CHAPTER 2 CURRENT CONDITIONS OF THE EXISITING WATER SUPPLY SYSTEM

2.1 Outline of the Water Supply System before the Earthquake

1) Water Source

Groundwater is used as the water source for the water supply system in Bam and Baravat areas. All the water sources are deep wells and there were originally 16 wells, where 12 of which locate around the warehouse of BWSC and 4 in the city. However, since one of the wells, Well No.3, had already been out of service, 15 wells were found operational. Since the water sources had sufficient collective capacity, only two to six wells were used before the earthquake. After the earthquake, BWSC had to use all the 15 wells because water consumption for irrigation use and the amount of unaccounted water has increased significantly.

The water source for Baravat is also groundwater and there are two wells from which water is distributed to the Baravat service area. In addition, about 30 l/s of water is transmitted to the Baravat service area from Bam water supply system.

All the water sources have good water quality, except for No.1 and No.2 wells that have relatively high concentration of EC, Sodium and Chloride. Chemical analysis is carried out twice a month in Kerman and bacteriological analysis is carried out in Bam. The result of the chemical analysis is presented in Table 2.1.1. Bacteriological analysis is carried out everyday at the wells, reservoirs and some of the public taps and they all show satisfactory results.

Table 2.1.1 Water Quality Analysis Results of Wells and Reservoirs

Well No.	Unit	1	2	5	6	7	8	9	10	11	12	Reservoir
Date of Analysis		Oct. 2003	Oct. 2003	Sep. 2003	Oct. 2003	Sep. 2003	Oct. 2003	Oct. 2003	Oct. 2003	Sep. 2003	Sep. 2003	Sep. 2003
Temporary hardness	mg/l	336	344	152	136	106	168	128	104	136	180	140
Permanent hardness	mg/l	116	68	0	0	3	0	0	0	0	0	0
pH	-	7.87	7.89	8.08	8.21	8.14	8.13	8.21	8.19	8.11	8.03	8.09
Turbidity	NTU	0.03	0.30	0.13	0.02	0.10	0.02	0.04	0.02	0.12	0.21	0.09
TDS	mg/l	983	1050	416	465	412	511	512	357	453	602	546
Electric Conductivity	microS/cm	1519	1618	694	739	636	963	788	627	798	1003	343
Calcium	mg/l	81.60	86.40	10.00	33.60	21.00	36.30	28.80	25.60	33.60	44.80	44.80
Magnesium	mg/l	31.63	30.72	12.48	12.40	11.52	18.24	13.44	9.60	12.48	16.32	8.64
Sodium	mg/l	235.57	246.10	37.91	123.72	92.12	159.52	125.82	115.29	132.14	141.62	111.08
Potassium	mg/l	6.20	6.40	3.70	4.40	3.90	6.40	4.40	3.80	4.40	5.80	4.40
Fluorine	mg/l	-	-	-	-	-	-	-	-	-	-	-
Bicarbonate	mg/l	268.40	336.72	204.26	219.60	195.20	229.36	200.08	195.20	170.32	212.60	219.60
Carbonate	mg/l	0	0	0	0	0	0	0	0	0	0	0
Nitrite	mg/l	0	0	0	0	0	0	0	0	0	0	0
Nitrate	mg/l	18.60	20.10	8.99	7.32	3.13	7.54	7.45	7.00	7.20	3.20	8.39
Chloride	mg/l	230.00	232.00	76.00	76.00	64.00	118.00	88.00	66.00	112.00	162.00	110.00
Sulphate	mg/l	254.00	241.00	92.40	102.00	79.60	136.50	107.20	82.20	94.40	100.60	92.60

Source: WSCK

2) Pumps, Wells and Reservoirs

The list of pumps for the 15 wells in Bam and the two wells in Baravat is shown in Table 2.1.2.and Table 2.1.3. The network of conveyance pipes for these wells is shown in Figure 2.1.1.

Table 2.1.2 Evaluation of Wells and Pumps

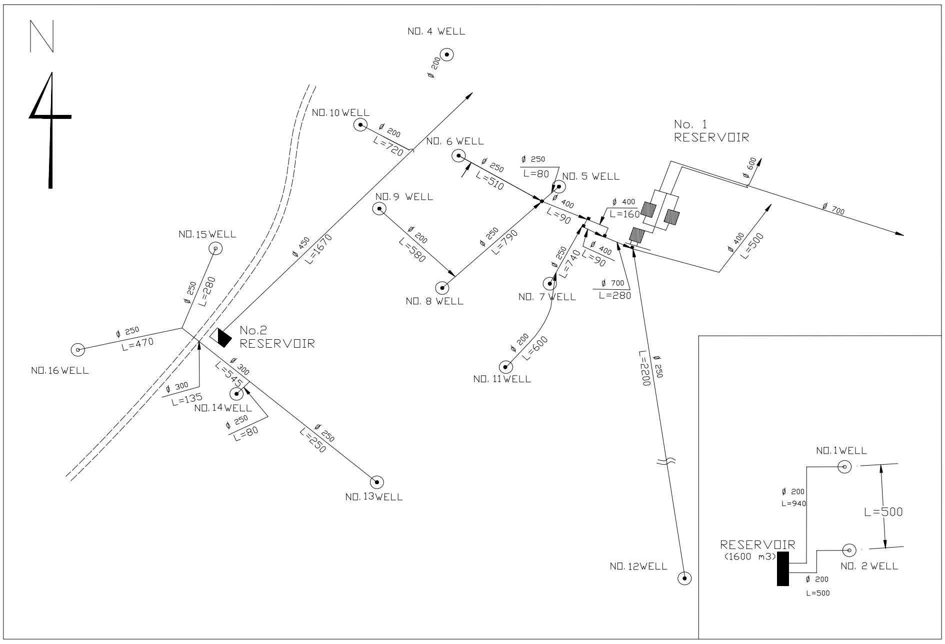
Location	Connected to	Well Nomber	Pump Type * 1	Specification of well				Actual *2 Discharge	Evaluation	Remarks	Coordinates Deg, Min, Sec	
				Well Depth (m)	Discharge Pipe Diameter	Pump Capacity (l/s)	Pump Power (kw)	(l/s)			N	E
Bam	Inside City	1	Sub	100	8	48	62.5	31	good	House cracked	29, 05, 50	58, 20, 40
		2	Sub	120	8	54	160	43	good	House cracked	29, 06, 57	58, 19, 08
	Direct to Network	3	Sub	-	6	-	92	-	out of use		-	-
		4	Grd	185	8	54	160	36	good		29, 06, 15	58, 18, 01
			Total			156	475	110				
	Bam well field	5	Sub	179	6	46	92	40	good		29, 05, 53	58, 18, 21
		6	Sub	185	6	73	110	48	good		29, 05, 59	58, 18, 05
	R1	7	Sub	200	6	73		30	good		29, 05, 38	58, 18, 19
		8	Sub	200	6	70	110	25	good		29, 05, 36	58, 18, 01
		9	Grd	185	8	54	160	45	good		29, 05, 50	58, 17, 51
		10	Sub	185	6	44	92	30	good		29, 06, 04	58, 17, 47
		11	Sub	185	8	41	92	30	good		29, 05, 23	58, 18, 13
		12	Sub	250	8	43	92	25	good		29, 04, 44	58, 18, 45
			Total			444	748	273				
	Bam well field	13	Sub	250	8	32	92	15	fair	pump mechanical trouble	29, 05, 05	58, 17, 51
		14	Sub	250	8	35	92	18	good	capacity decreased	29, 05, 20	58, 17, 26
	R2	15	Sub	250	8	35	92	55	good		29, 05, 44	58, 17, 23
		16	Sub	250	8	32	92	20	good		29, 05, 27	58, 17, 00
			Total			134	368	108				
Baravat		1		150	8	60	92	35	good	House collapsed	29, 04, 25	58, 24, 02
		2		150	6	45	110	47	good	House partly collapsed	29, 04, 39	58, 24, 01
			Total			105	202	82				

Note: *1 Sub: Submersible pump, Grd: Ground pump
*2 Measured after the earthquake, Feb. 2004
Source: JICA Study Team

Table 2.1.3 Well and Pump Information for Bam and Baravat

	Well No.	Depth (m)	Dynamic W.L .(m)	Static W.L .(m)	Well Diameter (inch)	Discharge (l/s)	Date of Discharge Measurement	Pump Type	Engine Type	Virtual Amp (A)	Discharge. Pipe Dia. (inch)	Cable Type	Installation Depth (m)
Bam	1	100	85	60	10	31	28 Feb. 2004	374.6a	9A 623-2 62.5kw/85hp	132	8	3x25	
	2	120	60	-	10	43	28 Feb. 2004	11 stage turbin	160kw/220hp	-	8	-	-
	3	-	200	-	12	-	-	425.5	92kw/125hp	-	-	-	-
	4	185	98	86	12	36	28 Feb. 2004	16 stage turbine	160kw/220hp	-	8	3x70+35	-
	5	179	135	90	12	40	28 Feb. 2004	374.8	92kw/125hp	187	6	3x75	-
	6	185	100	75	12	48	28 Feb. 2004	425.5	110kw/150hp	222	6	3x50	-
	7	-	200	90	12	30	28 Feb. 2004	425.5	110kw/150hp	-	6	3x50+25	-
	8	200	140	75	12	25	28 Feb. 2004	425.5	110kw/150hp	-	-	-	-
	9	185	110	100	12	45	28 Feb. 2004	15 stage turbine	160kw/220hp	-	8	3x50+25	-
	10	285	125	100	12	30	28 Feb. 2004	374.7	92kw/125hp	187	6	3x50	-
	11	185	140	105	12	30	28 Feb. 2004	374.7(425.5)	92kw/125hp (110kw/150hp)	187	8	3x70	-
	12	250	150	(120)	12	25	28 Feb. 2004	374.8	92kw/125hp	-	8	-	-
	13	(250)	(190)	(120)	(12)	15	28 Feb. 2004	(374.8)	(92kw/125hp)	-	-	-	-
	14	250	190	120	12	18	28 Feb. 2004	374.8	92kw/125hp	-	-	3x70	222
	15	250	190	120	12	55	28 Feb. 2004	374.8	92kw/125hp	-	-	3x70	222
	16	(250)	(190)	(120)	(12)	20	28 Feb. 2004	(374.8)	(92kw/125hp)	-	-	-	-
Baravat	1	150	95	-	12(10)	35(60)	28 Feb. 2004	374.8 (374.5)	92kw/125hp (55kw/75hp)	115	6	-	-
	2	150	90	-	12	47	28 Feb. 2004	425.5	110kw/150hp	222	8	3x50	-

Note: ( ) means uncertain figures
Source: WSCK



Source: WSCK

Figure 2.1.1 Network of Conveyance Pipes for Wells

The No.1 reservoir (R1), which is located to the north of BWSC warehouse, is composed of three reservoirs with a total capacity of 30,000 m^3 (10,000 m^3 x 3). The No.2 reservoir (R2) with a capacity of 5,000 m^3 is located 1,900 m away to the west of R1 (see Figure 2.1.1). The R2 was newly constructed and started its operation in 2003.

3) Disinfection

Disinfection is undergone by using gaseous chlorine at R1. At other water sources of No.1, No.2, and No.4 wells that do not have reservoirs, chlorination, injecting chlorine solution directly into the discharge pipe of the wells is applied for disinfection. A housing for chlorination facility is constructed at R2, and gas chlorination is planned to be used when it is completed, while chlorine solution is used for Baravat water sources.

4) Population Served and Supplied Amount

The following Table 2.1.4 summarizes the conditions of water supply before the earthquake.

Table 2.1.4 Condition of Water Supply before the Earthquake

Item	Bam City	Baravat
Population served	104,000	20,800
Service ratio	100%	100%
Supplied amount	23,391 m^3/day *	4,980 m^3/day
Number of house connections	21,812	3,678

Note: * including surrounding villages
Source: BWSC

The service ratio of Bam municipality and Baravat Township covers almost 100% of the areas and the Bam water supply system delivers water to the surrounding areas, rural area, as well.

5) Distribution Pipe Network

The distribution pipe network of Bam city is divided into two blocks. East Block, eastern lower area of the city and surrounding rural areas, is supplied with water from R1 by gravity. West Block, high elevation area of the western part of the city, is supplied with water from R2 by gravity. The diameters of distribution mains are 450 mm, 600 mm and 700 mm and 70% of the pipe materials including distribution pipes are asbestos. The rests are cast iron and polyethylene.

Baravat has a small urbanized area with a household connection of 3,678 that constitutes a single water supply block. The transmission pipe has a diameter of 300 mm, and that of distribution pipe is 200 mm or less. Pipe materials are same as those of Bam municipality.

2.2 Outline of Damage on the Water Supply System

1) Well and Pumping Station

The earthquake brought serious damage to some buildings of well pumping stations and some minor ones to the wells and pumps. The study team conducted a brief survey in February 2004 on the condition of the wells, and its results are summarized in Table 2.1.2 (see Evaluation column). The pump houses around R1 and R2 are made of brick and suffered quite big damage, especially, the pump houses of No.1 and No.2 wells, totally collapsed. The drawn quantity of two wells of No.13 and No.14 decreased to some extent according to the interview with a WSCK staff.

2) Distribution Reservoirs

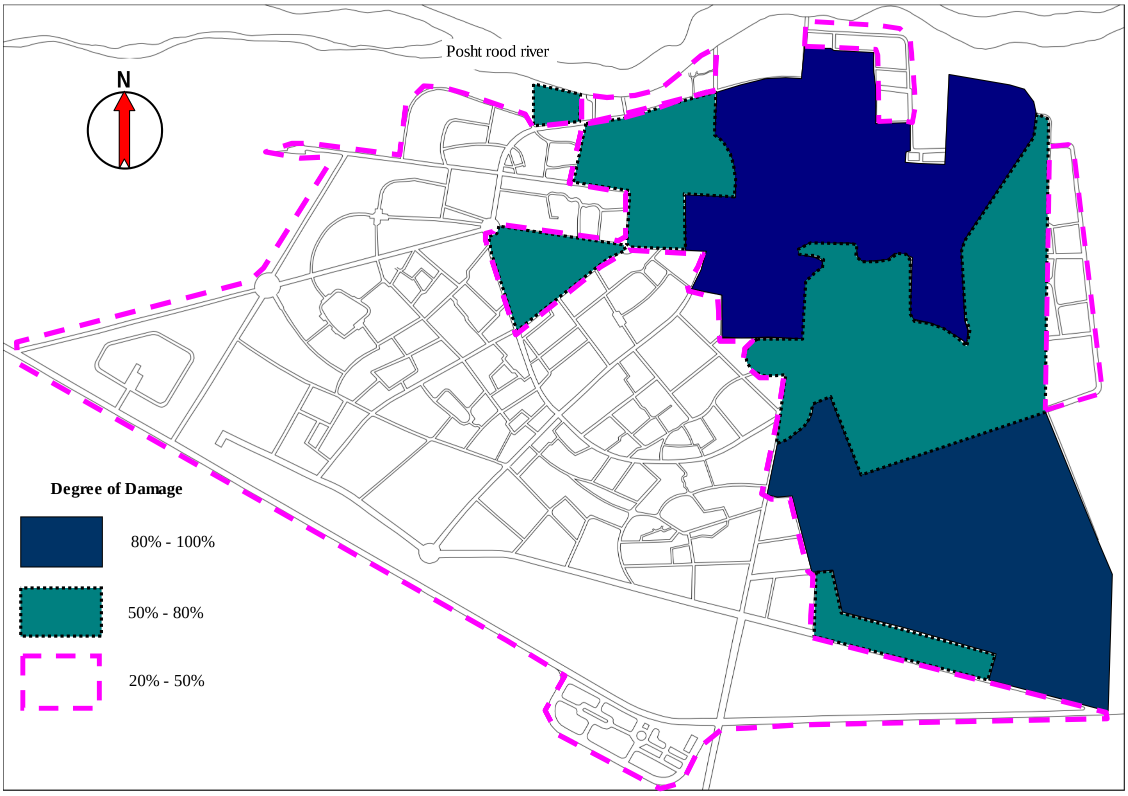
Distribution reservoirs in Bam (R1 and R2) had little damage. On the other hand, the reservoir (1,600 m^3) in Baravat was seriously damaged.

The Baravat reservoir is made up of two compartments. One compartment with the capacity of 1,000 m^3 is built with masonry structure. The other compartment with RC structure has a capacity of 600 m^3. The compartment with masonry structure was damaged with major cracks and they cause water leakage. The 1,000 m^3 compartment is not operational at present, so it has been forced to operate at less than half of its capacity. The housing for chlorination facilities was destroyed and the water has been distributed without chlorination. The pump houses of the two wells (No.1 and No.2 in Baravat) also had major damage and the houses have both collapsed and control panels were also heavily damaged. The pumping facilities are, therefore, nearly exposed but the pumps themselves have little damage and are being operated normally. The disinfection house of Baravat has also collapsed and the system is in operation without disinfection.

3) Distribution Pipe and House Connection

(1) Bam City

The system has a total of 9.3 km of conveyance pipe between wells and reservoirs and a total of 420 km of distribution pipe network. The network was heavily damaged and the extent of damages was estimated by BWSC. Although exact sites and numbers of breakage have not been identified yet, many leakage and broken pipes have been reported. BWSC sent out 10 teams of repair workers made up of 3 persons to troubled sites for repair. Although there was some disorder in management of materials in the first two weeks, the majority of problems have been solved and the situation was said to have stabilized after one and a half months. The Study team was only able to observe a 100 mm pipe under repair at the southern edge of Arg-e-Bam.



Source: BWSC

Figure 2.2.1 Classification of Damage on Water Supply Network in Bam

At present, there is no serious leakage within the network unless a high pressure is applied enabling fixed-point water supply with the pipe water. Temporary houses are under construction for relocation of disaster victims. The sites for such houses are scattered around the city.

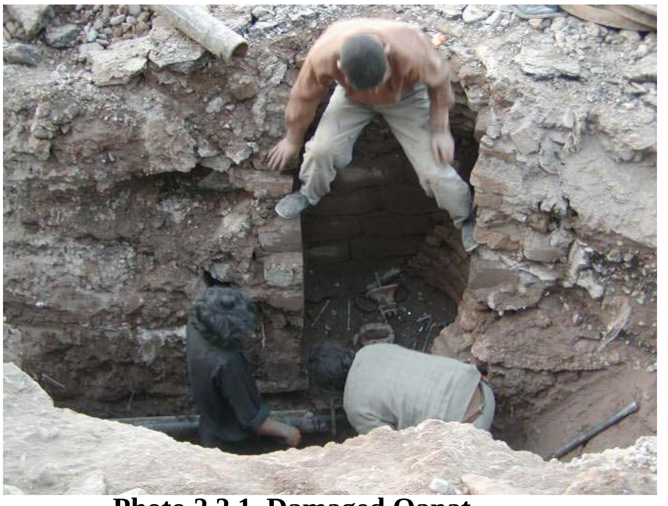


Photo 2.2.1 Damaged Qanat

(2) Baravat

According to the Bam and Baravat earthquake report by WSCK, the total length of transmission pipes in Baravat is 2,495 m and the diameter is 300 mm. The total length of distribution pipes is 90 km and the diameter is 200 mm or less. Around 50% of the network has been damaged.

(3) House Connection

The number of house connections in Bam was 21,812 as shown in Table 2.1.4. However, 85% of houses collapsed by the earthquake, and most of the service pipes in Bam are not used.

2.3 Outline of the Water Supply System after the Earthquake

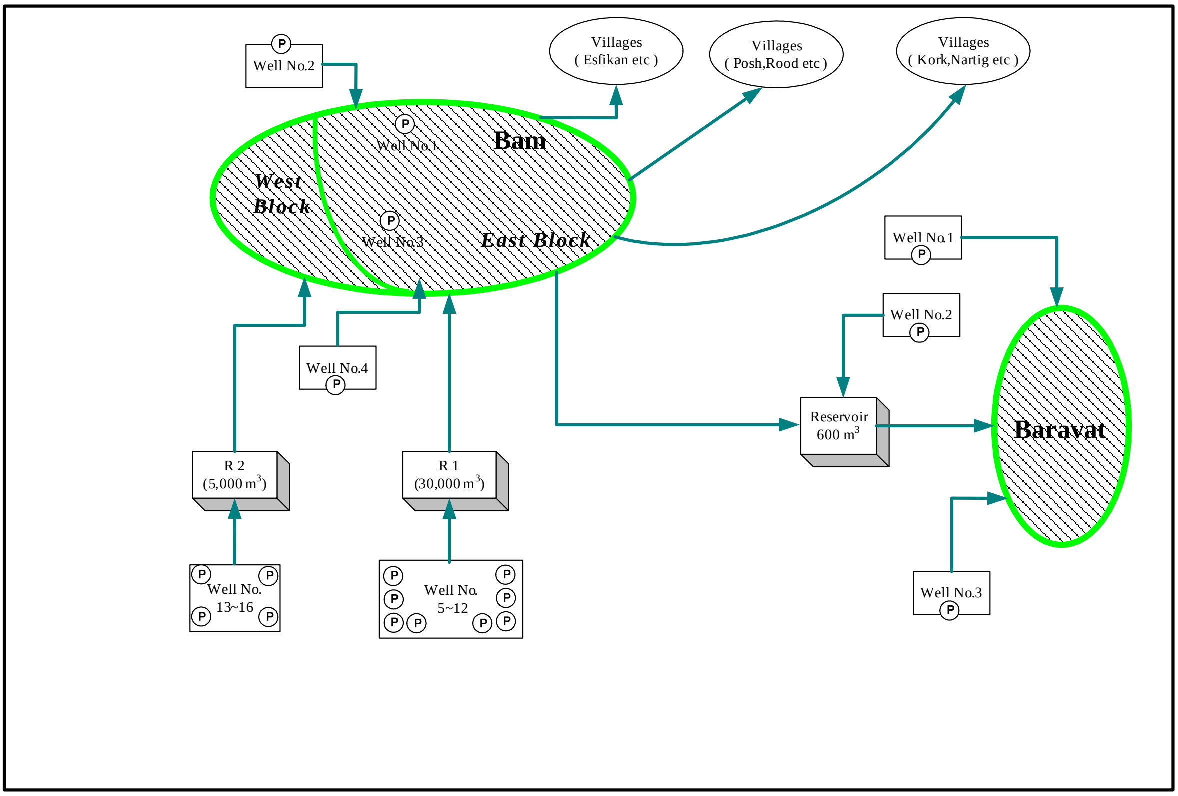
1) Pumps, Wells and Reservoirs

After the earthquake, water consumption amount has increased. The reasons are illustrated as follows:

- While the water from the water supply system is consumed only for domestic use before the earthquake, the water is also used for irrigation at present because some qanats for irrigation were broken.
- The leaking water quantity from distribution pipes and service pipes is added to the increase of water consumption.
- The water from public tap seems to be used improperly even after the earthquake, although the awareness of water conservation had arisen, to some extent.

Since water demand has increased in Bam and Baravat, WSCK expanded its water supply by renting one well in Bam from RWRCK and resuming the usage of one well in Baravat, which was not used then. Before the earthquake, 15 wells in Bam and two wells in Baravat were under operation. Since two wells were newly added after the earthquake due to the increased water demand, the total number of wells in the Bam and Baravat areas became 19 wells. Although consecutive statistical data is not available, it is estimated that each well produces approximately 30 l/sec of raw water. One newly added well in Bam directly provides water to the Bam area, and the other one in Baravat, located at No.3 pump house directly provides water to the Baravat area. After one compartment of Baravat reservoir was damaged, only No.2 well supplies raw water to the reservoir, and discharge pipes of No.1 and No.3 wells are connected to Bam distribution network.

Two reservoirs in Bam are still working under their original conditions, the capacity of Baravat reservoir decreased from 1,600 m³ to 600 m³ due to earthquake damage in masonry reservoir. The existing water supply system after the earthquake is shown in Figure 2.3.1.



Source: JICA Study Team

Figure 2.3.1 Water Supply System after the Earthquake

2) Water Supply by Truck and Public Tap

After the earthquake, the situation of water supply has changed day by day. Polyethylene hose or other similar materials are connected to functioning main pipes and tap as shown in the picture below.

Photo 2.3.1 Tap Water connected to Main Pipe

Water containers (0.5 – 2.0 m^3) were installed in many locations of the city by the Red Crescent of Iran, International Red Cross, WHO, UNICEF and some NGO/NPOs.

2.4 Management of the Water Supply System

1) Water and Sewage Company of Kerman (WSCK)

(1) Organization

WSCK is a public corporation under the Ministry of Energy to provide service water and treat waste water disposal for Kerman Province. The company oversees the management of local water supply companies in townships, districts and cities. It also provides operational advice to these local water companies spread in the province. WSCK, which locates in Kerman city, has a workforce of about 150 personnel under one managing director and the board of directors as its top management body.

(2) Financial Status

WSCK is a financially independent public corporation, and its entire budget comes from the water charges it collects throughout Kerman province. The revenue from penalty charges is set aside for special purposes, such as repairing pipe and for unexpected expenses. Although WSCK is fiscally sovereign, several forms of subsidies are given to the company from local governments to invest for capital infrastructure, such as distribution reservoir, piping and other water supply facilities.

(3) Water Supply of WSCK

About 110,000m³/day of water is produced and distributed for all the water supply systems in the province, including Bam Township. Almost all water sources of WSCK come from groundwater, while surface water resource is used only in Rabor in Baft Township, at a small scale.

Table 2.4.1 Treated Water Quantity and Capacity of Facilities

Year	Water before Disinfection		Volume of Reservoir (m³)	Collective Capacity of Wells (ℓ/s)
	Surface Water (m³/day)	Groundwater (m³/day)		
1996	900	95,906	314,690	5,354
1997	427	92,523	31,350	4,870
1998	473	100,402	332,620	6,623
1999	414	99,971	399,750	4,283
2000	619	108,683	368,850	6,257
2001	524	110,861	373,140	6,207
2002	227	114,206	384,580	6,554

Source: WSCK

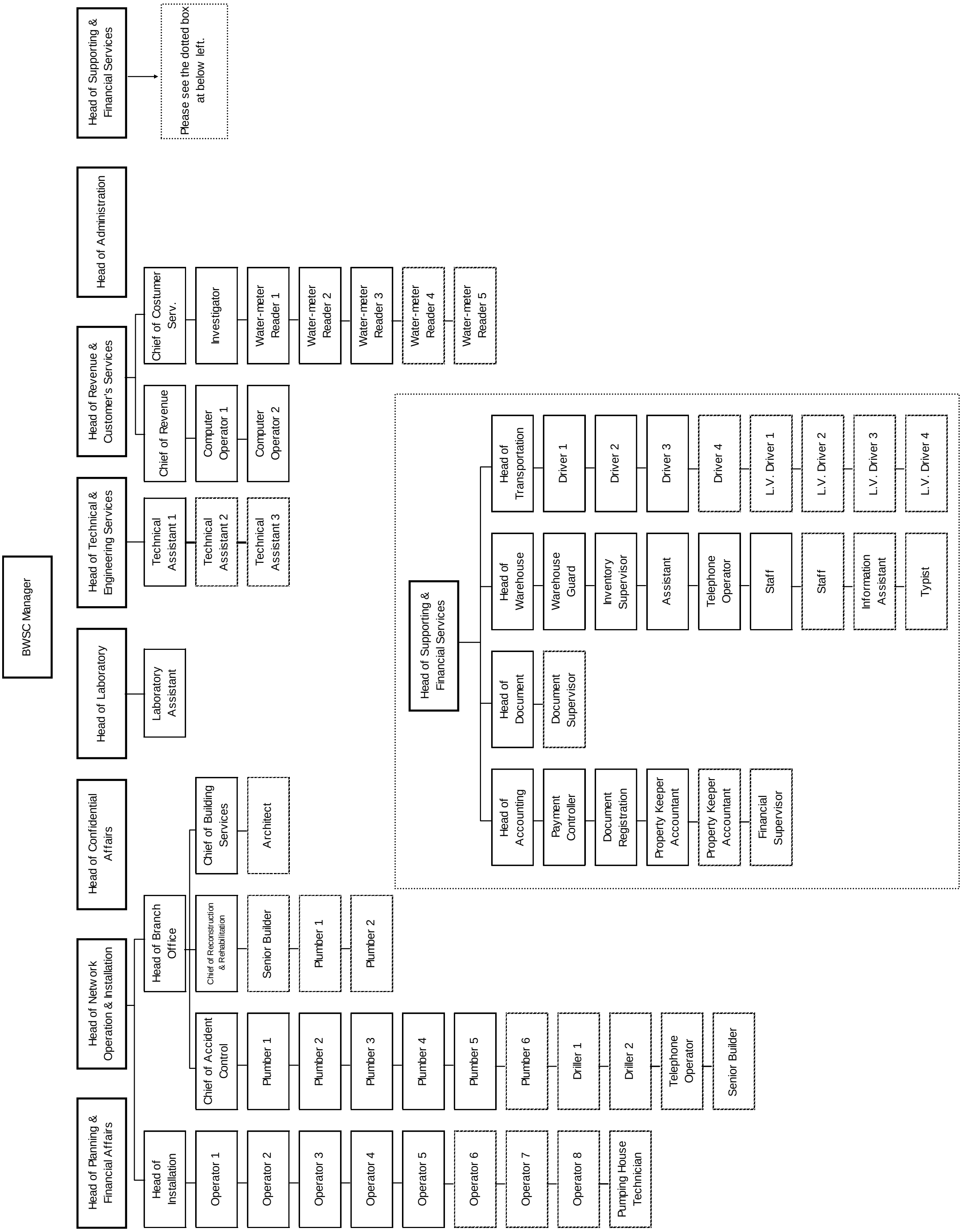
2) Bam Water Supply Company (BWSC)

(1) Organization

Bam Water Supply Company (BWSC) provides service water in Bam city and the Baravat area. From an organizational structure point of view, BWSC is under the umbrella of WSCK and under its management, but BWSC is financially and operationally independent from WSCK, to some extent. It only receives materials and technical support from WSCK and all capital investment in the territory of BWSC is borne by WSCK.

(2) Engineering Structure

According to the organizational planning, Bam Water Supply Company (BWSC) is supposed to have 79 employees under the Manager. However, 36 positions are not filled in because some of the employees were killed by the earthquake and some have been vacant even before the earthquake; therefore, the organization is now operated with 43 employees. As for the operation and maintenance of water supply facility, regardless of the size of the facility, it is significantly important to assign an engineer or establish a technical section to oversee the technical matters in the organization. As far as the study team understands, the existence of the project manager has been standing out in the organization. He is involved with all decisions concerning technical matters, operation and maintenance and customer services. As the organizational chart of BWSC shown in Figure 2.4.1, although the plan is to allocate a staff of four, including the head of section to "Technical Service", it has only two staff members. Taking into account that a chief engineer is usually assigned and responsible for overall technical matters at water supply section at the city level in Japan and other developed countries, it is pointed out that those technical services at BWSC is carried out without any chief engineer assigned to manage the section. Furthermore, only one person is assigned to the "Planning and Financial section," which has vital functions and responsibilities to set policy of water supply facility, as an engineering section administrating planning and designing of water supply systems. It should be noted that the position is vacant at the moment, so BWSC is operated under no staff available for formulating future planning in its organization.



Source: WSCK

Figure 2.4.1 Organizational Structure of Current BWSC

(3) Water Pipe Network

"Network Operation and Installation" section is responsible for water pipe network, and 16 out of 29 positions are currently vacant. The section is managed by a staff of 13 under the supervision of the Manager, as an acting head of the section, since the position of the section head is also vacant. Under the head of section, there are two divisions, namely "Installation" and "Branch Office." Installation division is responsible for operation of water disinfection facility, and Branch Office is responsible for the rehabilitation of water pipe network and repair of cracking pipe and the management of water pipe. The two positions of head of divisions are currently vacant likewise, and 13 staff members are actually coping with troubles on a three-shift-a-day basis, such as the leak of the water pipe network, explosion of pipe, temporary suspension of water supply, the trouble of pump at pump house, malfunction of electric system and valve problems. BWSC has been forced to operate with understaffed situations, since almost half of its staff was killed because of the earthquake. The company has been conducting the rehabilitation of leaking pipes, laying temporary water supply pipes and continuously repairing them. Meanwhile, the company has arranged water trucks to distribute water to the users with the cooperation from the heavy machinery service section.

It is unavoidable to allocate 25 persons, about 60% of workforce, to the "Network Operation & Installation," "Warehouse" and "Transportation" which mainly deal with rehabilitation and reconstruction of water supply systems in the disaster-stricken areas.

(4) Customer Services

"Revenue and Customer Services" section is responsible for dealing with water users; yet, it does not place much emphasis on the improvement of customer satisfaction. The main functions of the section are to check water-meters and to calculate water charges. According to the BWSC organizational chart, this section should have 11 staff members including the head of the section; however, only seven are currently assigned to this section. Although the users of water supply service had decreased dramatically after the earthquake, the quantity of water consumed has increased; therefore, BWSC has been operating all well pumps to supply water to the users. There are 21,812 house connections in year 2003. Once the water supply service goes back to normal conditions after the efforts made to rehabilitate the water supply facility, the works for not only checking water-meter, maintenance and replacing spare parts, but also educating and disseminating the proper manner of usage of water and controlling illegal usage of water, will increase and take the most part of their duties.

Table 2.4.2 shows Unaccounted for Water in Bam Municipality (2002 and 2003)

Table 2.4.2 Unaccounted for Water in Bam Municipality

Year	Production	Distribution (m^3)	UFW (m^3)	Ratio (%)
2002	8,538,538	6,909,226	1,629,132	19.1%
2003	9,763,961	4,972,447	4,791,514	49.1%

Source: WSCK

It is foreseen that there would be a vast amount of unaccounted for water in year 2004 because the confusion derived from the earthquake has been seen even after the end of fiscal year, March 2004.

With regard to the data in 2002, it is premature to reach to a conclusion because of a lack of breakdown data, but 19 % of unaccounted for water is not much significant.

(5) Water Quality Control

As for water quality control at BWSC, two employees are assigned to the Laboratory section, and BWSC has a laboratory to test water quality. Some biological tests have been entrusted to the laboratory at the WSCK even before the earthquake, but BWSC has carried out chemical tests by itself; however, due to the damage from the earthquake, the laboratory at BWSC is not functioning at present.

(6) Technical Competence Level

Table 2.4.3 shows the educational attainment of the staff at the BWSC.

Table 2.4.3 Educational Attainment of BWSC Staff

Educational Attainment	Number (person)	Rate (%)
University	7	15.2
College (diploma)	0	0.0
High School	26	56.5
Junior High School	5	10.9
Primary School	8	17.4
Total	46	100.0

Source: WSCK

Since BWSC employs a simple water disinfection system, which is to pump up raw water from deep wells and to disinfect it by chlorine, and then to distribute through water pipe network, and taking into account the significant decrease on water service users after the earthquake by 60,000 people, it is conceived that the average educational attainment at BWSC 71% of staff holding higher than high school degree is sufficient to run the operation and maintenance in Bam city in the future.

3) Baravat Water Supply Company

(1) Organization

The scale of the Baravat area is about one fifth of Bam city and water service supply population is about 16,000 persons at present, compared to 20,800 before the earthquake. According to the organizational chart, its Technical Service section is in charge of the operation of facilities, water pipe and distributing reservoir; Customer Service section takes charges of collecting water usage charge, and Supporting & Financial Service section deal with logistics (storage) and transportation under one manager. The total number of staff makes 11 persons with one vacancy. Like Bam city, there are no persons in charge for engineering, customer service and water quality control departments and it is also inevitable that most of workforce is limited to checking water meters and collecting water usage charges from the users.

(2) Water Quality Control

There is no Water Quality Control section at the Baravat water supply branch office. Before the earthquake, water quality tests except biological test, were conducted at the laboratory at the main office in Bam city; yet, since the laboratory is not in workable condition at present, because of the damage from the earthquake, all items of water quality test are now conducted at the laboratory in WSCK.

As a consequence, if unusual water quality is observed, it takes a couple of hours to a day to detect the occurrence of problem, and it is difficult to promptly take necessary countermeasures.

(3) Operation and Maintenance for Machinery and Electric Facility

Two operators at Technical Service section are responsible for the overall machinery and electric facility. They oversee and cope with troubles, such as temporary suspension of water supply, problems at pump house and malfunction of pump, electrical system and valve.

Since the chlorination house was destroyed due to the earthquake, chlorinate solution is directly added to distribution pipe at three pumping wells. Out of three pumping houses, No.1 and No.2 pumping house were destroyed, so the chlorination treatment has been conducted outside the pumping house. Pumping station No.3 does not have a building structure from the beginning, so it has been operated outside even before the earthquake.

A new distribution reservoir (2,000m^3), a chlorination house and a watching house are now being constructed by JICA's funding; so once the construction is completed, chlorination treatment will be operated in normal practices.

After the earthquake, Technical Service section has controlled and repaired damaged machinery and electrical facilities in cooperation with Supporting and Financial Service section. Under usual circumstances, the operation and maintenance structure of machinery and electrical function is sufficiently, yet it is expected that additional measures shall be necessary, considering the population growth in the designated areas and various developments targeting year 2023.

It is now under discussion that No.1 and No.2 pump houses, which had severe damage from the earthquake, will be demolished.

Table 2.4.4 shows Unaccounted for Water in Baravat (2002 and 2003)

Table 2.4.4 Unaccounted for Water in Baravat (2002 and 2003)

Year	Production	Distribution (m^3)	UFW (m^3)	Ratio (%)
2002	1,818,508	1,117,163	701,345	38.6%
2003	1,821,240	871,534	949,706	52.2%

Source: WSCK

It is foreseen that there would be a vast amount of unaccounted for water in year 2004 because the confusion derived from the earthquake has been seen even after the end of fiscal year, March 2004.

With regard to the data in 2002, 38.6 % of unaccounted for water in the Baravat areas is too much, so it is suggested to take appropriate countermeasures; but only after a thorough investigation as to the causes is conduced

(4) Technical Competence Level

Table 2.4.5 shows the educational attainment of the staff at the BrvtWSC.

Since BrvtWSC employs a simple water disinfection system, which is to pump up raw water from deep wells and to disinfect it by chlorine, and then to distribute through water pipe network, and taking into account it relatively small number of users, i.e. about 3,000 households, it is conceived that the average educational attainment at the BrvtWSC, 61 % of staff holding higher than high school degree, is sufficient to run the operation and maintenance in the Baravat areas in the future.

Table 2.4.5 Educational Attainment of the Staff at Baravat Water Supply Company

Educational Attainment	Number (person)	Rate (%)
University	2	15.4
College (diploma)	0	0.0
High School	6	46.2
Junior High School	1	8.0
Primary School	4	30.4
Total	13	100.0

Source; WSCK

(5) Human Resources Placement Plan for Operation and Maintenance

It has been stated previously that Bam Water Supply Company (BWSC) is presently operating with 43 employees instead of the planned allocation of 79. Out of the 43 employees, twelve are assigned to the Baravat area, and the actual number of employees working there is eleven (one position is vacant).

A new water distribution pipe network with DIP has been laid down in the Bam areas, taking into account temporary housings that have been built since the earthquake in both Bam and Baravat areas. Two distribution reservoirs, with capacities of 2,000 m³ and 3,000 m³ are now being built by JICA and WSCK, respectively in order to replace a partially broken reservoir due to the earthquake, and chlorination facility and an electromagnetic flowmeter will be installed with the reservoirs.

Considering the operation and maintenance in Bam municipality, it is not expected to introduce a vast number of additional monitoring items or to install complicated operational devices; thus, there is no need to significantly increase the number of employees, but it is suggested to fill in vacant posts, and to fulfill the required total number of personnel by the target year in 2023.

With regard to BrvtWSC, since the projected population will be 32,381 in year 2023 from the current population of 15,875, i.e. the population increases to twice the current population, it is suggested to increase the number of staff to 20 – 24 from 12 persons at present. It is strongly recommended, in particular, that a staff who has knowledge of water quality control should be placed at the Company.

4) Water Tariff

WSCK sets water tariff for all types of user and by region in the province. A water tariff structure, which is applied to the users of BWSC, is consisted of two components

- Fixed charge: basic monthly charge
- Variable charge (progressive charge): depending on the usage of water

The fixed charge is determined according to the type of user and also to the diameter of the pipe connected to the users as shown in Table 2.4.6. The variable charge only applies to residential users and employs a progressive charge system. In the system, up to 4 m^3/month of water use is free of charge and the use of 5 or more is progressively charged. For example, a household with a connection pipe diameter of one inch is charged a fixed rate of 12,040 rials/m^3 and is a progressive charge of 189 rials/m^3 for the use of 10 m^3 of water for a month. For non-residential users, the variable water charge is only divided into two price ranges and the threshold is 20m^3/month.

Table 2.4.6 Water Tariff (Basic Charge) by User Type

Unit: Rial/month

Code	Diameter (inch)	Public & Govt.	Commercial	Industry	Residential	Public Bath	Public Corporation
2	0.5	3,388	6,449	6,449	2,638	6,202	3,981
3	0.75	5,566	26,064	26,064	4,247	11,799	6,449
4	1	18,997	61,348	61,348	12,040	30,129	21,925
5	1.25	29,730	153,367	153,367	20,268	417,553	34,352
6	1.5	62,194	260,719	260,719	37,280	101,460	71,777
7	2	224,631	311,028	1,295,956	40,555	184,041	259,192
8	2.5	292,021	414,706	1,425,551	164,060	341,243	336,949
9	3	359,411	518,383	1,555,146	287,564	498,445	414,706
10	4	539,118	829,411	2,332,719	479,274	797,511	622,059
11	6	898,530	1,555,146	3,110,293	862,693	1,495,333	1,036,746
12	8	1,797,059	2,591,910	5,183,820	1,533,675	2,492,222	2,073,529

Source: WSCK

The exact charges are different depending on the characteristics of the users according to the tariff system. In principle, governmental users and public facilities such as schools and hospitals are charged far less than the other type of users.

In addition to these two charges of fixed and variable, WSCK imposes penalty charges for residential users who consume 24 m^3/day (29 m^3/day during summer) or more of water. The charge is also progressively determined. For example, a house is charged an additional 779 rials/m^3 for the use of 30 m^3 of water per month in Bam. Users are billed every three months and are required to pay the bill by bank transfer.

CHAPTER 3 GROUNDWATER RESOURCES STUDY

3.1 Background of the Groundwater Resources Study

Water source for existing water supply system in Bam is depending on groundwater. WSCK has supplied water by operating 15 wells in Bam and two wells in Baravat. According to the projection of future water demand in the target year of 2023, the present production amount cannot meet the future water demand. Before the earthquake struck Bam, WSCK has planned to stop using two wells located inside the residential area of Bam and two wells located in Baravat, because water quality of these wells is much worse than other wells.

Since the wells were constructed in the existing well field in Bam, the investigation of groundwater potential has not been carried out. And groundwater has been extracted by qanat with the period of more than 2,000 years without any severe problems. The aquifer, groundwater bearing layer, in the area is alluvium composed of gravel, sand and minor clay and silt, and has enough quantity of water. The alluvium aquifer has been constantly recharged by the precipitation in Jebalbarez mountain range. For a long time, extraction amount has not affected the water balance in the area. However, it is reported that groundwater level has been decreased. Severe drought that has continued six years may cause the phenomenon. In addition, increase of water consumption for agriculture purpose caused by economic growth might be one of the reasons. Considering the situation mentioned above, the groundwater resources study in Bam was carried out to evaluate the potential of groundwater in the well field for the sustainable use.

3.2 General Description of Study Area

1) Geomorphology and Geology

(1) Geomorphology

The Bam area belongs to upper part of Loot Desert watershed. The lowest elevation of the upper part is 700 m above msl (mean sea level) in the east of Bam municipality and its highest elevation is 3,740 m above msl at the mountain's peak. The general lay of the mountain range is northwest to southeast.

The geo-morphological features of Bam catchment area are as follows:

- The Drainage Pattern is mostly dendritic and trellis.
- The Drainage Texture is medium texture.
- The Drainage Density is 12 km in km^2.
- The Stream Frequency is 150 in km^2.

(2) Geology

The Bam water supply area is located in Eocene volcanic belt. The belt is also known as Urumiah – Dokhtar or Sahand – Bazman volcano-sedimentary belt and generally consists of volcano-sedimentary complex of Eocene age, 10%: of Sedimentary, 10% of Lavaflows, 75% of Pyroclastics, and 5% of Intrusive. The sedimentary rock masses of the zone are mainly formed out of sandstone, siltstone, conglomerate and limestone. The volcanic rocks consist of lavaflows and pyroclastics in forms of tuff and volcanic ash having compositions of andesite, andesite-basalt, trachyte and basalt.

The above formations are crossed and cut by deep pervious and semi-pervious masses. Exposure of the masses in the area is in the form of plutonic (intrusive) rock masses. Deep pervious rock masses are of the following types: Granodiorite, Diorite porphyry, Quartz diorite and Quartz mozonite. There are also semi-pervious rock masses which are exposed as dykes of diabase type.

(3) Stratigraphy

The area divided into four units. Details are shown in Table 3.2.1

I: Eocene volcano-sedimentary complex (Razak complex)

II: Intrusive rock of post Eocene

III: Neogene sedimentary rocks

IV: Quaternary sediments

Table 3.2.1 Stratigraphy of Bam Surrounding Area

Stratigraphy and Description			
I. Eocene volcano-sedimentary complex (Razak complex)			
	The Razak complex is the major formation that has outcrop in the mountainous area and divided into three sub-complexes.		
	1	Lower basic sub-complex (Er1)	Er1 consist of andesite, dacite, dacitic tuff with conglomerate of lower Eocene age.
	2	Middle acidic sub-complex (Er2)	Er2 consists of rhyolite and rhyolitic tuff of middle Eocene age.
	3	Upper basic sub-complex (Er3)	Er3 consists of andesite, agglomerate, dacitic tuff of upper Eocene age.
II. Intrusive rock of post Eocene			
	Intrusive rocks consist of granite, granodiorite, quartz-diorite, diorite, monzonite, granosynite and synite of Oligocene and Miocene periods.		
III. Neogene sedimentary rocks			
	Neogene rocks consist of conglomerate, marl, gypsiferous marl and sandstone. These formations act as bedrock in Bam plain.		
IV. Quaternary sediments			
	Quaternary sediments consist of older (Qt1) and younger (Qt2) alluvial fan and river terraces and river channel deposit (Qal) and clay flat (Qc). Fine grain material such as fine sand, silt and clay increases toward the center of plain (dasht). The major aquifer developed in Qt2		

	consisting of a mixture of gravel, sand, silt and clay with well sorting and rounding. The genesis of aggregates is mostly volcanic.

Source: JICA Study Team

(4) Tectonic

Hydrogeological conditions of Bam area are affected by two major tectonic factors of faulting and folding. There are at least four major faults namely Abareq fault, Tavakolabad fault, Kangero fault and Bam fault. All faults, except Tavakolabad fault which runs east- west, have a north-south orientation. These faults act as underground dam and in the other places make a fracture zone with high permeability.

2) Hydrology and Meteorology

Hydrological and Meteorological conditions in the Bam area are described as follows. Figure 3.2.1 shows the annual precipitation and annual mean temperature.

(1) Hydrological Condition

Mean annual discharge of Adori River = 2.774 MCM

Minimum annual discharge of Adori River = 0.72 MCM

Maximum annual discharge of Adori River = 11.5 MCM

Mean annual discharge of Nesa River = 228.34 MCM

Minimum annual discharge of Nesa River = 71.59 MCM

Maximum annual discharge of Nesa River = 377.74 MCM

(2) Meteorological Condition

Temperature (T) min. T = -2 C at February & max. T = 48.2 C in July

Temperature gradient: T = 29.65 – 0.0069 H, r = 0.99

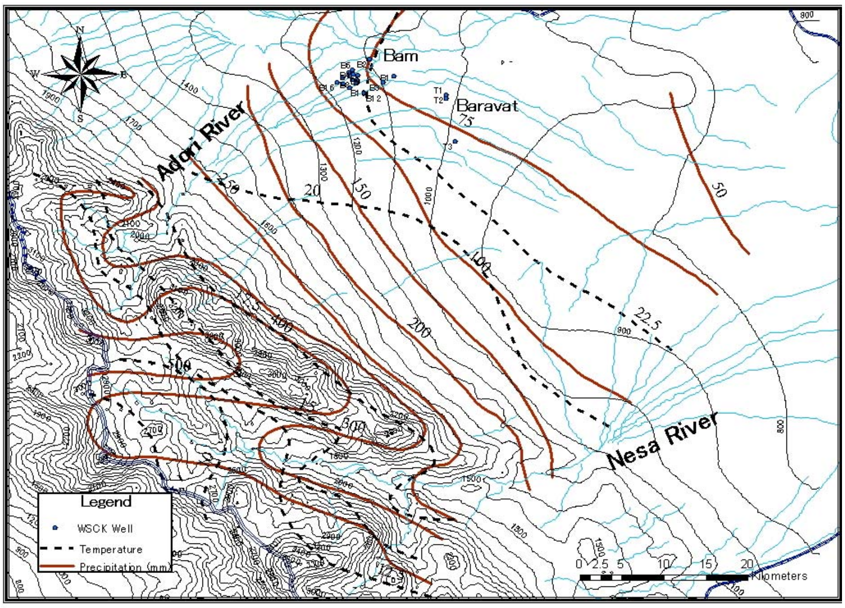
Mean annual Temperature T = 22 C

Evaporation (E) min. E=162 mm at January & max E=550mm in July

Wind velocity (W) max. W=20.6 at March & mean W = 2.8-4.3

Mean annual precipitation (P) = 56 mm

Precipitation gradient P= 0.11H- 23.5, r = 0.86

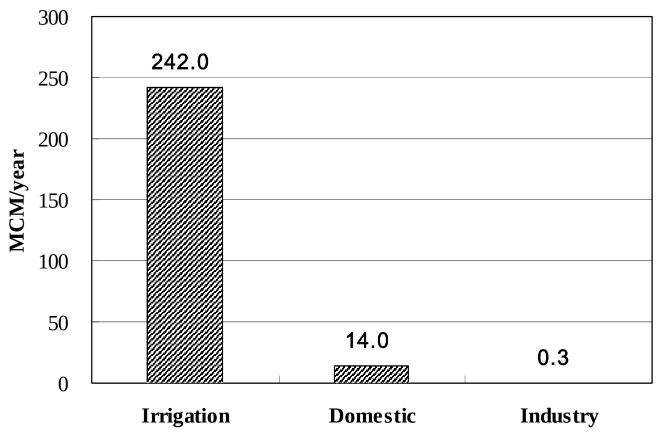


Source: Halilab Consulting Engineers (1998)

Figure 3.2.1 Annual Precipitation and Annual Mean Temperature

3) Water Usage

In the Bam area, groundwater is the only available water source for all activities for the people. As the precious resource, groundwater has been extracted by the qanats and wells, and has been utilized for irrigation, domestic and industrial purposes. According to the existing data provided by Regional Water Resources Company of Kerman, 52 qanats and 103 wells were registered in 1999 and 1997, respectively (see, Table AP2.1 and AP2.2 in Appendix). Unfortunately, some wells do not have discharge rates. However, the total discharge amount is estimated to be 256.3 MCM per year as minimum. The consumption of each water use is shown in Figure 3.2.2. Most of groundwater extracted, i.e. 94.4 %, was consumed in irrigation purpose.



Source: Regional Water Resources Company of Kerman

Figure 3.2.2 Water Consumption

For the irrigation purpose, the amount of 141 MCM of groundwater is extracted from qanats and the amount of 101 MCM of groundwater is extracted from wells. For the domestic and industrial use, the groundwater is extracted only from wells.

Since the earthquake in December 2003, all of existing wells belonging to Water and Sewage Company of Kerman (WSCK) have been used and operated 24 hours a day for all activities in Bam. According to the records of WSCK, 49,507 m^3/day of water, which corresponds to 18 MCM a year, has been supplied to Bam municipality. However, it does not meet actual water demand. One reason is that the supplied water has been used for the plantation because of damaged qanats. The other one is loss of supplied water due to rehabilitation of the network in progress.

4) Regulations for Groundwater Development in Bam Area

(1) General

Regional Water Resources Company of Kerman (RWRCK) is responsible for the water resources management. Groundwater development is under control of RWRCK. In order to keep sustainable usage of precious water resources in Bam, the official procedure to be taken is described further below.

(2) Official Procedure to be Taken

1. Bam Water Supply Company (BWSC) should request the construction of well(s) with the description of the necessity to RWRCK.
2. Inspection by experts of Bam water affairs should be carried out. The experts determine the location of drilling well.
3. After the expert of Bam water affairs provide the necessary document to RWRCK, the permission will be given to BWSC.
4. After issue of the permission, RWRCK will request WSCK to select a drilling company.
5. When WSCK makes a contract with a drilling company, RWRCK will permit the drilling company to start drilling under the supervision of Bam water affairs.
6. Before the drilling company commences the work, they must be given the permission by Bam water affairs, for the installation of drilling equipment at the selected location.
7. A technician from Bam water affairs must come and specify the place of well, in accordance with the permission.
8. After bam water affairs specify the location, drilling company will be allowed to install the equipment and will start drilling.

9. During the drilling an expert of Bam water affairs will inspect the form of drilling and the sample.
10. After drilling the drilling company should report to Bam water affairs and at the same time they start casing installation.
11. A technician will inspect the drilling and check the depth of well.
12. After the installation of casing the drilling company will inform Bam water affairs.
13. A technician of Bam water affairs will inspect the well together with a representative of the company and will provide the Minutes of Meeting in accordance with well specification.

3.3 Hydrogeological Conditions

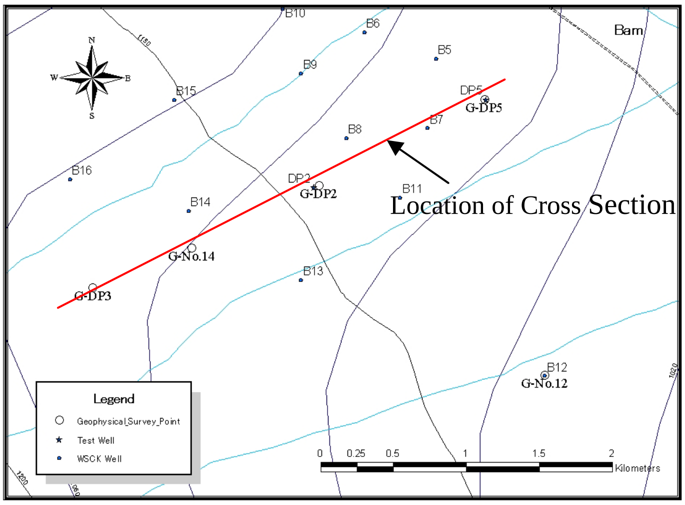
1) Test Borehole Construction

(1) General

In order to evaluate the groundwater potential in the well field of BWSC, test borehole construction was carried out. Test borehole construction is composed of geo-electrical exploration, borehole drilling and pumping test. The test results of these items are described below.

(2) Geo-electrical Exploration

Geo-electrical exploration was carried out at five points in the premise of BWSC to understand the geophysical characteristics of the geological formations. The measurement points are shown in Figure 3.3.1. Based on the results, the locations for two test boreholes were selected.



Source: JICA Study Team

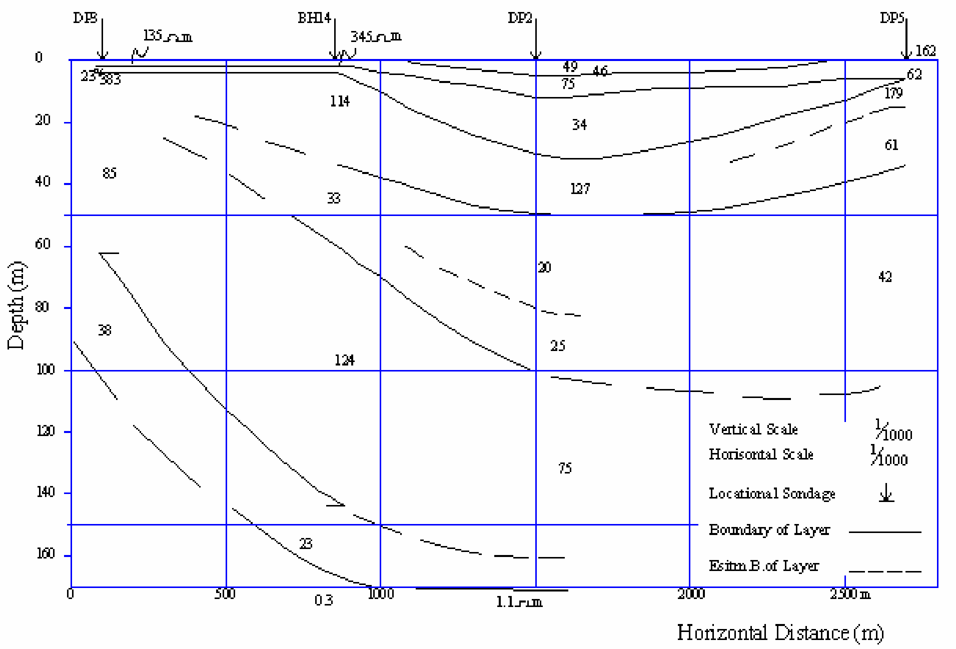
Figure 3.3.1 Measurement Point of Geo-electrical Exploration

The result of geo-electrical exploration is shown in Table 3.3.1 and Figure 3.3.2. There is a tendency of the depth to the base low resistivity layer to become shallow toward the south-west. Measurement points of DP2 and DP3 were selected to examine the possibility of the drilling. The result of DP3 shows that the layer below the depth of 73 m has low resistivity caused by the existence of clay-rich thick layer. Therefore, geo-electrical exploration was carried out at DP5 instead.

Table 3.3.1 Result of Geo-electrical Exploration

Measurement Points		Result of Analysis										
No.	Coordination		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
DP2	X: 58 17' 54.9" Y: 29 05' 25.6"	Depth (m)	0.89	2.8	5.44	11.8	30.9	50.3	80.8	104	173	
		Resistivity (ohm・m)	-	49.2	46	74.7	34	127	19.9	25	75.4	1.07
DP3	X: 58 17' 05" Y: 29 05' 03"	Depth (m)	1.46	3.51	11.9	21.9	72.6					
		Resistivity (ohm・m)	106	10.7	191	13.4	65.6	2.25				
DP5	X: 58 18' 31.7" Y: 29 05' 44.0"	Depth (m)	1.5	2.73	4.98	9.07	16.5	30.1	54.9	100		
		Resistivity (ohm・m)	155	58.1	51.2	111	92.3	172	20.9	42	144	
No.12	X: 58 31' 16.2" Y: 29 07' 54.6"	Depth (m)	1	2.5	5	7.3	13.1	28.1	50.1	106.4		
		Resistivity (ohm・m)	67.53	47.48	436	74.6	36.18	96.35	26.9	115.8	2	
No.14	X: 58 17' 26.7" Y: 29 05' 11.8"	Depth (m)	0.8	2.1	3.3	33.5	58.9	143	171			
		Resistivity (ohm・m)	345	31.9	433	114	32.8	124	22.9	0.28		

Source: JICA Study Team

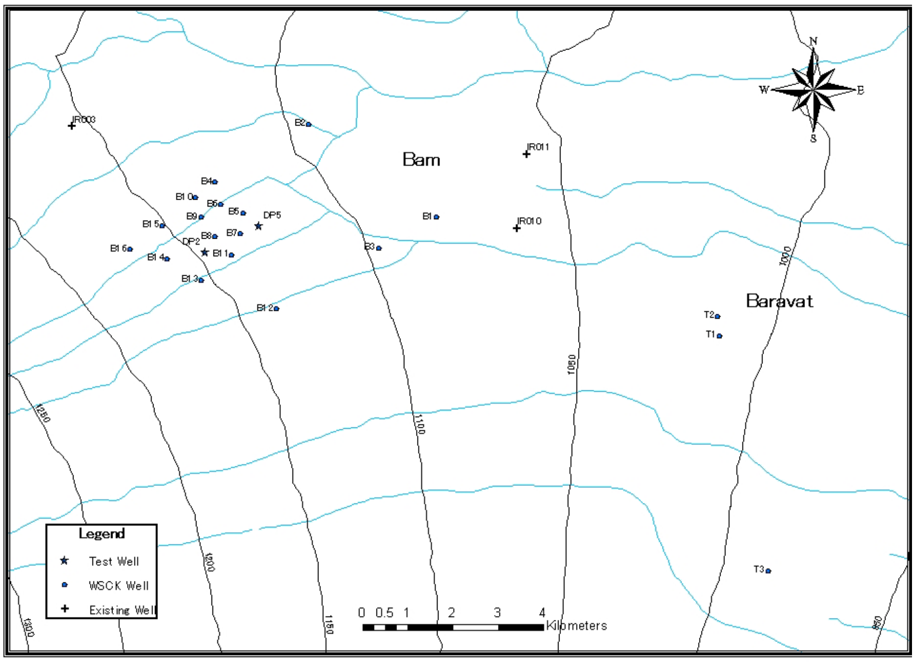


Source: JICA Study Team

Figure 3.3.2 Resistivity Cross Section

(3) Borehole Drilling

In the premise of well field of BWSC, two test boreholes were constructed. The locations are shown in Figure 3.3.3. The main purpose of test borehole drilling is to obtain hydrogeological information for the evaluation of groundwater potential.



Source: JICA Study Team

Figure 3.3.3 Location of Two Test Boreholes

Considering the future utilization of these boreholes for water supply, the design of the borehole is in accordance with the standard of WSCK. The standard design of the borehole, head facilities, and borehole emblems are shown in Figure AP3.1, Figure AP3.2 and Figure AP3.3, respectively. The drilling procedure is summarized in Table 3.3.2 and the basic data of the test borehole construction is shown in Table 3.3.2.

Table 3.3.2 Standard Drilling Procedure

Step No.	Work Description	Specific Requirements
1	Drill a conductor hole on the surface to the required depth	Hole size: at least 28" (711.2 mm)
2	Install a conductor pipe to the drilled depth.	Pipe size: 26" (660.4 mm OD)
3	Seal the annular space between the wall of a drilled hole and the conductor pipe by cementing.	
4	Resume drilling of the borehole to the required depth.	Bit size: 12" (304.8. mm) in maximum

5	Perform borehole geophysical logging through the drilled borehole.	Resistivity, Spontaneous Potential, Temperature, Gamma Ray.
6	Determine the position(s) of screen pipe through the instruction of the Engineer.	Will be informed by the Engineer
7	Ream the hole from 12" to 17" to the required depth	Bit size : 17" (431.8 mm)
8	Ream the hole from 17" to 24" to the required depth	Bit size : 24" (609.6 mm)
9	Install casing pipe and screen pipe as determined	Casing size : 16" (406.4 mm OD) Screen size : 16" (406.4 mm OD)
10	Make gravel packing for the annular space between the hole wall and screen pipe	2mm to 4mm grain size
11	Perform the development of a borehole.	By air-lifting (surging or bailing from time to time may be necessary)
12	Make clay pack and cement grout packing for the annular space between the hole wall and casing pipe	Up to the ground level
13	Carry out the pumping test by pump	Step draw down test, Constant discharge test and Time recovery test.
14	Construct the borehole head facilities and assist in installation of the water level recorder	

Source: JICA Study Team

Table 3.3.3 Result of Test Borehole Drilling

Well No.	Coordination		Altitude	Borehole Diameter	Drilled Depth	Cased Depth	Casing, Screen Diameter ID	Screen Depth	Screen Length	SWL
	Lat.	Long.	mASL	mm	m	m	mm	from, to	m	m
DP2	29 05' 25"	58 17' 55"	1148.6	609	232.75	230.54	393.6	117.05 - 225.06	108.01	117.18 (13Sep04)
DP5	29 05' 44"	58 18' 32"	1126.6	609	203	201.16	393.6	97.22 - 201.16	103.94	93.20 (03Oct04)

Source: JICA Study Team

(4) Pumping Test

Pumping tests at two test boreholes and two existing boreholes were carried out to estimate the aquifer properties. All tests were single-well test without observation wells, or piezometers.

A. Method of Pumping Test and Analysis

The following stages were applied to the pumping test in general. Besides, the additional pumping test to check the turbidity of the pumped water, requested by WSCK, was carried out from the viewpoint of safe water supply. For the pumping test at existing borehole, considering the existing usage conditions, short duration test was carried out.

Phase 1: Step drawdown test

Five steps were performed with each step measuring 60 minutes, if possible.

Phase 2: Constant discharge test

The test was done for 48 hours basically, if possible.

Phase 3: Recovery test

The test commenced immediately on completion of the constant discharge test and continued until the water level returned to its static water level or occasionally over a shorter period

<Measurement>

The original static water level in the borehole was always measured before any test pumping commenced. Throughout the duration of each test, the water level in the borehole was measured and recorded following the observation time schedule listed below:

Table 3.3.4 Observation Time Schedule

Time from start of pumping or pumping rate increase (minutes)	Time interval between observations (minutes)
0 - 5	0.5
5 - 10	1
10 - 30	2
30 - 60	5
60 - 120	10
120 - 240	20
240 - 360	40
360 - 720	60
720 - 2880	120
(2880 and longer)	(240)

Source: JICA Study Team

Electric conductivity (EC) and pH of water from the borehole were recorded during the pumping test at intervals corresponding to those for water level measurements.

<Analysis>

The well loss coefficient was calculated from the result of step drawdown test by using the formula, s = BQ + CQ2 where s is drawdown, B is formation loss, C is well loss and Q is discharge rate. Based on the result, expected drawdown with arbitrary discharge rate was estimated (the result is mentioned in Section 3.4, Calculation is in Appendix 2.1).

Specific capacity, which is the discharge per unit of drawdown, was calculated considering a constant rate long enough to establish an equilibrium drawdown.

Aquifer properties such as Transmissivity (T) that is the flow in m^3/day through a section of aquifer one meter wide under a hydraulic gradient of unity, and Coefficient of Permeability (K) were calculated based on the results of constant discharge test and recovery test. The characteristic of the aquifer is the unconfined single porous media aquifer. The borehole condition is fully penetrated in saturated part (at least 80 % of saturated part). Therefore, three fundamental analyzing methods, namely Theis type curve analysis, Theis recovery method and Neuman method, were applied in principle.

2) Result of Pumping Test

Pumping tests of two test boreholes and two existing boreholes have been completed.

Table 3.3.5 Well Loss Coefficient

Borehole	Formation Loss (B)	Well Loss (C)
DP2	0.1600	0.0013
DP5	0.0455	0.0001
No.8	0.0860	0.0310
IR003	0.0163	0.0011

Source: JICA Study Team

The results are summarized in Table 3.3.5 and Table 3.3.6 and graphed in Figure AP3.4 (1) to Figure AP3.4 (4) in Appendix. Calculation of the well loss coefficient is described in Appendix, as well.

(1) DP2 (Test Borehole)

Test borehole DP2 with the drilling depth of 230 m is located in the center of the well field. Step drawdown test was conducted with six steps. There is not much difference in the discharge rate from 4th to 6th step because of the limitation of capacity of pumping equipment. Considering the efficiency of well loss, the constant discharge rate was determined to be 35 l/sec. Transmissivity is estimated at 683 m^2/day, which is the average of the values of Theis type curve method and Theis recovery method.

(2) DP5 (Test Borehole)

Test borehole DP5 with the drilling depth of 203 m is located in the north part of the well field. Step drawdown test was conducted with five steps. Transmissivity is estimated at 1,532 m^2/day, which is the average of the values of Theis type curve method and Theis recovery method. This high transmissivity may suggest the existence of high porosity part and cause a flat corn of depression that may extend further out, if the homogeneous layer exists. Southern side of the DP5, the transmissivity is less. Therefore, high transmissivity area is distributed only in the adjacent area of DP5.

Table 3.3.6 Result of Pumping Test

<table>
<tr><th rowspan="2">Borehole</th><th rowspan="2">Location</th><th>Depth</th><th>Screen Length</th><th rowspan="2">Step No. / Constant</th><th>Pumping Rate</th><th>Duration</th><th>Drawdown</th><th>Specific Capacity</th><th>Theis Step</th><th>Theis</th><th>Recovery</th><th>Neuman</th></tr>
<tr><th>(m)</th><th>(m)</th><th>Q (l/sec)</th><th>(min)</th><th>s (m)</th><th>Q/s (m^3/day/m)</th><th colspan="4">T (m^3/day/m)</th></tr>
<tr><td rowspan="7">DP2</td><td rowspan="7">WSCK Premise</td><td rowspan="7">230</td><td rowspan="7">108.01</td><td>1st</td><td>13.7</td><td>30</td><td>2.87</td><td>412</td><td rowspan="4">-</td><td rowspan="4">678</td><td rowspan="4">688</td><td rowspan="4">160</td></tr>
<tr><td>2nd</td><td>23.4</td><td>26</td><td>4.33</td><td>467</td></tr>
<tr><td>3rd</td><td>30.96</td><td>30</td><td>6.18</td><td>433</td></tr>
<tr><td>4th</td><td>38.16</td><td>35</td><td>7.82</td><td>422</td></tr>
<tr><td>5th</td><td>41.6</td><td>8</td><td>8.42</td><td>427</td><td colspan="3" rowspan="3">683</td><td rowspan="3"></td></tr>
<tr><td>6th</td><td>43.2</td><td>52</td><td>9.33</td><td>400</td></tr>
<tr><td>Constant</td><td>34.92</td><td>840</td><td>6.89</td><td>438</td></tr>
<tr><td rowspan="6">DP5</td><td rowspan="6">WSCK Premise</td><td rowspan="6">200</td><td rowspan="6">103</td><td>1st</td><td>18.8</td><td>120</td><td>0.90</td><td>1805</td><td rowspan="3">-</td><td rowspan="3">2490</td><td rowspan="3">574</td><td rowspan="3">567</td></tr>
<tr><td>2nd</td><td>29.0</td><td>120</td><td>1.50</td><td>1670</td></tr>
<tr><td>3rd</td><td>40.0</td><td>120</td><td>1.90</td><td>1819</td></tr>
<tr><td>4th</td><td>43.2</td><td>120</td><td>2.20</td><td>1697</td><td colspan="3" rowspan="3">1532</td><td rowspan="3"></td></tr>
<tr><td>5th</td><td>49.0</td><td>120</td><td>2.34</td><td>1809</td></tr>
<tr><td>Constant</td><td>42.5</td><td>1440</td><td>2.40</td><td>1530</td></tr>
<tr><td rowspan="6">No.8</td><td rowspan="6">WSCK Premise</td><td rowspan="6">200</td><td rowspan="6">105</td><td>1st</td><td>13.7</td><td>60</td><td>10.32</td><td>115</td><td rowspan="3">-</td><td rowspan="3">255</td><td rowspan="3">642</td><td rowspan="3">32.6</td></tr>
<tr><td>2nd</td><td>16.2</td><td>60</td><td>12.02</td><td>116</td></tr>
<tr><td>3rd</td><td>20.8</td><td>60</td><td>15.20</td><td>118</td></tr>
<tr><td>4th</td><td>22.3</td><td>60</td><td>20.00</td><td>96</td><td colspan="3" rowspan="3">449</td><td rowspan="3"></td></tr>
<tr><td>5th</td><td>26.4</td><td>24</td><td>24.29</td><td>94</td></tr>
<tr><td>Constant</td><td>26.6</td><td>840</td><td>25.83</td><td>89</td></tr>
<tr><td rowspan="6">IR003</td><td rowspan="6">West Bam</td><td rowspan="6">120</td><td rowspan="6">90</td><td>1st</td><td>50.4</td><td>55</td><td>3.6</td><td>1210</td><td rowspan="3">1120</td><td rowspan="3">-</td><td rowspan="3">1620</td><td rowspan="3">-</td></tr>
<tr><td>2nd</td><td>57.6</td><td>265</td><td>5.15</td><td>966</td></tr>
<tr><td>3rd</td><td>61.2</td><td>220</td><td>5.39</td><td>981</td></tr>
<tr><td>4th</td><td>64.8</td><td>540</td><td>5.65</td><td>991</td><td colspan="3" rowspan="3">1370</td><td rowspan="3"></td></tr>
<tr><td>5th</td><td>68.4</td><td>720</td><td>6.85</td><td>863</td></tr>
<tr><td>Constant</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
</table>

Source: JICA Study Team

(3) No.8 (Existing Borehole)

The borehole No.8 is located in the well field and is 400 m north from the test borehole DP2. Transmissivity is estimated at 449 m^2/day, which is the average of the values of Theis type curve method and Theis recovery method.

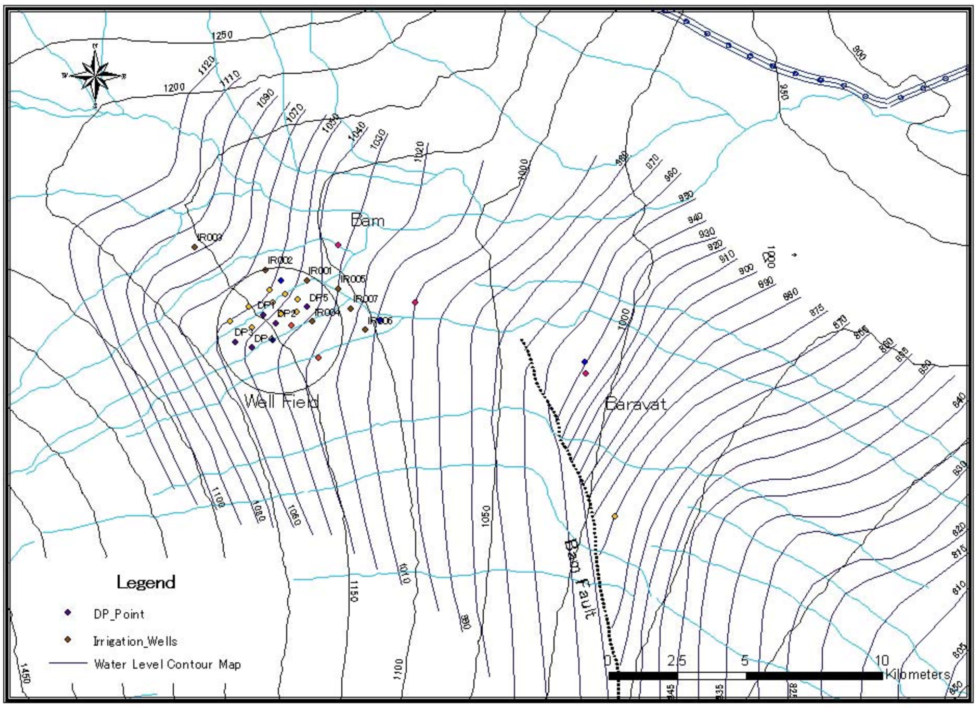
(4) IR003 (Existing Borehole)

The borehole IR003 is located on the flood plane of the ephemeral river Adori and is 2 km west from the well field. Only step test was carried out due to restriction of usage conditions of the borehole. Pumping equipment installed by the owner was used for the test. Transmissivity was estimated at 1,370 m^2/day. The value is the average of the results of Theis step and Theis recovery methods. Comparing the trasmissivities of the boreholes in the well field, the Transmissivity of the borehole IR003 is larger. It is deemed that the aquifer is composed of coarse grain materials delivered by the Adori River.

3) Groundwater Level

(1) Groundwater Level in the Study Area

According to the existing data, the general direction of groundwater flow in the study area is from west to east as shown in Figure 3.3.4. In the premise of existing well field, the groundwater level is from 1,030 to 1,060 meters above msl. Elevation of the area is from 1,120 to 1,170 meters above msl. The depth to the groundwater table varies from 90 to 110 m. The groundwater level contour line has been prepared using the average of around 10 years monitoring data. Therefore, there is a difference between the map and actual static groundwater level.



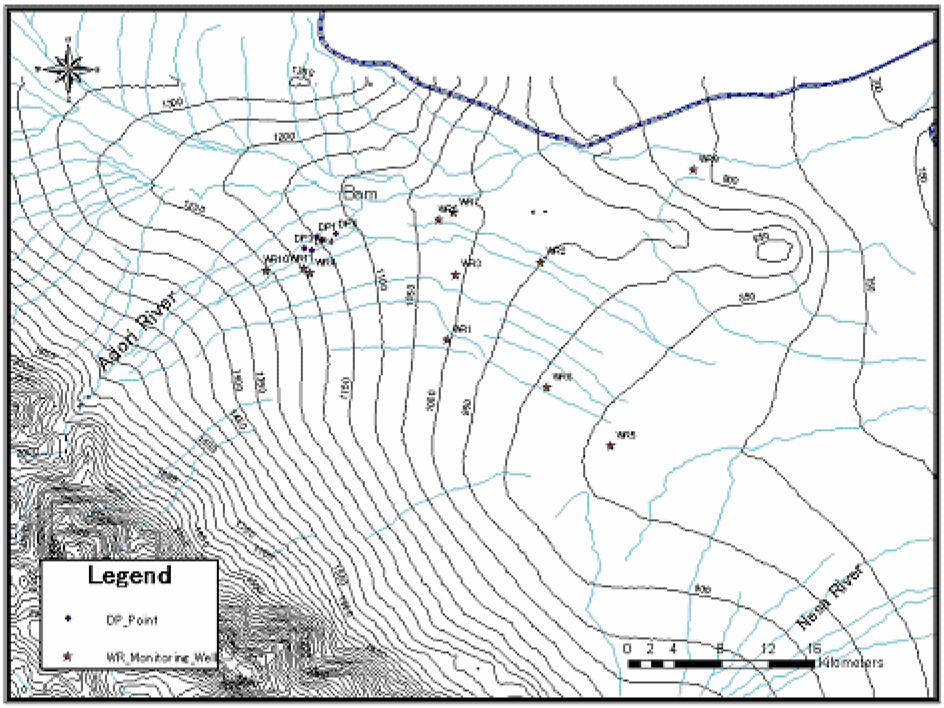
Source: Halilab Consulting Engineers (1998)

Figure 3.3.4 Water Level Contour Map

In the area of Baravat, groundwater level is affected by the Bam fault. Groundwater level in the west of the fault is around 940 meters above msl. In the east of the fault, water level varies from 940 in the north to 870 meters above msl or deeper in the south. In addition, the flow direction is changed by the fault from the west to east to the northwest to southeast. The change of direction of groundwater flow might be caused by the Bam fault, which acts as underground dam.

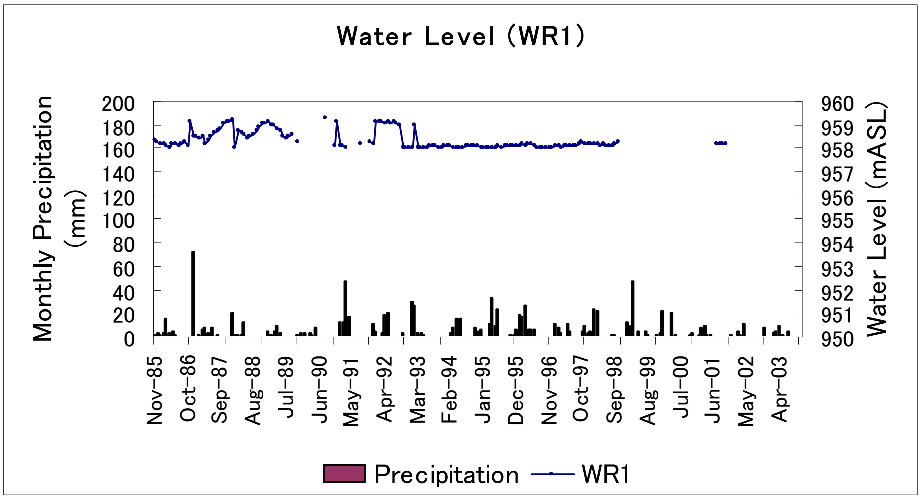
(2) Water Level Fluctuation

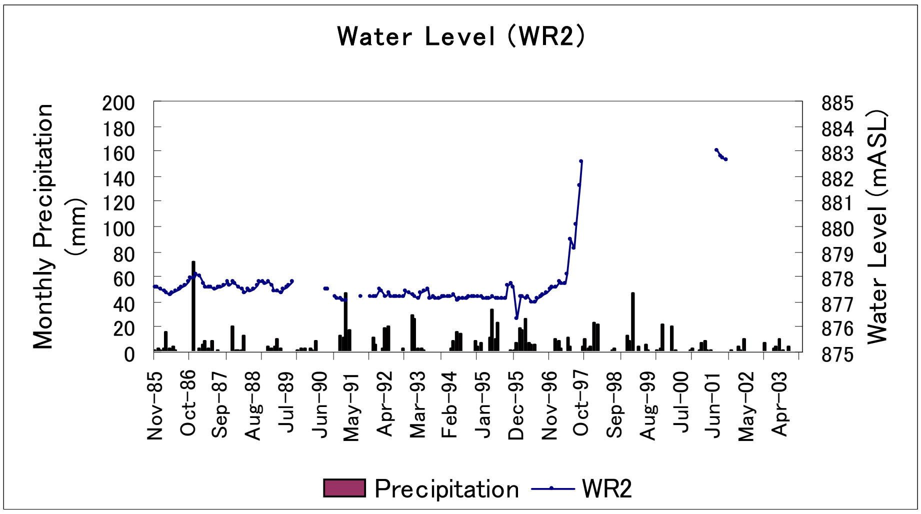
There are 11 monitoring wells around the Bam area (see Figure 3.3.5). RWRCK is responsible for these wells. Measurement of water level has been carried out every month by the staff of RWRCK since 1985. Monitoring data of 6 out of 11 wells were available. Figure 3.3.6 (1) and Figure 3.3.6 (2) show the monitoring data of these six wells. The water level of WR2, WR3 and WR6 wells, which are located in the east of Bam and Baravat, is showing a decreasing tendency year by year. In addition, the rate of decreasing at WR3 seems to be changed drastically since the severe drought has been occurred. The well WR5, which is located on the fun deposit of Nesa River, has same tendency of water level fluctuation with WR3. On the other hand, the monitoring data of well WR4, which is located on the south of Bam municipality, shows a tendency to be increasing until 1997, which is before the severe drought has started. The data of WR1 is almost flat. These monitoring data may reveal that the recharge from the Adori River is slightly faster than the appearance of effect caused by groundwater exploitation in the Bam municipality.

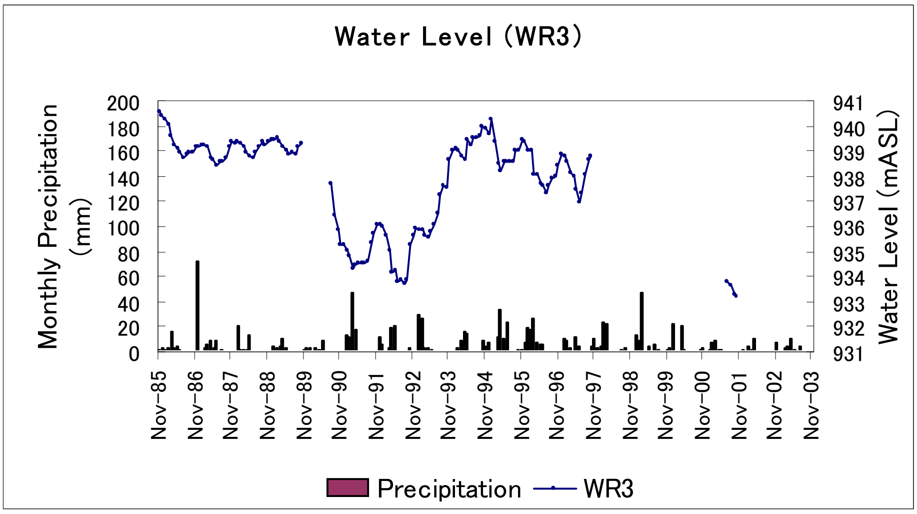


Source: Regional Water Resources Company of Kerman

Figure 3.3.5 Locations of Monitoring Wells

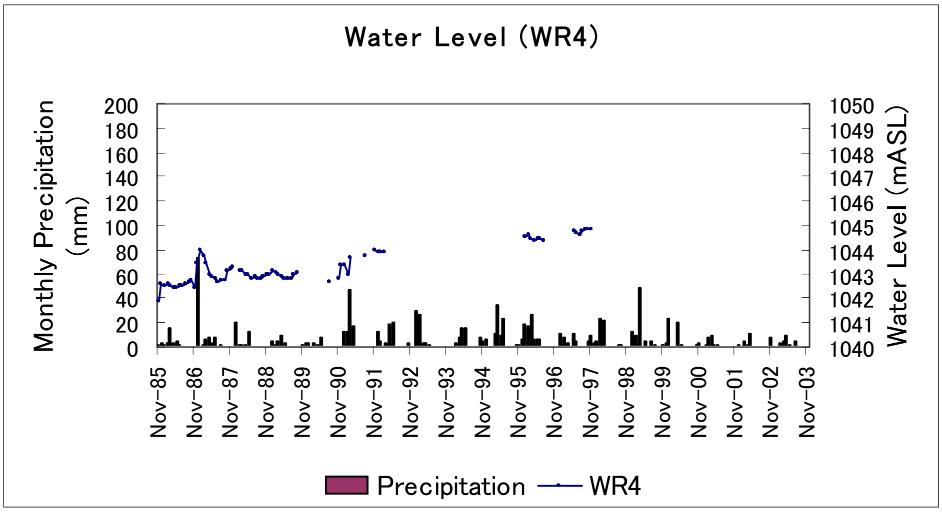


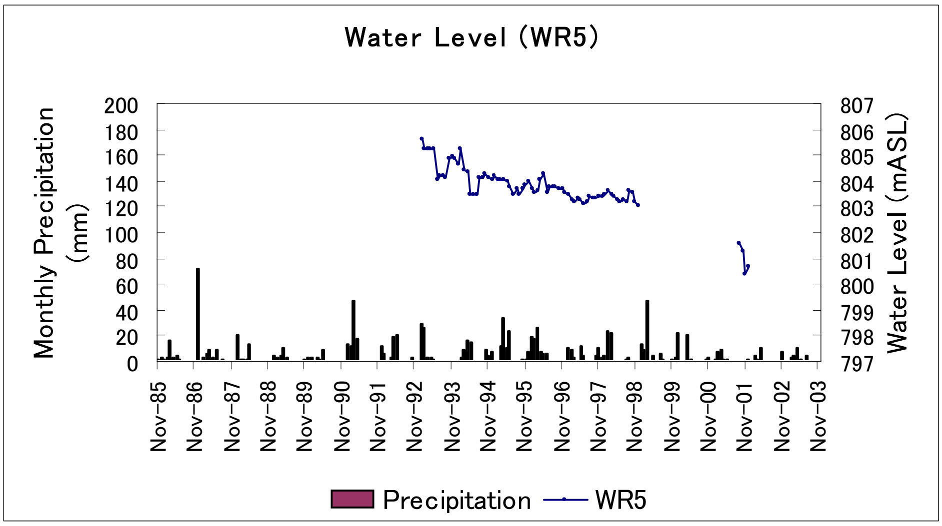


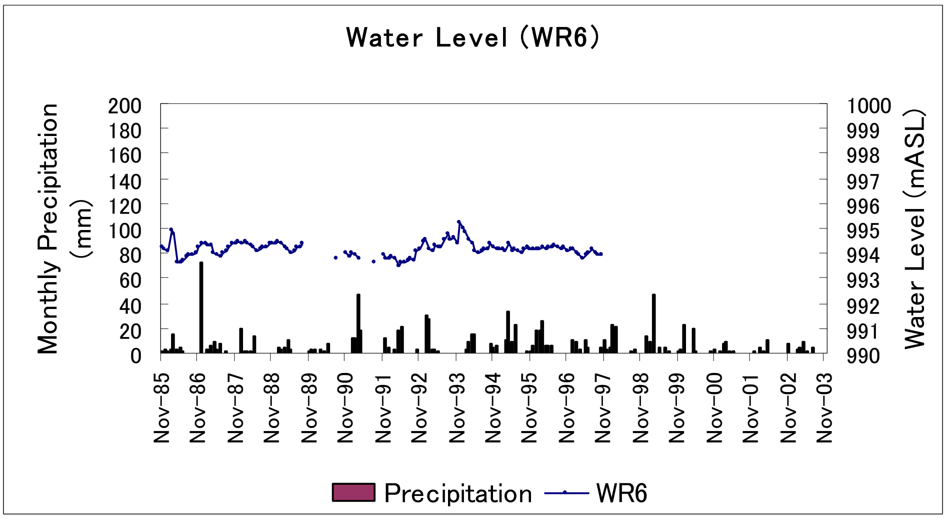


Source: Regional Water Resources Company of Kerman

Figure 3.3.6 (1) Groundwater Monitoring Data





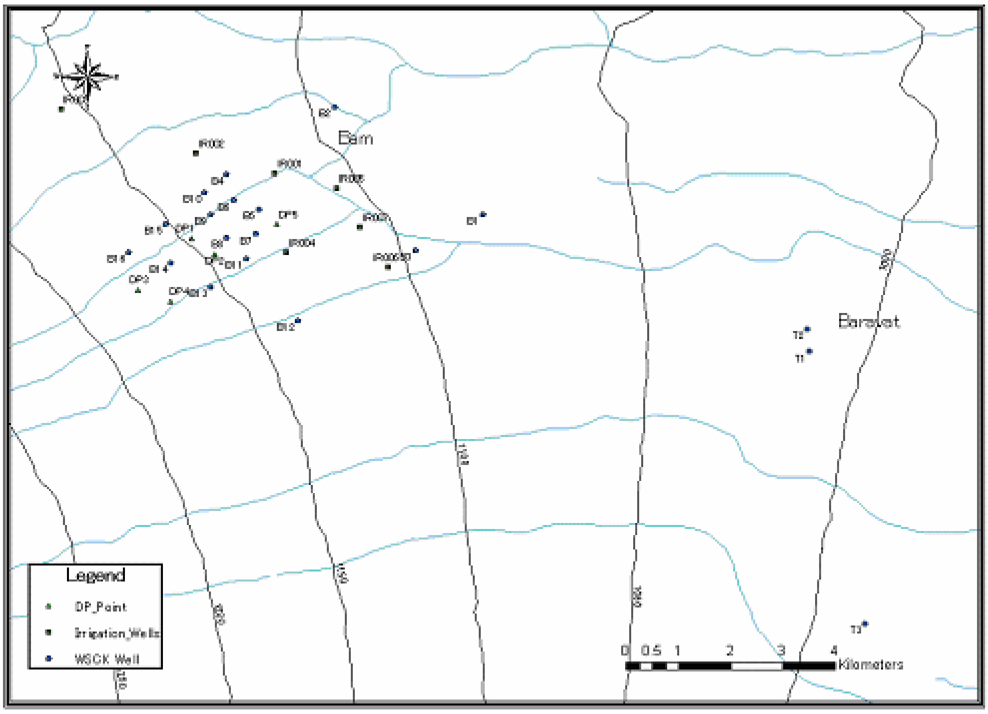


Source: Regional Water Resources Company of Kerman

Figure 3.3.6 (2) Groundwater Monitoring Data

4) Water Quality

WSCK has carried out water quality analysis for the water source at its own laboratory periodically. Locations of water source wells are shown in Figure 3.3.7. The result of analysis with Iranian drinking standard is shown in Table 3.3.7.



Source: JICA Study Team

Figure 3.3.7 Location of Water Quality Analysis Wells

Out of 14 wells in Bam area, it is observed that two wells (No.1 and 2) located inside the town area have high concentration of all substances. Concentration of sodium of these two wells exceeds the Iranian drinking standard. Concentration of chloride is also higher than other wells. As a result, electric conductivity (E.C.) becomes high. In addition, concentration of nitrate and sulfate of these wells are higher than others. Considering the land use pattern, the result may suggest the contamination of agricultural chemicals and/or domestic wastewater. In the area of Baravat, similar characteristics of concentration are observed.

During the study, water quality analyses for test wells and existing wells have been carried out (see Table 3.3.8). High concentration of substances is observed for the wells located inside the town.

Table 3.3.7 Result of Water Quality Analysis

		Iranian Driking Standard	Bam								
Substance	Unit	Maximum	**B1**	**B2**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
Date of Analysis			Oct. 2003	Oct. 2003		Sep. 2003	Oct. 2003	Apr. 2004	Apr. 2004	Apr. 2004	Apr. 2004
Temporary hardness	mg/l	-	336	344	no data	152	136	124	164	148	108
Permanent hardness	mg/l	-	116	68	no data	0	0	0	0	0	0
pH	-	-	7.87	7.89	no data	8.08	8.21	8.15	8.11	8.08	8.18
Turbidity	NTU	-	0.03	0.30	no data	0.13	0.02	0.25	0.15	0.08	0.57
TDS	mg/l	1500	983	1050	no data	416	465	411	510	577	411
Electric Conductivity	microS/cm	-	1519	1618	no data	694	739	634	962	888	633
Calcium	mg/l	250	81.60	86.40	no data	10.00	33.60	27.20	38.40	35.20	25.60
Magnesium	mg/l	50	31.63	30.72	no data	12.48	12.40	13.44	16.32	14.40	10.56
Sodium	mg/l	200	235.57	246.10	no data	37.91	123.72	107.92	151.10	143.72	108.97
Potassium	mg/l	-	6.20	6.40	no data	3.70	4.40	4.30	6.80	6.20	4.10
Fluorine	mg/l	-	-	-	no data	-	-	-	-	-	-
Bicarbonate (HCO_3)	mg/l	-	268.40	336.72	no data	204.26	219.60	214.72	248.88	248.88	224.48
Carbonate	mg/l	-	0	0	no data	0	0	0	0	0	0
Nitrite	mg/l	3	0	0	no data	0	0	0	0	0	0
Nitrate (NO_3)	mg/l	50	18.60	20.10	no data	8.99	7.32	7.03	7.08	7.19	6.69
Chloride	mg/l	400	230.00	232.00	no data	76.00	76.00	62.00	128.00	110.00	66.00
Sulphate	mg/l	400	254.00	241.00	no data	92.40	102.00	81.91	116.48	104.13	74.09

		Iranian Driking Standard	Bam						Baravat		
Substance	Unit	Maximum	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**	**T1**	**T2**	**T3**
Date of Analysis			Sep. 2003	Jun. 2004	Jun. 2004	Jun. 2004	Jun. 2004	Jun. 2004	Apr. 2004	Apr. 2004	Apr. 2004
Temporary hardness	mg/l	-	136	176	192	120	132	120	320	316	208
Permanent hardness	mg/l	-	0	0	36	0	0	0	68	28	0
pH	-	-	8.11	8.13	8.18	8.27	8.44	8.36	7.89	7.84	7.97
Turbidity	NTU	-	0.12	0.19	0.16	0.14	0.21	0.98	0.17	0.17	0.79
TDS	mg/l	1500	453	592	592	549	537	495	978	972	700
Electric Conductivity	microS/cm	-	798	986	979	930	916	853	1511	1497	1111
Calcium	mg/l	250	33.60	44.80	52.80	32.00	33.60	30.40	83.20	72.00	49.60
Magnesium	mg/l	50	12.48	15.36	14.40	9.60	11.52	10.56	26.88	32.64	20.16
Sodium	mg/l	200	132.14	151.10	146.34	163.18	144.78	130.03	226.37	239.01	161.63
Potassium	mg/l	-	4.40	6.20	3.60	5.80	5.80	4.20	7.50	6.70	4.00
Fluorine	mg/l	-	-	-	-	-	-	-	-	-	-
Bicarbonate (HCO_3)	mg/l	-	170.32	234.24	190.32	219.60	229.36	180.56	307.44	351.36	253.76
Carbonate	mg/l	-	0	0	0	0	0	0	0	0	0
Nitrite	mg/l	3	0	0	0	0	0	0	0	0	0
Nitrate (NO_3)	mg/l	50	7.20	7.68	7.48	6.18	6.63	8.90	17.61	19.81	11.25
Chloride	mg/l	400	112.00	160.00	124.00	134.00	126.00	100.00	226.00	208.00	154.00
Sulphate	mg/l	400	94.40	114.84	188.51	121.42	107.43	123.07	224.32	205.80	108.66

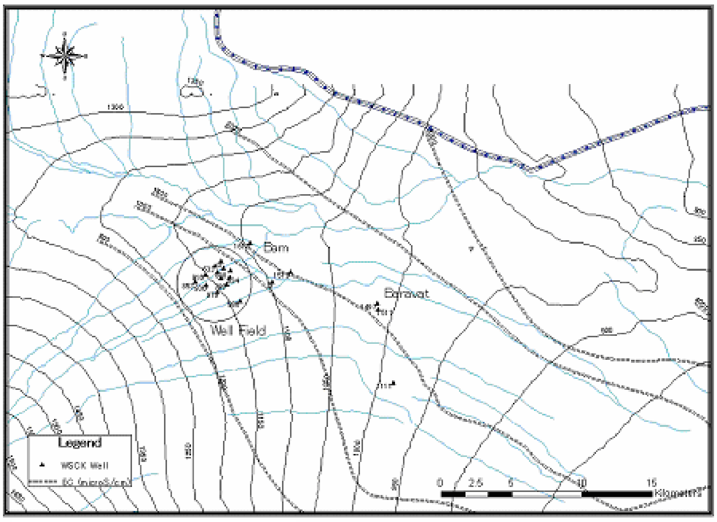
Source: Water Supply Company of Kerman

Table 3.3.8 Result of Water Quality Analysis of Existing and Test Wells

Well No.	Unit	Iranian Driking Standard	IR003	IR010	IR011	No.8	DP2	DP5
Date of sampling		Maximum	6-Sep-04	6-Sep-04	6-Sep-04	6-Sep-04	14-Sep-04	4-Oct-04
Date of Analysis			7-Sep-04	7-Sep-04	7-Sep-04	7-Sep-04	15-Sep-04	5-Oct-04
Temporary hardness	mg/l	-	112	280	476	108	100	96
Permanent hardness	mg/l	-	-	-	16	0	0	0
pH	-	-	7.87	7.68	7.45	7.80	7.87	8.02
Turbidity	NTU	-	-	-	-	-	-	-
TDS	mg/l	1500	417	770	1649	445	508	411
Electric Conductivity	microS/cm	-	707	1346	2557	794	846	633
Calcium	mg/l	250	28.80	73.60	120.00	28.80	30.40	25.60
Magnesium	mg/l	50	9.60	23.04	42.24	8.64	5.76	7.68
Sodium	mg/l	200	113.18	209.52	439.55	130.03	140.56	117.40
Potassium	mg/l	-	1.90	5.10	9.90	4.80	4.80	3.60
Fluorine	mg/l	-	-	-	-	-	-	-
Bicarbonate	mg/l	-	200.80	409.92	561.20	219.60	239.12	200.08
Carbonate	mg/l	-	0	0	0	0	0	0
Nitrite	mg/l	3	0	0	0	0	0	0
Nitrate	mg/l	50	4.54	20.93	39.22	7.70	7.09	7.60
Chloride	mg/l	400	76.00	172.00	408.00	94.00	100.00	66.00
Sulphate	mg/l	400	104.13	152.29	330.93	100.43	100.84	84.40

Source: JICA Study Team

Figure 3.3.8 shows the distribution of Electrical Conductivity (E.C.). Modification of the existing map has been made based on the results of water quality analysis of existing wells. The figure suggests that water quality is much better in the southwestern part of Bam than in the northeastern part of Bam. This characteristic is considered to be in accordance with the recharge system in this area.



Source: JICA Study Team

Figure 3.3.8 Electrical Conductivity (E.C.) Contour Map

5) Aquifer Properties

The obtained aquifer properties of each well are summarized in Table 3.3.9.

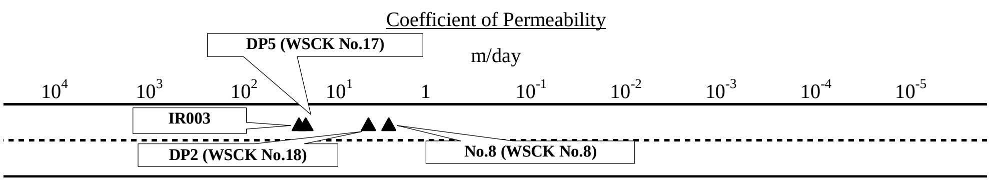
Table 3.3.9 Aquifer Properties

Borehole		Location	Depth	Screen Length	Specific Capacity	Transmissivity	Coefficient of Permeability	
			(m)	(m)	Q/s (m^3/day/m)	T (m^3/day/m)	(m/day)	(cm/sec)
1	DP2 (WSCK No.18)	WSCK Premise	230	108.01	438	683	6.32	7.32.E-03
2	DP5 (WSCK No.17)	WSCK Premise	203	103.94	1530	1532	14.74	1.71.E-02
3	No.8 (WSCK No.8)	WSCK Premise	200	105	89	449	4.28	4.95.E-03
4	IR003	West Bam	120	90	547 (by step drawdown test)	1370	15.22	1.76.E-02

Source: JICA Study Team

Table 3.3.10 shows the general ranges of Coefficient of Permeability (K) for soils and rocks. The values of clean sand and sand and gravel vary from 100 to 102 m/day. The range of the obtained values in the study area is also shown in the table.

Table 3.3.10 General Ranges of Coefficient of Permeability (K) for Soils and Rocks



Very high	High	Moderate	Low	Very low
Clean gravel	Clean sand and sand and gravel	Fine sand	Silt, clay, and mixtures of sand, silt, and clay	Massive clay
Vesicular and scorioceous basalt and covernous limestone and dolomite	Clean sandstone and fractured igneous and metamorphic rocks		Laminated sandstone, shale, and mudstone	Massive igneous and metamorphic rocks

after Kashef, A.I, GROUNDWATER ENGINEERING, 1987,
(U. S. Bureau of Reclamation, Ground Water Manual, U.S. Department of Interior, Washington, 1977.)

Source: JICA Study Team

3.4 Optimum Pumping Yield of Existing Wells

In order to evaluate the groundwater potential in the existing well field, optimum pumping yield of all existing wells are estimated based on the result of pumping test and existing data as described in Table 3.4.1. Considering the future water supply plan, two wells (B1 and B2) located in the Bam municipality and two wells in Baravat are eliminated. Coefficient of Permeability to be applied is 5.44 m/day. As a result, the optimum pumping yield of existing wells is estimated at 456 l/sec.

Table 3.4.1 Optimum Pumping Yield of Existing Wells

Well No.	Depth	Dynamic W.L.	Static W.L.	Estimated Thickness of Aquifer	Coefficient of Permeability		Estimated Transimissivity	Optimum Pumping Yield	Radius of Influence
	(m)	(mBGL)	(m)	(m)	(m/day)	(cm/sec)	(m2/day)	(litter/sec)	(m)
4	185	98	86	99	5.44	6.30E-03	539	35	200
5	179	135	90	89	5.44	6.30E-03	484	55	199
6	185	100	75	110	5.44	6.30E-03	598	28	203
7	(200)	200	90	110	5.44	6.30E-03	598	28	203
8	200	140	75	125	5.44	6.30E-03	680	20	207
9	185	110	100	85	5.44	6.30E-03	462	55	195
10	185	125	100	85	5.44	6.30E-03	462	55	195
11	185	140	105	80	5.44	6.30E-03	435	55	190
12	250	150	(120)	130	5.44	6.30E-03	707	25	215
13	(250)	(190)	(120)	130	5.44	6.30E-03	707	25	215
14	250	190	120	130	5.44	6.30E-03	707	25	215
15	250	190	120	130	5.44	6.30E-03	707	25	215
16	(250)	(190)	(120)	130	5.44	6.30E-03	707	25	215
								456	

Note: ( ) data was estimated based on various sources
Source: JICA Study Team

Optimum pumping yield of existing wells is estimated with the conditions mentioned below.

1. Radius of influence of each well

Radius of influence was estimated using aquifer properties obtained for the purpose of evaluation of groundwater potential of the well field. In the northern part of existing well field, the radius is set around 200 m considering actual location of wells. On the other hand, in the southern part of the well field, actual pumping rate is less than 20 l/sec with the dynamic water level of 190 m. In addition, it is reported that clay materials are predominant in this area. Considering such hydrogeological conditions, the radius is set at around 215 m.

The formula used for estimation of the radius of influence is as follows.

$s = Q/4\pi T*W(u)$

where

T : transmissivity (m^2/sec)

s : drawdown (m)

Q: discharge rate (m^3/sec)

S : effective porosity (alluvium, sandy gravel: 0.2-0.25)

t : duration of discharge (sec)

W(u) : well function

Drawdown at the end of radius of influence is set at 0.001 m. Then,

W(u) = 4πT/Q*0.001

u = R2S/4πT = b2

R = 2b*√ Tt/S

2. Duration of pumping

Duration of pumping is set at 20 hours.

3. Coefficient of permeability

Coefficient of permeability used for the estimation is the average of the results of pumping tests.

4. Aquifer thickness

Aquifer thickness of each well adopts the length of screen.

3.5 Groundwater Resources Development Plan

1) Evaluation of Groundwater Resources

The evaluation here of water source is carried out based on the optimum pumping yield with the view of possibility to meet the future water demand. The projected future water demand in the year 2023 is 746 l/sec as described in section 4.2.3. As mentioned in the above section, the optimum pumping yield of existing water source is estimated at 456 l/sec. In order to meet the demand, therefore, the amount of 290 l/sec of groundwater should be developed.

On the other hand, the optimum pumping yield of the two test wells combined is 40 l/sec as described in Table 3.5.1. The optimum pumping yield is calculated considering the radius of influence, since these two test wells are located in the existing well field. It is mentioned in the previous section that the radius of influence of DP5 is further extended due to high transmissivity. Therefore, the distance is set at 250 m in maximum with the yield of 10 l/sec.

Table 3.5.1 Optimum Pumping Yield of Test Wells

Well No.	Depth	Dynamic W.L.	Static W.L.	Estimated Thickness of Aquifer	Coefficient of Permeability		Estimated Transimissivity	Optimum Pumping Yield	Radius of Influence
	(m)	(mBGL)	(m)	(m)	(m/day)	(cm/sec)	(m2/day)	(litter/sec)	(m)
DP2	230	98	117.18	112.82	6.32	7.21E-03	683	30	208
DP5	203	135	93.2	99.06	14.74	1.71E-02	1532	10	257
								40	

Source: JICA Study Team

As a result, a total of 496 l/sec can be supplied to the water supply system. The remaining amount of 250 l/sec should be developed to meet the demand of the year 2023.

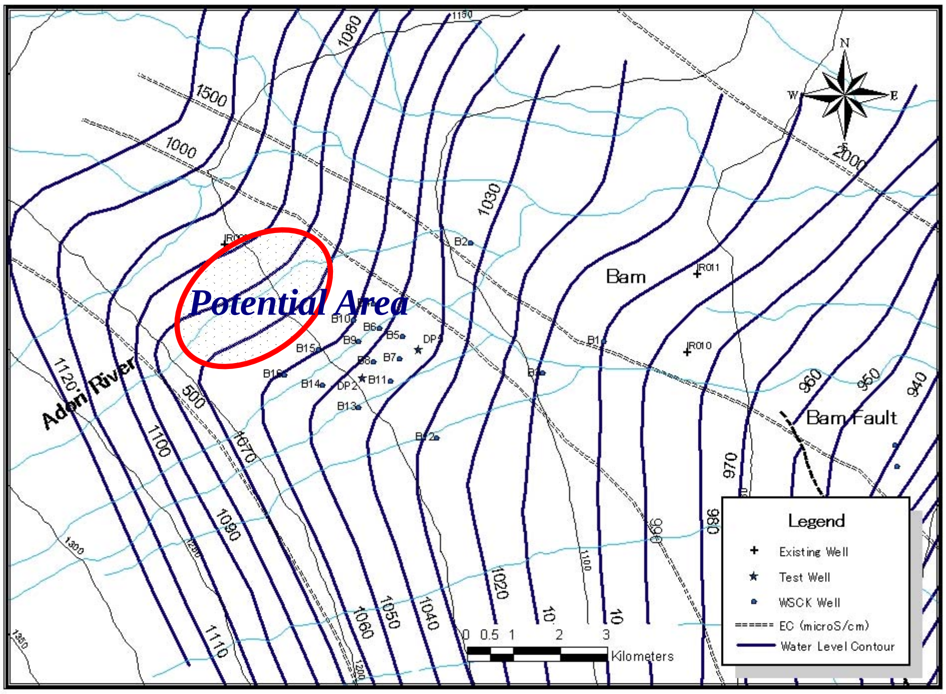
According to the result of pumping test, Adori River flood plain is deemed to have the potential for the groundwater development. Distribution of the plain is not investigated in the study. Therefore, it is estimated that if the distance of 550 m between each well could be kept within the distribution area of Adori River flood plain, the optimum pumping yield of each well would be 25 l/sec. However, it should be mentioned that the optimum pumping yield of 25 liter/sec estimated by using the Radius of Influence and Transimissivity, is the safe side yield. The Transmissivity is estimated by using the result of pumping test of one existing well. The average of actual pumping yield of existing wells is approximately 35 liter/sec without major problems. Considering these conditions, it is recommended that 30 liter/sec for one well is applied for the optimum pumping yield for groundwater resources development plan. Consequently, besides the two test wells, further eight wells are required to meet the water demand in the year 2023 and in total, 10 wells is required.

2) Potential Area for Groundwater Development

It is aforementioned that 250 l/sec of safe water should be developed by the year 2023. In order to cover this amount, the potential area for the future groundwater development is selected based on the result of hydrogeological analysis of the data obtained during the study. For the selection of the potential area, water quality, depth to the water level, and the coefficient of permeability are taken into consideration.

Figure 3.5.1 shows the potential area for the groundwater development. The selected area is located in the Adori River and its flood plain. This ephemeral river runs from the Jebalbarez mountain range with catchments area of around 276.5 km², and acts as one of the major recharge sources for the Bam desert groundwater basin. Electrical conductivity is less than

1,000 microS/cm. The depth to the water table is estimated at less than 100 m. The coefficient of permeability is 15.2 m/day. In addition, there is not any major source of pollution in the upstream. Considering these conditions, the Adori River and its flood plain, located 1.5 km west from the existing well field, is deemed to be a preferable water source for future groundwater resources development.



Source: JICA Study Team

Figure 3.5.1 Potential Area for Groundwater Development

3) Water Balance

The abovementioned study results are described from the point of view of Optimum Pumping Yield of wells. However, it is also necessary to take into consideration water balance in the watershed for sustainable development of the study area.

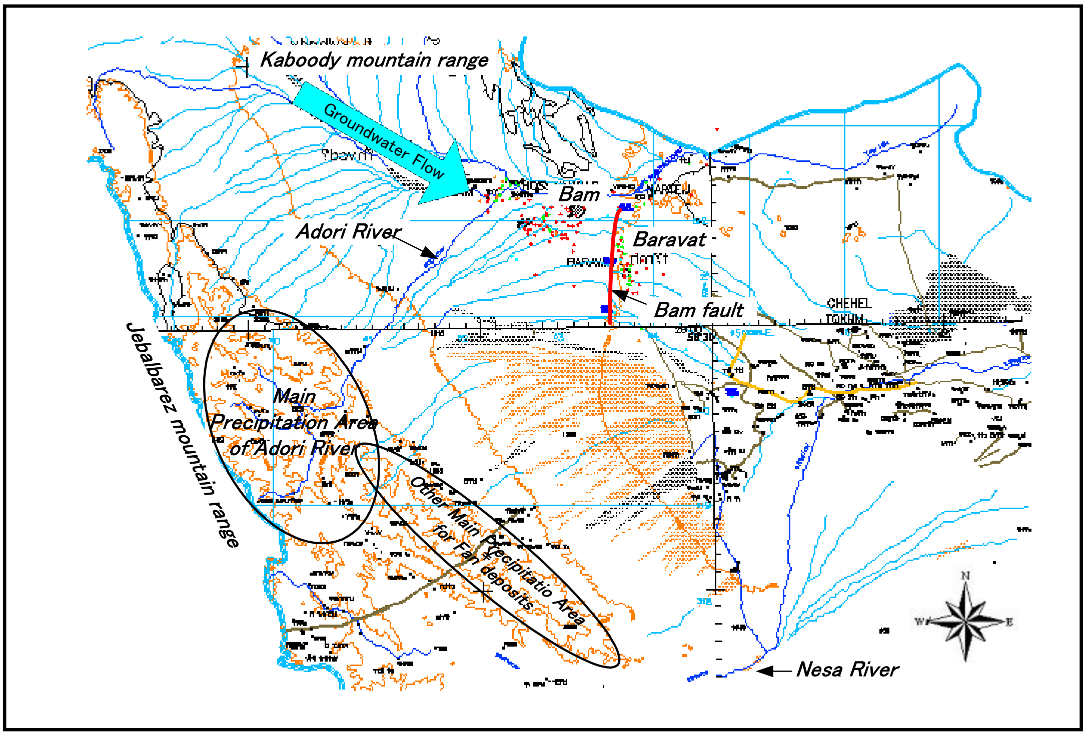
(1) Hydrological Characteristics of Bam and Baravat Surrounding Area

The cities of Bam and Baravat are located in south-west region of a wide watershed including Loot Desert (see Figure 3.5.2), that is to say, upper region of the whole watershed, Bam-Narmashir watershed unit. Groundwater has been flowing toward Loot Desert from this region; however, the quantity must be small because of large groundwater use in the upper region. The hydrological characteristics of this upper region can be summarized in following description.

There are two mountain ranges referred respectively to as “Kaboody” in the north and “Jebalbarez” in the south boundaries that are important sources of groundwater supply.

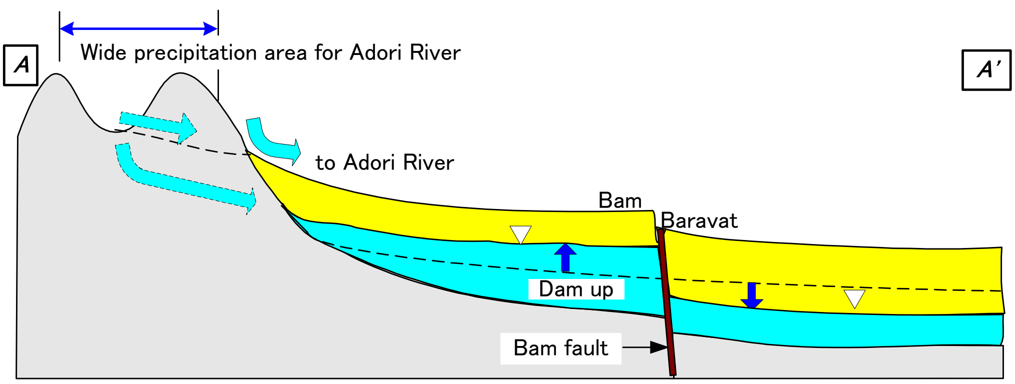
Especially Jebalbarez mountain range is comparatively the main source; its high elevation and low temperature produces high precipitation and low evaporation.

An especially dissected valley has been developed in Upper part of Adori River so that the upper part has a lot of precipitation compared with other rivers and the lower part of this river, and is abundant in groundwater resource. Furthermore, there is a famous fault referred to as “Bam fault” between Bam and Baravat municipality. The fault has worked as a natural “Underground Dam” (see Figure 3.5.3). Bam municipality has been developed as water abundant area since historical times under this favorable condition.



Source: Halilab Consulting Engineering (1998)

Figure 3.5.2 Hydrological Condition of Bam and Baravat Areas



Source: JICA Study Team

Figure 3.5.3 Schematic Cross Section of Adori River and Bam and Baravat Areas

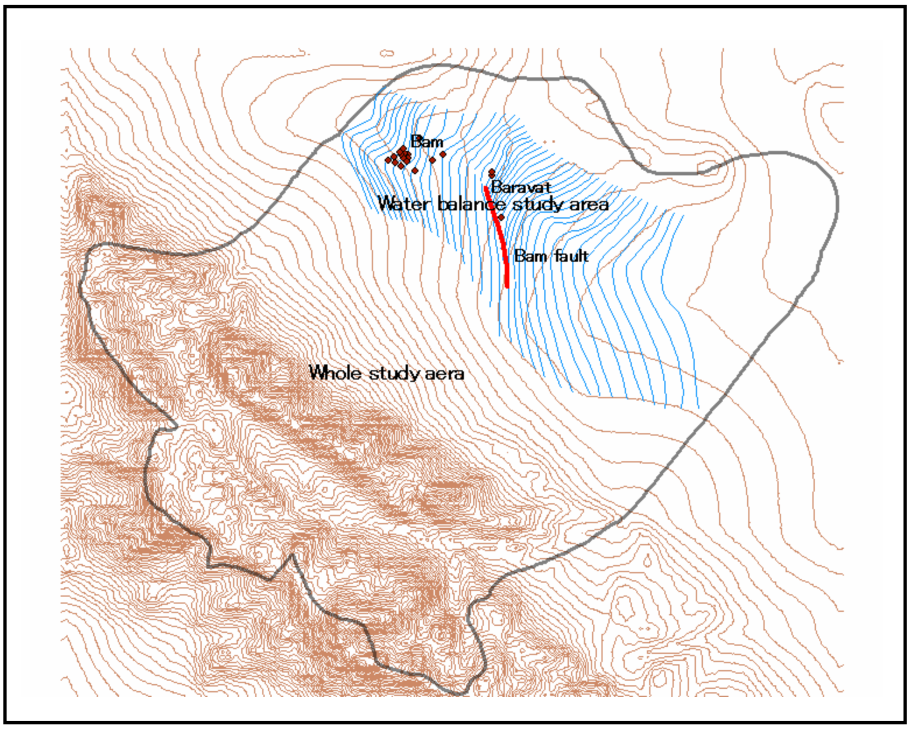
(2) Water Balance in the Upper Region of the Watershed

There are two kinds of approach in water balance study, that is to say, hydraulic approach and hydrological approach. Basically, there is no difference between the two; however, hydraulic approach is more suitable for detailed consideration and limited area than hydrological approach, because it needs more detail information and can obtain more concrete figures. In contrast, hydrological approach is suitable for large area and comprehensive study.

A. Hydraulic Approach to Water Balance in Limited Area

An existing water balance study in small area including Bam municipality is discussed here. The source is "The Study on Understanding of Water Resource in Bam and Arg-e-Jadid," Halilab Consulting Engineers, 1998. The whole area for which data was collected (2,792 km²) is located roughly between Adori River and Nesa River, and the area of water balance study is 780 km² including the cities of Bam and Baravat (see Figure 3.5.4).

The adopted calculation methods and assumptions are shown in Table 3.5.2 for each element of inflow and outflow.



Source: JICA Study Team based on the data from Halilab Consulting Engineering (1998)

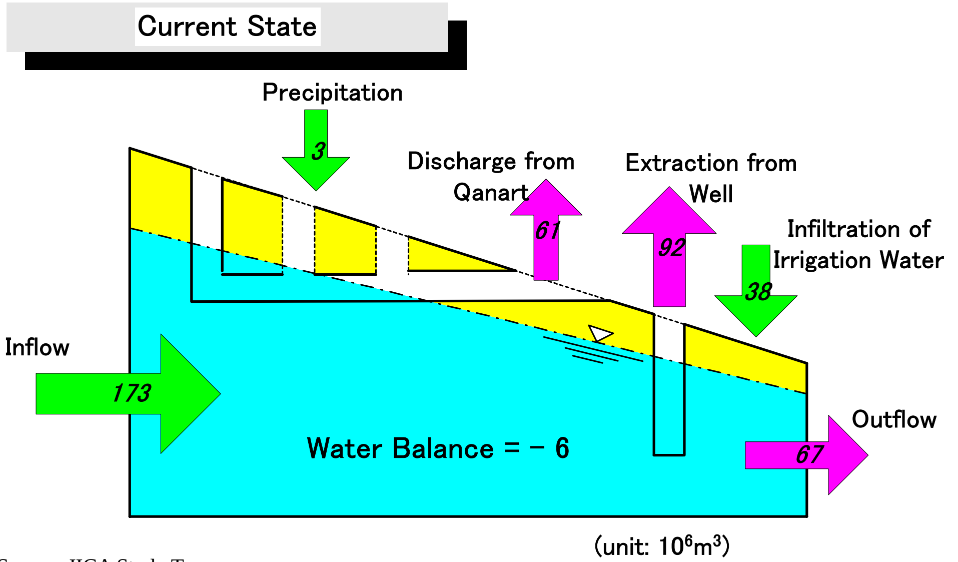
Figure 3.5.4 Study Area of Water Balance by Hydraulic Approach

Table 3.5.2 Calculation Method/Assumption of Water Balance Study

Item		Calculation Method or Assumption
Groundwater flow		Calculation implemented using hydraulic gradient of groundwater table and transmissivity. The hydraulic gradient of groundwater level was drawn using average yearly data from 1988 to 1998.
Infiltration	Precipitation	8 percent of total precipitation in the water balance study area
	Irrigation	25 percent of total irrigation water
Discharge	Wells	Whole extracted groundwater from Wells in the water balance study area
	Qanat	Whole discharges from qanats in the water balance study area. But there are still possibilities that some mother wells of qanats are located outside of the water balance area.

Source: JICA Study Team

The result of study is summarized in Figure 3.5.5, and water balance of the study area is a minus value. The shortage of water balance is "–six (6) MCM a year". This means that groundwater level lowering has continued in the water balance study area. The average quantity of lowering is eight (8) mm/year.



Source: JICA Study Team

Figure 3.5.5 Result of Water Balance by Hydraulic Approach

These several years drought has continued in Kerman province. It is noteworthy that in spite of this study being implemented using data obtained before drought period, still the water balance had a minus value.

B. Hydrological Approach to Water Balance in Bam Watershed

It is necessary for implementing a water balance study by hydrological approach to collect data such as precipitation, evaporation, surface discharge, groundwater level, extraction of groundwater, and infiltration of water in the whole watershed. When this approach applies to a partial area, information of groundwater inflow and outflow is requested at the boundary of the partial area. Available data is, however, limited to specific sites such as Bam and Baravat cities, well field of Bam and catchment area of Adori gaging station at present. Therefore, a water balance study is not yet to be carried out for whole watershed and even the upper region of the watershed. One of the studies implemented in limited area is "Hydrological Study on the Catchment of Adori Gaging Station" (RWRCK, 1993). The result is summarized as follows.

Table 3.5.3 Physical Properties of Catchment Area above Adori Gaging Station

Parameter	Quantity	Unit
Area	276.5	Km^2
Perimeter	77.5	Km
Average slope of the area	40.65	percent
Average slope of the water course	3.45	percent
Maximum length of water course	29	Km
Concentration time	4 hrs 46 min	hours & minutes
Average elevation	2,800	meters above msl

Source: RWRCK

Table 3.5.4 Long Term Average of Yearly Water Balance

Item	mm
Precipitation (P)	537
Direct Runoff (D)	214
Precipitation – Direct Runoff	323
Reference Potential Evapotranspiration (RPE)	1,230
Crop Potential Evapotranspiration (CPE=*Kc**RPE)	583
P-D-CPE	-260
Actual Evapotranspiration (AET)	287
Soil Moisture Deficit (D)	296
Moisture Surplus (S)	36
Runoff without Direct Runoff (R0)	36
Runoff including Direct Runoff (R0)	250

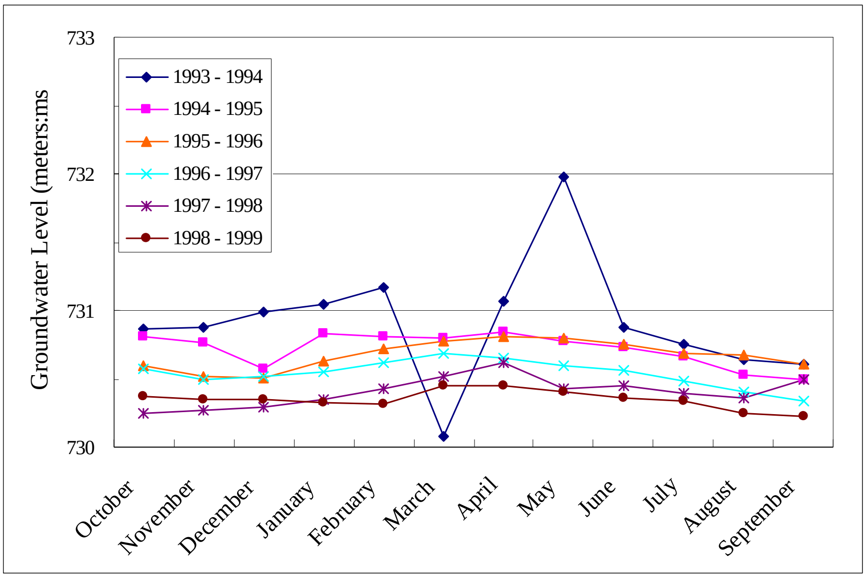
Source: RWRCK

It is noteworthy that almost 40 percent of precipitation discharged directly and over 50 percent of that evapotranspirated in mountainous range of Adori River. As had just been described, the catchment area of Adori River has good condition as resource area of groundwater supply.

C. Needs of Sustainable Groundwater Resource Development

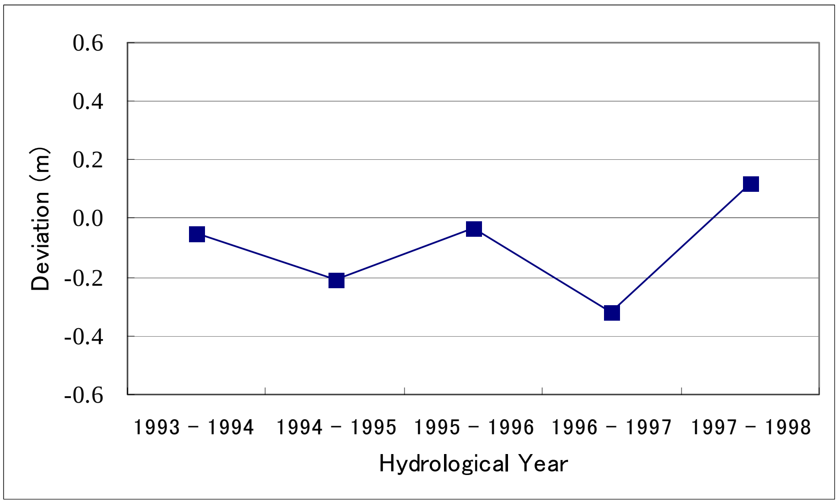
Despite the groundwater-rich condition of the surrounding areas of Bam and Baravat, a tendency of lowering groundwater level has been observed during recent drought period.

For example, Figures 3.5.6 and 3.5.7 show a monthly average groundwater level change and its deviation at each hydrological year, respectively (refer to Figure 3.5.4 for the study area). The lowering is not always clear looking at the data individually, but the tendency can be gleaned from Figure 3.5.7 despite the observation period of the data being before recent drought period.



Source: Halilab Consulting Engineers

Figure 3.5.6 Monthly Average Groundwater Level Change



Source: Halilab Consulting Engineering

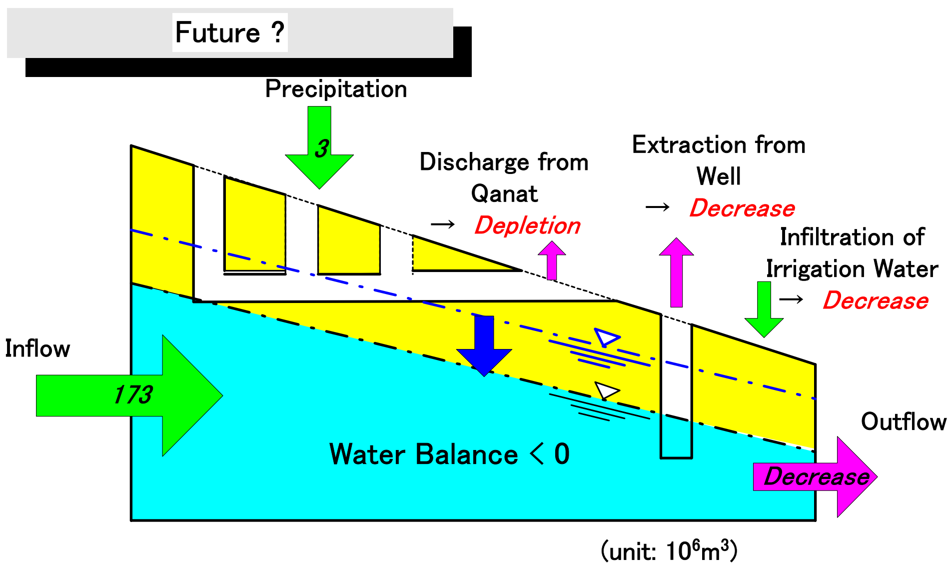
Figure 3.5.7 Groundwater Level Deviation of Each Hydrological Year

According to RWRCK, it can be estimated that outflow of the groundwater to the Loot Desert from the upper region of the watershed, Bam-Narmashir unit, will be only five to fifteen MCM a year. This amount will be consumed easily by developing the same number of wells in the well field of Bam, because each well has a basic pumping yield of about 1 MCM a year.

At any rate, groundwater storage capacity of the natural underground dam of Bam is so large that overuse of groundwater will not bring out much groundwater level lowering in near future, and extraction of groundwater by wells will be able to continue without significant influence against their water use.

However, there are a lot of qanats in Bam and Baravat surrounding area, and their amount of discharge is significantly affected by groundwater level. If the groundwater level lowering of 1 m happens, the discharge from existing qanats will be completely depleted. Since the amount of 141 MCM a year of groundwater is extracted from qanats for the irrigation purpose, it will be the issue of critical importance for regional sustainable development.

Therefore, the groundwater use under strict watershed management is essential to regional sustainable development. For realizing the watershed management to control water use, groundwater monitoring should be adopted.



Source: JICA Study Team

Figure 3.5.8 Possible State of Water Balance in Case of Non-Watershed Management

3.6 Groundwater Monitoring Plan

1) Groundwater Monitoring Plan

Systematic Groundwater Monitoring Plan should be adopted for sustainable development of this region. It means to implement watershed management for the BN-Unit. Figure 3.6.1 shows main part of the BN-Unit. The aquifer characteristic in the BN-Unit is said to be unconfined aquifer.

The hydrological cycle is conceptually helpful to understand the situation of the BN-Unit, but a more quantitative approach, a water balance analysis which accounts for all of the inputs and outputs to the watershed, is necessary for conducting watershed management. It is a conservation of mass approach. This can be expressed simply as "Inflow – Outflow = Change in Storage" within the BN-Unit. In a water balance scenario, if more water is leaving the BN-Unit than is entering, lowering of groundwater level will take place. The method of calculation will be computer simulation or simple calculation; it depends on quantity and quality of the collectable data. Furthermore, it is essential to know the hydrogeological structure of the basin, especially for computer simulation.

In case of the BN-Unit, it is necessary to collect the following information for watershed management.

Table 3.6.1 Major Components for Groundwater Monitoring Plan

<table>
<tr><th colspan="2">Inflow</th><th colspan="2">Outflow</th></tr>
<tr><td colspan="2">Precipitation</td><td colspan="2">Evapotranspiration</td></tr>
<tr><td colspan="2">Surface water discharge</td><td colspan="2">Surface water discharge</td></tr>
<tr><td colspan="2">Groundwater flux</td><td colspan="2">Groundwater flux</td></tr>
<tr><td rowspan="2">Infiltration</td><td>Infiltration facilities</td><td rowspan="2">Consumptive use</td><td>Extraction Wells</td></tr>
<tr><td>Irrigation</td><td>Qanats</td></tr>
<tr><td colspan="2">Imported water</td><td colspan="2">Exported water</td></tr>
</table>

Of all the components above mentioned, precipitation, surface water discharge and groundwater level observation are most important and should be done systematically. The basic idea of selecting observation points is as follows.

- Precipitation and other Meteorological Information

  Observation points should be installed more in mountainous area than in lower plain area, because to know the amount of water supply in recharge area, i.e. precipitation, is the most basic component.

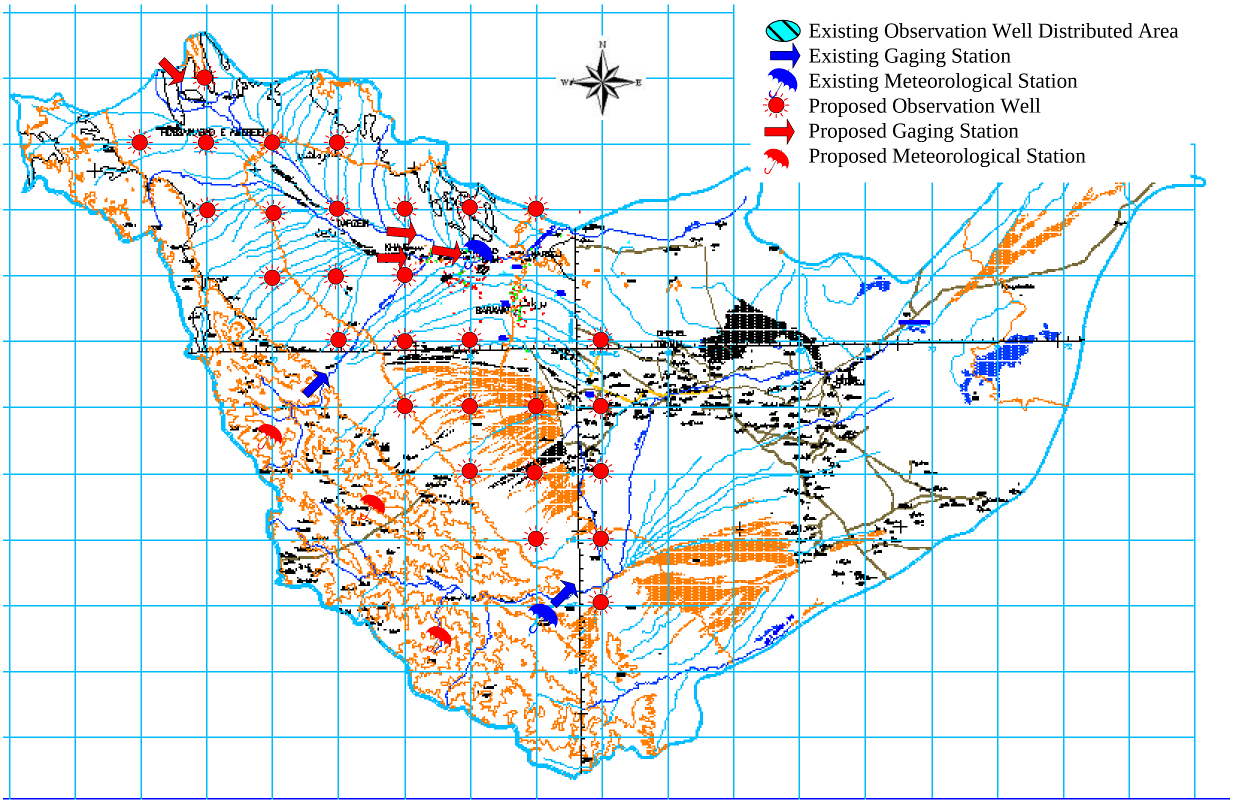
- Surface water discharge

Observation points should be installed at least near the boundary of mountainous and plain area to know the discharge from mountainous area, and in the vicinity of confluence points of rivers to know the groundwater and surface water interaction.

- Groundwater flux

It is very difficult to know groundwater flux directly. Instead of that, observation of groundwater level is usually done with geological investigation on the site to know the aquifer property such as Transmissivity. And monitoring of the variation of groundwater level is directly beneficial to understand the current state of amount of groundwater storage in the BN-Unit. Observation points should be appropriately distributed to whole plain area.

An example of distribution of observation points is shown in Figure 3.6.1.



Source: JICA Study Team

Figure 3.6.1 Groundwater Monitoring Plan in Bam-Narmashir Unit

2) Influence of Nesa Dam for Water Balance

Nesa Dam is now under construction at the upper stream of Nesa River. The dam is located in about 60 km away from Bam. The latitude is 28º39' and longitude is 58º22'. The catchment area is about 670 km². The long term discharge of Nesa River is estimated about 242 MCM.

The purpose of the dam construction is mainly water supply for irrigation. The base rock of the dam axis consists of sedimentary rocks formed in geological time of Eocene.

The watershed units of Adori River and Nesa River are adjoining each other so that the groundwater levels of each watershed unit has been interfering each other. After completion of the dam, the water balance in the study area will be affected. Therefore the continuous monitoring of groundwater level in Nesa flood plain is strongly recommended.

CHAPTER 4 LONG-TERM PLAN ON RECONSTRUCTION OF WATER SUPPLY SYSTEM

4.1 Introduction

A long-term plan on reconstruction of water supply system was formulated based on the comprehensive reconstruction plan of Bam and Baravat areas issued by the Ministry of Housing and Urban Planning in Kerman. The target year of the long-term plan is year 2023 and it consists of overall water supply reconstruction plans in Bam and its surrounding areas. The long-term plan essentially follows its fundamental data, i.e. population projection, water demand, general water supply development plan from the reconstruction plan formulated by WSCK. The study team has closely cooperated with Hengam Consulting Company, a managing consultant and Jooyab-nou Consulting Co., appointed by WSCK, in order to keep the long-term plan concurred to the water supply reconstruction plan.

A preliminary design of the distribution network was initially drawn by the JICA study team in February, and then the distribution network was designed in detail by Jooyab-nou Consulting Co., procured by WSCK.

WSCK does not have any expansion plan of conveyance system because the location of new wells is not yet certain and concrete plan for remote control system. Long-term development plan of water supply system, including remote control system and conveyance system are scrutinized, accordingly, in this chapter.

4.2 Planning Condition

1) Planned Service Area

Water supply service area covers Bam city (approx. 39 km²), Baravat urbanized area (approx. 17 km²), the northern and northeastern villages of Bam such as Posht rood, Esfikan, Rahim Abad, Khagei Bala, Nartig, and Kork.

2) Target Year

Target year for the distribution system development plan was decided as year 2031 at the meeting among Central Water and Sewage Company under the Ministry of Energy, WSCK and Jooyab-nou Consulting Co., while the target year for the well development plan, described in Chapter 3, was set for year 2023 by WSCK because there are many uncertain factors to conduct preliminary design for intake system confronting to the distribution system development for the target year 2031, i.e. 1) availability of using surface water from Nesa dam, 2) groundwater for irrigation in future and 3) sustainability of groundwater resources.

Regarding to well development, water drawn quantity can be increased in phase, so rather short year target is preferable for well development plan.

3) Planned Population Served

Bam city and its surrounding area are divided into 14 zones. These zones are established by Task Force for handling of reconstruction activities sponsored by Provincial Housing Foundation. These zones are shown in Figure 1.2.2. The future service population projected by zone is indicated below.

Table 4.2.1 Future Service Projected Population by Zone

Zone	Category	Population After Disaster	Population Served In 2031
1	Bam Rural	2,284	6,106
2	Bam Urban	4,333	11,583
3	Bam Urban	4,176	11,166
4	Bam Urban	9,459	25,290
5	Bam Urban	16,091	43,022
6	Bam Urban	10,992	29,390
7	Bam Urban	6,046	16,164
8	Bam Urban	3,396	9,081
9	Bam Urban	2,395	6,403
10	Bam Urban	4,517	12,077
11	Bam Urban	3,482	9,310
12	Bam Rural	*	*
14	Bam Rural	2,023	5,408
Total (Bam Urban)		64,887	173,486
Total (Bam Rural)		4,307	11,514
13	Baravat	15,875	43,905
Grand Total		85,069	228,905

Note: * means outside of service area
Source: Jooyab-nou Consulting Engineers

4) Water Demand

(1) Unit Water Demand

The daily average unit water demand per capita is given below:

Table 4.2.2 Daily Average Unit Water Demand per Capita

(Unit: m^3/person)

No.	Item	2003	2031
1	Domestic	151	164
2	Non-domestic	27	19
3	Losses	25	20
Total		203	203

Source: Jooyab-nou Consulting Engineers

(2) Water Demand

Maximum water demand for designing facilities, i.e. reservoir and pipe, is estimated based on the following conditions:

- Daily Peak factor for determining capacity of reservoir: 1.8
- Hourly peak factor for designing distribution network: 1.4 for Bam network
  1.5 for Baravat network

Table 4.2.3 Future Water Demand in 2031

Area	Population	Daily Ave.		Daily Max.		Peak Hourly	
		Unit Water Demand (lpcd)	Water Demand (m^3/day)	Unit Water Demand (lpcd)	Water Demand (m^3/day)	Unit Water Demand (lpcd)	Water Demand (l/s)
Bam	185,000	203	37,555	365	67,525	512	1,096
Baravat	43,905	203	8,913	365	16,025	548	279
Total	228,905	-	46,468	-	83,550	-	1,375

Source: Joyaab-nou Consulting, Consulting Engineer

Table 4.2.4 Future Water Demand in 2023

Area	Population	Daily Ave.		Daily Max.		Peak Hourly	
		Unit Water Demand (lpcd)	Water Demand (m^3/day)	Unit Water Demand (lpcd)	Water Demand (m^3/day)	Unit Water Demand (lpcd)	Water Demand (m^3/hour)
Bam	145,590	203	29,555	365	53,140	512	863
Baravat	31,660	203	6,427	365	11,556	548	201
Total	177,250	-	35,982	-	64,696	-	1,064

Source: JICA Study Team

The planned population served, unit water demand and peak factor are authorized as applied factors for the estimation by Central Water and Sewage Company under the Ministry of Energy.

4.3 Planned Distribution System

1) Distribution Block

Bam service area has a slope evenly tilting toward the east. The altitude ranges from 1,130 m at the westernmost point to 1,020 m at the easternmost point of the service area. Existing distribution reservoirs are located in the southwest of the city to distribute water by gravity. The service area of Bam is divided into two blocks; West Block and East Block. The No. 1 reservoir (R1), located near the intersection of Amir Kabir Street and the main road (Kerman to Bam), distributes water to East Block. The No. 2 reservoir (R2), located 1.7 km away from the main road, distributes water to West Block. The water level of this reservoir is approximately 1,160 m above the sea level.

The altitude of east block ranges from 1,080 to 1,020 m, so excessive water pressure may be seen through the distribution network in eastern part of the block during the night. Due to the excessive water pressure during the night, the east block shall be divided into two areas, connected with two pipelines. The water to the east area is supplied through western pipe network, and two pressure reducing valves are shown in Figure 4.3.2.

A planned service area of Baravat is approximately 17 km² and its altitude ranges from 960 to 1,010 m. The water is supplied from two reservoirs newly constructed at the middle of the service area of Bam and Baravat. The water level of these reservoirs is approximately 1,040 m above the sea level. The planned service area of Baravat is divided into two blocks, north and south.

2) Hydraulic Calculation

Hydraulic calculations to determine pipe diameter were made based on the following conditions:

- Computer software for analysis: EPANET 2.0
- Head loss formula: Hazen-Williams
- Roughness Coefficient
  Diameter 110 mm or less: 130
  Diameter 150 mm and over: 110
- Minimum water head at junction: 20 m

3) Planned Distribution Pipe Network

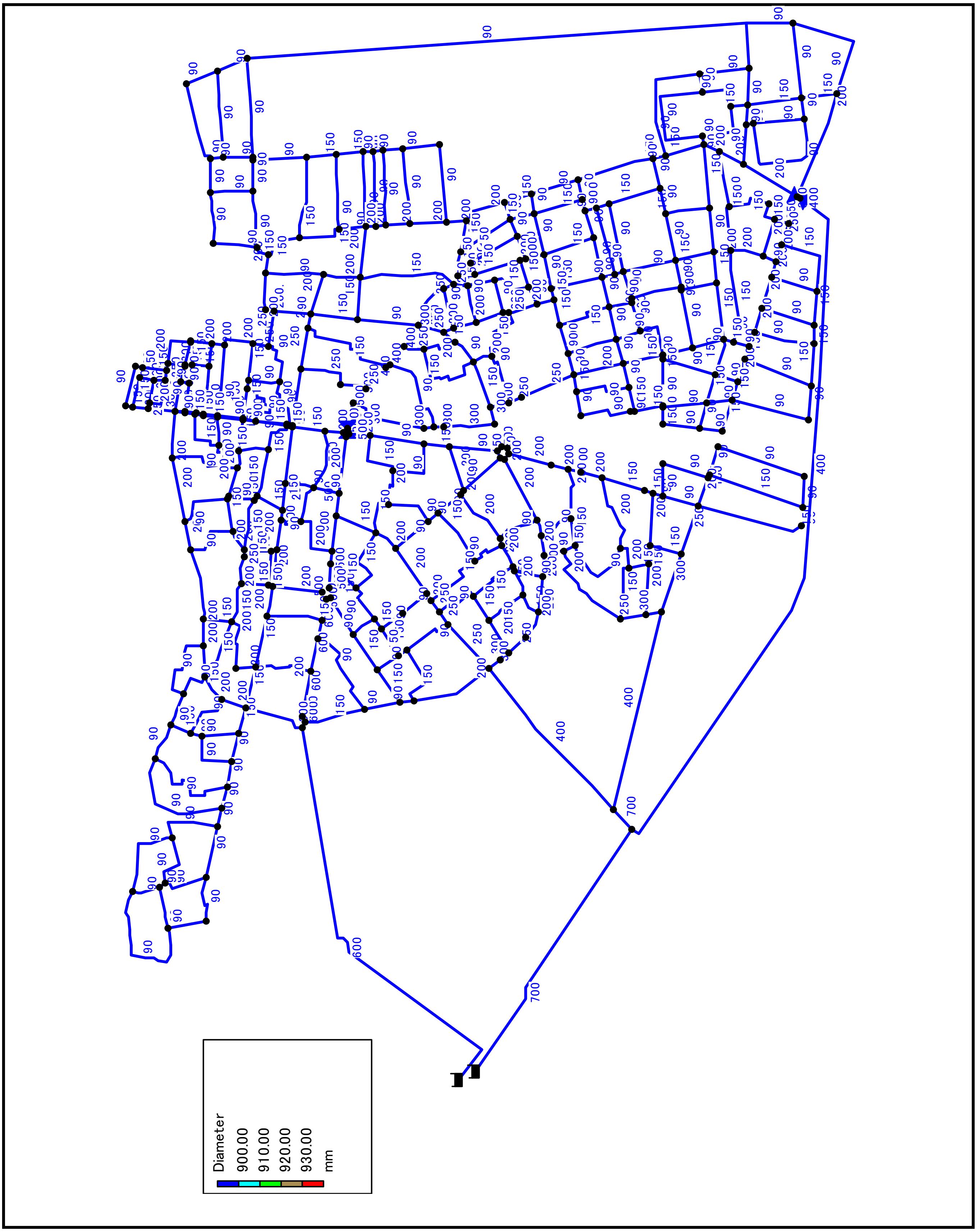
Preliminary design with target year 2031 was carried out by Jooyab-nou Consulting Engineers based on the aforementioned conditions. The planned pipe network is shown in Figure 4.3.1 to Figure 4.3.3. The lengths of the pipes by diameter are shown in Table 4.3.1.

Table 4.3.1 Length of Distribution Pipe by Diameter

(Unit: m)

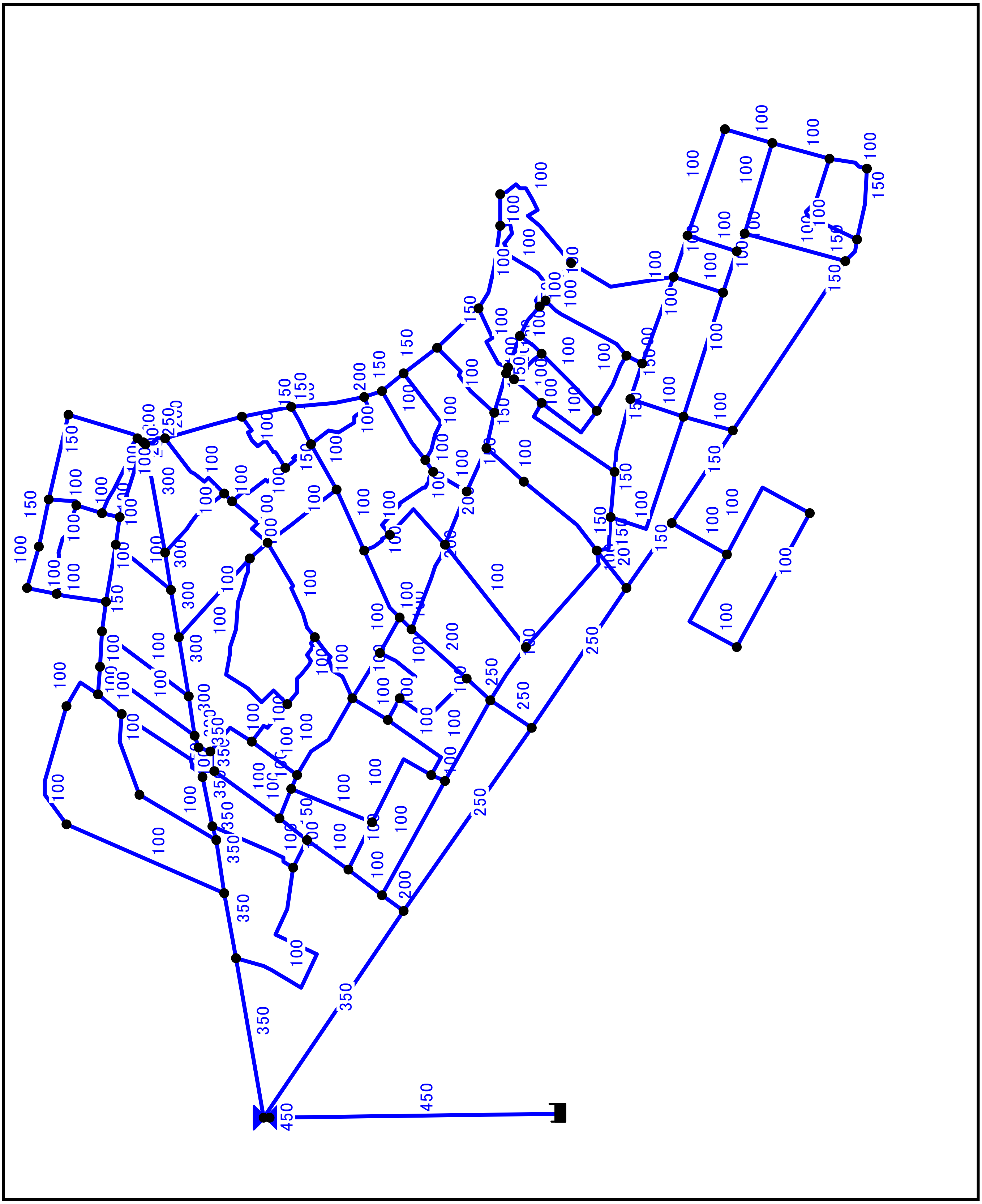
Dia.(mm)	Bam East	Bam West	Baravat North	Baravat South	Total
110	64,950	43,220	20,140	30,420	158,730
150	35,490	7,430	8,810	15,310	67,040
200	23,660	2,330	1,250	8,660	35,900
250	4,840	2,210	360	2,570	9,980
300	3,150	1,560	-	840	5,550
350	-	3,320	-	-	3,320
400	8,670	-	-	160	8,830
500	390	-	-	-	390
Total	141,150	60,070	30,560	57,960	289,740

Source: Jooyab-nou Consulting Engineer
Note: The table does not include the length of existing pipes, which will be used in the future.



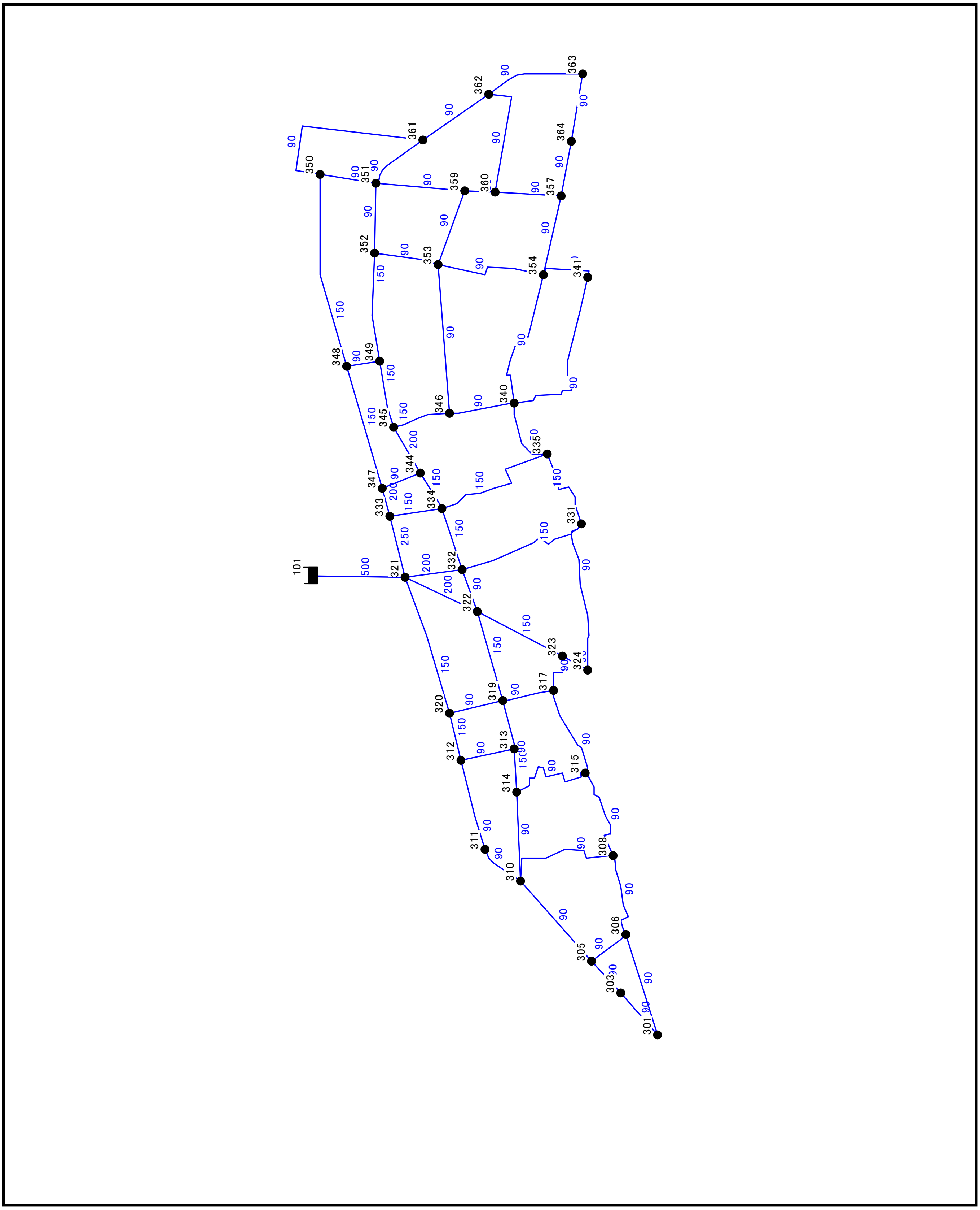
Source: Jooyab-nou Consulting Engineer

Figure 4.3.1 Planned Pipe Network (East Bam)



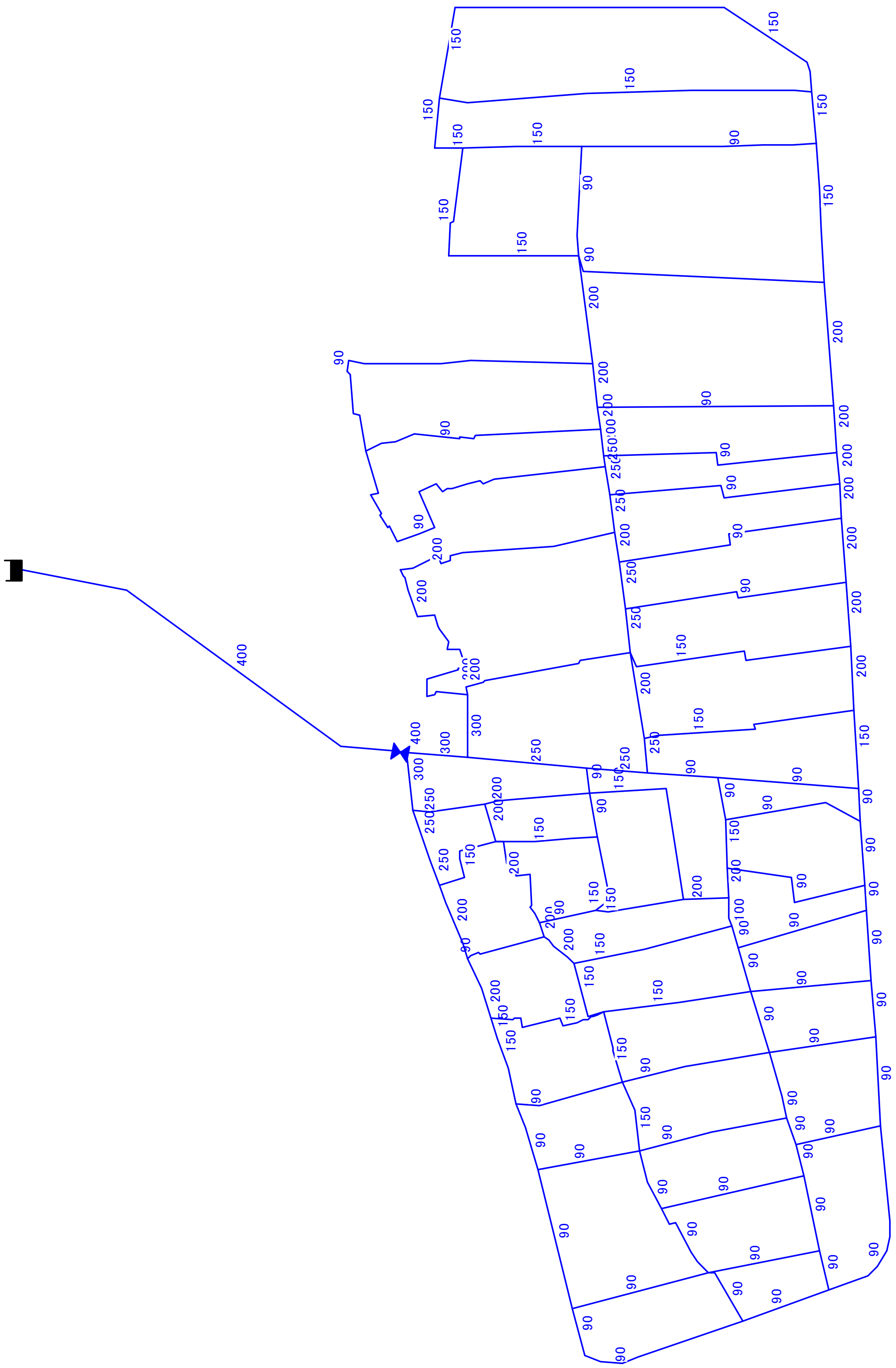
Source: Jooyab-nou Consulting Engineer

Figure 4.3.2 Planned Pipe Network (West Bam)



Source: Jooyab-nou Consulting Engineer

Figure 4.3.3 Planned Pipe Network (North Baravat)



Source: Jooyab-nou Consulting Engineer

Figure 4.3.4 Planned Pipe Network (South Baravat)

4.4 Planned Remote Control System for Well Pumps

1) Present Operation of Well Pumping Stations

As of October 2004, there are 19 well pumping stations working for Bam and Baravat water supply system as follows:

- Original well for Bam water supply system 15 wells
- Rented well for Bam water supply system 1 wells
- Baravat water supply system 3 wells

Before the earthquake, not all of the wells are under operation. After the earthquake, however, all wells are in operation round the clock due to increasing water consumption, although recurrent interruptions occur because of electrical failure. Information gathered from BWSC revealed that these electrical interruptions happen 8 to 12 times in a month. Some well pumps are also halted when water level in reservoir rises up to the warning level; however, it rarely happens. When it does happen, an operator has to go to the well to restart well pumps. The procedure of restarting pumps is described below;

- close the discharge valve;
- open the drain valve;
- start the pump to dispose of water mixed with sediments to outside and to release air dissolved in the water;
- wait for sometime until the water become clear and then open the discharge valve slowly;
- close the drain valve.

This is an exhausting work for operators, and it is difficult to take any immediate action in case of emergency. Flowmeters are not yet installed to each discharge pipe of well pump and reservoirs, so that it is not possible to grasp actual quantity of supplied water.

In order to improve the existing operation procedure for the existing water supply system, introducing a remote control system consisting of computer system, mechanical equipment, instruments and electrical facilities is proposed by the JICA study team.

2) Composition of Remote Control System

(1) Central/local Remote Control Units

The central/local remote control units consist of master computer, monitor, printer, software, communication link, remote terminal and signal transducer. These units have the following functions:

a) Controlling

b) Monitoring

c) Alarming

d) Tagging

e) Reporting

f) Historical trend recording

g) Printing

Proposed instrument diagram and typical control flow diagram are shown in Figure 4.4.1 and 4.4.2.

(2) Motor-operated valve

The motor-operated valves shall be gate plug valve for both discharge valve and drain valve.

(3) Flowmeter

The flowmeters shall be an ultrasonic type, and a sensor of the ultrasonic flowmeter is installed outside of the existing pipe. These devices are installed in each well pumping station, R1 reservoir and R2 reservoir.

(4) Pressure Transmitter

The pressure transmitter shall be electronic type, and capable of operating in the range of well pump discharge pressure, and be of the diaphragm type.

(5) Level Transmitters

The level transmitters shall be ultrasonic type for the reservoirs water level measurement and immersion type for each well water level measurement.

(6) Ammeters and Voltmeters

The ammeters and voltmeters shall be equipped for all distribution boards.

(7) Mimic Panel

The mimic panel indicates the status of pump operation and shall be wall mounted type. This panel shall be installed on the wall in the control room.

(8) Data transmission

A wireless communication shall be applied for gathering and transporting of information from remote locations such as each well pumping station and reservoirs back to the central control. The central control house is at a distance of maximum three (3) kilometers from each well pumping station.

Proposed communication method is shown in Figure 4.4.3.

(9) Control House

The control house should be decided considering locations of next to chlorination house. Therefore, the location of control house should be near the existing gate. And location was determined through discussion with WSCK and BWSC (see Figure 4.4.4).

Original quarter for BWSC staff, BWSC office and the guard house were destroyed by the quake. Therefore, hackneyed prefabricated houses are used for meeting room and quarter. To improve this situation, not only control room but also staff room is added in room plan of the control house. The room plan of proposed control house is shown in Figure 4.4.5.

3) Planned Electric Facilities

In connection with the proposed remote control system, the following electrical equipment and materials are also necessary.

(1) Distribution Board for each well pumping station

The existing distribution boards for pump motors in the well pumping stations (No.4 to 16) should be replaced with new ones. And new distribution boards shall be provided for both well pumping station DP2 and DP5. It feeds electric power to a pump motor, motor-operated valves, flowmeter, pressure transmitter, level transmitters and local unit of the remote control system at each well pumping station. It shall be installed in the each well pumping station.

(2) Distribution Boards for others

New distribution boards shall be provided to divert electric power to the followings.

- New central control house internal and external including air conditions, lightings, and others.
- The central unit of remote control system. It shall be installed in control room in the control house.
- Three flowmeters for the existing reservoir No.1 (Two for the reservoir No.1-1 and 1-2 discharge pipe and one for the bypass pipe) and three level transmitters for the reservoir No.1 (1-1, 1-2 and 1-3) including a local remote control unit.
- The flowmeter and level transmitters including the local remote control unit for the existing reservoir No.2.

Proposed electrical distribution board is shown in Figure 4.4.6.

(3) Cables

Cables shall be provided for all required connection of electrical equipment, instruments, distribution boards and remote control units including control house internal and external.

(4) Grounding System

Grounding system shall be provided for all electrical equipment including the remote control system and distribution boards.

(5) Lightning Protection

Lightning protection shall be provided to protect electrical equipment and antenna. Lightning arrester is needed to protect each communication system.

4) Cost Estimation for the Remote Control System

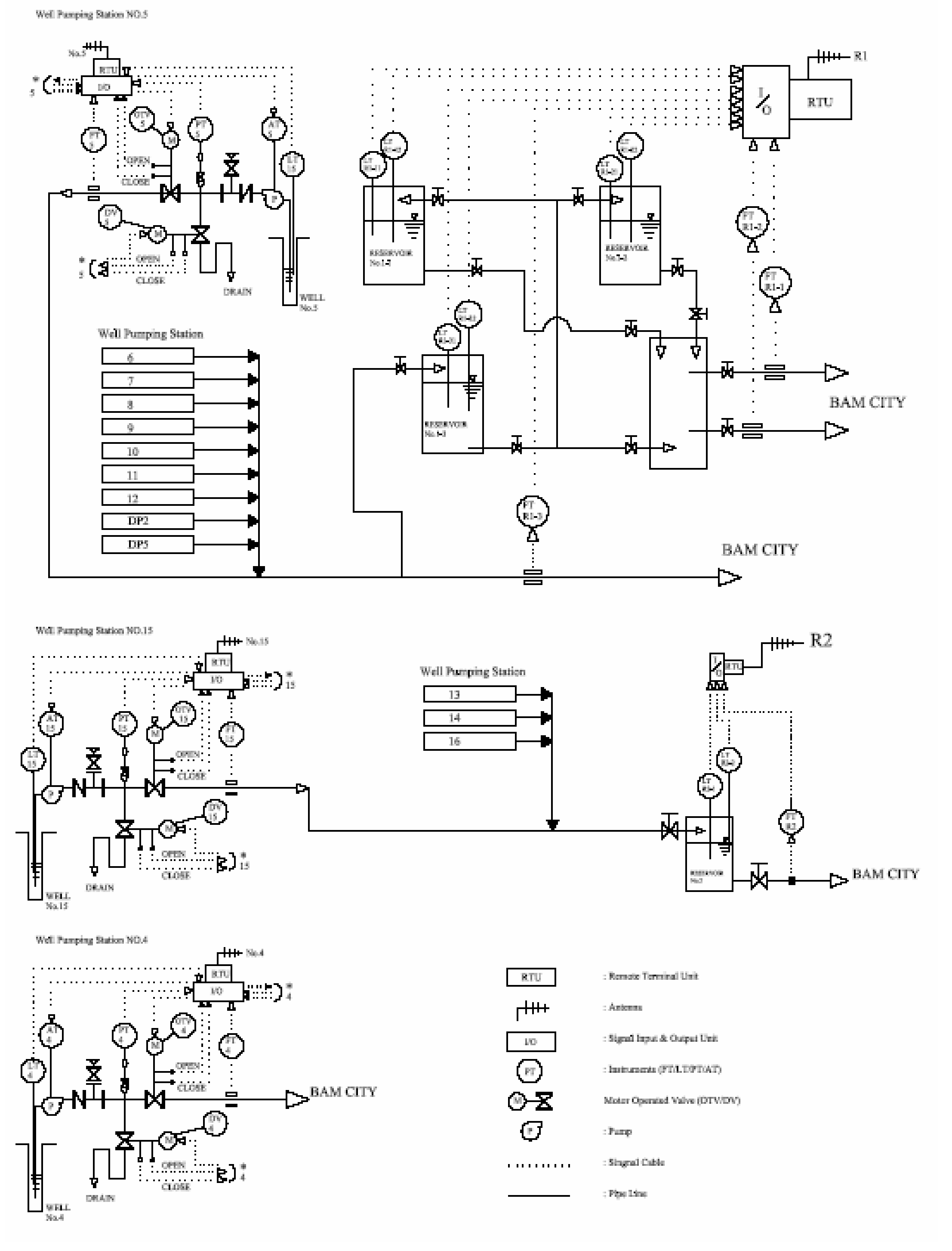
Introduction of proposed remote control system to 15 wells (No4~No.16, DP2 and DP5) is defined as phase1and future introduction targeting additional new 8 wells is defined as phase 2. Estimated construction cost by phase is shown below in 2004 price.

Table 4.4.1 Estimated Construction Cost by Phase

Unit: Euro (US$)

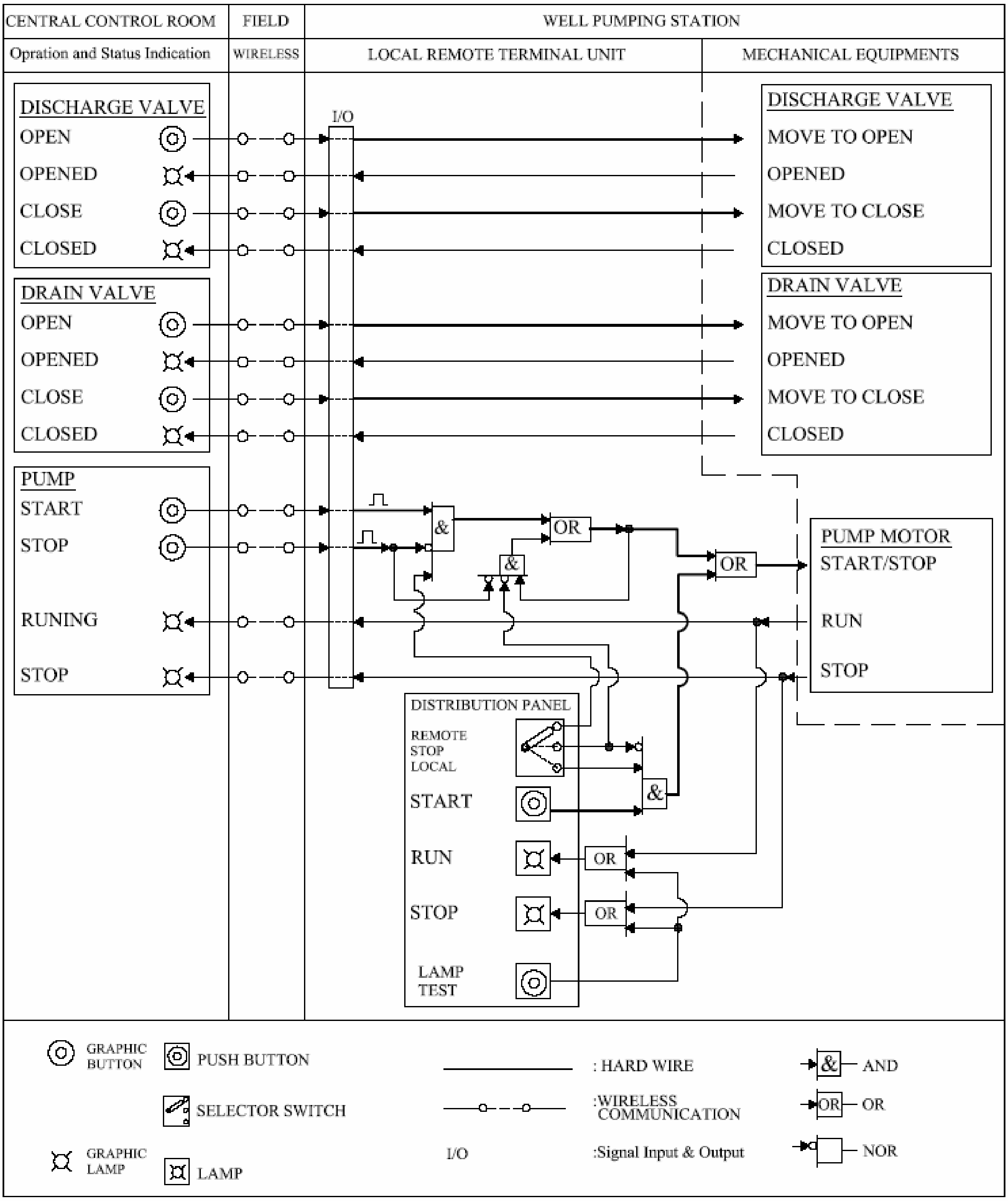
Item	Phase 1	Phase 2	Total
Remote Control System	160,000	100,000	260,000
Distribution Board	30,000	12,000	42,000
Cable	19,300	8,000	27,300
Construction materials	50,000	10,000	60,000
Motor operated valves	63,300	24,000	87,300
Instruments	182,400	80,000	262,400
Construction/installation	55,000	10,000	65,000
Training	38,000	10,000	48,000
Supervisor	38,000	10,000	48,000
Start-up	45,000	20,000	65,000
Control House	74,000	-	74,000
Total	755,000 (863,000)	284,000 (324,500)	1,039000 (1,187.5)

Source: JICA Study Team



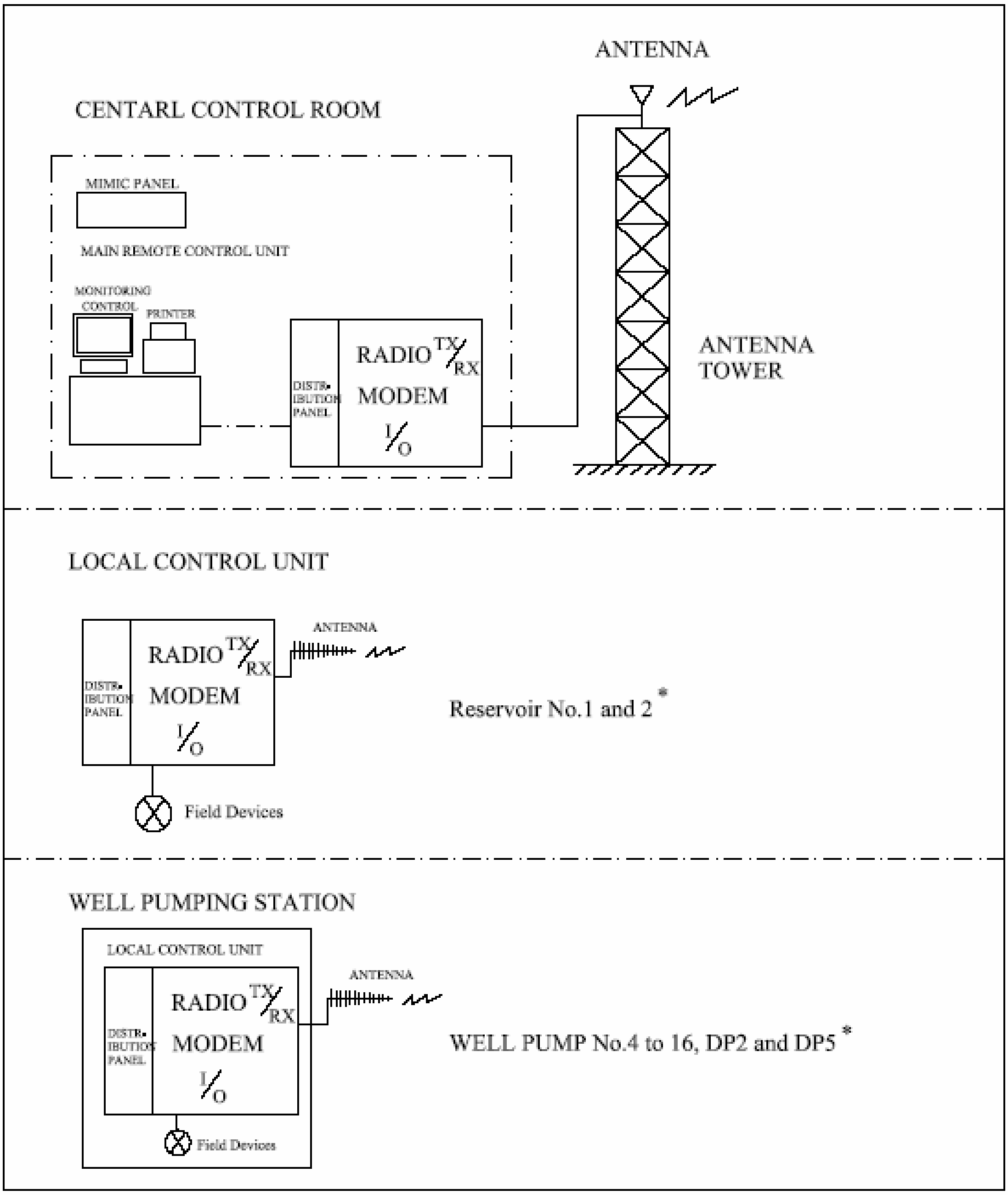
Source: JICA Study Team

Figure 4.4.1 Instrument Design



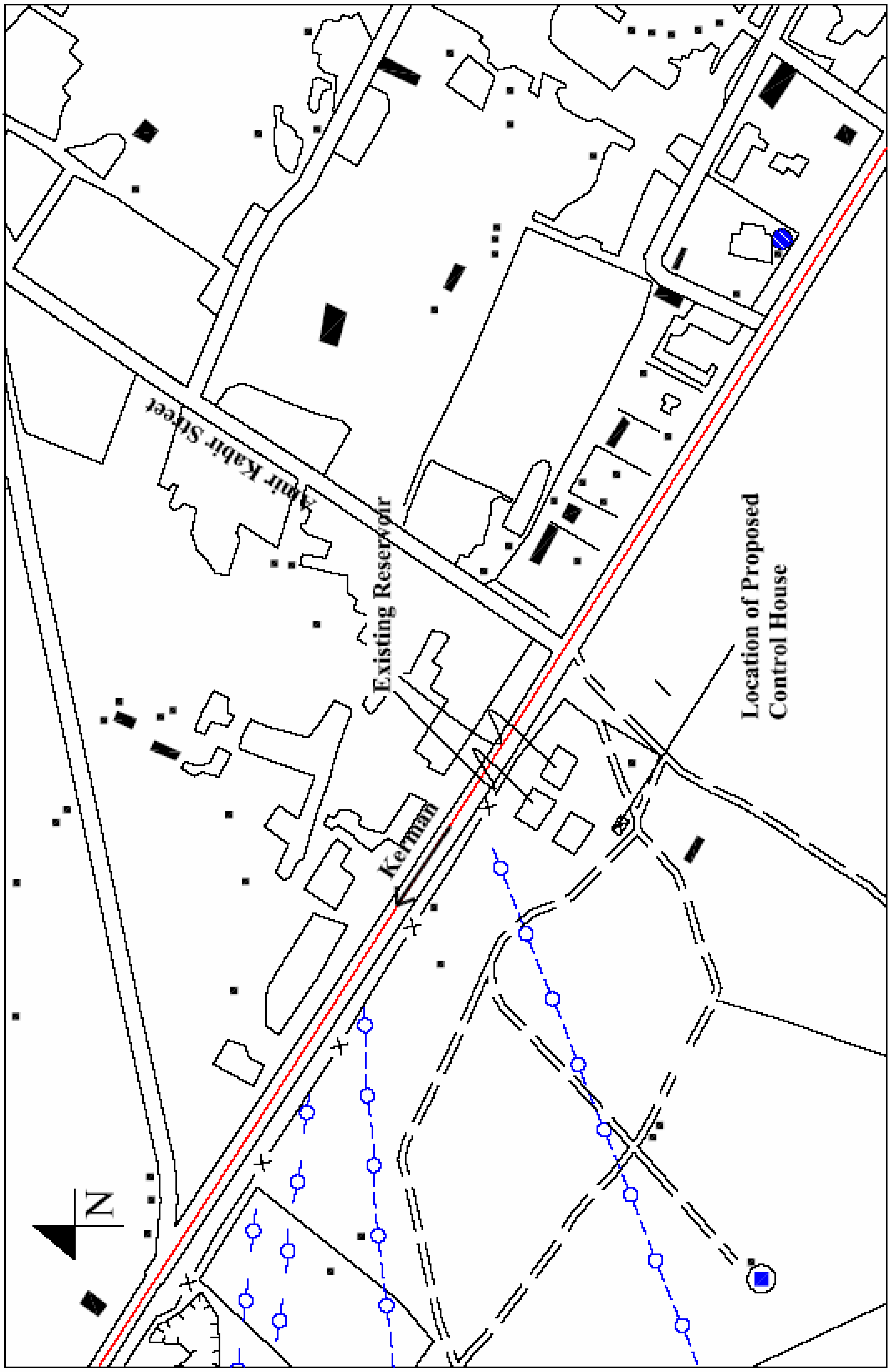
Source: JICA Study Team

Figure 4.4.2 Typical Control Flow Diagram



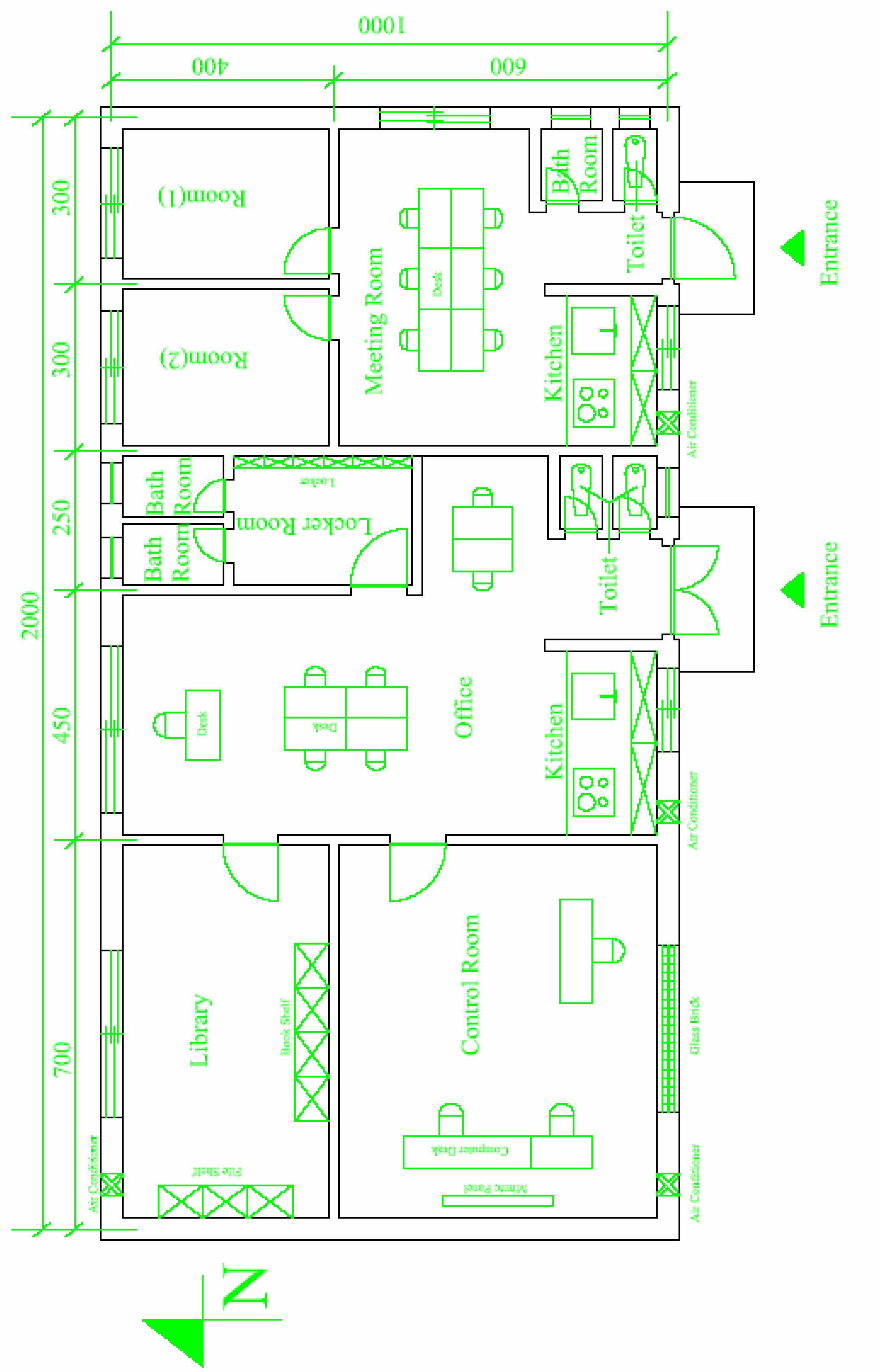
Note: Please refer Figure 4.4.1 Instrument Diagram for the details
Source: JICA Study Team

Figure 4.4.3 Communication Method for the Remote Control System



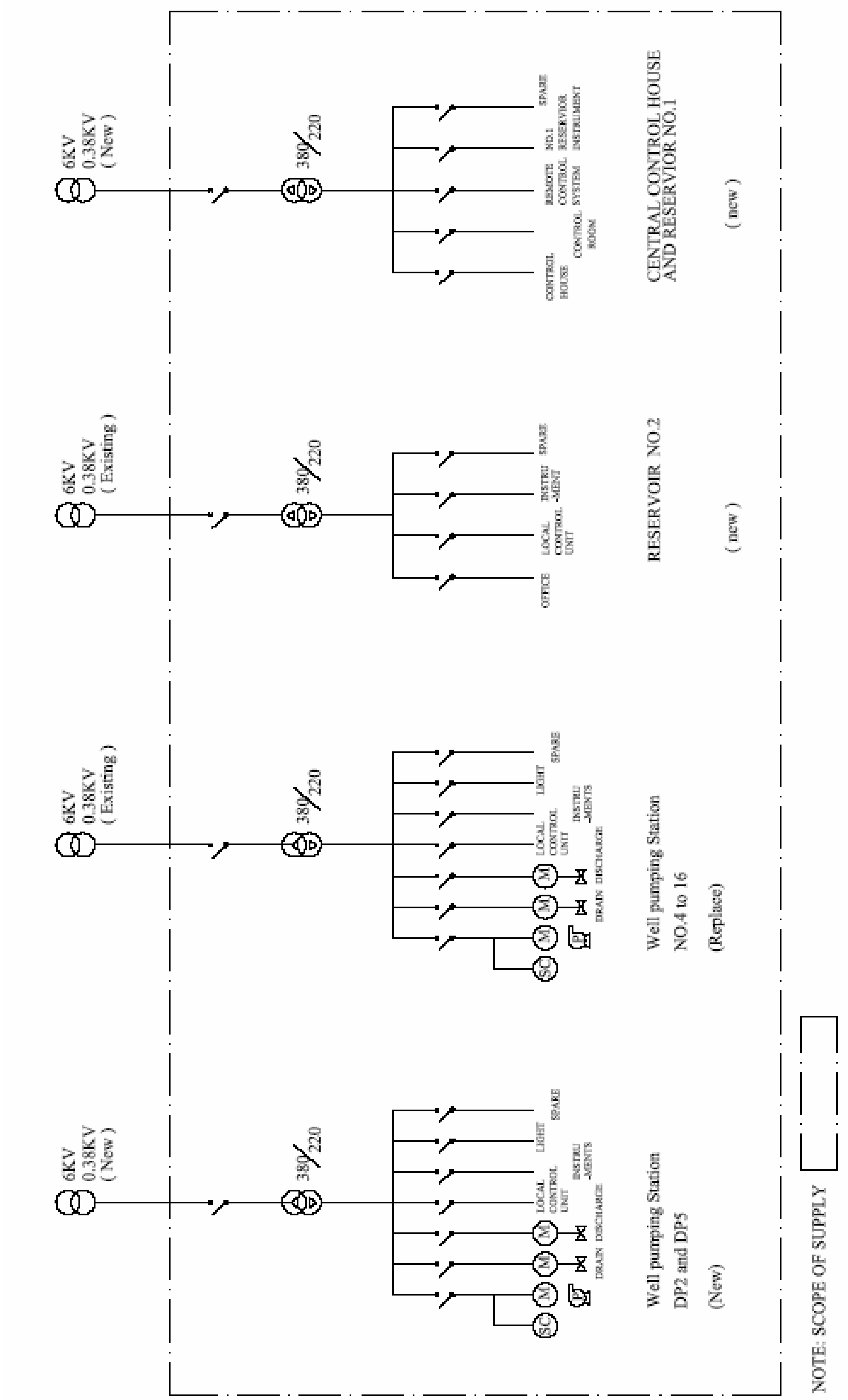
Source: JICA Study Team

Figure 4.4.4 Location of Proposed Control House



Source: JICA Study Team

Figure 4.4.5 Control House Plan



Source: JICA Study Team

Figure 4.4.6 Electrical Distribution Board

4.5 Proposed Conveyance Pipe

1) Evaluation of Existing Conveyance System for No. 1 Reservoir

There are 17 working wells in Bam and Baravat for the water supply system as of March 2004. The features of these wells were shown in Table 2.1.2. Among 17 wells, the eight wells, No. 5 to No. 12, transmit water to R1 reservoir as shown in Figure 4.5.1. A hydraulic calculation was conducted in order to examine whether the existing conveyance system is appropriately designed.

(1) Conditions for Calculation

The conditions for hydraulic calculation are as follows:

- Pipe length and diameter: as shown in Figure 2.1.1
- Roughness coefficient: 100
- Head loss formula: Hazen-Williams
- Parameters for pump: rated capacity from pump spec sheets

(2) Calculation Results

The result is illustrated in Figure 4.5.1.

- Total flow of water to the reservoir is 341 l/s
- Pressure is nearly zero at the top of Well No.12.

(3) Further Examination

According to the flow data actually measured at the wells, the total amount of flow from the eight wells, No.5 to No.12, is 273 l/s, about 80% of the calculated value. This difference is possibly caused by the following conditions:

- The actual head loss is larger than that of calculation because of rust and scales inside the pipes.
- The pumps have deteriorated and lost their original capacities due to long time use.
- Sand and clay particles have accumulated in the well bottom and clogged the screen pipes of the wells.

(4) Suggestions

The following measures may improve the situation:

- Replace all the conveyance pipes.

- Inspect the inside of wells and if necessary remove the sediment and rehabilitate the wells.
- Replace the pumps that have deteriorated. No. 8 well has greatly lost its original capacity.
- Redesign the conveyance system with more specific attention to pipe routes and diameters.

2) Evaluation of Existing Conveyance System for R2

Water from four wells (No.13 to No.16) is conveyed to R2 as shown in Figure 2.1.1. A hydraulic examination was conducted to evaluate whether the existing system is appropriately designed.

(1) Conditions for hydraulic calculation

- Pipe length and diameter: as shown in Figure 2.1.1
- Roughness coefficient: 110
- Head loss formula: Hazen-Williams
- Parameters for pump: rated capacity from pump spec sheets
- Maximum water level for R1 reservoir: 1,163.5 m

(2) Calculation Results

The calculated flows from each pump are compared to those of actual measurement in the following table.

Table 4.5.1 Comparison of Calculated and Measured Flows

Well	Calculated (l/s)	Measured (l/s)	
		After earthquake	Before earthquake
No. 13	25	15	25
No. 14	30	18	30
No. 15	28	55	45
No. 16	29	20	22
Total	112	108	122

Source: WSCK

(3) Further Examination

- Although it is not clear why the flow of Well No. 16 largely increased, the total capacity of the four wells decreased after the earthquake.
- The calculated flow from the four wells is 112 l/s and the value is close to that of actual measurement.

- The total water demand of West Block for 2023 is 102 l/s. The existing four wells have sufficient capacity to meet this demand.

3) Proposed Conveyance Pipes

(1) Introduction

As mentioned in section 4.2.3, the water demand for Bam in 2023 is 53,140 m³/d. Of the 53,140 m³/d (=615 l/s), 83% is needed for east distribution block according to the calculation of Jooyab-nou Consulting Engineers. This water amount will be distributed from R1 (30,000 m³/d) to east distribution block. Required water of 11,556 m³/d (134 l/s) for Baravat service area will be distributed from R1 because existing wells in Baravat will be discarded. The required quantity of water is clarified below.

Table 4.5.2 Required Quantity of Water drawn

Area	R1 System	R2 System	Total
Bam	510	105	615 l/s (53,140 m³/d)
Baravat	134	-	134 l/s (11,556 m³/d)
Total	644	105	746 l/s (64,696 m³/d)

Source: JICA Study Team

According to WSCK's planning, some modifications on existing wells are to be made as follows:

- Water drawn from Well No.4 will be connected to R1
- Well No.1-No.3 within Bam city will be discarded
- Well No.1-No.2 in Baravat will be discarded

Total quantity of R2 conveyance system becomes 309 l/s as follows:

Well No.5~No.12: 273 l/s (see Table 2.1.2)

Well No.4: 36 l/s (see Table 2.1.2)

The R2 conveyance system is relatively new and its pipe diameters and pipe routes are appropriate for the most part. According to measured discharge flow of wells for R2 system, its total is 108 l/s (see Table 2.1.2). Hence, additional wells and modification of conveyance pipe for R2 system might not be necessary. On the other hand, the conveyance pipe for R1 system should be expanded because additional wells are absolutely necessary to meet future demand of 644 l/s.

(2) Additional wells

The shortage amount of water drawn for R1 conveyance system is estimated at 335 l/s (=644 - 309). Assuming that 19 wells including additional 10 new wells for R1 conveyance system are required, the conveyance system is studied in this long term plan.

As of October 2004, out of 10 new wells the locations of three new wells are already determined. Further study on water sources is needed to determine suitable locations of the remaining seven wells. Supposing that these locations are near the Adori river, R1 conveyance system is planned in this long term plan (see Figure 4.5.2).

(3) Alignment of Proposed Conveyance Pipe

The existing conveyance pipes connect eight wells and R1 reservoir as shown in Figure 4.5.1. The water drawn from the eight wells are transmitted by pressure flow. On/off of each pump could exert negative effect to the other pumps in this system. Gravity flow is recommended in main conveyance pipes. The water from Well No. 4, No. 5, No. 6 and No. 10 is conveyed to the main conveyance pipe with pressure flow because ground elevations of these wells are lower than the main conveyance. The discharge pipe from well No.9 is connected to the main conveyance pipe with pressure flow because ground elevation difference between No.9 and the nearest point of the main conveyance is too small to use gravity flow. Length by diameter of conveyance pipe is shown in Table 4.5.3 and pipe route, length and diameter are shown in Figure 4.5.3.

Table 4.5.3 Total Length by Diameter

Diameter	Length (m)	Remarks
200 mm	1,230	pressure
200 mm	520	gravity
250 mm	5,740	gravity
300 mm	540	gravity
400 mm	440	gravity
500 mm	750	gravity
600 mm	890	gravity
700 mm	450	gravity
Total	11,380	

Source: JICA Study Team

The diameter of gravity pipes is calculated, assuming that:

- Water drawn quantity of each well is 35 l/s for convenience
- Manning’s formula as hydraulic calculation is adopted
- Roughness coefficient of 0.013 is adopted
- Pipe is laid as same as slope of ground surface.

Hydraulic calculation for R1 conveyance pipes is shown in Table 4.5.4.

(4) Pipe materials and Ventilation Pipe

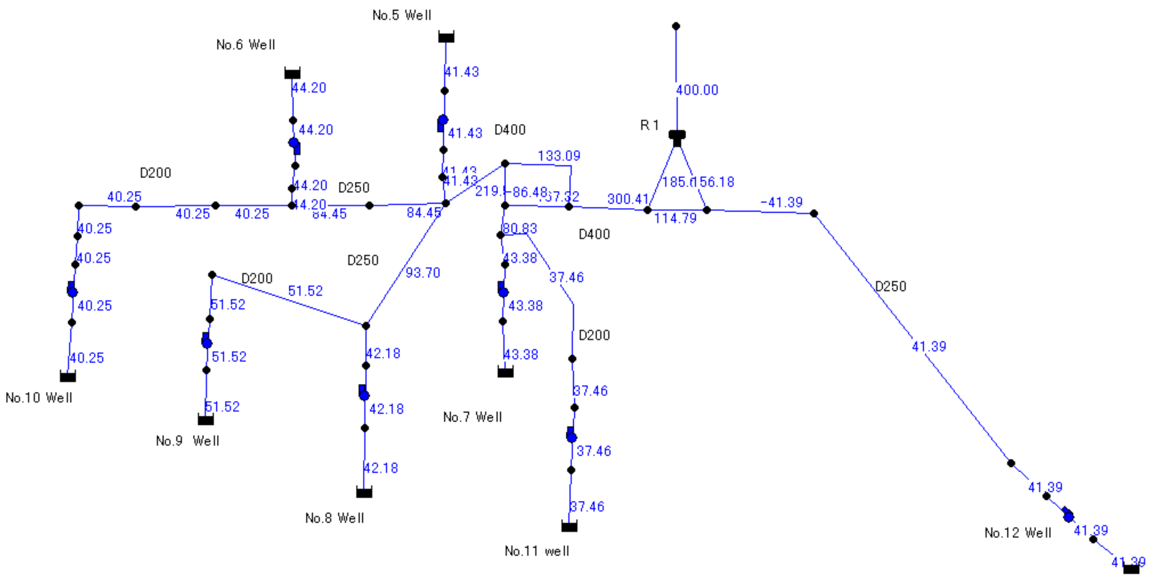
Ductile iron is recommended as pipe material for conveyance pipe except connections of discharge pipe from well and ventilation pipe.

Ventilation pipe is necessary in the discharging point to keep gravity flow. The ventilation pipe should be installed near pump house and fenced around to avoid accidents. This concept is illustrated in Figure 4.5.4.

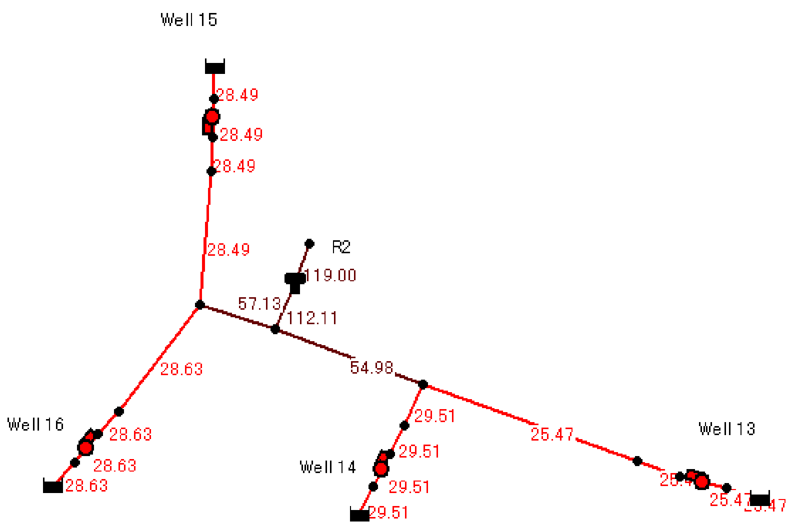
Table 4.5.4 Hydraulic Calculation of R1 Conveyance

Line Number	L (m)	Δh (m)	Slope I (1/1000)	Q l/s	diameter (mm)	Qfull l/s	Remarks
1	560	12	21	35	250	87	gravity
2	480	4	8	70	250	98	gravity
3	730	14	19	35	250	82	gravity
4-1	150	1	7	140	400	170	gravity
4-2	520	5	10	140	400	204	gravity
5	520	13	25	35	200	52	gravity
6	540	11	20	70	250	94	gravity
7	250	4	16	105	300	122	gravity
8	750	5	6	245	500	292	gravity
No.10 well	190	-	-	35	200		pressure
9	80	1	6	280	600	487	gravity
10	580	9	15	35	250	72	gravity
11	80	1	13	315	600	686	gravity
12	150	-	-	35	250	49	pressure
13	70	1	7	350	600	517	gravity
No.4 well	660	-	-	35	200		pressure
14	210	2	7	385	600	517	gravity
15	420	8	18	35	250	80	gravity
16	440	2	5	70	350	101	gravity
No.6 well	210	-	-	35	200		pressure
17	450	8	18	490	600	819	gravity
No.5 well	170	-	-	35	200		
18	150	1	7	525	700	758	gravity
19	420	9	20	35	250	85	gravity
20	290	3	11	70	300	101	gravity
21	260	3	13	595	700	1,060	gravity
22	2,010	12	6	35	250	47	gravity
23	40	1	13	665	700	1,036	gravity

Note: 1) △h: Difference of ground elevation
2) Qfull: Flow rate with full water depth
Source: JICA Study Team



Conveyance System for R1

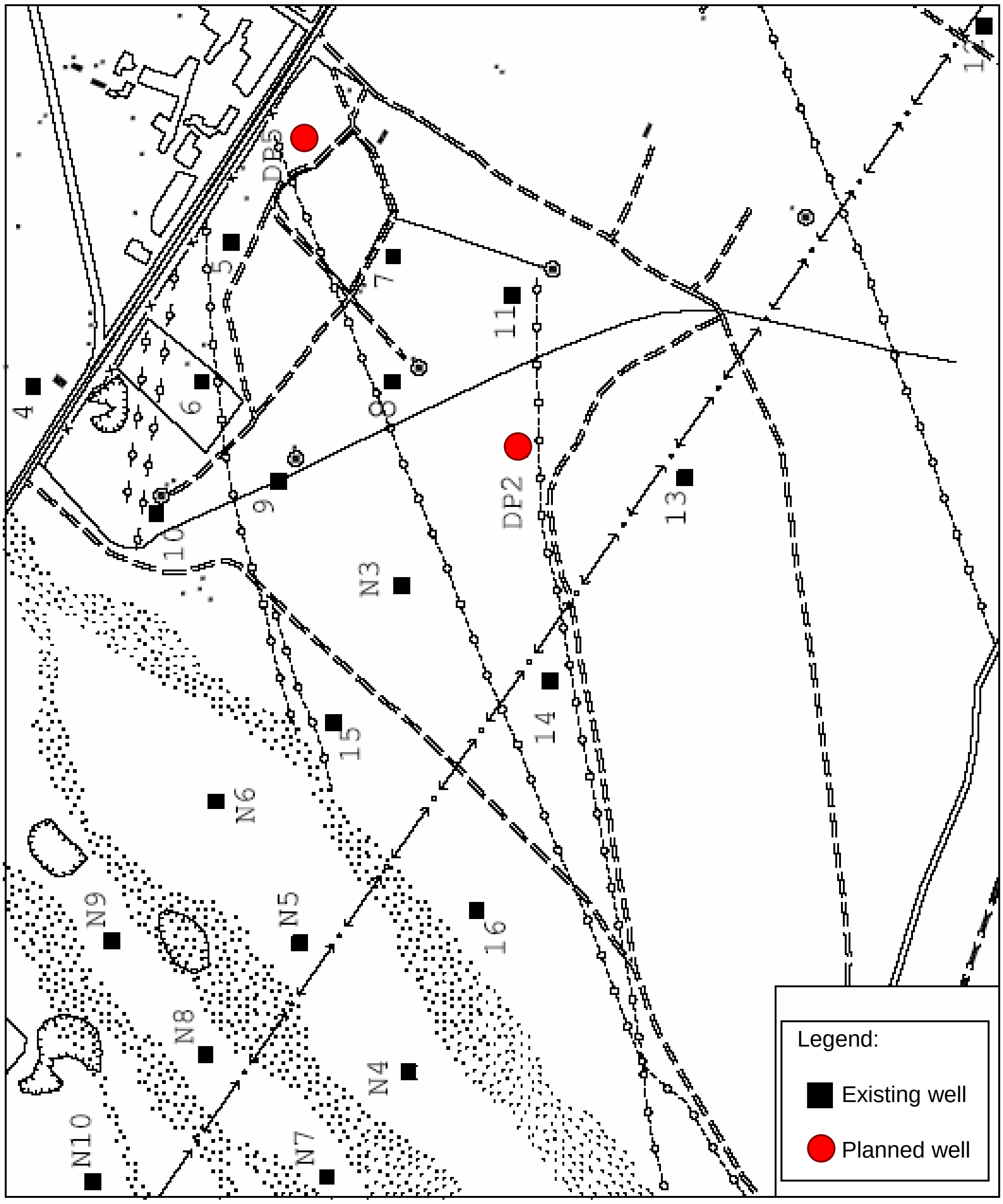


Conveyance System for R2

Note: Numbers on the pipes show simulated flow rate (l/s) at 15 hours
D300: Diameter of major pipes (mm)
Source: JICA Study Team

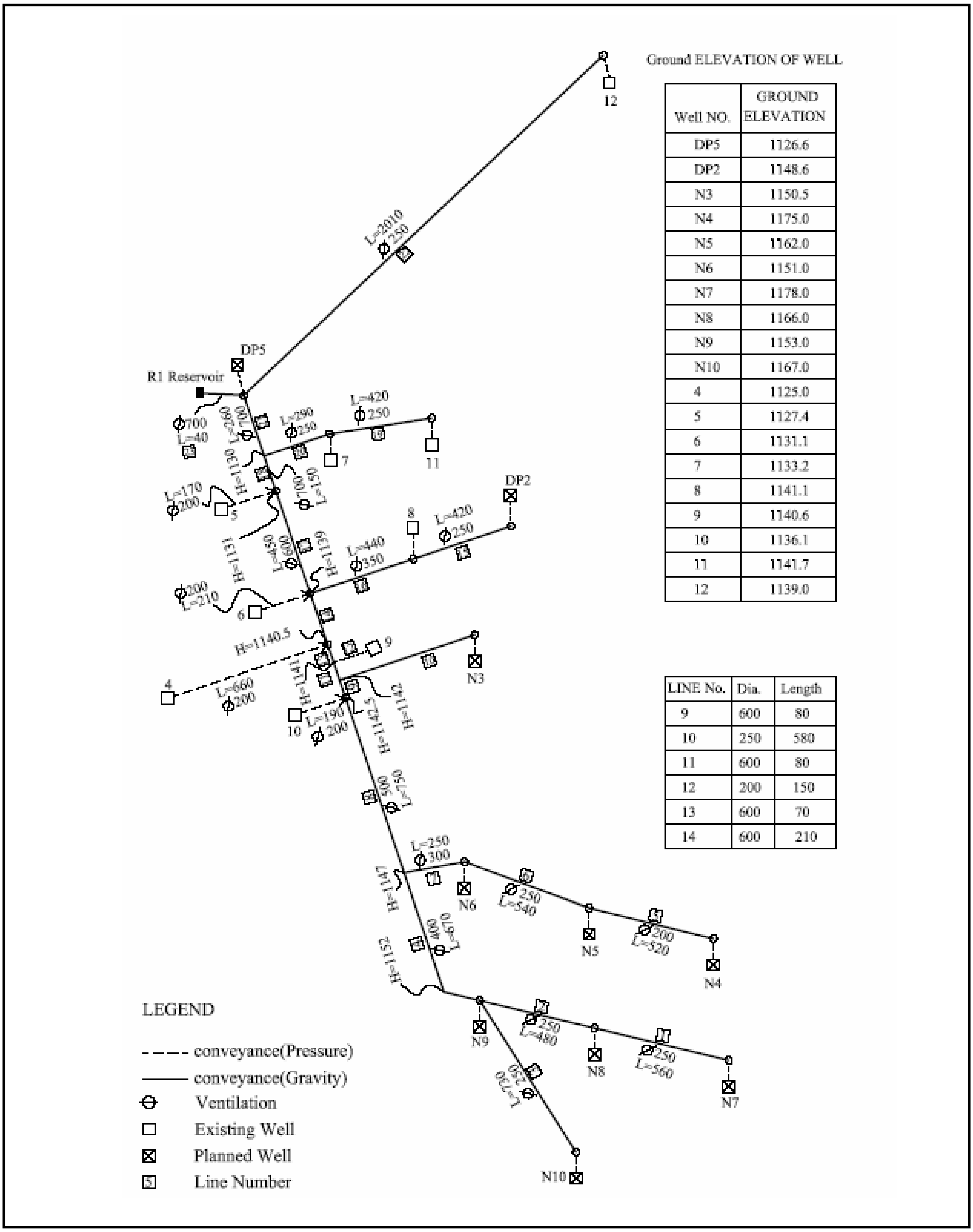
Figure 4.5.1 Hydraulic Models of Existing Conveyance System

C



Source: JICA Study Team

Figure 4.5.2 Location of Existing and Tentative Planned Wells

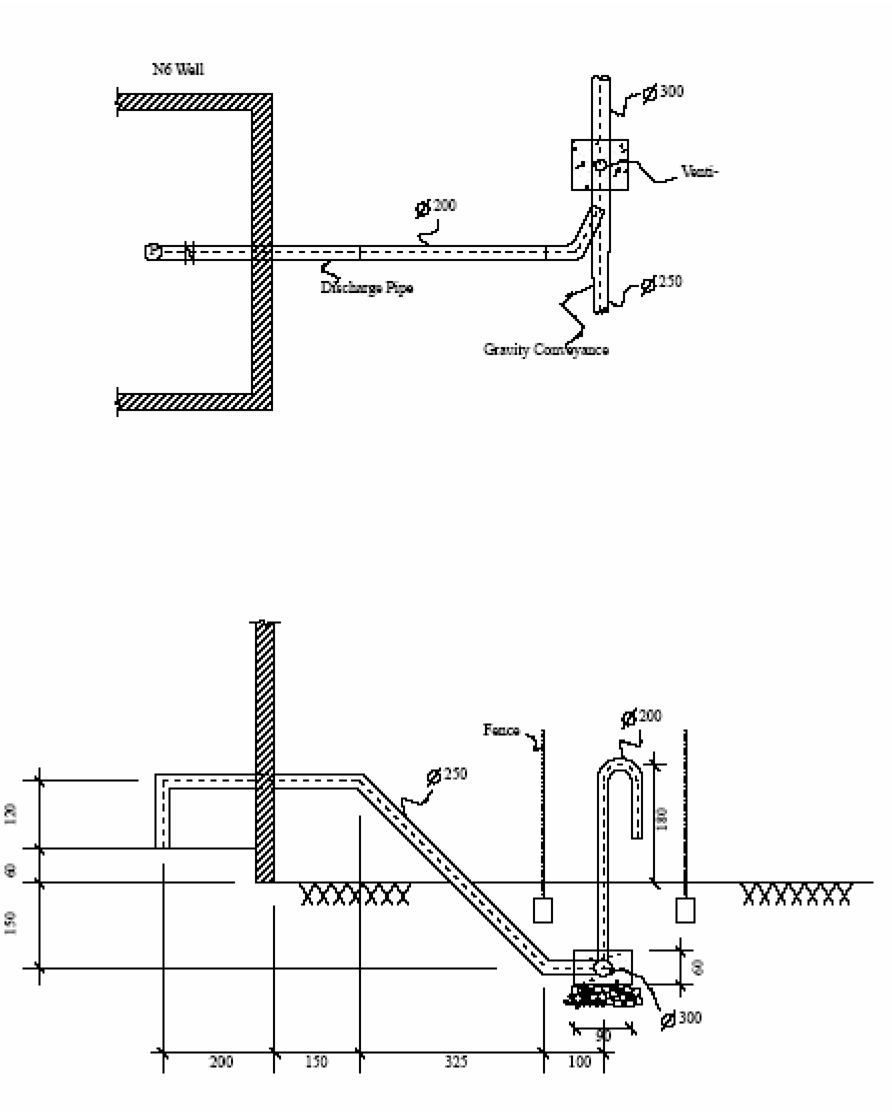


Well NO.	GROUND ELEVATION
DP5	1126.6
DP2	1148.6
N3	1150.5
N4	1175.0
N5	1162.0
N6	1151.0
N7	1178.0
N8	1166.0
N9	1153.0
N10	1167.0
4	1125.0
5	1127.4
6	1131.1
7	1133.2
8	1141.1
9	1140.6
10	1136.1
11	1141.7
12	1139.0

LINE No.	Dia.	Length
9	600	80
10	250	580
11	600	80
12	200	150
13	600	70
14	600	210

Source: JICA Study Team

Figure 4.5.3 Plan of R1 Conveyance System



Source: JICA Study Team

Figure 4.5.4 Gravity Conveyance and Ventilation

4.6 Implementation Schedule

The proposed water supply system is illustrated in Figure 4.6.1.

The reconstruction work of distribution system in Bam and Baravat started in August 2004. This work is divided into two packages:

The scope of work of first package consists of distribution network of West Block in Bam and Baravat and a distribution reservoir with a capacity of 3,000 m^3. The scope of work of the other package consists of distribution network of East Block in Bam and miscellaneous work in surrounding area of R1 reservoir. These works are expected to be completed within two years.

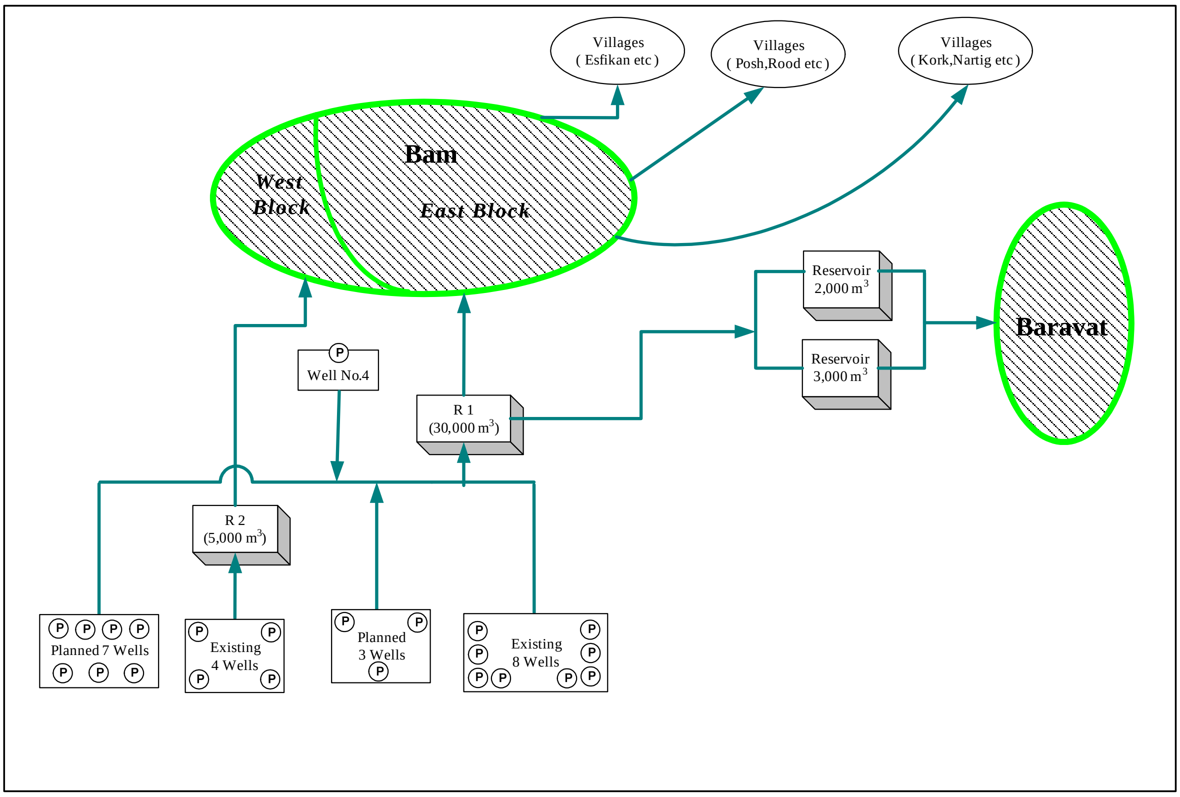
Moreover, construction project of Baravat reservoir (V=2,000 m^3) and distribution pipe (L=30 km) is proceeding under JICA fund. It would finish by the end of February 2005.

However, the schedule of construction of remote control system, new conveyance pipes, additional wells and secondary distribution pipe network has not been fixed yet. The JICA study team proposed the implementation schedule for reference as shown in Table 4.6.1.

Table 4.6.1 Implementation Schedule of Long-term Reconstruction Plan

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Distribution Pipe Network (West Bam)	—	—	—																	
Distribution Pipe Network (East Bam)	—	—	—																	
Distribution Pipe Network (Baravat)		—	—																	
Baravat reservoir (3,000m3)	—	—																		
Baravat Reservoir (2,000m3)	—																			
Well	2 —	2 —					2 —					2 —				2 —				
R1 Conveyance System		—	—				—					—				—				
Remote Control			—	—			—					—				—				
Secondary/tertiary Distribution pipe			—	—	—								—	—						

Source: JICA Study Team



Source: JICA Study Team

Figure 4.6.1 Proposed Water Supply System for Bam and Baravat

4.7 Cost Estimate

1) Basis of Cost Estimates

The project costs are estimated under the following conditions:

- All the costs are estimated under the economic conditions prevailing in October 2004.
- Exchange rate of currency is:

  USD 1.00= Rial 8,750,
  EURO 1.00= Rial 10,000
  Yen 1.00= Rial 78

- Engineering service cost, physical contingency and administration cost are assumed to be 8%, 10% and 2% of the total construction cost, respectively.
- Price inflation is not taken into account
- The project cost includes contributed portion by UNICEF, JICA and so on.

2) Basic Unit Cost

Table 4.7.1 Unit Cost of Labors

Item	Unit Cost (Rials)	Remarks
Unskilled Labor	400,000/month	market
Skilled Labor	900,000/month	market
Operator for excavator	600,000/month	market

Source: JICA Study Team

Table 4.7.2 Unit Cost of Materials

Item	Unit Cost (Rials)	Remarks
Gasoline	800/liter	market
Diesel Oil	165/liter	market
Cement	315,000/ton	market ,w/o carrying
Cement	395,000/ton	market with carrying
Reinforcing bar	7,500/kg	market, with carrying
Sand	35,000/ton	market
Ready mixed concrete	39,500/m^3	market, w/o pump
Ready mixed concrete	45,000/m^3	market, with pump

Source: JICA Study Team

Table 4.7.3 Unit Cost of Pipes

Pipe Cost	Unit	Unit: Rials
Description		Unit Cost
ASBESTOS PIPES (Procurement only)		
Asbestos -cement pipes 80 mm	m	24,589
Asbestos -cement pipes 100 mm	m	32,154
Asbestos -cement pipes 150 mm	m	52,619
Asbestos -cement pipes 200 mm	m	66,083
SDR POLYETHYLENE PIPES (Procurement only)		
SDR9 polyethylene pipes 40 mm	m	5,090
SDR9 polyethylene pipes 50 mm	m	7,880
SDR9 polyethylene pipes 60 mm	m	12,600
SDR9 polyethylene pipes 75 mm	m	17,600
SDR9 polyethylene pipes 90 mm	m	25,400
SDR9 polyethylene pipes 110 mm	m	37,800

Source: MPO

Table 4.7.4 Unit Cost of Machinery Earthworks

Machinery Earthworks Description	Unit	Unit: Rials
		Unit Cost
Removing slime with machines and carrying sand to a distance of 20 m from the site	m^3	4,900
Excavation in soft lands with machines and carrying sand to a distance of 20 m from the site	m^3	775
Excavation in hard lands with machines and carrying sand to a distance of 20 m from the site	m^3	1,640
Excavation in rocky lands with machines and carrying sand to a distance of 20 m from the site	m^3	7,720
Excavation in rocky lands, which need explosives, with machines and carrying sand to a distance of 20 m from the site	m^3	12,400
Digging canals with machines in soft lands up to 2 m deep and putting the sand just behind the canal	m^3	2,290
Digging canals with machines in hard lands up to 2 m deep and putting the sand just behind the canal	m^3	3,580
Digging canals with machines in slimy lands up to 2 m deep and carrying the sand to 20 m away	m^3	6,870

Source: MPO

3) Project Cost

The project is composed of construction of:

- Main and secondary/tertiary distribution pipe in Bam and Baravat,
- Two distribution reservoirs (capacity of 3,000 m³ and 2,000 m³) in Baravat,
- Ten well pumping stations in well field in Bam,
- Conveyance pipes connecting 19 wells including 10 new wells and R1, and
- Remote control system for wells including control house in Bam.

Summary of project cost is shown in Table 4.7.5 and breakdown of construction cost is shown in Table 4.7.6

Table 4.7.5 Summary of Project Cost

Unit: '000 US$

A.	Construction Cost		**22,137**
	1) Main distribution pipe	13,232	
	2) Secondary/tertiary distribution pipe	4,461	
	3) Baravat distribution reservoirs	1,150	
	4) New 10 wells	1,200	
	5) New conveyance	906	
	6) Remote control system	1,188	
B.	Indirect Cost		**4,477**
	1) Physical contingency (10% of A)	2,214	
	2) Land acquisition	50	
	3) Engineering service (8% of A)	1,771	
	4) Administration costs (2% of A)	442	
C.	Project Cost (A+B)		**26,614**

Table 4.7.6 Construction Cost (1/3)

1. Main Distribution							
Dia.(mm)	Bam East	Bam West	North Baravat	West Baravat	Total	unit cost ($/m)	Construction Cost ($)
110	64,950	43,220	20,140	30,420	158,730	33.8	5,365,074
150	35,490	7,430	8,810	15,310	67,040	47.0	3,150,880
200	23,660	2,330	1,250	8,660	35,900	63.6	2,283,240
250	4,840	2,210	360	2570	9,980	72.8	726,544
300	3,150	1,560		840	5,550	80.0	444,000
350		3,320		-	3,320	91.1	302,452
400	8,670	-		160	8,830	102.7	906,841
500	390	-		-	390	136.7	53,313
sub-total	141,150	60,070	30,560	57,960	289,740		**13,232,344**

Source: JICA Study Team

Table 4.7.6 Construction Cost (2/3)

Item	Diameter (mm)	Length (m)	Unit Cost ($/m)	Construction Cost (US$)
2. Secondary/tertiary				
	63	70,000	20.7	1,449,000
	90	120,000	25.1	3,012,000
Sub-total		190,000		**4,461,000**
3. Conveyance				
	200	1,900	52.2	99,180
	250	5,740	61.4	352,436
	300	540	68.6	37,044
	350	440	79.7	35,068
	400	670	91.3	61,171
	500	750	125.3	93,975
	600	890	158.6	141,154
	700	450	191.9	86,355
Sub-total		11,380		**906,383**

Source: JICA Study Team

Table 4.7.6 Construction Cost (3/3)

	Quantity	Unit Cost	Construction Cost (US$)	Remarks
4. Reservoirs				
2000m³			500,000	
3000m³			650,000	
Sub-total			**1,150,000**	
5. Wells	10	120,000	**1,200,000**	Unit cost is based on assumption
6. Remote Control			**1,187,500**	cf. Table 4.4.1
Grand total			**22,137,227**	

Source: JICA Study Team

4.8 Operation and Maintenance Plan

1) Institutional Development of BWSC

As a basis human needs, safe and sustainable drinking water supply forms a sound basis for prosperous community health; in particular, safe water supply becomes a crucial commodity for people affected by natural disaster, like a major earthquake in Bam and its surrounding areas. Utmost benefits can be only achieved when the water supply and sanitation facilities operate continuously and to full capacity in conformity with acceptable standards of quantity and quality, even during and after unexpected incident, i.e. natural disaster, social chaos and so on.

Effective and sustainable upheld quality of daily and periodic operation and maintenance, as well as sufficient preparation for such incidents could lessen adverse impacts and provide prompt recovery of water supply to the affected people. Carefully designed daily and periodic operation and maintenance tasks, which should be carried out in proper manner following evidently written manuals and instructions, will ensure providing safe and uninterrupted water supply and will extend the life-long of machinery and facility used.

However, there are many causes that hamper suitable practice of operation and maintenance tasks. Shortsightedness, i.e. lack of long-term maintenance plan supported with sound ground financial investment and trained staff, and inadequate financial resources combine to make the funding and standards of operation and maintenance a low priority. Lack of effective management and consistent functional command line, in addition, are a factor to be a negative influence on operation and maintenance on water supply services. It is particularly evident when a water service company does not have clearly defined goals for operation and maintenance; long-term planning and short-term program.

Therefore, it is crucial for such company to set 1) operational and management tools for programming, performance evaluation and control of activities, 2) information control to formulate operation and maintenance plans and to identify training needs, 3) more thorough consideration on operation and maintenance requirements at the stage of project planning, design and construction, and 4) effective preventive maintenance procedures to minimize breakdown, and prolong the operational life of the service.

(1) Operational and Management Tools

Operational and management tools consist of resources and activities necessary for formulating short to mid term plans of water supply system in terms of capital investment, structural strategic plan and periodical evaluations of such short-mid term plans with tangible and objective indicators.

Regarding to the operation and maintenance tools, long-term goals should be determined followed by objectives, inputs, outputs and indicators to measures those outputs and objectives for periodical evaluations and adjustment to meet the objectives. For instance, a performance evaluation can be a decrease in the number of interruptions of water supply or a decrease in leakage of water, and then activities of those can be set accordingly. If a lack of proper skills or personnel is found during the course of activities, the finding will be incorporated into short-mid term plan to either empower skills of staff or recruiting additional staff. In case additional staffing cannot even solve the problems, new technology or equipment shall be introduced based on the institution's strategic capital investment plan.

Therefore, it is significant to set tangible indicators to evaluate and pre-conditions, operational and management tools to carry out the activities carefully in advance to make decision effectively and practically.

(2) Information Control

Information control consists of basic manual, collection of information, database system, inventory of equipment, layout drawings, construction plan and map showing locations of other underground utilities, and dissemination of the information among BWSC. The information shall be easily searched, browsed and possessed in any forms.

BWSC shall define the instruments it needs for management as well as the corresponding information needs. The inputs supplied by different levels of the company will be the basis for the company's operation, administration and decision-making.

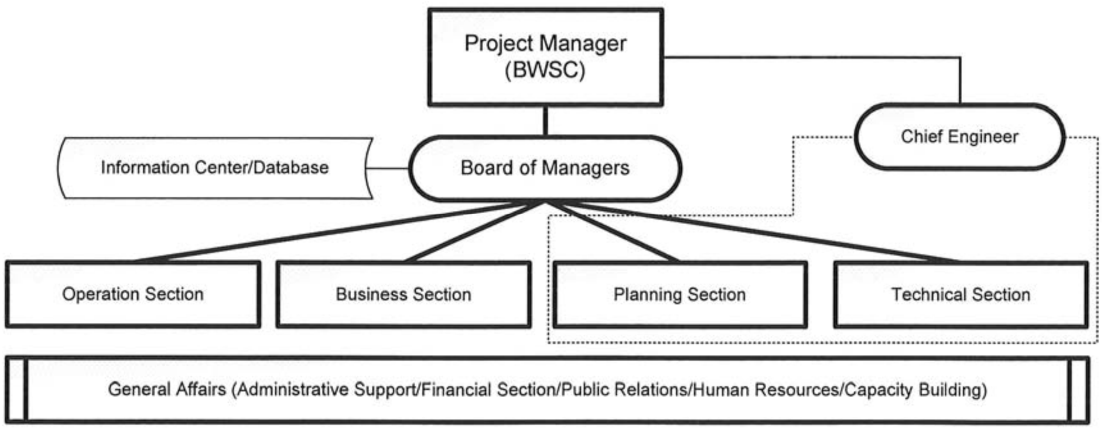
(3) Redefining Organizational Structure of BWSC

Likewise other relatively small-scale water supply operators, BWSC runs its operation with limited number of personnel, especially after the disaster of the earthquake, as explained in chapter 1. It is not necessary to immediately increase the number of personnel, as illustrated; yet, BWSC will need to redefine and restructure gradually to meet the estimated number of service water users in year 2023, as well as the company needs to uphold its high-quality of services and efficiency to the users in the service areas.

As it was pointed out in chapter 1, the project manager is involved in all decisions concerning technical matters and operations of the company, so, a board of managers is suggested to be established under the project manager. The board of managers shall be assisted by a secretariat office and an information center/database center shall be established under the board of managers to provide necessary and up-to-dated information about finance, management, operation and maintenance and even technical matters.

It should be also pointed out that current organizational structure is somehow a combination of functional structure and the structure based on facilities, i.e. there are functional sections of financial affairs, network operation and installation and technical services, and facility based structure of laboratory, warehouse and branch offices. The structure of company, therefore, should be redefine based on its planning function, business function, operational function and technical function. General affairs, such as administration, procurement, public relations, financial affairs and human resources are related to all functions and sections, so those functions shall be considered as a ground function of the institution.

The functional structure shall be divided into four divisions, and duty and responsibility of respective division shall be defined tangibly but not to be segregated as a vertical administrative system.



Source: JICA Study Team

Figure 4.8.1 Proposed Organizational Structure for BWSC

The function and primary duties of each section are described as followings;

A. Planning Section

Planning section is primary in charge for physical expansion and institutional development of BWSC, i.e. designing and planning water supply distribution system in the Bam areas and formulating short, mid and long term plans. It conducts study about water demand in future and proposes physical infrastructure plan, distribution pipe network and capital investment. The section will be under direct supervision of a chief engineer, who serves as a technical advisor to the project manager and oversee all planning, designing and technical matters at the company.

Planning section also oversees an institutional planning and programs to operate the company more efficient and effectively. The section scrutinizes the feasibility of company's goals, programs from the management information reported to the board of management, and controls their implementation. The company shall carry out the activities based on the different spans of plan and programs through its action plans for physical infrastructure planning, business and financial planning, institutional structure planning and capacity building.

The section also has tasks to design and supervise the construction of capital infrastructure as well as set standards of machinery and equipment procured for the company.

B. Technical Section

Current organizational structure shows all technical services are under the section chief of technical services with only two assistants. The section is even separated from laboratory section, operation and installation section and accident management sub-section, where almost all technicians belong.

The suggested organizational structure shows that a technical section shall be under direct supervision of a chief engineer and consists of all sub-sections related to technical matters, except operational tasks. Although the chief engineer does also oversee the operation section, it is suggested that the chief engineer and technical section shall be fairly separated from the operation section, in order to provide objective and independent opinion and advice to the operation section for its implementation of water supply facilities. Thus, it is suggested that the chief engineer and technical section will serve as a technical consulting section to other sub-sections to provide sound judgment on all technical matters in the company.

The technical section shall also have a laboratory sub-section, accident management sub-section, facility and equipment sub-section and a part of administration which has an investigator for water-meter under its section. The section shall compile all mechanical faults, accidents and technical shortage and report to the chief engineer, and also to the planning section as inputs to incorporate the difficulties and issues into forthcoming annual and mid-term planning.

C. Operation Section

Operation section is responsible for daily operation of water distribution to the service area. This section is the principal player of operation and maintenance for overall equipment, facility and infrastructure of BWSC.

Daily and periodic operation and maintenance shall be conducted based on check-list, operational guideline and manual prepared by the planning section in corporation with the technical section. Water quality control is also the important task of this section. In order to secure the independence of water quality control, the water quality test shall be conducted by the laboratory belonging to the technical section and directly supervised by the chief engineer.

Daily and periodical maintenance shall be recorded accordingly to the guideline and manual, and reported to the chief engineer and the planning sections as inputs for future reference. Accident management is also the crucial task of the section. The section shall work closely with the business section, which consists of customer service sub-section, to manage and promptly handle any accident or interruption of water supply to the end users.

In case of a natural disaster, such as the earthquake in December 2003, this section shall be in the first place to investigate the damage of facility, equipment and distribution pipes; thus, it is also suggested that the section prepare a manual for emergency situation, in corporation with the planning section and drill the manual periodically.

D. Business Section

The business section is a strategic element for attaining the objectives of the company by meeting service water demands within regulatory requirements, i.e. water quality, tariff and responsibility as a public corporation in the service area. The section is also a tool for promotion and sale of services for recovering the cost of delivering those services to the users. Although BWSC does not bear any capital investment costs at present, it must take into consideration the depreciation of facility, equipment and the infrastructure they are going to built under WSCK's initiatives. This section is also the front to encounter the customers, i.e. end users of water supply facility, so it is significant to take considerable efforts to train the staff.

BWSC currently does not have a separated section for customer service, which is commonly regarded in the business world. The section is combined with revenue and water-meter reader sub-sections and its primary function is to read water-meter at each household and send an invoice every three months. As it is indicated in chapter 1, the company does not put much emphasis on the improvement of customer satisfaction, taking into account the shortage of personnel compared to the number of users in the service area.

Customer's service does not necessary mean it only deals with complaints from the users, but also the section can extend its function to disseminate the information of BWSC and to educate users about water conservations.

It will be also envisaged that the business section incorporate with other utility company, i.e. electricity and telephone, and even with municipality to share the basic information of users. "One-stop service" is now widely practiced at local government level in many countries. Instead of making a resident or user goes around several companies and governmental offices to register himself, one-stop kiosk at local government office, in most cases, deals with all registration, change and even payment. As for private corporations, like a contractor, also do not need to go around getting information and permission from different public corporations, but just coming to a local government office to do it all. However, sharing of information such indicated above need vast amount of investment for physical infrastructure and application software to ensure the security of individual information and to prevent possible fraud.

E. General Affairs

General affairs consists of administrative support, financial section, public relations, human resources and capacity building, of all which are commonly established at any institutions. An administrative unit shall be set up at each section and all such units shall be supervised under a head of general affairs to provide uniform administrative services to all sections by employing regulatory template, guideline and practices. BWSC does not have such system in present organizational structure; hence, the practices of administrative tasks, such as procurement, contracting and documentation, are not uniformly conducted in effective and efficient manners.

Financial sub-section shall be separated from customer's service and water-meter reading sub-section. The tasks include all financial tasks, i.e. controlling all revenue and expenses and handle all procurements requested from respective sections, together with the procedures used for recording and evaluating financial operations and reporting on their results to the board of managers. The financial sub-section shall function as endorsement gate to prevent any frauds related to direct procurement by other operational sections.

Public relations, with close cooperation with the business section shall promote the eradication activities against illegal connection for water usage, and educate the users about water conservation, in order to save limited natural resources.

Human resources development and capacity building will be elaborated further in the following section in this chapter.

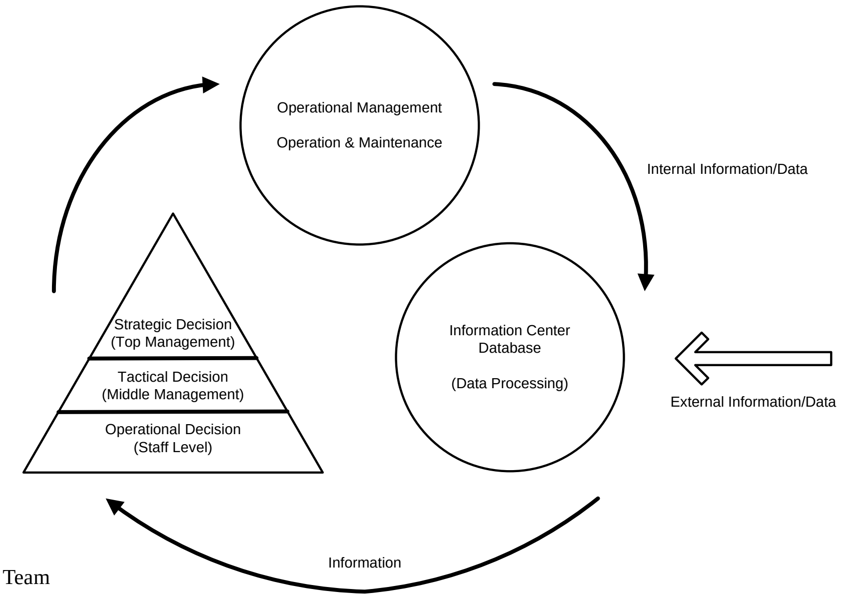
F. Information Center/Database

At present, BWSC does not have any information center or database center, but only one person is assigned for document registration and another for property keeper under general accounting sub-section. It is strongly recommended to establish an information center to amass all information collected through the operation.

It was observed during the study that essential information and data is scattered at the company and sometimes it was not available. Furthermore, it was found that BWSC did not keep as-built drawing of pipe network in the Bam areas, neither as-built drawings for essential underground utility cables from other utility companies.

Therefore, it is suggested that BWSC shall establish an information/database center to accumulate all necessary data and information, i.e. drawings, contract document, financial statement, economic and social indicators of the service areas and so on. Considering the experiences of the earthquake and the corresponding studies, it is also suggested to incorporate the lessons learned for emergency situations and to prepare for information back-up systems for such natural disasters in future.

Succeeding to the establishment of such information/database facility, information system structure shall be developed within BWSC and with WSCK. It is perceived that BWSC does not have intranet system at its office, so as WSCK. Unless collected information is shared among the related sections and companies, there is no use of it at all. Amassed information can be used wisely once the information is shared at all level of management, i.e. operational, middle management and top management levels as it shows in the figure below.



Source: JICA Study Team

Figure 4.8.2 Information Management Cycle

2) Human Resources Development

Training courses for BWSC staff shall be designed to cover from basic computer skills, administrative knowledge, i.e. accounting, financial management, procurement, human resources management and reporting skills; technical skills, i.e. water quality control, electrical machinery, pumping mechanism, plumbing, electric machinery; and other related knowledge and skills, such as public relations, project cycle management, designing and planning of mid-long term planning for water supply system, and so on.

Those training courses shall be designed to meet all level of training needs from entry to managerial level in different backgrounds and specialties. It is, however, suggested that cross sectoral or disciplinal trainings shall be incorporated into the courses offered by BWSC. For instance, a mechanical engineer might assume he does not need to know anything about accounting or procurement process; yet, it will be useful when he knows what depreciation means and how long he needs to keep existing machines until he could reasonably request the company to replace them, and to know proper procurement process and legal matters about services after the procurement, in order to avoid any mishaps in the future.

Since the training programs at BWSC are not available for reference, the suggestions are made based on the assumptions that BWSC does not offer comprehensive and structural training programs for its staff.

Training program, in most cases, are categorized into two main streams, structural and functional trainings. Structural training aims to build capacity and skills related to its structural position for section chief, manager and director, while functional training aims to build and empower the capacity and knowledge of respective skills related to functional tasks, such as planning, water quality control, pipe network investigation, plumbing and so on. Besides two primary trainings, basic administrative training, such as computer skill, documentation and procurement procedures shall be designed and provided to all staff at BWSC. The first point of designing training courses for its staff is to conduct a need assessment by questionnaire survey to all staff to identify the needs; and then outsource the development of training courses and materials to effectively implement such trainings.

3) Operation and Maintenance for Water Loss Control

The implementation of loss control programs are one of the most essential functions of the operational system, and hence of operation and maintenance of water supply company, in general. Before the earthquake, BWSC recorded about 19% of unaccounted water and it increased significantly after the earthquake at 49% due mostly to the damaged to pipe network. Unaccounted water level in year 2003, before the earthquake, is not that much significant compared to other regions in similar situations, but more efforts shall be expected to reduce the waste of limited natural resources.

A program consisting of a combination of countermeasure projects for control of water loss aims at achieving and maintains the lowest possible level of loss from leakage, overflow, illegal use of water, waste, operational consumption, special consumption, errors in metering or estimation. BWSC shall attain certain conditions, in order to achieve efficient and effective water supply management.

- Service water should meet predefined standards of water quality
- Service water should be supplied and delivered without interruption, continuity, and at sufficient pressure
- Operational management should be able to undertake problems liable to affect sustainable water supply. (reliability)
- Water supply system should be capable of collecting and distributing volumes of water adequate to meet the demands of the service areas. (quantity).
- Water quality, continuity, reliability and quantity are the four keywords and conditions to uphold the basis of operation and maintenance tasks. These four conditions must be the foundation to maintain the water supply management as prerequisite to any other operational programs.

Besides above four prerequisites of water supply operational management, a lack of efficient company's management could also hinder effectual distribution of water supply and result in poor water loss controls. It is, therefore, pointed out that an expansion of water supply facilities shall not be easily motivated exclusively by shortcoming in the supply but shall be based on reliable data and adequate planning study and in particular effective operational and enterprise management. Relying on the development of water sources easily and unnecessary without insightful considerations on the practices against the control of loss water becomes the causes which obstructs the valid use of the resources when the waste of water beyond the necessity wasn't only accepted, but also hamper the effective water source management in the long run. It is essential, thus, to use the existing water supply system to its fullest capacity before expanding a system that will continue to lose water, which could have been conserved. Taking into account the case of BWSC and BrvtWSC, there is a considerable room for both companies to take additional efforts to reduce the loss of water.

The loss is normally attributable to leakage, metering errors or non-recoverable uses of water.

Water not accounted for:

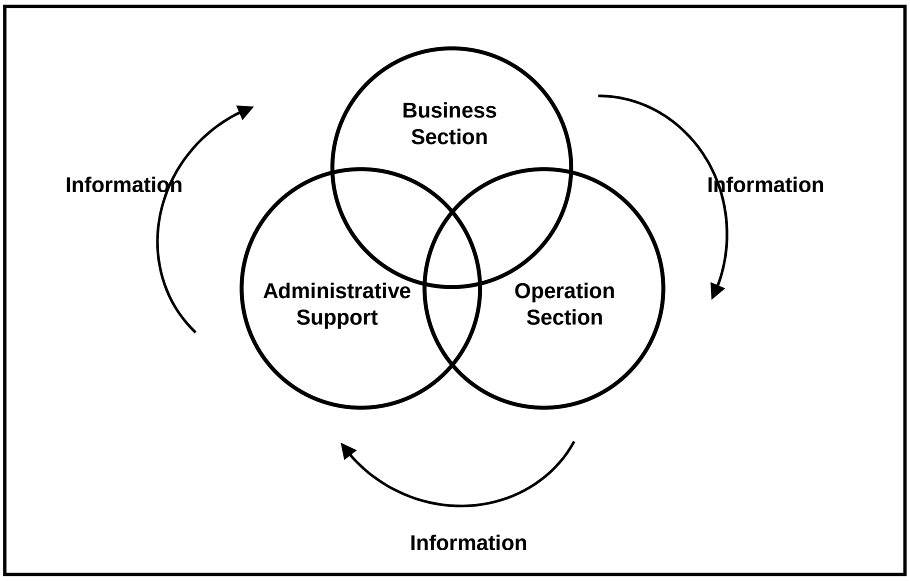
- Loss of Water — Overflow; Leakage; Waste of water
- Metering errors — Macrometering errors; Water-metering errors (house connection meter); Estimation error
- Special consumption
- Operational consumption
- Illegal consumption (illegal connection)

(Special consumption, Operational consumption, Illegal consumption: Non-revenue water)

- Leakage denotes a loss from discharge of water due to overflow of distribution reservoir and leakage from pipe or other parts of distribution system, including house connection. Leakage and overflow within BWSC properties, which are not metered is deemed leakage as well.
- Metering error accounts for a substantial part of total losses and are caused by inaccuracy in macrometering and metering equipment that measures water flow. The loss in metering error is an indication of the efficiency of metering system, to some extent.
- Non-revenue water represents losses of water that are not accounted for the income that BWSC can invoice. It includes operational consumption, special consumption (fire fighting, non-chargeable water used for public area), illegal connections and service water supplied with free of charge (charitable purpose).

A program to control water loss is set to diagnose how loss is caused first, and to formulate and implement activities to reduce it to a technically and economically acceptable minimum level. The activities mostly focus on operation and business section supported by sound technical supports from the technical section.

The objectives of the program are 1) to reduce losses to an acceptable level, 2) to meet additional demands with water made available from reduced losses, 3) to ensure that water supply system functions as efficiently as possible, 4) to increase the usable years of equipment and facility, and to 5) minimize the production cost.



Source: JICA Study Team

Figure 4.8.3 Cooperation for Water Loss Control among BWSC

Water Loss Control Activity

Water loss control activities consist of various measures, such as network survey, macro and micro metering control, leakage control, mapping and inventory management, improvement of housing connections and maintenance of distribution pipe network.

Network survey is to conduct different performance tests to obtain data about measurement of flows, pressures at cross-section of pressure mains over long periods, facts about consumption per capita and household, and the accuracy of metering devices, and disseminate operational data concerning water flows, pressures and levels, performing specific analysis of the operational units of water supply systems among the company to give inputs to formulate further water loss control programs and activities.

Macrometering is to collect routine operational data on water flows, pressures and levels, and then the analysis of those data shall be shared among BWSC. Macrometering activities include continuous evaluations of the hydraulic conditions of water supply system and analysis of those evaluations to determine or advise routine operation of the network or planning changes in its operation. Its periodic evaluations will also provide the assessment of the factors causing loss due to macrometering errors, house connecting meter errors, leakage and overflow from distribution pipe and unspecified operational consumption.

Mapping and inventory management is one of the vital components for BWSC to carry out without any delay, whereas new distribution pipe network is being installed and almost all network will be rebuild in the next few years in the Bam and Baravat areas. It is crucial for BWSC to take an initiative to up-to-date and ensure the accuracy of mapping and as-built drawing and inventory of distribution pipe network. It is also suggested to set up routine procedures for verifying and updating pipe route maps, drawing and inventory of pipes and fittings. It is also strongly recommended that GIS is used for base-map, mapping and drawing to ensure the accuracy the pipe network, and furthermore it is suggested to possibly exchange maps and as-built drawings in same plat-formed digital format with other public corporation and private utility services, such as electricity, telephone and cables.

Improvement of house connections and maintenance of distribution networks are the core activities to keep the sound operation and maintenance of water supply systems. The activities include a development of operating formation to design, install and inspect housing connection meter to control water leakage at house connection point. It is perceived that all sections, business, operation and technical sections must cooperate each other to develop such device and tools to periodically inspect the accuracy of house connection water-meter and reflect the outputs for following research and development for more effective systems. Maintenance of distribution network is mostly about empowerment of collaboration among administrative support, technical section and operation section. This activity is aim to improve the collaboration within BWSC to coordinate planning of administrative support, field work and technical support to conduct effective and efficient operation and maintenance through the use of adequate techniques, equipment, materials and human resources for field maintenance. Some derivative activities are to establish procedures for setting up maintenance schedules, to establish a certain repair procedures for standard services and feedback to refurbish the manual for standard services, and to monitor the productivity of operation and maintenance by type of services to provide inputs to formulate operation and maintenance strategic plans for short, middle and long-term.

4) Operation and Maintenance Costs in the Future

After all planned water supply facilities are constructed, BWSC will be the main operator to manage the facilities and carry out daily and periodic operation and maintenance under the supervision and technical advice from WSCK. Although BWSC is not technically entirely financially independent or so-called a profit generating public corporation, since it relies on its most of capital investment to WSCK and it has not borne all costs derived from the investment, BWSC, before the earthquake, has made enough revenue to cover its operation and maintenance costs. BWSC currently does not collect water charges from its service area, taking into account that majority of people are affected from the damages of the earthquake. According to the hearing, it was told that the central government decided to provide subsidies to make up the expenses to BWSC for next two to three years, instead of charging to the users in the heavily affected areas in Bam.

Given the current situation, all assumptions were made based on the grounds that the operation and maintenance for the facilities installed mostly in next five years will be managed by BWSC and water charge collections will be resumed after the suspension period, and water charges will be at least similar or higher than the level of previous water tariff structure before the earthquake.

With regard to the number of staff needed for managing facilities being built by year 2023, it is already pointed out that the shortage in number of staff will not be significant and their educational attainment is most probably at sufficient level. However, some additional staff shall be hired, especially, currently vacant positions shall be filled by the time the number of service population and the operation of services go back to the previous level, before the earthquake.

Financial estimate for future operation and maintenance in accordance with the water supply system development plan is scrutinized in this section. The basic conditions are same as the cost estimates for the projects illustrated in previous sections.

- All the costs are estimated under the economic conditions prevailing in October 2004.
- Exchange rate of currency is:
  USD 1.00= Rial 8,750,
  EURO 1.00= Rial 10,000
  Yen 1.00= Rial 78
- Operation and maintenance costs for annual remote control, reservoir and well are considered 2%, 1% and 1% of the construction costs, respectively.
- Current operation and maintenance costs are taken as a base and above additional operation and maintenance costs are added to the operation and maintenance costs every year after the capital investment year.
- Operation and maintenance costs consist of personnel, maintenance and repair, materials, raw water expenses and utility costs. Depreciation incurred for the past assets is not taken into considerations, while newly being built facilities are calculated separately and included in the calculations.
- Price inflation is not taken into account

Table 4.8.1 Estimated Operation and Maintenance Costs (2005-2023)

(Unit: Rials, otherwise stated)

Year	Daily Water Supply (m³/d)	Accounted-for Water (m³/d)	Yearly Water Supply (m³/y)	Accounted-for Water (m³/y)	Annual O&M Est. Cost	O&M Variables	Annual O&M Est. Cost (Rial)	O&M cost per supplied m³	O&M cost per accounted water
2003	21,109	14,776	7,705,000	5,394,000	855,033,000		4,012,908,000	521	744
2004	21,846	15,292	7,974,000	5,582,000	855,033,000		4,043,557,000	507	724
2005	22,582	15,807	8,242,000	5,769,000	855,033,000	64,750,000	4,138,841,000	502	717
2006	23,319	16,323	8,511,000	5,958,000	855,033,000	142,625,000	4,247,365,000	499	713
2007	24,056	16,839	8,780,000	6,146,000	855,033,000	301,525,000	4,436,914,000	505	722
2008	24,792	17,354	9,049,000	6,334,000	855,033,000	301,525,000	4,581,563,000	506	723
2009	25,529	17,870	9,318,000	6,523,000	855,033,000	301,525,000	4,612,212,000	495	707
2010	26,266	18,386	9,587,000	6,711,000	855,033,000	301,525,000	4,642,861,000	484	692
2011	27,002	18,901	9,856,000	6,899,000	855,033,000	401,275,000	4,773,260,000	484	692
2012	27,739	19,417	10,125,000	7,088,000	855,033,000	401,275,000	4,803,909,000	474	678
2013	28,476	19,933	10,394,000	7,276,000	855,033,000	401,275,000	5,073,958,000	488	697
2014	29,212	20,448	10,662,000	7,463,000	855,033,000	401,275,000	5,104,492,000	479	684
2015	29,949	20,964	10,931,000	7,652,000	855,033,000	401,275,000	5,135,141,000	470	671
2016	30,685	21,480	11,200,000	7,840,000	855,033,000	455,700,000	5,220,215,000	466	666
2017	31,422	21,995	11,469,000	8,028,000	855,033,000	455,700,000	5,250,864,000	458	654
2018	32,159	22,511	11,738,000	8,217,000	855,033,000	455,700,000	5,544,853,000	472	675
2019	32,895	23,027	12,007,000	8,405,000	855,033,000	455,700,000	5,575,502,000	464	663
2020	33,632	23,542	12,276,000	8,593,000	855,033,000	484,400,000	5,634,851,000	459	656
2021	34,369	24,058	12,545,000	8,782,000	855,033,000	484,400,000	5,665,500,000	452	645
2022	35,105	24,574	12,813,000	8,969,000	855,033,000	484,400,000	5,696,034,000	445	635
2023	35,842	25,089	13,082,000	9,157,000	855,033,000	484,400,000	5,726,683,000	438	625

Source: JICA Study Team

An average operation and maintenance cost per supplied water per m³ and accounted water is 480 rials and 680 rials, respectively, which is not much significantly high considering the current revenue level. However, it should be noted that the amount will increase to some extent, if the depreciation of facilities and equipment is taken into account.

If BWSC will be able to resume the previous level of revenue from water charges, it is considered feasible to cover the operation and maintenance expenses.

CHAPTER 5 RECOMMENDATIONS

5.1 Recommendation for Groundwater Resources Development

In the study, groundwater resources development plan is formulated based on the result of analysis of borehole construction. The outline of influence on the groundwater resources which may be caused by the development is described in the report. However, for the evaluation of the groundwater development plan, water balance should be considered in detail from the view point of sustainable water usage in the next step.

As it is mentioned in Chapter 3, most of extracted water was consumed for irrigation purpose. In Bam area, agriculture activity and its enlargement are an indispensable for the livelihood for people. There are a lot of qanats in the study area. The amount of discharge from qanats is significantly affected by the lowering of groundwater level. In fact, there is a report that menetions the shortage of water balance is 6MCM a year. Since the amount of 141MCM a year of groundwater is extracted from qanats for the irrigation purpose, some affect will be happened and will be critical issue for the regional sustainable economic development in future, unless the water consumption should be managed propery.

Therefore, considering the achievement of the sustainable economic development in Bam area after the earthquake, the water resources development and management plan should be formulated by the execution of study on comprehensive water resources in Bam desert.

1) To implement Monitoring of Groundwater Resource in Bam-Narmashir Watershed Unit

Groundwater resources are distributed in the Watershed Unit continuously in whole bam desert. Therefore, in order to understand the situation of water resources, more systematic groundwater resources monitoring listed below is strongly recommended in Bam-Narmashir Watershed Unit as a part of the study on water resources development and management plan. Recommended locations of each monitoring points are shown in Figure 3.6.1.

- groundwater level monitoring
- surface discharge monitoring
- precipitation and other meteorological components monitoring

2) To Keep Hydro-geological Information

It is strongly recommended that the information related to the hydro-geological conditions be analyzed, kept and monitored in terms of stability of water supply condition and sustainable use of groundwater resources. Hydro-geological information to be kept is as follows.

- geological description of drilled well with the coordinates

- result of pumping test (step test, continuous discharge test, recovery test)
- well structure (depth, diameter of well and casing pipe, length and position of screen
- groundwater level (static water level, dynamic water level)

5.2 Recommendations for Operation and Design of the Water Supply System

1) Review of Master Plan of Water Supply System

While the water distribution system is currently being constructed based on the master plan with the target year of 2031, it is recommended to review the master plan on water supply system in 2010 because the target year, 2031, is too far ahead and it is difficult to forecast recovery works after merely a year from the earthquake.

2) Non Revenue Water Control

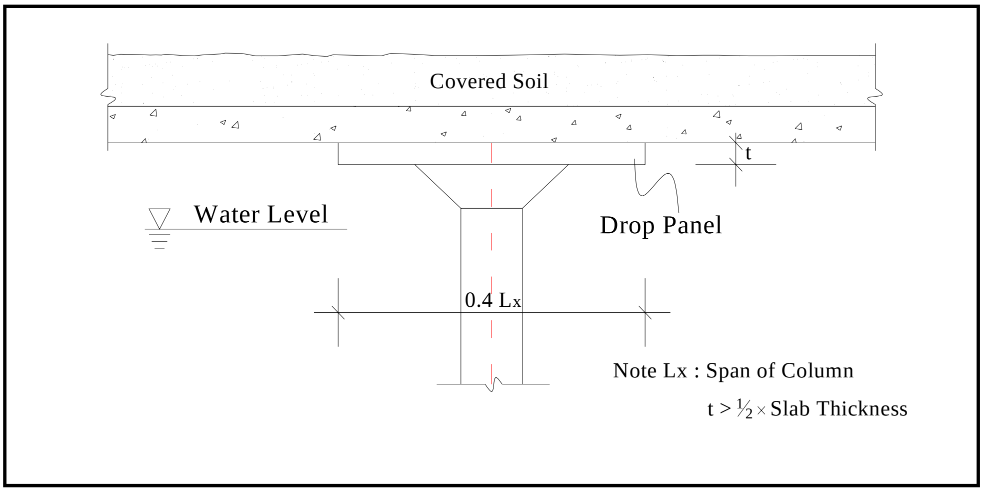
Bam east block is divided into two service areas connected with two pipelines. Installation of flowmeter on the pipelines is recommended for effective distribution system operation because the comparison of measurement of actual water quantity supplied and revenue water quantity can be more easily identified by locating leakage point and inefficient water use in smaller service area.

3) Installation of Emergency Shutoff Valve

In the existing water distribution system, the most water is transmitted from reservoirs to the consumers by gravity Therefore, if a pipe of distribution network is broken, water runs off automatically. This running off continues until the reservoir become empty or all valves concerning to the broken point are closed. Especially when a main pipe is broken, a lot of water would run off. Therefore installation emergency shut off valves at outlet pipe of the reservoirs is recommended.

4) Installation of Drop Panel to Reservoir Design

According to the collective typical drawings on ground type water reservoir published by MPO, top slab thickness corresponding to column span with 5.0 m is 25 cm. In this case big shear force acts on the top slab at columns. Therefore, arranging shearing bars on the top slab surrounding columns or thickening the slab is necessary. Thickening the slab may be safer or preferable than adding shearing bars. Flat slab with drop panel for water reservoir is widely employed from this point of view. Therefore JICA study team recommends adding Drop panel at the top of column to MPO typical design as shown below.



Source: JICA Study Team

Figure 5.2.1 Recommended Drop Panel for Flat Slab

5.3 Introduction of Mapping System

Introduction of mapping system is recommended for operation maintenance of water supply facilities. The mapping system concepts are described in chronological order as follows;

- Required computer device, such as printer, software, digitizer and so on, is installed at the BWSC main office in Bam municipality
- Preparation and collection of data, such as 1) topographic road map, qanat, stream and pole, 2) embedded facilities like cables and pipes, 3) as built drawing regarding distribution and conveyance pipes, and 4) property data of distribution and conveyance pipes, such as diameter, pipe material, time installed, contractor and so on
- Inputting and updating data; input and update data and information regularly

5.4 Recommendation on Environmental Aspects

Exiting daily average water demand of 21,109 m^3/d would reach to 35,842 m^3/d in 2023. This is 1.7 times of existing water demand; thus, wastewater amount also will increase accordingly. The increase of wastewater could deteriorate present environment conditions in Bam. Wastewater disposal system is expected to be employed in near future, in order to keep sound living environmental conditions.

5.5 Recommendation for Operation and Maintenance

It is recommended to redefine and demarcate the task, command line and responsibilities of respective sections in accordance with rational classification of objectives and activities. Capacity building shall be carried out with much emphasis, especially on technical skills, to empower the human resources.

When Bam city recovers from the earthquake disaster and the civic life becomes stable some years later, collecting tariff should be restarted.

For the meantime present tariff level could cover O/M cost of BWSC. However it is recommended to reassess the water tariff structure to recapture the investment costs with long-range vision.

APPENDIX

1 GENERAL

1.1 Study related Members

JICA Advisory Committee Members

Name	Position	Institution
Dr. Kimiro Meguro	Committee Leader	The University of Tokyo
Dr. Shuichi Takeya	Member	Ministry of Land, Infrastructure and Transport
Dr. Shingo Nagamatsu	Member	Disaster Reduction and Human Renovation Institution
Mr. Katsunori Ishida	Observer	Hyogo Prefecture Government

JICA Study Team

Name	Position
Mr. Itaru Mae	Team Leader
Mr. Ichiro Kobayashi	Deputy Team Leader / Urban Disaster Management
Mr. Osamu Nishii	Deputy Team Leader / Disaster Prevention and Management
Mr. Kanao Ito	Urban Planning (1)
Ms. Mihoko Ogasawara	Urban Planning (2)
Dr. Akio Hayashi	Building Structure
Mr. Ryoji Takahashi	Infrastructure and Lifeline
Dr. Nahoko Nakazawa	Community Disaster Prevention and Management (1)
Ms. Junko Okamoto	Community Disaster Prevention and Management (2)
Ms. Tomoko Show	Social Analysis
Mr. Masatoshi Kaneko	Economic Analysis
Mr. Schneider Klaus-Dieter	Organization and Institution for Disaster Management (1) / Project Implementation
Mr. Makoto Nakamura	Organization and Institution for Disaster Management (2)
Mr. Kazumi Akita	Disaster Rescue and Medical Response
Mr. Hiroyuki Maeda	GIS Specialist
Mr. Masahiro Satake	Disaster Information and Communication Management
Mr. Kazunori Seki	Reconstruction and Structure Plan
Mr. Shukyo Segawa	Seismology
Mr. Toshitsugu Shimodaira	Coordinator
Mr. Kazushige Mizui	Coordinator
The Study on Reconstruction Plan for Bam Water Supply System	
Mr. Nobuyuki Gonohe	Water Supply and Facility Plan
Mr. Yarai Sato	Pipeline Network Design and Cost Estimate
Mr. Naoki Yasuda	Cost Estimate
Ms. Atsuko Tsuruta	Community Restoration
Ms. Hitomi Tomizawa	Agricultural Restoration Plan

Name	Position
Mr. Keigo Obara	Social Environment and Impact Survey
Mr. Shuichi Yoshida	Structure Planning and Construction Supervision (2)
Mr. Ichiro Tanaka	Groundwater Recourses Planning (1)
Mr. Hiroyoshi Yamada	Groundwater Resources Planning (2)
Mr. Osamu Abe	Operation and Maintenance Planning
Mr. Mamoru Nakamura	Construction Supervision (1)
Mr. Osamu Heki	Construction Supervision (3)

JICA Tokyo Headquarters

Name	Position
Mr. Itsu Adachi	Group Director, Group III (Water Resources and Disaster Management), Global Environment Department
Mr. Masafumi Nagaishi	Team Director, Water Resources and Disaster Management Team II, Group III (Water Resources and Disaster Management), Global Environment Department
Ms. Ai Yamazaki	Staff, Water Resources and Disaster Management Team II, Group III (Water Resources and Disaster Management), Global Environment Department

JICA Expert

Name	Position
Mr. Junji Wakui	JICA Expert, ODA Advisor in Iran

1.2 Major Activities of the Study

Date	Topics and Activities
January 2004	Preparatory mission
May 14 2004	Contract with Japan International Cooperation Agency (JICA)
May 24 2004	Commencement of the Study at Bam in Kerman province
June 20 2004	Signing on Minutes of Meeting on the objectives of the study, scope, schedule, reporting schedule, demarcation of the responsibilities between counterpart agencies in Iran and JICA Study Team
July 28 2004	Commencement of the construction of test boreholes
August 1 2004	Commencement of the construction of distribution reservoir
October 23 2004	Workshop for the Study on Draft Final Report
October 23 2004	Signing on Minutes of Meeting on the submission of the draft final report
October 2004	Completion of test boreholes
December 25	Hand-over ceremony for distribution reservoir
December 26	Signing on hand-over ceremony for distribution reservoir

2 APPENDIX OF CHAPTER 3: GROUNDWATER RESOURCES STUDY

Table AP2.1 List of Qanat in Bam (1999)

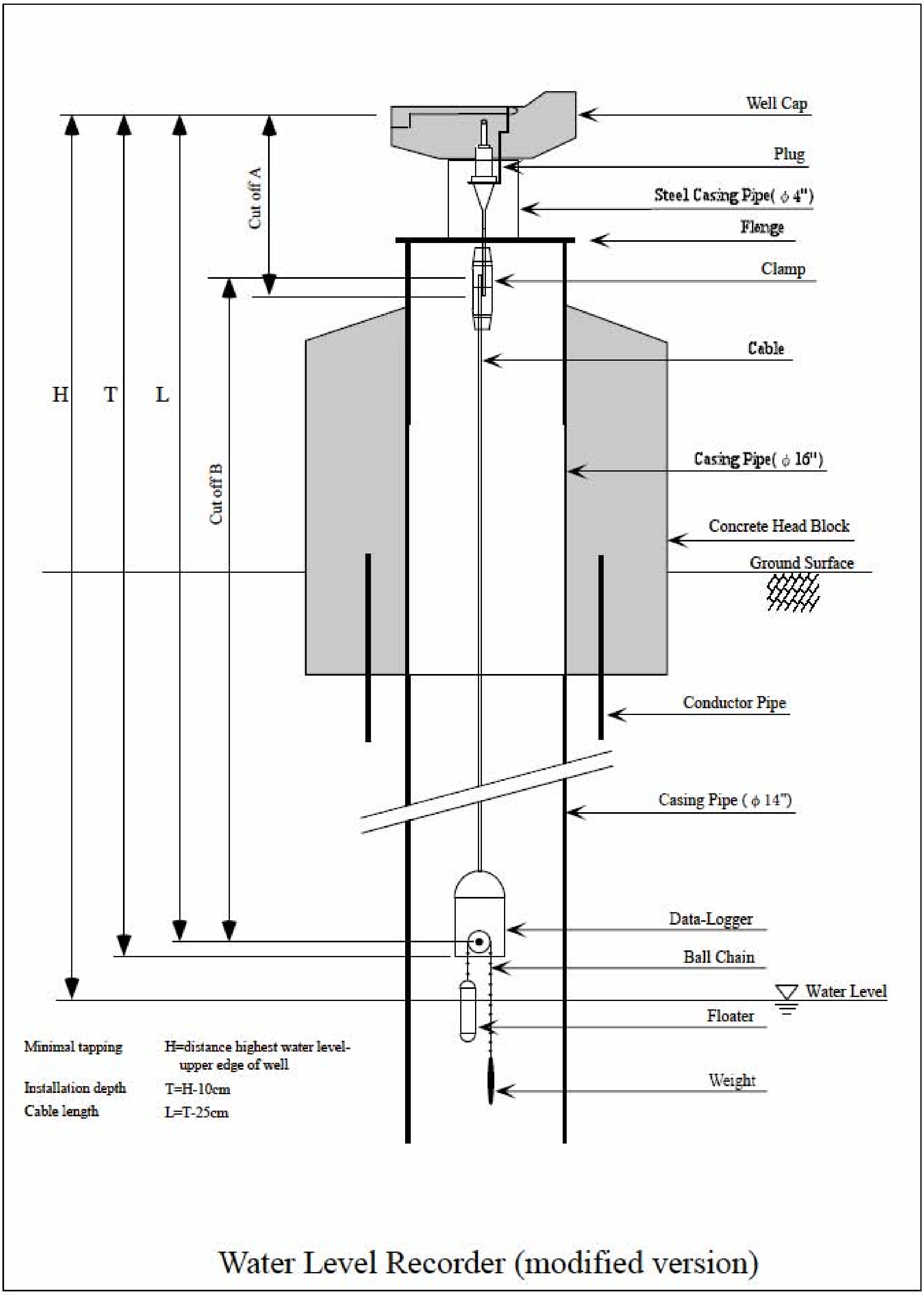
	Locality Information				Date of Inspection	Depth of Mother Well	Length	Q	Discharge
	No.	Name of Qanat	Coodination (UTM)	Area Name		(m)	(m)	(lit/sec)	(m3/year)
1	9H-1Q	SOBHAN ABAD	623315 - 3222120	KHAJEH ASKAR	76/04/04	95	3000	26	819936
2	9H-2Q	EAYSH ABAD	623420 - 3222113	KHAJEH ASKAR	76/04/04	90	3200	31	977616
3	9H-3Q	GAZDAR	621691 - 3222051	KHAJEH ASKAR	76/04/03	54	5900	116	3658176
4	9H-4Q	RAHMANEIA	623253 - 3224586	RAHMANEIA	76/04/03	81	8900	69	2175984
5	9H-5Q	MOHAMMAD ABAD	624032 - 3224137	BAGHCHAMAK	76/04/03	62	11200	152	4793472
6	9H-6Q	ASAD ABAD	624017 - 3223712	BAGHCHAMAK	76/04/03	41	3900	175	5518800
7	9H-7Q	OLYA	623951 - 3223354	BAGHCHAMAK	76/04/03	27	10300	44	1387584
8	9H-8Q	FATEMEAYE	624896 - 3223766	BAGHCHAMAK	76/04/04	59	7300	136	4288896
9	9H-9Q	MASSOMEAYE	624427 - 3224395	BAGHCHAMAK	76/04/04	48	5600	159	5014224
10	9H-10Q	PAAKAM	623487 - 3222508	KHAJEH ASKAR	76/04/18	43	3900	234	7379424
11	9H-11Q	DEHSHOTOR	623765 - 3222684	DEHSHOTOR	76/04/18	68	2800	275	8672400
12	9H-12Q	POSHTROUD	624808 - 3222245	POSHTROUD	77/08/18	40	1000	175	5518800
13	10H-1Q	HAFEZ ABAD	625682 - 3223690	DASHT E GAV	76/04/04	30	2400	72	2270592
14	10H-2Q	ABBASS ABAD	625547 - 3224070	DASHT E GAV	76/04/18	31	4400	106	3342816
15	10H-3Q	SEKOLEY	627952 - 3220626	HOOMEH E BAM	76/04/17	80	5000	18	567648
16	10H-4Q	AKBAR ABAD	628277 - 3220345	BAM	76/04/17	93	6900	100	3153600
17	10H-5Q	KAKH	625625 - 3222422	AMIR ABAD	77/06/09	57	5200	121	3815856
18	10H-6Q	EASAVEAYE	629491 - 3223812	ESPIKAN - EASAVEAYE	77/06/10	41	2800	142	4478112
19	10H-7Q	AMEREAYE	628372 - 3220369	BAM BOLVAR E SARGORD AZAR	77/06/15	90	4500	12	378432
20	10I-1Q	MAHDI ABAD	628979 - 3219037	HOOMEH E BAM	76/04/17		6300	89	2806704
21	10I-2Q	HASSAN ABAD	628205 - 3219582	HOOMEH E BAM	76/04/17	98	7200	51	1608336
22	10I-3Q	GHANBAR ABAD	629721 - 3218648	BAM	76/04/17	71	1800	218	6874848
23	10I-4Q	LENGGE FAKHR ABAD	629096 - 3218890	HOOMEH E BAM	76/04/17	91	8900	169	5329584
24	13G-1Q	BAGHERY	643667 - 3226078	KARK	76/04/02	34	3600	152	4793472
25	11H-1Q	HOSSAINEYE ESPIKAN	631372 - 3222669	ESPIKAN	76/06/09	64	6300	128	4036608
26	12H-1Q	HASSAN ABAD	638128 - 3221474	NARTEIJ	76/04/02	43	6900	43	1356048
27	12H-2Q	DOMKANI	638977 - 3221733	NARTEIJ	76/04/04	49	2300	104	3279744
28	12H-3Q	LOTF ABAD POSHTROUD	639159 - 3224033	HOOMEH E BAM	76/04/19			16	504576
29	12H-4Q	FARAH ABAD	639723 - 3222333	NARTEIJ	76/10/02	32	5800	43	1356048
30	12I-1Q	AKBAR ABAD	638115 - 3218063	BARAWAT	76/04/25	44	6900	168	5298048
31	12I-2Q	NOUROUZ ABAD	637640 - 3217697	BARAWAT	76/04/25	62	6900	188	5928768
32	12I-3Q	GHASSEM ABAD	638128 - 3218062	BARAWAT	76/04/25	44	2300	158	4982688
33	12I-4Q	SAEID ABAD	636133 - 3218738	BARAWAT	76/04/25	44	5800	77	2428272
34	12I-5Q	GHANNAD	636788 - 3217200	BARAWAT	76/04/26	59	4100	23	725328
35	12I-6Q	HAJ ALI	636669 - 3217286	BARAWAT	76/04/26	71	6200	6	189216
36	12I-7Q	MOHAMMAD ABAD	636011 - 3217420	BARAWAT	76/04/26	44	2900	41	1292976
37	12I-8Q	MAHDI ABAD	636611 - 3218268	BARAWAT	76/04/25	52	2900	53	1671408
38	12I-9Q	KOHNE	636882 - 3216562	BARAWAT	76/05/08	61	3800	54	1702944
39	12I-10Q	HASHR ABAD	636840 - 3217777	BARAWAT	76/04/26	53	4800	93	2932848
40	12I-11Q	GARDOON	636199 - 3217320	BARAWAT	76/04/26	48	2700	41	1292976
41	12I-12Q	BARZRASHEEDI	636763 - 3215201	BARAWAT	76/05/13	82	5800	11	346896
42	12I-13Q	JAHRE HOSSAIN ABAD	637612 - 3216280	BARAWAT	76/05/08	42	2100	90	2838240
43	12I-14Q	BARZHOSSAIN ABAD	637104 - 3216690	BARAWAT	76/05/08	51	2600	39	1229904
44	12I-15Q	SHAREIK ABAD	637564 - 3215250	BARAWAT	76/05/08	34	1600	53	1671408
45	12J-2Q	JAHR E KENAROU	637382 - 3213775	BARAWAT	76/05/08	109	2900	10	315360
46	12J-3Q	JAHRE RASHEIDI	637369 - 3214808	BARAWAT	76/05/13	44	4600	18	567648
47	12J-4Q	VAKIL ABAD	636599 - 3214860	BARAWAT	76/05/09	66	5200	66	2081376
48	12J-5Q	DOWLAT ABAD	637436 - 3213275	BARAWAT	76/05/09	102	4200	33	1040688
49	12J-6Q	MIRZAEI	637289 - 3213297	BARAWAT	76/05/09	41	4900	14	441504
50	12J-7Q	GHAEAM ABAD	637362 - 3213936	BARAWAT	76/05/09	49	7100	23	725328
51	12J-8Q	ALLAH ABAD	637439 - 3214197	BARAWAT	76/05/09	52	6200	14	441504
52	12K-1Q	HAJEI ABAD	638591 - 3208592	HAJI ABAD BARAWAT	76/04/10	42	4900	27	851472

Source: Regional Water Resources Company of Kerman

Table AP2.2 List of Well in Bam Area(1999)

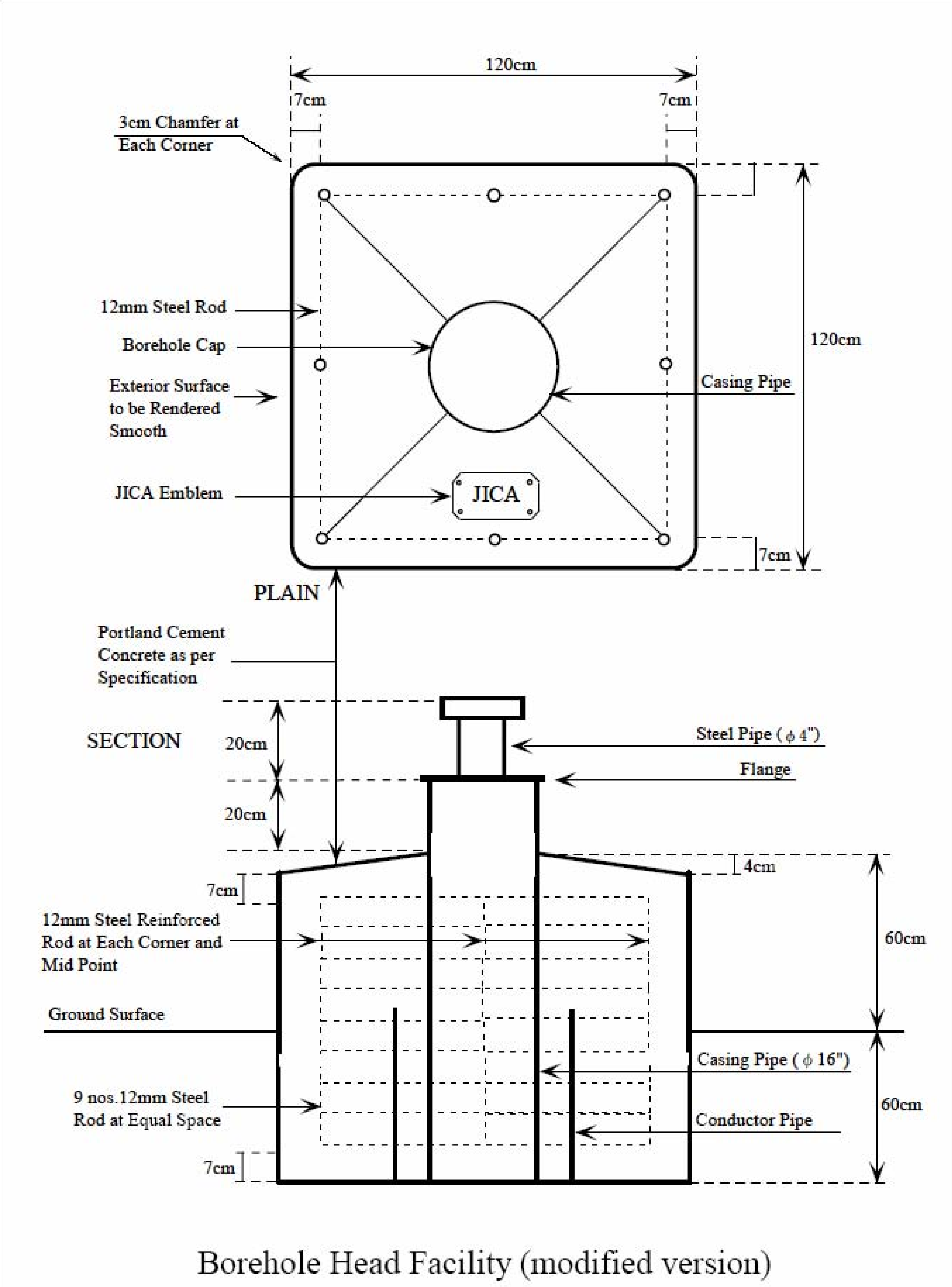
	Locality Information					Water Table	Depth of Well	Q	Operation Time		Annual Discharge		Year of Construction	Depth of Implementing Rotary	Diameter of Pipe	Engine Type	Motor Power	Date of Inspection	Purpose of utilization
	No.	No.	Area Name	UTM Area	UTM	(m)	(m)	(liter/sec)	(day/year)	(hrs/day)	(hrs/year)	(m3)		(m)	(inch)		(hp)		
1	13G-1S	3/5	KARK	640 - 3225	644920 - 3226154	6	12	23	360	4	1440	119232	1971	10	6	BLACKSTONE	26	97/4/2	Planting
2	14G-1S	3/7	MOHAMMAD ABAD KARK	645 - 3225	645493 - 3225908	6	20	20	360	12	4320	311040	1978	18	6	BLACKSTONE	26	97/4/2	Planting
3	14G-2D	3/8	KARK	645 - 3225	646628 - 3229633	85	170	0	360	10	3600	0	1992	99	6	VOLVO	161	97/4/2	Planting
4	9H-1D	1/27	HARARAN	620 - 3220	623353 - 3222287	0	50	25	365	12	4380	394200	1978	0	5	ELECTROMOTOR	30	97/4/19	Planting
5	9H-2D	1/25	KHAJEH ASKAR	620 - 3220	622436 - 3221996	18	100	42	365	10	3650	551880	1975	60	6	DORMAN	180	97/4/19	Dirinking water
6	9H-3D	1/24	BIDARAN - BAGHCHMAK	620 - 3220	622370 - 3222632	20	80	35	365	12	4380	551880	1979	0	6	DORMAN	180	97/4/19	Drinking and Washing
7	9H-4D	1/29	DARBAGH	620 - 3220	623798 - 3223394	17	70	33	365	10	3650	433620	1981	54	6	ELECTROMOTOR		97/4/19	Dirinking water
8	9H-5S	1/28	DARBAGH	620 - 3220	624001 - 3222143	8	25	0	0	0	0	0	1986	0	3	LISTER	0	97/4/19	Out of order
9	9H-6D	1/26	KHAJEH ASKAR	620 - 3220	622651 - 3222253	25	60	30	300	18	5400	583200	1980	30	6	ELECTROMOTOR		97/4/18	Planting
10	9H-7S	1-298	KHAJEH ASKAR	620 - 3220	622546 - 3220988	8	12	0	0	0	0	0	1992	10	6	BENZ	96	97/6/30	Out of order
11	10H-1D	2/11	SAHRAYE SOOFI ABAD	625 - 3220	627388 - 3220309	60	150	43	360	15	5400	835920	1978	0	8	ELECTROMOTOR	150	97/4/8	Planting
12	10H-3D	2-5	DEH SHOTOR	625 - 3220	629224 - 3221412	45	90	40	360	15	5400	777600	1977	0	6	ELECTROMOTOR	125	97/4/8	Planting
13	10H-4D	2/4	DEH SHOTOR	625 - 3220	628401 - 3221410	45	130	50	360	20	7200	1296000	1977	95	8	ELECTROMOTOR	220	97/4/8	Drinking water
14	10H-5D	2-3	ZEID ABAD - BAM	625 - 3220	6281997 - 3222166	75	150	0	365	10	3650	0	1982	0	6	VOLVO	220	97/4/8	Drinking water
15	10H-6D	1/215	DEH SHOTOR	625 - 3220	626310 - 3221840	60	120	50	360	16	5760	1036800	1981	0	6	ELECTROMOTOR	145	97/4/8	Planting
16	10H-7D	2-1	DEH SHOTOR - AMIR ABAD	625 - 3220	625522 - 3222246	70	100	34	360	15	5400	660960	1984	0	6	ELECTROMOTOR	145	97/4/8	Planting
17	10H-8D	2-6	KOOZERAN	625 - 3220	628652 - 3220836	52	120	65	360	20	7200	1684800	1980	0	8	ELECTROMOTOR	125	97/4/8	Planting
18	10H-9D	2/41	TAMIK - ESPIKAN	625 - 3220	629356 - 3222539	60	75	32	360	7	2520	290304	1978	0	6	BENZ	8TON	97/4/16	Planting
19	10H-10D	2-9	SAHRAYE SOOFI ABAD	625 - 3220	626045 - 3220543	69	150	0	0	0	0	0	1986	0	6	VOLVO	220	97/4/8	Planting
20	10H-11D	2/24	BOLVARE SARGORD AZAR	625 - 3220	628749 - 3220573	60	120	35	360	20	7200	907200	1978	0	8	ELECTROMOTOR	150	97/4/11	Planting
21	11H-1D	2/27	KHIABAN E FATEMEI	630 - 3220	630152 - 3220700	59	120	0	0	0	0	0	191997	0	8	ELECTROMOTOR	220	97/4/19	Dirinking water
22	11H-2D	2/26	BOOALI - DELGOSHA	630 - 3220	631088 - 3221004	60	130	45	360	20	7200	1166400	191997	0	6	ELECTROMOTOR	125	97/4/11	Planting
23	11H-3D	2-7	KOOZERAN	630 - 3220	630244 - 3221750	60	120	43	360	20	7200	1114560	1970	0	6	VOLVO	220	97/4/8	Planting
24	11H-4S	2/45	POSHTROUD E BAM	630 - 3220	632080 - 3223210	5	15	22	360	6	2160	171072	1981	0	4	FIAT	15	97/4/19	Planting
25	11H-5D	2/36	KHIABAN E TABATABAEI BAM	630 - 3220	632651 - 3221310	53	120	36	360	20	7200	933120	1987	95	6	ELECTROMOTOR	150	97/4/14	Planting
26	11H-6S	2/40	ESPIKAN	630 - 3220	630972 - 3223089	15	20	0	0	0	0	0	1969	0	4	LISTER	15	97/4/16	Planting
27	11H-7S	2/39	ESPIKAN	630 - 3220	631386 - 3223067	15	17	15	360	2	720	38880	1987	16	4	ELECTROMOTOR		97/4/16	Industrial
28	11H-8D	2/38	HAFEZ ABAD	630 - 3220	634482 - 3222609	40	90	20	360	20	7200	518400	1986	75	6	ELECTROMOTOR		97/4/15	Planting
29	11H-9D	2/37	BAM - MOGHABEL E TARBIAT BADANI	630 - 3220	632150 - 3221926	22	100	36	360	12	4320	559872	1981	86	6	ELECTROMOTOR		97/4/15	Planting
30	11H-10D	3/3	RAHEIM ABAD	630 - 3220	634779 - 3222119	35	100	25	360	12	4320	388800	1987	78	6	ELECTROMOTOR	125	97/4/1	Planting
31	11H-11D	2-306	BAM	630 - 3220	631773 - 3220583	80	100	0	0	0	0	0	1985	0	3	ELECTROMOTOR		97/9/27	Planting
32	11H-12D	2-8	KAMARBANDI SHOMALI	630 - 3220	63019976 - 3221267	60	120	31	360	20	7200	803520	1981	0	6	ELECTROMOTOR	110	97/4/8	Planting
33	12H-1S	2/43	BAM POSHTROUD	635 - 3220	635755 - 3223003	33	40	0	360	0.5	180	0	1987	0	0	ROMANY	60	97/4/16	Brick factory
34	12H-2S	2/42	BAM POSHTROUD	6353220	636888 - 3223601	23	35	14	360	10	3600	181440	1996	33	4	ELECTROMOTOR		97/4/16	Planting
35	12H-3D	3/1	JAHAD	6353220	639595 - 3222170	25	60	27	360	5	1800	174960	191997	45	6	ROMANY	66	97/4/1	Dirinking water
36	12H-4S	3-4	RAHEIM ABAD	6353220	636279 - 322121997	15	24	0	0	0	0	0	1972	0	6	0	0	97/4/1	Planting
37	13H-1S	3/6	KARK	640 - 3220	643855 - 3222658	30	35	0	0	0	0	0	1971	33	0	PERKINZ	86	97/4/2	Planting
38	13H-2S	3/2	NARTEIJ	640 - 3220	640550 - 3224400	18	22	0	0	0	0	0	1981	20	6	0	0	97/4/1	Planting
39	10I-1D	1/3	JANOOB E JADEH BAM	625 - 3215	626949 - 3218995	75	200	63	365	20	7300	1655640	1986	123	8	ELECTROMOTOR	125	97/4/21	Drinking and Washing
40	10I-2D	1/31	JANOOB E JADEH BAM	625 - 3215	626669 - 3218643	80	200	0	0	0	0	0	1988	0	0	0	0	97/4/21	Dirinking water
41	10I-3D	1/32	JANOOB E JADEH BAM	625 - 3215	626447 - 3218975	80	200	35	365	20	7300	919800	1986	135	8	ELECTROMOTOR	150	97/4/21	Drinking and Washing
42	10I-4D	1/34	JANOOB E JADEH BAM	625 - 3215	626557 - 3219822	85	200	0	0	0	0	0	1988	0	0	0	0	97/4/21	0
43	10I-5D	1/35	JANOOB E JADEH BAM	625 - 3215	626635 - 3219879	80	200	49	365	20	7300	1287720	1986	123	8	ELECTROMOTOR	150	97/4/22	Dirinking water
44	10I-6D	1/36	JANOOB E JADEH BAM	625 - 3215	627135 - 3219720	85	200	65	365	20	7300	1708200	1986	129	8	ELECTROMOTOR		97/4/22	Dirinking water
45	10I-7D	1/37	BAGHDASHT	625 - 3215	627433 - 3218460	80	140	40	365	8	2920	420480	1972	132	6	ELECTROMOTOR	132	97/4/22	Planting
46	10I-8D	1/39	JANOOB E JADEH BAM	625 - 3215	626789 - 3218961	100	150	20	365	10	3650	262800	1989	120	6	ELECTROMOTOR	125	97/4/22	Industrial
47	10I-9D	1/4	BAGHDASHT	625 - 3215	628973 - 321719971	100	125	24	365	3	1095	94608	1995	120	4	ELECTROMOTOR		97/4/23	Industrial planting
48	10I-10D	1/33	JANOOB E JADEH BAM	625 - 3215	626322 - 3219214	93	200	60	365	20	7300	1576800	1986	123	8	ELECTROMOTOR		97/4/21	Dirinking water
49	10I-11D	2/19	KHEIABAN E AMIRKABEIR	625 - 3215	627520 - 3219584	50	90	25	300	10	3000	270000	1979	85	8	ELECTROMOTOR		97/4/10	Green place
50	10I-12D	2/18	BAGHDASHT	625 - 3215	629296 - 3218453	62	150	45	360	13	4680	758160	1970	120	8	ELECTROMOTOR	75	97/4/10	Planting
51	10I-13D	2/17	BAGHKHAN	625 - 3215	629719 - 3219903	54	120	50	360	20	7200	1296000	1973	0	8	ELECTROMOTOR	125	97/4/11	Planting
52	10I-14D	2/15	JADEH BAM - KERMAN	625 - 3215	628370 - 3219002	95	120	0	365	5	1825	0	1994	0	3	ELECTROMOTOR		97/4/9	Drinking and Washing
53	10I-15D	2/23	BAGHDASHT	625 - 3215	629710 - 3218839	61	90	40	360	20	7200	1036800	1979	80	6	ELECTROMOTOR	125	97/4/10	Drinking and Washing
54	10I-16D	2/12	KHEIABAN E AMIRKABEIR	625 - 3215	627877 - 3219475	75	150	25	360	12	4320	388800	1974	120	6	ELECTROMOTOR	125	97/4/9	Planting
55	10I-17D	2/44	BAGHDASHT- MAHDI ABAD	625 - 3215	629223 - 3218793	1997	120	40	360	14	5040	725760	1979	100	6	ELECTROMOTOR	150	97/4/18	Planting
56	10I-18D	1/38	JANOOB E JADEH BAM	625 - 3215	627047 - 3217559	110	180	0	0	0	0	0	1991	150	6	KOMENZ	330	97/4/22	Planting
57	10I-19D	2/14	KHEIABAN E AMIRKABEIR	625 - 3215	628478 - 3219996	60	170	1997	360	20	7200	51762240	1981	0	8	ELECTROMOTOR	220	97/4/9	Planting
58	10I-20D	2/16	ARABKHANEH	625 - 3215	628745 - 3219326	75	125	70	360	20	7200	1814400	1980	0	8	ELECTROMOTOR	220	97/4/9	Planting
59	10J-1D	1/41	BAM - DASHTE SEYYADI	625 - 3210	627515 - 3214356	0	150	0	0	0	0	0	1994	0	0	0	0	97/4/23	Planting
60	11I-1D	2/3	BOLVARE SHAHEID RAJAEI	630 - 3215	631460 - 3216758	54	80	10	360	4	1440	51840	1989	0	4	ELECTROMOTOR		97/4/12	Drinking and Green place
61	11I-2D	2/29	BOLVARE SHAHEID RAJAEI	630 - 3215	630326 - 3218128	65	130	45	360	10	3600	583200	1974	0	6	ELECTROMOTOR	150	97/4/12	Planting
62	11I-3D	2/28	BAM - KARKHANEH HANA	630 - 3215	630791 - 3218233	65	130	0	0	0	0	0	1974	0	3	ELECTROMOTOR	16	97/4/12	Planting
63	11I-4D	2/25	KAMARBANDI MAHDAB	630 - 3215	630978 - 3219453	0	120	44	360	10	3600	570240	1965	0	6	ELECTROMOTOR	0	97/4/11	Drinking water
64	11I-5D	2/22	KHEIABAN E CHAMRAN	630 - 3215	630300 - 3218560	63	120	40	300	20	6000	864000	1990	80	8	ELECTROMOTOR	160	97/4/10	Planting
65	11I-6D	2/21	KHEIABAN E FERDOSSI	630 - 3215	631374 - 3219422	53	120	54	360	17	6120	1189728	1975	90	8	ELECTROMOTOR	150	97/4/10	Planting
66	11I-7D	2/20	SOOFI ABAD	630 - 3215	630461 - 3219918	55	120	60	360	20	7200	1555200	1973	90	8	ELECTROMOTOR	175	97/4/10	Planting
67	11I-8D	2/32	BAM MANTAGHEH ENTEZAMI	630 - 3215	631533 - 3217454	66	125	16	360	4	1440	82944	1986	0	3	ELECTROMOTOR		97/4/14	Planting and dirinking
68	11I-9D	2/35	AESH ABAD	630 - 3215	632214 - 3219820	54	105	35	360	10	3600	453600	1964	90	6	ELECTROMOTOR	125	97/4/14	Green place and dirinking
69	11I-10D	2 - 34	AESH ABAD	630 - 3215	631991 - 3219573	60	120	63	360	20	7200	1632960	1975	93	8	ELECTROMOTOR	150	97/4/14	Planting
70	11I-12D	2/33	BAM - KOOCHEH KHALILZADEH	630 - 3215	630714 - 3218540	60	120	56	360	20	7200	1451520	1975	90	8	ELECTROMOTOR	150	97/4/14	Planting
71	11I-13D	2/31	BAM - BAGHDASHT	630 - 3215	630869 - 3218101	65	140	28	360	8	0	0	1986	0	6	ELECTROMOTOR		97/4/14	Planting
72	11I-14D	2/46	BAM	630 - 3215	631873 - 3218740	55	120	0	0	0	0	0	1973	0	6	0		97/4/19	Planting
73	11I-15D	2/13	KHEIABAN E AMIRKABEIR	625 - 3215	627887 - 3219475	70	120	34	360	12	4320	528768	1975	100	8	ELECTROMOTOR	220	97/4/9	Planting
74	12I-1D	1/59	BARAWAT	635 - 3215	637080 - 3215380	110	180	39	330	20	6600	926640	1975	126	6	ELECTROMOTOR	200	97/5/5	Planting
75	12I-2D	1/58	BARAWAT	635 - 3215	638161 - 3216689	90	150	50	330	20	6600	1188000	1978	126	8	ELECTROMOTOR	150	97/5/5	Planting
76	12I-3D	1/57	BARAWAT	635 - 3215	639356 - 3216186	75	150	36	365	20	7300	946080	1981	99	6	ELECTROMOTOR	150	97/5/4	Planting
77	12I-4D	1/56	BARAWAT	635 - 3215	638775 - 321519979	75	150	53	330	20	6600	1259280	1981	135	6	ELECTROMOTOR	125	97/5/5	Planting
78	12I-5D	1/55	BARAWAT CHEHEL MANEI	635 - 3215	637251 - 3215505	95	180	53	330	18	5940	1133352	1979	129	8	ELECTROMOTOR	220	97/5/5	Planting
79	12I-6D	1/54	BARAWAT - HOSSAINSHAHEI	635 - 3215	638378 - 3218514	90	160	46	365	16	5840	967104	1981	135	6	ELECTROMOTOR	150	97/5/4	Planting
80	12I-7D	1/52	BARAWAT	635 - 3215	638504 - 3215057	90	180	69	330	20	6600	1639440	1973	135	8	ELECTROMOTOR	150	97/5/4	Planting
81	12I-8D	1/51	BARAWAT E VOSTA	635 - 3215	637592 - 3215370	80	180	63	365	20	7300	1655640	1981	140	8	ELECTROMOTOR	132	97/5/4	Planting
82	12I-9D	1/50	BARAWAT	635 - 3215	636607 - 3216103	90	180	60	300	20	6000	1296000	1980	120	8	ELECTROMOTOR	125	97/4/24	Planting
83	12I-10D	1/49	BARAWAT	635 - 3215	636645 - 3216731	75	150	37	365	20	7300	972360	1978	90	6	ELECTROMOTOR	200	97/4/23	Planting
84	12I-11D	1/48	BARAWAT	635 - 3215	637339 - 3218377	0	0	0	0	0	0	0	1996	0	0	0	0	97/4/24	0
85	12I-12D	1/47	BARAWAT	635 - 3215	638286 - 3218308	60	100	35	365	20	7300	919800	1981	90	8	VOLVO	161	97/4/24	Planting
86	12I-13D	1/46	BARAWAT	635 - 3215	637252 - 321199780	75	150	34	300	20	6000	734400	1981	120	6	ELECTROMOTOR	150	97/4/24	Planting
87	12I-14D	1/45	BARAWAT	635 - 3215	636534 - 3217987	60	150	63	365	20	7300	1655640	1978	100	8	ELECTROMOTOR	150	97/4/24	Planting
88	12I-15D	1/44	BARAWAT	635 - 3215	636310 - 3217487	65	150	51	365	20	7300	1340280	1981	87	8	ELECTROMOTOR	175	97/4/23	Dirinking water
89	12I-16D	1/43	BARAWAT	635 - 3215	636291 - 3216857	65	150	45	365	20	7300	1182600	1978	87	6	ELECTROMOTOR	120	97/4/23	Dirinking water
90	11J-1D	1/42	RAH AHAN	630 - 3210	631539 - 3213157	100	140	12	365	10	3650	157680	1996	124	4	ELECTROMOTOR		97/4/23	Planting and industrial
91	12J-1D	1/6	BARAWAT MOHALLEH RASHEIDEI	635 - 3210	636870 - 3214734	110	150	32	165	20	3300	380160	1979	123	6	ELECTROMOTOR	160	97/5/6	Planting
92	12J-2D	3/12	BARAWAT	635 - 3210	639246 - 321491997	100	180	0	0	0	0	0	1991	0	6	VOLVO	161	97/5/4	Planting
93	12J-3D	1/61	BARAWAT	635 - 3210	636910 - 3214066	110	160	36	365	18	6570	851472	1979	120	6	ELECTROMOTOR	200	97/5/6	Planting
94	12J-4D	1/65	BARAWAT	635 - 3210	637249 - 3212735	110	180	30	365	15	5475	591300	1979	150	6	ELECTROMOTOR	125	97/5/6	Planting
95	12J-5D	1/63	BARAWAT	635 - 3210	638433 - 3213223	90	150	29	365	20	7300	762120	1981	135	6	ELECTROMOTOR	125	97/5/6	Planting
96	12J-6D	1/64	BARAWAT	635 - 3210	638165 - 3212402	120	160	24	365	15	5475	473040	1993	150	5	VOLVO	161	97/5/6	Planting
97	12J-7D	1/66	BARAWAT	635 - 3210	638123 - 3214536	95	150	43	270	20	5400	835920	1979	129	6	ELECTROMOTOR	200	97/5/7	Planting
98	12J-8D	1/71	BARAWAT	635 - 3210	636900 - 3214232	130	160	33	330	20	6600	784080	1980	140	6	ELECTROMOTOR	150	97/5/11	Planting
99	12J-9D	1/62	BARAWAT SOFLA	635 - 3210	63199749 - 3213593	120	180	25	365	20	7300	657000	1971	150	8	ELECTROMOTOR	250	97/5/6	Planting
100	12J-10D	1/67	BARAWAT	635 - 3210	638130 - 3214530	70	120	14	52	10	520	26208	1993	100	4	ELECTROMOTOR		97/5/7	Industrial
101	13J-1D	1/68	BARAWAT	640 - 3210	640984 - 3214364	75	150	32	365	12	4380	504576	1993	108	6	VOLVO	279	97/5/7	Planting
102	13J-2D	1/7	BARAWAT	640 - 3210	641870 - 3210363	90	180	0	365	20	7300	0	1995	150	6	ELECTROMOTOR		97/5/7	Planting
103	12K-1D	1/69	BARAWAT	635 - 3205	639909 - 3209878	105	108	0	363	22	7986	0	1992		6	ELECTROMOTOR	160	97/5/7	Planting

Source: Regional Water Resources Company of Kerman



Source: JICA Study Team

Figure AP3.1 Standard Design of Borehole

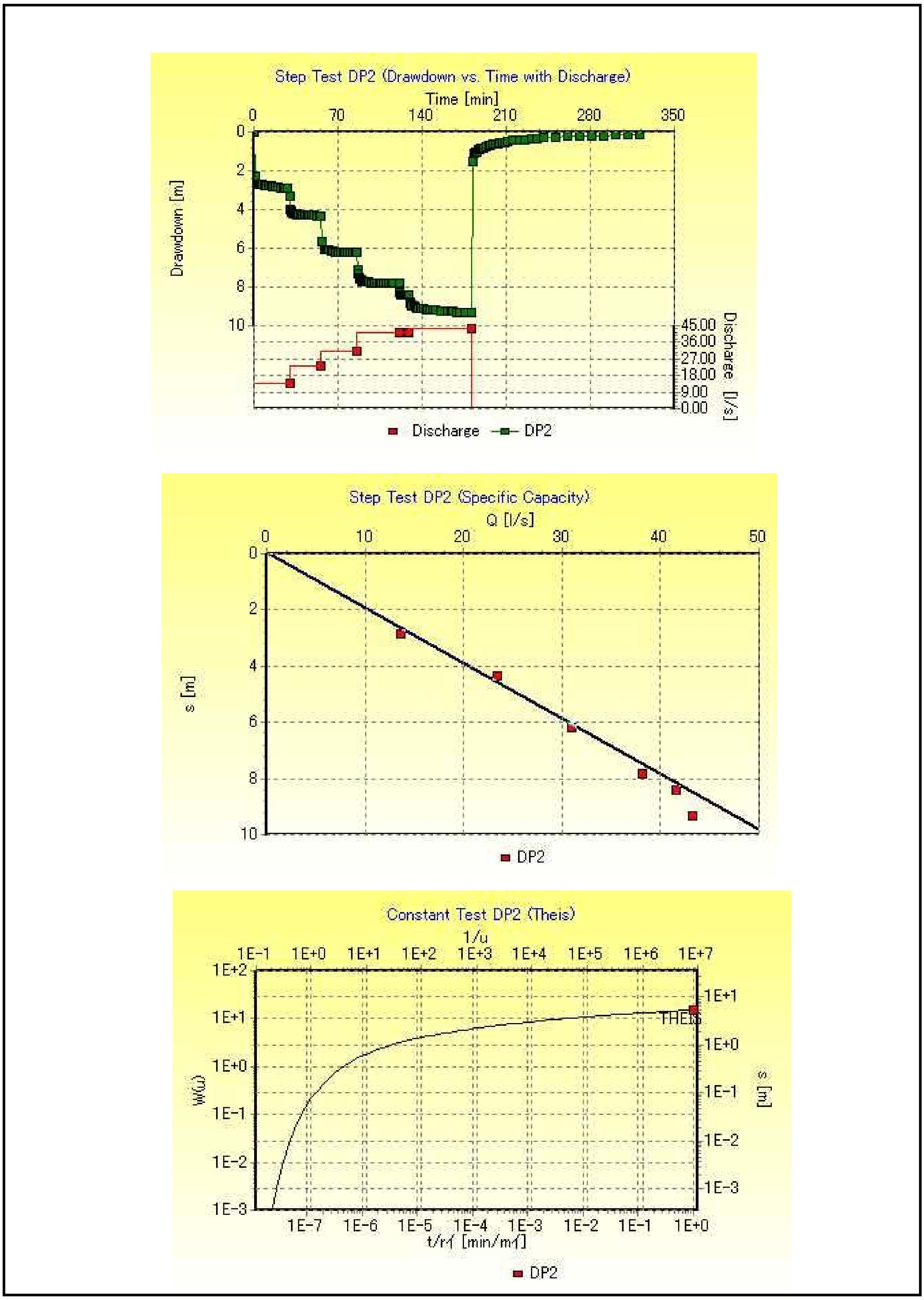


Source: JICA Study Team

Figure AP3.2 Head Facilities of Borehole

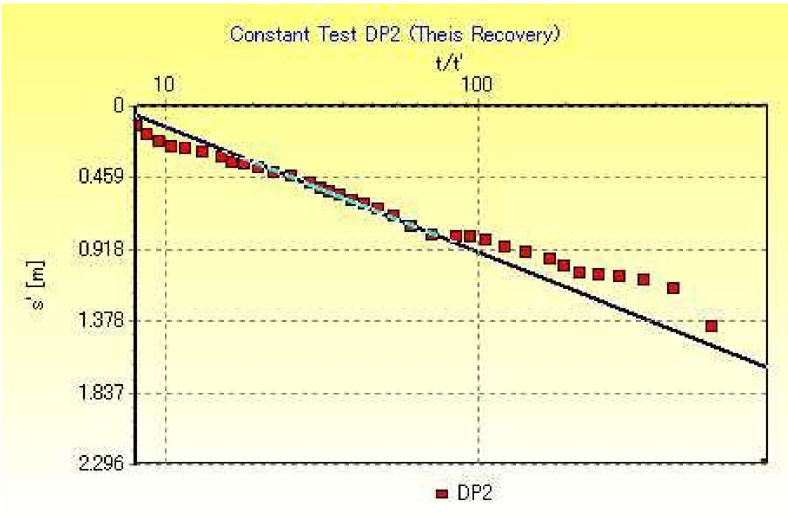
Source: JICA Study Team

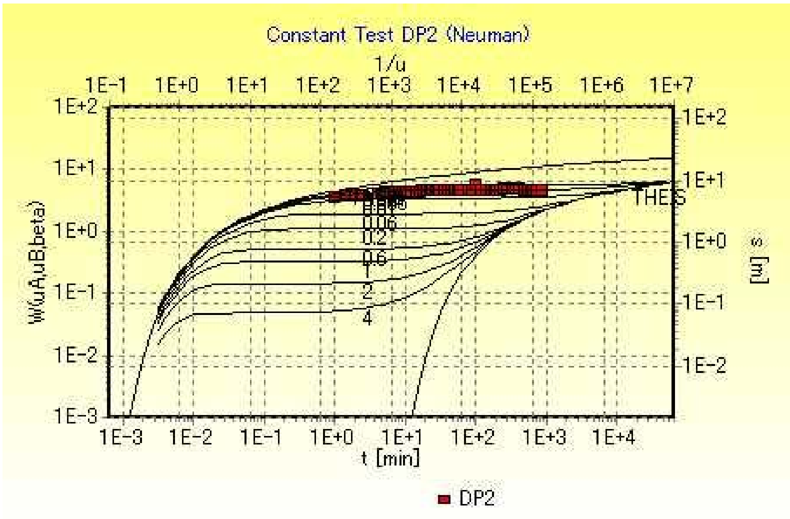
Figure AP3.3 Borehole Emblem



Source: JICA Study Team

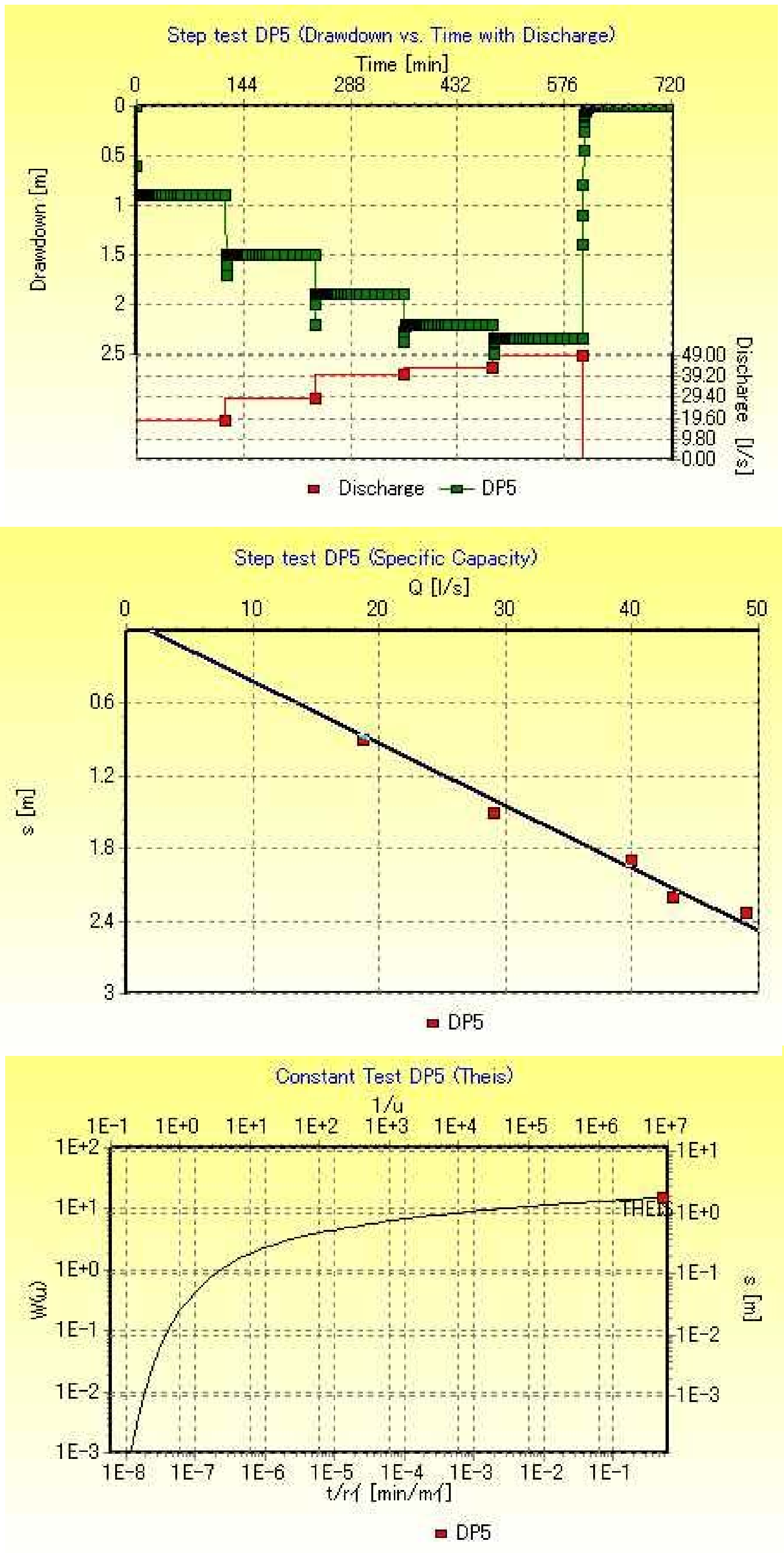
Figure AP3.4 (1) Pumping Test of Test Borehole: No. DP2 (WSCK No.18) (1/2)





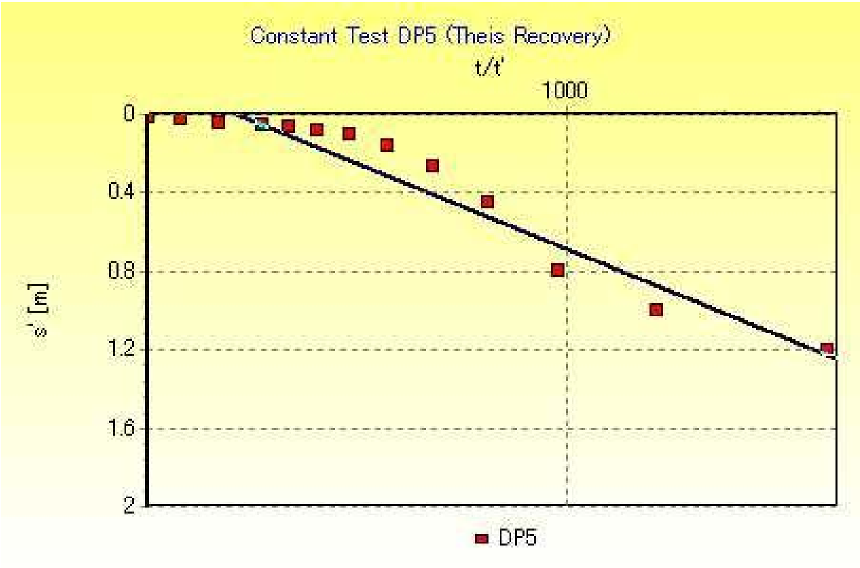
Source: JICA Study Team

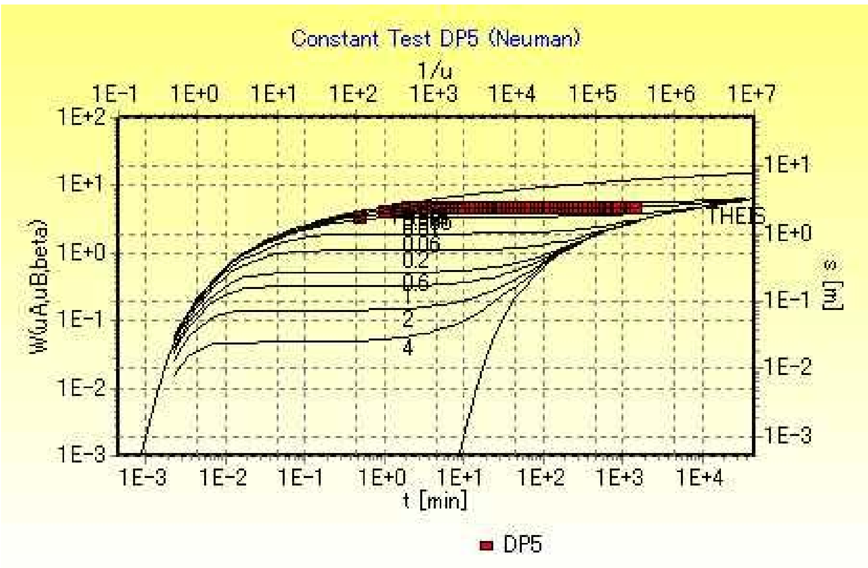
Figure AP3.4 (1) Pumping Test of Test Borehole: No.DP2 (WSCK No.18) (2/2)



Source: JICA Study Team

Figure AP3.4 (2) Pumping Test of Test Borehole: No. DP5 (WSCK No.17) (1/2)





Source: JICA Study Team

Figure AP3.4 (2) Pumping Test of Test Borehole: No. DP5 (WSCK No.17) (2/2)

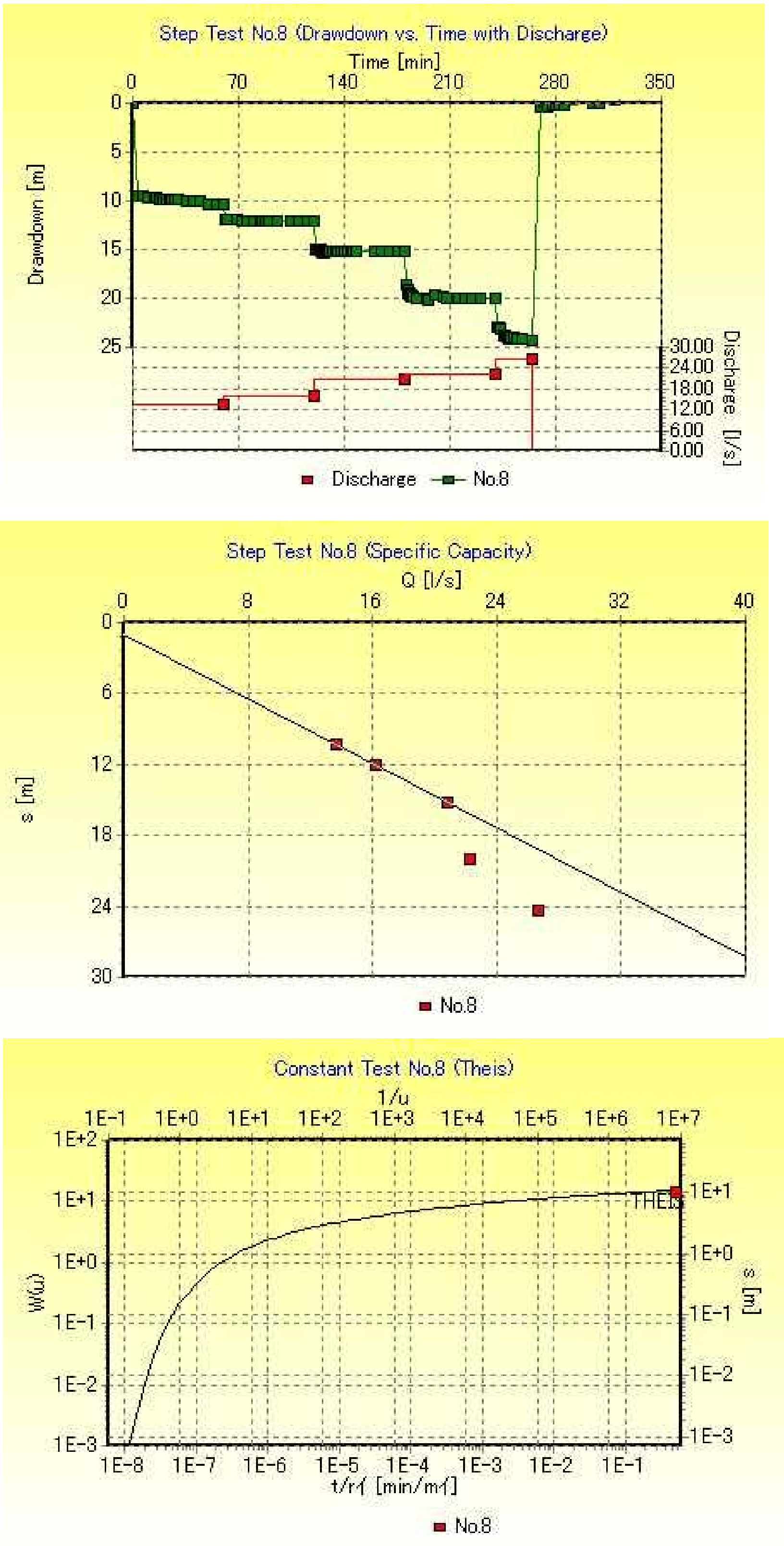
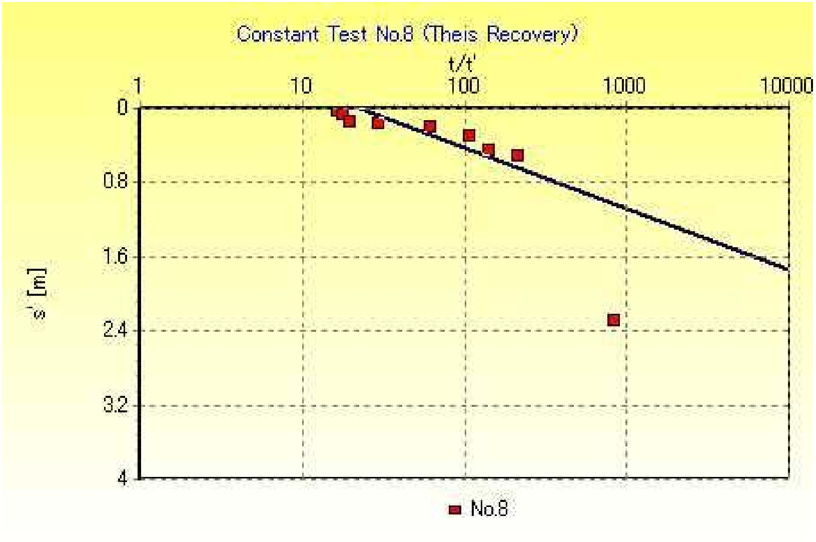
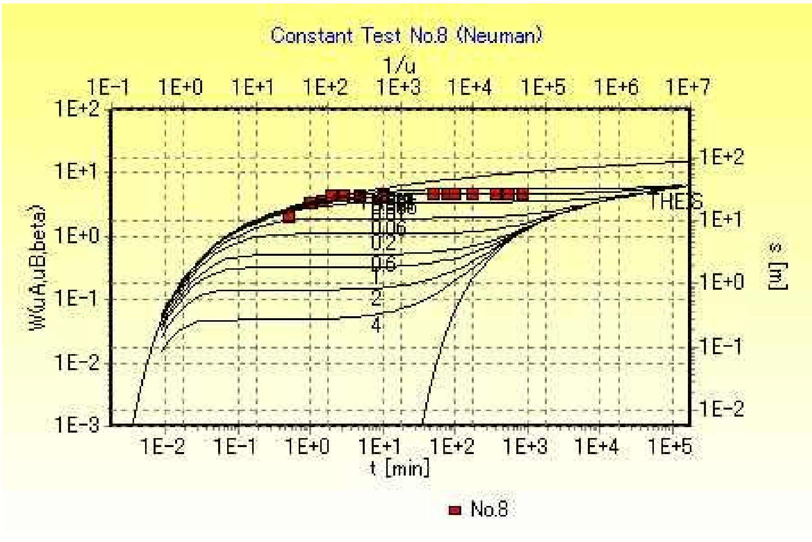


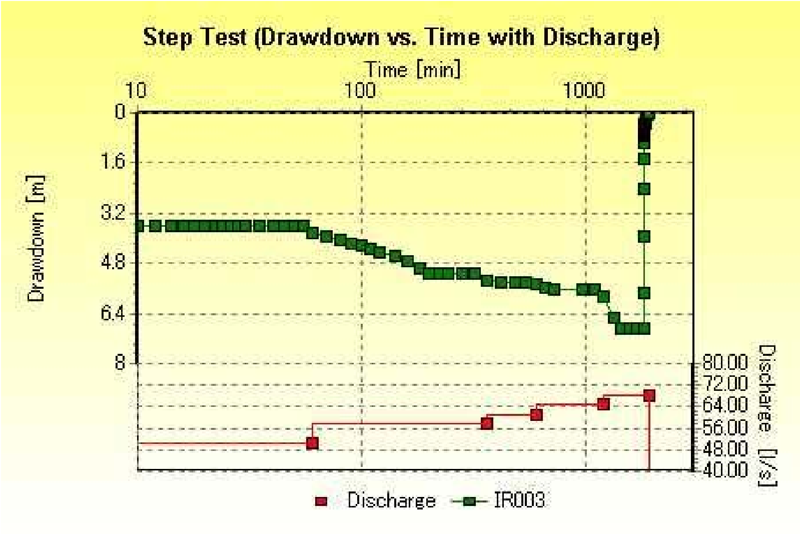
Figure AP3.4 (3) Pumping Test of Test Borehole: No. DP8 (1/2)

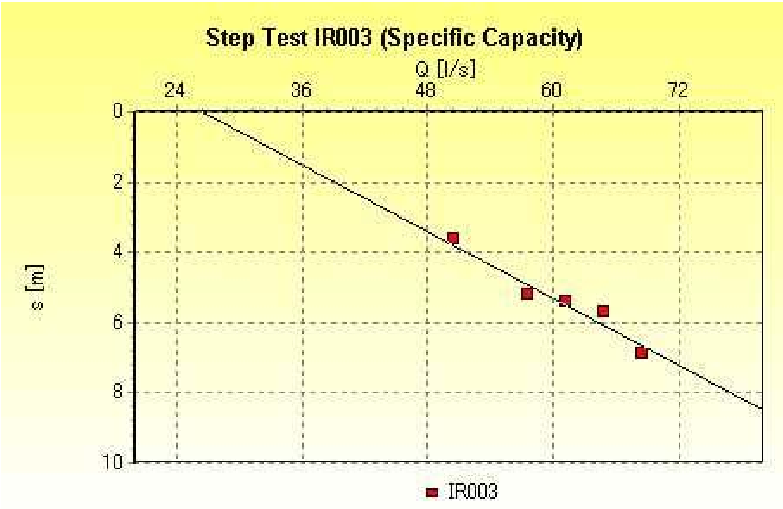




Source: JICA Study Team

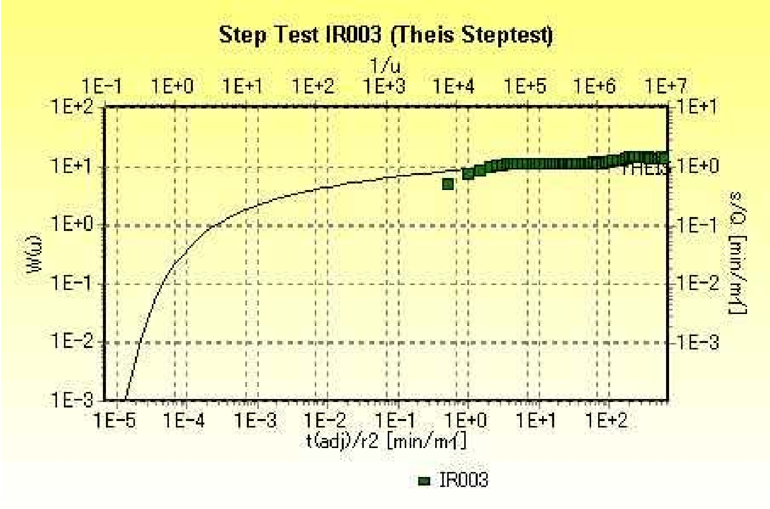
Figure AP3.4 (3) Pumping Test of Test Borehole: No. DP8 (2/2)

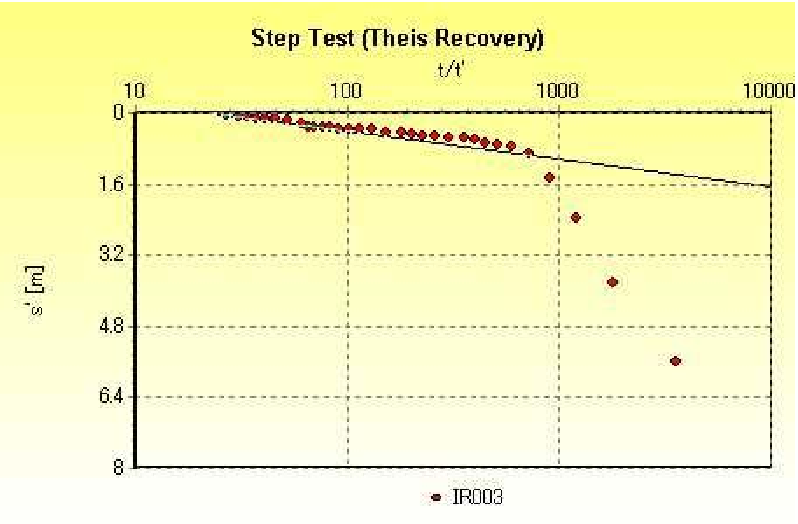




Source: JICA Study Team

Figure AP3.4 (4) Pumping Test of Existing Well: IR003 (1/2)





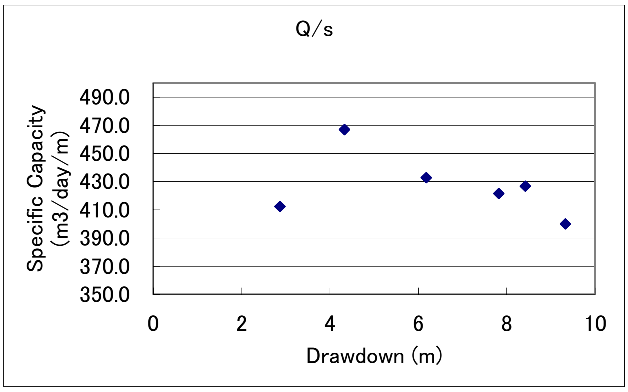
Source: JICA Study Team

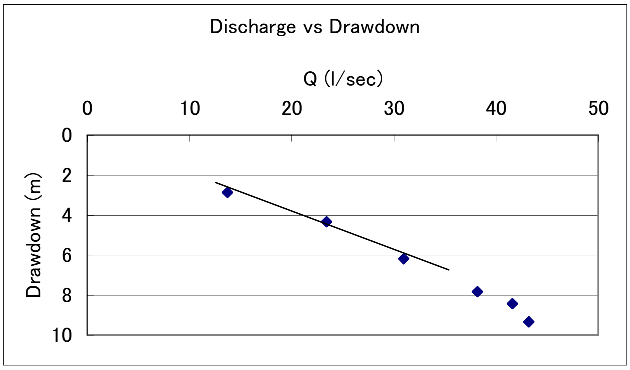
Figure AP3.4 (4) Pumping Test of Existing Well: IR003 (2/2)

2.1 Well Loss Calculation

1) DP2

Q		s	Q/s	S0
l/sec	m3/day			
13.7	1,184	2.87	412.4	0.209489
23.4	2,022	4.33	466.9	0.185043
30.96	2,675	6.18	432.8	0.199612
38.16	3,297	7.82	421.6	0.204927
41.6	3,594	8.42	426.9	0.202404
43.2	3,732	9.33	400.1	0.215972





Source: JICA Study Team

S1: 6.18
Q1: 30.96
S2: 9.3

Q2: 43.2

S1=BQ1+C(Q1)2
S2=BQ2+C(Q2)2

Formation Well
B = ((S1(Q2)2-S2(Q1)2) / (Q1(Q2)2-Q2(Q1)2)
C = (S1Q2-S2Q1) / ((Q1)2Q2-(Q2)2Q1)

B= 0.1600
C= 0.0013

S=0.1600*Q+0.013*Q2

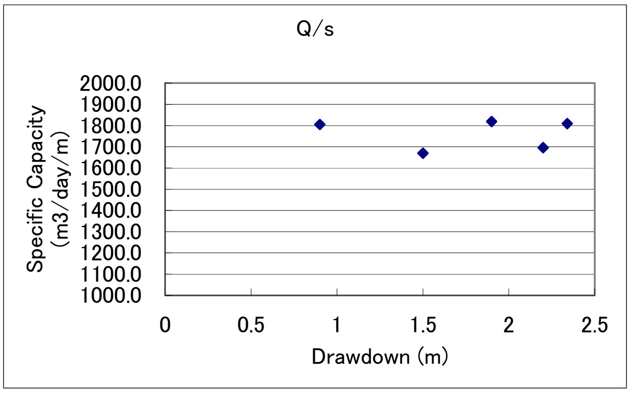
SWL:117.18m

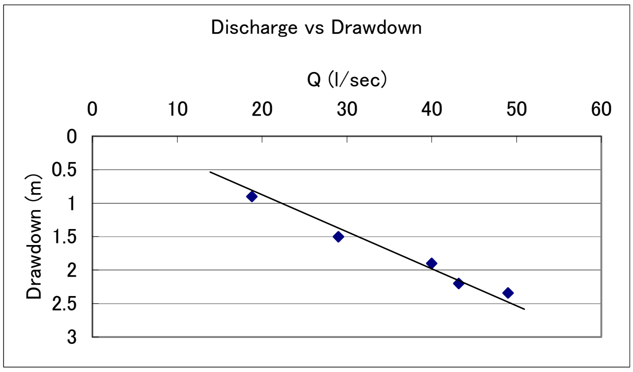
Q(l/s)	S(m)	WL(m)
25	4.8	122.0
30	6.0	123.1
35	7.2	124.3
40	8.4	125.6
45	9.8	127.0
50	11.2	128.4

Depth of Well: 230m

2) DP5

Q		s	Q/s	S0
l/sec	m3/day			
18.8	1,624	0.9	1804.8	0.047872
29	2,506	1.5	1670.4	0.051724
40	3,456	1.9	1818.9	0.0475
43.2	3,732	2.2	1696.6	0.050926
49	4,234	2.34	1809.2	0.047755





Source: JICA Study Team

S1: 0.9
Q1: 18.8
S2: 2.2
Q2: 43.2

S1=BQ1+C(Q1)2
S2=BQ2+C(Q2)2

Formation Well

B = ((S1(Q2)2-S2(Q1)2) / (Q1(Q2)2-Q2(Q1)2)
C = (S1Q2-S2Q1) / ((Q1)2Q2-(Q2)2Q1)

B= 0.0455
C= 0.0001

S=0.0455*Q+0.0001*Q2

SWL:93.20m

Q(l/s)	S(m)	WL(m)
25	1.2	94.4
30	1.5	94.7
35	1.7	94.9
40	2.0	95.2
45	2.3	95.5
50	2.6	95.8

Depth of Well: 203m

3) No.8

Q		s	Q/s	S0
l/sec	m3/day			
13.7	1,184	10.32	114.7	0.753285
16.2	1,400	12.02	116.4	0.741975
20.8	1,797	15.2	118.2	0.730769
22.3	1,927	20	96.3	0.896861
26.64	2,302	24.29	94.8	0.911787

S1: 15.2
Q1: 20.8
S2: 24.29
Q2: 26.64

S1=BQ1+C(Q1)2
S2=BQ2+C(Q2)2

Formation Well

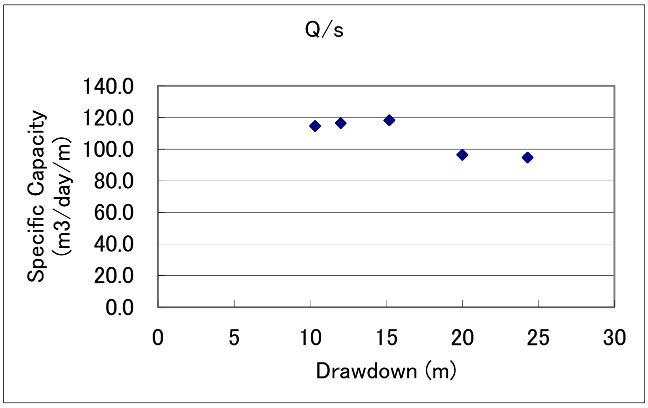
B = ((S1(Q2)2-S2(Q1)2) / (Q1(Q2)2-Q2(Q1)
C = (S1Q2-S2Q1) / ((Q1)2Q2-(Q2)2Q1)

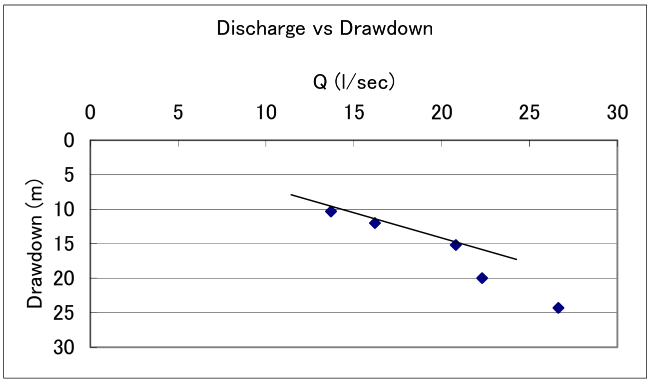
B= 0.0860
C= 0.0310

S=0.086*Q+0.031*Q2

SWL:107m

Q(l/s)	S(m)	WL(m)
25	21.5	128.5
30	30.5	137.5
35	41.0	148.0
40	53.0	160.0
45	66.6	173.6
50	81.8	188.8



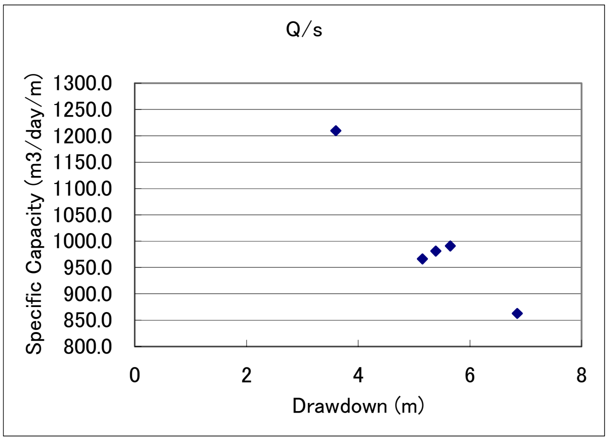


Source: JICA Study Team

4) IR003

Q		s	Q/s	S_0
l/sec	m^3/day			
50.4	4,355	3.6	1209.6	0.07143
57.6	4,977	5.15	966.3	0.08941
61.2	5,288	5.39	981.0	0.08807
64.8	5,599	5.65	990.9	0.08719
68.4	5,910	6.85	862.7	0.10015

S1: 3.6
Q1: 50.4
S2: 5.65
Q2: 64.8



$S1=BQ1+C(Q1)^2$
$S2=BQ2+C(Q2)^2$

Formation Well

$B = ((S1(Q2)^2-S2(Q1)^2) / (Q1(Q2)^2-Q2(Q1)^2)$
$C = (S1Q2-S2Q1) / ((Q1)^2Q2-(Q2)^2Q1)$

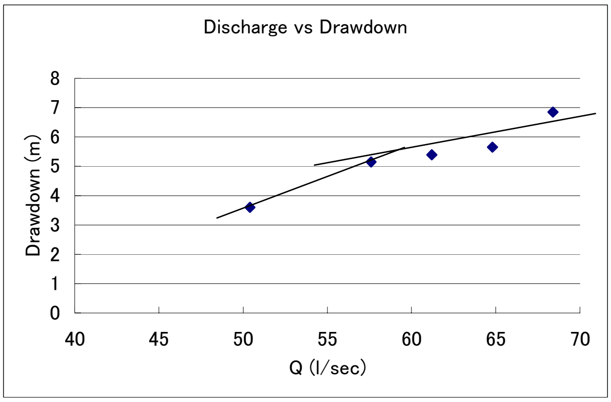
B= 0.0163
C= 0.0011

$S=0.0163*Q+0.011*Q^2$

SWL:22.25m

Q(l/s)	S(m)	WL(m)
25	1.1	23.3
30	1.5	23.7
35	1.9	24.2
40	2.4	24.7
45	2.9	25.2
50	3.5	25.8
55	4.2	26.5
60	4.9	27.2
65	5.7	27.9
70	6.5	28.8

Depth of Well: 120m



Source: JICA Study Team