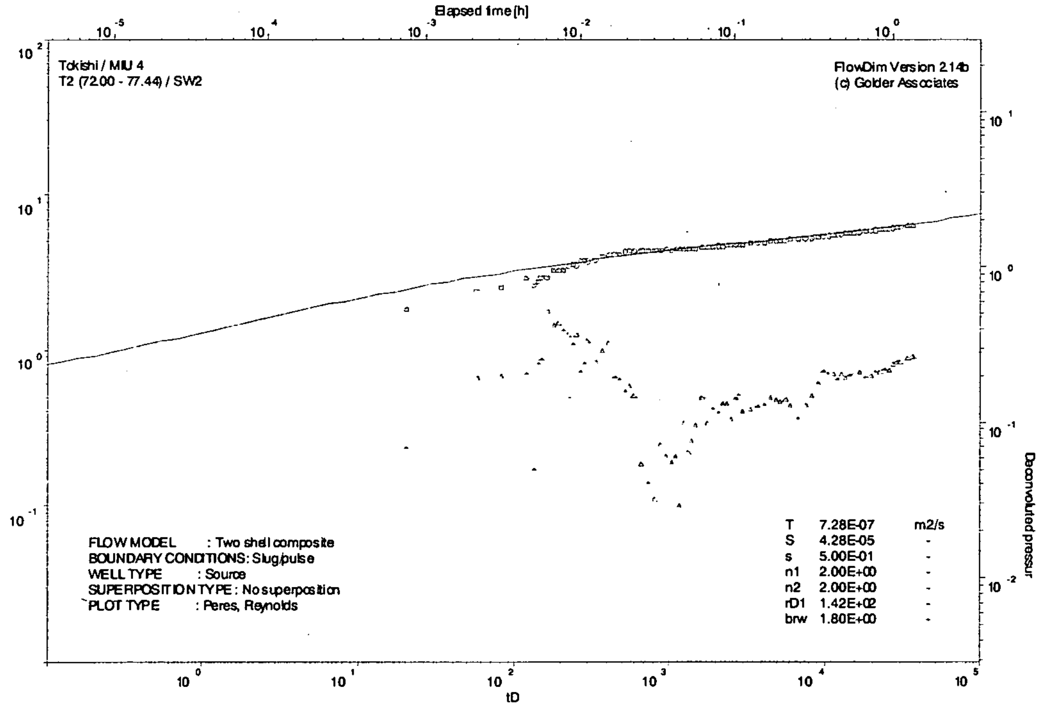

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T2 (72.00 - 77.44)
Event name			:	SWS2
Date			:	
Input file name			:	sws2.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	5.44E+00
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	1.3199
Flow rate	(q)	[l/min]	:	5.94E-01
Test duration	(tt)	[h]	:	1.25E+00
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Agarwal
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.29E-13
Transmissivity	(Th)	[m2/s]	:	9.73E-07
Storage	(S)	[m/Pa]	:	1.49E-08
Storativity	(Sh)	[-]	:	1.46E-04
Wellbore storage coefficient	(C)	[m3/Pa]	:	3.37E-10
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	3.55E+01
Mobility ratio	(sg)	[-]	:	1.70E+00
Time match	(TM)	[1/h]	:	6.66E+03
Pressure match	(PM)	[1/kPa]	:	6.29E-02

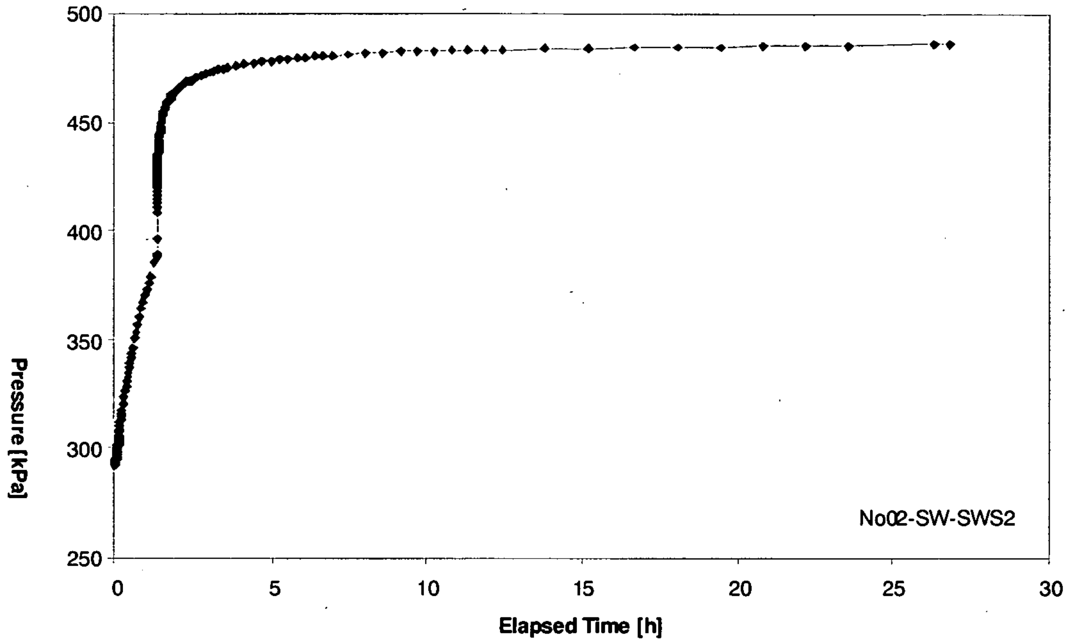

Fig. 1: CARTESIAN plot

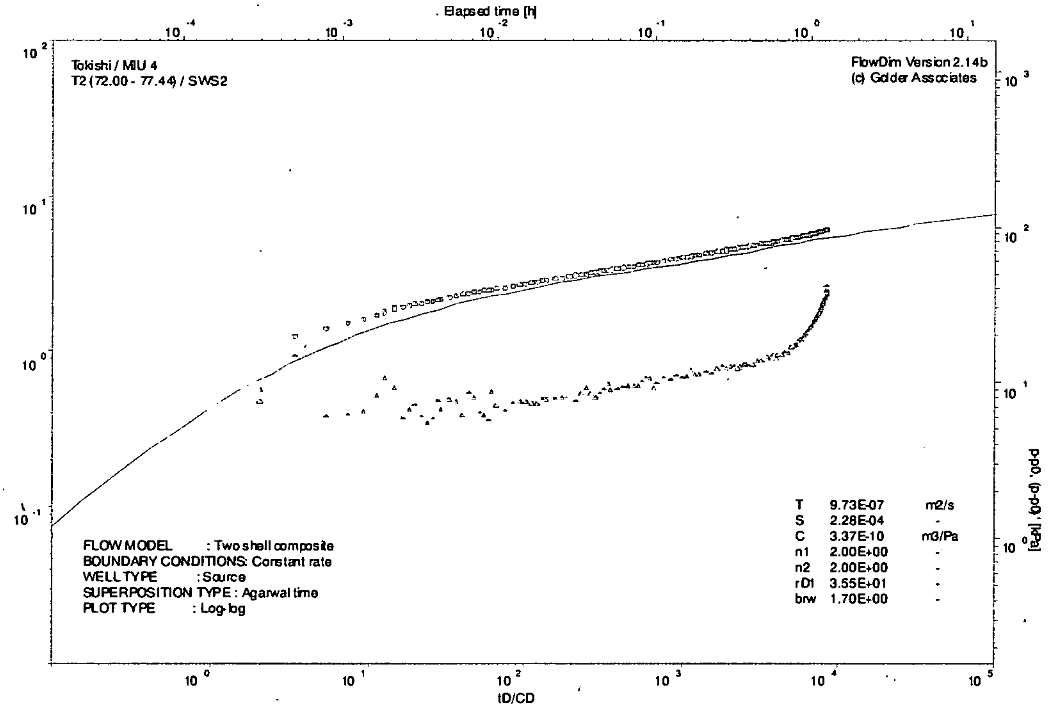

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT				13.09.2002
IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T2 (72.00 - 77.44)
Event name			:	RW
Date			:	
Input file name			:	rw.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	5.44E+00
TESTPARAMETERS				
Flow rate	(q)	[l/min]	:	3.46E-01
Test duration	(tt)	[h]	:	5.28E+01
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	2.857E-14
Transmissivity	(Th)	[m2/s]	:	2.16E-07
Storage	(S)	[m/Pa]	:	1.36E-07
Storativity	(Sh)	[-]	:	1.33E-03
Wellbore storage coefficient	(C)	[m3/Pa]	:	3.07E-07
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	9.80E+01
Mobility ratio	(sg)	[-]	:	1.93E-01
Time match	(TM)	[1/h]	:	1.62E+00
Pressure match	(PM)	[1/kPa]	:	2.39E-02

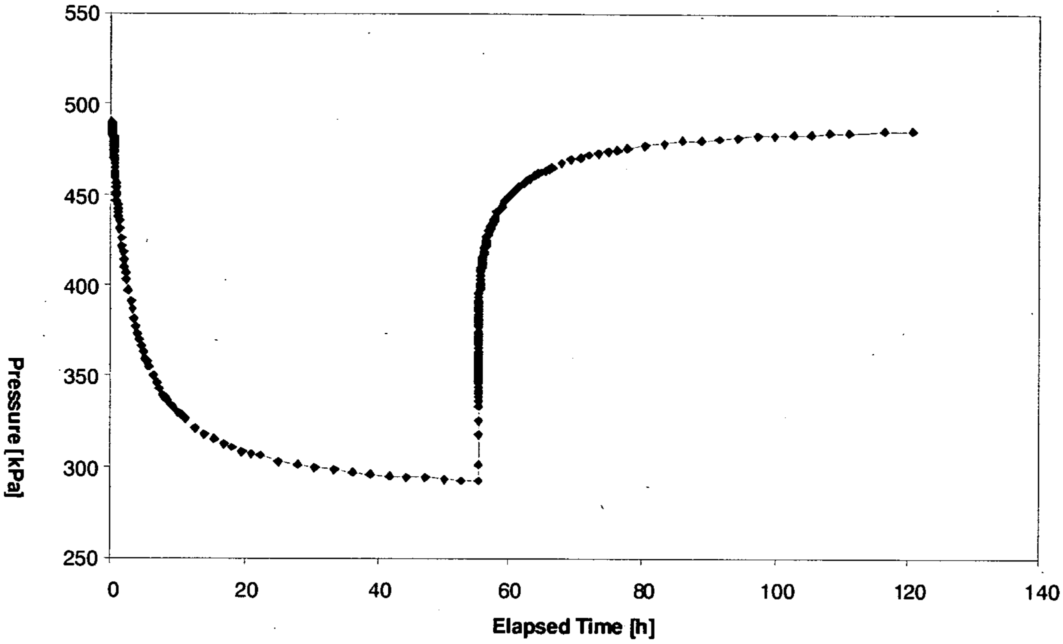

Fig. 1: CARTESIAN plot

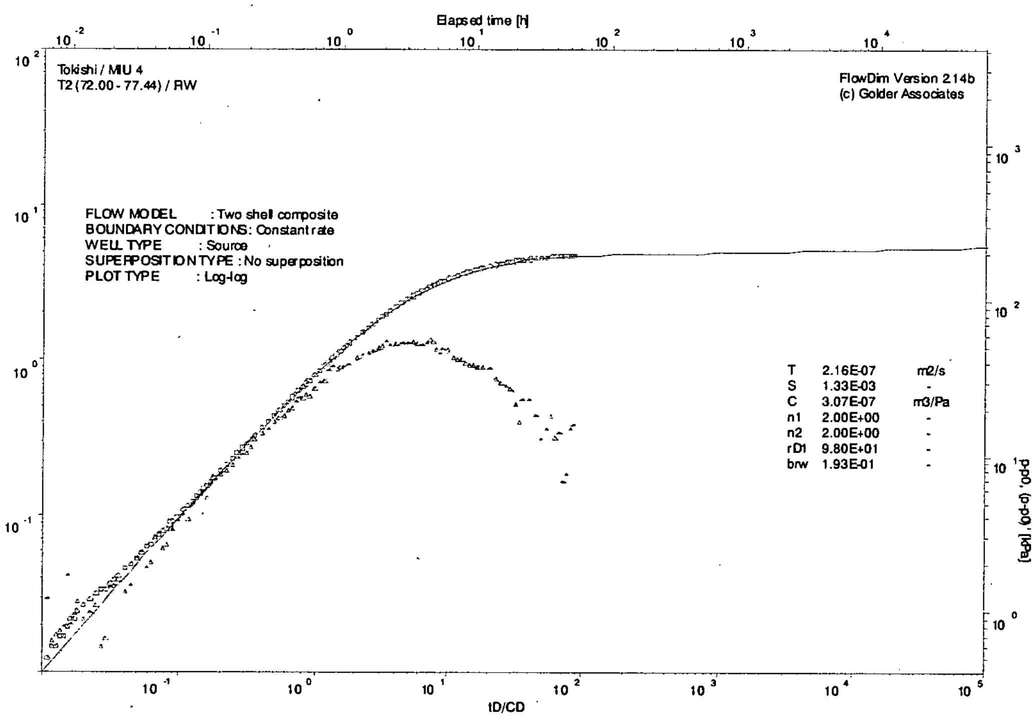

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T2 (72.00 - 77.44)
Event name			:	RWS
Date			:	
Input file name			:	rws.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	5.44E+00
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	5.53E+01
Flow rate	(q)	[l/min]	:	3.46E-01
Test duration	(tt)	[h]	:	6.55E+01
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Buildup
TEST RESULTS				
Transmissibility	(T)	[m3]	:	4.49E-14
Transmissivity	(Th)	[m2/s]	:	3.39E-07
Storage	(S)	[m/Pa]	:	3.29E-09
Storativity	(Sh)	[-]	:	3.22E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	2.23E-10
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	1.15E+02
Mobility ratio	(sg)	[-]	:	1.54E+00
Time match	(TM)	[1/h]	:	3.50E+03
Pressure match	(PM)	[1/kPa]	:	3.76E-02

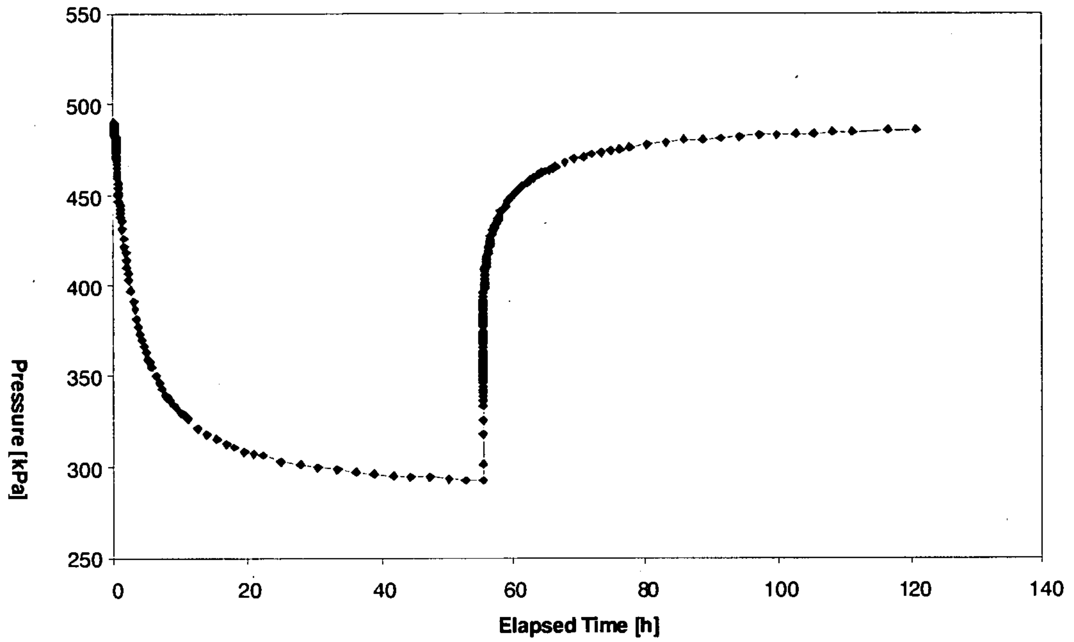

Fig. 1: CARTESIAN plot

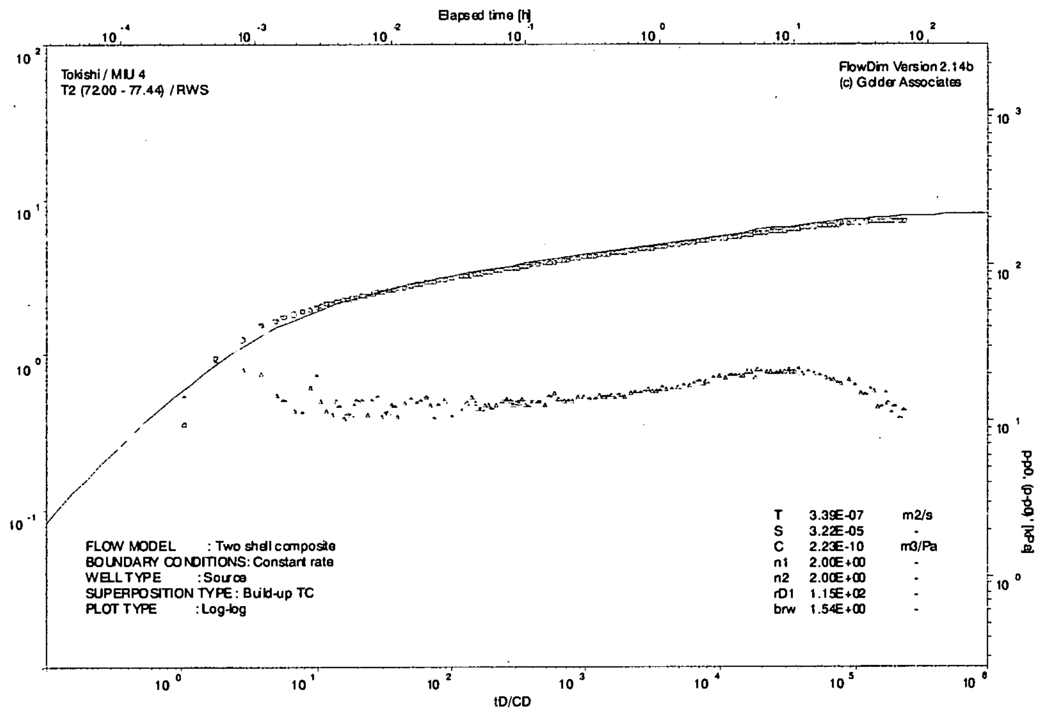

Fig. 2: Log-Log plot

Appendix C: Flow Dim Analysis Report MIU4-03

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T3 (83.03 - 117.84)
Event name			:	SW1
Date			:	
Input file name			:	sw1.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	3.92E-02
Interval length	(h)	[m]	:	3.48E+01
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	3.18E+02
Static formation pressure	(pi)	[kPa]	:	5.93E+02
Test duration	(tt)	[h]	:	3.34E-01
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	DP-PSS
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.61E-13
Transmissivity	(Th)	[m2/s]	:	1.21E-06
Storage	(S)	[m/Pa]	:	2.18E-09
Storativity	(Sh)	[-]	:	2.13E-05
Skin	(s)	[-]	:	0.00E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Lambda	(La)	[-]	:	1.35E-04
Omega	(Om)	[-]	:	7.01E-01
Time match	(TM)	[1/h]	:	5.68E+04
Pressure match	(PM)	[1/kPa]	:	5.68E+00

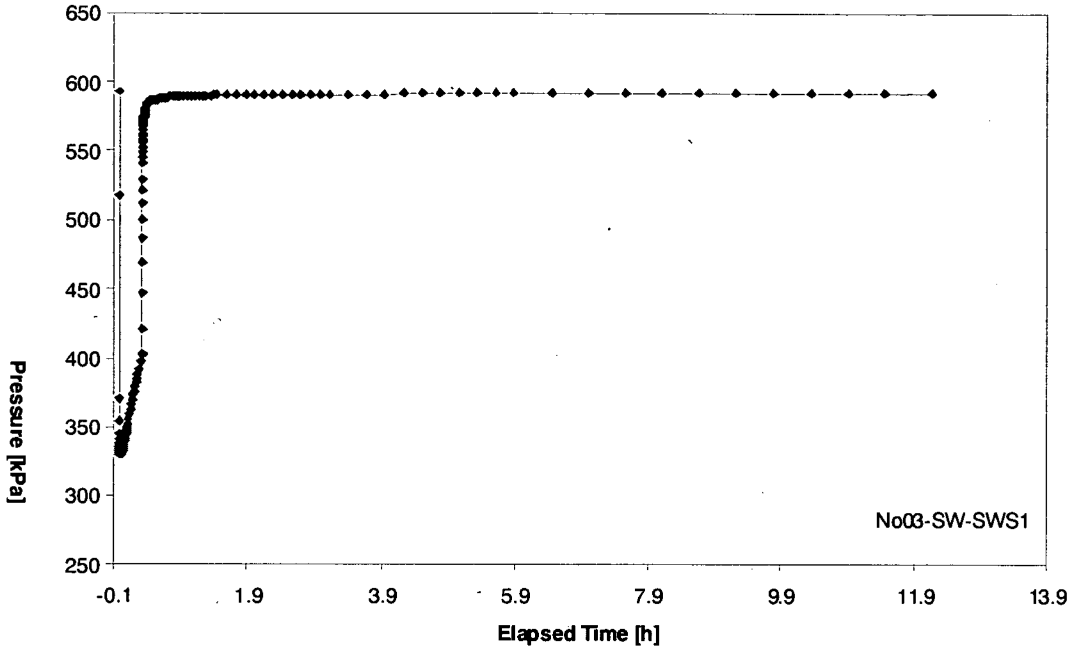

Fig. 1: CARTESIAN plot

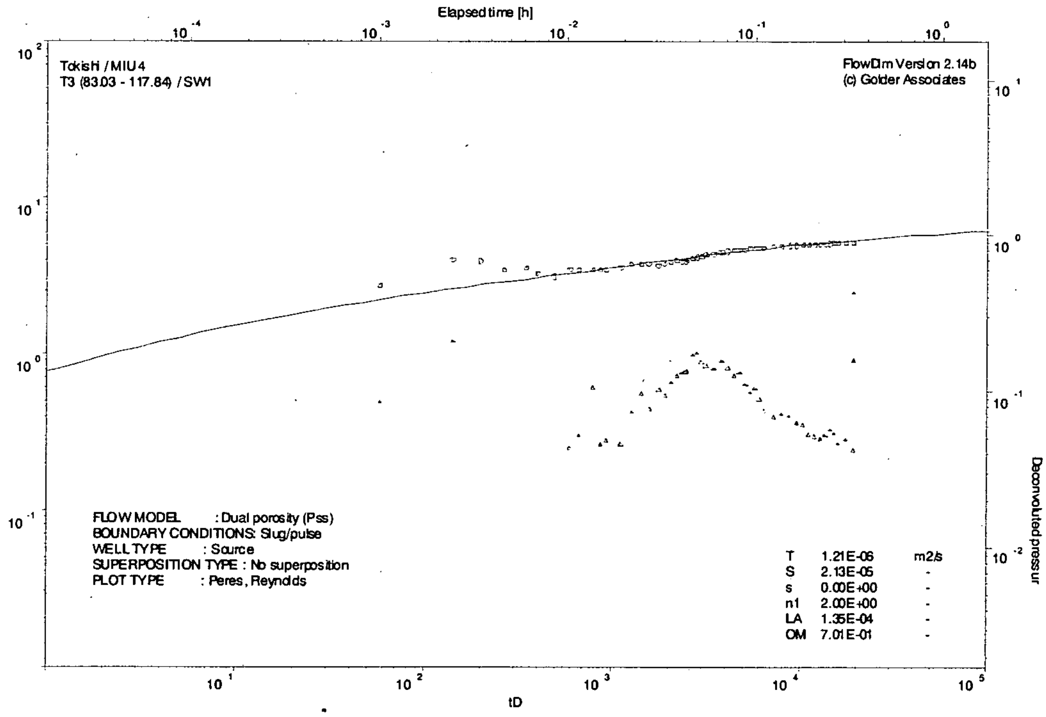

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T3 (83.03 - 117.84)
Event name			:	SWS1
Date			:	
Input file name			:	sws1.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	3.48E+01
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	3.15E-01
Flow rate	(q)	[l/min]	:	7.67E-01
Test duration	(tt)	[h]	:	3.06E-01
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Homogeneous
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Agarwal
TEST RESULTS				
Transmissibility	(T)	[m3]	:	3.02E-13
Transmissivity	(Th)	[m2/s]	:	2.28E-06
Storage	(S)	[m/Pa]	:	1.66E-23
Storativity	(Sh)	[-]	:	1.63E-19
Wellbore storage coefficient	(C)	[m3/Pa]	:	3.66E-10
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Time match	(TM)	[1/h]	:	1.44E+04
Pressure match	(PM)	[1/kPa]	:	1.15E-01

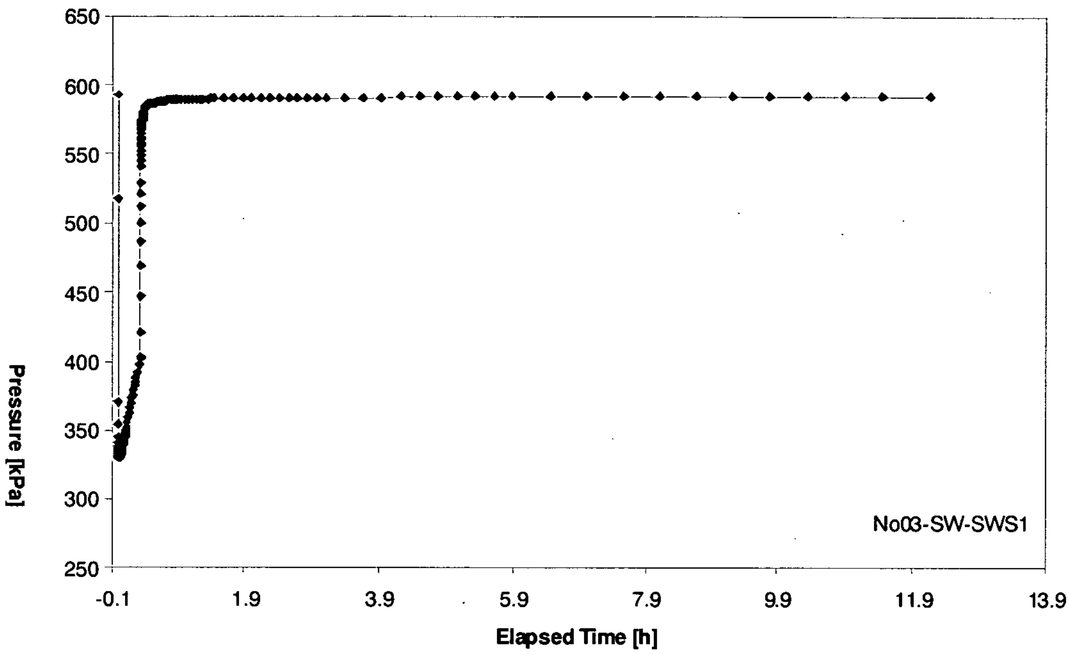

Fig. 1: CARTESIAN plot

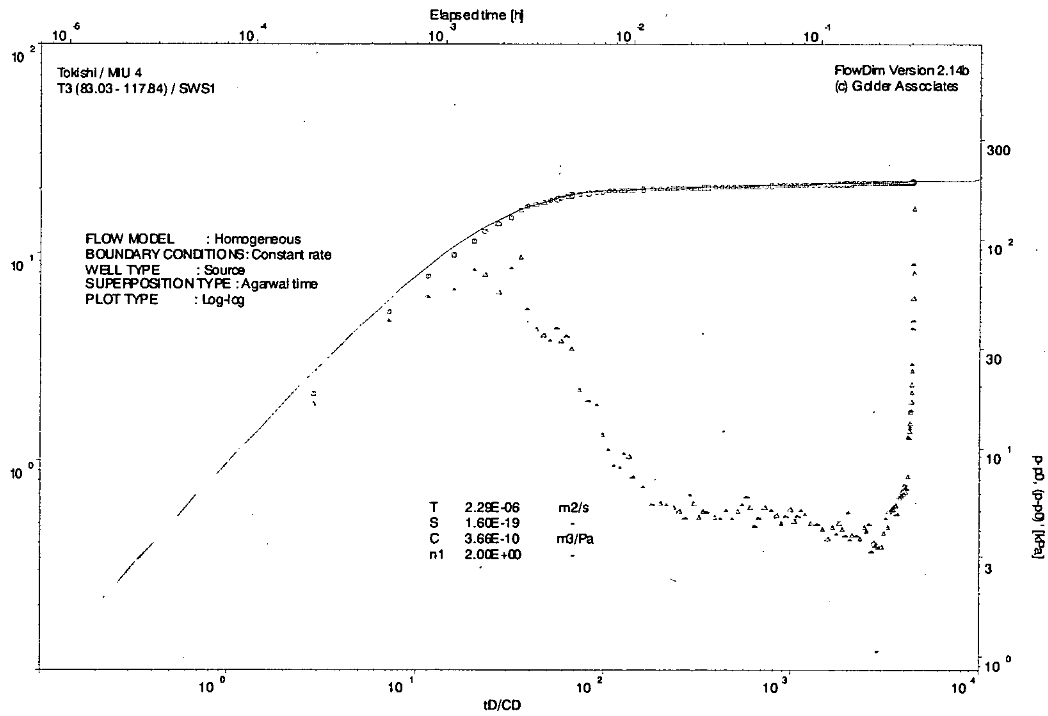

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION			
Site name			: Tokishi
Well name			: MIU 4
Interval name			: T3 (83.03 - 117.84)
Event name			: SW2
Date			:
Input file name			: sw2.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Tubing radius	(ru)	[m]	: 3.92E-02
Interval length	(h)	[m]	: 3.48E+01
TESTPARAMETERS			
Initial slug pressure	(p0)	[kPa]	: 3.49E+02
Static formation pressure	(pi)	[kPa]	: 5.91E+02
Test duration	(tt)	[h]	: 3.58E-01
FLUID AND FORMATION PARAMETERS			
Density	(d)	[kg/m3]	: 1.00E+03
Viscosity	(誣)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Homogeneous
Boundary conditions			: Slug/Pulse
Well type			: Source
Superposition type			: Drawdown
TEST RESULTS			
Transmissibility	(T)	[m3]	: 1.19E-13
Transmissivity	(Th)	[m2/s]	: 8.95E-07
Storage	(S)	[m/Pa]	: 2.18E-09
Storativity	(Sh)	[-]	: 2.13E-05
Skin	(s)	[-]	: 0.00E+00
Inner shell flow dimension	(n1)	[-]	: 1.84E+00
Time match	(TM)	[1/h]	: 6.27E+04
Pressure match	(PM)	[1/kPa]	: 8.00E+00

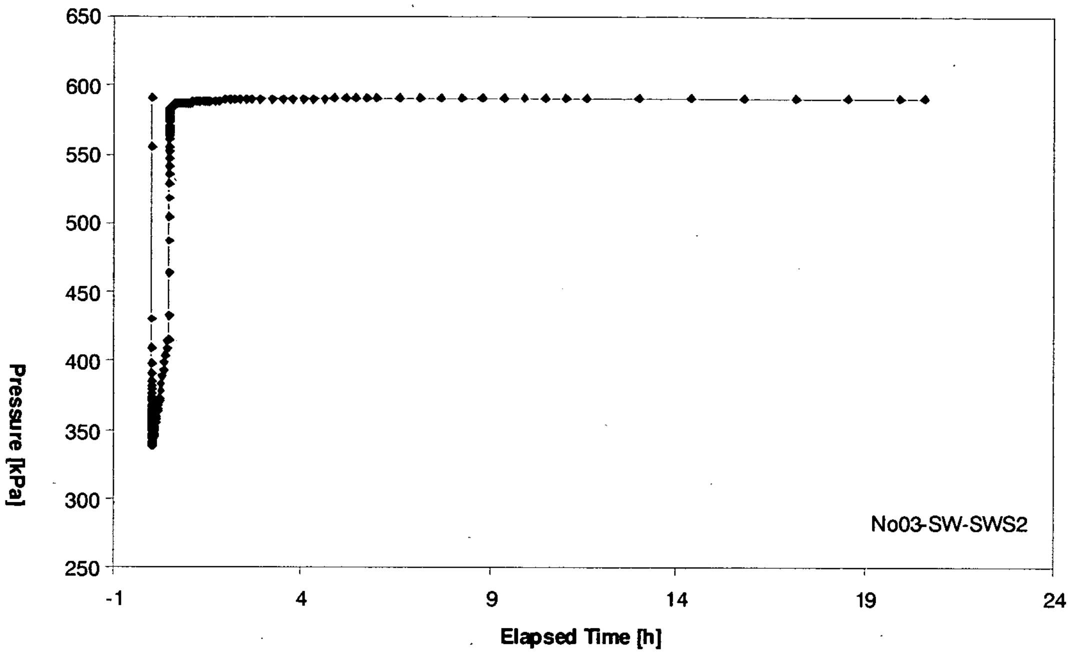

Fig. 1: CARTESIAN plot

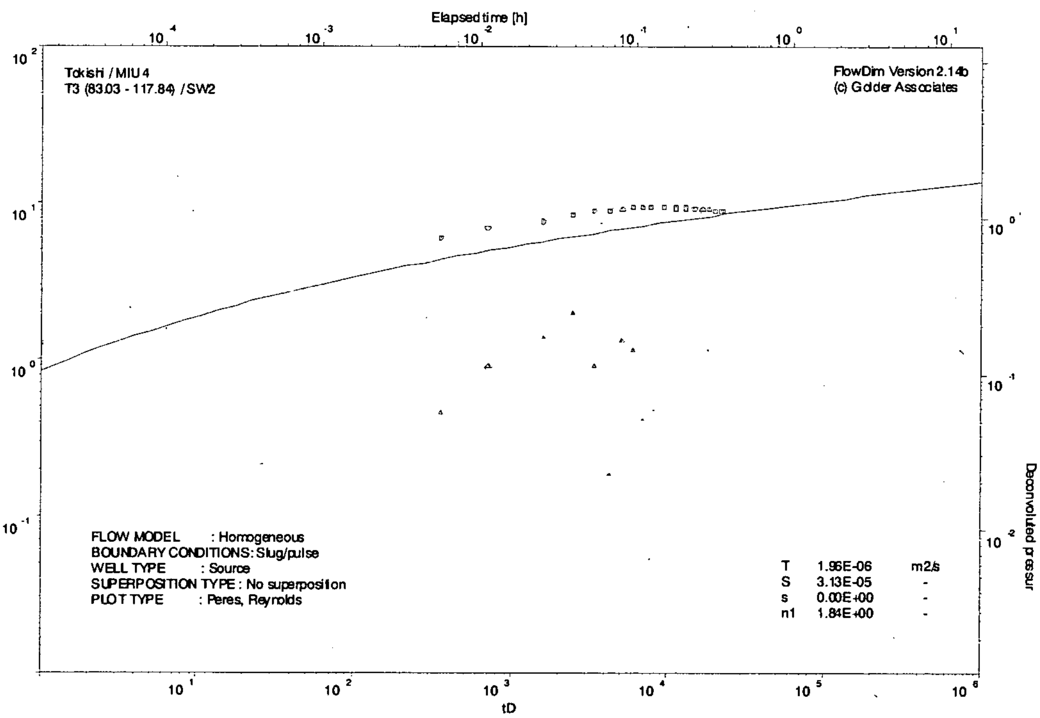

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION			
Site name			: Tokishi
Well name			: MIU 4
Interval name			: T3 (83.03 - 117.84)
Event name			: SWS2
Date			:
Input file name			: sws2.REC
WELL PARAMETERS			
Well depth		[m brp]	: 1.00E+00
Reference point elevation		[m asl]	: 0.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Interval length	(h)	[m]	: 3.48E+01
TESTPARAMETERS			
Production/Injection time	(tP)	[h]	: 4.10E-01
Flow rate	(q)	[l/min]	: 1.50E+00
Test duration	(tt)	[h]	: 4.02E-01
FLUID AND FORMATION PARAMETERS			
Viscosity	(誣)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Homogeneous
Boundary conditions			: Constant rate
Well type			: Source
Superposition type			: Agarwal
TEST RESULTS			
Transmissibility	(T)	[m3]	: 1.09E-12
Transmissivity	(Th)	[m2/s]	: 8.22E-06
Storage	(S)	[m/Pa]	: 4.57E-38
Storativity	(Sh)	[-]	: 4.48E-34
Wellbore storage coefficient	(C)	[m3/Pa]	: 1.03E-09
Inner shell flow dimension	(n1)	[-]	: 2.01E+00
Time match	(TM)	[1/h]	: 1.83E+04
Pressure match	(PM)	[1/kPa]	: 2.11E-01

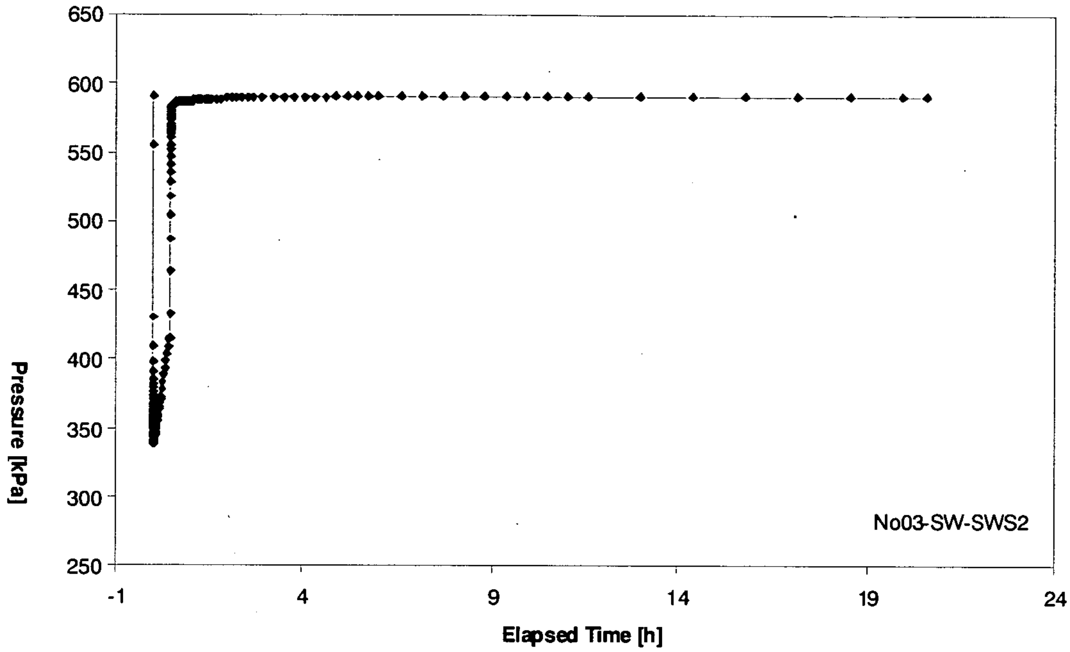

Fig. 1: CARTESIAN plot

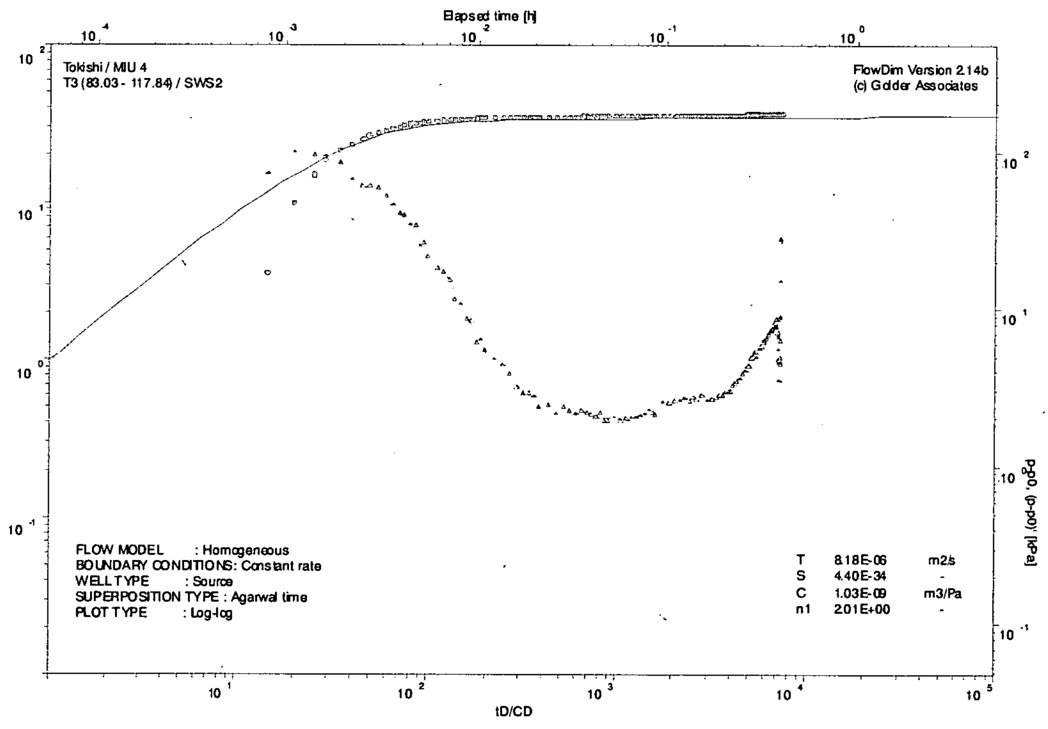

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU 4
Interval name			:	T3 (83.03 - 117.84)
Event name			:	RW
Date			:	
Input file name			:	rw.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	0.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	3.48E+01
TESTPARAMETERS				
Flow rate	(q)	[l/min]	:	2.19E+00
Test duration	(tt)	[h]	:	1.07E+02
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Homogeneous
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	2.27E-13
Transmissivity	(Th)	[m2/s]	:	1.71E-06
Storage	(S)	[m/Pa]	:	1.62E-09
Storativity	(Sh)	[-]	:	1.59E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	3.57E-07
Inner shell flow dimension	(n1)	[-]	:	2.02E+00
Time match	(TM)	[1/h]	:	1.02E+01
Pressure match	(PM)	[1/kPa]	:	2.76E-02

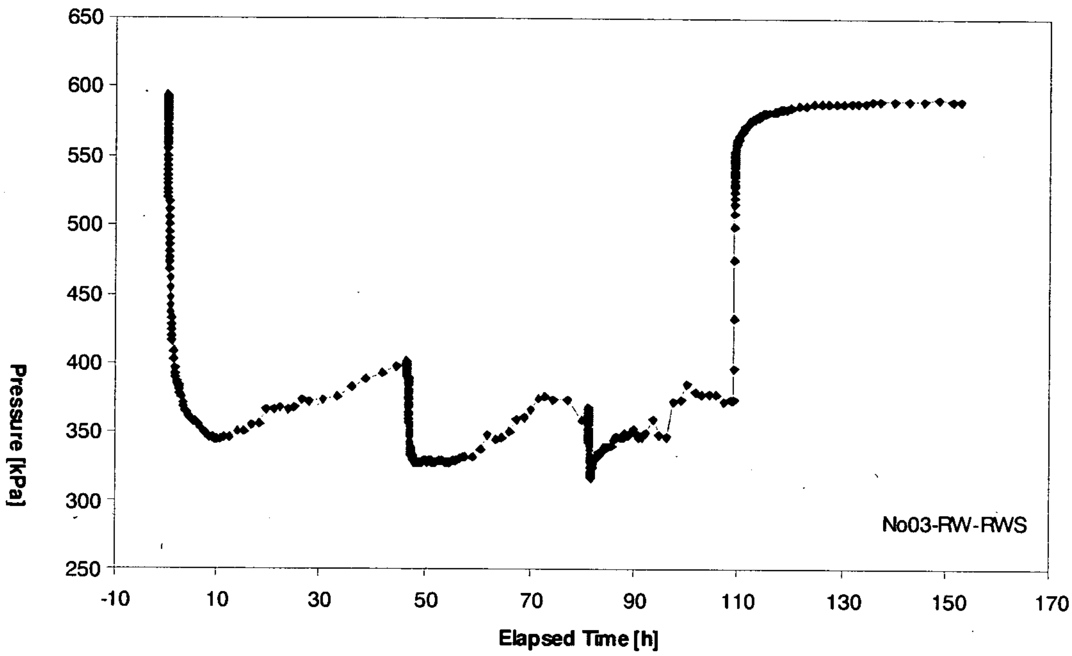

Fig. 1: CARTESIAN plot

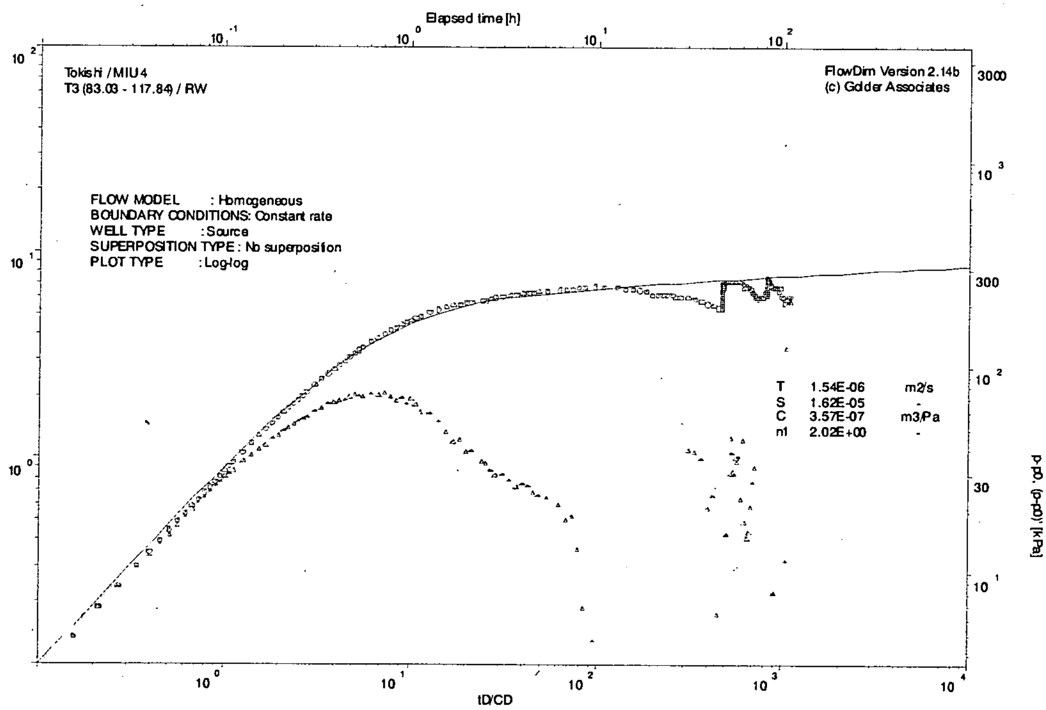

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	Tokishi
Well name			:	MIU4
Interval name			:	Test3
Event name			:	RWS
Date			:	xxx
Input file name			:	rws.REC
WELL PARAMETERS				
Well depth		[m brp]	:	1.00E+00
Reference point elevation		[m asl]	:	1.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	3.95E+01
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	1.09E+02
Flow rate	(q)	[l/min]	:	3.30E+00
Test duration	(tt)	[h]	:	4.33E+01
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Buildup
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.76E-12
Transmissivity	(Th)	[m2/s]	:	1.33E-05
Storage	(S)	[m/Pa]	:	4.45E-28
Storativity	(Sh)	[-]	:	4.36E-24
Wellbore storage coefficient	(C)	[m3/Pa]	:	1.01E-09
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	1.28E+12
Mobility ratio	(sg)	[-]	:	2.67E+00
Time match	(TM)	[1/h]	:	3.05E+04
Pressure match	(PM)	[1/kPa]	:	1.55E-01

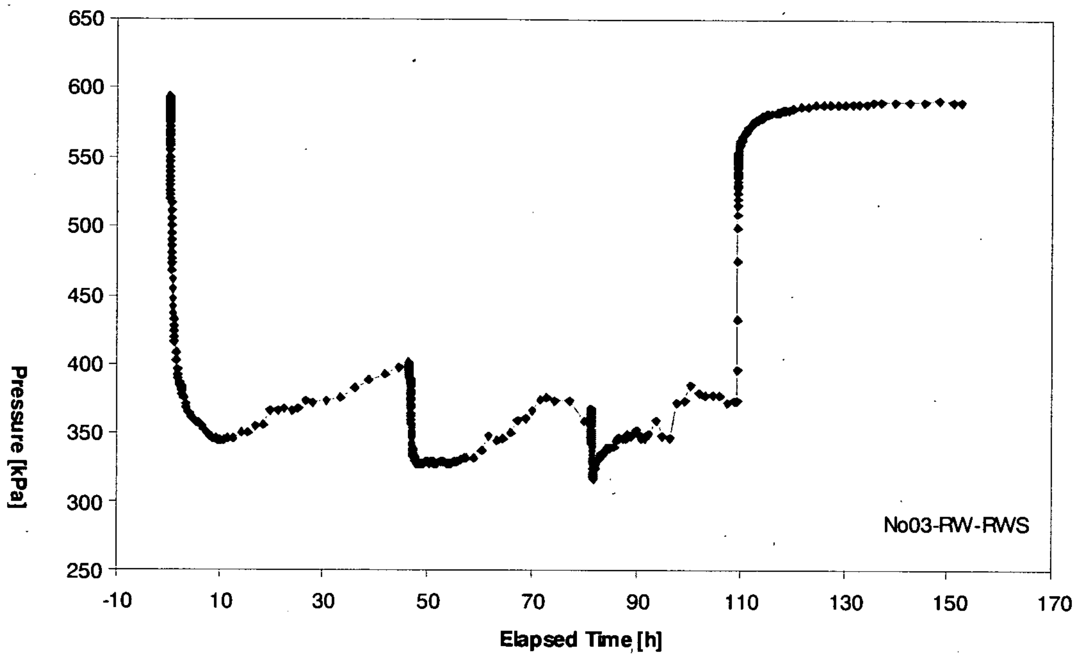

Fig. 1: CARTESIAN plot

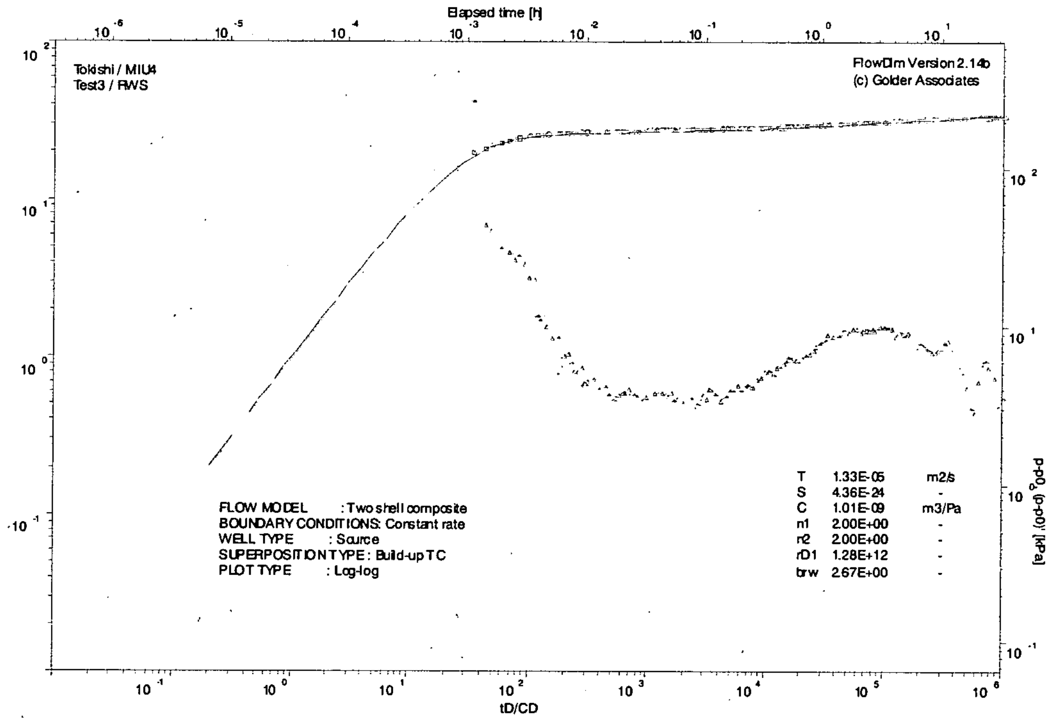

Fig. 2: Log-Log plot

Appendix D: Flow Dim Analysis Report MIU4-04

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	314.95 - 316.95
Event name			:	SW1
Date			:	
Input file name			:	sw1.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	3.92E-02
Interval length	(h)	[m]	:	2.00E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	2.42E+03
Static formation pressure	(pi)	[kPa]	:	2.48E+03
Test duration	(tt)	[h]	:	5.76E+00
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(謳)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Homogeneous
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	7.63E-13
Transmissivity	(Th)	[m2/s]	:	5.76E-06
Storage	(S)	[m/Pa]	:	3.43E-07
Storativity	(Sh)	[-]	:	3.37E-03
Skin	(s)	[-]	:	3.50E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Time match	(TM)	[1/h]	:	1.71E+03
Pressure match	(PM)	[1/kPa]	:	2.70E+01

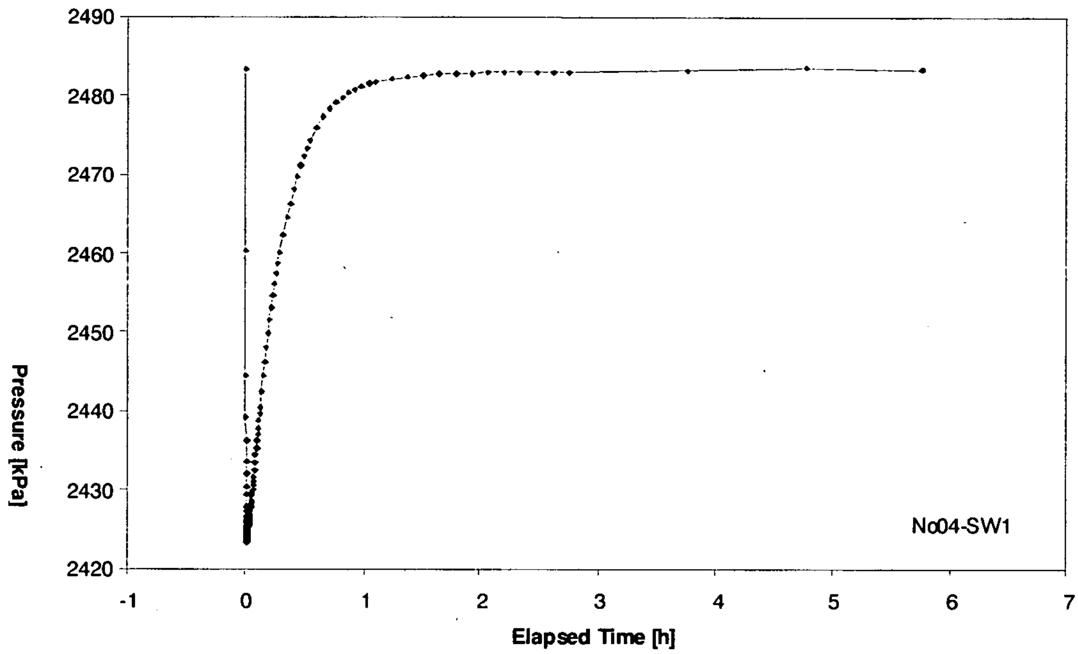

Fig. 1: CARTESIAN plot

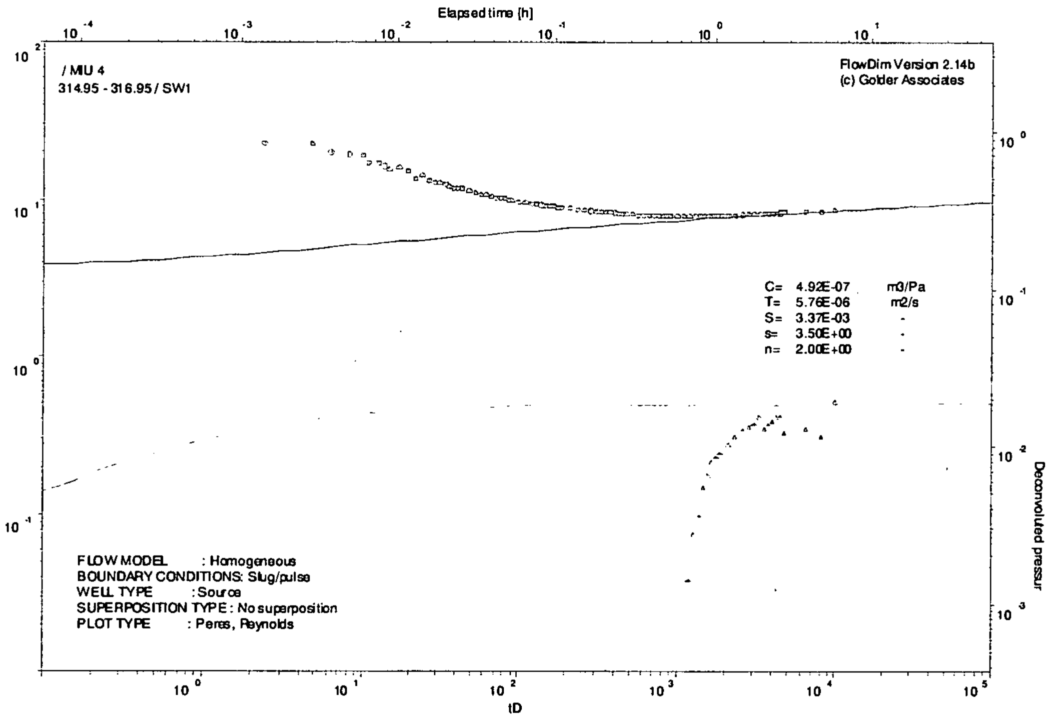

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	314.95 - 316.95
Event name			:	SW2
Date			:	
Input file name			:	sw2.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	3.92E-02
Interval length	(h)	[m]	:	9.12E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	2.42E+03
Static formation pressure	(pi)	[kPa]	:	2.48E+03
Test duration	(tt)	[h]	:	2.36E-02
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(μ)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Homogeneous
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.69E-12
Transmissivity	(Th)	[m2/s]	:	1.27E-05
Storage	(S)	[m/Pa]	:	2.18E-25
Storativity	(Sh)	[-]	:	2.13E-21
Wellbore storage coefficient	(C)	[m3/Pa]	:	4.92E-07
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Time match	(TM)	[1/h]	:	5.97E+01
Pressure match	(PM)	[1/kPa]	:	1.00E+00

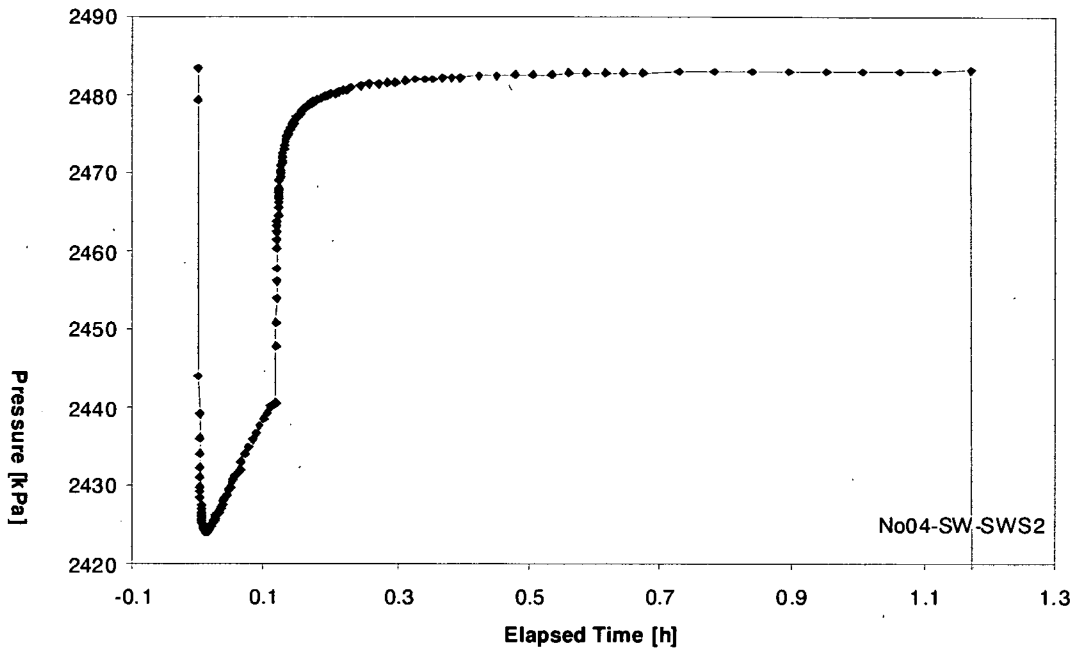

Fig. 1: CARTESIAN plot

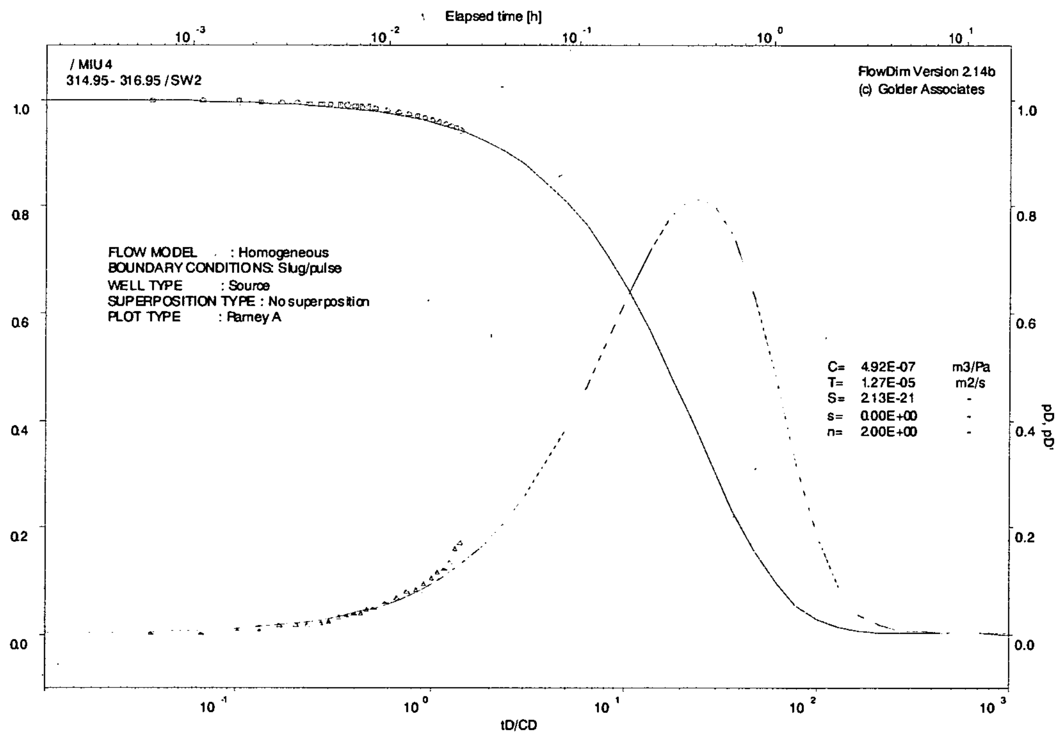

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	314.95 - 316.95
Event name			:	SWS2
Date			:	
Input file name			:	sws2.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	2.00E+00
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	1.10E-01
Flow rate	(q)	[l/min]	:	1.19E+00
Test duration	(tt)	[h]	:	9.96E-02
FLUID AND FORMATION PARAMETERS				
Viscosity	(謳)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Homogeneous
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Agarwal
TEST RESULTS				
Transmissibility	(T)	[m3]	:	4.55E-12
Transmissivity	(Th)	[m2/s]	:	3.43E-05
Storage	(S)	[m/Pa]	:	9.88E-09
Storativity	(Sh)	[-]	:	9.70E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	2.86E-09
Inner shell flow dimension	(n1)	[-]	:	1.97E+00
Time match	(TM)	[1/h]	:	3.70E+03
Pressure match	(PM)	[1/kPa]	:	1.48E-01

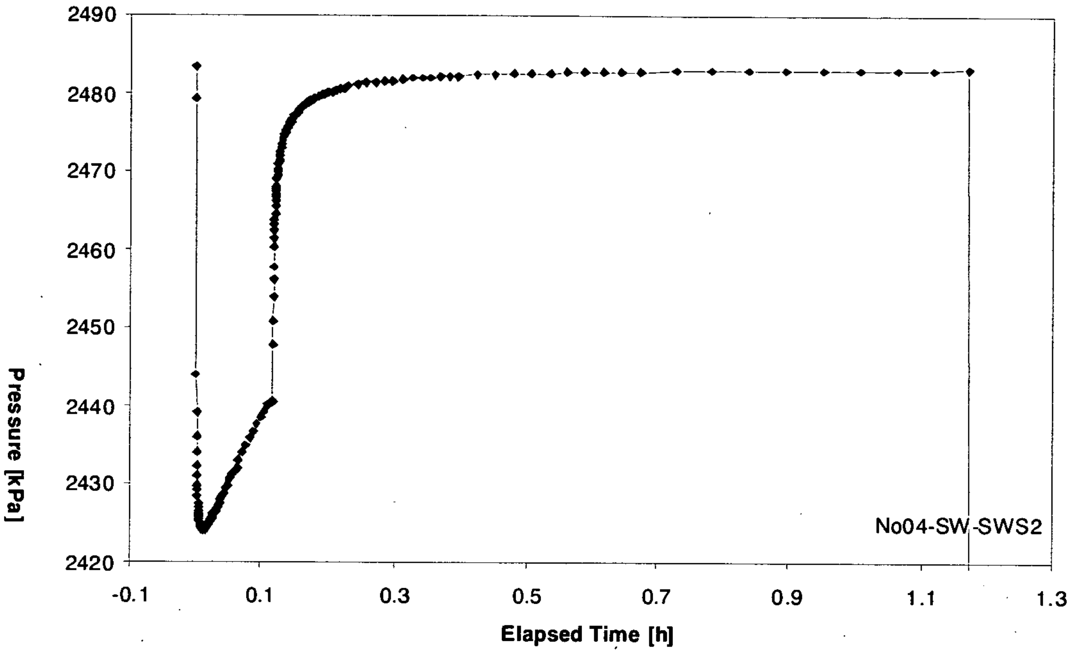

Fig. 1: CARTESIAN plot

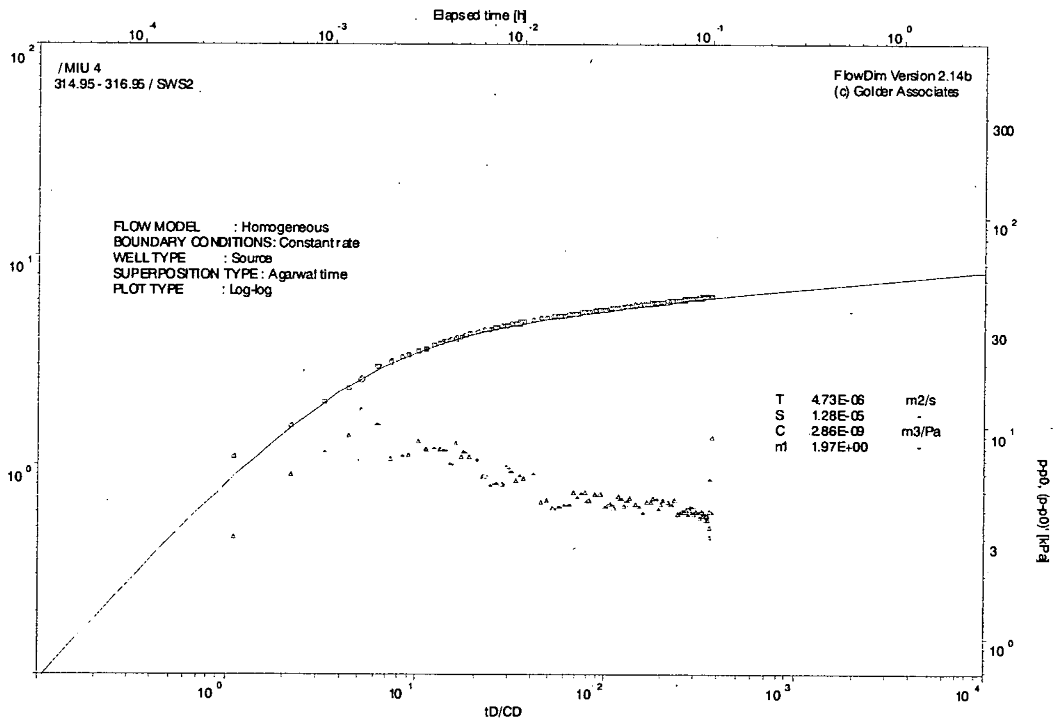

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	314.95 - 316.95
Event name			:	PW
Date			:	
Input file name			:	pw.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	1.90E-03
Interval length	(h)	[m]	:	2.00E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	2.46E+03
Static formation pressure	(pi)	[kPa]	:	2.48E+03
Test duration	(tt)	[h]	:	1.58E+00
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	9.89E-14
Transmissivity	(Th)	[m2/s]	:	7.46E-07
Storage	(S)	[m/Pa]	:	1.86E-09
Storativity	(Sh)	[-]	:	1.82E-05
Skin	(s)	[-]	:	**********
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	1.00E+02
Mobility ratio	(sg)	[-]	:	2.43E+01
Time match	(TM)	[1/h]	:	4.09E+04
Pressure match	(PM)	[1/kPa]	:	1.49E+03

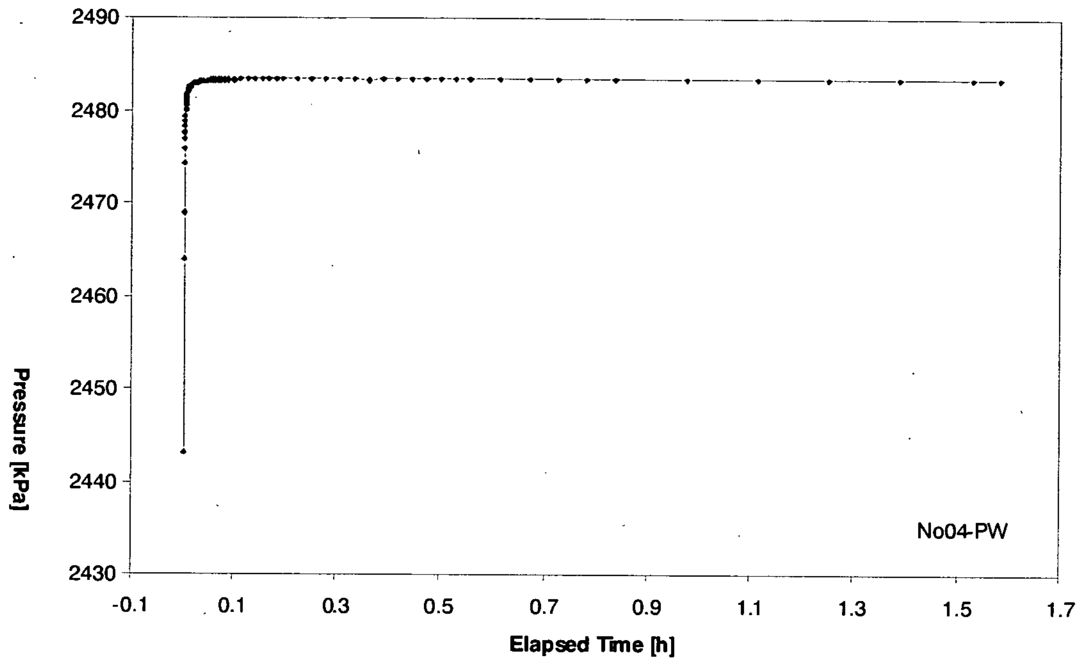

Fig. 1: CARTESIAN plot

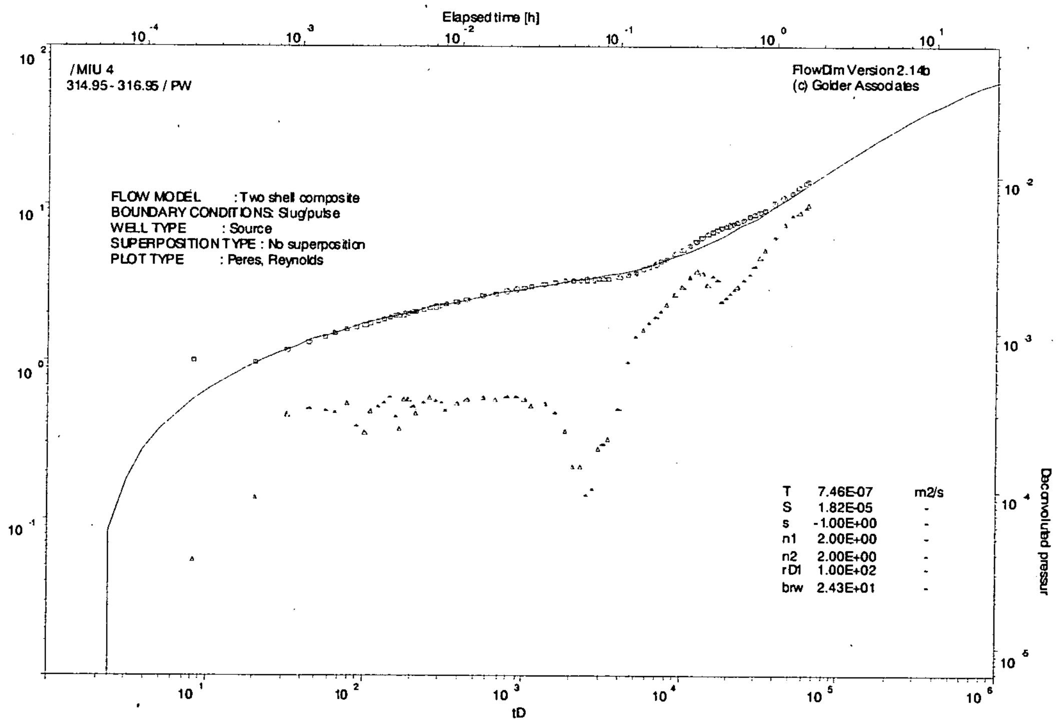

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	314.95 - 316.95
Event name			:	SW
Date			:	
Input file name			:	rw.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	2.00E+00
TESTPARAMETERS				
Flow rate	(q)	[l/min]	:	4.51E+00
Test duration	(tt)	[h]	:	1.50E+02
FLUID AND FORMATION PARAMETERS				
Viscosity	(瀝)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	6.97E-13
Transmissivity	(Th)	[m2/s]	:	5.26E-06
Storage	(S)	[m/Pa]	:	2.06E-09
Storativity	(Sh)	[-]	:	2.02E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	4.65E-07
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	8.62E+02
Mobility ratio	(sg)	[-]	:	3.05E-01
Time match	(TM)	[1/h]	:	2.61E+01
Pressure match	(PM)	[1/kPa]	:	4.48E-02

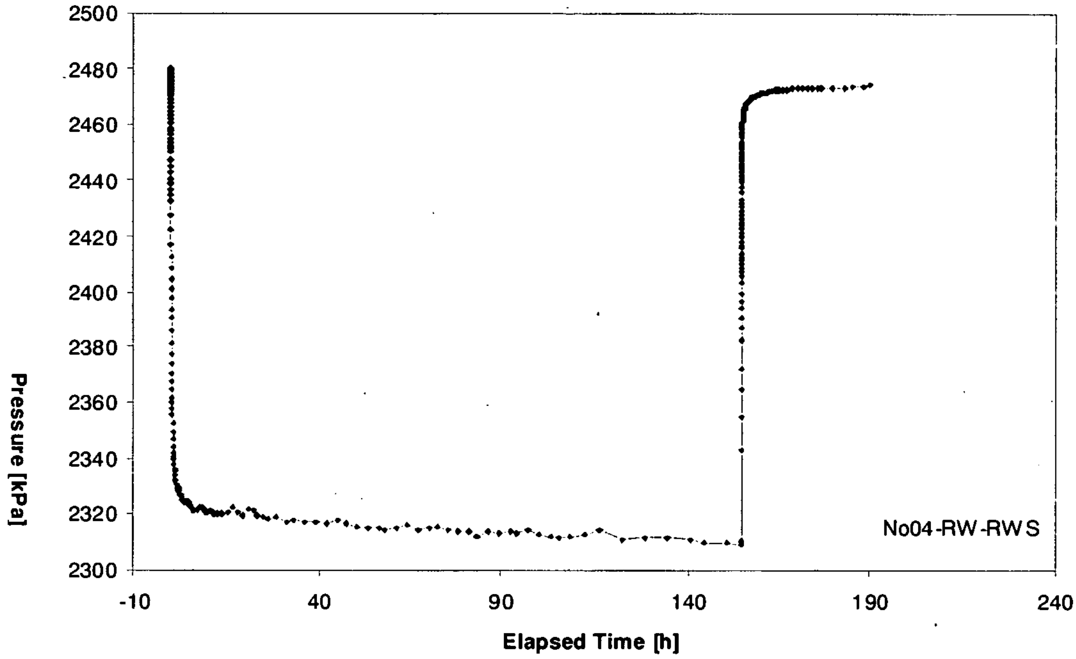

Fig. 1: CARTESIAN plot

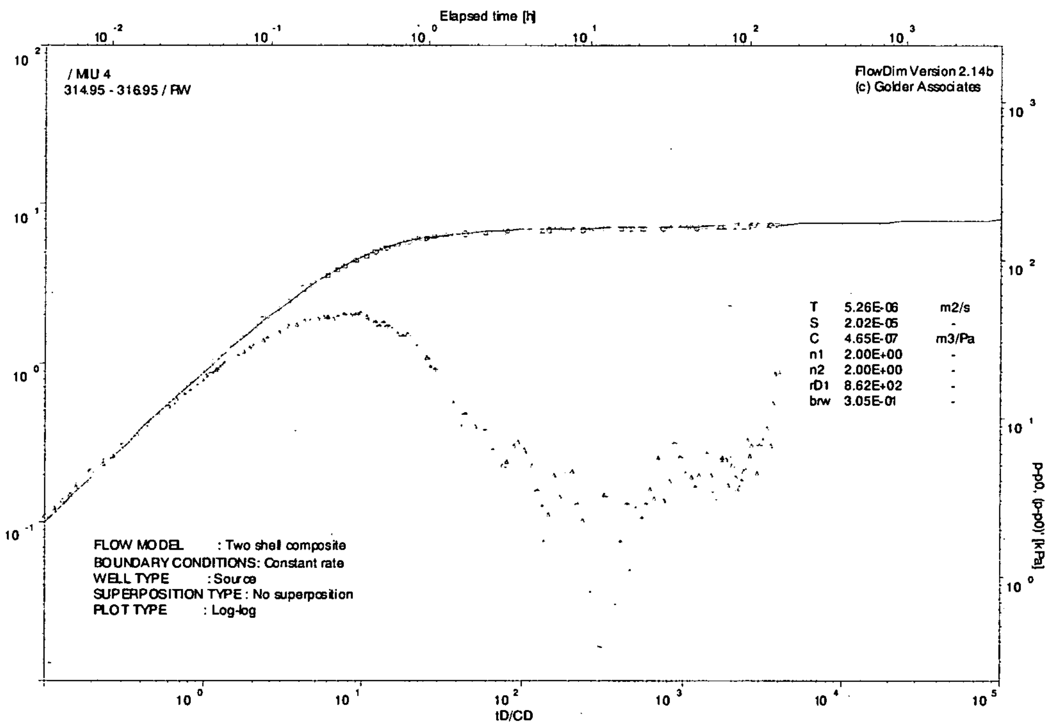

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION			
Site name			:
Well name			: MIU 4
Interval name			: 314.95 - 316.95
Event name			: RWS
Date			:
Input file name			: rws.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Interval length	(h)	[m]	: 2.00E+00
TESTPARAMETERS			
Production/Injection time	(tP)	[h]	: 1.54E+02
Flow rate	(q)	[l/min]	: 4.51E+00
Test duration	(tt)	[h]	: 2.87E+01
FLUID AND FORMATION PARAMETERS			
Viscosity	(䜣)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Composite
Boundary conditions			: Constant rate
Well type			: Source
Superposition type			: Agarwal
TEST RESULTS			
Transmissibility	(T)	[m3]	: 8.65E-13
Transmissivity	(Th)	[m2/s]	: 6.53E-06
Storage	(S)	[m/Pa]	: 2.03E-11
Storativity	(Sh)	[-]	: 1.99E-07
Wellbore storage coefficient	(C)	[m3/Pa]	: 4.59E-09
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Outer shell flow dimension	(n2)	[-]	: 2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	: 5.01E+03
Mobility ratio	(sg)	[-]	: 2.92E-01
Time match	(TM)	[1/h]	: 3.28E+03
Pressure match	(PM)	[1/kPa]	: 5.56E-02

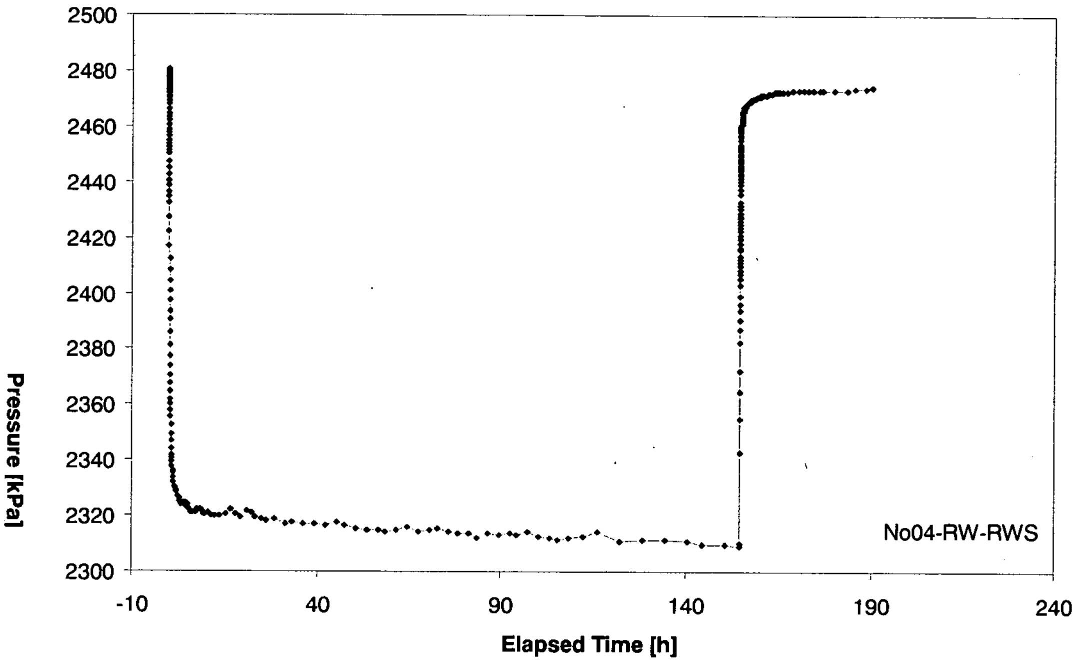

Fig. 1: CARTESIAN plot

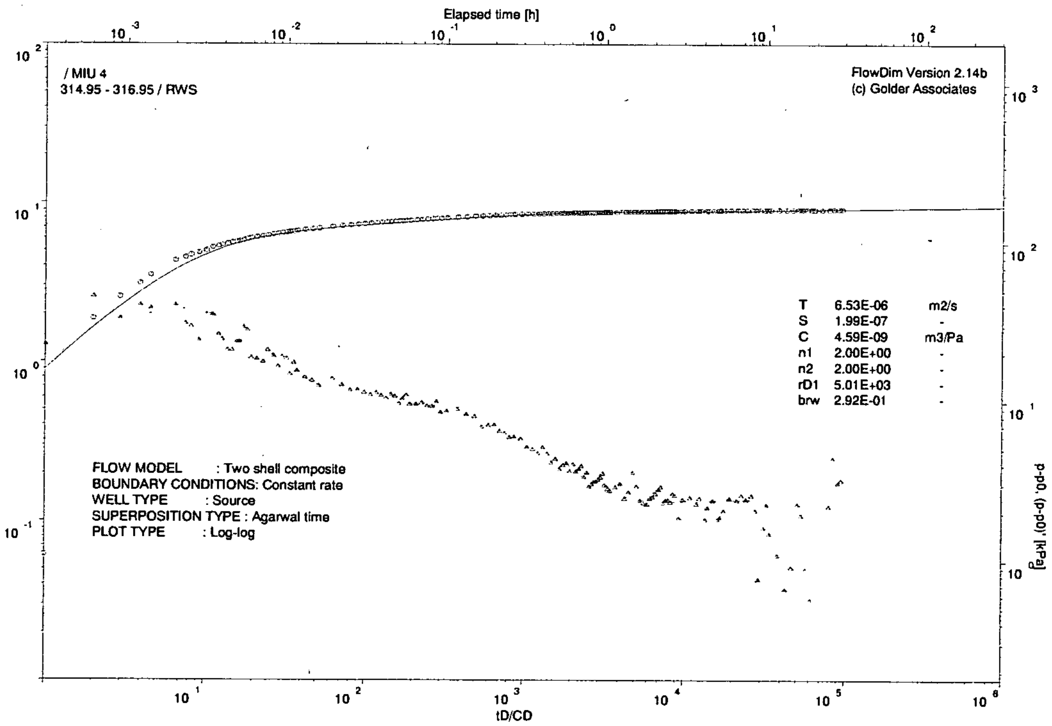

Fig. 2: Log-Log plot

Appendix E: Flow Dim Analysis Report MIU4-06

TEST ANALYSIS REPORT				13.09.2002
IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	584 - 647.11
Event name			:	SW2
Date			:	
Input file name			:	sw2.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	3.92E-02
Interval length	(h)	[m]	:	6.31E+01
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	4.62E+03
Static formation pressure	(pi)	[kPa]	:	4.73E+03
Test duration	(tt)	[h]	:	1.50E-01
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	7.28E-13
Transmissivity	(Th)	[m2/s]	:	5.49E-06
Storage	(S)	[m/Pa]	:	1.13E-09
Storativity	(Sh)	[-]	:	1.11E-05
Skin	(s)	[-]	:	0.00E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.16E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	1.54E+02
Mobility ratio	(sg)	[-]	:	1.03E-01
Time match	(TM)	[1/h]	:	4.61E+05
Pressure match	(PM)	[1/kPa]	:	2.57E+01

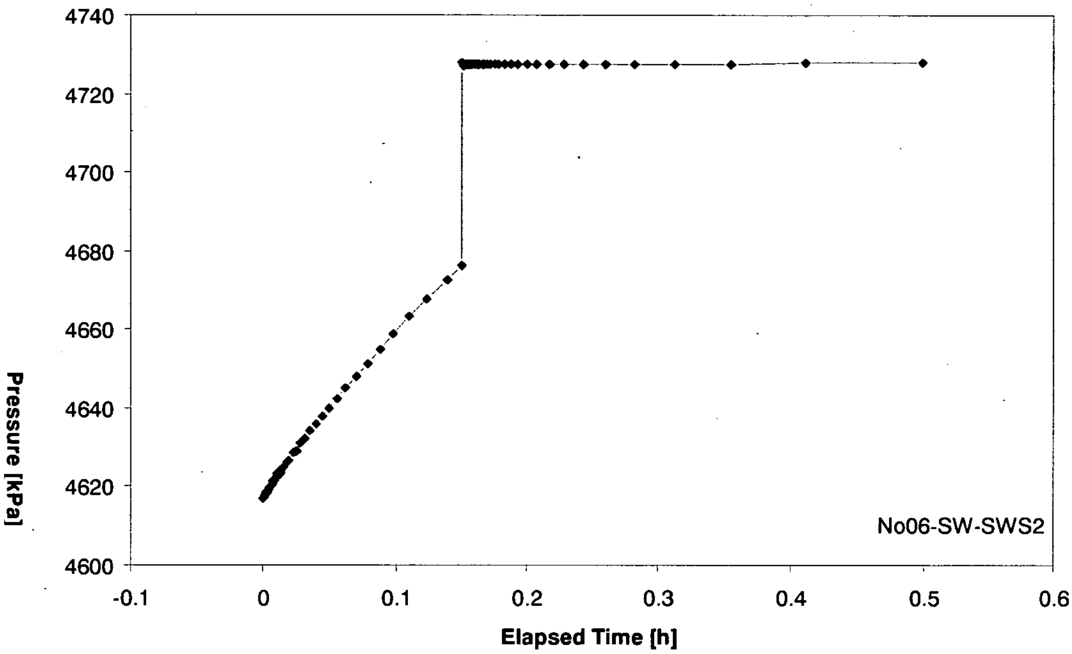

Fig. 1: CARTESIAN plot

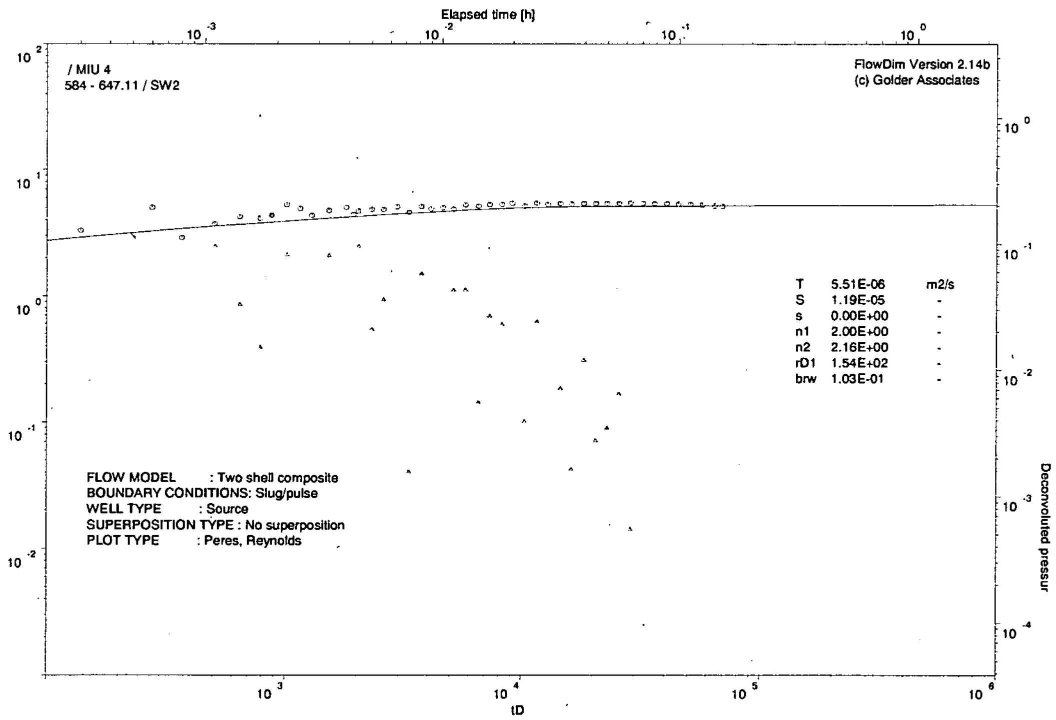

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	584 - 647.11
Event name			:	SWS2
Date			:	
Input file name			:	sws2.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	6.31E+01
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	1.50E-01
Flow rate	(q)	[l/min]	:	3.20E+00
Test duration	(tt)	[h]	:	1.05E-01
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Agarwal
TEST RESULTS				
Transmissibility	(T)	[m3]	:	6.40E-13
Transmissivity	(Th)	[m2/s]	:	4.83E-06
Storage	(S)	[m/Pa]	:	1.19E-09
Storativity	(Sh)	[-]	:	1.17E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	2.70E-10
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	2.00E+01
Mobility ratio	(sg)	[-]	:	1.00E-02
Time match	(TM)	[1/h]	:	4.13E+04
Pressure match	(PM)	[1/kPa]	:	5.79E-02

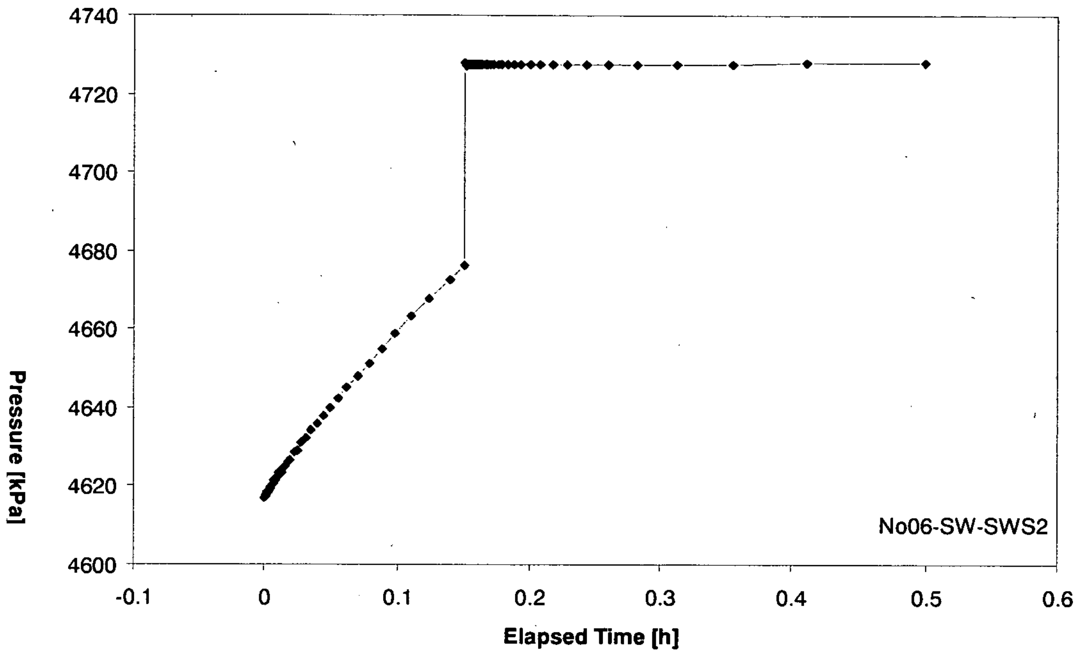

Fig. 1: CARTESIAN plot

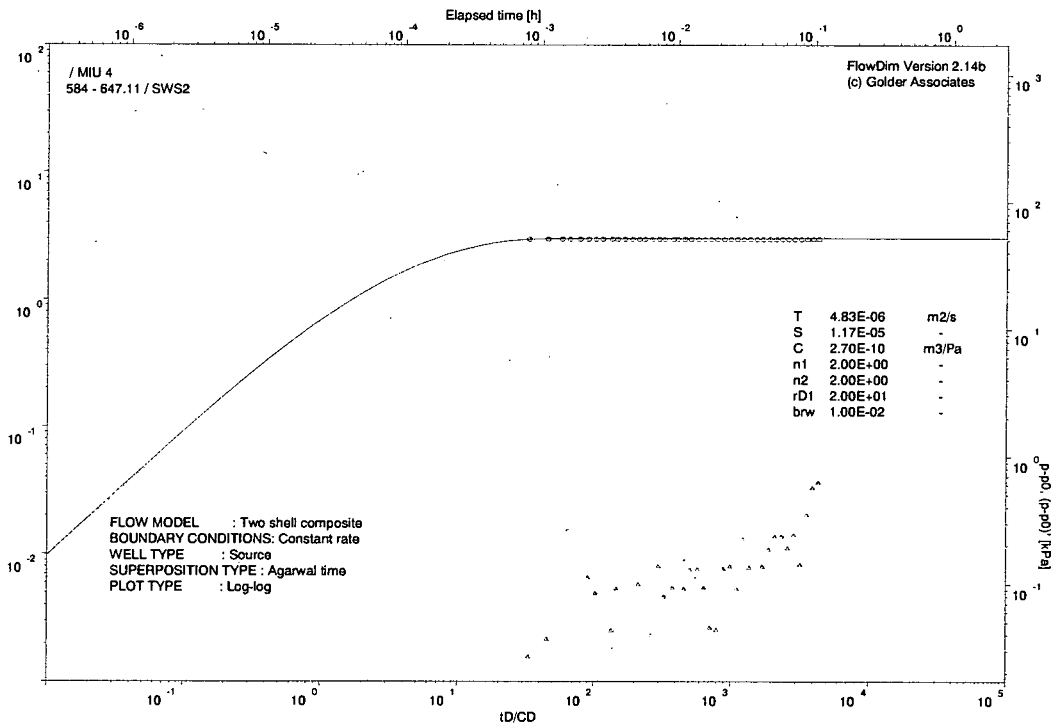

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION

Site name			:	
Well name			:	MIU 4
Interval name			:	584.00 - 647.11
Event name			:	SW3
Date			:	
Input file name			:	sw3.REC

WELL PARAMETERS

Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	3.92E-02
Interval length	(h)	[m]	:	9.12E+00

TESTPARAMETERS

Initial slug pressure	(p0)	[kPa]	:	4.70E+03
Static formation pressure	(pi)	[kPa]	:	4.73E+03
Test duration	(tt)	[h]	:	1.46E+00

FLUID AND FORMATION PARAMETERS

Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02

MODEL ASSUMPTIONS

Flow model	:	Homogeneous
Boundary conditions	:	Slug/Pulse
Well type	:	Source
Superposition type	:	Drawdown

TEST RESULTS

Transmissibility	(T)	[m3]	:	3.26E-12
Transmissivity	(Th)	[m2/s]	:	2.46E-05
Storage	(S)	[m/Pa]	:	4.50E-09
Storativity	(Sh)	[-]	:	4.41E-05
Skin	(s)	[-]	:	3.50E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Time match	(TM)	[1/h]	:	5.58E+05
Pressure match	(PM)	[1/kPa]	:	1.15E+02

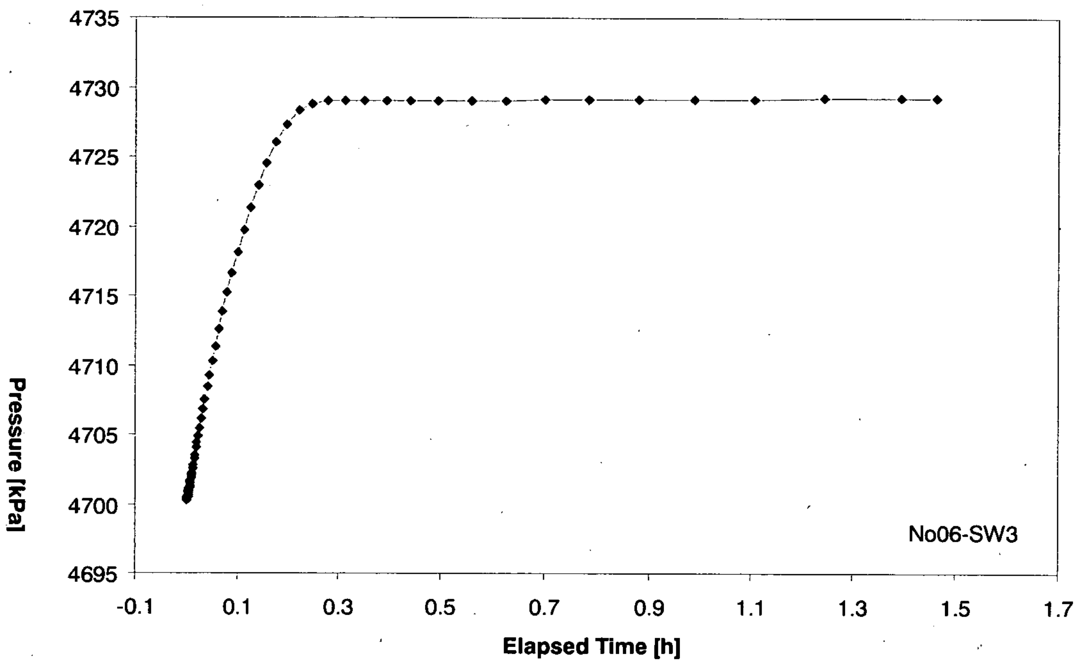

Fig. 1: CARTESIAN plot

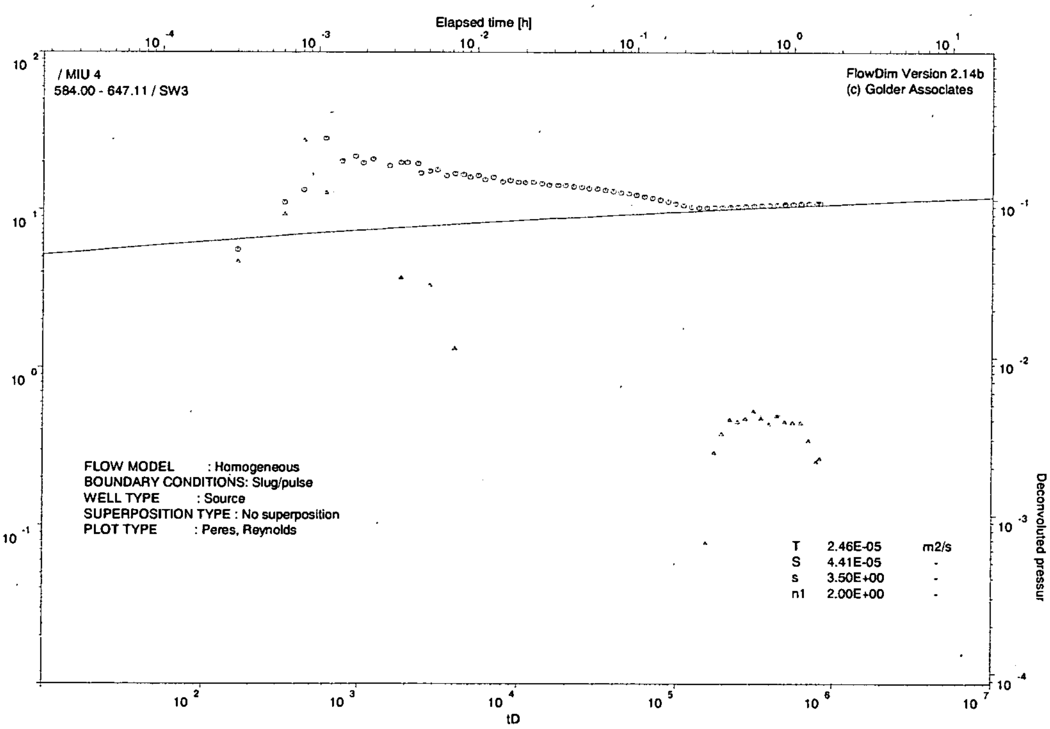

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	584.00 - 647.11
Event name			:	RW
Date			:	
Input file name			:	rw.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	6.31E+01
TESTPARAMETERS				
Flow rate	(q)	[l/min]	:	7.86E+00
Test duration	(tt)	[h]	:	4.94E+01
FLUID AND FORMATION PARAMETERS				
Viscosity	(巫)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Homogeneous
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	7.44E-12
Transmissivity	(Th)	[m2/s]	:	5.61E-05
Storage	(S)	[m/Pa]	:	2.67E-13
Storativity	(Sh)	[-]	:	2.62E-09
Wellbore storage coefficient	(C)	[m3/Pa]	:	1.32E-06
Inner shell flow dimension	(n1)	[-]	:	1.98E+00
Time match	(TM)	[1/h]	:	1.13E+02
Pressure match	(PM)	[1/kPa]	:	3.15E-01

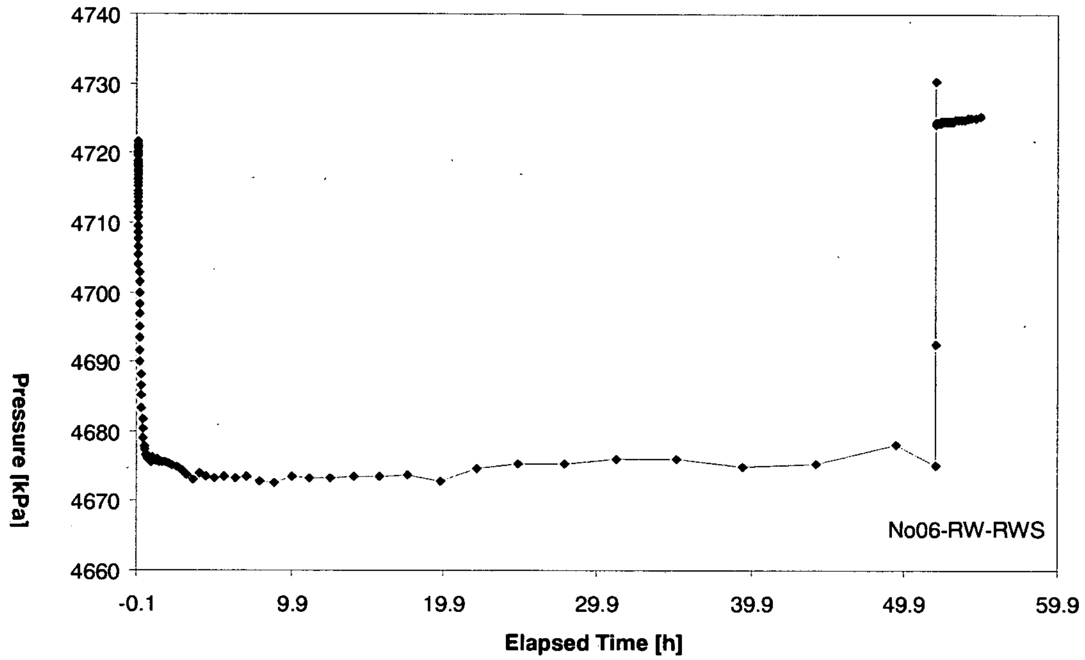

Fig. 1: CARTESIAN plot

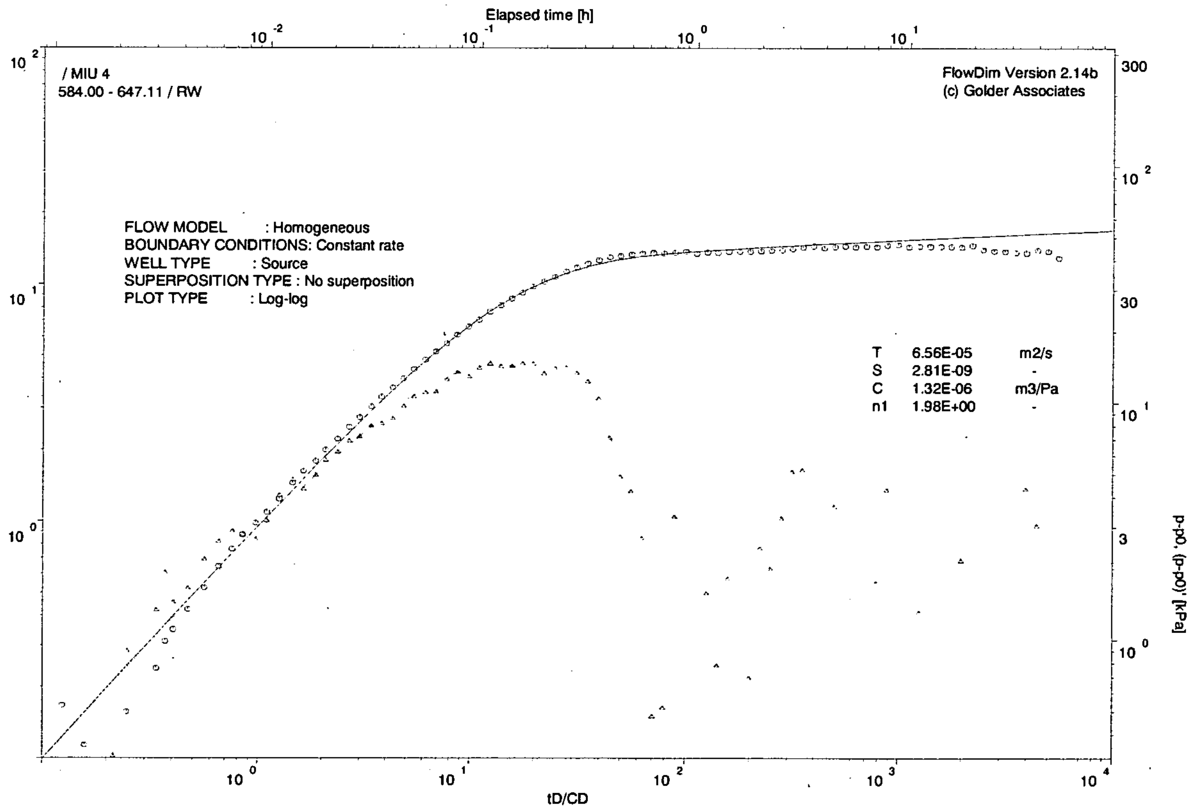

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	584 - 647.11
Event name			:	RWS
Date			:	
Input file name			:	rws.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	6.31E+01
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	5.20E+01
Flow rate	(q)	[l/min]	:	7.86E+00
Test duration	(tt)	[h]	:	2.79E+00
FLUID AND FORMATION PARAMETERS				
Viscosity	(䴈)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Agarwal
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.73E-12
Transmissivity	(Th)	[m2/s]	:	1.30E-05
Storage	(S)	[m/Pa]	:	7.87E-09
Storativity	(Sh)	[-]	:	7.72E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	1.78E-09
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	2.00E+01
Mobility ratio	(sg)	[-]	:	1.00E-02
Time match	(TM)	[1/h]	:	1.69E+04
Pressure match	(PM)	[1/kPa]	:	6.36E-02

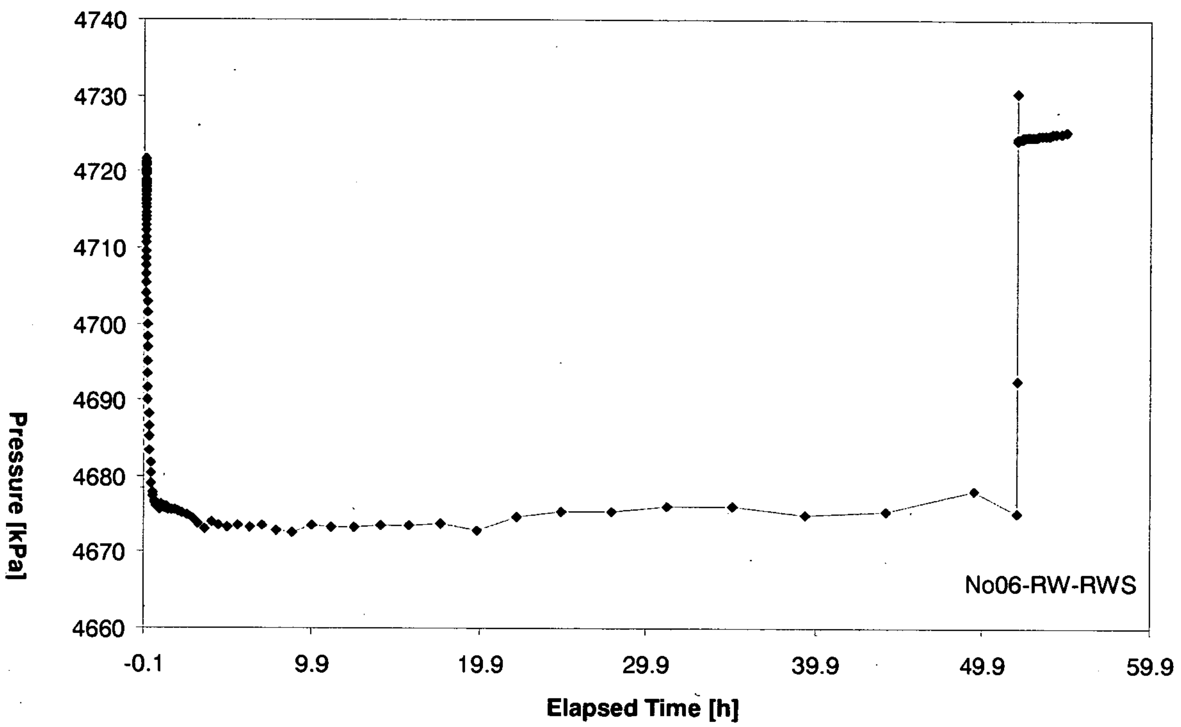

Fig. 1: CARTESIAN plot

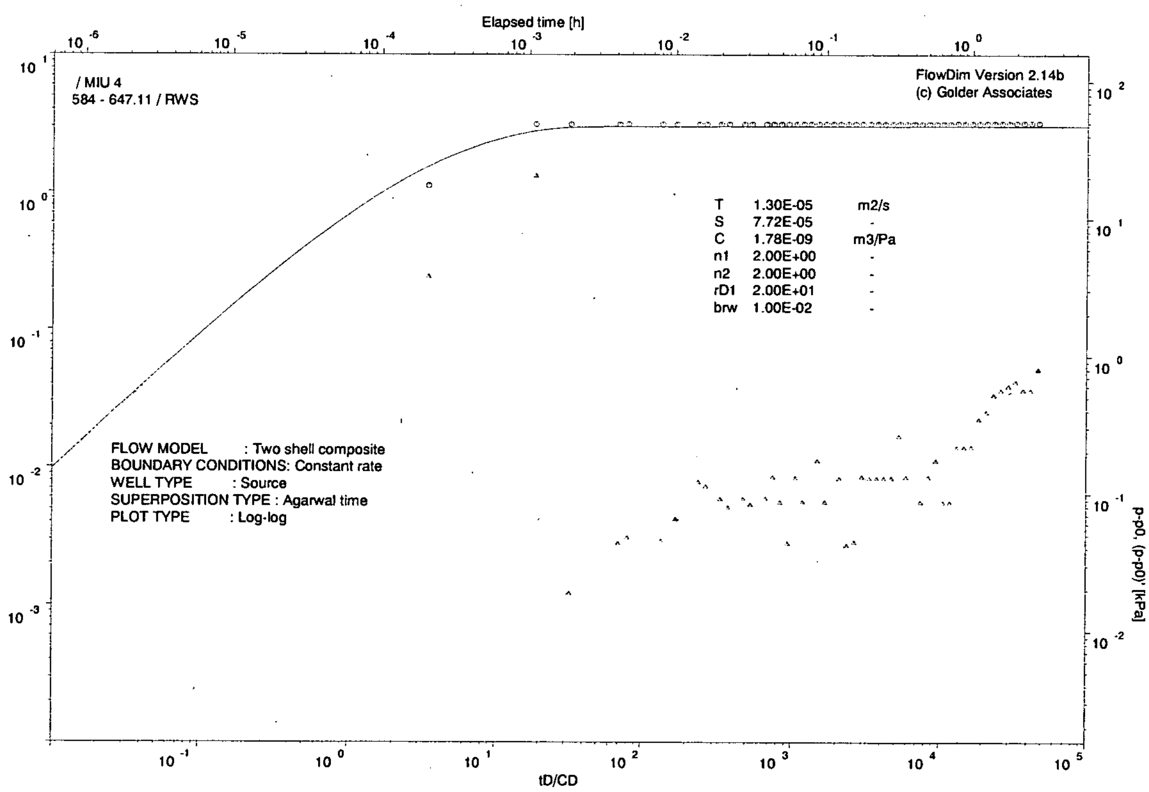

Fig. 2: Log-Log plot

Appendix F: Flow Dim Analysis Report MIU4-07

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	183.20 - 254.20
Event name			:	PW
Date			:	
Input file name			:	pw.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	1.90E-03
Interval length	(h)	[m]	:	7.10E+01
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	9.92E+02
Static formation pressure	(pi)	[kPa]	:	1.31E+03
Test duration	(tt)	[h]	:	1.01E-01
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(謳)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.51E-13
Transmissivity	(Th)	[m2/s]	:	1.14E-06
Storage	(S)	[m/Pa]	:	2.50E-09
Storativity	(Sh)	[-]	:	2.46E-05
Skin	(s)	[-]	:	5.00E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	5.14E+01
Mobility ratio	(sg)	[-]	:	2.08E-01
Time match	(TM)	[1/h]	:	4.65E+04
Pressure match	(PM)	[1/kPa]	:	2.28E+03

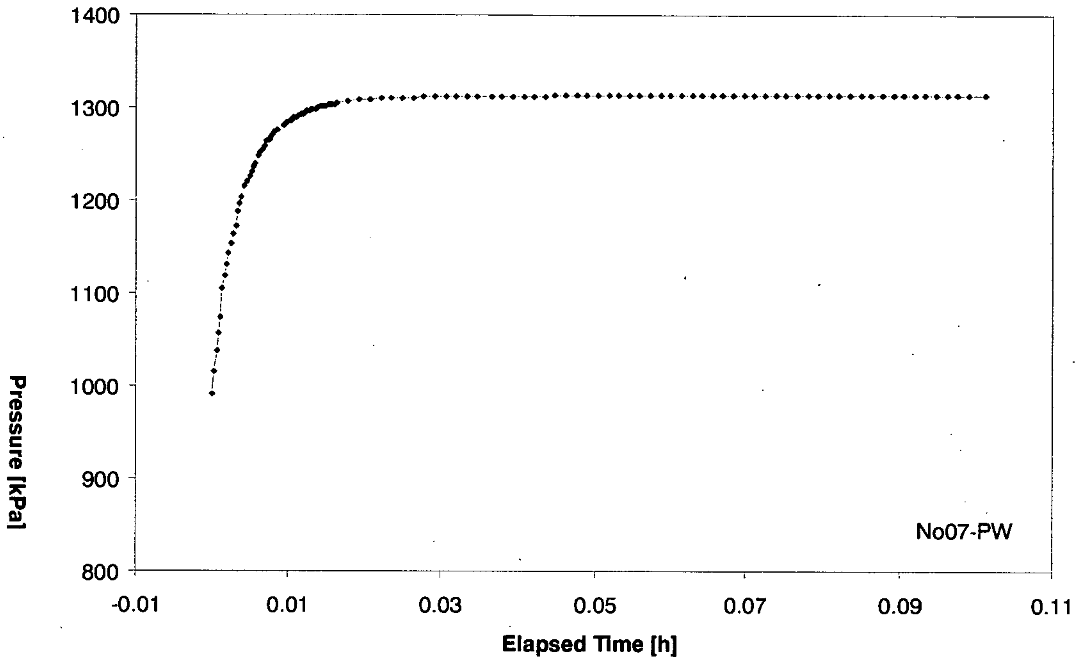

Fig. 1: CARTESIAN plot

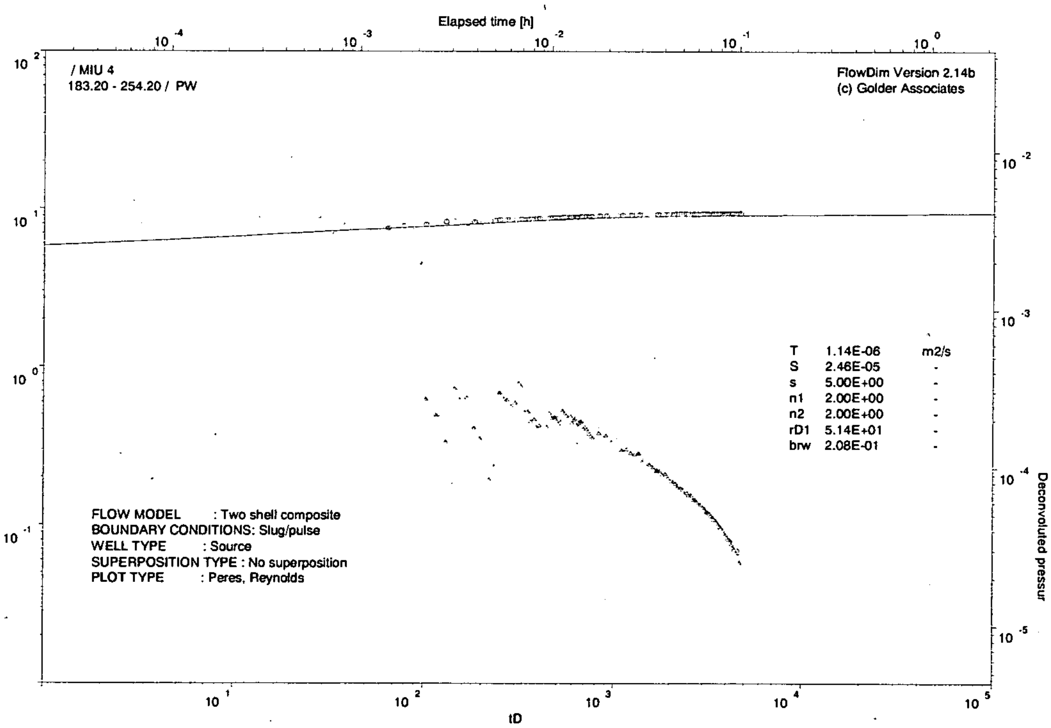

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION			
Site name			:
Well name			: MIU 4
Interval name			: 183.20 - 254.20
Event name			: RW1
Date			:
Input file name			: rw1.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Interval length	(h)	[m]	: 7.90E+01
TESTPARAMETERS			
Flow rate	(q)	[l/min]	: 2.50E-01
Test duration	(tt)	[h]	: 1.39E+01
FLUID AND FORMATION PARAMETERS			
Viscosity	(謳)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Homogeneous
Boundary conditions			: Constant rate
Well type			: Source
Superposition type			: Drawdown
TEST RESULTS			
Transmissibility	(T)	[m3]	: 6.1839E-14
Transmissivity	(Th)	[m2/s]	: 4.67E-07
Storage	(S)	[m/Pa]	: 1.37E-11
Storativity	(Sh)	[-]	: 1.35E-07
Wellbore storage coefficient	(C)	[m3/Pa]	: 3.11E-07
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Time match	(TM)	[1/h]	: 3.46E+00
Pressure match	(PM)	[1/kPa]	: 7.17E-02

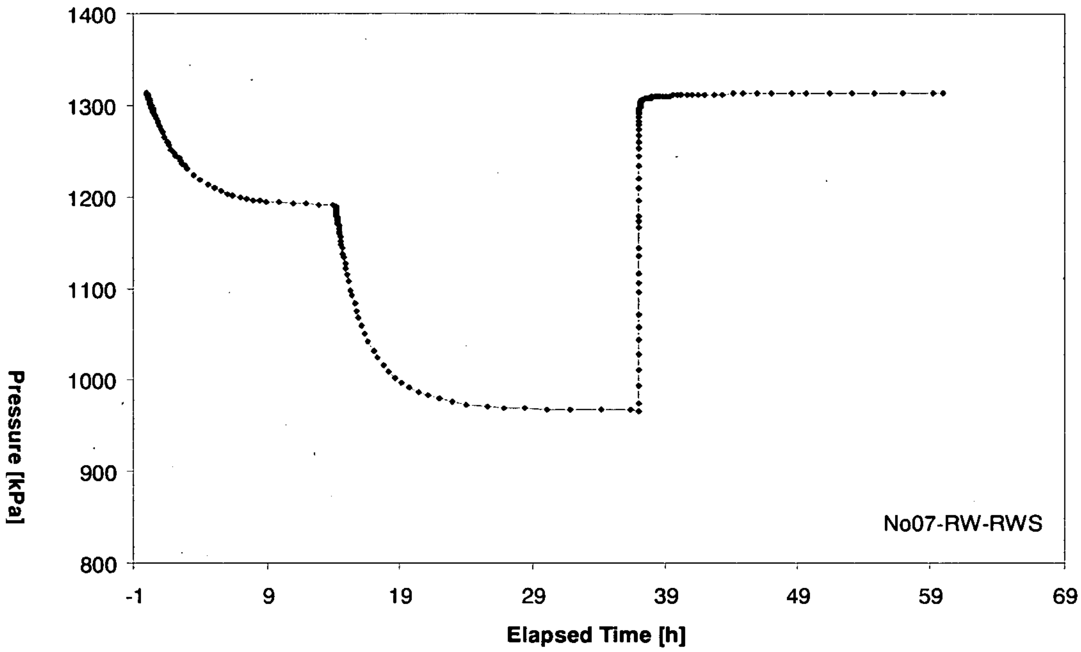

Fig. 1: CARTESIAN plot

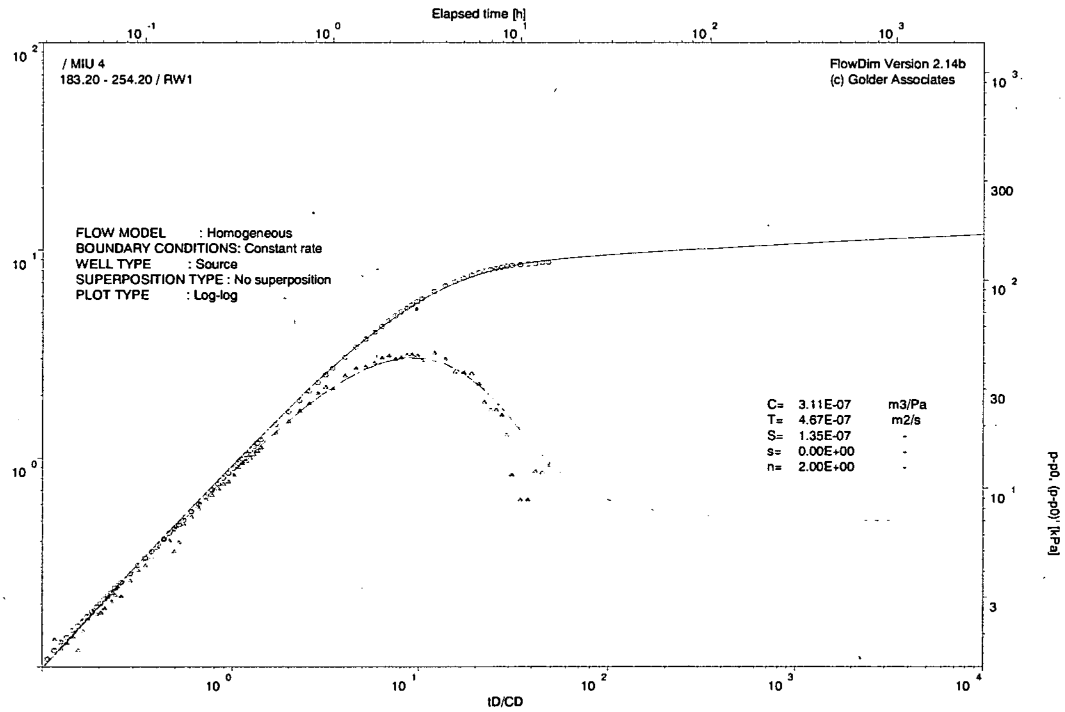

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	183.20 - 254.20
Event name			:	RW2
Date			:	
Input file name			:	rw2.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	7.90E+01
TESTPARAMETERS				
Flow rate	(q)	[l/min]	:	8.30E-01
Test duration	(tt)	[h]	:	2.22E+01
FLUID AND FORMATION PARAMETERS				
Viscosity	(謳)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Homogeneous
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.2096E-13
Transmissivity	(Th)	[m2/s]	:	9.13E-07
Storage	(S)	[m/Pa]	:	1.99E-11
Storativity	(Sh)	[-]	:	1.95E-07
Wellbore storage coefficient	(C)	[m3/Pa]	:	4.49E-07
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Time match	(TM)	[1/h]	:	4.68E+00
Pressure match	(PM)	[1/kPa]	:	4.22E-02

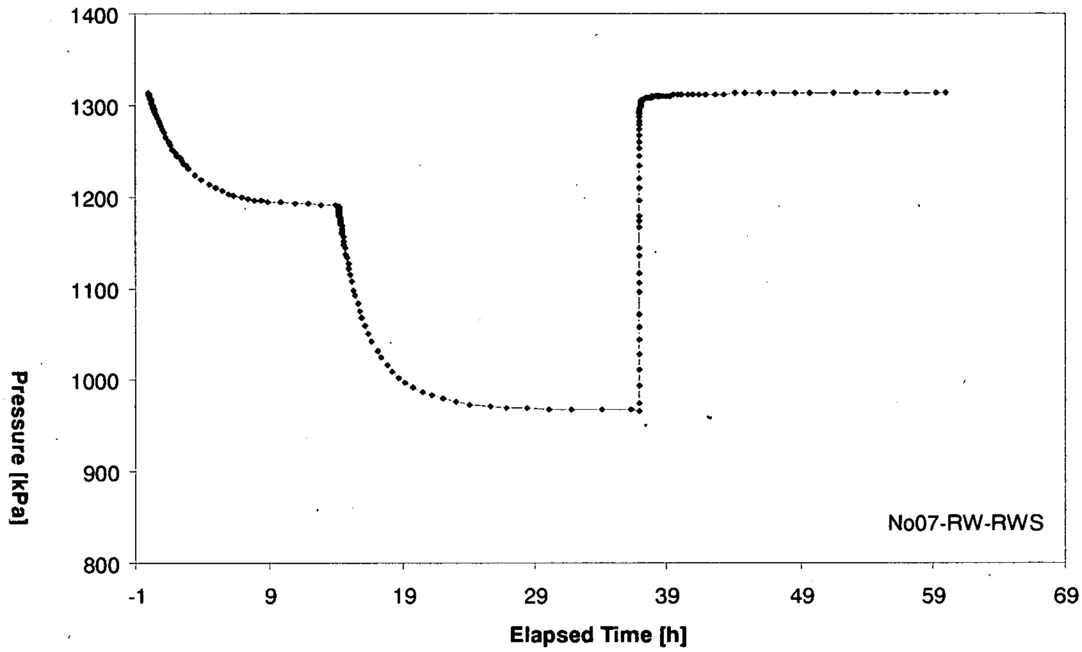

Fig. 1: CARTESIAN plot

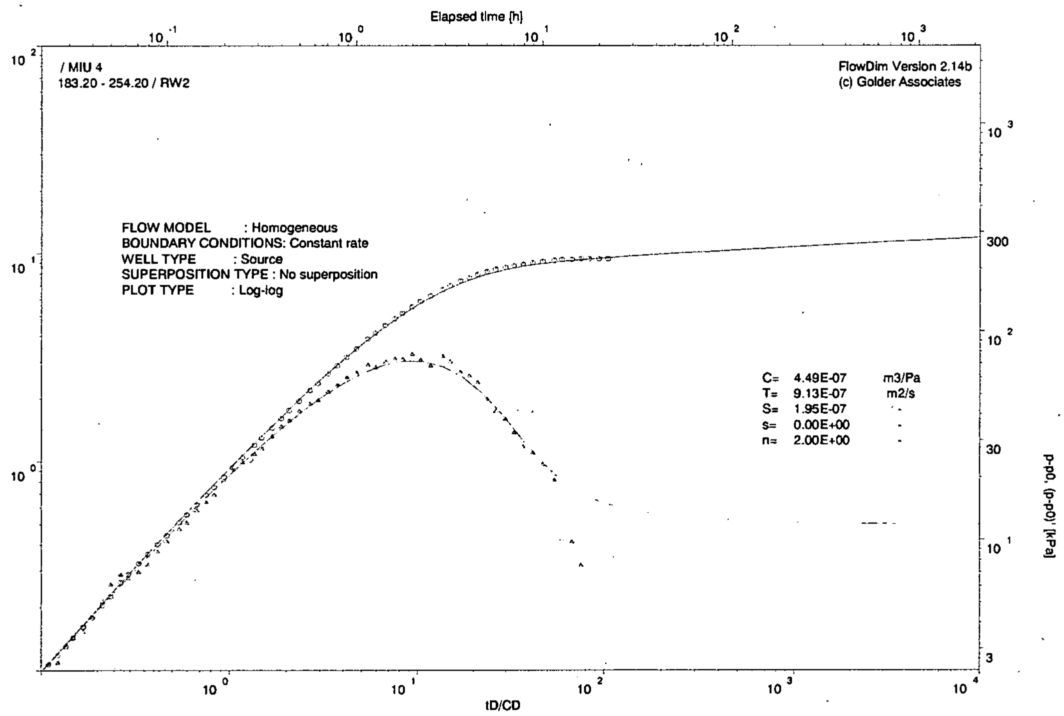

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	183.20 - 254.20
Event name			:	RWS
Date			:	
Input file name			:	rws.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	7.90E+01
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	3.69E+01
Flow rate	(q)	[l/min]	:	6.07E-01
Test duration	(tt)	[h]	:	1.42E+01
FLUID AND FORMATION PARAMETERS				
Viscosity	(謳)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Agarwal
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.40E-14
Transmissivity	(Th)	[m2/s]	:	1.05E-07
Storage	(S)	[m/Pa]	:	1.83E-09
Storativity	(Sh)	[-]	:	1.80E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	4.14E-10
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.52E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	8.63E+00
Mobility ratio	(sg)	[-]	:	5.06E-01
Time match	(TM)	[1/h]	:	5.86E+02
Pressure match	(PM)	[1/kPa]	:	6.67E-03

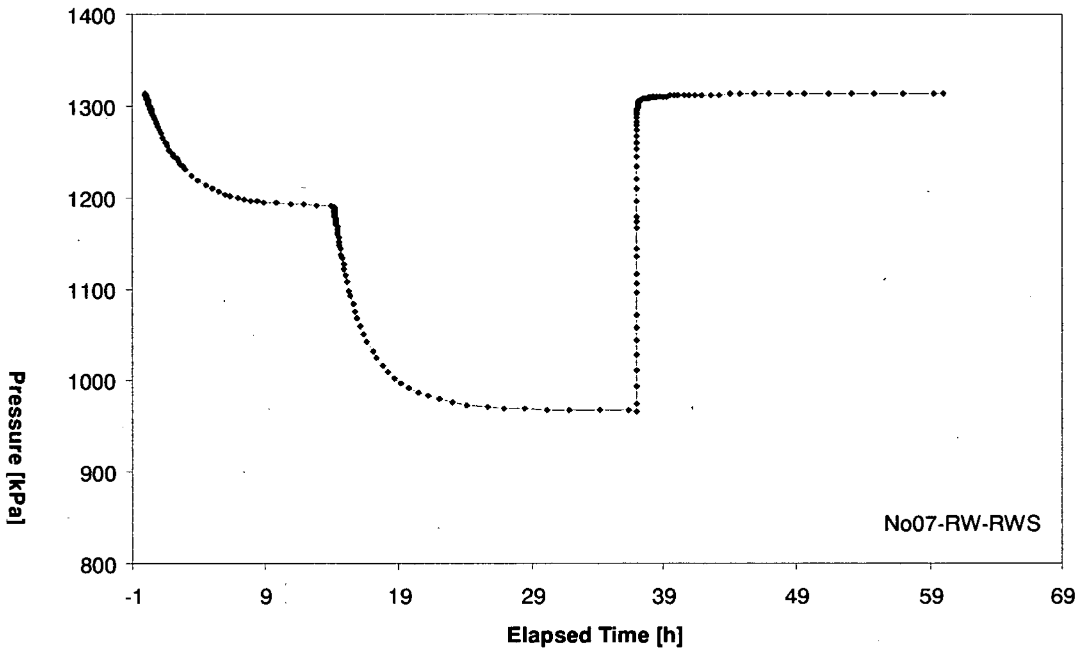

Fig. 1: CARTESIAN plot

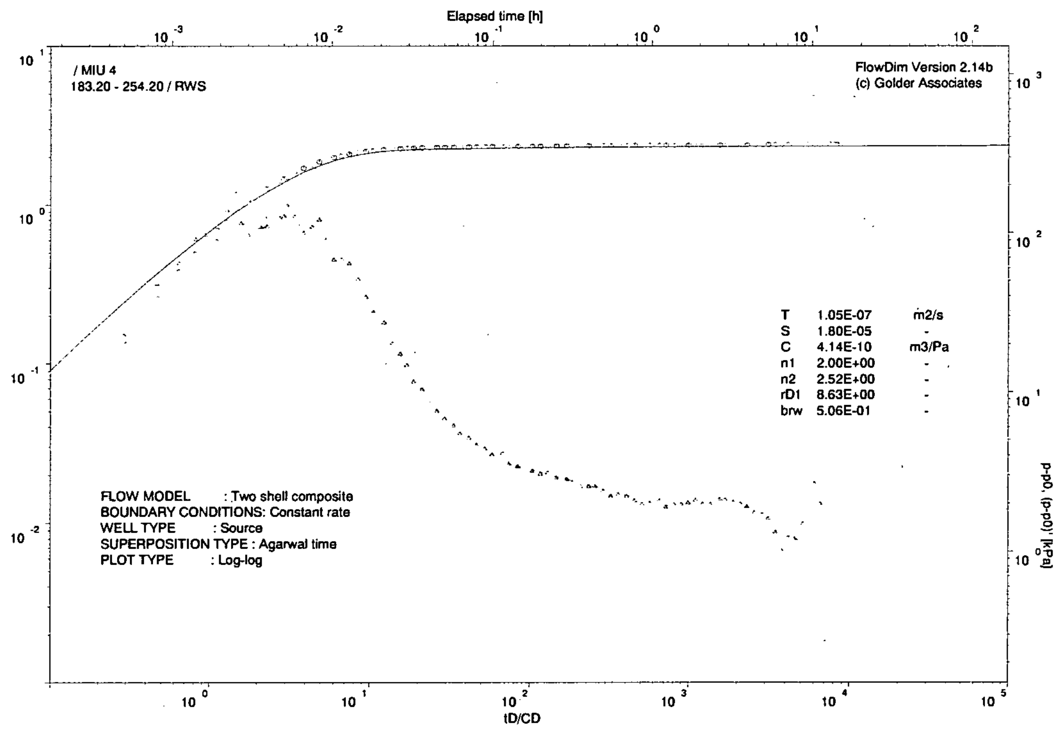

Fig. 2: Log-Log plot

Appendix G: Flow Dim Analysis Report MIU4-08

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION			
Site name			:
Well name			: MIU 4
Interval name			: 754.50 - 790.10
Event name			: PW
Date			:
Input file name			: pw.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Tubing radius	(ru)	[m]	: 1.90E-03
Interval length	(h)	[m]	: 3.56E+01
TESTPARAMETERS			
Initial slug pressure	(p0)	[kPa]	: 6.49E+03
Static formation pressure	(pi)	[kPa]	: 6.58E+03
Test duration	(tt)	[h]	: 1.84E+00
FLUID AND FORMATION PARAMETERS			
Density	(d)	[kg/m3]	: 1.00E+03
Viscosity	(誣)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Composite
Boundary conditions			: Slug/Pulse
Well type			: Source
Superposition type			: Drawdown
TEST RESULTS			
Transmissibility	(T)	[m3]	: 2.29E-12
Transmissivity	(Th)	[m2/s]	: 1.73E-05
Storage	(S)	[m/Pa]	: 3.32E-09
Storativity	(Sh)	[-]	: 3.26E-05
Skin	(s)	[-]	: 3.50E+00
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Outer shell flow dimension	(n2)	[-]	: 2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	: 5.00E+01
Mobility ratio	(sg)	[-]	: 1.00E+01
Time match	(TM)	[1/h]	: 5.32E+05
Pressure match	(PM)	[1/kPa]	: 3.45E+04

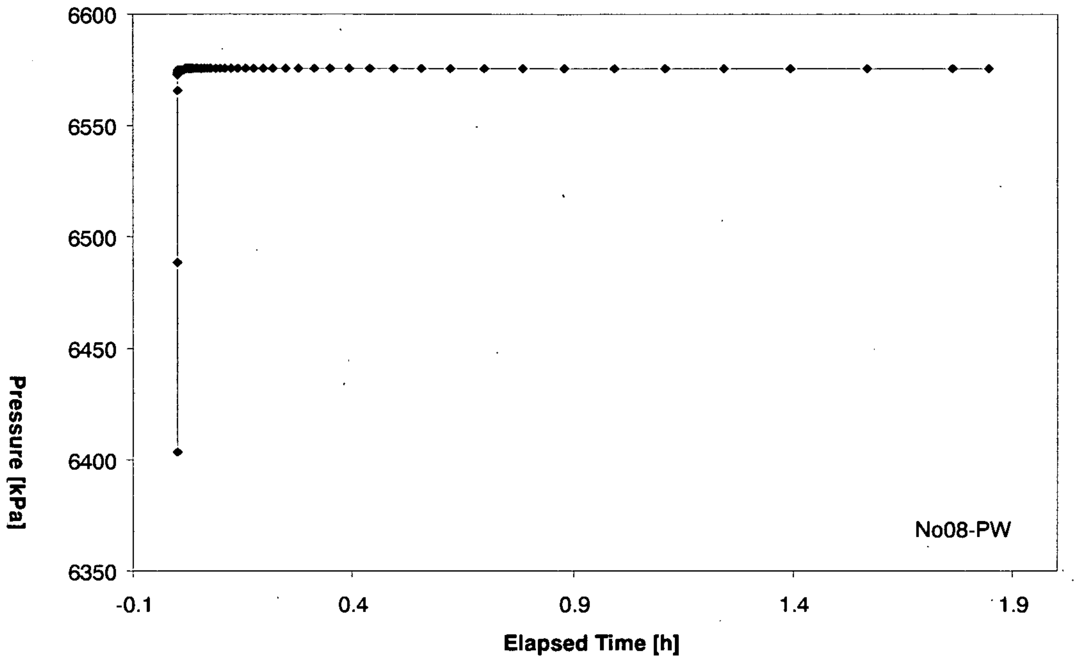

Fig. 1: CARTESIAN plot

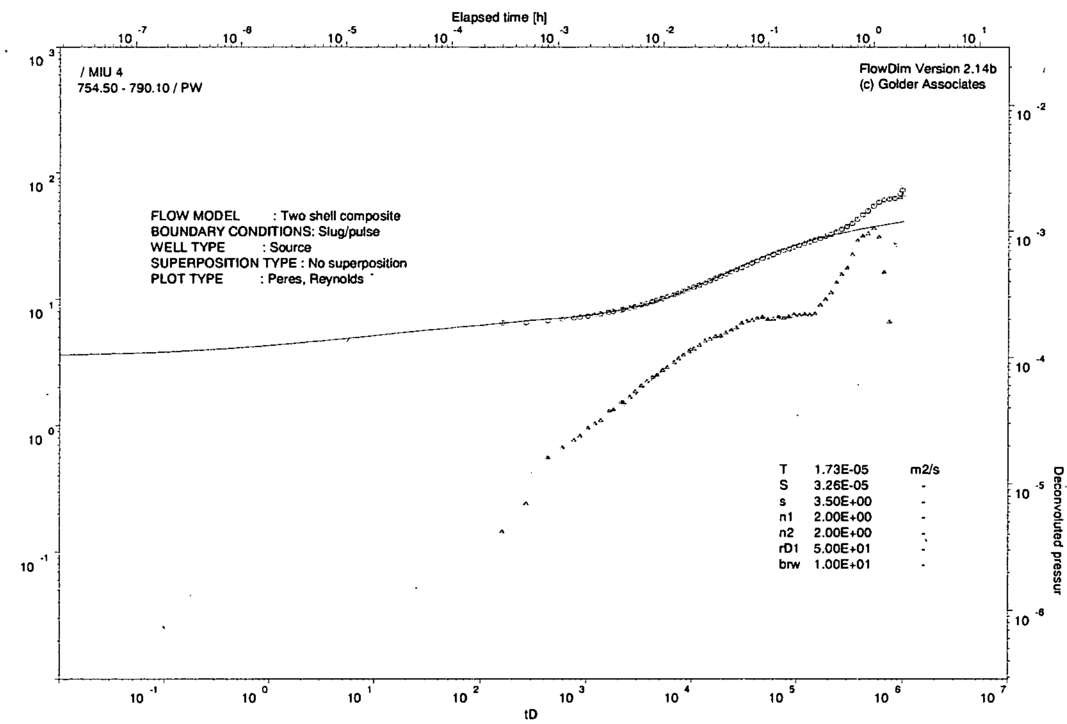

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	754.50 - 790.10
Event name			:	RW
Date			:	
Input file name			:	rw.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	3.56E+01
TESTPARAMETERS				
Flow rate	(q)	[l/min]	:	4.67E+00
Test duration	(tt)	[h]	:	7.41E-02
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Homogeneous
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.8306E-12
Transmissivity	(Th)	[m2/s]	:	1.38E-05
Storage	(S)	[m/Pa]	:	6.79E-09
Storativity	(Sh)	[-]	:	6.66E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	1.54E-06
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Time match	(TM)	[1/h]	:	2.07E+01
Pressure match	(PM)	[1/kPa]	:	1.14E-01

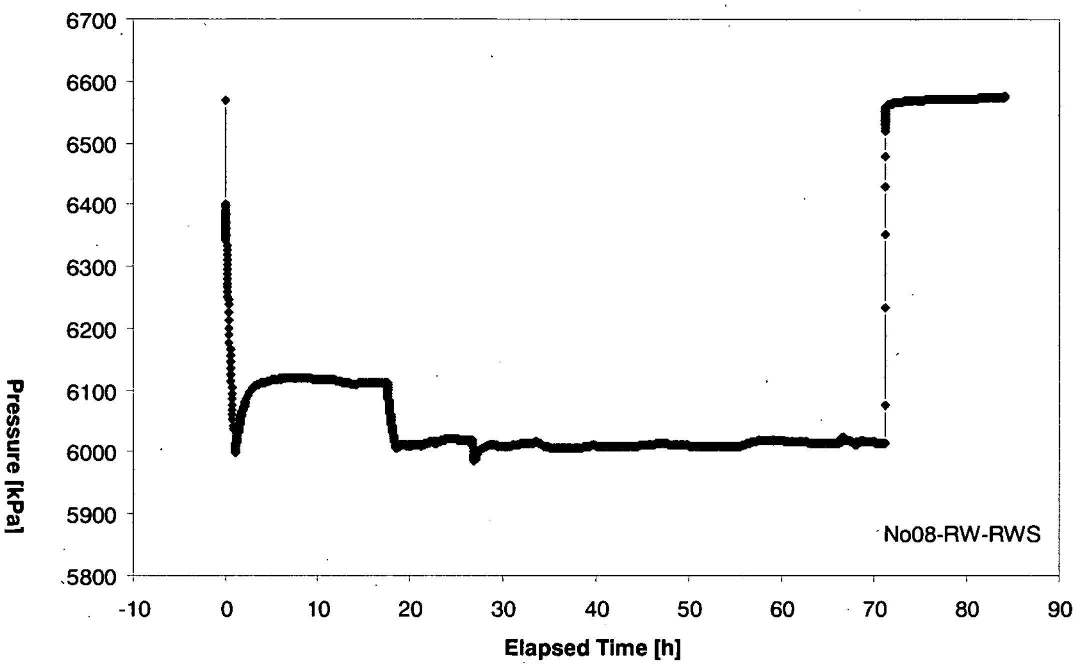

Fig. 1: CARTESIAN plot

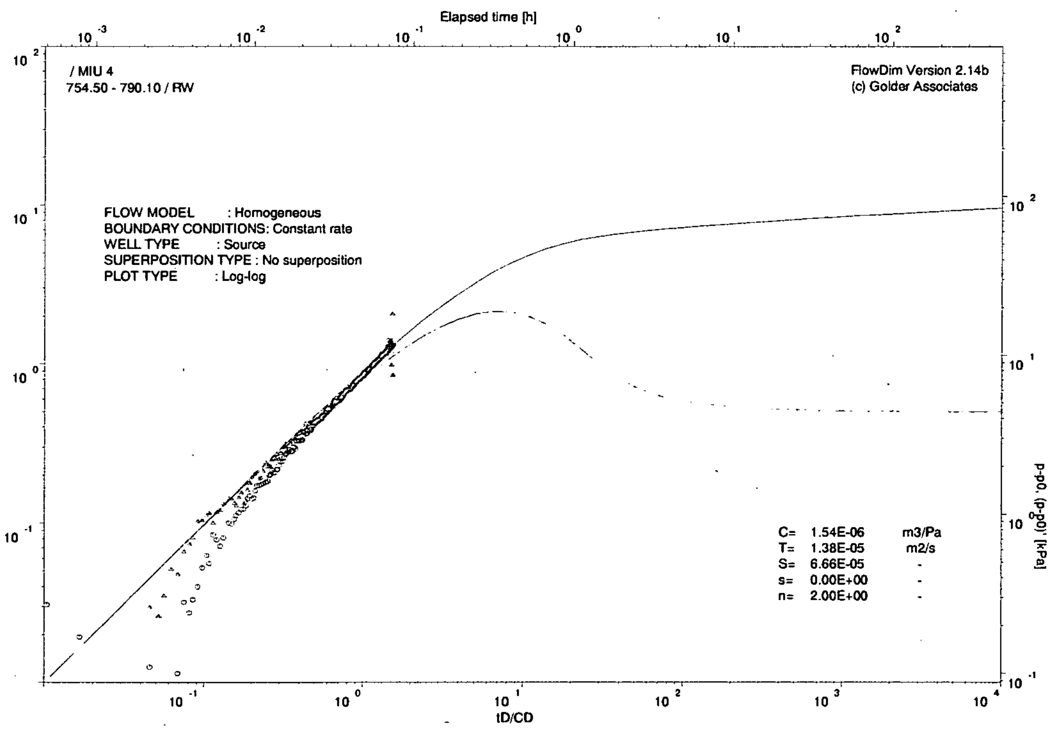

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	754.50 - 790.10
Event name			:	RWS
Date			:	
Input file name			:	rws.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	4.80E-02
Interval length	(h)	[m]	:	3.56E+01
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	7.12E+01
Flow rate	(q)	[l/min]	:	4.67E+00
Test duration	(tt)	[h]	:	1.09E+01
FLUID AND FORMATION PARAMETERS				
Viscosity	(鄹)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Agarwal
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.13E-13
Transmissivity	(Th)	[m2/s]	:	8.54E-07
Storage	(S)	[m/Pa]	:	1.51E-10
Storativity	(Sh)	[-]	:	1.48E-06
Wellbore storage coefficient	(C)	[m3/Pa]	:	2.17E-10
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.42E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	3.49E+01
Mobility ratio	(sg)	[-]	:	9.01E-01
Time match	(TM)	[1/h]	:	9.03E+03
Pressure match	(PM)	[1/kPa]	:	7.01E-03

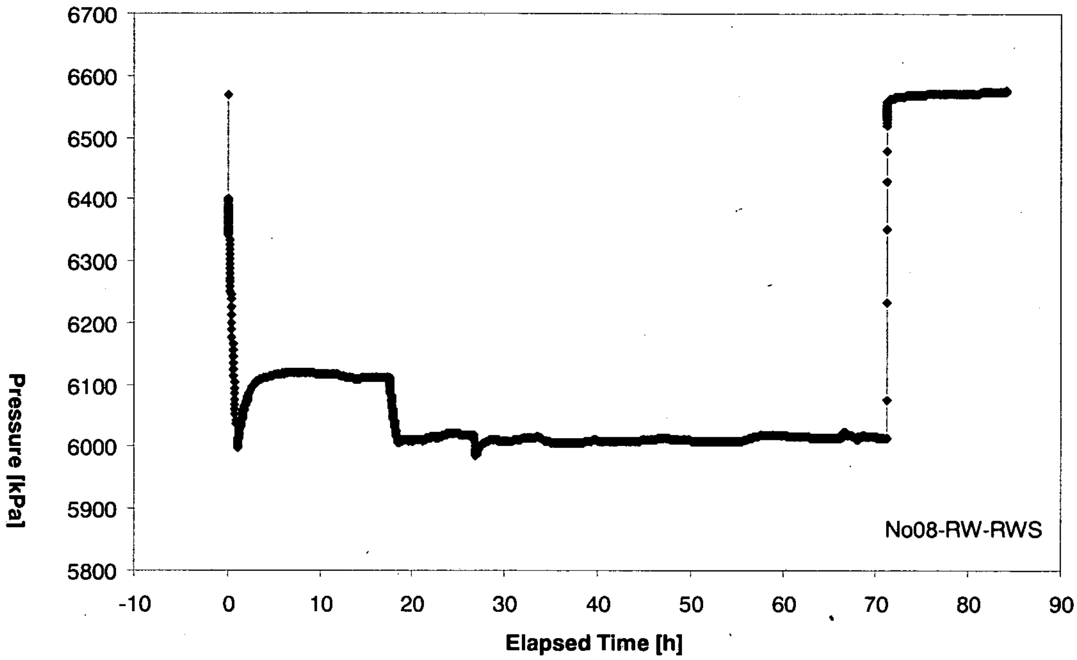

Fig. 1: CARTESIAN plot

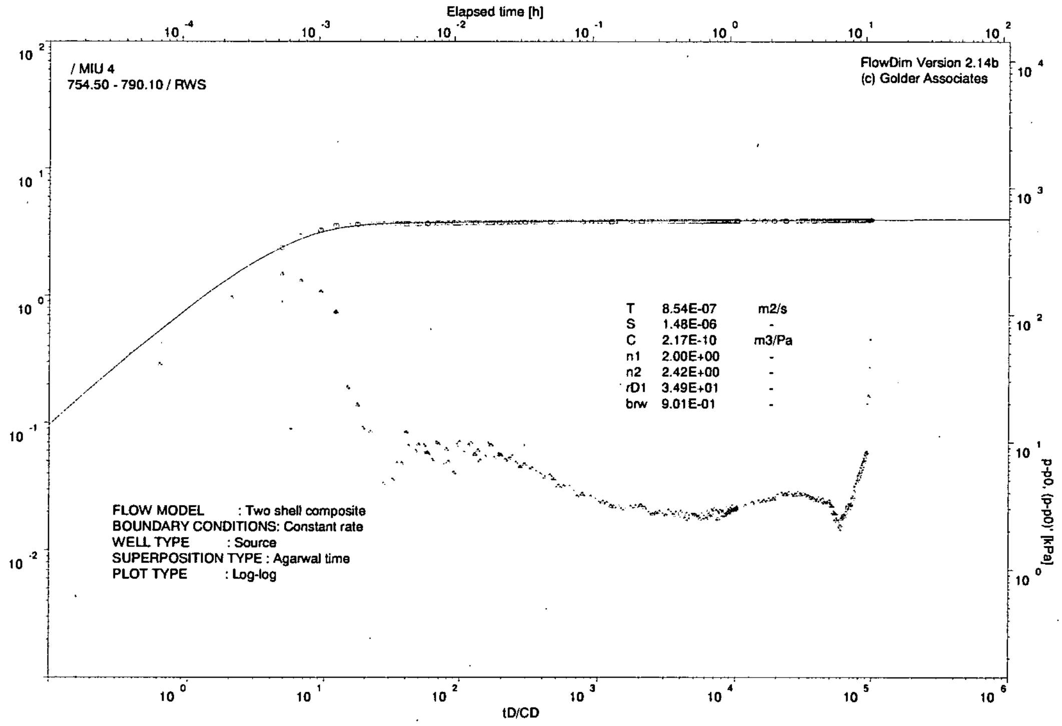

Fig. 2: Log-Log plot

Appendix H: Flow Dim Analysis Report MIU4-09

TEST ANALYSIS REPORT			13.09.2002
IDENTIFICATION			
Site name			:
Well name			: MIU 4
Interval name			: 669.5 - 677.00
Event name			: PW1
Date			:
Input file name			: pw.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Tubing radius	(ru)	[m]	: 1.90E-03
Interval length	(h)	[m]	: 7.50E+00
TESTPARAMETERS			
Initial slug pressure	(p0)	[kPa]	: 5.09E+03
Static formation pressure	(pi)	[kPa]	: 5.60E+03
Test duration	(tt)	[h]	: 4.22E-01
FLUID AND FORMATION PARAMETERS			
Density	(d)	[kg/m3]	: 1.00E+03
Viscosity	(μ)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Composite
Boundary conditions			: Slug/Pulse
Well type			: Source
Superposition type			: Drawdown
TEST RESULTS			
Transmissibility	(T)	[m3]	: 1.23E-13
Transmissivity	(Th)	[m2/s]	: 9.28E-07
Storage	(S)	[m/Pa]	: 1.16E-08
Storativity	(Sh)	[-]	: 1.14E-04
Skin	(s)	[-]	: 0.00E+00
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Outer shell flow dimension	(n2)	[-]	: 2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	: 3.28E+01
Mobility ratio	(sg)	[-]	: 7.56E-01
Time match	(TM)	[1/h]	: 1.27E+04
Pressure match	(PM)	[1/kPa]	: 1.85E+03

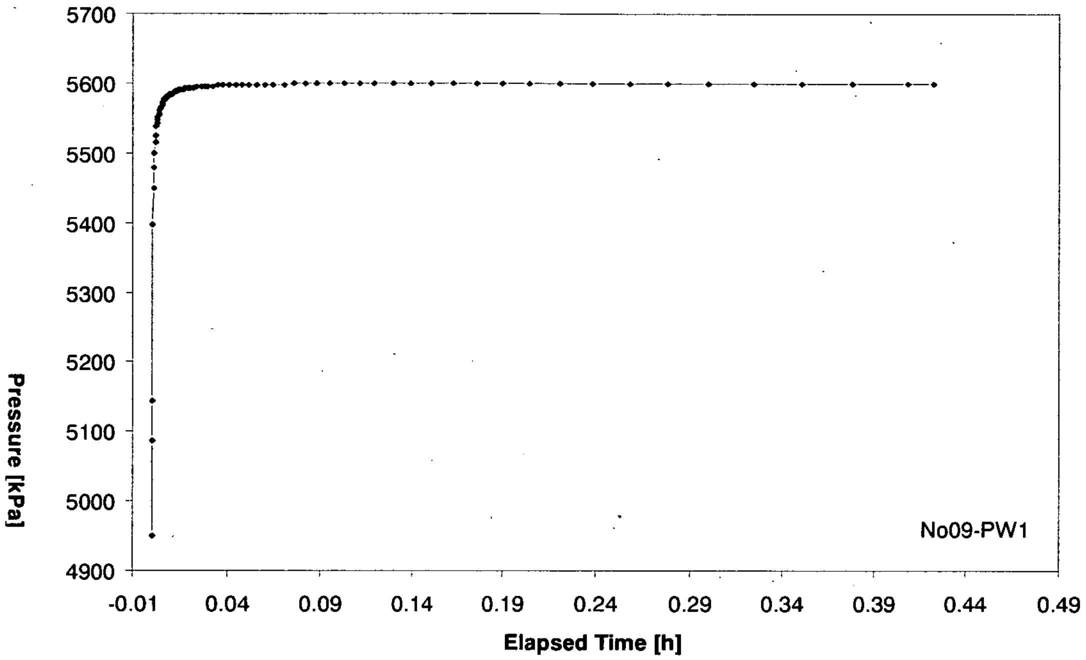

Fig. 1: CARTESIAN plot

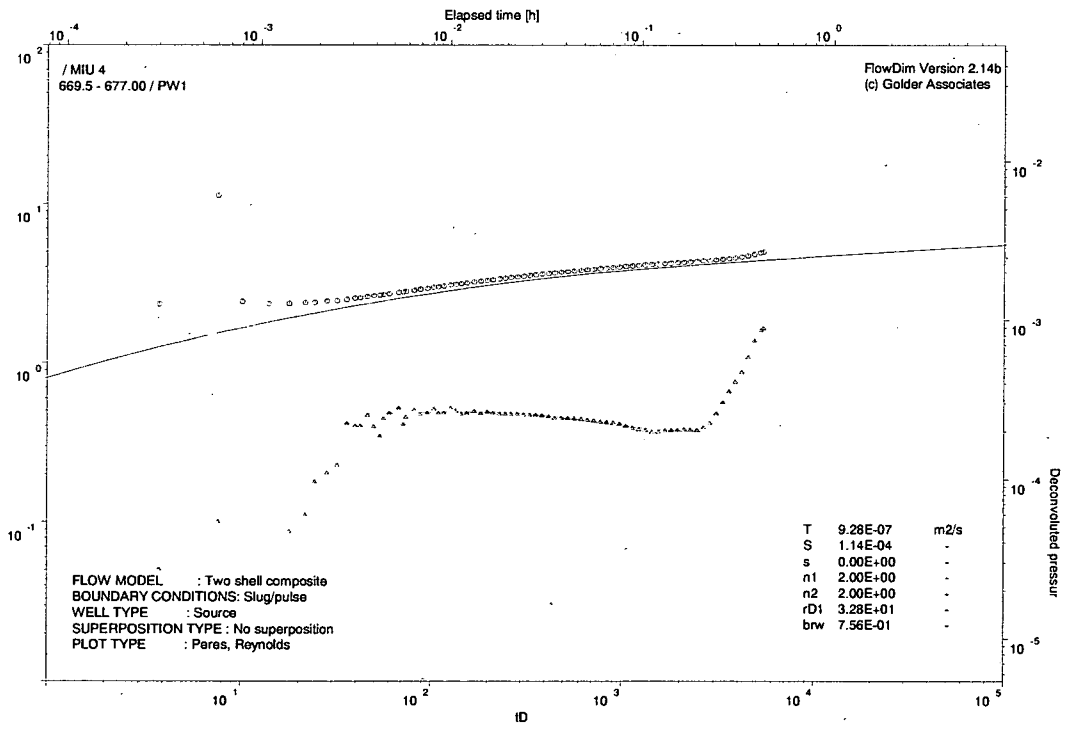

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION			
Site name			:
Well name			: MIU 4
Interval name			: 669.5 - 677.00
Event name			: PW2
Date			:
Input file name			: pw2.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Tubing radius	(ru)	[m]	: 1.90E-03
Interval length	(h)	[m]	: 9.12E+00
TESTPARAMETERS			
Initial slug pressure	(p0)	[kPa]	: 5.41E+03
Static formation pressure	(pi)	[kPa]	: 5.54E+03
Test duration	(tt)	[h]	: 1.74E-01
FLUID AND FORMATION PARAMETERS			
Density	(d)	[kg/m3]	: 1.00E+03
Viscosity	(謳)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Composite
Boundary conditions			: Slug/Pulse
Well type			: Source
Superposition type			: Drawdown
TEST RESULTS			
Transmissibility	(T)	[m3]	: 6.02E-14
Transmissivity	(Th)	[m2/s]	: 4.54E-07
Storage	(S)	[m/Pa]	: 1.62E-08
Storativity	(Sh)	[-]	: 1.59E-04
Skin	(s)	[-]	: 1.00E+00
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Outer shell flow dimension	(n2)	[-]	: 2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	: 1.12E+01
Mobility ratio	(sg)	[-]	: 1.58E+00
Time match	(TM)	[1/h]	: 2.87E+03
Pressure match	(PM)	[1/kPa]	: 9.06E+02

FlowDim V2.14b-Copyright (c) Golder Associates 1994

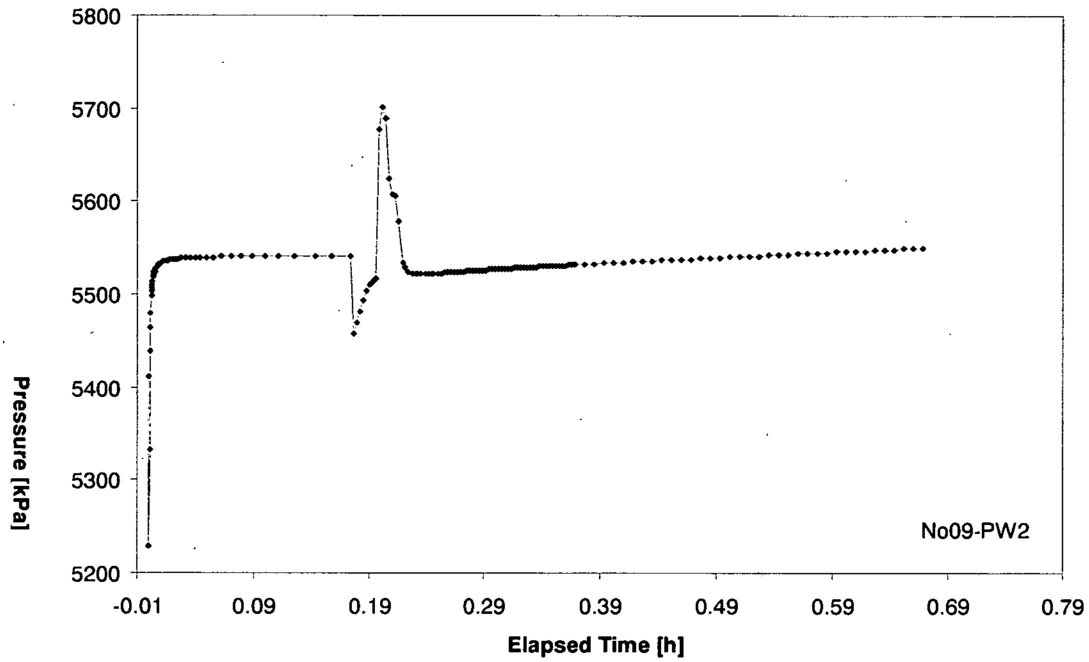

Fig. 1: CARTESIAN plot

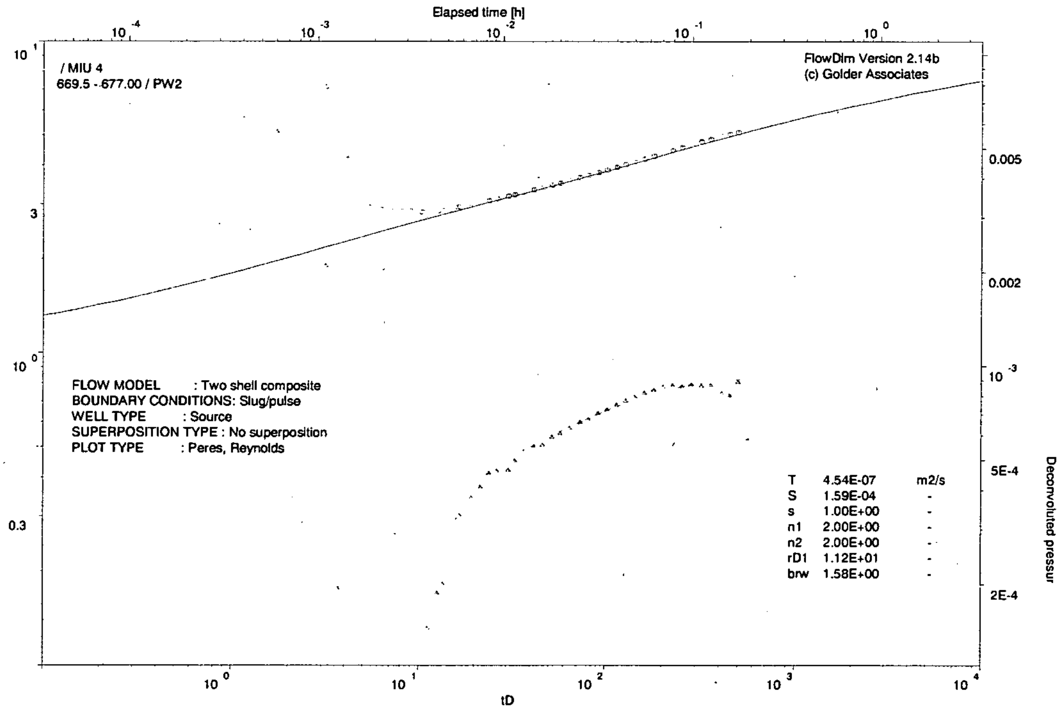

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	669.50 - 677.00
Event name			:	SW
Date			:	
Input file name			:	sw.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	3.92E-02
Interval length	(h)	[m]	:	9.12E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	5.01E+03
Static formation pressure	(pi)	[kPa]	:	5.60E+03
Test duration	(tt)	[h]	:	5.13E+00
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	3.24E-14
Transmissivity	(Th)	[m2/s]	:	2.44E-07
Storage	(S)	[m/Pa]	:	3.59E-08
Storativity	(Sh)	[-]	:	3.52E-04
Skin	(s)	[-]	:	3.00E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	2.20E+01
Mobility ratio	(sg)	[-]	:	5.21E+00
Time match	(TM)	[1/h]	:	6.93E+02
Pressure match	(PM)	[1/kPa]	:	1.14E+00

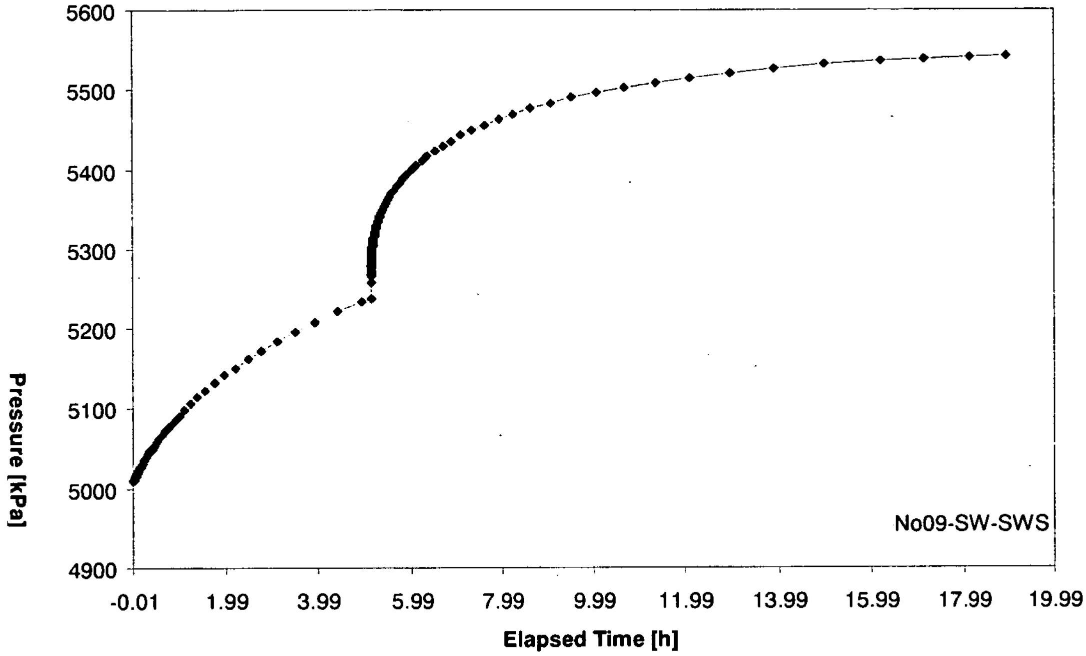

Fig. 1: CARTESIAN plot

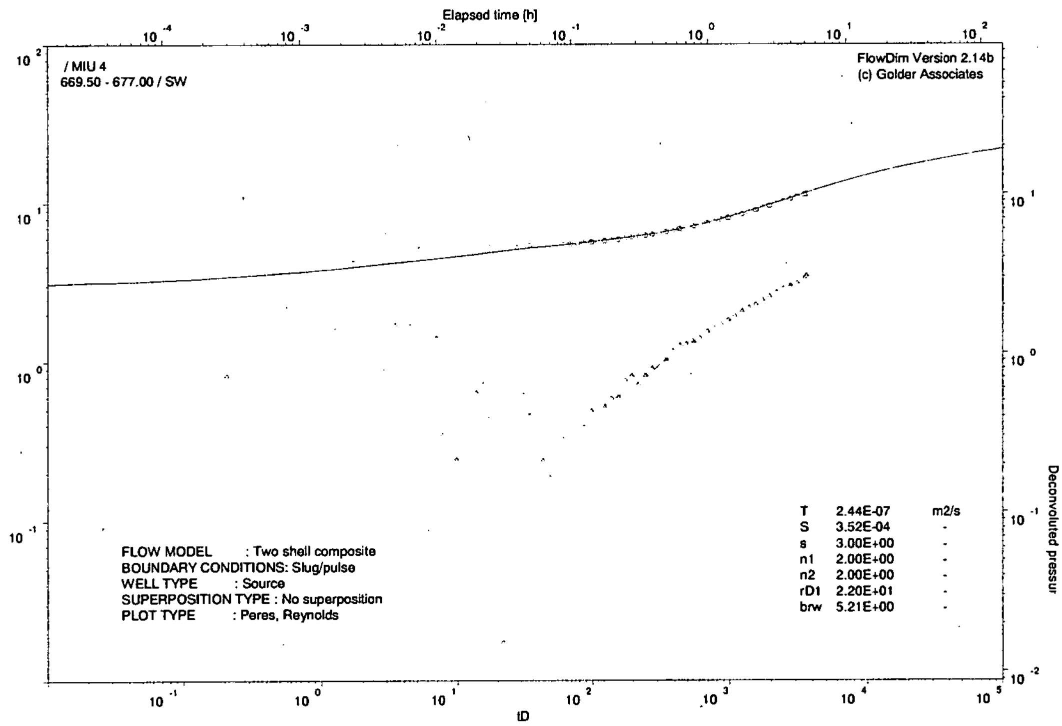

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	669.5 - 677
Event name			:	SWS
Date			:	
Input file name			:	sws.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	7.50E+00
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	5.11E+00
Flow rate	(q)	[l/min]	:	3.66E-01
Test duration	(tt)	[h]	:	1.38E+01
FLUID AND FORMATION PARAMETERS				
Viscosity	(証)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Buildup
TEST RESULTS				
Transmissibility	(T)	[m3]	:	7.5714E-14
Transmissivity	(Th)	[m2/s]	:	5.71E-07
Storage	(S)	[m/Pa]	:	2.31E-09
Storativity	(Sh)	[-]	:	2.27E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	1.57E-10
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	1.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	2.47E+01
Mobility ratio	(sg)	[-]	:	1.73E-02
Time match	(TM)	[1/h]	:	8.40E+03
Pressure match	(PM)	[1/kPa]	:	6.00E-02

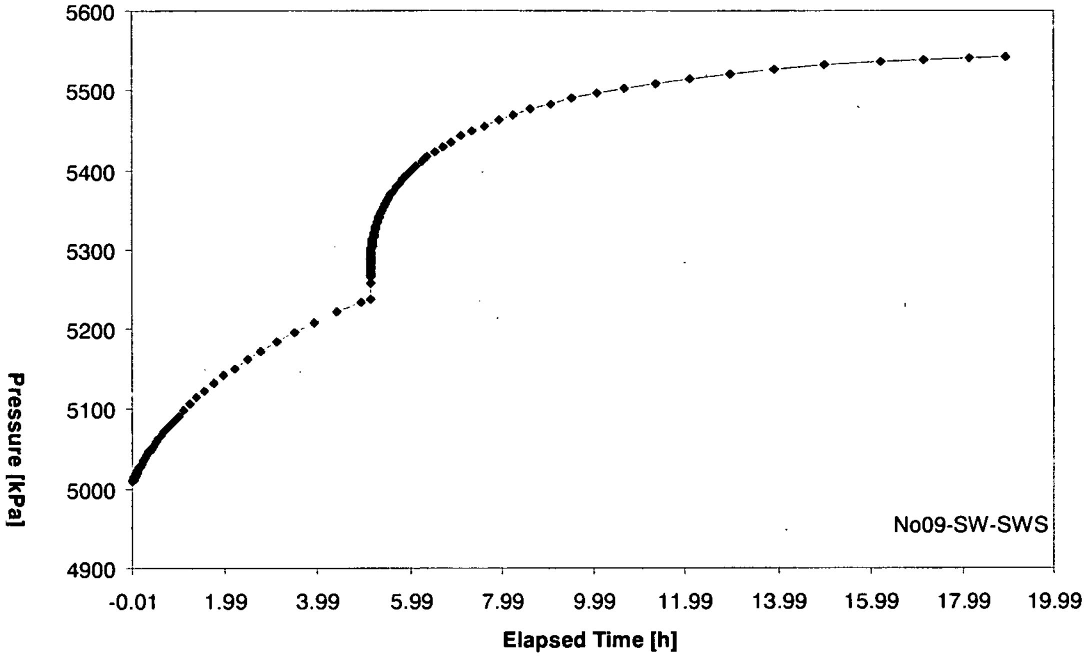

Fig. 1: CARTESIAN plot

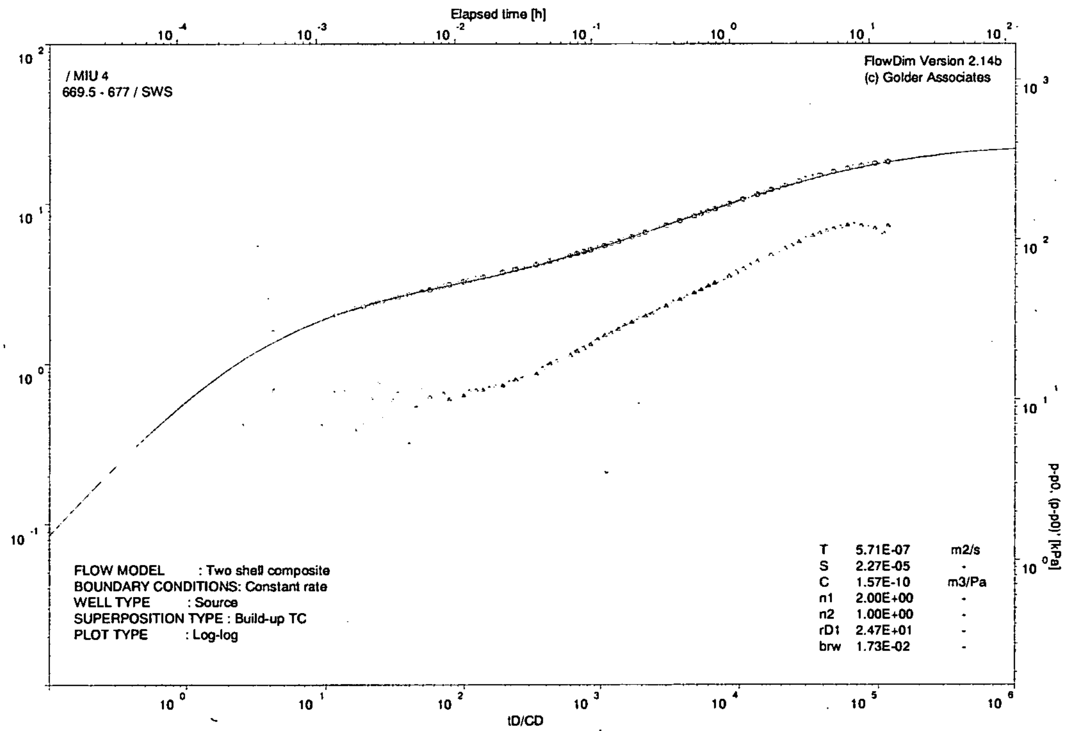

Fig. 2: Log-Log plot

Appendix I: Flow Dim Analysis Report MIU4-10

TEST ANALYSIS REPORT				13.09.2002
IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	690.50 - 753.00
Event name			:	PW1
Date			:	
Input file name			:	pw1.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	4.80E-02
Tubing radius	(ru)	[m]	:	1.90E-03
Interval length	(h)	[m]	:	9.12E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	5.78E+03
Static formation pressure	(pi)	[kPa]	:	5.97E+03
Test duration	(tt)	[h]	:	1.70E+00
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(諏)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.03E-13
Transmissivity	(Th)	[m2/s]	:	7.80E-07
Storage	(S)	[m/Pa]	:	2.68E-09
Storativity	(Sh)	[-]	:	2.62E-05
Skin	(s)	[-]	:	1.00E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	8.13E+01
Mobility ratio	(sg)	[-]	:	1.63E+01
Time match	(TM)	[1/h]	:	4.64E+04
Pressure match	(PM)	[1/kPa]	:	1.55E+03

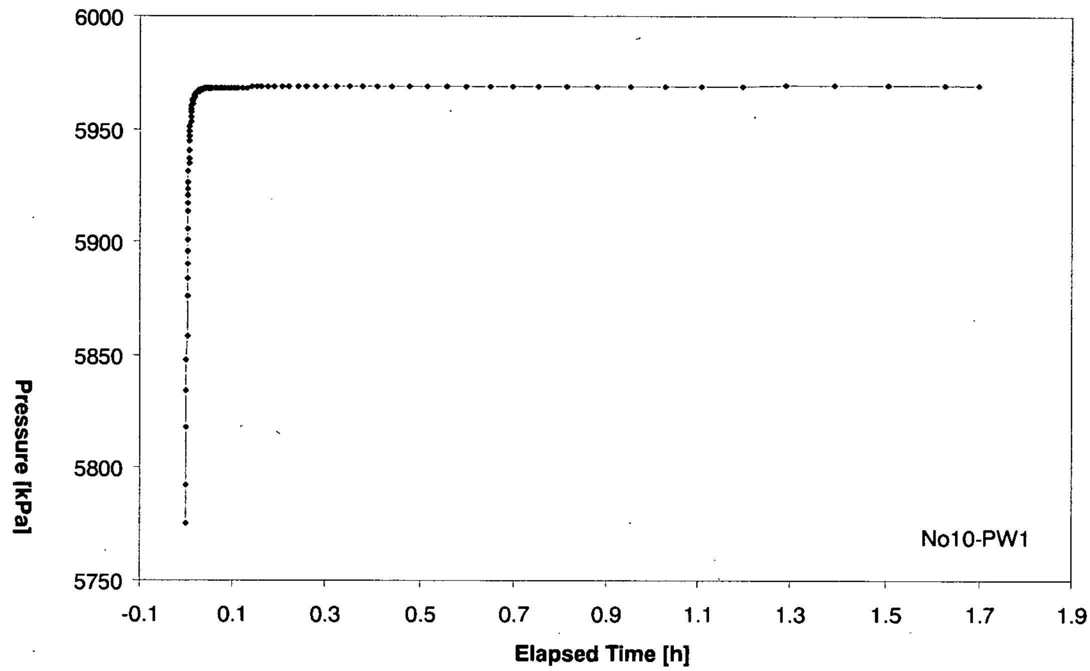

Fig. 1: CARTESIAN plot

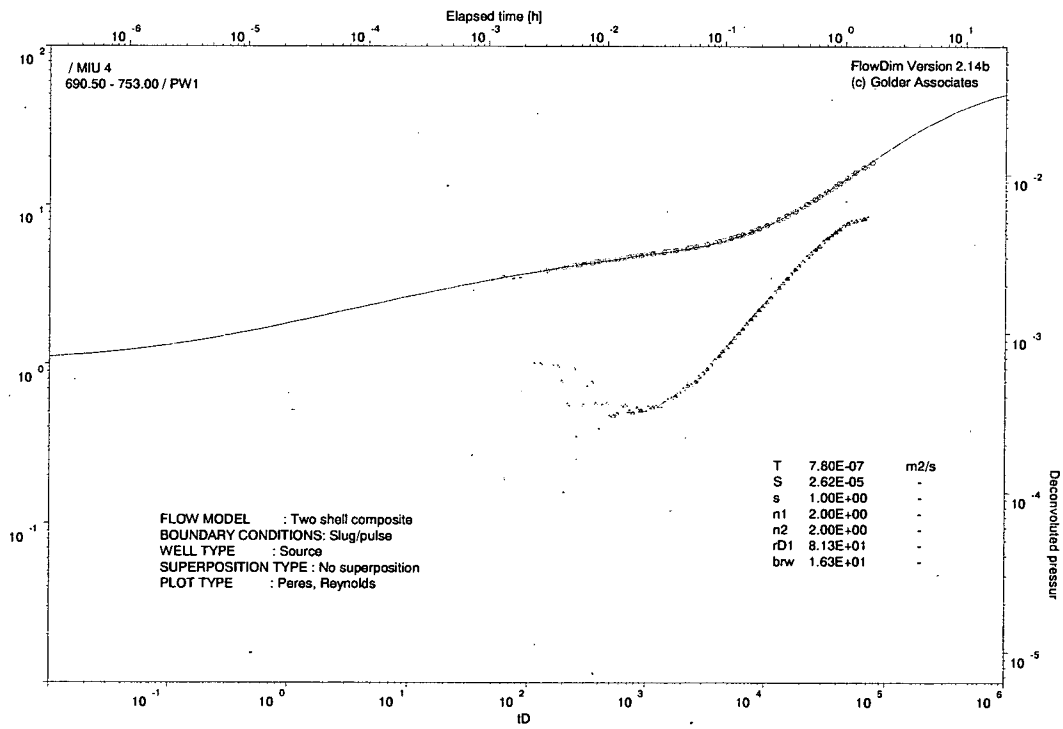

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION			
Site name			:
Well name			: MIU 4
Interval name			: 690.50 - 753.00
Event name			: SW
Date			: kjhoipuhoiu
Input file name			: pw2.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Tubing radius	(ru)	[m]	: 1.90E-03
Interval length	(h)	[m]	: 6.25E+01
TESTPARAMETERS			
Initial slug pressure	(p0)	[kPa]	: 5.81E+03
Static formation pressure	(pi)	[kPa]	: 5.97E+03
Test duration	(tt)	[h]	: 6.41E-01
FLUID AND FORMATION PARAMETERS			
Density	(d)	[kg/m3]	: 1.00E+03
Viscosity	(誣)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Composite
Boundary conditions			: Slug/Pulse
Well type			: Source
Superposition type			: Drawdown
TEST RESULTS			
Transmissibility	(T)	[m3]	: 9.26E-14
Transmissivity	(Th)	[m2/s]	: 6.99E-07
Storage	(S)	[m/Pa]	: 2.13E-09
Storativity	(Sh)	[-]	: 2.09E-05
Skin	(s)	[-]	: 3.01E+00
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Outer shell flow dimension	(n2)	[-]	: 2.09E+00
Dimensionles discontinuity radius	(rd1)	[-]	: 1.17E+02
Mobility ratio	(sg)	[-]	: 7.07E+00
Time match	(TM)	[1/h]	: 5.00E+04
Pressure match	(PM)	[1/kPa]	: 2.09E+03

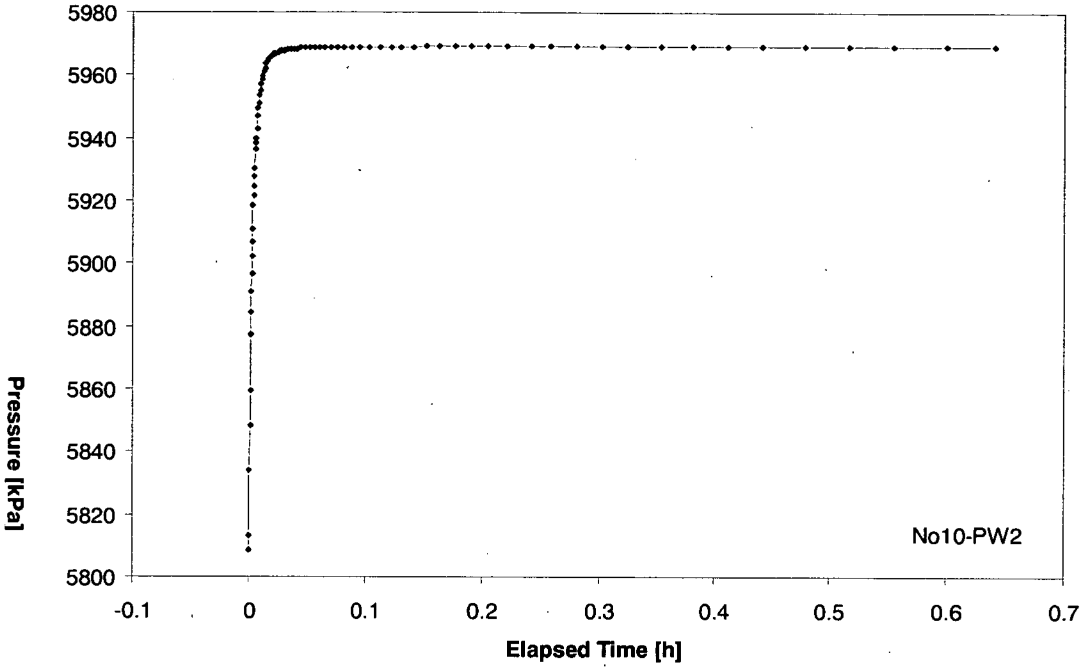

Fig. 1: CARTESIAN plot

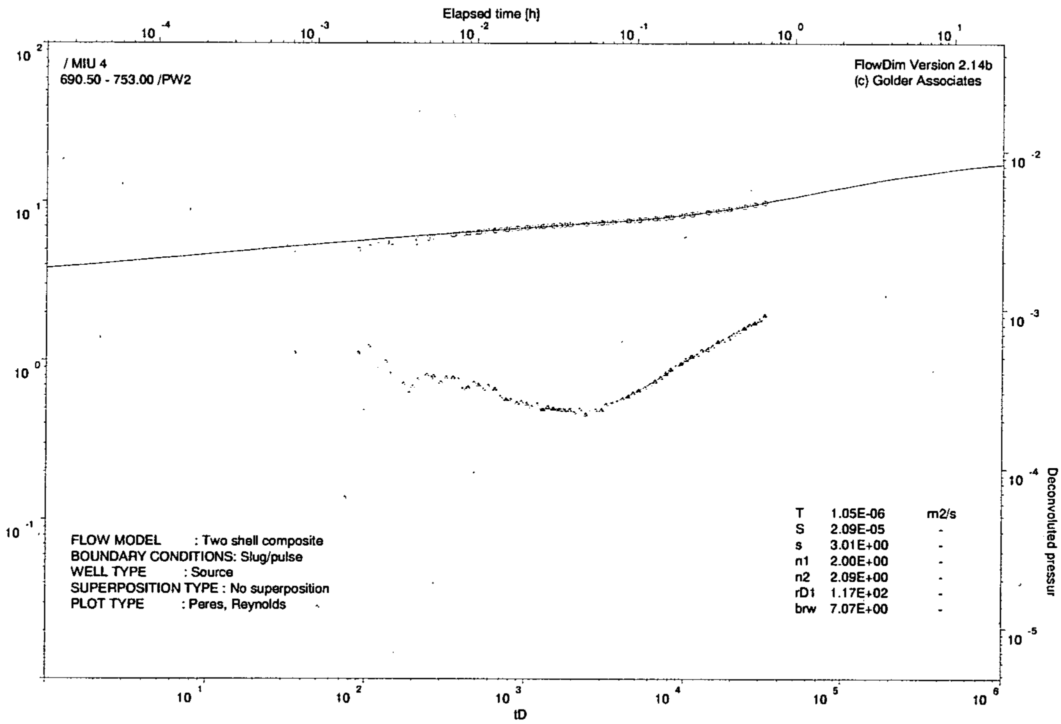

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION			
Site name			:
Well name			: MIU 4
Interval name			: 690.50 - 753.00
Event name			: SW
Date			:
Input file name			: sw.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 4.80E-02
Tubing radius	(ru)	[m]	: 3.92E-02
Interval length	(h)	[m]	: 9.12E+00
TESTPARAMETERS			
Initial slug pressure	(p0)	[kPa]	: 5.49E+03
Static formation pressure	(pi)	[kPa]	: 5.97E+03
Test duration	(tt)	[h]	: 1.67E+00
FLUID AND FORMATION PARAMETERS			
Density	(d)	[kg/m3]	: 1.00E+03
Viscosity	(μ)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Composite
Boundary conditions			: Slug/Pulse
Well type			: Source
Superposition type			: Drawdown
TEST RESULTS			
Transmissibility	(T)	[m3]	: 1.74E-14
Transmissivity	(Th)	[m2/s]	: 1.32E-07
Storage	(S)	[m/Pa]	: 1.07E-07
Storativity	(Sh)	[-]	: 1.05E-03
Skin	(s)	[-]	: 0.00E+00
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Outer shell flow dimension	(n2)	[-]	: 3.42E+00
Dimensionles discontinuity radius	(rd1)	[-]	: 4.27E+00
Mobility ratio	(sg)	[-]	: 2.59E+00
Time match	(TM)	[1/h]	: 1.95E+02
Pressure match	(PM)	[1/kPa]	: 6.16E-01

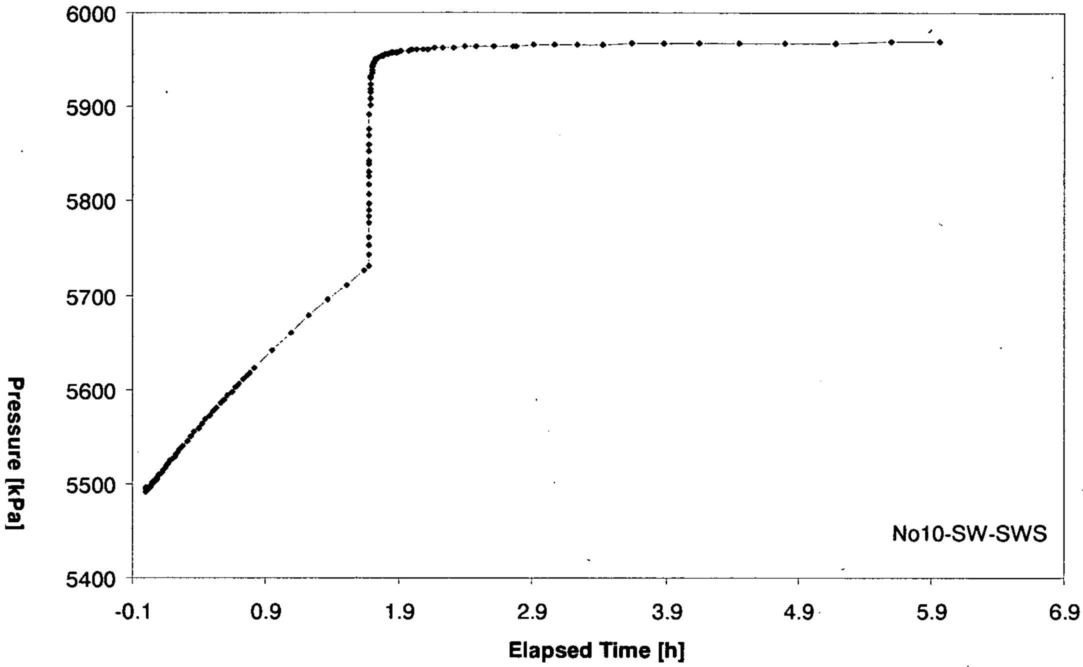

Fig. 1: CARTESIAN plot

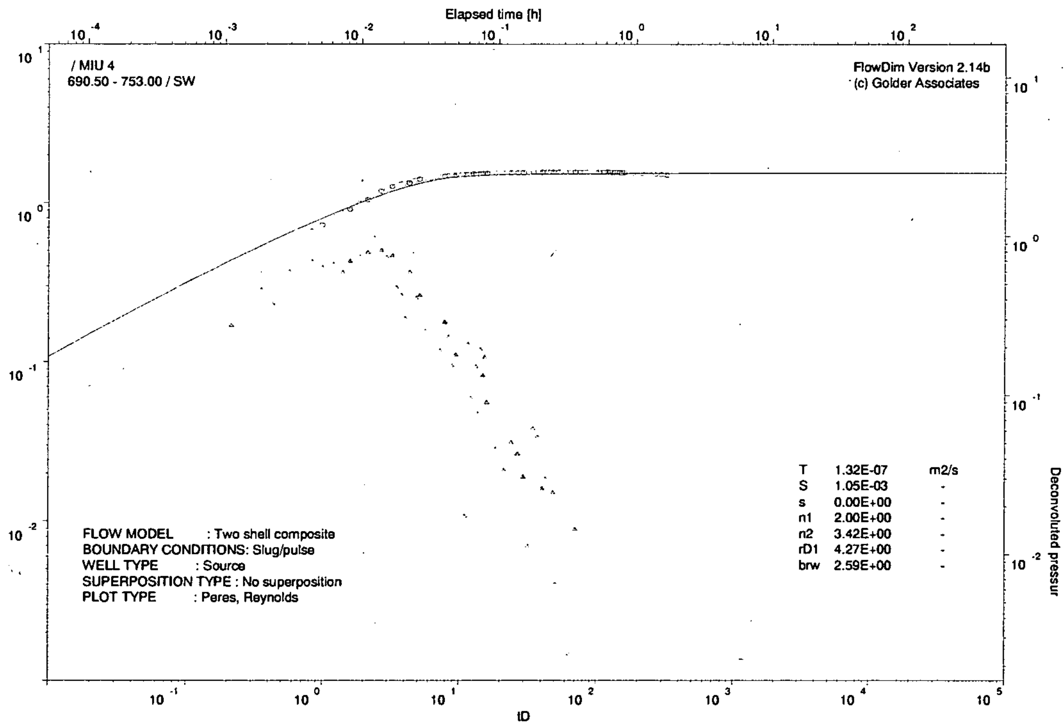

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT				13.09.2002
IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	690.5 - 753.00
Event name			:	SWS
Date			:	
Input file name			:	sws.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	1.25E+01
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	1.66E+00
Flow rate	(q)	[l/min]	:	1.17E+00
Test duration	(tt)	[h]	:	4.30E+00
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Buildup
TEST RESULTS				
Transmissibility	(T)	[m3]	:	7.7856E-14
Transmissivity	(Th)	[m2/s]	:	5.88E-07
Storage	(S)	[m/Pa]	:	6.62E-10
Storativity	(Sh)	[-]	:	6.49E-06
Wellbore storage coefficient	(C)	[m3/Pa]	:	1.50E-09
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	1.87E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	5.74E+01
Mobility ratio	(sg)	[-]	:	9.95E-02
Time match	(TM)	[1/h]	:	9.05E+02
Pressure match	(PM)	[1/kPa]	:	1.92E-02

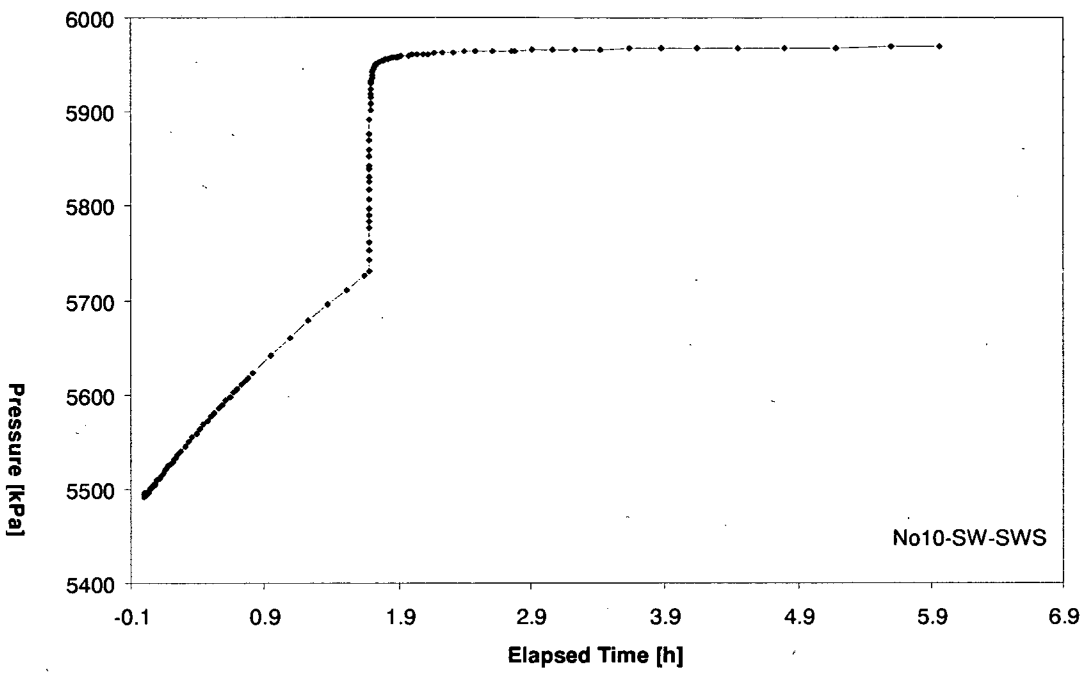

Fig. 1: CARTESIAN plot

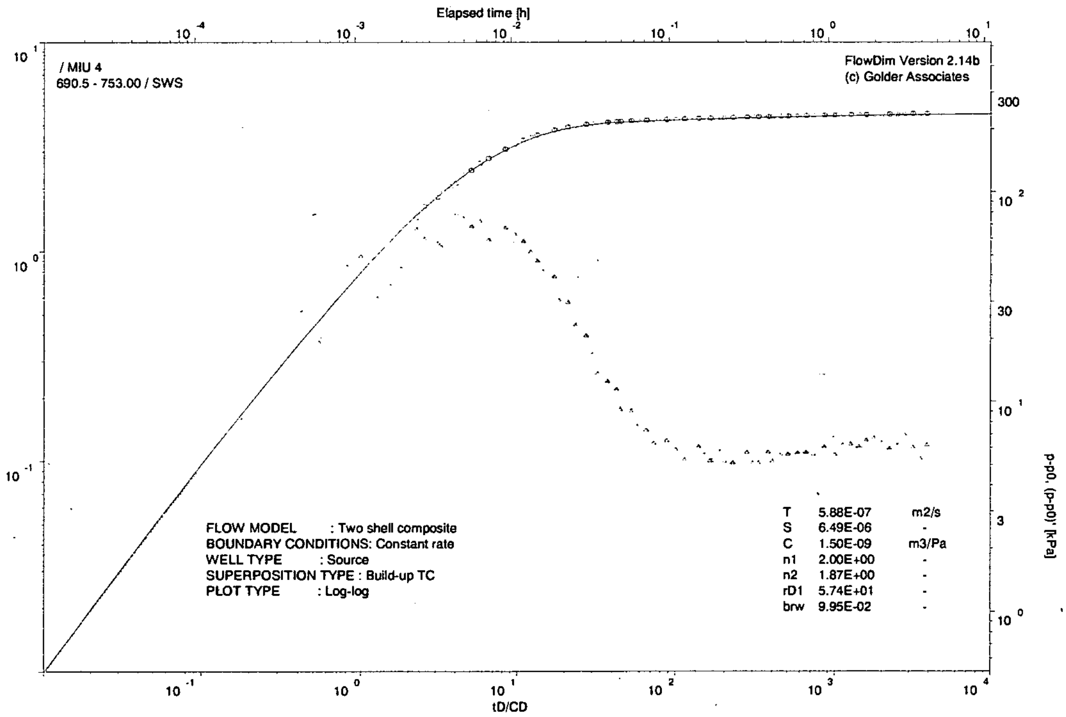

Fig. 2: Log-Log plot

Appendix J: Flow Dim Analysis Report MIU4-11

TEST ANALYSIS REPORT			13.09.2002
IDENTIFICATION			
Site name			:
Well name			: MIU 4
Interval name			: 500.3 - 562.80
Event name			: PW1
Date			:
Input file name			: pw1.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Tubing radius	(ru)	[m]	: 1.90E-03
Interval length	(h)	[m]	: 9.12E+00
TESTPARAMETERS			
Initial slug pressure	(p0)	[kPa]	: 3.74E+03
Static formation pressure	(pi)	[kPa]	: 4.12E+03
Test duration	(tt)	[h]	: 2.83E-01
FLUID AND FORMATION PARAMETERS			
Density	(d)	[kg/m3]	: 1.00E+03
Viscosity	(謳)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Composite
Boundary conditions			: Slug/Pulse
Well type			: Source
Superposition type			: Drawdown
TEST RESULTS			
Transmissibility	(T)	[m3]	: 2.43E-12
Transmissivity	(Th)	[m2/s]	: 1.83E-05
Storage	(S)	[m/Pa]	: 1.22E-09
Storativity	(Sh)	[-]	: 1.19E-05
Skin	(s)	[-]	: 3.00E+01
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Outer shell flow dimension	(n2)	[-]	: 2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	: 5.16E+02
Mobility ratio	(sg)	[-]	: 7.00E+00
Time match	(TM)	[1/h]	: 1.54E+06
Pressure match	(PM)	[1/kPa]	: 3.66E+04

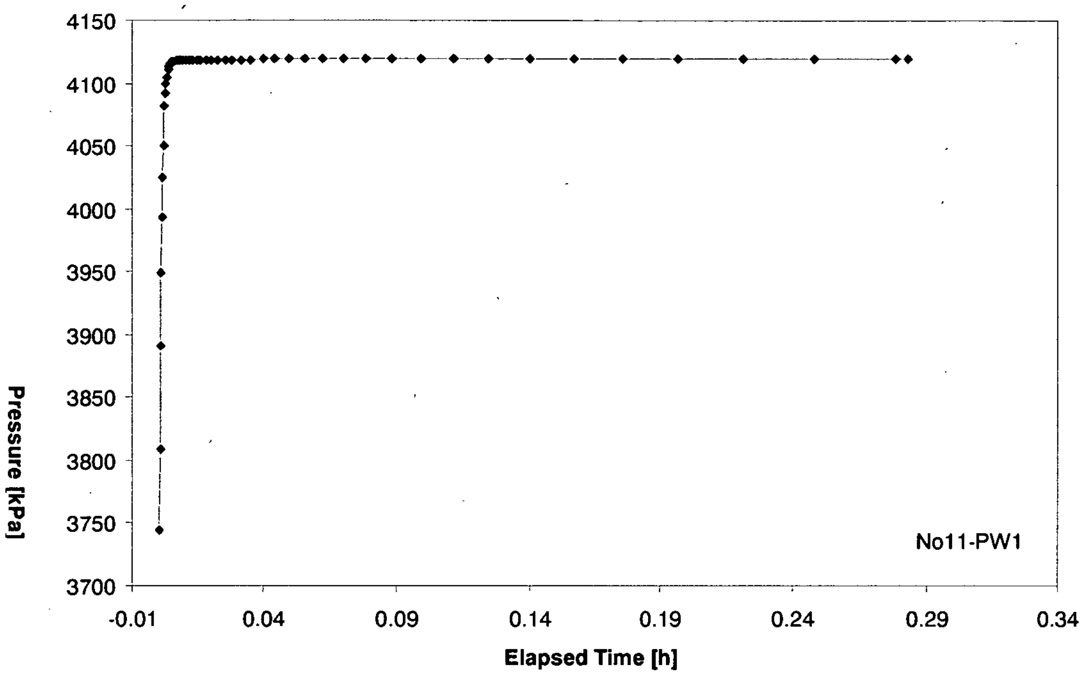

Fig. 1: CARTESIAN plot

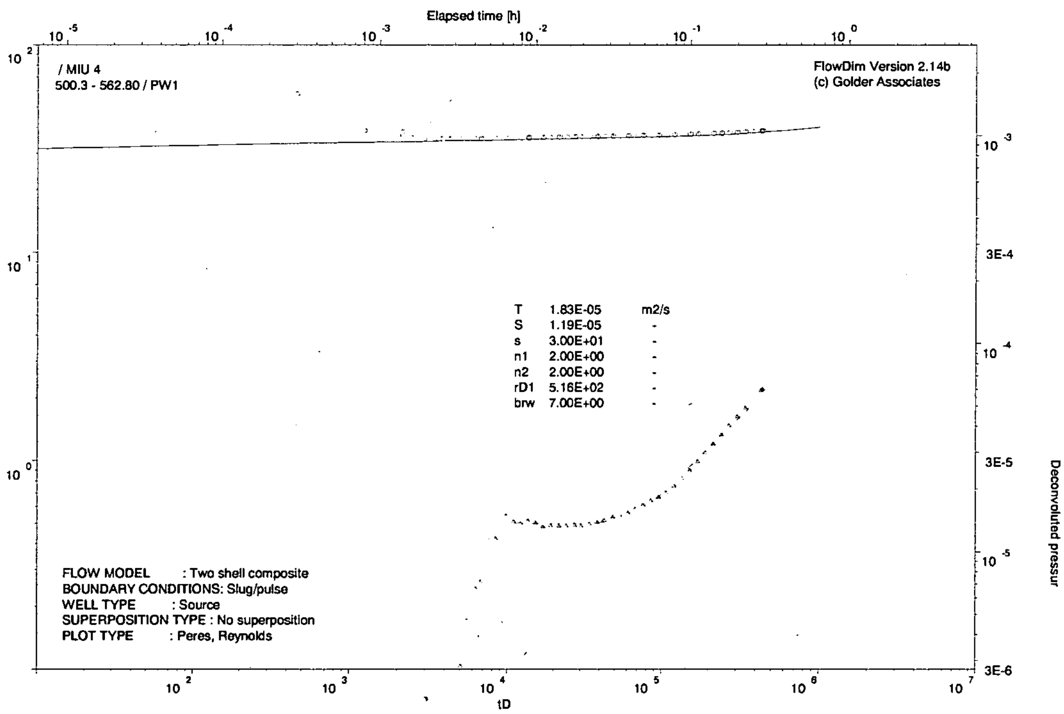

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION			
Site name			:
Well name			: MIU 4
Interval name			: 500.30 - 562.80
Event name			: PW2
Date			:
Input file name			: pw2.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Tubing radius	(ru)	[m]	: 1.90E-03
Interval length	(h)	[m]	: 9.12E+00
TESTPARAMETERS			
Initial slug pressure	(p0)	[kPa]	: 3.84E+03
Static formation pressure	(pi)	[kPa]	: 4.12E+03
Test duration	(tt)	[h]	: 1.54E+00
FLUID AND FORMATION PARAMETERS			
Density	(d)	[kg/m3]	: 1.00E+03
Viscosity	(誣)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Composite
Boundary conditions			: Slug/Pulse
Well type			: Source
Superposition type			: Drawdown
TEST RESULTS			
Transmissibility	(T)	[m3]	: 1.89E-12
Transmissivity	(Th)	[m2/s]	: 1.42E-05
Storage	(S)	[m/Pa]	: 3.10E-09
Storativity	(Sh)	[-]	: 3.04E-05
Skin	(s)	[-]	: 2.30E+01
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Outer shell flow dimension	(n2)	[-]	: 2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	: 1.79E+02
Mobility ratio	(sg)	[-]	: 2.47E+01
Time match	(TM)	[1/h]	: 4.68E+05
Pressure match	(PM)	[1/kPa]	: 2.84E+04

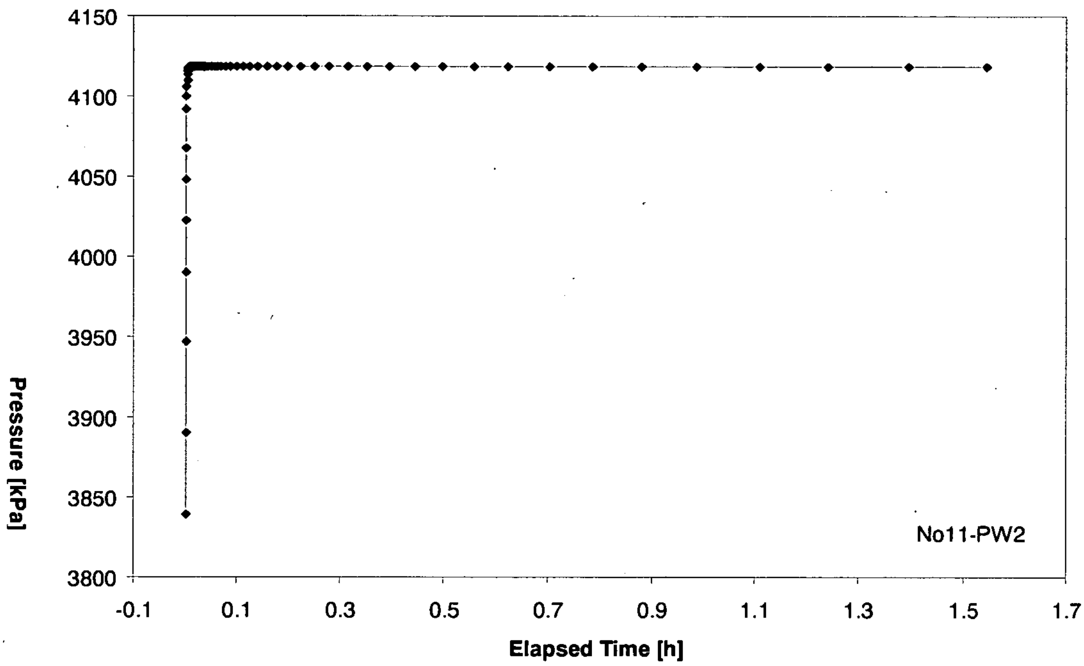

Fig. 1: CARTESIAN plot

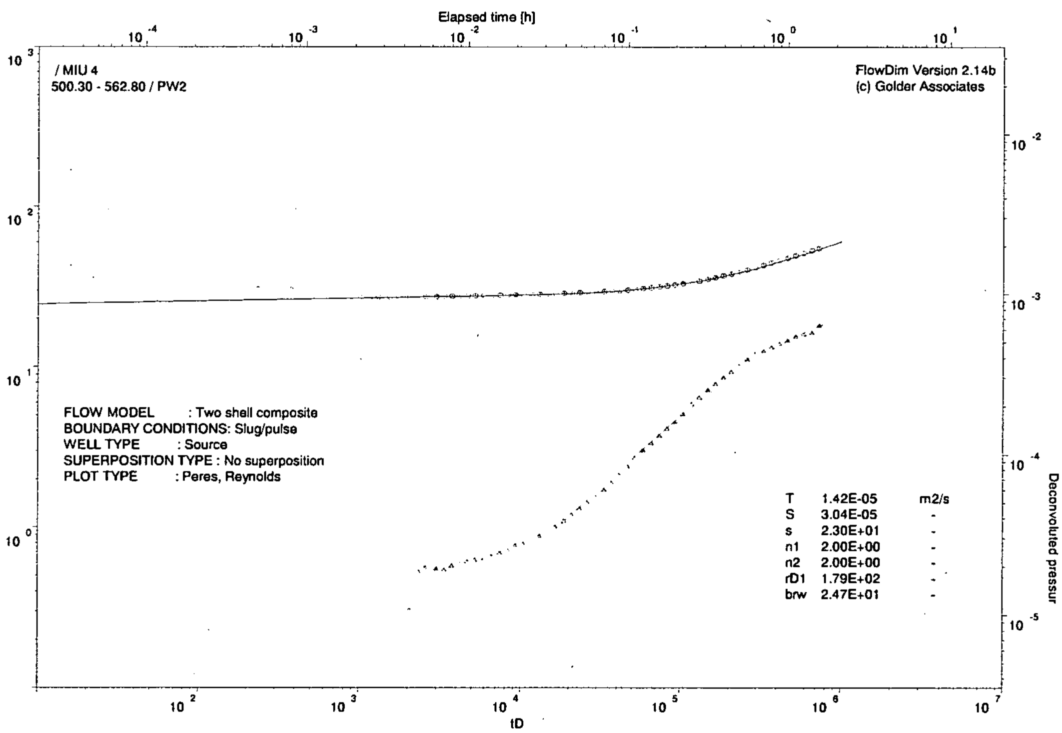

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT

13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	500.30 - 562.80
Event name			:	SW
Date			:	
Input file name			:	sw.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	3.92E-02
Interval length	(h)	[m]	:	9.12E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	3.62E+03
Static formation pressure	(pi)	[kPa]	:	4.12E+03
Test duration	(tt)	[h]	:	7.43E-01
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	4.01E-14
Transmissivity	(Th)	[m2/s]	:	3.03E-07
Storage	(S)	[m/Pa]	:	3.02E-08
Storativity	(Sh)	[-]	:	2.96E-04
Skin	(s)	[-]	:	0.00E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	5.00E+00
Mobility ratio	(sg)	[-]	:	1.00E-01
Time match	(TM)	[1/h]	:	1.02E+03
Pressure match	(PM)	[1/kPa]	:	1.42E+00

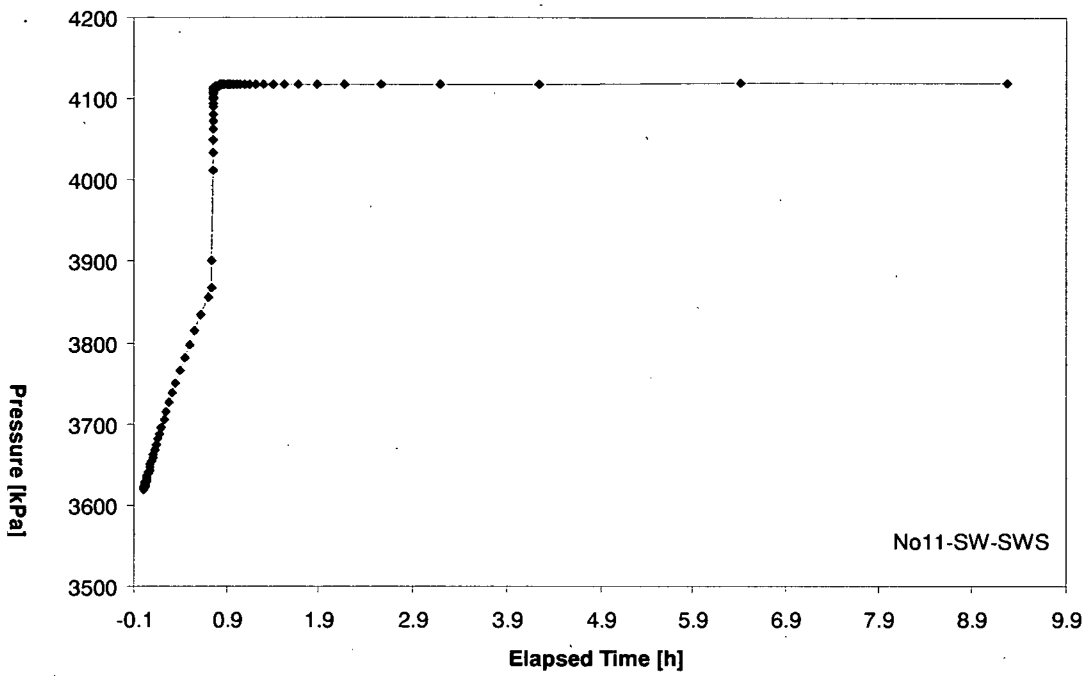

Fig. 1: CARTESIAN plot

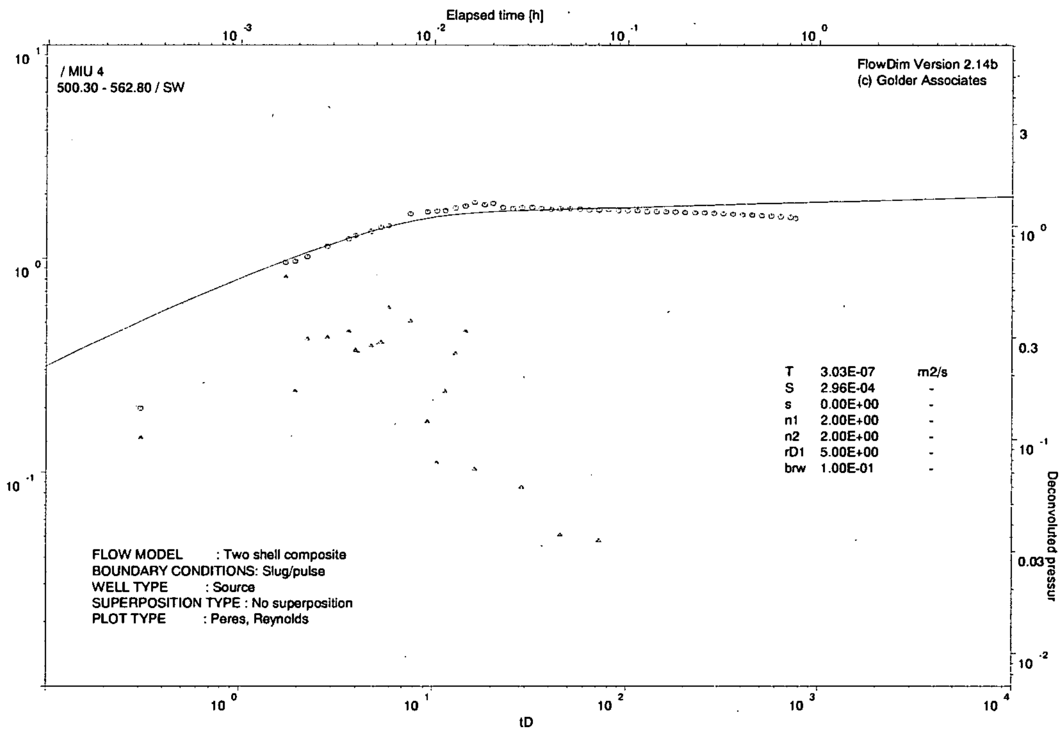

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	500.30 - 562.80
Event name			:	SWS
Date			:	
Input file name			:	sws.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	6.15E+01
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	7.38E-01
Flow rate	(q)	[l/min]	:	2.75E+00
Test duration	(tt)	[h]	:	8.53E+00
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Buildup
TEST RESULTS				
Transmissibility	(T)	[m3]	:	9.32E-14
Transmissivity	(Th)	[m2/s]	:	7.03E-07
Storage	(S)	[m/Pa]	:	1.99E-09
Storativity	(Sh)	[-]	:	1.95E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	4.50E-10
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	3.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	8.63E+00
Mobility ratio	(sg)	[-]	:	5.57E+00
Time match	(TM)	[1/h]	:	3.60E+03
Pressure match	(PM)	[1/kPa]	:	9.82E-03

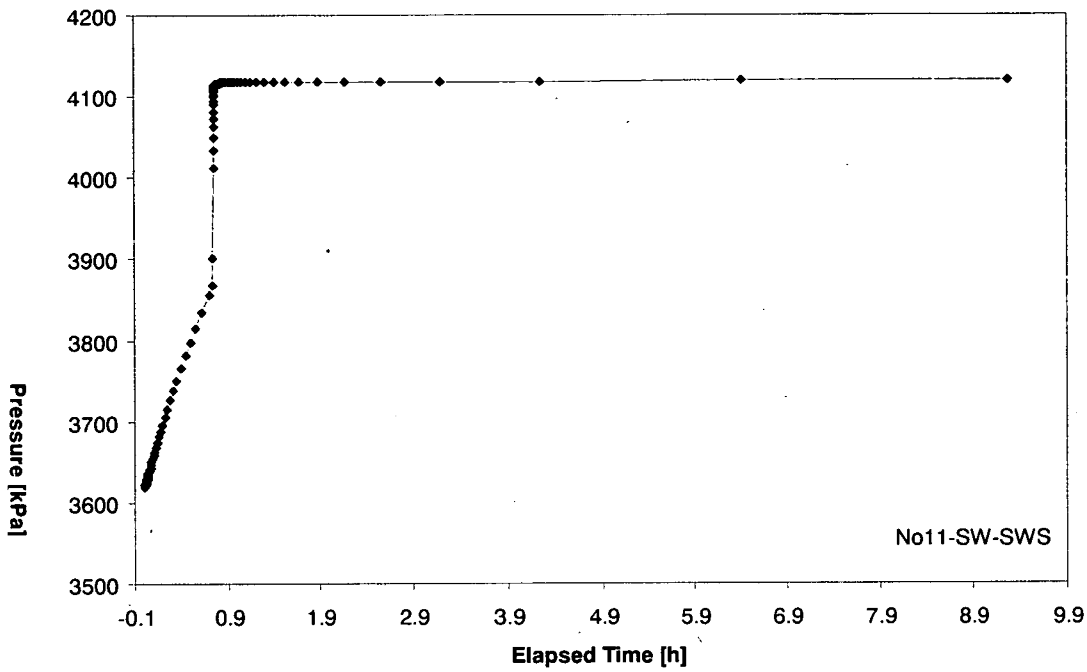

Fig. 1: CARTESIAN plot

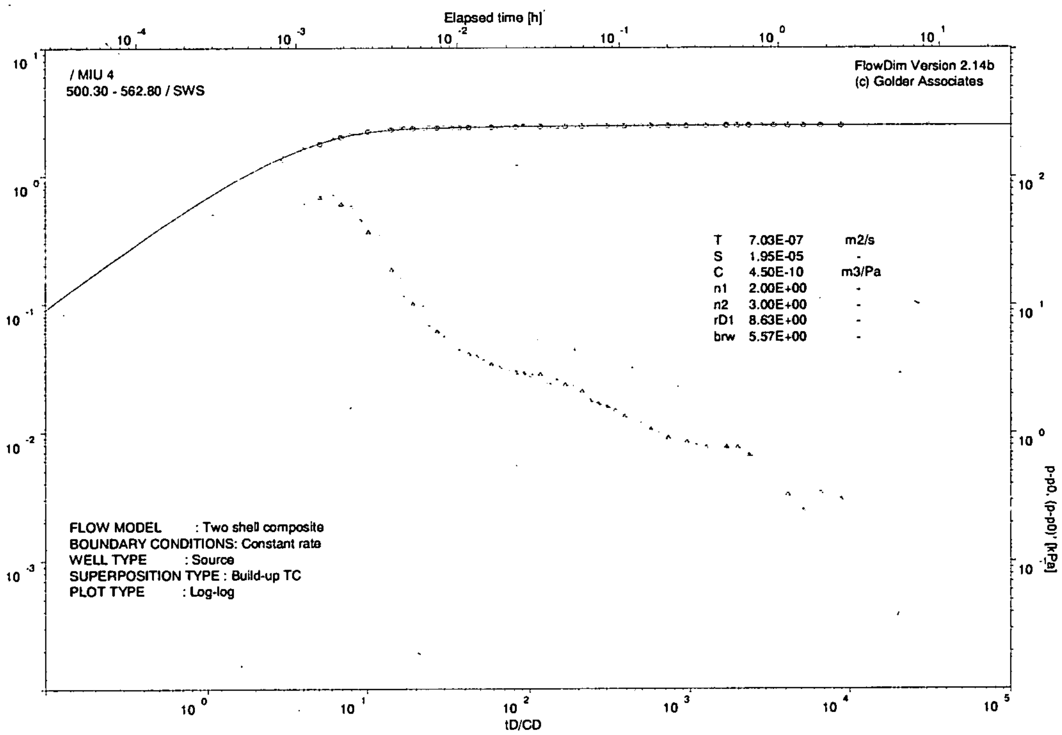

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	500.30 - 562.80
Event name			:	RW1
Date			:	
Input file name			:	rw1.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	6.15E+01
TESTPARAMETERS				
Flow rate	(q)	[l/min]	:	3.50E-01
Test duration	(tt)	[h]	:	1.24E+01
FLUID AND FORMATION PARAMETERS				
Viscosity	(謳)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Homogeneous
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	3.66E-13
Transmissivity	(Th)	[m2/s]	:	2.76E-06
Storage	(S)	[m/Pa]	:	1.56E-09
Storativity	(Sh)	[-]	:	1.53E-05
Wellbore storage coefficient	(C)	[m3/Pa]	:	3.52E-07
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Time match	(TM)	[1/h]	:	1.81E+01
Pressure match	(PM)	[1/kPa]	:	3.03E-01

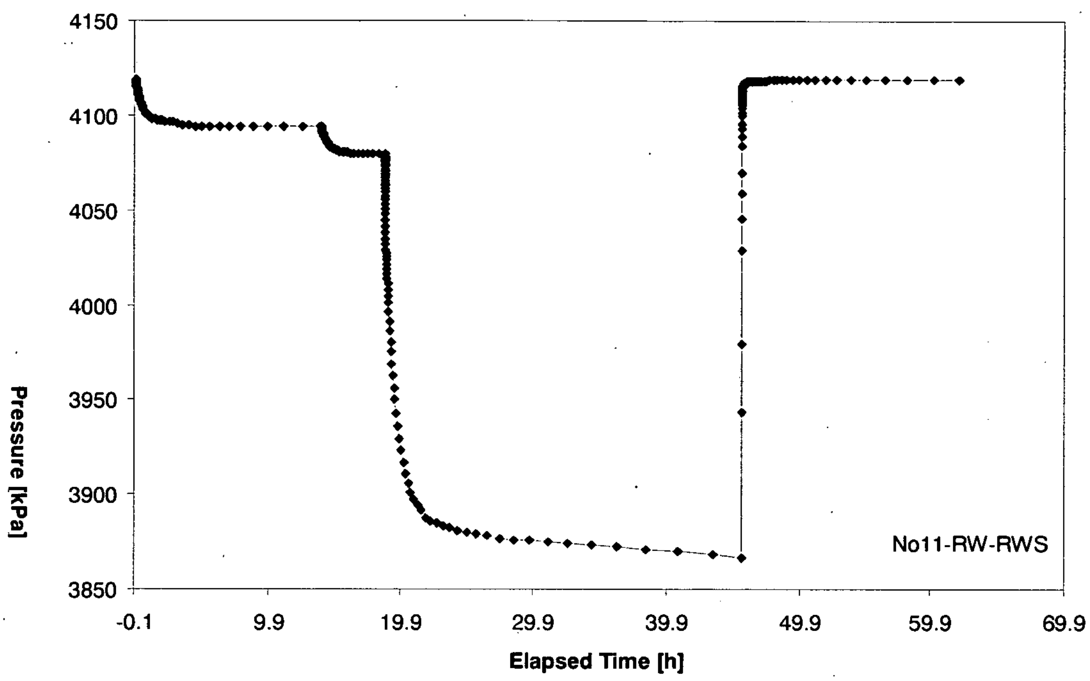

Fig. 1: CARTESIAN plot

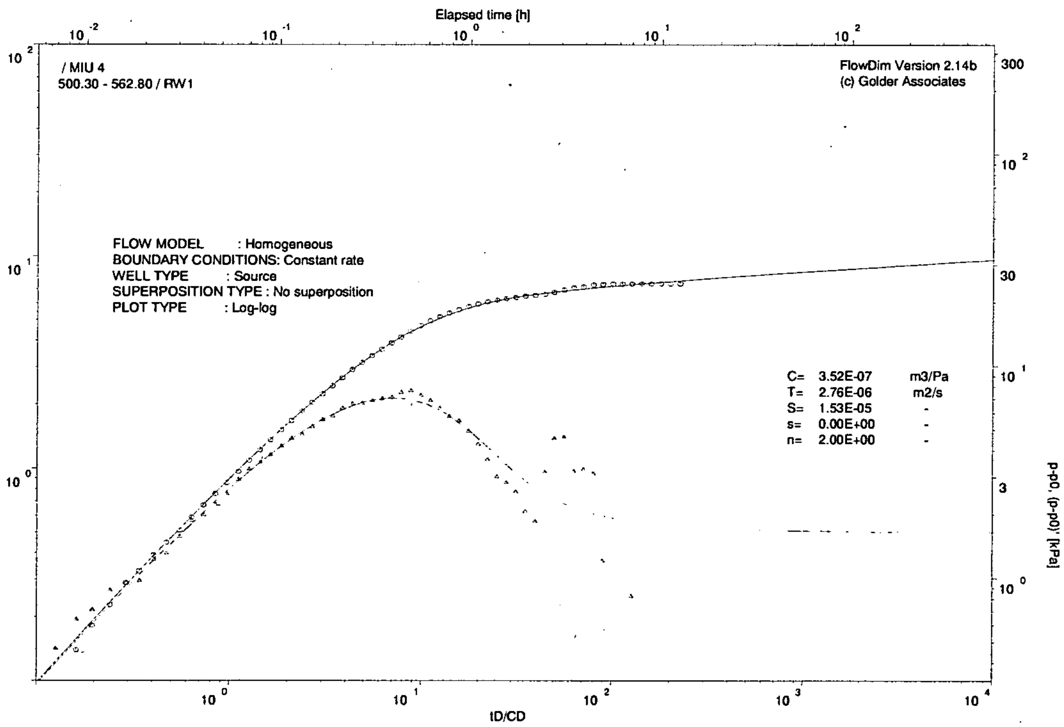

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION

Site name			:
Well name			: MIU 4
Interval name			: 500.30 - 562.80
Event name			: RW2
Date			:
Input file name			: rw2.REC

WELL PARAMETERS

Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Interval length	(h)	[m]	: 6.15E+01

TESTPARAMETERS

Flow rate	(q)	[l/min]	: 5.00E-01
Test duration	(tt)	[h]	: 4.41E+00

FLUID AND FORMATION PARAMETERS

Viscosity	(誣)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02

MODEL ASSUMPTIONS

Flow model			: Homogeneous
Boundary conditions			: Constant rate
Well type			: Source
Superposition type			: Drawdown

TEST RESULTS

Transmissibility	(T)	[m3]	: 8.03E-13
Transmissivity	(Th)	[m2/s]	: 6.06E-06
Storage	(S)	[m/Pa]	: 4.14E-09
Storativity	(Sh)	[-]	: 4.06E-05
Wellbore storage coefficient	(C)	[m3/Pa]	: 9.35E-07
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Time match	(TM)	[1/h]	: 1.49E+01
Pressure match	(PM)	[1/kPa]	: 4.66E-01

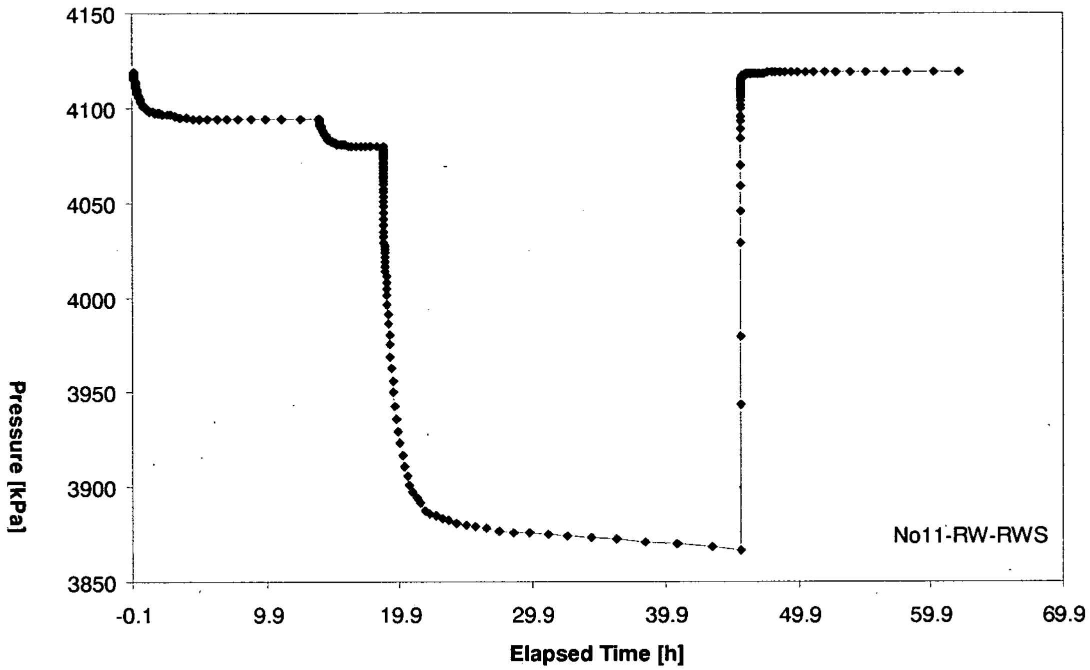

Fig. 1: CARTESIAN plot

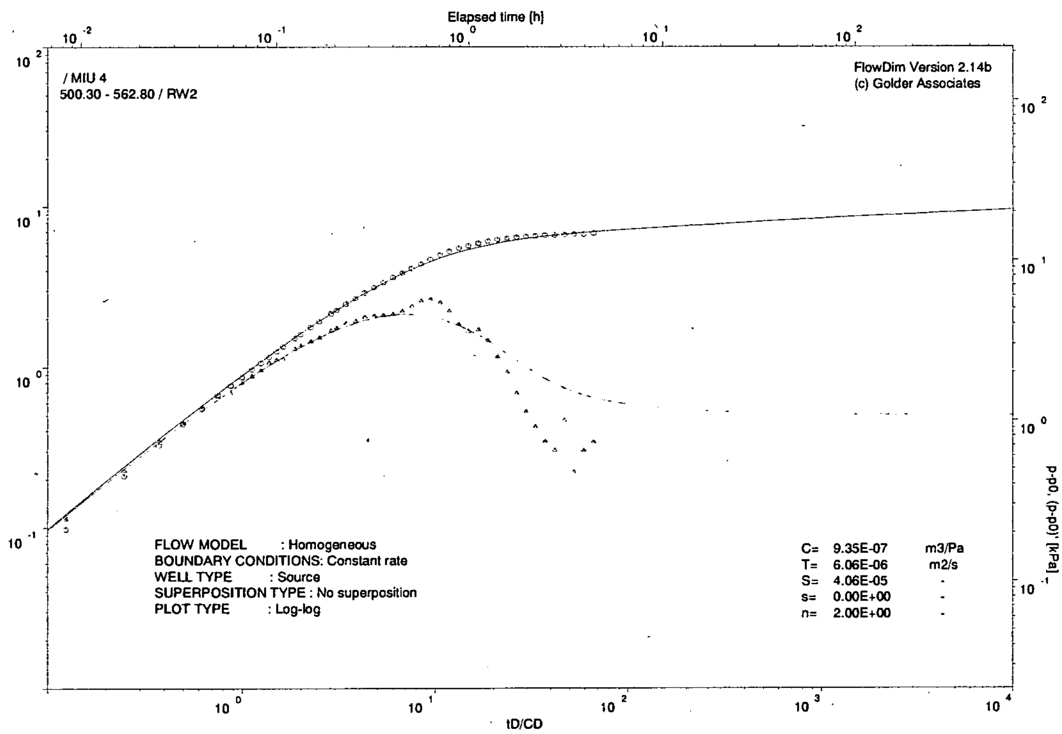

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	500.30 - 562.80
Event name			:	RW3
Date			:	
Input file name			:	rw3.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	6.15E+01
TESTPARAMETERS				
Flow rate	(q)	[l/min]	:	2.00E+00
Test duration	(tt)	[h]	:	2.48E+01
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Homogeneous
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	4.30E-13
Transmissivity	(Th)	[m2/s]	:	3.25E-06
Storage	(S)	[m/Pa]	:	9.78E-14
Storativity	(Sh)	[-]	:	9.59E-10
Wellbore storage coefficient	(C)	[m3/Pa]	:	4.42E-07
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Time match	(TM)	[1/h]	:	1.69E+01
Pressure match	(PM)	[1/kPa]	:	6.24E-02

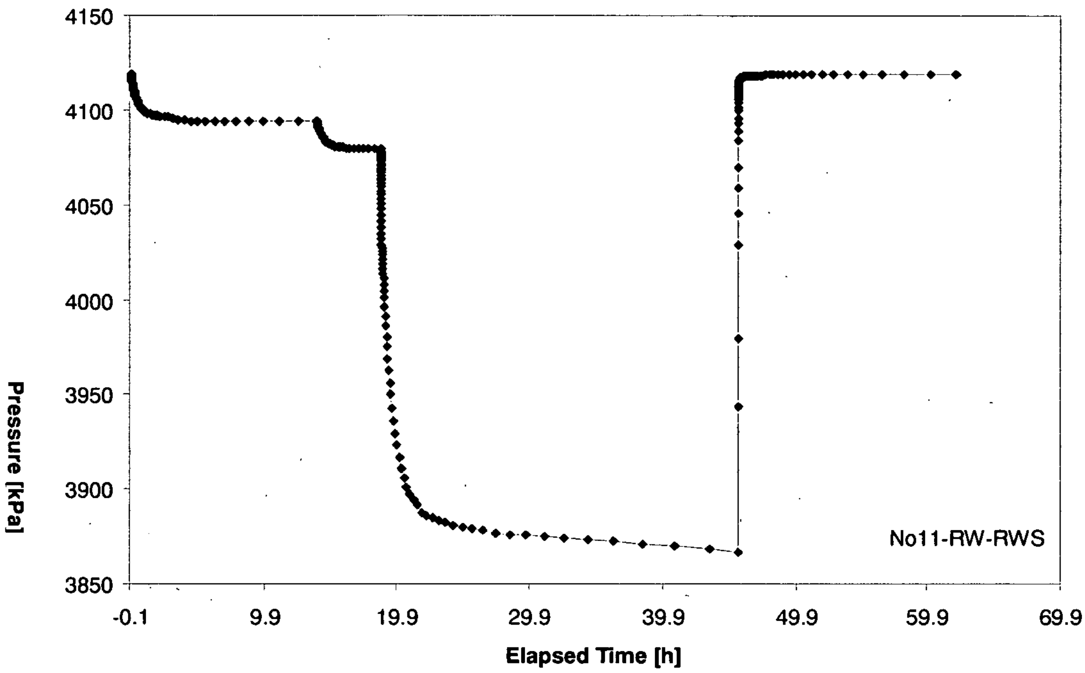

Fig. 1: CARTESIAN plot

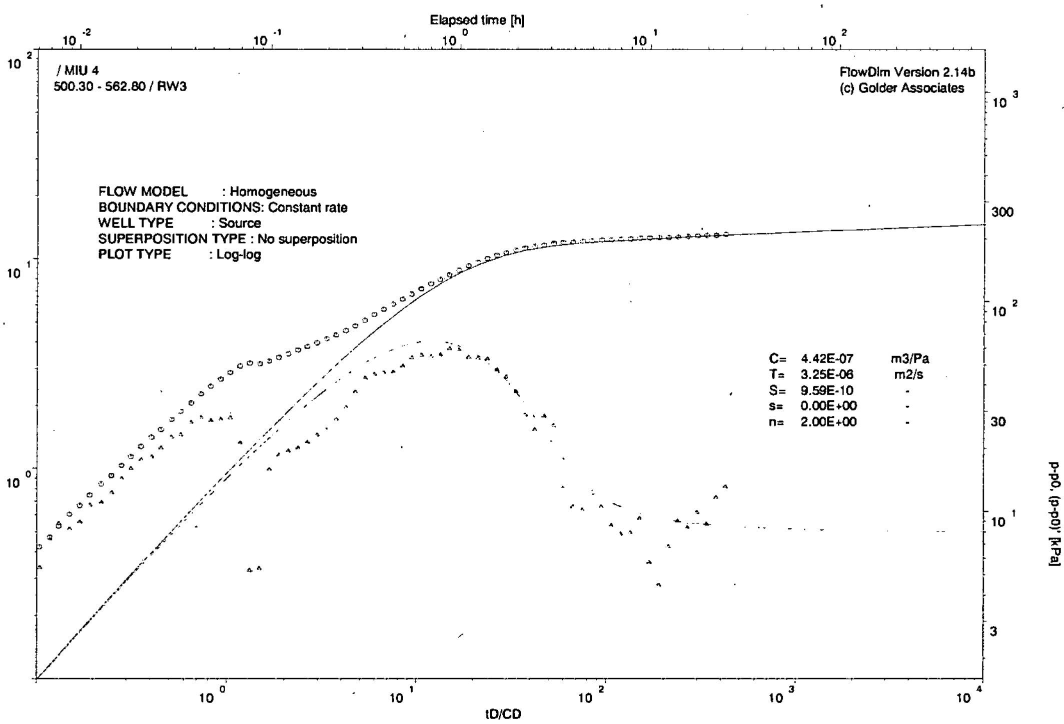

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	500.30 - 562.80
Event name			:	RWS
Date			:	
Input file name			:	rws.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	6.15E+01
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	4.55E+01
Flow rate	(q)	[l/min]	:	1.34E+00
Test duration	(tt)	[h]	:	1.21E+01
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Agarwal
TEST RESULTS				
Transmissibility	(T)	[m3]	:	4.97E-14
Transmissivity	(Th)	[m2/s]	:	3.75E-07
Storage	(S)	[m/Pa]	:	1.00E-09
Storativity	(Sh)	[-]	:	9.81E-06
Wellbore storage coefficient	(C)	[m3/Pa]	:	2.26E-10
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	3.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	1.01E+01
Mobility ratio	(sg)	[-]	:	5.59E+00
Time match	(TM)	[1/h]	:	3.83E+03
Pressure match	(PM)	[1/kPa]	:	1.08E-02

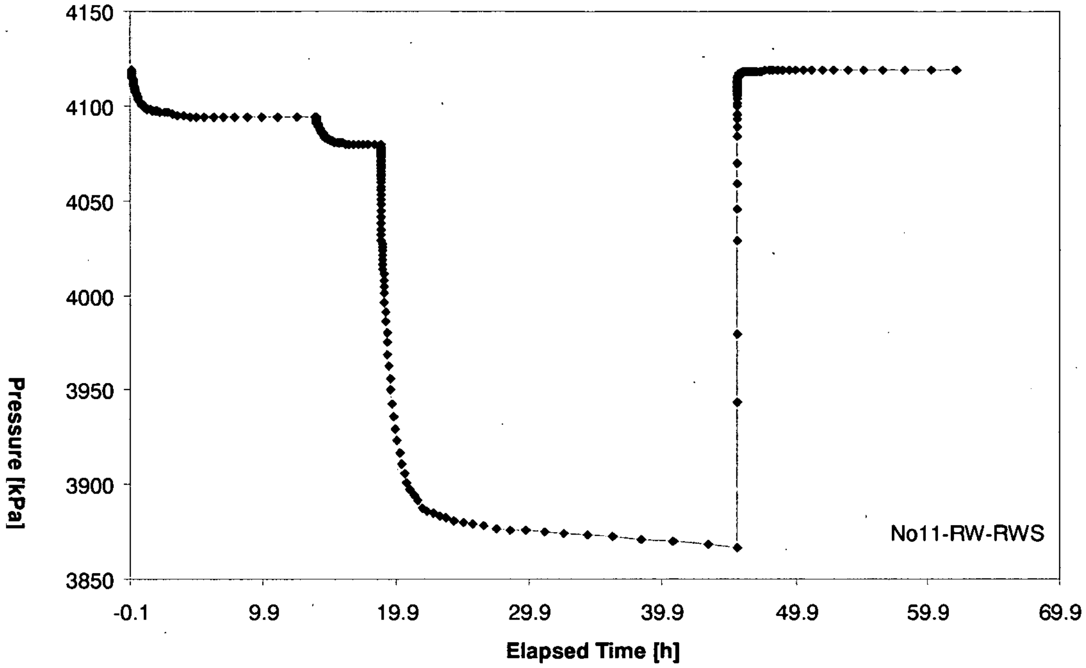

Fig. 1: CARTESIAN plot

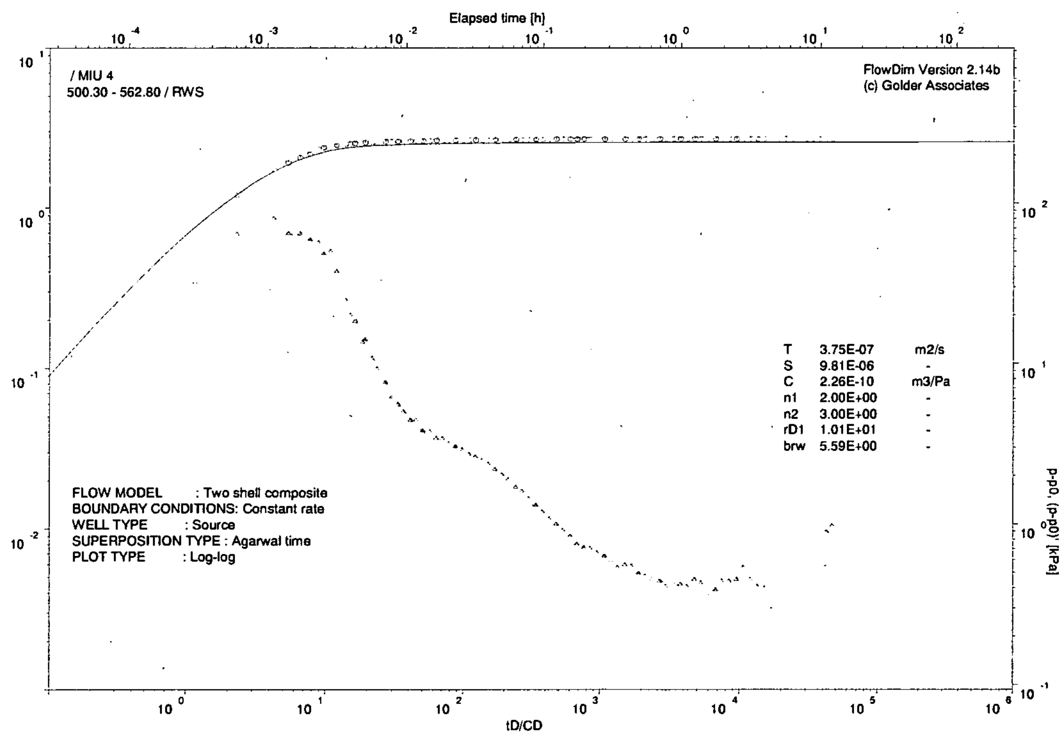

Fig. 2: Log-Log plot

Appendix K: Flow Dim Analysis Report MIU4-12

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	test
Well name			:	12
Interval name			:	361.60 - 424.10
Event name			:	PW
Date			:	
Input file name			:	pw.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Tubing radius	(ru)	[m]	:	1.90E-03
Interval length	(h)	[m]	:	9.12E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	2.65E+03
Static formation pressure	(pi)	[kPa]	:	2.92E+03
Test duration	(tt)	[h]	:	4.82E-01
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	1.93E-12
Transmissivity	(Th)	[m2/s]	:	1.46E-05
Storage	(S)	[m/Pa]	:	9.53E-10
Storativity	(Sh)	[-]	:	9.35E-06
Skin	(s)	[-]	:	2.70E+01
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	4.52E+02
Mobility ratio	(sg)	[-]	:	1.00E+02
Time match	(TM)	[1/h]	:	1.56E+06
Pressure match	(PM)	[1/kPa]	:	2.91E+04

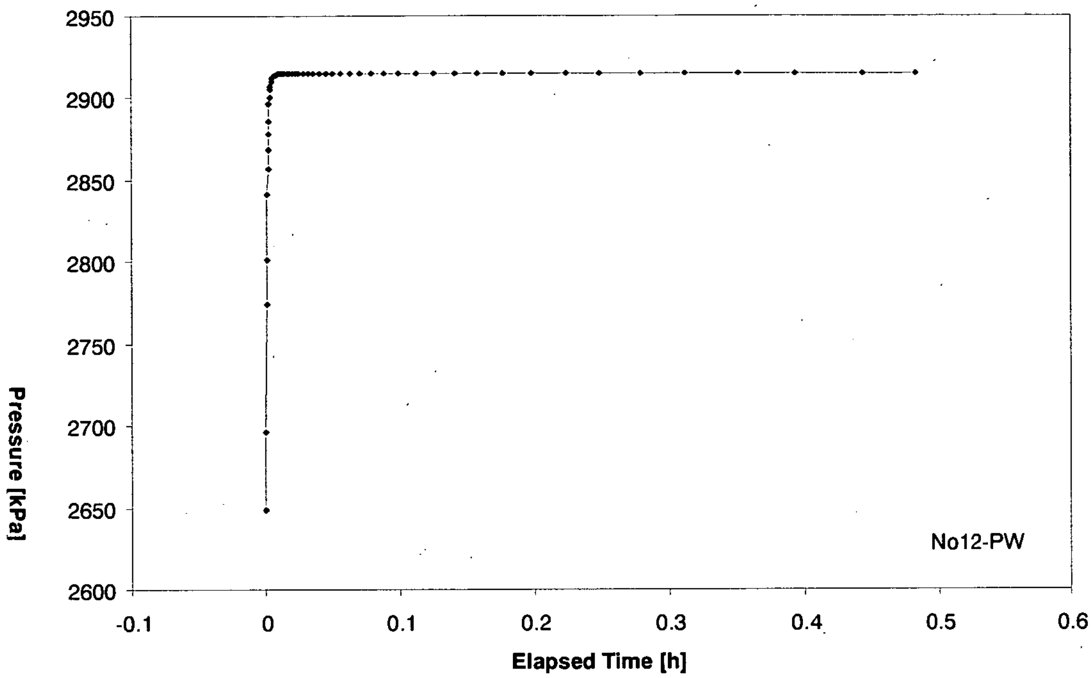

Fig. 1: CARTESIAN plot

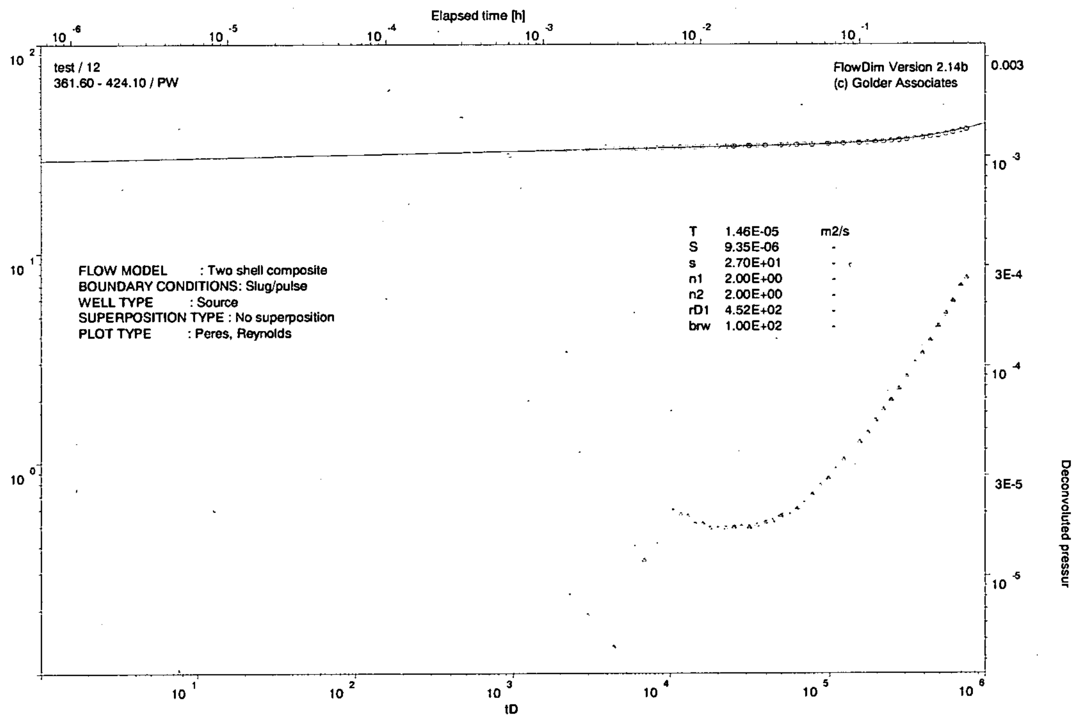

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	361.60 - 424.10
Event name			:	SW
Date			:	
Input file name			:	sw.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	4.80E-02
Tubing radius	(ru)	[m]	:	3.92E-02
Interval length	(h)	[m]	:	9.12E+00
TESTPARAMETERS				
Initial slug pressure	(p0)	[kPa]	:	2.42E+03
Static formation pressure	(pi)	[kPa]	:	2.92E+03
Test duration	(tt)	[h]	:	8.54E-01
FLUID AND FORMATION PARAMETERS				
Density	(d)	[kg/m3]	:	1.00E+03
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Slug/Pulse
Well type			:	Source
Superposition type			:	Drawdown
TEST RESULTS				
Transmissibility	(T)	[m3]	:	4.10E-14
Transmissivity	(Th)	[m2/s]	:	3.09E-07
Storage	(S)	[m/Pa]	:	7.78E-09
Storativity	(Sh)	[-]	:	7.64E-05
Skin	(s)	[-]	:	0.00E+00
Inner shell flow dimension	(n1)	[-]	:	2.00E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	1.00E+01
Mobility ratio	(sg)	[-]	:	1.00E-01
Time match	(TM)	[1/h]	:	6.33E+03
Pressure match	(PM)	[1/kPa]	:	1.45E+00

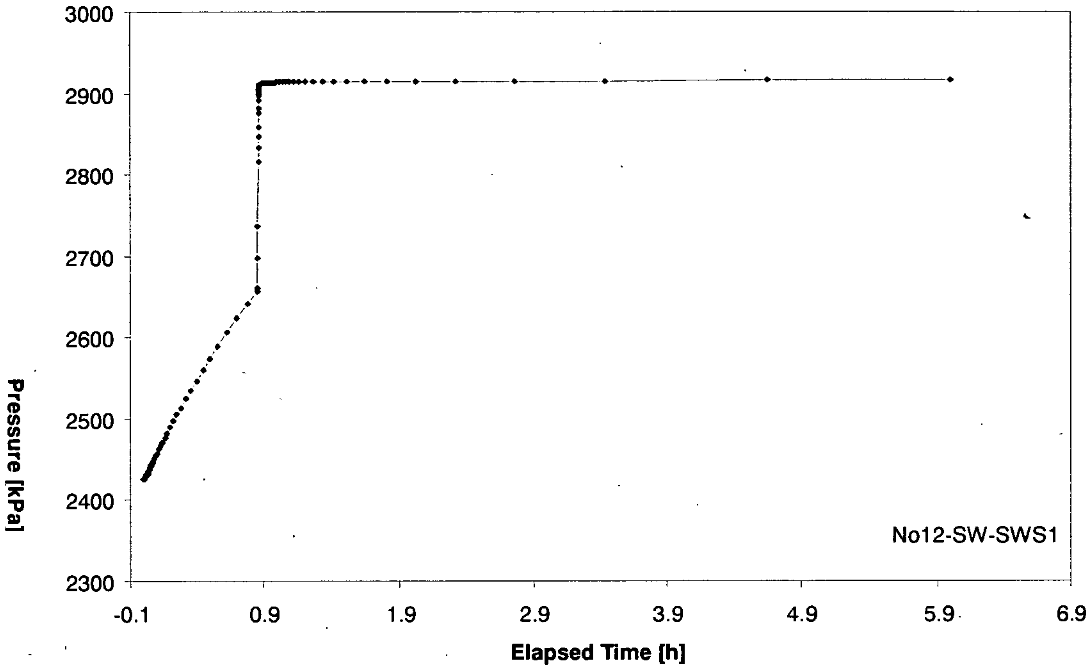

Fig. 1: CARTESIAN plot

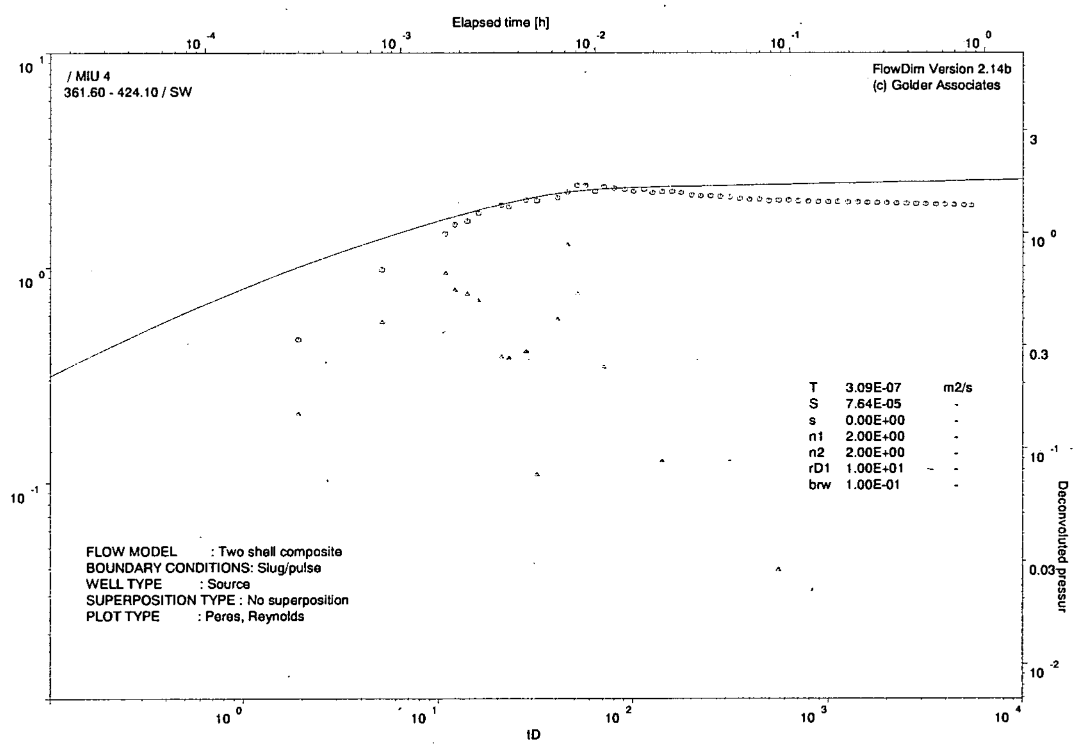

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION				
Site name			:	
Well name			:	MIU 4
Interval name			:	361.60 - 424.10
Event name			:	SWS
Date			:	
Input file name			:	sws.REC
WELL PARAMETERS				
Well depth		[m brp]	:	2.29E+02
Reference point elevation		[m asl]	:	2.00E+00
Wellbore radius	(rw)	[m]	:	6.00E-02
Interval length	(h)	[m]	:	6.25E+01
TESTPARAMETERS				
Production/Injection time	(tP)	[h]	:	8.48E-01
Flow rate	(q)	[l/min]	:	2.23E+00
Test duration	(tt)	[h]	:	5.14E+00
FLUID AND FORMATION PARAMETERS				
Viscosity	(誣)	[Pa s]	:	1.30E-03
Total compressibility	(ct)	[1/Pa]	:	2.00E-09
Porosity	(n)	[-]	:	1.00E-02
MODEL ASSUMPTIONS				
Flow model			:	Composite
Boundary conditions			:	Constant rate
Well type			:	Source
Superposition type			:	Buildup
TEST RESULTS				
Transmissibility	(T)	[m3]	:	4.16E-14
Transmissivity	(Th)	[m2/s]	:	3.14E-07
Storage	(S)	[m/Pa]	:	2.09E-12
Storativity	(Sh)	[-]	:	2.05E-08
Wellbore storage coefficient	(C)	[m3/Pa]	:	7.13E-10
Inner shell flow dimension	(n1)	[-]	:	2.54E+00
Outer shell flow dimension	(n2)	[-]	:	2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	:	3.58E+03
Mobility ratio	(sg)	[-]	:	3.25E-02
Time match	(TM)	[1/h]	:	1.53E+03
Pressure match	(PM)	[1/kPa]	:	8.17E-03

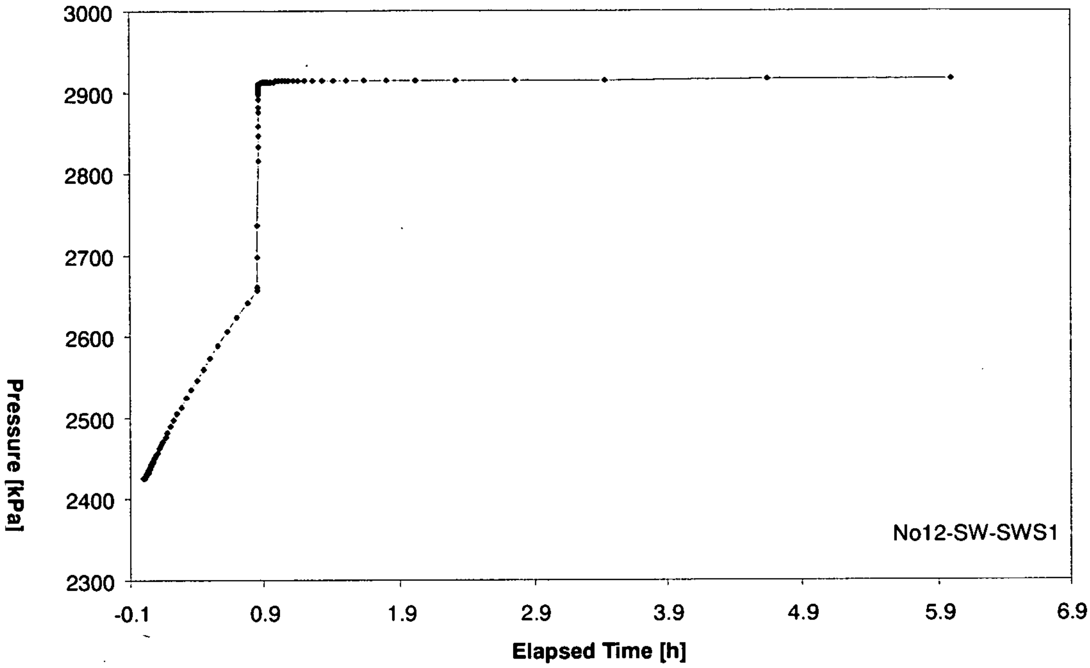

Fig. 1: CARTESIAN plot

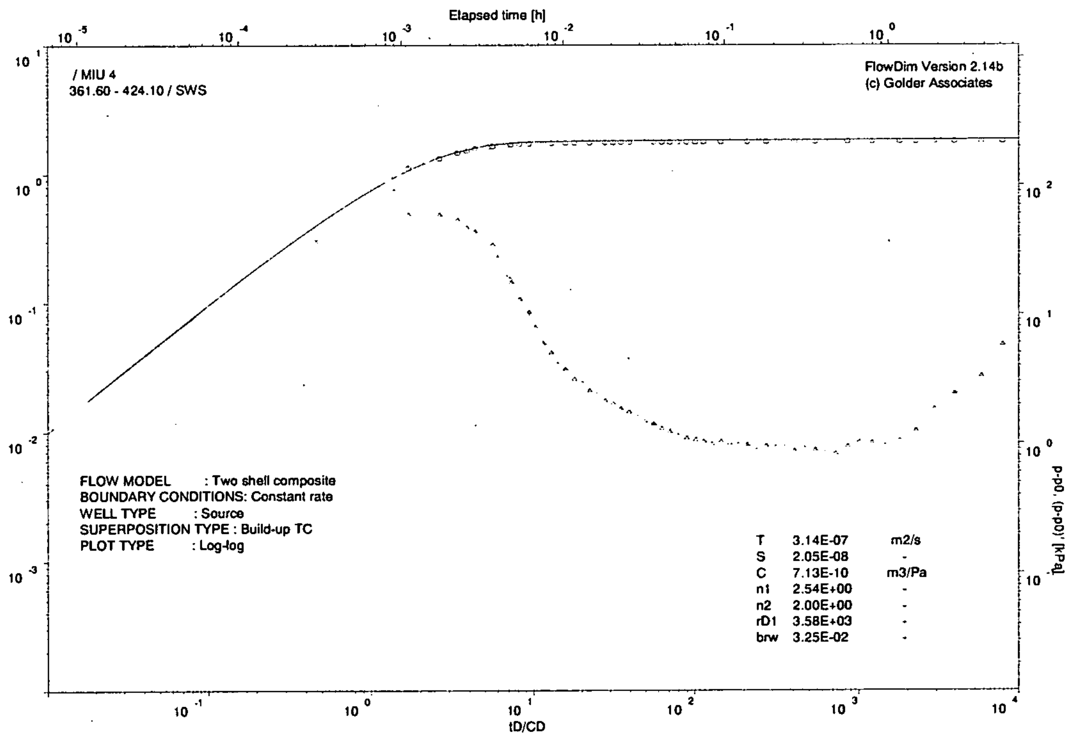

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION			
Site name			:
Well name,			: MIU 4
Interval name			: 361.60 - 424.10
Event name			: RW
Date			:
Input file name			: rw.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Interval length	(h)	[m]	: 6.25E+01
TESTPARAMETERS			
Flow rate	(q)	[l/min]	: 1.62E+00
Test duration	(tt)	[h]	: 3.87E+01
FLUID AND FORMATION PARAMETERS			
Viscosity	(誣)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Composite
Boundary conditions			: Constant rate
Well type			: Source
Superposition type			: Drawdown
TEST RESULTS			
Transmissibility	(T)	[m3]	: 1.3162E-13
Transmissivity	(Th)	[m2/s]	: 9.93E-07
Storage	(S)	[m/Pa]	: 1.40E-09
Storativity	(Sh)	[-]	: 1.37E-05
Wellbore storage coefficient	(C)	[m3/Pa]	: 3.16E-07
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Outer shell flow dimension	(n2)	[-]	: 2.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	: 4.94E+02
Mobility ratio	(sg)	[-]	: 2.40E-01
Time match	(TM)	[1/h]	: 7.24E+00
Pressure match	(PM)	[1/kPa]	: 2.36E-02

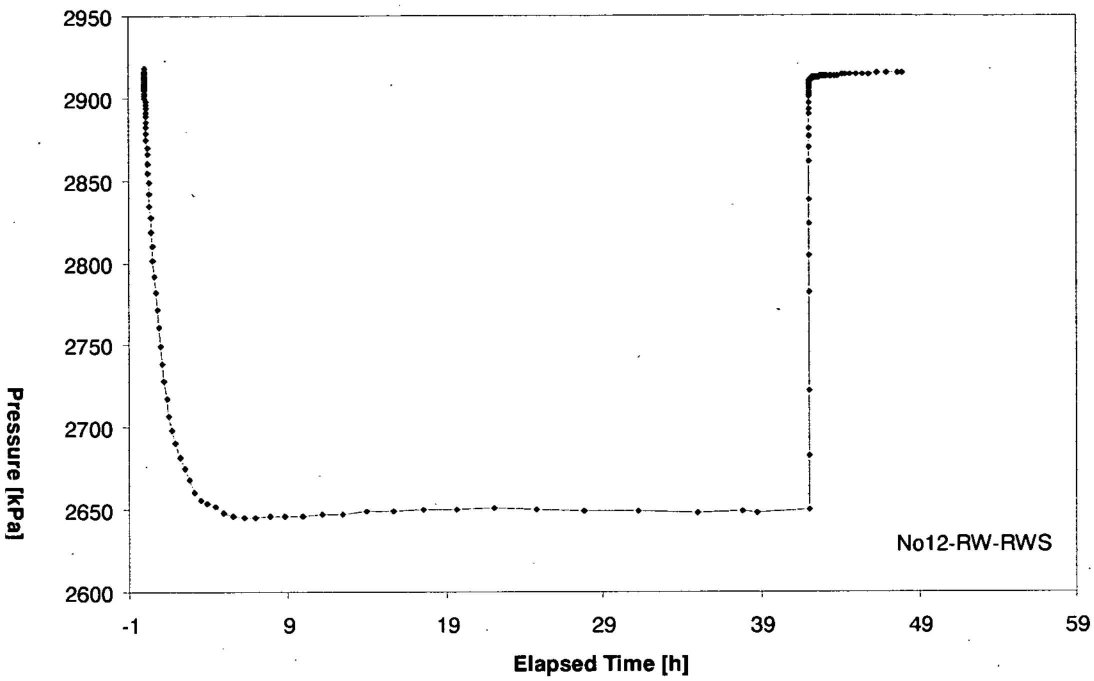

Fig. 1: CARTESIAN plot

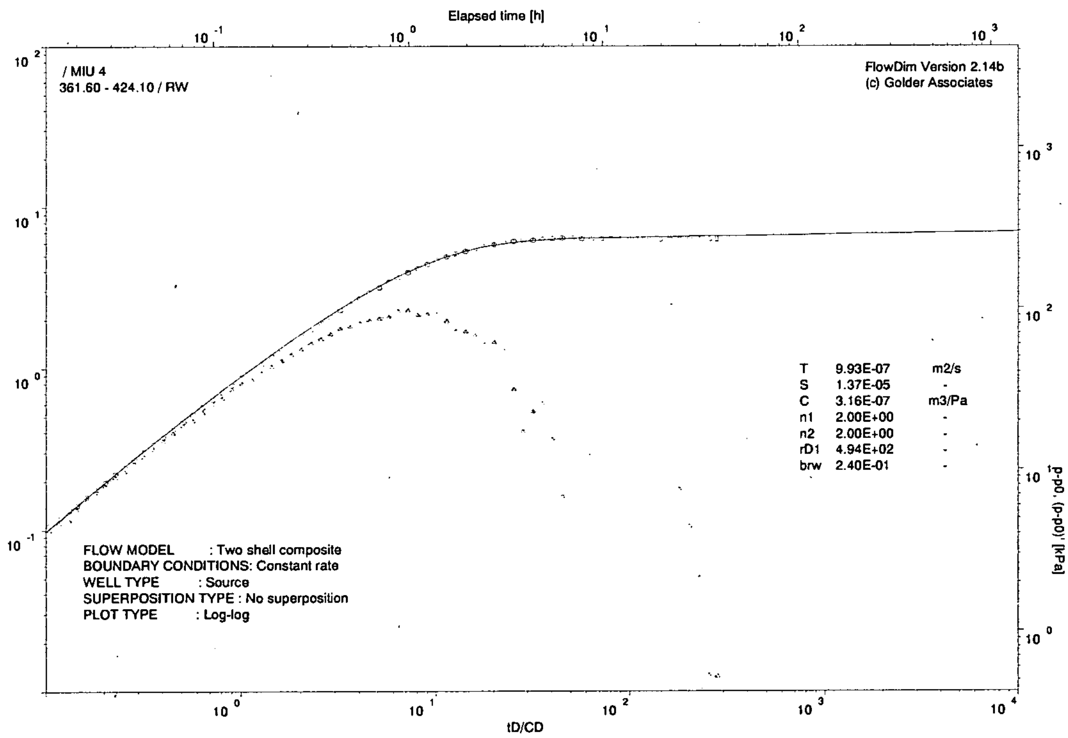

Fig. 2: Log-Log plot

TEST ANALYSIS REPORT 13.09.2002

IDENTIFICATION			
Site name			:
Well name			: MIU 4
Interval name			: 361.60 - 424.10
Event name			: RWS
Date			:
Input file name			: rws.REC
WELL PARAMETERS			
Well depth		[m brp]	: 2.29E+02
Reference point elevation		[m asl]	: 2.00E+00
Wellbore radius	(rw)	[m]	: 6.00E-02
Interval length	(h)	[m]	: 6.25E+01
TESTPARAMETERS			
Production/Injection time	(tP)	[h]	: 4.20E+01
Flow rate	(q)	[l/min]	: 1.62E+00
Test duration	(tt)	[h]	: 5.97E+00
FLUID AND FORMATION PARAMETERS			
Viscosity	(誣)	[Pa s]	: 1.30E-03
Total compressibility	(ct)	[1/Pa]	: 2.00E-09
Porosity	(n)	[-]	: 1.00E-02
MODEL ASSUMPTIONS			
Flow model			: Composite
Boundary conditions			: Constant rate
Well type			: Source
Superposition type			: Buildup
TEST RESULTS			
Transmissibility	(T)	[m3]	: 4.44E-14
Transmissivity	(Th)	[m2/s]	: 3.35E-07
Storage	(S)	[m/Pa]	: 1.83E-09
Storativity	(Sh)	[-]	: 1.80E-05
Wellbore storage coefficient	(C)	[m3/Pa]	: 4.14E-10
Inner shell flow dimension	(n1)	[-]	: 2.00E+00
Outer shell flow dimension	(n2)	[-]	: 3.00E+00
Dimensionles discontinuity radius	(rd1)	[-]	: 6.51E+00
Mobility ratio	(sg)	[-]	: 1.90E+00
Time match	(TM)	[1/h]	: 1.87E+03
Pressure match	(PM)	[1/kPa]	: 7.98E-03

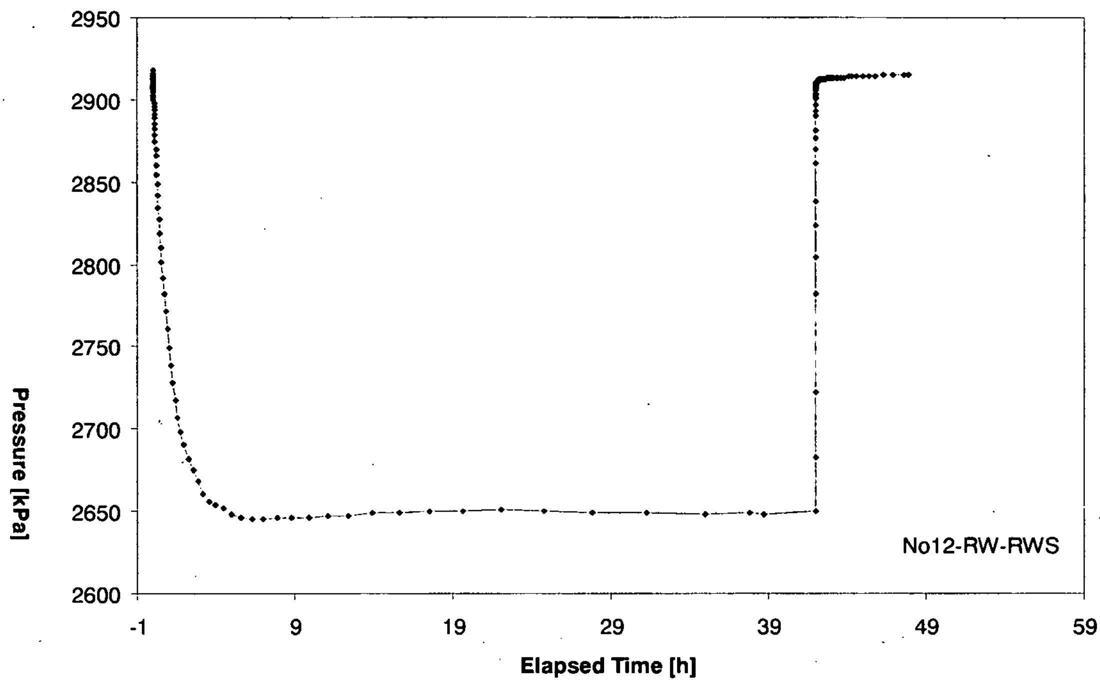

Fig. 1: CARTESIAN plot

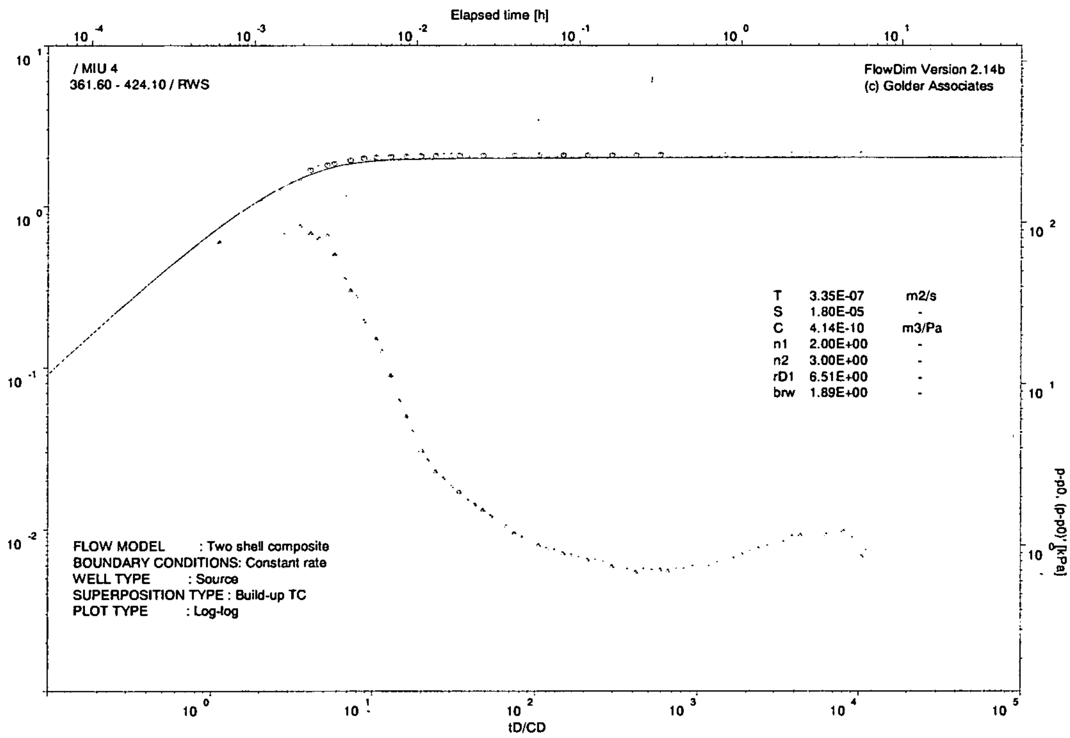

Fig. 2: Log-Log plot

APPENDIX E

GENERALIZED DIMENSION ANALYSIS OF LONG TERM PUMP TESTS AT THE MIU SITE

MIU

UNDERGROUND ROCK LABORATORY

TECHNICAL NOTE

HYDROSTRUCTURAL ANALYSIS

GENERALIZED DIMENSION ANALYSIS OF LONG TERM PUMP TESTS AT THE MIU SITE

Version 1.0

THOMAS DOE

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1. INTRODUCTION

This report provides a summary of Golder Associates support for the data analysis and conceptual model development for the Mizunami underground research laboratory.

During Heisei-14, these activities have included support to hydrostructural model development through review and analysis of the Long Term Pumping Test (LPT) results.

2. LONG-TERM PUMPING TEST — SOURCE WELL

The long term pumping test at the MIU was performed at the end of 2001 and early in 2002. The test used two source zones, one in the hanging wall of the Tsukiyoshi Fault and one in the foot wall.

The interpretation of the source zone data is complicated by pressure history effects that arise from cross flow in MIU-2, the source hole, when the MP monitoring casing was being replace by packers for testing. The foot wall of the Tsukiyoshi fault has considerably higher heads than the hanging wall, and connecting the two hydro-stratigraphic units through MIU-2 caused significant cross flow between the two units. The pressure effects of this cross flow are not dissipated before the LPT testing. Additional cross flow occurred when the packers were moved for the second, hanging wall, test. The drawdowns and pressure build-ups due to cross flow exceed those that could be achieved by the pumping test.

The analysis of the LPT data required filtering of the background effects. This was done by the testing contractor, but the results are not consistent among the separately analyzed phases of the tests. Based on a review of the LPT data in Tono during October, 2002, Golder Associates proposed reconciling the discrepancies between the results of separate phases by analyzing the test as single phase with multiple steps. Interpret II, a standard petroleum analysis package, has this capability. The effective pumping rate between the hanging wall and the footwall is not know precisely, but it can be estimated from flow logs that were run while the packers were removed from the hole. Also, the rate during packer removal can be treated as a variable and determined from an optimized match to the data.

Once the approximate hydraulic properties are determined from the Interpret II match, a more detailed flow model using FracMan can be used to match the data using more complicated hydro-structural conditions with the inferred rate history from the Interpret II match.

3. LONG-TERM PUMPING TEST — OBSERVATION WELLS

JNC-Tono supplied Golder Associates with the pressure interference data for the LPT experiments. The data cover four observation sections in MIU-1 for the hanging wall test and four sections in MIU-3 for the footwall test. As discussed above, the data have superposed trends from the cross flow during packer removal in MIU-2. The contractor-supplied data from JNC include data that corrected for the background trend. Golder Associates analyzed these corrected data using FlowDim. The FlowDim analysis results are given in Table 1 and Figures 1 and 2.

There are significant differences between the responses to the hanging wall and the foot wall test. The hanging wall tests are best fit using dimension-2 type curves. The transmissivity values range from 1.0×10^{-5} m^2/s to 1.8×10^{-5} m^2/s. Storativity values range from 5.9×10^{-5} to 1.2×10^{-4}. These values define diffusivity as having a range from 0.14 to 0.31 m^2/s. The diffusivity values are relatively low for major conducting zones, when compared with similar conductors in the Äspö TRUE Block Scale Experiment (which are in a range from 4 to 38 m^2/s). Given the high transmissivity of the fault hanging wall, the low diffusivity would appear to be the result of very high storage, hence one might expect that the fault zone has a large porosity as compared with other typical fracture zones.

The foot wall tests in Figure 2 differ from the hanging wall tests in both dimension and diffusivity. The dimension of the responses in the foot wall are 1.25 with one observation MIU 3-6) having a dimension of 1.6. These data suggest that the conductive feature in the foot wall has a linear geometry with some leakage, as compared with the hanging wall which behaves as a planar, two dimensional feature. The diffusivity value for MIU 3-6 is similar to that of the hanging wall (0.24 m^2/s), which the other observation zones see diffusivities ranging from 1.3 to 2.8 m^2/s. Table 1 gives transmissivity and storativity values from the foot wall test. These are about 2-3 orders of magnitude larger than the values for the hanging wall, however it should be noted that for a given magnitude of pumping, the transmissivity is larger for a smaller dimension match.

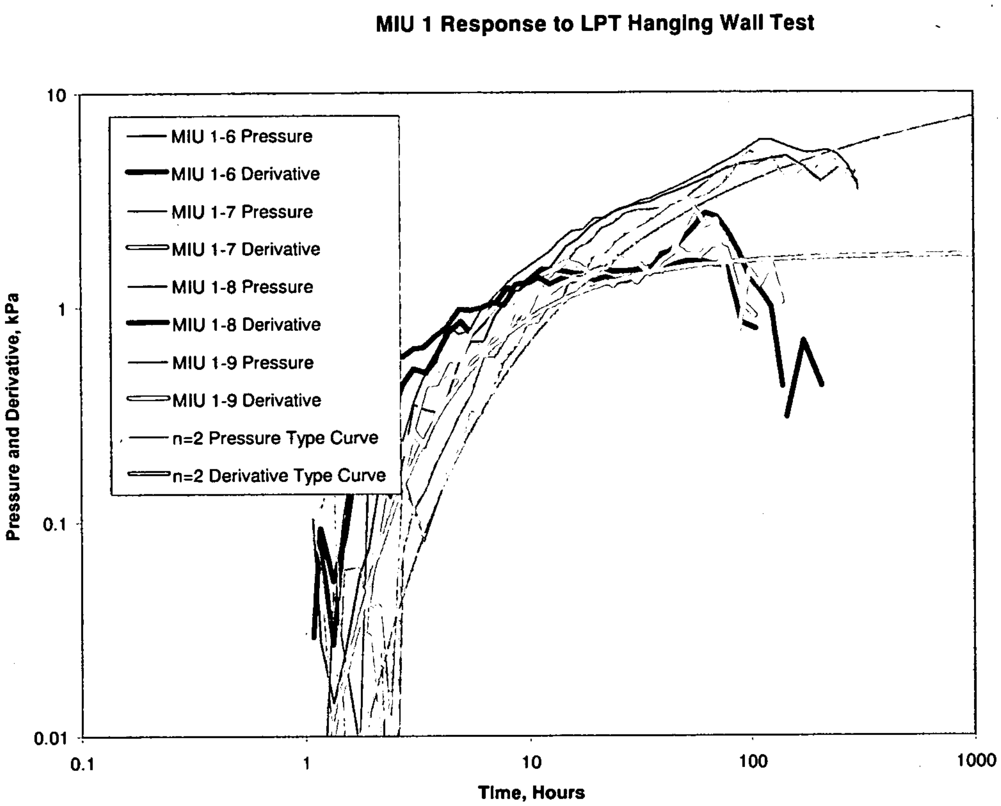

Figure 3-1. Pressure Interference in the Hanging Wall of the Tsukiyoshi Fault From the LPT Experiment

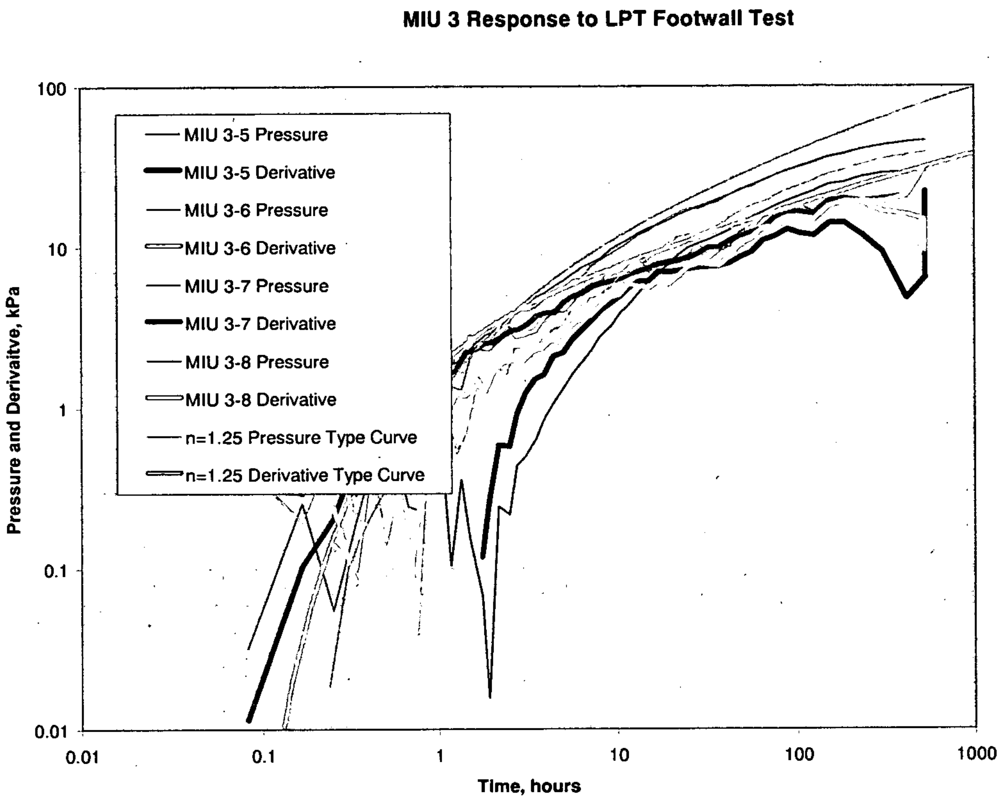

Figure 3-2. Pressure Interference in the Foot Wall of the Tsukiyoshi Fault From the LPT Experiment

Table 3-1. Hydraulic Properties and Flow Dimensions for LPT Interference Tests

Source	Observation	T, m^2/s	S, -	η, Diffusivity, m^2/s	Dimension n
MIU-2 Foot Wall	MIU3-5	1.10E-03	4.60E-03	0.24	1.6
	MIU3-6	7.20E-02	2.70E-02	2.67	1.25
	MIU3-7	7.22E-02	2.60E-02	2.78	1.25
	MIU3-8	6.90E-02	5.20E-02	1.33	1.25
MIU-2 Hanging Wall	MIU1-6	1.70E-05	7.90E-05	0.22	2
	MIU1-7	1.40E-05	1.00E-04	0.14	2
	MIU1-8	1.80E-05	5.90E-05	0.31	2
	MIU1-9	1.50E-05	1.20E-04	0.13	2

APPENDIX F

SHI YU-U CHI INITIAL MODEL SUPPORT

MIU

UNDERGROUND ROCK LABORATORY

TECHNICAL NOTE

SHI YU-U CHI INITIAL MODEL SUPPORT

Ver 1.0

THOMAS DOE

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1. INTRODUCTION

During H-14, Golder assisted JNC in development of an initial hydrostructural model for discrete features localized to the Shi Yu-u Chi site. This analysis focused on analysis of borehole DH-2, which is the key to hydrostructural analysis in the Shi Yu-u Chi area.

2. DH-2 ANALYSIS

2.1 Background

The DH-2 borehole testing is the primary source for data to understand the hydrostructural framework for the Shi Yu-u Chi Site. DH-2 has produced some results that are inconsistent with normal hydrologic testing concepts. The two major anomalies are (1) periods of pressure recovery during constant-rate pumping tests, and (2) major discrepancies between production and recovery behaviors. The cause of pressure recoveries may be related to increased conductivity during the test. Increase in conductivity can be the result of changes to skin, possibly from erosion of fracture-filling materials. Another rock-based cause for recovery is ex-solution of gas, as gas-bearing water has a lower viscosity than single-phase water, resulting in a higher hydraulic conductivity due to reduced viscosity. A third possible cause of recovery during the test can be some equipment leakage (i.e., the permeability of equipment goes up).

The second discrepancy results from the virtually instant recovery from the tests. Despite pumping drawdowns that develop gradually, the recovery is almost instantaneous. Part of this rapid recovery can be caused by the shutting-in of the test interval during recovery. However, this only removes that portion of recovery that comes from well-bore storage and skin effects. The instant recovery almost suggests that the aquifer or fractures were not drawn down at all, and the production was coming from equipment leakage.

The data from the testing of borehole DH-2 exhibit two severe well testing anomalies. These are:

- Partial recovery of the pressure during the pumping period
- Very rapid recovery at the end of the test

This report discusses these anomalies and some preliminary analyses of the data to understand the DH-2 measurements.

2.2 Qualitative Evaluation

During most of the well tests in DH-2, the pressure began to recover during the pumping phase of the test. Most often, such a pressure recovery is caused by decreases in the flow rate. The main remedy involves using an analysis approach that incorporates the variable flow rates.

In the DH-2 tests, however, rate controls were in place such that the flow rate should have been constant, and the tests exhibited partial recovery anyway. The only cause for such partial recoveries is a change in the mobility, that is the conductivity, of the tested materials during the test. Such changes may be increases in the hydraulic conductivity of the rock, development of leaks in the equipment, or development of leaks along the borehole wall. The rapid recovery of the major part of the DH-2 well tests indicates that the permeabilities were changing during the test.

Figure 1 shows and example of this behavior. Thirteen of the nineteen intervals showed some partial recovery, and most the remaining intervals showed a leveling of the pressure drawdown before resuming an increased drawdown rate. Table 1 summarizes the effect in terms of the time at which the recovery begins to occur and the amount of recover expressed as a percent of the pressure drawdown at the time the recovery began.

A qualitative examination of the data indicate that the onset of recovery is an inverse function of the transmissivity of the interval, since the recovery begins earlier in more transmissive zones. The amount of recovery varies from none to 15% with most recoveries in the range of a few percent.

2.3 Flow Dim Type Curve Analysis

FlowDim type curve derivative analysis is particularly useful for understanding flow geometrics. The results of FlowDim analysis of the DH-2 tests are summarized in Table 1. Figure 2 provides the derivative curves for all the DH-2 tests.

Analysis of FlowDim results indicates the following:

1. All tests show evidence of a constant pressure-boundary.

2. Assuming a storage of 1×10^{-5}, the boundary lies at a radius of a few tens of meters for all tests.
3. No tests show stabilization to two-dimensional flow, though some tests can be matched using type curves with skin and storage.
4. Most tests can be matched with linear flow.
5. The boundary effects appear at a range of times between 0.1 and 2.5 hours. This is significantly earlier than the onset of the partial recoveries.
6. The time of the onset of boundary effects is a clear function of the transmissivity (Figure 3).

2.4 Discussion

There are a number of possible explanations for the unusual behaviors of the DH-2 well tests. However, the similarity of the behaviors of the major portion of the tests would give reason to consider a factor related to the equipment or the borehole conditions.

The linear flow suggests that the test is strongly effected by a channel conductor. The partial recovery of the pressure shows that permeability of this conductor is increasing as the testing continues, and the rapid recovery suggests that the permeability change was non-reversible. One possibility is the erosion or "washing out" of the conductor as the test proceeds. Another possibility is that the linear flow is due to flow along the borehole, due to leaking packers.

Leakage around packers could also explain the observed constant pressure boundary. However, the timing of the onset of constant pressure boundary effects would suggest that the boundary is at a greater distance than the length of a packer. It is curious, however, that the time to the onset of the boundary varies with transmissivity, and the distance calculations suggest a similar distance for all tests.

Table 1. Summary of DH-2 Analyses

Test	Recovery During Pumping		Boundary Analysis				Properties
	Onset Time, h	Percent	Onset Time, h	Dimension	Derivative kPa/(l/m)	Distance, m (S=1E-5)	T, m^2/s
DH2-1	none		0.18	1	1.4	15.5	9.3E-06
DH2-2	3.9	2%	0.88	1	40	20.3	3.2E-07
DH2-3	1.9	0.14%	0.14	1	2.7	31.2	4.8E-06
DH2-4	2	0.4%	0.18	1	2.0	40.5	6.5E-06
DH2-5a	3.2	3%	0.18	1	8.8	19.6	1.5E-06
DH2-5b	1.5	15%					
DH2-6	10	2%	1.0	1.0	72	16.1	1.8E-07
DH2-7	unclear		0.125	1	0.56	64.6	2.3E-05
DH2-8	step test		0.097	2	0.74	49.5	1.8E-05
DH2-9	2	1%	0.10	1 or 2	2.0	30.6	6.5E-06
DH2-10	4.5	1%	0.8	1 or 2	2.5	77.4	5.2E-06
DH2-11	2	1%	0.13	1	3.2	27.6	4.1E-06
DH2-12	4	0.32%	1.2	1	36	25.0	3.6E-07
DH2-13	11	3%	2.5	1	110	20.6	1.2E-07
DH2-15	none		0.056	2?	0.26	63.5	5.0E-05
DH2-16	1.5	3%	0.044	1	0.26	56.3	5.0E-05
DH2-17	none		0.044	1.5	0.26	56.3	5.0E-05
DH2-18	none		0.12	1.5	2.8	28.3	4.6E-06
DH2-19	6	1%	0.17	1 or 2	42	8.7	3.1E-07

Note: Transmissivity based on cylindrical flow conversion of derivative. Linear flow values will be larger.

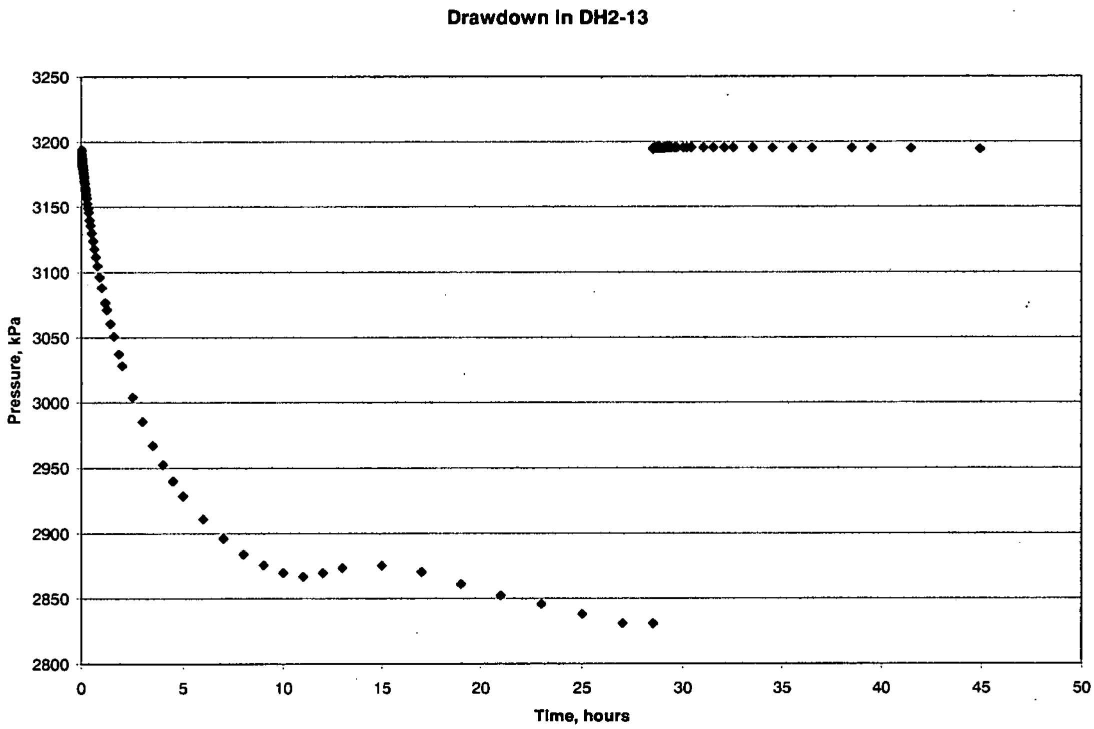

Figure 1. Example of Partial Pressure Recovery

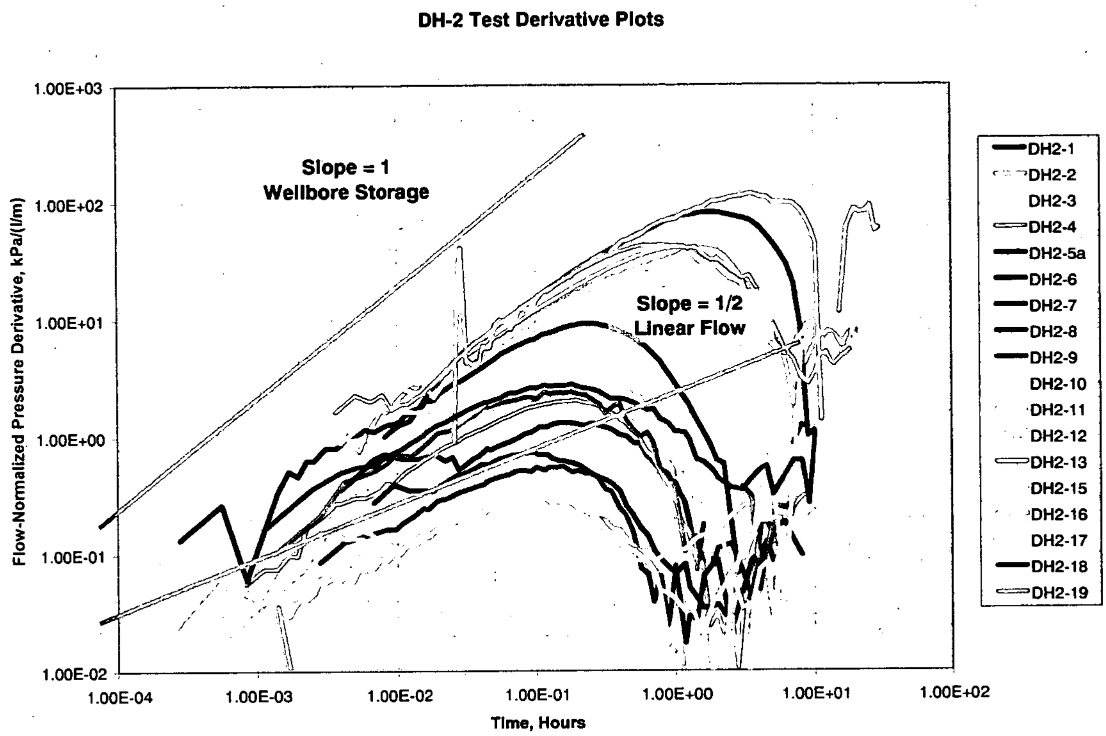

Figure 2. Derivative plots for DH-2 well tests

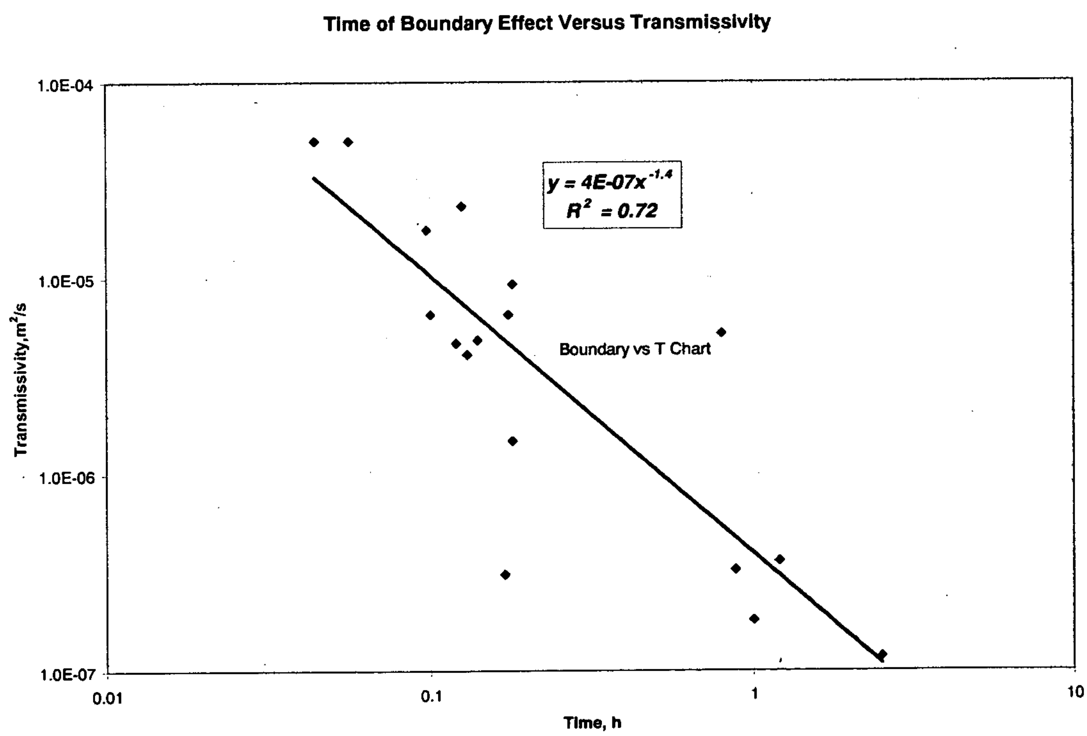

Figure 3. Time of onset of constant pressure boundary versus apparent transmissivity

3. CONCLUSIONS

Analysis of DH-2 has provided significant insights into the hydrologic behavior of the Shi Yu-u Chi site. The analysis presented in this report raises the following issues:

1. Has the later time pressure recovery during pumping been understood yet? That recovery happens later in the test than these derivatives show, but it still needs an explanation. Before publishing it would be good to make sure that whatever is causing the pressure recovery is not affecting the earlier time data that appear in the derivative plots.
2. The linear flow can be caused by fracture intersection zones (FIZ), but it can also be caused by lots of other things. We have analysed similar well tests from granitic reservoirs in southeast Asia. Our analysis of these tests indicated that many different geometries could create this behavior.
3. The key thing is to use knowledge of geology to decide which of the many possibilities are reasonable. One interesting geological hypotheses is that these tests are all seeing a major subvertical conductor at a distance of 50-100m from the borehole. Does this idea make any geological sense?
4. Some additional information on storage is very important to get the diffusivities. Knowledge of diffusivity will make it possible to more definitively estimate the length scales for the boundary effects. Diffusivity also facilitates derivation of permeability from the testing. Keep in mind that the linear flow equations are different from cylindrical flow, and the log-log 1/2 slope lines give the product of K and Ss. 2-D flow solutions provide transmissivity (m^2/s).