Chapter 5 Wehda-Irbid Water Supply

CHAPTER 5
WEHDA-IRBID WATER SUPPLY

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5.1 Basic Conditions

(1) Reference Study

Water supply system from Wehda Dam to Irbid was once studied in 1979 by JVA under the name of "Domestic Water Project North Jordan", and the feasibility study report was completed by Stanley Consultants, December 1979. As mentioned below, after more than 20 years, there are some basic points to be reviewed but the report will be utilized for this pre-feasibility study as reference.

(2) Scope of Pre-feasibility Study

Water treatment facilities at the dam site and transfer system including pump stations, pipeline, and reservoirs are to be considered as a scope of pre-feasibility study. Water intake structure and transfer system to the water treatment plant are needed in addition but they are related to the dam development plan (location, water levels etc) and shall be studied in full-scale study.

(3) Completion Year of Wehda Dam and Target Year of the Project

Implementation of Wehda Dam Project has been commenced and completion of dam construction including water filling is scheduled in 2005. Target year of planning for this water supply project is year of 2010, considering the possibility of expansion to the next 10 years MIT water demand and allocation.

(4) Water Allocation from Wehda to Irbid

Since the previous JVA study aimed at the demand of year 2000, it is necessary to consider the demand projection and the water allocation for Irbid Governorate which is proposed in Water Resources Management Master Plan of JICA as shown in Table 5.1.1-1 below.

Table 5.1.1-1 Water Use and Allocation in Irbid

Year	Demand	Surface Water		Groundwater			TWWE Reuse	Total Resource
	M-I-T	Upland	Wehda	Upland	JRV	Fr. MF		
1998	31	4	0	4	21	3	0	32
2005	49	4	22	9	14	0	0	49
2010	67	4	40	10	8	0	5	67

TWWE: Treated wastewater effluent

(5) Locations of Water Treatment Plant and Transfer Pump Station

Locations of water treatment plant and transfer pump station are as proposed in JVA study in 1979 because there is no significant obstacle found in the field reconnaissance and hearing survey in WAJ-Irbid on April 28th and May 7th, 2001.

(6) Route of Piping and Terminal Reservoir

Alternative routes of piping and terminal reservoir shown in Fig. A-5.1-1 will be considered in the study in place of the one proposed in JVA study 1979 because urban development in Irbid has shown a different aspect from then especially in northern area.

5.2 Review on Design Raw and Treated Water Quality

5.2.1 Current Water Quality of Yarmouk River

In the reference study, there were some water quality analysis data of Yarmouk River as summarized in Table 5.2.1-1. However water quality changed somewhat in these twenty years and therefore current water quality data are to be considered in the pre-feasibility study.

Table 5.2.1-1 Water Quality Data Wehda Dam Site (1979)

Site Name		Al- Wehda Dam Site			
Parameter	Unit	July	Sept.	Oct.	Nov.
EC	μS/cm	800	760	722	610
TDS	mg/L	472	424	439	452
PH	-	8.30	8.25	8.20	8.25
Na	mg/L	102.3	55.5	61.5	65.0
K	mg/L	3.5	6.3	4.6	4.8
Ca	mg/L	24.1	36.7	56.1	30.2
Mg	mg/L	25.3	26.7	12.1	24.9
Cl	mg/L	90.5	84.8	84.8	79.1
SO_4	mg/L	78.2	65.4	64.2	59.7
HCO_3	mg/L	237.9	219.6	213.5	210.5
NO_3	mg/L	11.0	15.0	48.0	14.0
NH_3	mg/L	0.06	0.14	0.52	0.32
P_2O_5	mg/L	trace	Trace	trace	trace
Fe	mg/L	0.09	0.00	--	--
Total Hardness	mg/L	164.1	201.6	--	--
Total Alkali	mg/L	195.0	180.0	--	--
Color	--	2.0	10.0	10.0	10.0

Source: Reference JVA Study
Color is measured on the filtrate using standard platinum cobalt procedure.

Regarding water quality at the Wehda Dam site, Jordan Valley Authority (JVA) has conducted sampling and analysis from two locations – Bridge and Al Hadier. Table 5.2.1-2 shows the maximum, minimum and average values of the water quality data for 12 parameters.

Table 5.2.1-2 JVA Water Quality Data for Wehda Dam (1995-2000)

Site Name		Al- Wehda Dam Bridge			Al- Wehda Dam -Al Hadier		
Parameter	Unit	Ave.	Max.	Min.	Ave.	Max.	Min.
EC	μS/cm	845	1060	770	988	1240	810
PH	-	8.36	8.6	8	8.4	8.65	7.98
Na	mg/L	92.07	124.2	80.5	105.55	138	68.31
K	mg/L	6.76	10.56	4.3	10.71	14.86	4.69
Ca	mg/L	52.87	76.15	26.65	72.06	164.33	36.07
Mg	mg/L	23.84	34.52	13.37	28.47	65.64	13.37
Cl	mg/L	96.92	120.88	80.83	123.22	152.79	85.08
SO_4	mg/L	59.76	95.11	19.21	68.93	105.68	14.41
HCO_3	mg/L	250.34	281.82	219.6	274.26	317.2	231.8
NO_3	mg/L	27.11	53.29	19.4	38.34	48.6	19.54
B	mg/L	0.21	0.49	0.09	0.33	0.64	0.13
SAR	-	2.65	3.29	2.36	2.76	3.52	1.46

Source: JVA Laboratory

Recently, in order to study the quality of water from different sources to the King Abdullah Canal (KAC), the Laboratory of Water Authority of Jordan (WAJ) and Royal Scientific Society (RSS) have started water quality monitoring programs at different locations along the KAC. One of their samples is collected from the water source from the Yarmouk River. The analysis results are shown in Table 5.2.1-3 and Table 5.2.1-4.

From these data, it is understood that the quality of water at the dam site, i.e. from the Yarmouk River is generally good as the source water for domestic water supply. The average salinity is about 1000 μS/cm as EC or about 650 mg/L as TDS if a factor of 0.65 between these two parameters is considered, and the constituent ions such as Cl, SO4, NO3, Na are with concentrations lower than the maximum allowable levels of the Jordanian Drinking Water Quality Standard (JS-286). However, although the concentration of Chl-a which is an indicator of algae growth is not high, the occasionally high value of T-P indicates that the nutrient level is not low and algae growth may occur in the summer season, especially after the water is stored in the dam. Turbidity or suspended solids (SS) data are unavailable, but it is considered that during storage in the dam most of the coarse particulate matters can be settled out, and the water turbidity may be low or moderate. Contrarily, floating substances including those from the incoming water and those from algae growth in the dam may be a factor to be considered in the design of the water treatment plant.

Table 5.2.1-3 WAJ Water Quality Data for Yarmouk River

Item	EC	PH	NO_3	PO_4	Chl-a	TOC	Odor	NH_4
Unit	μS/cm	-	mg/L	mg/L	μg/L	mg/l	TON	mg/L
Jan-99	1012	8.4	16.4	1.1	-	2.56	-	1.5
Feb-99	1047	8.34	18.18	0.95	-	1.75	8	0.13
Mar-99	1044	8.39	16.7	0.66	-	-	-	0.11
Apr-99	1070	8.35	16.61	0.65	-	2.37	4	0.12
May-99	1124	8.23	20.34	0.42	-	2.09	8	0.12
Jun-99	1037	8.32	17.54	0.24	-	2.68	17	0.11
Jul-99	985	8.92	11.16	0.34	-	1.83	17	0.16
Aug-99	988	8.22	10.58	0.39	-	1.83	17	0.11
Sep-99	969	8.42	7.35	0.26	2.4	1.68	12	0.12
Oct-99	1062	8.33	11.19	0.28	2.27	2.31	17	0.15
Nov-99	1062	8.33	11.19	0.51	2.27	2.32	12	0.16
Dec-99	1040	8.3	13.45	0.45	3.23	2.34	12	0.16
Jan-00	980	8.29	23.04	0.46	1.7	4.14	8	0.17
Feb-00	996	8.34	23.14	0.49	1.95	2.2	12	0.13
Mar-00	631	8.29	20.6	0.63	1.76	2.19	17	0.13
Apr-00	1079	8.43	17.98	0.37	1.86	2.06	17	0.26
May-00	715	8.33	17.45	0.19	2.27	1.8	17	0.26
Jun-00	1103	8.23	14.95	0.16	2.08	1.7	17	0.2
Jul-00	1029	8.18	9.13	0.1	2.43	1.05	17	0.1
Aug-00	1014	8.2	7.43	0.08	2.76	1.43	12	0.1
Average	999	8.34	15.22	0.44	2.25	2.12	13.4	0.22

Table 5.2.1-4 RSS Water Quality Data for Yarmouk River

Item	DO	PH	NO_3	T.Kj-N	PO_4-P	T-P	TOC
Unit	mg/L	-	mg/L	mg/L	mg/L	mg/L	mg/L
Aug-98	8.1	7.8	11.6	1	0.3	0.1	-
Sep-98	7.8	8.1	12.1	1	0.5	0.2	-
Oct-98	7.5	8.32	12.8	1.1	0.5	0.2	-
Nov-98	7.5	8.36	13	1	0.77	0.36	2
Dec-98	4	8.14	2	1	0.06	0.1	3
Jan-99	8.5	8.24	16	2	0.95	1.97	7
Feb-99	6.6	8.3	15	1	0.59	0.28	2
Mar-99	6.6	8.5	16	1	1.15	0.74	4
Apr-99	6	8.54	16	1	0.55	0.37	2
May-99	6.3	8.5	22	1	0.33	0.25	2
Jun-99	7.2	8.57	24	1	0.26	0.19	2
Jul-99	6.8	8.5	23	1	0.25	0.11	2
Aug-99	6.2	8.45	20	1	0.23	0.43	2
Average	6.86	8.33	15.65	1.08	0.5	0.41	2.8

5.2.2 Required Quality by Treatment

The Jordanian drinking water quality standard was regulated in 1997 as JS-286 for Water - Drinking Water by the Department for Standards and Metrology. Table 5.2.2-1 summarizes all the parameters and their standard values. Water treatment of this project shall have the process to satisfy these requirements.

Table 5.2.2-1 Jordanian Drinking Water Quality Standard

Item	Maximum Allowable Level	Maximum Limit Level
(1) Bacteriological parameters		
Total coliform	1.1 MPN/100 mL (multi-tube method) MPN free from 100 mL sample (membrane filtration method)	
Thermotolerant coliform	Free from 100 mL sample	
Disease germs and intestinal viruses	Free from 100 mL sample	
* Drinking water should be free from all phases of living microorganisms		
(2) Aesthetic parameters		
Taste	No abnormality	
Odor	No abnormality	
Color (unit)	10	15
Turbidity	1	5
Residual free chlorine	0.2 – 1.0 mg/L after contact time for 15 min	
(3) Parameters with negative effects (mg/L)		
PH	6.5 – 8.5	
TDS	500	1500
Total Hardness	100	500
MBAS	0.2	0.5
NH_4	0.5	
Al	0.1	0.2
Mn	0.1	0.5
Fe	0.3	1.0
Cu	1.0	1.5
Zn	3.0	5.0
Na	200	400
Cl	200	500
SO_4	200	500
(4) Health significant parameters (mg/L)		
As	0.01	
Ba	0.2	
Pb	0.01	
Se	0.01	
B	0.3	
Cd	0.003	
Cr	0.05	
CN	0.07	
Hg	0.002	
Ni	0.1	
Sb	0.2	
F	0.005	
NO_2	1.5	
NO_3	50	70*
TTHM (μg/L)**		
* In case no other resource available		

Item	Maximum Allowable Level	Maximum Limit Level
** Include bromoform, dibromochloromethane, bromodichloromethane, chloroform		
(5) Radioactive constituents (Bq/L)		
Alpha emitters	0.1	
Beta emitters	1.0	
(6) Organic chemicals (mg/L)		
Parathion	0.035	
Endrin	0.0002	
Lindane	0.004	
Methoxychlor	0.1	
Toxaphene	0.005	
Malathion	0.15	
Permethrin	0.002	
Dimethoate	0.02	
Diazinon	0.02	
BHC	0.04	
Chlorophenoxy acids		
2,4-D	0.1	
2,4,5-TP	0.01	
* The grand total for pesticides should not exceed 0.1 mg/L		

5.3 Review on Water Treatment Plant

5.3.1 Consideration on Treatment Process

A problem that extremely bad taste and odor from the potable water supplied from the Zai water treatment plant arose in July through August 1998 and it was not possible to eliminate these taste and odor with the current treatment system. Investigations were conducted by the Government of Jordan, WHO and others, and it was learned as a result that the taste and odor, dead nematodes are caused by algae.

In the KAC, which is the supply source for the Zai water treatment plant, the flow velocity of the water through the canal is slow and the stay time is long. Therefore, silt, sludge and organic matters tend to accumulate at the bottom of the canal, and this sediment accelerate breeding of algae under various conditions such as staying for a long time, appropriate nutritive salts, water temperature and sunlight. The accurate reaseon of the problem is not clear, but it is considered that algae and nemarodes bred in silt and sediment of organic matters in the KAC.

It is considered that the raw water from Wehda dam may have the same problem of algae and therefore the countermeasures to the problem should be incorporated in the design of the water treatment plant for Wehda Irbid water supply.

Points to be considered are as follows.

(1) Changing the activated charcoal filling point

(2) Changing the coagulant

(3) Increasing activated charcoal filling rate

(4) Change to potassium permanganate filling point

(5) Filling chlorine dioxide

(6) Changing mixing basin mixing method

(7) Provision of floc formation basin rectifier wall (perforated inlet wall) and filling of high molecular coagulant

(8) Provision of sedimentation basin rectifier wall (perforated outlet wall)

(9) Filling high molecular coagulant for backwashing sand filtration equipment

(10) Change filtration basin backwash method

(11) Adjustment of filtration basin washing wastewater recovery rate

5.3.2 Preliminary Design

It needs to examine implementation of identical improvement in the water purification system. Preliminary design of the treatment plant is shown in Fig. 5.3.2-1 and Fig. 5.3.2-2. The configuration of the plant are described below:

(1) Intake pump station

It is desirable that chlorine dioxide is filled at the intake pump station. The merits of filling of chlorine dioxide are that generation of trihalomethane is minor, effective for non-activation of algae and nematodes and it is possible to eliminate taste and odor. It is also possible to suppress activated charcoal filling rate as a result. Joint use of potassium permanganate is even more effective.

(2) Regulating reservoir

Filling of activated charcoal, potassium permanganate and pre-chlorine before the regulating reservoir is planned. With activated charcoal, it is necessary that it is filled into the raw water before coagulant is filled, and that sufficient contact time is secured for eliminating taste and odor.

Filling of activated charcoal at the intake pump station is optimum when contact time is taken into account, but filling of activated charcoal at a pump station should be avoided because activated charcoal accelerates wear to equipment such as pumps and causes damage to them. Therefore, the regulating reservoir is used as the activated charcoal contact reservoir, and flow obstructing plates are provided in the reservoir to prevent occurrence of short-circuiting flow, to secure contact time and to prevent sedimentation of activated charcoal.

As potassium permanganate is also effective for non-activation of algae and nematodes, their filling at the intake pump station is desirable. The contact time is long if they are filled in the intake pump station. Therefore, their effect is large.

(3) Mixing basin

Filling of activated charcoal and aluminum sulfate is planned at the mixing basin. If activated charcoal and aluminum sulfate are filled simultaneously, however, particles of activated charcoal become nuclei of flocs before activated charcoal absorbs taste and odor and the effect of activated charcoal is no exhibited. Therefore, activated charcoal is filled in the regulating reservoir as stated earlier.

Regarding aluminum sulfate, it is considered that use of ferric sulfate is more suitable because the pH level of the raw water is high and ferric sulfate is expected to form heavier flocs for treatment of nematodes. Besides, use of ferric chloride will also be examined. But ferric sulfate is adopted from the viewpoints of economy, ease of handling and that it needs to select corrosion resistant materials for the equipment to be used.

(4) Floc formation basin

A mechanical flocculator will be adopted for effective formation of flocs. The flocculator will be of such an arrangement that the first row is of high speed and the second and third rows are of low speed. But the first row will be of variable speed for forming larger flocs. The high molecular coagulant to be filled as auxiliary polymer coagulant will be of cation type. It will be filled in the vicinity of the flocculator impeller, for increasing the coagulation effect.

(5) Sedimentation basin

The sedimentation basin will be of cross flow type, and a sludge scraper will be installed. Since the trough of a sedimentation basin may trigger formation of short-circuiting flow and dead area, whether it will be provided or not will be determined upon examination. A system that positively causes sedimentation of as small flocs as possible in the sedimentation basin will be adopted. Furthermore, nonionic high molecular coagulant will be injected to the sedimentation basin supernatant water, to positively seize flocs, which overflow from the sedimentation basin to the filtration basin, in the filtration basin.

(6) Filtration basin

The multi-layer filtration system that is composed of anthracite, filtering sand and gravel will be adopted to cope with high filtration rate. Furthermore, the backwash method will be changed to air cleaning + backwash method from surface wash + backwash, so that large agitation effect can be obtained for preventing breeding of nematodes. Furthermore, high molecular coagulant will be injected with enhancement of backwash effect as the objective.

(7) Chemical injection equipment

The following chemicals will be used.

- Chlorine dioxide — Non-activation of algae and nematodes, oxidation of taste and odor generating substances
- Potassium permanganate — Same as above
- Activated charcoal — Elimination of taste and odor, reduction of trihalomethane precursor
- Ferric sulfate — Effective formation of flocs
- High molecular coagulant (cation type) — Assisting coagulation
- High molecular coagulant (anion type) — Assisting coagulation
- High molecular coagulant (nonionic type) — Cleaning of filtration basin
- Caustic soda — pH adjustment
- Intermediate chlorine, post chlorine Sterilization

It is considered that the frequency of use of caustic soda for pH adjustment is minor because the pH level of the raw water is high.

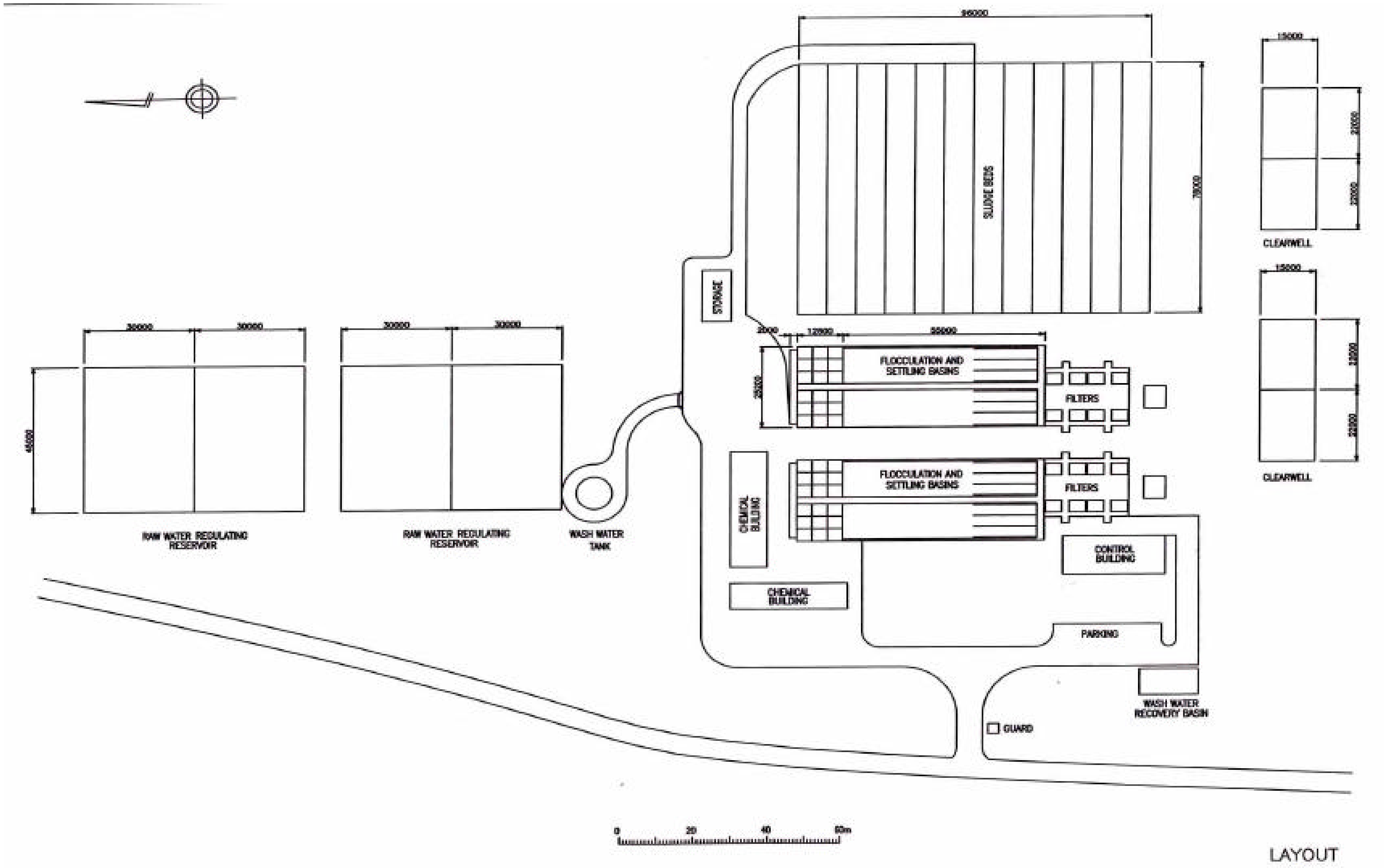

Fig. 5.3.2-1 Preliminary Layout of Treatment Plant

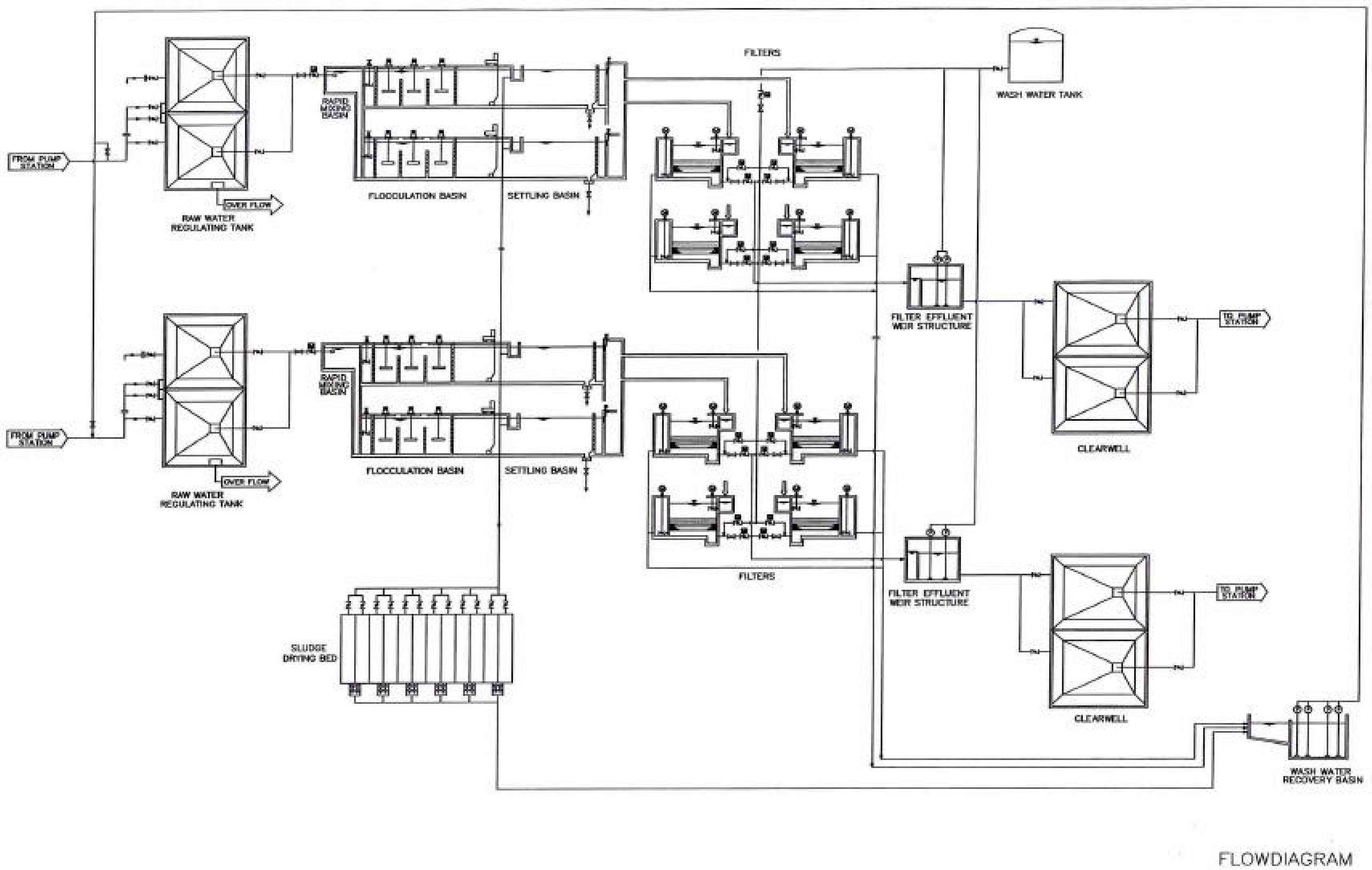

Fig. 5.3.2-2 Preliminary Flow-diagram of Treatment Plant

5.4 Review on Transfer Pump Station

5.4.1 Pump System

(1) Type of Pump

There are two types of pump shaft and they are vertical shaft type and horizontal shaft type.

<u>Vertical type</u>

Advantage :

a. Motor can be installed above water level to avoid immersion but as for this pump station, it is not connected with river or lake.Therefore there is no risk of immersion of motor.

b. Less space for pump and motor.

Disadvantage :

a. Height of pumping station become high or excavation become deep.

b. Dynamic weight on the pump floor is heavier than horizontal shaft pump.

c. Maintainability is inferior.

<u>Horizontal shaft pump</u>

Advantage :

a. Height of pumping station become low or excavation become shallow.

b. Dynamic weight on the pump floor is lighter than vertical shaft pump.

c. Maintainability is good.

Disadvantage :

a. Floor space of the pump house is somewhat larger than the house for vertical pump. But it is able to reduce floor space if staggered arrangement is adopted.

Since pumps will be operated 24hours continuously, periodically check and maintenance of the equipment are very important to maintain soundness of the pump station. Therefore horizontal shaft pump is selected in view of good accessibility and maintainability.

The pump has plural impeller due to very high total head (291.6m). That is multi-stage pump. Approx. three stage pump is applied.
Therefore type of the pump is horizontal shaft type, double suction multi-stage volute pump.

(2) Pump Station Arrangement

The pump specifications which should be taken the system and the future improvement into consideration. The pump station has one set main pump and motor additionally as spare to make possible supplying enough water even maintenance period or during repairs on trouble unit. For the point of dangerous decentralization, it is better to increase number of pumps.

However initial cost and maintenance fee will rise in proportion to the number of unit increases. Three duty unit and one spare unit are installed in the pump station take water demand of year 2005 and 2010 into consideration.

Discharge capacity of each pump is one third of water demand of year 2010. That is 0.424m3/s. (25.4m3/min.) Total head of pump is 291.6m. If two pump units are operated, much water will be supplied than water demand of year 2005. (Supplied water: more than 26.7MCM > Water demand: 22MCM) If three pump units are operated, much water will be supplied than water demand of year 2010.(Supplied water: 40.1MCM > Water demand : 40MCM)

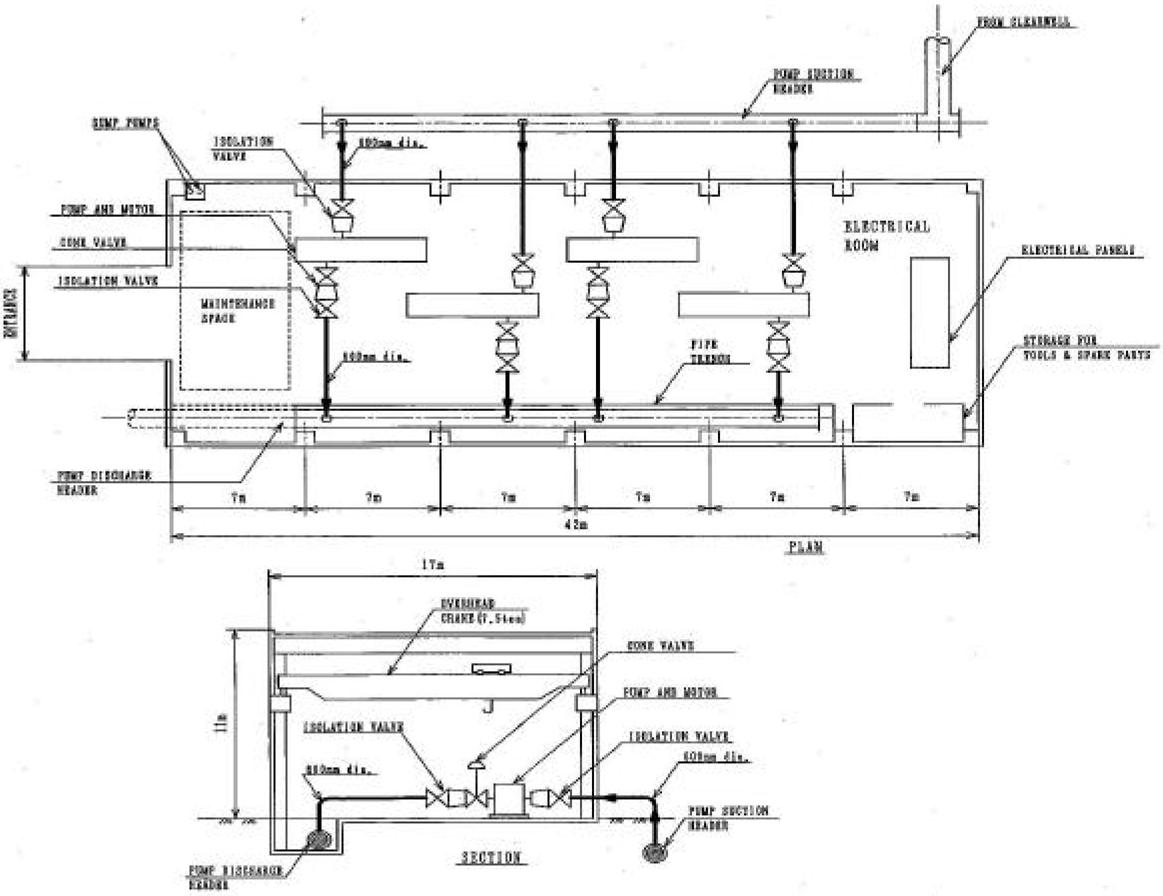

Fig. 5.4.2-1 Preliminary Arrangement of Pump Station

5.4.2 Electrical Arrangement

Specifications of the pump drive motor are 1700kW, 4pole, 1500rpm(S.S) induction motor. Voltage of the motor is 6.6kV, 50Hz that is standard voltage for 1700kW output. In order to reduce starting current, the motor will be started by reduced voltage start such as Kondorfer start method. Single line diagram for the pump station is attached for reference.

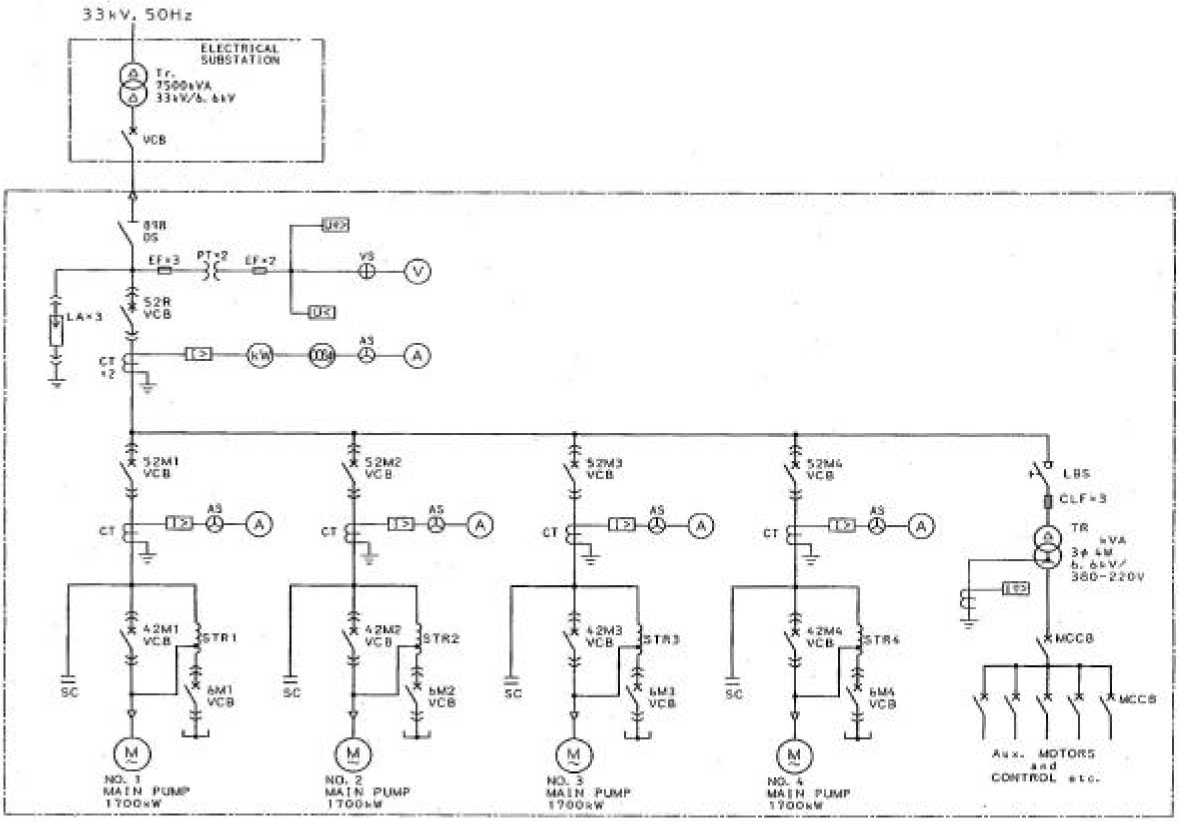

Fig. 5.4.2-2 Preliminary Electrical Single Line Diagram

5.5 Review on Pipeline

5.5.1 Review on Pipe Diameter and material Based on Water Allocation

Pipe diameter and material were reviewed in Japan. There are several pipe materials. Steel, ductile iron, and pre-stressed concrete are mainly used for water transmission systems. But considering with high internal pressure of this pipeline, steel is the recommended as pipe material. In the reference study also, steel pipe with coating protection is recommended as material and seems quite acceptable for the preliminary design.

For the diameter of the pipe three diameters were anticipated preliminary of 1,100 – 1,300 mm from the water quantity to be transferred as summarized in Table 5.5.1-1. Total length of pipe for Alternative-1 is approximately 24 km from the water treatment plant to the terminal reservoir at Zabda.

Among the three alternatives, diameter of 1,100 mm was adapted considering the initial construction cost of pipeline and transfer pump station and operation cost of electricity for life time.

Table 5.5.1-1 Cost Comparison by Pipe Size

1. Electrical Power Cost			
Pipe Diameter (mm)	1000	1100	1200
1－1. PumpStation No,2～Beit Ras (11.5km)			
Q 1 (m^3/sec)	1.27	1.27	1.27
V 1 (m/sec)	1.62	1.34	1.12
Pipeline Loss1 (m)	27.2	17.1	11.2
1－2. Beit Ras～Terminal Reservior (12km)			
Q 2 (m^3/sec)	1.15	1.15	1.15
V 2 (m/sec)	1.46	1.21	1.02
Pipeline Loss2 (m)	23.0	14.5	9.5
Total Pipeline Loss (m) (Loss1+Loss2)	50.2	31.6	20.7
Total Head (m)	310.2	291.6	280.7
Pump Output (kW)	5433	5107	4916
Electrical Power Cost (JD/hr) (1kWh=0.034JD)	184.7	173.6	167.1
Electrical Power Cost (JD/30years×365days)	48,548,805	45,631,601	43,925,715
2. Initial cost			
2－1. Steel Pipe Price (23. 2km)	10,556,000	12,272,800	14,152,000
2－2. Pipe Installation			
2－2－1. Excavation (23. 2km×3. 5JD/m^3)	324,800	397,880	470,960
2－2－1. Backfill (23. 2km×2. 5JD/m^3)	232,000	284,200	336,400
2－3. Pump Facility (JD)	2,200,000	2,200,000	2,200,000
2－4. Electrical Facility (JD)	2,410,000	2,380,000	2,360,000
2－5. Water Hammer Facility (JD)	410,000	390,000	380,000
Total Initial Cost (JD)	16,132,800	17,924,880	19,899,360
Total Cost (JD)	64,681,605	63,556,481	63,825,075
Total Cost (%)	101.8	100.0	100.4

5.5.2 Reconnaissance on the Proposed Piping Route

Based on the reconnaissance on the proposed pipeline in the reference study, two alterntive transfer pipelines are considered. Original and alternative pipelines from the pump station in the water treatment plant to the terminal reservoirs (Originally proposed reservoir and existing Zabda or Houfa reservoirs) are shown on Fig. 5.5.2-1 and its longitudinal section and hydraulic grade line is typically shown for Pipe Route Alternative-1 on Fig. 5.5.2-2.

a. Wehda-Irbid City

From Dam to Irbid City pipeline route is mostly agricultural field and there is no significant obstacles found in the reconnaissance. In Alternative-1, western route is taken in order to avoid heavy traffic and urban area.

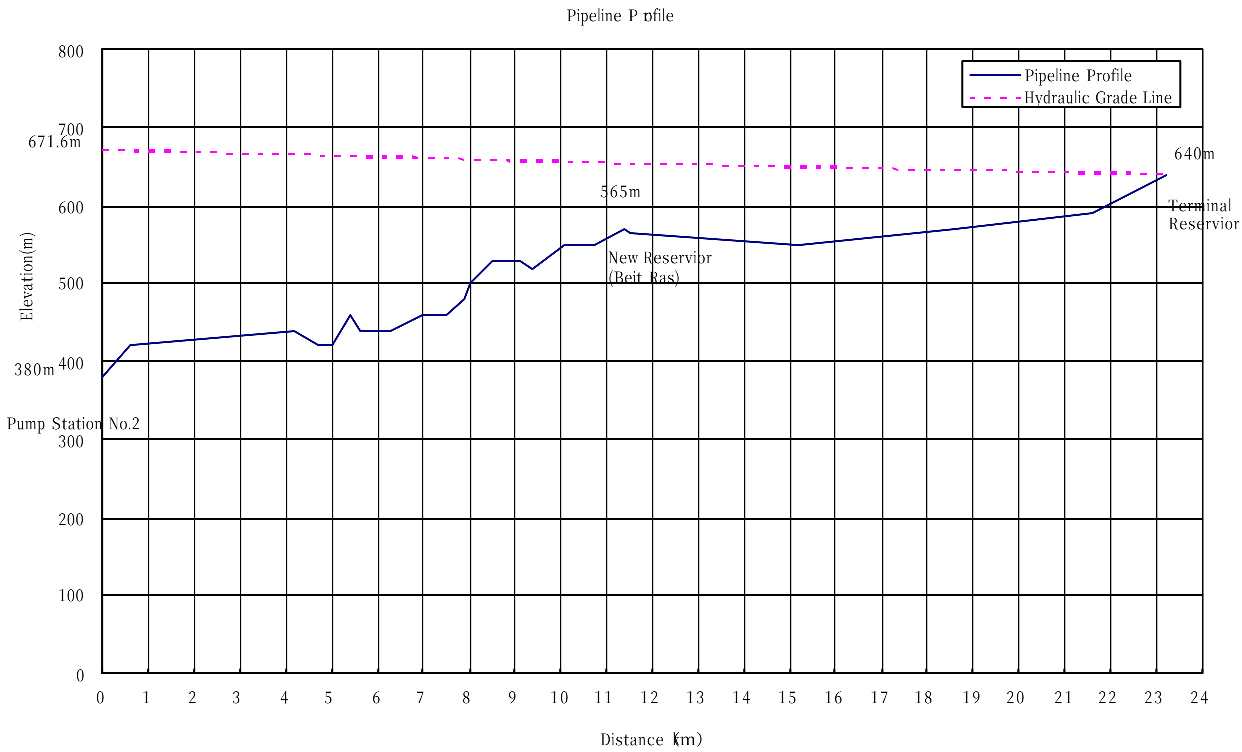

Fig. 5.5.2-1 Profile of Proposed Route

b. Inside the Irbid City

Pipe route proposed in 1979 and Alternative-1 inside the city of Irbid to Zabda terminal reservoir are shown on the Fig. 5.2.2-2. Original pipe route passes in rather hardly urbanized areas but Alternative-1 runs along perimeter of the current urban area, which is avoiding inconvenience during construction period.

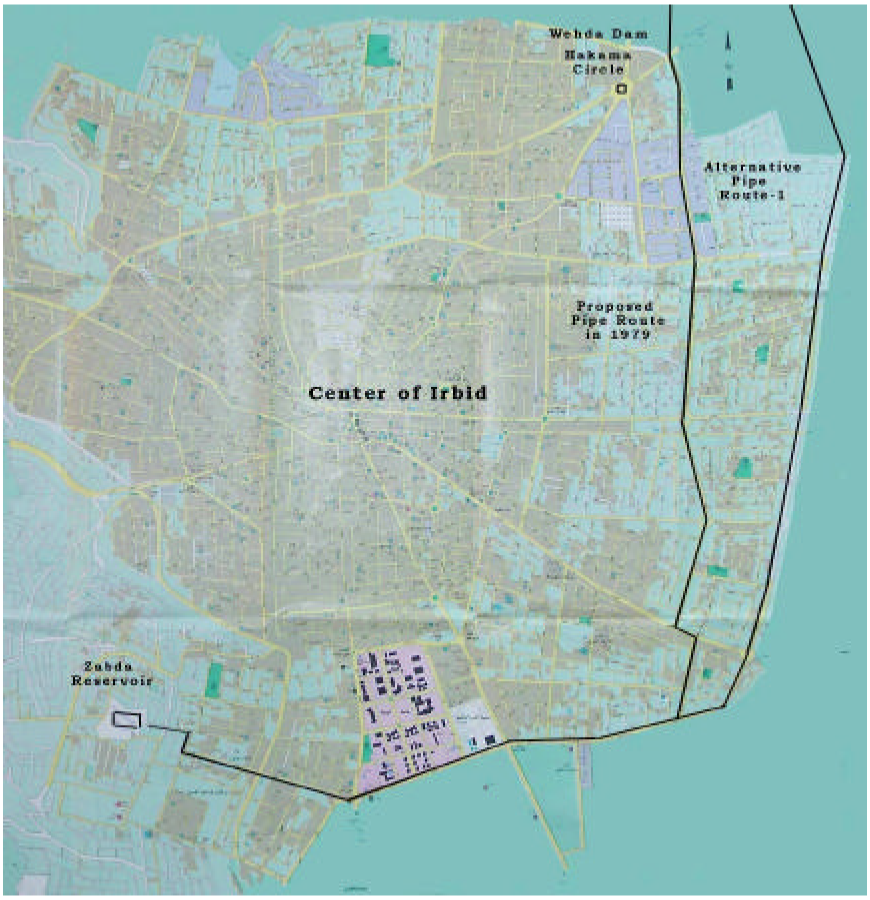

Fig. 5.2.2-2 Pipe Route in the City

5.5.3 Branch Reservoir at Beit Ras

Urban development of northern part of Irbid such as Benikina and Beit Ras areas are rapid compared with the reference study in 1979 and these areas are currently supplied from Zabda reservoir by pumping crossing the city center. Therefore one branch from main pipeline with a proper reservoir may be considered at Beit Ras where the elevation is highest (El + 580 meter) in these areas. Northeast area of Irbid such as Hakama and Harema have wells inside the area and can be afforded until 2010.

Required water supply to Beit Ras and Benikina areas are assumed 9.6 % of total demand of Irbid in the pre-feasibility study based on the information of current number of subscribers below.

Subscribers in 1999 (WAJ in Irbid)

Benikina:	8,938	
Beit Ras:	1,435	
Subtotal	10,373	(9.6%)
Irbid Governorate:	108,000	

Required water supply to Benikina and Beit Ras in 2010 (MCM/a and m^3/day)

Benikina:	5,545,000	15,200
Beit Ras:	890,000	2,400
Subtotal	6,435,000	17,600
Irbid Governorate:	67,000,000	183,500

When we consider the reservoir capacity of 12 hours, which is common practice in Jordan, 9,000 m^3 reservoir will be required at Beit Ras.

5.5.4 Analysis and Counter Measure for Water Hammer

The Pressure in the pipeline is shown in Fig. 5.5.3-1 which also shows the distribution of the surge tanks.

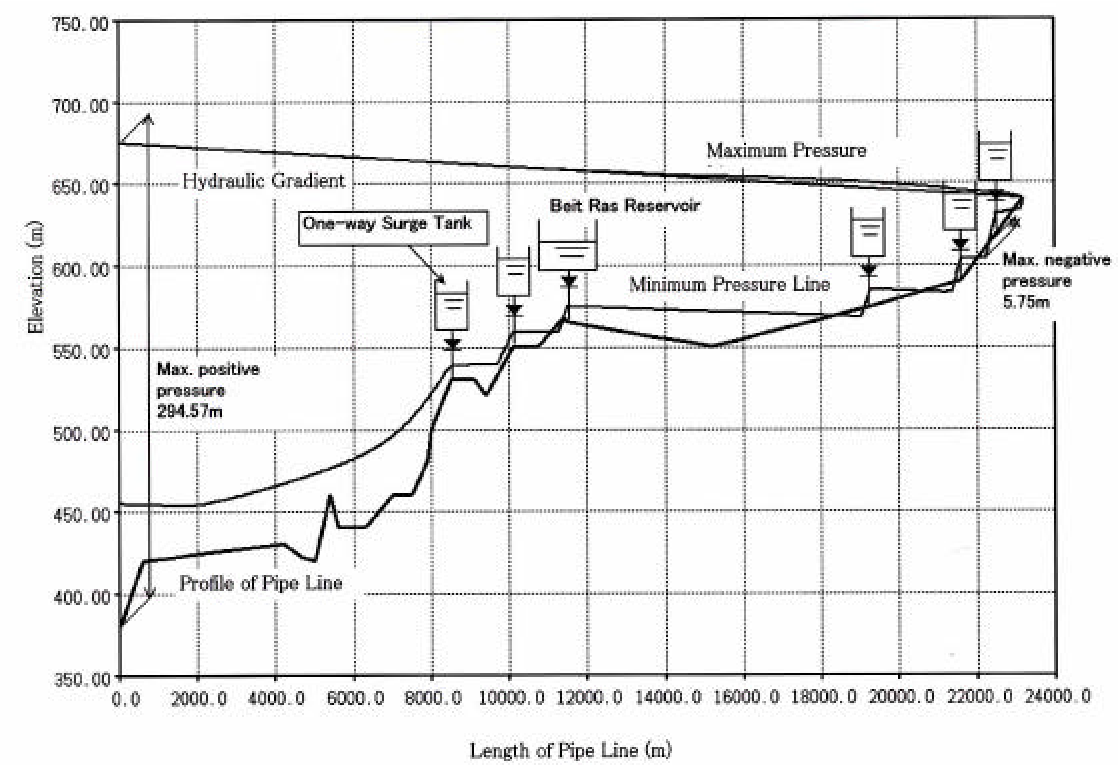

Fig. 5.5.3-1 Pressure Distribution in the Pipeline

5.5.5 Terminal Reservoir

Study in 1979 was considering a terminal reservoir between Irbid and Idoun town based on the Master Plan as shown on the Fig. A-5.1-1. However in the implementation of water supply facilities construction, groundwater resource in Wadi Arab well fields was developed and a reservoir of 110,000 m3 capacity was constructed at Zabda (EL+640m) for the City and a reservoir of 17,000 m3 capacity was constructed at Houfa (EL+790m) for the connection from/to Irbid. And these two reservoirs are connected with 600 mm pipe.

Main consuming area of surface water from Wehda is Irbid city area until 2010 and from topographical conditions Zabda is considered suitable as the terminal reservoir of this pipeline and water will be transferred from Zabda to Houfa as required.

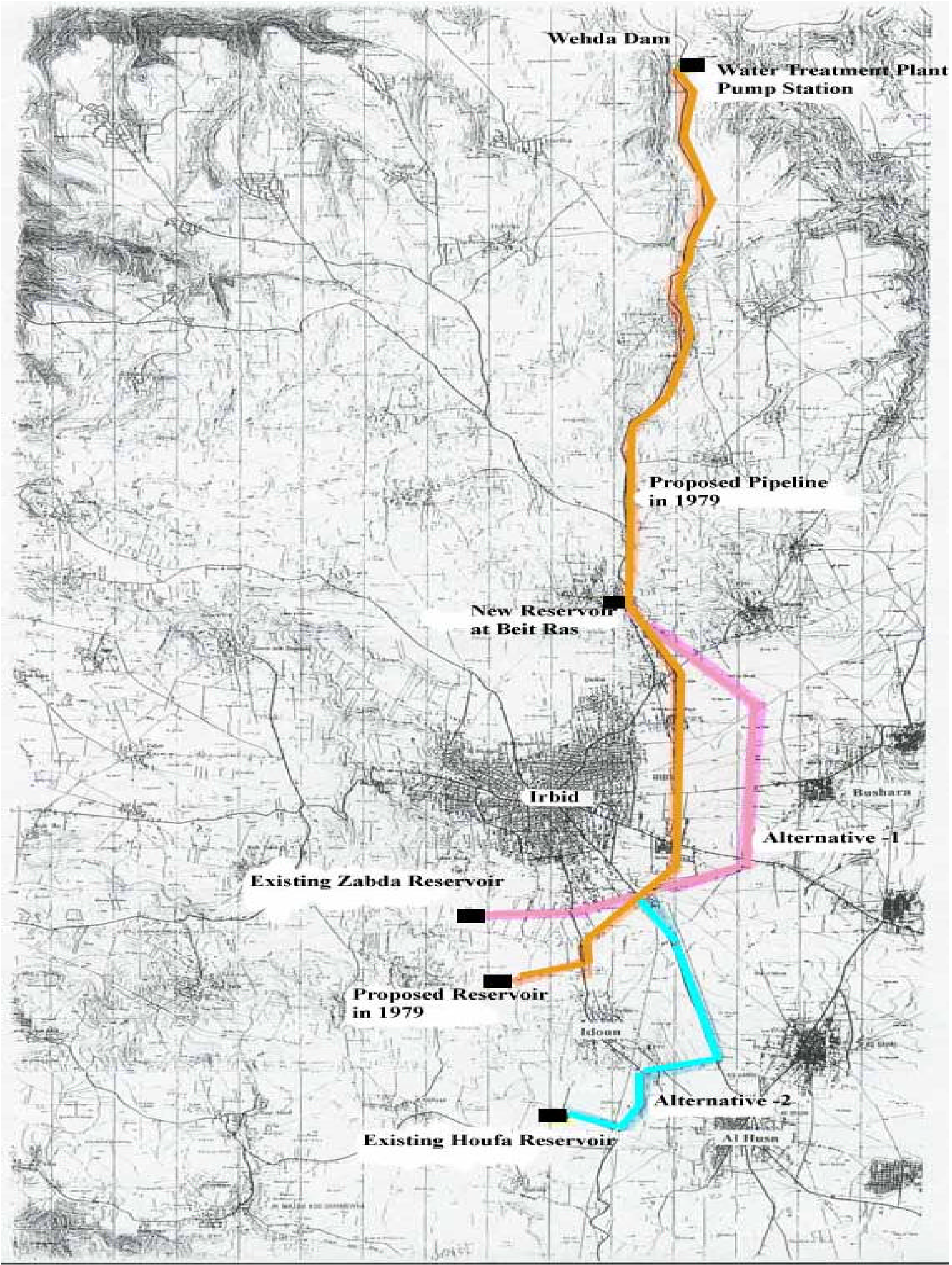

Fig. 5.5.5-1 General Layout of Pipeline

5.5.6 Electricity

Electricity supply in 133 KVA shall be prepared for the water intake, water treatment plant and pump station at the dam site.