3.3.3 Study of Treatment Processes

The existing Kaolieo and Chinaimo Water Treatment plants adopt the rapid filtration system which is the most popular treatment system in the world. The raw water from the Mekong River is treated through the system with the help of three kinds of chemicals, i.e. aluminium sulfate (alum), anionic polymer (polymer) and calcium hypochlorite (hypo). For the extension of the Kaolieo Water Treatment Plant, the rapid sand filtration system is also proposed for the additional production capacity of 40,000 m3/day. Figure 33-1 shows the flow diagram of the proposed treatment process.

The following is a summary of the study on each process in the rapid sand filtration system.

(1) Grit Chamber

The grit chamber is a plain sedimentation basin that removes grit, that is, by simple gravitational sedimentation. The purpose of this chamber is to protect moving mechanical equipment such as pumps and mixers from the abrasive substances in the raw water, and to prevent the accumulation of grit in the raw water line and the pre-treatment processes, including mixing, flocculation and sedimentation basins.

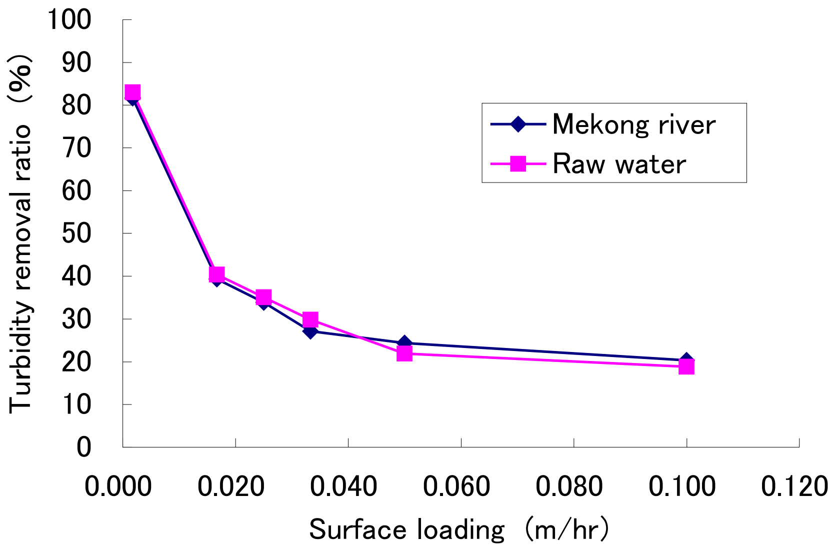
The necessity of the grit chamber is examined from the results of the subsidence test. Characteristics of the subsidence have strong relation with the size of particle of the turbidity. According to the results of subsidence test using water from the Mekong River and raw water of the Kaolieo Treatment Plant, rate of subsidence was 0.038 m/hr and it was very small value because of the majority of turbidity of the Mekong River is very fine silts. The results of the subsidence test are shown on table below.

Results of the Subsidence Test

	Mekong river			Raw water		
Time (min)	Turbidity (NTU)	Removal Ratio (%)	Subsidence Rate m/hr	Turbidity (NTU)	Removal Ratio (%)	Subsidence Rate m/hr
0	295	–	–	265	–	–
30	235	20.3	0.100	215	18.9	0.100
60	223	24.4	0.050	207	21.9	0.050
90	215	27.1	0.033	186	29.8	0.033
120	195	33.9	0.025	172	35.1	0.025
180	179	39.3	0.017	158	40.4	0.017
1680	54	81.7	0.002	45	83.0	0.002
Ave			0.038			0.038

Figure below shows the relation between turbidity removal ratio and subsidence rate. If the turbidity removal at 30 % is expected at the grit chamber, subsidence rate, in other words surface load, should maintain as 0.025 m/hr from the figure below.

Relation between Turbidity Removal Ratio and Subsidence Rate (Surface Load)



Area required for the grit chamber will be calculated from the results of subsidence test as follows:

Capacity of Treatment Plant:	60,000 m3/day
Surface Load at 30 % removal:	0.025 m/hr
Required area of Grit Chamber:	60,000 m3/day / 24 hour / 0.025 m/hr
	= 100,000 m2 (10 ha)

Even though only 30 % of turbidity removal is expected, huge area, about 10 ha, grit chamber will be required because of low subsidence rate. Therefore, construction of the grit chamber is judged not realistic and not feasible.

(2) Rapid Mixing

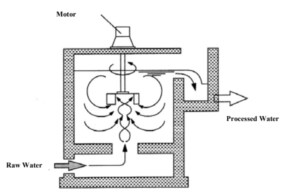
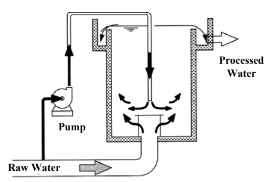
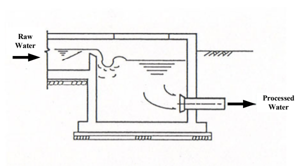
The coagulo-sedimentation process involves three processes; mixing, flocculation and sedimentation. The mixing of chemicals and the coagulation process coagulates the fine particles or colloidal particles to minute flocs by the rapid mixing after feeding coagulant to raw water. Available mixing types are:

a. Machinery mixing

b. Pump power mixing
c. Gravitational force mixing by weir

Although there are three kinds of the rapid mixing such as mixing by machine, pump or gravity, the mixing by gravity is recommended for the study, taking into account the required future maintenance. Comparison of the mixing types is as shown in Table-33-2. The existing Kaolieo and Chinaimo Water Treatment Plants also employ the gravitational force mixing by weir system. Therefore, the gravitational force mixing by weir is proposed for the rapid mixing process in order to mix raw water with a coagulant.

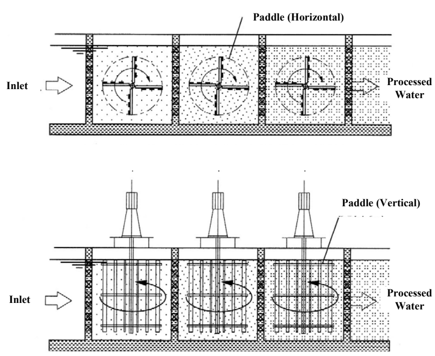
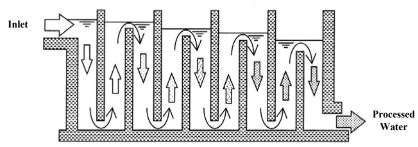
Table 33-2 Comparative Table of Rapid Mixing

	Machinery Mixing	**Pump Power Mixing**	**Gravity Weir Mixing**
Mixing	Driving device Supporting Axis with screw Electrical equipment	Injection pump Piping and installation Agitator Electrical equipment	Weir plate
Mechanism	Agitation by a mixer	A part of raw water taken from inlet is injected to the bell mouth by booster pump.	Mixing is done in the turbulence caused by gravity fall after a weir.
Advantages	Capable in response to fluctuation of inflow quantity. No hydraulic head is required.	Capable in response to fluctuation of inflow quantity. No hydraulic head is requried.	Small construction cost Machinery trouble will not occur Less maintenance cost Small installation area
Disadvantages	High construction cost High power cost Countermeasures against noise are required. Periodic maintenance is required. High maintenance cost	High construction cost High power cost Large area is requried. Periodic maintenance is required. High maintenance cost	Measures to adjust inflow quantity fluctuation are needed. Hydraulic head is required.
Evaluation	Construction, power and maintenance costs are high. Countermeasures against noise are required. High skills for operation are required.	Almost same as the left. Pump installation area is additionally required. High skills for operation are required.	By regulating a height, sufficient hydraulic head can be secured. Construction cost is small, and power and maintenance costs are smaller
	not recommendable	not recommendable	recommendable
Drawing			

(3) Flocculation

A vertical baffled channel type is recommended for the flocculation basin. The existing Kaolieo and Chinaimo Water Treatment Plants also employ this flocculation type. A machinery agitation type is also popular for the flocculation, however, considering the operation and maintenance, the baffling type is the recommended type for the proposed treatment plant. The comparison between these three types are summarised in Table 33-3.

Table 33-3 Comparative Table of Flocculation

	Machinery Agitation (Flocculator)	Baffling- Type
Functions and Arrangement	One or a few rows of mixers with paddles are installed in the basin. There are two types of axis of paddles; vertical and horizontal. Rotation can be adjusted with the treatment quantity by changing a mixing strength (G Value). Depth in the basin is 3-5 m.	There are two kinds of this type; vertical and horizontal flow types. Both might be used concurrently. Using the hydraulic head and baffles, measurement of inflow quantity alteration is needed. Attention should be paid for sludge sedimentation when turbidity is high. Detention time and depth are the same as machinery agitation.
Configuration	Driving device (motor and reduction gear) and paddles Submersible axis bearings	Baffle wall and plate
Detention Time: T	20-40 min.	20-40 min.
Paddle Velocity	15-80 cm/sec (At most outer part)	—
G Value	10-75 sec^{-1}	10-75 sec^{-1}
GT	23,000-230,000	23,000-230,000
Maintenance	Machine maintenance is needed.	Ease of maintenance
Advantages	Capable adjusting to quantity and quality alteration No hydraulic head is required.	Small construction cost Easy operation and maintenance
Disadvantages	Large construction cost Needs periodic maintenance (cost) Maintenance cost is high.	Hydraulic head is needed. Difficulty in adjustment to quantity alteration
Evaluation	Construction, power and maintenance costs are high, and high-level of skills is required.	Both construction and maintenance costs are low. Capable of adjusting to quantity alteration by changing number of basins used.
	not recommendable	recommendable
Drawing		

(4) Sedimentation

A conventional horizontal-flow sedimentation basin (uni-flow type) is applied for this process. The existing sedimentation basins at the Kaolieo WTP have gravel filters at the end of the basins, however, the new basin does not furnish the gravel filters. The existing gravel filters do not function well based on the results of the water quality test.

(5) Filtration

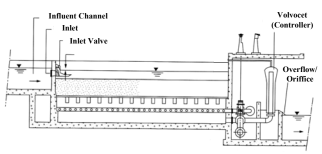
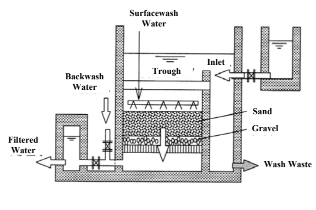
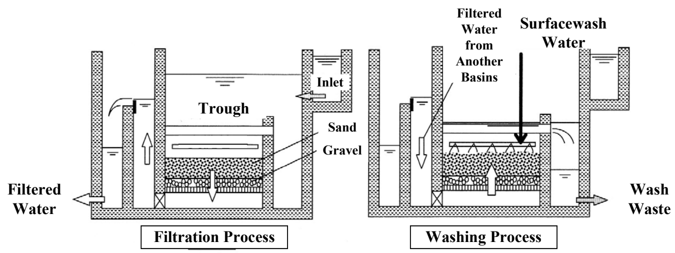
Rapid sand filtration is the final process to finish and obtain safe and hygienic water; the fundamental objective of waterworks for supplying clean water to the user by improving water quality to the required level. In the process, the fine flocs not removed in the sedimentation basin are removed by passing through a filter medium such as a sand layer; at the same time, the substances inside the flocs might consume the free residual chlorine and make the water non-resistant to the contamination from outside of the distribution pipes as well, as cause secondary affections inside the pipes, are removed. Available rapid sand filtration types are:

a. Rapid sand filtration, air scouring type (Chinaimo Type)
b. Standard-type rapid sand filtration (Kaolieo Type)
c. Rapid sand filtration, automatic backwashing type (by valve)
d. Rapid sand filtration, automatic backwashing type (by siphon)

Among these types, the standard-type rapid sand filtration process requires high levels of technical skills in adjustment of the filtration volume as well as in operational control. The rapid sand filtration, automatic backwashing type (by siphon) also requires a high-level of skill in operation, control and maintenance, due to the number of devices used compared to rapid sand filtration, automatic backwashing type (by valve). The rapid sand filtration, automatic backwashing type (by valve) and air scouring type have the characteristics of easy operation, control, and require less frequent maintenance practice owing to less system devices. The rapid sand filtration, air scouring type has the advantages of using less backwashing water, as well an existing knowledge for the operation and maintenance of rapid sand filtration systems due to the same type of process being used at the existing Chinaimo plant, compared with the rapid sand filtration, automatic backwashing type (by valve). The examination and comparison of these 4 types is shown in Table-33-4. In consequence, the rapid sand filtration, air scouring type (Chinaimo Type) is recommended to be adopted in the project.

Table 33-4 Comparative Table of Filtration

		Air-scouring Type (Chinaimo Type)	Standard Type (Kaolieo Type)	Automatic Backwash Type (by Valve)	Automatic Backwash Type (by Siphon)
Filtration	Raw Water Inlet	By Difclap, gate or valve	By valve or gate	By movable adjusting weir and valve	By siphon and movable adjusting weir
Filtration	Filtration Velocity Control	By Volvoset (Pneumatic drive)	Flow meter and Operation valve	Movable adjusting weir	
Filtration	Filtration Velocity Control Mechanism	Water level in the basin is kept constant. Constant filtration velocity by controlling the constant water level in the filtered cell with the Volvoset against the filtration clogging.	Water level in the basin is kept constant. Constant filtration velocity by controlling valve with flow meter against the filtration clogging.	Constant filtration velocity by keeping required hydraulic head byraising water level in the basin when filter clogged.	
Filer Washing	Washing Method	Air Scouring and Back Washing by Water	Surface Wash and Back Washing by Water		
Filer Washing	Backwashing Discharge	—	By valve or gate		By siphon
Filer Washing	Washing Rates	Back Wash Rate: 0.35 $m^3/min/m^3$ Air Scouring Rate: 1.00$m^3/min/m^3$	Surface Wash Rate: 0.15～0.20 $m^3/min/m^3$ Back Wash Rate: 0.60～0.90 $m^3/min/m^3$		
Filer Washing	Backwashing Mechanism	Responding to an increment of head-loss to the set point, backwashing starts. The backwashing water is pumped from the reservoir after the chlorination.		Responding to an increment of head-loss to the highest level, operation of discharge gate lowers water level to the drainage trough level, then backwashing starts. Backwashing water with head comes from other filters in operation.	Responding to an increment of head-loss to the highest level, water flow in the inflow siphon is suspended by allowing air flow into the siphon, drainage siphon works to lower water level to drainage trough; backwashing starts automatically. Backwashing water with comes from other filters with head.
Filtration Layer		Effective Diameter: > 1.0 mm Uniformity Coefficient: < 1.7 Layer Thickness: > 1.0 m	Effective Diameter: 0.6-0.7 mm Uniformity Coefficient: < 1.7 Layer Thickness: 0.6-0.7 m		
Water Collecting Device		Perforated Board	Perforated Block, Strainer or Perforated Board	Automatic Washing Type of Perforated Block or Perforated Board	
Space Necessary for Installation		Small corridor is required for the installation of pipes; comparatively large space for valves both outlet including Volvoset operation and backwash.	Large space including corridor for maintenance and inspection is needed because of many installation of big pumps/valves.	Large space is not required, due to installation of pipes and gate both for inlet and outlet.	Small corridor is required for the installation of small pipes; and comparatively large space for inflow and drainage siphon, including siphon operation space.
Construction Cost		Height of filter structure is around 4	Height of filter structure is less 4.5	Height of filter structure is around 5	Height of filters is 5.5 m due to

	Air-scouring Type (Chinaimo Type)	**Standard Type (Kaolieo Type)**	**Automatic Backwash Type (by Valve)**	**Automatic Backwash Type (by Siphon)**
	m with a simple design. Construction cost is minimal. Only four kinds of valves (for inflow, outflow of Volvoset, backwashing and air blow) are required in each basin. Two kinds of pumps (air blow and back washing) and their control panels are required. Construction cost is small.	m. Large clear water conduit down to the filtration basin as well as the complicated structure will cause higer construction costs. The different big-size equipment is required, and their control panels should be of high standard.	m with a simple design. Construction cost is rather small. Only four kinds of valves (for inflow, outflow, drainage and surface washing) are required in each basin. Two kinds of pumps (surface washing and replenishment) and their control panels are required. Construction cost is rather small.	siphon structure. Some space is required for siphon equipment of small pipes, vacuum generator, compressor and so forth; therefore, construction cost is rather high. Although these kinds of equipment are not so big-size as in standard type, complicated siphon generating unit, vacuum unit and their control panels require complicated operation and high cost.
Construction Cost Ratio	0.85	1.0	0.85	0.9
Maintenance Cost Ratio	0.8	1.0	0.8	0.9
Evaluation	Only four valves ; inlet, outlet, back washing and air blow, are required. Complicated outflow adjusting mechanism is not required; therefore, no high-level technical skills are needed. Costs of both construction and maintenance are small. No frequent maintenance practice is required due to well knowledge of existing system. The amount of back washing water is less than other types.	High-level skills are needed in flow control. Bigger pumps and back washing valves will make cost higher. High-level skills for O/M and frequent maintenance will be needed.	Only three valves; inlet, drainage and surface washing are required. Without complicated outflow adjusting mechanism, no high-level technical skills are needed. Costs of both construction and maintenance are small. No frequent maintenance is required due to less use of devices.	Complicated siphon mechanism for inflow and drainage composed of many equipment require high-level of technical skills in operation more than the standard-type. The height is bigger, 30-50 cm higher than the valve-type. Countermeasures to siphon breaking noise are required.
	recommendable	not recommendable	not recommendable	not recommendable
Drawing				

(6) Chemical Feedings

The proposed treatment plant uses three kinds of chemical i.e. aluminium sulphate (alum), anionic polymer (polymer) and calcium hypochlorite (hypo).

Based on the water quality data, analysis on chemical feeding at the Kaolieo Treatment Plant is discussed as follows.

1) Raw Water Quality

a) Turbidity

The records of turbidity of Chinaimo and Kaolieo Treatment Plants in 2000 – 2002 are shown in table below. The average values of turbidity of raw water at Kaolieo and Chinaimo treatment plants are almost at the same level. However, the maximum turbidity of the raw water at Chinaimo treatment plant is higher than the one of Kaolieo treatment plant. The turbidity is an important parameter for determination of the coagulant dosage rate. Since the turbidity meter equipped at the Kaolieo treatment plant is out of date and the reliability of the turbidity data is low, the chemical dosage rate was considered based on the turbidity data of the Chinaimo Treatment Plant.

Record of Raw Water Turbidity at the Chinaimo and Kaolieo Treatment Plants

Month	Chinaimo Water Treatment Plant			Kaolieo Water Treatment Plant		
	Maximum (mg/l)	Minimum (mg/l)	Average (mg/l)	Maximum (mg/l)	Minimum (mg/l)	Average (mg/l)
Jan	106	28	57	188	121	140
Feb	77	21	39	138	70	99
Mar	53	12	30	100	74	82
Apr	90	2	13	85	41	59
May	544	21	182	550	30	204
Jun	1,910	229	487	1,835	224	444
Jul	4,645	237	1,164	3,521	335	1,107
Aug	4,660	645	1,370	2,415	610	1,407
Sep	1,653	334	782	1,324	275	649
Oct	1,165	270	553	778	204	384
Nov	757	136	494	282	190	230
Dec	875	23	209	365	141	215
	4,660	2	448	3,521	30	418

Based on the record shown above in 2002, the maximum turbidity was 4660 NTU. The turbidity more than 4600 NTU were recorded in two months (July and August). Under such condition the Chinaimo treatment plant was designed based on the maximum turbidity was 6,000 NTU. For the expansion of the Kaolieo treatment plant, same maximum value, 6,000 NTU is recommended to employ for the facility design.

According to the average turbidity during 2000 - 2002 was 432 NTU, therefore, the design average turbidity is set as 450 NTU. Although the minimum turbidity in 2002 was 2 NTU, since it is about 10 NTU during 2000 - 2001, design minimum turbidity is set as 10 NTU. The design turbidity values for the maximum, average, and minimum are summarized as follows:

Maximum	:	6000	NTU
Average	:	450	NTU
Minimum	:	10	NTU

b) Ammonia Nitrogen

According to the results of raw water quality analysis of the Kaolieo treatment plant during 2000 - 2002, concentration ranged from 0.01 to 0.06 mg/litre. There was no significant fluctuation of the concentration during these three years; it is assumed that this tendency would continue at the same level as the present condition. Maximum concentration of the Ammonia Nitrogen was set as 0.1 mg/ litre for the facility design.

c) Iron and manganese

Iron and Manganese are detected in raw water regardless the rainy and dry seasons. There was no significant fluctuation of Iron and Manganese concentration during the last three years, it was assumed that this tendency would continue as same level as the present condition. The maximum concentration of Iron is set as 0.50 mg/litre and the maximum concentration of Manganese is set as 0.10 mg/litre.

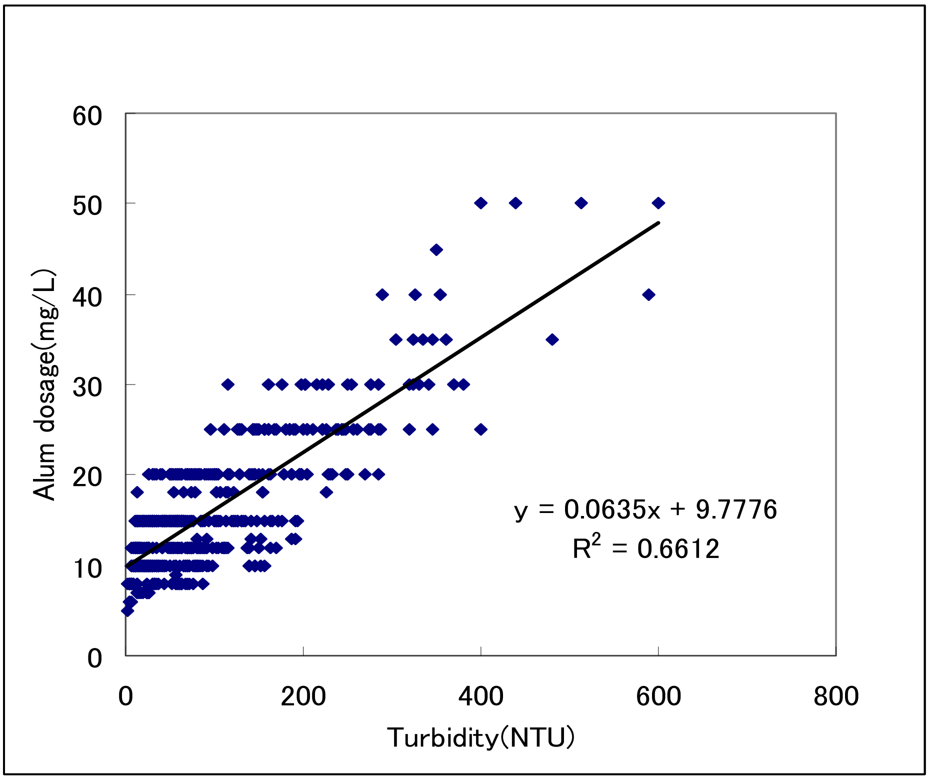
2) Coagulants (Alum (Aluminium Sulphate) and Polymer)

Alum(aluminium sulphate) will be dosed as a coagulant which is applied at the existing treatment plants. Polymer is also applied as a coagulant aid. Since correlation with that the dosage rate of aluminium sulphate and raw water turbidity at the Kaolieo treatment plant is deficient, it is difficult to calculate the dosage rate of coagulants from the actual records of Kaolieo. Then, coagulants dosage rates were derived from the records of the Chinaimo Treatment Plant. At the Chinaimo water treatment plant, polymer is dosed when the turbidity becomes more than 300 NTU, the polymer will be similarly dosed from about 300 NTU at the Kaolieo treatment plant..

The relation between turbidity and aluminium sulphate dosage rate, without polymer case, is expressed with the following formula from figure below.

$$\text{Aluminium sulphate dosage (mg/L)} = 0.0635 \times \text{turbidity (NTU)} + 9.7776 \qquad (1)$$

Relation between raw water turbidity and aluminium sulphate dosage (Chinaimo water treatment plant actual result)

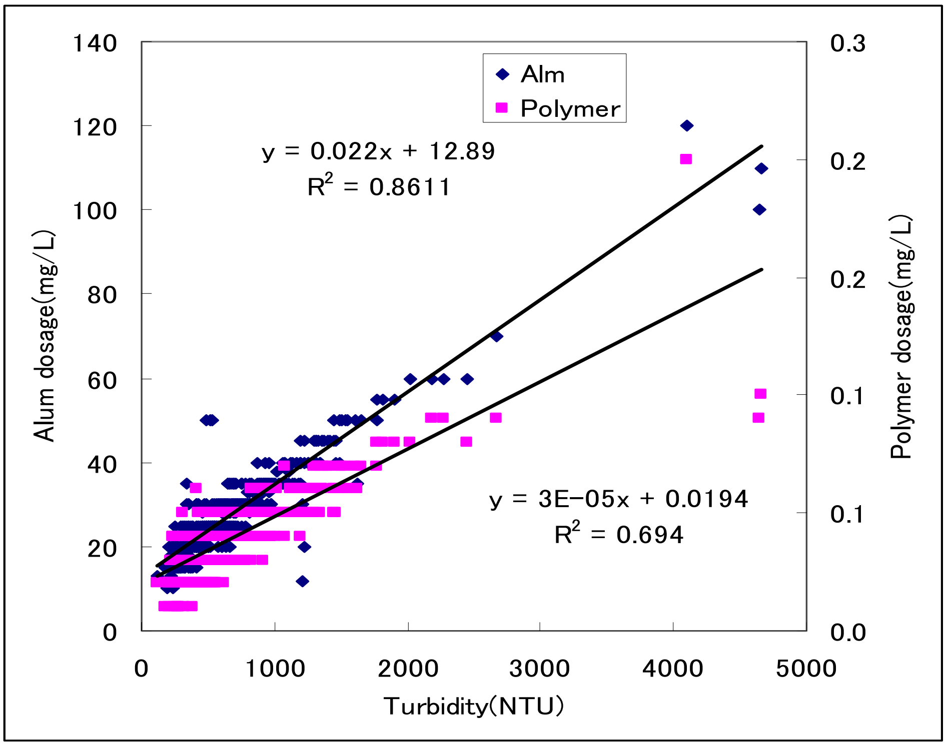


The relation between turbidity and dosage rates of aluminium sulphate and polymer is expressed with the following formula from figure below.

Aluminium sulphate dosage (mg/L) = 0.022× turbidity (NTU) + 12.89 (2)

Polymer dosage (mg/L) = 0.00003× turbidity (NTU) + 0.0194 (3)

Relation between raw water turbidity and dosage rates of aluminium sulphate and polymer dosage.



a) The Maximum Dosage Rates

Since the maximum turbidity of Kaolieo is 6000 NTU, dosage rate will be calculated from formula (2) and (3) above.

Alum dosage $=0.022 \times 6000 + 12.89$

$=144.89$ 150mg/L

The maximum aluminium sulphate dosage rate is derived as 150mg/liter.

The dosage rate of the polymer is calculated as follows.

Polymer dosage $=0.00003 \times 6000 + 0.0194$

$=0.1994$ 0.2mg/L

The maximum polymer dosage rate is as 0.2mg/liter.

b) The Average Dosage Rates

Since the average turbidity of Kaolieo is 450 NTU, dosage rate will be calculated from formula (2) and (3) above.

Alum dosage $=0.022 \times 450 + 12.89$

$=22.79$ 23.0mg/L

The average aluminium sulphate dosage rate is derived as 23 mg/liter.

The dosage rate of the polymer is calculated as follows.

Polymer dosage ＝0.00003×450＋0.0194

＝0.033 0.03mg/L

The average polymer dosage rate is as 0.03mg/liter.

c) The Minimum Dosage Rates

Since the average turbidity of Kaolieo is 10 NTU, dosage rate will be calculated from formula (2) and (3) above.

Alum dosage ＝0.0635×10＋9.7776

＝10.41 10mg/L

The average aluminium sulphate dosage rate is derived as 10 mg/liter.

The results of above mentioned calculation are summarized as follows.

Aluminium sulphate and polymer dosage rate (unit: mg/litre)

Aluminium sulphate			polymer		
Max	Min	Ave	Max	Min	Ave
150	10	25	0.2	0	0.03

The JICA Study Team conducted analysis of acrylamidemonomer which is contained in polymer used by the NPVC. According to the results of the analysis, concentration of acrylamidemonomer will be 0.002μg/liter at the planned maximum dosage rate of polymer. This concentration as of 0.002μg/litre is far lower than the WHO Water Quality Guidelines, 0.5μg/litre and furthermore, much lower than the Ministerial ordinance of Health, Labour and Welfare, Japan, 0.005μg/litre. Therefore, the usage of polymer at the Treatment Plant will not affect the human health.

3) Chlorine (Calcium Hypochlorite: Hypo)

Residual chlorine should be maintained in the treated water. Since chlorine is consumed by substances contained in the raw water and treated water such as Ammonia Nitrogen, Iron, and Manganese, dosage rate of the chlorine will be calculated from the concentrations of these substances.

a) Ammonia Nitrogen

Chlorine consumption will be calculated based on the maximum concentration of ammonia nitrogen, 0.1 mg/litre, as follows.

Ammonia nitrogen ：1mg/L＝10mg/L

0.1mg/L×10mg/L＝1.0mg/L

b) Iron

Chlorine consumption will be calculated based on the maximum concentration of Iron, 0.5 mg/litre, as follows.

Iron :1mg/L＝0.63mg/L

0.5mg/L×0.63mg/L＝0.315 0.32mg/L

c) Manganese

Chlorine consumption will be calculated based on the maximum concentration of Manganese, 0.1 mg/litre, as follows.

Manganese ：1mg/L＝1.29mg/L

0.1mg/L×1.29mg/L＝0.129 0.13mg/L

The total chlorine consumption therefore will be calculated as follows.

Total chlorine consumed＝1.0mg/L＋0.32mg/L＋0.13mg/L

＝1.45mg/L 1.5mg/L

Although the total chlorine consumption is calculated as 1.5 mg/litre, the maximum chlorine dosage is set as 5 mg/litre. Chlorine consumption substance and the turbidity will fall at the dry season, intermediate chlorine dosing will be desirable. A chlorine dosage rates are summarized as follows.

Chlorine dosage rate (unit : mg/litre)

	Max	Min	Ave
Pre	5	1	3
Intermediate	5	1	3
Post	2	0.5	1

Pre and intermediate simultaneous dosage will not be allowed

4) Lime

Alkalinity has an effect in pH adjustment and a corrosion prevention of tap water. Raw water from the Mekong River contains enough alkalinity, 90 mg/litre (results at the Chinaimo treatment plant) in raw water. Since it remains 22.5 mg/litre (90-150×0.45=22.5 mg/L) at the maximum aluminium sulphate dosage, it is assumed that the problem of corrosion will not be generated. Moreover, pH of raw water is 8.0-8.4 (2000 - 2002: results at the Kaolieo treatment plant), and even if aluminium sulphate dosage becomes the maximum, pH was maintained about 7.0. Therefore, the post lime dosage is judged not required.

The chemical feeding facility is planned not only for the expansion works but also for the rehabilitation work. The new chemical feeding facilities, which will be constructed as a part of the expansion work, will be shared by both the existing and new facilities. The chemical dosage rates for aluminium sulphate (alum), anionic polymer (polymer) and calcium hypochlorite (hypo) are summarized as shown below.

Summary of Chemical Feeding Rate at Kaolieo Water Treatment Plant (unit: mg/litre)

		Max	Min	Ave	Remark
Aluminium sulphate		150	10	25	Value of Min. is without polymer
Polymer		0.2	0.0	0.03	
Hypo	Pre	5.0	1.0	3.0	Pre- and Intermediate will not dosed simultaneously
	Intermediate	5.0	1.0	3.0	
	Post	2.0	0.5	1.0	

3.3.4 Distribution Facilities

(1) Clear Water Reservoir and Distribution Pump Building

In order to secure the steady distribution of water, a new reservoir with a capacity of 11,000 m3/d which is equivalent to 6 hours of the distribution capacity, will be constructed. The existing and new reservoir will be connected by an interconnection pipeline using the same high water level.

To save space, the administrative building and offices, the laboratory, and the chemical feeding facility will be constructed over the reservoir.

(2) Distribution Pumps

In order to meet the hourly fluctuations of demand, the distribution pumps are planned in consideration of the hourly peak factor of 1.3. The peak factor is calculated from results of flow measurement survey are attached in Annex 10 and the basis of these calculations are shown in Annex

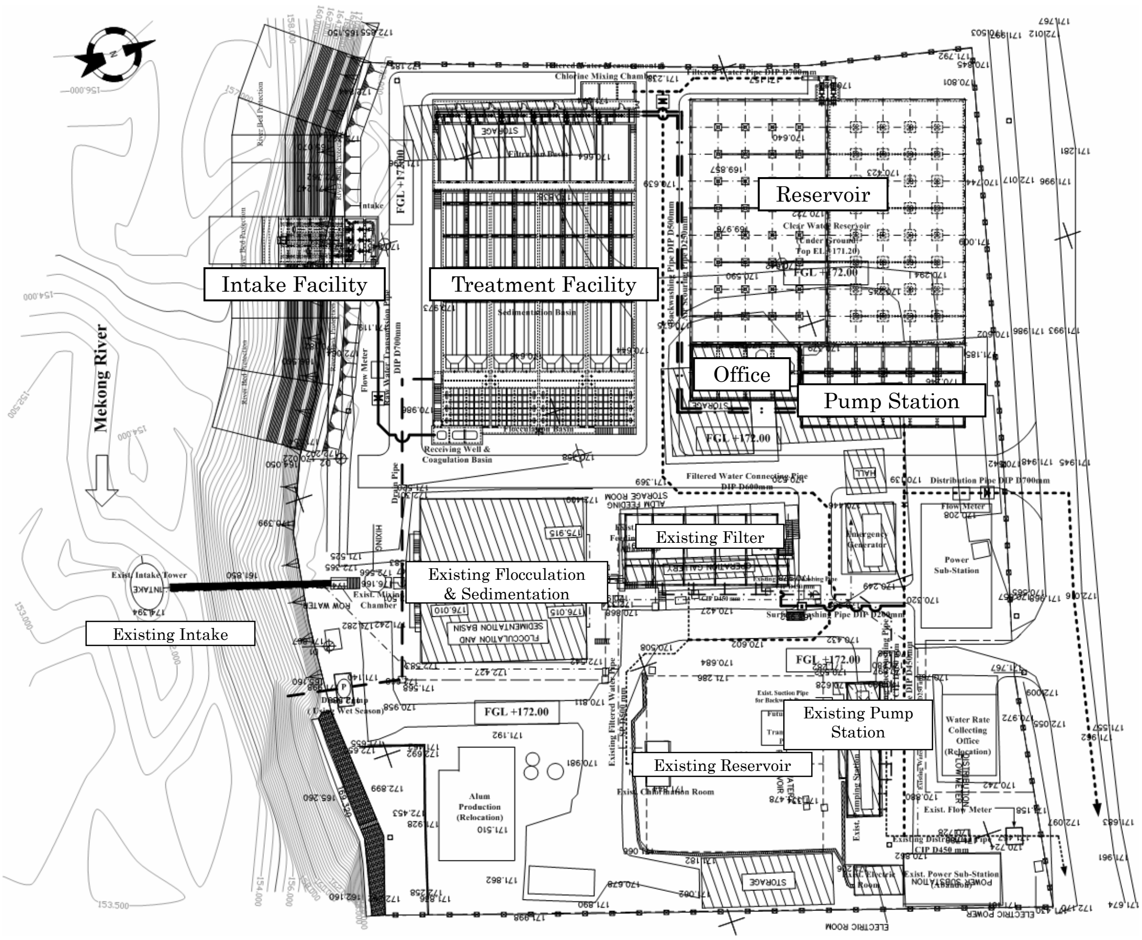
15.

The type of the distribution pumps will be a double suction volute pump (centrifugal pump) which is suited for a middle range of pumping head and relatively large amounts of flow rate. This type is most popular for the distribution and transmission pumps of waterworks on a global scale. The control of the distribution flow rate is done by the control of number of operating pumps, not by the revolving speed control. The specification of the distribution pumps is 12.1 m3/min x H 67.0 m x 4 units including one stand-by pump. The pumping head of 67 m is the same as the existing pump head, because the existing and new distribution pipelines will be connected.

(3) Distribution Pipeline

When the new distribution facility is constructed, the new distribution pipeline will be connected to the existing distribution pipeline. In addition, an interconnection pipeline between the existing and new reservoirs will be installed. Figure 33-7 shows the pipe alignments and a plan of the existing and proposed treatment plants.

Figure 33-7 Yard Piping Arrangement for Kaolieo Treatment Plant



3.3.5 Electrical Facilities

The electrical facilities, including the power receiving equipment, transformer, power supply equipment, emergency generator and instrumentation equipment, will be constructed corresponding with the planned expansion facilities.

The power sub-station in the existing Kaolieo Treatment Plant was constructed in 1964, and a lot of the equipment and facilities are now 40 years old. Therefore, the rehabilitation works for the electrical facility are included in the expansion works and the existing and new plants will share the following electrical facilities.

a. power receiving and transformer equipment,

b. power supply equipment,

c. generator for emergency power during the power failures, and

d. instrumentation equipment.

3.3.6 Summary of Preliminary Design of Kaolieo Treatment Plant Expansion Works

The results of the preliminary design of the Kaolieo Treatment plant are shown in the drawings attached to Annex 29 and the details of each facility are summarised in the Table 33-5.

Table 33-5 Expansion Work of the Existing Kaolieo Treatment Plant

Name of Facility	Name of Component	Specifications
Intake Facilities	Intake Structure	Construction of New Intake Pipe Type
	Bank Protection	River Bed and River Bank Protection: L=20 m
	Intake Pump	15.3 m3/min×18.5 m×70 Kw×3 Units
		Check & Sluice Valves with Motorized Operating Stand
	Inlet Pipes & Butterfly Valves	D1,000mm×3 Units with Manual Operating Stand
	Flashing Piping & Valves	D300mm with Manual Operating Stand
	Stop Valve for Discharge Main	D700mm Butterfly Valve with Manual Operating Stand
	Hoist Crane	Electric Crane with Associated Equipment
	Stop Log for Bottom Pipe	D1,000mm with Manual Operating Stand
Raw Water Transmission Pipe	Raw Water Transmission Main	D700mm×40 m
	Flow Meter & Flow Control Valve Chamber	Meter and Valve Chamber
		Ultrasonic Flow Meter
		Raw Water Flow Control Valve and Panel
Receiving Well & Mixing Well	Receiving Well	1 Basin, Detention Time=2.3 min
	Mixing Well	Gravity Type(Weir), 1 Basin, Detention Time=1.0 min
Flocculation & Sedimentation Basins	Flocculation Basin	Up and Flow Baffle Channel Type, 4 Basins
		Detention Time=23.7 min
		D300mm Sludge Valve with Manual Operating Stand
	Sedimentation Basin	Horizontal Flow Type with Outlet Launder, 4 Basin
		Detension Time=2.1 hr (Substantial D. Time=3.5 hr)
		D300mm Sludge Valve with Manual Operating Stand
		Pressurized Cleaning Piping System
Filtration Facilities	Filter Basin	Air-Scouring Type, Filter Area=49.35 m2/Basin
		6 Basin, Filtration Rate=148.6m/d
	Filter Media	Effective Size=1.0mm, Depth of Sand=1.0m
	Underdrain System	Pourous Concrete Type
	Rate of Backwashing and Air-scouring	Backwash Rate=0.40m3/min/m2,
		Air-scouring Rate=1.00m3/min/m2
	Oprerating Valves for Filtration	Inlet Gate with Motorized Operating Stand
		Motorized Outlet, Backwash & Air-scouring Valves
		Flow Controller (Volvoset)
	Backwash Pump & Air Blower	Backwash Pump:19.74 m3/min×30 Kw×2 Units
		Air Blower: 49.35 m3/min×45 Kw×2 Units

Name of Facility	Name of Component	Specifications
Measurement & Mixing Chamber	Flow Measurement Chamber	1 Basin, Detention Time=1.8 min
	Chlorine Mixing Chamber	Gravity Type (Weir), 1 Basin, Detention Time=0.7 min
Clear Water Reservoir	Clear Water Reservoir	V=10,000 m3 (11,000 m3), Detention Time=6 hr
	Operating Valves and Piping	D700mm Butterfly Valves with Manual Operating Stand
		D700mm Inlet Pipe & D600mm Connecting Pipe
Distribution Facilities	Distribution Pump Building	Area=300 m2 on the Clear Water Reservoir
	Distribution Pump	12.1 m3/min×67 m×195 Kw×4 Units
		Check and Sluice Valves with Motorized Valves
		Vacuum Pump and Incidental Accessaries
	Hoist Crane	Electric
	Flow Control Valve	Motorized Butterfly Valve
	Distribution Pipe	D700mm×80 m
Chemical Feeding Facilities	Chemical Building	Located in the Administration Building
	Feeding Equipment & Solution Tank	Aluminium Sulfate & Polymer in the Chemical Building
		Calcium Hypochlorite at the each Local Feeding Point
Electrical Facilities	Power Receiving Facility	Power Receiving and Transformer Equipment
	Power Supply Facility	Intake Pump Control Panel
		Distribution Pump Control Panel
		Operation of Filtration Control Panel
		Central Supervising Panel
	Emergency Generator Facility	Generator Room with Fuel Tank
		Generator Capacity for 1/3 Distribution Pump Capacity
	Instrumentation Facility	CRT Supervising Equipment Facility
		Intake Level Meter
		Raw Water Flow Meter (Ultrasonic Type)
		Filtered Water Flow Meter (Weir Type by Float)
		Filtered Head Loss Meter
		Clear Water Reservoir Level Meter
		Pressure Meter of Distribution Line
		Distribution Flow Meter (Ultrasonic Type)
Administration Building		A=200 m2×2F on the Clear Water Reservoir
Laboratory		Located in the Administration Building
		Water Quality Analysis Equipment and Reagent
Landscaping and Others		Site Preparation, Embankment, Roads, Lighting, etc.
		Including Demolition and Relocation of the existing housings

3.3.7 Water Source for the 1st Stage Project

An additional water source will be required for the expansion of the existing Kaolieo Treatment Plant. The quantity of additional raw water will be 44,000 m3/day, including 4,000 m3/day to be allowed for treatment loss which is unavoidable within the treatment process.

To abstract additional raw water at the Kaolieo Treatment Plant, the JICA study team had consultations with the WASA, DHUP, MCTPC and the additional raw water intake was consequently confirmed by the Water and Water Resources Law and Decree to Implement the Law on Water and Water Resources.

The Water and Water Resources Law was enforced in November 1996 by a Presidential Statement. According to the Law, the water source for the water supply is categorized for “Small Scale Use” by Article 15.

The decree to Implement the Law on Water and Water Resources was issued in October 2001 by the Prime Minister, “Article 3: Organizations Responsible for Water and Water Resources” and defines the MCTPC as the responsible organisation for use of water resources for water supply as follows; “Ministry of Communication, Transportation, Post and Construction (MCTPC): responsible for the management, exploitation, development and use of water and water resources in the fields of communication, transportation, town water supply, urban drainage, protection of river banks, prevention and control of flooding. In addition, MCTPC is responsible for collection of hydrological data and hydrographic surveys for navigation”.

Based on the Law and Decree, the WASA and MCTPC confirmed that additional raw water source from the Mekong River would be secured by the MCTPC.

3.4 Improvement of Km 6 Booster Pumping Station

The existing Km6 Booster pumping station receives water from Phonekheng through 350 – 300 mm SP and sends water to the Dongdok Ground Reservoir through 300 mm SP. At present the pumping station does not distribute water to the northern area along the National Road No.13. Although the total amount of pumped water is transmitted to the Dongdok Reservoir, the water supply system is faced with a problem of water shortage in the Dongdok area. This is mainly caused by a lack of pumping capacity and head of the booster pumps. The specification of the existing pump is 3.6 m3/min × 25m × 2 units.

According to the network analysis attached in Annex 25, for the development of the Vientiane water supply system, the following improvement works in Table 34-1 to the pumping station are required.

The transmission pumps for pumping water directly to the Dongdok Reservoir and the distribution pumps for distributing water to the northern area along the National Roads No.10 & No.13 will be installed for the booster pumping station at the existing site. An expansion of the pumping building is necessary for the installation of new transmission pumps. For the new distribution pumps, the existing pumping building can be utilised.

Through the improvement of the Km6 Booster Pumping Station, the installation of transmission pipeline branched from the existing transmission pipeline near Hongxeng Bridge to the Km6 Booster Pumping Station and the improvement of the Chinaimo Treatment Plant, water for the Dongdok Area can be transmitted from the Chinaimo Treatment Plant without the influence of the distribution system. The over-all system flow diagram of the transmission and distribution systems is shown in Figure 35-1.

Table 34-1 Improvement Work of Km6 Booster Pumping Station

Name of Facility	Name of Component	Specifications
Pump Facilities	Pumping Building	Area=35 m2×B1×2F
	Transmission Pump	4.8 m3/min×50 m×57 Kw×2 Units
		Check and Sluice Valves with Motorized Valves
	Distribution Pump	6.0 m3/min×50 m×72 Kw×3 Units
		Check and Sluice Valves with Motorized Valves
Electrical Facilities	Power Receiving Facility	Power Receiving and Transformer Equipment
	Power Supply Facility	Distribution Pump Control Panel
		Transmission Pump Control Panel
	Emergency Generator Facility	Generator Room with Fuel Tank
		Generator Capacity for 1/3 Dist. & Trans. Pump Capacity
	Instrumentation	Pressure Meter of Distribution and Transmission Line
		Supervising Panel
Landscaping and Others		Site Preparation, Lighting, etc.

3.5 Improvement of Transmission and Distribution System

3.5.1 General

The improvement of the distribution network system was not included in the original JICA study because of the demarcation of the study between JICA and AFD. To complete the 1st stage of the master plan, however, the installation of 24.2 km length of distribution mains are required. Selection of the priority projects and the feasibility study of the distribution system were originally scheduled to be conducted by the AFD study according to the demarcation.

The distribution network system is also indispensable for maintaining the function of the water supply system properly, and should be implemented at the same time as the projects selected by the JICA study. It should be noted that without strengthening the distribution network system, the water supply system will not function properly even though the production capacity will be increased and the transmission system will be developed as a result of the JICA study. It was recommended that the minimum required distribution mains for the system should be installed at the same time as the expansion of the treatment plant capacity and the development of the transmission system for the Vientiane water supply development. Therefore, the JICA proposed, and the AFD and other agencies concerned i.e. WASA and NPVC, agreed to include the minimum required distribution mains into the JICA feasibility study at the Kick-off Meeting for the feasibility study held on 11th September 2003. It is noted that even though the minimum required distribution mains are included in the JICA study, these mains are not eliminated from the AFD study because the study of the overall distribution network system to be carried out by AFD should consider all the distribution mains including the minimum required distribution mains.

In the analysis to identify the minimum required distribution trunk mains, which was conducted during the master planning, the minimum residual pressure at each junction was not maintained at 15m (1.5 kg/cm2), but the average residual pressure should measure more than zero. This means that water is only available at intermittent periods throughout the day. The purpose of this network analysis is to verify whether the average residual pressure at each junction should be maintained at more than zero based on the data of the investigation results carried out during the feasibility study.

3.5.2 Results of Field Investigation for Pipeline Routes

During the second field investigation for the Phase III Feasibility Study on the Priority Projects from August to November 2003, the JICA study team conducted a line survey including the longitudinal and cross sections along the proposed pipeline routes for the transmission mains and the minimum required distribution mains. In the Phase II Preparation of Master Plan, the lengths of the proposed pipelines were estimated from the drawings of the NPVC. Based on the results of the survey, considering the detailed field investigation, and referring to the on-going projects, the length of the proposed pipelines for the priority projects are compared in Table 35-1. For the network analysis in the following section, the pipeline lengths obtained from the survey are used.

Table 35-1 Comparison of Pipeline Length

Dia (mm)	Minimum Required Distribution Mains (km)		Transmission Mains (km)	
	M/P	F/S	M/P	F/S
150	4.57	4.57	-	-
250	3.22	3.24	-	-
400	4.89	4.65	-	-
450	-	-	2.22	1.88
600	1.76	1.62	-	-
700	0.68	0.50	0.58	0.72
Total	15.12	14.58	2.80	2.60

Note: Figures in "M/P" were estimated at Phase II of the Preparation of Master Plan.
Figures in "F/S" are adopted for the preliminary design of the priority projects based on the investigations conducted during the Phase III of the Feasibility Study on the Priority Projects.

3.5.3 Network Analysis for the 1st Stage Project

(1) Conditions of Network Analysis

Methods of the network analysis for the 1st stage project in the target year of 2007 including the priority projects are same as the network analysis for the master plan which is detailed in Section 4.5of the Comparative Study of Alternatives of Volume II of the Master Plan and Annexes 15 and 20. Differences in the conditions of the network analysis attached in Annex 20 are mainly the pipeline length of the minimum required distribution mains and the transmission mains as shown in Table 35-1.

The network analysis has been conducted using WaterCAD. Conditions of the network analysis are as follows:

a. Formula for friction loss calculation: Hazen-Williams Formula
b. C value for all pipes: 110
c. Velocity Range: 1.0 m/s – 1.5 m/s as the target
d. Hourly peak factor for domestic demand is estimated at 1.4. Half of non-domestic demand is assumed to be the same hourly peak factor as the domestic demand. For the remaining non-domestic demand, hourly peak factors are not applied since non-domestic customers have their own reservoir. The basis of calculations of the hourly peak factor is shown in Annex-15. The overall hourly peak factor, the average of domestic and non-domestic demand is calculated as 1.3.

Conditions of the pumps, reservoirs and tanks for the network analysis are shown in Figure 35-1.

(2) Results of Network Analysis

As the results of the analysis, it was confirmed that the average residual pressure at each junction will be maintained at more than zero in cases where the minimum required distribution mains were installed at the same time as the expansion of treatment plant capacity and the development of the transmission system.

The results of the network analysis are summarised in Annex 25. After the completion of the priority project, the transmission and distribution systems of the Vientiane Water Supply System will be developed as shown in Figure 35-2.

It is, however, noted that to install only the minimum required distribution mains is not the appropriate development of the distribution network system in 2007. Essentially the appropriate system should follow the master plan prepared in Chapter 4. A detailed study on the distribution network system will be conducted by the AFD study.

Figure 35-1 Transmission and Distribution System

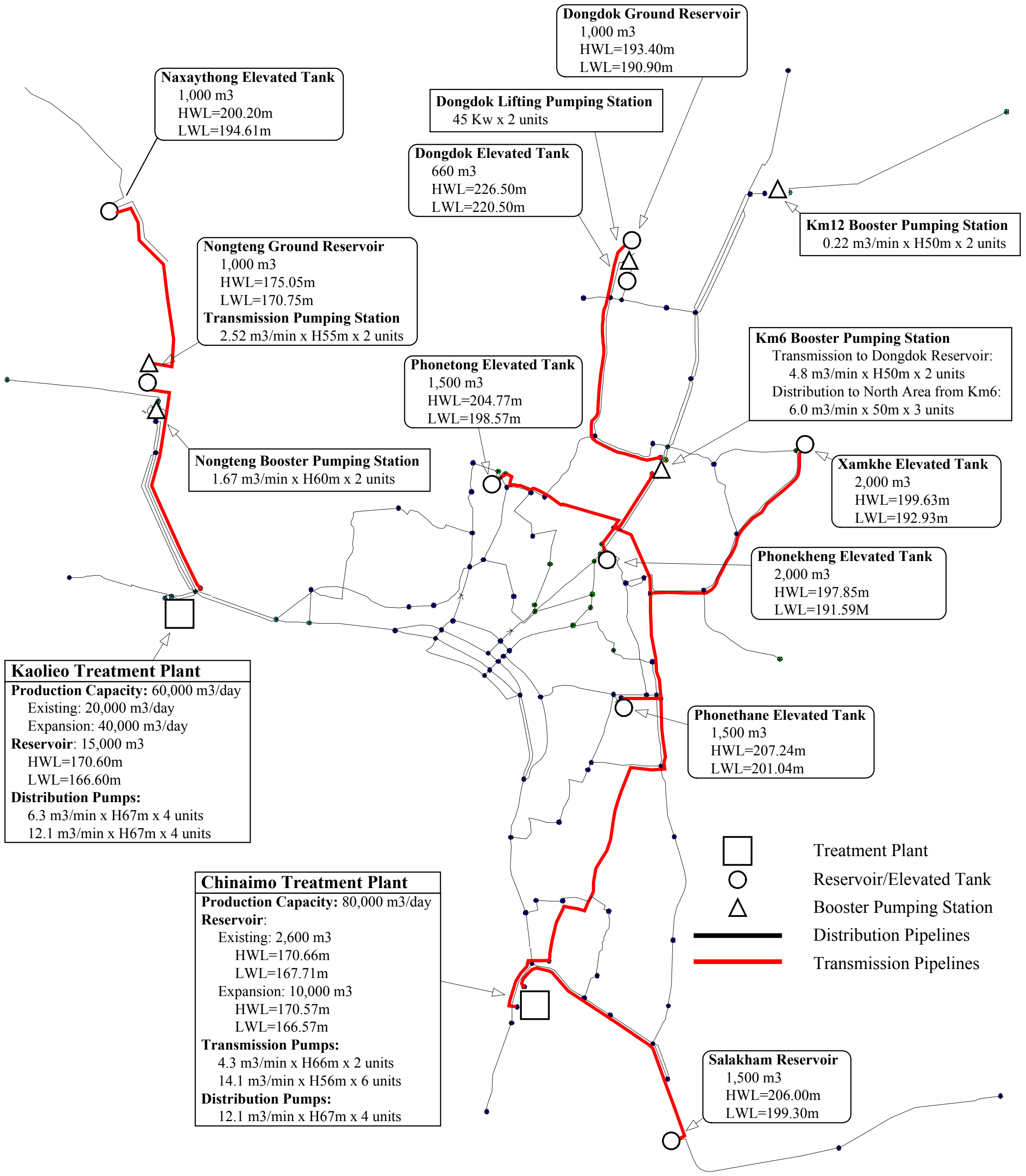
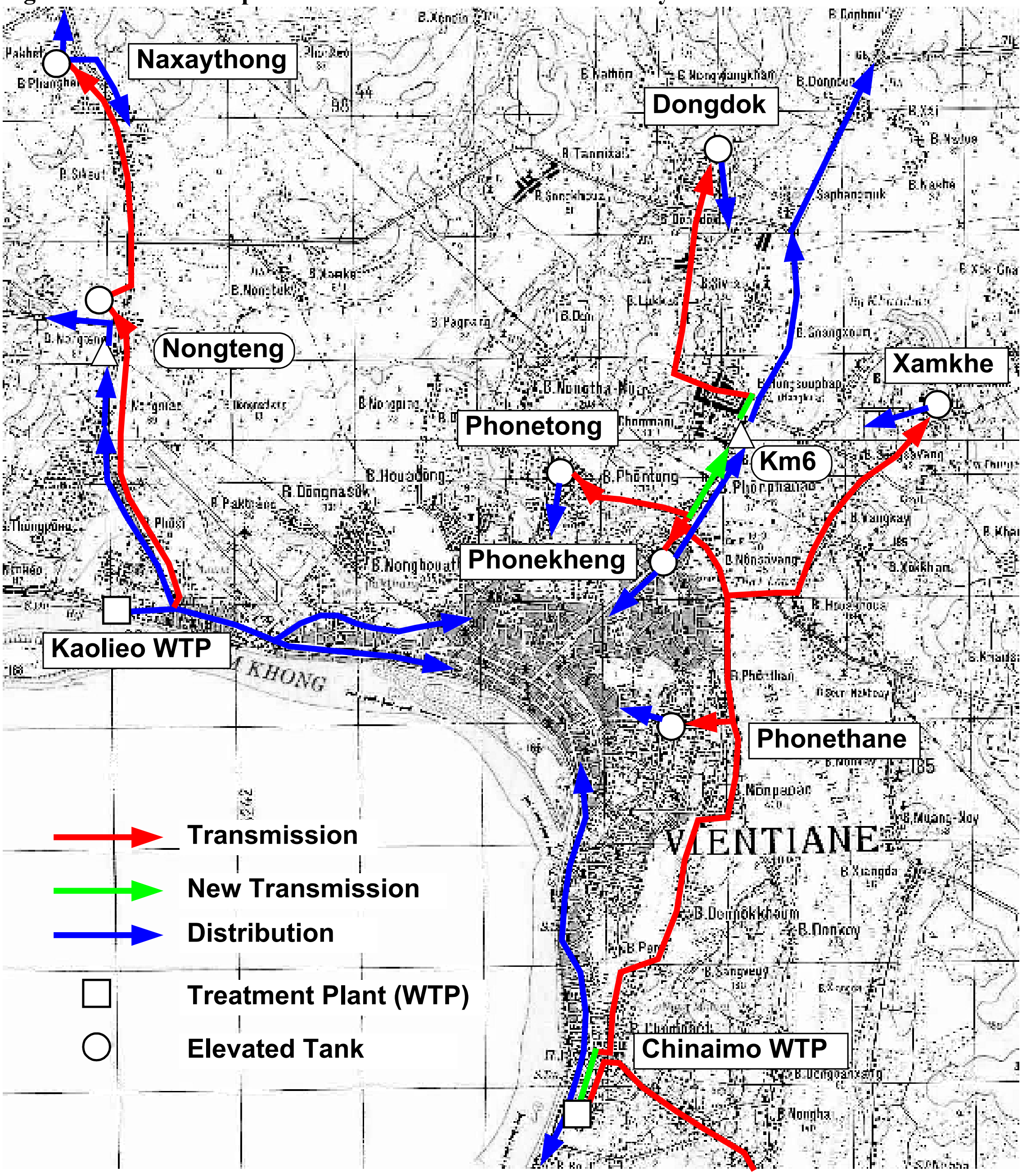


Figure 35-2 Proposed Transmission and Distribution Systems



3.5.4 Selection of Pipe Materials

Given the important role of the transmission and distribution mains which will be installed along the major roads, the strength and durability of pipes are among the first factors to be considered. To achieve these requirements, pipes made from, Ductile Cast Iron Pipe (DIP) or Steel Pipe (SP) will be selected as the pipe materials for the transmission and distribution mains. If the soil nature is corrosive, the DIP, which has better corrosions resistance properties than SP, will have advantages. For pipelines used which have a diameter of less than 300 mm, it is proposed to use Polyvinyl Chloride (PVC) Pipe.

This study recommends DIP for the installation of transmission and distribution pipelines because of the difficulty of welding joins in SP and testing of the welded joint. Also based on the preliminary cost estimates, costs for SP works including materials, civil works, installation works and restoration works are marginally more expensive than the costs for DIP. However, this does not exclude the use of SP from the projects. If the correct conditions are met, there is no objection to select SP for use in the project.

In addition to the above, the following advantages to apply the DIP will be considered:

- Easier maintenance and repair compared with using SP which requires removal of coating and replacing it when new branches are installed from the existing mains or the existing pipe is required to be cut for repair and re-joined again.
- Quick and easier installation even by unskilled labour even using mechanical joint
- Flexible joint which allows adjustment of pipeline alignment in accordance with shapes of road in limited spaces and avoiding unforeseeable underground obstacles during pipe laying work, which sometimes happens.
- For sizes of pipeline which are less than 600 mm in diameter, and when SP is used for these sizes of pipes, repairing of lining after welding can be applied.
- Weather conditions and the existence of a high groundwater table will not be critical for joining DIP.