527572

Sandia National Laboratories
Waste Isolation Pilot Plant

Records Package

for

AP-088 Task 4
Conditioning of Base T Fields to Transient Heads:
Compilation and Reduction of Transient Head Data

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1. INTRODUCTION AND OBJECTIVES

This Records Package documents the compilation and reduction of transient head data to be used in the calibration of transmissivity (T) fields for the Culebra Dolomite Member of the Rustler Formation at the Waste Isolation Pilot Plant (WIPP) site. The data will be used to accomplish Task 4, Conditioning of Base T Fields to Transient Heads, of Analysis Plan 088 (Beauheim, 2002). The first step in this task is to define the hydraulic-stress events (e.g., pumping tests) to be used in the model calibration. Once the events are defined, the head data representing transient responses to these events at nearby observation wells can be identified, compiled, and reduced to formats and frequencies suitable for use in model calibration. In addition, this Records Package also documents the determination of an appropriate storativity value to be used for the transient calibration.

2. APPROACH TO TRANSIENT CALIBRATION

The transient calibration of Culebra T fields that was performed for the WIPP Compliance Certification Application (CCA) sought to match simulated freshwater heads (in meters above mean sea level (m amsl)) to the freshwater heads calculated from observed water levels (U.S. DOE, 1996, Appendix TFIELD). This approach assumed that a steady-state head condition existed at the start of the simulation, and that the Culebra was continually trying to recover to that condition. This approach necessitated including a large number of stresses that affected Culebra heads over the time period covered by the simulation, which was from January 1, 1981 through April 1, 1996 (U.S. DOE, 1996, Table TFIELD-9).

The transient calibration that will be performed under Analysis Plan 088 will seek to match simulated changes in freshwater head from the start of each simulated event to the observed changes, not the values of the heads in terms of elevation above mean sea level. This approach does not require that we assume that a steady-state head condition existed in the Culebra at the beginning of the simulation, but that the stress events that we include in the simulation be the dominant causes of head changes during the calibration periods. To implement this approach to transient calibration, we must define the events to be included, the locations at which simulated and observed responses will be compared, and the time periods of the comparisons. In addition, an appropriate value of storativity must be determined to use in the transient model calibration.

3. EVENTS TO BE INCLUDED IN TRANSIENT CALIBRATION

The events to be included in the transient calibration were selected with four requirements in mind:

1. the pressure or flow-rate conditions during the event must be known;
2. the event must involve measured responses at multiple wells on other drilling pads;
3. insofar as possible, the event should be the only hydraulic stress affecting the observed responses (i.e., no superimposed responses to other events);
4. the ensemble of events selected should provide as complete areal coverage of the WIPP site and surroundings as possible.

As will be discussed below, fulfilling the fourth requirement necessitated some compromises with regard to the third requirement. Two types of events were candidates for inclusion: events occurring in the WIPP shafts and pumping tests at various well locations.

Of the four WIPP shafts, only the salt shaft (originally known as the exploratory shaft) and the waste-handling shaft (originally known as the ventilation shaft) were constructed at times when no other hydraulic events were significantly affecting Culebra heads near the center of the WIPP site. Construction and lining of the exhaust shaft occurred between September 1983 and January 1985 (Holt and Powers, 1986), during which time slug and pumping tests were conducted at H-2 (INTERA Technologies and Hydro Geo Chem, 1985), pumping and tracer tests were conducted at H-3 (INTERA Technologies, 1986), and pumping tests were conducted at H-11 (INTERA Technologies and Hydro Geo Chem, 1985). Construction and lining of the air-intake shaft occurred between December 1987 and December 1988 (Holt and Powers, 1990), during which period the H-11 multipad/tracer test was conducted (Beauheim, 1989). Thus, only events associated with construction of the salt and waste-handling shafts meet the third requirement given above. Culebra water levels were monitored at H-1 and H-3b1 during construction of these shafts, showing clear responses.

For the salt shaft, the period selected for inclusion in the transient calibration is from August 7, 1981 through April 16, 1983. August 7, 1981 is the date that shaft drilling reached the top of the Culebra, and April 16, 1983 is the date of the last set of water-level measurements made at H-1 and H-3b1 before the effects of pumping at DOE-1 were observed. During this period, the shaft was drilled and lined, and then served as a drain (sink) on the Culebra. For the waste-handling shaft, the period included in the transient calibration is from January 30, 1982, when drilling first reached the Culebra, to April 16, 1983. The waste-handling shaft served as a drain (sink) on the Culebra throughout this period.

The pumping tests selected for inclusion in the transient calibration were the following:

- H-3 multipad pumping test
- WIPP-13 multipad pumping test
- P-14 pumping test
- H-19 tracer tests conducted in 1995 and 1996
- H-11 tracer tests conducted in 1996
- WQSP-1 pumping test
- WQSP-2 pumping test

The H-19 and H-11 tracer tests provided ideal events for inclusion in the transient calibration from the standpoint of involving observed responses at multiple well locations covering a wide area. However, these responses included superimposed effects of other pumping events that occurred in 1995, including the WQSP-4 pumping test and multiple well-development or other pumping events in wells on the H-19 and H-11 hydropads. Therefore, these other pumping events might need to be included as stresses in the transient calibration to create the proper superposition of responses, even though the calibration will not involve fitting directly to the responses observed during these events. Information on all the events to be used in transient calibration of the Culebra transmissivity fields has been assembled in Excel file ***Events.xls***.

Information on the events with corresponding well responses to be included in the transient calibration is given in Table 1, which is extracted from file ***Events.xls***. The locations where the Culebra was stressed and the observation wells for each event are shown in Figure 1. The additional pumping events that might be included in the transient calibration to create the proper superposition of responses are listed in Table 2, also extracted from file ***Events.xls***. The CCA transient calibration of Culebra T fields, in comparison, did not include the P-14, WQSP-4, and WQSP-1 pumping tests, but did include additional events in all four WIPP shafts as well as additional pumping events at H-3 and H-11 (U.S. DOE, 1996, Table TFIELD-9). The CCA simulation also did not calibrate to the 1995-96 H-19, H-11, and WQSP-2 pumping events, but included them as "model-validation" events.

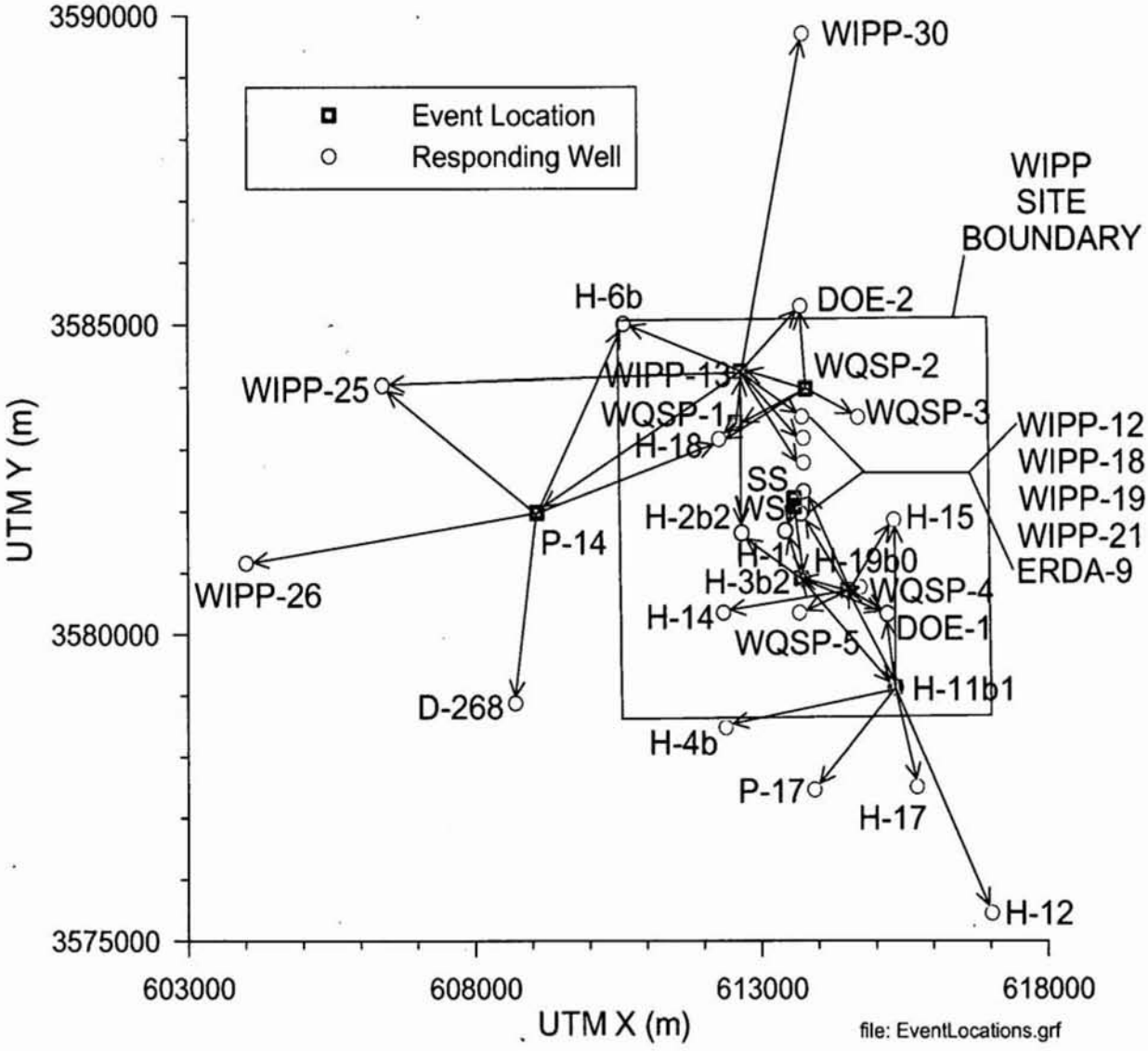

Figure 1. Locations of events and responding wells.

Table 1. Events to be Included in Transient Calibration.

Stress Location	Start Date	Start Time	Start Time in Simulation (s)	End Date	End Time	End Time in Simulation (s)	Pumping Rate (L/s)	Freshwater Head (m amsl)	Observation Wells	Reference
Exploratory Shaft	8/7/1981	12:00	86400	8/8/1981	12:00	172800		875.46	H-1, H-3b1	CCA, Table TFIELD-9
	8/8/1981	12:00	172800	8/9/1981	12:00	259200		839.75		
	8/9/1981	12:00	259200	8/10/1981	12:00	345600		836.18		
	8/10/1981	12:00	345600	8/11/1981	12:00	432000		832.60		
	8/11/1981	12:00	432000	8/12/1981	12:00	518400		829.03		
	8/12/1981	12:00	518400	8/13/1981	12:00	604800		825.46		
	8/13/1981	12:00	604800	8/14/1981	12:00	691200		821.89		
	8/14/1981	12:00	691200	8/15/1981	12:00	777600		818.39		
	8/15/1981	12:00	777600	10/25/1981	12:00	6912000		814.37		
	10/25/1981	12:00	6912000	10/28/1981	12:00	7171200		996.48		
	10/28/1981	12:00	7171200	10/31/1981	12:00	7430400		1003.01		
	10/31/1981	12:00	7430400	11/2/1981	12:00	7603200		1009.54		
	11/2/1981	12:00	7603200	11/5/1981	12:00	7862400		1016.07		
	11/5/1981	12:00	7862400	11/8/1981	12:00	8121600		1022.60		
	11/8/1981	12:00	8121600	11/11/1981	12:00	8380800		1029.14		
	11/11/1981	12:00	8380800	11/14/1981	12:00	8640000		1035.67		
	11/14/1981	12:00	8640000	11/17/1981	12:00	8899200		1042.20		
	11/17/1981	12:00	8899200	12/6/1981	12:00	10540800		1097.20		
	12/6/1981	12:00	10540800	3/16/1983	12:00	50716800	0.032			
Ventilation Shaft	1/30/1982	12:00	15292800	3/16/1983	12:00	50716800		814.50	H-1, H-3b1	CCA, Table TFIELD-9
H-3b2	10/15/1985	9:00	132267600	12/16/1985	9:00	137624400	0.303		H-1, H-2b2, H-11b1, DOE-1	Beauheim (1987a)
WIPP-13	1/12/1987	9:00	171493200	2/17/1987	9:00	174603600	1.89		H-2b2, H-6b, DOE-2, P-14, WIPP-12, WIPP-18, WIPP-19, WIPP-25, WIPP-30	Beauheim (1987b)

Table 1. Events to be Included in Transient Calibration (continued).

Stress Location	Start Date	Start Time	Start Time in Simulation (s)	End Date	End Time	End Time in Simulation (s)	Pumping Rate (L/s)	Freshwater Head (m amsl)	Observation Wells	Reference
P-14	2/14/1989	9:01	237502860	2/14/1989	9:50	237505800	4.82		H-6b, H-18, D-268, WIPP-25, WIPP-26	Beauheim and Ruskauff (1998)
	2/14/1989	12:01	237513676	2/14/1989	13:24	237518688	4.38			
	2/14/1989	13:24	237518688	2/14/1989	21:29	237547788	3.92			
	2/14/1989	21:29	237547788	2/15/1989	14:00	237607200	3.70			
	2/15/1989	14:00	237607200	2/15/1989	19:30	237627000	3.42			
	2/15/1989	19:30	237627000	2/16/1989	22:00	237722400	3.64			
	2/16/1989	22:00	237722400	2/17/1989	10:00	237765600	3.40			
	2/17/1989	10:00	237765600	2/17/1989	12:00	237772800	3.22			
H-19b0	6/16/1995	11:00	437353200	7/28/1995	7:00	440967600	0.236		H-1, H-2b2, H-3b2, H-14, H-15, DOE-1, ERDA-9, WIPP-21, WQSP-4, WQSP-5	Meigs et al. (2000)
	12/15/1995	11:30	453079800	1/17/1996	19:00	455958000	0.271			
	1/17/1996	19:00	455958000	2/19/1996	12:50	458787000	0.252			
	2/19/1996	12:50	458787000	4/11/1996	11:30	463275000	0.155			
WQSP-1	1/25/1996	13:18	456628680	1/28/1996	7:41	456867660	0.43		H-18, WIPP-13	Beauheim and Ruskauff (1998)
H-11b1	2/7/1996	10:00	457740000	3/11/1996	15:00	460609200	0.223		H-4b, H-12, H-17, P-17, DOE-1	Meigs et al. (2000)
	3/11/1996	15:00	460609200	3/28/1996	8:25	462054300	0.376			
WQSP-2	2/20/1996	11:30	458868600	2/24/1996	11:30	459214200	0.45		DOE-2, H-18, WIPP-13, WQSP-1, WQSP-3	Beauheim and Ruskauff (1998)

Table 2. Additional Pumping Events to be Potentially Included in Transient Calibration.

Stress Location	Start Date	Start Time	Start Time in Simulation (s)	End Date	End Time	End Time in Simulation (s)	Pumping Rate (L/s)	Reference
WQSP-4	2/15/1995	10:01	426895260	2/17/1995	15:06	427086360	0.26	Beauheim and Ruskauff (1998)
	2/17/1995	15:06	427086360	2/19/1995	15:45	427261500	0.14	
H-19b0	4/24/1995	19:42	432805320	4/26/1995	13:03	432954180	0.226	ERMS 420023
H-19b3	5/5/1995	10:03	433720980	5/5/1995	13:05	433731900	0.261	ERMS 420033
	5/5/1995	13:05	433731900	5/6/1995	12:42	433816920	0.131	
H-19b2	5/23/1995	20:32	435313920	5/24/1995	2:38	435335880	0.12	Beauheim and Ruskauff (1998)
	5/24/1995	2:38	435335880	5/25/1995	4:23	435428580	0.24	
	5/25/1995	4:23	435428580	5/25/1995	6:04	435434640	0.66	
	5/25/1995	6:04	435434640	5/25/1995	6:10	435435000	0.24	
	9/18/1995	16:14	445493640	9/19/1995	7:00	445546800	0.182	ERMS 420030
H-19b4	6/5/1995	17:05	436424700	6/6/1995	12:34	436494840	0.120	ERMS 420037
	6/6/1995	12:34	436494840	6/7/1995	15:43	436592580	0.238	
H-11b1	8/10/1995	19:30	442135800	8/25/1995	18:35	443428500	0.244	
H-19b7	8/24/1995	11:00	443314800	8/25/1995	19:02	443430120	0.247	ERMS 420054
H-19b6	8/30/1995	11:20	443834400	9/3/1995	13:13	444186780	0.221	ERMS 420042
H-19b5	9/8/1995	14:45	444624300	9/8/1995	16:25	444630300	0.247	ERMS 420040
	9/8/1995	16:25	444630300	9/11/1995	15:27	444886020	0.124	
	9/11/1995	15:27	444886020	9/13/1995	15:00	445546800	0.179	

4. COMPILATION AND REDUCTION OF TRANSIENT HEAD DATA

Transient head data were collected using three methods during the events to be used for model calibration:

1. Manual measurements using electric water-level sounders;
2. Pressure-transducer measurements obtained using a computerized data-acquisition system (DAS); and
3. Pressure-transducer measurements obtained using Trolls (programmable, self-contained downhole pressure gauges).

Data-reduction procedures are different for each type of data. Water-level data are typically measured and recorded as depth below top of casing (or some other datum near ground surface). By knowing the depth to the center of the Culebra, the height of the water column in the well above the center of the Culebra can be calculated. By knowing the density of the water in the well, the height of the column of freshwater that would exert the same pressure at the center of the Culebra can be calculated. If desired, by knowing the elevation of the center of the Culebra, the freshwater head can also be expressed in terms of elevation. The change in freshwater head during any hydraulic-stress event can be calculated by subtracting the head at the start of the event from subsequent heads. Water-level-measurement frequencies varied from several times a day to monthly during the events to be used for transient calibration. No thinning of these data for use in model calibration is required.

Pressure-transducer measurements obtained using a DAS are typically recorded as pressures (in psi or Pa) above the transducer. These pressures can readily be converted to meters of freshwater above the transducer using the known density of freshwater. The change in freshwater head during any hydraulic-stress event can then be calculated by subtracting the head at the start of the event from subsequent heads. Data-acquisition rates varied from every few seconds to every few hours during pumping tests. Generally, the same data density that was used for well-test analysis will be passed on for use in model calibration. The data may be thinned as the calibration procedure is set up.

Trolls are manufactured by In-Situ, Inc. and are operated using Win-Situ software written by In-Situ. They measure and record pressure and temperature at programmed time intervals. Trolls create binary data files that can only be read by the In-Situ Data Manager. Within Data Manager, the desired units for Elapsed Time (since data acquisition began), Pressure/Head, and Temperature can be specified. Data Manager can export an ASCII text file of the data using the desired units. For this application, an Elapsed Time in minutes was specified (irrelevant because this column was discarded and the raw Date and Time were used), Pressure/Head was specified to be meters of freshwater above the Troll's sensor, and Temperature was specified to be in degrees Fahrenheit (not used). The exported ASCII files were given the same name as the original binary file, with the .BIN suffix changed to .TXT. Troll measurements were made at intervals ranging from tens of seconds to a few hours, in some cases over periods approaching a year. The resulting data files are in some cases too large to use directly in model calibration, and can be reduced to hourly readings with no loss in important information. (Measurements made

during the first seconds or minutes of an event are unimportant when the observation wells are located hundreds to thousands of meters from the stress point.)

In some instances, Troll data are to be merged with water-level data to create records spanning long periods of time. Details of how this merger is accomplished will be discussed below with respect to the events and wells involved.

The zero time for all data was defined as 12:00 on August 6, 1981, one day before the start of the first transient event. All times are tracked in elapsed seconds from that starting point to provide a common time base for simulation.

4.1 Shaft Events

The history of shaft events given in Table TFIELD-9 of the CCA (U.S. DOE, 1996) from August 7, 1981 through April 16, 1983 will be used unchanged for the calibration of the new T fields. Because that table provides only dates and not times, all events listed will be assumed to have occurred at 12:00 noon on the dates listed. Given the sparsity of the observation data (approximately weekly water-level measurements), an error in the initiation time of an event of a few hours should not be significant.

Table TFIELD-9 of the CCA lists absolute pressures applied to the Culebra by the presence (or absence) of drilling fluid in the shafts in units of Pascals (Pa, or kg/ms^2). Thus, for an atmospheric pressure condition (Culebra freely draining), a value of 1.013E5 Pa is given. The pressures from Table TFIELD-9 are given in kPa in column N of file ***Events.xls***. These pressures are converted to meters of freshwater head in column O by first subtracting atmospheric pressure (101.3 kPa (1000 kg/ms^2)), dividing by the acceleration of gravity (9.8 m/s^2) times the density of freshwater (1000 kg/m^3), and adding the elevation (m amsl) of the base of the Culebra at the shaft location. The elevation used for the base of the Culebra is the elevation of the top of the Culebra assigned to the nearest grid point in the Culebra model, minus the 7.75-m thickness of the Culebra used in the model. This information is given in Table 3.

Table 3. Assignment of Culebra Elevation at WIPP Shafts.

Shaft	Shaft UTM X (m)[1]	Shaft UTM Y (m)[1]	Nearest Model UTM X (m)[2]	Nearest Model UTM Y (m)[2]	Model Culebra Top Elevation (m amsl)[2]	Model Culebra Base Elevation (m amsl)[3]
Exploratory	613571	3582201	613550	3582200	822.12	814.37
Ventilation	613579	3582079	613600	3582100	822.25	814.50

[1] Gonzales (1989; Table 3-7)
[2] ERMS 523889 (file: culebra_top.txt)
[3] Culebra top – 7.75 m

Culebra water levels were measured approximately weekly in wells H-1 and H-3b1 (then known simply as H-3) by the U.S. Geological Survey (USGS) during the period given above (Richey, 1987). The data were entered in Excel files ***H-1-shafts.xls*** and ***H-3b1-shafts.xls***. No times are given by Richey (1987) for the measurements, so they will be assumed to have occurred at 12:00 noon (Column B) on the dates listed (Column A). The elapsed time in seconds from 12:00 on August 6, 1981 was calculated in Column C. Using land surface elevations given in Gonzales (1989; Table 3-6), the depths to water (Column D) were converted to elevations (Column E in ft, Column F in m). The water level on August 3, 1981 was assumed to represent the water level when the first shaft event occurred on August 6, 1981. Column G shows the change in water level (in m) from the August 3, 1981 measurement. Finally, Column H shows the change in freshwater head (in m) obtained by multiplying Column G by the borehole fluid density given by Cauffman et al., 1990; Appendix F). All relevant information and data sources are given in the header lines of the Excel files. The change-in-freshwater-head data for H-1 and H-3b1 are shown in Figures 2 and 3, respectively.

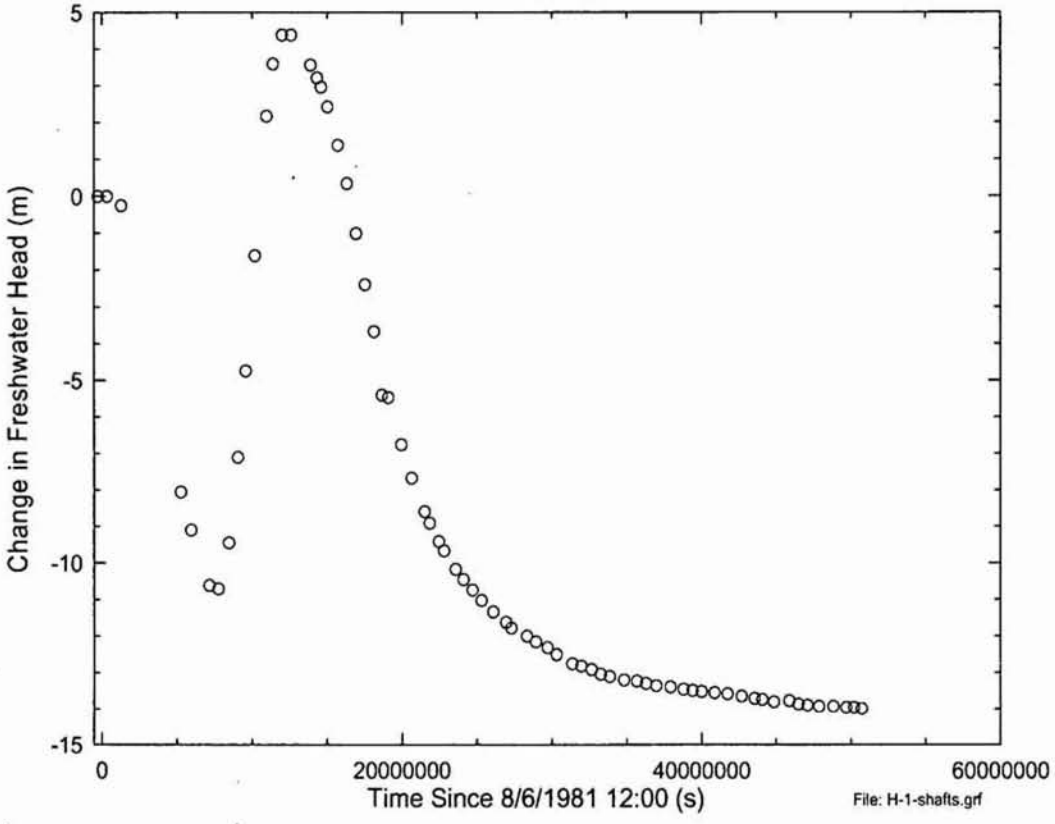

Figure 2. H-1 response to shaft events.

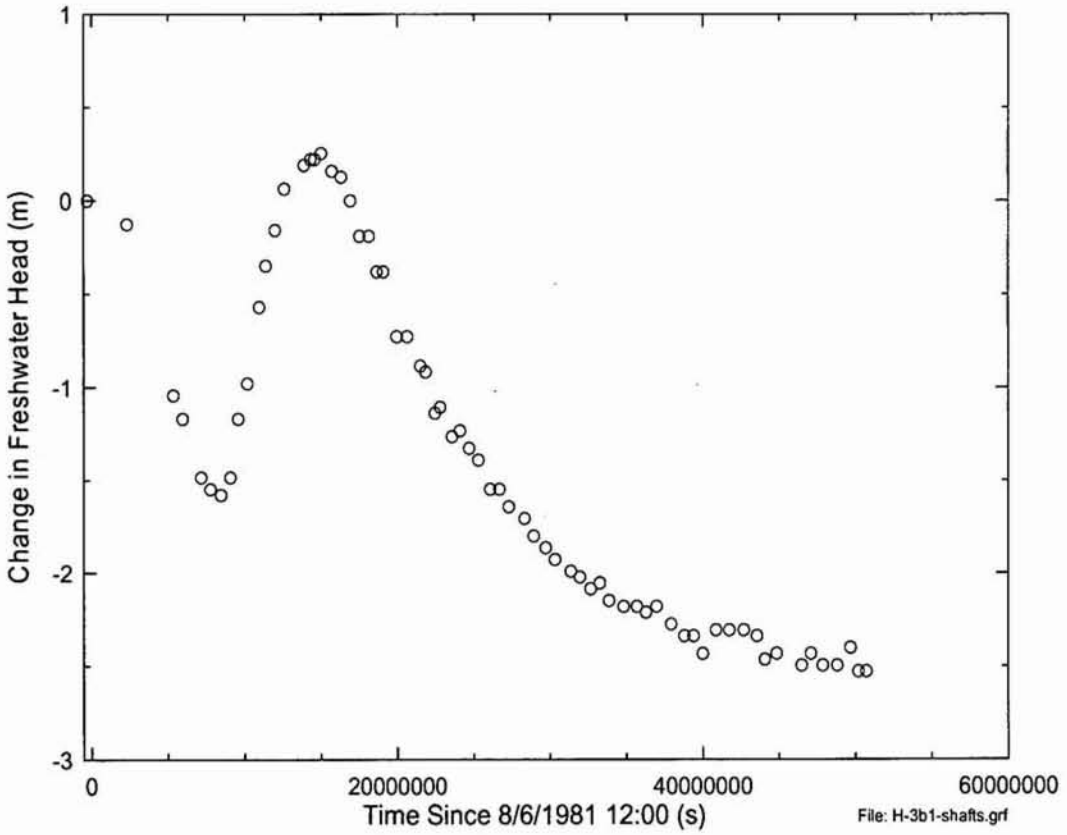

Figure 3. H-3b1 response to shaft events.

4.2 H-3 Multipad Pumping Test

The H-3 multipad pumping test was conducted by pumping H-3b2 at a rate of 4.8 gpm (0.30 L/s) from October 15 to December 16, 1985 (Beauheim, 1987a). Responses to the pumping were measured in wells H-1, H-2b2, H-11b1, and DOE-1 until April 2 to 21, 1986, and are given in Tables B-2 through B-5 of Beauheim (1987a). For each of these wells, a modified pressure is given that compensates for pre-test trends in the water levels.

4.2.1 DOE-1 Response

The data from DOE-1 were taken from Table B-5 of Beauheim (1987a). A modified pressure was calculated for the first 20 entries in the table using the equation given in Beauheim (1987a). The Elapsed Time, Pressure, and Modified Pressure columns were inserted in Excel file ***H3DOE1.xls*** as columns A, C, and D, respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (132267600 s; see Table 1). An initial pressure was calculated (Column G) by averaging the first 21 modified pressures made over the first 72.305 hr of the test when Beauheim (1987a) thought DOE-1 was not yet responding to the pumping at H-3b2. Column E was then created of "Head Change (m of freshwater)" by multiplying the change in pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 4.

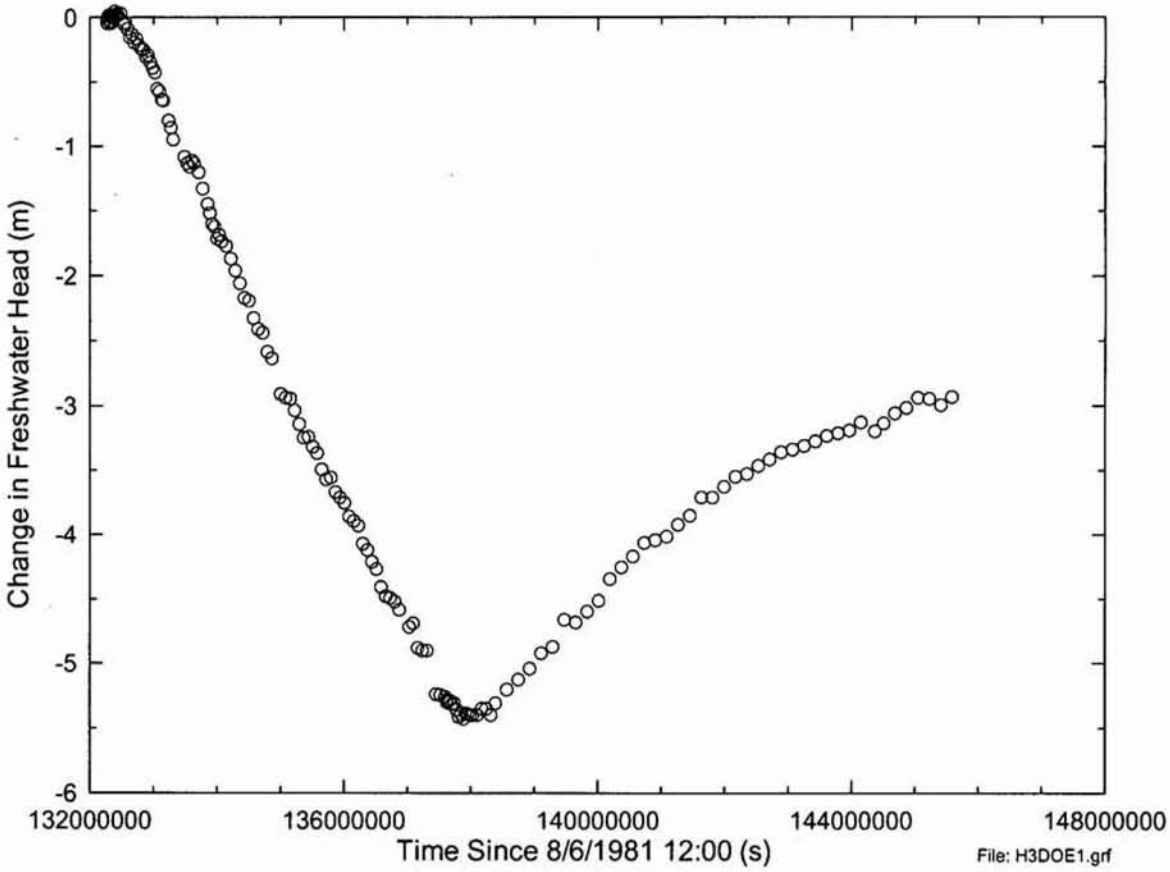

Figure 4. DOE-1 response to H-3 multipad pumping test.

4.2.2 H-1 Response

The data from H-1 were taken from Table B-2 of Beauheim (1987a). A modified pressure was calculated for the first six entries in the table using the equation given in Beauheim (1987a). The Elapsed Time, Pressure, and Modified Pressure columns were inserted in Excel file ***H3H1.xls*** as columns A, C, and D, respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (132267600 s; see Table 1). Column E was then created of "Head Change (m of freshwater)" by multiplying the change in pressure (psi (lb/in^2)) from the start of the test by (($(144\ in^2/ft^2)/(62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 5.

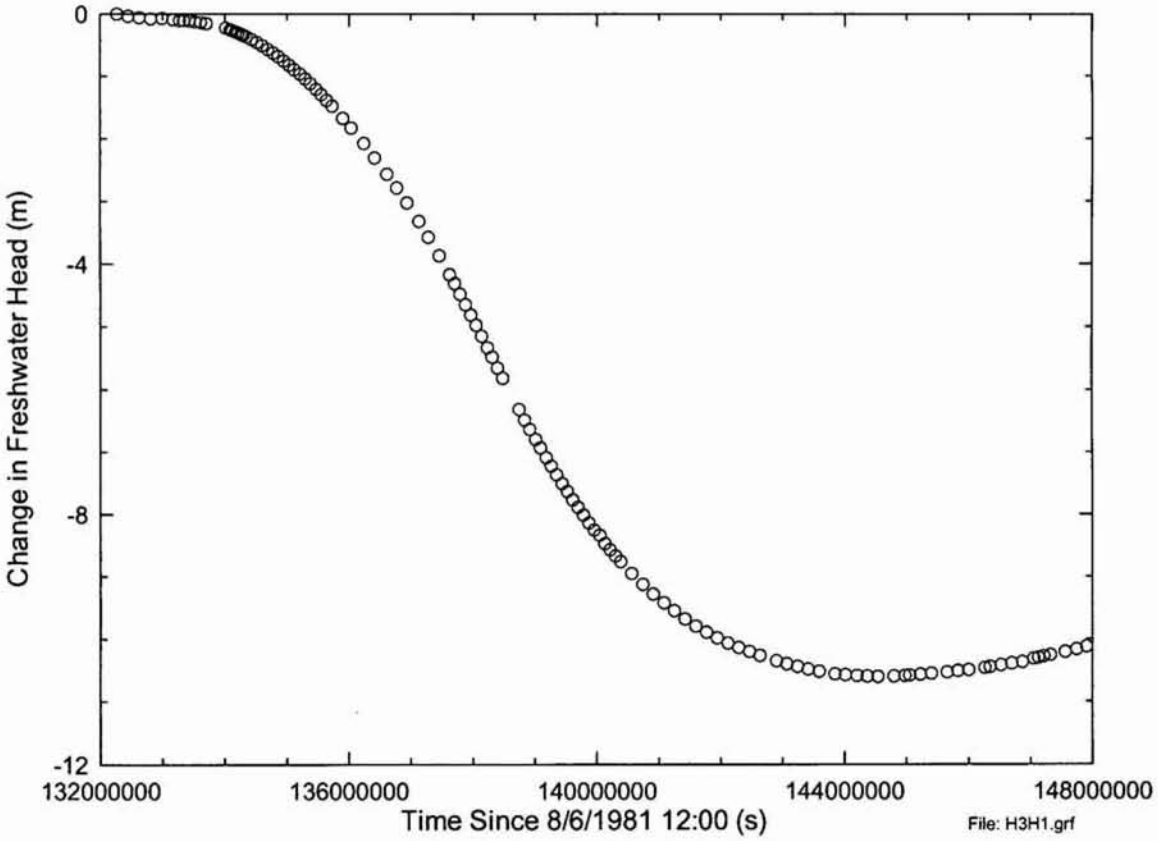

Figure 5. H-1 response to H-3 multipad pumping test.

4.2.3 H-2b2 Response

The data from H-2b2 were taken from Table B-3 of Beauheim (1987a). A modified pressure was calculated for the first 14 entries in the table using the equation given in Beauheim (1987a). The Elapsed Time, Pressure, and Modified Pressure columns were inserted in Excel file ***H3H2b2.xls*** as columns A, C, and D, respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (132267600 s; see Table 1). An initial pressure was calculated (Column G) by averaging the first 14 modified pressures made over the first 407.9 hr of the test when Beauheim (1987a) thought H-2b2 was not yet responding to the pumping at H-3b2. Column E was then created of "Head Change (m of freshwater)" by multiplying the change in pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 6.

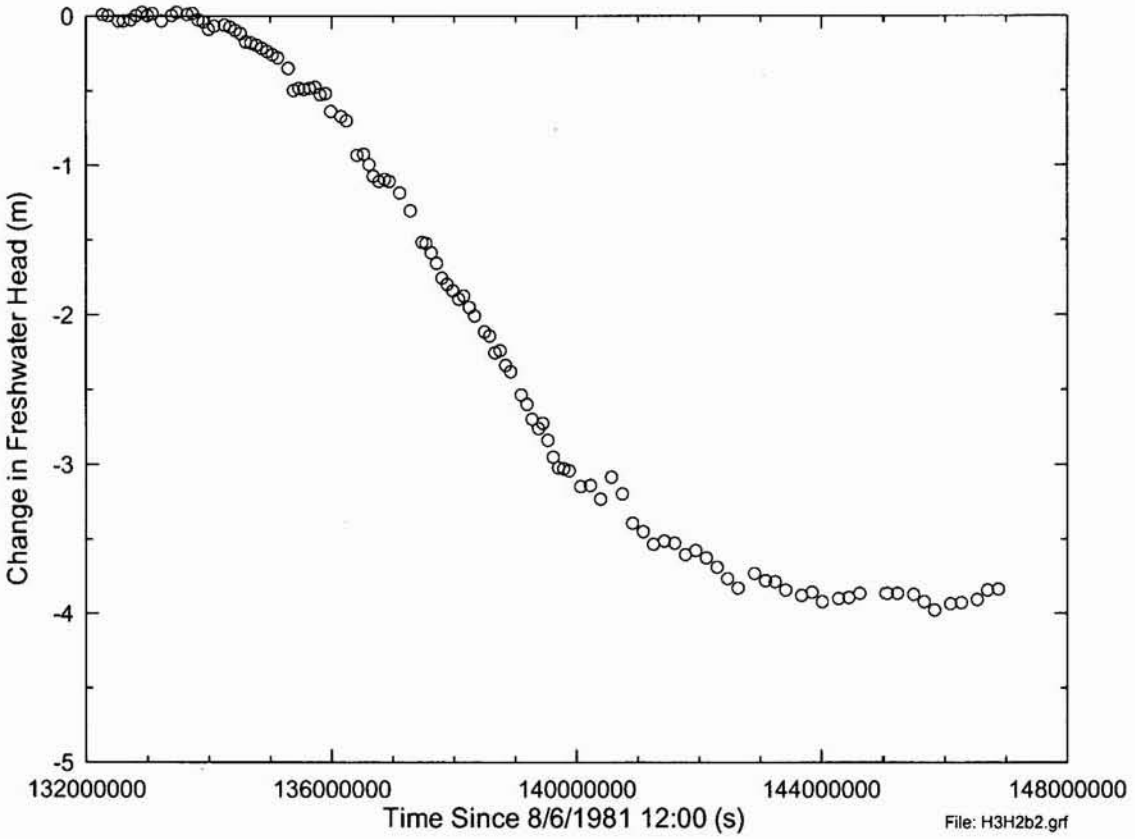

Figure 6. H-2b2 response to H-3 multipad pumping test.

4.2.4 H-11b1 Response

The data from H-11b1 were taken from Table B-4 of Beauheim (1987a). A modified pressure was calculated for the first three entries in the table using the equation given in Beauheim (1987a). The Elapsed Time, Pressure, and Modified Pressure columns were inserted in Excel file ***H3H11b1.xls*** as columns A, C, and D, respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (132267600 s; see Table 1). An initial pressure was calculated (Column G) by averaging the first 4 modified pressures made over the first 73.05 hr of the test when Beauheim (1987a) thought H-11b1 was not yet responding to the pumping at H-3b2. Column E was then created of "Head Change (m of freshwater)" by multiplying the change in pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 7.

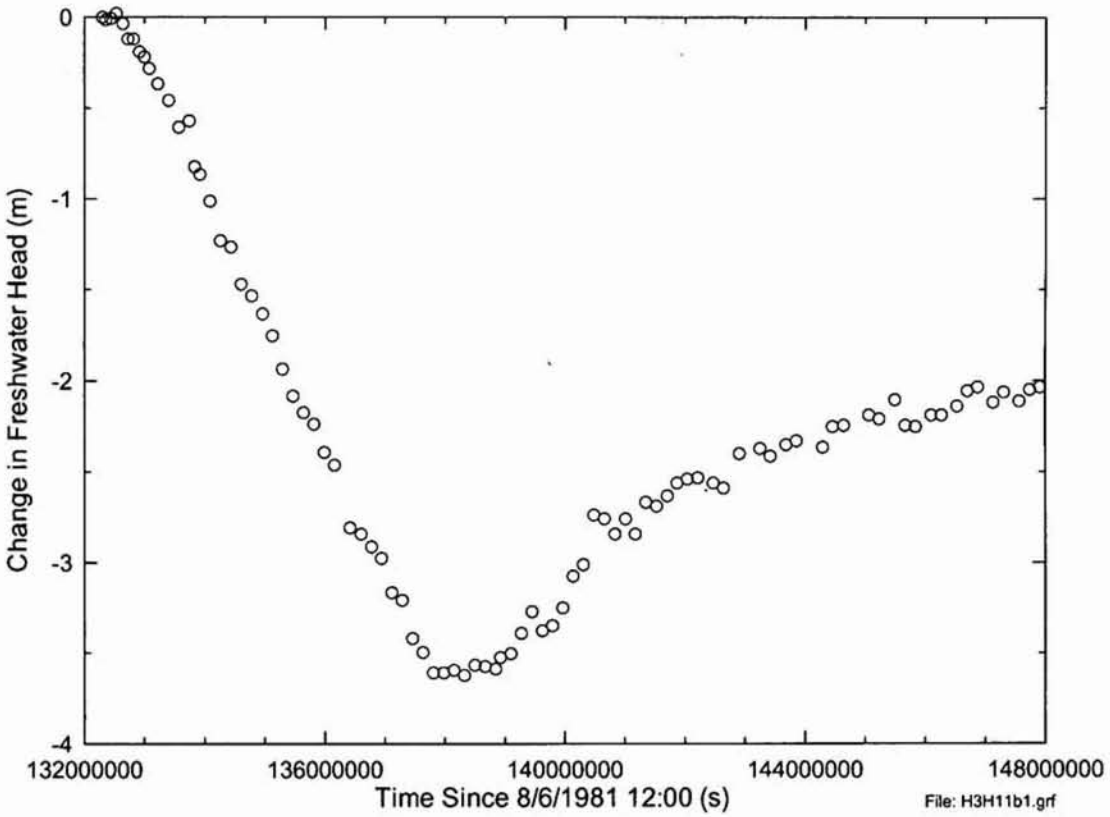

Figure 7. H-11b1 response to H-3 multipad pumping test.

4.3 WIPP-13 Multipad Pumping Test

The WIPP-13 multipad pumping test was conducted by pumping WIPP-13 at a rate of 30 gpm (1.89 L/s) from January 12 to February 17, 1987 (Beauheim, 1987b). Responses to the pumping were measured in wells DOE-2, H-2b2, H-6b, P-14, WIPP-12, WIPP-18, WIPP-19, WIPP-25, and WIPP-30 until May 15, 1987 (April 2, 1987 for WIPP-25 only), and are given in Tables A-16, A-10, A-14, A-17, A-2, A-3, A-4, A-7, and A-8, respectively, of Beauheim (1987b). For some of these wells, a compensated pressure is given that compensates for the effects of changes in barometric pressure and a modified pressure is given that then compensates for pre-test trends in the water levels (or pressures).

4.3.1 DOE-2 Response

The data from DOE-2 were taken from Table A-16 of Beauheim (1987b). The Elapsed Time and Depth to Water columns were inserted in Excel file ***W13DOE2.xls*** as columns A and C, respectively, beginning at the start time of the test. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (171493200 s; see Table 1). Column D was then created of "Drawdown (m freshwater)" by multiplying the change in depth to water (ft) from the initial reading by (1.04*0.3048 m/ft), where 1.04 is the specific gravity for DOE-2 fluid used by Beauheim (1987b, p. 27). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 8.

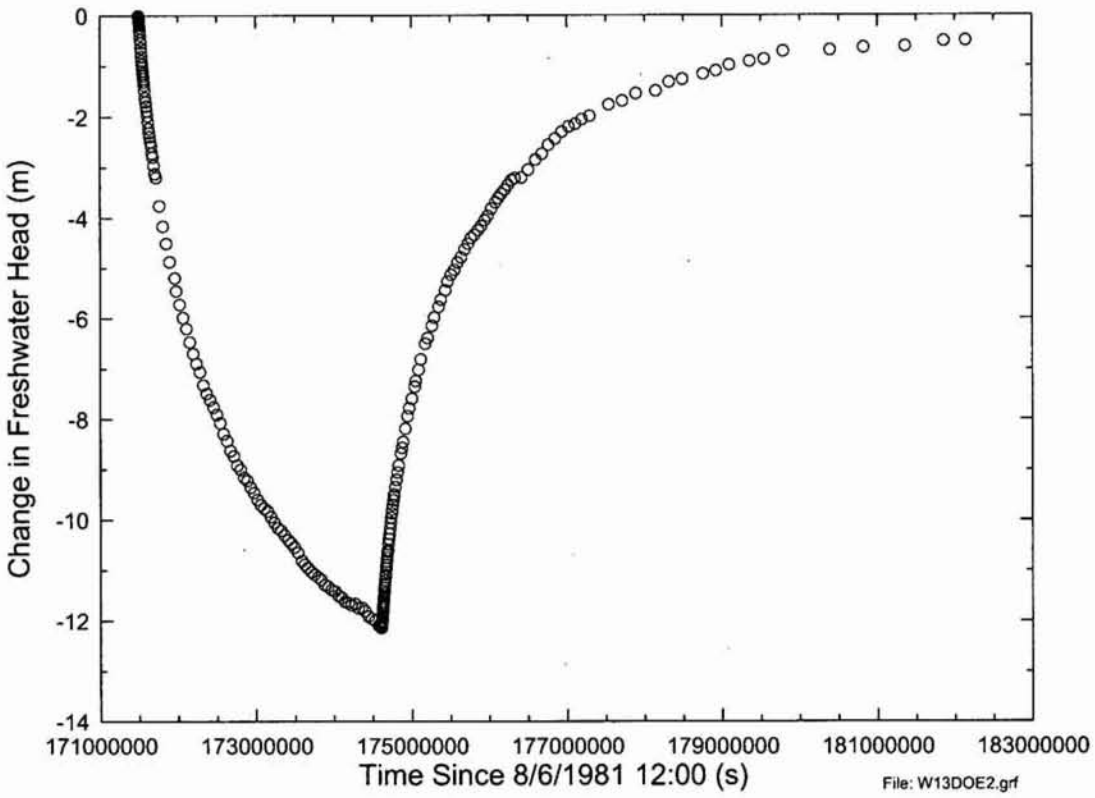

Figure 8. DOE-2 response to WIPP-13 multipad pumping test.

4.3.2 H-2b2 Response

The data from H-2b2 were taken from Table A-10 of Beauheim (1987b). The Elapsed Time, Depth to Water, Pressure, Compensated (renamed Converted) Pressure, and Modified Pressure columns were inserted in Excel file ***W13H2b2.xls*** as columns A, C, D, E, and F, respectively, beginning at the start time of the test. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (171493200 s; see Table 1). Column G was then created of "Drawdown (m freshwater)" by multiplying the change in modified pressure (psi (lb/in^2)) from the initial pressure by (($(144\ in^2/ft^2)/(62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 9.

4.3.3 H-6b Response

The data from H-6b were taken from Table A-14 of Beauheim (1987b). The Elapsed Time and Depth to Water columns were inserted in Excel file ***W13H6b.xls*** as columns A and C, respectively, beginning at the start time of the test. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (171493200 s; see Table 1). Column D was then created of "Drawdown (m freshwater)" by multiplying the change in depth to water (ft) from the initial reading by (1.042*0.3048 m/ft), where 1.042 is the specific gravity for H-6b fluid used by Beauheim (1987b, p. 27). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 10.

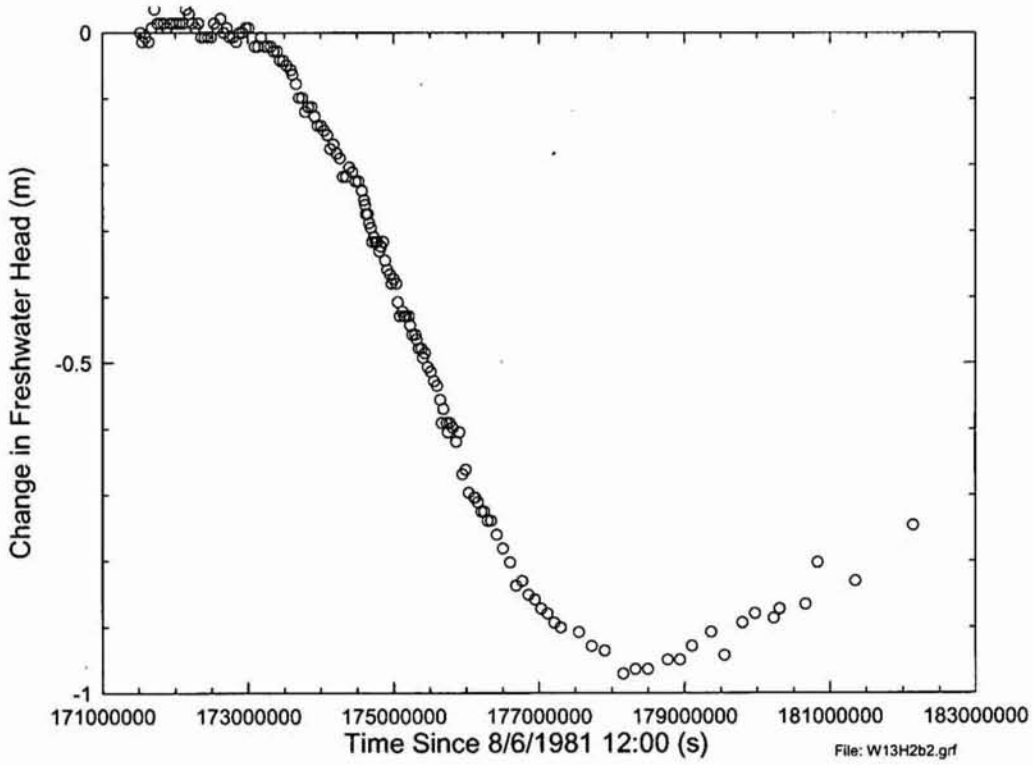

Figure 9. H-2b2 response to WIPP-13 multipad pumping test.

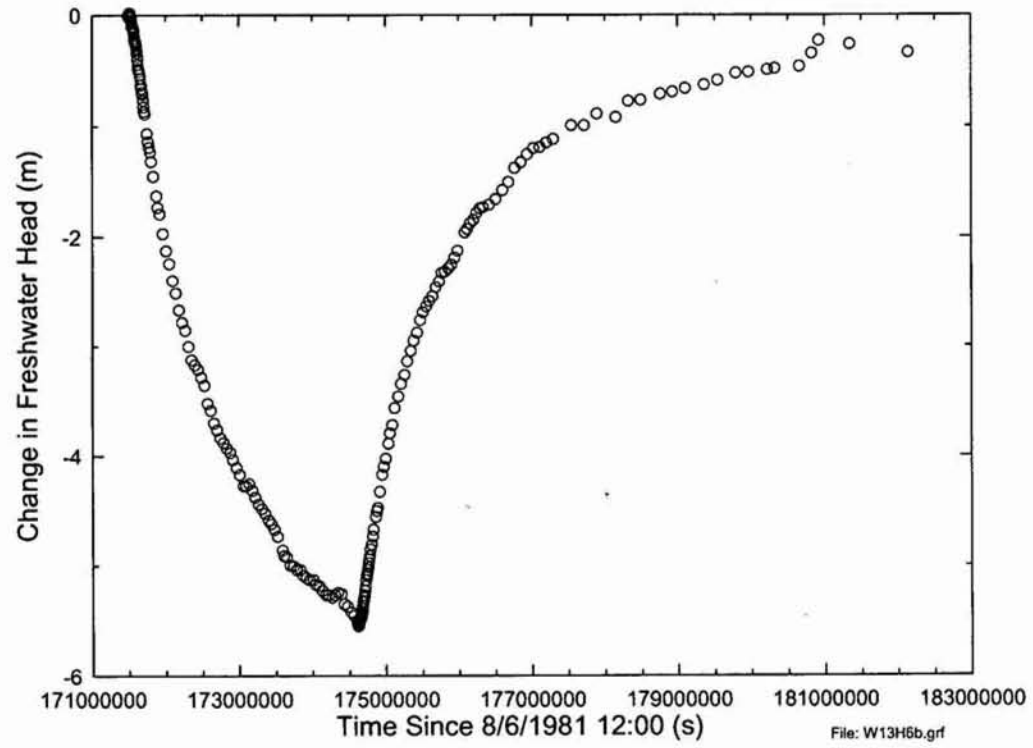

Figure 10. H-6b response to WIPP-13 multipad pumping test.

4.3.4 P-14 Response

The data from P-14 were taken from Table A-17 of Beauheim (1987b). The Elapsed Time, Depth to Water, Pressure, and Compensated (renamed Converted) Pressure columns were inserted in Excel file ***W13P14.xls*** as columns A, C, D, and E, respectively, beginning at the start time of the test. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (171493200 s; see Table 1). Column F was then created of "Drawdown (m freshwater)" by multiplying the change in converted pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 11.

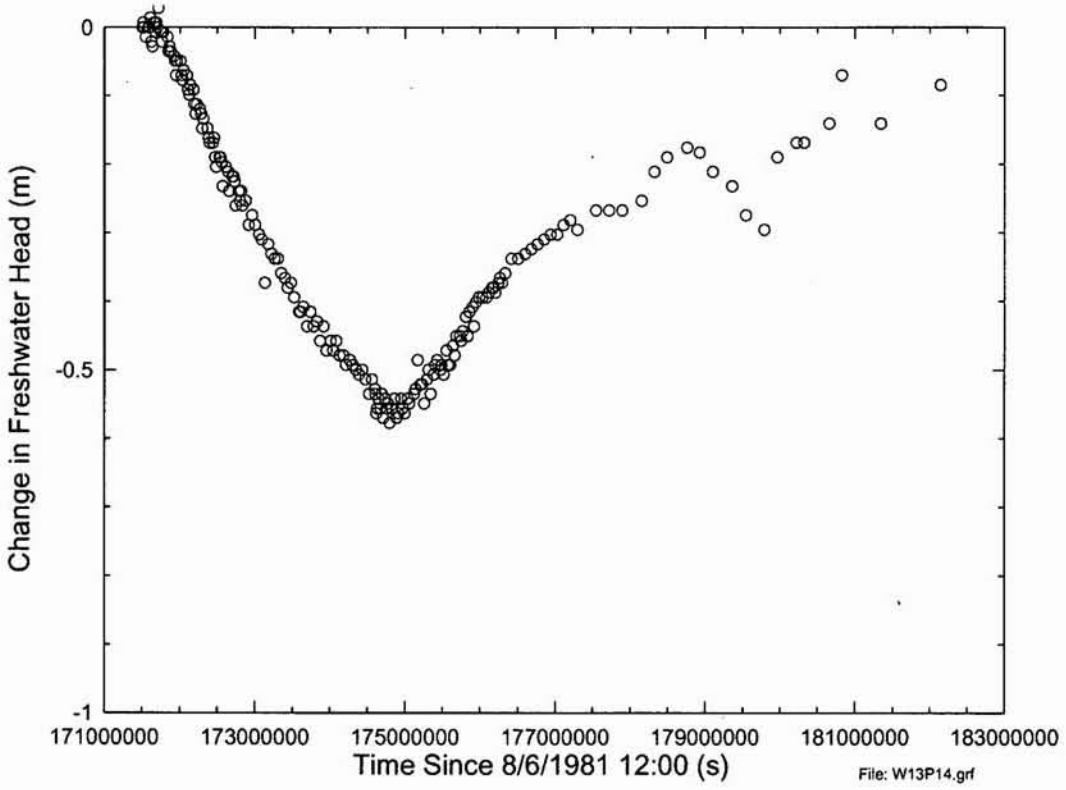

Figure 11. P-14 response to WIPP-13 multipad pumping test.

4.3.5 WIPP-12 Response

The data from WIPP-12 were taken from Table A-2 of Beauheim (1987b). The Elapsed Time, Depth to Water, Pressure, and Modified Pressure columns were inserted in Excel file ***W13W12.xls*** as columns A, C, D, and E, respectively, beginning at the start time of the test. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (171493200 s; see Table 1). Column F was then created of "Drawdown (m freshwater)" by multiplying the change in modified pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 12.

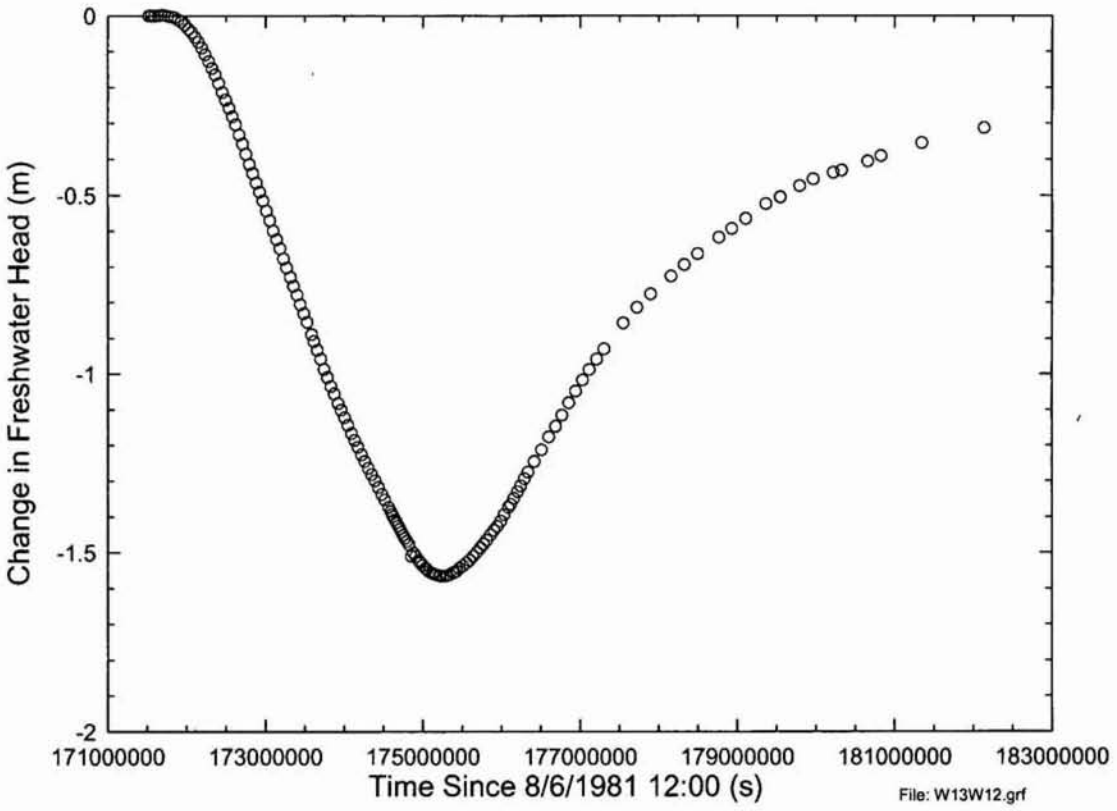

Figure 12. WIPP-12 response to WIPP-13 multipad pumping test.

4.3.6 WIPP-18 Response

The data from WIPP-18 were taken from Table A-3 of Beauheim (1987b). The Elapsed Time, Depth to Water, Pressure, and Modified Pressure columns were inserted in Excel file ***W13W18.xls*** as columns A, C, D, and E, respectively, beginning at the start time of the test. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (171493200 s; see Table 1). Column F was then created of "Drawdown (m freshwater)" by multiplying the change in modified pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 13.

4.3.7 WIPP-19 Response

The data from WIPP-19 were taken from Table A-4 of Beauheim (1987b). The Elapsed Time, Depth to Water, Pressure, and Modified Pressure columns were inserted in Excel file ***W13W19.xls*** as columns A, C, D, and E, respectively, beginning at the start time of the test. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (171493200 s; see Table 1). Column F was then created of "Drawdown (m freshwater)" by multiplying the change in modified pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 14.

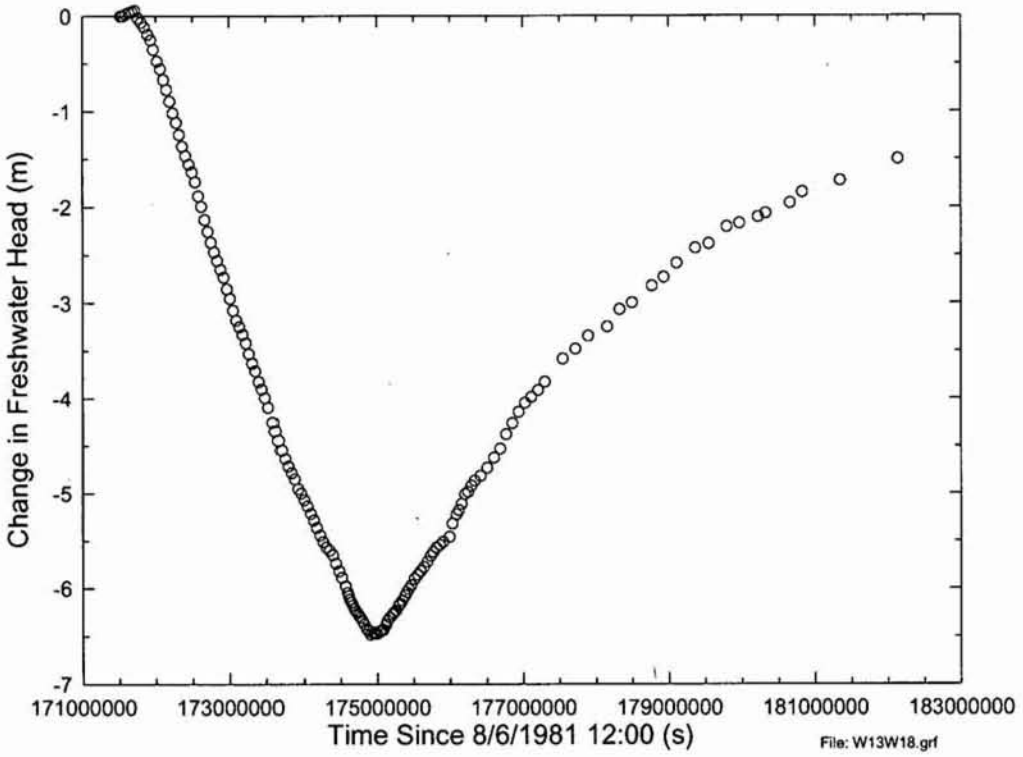

Figure 13. WIPP-18 response to WIPP-13 multipad pumping test.

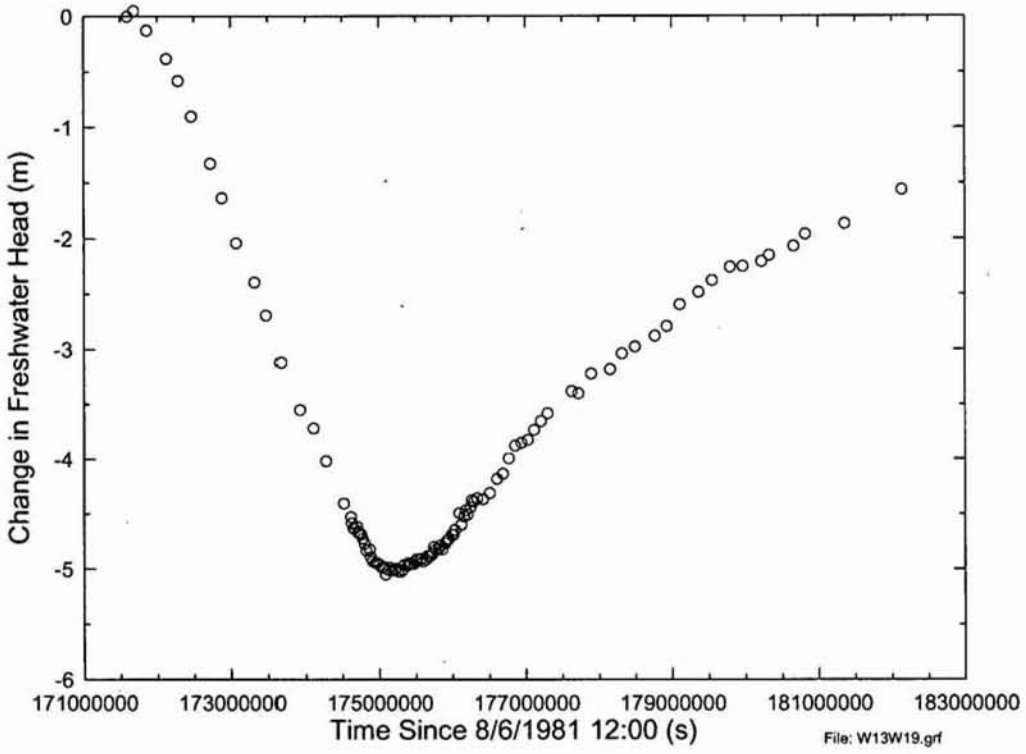

Figure 14. WIPP-19 response to WIPP-13 multipad pumping test.

4.3.8 WIPP-25 Response

The data from WIPP-25 were taken from Table A-7 of Beauheim (1987b). The Elapsed Time, Depth to Water, Pressure, and Compensated (renamed Converted) Pressure columns were inserted in Excel file ***W13W25.xls*** as columns A, C, D, and E, respectively, beginning at the start time of the test. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (171493200 s; see Table 1). Column F was then created of "Drawdown (m freshwater)" by multiplying the change in converted pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 15.

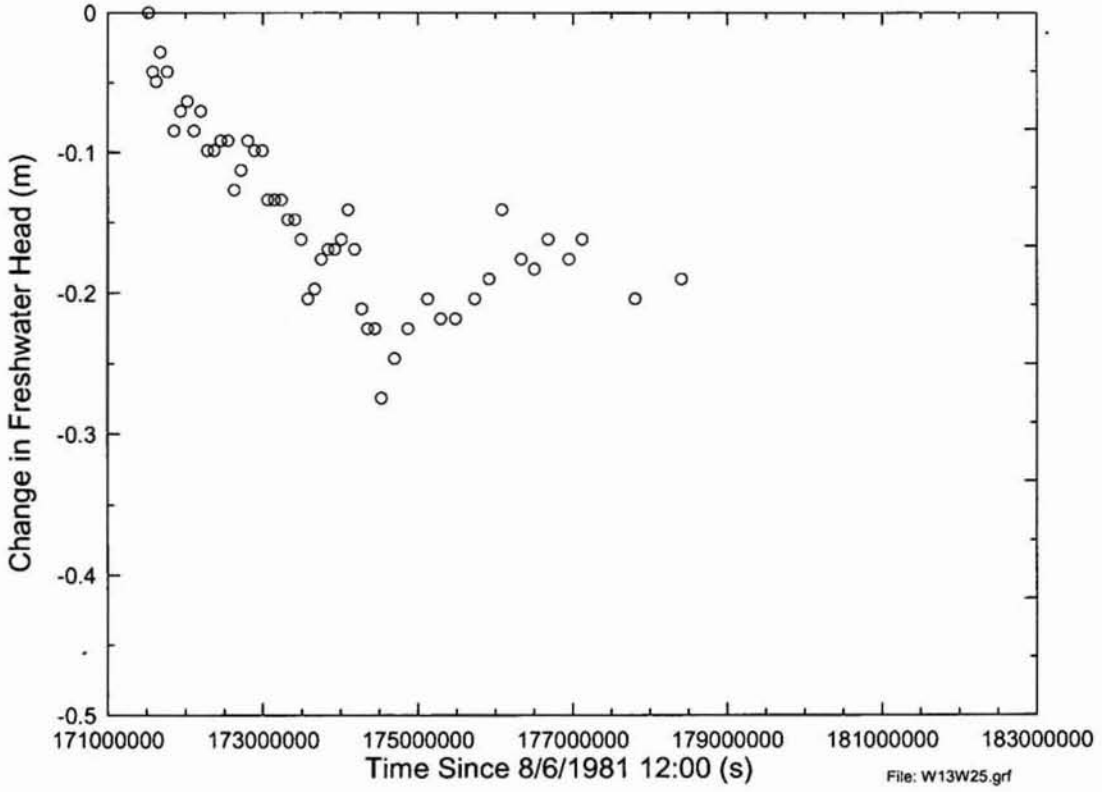

Figure 15. WIPP-25 response to WIPP-13 multipad pumping test.

4.3.9 WIPP-30 Response

The data from WIPP-30 were taken from Table A-8 of Beauheim (1987b). The Elapsed Time, Depth to Water, Pressure, and Modified Pressure columns were inserted in Excel file ***W13W30.xls*** as columns A, C, D, and E, respectively, beginning at the start time of the test. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (171493200 s; see Table 1). Column F was then created of "Drawdown (m freshwater)" by multiplying the change in modified pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 16.

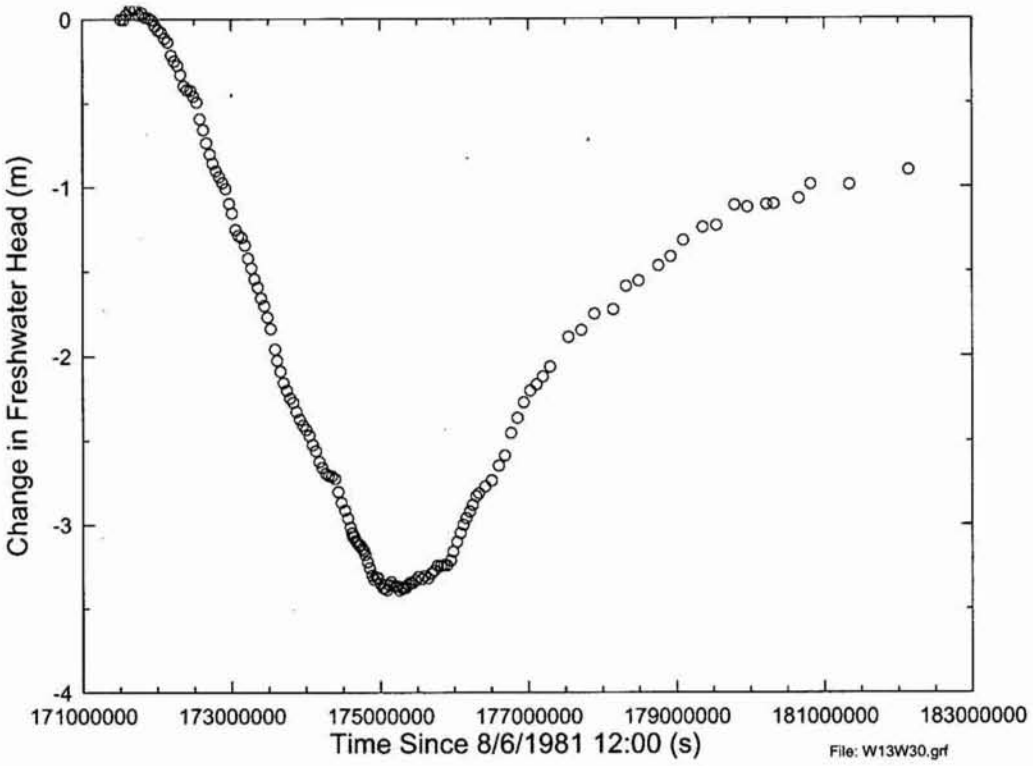

Figure 16. WIPP-30 response to WIPP-13 multipad pumping test.

4.4 P-14 Pumping Test

The P-14 pumping test was conducted by pumping P-14 at variable rates from February 14 to 17, 1989 (Beauheim and Ruskauff, 1998). The pumping-rate history was divided into eight constant-rate periods, shown in Table 1, in the Culebra Hydraulic Tests Analysis Package (ERMS 238487). Responses to the pumping were measured in wells D-268, H-6b, H-18, WIPP-25, and WIPP-26 until March 7 or 10, 1989, and are given in Tables F1.43, F1.19, F1.41, F1.57, and F1.58, respectively, of Stensrud et al. (1990). Beauheim and Ruskauff (1998) used compensated pressures calculated in ERMS 238487 that compensate for the effects of changes in barometric pressure for their test interpretations. Those compensated pressures will be used in transient Culebra model calibration as well.

4.4.1 D-268 Response

The data for D-268 were taken from file ***D268CP.xls*** in ERMS 238487. The "Time since 45.375694 (hr)", "Depth to water (ft)", "Pressure (psig)", and "Pressure B.E.=0.6" columns beginning with the first positive time entry were inserted in Excel file ***P14D268.xls*** as columns A (Time Since Pump On in P-14 (hr)), C (Depth to Water (ft)), D (Pressure at Middle of Culebra (psig)), and E (Pressure Compensated with B.E.=0.6 (psig)), respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (237502860 s; see Table 1). Column F was then created of "Drawdown (m freshwater)" by multiplying the change in compensated pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 17.

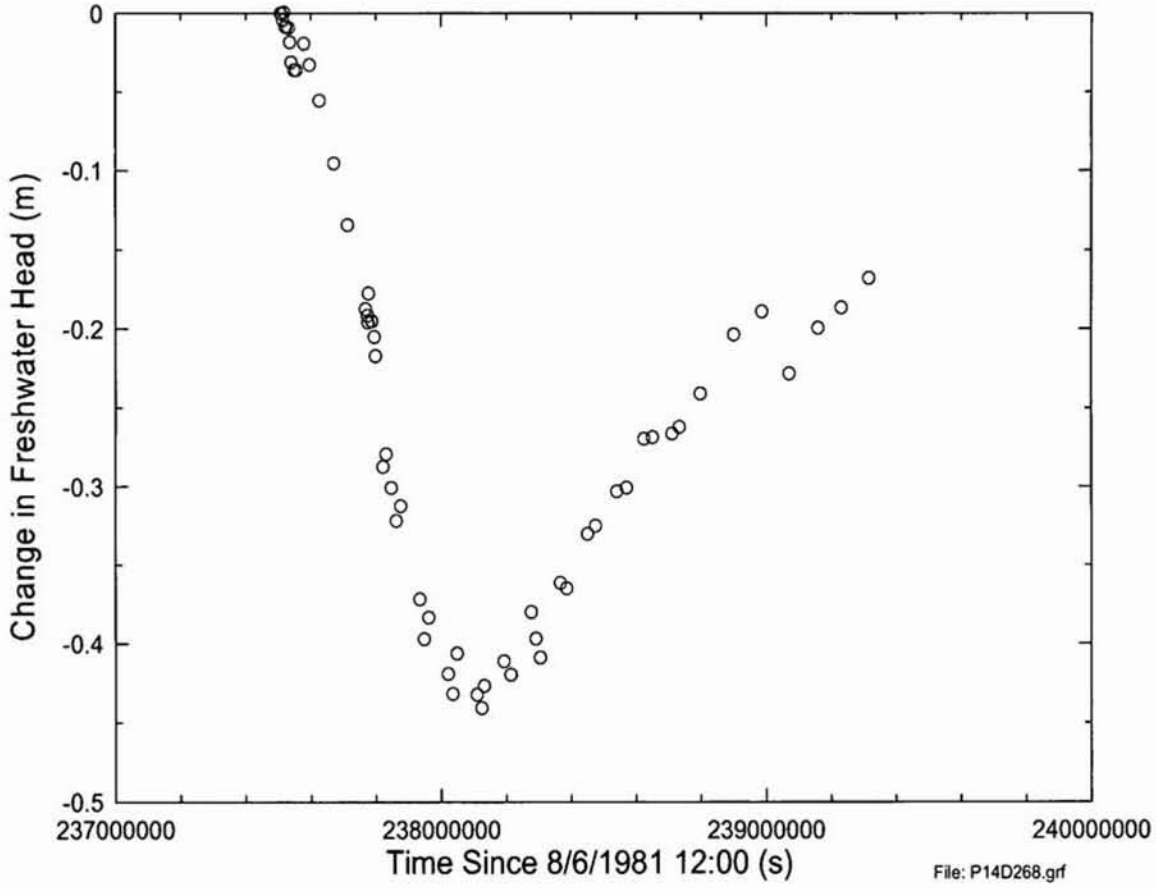

Figure 17. D-268 response to P-14 pumping test.

4.4.2 H-6b Response

The data for H-6b were taken from file ***H6BCP.xls*** in ERMS 238487. The "Time since 45.375694 (hr)", "Depth to water (ft)", "Pressure (psig)", and "Pressure B.E.=0.6" columns beginning with the first positive time entry were inserted in Excel file ***P14H6b.xls*** as columns A (Time Since Pump On in P-14 (hr)), C (Depth to Water (ft)), D (Pressure at Middle of Culebra (psig)), and E (Pressure Compensated with B.E.=0.6 (psig)), respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (237502860 s; see Table 1). Column F was then created of "Drawdown (m freshwater)" by multiplying the change in compensated pressure (psi (lb/in^2)) from the initial pressure by ((144 in^2/ft^2)/(62.4 lb/ft^3 of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 18.

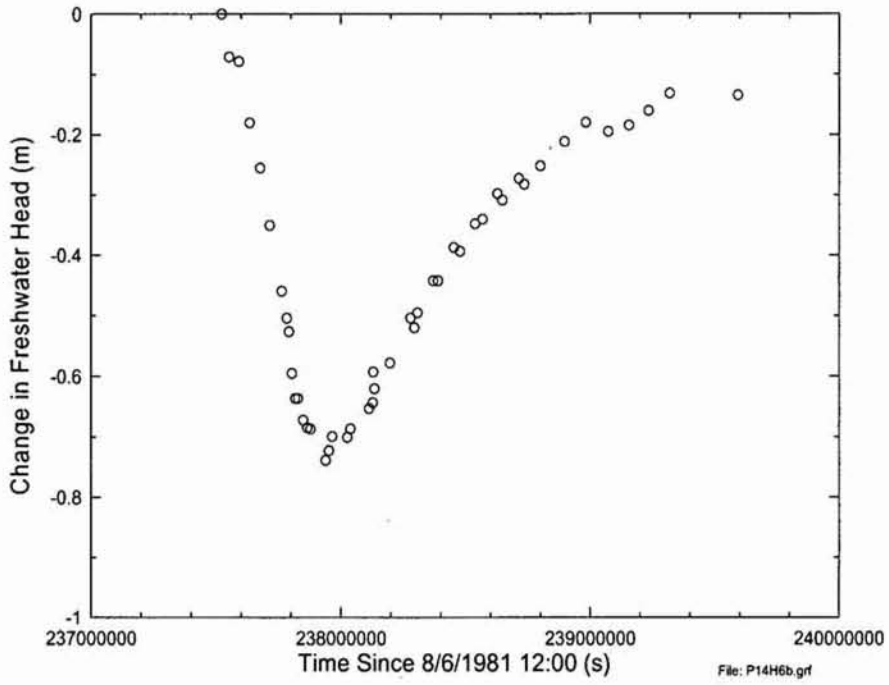

Figure 18. H-6b response to P-14 pumping test.

4.4.3 H-18 Response

The data for H-18 were taken from file ***H18CP.xls*** in ERMS 238487. The "Time since 45.375694 (hr)", "Depth to water (ft)", "Pressure (psig)", and "Pressure B.E.=0.6" columns beginning with the first positive time entry were inserted in Excel file ***P14H18.xls*** as columns A (Time Since Pump On in P-14 (hr)), C (Depth to Water (ft)), D (Pressure at Middle of Culebra (psig)), and E (Pressure Compensated with B.E.=0.6 (psig)), respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (237502860 s; see Table 1). Column F was then created of "Drawdown (m freshwater)" by multiplying the change in compensated pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 19.

4.4.4 WIPP-25 Response

The data for WIPP-25 were taken from file ***W25CP.xls*** in ERMS 238487. The "Time since 45.375694 (hr)", "Depth to water (ft)", "Pressure (psig)", and "Pressure B.E.=0.6" columns beginning with the first positive time entry were inserted in Excel file ***P14W25.xls*** as columns A (Time Since Pump On in P-14 (hr)), C (Depth to Water (ft)), D (Pressure at Middle of Culebra (psig)), and E (Pressure Compensated with B.E.=0.6 (psig)), respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (237502860 s; see Table 1). Column F was then created of "Drawdown (m freshwater)" by multiplying the change in compensated pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 20.

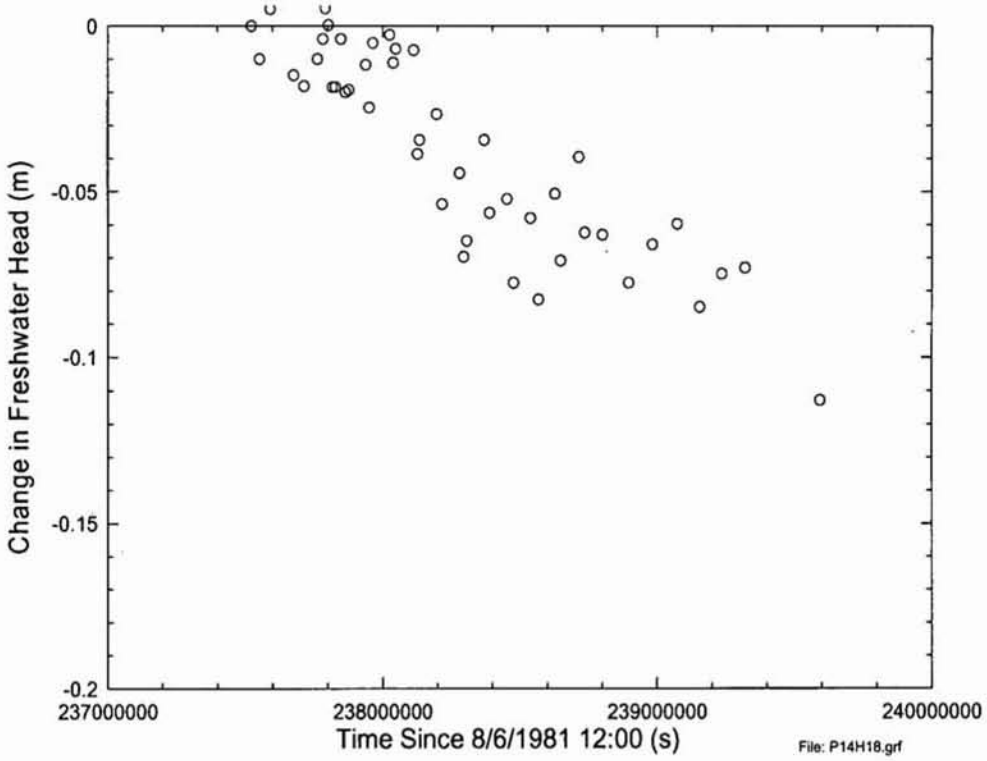

Figure 19. H-18 response to P-14 pumping test.

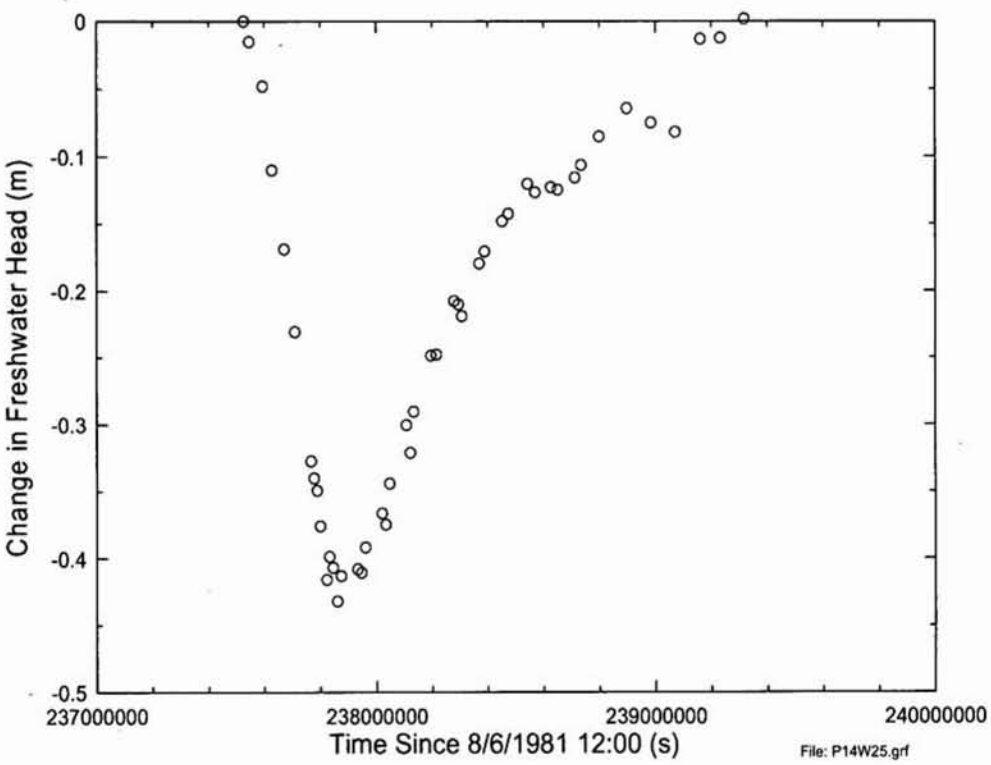

Figure 20. WIPP-25 response to P-14 pumping test.

4.4.5 WIPP-26 Response

The data for WIPP-26 were taken from file ***W26CP.xls*** in ERMS 238487. The "Time since 45.375694 (hr)", "Depth to water (ft)", "Pressure (psig)", and "Pressure B.E.=0.6" columns beginning with the first positive time entry were inserted in Excel file ***P14W26.xls*** as columns A (Time Since Pump On in P-14 (hr)), C (Depth to Water (ft)), D (Pressure at Middle of Culebra (psig)), and E (Pressure Compensated with B.E.=0.6 (psig)), respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (237502860 s; see Table 1). Column F was then created of "Drawdown (m freshwater)" by multiplying the change in compensated pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 21.

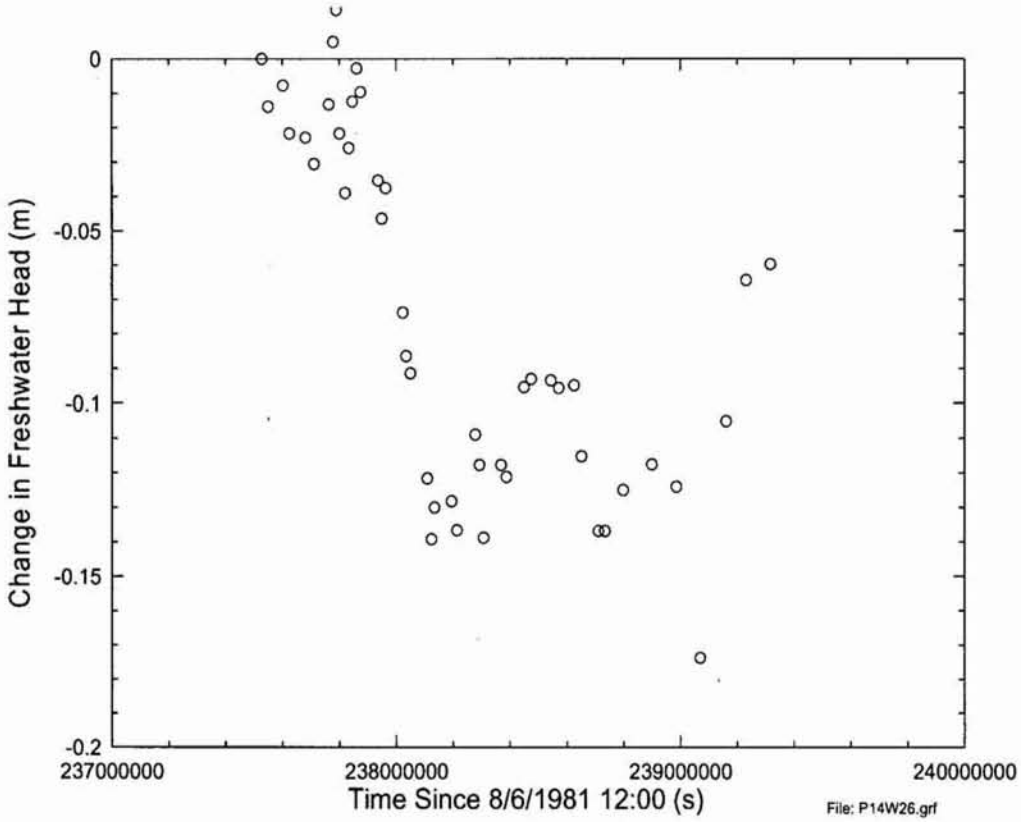

Figure 21. WIPP-26 response to P-14 pumping test.

4.5 1995-96 H-19 and H-11 Tracer Tests

Two sets of tracer tests were conducted at the H-19 hydropad in 1995 and 1996. The first set of tracer tests involved pumping H-19b0 at an average rate of 0.236 L/s from June 16 to July 28, 1995 (Table 1). For the second set of tests, H-19b0 was pumped at an average rate of 0.271 L/s from December 15, 1995 to January 17, 1996, then at an average rate of 0.252 L/s until February 19, 1996, and finally at an average rate of 0.155 L/s until April 11, 1996 (Table 1). The H-11 tracer test was conducted by pumping H-11b1 at an average rate of 0.223 L/s between February 7 and March 11, 1996, and then at an average rate of 0.376 L/s until March 28, 1996 (Table 1).

Water-level responses to the H-19 and/or H-11 tracer tests were observed in 14 other wells: DOE-1, ERDA-9, H-1, H-2b2, H-3b2, H-4b, H-12, H-14, H-15, H-17, P-17, WIPP-21, WQSP-4, and WQSP-5. Beginning in the spring of 1995, water-level measurements were supplemented with Trolls installed in DOE-1, ERDA-9, H-1, H-3b2, H-15, and WQSP-5 to monitor responses, first, to drilling and development of the wells on the H-19 hydropad, and then to the hydraulic and tracer testing activities both at H-19 and H-11. Because of the other pumping events that occurred at H-19, H-11, and WQSP-4 in 1995 (Table 2), observation-well responses to just the H-19 and H-11 tracer tests cannot be clearly defined. Consequently, we have prepared files of freshwater heads for all of 1995 and 1996 for the 14 wells listed above. This data format provides the maximum flexibility for transient Culebra T-field calibration, as changes in head over any time period can easily be calculated.

The Troll data compiled and reduced in this records package were collected over periods between April 18, 1995 and October 30, 1996. The .BIN data files collected for each well are listed in Table 4. The corresponding .TXT files for each well were read into Excel, where they were compiled into a single continuous file. The Elapsed Time column from the .TXT files was replaced with a column of Days Elapsed Since 00:00 1/1/1995. The compiled files were given names using the convention ***"Well name"-troll.xls*** as shown in Table 4.

The compiled data files contained between 11,000 and 79,000 lines of data, which is both cumbersome and excessive for purposes of model calibration. In addition, they contained data from periods when data acquisition had been started but the Troll was not yet in the well, data from periods when the Troll was being installed or removed from the well, and data from periods immediately after Troll installation when the water level in the well was responding to the displacement caused by immersion of the Troll. The data from these three types of periods are what we refer to as "erroneous" data. Downloading data from the Trolls required removing the Troll from the well, after which it had to be repositioned. Invariably, this procedure resulted in a slight shift in the depth at which the Troll was placed, causing an offset in the head measurements. Greater offsets occurred when Trolls had to be repositioned during periods of significant drawdown or recovery to keep the head within the measurement range of the instrument.

Data reduction, therefore, involved three phases: removal (filtering) of "erroneous" data, correction of offsets, and thinning the remaining data to a more useful size. Identifying erroneous readings and offsets, removing the erroneous data and correcting the offsets, and reducing the volume of data was accomplished by, first, developing mathematical and logical functions within Excel that would identify variances in readings larger than the normally observed changes in head. We observed that, in most cases, heads did not change more than 0.03 m from reading to reading, while the majority of consecutive readings varied by less than 0.005 m. We created a function that identified variances of greater than 0.01 m to ensure each erroneous variation was captured while scanning a sizeable amount of data. After identification, the erroneous readings could be filtered out and mathematical functions utilized to correct subsequent readings (revised data) that accounted for both offsets and trends over whatever period the data had been determined to be erroneous (or simply missing). Finally, the revised data were reduced by creating functions that identified the first reading of each hour and copied those readings to a separate worksheet for ease of use.

Table 4. Troll Files Associated with H-19 Tracer Tests

Well With Troll	Original Data Files (.BIN Files)	ERMS Number of Original Data File	Compiled Data Files	Generated Files
DOE-1	H190CT35	422203	DOE-1-troll.xls	DOE-1-troll_revised.xls
	H192CT12	422203		DOE-1-troll_Revised_Graph.xls
	H196CT04	422203		
	H196CT11	422203		
	H195CT04	422203		
	H190CT41	422280		
	H190CT54	422158		
ERDA-9	H190CT34	422203	ERDA-9-troll.xls	ERDA-9-troll_revised.xls
	H192CT11	422203		ERDA-9-troll_Revised_Graph.xls
	H196CT03	422203		
	H196CT10	422203		
	H195CT03	422203		
	H190CT45	422280		
	QSP5CT07	422390		
	H190CT51	422158		
	H190CT62	422158		
H-1	H190CT37	422203	H-1-troll.xls	H-1-troll_revised.xls
	H192CT14	422203		H-1-troll_Revised_Graph.xls
	H196CT06	422203		
	H196CT13	422203		
	H195CT06	422203		
	H190CT44	422280		
	QSP5CT03	422390		
	H190CT52	422158		
	H190CT61	422158		

Table 4. Troll Files Associated with H-19 Tracer Tests (continued).

Well With Troll	Original Data Files (.BIN Files)	ERMS Number of Original Data File	Compiled Data Files	Generated Files
H-15	H190CT33	422203	H-15-troll.xls	H-15-troll_revised.xls
	H192CT10	422203		H-15-troll_Revised_Graph.xls
	H196CT02	422203		
	H196CT09	422203		
	H195CT02	422203		
	H190CT43	422280		
	QSP5CT02	422390		
H-3b2	H190CT04	422203	H-3b2-troll.xls	H-3b2-troll_revised.xls
	H190CT05	422203		H-3b2-troll_Revised_Graph.xls
	H190CT06	422203		
	H193CT05	422203		
	H193CT07	422203		
	H192CT03	422203		
	H192CT07	422203		
	H190CT13	422203		
	H193CT14	422203		
	H190CT16	422203		
	H194CT03	422203		
	H190CT20	422203		
	H190CT25	422203		
	H190CT32	422203		
	H192CT15	422203		
	H196CT07	422203		
	H196CT14	422203		
	H195CT07	422203		
	H190CT42	422280		
	QSP5CT06	422390		
	H190CT55	422158		

Table 4. Troll Files Associated with H-19 Tracer Tests (continued).

Well With Troll	Original Data Files (.BIN Files)	ERMS Number of Original Data File	Compiled Data Files	Generated Files
WQSP-5	H190CT07	422203	WQSP-5-troll.xls	WQSP-5-troll_revised.xls
	H190CT08	422203		WQSP-5-troll_Revised_Graph.xls
	H190CT09	422203		
	H193CT06	422203		
	H192CT04	422203		
	H192CT08	422203		
	H190CT12	422203		
	H193CT13	422203		
	H190CT17	422203		
	H194CT04	422203		
	H190CT21	422203		
	H190CT26	422203		

The files showing all of the data-reduction steps were given names using the convention ***"Well name"-troll_revised.xls***. Then the files containing only the hourly readings were given names using the convention ***"Well name"-troll_Revised_Graph.xls*** as shown in Table 4.

The next step in the data compilation process was to combine the Troll measurements with water-level measurements from the same well. The water-level measurements were first converted to freshwater heads (m amsl). Then for each continuous segment of Troll data, a water-level measurement made at approximately the same time as a Troll measurement was identified. The water-level measurement (or freshwater head) served to "anchor" the Troll measurements (which are relative to the position of the Troll) to a specific elevation, hence we term these points "anchor points". By setting the Troll head at the anchor point equal to the freshwater head calculated from the measured water level, the remainder of the Troll measurements in that segment of data could also be converted to elevations. Finally, the water-level measurements from the periods of time when the Trolls were not operational were added to the Troll data files to create a more continuous record of freshwater heads.

The conversion, or "reconciliation", of Troll head measurements to elevations is shown in the ***"Well name"-troll_Revised_Graph.xls*** files. The water-level measurements and their conversion to freshwater heads are shown in ***"Well name"-waterlevels.xls*** files, and the combined Troll and water-level freshwater head data are shown in ***"Well name"-combined.xls*** files. However, the absolute values of freshwater head are unimportant; the transient model calibration will use only *changes* in freshwater head from the start of pumping events.

4.5.1 DOE-1 Response

The head readings from the Troll in DOE-1 were compiled in the Excel workbook ***DOE-1-troll.xls***. The data, 24,491 readings over approximately a 12-month period, contain erroneous readings and offsets caused by the removal and replacement of the instrument. By creating functions within Excel, the process of identifying the suspect readings, evaluating trends and applying corrective, mathematically derived values to the readings was automated; the analysis of the data could then focus on actual head changes. The volume of revised readings was then reduced to the first reading of each hour, over the period, to further simplify and make the data more manageable. The resultant file, ***DOE-1-troll_revised.xls***, contains all the original data plus the functions and revised values, as described below.

Added Columns:

F: Revised Head
G: Action Taken
H: Head Change
I: Calculations
J: Notes
K: ABS Variance > 0.01?
L: Revised Head per Hour

We added a worksheet for revised head data containing the times from the data table (Columns A and B) and the revised head data per hour (Column L). All times with no associated head reading (as derived from data worksheet) were then deleted.

Column F is the head reading +/- whatever derived value (if any). The derived value used to revise the head reading is whatever value is calculated by the *Total (Revision)* calculation found in Column I.

- Example: Cell F585 is =D585-0.052

  Where D585 is the original head reading and 0.052 is the calculated change in head reading needing to be subtracted in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well. The value is calculated in the *Total (Revision)* step described below.

Column G is the annotation "Deleted," the length of time deleted from the trend determination, or the calculated total revision value to be added or subtracted, i.e. "Trend Over 1:30".

Column H is the head change from reading to reading, values generated by subtracting the previous reading from the current reading (current reading for the associated line).

Example: Cell H571 is =D571-D570

Where D571 is the original head reading for that time (same row as Column A) and D570 is the previous, actual head reading.

Column I is one of four calculations:

Deleted Hours – Change in time from the first to last associated deleted reading.

Example: Cell I582 is =A584-A582

For this example, readings from rows 582 through 584 were deleted due to large variances (identified in Column K) assumed associated with the moving of the troll. A584 is the time of the last reading deleted and A582 is the time of the first reading deleted for this set.

Trend – The trend over the previous time equal to the amount of time deleted. Calculated by adding the head change values (Column H) over a period of time equal to the time deleted (derived by the deleted hours calculation).

Example: Cell I581 is =SUM(H579:H581)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H579:H581 is the range of head change values covering the

amount of time (identified by the *Deleted Hours* calculation) prior to the first deleted reading.

Difference – The head value change spanning the deleted readings time frame.

Example: Cell I584 is =SUM(H582:H584)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H582:H584 is the range of head change values covering the span of deleted readings.

Total (Revision) – The total calculated change in head value needing to be added (or subtracted) in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well.

Example: Cell I2881 is =0.052+I2880-I2877

Where 0.052 is the previous calculated change in head value, I2880 is the *Difference* (described above) and I2877 is the *Trend* (described above).

Column J is used for notes (identifying missing data periods) or to identify which calculation was used in Column H, i.e. "Hrs Deleted".

Column K is a logical function used to identify a "variance" in head readings greater than 0.01 m (positive or negative). The function looks at the head change value (Column H) and decides if the value identifies a head change of more than 0.01 m.

Example: Cell K583 is

=IF(H583>0.01,"Variance",IF(H583<-0.01,"Variance",""))

Where IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. H583>0.01 is the condition (is the head change value greater than 0.01?), if evaluated true, then the annotation "Variance" is written to the cell. If the evaluation is false, then another IF function evaluates the condition H583<-0.01 (is the head change value less than –0.01?). If this evaluation is true, then the annotation "Variance" is written to the cell. If the evaluation is false, then nothing is written to the cell.

Column L is a logical function that identifies the first reading of the hour and writes its value to the cell. Should the time be other than the first reading of the hour no value is written.

Example: Cell L573 is

=IF((HOUR(A573)>HOUR(A572)),F573,IF((DAY(A573)>DAY(A572)),F573,""))

Where: IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. HOUR is the name of the function that identifies the hour value from a referenced cell. DAY is the name of the function that identifies the day value from a referenced cell. The condition asks if the hour value of cell A573 is greater than the hour value of cell A572. If the evaluation is true (meaning the reading is from a new hour), then the revised head value (F573) is written to the cell. If the evaluation is false, then another IF function evaluates the condition of if the day value from A573 is greater than the day value from A572. If the evaluation is true (meaning the reading is from a new day), then the revised head value (F573) is written to the cell. If the evaluation is false, then nothing is written to the cell.

The head values written in Column L (described above) and the corresponding times from the same row of columns A and B are transferred to file ***DOE-1-troll_Revised_Graph.xls*** to create a data file of a more manageable size. The date and time columns are merged into a new column A, and the hourly head values are put in column C. A column B of "Elapsed time since 8/6/1981 12:00 (s)" was created.

The compiled raw data from ***DOE-1-troll.xls*** are shown graphically in Figure 22. Figure 23 shows the data written from ***DOE-1-troll_revised.xls*** to ***DOE-1-troll_Revised_Graph.xls*** for use in T-field calibration. Note that the data-reduction process resulted in some negative head values. This is irrelevant because T-field calibration will consider only changes in head.

The next step in the data-reduction process was to reconcile the Troll data, which are expressed in meters of freshwater head relative to the position of the Troll, with water-level measurements made in the well. To do this, the water-level measurements were first converted to freshwater heads by converting the measurement from depth to water from top of casing to height of water column above the center of the Culebra. The height of this column was then multiplied by the specific gravity of the fluid in the well, and added to the elevation of the center of the Culebra to obtain the freshwater head. These conversions are shown in the file ***DOE-1-waterlevels.xls***, which also provides references for the elevations and specific-gravity values used. Next, three water-level measurements (anchor points) were identified that were made at approximately the same times as Troll measurements in the three continuous segments of data shown in Figure 23. These measurements were made on 9/7/1995, 3/12/1996, and 4/17/1996. The first anchor point was used to convert the Troll measurements made between 8/1/1995 and 10/16/1995 to freshwater heads, the second anchor point was used to convert the data from 11/29/1995 to 4/1/1996, and the third anchor point was used to convert the data from 4/1/1996 to 8/6/1996. These conversions are shown in column D of file ***DOE-1-troll_Revised_Graph.xls***. These anchor points, and the agreement they provide between the Troll and water-level measurements, are shown in Figure 24. The merged data sets, with the water-level measurements made during the times the Troll was in operation removed, are shown in Figure 25 and stored in file ***DOE-1-combined.xls***.

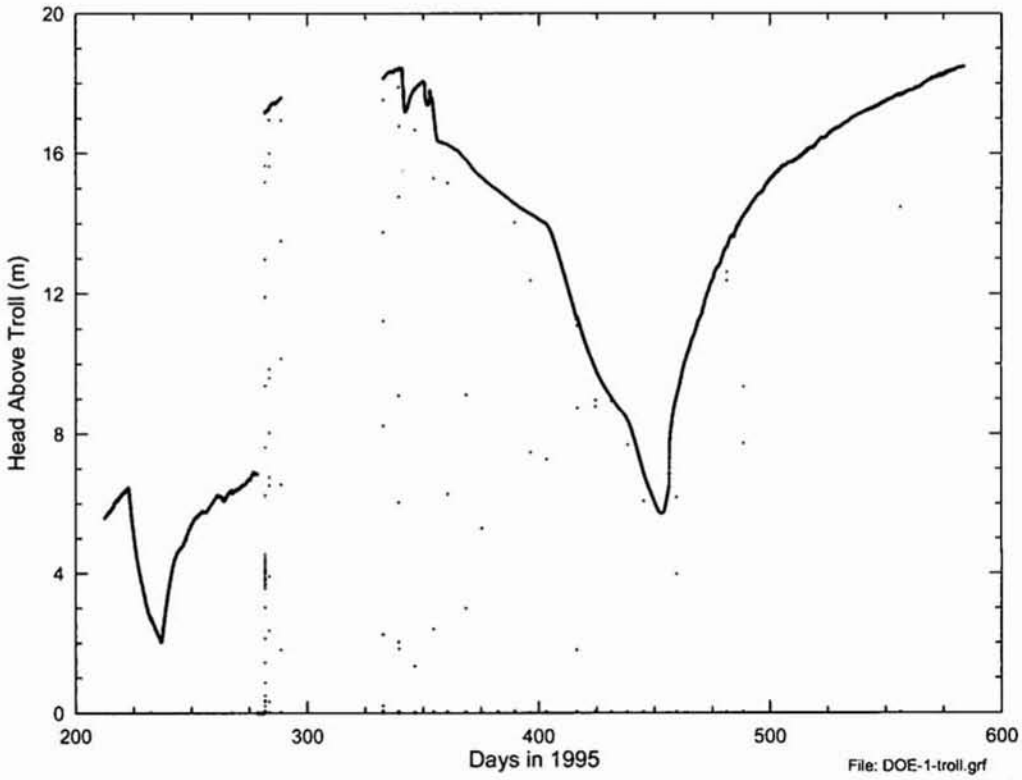

Figure 22. DOE-1 Raw Troll Data.

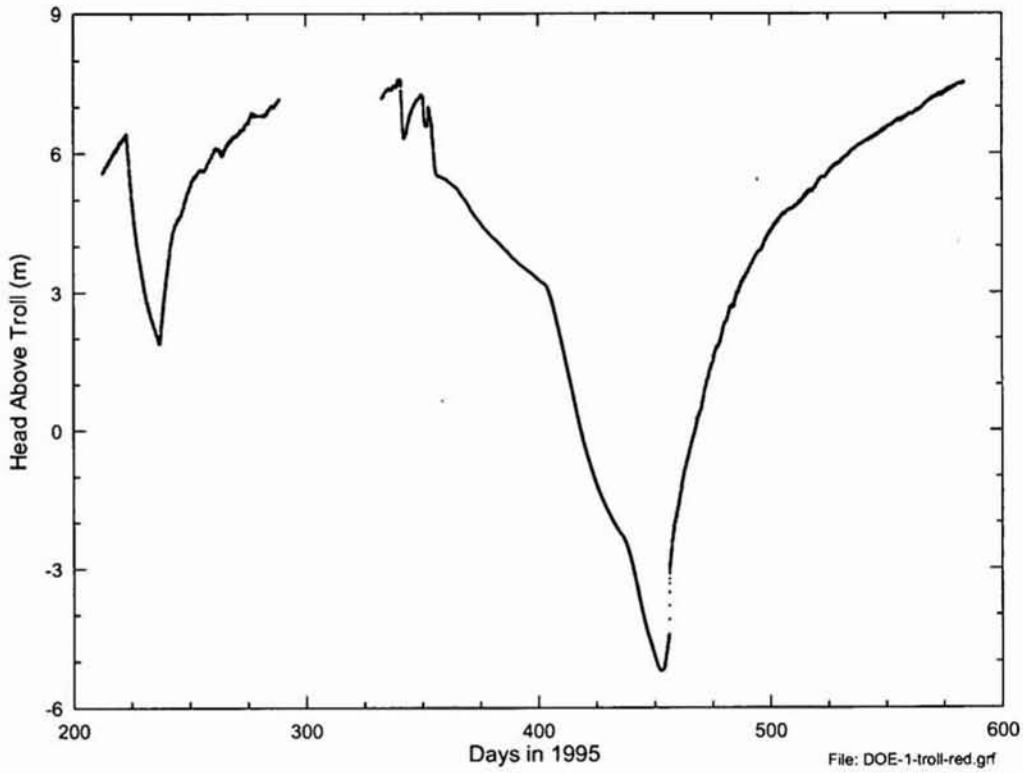

Figure 23. DOE-1 Reduced Troll Data.

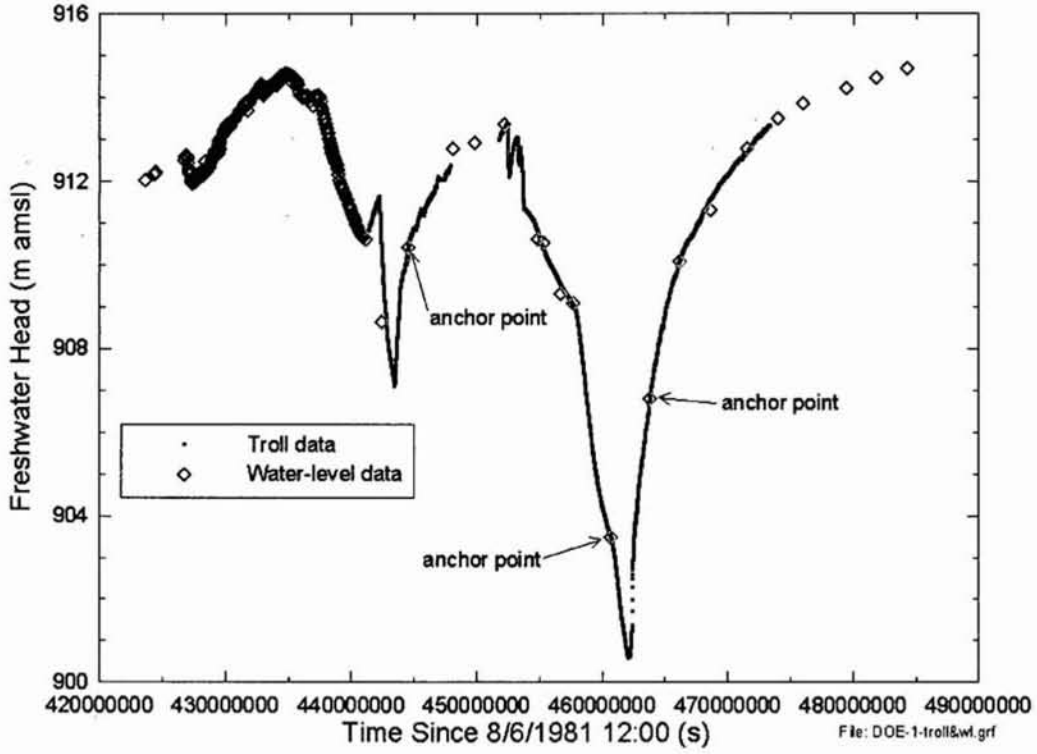

Figure 24. DOE-1 Troll data reconciled with water-level data.

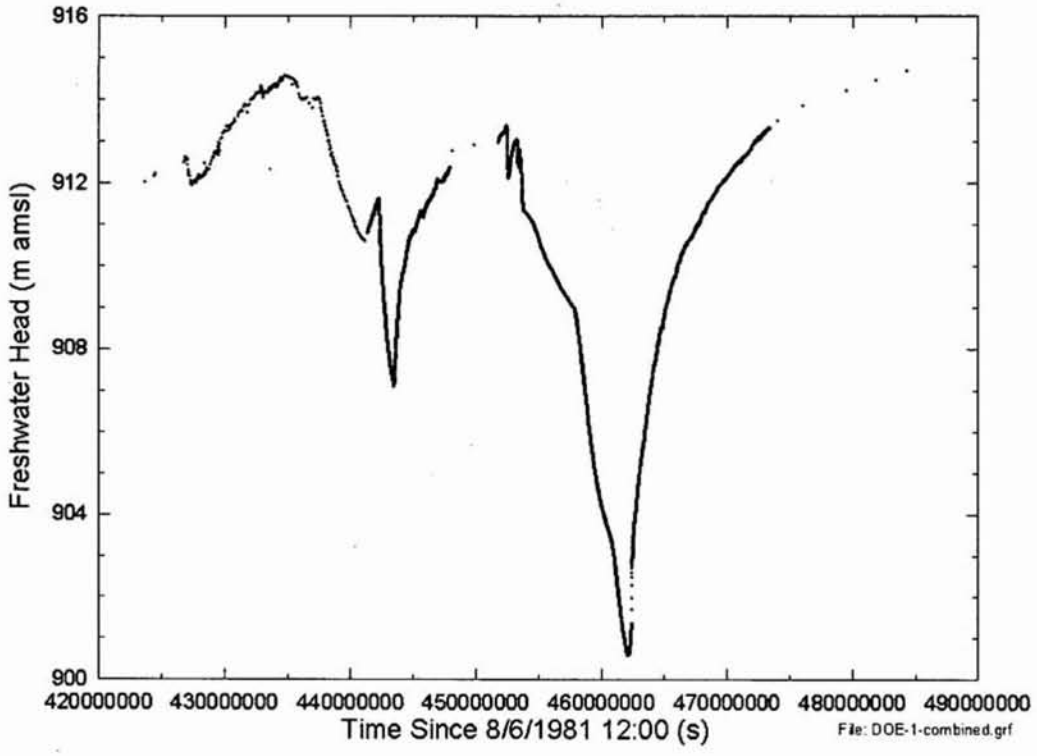

Figure 25. DOE-1 combined Troll and water-level data.

4.5.2 ERDA-9 Response

The head readings from the Troll in ERDA-9 were compiled in the Excel workbook ***ERDA-9-troll.xls***. The data, 28,337 readings over approximately a 15-month period, contain erroneous readings and offsets caused by the removal and replacement of the instrument. By creating functions within Excel, the process of identifying the suspect readings, evaluating trends and applying corrective, mathematically derived values to the reading was automated; the analysis of the data could then focus on actual head changes. The volume of revised readings was then reduced to the first reading of each hour, over the period, to further simplify and make the data more manageable. The resultant file, ***ERDA-9-troll_revised.xls***, contains all the original data plus the functions and revised values, as described below.

Added Columns:

F: Revised Head
G: Action Taken
H: Head Change
I: Calculations
J: Notes
K: ABS Variance > 0.01?
L: Revised Head per Hour

We added a worksheet for revised head data containing the times from the data table (Columns A and B) and the revised head data per hour (Column L). All times with no associated head reading (as derived from data worksheet) were then deleted.

Column F is the head reading +/- whatever derived value (if any). The derived value used to revise the head reading is whatever value is calculated by the *Total (Revision)* calculation found in Column I.

Example: Cell F2887 is =D2887+0.009

Where D2887 is the original head reading and 0.009 is the calculated change in head reading needing to be added in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well. The value is calculated in the *Total (Revision)* step described below.

Column G is the annotation "Deleted," the length of time deleted from the trend determination, or the calculated total revision value to be added or subtracted, i.e. "Trend Over 1:30".

Column H is the head change from reading to reading, values generated by subtracting the previous reading from the current reading (current reading for the associated line).

Example: Cell H2879 is =D2879-D2878

Where D2879 is the original head reading for that time (same row as Column A) and D2878 is the previous, actual head reading.

Column I is one of four calculations:

Deleted Hours – Change in time from the first to last associated deleted reading.

Example: Cell I2882 is =A2886-A2882

For this example, readings from rows 2882 through 2886 were deleted due to large variances (identified in Column K) assumed associated with the moving of the troll. A2886 is the time of the last reading deleted and A2882 is the time of the first reading deleted for this set.

Trend – The trend over the previous time equal to the amount of time deleted. Calculated by adding the head change values (Column H) over a period of time equal to the time deleted (derived by the deleted hours calculation).

Example: Cell I2881 is =SUM(H2876:H2881)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H2876:H2881 is the range of head change values covering the amount of time (identified by the *Deleted Hours* calculation) prior to the first deleted reading.

Difference – The head value change spanning the deleted readings time frame.

Example: Cell I2886 is =SUM(H2882:H2886)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H2882:H2886 is the range of head change values covering the span of deleted readings.

Total (Revision) – The total calculated change in head value needing to be added (or subtracted) in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well.

Example: Cell I4161 is =-0.009+I4160-I4155

Where -0.009 is the previous calculated change in head value, I4160 is the *Difference* (described above) and I4155 is the *Trend* (described above).

Column J is used for notes (identifying missing data periods) or to identify which calculation was used in Column H, i.e. "Hrs Deleted".

Column K is a logical function used to identify a "variance" in head readings greater than 0.01 m (positive or negative). The function looks at the head change value (Column H) and decides if the value identifies a head change of more than 0.01 m.

Example: Cell K2883 is

=IF(H2883>0.01,"Variance",IF(H2883<-0.01,"Variance",""))

Where IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. H2883>0.01 is the condition (is the head change value greater than 0.01?), if evaluated true, then the annotation "Variance" is written to the cell. If the evaluation is false, then another IF function evaluates the condition H2883<-0.01 (is the head change value less than –0.01?). If this evaluation is true, then the annotation "Variance" is written to the cell. If the evaluation is false, then nothing is written to the cell.

Column L is a logical function that identifies the first reading of the hour and writes its value to the cell. Should the time be other than the first reading of the hour no value is written.

Example: Cell L2877 is

=IF((HOUR(A2877)>HOUR(A2876)),F2877,IF((DAY(A2877)>DAY(A2876)),F2877,""))

Where: IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. HOUR is the name of the function that identifies the hour value from a referenced cell. DAY is the name of the function that identifies the day value from a referenced cell. The condition asks if the hour value of cell A2877 is greater than the hour value of cell A2876. If the evaluation is true (meaning the reading is from a new hour), then the revised head value (F2877) is written to the cell. If the evaluation is false, then another IF function evaluates the condition of if the day value from A2877 is greater than the day value from A2876. If the evaluation is true (meaning the reading is from a new day), then the revised head value (F2877) is written to the cell. If the evaluation is false, then nothing is written to the cell.

The head values written in Column L (described above) and the corresponding times from the same row of columns A and B are transferred to file ***ERDA-9-troll_Revised_Graph.xls*** to create a data file of a more manageable size. The date and time columns are merged into a new column A, and the hourly head values are put in column C. A column B of "Elapsed time since 8/6/1981 12:00 (s)" was created.

The compiled raw data from ***ERDA-9-troll.xls*** are shown graphically in Figure 26. Figure 27 shows the data written from ***ERDA-9-troll_revised.xls*** to ***ERDA-9-troll_Revised_Graph.xls*** for use in T-field calibration.

The next step in the data-reduction process was to reconcile the Troll data, which are expressed in meters of freshwater head relative to the position of the Troll, with water-level measurements made in the well. To do this, the water-level measurements were first converted to freshwater heads by converting the measurement from depth to water from top of casing to height of water

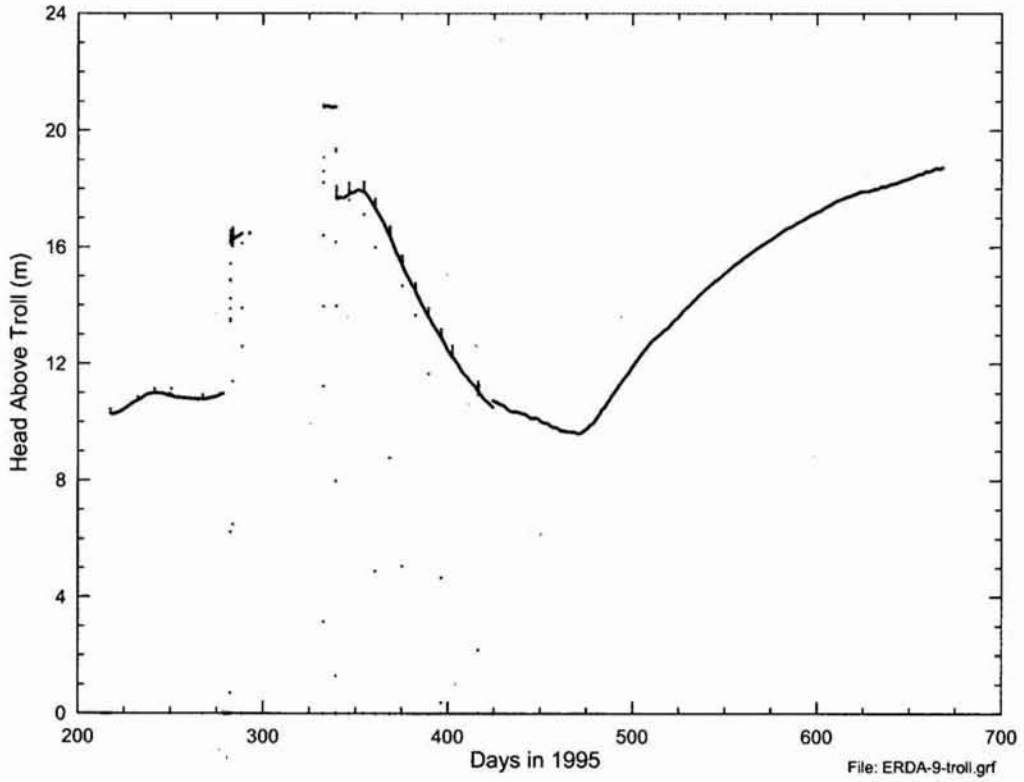

Figure 26. ERDA-9 Raw Troll Data.

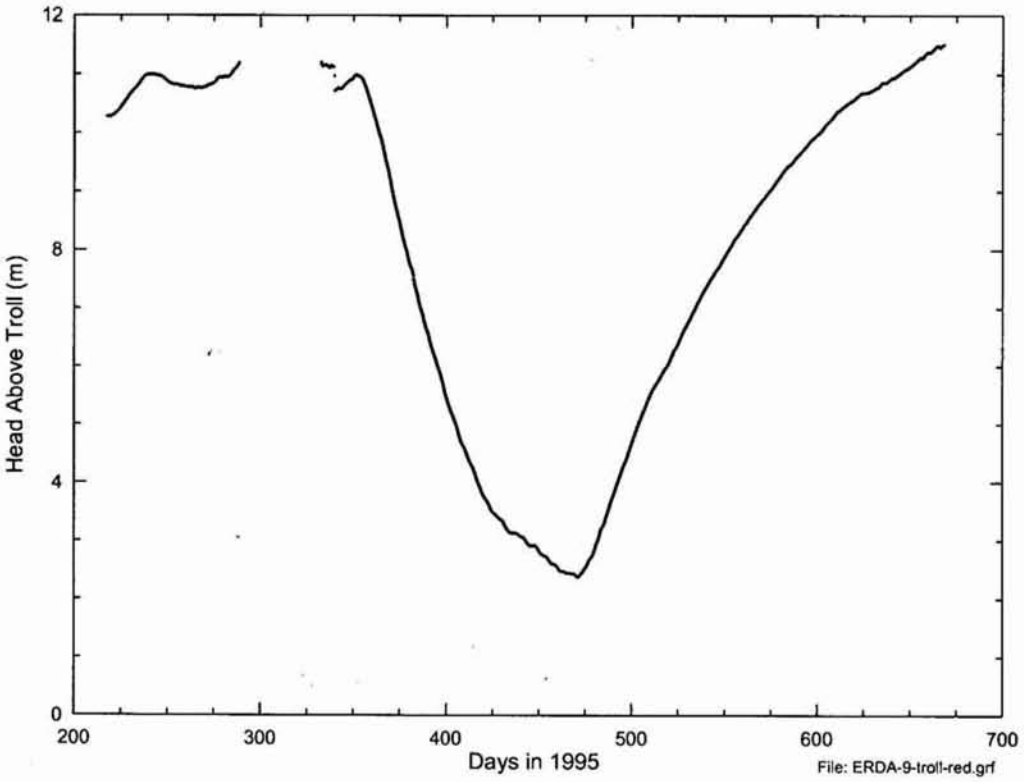

Figure 27. ERDA-9 Reduced Troll Data.

column above the center of the Culebra. The height of this column was then multiplied by the specific gravity of the fluid in the well, and added to the elevation of the center of the Culebra to obtain the freshwater head. These conversions are shown in the file ***ERDA-9-waterlevels.xls***, which also provides references for the elevations and specific-gravity values used. Next, two water-level measurements (anchor points) were identified that were made at approximately the same times as Troll measurements in the two continuous segments of data shown in Figure 27. These measurements were made on 8/17/1995 and 5/15/1996. The first anchor point was used to convert the Troll measurements made between 8/6/1995 and 10/16/1995 to freshwater heads, and the second anchor point was used to convert the data from 11/29/1995 to 10/30/1996. These conversions are shown in column D of file ***ERDA-9-troll_Revised_Graph.xls***. These anchor points, and the agreement they provide between the Troll and water-level measurements, are shown in Figure 28. The merged data sets, with the water-level measurements made during the times the Troll was in operation removed, are shown in Figure 29 and stored in file ***ERDA-9-combined.xls***.

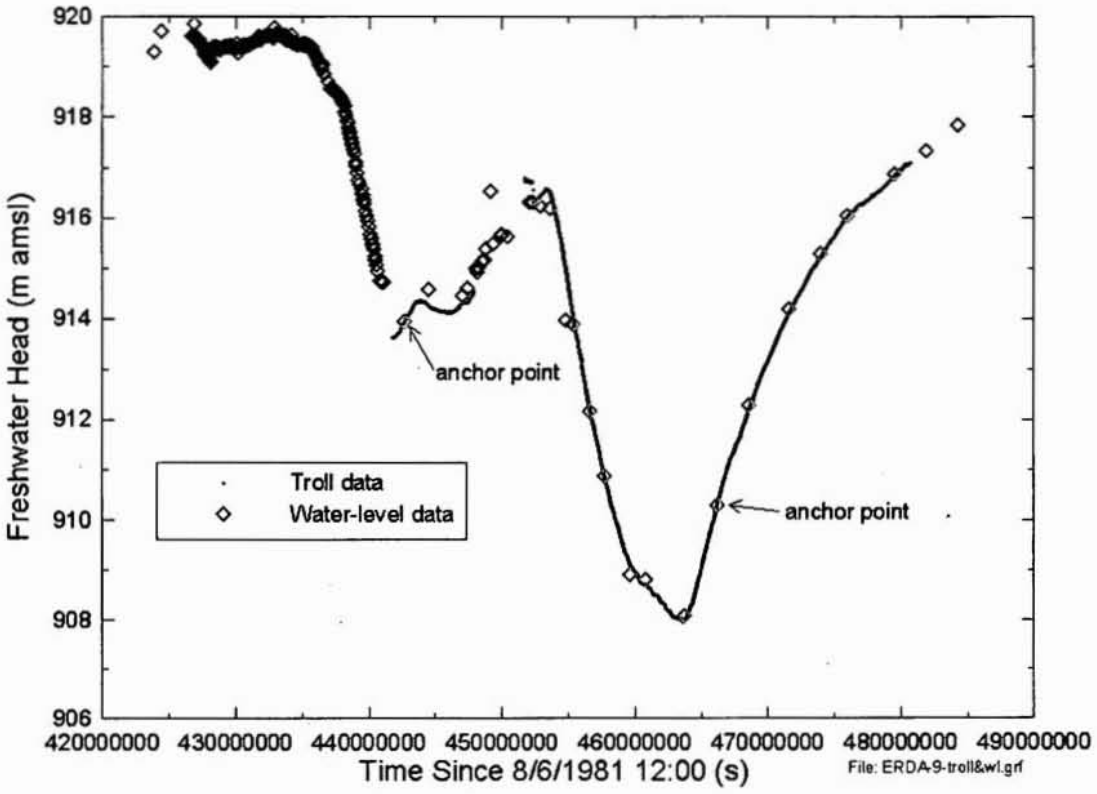

Figure 28. ERDA-9 Troll data reconciled with water-level data.

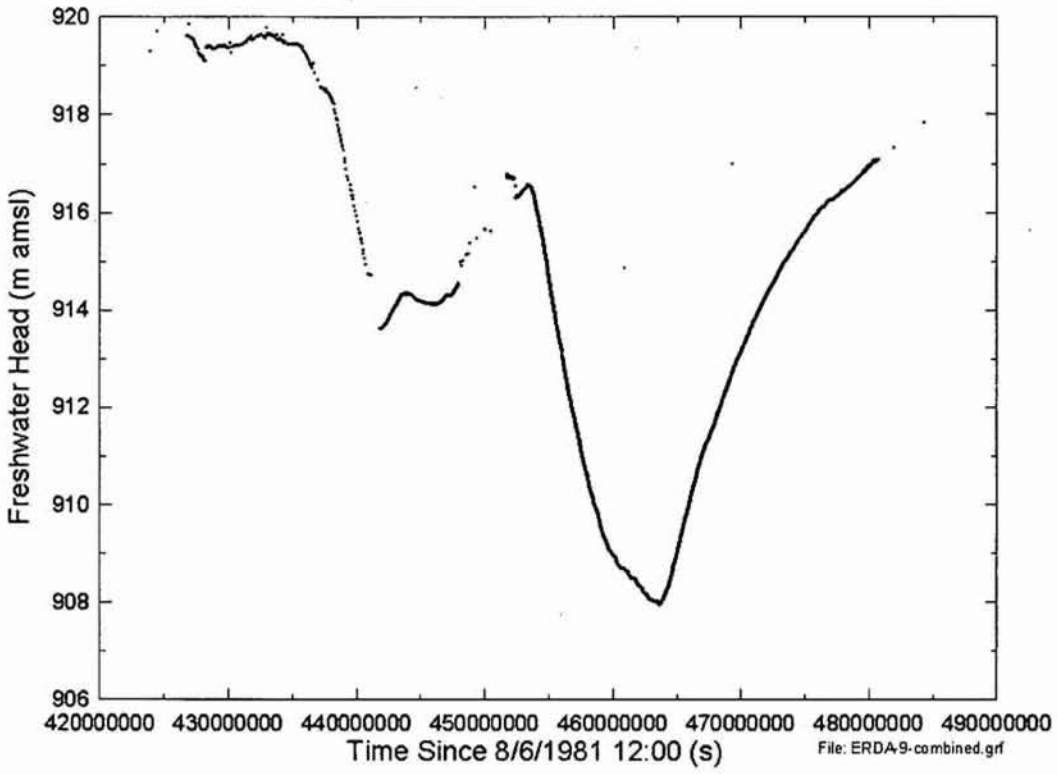

Figure 29. ERDA-9 combined Troll and water-level data.

4.5.3 H-1 Response

The head readings from the Troll in H-1 were compiled in the Excel workbook ***H-1-troll.xls***. The data, 28,382 readings over approximately a 15-month period, contain erroneous readings and offsets caused by the removal and replacement of the instrument. By creating functions within Excel, the process of identifying the suspect readings, evaluating trends and applying corrective, mathematically derived values to the readings was automated; the analysis of the data could then focus on actual head changes. The volume of revised readings was then reduced to the first reading of each hour, over the period, to further simplify and make the data more manageable. The resultant file, ***H-1-troll_revised.xls***, contains all the original data plus the functions and revised values, as described below.

Added Columns:

F: Revised Head
G: Action Taken
H: Head Change
I: Calculations
J: Notes
K: ABS Variance > 0.01?
L: Revised Head per Hour

We added a worksheet for revised head data containing the times from the data table (Columns A and B) and the revised head data per hour (Column L). All times with no associated head reading (as derived from data worksheet) were then deleted.

Column F is the head reading +/- whatever derived value (if any). The derived value used to revise the head reading is whatever value is calculated by the *Total (Revision)* calculation found in Column I.

Example: Cell F580 is =D580-0.029

Where D580 is the original head reading and 0.029 is the calculated change in head reading needing to be subtracted in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well. The value is calculated in the *Total (Revision)* step described below.

Column G is the annotation "Deleted," the length of time deleted from the trend determination, or the calculated total revision value to be added or subtracted, i.e. "Trend Over 1:30".

Column H is the head change from reading to reading, values generated by subtracting the previous reading from the current reading (current reading for the associated line).

Example: Cell H571 is =D571-D570

Where D571 is the original head reading for that time (same row as Column A) and D570 is the previous, actual head reading.

Column I is one of four calculations:

Deleted Hours – Change in time from the first to last associated deleted reading.

Example: Cell I576 is =A579-A576

For this example, readings from rows 576 through 579 were deleted due to large variances (identified in Column K) assumed associated with the moving of the troll. A579 is the time of the last reading deleted and A576 is the time of the first reading deleted for this set.

Trend – The trend over the previous time equal to the amount of time deleted. Calculated by adding the head change values (Column H) over a period of time equal to the time deleted (derived by the deleted hours calculation).

Example: Cell I579 is =SUM(H572:H575)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H572:H575 is the range of head change values covering the

amount of time (identified by the *Deleted Hours* calculation) prior to the first deleted reading.

Difference – The head value change spanning the deleted readings time frame.

Example: Cell I579 is =SUM(H576:H579)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H576:H579 is the range of head change values covering the span of deleted readings.

Total (Revision) – The total calculated change in head value needing to be added (or subtracted) in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well.

Example: Cell I2886 is =0.029+I2885-I2882

Where 0.029 is the previous calculated change in head value, I2885 is the *Difference* (described above) and I2882 is the *Trend* (described above).

Column J is used for notes (identifying missing data periods) or to identify which calculation was used in Column H, i.e. "Hrs Deleted".

Column K is a logical function used to identify a "variance" in head readings greater than 0.01 m (positive or negative). The function looks at the head change value (Column H) and decides if the value identifies a head change of more than 0.01 m.

Example: Cell K577 is

=IF(H577>0.01,"Variance",IF(H577<-0.01,"Variance",""))

Where IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. H577>0.01 is the condition (is the head change value greater than 0.01?), if evaluated true, then the annotation "Variance" is written to the cell. If the evaluation is false, then another IF function evaluates the condition H577<-0.01 (is the head change value less than –0.01?). If this evaluation is true, then the annotation "Variance" is written to the cell. If the evaluation is false, then nothing is written to the cell.

Column L is a logical function that identifies the first reading of the hour and writes its value to the cell. Should the time be other than the first reading of the hour no value is written.

Example: Cell L573 is

=IF((HOUR(A573)>HOUR(A572)),F573,IF((DAY(A573)>DAY(A572)),F573,""))

Where: IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. HOUR is the name of the function that identifies the hour value from a referenced cell. DAY is the name of the function that identifies the day value from a referenced cell. The condition asks if the hour value of cell A573 is greater than the hour value of cell A572. If the evaluation is true (meaning the reading is from a new hour), then the revised head value (F573) is written to the cell. If the evaluation is false, then another IF function evaluates the condition of if the day value from A573 is greater than the day value from A572. If the evaluation is true (meaning the reading is from a new day), then the revised head value (F573) is written to the cell. If the evaluation is false, then nothing is written to the cell.

The head values written in Column L (described above) and the corresponding times from the same row of columns A and B are transferred to file ***H-1-troll_Revised_Graph.xls*** to create a data file of a more manageable size. The date and time columns are merged into a new column A, and the hourly head values are put in column C. A column B of "Elapsed time since 8/6/1981 12:00 (s)" was created.

The compiled raw data from ***H-1-troll.xls*** are shown graphically in Figure 30. Figure 31 shows the data written from ***H-1-troll_revised.xls*** to ***H-1-troll_Revised_Graph.xls*** for use in T-field calibration. Note that the data-reduction process resulted in some negative head values. This is irrelevant because T-field calibration will consider only changes in head.

The next step in the data-reduction process was to reconcile the Troll data, which are expressed in meters of freshwater head relative to the position of the Troll, with water-level measurements made in the well. To do this, the water-level measurements were first converted to freshwater heads by converting the measurement from depth to water from top of casing to height of water column above the center of the Culebra. The height of this column was then multiplied by the specific gravity of the fluid in the well, and added to the elevation of the center of the Culebra to obtain the freshwater head. These conversions are shown in the file ***H-1-waterlevels.xls***, which also provides references for the elevations and specific-gravity values used. Next, two water-level measurements (anchor points) were identified that were made at approximately the same times as Troll measurements in the two continuous segments of data shown in Figure 31. These measurements were made on 9/7/1995 and 6/12/1996. The first anchor point was used to convert the Troll measurements made between 8/1/1995 and 10/16/1995 to freshwater heads, and the second anchor point was used to convert the data from 11/29/1995 to 10/30/1996. These conversions are shown in column D of ***H-1-troll_Revised_Graph.xls***. These anchor points, and the agreement they provide between the Troll and water-level measurements, are shown in Figure 32. The merged data sets, with the water-level measurements made during the times the Troll was in operation removed, are shown in Figure 33 and stored in file ***H-1-combined.xls***.

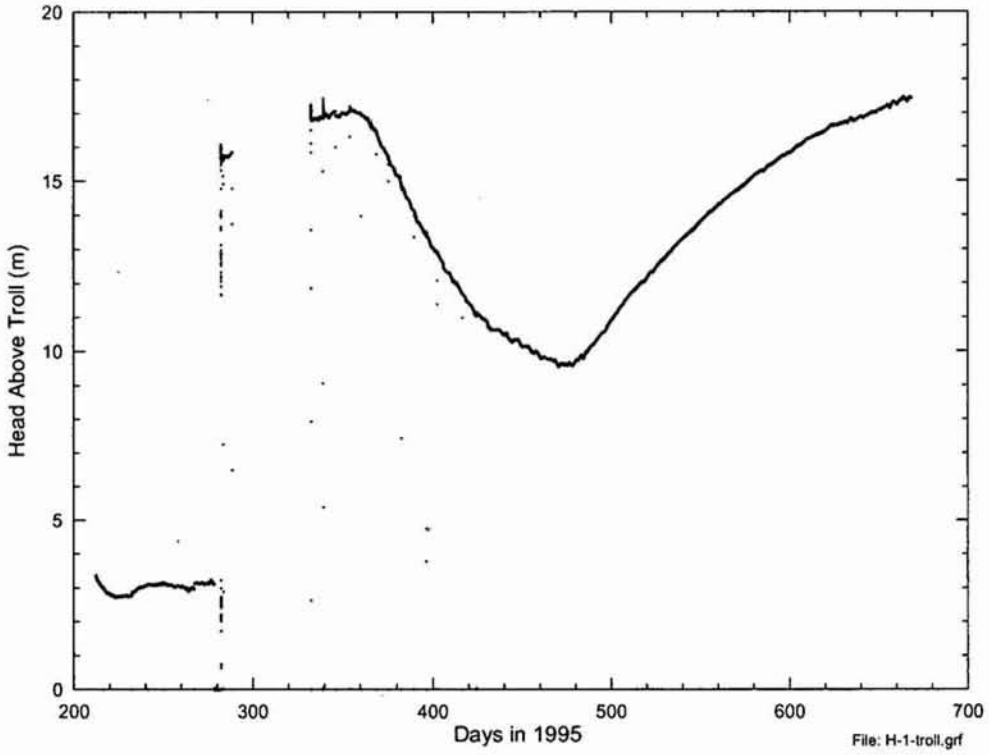

Figure 30. H-1 Raw Troll Data.

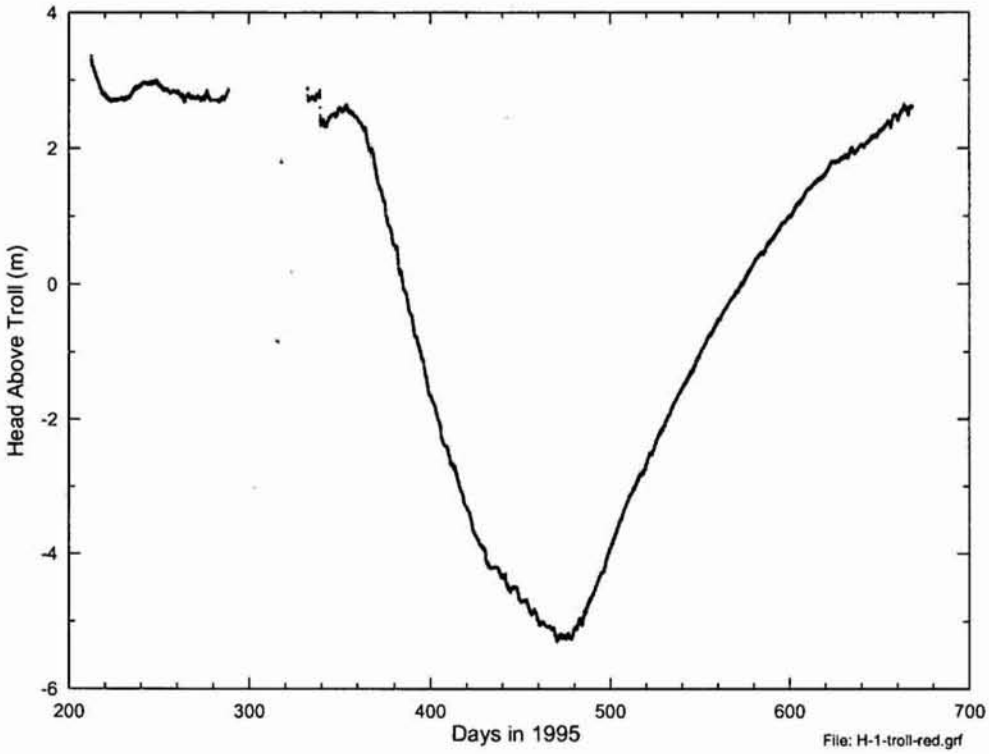

Figure 31. H-1 Reduced Troll Data.

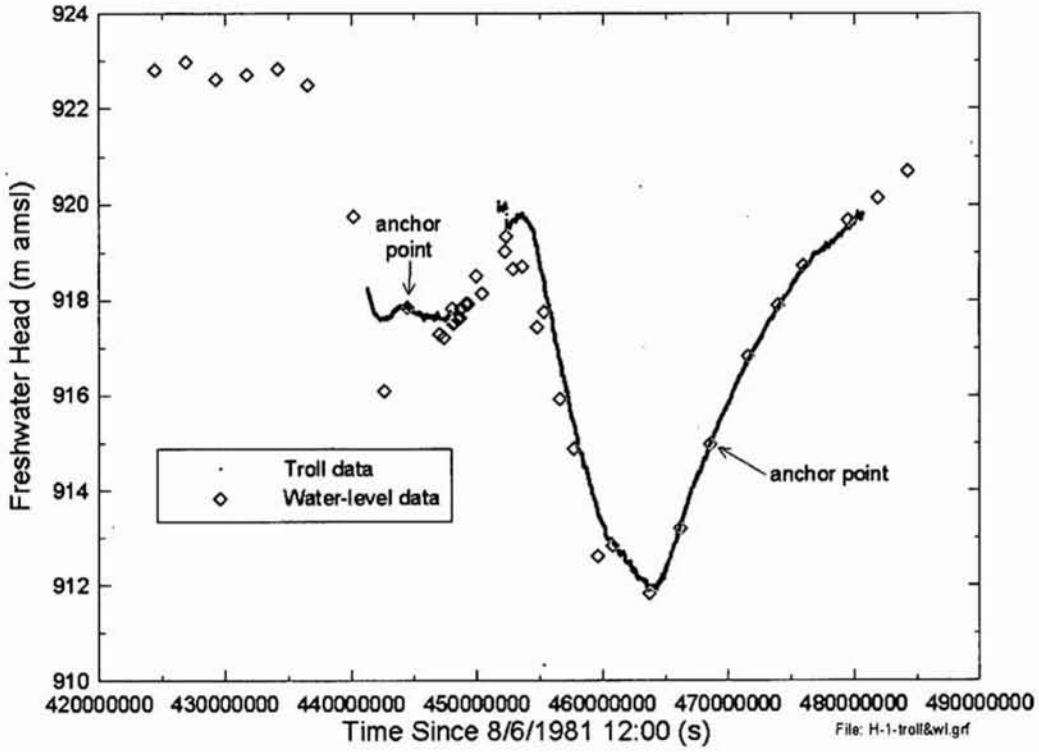

Figure 32. H-1 Troll data reconciled with water-level data.

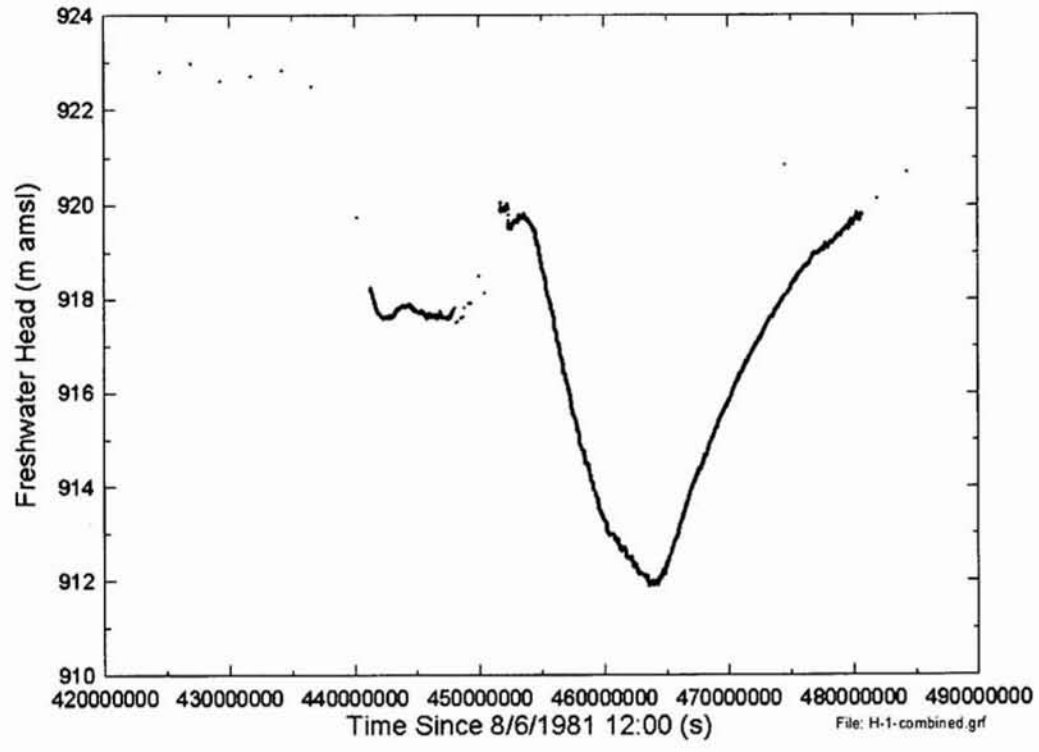

Figure 33. H-1 combined Troll and water-level data.

4.5.4 H-2b2 Response

In 1995 and 1996, Culebra heads at H-2b2 were rising in response to grouting of the Culebra in the Air-Intake Shaft and also as part of a longer term rising trend. Figure 34 shows the drawdown that was observed at H-2b2 during the H-19 and H-11 pumping events, and also a sustained rise of approximately 0.265 m/yr that has occurred since early 1998. To calculate the changes in freshwater head that occurred at H-2b2 in 1995 and 1996, we assume that the 0.265 m/yr rising trend existed during those years as well. File ***H-2b2-waterlevels.xls*** shows the water-level data from 1995 and 1996, conversion of water levels to freshwater heads, and compensation for the rising trend. The compensated data are shown in Figure 35.

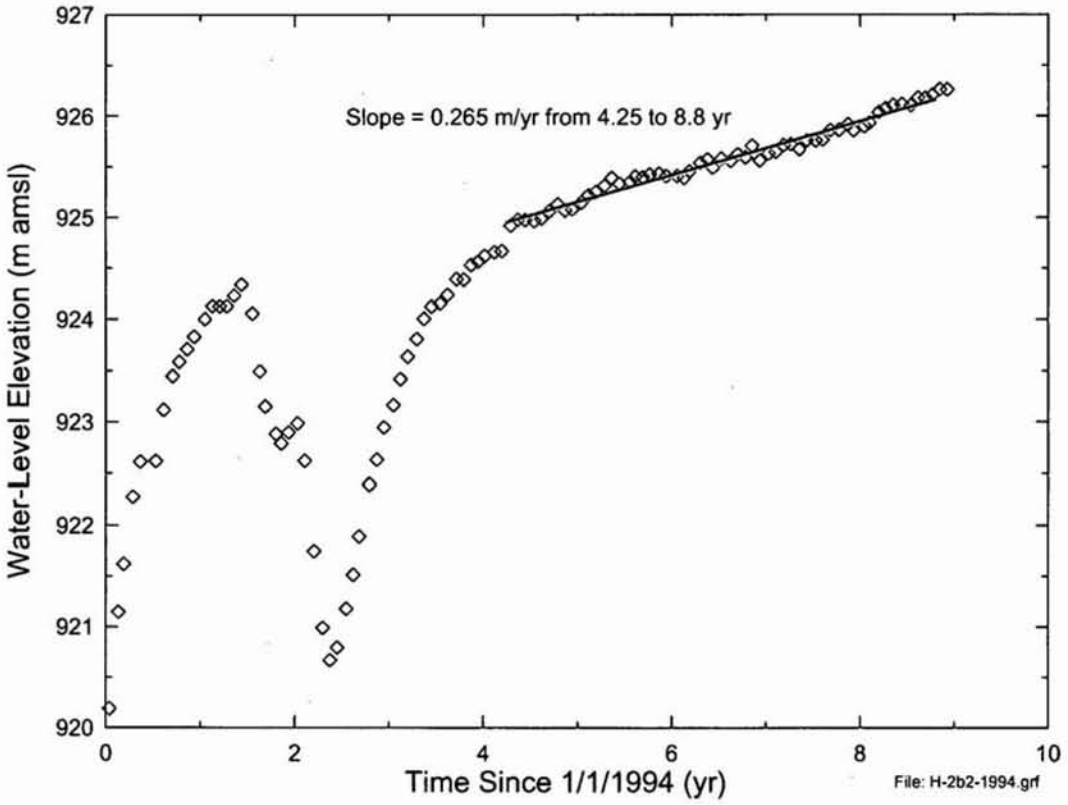

Figure 34. Rising water-level trend at H-2b2.

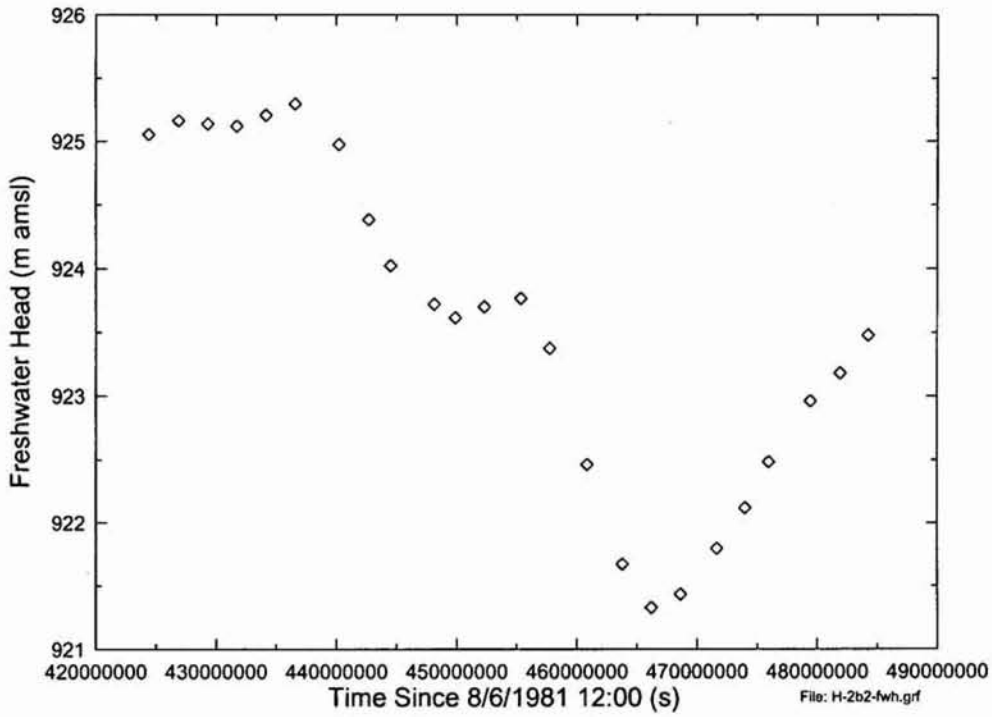

Figure 35. H-2b2 1995-96 freshwater heads.

4.5.5 H-3b2 Response

The head readings from the Troll in H-3b2 were compiled in the Excel workbook ***H-3b2-troll.xls***. The data, 79,035 readings over approximately a 16-month period, contain erroneous readings and offsets caused by the removal and replacement of the instrument. By creating functions within Excel, the process of identifying the suspect readings, evaluating trends and applying corrective, mathematically derived values to the readings was automated; the analysis of the data could then focus on actual head changes. The volume of revised readings was then reduced to the first reading of each hour, over the period, to further simplify and make the data more manageable. The resultant file, ***H-3b2-troll_revised.xls***, contains all the original data plus the functions and revised values, as described below.

Added Columns:

F: Revised Head
G: Action Taken
H: Head Change
I: Calculations
J: Notes
K: ABS Variance > 0.01?
L: Revised Head per Hour

We added a worksheet for revised head data containing the times from the data table (Columns A and B) and the revised head data per hour (Column L). All times with no associated head reading (as derived from data worksheet) were then deleted.

Column F is the head reading +/- whatever derived value (if any). The derived value used to revise the head reading is whatever value is calculated by the *Total (Revision)* calculation found in Column I.

Example: Cell F195 is =D195-0.189

Where D195 is the original head reading and 0.189 is the calculated change in head reading needing to be subtracted in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well. The value is calculated in the *Total (Revision)* step described below.

Column G is the annotation "Deleted," the length of time deleted from the trend determination, or the calculated total revision value to be added or subtracted, i.e. "Trend Over 1:30".

Column H is the head change from reading to reading, values generated by subtracting the previous reading from the current reading (current reading for the associated line).

Example: Cell H180 is =D180-D179

Where D180 is the original head reading for that time (same row as Column A) and D179 is the previous, actual head reading.

Column I is one of four calculations:

Deleted Hours – Change in time from the first to last associated deleted reading.

Example: Cell I185 is =A194-A185

For this example, readings from rows 185 through 194 were deleted due to large variances (identified in Column K) assumed associated with the moving of the troll. A194 is the time of the last reading deleted and A185 is the time of the first reading deleted for this set.

Trend – The trend over the previous time equal to the amount of time deleted. Calculated by adding the head change values (Column H) over a period of time equal to the time deleted (derived by the deleted hours calculation).

Example: Cell I184 is =SUM(H175:H184)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H175:H184 is the range of head change values covering the amount of time (identified by the *Deleted Hours* calculation) prior to the first deleted reading.

Difference – The head value change spanning the deleted readings time frame.

Example: Cell I194 is =SUM(H185:H194)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H185:H194 is the range of head change values covering the span of deleted readings.

Total (Revision) – The total calculated change in head value needing to be added (or subtracted) in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well.

Example: Cell I1444 is =0.189+I1443-I1411

Where 0.189 is the previous calculated change in head value, I1443 is the *Difference* (described above) and I1411 is the *Trend* (described above).

Column J is used for notes (identifying missing data periods) or to identify which calculation was used in Column I, i.e. "Hrs Deleted".

Column K is a logical function used to identify a "variance" in head readings greater than 0.01 m (positive or negative). The function looks at the head change value (Column H) and decides if the value identifies a head change of more than 0.01 m.

Example: Cell K186 is

=IF(H186>0.01,"Variance",IF(H186<-0.01,"Variance",""))

Where IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. H186>0.01 is the condition (is the head change value greater than 0.01?), if evaluated true, then the annotation "Variance" is written to the cell. If the evaluation is false, then another IF function evaluates the condition H186<-0.01 (is the head change value less than –0.01?). If this evaluation is true, then the annotation "Variance" is written to the cell. If the evaluation is false, then nothing is written to the cell.

Column L is a logical function that identifies the first reading of the hour and writes its value to the cell. Should the time be other than the first reading of the hour no value is written.

Example: Cell L183 is

=IF((HOUR(A183)>HOUR(A182)),F183,IF((DAY(A183)>DAY(A182)),F183,""))

Where: IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. HOUR is the name of the function that identifies the hour value from a referenced cell. DAY is the name of the function that identifies the day value from a referenced cell. The condition asks if

the hour value of cell A183 is greater than the hour value of cell A182. If the evaluation is true (meaning the reading is from a new hour), then the revised head value (F183) is written to the cell. If the evaluation is false, then another IF function evaluates the condition of if the day value from A183 is greater than the day value from A182. If the evaluation is true (meaning the reading is from a new day), then the revised head value (F183) is written to the cell. If the evaluation is false, then nothing is written to the cell.

The head values written in Column L (described above) and the corresponding times from the same row of columns A and B are transferred to file ***H-3b2-troll_Revised_Graph.xls*** to create a data file of a more manageable size. The date and time columns are merged into a new column A, and the hourly head values are put in column C. A column B of "Elapsed time since 8/6/1981 12:00 (s)" was created.

The compiled raw data from ***H-3b2-troll.xls*** are shown graphically in Figure 36. Figure 37 shows the data written from ***H-3b2-troll_revised.xls*** to ***H-3b2-troll_Revised_Graph.xls*** for use in T-field calibration. Note that the data-reduction process resulted in some negative head values. This is irrelevant because T-field calibration will consider only changes in head.

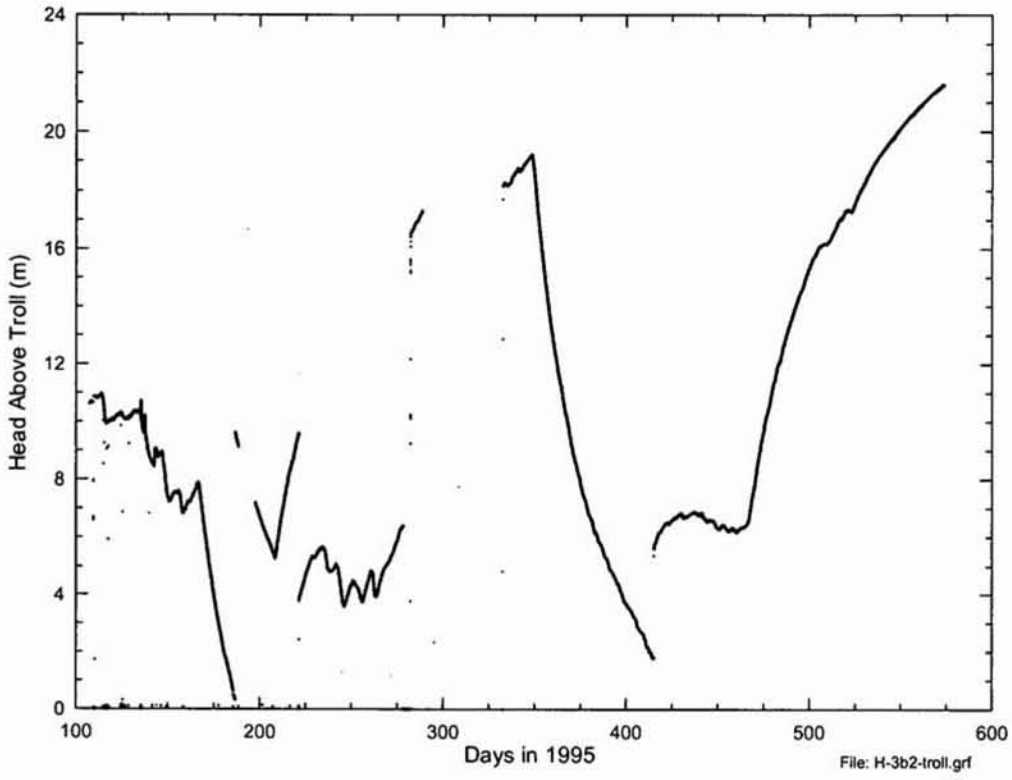

Figure 36. H-3b2 raw Troll data.

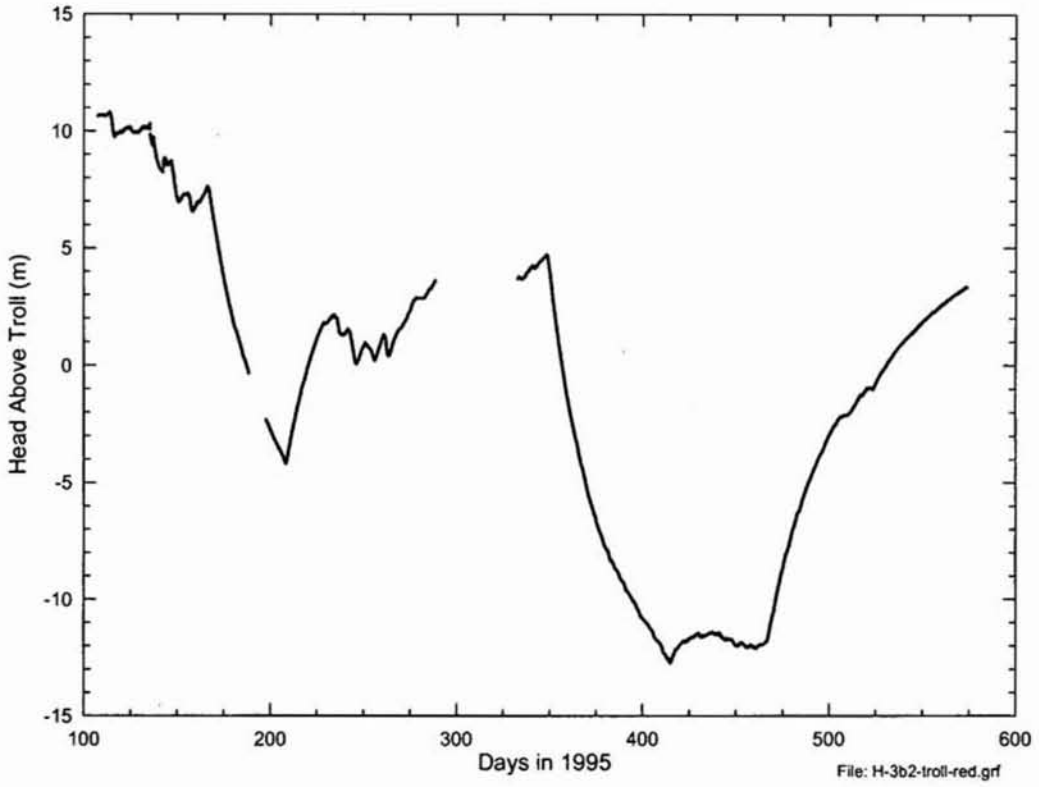

Figure 37. H-3b2 Troll reduced data.

The next step in the data-reduction process was to reconcile the Troll data, which are expressed in meters of freshwater head relative to the position of the Troll, with water-level measurements made in the well. To do this, the water-level measurements were first converted to freshwater heads by converting the measurement from depth to water from top of casing to height of water column above the center of the Culebra. The height of this column was then multiplied by the specific gravity of the fluid in the well, and added to the elevation of the center of the Culebra to obtain the freshwater head. These conversions are shown in the file ***H-3b2-waterlevels.xls***, which also provides references for the elevations and specific-gravity values used. Next, two water-level measurements (anchor points) were identified that were made at approximately the same times as Troll measurements in the two continuous segments of data shown in Figure 37 (before and after 1995 day 300). These measurements were made on 4/26/1995 and 4/17/1996. The first anchor point was used to convert the Troll measurements made between 4/18/1995 and 10/16/1995 to freshwater heads, and the second anchor point was used to convert the data from 11/29/1995 to 7/27/1996. These conversions are shown in column D of ***H-3b2-troll_Revised_Graph.xls***. These anchor points, and the agreement they provide between the Troll and water-level measurements, are shown in Figure 38. The merged data sets, with the water-level measurements made during the times the Troll was in operation removed, are shown in Figure 39 and stored in file ***H-3b2-combined.xls***.

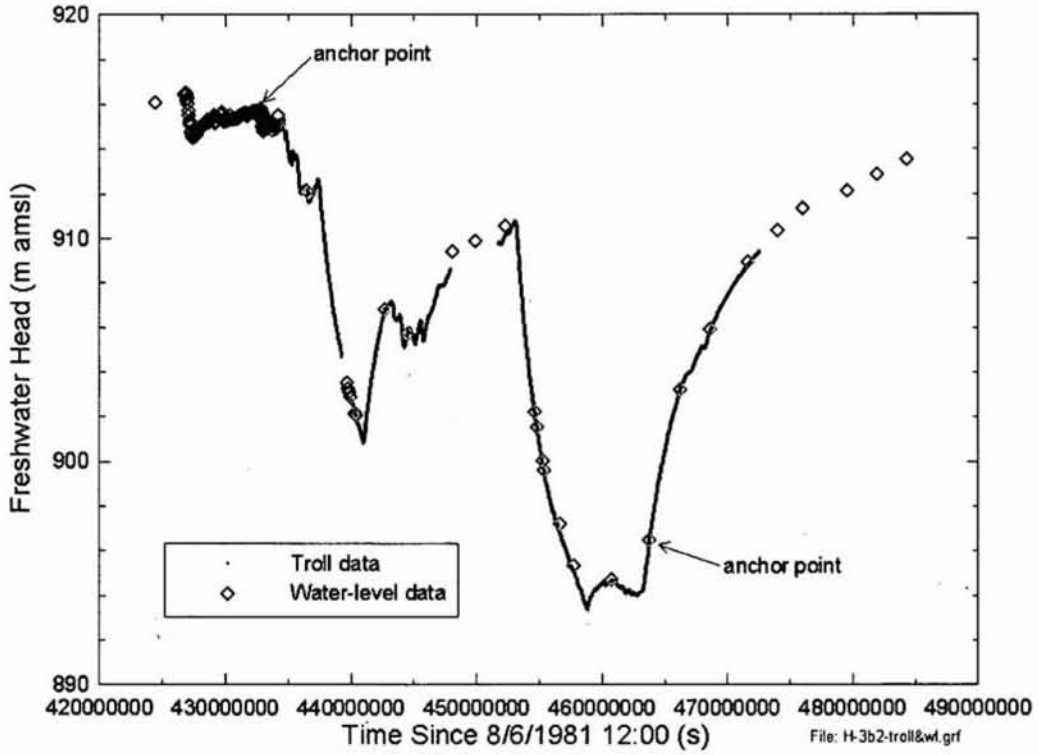

Figure 38. H-3b2 Troll data reconciled with water-level data.

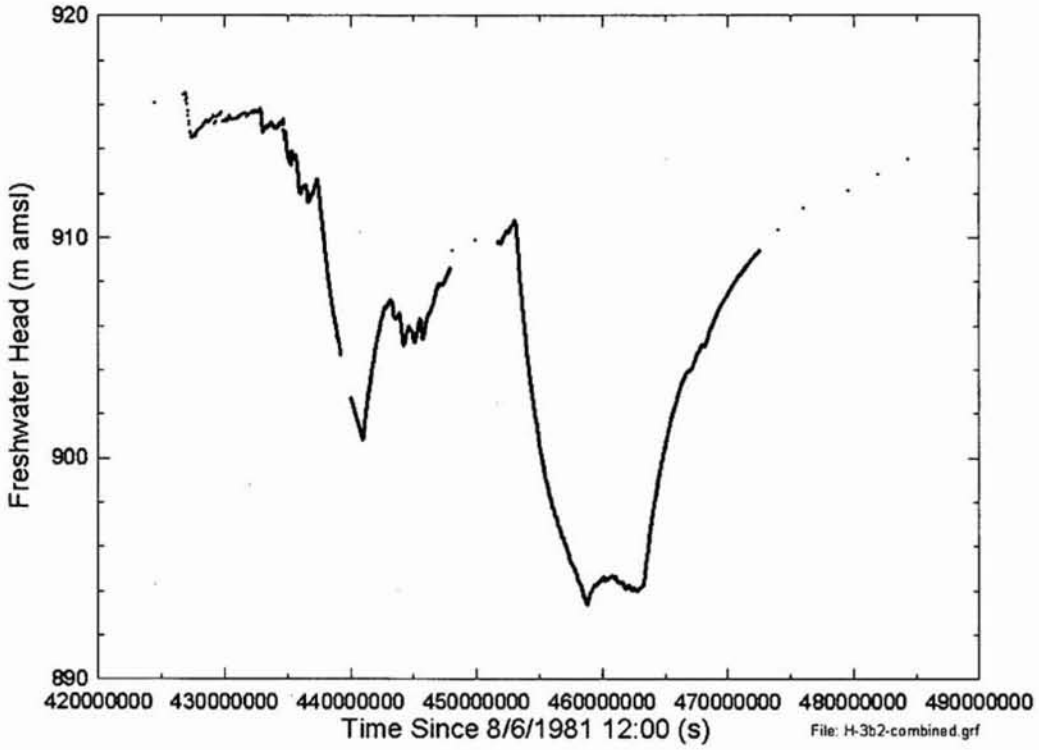

Figure 39. H-3b2 combined Troll and water-level data.

4.5.5 H-4b Response

Culebra water levels were measured in H-4b by Washington TRU Solutions, LLC (WTS) in 1995 and 1996 (ERMS 525179). File ***H-4b-waterlevels.xls*** shows the water-level data from 1995 and 1996 and conversion of water levels to freshwater heads. The freshwater-head data are shown in Figure 40.

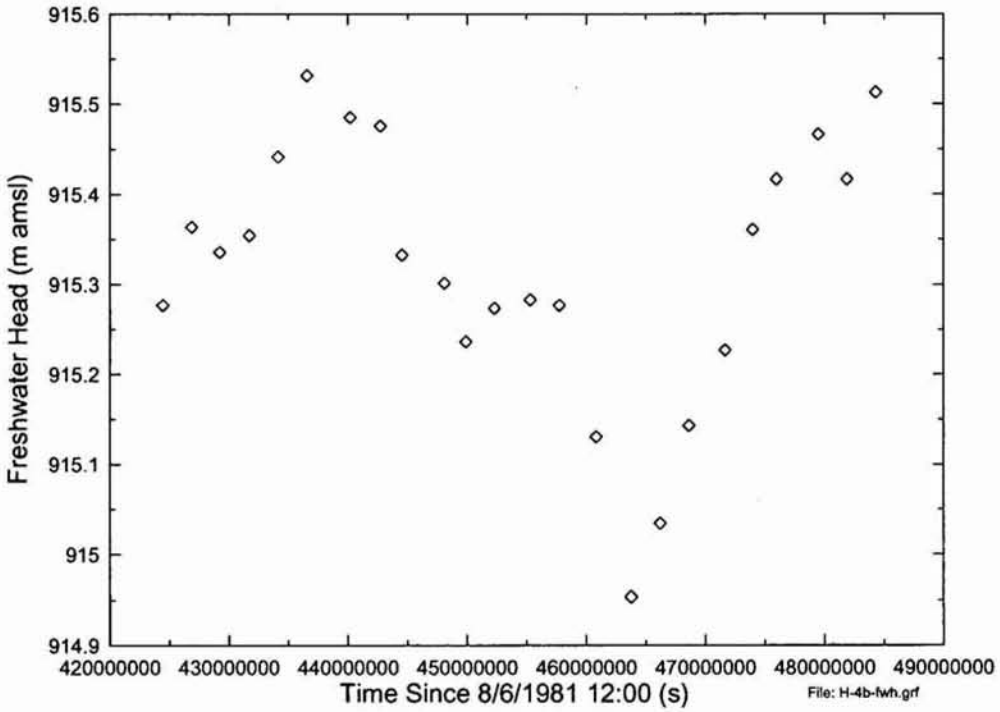

Figure 40. H-4b 1995-96 freshwater heads.

4.5.6 H-12 Response

Culebra water levels were measured in H-12 by WTS in 1995 and 1996 (ERMS 525179). File ***H-12-waterlevels.xls*** shows the water-level data from 1995 and 1996 and conversion of water levels to freshwater heads. The freshwater-head data are shown in Figure 41.

4.5.7 H-14 Response

Culebra water levels were measured in H-14 by WTS in 1995 and 1996 (ERMS 525179). File ***H-14-waterlevels.xls*** shows the water-level data from 1995 and 1996 and conversion of water levels to freshwater heads. The freshwater-head data are shown in Figure 42.

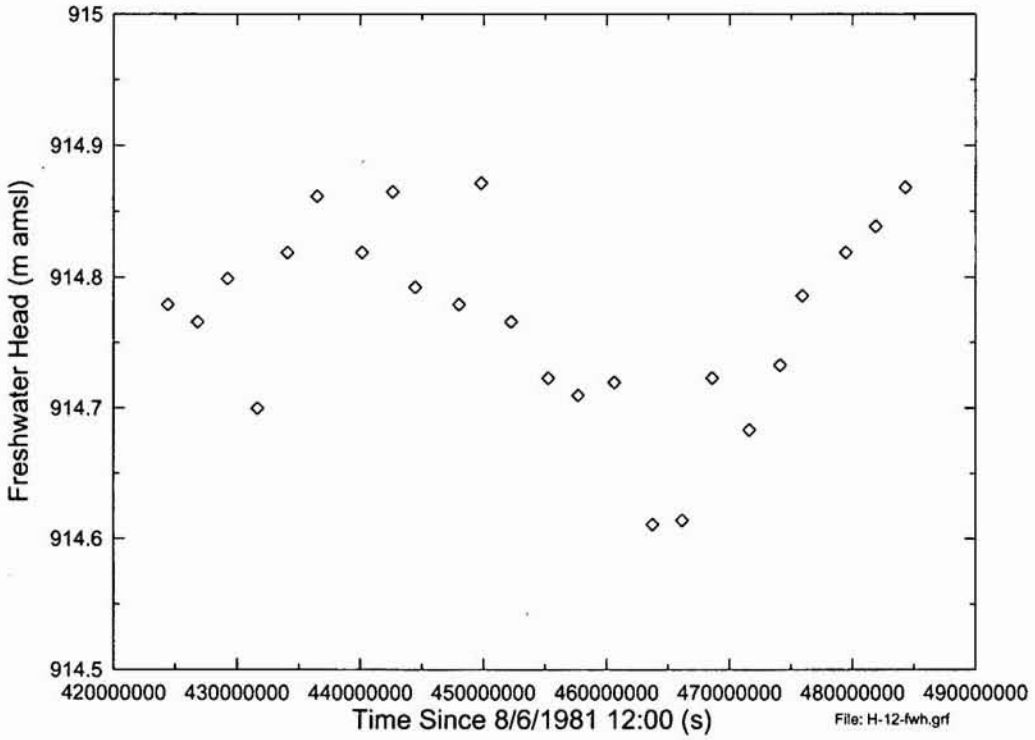

Figure 41. H-12 1995-96 freshwater heads.

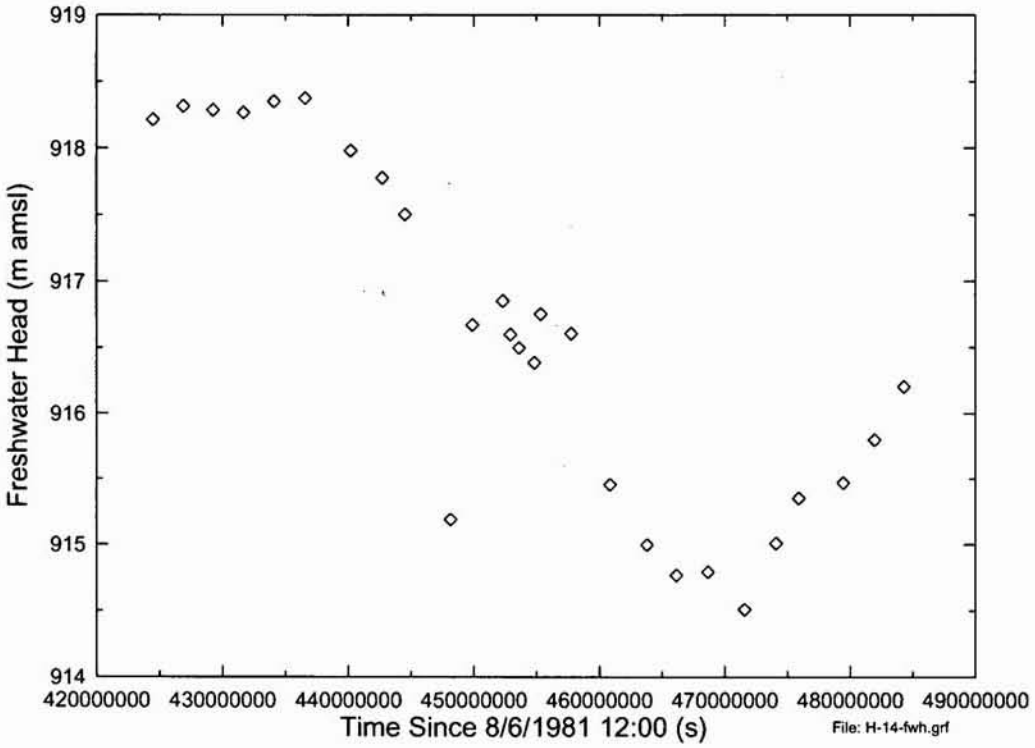

Figure 42. H-14 1995-96 freshwater heads.

4.5.9 H-15 Response

The head readings from the Troll in H-15 were compiled in the Excel workbook ***H-15-troll.xls***. The data, 11,184 readings over approximately a 4-month period, contain erroneous readings and offsets caused by the removal and replacement of the instrument. By creating functions within Excel, the process of identifying the suspect readings, evaluating trends and applying corrective, mathematically derived values to the readings was automated; the analysis of the data could then focus on actual head changes. The volume of revised readings was then reduced to the first reading of each hour, over the period, to further simplify and make the data more manageable. The resultant file, ***H-15-troll_revised.xls***, contains all the original data plus the functions and revised values, as described below.

Added Columns:

F: Revised Head
G: Action Taken
H: Head Change
I: Calculations
J: Notes
K: ABS Variance > 0.01?
L: Revised Head per Hour

We added a worksheet for revised head data containing the times from the data table (Columns A and B) and the revised head data per hour (Column L). All times with no associated head reading (as derived from data worksheet) were then deleted.

Column F is the head reading +/- whatever derived value (if any). The derived value used to revise the head reading is whatever value is calculated by the *Total (Revision)* calculation found in Column I.

Example: Cell F583 is =D583-0.107

Where D583 is the original head reading and 0.107 is the calculated change in head reading needing to be subtracted in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well. The value is calculated in the *Total (Revision)* step described below.

Column G is the annotation "Deleted," the length of time deleted from the trend determination, or the calculated total revision value to be added or subtracted, i.e. "Trend Over 1:30".

Column H is the head change from reading to reading, values generated by subtracting the previous reading from the current reading (current reading for the associated line).

Example: Cell H576 is =D576-D575

Where D576 is the original head reading for that time (same row as Column A) and D575 is the previous, actual head reading.

Column I is one of four calculations:

Deleted Hours – Change in time from the first to last associated deleted reading.

Example: Cell I580 is =A582-A580

For this example, readings from rows 580 through 582 were deleted due to large variances (identified in Column K) assumed associated with the moving of the troll. A582 is the time of the last reading deleted and A580 is the time of the first reading deleted for this set.

Trend – The trend over the previous time equal to the amount of time deleted. Calculated by adding the head change values (Column H) over a period of time equal to the time deleted (derived by the deleted hours calculation).

Example: Cell I579 is =SUM(H577:H579)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H577:H579 is the range of head change values covering the amount of time (identified by the *Deleted Hours* calculation) prior to the first deleted reading.

Difference – The head value change spanning the deleted readings time frame.

Example: Cell I582 is =SUM(H580:H582)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H580:H582 is the range of head change values covering the span of deleted readings.

Total (Revision) – The total calculated change in head value needing to be added (or subtracted) in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well.

Example: Cell I2887 is =0.107+I2886-I2883

Where 0.107 is the previous calculated change in head value, I2886 is the *Difference* (described above) and I2883 is the *Trend* (described above).

Column J is used for notes (identifying missing data periods) or to identify which calculation was used in Column I, i.e. "Hrs Deleted".

Column K is a logical function used to identify a "variance" in head readings greater than 0.01 m (positive or negative). The function looks at the head change value (Column H) and decides if the value identifies a head change of more than 0.01 m.

Example: Cell K581 is

=IF(H581>0.01,"Variance",IF(H581<-0.01,"Variance",""))

Where IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. H581>0.01 is the condition (is the head change value greater than 0.01?), if evaluated true, then the annotation "Variance" is written to the cell. If the evaluation is false, then another IF function evaluates the condition H581<-0.01 (is the head change value less than –0.01?). If this evaluation is true, then the annotation "Variance" is written to the cell. If the evaluation is false, then nothing is written to the cell.

Column L is a logical function that identifies the first reading of the hour and writes its value to the cell. Should the time be other than the first reading of the hour no value is written.

Example: Cell L573 is

=IF((HOUR(A573)>HOUR(A572)),F573,IF((DAY(A573)>DAY(A572)),F573,""))

Where: IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. HOUR is the name of the function that identifies the hour value from a referenced cell. DAY is the name of the function that identifies the day value from a referenced cell. The condition asks if the hour value of cell A573 is greater than the hour value of cell A572. If the evaluation is true (meaning the reading is from a new hour), then the revised head value (F573) is written to the cell. If the evaluation is false, then another IF function evaluates the condition of if the day value from A573 is greater than the day value from A572. If the evaluation is true (meaning the reading is from a new day), then the revised head value (F573) is written to the cell. If the evaluation is false, then nothing is written to the cell.

The head values written in Column L (described above) and the corresponding times from the same row of columns A and B are transferred to file ***H-15-troll_Revised_Graph.xls*** to create a data file of a more manageable size. The date and time columns are merged into a new column A, and the hourly head values are put in column C. A column B of "Elapsed time since 8/6/1981 12:00 (s)" was created.

The compiled raw data from ***H-15-troll.xls*** are shown graphically in Figure 43. Figure 44 shows the data written from ***H-15-troll_revised.xls*** to ***H-15-troll_Revised_Graph.xls*** for use in T-field calibration.

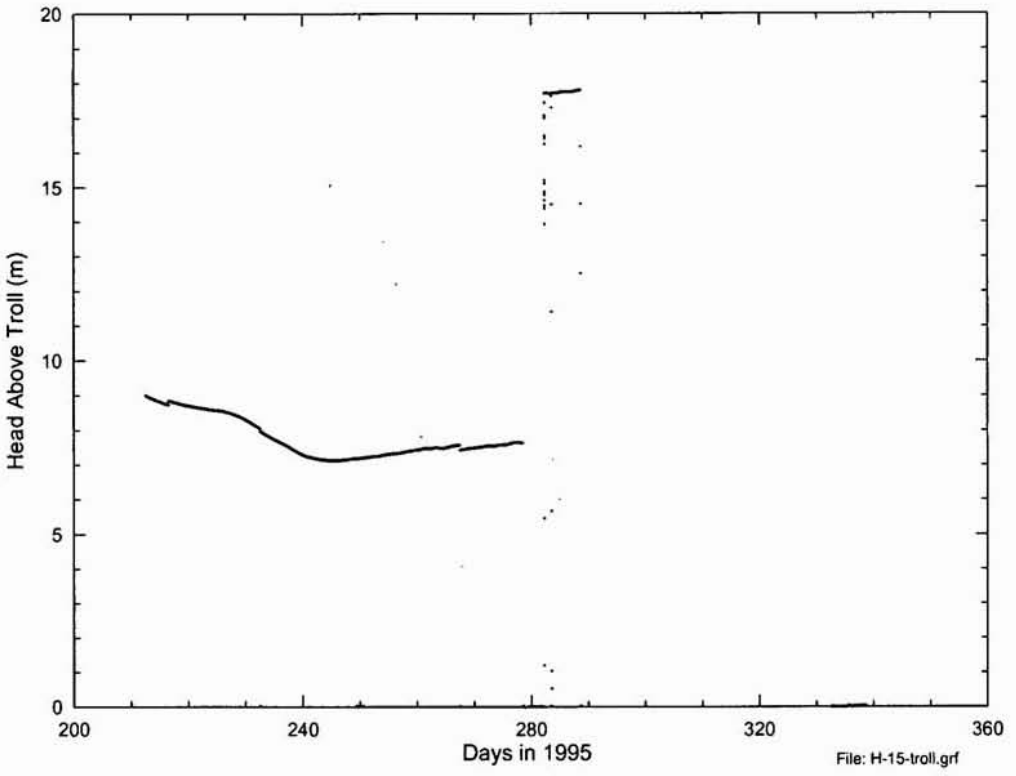

Figure 43. H-15 Raw Troll Data.

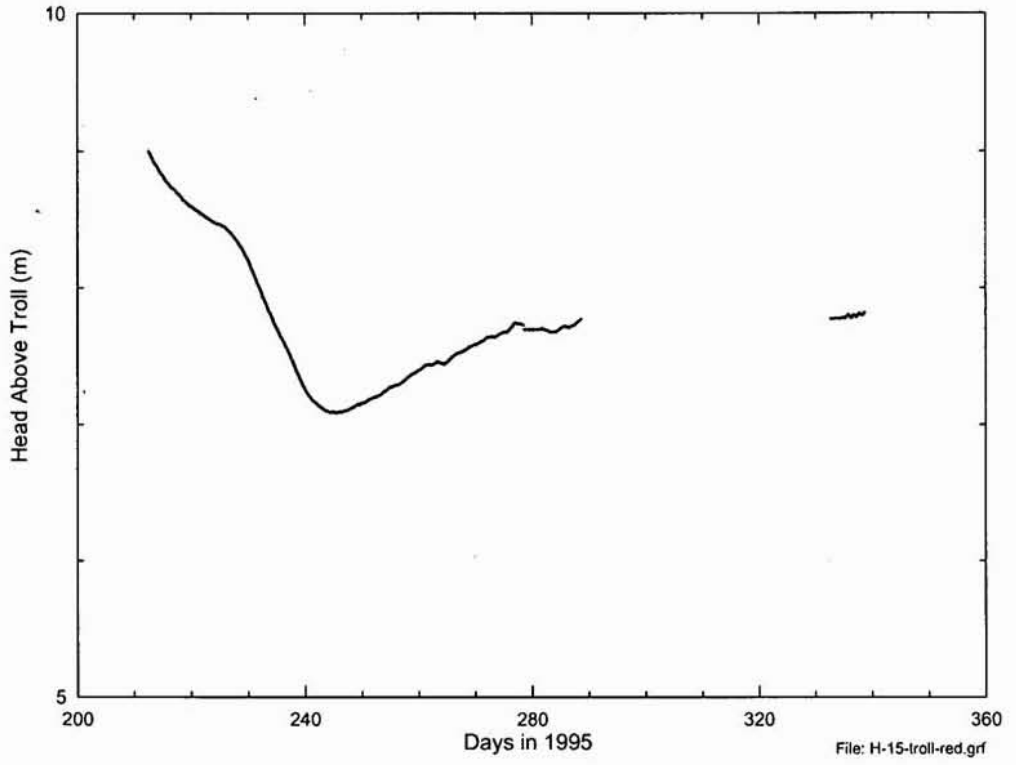

Figure 44. H-15 Reduced Troll Data.

The next step in the data-reduction process was to reconcile the Troll data, which are expressed in meters of freshwater head relative to the position of the Troll, with water-level measurements made in the well. To do this, the water-level measurements were first converted to freshwater heads by converting the measurement from depth to water from top of casing to height of water column above the center of the Culebra. The height of this column was then multiplied by the specific gravity of the fluid in the well, and added to the elevation of the center of the Culebra to obtain the freshwater head. These conversions are shown in the file ***H-15-waterlevels.xls***, which also provides references for the elevations and specific-gravity values used. Next, two water-level measurements (anchor points) were identified that were made at approximately the same times as Troll measurements in the two continuous segments of data shown in Figure 44. These measurements were made on 8/17/1995 and 12/4/1995. The first anchor point was used to convert the Troll measurements made between 8/1/1995 and 10/16/1995 to freshwater heads, and the second anchor point was used to convert the data from 11/29/1995 to 12/5/1995. These conversions are shown in column D of ***H-15-troll_Revised_Graph.xls***. These anchor points, and the agreement they provide between the Troll and water-level measurements, are shown in Figure 45. The merged data sets, with the water-level measurements made during the times the Troll was in operation removed, are shown in Figure 46 and stored in file ***H-15-combined.xls***.

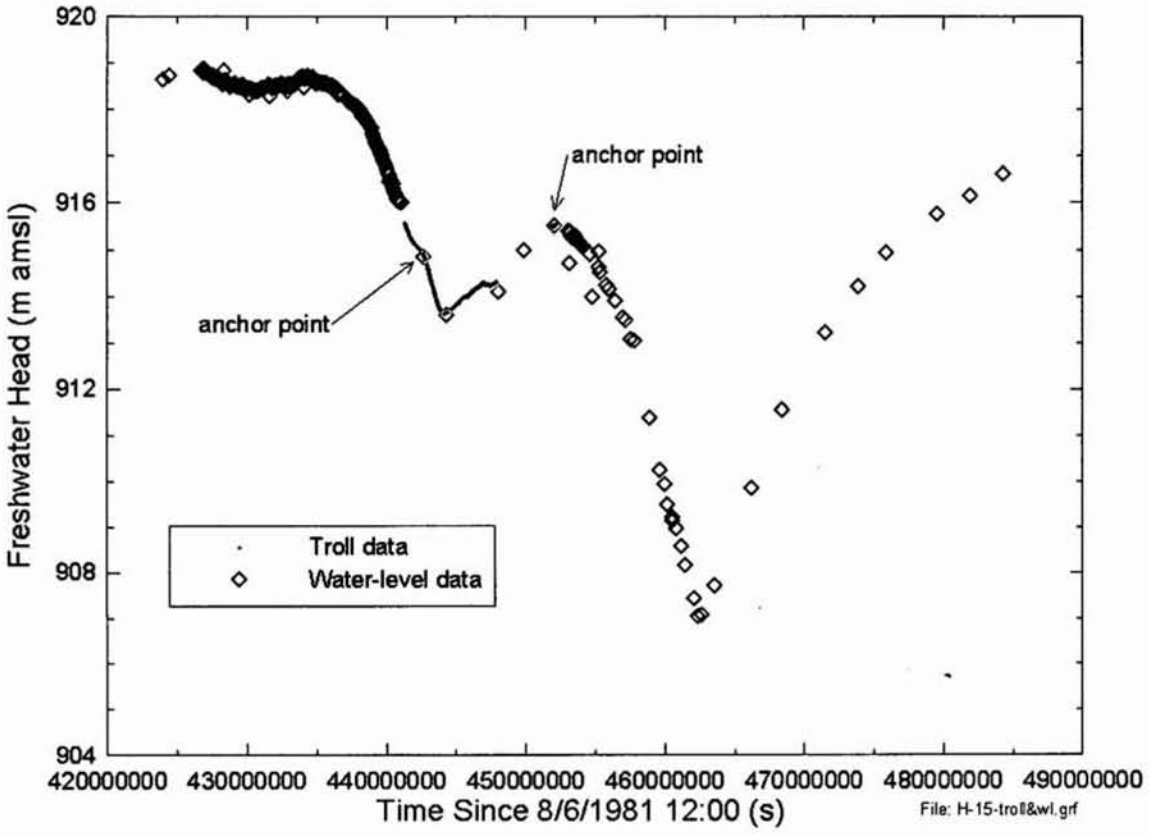

Figure 45. H-15 Troll data reconciled with water-level data.

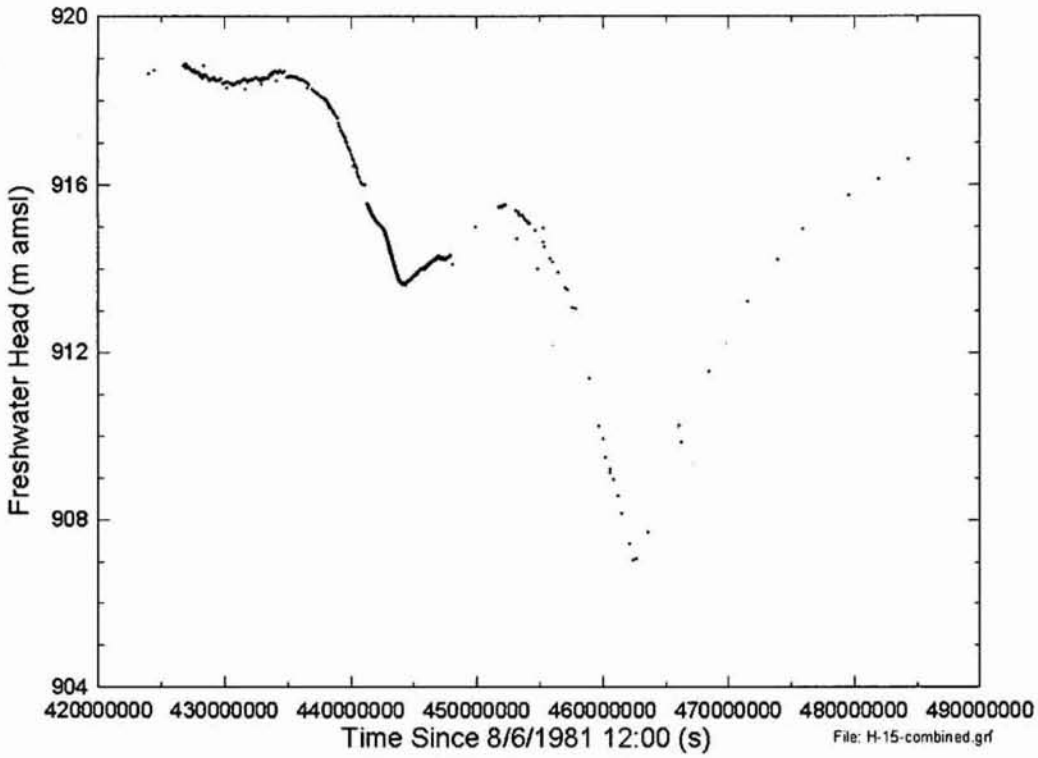

Figure 46. H-15 combined Troll and water-level data.

4.5.10 H-17 Response

Culebra water levels were measured in H-17 by WTS (ERMS 525179) and Sandia National Laboratories (SNL) (ERMS 422157) in 1995 and 1996. File ***H-17-waterlevels.xls*** shows the water-level data from 1995 and 1996 and conversion of water levels to freshwater heads. The freshwater-head data are shown in Figure 47.

4.5.11 P-17 Response

Culebra water levels were measured in P-17 by WTS (ERMS 525179) and SNL (ERMS 422157) in 1995 and 1996. File ***P-17-waterlevels.xls*** shows the water-level data from 1995 and 1996 and conversion of water levels to freshwater heads. The freshwater-head data are shown in Figure 48.

4.5.12 WIPP-21 Response

Culebra water levels were measured in WIPP-21 by WTS (ERMS 525179) and SNL (ERMS 422157) in 1995 and 1996. File ***WIPP-21-waterlevels.xls*** shows the water-level data from 1995 and 1996 and conversion of water levels to freshwater heads. The freshwater-head data are shown in Figure 49.

4.5.13 WQSP-4 Response

Culebra water levels were measured in WQSP-4 by WTS (ERMS 525179) and SNL (ERMS 422157) in 1995 and 1996. File ***WQSP-4-waterlevels.xls*** shows the water-level data from 1995 and 1996 and conversion of water levels to freshwater heads. The freshwater-head data are shown in Figure 50.

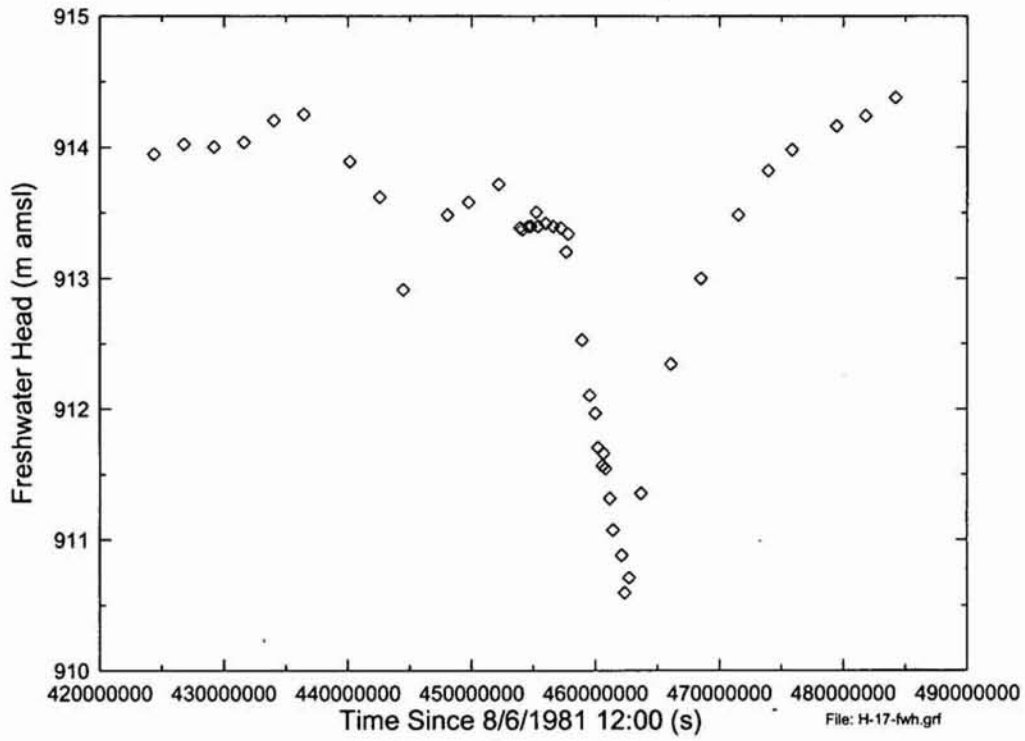

Figure 47. H-17 1995-96 freshwater heads.

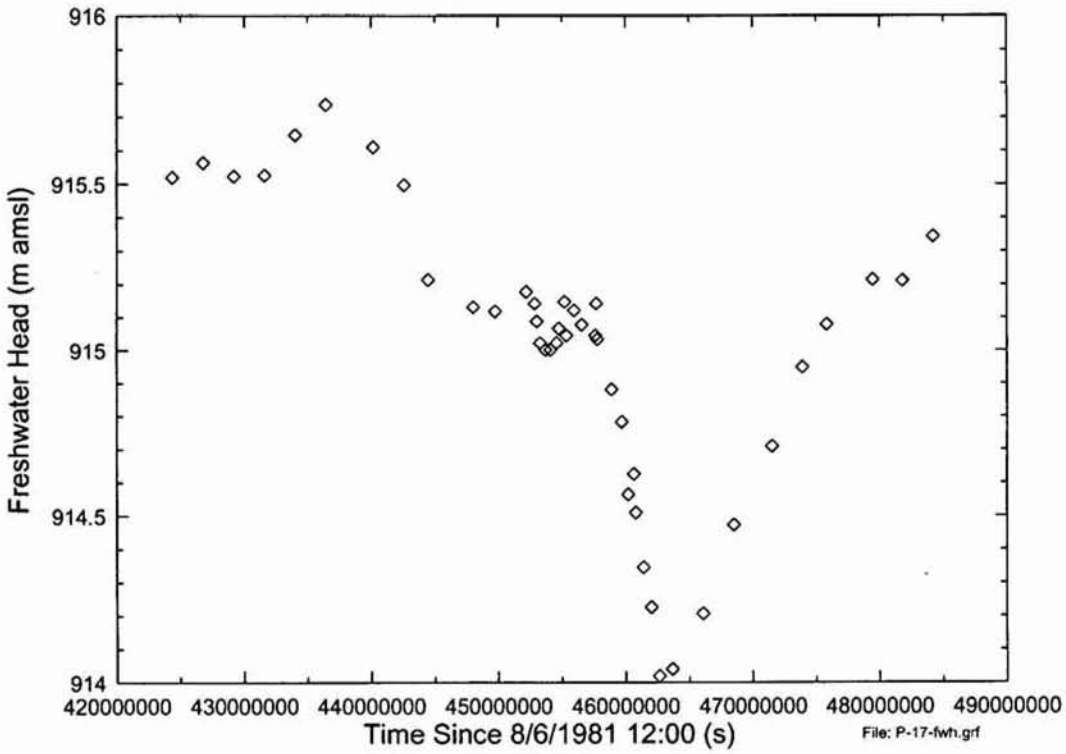

Figure 48. P-17 1995-96 freshwater heads.

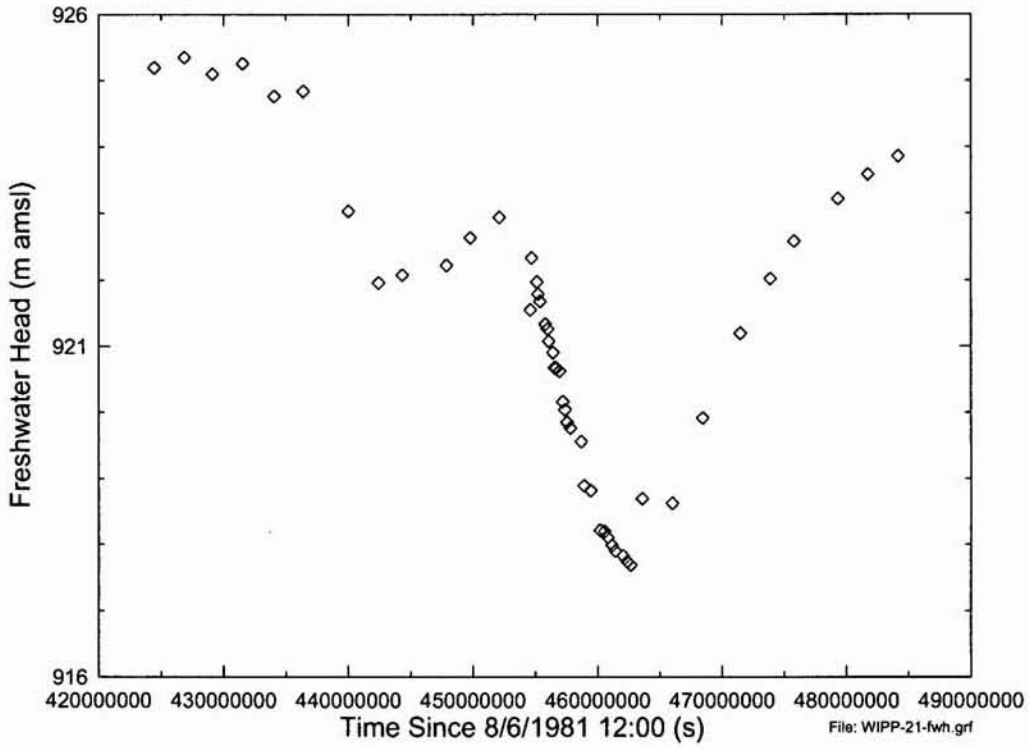

Figure 49. WIPP-21 1995-96 freshwater heads.

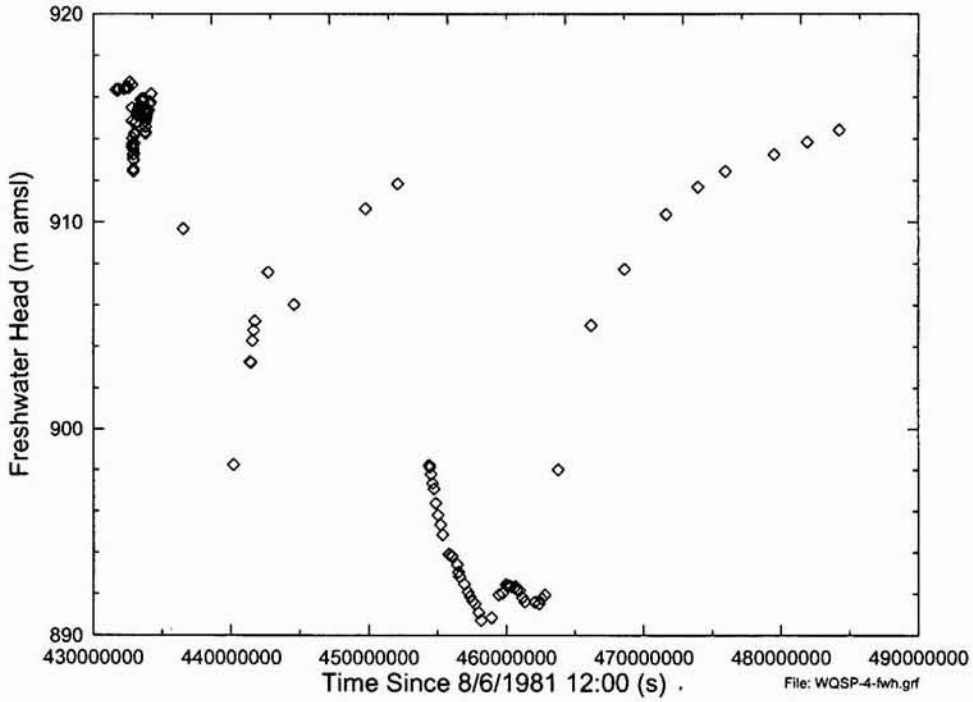

Figure 50. WQSP-4 1995-96 freshwater heads.

4.5.14 WQSP-5 Response

The head readings from the Troll in WQSP-5 were compiled in the Excel workbook ***WQSP-5-troll.xls***. The data, 61,816 readings over approximately a 4-month period, contain erroneous readings and offsets caused by the removal and replacement of the instrument. By creating functions within Excel, the process of identifying the suspect readings, evaluating trends and applying corrective, mathematically derived values to the readings was automated; the analysis of the data could then focus on actual head changes. The volume of revised readings was then reduced to the first reading of each hour, over the period, to further simplify and make the data more manageable. The resultant file, ***WQSP-5-troll_revised.xls***, contains all the original data plus the functions and revised values, as described below.

Added Columns:

F: Revised Head
G: Action Taken
H: Head Change
I: Calculations
J: Notes
K: ABS Variance > 0.01?
L: Revised Head per Hour

We added a worksheet for revised head data containing the times from the data table (Columns A and B) and the revised head data per hour (Column L). All times with no associated head reading (as derived from data worksheet) were then deleted.

Column F is the head reading +/- whatever derived value (if any). The derived value used to revise the head reading is whatever value is calculated by the *Total (Revision)* calculation found in Column I.

Example: Cell F189 is =D189-0.048

Where D189 is the original head reading and 0.048 is the calculated change in head reading needing to be subtracted in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well. The value is calculated in the *Total (Revision)* step described below.

Column G is the annotation "Deleted," the length of time deleted from the trend determination, or the calculated total revision value to be added or subtracted, i.e. "Trend Over 1:30".

Column H is the head change from reading to reading, values generated by subtracting the previous reading from the current reading (current reading for the associated line).

Example: Cell H180 is =D180-D179

Where D180 is the original head reading for that time (same row as Column A) and D179 is the previous, actual head reading.

Column I is one of four calculations: '

Deleted Hours – Change in time from the first to last associated deleted reading.

Example: Cell I183 is =A188-A183

For this example, readings from rows 183 through 188 were deleted due to large variances (identified in Column K) assumed associated with the moving of the troll. A188 is the time of the last reading deleted and A183 is the time of the first reading deleted for this set.

Trend – The trend over the previous time equal to the amount of time deleted. Calculated by adding the head change values (Column H) over a period of time equal to the time deleted (derived by the deleted hours calculation).

Example: Cell I182 is =SUM(H172:H182)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H172:H182 is the range of head change values covering the amount of time (identified by the *Deleted Hours* calculation) prior to the first deleted reading.

Difference – The head value change spanning the deleted readings time frame.

Example: Cell I188 is =SUM(H183:H188)

Where SUM is the name of the function that adds a series of values (found in parenthesis) and H183:H188 is the range of head change values covering the span of deleted readings.

Total (Revision) – The total calculated change in head value needing to be added (or subtracted) in order to eliminate erroneous readings and account for trend and equilibrium values after the troll is relocated within the well.

Example: Cell I1450 is =0.048+I1449-I1390

Where 0.048 is the previous calculated change in head value, I449 is the *Difference* (described above) and I1390 is the *Trend* (described above).

Column J is used for notes (identifying missing data periods) or to identify which calculation was used in Column I, i.e. "Hrs Deleted".

Column K is a logical function used to identify a "variance" in head readings greater than 0.01 m (positive or negative). The function looks at the head change value (Column H) and decides if the value identifies a head change of more than 0.01 m.

Example: Cell K184 is

=IF(H184>0.01,"Variance",IF(H184<-0.01,"Variance",""))

Where IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. H184>0.01 is the condition (is the head change value greater than 0.01?), if evaluated true, then the annotation "Variance" is written to the cell. If the evaluation is false, then another IF function evaluates the condition H184<-0.01 (is the head change value less than –0.01?). If this evaluation is true, then the annotation "Variance" is written to the cell. If the evaluation is false, then nothing is written to the cell.

Column L is a logical function that identifies the first reading of the hour and writes its value to the cell. Should the time be other than the first reading of the hour no value is written.

Example: Cell L183 is

=IF((HOUR(A183)>HOUR(A182)),F183,IF((DAY(A183)>DAY(A182)),F183,""))

Where: IF is the name of the function that returns one value if the conditions specified evaluates to true and another if false. HOUR is the name of the function that identifies the hour value from a referenced cell. DAY is the name of the function that identifies the day value from a referenced cell. The condition asks if the hour value of cell A183 is greater than the hour value of cell A182. If the evaluation is true (meaning the reading is from a new hour), then the revised head value (F183) is written to the cell. If the evaluation is false, then another IF function evaluates the condition of if the day value from A183 is greater than the day value from A182. If the evaluation is true (meaning the reading is from a new day), then the revised head value (F183) is written to the cell. If the evaluation is false, then nothing is written to the cell.

The head values written in Column L (described above) and the corresponding times from the same row of columns A and B are transferred to file ***WQSP-5-troll_Revised_Graph.xls*** to create a data file of a more manageable size. The date and time columns are merged into a new column A, and the hourly head values are put in column C. A column B of "Elapsed time since 8/6/1981 12:00 (s)" was created.

The compiled raw data from ***WQSP-5-troll.xls*** are shown graphically in Figure 51. Figure 52 shows the data written from ***WQSP-5-troll_revised.xls*** to ***WQSP-5-troll_Revised_Graph.xls*** for use in T-field calibration. Note that the data-reduction process resulted in some negative head values. This is irrelevant because T-field calibration will consider only changes in head.

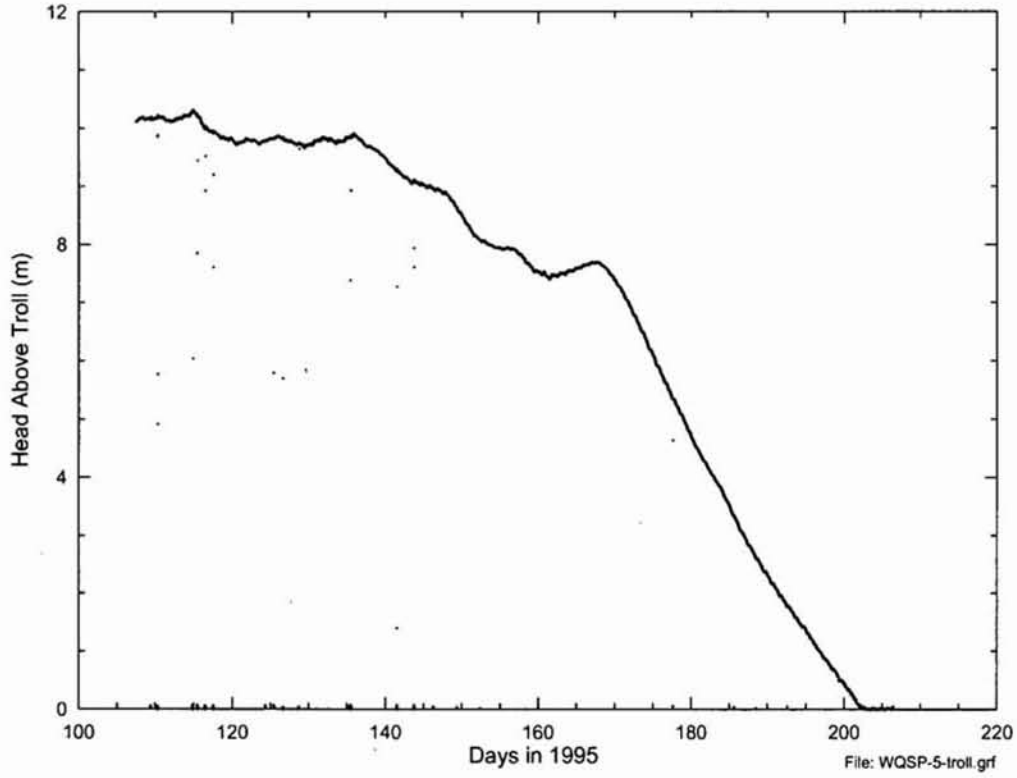

Figure 51. WQSP-5 Raw Troll Data.

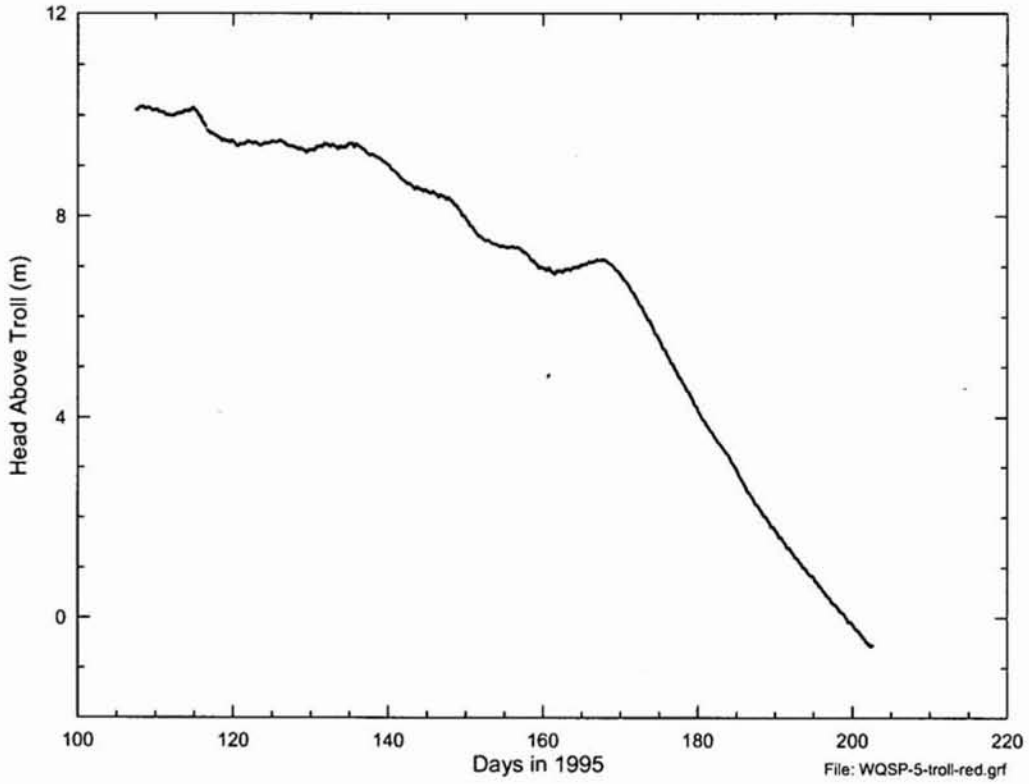

Figure 52. WQSP-5 Reduced Troll Data.

The next step in the data-reduction process was to reconcile the Troll data, which are expressed in meters of freshwater head relative to the position of the Troll, with water-level measurements made in the well. To do this, the water-level measurements were first converted to freshwater heads by converting the measurement from depth to water from top of casing to height of water column above the center of the Culebra. The height of this column was then multiplied by the specific gravity of the fluid in the well, and added to the elevation of the center of the Culebra to obtain the freshwater head. These conversions are shown in the file ***WQSP-5-waterlevels.xls***, which also provides references for the elevations and specific-gravity values used. Next, a water-level measurement (anchor point) was identified that was made at approximately the same time as a Troll measurement. This measurement was made on 7/19/1995 and was used to convert all of the Troll measurements to freshwater heads. These conversions are shown in column D of file ***WQSP-5-troll_Revised_Graph.xls***. This anchor point, and the agreement it provides between the Troll and water-level measurements, are shown in Figure 53. The merged data sets, with the water-level measurements made during the times the Troll was in operation removed, are shown in Figure 54 and stored in file ***WQSP-5-combined.xls***.

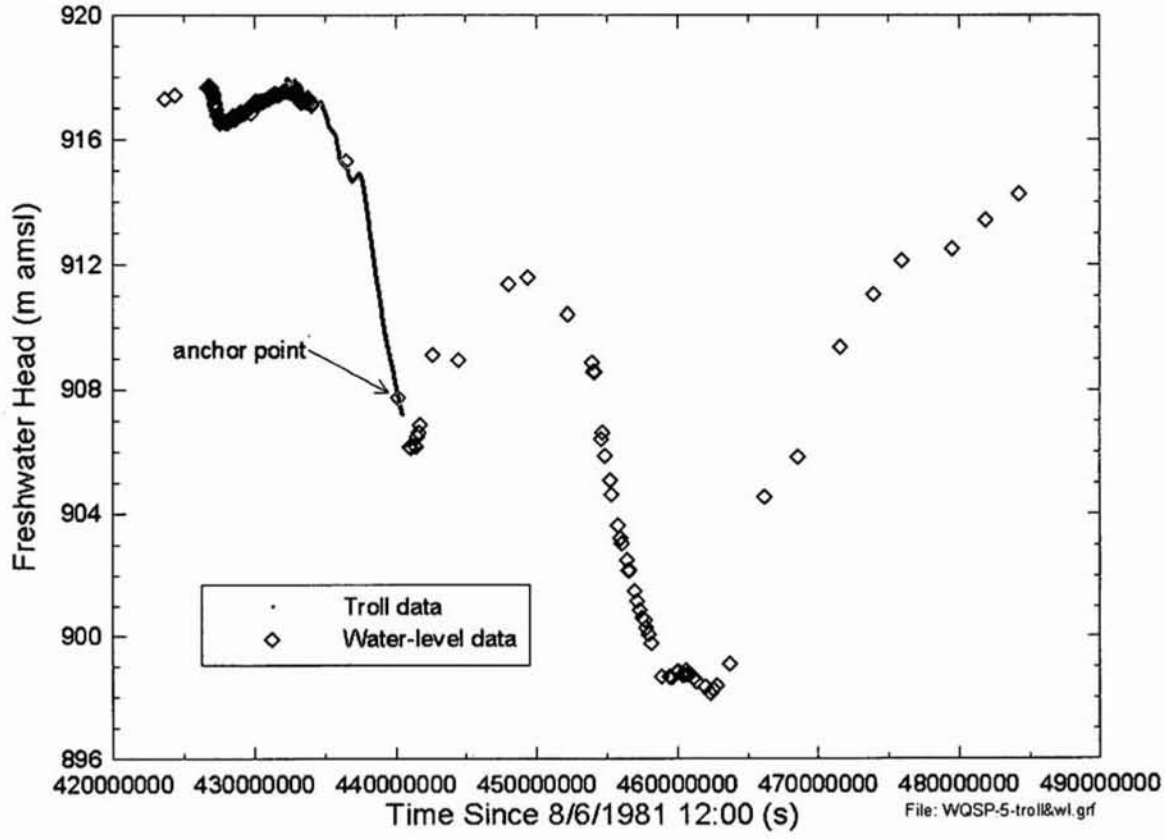

Figure 53. WQSP-5 Troll data reconciled with water-level data.

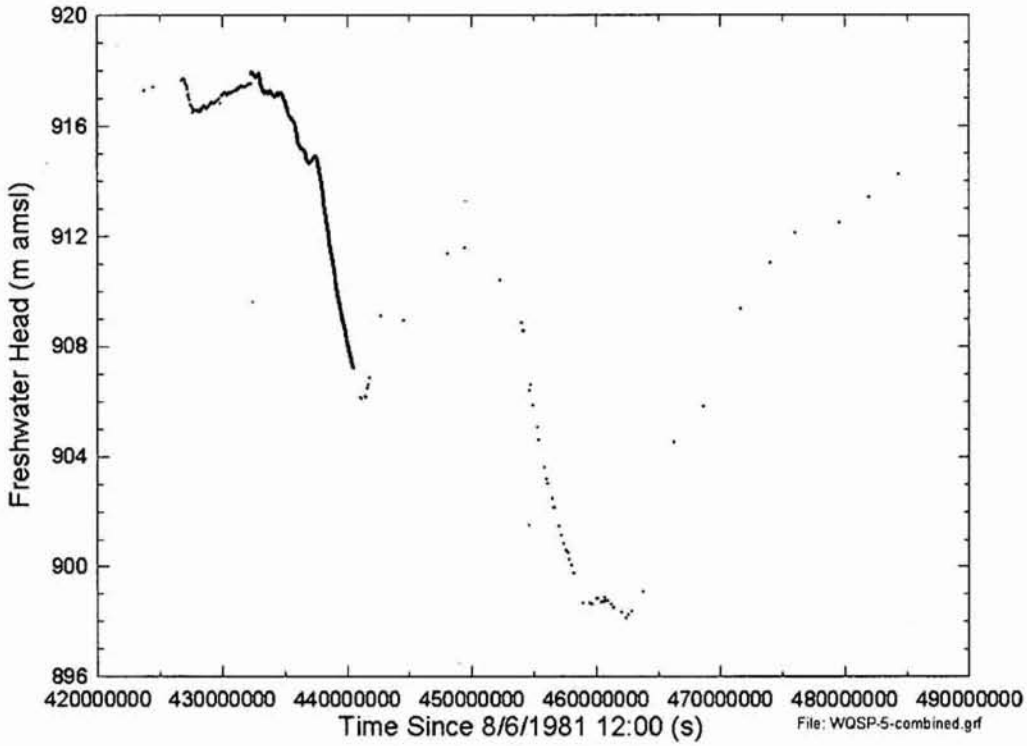

Figure 54. WQSP-5 combined Troll and water-level data.

4.6 WQSP-1 Pumping Tests

The WQSP-1 pumping test was conducted by pumping WQSP-1 from January 25 to 28, 1996 at an average rate of 0.43 L/s (Beauheim and Ruskauff, 1998). Responses to the pumping were measured in wells H-18 and WIPP-13 using Trolls. Beauheim and Ruskauff (1998) used compensated pressures calculated in ERMS 238487 that compensate for the effects of changes in barometric pressure for their test interpretations. Those compensated pressures will be used in transient Culebra model calibration as well.

4.6.1 H-18 Response

The data for H-18 were taken from file ***H18WQSP1.xls*** in ERMS 238487. The "Time since 25.55439 (hr)", "H-18 Pres (psig)", and "Comp. P B.E.=0.6" columns beginning with the first positive time entry were inserted in Excel file ***WQSP1H18.xls*** as columns A (Time Since Pump On in WQSP-1 (hr)), C (Pressure (psi)), and D (Compensated Pressure with B.E.=0.6 (psi)), respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (456628680 s; see Table 1). Column E was then created of "Drawdown (m freshwater)" by multiplying the change in compensated pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft).

Examination of the hydrograph of H-18 water levels since 1988 shows that water levels were generally rising before and after the WQSP-1 pumping test (Figure 55). Between the beginning of 1994 and the middle of 1997, the water level was rising at a rate of 0.368 m/yr. This rise would not be accounted for in any way during transient calibration of the Culebra T fields, so we

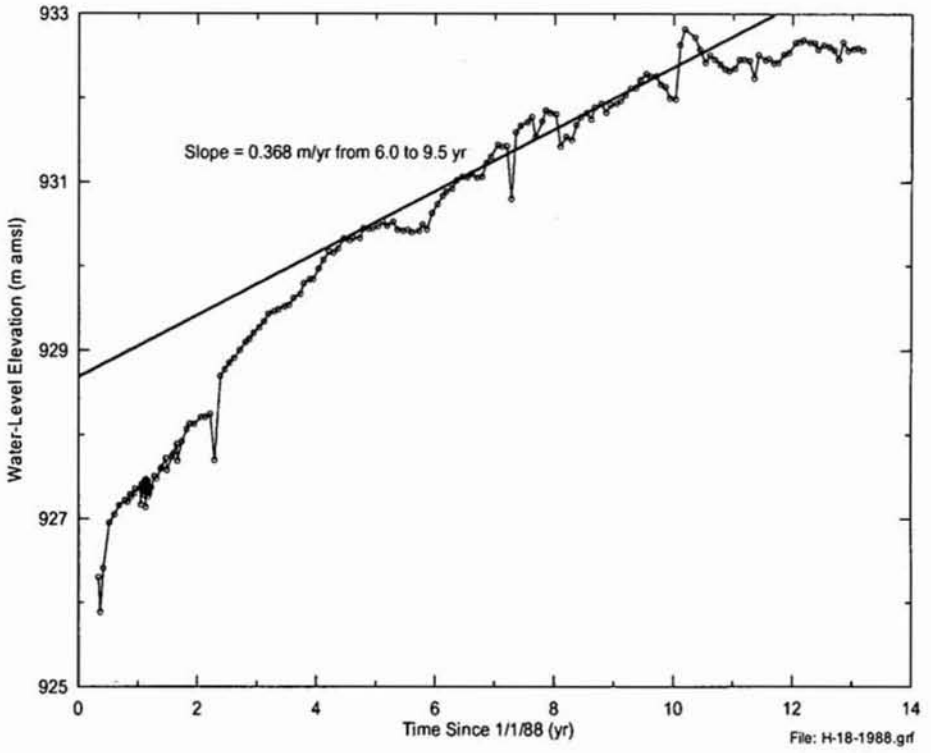

Figure 55. Trend in H-18 water levels over period of WQSP-1 and WQSP-2 pumping tests.

needed to remove the trend from the data to be used. Consequently, we created a column F (Drawdown (m freshwater) Compensated for 0.368 m/yr rising trend) by subtracting from Column E the elapsed time (hr) since the initial measurement multiplied by 0.368 m/yr *1.044 (density of H-18 fluid (Cauffman et al., 1990, p. F-110))/8760 hr/yr. A plot of this corrected Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 56.

4.6.2 WIPP-13 Response

The data for WIPP-13 were taken from file ***W13WQSP1.xls*** in ERMS 238487. The "Pumping dtime (hr)", "WIPP-13 Pressure (psig)", and "W-13 Pres. B.E.=0.7" columns beginning with the first positive time entry were inserted in Excel file ***WQSP1W13.xls*** as columns A (Time Since Pump On in WQSP-1 (hr)), C (Pressure (psi)), and D (Compensated Pressure with B.E.=0.7 (psi)), respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (237502860 s; see Table 1). Column E was then created of "Drawdown (m freshwater)" by multiplying the change in compensated pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft).

Examination of the hydrograph of WIPP-13 water levels since 1988 shows that water levels were generally rising before and after the WQSP-1 pumping test (Figure 57). Between early 1994 and the middle of 1997, the water level was rising at a rate of 0.1765 m/yr. This rise would not be accounted for in any way during transient calibration of the Culebra T fields, so we needed to remove the trend from the data to be used. Consequently, we created a column F (Drawdown (m

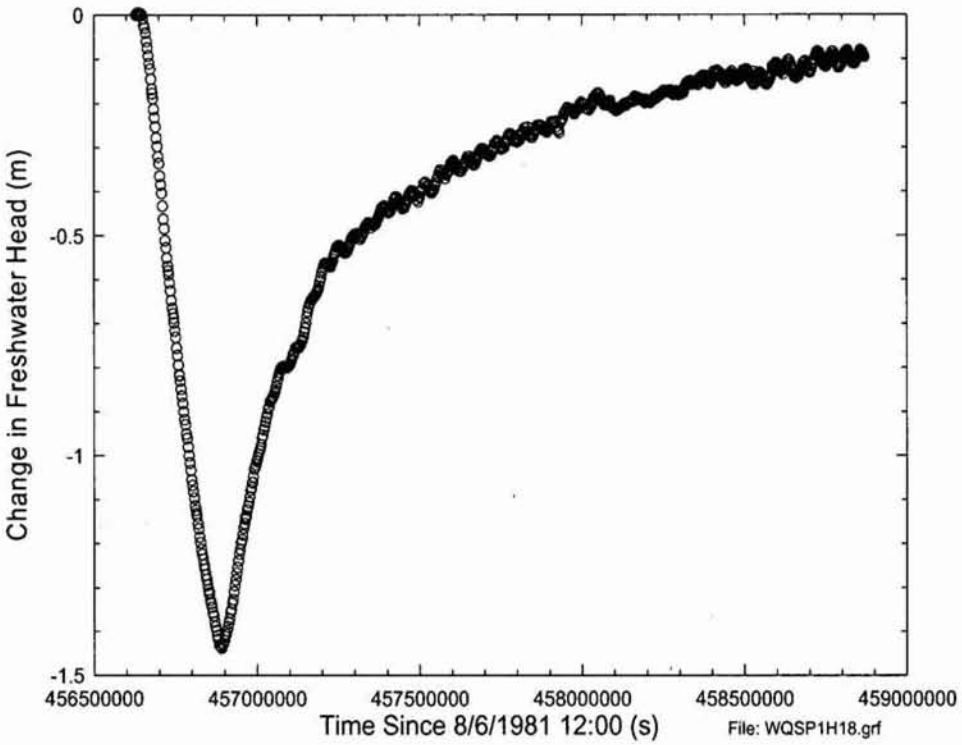

Figure 56. H-18 response to WQSP-1 pumping test.

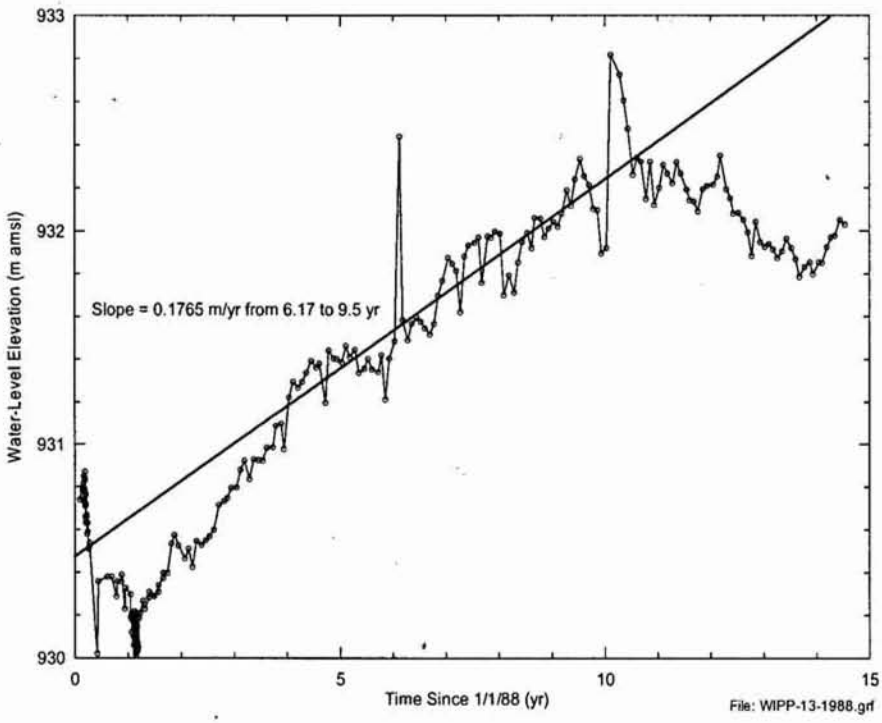

Figure 57. Trend in WIPP-13 water levels over period of WQSP-1 and WQSP-2 pumping tests.

freshwater) Compensated for 0.1765 m/yr rising trend) by subtracting from Column E the elapsed time (hr) since the initial measurement multiplied by 0.1765 m/yr *1.029 (density of WIPP-13 fluid (Cauffman et al., 1990, p. F-137))/8760 hr/yr. A plot of this corrected Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 58.

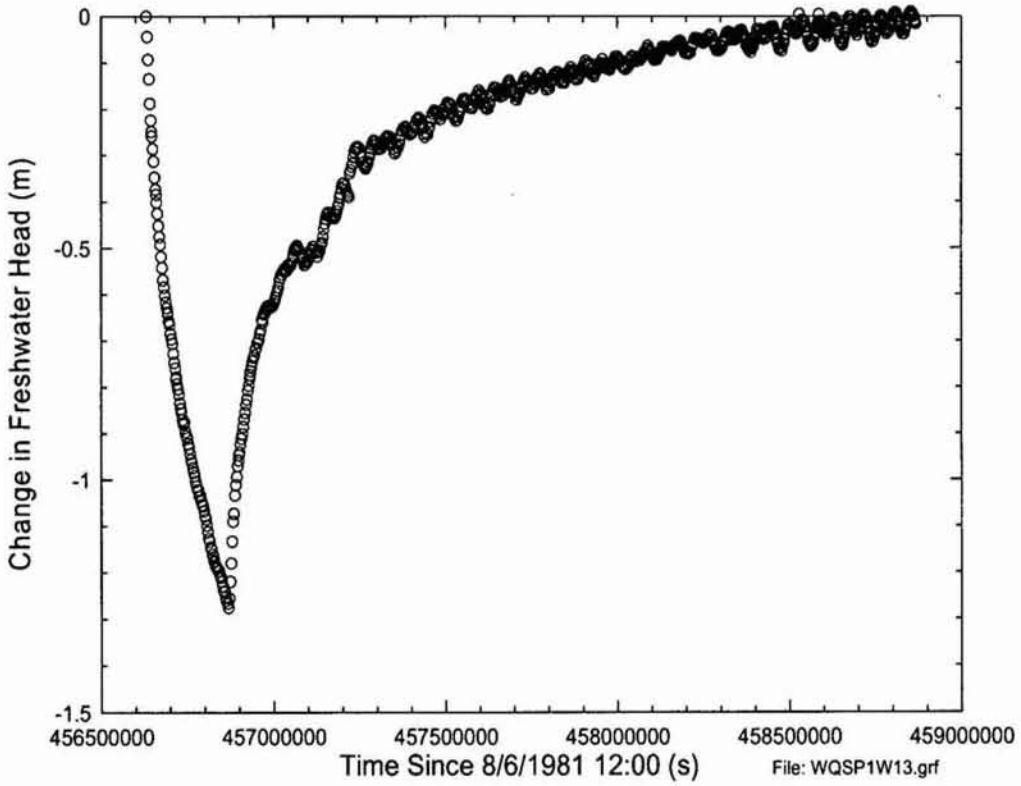

Figure 58. WIPP-13 response to WQSP-1 pumping test.

4.7 WQSP-2 Pumping Test

The WQSP-2 pumping test was conducted by pumping WQSP-2 from February 20 to 24, 1996 at an average rate of 0.45 L/s (Beauheim and Ruskauff, 1998). Responses to the pumping were measured in wells DOE-2, H-18, and WIPP-13 using Trolls. Water levels were measured in wells WQSP-1 and WQSP-3. Beauheim and Ruskauff (1998) used compensated pressures calculated in ERMS 238487 that compensate for the effects of changes in barometric pressure for their interpretations of the responses of DOE-2, H-18, WIPP-13, and WQSP-1. Those compensated pressures will be used in transient Culebra model calibration as well.

4.7.1 DOE-2 Response

The data for DOE-2 were taken from file ***DOE2WQSP2.csv*** in ERMS 238487. The "Time since WQSP-2 pump on (hr)" and "Pressure with B.E. 0.7 (psig)" columns beginning with the first positive time entry were inserted in Excel file ***WQSP2DOE2.xls*** as columns A (Time Since Pump On in WQSP-2 (hr)) and C (Compensated Pressure with B.E.=0.7 (psi)), respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for

the simulations (456628680 s; see Table 1). Column D was then created of "Drawdown (m freshwater)" by multiplying the change in compensated pressure (psi (lb/in^2)) from the initial pressure by ((144 in^2/ft^2)/(62.4 lb/ft^3 of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 59.

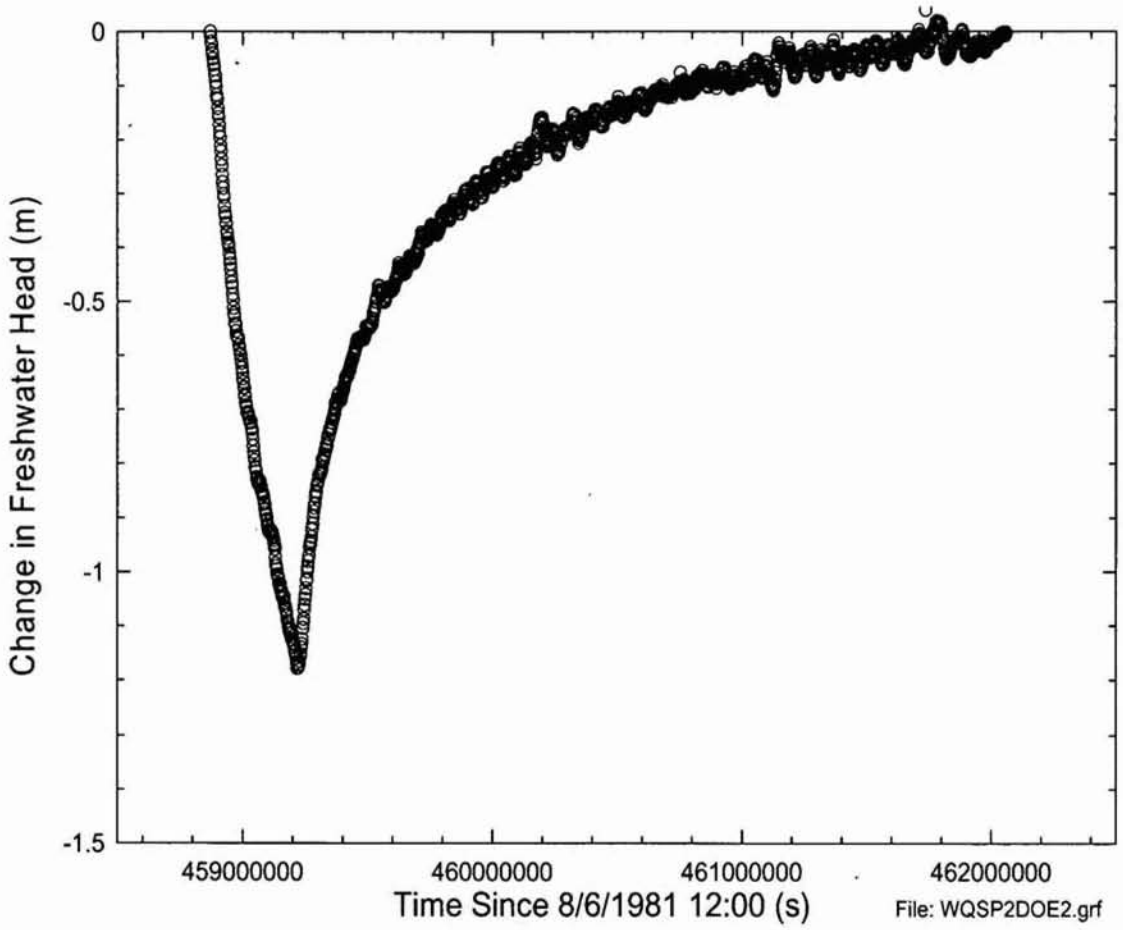

Figure 59. DOE-2 response to WQSP-2 pumping test.

4.7.2 H-18 Response

The data for H-18 were taken from file ***H18WQSP2.csv*** in ERMS 238487. The "Time since WQSP-2 pump on (hr)" and "Bar. Comp. Pressure B.E.=0.6 (psig)" columns beginning with the first positive time entry were inserted in Excel file ***WQSP2H18.xls*** as columns A (Time Since Pump On in WQSP-2 (hr)) and C (Compensated Pressure with B.E.=0.6 (psi)), respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (456628680 s; see Table 1). Column D was then created of "Drawdown (m freshwater)" by multiplying the change in compensated pressure (psi (lb/in^2)) from the initial pressure by ((144 in^2/ft^2)/(62.4 lb/ft^3 of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 60.

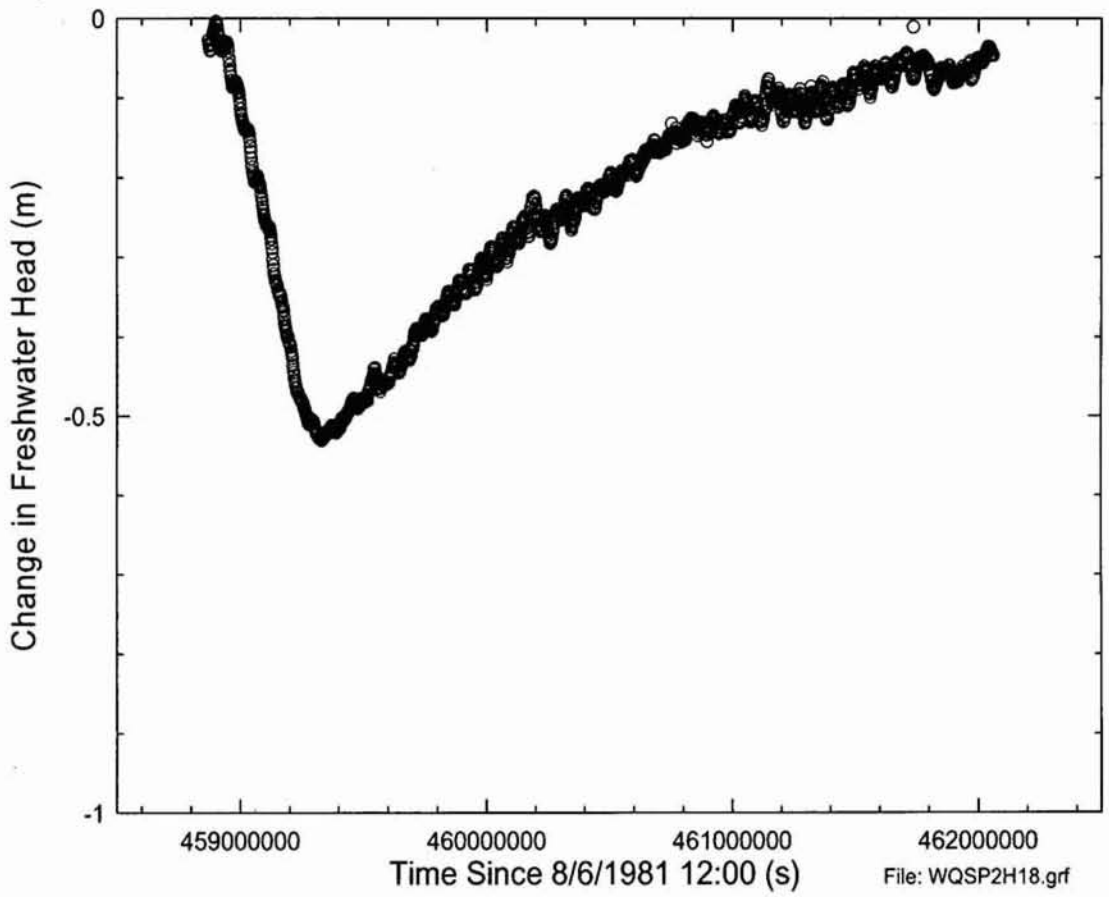

Figure 60. H-18 response to WQSP-2 pumping test.

4.7.3 WIPP-13 Response

The data for WIPP-13 were taken from file ***W13WQSP2.csv*** in ERMS 238487. The "Time since WQSP-2 pump on (hr)" and "Barometric corrected pressure B.E.=0.7" columns beginning with the first positive time entry were inserted in Excel file ***WQSP2W13.xls*** as columns A (Time Since Pump On in WQSP-2 (hr)) and C (Compensated Pressure with B.E.=0.7 (psi)), respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (456628680 s; see Table 1). Column D was then created of "Drawdown (m freshwater)" by multiplying the change in compensated pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). As discussed above in Section 4.7.2, we compensated for a pre-existing rising trend (Figure 57) by creating a column E (Drawdown (m freshwater) Compensated for 0.1765 m/yr rising trend) by subtracting from Column D the elapsed time (hr) since the initial measurement multiplied by 0.1765 m/yr *1.029 (density of WIPP-13 fluid (Cauffman et al., 1990, p. F-137))/8760 hr/yr. A plot of this corrected Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 61. Note that even with the compensation for the pre-existing rising trend, the WIPP-13 water level recovered beyond its initial value. This will present a problem in Culebra T field calibration.

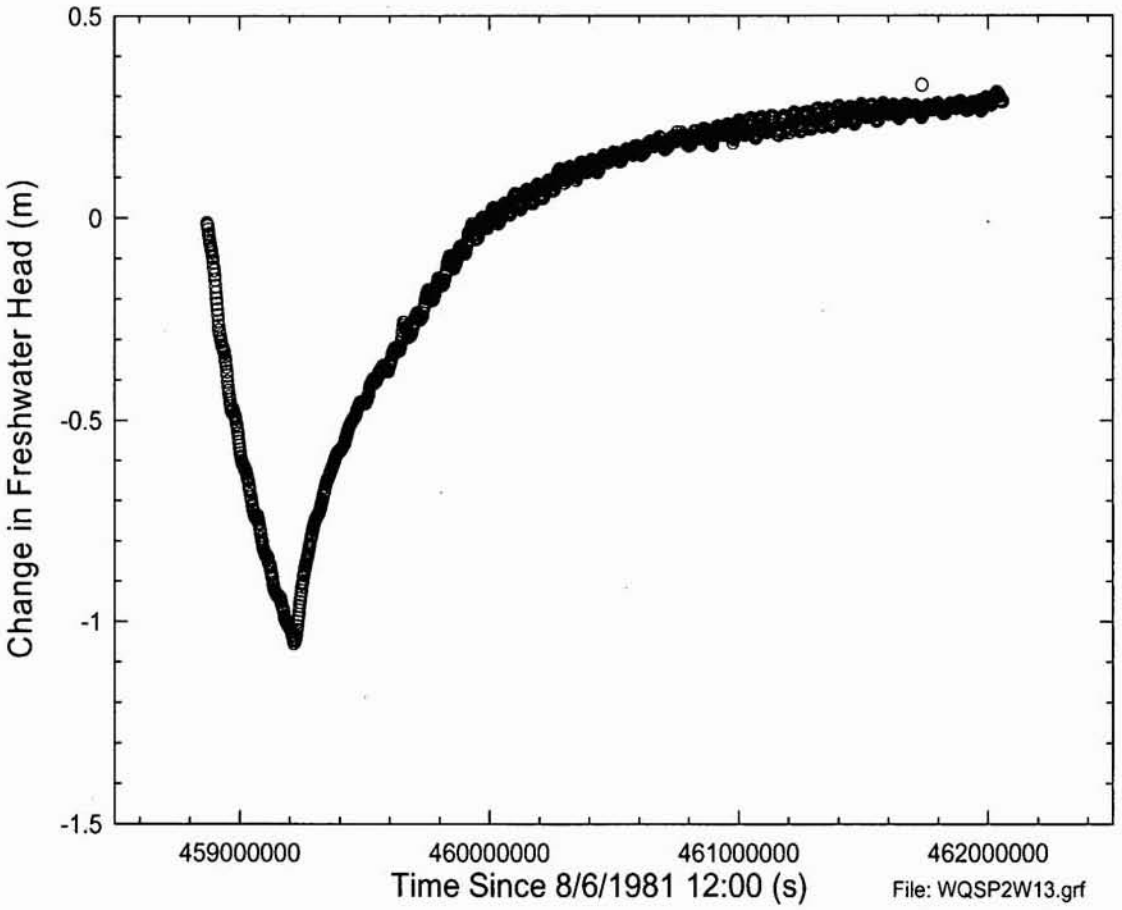

Figure 61. WIPP-13 response to WQSP-2 pumping test.

4.7.4 WQSP-1 Response

The data for WQSP-1 were taken from file ***WQSP1WQSP2.csv*** in ERMS 238487. The "Time pump on (hr)" and "Pressure B.E.=0.8" columns beginning with the first positive time entry were inserted in Excel file ***WQSP2WQSP1.xls*** as columns A (Time Since Pump On in WQSP-2 (hr)) and C (Compensated Pressure with B.E.=0.8 (psi)), respectively. Column B was created of "Time Since Start of Simulation (s)" by adding the elapsed times from column A (converted from hr to s) to the starting time of the test relative to the starting time for the simulations (456628680 s; see Table 1). Column D was then created of "Drawdown (m freshwater)" by multiplying the change in compensated pressure (psi (lb/in^2)) from the initial pressure by (($144\ in^2/ft^2$)/($62.4\ lb/ft^3$ of freshwater))*(0.3048 m/ft). A plot of Change in Freshwater Head versus Time Since 8/6/1981 12:00 is shown in Figure 62.

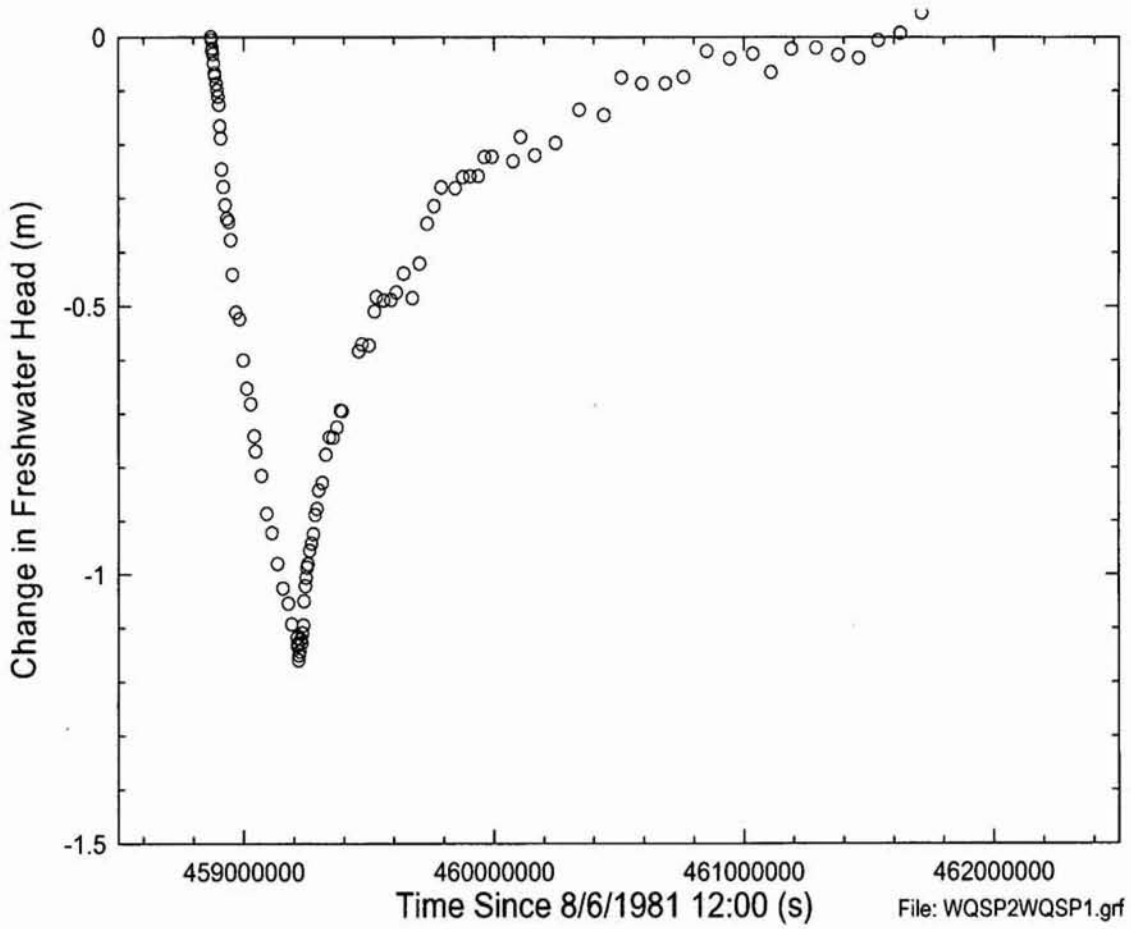

Figure 62. WQSP-1 response to WQSP-2 pumping test.

4.7.5 WQSP-3 Response

Culebra water-level measurements recorded in ERMS 422385 were entered into Excel file ***WQSP2WQSP3.xls***. A plot of Water-Level Elevation versus Time Since 8/6/1981 12:00 is shown in Figure 63. The plot shows no apparent response at WQSP-3 while WQSP-2 was being pumped. A slight (0.1-0.2 m) delayed drawdown response may have occurred several days after pumping ceased at WQSP-2, but we cannot be sure about this. Transient Culebra T-field calibration should seek to obtain zero drawdown at WQSP-3 in response to the WQSP-2 pumping test.

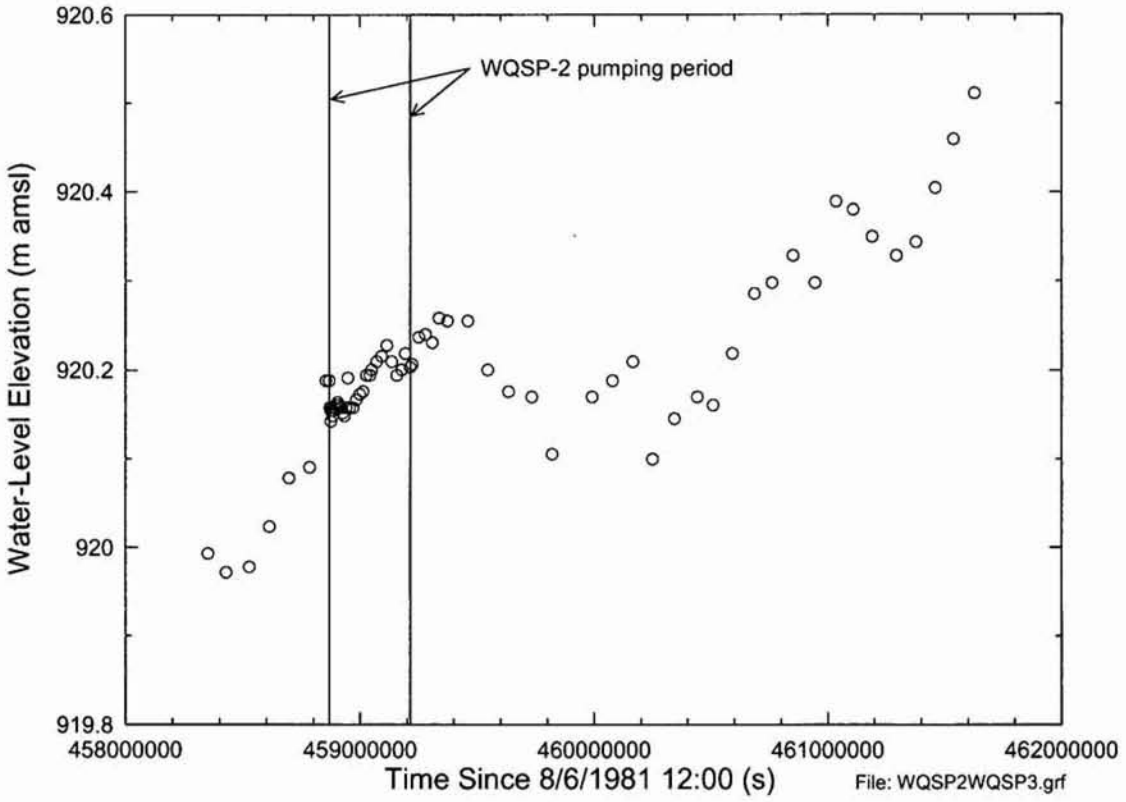

Figure 63. WQSP-3 response to WQSP-2 pumping test.

5. DETERMINATION OF STORATIVITY

Transient calibration of a groundwater flow model requires an estimate of the storativity of the aquifer. For most of the observation-well responses to the pumping tests discussed in this Records Package, values of apparent storativity were derived as part of the hydraulic-test interpretation. The true storativity can only be determined if an aquifer is homogeneous, which is clearly not the case for the Culebra. Hence, we approximate the true storativity from each test by taking the geometric mean of the apparent storativity values. The apparent and geometric-mean storativities are given in Table 5. No interpretation has been made of the responses to the H-19 and H-11 tracer tests discussed in this Records Package. However, Beauheim and Ruskauff (1998, p. 152) inferred a storativity value of 4.9×10^{-5} for the area around H-19 from the responses of the other H-19 wells during the early days of the 1995-96 tracer test. Beauheim and Ruskauff (1998, p. 127) also inferred a geometric-mean storativity of 4.5×10^{-5} for the area around H-11 from the responses of the other H-11 wells during the early days of the 1996 tracer test. These values are also given in Table 5.

The values given in Table 5 show that storativity varies across the WIPP site. Storativities appear to be highest near H-19 and H-11, and lowest around WQSP-2. In addition, the apparent storativities inferred from the well responses to the WIPP-13 test show a bimodal distribution, with the values from DOE-2, H-6b, and WIPP-30 (all to the north of WIPP-13) having a geometric mean of 6.1×10^{-6}, and the values from the other six wells (all to the south of WIPP-13) having a geometric mean of 4.9×10^{-5}. This indicates that a model-calibration procedure that allowed adjustments to both transmissivity and storativity might be preferable to the present procedure that allows adjustments only to transmissivity. For calibration of future generations of Culebra T fields, we will investigate the feasibility of adding storativity as a calibration parameter. But for the current modeling exercise, we will use only a single value of storativity. The overall geometric mean of the geometric-mean values from the seven tests listed in Table 5 is 2.1×10^{-5}, so that is the value that will be used in Culebra T-field calibration.

Table 5. Summary of Storativity Information.

Test Well	Observation Well	Apparent Storativity	Geometric-Mean Storativity	Reference
H-3b2	DOE-1	1.0×10^{-5}	1.6×10^{-5}	Beauheim (1987a, Table 6-4)
	H-1	2.7×10^{-5}		
	H-2b2	3.0×10^{-5}		
	H-11b1	7.4×10^{-6}		
WIPP-13	DOE-2	5.1×10^{-6}	2.4×10^{-5}	Beauheim (1987b, Table 6-1)
	H-2b2	7.3×10^{-5}		
	H-6b	7.9×10^{-6}		
	P-14	5.2×10^{-5}		
	WIPP-12	3.6×10^{-5}		
	WIPP-18	4.0×10^{-5}		
	WIPP-19	4.0×10^{-5}		
	WIPP-25	6.4×10^{-5}		
	WIPP-30	5.6×10^{-6}		
P-14	D-268	2.5×10^{-5}	1.6×10^{-5}	Beauheim and Ruskauff (1998, Table 6-1)
	H-6b	1.1×10^{-5}		
	WIPP-25	1.5×10^{-5}		
H-19b0	H-19b2, 3, 4, 5, 6, and 7	NA	4.9×10^{-5} *	Beauheim and Ruskauff (1998, Table 6-2)
H-11b1	H-11b2	6.7×10^{-5}	4.5×10^{-5}	Beauheim and Ruskauff (1998, Table 6-1)
	H-11b3	4.2×10^{-5}		
	H-11b4	3.3×10^{-5}		
WQSP-1	H-18	3.5×10^{-5}	1.9×10^{-5}	Beauheim and Ruskauff (1998, Table 6-1)
	WIPP-13	1.0×10^{-5}		
WQSP-2	DOE-2	6.6×10^{-6}	7.3×10^{-6}	Beauheim and Ruskauff (1998, Table 6-1)
	H-18	9.8×10^{-6}		
	WIPP-13	7.2×10^{-6}		
	WQSP-1	6.2×10^{-6}		

* "Actual" storativity, not geometric mean

6. SOFTWARE USED

All software used in preparation of the transient data for T-field calibration was commercial, off-the-shelf software to which we lack access to the source code. All software was run on Dell or Hewlett Packard PC's running **Windows 2000 Professional**.

Troll binary files were read and converted to Excel files using **Data Manager 3.70**. This software is provided by In-Situ, Inc., the manufacturer of the Trolls.

All data files were processed using **Excel 2000** from Microsoft.

Graphing was performed using **Grapher 3.03** from Golden Software, Inc.

7. LISTING OF COMPUTER FILES ON CD

Also available on the CMS library @ LIBTFIELDS

Events.xls	transient events to be used in T-field calibration
Shafts directory:	
H-1-shafts.xls	H-1 response to shaft events
H-3b1-shafts.xls	H-3b1 response to shaft events
H-3 MP directory:	
H3DOE1.xls	DOE-1 response to H-3 multipad pumping test
H3H1.xls	H-1 response to H-3 multipad pumping test
H3H2b2.xls	H-2b2 response to H-3 multipad pumping test
H3H11b1.xls	H-11b1 response to H-3 multipad pumping test
WIPP-13 MP directory:	
W13DOE2.xls	DOE-2 response to WIPP-13 multipad pumping test
W13H2b2.xls	H-2b2 response to WIPP-13 multipad pumping test
W13H6b.xls	H-6b response to WIPP-13 multipad pumping test
W13P14.xls	P-14 response to WIPP-13 multipad pumping test
W13W12.xls	WIPP-12 response to WIPP-13 multipad pumping test
W13W18.xls	WIPP-18 response to WIPP-13 multipad pumping test
W13W19.xls	WIPP-19 response to WIPP-13 multipad pumping test
W13W25.xls	WIPP-25 response to WIPP-13 multipad pumping test
W13W30.xls	WIPP-30 response to WIPP-13 multipad pumping test
P-14 PT directory:	
D268CP.xls	input data for D-268 response to P-14 pumping test
H6BCP.xls	input data for H-6b response to P-14 pumping test
H18CP.xls	input data for H-18 response to P-14 pumping test
W25CP.xls	input data for WIPP-25 response to P-14 pumping test
W26CP.xls	input data for WIPP-26 response to P-14 pumping test
P14D268.xls	D-268 response to P-14 pumping test
P14H6b.xls	H-6b response to P-14 pumping test
P14H18.xls	H-18 response to P-14 pumping test
P14W25.xls	WIPP-25 response to P-14 pumping test
P14W26.xls	WIPP-26 response to P-14 pumping test
H-19 & H-11 TT directory:	
DOE-1-troll.xls	DOE-1 Troll data compiled into a single file
DOE-1-troll_revised.xls	DOE-1 Troll data corrected for errors, offsets, and trends
DOE-1-troll_Revised_Graph.xls	DOE-1 Troll data reduced to hourly readings
DOE-1-waterlevels.xls	DOE-1 water-level and freshwater-head data
DOE-1-combined.xls	DOE-1 combined Troll and freshwater-head data

ERDA-9-troll.xls	ERDA-9 Troll data compiled into a single file
ERDA-9-troll_revised.xls	ERDA-9 Troll data corrected for errors, offsets, and trends
ERDA-9-troll_Revised_Graph.xls	ERDA-9 Troll data reduced to hourly readings
ERDA-9-waterlevels.xls	ERDA-9 water-level and freshwater-head data
ERDA-9-combined.xls	ERDA-9 combined Troll and freshwater-head data
H-1-troll.xls	H-1 Troll data compiled into a single file
H-1-troll_revised.xls	H-1 Troll data corrected for errors, offsets, and trends
H-1-troll_Revised_Graph.xls	H-1 Troll data reduced to hourly readings
H-1-waterlevels.xls	H-1 water-level and freshwater-head data
H-1-combined.xls	H-1 combined Troll and freshwater-head data
H-3b2-troll.xls	H-3b2 Troll data compiled into a single file
H-3b2-troll_revised.xls	H-3b2 Troll data corrected for errors, offsets, and trends
H-3b2-troll_Revised_Graph.xls	H-3b2 Troll data reduced to hourly readings
H-3b2-waterlevels.xls	H-3b2 water-level and freshwater-head data
H-3b2-combined.xls	H-3b2 combined Troll and freshwater-head data
H-15-troll.xls	H-15 Troll data compiled into a single file
H-15-troll_revised.xls	H-15 Troll data corrected for errors, offsets, and trends
H-15-troll_Revised_Graph.xls	H-15 Troll data reduced to hourly readings
H-15-waterlevels.xls	H-15 water-level and freshwater-head data
H-15-combined.xls	H-15 combined Troll and freshwater-head data
WQSP-5-troll.xls	WQSP-5 Troll data compiled into a single file
WQSP-5-troll_revised.xls	WQSP-5 Troll data corrected for errors, offsets, and trends
WQSP-5-troll_Revised_Graph.xls	WQSP-5 Troll data reduced to hourly readings
WQSP-5-waterlevels.xls	WQSP-5 water-level and freshwater-head data
WQSP-5-combined.xls	WQSP-5 combined Troll and freshwater-head data
H-2b2-waterlevels.xls	H-2b2 water-level and freshwater-head data
H-4b-waterlevels.xls	H-4b water-level and freshwater-head data
H-12-waterlevels.xls	H-12 water-level and freshwater-head data
H-14-waterlevels.xls	H-14 water-level and freshwater-head data
H-17-waterlevels.xls	H-17 water-level and freshwater-head data
P-17-waterlevels.xls	P-17 water-level and freshwater-head data
WIPP-21-waterlevels.xls	WIPP-21 water-level and freshwater-head data
WQSP-4-waterlevels.xls	WQSP-4 water-level and freshwater-head data

WQSP-1 PT directory:

H18WQSP1.xls	input data for H-18 response to WQSP-1 pumping test
W13WQSP1.xls	input data for WIPP-13 response to WQSP-1 pumping test
WQSP1H18.xls	H-18 response to WQSP-1 pumping test
WQSP1W13.xls	WIPP-13 response to WQSP-1 pumping test

WQSP-2 PT directory:

DOE2WQSP2.csv	input data for DOE-2 response to WQSP-2 pumping test
H18WQSP2.csv	input data for H-18 response to WQSP-2 pumping test
W13WQSP2.csv	input data for WIPP-13 response to WQSP-2 pumping test
WQSP1WQSP2.csv	input data for WQSP-1 response to WQSP-2 pumping test
WQSP2DOE2.xls	DOE-2 response to WQSP-2 pumping test
WQSP2H18.xls	H-18 response to WQSP-2 pumping test
WQSP2W13.xls	WIPP-13 response to WQSP-2 pumping test
WQSP2WQSP1.xls	WQSP-1 response to WQSP-2 pumping test
WQSP2WQSP3.xls	WQSP-3 water levels during WQSP-2 pumping test

Note: Original Troll binary files are listed in Table 4.

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