

**Scientific Analysis  
Administrative Change Notice**

*Complete only applicable items.*

DOC.20051010.0001

<b>1. Document Number:</b>	ANL-NBS-HS-000005	<b>2. Revision:</b>	03	<b>3. ACN:</b>	01
<b>4. Title:</b>	In Situ Field Testing of Processes				
<b>5. No. of Pages Attached:</b>	8				

<b>6. Approvals:</b>		
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7. Affected Pages	8. Description of Change:
1-7	<p>Editorial Change</p> <p>Figure 1-1, change the caption of the figure:</p> <p>“Schematic Illustration of Spatial Distribution of Hydrogeologic Units Intersected by the Repository Horizon (Ttpul, Ttpmn, Ttpll, and Ttpln)”</p> <p>To</p> <p>“Schematic Illustration of Spatial Distribution of Lithostratigraphic Units Intersected by the Repository Horizon (Ttpul, Ttpmn, Ttpll, and Ttpln)”</p> <p>This error is identified in CR-5920</p>
1-8	<p>Correct figure</p> <p>Figure 1-2 “Schematic Illustration of Alcove and Niche Locations in the Exploratory Studies Facility at Yucca Mountain”, <b>delete the background geology.</b></p> <p>Note: This figure should only show the locations of ESF alcoves, niches, and station numbers. The geology is provided in Figure 1-1.</p> <p>This error was identified in CR-5920</p>

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1-11	<p>Added clarification</p> <p>Section 1.4 "Constraints and Limitaions", 2<sup>nd</sup> and 3<sup>rd</sup> sentences, change:</p> <p>"One niche, Niche 5 (Niche CD 1620), has been excavated in the Tptpll unit. Most of the other existing testing alcoves and niches in the ESF (shown in Figure 1-2) are located at or above the horizon of the Tptpmn unit."</p> <p>To</p> <p>"One niche in the <b>ECRB</b>, Niche 5 (Niche CD 1620), has been excavated in the Tptpll unit (see <b>Figure 1-1</b>). Most of the other existing testing alcoves and niches in the ESF (shown in Figure 1-2) are located at or above the horizon of the Tptpmn unit (see <b>Figure 1-1</b>)."</p> <p>This error was identified in CR-5920</p>									
4-11	<p>Delete an indirect input</p> <p>Table 4-10c "Data on Water Potential and Saturation Measurements (For Reference)", delete 5<sup>th</sup> row:</p> <table border="1" style="width: 100%; margin-top: 10px;"> <tr> <td style="width: 30%;"><b>GS980308312242.004 [DIRS 107172]</b></td> <td style="width: 10%; text-align: center;">-</td> <td style="width: 10%; text-align: center;">-</td> <td style="width: 10%; text-align: center;">6-25</td> <td style="width: 30%;"><b>18 north ramp boreholes, 3 Alcove 4 boreholes, and 46 south ramp boreholes, HQ, 2 m length water potential.</b></td> </tr> </table> <p>Note: One of the purposes of this report is to list in one place all available data from field testing of processes. Accordingly, DTN: GS98030812242.004 [DIRS 107172] is cited only twice in ANL-NBS-HS-000005 as indirect input, and that is only to refer to its existence. The data themselves are never reported, plotted, or discussed. Deletion of this DTN from the input data will have no effect on the conclusions of this report.</p> <p>This error was identified in CR-6034</p>					<b>GS980308312242.004 [DIRS 107172]</b>	-	-	6-25	<b>18 north ramp boreholes, 3 Alcove 4 boreholes, and 46 south ramp boreholes, HQ, 2 m length water potential.</b>
<b>GS980308312242.004 [DIRS 107172]</b>	-	-	6-25	<b>18 north ramp boreholes, 3 Alcove 4 boreholes, and 46 south ramp boreholes, HQ, 2 m length water potential.</b>						
6-2	<p>Typographical error</p> <p>Section 6 "Scientific Analysis Discussion", 6<sup>th</sup> paragraph, 2<sup>nd</sup> sentence, change:</p> <p>"The crossover point is located in the northern pabrt of the ESF, as illustrated in Figure 1-2 and Figure 1-3."</p> <p>To</p> <p>"The crossover point is located in the northern part of the ESF, as illustrated in <b>Figure 1-1</b> and Figure 1-3."</p> <p>This error was identified in CR-5920</p>									

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1. Document Number: ANL-NBS-HS-000005		2. Revision: 03		3. ACN: 01	
4. Title: In Situ Field Testing of Processes					
6-186	Delete an indirect input				
	Table 6-25 "Water-Potential Measurements in the Exploratory Studies Facility and in the Enhanced Characterization of the Repository Block Cross-Drift", delete 6 <sup>th</sup> row, delete:				
	North Ramp 7+27 to 10+70 South Ramp 69+65 to 76+33— filter paper	18 North Ramp boreholes, 3 Alcove 4 boreholes, and 46 South Ramp boreholes, HQ, 2-m length	GS980308312242.004 [DIRS 107172]		
This error was identified in CR-6034					
6-189	Added clarification				
	Section 6.10.1.2.1 "Observation of Moisture Conditions in Ventilated ESF Main Drift", last paragraph on page 6-189, 3 <sup>rd</sup> and 4 <sup>th</sup> lines, change:  "Niche 1 (Niche 3566), Alcove 7, and the last section of the ECRB Cross-Drift (Figure 1-1 and Figure 1-2) have been closed ...." To "Niche 1 (Niche 3566) and Alcove 7 in the ESF (Figure 1-2), and the last section of the ECRB Cross-Drift (Figure 1-1) have been closed ...."  This error was identified in CR-5920				
6-189	Deleted text for clarification				
	Section 6.10.1.2.2 "Observation of Moisture Effects in Alcove 3 and Alcove 4", 1 <sup>st</sup> sentence, delete:  "The north ramp of the ESF penetrates the TCw, the PTn, and reaches the TSw in sequence, as illustrated in Figure 1-1 and Figure 1-2."  This error was identified in CR-5920				
8-33	Delete a reference				
	Section 8.3 "Source Data, Listed by Data Tracking Number", delete a source data with DIRS number 107172; delete:  "GS980308312242.004. Water Potential Measurements Using the Filter Paper Technique for Borehole Samples from the ESF North Ramp (ESF Station 7+27 M to ESF Station 10+70 M) and the ESF South Ramp (ESF Station 59+65 M to 76+33 M). Submittal date: 03/19/1998."  This error was identified in CR-6034				



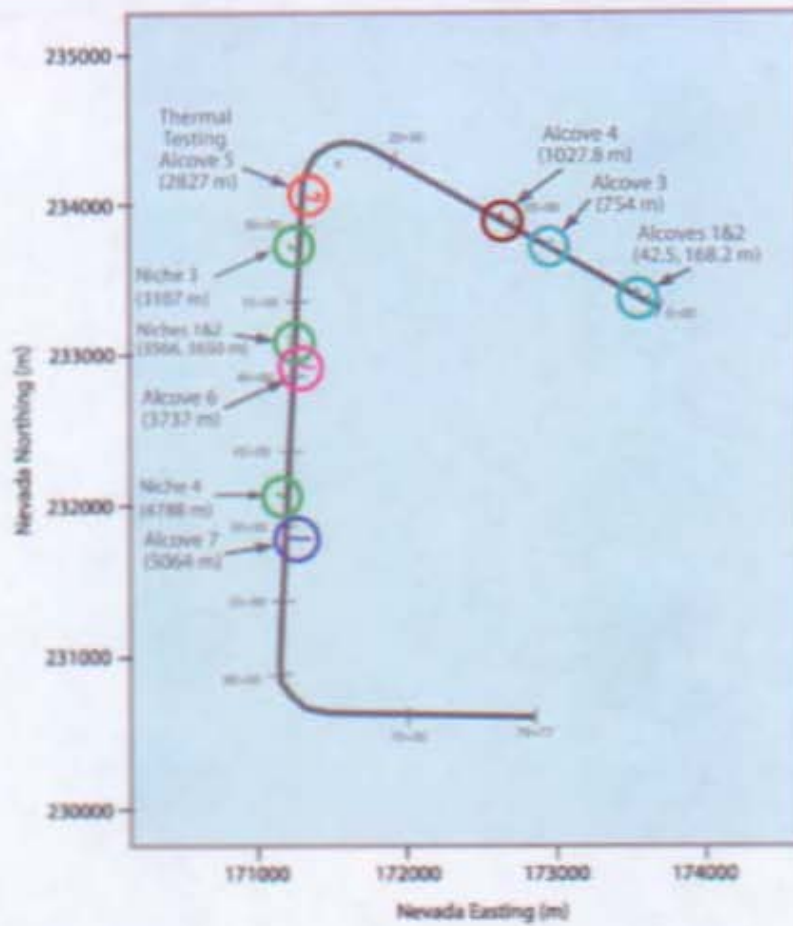


Figure 1-2. Schematic Illustration of Alcove and Niche Locations in the Exploratory Studies Facility at Yucca Mountain



Table 1-3. Features, Events, and Processes Addressed in this Scientific Analysis Report

LA FEP Number	FEP Name	Relevant Section(s) of This Report
1.2.02.01.0A	Fractures	Sections 6.1, 6.2, 6.6, and 6.9
2.2.01.01.0A	Mechanical effects of excavation/construction in the near field	Section 6.1
2.2.07.02.0A	Unsaturated groundwater flow in the geosphere	Sections 6.1 and 6.2
2.2.07.08.0A	Fracture flow in the UZ	Sections 6.2, 6.6, and 6.9
2.2.07.09.0A	Matrix imbibition in the UZ	Sections 6.4 and 6.7
2.2.07.18.0A	Film flow into the repository	Section 6.2
2.2.07.20.0A	Flow diversion around repository drifts	Sections 6.2 and 6.11.3
2.3.11.03.0A	Infiltration and recharge	Section 6.12

NOTES: FEP = feature, event, and process; LA = license application; UZ = unsaturated zone.

This scientific analysis report also supports the resolutions of Key Technical Issues, including: ECRB moisture monitoring (Section 6.10); Alcove-8/Niche-3 (Niche 3107) testing (Section 6.11); flow through the Calico Hills nonwelded vitric (Section 6.13); and analogue radionuclide data from test blocks at Busted Butte (Section 6.13).

#### 1.4 CONSTRAINTS AND LIMITATIONS

The field-testing activities and the associated analyses are subject to the constraints and limitations of spatial locations and temporal durations for tests conducted in the underground drifts. One niche in the ECRB, Niche 5 (Niche CD 1620), has been excavated in the Tptpll unit (see Figure 1-1). Most of the other existing testing alcoves and niches in the ESF (shown in Figure 1-2) are located at or above the horizon of the Ttpmn unit (see Figure 1-1). Test results and analyses from these sites provide data for the upper and middle tuff units. Some of the active flow tests were conducted within a few hours to a few days of each other because of limited accessibility to the test beds in the evenings and on weekends. Depending on system characteristics, the establishment of steady-state conditions can require longer tests. Some tests used automatic data acquisition systems for long-term monitoring and liquid releases, subject to power interruptions and equipment malfunctions. These constraints and limitations are addressed in the analyses of Section 6, if applicable.

## 4.1.10.3 Data on Water Potential and Saturation Measurements (For Reference)

Table 4-10c. Data on Water Potential and Saturation Measurements (For Reference)

Inputs	Used in			Description
	Section	Figure	Table(s)	
LB0406ESFNH2OP.001 <sup>a</sup> [DIRS 171588]	–	–	6-25	3 main boreholes, 5 lateral boreholes in Niche 1 (Niche 3566) water potential.
GS980908312242.022 [DIRS 135157]	–	–	6-25	Heat-dissipation-probe drill holes water potential.
GS980908312242.033 [DIRS 107168]	–	–	6-25 6-26	1 core hole in Alcove 3 water potential and saturation.
GS980908312242.032 [DIRS 107177]	–	–	6-25 6-26	2 core holes in Alcove 4 water potential and saturation.
GS980308312242.002 [DIRS 135163]	–	–	6-25	Heat-dissipation-probe drill holes water potential.
LB980901233124.014 <sup>b</sup> [DIRS 105858]	–	–	6-25 6-26	43 psychrometers on ESF drift walls, 1 slant borehole below the invert, 43 TDR probes on ESF drift walls.
GS980908312242.036 [DIRS 119820]	–	–	6-25	6 heat-dissipation-probe drill holes water potential.
GS970808312232.005 [DIRS 105978]	–	–	6-25	USW NRG-7a, UE-25 UZ#4, UE-25 UZ#5, USW UZ-7a, and USW SD-12 water potential.
GS971108312232.007 [DIRS 105980]	–	–	6-25	USW NRG-7a, UE-25 UZ#4, UE-25 UZ#5, USW UZ-7a, and USW SD-12 water potential.
GS980408312232.001 [DIRS 105982]	–	–	6-25	USW NRG-7a, UE-25 UZ#4, UE-25 UZ#5, USW UZ-7a, and USW SD-12 water potential.
GS031208312232.002 [DIRS 171748]	–	–	6-25	USW NRG-7a, UE-25 UZ#4, UE-25 UZ#5, USW UZ-7a, and USW SD-12 water potential.
GS980908312242.018 [DIRS 135170]	–	–	6-26	3 main boreholes, 6 lateral boreholes in Niche 1 (Niche 3566).
GS980908312242.020 [DIRS 135172]	–	–	6-26	7 main boreholes in Niche 2 (Niche 3650).
GS980908312242.029 [DIRS 135175]	–	–	6-26	3 boreholes in Alcove 6.
GS980908312242.028 [DIRS 135176]	–	–	6-26	1 borehole in Alcove 7 saturation.
GS980308312242.005 [DIRS 107165]	–	–	6-26	PTn Borehole core saturation.
GS980308312242.003 [DIRS 135180]	–	–	6-26	South ramp core saturation.
GS980308312242.001 [DIRS 135181]	–	–	6-26	TDR measurements of saturation.
GS980908312242.030 [DIRS 135224]	–	–	6-26	1 slant borehole core saturation.

<sup>a</sup> Also used as input in Section 6.8 on niche water-potential measurement, as shown in Table 4-8.

<sup>b</sup> Also used as input in Section 6.9 on construction-water migration, as shown in Table 4-9.

ESF = Exploratory Studies Facility; TDR = time domain reflectometry.

- Section 6.13 presents the results of different phases of transport tests at Busted Butte.
- Section 6.14 summarizes geochemical and isotope data in pore water, rocks, and fracture in-fill minerals collected from test locations in different tuff units.

The list of data supporting these analyses can be found in the tables labeled “b” and “c” of Section 4.1.

The tests performed in niches and alcoves along the ESF are illustrated in Figure 6-1. Seepage into drifts at the repository level is related to water percolating down from the ground surface. Drift-seepage tests at niche sites quantify the seepage from liquid pulses released above the niches. Percolation flux has a fast fracture-flow component and a slow matrix-flow component. This partitioning of flow is evaluated at the fracture-matrix test bed in Alcove 6. The heterogeneous hydrogeologic setting (with alternating tuff layers) determines the percolation distribution throughout the UZ, with input from infiltration at the ground surface boundary. The mechanism of redistributing near-surface fracture flow by the porous PTn, especially the flow-damping process by the PTn unit, is studied in a test bed in Alcove 4. The PTn unit examined at Alcove 4 consists of layered, altered, and bedded tuffs transected by a fault. Wetter climate conditions increase the infiltration, as quantified in an artificial infiltration test in Alcove 1 and in moisture monitoring at depth in Alcove 7. The seepage threshold data from niches and from systematic hydrological characterization are inputs to the model report *Seepage Calibration Model and Seepage Testing Data* (BSC 2004 [DIRS 171764]).

Figure 6-1 illustrates general issues (DOE 1998 [DIRS 100550], Section 3.1; Figure 3-1) pertaining to UZ flow processes of seepage, percolation, and infiltration. The tests illustrated in Figure 6-1 focus on different issues to quantify the functional relationships among these processes. Seepage is smaller than percolation flux because of capillarity-induced drift diversion (BSC 2004 [DIRS 171764], Section 6), and percolation may be smaller than infiltration because of lateral diversion of percolating water along tuff interfaces to bounding faults. All tests use tracers to assist the characterization of plume migration.

Figure 6-2 illustrates the ECRB cross-drift to ESF main drift seepage collection system to study the migration of water and tracer flow from one drift to another. The crossover point is located in the northern part of the ESF, as illustrated in Figure 1-1 and Figure 1-3. In 1998, the seepage monitoring system was used to monitor the migration of construction water from the ECRB cross-drift. Niche 3 (Niche 3107), originally excavated and used for the drift seepage study, is part of the drift-to-drift study as a seepage collection site. The existing horizontal boreholes at Niche 3 (Niche 3107) are used for wetting-front monitoring for liquid released from Alcove 8, excavated from the ECRB cross-drift and directly above Niche 3 (Niche 3107).

Because neither the ESF main drift nor the ECRB cross-drift reaches the Calico Hills hydrogeologic tuff unit (CHn) below the repository block, a dedicated drift complex was excavated at Busted Butte, 8 km southeast of Yucca Mountain, to evaluate flow and transport processes in vitric CHn. Early results were first reported in the report *Unsaturated Zone and Saturated Zone Transport Properties* (CRWMS M&O 2001 [DIRS 154024]). The different field-testing phases and recent updates are presented in Section 6.13.



Table 6-25. Water-Potential Measurements in the Exploratory Studies Facility and in the Enhanced Characterization of the Repository Block Cross-Drift

Potential Measurement	Description <sup>a</sup>	DTN
Niche 1 (Niche 3566)— psychrometer Niche 2 (Niche 3650)— psychrometer	3 main boreholes, 5 lateral boreholes in Niche 1 (Niche 3566), 5/9/97— 10/21/97; 6 main boreholes in Niche 2 (Niche 3650), 7/1/97—7/28/97	LB0406ESFNH2OP.001 [DIRS 171588] (see Section 6.8.2 of this report)
Niche 1 (Niche 3566)—heat dissipation probe	21 heat dissipation probe drill holes, 11/4/97—7/31/98	GS980908312242.022 [DIRS 135157]
Niche 3 (Niche 3107)— psychrometer	3 main boreholes, 12/22/97—1/8/98	LB0406ESFNH2OP.001 [DIRS 171588] (see Section 6.8.2.4 of this report)
Alcove 7—heat dissipation probe	Heat dissipation probe drill holes, 12/9/97—1/31/98	GS980908312242.022 [DIRS 135157]
Alcove 3—filter paper Alcove 4—filter paper	1 core hole in Alcove 3, 2 core holes in Alcove 4	GS980908312242.033 [DIRS 107168], GS980908312242.032 [DIRS 107177]
South Ramp—heat dissipation probe	Heat dissipation probe drill holes, 8/1/97—1/4/98	GS980308312242.002 [DIRS 135163]
ECRB Cross-Drift Starter Tunnel—psychrometer & electrical resistivity probe	1 slant borehole below the invert	LB980901233124.014 [DIRS 105858] (see Section 6.9.2.1 of this report)
ECRB Cross-Drift 0+50 to 7+75—heat dissipation probe	6 heat dissipation probe drill holes, 4/23/98—7/31/98	GS980908312242.036 [DIRS 119820]
Surface Based Boreholes— psychrometer	USW NRG-7a, UE-25 UZ#4, UE-25 UZ#5, USW UZ-7a and USW SD-12; 1/1/97—6/30/97; 7/1/97—9/30/97; 10/1/98—3/31/98; 4/1/98—9/30/98	GS970808312232.005 [DIRS 105978], GS971108312232.007 [DIRS 105980], GS980408312232.001 [DIRS 105982], GS031208312232.002 [DIRS 171748]

<sup>a</sup> Description taken from Automated Technical Data Tracking database.

ECRB = Enhanced Characterization of the Repository Block.

ESF = Exploratory Studies Facility.

barometric signals from the ground surface, less attenuation and phase lag were observed for signals from the ESF. For Borehole NRG-7a, which is within 30 m (in horizontal distance) from the ESF tunnel, the changes in water potential could also be related to the ESF dryout (see the last entry of Table 6-25 for DTNs of surface-based boreholes).

The main effects of ESF ventilation are the drying of rocks around the tunnel, the suppression of potential seepage into tunnels, and the perturbation of the gas flow field around the tunnel. Niche 1 (Niche 3566) and Alcove 7 in the ESF (Figure 1-2), and the last section of the ECRB Cross-Drift (Figure 1-1) have been closed for long periods (see Section 6.10.2 below), to minimize or eliminate the ventilation effects, and to gain additional information on the rewetting processes and potential seepage events under near-natural conditions (with drift entrances blocked off). Both the data collected during active ventilation phases and the data collected during passive nonventilation phases will contribute to the assessment of UZ responses to large-scale perturbations at Yucca Mountain.

#### **6.10.1.2.2 Observation of Moisture Effects in Alcove 3 and Alcove 4**

Alcove 3 and Alcove 4 were excavated in the vicinity of the TCw-PTn and PTn-TSw interfaces, respectively (Section 1.2). Corroborating studies have been performed between Alcove 3 and Alcove 4 that quantified in situ water-potential, moisture, and temperature fluctuations in the nonwelded units of the Paintbrush Group (PTn), to identify gradients between the PTn and adjacent Tiva Canyon tuff and Topopah Spring tuff (DTN: GS021008312242.003 [DIRS 162178]). The studies identified an effect of ventilation-induced drying to a depth of 4.9 m into the tuff from the ESF. As a result, water-potential values were more negative (lower moisture content) near the tunnel surface and greater (higher moisture content) beyond the zone influenced by ventilation. From surface to depth, water-potential values were:

- Tiva Canyon – 27.0 bars to –3.5 bars (ventilation effects),
- Paintbrush nonwelded – 1.7 bars to –0.1 bars, and
- Topopah Spring – 1.4 bars to –0.6 bars.

The combined evidence of high moisture values at the Tpbt2/Tptrv3 contact (–0.1 and –0.3 bars), along with the 10° east dip of the beds, indicates a high potential for lateral water flow in the PTn (DTN: GS021008312242.003 [DIRS 162178]; LeCain et al. 2002 [DIRS 158511]). The PTn lateral flow has been evaluated in *UZ Flow Models and Submodels* (BSC 2004 [DIRS 169861]).

GS971108314224.022. Revision 1 of Detailed Line Survey Data, Station 8+00 to Station 10+00, North Ramp, Exploratory Studies Facility. Submittal date: 12/03/1997.	106009
GS971108314224.023. Revision 1 of Detailed Line Survey Data, Station 10 + 00 to Station 18 + 00, North Ramp, Exploratory Studies Facility. Submittal date: 12/03/1997.	106010
GS971108314224.024. Revision 1 of Detailed Line Survey Data, Station 18+00 to Station 26+00, North Ramp, Exploratory Studies Facility. Submittal date: 12/03/1997.	106023
GS971108314224.025. Revision 1 of Detailed Line Survey Data, Station 26+00 to Station 30+00, North Ramp and Main Drift, Exploratory Studies Facility. Submittal date: 12/03/1997.	106025
GS971108314224.026. Revision 1 of Detailed Line Survey Data, Station 45+00 to Station 50+00, Main Drift, Exploratory Studies Facility. Submittal date: 12/03/1997.	106032
GS971108314224.028. Revision 1 of Detailed Line Survey Data, Station 55+00 to Station 60+00, Main Drift and South Ramp, Exploratory Studies Facility. Submittal date: 12/03/1997.	106047
GS980308312242.001. Time Domain Reflectometry Measurements in the South Ramp of the ESF, August 1, 1997 to January 4, 1998. Submittal date: 03/04/1998.	135181
GS980308312242.002. Heat Dissipation Probe Measurements in the South Ramp of the ESF, August 1, 1997 to January 31, 1998. Submittal date: 03/09/1998.	135163
GS980308312242.003. Physical Properties of Borehole Samples from the ESF South Ramp (ESF Station 59+65M to ESF Station 76+33M). Submittal date: 03/16/1998.	135180
GS980308312242.005. Physical Properties of Lexan-Sealed Borehole Samples from the PIN Exposure in the ESF North Ramp (ESF Station 7+27 M to ESF Station 10+70 M). Submittal date: 03/11/1998.	107165
GS980308315215.008. Line Survey Information from the Exploratory Studies Facility Obtained to Estimate Secondary Mineral Abundance. Submittal date: 03/24/1998.	107355
GS980408312232.001. Deep Unsaturated Zone Surface-Based Borehole Instrumentation Program Data from Boreholes USW NRG-7A, UE-25 UZ #4, USW NRG-6, UE-25 UZ #5, USW UZ-7A and USW SD-12 for the Time Period 10/01/97 - 03/31/98. Submittal date: 04/16/1998.	105982