APPENDIX G

LEAKAGE RECORD OF DISTRIBUTION MAINS

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1. EXISTING DISTRIBUTION MAINS

1.1 Present Condition of Distribution Mains

- Total Length : 1,116 km
- Type of the Pipe : Ductile Iron Pipe (928 km, 83.2% of the total length)
  Cast Iron Pipe (124 km, 11.1% of the total length)
  Steel Pipe (64 km, 5.7% of the total length)
- Water Pressure : 2.5 - 8.0 kgf/cm^2
- System Loss Rate : 35% (1995)
- Leakage Amount : about 7.9 m^3/h/km

('System Loss Amount in 1995' divided by 'Total Length of Distribution Pipe')

- Average Age of Pipes :
  - Ductile Iron Pipe : 12 years (Year of Installation: 1975 - 1997)
  - Cast Iron Pipe : 42 years (Year of Installation: 1920 - 1975)
  - Steel Pipe : 30 years (Year of Installation: 1945 - 1988)
- Rate of Pipe Replacement 1997
  : 0.3% (No pipes were replaced before 1997)
- Frequency of Pipe Repairing Works for Leakage
  - Distribution Pipe : 30.5 repairs/month
    : 0.23 repair/km/month
    (per total length of cast iron pipes)
  - Service Pipe : 348.3 repairs /month
- Frequency of Service Pipe Repairing Works per Connection
  : 1.46 repairs/1,000 connections/month

1.2 Maintenance System for Distribution Mains

The Distribution Directorate is responsible for maintaining the distribution network in Damascus City. The Distribution Directorate has 6 Departments as below:

a) Network Inspection Department

b) Emergency Department

c) Periodical Maintenance Department
d) Department of Construction of Branch Networks
e) Department of Drawing, Plans and Archives
f) Department of Annual Excavation and Contracts

(1) Leakage Detection

The Leakage Detection Section of the Network Inspection Department deals with detecting leakage in the pipes. The periodical leakage inspection have only started since the JICA Study team recommendations were made in 1996. Complaints from inhabitants in Damascus City are the major information source of information for leakage detection efforts.

(2) Repair of leaking pipes

Repairing work is carried out by the Emergency Department and Periodical Maintenance Department. The Pipe Repair Section in Periodical Maintenance Department mainly deals with repairing works for distribution pipes. Emergency Department mainly deals with repairing works for service pipes.

Repair works is carried out in three 8 hours shifts per day by two team with 3 crews. The pipes which are installed near reservoirs and pumping stations and/or have big diameter, are repaired as a first priority. Only 30 - 50% of pipes can be repaired immediately after detecting leakage.

2. RECORD OF LEAKAGE AND REPAIRING WORKS

2.1 Distribution Mains

(1) Historical background

In 1997, 3,300 m old lead jointed cast iron pipes was replaced in Damas Center Medium 1 (D04) pressure zone with ductile iron. This is the first time since they were first installed in 1920 that any of the distribution mains have been replaced.

The average age of the existing cast iron pipes is estimated at 42 years, which greatly exceeds the life of cast iron pipe generally considered to be 25 years. Replacement of the cast iron pipes is therefore an urgent priority since over 70% of the cast iron pipes are already past their useful life. To detect the expansion of the distribution network has had priority over the rehabilitation and replacement existing distribution network because of the rapidly growing population, see Figure G-2.1.

The problem of leakage from lead jointed cast iron pipes has been reported frequently since the 1980's, and leaking water has been noted to erode the road surface above the leaking pipes. Repairing works on the leaking cast iron pipes has been carried out continuously, however the levels of leakage have not been reduced.

Water shortage problems did not occur before 1987, because the yield capacity of water resource were sufficient to satisfy the water demand for the City. However, by 1987 growing water demands combined with the increasing losses in serious shortages. The development of new water resources is very difficult and costly due to limited potable water source in and around the Damascus City. The availability of water can be increased by reducing the amount of leakage through a rehabilitation program.

Most of the known leakage problems are detected usually when water appears on the ground surface. The actual number of leakage problems is probably several times larger than those that are visibly detected. The cast iron pipes form the central part of the network of distribution mains in Damascus City. The leakage problem has significant negative impact;

a) Decreasing of water supply amount (and water pressure) in a wide area of the network
b) Disturbing traffic condition by the damage to the road surface
c) Decreasing the economic benefit to DAWSSA

Financial constraints and the fact that the existing per capita production is sufficient to meet system demands if the system were tight make rehabilitation of leaking waters a very urgent priority.

(2) Present conditions

Leakage problems occur mainly on the cast iron pipes, which form 11.1 % of the total length of the distribution mains in the network. Leakage of ductile pipes only occurs almost once a month to accidents with construction machinery, improperly seated rubber joints and connections made by informal water users.

Records for the repair of cast iron pipes are shown in Table G-2.1. For the cast iron pipes, the average number of monthly leakage repair works on the distribution mains is 30.5 repairs/month from January 1993 to December 1996s resulting in 0.23 repairs/km/ month.

The DAWSSA does not have sufficient capacity to deal with rate of leakage. The following pipes are given priority for repair work:

a) The pipes considered as important line in the network
b) The pipes with big diameter
c) The pipes installed under principal road

Other pipes may be left unrepaired, if it does not have a serious impact.

The frequency of repair works on distribution pipes and service pipes has recorded about unchanged for the last 4 years, see Figure G-2.2. This indicates that, the condition of leakage on the cast iron pipes has not been improved in spite of continuous repair effects. It

is also an indication that most of the cast iron pipes are too old and have too many weak points for repairs to be effective. Therefore, the cast iron pipes must be replaced.

It is observed from, Figure G-2.3, that the frequency of repairing works during the dry season are higher than the frequency during the rainy season. This is likely due to the fluctuation of water pressure caused by water rationing during dry season which stresses the weak cast iron pipe. Table G-2.2 indicates the frequency of repair on large diameter pipes tends to be higher than that of small diameter pipes, and the frequency of repair on cast iron pipes do not correlate with the age of the pipes.

2.2 Pipes in Damas Center Medium 1

The Damascus Center Medium 1 (D04) pressure zone was serviced by a lead jointed cast iron pipe line, installed under the principal road facing the presidential area , see Figure G-2.4. The summary of the pipe line characteristics is shown below;

- Total Length of Pipes	:	about 3,300 m
- Pipe Diameter	:	600 mm
- Type of Pipe	:	Cast Iron Pipe with lead joint
- Estimated Water Pressure in pipe	:	2.5 - 4.0 kgf/cm
- Average of the Pipe	:	42 years
- Replacement of the Pipes	:	0.0 % (1955 - 1996)
- Frequency of Leakage and Repairing Works	:	0.6 repair/km/month (Jan. 1993 - April 1997)

The frequency of repair for this pipe line 0.6 /km/month, is higher than the average frequency in Damascus City of 0.23 /km/month, because all of detected leakage points on this line were repaired immediately, see Figure G-2.5. The work load of continuously repairing the line (Length: 3.3 km) has not changed as shown on Figure G-2.6 and takes estimated 10 % of the total capacity of repair team of the Periodical Maintenance Department. The repair rate on this line is 100%, however the condition of leakage was not improved until the pipes were replaced with ductile iron.

The leakage and repairing work condition from January 1995 to April 1997 are summarized in Table G-2.3 and Figure G-2.7 as below;

- The condition of leakage on the line was not improved in spite of continuous repair work for all of detected leakage points
- Many of the leakage points used to be repaired on the line would be leaked again.

It is concluded that there have already been so many leakage points, some of them were detected, but many part of them are not detected. Even if the most serious leakage point is repaired, the second serious leakage point shall become to be bigger leakage points because all of the pipe lines have already been out of the life.

The leakage on the pipe line tends to be happen at the bending points of pipe line and the points under high traffic density area like intersection and rotary of the road, see Figure G-2.3. Most of leakage come from weak points of lead joints of the pipes, and sometimes from weak points of the pipes themselves. Leaked points tend to be leaked again several months after every repairing works, see Figure G-2.7. On other word, the points used to be leaked would not be improved completely.

It is therefore judged that the leakage condition of the pipe line can not be improved by repair work, and replacement of the old cast iron pipes is required.

DAWSSA made the plan to replace 3 km of ND 800 mm of the pipe line with ductile iron pipes in 1994. It took three years for completion of financial arrangements for the replacement works. Leakage conditions did not improve until the completion of the replacement project in 1997. It is estimated that all of the cast iron pipes installed in Damascus City are in the same condition as the pipes of this line. The cost for the ductile iron pipes was US$845,000, and the construction cost SL 23,000,000. Direct cost for repair for the pipes on the line had been used SL 1,000,000 for the 3 years.

2.3 Service Pipes

According to maintenance records shown in Table G-2.1, the average number of the monthly leakage repair works for service pipes is 348.3 repairs/month from January 1993 to December 1996. This is rather high compared to the monthly leakage repair works for distribution pipes is 30.5 repair/month. The two figures result in a total of repairs 378.8/month. The leakage repair work on service pipes accounts for about 92 % of the total leakage repair works.

Many of the leakage points are not detected, and some of the detected leakage points are not repaired. The frequency of repair for distribution pipes are estimated to be smaller than the frequency of leakage. The frequency of leakage on Damas Center Medium 1 (D04) is 0.6 /km/month, which is about 3 times of the frequency of repair for general distribution pipes. On the other hand, most of leakage points on service pipes are estimated to be repaired, because these leakage points are usually informed to DAWSSA by customers as emergency cases.

The frequency of leakage on service pipes per house connection is estimated about 1.46 /1,000 connections /month. Unfortunately, the repair records, rarely note what kind of distribution pipes the service pipes are connected to. However, it is assumed that service pipes connected to the cast iron mains pipes probably account for the majority of the all of leaking service pipes, simply because the service pipes are as old as the cast iron pipes. Service pipes connected to the cast iron pipes shall also be replaced because the connection points are usually a weak points prone to leakage.

3. ECONOMICAL AND SOCIAL BENEFITS OF PIPE REPLACEMENT

The principal objective of a water utility is safe and reliable water supply with effective use of existing water resources. This objective can not be achieved without proper maintenance of the distribution mains that are critical link in the water distribution system. Generally, in water utilities with long history of operation, programs to replace old distribution mains are carried out as priority measure for leakage prevention or improvement of accounted for water. Most of the replacement programs in the water utilities of Japan is aimed mainly of lead jointed cast iron pipes like those at DAWSSA. The rate of accounted for water as percent of total of the water produced by utilities is obviously improved for each year after a water main replacement project implemented.

Selective replacement of old cast iron pipes of distribution main will not only reduce leakage but also improve the reliability of the network and minimize the risk of unexpected large scale water losses from water mains. According to the acoustic leakage sound detection method by experienced expert judgment, the average leakage amounts of cast iron pipes of DAWSSA is estimated at about 30 m^3/h/km. Leakage in ductile pipe was not detected. It is recommended that, cast iron pipes be replaced with ductile iron pipes as soon as possible.

The old cast iron pipe water main replacement program in the Phase I M/P Study consist of 98 km in length, so that total leakage water from old cast iron pipes is surmise about 70,500 m^3/d which can be saved by the water main replacement program. This amounts is equivalent to about 34 % of estimated system losses (207,540m^3/d) in 1995. The amount of saved water can be supply about 371,000 domestic consumers per day or 25.7 million m^3/y, and can provide approximately 1.7 million US$ in additional revenue per year at current tariff levels.

Following economic and social benefits are expected from the replacement of old cast iron pipes.

a) Reduction of leakage water amounts and leakage repair works resulting in increased revenues and decreased operation costs

b) The amounts of water saved will defer the investment cost of water resource development.

c) All of the detected leakage can be repaired due to reduction of leakage cases.

d) Reduction of unexpected water shortage by suspended service work due to reduction of leakage repair works.

e) Improve the reliability of the network and minimize the risk of unexpected large scale water losses from main breaks.

f) Improve the traffic activity because of reduction of road construction caused by unexpected large scale water leakage and repairing work at main road.

g) Safe water supply system can be established due to the reduced the risk of contamination by leakage.

TABLES

Table G-2.1 List of Monthly Leakage Repair Works

The Number of Repair Works for Leakage on Distribution Pipe

Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1993	27	18	15	34	37	42	46	41	41	51	50	41	443
1994	50	33	23	21	27	30	43	36	35	30	25	20	373
1995	15	14	17	20	30	35	33	33	33	31	21	30	312
1996	32	23	23	21	26	32	27	29	43	23	33	24	336

Frequency of repair per km per month — Source: Pipe Repair Section of DAWSSA

30.5 /month 134.69 *km 0.23 /km /month

Note: *:Total length of cast iron distribution pipes

The Number of Repair Works for Leakage on Service Pipe

Year	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1993	334	327	354	321	347	344	371	397	323	339	402	362	4221
1994	369	380	311	371	359	328	368	397	383	342	367	375	4350
1995	317	300	350	325	360	337	378	321	400	331	367	344	4130
1996	312	291	401	298	330	362	308	339	359	315	346	358	4019

Frequency of repair per km per month — Source: Emergency Section of DAWSSA

348.3 /month 1,096 **km 0.32 km /month

Note: **Total length of all distibution pipes

Frequency of repair per connection 1.46 /1,000 connections /month

Table G-2.2 Summary of Leakage Repair Works of Cast Iron Pipes

(By Installed Year)

Installed year	Length (m)	(%)	Repair per month Carried	Frequency of Leakage Repair
1920	3,100	2.3%	0.54	0.17 /km
1930	9,500	7.1%	0.77	0.08 /km
1940	16,450	12.2%	3.48	0.21 /km
1950	60,300	44.8%	13.34	0.22 /km
1960	42,440	31.5%	11.04	0.26 /km
1970	2,900	2.2%	1.33	0.46 /km
	134,690	100.0%	30.50	0.23 /km

(By Pipe Diameter)

Pipe Dia(mm)	Length (m)	(%)	Repair per month Carried	Frequency of Leakage Repair
80	2,500	1.9%	0.15	0.06 /km
100	22,620	16.8%	3.46	0.15 /km
150	19,200	14.3%	3.85	0.20 /km
200	26,400	19.6%	4.48	0.17 /km
250	35,970	26.7%	7.81	0.22 /km
400	9,600	7.1%	2.65	0.28 /km
500	7,300	5.4%	1.58	0.22 /km
600	11,100	8.2%	6.52	0.59 /km
	134,690	100.0%	30.50	0.23 /km

Source: DAWSSA

Table G-2.3 Leakage Repair Inventory of 600 mm Water Main of Damas Center Medium I
(From January 1995 to April 1997)

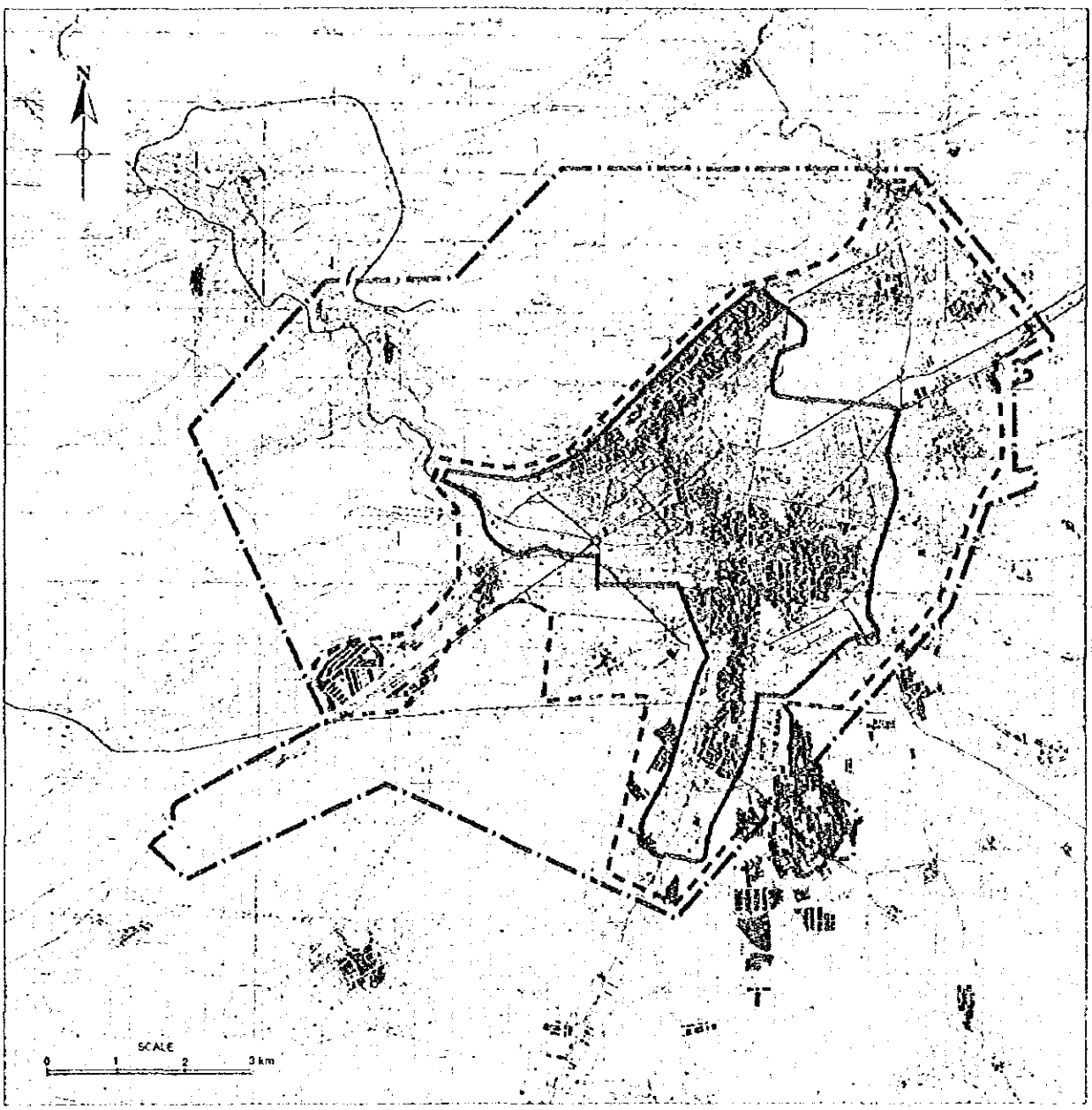
No.	Year	Date	Month	Distance(m)		Repaire		Location
				*1	*2	Place	Times	
1	1995	1	Feb.		2780	joint	1st	May sat square, Rukn Aldine
2		18		3040		joint		Sit al sham school, Rukn Aldine
3		23			960	joint	1st	Maki square, Mansour street
4		28		1810		joint		Afif, sunbul street
5		5	Apr.	950		joint		Malki square
6		21		2100		joint		Jebbeh, Sheikh muhiddin near fire fihting center
7		5	May	3240		joint		rukn Aldine, Second commericail tunnel
8		21			960	joint	2nd	Mansour street, Malki square
9		5	June	3230		joint		Rukn Aldine, subway
10		3	July	2800		joint		Maysat square, Rukn Aldine
11		3	Aug.	1820		joint		Afif, sunbul street
12		23		3260		joint		Rukn Aldine, subway
13		3	Sept.	3280		joint		Rukn Aldine,Eben Alamid bakerien
15		4		3270		joint		Rukn Aldine, subway
16		13			2780	joint	2nd	Maysat square, beginning of Ruken Aldine street
17		11		3290		joint		Ruken Aldine , Nahhas bridge
18		12		2120		joint		Sheikh Muhidden street
19		21		980		joint		Malki, Mansour street
20		10	Oct.	2160		joint		Sheikh Muhiddin, Jebbeh
21		19			970	joint		Malki square
22		25	Nov.	2750		joint		Maisat square, near supper market
23		3	Dec.	3240		joint		Maisat square, Rukur Aldine, Nakhas bridge
24		19		3270		joint		Rukn Aldin, Eben Alamid bakeries
25	1996	4	Jan.	3060		joint		Rukn Aldine, sit alsham school
26		11		400		joint		Muhajrine, Atif stree
27		15	Feb.	2140		joint		Sheikh Muhiddin, Jebbeh
28		28		1150		joint		Malki street
29		7	March	1170		joint		Malki stree
30		20			1820	joint		Afif, in fron t of Rawada palace
31		2	April	2980		joint		Maisat square, Rukn aldine street
32		11	May	3000		joint		Rukn Aldine street, after Maisut square
33		21			1780	joint		Afif, near French Embassy
34		22		1830		joint		Afif, Rawada Palace
35		16	June	1880		joint		Jebbeh, near the flower shop
36		11	July	920		joint		Malki square, Mansour street
37		15		50		pipe		Muhajrine near Wali reservoir
38		4	Aug.	1750		joint		Muhajrine shora in front of Rawada Place
39		13		900		joint		Malki square, Mosour street
40		21			1800	pipe	1st	Afifi, entrance of sunbule street
41		1	Spt.	2280		joint		Sheikh Muhiddin, Jebbeh, Shabandar square
42		11		3080		joint		Ruken Aldine, sit alsham school
43		23		2730		joint		Maiset square
44		7	Oct.	1220		joint		Malki square, Mansour street
45		12	Nov.		1800	pipe	2nd	Afif, entrance of sunbul street
46		26	Dec.	450		joint		Muhajrine, Atif street
47	1997	1	Feb.	1200		joint		Malki square
49		2	Mar.	850		joint		Malki street before square
50		25		3150		joint		Rukn Aldine, in front of Eben alnafis
51		29		3020		joint		Rukn Aldine, near sit alsham school
52		1	April	3300		joint		Ruku Aldine, Eben Alamid bakeries
53		7		300		joint		Muhajrine, third alley

Source:DAWSSA

Note: *1;Distance of normal scale leakage repair place from Wali Resevoir out let

*2;Distance of very large scale leakage repair place from Wali Resevoir out let

FIGURES



LEGEND

- Boundary of Damascus City in 1940
- Existing Boundary of Damascus City (Since 1965)
- Proposed Service Area of 1968 M/P for DAWSSA

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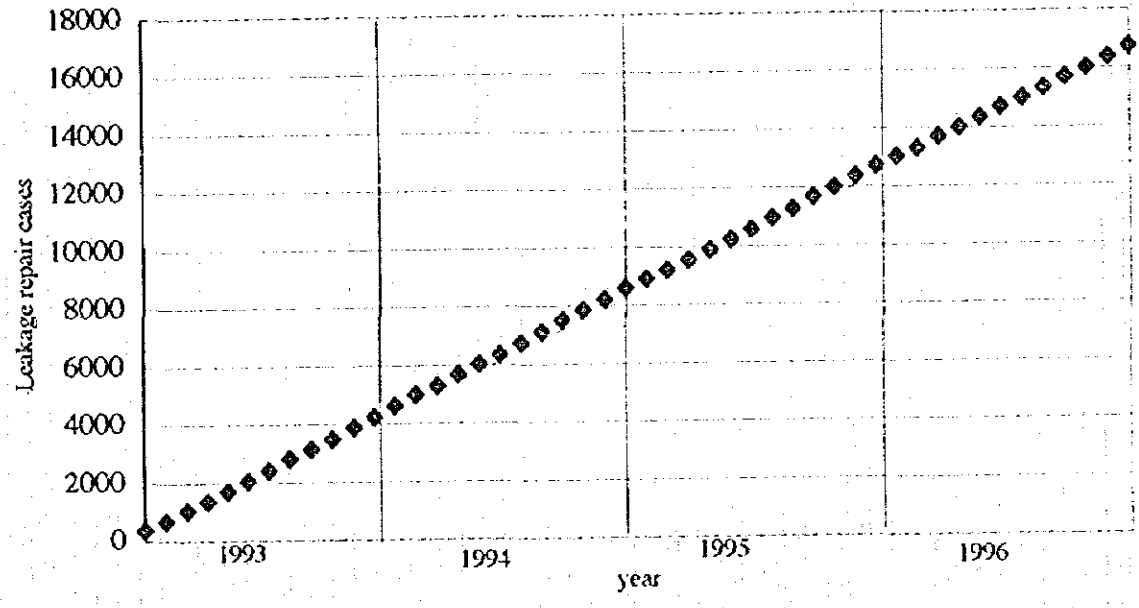
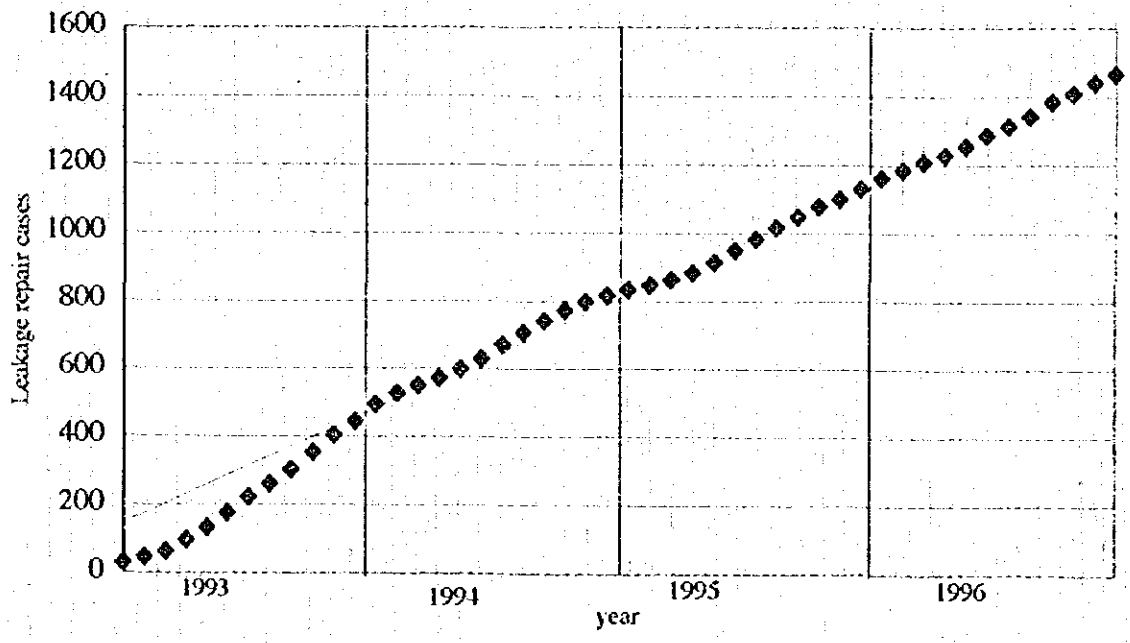
THE STUDY ON THE DEVELOPMENT OF WATER SUPPLY SYSTEM FOR THE DAMASCUS CITY
Figure G-2.1 Administrative area of Damascus City
NIPPON KOEI CO., LTD.

Cumulative monthly repair record from January 1993 to December 1996
for leakage on service pipes



Cumulative monthly repair record from January 1993 to December 1996
for leakage on distribution pipes



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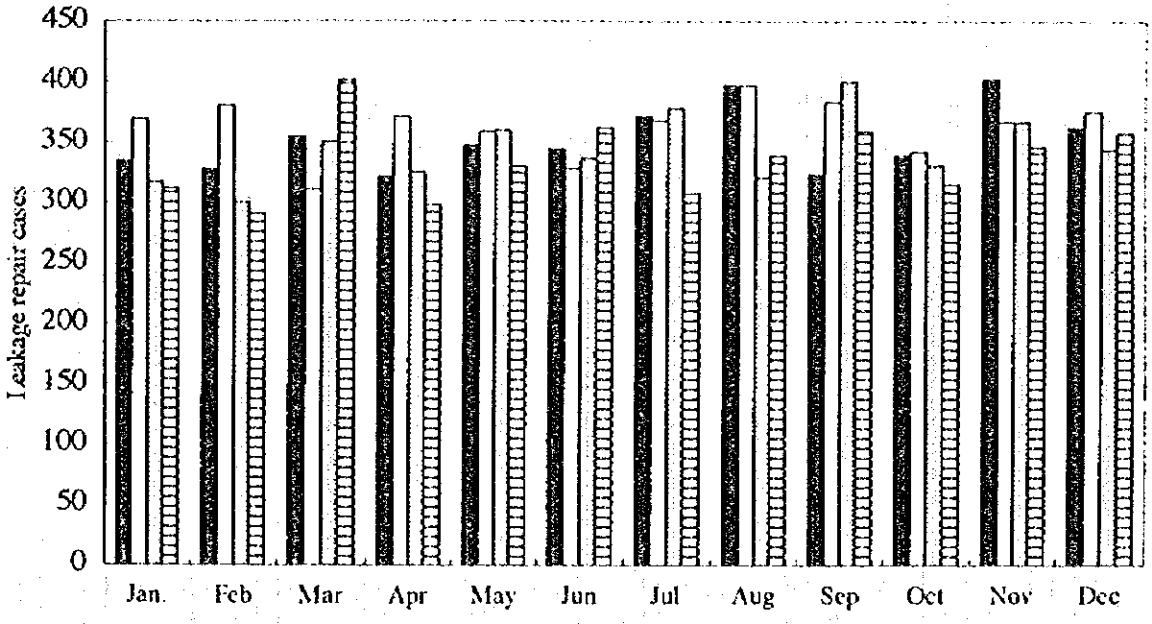
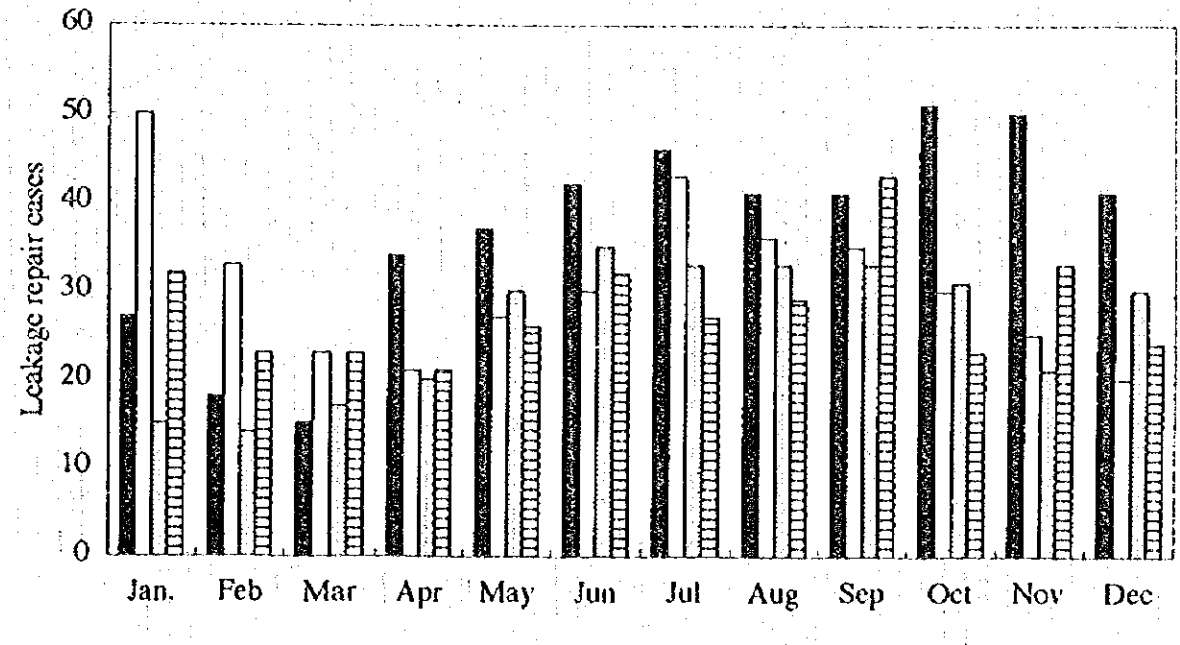
THE STUDY ON THE DEVELOPMENT OF WATER SUPPLY SYSTEM FOR THE DAMASCUS CITY
Figure G-2.2 Cumulative Monthly Leakage Repair Record
NIPPON KOEI CO., LTD.

The monthly repair record from January 1993 to December1996
for leakage on service pipes



The monthly repair record from January 1993 to December 1996
for leakage on distribution pipes



LEGEND

- 1993
- 1994
- 1995
- 1996

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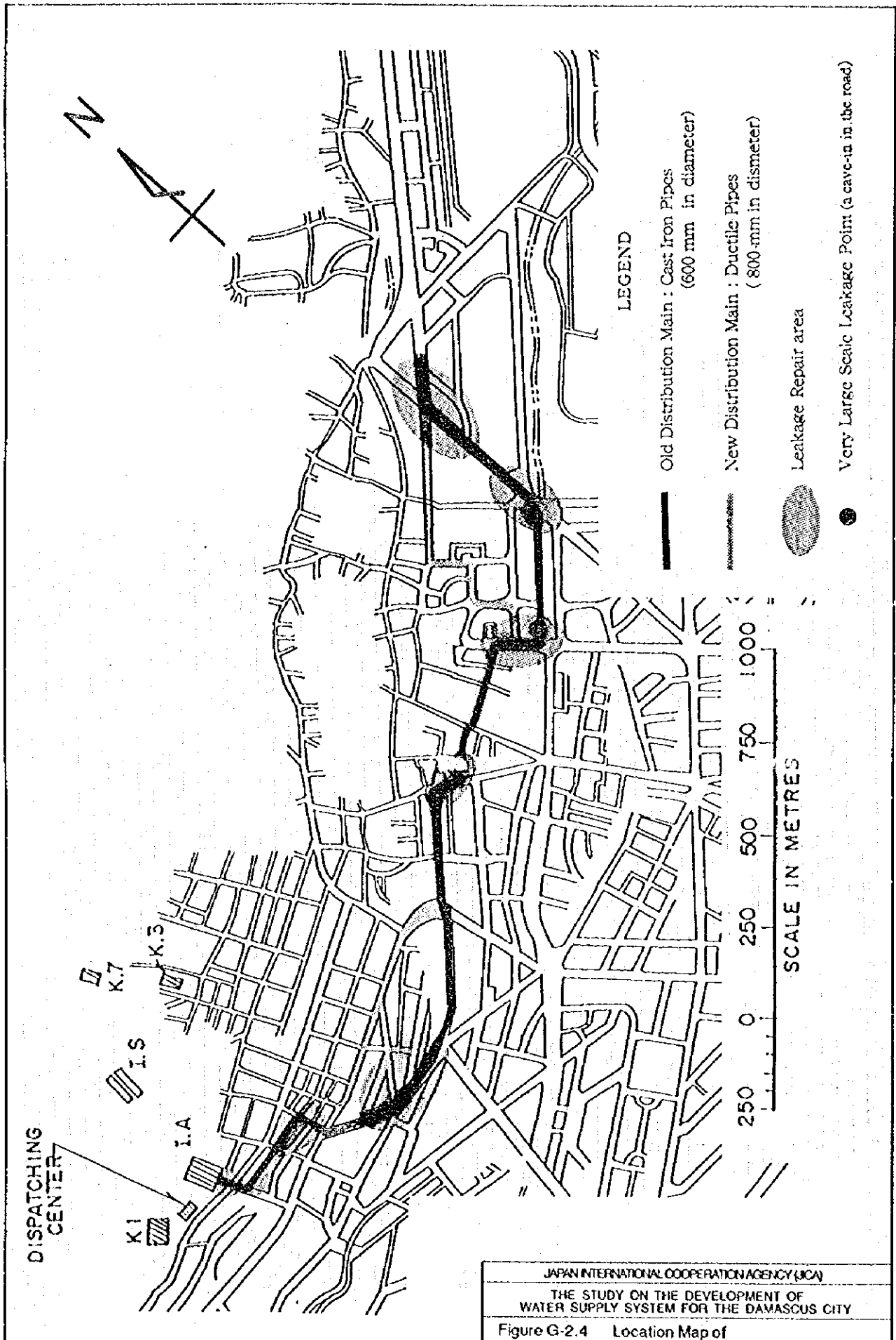
THE STUDY ON THE DEVELOPMENT OF
WATER SUPPLY SYSTEM FOR THE DAMASCUS CITY

Figure G-2.3
Monthly Leakage Repair Record

NIPPON KOEI CO., LTD.



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THE STUDY ON THE DEVELOPMENT OF WATER SUPPLY SYSTEM FOR THE DAMASCUS CITY

Figure G-2.4 Location Map of Water Main of Damas Center Medium 1

NIPPON KOEI CO., LTD.

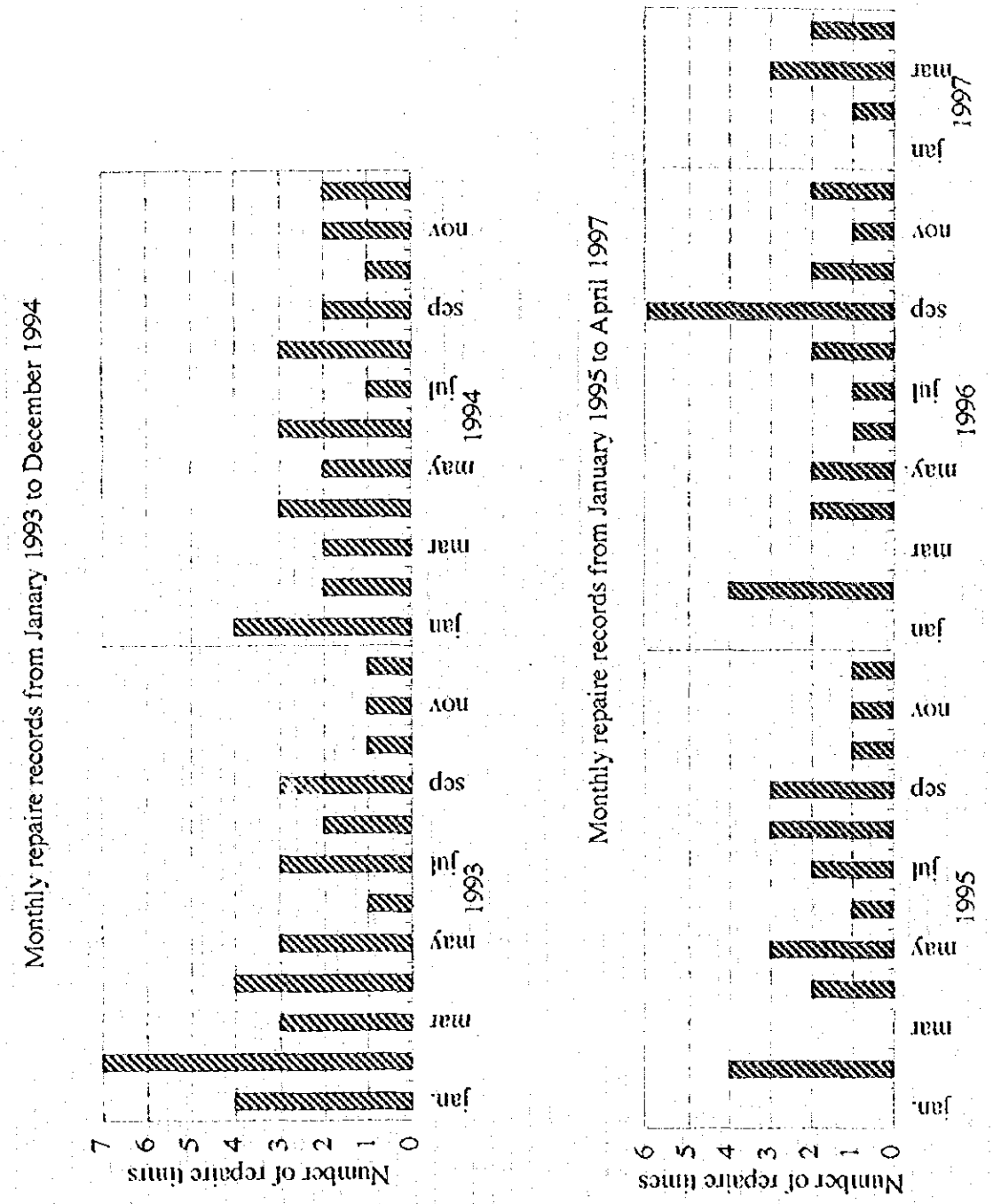

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Figure G-2.5	Monthly Repair Records of Water Main of Damas Center Medium 1
NIPPON KOEI CO., LTD.	

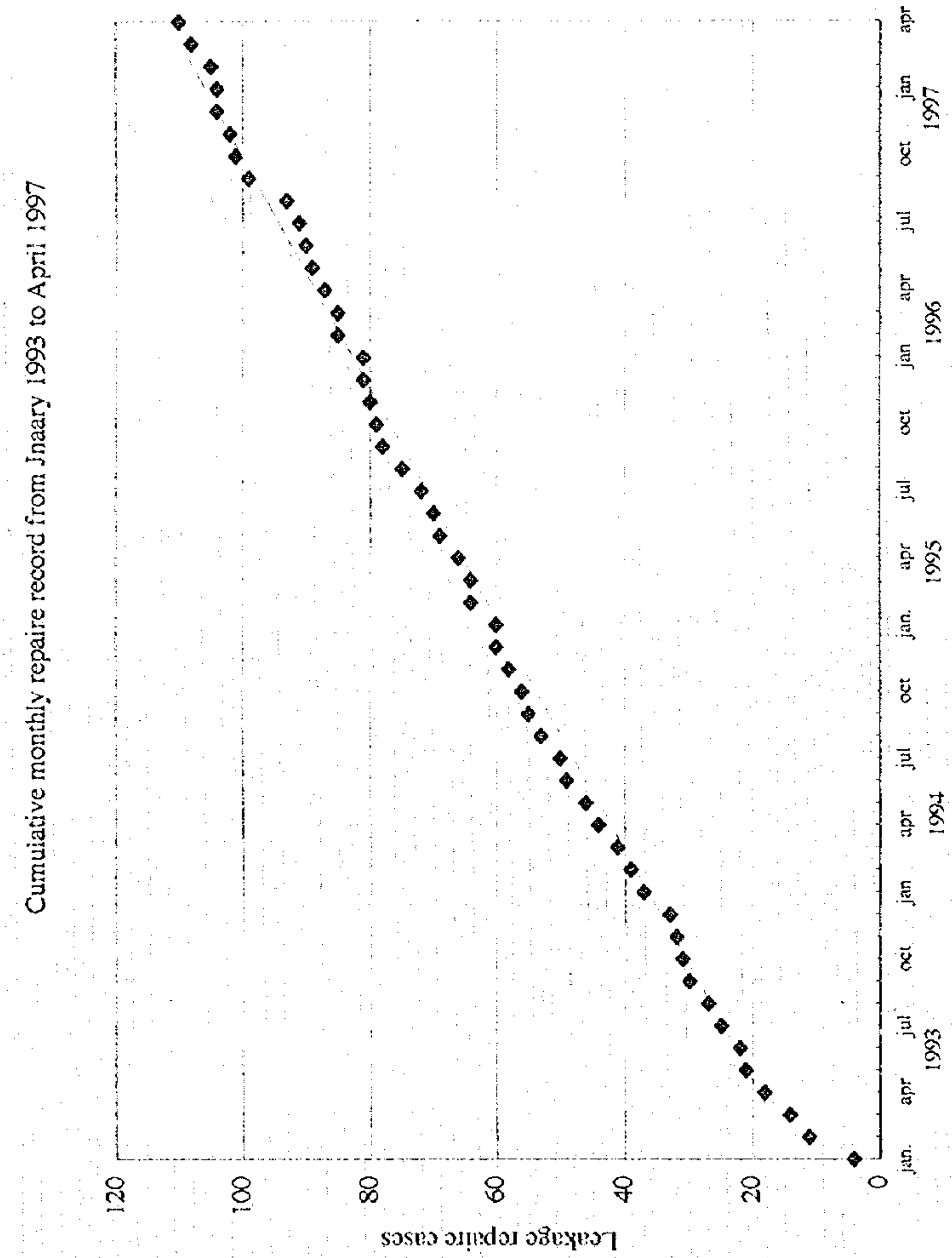

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Figure G-2.6 Cumulative Leakage Repair of Water Main of Damas Center Medium 1
NIPPON KOEI CO., LTD.

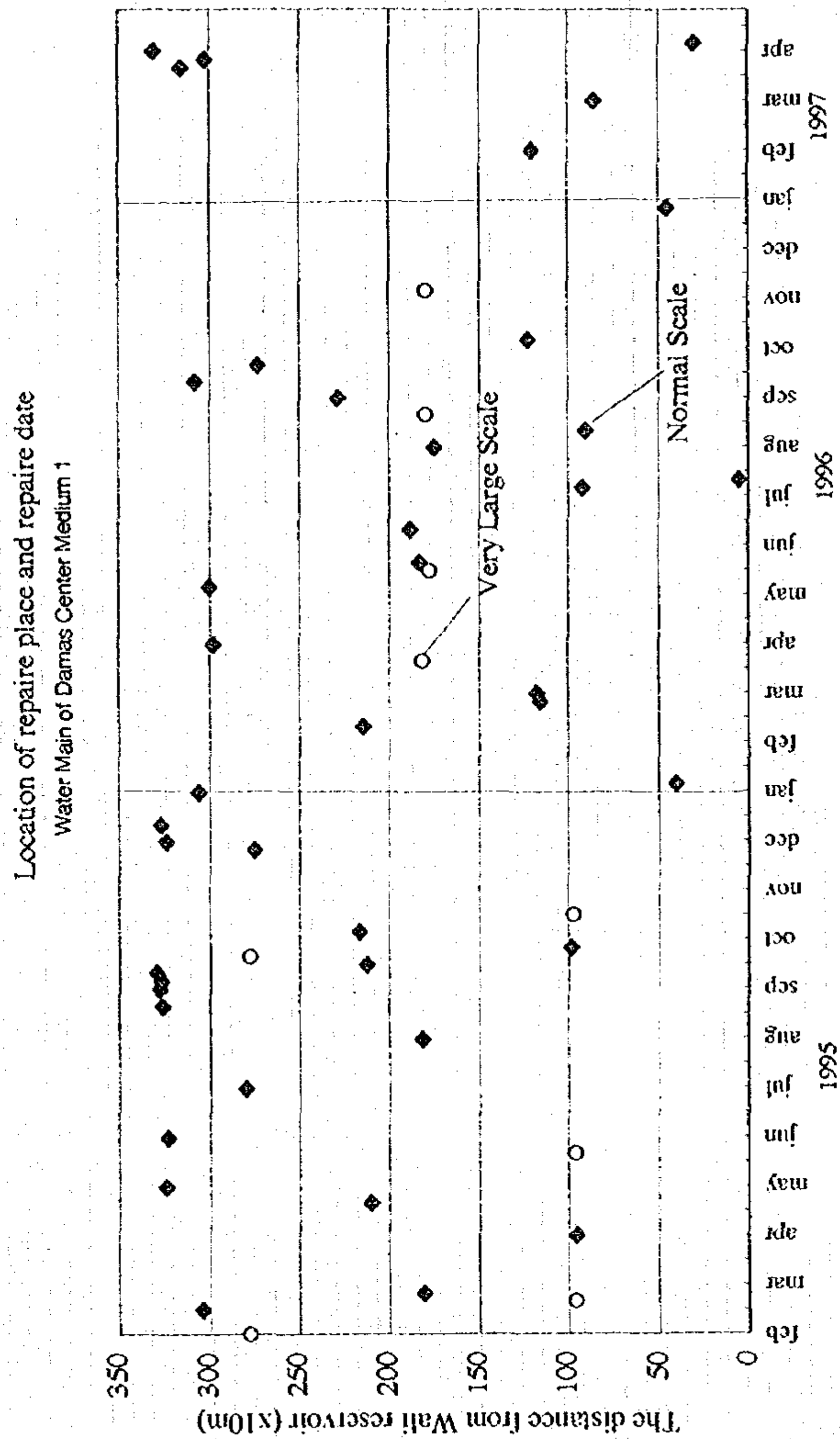

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Figure G-2.7 Location and Data of Leakage Repair

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