6. Water Quality Analysis for Existing Wells

1) Temperature of Groundwater Measured at Each Well

Temperature of the groundwater in dug wells and driven wells varies considerably very much depending on air temperature. It was observed 25.4°C to 32.2°C in the period of January 26 to February 2, 1997, and 26.9°C to 36.0°C from June 11 to 18, 1997.

Temperature of groundwater in wells equipped with hand pump or motor pump is mostly affected by the rising pipes. The lowest temperature in such wells seems to be most likely near the temperature of groundwater, i.e., 25.6°C in January, and 28.3°C in June 1997, for the hand pump well No.35, and 28.0°C for the well No.43 in January 1997, and 28.5°C for the well No.49 of motor pump well in June 1997. It is indicated that the temperature of deeper wells is almost the same throughout all seasons.

2) Electric Conductivity (EC) and pH of Groundwater Measured at Each Site

EC and pH values reflect contained materials and soluble contents in groundwater. EC value of groundwater in dug well and driven well varies with location and season. In general, EC value in the existing 14 dug wells ranges from 28 to 454 us/cm. The half of 14 dug wells showed decreased values in June 1997. The reason of decrease is that the groundwater of such type of wells is easily mixed with rains. The rest 7 data showed increased EC values in June 1997. The reason is considered that contaminated surface water may be entered into the wells after rain. EC value of groundwater in the driven wells with concrete lining has the same characteristics as the dug well.

pH values of groundwater in the dug well and the driven well with concrete lining are decreased and/or nearly the same value as that in January 1997 in general.

EC value of groundwater in the hand pump well is mostly less than 100 uS/cm. pH value of 5 to 7 in the well is mostly same in January 1997, and/or slightly decreased in June 1997. EC value of groundwater in the motor pump installed deep tube wells is about 50uS/cm in most cases. pH value is constantly in the range of 4.8-5.5. There is no big difference between January 1997 and June 1997.

3) Water Quality Test Result in the Laboratory (JICA study team)

Water samples of 79 existing wells were analyzed during the period of January to February 1997 using JICA instrument (HACH) in the laboratory of the JICA study team. The test items are temperature, pH, color, EC, hardness (total $CaCO_3$), Nitrite ($N0_2$), Nitrate (NO_3), Ammonium (NH_4), Manganese (Mn), Ferrite (Fe), Chlorite (Cl), Calcium (Ca), Chemical Oxygen Demand (COD), General Bacteria and Coliform.

Table 6.1 Seasonal Change of Water Quality of Existing Wells

(June / January - February, 1997)

Well No	12	31	34	63
NO_2	0.8	No data	No data	No data
NO_3	1.5	No data	No data	No data
NH_4	0.9	1.3	1.5	0.8
Mn	2.6	6.0	5.0	5.0
Fe	1.8	5.6	2.8	2.3
Cl	1.5	0.9	0.9	1.4
Ca	0.7	0.3	0.3	1.0
Mg	0.7	0.4	3.3	1.7
Bacteria	Disappear	Disappear	Disappear	Disappear

The figures in the table is obtained by deviding the June data by Jan. to Feb. 1997 data for each item. The original data is shown in Data Book. The data may include an error of 10 to 20%, judging from mutual checking by various agencies.

Increase of Cl value in the well No.12 can be understood by the interview that the user sometime treated water by chlorinating. The reason of Fe and Mn increase may be resulted from the groundwater has been occupied by percolation without infiltration of surface water, after the dry season from January to April 1997.

4) Findings in the data tested in January to February 1997

Hardness (total $CaCO_3$) is normally less than 1 mg per liter for most case, except the southern area and Siem Reap Town area. Hardness in the exceptional area and Siem Reap Town ranges from 10 to 200 mg per liter, and the average is 20 mg per liter.

Nitrite (NO_2), Nitrate (NO_3), Chloride (Cl), Calcium (Ca), Manganese (Mn), and Magnesium (Mg) are almost negligible in the most cases, which is below the standards of WHO and Japan Water Supply.

The result of Ammonium (NH_4) shows around 10 times differences among different tests. However, the data reveals that the groundwater of the open wells shows higher value than that of hand pump and motor pump wells.

Ferrite (Fe) content of the groundwater shows very high value. It was sometimes ten times than that of the standards.

The general bacterial is found from open wells in most cases. The groundwater of motor pump installed deep tube wells and hand pump wells are not contained with Coliform.

7. Constructed Monitoring Wells

7.1 Drilling Quantity

1) The 8 Core Drilling

The 8 core drilling were carried out in 1997-1998. The revised 8 drilling logs and 11 geological profiles are in Annex 3.3.1 “Geology”. The revised results were perfectly and effectively utilized for the simulation modeling.

2) The 14 Exploratory and Observation Wells

In the same locations of the core drilling except with WT1, the 8 observation wells were constructed. Also, shallow well of 40 m and deep well of some 80m were constructed in the 2 land subsidence monitoring stations with the same depth of the GWL observation well. The locations of the 2 sets of observation wells are:

Station-9 or called as Station-a in the teacher's training school

- LTa-1 observation well (l=72m) for land subsidence and GWL monitoring
- LTa-2 observation well (l=35m) for land subsidence and GWL monitoring
- WT9 well for LTa-2 and WT11 well for LTa-1 were also constructed for the pumping test.

Station-10 or called as Station-b in the west side front of Angkor Wat

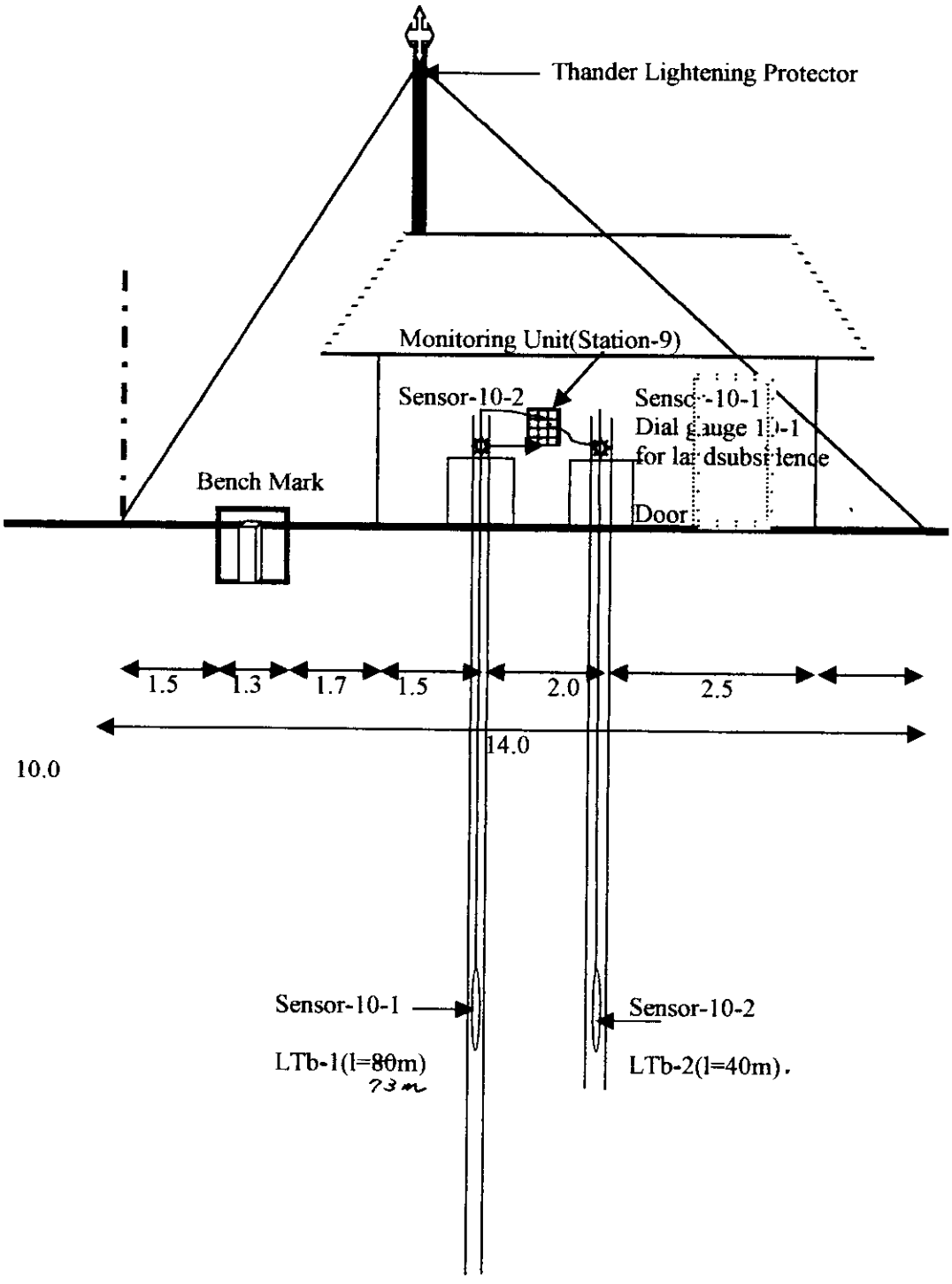
- LTb-1 observation well (l=73m) for land subsidence and GWL monitoring
- LTb-2 observation well (l=40m) for land subsidence and GWL monitoring
- WT2 well is for LTb-1 pumping test, and WT10 well is for LTb-2 test.

The detail of observation wells in Station-a and Station-b is shown in Figure 7.1.1 and Figure 7.1.2 respectively.

The following table shows the purpose, well depth and materials:

Table 7.1.1 Well Design and Monitoring Purpose

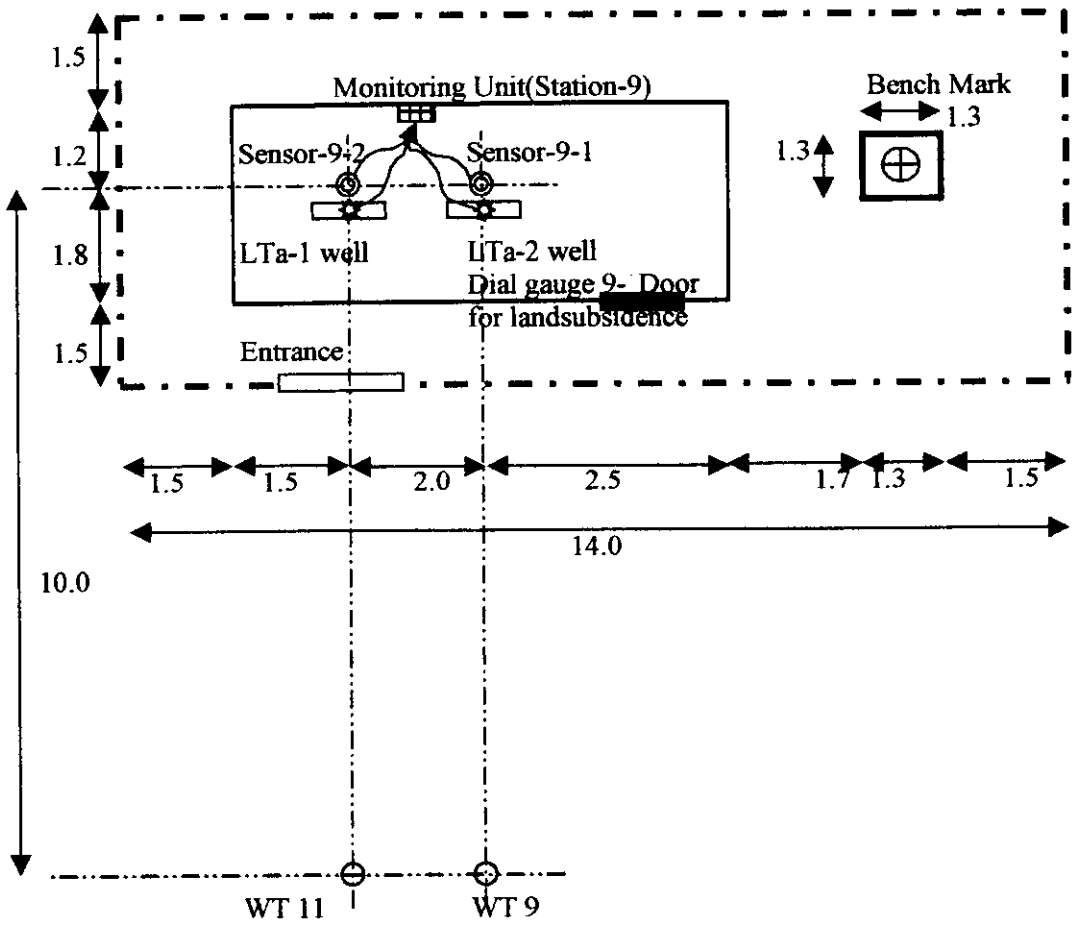
Well No	Screen depth(m)	Purpose	Materials
WT1		Abandoned	
WT2	61.38-73.20	Pumping test with LTb-1	PVC6"
WT3	20.38-32.20	GWL monitoring	PVC6"
WT4	13.38-25.20	GWL monitoring	PVC6"
WT5	42.38-54.20	GWL monitoring	PVC6"
WT6	13.38-25.20	GWL monitoring	PVC6"
WT7	44.38-56.20	GWL monitoring	PVC6"
WT8	67.38-79.20	GWL monitoring	PVC6"
WT9	26.38-39.20	Pumping test with LTa-2	PVC 6"
WT10	27.38-39.20	Pumping test with LTb-2	PVC 6"
WT11	61.38-73.20	Pumping test with LTa-1	PVC 6"
LTa-1	63.62-71.90	Land subsidence monitoring	100A,STPG
LTa-2	26.61-34.90	Land subsidence monitoring	100A,STPG
LTb-1	64.61-72.90	Land subsidence monitoring	100A,STPG
LTb-2	31.61-39.90	Land subsidence monitoring	100A,STPG



Note: Sign Board is installed along the road of Angkor Wat

Location : In front of Angkor Wat

The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 7.1.1 Layout of the Observation Wells (Station-a)**
Japan International Cooperation Agency	



Location : Teacher's Training School

Note: Sign Board is installed in front of the School(along the road to Angkor Wat)

The Study on Water Supply System for Siem Reap Region in Cambodia	**Figure 7.1.2** Layout of the Observation Wells (Station-b)
Japan International Cooperation Agency	

7.2 Pumping Test Result in 1997 and 1998

The following table shows the pumping test results:

Table 7.2.1 Summary of Pumping Test

Well No	Screen depth(m)	Discharge	Specific capacity	SWL-DWL
WT3	20.38-32.20	48	3	1.6-16.7
WT4	13.38-25.20	444	81	0.9-6.5
WT5	42.38-54.20	307	15	2.9-21.0
WT6	13.38-25.20	307	46	1.8-8.5
WT7	44.38-56.20	61	1	0.4-44.8
WT8	67.38-79.20	<1	-	4.9-60.0
LTa-1	63.62-71.90	-	-	1.9-63.0
LTa-2	26.61-34.90	417	129	3.6-6.9
LTb-1	64.61-72.90	9	0.6	3.3-18.2
LTb-2	31.61-39.90	417	46	2.1-11.1

Note: Screen length were equally 12m.

The above result reveals that the wells of WT4, LTa-2 and LTb-2 installed the screen in alluvial and diluvial sand layer have a good capacity. Also, WT5 and WT6 wells are second good performance wells. They are installed the screen in alluvial and diluvial deposits. However, the WT 3 well installed in the same layers in the north area has very poor capacity. The wells installed the screen in deeper portions such as WT7, WT8, LTa-1 and LTb-1 were extremely low pumping discharge. No preferable aquifer was found there. The detail is shown in Data Book.

When a screen is installed in longer than 12 m in the vicinity of WT4 or near the area of air port , a discharge of more than 444 liters/minute can be expected. The two pilot production wells were constructed in the said area in the same design at the feasibility stage. The result is described in Main Report.

7.3 Monitoring of Groundwater Level and Land Movement

1) Monitoring Records of Groundwater Level

A total 8 automatic monitoring units were installed at the 8 locations. Almost all units had been well recording from February 1998 until November 1999, except with the WT6 unit and Station-b. The unit WT6 had been replaced with spare unit of No.2 at the end of Dec. 1998. The unit WT4 was repaired in Tokyo in May 1998.

The 9 recording units were very effectively used at present for an interpolation of

the monthly simultaneous data of the existing wells and so on.

2) 4 units of land subsidence monitoring and GWL monitoring

The 2 sets of monitoring units for upper aquifer and deeper aquifer had been installed at the teacher's training school and in front of Angkor Wat, respectively. Unfortunately the unit in the teacher's training school had stopped due to power circuit trouble since the end May 1998. The unit was repaired in Tokyo by May 1998.

3) Relationship between GWL fluctuation and land settlement records

The records of the LTb-1 and LTb-2 installed in front of Angkor Wat were effectively used in this study for the relation between land movement and GWL fluctuation.

The data in front of Angkor Wat from Feb. 1998 to August 1999 reveal that the shallow GWL fluctuation is 2.5 m and deep G/W/L fluctuation is 1.5m. Its land movement in the same period was reversible and slightly responding with 1.3 mm ranging for the deep GWL fluctuation. The record is shown in Attachment-1. In the epoc of rising the land movement from the bottom in May-July 1998, the GWL was inactive or very slowly rising. The reason can be that the groundwater had started to flow very actively without changing the water level through the upper aquifer at that period, the groundwater was acted as pore water in the upper aquifer to rebound, due to caused pressure i.,e, caused pore water pressure.

The obtained monitoring records of WT3 – WT8 and Station-a are compiled in Attachment-1 for the period from February 1998 to August 1999. The further continuos recording shall be carried out for total 8 monitoring wells.