Libyan Arab Republic

Kufra and Sarir Authority

Jalu - Tazerbo Project: Phase 2

APPENDIX 1

T(U1-65)

SITE REPORT

Hydrogeological Department

Institute of Geological Sciences

Exhibition Road, London SW7 2DE

1974

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Jalu–Tazerbo Project: Phase 2

Appendix 1: T(U1-65) Site Report

1. Location: 27° 39' 21" North, 22° 09' 32" East in the vicinity of U1-65.

2. Ground elevation: 350 feet above mean sea level approximately at U1-65.

3. Site plan and elevations: Figure 1 and Table I.

4. Existing water wells: Details of the three existing water wells are shown in Tables II and III.

5. Geophysical logs: The following logs are available on file but not enclosed with this report:

   i U1-65 final lithological/gamma ray/ neutron log to 3200 feet.

   ii T(U1-65)01 long string. Gamma ray log (IGS) to 618 feet below ground level.

   iii T(U1-65)01A. Gamma ray log (IGS) to 597 feet.

   iv T(U1-65)P2. Gamma ray log (IGS) to 501 feet.

   v U1-65 Water Well East. Gamma ray log (IGS) to 244 feet.

6. Drilling and completion:

   (a) T(U1-65)01 was drilled by rotary rig using Quiktrol mud. This is a dual completion well, and the two strings were emplaced in a $12\frac{1}{4}$ inch hole drilled to 648 feet. Continuous lithological sampling was carried out at 10 foot intervals from 100 to 648 feet. Both long and short string wellscreens were of 80 mm Hagusta, the long string screens extending from 158.3 feet to 167.1 feet and 548.1 feet to 556.9 feet.

TABLE I

Ground and casing top elevations above mean sea level

Site	Ground Level ft	Ground Level m	Top of Casing ft	Top of Casing m	
U1-65	350	106.67	-	-	
W.W. West	349.52	106.53	350.00	106.67	
W.W. Central	349.95	106.66	351.59	107.16	
W.W. East	350.05	106.69	351.85	107.24	
01(long)	346.97	105.75	349.13	106.41	- Casing top before trimming
01(short)	346.97	105.75	349.13	106.41	- Casing top before trimming
01A	346.64	105.65	349.33	106.47	- Casing top before trimming
P2	344.59	105.03	345.59	105.33	- (Top of Plinth)

TABLE II

Data from original B. P. Exploration Company (Libya) Limited well records

1	2	3
154	260	217-260
155	266	222-266
156	270	226-270

1. Company well file number
2. Total depth on completion in feet
3. Perforated interval below ground level, in feet.

TABLE III

Current data, existing water wells

1	2	3
W.W. East	May 1973	268
W.W. Central	May 1973	266
W.W. West	May 1973	250

1. Well location (see figure 1)
2. Date of cleaning
3. Total depth after cleaning, in feet

The short string Hagusta extended from 311.1 feet to 319.9 feet and 411.2 feet to 420.1 feet. Cement plugs were set at 210-240 feet and 509.5-529.5 feet and the space around the strings filled with formation stabiliser. While the short string developed satisfactorily the lower screens of the long string cracked and this string had eventually to be abandoned as attempts to seal off the lower section resulted in the upper screens being cemented up.

(b) T(U1-65)01A (Figure 2) the replacement for the long string of T(U1-65)01, was likewise drilled by rotary rig using Quiktrol mud. Development by swabbing and airlifting resulted in a yield of 15-16 U.S. galls/minute from this observation well.

(c) T(U1-65)P1 was abandoned when the 16 inch casing became fast at 197 feet.

(d) T(U1-65)P2 (Figure 3) has a 16 inch cased section to 250 feet cemented in a 20 inch hole. The continuation to TD of 503.6 feet is a $12\frac{1}{2}$ inch boring drilled with Revert and Quiktrol fluid (Revert alone suffered circulation losses aggravated by high air temperatures at the time of drilling) and cased with 200 mm Hagusta screen and blank set as shown, to give a total screened interval of 50 m. The well was then developed by swabbing and airlifting.

7. Lithology and stratigraphy: Details of the main units are shown in Table IV. A graphical log to the base of the Oligocene is shown in cross-section BB' of the main report and of the section to 630 feet in Figure 4 of this Appendix. The Upper and Middle Aquifer Units are essentially lithological subdivisions. The upper surface of the Oligocene is based upon a sonic log change and does not exactly correspond with the main lithological break between clays and arenaceous strata.

Selected grain size and other data for the drilled section is shown in Table V. The Upper Aquifer Unit is a very heterogeneous sequence of sands, sandstones, sandy clays, clays etc, and in considering the grain size and permeability data, this characteristic as well as some anomalous features in the log interpretations should be taken into account. The lithology based on samples and the IGS gamma-ray logs does not always correspond in detail with the Schlumberger log of the exploration oil well. The frequent absence of thin clay layers, less than 10 feet, in the latter may sometimes be ascribed to the speed with which the Schlumberger log was run, as well as the hole diameter and possible the time constant. In other instances, it would appear that the layer has pinched out or been shifted in the sequence. The system adopted has been to base the main evaluation on the Schlumberger suite of logs but to include additional significant clay layers determined by the more accurate IGS logs provided that they do not simply represent a shift in the sequence. The clay layers are particularly important in relation to screen settings and boundary conditions.

The grain size analyses show that the component sands are in general fairly uniform and medium grained. The low porosity sand horizons (ss) include one at a high level whose grain size distribution indicates low permeability and probably low porosity. The presence of interstitial cement cannot in general be inferred from the size analysis data.

8. Test pumping:

(a) Air lift test from W.W. East. A short duration (130 minutes) air lift pumping test was carried out using W.W. East for production and making observations in the other two existing wells. The discharge rate was 9.2 litres/sec and the results are shown in Table VIII. Although the results have uncertain quantitative significance in relation to the aquifer, they do show that the two observation wells have responded consistently.

(b) Development pumping: T(U1-65)P. This was carried out during 30/31 August over a 24 hour period and at three different pumping rates. Details are shown in Table VII and the specific capacity refers to the end of each pumping period.

(c) Down-hole flow velocity. Logs were run on the 31 August during development pumping and on the 6 September during the main aquifer test. The plotted data are shown in Figure 5. A fairly good correlation exists between the calculated flow near the top of the screen and the measured surface discharge as the following computations show:-

1. Maximum count rate (per minute) at 272' bgl = 315
2. Equivalent velocity in cm/sec from calibration curve = 163
3. Screen Diameter in cm. = 20
4. Screen cross-sectional

area in sq. cm = 314

5. Flow rate (velocity x area) in cc's/min. = 3,070,920
   - in U.S. galls/min = 811
6. Measured surface discharge in U.S. galls/min = 834

A number of significant points emerge from a consideration of the plot. (i) Apart from the reading at 420 ft bgl, there is an extremely close coincidence of percentage flows at the two pumping rates. This is in itself somewhat surprising. (ii) Clay zones are poorly productive. Clay zones are also apparent in the sieve analysis data from the poor sorting of the residual sand fraction. (iii) The zones of low porosity determined from certain logs correspond generally with low to moderate grain size permeability as well as low productivity. The feature suggests that the low porosity is due to poor sorting that will also reflect in a low value of permeability. There are some anomalies, notably between 460 and 480', but in this interval there is some uncertainty in lithology. (iv) The most productive zones generally correspond with moderate to high values of grain size permeability.

(d) Main aquifer test. This commenced on 2 September at 16.18 hours and continued until 16.12 hours on the 7 September.

The pumping rate averaged 749 U.S. galls/min (47.26 litres/sec) and was maintained at a fairly constant level with a variation of 2% below and 1% above the average rate. The final specific capacity was 6.87 U.S. galls/min/foot (1.42 litres/sec/metre).

(e) Aquifer analysis. Selected results are shown in Table VIII. The discharge rate was maintained fairly constant although there was a relatively sharp drop at about 1500 minutes from 775 to 750 U.S. galls/min. The form of the drawdown log-log plots showed a general correspondence with the Theis artesian curves but with a levelling off after about 1200 minutes in all plots. This phase was succeeded by an increasing rate of fall along a Theis trend which suggests that the feature was due to a change of pumping rate rather than an aquifer effect. Confirmation of artesian conditions was provided by the measurement in T(U1-65)01-A which is screened at levels both above and below the main responding level. A casing packer, in-hole cement plugs, and a pressure transducer system permitted piezometric head measurements at both these horizons to be made throughout the test. Drawdowns in the upper level did not exceed 0.07 m throughout the entire test which is of the order of a barometric change. In the lower level, within the instrument resolution, no significant change could be detected during the period of the test, which indicates no vertical inflow to the assumed responding section from below.

The method of curve fitting showed minor asymptotic deviation from the type trend for the first 50 minutes, the amounts being consistent with storage and skin effects. In W.W. East, the total drawdown after 50 minutes was 0.53 m and the deviation after 16 minutes for the type curve was 0.038 m. The two other existing wells showed comparable results. In 01 (short string), the type curve was attained after 20 minutes when the observed drawdown was 1.75 m. At 15 minutes, the deviation was 0.27 m. All deviations occur below the type curve ie drawdowns less than expected. The semi-log plots all showed clear straight line sections. In the drawdown plots of the existing wells, the tsl values were not quite attained and the transmissivity results are likely to be high.

The calculated transmissivities and storage coefficients of the three existing wells and 01 (short string) are comparable, the three former being rather higher. It is possible that the response of the existing wells relates to a more restricted section than that of 01 (ss) which has a spread of screens across the entire producing interval. The flow meter log showed that only 20% of the inflow was derived above clay layer 4 and if this lower value is applied to the drawdown data of the existing wells, a T value of some 86 m/day results. This value is lower but of the same order as those derived from the air lift test and could relate to the limited section from clay layers 2/3 to 4/5. The transmissivity value resulting from a distance drawdown plot is 210 m^2/day which suggests also that the existing wells' drawdown is lower than is to be expected, if the aquifer is homogeneous and all wells are responding to the same discharge interval. The difference could also relate to radial heterogeneity.

Using a value of transmissivity of 375 m^2/day (30,195 U.S. galls/day/ft and the average of all wells), the pumping well efficiency is calculated to be 54%; for the lower transmissivity value of 335 m^2/day for 01 (ss) (26,974 U.S. galls/day/ft), the efficiency is 60%. Both values are on the low side but the second is perhaps more realistic.

(f) Lithological correlation. The sequence at this site is rather variable but considering mainly the low porosity section between 370 and 390 feet bgl and the main sand sections between 270 and 320 feet and between 390 and 430 feet, and assuming a total transmissivity of 375 m^2/day, the calculated permeability for the sands and clayey sands is 6.4 m/day and for the low porosity sands or sandstones, sandy carbonates etc, 3.2 m/day. These values have been determined using the flow velocity log to assess relativities.

TABLE IV

U1-65: Stratigraphical and Lithological Data

	feet w.r.t. sea level	feet below ground level
U1-65	350	0
S.W.L.	240	110
Base Calanscio	-152	502
Base Upper Aquifer Unit	-283	633
Top Middle Aquifer Unit	-528	878
Base Middle Aquifer Unit	-713	1063
Top Oligocene?	-1469	1819
Base Oligocene	-2561	2911

TABLE V is on page 6

TABLE VI

U1-65 Water Wells: Pre Test Data

Well	Barometric Efficiency (percentage)	Slug Test Transmissivity m^2/day	Permeability 'screen section' m/day
01 (ss)	38	4.9	1.2
01A	-	-	-
W.W. West	34.5	15.12	1.08
W.W. East	38	35.7	2.7
W.W. Central	46	37.8	2.82

TABLE VII

T[U1-65]P: Development Pumping

r.p.m.	Period (minutes)	Discharge (U.S. galls/min)	Specific capacity (U.S. galls/min/ft)
1600	423	435	6.69
1860	370	695	7.02
1990	106	844	7.15

TABLE V

U1-65: grain size data

[Standard deviation and permeability calculated according to methods described in Masch and Denny, 1966]

Depth interval in feet below ground level		D50 microns	D90 microns	Cu		K	U.S. galls/day/ft^2
100	110	920	450	2.22	0.679	1250	
110	120	-	-	-	-	-	
120	130	970	325	3.32	0.897	620	
130	140	680	340	2.29	0.782	700	
140	150	700	300	2.73	0.854	680	
150	160	1200	340	4.12	0.907	1100	
160	170	1450	520	2.88	0.713	2200	
170	180	800	340	2.79	0.869	760	
180	190	530	210	3.10	1.170	320	
190	200	560	180	4.17	1.363	230	
200	210	410	170	2.76	1.033	300	
210	220	470	200	2.80	0.976	360	
220	230	700	220	4.90	1.340	260	
230	240	420	185	2.70	0.994	310	
240	250	610	285	2.46	0.883	540	
250	260	760	290	3.14	1.089	460	
260	270	1000	385	3.38	0.840	1000	
270	280	820	385	2.47	0.812	840	
280	290	990	325	3.69	0.912	820	
290	300	470	205	2.59	0.911	380	
300	310	630	225	3.29	0.984	490	
310	320	580	196	3.52	1.039	430	
320	330	680	225	3.60	1.126	450	
330	340	410	180	2.78	1.122	270	
340	350	400	160	2.94	1.148	260	
350	360	350	142	2.96	1.122	230	
360	370	285	125	2.64	0.949	220	
370	380	295	118	3.05	1.014	205	
380	390	390	195	2.41	1.022	270	
390	400	380	185	2.49	1.025	270	
400	410	370	185	2.34	0.994	265	
410	420	550	270	2.30	0.691	660	
420	430	480	245	2.24	0.752	480	
430	440	1410	260	6.0	1.190	600	
440	450	530	165	4.12	1.429	180	
450	460	530	190	3.47	1.270	250	
460	470	490	205	2.93	1.175	300	
470	480	620	290	3.63	1.115	480	
480	490	600	200	3.85	1.360	230	
490	500	580	205	3.61	-	-	
500	510	670	190	4.63	1.725	140	
510	520	395	168	2.80	1.335	190	
520	530	470	150	4.07	1.703	120	
530	540	255	125	2.22	1.035	180	
540	550	245	122	2.50	1.075	185	
550	560	290	130	2.53	1.036	215	
560	570	370	130	3.38	1.315	200	
570	580	340	125	3.32	1.327	210	
580	590	-	-	-	-	-	
590	600	290	100	3.55	1.38	155	
600	610	325	125	3.12	0.954	250	
610	620	290	120	2.96	1.197	205	
620	630	225	120	2.12	0.836	220	

TABLE VIII

Selected Aquifer Test Results

Well	Transmissivity m^2/day	Storage Coefficient x 10^{-4}	Analysis[1]
Air lift test from W.W. East			
W.W. Central r = 28 m	130	-	RDD/SL
W.W. West r = 54 m	90	5.4	DD/LL; tsl = 315 mins
	132	4.7	DD/SL; slp from 15-100 mins
	144	4.7	RDD/SL
Main test from T[U1-65]P			
01	308	4.3	DD/LL; tsl = 164
(short string)	284	4.1	DD/SL; T1 from 10-130 mins
r = 81 m	385	1.8	DD/SL; T2 from 130-1000 mins
	290	3.7	R/LL
	266	3.3	R/SL
	476	2.3	RDD/SL
	335	3.3	Average values 01-ss
Existing wells:			
1.. W.W. East	421	5.2	DD/LL; tsl = 1196 mins
r = 231 m	489	3.9	DD/SL; slp, 60-1200 mins
	407	4.2	R/LL
	434	3.3	R/SL
	434	-	RDD/SL
	330	5.4	Chow
	418	4.4	Average values W.W. East
2. W.W. West	391	7.5	DD/LL; tsl = 1093 mins
r = 177 m	468	5.8	DD/SL; slp = 40-1400 mins
	385	-	RDD/SL
	415	6.7	Average values W.W. West
3. W.W. Central	387	5.7	DD/LL; tsl = 1114 mins
r = 204 m	390	2.4	DD/SL; Chow analysis
	471	3.9	DD/SL; slp from 40-1000 mins
	416	4.0	Average values W.W. Central
	416	5.0	Average values all existing wells
	375	4.2	Average values all existing wells and 01
All wells	210	8.9	Distance drawdown

[1]Analysis:

- DD : drawdown
- LL : log-log
- SL : semi-log
- slp : straight line plot
- R : recovery
- RDD : residual drawdown
- tsl : time before straight line plot becomes theoretically valid

TABLE IX

Field and Laboratory Chemical Analysis (U1-65)P2

IGS reference			74/146
Date of sampling	3.9.73	5.9.73	7.9.73
Formation temperature (° C)	28°	29°	28°
Specific electrical conductance	1430	1340	1360
pH (field)	7.72	7.32	7.63
eH (mv)			+129
Ca^{2+}			58
Ma^{2+}			31
Na^{+}			174
k^{+}			28
HCO_3^- (field)	346	353	351
SO_4^{2-}			225
Cl			198
NO_3			< 20
Total determined major constituents			1065
Sr^{2+}			1.9
F^-			1.73
Total Fe			0.034
Total Mn			0.029
Cd			0.0005
Co			0.002
Cu			0.027
Ni			0.005
Pb			0.011
Zn			0.021
Σ cations			13.72
Σ anions			13.87
Ionic balance			-0.54
SO_4/Cl			0.46
Mg/Ca			0.88
K/Na			0.094
SAR (Sodium adsorption ratio)			4.58

TABLE X

Corrater Readings and Corrosion Rates (5.9.73)

Metal/alloy	A	B	R
Copper	1.25	1.25	1.25
Stainless steel 316	1.00	1.02	1.01
Aluminium 6063	1.05	1.00	1.03
Aluminium 5052	1.00	1.00	1.00
Zinc	0.80	2.10	1.45
Mild steel 1010	0.50	2.50	1.50
Mild steel 1020	3.60	1.30	2.45
Bronze 660	1.17	1.10	1.14
Red brass 123	1.20	1.20	1.20
AP1 H40	11.00	4.00	7.50
308 L Stainless	1.00	1.02	1.01

Note: Columns A and B refer to readings at different polarity, R is the average

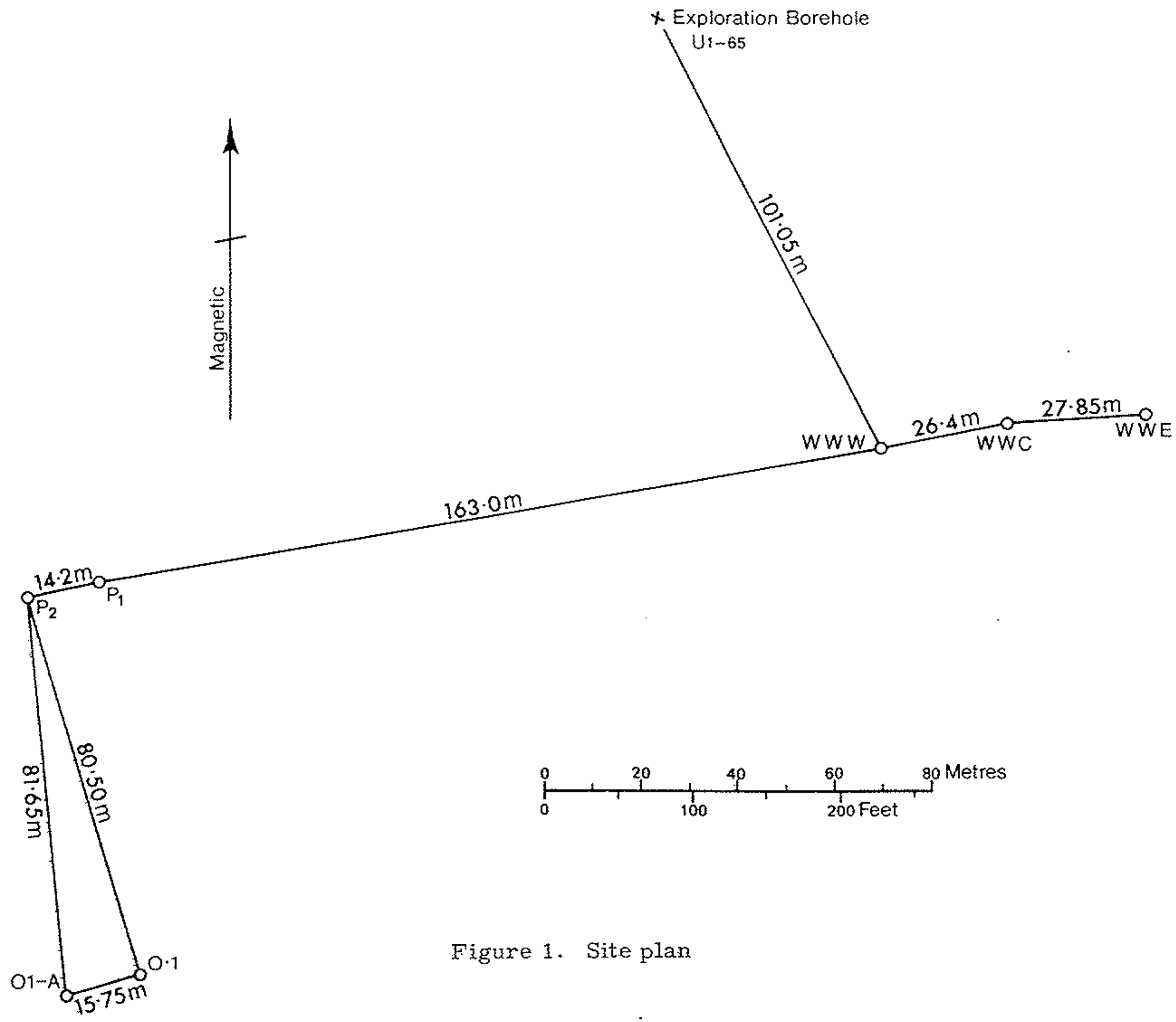
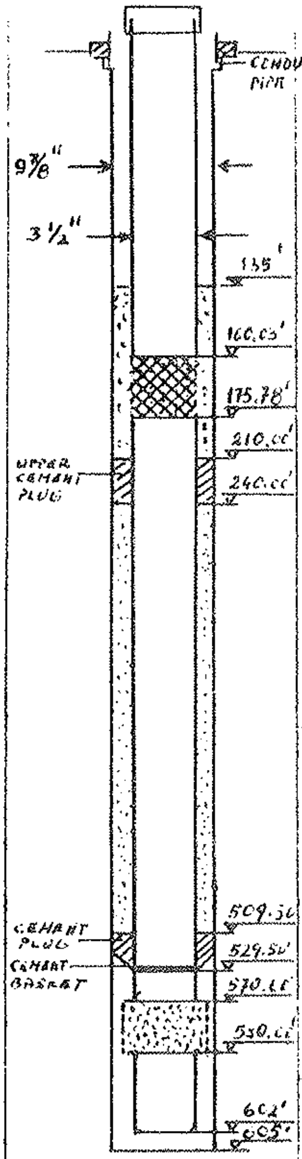


Figure 1. Site plan

WATER WELL

CUSTOMER : KAC LOCATION : T(U1-65)-01A	RIGGING UP ON: 19 7 73 AT RELEASE LOCATION: AT 31 7 73.	TOOL PUSHER: DRILLERS: BIZJAK D. MILOSHEVICH	4

FORMATION	SKETCH OF WELL	
		see below

DRILLING

Bit Ø 9 7/8" ..... from .. 0.00' .... to 605.00' ..

LOST CIRCULATION from .... to ....

MUD MATERIALS USED

Bentonite .... kg Spersen .... kg

Caustic Soda .... kg CMC .... kg

QUIK TROL 50 SK

~~CASING~~ TUBING Ø OD 3 1/2" from +3' ...... to 160.03' ...

from 175.78' .... to 570.60' ....

from 580.00' .... 604.00" ....

HAGUSTA-SCREENS Ø ID 80 mm from 570.60' .. to 580.00' ....

~~AND~~ SLOTTED TBG WIRE WRAPPED Ø 3 1/2" OD 160.03' 175.78' ....

PLUG UPPER FROM 210' TO 240', LOWER FROM 509.5' TO 529.5'

CEMENT BASKET AT 529.5' ....

BACKFILLING FROM 509.50' TO 240.00'

BACK FILLING FROM 210.00' TO 135.00', TOTAL 344.5' BACK FILLED.

JETTING PIPE Ø to ....

Range :

WELL DELIVERY

UPPER SCREEN 13 GAL/MIN Dynamic W.L. 1 ....

LOWER SCREEN 17 GAL/MIN Dynamic W.L. ....

STATIC WATER LEVEL after jetting 100' ....

WELL HEAD

FUEL .... Toolpusher signature

GAZOLINE ....

Figure 2. Site T[U1-65]01A: contractor's completion report

WATER WELL

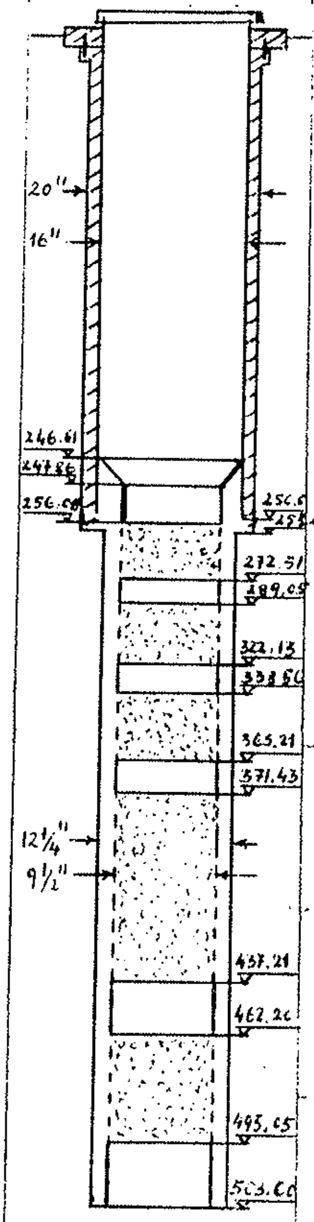
CUSTOMER : KAC
LOCATION : T(U1-65)-P2

RIGGING UP ON: 1.7.73 AT
RELEASE LOCATION: AT 15.7.1973.

TOOL PUSHER:
DRILLERS: MILOSHEVICH
: BIZJAK
: KARADICH

RIG NO 4

FORMATION	SKETCH OF WELL



DRILLING

Bit Ø 20" from 0.00' to 258.0'
12¼" 258.0' 504.0'

LOST CIRCULATION from.........., to..........

MUD MATERIALS USED

Bentonite 42 sx kg Spersen ....kg
Caustic Soda 10 kg CMC ....kg
REVERT 82 sx QUIKTROL 35 sx

CASING Ø OD 16" from +2' to 250'
CONDUCTOR Ø 24" from +3 to 7'

SCREENS Ø ID ** from.......... to..........
or SLOTTED CG

PLUG..........
CEMENTED ~~BASKET~~ ANNULUS 20"/16" FROM 0.0 TO 258'
CONCRETE BASE ON SURFACE 4'x4'x3'

JETTING PIPE Ø to..........
Range :
WELL DELIVERY
.... Dynamic W.L. ....
.... Dynamic W.L. ....
STATIC WATER LEVEL after jetting..........
WELL HEAD

FUEL..........
GAZOLINE..........

Toolpusher signature

** SCREEN INSTALLATION.

LEAD SEAL FROM 246.61' TO 247.86'

BLANK	FROM	247.86'	TO	256.05'
-"-	-"-	272.51'	TO	289.05'
-"-	-"-	322.13'	TO	338.56'
-"-	-"-	365.21'	TO	371.43'
-"-	-"-	437.21'	TO	462.26'
-"-	-"-	495.65'	TO	505.60'
BLANK TOTAL				32.95'

HAGUSTA SCREEN

FROM	256.05'	TO	272.51'
-"-	289.05'	TO	322.13'
-"-	338.56'	TO	365.21'
-"-	371.43'	TO	437.21'
-"-	462.26'	TO	495.65'
HAGUSTA TOTAL			172.79'

REMARK:
THREE EXISTING WELLS HAS BEEN CLEANED AND AIR LIFT TESTED IN THIS SITE.

TOTAL SCREEN + BLANK + LEAD SEAL = 256.95'

Figure 3. Site T[U1-65]P2: contractor's completion report

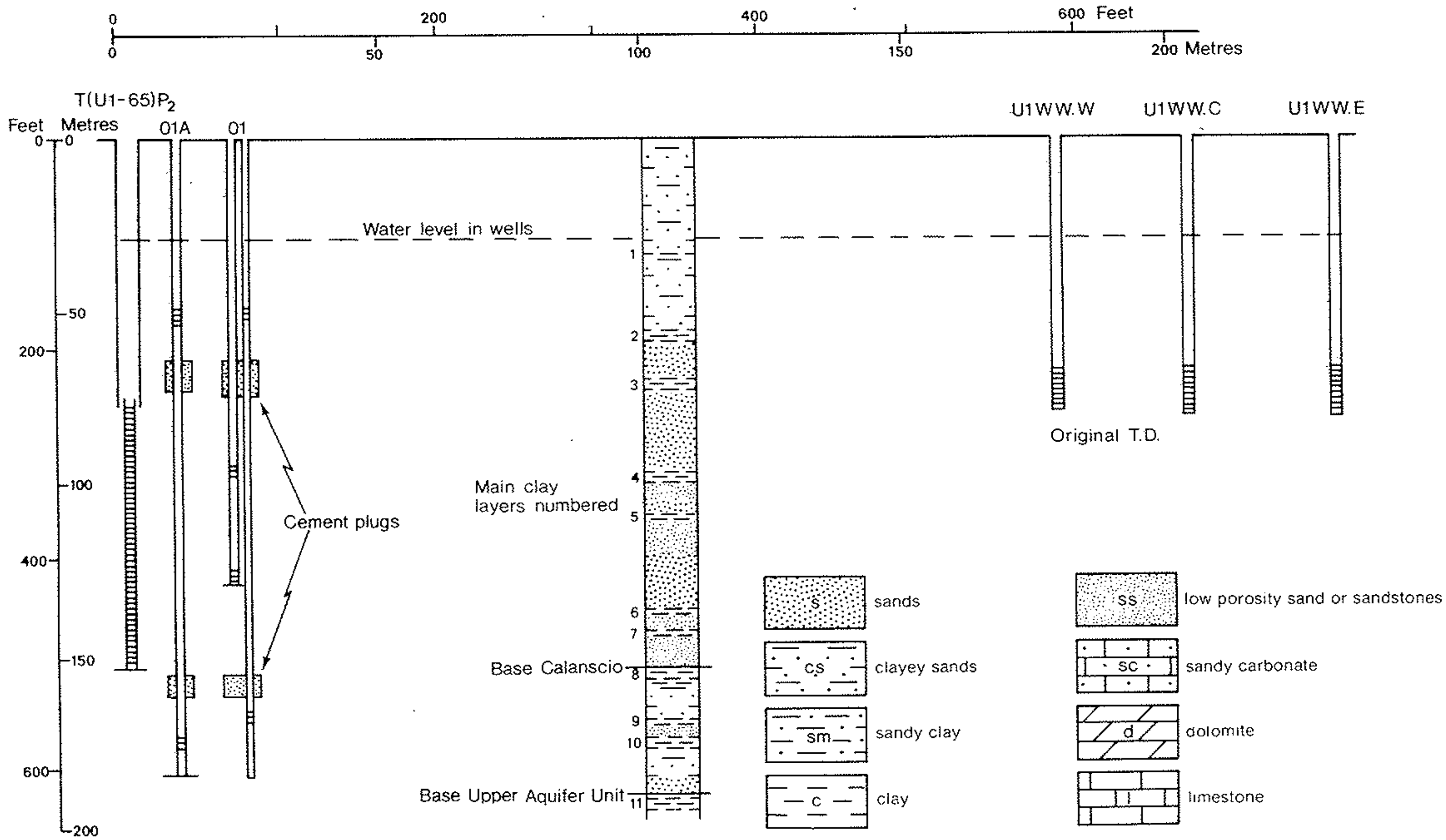


Figure 4. Lithological log and cross-section

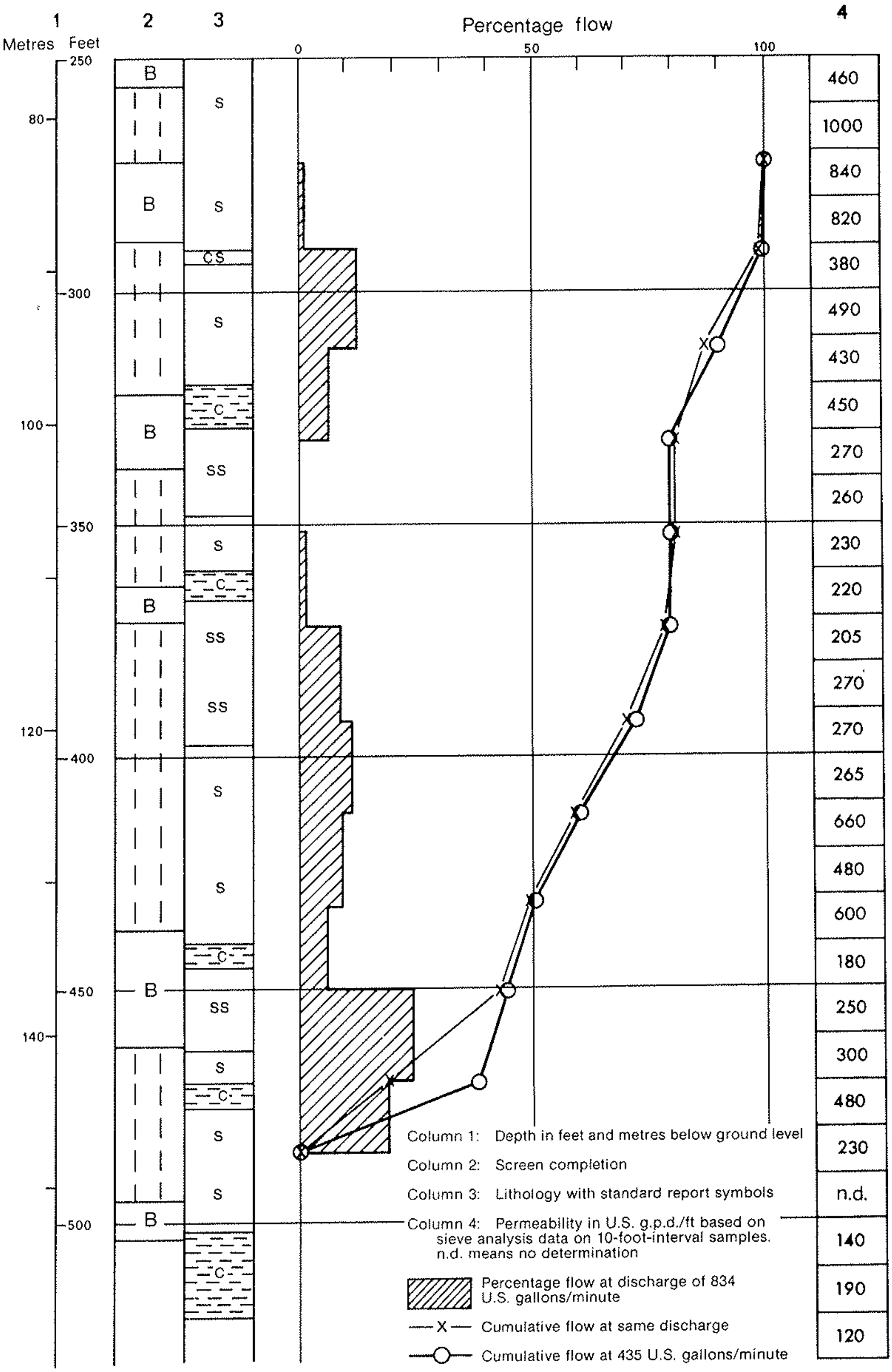


Figure 5. Flow velocity log in T[U1-65] P2