ANNEX 4.3.1

COMPARATIVE STUDY ON ALTERNATIVE WATERSOURCES

THE STUDY ON WATER SUPPLY SYSTEM
FOR SIEM REAP REGION IN CAMBODIA

FINAL REPORT
Vol. III SUPPORTING REPORT

ANNEX 4.3.1 COMPARATIVE STUDY ON ALTERNATIVE WATER SOURCES

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ANNEX 4.3.1 COMPARATIVE STUDY ON ALTERNATIVE WATER SOURCES

1. Method of Comparison

1.1 Alternative Sources

As discussed in the Main Report, 4.2 Development Potential of Water Sources, four alternative water sources,

Alternative – 1 :Groundwater,
Alternative – 2 :West Baray,
Alternative – 3 :Siem Reap River, and
Alternative – 4 :Lake Tonle Sap,

are considered as potential water sources for future water supply in Siem Reap Town. Methodology and results of comparative study to select the most suitable water source from these potential water sources are described in this Annex.

1.2 Basis of Comparison

To select the best water source, comprehensive comparative study was conducted. It is apparent that these alternative water sources can not be compared only by respective characteristics and water source development costs. For instance, one water source with less development costs may require huge construction, and operation and maintenance costs for water supply system. The other water source with high development costs may require less operation and maintenance costs.

Therefore for the comparison, not only the aspect of water source development but also the aspect of water supply system development for the respective source are comprehensively considered and compared. Water supply system for each water source are discussed in the following sections. These water supply systems were planned based on the capacity of 12,000 m^3/day which was projected as Daily Maximum Water Demand in Year 2010.

In addition to the cost comparison, other criteria are also taken into account. Criteria for the comparison are described in the following sections.

1.3 Criteria for Comparison

For the selection of the best water source, the following criteria are considered.

1.3.1 Lower Cost

(1) Investment Cost

Investment cost should be economically minimized. Costs required for water source development and construction costs of water supply system are calculated for each alternative. Cost for distribution trunk main to the center of the town is included and the cost for distribution network is excluded from the relative investment cost because the cost is common to all alternatives.

(2) Operation and Maintenance Cost

Operation cost such as electricity cost, chemical cost, and salary are calculated for each water supply system. Maintenance cost is also calculated as 1% of total construction costs.

For comparison, total costs in terms of Net Present Value were calculated from the cost of water source development, water supply facility construction and operation and maintenance. Discount rate for NPV is 10% and duration of NPV calculation is 30 years. (Figure 1.3.1)

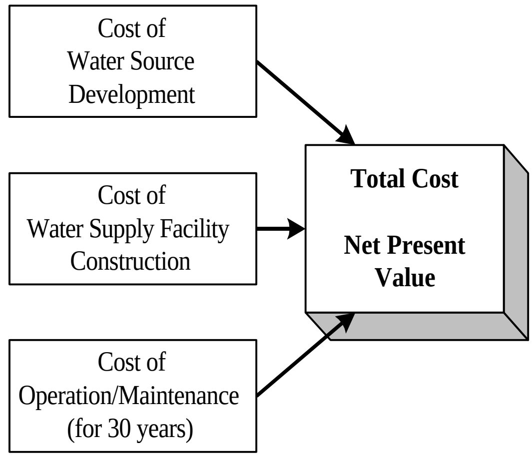


Figure 1.3.1 Net Present Value

1.3.2 Easy Operation and Maintenance

System operation should be simple and be sustainable without complicated maintenance work. Water source which will make water supply facility simple is the most suitable.

1.3.3 Less Impact to Angkor Heritage

Impact to the Angkor Heritage which will be caused by water source development or by construction of water supply facilities should be minimized. Water source which will not cause significant adverse side effects should be selected.

1.3.4 Reliability

Water supply system should be operated continuously without termination. In this aspect, water source of water supply system should have high reliability even in the drought season.

1.3.5 Stable and Suitable Water Quality

Fluctuation of the raw water quality will make water treatment difficult in terms of operation and will increase cost of treatment system operation. Operation cost, specially chemical costs, will be minimized in case the raw water quality is suitable for potable water supply.

1.3.6 Flexibility of the System

Water supply system should have flexibility to overcome unforeseen condition.

1.3.7 Less Impact to Environment

In the selection process of the most suitable water source, proper consideration is given in order to have less environmental impacts. The major criteria are social environment, natural environment and pollution. Environmental impacts expected from the development of each alternative are carefully examined and utmost efforts are given to select an alternative with less impact.

2. Alternative – 1 : Groundwater System

2.1 Characteristics of the Groundwater System

2.1.1 Advantages

As described in the previous section, water quality of the groundwater in the southern area of the Siem Reap Airport is suitable and stable as a source of water supply. No treatment will be required and water will be supplied directly after disinfection by liquid chlorine.

Because of no treatment, operation and maintenance of the system is much easier comparing with other alternative sources, and it will result in low operation and maintenance cost.

2.1.2 Disadvantages

Groundwater level should be always monitored and adequate abstraction rate should be reviewed to avoid excessive drawdown.

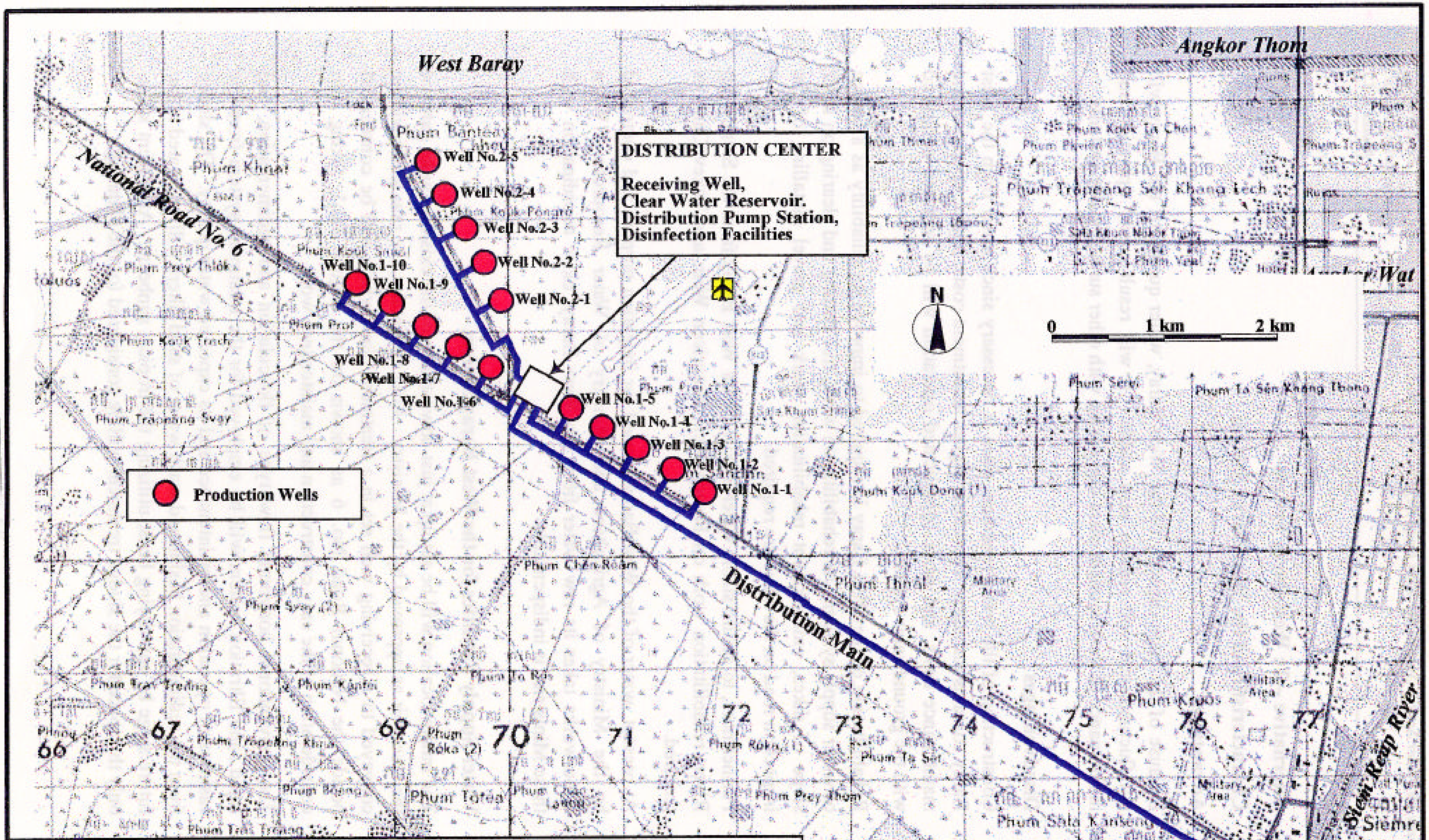
At the same time, effect to Angkor Heritage should be monitored continuously to avoid any damage to the heritage. According to the results of groundwater simulation, planned abstraction of groundwater, 12,000 m^3/day at southern area of Siem Reap Airport, will not cause significant land subsidence at Angkor Heritage.

2.2 Water Supply Facilities for Groundwater System

Taking account of all influences originating from abstraction of groundwater and based on the results of groundwater simulation, the well field was selected at the north-west area of Siem Reap Town along the National Road No. 6.

The facilities of the groundwater system will consist of the structures/facilities described below and System layout is shown on Figure 2.2.1.

Well :	ϕ450 x Depth 50 m x 15 wells + 2.2 ～ 3.7 kW
Well House :	25 m^2 x 15 locations
Connecting Pipelines :	DIP ϕ150 mm ～ 250 mm x L = 6,900 m
	ϕ150 mm x L1,500 m
	ϕ200 mm x L2,400 m
	ϕ250 mm x L3,000 m
Receiving Well :	Depth 3 m x Area 14 m^2
Clear Water Reservoir	
Size :	W15.0 m x L25.0 m x Depth 3.5 m x 3 reservoirs
Detention Time :	7.9 hours
Appurtenances :	Inlet and Outlet Pipes, Ventilators, Level Meter
Distribution Pumps :	5.0 m^3/min x H40 m x 3 pumps
	(2 operation, 1 stand-by) 55 kW/pump
Pump House :	100 m^2
Distribution Main :	DIP ϕ500 x 8,400 m
Chlorinator :	2 sets (including water feeding pumps)
Chlorinator House :	W7 m×L15 m
Generator and Generator House :	50 m^2
Instrumentation Required	



A4.3.1-5

The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 2.2.1 Altanative - 1 : General Plan of Groundwater System
Japan International Cooperation Agency	

3. Alternative – 2 : West Baray System

3.1 Characteristics of the West Baray System

3.1.1 Advantages

Because of the huge capacity of the West Baray, water quality of the Baray will not fluctuate and will remain very stable. It will result easier operation and maintenance of the treatment plant comparing with other surface water systems.

3.1.2 Disadvantages

Construction of the water treatment plant is necessary since water from the West Baray contains turbidity. Therefore, higher investment costs, higher operation and maintenance costs, and more complicated operation will be required compared with the groundwater system.

Rehabilitation of the West Baray is required to improve its reliability as a source of water supply system. As rehabilitation work, tree cutting and clearing on inner slope of dikes, embankment rehabilitation work and gravel metalling of the inspection road on the dikes are required.

Furthermore, to assure stable water inflow to the West Baray from the Siem Reap River, rehabilitation work on French Weir, American Weir, and Takev Canal is required.

At present, water of the West Baray is used for irrigation purpose and controlled by the Ministry of Agriculture and Ministry of Water Resources. When Waterworks takes its raw water from the West Baray, close coordination with these Ministries is indispensable.

3.2 Water Supply Facilities for the West Baray System

The intake location will be set up at just downstream of the existing outlet gates of the reservoir as approved by the Ministry. After the intake, the raw water will be conveyed to a receiving well set in a treatment plant which will be constructed beside the National Road No. 6 as shown on the Figure 3.2.1, taking into consideration of the easy construction and maintenance work.

The conventional horizontal flow type of flocculation and sedimentation, and rapid sand filtration system will be employed for the treatment system from the easiness of operation and maintenance and its expected water quality. The sludge from the sedimentation basins and wash water of sand filters will be treated in the future stage by sun-drying beds, utilizing the tropical sunbeam. At present stage, only the space for the sludge treatment will be considered for the planning.

The facilities of the West Baray System will consist of the structures described below:

a) Intake Facilities

Intake Weir

Size : Top W 1 m × Bottom W 2.5 m × L 16 m × H 2.5 m

Structure : Gravity Weir Type (RC made) × 1 weir

Intake Gate and Connecting Culvert

Gate Size : H 1.0 m × W 1.5 m × 2 sets (1 standby)

Inflow Area : H 0.4 m × W 1.5 m = 0.6 m^2

Inflow Velocity : [0.139 m^3/sec]/0.6 m^2 = 0.2 m/sec

Connecting Culvert: H 2.0 m × W 1.5 m × L 30 m × 1 culvert

Appurtenances : Bar Screen, Net Screen,

Protection of Banks

Protection Size : W 13.0 m × L 50 m × 2 sides = 1,300 m^2

Structure : Precast Concrete Block

b) Conveying Facilities

Pump Well

Size : B 2.0 m × L 6.0 m × H 2.5 m = 30.0 m^3

Detention Time : [30.0 m^3]/8.33 m^3/min = 3.6 min

Structure : RC made

Appurtenances: Inlet Gate, Drain Valve

Pump Station

Size : W 6.0 m × L 12.0 m × 1 station

Structure : RC made, One-story House

Pumps : φ200 × Q 4.6 m^3/min × H 19.5 m × 22 kW × 3 sets (2 sets - ordinal use, 1 set - standby)

Conveying Pipeline

Pipeline : DIP Cement Lining φ400 × L 2,800 m × 1 pipeline

Appurtenances: Stop Valves, Drain Valves, Air Valves

c) Treatment Facilities

Receiving Well

Size : W 4.0 m × L 4.0 m × D 3.0 m = 48.0 m^3

Detention Time : $48.0/8.33\ m^3/min = 5.8\ min$
Appurtenances: Perfect Over Flow Weir, Inlet Valve ϕ450, Chemical Dosing Pipes

Flocculation Basins
Size : W 7.0 m × L 6.0 m × D 2.0 m x 2 basin = 168.0 m^3
Basin Type : Up-Down Baffled Cannel Mixing
Detention Time : $168/8.33\ m^3/min = 20.2\ min$
Appurtenances: Washing Pipes, Drain Gates

Sedimentation Basins
Size : W 6.0 m × L 35.0 m × D 3.5 m x 2 basin = 1,470.0 m^3
Basin Type : Horizontal Flow Sedimentation
Detention Time : $1,470.0/8.33\ m^3/min = 2.9\ hours$
Surface Load : 19.8 mm/min (15 – 30 mm/min, Japanese Design Criteria)
Average Velocity : 0.20 m/min (less than 0.4 m/min, Japanese Design Criteria)
Appurtenances: Drain Valves, Washing Pipelines, Outlet Troughs

Rapid Sand Filters
Size : W 4.0 m × L 7.0 m × 4 beds = 112 m^2
Filtration Speed : 107 m/day
Washing System : Surface Wash and Back Wash, Pipe Gallery

Clear Water Reservoir
Size : W15.0 m x L25.0 m x Depth 3.5 m x 3 reservoirs
Detention Time : 7.9 hours
Appurtenances: Inlet and Outlet Pipes, Ventilators, Level Meter

Operation Building
Size : W 10.0 m × L 20.0 m × 2 Stories = 400.0 m^2
Structure : RC

Chemical Building
Size : W 7.0 m × L 15.0 m × 2 Stories = 210 m^2
Structure : RC

Connecting Pipelines
Size : DIPϕ600 ~ϕ400 × L 1,000 m

Concrete Pipe ϕ800 ~ ϕ300 × L 500 m

Appurtenances: Valve Chambers, Manholes

Instrumentation System

Operation and Control System : L.S.

Desludging Facilities

Space : W 100 m × L 100 m for the future treatment

d) Distribution Facilities

Pump Station

Size : W 6.0 m × L 12.0 m × 1 station

Structure : RC made, One-story House

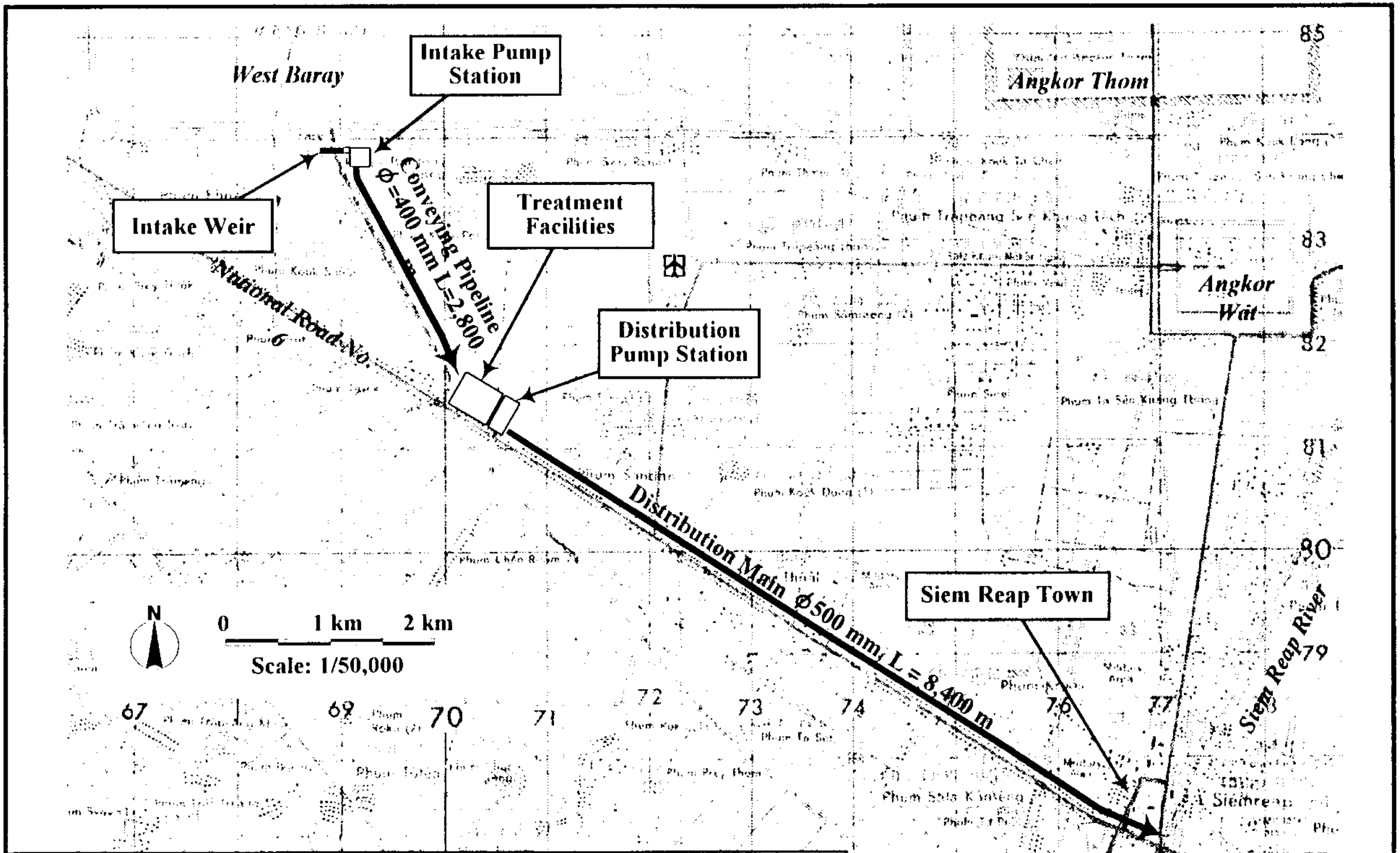
Pumps : ϕ200 × Q 5.0 m^3/min × H 40 m × 55 kW × 3 sets (2 sets - ordinal use, 1 set - standby)

Appurtenances: Hoist Crane

Distribution Main

Pipeline : ϕ500 mm x L=8,400 m

Appurtenances: Drain Pipes, Air Valves



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 3.2.1 Alternative-2 : General Plan of West Baray System
Japan International Cooperation Agency	

4. Alternative – 3 : Siem Reap River System

4.1 Characteristics of the Siem Reap River System

4.1.1 Advantages

In the case of the Siem Reap River System, intake facility will be located at north of the town, in between Angkor Heritage and the town, to avoid raw water contamination by wastewater from the town. Treatment plant should be required and will be constructed near the intake. Therefore, water intake and treatment plant will be located near from the town, the demand area.

4.1.2 Disadvantages

According to the hydrological analysis, possible water yield of the Siem Reap River in dry season will not be enough for water supply. Re-development of North Baray as raw water reservoir to substitute raw water shortage in drought season should be considered. In the rainy season, river water will be stored in the North Baray by pumping water up to the Baray. In dry season, water stored in the Baray will be released to the river by gravity.

Because of the high turbity, construction of the treatment plant is indispensable. Operation and maintenance of the plant will be rather difficult compared with the groundwater system.

4.2 Water Supply Facilities for the Siem Reap River System

The site of the Intake and Treatment Plant was selected at Ph Trang (Phoun Trang Village) located about 4 km north-east from Siem Reap Town center as shown on Figure 4.2.1. The selected area is also far enough from the renowned Angkor Heritage, and will be free from any flood. The soil condition looks hard enough for the foundation of structures.

The water treatment system similar to the West Baray System will be employed from the standpoint of stable and comparatively easy operation. The sludge treatment will not be considered for the first stage except for the space arrangement for future treatment.

The facilities of the Siem Reap River System will consist of the structures described below:

a) Intake Facilities

Intake Weir

Size : Top W 1 m × Bottom W 2.5 m × L 25 m × H 2.5 m

Structure : Gravity Weir Type (RC made) × 1 weir
Appurtenances: Sand Scouring Gate, Connecting Bridge

Intake Tower
Size : φ3.0 m × H 6.0 m × 1 set
Pump : φ300 mm × Q 4.6 m^3/min × H12 m × 15 kW × 3 sets
Appurtenances: Screen, Intake Gates, Intake Pipe (φ300 x 100 m)

b) Treatment Facilities

Receiving Well
Size : W 4.0 m × L 4.0 m × D 3.0 m = 48.0 m^3
Detention Time : 48.0/8.33 m^3/min = 5.8 min
Appurtenances: Perfect Over Flow Weir, Inlet Valve φ450, Chemical Dosing Pipes

Flocculation Basins
Size : W 7.0 m × L 6.0 m × D 2.0 m x 2 basin = 168.0 m^3
Basin Type : Up-Down Baffled Cannel Mixing
Detention Time : 168/8.33 m^3/min = 20.2 min
Appurtenances: Washing Pipes, Drain Gates

edimentation Basins
Size : W 6.0 m × L 35.0 m × D 3.5 m x 2 basin = 1,470.0 m^3
Basin Type : Horizontal Flow Sedimentation
Detention Time : 1,470.0/8.33 m^3/min = 2.9 hours
Surface Load : 19.8 mm/min (15 – 30 mm/min, Japanese Design Criteria)
Average Velocity : 0.20 m/min (less than 0.4 m/min, Japanese Design Criteria)
Appurtenances: Drain Valves, Washing Pipelines, Outlet Troughs

Rapid Sand Filters
Size : W 4.0 m × L 7.0 m × 4 beds = 112 m^2
Filtration Speed : 107 m/day
Washing System : Surface Wash and Back Wash, Pipe Gallery

Clear Water Reservoir
Size : W15.0 m x L25.0 m x Depth 3.5 m

x 3 reservoirs
Detention Time : 7.9 hours
Appurtenances: Inlet and Outlet Pipes, Ventilators, Level Meter

Operation Building
Size : W 10.0 m × L 20.0 m × 2 Stories = 400.0 m^2
Structure : RC

Chemical Building
Size : W 7.0 m × L 15.0 m × 2 Stories = 210 m^2
Structure : RC

Connecting Pipelines
Size : DIP ϕ600 ~ϕ400 × L 1,000 m
Concrete Pipe ϕ800 ~ ϕ300 × L 500 m
Appurtenances: Valve Chambers, Manholes

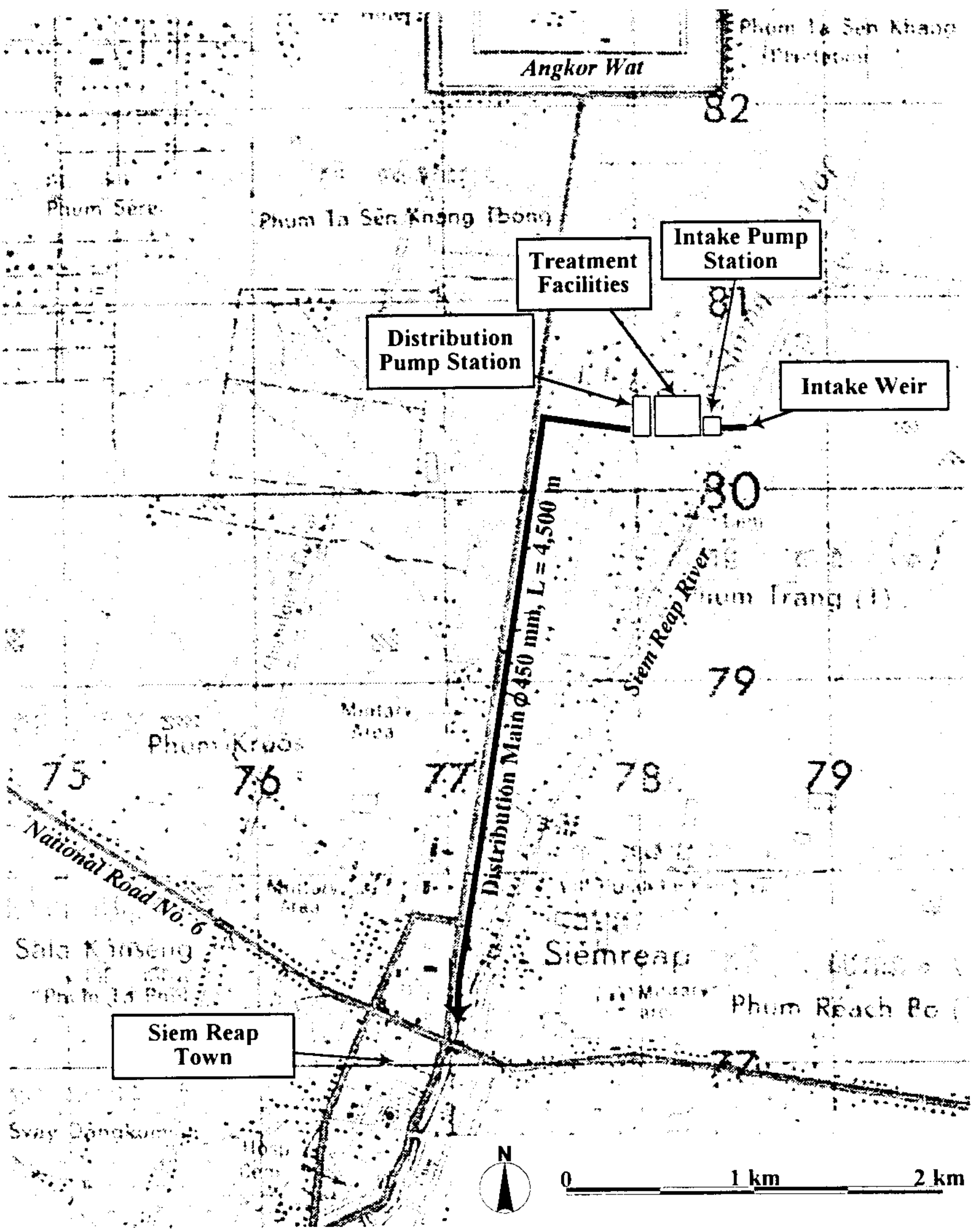
Instrumentation System
Operation and Control System : L.S.

Desludging Facilities
Space : W 100 m × L 100 m for the future treatment

c) Distribution Facilities

Pump Station
Size : W 6.0 m × L 12.0 m × 1 station
Structure : RC made, One-story House
Pumps : ϕ200 × Q 5.0 m^3/min × H 34 m × 45 kW × 3 sets
(2 sets - ordinal use, 1 set - standby)
Appurtenances: Hoist Crane

Distribution Main
Pipeline : ϕ450 x L= 4,500 m
Appurtenances: Drain Pipes, Air Valves



The Study on Water Supply System for Siem Reap Region in Cambodia	Figure 4.2.1 Alternative-3 : General Plan of Siem Reap River System
Japan International Cooperation Agency	

5. Alternative – 4 : Lake Tonle Sap System

5.1 Characteristics of the Lake Tonle Sap System

5.1.1 Advantages

Lake Tonle Sap is the largest permanent freshwater lake in Southeast Asia and its storage is more than 1,300 million m^3 even at the lowest water stage below EL. 1 m at the end of the dry season. The possible yield from the lake can be considered practically as unlimited.

5.1.2 Disadvantages

From a hydrological viewpoint, the intake site should be located below approximately EL. 0.7 m, which is 20-year return period minimum water stage in the dry season. Therefore, the available intake site is recommended to be located at least 4 km offshore from the existing boat station, the shoreline at the lowest stage. Also from the water quality viewpoint, water near the boat station is contaminated by wastewater from boats and habitat nearby. Therefore, intake point should be located far from the boat station.

The distance from the intake point to the town via. treatment plant will be around 20 km. It is naturally impossible to convey the raw water by gravity and huge pipeline cost and pumping cost will be requried.

5.2 Water Supply Facilities for the LakeTonle Sap System

The intake point was selected offshore from Ph Moat Peam about 4 km, as shown on Figure 5.2.1, to secure sufficient water depth in the dry season. Intake pump station will be set on a tower-like pump house at Boat Station. The Treatment Plant site will be selected at Ph Speanchraw (about GL +10 m) area where the ground level is higher than the highest water level of the Lake.

The Plant system employed will be the same as the previously selected types: conventional horizontal flow sedimentation and rapid sand filtration system. The sludge treatment will not be considered for the time being except its space for future consideration.

The facilities of the Lake Tonle Sap System will consist of the structures described below:

a) Intake Facilities

Intake Pipe

Intake Head : Steel Head ϕ 2.0 m × H 1.0 m × 1 set

Inlet Velocity : Q = 0.116 m^3/sec
A = 3.14 × 2.0 × H 0.7 = 4.40 m^2
v = Q/A = 0.153/4.40 = 0.035 m/sec
Intake Pipe : Steel Pipe ϕ500 × L 4,000 m × 1 pipeline
Appurtenances : Mark Buoys, Marks for Pipeline

Intake Pump Station
Pump Station : W 6.0 m × L 6.0 m × H 12.0 m × 1 set
Submergible Pump : ϕ300 mm × Q 4.6 m^3/min × H 25 m × 30 kW x 3 sets
Pump Pit & Screen : W 6.0 m × L 3.0 m × D 3.0 m × 2 pits
Appurtenances : Generators, Fuel Tank, Patrol Boat

b) Conveying Facilities

Pump Well
Size : B 2.0 m × L 6.0 m × H 2.5 m = 30.0 m^3
Detention Time : [30.0 m^3]/8.33 m^3/min = 3.6 min
Structure : RC made
Appurtenances: Inlet Gate, Drain Valve

Pump Station
Size : W 6.0 m × L 12.0 m × 1 station
Structure : RC made, One-story House
Pumps : ϕ200 × Q 4.6 m^3/min × H 19.5 m × 22 kW × 3 sets (2 sets - ordinal use, 1 set - standby)

Conveying Pipeline
Pipeline : DIP Cement Lining ϕ400 × L 2,800 m × 1 pipeline
Appurtenances: Stop Valves, Drain Valves, Air Valves

c) Treatment Facilities

Receiving Well
Size : W 4.0 m × L 4.0 m × D 3.0 m = 48.0 m^3
Detention Time: 48.0/8.33 m^3/min = 5.8 min
Appurtenances: Perfect Over Flow Weir, Inlet Valve ϕ450, Chemical Dosing Pipes

Flocculation Basins
Size : W 7.0 m × L 6.0 m × D 2.0 m x 2 basin = 168.0 m^3
Basin Type : Up-Down Baffled Cannel Mixing
Detention Time: 168/8.33 m^3/min = 20.2 min
Appurtenances: Washing Pipes, Drain Gates

Sedimentation Basins

Size	:	W 6.0 m × L 35.0 m × D 3.5 m x 2 basin = 1,470.0 m^3
Basin Type	:	Horizontal Flow Sedimentation
Detention Time:		1,470.0/8.33 m^3/min = 2.9 hours
Surface Load	:	19.8 mm/min (15 – 30 mm/min, Japanese Design Criteria)
Average Velocity:		0.20 m/min (less than 0.4 m/min, Japanese Design Criteria)
Appurtenances:		Drain Valves, Washing Pipelines, Outlet Troughs

Rapid Sand Filters

Size	:	W 4.0 m × L 7.0 m × 4 beds = 112 m^2
Filtration Speed:		107 m/day
Washing System:		Surface Wash and Back Wash, Pipe Gallery

Clear Water Reservoir

Size :		W15.0 m x L25.0 m x Depth 3.5 m x 3 reservoirs
Detention Time :		7.9 hours
Appurtenances:		Inlet and Outlet Pipes, Ventilators, Level Meter

Operation Building

Size	:	W 10.0 m × L 20.0 m × 2 Stories = 400.0 m^2
Structure	:	RC

Chemical Building

Size	:	W 7.0 m × L 15.0 m × 2 Stories = 210 m^2
Structure	:	RC

Connecting Pipelines

Size	:	DIP ϕ600 ~ϕ400 × L 1,000 m Concrete Pipe ϕ800 ~ ϕ300 × L 500 m
Appurtenances:		Valve Chambers, Manholes

Instrumentation System

Operation and Control System : L.S.

Desludging Facilities

Space	:	W 100 m × L 100 m for the future treatment

d) Distribution Facilities

Pump Station

Size	:	W 6.0 m × L 12.0 m × 1 station
Structure	:	RC made, One-story House
Pumps	:	ϕ200 × Q 5.0 m^3/min × H 36 m × 45 kW × 3 sets (2 sets - ordinal use, 1 set - standby)

Appurtenances: Hoist Crane

Distribution Main

Pipeline : φ500 mm x L= 4,500 m

Appurtenances: Drain Pipes, Air Valve

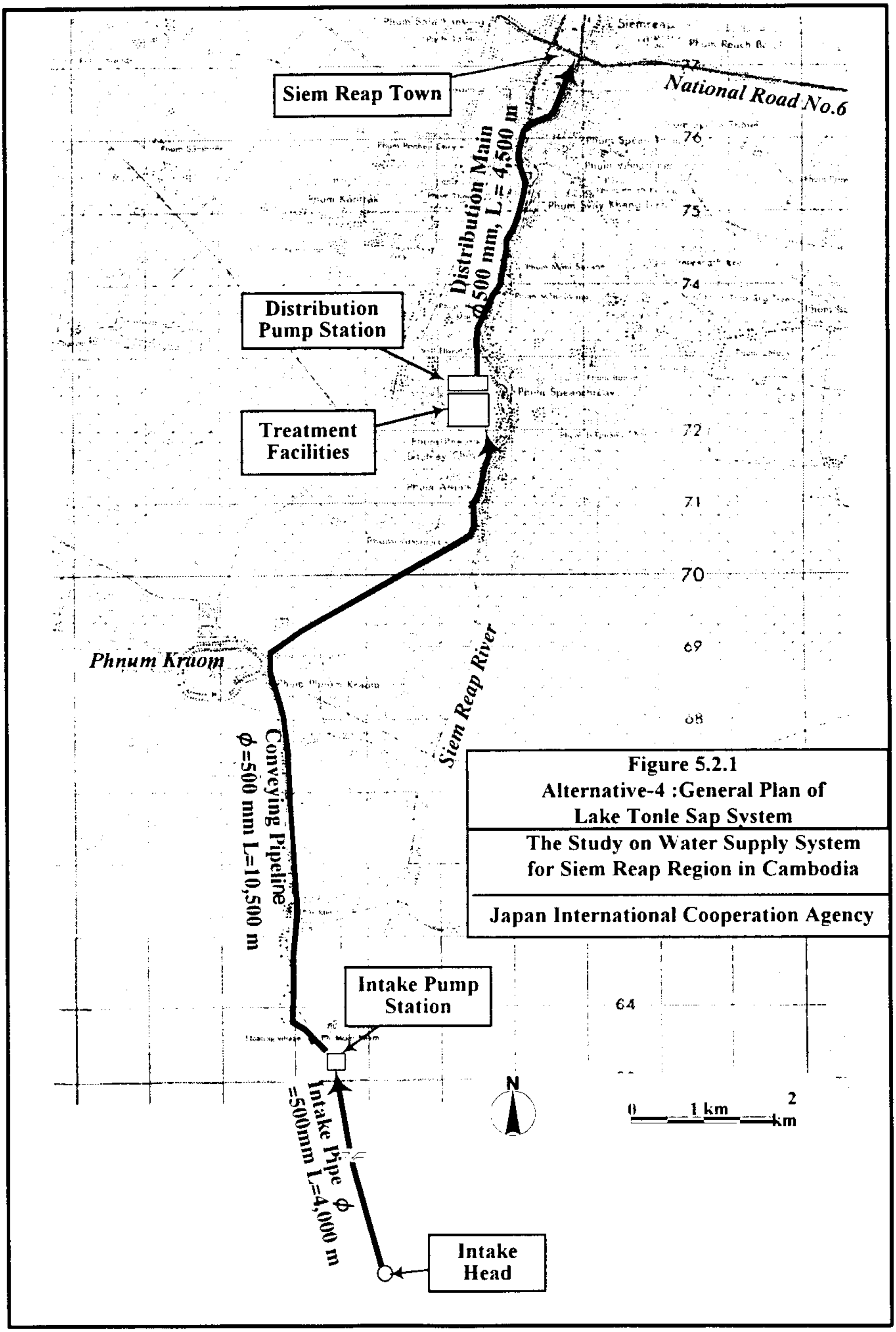


Figure 5.2.1
Alternative-4 :General Plan of Lake Tonle Sap System

The Study on Water Supply System for Siem Reap Region in Cambodia

Japan International Cooperation Agency