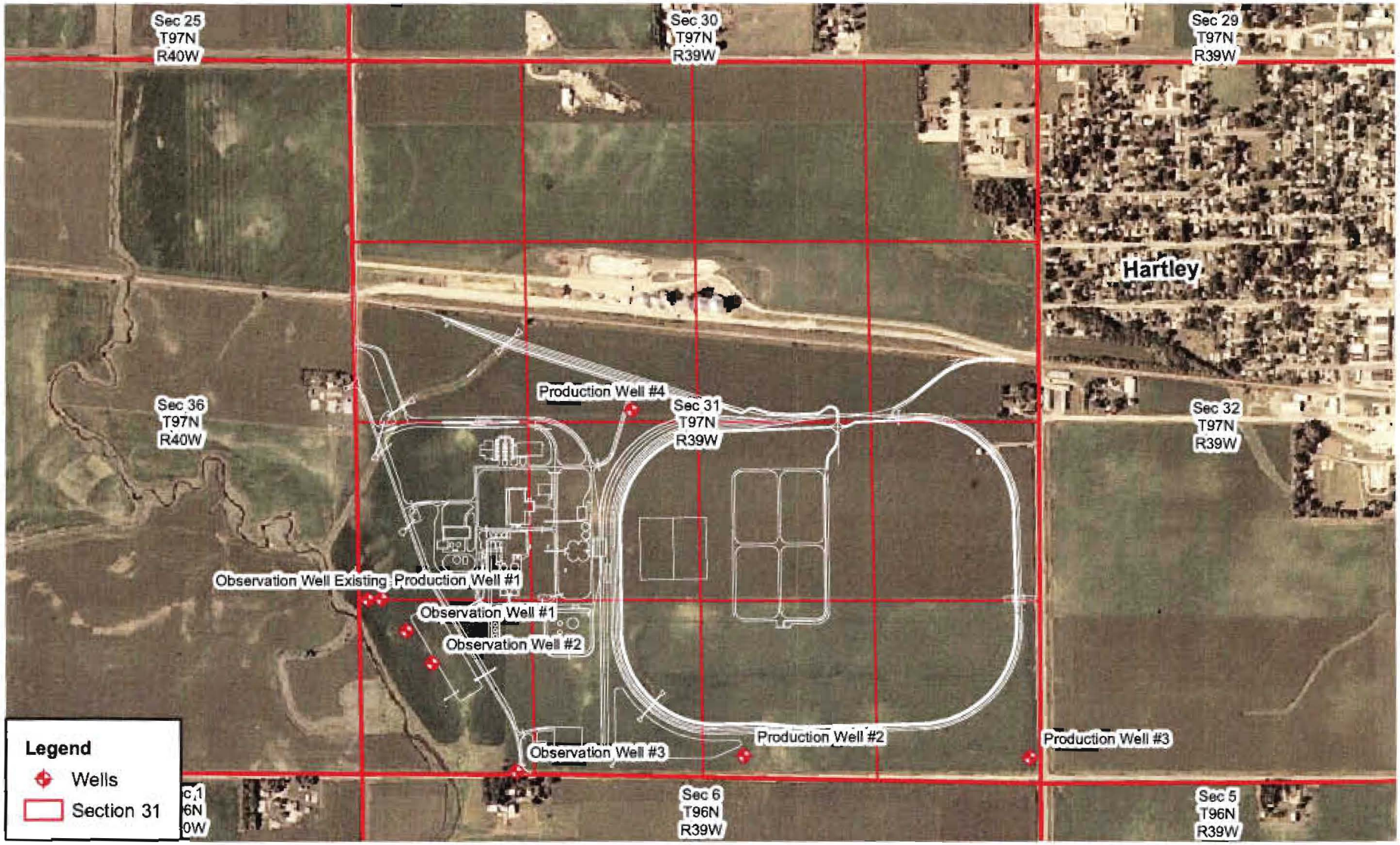
Z:\Projects\VeraSun\39937_Site_Investigation_Study\map_docs\arcmap\Proposed_Well_Drilling_Plan.mxd\march07\jcm



Source: 2004 NAIP

1,000 500 0 1,000 Feet

Scale

HDR

Proposed Well Drilling Plan

VeraSun

Hartley, IA
Greenfield Ethanol Plant Site

DATE
March 2007

FIGURE
1

Memorandum

Date: July 27, 2006

To: Terry Heiliger

From: Luca DeAngelis, P.E., R.G.

cc:

RE: VeraSun Energy Hydro Report

The following memorandum describes an evaluation of the aquifer tests performed by Layne Christensen Company (Layne) for VeraSun Energy, which is represented by HDR Engineering Inc. (HDR). The project objective is to evaluate two proposed development sites for the Greenfield Ethanol Plant (Plant), which are located in Hartley and Everly, Iowa (Site). A water supply of approximately 1.4 million gallons per day (mgd) is required for the development of the Plant. The objective of this memorandum is to evaluate the aquifer tests performed at each site, and to provide the following:

- An estimate of sustainable yield for a full scale production well;
- A well spacing recommendation for the production wells; and
- Propose construction details for the production wells.

REGIONAL HYDROGEOLOGY

The two potential Plant location sites are located in northwestern Iowa. The primary groundwater resource in this area is the Cretaceous aquifer, which is comprised of a sequence of sandstone, limestone, and shale deposited during the Cretaceous Period by five major transgressive-regressive marine cycles that inundated Minnesota, Iowa, and western Wisconsin from the west (USGS, 1992).

The primary water bearing units of the Cretaceous aquifer are the sandstone beds in the Dakota Formation. Water in the Dakota Formation is confined by the overlying Graneros Shale and locally by fine-grained glacial deposits that overlie the eroded surface of the Cretaceous rocks. The Cretaceous aquifer is a confined aquifer, as evidenced by the potentiometric surface, which is above the top of the aquifer in most places. Recharge to the Cretaceous aquifer is limited, and is obtained primarily from water which moves vertically through the surficial aquifer system, mostly through the confining beds. Locally, the Cretaceous aquifer also is connected hydraulically to underlying aquifers in Paleozoic and Precambrian rocks.

Well yields in the Cretaceous system range from less than 100 to slightly more than 1,000 gallons per minute (gpm). The aquifer properties of the Cretaceous aquifer system are typically bracketed as follows:

- Hydraulic-conductivity values range from 37 to 50 feet per day
- Transmissivity values range from 3,900 to 7,600 feet squared per day
- Aquifer thickness values range from 89 to 162 feet (USGS, 1992).

TEST WELL CONSTRUCTION/SITE GEOLOGY – HARTLEY SITE

A five (5) inch diameter well was installed inside a ten (10) inch diameter boring for the purposes of conducting an aquifer test at the Site. The test well was constructed as a filter packed well with a 100 foot screen interval, screened from 447 feet below ground surface (ft bgs) to 577 ft bgs. A well construction diagram is included in Attachment A. Based on the well log provided, the test well is screened primarily in a fine to medium sandstone material, which is most likely the Cretaceous Dakota Formation.

TEST WELL CONSTRUCTION/SITE GEOLOGY – EVERLY SITE

A five (5) inch diameter well was installed inside a ten (10) inch diameter boring for the purposes of conducting an aquifer test at the Site. The test well was constructed as a filter packed well with an 80 foot screen interval, screened from 332 ft bgs to 412 ft bgs. A well construction diagram is included in Attachment A. Based on the well log provided, the test well is screened primarily in a medium sandstone material, which is most likely the Cretaceous Dakota Formation.

AQUIFER TEST – HARTLEY SITE

A 24-hour aquifer test was performed at Test Hole #01-06 on July 17 and 18, 2006. A pressure transducer was installed in the well to measure and record changes in the water level within the pumping well, however there was a malfunction with the pressure transducer and those data were not recorded. However, manual water level measurements were collected from the pumping well, using an electronic water level indicator, at regular intervals throughout the duration of the aquifer test. The well was pumped at a constant discharge rate of approximately 44 gpm.

The manual water levels collected are presented on Figure 1. As shown on Figure 1, the pumping water level reaches a maximum drawdown level within the first few minutes of the test and then rebounded maintaining a drawdown between 2.1 and 2.3 feet for the remainder of the test. Based on these data, it appears the well was not completely developed and gained efficiency during the test or the well encountered a recharge boundary after approximately 10 minutes of pumping. These data were not usable to produce a time drawdown curve which is required to perform most hydraulic analyses. However, a long term specific capacity of 14 gallons per minute per foot of drawdown (gpm/ft) was obtained from the 24-hour aquifer test. The specific capacity obtained at the end of the pumping test was used to estimate the potential

yield of a full scale production well using the following empirical relationship, presented in Driscoll (1989):

$$\frac{Q}{s} = \frac{T}{2{,}000}$$

where:

Q/s = Well specific capacity (gpm/ft)
T = aquifer transmissivity (gpd/ft)

The relationship presented above is valid for confined aquifers, such as the Cretaceous aquifer found at the Site. Based on this relationship, the transmissivity of the aquifer at the Hartley site is approximately 28,000 gpd/ft or 3,740 feet squared per day (ft^2/day). This value is comparable to the low value presented for the Cretaceous aquifer system (USGS, 1992). The aquifer thickness at the Hartley site is approximately 175 feet, which yield a hydraulic conductivity of approximately 21 feet per day (ft/day), which is slightly lower than the value presented for the Cretaceous aquifer system (USGS, 1992).

AQUIFER TEST – EVERLY SITE

A 24-hour aquifer test was performed at Test Hole #01-06 on July 6 and 7, 2006. Changes in the water level within the pumping well were measured and recorded using a pressure transducer/data logger. Additionally, manual water level measurements were collected from the pumping well, using an electronic water level indicator, at regular intervals throughout the duration of the aquifer test. The well was pumped at a constant discharge rate of approximately 82 gpm.

The data collected by the pressure transducer are presented on Figure 2. As shown on Figure 2, the pumping water level reaches a maximum drawdown level within the first few minutes of the test and then stabilizes between 2.6 and 2.8 feet of drawdown for the remainder of the test. Based on these data, it appears the well was not sufficiently stressed to produce a useable time drawdown curve. However, a long term specific capacity of 29 gpm/ft was obtained from the 24-hour aquifer test. The specific capacity obtained at the end of the pumping test was used to estimate the potential yield of a full scale production well using Driscoll's empirical relationship previously presented

Based on Driscoll's relationship, the transmissivity of the aquifer at the Everly site is approximately 58,000 gpd/ft or 7,750 feet squared per day (ft^2/day). This value is comparable to the high value presented for the Cretaceous aquifer system (USGS, 1992). The aquifer thickness at the Everly site is approximately 150 feet, which yield a hydraulic conductivity of approximately 50 feet per day (ft/day), which is also on the comparable to the high value presented for the Cretaceous aquifer system (USGS, 1992).

AQUIFER TEST – SUMMARY

The following is a summary of the aquifer conditions at the two test Sites:

- Hartley Site
  - Static Water Level – 248 ft bgs;
  - Aquifer Thickness – 175 ft;
  - Aquifer Material – described as fine to medium sandstone;
  - Available Drawdown (to top of formation) – 154 feet; and
  - Transmissivity - 28,000 gpd/ft.

- Everly Site
  - Static Water Level – 151 ft bgs;
  - Aquifer Thickness – 150 ft;
  - Aquifer Material – described as medium sandstone;
  - Available Drawdown (to top of formation) – 111 feet; and
  - Transmissivity - 58,000 gpd/ft.

MAXIMUM SUSTAINABLE PUMPING RATE

Once site specific aquifer parameters were estimated, the long term maximum sustainable pumping rate for a well at the two Sites was estimated using the Cooper-Jacob non-equilibrium equation (Cooper-Jacob, 1946). This approach incorporates the calculated aquifer parameters, available drawdown, and time of pumping to develop an estimate of well yield. The Cooper-Jacob non-equilibrium equation is presented below, assuming consistent units:

$$s = \frac{2.3Q}{4\pi T} \log \frac{2.25Tt}{r^2 S}$$

where:

s = aquifer drawdown (feet)
Q = pumping rate (ft^3/day)
T = aquifer transmissivity (ft^2/day)
t = time of pumping (days)
r = effective well radius (feet)
S = aquifer storage (dimensionless)

The maximum sustainable pumping rate was estimated by rewriting the above equation to solve for Q. The equation was solved for a prescribed available drawdown which assumed a 70% efficient well and a 20 foot water column above the screen (approximately 10 percent of the original available drawdown). Additionally, another 20 feet of drawdown were added to the pumping level to approximate the impact of well interference from the other plan wells. Based on this approach, the following maximum yields were estimated:

- Hartley Site – 850 gpm
- Everly Site – 1,050 gpm

Detailed calculations are included in Attachment C.

WELL SPACING ESTIMATE

Recommended well spacing values for the production wells were developed using the Cooper-Jacob non-equilibrium equation previously presented. Recommended well spacing values were calculated assuming the following:

- Pumping well will operate near the maximum pumping rate;
- Well interference drawdown is equal to ten percent of the aquifer thickness;
- Time to reach near steady-state conditions, where recharge is approximately equal to pumping, is 60 days.
- Site specific transmissivity values calculated from the pumping test are representative of the long term transmissivity of the aquifer.

Based on this approach, the following recommended well spacing values were generated:

- Hartley Site – 2,600 feet
- Everly Site – 1,600 feet

Calculations are included in Attachment C.

WELL DESIGN

A recommended well design was developed for a full scale production well at each potential Site. The design is based on the aquifer samples collected during the recent exploration drilling activities. The following summarizes the recommended well designs.

HARTLEY SITE

- Bore hole diameter – 32 inches
- Well diameter – 14 inches
- Screen material – Type 304 stainless steel wire wrap with 0.025 inch slot openings
- Screen interval – 477 to 577 ft bg
- Filter pack interval – 390 to 577 ft bgs
- Filter Pack - Northern Gravel "O" Gravel Pack

EVERLY SITE

- Bore hole diameter – 32 inches
- Well diameter – 14 inches
- Screen material – Type 304 stainless steel wire wrap with 0.025 inch slot openings
- Screen interval – 332 to 412 ft bg
- Filter pack interval – 255 to 412 ft bgs
- Filter Pack - Northern Gravel "O" Gravel Pack

Proposed well construction details and all well construction related calculations are included in Attachment D.

CONCLUSIONS AND RECOMMENDATIONS

Based on the data obtained from the aquifer tests performed at the Hartley and Everly Sites, it appears that water availability for the construction of the Greenfield Ethanol Plant will not be an issue at either site. Based strictly on groundwater production potential, it appears that the aquifer at the Everly Site will produce higher yielding supply wells than the Hartley Site.

Regardless of which site is selected for development, it is recommended that three production wells be installed to provide the required raw water for the Plant. Two wells will be used for daily operations, while one well should remain as a backup to supply water if one of the daily wells needs to be serviced. The pumping rates presented in this report are maximum pumping rates that the supply wells should produce assuming there are no outside influences on the aquifer (off site production wells) that adversely impact the aquifer. It is recommended that the pumps to be installed in the supply wells should be rated for 600 to 700 gpm. With two wells operating concurrently, the wells should provide more water capacity than is required by the Plant.

REFERENCES:

Driscoll, 1989. Groundwater and Wells. Johnson Filtration Systems Inc. St. Paul, Minnesota.

IDNR, 1983. Hydrogeology And Stratigraphy Of The Dakota Formation In Northwest Iowa. Iowa Department of Natural Resources, Geological Survey Bureau,
Water Supply Bulletin 13, 1983, 55 p.

Kruseman, G.P. and de Ridder, N.A., 1994. Analysis and Evaluation of Pumping Test Data. International Institute for Land Reclamation and Improvement. The Netherlands.

USGS, 1992. Ground Water Atlas of the United States - Iowa, Michigan, Minnesota, Wisconsin. HA 730-J

ATTACHMENT A

WELL CONSTRUCTION/BORING LOG

Layne-Western
5600 Gateway Drive, Suite B
Grimes, IA 50111
(515) 986-3462 / 3474 Fax

TEST WELL INSTALLATION REPORT

CUSTOMER: VeraSun Energy **TEST WELL NO:** Hartley 01-06

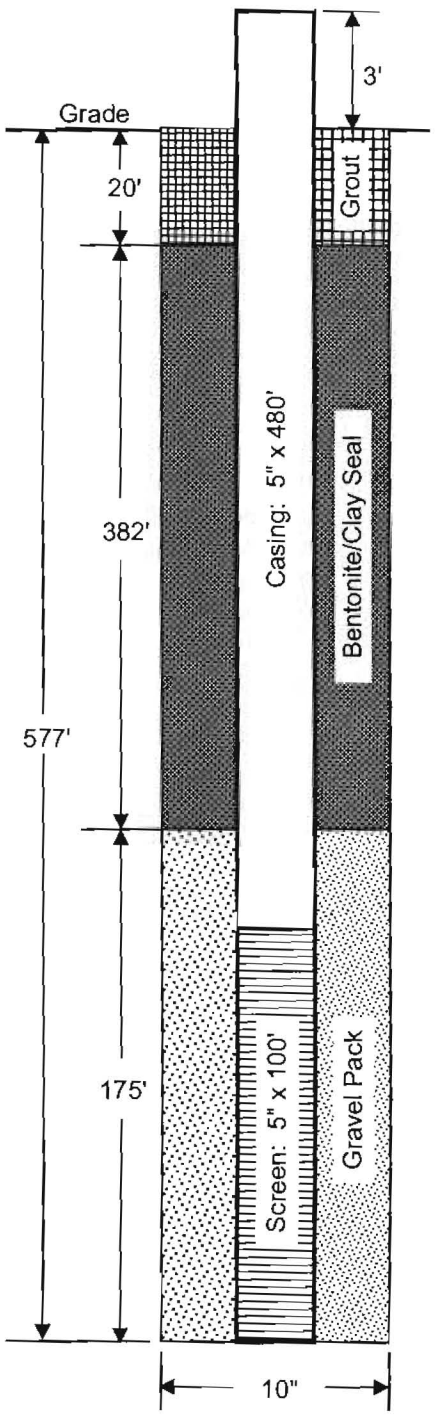
JOB NO: 59-0193 **DATE:** 06/26/06 **DRILLER:** Mark Leslie

CITY: Hartley **STATE:** Iowa

TEST WELL LOCATION: GPS: N 43° 10' 27.0" - W 95° 30' 18.2"

LOG OF WELL FROM GROUND LEVEL:

FROM	TO	MUD VIS. (SEC)	PIT LOSS (IN)	FORMATION
0	3			Top soil
3	18			Sand & gravel w/cobbles
18	24			Gray clay
24	119			Gray till w/gravel layers
119	128			Sand
128	168			Gray till
168	182			Medium sand
182	206			Gray till
206	236			Shale
236	242			Dark gray shale
242	274			Shale w/sandstone seams
274	282			Shale
282	316			Sandstone
316	325			Medium sandstone
325	344			Shale
344	360			Shale w/sandstone seams
360	375			Hard shale
375	384			Shale
384	401			Hard gray shale
401	443			Fine to medium sandstone - clean
443	455			Sandstone w/shale seams
455	527			Fine sandstone
527	539			Sandstone w/shale seams
539	577			Fine to medium sandstone - clean
577	578			Limestone



Pit Size: 2' (WIDTH) x 15' (LENGTH) x 6' (DEPTH)

Comments: **Static Level = 248'**
Pumping Level = 251.1' @ 44 gpm

Layne-Western
5600 Gateway Drive, Suite B
Grimes, IA 50111
(515) 986-3462 / 3474 Fax

TEST WELL INSTALLATION REPORT

CUSTOMER: VeraSun Energy **TEST WELL NO:** Everly 01-06

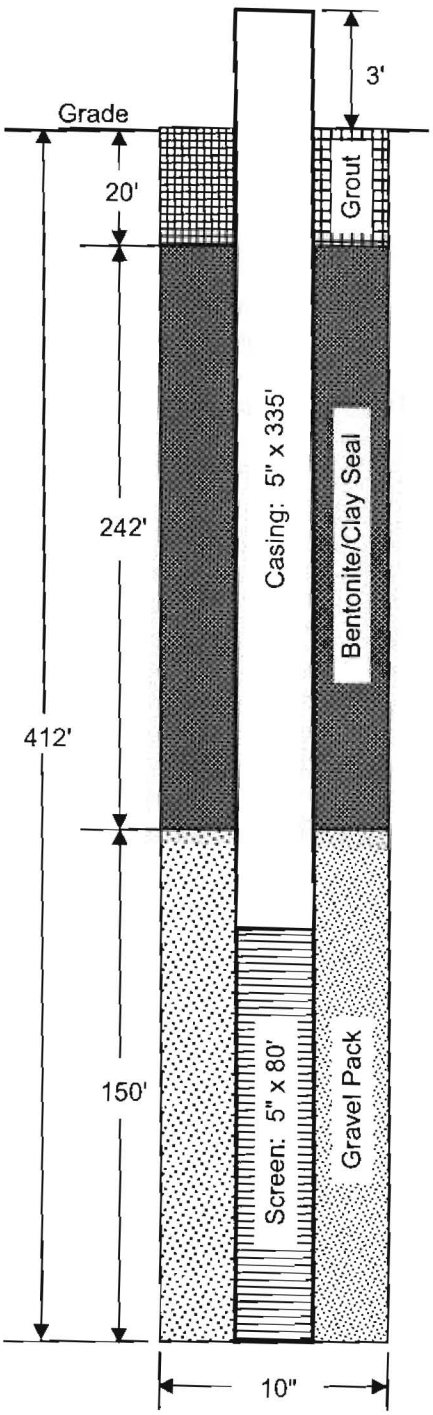
JOB NO: 59-0193 **DATE:** 06/24/06 **DRILLER:** Mark Leslie

CITY: Everly **STATE:** Iowa

TEST WELL LOCATION: GPS: N 43° 09' 37.7" - W 95° 18' 07.7"

LOG OF WELL FROM GROUND LEVEL:

FROM	TO	MUD VIS. (SEC)	PIT LOSS (IN)	FORMATION
0	2			Top soil
2	16			Sand & gravel
16	90			Gray till
90	94			Sand
94	130			Gray till
130	137			Sand
137	238			Gray till
238	240			Hard layer
240	248			Gray clay
248	259			Sandy clay
259	275			Sandstone w/shale seam
275	316			Fine sandstone
316	321			Gray shale
321	340			Medium sandstone
340	358			Medium sandstone w/shale seams
358	391			Medium sandstone
391	412			Fine sandstone
412	418			Shale
418	420			Limestone



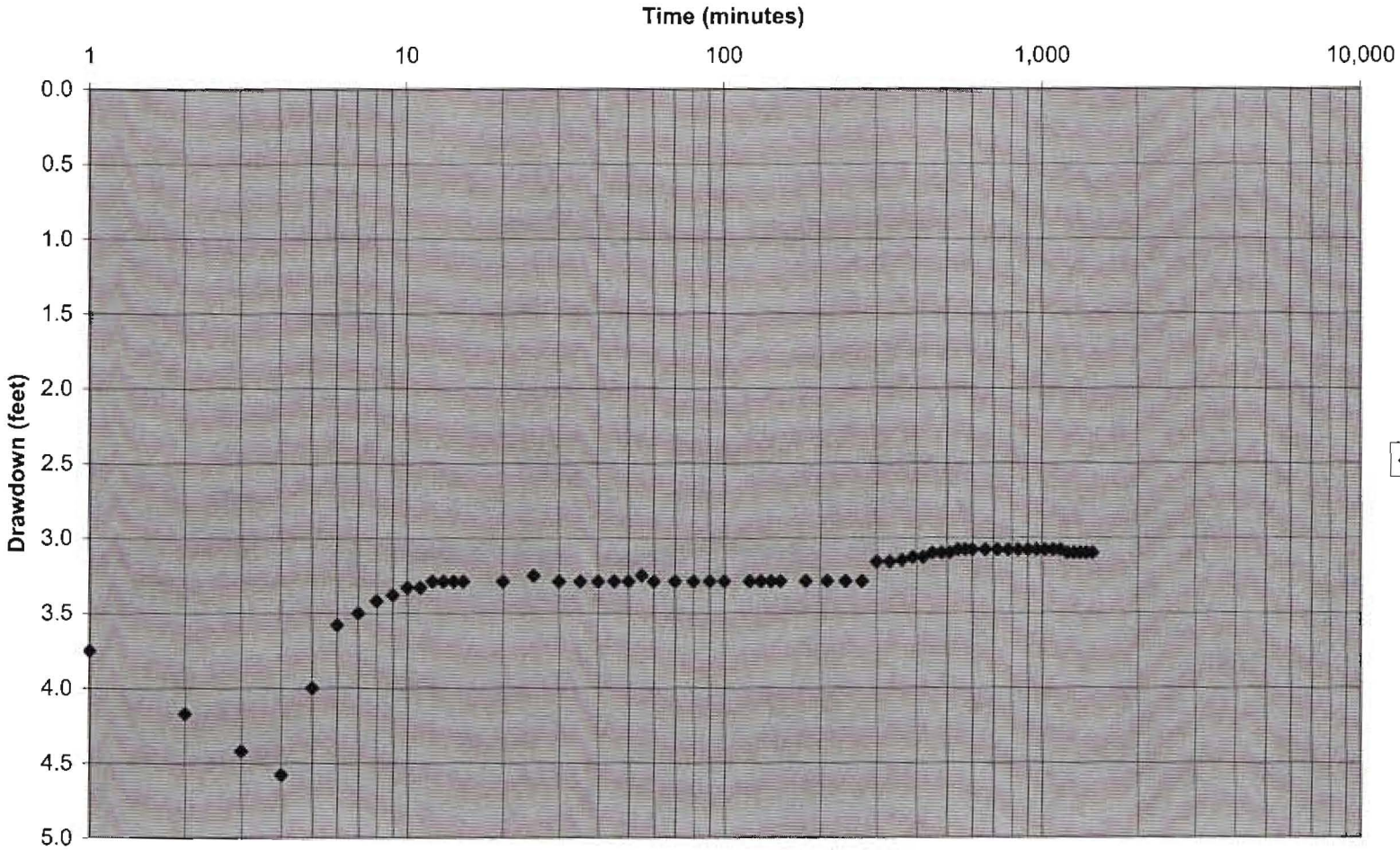
Pit Size: 2' (WIDTH) x 12' (LENGTH) x 6' (DEPTH)

Comments: **Static Level = 151'**
Pumping Level = 156.5' @ 75 GPM

ATTACHMENT B

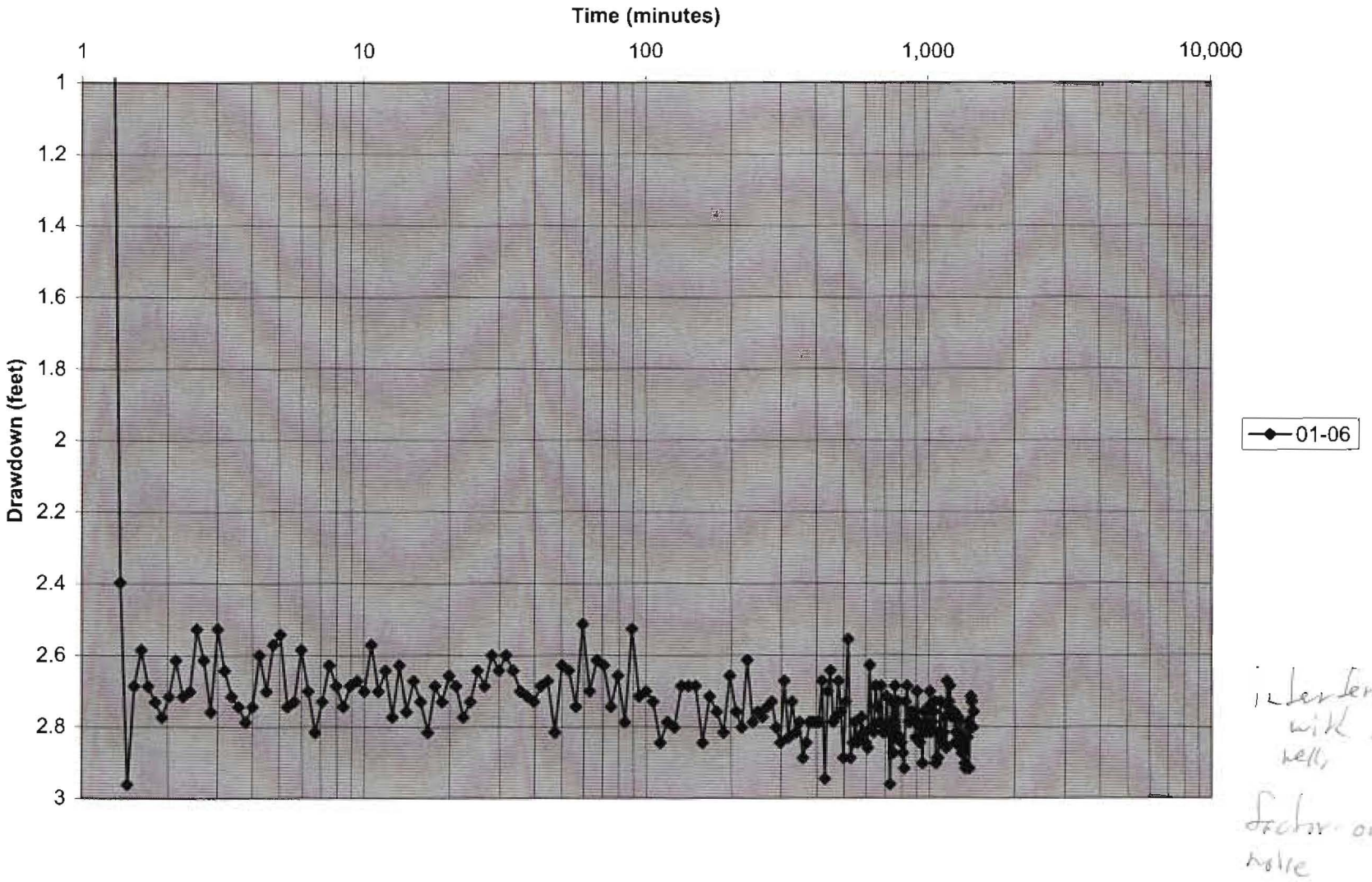
AQUIFER TEST ANALYSIS

Figure 1
Time Drawdown Curve
Pumping Well - Hartley Site



interference from other well?

Figure 1
Time Drawdown Curve
Pumping Well - Everly Site



interference with nearby well,

factor on noise

ATTACHMENT C

CALCULATIONS

WELL YIELD ESTIMATE/SPACING ESTIMATES

Hartley Site - Vertical Well Calculation Sheet

Calulation Input Parameter	VALUE
B_{DIA} = Borehole diameter (inches)	10
S_D = Screen diameter (inches)	5
S_L = Screen length feet	175
S_I = Screen interval = 402 – 577 ft bgs	

Drawdown in Pumping Well calculation (Maximum operating rate)

$$Q = s_{100} * \left(\frac{T}{264 \log \frac{0.3Tt}{r^2 S}} \right)$$

Where:	VALUE	Notes	
s_{100} = drawdown in the pumped well (feet) - 100% Efficient	Presented below		
T = aquifer Transmissivity (gal/day/foot)	28,000	calculated	
Q = well pumping rate (gal/min)	NA		
t = estimated time to reach steady state (days)	60	estimated	for 10 year period?
S = aquifer storage (dimensionless)	0.0003	estimated	typical for Dakota (KGS, 1996)
r = radius of pumping well borehole (feet)	0.411		

Calcluate allowable "real world" drawdown

s_{70} = Top of Screen - Depth to Water - 10 feet (safety factor)

Pump Inlet	382	Assume pump is installed 20 ft above screen
Depth to Water	248	

Calculate corresponding drawdown in a 100% efficient well

s_{100} = Pump Inlet - Depth to Water - 20 feet (safety factor)*0.7 (well efficiency) — 20 feet is estimated well interference plus safety factor

s_{100} = 79.8

Calculete Max operating Rate

Q_{design}(gpm) = 847

Specific Capacity Check

SC at 48 hrs	14
70 % of SC	9.8

Calculete available drawdonw, assuming pumping level 20 ft above pump inlet

s = Pump Inlet - Depth to Water - 20 feet

Available drawdown 114

Calculate Max operating Rate

Q_{design}(gpm) = 1,117

Hartley SITE – Well Spacing Calculations

Calulation Input Parameters	VALUE	
Q = Pumping Rate (gpm)	800	Input value
Q = Pumping Rate (ft3/day)	154,011	
T = Transmissivity (gal/day/ft)	28,000	
T = Transmissivity (ft2/day)	3,743	
t = pumping time (days)	60	
s = desired well spacing drawdown (feet)	18	10% aquifer thickness
Storage Coefficient	0.0003 (KGS, 1996)	

CALCULATION 1

Governing Equation - Non Equilibrium Equation (Domenico and Schwartz pg. 151)

$$s = \frac{2.3Q}{4\pi T}\log\frac{2.25Tt}{r^2 S_y}$$

Re-arrange variables and solve for r

$$r = \sqrt{\frac{2.25\ Tt}{S_y * 10^{\frac{4\pi Ts}{2.3Q}}}}$$

Calculate distance to 1 foot drawdown contour - assuming no impact from boundaries

r (feet) = 2618.571

Everly Site - Calculation Sheet

Calulation Input Parameter	VALUE
B_{DIA} = Borehole diameter (inches)	10
S_D = Screen diameter (inches)	5
S_L = Screen length feet	80
S_t = Screen interval = 332 – 412 ft bgs	

Drawdown in Pumping Well calculation (Maximum operating rate)

$$Q = s_{100} * \left(\frac{T}{264 \log \frac{0.3Tt}{r^2 S}} \right)$$

Where:	VALUE	
s_{100} = drawdown in the pumped well (feet) - 100% Efficient	Presented below	
T = aquifer Transmissivity (gal/day/foot)	58,500	calculated
Q = well pumping rate (gal/min)	NA	
t = estimated time to reach steady state (days)	60	estimated
S = aquifer storage (dimensionless)	0.0001	estimated typical for confined
r = radius of pumping well borehole (feet)	0.411	

Calcluate allowable "real world" drawdown

s_{70} = Top of Screen - Depth to Water - 10 feet (safety factor)

Pump Inlet	242	Assume pump is installted 20 ft above screen
Depth to Water	151	

Calculate corresponding drawdown in a 100% efficient well

s_{100} = Pump Inlet - Depth to Water - 20 feet (safety factor)*0.7 (well efficiency) — 20 feet is estimated well interference plus safety factor

s_{100} = 49.7

Calculate Max operating Rate

Q_{design}(gpm) = 1,020

Specific Capacity Check

SC at 48 hrs	29
70 % of SC	20.3

Calculate available drawdonw, assuming pumping level 20 ft above pump inlet

s = Pump Inlet - Depth to Water - 20 feet

Available drawdown 71

Calculate Max operating Rate

Q_{design}(gpm) = 1,441

Everly SITE – Well Spacing Calculations

Calulation Input Parameters	VALUE	
Q = Pumping Rate (gpm)	1,050	Input value
Q = Pumping Rate (ft3/day)	202,139	
T = Transmissivity (gal/day/ft)	58,000	
T = Transmissivity (ft2/day)	7,754	
t = pumping time (days)	60	
s = desired well spacing drawdown (feet)	15	10% aquifer thickness
Storage Coefficient	0.0003 (KGS, 1996)	

CALCULATION 1

Governing Equation - Non Equilibrium Equation (Domenico and Schwartz pg. 151)

$$s = \frac{2.3Q}{4\pi T}\log\frac{2.25Tt}{r^2 S_y}$$

Re-arrange variables and solve for r

$$r = \sqrt{\frac{2.25\ Tt}{S_y * 10^{\frac{4\pi Ts}{2.3Q}}}}$$

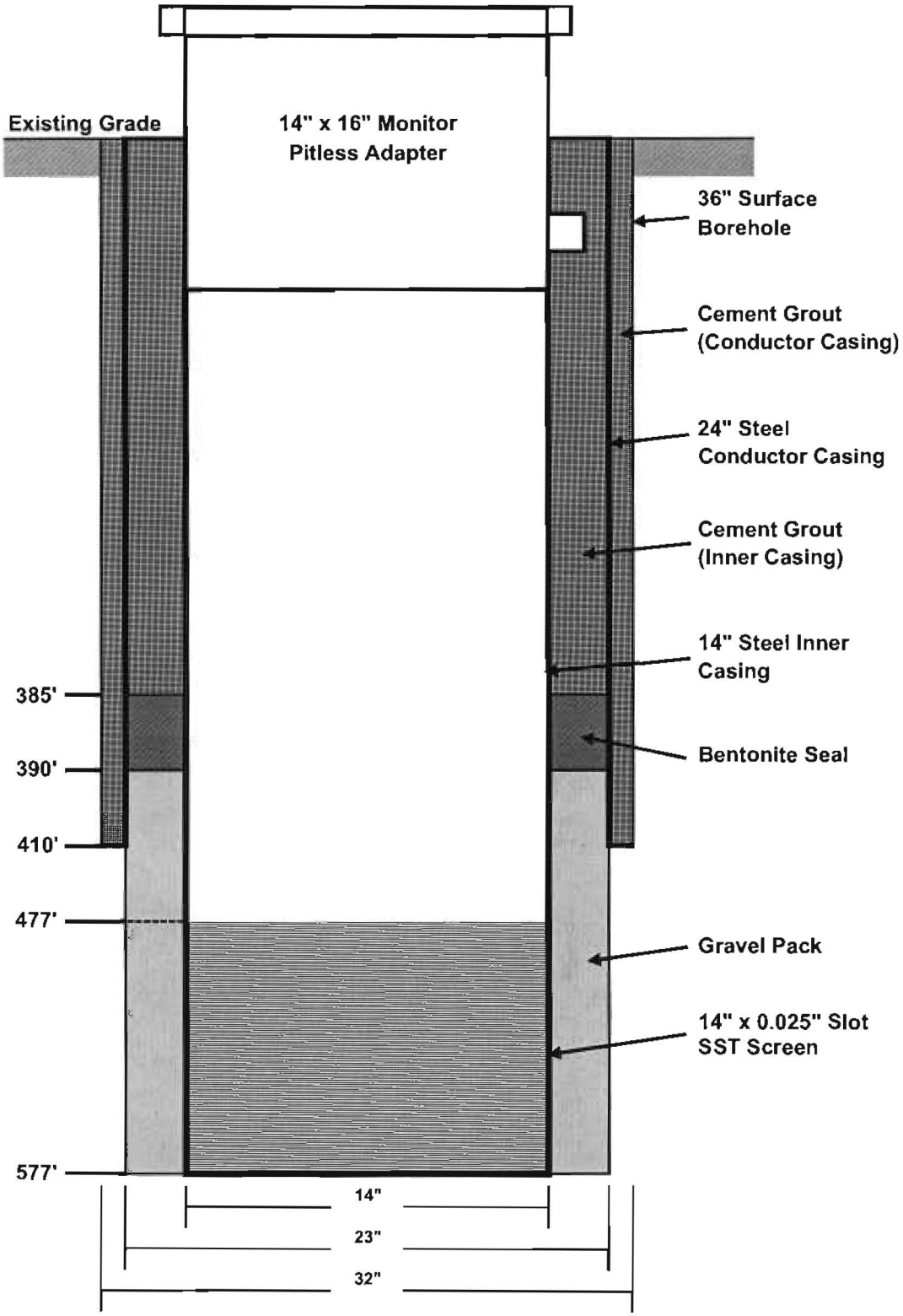
Calculate distance to 1 foot drawdown contour - assuming no impact from boundaries

r (feet) = 1583.035

ATTACHMENT D

WELL DESIGN CALCULATIONS

PROPOSED WELL CONSTRUCTION DETAIL
VERASUN ENERGY, INC. - HARTLEY, IOWA
JULY 27, 2006



NOT TO SCALE

WELL SCREEN FLOW CALCULATION
VERASUN ENERGY, INC.
HARTLEY, IOWA PLANT SITE

July 27, 2006

KNOWN PARAMETERS:

1.	Screen Diameter:	14 inches
2.	Screen Length:	100 feet
3.	Open Area of 0.025" Slot Wire Wrap Screen	76 in^2/lf
4.	Maximum Allowable Entrance Velocity of Water Entering Well Screen:	0.1 ft/sec

ASSUMED PARAMETERS:

1.	Percent Blockage of Open Area by Gravel Pack	50 %

STANDARD FLOW CALCULATION FORMULA: Q = VA

WHERE: Q = FLOW RATE PER FOOT OF SCREEN, GPM

Q_{MAX} = MAXIMUM TOTAL ALLOWABLE FLOW RATE, GPM

V = VELOCITY OF WATER ENTERING THE SCREEN, FT/SEC

A = OPEN AREA OF THE SCREEN, FT^2

Q = VA

Q = [0.1 ft/sec][76.0 in^2/lf][0.5 for blockage]

Q = [0.1 ft/sec][38.0 in^2/lf]

Q = [0.1 ft/sec][60 sec/min][38.0 in^2/lf][1 ft^2/ 144 in^2][7.48 gal/ft^2]

Q = 11.8 gpm/lf of screen

Q_{MAX} = [11.8 gpm/lf of screen][100 lf of screen]

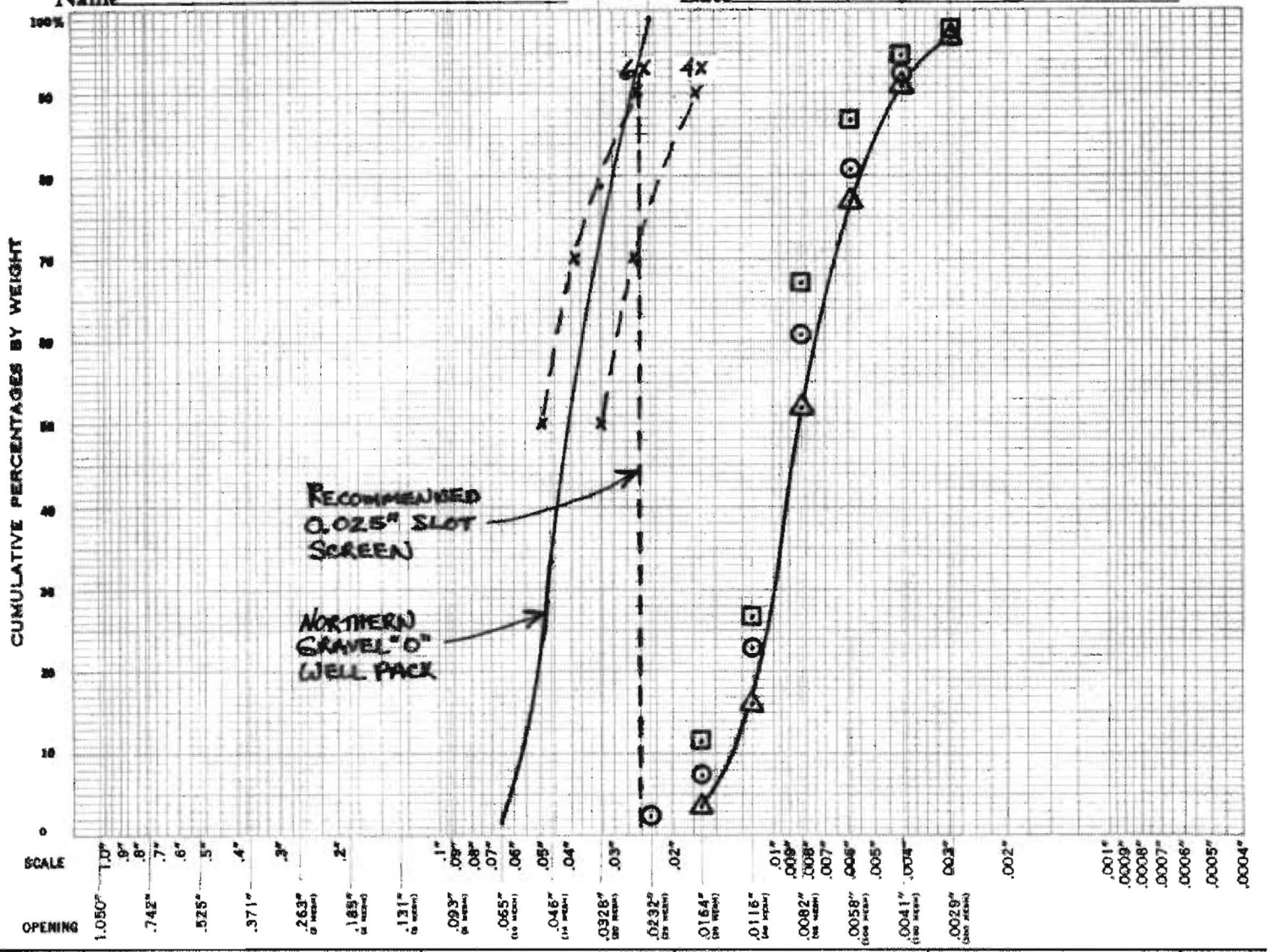
Q_{MAX} = 1,184 GPM

The Tyler Standard Screen Scale

Cumulative Logarithmic Diagram of Screen Analysis on Sample of HARTLEY, IA TH 01-06

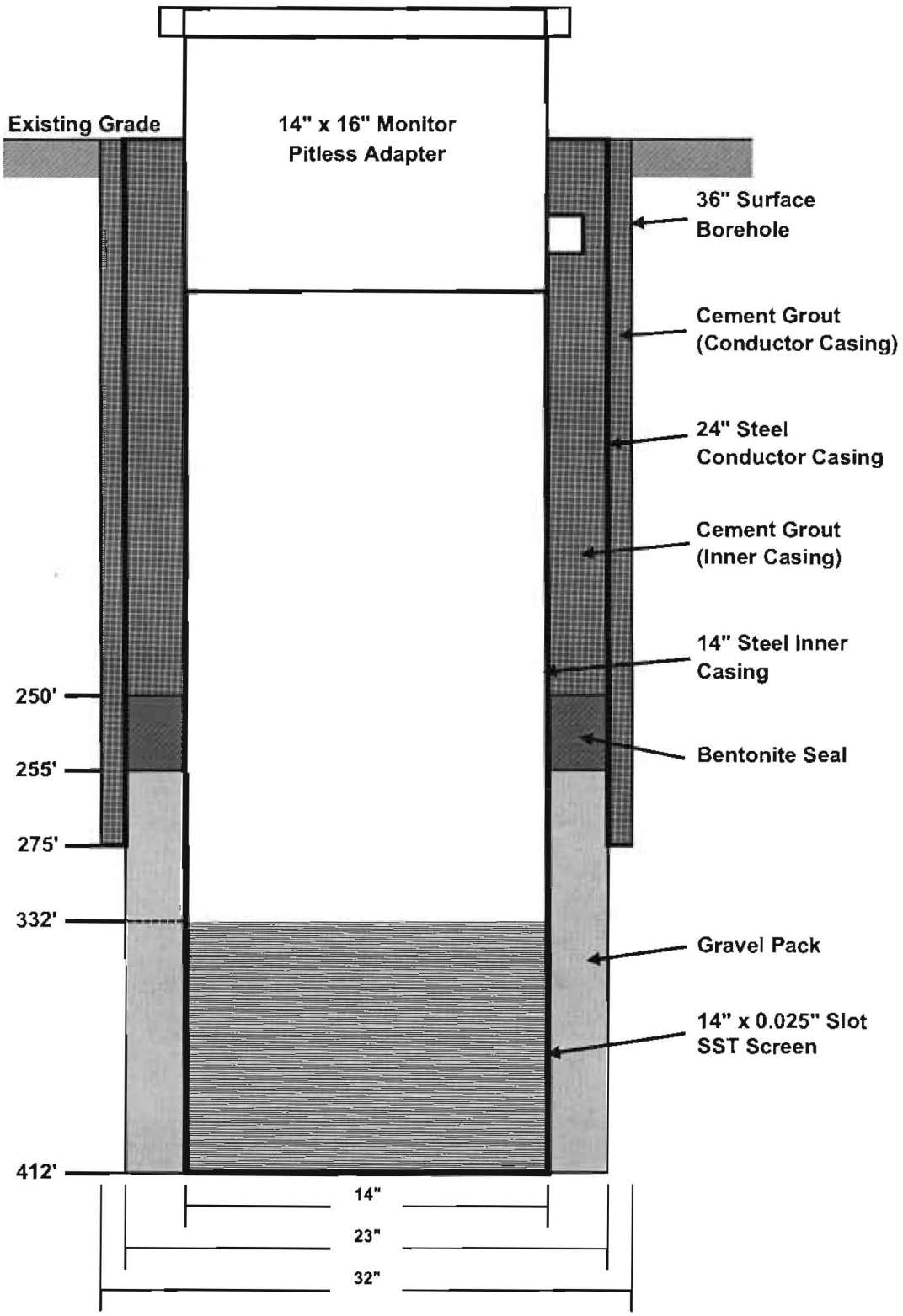
L-3

Name VERASUN ENERGY, INC. Date DRILLED 6/26/06



	SCREEN SCALE RATIO 1.414				530' - 535' ○			535' - 540' △			540' - 545' □		
	Openings		Tyler Mesh	U. S. No.	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights
	Inches	Milli-meters											
	1.050	26.67											
	.742	16.85											
	.525	13.33											
	.371	9.423											
	.263	6.680	3										
	.185	4.699	4	4									
	.131	3.327	6	6									
	.093	2.362	8	8									
	.065	1.651	10	12									
	.046	1.168	14	16									
	.0328	.833	20	20									
	.0232	.589	28	30	12.2	2.4	2.4						
	.0164	.417	35	40	25.0	5.0	7.4	18.3	3.7	3.7	55.6	11.5	11.5
	.0116	.295	48	50	77.4	15.5	22.9	62.0	12.4	16.1	73.8	15.3	26.8
	.0082	.208	65	70	189.0	37.8	60.7	178.9	35.8	51.9	195.3	40.4	67.1
	.0058	.147	100	100	100.3	20.1	80.8	125.8	25.2	77.0	95.3	19.7	86.8
	.0041	.104	150	140	57.8	11.6	92.3	68.2	13.6	90.7	38.7	8.0	94.8
	.0029	.074	200	200			92.3	31.3	6.3	96.9	13.9	2.9	97.7
Pass	.0029	.074	200	200	38.3	7.7	100.0	15.3	3.1	100.0	11.1	2.3	100.0
				Totals	500.0			499.8			483.7		

PROPOSED WELL CONSTRUCTION DETAIL
VERASUN ENERGY, INC. - EVERLY, IOWA
JULY 27, 2006



NOT TO SCALE

WELL SCREEN FLOW CALCULATION
VERASUN ENERGY, INC.
EVERLY, IOWA PLANT SITE

July 27, 2006

KNOWN PARAMETERS:

1. Screen Diameter:	14 inches
2. Screen Length:	80 feet
3. Open Area of 0.025" Slot Wire Wrap Screen	76 in^2/lf
4. Maximum Allowable Entrance Velocity of Water Entering Well Screen:	0.1 ft/sec

ASSUMED PARAMETERS:

1. Percent Blockage of Open Area by Gravel Pack	50 %

STANDARD FLOW CALCULATION FORMULA: Q = VA

WHERE: Q = FLOW RATE PER FOOT OF SCREEN, GPM

Q_{MAX} = MAXIMUM TOTAL ALLOWABLE FLOW RATE, GPM

V = VELOCITY OF WATER ENTERING THE SCREEN, FT/SEC

A = OPEN AREA OF THE SCREEN, FT^2

Q = VA

Q = [0.1 ft/sec][76.0 in^2/lf][0.5 for blockage]

Q = [0.1 ft/sec][38.0 in^2/lf]

Q = [0.1 ft/sec][60 sec/min][38.0 in^2/lf][1 ft^2/ 144 in^2][7.48 gal/ft^2]

Q = 11.8 gpm/lf of screen

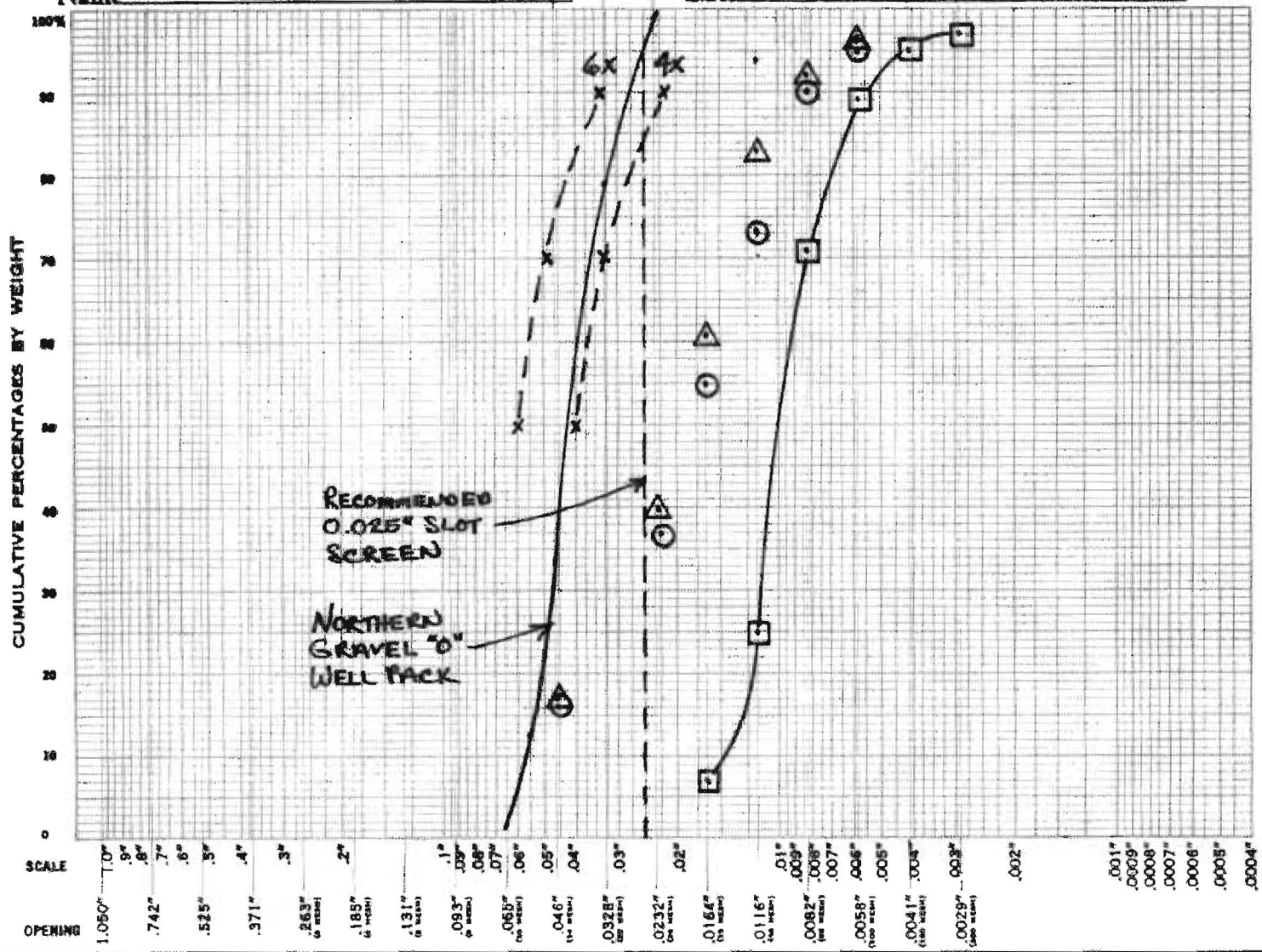
Q_{MAX} = [11.8 gpm/lf of screen][80 lf of screen]

Q_{MAX} = 947 GPM

The Tyler Standard Screen Scale

Cumulative Logarithmic Diagram of Screen Analysis on Sample of EVERLY, IA TH 01-06

Name VERASUN ENERGY, INC. Date DRILLED 6/16/06



	SCREEN SCALE RATIO 1.414				259' - 265' ○			270' - 275' △			280' - 285' □		
	Openings		Tyler Mesh	U. S. No.	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights	Sample Weights	Per Cent	Per Cent Cumulative Weights
	Inches	Millimeters											
	1.050	26.67											
	.742	18.85											
	.525	13.33											
	.371	9.423											
	.263	6.680	3										
	.185	4.699	4	4									
	.131	3.327	6	6									
	.093	2.362	8	8									
	.065	1.651	10	12									
	.046	1.168	14	16	82.7	16.5	16.5	85.4	17.1	17.1			
	.0328	.833	20	20			16.5			17.1			
	.0232	.589	28	30	106.1	21.2	37.7	117.9	23.6	40.7			
	.0164	.417	35	40	87.9	17.6	55.3	103.5	20.7	61.4	36.7	7.3	7.3
	.0116	.295	48	50	91.5	18.3	73.6	94.4	18.9	80.3	88.0	17.6	25.0
	.0082	.208	65	70	81.9	16.4	90.0	58.6	11.7	92.0	233.7	46.8	71.8
	.0058	.147	100	100	26.9	5.4	95.4	21.7	4.3	96.3	90.5	18.1	89.9
	.0041	.104	150	140			95.4			96.3	28.3	5.7	95.6
	.0029	.074	200	200			95.4			96.3	11.9	2.4	97.9
Pass	.0029	.074	200	200	23.2	4.6	100.0	18.3	3.7	100.0	10.3	2.1	100.0
				Totals,	500.2			499.8			499.4		

Layne-Western — *a division of Layne Christensen Company*

620 South 38th Street • Kansas City, Kansas 66106 • Phone: (913) 321-5000 Fax: (913) 321-5012

Review and get back to Lyle Nelson

October 17, 2007

Mr. Lyle R. Christensen, PE
Water Facilities Section, Senior Project Manager
HDR Engineering, Inc.
8404 Indian Hills Drive
Omaha, NE 68114-4098

RE: Aquifer Test Analysis for VeraSun Hartley, LLC, Hartley, Iowa

Dear Mr. Christensen:

Layne Christensen Company (Layne) has been retained by VeraSun Hartley, LLC to evaluate the drawdown conditions, estimated well yields, and possible well interference issues within the well field currently under construction at the VeraSun Hartley, LLC ethanol plant (Site) in Hartley, Iowa. To achieve these objectives, Layne conducted a 72 hour constant rate aquifer pumping test that was performed in Production Well #1. This letter report presents the findings and conclusions of this test.

SITE GEOLOGY

The Plant site is located in northwestern Iowa. The primary groundwater resource in this area is the Cretaceous aquifer, which is comprised of a sequence of sandstone, limestone, and shale deposited during the Cretaceous Period (USGS, 1992).

The primary water bearing units of the Cretaceous aquifer are the sandstone beds in the Dakota Formation. The Nishnabotna and Woodbury members are the regional water bearing members of this formation. Water in the Dakota Formation is confined by the overlying Graneros Shale and locally by fine-grained glacial deposits that overlie the eroded surface of the Cretaceous rocks. The Cretaceous aquifer is a confined aquifer, as evidenced by the potentiometric surface which is above the top of the aquifer in most locations. Recharge to the Cretaceous aquifer is limited and is obtained primarily from water which moves vertically through the surficial aquifer system (mostly through the confining beds). Locally, the Cretaceous aquifer also is connected hydraulically to underlying aquifers in Paleozoic and Precambrian rocks.

On a regional scale, the Nishnabotna member is regarded as the major producing aquifer of the Dakota Formation. The Nishnabotna member is of fluvial origin and is heterogeneous in nature consisting of fine to coarse sandstones with interbedded shale layers. The test well is screened in the Nishnabotna member at a depth of 474 to 574 below ground surface (bgs). The base of the aquifer at the Production Well #1 site was approximately 574 feet below ground surface and consists mainly of limestone. Depth to water ranges from approximately 250 feet bgs at Production Well #1 to 253.40 bgs at well OW-1,500 (located 1,500 feet from the test well).

Well yields in the Cretaceous system range from less than 100 to slightly more than 1,000 gallons per minute (gpm). The aquifer properties of the Cretaceous aquifer system are typically bracketed as follows:

- Hydraulic-conductivity values range from 33 to 77 feet per day (ft/day);

- Transmissivity values range from 4,000 to 12,000 feet squared per day (ft^2/day) (IGS, 1983); and
- Aquifer thickness values range from 89 to 162 feet (USGS, 1992).

WELL CONSTRUCTION

One production test well (Production Well #1) was constructed at the Site and was screened from 474 to 574 feet below ground surface (bgs). Four observation wells were installed to monitor changes in the potentiometric surface during the aquifer test. One existing 5-inch supply well was located approximately 100 feet from the test well. Three 2-inch observation wells were installed at distances of 300, 600, and 1500 feet from the test well.

TRANSMISSIVITY ESTIMATE

A 72-hour constant rate aquifer tests was performed at Production Well #1 on September 19 through 22, 2007. Changes in the potentiometric surface were monitored at the pumping well and at the observation wells. Water level measurements were collected and recorded using electronic pressure transducers/data loggers and an electronic water level indicator. The constant rate test was performed at discharge rate of approximately 640 gpm. Flow rates were maintained constant for the course of the test. To estimate the aquifer transmissivity, both the Cooper-Jacob (1944) straight line method and Theis (1935) curve fitting method were used. The following sections present the transmissivity analysis.

Theis Curve Fitting Method

The first method used to estimate the transmissivity of the aquifer was the Theis curve fitting method (Kruseman and deRidder, 1994). This method is applicable for confined aquifers and was developed with the following assumptions:

1. The aquifer is confined;
2. The aquifer has a seemingly infinite areal extent;
3. The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the test;
4. Prior to pumping, the potentiometric surface of the aquifer is nearly horizontal;
5. The aquifer is pumped at a constant discharge rate; and
6. The well penetrates the entire thickness of the aquifer and receives water by horizontal flow.

Cooper-Jacob Straight Line Method

The second method used to estimate the transmissivity of the aquifer was Jacob's straight line method (Kruseman and de Ridder, 1994). This method is also applicable for confined aquifers and was developed with the following assumptions:

1. The aquifer is confined;
2. The aquifer has a seemingly infinite areal extent;
3. The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the test;
4. Prior to pumping, the potentiometric surface of the aquifer is nearly horizontal;
5. $u<0.1$, where $u= r^2S/4Tt$
6. The aquifer is pumped at a constant discharge rate; and
7. The well penetrates the entire thickness of the aquifer and receives water by horizontal flow.

All aquifer test analyses have been included in Appendix A. Logarithmic time drawdown plots (Figures 1a though 1d) and semi-logaritbmic time drawdown plots (Figures 2a through 2d) were prepared using data collected from the pumping well and observation wells located at each site. Time recovery plots

(Figures 3a through 3d) were used to verify the accuracy of the time drawdown plots. A best fit line was matched to the drawdown and recovery curves, and the change in drawdown and recovery per log cycle of time was used to calculate the aquifer parameters. The results of the analysis indicate that transmissivity of the aquifer ranges from approximately 6,700 square feet per day (ft^2/day) or 50,110 gallons per day per foot (gpd/ft) to 10,040 ft^2/day or 75,090 gpd/ft. Based on the boring logs the aquifer thickness is approximately 175 feet. The storage coefficient of the aquifer ranges from 0.001 to .0002, which are reasonable values for a confined or leaky confined aquifer.

A semi-logarithmic distance drawdown plot is included in Appendix A as Figure 4. The distance-drawdown method uses an especially wide area for the analysis and generates an estimate of the *regional* value of the hydraulic parameters of the aquifer. As shown, there was an excellent correlation between observed drawdown and theoretical drawdown at a transmissivity of 50,110 gpd/ft and a storage coefficient of 0.001.

Once the site specific aquifer parameters were estimated, those values were introduced into the equation to solve for u, to evaluate the applicability of the Cooper-Jacob solution for this test. Based on the aquifer parameter values calculated, the practical condition for applicability of the Cooper-Jacob solution was satisfied. A table of the calculated transmissivity and storage coefficient values is presented below.

METHOD	WELL ID	TRANSMISSIVITY gpd/ft	STORAGE COEFICIENT
Distance Drawdown	All OWs	50,110	0.001
Theis/Cooper-Jacob	OW-100	57,970	0.0001
Theis/Cooper-Jacob	OW-300	58,570	0.0002
Theis/Cooper-Jacob	OW-600	62,230	0.0002
Theis/Cooper-Jacob	OW-1,500	72,850	0.0002
Time Recovery	OW-100	59,080	NA
Time Recovery	OW-300	59,280	NA
Time Recovery	OW-600	62,120	NA
Time Recovery	OW-1,500	75,090	NA

NA - Not Applicable

When the results of the analysis performed are compared, the various analytical methods yield similar results except for the time drawdown/recovery for OW 1,500 Data from this observation well appear to be impacted by leakage effects or by the heterogeneity of the aquifer (OW-1,500 is located in a more permeable portion of the aquifer).

Based on the analysis performed, Layne concludes that a representative transmissivity of the aquifer at the test site is 50,100 gpd/ft (6,700 ft^2/day) and the storage coefficient of the aquifer is 0.0001. From the boring logs, the aquifer thickness at the Site is 175 feet, which yields a hydraulic conductivity of 38 ft/day. The calculated aquifer parameters are be within the range of values for the Dakota Formation (IGS, 1983).

SAFE YIELD ANALYSIS

A qualitative review of the aquifer safe yield was performed by evaluating the drawdown and recovery data collected from the observation wells. Several qualitative rules of thumb are used by groundwater practitioners to evaluate the safe yield of an aquifer based on results of a pumping test. Generally, one of the following three responses is observed during the recovery phase of the aquifer test:

1. Recovery occurs in a period of time that is shorter than the time the well was pumped. For this situation it can be stated that the well was pumped below the safe yield of the system.
2. Recovery occurs in a period of time that is greater than the time the well was pumped. For this situation it can be stated that the well was pumped above the safe yield of the system.
3. Recovery occurs in a period of time that is approximately equal to the time the well was pumped. For this situation it can be stated that the well was pumped at the safe yield of the system.

The observation wells all recovered to near static water level conditions within approximately fifty (50) hours after pumping had stopped. Because the observed time to near full recovery was much less than the pumping time (72 hours) it can be stated that the well was tested at a rate that is lower than the safe yield of the aquifer.

RECOMMENDED PUMP SETTING

The calculated site specific aquifer parameters were used to develop an estimate of the long term pumping level in a supply well at the Site. The supply well pumping water level was estimated using the Cooper-Jacob non-equilibrium equation (Cooper-Jacob, 1946). This approach incorporates the calculated aquifer parameters, available drawdown, and time of pumping to develop an estimate of well yield. The Cooper-Jacob non-equilibrium equation is presented below, assuming consistent units:

$$s = \frac{2.3Q}{4\pi T} \log \frac{2.25Tt}{r^2 S}$$

where:

s = aquifer drawdown (feet)
Q = pumping rate (ft^3/day)
T = aquifer transmissivity (ft^2/day)
t = time of pumping (days)
r = effective well radius (feet)
S = aquifer storage (dimensionless)

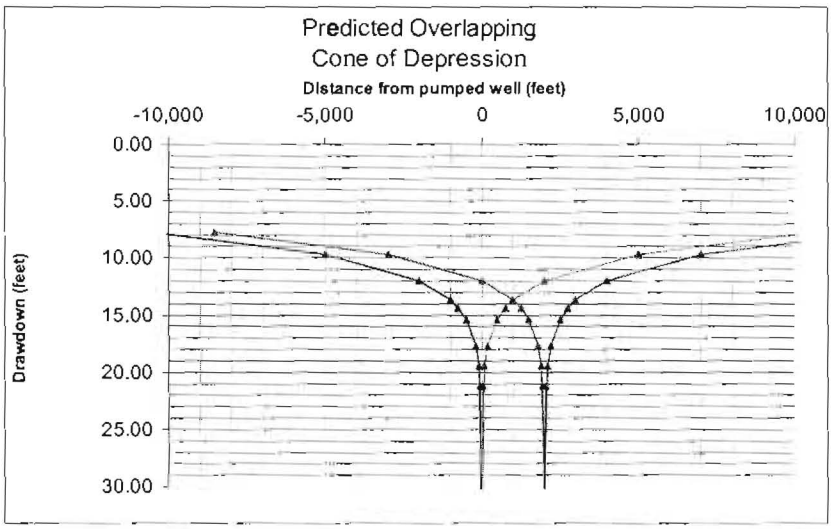
The long term supply well pumping level was estimated using the following input parameters:

Q = 550 gpm – converted to ft^3/day
T = 6,700 ft^2/day
t = 365 days
r = 1 foot (approximate borehole radius)
S = 0.0001

The pumping level in the supply well was calculated assuming the well efficiency will decrease from near 100% to 50%. Given this approach, the theoretical aquifer drawdown within the pumping well ranged from 31.1 to 62.1 feet. The static water level was recorded at 252 feet bgs, which equates into a pumping

water level of 283.1 feet (100% efficiency) to 314.1 feet bgs (50% efficiency). Calculations are presented in Appendix B.

VeraSun will operate two wells concurrently to supply the plant with process water. Therefore, estimating long term pumping levels in a supply well requires the estimation of the drawdown caused by well interference. Well interference drawdown was calculated using the Cooper-Jacob equation presented above, assuming the wells would be spaced 2,000 feet apart and will both operate at 550 gpm. Based on these input values, the calculated drawdown from well interference is approximately 12 feet, which equates into a pumping water level of 295.1 feet (100% efficiency) to 326.1 feet bgs (50% efficiency). The predicted overlapping cones of depression are shown on the figure below. Calculations are presented in Appendix B.



The lowest predicted pumping level is 326.1 feet bgs, calculated assuming a well efficiency of 50%. In practice, pump drop pipe is available in 21-foot lengths and the pitless adapter will be installed to a depth of 7 feet from grade. Therefore, Layne recommends the following pump setting options:

- 17 pipe joints: 357 feet of pipe + 7 feet of pitless = 364 feet total pump setting

SUMMARY AND CONCLUSIONS

Layne performed aquifer testing on Production Well #1 to determine drawdown, estimated yield, and interference between future wells. The test well is screened in the Dakota Formation, a confined aquifer that is locally divided into two separate and distinct aquifers. These aquifers consist of fine to coarse grained sands and gravel intermixed with sandy clay lenses.

The results of the analysis indicate that transmissivity of the aquifer range from approximately 6,700 ft^2/day or 50,110 gpd/ft to 10,040 ft^2/day or 75,090 gpd/ft. Based on the boring log the aquifer thickness is approximately 175 feet. The storage coefficient of the aquifer ranges from 0.001 to 0.0002, which are reasonable values for a confined or leaky confined aquifer. Based on the analysis performed, Layne concludes that a representative transmissivity of the aquifer at the test site is 50,100 gpd/ft (6,700 ft^2/day) and the storage coefficient of the aquifer is 0.0001.

Using the calculated aquifer parameters, Layne estimates that the operating a supply well at 550 gpm will generate approximately 62.1 feet of drawdown (assuming a 50% efficiency well). Two supply wells will be operated concurrently to supply the Plant with process water. Layne estimates the additional

drawdown in each supply well due to well interference will be approximately 12 feet. Using these calculated values, the lowest predicted pumping level is 326.1 feet bgs (assuming a well efficiency of 50%).

In practice, pump drop pipe is available in 21-foot lengths and the pitless adapter will be installed to a depth of 7 feet from grade. Therefore, Layne recommends the following pump setting options:

- 17 pipe joints: 357 feet of pipe + 7 feet of pitless = 364 feet total pump setting

Layne appreciates the opportunity to work with VeraSun Hartley, LLC on this important project. Your questions are appreciated and expected.

Sincerely,

Mark Vishnefske
Staff Hydrogeologist

Luca DeAngelis, P.E., R.G.
Senior Engineer/Hydrogeologist

Layne Western

a division of Layne Christensen Company

- Pump Test was conducted for 72-hrs
- " " involved Q = 640 gpm which was sufficient to stress the aquifer
- 4 OB wells were used at 100', 300', 600', 1500' to observe the ~~rate effects~~ variation & heterogeneity of the aquifer
- Various methods of analysis were used that indicated a range in T 50,400 to 75,090.
- The Q and the corresponding d.d. in the on-site well was evaluated, but not ~~of~~ interference with the rest of Hartley wells.
- well efficiency was factored into the estimated d.d.
- Cooper-Jacob non-equilibrium equation indicated a combined estimated interference with City of Hartley wells of 14.8' feet additional after 1 year and 20' after 10 years.

REFERENCES:

Cooper, H.H. and C.E. Jacob, 1946. A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well Field History. Am. Geophys. Union Trans. Vol. 27, pp. 526-534.

Kruseman, G.P. and de Ridder, N.A., 1994. Analysis and Evaluation of Pumping Test Data. International Institute for Land Reclamation and Improvement. The Netherlands.

Theis, C.V., 1935. The relations between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. Trans. Am. Geophys. Union Trans. Vol. 16, pp. 519-524.

Munter, J.A., Ludvigson, G.A., Bunker, B.J., 1942. Hydogeology and Stratigraphy of the Dakota Formation in Northwest Iowa. Iowa Geological Survey Bulletin No. 13. 55p.

APPENDIX A

AQUIFER TEST ANALYSIS

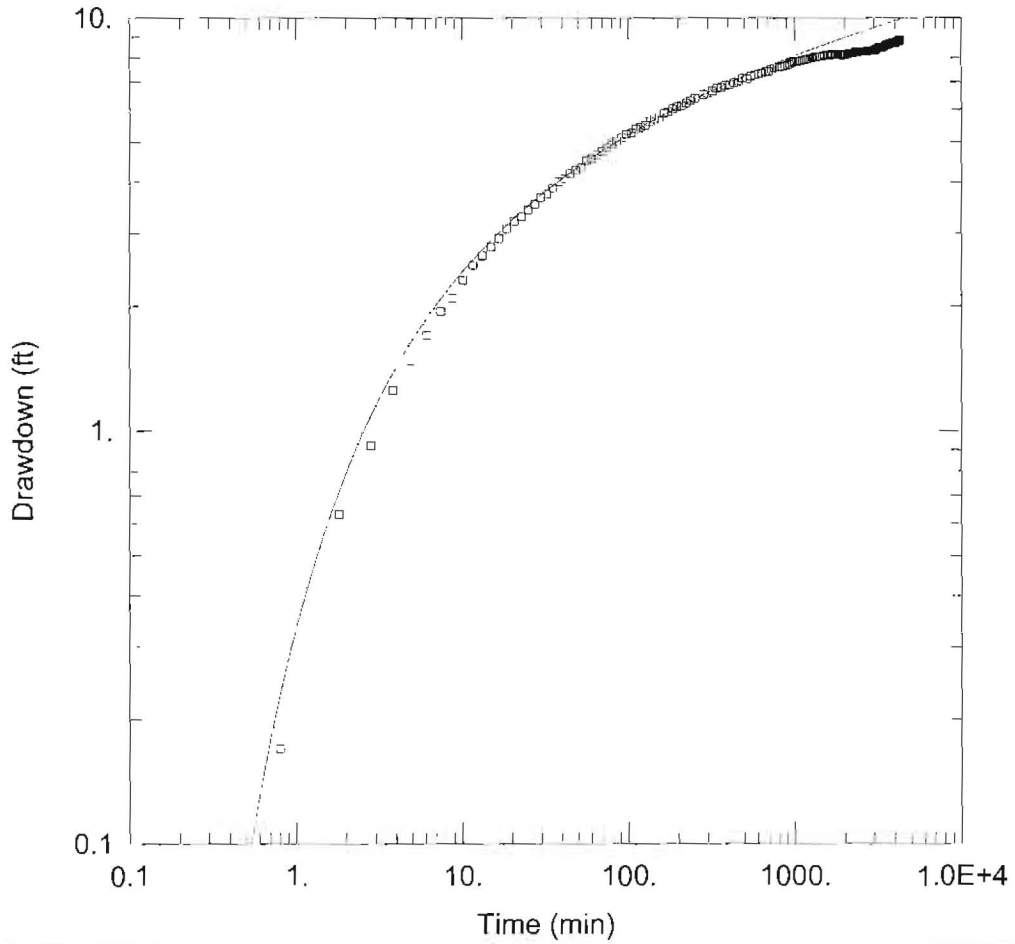


FIGURE 1B

PROJECT INFORMATION

Company: Layne
Client: VeraSun Energy
Location: Hartley,IA
Test Well: Test Well
Test Date: 9/19/07

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (ft)	Y (ft)	Well Name	X (ft)	Y (ft)
Test Well	0	0	OW-300	300	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 7831.1 ft^2/day
S = 0.0002147
Kz/Kr = 1.
b = 175. ft

44 88/km

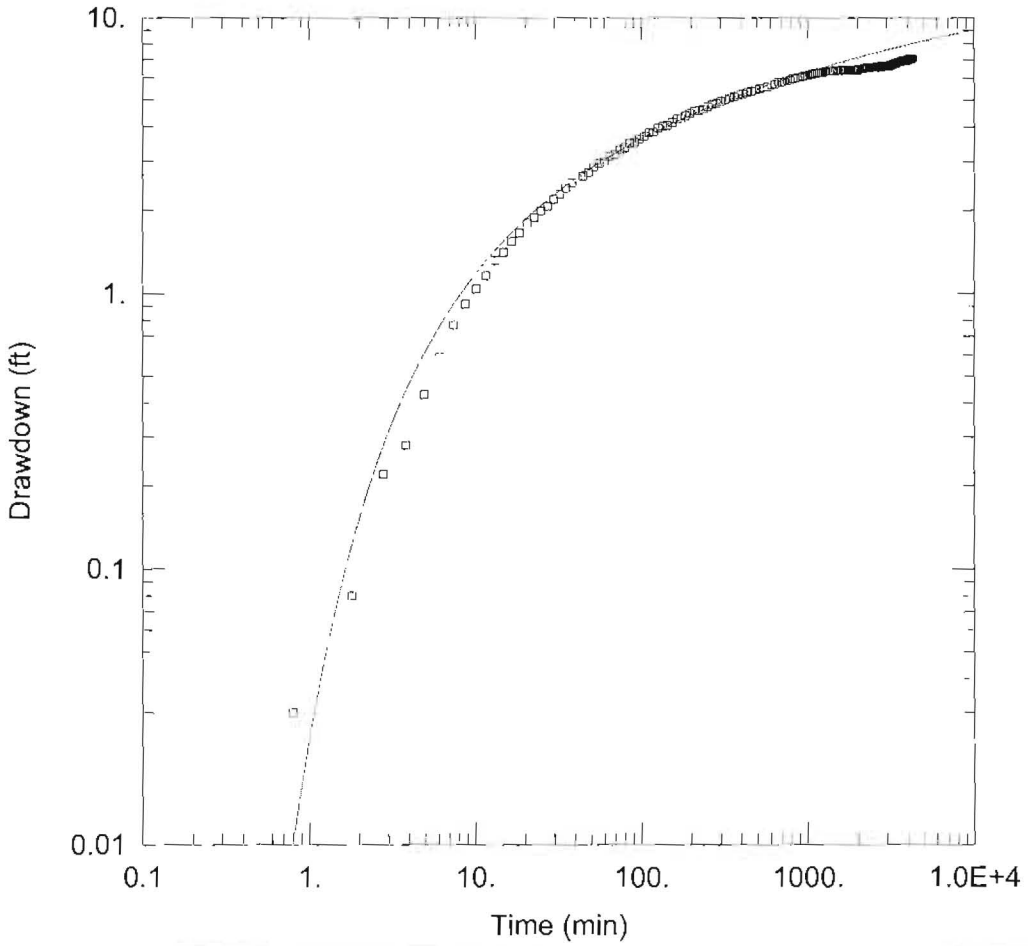


FIGURE 1C

PROJECT INFORMATION

Company: Layne
Client: VeraSun Energy
Location: Hartley,IA
Test Well: Test Well
Test Date: 9/19/07

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Test Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
OW-600	600	0

SOLUTION

Aquifer Model: Confined
T = 8321.7 ft^2/day
Kz/Kr = 1.

Solution Method: Theis
S = 0.0001711
b = 175. ft

47 sd/day

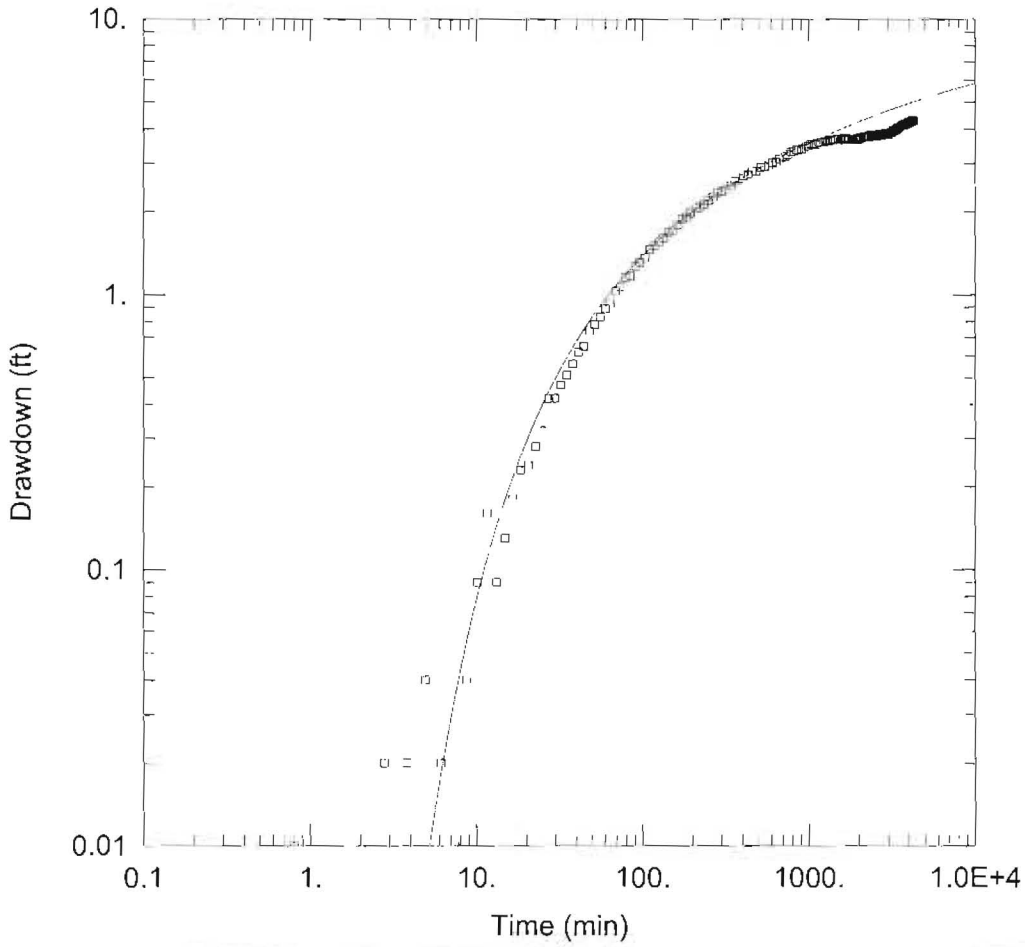


FIGURE 1D

PROJECT INFORMATION

Company: Layne
Client: VeraSun Energy
Location: Hartley,IA
Test Well: Test Well
Test Date: 9/19/07

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Test Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
OW-1500	1500	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 9740.7 ft^2/day
S = 0.0002018
Kz/Kr = 1.
b = 175. ft

55.6 ft/day

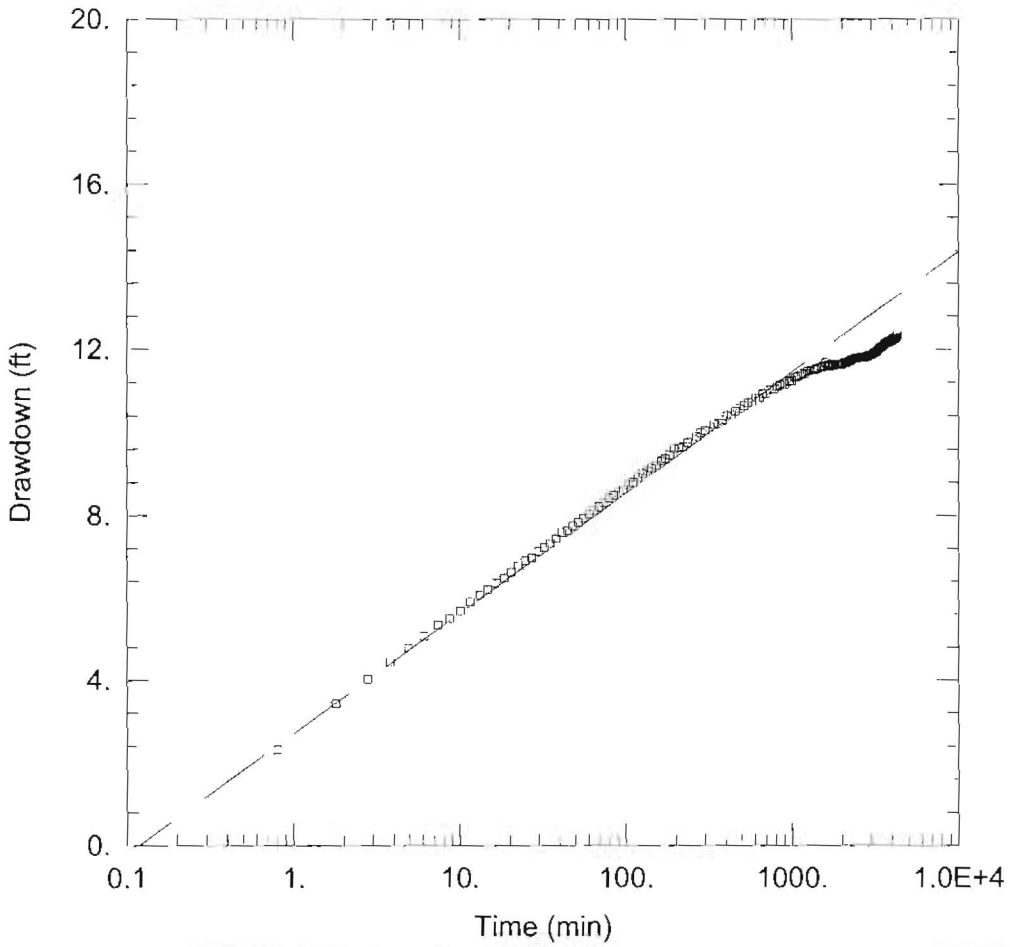


FIGURE 2A

PROJECT INFORMATION

Company: Layne
Client: VeraSun Energy
Location: Hartley,IA
Test Well: Test Well
Test Date: 9/19/07

AQUIFER DATA

Saturated Thickness: 175. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Test Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
OW-100	100	0

SOLUTION

Aquifer Model: Confined

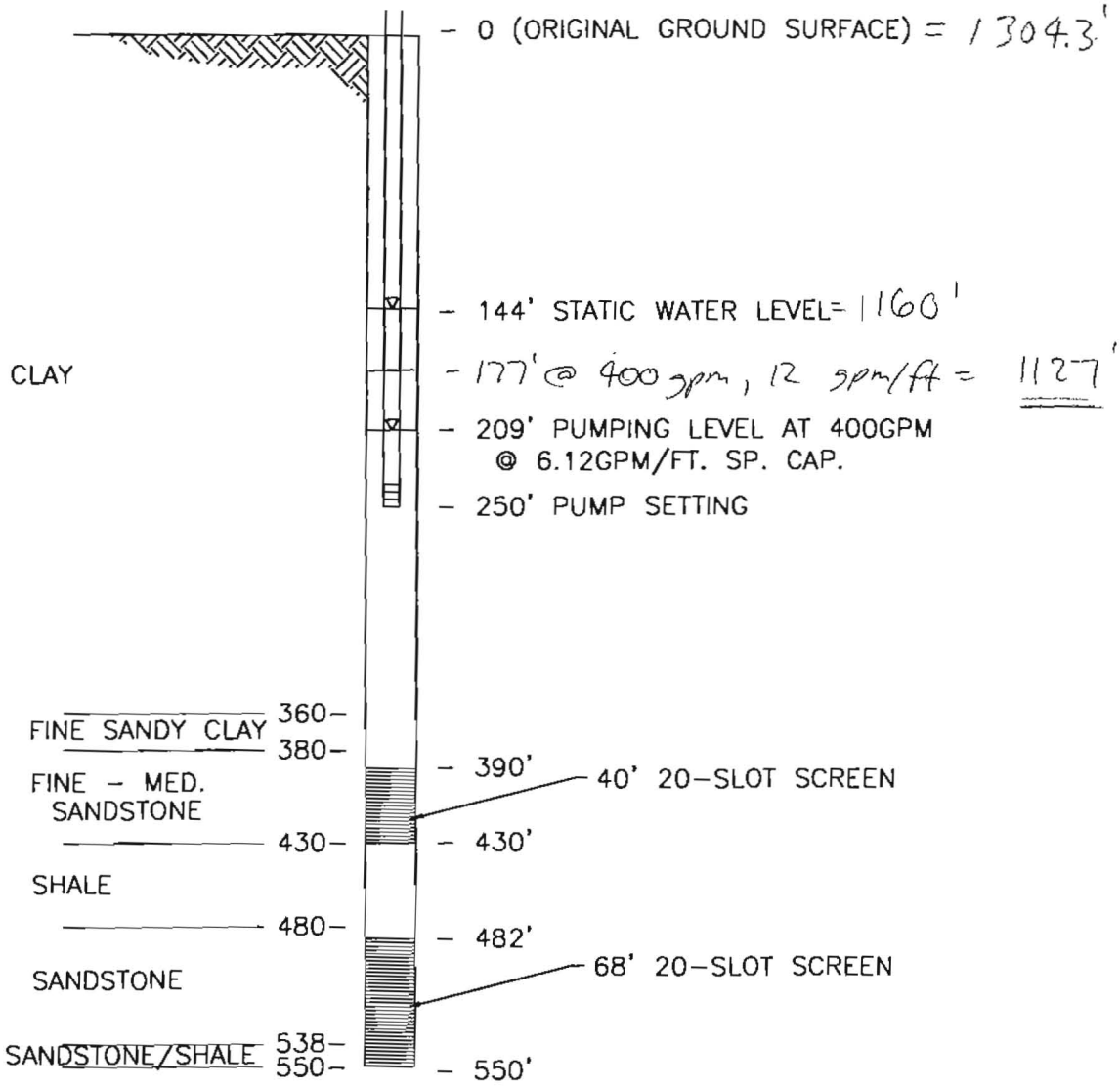
Solution Method: Cooper-Jacob

T = 7755.5 ft^2/day

S = 0.0001433

49 58/59

T/aerator @ 1350'



DEEP WELL SECTION (WELL#9)

VERTICAL SCALE: 1"= 100'

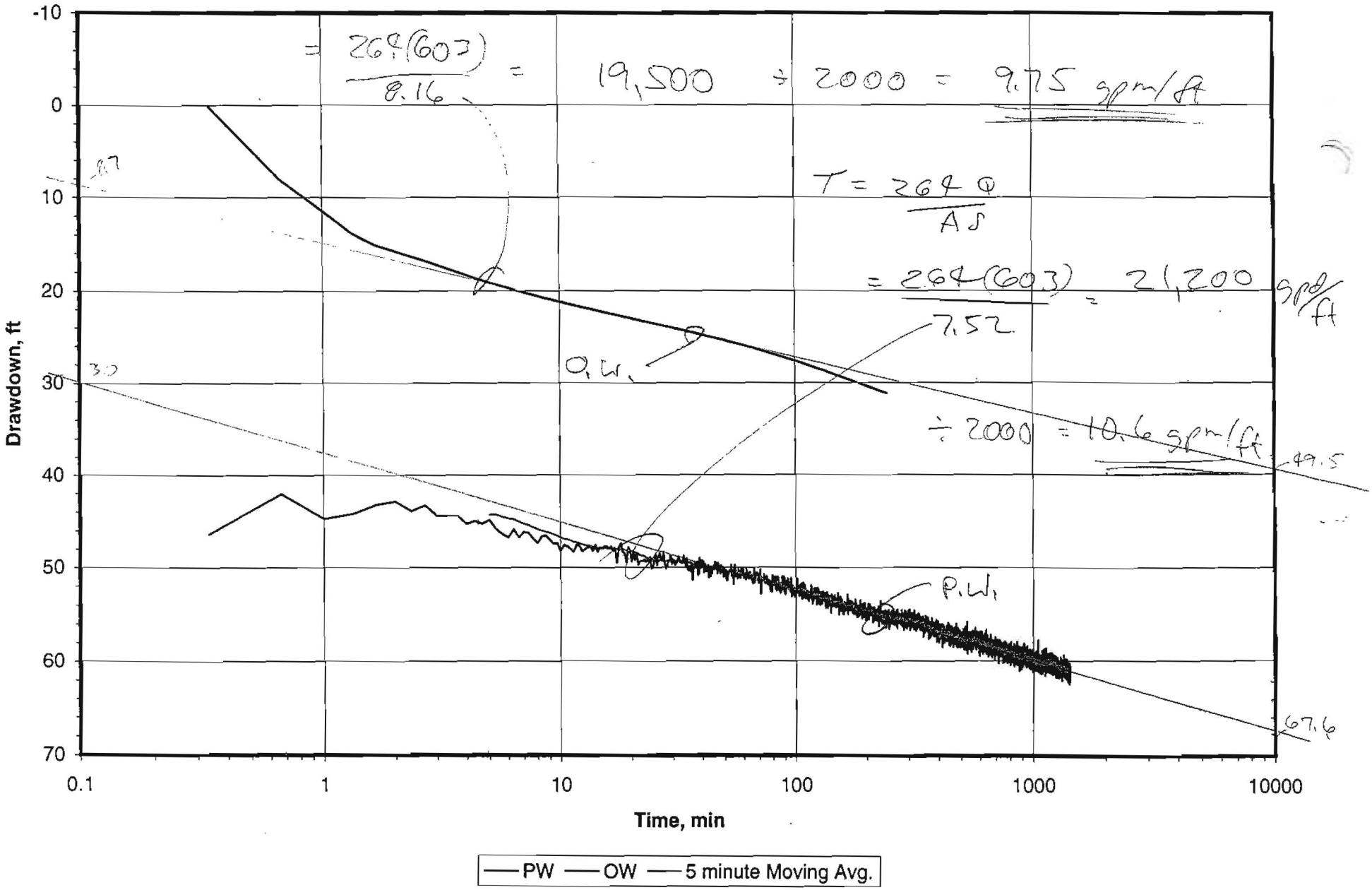
P:\08\178\01\WELLDWG\WO9ELEV.DWG

DeWild Grant Reckert and Associates Company
Consulting Engineers
Rock Rapids, Iowa
Sioux Falls, South Dakota
Sioux City, Iowa

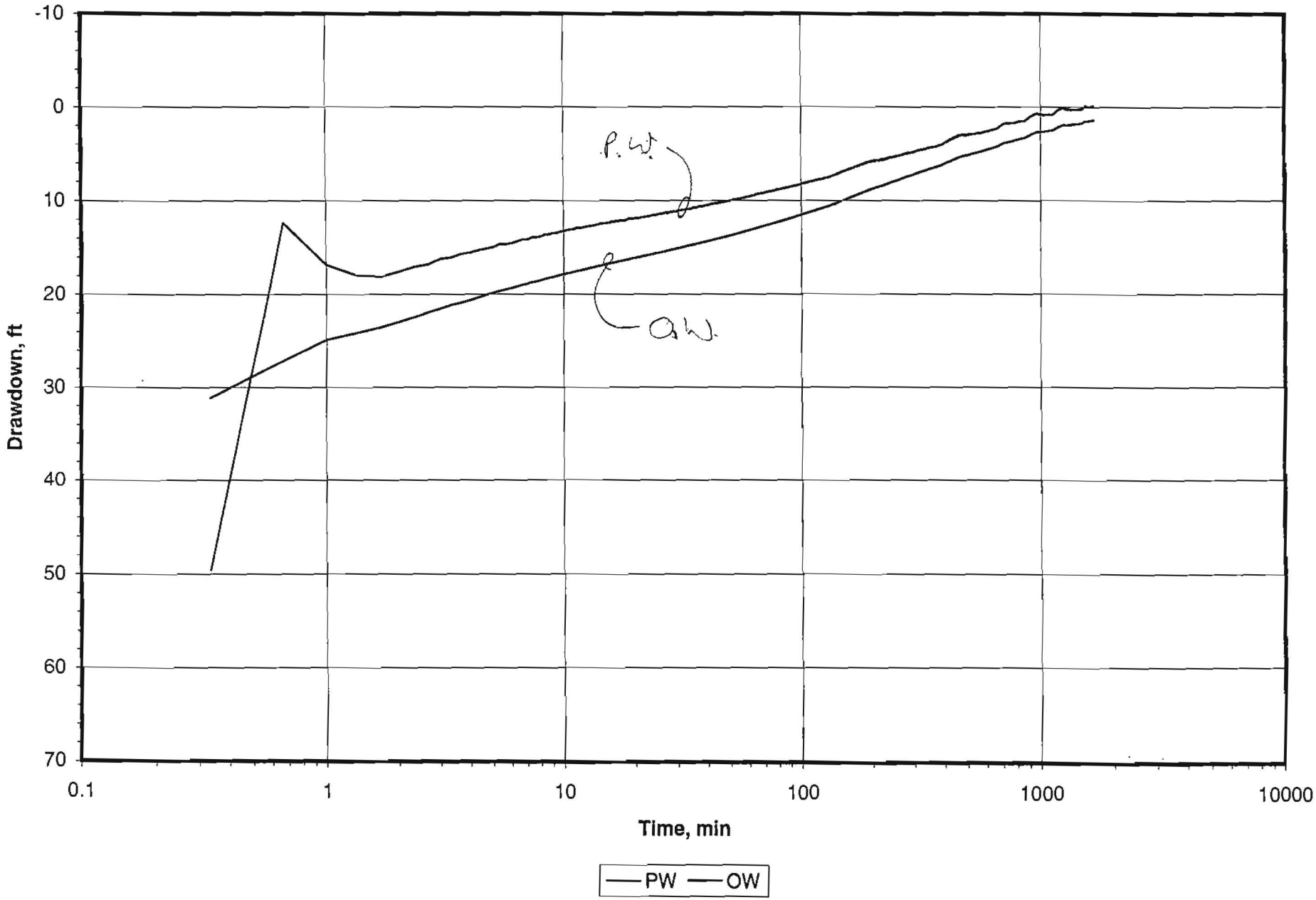
Date August 2001
Drawn By WBR
Approved GJP
Revised
Project No. 817801

CITY OF REMSEN
WELLS 8 AND 9

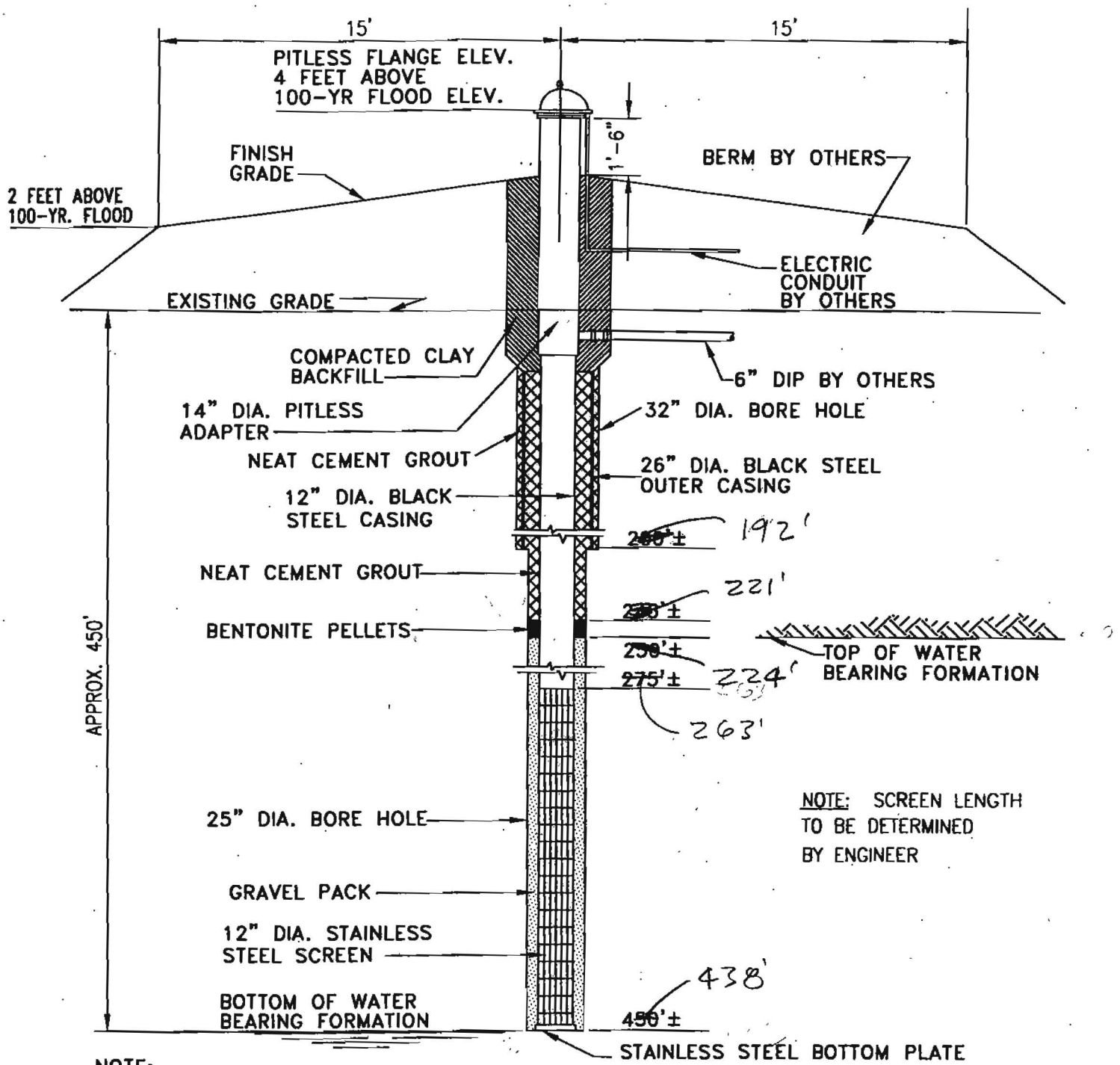
Remsen Deep Well Pump Test - 24 hr Test
July 10-11, 2001



Remsen Deep Well Pump Test - Recovery Test
July 11-12, 2001



Well D-3



NOTE:
CONTRACTOR SHALL INSTALL PITLESS ADAPTER AND PUMP. TERMINATE MOTOR CABLE AT PITLESS CAP. CAP AND SEAL PITLESS DISCHARGE TO PREVENT ENTRY OF GROUND WATER.

SECTION VIEW

PRODUCTION WELL AND PITLESS UNIT

NOT TO SCALE (17801020\17801021)

P:\08\018\05\F085X11.DWG

DGR
DeWild Grant Reckert and Associates Company
Consulting Engineers
Rock Rapids, Iowa
Sioux City, Iowa
Sioux Falls, South Dakota

Date Oct. 2000
Drawn By WBR
Approved GJP
Revised
Project No. 801805

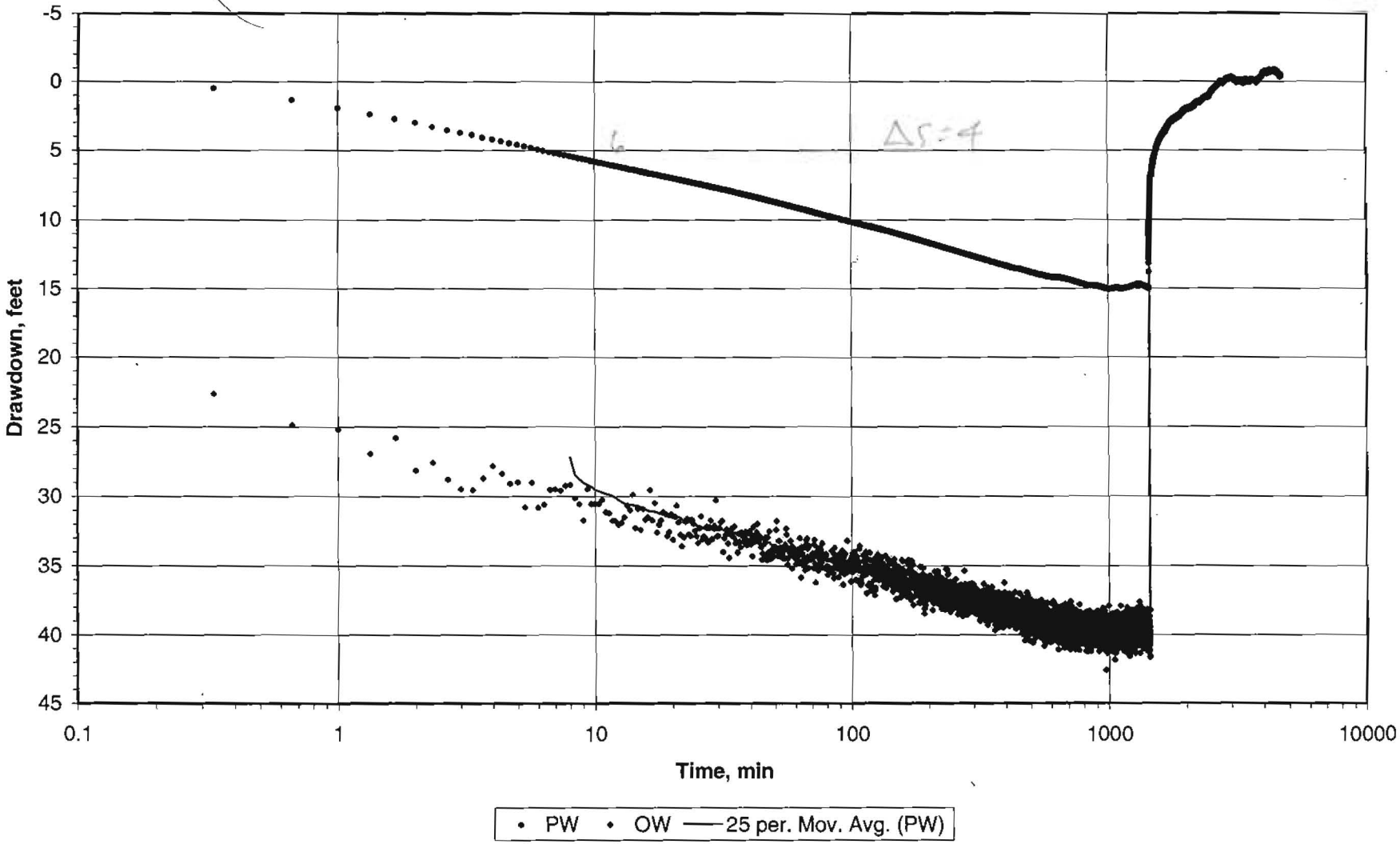
SOUTHERN SIOUX COUNTY RURAL WATER SYSTEM
IRETON, IOWA

1,000 gpm

SSCRWS Well D-3 24-hr Test
June 8-9, 2001

$T = \frac{(264)Q}{\Delta s} = \frac{264{,}000}{4}$

66,000 gpd/ft



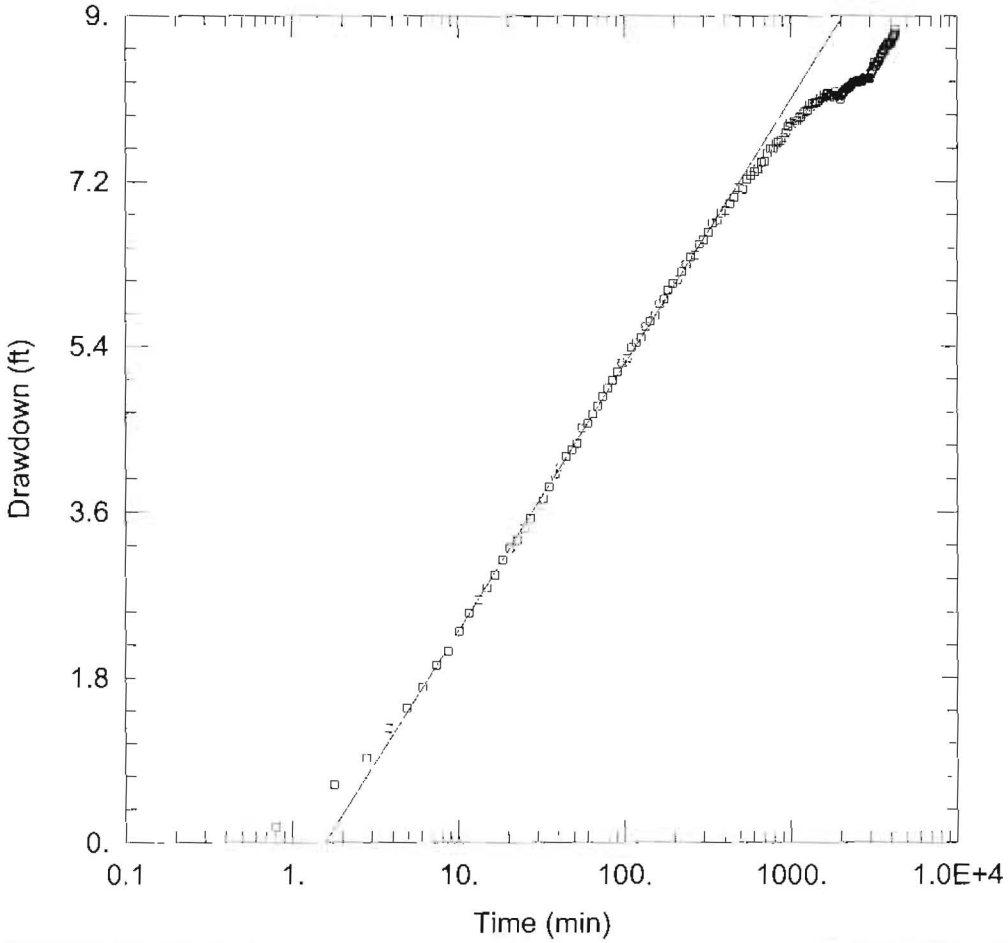


FIGURE 2B

PROJECT INFORMATION

Company: Layne
Client: VeraSun Energy
Location: Hartley,IA
Test Well: Test Well
Test Date: 9/19/07

AQUIFER DATA

Saturated Thickness: 175. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Test Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
OW-300	300	0

SOLUTION

Aquifer Model: Confined

Solution Method: Cooper-Jacob

T = 7831.1 ft^2/day

S = 0.0002147

45 51/85

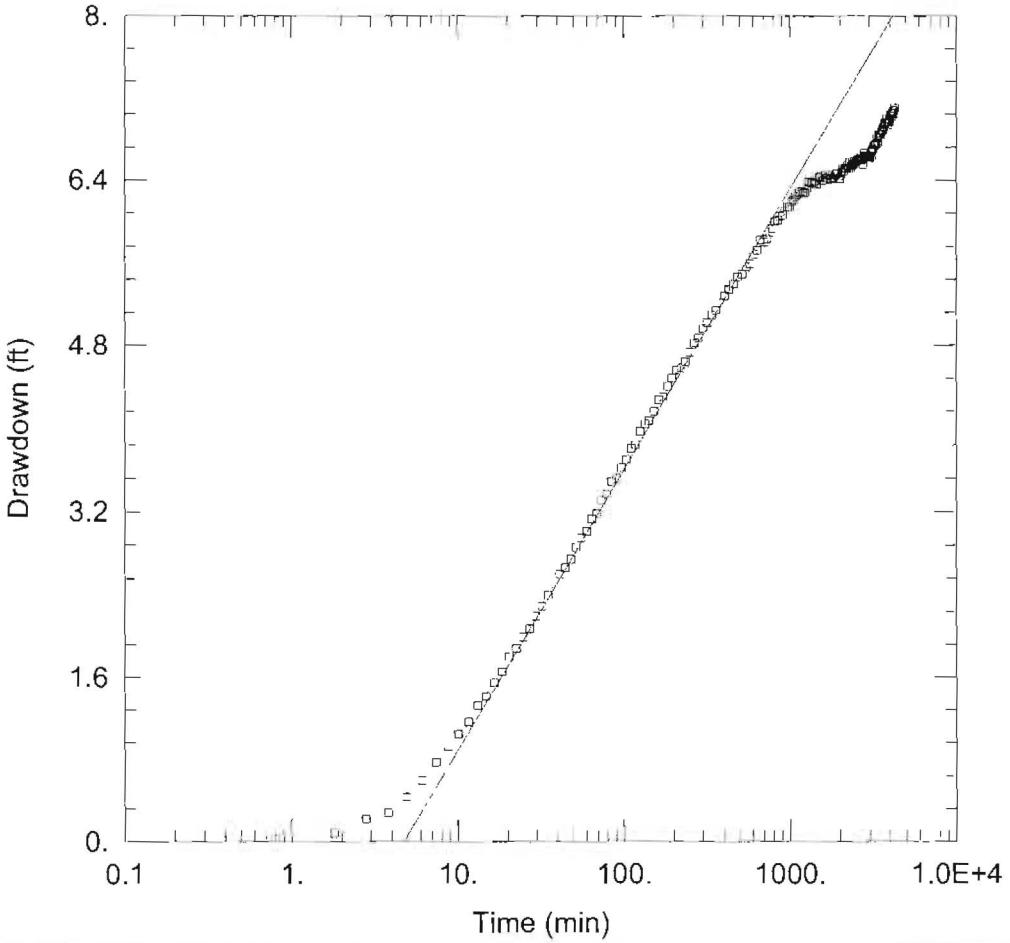


FIGURE 2C

PROJECT INFORMATION

Company: Layne
Client: VeraSun Energy
Location: Hartley,IA
Test Well: Test Well
Test Date: 9/19/07

AQUIFER DATA

Saturated Thickness: 175. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Test Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
OW-600	600	0

SOLUTION

Aquifer Model: Confined

Solution Method: Cooper-Jacob

T = 8321.7 ft^2/day

S = 0.0001711

48 SH/MG

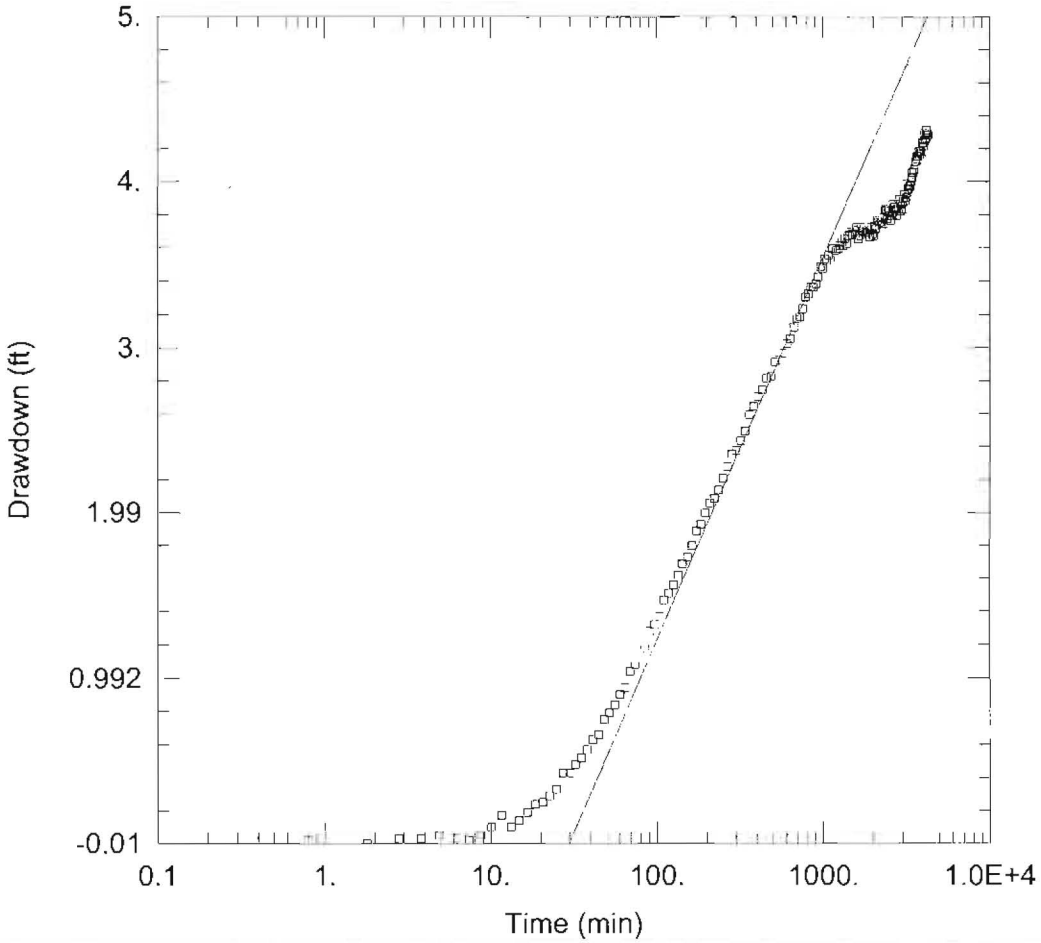


FIGURE 2D

PROJECT INFORMATION

Company: Layne
Client: VeraSun Energy
Location: Hartley,IA
Test Well: Test Well
Test Date: 9/19/07

AQUIFER DATA

Saturated Thickness: 175. ft

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Test Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
OW-1500	1500	0

SOLUTION

Aquifer Model: Confined

Solution Method: Cooper-Jacob

T = 9740.7 ft^2/day

S = 0.0002018

56 SS/03

Figure3b
VeraSun Energy
Hartley,IA
Time Recovery Analysis

OW-300

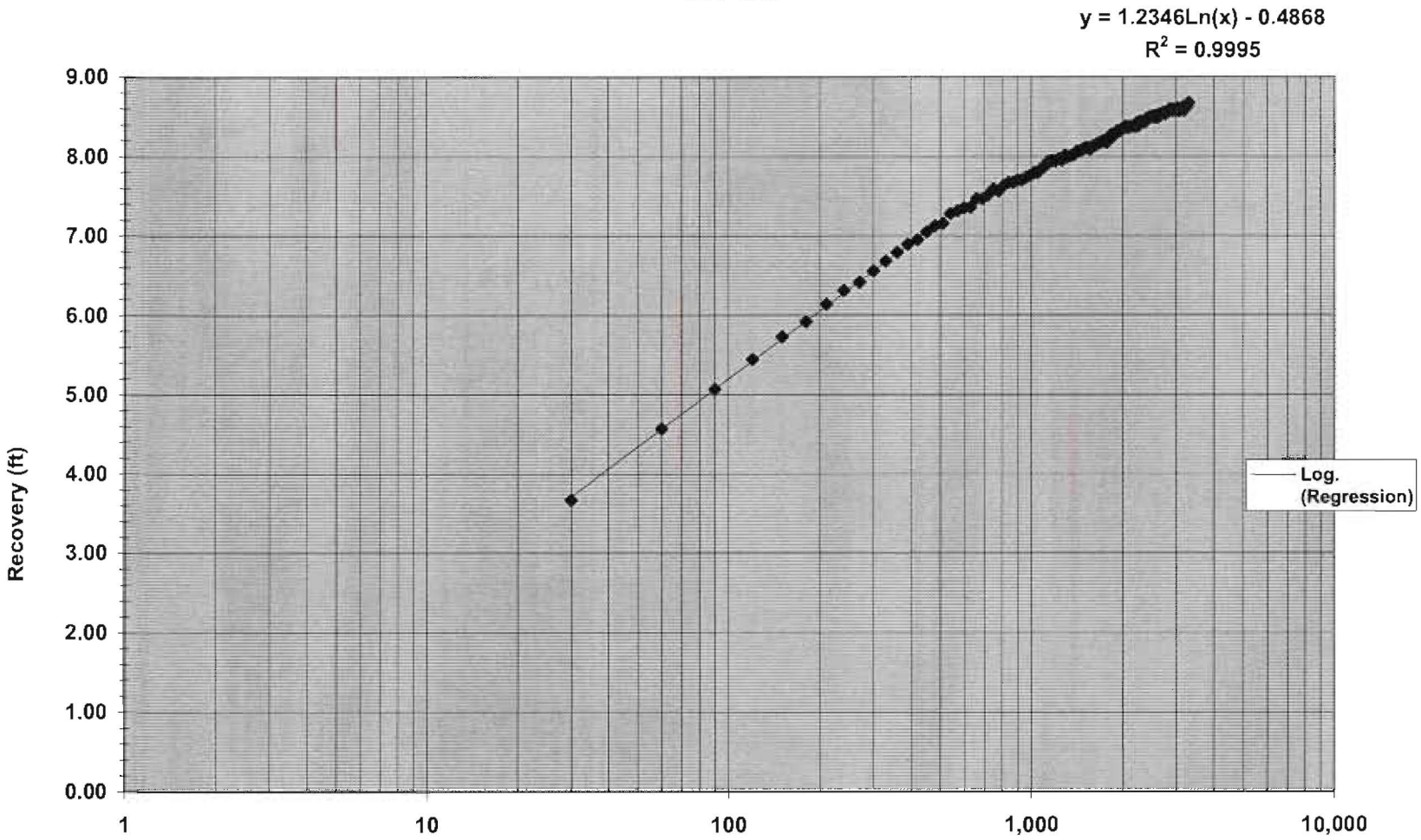


Figure 3c
VeraSun Energy
Hartley,IA
Time Recovery Analysis

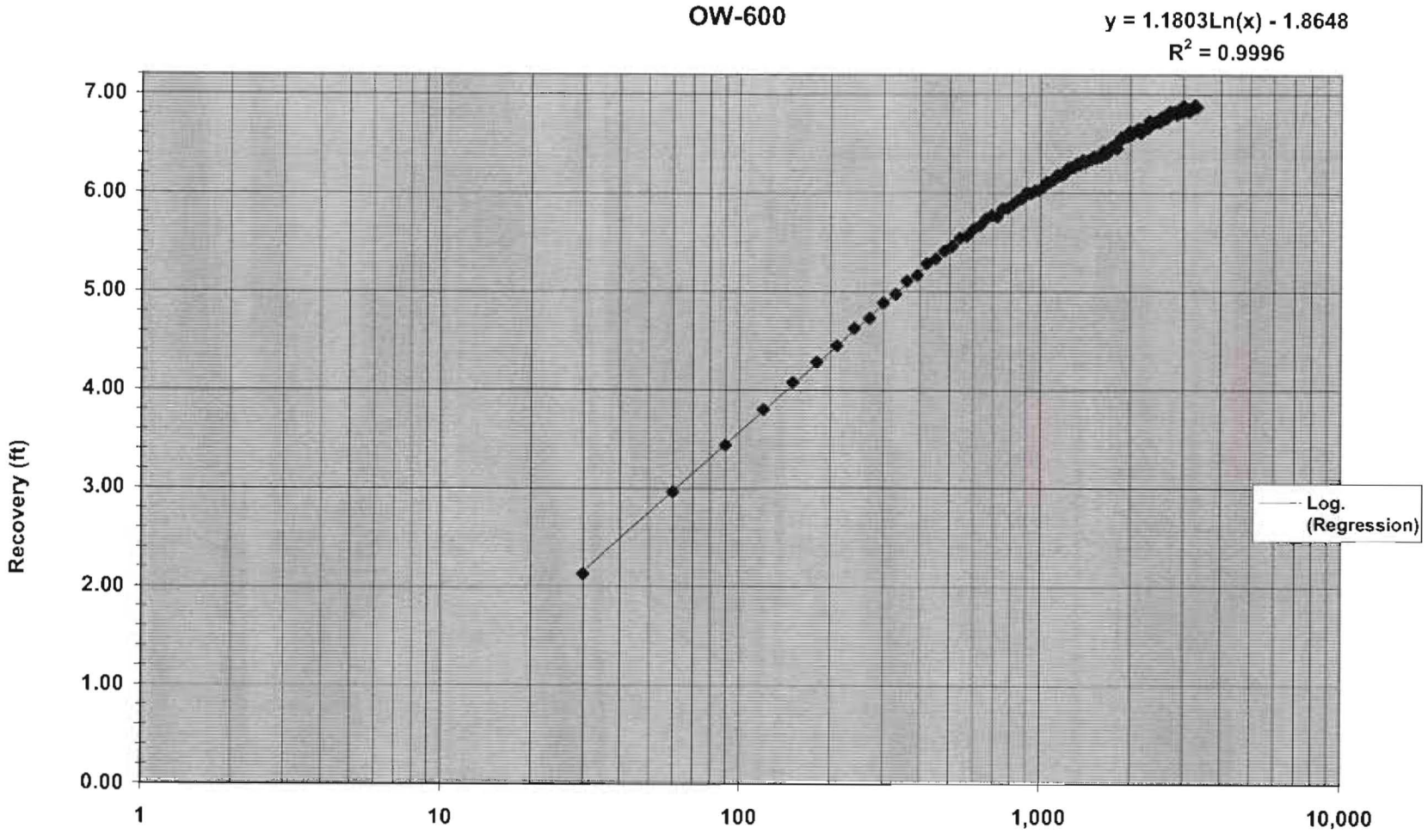
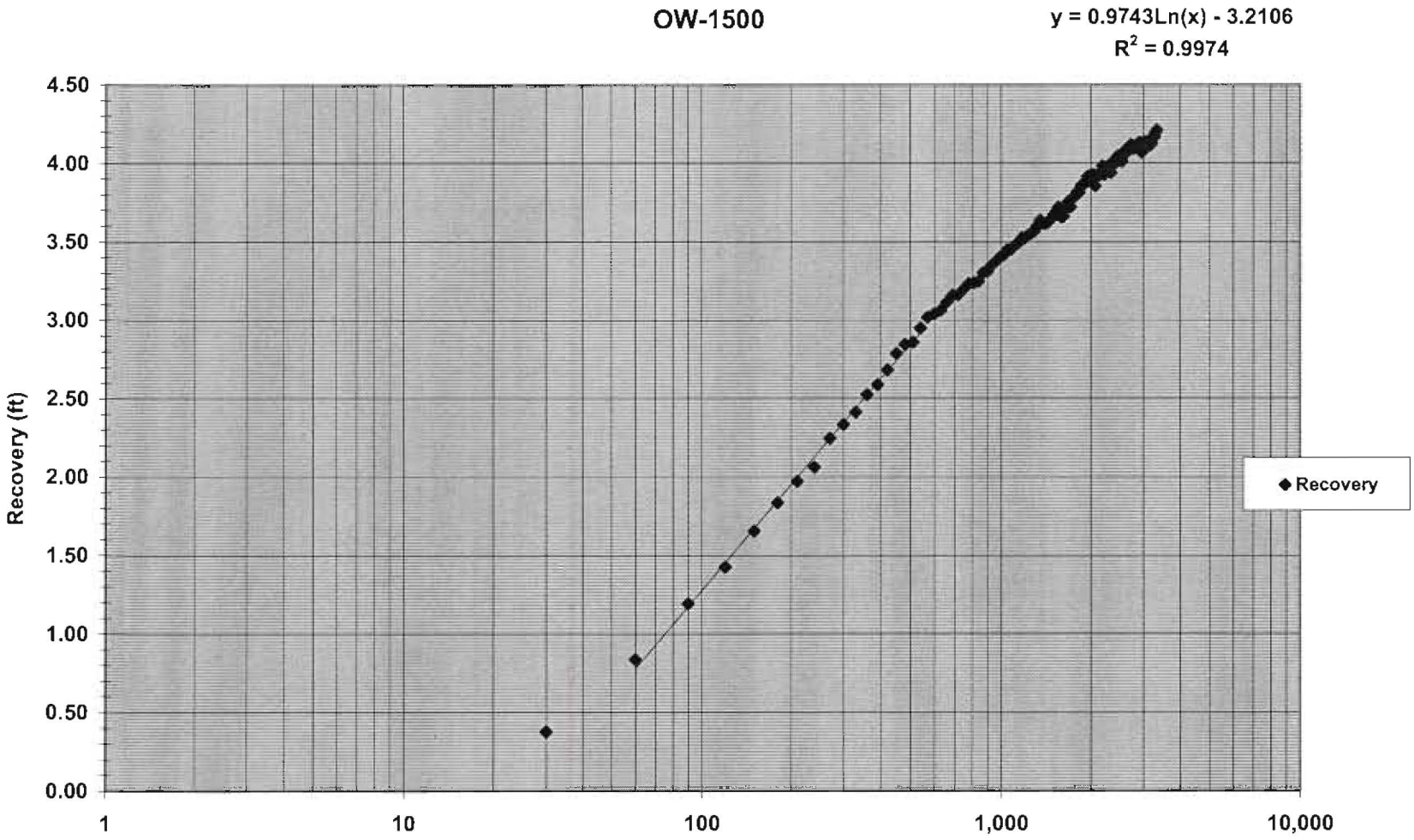


Figure3d
VeraSun Energy
Hartley,IA
Time Recovery Analysis



Time Recovery Analysis

$$T = \frac{264\ Q}{\text{delta s}}$$

Q (pump rate) (gpm) 640
T (transmissivity)

OW-100

Delta s =	2.86	100	5.74
T (gal/day/ft)	59076.92	1000	8.6
T (ft^2/day)	7897.98	delta s	2.86

OW-300

Delta s =	2.85	10	2.35
T (gal/day/ft)	59284.21	100	5.2
T (ft^2/day)	7925.70	delta s	2.85

OW-600

Delta s =	2.72	10	0.85
T (gal/day/ft)	62117.65	100	3.57
T (ft^2/day)	8304.50	delta s	2.72

OW-1500

Delta s =	2.25	10	-0.97
T (gal/day/ft)	75093.33	100	1.28
T (ft^2/day)	10039.22	delta s	2.25

Figure 3a
VeraSun Energy
Hartley, IA
Time Recovery Analysis

OW-100

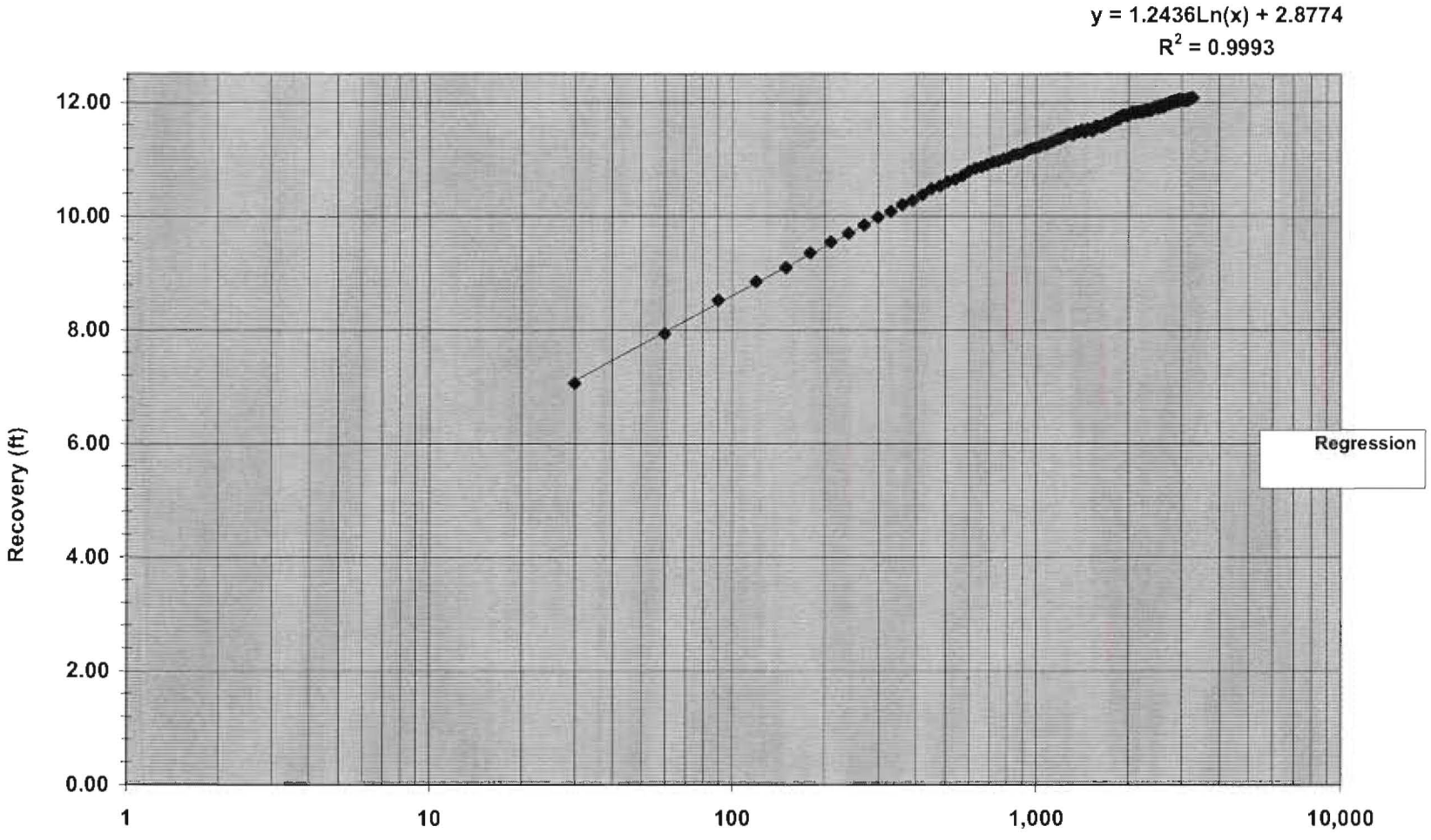
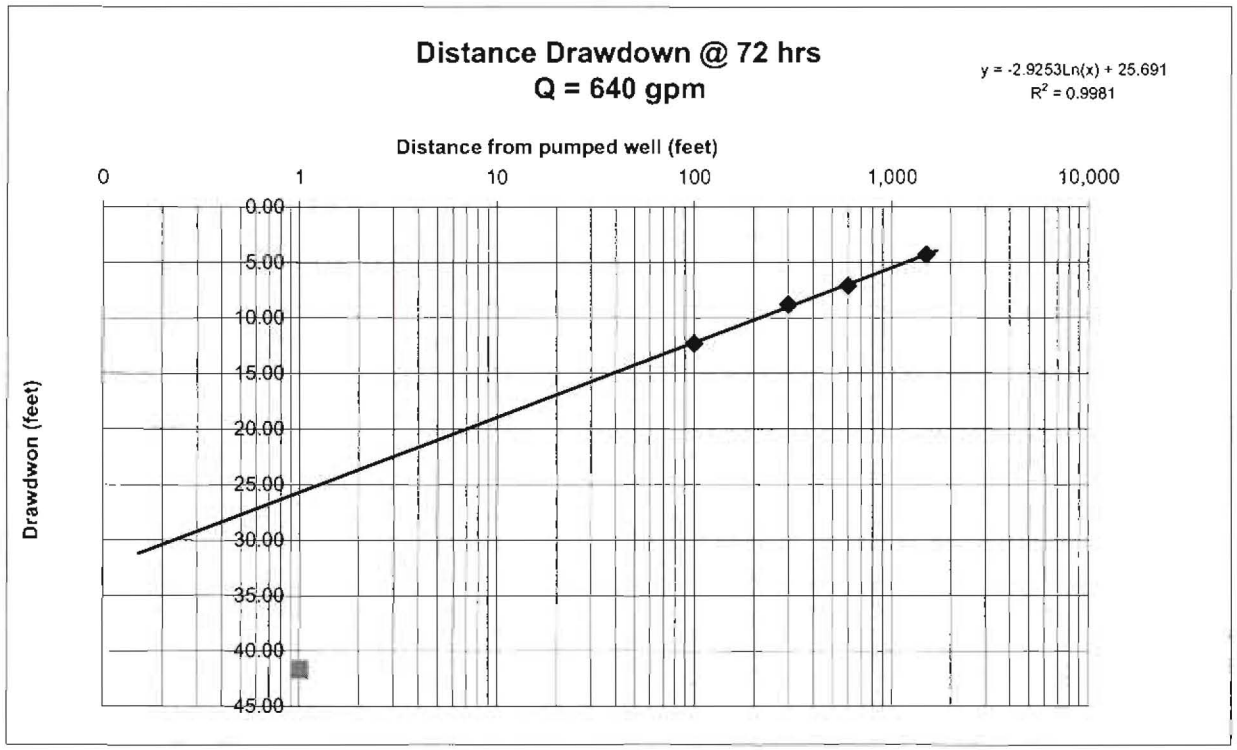


Figure 4
VeraSun Energy
Hartley, Iowa
Distance Drawdown Analysis

Project. Vera Sun - Hartley, IA Site
Well. TW-1 Time
Location: 72 hrs
Date 9/19/2007

Well Efficiency Using Distance Drawdown for Well TW-1

Well	Distance from pumped well (feet)	Static Water Level (ft below TOC)	Water Level End (ft below TOC)	Observed Drawdown End (feet)
TW-1	1.00			41.67
OW-100	100	248.00	260.30	12 30
OW-300	300	253.30	262 10	8.80
OW-600	600	248.30	255.40	7.10
OW-1500	1,500	254.00	258.30	4.30



L:\Common\Hydrology\Omaha\DesMoines Office\VeraSun\pump test data\Hartley Design Test September 2007\Preliminary_distance_Drawdown.xls

Distance Drawdown Data

$$T = \frac{2.3Q}{2\pi\Delta s}$$

	PUMP WELL	
	gpm	ft3/day
Q =	640	123208.6
delta s (ft) =	6.74	
T (ft2/day) =	6,696	
T (gal/day/ft)	50,085	
b(feet)=	175	ESTIMATED
K(ft/day)=	38.26176977	

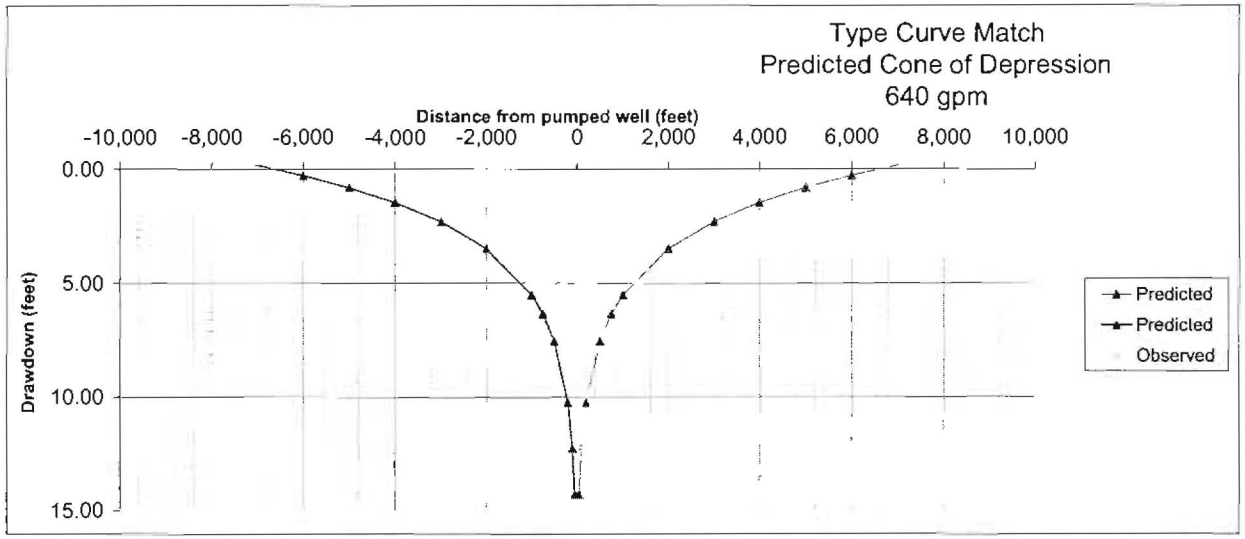
$$S = \frac{2.25\,Tt_0}{r^2}$$

r (feet)	6620
to (day)	3.00
S	0.001031314

VeraSun Energy
Hartley,Iowa
Distance Drawdown Analysis

Distance Drawdown Data

Pumping Rate (gpm)	Radius of Cone of Depression (ft)	Estimated Drawdown at Edge of Cone of depression (feet)	Radius of Cone of Depression (ft)	Estimated Drawdown at Edge of Cone of depression (feet)
640	50	14.29	-50	14.29
	100	12.26	-100	12.26
	200	10.24	-200	10.24
	500	7.56	-500	7.56
	750	6.37	-750	6.37
	1,000	5.53	-1,000	5.53
	2,000	3.50	-2,000	3.50
	3,000	2.32	-3,000	2.32
	4,000	1.47	-4,000	1.47
	5,000	0.82	-5,000	0.82
	6,000	0.29	-6,000	0.29
	7,000	-0.16	-7,000	-0.16
	8,000	-0.55	-8,000	-0.55
	10,000	-1.21	-10,000	-1.21



APPENDIX B

PUMP SETTING CALCULATIONS

VeraSun Energy
Hartley,Iowa
Impact of Future Well

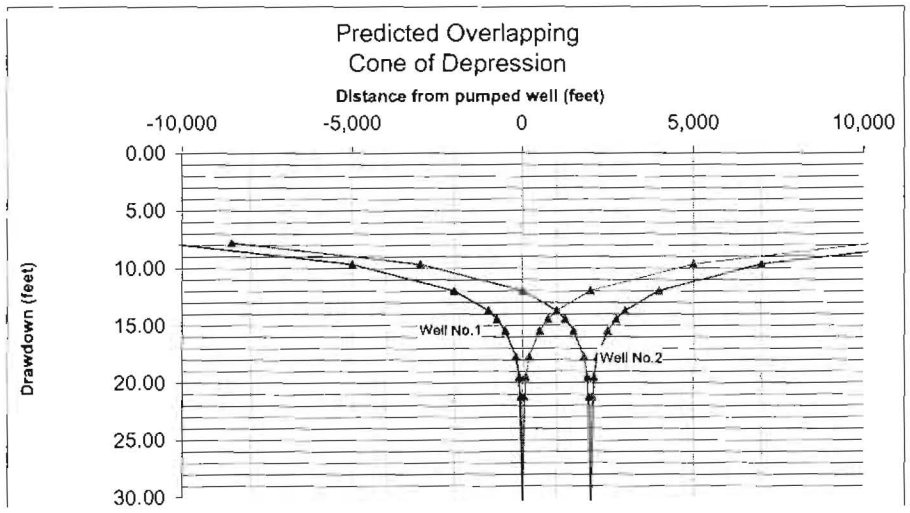
Distance Drawdown Data

Pumping Rate (gpm)	Radius of Cone of Depression (ft)	Estimated Drawdown at Edge of Cone of depression (feet)	Radius of Cone of Depression (ft)	Estimated Drawdown at Edge of Cone of depression (feet)
550	50	21.23	-50	21.23
	1	31.07	-1	31.07
	100	19.49	-100	19.49
	200	17.75	-200	17.75
	500	15.44	-500	15.44
	750	14.43	-750	14.43
	1,000	13.70	-1,000	13.70
	2,000	11.96	-2,000	11.96
	5,000	9.66	-5,000	9.66
	10,560	7.78	-10,560	7.78

wells (feet)

Second Well

	-x	x	
2000	1950.00	2050.00	21.2
	1999.00	2001.00	31.1
	1900.00	2100.00	19.5
	1800.00	2200.00	17.7
	1500.00	2500.00	15.4
	1250.00	2750.00	14.4
	1000.00	3000.00	13.7
	0.00	4000.00	12.0
	-3000.00	7000.00	9.7
	-8560.00	12560.00	7.8



Supply well pumping level

Non Equilibrium Equation

$$s = \frac{2.3Q}{4\pi T} \log \frac{2.25Tt}{r^2 S}$$

Where:
Q=Well Pumping Rate (ft3/day)
t=time of pumping (days)
T=Aquifer Transmissivity (ft2/day)
S=Aquifer Storage (dimensionless)
r=radius of well bore (ft)
s=theoretical drawdown (100% efficient well)

Q (gpm)	Q (ft3/day)
550	105882.353

t (day)
365

T(ft2/day)
6696

S (dimensionless)
0.0001

r (ft)
1

SOLUTION
s = 31.08

Drawdown in Pumping Well - Various Well Efficiencies

Theoretical Drawdown	Estimated Pumping Level	% Efficiency
31.1	283.1	100
34.5	286.5	90
38.9	290.9	80
44.4	296.4	70
51.8	303.8	60
62.2	314.2	50