MINISTRY OF EDUCATION AND TRAINING
HANOI UNIVERSITY OF MINING AND GEOLOGY

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INCREASING THE EFFICIENCY OF THE REVERSE CIRCULATION DRILLING TECHNOLOGY FOR THE UNDERGROUNDWATER EXTRACTION WELLS IN THE UNCONSOLIDATED SEDIMENTARY STRATA AT NHON TRACH, DONG NAI ZONE

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SUMMARY OF TECHNICAL DOCTORAL THESIS

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The thesis is available at **the National library of Vietnam** or **the library of Hanoi University of Mining and Geology**

INTRODUCTION

1. The necessity of the thesis

Nhon Trach, Dong Nai industrial zone includes 1,2,3,4,5 zones located in center of southern economic area. In Nhon Trach industrial zone, there has been Tuy Ha water plant with capacity of 22,000 m^3/day-night to industrial zone. After a long time of its operation, some of its wells have been out of order, leading to its weak potential water mining capacity.

For adequate water supply from Tuy Ha water plant to Nhon Trach industrial zone and adjacent areas, in April, 6^{th}, 2015, according to the Order N^0 267/TNN-NDĐ from Water resources Administration, Nhon Trach, industrial zone has been allowed to additionally drill some more groundwater extraction drilling wells and some more wells replacing failure ones.

Up to now in Vietnam and at Nhon Trach industrial zone, the direct circulation rotary drilling technology for the groundwater wells. The fact, when drilling exploit underground water in unconsolidated sedimentary stratum, they use clay mud to limit collapse into a well; this reduces the ability of the well to recover water and in many cases it is necessary to use a casing to separate it, resulting in an increase in the actual construction cost and duration of the well.

2. The purpose of this thesis

Increasing the efficiency of reverse circulation drilling technology for the groundwater extraction drilling wells in unconsolidated sedimentary at Nhon Trach, Dong Nai zone.

3. Target and area of this study

- Target of this study: the reverse circulation drilling technology for groundwater extraction drilling wells.

- Area of this study: the drilling wells in unconsolidated sedimentary at Nhon Trach, Dong Nai industrial zone.

4. Study method and data processing

- Directory method: Collecting, statistics and analyzing data related to the study scope of the thesis.

- Theoretical method: Study the reverse circulation drilling technology and sellecting the solutions for increasing the drilling efficiency for groundwater wells at Nhon Trach industrial zone.

- Test method: Testing the production conditions.

- Method of calculation: Applying the probability math, statistics math, Excel program for processing the data and analyzing.

5. Base documents of the thesis:

The thesis has been estasblished on the research works have been published; on the author's scientific works published in the scientific journals in Vietnam.

6. Scientific and practical significances

- Scientific significance: The research results of the thesis has contributed to improvement of drilling technology as well as the solutions for increasing the efficiency not only for the groundwater extraction drilling wells in unconsolidated sedimentary at Nhon Trach, Dong Nai industrial zone but also for the groundwater extraction drilling wells having the similar conditions in Vietnam.

- Practical significance: Basing on the research results of the thesis, experts and the managers in the field of the groundwater extraction could select method, suitable to the strata conditions, suitable to the existing equipment to construct the groundwater extraction drilling wells with highest efficiency.

7. The novelty and the contribution the thesis

- The reverse circulation drilling technology has been proposed to be applied with airlift and technical water for cleaning the wells replacing the tradional drilling technologies with drilling fluid when constructing groundwater extraction drilling wells in unconsolidated sedimentary in Vietnam.

- The research results have contributed to improvement constructing groundwater extraction drilling wells in unconsolidated sedimentary at Nhon Trach, Dong Nai industrial zone and groundwater extraction drilling wells having the similar conditions.

8. Primary arguments of this thesis

- ***Argument 1***: Applying the reverse circulation drilling technology with using airlift pump and technical water for scavenging the wells when the groundwater extraction drilling wells in unconsolidated sedimentary at Nhon Trach, Dong Nai industrial zone is reasonable, in increasing the drilling efficiency and the quality of the wells.

- ***Argument 2:*** To the stratum at Nhon Trach, Dong Nai industrial zone, in order to transport drilling mud with gravels size from 30 mm - 50 mm to the surface, in the case of using drill pipe with inside diameter of 115 mm, it is necessary to maintain the velocity of the wash liquid flow to the surface from 4.2 m/s - 7.8 m/s with the corresponding compressed air flow of 3 m^3/m - 3.5 m^3/m.

9. Volume and structure of the thesis

The thesis includes forewords, 4 chapters of its content, conclusions, proposals, list of author's published scientific works, reference materials and appendix. All content of thesis has been represented in A4 sized 111 pages, 14 sized Time New Roman leters, including 45 figures and 18 tables.

CHAPTER 1

OVERALL OF REVERSE CIRCULATION DRILLING TECHNOLOGY ON THE WORLD AND IN VIETNAM

1.1. Analysis and avaluation of the advantage and disadvantage of circulation muds methods in wells.

In the exploratory rotary boring, well groundwater drilling, have 3 muds circulation methods: Direct circulating; reverse circulation method; circulation combination method.

1.2. Facilities for maintaining the reverse circulation mud in the drilling wells

For maintaining the reverse circulation mud following facilities have been used: the wash liquid pump together with device for sealing the well mouth, airlift pump, centrifugal pump with vacuum pump, centrifugal pump with injection nozzle.

Using the airlift pump for maintaining the reverse circulation mud has more advantages than others; could be applied to the groundwater extraction drilling wells with the depth up to 500 m, the diameter of 800 mm and it could push up the wash mud column having 40% - 60% borings content to 300 m - 400 m.

1.3. Present situation of study and application of reverse circulation drilling technology on the world

The research results show that, when the compressed air flow Q_K increases, the pump flow Q_{AP} also increases (figure 1.14) but only to the maximum value $Q_{AP,max}$,, corresponding to the value $Q_K = Q_{K,2}$.

In the case Q_K continues to increase, the pump flow Q_{AP} will decrease because the redundant compressed air flow takes space, and the sliding speed of the compressed air and the pressure drop due to the friction increase.

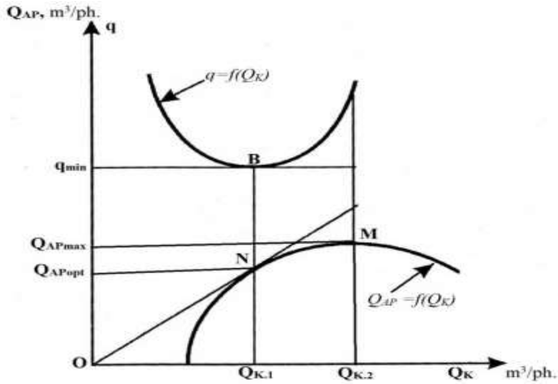

Figure 1.14. The dependence of the wash liquid flow Q_{AP} and the compressed air consumption q to the compressed air flow Q_K

The curve $Q_{AP}= f(Q_K)$ consists of 2 working mode points:

- The contact point N characterizes to the best pump mode. At this point, the compressed air consumption for transporting $1m^3$ of wash liquid is minimum level (point B).

- Point M characterizes to the maximum pump flow. During the drilling process, the selected pump flow and corresponding compressed air flow are in the range of points N and M, and it is better to close the point M.

The dependence $Q_{AP}= f(Q_K)$ when the depth and the sinking coefficient of the air mixing chamber change (figure 1.15) show that, when the sinking depth of the air mixing chamber increases, the airlift pump flow also increase despite of the constant compressed air flow to the air mixing chamber.

The sinking coefficient α has been determined in the formula written by V.G.Bogdasarov, A.Nenes, D.Assimacopoulos, Xu Liu Wan:

$$\alpha = \frac{h}{h_0 + h} = \frac{h}{H} \qquad (1.1)$$

α - The sinking coefficient of the air mixing chamber ; h_0- The lifting height of the wash liquid column, from the dynamic water level to the lift column mouth, m; *h*- The sinking depth of the air mixing chamber compared with the dynamic water level, m; $H= h_o+ h$- The lifting height of the wash liquid column, from the air mixing chamber to the lift column mouth, m. Airlift pump has high working efficiency when 0,5 < α <1.

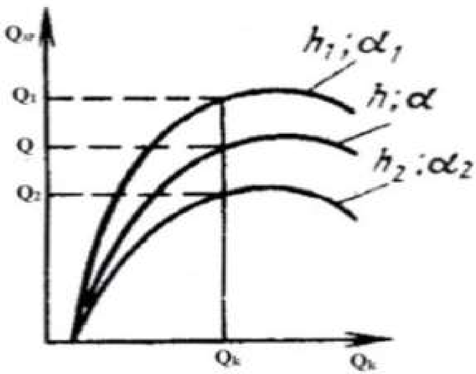

Figure 1.15. The dependence $Q_{AP}=f(Q_K)$ when the depth and the sinking coefficient change. $h_1 > h > h_2$ and $\alpha_1 > \alpha > \alpha_2$

1.4. Present situation of study and application of the reverse circulation drilling technology in Vietnam

In 1999, within the project "*Study on the groundwater in Mekong Delta*", Confederation of Planning and Investigation of Southern Water Resources had imported the reverse circulation drilling equipment Drillcon WWR/25/TM for well Q401 for surveying groundwater behaviour at Southern Delta. Q401 survey well cluster have the depth of 282 m, consisting of 7 wells for surveying groundwater behaviour with different depth.

In 2004, Confederation of Planning and Investigation of Southern Water Resources had been assigned to carry out the theme: *"Switching the circulating drilling technology to the reverse circulation drilling technology for groundwater extraction drilling operations in Vietnamese conditions"* by Ministry of Natural Resources and Environment. The research results from the theme, some of Russian drilling equipments have been sucessfully improved and could be used the reverse circulation drilling technology.

In the project *"Study the application of the reverse circulation drilling technology in hard rock to the exploratory boring and the groundwater extraction at South East of Vietnam",* the reverse circulation air blowing drilling technology with using pneumatic hammer and double boring.

In 2013, Southern Institute of Mining and Drilling Technology had drilled 5 wells such as H2A, H3A, H4A, GK1A and GK2A in Nhon Trach industrial zone 1 with the reverse circulation drilling technology with using bentonite clay mud.

1.5. Complicated and the causing decrease of the drilling efficiency in the reverse circulation drilling

When the groundwater well drilling in sedimentary stratum, there always be the phenomena such as mud consumption, well wall failures, impacting on the productivity, drilling efficiency and well quality.

Comments:

1. The reverse circulation drilling technology has been widely applied for mineral exploratory drilling, hydrogeology drilling and the groundwater extraction drilling.

2. In Vietnam, the reverse circulation drilling technology has not been studied systematically; only mentioned to the improvement of available equipment, apparatus suitable; the drilling technology characteristics and the solutions for increasing drilling efficiency have not studied.

CHAPTER 2

GEOLOGICAL AND HYDROGEOLOGICAL CHARACTERISTICS AT NHON TRACH, DONG NAI AND SELECTION OF REVERSE CIRCULATION DRILLING TECHNOLOGY FOR GROUNDWATER WELLS

2.1. Background on the geographical conditions and socio-economic at the studied area

The studied area belongs to Nhon Trach, Dong Nai province, Ho Chi Minh city on the North and the West, Ba Ria - Vung Tau on the South and Long Thanh district on the East. This industrial zone has developped on the trend of industrialization and attracted many investors from many countries on the world.

2.2. Hydrogeological conditions and water bearing complexes

According to the hydrogeological conditions, Nhon Trach area has divided into the following water horizons:

- Water horizons in sediment Holoxen (Q_{IV});
- Water horizons in sediment Pleistoxen (Q_{I-III});
- Water horizons sediment Plioxen (N_2);

- Water in foundation stone.

Water horizons Plioxen (N_2) is the horizons that can be extracted for serving the industrial and residential zones.

2.3.Characteristics of strata structure and mechanical properties of rock

The strata structure includes layers of close sand, clay loam, medium to coarse grained sand bearing laterite pebbles with different size: the size 5 mm - 2 mm accounting 6.6%; size 10 mm - 5 mm accounting 13.3%,size more than 10mm accounting 29.3%; in which, gravels of size of 30 mm - 40 mm accounting 35% (figures 2.7, 2.8).

The porosity of the rock is from 35% - 44%; the compressive strength of the rock is from 11.85 N/cm^2 - 14.58 N/cm^2.

2.4. Selection reverse circulation drilling technology for the groundwater drilling wells at Nhon Trach, Dong Nai.

The reverse circulation drilling technology has been selected on the basis: geological and hydrogeological conditions; technological demands for the groundwater extraction drilling wells.

Figure 2.7. Yellow mixed clay with gravels

Figure 2.8. Size of gravels in water horizons

Comparing with other reverse circulation drilling methods, the reverse circulation drilling method with airlift have many advantages and more efficient; the well depth greater, the higher the pump flow and stability are (figure 2.11).

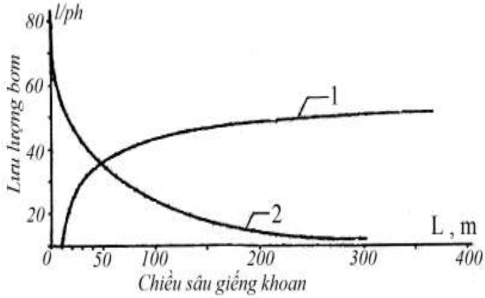

Figure 2.11. Comparative graph of the pump flow depending to the well height in the reverse circulation drilling method.
1. The reverse circulation drilling by airlift. 2. The reverse circulation drilling with centrifugal pump and vacuum pump

Basing on the geological conditions, the author has selected the reverse circulation drilling method with airlift to drill the groundwater wells having diameters of 500 mm in the Pliocene sedimentary mixed with gravels with the size up to 30 mm - 50 mm at Nhon Trach, Dong Nai industrial zone.

Comments:

1. The rock in Nhon Trach area belong to soft, weak and unconsolidated sedimentary. The porosity of the rock is from 35% to 44%; the compressive strength of the rock is from 11.85 N/cm^2 to 14.58 N/cm^2.

2. The compositions of the rock in sediment Plioxen include laterite pebbles with different size, the size of 30 mm - 50 mm accounting for 35%.

3. Applying the reverse circulation drilling method with airlift to drilling the groundwater wells having diameters of 500 mm is reasonable, suitable to the strata conditions of sedimentary with laterite pebbles having size up to 50 mm and at the same time, meeting the demands of well structure and capacity.

CHAPTER 3
STUDY ON THE SOLUTIONS FOR INCREASING THE EFFICIENCY OF THE REVERSE CIRCULATION DRILLING TECHNOLOGY WITH AIRLIFT PUMP FOR GROUNDWATER DRILLING EXTRATION WELLS AT NHON TRACH, DONG NAI ZONE

3.1. Characteristics of the reverse circulation drilling technology with airlift

Work efficiency of airlift pump used in the reverse circulation drilling depends on the parameters drilling, necessary flow for cleaning up and transporting cuttings with different content and size to the surface.

The reverse circulation drilling technology with airlift has the following characteristics:

- The velocity of the flow in drill pipe string is greater from 2 m/s to 3.5 m/s, ensuring that cuttings with pebbles, gravels could be transported to the surface.
- Rotational speed of the drill pipe string selected from 40 rpm - 80 rpm; in the case the diameter of the drilling well is more than 800 mm, the rotational speed to 18 rpm - 20 rpm.

Efficiency of the reverse circulation drilling with airlift pump have been evaluated by norms of compressed air q (m^3/m^3) for pumping up 1 m^3 of wash mud, cutting, pebbles, gravels and water to the surface as follows:

$$q = 0,767\alpha^{-2,2} = \frac{0,767}{\alpha^{2,2}} \qquad (3.4)$$

3.2. Factors affecting to the efficiency of the reverse circulation drilling technology with airlift pump

The efficiency of reverse circulation drilling technology with airlift pump depends on many factors, in which, geological factors, drilling technological factors and the operation factors of airlift pump are essential.

The velocity V_V (m/s) of the upstream wash fluid flow in the reverse circulation drilling is determined by the following formula:

$$V_V = k_v(u + c) \tag{3.6}$$

Of which, k_v = 1,1 - 1,3 is the coefficient related to uneven movement of the wash liquid flow; u - the settlement velocity of drilling grains due to their gravity, m/s; c - the necessary velocity for lifting drilling grains, m/s. The settlement velocity u is determined by the formula written by Y. Meiz:

$$u = \sqrt{\frac{2g}{1{,}12} d_h \left(\frac{\rho_h}{\rho_{md}} - 1 \right)} \tag{3.7}$$

In which, d_n - the diameter of cutting grain, m; ρ_h, ρ_{md} - corresponding to specific weight of mud grains and specific weight of the wash fluid mixed with cutting, g/cm^3; g =9,8 m/s^2 - gravitational acceleration. Take $c = 0{,}25u$. After being converted, the formula (3.6) will be written as folfows :

$$V_V = 5{,}225 k_v \sqrt{d_h \left(\frac{\rho_h}{\rho_{md}} - 1 \right)} \tag{3.11}$$

Basing on the grain composition of the rock and the formulae (3.6),(3.7), author has calculated and established the dependency graph $u = f(d_h)$ và $V_v = f(d_h)$ (figures 3.4 and 3.5) in wash fluid having specific weight ρ_{md} = 1.05 g/cm^3.

It is clear that, for transporting the drilling grains with size of 50 mm, the specific weight of 2.8 g/cm^3 in wash mud ρ_{md} = 1.05 g/cm^3, it is necessary to maintain the velocity of wash mud flow more than 1.26 m/s.

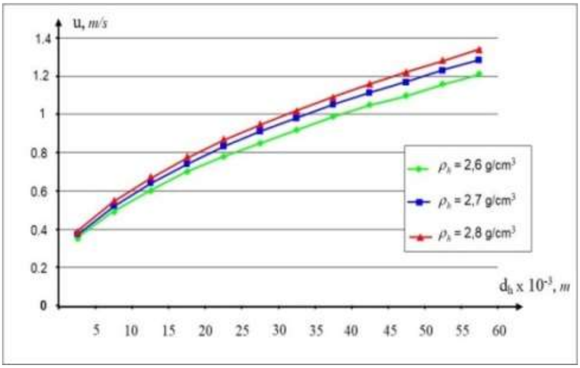

Figure 3.4. The dependence of sediment velocity u on the size and the specific weight of mud grains

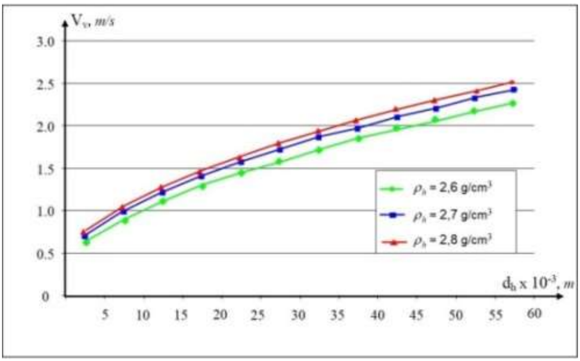

Figure 3.5. The dependence of upstream flow velocity V_V the wash mud flowon size and the specific weight of mud grains

3.3. Solutions for increasing the reverse circulation drilling technology with airlift pump for the groundwater drilling extration wells at Nhon Trach, Dong Nai

3.3.1. Targets for selecting the solutions for increasing efficiency of the reverse circulation drilling with airlift pump

- The drilling regime reasonabble mode, for to increase the drilling schedule and quality of groundwater drilling extration wells.

- Reasonable wash fluid type and flow and the corresponding compressed air flow to clean up and transport drilling grains and pebbles, gravels with the size from 30 mm to 50 mm to surface;

- Ensuring the well quality and increasing the maximum water recovery capability for the groundwater wells.

3.3.2. Solutions for increasing the efficency of reverse circulation drilling technology with airlift pump

For increasing the efficiency and increasing groundwater extraction capability to apply the following solutions:

1. Carrying out the reverse circulation drilling operations together with using technical water for cleaning up wells and inerease water recovery for groundwater wells.

2. Applying the regime reasonable drilling technological mode, suitable to the strata characteristics (table 3.2).

3. Applying the reasonable washing and punping mode for increasing capability of cleaning up well bottoms and transporting utting and pebbles the size 30 mm - 40 mm up to the surface.

The wash liquid flow Q_{AP} (m^3/ph.) and compressed air flow Q_K (m^3/ph.) are determined in the following experimental formula:

$$Q_{AP} = CD_1^{2,5} \qquad (3.14)$$

In which: $$C = 8,96\alpha - 1,91 \quad (3.15)$$

The compressed air flow

$$Q_K = qQ_{AP} \quad (3.16)$$

D_1- Inside diameter of the boring rods, m;

Table 3.2. The regime reasonable drilling in reverse circulation drilling with airlift pump using technical water for groundwater extraction wells at Nhon Trach, Dong Nai zone

Layer N^0	Rock characterisitics	Drilling parameters				Drilling penetrtion rate V_m, m/h.
		Q_{AP} m^3/h	Q_K m^3/min	G, kN	n, v/min	
1	Sand mixed with clay golden brown laterite pebbles; hardness of I - III, to the drilling mode	30 - 75	2,5-3	1-2	28;49	1,5
2	Medium and coarse grained sand with laterite pebbles golden brown, gray white, hardness of I - III, to the drilling mode	40 - 90	3-4	1-3	28;49	1,8
3	Sandstone with laterite pebbles gray white of III - IV, to the drilling mode	40 - 90	3,5-4	3-4	49;80	1,75
4	Sandstone with laterite pebbles gray white of III - IV, to the drilling mode	30 - 85	3-3,5	4-5	49;80	2,1
5	Gray base rock, hardness of VI, to the drilling mode	30 - 75	2,5-3	6-8	49;80	1,35

Basing on the collected data from the test (table 3.3), the author has established the graph $Q_{AP} = f\ (Q_K)$ when the depth and sinking coefficient of air mixing chamber change (figure 3.9).

Table 3.3. The dependence Q_{AP}, V_V and V_h on the compressed air flow Q_K when the depth h and the sinking coefficient α of the air mixing chamber change

a/ h= 30 m, α = 0,81; air compression coefficient K_n = 0,7

Q_K	Q_{AP}		V_V		V_h	
m^3/min	m^3/h	m^3/min	m/min	m/s	m/min	m/s
2,0	7,3	0,122	147	2,45	11,8	0,2
2,5	17,3	0,288	197	3,28	16,7	0,28
3,0	**29,7**	**0,495**	**250**	**4,17**	**48**	**0,8**
3,5	**38,3**	**0,638**	**298**	**4,97**	**61,6**	**1,03**
4,0	**45,0**	**0,75**	**343**	**5,7**	**72**	**1,2**
4,5	**50,7**	**0,845**	**386**	**6,43**	**82**	**1,36**
5,0	49,3	0,82	417	6,9	79	1.32
5,5	50	0,83	452	7,5	75	1,25
6,0	46,7	0,78	481	8,0	75	1,25

b/ h= 50 m, α = 0,88; air compression coefficient K_n=0,7

Q_K m^3/min	Q_{AP}		V_V		V_h	
	m^3/h	m^3/min	m/min	m/s	m/min	m/s
2,0	20,3	0,33	167	2,78	32	0,54
2,5	42,0	0,7	236	3,94	67,5	1,13
3,0	**52,6**	**0,877**	**287**	**4,79**	**84,6**	**1,41**
3,5	**61,0**	**1,02**	**335**	**5,58**	**98,5**	**1,64**
4,0	**68,6**	**1,14**	**380**	**6,34**	**110**	**1,83**
4,5	**80,0**	**1,33**	**432**	**7,2**	**128,4**	**2,14**

5,0	78,3	1,31	464	7,7	126	2,09
5,5	80,0	1,33	500	8,3	128	2,14
6,0	76,0	0,78	528	8,8	122	2,03

c/ h= 70 m, α = 0,91; air compression coefficient K_n =0,7

Q_K m³/min.	Q_{AP}		V_V		V_h	
	m³/h	m³/min	m/min	m/s	m/min	m/s
2,0	30	0,5	183	3,06	48,3	0,8
2,5	61	1,02	267	4,46	98,5	1,64
3,0	**75**	**1,25**	**323**	**5,39**	**121**	**2,01**
3,5	**86**	**1,43**	**374**	**6,24**	**138**	**2,3**
4,0	**92**	**1,53**	**418**	**6,96**	**148**	**2,5**
4,5	**101**	**1,68**	**466**	**7,76**	**162**	**2,7**
5,0	96	1,6	492	8,2	154	2,6
5,5	98	1,63	529	8,8	157	2,6
6,0	96	1,60	560	9,33	154	2,57

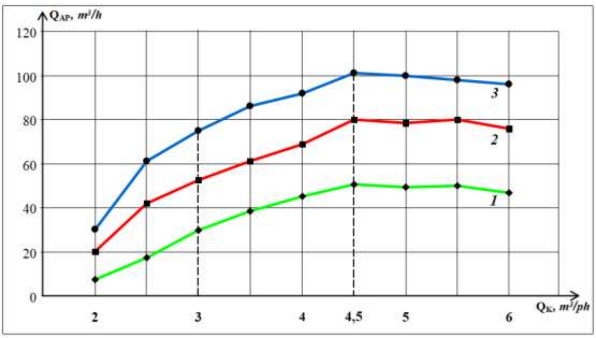

Figure 3.9. The dependence of the flow on compressed air flow and depth of air mixing chamber.

1. h= 30 m, α = 0,81; 2. h= 50 m, α = 0,88; 3. h= 70 m, α = 0,91

4. Increasing the ability for destructing and cutting rock to create grains with small size by using roller bit suitable to the rock properties, combined with reasonable drilling technological mode.

5. Selecting the size of the drilling pipe for transporting the cutting grains with the size of 50 mm to surface.

From the actual experiences, the inside diameter of the drilling pipes needs to ensure the condition:

$$D_1 \geq (2-3)d_h \qquad (3.18)$$

The velocity V_{AP} (m/s) flowing up to surface of 3- phas of drilling mud, air, and water has been determined as follows:

$$V_{AP} = 1,27\frac{Q_{AP} + K_n Q_K}{D_1^2} \qquad (3.19)$$

The velocity V_{AP} needs to ensure the condition: $V_{AP} \geq V_V$.

The velocity V_h (m/s) of the mixed wash fluid in the drilling pipe under the air mixing chamber has been determined as follows:

$$V_h = \frac{4Q_{AP}}{\pi D_1^2} \qquad (3.20)$$

and ensures the condition $V_h > u$.

Basing on the observed data at 03 test drilling wells and formulas (3.19), (3.20), the author has calculated Q_{AP}, V_{AP} and V_h (table 3.3) depending on compressed air flow for each drilling depth section when using drilling pipes having inside diameter of 115mm.

Comments:

1. For increasing the efficiency in drilling groundwater extration wells, to apply the reverse circulation drilling technology with airlift pump and using technical water for cleaning up the wells.

2. For overcoming the complicated phenomena, always keeping the wash fluid level in torus well compartment equal to well mouth; maintaining the velocity of upstream wash fluid flow into the torus well compartment from 0.07 m/s - 0.08 m/s; maximally restricting mechanical impacts and hydrodynamics on well walls.

3. For transporting the pebbles with size of 30 mm - 50 mm, depending on the sinking depth of air mixing chamber, it is necessaty to maintain velocity of upstream wash fluid flow of 4.2 m/s - 7.8 m/s, corresponding compressed air flow of 3 m^3/m - 5 m^3/m when using the drilling pipe having inside diameter of 115 mm.

CHAPTER 4

TESTING IN PRODUCTION CONDITIONS AND RESULTS FROM INDUSTRIAL APPLICATION

4.1.Test purposes

Testing in production conditions in order to evaluate correctness of the research results and select the reasonable solutions.

4.2. Test conditions

Tests have been carried out at 03 drilling wells with mark numbers of GK5A, GK4A and GK45-3A.

Testing drilling equipment: drilling rig URB-3AM (УРБ-3АМ) and air compressor Aicomp for testing drill operations with the capacity of 12 m^3/min, the working pressure of 1 MPa - 1.2 MPa.

Test drilling tools: drilling pipe having outside diameter of 127 mm, inside diameter of 115 mm, installed with 2 compressed air conduits having outside diameter of 33 mm and inside diameter of 27 mm, symmetric to each other on the surface outside drill pipe; bit 2 - blade and 3 - dlade having the diameter of 550 mm.

4.3. Evaluation of the test results

Test results from 3 drilling wells have been compared with results reverse circulation drilling using clay mud (table 4.6) show that, the drilling penetration rate increases 9.82%; the average time cleaning the well decreases 43.2%, the average draw - down level in well decreases 18.8% and average flow in 1 well increases 10.2%.

Table 4.6. Comparison of test results reverse circulation drilling using technical water with the test results the reverse circulation drilling using clay muds at Nhon Trach 1, Dong Nai.

Criteria	Reverse circulation drilling with airlift using clay muds	Reverse circulation drilling with airlift using technical water	Increase, decrease compared with reverse circulation drilling using clay muds
Number of the investigation wells, well	5	3	-
Average depth of the well, m	70	76	-
Average drilling time, h/well	61	105*	-
Average drilling penetration rate, m/h	1,47	1,63	Increase 9,82%
Average time for cleaning well, h/well	47	26,7	Decrease 43,2%

Average draw-down level in well, m	8,04	6,25	Decrease 22,3%
Average flow in 1 well, m^3/h	103	114,7	Increase 10,2%

*Notes * Average drilling time includes testing time, time for observation and test document collection.*

4.4. Results of application reverse circulation drilling with airlift pump at Nhon Trach 5, Dong Nai industrial zone.

Results of application reverse circulation drilling technology with airlift pump have been shown in the table 4.11.

Table 4.11. Comparison the results of groundwater drilling operations at Nhon Trach, Dong Nai with reverse circulation drilling using technical water with the reverse circulation drilling and the circulating drilling technology direct using clay muds.

Criteria	Reverse circulation drilling with using technical water	Reverse circulation drilling with using clay mud	Direct circulation drilling using clay mud	Increasing, decreasing rate compared with reverse circulation drilling / direct circulating drilling using clay mud
Number investigation wells, well	5	5	5	-
Average depth of well, m	78	70	78	-

Average drilling time, h/well	47	61	71	Decrease 23%/33,8%
Average drilling penetration rate, m/h	1,66	1,47	1,3	Increase 11,5%/ 21,7%
Average time for cleaning well, h/well	25,2	47	53,4	Decrease 46,4%/52,8%
Average draw-down level in the well, m	6,44	8,04	9,7	Decrease 20%/ 33,6%
Average flow in 1 well, m^3/h	120,6	103	92	Increase 14,6%/23,7%

CONCLUSION

1. Strata at Nhon Trach, Dong Nai belong to soft and weak, with pebbles,gravels having size of 30 mm - 50 mm;

2. Application of reverse circulation drilling with airlift pump with technical water for cleaning up the well is reasonable, suitable to demands in increasing drilling efficiency and quality of the groundwater wells.

3. For increasing the efficiency in transporting drilling mud, pebbles, gravels size 30 mm-50 mm to surface when drilling groundwater extraction wells the diameter of 550mm and using

drilling pipes with inside diameter 115 mm, it is necessary to maintain the velocity of upstream wash mud flow in range of 4.2 m/s - 7.8 m/s, corresponding to the compressed air flow of 3 m^3/min - 4.5 m^3/min, compressed air pressure of 0.3 MPa - 0.4 MPa; the velocity of the mixed wash mud consisting water - drilling mud from the well bottom up to air mixing from 0.8 m/s - 2.7 m/s.

4. Always keeping the wash liquid level in the torus well compartment equal to the well mouth; maintaining the velocity of the upstream wash fluid flow into the torus well compartment from 0.07 m/s - 0.08 m/s. maximally restricting the mechanical impacts and hydrodynamics on the well walls.

5. Application reverse circulation drilling with airlift pump using technical water should help to increase the average flow in 1 well to 14.6% compared with reverse circulation drilling using airlift pump with clay muds and 23.7% increase compared with direct circulating drilling using clay muds; average draw-down level in well decreases 20% compared with reverse circulation drilling using clay muds and 33.6% compared with direct circulating drilling using clay muds; average drilling penetration rate increases 11.5% compared with reverse circulation using clay muds and 21.7% compared with direct circulating drilling using clay muds; average drilling time decreases 23% compared with reverse circulation drilling using clay muds and 33.8% compared with direct circulating drilling using clay muds; time for cleaning well decreases 46.4% compared with reverse circulation drilling using clay muds and 52.8% compared with direct circulating drilling.

PROPOSALS

Wide application the reverse circulation drilling with airlift pump and using technical water to the groundwater extraction drilling in unconsolidated sedimentary at Southern Delta and Red river Delta.

LIST OF AUTHOR'S PUBLISHED WORKS

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