AQUIFER CHARACTERIZATION AND GROUNDWATER CAPTURE ANALYSIS FOR THE KAISER MEAD FACILITY

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AQUIFER CHARACTERIZATION AND GROUNDWATER CAPTURE ANALYSIS FOR THE KAISER MEAD FACILITY

1.0 INTRODUCTION

This memorandum describes the results of a recent investigation conducted at the former Kaiser Mead Works Facility to further assess aquifer characteristics at the site within the Zone A and Zone B groundwater systems in the area downgradient of the Spent Pot Liner (SPL) pile.

In 2002, a cleanup action plan (CAP) was prepared by Ecology that called for implementing a combination of source controls and a pump and treat system to achieve water quality compliance. The pump and treat system would only be implemented if source control cleanup measures were not successful at bringing groundwater quality into compliance with established clean-up levels for fluoride and WAD cyanide at the downgradient compliance boundary. A performance evaluation conducted in 2010 (Hydrometrics, 2010) showed that the established cleanup levels were not being met five years after completion of the source controls measures.

This investigation was initiated to provide further assessment of aquifer characteristics at potential extraction sites and reconfirm the pumping rates required for hydraulic control of the plume so that remediation alternatives can be more accurately evaluated in the feasibility study. This investigation is not intended to focus the assessment of remediation alternatives on a specific solution (i.e., pump and treat) since groundwater capture could be used in conjunction with various remediation alternatives including in-situ treatment, passive treatment technologies and in targeted groundwater capture scenarios.

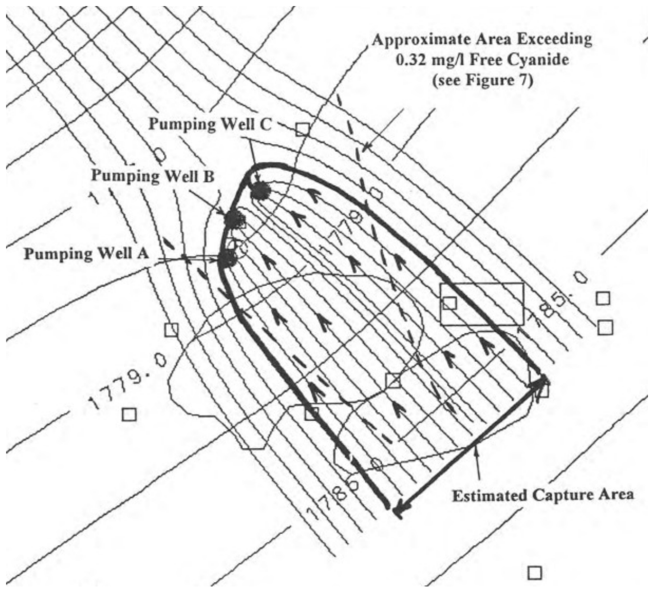
Previous investigations have relied on very limited testing to define aquifer characteristics and the tests that were performed utilized relatively low pumping rates (10 to 20 gpm) that produced minimal drawdown response in the aquifer. Tests that do not place sufficient stress on the aquifer may over estimate aquifer hydraulic conductivity, which in turn may yield high extraction rates in a capture analyses. Since the capital and operational costs associated with water treatment are very high, further investigation was proposed to verify the accuracy of the aquifer hydraulic conductivity estimates and associated extraction estimates.

1.1 PREVIOUS INVESTIGATIONS

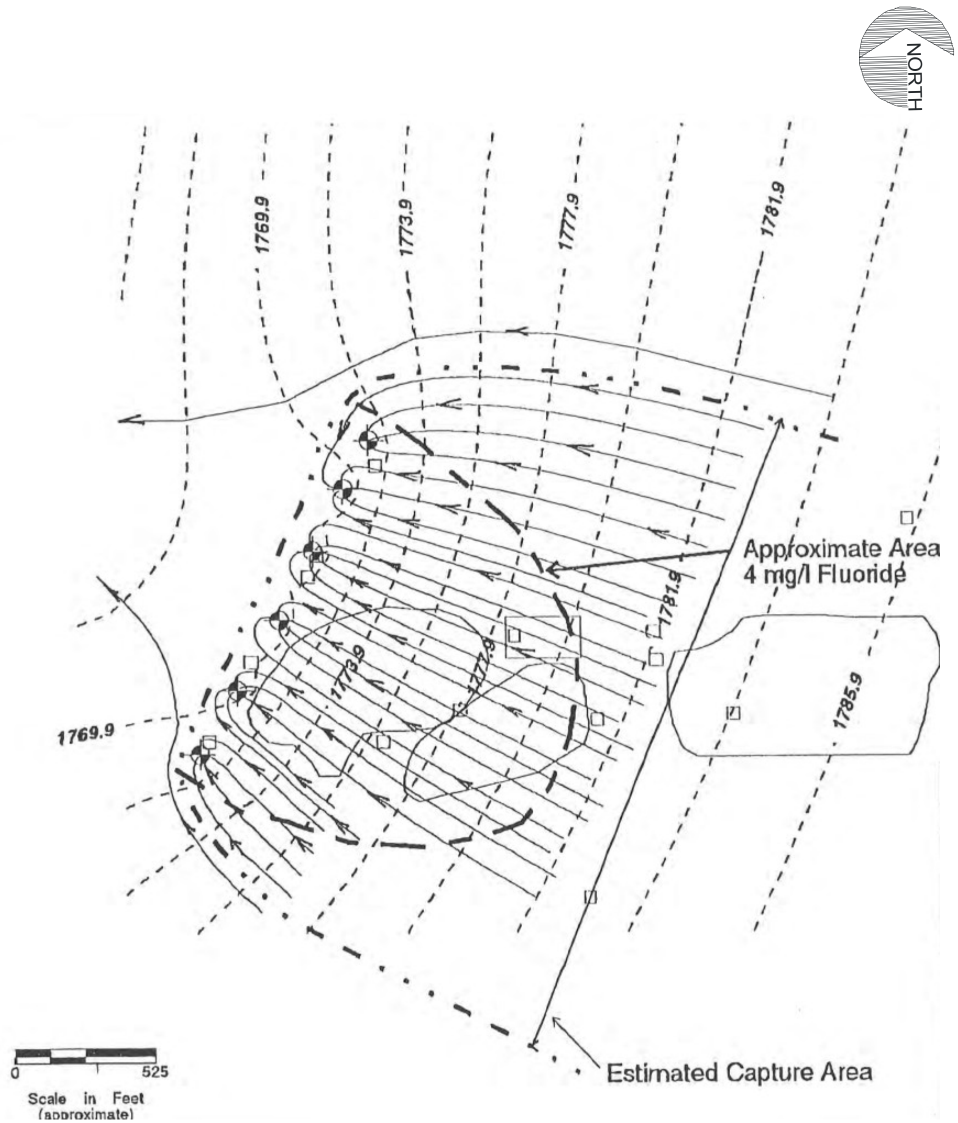
Aquifer tests and groundwater capture analyses were generated in the initial site investigation and feasibility assessment conducted by Hart Crowser (1988). Hart Crowser conducted two short term pumping tests (2 to 3 hours in duration) at monitoring wells ES-9 and ES-10 (Figure 1), which were completed in the shallow Zone-A sands upgradient and adjacent to the SPL pile. The tests were conducted at a rate of 12 gpm and determined hydraulic conductivities of 240 to 374 ft/day for ES-10, and 548 to 642 ft/day for ES-9.

Hart Crowser evaluated a groundwater capture scenario as a remedial alternative that entailed three wells located along the plume centerline at 500 foot intervals pumping a combined total of 200 gpm. No specifics are provided in the 1988 report regarding the assumptions used in the capture analysis.

Groundwater capture rates were also assessed in a subsequent feasibility analyses conducted by ReTec (1993 and 1996). Using an assumed hydraulic conductivity of 374 ft/day based on Hart Crower’s pumping test results for ES-10, ReTec estimated two to three wells with a combined pumping rate of 200 to 300 gpm would be sufficient to capture the cyanide plume in the Zone A aquifer immediately downgradient of the SPL pile (Figure 1).



ReTec, 1993. 3 Wells pumping at a combined rate of 250 gpm



ReTec, 1996. Revised analysis with 6 wells pumping at a combined rate of 625 gpm

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RETEC GROUNDWATER
CAPTURE ANALYSES

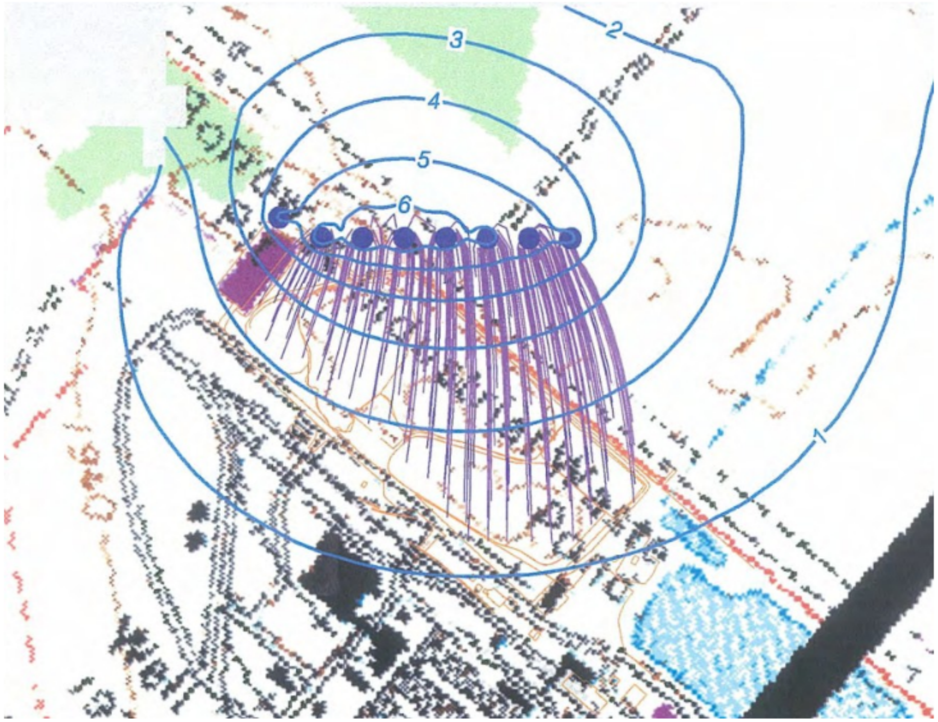
FIGURE
1

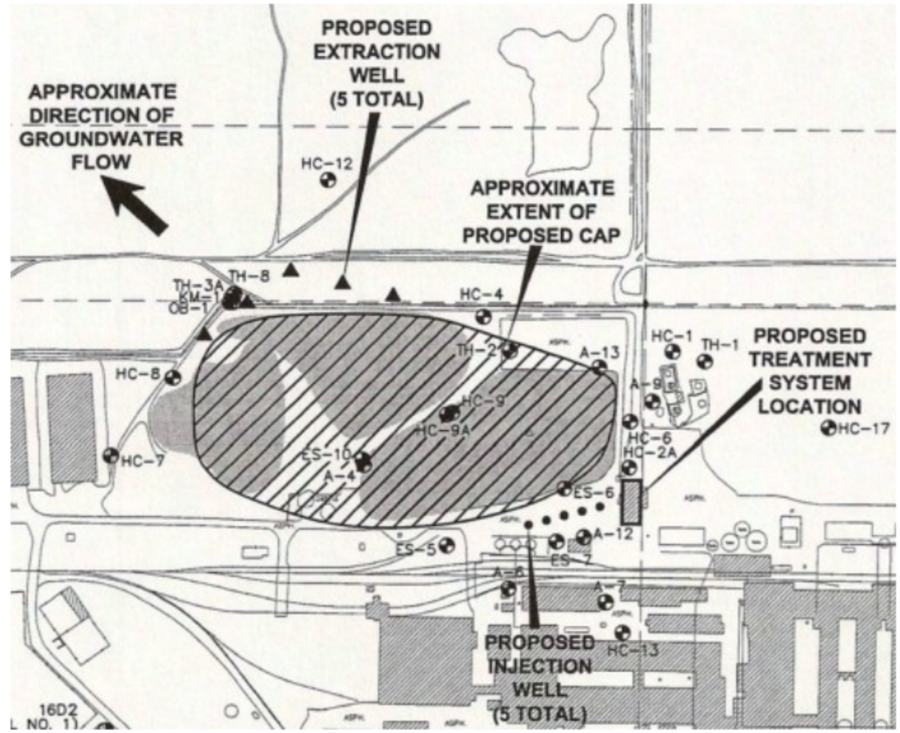
k:/project/9088/Capture/Fig 1 ReTec Analysis.srf

In 1996 ReTec produced a revised analysis with an expanded capture area where fluoride concentrations exceeded 4 mg/L. ReTec concluded that this would require 5 to 6 pumping wells with a combined extraction rate of 550 to 650 gal/min (Figure 1).

In 2000, MFG conducted additional aquifer tests in the Zone A aquifer and used a numerical model to further evaluate groundwater capture scenarios and provide specific recommendations for a pump and treat clean-up alternative. MFG installed a 4-inch test well (KM-1) which was used as a pumping well and monitored drawdown effects at nearby monitoring wells TH-8 and TH-3A. KM-1 was pumped at a rate of 20.5 gpm over a 24 hour period which produced approximately 0.5 feet of drawdown in the pumping well and approximately 0.1 feet of drawdown in the observations wells that was attributable to the pumping effects (MFG, 2000). Hydraulic conductivity values of 241 to 897 feet per day were estimated from the pumping test data with the lower range estimates (241-278 ft/day) from the pumping well and higher range values (530 to 897 ft/day) from the monitoring wells. MFG used a hydraulic conductivity value of 500 ft/day to represent the Zone A sand in their subsequent modeling analysis and a value of 750 ft/day to represent the Zone B sand.

MFG (2001) evaluated targeted capture scenarios with pumping rates of 25, 50 and 100 gpm. They ultimately recommended a pump and treat scenario that utilized five capture wells pumping 5 gpm each with a combined extraction rate of 25 gpm operating over a two year period (MFG, 2001). This capture alternative would only be used if necessary to augment source control measures by removing "an appreciable mass of cyanide and fluoride, while minimizing the extraction of more dilute groundwater that may be pulled into the area under higher extraction rates." It should be noted that pumping at 5 gpm would only produce approximately 0.12 feet of drawdown in a pumping well at MFG's assumed hydraulic conductivity of 500 feet per day; therefore MFG's 25 gpm targeted capture alternative was not intended to provide hydraulic control, but rather was proposed to facilitate load reductions in the shallow groundwater system in conjunction with source control measures. MFG concluded from their modeling analyses that to provide complete capture of the plume within the Zone A sand would require eight capture wells pumping a total of 336 gpm (Figure 2).





MFG, 2000. Eight wells pumping at a combined rate of 325 gpm for full capture

MFG, 2001. Recommended Capture System Five wells pumping at a combined rate of 25 gpm. (objective is load reduction rather than complete capture)

KAISER MEAD AQUIFER CHARACTERIZATION AND GROUNDWATER CAPTURE ANALYSIS	MFG GROUNDWATER CAPTURE ANALYSES	FIGURE 2

k:/project/9088/Capture/Fig 2 MFG Capture Analysis.srf

1.2 DATA LIMITATIONS

These groundwater capture analyses are based on very minimal aquifer testing at pumping rates much lower than the extraction rates that would be necessary for plume capture. The existing tests effectively under-stress the aquifer and under these circumstances small heterogeneities in the aquifer can limit observed drawdown effects in outlying wells and thereby yield overestimates of the aquifer hydraulic conductivity. This is a concern for some of the existing analyses which show much higher hydraulic conductivity estimates based on monitoring well data than the pumping well data. In addition, the predicted hydraulic conductivities in some cases are much higher than expected based on the grain size distribution of the aquifer materials measured at the same location. Observed drawdown results, nevertheless may be representative of what might be achieved by a capture well if the pumping rates in the tests are similar to proposed extraction rates. However, based on the permeability estimates, extraction rates would need to be significantly greater than the test rates of 10 to 20 gpm to achieve significant plume capture.

Hydrometrics conducted slug tests on a number of existing wells in April 2011 to further assess representative hydraulic conductivity values at Zone A, Zone B and Zone C wells (Hydrometrics, 2010). The tests yielded hydraulic conductivity estimates ranging from 0.5 to 294 feet per day with a median value of 202 ft/day (Table 1).

TABLE 1. SUMMARY OF APRIL 2011 SLUG TEST RESULTS

A Zone Wells	**Hydraulic Conductivity (ft/d)**
KM-2	202
ES-10	294
HC-2A	182
HC-12	0.5
B zone wells	
KMCP-1	285
OB-1	266
C zone wells	
TH-6	128

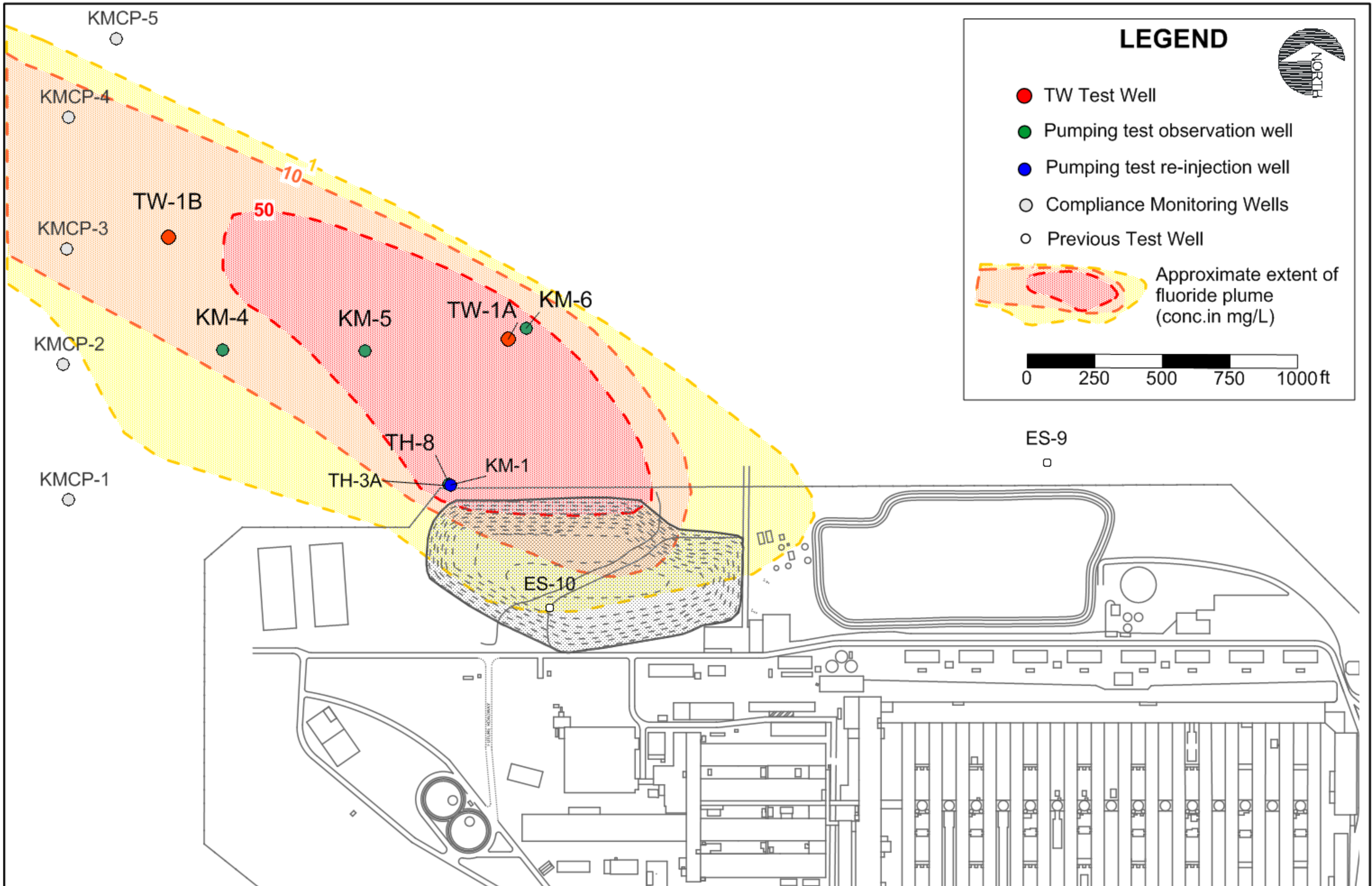
These results are similar to low range estimates determined in some of the previous testing and are significantly lower than hydraulic conductivity values used in the MFG capture analyses. Additional testing and evaluation of potential capture well extraction rates was undertaken in the current investigation to confirm appropriate parameter ranges and capture rates as they may apply to the evaluation of remediation options.

1.3 CURRENT INVESTIGATION - SCOPE AND METHODOLOGY

Two 6 inch diameter test wells (TW-1A and TW-1B) were drilled and installed at the site for aquifer testing. The TW-1A test well was sited downgradient of the SPL pile in an area with high cyanide and fluoride concentrations. The TW-1B well was located upgradient of the compliance wells where groundwater flow from the shallow Zone A sands appears to drop down into the deeper Zone B aquifer (Figure 3).

The wells were drilled from January 9, 2013 through January 13, 2013 by H2O Well Service out of Hayden Lake, Idaho using conventional air rotary drilling rigs. Split spoon samples were collected in the saturated zone at 5 foot intervals at each well site. Soils were logged and sieve analyses were conducted on representative samples from the screened interval of each well to properly size well screens. Wells were completed with manufactured stainless steel wire-wrap screens and developed with air.

Aquifer pumping tests were performed on the completed wells. A short step test was conducted at each well followed by a constant rate pumping test. Discharge water from the TW-1A test was reinjected into the Zone A aquifer at KM-1, MFG's 4-inch test well. Discharge water from the TW-1B test was reinjected into TW-1A. Drawdown during the pumping tests were monitored both manually and using transducer/dataloggers. Field parameters (temperature, pH and SC) were monitored at hourly intervals throughout the test and water quality samples were collected at the completion of the constant rate pumping test and submitted to SVL Analytical in Kellogg, Idaho for analysis of total cyanide, WAD cyanide and fluoride.



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SITE MAP

FIGURE 3

k:/project/9088/Capture/Fig 3 Site Map.srf

The aquifer test results were evaluated using standard analytical curve matching techniques, and capture well analysis were performed using a Theis analytical drawdown solution in AQTESOLVE for a series of pumping wells in an unconfined aquifer. The capture radius was derived by superimposing the resultant drawdown field on the ambient flow field and contouring the resultant potentiometric surface and defining flow vectors in Golden Software's Surfer (ver. 11). Capture well scenarios were evaluated at varying pumping rates to assess varying extraction rates and capture effects.

2.0 FIELD INVESTIGATION RESULTS

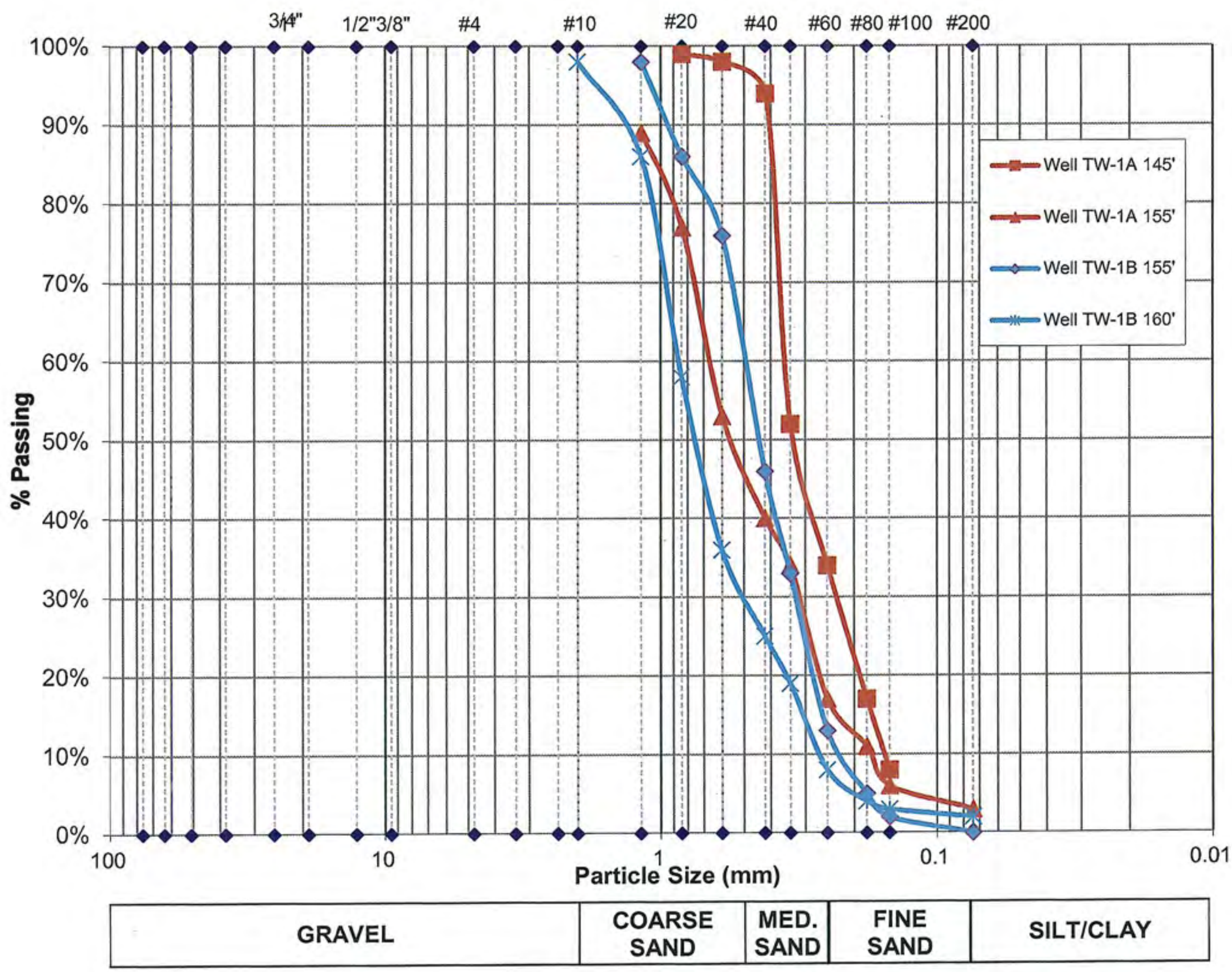
2.1 WELL INSTALLATION

Well TW-1A was drilled from January 10-17, 2013. The saturated Zone A sands should have been encountered at a depth of approximately 139 at TW-1A, however, groundwater inflow to the borehole at the time of drilling was first noted at 150 feet bgs at 1 gpm. The 4 foot clay layer that defines the base of Zone A at KM-5 and KM-6 was anticipated to be present at TW-1A at a depth of approximately 150, but was not observed during drilling. Split spoon samples at 150 and 155 feet showed loose medium grained sand and there was no evidence of clay in the rotary cuttings. The well was completed at a total depth of 162 feet without encountering a clay layer. A stainless steel screen was set from 151 to 161 feet bgs. After the well was completed, the driller developed it by surging it with air for approximately 2 hours. A well log for TW-1A is included in Appendix A.

The static water level in TW-1A was 147 bgs at the time of completion which is similar to elevations in the Zone B sand interval. Zone A water levels are approximately 10 feet higher in elevation (139-140 ft bgs). The absence of groundwater inflow in the Zone A interval during drilling could be due to a lower permeability of the Zone A sands at this location. The estimated hydraulic conductivity of the Zone A sands at nearby well HC-12 was only 1 foot/day based on slug testing results (Hydrometrics, 2012).

Sieve analyses were conducted on soil samples collected at 145 and 155 feet. Grain size distributions for each of the samples are shown in Figure 4 and display medium to fine sands at 145 feet and coarse to medium sand at 155 feet.

A water quality sample was collected from the completed well on January 17, 2013 for analysis of total cyanide, WAD cyanide and fluoride concentrations. The results from this water quality sample are similar to water quality at Zone A monitoring wells KM-5 and KM-6 (Table 2). In contrast the absence of a distinct clay layer at the base of the Zone A interval and the lower water levels in the completed well suggest that the well screen is not isolated to the Zone A groundwater system.



KAISER MEAD AQUIFER CHARACTERIZATION AND GROUNDWATER CAPTURE ANALYSIS	GRAIN SIZE ANALYSIS FOR TW-1A AND TW-1B SOIL SAMPLES	FIGURE 4

K:\project\9088\Capture\Fig 4 Grainsize graph.xls Fig 4 Grainsize graph.xls

TABLE 2. COMPARISON OF TW-1A WATER QUALITY WITH NEARBY ZONE A WELLS

Well ID	Sample Date	pH (Std Units)	Total CN (mg/L)	WAD CN (mg/L)	F (mg/L)
TW-1A	1/17/2013	9.71	134	0.189	68
KM-5	11/6/2012	9.24	54	0.925	56
KM-6	11/5/2012	9.2	129	0.287	75

Well TW-1B was drilled from January 9-13, 2013. The well was drilled to a depth of 165 feet bgs. Silty clay was encountered from 163 to 165 feet bgs and represents the base of the Zone B interval. The well was completed with a stainless-steel wire-wrap screen from 153 to 163 feet bgs. The well was developed for approximately 2 hours by surging the well with air. A well log for TW-1B is included in Appendix A.

Well TW-1B is completed at a depth similar to downgradient Zone B wells and like other wells in the area, it does not have a Zone A clay layer evident. Sieve tests were conducted on split spoon samples collected at 155 and 160 feet bgs. Sieve analysis shows the aquifer material at 155 feet is a medium to coarse sand and at 165 ft is coarse to medium sand. No water quality sample was collected at well completion, but both TW-1A and TW-1B were sampled during aquifer testing.

2.2 TW-1A PUMPING TEST

The TW-1A pumping test was conducted on February 19, 2012. Water levels were monitored during the test at nearby well KM-6, and in wells KM-5, TH-8 and KM-2. Table 3 provides a summary of well completion information and the distance of observation wells from the pumping and reinjection wells.

TABLE 3. AQUIFER TEST WELL CONFIGURATION SUMMARY

Test	TW-1A				TW-1B
Well:	TW-1A	TH-8	KM-5	KM-6	TW-1B
Well Type:	Pumping	Obs Well	Obs Well	Obs Well	Pumping
Distance from Pumping Well (ft)	0	580	530	80	0
Distance from reinjection well KM-1 (ft)	580	7	590	640	1390
Casing Elevation (ft MSL)	1920.62	1926.19	1927.63	1922.99	1919.04
PreTest W. L. Depth (ft below TOC)	150.39	142.89	144.56	138.62	150.28
Static WL Elevation (ft MSL)	1770.23	1783.30	1783.07	1784.37	1768.76
Screen Interval Elevation (ft MSL)	1769-1759	1772-1767	1787-1777	1778-1767	1756-1766'

The pumping well was instrumented with a digital paddle wheel flow meter and datalogger that was set to record discharge measurements at 4 minute intervals throughout the duration of the test. Water levels were monitored in the pumping well both manually and with an InSitu Level Troll 700 vented transducer/datalogger. Water levels were monitored during the test at nearby well KM-6, and in wells KM-5, TH-8 and KM-2 using Solinst Levellogger II unvented transducer/dataloggers. Barometric fluctuations during the test were recorded with a separate barologger and used to correct drawdown readings for barometric influence.

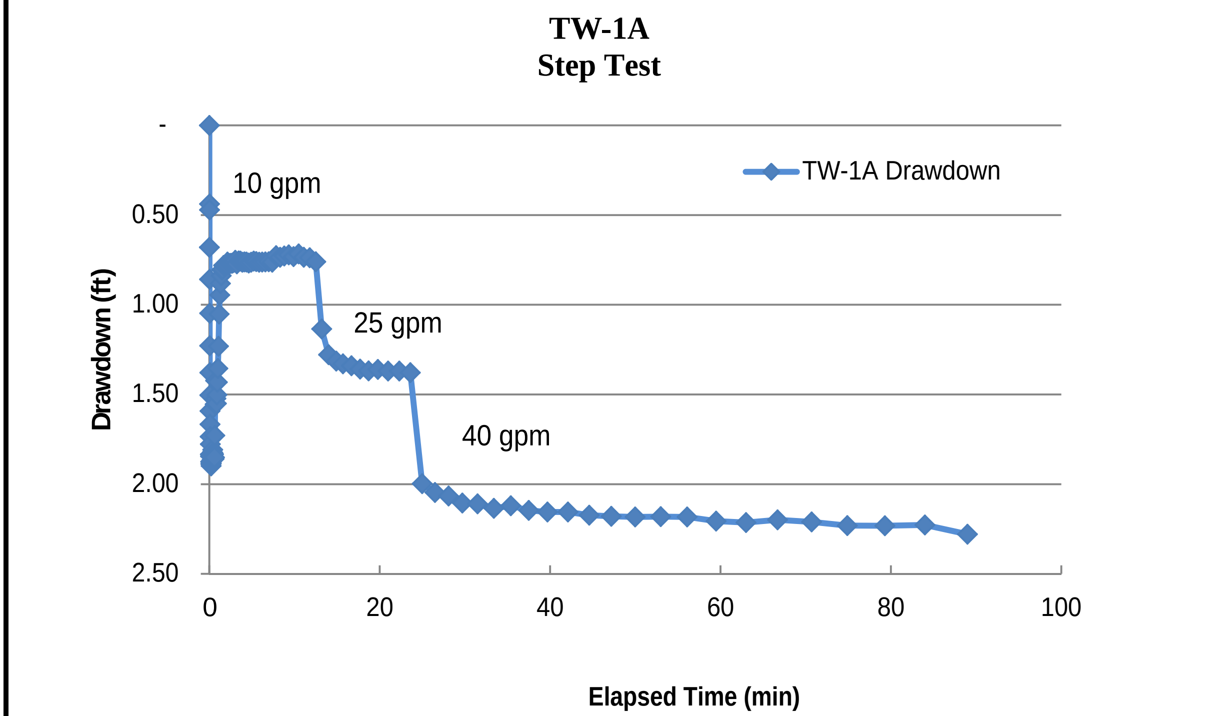
Prior to conducting the constant rate pumping test a short step test was conducted at TW-1A at pumping rates of 10 gpm, 25 gpm and 40 gpm (the maximum capacity of the pump) to assess the drawdown response of the well at varying pumping rates and verify that the well was capable of sustained pumping at the proposed pumping rate. The step drawdown test produced a maximum drawdown of 2.2 feet (a graph of the results is included in Appendix B). The step test results indicated that the well was capable of sustained pumping at the maximum step test pumping rate of 40 gpm therefore the test was allowed to proceed as a constant rate pumping test.

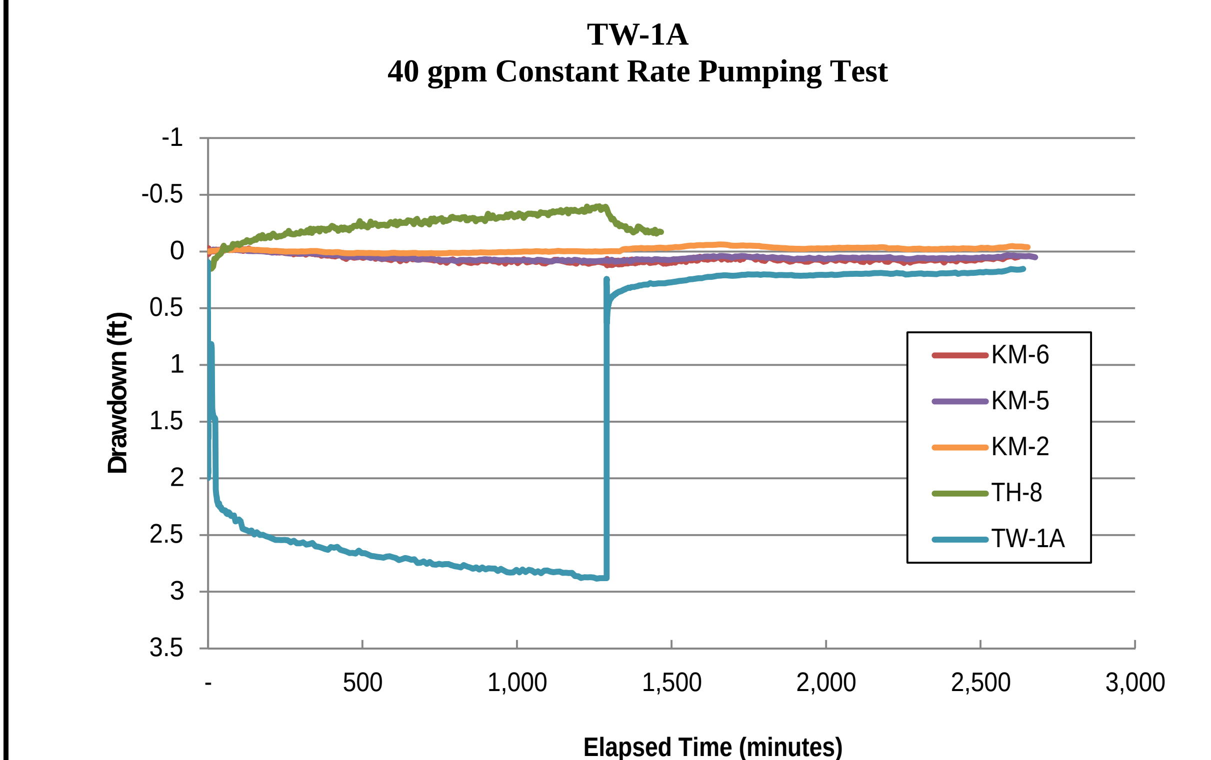
The constant rate pumping test at TW-1A was 21 hours in length. The test results are summarized in Table 4 and a drawdown graph is shown in Figure 5. Electronic data files with discharge readings, water measurements and barometric readings for the test are included on an attached CD at the back of this report. Slightly less than 3 feet of total drawdown was observed in the pumping well over the course of the test. Slightly over a tenth of a foot of drawdown was measured at monitoring well KM-6 approximately 70 feet away from the pumping well and a similar water level trend was exhibited at KM-5 over 500 feet from the pumping well. No measureable drawdown was observed at KM-2. The water level recovery response at TW-1A after the pumping test was completed was influenced in the first minute by a leaking check valve. Closing the gate valve at the well head eliminated the backflow, but the water levels had already recovered significantly affecting the recovery response.

TABLE 4. SUMMARY OF TW-1A AQUIFER TEST RESULTS

Test	Test Start Time	Test Stop Time	Initial Response Time	Max Drawdown Time	Max Drawdown (ft)
TW-1A	2/19/13 12:00	2/20/13 9:08	2/19/13 12:01	2/20/13 9:08	2.88
KM-6	--	--	2/19/13 15:20	2/20/13 9:32	0.14
KM-5	--	--	2/19/13 12:06	2/20/13 1:16	0.11
TH-8	--	--	2/19/13 12:01	2/19/13 11:01	-2.48
KM-2	--	--	--	--	0
TW-1B	2/21/2013 11:30	2/21/2013 19:45	2/21/2013 11:33	2/21/2013 19:38	1.00

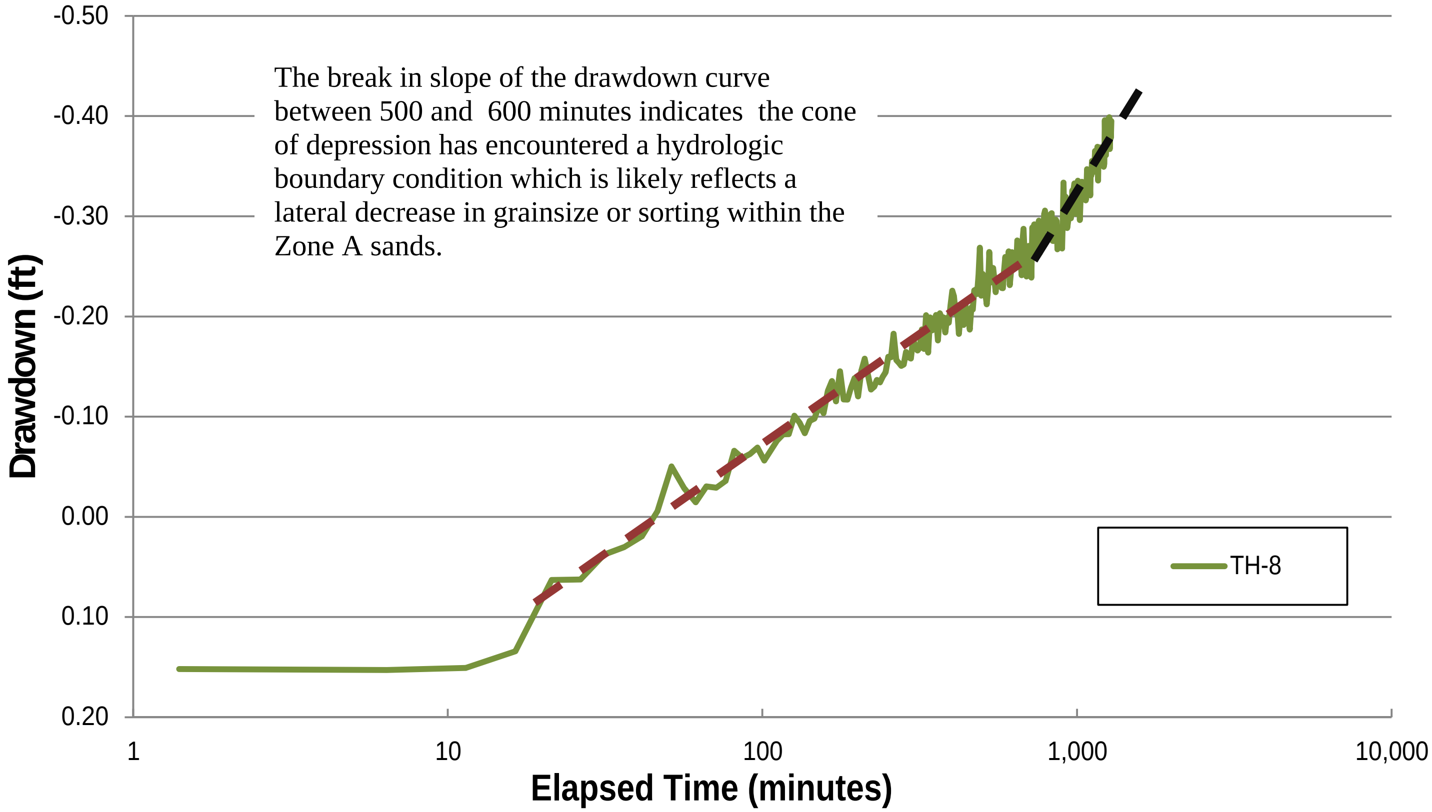
Water levels at TH-8 increased 0.5 feet over the course of the test. The increase in water levels in this well reflects mounding due to reinjection of test water at nearby well KM-1 (less than 10 feet from TH-8). The rate of water level change at TH-8 increased in the later stages of the test which is indicative of a hydrologic boundary condition (Figure 6). This response is similar to MFG’s testing results at this location and likely indicates there are lateral limits to the higher permeability sands that the well is completed in.





AQUIFER CHARACTERIZATON AND CAPTURE ANALYSIS	DRAWDOWN RESULTS FOR TW-1A PUMPING TEST	FIGURE 5

K:\project\9088 Kaiser\pumping tests\TW-A Test\TW-A.xlsx Graph 2



Note: negative results indicate mounding due to proximity of TH-8 to injection well KM-1

AQUIFER CHARACTERIZATON AND CAPTURE ANALYSIS	DRAWDOWN RESULTS FOR TH-8	FIGURE 6

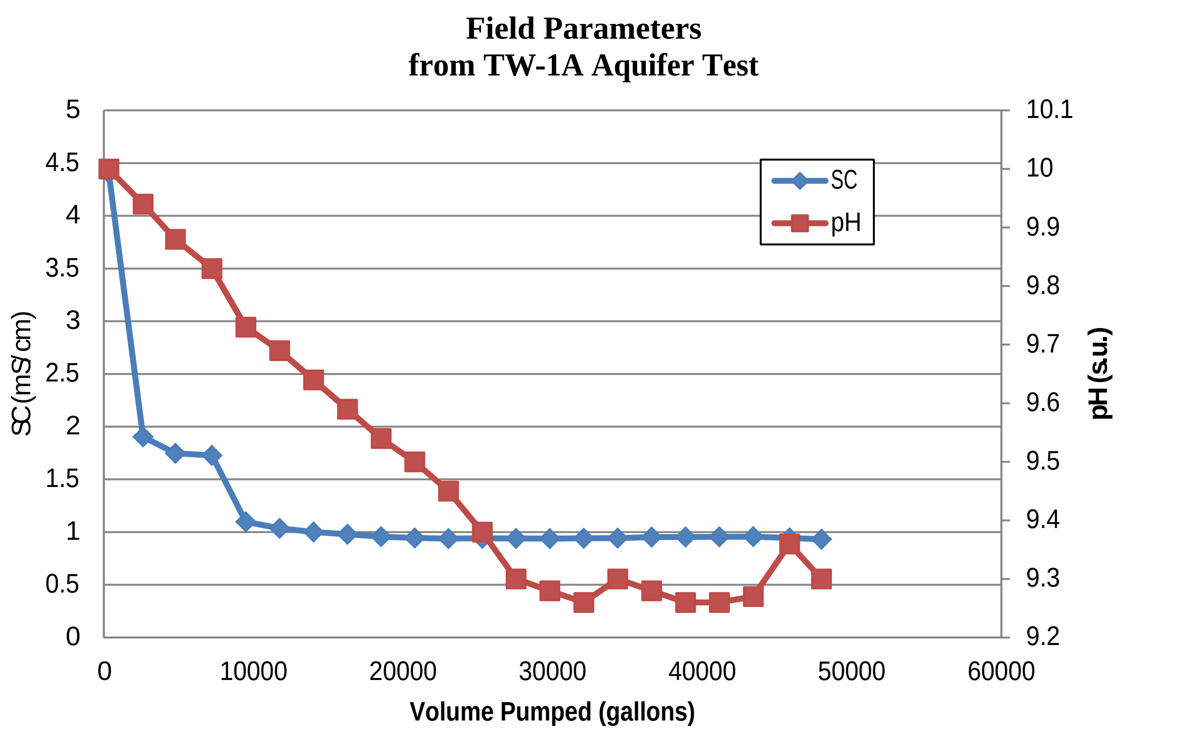
K:\project\9088 Kaiser\pumping tests\TW-A Test\TW-A.xlsx Graph 2

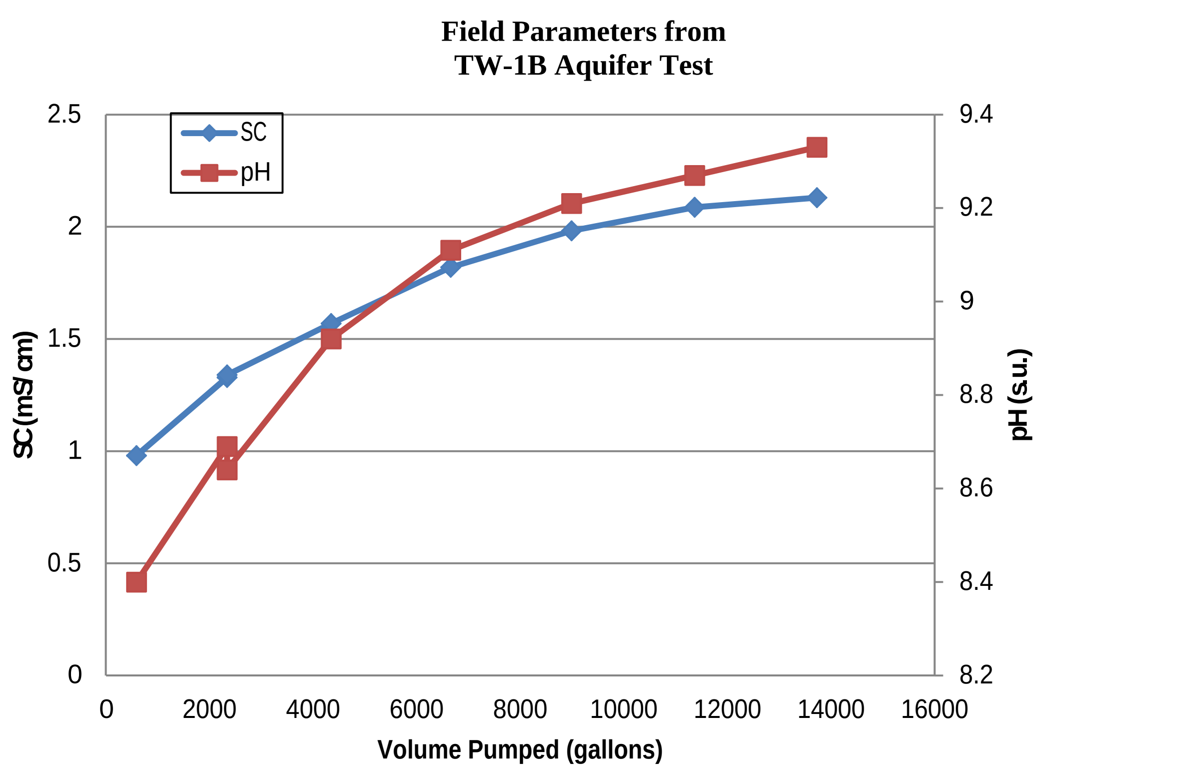
Water quality parameters (temperature SC, pH and Eh) in discharge water were monitored hourly throughout the pumping test. The water quality results show a rapid drop in specific conductance along with a progressive drop in pH throughout the test (Figure 7). SC at the start of the test was 4400 umhos/cm and gradually dropped to 930 umhos/cm by the end of the test. The pH showed a similar trend with a starting pH of 10.0 which gradually decreased to 9.3 by the conclusion of the test. A water quality sample was collected at the conclusion of the test and analyzed for total cyanide, WAD cyanide and fluoride. Results are compared to pretest sampling results in Table 5 and with the exception of WAD cyanide show significantly lower parameter concentrations when pumping the well.

The water quality results suggest mixing of Zone A and Zone B water quality in the well during the test. The well under static conditions would receive groundwater preferentially from the shallower strata since there is a downward gradient between the Zone A and Zone B groundwater systems that would cause water to flow into the well from the shallower groundwater system under static conditions. When the well is pumped however, it would receive groundwater inflow from the entire saturated interval and preferentially from higher permeability strata. The induced mixing in the well would result in lower concentrations. The variation in WAD cyanide concentrations is extremely difficult to evaluate due to the fact that WAD cyanide concentrations have a complicated non-linear response to relatively small changes in pH, which cannot be readily resolved without much more detailed geochemical profiling.

TABLE 5. COMPARISON OF PRE- AND POST-TEST WATER QUALITY AT TW-1A

Descriptive Name Well ID	Date Sampled	pH (Std Units)	SC (umhos/cm)	Total CN (mg/L)	WAD CN (mg/L)	F (mg/L)
TW-1A	1/17/2013	9.71	>2999	134	0.189	68.1
TW-1A	2/20/2013	9.36	945	14.3	0.34	6.69





AQUIFER CHARACTERIZATON AND CAPTURE ANALYSIS	SC AND pH TRENDS DURING TW-1A AND TW-1B AQUIFER TESTS	FIGURE 7

K:\project\9088 Kaiser\pumping tests\Field Parameters\Field Parameters.xlsx

Water level data from the TW-1A pumping test were analyzed in AQTESOLVE (ver. 4.2) using standard Theis (1935), Cooper and Jacob (1946), and Neuman (1974) unconfined aquifer analytical solutions.

These methods assume that:

- The aquifer has infinite areal extent;
- The aquifer is homogeneous and has uniform thickness;
- The aquifer potentiometric surface is initially horizontal;
- The pumping well is fully or partially penetrating;
- The aquifer is unconfined with delayed gravity response;
- Flow is unsteady; and
- The diameter of pumping well is very small so that storage in the well can be neglected.

Curve matching solutions are shown in Appendix B and estimated hydraulic conductivity values are summarized in Table 6. Hydraulic conductivity estimates for TW-1A range from 278-321 ft/day and are characteristic of a fairly well sorted coarse sand aquifer. Results from KM-6 are considerably higher at 750 ft/day, but are not definitive since the water levels in the pumping well suggest it is not screened exclusively in the TW-1A aquifer. The KM-5 and KM-6 water level response is therefore not an accurate basis for assessing hydraulic conductivity estimates for the Zone A aquifer since water may have been derived from both Zone A and Zone B intervals. Drawdown results at the TW-1A pumping well provide a general estimate of the hydraulic conductivity for the medium to coarse sands encountered at that location, but do not represent drawdown effects from removal of 40 gpm from the Zone A aquifer. The permeability of the Zone A sands may be lower at TW-1A than indicated by TW-1A drawdown results based on the absence of groundwater inflow from the Zone A system at the time of drilling.

TABLE 6. HYDRAULIC CONDUCTIVITY ESTIMATES FROM TW-1A PUMPING TEST

Observation Well	Sat. Thickness (ft)	Hydraulic Conductivity (ft/d)		
		Theis	Cooper Jacob	Neuman
TW-1A Step Test	12	278		
TW-1A	12	321	302	206
TH-8	12	452	NA	NA
KM-6	12	750	NA	NA

2.3 TW-1B PUMPING TEST

The TW-1B pumping test was conducted on February 21, 2012. A short step test was conducted at pumping rates of 10 gpm, 26 gpm and 40 gpm (the maximum capacity of the pump). The maximum pumping rate of 40 gpm produced slightly over 0.9 feet of drawdown. Water levels were fully recovered within 20 minutes of the completion of the step test. A constant rate pumping test was then started at a discharge rate of 39 gpm. Flow rates were monitored and recorded over the duration of the test at 4 minute intervals with a digital paddlewheel flow meter and data logger. Water levels were monitored in the pumping well both manually and with an InSitu Level Troll 700 vented transducer/data logger. Water levels were monitored during the test at KM-6, KM-5, and KM-4 using Solinst Levellogger II unvented transducer/data loggers.

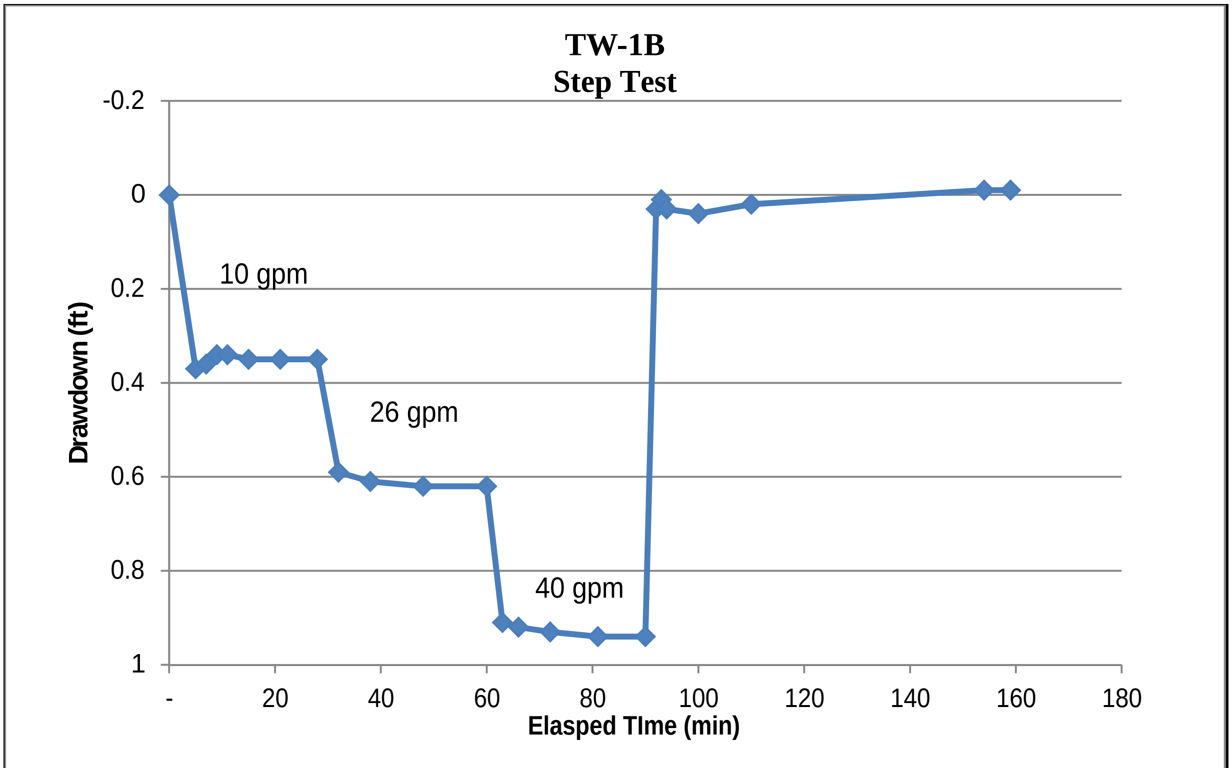
Barometric fluctuations during the test were recorded with a separate barologger and used to correct drawdown readings for barometric influence. These monitoring wells are all Zone A wells and monitored the response of re-injection at TW-1A. An attempt was also made to monitor drawdown at the Zone B compliance well KMCP-3B during the TW-1B pumping test; however, monitoring instrumentation could not be installed in well due to downhole obstructions in the well casing. The TW-1B test, therefore, was a single well test. It was used to establish information on aquifer hydraulic conductivity in the Zone B groundwater system at this location. It does not, however, allow calculations of aquifer storage coefficients or show the degree of variability in hydraulic conductivity conditions in the surrounding area.

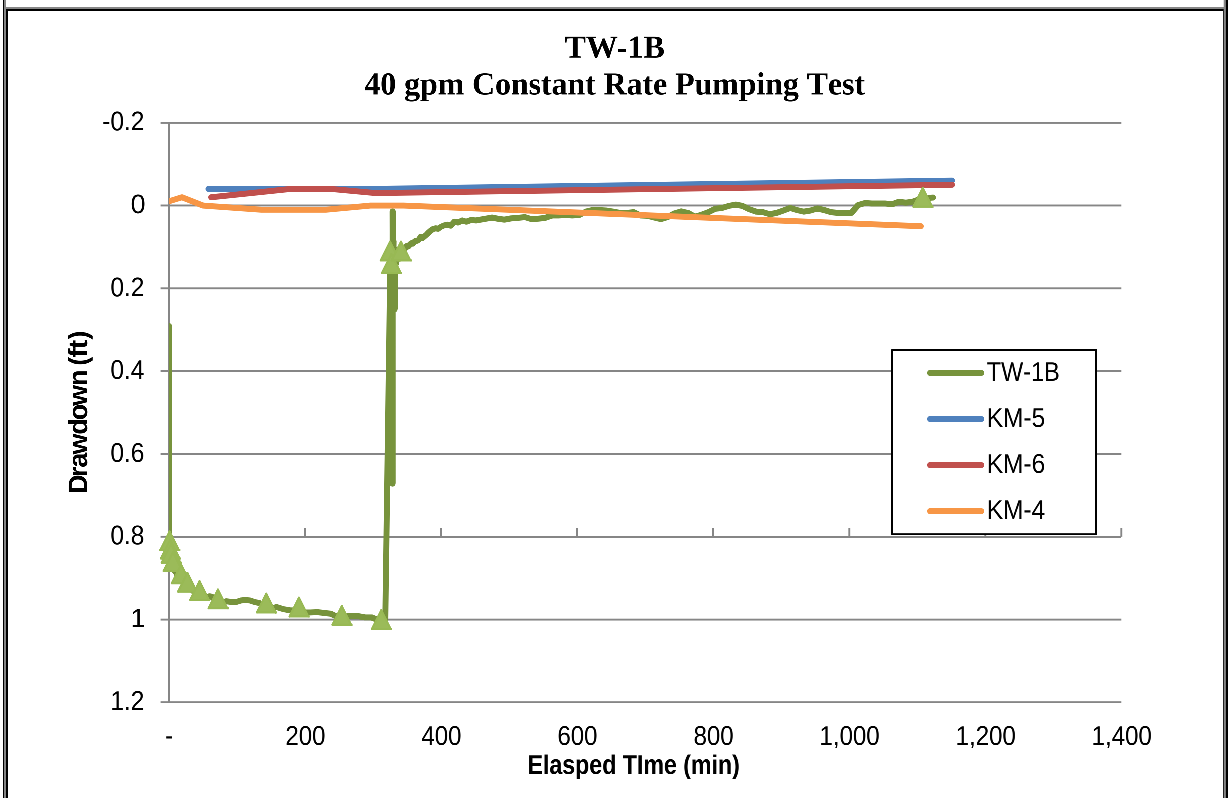
The constant rate pumping test at TW-1B was 4 hours and 38 minutes in length and resulted in 1 foot of total drawdown in the pumping well. There was no observable drawdown in any of the monitoring wells during this test. KM-5 and KM-6 showed slight increases of several hundredths of a foot, however, there was no clear correlation with pumping/reinjection time periods. Water level trends in the pumping well and observation wells are shown in Figure 8.

Water quality parameters (temperature SC, pH and Eh) in the discharge from TW-1B were monitored hourly throughout the pumping test. The water quality results (tabulated in Appendix B) show a gradual increase in SC and pH through the test (Figure 7). SC at the start of the test was 1000 umhos/cm to 2100 umhos/cm by the end of the test. The pH showed a similar trend with a starting pH of 8.40 which gradually increased to 9.3 by the conclusion of the test. A water quality sample was collected at the conclusion of the test and analyzed for total cyanide, WAD cyanide and fluoride. Water quality results for TW-1B are similar in quality to nearby Zone B compliance (Table 7). The increase in field parameters is an indication that well is drawing water preferentially from portions of the aquifer with higher contaminant concentrations; however, it is not possible to speculate how cyanide complexes and other constituents relate to these changes in field parameters based on the limited amount of information available.

TABLE 7. COMPARISON OF TW-1B WATER QUALITY WITH NEARBY ZONE B WELLS

Well ID	Date Sampled	pH (Std Units)	Conductivity (umhos/cm)	Total CN (mg/L)	WAD CN (mg/L)	F (mg/L)
TW-1B	2/21/2013	9.35	2139	36.7	0.703	16.9
KMCP-3B	2/20/2013	9.4	3257	56.8	0.542	29.4
KMCP-4B	2/20/2013	8.31	1670	13.9	0.54	16.3





AQUIFER CHARACTERIZATON AND CAPTURE ANALYSIS	DRAWDOWN RESULTS FOR TW-1B PUMPING TEST	FIGURE 8

K:\project\9088 Kaiser\pumping tests\TW-B Test\ TW-B.xlsx

Water level data from the TW-1B pumping test was analyzed in AQTESOLVE using unsaturated zone analytical solutions. Curve matching solutions are shown in Appendix B and estimated hydraulic conductivity values are summarized in Table 8.

TABLE 8. HYDRAULIC CONDUCTIVITY ESTIMATES FROM TW-1B PUMPING TEST

Observation Well	Sat. Thickness (ft)	Hydraulic Conductivity (ft/d)		
		Theis	Cooper Jacob	Neuman
TW-1B	12	641	NA	437

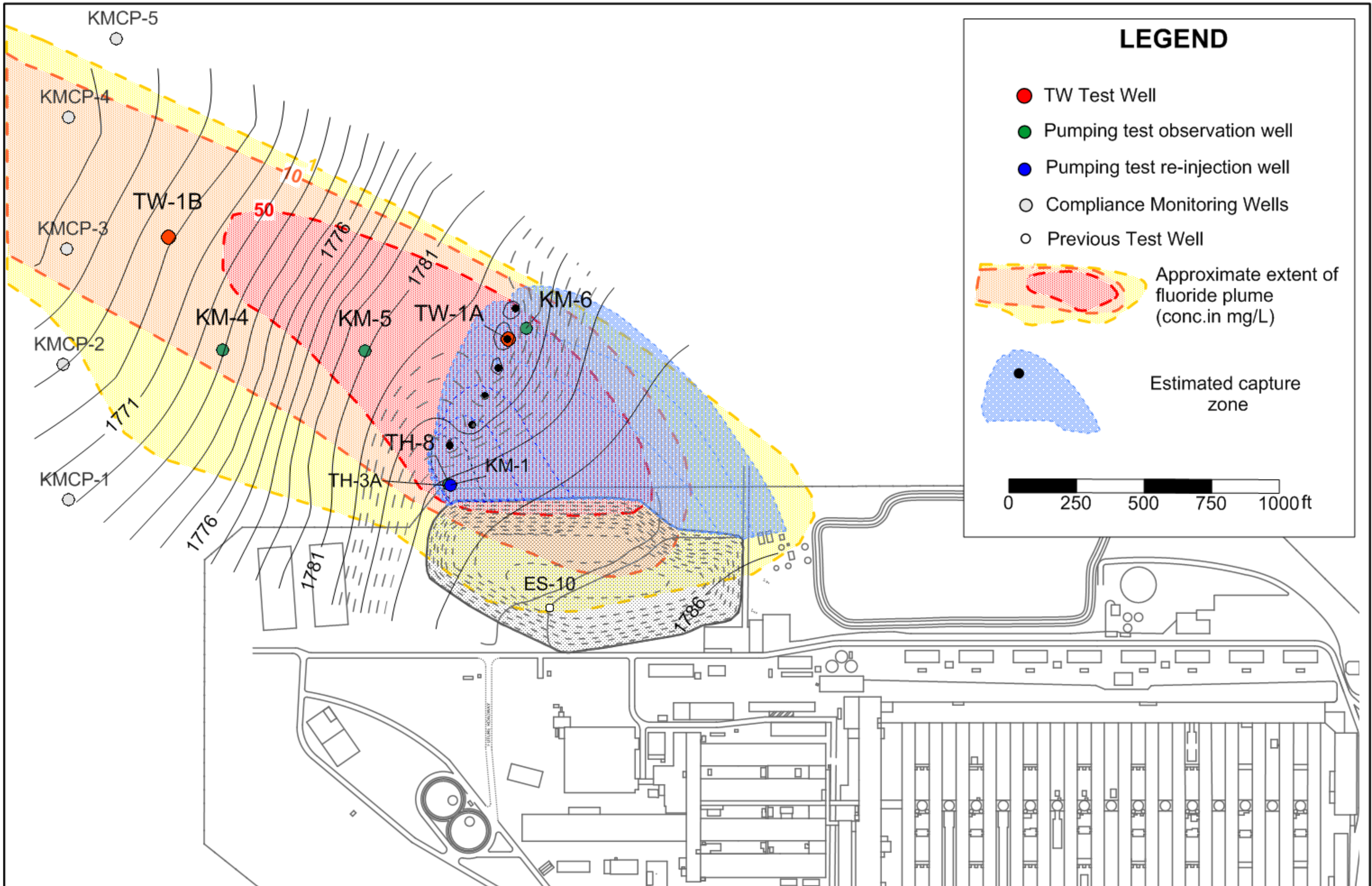
The higher hydraulic conductivity range of this well compared to TW-1A is consistent with the coarser grain sizes found in the saturated zone at this site, but appear to be on the high end of values expected for a mixture of medium to coarse sands. As previously noted, this is a single well test and the results are representative of localized conditions in the vicinity of the test well. It is uncertain how representative they may be of the aquifer properties in surrounding areas. For the purpose of this analysis the results are assumed to be representative of the B-Zone aquifer upgradient of the compliance wells. If a remedial design alternative is developed that includes groundwater capture wells in this area, more detailed testing would be warranted as part of the design analysis.

3.0 GROUNDWATER CAPTURE ANALYSIS

A capture analysis was conducted to reexamine the flow rates necessary to establish hydraulic control of the cyanide and fluoride plume within Zone A sands in proximity to the SPL pile and in Zone B sands upgradient of the compliance point. Groundwater capture could be part of a conventional pump and treat remediation scenario or used in conjunction with passive or insitu treatment alternatives. This analysis is not intended to focus the selection of remedial alternatives on a specific remediation scenario. The preferred remediation alternative developed by MFG entailed targeted capture using five wells with a combined extraction rate of 25 gpm to be used in conjunction with source controls if necessary to achieve water quality compliance. Targeted capture, however, is most effective when site characterization has identified preferential flow paths in high concentrations plume areas that can be captured to significantly reduce contaminant loads in the groundwater system. Current site characterization activities in the vicinity of the SPL containment area may provide the basis for a more refined evaluation of targeted capture. This analysis simply reexamines requirements to establish full hydraulic control of the plume as an upper estimate of the potential groundwater extraction rates that could be required in a groundwater capture scenario.

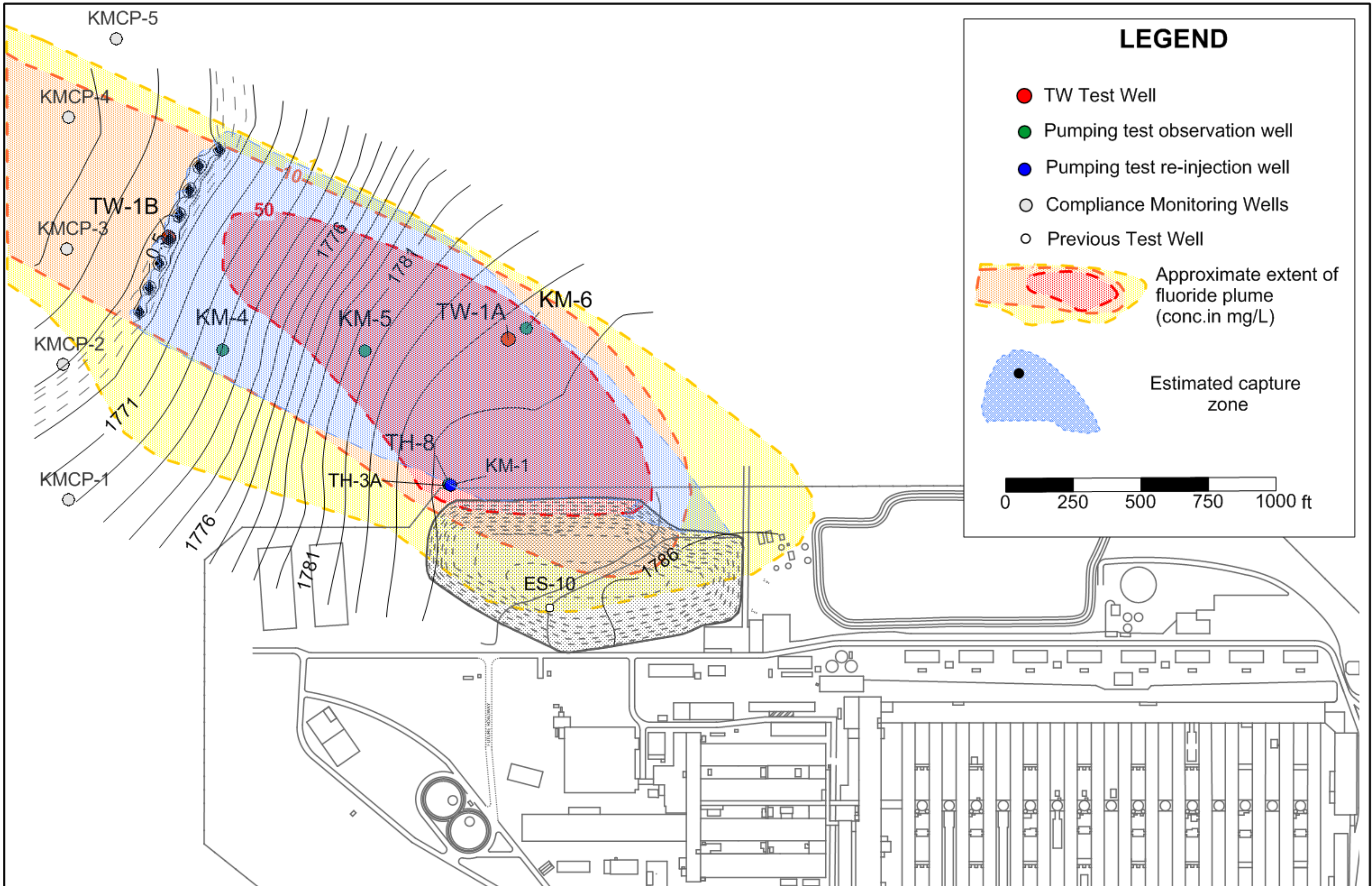
Drawdown for a series of capture wells was calculated in AQTESOLVE for Zone A and Zone B groundwater systems based on hydraulic conductivity results from the pumping tests and the Theis (1935) analytical solution for drawdown in an unconfined aquifer. The resultant drawdown was superimposed on the regional potentiometric surface using Surfer contouring software to define the approximate capture radius for each well. The pumping rates and number of wells were adjusted to provide capture across the width of the high concentration cyanide and fluoride plumes.

Representative capture scenarios are shown for Zone A and Zone B locations in Figures 9 and 10. Zone A capture required extraction rates of 180 to 250 gpm utilizing 5 to 6 capture wells with an assumed hydraulic conductivity of the Zone A aquifer of 300 feet per day. Zone B plume capture required 6 to 8 wells with a combined extraction rate of 400 to 500



KAISER MEAD AQUIFER CHARACTERIZATION AND GROUNDWATER CAPTURE ANALYSIS	ZONE A GW CAPTURE WITH 6 WELLS PUMPING A TOTAL OF 180 GPM	FIGURE 9

k:/project/9088/Capture/Fig 9 Zone A Capture.srf



KAISER MEAD
AQUIFER CHARACTERIZATION AND
GROUNDWATER CAPTURE ANALYSIS

ZONE B GW CAPTURE WITH
8 WELLS PUMPING
A TOTAL OF 500 GPM

FIGURE 10

k:/project/9088/Capture/Fig 10 TW-B Capture.srf gpm with an assumed hydraulic conductivity at the Zone B capture wells of 500 feet per day. The greater extraction rate in the Zone B aquifer reflects both higher permeability and greater saturated thickness of the Zone B sands. The assumed hydraulic conductivity for the Zone A sands is generally consistent with slug tests and pumping well results from previous Zone A tests and therefore may be reasonably representative of what would be encountered in other portions of the aquifer in this area. The decrease in fluoride and total cyanide concentration in TW-1A as it was pumped suggests vertical stratification of water quality within the screened interval of the well. If capture wells are proposed for this area, the screened interval should be decreased and should more concisely target contaminant zones. This would require more detailed characterization. The limited saturated thickness of the Zone A sands in this area could potentially make it difficult to maintain capture wells on a long term basis, particularly if the contaminant zone is within a discrete stratigraphic interval. Further stratigraphic sampling and characterization at potential capture well locations should be considered prior to design of a capture well system.

The data for Zone B are limited and therefore it is not known whether the higher hydraulic conductivity range obtained from the recent testing at this site is representative of the areas where capture wells would be required. Slug test data indicated values closer to those observed in the Zone A test wells. Nevertheless, the greater saturated thickness and lower contaminant concentrations in Zone B would require treatment of greater volumes to remove an equivalent contaminant load. Conversely, pumping wells would be easier to operate with the greater saturated thickness in the Zone B sands.

4.0 CONCLUSIONS

This evaluation provided aquifer testing at higher extraction rates than previous tests that are more comparable to those that would be necessary for operation of capture wells. The estimated hydraulic conductivities from the tests are typical of permeabilities for coarse sand aquifers, and while the permeabilities are lower than values that have been assumed in some of the previous capture assessments they still require relatively high extraction rates to achieve plume capture. The estimated extraction rates are 180 to 250 gpm for plume capture in Zone A and 400 to 500 gpm in Zone B. The revised hydraulic conductivity estimates and extraction rates are intended to provide a general basis for assessing potential remedial measures. However, this analysis only examines scenarios that entail full hydraulic capture of the cyanide and fluoride plume. Alternate approaches may also be feasible that provide more localized extraction in high concentration plume areas to achieve sufficient load reductions to meet water quality limits at the compliance boundary. Evaluation of these scenarios would require a more detailed assessment that is beyond the scope of this report. Assessment and selection of remedial alternatives will be conducted as part of a separate Feasibility Study.

5.0 REFERENCES

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APPENDIX A

WELL LOGS

Hydrometrics, Inc.
Consulting Scientists and Engineers
Helena, Montana

Hole Name: TW-1A

Date Hole Started: 01/10/13 Date Hole Finished: 01/17/13

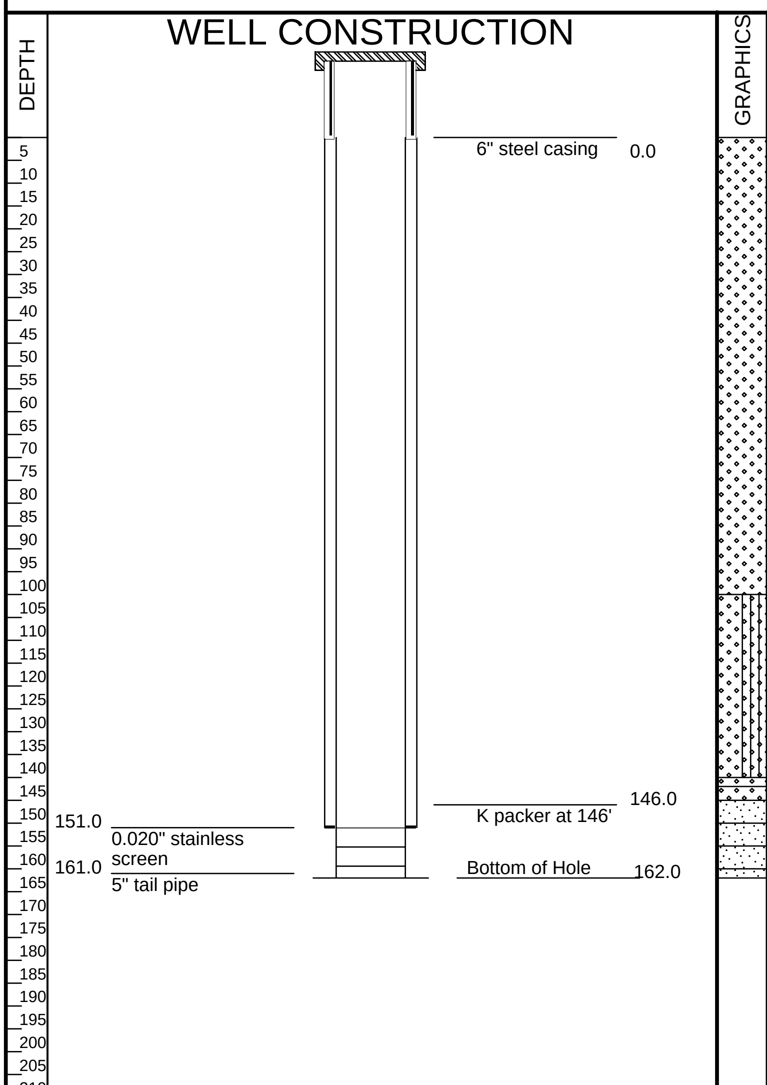
Client: Mead Custodial Trust
Project: Kaiser Mead NPL
County: Spokane State: Washington
Property Owner: Kaiser Aluminum Investments Co
Legal Description: Tax ID: 36096.9060
Location Description: Approximately 70' W/SW of Monitoring Well KM-6
Recorded By: LMJ
Drilling Company: H2O Well Service
Driller: Mark
Drilling Method: Conventional Rotary
Drilling Fluids Used: Air/Water
Purpose of Hole: Aquifer Testing
Target Aquifer: Zone A
Hole Diameter (in): 6-inch
Total Depth Drilled (ft): 162

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	6 inch Steel Casing	+2 - 162
Surface Casing Used?	Y	Temporary 10" casing	+2 - 18
Screen/Perforations?	Y	0.020-inch slot	151 - 161
Sand Pack?	N		
Annular Seal?	Y	Bentonite Chips	0 - 18
Surface Seal?	Y	Bentonite annular seal	
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Air development	
Water Samples Taken?	Y	pre-and post-pumping test samples	
Boring Samples Taken?	Y	Split Spoon Samples from 145-160	5' intervals

Northing: 2488751 Easting: 296137
Static Water Level Below MP: 147 Surface Casing Height (ft): +2
Date: 1/17/2013 Ground Surface Elevation (ft): 1920.06
MP Description: Top of Steel Casing MP Elevation (ft): 1922.62
MP Height Above or Below Ground (ft): 2'

Remarks: Field notes reference this well as TW-A, which was corrected to TW-1A in compiled Logs and field investigation report

WELL CONSTRUCTION



GEOLOGICAL DESCRIPTION

0.0 - 100.0' **Sand**
Hole was advanced to 100 feet before geologist arrived. See log for KM-6 for log down to 100 feet. Set 10 inch casing to 18 feet.

100.0 - 140.0' **Fine Grained Sand with Silt**
Fine to medium grained sand with some silt. Injecting water to maintain circulation at 100 feet.

140.0 - 142.0' 140' Damp. Testing for water with solinst and with bailer, bailer comes up dry, erratic results, mud in casing; spoon sample, medium to coarse grained sand plus or minus silt.

142.0 - 145.0' **Sand**
Medium to coarse grained sand. damp to moist.

145.0 - 150.0' **Sand**
145' Medium sand, damp to moist

150.0 - 155.0' **Sand**
150' Medium sand, trace of water but dried up as hole was advanced

155.0 - 160.0' **Sand**
155' Medium sand, water at beginning of interval. Measured water at 154.5 with Solinst

160.0 - 162.0' **Sand**
Medium to coarse sand. TD hole at 162'.

Hydrometrics, Inc.
Consulting Scientists and Engineers
Helena, Montana

Hole Name: TW-1B

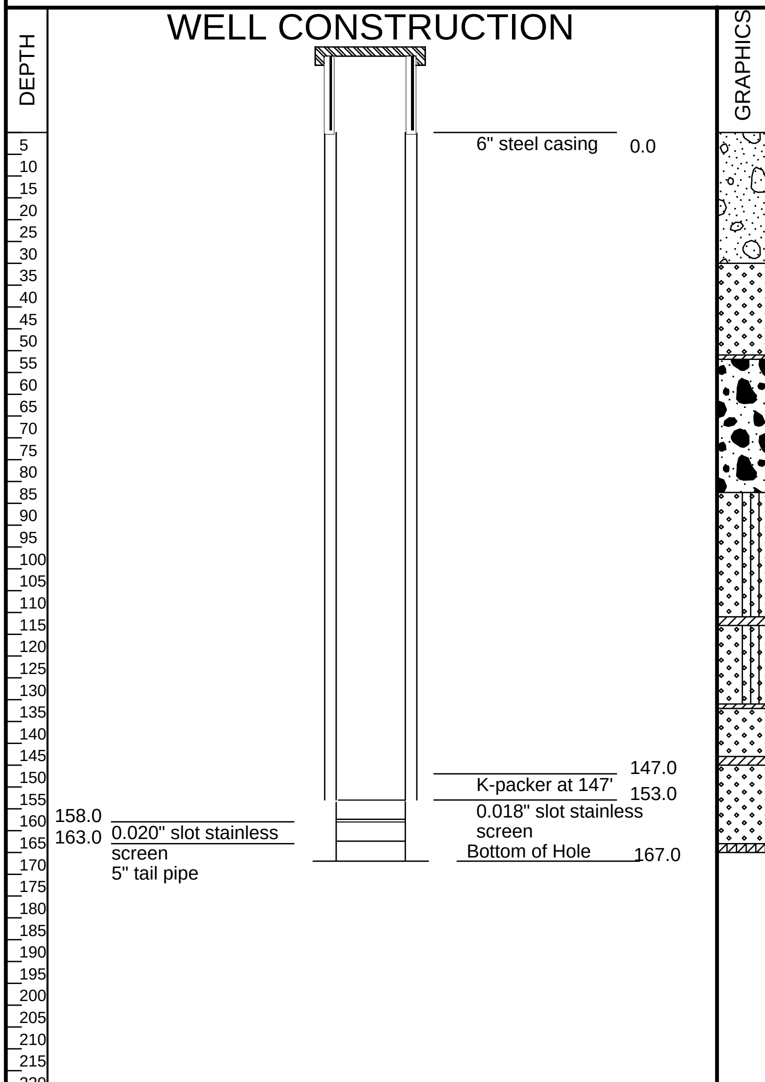
Date Hole Started: 01/09/13 Date Hole Finished: 01/13/13

Client: Mead Custodial Trust
Project: Kaiser Mead NPL
County: Spokane State: Washington
Property Owner: Kaiser Aluminum Investments Co
Legal Description: Tax ID: 36096.9060
Location Description: Approximately 300' east of Compliance well KMCP-3
Recorded By: LMJ
Drilling Company: H2O Well Service
Driller: Mark
Drilling Method: Conventional Rotary
Drilling Fluids Used: Air/Water
Purpose of Hole: Aquifer Testing
Target Aquifer: Zone B
Hole Diameter (in): 6-inch
Total Depth Drilled (ft): 167

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	6 inch Steel Casing	+2 - 167
Surface Casing Used?	Y	Temporary 10" casing	+2 - 18
Screen/Perforations?	Y	0.018" slot; 0.020" slot stainless	153 - 158; 158 - 163
Sand Pack?	N		
Annular Seal?	Y	Bentonite Chips	0 - 18
Surface Seal?	Y	Bentonite annular seal	
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Air development	
Water Samples Taken?	Y	pumping test sample	
Boring Samples Taken?	Y	Split Spoon Samples from 145-160	5' intervals

Northing: 2487494 Easting: 296512
Static Water Level Below MP: 147 Surface Casing Height (ft): +2
Date: 1/16/2013 Ground Surface Elevation (ft): 1916.60
MP Description: Top of Steel Casing MP Elevation (ft): 1919.04
MP Height Above or Below Ground (ft): 2'

Remarks: Field notes reference this well as TW-B, which was corrected to TW-1B in compiled Logs and field investigation report



GEOLOGICAL DESCRIPTION

0.0 - 30.0' **Coarse Sand with Gravel**
Dark gray to brown, poorly sorted coarse sand with minor pebbles, set 10 inch casing to 18 feet, 20 foot plugging casing, injecting water.

30.0 - 51.0' **Fine to Medium Grained Sand**
Fine to medium grained sand with some silt.

51.0 - 52.0' **Clay**
Clay, less than one foot thick.

52.0 - 82.5' **Sand with Gravel**
Coarse sand with gravel, pebbles to 1/2", 60 feet, occasional pebble to 1 inch, 62 feet, decreasing pebbles, sand fining downward, 82 feet, 1/2 inch pebbles.

82.5 - 111.0' **Fine Grained Sand with Silt**
Fine grained sand with minor silt.

111.0 - 113.0' **Clay**
Light gray to green gray plastic clay.

113.0 - 131.0' **Fine Grained Sand with Silt**
Fine grained sand plus or minus silt. Spoon sample at 115 - 116.5, very fine grained sand with silt - dry.

131.0 - 132.0' **Clay**
Light gray to green gray plastic clay.

132.0 - 143.0' **Sand**
Fine grained sand, coarser grained at 134 feet.

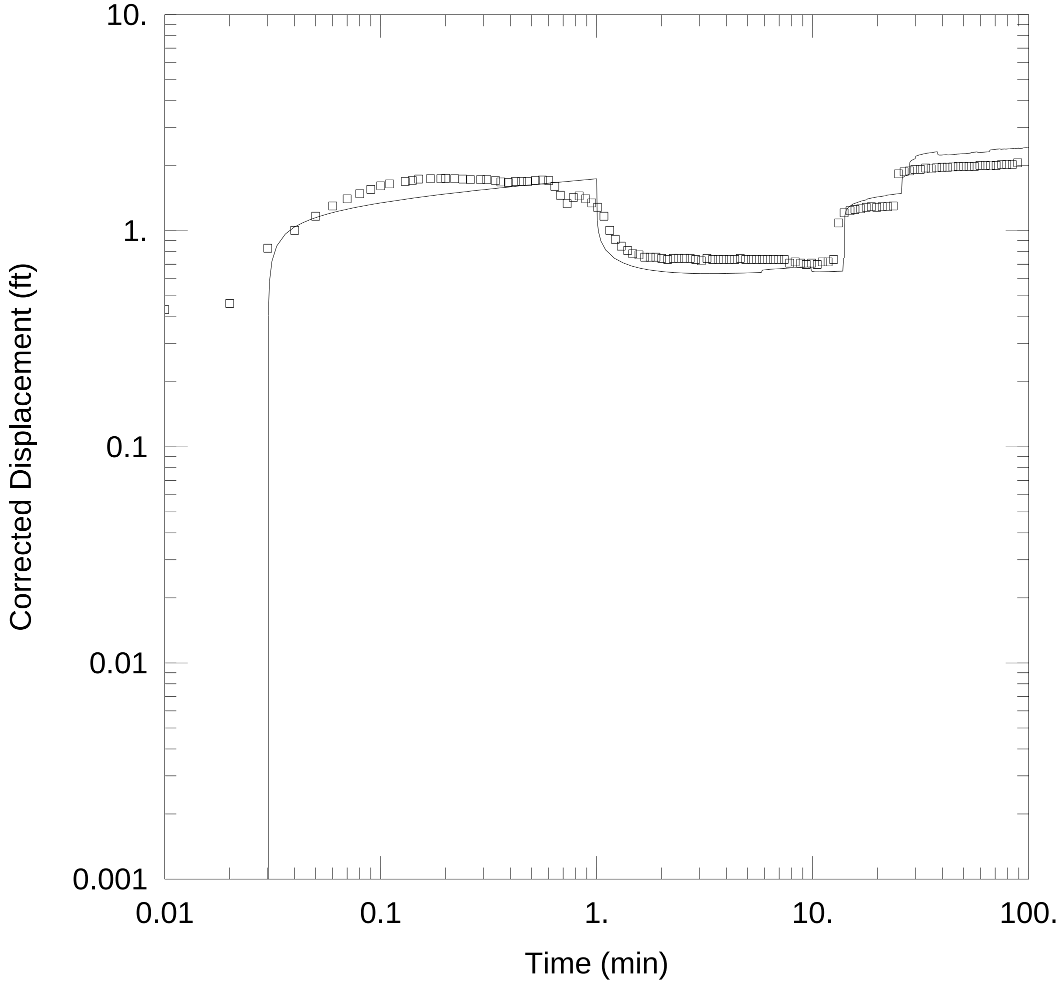
143.0 - 145.0' **Clay**
Light gray to green gray plastic clay.

145.0 - 163.0' **Fine to Coarse Grained Sand**
Heaving sands, drill string gets sandpacked, have to inject water to free up drill rods. Let hole sit overnight and SWL = 147 feet, sample water with bailer, pH = 8.67, SC = 1249, about 1 foot of sand heave. Spoon samples at 155 feet and 160 feet, wet coarse sand, 162 feet making less than 5 gpm.

163.0 - 165.0' **Clay with Silt**
Green gray, firm, dense clay with silt, cuttings become dry.
TD at 165 feet.

APPENDIX B

AQUIFER TEST CURVE MATCHING RESULTS



WELL TEST ANALYSIS

Data Set: K:\project\9088 Kaiser\pumping tests\TW-A Test\TW-A step theis.aqt
Date: 06/10/13 Time: 11:00:35

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Kaiser Mead
Project: 9088
Test Well: TW-A
Test Date: 2/19/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TW-A	2488751	296137

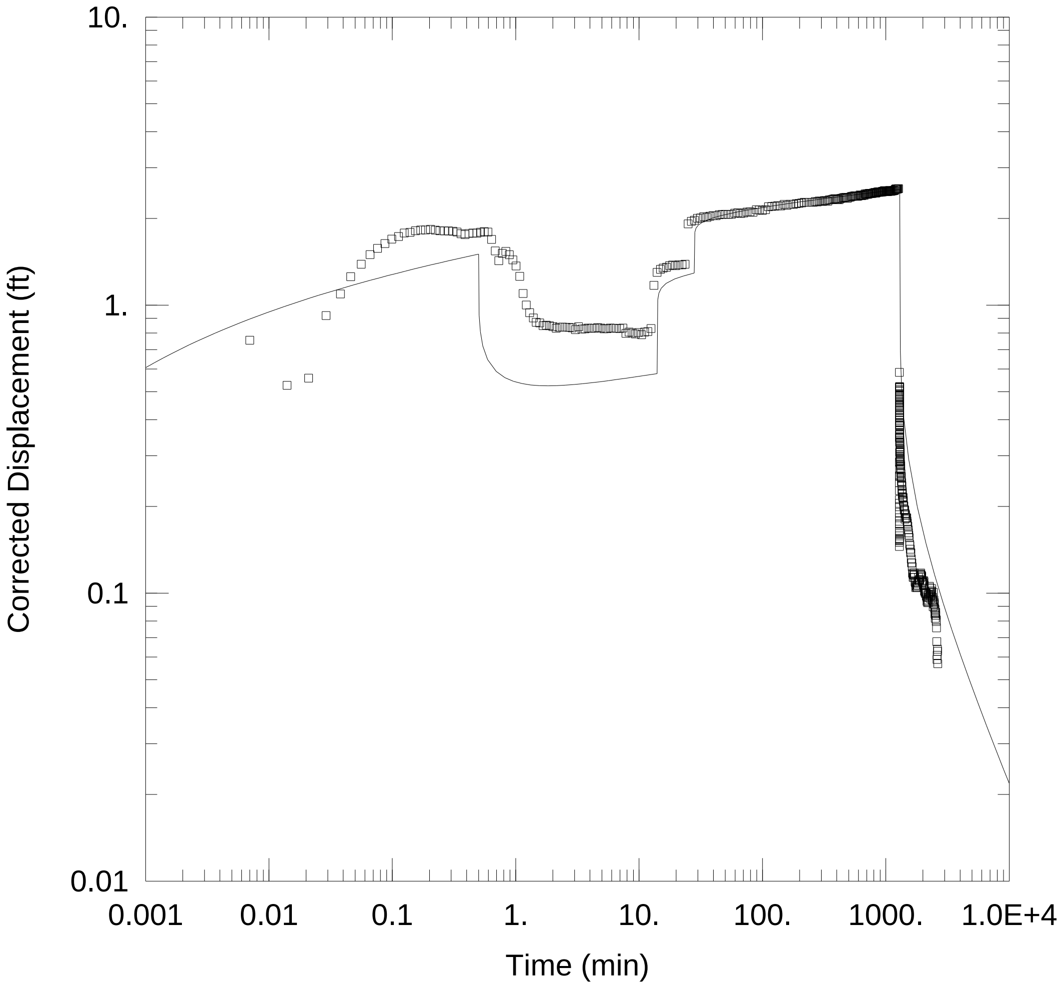
Observation Wells

Well Name	X (ft)	Y (ft)
□ TW-1A	2488751	296137

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 3342.9 ft^2/day
Kz/Kr = 0.1259
S = 0.001589
b = 12. ft



WELL TEST ANALYSIS

Data Set: K:\project\9088\pumping tests\TW-A Test\TW-A.aqt
Date: 03/15/13 Time: 13:03:38

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Kaiser Mead
Project: 9088
Test Well: TW-A
Test Date: 2/19/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TW-A	2488751	296137

Observation Wells

Well Name	X (ft)	Y (ft)
□ TW-1A	2488751	296137

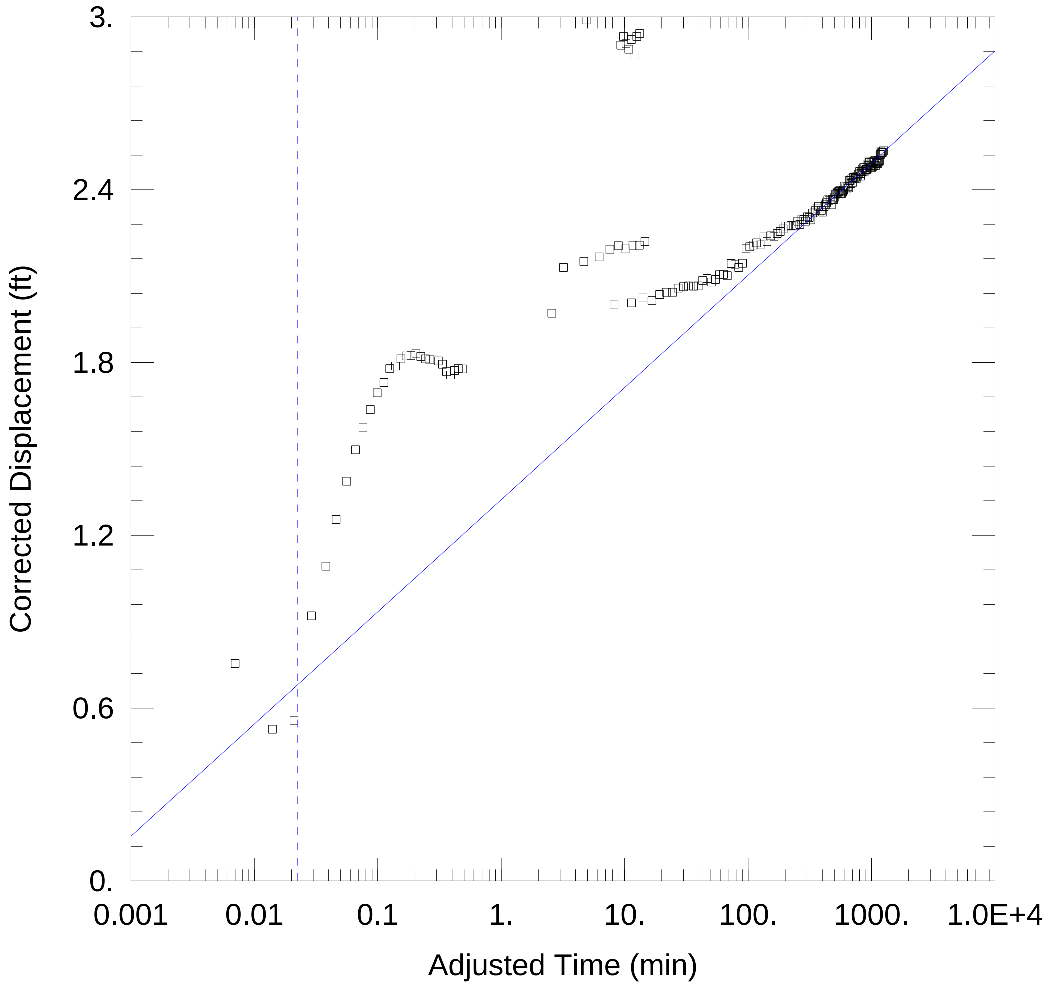
SOLUTION

Aquifer Model: Unconfined

Solution Method: Theis

T = 3848. ft^2/day
Kz/Kr = 0.1259

S = 0.001949
b = 12. ft



WELL TEST ANALYSIS

Data Set:
Date: 02/27/13 Time: 13:47:35

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Kaiser Mead
Project: 9088
Test Well: TW-A
Test Date: 2/19/13

AQUIFER DATA

Saturated Thickness: 12. ft Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TW-A	2489126	296210

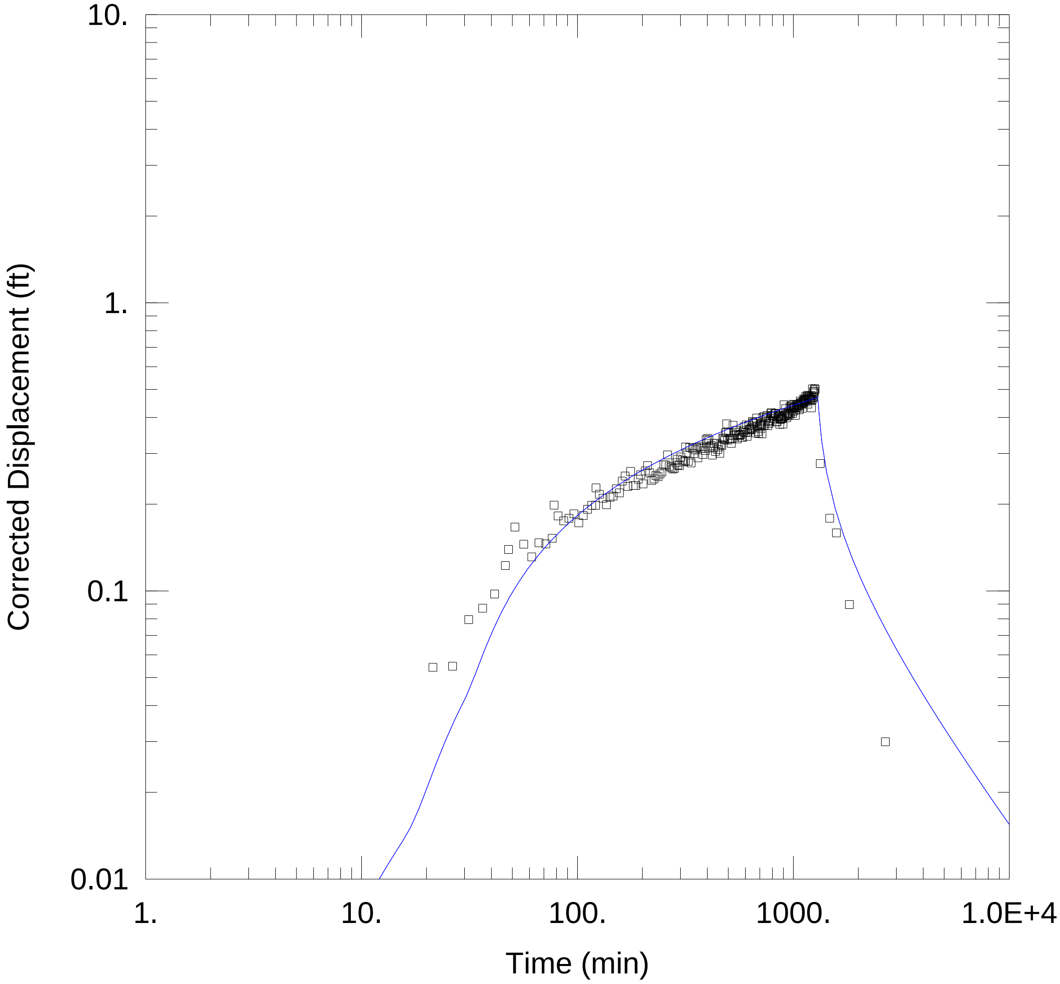
Observation Wells

Well Name	X (ft)	Y (ft)
□ TW-A	2489126.25	296210

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 3622. ft^2/day S = 0.03618



WELL TEST ANALYSIS

Data Set: K:\project\9088\pumping tests\TW-A Test\TW-A.aqt
Date: 03/12/13 Time: 10:10:01

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Kaiser Mead
Project: 9088
Test Well: TW-A
Test Date: 2/19/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
KM-1	2488540	295599

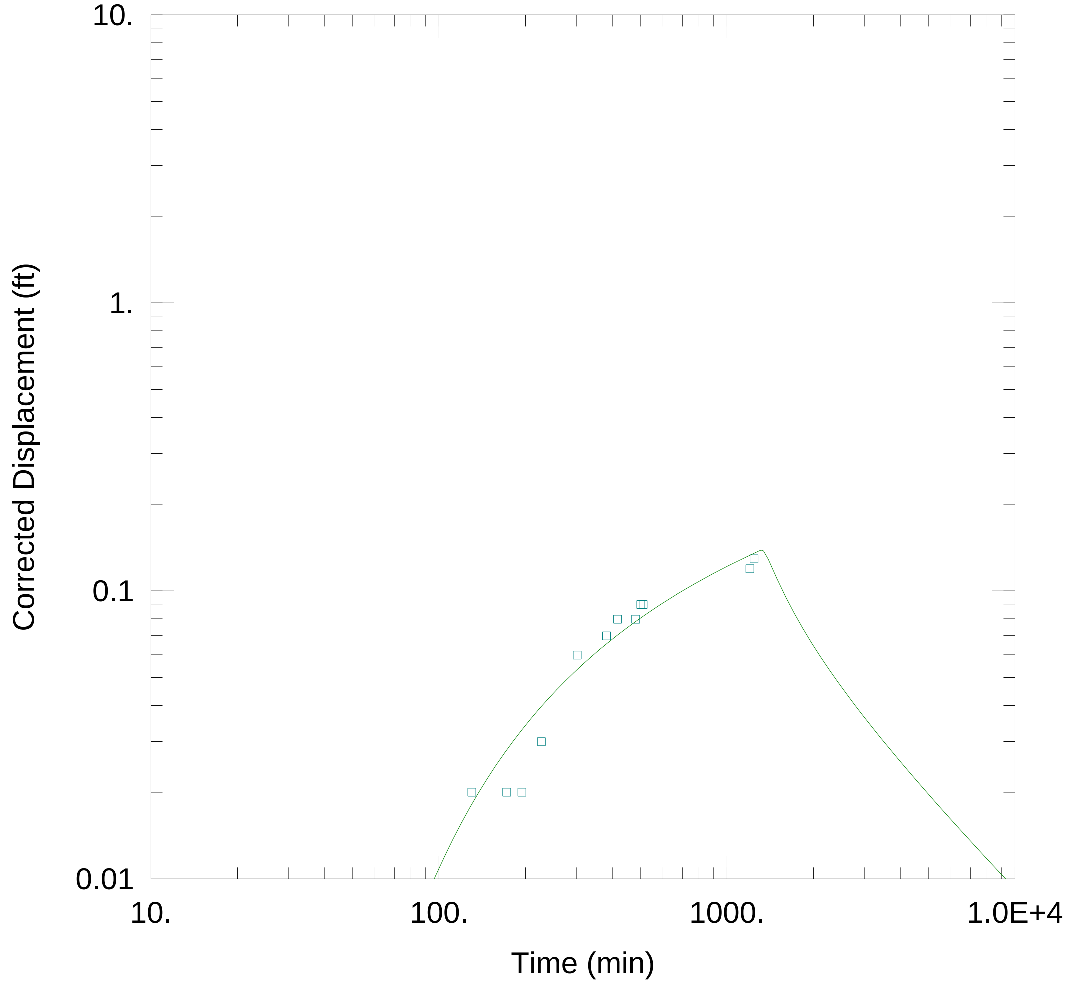
Observation Wells

Well Name	X (ft)	Y (ft)
□ TH-8	2488533	295602
□ TH-8 DL	2488533	295602

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 5427.7 ft^2/day
Kz/Kr = 0.09185
S = 2.719
b = 12. ft



WELL TEST ANALYSIS

Data Set: K:\project\9088\pumping tests\TW-A Test\TW-A.aqt
Date: 03/15/13 Time: 13:09:36

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Kaiser Mead
Project: 9088
Test Well: TW-A
Test Date: 2/19/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TW-A	2488751	296137

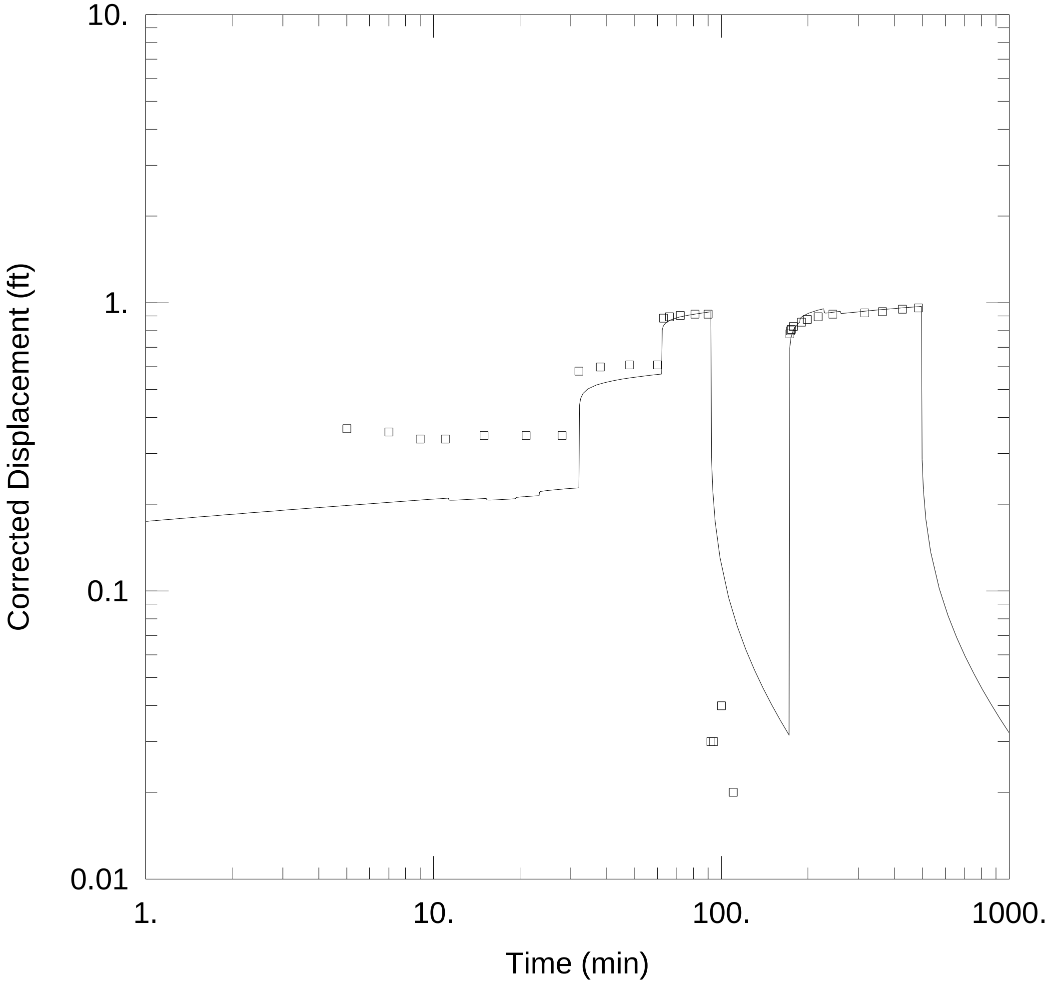
Observation Wells

Well Name	X (ft)	Y (ft)
□ KM-6	2488800	296177.97

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 9000. ft^2/day
Kz/Kr = 0.1259
S = 0.6231
b = 12. ft



WELL TEST ANALYSIS

Data Set: K:\project\9088\pumping tests\TW-B Test\TW-B.aqt
Date: 03/15/13 Time: 13:49:57

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Kaiser Mead
Project: 9088
Test Well: TW-A
Test Date: 2/19/13

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TW-B	2488751	296137

Observation Wells

Well Name	X (ft)	Y (ft)
□ TW-B	2488751	296137

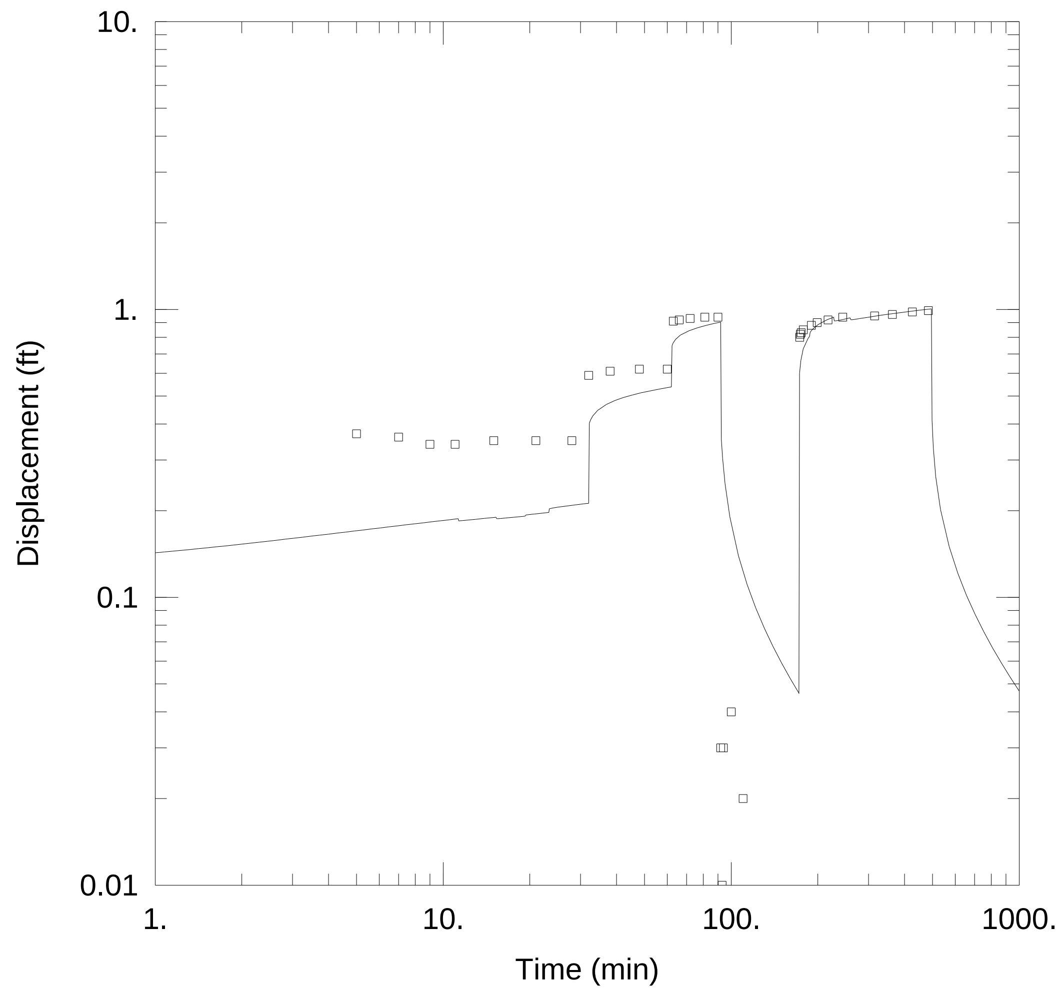
SOLUTION

Aquifer Model: Unconfined

Solution Method: Theis

T = 1.025E+4 ft^2/day
Kz/Kr = 0.188

S = 0.00181
b = 16. ft



WELL TEST ANALYSIS

Data Set: K:\project\9088\pumping tests\TW-B Test\TW-B.aqt
Date: 03/15/13 Time: 13:47:27

PROJECT INFORMATION

Company: Hydrometrics, Inc.
Client: Kaiser Mead
Project: 9088
Test Well: TW-A
Test Date: 2/19/13

AQUIFER DATA

Saturated Thickness: 12. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
TW-B	2488751	296137

Observation Wells

Well Name	X (ft)	Y (ft)
□ TW-B	2488751	296137

SOLUTION

Aquifer Model: Unconfined Solution Method: Neuman

T = 6984. ft^2/day
S = 0.0005253
Sy = 0.3338
ß = 0.001

AQUIFER TEST DATA

(LOCATED ON CD)