CHPRC ADMINISTRATIVE DOCUMENT PROCESSING AND APPROVAL

DOCUMENT TITLE: Analysis of Slug Test Data at the 100-HR-3 OU	**OWNING ORGANIZATION/FACILITY:** S&GRP
Document Number: ECF-100HR3-12-0011	**Revision/Change Number:** 0

DOCUMENT TYPE *(Check Applicable)* [ ] Plan [✓] Report [ ] Study [ ] Description Document [ ] Other

DOCUMENT ACTION *(Check One)* [X] New [ ] Revision [ ] Cancellation

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APPROVAL SIGNATURES

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A-6005-184 (REV 3)

From:	Oldham, Richard W
To:	Adams, M R (Margie)
Subject:	Approve: Document ECF-100HR3-12-0011 Rev 0 for Approval
Date:	Wednesday, May 02, 2012 10:34:17 AM
Importance:	High

From: Huggins, Stewart L
To: Adams, M R (Margie)
Subject: Approve: Document ECF-100HR3-12-0011 Rev 0 for Approval
Date: Friday, May 04, 2012 9:32:10 AM
Importance: High

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Date Received for Clearance Process (MM/DD/YYYY) 05/10/2012

A. Information Category

- [ ] Abstract
- [ ] Journal Article
- [ ] Summary
- [ ] Internet
- [ ] Visual Aid
- [ ] Software
- [ ] Full Paper
- [x] Report
- [ ] Other

B. Document Number ECF-100HR3-12-0011, Revision 0

C. Title Analysis of Slug Test Data at the 100-HR-3 OU

D. Proposed Internet Address

E. Required Information (MANDATORY)

1. Is document potentially Classified? (●) No ( ) Yes

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9. Release Level? (●) Public ( ) Limited

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1. Title of Journal

G. Complete for a Presentation

1. Title for Conference or Meeting ____
2. Group Sponsoring ____
3. Date of Conference ____
4. City/State ____
5. Will Information be Published in Proceedings? ( ) No ( ) Yes
6. Will Material be Handed Out? ( ) No ( ) Yes

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dmp 5-10-12
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APPROVED
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A-6001-401 (REV 5)

From:	Swenson, Raymond T
To:	Adams, M R (Margie)
Subject:	Approve: Document ECF-100HR3-12-0011 Rev 0 for Approval
Date:	Wednesday, May 02, 2012 12:05:39 PM
Importance:	High

ECF-100HR3-12-0011
Revision 0

Analysis of Slug Test Data at the 100-HR-3 OU

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

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ECF-100HR3-12-0011
Revision 0

Analysis of Slug Test Data at the 100-HR-3 OU

Document Type: TR Program/Project: SGRP

P. Khambhammettu
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Date Published
May 2012

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APPROVED
By D. M. Pinkal at 8:43 am, May 10, 2012

Release Approval Date

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ECF-100HR3-12-0011
Revision 0

Total Pages: 134

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ECF-100HR3-12-0011, REV 0

Environmental Calculation Cover Page

Part 1: Completed by the Responsible Manager

Project: Soil and Groundwater Remediation **Date: 09-March-2012**

Calculation Title & Description: Analysis of Slug Test Data at the 100-HR-3 OU

Preparer: P Khambhammettu	**Basis of Qualification: Project Engineer**
Checker: A Spiliotopoulos	**Basis of Qualification: Senior Project Hydrogeologist**
Senior Reviewer: CJ Neville	**Basis of Qualification: Senior Hydrogeologist**

Part 2: Completed by Preparer

Calculation No.: ECF-100HR3-12-0011 **Revision No.: 0**

Revision History:

Revision No.	Description	Date	Affected Pages
0	Initial Issue	09-Mar-2012	All

Part 3: Document Review & Approval:

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Contents

Figures

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1. Purpose

The purpose of this environmental calculation brief is to present the analysis of slug test data at wells in the 100-HR-3 Operating Unit. Withdrawal slug test data at sixteen wells are analyzed with AQTESOLV software. First-cut and refined estimates of hydraulic conductivity are provided.

2. Methodology

An effective initial displacement is estimated for each withdrawal test by back-fitting the measured displacement values to zero time. This effective initial displacement is compared with the theoretical initial displacement value for verification. The displacements are normalized by the effective initial displacement and analyzed using AQTESOLV aquifer test software which has computerized implementations of several analytical methods. A first-cut estimate of the hydraulic conductivity is estimated with the Cooper, Bredehoeft and Papadopulos [CBP] model (Cooper et al., 1967). A refined estimate is made with the Kansas Geological Survey [KGS] model for partial penetration (Hyder et al., 1994). Details regarding the two models are presented subsequently.

2.1 CBP Model

The CBP model considers a well that fully penetrates a ‘Theissian aquifer’ (infinite in areal extent, uniform and perfectly confined) (Cooper et al., 1967). The model has two important advantages over approximate methods such as those of Hvorslev (1951) and Bouwer and Rice (1976):

1. The model incorporates storage in the formation; and
2. The model incorporates a rigorous representation of the geometry of the tests.

The CBP model assumes purely radial flow which is strictly valid for a well penetrating the full thickness of an aquifer. For partially penetrating wells the assumption of purely radial flow is invalidated to some degree. In general, the error introduced by ignoring partial penetration is typically not very significant. If the length of the screen is greater than about 20 times the radius, then flow will be essentially radial. The errors introduced by neglecting vertical components of flow are further limited in vertically anisotropic aquifers in which the vertical hydraulic conductivity is lower than the horizontal, if it is assumed that the effective thickness of the aquifer is equal to the length of the well screen.

The solution can be plotted as a set of type curves which show the variation of normalized displacement over time; each curve corresponding to a combination of transmissivity, storage coefficient, casing and screen radii. The aquifer parameters can be estimated by matching the type curve from the observed data with the library of analytical type curves. AQTESOLV provides the option of matching the curves visually or using automatic parameter-estimation methods.

2.2 KGS Models

The KGS models were developed for analyzing slug tests in wells that penetrate a portion of a perfectly confined or unconfined aquifer that is uniform, anisotropic and infinite in areal extent (Hyder et al., 1994). As with the CBP model, these models incorporate storage in the formation and are based on a correct fluid balance for the well screen; while also accommodating a well of any radius and extending over any length of the aquifer. They also consider two alternative boundary conditions for the top of the formation: no-flow (as with the CBP model) and constant-head.

The KGS models represent state-of-the-art in slug test interpretation. They are free of restrictive geometries and also free of questionable conceptions of hydraulic processes. AQTESOLV can estimate the aquifer parameters with the KGS models with the aid of automatic parameter-estimation methods.

Approximate methods of analysis, such as the Bouwer and Rice method, are not applied in this investigation. The CBP and KGS analyses are more rigorous, and have the advantage of being able to match the entire responses, instead of restricting attention to that portion of the data which appears to approximate a straight line.

3. Software Applications, Descriptions, Installation & Checkout, and Statements of Validity

3.1 Description

AQTESOLV (Calculation Software)

- Software Title: AQTESOLV by HydroSolve Inc. (www.aqtesolv.com); software for the design and analysis of aquifer tests in confined, unconfined, leaky and fractured aquifers.
- Software Version: Version 4.5 for Windows.
- The software identified above was used consistent with its intended use for, and is a valid use of this software for, the problem addressed in this application.
- The software was used within its limitations.

4. Calculation

The well locations for the D-Area Wells and the H-Area wells are shown in Figures 4-1 and Figure 4-2 respectively. The locations of the D and H areas and other Hanford groundwater interest areas are visually shown in Figure 5-1 of section 5. The well/screen information for the D Area Wells and the H Area Wells is tabulated respectively on Tables 4-1 and Table 4-2.

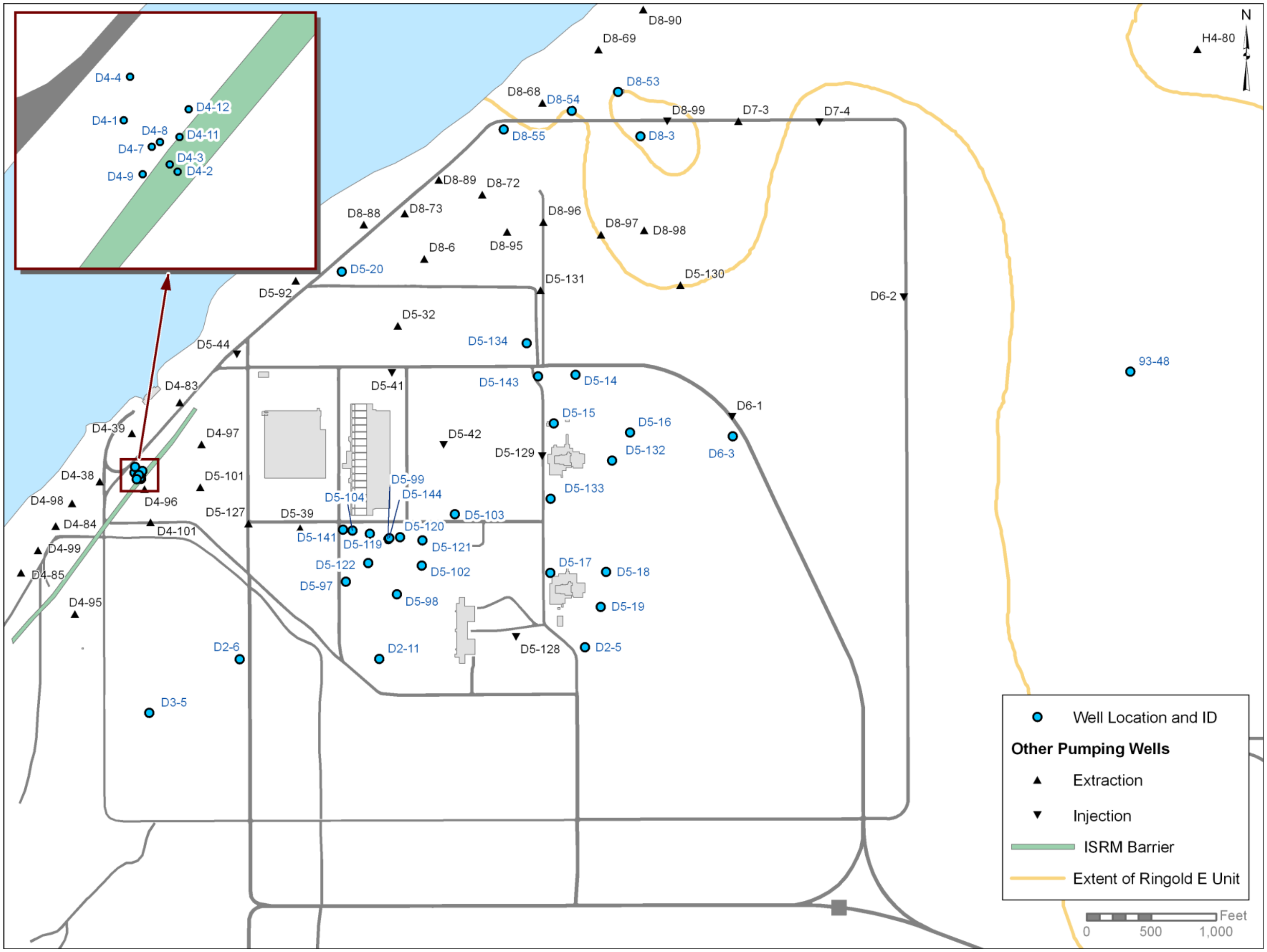

Figure 4-1. Well locations for D-Area Wells

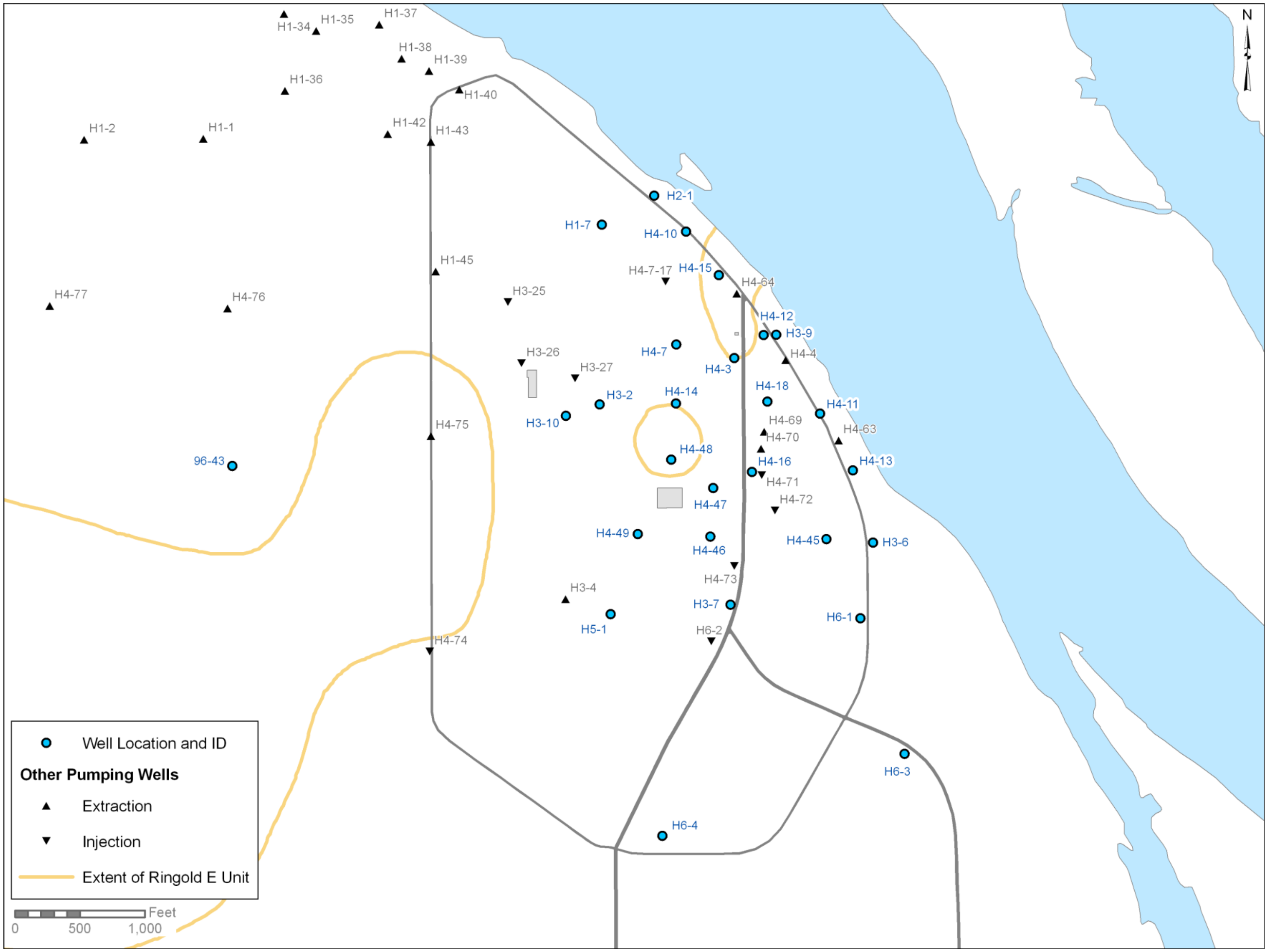

Figure 4-2. Well locations for H-Area Wells

Table 4-1. Well / screen information for D-Area Wells.

	199-D3-5	199-D5-132	199-D5-133	199-D5-134	199-D5-141	199-D5-143	199-D5-144	199-D6-3
Easting (m)	572787.66	573875.35	573731.55	573675.32	573243.43	573701.53	573352.03	574159.09
Northing (m)	150994.54	151586.87	151497.37	151862.46	151424.51	151784.26	151404.83	151643.85
Land Surface Elevation (m)	144.78	145.07	144.12	144.33	144.94	144.43	144.94	143.93
Hanford-Ringold unit E Contact Elevation (m)	117.14	128.85	126.98	127.48	126.21	126.31	126.62	125.17
Top of RUM (m)	111.94	112.76	111.48	110.58	110.11	111.71	111.17	112.47
Water Table Elevation (m)	118.78	119.77	120.13	118.56	118.77	119.60	119.83	118.93
Screen Top Elevation (m)	123.03	121.14	121.93	104.92	96.61	121.05	123.48	121.43
Screen Bottom Elevation (m)	113.89	113.52	112.80	101.84	93.56	113.43	112.82	113.81
Casing Diameter (inches)	6	6	6	6	6	6	4	6
Borehole diameter (inches)	10.75	10.75	10.75	10.75	10.75	10.75	8.75	10.75
Well log description	Mixture of Sand, Gravel, and Silt	Mixture of Sand, Gravel, and Silt	Mixture of Sand, Gravel, and Silt	Gravelly Sandy Silt	Gravelly Silt	Silty Sandy Gravel	Mixture of Sand, Gravel, and Silt	Silty Sandy Gravel
Geologic Unit in 100 Area Model	Hanford and Ringold E	Ringold E	Ringold E	RUM	RUM	Ringold E	Ringold E	Ringold E

Table 4-2. Well / screen information for H-Area Wells.

	199-H2-1	199-H3-6	199-H3-7	199-H3-9	199-H3-10	199-H6-3	199-H6-4	199-H1-7
Easting (m)	577752.31	578266.47	577931.74	578039.12	577545.14	578340.40	577771.59	577629.60
Northing (m)	153239.89	152425.33	152279.97	152913.60	152723.52	151929.35	151737.10	153172.10
Land Surface Elevation (m)	124.10	128.53	129.07	127.02	129.01	128.40	127.46	125.53
Hanford-Ringold unit E Contact Elevation (m)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Top of RUM (m)	112.65	111.45	112.79	110.84	111.45	109.66	110.09	114.15
Water Table Elevation (m)	116.21	115.56	116.21	115.17	116.80	115.45	116.21	116.37
Screen Top Elevation (m)	105.49	118.93	118.68	104.05	98.54	117.98	118.62	119.77
Screen Bottom Elevation (m)	102.44	112.84	114.11	101.00	95.49	110.36	111.00	116.72
Casing Diameter (inches)	6	6	6	6	6	6	6	6
Borehole diameter (inches)	10.625	10.75	10.75	10.625	10.625	10.75	10.75	10.75
Well log description	Slightly Silty Sand	Sandy Gravel	Sandy Gravel	Sand	Sand and Sandy Silt	Mixture of Sand, Gravel, and Silt	Sandy Gravel	Mixture of Sand, Gravel, and Silt
Geologic Unit in 100 Area Model	RUM	Hanford	Hanford	RUM	RUM	Hanford	Hanford	Hanford

4.1 Analysis of Slug Test Data at well 199-D3-5

Three withdrawal tests were conducted at 199-D3-5 and all of them are analyzed here.

4.1.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.3. The normalized displacements in section 4.1.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.1.2.

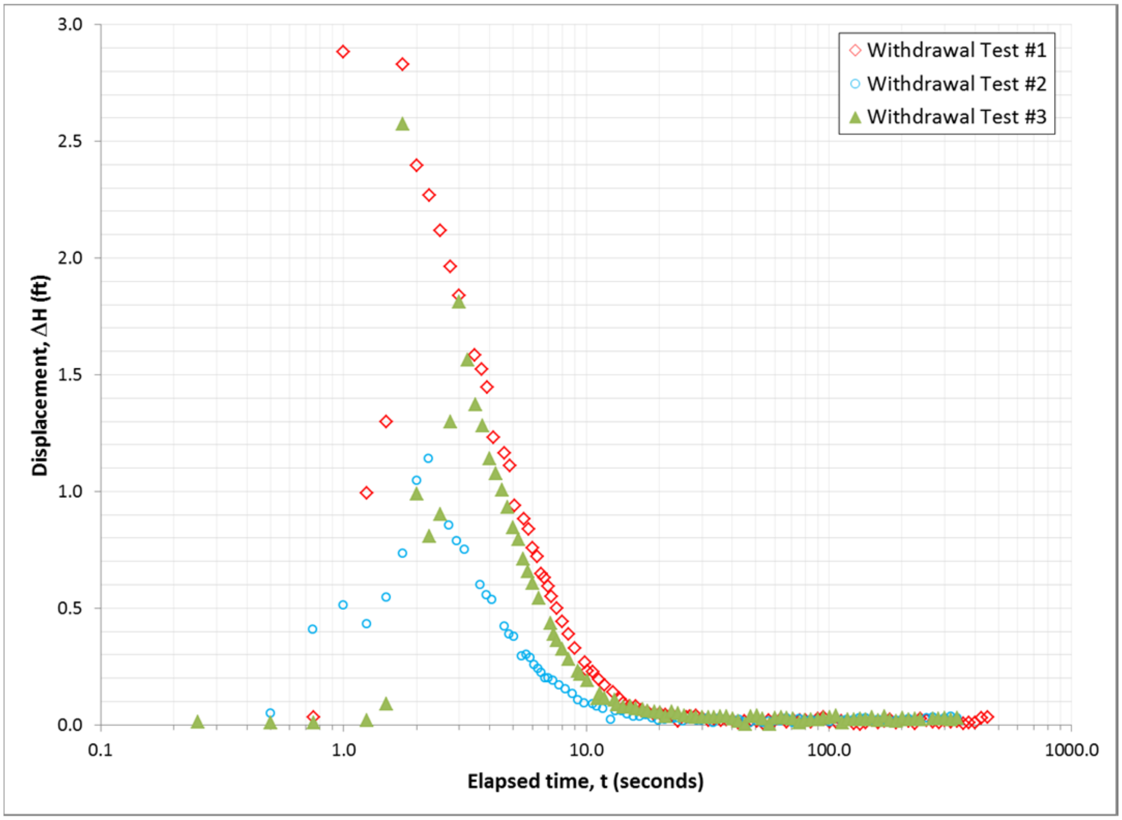

Figure 4-3. Displacements from three withdrawal tests at 199-D3-5

4.1.2 Estimation of effective start time

Effective start times of 1.75 seconds, 2.25 seconds and 1.75 seconds are estimated for the three withdrawal tests respectively.

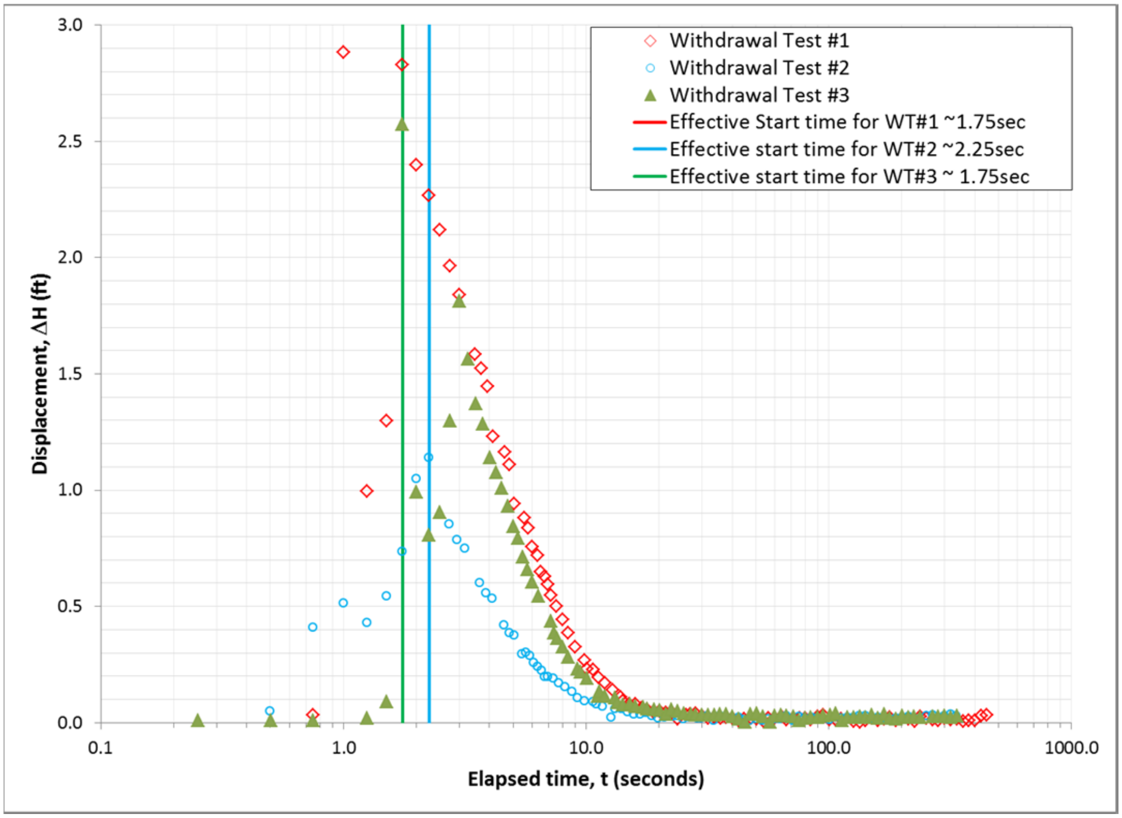

Figure 4-4. Effective start time for withdrawal tests at 199-D3-5

4.1.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-5. Effective initial displacements of 2.6 ft., 0.9 ft., and 1.75 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are less than the theoretical estimates probably because of the non-instantaneous nature of the tests.

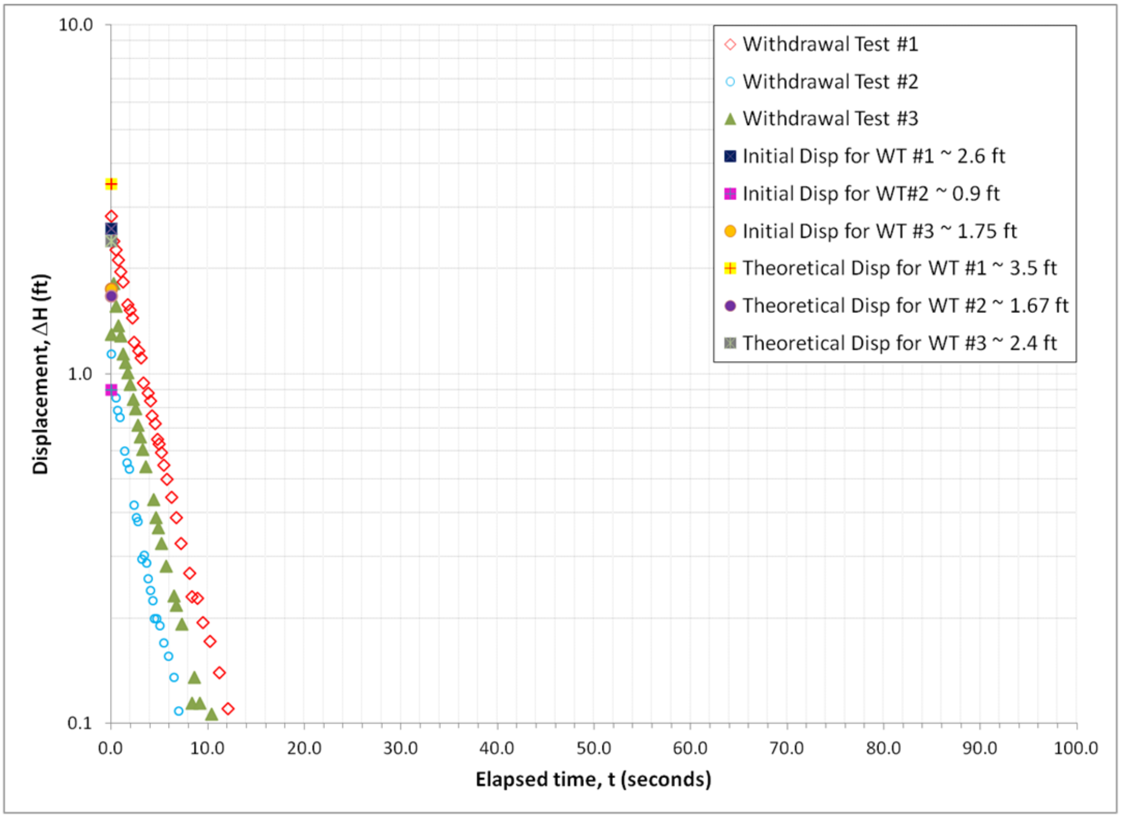

Figure 4-5. Estimation of effective initial displacement at 199-D3-5

4.1.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-6 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis because its record is the most complete.

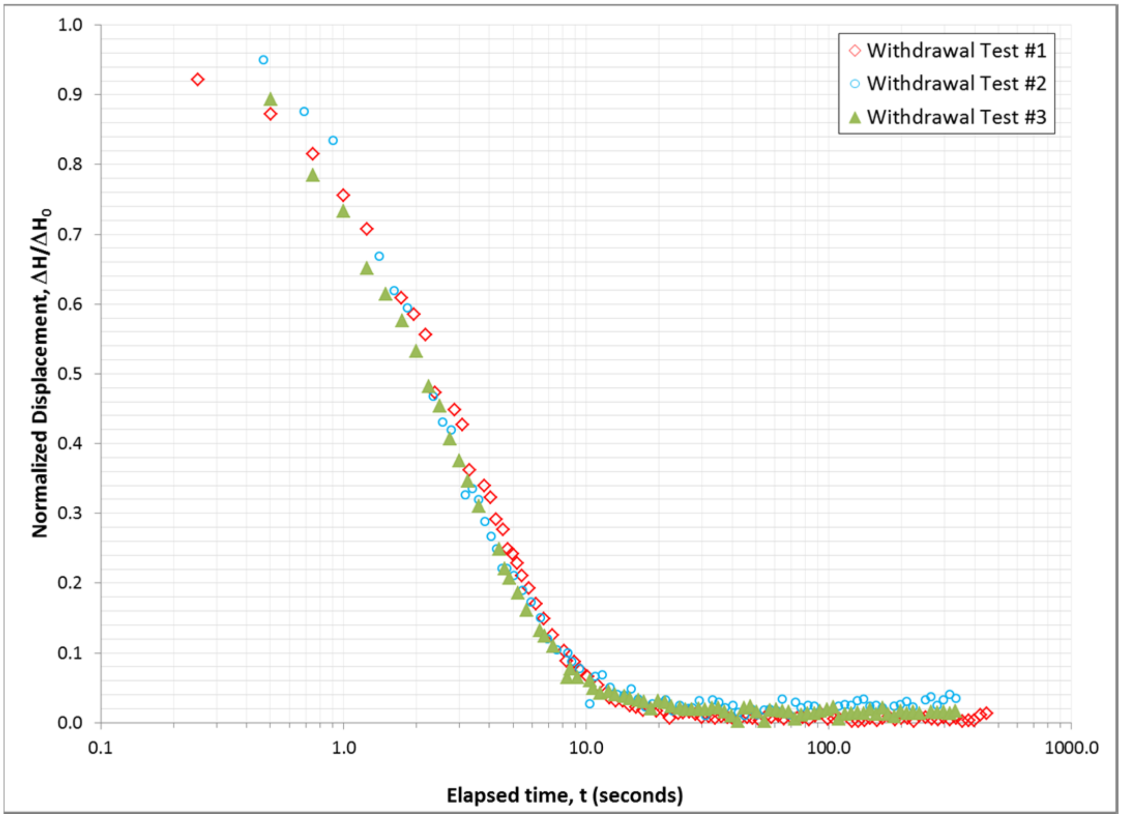

Figure 4-6. Normalized displacement at 199-D3-5

4.1.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-7. A good match to the observations is achieved with a storage coefficient, *S*, of 10^{-5}, and a fitted transmissivity, *T*, of 440 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-1, we see that for well 199-D3-5, this is not the case. The aquifer (Hanford and Ringold unit E) is about 6.94 m (118.78 m – 111.94 m) thick at this location, and the length of the well screen is about 4.9 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 16.05 ft. (4.9 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **90 m/d or 1.0×10^{-3} m/s.**

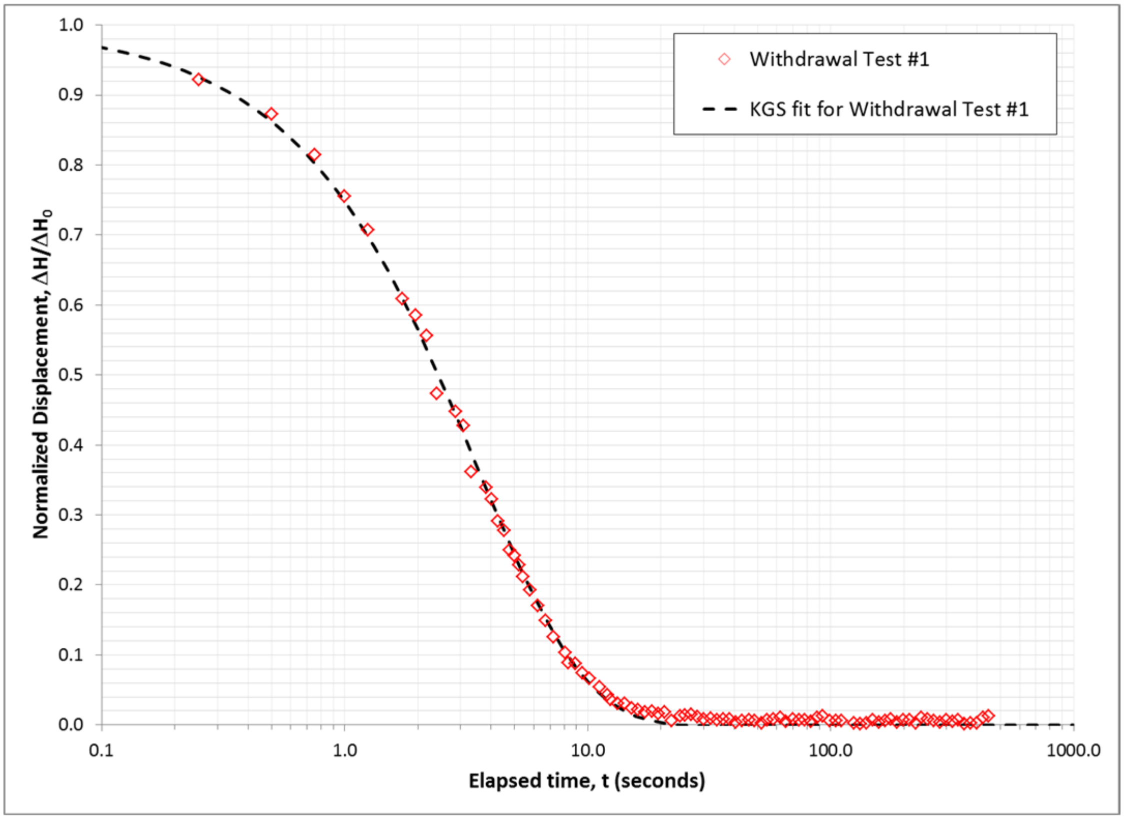

Figure 4-7 CBP Model fit at 199-D3-5

4.1.6 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-8. A good match to the observations is achieved with a specific storage, S_s, of 2.0×10^{-6} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **55 m/d** or **6.4×10^{-4} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 10^{-5} by the well screen length (16.05 ft. or 4.9 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of coarse sand and gravel. This is consistent with the well log which describes the screened interval as a mixture of Sand, Gravel and Silt.

The estimated hydraulic conductivity is in the middle of the range for clean sand and at the higher end of the range for silty sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This is consistent with the well log which describes the screened interval as a mixture of Sand, Gravel and Silt.

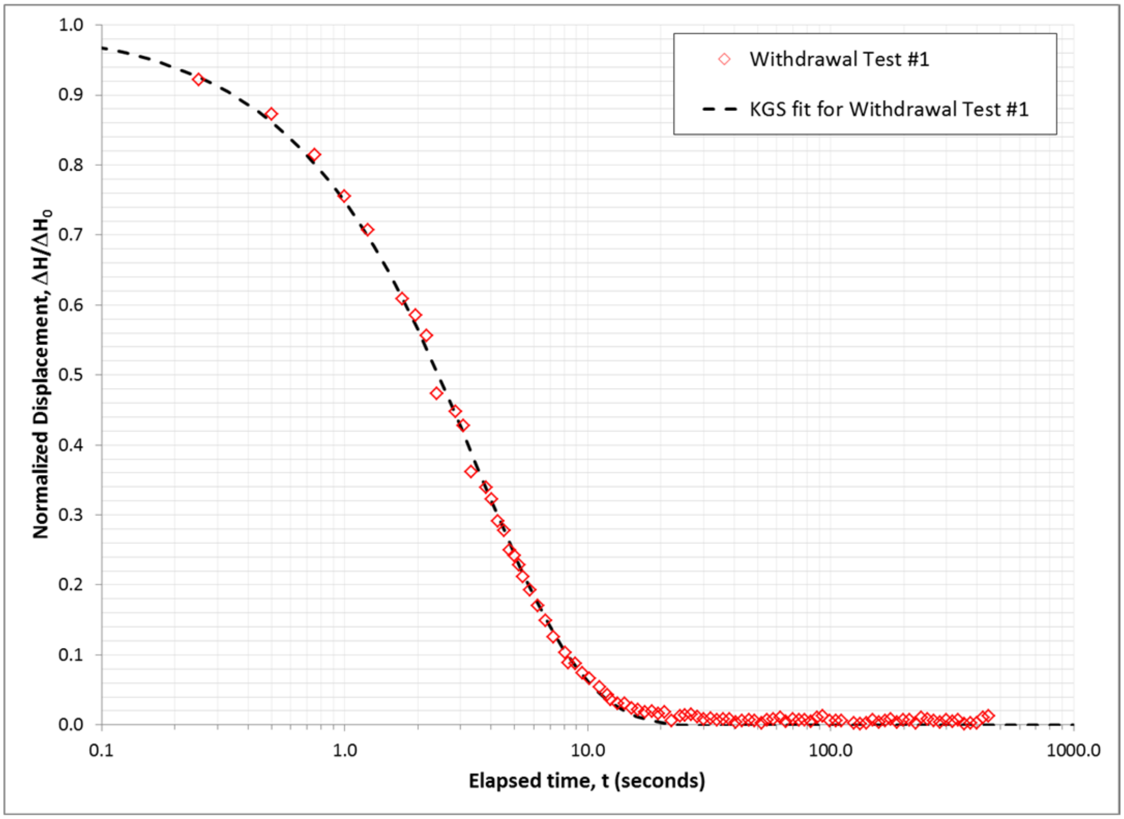

Figure 4-8. KGS Model fit at 199-D3-5

4.2 Analysis of Slug Test Data at well 199-D5-132

Three withdrawal tests were conducted at 199-D5-132 and all of them are analyzed here.

4.2.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4-9. The normalized displacements in section 4.2.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.2.2.

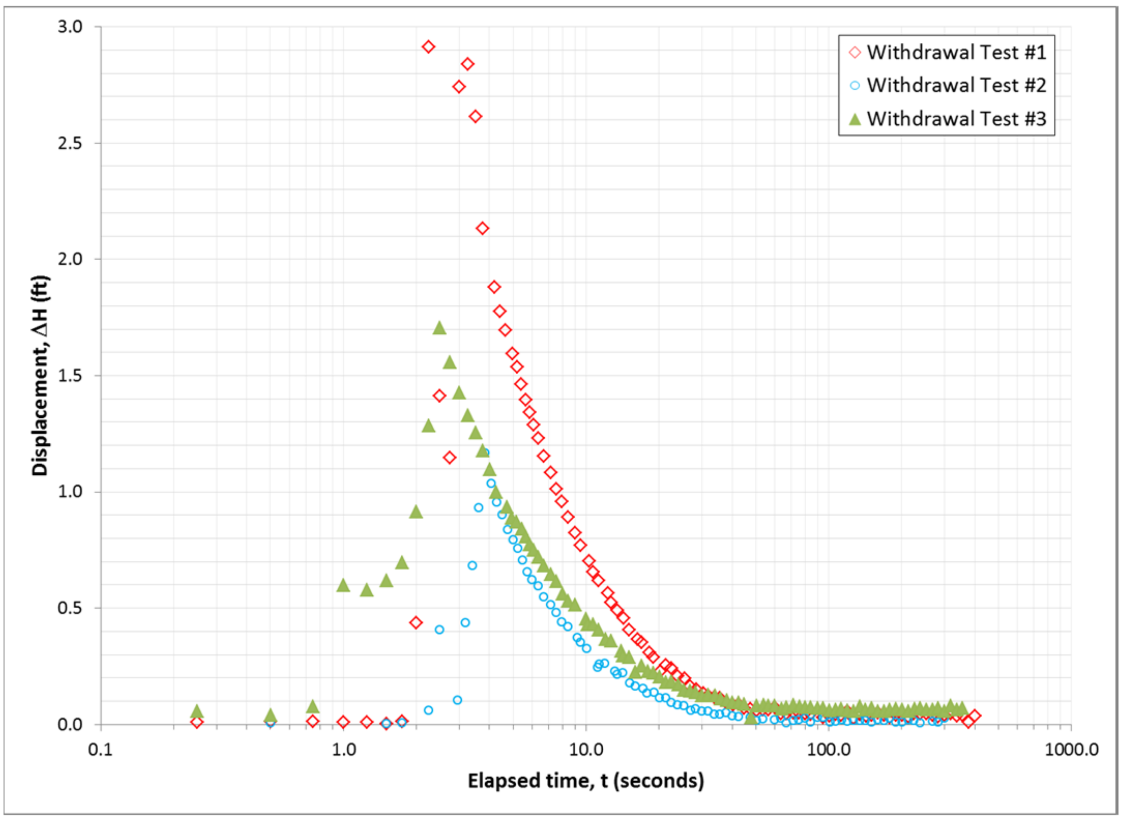

Figure 4-9. Displacements from three withdrawal tests at 199-D5-132

4.2.2 Estimation of effective start time

Effective start times of 3.25 seconds, 3.8 seconds and 2.5 seconds are estimated for the three withdrawal tests respectively as shown in Figure 4-10.

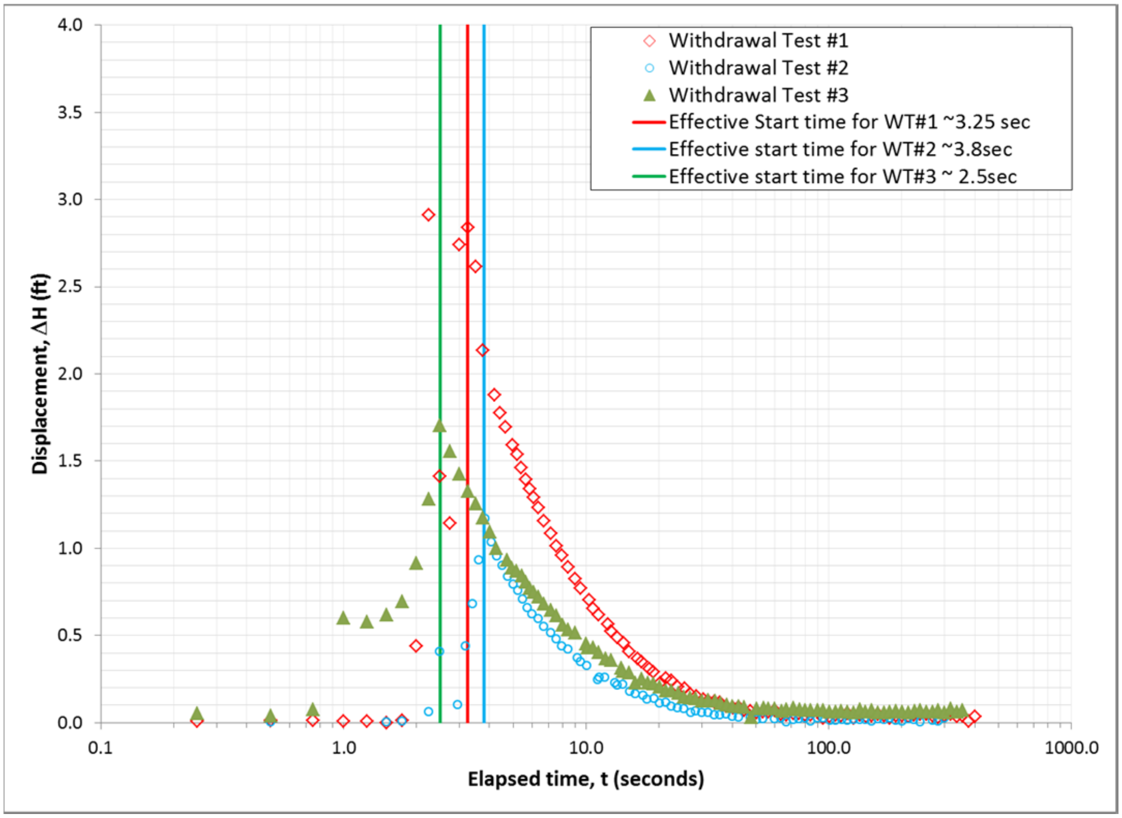

Figure 4-10. Effective start time for withdrawal tests at 199-D5-132

4.2.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-11. Effective initial displacements of 2.45 ft., 1.1 ft., and 1.65 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are lesser than the theoretical estimates probably because of the non-instantaneous nature of the tests.

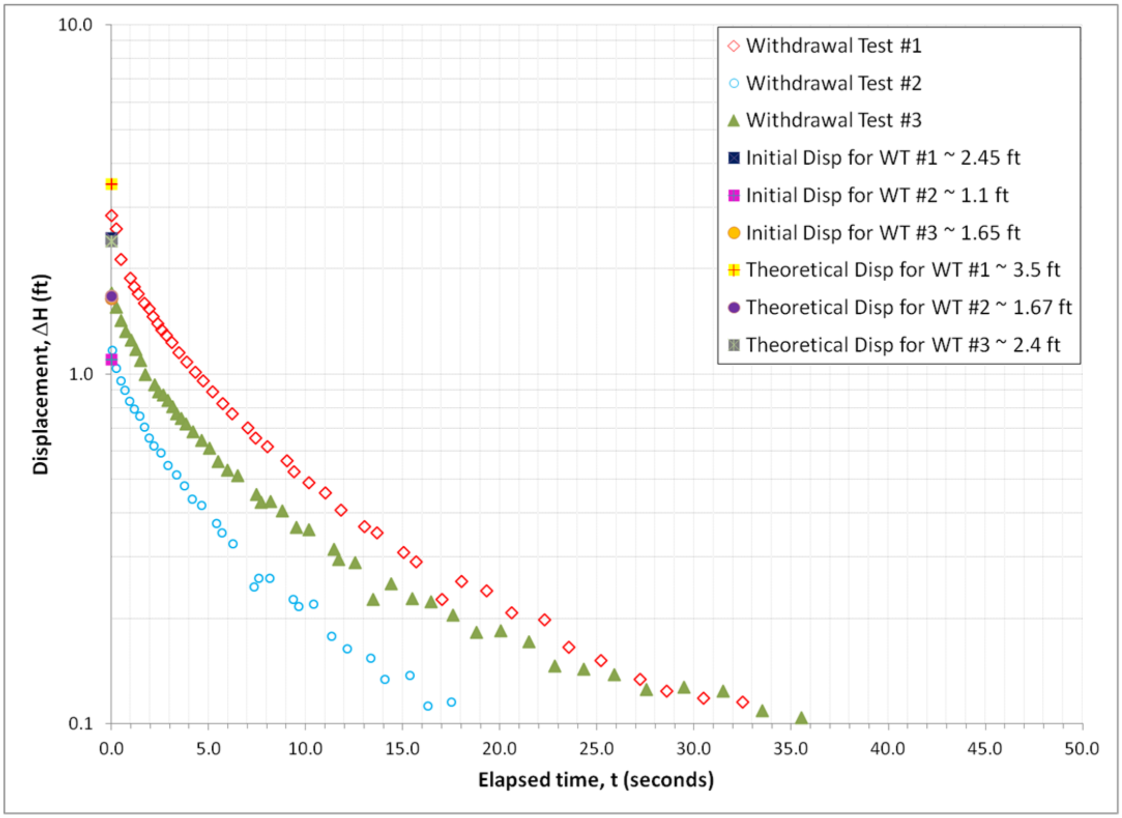

Figure 4-11. Estimation of effective initial displacement at 199-D5-132

4.2.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses are plotted in Figure 4-12. The responses of the three tests are consistent for the first 10 seconds. After 10 seconds, the first two tests are consistent but the displacements in the third test do not dissipate quickly. The third test is therefore not considered for further analysis. The close correspondence of the normalized displacement curves of the first two tests suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis because its record is the most complete.

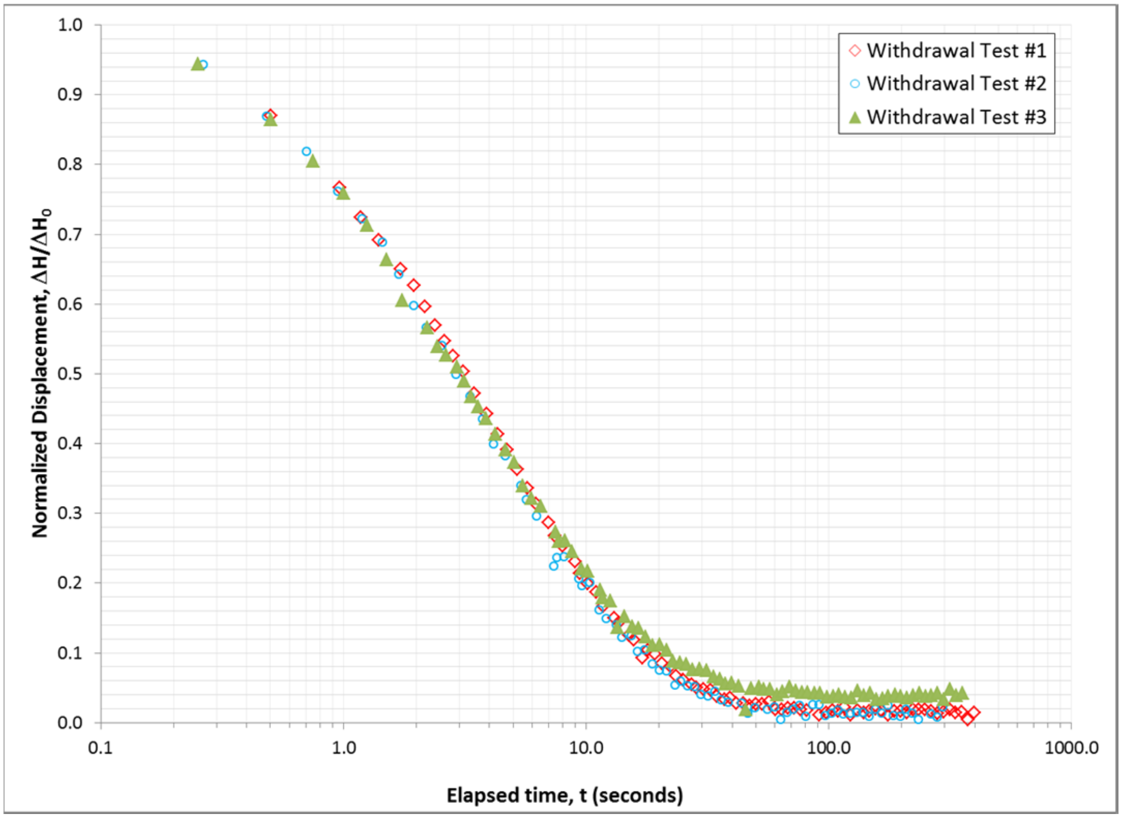

Figure 4-12. Normalized displacement at 199-D5-132

4.2.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-13. A good match to the observations is achieved with a storage coefficient, *S*, of 4×10^{-3}, and a fitted transmissivity, *T*, of 129 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-1, we see that for well 199-D5-132, this is not the case. The aquifer (Ringold unit E) is about 7.01 m (119.77 m – 112.76 m) thick at this location, and the length of the submerged well screen is about 6.25 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 20.515 ft. (6.25 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **21 m/d or 2.4×10^{-4} m/s.**

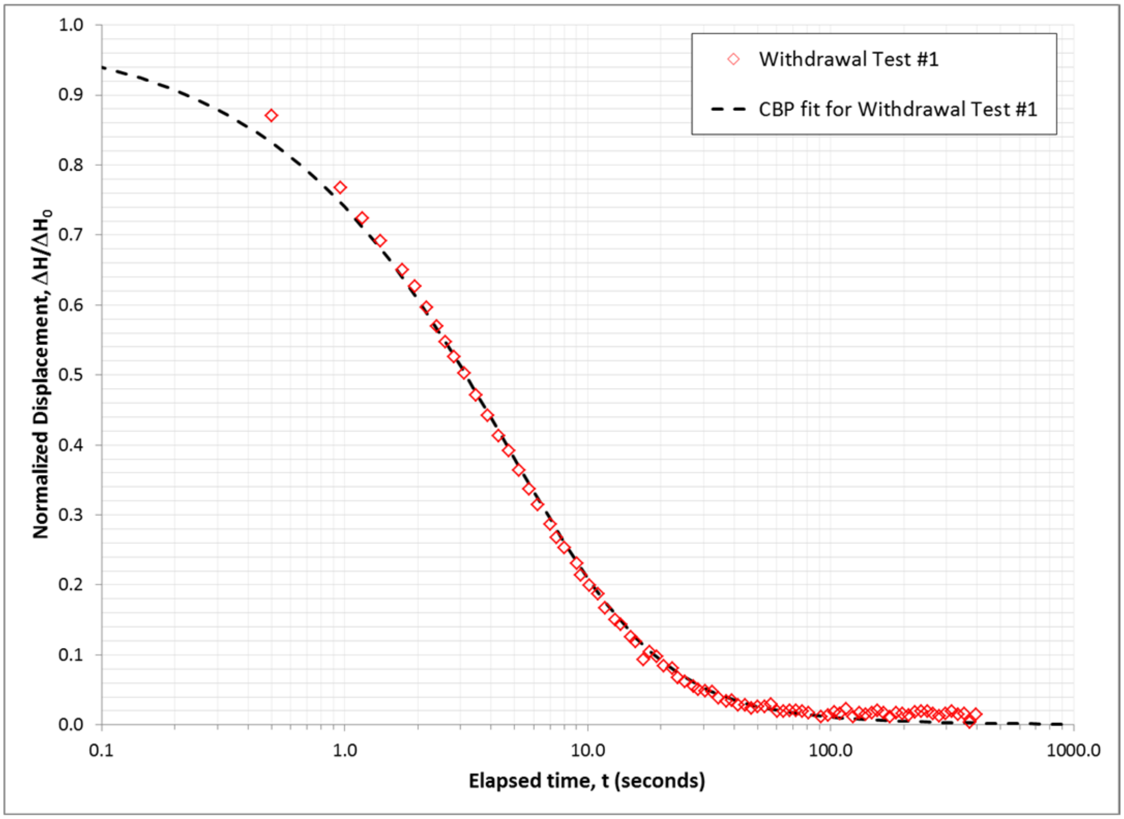

Figure 4-13 CBP Model fit at 199-D5-132

4.2.6 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-14. A good match to the observations is achieved with a specific storage, S_s, of 6.4×10^{-4} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **19 m/d** or **2.2×10^{-4} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 4×10^{-3} by the well screen length (20.615 ft. or 6.25 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of silt, fine sand and medium sand. This is consistent with the well log which describes the screened interval as a mixture of Sand, Gravel and Silt.

The estimated hydraulic conductivity is in the middle of the range for clean sand and at the higher end of the range for silty sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This is consistent with the well log which describes the screened interval as a mixture of Sand, Gravel and Silt.

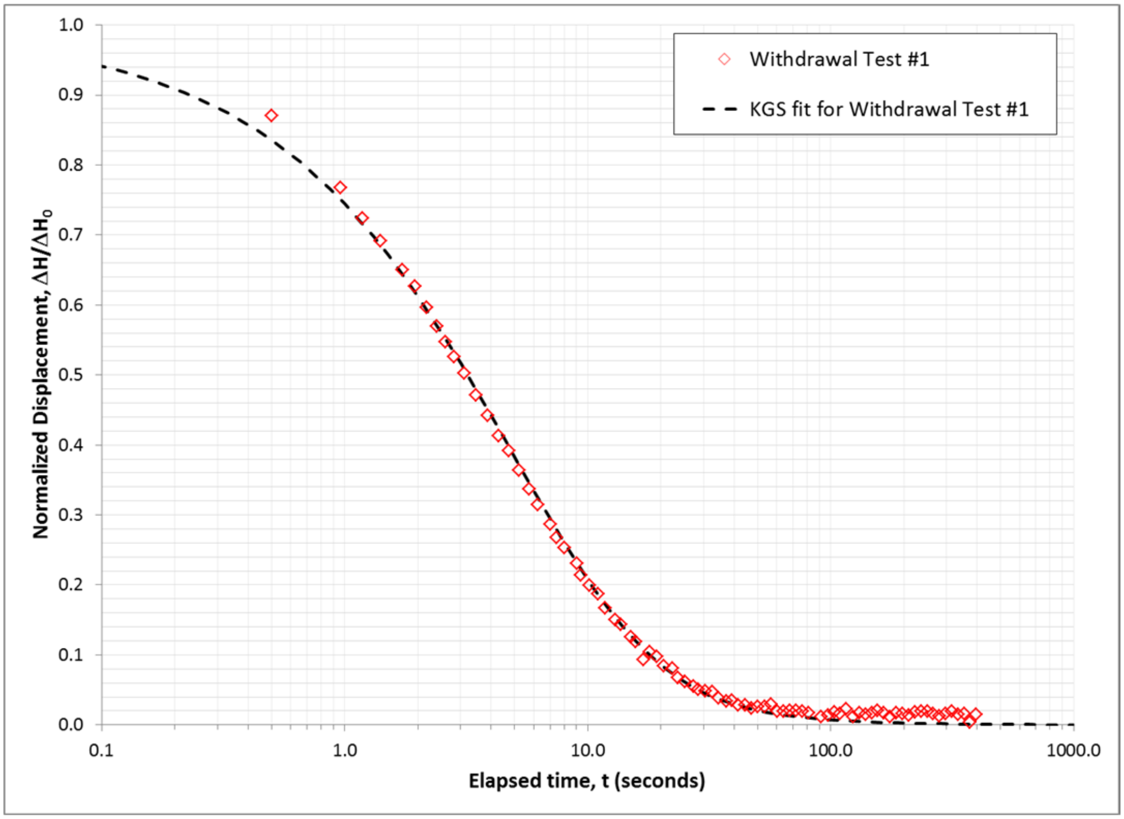

Figure 4-14. KGS Model fit at 199-D5-132

4.3 Analysis of Slug Test Data at well 199-D5-133

Three withdrawal tests were conducted at 199-D5-133 and all of them are analyzed here.

4.3.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.15. The normalized displacements in section 4.3.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.3.2.

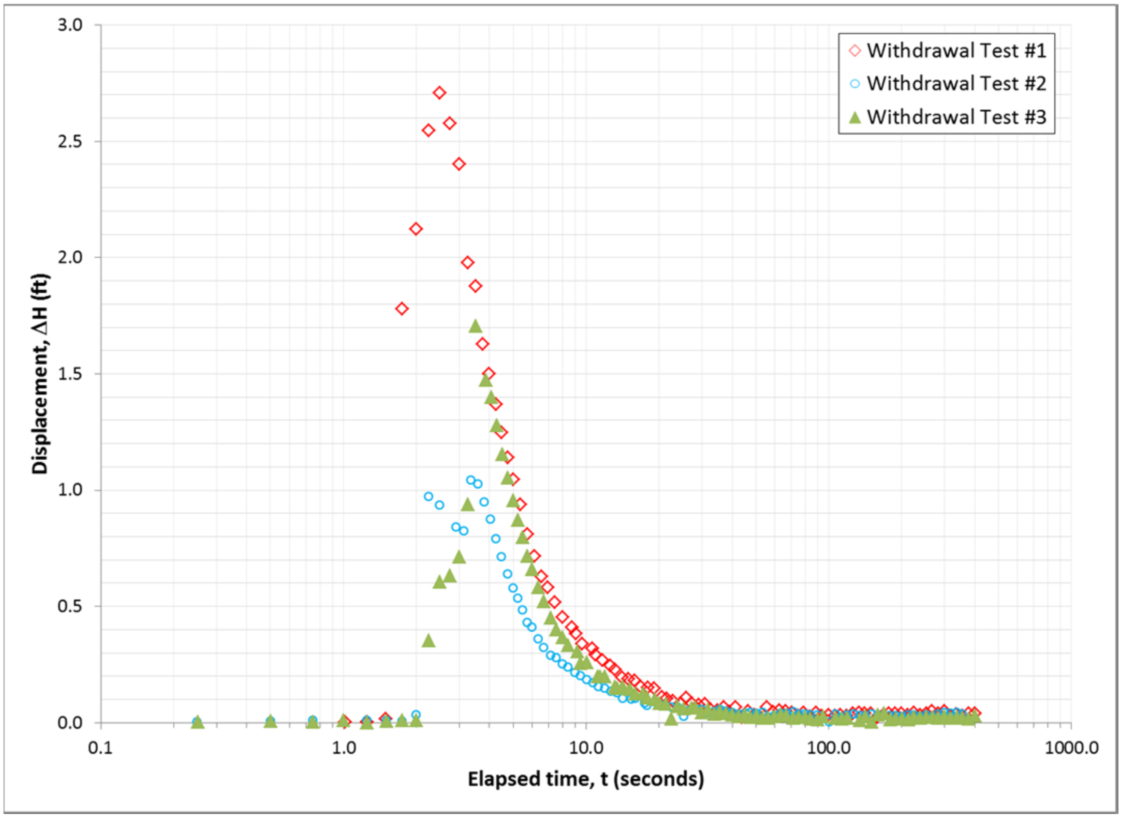

Figure 4-15. Displacements from three withdrawal tests at 199-D5-133

4.3.2 Estimation of effective start time

Effective start times of 2.75 seconds, 3.3 seconds and 3.5 seconds are estimated for the three withdrawal tests respectively.

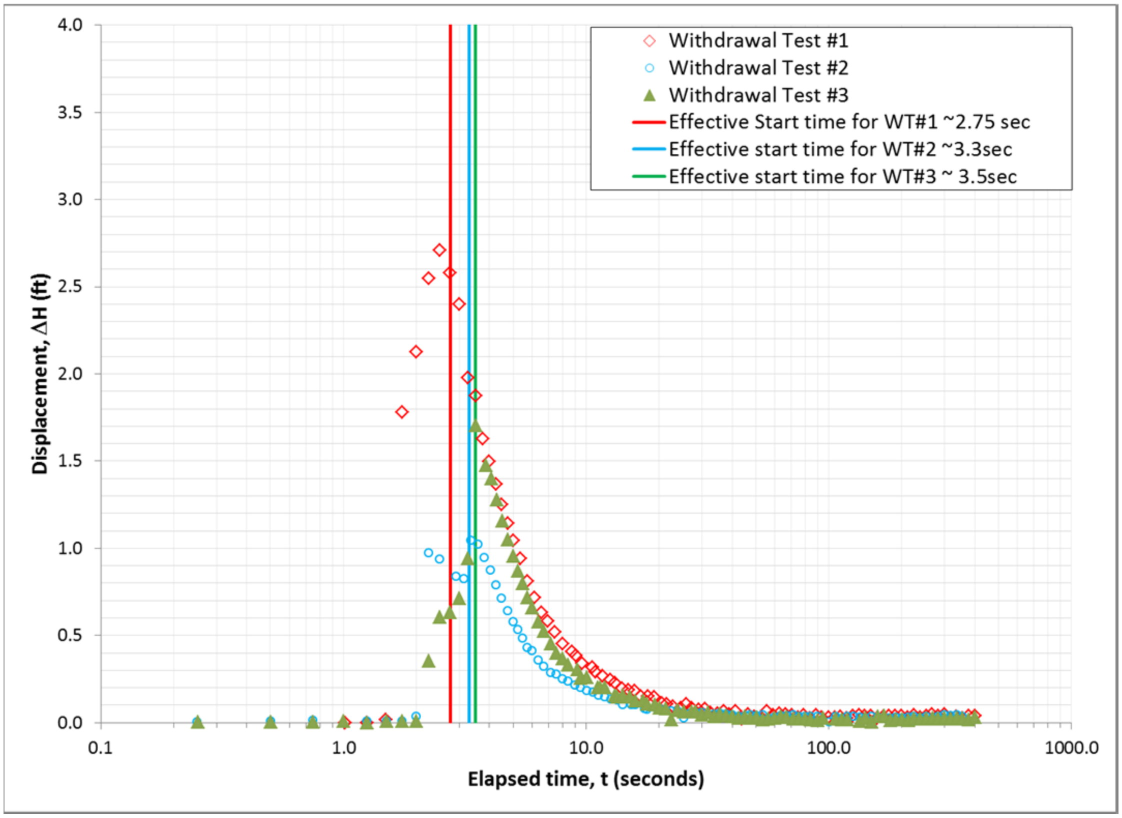

Figure 4-16. Effective start time for withdrawal tests at 199-D5-133

4.3.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-17. Effective initial displacements of 2.4 ft., 1.1 ft., and 1.7 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are lesser than the theoretical estimates probably because of the non-instantaneous nature of the tests.

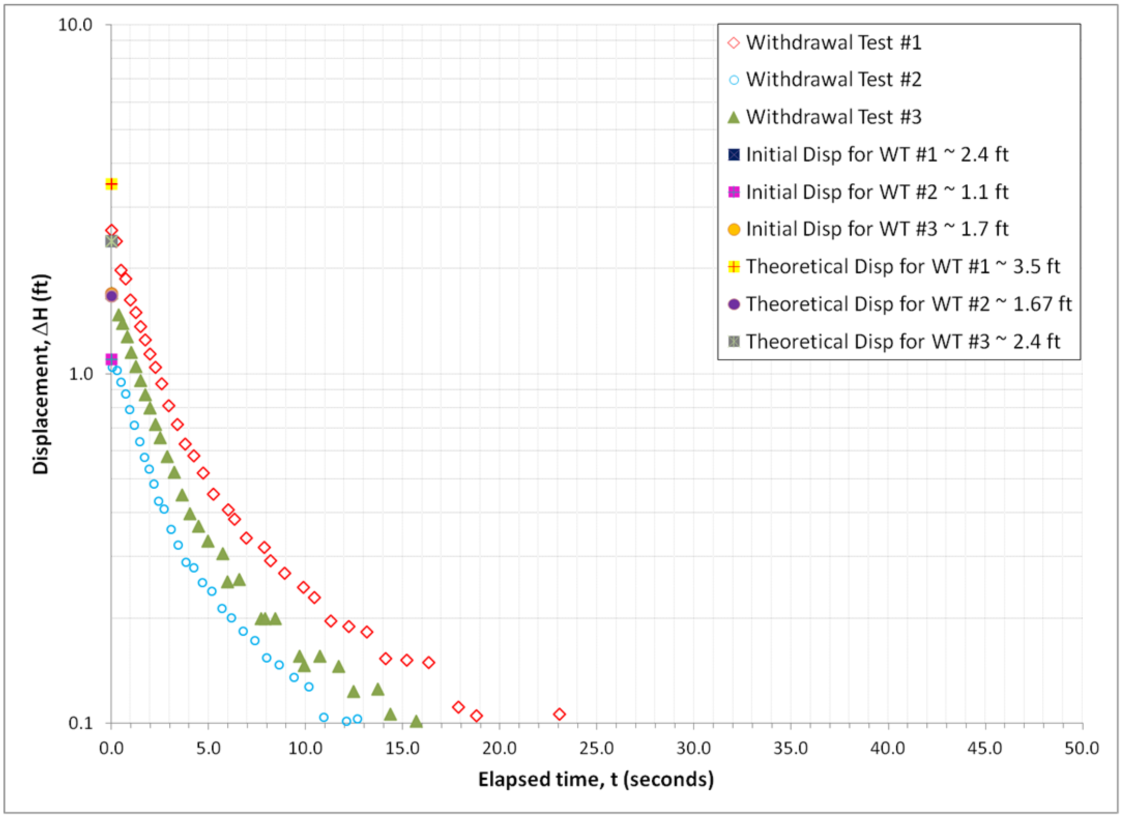

Figure 4-17. Estimation of effective initial displacement at 199-D5-133

4.3.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-18 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The third withdrawal test is chosen for analysis because its record is the most complete.

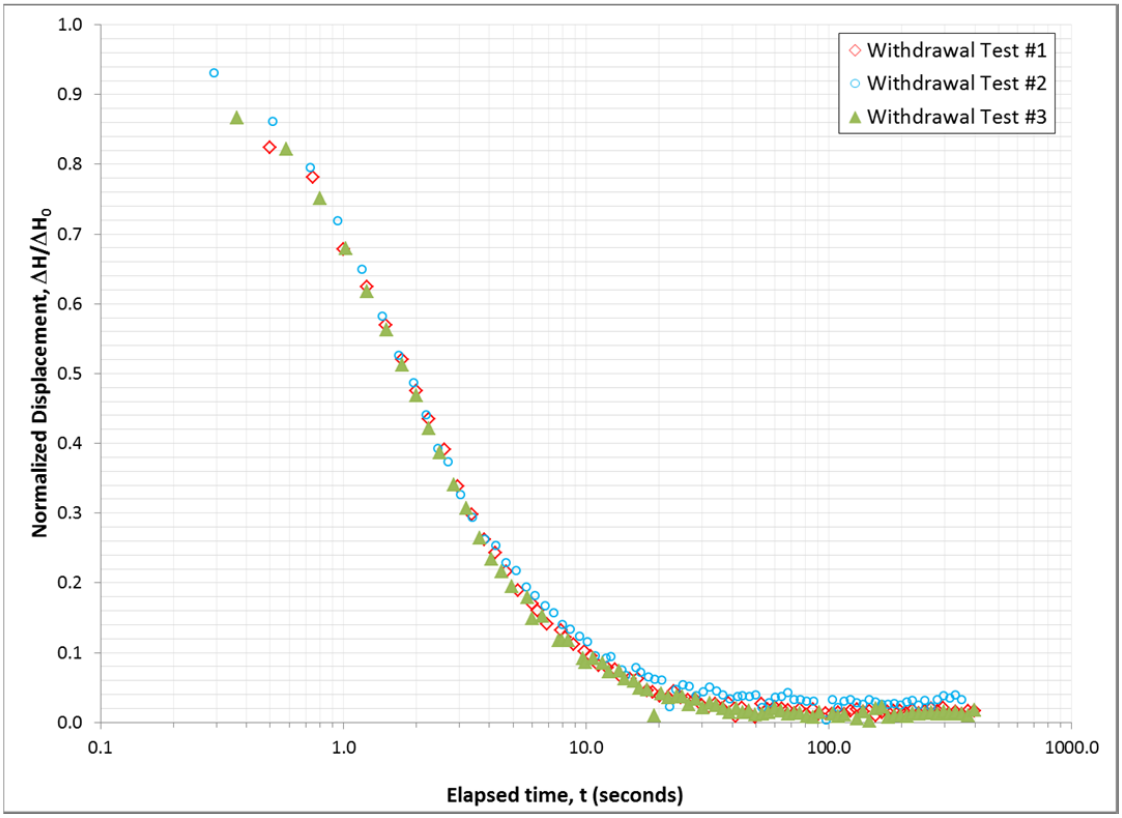

Figure 4-18. Normalized displacement at 199-D5-133

4.3.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the third withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-19. A good match to the observations is achieved with a storage coefficient, *S*, of 1.5×10^{-3}, and a fitted transmissivity, *T*, of 288 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-1, we see that for well 199-D5-133, this is not the case. The aquifer (Ringold unit E) is about 8.65 m (120.13 m – 111.48 m) thick at this location, and the length of the well screen is about 7.34 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 24.07 ft. (7.34 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **39 m/d or 4.5×10^{-4} m/s**.

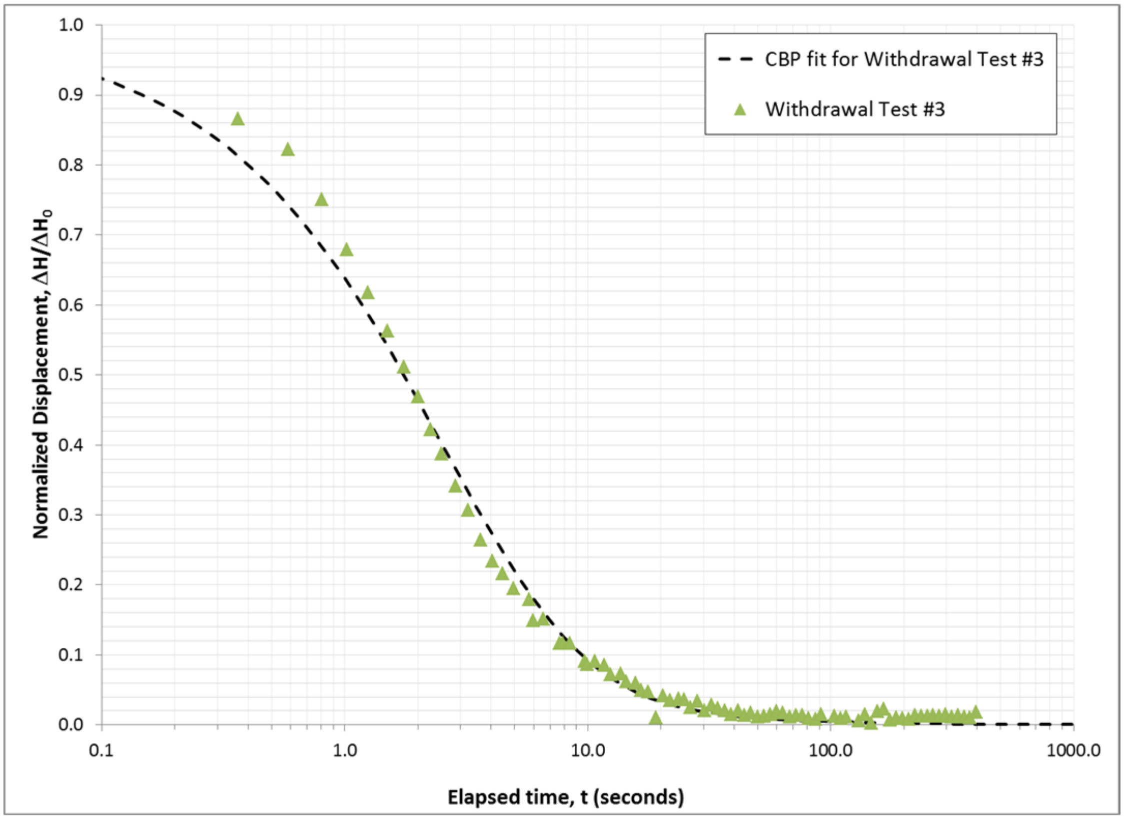

Figure 4-19. CBP Model fit at 199-D5-133

4.3.6 Refined analysis

For a more refined analysis, the normalized displacements for the third withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-20. A good match to the observations is achieved with a specific storage, S_s, of 2.0×10^{-4} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **38 m/d** or **4.4×10^{-4} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 1.5×10^{-3} by the well screen length (24.07 ft. or 7.34 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of silt, fine sand and medium sand. This is consistent with the description of the screened interval as a mixture of sand, silt and gravel.

The estimated hydraulic conductivity is in the middle of the range for clean sand and at the higher end of the range for silty sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This is consistent with the description of the screened interval as a mixture of sand, silt and gravel.

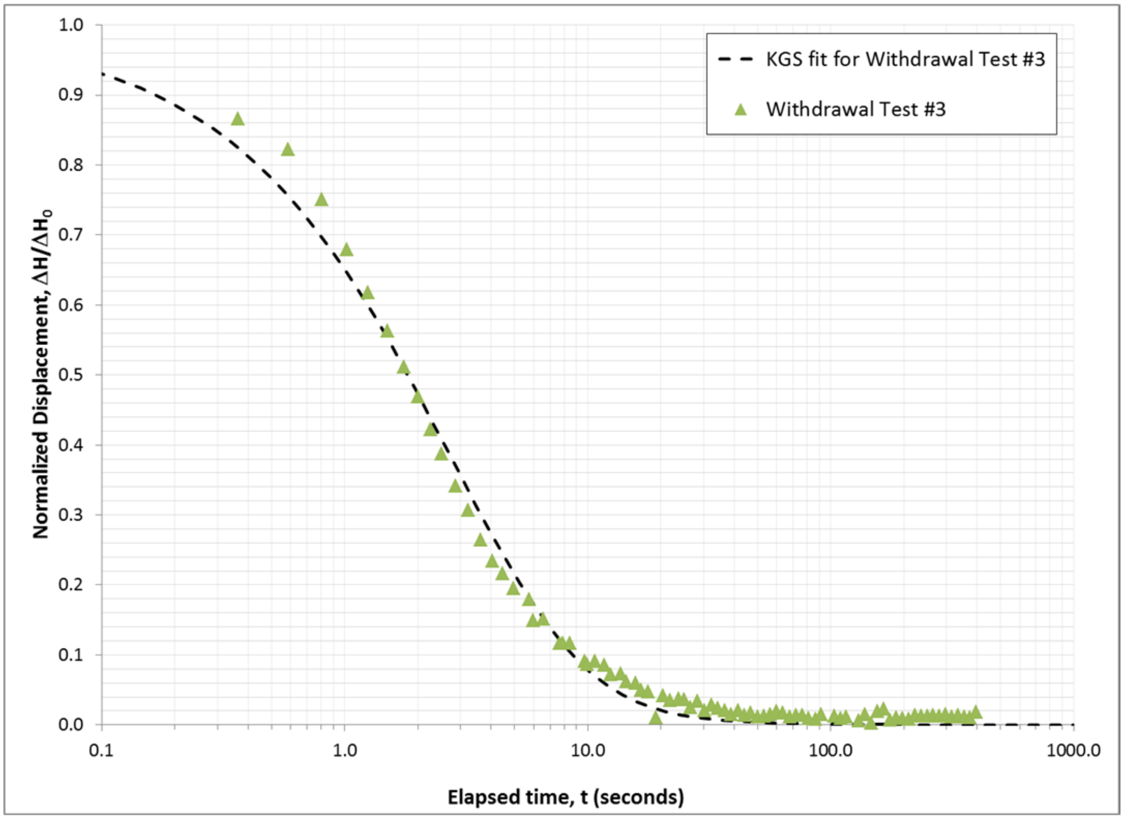

Figure 4-20. KGS Model fit at 199-D5-133

4.4 Analysis of Slug Test Data at well 199-D5-134

Three withdrawal tests were conducted at 199-D5-134 and all of them are analyzed here.

4.4.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.21. The normalized displacements in section 4.4.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.4.2.

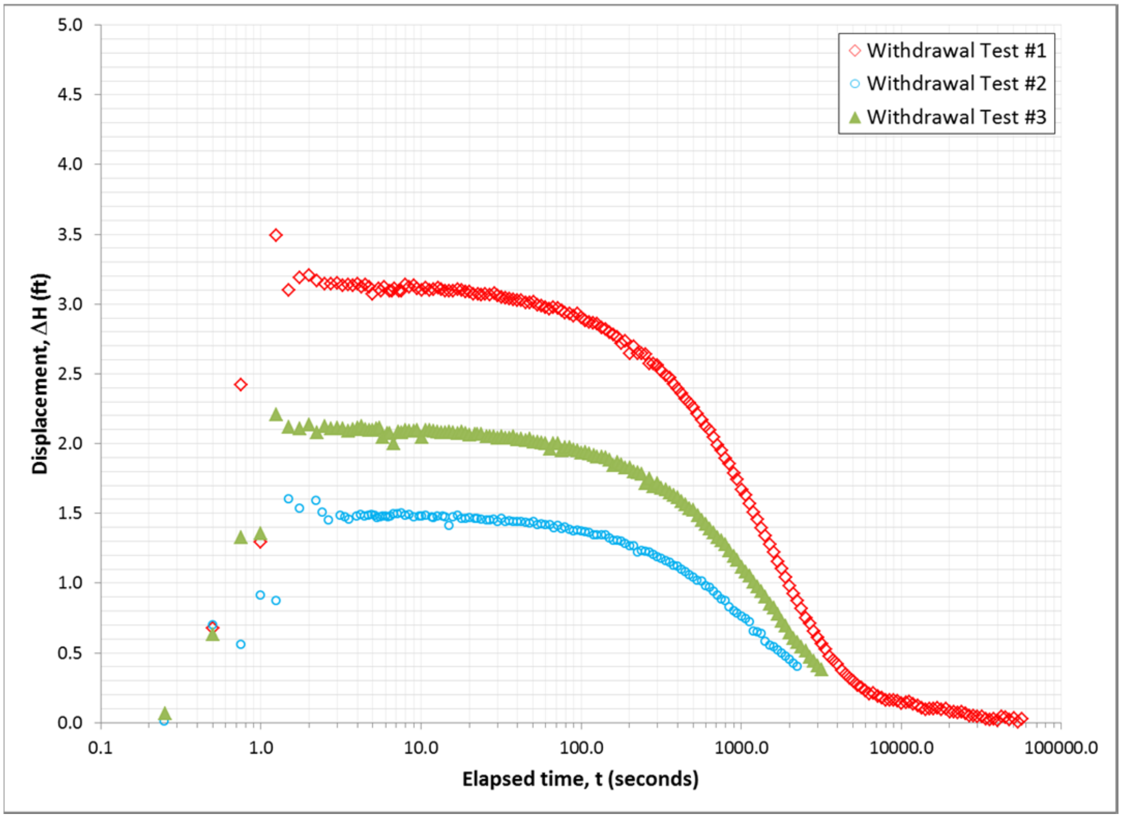

Figure 4-21. Displacements from three withdrawal tests at 199-D5-134

4.4.2 Estimation of effective start time

Effective start times of 1.75 seconds, 1.5 seconds and 1.25 seconds are estimated for the three withdrawal tests respectively.

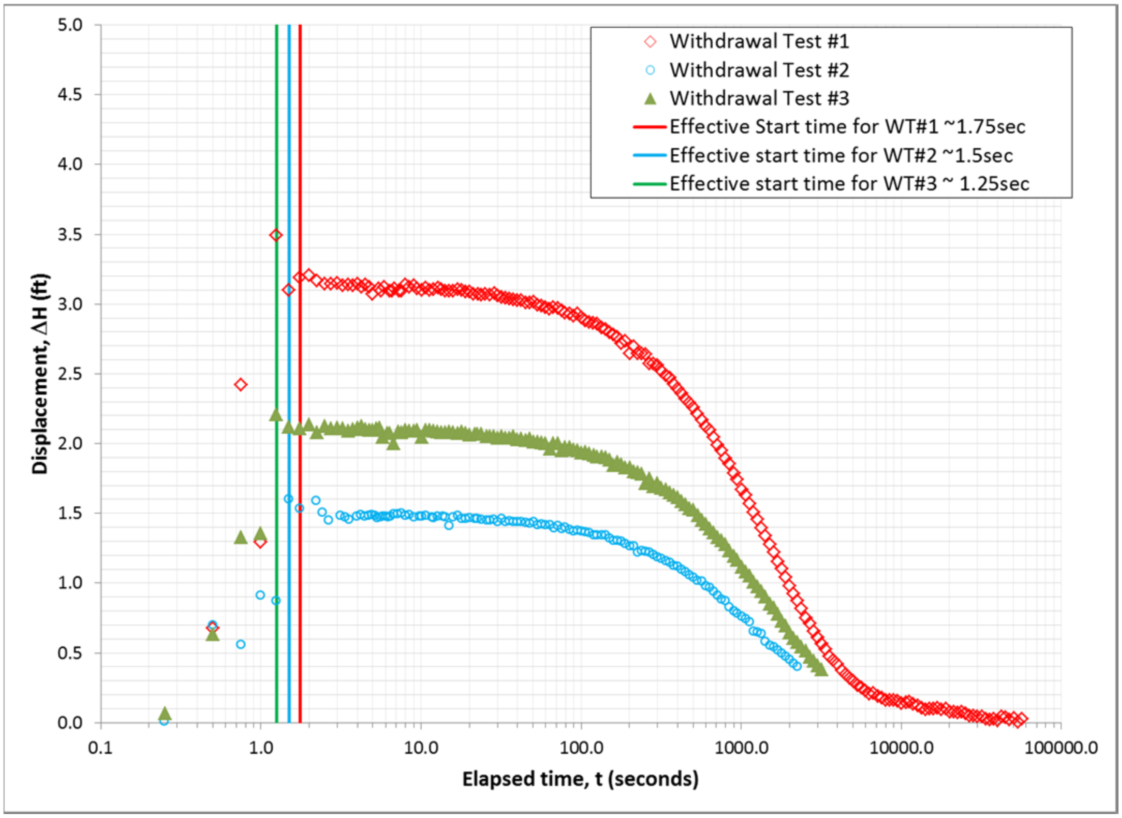

Figure 4-22. Effective start time for withdrawal tests at 199-D5-134

4.4.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-23. Effective initial displacements of 3.2 ft., 1.5 ft., and 2.1 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are comparable to the theoretical estimates suggesting that the test data are reliable.

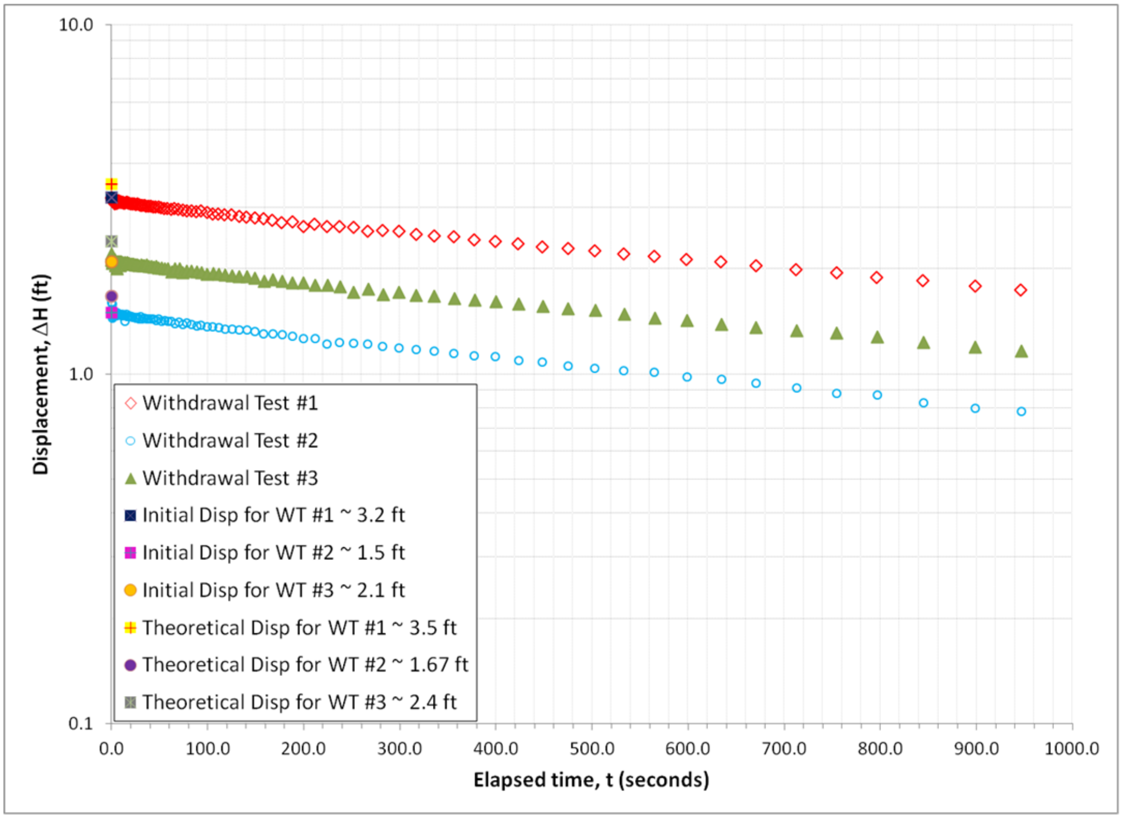

Figure 4-23. Estimation of effective initial displacement at 199-D5-134

4.4.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-24 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis because its record is the most complete.

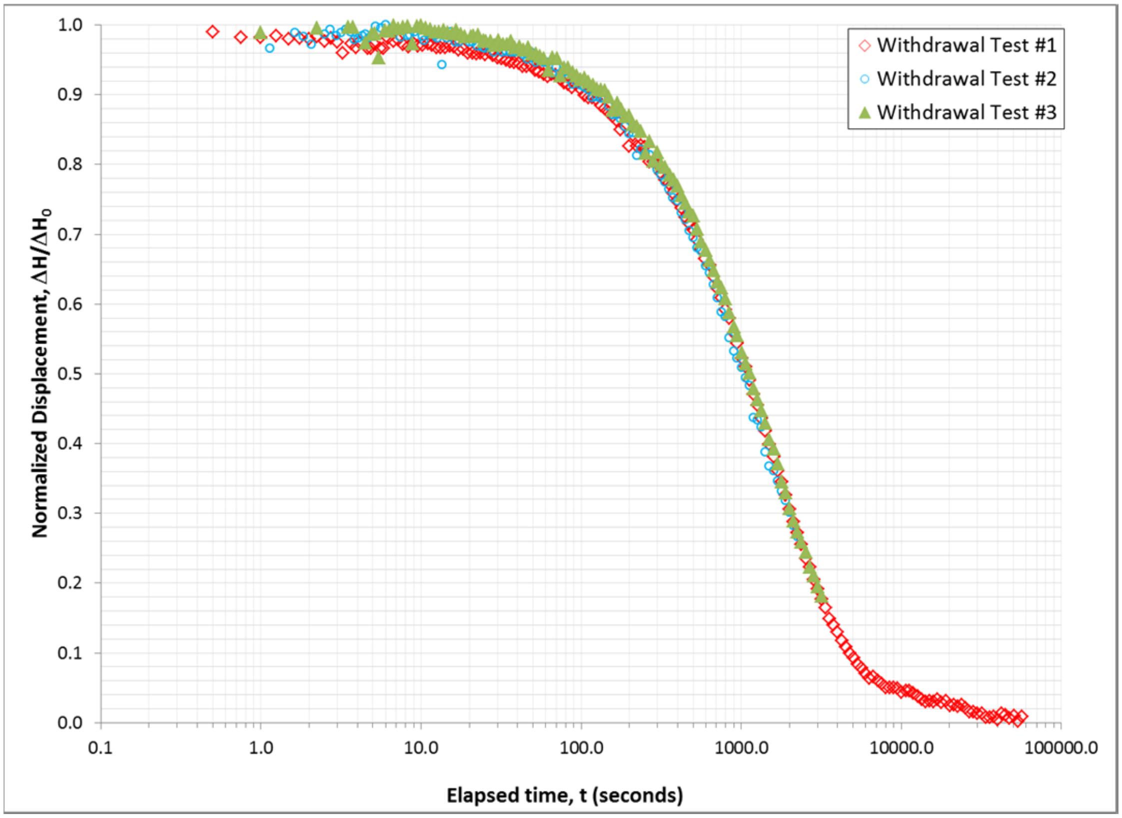

Figure 4-24. Normalized displacement at 199-D5-134

4.4.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-25. A good match to the observations is achieved with a storage coefficient, *S*, of 4×10^{-3}, and a fitted transmissivity, *T*, of 0.4 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-1, we see that for well 199-D5-134, this is not the case. The aquifer (RUM) is at least 8.74 m (110.58 m – 101.84 m) thick at this location, and the length of the well screen is about 3.08 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 10.1 ft. (3.08 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **0.1 m/d** **or** **1.2×10^{-6} m/s.**

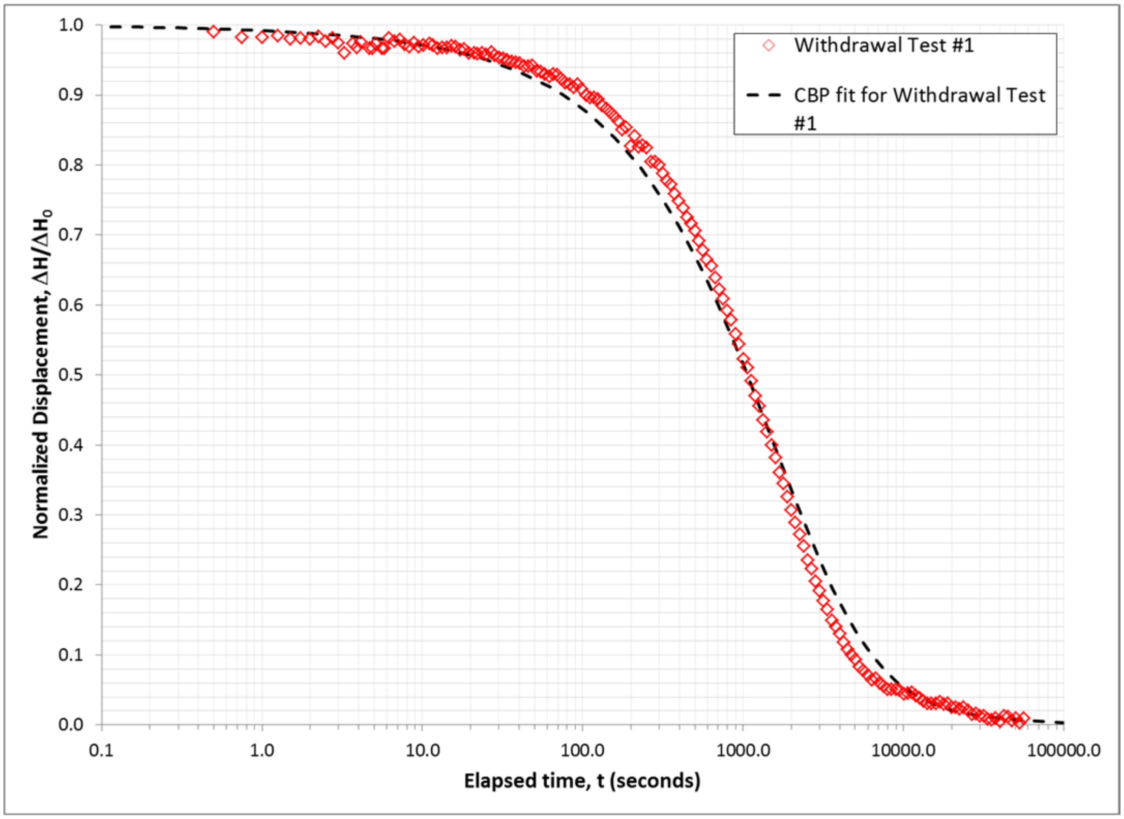

Figure 4-25. CBP Model fit at 199-D5-134

4.4.6 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-26. A good match to the observations is achieved with a specific storage, S_s, of 1.3×10^{-3} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **0.1 m/d** or **1.2×10^{-6} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 4.0×10^{-3} by the well screen length (10.1 ft. or 3.08 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of clay, silt and fine sand. This is consistent with the description of the material across which the well is screened as 'Gravelly Sandy Silt'.

The estimated hydraulic conductivity is in the middle of the range for 'silt, loess' and at the lower end of the range for silty sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This corresponds well with the description of the screened interval.

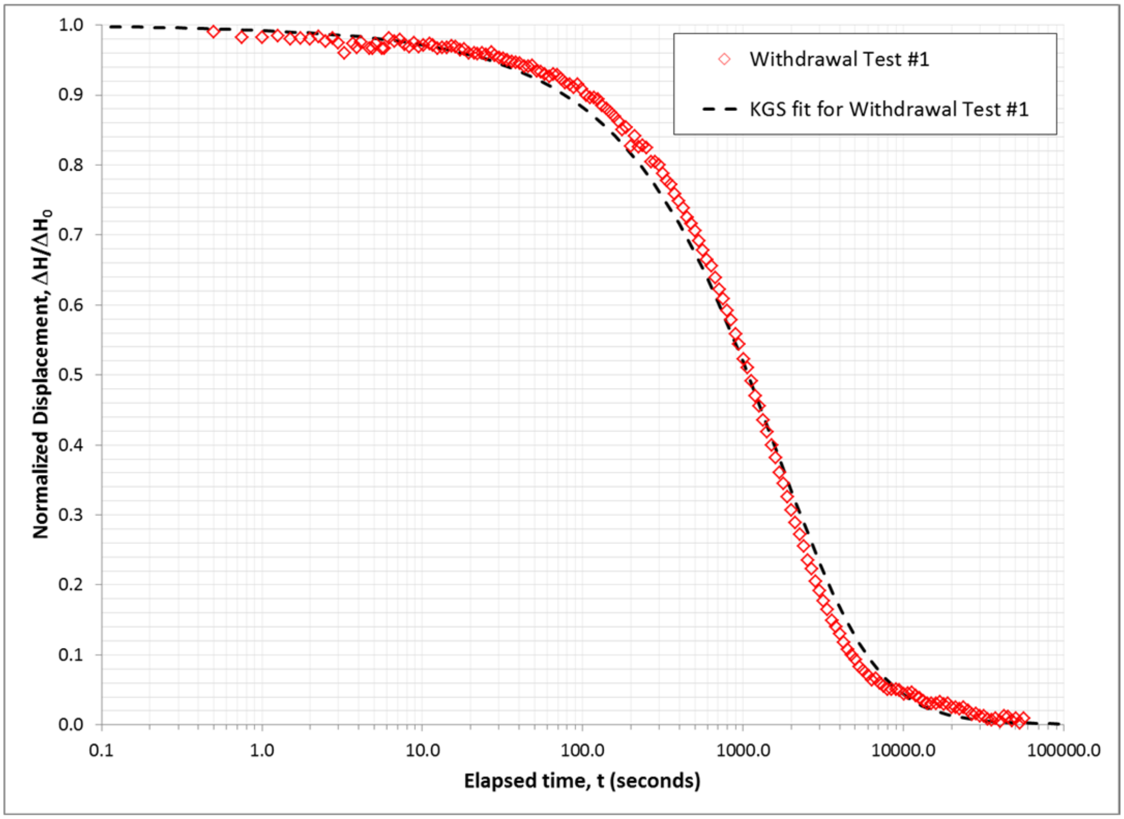

Figure 4-26. KGS Model fit at 199-D5-134

4.5 Analysis of Slug Test Data at well 199-D5-141

Three withdrawal tests were conducted at 199-D5-141 and all of them are analyzed here.

4.5.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.27. The normalized displacements in section 4.5.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.5.2.

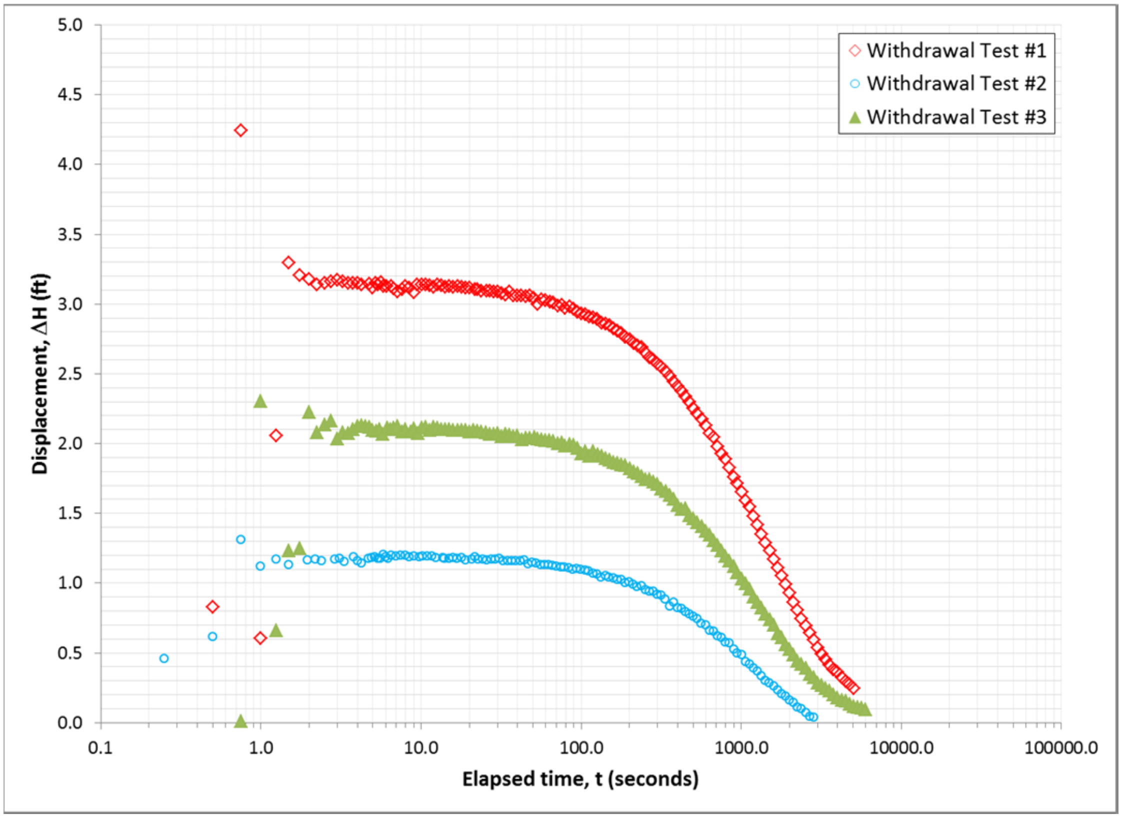

Figure 4-27. Displacements from three withdrawal tests at 199-D5-141

4.5.2 Estimation of effective start time

Effective start times of 1.75 seconds, 1.0 seconds and 2.0 seconds are estimated for the three withdrawal tests respectively.

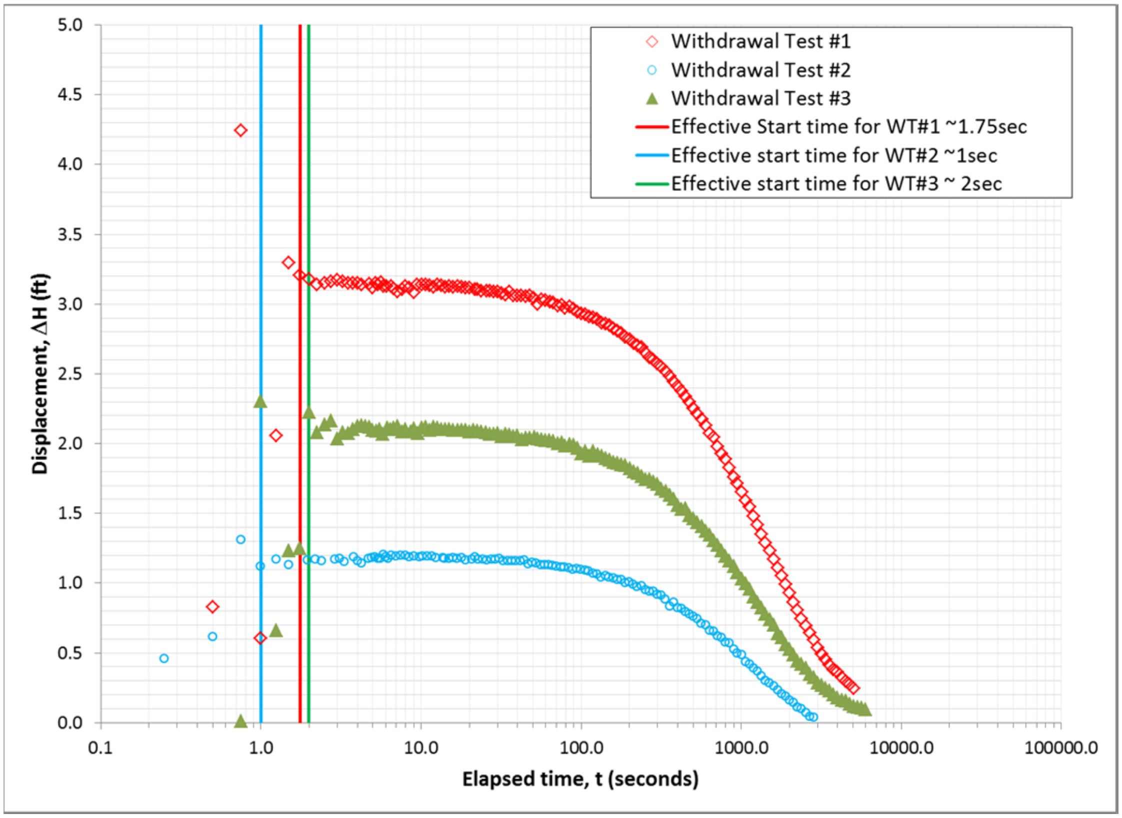

Figure 4-28. Effective start time for withdrawal tests at 199-D5-141

4.5.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-29. Effective initial displacements of 3.2 ft., 1.5 ft., and 2.15 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are comparable to the theoretical estimates suggesting that the test data are reliable.

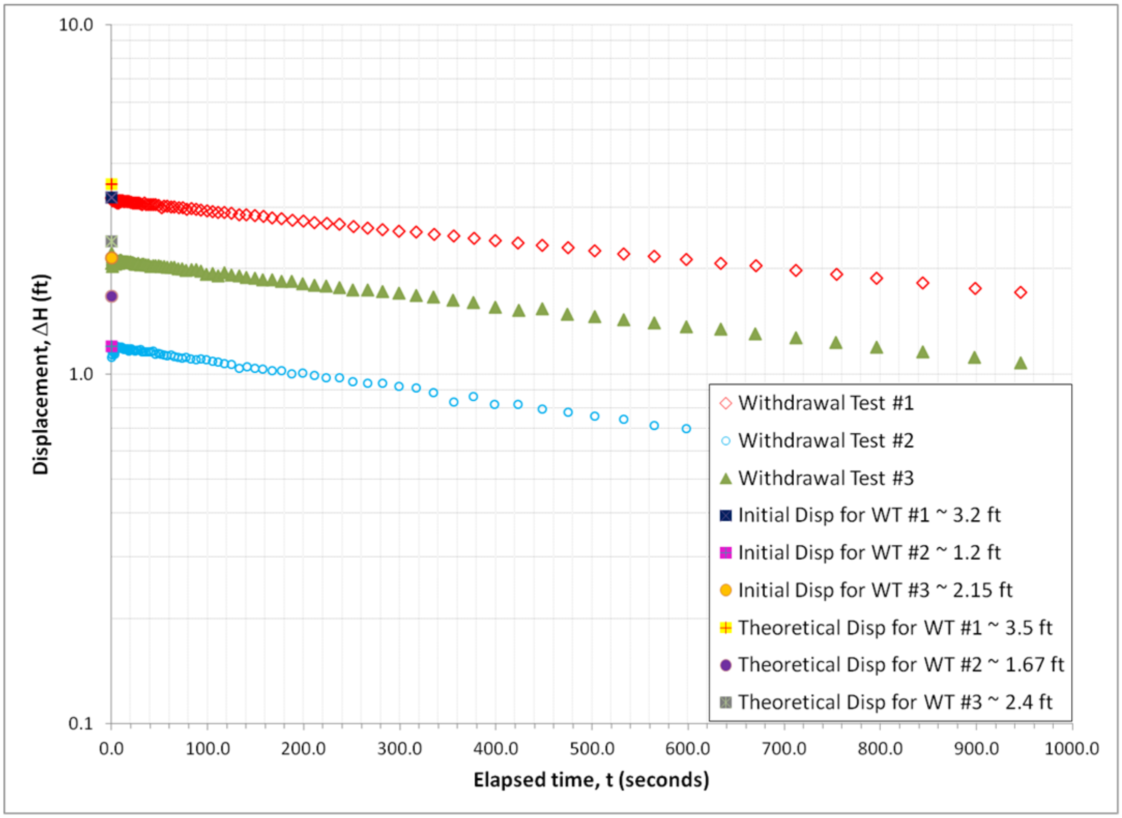

Figure 4-29. Estimation of effective initial displacement at 199-D5-141

4.5.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement and plotted in Figure 4-30. The responses of the first and third tests are internally consistent but the second test's response deviates from the others after 300 seconds. An inspection of the field log indicates that the second slug test was abandoned midway because the recovery was too long. Therefore, it was excluded from further analysis. The close correspondence of the other normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The third withdrawal test is chosen for analysis because its record is the most complete.

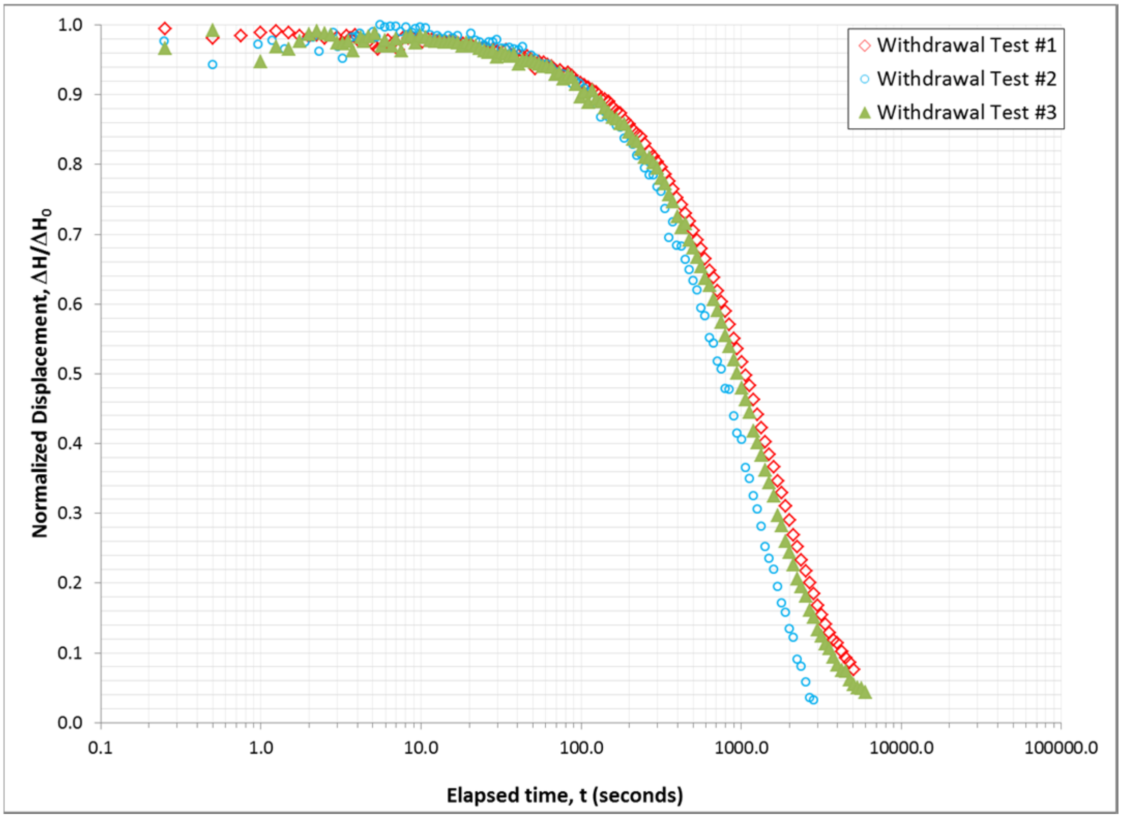

Figure 4-30. Normalized displacement at 199-D5-141

4.5.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the third withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-31. A good match to the observations is achieved with a storage coefficient, *S*, of 1×10^{-3}, and a fitted transmissivity, *T*, of 0.59 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-1, we see that for well 199-D5-141, this is not the case. The aquifer (RUM) is at least 16.55 m (110.11 m – 93.56 m) thick at this location, and the length of the well screen is about 3.05 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 10 ft. (3.05 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **0.2 m/d** **or** **2.3×10^{-6} m/s.**

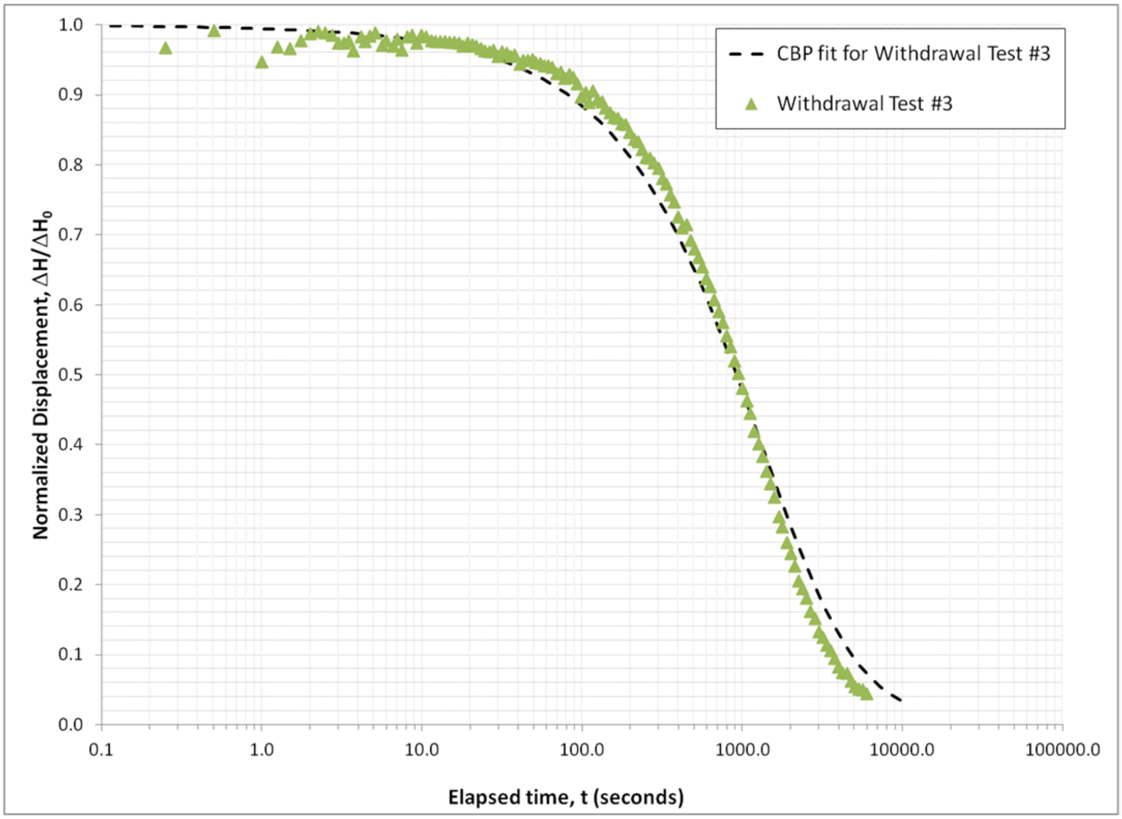

Figure 4-31. CBP Model fit at 199-D5-141

4.5.6 Refined analysis

For a more refined analysis, the normalized displacements for the third withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-32. A good match to the observations is achieved with a specific storage, S_s, of 3.3×10^{-4} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **0.2 m/d** or **2.3×10^{-6} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 1.0×10^{-3} by the well screen length (10 ft. or 3.05 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of clay, silt and fine sand. This is consistent with the description of the material across which the well is screened as ‘Gravelly Silt’.

The estimated hydraulic conductivity is at the higher end of the range for ‘silt, loess’ and at the lower end of the range for silty sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This corresponds well with the description of the screened interval.

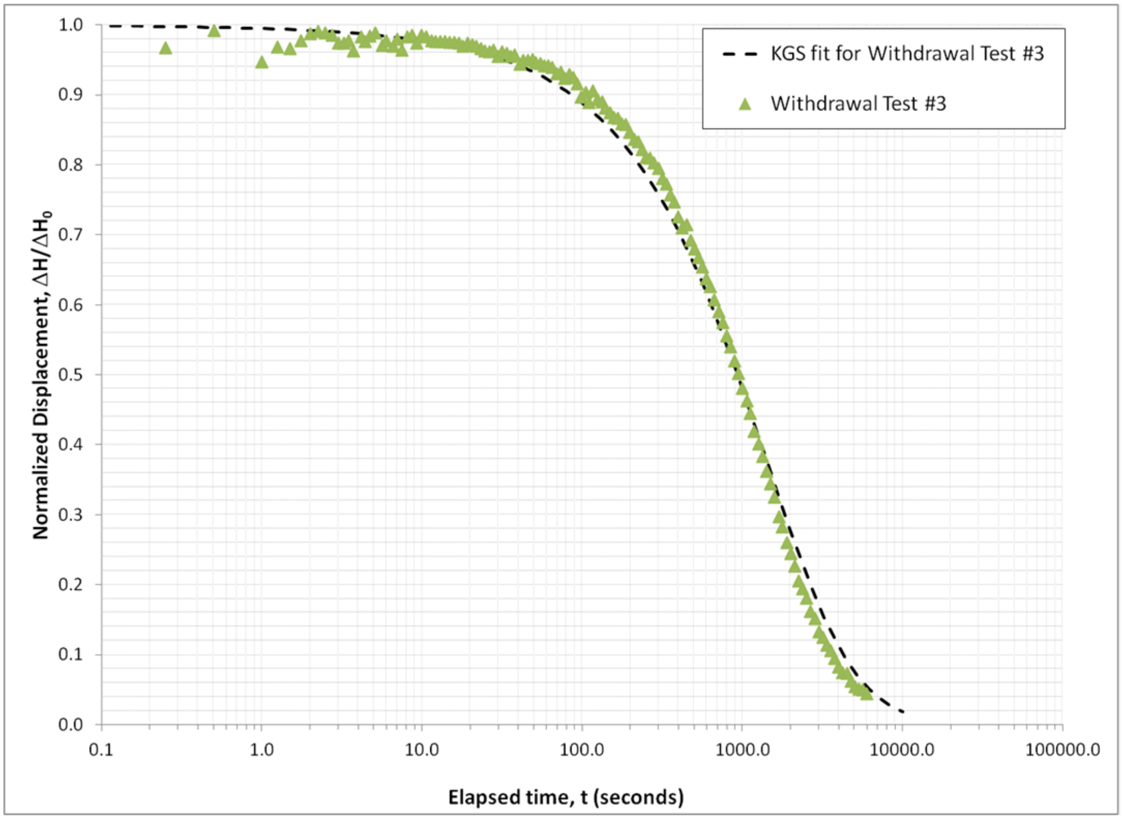

Figure 4-32. KGS Model fit at 199-D5-141

4.6 Analysis of Slug Test Data at well 199-D5-143

Three withdrawal tests were conducted at 199-D5-143 and all of them are analyzed here.

4.6.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.33. The normalized displacements in section 4.6.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.6.2.

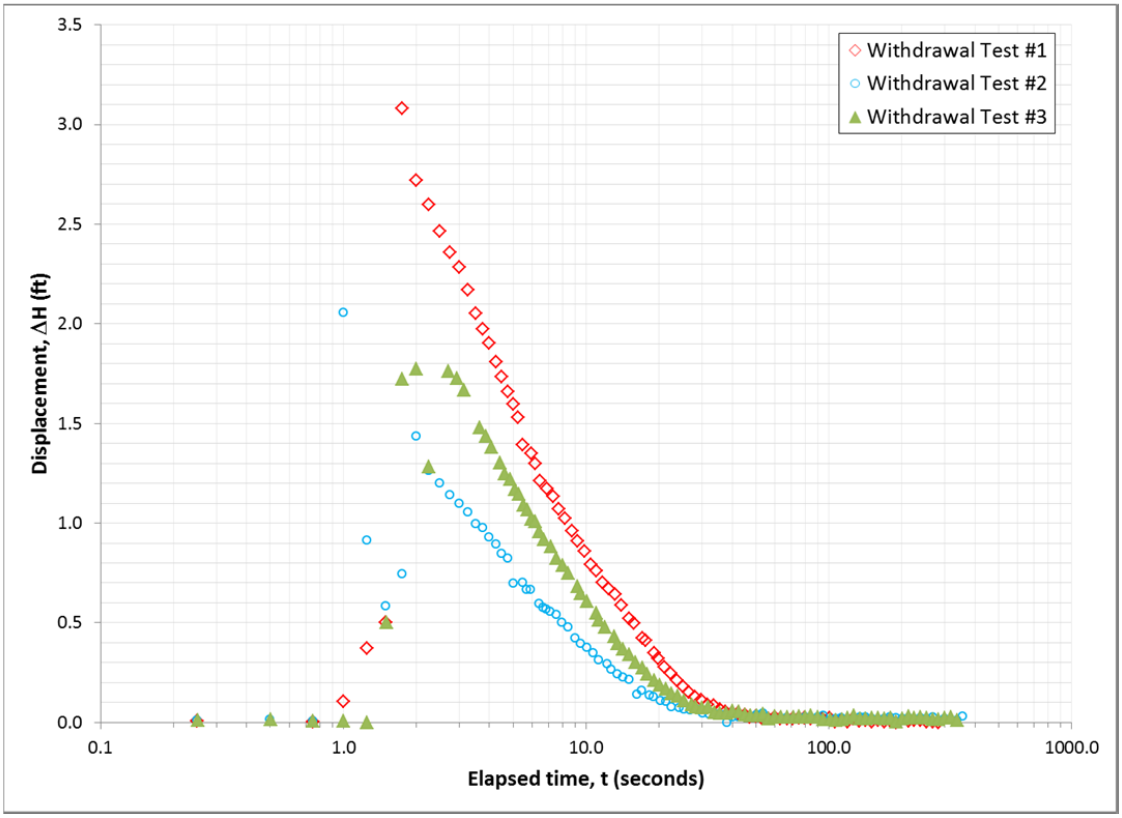

Figure 4-33. Displacements from three withdrawal tests at 199-D5-143

4.6.2 Estimation of effective start time

Effective start times of 1.75 seconds, 2 seconds and 2.7 seconds are estimated for the three withdrawal tests respectively.

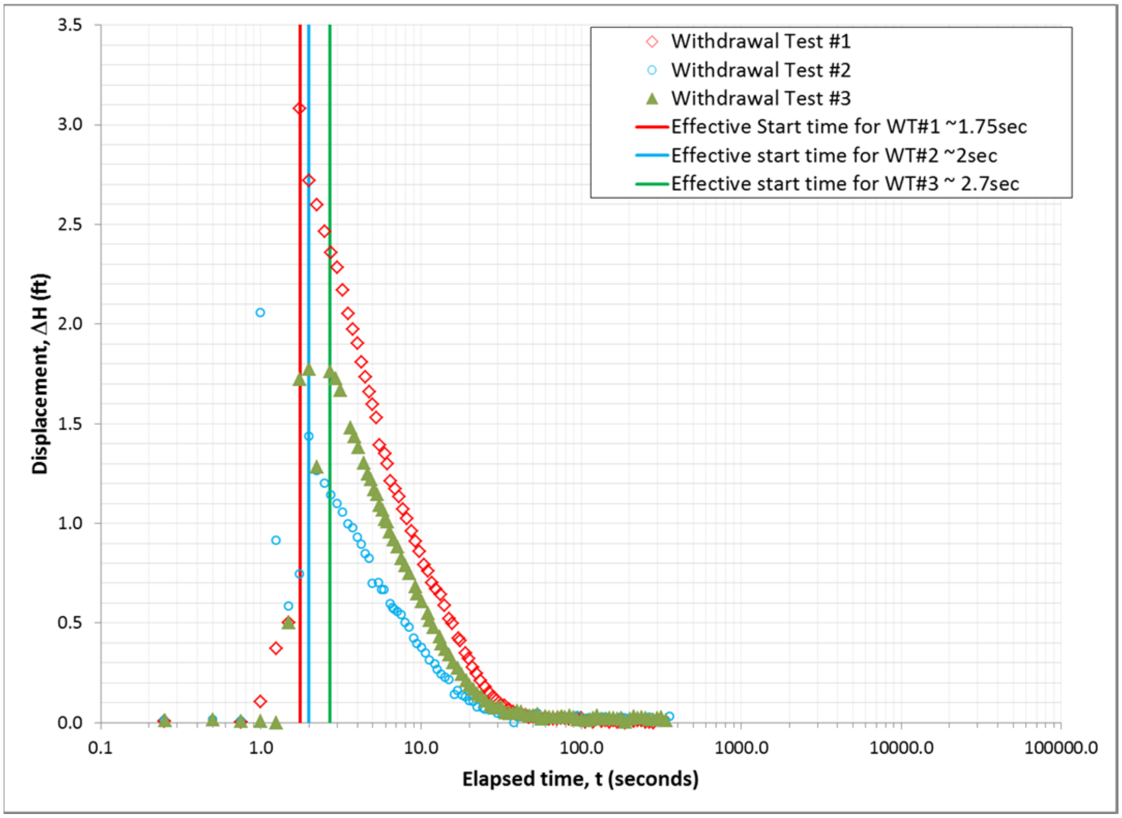

Figure 4-34. Effective start time for withdrawal tests at 199-D5-143

4.6.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-35. Effective initial displacements of 2.9 ft., 1.35 ft., and 1.8 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are lesser than the theoretical estimates probably because of the non-instantaneous nature of the tests.

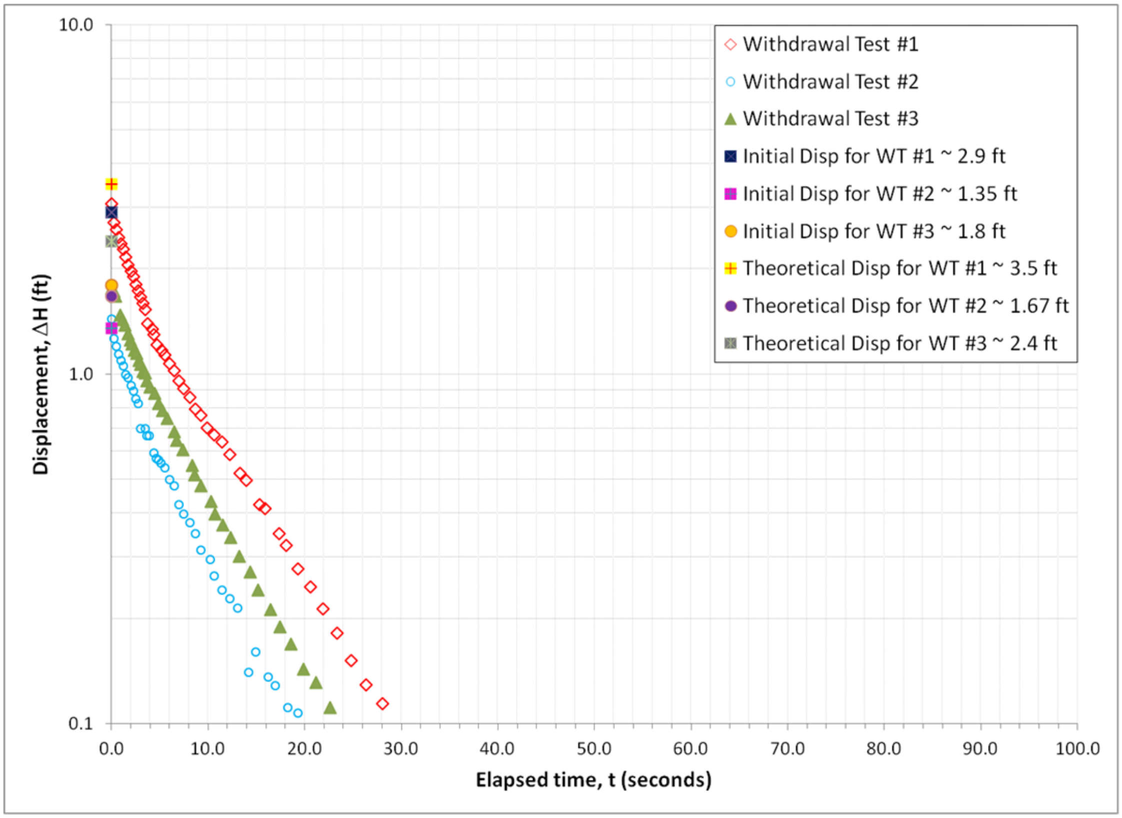

Figure 4-35. Estimation of effective initial displacement at 199-D5-143

4.6.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-36 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis.

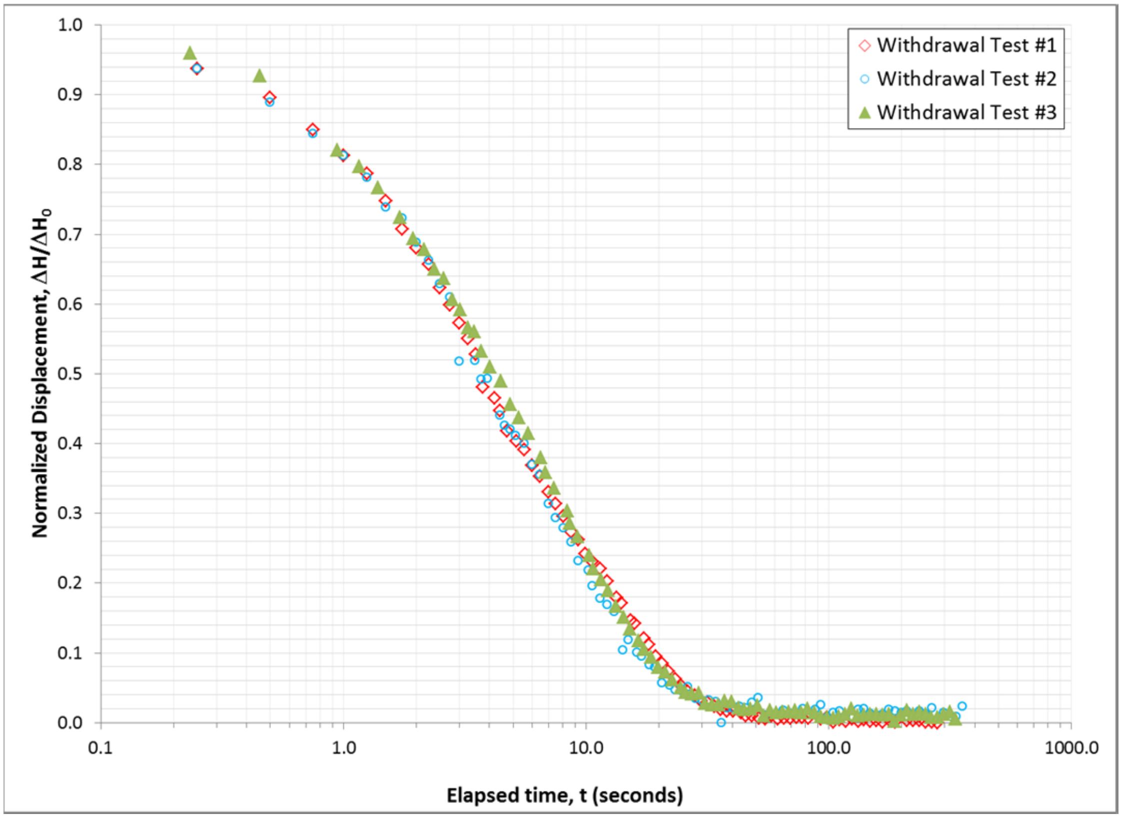

Figure 4-36. Normalized displacement at 199-D5-143

4.6.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-37. A good match to the observations is achieved with a storage coefficient, *S*, of 1.2×10^{-3}, and a fitted transmissivity, *T*, of 137 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-1, we see that for well 199-D5-143, this is not the case. The aquifer (Ringold unit E) is about 7.89 m (119.60 m – 111.71 m) thick at this location, and the length of the well screen is about 6.16 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 20.225 ft. (6.16 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **22 m/d** **or** **2.5×10^{-4} m/s**.

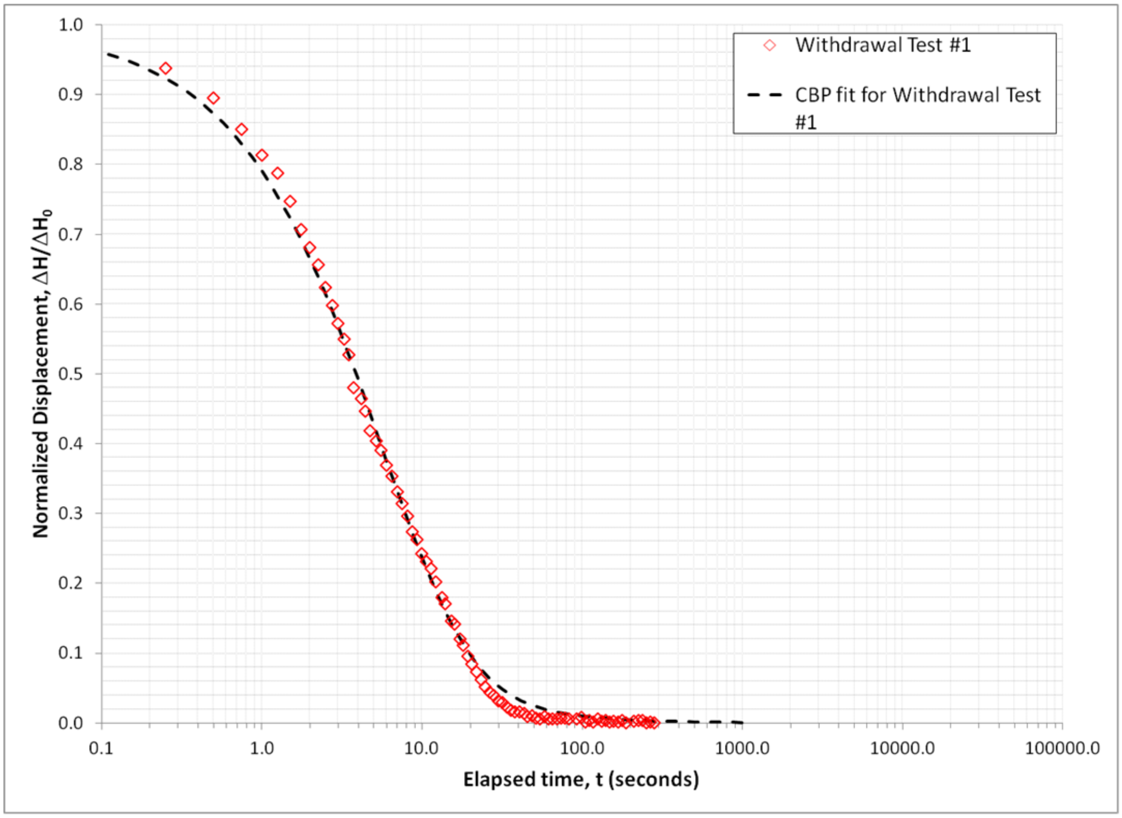

Figure 4-37. CBP Model fit at 199-D5-143

4.6.6 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-38. A good match to the observations is achieved with a specific storage, S_s, of 2.0×10^{-4} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **20 m/d** or **2.3×10^{-4} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 1.2×10^{-3} by the well screen length (20.225 ft. or 6.16 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of medium sand, fine sand and silt. This does not correspond well with the 'Silty Sandy Gravel' description of the screened interval. It is possible that there could be some fines in the screened interval accounting for the higher specific storage.

The estimated hydraulic conductivity is in the middle of the range for clean sand and at the higher end of the range for silty sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This does not correspond well with the 'Silty Sandy Gravel' description of the screened interval. It is possible that there could be some unreported fines in the aquifer across from the screened interval accounting for the lower hydraulic conductivity.

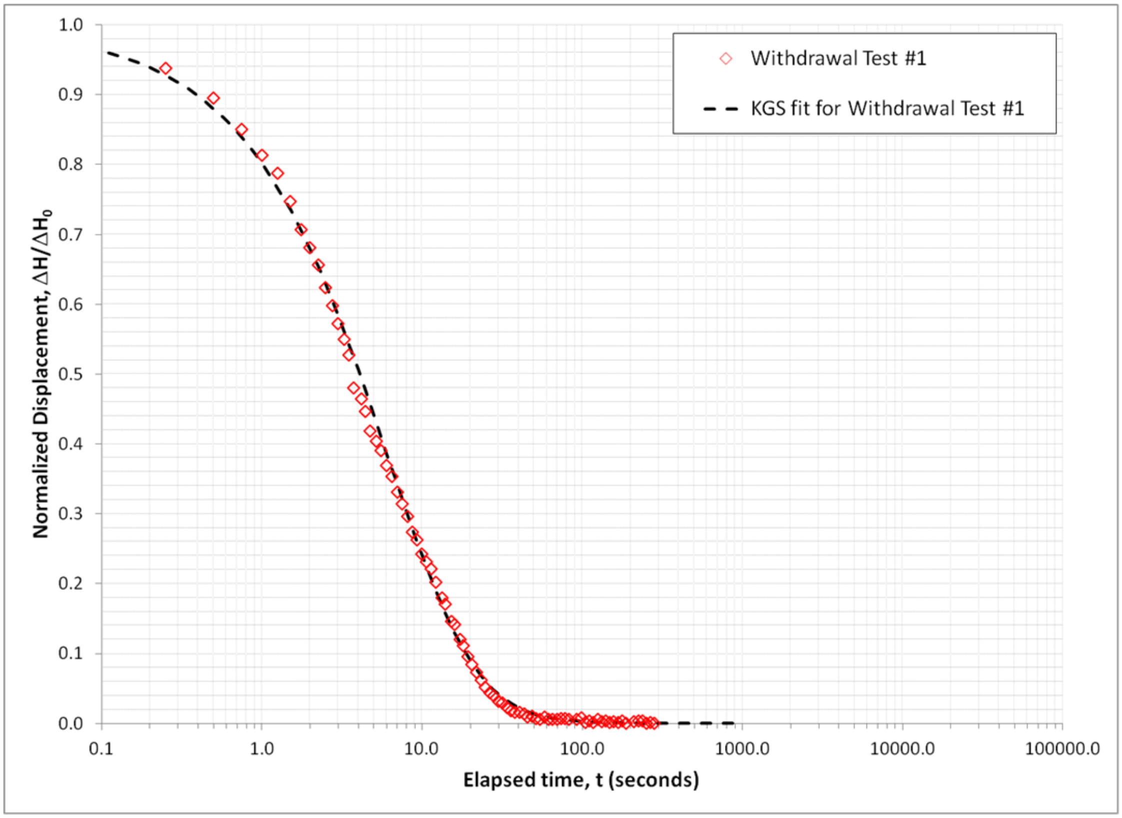

Figure 4-38. KGS Model fit at 199-D5-143

4.7 Analysis of Slug Test Data at well 199-D5-144

Two withdrawal tests were conducted at 199-D5-144 and both are analyzed here.

4.7.1 Raw displacement data for withdrawal tests

The two withdrawal tests were conducted with a slug of volume 0.328 ft^3. The displacements are plotted in Figure 4.39. The agreement in the responses between the two tests suggests that the test data are reliable. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.7.2.

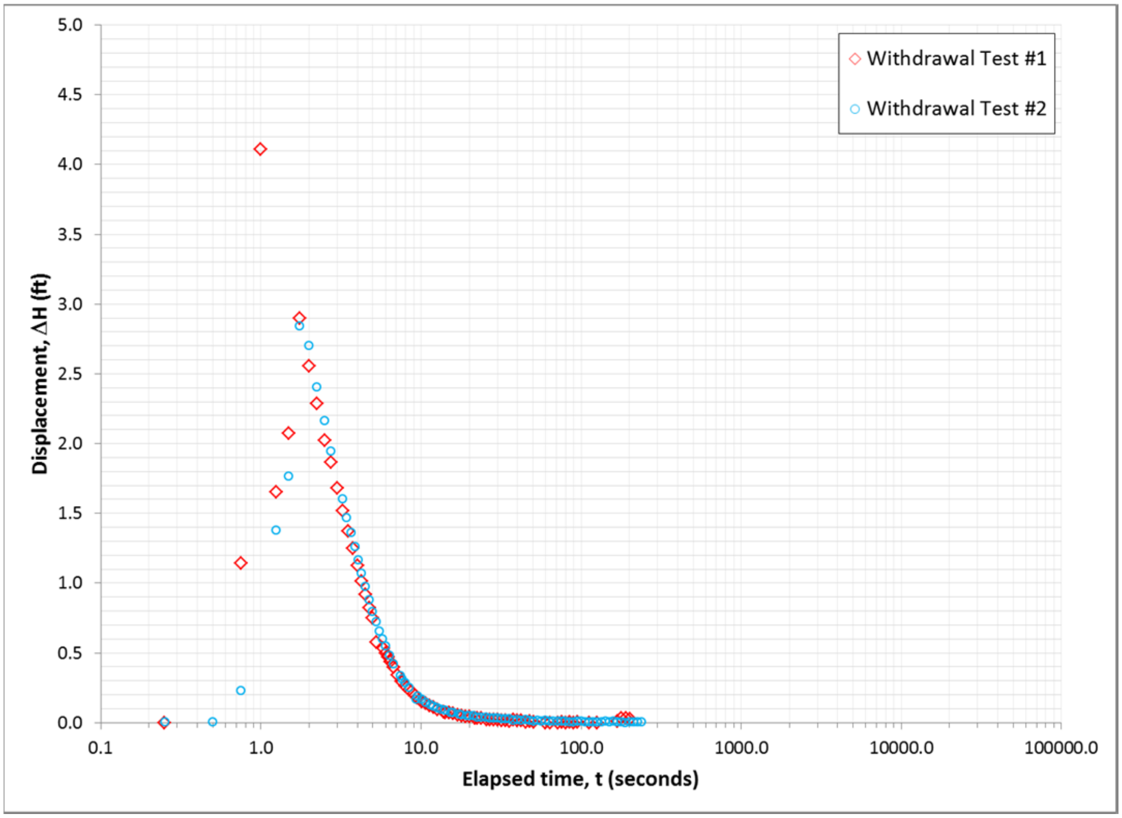

Figure 4-39. Displacements from two withdrawal tests at 199-D5-144

4.7.2 Estimation of effective start time

An effective start time of 1.75 seconds was estimated for the two withdrawal tests as shown in Figure 4-40.

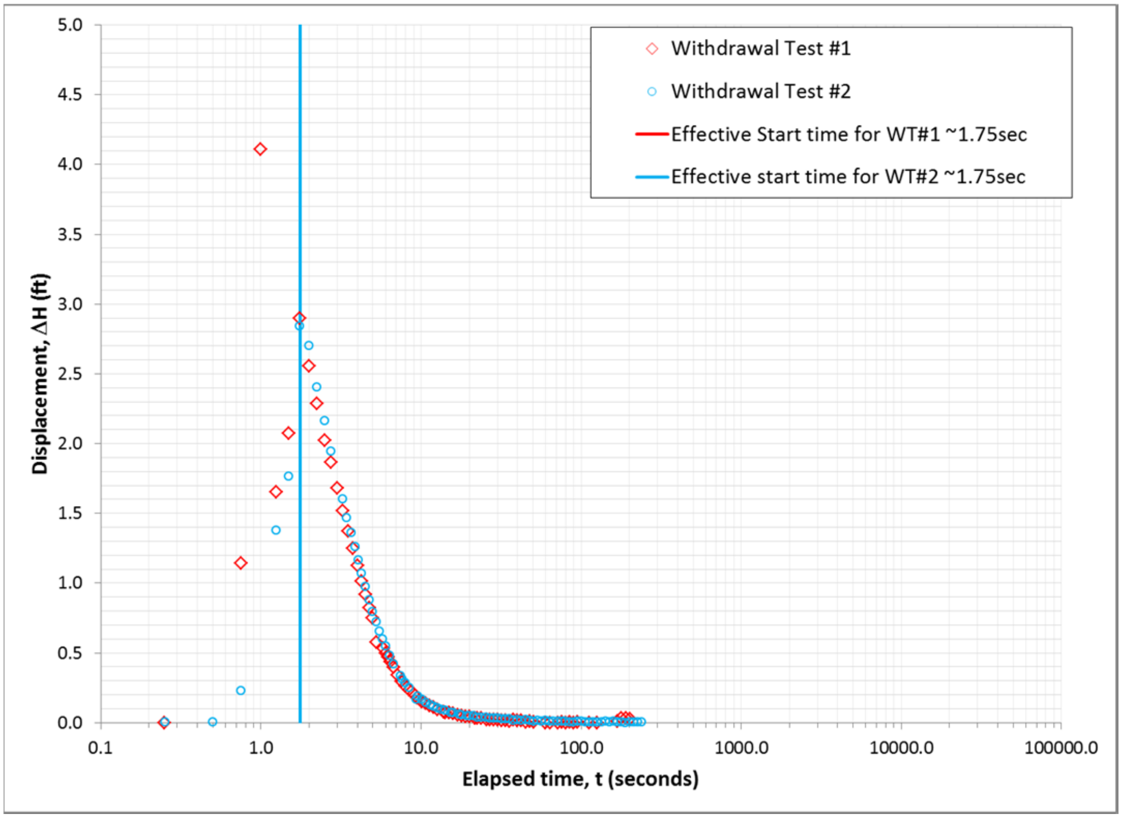

Figure 4-40. Effective start time for withdrawal tests at 199-D5-144

4.7.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-41. Effective initial displacements of 2.78 ft., and 2.88 ft. are estimated for the two withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.328 ft^3 and a casing radius (r_c) of 2 inches, a theoretical initial displacement (H_0) of 3.75 ft. is calculated ($H_0 = V/\pi r_c^2$). The visually estimated initial displacements are close to the theoretical estimates suggesting that the test data are reliable.

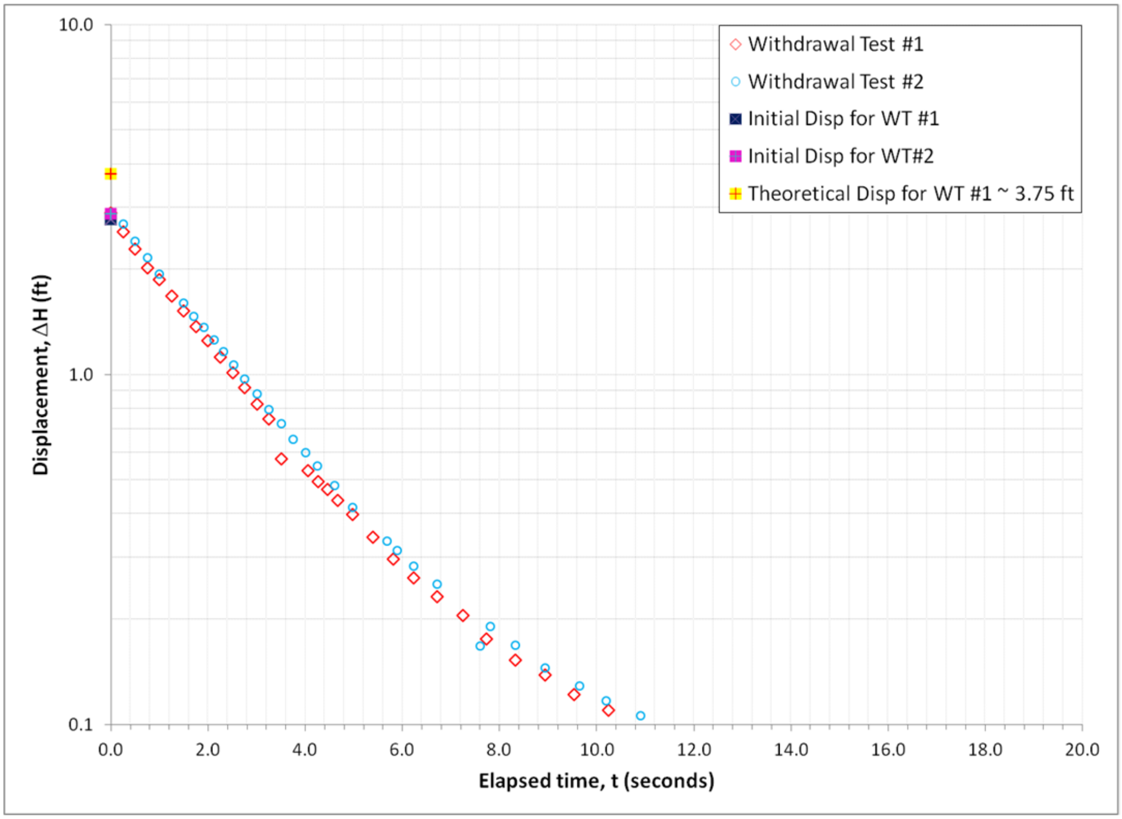

Figure 4-41. Estimation of effective initial displacement at 199-D5-144

4.7.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-42 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis.

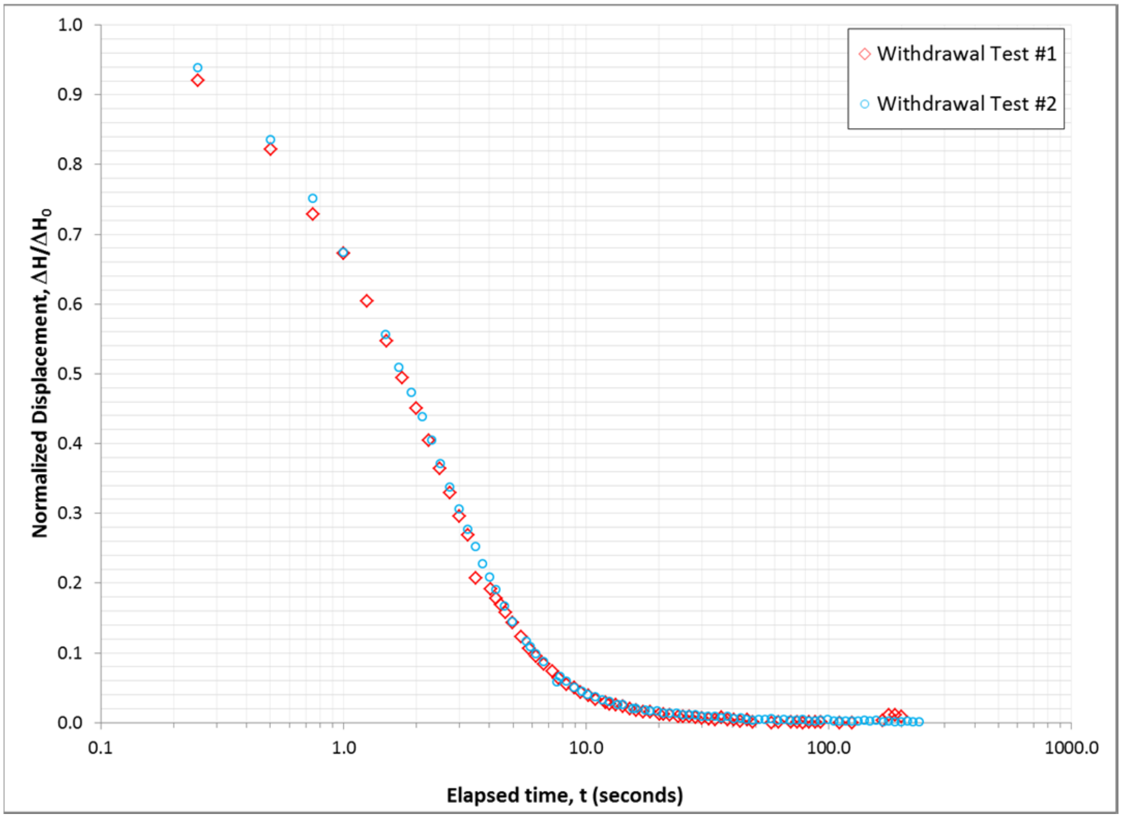

Figure 4-42. Normalized displacement at 199-D5-144

4.7.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-43. A good match to the observations is achieved with a storage coefficient, *S*, of 4.6×10^{-4}, and a fitted transmissivity, *T*, of 173 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-1, we see that for well 199-D5-144, this is not the case. The aquifer (Ringold unit E) is about 8.66 m (119.83 m – 111.17 m) thick at this location, and the length of the well screen is about 7 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 23 ft. (7 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **25 m/d** or **2.9×10^{-4} m/s.**

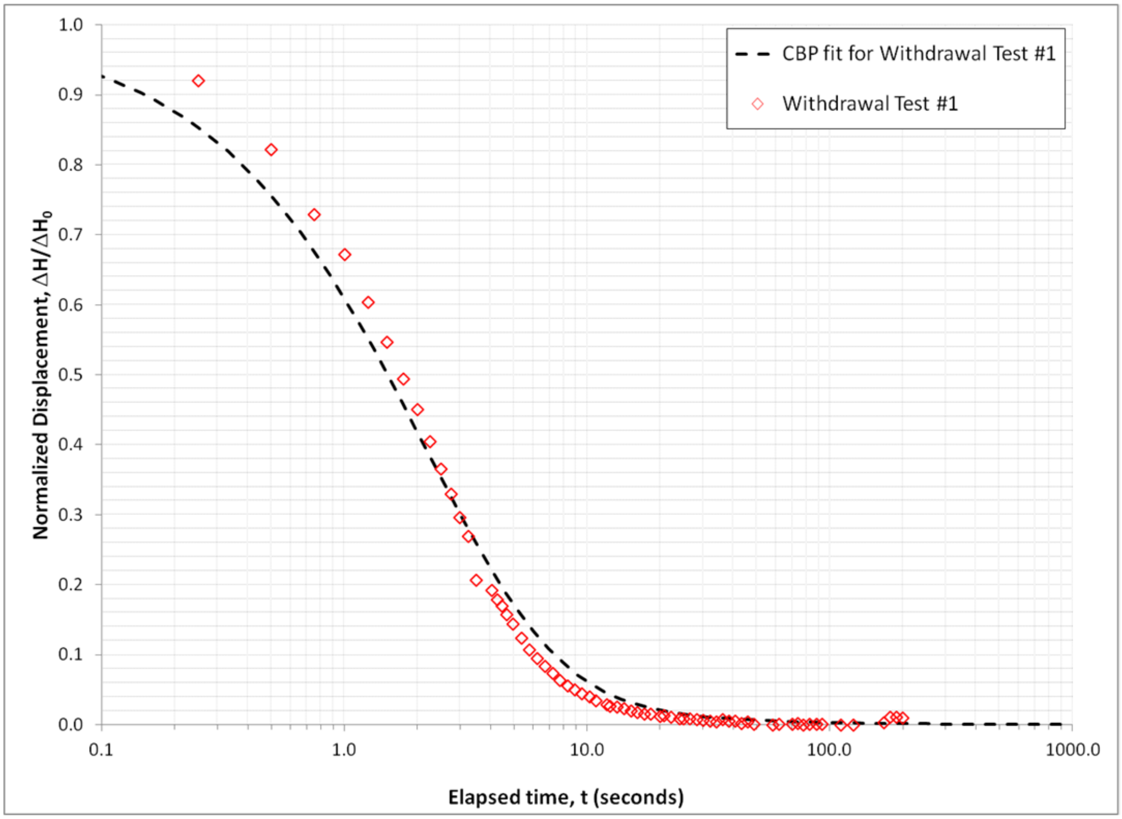

Figure 4-43. CBP Model fit at 199-D5-144

4.7.6 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-44. A good match to the observations is achieved with a specific storage, S_s, of 6.6×10^{-5} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **23 m/d** or **2.7×10^{-4} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 4.6×10^{-4} by the well screen length (23 ft. or 7 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of medium sand and coarse sand. This corresponds well with the well log which describes the screened interval as a mixture of sand, gravel and silt.

The estimated hydraulic conductivity is in the middle of the range for clean sand and at the higher end of the range for silty sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This corresponds well with the well log which describes the screened interval as a mixture of sand, gravel and silt.

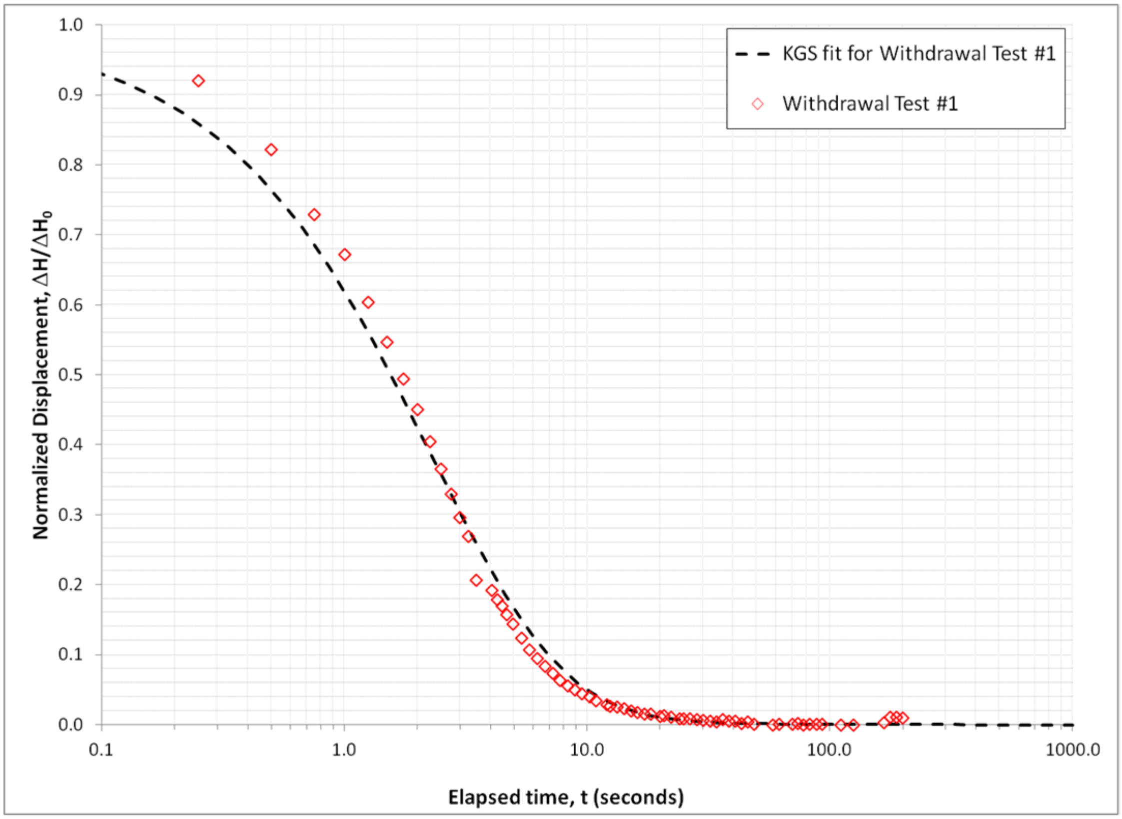

Figure 4-44. KGS Model fit at 199-D5-144

4.8 Analysis of Slug Test Data at well 199-D6-3

Three withdrawal tests were conducted at 199-D6-3 and all of them are analyzed here.

4.8.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.45. The normalized displacements in section 4.8.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.8.2.

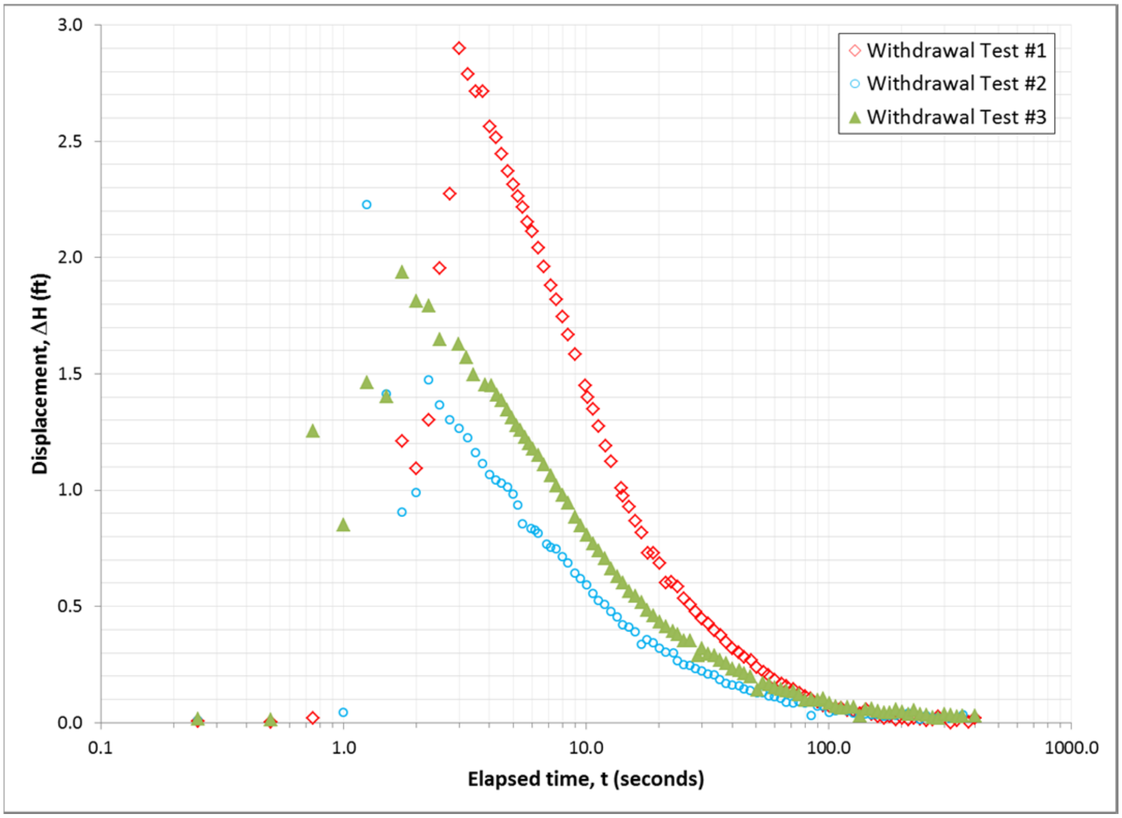

Figure 4-45. Displacements from three withdrawal tests at 199-D6-3

4.8.2 Estimation of effective start time

Effective start times of 3 seconds, 2.25 seconds and 1.75 seconds are estimated for the three withdrawal tests respectively.

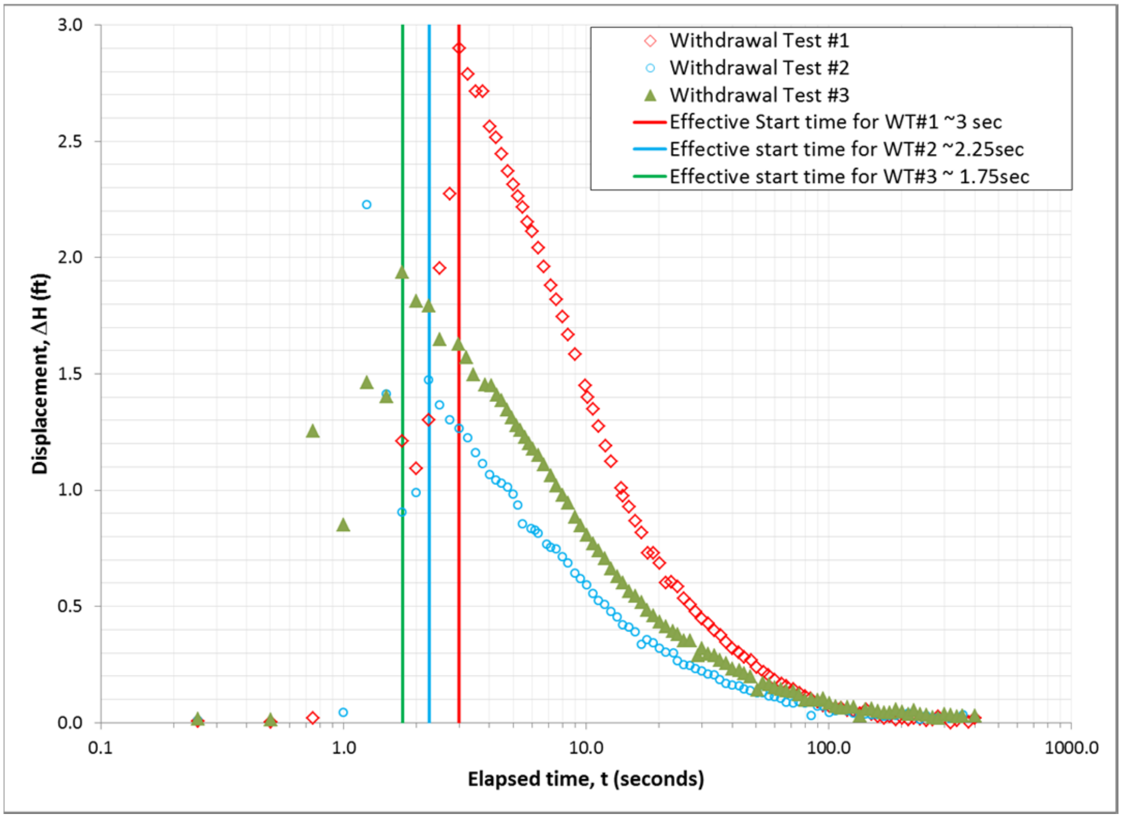

Figure 4-46. Effective start time for withdrawal tests at 199-D6-3

4.8.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-47. Effective initial displacements of 2.95 ft., 1.4 ft., and 1.9 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are lesser than the theoretical estimates probably because of the non-instantaneous nature of the tests.

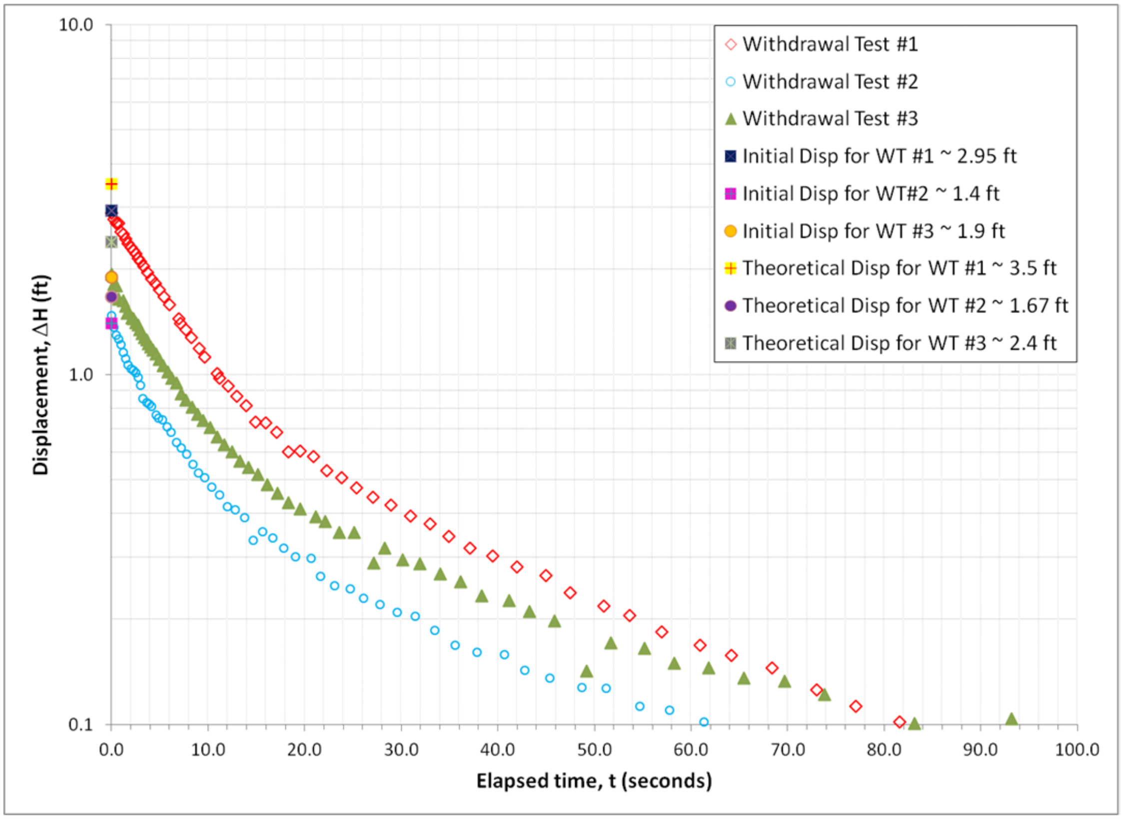

Figure 4-47. Estimation of effective initial displacement at 199-D6-3

4.8.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-48 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis.

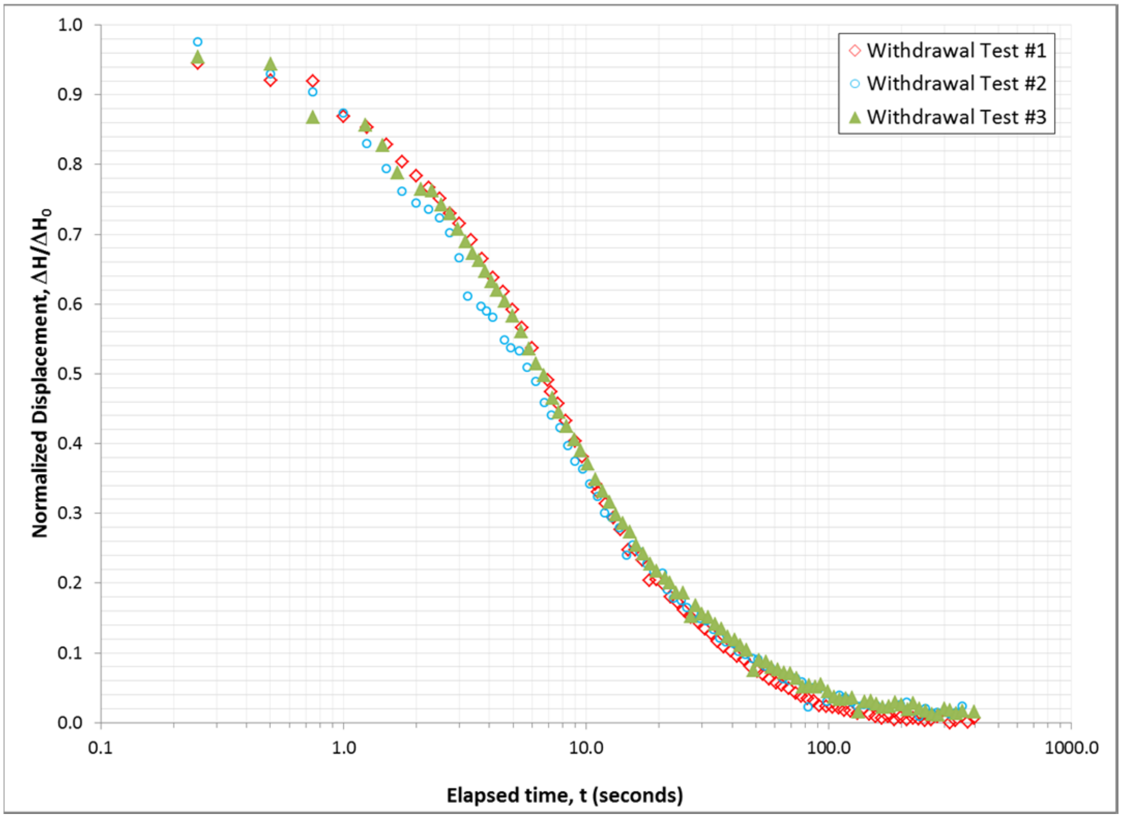

Figure 4-48. Normalized displacement at 199-D6-3

4.8.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-49. A good match to the observations is achieved with a storage coefficient, *S*, of 3×10^{-3}, and a fitted transmissivity, *T*, of 65 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-1, we see that for well 199-D6-3, this is not the case. The aquifer (Ringold unit E) is about 6.46 m (118.93 m – 112.47 m) thick at this location, and the length of the well screen is about 5.11 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 16.78 ft. (5.11 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **13 m/d** **or** **1.5×10^{-4} m/s**.

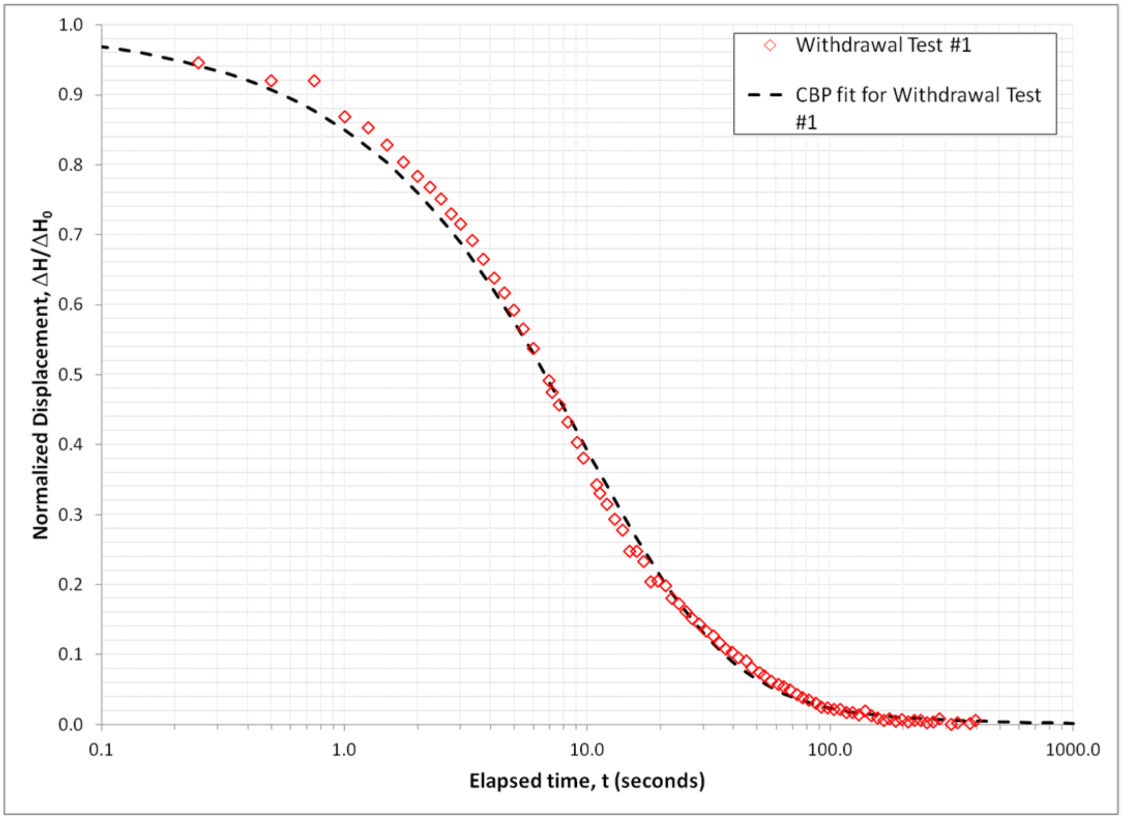

Figure 4-49. CBP Model fit at 199-D6-3

4.8.6 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-50. A good match to the observations is achieved with a specific storage, S_s, of 5.9×10^{-4} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **12 m/d** or **1.4×10^{-4} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 3×10^{-3} by the well screen length (16.78 ft. or 5.11 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of medium sand, fine sand and silt. This does not correspond well with the 'Silty Sandy Gravel' description of the screened interval. It is possible that there could be some fines in the aquifer across the screened interval accounting for the higher specific storage. Further discussion with personnel who had knowledge of drilling activities at this well revealed that the geologist could have missed the fines because of the well was drilled with a very fast dual percussion method using air.

The estimated hydraulic conductivity is in the middle of the range for clean sand and at the higher end of the range for silty sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This does not correspond well with the 'Silty Sandy Gravel' description of the screened interval. It is possible that there could be some fines in the aquifer across from the screened interval accounting for the lower hydraulic conductivity.

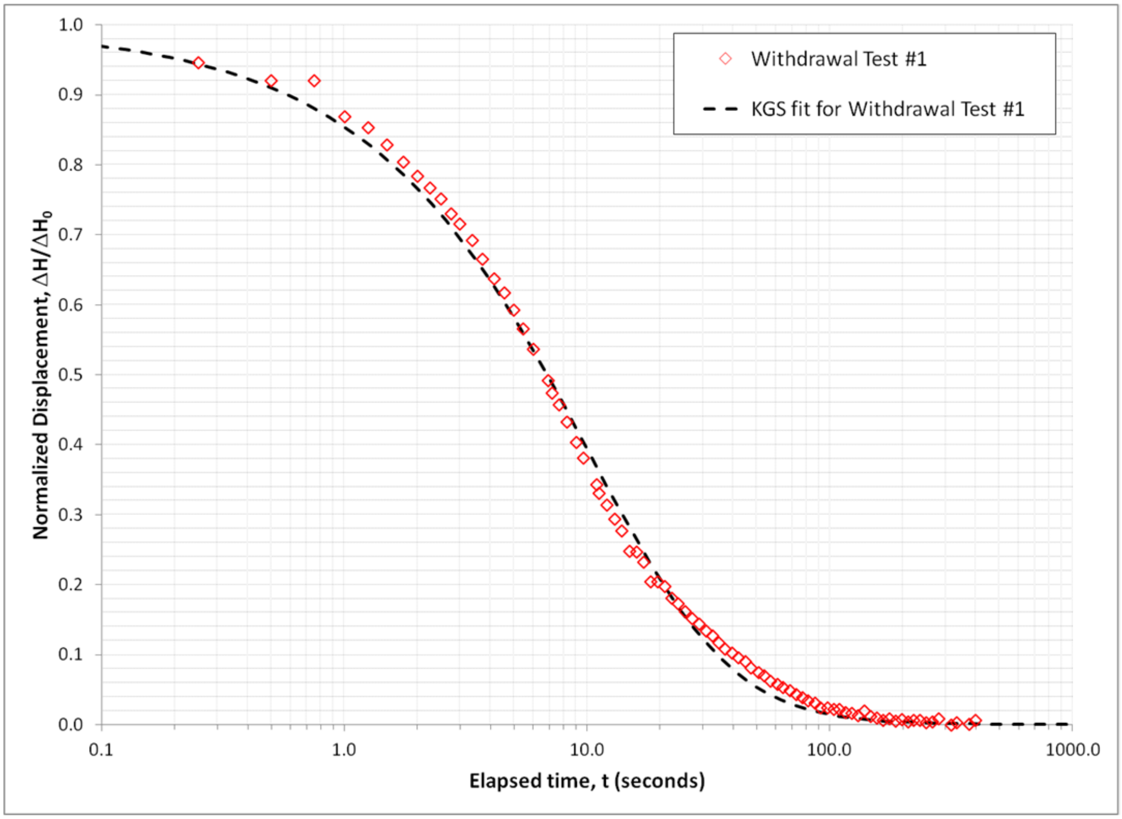

Figure 4-50. KGS Model fit at 199-D6-3

4.9 Analysis of Slug Test Data at well 199-H2-1

Three withdrawal tests were conducted at 199-H2-1 and all of them are analyzed here.

4.9.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4-51. The normalized displacements in section 4.9.3 will tell us if these responses are consistent.

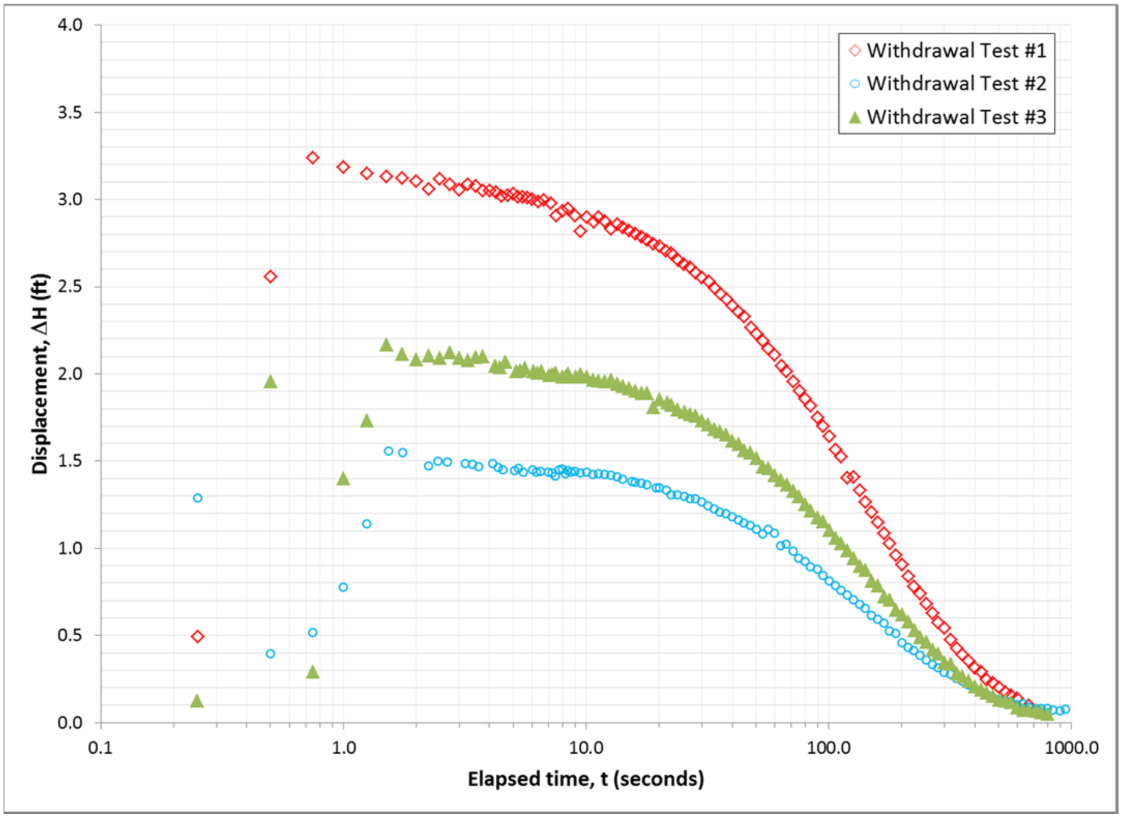

Figure 4-51. Displacements from three withdrawal tests at 199-H2-1

4.9.2 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-52. Effective initial displacements of 3.2 ft., 1.54 ft., and 2.14 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are relatively close to the theoretical estimates suggesting that the test data are reliable.

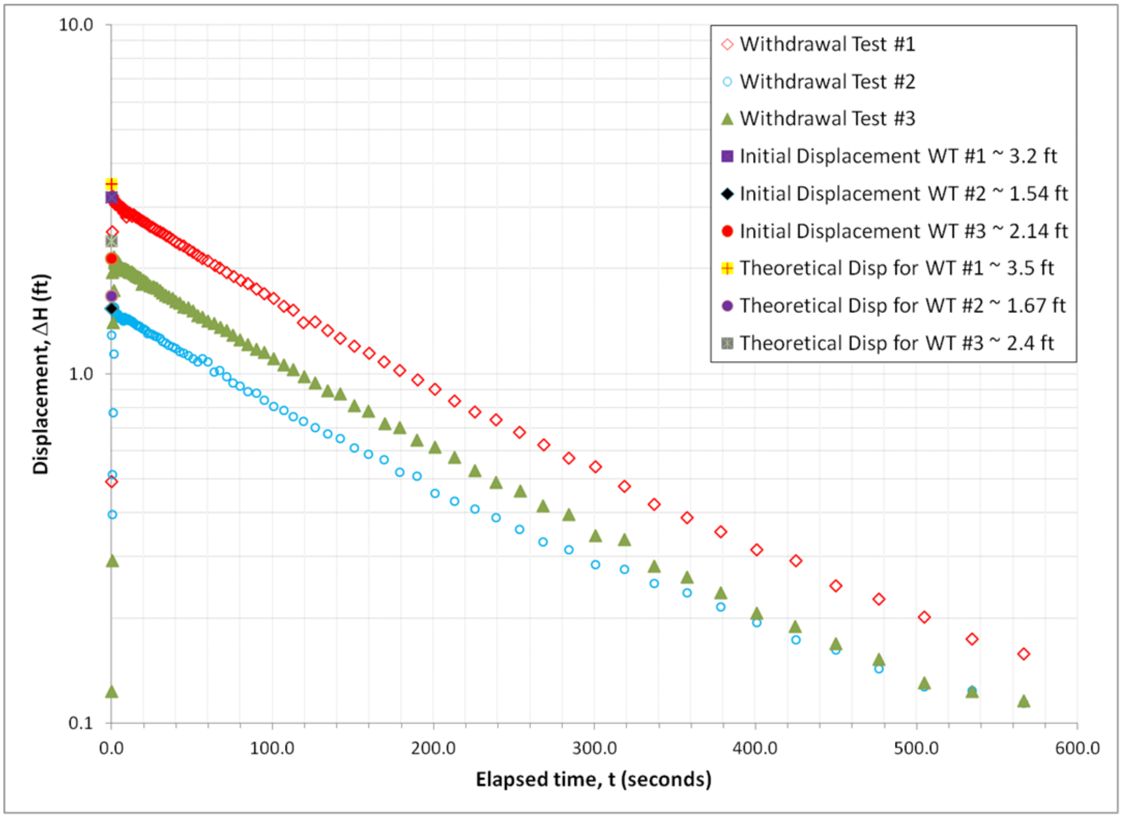

Figure 4-52. Estimation of effective initial displacement at 199-H2-1

4.9.3 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-53 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis.

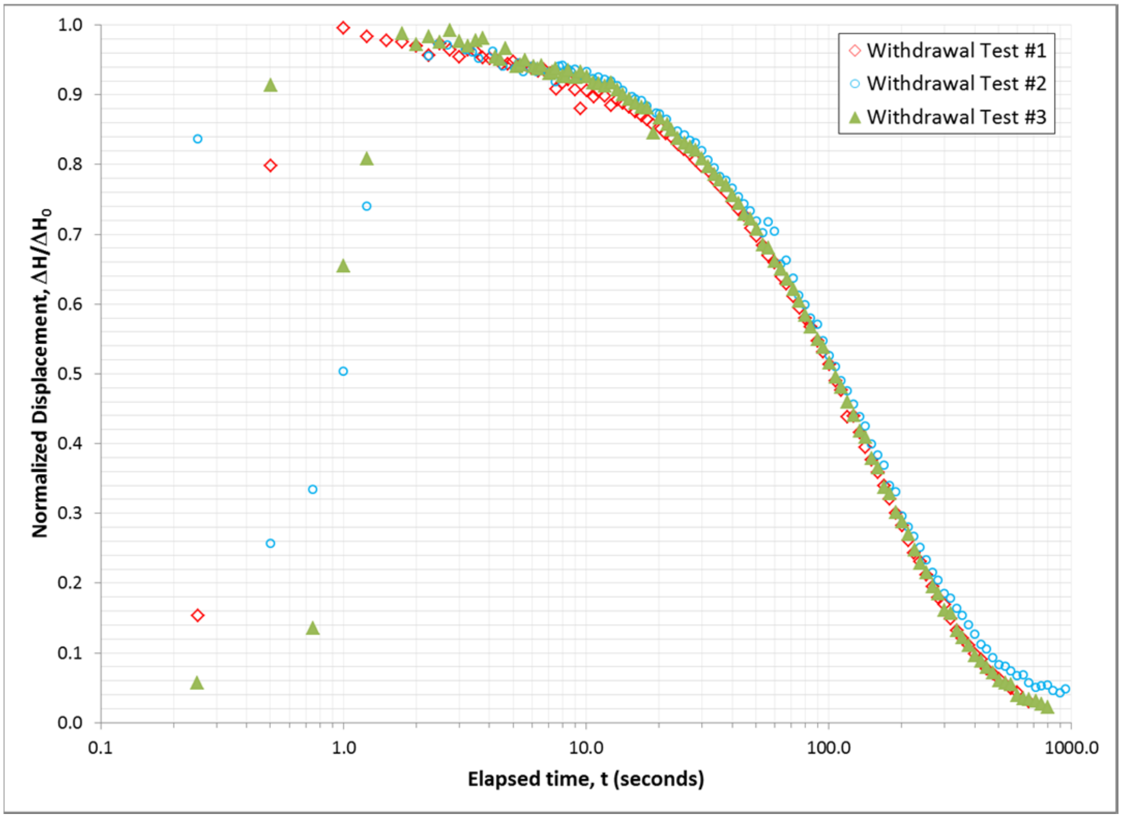

Figure 4-53. Normalized displacement at 199-H2-1

4.9.4 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-54. A good match to the observations is achieved with a storage coefficient, *S*, of 4×10^{-4}, and a fitted transmissivity, *T*, of 6.8 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-2, we see that for well 199-H2-1, this is not the case. The aquifer (RUM) is at least 10.21 m (112.65 m – 102.44 m) thick at this location, and the length of the well screen is about 3.05 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 10 ft. (3.05 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **2.2 m/d** **or** **2.5 $\times10^{-5}$ m/s.**

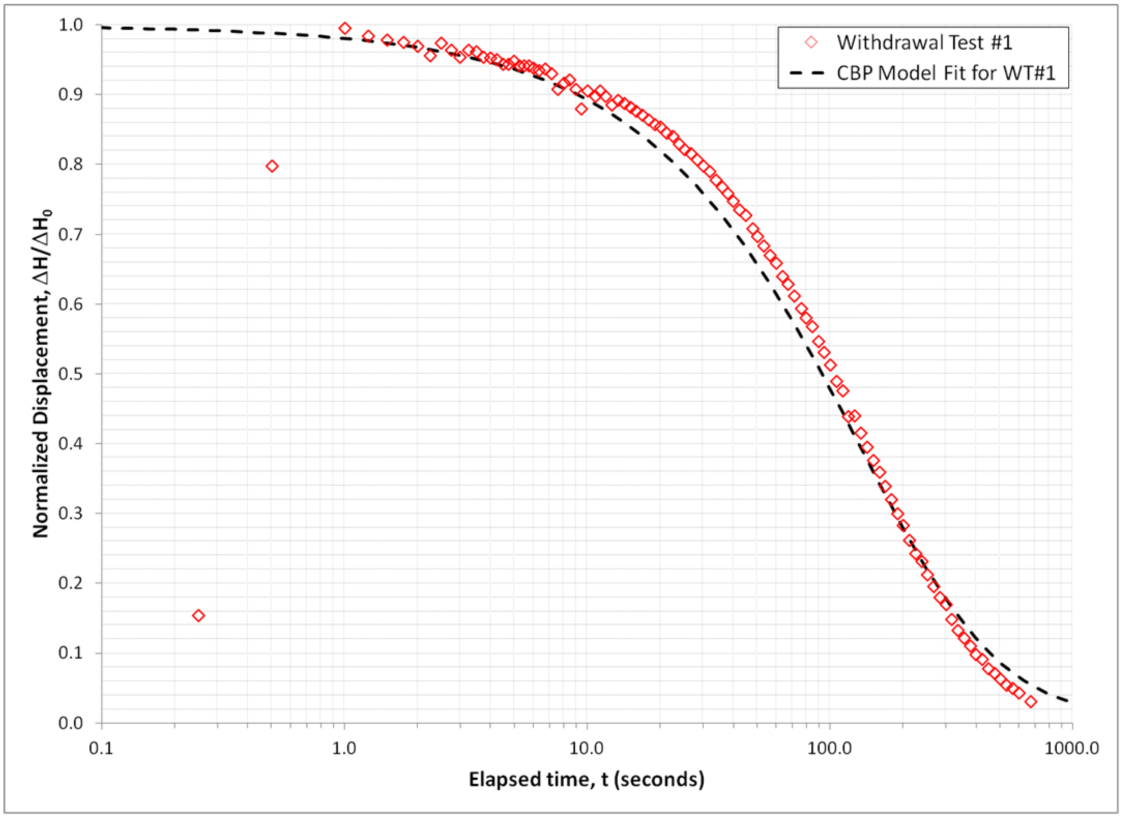

Figure 4-54. CBP Model fit at 199-H2-1

4.9.5 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-55. A good match to the observations is achieved with a specific storage, S_s, of 1.3×10^{-4} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **2 m/d** or **2.3×10^{-5} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 4×10^{-4} by the well screen length (10 ft. or 3.05 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of medium sand, fine sand and silt. This corresponds well with the 'Slightly Silty Sand' description of the screened interval.

The estimated hydraulic conductivity is in the middle of the range for silty sand and at the lower end of the range for clean sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This corresponds well with the 'Slightly Silty Sand' description of the screened interval.

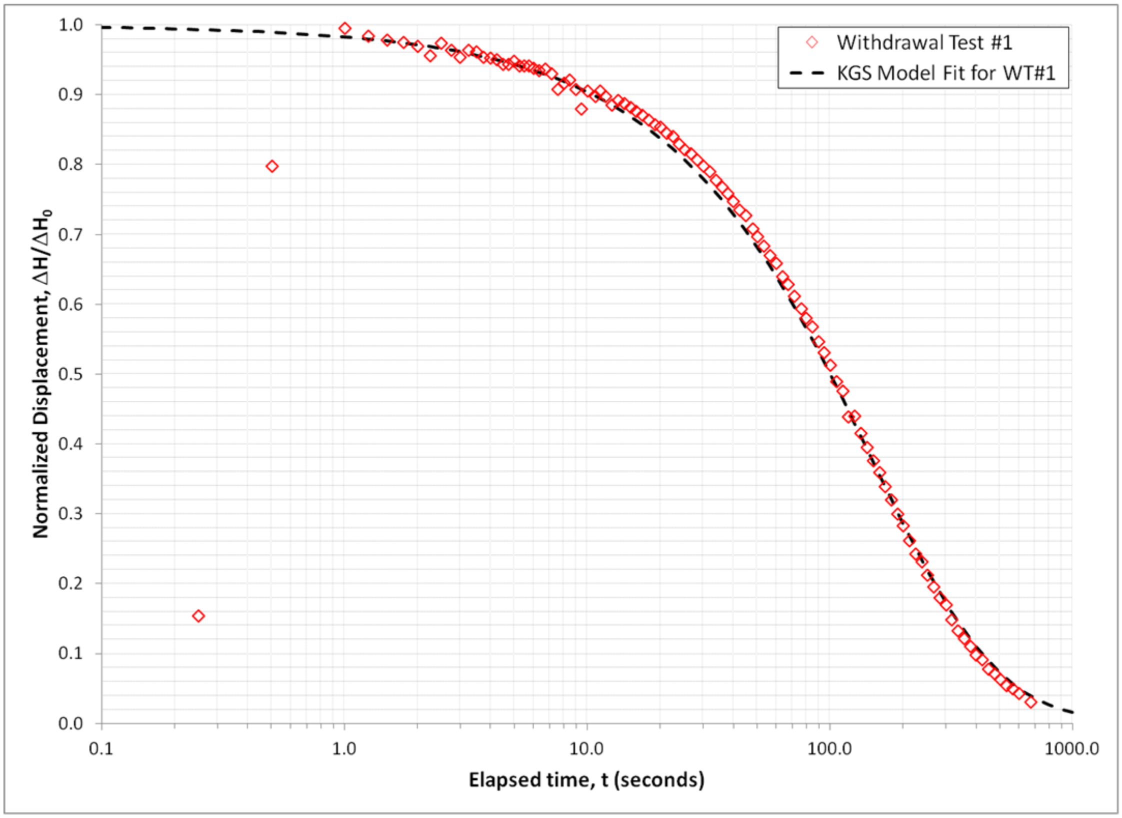

Figure 4-55. KGS Model fit at 199-H2-1

4.10 Analysis of Slug Test Data at well 199-H3-6

Three withdrawal tests were conducted at 199-H3-6 and all of them are analyzed here.

4.10.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.56. The first two tests show dissipation after a few hundred seconds whereas the third test dissipates in less than ten seconds. Inspection of the field log reveals that the transducer slipped during the third test. Therefore, the third test's response is not considered for further analysis. The normalized displacements in section 4.10.4 will tell us if the responses from the first two tests are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.10.2.

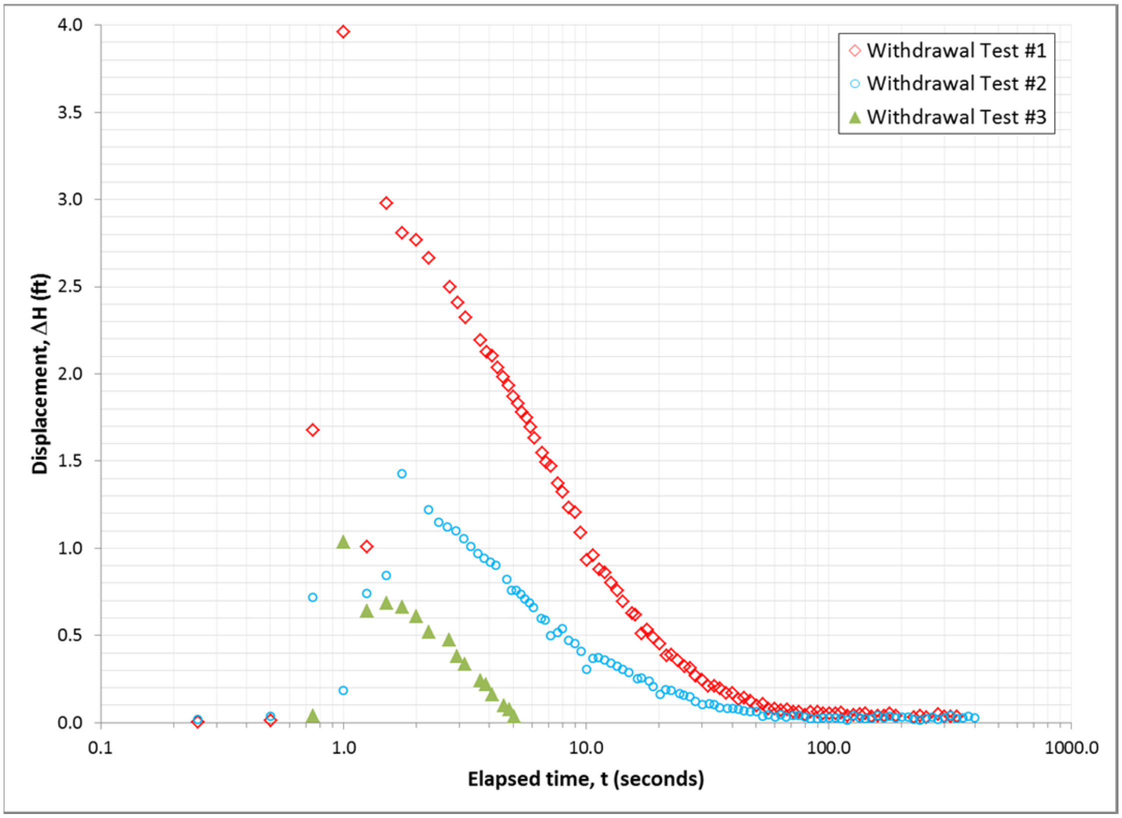

Figure 4-56. Displacements from three withdrawal tests at 199-H3-6

4.10.2 Estimation of effective start time

Effective start times of 1.5 seconds and 1.75 seconds are estimated for the first and second withdrawal tests respectively.

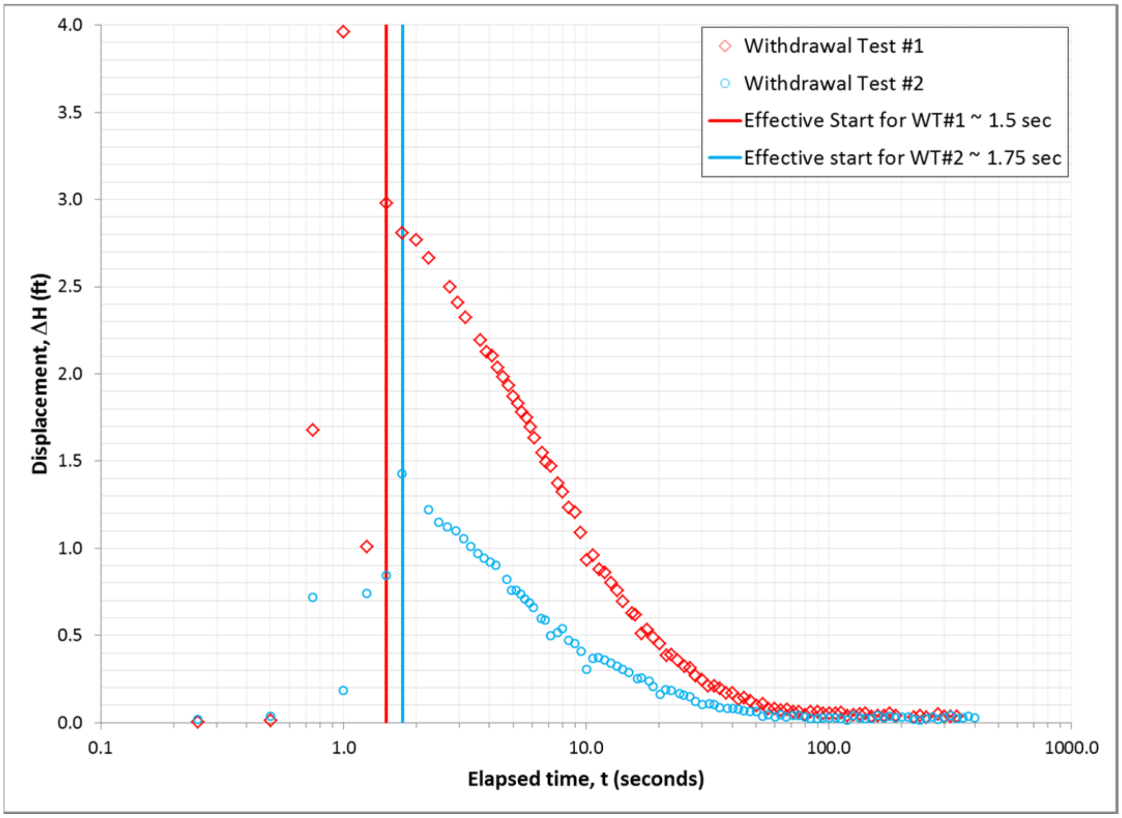

Figure 4-57. Effective start time for withdrawal tests at 199-H3-6

4.10.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-58. Effective initial displacements of 3.0 ft. and 1.3 ft. are estimated for the withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, a theoretical initial displacement of 1.67 ft. is estimated for the slug volume of 0.328 ft^3. The visually estimated initial displacements are less than the theoretical estimates probably because of the non-instantaneous nature of the tests.

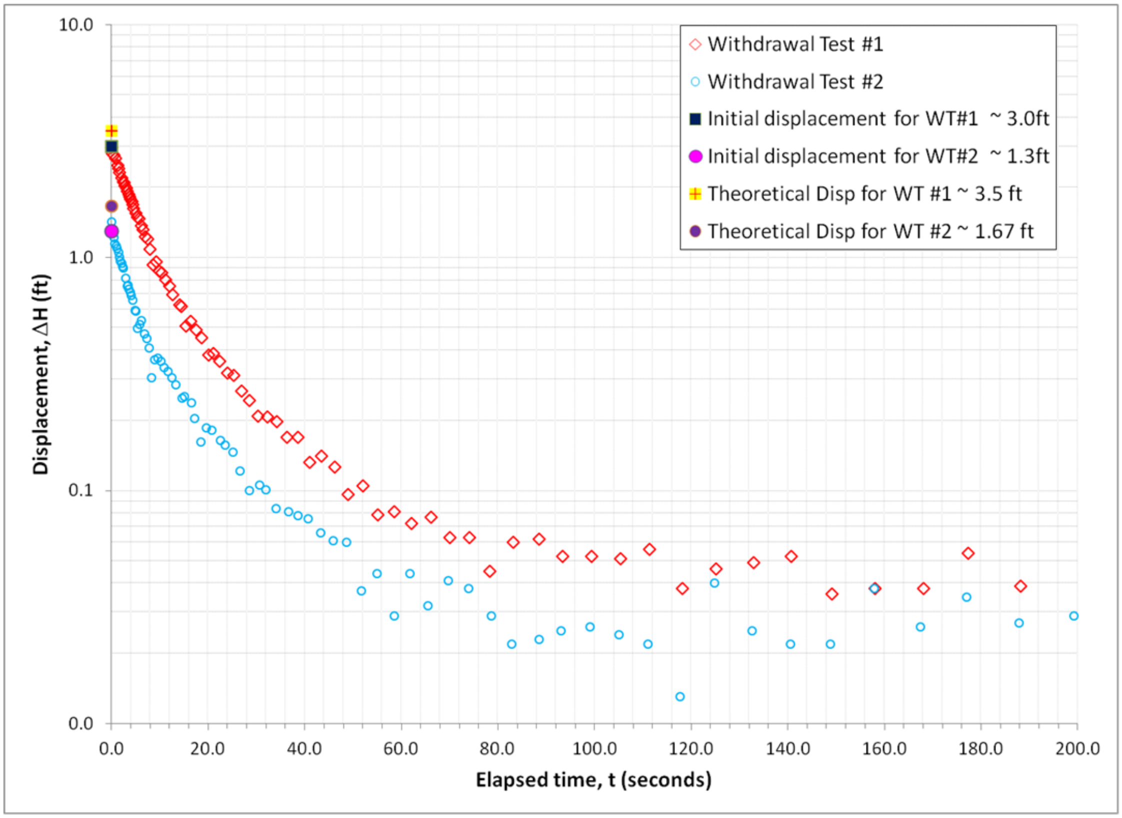

Figure 4-58. Estimation of effective initial displacement at 199-H3-6

4.10.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-59 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis.

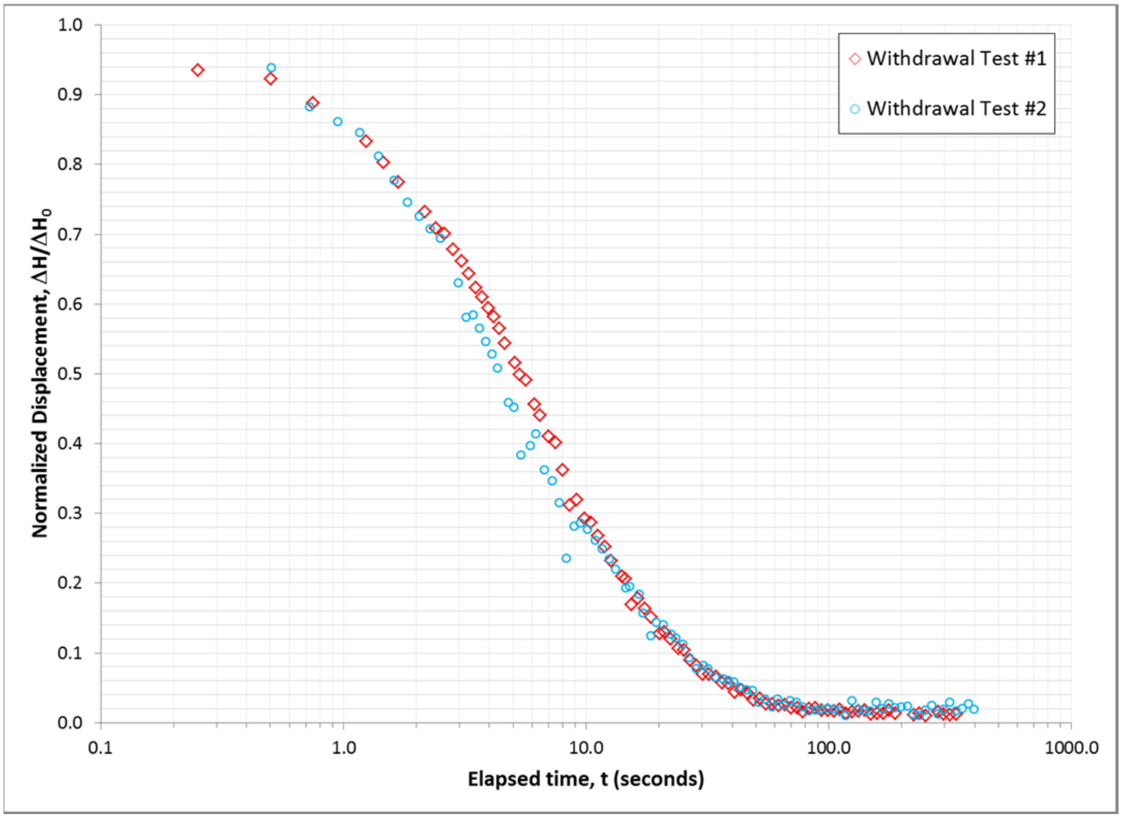

Figure 4-59. Normalized displacement at 199-H3-6

4.10.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-60. A good match to the observations is achieved with a storage coefficient, *S*, of 6×10^{-4}, and a fitted transmissivity, *T*, of 113 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-2, we see that for well 199-H3-6, this is not the case. The aquifer (Hanford) is about 4.11 m (115.56 m – 111.45 m) thick at this location, and the length of the well screen is about 2.73 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 8.95 ft. (2.73 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **41 m/d** **or** **4.7×10^{-4} m/s.**

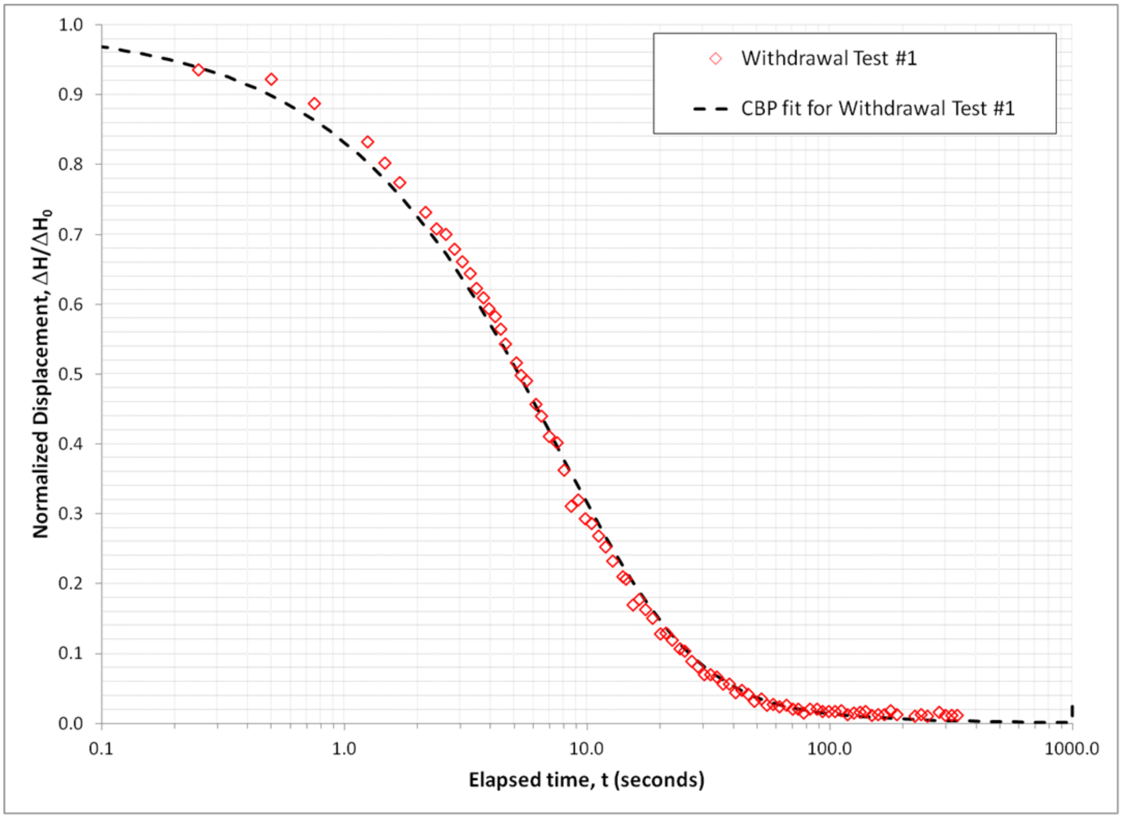

Figure 4-60. CBP Model fit at 199-H3-6

4.10.6 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-61. A good match to the observations is achieved with a specific storage, S_s, of 2.2×10^{-4} m^{-1}, an anisotropy ratio K_V/K_H of 0.01, and a fitted horizontal hydraulic conductivity, K_H, of **38 m/d** or **4.4×10^{-4} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 6×10^{-4} by the well screen length (8.95 ft. or 2.73 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of medium sand and coarse sand. This partly corresponds with the 'Sandy Gravel' description of the screened interval. It is possible that there could be some fines in the screened interval accounting for the higher specific storage.

The estimated hydraulic conductivity is in the middle of the range for clean sand and at the higher end of the range for silty sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This partly corresponds with the 'Sandy Gravel' description of the screened interval. It is possible that there could be some fines in the screened interval accounting for the lower hydraulic conductivity.

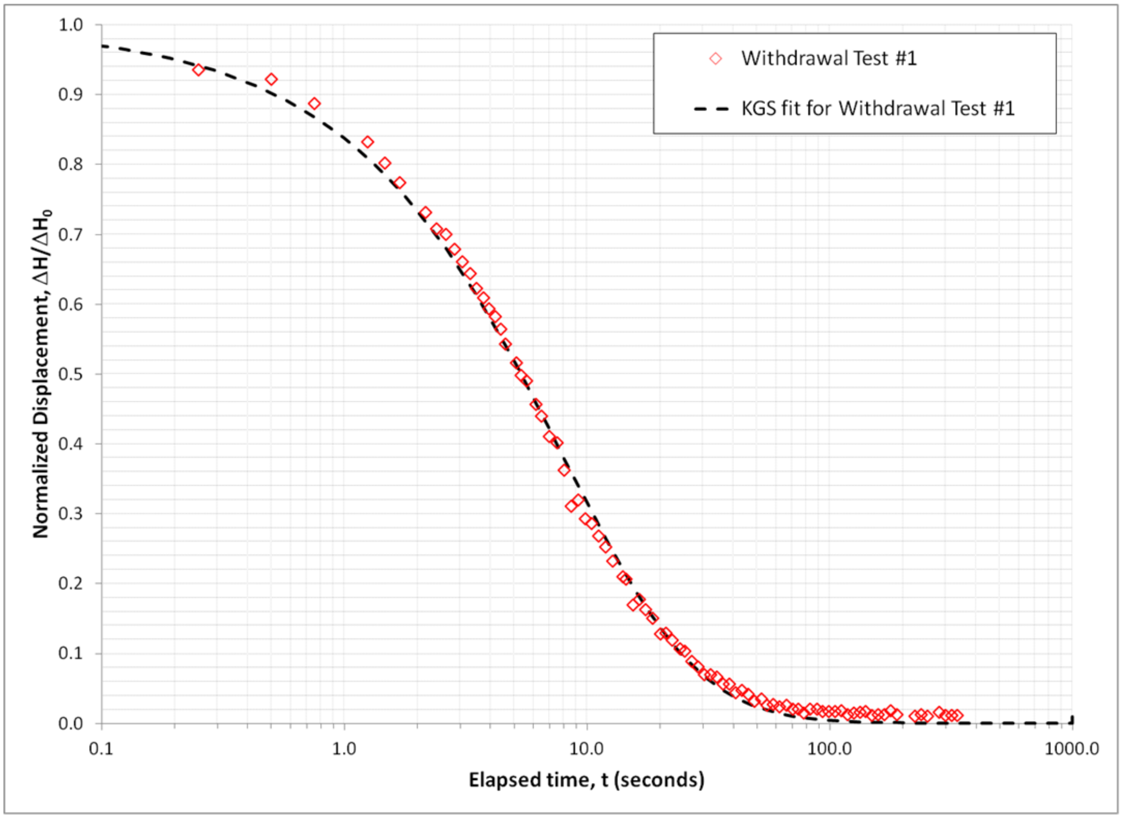

Figure 4-61. KGS Model fit at 199-H3-6

4.11 Analysis of Slug Test Data at well 199-H3-7

Three withdrawal tests were conducted at 199-H3-7 and all of them are analyzed here.

4.11.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.62. The normalized displacements in section 4.11.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.11.2.

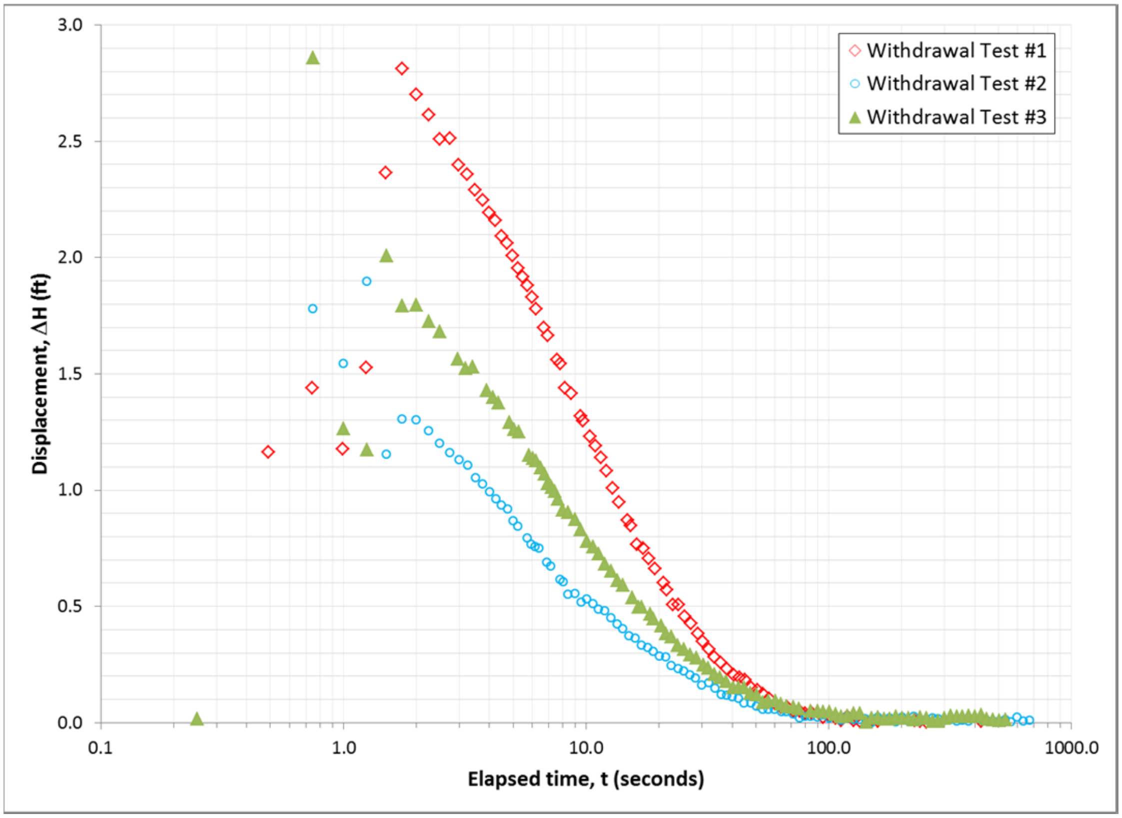

Figure 4-62. Displacements from three withdrawal tests at 199-H3-7

4.11.2 Estimation of effective start time

Effective start times of 1.7 seconds, 1.75 seconds and 1.5 seconds are estimated for the three withdrawal tests respectively.

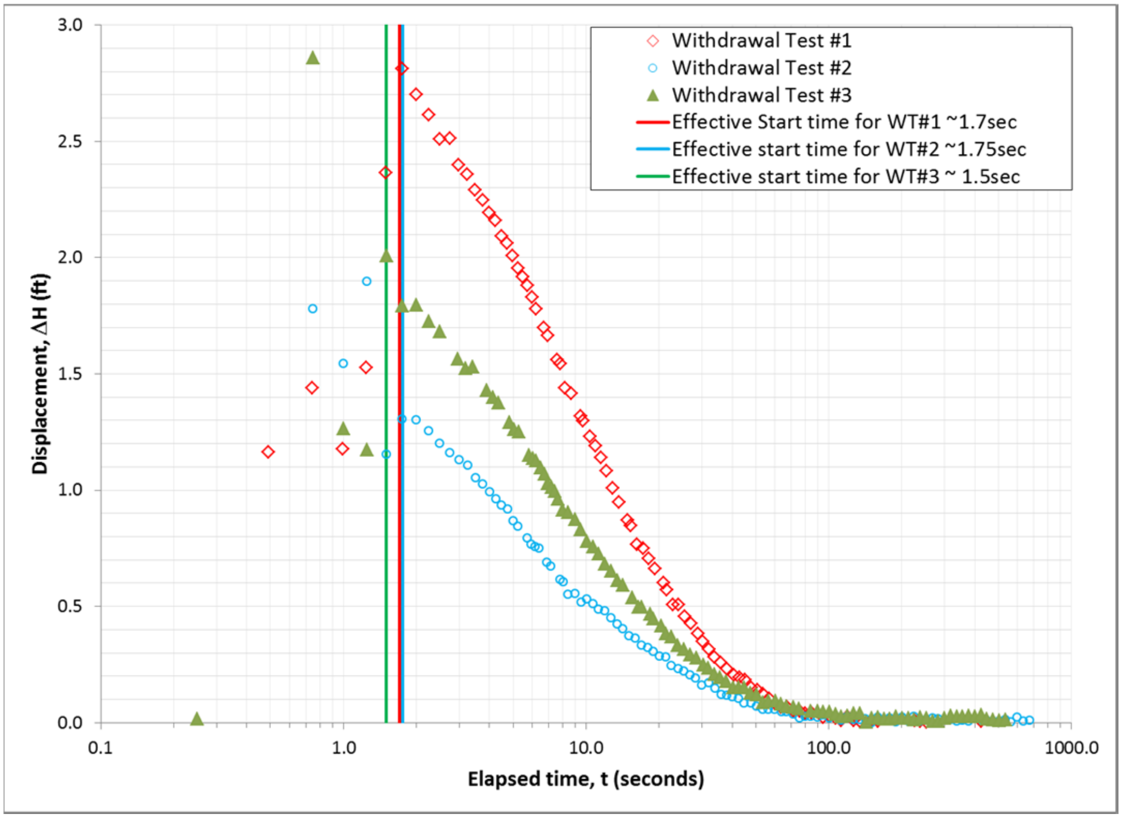

Figure 4-63. Effective start time for withdrawal tests at 199-H3-7

4.11.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-64. Effective initial displacements of 2.8 ft., 1.3 ft., and 1.85 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are lesser than the theoretical estimates probably because of the non-instantaneous nature of the tests.

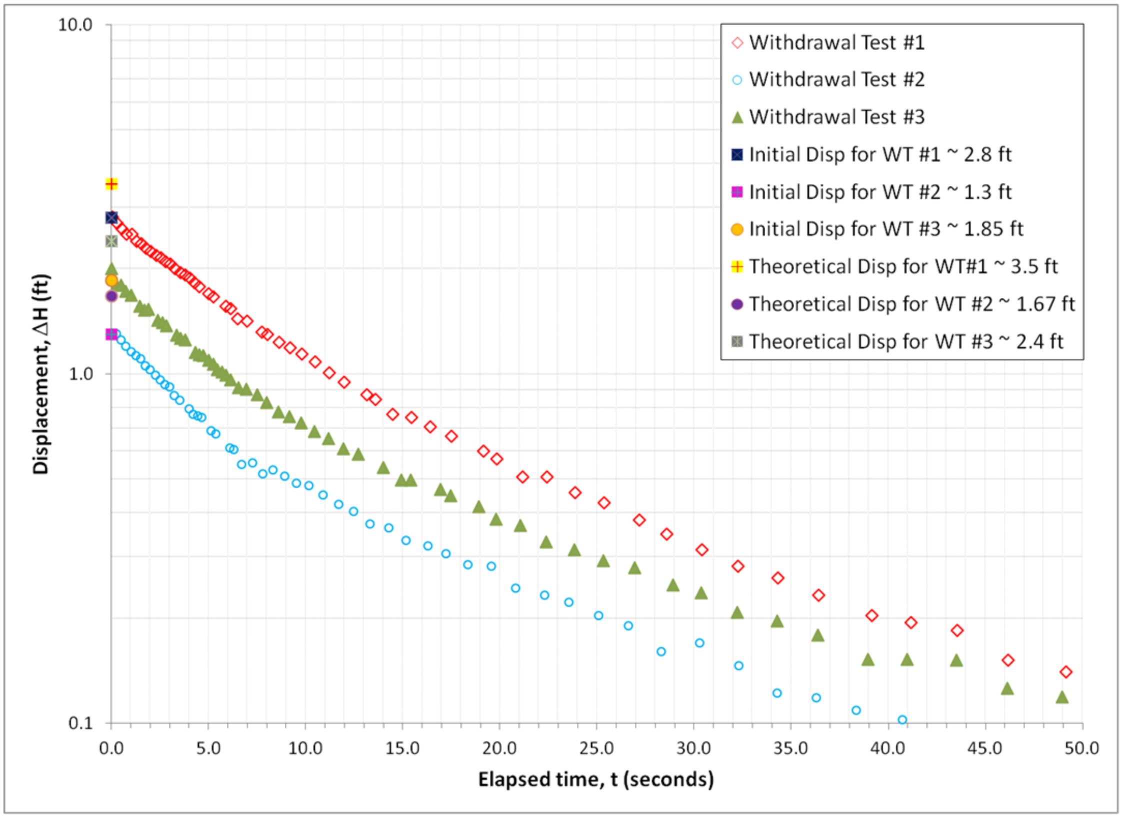

Figure 4-64. Estimation of effective initial displacement at 199-H3-7

4.11.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-65 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis.

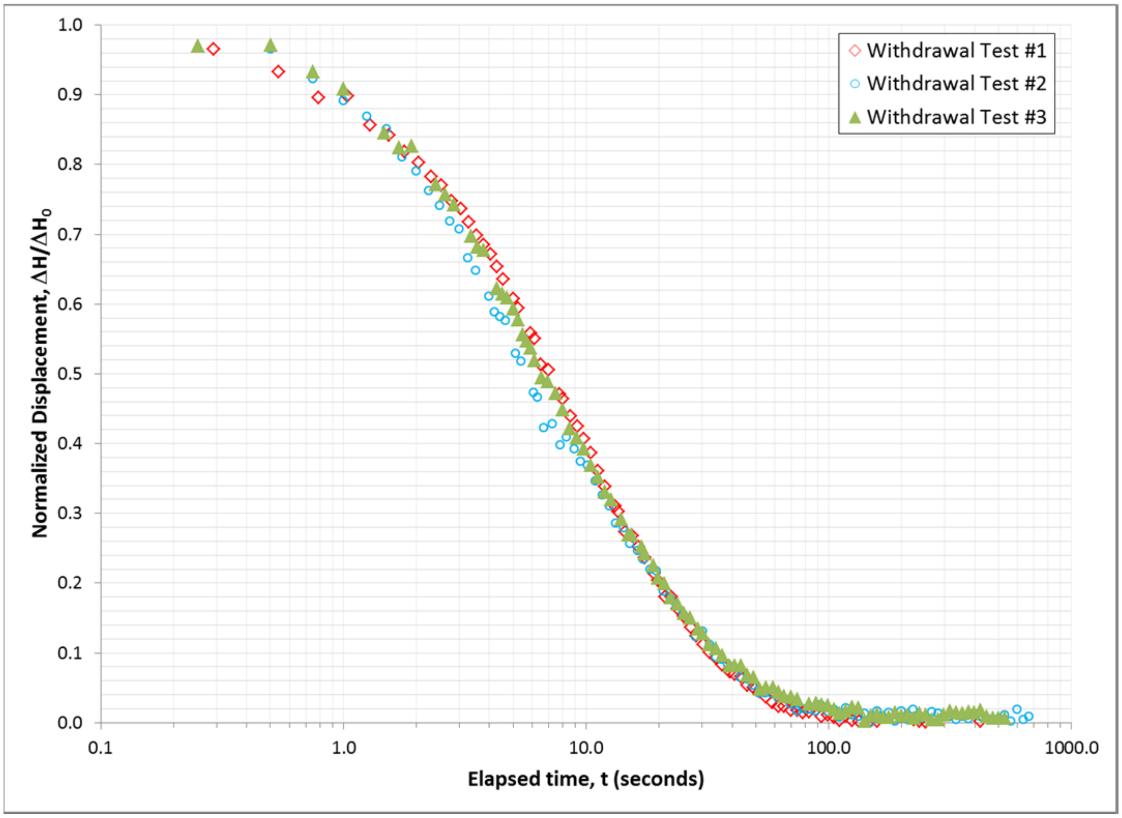

Figure 4-65. Normalized displacement at 199-H3-7

4.11.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-66. A good match to the observations is achieved with a storage coefficient, *S*, of 1.5×10^{-3}, and a fitted transmissivity, *T*, of 71 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-2, we see that for well 199-H3-7, this is not the case. The aquifer (Hanford) is about 3.42 m (116.21 m – 112.79 m) thick at this location, and the length of the well screen is about 2.1 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 6.88 ft. (2.1 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **34 m/d** or **3.9×10^{-4} m/s.**

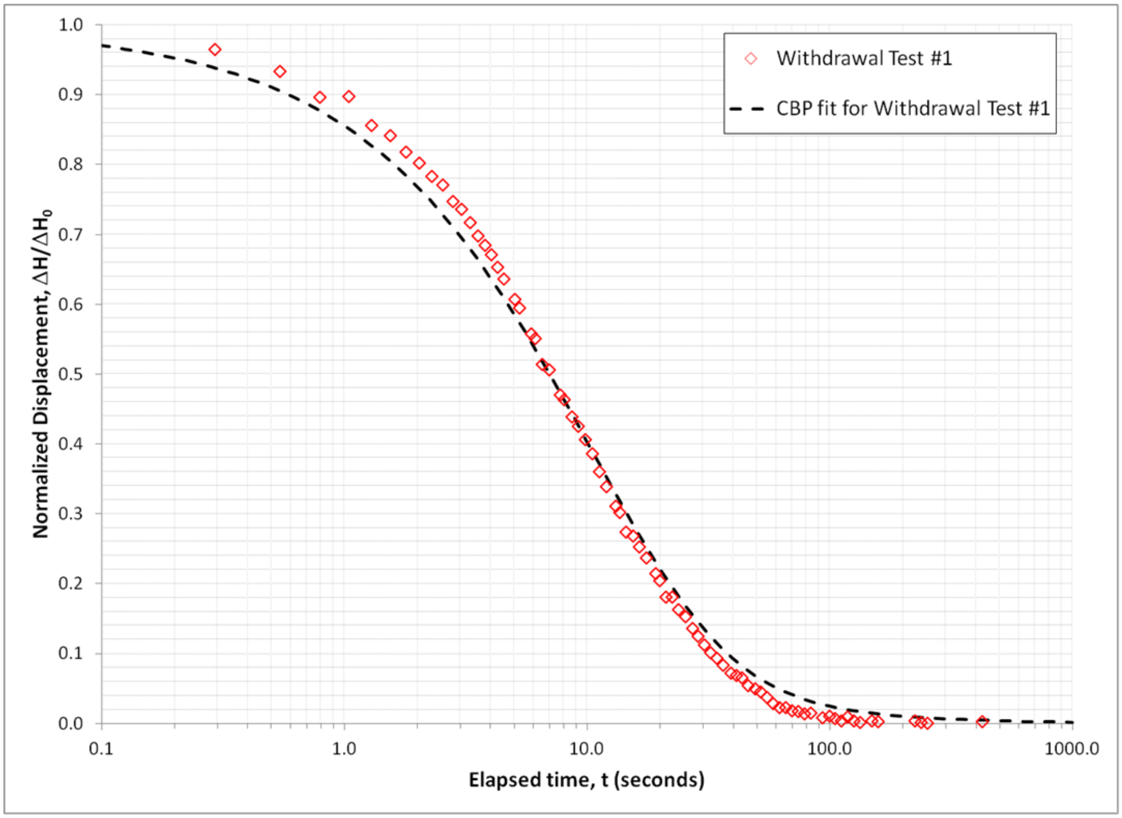

Figure 4-66. CBP Model fit at 199-H3-7

4.11.6 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-67. A good match to the observations is achieved with a specific storage, S_s, of 7.2×10^{-4} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **27 m/d** or **3.1×10^{-4} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 1.5×10^{-3} by the well screen length (6.88 ft. or 2.1 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of medium sand, fine sand and silt. This does not correspond well with the ‘Sandy Gravel’ description of the screened interval. It is possible that there could be some fines in the screened interval accounting for the higher specific storage.

The estimated hydraulic conductivity is in the middle of the range for clean sand and at the higher end of the range for silty sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This does not correspond well with the ‘Sandy Gravel’ description of the screened interval. It is possible that there could be some fines in the screened interval accounting for the lower hydraulic conductivity.

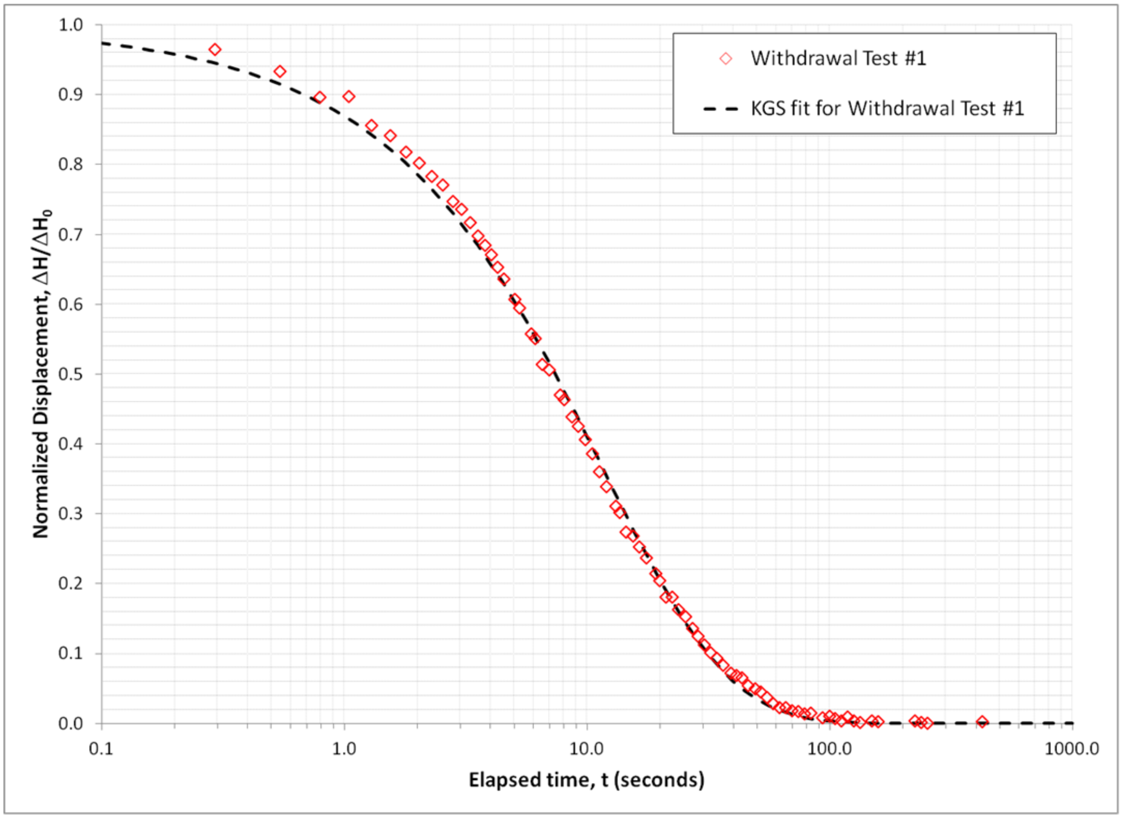

Figure 4-67. KGS Model fit at 199-H3-7

4.12 Analysis of Slug Test Data at well 199-H3-9

Three withdrawal tests were conducted at 199-H3-9 and all of them are analyzed here.

4.12.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.68. The normalized displacements in section 4.12.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.12.2.

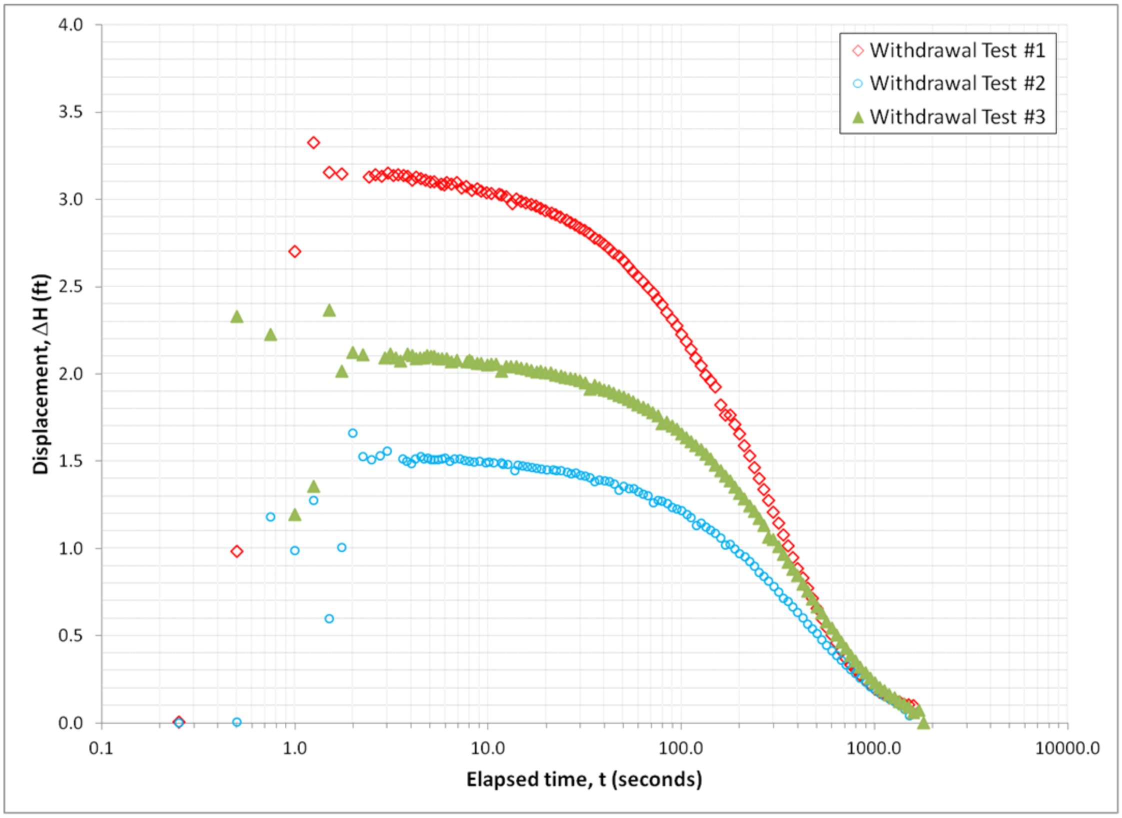

Figure 4-68. Displacements from three withdrawal tests at 199-H3-9

4.12.2 Estimation of effective start time

Effective start times of 2.75 seconds, 3.6 seconds and 3 seconds are estimated for the three withdrawal tests respectively.

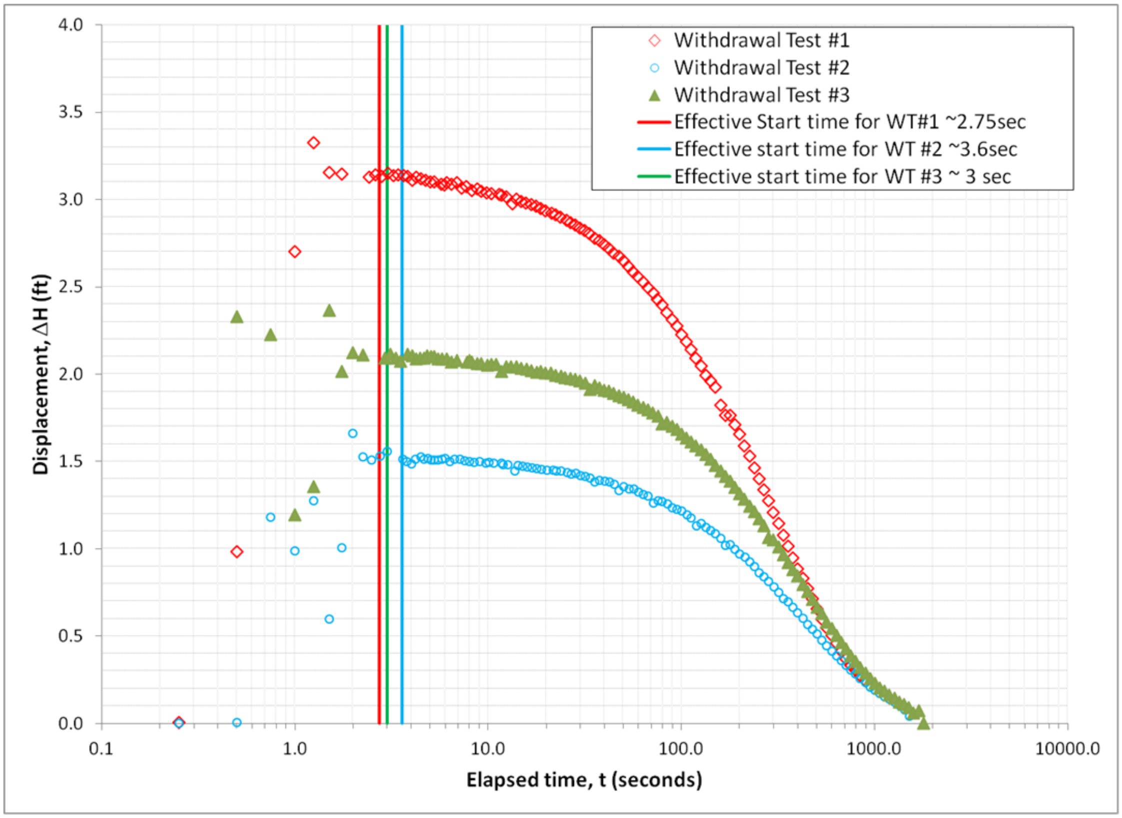

Figure 4-69. Effective start time for withdrawal tests at 199-H3-9

4.12.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-70. Effective initial displacements of 3.15 ft., 1.55 ft., and 2.12 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are lesser than the theoretical estimates probably because of the non-instantaneous nature of the tests.

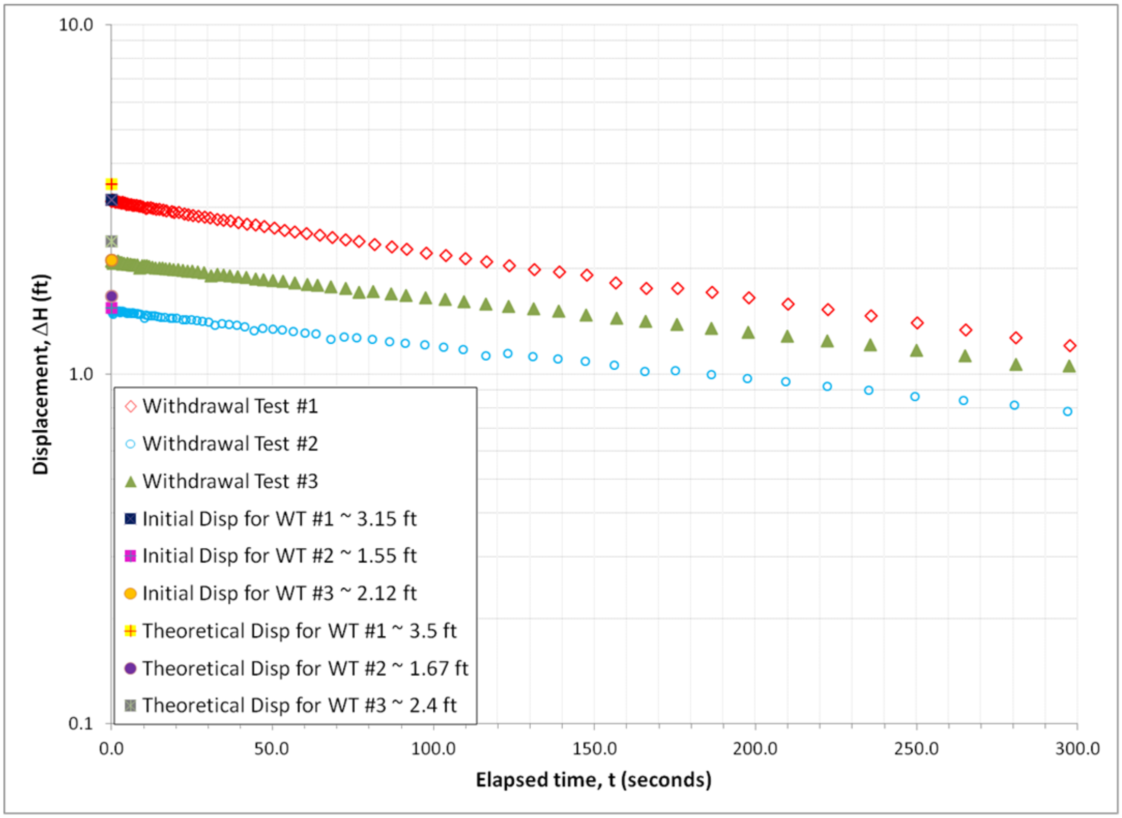

Figure 4-70. Estimation of effective initial displacement at 199-H3-9

4.12.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses are plotted in Figure 4-71. The displacements for the second and third withdrawal tests are internally consistent. However, the first test exhibits a different response. The field log did not yield any clues for the cause of this discrepancy. The close correspondence of the second and third normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The third withdrawal test is chosen for analysis. In the refined analysis section, the first withdrawal test is also considered to check if the resulting hydraulic conductivity values would differ between the first and third tests.

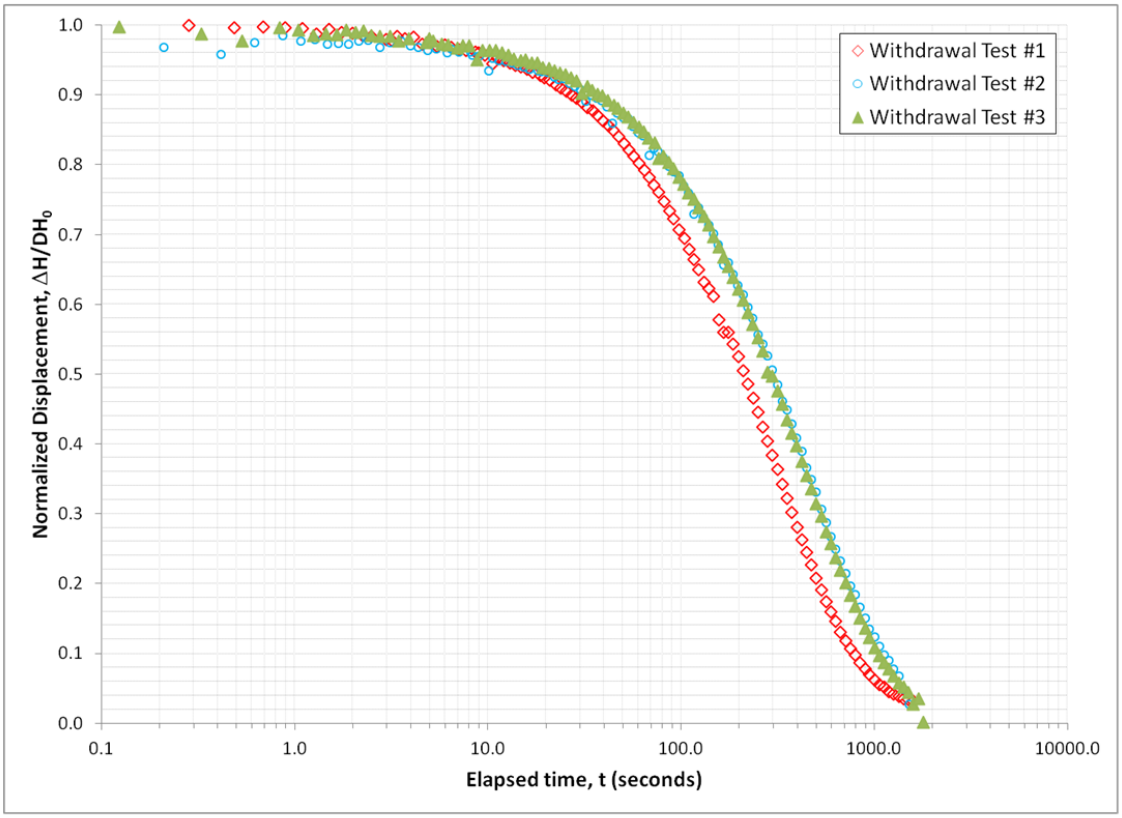

Figure 4-71. Normalized displacement at 199-H3-9

4.12.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the third withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-72. A good match to the observations is achieved with a storage coefficient, *S*, of 4×10^{-4}, and a fitted transmissivity, *T*, of 2.2 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-2, we see that for well 199-H3-9, this is not the case. The aquifer (RUM) is at least 14.17 m (115.17 m – 101.00 m) thick at this location, and the length of the well screen is about 3.05 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 10 ft. (3.05 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **0.7 m/d** or **8.1×10^{-6} m/s.**

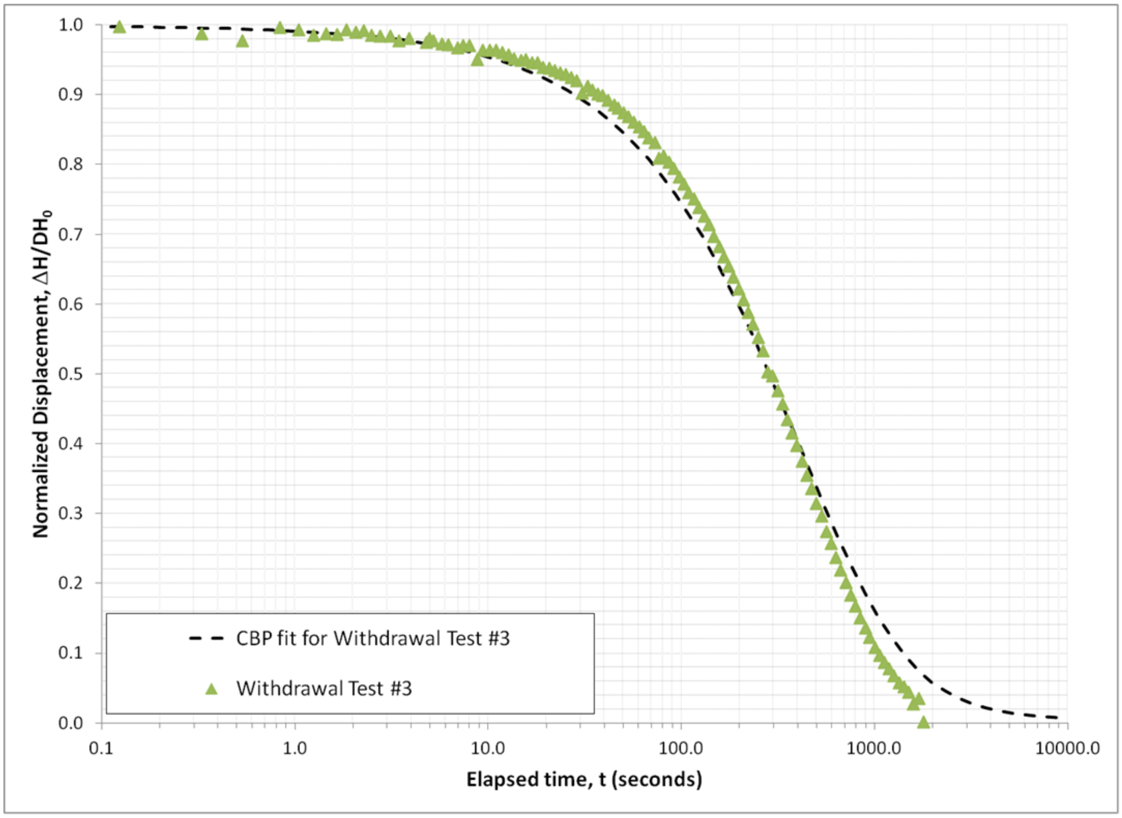

Figure 4-72. CBP Model fit at 199-H3-9

4.12.6 Refined analysis

For a more refined analysis, the normalized displacements for the first and third withdrawal tests are fit with the KGS model for an unconfined aquifer.

The KGS model fit for the third withdrawal test is shown in Figure 4-73. A good match to the observations is achieved with a specific storage, S_s, of 1.3×10^{-4} m^{-1}, an anisotropy ratio K_V/K_H of 1.0, and a fitted horizontal hydraulic conductivity, K_H, of **0.5 m/d** or **5.8×10^{-6} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 4×10^{-4} by the well screen length (10 ft. or 3.05 m). The KGS model fit for the first withdrawal test is shown in Figure 4-74. Using the specific storage and anisotropy from the third test, a good match to the observations is achieved with a fitted horizontal hydraulic conductivity, K_H, of **0.7 m/d** or **8.1×10^{-6} m/s**. Since there is negligible difference between the two estimates, it is sufficient to report only one of them. The relatively conservative estimate from the third test, K_H, of **0.5 m/d** or **5.8×10^{-6} m/s** is reported.

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of medium sand. This corresponds well with the well log which describes the screened interval as 'Sand'.

The estimated hydraulic conductivity values are in the middle of the range for silty sand and at the lower end of the range for clean sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This corresponds well with the well log which describes the screened interval as 'Sand'.

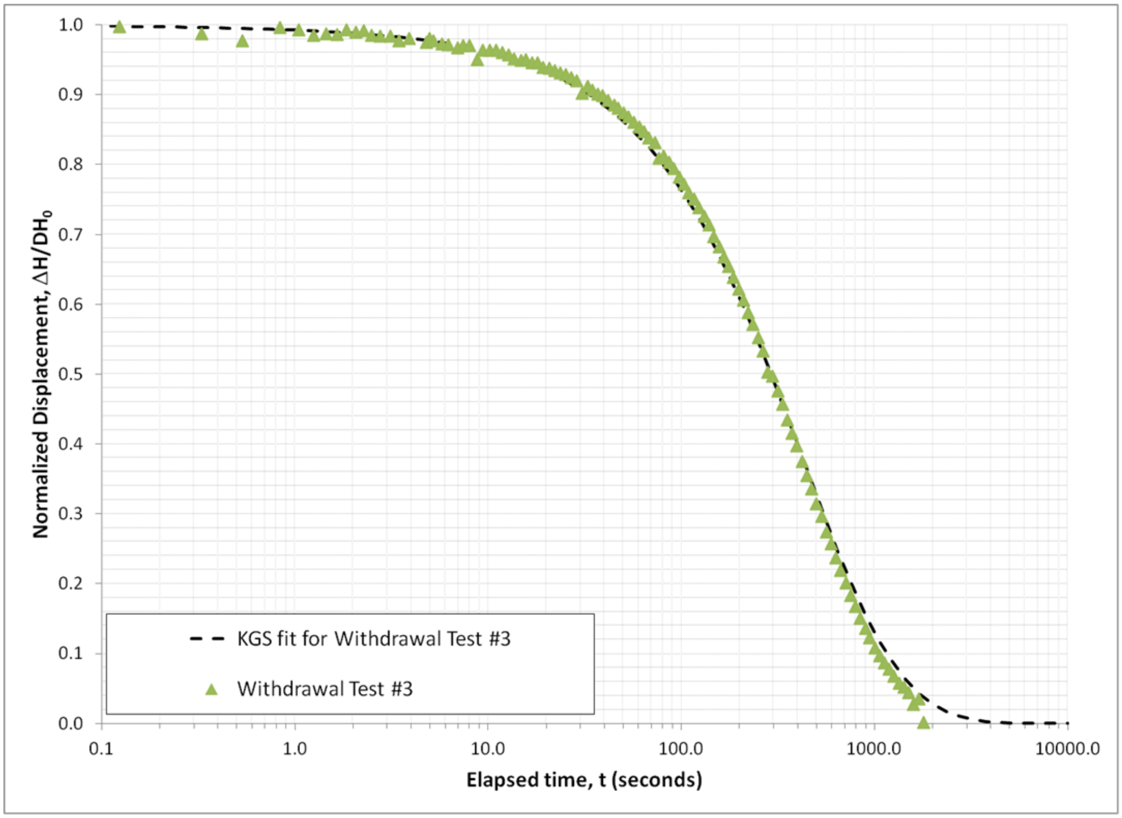

Figure 4-73. KGS Model fit for WT#3 at 199-H3-9

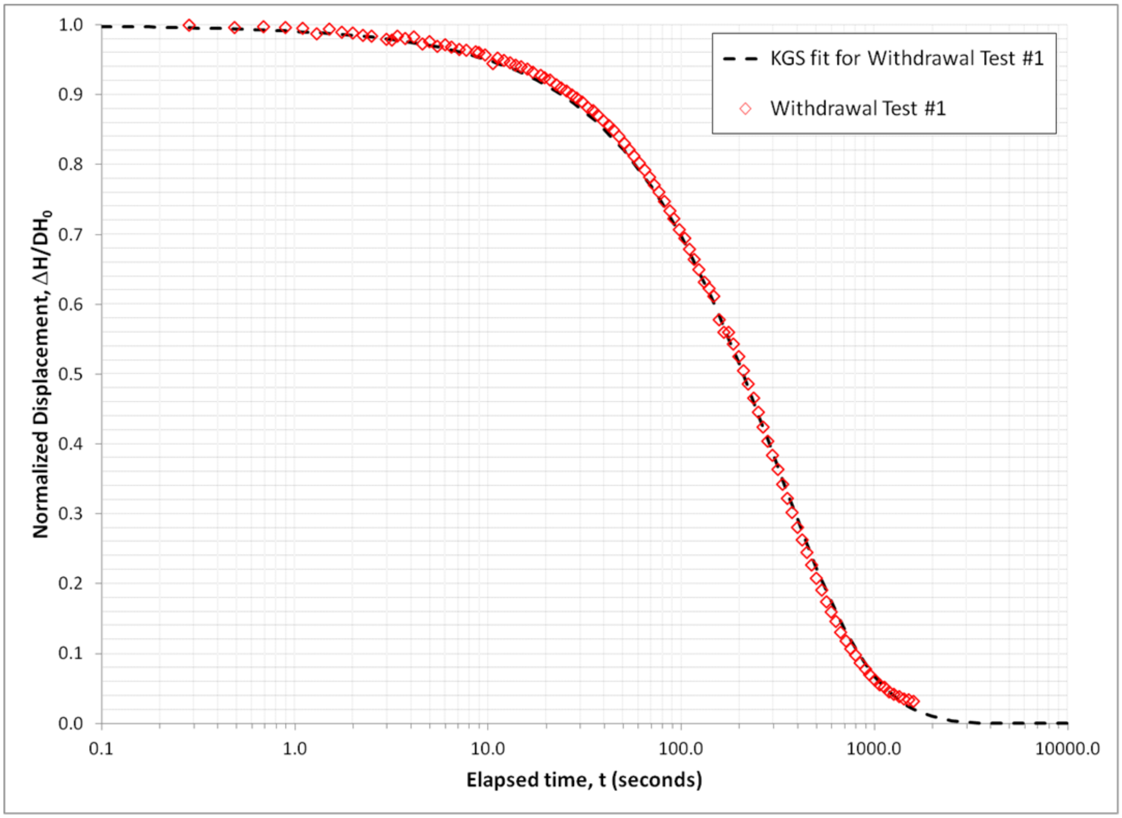

Figure 4-74. KGS Model fit for WT #1 at 199-H3-9

4.13 Analysis of Slug Test Data at well 199-H3-10

Three withdrawal tests were conducted at 199-H3-10 and all of them are analyzed here.

4.13.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.75. The normalized displacements in section 4.13.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.13.2.

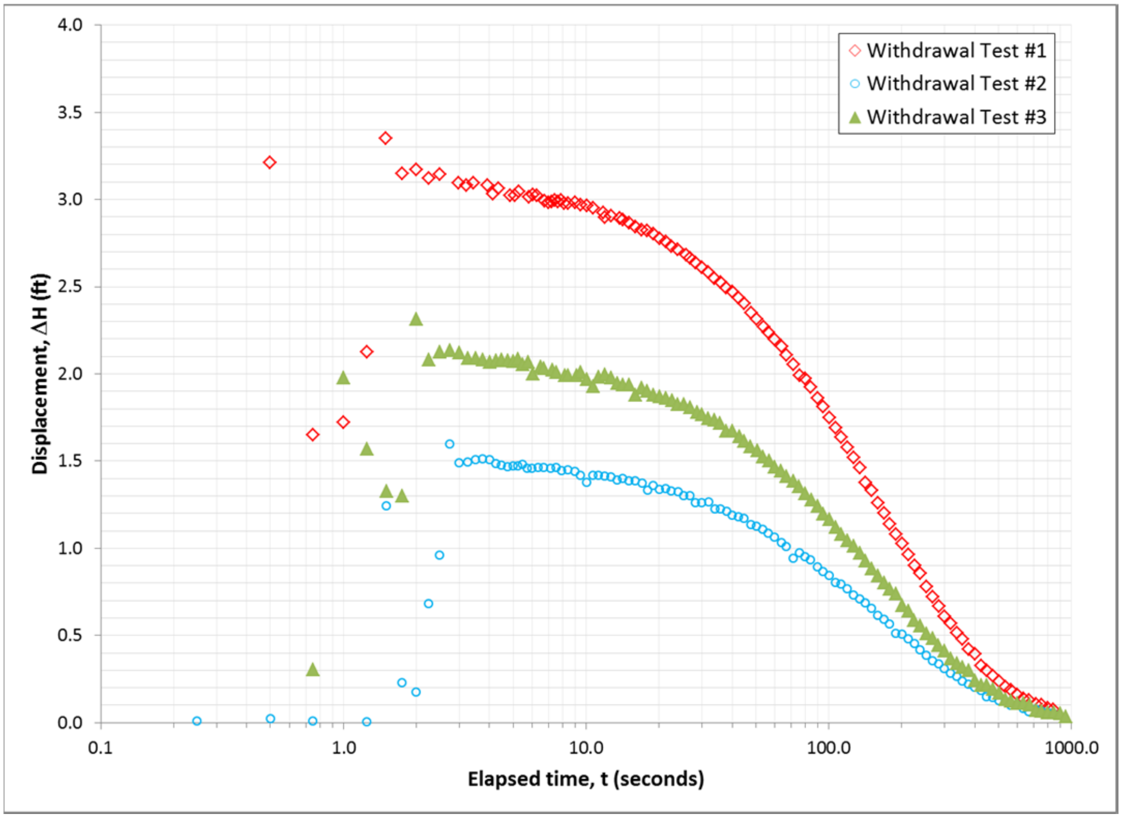

Figure 4-75. Displacements from three withdrawal tests at 199-H3-10

4.13.2 Estimation of effective start time

Effective start times of 1.75 seconds, 3 seconds and 2 seconds are estimated for the three withdrawal tests respectively.

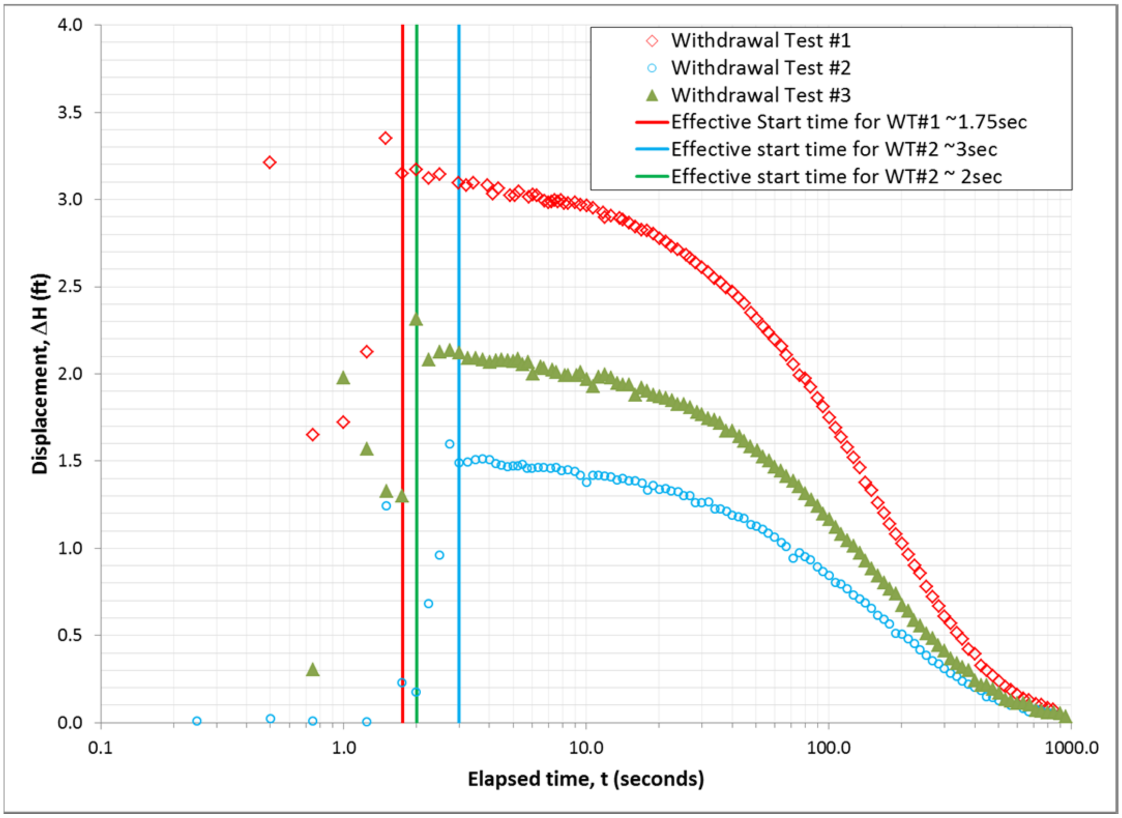

Figure 4-76. Effective start time for withdrawal tests at 199-H3-10

4.13.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-77. Effective initial displacements of 3.15 ft., 1.5 ft., and 2.1 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are lesser than the theoretical estimates probably because of the non-instantaneous nature of the tests.

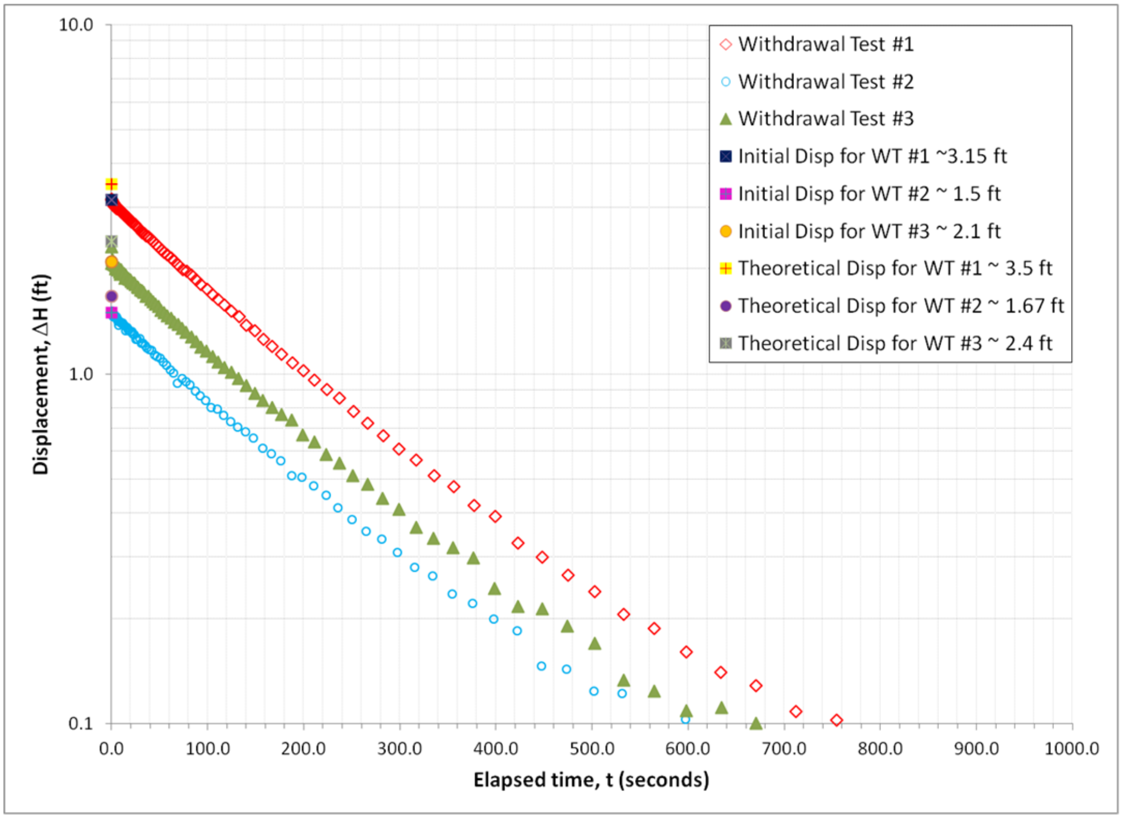

Figure 4-77. Estimation of effective initial displacement at 199-H3-10

4.13.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-78 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis.

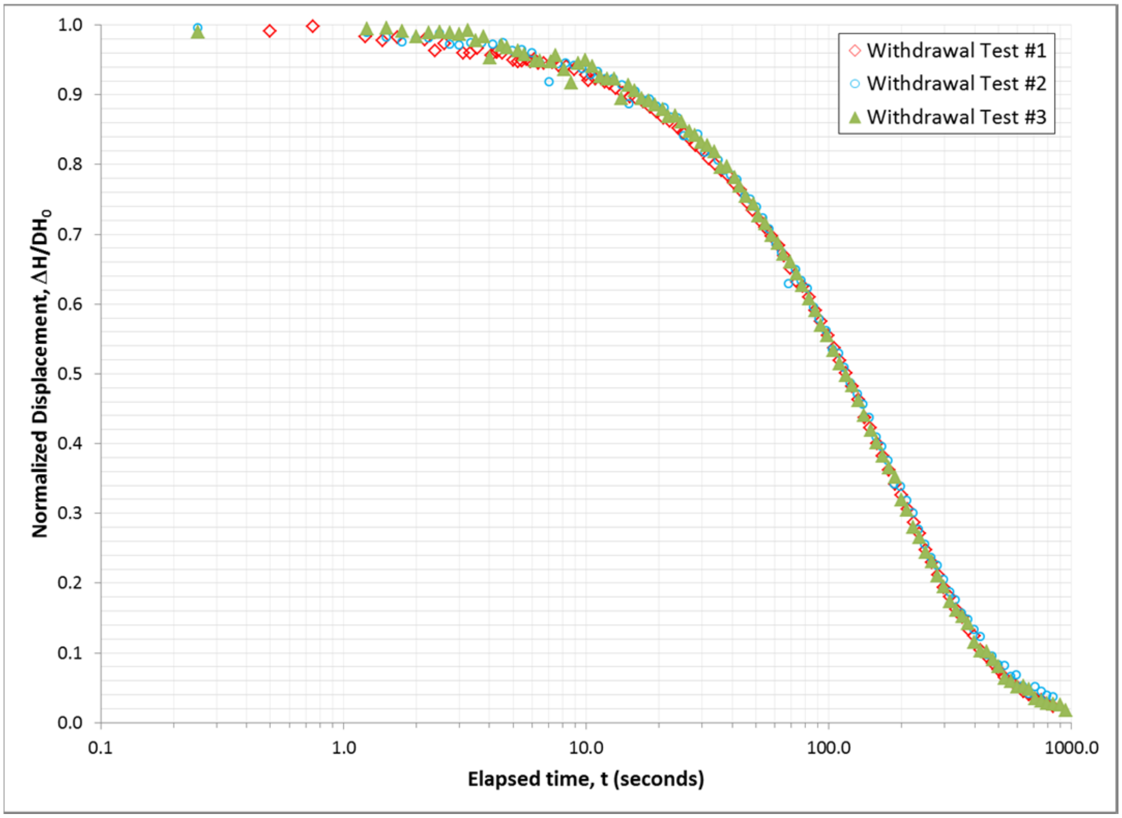

Figure 4-78. Normalized displacement at 199-H3-10

4.13.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-79. A good match to the observations is achieved with a storage coefficient, *S*, of 5×10^{-4}, and a fitted transmissivity, *T*, of 5.3 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-2, we see that for well 199-H3-10, this is not the case. The aquifer (RUM) is at least 15.96 m (111.45 m – 95.49 m) thick at this location, and the length of the well screen is about 3.05 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 10 ft. (3.05 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **1.7 m/d** or **2.0×10^{-5} m/s.**

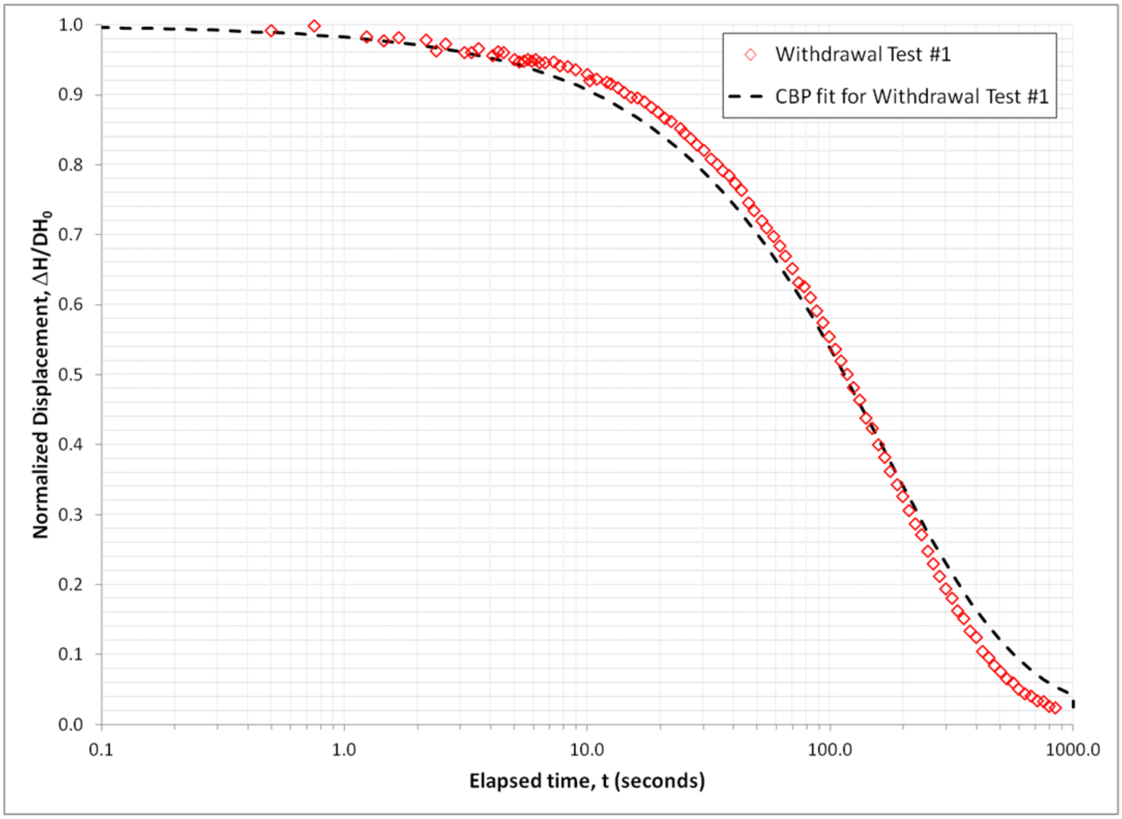

Figure 4-79. CBP Model fit at 199-H3-10

4.13.6 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-80. A good match to the observations is achieved with a specific storage, S_s, of 1.6×10^{-4} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **1.6 m/d** or **1.9×10^{-5} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 5×10^{-4} by the well screen length (10 ft. or 3.05 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of medium sand, fine sand and silt. This corresponds well with the 'Sand and Sandy Silt' description of the screened interval.

The estimated hydraulic conductivity is in the middle of the range for silty sand and at the lower end of the range for clean sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This corresponds well with the 'Sand and Sandy Silt' description of the screened interval.

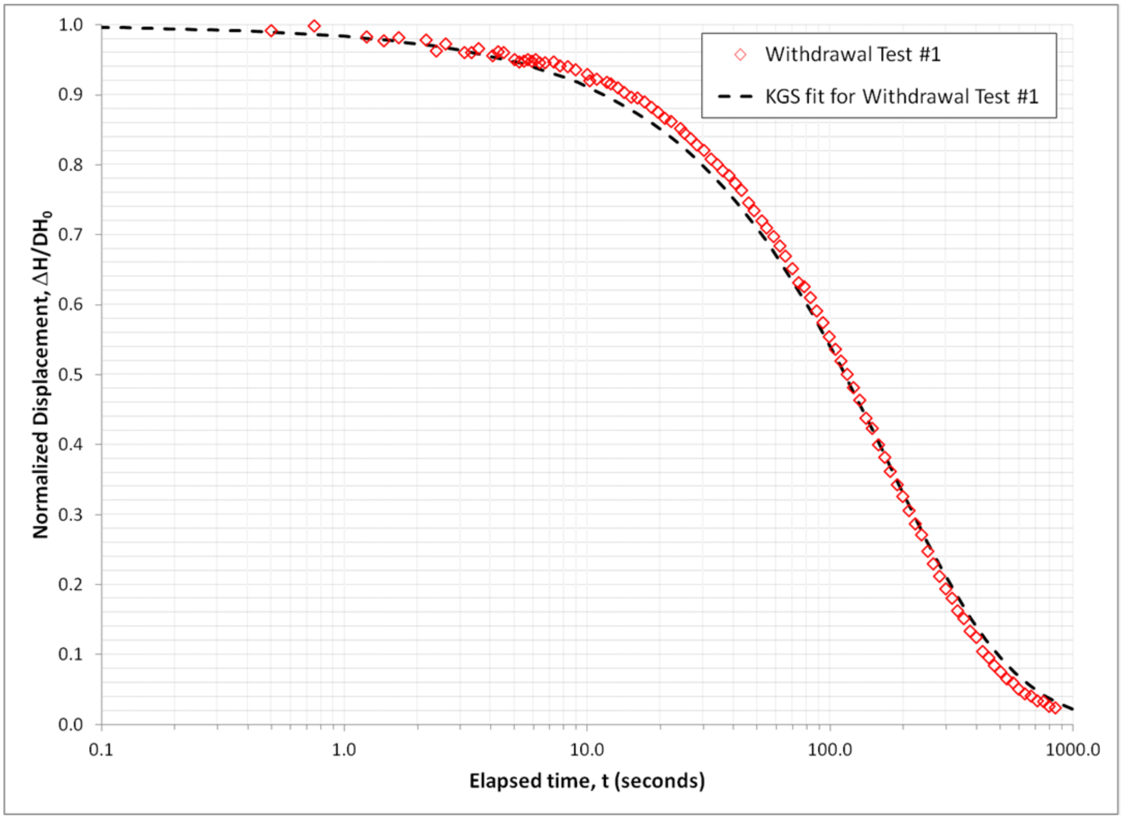

Figure 4-80. KGS Model fit at 199-H3-10

4.14 Analysis of Slug Test Data at well 199-H6-3

Three withdrawal tests were conducted at 199-H6-3 and all of them are analyzed here.

4.14.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.81. The normalized displacements in section 4.14.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.14.2.

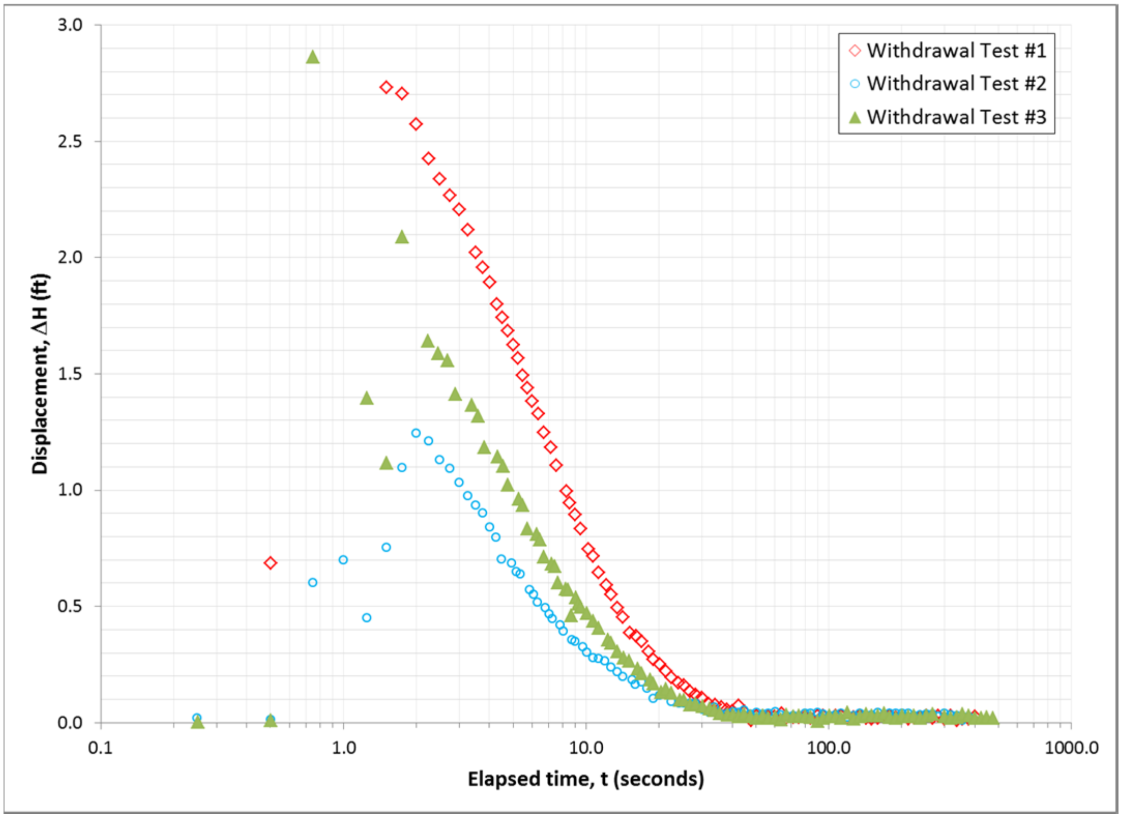

Figure 4-81. Displacements from three withdrawal tests at 199-H6-3

4.14.2 Estimation of effective start time

Effective start times of 1.5 seconds, 2 seconds and 2.25 seconds are estimated for the three withdrawal tests respectively.

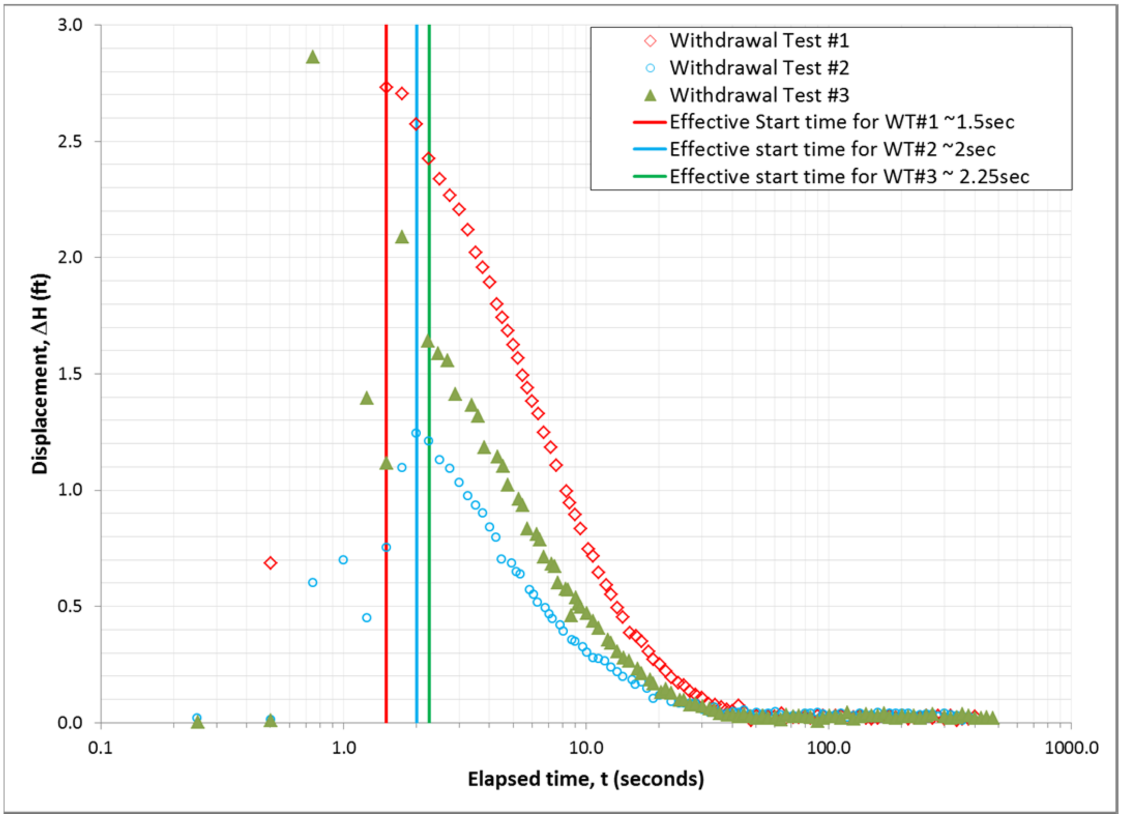

Figure 4-82. Effective start time for withdrawal tests at 199-H6-3

4.14.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-83. Effective initial displacements of 2.8 ft., 1.2 ft., and 1.6 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are lesser than the theoretical estimates probably because of the non-instantaneous nature of the tests.

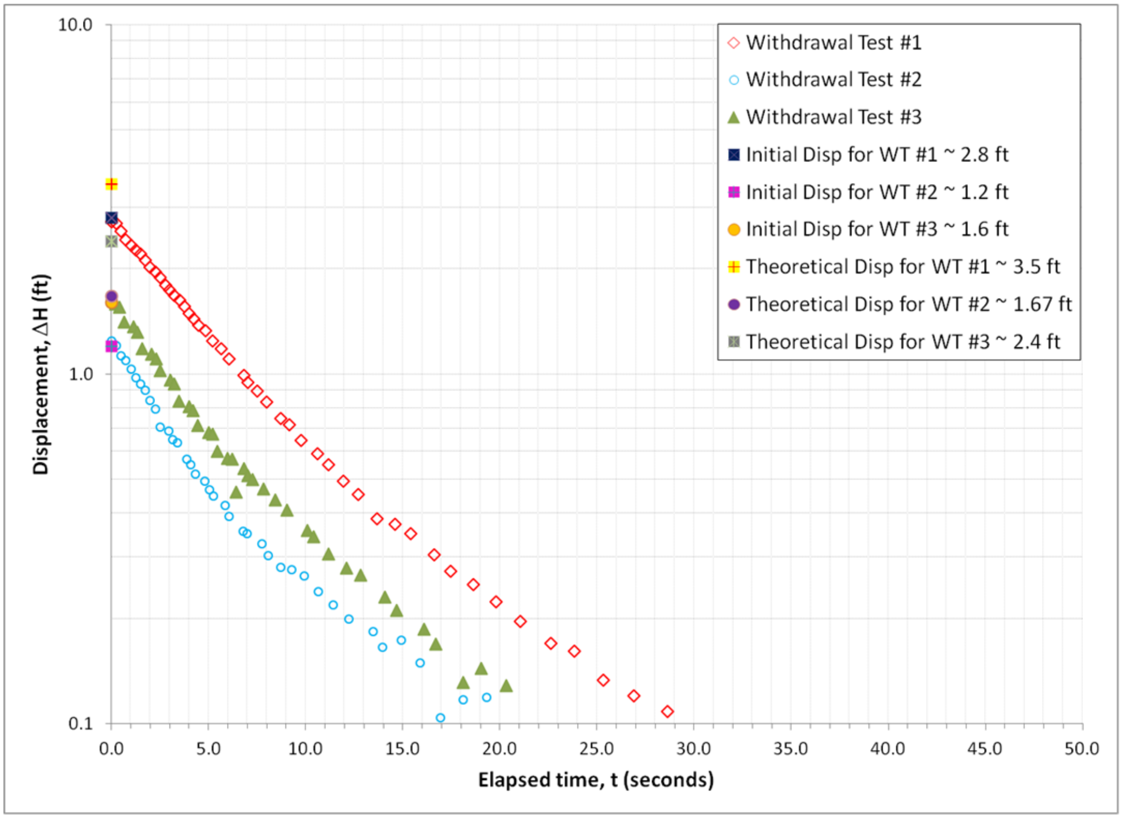

Figure 4-83. Estimation of effective initial displacement at 199-H6-3

4.14.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-84 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis.

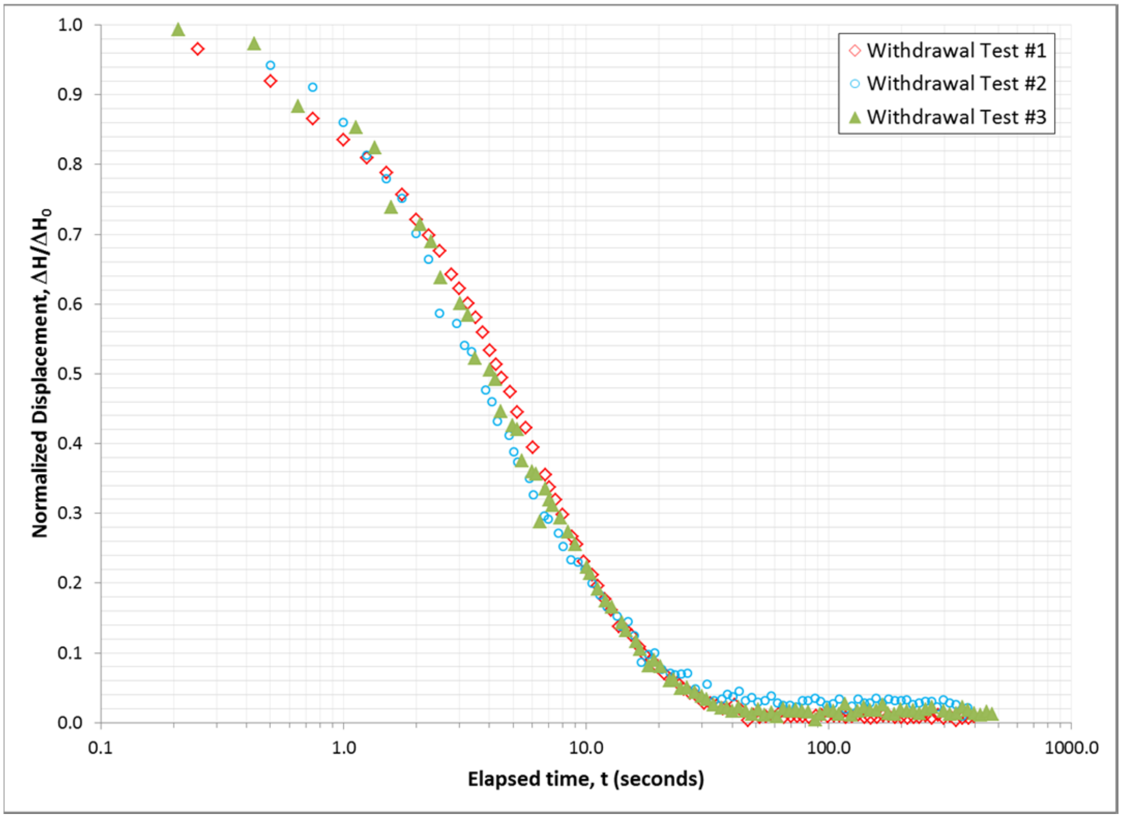

Figure 4-84. Normalized displacement at 199-H6-3

4.14.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-85. A good match to the observations is achieved with a storage coefficient, *S*, of 1×10^{-4}, and a fitted transmissivity, *T*, of 180 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-2, we see that for well 199-H6-3, this is not the case. The aquifer (Hanford) is about 5.79 m (115.45 m – 109.66 m) thick at this location, and the length of the well screen is about 5.09 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 16.7 ft. (5.09 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **35 m/d** **or** **4.1×10^{-4} m/s.**

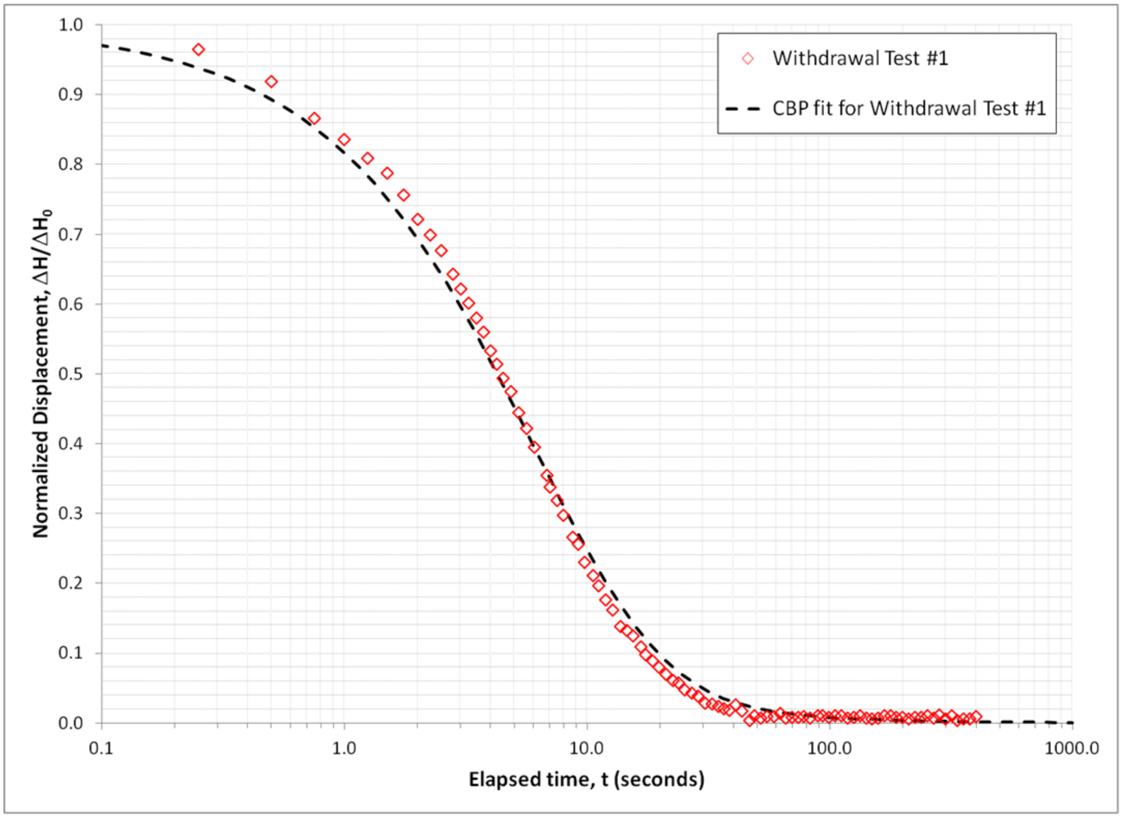

Figure 4-85. CBP Model fit at 199-H6-3

4.14.6 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-86. A good match to the observations is achieved with a specific storage, S_s, of 2.0×10^{-5} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **27 m/d** or **3.1×10^{-4} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 1×10^{-4} by the well screen length (16.7 ft. or 5.09 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of medium sand and coarse sand. This corresponds reasonably well with the description of the screened interval as a mixture of sand, gravel, and silt.

The estimated hydraulic conductivity is in the middle of the range for clean sand and at the higher end of the range for silty sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This corresponds reasonably well with the description of the screened interval as a mixture of sand, gravel, and silt.

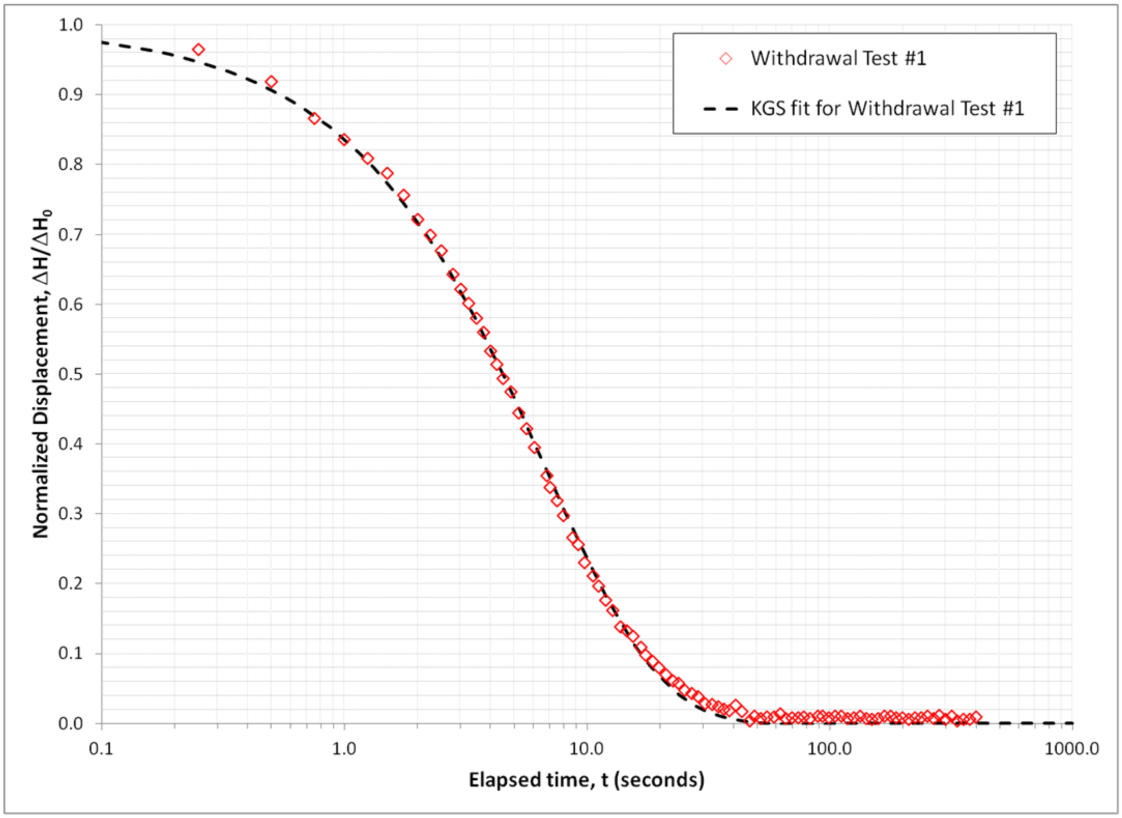

Figure 4-86. KGS Model fit at 199-H6-3

4.15 Analysis of Slug Test Data at well 199-H6-4

Three withdrawal tests were conducted at 199-H6-4 and all of them are analyzed here.

4.15.1 Raw displacement data for withdrawal tests

The three withdrawal tests were conducted with slugs of volume 0.688 ft^3, 0.328 ft^3 and 0.472 ft^3 respectively. The displacements are plotted in Figure 4.87. The normalized displacements in section 4.15.4 will tell us if these responses are consistent. Inspection of the displacements suggests that the tests are not instantaneous but that there is an effective start time for each test. These effective start times are estimated in section 4.15.2.

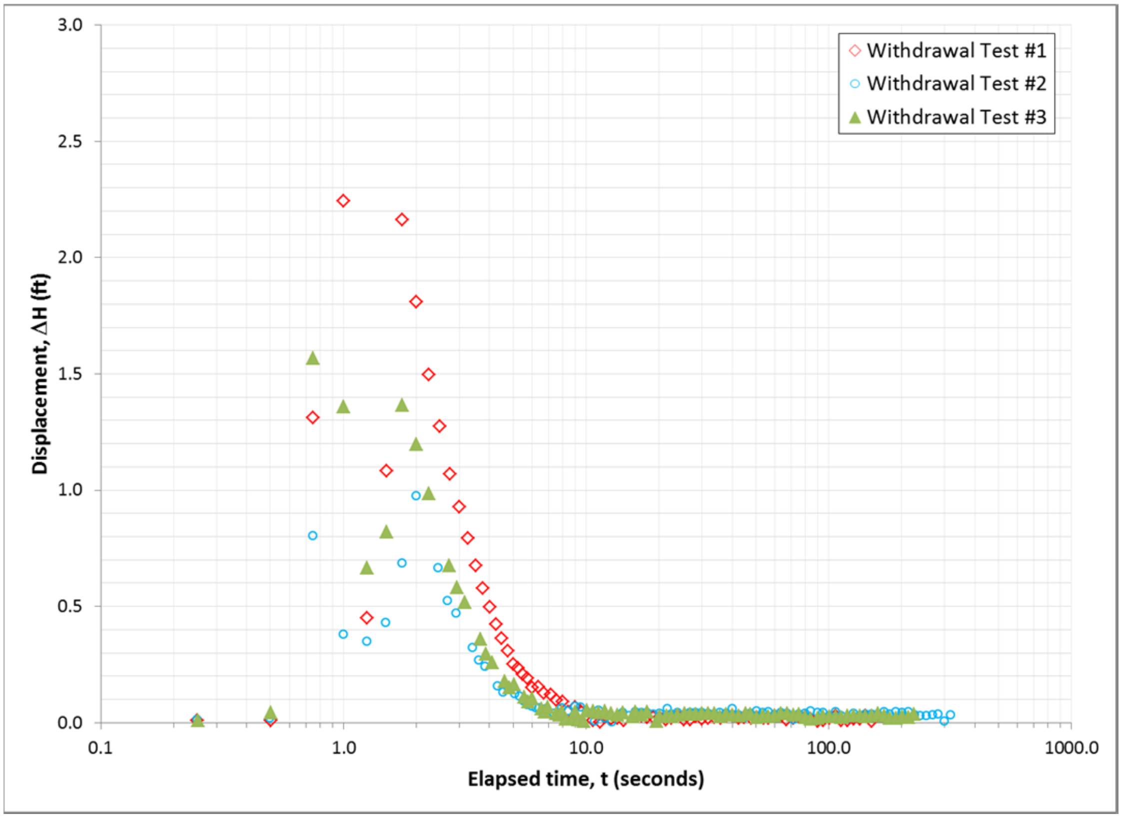

Figure 4-87. Displacements from three withdrawal tests at 199-H6-4

4.15.2 Estimation of effective start time

Effective start times of 1.75 seconds, 2 seconds and 1.75 seconds are estimated for the three withdrawal tests respectively.

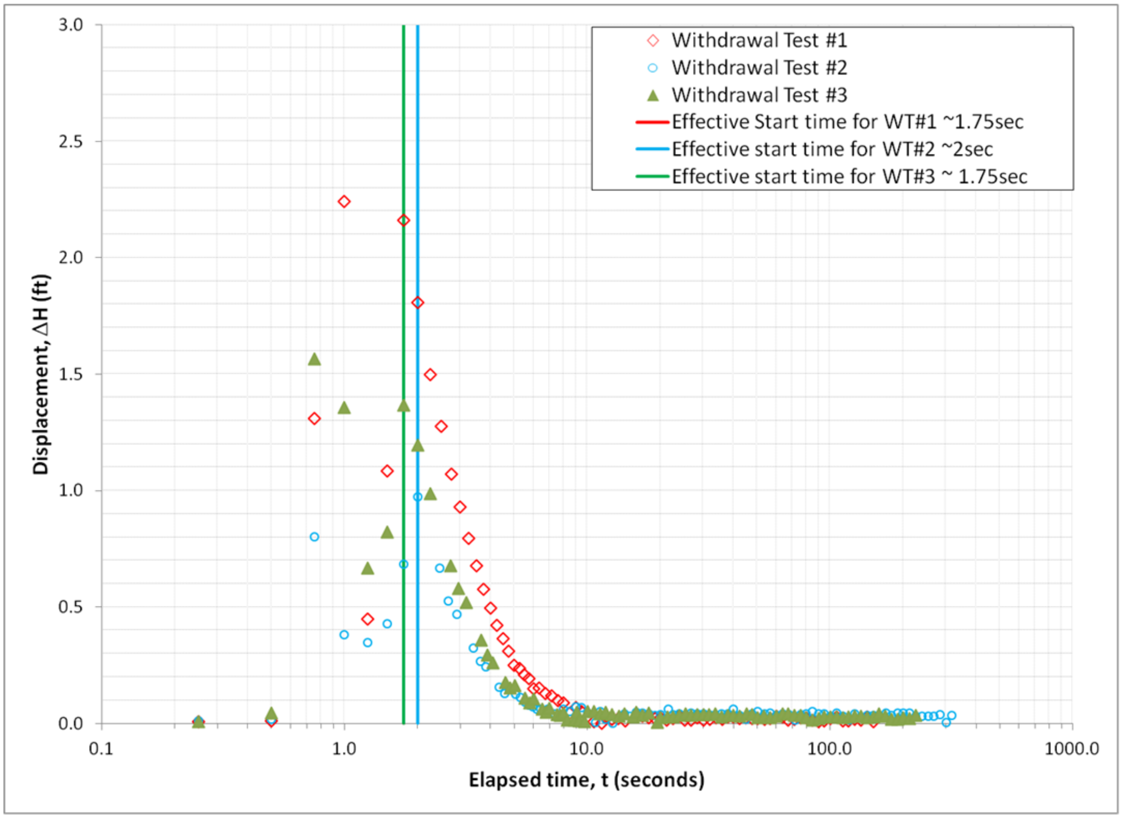

Figure 4-88. Effective start time for withdrawal tests at 199-H6-4

4.15.3 Estimation of effective initial displacement

Adjusted elapsed times are calculated by subtracting the effective start time from the reported elapsed times. The displacements are plotted against the adjusted elapsed times. The estimation of the initial displacements is shown in Figure 4-89. Effective initial displacements of 2.1 ft., 1.0 ft., and 1.4 ft. are estimated for the three withdrawal tests by back-fitting the observations to 0.0 elapsed time. For a slug volume (V) of 0.688 ft^3 and a casing radius (r_c) of 3 inches, a theoretical initial displacement (H_0) of 3.5 ft. is calculated ($H_0 = V/\pi r_c^2$). Similarly, theoretical initial displacements of 1.67 ft. and 2.4 ft. are estimated for the slug volumes of 0.328 ft^3 and 0.472 ft^3. The visually estimated initial displacements are lesser than the theoretical estimates probably because of the non-instantaneous nature of the tests.

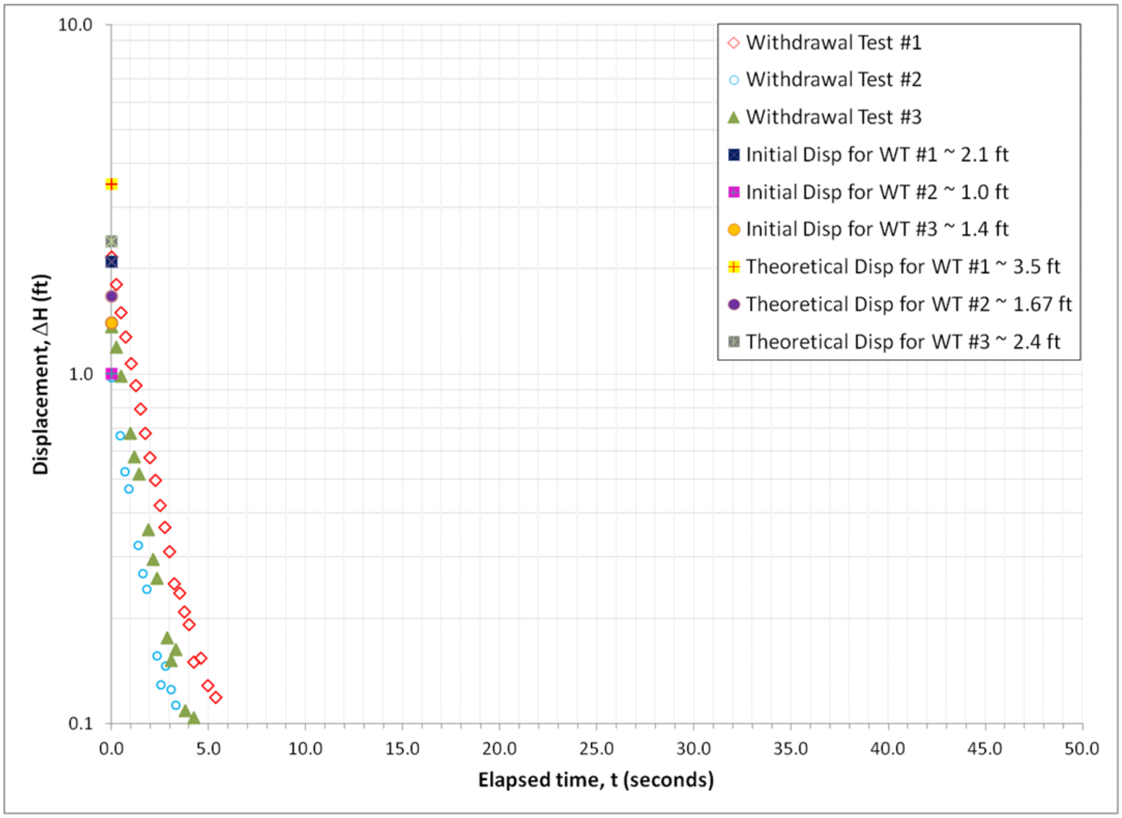

Figure 4-89. Estimation of effective initial displacement at 199-H6-4

4.15.4 Normalized displacements

The normalized displacements are calculated by dividing the observed displacements for the withdrawal tests by their respective effective initial displacement. The normalized responses plotted in Figure 4-90 confirm that the results for all the withdrawal tests are internally consistent. The close correspondence of the normalized displacement curves suggests that it is sufficient to analyze the data from only one of the withdrawal tests. The first withdrawal test is chosen for analysis.

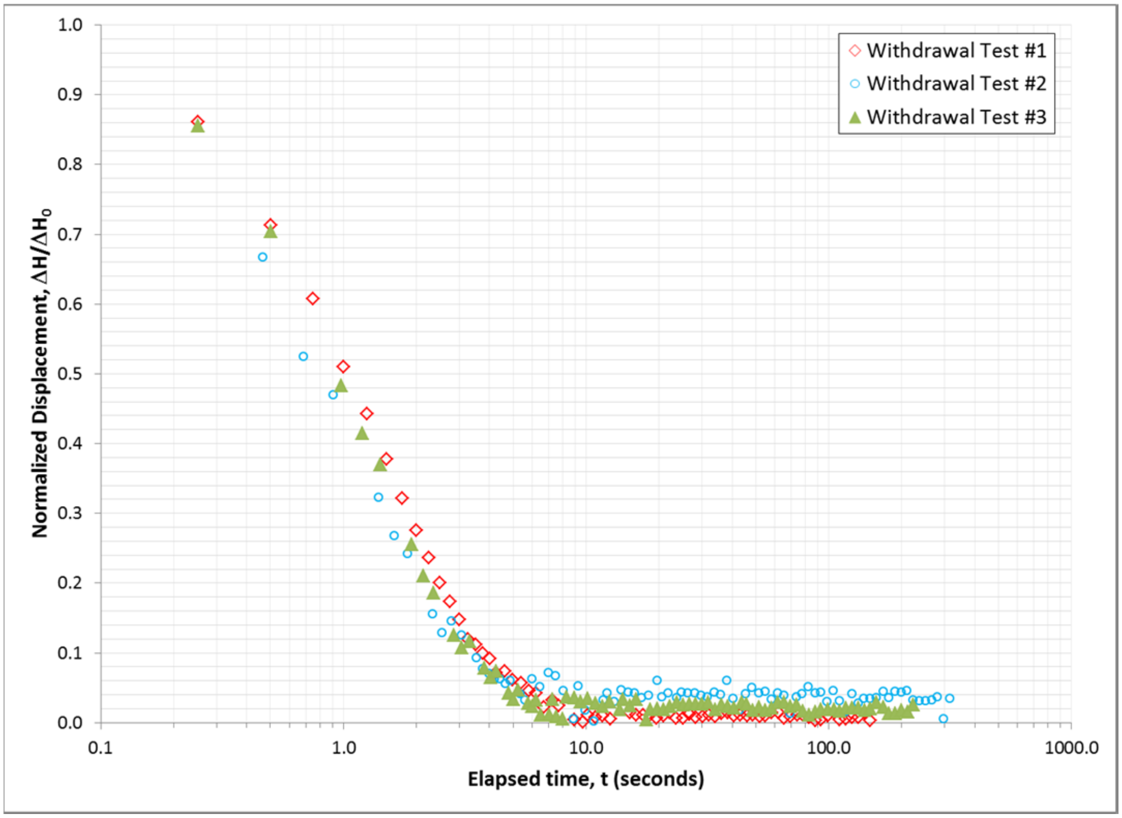

Figure 4-90. Normalized displacement at 199-H6-4

4.15.5 Preliminary analysis

For a first-cut analysis, the normalized displacements for the first withdrawal test are fit with the CBP model. The CBP model fit is shown in Figure 4-91. A good match to the observations is achieved with a storage coefficient, *S*, of 5×10^{-5}, and a fitted transmissivity, *T*, of 876 m^2/d. This analysis assumes that the well penetrates the full thickness of the aquifer. Referring to Table 4-2, we see that for well 199-H6-4, this is not the case. The aquifer (Hanford) is about 16.12 m (116.21 m – 110.09 m) thick at this location, and the length of the well screen is about 5.21 m. Cooper et al. (1967) suggested that in the case of a well that penetrates only a portion of the thickness of the aquifer, the effective thickness of the aquifer can be specified as the effective length of the well screen. Since the length of the submerged well screen length is 17.1 ft. (5.21 m), the estimated transmissivity corresponds to a horizontal hydraulic conductivity, K_H, of **168 m/d** or **1.9×10^{-3} m/s.**

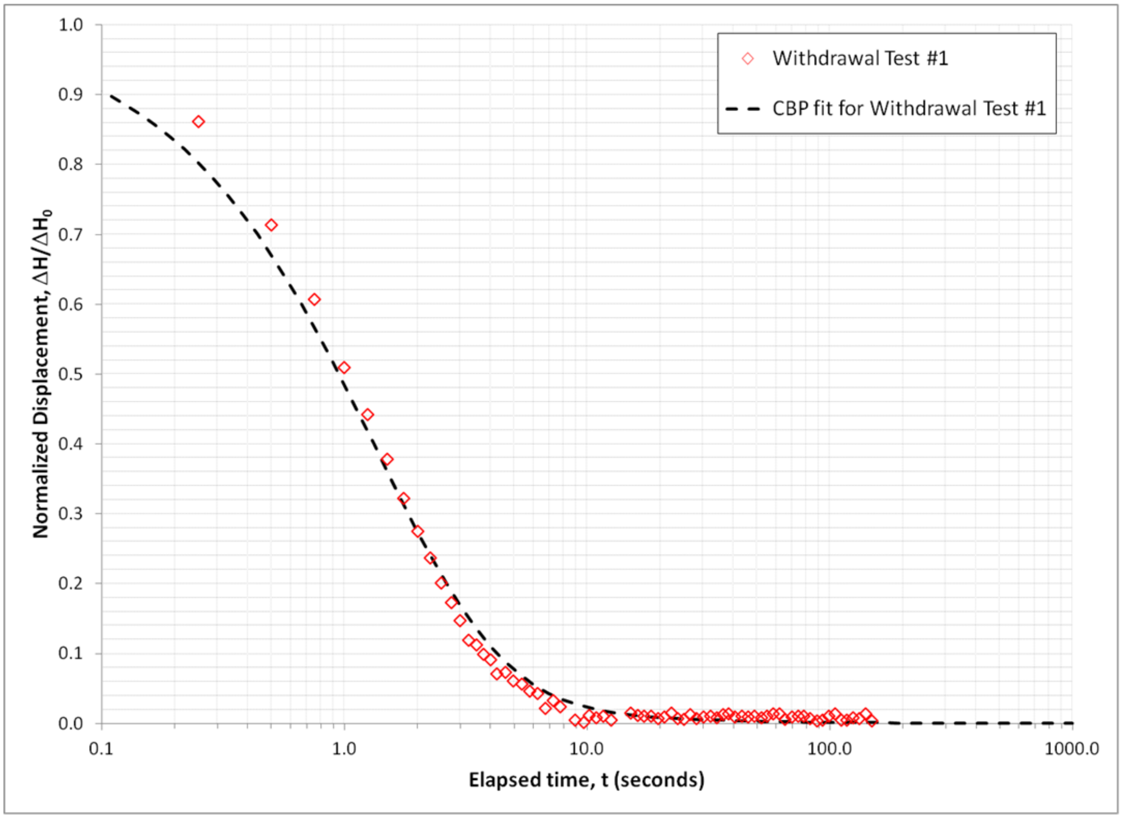

Figure 4-91. CBP Model fit at 199-H6-4

4.15.6 Refined analysis

For a more refined analysis, the normalized displacements for the first withdrawal test are fit with the KGS model for an unconfined aquifer. The KGS model fit is shown in Figure 4-92. A good match to the observations is achieved with a specific storage, S_s, of 9.6×10^{-6} m^{-1}, an anisotropy ratio K_V/K_H of 0.1, and a fitted horizontal hydraulic conductivity, K_H, of **118 m/d** or **1.4×10^{-3} m/s**. The specific storage value is not iteratively estimated but instead calculated by dividing an assumed storage coefficient of 5×10^{-5} by the submerged well screen length (17.1 ft. or 5.21 m).

The fitted value of the specific storage value falls in the range suggested by Younger (1993) as representative of aquifer materials that consist of coarse sand and gravel. This corresponds well with the 'Sandy Gravel' description of the screened interval.

The estimated hydraulic conductivity at the lower end of the range for gravel and at the higher end of the range for clean sand reported in the literature (see for example, Freeze and Cherry, 1979; Table 2.2). This corresponds well with the 'Sandy Gravel' description of the screened interval.

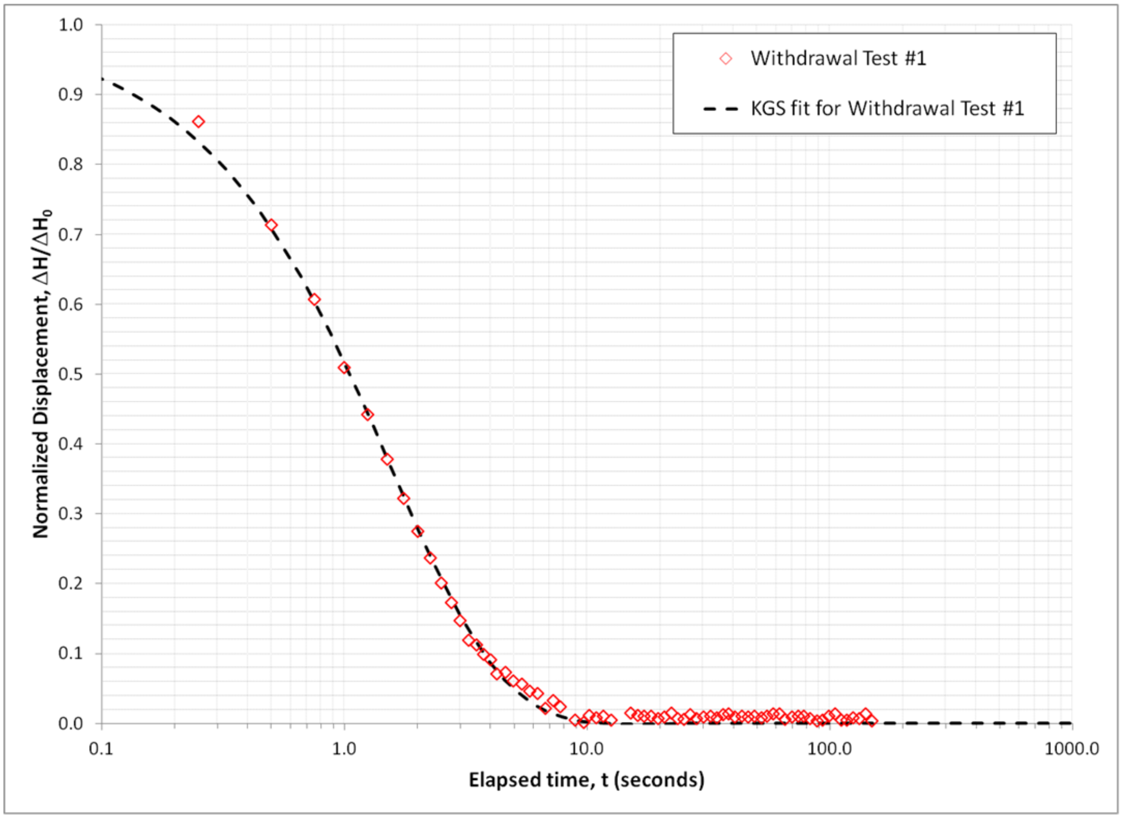

Figure 4-92. KGS Model fit at 199-H6-4

4.16 Analysis of Slug Test Data at well 199-H1-7

One withdrawal test was conducted at 199-H1-7 and it is analyzed here.

4.16.1 Raw displacement data for withdrawal tests

The withdrawal test was conducted with a slug of volume 0.688 ft^3. The displacements are plotted in Figure 4-93. Unlike the tests at other wells in the vicinity, the response at this well remains nearly static for about 230 seconds before dissipation commences. Additionally, the measured response did not document the recovery completely. According to the field log, the slug could not be fully inserted into the well screen and hit the bottom of the well during the test. An inspection of Table 4-1 reveals that the water table is below the screen elevation. Because of the above mentioned reasons, this test was not considered reliable. We recommend testing of this well with a smaller slug when the water level is within the well screen.

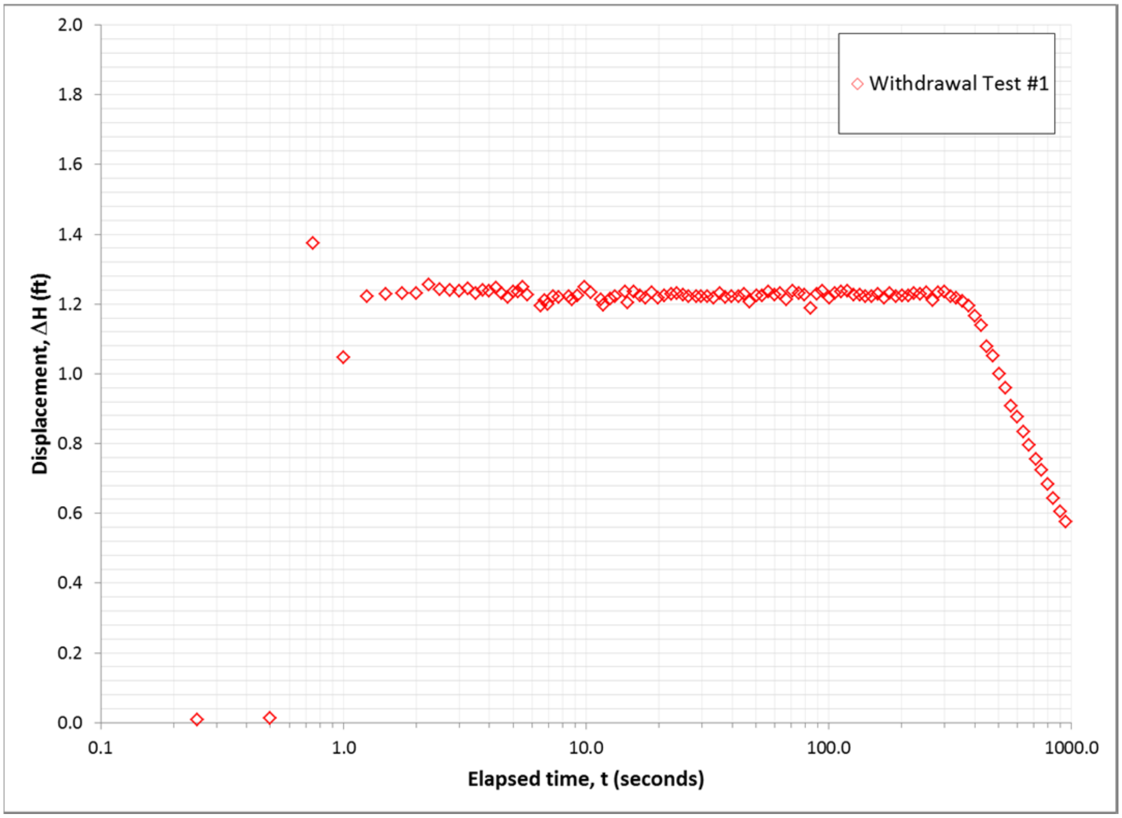

Figure 4-93. Displacements from one withdrawal test at 199-H1-7

5. Summary of interpretations

5.1 Summary of Slug Test Data

Slug test data at sixteen wells in the 100-D-Area and 100-H-Area has been analyzed with the CBP and KGS methods. The locations of the D and H areas and other Hanford groundwater interest areas are shown in Figure 5-1. The slug tests were conducted in materials of the Hanford formation, Ringold E Formation and the underlying RUM unit. The estimated specific storage and hydraulic conductivities for the D-Area and H-Area are tabulated on Table 5-1 and Table 5-2 respectively. The new estimates of hydraulic conductivity are compared with historical estimates from slug tests and pumping tests. Maps of all well locations (historical and new) are provided in Figures 5-2 and 5-6. In Figures 5-3 and 5-7, the estimates are classified according to the test type: historical slug test, historical pumping test or new slug test. In Figures 5-4 and 5-8, the estimates are classified by magnitude with the new test estimates displayed in red and the historical estimates displayed in green. In Figures 5-5 and 5-9, the estimates are classified by formation. The well screen elevations along with the elevation of the water table and the top of the RUM are shown in Figures 5-10 and 5-11.

The reported hydraulic conductivity values on Tables 5-1 and Table 5-2 are from the refined KGS analysis. While the KGS model is more refined, the CBP model has provided a useful first-cut estimate of the storage coefficient and hydraulic conductivity. Since the CBP model neglects vertical flow, it yields an upper bound estimate of the hydraulic conductivity. It is to be noted that the reported storages are the specific storage and not the specific yield. In an unconfined aquifer, the drainage of the pores of the formation at the water table is quantified with the specific yield, also referred to as the drainable porosity. The effects of the slug tests are not sufficient to cause drainage of pores; therefore, the specific yield does not enter into the analysis. Rather, the changes in storage reflect an elastic response, and are more appropriately quantified with the specific storage or confined storage coefficient, also referred to as the storativity.

In the D-Area, the RUM wells 199-D5-134 and 199-D5-141 yield the lowest hydraulic conductivity values of 0.1 m/d and 0.2 m/d, respectively. Out of the remaining six wells, five were screened in the Ringold E Formation. Among these wells, the hydraulic conductivity ranged from 13 m/d to 40 m/d. The remaining well 199-D3-5 which was screened in both the Hanford and Ringold E units had a higher hydraulic conductivity of 59 m/d. The comparison with the historical data shows that there is generally good agreement between the two datasets. The vertical anisotropy ratio was assumed to be 0.1 for all the D-wells. Changing the anisotropy ratio did not lead to a very different value of the horizontal hydraulic conductivity. For instance, at 199-D5-132, the hydraulic conductivity for an anisotropy ratio of 0.01 was estimated to be 23 m/d. This estimate is very close to that of 22 m/d for an anisotropy ratio of 0.1.

In the H-Area, three wells were screened in the RUM with hydraulic conductivities ranging from 0.6 m/d to 2 m/d. All the remaining wells were screened in the Hanford formation. The hydraulic conductivities at these wells ranged from 30 m/d to 127 m/d. The dataset for 199-H1-7 was not analyzed because the water table was below the well screen. The comparison with the historical data shows that there is generally good agreement between the two datasets. With the exception of 199-H3-6 (0.01) and 199-H3-9 (1.0), an assumed anisotropy ratio of 0.1 lead to good fits.

With the exception of 199-H1-7, the tests show 'near-textbook' responses suggesting that excellent field practices were in use during the tests. For several wells, the estimated hydraulic conductivity was not quite consistent with the value that would be inferred by matching the geologic description with typical ranges of values reported in Freeze and Cherry (1979). It was hypothesized that this likely reflects the effects of fine-grained materials. As shown in Figure 5- 12, the hydraulic conductivity decreases by orders of magnitude for even relatively small amounts of fines.

In addition to the slug test data, well development data were also analyzed in the H-area to help in the delineation of Ringold E in the Horn area. This analysis is summarized in the next section.

Table 5-1. Estimated Aquifer Properties for D-Area Wells.

Well name	Geologic Unit	KGS method				
		Specific Storage (m^{-1})	Horizontal Hydraulic Conductivity K_H (m/d)	Horizontal Hydraulic Conductivity K_H (m/s)	Horizontal Hydraulic Conductivity K_H (cm/s)	Vertical Anisotropy Ratio (K_V/K_H)
199-D3-5	Hanford and Ringold E	2.0×10^{-6}	55	6.4×10^{-4}	6.4×10^{-2}	0.1
199-D5-132	Ringold E	6.4×10^{-4}	19	2.2×10^{-4}	2.2×10^{-2}	0.1
199-D5-133	Ringold E	2.0×10^{-4}	38	4.4×10^{-4}	4.4×10^{-2}	0.1
199-D5-134	RUM	1.3×10^{-3}	0.1	1.2×10^{-6}	1.2×10^{-4}	0.1
199-D5-141	RUM	3.3×10^{-4}	0.2	2.3×10^{-6}	2.3×10^{-4}	0.1
199-D5-143	Ringold E	2.0×10^{-4}	20	2.3×10^{-4}	2.3×10^{-2}	0.1
199-D5-144	Ringold E	6.6×10^{-5}	23	2.7×10^{-4}	2.7×10^{-2}	0.1
199-D6-3	Ringold E	5.9×10^{-4}	12	1.4×10^{-4}	1.4×10^{-2}	0.1

Table 5-2. Estimated Aquifer Properties for H-Area Wells.

Well name	Geologic Unit	KGS method				
		Specific Storage (m^{-1})	Horizontal Hydraulic Conductivity K_H (m/d)	Horizontal Hydraulic Conductivity K_H (m/s)	Horizontal Hydraulic Conductivity K_H (cm/s)	Vertical Anisotropy Ratio (K_V/K_H)
199-H2-1	RUM	1.3×10^{-4}	2	2.3×10^{-5}	2.3×10^{-3}	0.1
199-H3-6	Hanford	2.2×10^{-4}	38	4.4×10^{-4}	4.4×10^{-2}	0.01
199-H3-7	Hanford	7.2×10^{-4}	27	3.1×10^{-4}	3.1×10^{-2}	0.1
199-H3-9	RUM	1.3×10^{-4}	0.5	5.8×10^{-6}	6.9×10^{-4}	1.0
199-H3-10	RUM	1.6×10^{-4}	1.6	1.9×10^{-5}	1.9×10^{-3}	0.1
199-H6-3	Hanford	2.0×10^{-5}	27	3.1×10^{-4}	3.1×10^{-2}	0.1
199-H6-4	Hanford	9.6×10^{-6}	118	1.4×10^{-3}	1.4×10^{-1}	0.1
199-H1-7	Hanford	Dataset unreliable. Recommend re-testing with smaller slug during high water level.				

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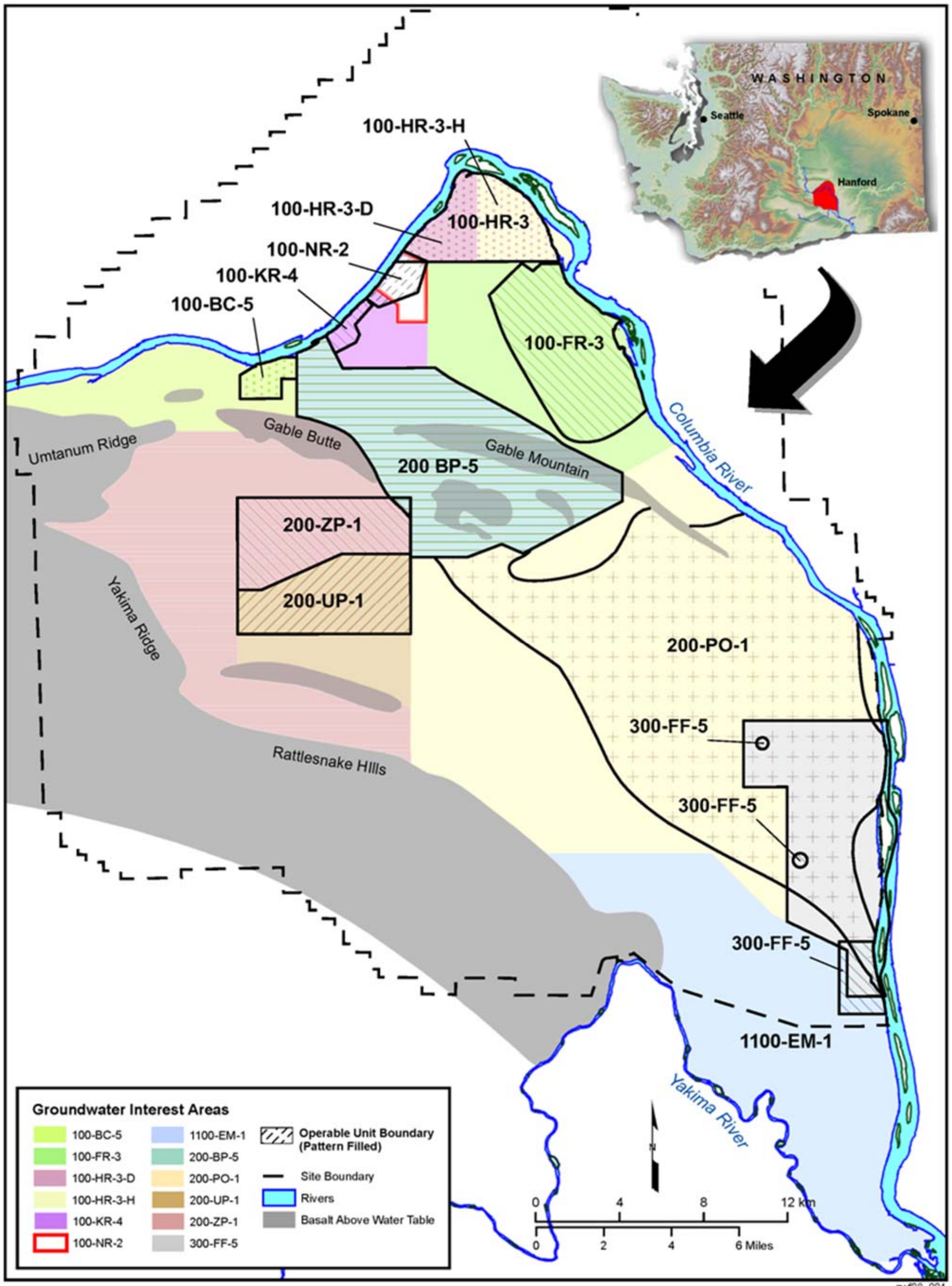

Source: DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008.*

Figure 5-1. Location of 100 Area Groundwater Operable Units in Relation to Other Hanford Site Groundwater Operable Units

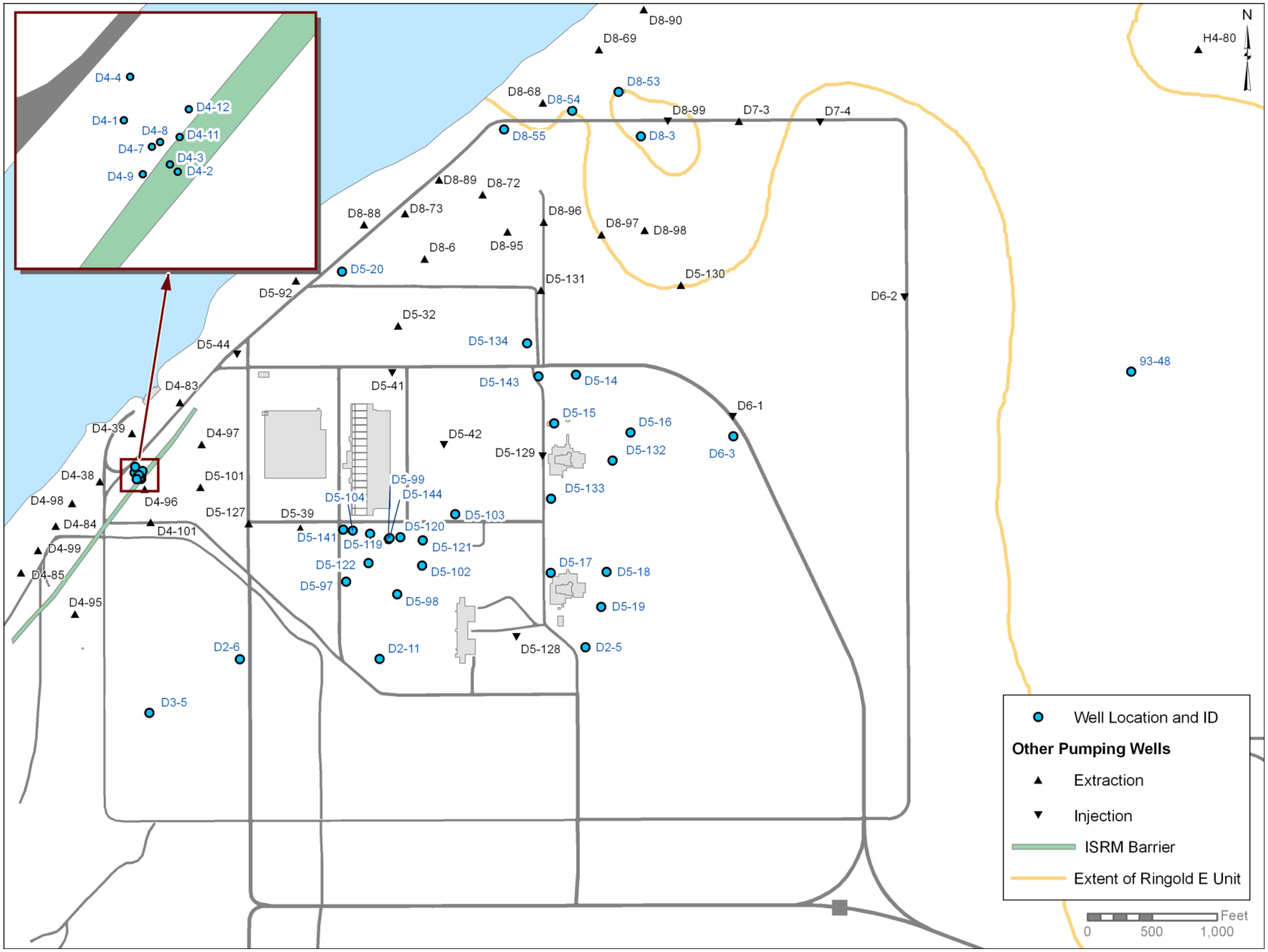

Figure 5-2. Wells: D-Area

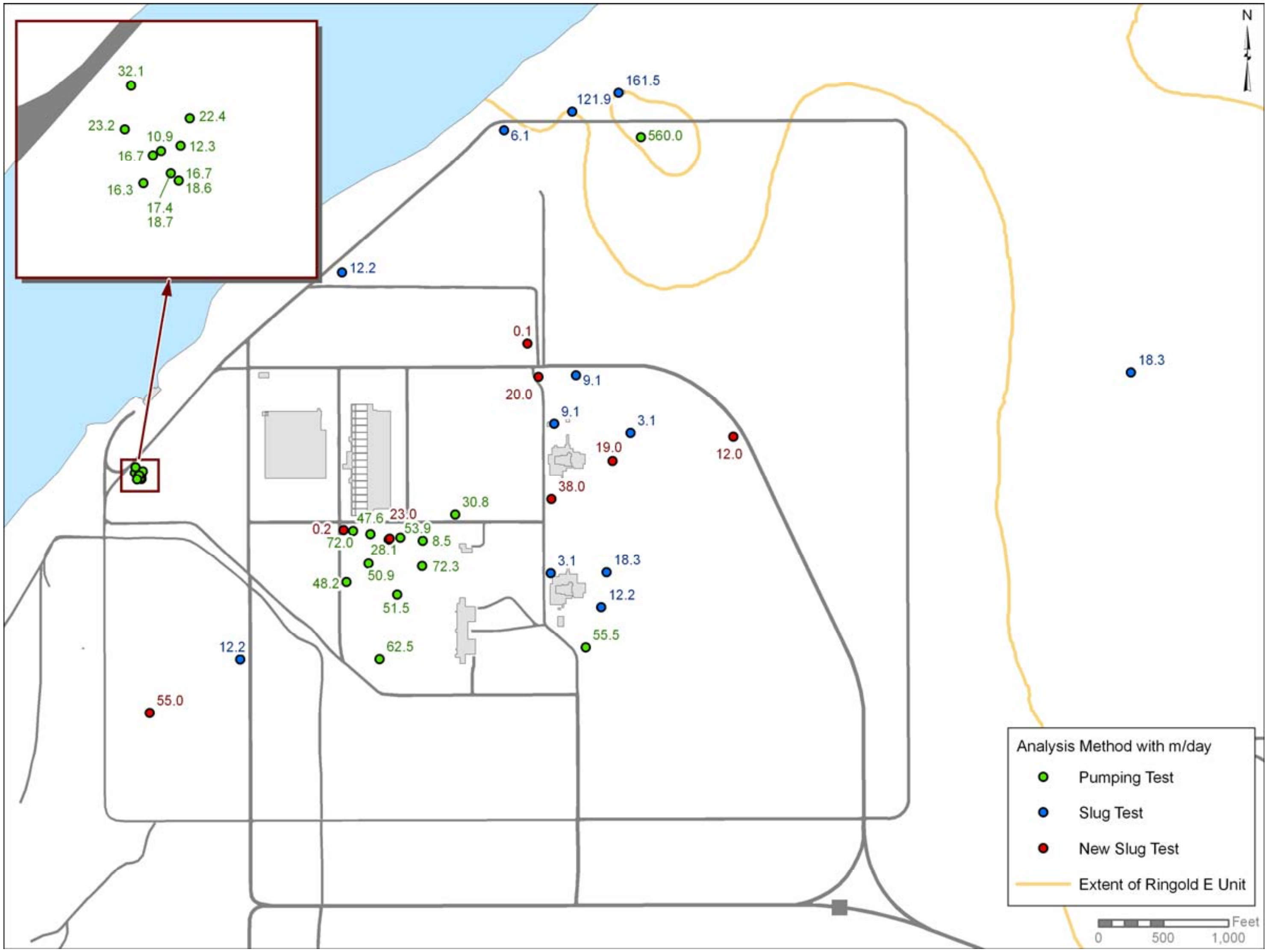

Figure 5-3. Hydraulic Conductivity (m/d) Estimates by Test Type: D-Area

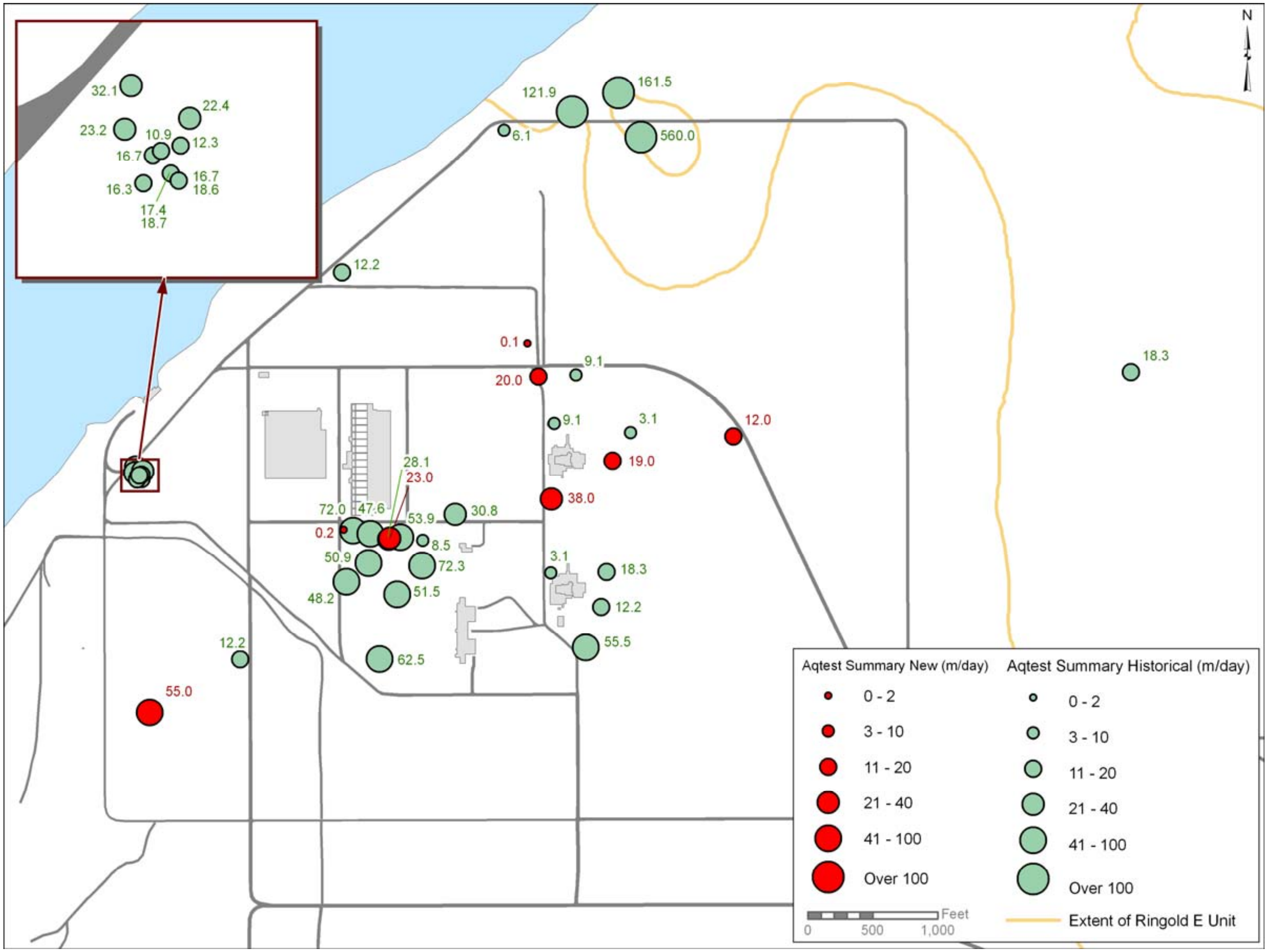

Figure 5-4. Hydraulic Conductivity (m/d) Estimates by Magnitude: D-Area

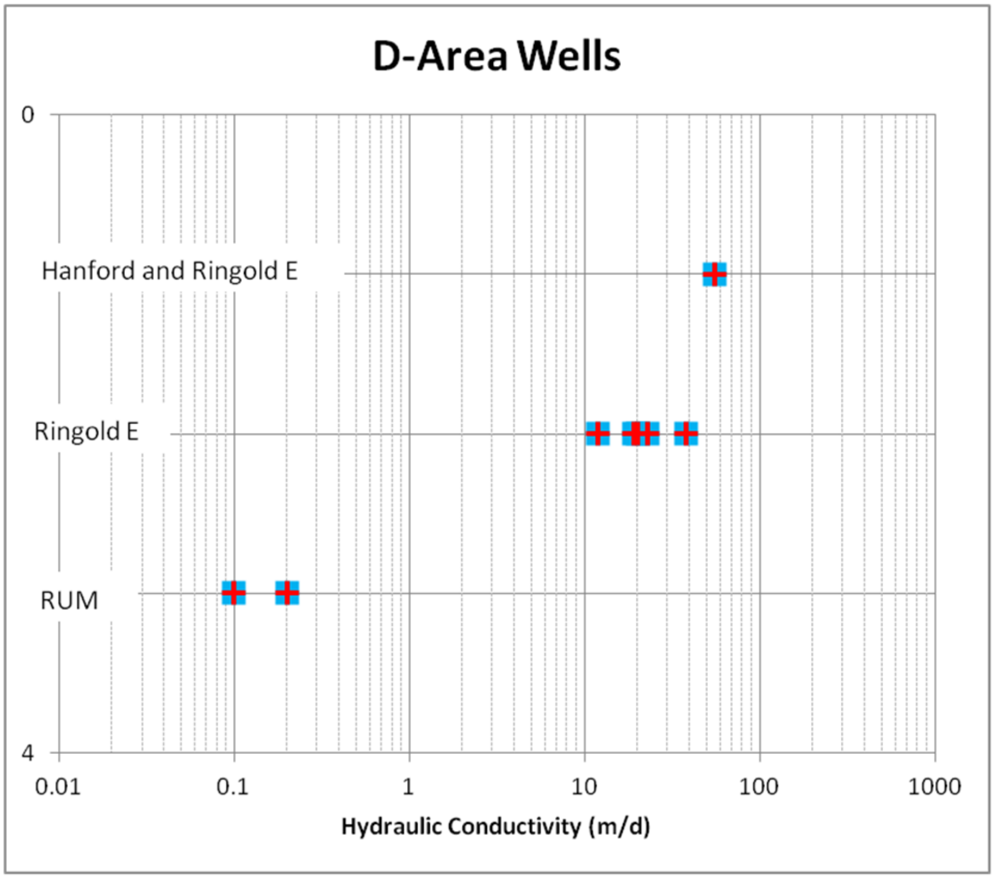

Figure 5-5. Hydraulic Conductivity (m/d) Estimates by Formation Type: D-Area

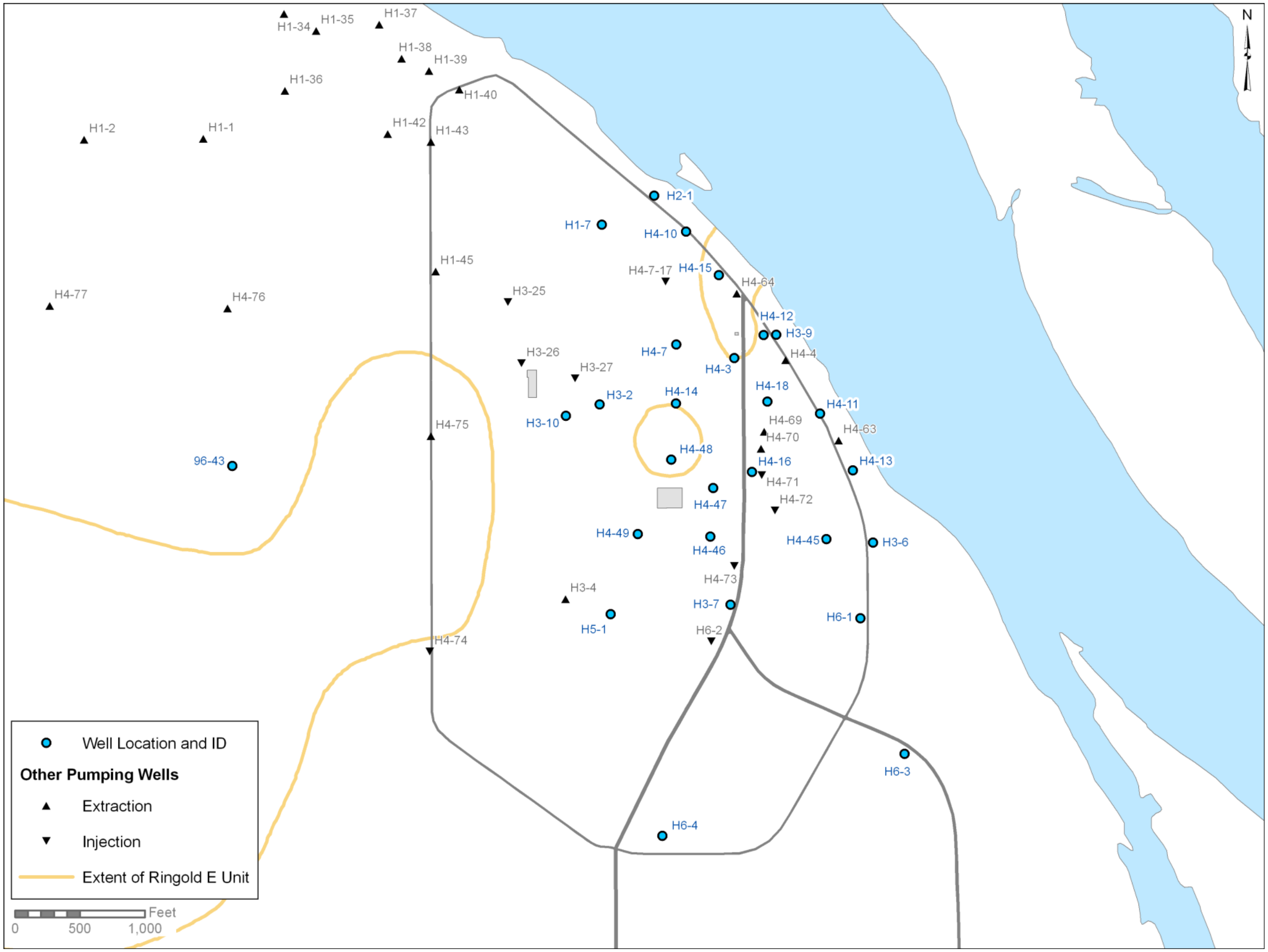

Figure 5-6. Wells: H-Area

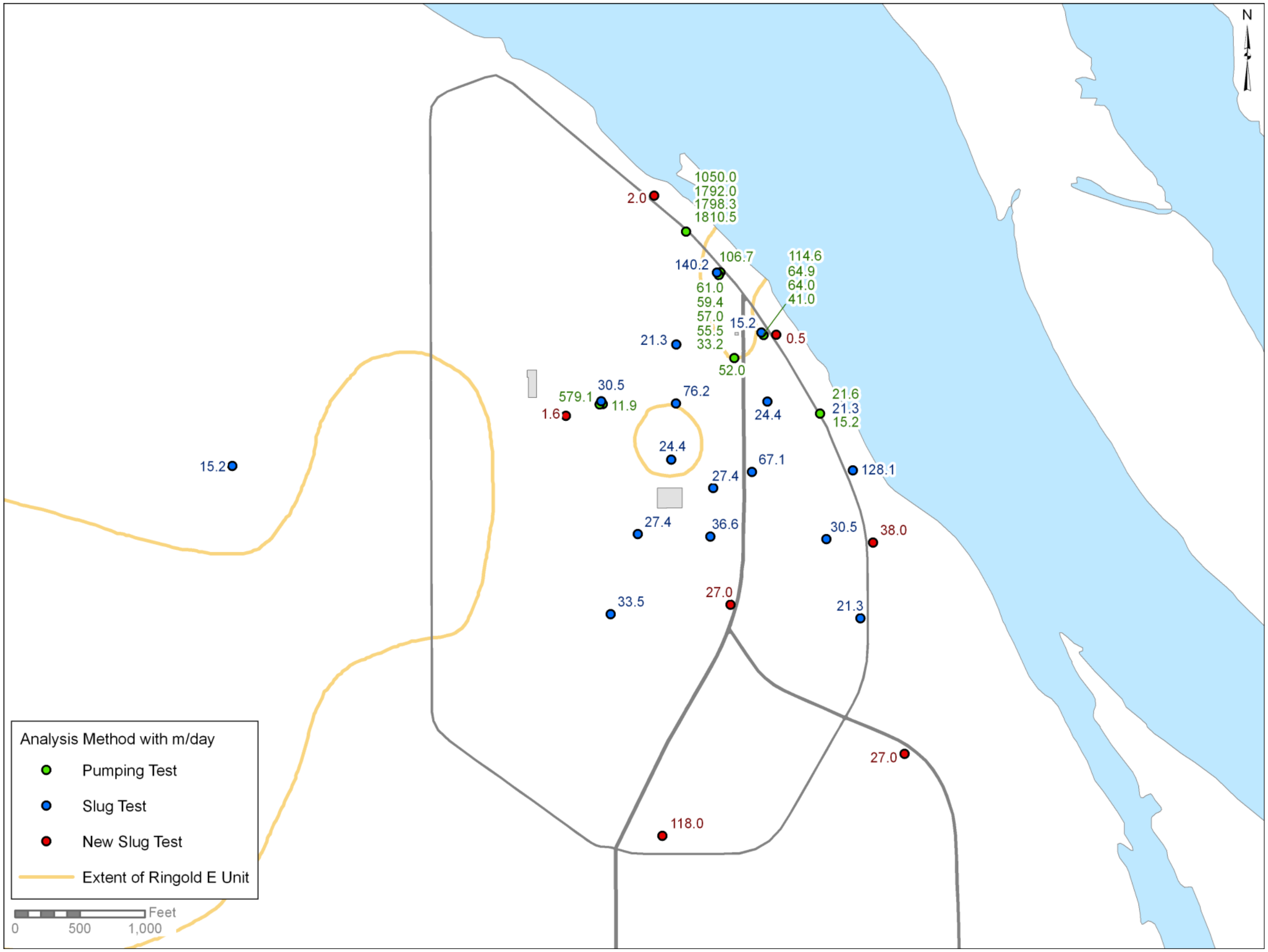

Figure 5-7. Hydraulic Conductivity (m/d) Estimates by Test Type: H-Area

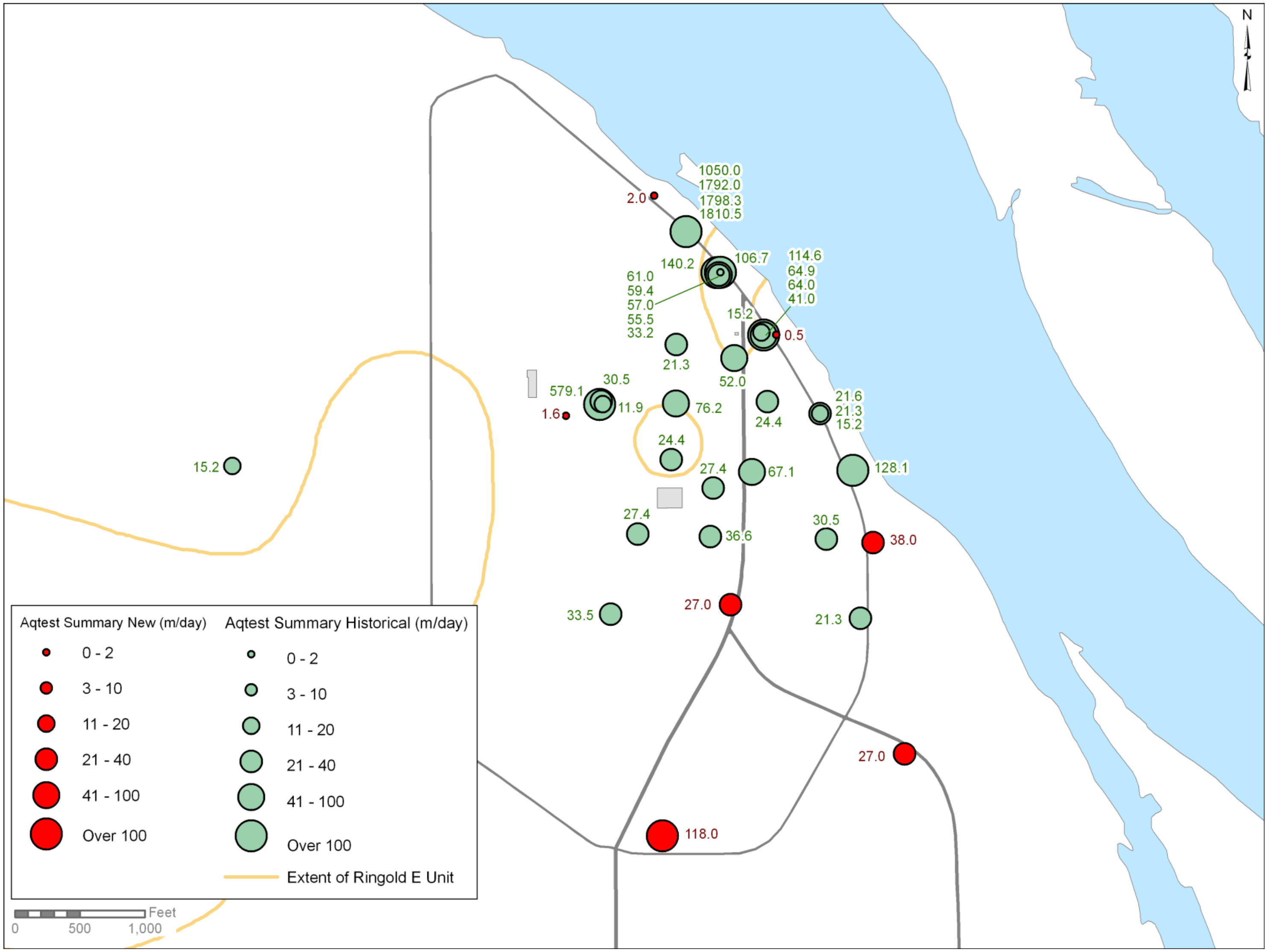

Figure 5-8. Hydraulic Conductivity (m/d) Estimates by Magnitude: H-Area

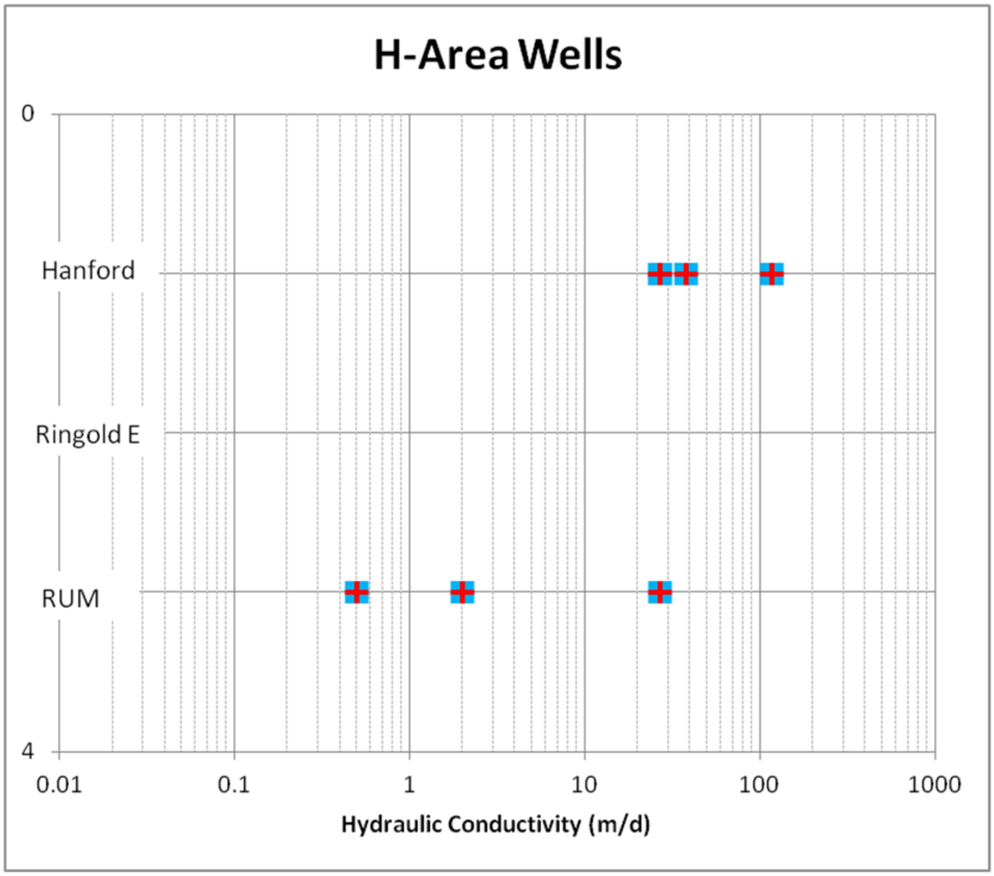

Figure 5-9. Hydraulic Conductivity (m/d) Estimates by Formation Type: H-Area

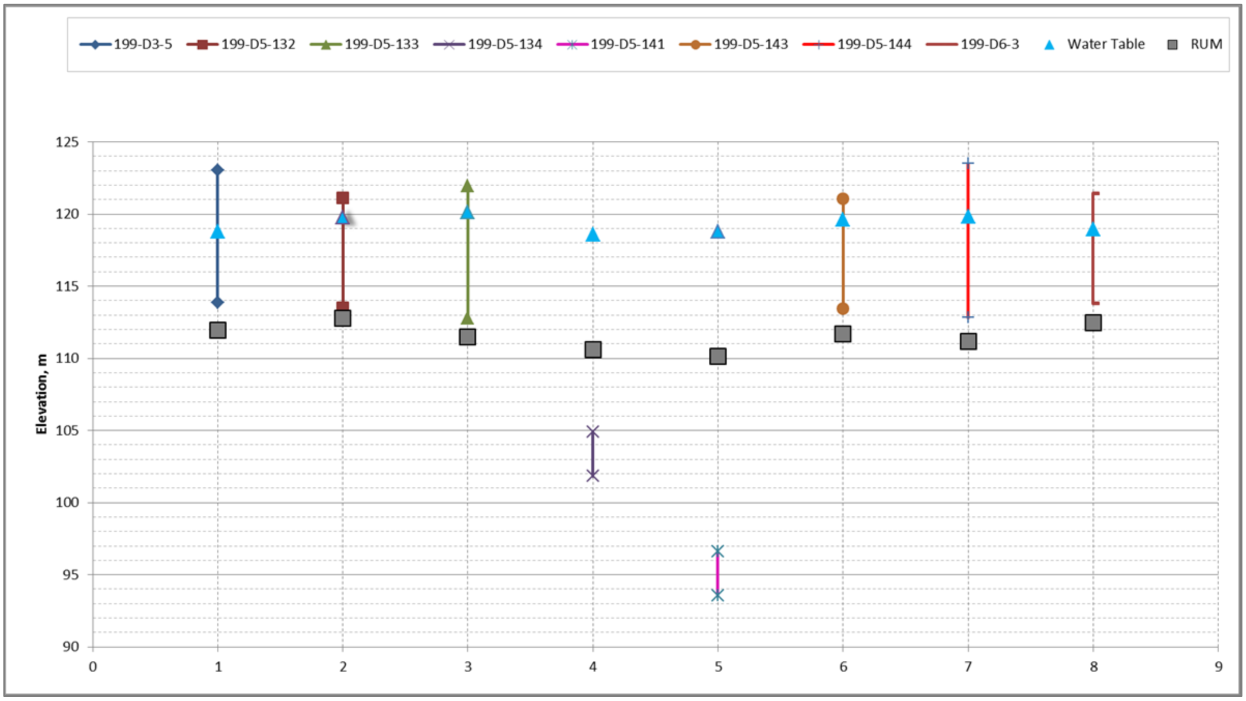

Figure 5-10. Well Screen Elevations in D-Area

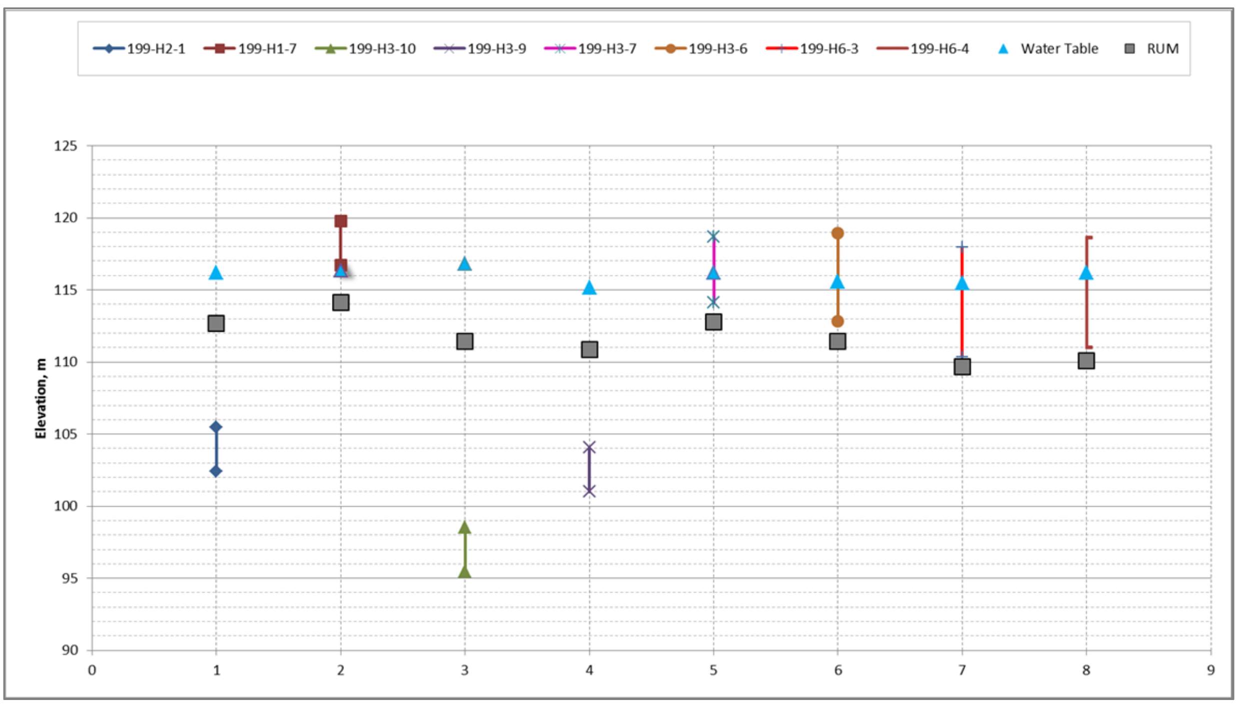

Figure 5-11. Well Screen Elevations in H-Area

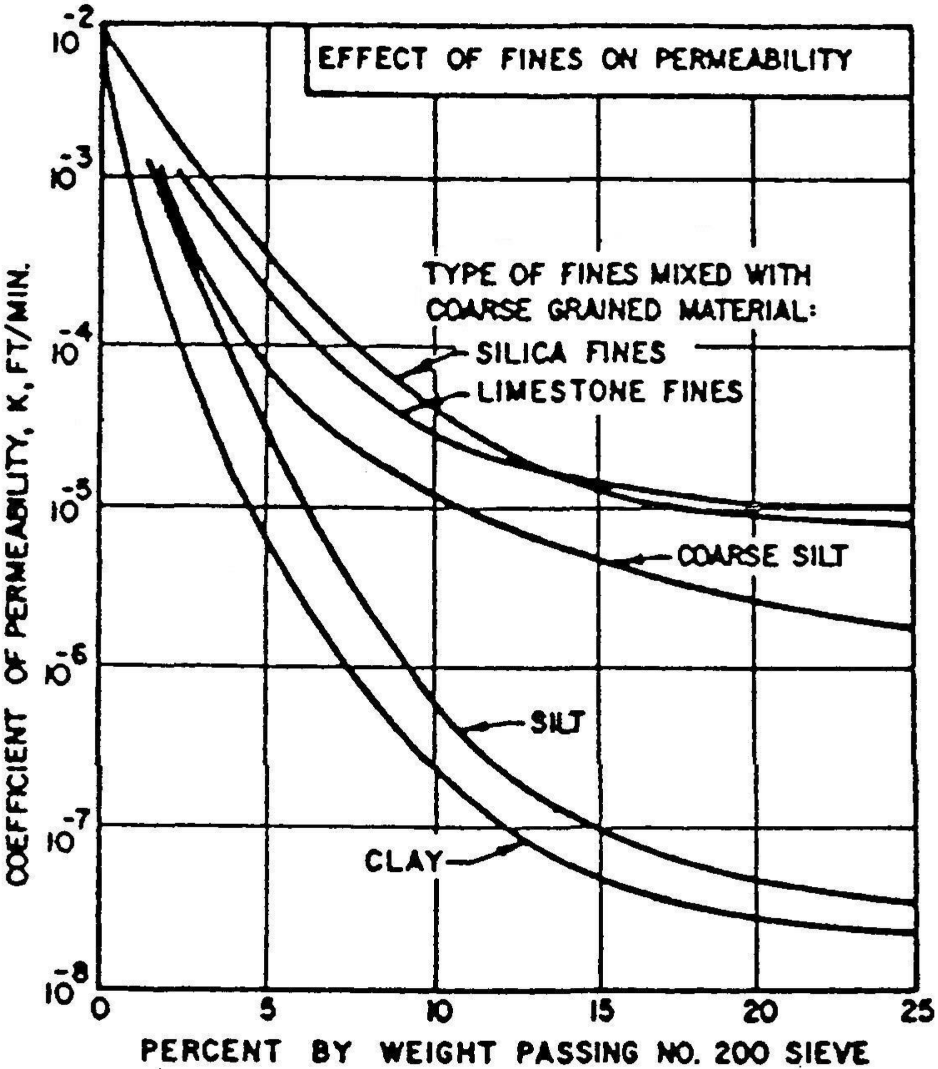

Figure 5-12. Effect of fines on the hydraulic conductivity of gravel

Source: From United States NAVFAC SM Design Manual 7.01, Figure 6 (1986)

5.2 Summary of Well Development Data

Well development was analyzed at 19 wells in HR-3 and the specific capacity calculated when data were available. When the pumping rate was known, the specific capacity was estimated to be the pumping rate divided by the maximum drawdown. The calculated specific capacities are tabulated on Table 5-3 and shown visually in Figure 5-14. When both the hydraulic conductivity and the specific capacity data were available, the two datasets were plotted against each other. As we can see in Figure 5-13, there appears to be a clear correlation between the specific capacity and hydraulic conductivity. This serves as an additional qualitative assessment of the reliability of the hydraulic conductivity estimates.

Table 5-3. Specific Capacities for H-Area Wells.

	Initial Submergence (ft.)	Maximum Drawdown (ft.)	Pumping Rate (gpm.)	Specific Capacity (gpm/ft)	Specific Capacity (m^2/d)
699-95-48	12.096	11.97	20	1.67	29.9
699-94-43	10.375	10.34	3.25	0.31	5.6
699-93-48	51.62	0.85	12.82	15.08	269.7
199-H6-4	13.658	0.727	38.9	53.51	956.7
199-H6-4	13.658	0.339	17.9	52.8	944.1
199-H6-3	7.78	3.8	29	7.63	136.5
199-H4-80	5.93	1.26	68.8	54.6	976.3
199-H4-80	19.86	1.233	68.8	55.8	997.7
199-H4-78	14.95	11.58	unknown		
199-H4-74	4.45	2.38	21	8.82	157.8
199-H3-9	44.7	44.67	6.7	0.15	2.7
199-H3-7	2.496	2.45	7.9	3.22	57.7
199-H3-6	6.25	4.01	18	4.49	80.3
199-H3-10	65.125	56.37	24	0.43	7.6
199-H3-10	65.125	56.1	20	0.36	6.4
199-H2-1	41.25	40.18	unknown		
199-H2-1	41.25	41.168	unknown		
199-H1-5	8.18	6.525	65.8	10.08	180.3
199-H1-5	14.56	9.6	71.8	7.48	133.7

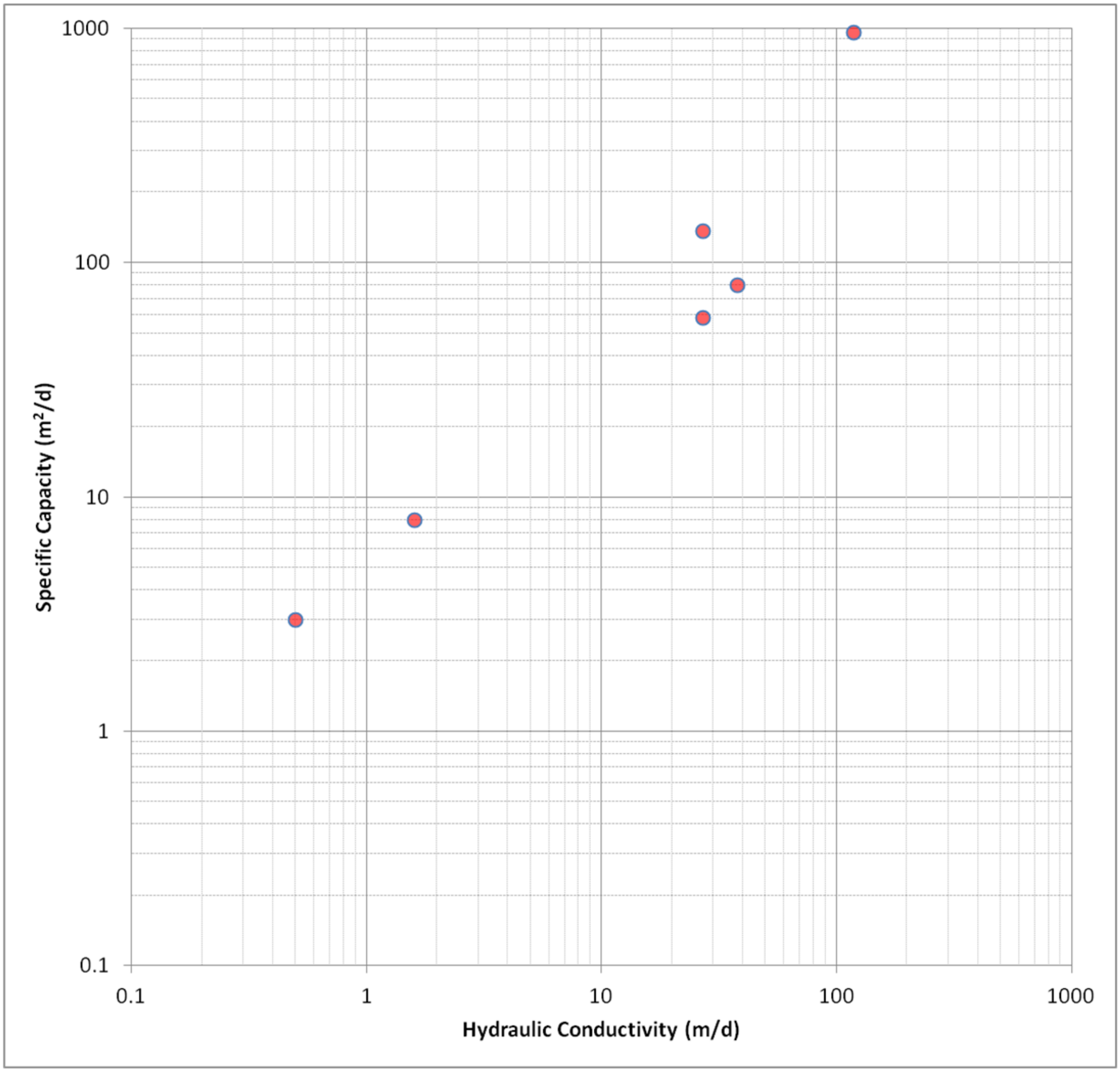

Figure 5-13. Specific Capacity vs. Hydraulic Conductivity: H-Area

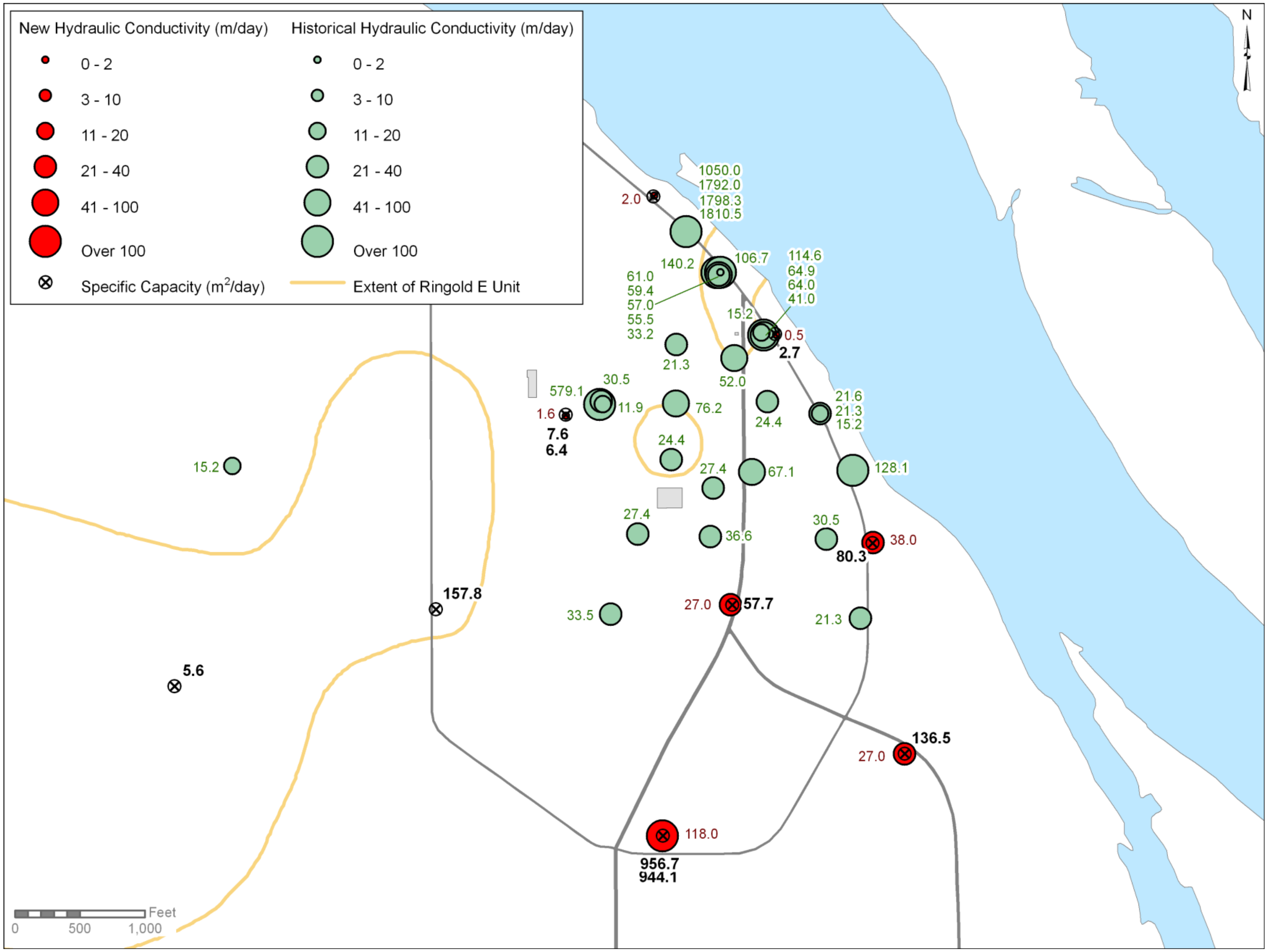

Figure 5-14. Spatial plot of Specific Capacity and Hydraulic Conductivity: H-Area

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