JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

EMPRESA NICARAGÜENSE DE ACUEDUCTOS Y ALCANTARILLADOS SANITARIOS (ENACAL)

THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN MANAGUA IN THE REPUBLIC OF NICARAGUA

FINAL REPORT

Supporting Report No.7
Improvement of Water Transmission and Distribution Systems

DECEMBER 2005

NIHON SUIDO CONSULTANTS CO., LTD.
ASIA AIR SURVEY CO., LTD.

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7.1 OBJECTIVES OF THE STUDY

During the field surveys and measurement works, some problems were found in the existing water supply system in Managua. Among existing problems the ENACAL is facing, significant problems are identified as follows.

- Water is not transmitted and/or distributed properly to whole service area, especially for three areas, (a) San Judas Area, (b) Schick Area and (c) Laureles Sur Area as shown in **Figure 7.1.1**.
- Deterioration of water quality of water sources, Asososca Lake and wells in Zona Baja and in the east of Zona Alta.
- Low effective water ratio (high leakage and wastage ratio)
- Decrease of production capacity of existing wells by aging well pumps and deterioration of wells themselves, including Managua I and Managua II Systems
- Delay in development of water supply facilities for demand increasing area located in high altitude area indicated as "d" area in **Figure 7.1.1** and Ticuantepe and Nindiri outside of Managua

At present ENACAL, therefore, does not provide satisfied water supply services for their all customers especially at three areas as shown in **Figure 7.1.1**.

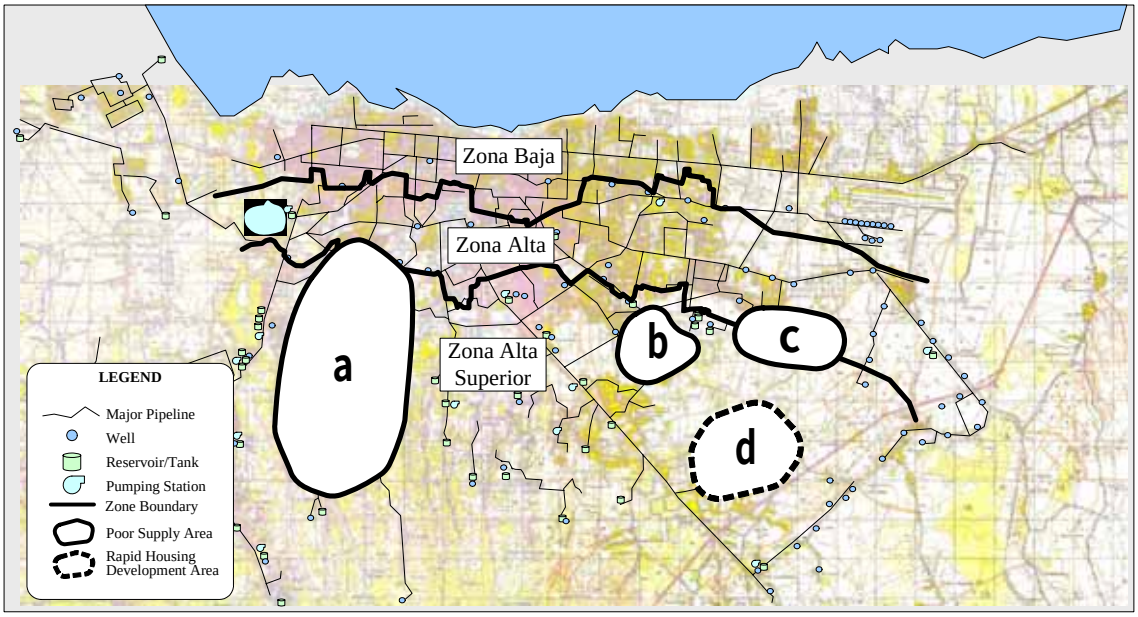


Figure 7.1.1 Poor Water Supply Service Areas

It is confirmed that the total amount of water sources will be secured for the demand in 2015, as detailed in **Supporting Report No.3**. The new water source is not needed to be developed, however, in order to meet the demand in 2015 and to provide satisfied water supply for whole service area it is necessary to increase the effective water ratio as the alternative water sources and improve the efficiency of transmission and distribution system. Although new water source development is not considered for the Master Plan, the well constructions by control of intake amount from Asososca Lake, relocations of wells which water qualities have deteriorated and rehabilitations of the existing wells will be required and included in the Master Plan.

In order to secure water supply, the study, therefore, considered that it is indispensable to restore the existing Managua I and Managua II system including rehabilitation works for wells to be able to function efficiently before the improvement of transmission and distribution system.

At the same time it should be necessary to improve the effective water ratio for securing the amount of water sources in 2015

The Managua I and Managua II System, which have well production capacities of 71,000 m^3/day and 56,160 m^3/day respectively, was constructed in 1997 and 2001 by Japan grand aid projects. According to the statistic data of ENACAL and Flow Measurement Survey by this Study as detailed in **Supporting Report No.5**, production and transmission amounts have decreased compared with the original design capacities because of problems of well pumps and deterioration of wells. Detailed evaluation and countermeasures against wells of Managua I and Managua II are described in **Supporting Report No.3**.

In order to improve the efficiency of transmission and distribution system, it is necessary to understand how much water is flowed into which area. For that purpose the service area of Managua Water Supply System should be divided into distribution zones (macro sectors) which have one major water supply source such as distribution tank or distribution pumping station. This is essential for improving the efficiency of transmission and distribution system and simultaneously effective for selecting the priority area for increase of effective water ratio.

As discussed above, the Master Plan on Water Supply System in Managua will put the priority on the following projects in order to solve the existing problems of ENACAL and their customers and to secure the improvement of water supply services for the citizens in the Study Area, Managua and urban area of Ticuantepe and Nindiri.

- Rehabilitation of the Existing Wells especially Managua I and Managua II Systems
- Macro Sectoring
- Improvement of Transmission and Distribution System
- Improvement of Effective Water Ratio

This supporting report concentrates a macro sectoring and an improvement of the efficiency of transmission and distribution system. Increase of effective water ratio is prepared in **Supporting Report No.4**. The aim of the study on improvement of water transmission and distribution system is to develop the efficient water transmission and distribution system designed to meet future water demands in order to solve the existing problems of ENACAL and their customers and to secure the improvement of water supply services for the citizens in the Study Area, Managua and urban area of Ticuantepe and Nindiri.

7.2 SUMMARY OF THE STUDY RESULTS

In order to improve the efficiency of transmission and distribution systems and to secure the water supply service to whole Study Area by year 2015, the Study proposes to implement the following activities as schematically shown in **Figure 7.2.1**.

- up to year 2010
  - Separation of 19 Macro Sectors in the Study Area
  - Improvement of Water Supply System for San Judas (Sierra Maestra) Area including well relocations
  - Improvement of Water Supply System for Esquipulas, Schick and Laureles Sur Areas
  - Measures against four wells to be abandoned in Sabana Grande which have high levels of arsenic concentration including constructions of substitute wells and distribution facilities
  - Improvement of Water Supply System for Ticuantepe including Well Development
  - Improvement of Water Supply System for Veracrus Area and Area along the Masaya Road (Nindiri) including Well Development
  - Rehabilitation of Pumping Facilities

- Installation of Secondary and Tertiary Distribution Mains
- Installation of House Connections

- up to year 2015
  - Improvement of Water Supply System in Zona Baja including Transmission Facilities to San Cristobal Tank
  - Improvement of Water Supply System Esquipulas, Schick and Laureles Sur Areas (Well Development)
  - Measures against three wells which have relatively high levels of arsenic concentration including constructions of transmission pipelines for mixing with other sources
  - Rehabilitation of Pumping Facilities
  - Installation of Secondary and Tertiary Distribution Mains
  - Installation of House Connections

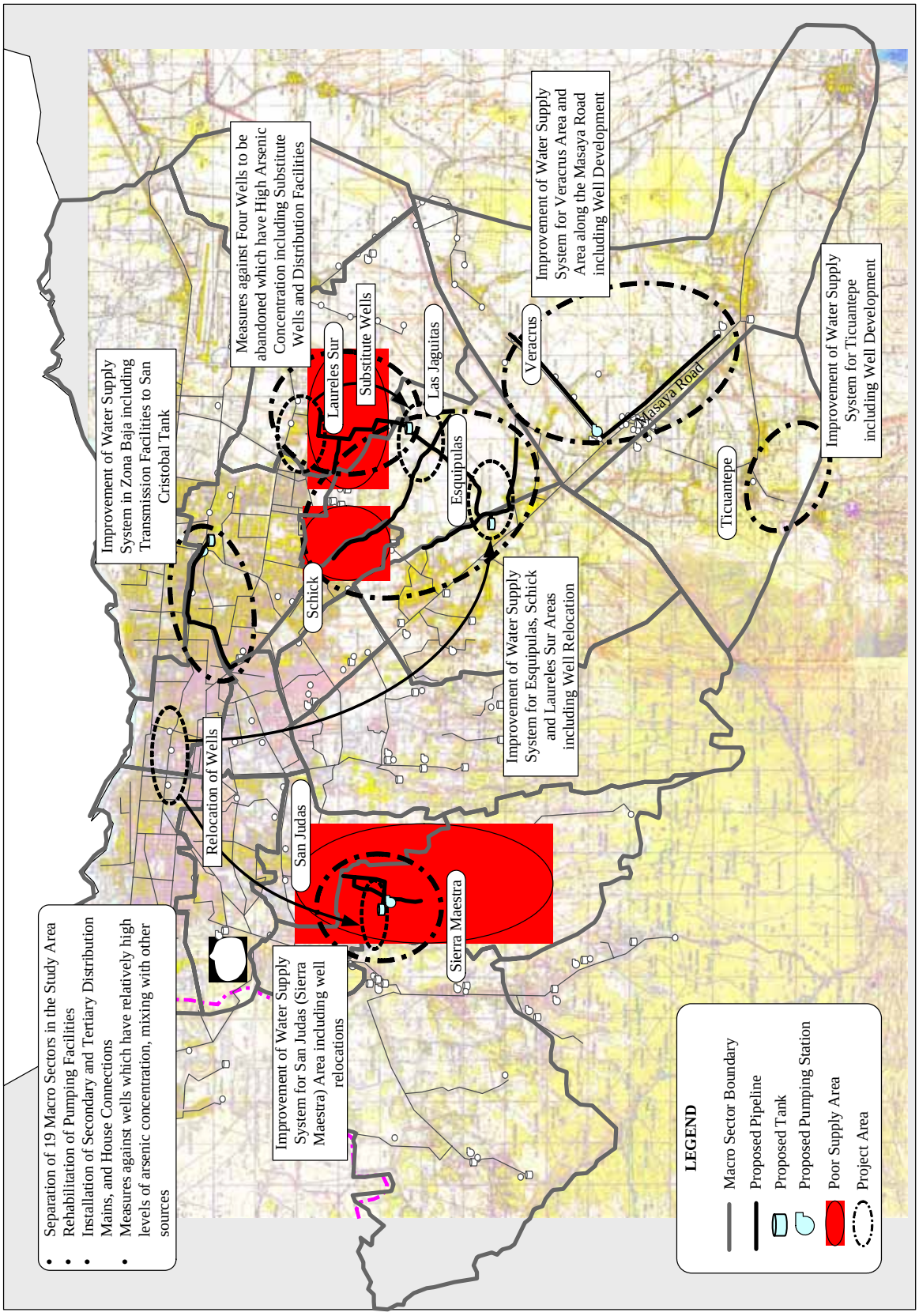


Figure 7.2.1 Summary of Proposed Transmission and Distribution System

7.3 MACRO SECTOR

7.3.1 Macro Sectoring

(1) Considerations for Macro Sectoring

As mentioned above in order to improve the efficiency of water transmission and distribution system, that is to say, in order to distribute effectively required water to users, it is necessary to understand a balance between supply and demand not only for entire system but also for each distribution zone (macro sector) which has only one major water supply point. To divide the entire system into the distribution zone (macro sector) with one major water supply point is called as "Macro Sectoring". The following items are considered in the macro sectoring

- Existing Hydraulical Boundary of ENACAL such as Zona Baja, Zona Alta and Zona Alta Superior
- Existing Zoning System such as Commercial Zone of ENACAL and District Zone of Municipality
- Exiting Water Sources especially major sources such as Asososca Lake, Las Mercedes Well Field, Managua I System, Managua II System, Veracrus Well Field
- Reduction of intake amount from Asososca Lake up to 30,000 m^3/day for prevention of deterioration of water quality by water level lowering
- Relocation of water source in stead of reduced intake amount from Asososca Lake (candidate area for relocation is in Nindiri and Ticuantepe)
- Relocation of 3 wells in Zona Baja because of deterioration of water quality (candidate areas for relocation are in Sierra Maestra near San Judas and Esquipulas)
- Relocation of 4 wells in Sabana Grande because of high levels of arsenic concentrations (candidate area for relocation is in Las Jaguitas)
- 5 distribution tanks at Km8 Carretera Masaya, Schick, Altamira, Unan and San Judas and transmission system to these tanks of Managua I System
- 1 distribution tank at Las Americas of Managua II System
- Other existing transmission and distribution facilities, such as, tanks, pumps and pipelines
- Existing Operation System
- Save Energy (pumping to gravity)

As the results, Managua Water Supply System was divided into 17 macro sectors in Managua Municipality, 1 macro sector in Ticuantepe and 1 macro sector in Nindiri as shown in **Figure 7.3.1**.

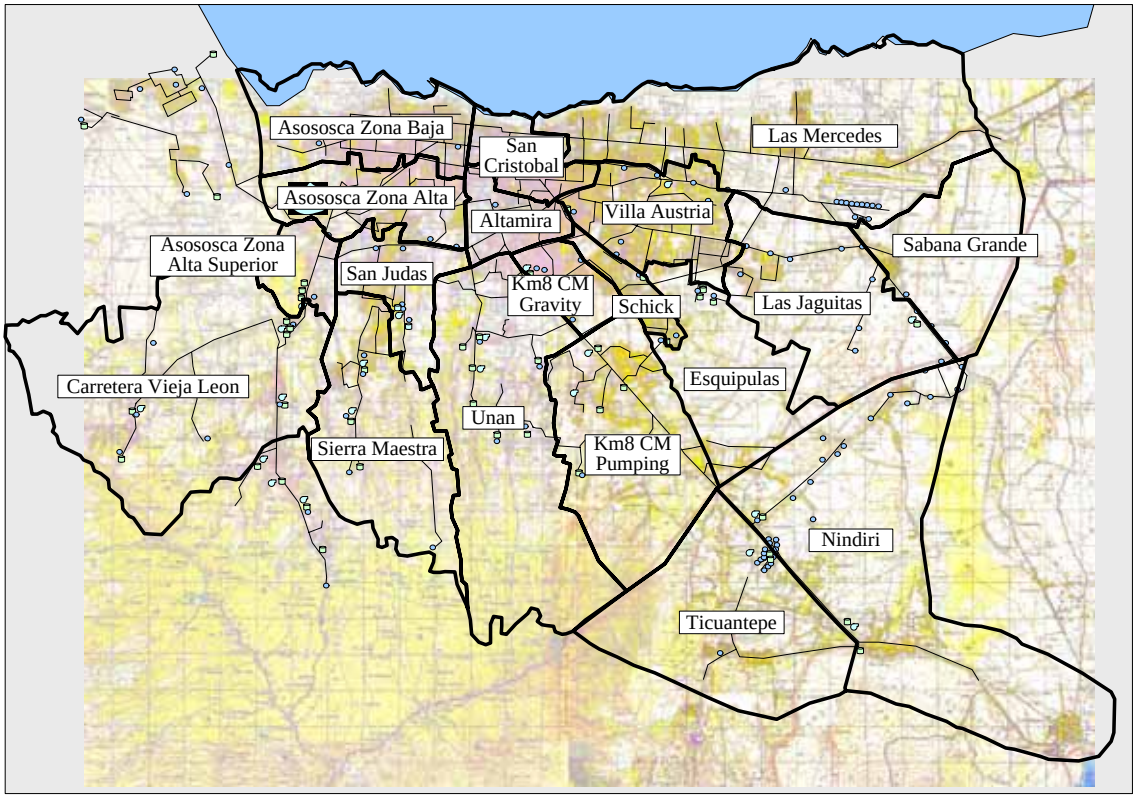


Figure 7.3.1 Macro Sectoring in the Study Area

(2) Isolation of Macro Sector

It is necessary to separate completely the macro sectors adjoined mutually to understand a balance between supply and demand for each macro sector. Some valves and pipelines are required for the isolation of the macro sector with neat macro sector.

ENACAL operates the Managua Water Supply System separately for three elevation zones, Zona Baja for low elevation zone, Zona Alta for middle elevation Zone and Zona Alta Superior for high elevation zone. These three elevation zones have been separated each other, and the boundaries for the elevation zone were considered in the macro sectoring as mentioned previous section. Therefore, the separations along the boundaries of the elevation zones (vertical boundaries) are comparatively easy, and are only confirmed. On the other hand, for the separation of horizontal boundary, diameter and location of pipelines across the boundary should be surveyed and then some valves and pipes can be installed.

7.3.2 Water Balance in Macro Sector

As the results of macro sectoring, amount of water source and water demand in 2010 and 2015 are shown in **Figure 7.3.2** and **Figure 7.3.3** and summarized in **Table 7.3.1**.

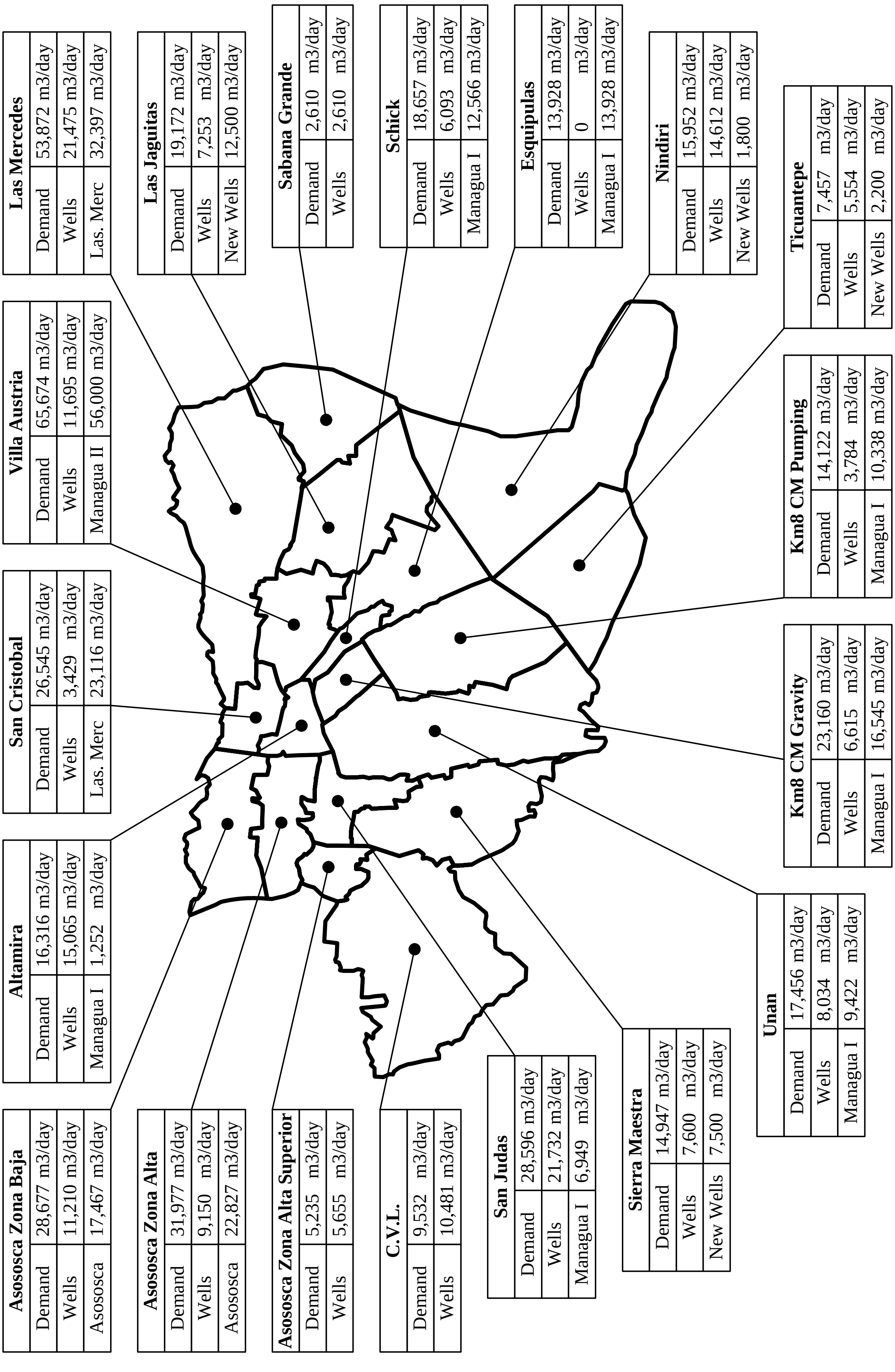


Figure 7.3.2 Water Balance in Macro Sector in 2010

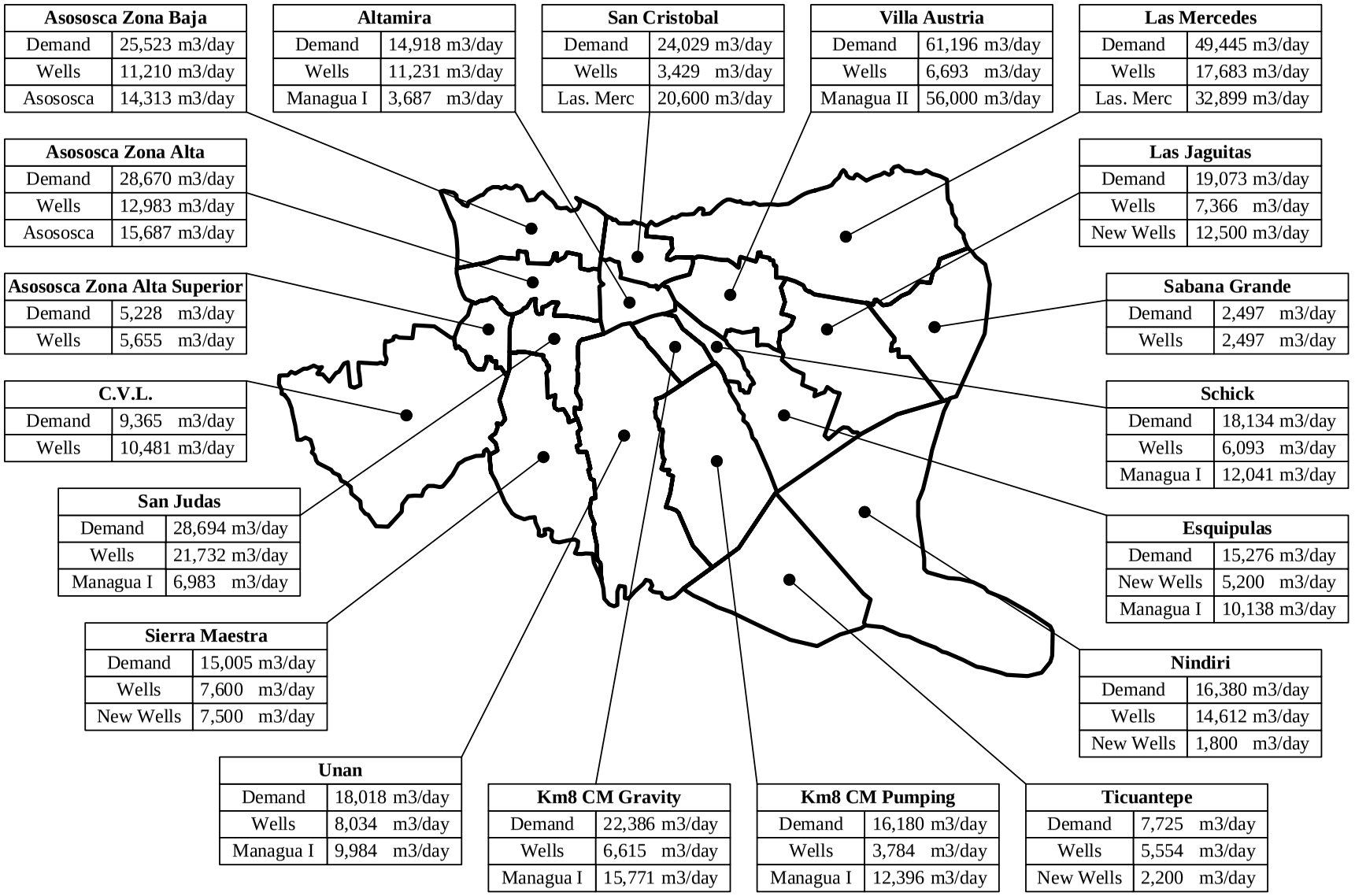


Figure 7.3.3 Water Balance in Macro Sector in 2015

Table 7.3.1 Water Balance in Macro Sector

Macro Sector	Elevation Zone	Demand		Supply					Balance	
				Major Supply Source			Production of Other Existing Wells			
		in 2010 (m3/day)	in 2015 (m3/day)	in 2010 (m3/day)	in 2015 (m3/day)	supplied from	in 2010 (m3/day)	in 2015 (m3/day)	in 2010 (m3/day)	in 2015 (m3/day)
Asososca Zona Baja	Zona Baja	28,677	25,523	17,467	14,313	Asososca Lake by gravity	11,210	11,210	0	0
San Cristobal	Zona Baja	26,545	24,029	23,116	20,600	Las Mercedes Wells through San Cristobal Tank	3,429	3,429	0	0
Las Mercedes	Zona Baja	53,872	49,445	32,397	32,899	Las Mercedes Wells	21,475	17,683	0	-1,137
Asososca Zona Alta	Zona Alta	31,977	28,670	22,827	15,687	Asososca Lake by pumping	9,150	12,983	0	0
Altamira	Zona Alta	16,316	14,918	1,252	3,687	Managua I System	15,065	11,231	-1	0
Villa Austria	Zona Alta	65,674	61,196	56,000	56,000	Managua II System	11,695	6,693	-2,021	-1,497
Las Jaguitas	Zona Alta	19,172	19,073	7,253	7,366	Sabana Grande Well No.4&5	0	0	-581	-793
				12,500	12,500	Relocated New Wells				
Sabana Grange	Zona Alta	2,610	2,497	2,610	2,497	Sabana Grande Well No.5	0	0	0	0
Asososca Zona Alta Superior	Zona Alta Superior	5,235	5,228	5,655	5,655	Wells in Macro Sector	0	0	-420	-427
Carretera Vieja Leon	Zona Alta Superior	9,532	9,365	10,481	10,481	Wells in Macro Sector	0	0	-949	-1,116
San Judas	Zona Alta Superior	28,596	28,694	6,949	6,983	Managua I System	21,732	21,732	-85	-21
Sierra Maestra	Zona Alta Superior	14,947	15,005	7,600	7,600	Wells in Macro Sector	0	0	-153	-95
				7,500	7,500	Relocated New Wells				
Unan	Zona Alta Superior	17,456	18,018	9,422	9,984	Managua I System	8,034	8,034	0	0
Km8 Carretera Masaya Gravity	Zona Alta Superior	23,160	22,386	16,545	15,771	Managua I System	6,615	6,615	0	0
Km8 Carretera Masaya Pumping	Zona Alta Superior	14,122	16,180	10,338	12,396	Managua I System	3,784	3,784	0	0
Schick	Zona Alta Superior	18,657	18,134	12,566	12,041	Managua I System	6,093	6,093	-2	0
Esquipulas	Zona Alta Superior	13,928	15,276	13,928	10,138	Managua I System	0	0	0	-62
				0	5,200	Relocated New Wells				
Ticuantepe	Outside Managua	7,457	7,725	5,554	5,554	Wells in Macro Sector	0	0	-297	-29
				2,200	2,200	Relocated New Wells				
Nindiri	Outside Managua	15,952	16,380	13,532	13,532	Veracrus Wells	1,080	1,080	-460	-32
				1,800	1,800	Relocated New Wells				
TOTAL		413,884	397,741	299,492	292,384		119,362	110,567	-4,969	-5,210
				71,000	71,000	Managua I Total				
				55,513	53,499	Las Mercedes Total				
				40,294	30,000	Asososca Total				

7.4 WATER TRANSMISSION TO MACRO SECTOR

7.4.1 Transmission System of Managua I

(1) Original Transmission System of Managua I

Managua I System produces water from 15 wells located in Km15.5 Carretera Masaya and then transmits produced water to Santo Domingo Tank by transmission pumps. From Santo Domingo Tank water is transmitted to 5 tanks, Km8 Carretera Masaya, Altamira, Unan, San Judas and Schick, by gravity. These five tanks are water supply points of one macro sector in this Master Plan respectively. Original Managua I Transmission System is as shown in **Figure 7.4.1**.

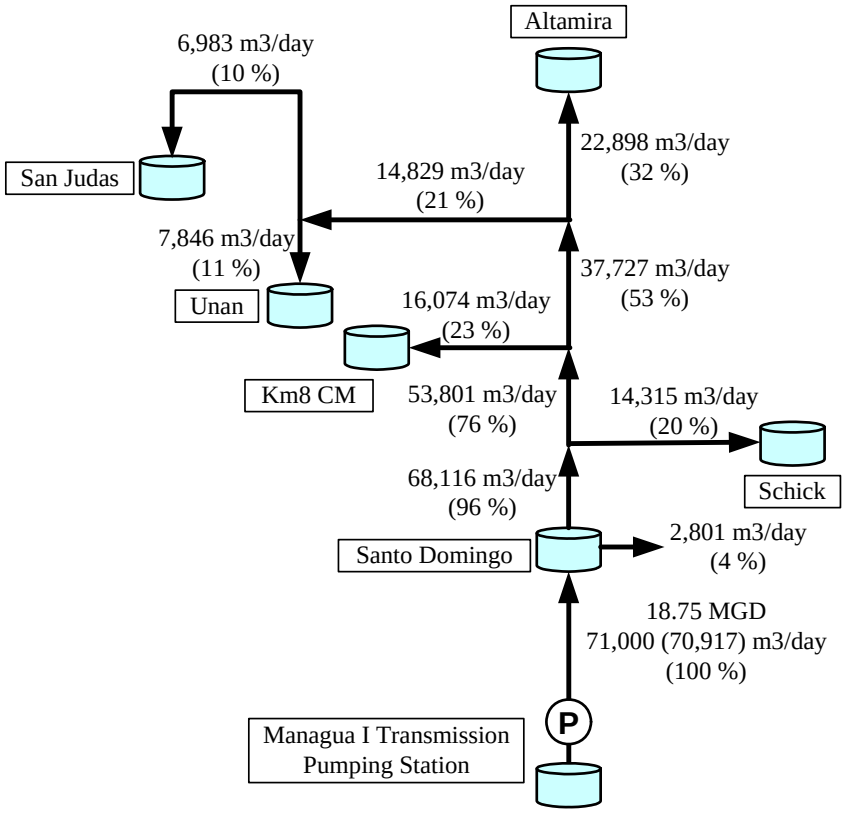


Figure 7.4.1 Original Transmission System of Managua I

It is noted that the production amount from wells have decreased to about 53,000 m^3/day because of problems of well pumps and deterioration of wells. Therefore the rehabilitation works of well pumps or wells themselves are required. Detailed evaluation and countermeasures against wells are described in **Supporting Report No.3**. There is no problem at present for transmission facilities such as pumps and pipelines and distribution facilities at each tank.

(2) Proposed Transmission System of Managua I

1) Necessary Transmission Volume for Each Macro Sector by Managua I System
According to the water balance in macro sectors as shown in **Table 7.3.1** in previous section, future water balances of 5 macro sectors which receive water transmitted by the Managua I System are shown in **Table 7.4.1**.

Table 7.4.1 Water Balance of 5 Macro Sectors under the Managua I System

Macro Sector	Demand		Supply			
			Production of Existing Wells		Transmitted from Managua I System	
	in 2010 (m3/day)	in 2015 (m3/day)	in 2010 (m3/day)	in 2015 (m3/day)	in 2010 (m3/day)	in 2015 (m3/day)
Altamira	16,316	14,918	15,065	11,231	1,252	3,687
San Judas	28,596	28,694	21,732	21,732	6,949	6,983
Unan	17,456	18,018	8,034	8,034	9,422	9,984
Km8 Carretera Masaya Gravity	23,160	22,386	6,615	6,615	16,545	15,771
Km8 Carretera Masaya Pumping	14,122	16,180	3,784	3,784	10,338	12,396
Schick	18,657	18,134	6,093	6,093	12,566	12,041
Capacity of Managua I System					71,000	71,000
Balance					13,928	10,138

There is a balance of 13,928 m^3/day in 2010 and 10,138 m^3/day in 2015 compared with the capacity of Managua I System of 71,000 m^3/day. However, by the rapid population increase along the Masaya Road, Esquipulas Area located at east side of the Masaya Road which is newly developed as the housing area has no enough water sources to supply. Therefore, the Study proposed to use the balance effectively for supplying Esquipulas Area. The Managua I Transmission System has, therefore, 6 tanks as shown in **Figure 7.4.2**.

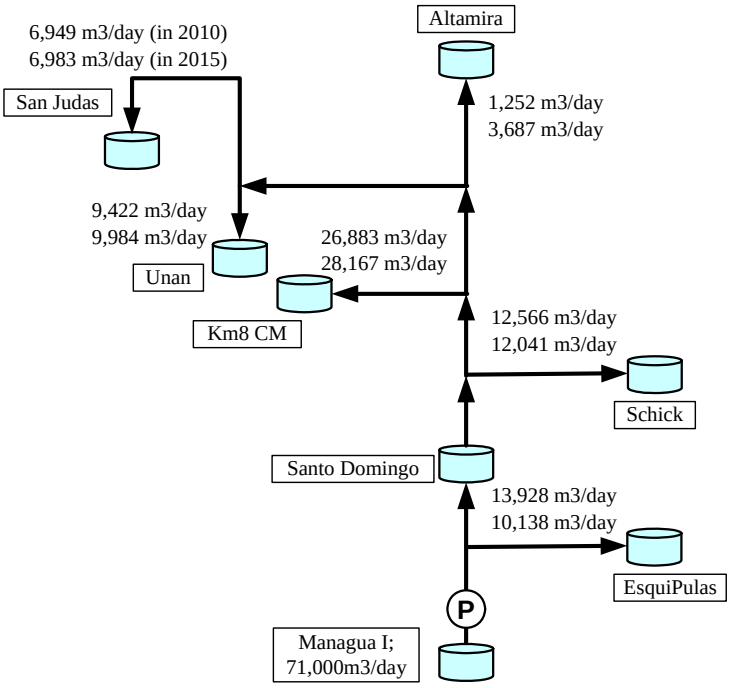


Figure 7.4.2 Proposed Transmission System of Managua I

2) Hydraulic Analysis for Proposed Transmission System

Hydraulic analyses were conducted using WaterCAD by an extended period simulation which indicates whether the system has the ability to provide acceptable levels of service over a period of hours. Conditions of the hydraulic network analyses are as follows:

- Formula for friction loss calculation : Hazen-Williams Formula
- C value for all pipes : 110
- Hourly peak factor for distribution system : 1.7

The basis of estimation of the hourly peak factors are shown in **Supporting Report No.1**. Transmission to tanks of Km8 Carretera Masaya and Unan from Santo Domingo Tank is considered in the hourly fluctuation because those tanks do not have enough capacity for hourly peak demand. Transmission volume to other tanks is constant over the day.

As the results of hydraulic analyses, it is confirmed that Managua I Transmission System can be used effectively for proposed transmission system as shown in **Annex 7B**.

7.4.2 Transmission Systems for Other Macro Sectors

(1) Managua II

Managua II System produces water from 16 wells located at Sabana Grande in east of Managua City and then transmits produced water to Las Americas Tank by transmission pumps. From Las Americas Tank water is distributed by gravity. Available transmission amount from Managua II System of 56,160 m^3/day does not change in this Master Plan. Production amount from wells have decreased to about 44,000 m^3/day because of problems of well pumps and deterioration of wells. Therefore the rehabilitation works of wells are required. Detailed evaluation and countermeasures against wells of Managua I and Managua II are described in **Supporting Report No.3**. There is no problem at present for transmission facilities such as pumps and pipelines.

(2) Others

Future transmission system in 2015 of Managua Water Supply including Managua I and Managua II Systems are schematically as shown in **Figure 7.4.3**.

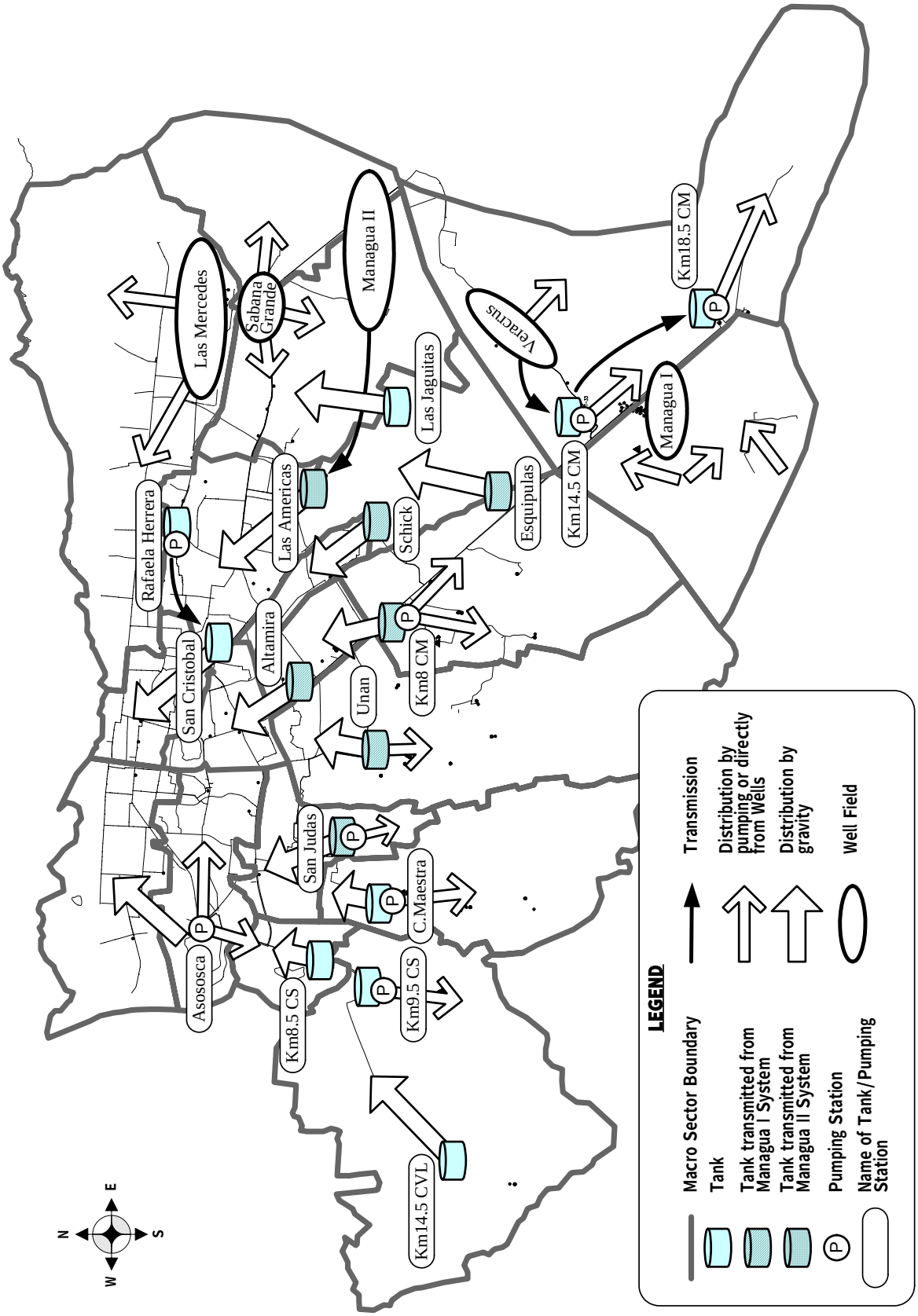


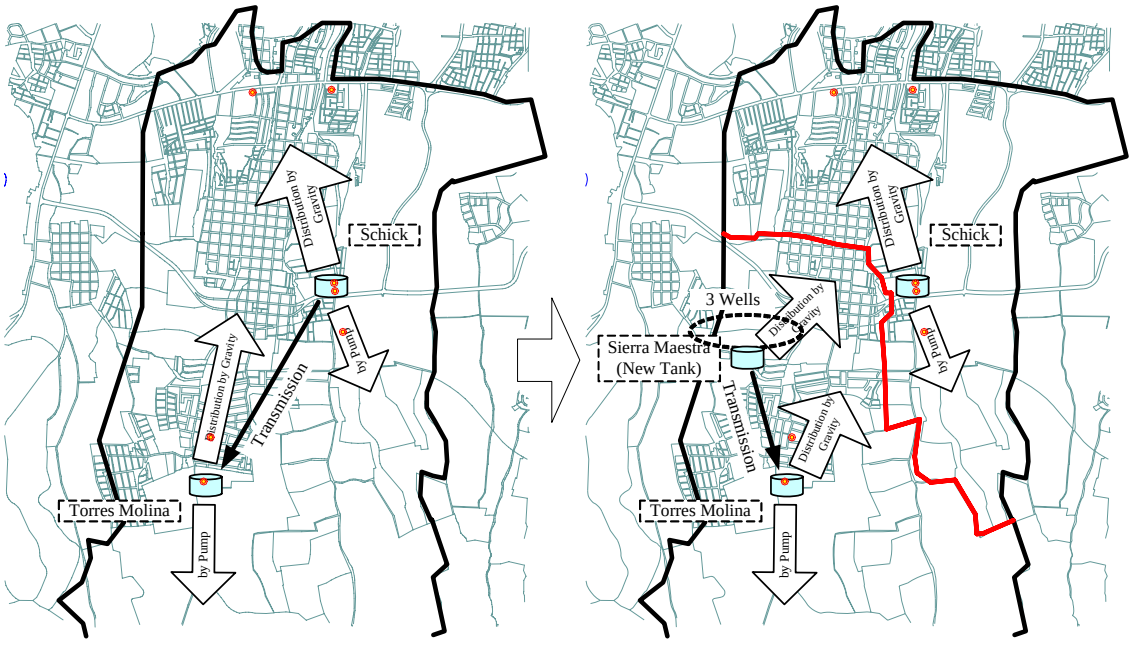
Figure 7.4.3 Transmission System in 2015

7.5 PROPOSED WATER TRANSMISSION AND DISTRIBUTION FACILITIES

7.5.1 San Judas Area

San Judas Area is receiving water supply from San Judas Tank expanded by Managua I Project and wells scattered in the southern part. However, this area has suffered from chronic water shortage mainly caused by increase of population including asentamientos and decrease of transmission amount from Managua I System to San Judas Tank. In order to secure the water supply to this area the Study recommends to divide this area into two sectors, San Judas and Sierra Maestra as shown in **Figure 7.5.1**. Water demands for these sectors are estimated as follows;

- San Judas Area : 28,596 m^3/day in 2010, 28,694 m^3/day in 2015
- Sierra Maestra Area : 14,947 m^3/day in 2010, 15,005 m^3/day in 2015



Present Water Supply System from San Judas Tank

Proposed Water Supply System divided into 2 Sectors from San Judas Tank and Proposed New Tank at Sierra Maestra

Figure 7.5.1 Separation of San Judas Area into Two Macro Sectors

(1) Water Sources

1) San Judas Area

Managua I System can transmit water of 6,983 m^3/day which is original designed transmission capacity to San Judas Tank, however subject to recovery of the production capacity of Managua I Well Field. In this area there are 5 existing wells with total production capacity of 15,373 m^3/day. In addition the developments of two wells with total production capacity of 6,359 m^3/day are in progress, which are considered as the existing wells. Therefore this area has enough water sources to supply water until 2015.

2) Sierra Maestra Area

This area has 5 existing wells with the production capacity of 7,600 m^3/day. In addition by the relocation of 3 Wells located at Zona Baja as shown in **Figure 7.5.2** and listed below, the production capacity of wells increases by 7,500 m^3/day (2,500 m^3/day x 3 wells) and becomes 15,100 m^3/day in total.

- San Antonio: 4,680 m^3/day (860 gpm)
- Olof Palme: 4,310 m^3/day (792 gpm)
- Mercado Oriental: 3,970 m^3/day (730 gpm)

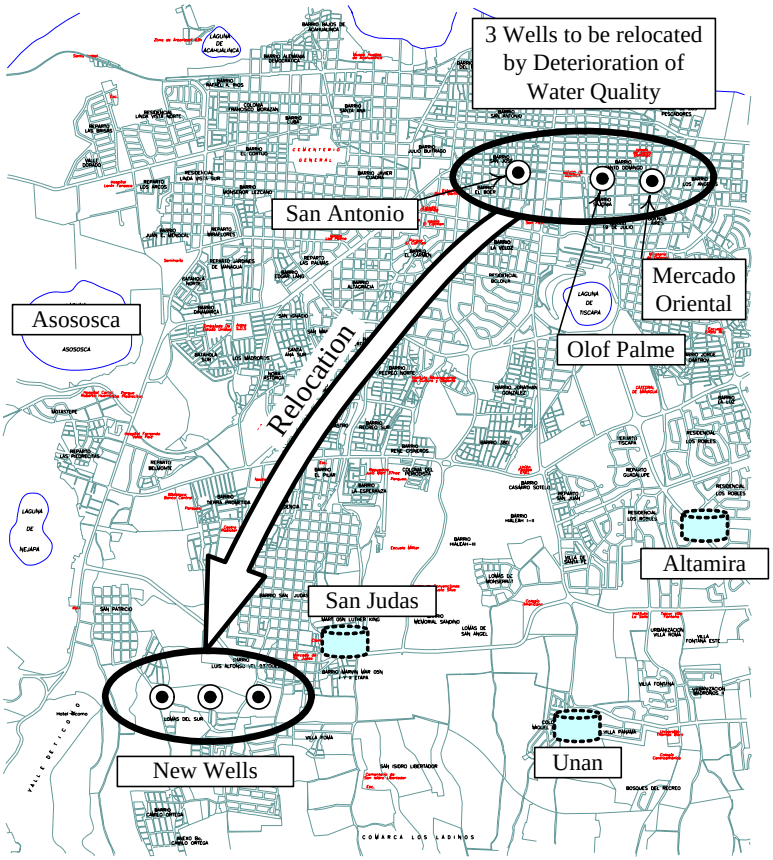


Figure 7.5.2 Relocation of Wells

(2) Transmission and Distribution Facilities

In order to secure the water supply of additional production capacity of relocated wells in Sierra Maestra Area, the following transmission and distribution facilities are proposed to construction until 2010 (see **Figure 7.5.3**).

- Transmission Facilities (to Torres Molina):
  - Pumps: 1.8 m^3/min x H 75 m x 37 kW x 2 units
  - Pipeline: PVC 150 mm x L 1.5 km
- Distribution Facilities
  - Tank: 2,500 m^3 (660,000 gallon)
  - Pipeline: DIP 350 mm x L 0.3 km
    PVC 250 mm x L 2.7 km

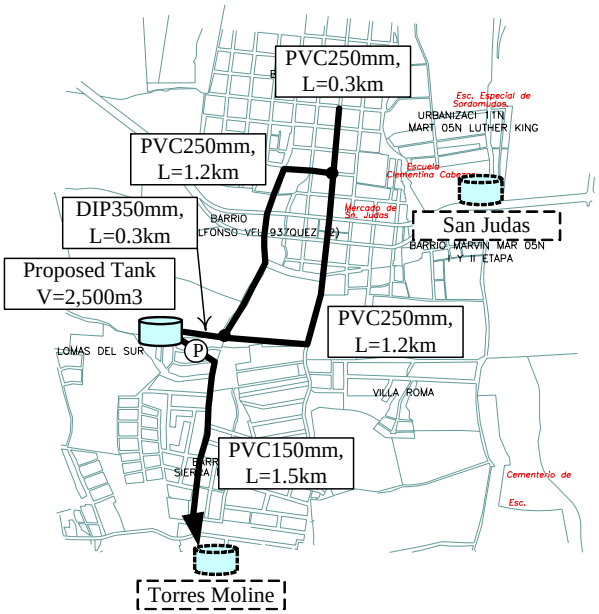


Figure 7.5.3 Proposed Transmission and Distribution Facilities in Sierra Maestra

7.5.2 Schick Area

Water for this area (see **Figure 7.5.4**) is supplied originally from Schick Tank. Because enough water can not be transmitted to Schick Tank from Managua I System through Santo Domingo Tank and then the water to meet the demand in this area can not be supplied, the water supply condition of this area is very bad. Therefore, the water supply for north part of this service area is supplied mainly from Altamira Tank by pumping or sometimes from Las Americas Tank by gravity.

If enough water is transmitted to Schick Tank by Managua I System as mentioned in previous section, "7.4 Water Transmission to Macro Sector", water supply for this service area to meet the demand in 2015 can be provide through the existing distribution network. Therefore, in order to improve the water supply services for this area, it is indispensable to recover the production capacity of Managua I System and to operate appropriately the transmission system of Managua I. No additional facilities for transmission and distribution system are required.

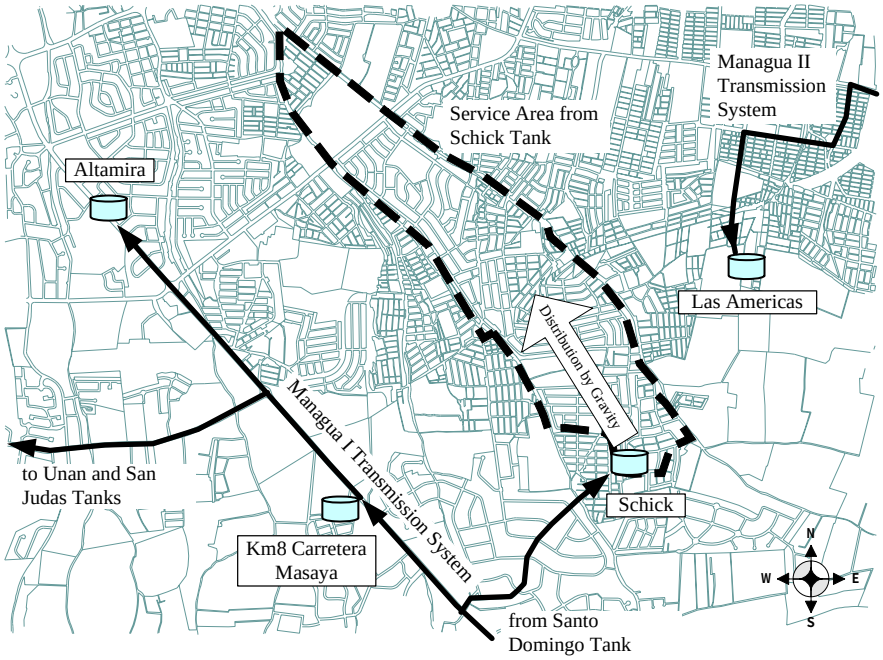


Figure 7.5.4 Supply Area (Macro Sector) from Schick Tank

7.5.3 Laureles Sur Area

Area as shown in **Figure 7.5.5** including Asentamientos of Laureles Sur, Lomas de Guadalupe, Sol de Libertad and Anexo Villa Libertad located at boundary between Zona Alta and Zona Alta Superior, at present, gets water mainly from the Sabana Grande Well Field. However, water supply conditions are very bad because the distribution network system for the area has not been developed properly corresponding to the rapid population increase. The water supply for this area has become one of social issues and in this area there are many illegal connections.

In addition, the results of water quality tests show that four wells (Well Nos.27, 28, 29 and 46) in Sabana Grande have high arsenic concentrations of more than 10.0 ppb. These wells are recommended to be abandoned and substitute wells will be constructed in Las Jaguitas Area where is the south of Sabana Grande to supply areas which are currently supplied by these four wells as shown in **Figure 7.5.5**. Although Well No.30 in Sabana Grande has also relatively high level of arsenic concentration, water from the well is proposed to be mixed with water from the neighboring Well No.31 before it is distributed to customers. Measures against Well No.30 are described in following sub-section, 7.5.7 Improvement of Deteriorated Well Water Quality (measures against high levels of arsenic concentration).

Therefore the improvement of water supply condition for this area should be considered the following two issues:

- improvement of the water supply conditions of asentamientos area
- measures against wells that have high levels of arsenic concentration

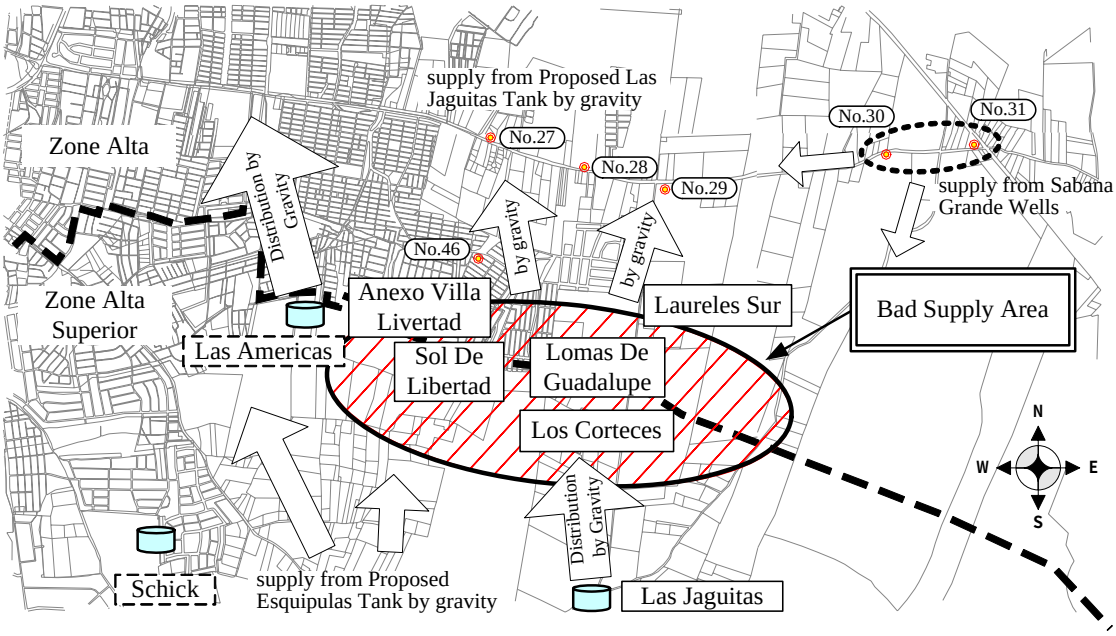


Figure 7.5.5 Area including Asentamientos of Laureles Sur, Lomas de Guadalupe, Sol de Libertad and Anexo Villa Libertad

(1) Water Sources

Water supply for Laureles Sur Area ("c" area in **Figure 7.1.1**) and areas along the Sabana Grande Road (Las Jaguitas Macro Sector) is planned to be supplied from substitute five wells with total capacity of 12,500 m^3/day in Las Jaguitas by gravity as shown in **Figure 7.5.5**.

Total capacity of water sources for Las Jaguitas Macro Sector is as follows;

Existing Two Wells, No.30 and No.31:		9,863 m^3/day
Substitute Five Well in Las Jaguitas	:	12,500 m^3/day
Total Capacity of Water Sources	:	22,363 m^3/day

(2) Distribution Facilities

In order to secure the water supply for Las Jaguitas Macro Sector from the substitute wells in Las Jaguitas, the following distribution facilities as shown in **Figure 7.5.6** are necessary.

- Tank: 4,000 m^3 (1,057,000 gallon)
- Pipeline: DIP 450 mm x L 2.0 km, DIP 300 mm x L 0.9 km, PVC 250 mm x L 1.1 km

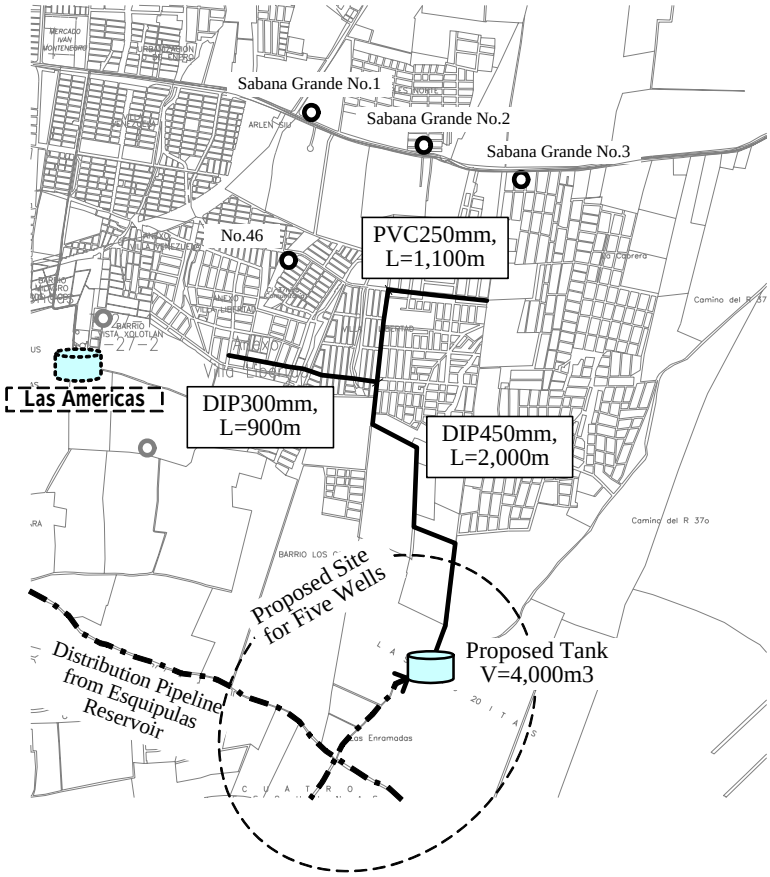


Figure 7.5.6 Proposed Distribution Facilities in Las Jaguitas

In order to improve the water supply conditions of these asentamientos area, development of secondary and tertiary distribution network inside asentamientos is required and detailed in **Supporting Report No.10**.

7.5.4 Esquipulas Area

Esquipulas area is located at east side of Masaya Road in the suburb of Managua and has been growing into new housing area for Managua. For the rapid growth the development and improvement of water supply system for this area have not caught up with demands. The supply area covers not only Esquipulas but also Milagro de Dios, Villa Flor Sur, Sol de Libertad and Los Corteces. It is, therefore, indispensable to develop the water supply system in this Macro Sector in order to improve the water supply condition for Area B and Area C as shown in **Figure 7.1.1**. Since this area descends toward the northeast gently, it is possible to supply water to these areas by gravity from proposed tank at Esquipulas as shown in **Figure 7.5.7**.

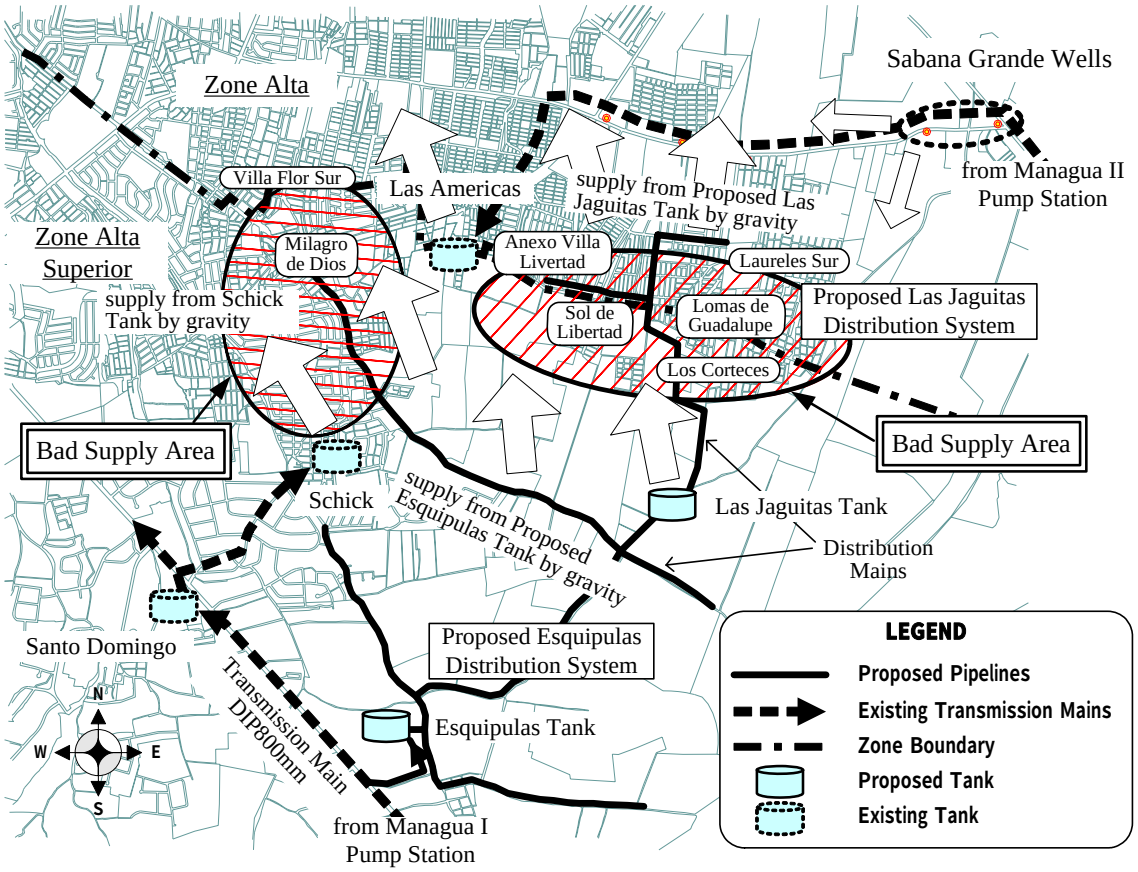


Figure 7.5.7 Supply Area from Proposed Esquipulas Tank and Las Jaguitas Tank

(1) Water Sources

As the water source for this supply area, water is transmitted from Managua I System because there is no exiting well at this area. Transmission pipeline to proposed Esquipulas tank is branched from transmission pipeline of dia. 750 mm DIP from Managua I Transmission Pumping Station to Santo Domingo Tank. Possible transmission amount to the tank is estimated as shown in **Table 7.5.1**. **Table 7.5.1** also shows the water demand in 2010 and 2015.

Table 7.5.1 Transmission Amount from Managua I System

year	2010	2015
Transmission Amount	13,928 m^3/day	10,138 m^3/day
Water Demand	13,928 m^3/day	15,276 m^3/day
Balance	0 m^3/day	5,138 m^3/day

In 2015 it will be, therefore, necessary to develop two wells of 5,200 m^3/day capacity for meeting future demand in Esquipulas by the relocation of 3 wells located at Zone Baja which water quality have deteriorated.

(2) Transmission and Distribution Facilities

In order to secure the water supply for this area, the following transmission and distribution facilities are proposed (see **Figure 7.5.8**).

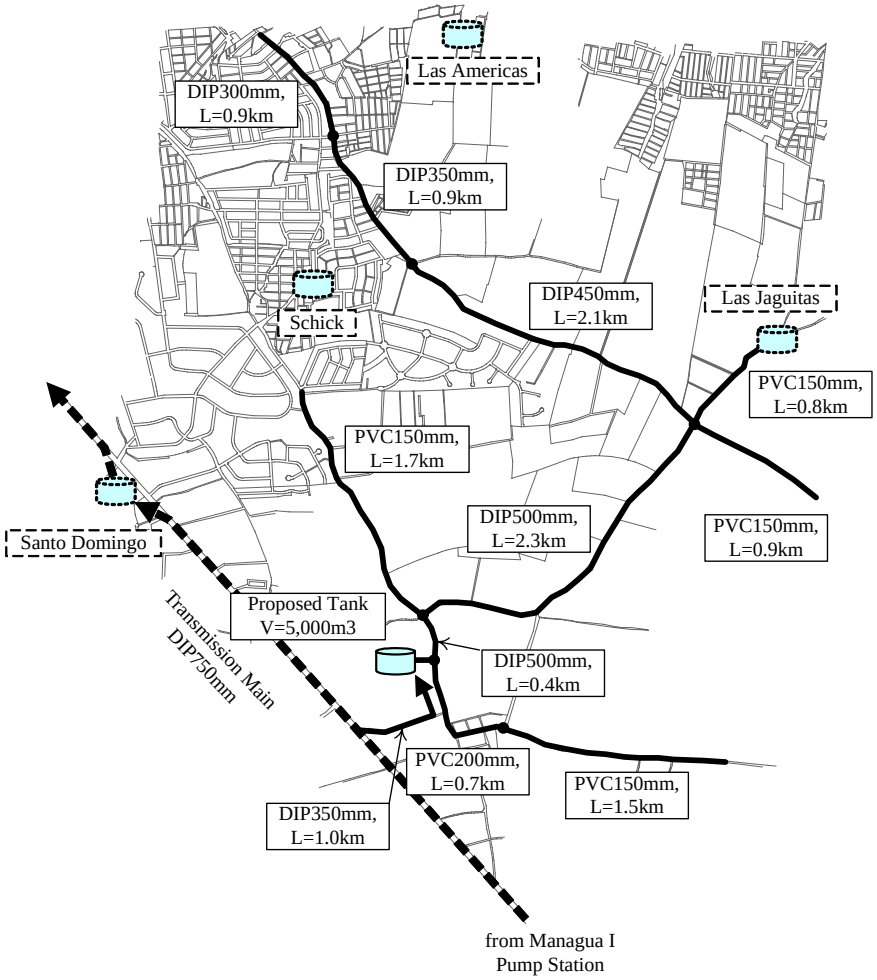


Figure 7.5.8 Proposed Transmission and Distribution Facilities in Esquipulas

- Transmission Mains (branched from Managua I Transmission Main):
  - Pipeline: PVC 350 mm x L 1.0 km
- Distribution Facilities
  - Tank: 5,000 m^3 (1,320,000 gallon)
  - Pipeline: DIP 500 mm x L 2.7 km
    DIP 450 mm x L 2.1 km
    DIP 350 mm x L 0.9 km
    DIP 300 mm x L 0.9 km
    PVC 200 mm x L 0.7 km
    PVC 150 mm x L 4.9 km

7.5.5 San Cristobal Area

At present Zona Baja is supplied from Asososca by gravity and Las Mercedes Wells directory. Asososca covers mainly west of Zona Baja and Las Mercedes covers mainly east of Zona Baja. Central area of Zona Baja gets water from these two supply sources partly through San Cristobal Tank, sometimes from Asososca and sometimes from Las Mercedes depending on water pressure balance. Due to the reduction of intake from Asososca Lake it is proposed to supply water to Zona Baja Central from Las Mercedes Well Field through San Cristobal Tank by gravity. Therefore, transmission facilities from Rafaela Herrera to San Cristobal Tank are recommended for securing stable water supply to Zona Baja Central from San Cristobal Tank by

gravity.

Because there is a possibility of taking countermeasures against the arsenic issue of Las Mercedes Well Field, water supply for Zona Baja Central is provided from Las Mercedes Wells directly not through San Cristobal Tank by gravity in the meanwhile until being confirmed that there is no problem of sustainability to use Las Mercedes Wells as water supply source. Therefore, the Study proposed to implement this transmission system after 2010 up to 2015.

(1) Water Sources

The area covered from San Cristobal Tank has two wells with the production capacity of 3,429 m^3/day. Therefore, other necessary water for water supply should be transmitted to San Cristobal Tank from Las Mercedes Well Field through Rafaela Herrera. Water balance for this area is summarized as shown in **Table 7.5.2**.

Table 7.5.2 Water Balance in San Cristobal Area

Water Demand in 2015	24,029 m^3/day
Capacity of the existing wells	3,429 m^3/day
Balance (Necessary transmission volume to San Cristobal Tank)	20,600 m^3/day

(2) Transmission Facilities

In order to transmit necessary water to San Cristyobal Tank from Rafaela Herrera, the following transmission facilities are proposed (see **Figure 7.5.9**).

- Receiving Tank at Rafaela Herrera: 1,000 m^3 (265,000 gallon)
- Pumps: 4.8 m^3/min x H 60 m x 75 kW x 4 units
- Pipeline: DIP 450 mm x L 4.4 km

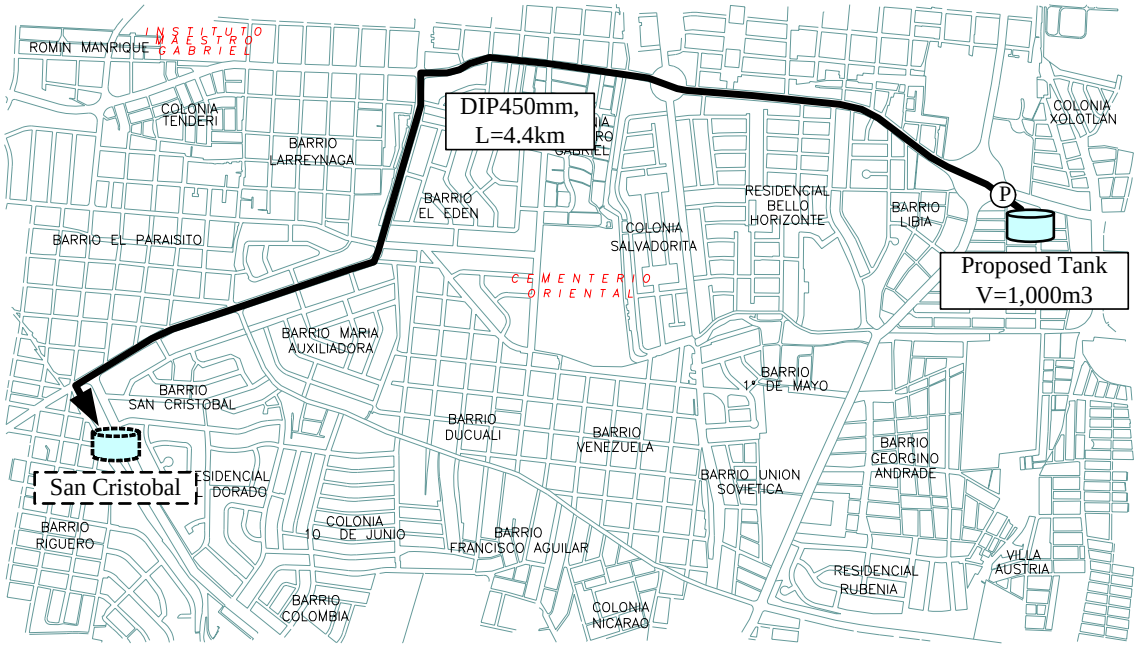


Figure 7.5.9 Transmission System to San Cristobal Tank

7.5.6 Ticuantepe and Nindiri Areas

At present water supply for Ticuantepe and Nindiri is provided by 9 existing wells. The total production capacity (sustainable yield) of the wells in 2015 is evaluated at 20,166 m^3/day. Water demands for Ticuantepe and Nindiri are estimated as shown in **Table 7.5.3**.

Table 7.5.3 Future Water Demand in Ticuantepe and Nindiri

Year	2010	2015
Ticuantepe	9,943	10,300
Nindiri	13,466	13,805
Total	23,409	24,105

According to future demand and production capacity of the existing wells, water of 3,243 m^3/day in 2010 and 3.939 m^3/day in 2015 will be insufficient. Water supply system for Ticuantepe and Nindiri is shown in **Figure 7.5.10** schematically. Macro sector for Nindiri covers a part of Ticuantepe where is located along the Masaya Road

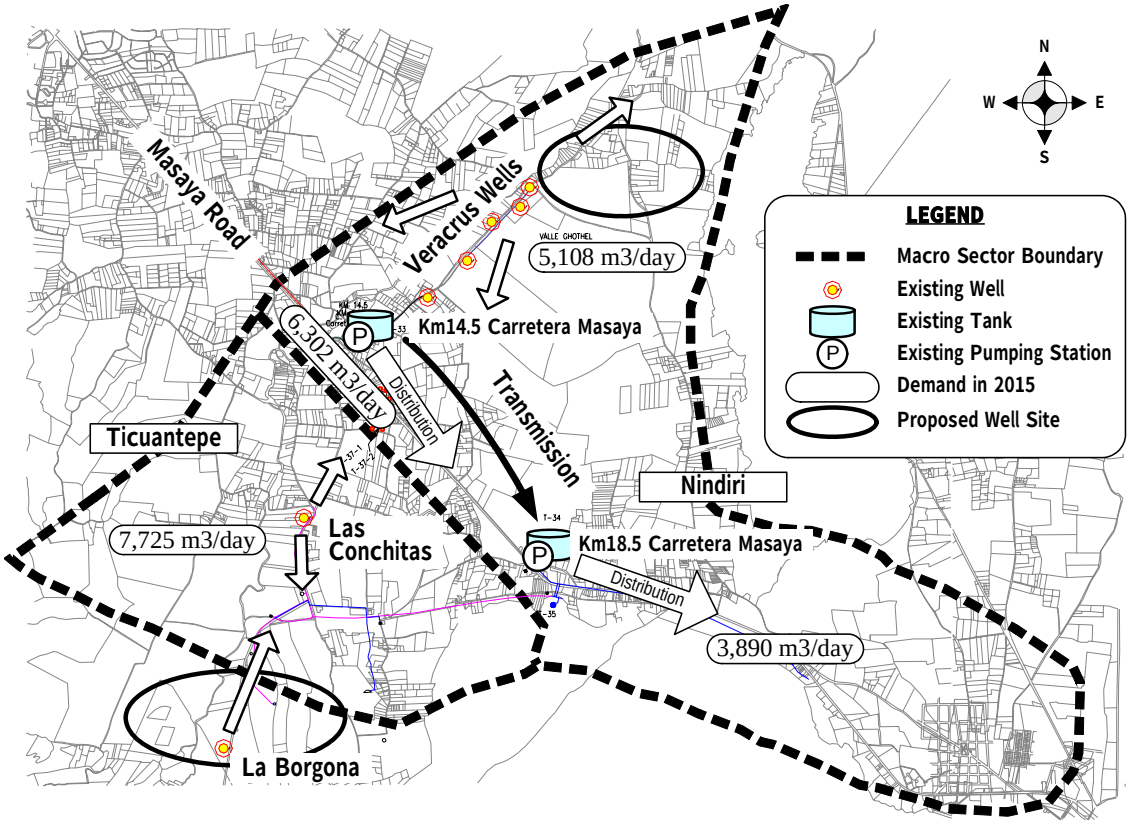


Figure 7.5.10 Water Supply System in Ticuantepe and Nindiri

(1) Water Sources

Recently, the population of Ticuantepe and Nindiri especially fringe area of Managua along the Masaya Road and Veracrus Area in Nindiri has increased rapidly by the housing and commercial area developments. This population increase is mainly caused by movement from Zona Baja. That means that the demand in Zona Baja is moving to Zona Alta Superior. It is, therefore, necessary to relocate some water sources from Zona Baja to Zona Alta Superior.

The study has recommended that the intake amount from Asososca Lake is decreased up to 30,000 m^3/day from the viewpoint of water quality control. As the relocation of water sources in stead of decrease of intake amount from Asososca Lake, new well constructions will be proposed for water supply to Ticuantepe and Nindiri. The necessary production capacity of new well is assumed to be a deficit in the production capacity of the existing wells to meet the future demand.

Two wells with production capacities of 2,200 m^3/day and 1,800 m^3/day are planned to be constructed at Vorgoña Area in Ticuantepe and at Veracrus Area in Nindiri near the existing wells respectively. Exact locations for well constructions should be determined based on more detailed groundwater investigation.

New well at Vorgoña Area in Ticuantepe will be connected directly with the existing distribution network system in Ticuantepe. Produced water from new wells at Veracrus is transmitted to the existing tanks at the pumping station of Km14.5 Carretera Masaya. Raw water transmission pipeline is assumed to be PVC 200 mm with 4.0 km length.

(2) Transmission and Distribution Facilities

In order to secure the water supply for the urban area along the Masaya Road in Nindiri, the following transmission and distribution facilities are proposed to construction (see **Figure 7.5.11**).

- Transmission Facilities at Km14.5 Carretera Masaya (to Km18.5 Carretera Masaya):
  - Pumps: 2.7 m^3/min x H 107 m x 75 kW x 2 units
  - Pipeline: PVC 250 mm x L 4.1 km
- Distribution Facilities
  - Pumps: 2.5 m^3/min x H 107 m x 75 kW x 3 units
  - Pipeline: DIP 350 mm x L 0.6 km

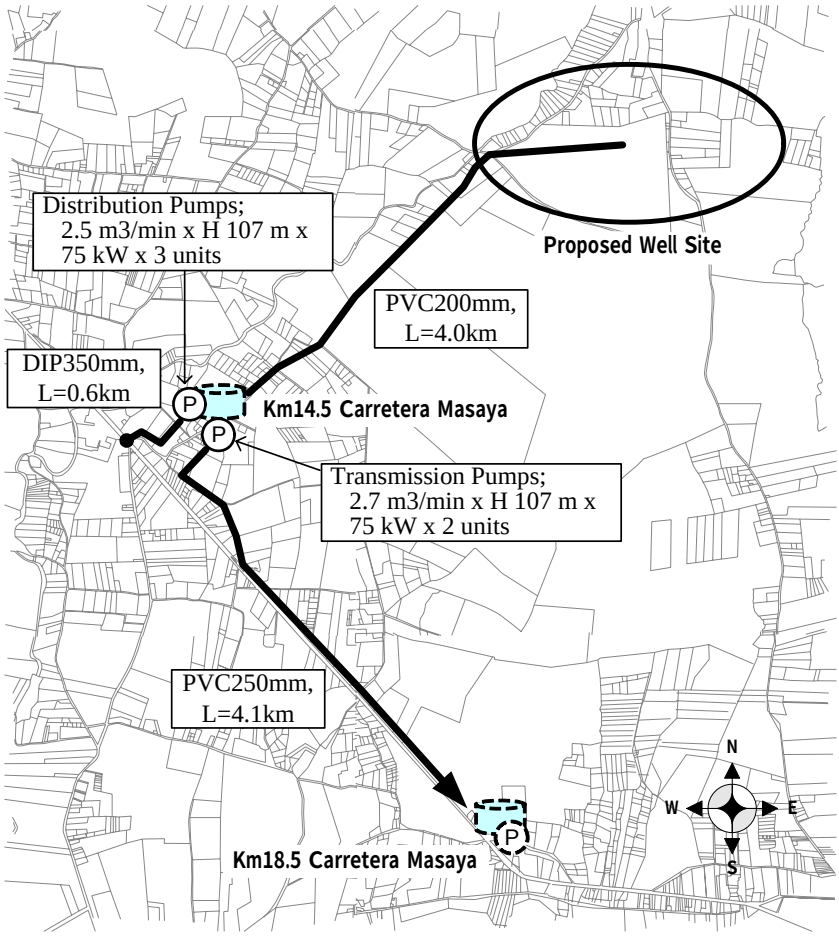


Figure 7.5.11 Transmission and Distribution System in Nindiri

7.5.7 Improvement of Deteriorated Well Water Quality (Measures Against High Levels of Arsenic Concentration)

Based on the results of water quality tests, some wells have relatively high levels of arsenic concentrations. Measures against these wells are proposed as follows and summarized in **Figure 7.5.12**.

- Wells No.8, 10, 11, 14, 52, 91 : abandoned by 2010 or 2015
- Wells No.27, 28, 29, 46 : abandoned and construction of substitute wells by 2010 (refer to section 7.5.3)
- Wells No.30, 57, 68, 77, 78, 112: mixed with water from other sources by 2015

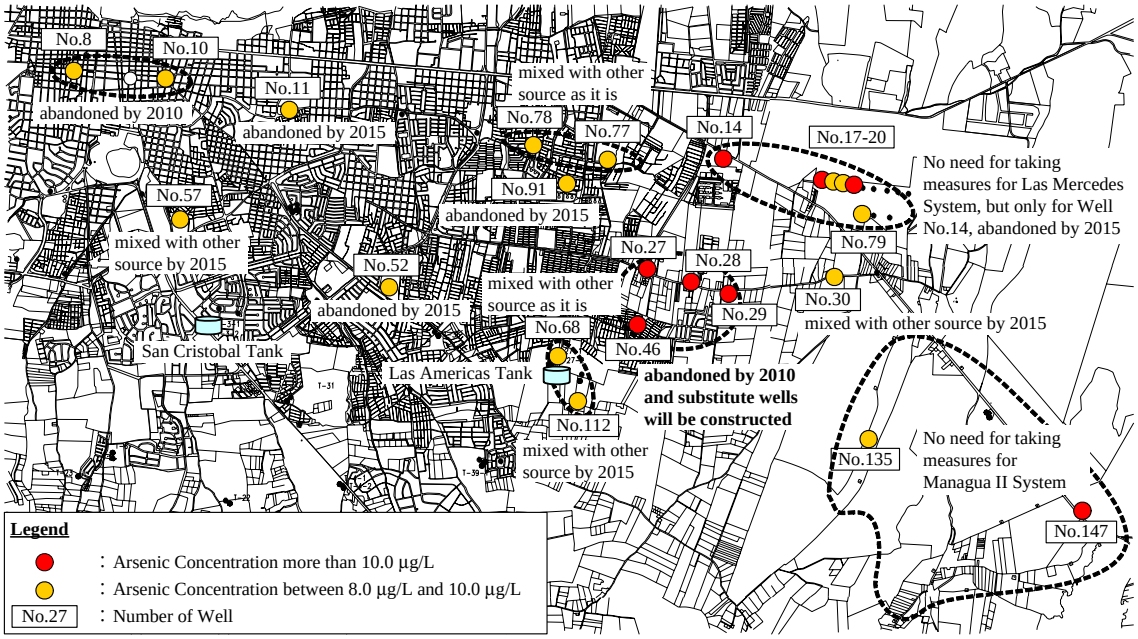


Figure 7.5.12 Measures against Wells having High Arsenic Concentration

For six wells, No.30, No.57, No.68, No.77, No.78 and No.112, it is difficult to find out and plan substitute wells or alternative sources and to abandon these wells for securing stable water supply to the area covered by these wells. In order to reduce the levels of arsenic concentrations to the safe level (below 8.0 µg/L), therefore, mixture and dilution with water from other sources are recommended as shown in **Table 7.5.4**.

Table 7.5.4 Measures against Wells Having High Arsenic Concentration

Well	Name	Measures for Improvement
No.30	Sabana Grande No.4	Water from the well will be mixed with water from the neighboring Well No.31 before it is distributed to customers. The work will include the construction of transmission pipe (PVC250:0.7km) and associated valves
No.57	Plaza el Sol	Water from the well will be first transmitted to the Altamira Tank for mixing with water from other sources such as Managua I and then distributed from the tank. The work will include the construction of transmission pipe (PVC250:2.4km) and associated valve
No.68	Villa Austria	Water from this well is now being injected into the Las Americas Tank and mixed with water from Managua II Well Field. Therefore additional facility for mixing is not necessary.
No.77	Villa Fraternidad	Water from these wells is now being injected into the 900 mm diameter distribution trunk main and mixed with water from Las Mercedes Well Field. Therefore additional facility for mixing is not necessary.
No.78	Buenos Aires	
No.112	Anexo V. Libertad	Water from the well will be first transported to the Las Americas Tank for mixing with water from Managua II well field and then distributed from the tank. The work will include the construction of transmission pipe (PVC150:1.1km) and associated valve

7.5.8 Installation of Secondary/Tertiary Distribution Pipes and House Connections

The increase of service area by improved the transmission and distribution facilities as mentioned above will require an extension of the secondary and tertiary pipes which are branched or connected to houses and an installation of house connections. Increase number of house connections corresponding increase of population served is estimated at about 50,000 connections by 2015 as shown in **Table 7.5.5**. Therefore, ENACAL should install the secondary and tertiary distribution mains and house connections surely every year, since the delay of these installations is directly related to the decline of water supply services.

Table 7.5.5 Increase Number of House Connection

	2004	2005	2010	2015
Population Served	1,049,837	1,071,802	1,187,902	1,317,189
Increased Population Served		21,965	116,101	129,287
Increase Number of Connection		4,068	21,500	23,942

In addition, to deal with increasing house connections, the ENACAL should increase staffing for meter reading in line with the expansion of the water supply services.

7.6. REHABILITATION OF EXISTING TRANSMISSION AND DISTRIBUTION FACILITIES

The existing transmission and distribution pumping station is needed to be rehabilitated in order to recover the pumping capacity and to secure the necessary transmission and distribution flows. According to the investigation of the existing conditions, three of four existing pumps at Km14.5 Carretera Masaya Pumping Station which is an important pumping station for present Managua Water Supply System and supply water to area along the Masaya Road, Ticuantepe and Nindiri were out of service. Therefore, the rehabilitation work of the existing pumps at Km14.5 Carretera Masaya Pumping Station has priority and is proposed as the improvement of water transmission and distribution system in Nindiri as mentioned in **Section 7.5.6**.

Although other pumping stations are operating without serious problem, it is recommended that the existing pump equipment is replaced by year 2015, because for almost all pumps 10 years or more have passed since they were originally installed even though the pumps are repaired. The list of the existing pumping stations which will be used continuously until 2015 is as follows;

- Asososca Pumping Station (for Zona Alta)
- Km8 Carretera Masaya Pumping Station
- Km18.5 Carretera Masaya Pumping Station
- Km8.5 Carretera Sur Pumping Station
- Km9.5 Carretera Sur Pumping Station
- Km11.5 Carretera Sur Pumping Station
- San Judas Pumping Station
- Unan Pumping Station
- Km14.5 Carretera Vieja Leon Pumping Station
- Torres Molina Pumping Station
- Pochoquape Pumping Station
- Jocote Dulse Pumping Station
- El Mirador Pumping Station

7.7 OPERATION AND MAINTENANCE FOR EXISTING AND PROPOSED FACILITIES

7.7.1 Operation of Facilities

(1) General

ENACAL controls the transmission and distribution flow by operating regulation valves and pumps in order to supply water to the overall service area properly, by the directions of P3 personnel of Depto. Eeplotation, GCIA. de Operationes who stay at Asososca Pumping Station located at ENACAL Head Quarter. But these directions are only based on their experiences and are not available in the form of standard operation manuals. It is recommended that manuals should be prepared in order to control flows into each macro sector and keep adequate pressures in each macro sector.

(2) Operation of Water Transmission System

Independent water transmission systems from connected distribution pipelines should be established after the completion of macro sectoring and improvement works, since it was hard that there was some illegal connection from the transmission pipeline during the field

investigation. Especially water from the Managua I and Managua II Systems is transmitted through an independent transmission pipeline to distribution tanks.

Hourly fluctuations of water levels of tanks should be recorded and this information should be relayed to the operators of the transmission pumping stations and the P3 operators at Asososca. The operators of the transmission pumping stations will be able to operate pumps to secure water transmission to each tank by referring to the data of the water level fluctuation and pressure and flow quantity at the outlet of the pumps.

Based on the water level fluctuation data, valve adjustment will also be required. When comparing the water level pattern at the respective tanks, the valves on pipes should be adjusted, closing the valve on the pipeline to always fulfilled tank or open the valve on pipeline to always low water level tank.

(3) Operation of Water Distribution System

The most important task for the water distribution system is for the reduction of ineffective water ration including leakage and wastage. The reduction of the ineffective water entails the finding and repair of leakages and the prevention of leakage. The detailed leakage control is described **Supporting Report No.4**.

To prevent leakage, pressure control in the distribution system is indispensable. To conduct pressure control, ENACAL should know the pressure distribution in the service area. It is recommended to establish fixed pressure monitoring points at the same locations as the water pressure monitoring points should measured periodically. Based on the pressure records from these fixed monitoring points, valve adjustments should be conducted to avoid extreme high pressure and to stabilize pressure distribution in the service area as much as possible.

(4) Data Collections and Records

As mentioned above in order to operate the facilities the following data should be collected and recorded properly and then utilized effectively for the flow and pressure controls.

- production amount from wells and intake amount from Asososca Lake
- transmission flows from pumping stations and tanks
- distribution flows from pumping stations and tanks
- water level of tanks
- distribution flow into each macro sector
- pressures in the service area

Some data have already collected and recorded by ENACAL but it is recommended that the flow rates should not be calculated from pump operation hours but read directly from the flow meters if the flow meters are installed. The number of flow measurements will increase by macro sectoring.

7.7.2 Maintenance of Facilities

Although individual staff of ENACAL are doing good job at the existing facilities, maintenance work seems to be conducted in an allopathic manner. Once the condition of equipment demands attention, it is only then maintenance work is done. However, equipment or facility usually requires periodical maintenance including function check, inspection and replacement of parts in order to prevent malfunction and accident. ENACAL should prepare periodical

maintenance schedules with the required frequency, such as daily, monthly, and yearly for the necessary maintenance work as follows.

(1) Tanks

- inspection and maintenance of equipment such as tank level indicators, inlet and outlet valves
- check and repair of flow meters including meter calibration
- repainting of tank surfaces,
- cleaning of inside and outside tank,
- leakage survey

(2) Transmission and Distribution Pipelines

- check and repair of equipment such as valves, air valves, blow-off valves including check of valve chambers and manhole covers
- check and repair of flow meters for macro sectors including meter calibration
- leakage detection and repair
- inspection patrol of pipeline route for finding the visual leakage

(3) Transmission and Distribution Pumping Stations

- inspection and maintenance of equipment based on the manufacturer's recommendation
- cleaning of inside and outside pumping station and repainting of walls of the stations
- check and repair of flow meters including meter calibration

(4) House Connections

- leakage detection and repair
- inspection of meters
- replacement of individual meters periodically

In addition, mechanical and electrical workshop and meter repairing workshop should be improved for proper maintenance and repair works of water supply equipment with some stock of well pumps and adequate spare parts.