Supporting-C Leakage Study

SUPPORTING-C LEAKAGE STUDY

1. INTRODUCTION

It has been widely believed that the present water supply system of Tegucigalpa has a big water leakage problem. It counts about 40 to 50 % of a total water production according to information from SANAA. If it is correct, it could be possible to supplement a current shortage of water supply by controlling water leakage. Therefore, leakage control may be regarded as one of potential water sources.

In spite of such an importance of leakage control, there is little information with solid technical background about features of actual water leakage including amount of leakage. The leakage study was organized to acquire technical information to evaluate a potential as an alternative water source and to prepare a leakage control program.

The study consisted of field surveys to make actual measurements of water flows and pressures and to detect underground leakage in selected water distribution areas and analysis of SANAA's leakage repairing work records.

2. FIELD SURVEY

2.1 PURPOSES

The field survey was carried out i) to estimate actual water leakage by actual measurements of differences between inflow rates and water consumption rates and time serial fluctuations of water flow and pressure in selected water distribution areas, and ii) to locate actual leakage spots by a sound detection.

2.2 METHODS

(1) Selection of Survey Areas

Ten (10) water distribution areas were selected from about 40 distribution areas by considering following conditions:

- Separation from other distribution areas, which makes it enable to measure a specific water balance.
- Living conditions of areas that affect water consumption patterns.
- Major materials of distribution pipe that may be a possible cause of water leakage.
- Pipe installation age that may be a cause of water leakage.

Features of the selected distribution areas are shown in *Table C.2.1*. The selection of the areas had been carried out so that the selected areas could represent the above-mentioned conditions, however, there was few way to select the areas other than by easiness in setting a flowmeter and availability of background information such as pipe lying drawings. Major difficulties experienced in setting up the flowmeter were difficulties in locating distribution pipe and problems in securing space for the flowmeter at a site due to a heavy traffic.

Some of the selected areas had inter-connections with adjoining distribution areas. For those areas, water shut-off valves were installed to measure a specific water balance.

Table C.2.1 Features of the Selected Areas for Field Survey

No.	Selected Area (Name of Neighbourhood)	Classfi-[1] cation of Neigh-borhood	Number[2] of House holds	Length of [3] Dsitribution Pipe (km)	Major[4] Pipe Material	Diameters of[3] Distribution Pipe(mm)	Year of[4] Installation	Time Schedule[3] of Water Rationing
1	Colonia America	A	319	6.0	PVC	13 to 100	1974	12pm-1pm 9pm-12am
2	Colonia Pradera	T	664	5.2	PVC	13 to 100	1976	12pm-1pm, 9pm-1am
3	Colonia Satelite	M	599	7.7	Steel	13 to 150	1965	5am-9pm
4	Colonia Los.Colinas	M	811	6.0	ACP	13 to 100	1975	3am-10am 3pm-10pm
5	Colonia Los.Girasoles	P	366	3.5	PVC	13 to 100	1988	4hrs
6	Colonia Cerro Grande	M	2,842	13.0	PVC	13 to 100	1978	10hrs (Twice a week)
7	Colonia Loma Linda.Norte	S	305	5.0	PVC	13 to 75	1977	3am-10am 3pm-10pm
8	Colonia La.Rosa	T	439	3.3	PVC	13 to 100	1990	12pm-1pm 9pm-12am
9	Colonia Bella.Oriente	M	135	9.0	PVC	13 to 100	1978	9pm-9am
10	Colonia El.Modelo	S	103	5.5	PVC	13 to 150	1970	12pm-1pm 9pm-12am

1): SANAA's classification for neighborhoods. Refer to Supporting , for details of the classification.
2): Data from Pre-Census 2000.
3): Information from SANAA's drawings.
4): Verbal information from SANAA.

(2) Measurement of Time Serial Fluctuation of Water Flow

Time serial fluctuation of water flow was measured by a ultrasonic flowmeter equipped with a data logger mounted on a distribution pipe. Measuring points were established at a point where whole amount of water to the selected areas flows.

The flowmeter was mounted on outside of the distribution pipe after exposing the pipe by excavation.

The measurement was carried out continuously during a water rationing period that had been informed from SANAA.

(3) Measurement of Time Serial Fluctuation of Water Pressure

Time serial fluctuation of water pressure was measured by a Burdon tube pressure gauge equipped with a self-recording device mounted on a distribution pipe. Measuring points were established at several points in the selected areas.

The gauges were mounted on fire hydrants. The measurement was carried out continuously during a water rationing period that had been informed from SANAA.

(4) Measurement of Water Consumption Rate in the Areas

Water consumption rates in the selected survey areas were estimated based on water consumption amounts measured by reading watermeters of selected houses. Although it is more preferable to measure every houses in the survey areas, the houses to be measured were selected from houses equipped with the watermeter, since not every house has the watermeter in Tegucigalpa. Name of the survey areas selected for the measurement of the water consumption rates and the number of the houses to be measured are shown in *Table C.2.2*. The numbers of selected houses are about 10 % of the total houses.

Water consumption rate of each house was calculated from a balance between an initial reading, which was read at the time when the time serial water flow measurement started, and an end reading, which was read at the time of the flow measurement was completed.

Table C.2.2 Survey Areas and Number of Houses Selected for Water Consumption Rates Measurement

Selected Area (Name of Neighbourhood)	Classfication of Neigh-borhood	Numbe of House[1] holds	Number of Houses Selected for Measurement of Water Consumption Rate [2]	Time Schedule of Water Rationing (1/2, %)
Colonia America	A	319	33	10.3
Colonia Satelite	M	599	64	10.6
Colonia El.Modelo	S	103	17	16.5

(5) Detection of Leakage

Leakage detection was carried out by using a sound detector (a sound hearing rod) in the survey areas. Sound detection was performed by hearing leakage sounds from the ground surface at a certain interval along buried pipelines. The buried pipelines were located by SANAA's drawings and instructions by counterpart members in charge at sites. Lengths of pipelines surveyed are as shown in *Table C.2.3*

When the leakage sound was detected, an exact point of leakage was identified by repeating sound detection at shorter intervals.

Table C.2.3 Length of Pipelines Surveyed for Leakage Sound detection

No.	Name of Survey Area	Length of a Total Burried Pipelines (km)	Length of Detection Conducted (km)
1	Colonia America	6.0	4.5
2	Colonia Pradera	5.2	5.2
3	Colonia Satelite	7.7	5.0
4	Colonia Los.Colinas	6.0	5.0
5	Colonia Los.Girasoles	3.5	3.5
6	Colonia Cerro Grande	13.0	5.0
7	Colonia Loma Linda.Norte	5.0	5.0
8	Colonia La.Rosa	3.3	3.3
9	Colonia Bella.Oriente	9.0	4.5
10	Colonia El.Modelo	5.5	5.5

2.3 RESULTS OF FIELD SURVEY

(1) Time Serial Fluctuation of Water Flows and Pressures (Estimation of Unaccounted for Water)

A water flow in distribution areas varies depending on activities of the areas. In general, the water flow increases in daytime due to people's daily activities and decreases from nighttime to midnight. This tendency is more significant in residential areas because little water use is expected while people are sleeping. Therefore, a minimum flow recorded during midnight is often regarded as a flow caused by a leakage.

The measurement of time serial fluctuation of water flow and pressure in this field survey was carried out with aim to investigate a leakage flow from the minimum flow. *Table C.2.4* summarizes results of the measurement of water flow.

Table C.2. 4 Summary of Results of the Time Serial Fluctuation Measurement

Name of Survey Area	Classfication of Neighborhood	Period of [1] Measurement (hr)	Average Flow[2] Rate During Measurement (m^3/hr)	Minimum Flow Rate Recorded (m^3/hr)	Time Minimum Flow Recorded
Colonia America	A	14	45.5	14.7	3:20
Colonia Pradera	T	16	29.8	9.0	1:30
Colonia Satelite	M	14	43.4	12.0	4:00
Colonia Los.Colinas	M	13	186.0	68.0	2:30
Colonia Los.Girasoles	P	10	31.0	13.4	3:00
Colonia Cerro Grande	M	11	151.1	132.0	13:40[3]
Colonia Loma Linda.Norte	S	7	59.8	42.6	10:10[3]
Colonia La.Rosa	T	15	34.0	8.2	1:00
Colonia Bella.Oriente	M	10	57.4	17.0	4:30
Colonia El.Modelo	A	16	29.5	10.0	5:30

1): The period of the measurement accords to the water rationing period on the day.
2): The average was calculated by dividing the accumulated flow rate by the period of the measurement.
3): The period of the water rationing is only in daytime.

They have low stable flow rates during nighttime with high stable pressures. This indicates there is a stable flow less affected by water use by people's activities. As the water supply is not continuous operation and 20 % to 30% of the households have their own water storage tank in their house to be prepared for a no-water period, their water use patterns may differ from the ones in the continuous water supply operation. Water flow during the low flow period in midnight could include water flow for filling the storage tanks. Therefore, by considering that the minimum flow represents unaccounted for water, unaccounted for water were calculated as shown in *Table C.2.5*.

Table C. 2.5 Calculation of Unaccounted Water based on Minimum Flow

Name of Survey Area	Classfication of Neighborhood	Period of Measurement (hr)	Total Water [1] Flow during the Measurement Period (m^3)	Unaccounted [2] Water Calculated from Minimum Flow (m^3)	Rate of Unaccounted Water (%)
Colonia America	A	14	636	205	32.2
Colonia Pradera	T	16	477	143	30.0
Colonia Satelite	M	14	608	169	27.7
Colonia Los.Colinas	M	13	2,418	884	36.6
Colonia Los.Girasoles	P	10	310	134	43.2
Colonia Cerro Grande	M	11	1,662	- [3]	-
Colonia Loma Linda.Norte	S	7	419	- [3]	-
Colonia La.Rosa	T	15	510	123	24.1
Colonia Bella.Oriente	M	10	574	170	29.6
Colonia El.Modelo	A	16	472	160	33.9

1): Measured by integrating flowmeter
2): (Minimum Flow) x (Measurement period)
3): Not available as the minimum flows occurred in daytime.

Colonia Cero Grande and Colonia Loma Linda Norte were excluded from the calculation because the minimum flows occurred in daytime in these areas, thus it is not considered that the minimum flow represents the unaccounted for flow. The calculated unaccounted for water varies 24.1 to 43.2 % of a total water supplied.

(2) Water Consumption Rate (Estimation of Leakage Water)

A comparison between the inflow water and consumption rates in a specific area could give more direct estimation of leakage. In a such measurement, consumption rates should be measured by every water consumption existing in the area. However, watermeter installation does not cover all the users in the Study area, thus the consumption was estimated by an average consumption rate of selected numbers of users. *Table C.2.6* shows the result of the estimated leakage amount.

Estimated leakage ratios are 27.5% to 32%. It should be noted that they are just an estimation with a certain range because the consumption rates were estimated from limited numbers of samples. Furthermore, the surveyed areas may be incommensurate (a total population of the three surveyed areas counts only less than 1% of the total.) to represent the leakage of the whole system. However, even though, they are still only available qualitative information with certain technical background.

Table C.2.6 Leakage Ratios Estimated Based on Water Inflow and Water Consumption rates

Selected Area (Name of Neighbourhood)	Period of Water Supply	Numbe of Users	Measures[1)] Inflow Rate (m^3)	Average[2)] Water Consumption per User (m^3/User)	Total Water[3)] Consumption (m^3)	Leakage[4)] Amount (m^3)	Leakage [5)] Ratio (%)
Colonia America	17:30 June 28 to 11:30 June 29	319	580.6	1.3	420.9	159.7	27.5
Colonia Satelite	15:30 June 27 to 10:30 June 28	599	575.6	0.7	391.4	184.2	32
Colonia El.Modelo	20:00 June 29 to 3:00 June 30	103	177.8	1.2	121.8	56.0	31.5

1): Measured by ultrasonic flowmeter installed at the inflowing point.

2): Average of water consumption measured by a balance between meter readings before and after the measurement at each selected user..

3): 2) x Number of Users

4): 1) - 3)

5). 4) / 1) x 100

(3) Leakage Identified by Sound Detection

In the leakage detection, leakage points were detected by hearing a leakage sound from the ground surface. When the leakage sound is detected, hearing are repeated in the vicinity to locate the leakage point. At same time, a magnitude of leakage sound are recorded to provide leakage amount estimation with qualitative information. *Table C.2.7* shows locations where and pipe diameters in which leakage were detected together with qualitative expressions of a magnitude of leakage sounds.

26 leakage were located in the surveyed 46.5 km of distribution pipe. 17 leakage among them (65%) were found in service pipes. Therefore, it can be said that leakage occur mainly in the service pipe. However, as indicated from a magnitude of leakage sounds, leakage from service pipe may not be a predominant cause of leakage problems in term of leakage amount.

By assuming that the result represents the whole system, it is estimated that there exist about 1100 leakage in the system at the time of the survey by multiplying a measured liner density of leakage occurrence (26 / 46.5km = 0.56 numbers/km) with total length of distribution pipe (2000 km).

Table C.2.7 Located Leakage

Site Name	Diameter	Piping	
		Main [1)]	Service [2)]
Colonia America	2"	Big	
	2"	Medium	
Colonia Pradera	2"	Big	
	3"	Medium	
	2"	Medium	
	2"	Slight	
	1/2"		Slight
	1/2"		Slight
	1/2"		Slight
	1/2"		Slight
	1/2"		Slight
	1/2"		Slight
	1/2"		Slight
Colonia Satelite	3"	Big	
Colonia Bella.Oriente	1/2"		Slight
Colonia Los.Colinas	1/2"		Medium
	1/2"		Slight
Colonia Los.Girasoles	1/2"		Slight
	2"	Medium	
Colonia Cerro.Grande	2"	Big	
	1/2"		Slight
	1/2"		Slight
	1/2"		Big
Colonia Loma.Linda			
Colonia El.Modelo	1/2"		Slight
	1/2"		Slight
Colonia La.Rosa	1/2"		Slight
Total		9	17

Note: Big, medium and slight indicate a magnitude of leakage sounds heard.

1) Pipes generally installed under roads supply water users through a service pipe that connects the main pipe and users.

2) Pipes conveying water from the main pipe to a user's meter box. In case users do not have a meter, service pipe means a pipe between the main pipe and user's premise.

3. ANALYSIS OF SANAA LEAKAGE REPAIRING RECORDS

3.1 SANAA LEAKAGE REPAIRING

SANAA has a department responsible for leakage control, CROPECO. The department conducts repairing works for leakage that are found by field patrols and information from citizens. It performed 5000 to 6000 repairing works in 1998 and 1999. There are records that describe contents of daily repairing work including information amount leakage conditions such as diameters and types of pipe and causes of leakage.

3.2 CHARACTERISTICS OF LEAKAGE (BASED ON 1999 RECORDS)

Table C.3.1 is summarized information about diameters and types of pipes where leakage were found and causes of leakage.

About 70% of leakage occur in PVC pipe, then 21% occur in steel pipe. However, it does not necessarily mean that types of pipe affect the occurrence of leakage because more than 90% of pipes are PVC. Also most of leakage occur in smaller pipes, but it was reported that more than 90% of pipes are less than 8 inches.

For the causes of leakage, the biggest cause is aging of pipe followed by improper installation works. It seems natural that aged pipes causes leakage. However, if the ratio of aged pipes is considered, which is reported to be about 30%, it can not be said that an occurrence of leakage in the aged pipe is specifically high.

4. CONCLUSION

4.1 LEAKAGE AMOUNT

Through the field survey, information on the unaccounted water and leakage water were obtained based on the actual measurements, but still it is not enough to determine values that can be applied to the whole system because of representativeness of the obtained data. Information on leakage amount for the whole system with solid justification will be given by enough flow rate information through the system.

The study assumes that unaccounted water and leakage water are 40% and 30 % of the present water production, respectively, for the demand projection at present and future. They are no better than assumption, however, they have technical background, even though they are incommensurate.

4.2 LEAKAGE CONTROL PLAN

As mentioned above, most important and urgent things for the leakage control to obtain precise information about actual leakage. This will provide basic information for the planning of leakage control.

On the other hand, it would be a matter of fact that the distribution system needs physical rehabilitation to reduce current leakage and to control future leakage. While details of a control plan should be determined with exact information of leakage, the study proposes outlines of required activities for the leakage control.

The proposed plan consists of three stage activities to control the leakage:

(1) 1st Stage

Major 1st stage activity is installation of water flow measuring devices to WTPs, reservoir tanks and users. This will enable the measurement of a water balance of the whole system which provide quantitative information on leakage amount of in a specific area, as well as of whole system.

The installation of watermeter to users should include the replacement of the service pipes, where many leakage presently exist. As shown in *Table C.3.1*, occurrences of leakage of pipe size less than 3/4 inches, which is considered to be a service pipe, count more than 30% of the total leakage occurrences.

Details of 1st stage activities are proposed as Leakage Control Project, which is one of the components of the Master Plan, as explained later.

(2) 2nd Stage

2nd stage activities are planning of leakage repairing, or rehabilitation of distribution network. Accumulation of data obtained from water amount measuring devices in the first stage would present a leakage amount by reservoir tank and of the whole system.

Using these data, following matters should be analyzed:

Leakage amount of the whole system:	This will identify necessity of the rehabilitation work and estimate effects of the rehabilitation.
Difference of leakage by distribution area:	This will prioritize the distribution areas for the rehabilitation.

Based on these analysis, the rehabilitation plan that include rehabilitation methods and priority of work ordering, shall be prepared.

(3) 3rd Stage

This is an implementation stage of the rehabilitation of distribution network.

4.3 LEAKAGE CONTROL PROJECT

(1) General

Ultimate goal of the leakage control project is to reduce the physical loss to a certain acceptable level. Leakage Control Program consists of following strategies:

i) To acquire information necessary for implementing leakage reducing program, such as water quantity data through out the system, as-built drawings of distribution pipe laying and pipe registers.
ii) To set up task force for leakage repairing.
iii) To establish a leakage reducing program.
iv) To implement the leakage reduction program.

The Leakage Study conducted in the Study revealed that there is not enough basic information necessary for establishing effective measures. Therefore, the Master Plan proposes to implement water quantity measuring system as a first step of the leakage control. Actual reducing program should be established after accumulating water quantity data throughout the system for several years. The Master Plan also proposes a task force that increases a capacity of the leakage repairing section.

(2) Strengthening of Leakage Repairing Capacity

Required manpower and equipment necessary for strengthening leakage repairing capacity are shown in *Table C.4.1*.

Table C.4.1 Required Manpower and Equipment for Strengthening Leakage Rearing Capacity

Works	Description	Remarks
Leakage Patrol	Leakage Detector (Hearing rod, Drill, Flowmeter) x 2 sets	Frequency of patrol: 4 times/year
	Patrol Vehicle x 2	
	Inspector x 4	
Repairing Works	Repairing tools 5sets Vehicle x 5	Repair: 10 leakage/day
	Worker x 15	

(3) Water Quantity Measurement

Water measurement devices for treated water of WTPs are not working properly in the existing three WTPs and no water devices are equipped in the existing distribution reservoirs. Although it would be not easy to install water meters to all the users, measurement of treated water and water inflow to each distribution reservoirs could improve understanding of the actual water balance. Therefore, the master plan proposes the installation of water meters at WTP and distribution reservoirs. Required meter installation is shown in *Table C.4.2*.

Table C.4.2 Required Devices for Water Quantity Measurement

Facilities	Measuring Point	Type of Flowmeter	Number of Facilities	Required Quantity	Remarks
Water Treatment Plant	Inlet and outlet	Flow rate and Integrated Value	1	2	
Pumping Stations	Outlet	Flow rate and Integrated Value	8	8	
Distribution Reservoirs	Outlet	Flow rate and Integrated Value	12	12	
Existing Distribution Reservoirs	Outlet	Flow rate and Integrated Value	44	101	Some distribution tanks have several outlets.
Water Meters	Service Pipe	Integrated Value	48,500	48,500	

Note: Only for the existing facilities. For the new facilities, it is supposed that necessary flow measurement devices are installed in all the facilities..

Table C.3.1 Leakage Occurrence by Pipe Size, Material and Causes

Pipe Sizes (Inch)	Materials of Pipe				Causes of Leakage				Total by Pipe Size		
	PVC	Steel	IDCP	Asbest	Pressure	Installation	Pipe Age	Others	No.	%	Accumulated %
1/2	1171	344	0	0	127	458	536	394	1515	25.7	25.7
3/4	167	288	0	0	12	45	276	122	455	7.7	33.5
1	52	59	0	0	10	16	58	27	111	1.9	35.4
1+1/2	92	66	0	1	10	20	78	51	159	2.7	38.1
2	1589	350	7	130	157	498	803	618	2076	35.3	73.3
2+1/2	13	6	4	0	0	3	10	10	23	0.4	73.7
3	441	80	3	84	63	148	222	175	608	10.3	84.0
4	279	56	28	28	47	110	87	147	391	6.6	90.7
6	187	14	29	8	35	64	45	94	238	4.0	94.7
8	74	0	70	7	12	46	39	54	151	2.6	97.3
10	11	0	40	8	8	6	10	35	59	1.0	98.3
12	14	0	37	0	5	6	5	35	51	0.9	99.2
14	0	0	4	2	1	3	3	2	9	0.2	99.3
16	7	0	20	0	3	11	0	10	24	0.4	99.7
18	0	0	3	0	1	0	1	1	3	0.1	99.8
20	0	0	0	0	0	0	0	0	0	0.0	99.8
22	0	0	0	0	0	0	0	0	0	0.0	99.8
24	0	0	4	0	1	2	1	0	4	0.1	99.8
26	0	0	7	0	1	3	0	3	7	0.1	100.0
28	0	0	1	0	1	0	0	0	1	0.0	100.0
30	0	0	1	0	0	0	1	0	1	0.0	100.0
Total	4097	1263	258	268	494	1439	2175	1778	5886		
Ratio to Total (%)	69.6	21.5	4.4	4.6	8.4	24.4	37.0	30.2	100.0		

Source: SANAA Leakage repairing records, 1999