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IDENTIFICATION AQUIFER PARAMETERS THROUGH SINGLE WELL PUMPING TEST SERIES AT PT. KALTIM KARIANGAU TERMINAL, BALIKPAPAN, EAST KALIMANTAN

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Abstract

Aquifer Parameters are very important in groundwater and well management. The objective of this research is to determine aquifer parameter in order to be used in determining suitable production rate of well. Research was carried out in PT. Kaltim Kariangau Terminal, which is administratively, located in Balikpapan City, East Kalimantan, Indonesia. PT. Kaltim Kariangau Terminal has developed four wells with distance of each of well is between 50 and 300 meters, but it is a pity because just one well was completed by pumping test without observation well. Result of constant pumping test analyzing through Cooper – Jacob method has shown that value of Transmissivity (T) of aquifer is 319.0718283 m2/day, and it is known from geophysical logging and well construction design that the thickness of aquifer is 48 m, so hydraulic conductivity (K) of aquifer is 6.6473 m/day. Coefficient of aquifer loss is 0.0013 and coefficient of well loss is 0.0000008. Factors development of well could be classified as very effective with the well condition is properly designed and developed.

Keyword: groundwater, aquifer, transmissivity, hydraulic conductivity.

INTRODUCTION

Human body consists of almost 50-70% of water (Slamet, 1994), therefore it is undeniable that water is vital source of life, even bad quality of water in Indonesia has been reported for causing up to 88% dead of child (UNICEF, 2012). It has been known for thousand years ago, in order to support human living, people has been using many source of water such as, rain, stream, and groundwater. In many area that geologically have ground water reserves most people get ground water through, spring, qanats, artesian well, dug well and drilled deep well.

Groundwater reserves in this world is 0.61% and surface water is 0.009% from total groundwater reserves (Fetter, 1994). This means ratio between surface water and groundwater is 1/67.78. Now day, where the existing of ground water could be detected through many tools such as hydrogeological knowledge, geophysical survey so that, groundwater have been explored and exploited much more.

Groundwater exploitation through deep well has become alternative to get more water which is needed in abundant amount for various industry need, such as hotels, textile, drinking water, hospital, agriculture etc. Recently, the advance of drilling technology and subsurface knowledge enable well getting much deeper that cross cut several aquifers systems so it could collect more water and increase well productivity. Meanwhile well productivity will be determined by aquifer parameters such as hydraulic conductivity, transmissivity, and well construction design or development factors of well. So that getting data of Transmissivity and hydraulic conductivity is paramount, because transmissivity and hydraulic conductivity are among the most important hydrogeological data needed for managing groundwater resources (Kumar et al., 2014).

The installation of water pump is done after serial of pumping test conducted. The series of pumping tests consist of constant rate test/long term test, recovery test, steps drawdown test. The one final aim of those test is to determine the feasibility of well, optimum pumping rate, and suitable pump specification.

The research objective is to determine parameters of aquifer such as hydraulic conductivity and transmissibility. This research is also aimed to determine well loss, aquifer loss, development factors of well. .

Research was carried out in PT. Kaltim Kariangau Terminal. Administratively, Research area is located in Balikpapan City, East Kalimantan, Indonesia. According to the planning of Development Planning Body of Balikpapan City and East Kalimantan Province, it will be developed as seaport with its facilities and integrated with industrial area to support the development of Kariangau Special Economic Zone.

RESEARCH METHOD

This research involved many activities, starting from desk study, collecting data, analyzing and drawing conclusion. Technical data such as geophysical logging, well construction design and pumping test data were obtained from management of PT. Kaltim Kariangau Terminal as owner of the project. Other secondary data was collecting from Balikpapan City Development Planning Body such geological and city spatial planning map.

In order to have better understanding of the underlying aquifer, Cooper-Jacob method was employed to analyze pumping test data of the well and to get aquifers parameter such as transmissivity, hydraulic conductivity, aquifer loss, well loss, development factor and efficiency of well. Geological interpretation was done to identify potential environmental impacts the activity of ground water pumping in long term.

PT. Kaltim Kariangau Terminal has developed four wells, and as measured by GPS their location in UTM respectively; Well KKT DWW # 01 Easting 0476364 m, Northing 9872219 m, well KKT DWW #02 Easting 0476315 m, Northing 9872161 m well KKT DWW #03 Easting 0476191 m, Northing 9872169 m KKT DWW #04 Easting 0476291 m, Northing 9871811m.

It is a pity from four wells only one well was completed with pumpping test without observation well. These well is located in Kutai Basin, they have depth more than 200 meters. Geologically, it passes through Pleistocene Kampung Baru Formation which is dominated by silt and clay. The underneath formation is member of Balikpapan Group (Late Miocene Sepinggan Formation) which is characterized by sandstone slit clay and coal (Satyana et al., 1999) as showing by geological map and geophysical logging profile. Having three other close wells have no pumping test data, they can't be further more analyzed for both of their hydraulic conductivity and transmissivity

RESULT AND DISCUSSION

According to Cooper – Jacob Method in Todd, 1980 a value of transmissivity (T) is governed by this formula:

$$T = \frac{2.30Q}{4\pi\Delta s} \text{ ....(1)}$$

From the first equation, it can be simplified become equation 2:

$$T = 1{,}183Q/\Delta S' \text{ ....(2)}$$

Where Q is pumping rate, Δs is drawdown difference per log cycle

And hydraulic conductivity can be solved as follow:

K = T/b ....(3)

Where b is aquifer thickness.

And specific capacity (Sc) can be calculated using the following formula

Sc = Q/Sw ....(4)

Here is the determination of transmissivity and hydraulic conductivity through analysis of continuous pumping, recovery and step drawdown test.

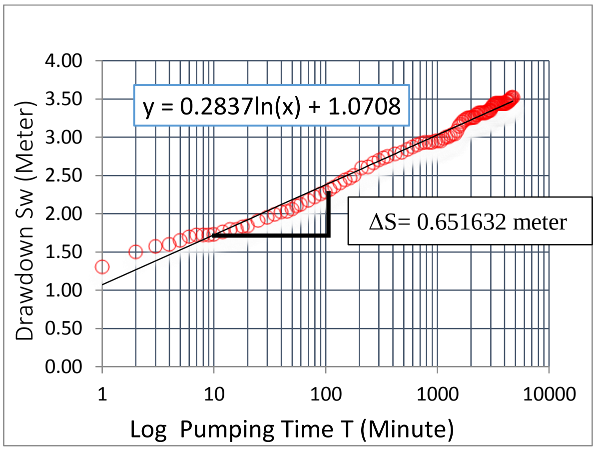

Figure 1. Semilogarithmic plot of constant pumping rate test

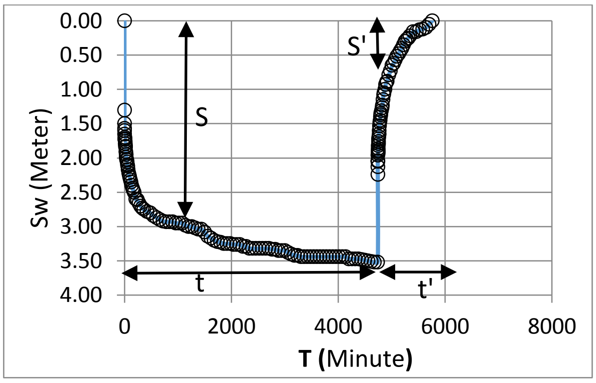

Figure 2. Constant pumping rate and recovery plot,

From constant pumping rate plot in Figure 1, it can be calculated transmissivity (T) and hydraulic conductivity K of aquifer as follow,

Equilibrium of the curve is:

y = 0. 283ln(x) + 1.070

Then drawdown per log cycle can be determined as follow;

ΔS =y2 – y1 = y(100) – y(10)

ΔS = 0.283ln(100) + 1.070 - 0.283ln(10) + 1.070

ΔS = 2,373263163 - 1,721631581

ΔS = 0.651632 meter

And transmissivity

$T = 1{,}183Q/\Delta S$

T = 1,183 * 0,01315/ 0,651632

T = 0,003692961 m²/second

T = 319.0718283 m²/day

the thickness of aquifer (b) is 48 meters (known from geophysical logging profile and length of screen in well construction design) then hydraulic conductivity can be calculated using this equation 3:

K = T/b

K = 319.0718283/48

K = 6.6473 m/day

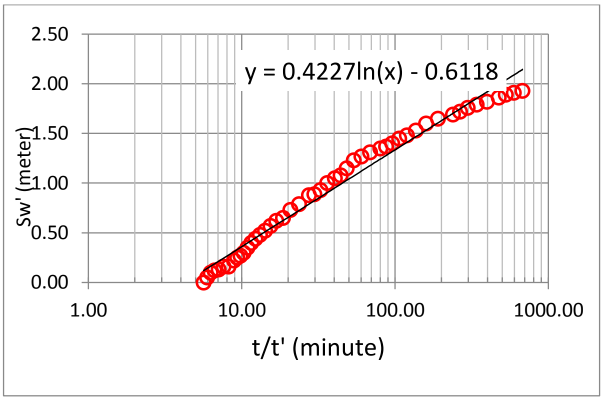

Figure 3. Semilogarithmic plot of constant pumping recovery

We can compare the above T and K parameters from its recovery as calculated bellow (see Figure 3).

y = 0.422 ln (x) – 0.611

ΔS' =y2 – y1 = y(100) – y(10)

ΔS' = (0.422 ln (100) – 0.611) – (0.422 ln (10) – 0.611)

ΔS = 1.333303 - 0.361151

ΔS = 0.972151 meter

$T = 1{,}183Q/\Delta S'$

T = 1.183 * 0,01315/0,972151

T = 0.002475 m²/second

T = 213.8733 m²/day

K = 213.8733/48

K = 4.4557 m/day

Using similar method of calculation of transmissivity (T) and hydraulic conductivity (K) as above calculation, here is the result of calculation of T and K from step drawdown test.

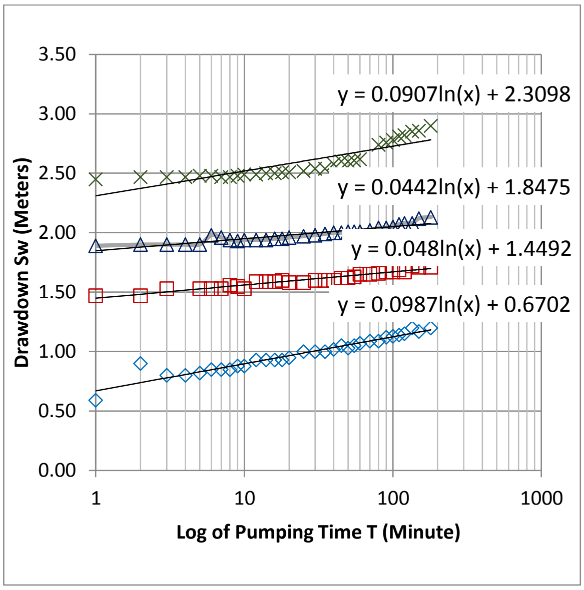

Figure 4. Semilogarithmic plot of step drawdown test

Table 1. Pumping rate, Transmissivity and Hydraulic Conductivity of each step

	Pumping Rate (Q) m^3/day	Transmissivity (T) m^2/day	Hydraulic Conductivity K m/day	Specific Capacity (Sc) m^2/day
STEP I	624.6720	506.5955	10.54407	520.56
STEP II	978.0480	1616.54	33.67791	575.3223
STEP III	1046.3040	1888.347	39.3406	491.2225
STEP IV	1136.1600	1007.118	20.9816	391.7793

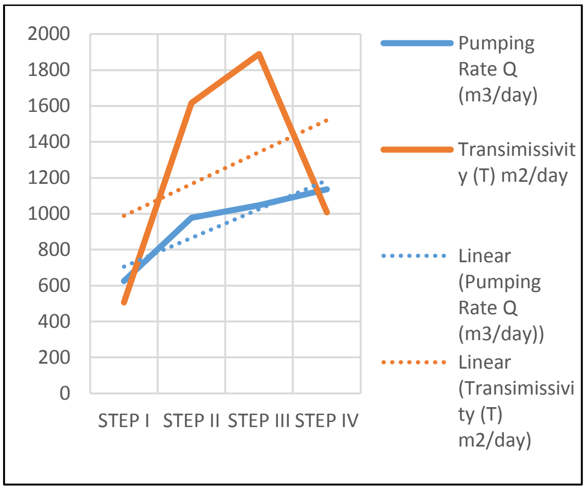

Figure 5. Correlation of pumping rate and transmissivity,

According to the classification of transmissivity magnitude (Krásný, 1993), The class transmissivity magnitude of aquifer in research area is II, high magnitude, groundwater supply potential is Withdrawals of lesser regional importance, with very approximate discharge of single well 5 up to 50 liters/second.

Transmissivity (T) is defined as average of all horizontal hydraulic conductivities at various depths multiplied by the vertical saturated thickness of aquifer (Nielsen, 1991). Transmissivity has dimension square length per time that means velocity per wide unit. There is positive correlation between pumping rate and transmissivity as showing by trend line of chart that prove that velocity of groundwater toward well getting bigger as pumping rate increase.

Drawdown in the well consist of aquifer loss and well loss, that can be solved using step drawdown test data as follow:

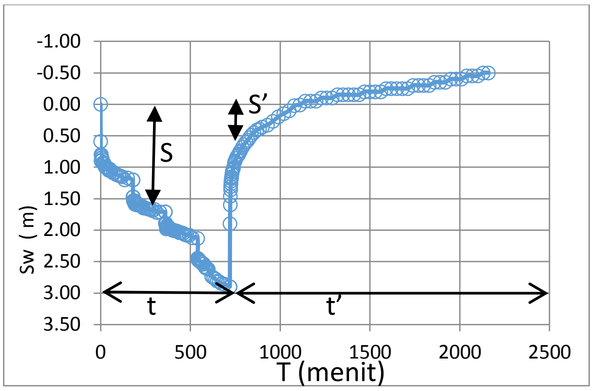

Figure 6. Step drawdown test and recovery plot.

The following chart gives illustration volume of water that has been discharge during step drawdown test and volume of water that has been naturally filled back during recovery test.

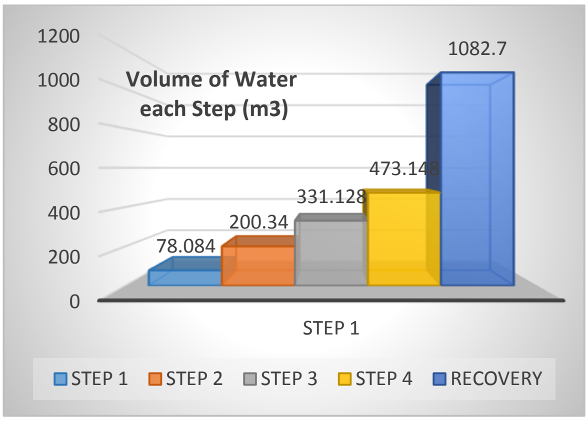

Figure 7. Volume of water in each step and recovery test.

Table 2. Pumping Rate, Drawdown, Drawdown/Pumping Rate

	Pumping Rate (Q) lt/s	Pumping Rate (Q) m^3/day	Draw down (Sw) m	Sw/Q
STEP 1	7,23	624,6720	1,20	0.001921
STEP 2	11,32	978,0480	1,71	0.001748
STEP 3	12,11	1046,3040	2,13	0.002036
STEP 4	13,15	1136,1600	2,90	0.002552

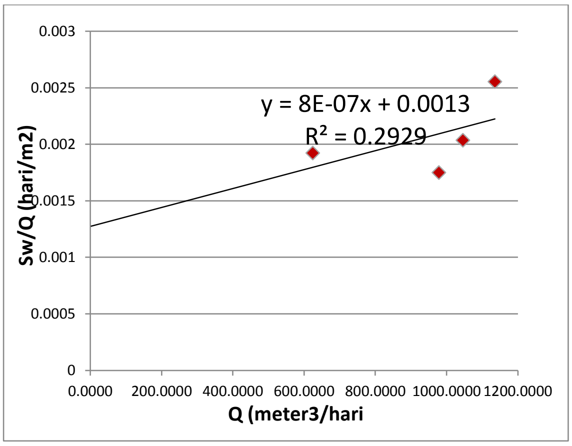

Figure 8. Linear plot to determine coefficient aquifer loss and well loss.

If Sw designs the drawdown inside the well in meter, B the formation resistance, C well loss and Q the discharge (m^3day^{-1}) we can write :

$Sw = BQ + CQ^2$……..……………….(4) (Chenini, 2008) furthermore in order to find linier of pumping test. The equation (4) can be made become equation (5)

$Sw/Q = B + CQ$………………………….(5)

From linier plot of figure 8, B and C can be determined

$Sw/Q = 0.0013 + 0.0000008Q$

$Sw = 0.0013Q + 0.0000008Q^2$

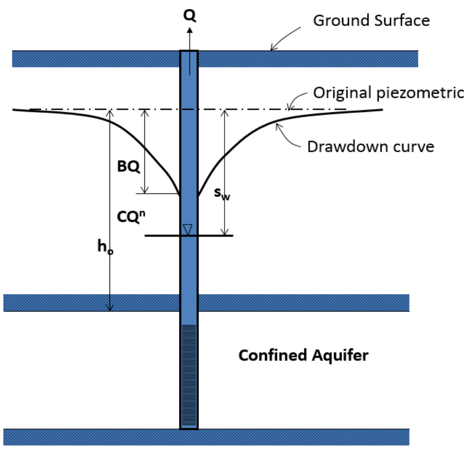

Figure 9. Aquifer Loss and Well Loss (Tod, 1980)

Factor development of well

$Fd = \frac{C}{B}.100$ ………………………..(6)

= (0.0000008/0.0013) * 100

=0.0615

Value of factor development (Fd) of well less than 0.1 day/m^3 well can be classified as "very effective" (Bierschenk, 1963). Moreover value of C less than 0.5 $minute^2/m^5$ can be classified well condition is "properly designed and developed" (Walton, 1962 in Tod, 1980)

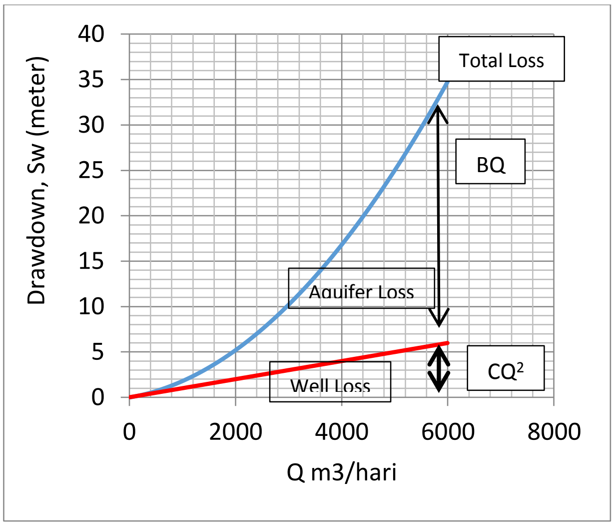

Figure 10. Simulated aquifer loss, well loss.

In the operation planning, pumping rate of KKT DWW # 01 will be 0.001 m^3/second or 86.4 m^3/day, so that the well lost can be calculated as follow

CQ^2 = 0.0000008 * 86.4*86.4

= 0.0059 m

= 5.9 mm

And aquifer loss

BQ = 0.0013*86.4

= 0.1123 m

= 112.3 mm

Then total loss is

Sw = 112.3 + 5.9

= 118.2 m

Through computer simulation well efficiency Ew, given as percentage (Tod, 1980) by

$E_w = 100.\frac{BQ}{S_w}$ ………………………..(7)

we can develop chart of well efficiency versus Pumping Rate as below.

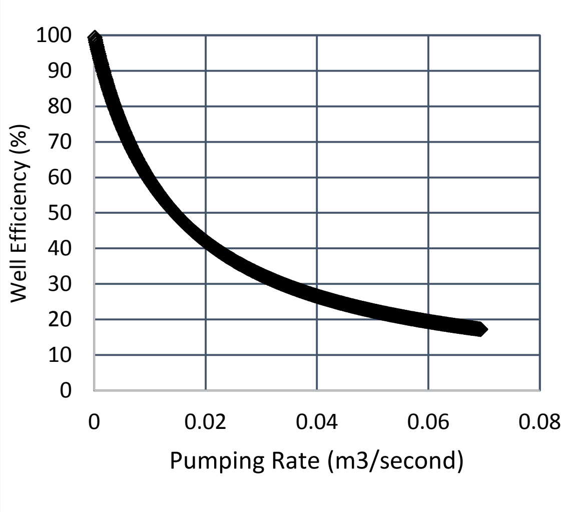

Figure 11. Simulated well efficiency plot.

In the pumping rate 10 liters/second or 0.001 m^3/ second, KKT DWW # 01 well efficiency can reach 93.53%.

CONCLUSION AND RECOMMENDATION

According to KKT DWW # 01 well data, after analyzing using Cooper-Jacob method it can be concluded that transmissivity from constant long term test is 319.0718283 m^2/day and hydraulic conductivity 6.6473 m/day. At the pumping rate 10 liters/second well efficiency is 93.53%. Coefficient of aquifer loss is 0.0013 and coefficient of well loss is 0.0000008. Factors development of well could be classified as very effective with the well condition is properly designed and developed. The transmissivity is high magnitude, groundwater supply potential is Withdrawals of lesser regional importance.

Although technically this well feasible for production with pumping rate 10 liters/second, but there three other well which is located close each other and their location close the coast therefore, so that it is highly recommended that wells should be monitored routinely in order to avoid salt water upcoming in the interface of freshwater and salt water, and other possible environmental impacts.

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Appendix 1. Step Test Data of **KKT DWW # 01**

Pumping Test Data

Step 1

Date	Time	Minute	DWL (m)	Draw Down (m)	V Notch Head (cm)	Debit Q
19/11/12						
	08:00:00	0	16.60	0.00	12.02	7.23
		1	17.19	0.59		
		2	17.5	0.90		
		3	17.4	0.80		
		4	17.4	0.80		
		5	17.42	0.82		
		6	17.45	0.85		
		7	17.45	0.85		
		8	17.45	0.85		
		9	17.48	0.88		
		10	17.48	0.88		
		12	17.53	0.93		
		14	17.53	0.93		
		16	17.53	0.93		
		18	17.53	0.93		
		20	17.55	0.95		
		25	17.6	1.00		
		30	17.6	1.00		
		35	17.6	1.00		
		40	17.62	1.02		
		45	17.65	1.05		
		50	17.63	1.03		
		55	17.65	1.05		
	09:00:00	60	17.67	1.07		
		70	17.69	1.09		
		80	17.69	1.09		
		90	17.72	1.12		
		100	17.73	1.13		
		110	17.74	1.14		
	10:00:00	120	17.75	1.15		
		135	17.8	1.20		
		150	17.77	1.17		
	11:00:00	180	17.8	1.20		

Pumping Test Data

Step 2

Date	Time	Min	DWL (m)	Draw Down (m)	V Notch Head (cm)	Debit Q
19/11/12	11:00:00	0	17.8	1.2	14.06	11.32
		1	18.07	1.47		
		2	18.07	1.47		
		3	18.13	1.53		
		5	18.13	1.53		
		6	18.13	1.53		
		7	18.13	1.53		
		8	18.16	1.56		
		9	18.15	1.55		
		1	18.13	1.53		
		1	18.19	1.59		
		1	18.19	1.59		
		1	18.19	1.59		
		1	18.2	1.6		
		2	18.18	1.58		
		2	18.18	1.58		
		3	18.2	1.6		
		3	18.2	1.6		
		4	18.2	1.6		
		4	18.22	1.62		
		5	18.22	1.62		
		5	18.23	1.63		
	12:00:00	6	18.25	1.65		
		7	18.25	1.65		
		8	18.26	1.66		
		9	18.27	1.67		
		1	18.27	1.67		
		1	18.29	1.69		
	13:00:00	1	18.27	1.67		
		1	18.32	1.72		
		1	18.31	1.71		
	14:00:00	1	18.31	1.71		

Pumping Test Data

Step 3

Date	Time	Minute	DWL (m)	Draw Down (m)	V Notch Head (cm)	Debit Q
19/11/12	14:00:00	0.00	18.31	1.71	15	12.11
		1.00	18.49	1.89		
		2.00	18.50	1.90		
		3.00	18.50	1.90		
		4.00	18.50	1.90		
		5.00	18.50	1.90		
		6.00	18.58	1.98		
		7.00	18.56	1.96		
		8.00	18.54	1.94		
		9.00	18.53	1.93		
		10.00	18.54	1.94		
		12.00	18.54	1.94		
		14.00	18.54	1.94		
		16.00	18.55	1.95		
		18.00	18.55	1.95		
		20.00	18.56	1.96		
		25.00	18.57	1.97		
		30.00	18.58	1.98		
		35.00	18.59	1.99		
		40.00	18.60	2.00		
		45.00	18.60	2.00		
		50.00	18.61	2.01		
		55.00	18.61	2.01		
	15:00:00	60.00	18.61	2.01		
		70.00	18.62	2.02		
		80.00	18.64	2.04		
		90.00	18.64	2.04		
		100.00	18.65	2.05		
		110.00	18.67	2.07		
	16:00:00	120.00	18.68	2.08		
		135.00	18.68	2.08		
		150.00	18.72	2.12		
	17:00:00	180.00	18.73	2.13		

Pumping Test Data

Step 4

Date	Time	Minute	DWL (m)	Draw Down (m)	V Notch Head (cm)	Debit Q
19/11/12	17:00:00	0	19.05	2.45	15.5	13.15
		1	19.05	2.45		
		2	19.07	2.47		
		3	19.07	2.47		
		4	19.07	2.47		
		5	19.08	2.48		
		6	19.08	2.48		
		7	19.07	2.47		
		8	19.07	2.47		
		9	19.08	2.48		
		10	19.09	2.49		
		12	19.09	2.49		
		14	19.1	2.50		
		16	19.1	2.50		
		18	19.11	2.51		
		20	19.11	2.51		
		25	19.12	2.52		
		30	19.14	2.54		
		35	19.14	2.54		
		40	19.18	2.58		
		45	19.2	2.60		
		50	19.2	2.60		
		55	19.21	2.61		
	18:00:00	60	19.22	2.62		
		70	19.3	2.70		
		80	19.34	2.74		
		90	19.36	2.76		
		100	19.38	2.78		
		110	19.41	2.81		
	19:00:00	120	19.42	2.82		
		135	19.45	2.85		
		150	19.46	2.86		
	20:00:00	180	19.5	2.90		

Appendix 2. Recovery Test of **KKT DWW # 01**

Date	Time	Minute (t)	:'	t/t'	DWL (m)	Residual Draw Down (m)
19/11/12	20:00:00	720	0	0.00	19.50	2.90
		721	1	721.00	18.50	1.90
		722	2	361.00	18.20	1.60
		723	3	241.00	18.06	1.46
		724	4	181.00	17.96	1.36
		725	5	145.00	17.91	1.31
		726	6	121.00	17.86	1.26
		727	7	103.86	17.82	1.22
		728	8	91.00	17.78	1.18
		729	9	81.00	17.77	1.17
		730	10	73.00	17.75	1.15
		732	12	61.00	17.71	1.11
		734	14	52.43	17.68	1.08
		736	16	46.00	17.65	1.05
		738	18	41.00	17.63	1.03
		740	20	37.00	17.61	1.01
		745	25	29.80	17.52	0.92
		750	30	25.00	17.50	0.90
		755	35	21.57	17.46	0.86
		760	40	19.00	17.43	0.83
		765	45	17.00	17.41	0.81
		770	50	15.40	17.39	0.79
		775	55	14.09	17.36	0.76
	21:00:00	780	60	13.00	17.34	0.74
		790	70	11.29	17.28	0.68
		800	80	10.00	17.24	0.64
		810	90	9.00	17.20	0.60
		820	100	8.20	17.17	0.57
		830	110	7.55	17.13	0.53
	22:00:00	840	120	7.00	17.09	0.49
		855	135	6.33	17.05	0.45
		870	150	5.80	17.01	0.41
		885	165	5.36	16.99	0.39
	23:00:00	900	180	5.00	16.96	0.36
		930	210	4.43	16.93	0.33
20/11/12	24:00:00	960	240	4.00	16.87	0.27
		990	270	3.67	16.80	0.20
	01:00:00	1020	300	3.40	16.75	0.15
		1050	330	3.18	16.70	0.10
	02:00:00	1080	360	3.00	16.62	0.02
		1110	390	2.85	16.61	0.01
	03:00:00	1140	420	2.71	16.55	-0.05
		1170	450	2.60	16.55	-0.05
	04:00:00	1200	480	2.50	16.55	-0.05
		1230	510	2.41	16.50	-0.10
	05:00:00	1260	540	2.33	16.50	-0.10
		1290	570	2.26	16.50	-0.10
	06:00:00	1320	600	2.20	16.45	-0.15
		1350	630	2.14	16.45	-0.15
	07:00:00	1380	660	2.09	16.45	-0.15
		1410	690	2.04	16.45	-0.15
	08:00:00	1440	720	2.00	16.45	-0.15
		1470	750	1.96	16.40	-0.20
	09:00:00	1500	780	1.92	16.40	-0.20
		1530	810	1.89	16.40	-0.20
	10:00:00	1560	840	1.86	16.40	-0.20
		1590	870	1.83	16.35	-0.25
	11:00:00	1620	900	1.80	16.35	-0.25
		1650	930	1.77	16.35	-0.25
	12:00:00	1680	960	1.75	16.35	-0.25
		1710	990	1.73	16.35	-0.25
	13:00:00	1740	1020	1.71	16.30	-0.30
		1770	1050	1.69	16.30	-0.30
	14:00:00	1800	1080	1.67	16.30	-0.30
		1830	1110	1.65	16.30	-0.30
	15:00:00	1860	1140	1.63	16.25	-0.35
		1890	1170	1.62	16.25	-0.35
	16:00:00	1920	1200	1.60	16.25	-0.35
		1950	1230	1.59	16.20	-0.40
	17:00:00	1980	1260	1.57	16.20	-0.40
		2010	1290	1.56	16.20	-0.40
	18:00:00	2040	1320	1.55	16.15	-0.45
		2070	1350	1.53	16.15	-0.45
	19:00:00	2100	1380	1.52	16.15	-0.45
		2130	1410	1.51	16.10	-0.50
	20:00:00	2160	1440	1.50	16.10	-0.50

Note t = time after pump is switched on

t' = time after pump is switched off