City of Winnipeg
Water and Waste Department

Combined Sewer Overflow Management Study

PHASE 3 Technical Memoranda

Appendix No. 5b

NE / NW MONITORING

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0510-A-38

Internal Document by:

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In Association With:

Gore & Storrie Limited and **EMA** Services Inc.

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1. NEWPCC FLOW MONITORING

Monitoring of dry weather flows (DWF) and wet weather flows (WWF) in the interceptors tributary to the NEWPCC was undertaken to accurately determine base flows, the amount of extraneous flow entering the system, and its effect on system capacity, hydraulic response, and influence on pump operations at the NEWPCC. This information was instrumental to the accurate calibration of the interceptor system for a range of rainfall conditions. Direct measurement of flows in the Main Interceptor was not considered feasible due to the hostile conditions in the Main Interceptor, that is, confined entry, busy streets, high flows and velocities, depth and fog. To obtain an accurate hydraulic description of the system under dry and wet weather conditions, the monitoring of the DWF and WWF to the NEWPCC consisted of the following:

- Weirs and level recorders in the Northeast and Northwest Interceptors
- Recording of the pump flow data and the surge tank levels at the NEWPCC
- Depth of flow levels and times at points along the Main Interceptor

The following sections will describe the monitoring program, the data collected, hydraulic analysis of the interceptor system and NEWPCC pump operations, and the influence of the Northeast and Northwest Interceptors on wet weather operations and CSO control.

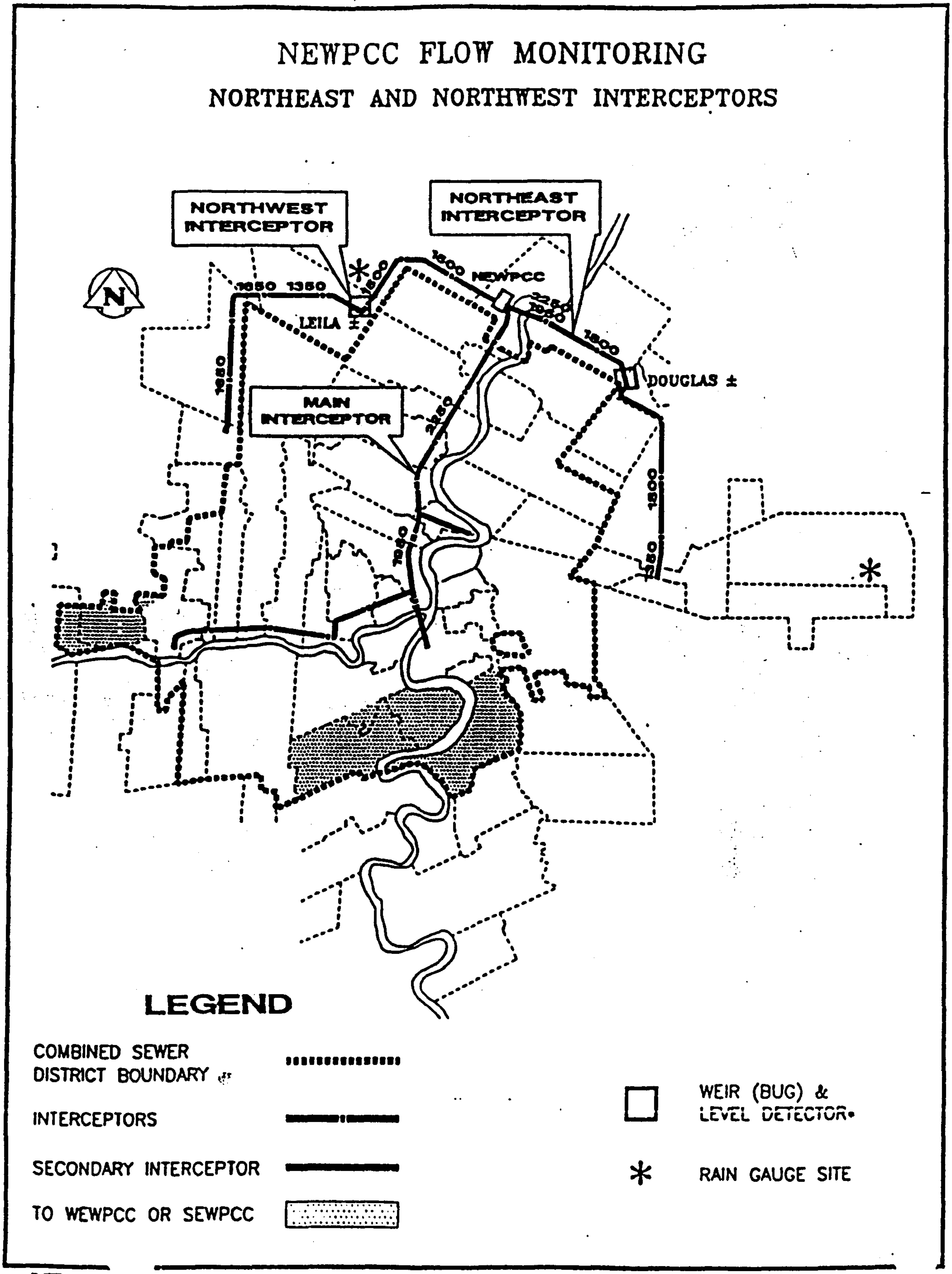


FIGURE 2.1 NORTHEAST AND NORTHWEST INTERCEPTORS – FLOW MONITORING LOCATIONS

2. NORTHEAST AND NORTHWEST INTERCEPTORS

Compound fixed weir monitoring stations were installed in the Northeast and Northwest Interceptors in March 1995. The installation sites were on the 1500 mm wastewater sewer on Leila Avenue (Northwest) at the second manhole west of McPhillips Street, and the 1800 mm wastewater sewer on Douglas Avenue (Northeast) at the second manhole downstream of Rothesay Street, as shown on Figure 2.1. The stations consisted of calibrated weirs (constructed and installed by G&S staff) and level recorders. (See erection and in-place photographs appended to this section.)

Water levels upstream and downstream of the weirs were monitored by pressure transducers and used to determine the flow through the compound weir. Recorded at ten minute intervals data loggers were designed to store approximately one month of continuous data. Data was routinely download initially by CG&S and later by City of Winnipeg forces. This data was converted to flow based on the head discharge relationship of the weir. The individual weir rating curves are contained in the April 17, 1997, CG&S report appended to this section.

The 1995 monitoring program provided sufficient data to establish an accurate description of DWF characteristics in the Northeast and Northwest Interceptors. Unfortunately, the drier than average year provided few opportunities to gather WWF data on a representative number and range of rainfall events to adequately determine the WWF response of the Northeast and Northwest Interceptor system. A series of equipment malfunctions had occurred in 1995 and limited the number of events that were monitored and could be used to assess WWF response in the Northeast and Northwest Interceptors under a range of rainfall conditions. Accordingly, the program was extended into 1996 and 1997 to rectify data acquisition problems and gather the data needed in the CSO Study to evaluate the influence of the Northeast and Northwest Interceptors on potential CSO plans.

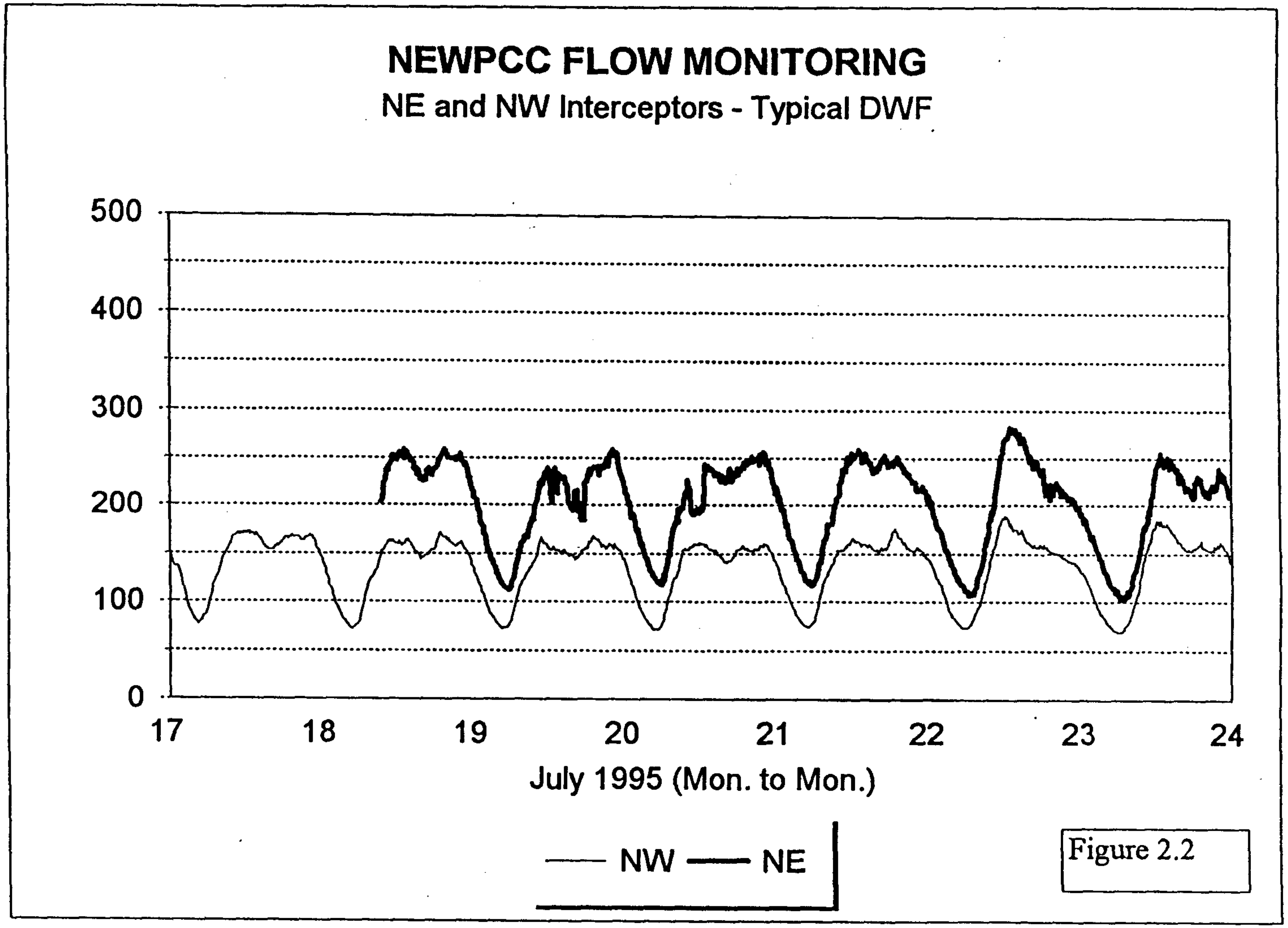

NEWPCC FLOW MONITORING
NE and NW Interceptors - Typical DWF
500
400
300
200
100
0
17
18
19
20
21
22
23
24
July 1995 (Mon. to Mon.)
NW
NE

Figure 2.2

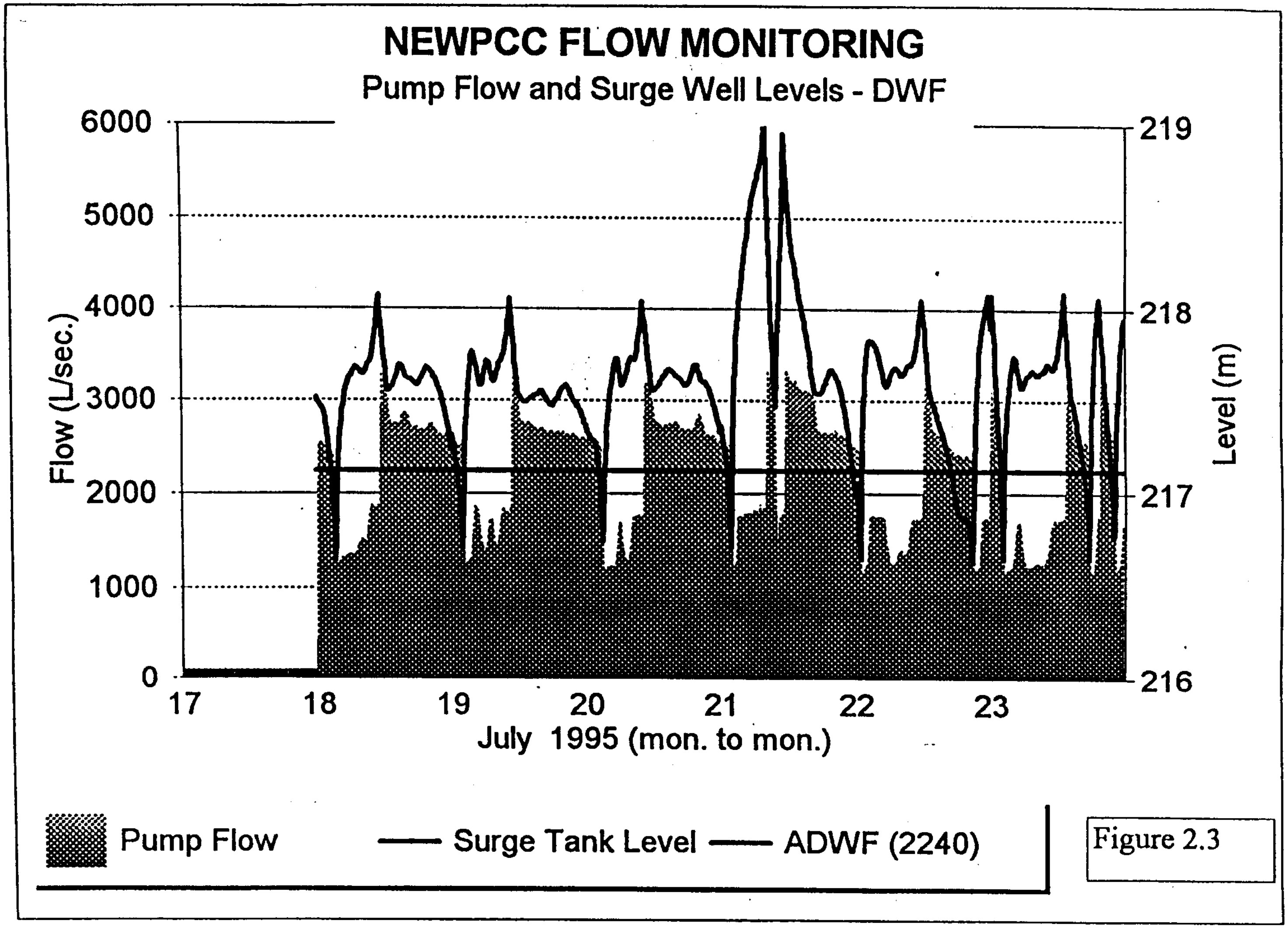
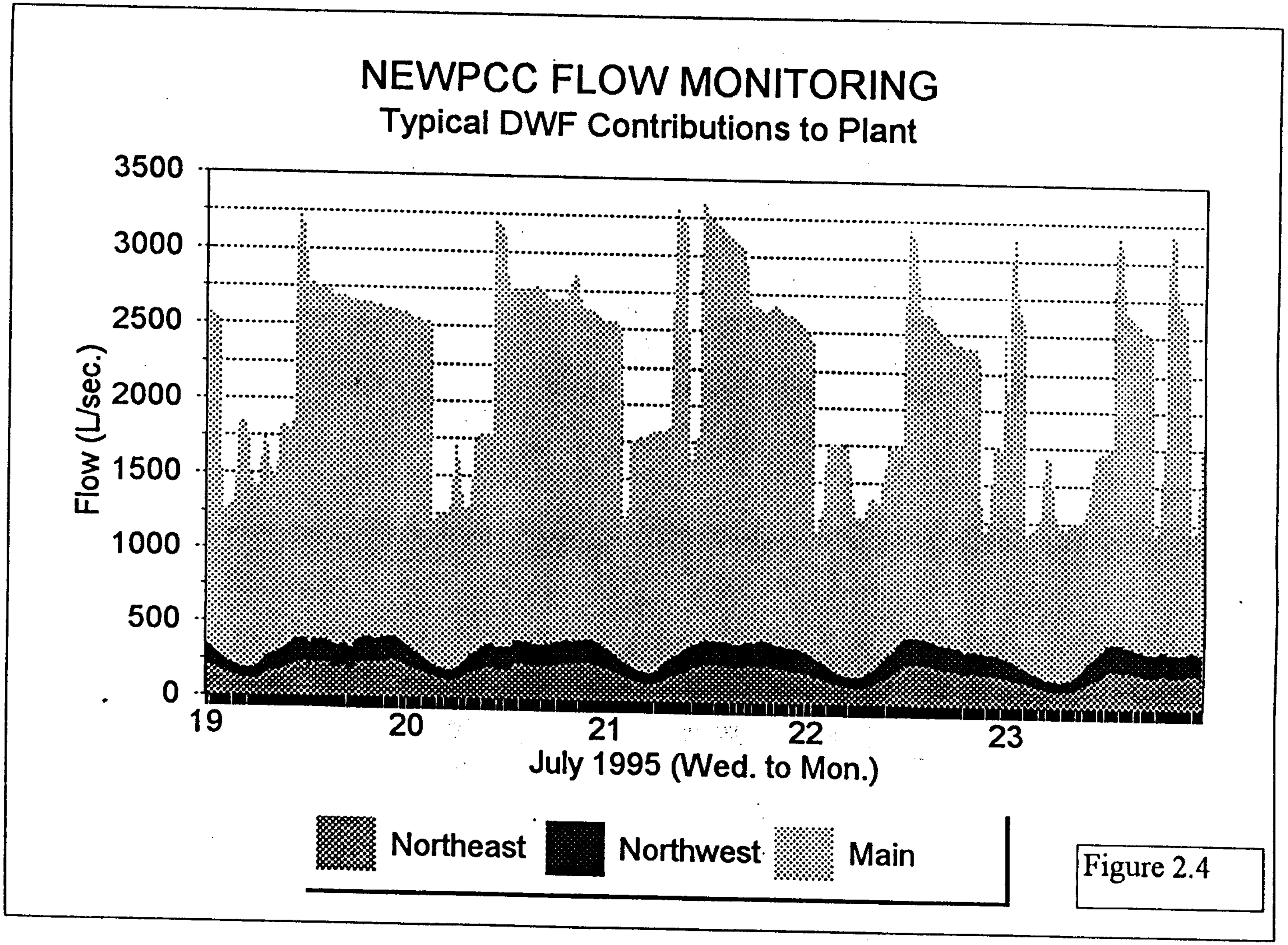

NEWPCC FLOW MONITORING
Pump Flow and Surge Well Levels - DWF
Flow (L/sec.)
Level (m)
6000
5000
4000
3000
2000
1000
0
219
218
217
216
17
18
19
20
21
22
23
July 1995 (mon. to mon.)
Pump Flow
Surge Tank Level
ADWF (2240)

Figure 2.3



NEWPCC FLOW MONITORING
Typical DWF Contributions to Plant
Flow (L/sec.)
3500
3000
2500
2000
1500
1000
500
0
19
20
21
22
23
July 1995 (Wed. to Mon.)
Northeast
Northwest
Main

Figure 2.4

2.1 1995 DRY WEATHER FLOW ANALYSIS

DWF analysis was carried out after a review of the wastewater sewer flows and rainfall data for the period from mid-March to mid-September 1995. This was done by selecting dry weather periods (without any significant rainfall events), from the available data monitored in the Northeast and Northwest Interceptors and pumping records at the NEWPCC. Based on this review, the period from July 17 to July 24 (Monday to Monday) was selected as a "typical DWF week." A full week of data was not available for the Northeast Interceptor; however, sufficient data was available to complete the analysis. The recorded DWF in the interceptors are plotted on Figure 2.2.

The recorded DWF patterns are very similar for the Northeast and Northwest Interceptors. The weekday patterns have double peaks, one in the AM and a second similar peak in the PM. Conversely, the weekend pattern has a pronounced AM peak that tapers off during the day. The average DWF in the Northeast Interceptor are approximately 100 L/sec greater than the Northwest Interceptor.

The pumped flows and wet well level data from the NEWPCC were also analyzed for the same period. Plots of pump flow and surge tank levels are shown on Figure 2.3. The data from July 17 was not included due to highly variable surge well levels and pump rates which suggests that levels were being manually adjusted. The data for the remainder of the week was deemed representative of a typical DWF week. Figure 2.3 indicates that surge well levels are generally maintained between elevation 216.7 m and 218 m during DWF conditions. The figure also indicates, for the most part, how the levels are used to regulate pump flows. Pump flows during the "typical week" period fluctuate between 1200 and 3100 L/sec. For comparison, the ADWF value of 2240 L/sec is also plotted in Figure 2.3.

The flows in Figure 2.3 are the total flows to the NEWPCC. The next step in the analysis involved the determination of flows in the Main Interceptor. This was accomplished by subtracting the monitored flows in the Northeast and Northwest Interceptors form the recorded pumped flows at the NEWPCC. The result of this analysis is shown on Figure 2.4 that illustrates that the flows to the WPCC are dominated by the Main Interceptor, which is tributary to the combined sewer districts.

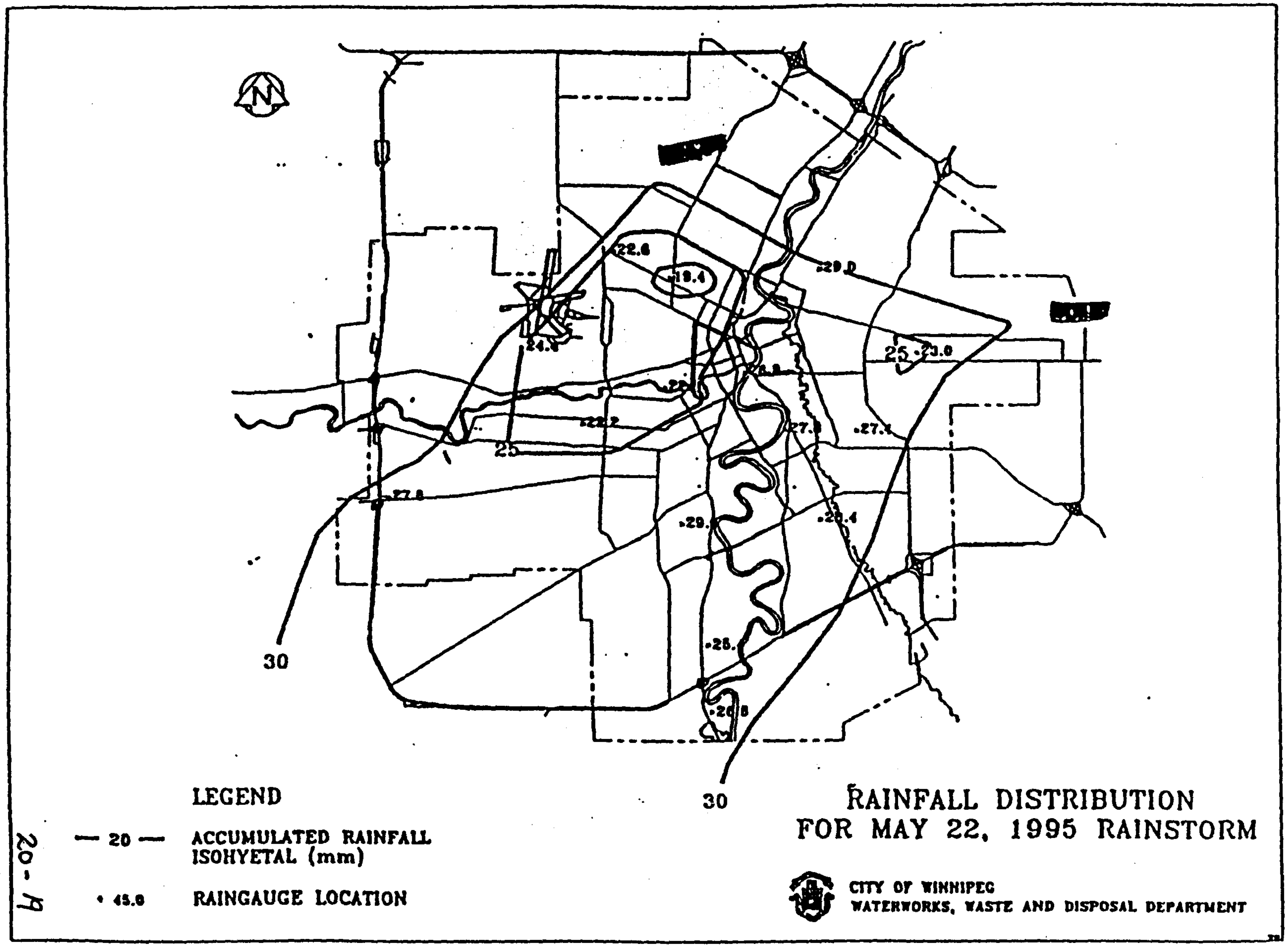

22.6
19.4
29.0
25
23.0
22.2
25
30
30
LEGEND
— 20 — ACCUMULATED RAINFALL ISOHYETAL (mm)
• 45.0 RAINGAUGE LOCATION
RAINFALL DISTRIBUTION FOR MAY 22, 1995 RAINSTORM
CITY OF WINNIPEG
WATERWORKS, WASTE AND DISPOSAL DEPARTMENT
20-19

FIGURE 2.5

The last step in the analysis was to determine the individual average summer dry weather flow (ADWF) and peak summer dry weather flow (PDWF) values for the three interceptor systems and the combined effect at the NEWPCC. This involved an analysis of ADWF over three different periods, including weekly, weekdays and weekend to determine if a wide variation occurred. The PDWF recorded during the period was calculated as a multiple of ADWF to determine the peaking factor. The variability of flows to the NEWPCC are a result of the pumping protocols in effect at any one time. Accordingly, it was not possible to "breakdown" the NEWPCC flows to calculate, with any degree of accuracy, the flows on a finer basis, such as weekday or weekend. However, it is assumed that the dry weather flows in the Main Interceptor closely follows the dry weather flow patterns in the Northeast and Northwest Interceptors. The results are shown in the following table.

	LITRES PER SECOND			
	Northeast	**Northwest**	**Main**	**NEWPCC**
ADWF (week)	209	105	1926	2240
ADWF (weekday)	205	100	---	---
ADWF (weekend)	219	117	---	---
PDWF	334	196	---	---
PDWF (factor)	1.6	1.87	---	---

2.2 1995 WET WEATHER FLOW ANALYSIS

There were only two rainfall events in 1995 (May 22 and August 18) that provided sufficient WWF data to assess wet weather response of the interceptor system. The May 22 event provided the most complete data set since the Northeast and Northwest Interceptor monitors and the WPCC provided flow data for comparison to the rainfall data. Unfortunately, the Northeast Interceptor monitor malfunctioned during the August event.

2.2.1 May 22, 1995, Event

The May 22, 1995, rainfall event consisted of approximately 30 mm of rain over an 18 hour period. The rainfall distribution isohyetal for this event (shown on Figure 2.5) indicates that the rainfall was fairly uniform over the Northeast and Northwest Interceptor tributary areas,

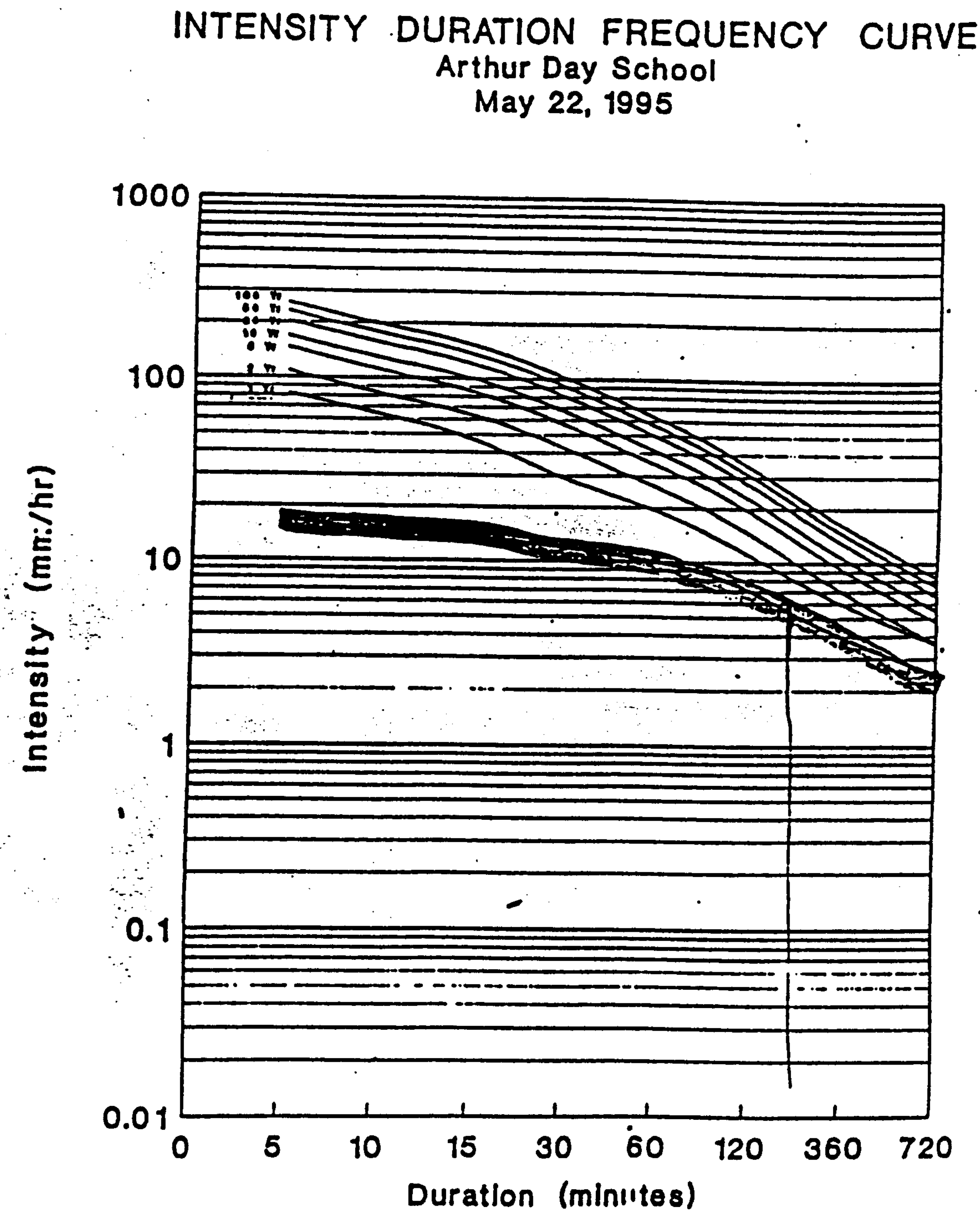


FIGURE 2.6 IDF CURVE – MAY 22, 1995, RAINSTORM

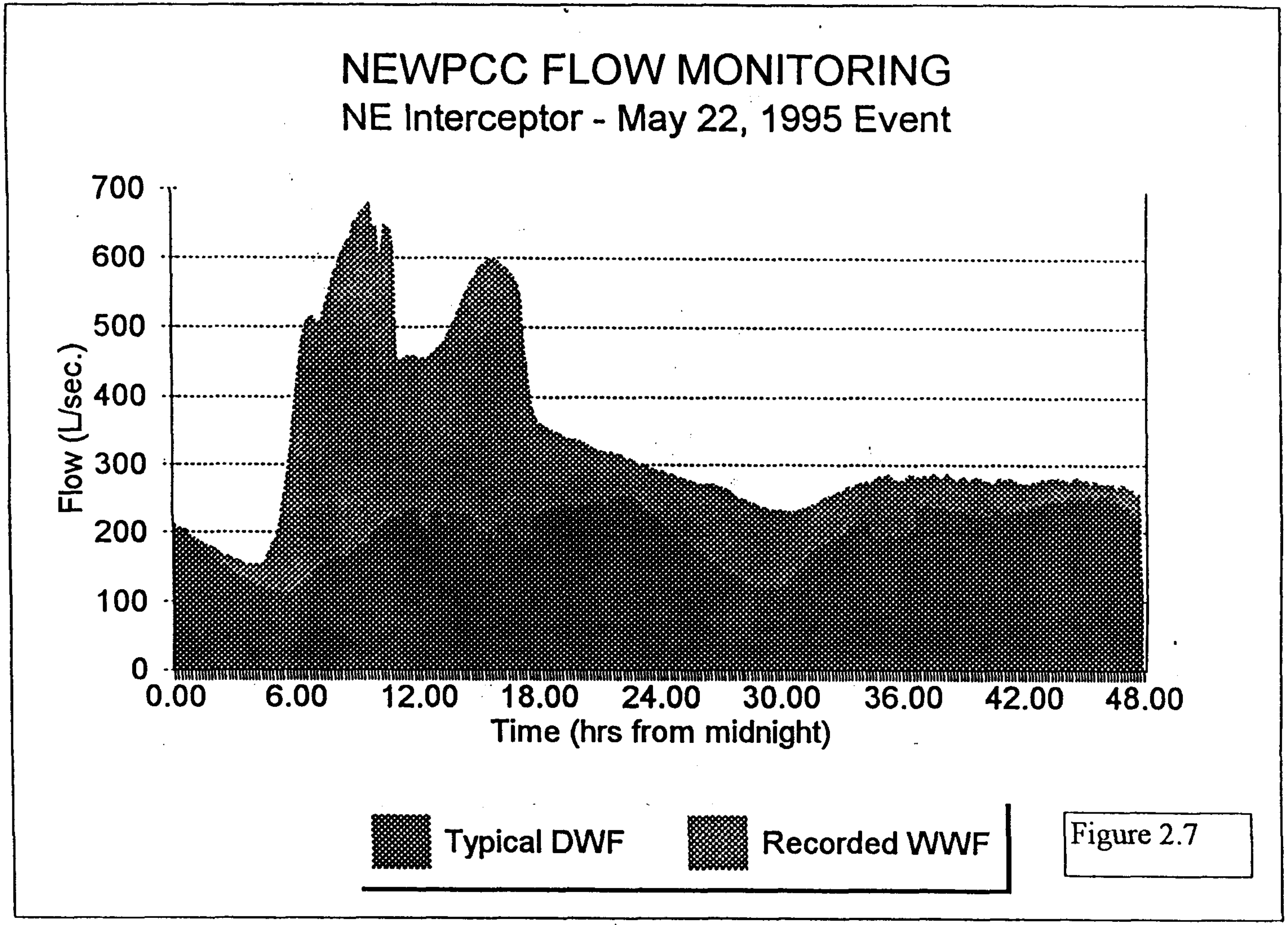

NEWPCC FLOW MONITORING
NE Interceptor - May 22, 1995 Event
Flow (L/sec.)
700
600
500
400
300
200
100
0
0.00
6.00
12.00
18.00
24.00
30.00
36.00
42.00
48.00
Time (hrs from midnight)
Typical DWF
Recorded WWF

Figure 2.7

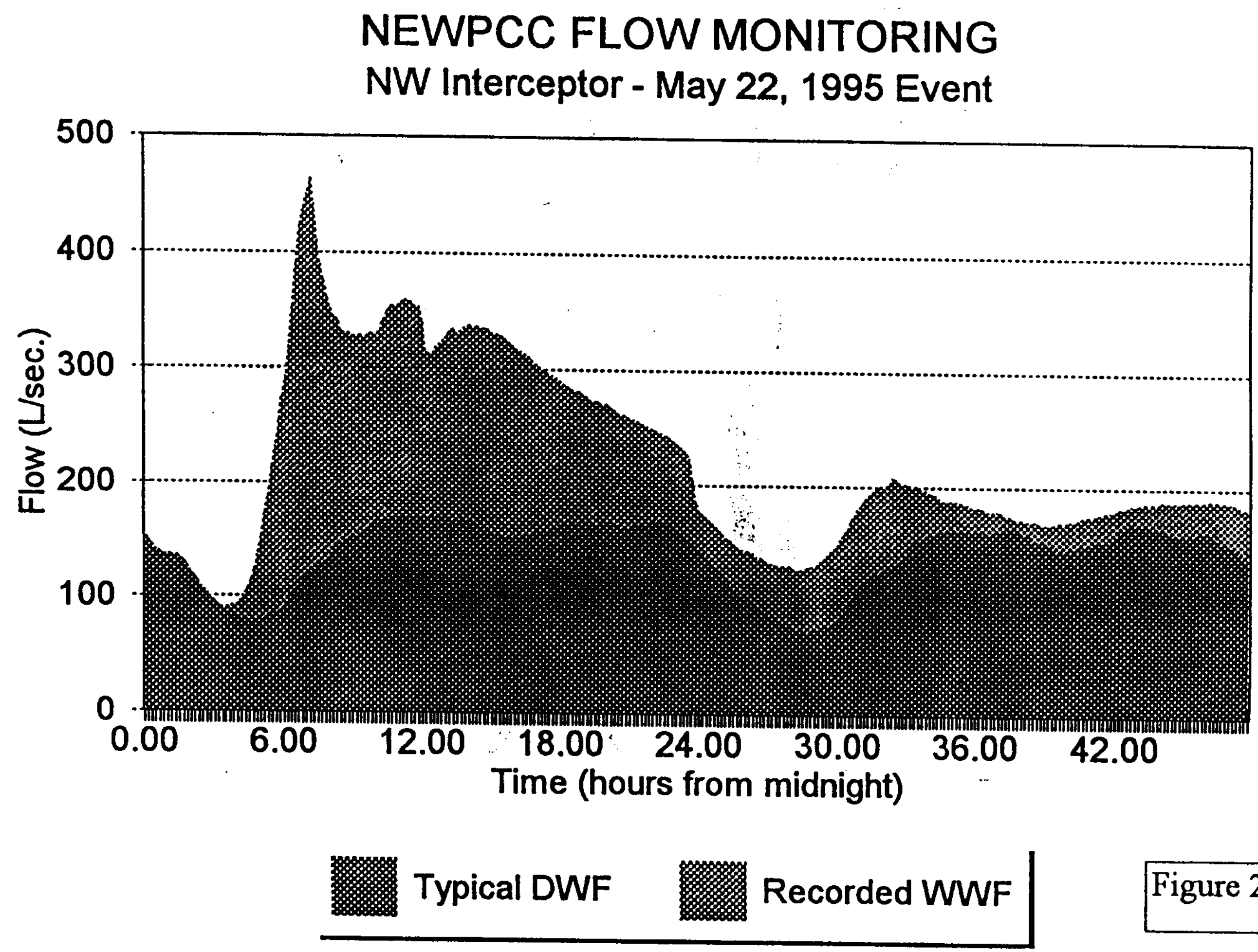

NEWPCC FLOW MONITORING
NW Interceptor - May 22, 1995 Event
Flow (L/sec.)
500
400
300
200
100
0
0.00
6.00
12.00
18.00
24.00
30.00
36.00
42.00
Time (hours from midnight)
Typical DWF
Recorded WWF

Figure 2.8

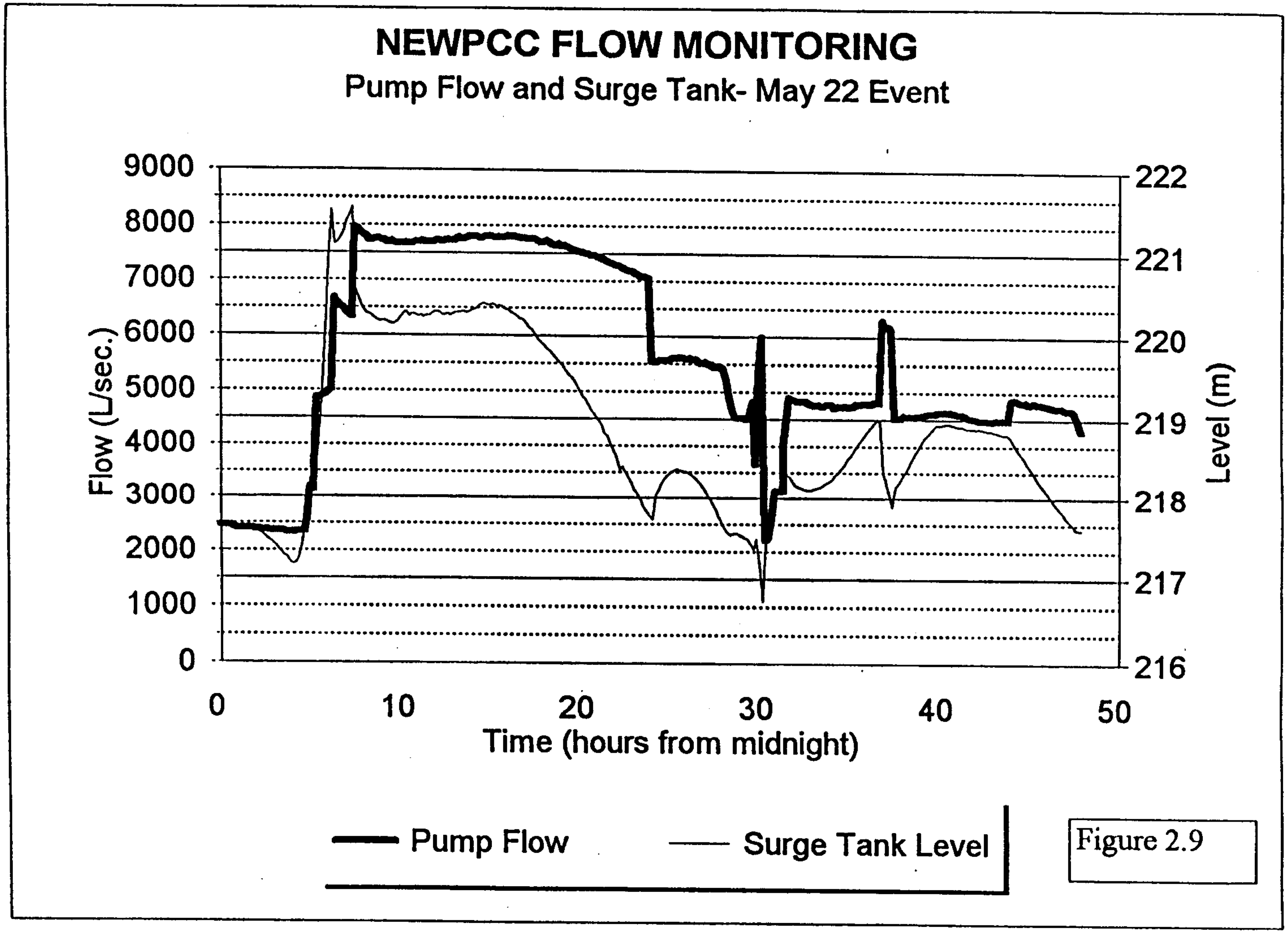

NEWPCC FLOW MONITORING
Pump Flow and Surge Tank- May 22 Event
Flow (L/sec.)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Level (m)
222
221
220
219
218
217
216
0
10
20
30
40
50
Time (hours from midnight)
Pump Flow
Surge Tank Level

Figure 2.9

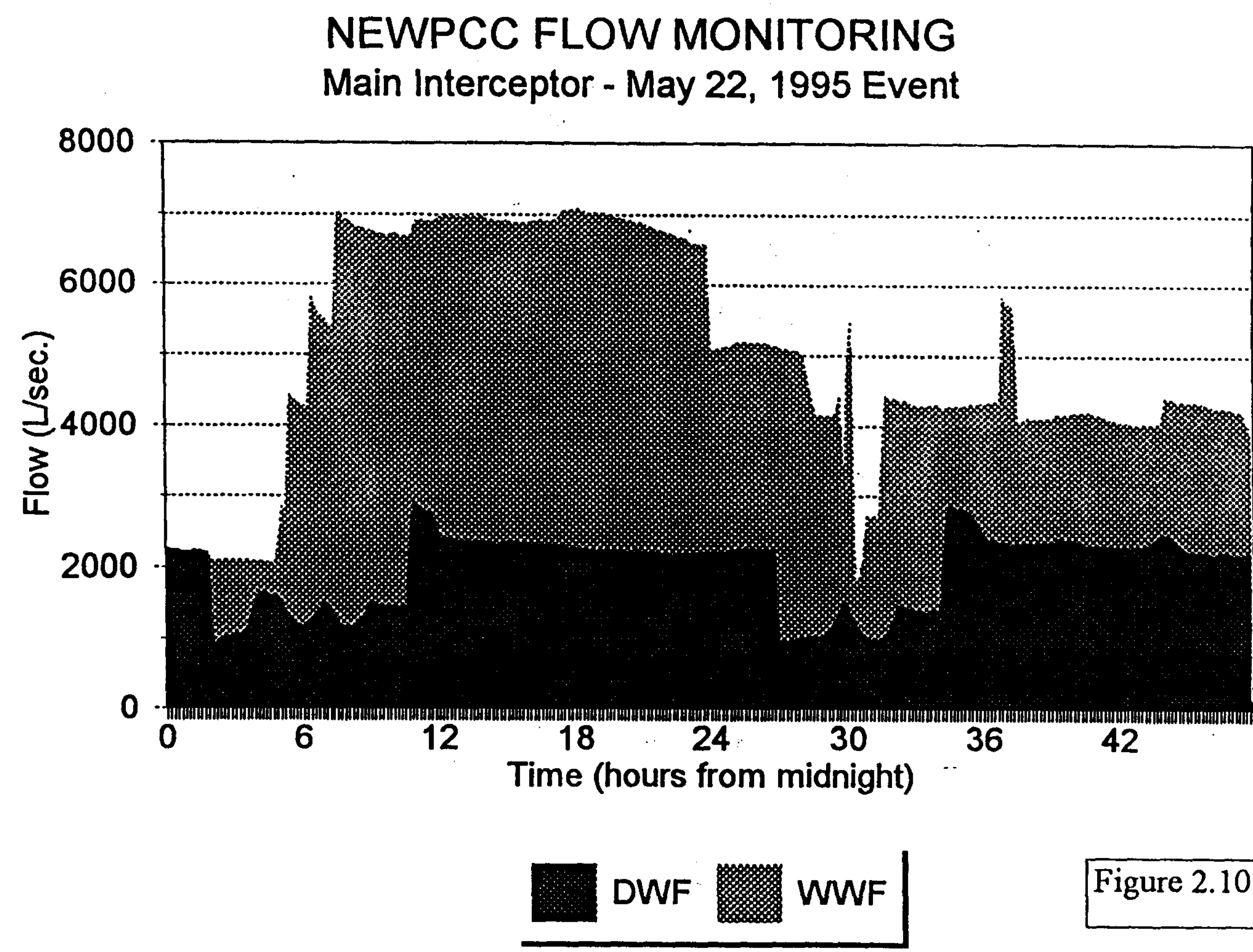
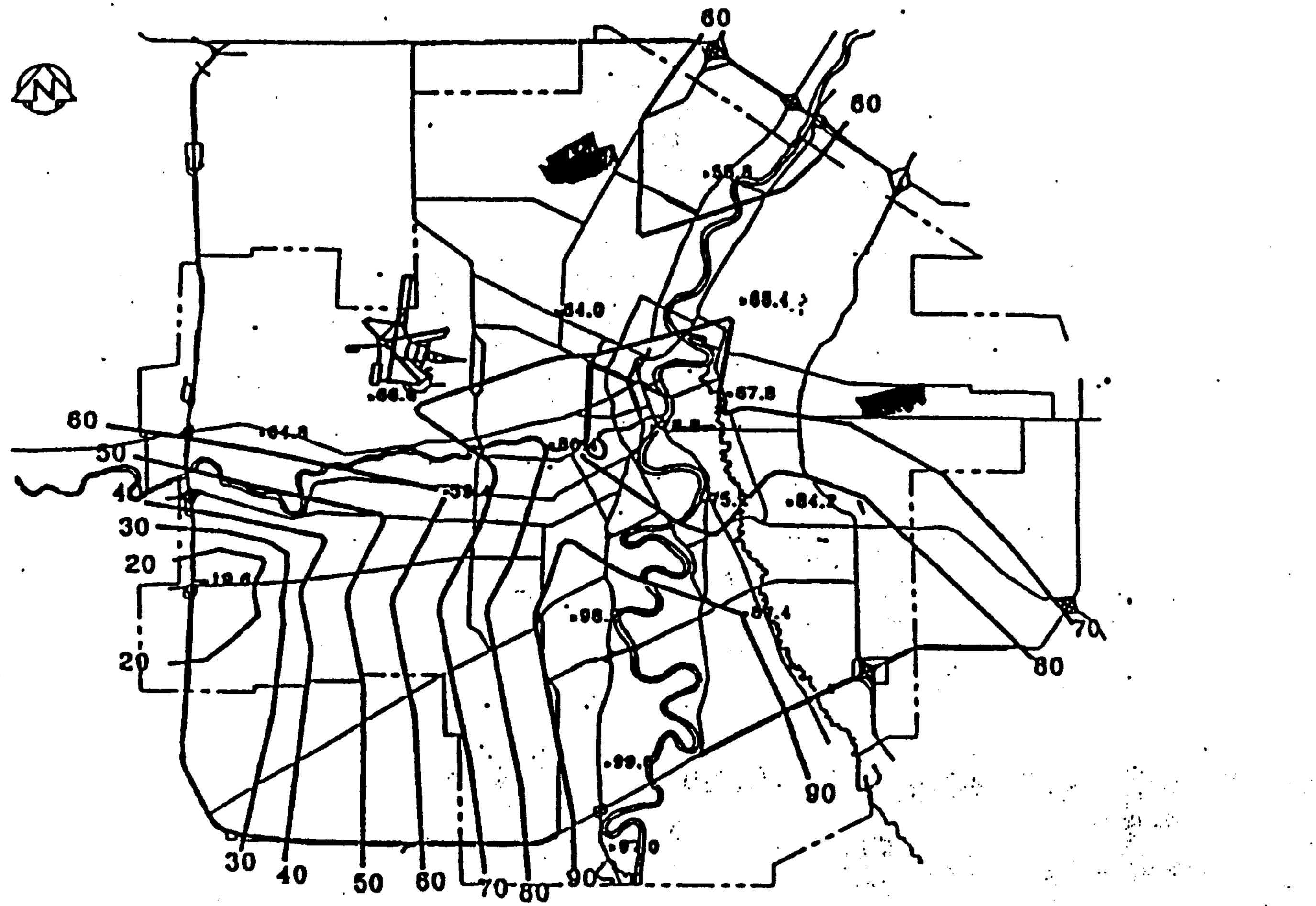

NEWPCC FLOW MONITORING
Main Interceptor - May 22, 1995 Event
8000
6000
4000
2000
0
Flow (L/sec.)
0
6
12
18
24
30
36
42
Time (hours from midnight)
DWF
WWF

Figure 2.10



LEGEND

— 20 — ACCUMULATED RAINFALL ISOHYETAL (mm)

• 45.0 RAINGAUGE LOCATION

RAINFALL DISTRIBUTION
FOR AUGUST 18,1995 RAINSTORM

CITY OF WINNIPEG
WATERWORKS, WASTE AND DISPOSAL DEPARTMENT

20-25

FIGURE 2.11

INTENSITY DURATION FREQUENCY CURVE
Mission Gardens Lift Station
AUGUST 18,1995

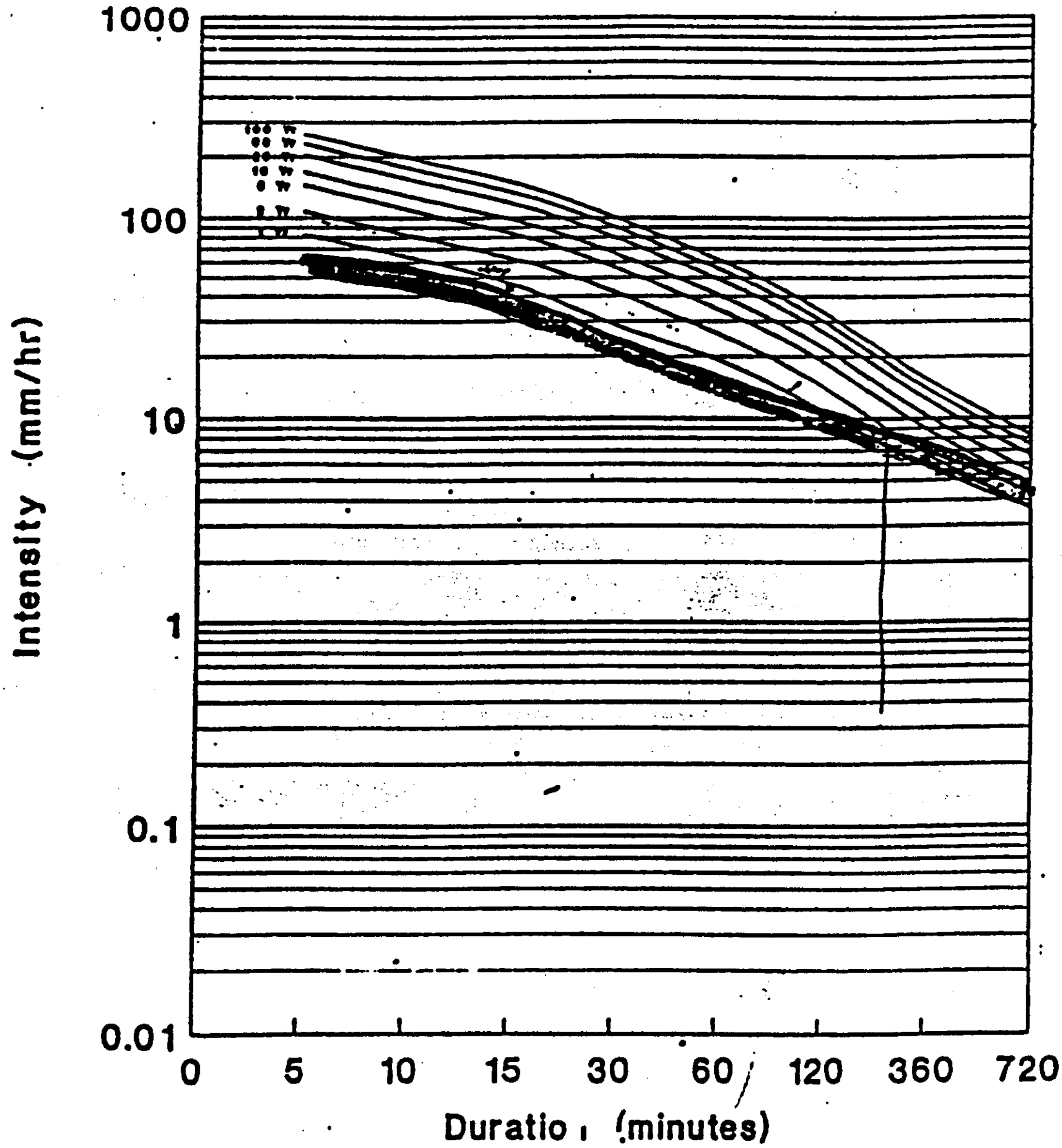


FIGURE 2-12

with slightly less rainfall in the southern portions of the City. The Intensity Duration Frequency (IDF) curve, shown on Figure 2.6, indicates that the storm had a less than one year return period (i.e., would statistically occur more than once per year).

The recorded WWF in the Northeast and Northwest Interceptors are shown on Figures 2.7 and 2.8, respectively. The figures indicate the total WWF, as well as the typical DWF. The difference between the flows represents the Infiltration and Inflow (I/I) components. The DWF component is based on the results of the DWF analysis from the previous section. The peak flows monitored in the Northeast and Northwest Interceptors for this event was 675 L/sec and 470 L/sec, respectively.

In comparison, the peak flow recorded at the NEWPCC was nearly 8000 L/sec. The pump flows, along with the surge tank levels, are plotted on Figure 2.9. The hydraulic complexity of the system is clearly depicted by the pumping operation under rising and falling levels in the surge well (see Phase 2, TM #2 for a description of WWF pumping protocol).

The flows in the Main Interceptor were calculated by subtracting the monitored flows in the Northeast and Northwest from the pumped flow at the NEWPCC. The result is shown in Figure 2.10, which also shows the assumed split between DWF and rainfall induced flows.

2.2.2 August 18, 1995, Event

Flow data was only available for the Northeast Interceptor for this event. The data does not provide an indication of the sanitary system's response to a more severe storm event in the Northeast system which is believed to be representative of the Northwest system (see Figures 2.7 and 2.8).

The August 18, 1995, storm event deposited between 60 to 70 mm of rain on the Northeast Interceptor's tributary area (see Figure 2.11). The rainfall pattern was not intense, but was steady over the period. The IDF curve for the event (Figure 2.12) shows that for a one hour duration the storm had less than a one-year return frequency; however, for a four hour duration, the storm had between and one and two year return frequency.

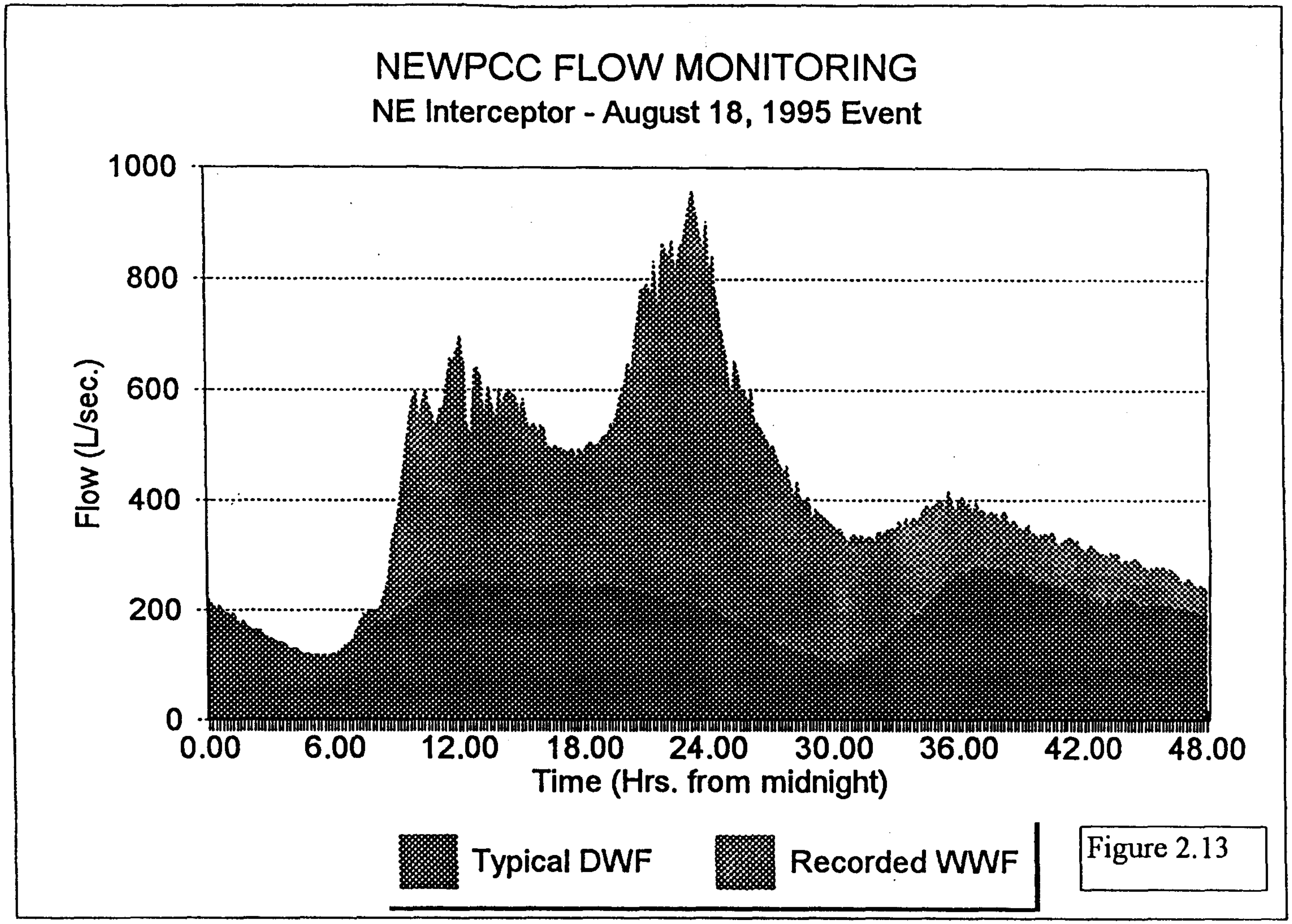

NEWPCC FLOW MONITORING
NE Interceptor - August 18, 1995 Event
1000
800
600
400
200
0
Flow (L/sec.)
0.00
6.00
12.00
18.00
24.00
30.00
36.00
42.00
48.00
Time (Hrs. from midnight)
Typical DWF
Recorded WWF

Figure 2.13

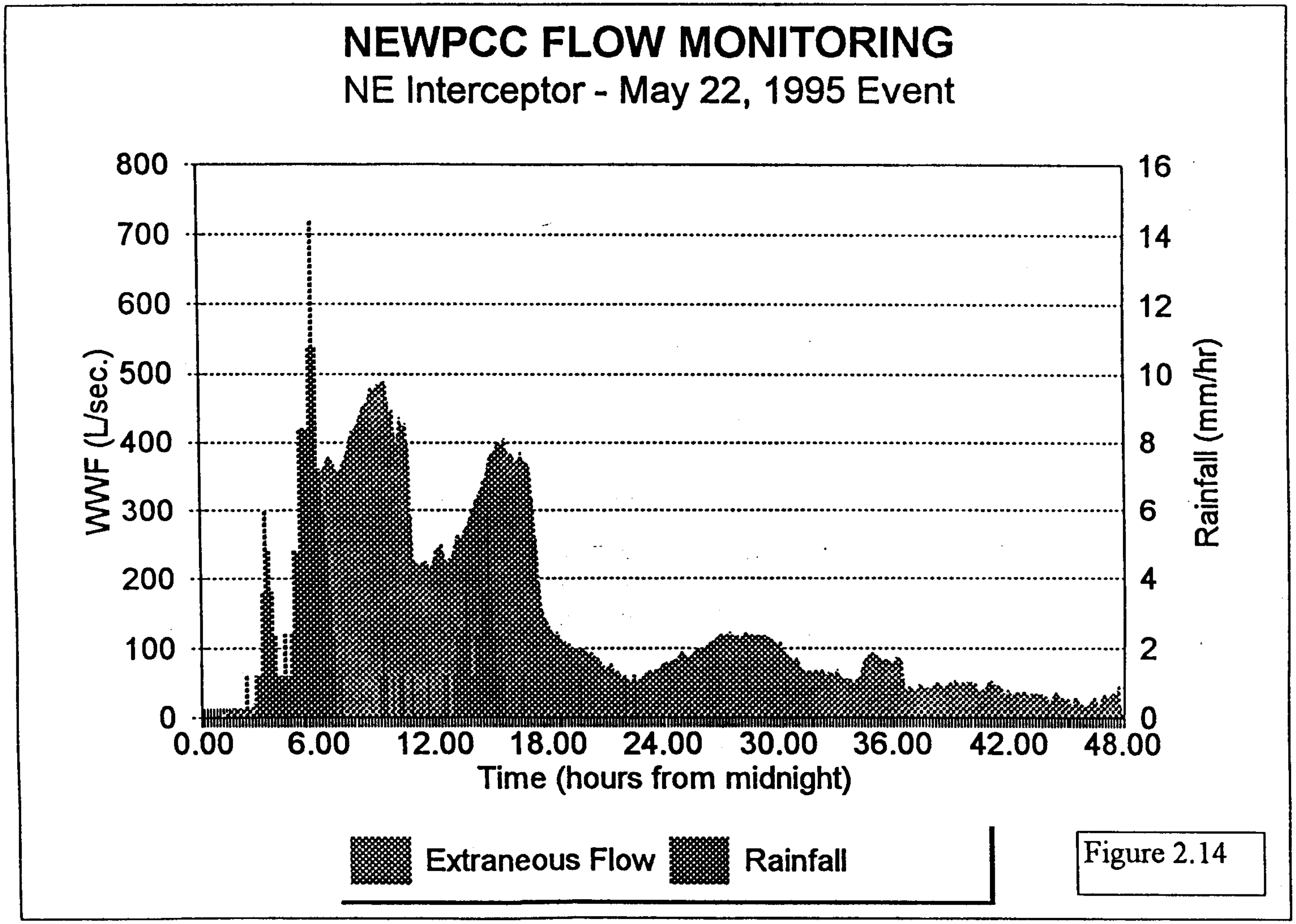

NEWPCC FLOW MONITORING
NE Interceptor - May 22, 1995 Event
WWF (L/sec.)
800
700
600
500
400
300
200
100
0
Rainfall (mm/hr)
16
14
12
10
8
6
4
2
0
0.00
6.00
12.00
18.00
24.00
30.00
36.00
42.00
48.00
Time (hours from midnight)
Extraneous Flow
Rainfall

Figure 2.14

The total flow in the Northeast Interceptor, as well as the split between DWF and I/I, are shown on Figure 2.13. The measured PWWF was approximately 950 L/sec.

2.2.3 Response to Rainfall

The WWF flow response in the Northeast and Northwest sanitary sewer systems was analyzed to accurately characterize the amount of extraneous runoff that enters the system as a result of rainfall. To accomplish this, the rainfall from each event was plotted against I/I flows in the Northeast Interceptor. The I/I flow was calculated by subtracting the typical DWF rates from the recorded WWF.

The flow response as recorded at the NEWPCC to the May 22, 1995, rainfall event is shown on Figure 2.14. The storm has two separate peaks, separated by approximately six hours, with a matching peak flow recorded in the sewer. From the first peak to the corresponding peak I/I flow, there is a four-hour lag or time of concentration. This lag time is noticeably shorter for the second peak and is most likely due to reduced infiltration rates resulting in more and quicker runoff.

A similar analysis was also carried out for the August 18, 1995, event. This analysis also indicated a four-hour lag between the peak rainfall and the peak flow in the Northeast interceptor.

The results of this analysis indicate that there is a direct response between the timing and magnitude of rainfall events and the WWFs in the interceptor system. In addition, the time of concentration in the Northeast Interceptor is approximately four hours, although it is anticipated that antecedent moisture conditions will impact the time of concentration.

2.2.4 Wet Weather Flow Peaking Factors

The ADWF rates for the Northeast, Northwest and Main Interceptors, and the NEWPCC have been established based on a typical week DWF data. These values were compared to PDWF and PWWF values to determine peaking factors in each interceptor sewer. The

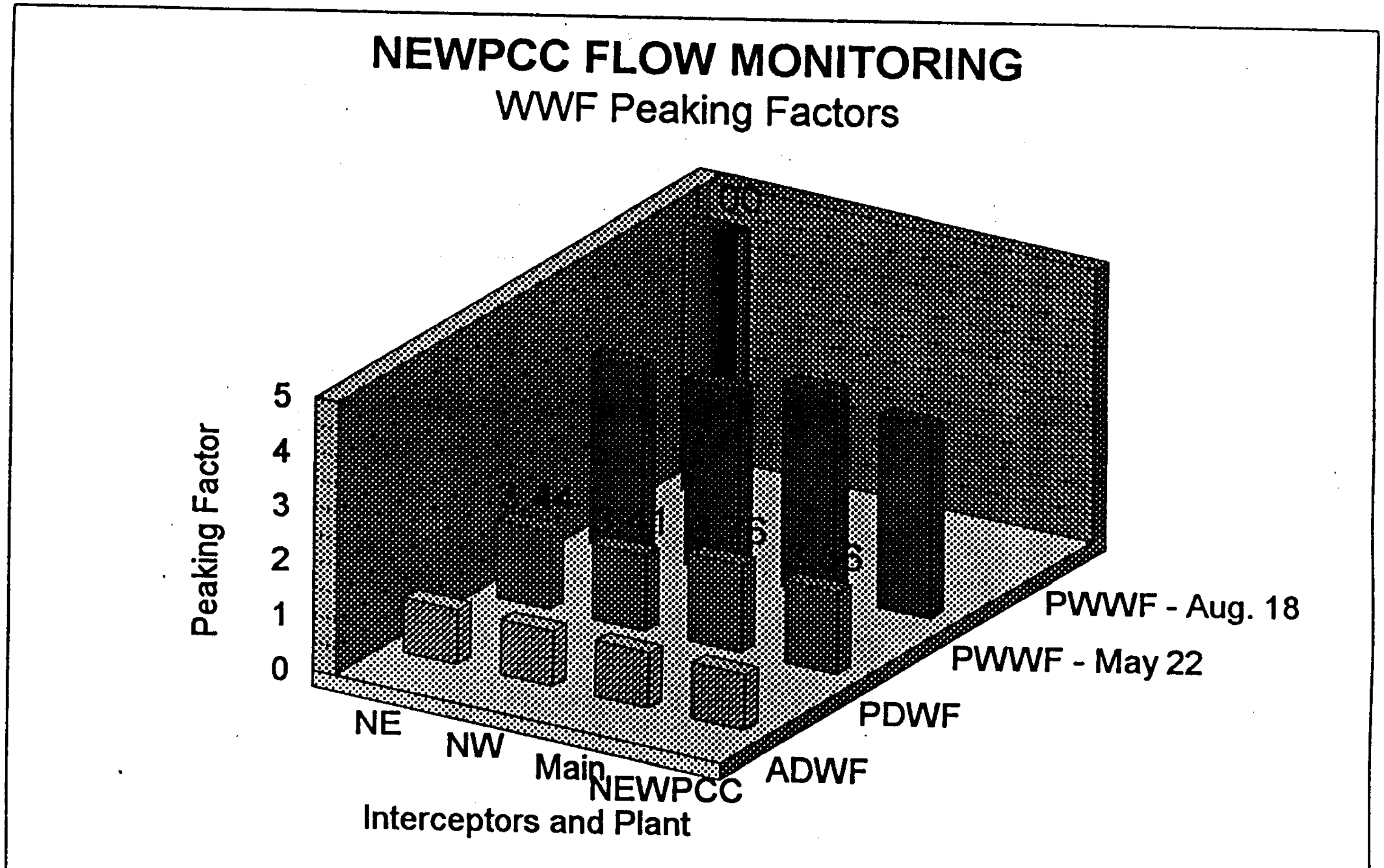

NEWPCC FLOW MONITORING
WWF Peaking Factors
Peaking Factor
0
1
2
3
4
5
NE
NW
Main
NEWPCC
Interceptors and Plant
ADWF
PDWF
PWWF - May 22
PWWF - Aug. 18

Figure 2.15

results of this analysis are shown on Figure 2.15. PDWF rates range form 1.38 to 1.6, which are reasonable for the mainly residential tributary areas.

The PWWF rates range from 3.41 to 3.76 times ADWF for the May 22, 1995, event. It is interesting that the multiples in the Northeast and Northwest Interceptors (tributary to separate sewer systems) are nearly identical at 3.44 and 3.41, respectively. The Main Interceptor experienced a peak flow of 3.76 times ADWF. This agrees with our Phase 2 analysis that indicated that the various district diversion facilities, particularly the gravity flow district, could divert in excess of 2.75 times ADWF to the Main Interceptor.

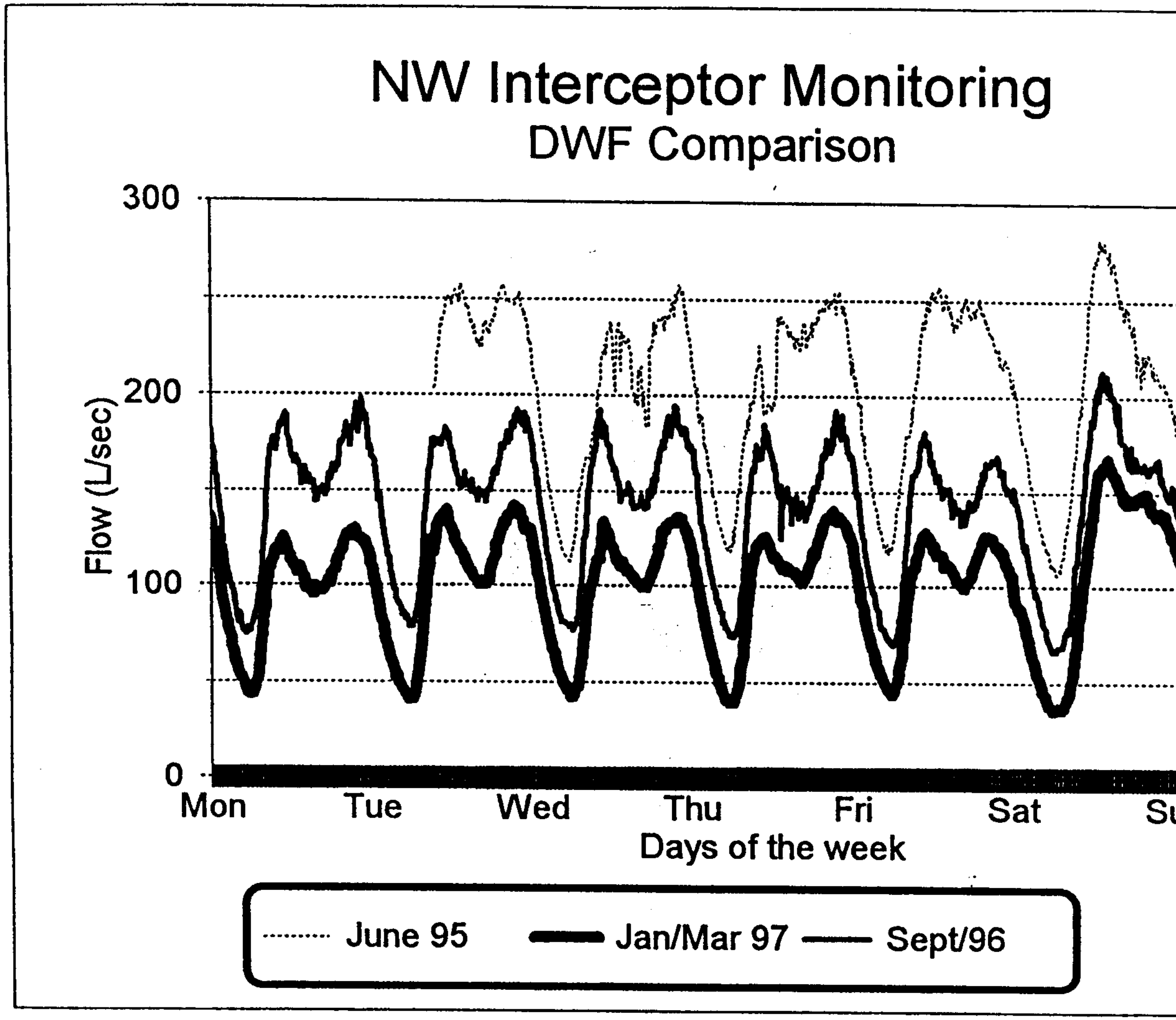
The August 18, 1995, event produced a PWWF of 4.85 times ADWF in the Northeast Interceptor (other values could not be determined). This shows a significant increase in peak flow from the May 22, 1995, event (3.44* ADWF). This indicates that PWWF is in some way proportional to storm intensity; therefore, it is safe to assume that storms of greater intensity will produce PWWFs in excess of 5*ADWF and may reach the seven to nine times ADWF as noted in the Phase 2 TM#2 (section 2.5).

2.3 1996 ANALYSIS

The 1996 monitoring program was essentially the same as the 1995 program (i.e., flows were measured on the Northeast and Northwest Interceptors, and pump flow and surge tank levels were recorded at the NEWPCC. In addition, level monitors were installed on the Main Interceptor at the following locations:

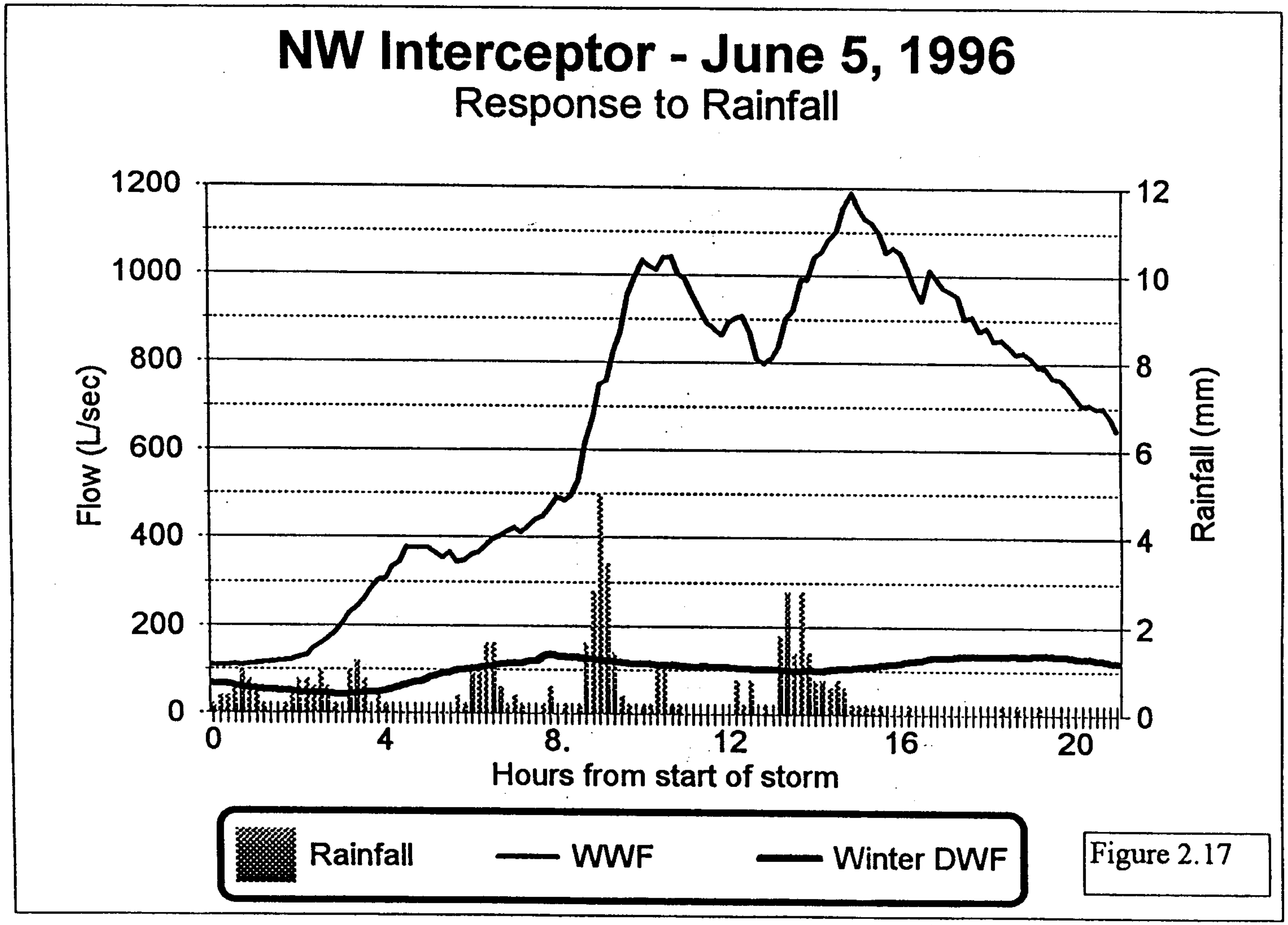
- Main Street, first manhole downstream of Sutherland Avenue
- Broadway and Donald Street

This information was collected to assist in the calibration of the Main Interceptor model.



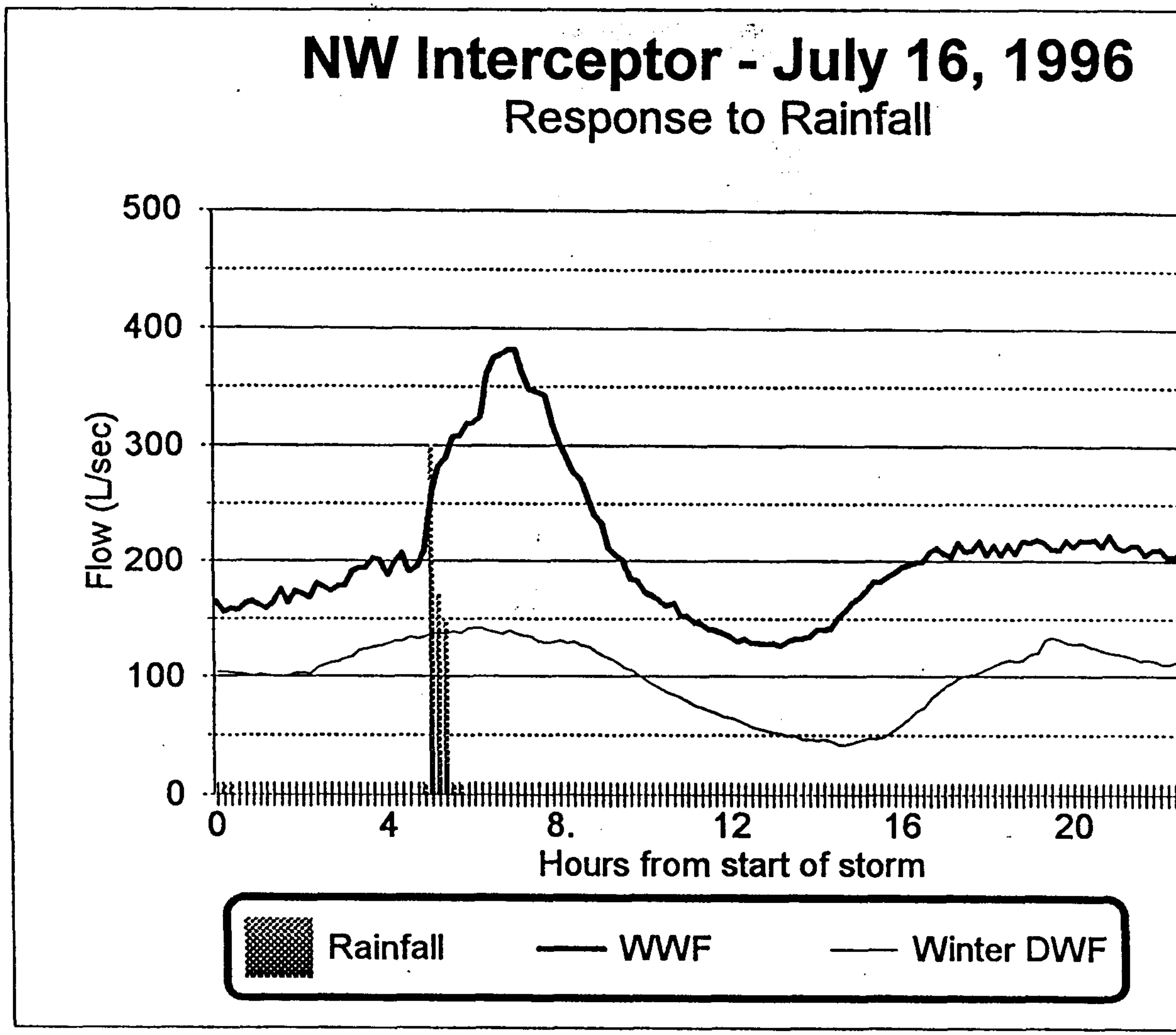
NW Interceptor Monitoring
DWF Comparison
300
200
100
0
Flow (L/sec)
Mon
Tue
Wed
Thu
Fri
Sat
Sun
Days of the week
June 95
Jan/Mar 97
Sept/96

Figure 2.16



NW Interceptor - June 5, 1996
Response to Rainfall
Flow (L/sec)
1200
1000
800
600
400
200
0
Rainfall (mm)
12
10
8
6
4
2
0
0
4
8
12
16
20
Hours from start of storm
Rainfall
WWF
Winter DWF

Figure 2.17


NW Interceptor - July 16, 1996
Response to Rainfall
Flow (L/sec)
Rainfall (mm)
500
400
300
200
100
0
10
8
6
4
2
0
0
4
8.
12
16
20
24
Hours from start of storm
Rainfall
WWF
Winter DWF
Figure 2.18

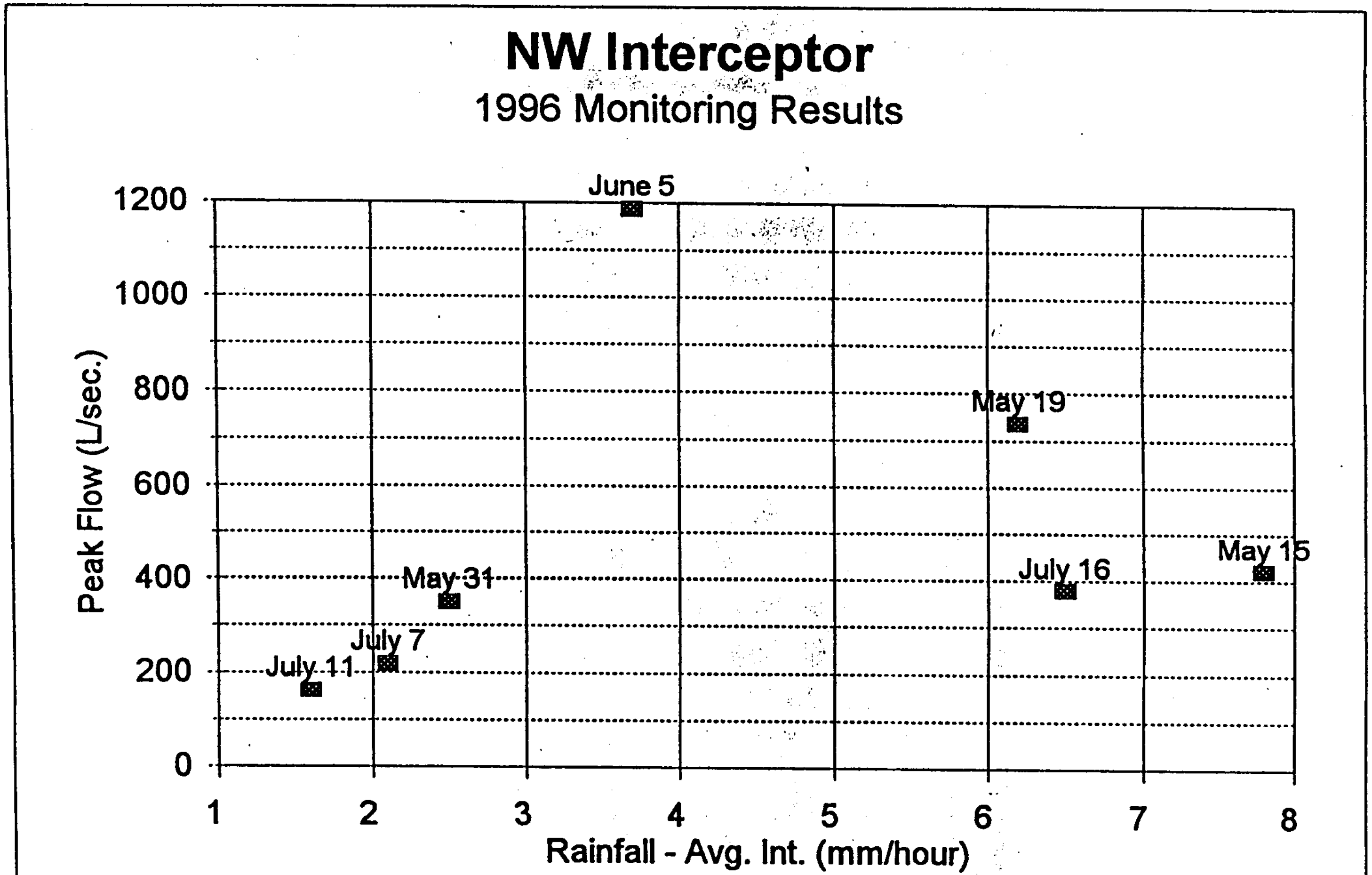

NW Interceptor
1996 Monitoring Results
Peak Flow (L/sec.)
1200
1000
800
600
400
200
0
June 5
May 19
May 31
July 16
May 15
July 7
July 11
1
2
3
4
5
6
7
8
Rainfall - Avg. Int. (mm/hour)

Figure 2.19

2.3.1 Dry Weather Flow Analysis

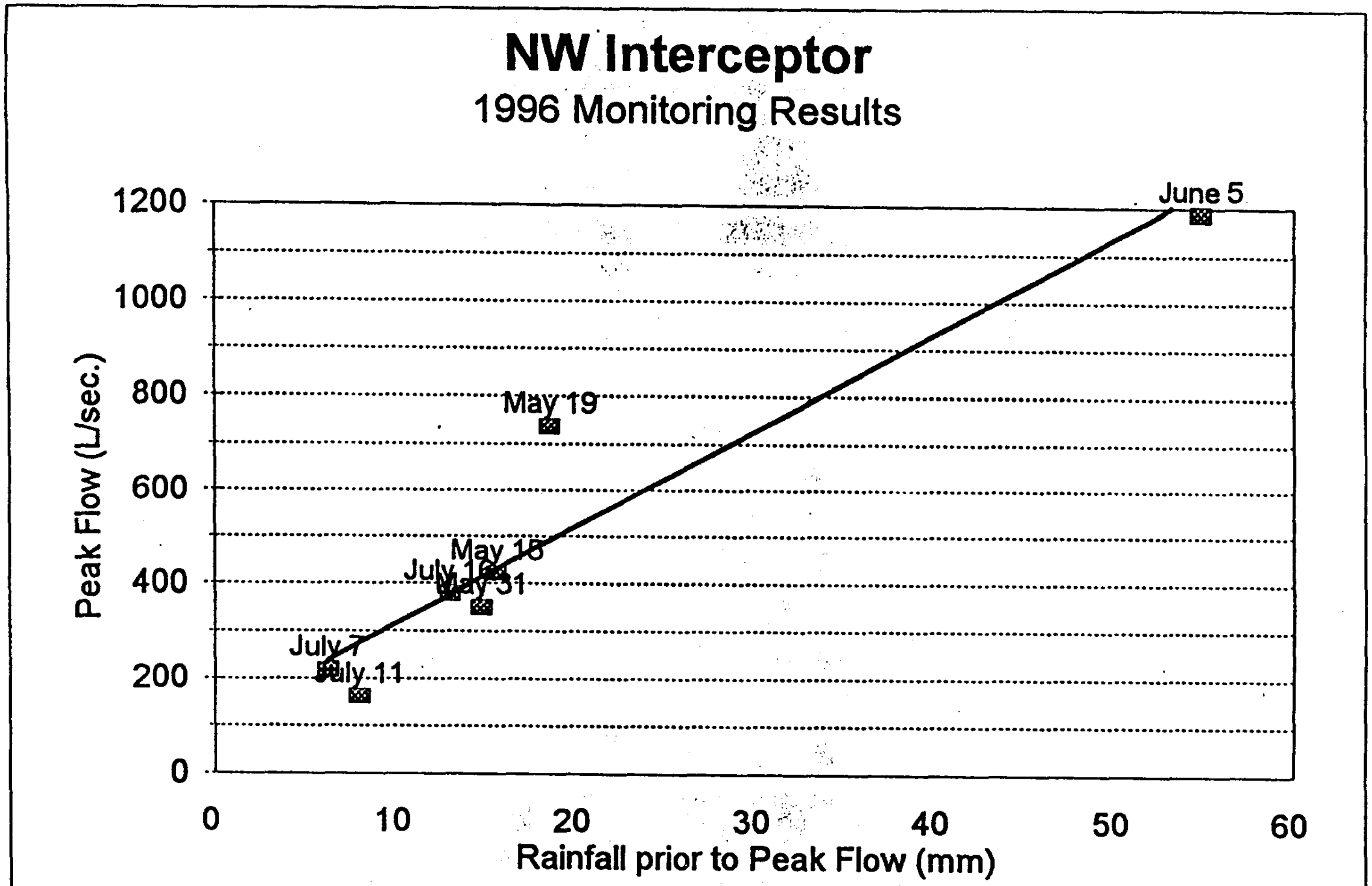
DWF data was collecting during September 1996, and the period from January to March 1998. The latter period was significant as it provided the first set of “deep winter” DWF data since the inception of the monitoring program. This data was then compared to the earlier DWF data from June 1995 (see Figure 2.16). This comparison indicates that significantly higher DWFs occur during the warm weather months. Warm weather average DWF values range from 1.5 to 2.0 times the recorded winter period values. This data implies that extraneous flows such as groundwater infiltration and/or cooling waters are a significant portion of summertime DWF. In any event, the varying DWF rates must be considered in the assessment of WWF peaking factors.

2.3.2 1996 Wet Weather Flow Analysis

There were a total of nine significant rainfall events from May to September 1996. More data was collected from the Northwest Interceptor (nine events) than from the Northeast Interceptor (four events). Accordingly, the WWF analysis focused on the Northwest Interceptor data. The Northwest Interceptor’s response to rainfall was reviewed by comparing measured rainfall and the recorded WWF to typical DWF conditions. The response to the events June 5 and July 16, 1996, are shown on Figures 2.17 and 2.18, respectively.

The June 5, 1996, event had an approximate return period of 3.5 years and resulted in a peak flow of nearly 1200 L/sec. Considering winter DWF rates, this results in a WWF peaking factor of approximately 12. This high peaking factor is reasonable considering that earlier studies have indicated WWF peaking factors of 7 for a one year return event in sanitary sewer systems.

From the 1996 data, an attempt was made to correlate peak flow in the interceptor to rainfall. The first trail compared peak flow to average rainfall intensity over the event and is shown on Figure 2.19. The random order of the plotting points suggests that, even considering the scarcity of the data, there is no correlation. Plotting the peak flow against



NW Interceptor
1996 Monitoring Results
Peak Flow (L/sec.)
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
Rainfall prior to Peak Flow (mm)
June 5
May 19
May 15
July 16
May 31
July 7
July 11

Figure 2.20

the total rainfall prior to the peak flow in the interceptor (Figure 2.20) and using a linear regression analysis provided a good correlation. This indicates that peak flows in the interceptor system are more sensitive to total rainfall than to rainfall intensities.

2.3.3 Additional Northeast and Northwest Flow Analysis (CG&S)

The raw data collected during the Northeast/Northwest monitoring program contained a number of flow anomalies. These were a result of the severe conditions in the sewers, equipment malfunction and lack of maintenance. As a result, the entire data set was reviewed and reprocessed. This activity also led to the development of a rating curve, as well as an I/I predictive model, for each interceptor. Details of this analysis, as well as the corrected 1996/97 flow data, are appended.

3. CONCLUSIONS

The following conclusions were made during the preliminary analysis of the Northeast and Northwest Interceptor and NEWPCC monitoring program:

- The Northeast and Northwest Interceptor monitoring program provided useful DWF and WWF data to better understand the peaking response of flows in sanitary sewered areas. The development of a rating curve for each interceptor will allow the removal of the weirs and flow monitors and provide a method of gauging flows in these interceptors.

- The PWWF in the Northeast and Northwest Interceptors is rainfall dependent but can be considered to have a time of concentration of approximately two to four hours for significant rainfall events.

- PWWFs are related to storm intensity and duration. A maximum peaking factor of 12 was observed for the June 5, 1996, rainfall event (approximately 3.5 return frequency).

- The NEWPCC data shows the complex relationship between pump flow and surge tank levels which, in turn, impacts the flows in the Main Interceptor.

- WWF in the Main Interceptor routinely exceeds the 2.75 times ADWF design basis for the individual diversion facilities.

4. RECOMMENDATIONS

The following recommendation is based on the preceding analysis of the NEWPCC flow monitoring program:

- The monitoring installations should be removed and replaced by level monitors (at the rating curve locations) once sufficient data is available to verify the rating curves. The continuation of flow measurement in the Northeast and Northwest Interceptors is recommended to better understand WWFs.

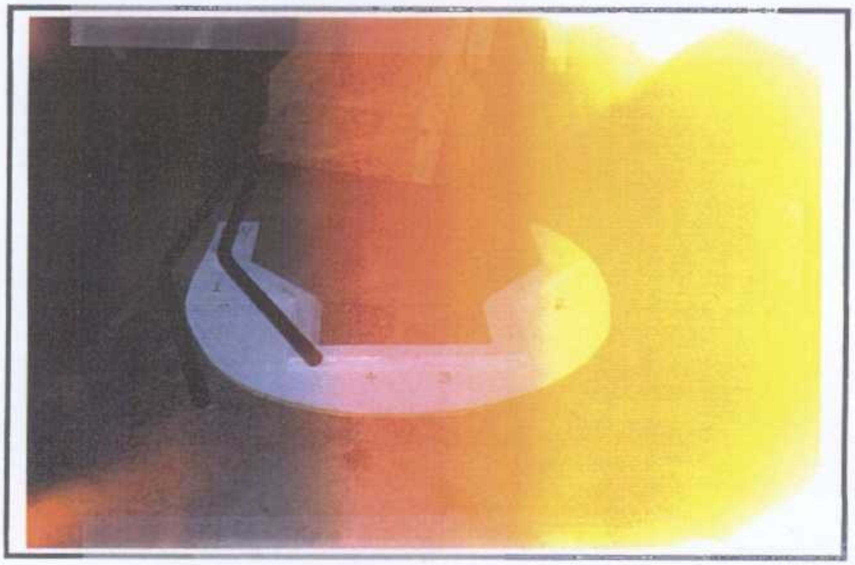
ATTACHMENT 1

Photographs of Weir

Construction and Installation

City of Winnipeg CSO Flow Monitoring Program
Site Photographs

Leila Avenue
North West Interceptor



Douglas Avenue
North East Interceptor

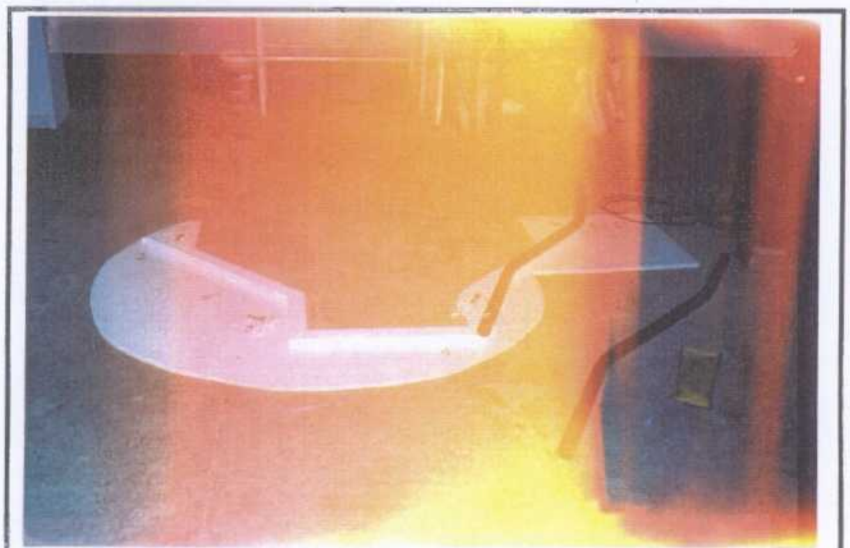


Figure 1

ATTACHMENT 2

CG&S April 17, 1997, Report on Rating Curve Determination for City Monitoring Sites and Rating Curves for Weir Installations

CH2M Gore & Storrie Limited
255 Consumers Road
North York, ON, M2J 5B6
Canada
Tel 416.499.9000
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CG&S
CH2M Gore & Storrie Limited

April 17, 1997

111T 7681

TetrES Consultants Inc.
603 - 386 Broadway
Winnipeg, Manitoba
R3CRACK 3R6

Attention: **Mr. Nicholas T. Szoke, P.Eng.**

Dear Sir:

Subject: **Winnipeg CSO Study - Addressing Items Requested by Brian Station in February 25, 1998 Letter**

We are pleased to enclose rating curves for the three sites (4 data sets) provided to us by Brian Station of the City in his letter dated February 25, 1998.

In addition we have addressed the three items requested from us in that letter.

Our discussion is presented under the following headings:

- Rating Curve Determination for the City monitoring sites
- Rating Curves for CG&S Winnipeg weirs
- Comments on location of stilling wells / sensors (including video)
- Concluding remarks

Rating Curve Determination for City Monitoring Sites

We were provided with data sets (depth, velocity, flow) and location sketches for the following velocity-area meter monitoring stations set up by the City.

1. Leila Avenue in first manhole downstream of CG&S monitoring station in 1500mm north west interceptor.
   Dataset for July 5, 1996 to July 29, 1996

2. Henderson Highway, a short distance downstream of CG&S monitoring station in 1800mm north east interceptor.
   Dataset for July 30, 1997 to August 28, 1997

3. McPhillips Street, a short distance downstream of CG&S monitoring station in 1500mm north west interceptor.
   Dataset for July 30, 1997 to September 9, 1997
   Dataset for September 9, 1997 to November 13, 1997

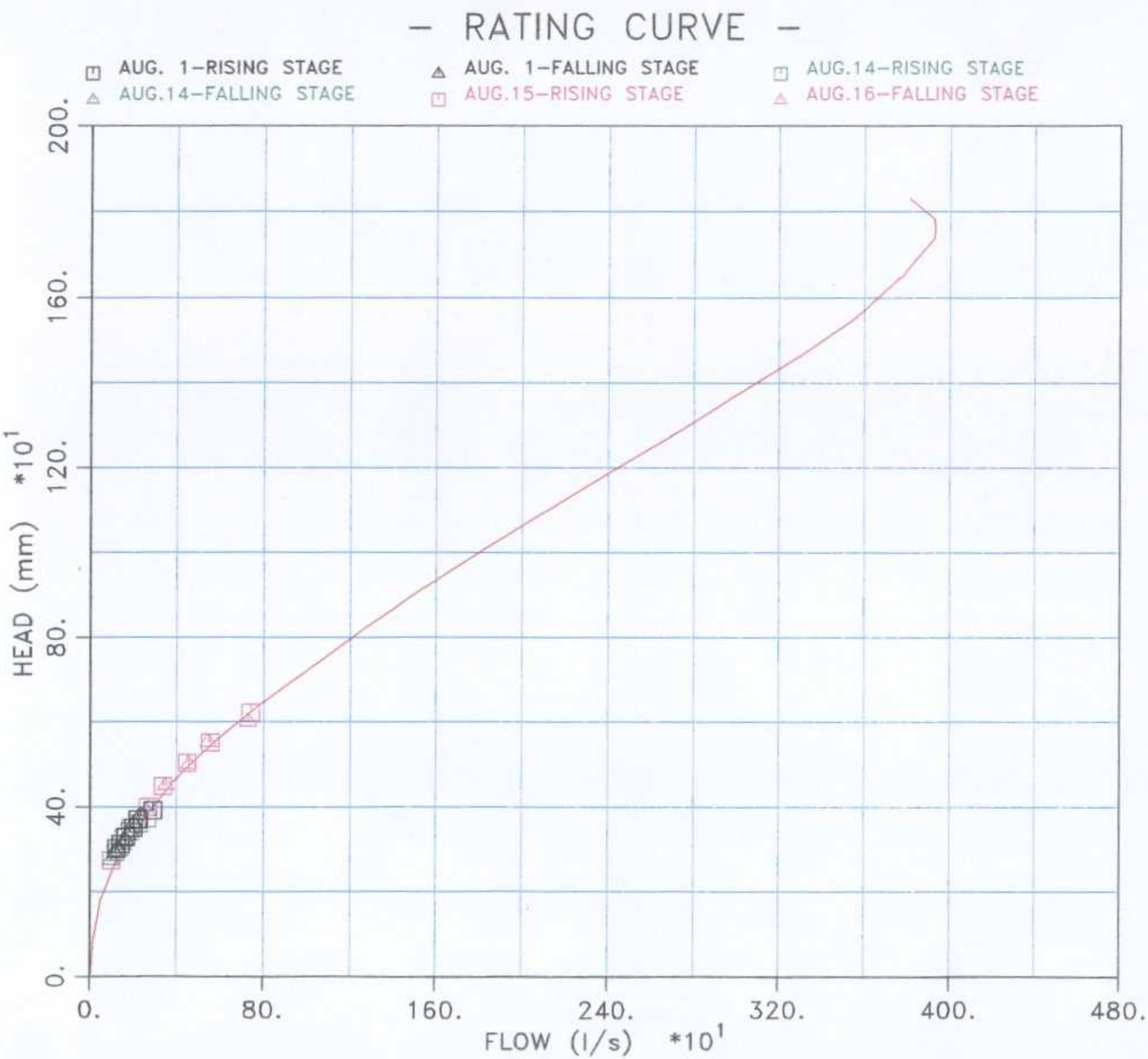
A rating curve for the Henderson site was previously determined and forwarded along with a description of the approach used to derive it. The rating curve is based on fitting the dimensionless Manning equation formulation with "n" depth variable to depth / flow data obtained from the station. Identifiable "sets" of data points throughout the period of record for rising and falling stages are used to allow checks for hysteresis and sensor drift. The full pipe "n" value is varied to get the best fit, using "blow-up" plots of the lower portion of the curve for which data is available. Once an "n" value is selected, a full range curve is produced in plotted and printed form. This procedure assumes that pipe slopes are correct, and that depths have been adjusted to match manual readings if necessary. It also determines the effective "n" value for the sewer.

A slightly improved version of the dimensionless curve was obtained and used since we provided the original curve for the Henderson site. As a result, we have re-run it for a check and provided its data along with that for the other sites. All three sites are good candidates for this type of monitoring (measuring depth and converting to flow) since there does not appear to be hysteresis. (With hysteresis the falling stage points from an event would consistently lie to the left of those for the rising stage.) All three sites were found to have effective full pipe "n" values of 0.014 which tends to reinforce the validity of all three curves. This result also confirms the wisdom of the City's use of "n" = 0.015 for design purposes.

The McPhillips site shows the greatest signs of possible velocity sensor fouling during the October 9, 1997 event when "points" did not seem to lie on the same curve as for the larger August 15/16 event. Greater attention was paid to the August 15/16, 1997 data for this site since it covered the broadest range and resulted in the same "n" value found for the other two sites. The effective "n" values were somewhat higher than we consistently found in similar analyses for Metro Toronto, a factor which could be related to the difference in pipe slopes. We have enclosed an excerpt from a report we did for Metro Toronto covering this type of analysis.

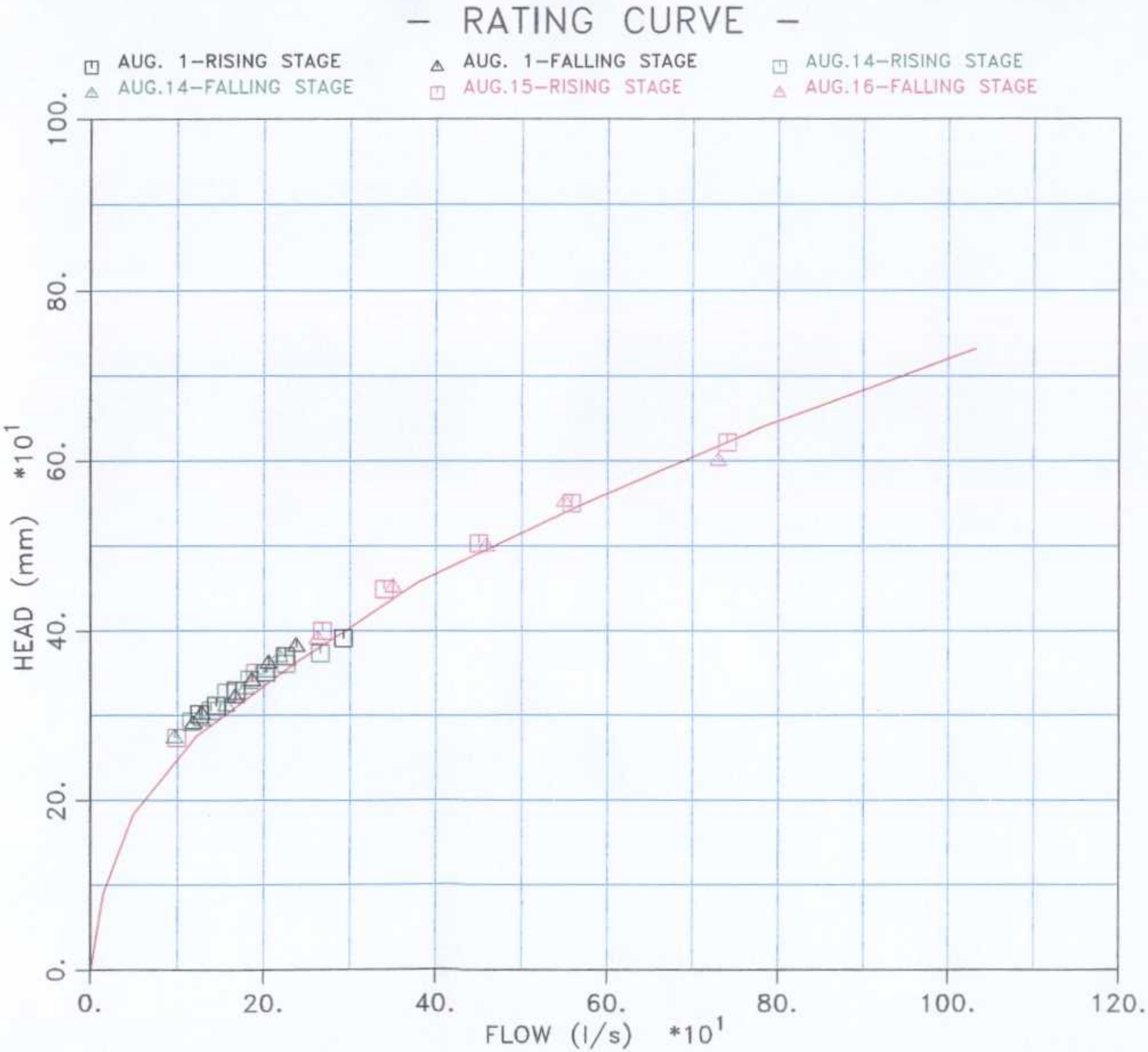
DEVELOP RATING CURVE FOR HENDERSON HW.

1800 mm PIPE , 1997 DATA , MH IN PARKING LOT , n=0.014



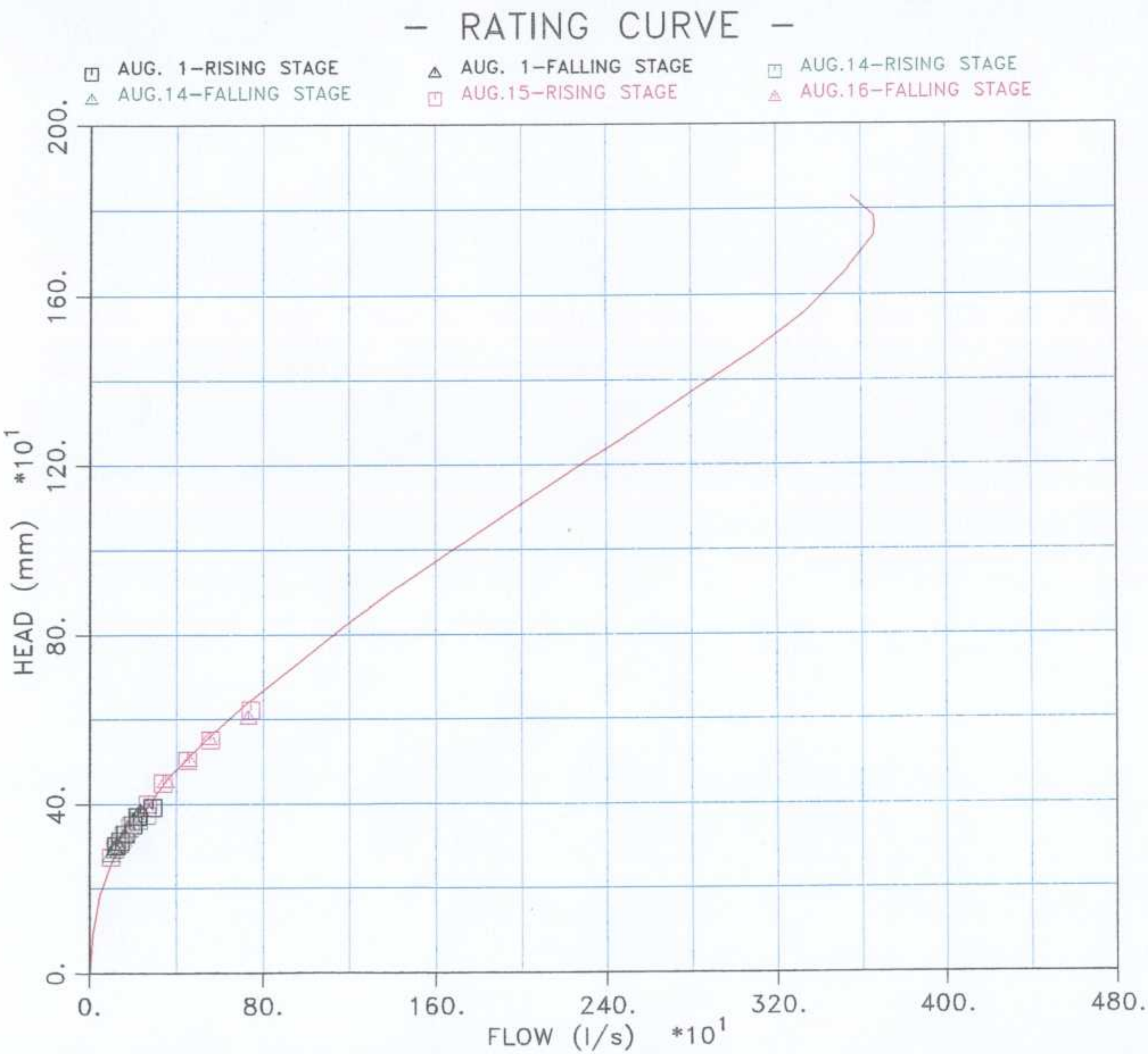
RATING CURVE : HENDERSON (lower portion)

1800 mm PIPE , 1997 DATA , MH IN PARKING LOT , n=0.014



DEVELOP RATING CURVE FOR HENDERSON HW.

1800 mm PIPE , 1997 DATA , MH IN PARKING LOT , n=0.015

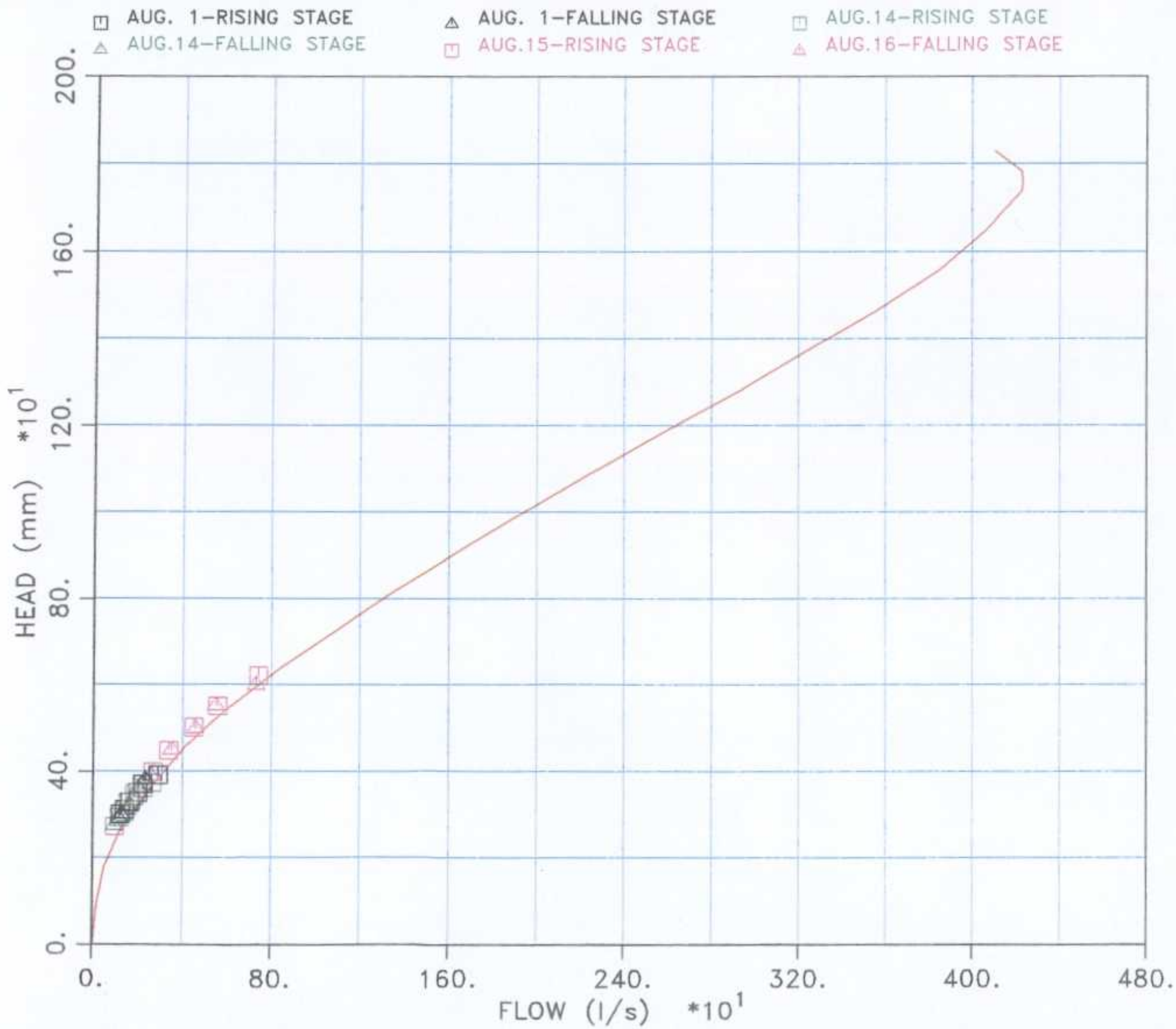


FLOW (l/s) *10

DEVELOP RATING CURVE FOR HENDERSON HW.

1800 mm PIPE , 1997 DATA , MH IN PARKING LOT , n=0.013

– RATING CURVE –



PIPE RATING CURVE CALCULATION
****

- BASED ON INPUT d/D & q/Q CURVES

DEVELOP RATING CURVE FOR HENDERSON HW.
1800 mm PIPE , 1997 DATA , MH IN PARKING LOT , n=0.014

PIPE DATA
============

DIA = 1829.0 mm
N(full) = .014
SLOPE = .0012

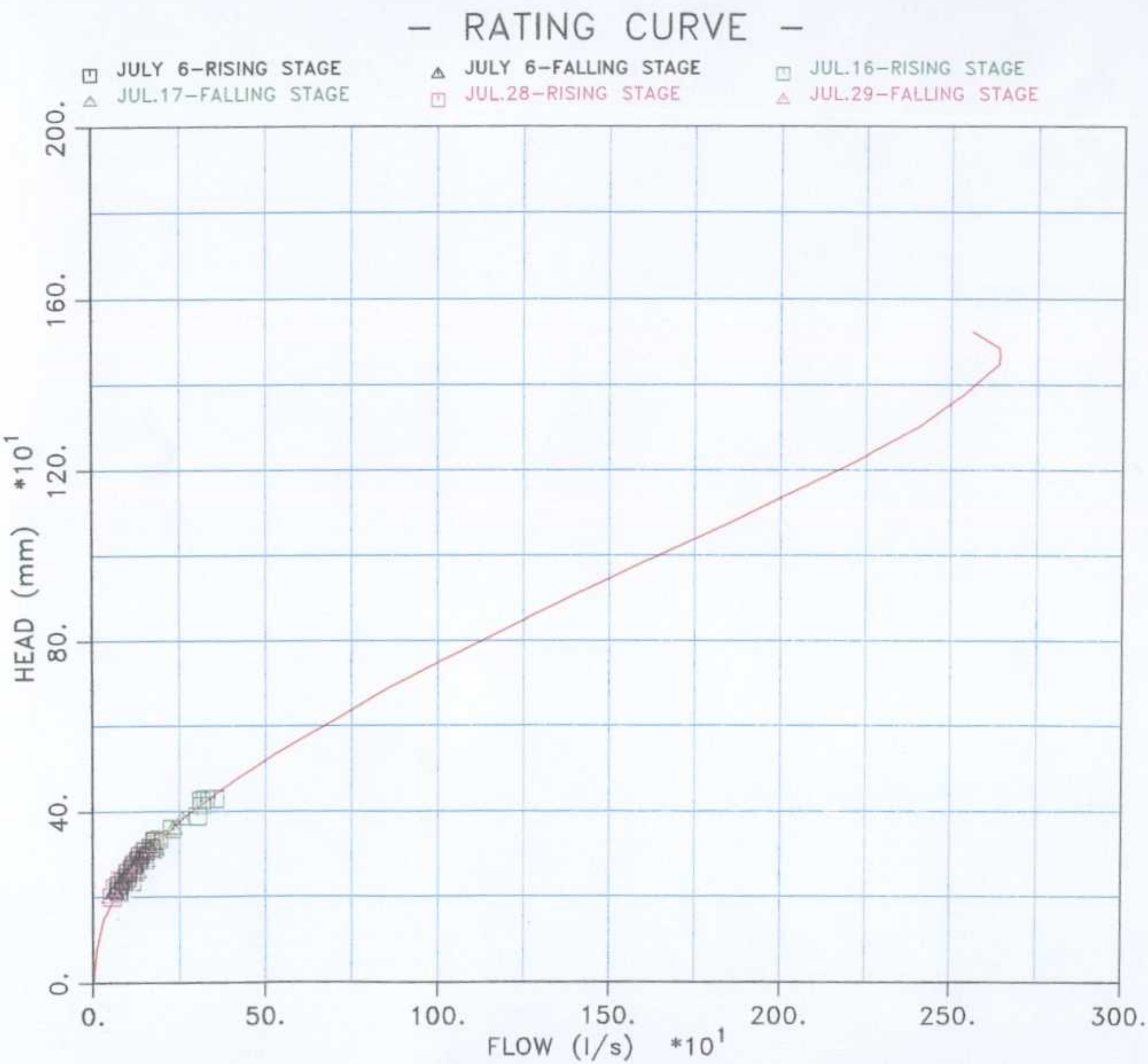
RATING CURVE CALCULATION

****

LEVEL (mm)	FLOW (l/s)	"N"
.0	.0	
91.4	15.2	
182.9	49.5	
274.4	121.9	
365.8	243.8	
457.3	381.0	
548.7	571.5	
640.2	784.8	
731.6	1032.5	
823.0	1272.5	
914.5	1543.0	
1005.9	1824.9	
1097.4	2114.5	
1188.8	2411.6	
1280.3	2720.2	
1371.8	3006.0	
1463.2	3299.3	
1554.7	3566.0	
1646.1	3764.1	
1737.6	3924.1	
1760.4	3928.0	
1783.3	3924.1	
1829.0	3809.8	

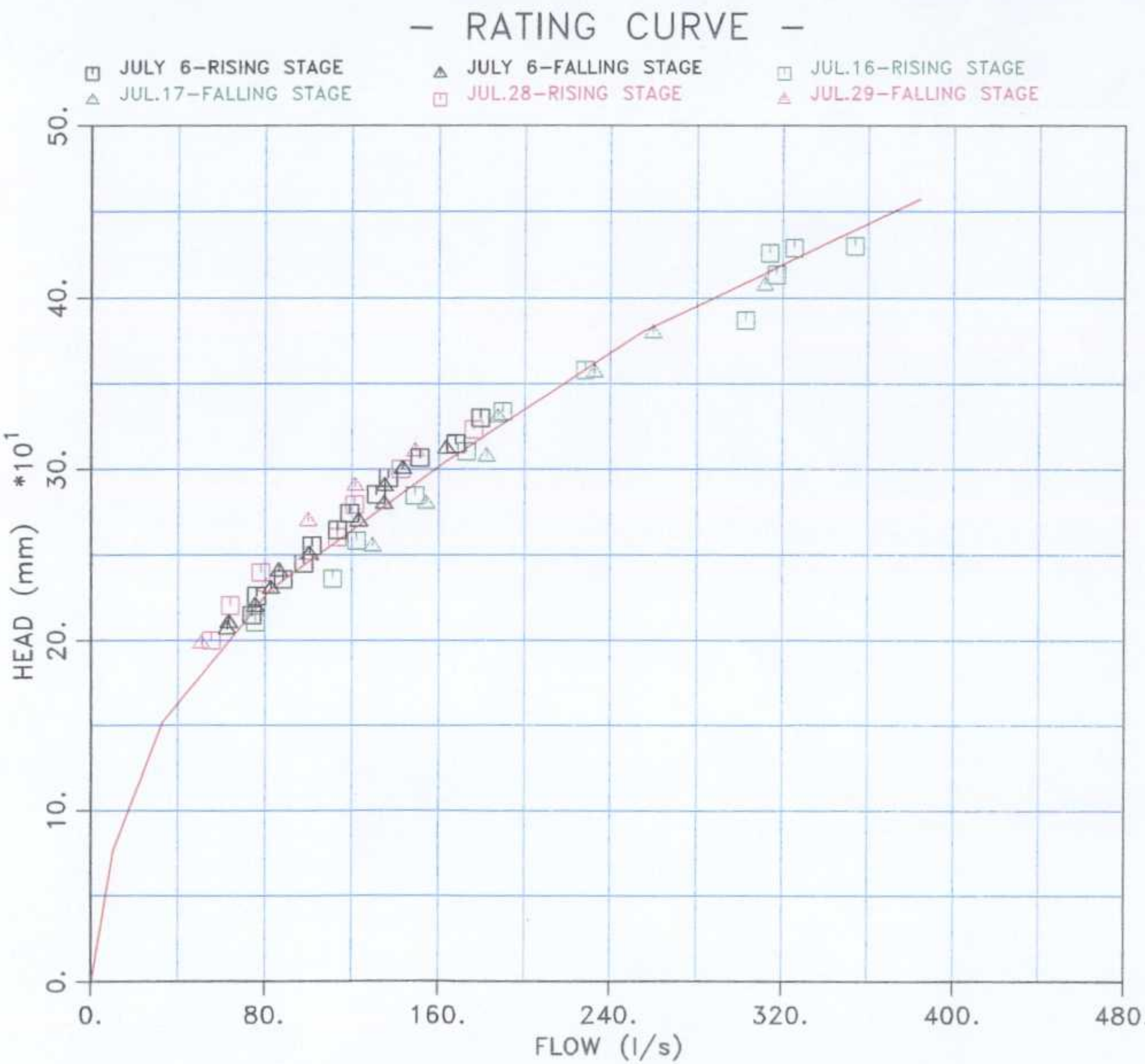
RATING CURVE : LEILA W. OF McPHILLIPS

1500 mm PIPE , 1996 DATA , INTERCEPTOR MH , n=0.014



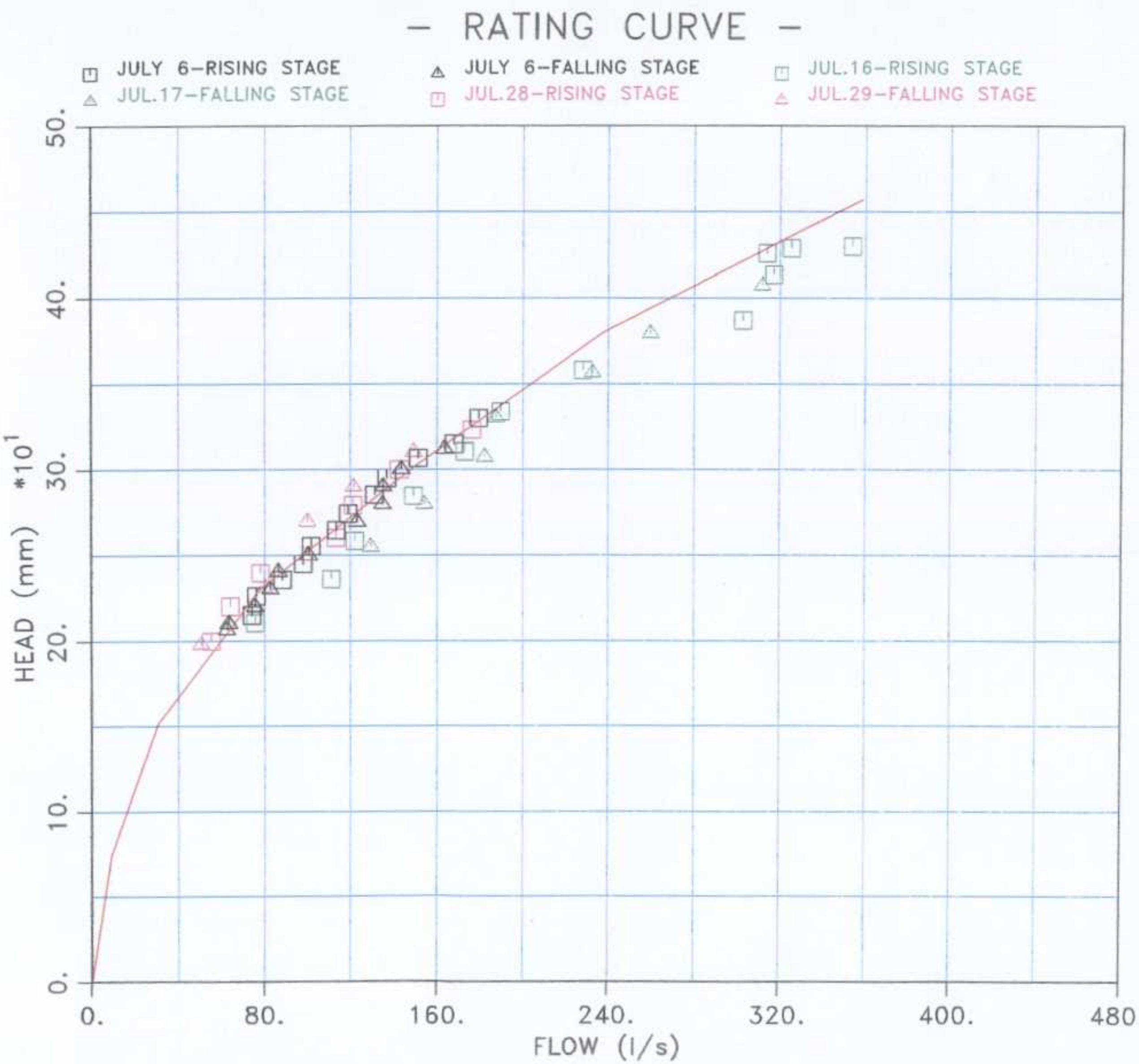
RATING CURVE : LEILA (lower portion)

1500 mm PIPE , 1996 DATA , INTERCEPTOR MH , n=0.014



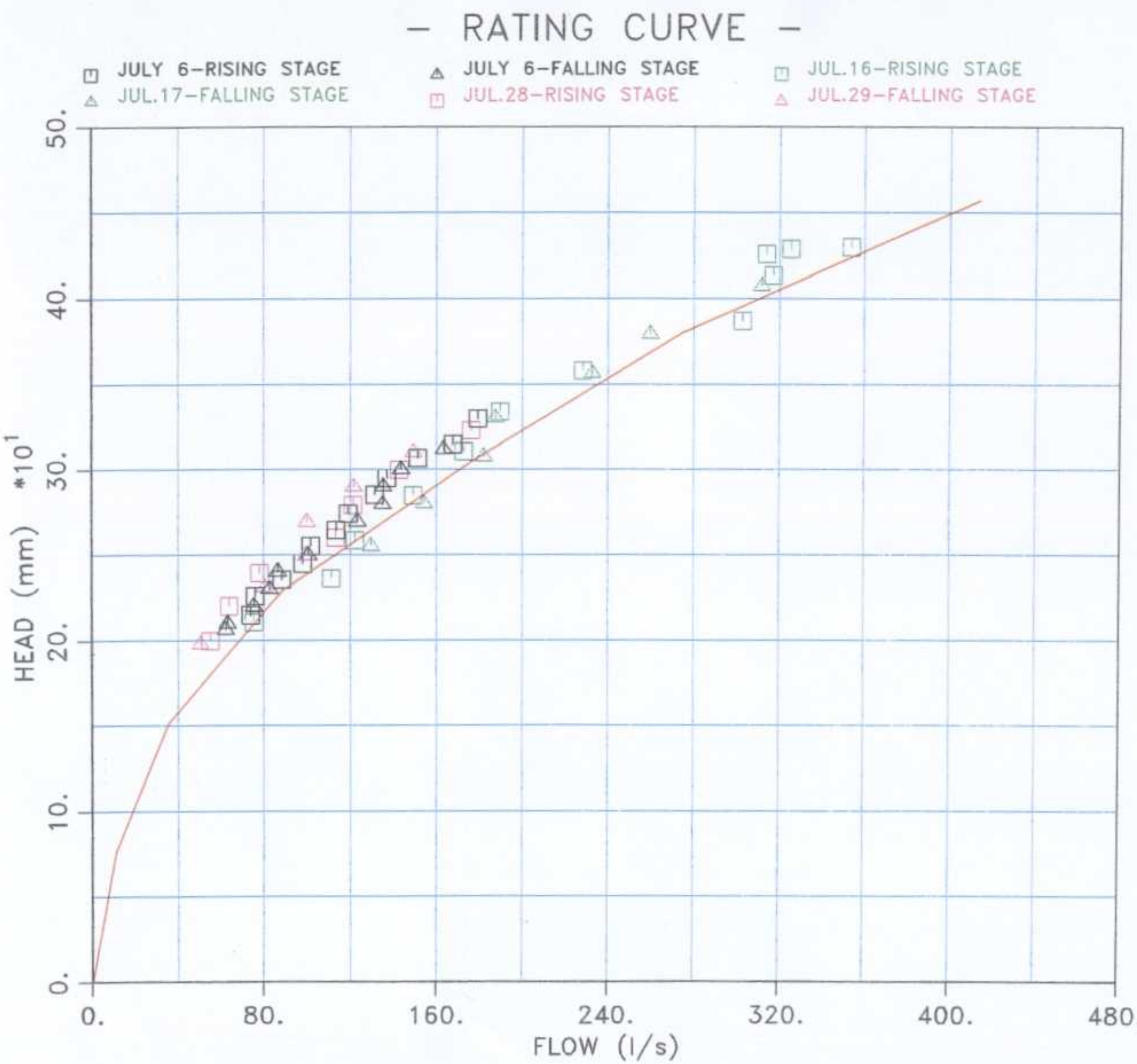
RATING CURVE : LEILA (lower portion)

1500 mm PIPE , 1996 DATA , INTERCEPTOR MH , n=0.015



RATING CURVE : LEILA (lower portion)

1500 mm PIPE , 1996 DATA , INTERCEPTOR MH , n=0.013



PIPE RATING CURVE CALCULATION
****

- BASED ON INPUT d/D & q/Q CURVES

RATING CURVE : LEILA W. OF McPHILLIPS
1500 mm PIPE , 1996 DATA , INTERCEPTOR MH , n=0.014

PIPE DATA
===========

DIA = 1524.0 mm
N(full) = .014
SLOPE = .0014

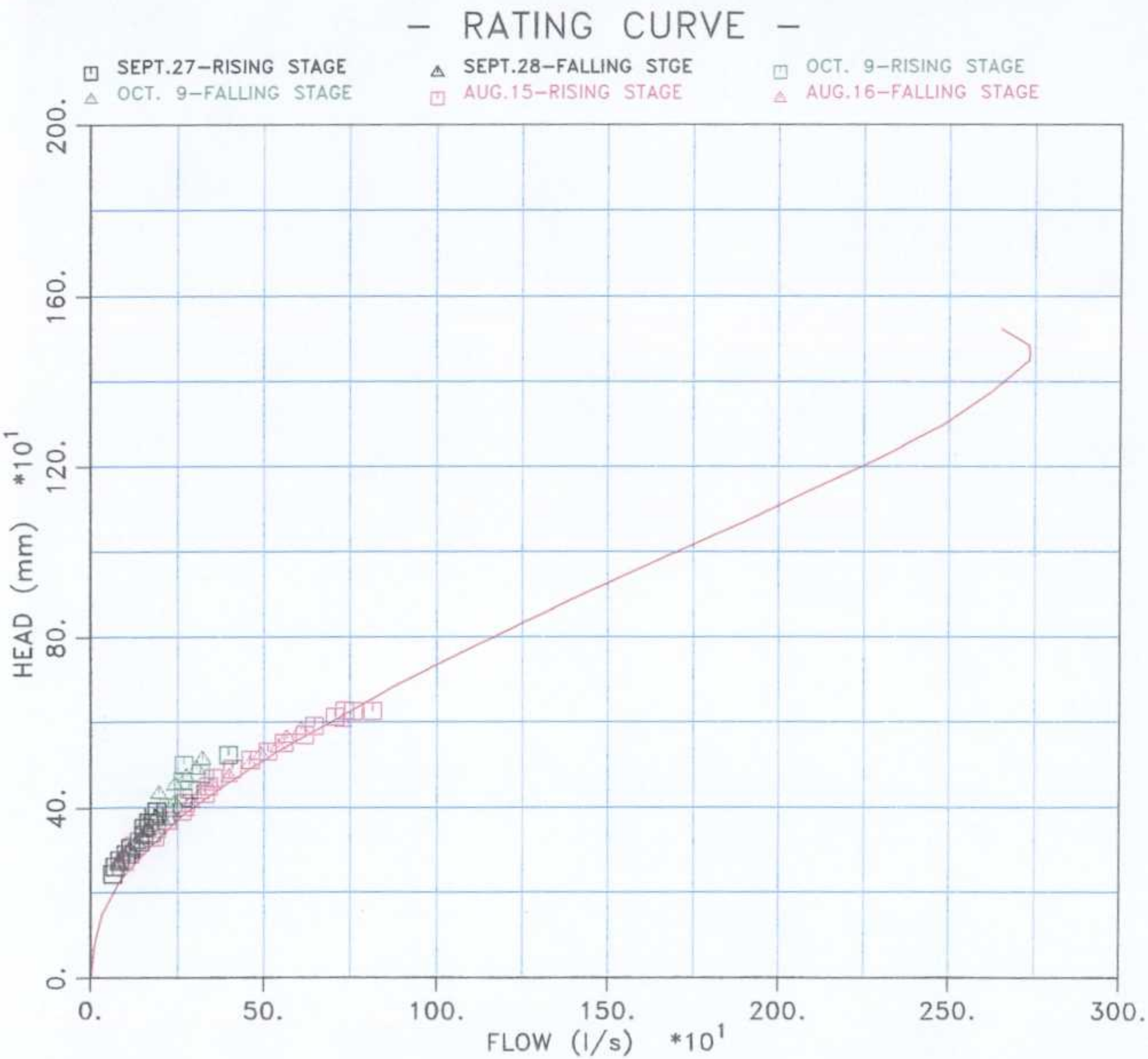
RATING CURVE CALCULATION

****

LEVEL (mm)	FLOW (l/s)	"N"
.0	.0	
76.2	10.2	
152.4	33.3	
228.6	82.0	
304.8	164.0	
381.0	256.2	
457.2	384.3	
533.4	527.8	
609.6	694.3	
685.8	855.7	
762.0	1037.7	
838.2	1227.3	
914.4	1422.0	
990.6	1621.8	
1066.8	1829.4	
1143.0	2021.5	
1219.2	2218.8	
1295.4	2398.1	
1371.6	2531.4	
1447.8	2639.0	
1466.9	2641.5	
1485.9	2639.0	
1524.0	2562.1	

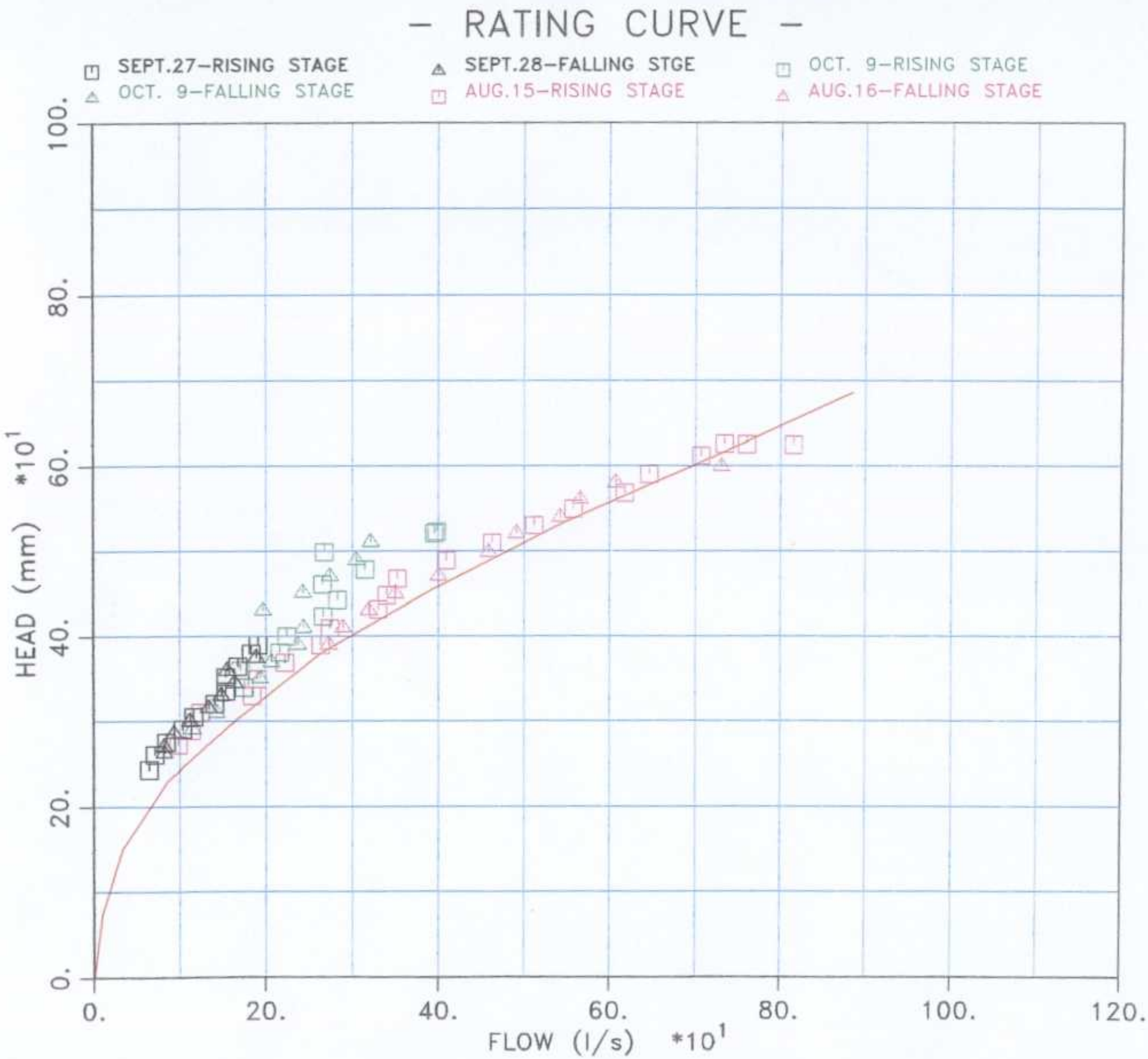
RATING CURVE : McPHILLIPS S. OF COURT Av

1500 mm PIPE , 1997 DATA , INTERCEPTOR MH , n=0.014



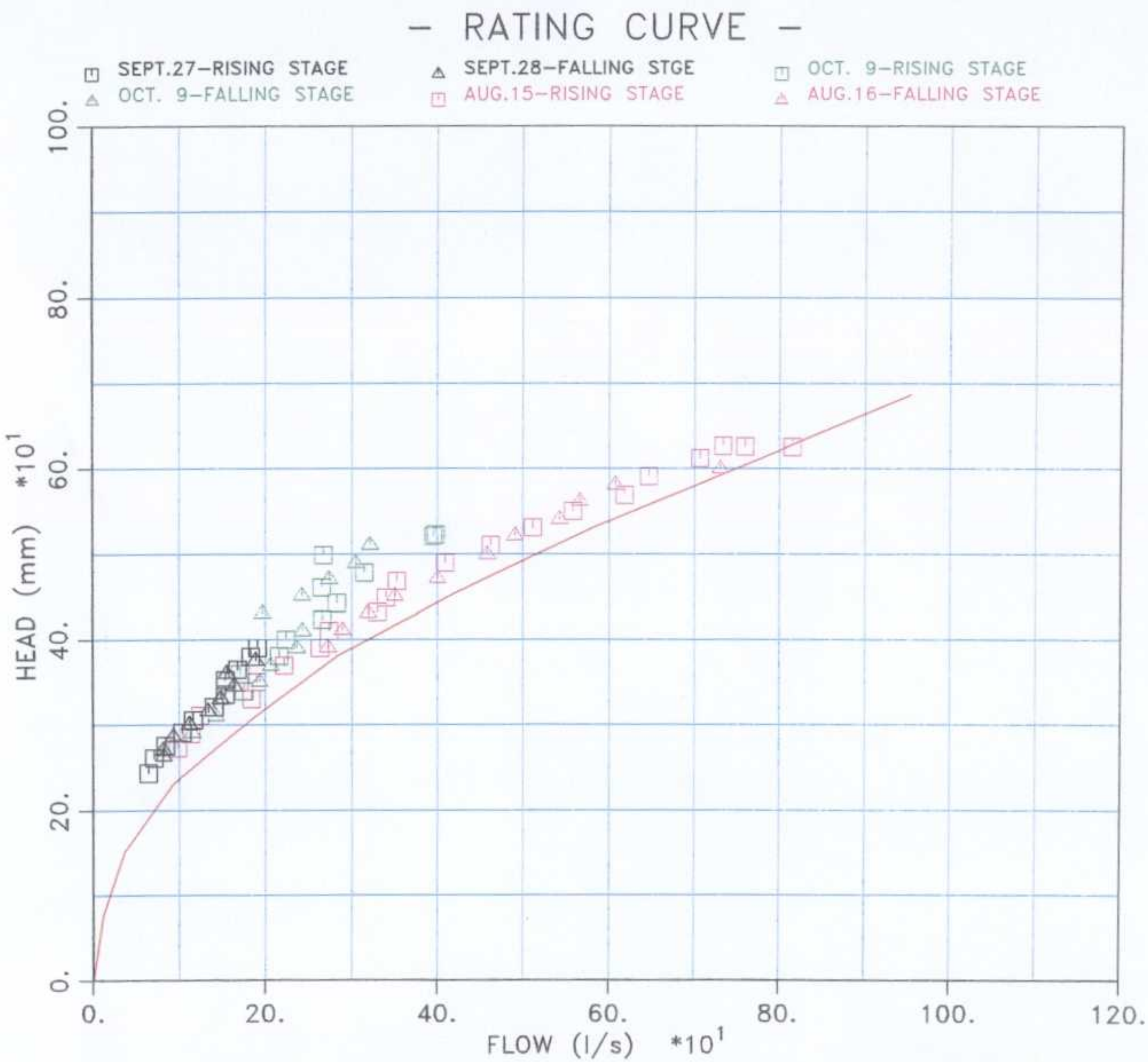
RATING CURVE : McPHILLIPS(LOWER PORTION)

1500 mm PIPE , 1997 DATA , INTERCEPTOR MH , n=0.014



RATING CURVE : McPHILLIPS(LOWER PORTION)

1500 mm PIPE , 1997 DATA , INTERCEPTOR MH , n=0.013



PIPE RATING CURVE CALCULATION
****

- BASED ON INPUT d/D & q/Q CURVES

RATING CURVE : McPHILLIPS S. OF COURT Av
1500 mm PIPE , 1997 DATA , INTERCEPTOR MH , n=0.014

PIPE DATA
============

DIA = 1524.0 mm
N(full) = .014
SLOPE = .0015

RATING CURVE CALCULATION
****

LEVEL (mm)	FLOW (l/s)	"N"
.0	.0	
76.2	10.6	
152.4	34.5	
228.6	84.9	
304.8	169.7	
381.0	265.2	
457.2	397.8	
533.4	546.3	
609.6	718.7	
685.8	885.8	
762.0	1074.1	
838.2	1270.3	
914.4	1471.9	
990.6	1678.7	
1066.8	1893.6	
1143.0	2092.5	
1219.2	2296.7	
1295.4	2482.3	
1371.6	2620.2	
1447.8	2731.6	
1466.9	2734.3	
1485.9	2731.6	
1524.0	2652.0	

Rating Curves for CG&S Weirs

We have enclosed both plotted and printed versions of the rating curves used for the CG&S weirs in the NE and NW interceptors. The plots also contain a diagram with the opening configuration and dimensions.

Comments on Location of Stilling Wells / Sensors

During our visit of December 10, 1997 some video footage was taken showing the condition of the sites and proper location of the stilling wells. A copy of this tape is enclosed.

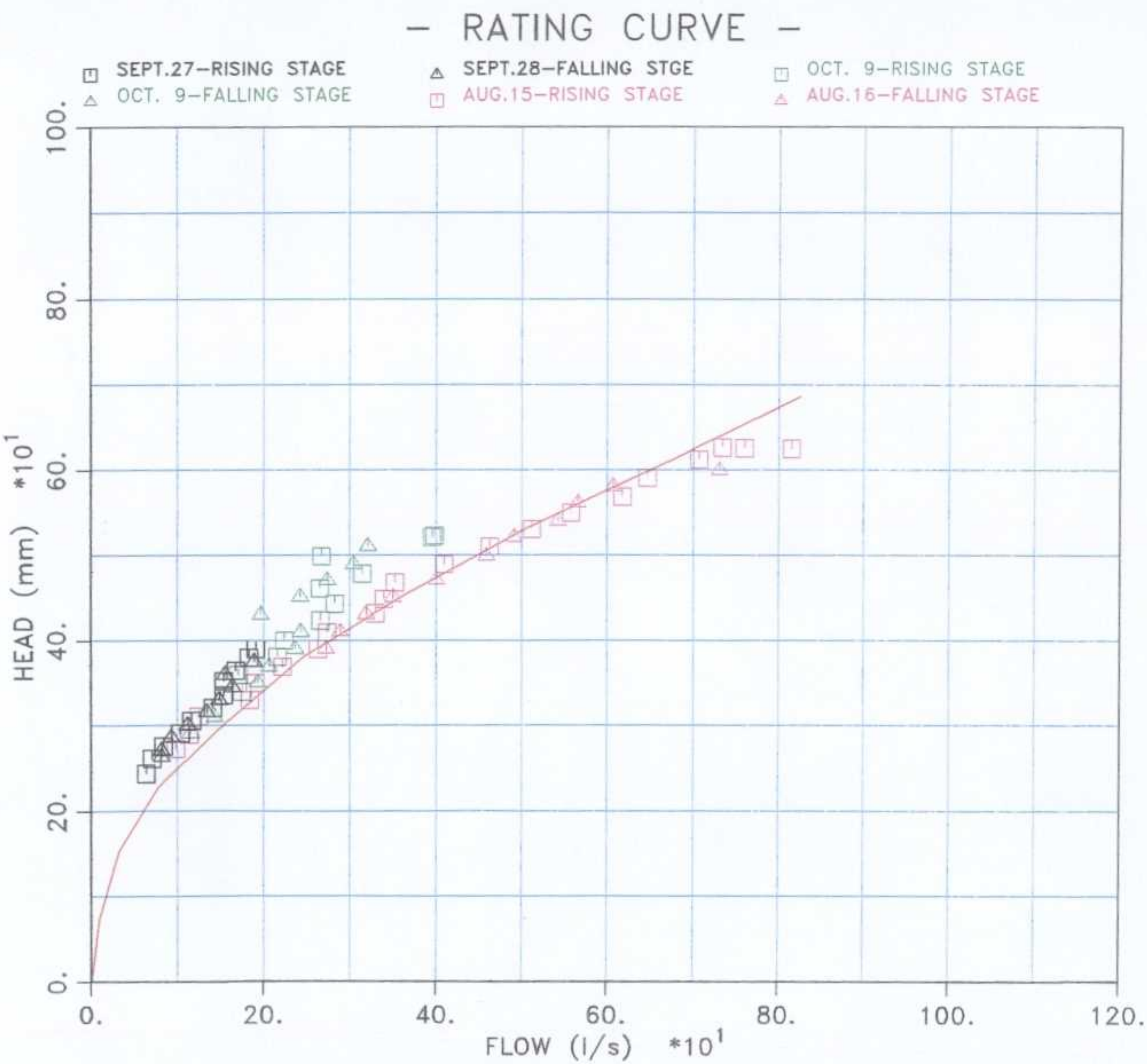
When the NE (Douglas) site was first constructed, the D1 value (distance from the top of the bracket to the weir lip) was 1200mm. When visited on December 10, 1997, the bracket was bent slightly and the value was 1193mm. The bracket was subsequently straightened and then the D1 value was 1198mm. The value of 1198mm for D1 at this site should now be used and the bracket checked periodically to see that it is straight. A value of 1193 is being used for D1 for reduction of data collected in 1997.

The D1 value for the NW (Leila) site was originally 914mm but is now 908mm. The value of 908 is now being used for final data reduction for 1997.

The intent is to measure the full "head" acting on the weirs. This requires that the stilling wells / sensors be located outside the drawdown curve, the extent of which will vary with flow rate. They should also be located in a location where the velocity head ($V^2/2g$) is small so that the EGL = HGL. For an approach velocity of 0.3 m/sec (1 ft/sec) the velocity head is less than 5mm which is minimal for these weirs. If it is not possible to locate the stilling well / sensor far enough upstream to be out of the drawdown curve or if the approach velocity is high, then the sensor can be located right against the weir face off to the side from the opening. At this location the forward velocity is zero and the HGL rises to the EGL. Care must be taken, however, to ensure that the weir opening is not partially blocked by the stilling wells when mounted to the weir or the rating curve will likely be affected. Another "trick" is to mount the stilling well on the upstream side of a "2x4" located about a metre upstream of the weir. In such a case the HGL will be forced up to the EGL at the sensor location.

RATING CURVE : McPHILLIPS(LOWER PORTION)

1500 mm PIPE , 1997 DATA , INTERCEPTOR MH , n=0.015



RATING CURVE CALCULATION
****

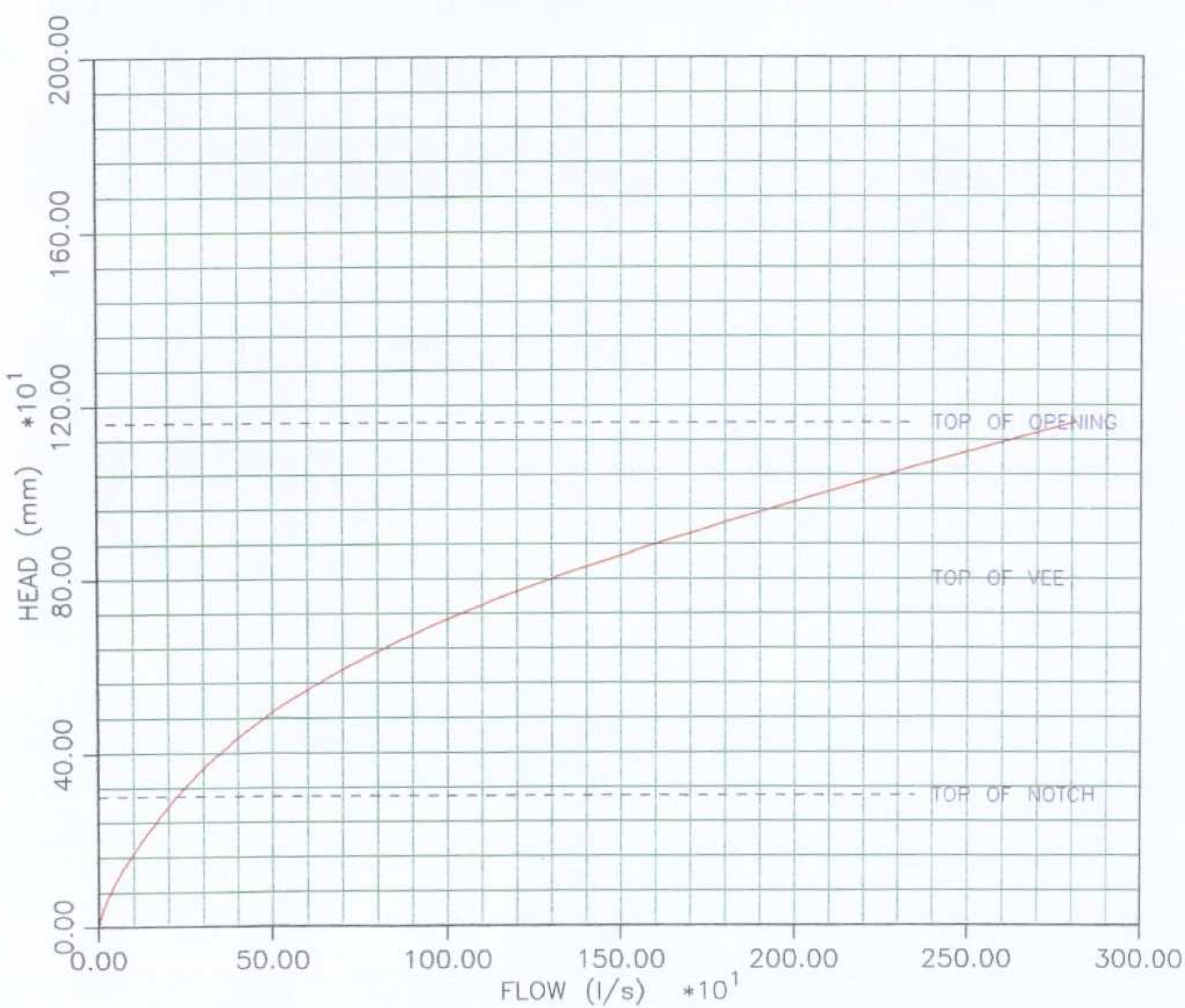
RAW HEAD (mm)	H notch (mm)	L notch (mm)	Q notch (l/s)	H vee (mm)	L vee (mm)	Q vee (l/s)	Q total (l/s)
.000	.000	600.000	.000	-300.000	.000	.000	.000
15.000	15.000	596.250	2.848	-285.000	.000	.000	2.848
30.000	30.000	592.500	8.005	-270.000	.000	.000	8.005
45.000	45.000	588.750	14.612	-255.000	.000	.000	14.612
60.000	60.000	585.000	22.354	-240.000	.000	.000	22.354
75.000	75.000	581.250	31.040	-225.000	.000	.000	31.040
90.000	90.000	577.500	40.540	-210.000	.000	.000	40.540
105.000	105.000	573.750	50.755	-195.000	.000	.000	50.755
120.000	120.000	570.000	61.606	-180.000	.000	.000	61.606
135.000	135.000	566.250	73.027	-165.000	.000	.000	73.027
150.000	150.000	562.500	84.964	-150.000	.000	.000	84.964
165.000	165.000	558.750	97.368	-135.000	.000	.000	97.368
180.000	180.000	555.000	110.198	-120.000	.000	.000	110.198
195.000	195.000	551.250	123.417	-105.000	.000	.000	123.417
210.000	210.000	547.500	136.989	-90.000	.000	.000	136.989
225.000	225.000	543.750	150.885	-75.000	.000	.000	150.885
240.000	240.000	540.000	165.076	-60.000	.000	.000	165.076
255.000	255.000	536.250	179.536	-45.000	.000	.000	179.536
270.000	270.000	532.500	194.240	-30.000	.000	.000	194.240
285.000	285.000	528.750	209.166	-15.000	.000	.000	209.166
300.000	300.000	525.000	224.292	.000	.000	.000	224.292
300.000	300.000	525.000	224.292	.000	.000	.000	224.292
315.000	315.000	525.000	241.323	7.500	30.000	.051	241.373
330.000	330.000	525.000	258.764	15.000	60.000	.287	259.050
345.000	345.000	525.000	276.606	22.500	90.000	.790	277.395
360.000	360.000	525.000	294.840	30.000	120.000	1.621	296.461
375.000	375.000	525.000	313.458	37.500	150.000	2.832	316.290
390.000	390.000	525.000	332.452	45.000	180.000	4.467	336.920
405.000	405.000	525.000	351.815	52.500	210.000	6.568	358.383
420.000	420.000	525.000	371.541	60.000	240.000	9.171	380.712
435.000	435.000	525.000	391.621	67.500	270.000	12.311	403.932
450.000	450.000	525.000	412.051	75.000	300.000	16.021	428.072
465.000	465.000	525.000	432.824	82.500	330.000	20.331	453.156
480.000	480.000	525.000	453.936	90.000	360.000	25.272	479.208
495.000	495.000	525.000	475.379	97.500	390.000	30.870	506.250
510.000	510.000	525.000	497.150	105.000	419.999	37.154	534.304
525.000	525.000	525.000	519.244	112.500	449.999	44.148	563.392
540.000	540.000	525.000	541.655	120.000	479.999	51.878	593.533
555.000	555.000	525.000	564.380	127.500	509.999	60.368	624.748
570.000	570.000	525.000	587.414	135.000	539.999	69.641	657.056
585.000	585.000	525.000	610.754	142.500	569.999	79.720	690.474
600.000	600.000	525.000	634.394	150.000	599.999	90.628	725.022
615.000	615.000	525.000	658.332	157.500	629.999	102.384	760.716
630.000	630.000	525.000	682.564	165.000	659.999	115.012	797.575
645.000	645.000	525.000	707.085	172.500	689.999	128.530	835.615
660.000	660.000	525.000	731.894	180.000	719.999	142.960	874.854
675.000	675.000	525.000	756.986	187.500	749.999	158.320	915.306
690.000	690.000	525.000	782.359	195.000	779.999	174.630	956.989
705.000	705.000	525.000	808.008	202.500	809.999	191.909	999.917
720.000	720.000	525.000	833.933	210.000	839.999	210.175	1044.107
735.000	735.000	525.000	860.128	217.500	869.999	229.446	1089.574
750.000	750.000	525.000	886.593	225.000	899.999	249.740	1136.333
765.000	765.000	525.000	913.323	232.500	929.999	271.075	1184.398
780.000	780.000	525.000	940.317	240.000	959.999	293.468	1233.784

800.000	800.000	525.000	976.715	250.000	1000.000	325.000	1301.715
809.999	809.999	525.000	995.084	259.999	997.000	343.659	1338.743
824.999	824.999	525.000	1022.853	274.999	992.500	372.136	1394.989
839.999	839.999	525.000	1050.875	289.999	988.000	401.168	1452.043
854.999	854.999	525.000	1079.149	304.999	983.500	430.721	1509.870
869.999	869.999	525.000	1107.672	319.999	979.000	460.765	1568.437
884.999	884.999	525.000	1136.442	334.999	974.500	491.271	1627.713
899.999	899.999	525.000	1165.456	349.999	970.000	522.211	1687.667
914.999	914.999	525.000	1194.714	364.999	965.500	553.559	1748.273
929.999	929.999	525.000	1224.212	379.999	961.000	585.290	1809.502
944.999	944.999	525.000	1253.949	394.999	956.500	617.380	1871.330
959.999	959.999	525.000	1283.923	409.999	952.000	649.808	1933.731
974.999	974.999	525.000	1314.132	424.999	947.500	682.551	1996.683
989.999	989.999	525.000	1344.575	439.999	943.000	715.588	2060.163
.004.999	1004.999	525.000	1375.249	454.999	938.500	748.900	2124.149
.019.999	1019.999	525.000	1406.153	469.999	934.000	782.467	2188.620
.034.999	1034.999	525.000	1437.284	484.999	929.500	816.271	2253.555
.049.999	1049.999	525.000	1468.643	499.999	925.000	850.294	2318.937
.064.999	1064.999	525.000	1500.226	514.999	920.500	884.519	2384.744
.079.999	1079.999	525.000	1532.032	529.999	916.000	918.929	2450.960
.094.999	1094.999	525.000	1564.060	544.999	911.500	953.507	2517.567
.109.999	1109.999	525.000	1596.308	559.999	907.000	988.239	2584.547
.124.999	1124.999	525.000	1628.775	574.999	902.500	1023.108	2651.883
.139.999	1139.999	525.000	1661.458	589.999	898.000	1058.100	2719.559
.154.999	1154.999	525.000	1694.358	604.999	893.500	1093.201	2787.559
.160.000	1160.000	525.000	1705.374	610.000	892.000	1104.925	2810.300

WINNIPEG CSO STUDY – FLOW MONITORING '95

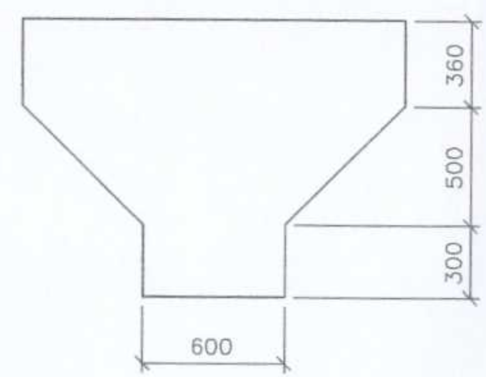
NORTH EAST INTERCEPTOR (72 INCH)

– RATING CURVE –



– WEIR –

(DIMENSIONS IN mm)



RATING CURVE CALCULATION
****

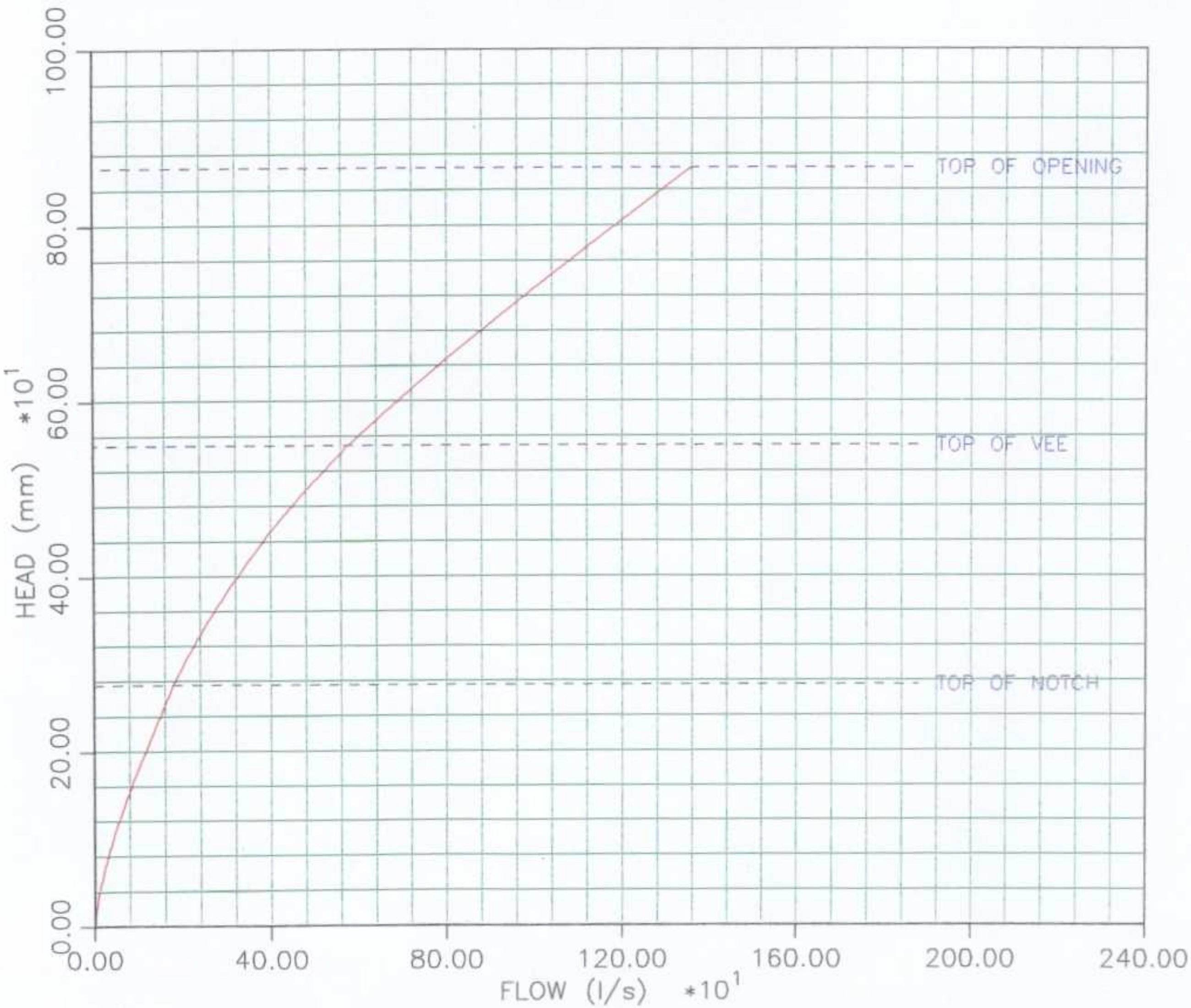
RAW HEAD (mm)	H notch (mm)	L notch (mm)	Q notch (l/s)	H vee (mm)	L vee (mm)	Q vee (l/s)	Q total (l/s)
.000	.000	547.000	.000	-275.000	.000	.000	.000
10.000	10.000	544.500	1.416	-265.000	.000	.000	1.416
20.000	20.000	542.000	3.986	-255.000	.000	.000	3.986
30.000	30.000	539.500	7.289	-245.000	.000	.000	7.289
40.000	40.000	537.000	11.170	-235.000	.000	.000	11.170
50.000	50.000	534.500	15.537	-225.000	.000	.000	15.537
60.000	60.000	532.000	20.329	-215.000	.000	.000	20.329
70.000	70.000	529.500	25.497	-205.000	.000	.000	25.497
80.000	80.000	527.000	31.004	-195.000	.000	.000	31.004
90.000	90.000	524.500	36.820	-185.000	.000	.000	36.820
100.000	100.000	522.000	42.918	-175.000	.000	.000	42.918
110.000	110.000	519.500	49.277	-165.000	.000	.000	49.277
120.000	120.000	517.000	55.877	-155.000	.000	.000	55.877
130.000	130.000	514.500	62.701	-145.000	.000	.000	62.701
140.000	140.000	512.000	69.733	-135.000	.000	.000	69.733
150.000	150.000	509.500	76.958	-125.000	.000	.000	76.958
160.000	160.000	507.000	84.365	-115.000	.000	.000	84.365
170.000	170.000	504.500	91.941	-105.000	.000	.000	91.941
180.000	180.000	502.000	99.675	-95.000	.000	.000	99.675
190.000	190.000	499.500	107.557	-85.000	.000	.000	107.557
200.000	200.000	497.000	115.578	-75.000	.000	.000	115.578
210.000	210.000	494.500	123.728	-65.000	.000	.000	123.728
220.000	220.000	492.000	132.000	-55.000	.000	.000	132.000
230.000	230.000	489.500	140.384	-45.000	.000	.000	140.384
240.000	240.000	487.000	148.874	-35.000	.000	.000	148.874
250.000	250.000	484.500	157.463	-25.000	.000	.000	157.463
260.000	260.000	482.000	166.142	-15.000	.000	.000	166.142
270.000	270.000	479.500	174.907	-5.000	.000	.000	174.907
275.000	275.000	478.250	179.319	.000	.000	.000	179.319
280.000	280.000	478.250	184.232	2.500	10.000	.003	184.235
290.000	290.000	478.250	194.189	7.500	30.000	.051	194.240
300.000	300.000	478.250	204.320	12.500	50.000	.182	204.501
310.000	310.000	478.250	214.620	17.500	70.000	.421	215.042
320.000	320.000	478.250	225.088	22.500	90.000	.790	225.878
330.000	330.000	478.250	235.721	27.500	110.000	1.304	237.026
340.000	340.000	478.250	246.517	32.500	130.000	1.980	248.497
350.000	350.000	478.250	257.472	37.500	150.000	2.832	260.304
360.000	360.000	478.250	268.585	42.500	170.000	3.873	272.458
370.000	370.000	478.250	279.853	47.500	190.000	5.114	284.968
380.000	380.000	478.250	291.275	52.500	210.000	6.568	297.843
390.000	390.000	478.250	302.848	57.500	230.000	8.245	311.093
400.000	400.000	478.250	314.571	62.500	250.000	10.156	324.727
410.000	410.000	478.250	326.440	67.500	270.000	12.311	338.751
420.000	420.000	478.250	338.456	72.500	290.000	14.719	353.175
430.000	430.000	478.250	350.615	77.500	310.000	17.389	368.005
440.000	440.000	478.250	362.917	82.500	330.000	20.331	383.248
450.000	450.000	478.250	375.359	87.500	350.000	23.553	398.912
460.000	460.000	478.250	387.940	92.500	370.000	27.064	415.004
470.000	470.000	478.250	400.659	97.500	390.000	30.871	431.529
480.000	480.000	478.250	413.514	102.500	410.000	34.982	448.495
490.000	490.000	478.250	426.503	107.500	430.000	39.405	465.908
500.000	500.000	478.250	439.626	112.500	450.000	44.148	483.774
510.000	510.000	478.250	452.880	117.500	470.000	49.218	502.099
520.000	520.000	478.250	466.265	122.500	490.000	54.623	520.888

540.000	540.000	478.250	493.422	132.500	530.000	66.462	559.884
549.000	549.000	478.250	505.809	137.000	548.000	72.249	578.059
550.000	550.000	478.250	507.192	138.000	547.700	73.002	580.193
560.000	560.000	478.250	521.087	148.000	544.700	80.635	601.721
570.000	570.000	478.250	535.107	158.000	541.700	88.454	623.560
580.000	580.000	478.250	549.250	168.000	538.700	96.446	645.696
590.000	590.000	478.250	563.516	178.000	535.700	104.598	668.114
600.000	600.000	478.250	577.903	188.000	532.700	112.899	690.802
610.000	610.000	478.250	592.411	198.000	529.700	121.339	713.749
620.000	620.000	478.250	607.038	208.000	526.700	129.906	736.944
630.000	630.000	478.250	621.783	218.000	523.700	138.592	760.375
640.000	640.000	478.250	636.646	228.000	520.700	147.388	784.034
650.000	650.000	478.250	651.625	238.000	517.700	156.285	807.910
660.000	660.000	478.250	666.721	248.000	514.700	165.274	831.994
670.000	670.000	478.250	681.931	258.000	511.700	174.348	856.279
680.000	680.000	478.250	697.255	268.000	508.700	183.500	880.755
690.000	690.000	478.250	712.692	278.000	505.700	192.723	905.414
700.000	700.000	478.250	728.241	288.000	502.700	202.009	930.250
710.000	710.000	478.250	743.902	298.000	499.700	211.352	955.254
720.000	720.000	478.250	759.673	308.000	496.700	220.746	980.419
730.000	730.000	478.250	775.554	318.000	493.700	230.185	1005.739
740.000	740.000	478.250	791.545	328.000	490.700	239.662	1031.207
750.000	750.000	478.250	807.644	338.000	487.700	249.173	1056.816
760.000	760.000	478.250	823.850	348.000	484.700	258.711	1082.561
770.000	770.000	478.250	840.164	358.000	481.700	268.271	1108.435
780.000	780.000	478.250	856.584	368.000	478.700	277.848	1134.432
790.000	790.000	478.250	873.109	378.000	475.700	287.438	1160.547
800.000	800.000	478.250	889.740	388.000	472.700	297.034	1186.773
810.000	810.000	478.250	906.474	397.999	469.700	306.632	1213.106
820.000	820.000	478.250	923.313	407.999	466.700	316.228	1239.541
830.000	830.000	478.250	940.254	417.999	463.700	325.817	1266.071
840.000	840.000	478.250	957.297	427.999	460.700	335.395	1292.692
850.000	850.000	478.250	974.443	437.999	457.700	344.957	1319.400
859.999	859.999	478.250	991.689	447.999	454.700	354.499	1346.188
865.000	865.000	478.250	1000.351	453.000	453.200	359.261	1359.613

WINNIPEG CSO STUDY – FLOW MONITORING '95

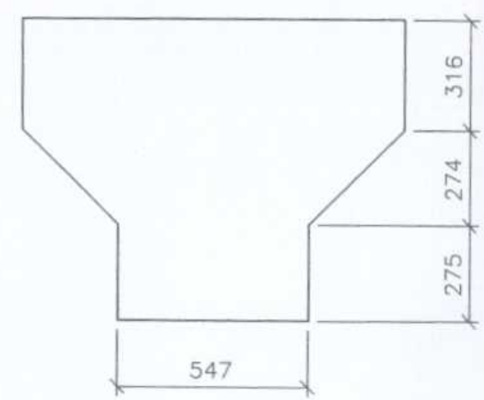
NORTH WEST INTERCEPTOR (60 INCH)

– RATING CURVE –



– WEIR –

(DIMENSIONS IN mm)



Concluding Remarks

The final data reduction and quality checks for the 1996/97 data are nearly complete. This work is taking into account the changed D1 values, and the fact that City crews were measuring to the bottom rather than the top of the D2 brackets. The rating curve at the NE site is also being adjusted to compensate for the partial blockage of the opening by the stilling wells. Daily average flows for the 1996 and 1997 years will be compared as a further quality check before final plots of events of interest are prepared. I intend to complete this work and have the data ready for transmittal on April 21, 1998.

Yours very truly,

Adrian Ufcoombe

for Larry Thompson, M.A.Sc., P.Eng.

M. Parente

Mario Parente, P.Eng.

awc
Enclosures

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3.4.2 *Determination of Rating Curves and Conversion of Levels to Flowrates*

In order to convert measured levels to flowrates, rating curves were needed for each station. A rating curve is a relationship (a "curve" or a plot) between depth of flow and flowrate. Rating curves can be generated for the stations using Manning's equation as shown below:

$Q = \frac{1}{n} AR^{2/3} S^{1/2}$ where

Q = flow in m^3/s
n = roughness coefficient known as Manning's "n"
A = cross sectional flow area (m^2)
R = hydraulic radius = A/P
P = wetted perimeter (m)
S = slope of energy grade line which is assumed equal to pipe slope (uniform flow assumption)

A Manning's "n" of 0.013 is typically used for design but it was desired to verify this if possible for use in flow monitoring.

Upon review of the Level Fixing Sheet for Station 70, (see Table 3.3) it was noted that on the October 8, 1991 data retrieval, the FLO-TOTE velocity closely matched that obtained with two different current meters. The FLO-TOTE level also compared well with the manually measured level.

Thus, the directly measured FLO-TOTE flows were valid at that point in time. It was decided to abstract a range of level-flow values for a few days near October 8 for use in verifying a rating curve. The level-flow values were separated into two groups as follows:

- rising stage (values obtained when levels are rising)
- falling stage (values obtained when levels are falling)

This was done to check for hysteresis and thus the validity of uniform flow assumptions. The data were input into a rating curve program based on Manning's equation with "n" varying with flow depth (as used by Metro flow monitoring group). The full pipe "n" was varied to get the best fit of observed points to the calculated curve (see Figure 3.2). It was found that a value of 0.015 gave a close agreement, and there was no evidence of hysteresis. However, the validation data only covered a small portion of the rating curve.

In order to assess the high flow portion of the rating curve, values of level-flow during periods of high flow rate, were reviewed even though field checks indicated the velocity was in error. These additional groups of uncorrected level-flow pairs were input to the rating curve program and a new plot produced (see Figure 3.3).

It was noted that these new groups of data appeared to come from separate "populations". From Table 3.3, velocity correction factors were determined for each

CIRCULAR PIPE RATING CURVE - VARIABLE "N

METRO MON. STN. #70 (60 in) - WEST DON STS. - "Nfull"=0.013

- RATING CURVE -

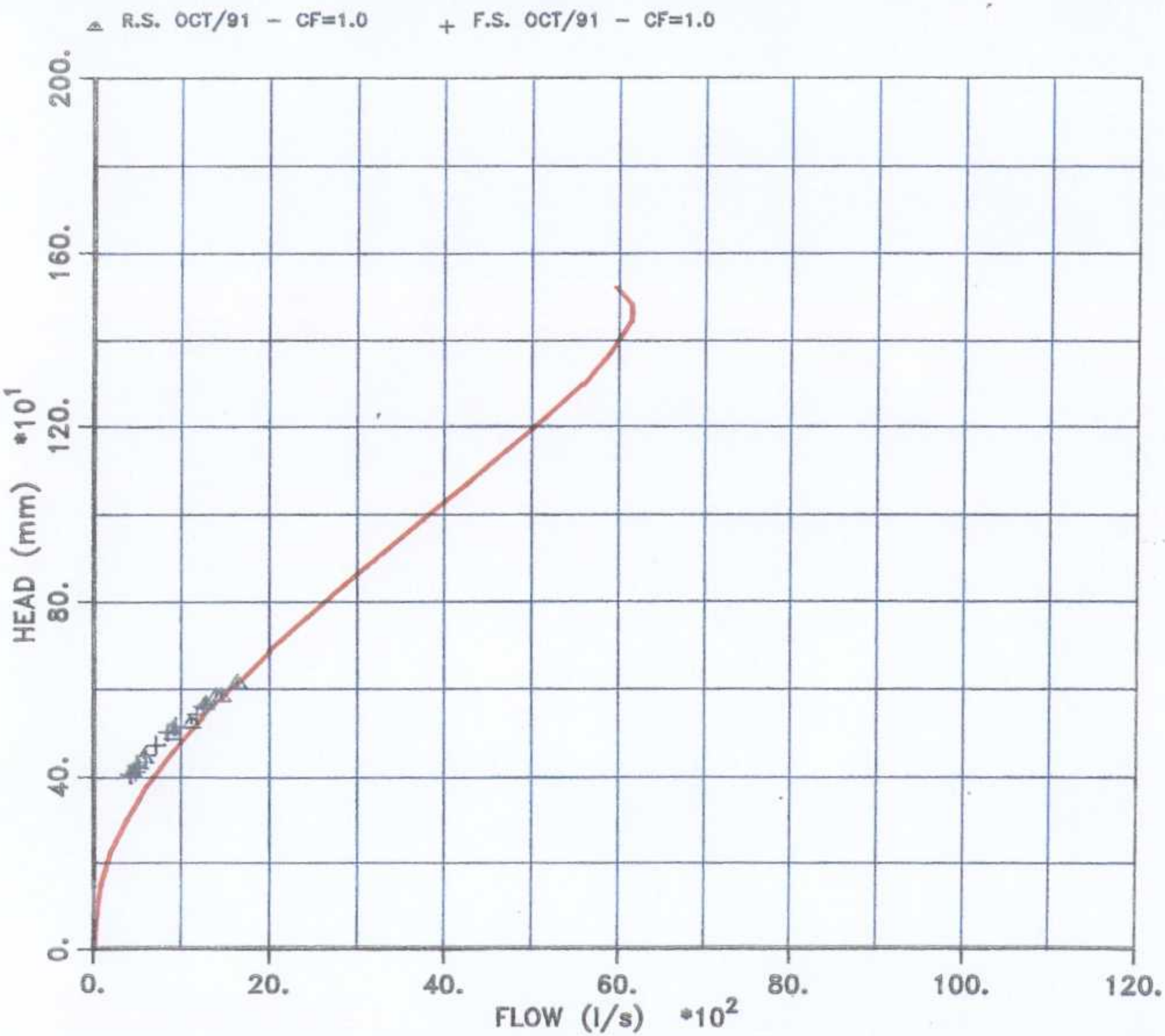
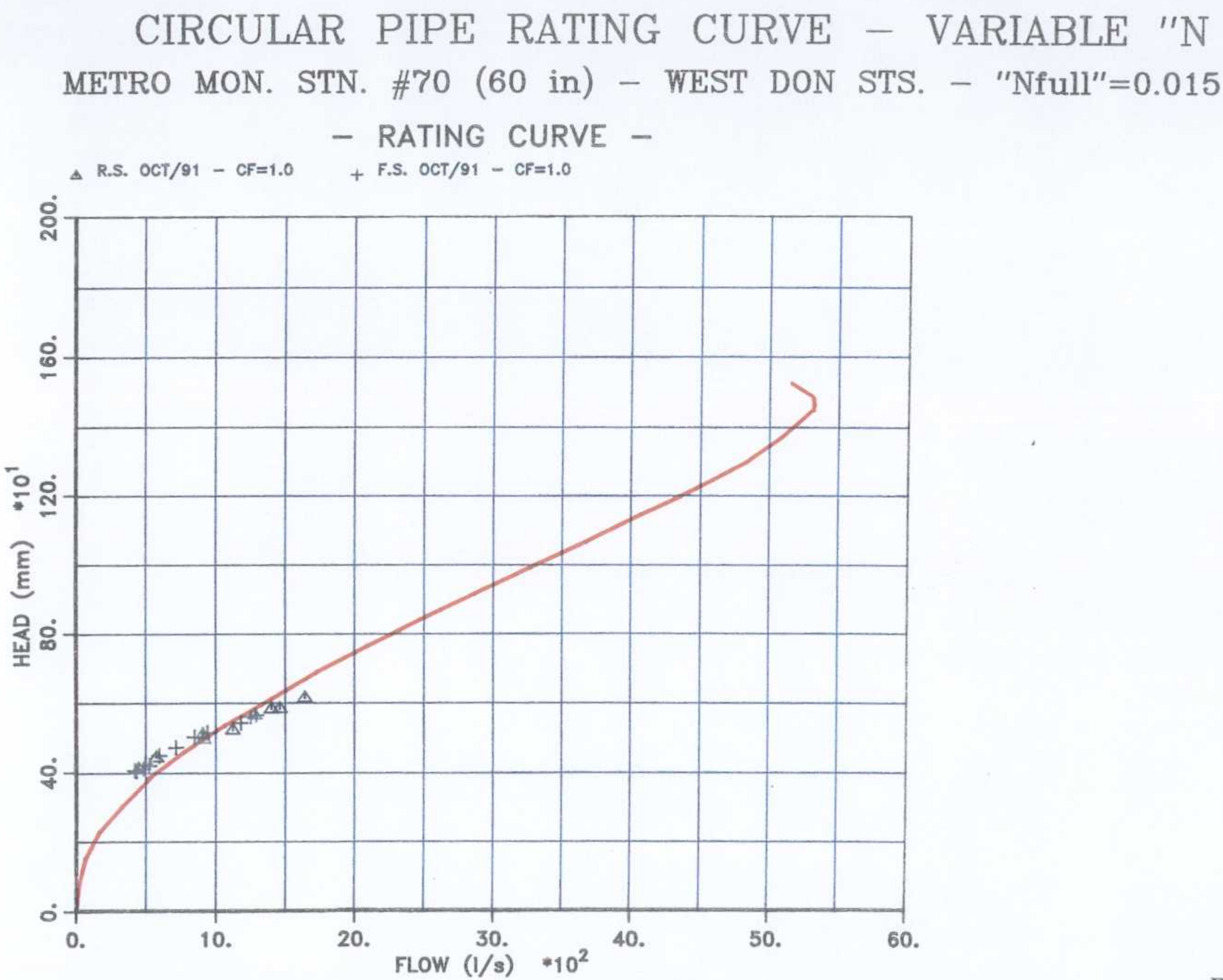


Figure 3.1



CIRCULAR PIPE RATING CURVE - VARIABLE "N
METRO MON. STN. #70 (60 in) - WEST DON STS. - "Nfull"=0.015
- RATING CURVE -
R.S. OCT/91 - CF=1.0
F.S. OCT/91 - CF=1.0
HEAD (mm) *10^1
0.
40.
80.
120.
160.
200.
FLOW (l/s) *10^2
0.
10.
20.
30.
40.
50.
60.

Figure 3.2

CIRCULAR PIPE RATING CURVE - VARIABLE "N

METRO MON. STN. #70 (60 in) - WEST DON STS. - "Nfull"=0.015

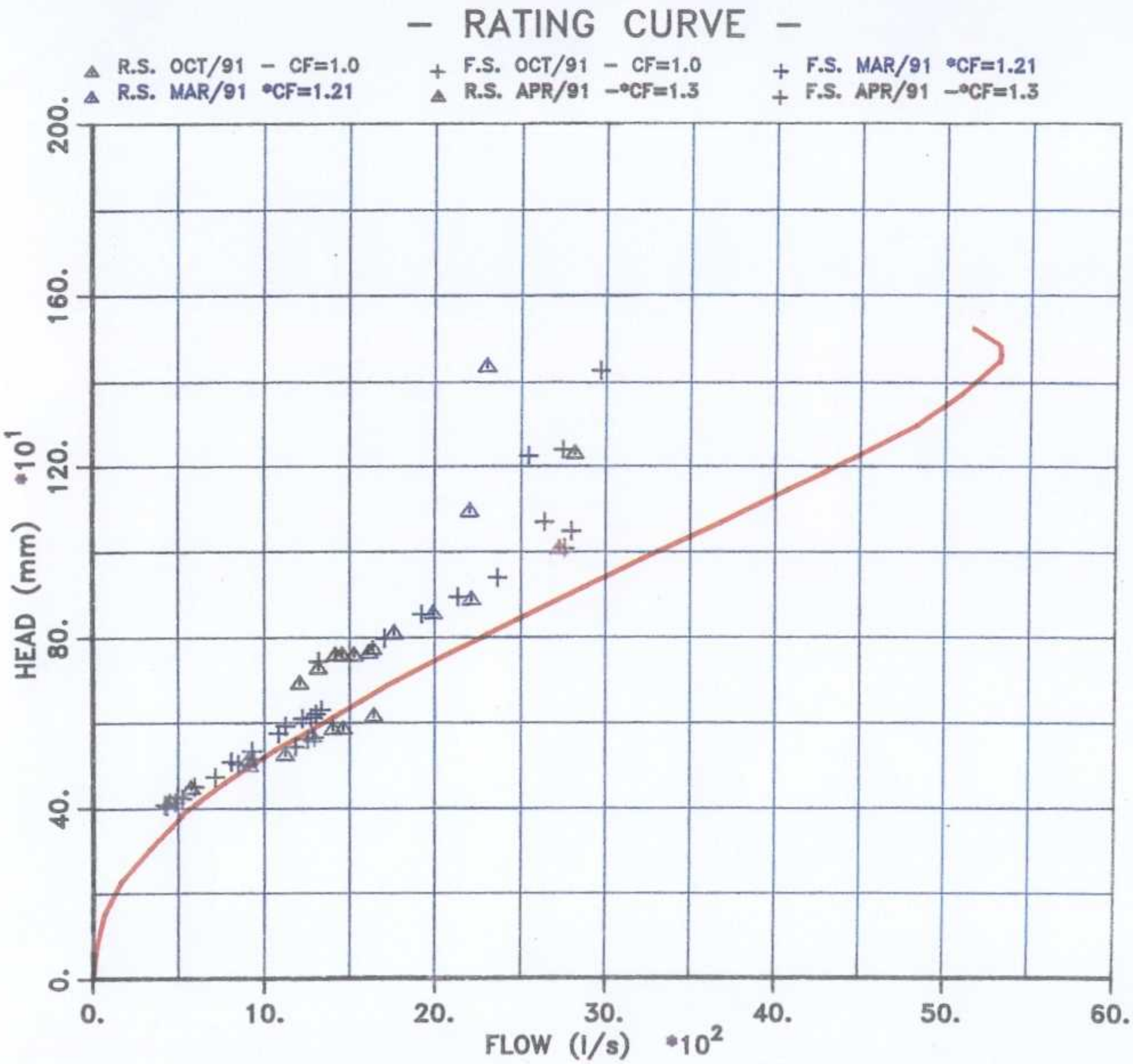


Figure 3.3

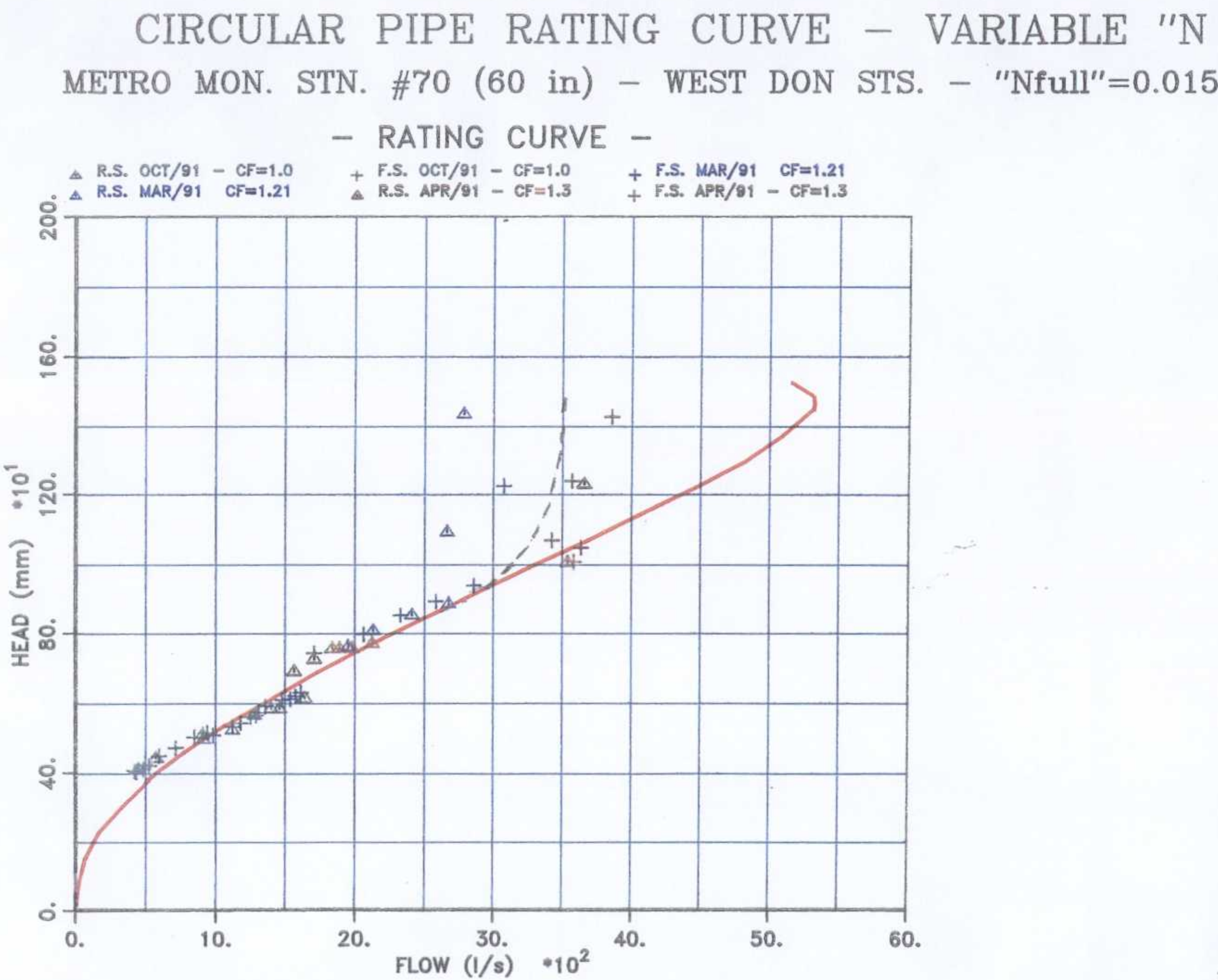

CIRCULAR PIPE RATING CURVE - VARIABLE "N
METRO MON. STN. #70 (60 in) - WEST DON STS. - "Nfull"=0.015
- RATING CURVE -
R.S. OCT/91 - CF=1.0
R.S. MAR/91 CF=1.21
F.S. OCT/91 - CF=1.0
R.S. APR/91 - CF=1.3
F.S. MAR/91 CF=1.21
F.S. APR/91 - CF=1.3
HEAD (mm) *10¹
FLOW (l/s) *10²
0.
40.
80.
120.
160.
200.
10.
20.
30.
40.
50.
60.

Figure 3.4

group of points based upon the current meter versus FLO-TOTE velocities at each data retrieval. These correction factors were applied to the data and the rating curve replotted (Figure 3.4). From Figure 3.4, it can be seen that the observed points from all groups compare closely with the computed curve until the level reaches approximately 75% of the full pipe depth. At this point, the observed points vary significantly from the computed curve and between events.

This suggests the presence of excessive hydraulic losses at the location of Station 70. These could originate from the manhole configuration at this location and could most likely be rectified. At the present time, however, the full pipe capacity at Station 70 appears to be about 3500 l/s, significantly less than what would normally be expected. The cause of the apparent loss of capacity should be investigated.

For all stations, where valid velocity data could be found, this procedure just described for Station 70 was applied to calibrate the effective Manning's "n". The following results were obtained for stations listed below:

Station	Calibrated "n"
40	.013
69	.011
57	.012
70	.015
55	.011
64	.011
68	.011

No evidence of excessive losses was found at these other stations. Manning's "n" for other stations not listed above were selected based on calibrated values on the same trunk sewer or set to the design value of .013 in the absence of nearby calibrated values.

Rating curves for all circular pipe monitoring stations may be found in Appendix A.

It is important to note that the values obtained in this manner are intended for use in converting measured depths to flowrates. For design purposes, the higher, and therefore more conservative value of .012 or .013 (except for Station 70), would be appropriate to ensure a factor of safety.

The rating curves developed above were used by a program to convert the database of flow depths to flowrates.

3.5 RAINFALL DATA

Rainfall data for 1991 were obtained from the City of Toronto for their Kimberley rain gauge located in the vicinity. These data were also input to the database for comparison with the monitored levels and flows.

ATTACHMENT 3

Flow Monitoring Plots

- 1996/97 – Yearly
- 1996 – Biweekly
- 1997 – Biweekly
- 1996 – Event Plots
- 1997 – Event Plots

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RECEIVED
MAY 07 1998
TetrES

TetrES Consultants INC.,
603-386 Broadway,
Winnipeg, Manitoba,
Ontario.
R3C 3R6

May 3, 1998

Attention: Mr. Nick Szoke, P. Eng.,
Senior Engineer, Associate

Dear Nick :

Re: **Winnipeg CSO Project – Flow Monitoring**

You should have recently received the following colour copy sets of flow plots for this project :

- Yearly flow plots for 1996 & 1997
- Biweekly flow plots for 1996
- Biweekly flow plots for 1997
- Event plots for 1996 (5 plots)
- Event plots for 1997 (7 plots)

This letter is intended to accompany and describe these sets of flow plots that were produced following the re-processing of "raw water levels" to flows.

DATA REDUCTION

In carrying out this processing of data, attention was paid not just to the instantaneous values obtained in the field but also the values in the dataset at the time of data retrieval (particularly at times when there was "chatter" in the readings). This work also took into account additional field inspection readings, which we did not previously have, and certain other factors, which we became aware of during our visit in December, 1997.

The first factor was that the stilling well locations at the Douglas site had been changed in such a way that the "weir" opening was partially blocked, thereby affecting the rating curve. The rating curve was adjusted slightly to try to compensate for this and it was assumed that the change occurred in April, 1996 when the downstream sensor was moved upstream to add redundancy. The stilling wells were reset to the intended orientation during our December 10, 1997 visit.

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4129 Varden Court
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The second factor was that the reference points for manual measurement of "head" on the weir (D2 brackets) which had been set "flush" with the top of the "weir" crossbar had been bent slightly downward at some point in time. Thus the distance from the reference point to the weir lip (D1) was slightly less than was believed making all measured "heads" less by the same amount. This factor was most noticeable at the Douglas site where D1 was found to be 1193 mm rather than the original 1200. The bracket there was straightened on December 10, 1997 such that the D1 value became 1198 mm. At the Leila site the D1 value had been reduced to 908 mm from the original 914 mm and it was left at that. We do not know when these reference points changed but have assumed it was before re-installation of the sensors in April of 1996.

The third factor was that the field crew personnel told us that they had frequently taken manual readings from the bottom rather the top of the D2 brackets. This would make a difference of about 20 mm in the readings. It is not known at what time which crew members began taking readings in this manner but knowing it occurred was very helpful. The manual readings are used to establish the elevation of the weir lip relative to the water level sensor, to check on the accuracy of the data, and to check for movement of the sensor. If the sensor is at the same location, and working correctly the adjustment of "raw levels" to "heads" should be a constant. Successive manual readings should indicate the same adjustment +/- a tolerance (accuracy of reading, water surface fluctuations, and sensor stability). The mean of a number of such adjustments will be much more accurate than any one reading since the random errors will tend to cancel out. In carrying out this new data processing we initially assumed all City crew readings were taken from the bottom of the D2 bracket. We then found that most readings were "clustered" around one adjustment value but that there were a number of readings which indicated a value which differed from the first by about 20 mm. We then assumed that these were occasions when the measurement was taken from the top of the D2 bracket as was originally intended.

Another complicating factor was the time base of the loggers relative to that of the manual readings. It was intended that the loggers be kept at CST as is the practice of the WSC and notations were to be put at the bottom of the inspection sheets to assist in converting from local time to CST when they differ during the summer (April-October) so that the manual reading times would also be at CST. From carefully examining the data it was apparent that the time of some manual readings were recorded as local rather than CST. An example of this was the logger re-installation on April 11, 1996. The time of the manual readings/installation was given as 10:30 but the loggers started recording data at 9:30. We have found this to be a common problem with all field crews and now simply request "local" time and make adjustments as necessary in the office (we at least know for certain when the readings were taken). The City instituted an excellent check on this with their new inspection sheet format, which came into use during 1997. On this form both logger and local time are recorded. There is also mention made of changing the time of the loggers on one occasion to match local time, which would create a problem since either a gap or an overlap of data occurs. Knowing the correct time of manual readings is particularly critical when inspections are done in mid-morning (when most were) since at that time of day the levels change greatly over a one hour time span. The timing of measurements made in the early afternoon is less critical since levels are fairly stable at that time of day. When reducing the data attempts were made to check for local versus CST time by comparing the instantaneous logger's readings recorded to those in the logger dataset at the noted time. If the values were in general agreement it was concluded that the time recorded on the sheet matched that in the logger. If values differed significantly during the DST time of year, the logger value 1 hour previous was checked.

COMMENTS ON SOME DATA ANOMOLIES

The City has previously noted that data from the Douglas site does not appear to be as stable as that for the Leila site during the winter months. On our visit in February, 1996, the logger at the Douglas site was found frozen in a block of ice whereas the Leila logger was simply wet. The Leila logger is in a warmer location since the sewer is shallower (logger closer to "warm" flow) and is under a heavily travelled roadway. When the logger gets frozen in a block of ice one or more of the sensor atmospheric reference vents can become blocked. In such a case the affected sensor will record absolute rather than relative pressure and readings will fluctuate with barometric pressure. Barometric pressure can vary by 1 inch of mercury from day to day, which corresponds to 13.6 inches of water. This factor would be a problem with any instrument that uses pressure transducers to measure water depth (including almost all commercial V-A meters).

The City has also noted that following surcharge events both the 2.5 and 5.0 psi sensors at the Douglas site differ although they may have agreed before the event. There are a couple of reasons this could occur.

The first of these is that when the 2.5 psi sensor is over pressured it appears to read low for about a day afterwards. An example of this can be seen on the plot for the June 6, 1996 event, which exceeded the range of the 2.5 but not the 5.0 psi sensor. The 2.5 psi sensor matched the 5.0 well before and during the event but read lower for almost a day afterwards. After this surcharge event it's readings gradually converged on those of the 5.0 psi sensor.

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Another cause that can affect either sensor during surcharge is if debris becomes caught on the sensor cable, which then pulls the sensor up the stilling well causing a low reading. There was at least one instance where levels after a large event were somewhat different than expected but shifted to normal abruptly following an inspection.

During very large surcharge events the 5.0 psi sensor at the Douglas site indicates that the surcharge fluctuated up and down very rapidly. Data from the May 20, 1996 event reveals that this may not actually be what is happening. During this event the both sensors were over pressured .The 5.0 psi sensor showed the level during the apparent peak of the event to drop suddenly within the range of the 2.5 psi sensor which did not show such a drop. We suspect that when the 5.0 psi sensor is over pressured, it does continue to approximately track the rising level but shows it as a "reflection " about its nominal maximum value.

CONCLUDING REMARKS

There are a number of events for which the data appears excellent. This is confirmed by agreement between "redundant" probes and by agreement with manual readings obtained shortly before or after the event. We are unfortunately missing even daily rainfall amounts for the largest events, which seem to occur in April. It is possible that snowmelt may be a factor in some of these as well in which case snow course and/or temperature data would be useful.

We look forward to discussing this data with you. Please EMAIL or call at your convenience.

Yours truly,

Larry Thompson

Larry Thompson, M.A.Sc., P. Eng.
President,
Thompson Flow Investigations Inc.

cc: Mr. Mario Parente, P.Eng.
CH2M Gore & Storrie Limited

lrt/KDD

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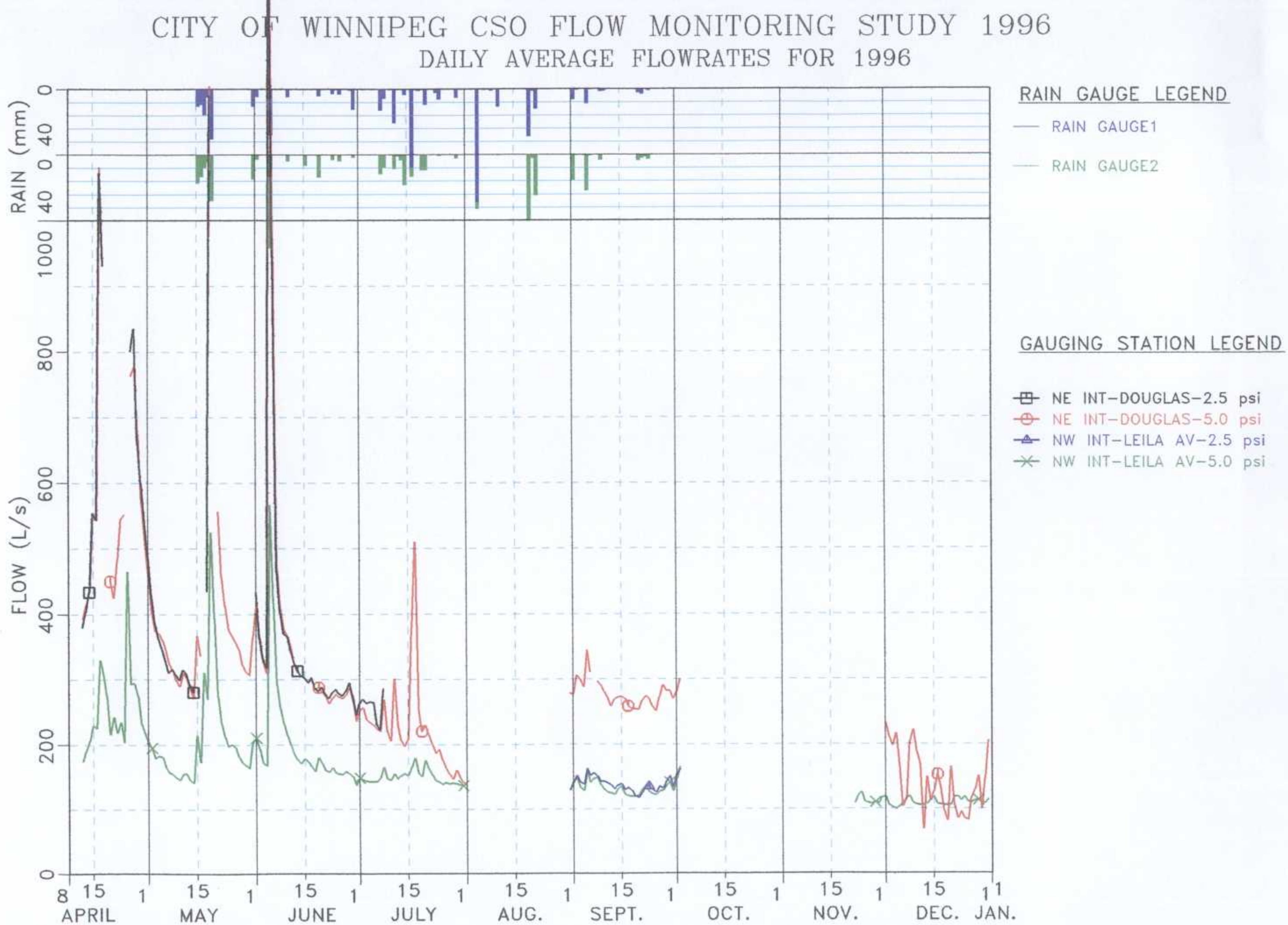
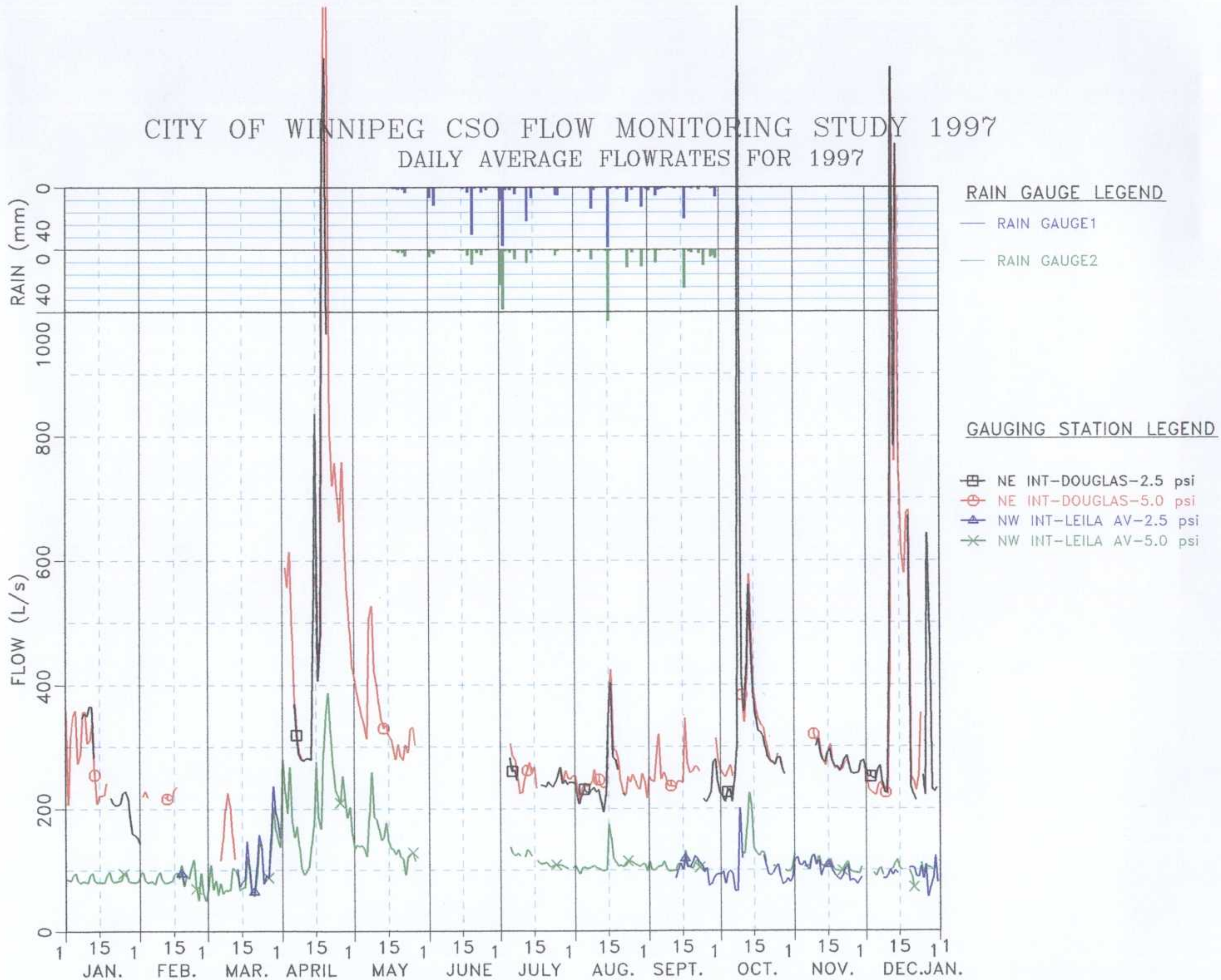
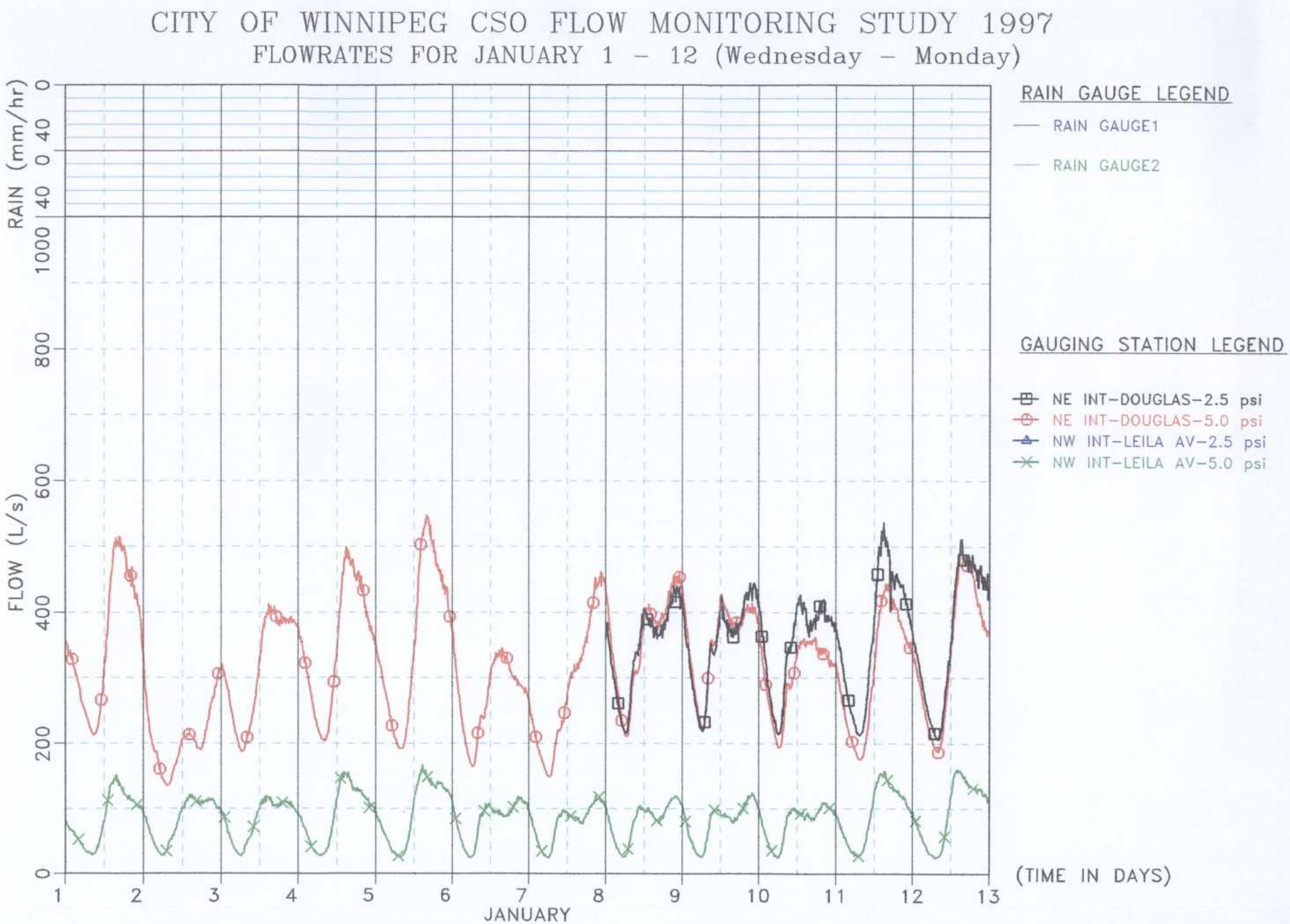


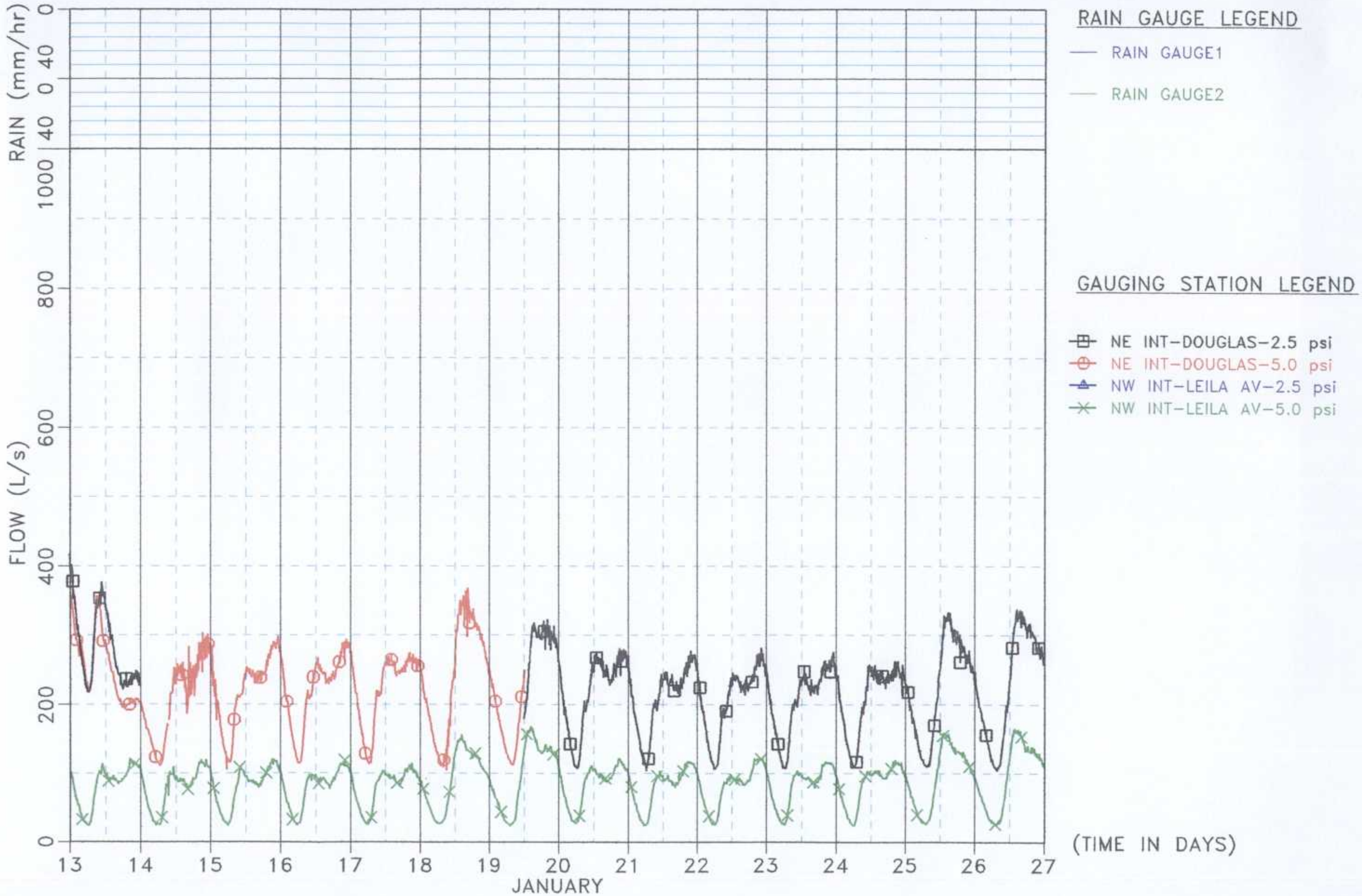
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996
DAILY AVERAGE FLOWRATES FOR 1996
RAIN (mm)
FLOW (L/s)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.

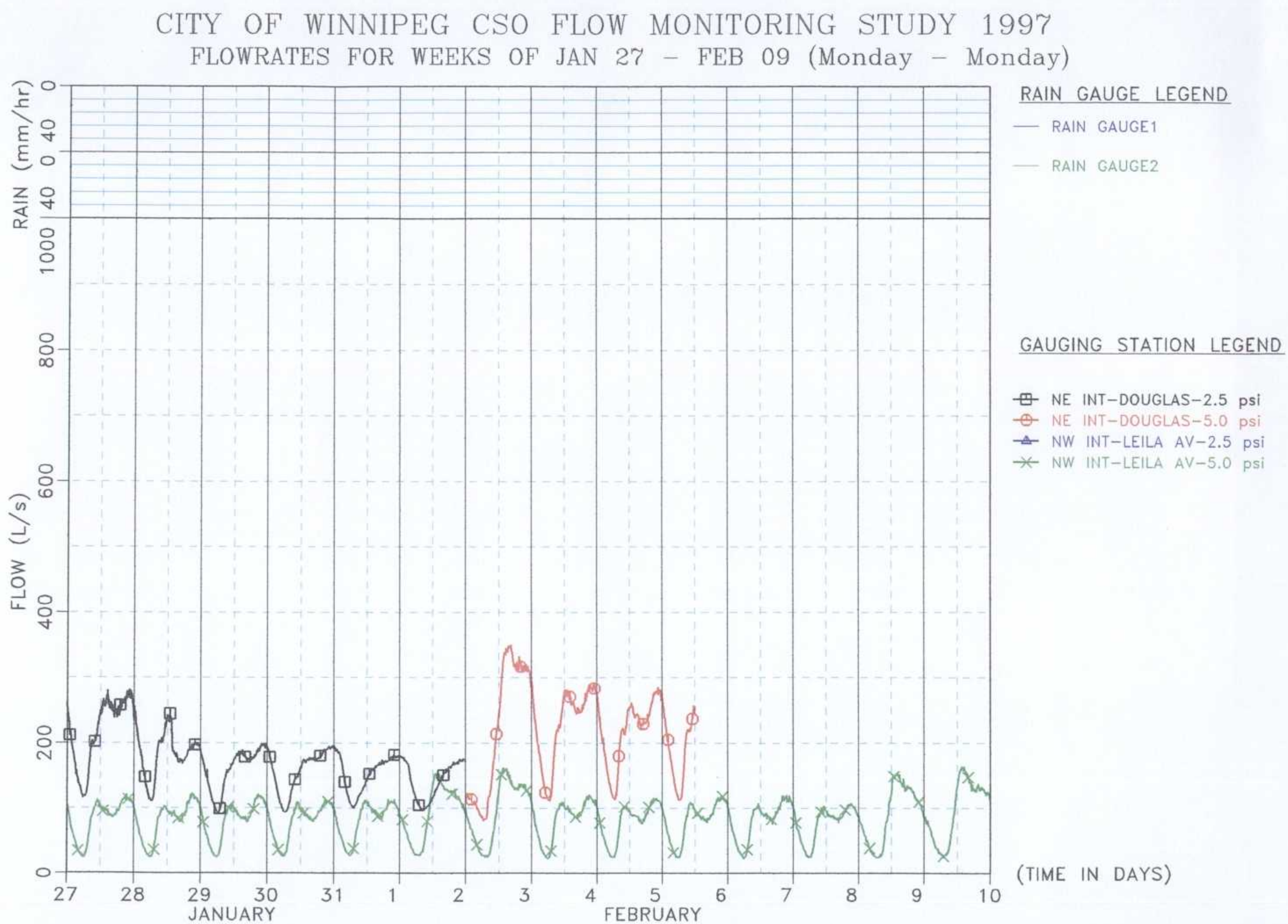


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
DAILY AVERAGE FLOWRATES FOR 1997
RAIN (mm)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
1 15 1 15 1 15 1 15 1 15 1 15 1 15 1 15 1 15 1 15 1 15 1 15 1 1
JAN. FEB. MAR. APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN.
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi

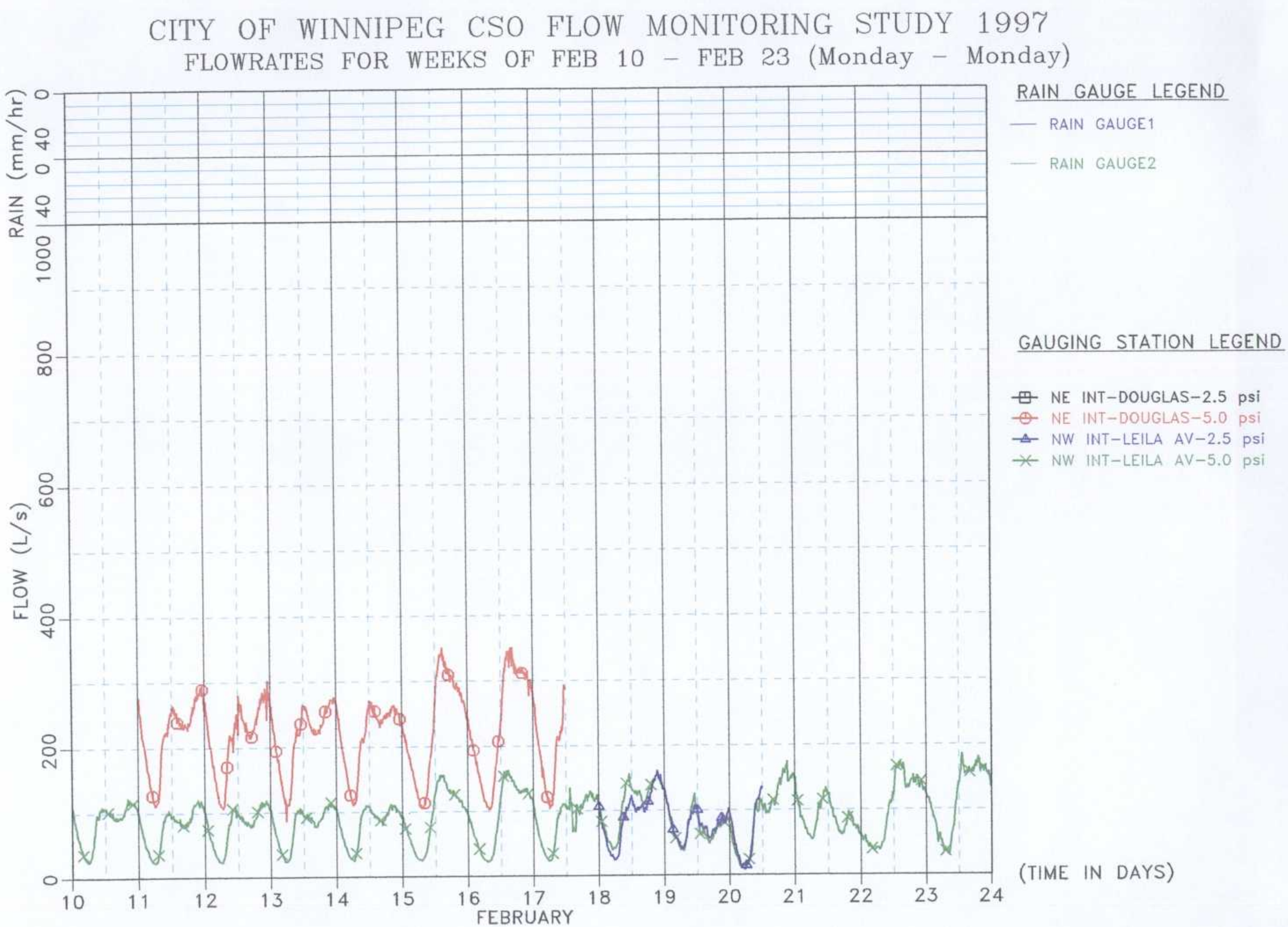

CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR JANUARY 1 - 12 (Wednesday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)
1
2
3
4
5
6
7
8
9
10
11
12
13
JANUARY

CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF JAN 13 - JAN 26 (Monday - Monday)





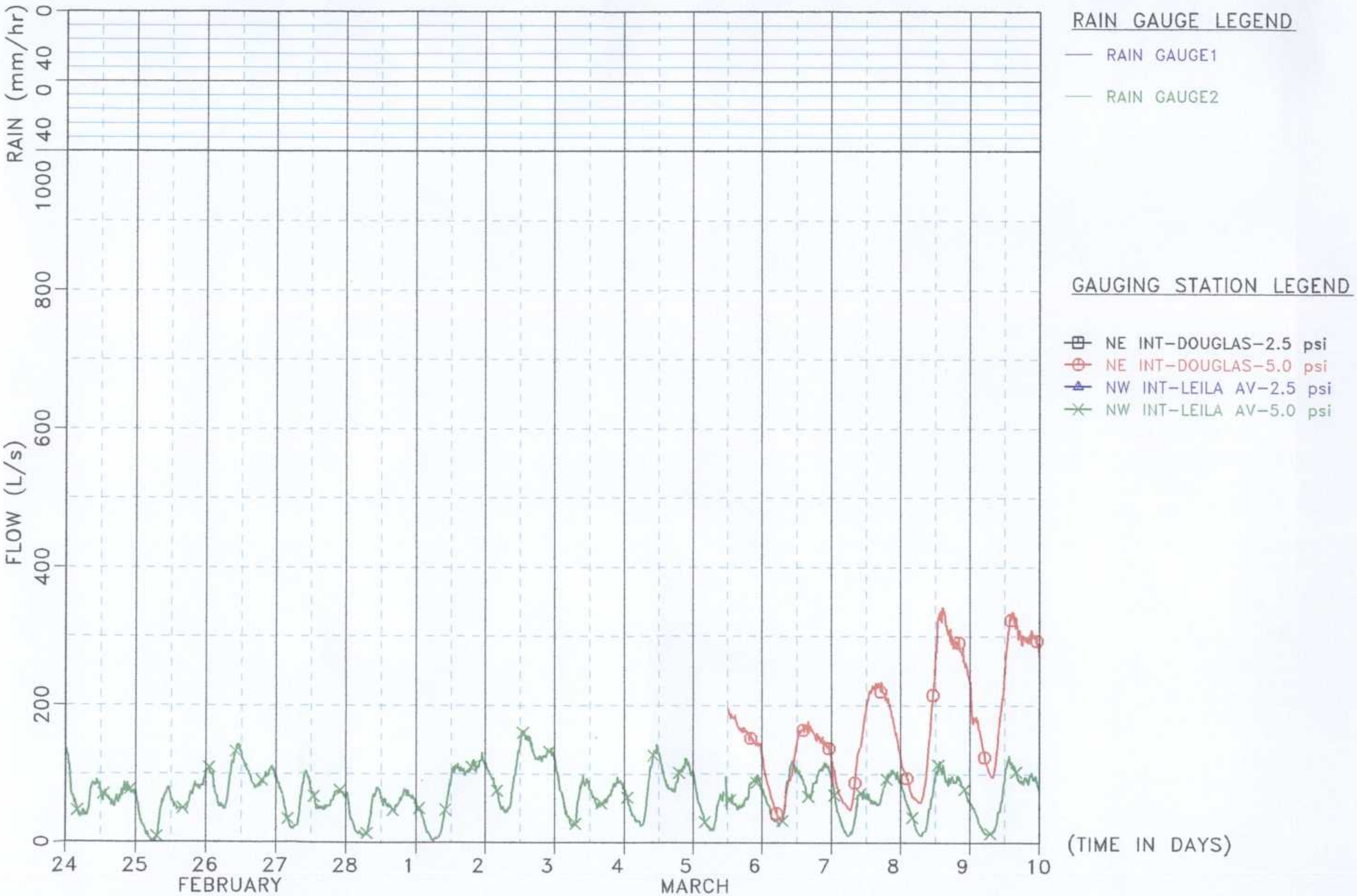
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF JAN 27 - FEB 09 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
27
28
29
30
31
1
2
3
4
5
6
7
8
9
10
JANUARY
FEBRUARY
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi



CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF FEB 10 - FEB 23 (Monday - Monday)
RAIN (mm/hr)
FLOW (L/s)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)
FEBRUARY

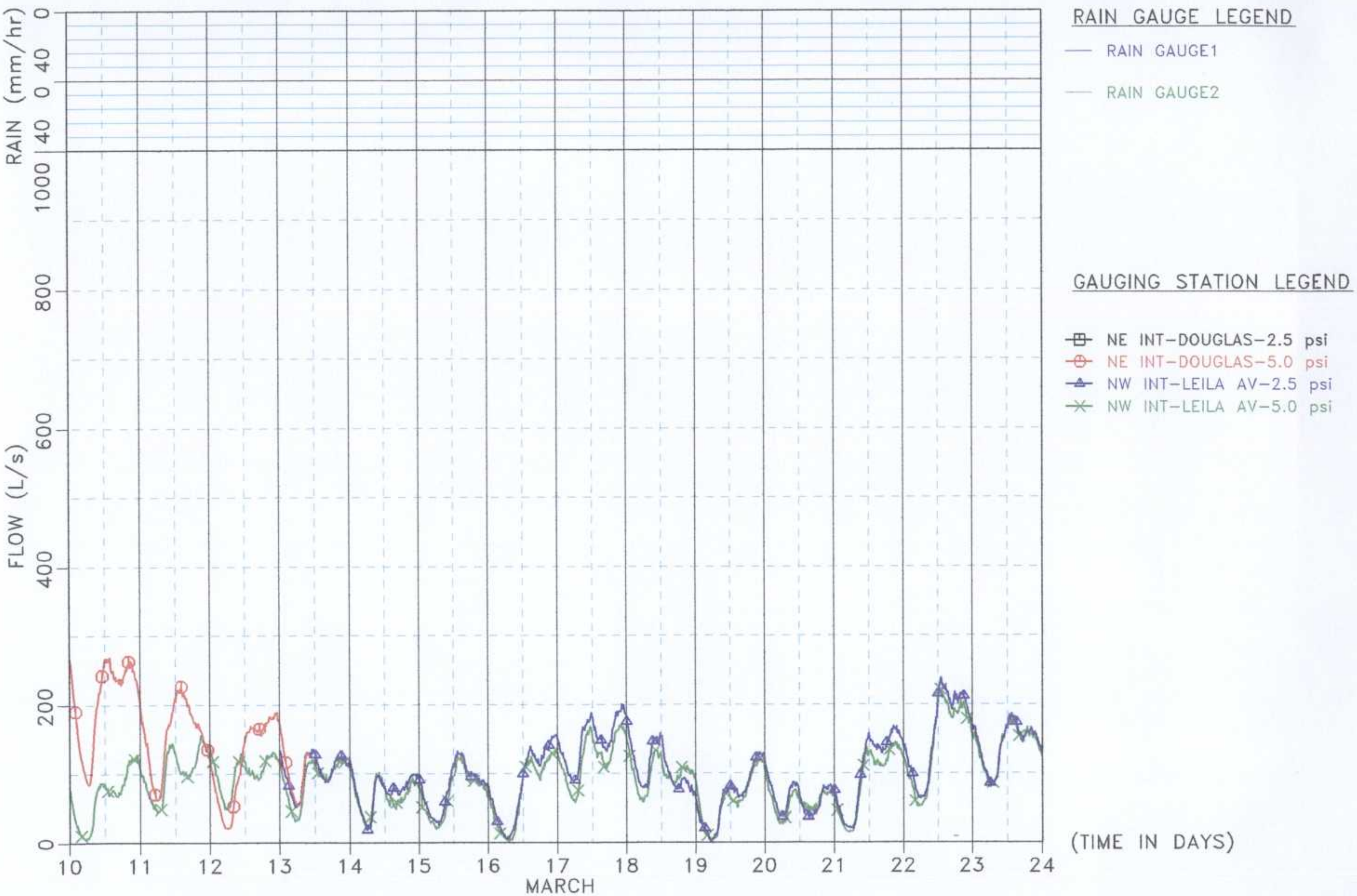
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997

FLOWRATES FOR WEEKS OF FEB 24 - MAR 09 (Monday - Monday)



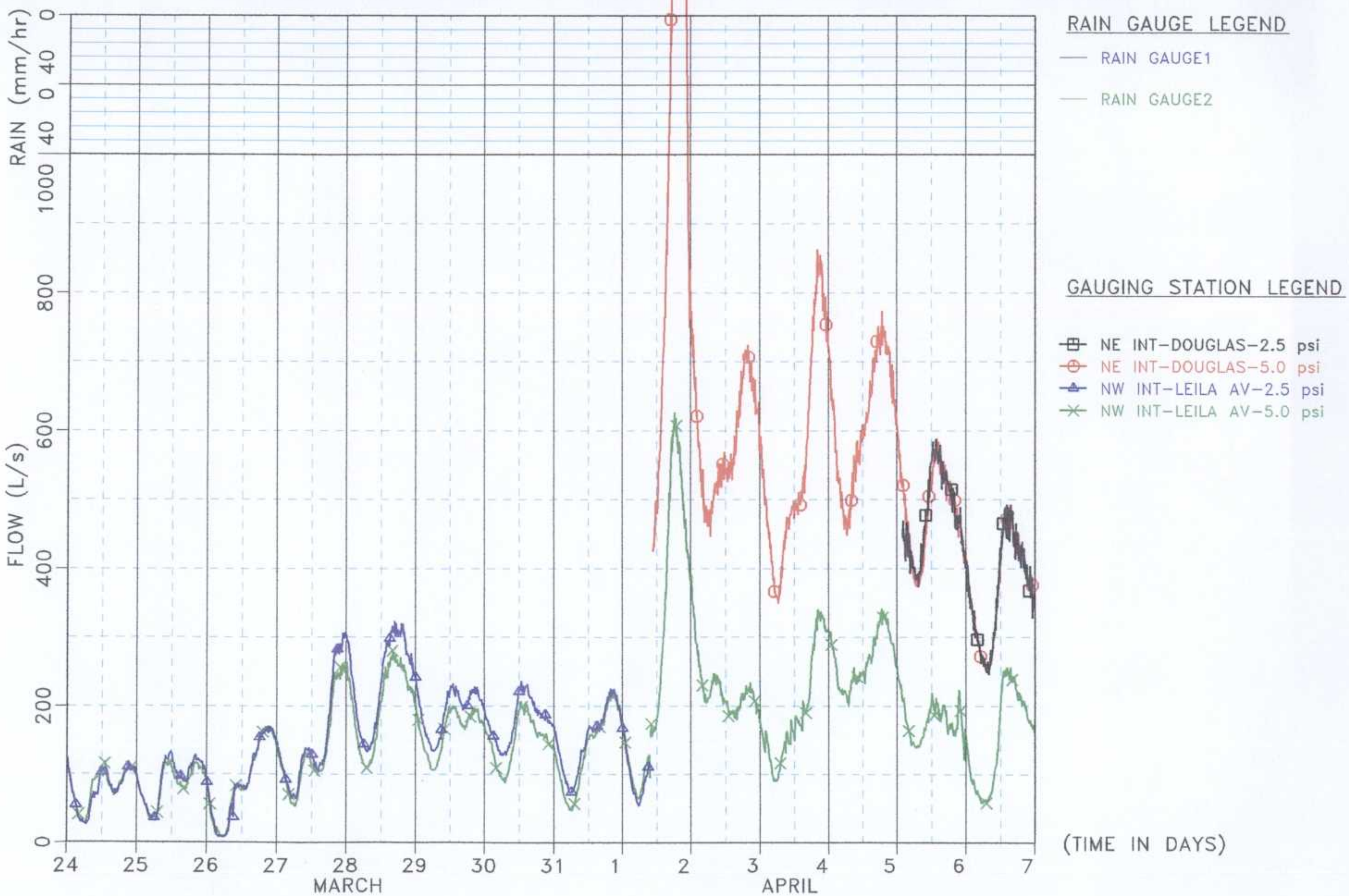
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997

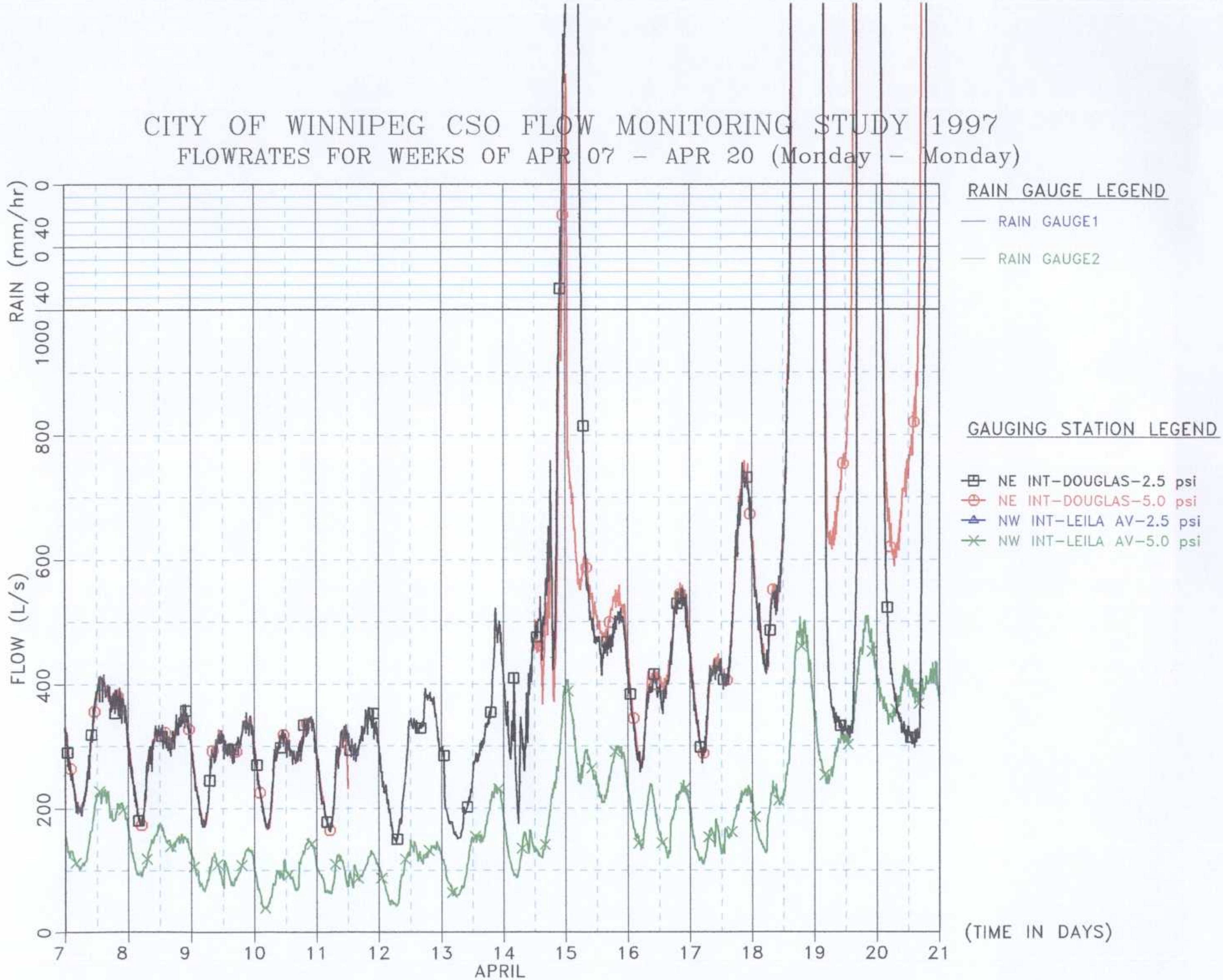
FLOWRATES FOR WEEKS OF MAR 10 - MAR 23 (Monday - Monday)



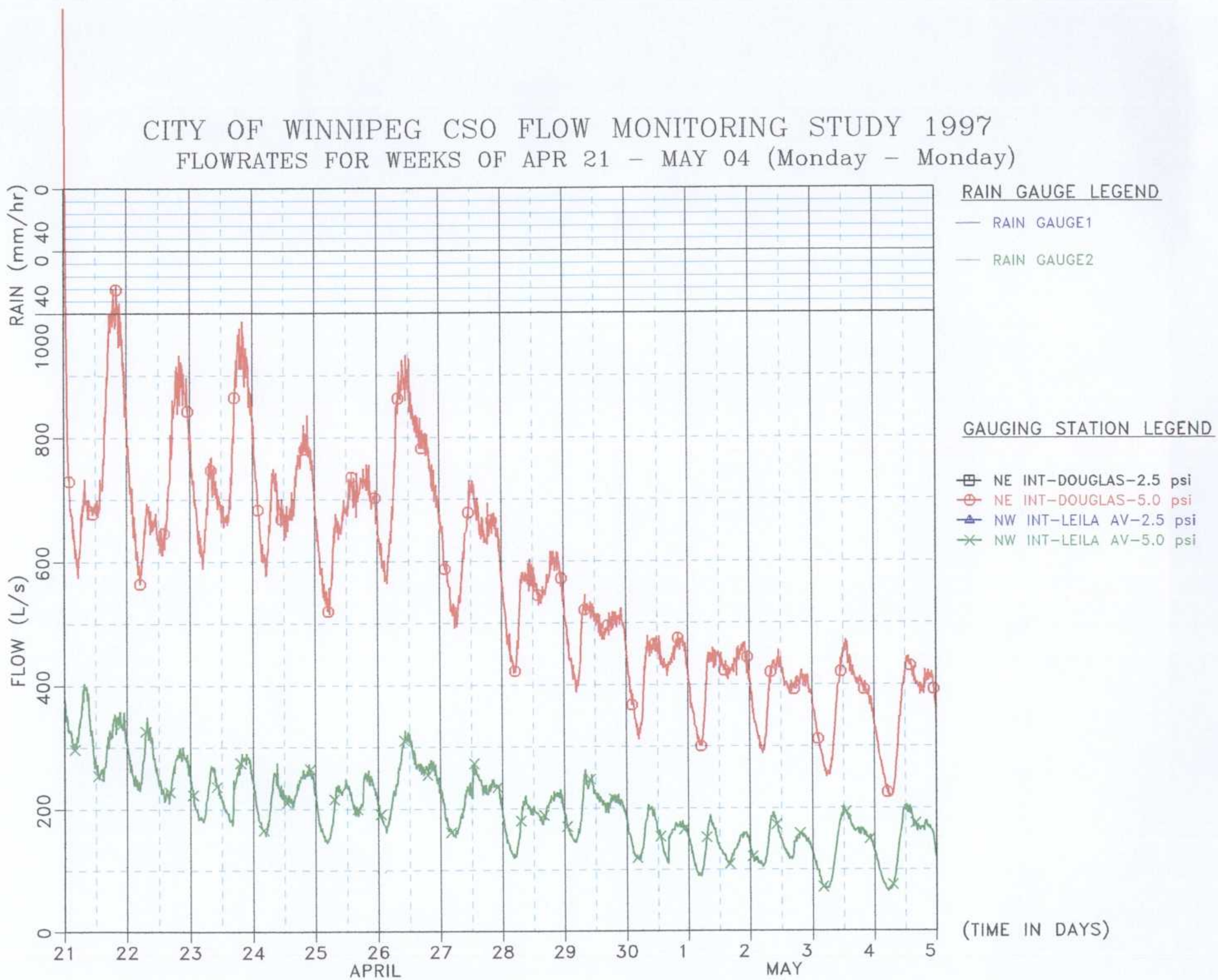
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997

FLOWRATES FOR WEEKS OF MAR 24 - APR 06 (Monday - Monday)

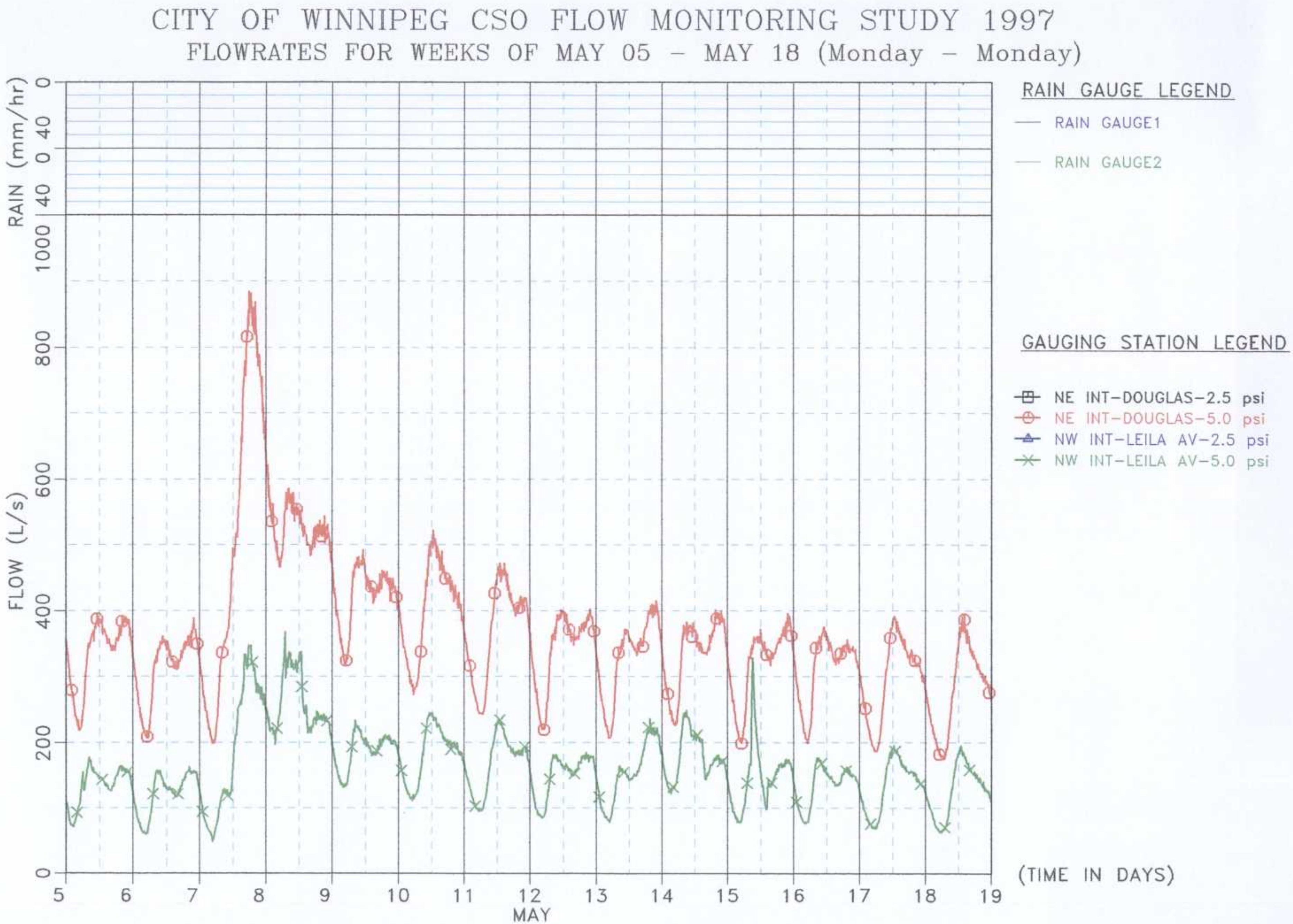




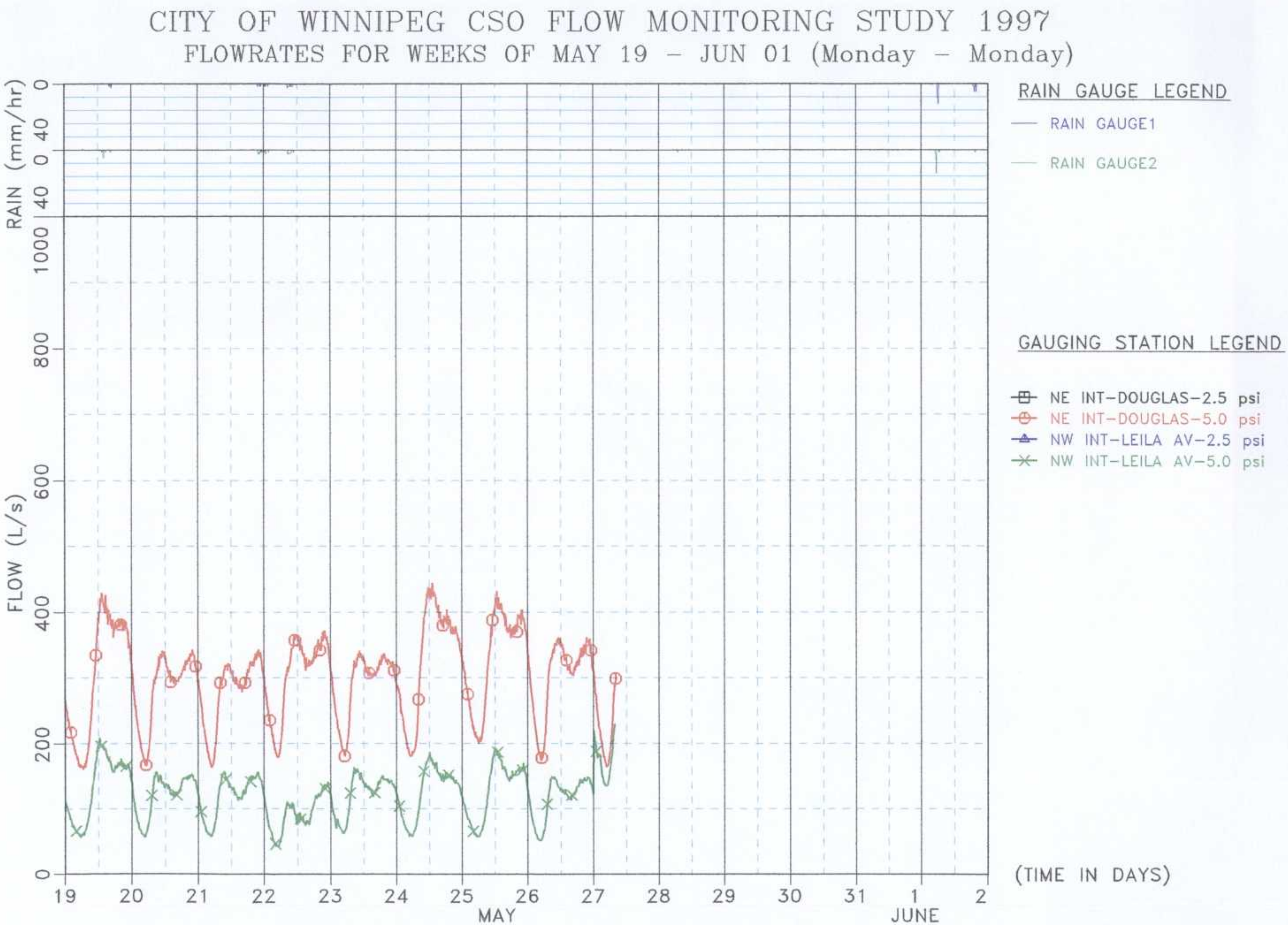
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF APR 07 - APR 20 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
0
200
400
600
800
1000
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
APRIL
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi

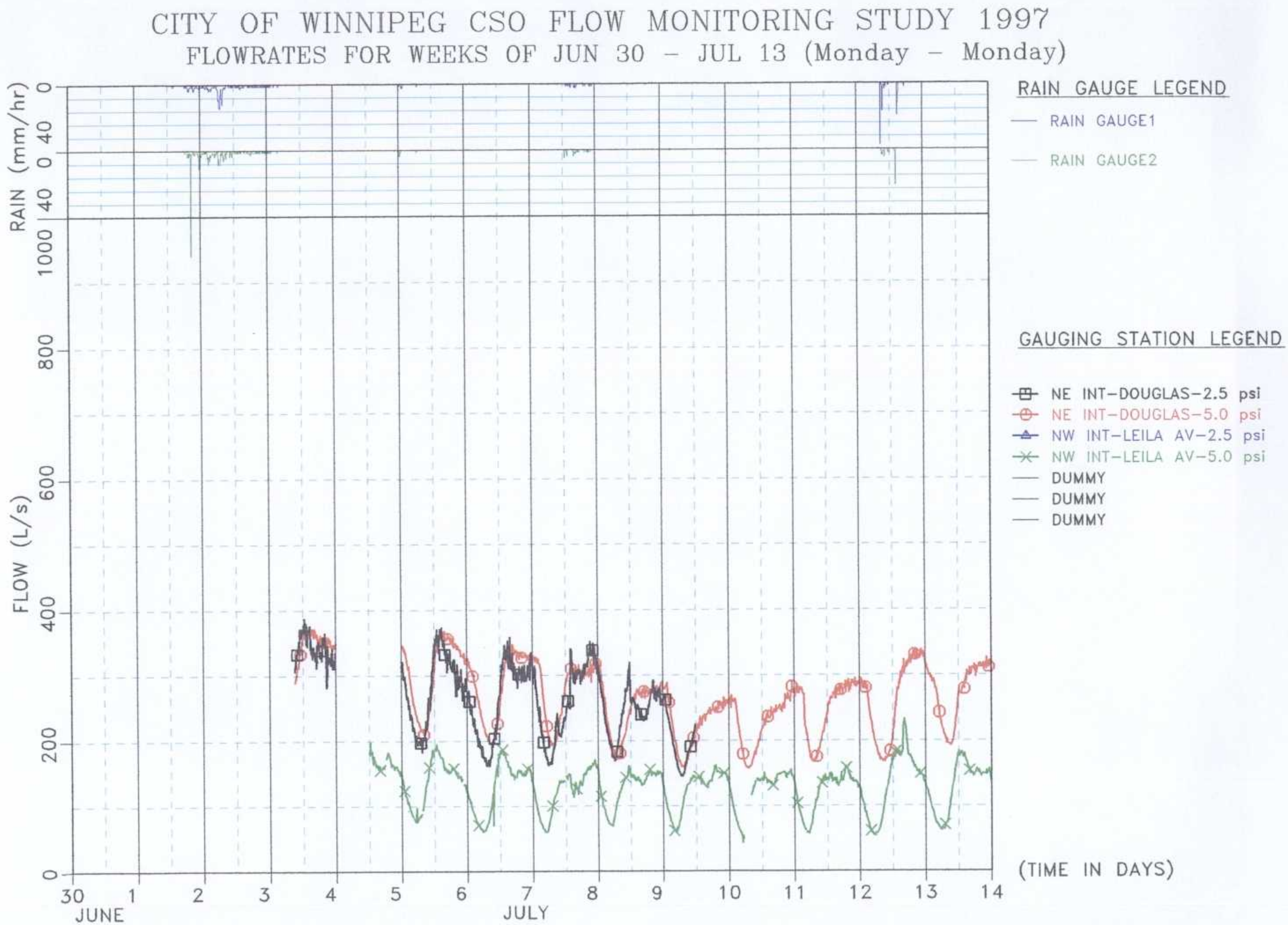


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF APR 21 - MAY 04 (Monday - Monday)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
21
22
23
24
25
26
27
28
29
30
1
2
3
4
5
APRIL
MAY
(TIME IN DAYS)

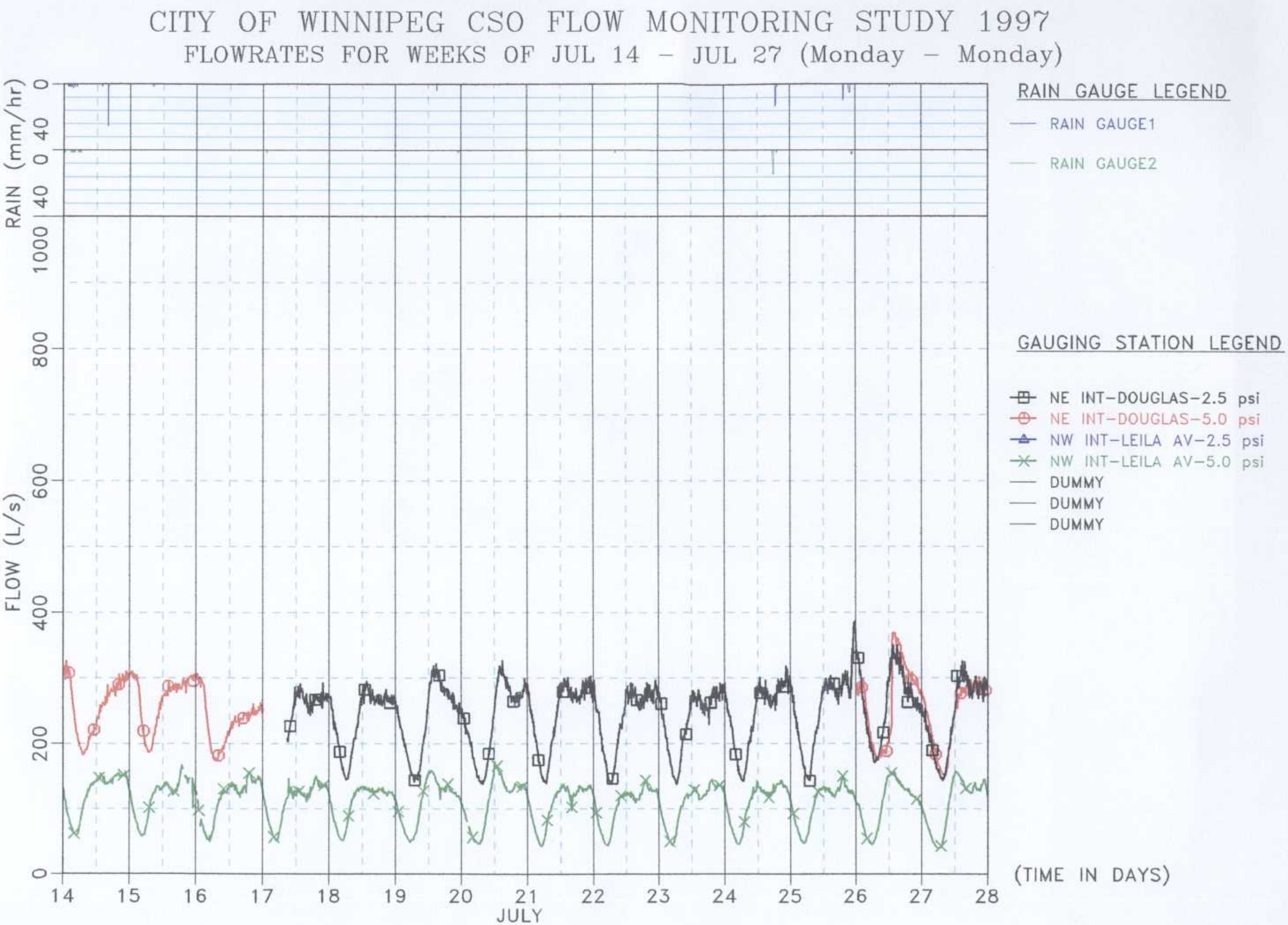


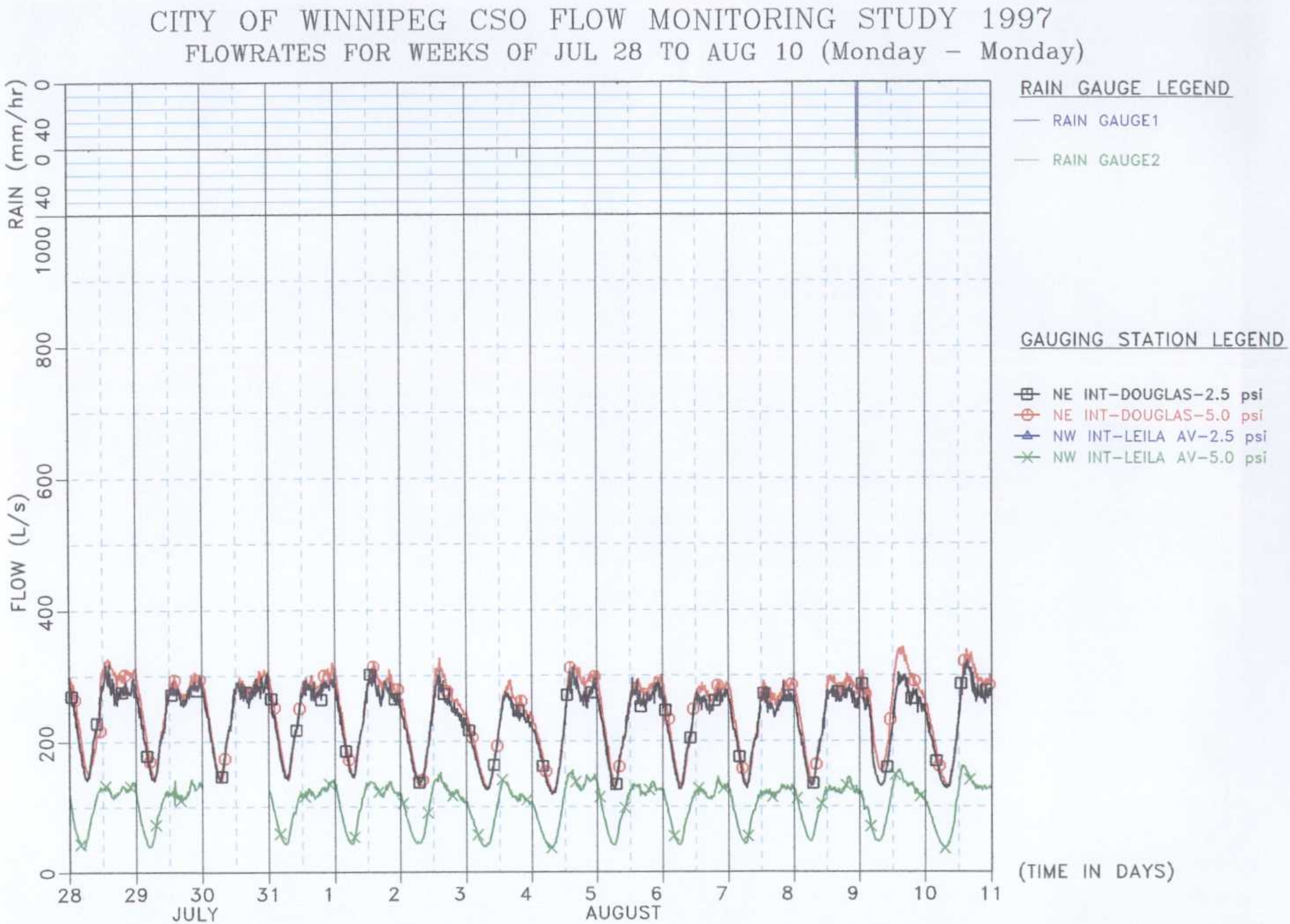
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF MAY 05 - MAY 18 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
MAY
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF MAY 19 - JUN 01 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
FLOW (L/s)
1000
800
600
400
200
0
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)
19
20
21
22
23
24
25
26
27
28
29
30
31
1
2
MAY
JUNE

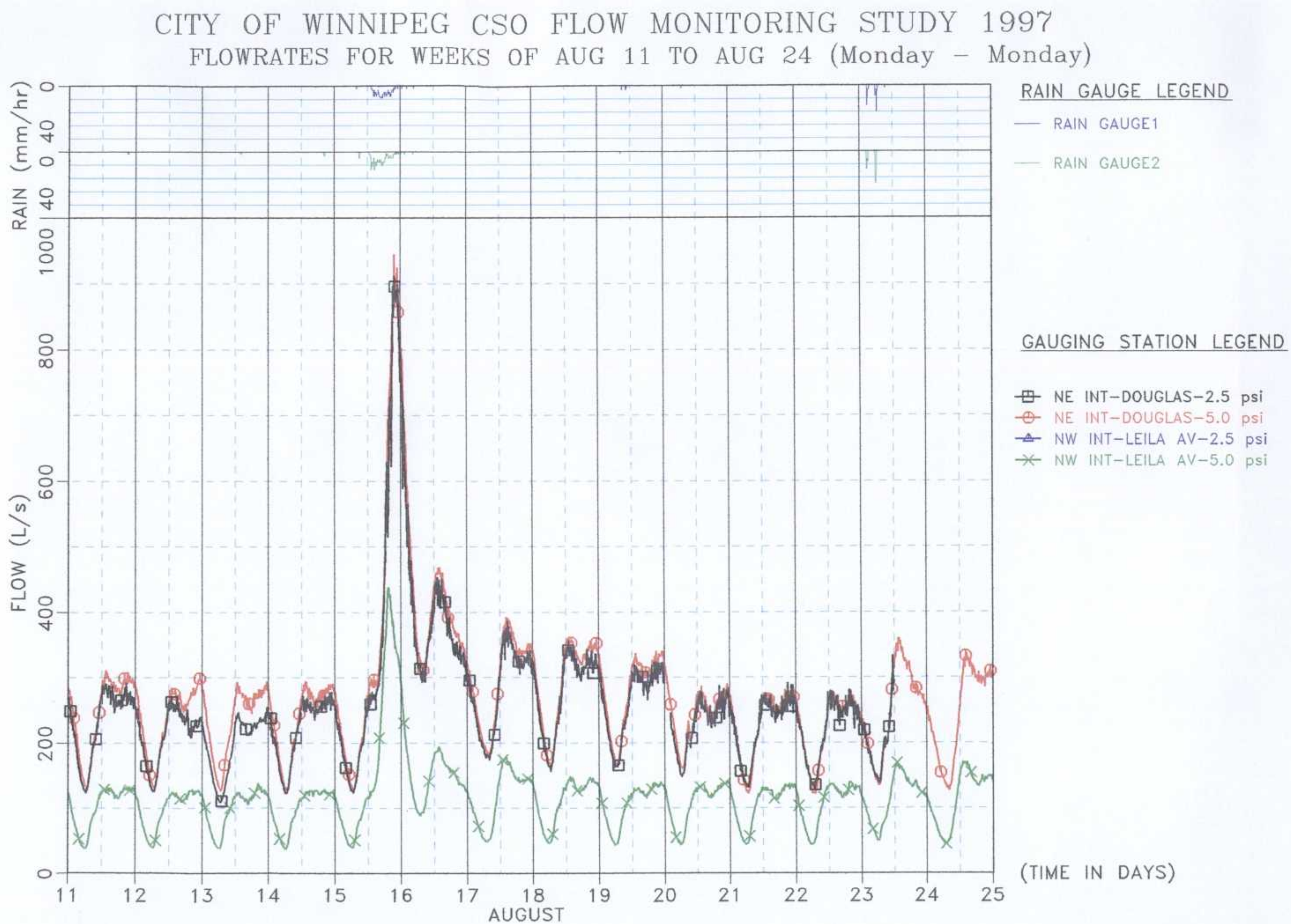


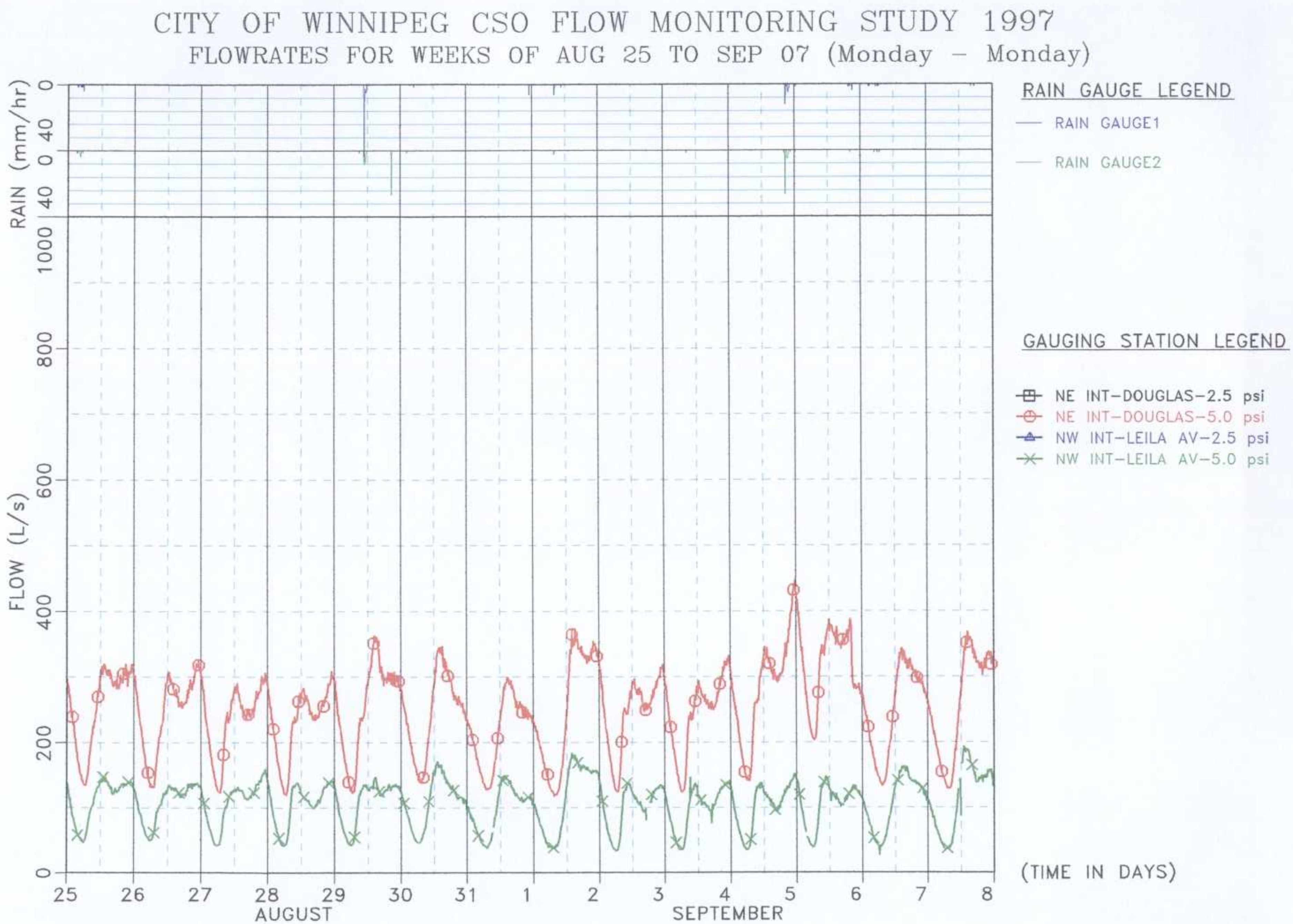
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF JUN 30 - JUL 13 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
DUMMY
DUMMY
DUMMY
30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
JUNE
JULY
(TIME IN DAYS)


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF JUL 14 - JUL 27 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
JULY
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
DUMMY
DUMMY
DUMMY

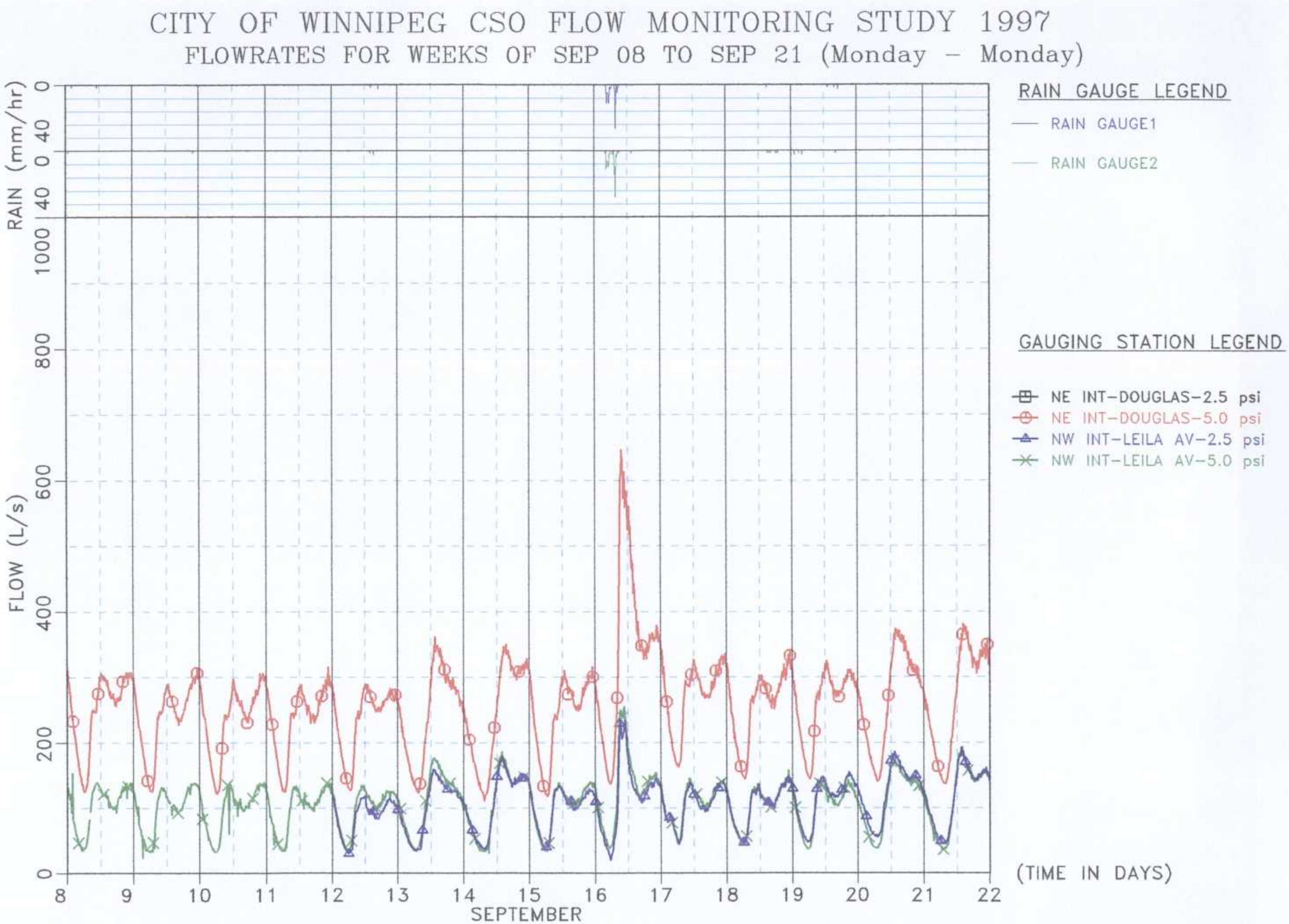


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF JUL 28 TO AUG 10 (Monday - Monday)
RAIN (mm/hr)
FLOW (L/s)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)
JULY
AUGUST

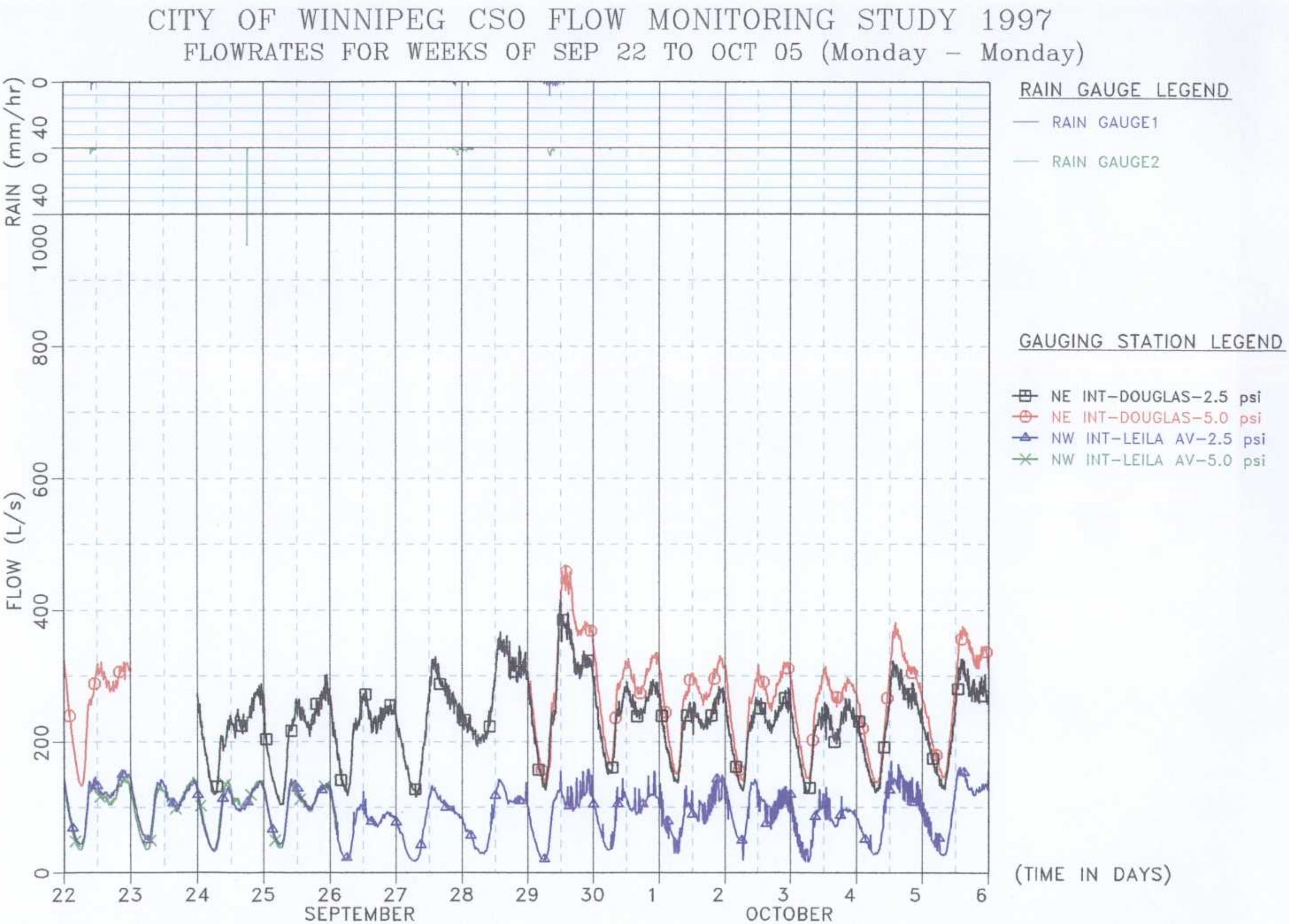

CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF AUG 11 TO AUG 24 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
0
200
400
600
800
1000
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
AUGUST
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi

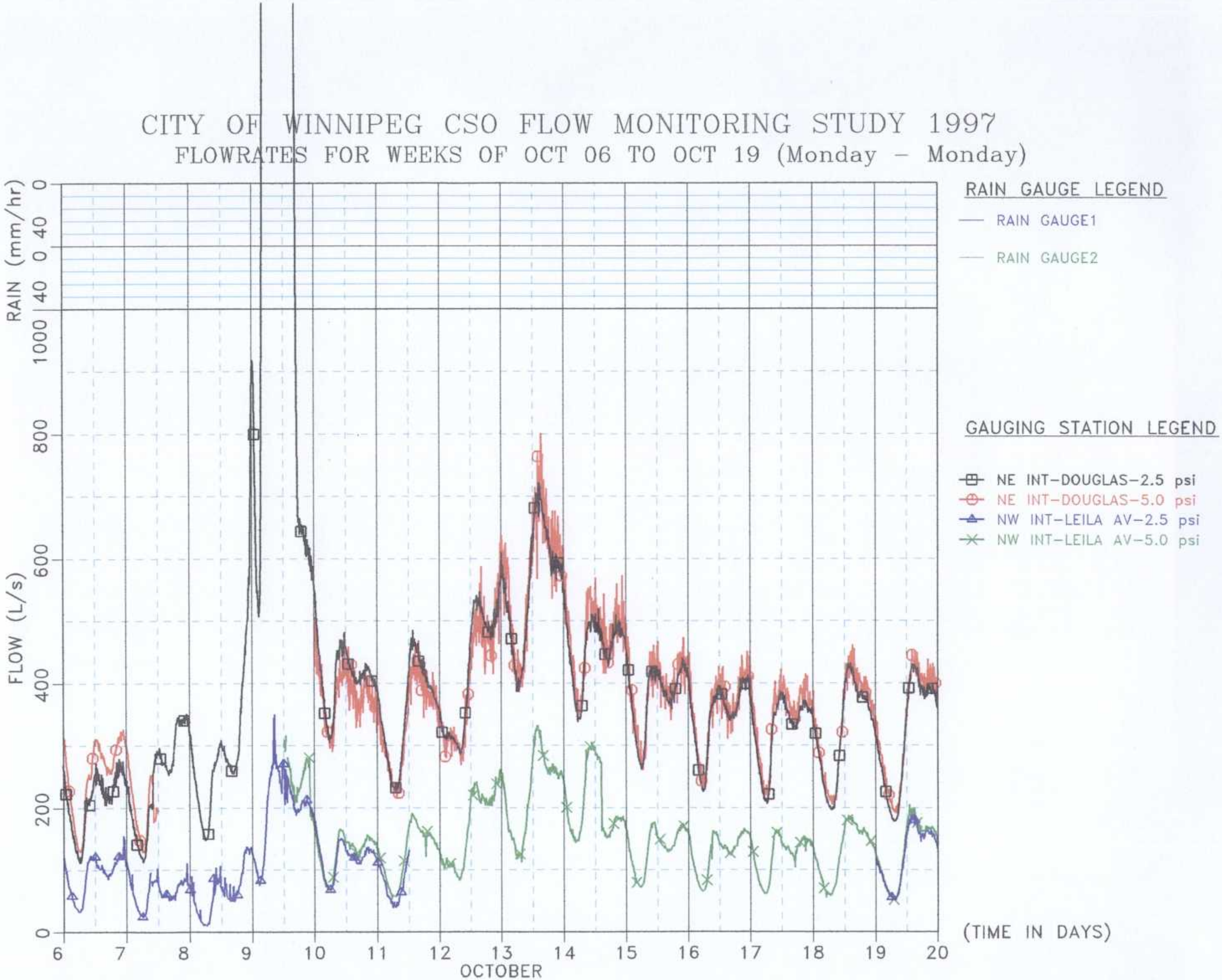


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF AUG 25 TO SEP 07 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)
25
26
27
28
29
30
31
1
2
3
4
5
6
7
8
AUGUST
SEPTEMBER



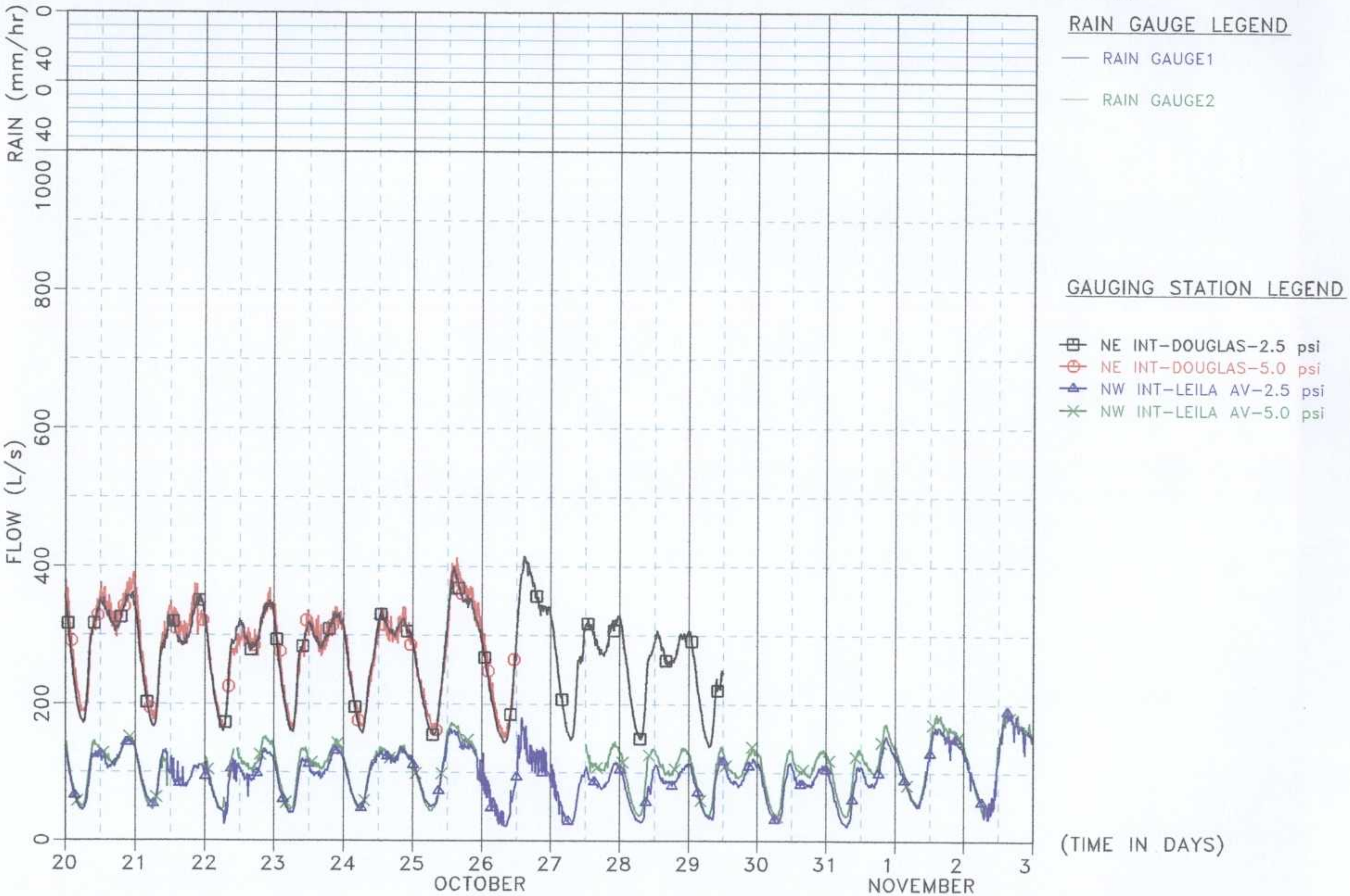
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF SEP 08 TO SEP 21 (Monday - Monday)
RAIN (mm/hr)
FLOW (L/s)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)
SEPTEMBER

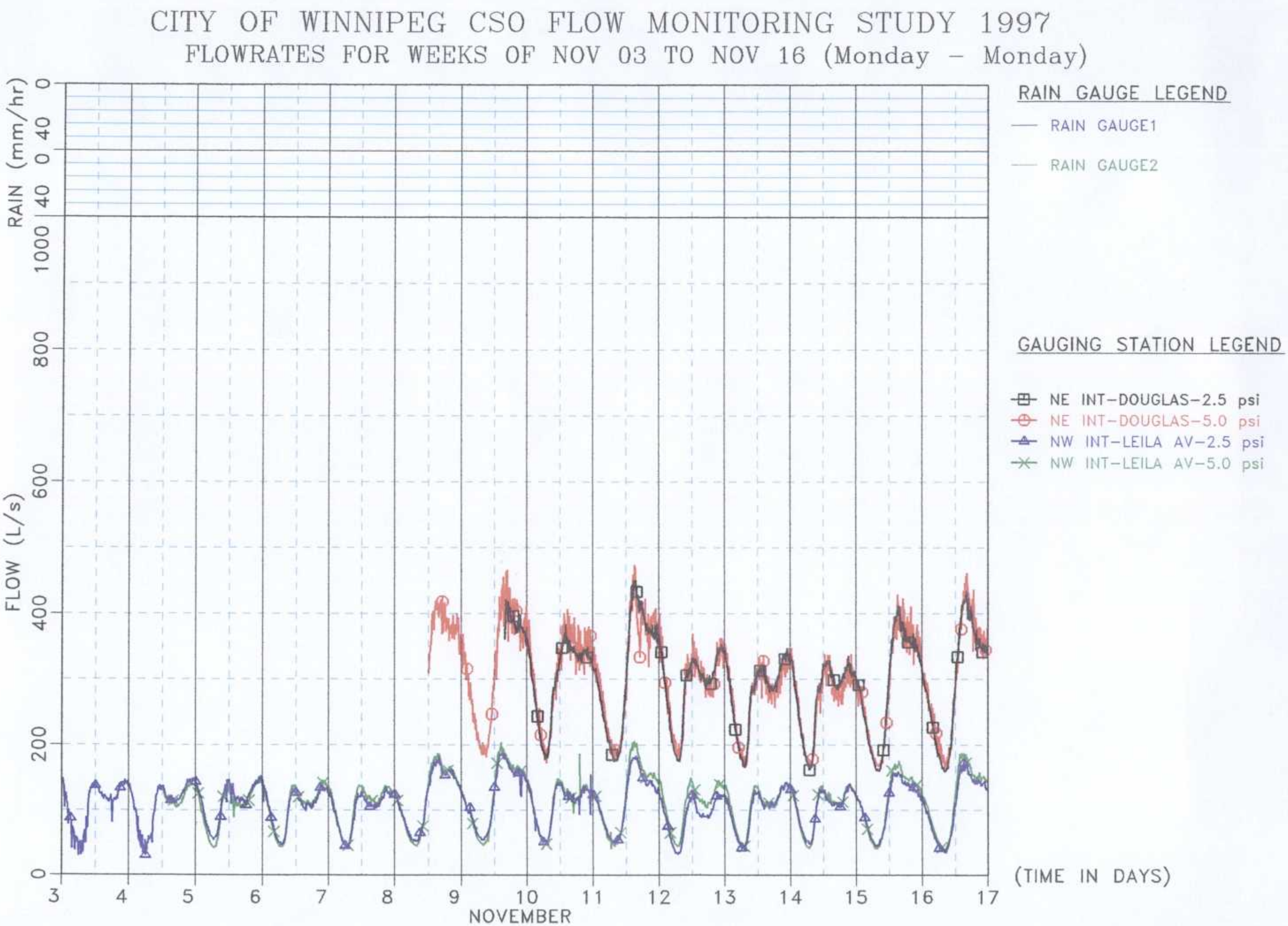

CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF SEP 22 TO OCT 05 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)
22 23 24 25 26 27 28 29 30 1 2 3 4 5 6
SEPTEMBER
OCTOBER


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF OCT 06 TO OCT 19 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
0
200
400
600
800
1000
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
OCTOBER

CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997

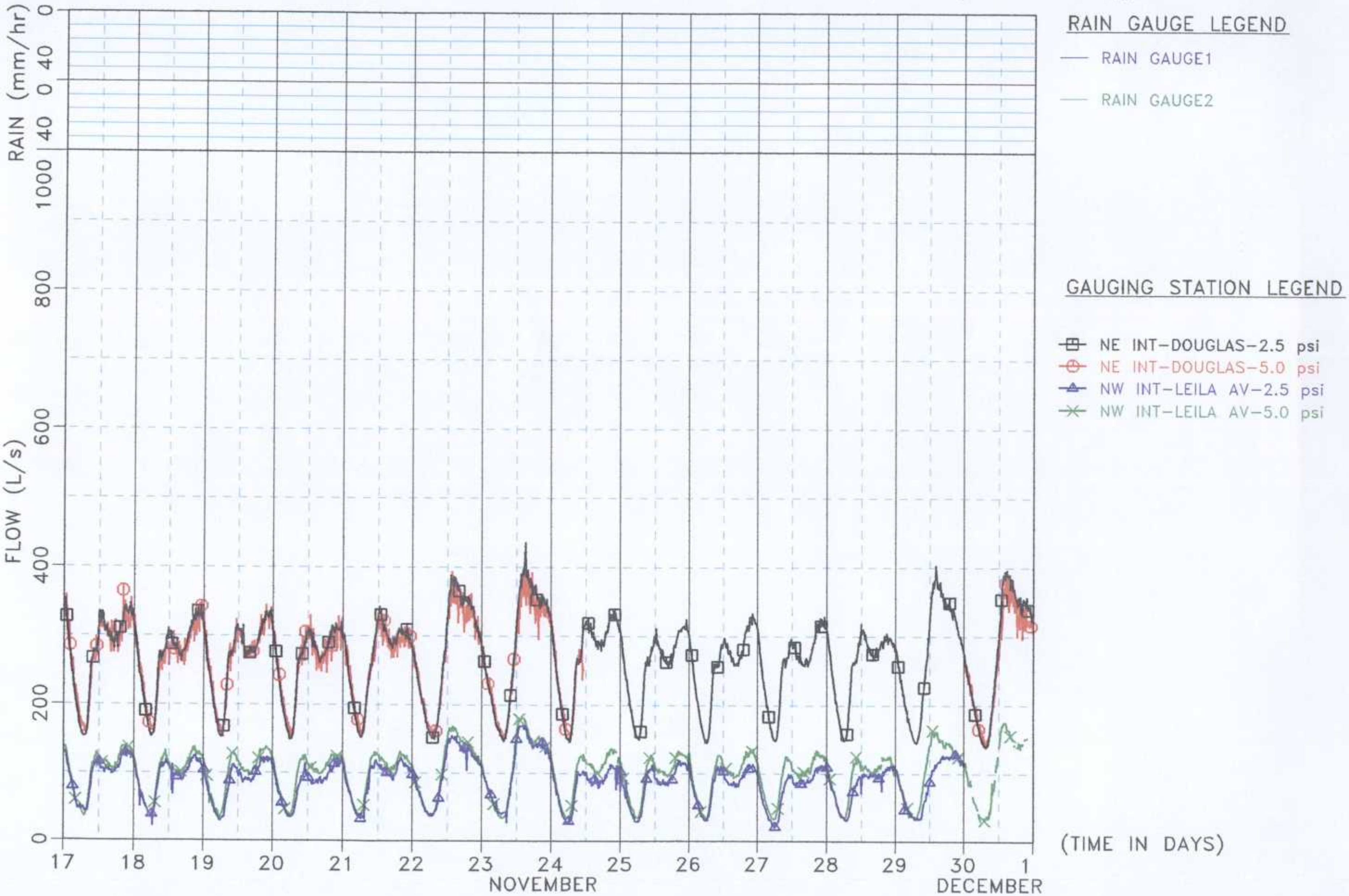
FLOWRATES FOR WEEKS OF OCT 20 TO NOV 02 (Monday - Monday)

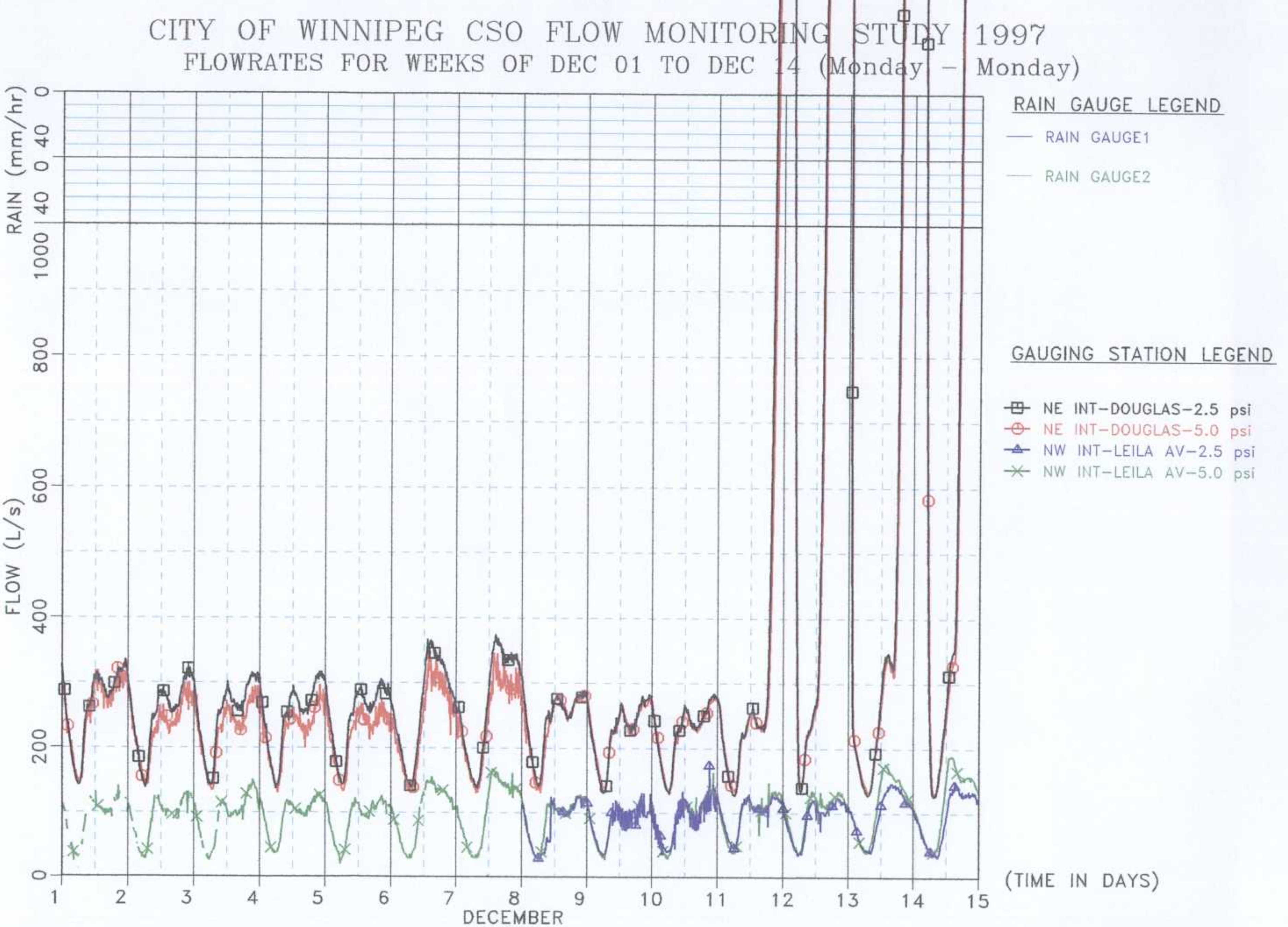




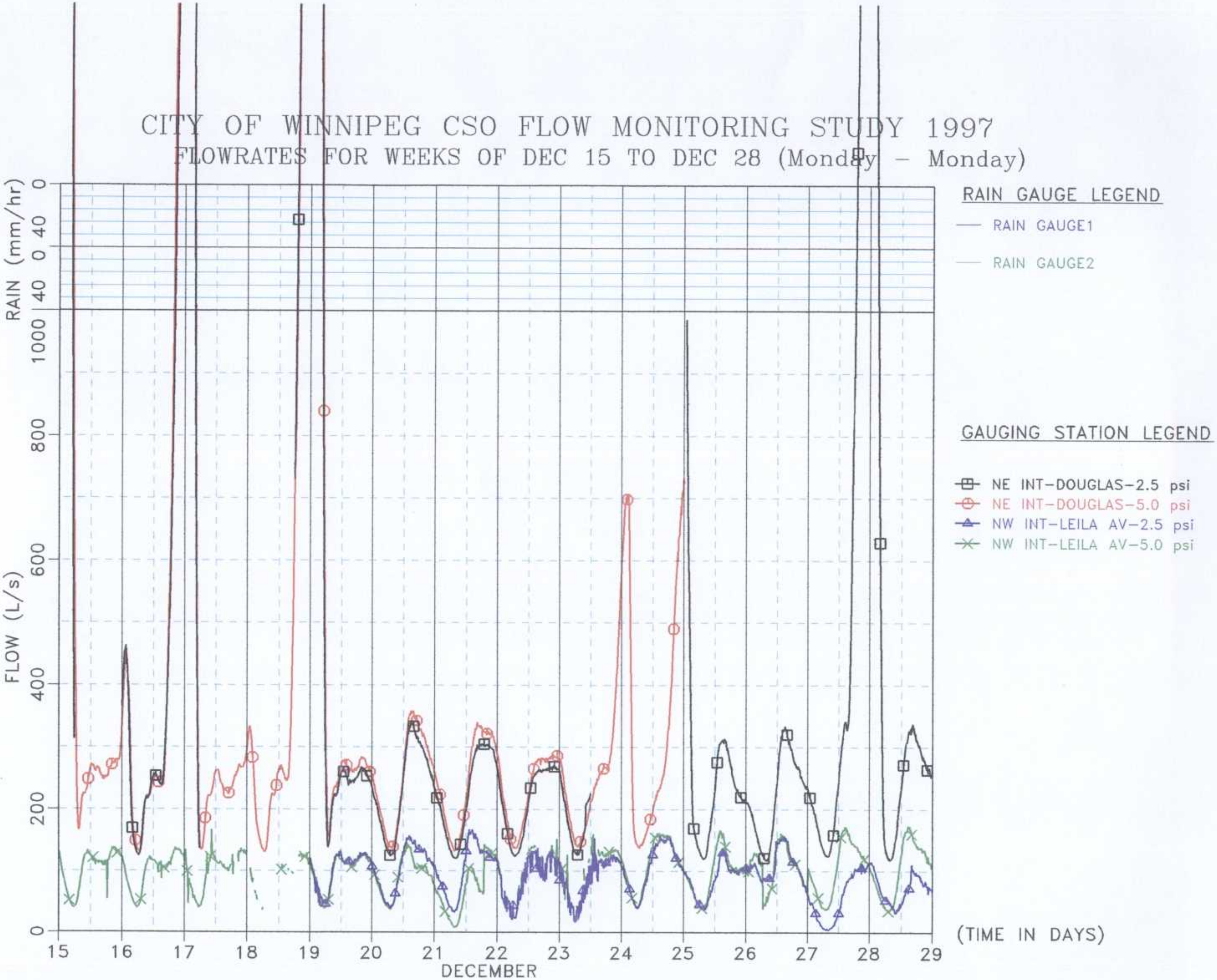
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF NOV 03 TO NOV 16 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
NOVEMBER
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi

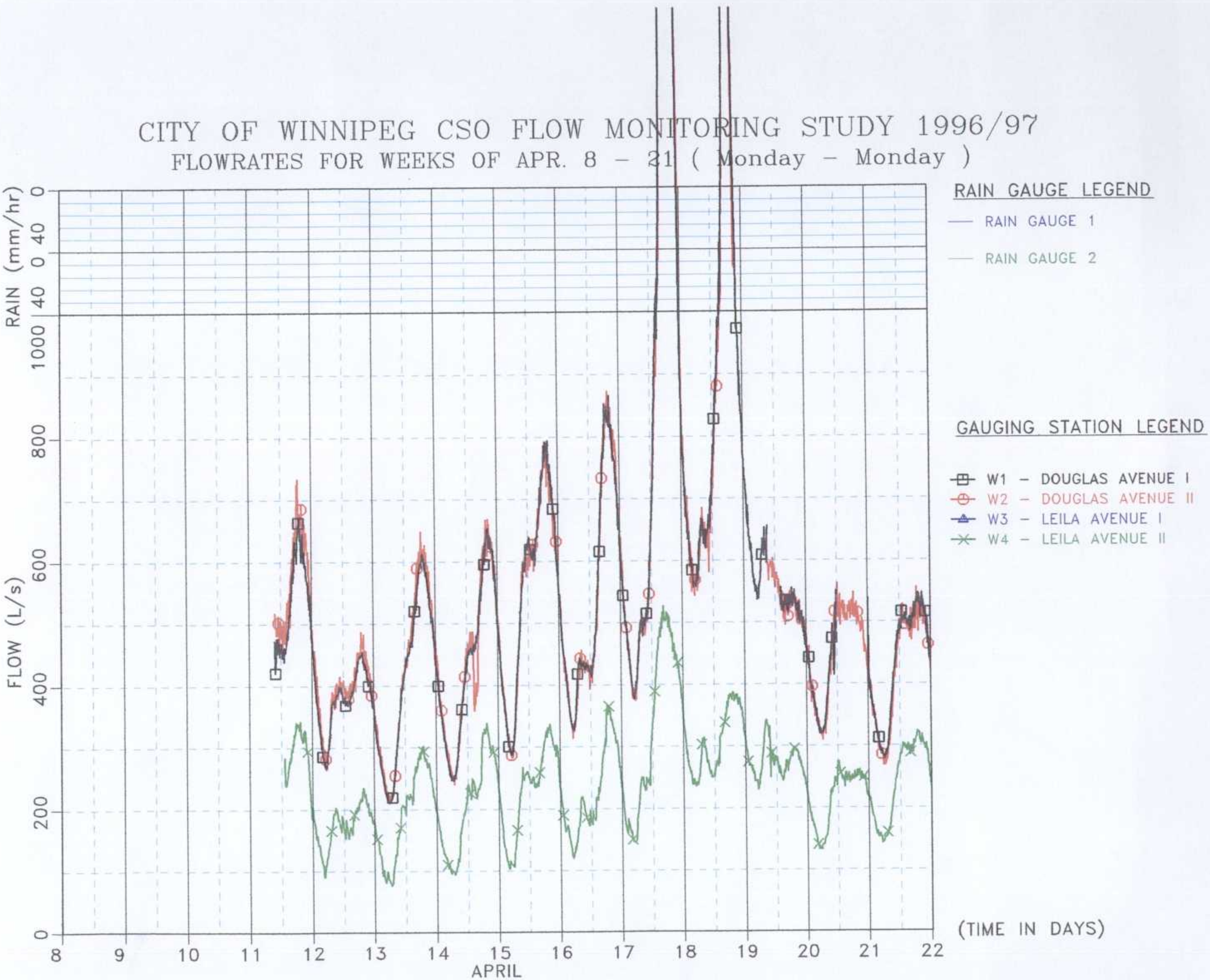
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF NOV 17 TO NOV 30 (Monday - Monday)

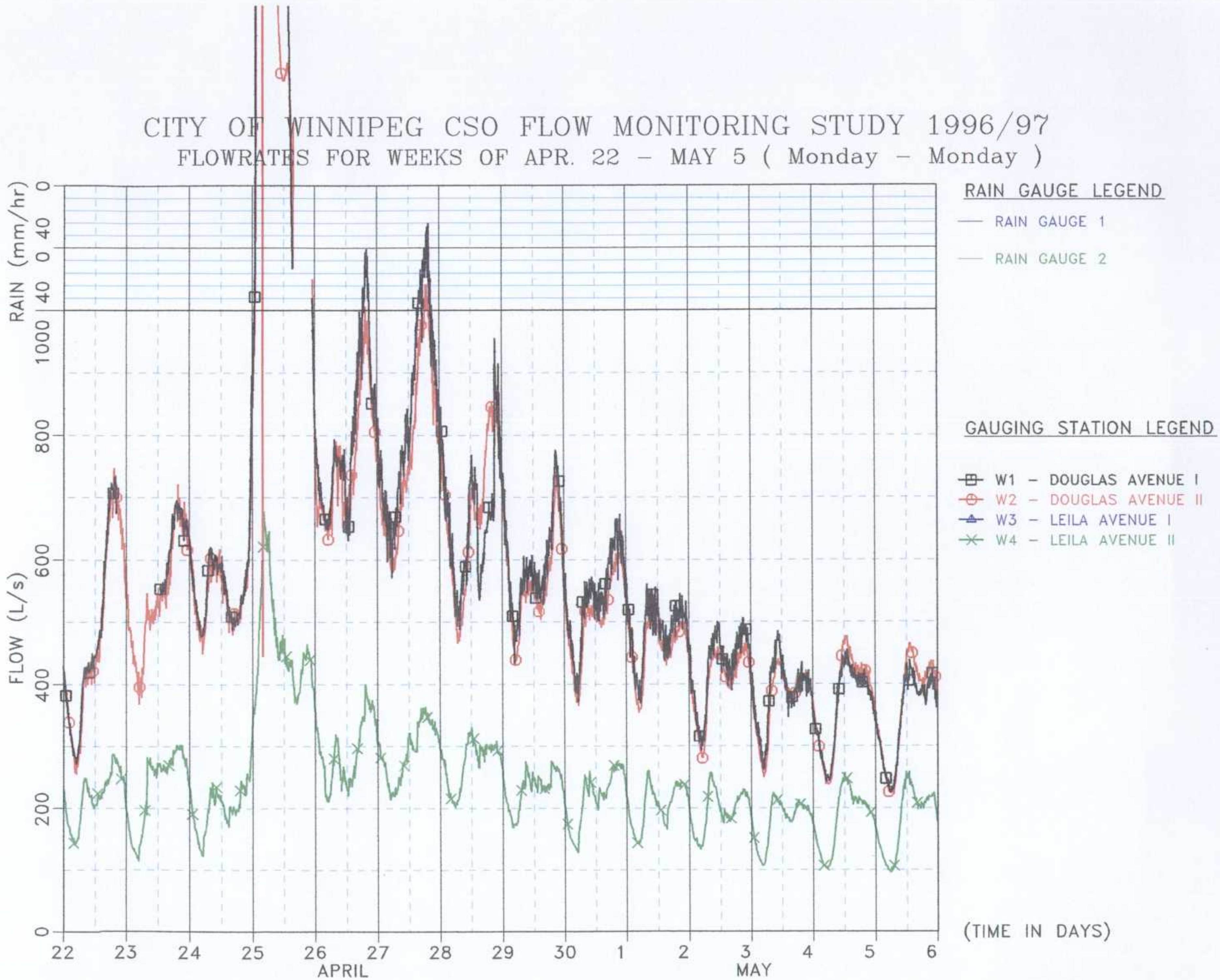




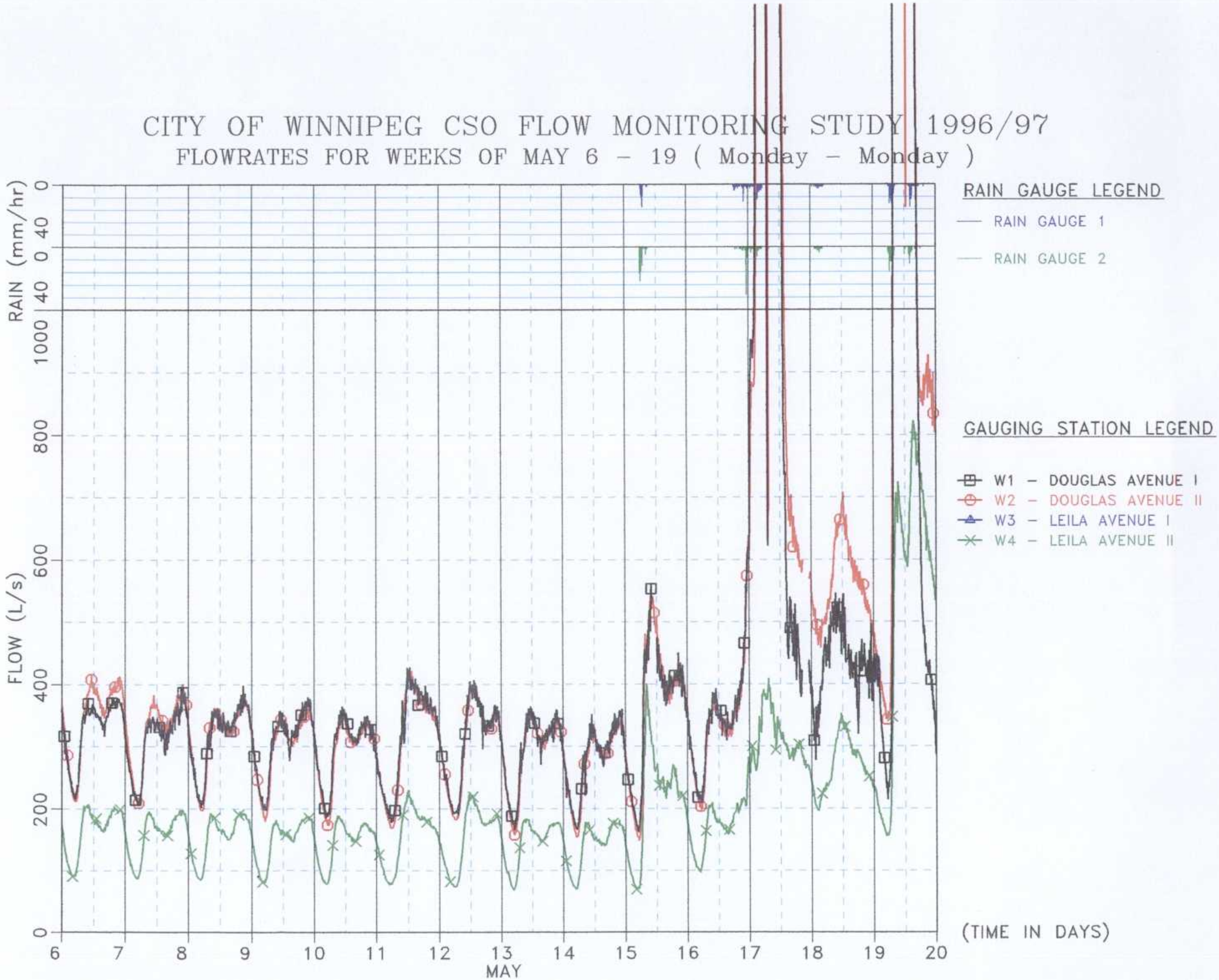
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF DEC 01 TO DEC 14 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
0
200
400
600
800
1000
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
DECEMBER
(TIME IN DAYS)


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1997
FLOWRATES FOR WEEKS OF DEC 15 TO DEC 28 (Monday - Monday)
RAIN (mm/hr)
FLOW (L/s)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)
DECEMBER

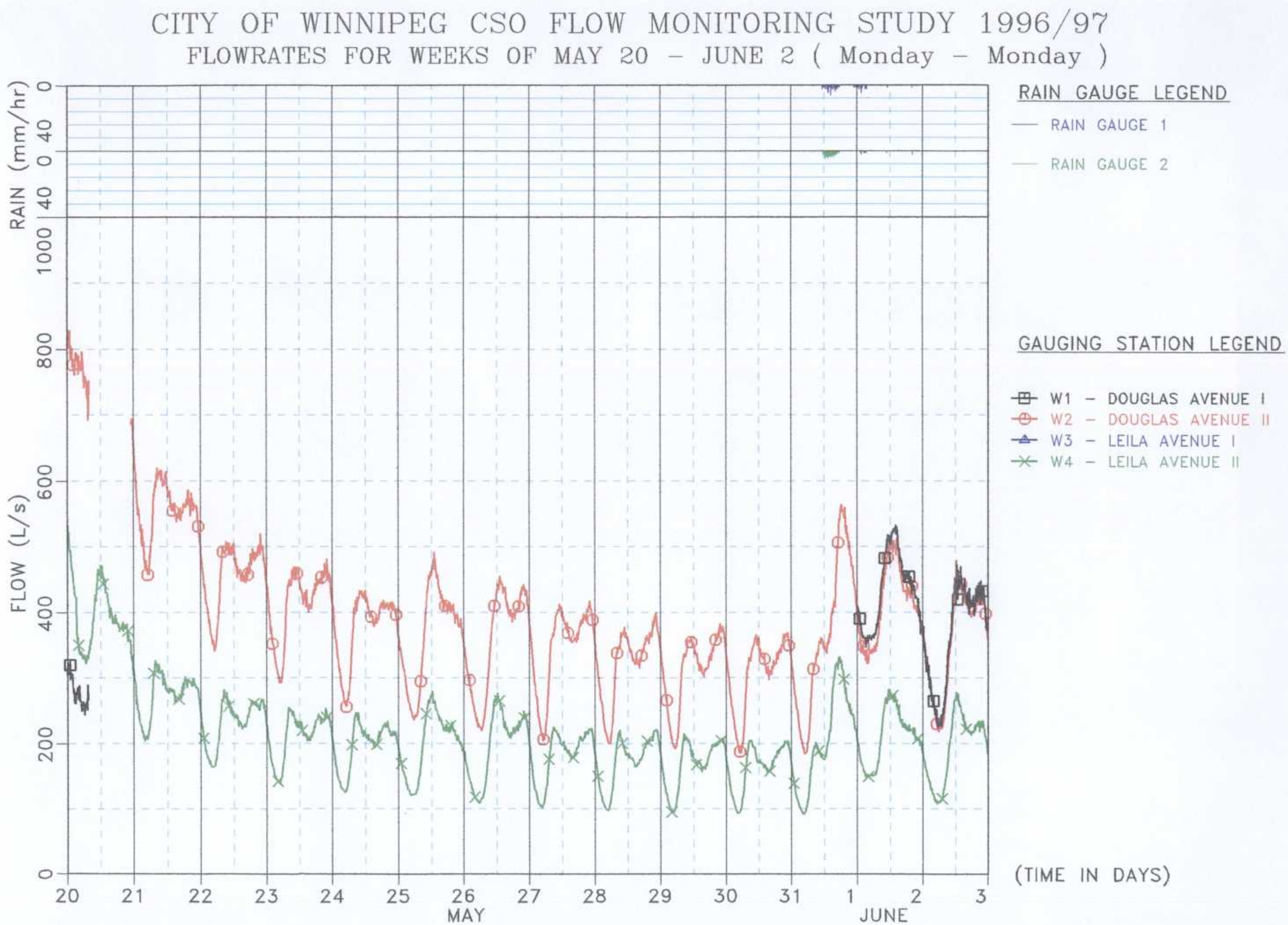

CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF APR. 8 – 21 (Monday – Monday)
RAIN (mm/hr)
FLOW (L/s)
APRIL
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W1 – DOUGLAS AVENUE I
W2 – DOUGLAS AVENUE II
W3 – LEILA AVENUE I
W4 – LEILA AVENUE II

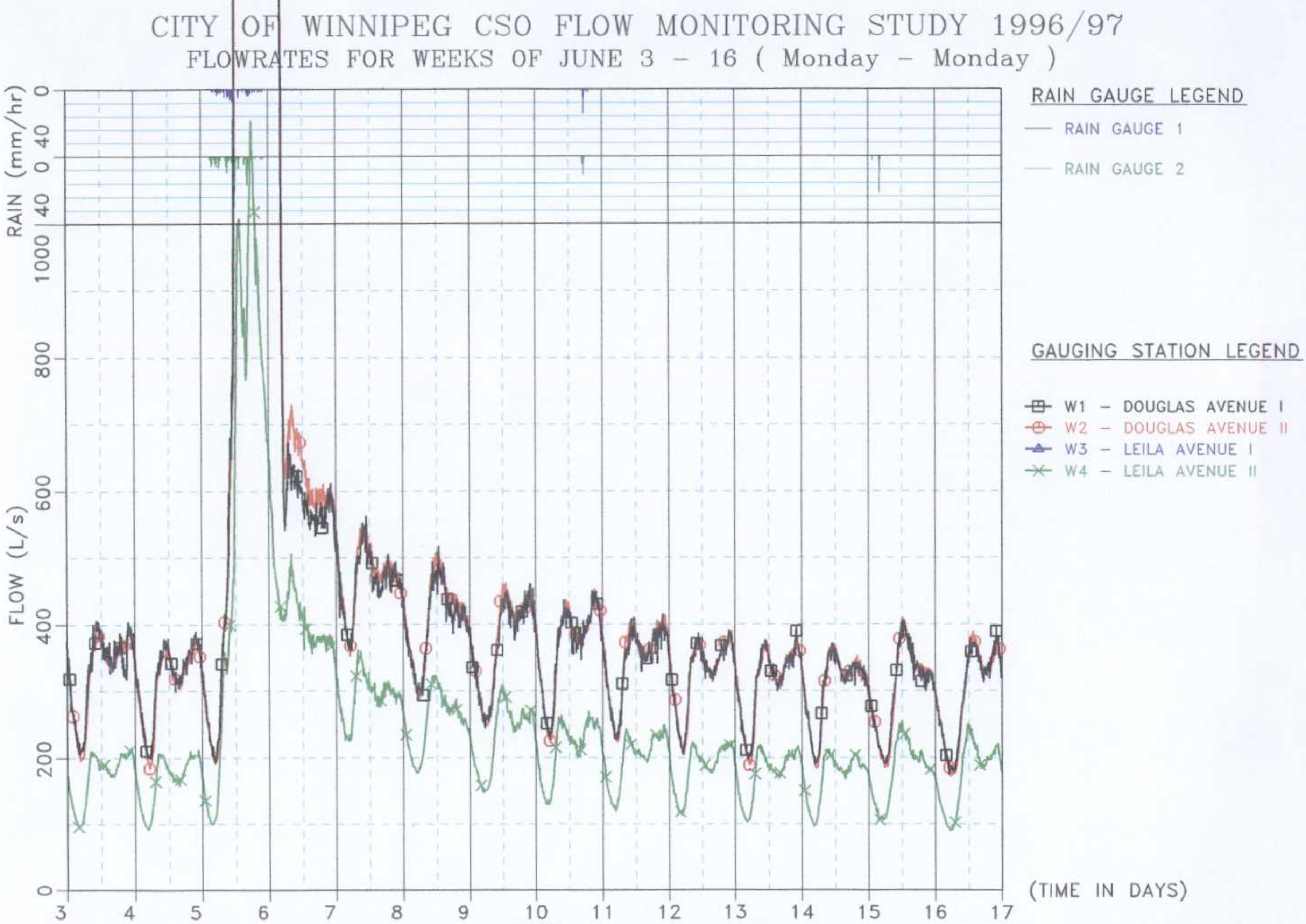


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF APR. 22 - MAY 5 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W1 - DOUGLAS AVENUE I
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II
(TIME IN DAYS)
22
23
24
25
26
27
28
29
30
1
2
3
4
5
6
APRIL
MAY

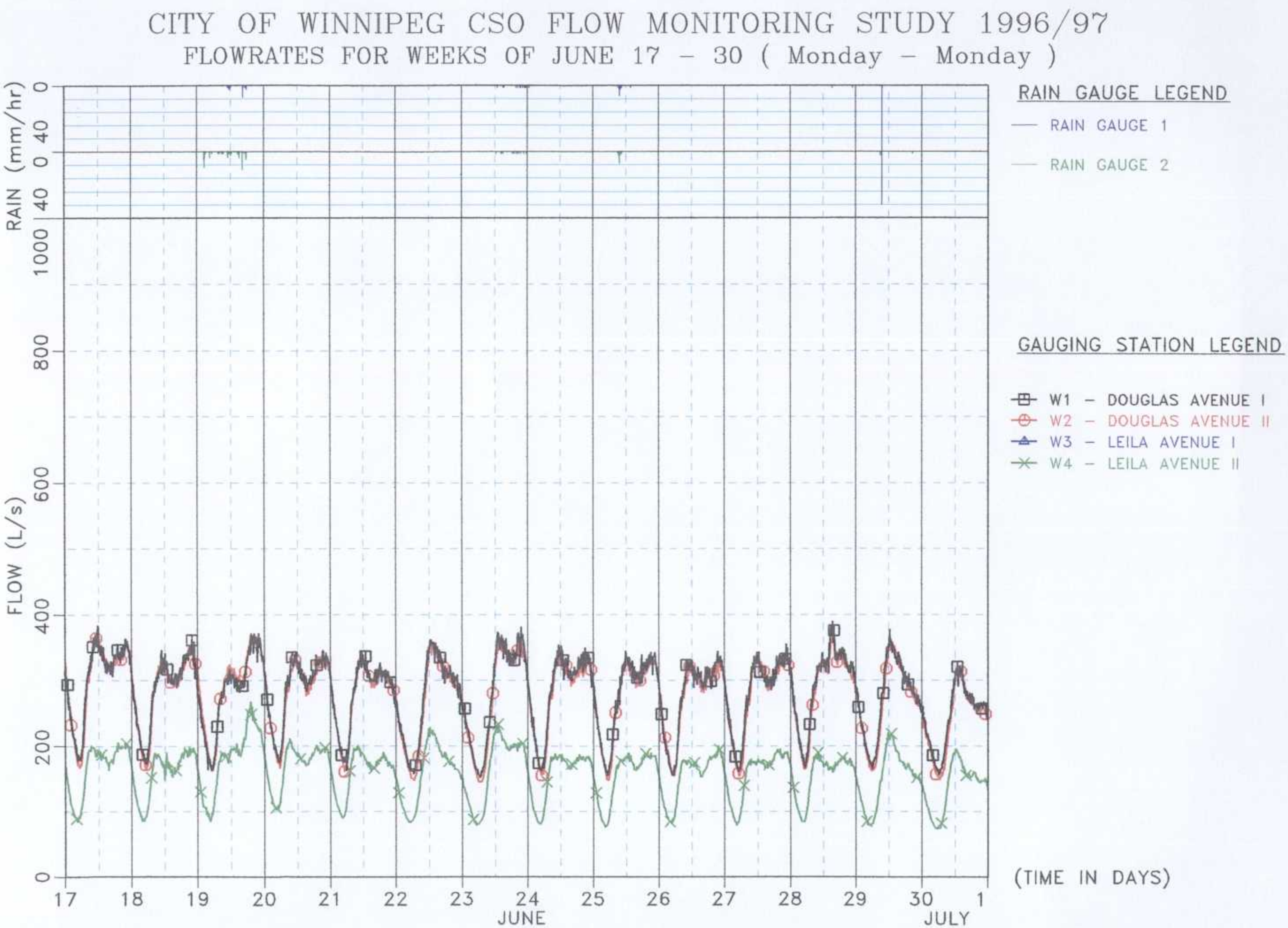


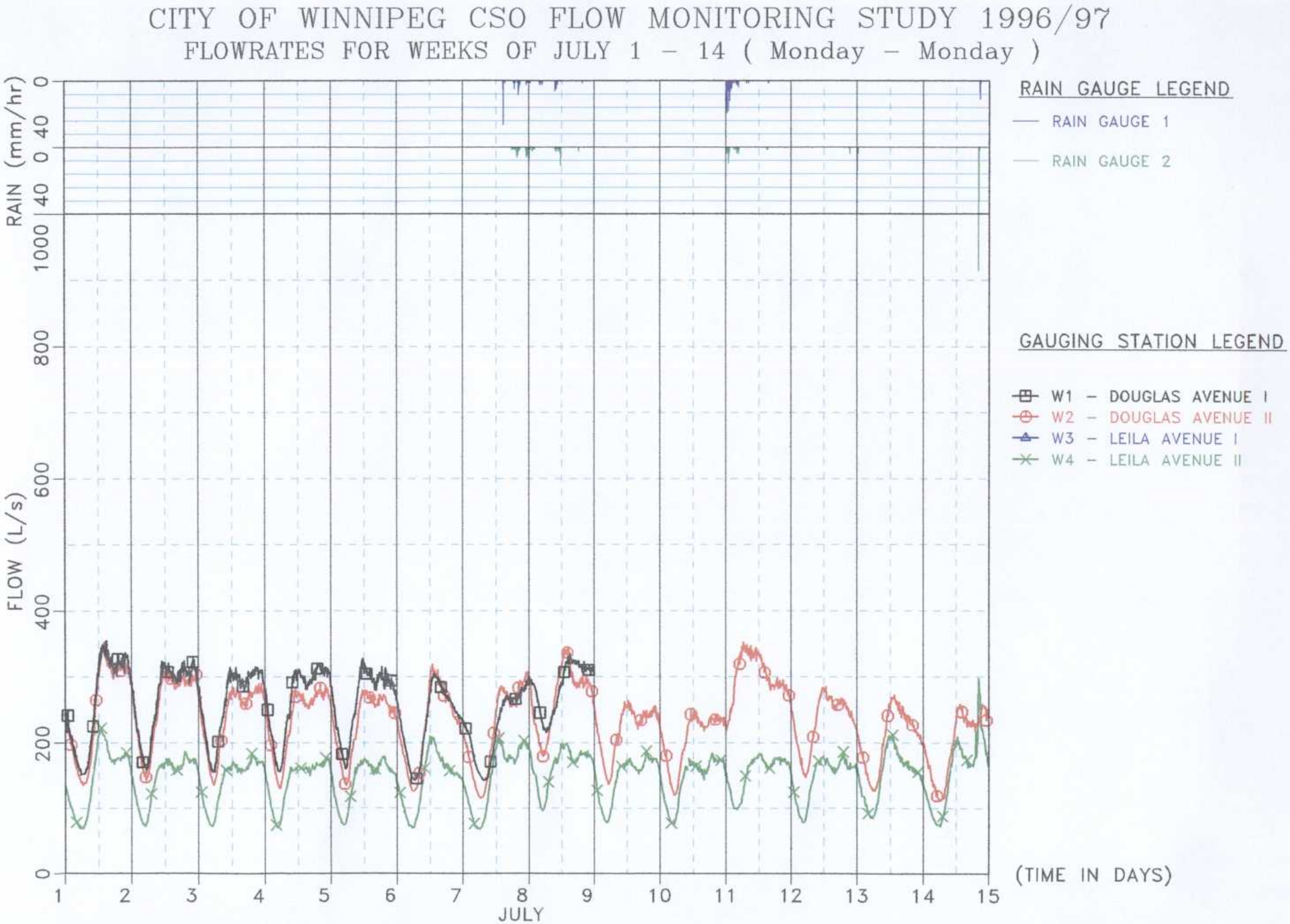
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF MAY 6 - 19 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
MAY
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W1 - DOUGLAS AVENUE I
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II

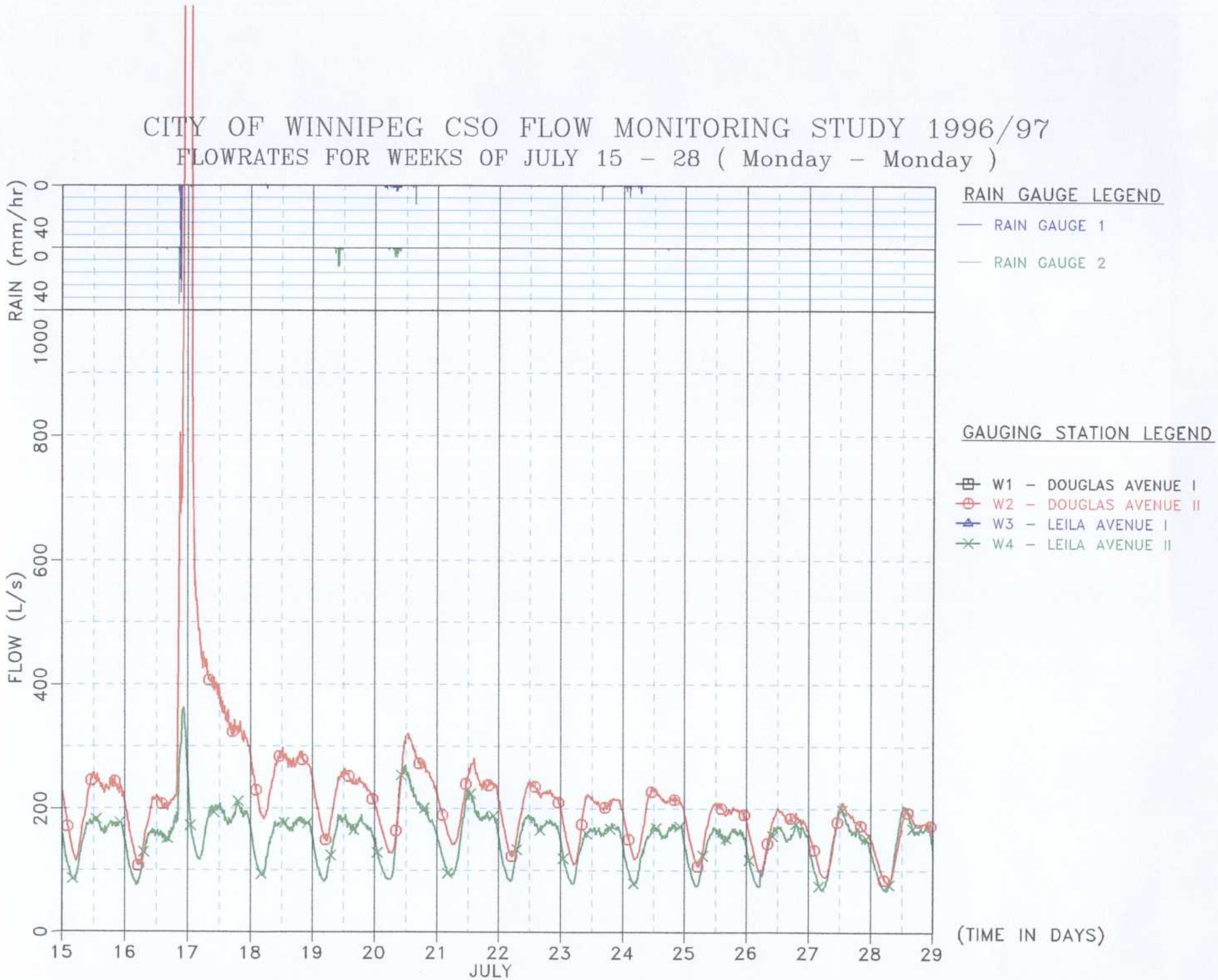

CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF MAY 20 - JUNE 2 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
20
21
22
23
24
25
26
27
28
29
30
31
1
2
3
MAY
JUNE
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W1 - DOUGLAS AVENUE I
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II
(TIME IN DAYS)



CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF JUNE 3 - 16 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
JUNE
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W1 - DOUGLAS AVENUE I
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF JUNE 17 - 30 (Monday - Monday)
RAIN (mm/hr)
FLOW (L/s)
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W1 - DOUGLAS AVENUE I
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II
(TIME IN DAYS)
JUNE
JULY

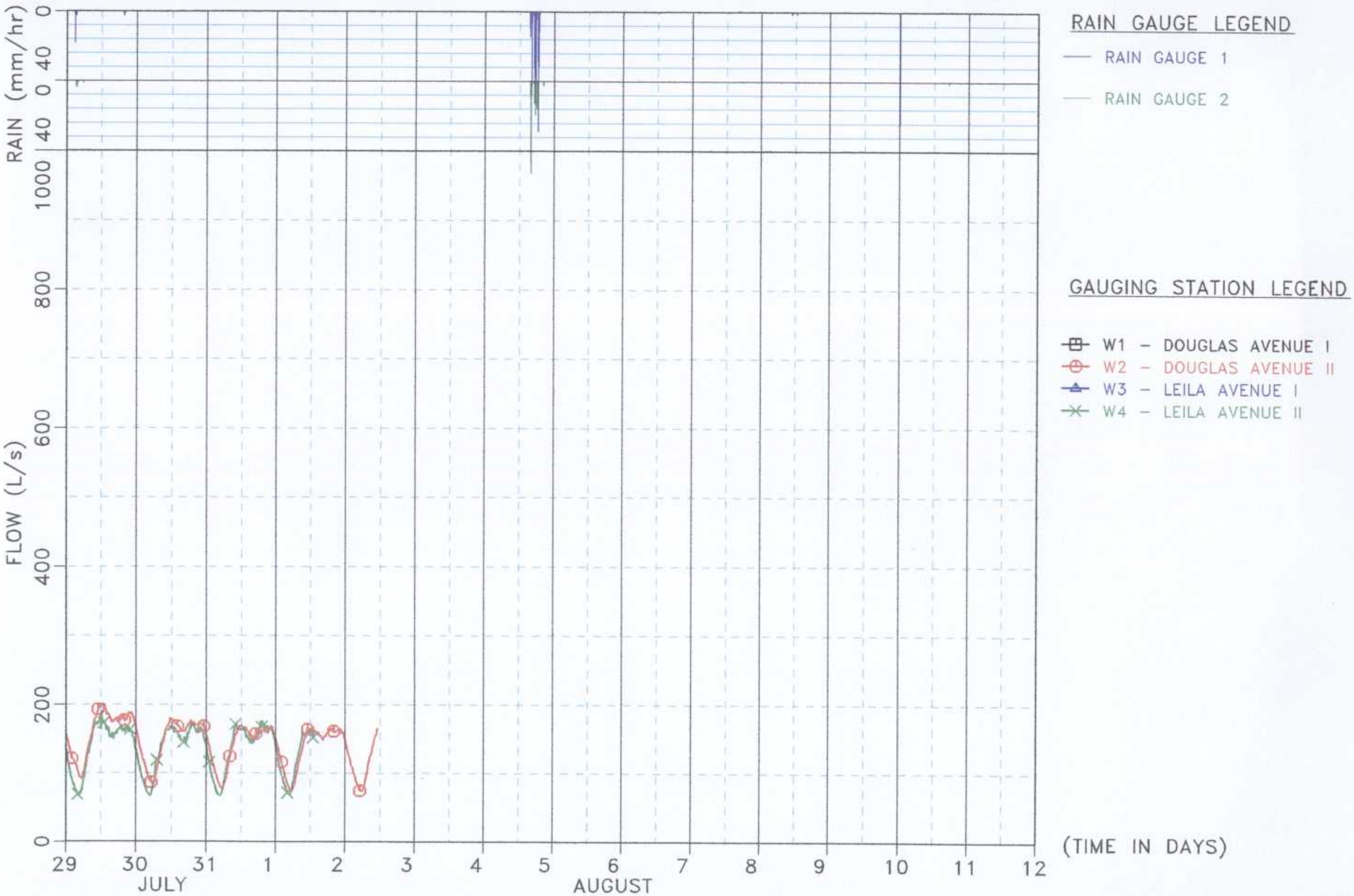

CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF JULY 1 - 14 (Monday - Monday)
RAIN (mm/hr)
FLOW (L/s)
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W1 - DOUGLAS AVENUE I
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II
(TIME IN DAYS)
JULY

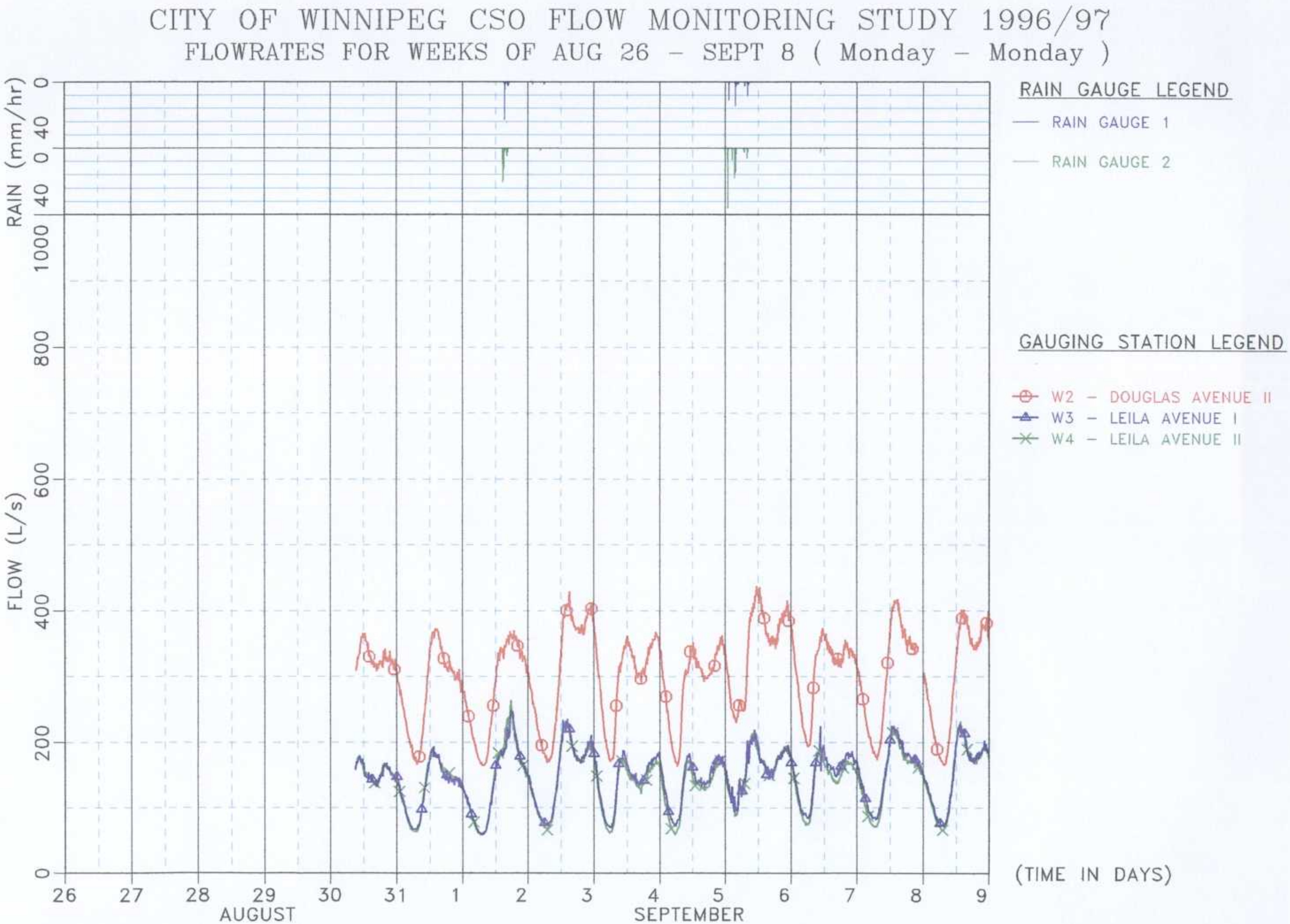


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF JULY 15 - 28 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
JULY
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W1 - DOUGLAS AVENUE I
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II

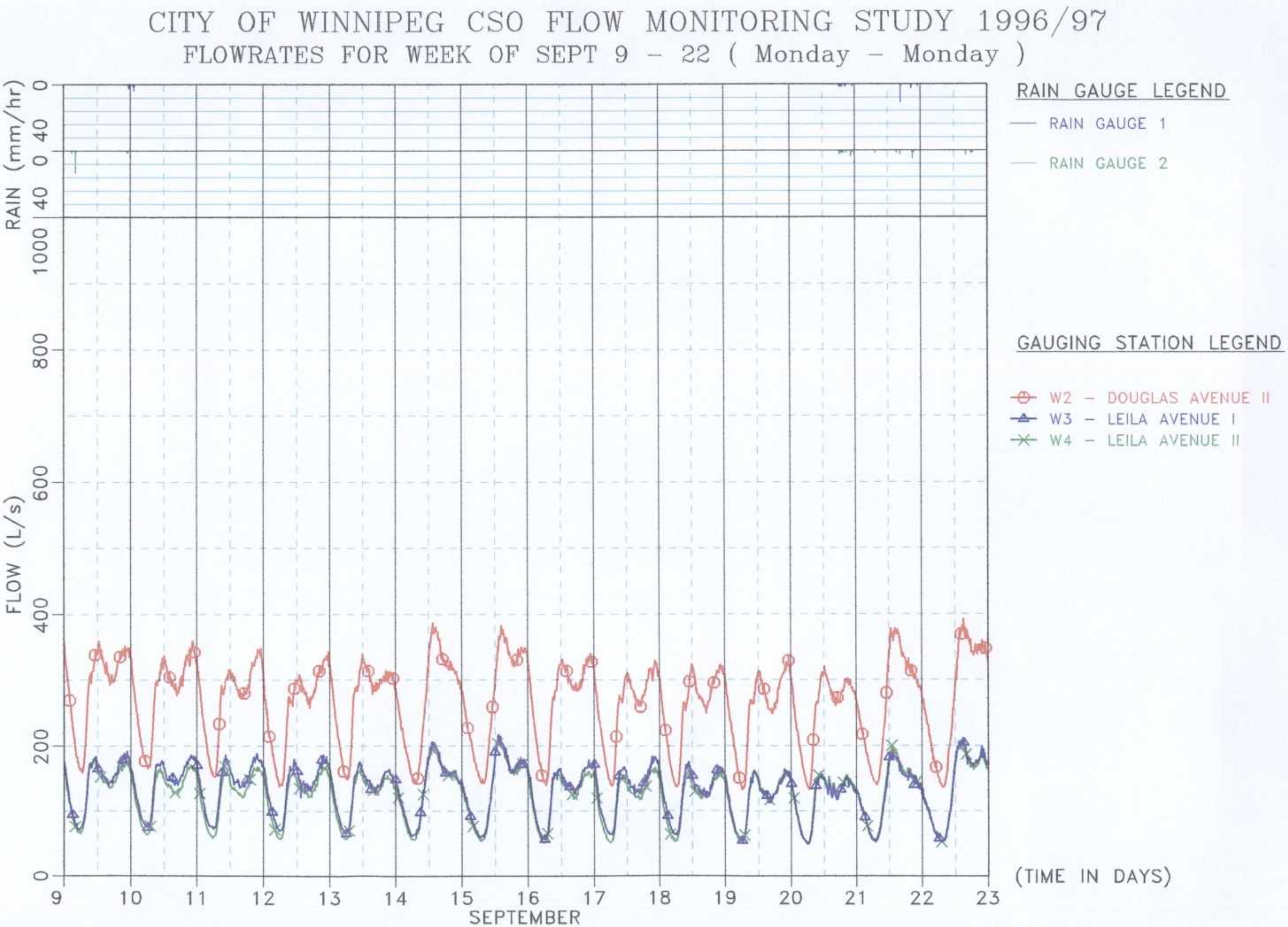
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97

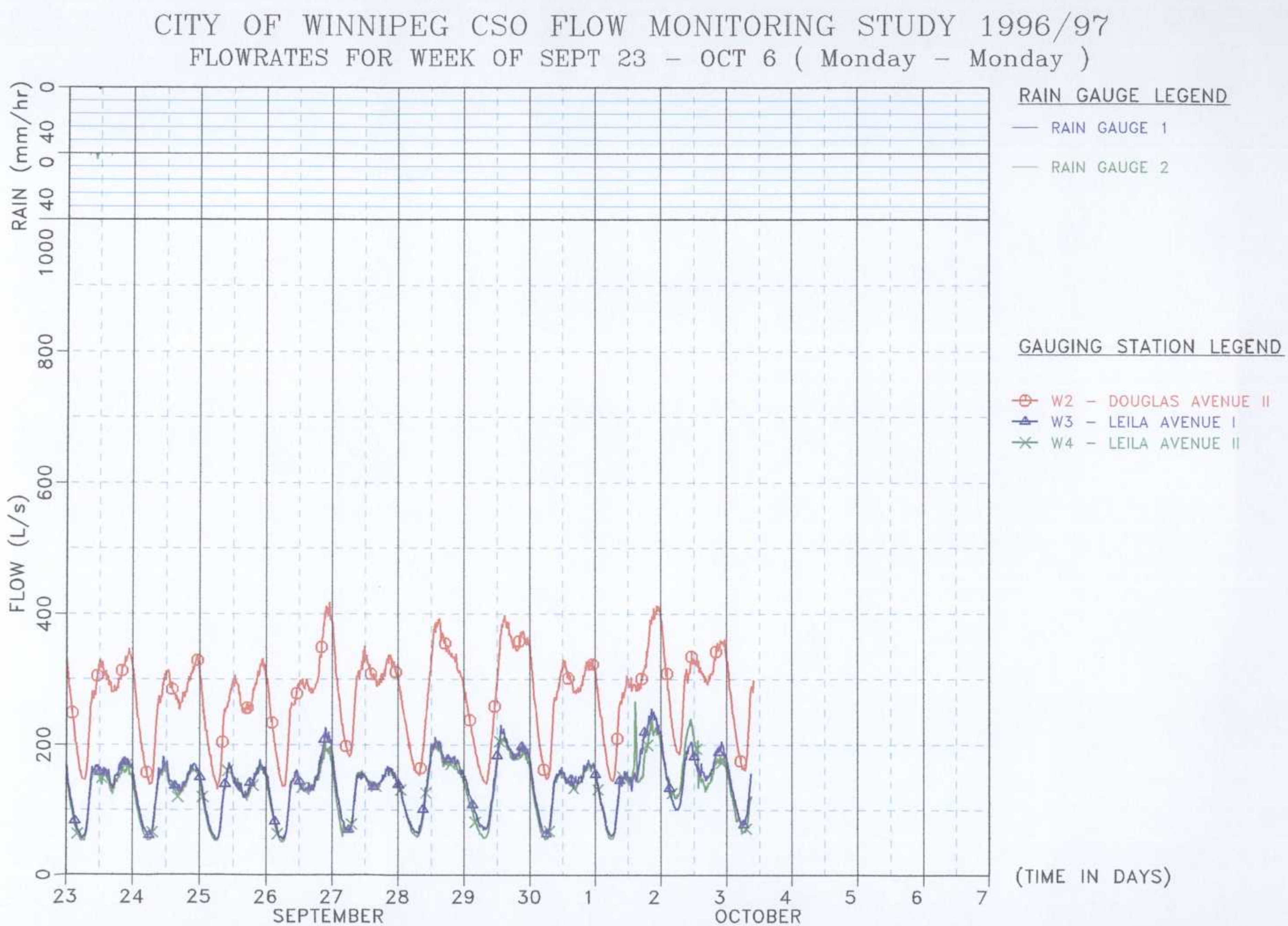
FLOWRATES FOR WEEKS OF JULY 29 - AUG. 11 (Monday - Monday)



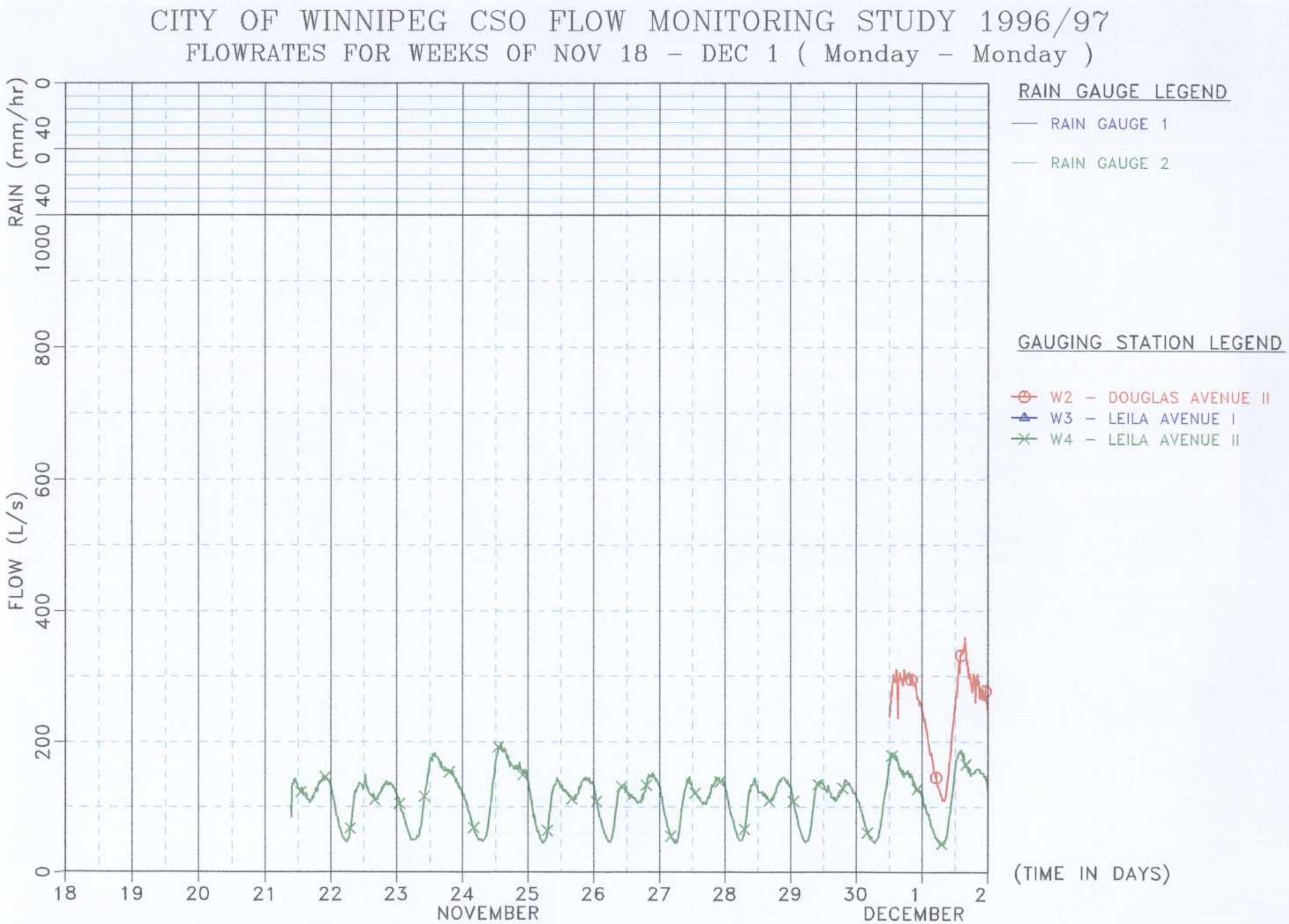


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF AUG 26 - SEPT 8 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
0
200
400
600
800
1000
26
27
28
29
30
31
1
2
3
4
5
6
7
8
9
AUGUST
SEPTEMBER
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II

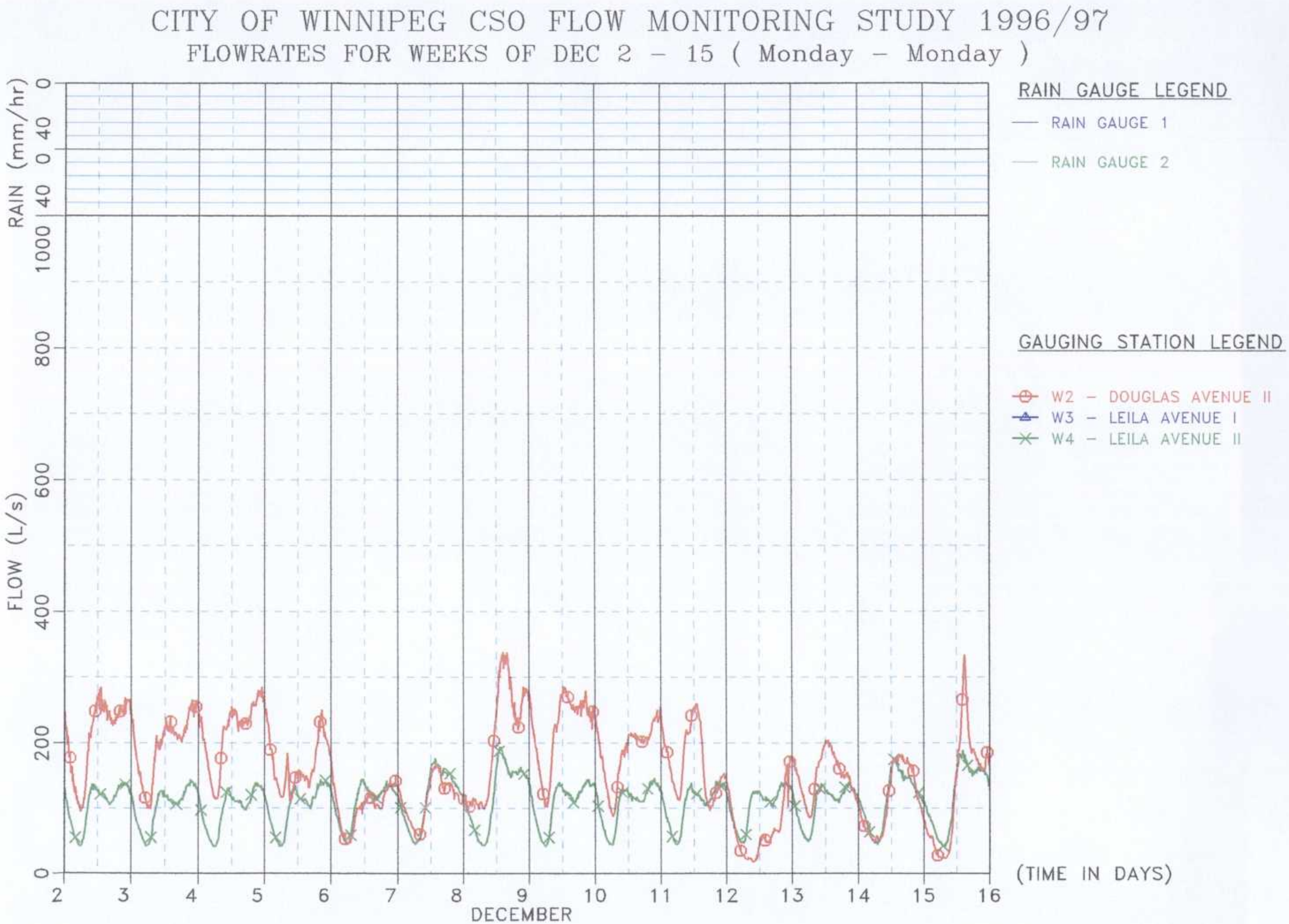

CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEK OF SEPT 9 - 22 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
0
200
400
600
800
1000
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
SEPTEMBER
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II
(TIME IN DAYS)



CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEK OF SEPT 23 - OCT 6 (Monday - Monday)
RAIN (mm/hr)
FLOW (L/s)
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II
(TIME IN DAYS)
SEPTEMBER
OCTOBER

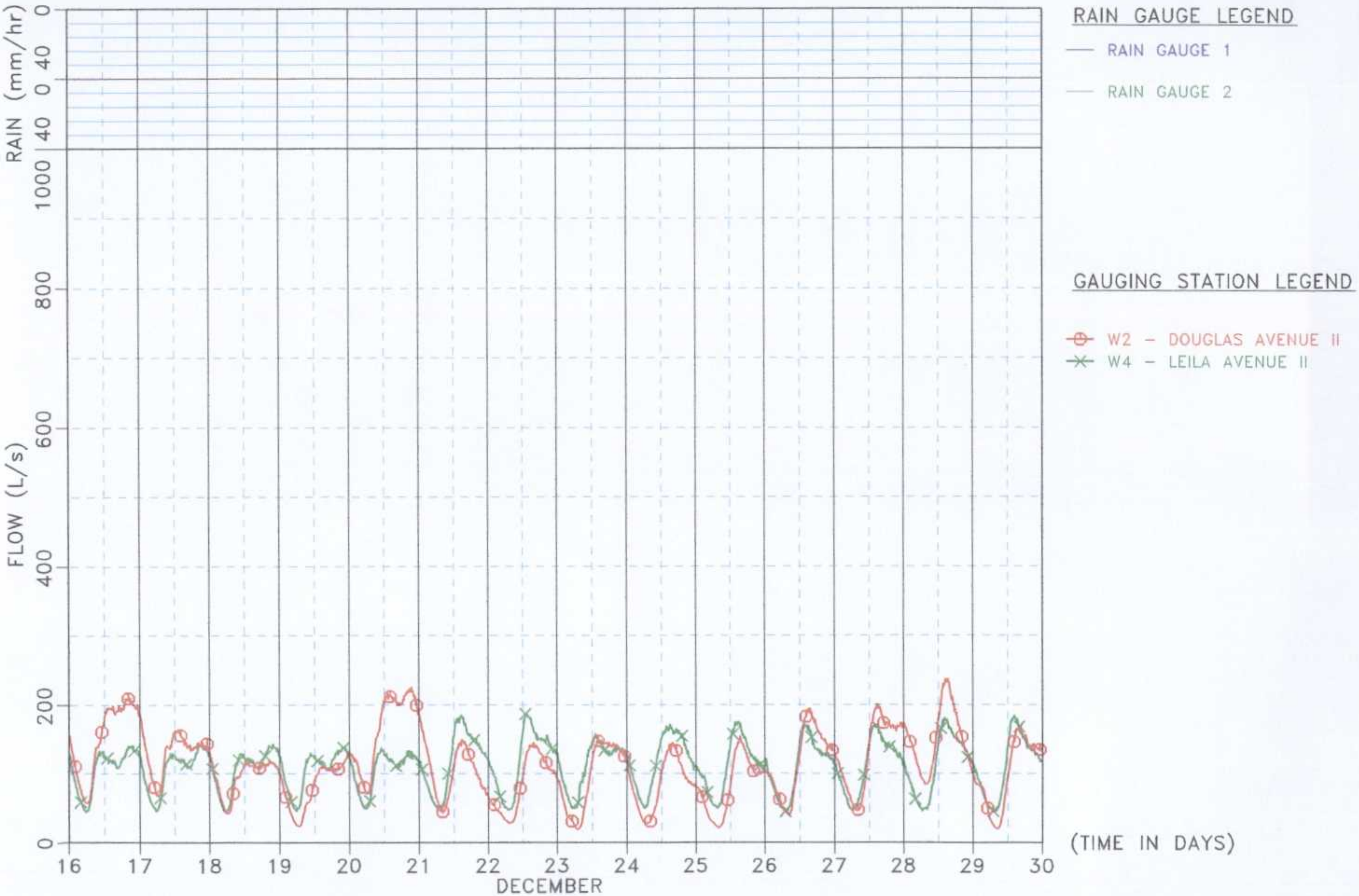


CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF NOV 18 - DEC 1 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
18
19
20
21
22
23
24
25
26
27
28
29
30
1
2
NOVEMBER
DECEMBER
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II
(TIME IN DAYS)



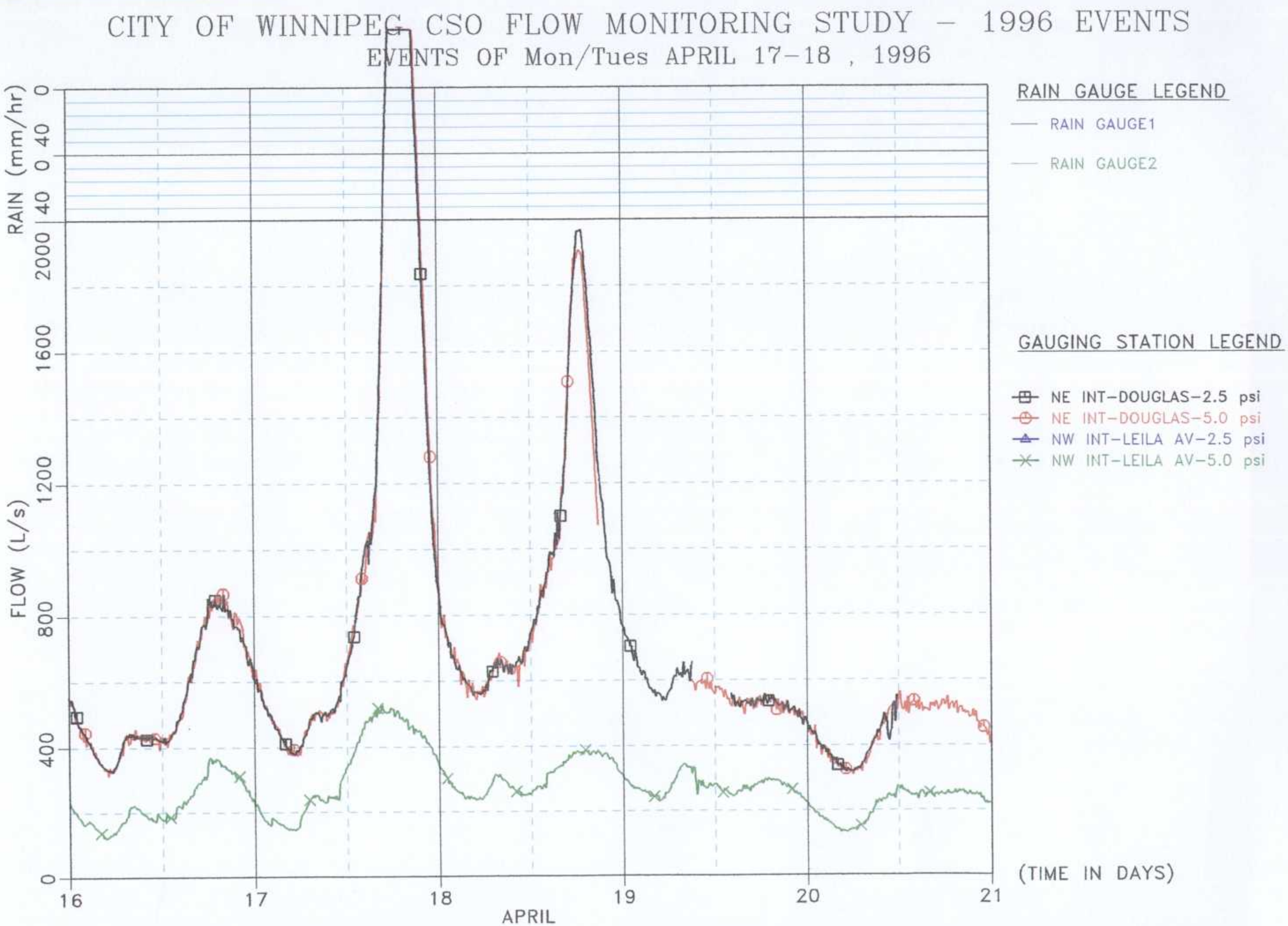
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF DEC 2 - 15 (Monday - Monday)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
0
200
400
600
800
1000
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
DECEMBER
RAIN GAUGE LEGEND
RAIN GAUGE 1
RAIN GAUGE 2
GAUGING STATION LEGEND
W2 - DOUGLAS AVENUE II
W3 - LEILA AVENUE I
W4 - LEILA AVENUE II
(TIME IN DAYS)

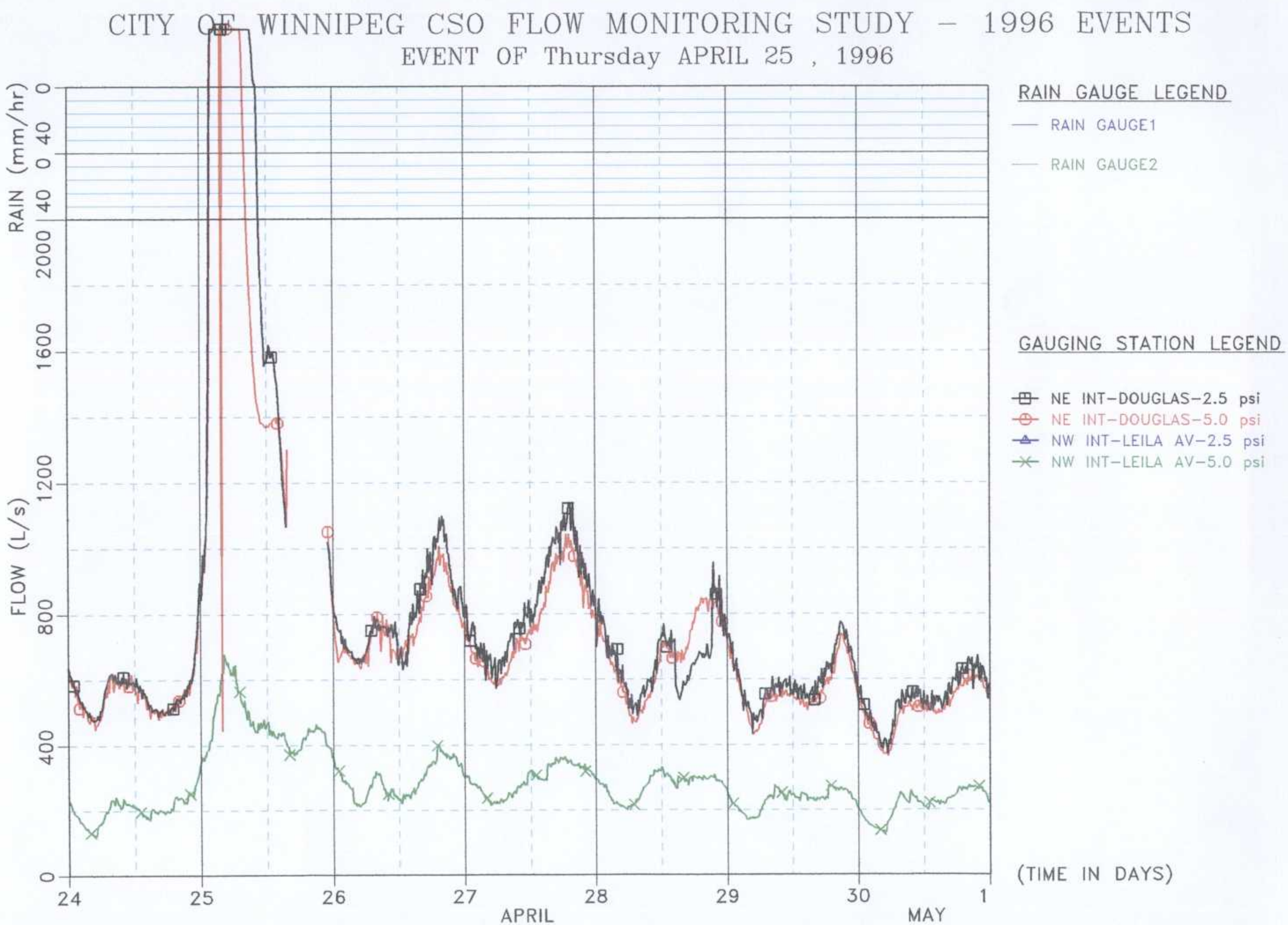
CITY OF WINNIPEG CSO FLOW MONITORING STUDY 1996/97
FLOWRATES FOR WEEKS OF DEC 16 - 29 (Monday - Monday)



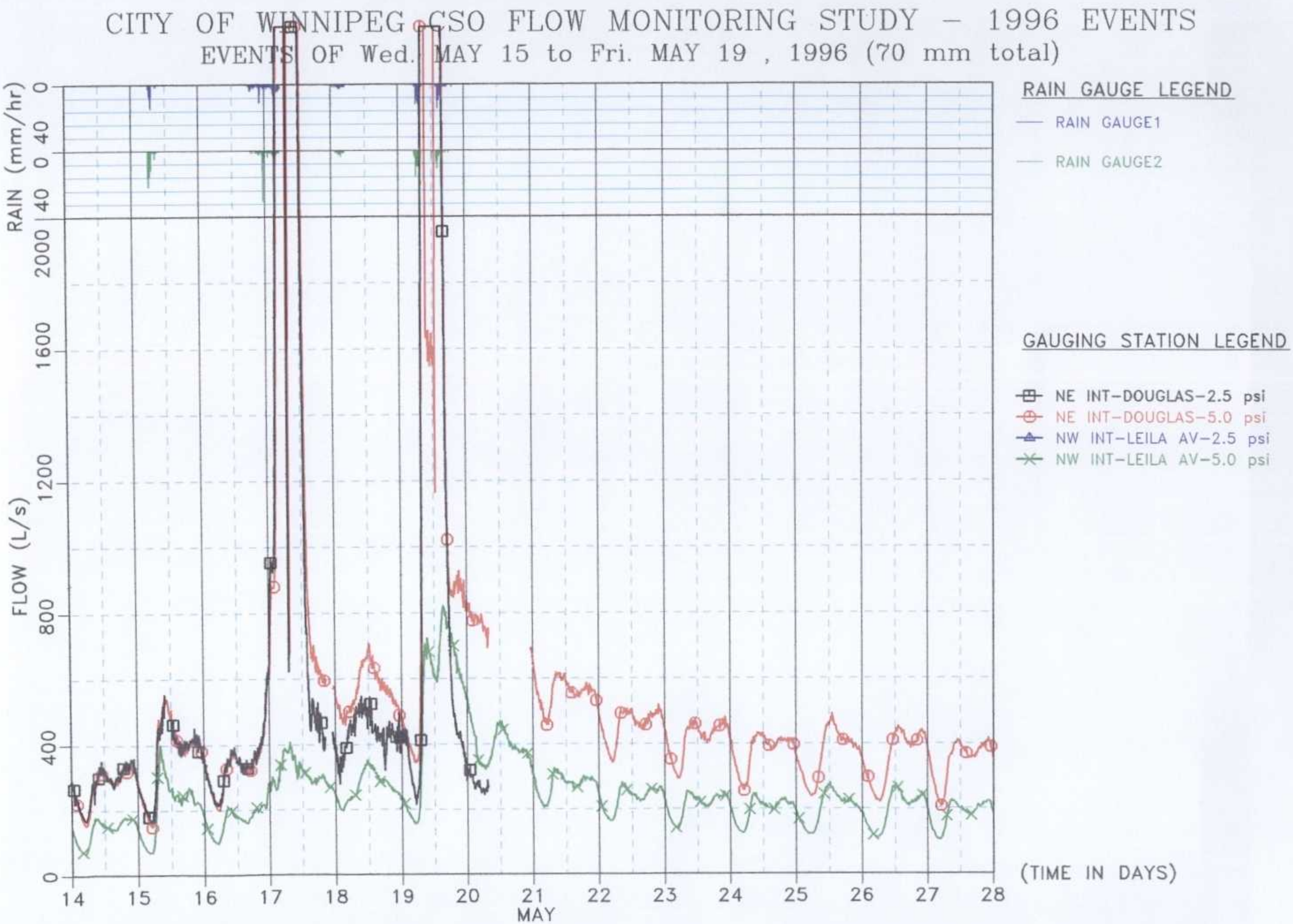
1996 EVENTS

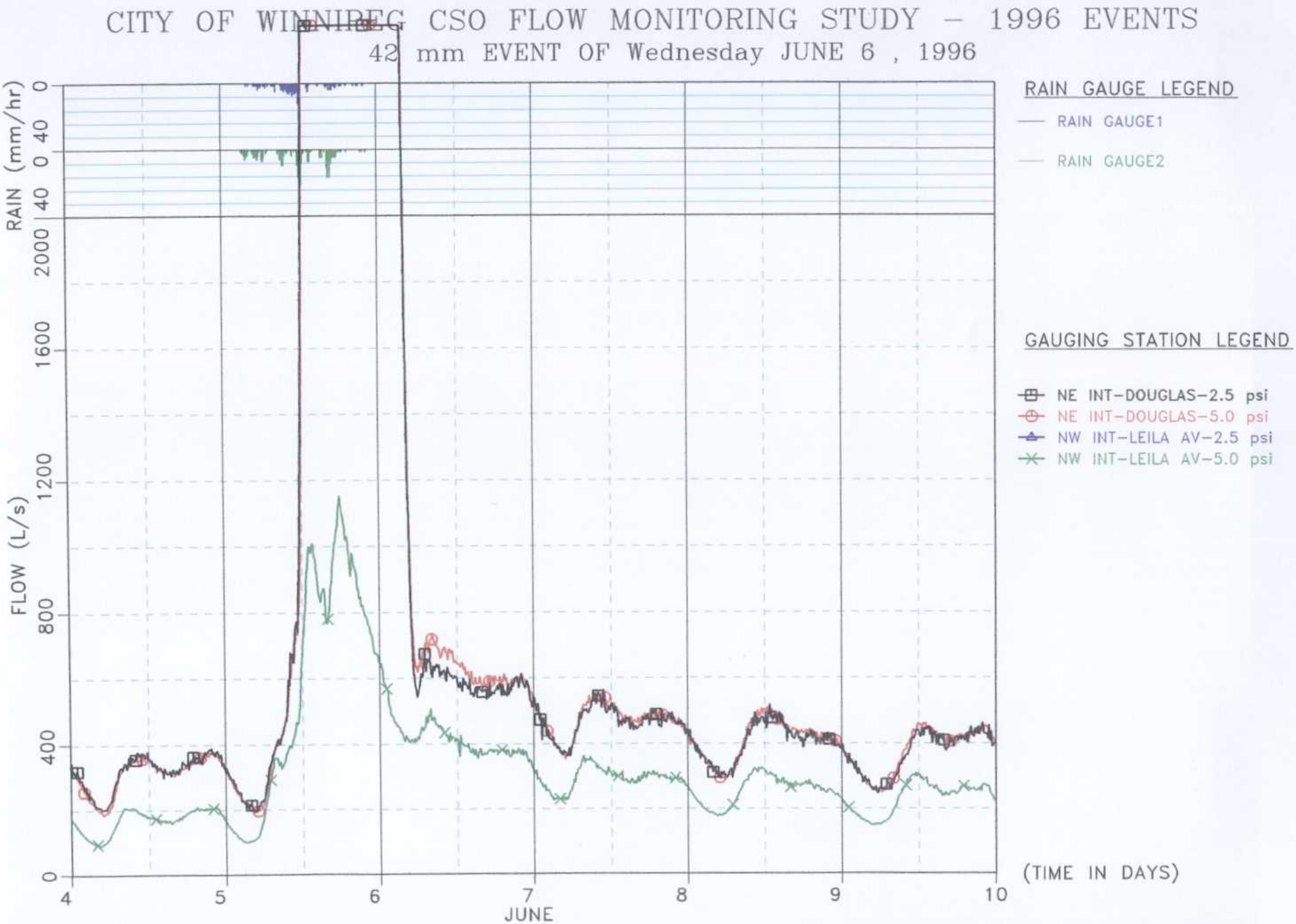
FULL SCALE = 2000 l/s

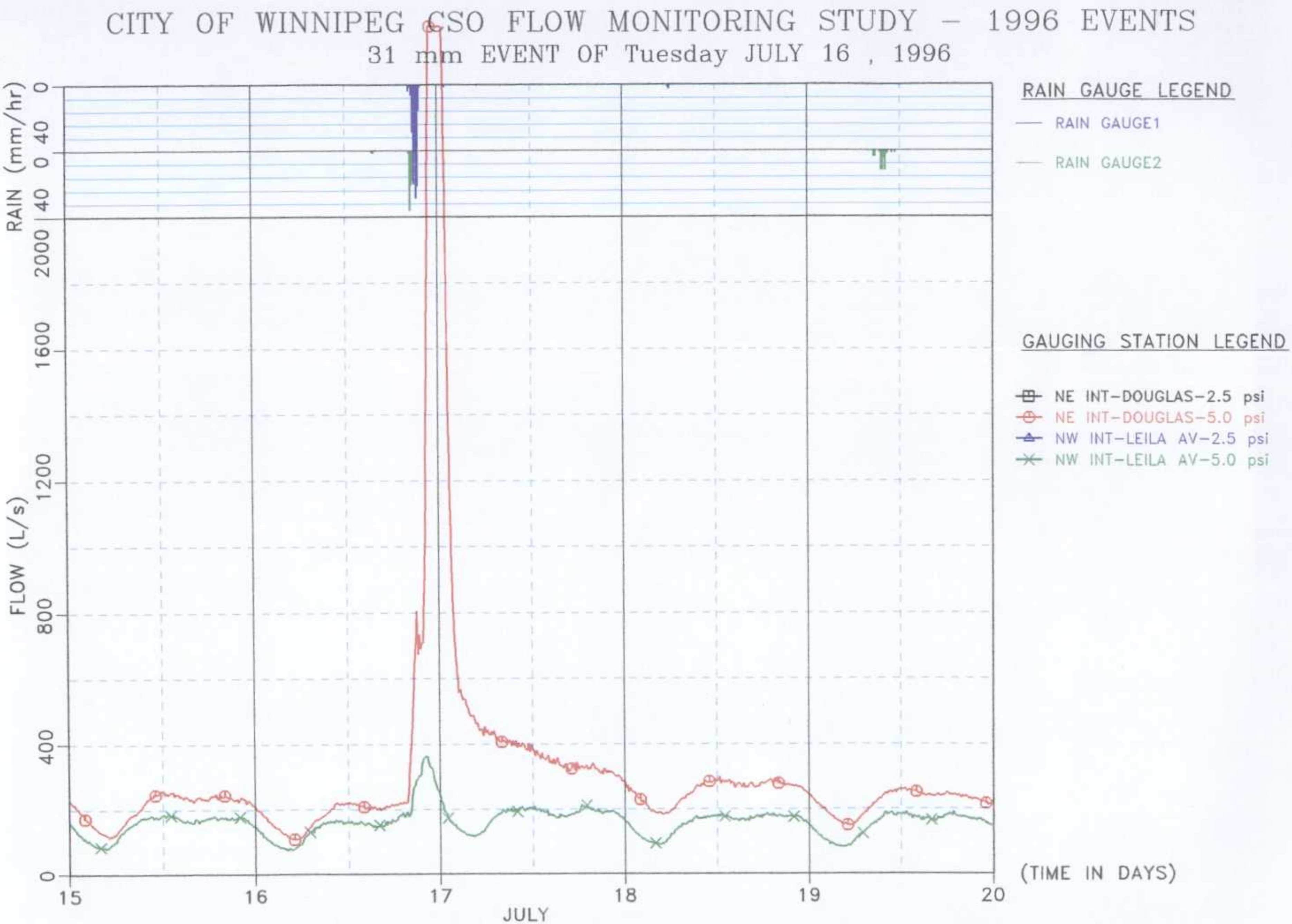




CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1996 EVENTS
EVENT OF Thursday APRIL 25 , 1996
RAIN (mm/hr)
0
40
0
40
2000
1600
1200
800
400
0
FLOW (L/s)
24
25
26
27
28
29
30
1
APRIL
MAY
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)

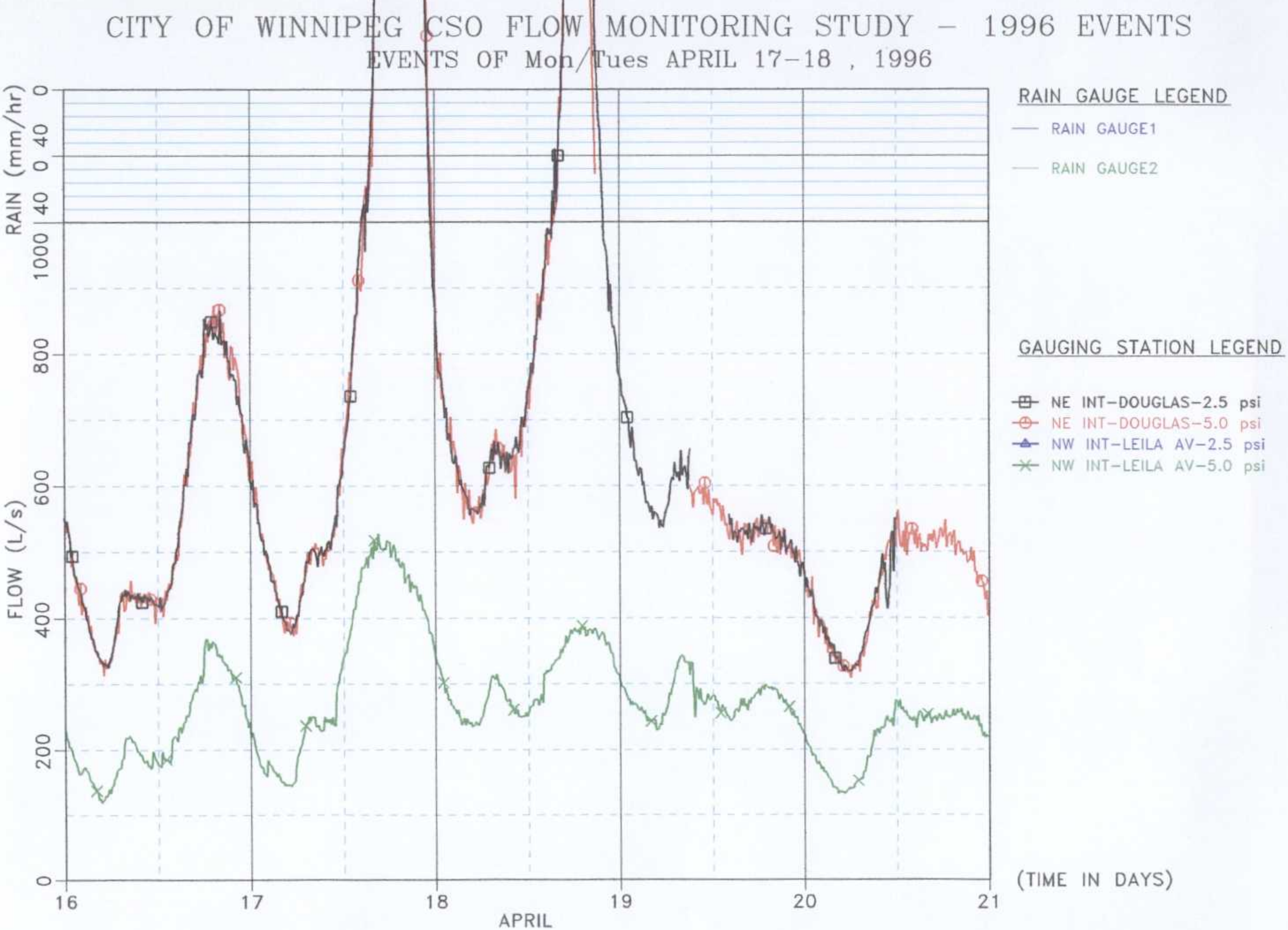

CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1996 EVENTS
EVENTS OF Wed. MAY 15 to Fri. MAY 19 , 1996 (70 mm total)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
2000
1600
1200
800
400
0
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
MAY
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi

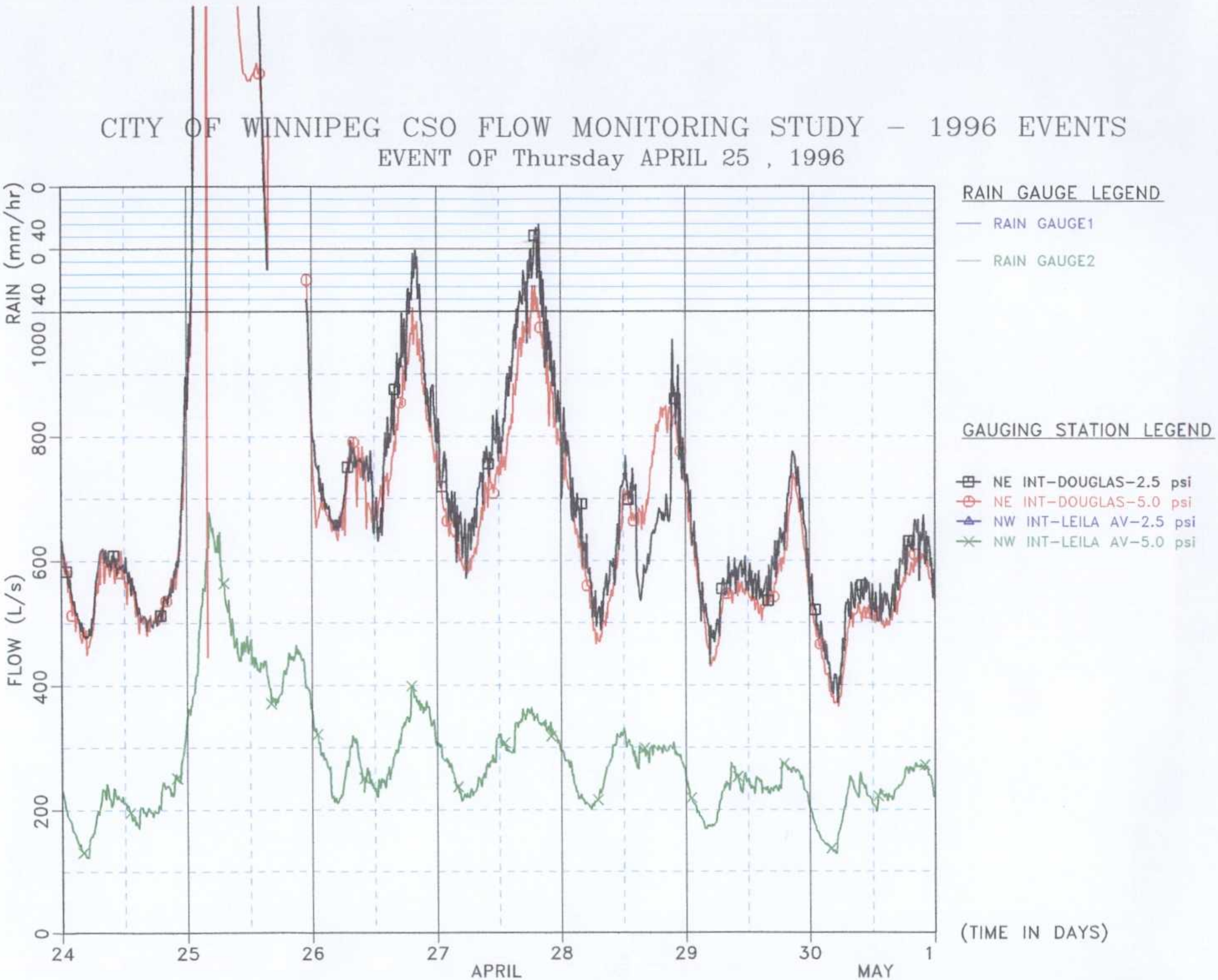

CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1996 EVENTS
42 mm EVENT OF Wednesday JUNE 6 , 1996
RAIN (mm/hr)
FLOW (L/s)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)
JUNE

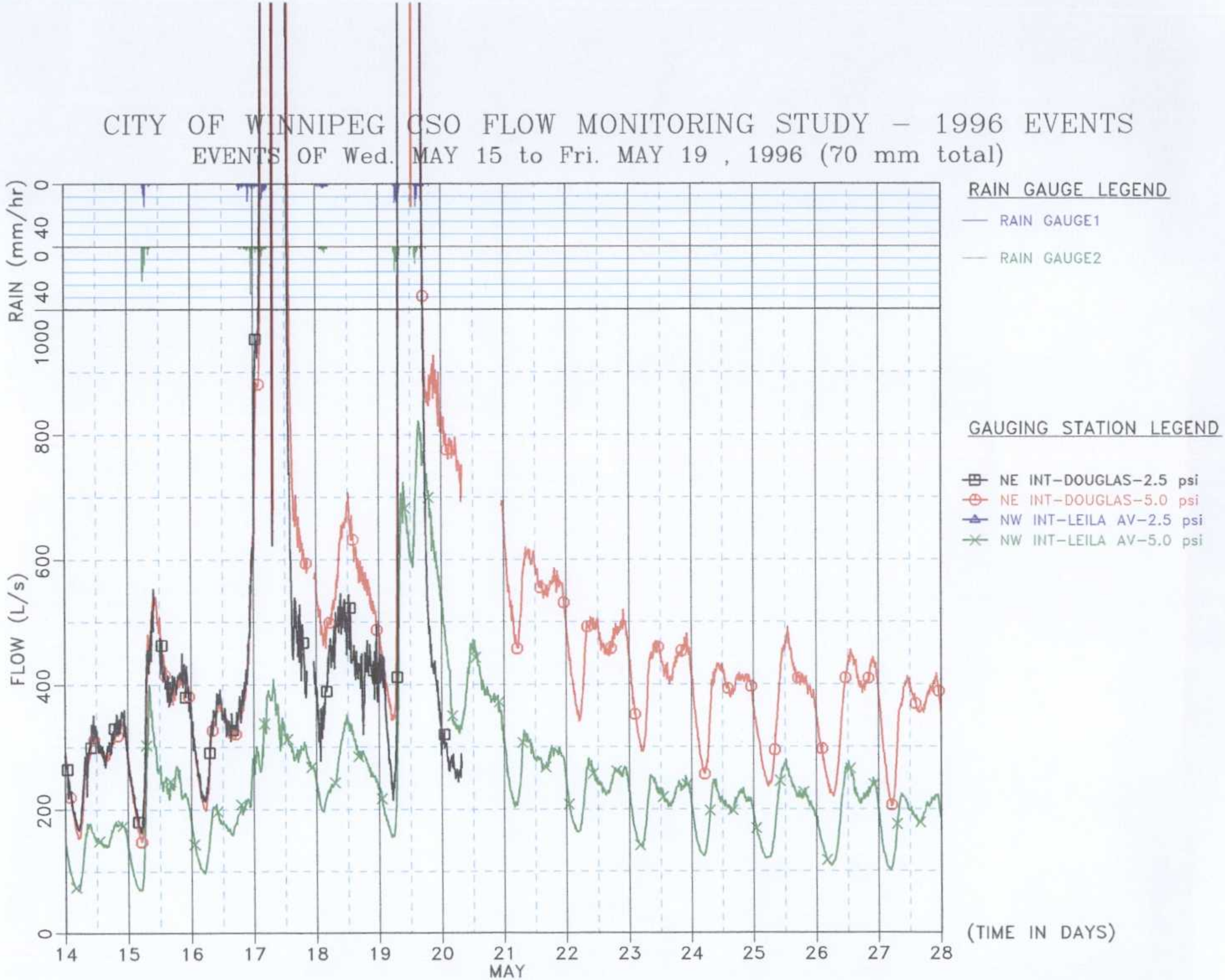

CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1996 EVENTS
31 mm EVENT OF Tuesday JULY 16 , 1996
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
2000
1600
1200
800
400
0
15
16
17
18
19
20
JULY
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi

1996 EVENTS

FULL SCALE = 1000 l/s

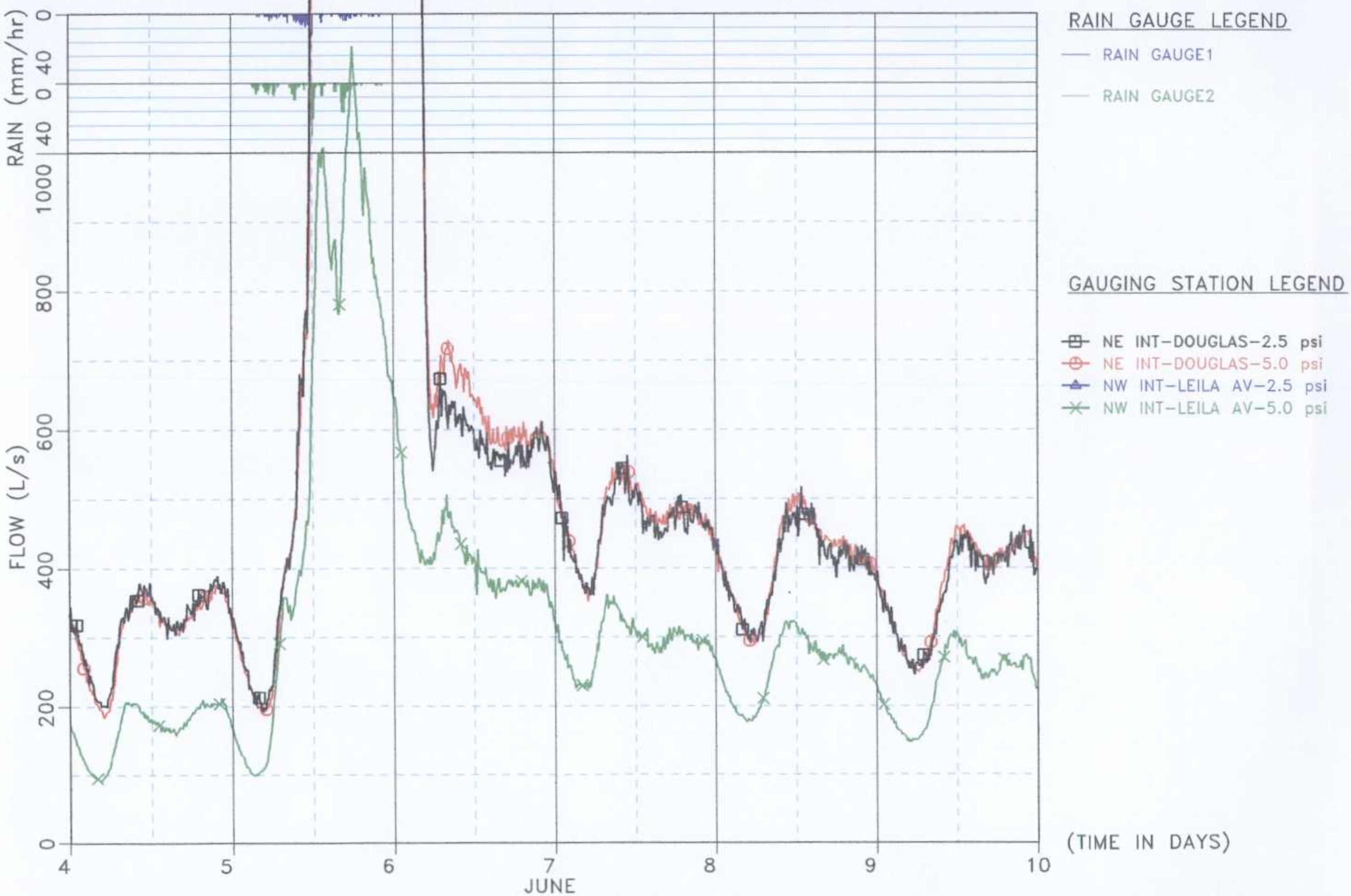


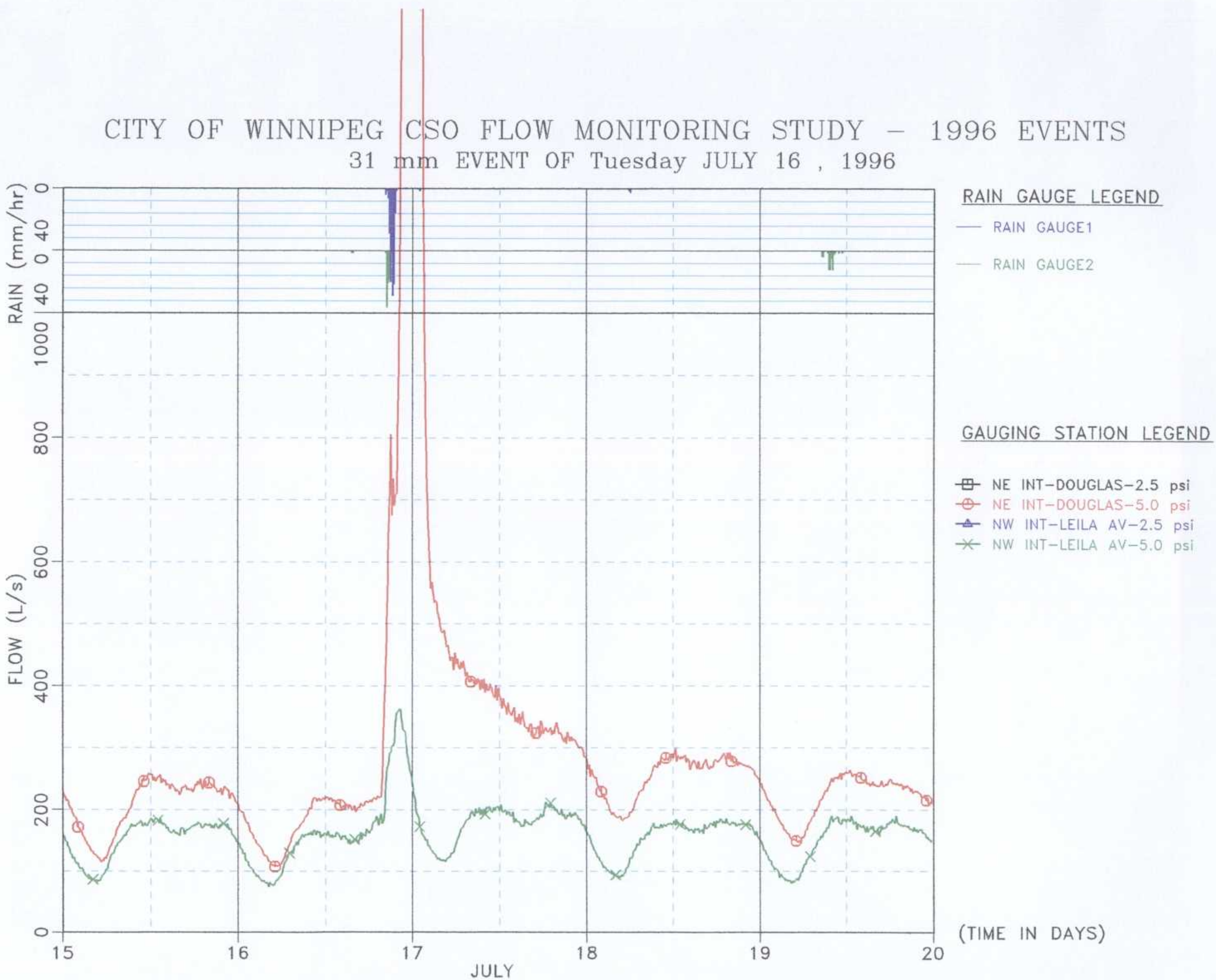

CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1996 EVENTS
EVENT OF Thursday APRIL 25 , 1996
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
24
25
26
27
28
29
30
1
APRIL
MAY
(TIME IN DAYS)


CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1996 EVENTS
EVENTS OF Wed. MAY 15 to Fri. MAY 19 , 1996 (70 mm total)
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
0
200
400
600
800
1000
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
MAY
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi

CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1996 EVENTS

42 mm EVENT OF Wednesday JUNE 6 , 1996



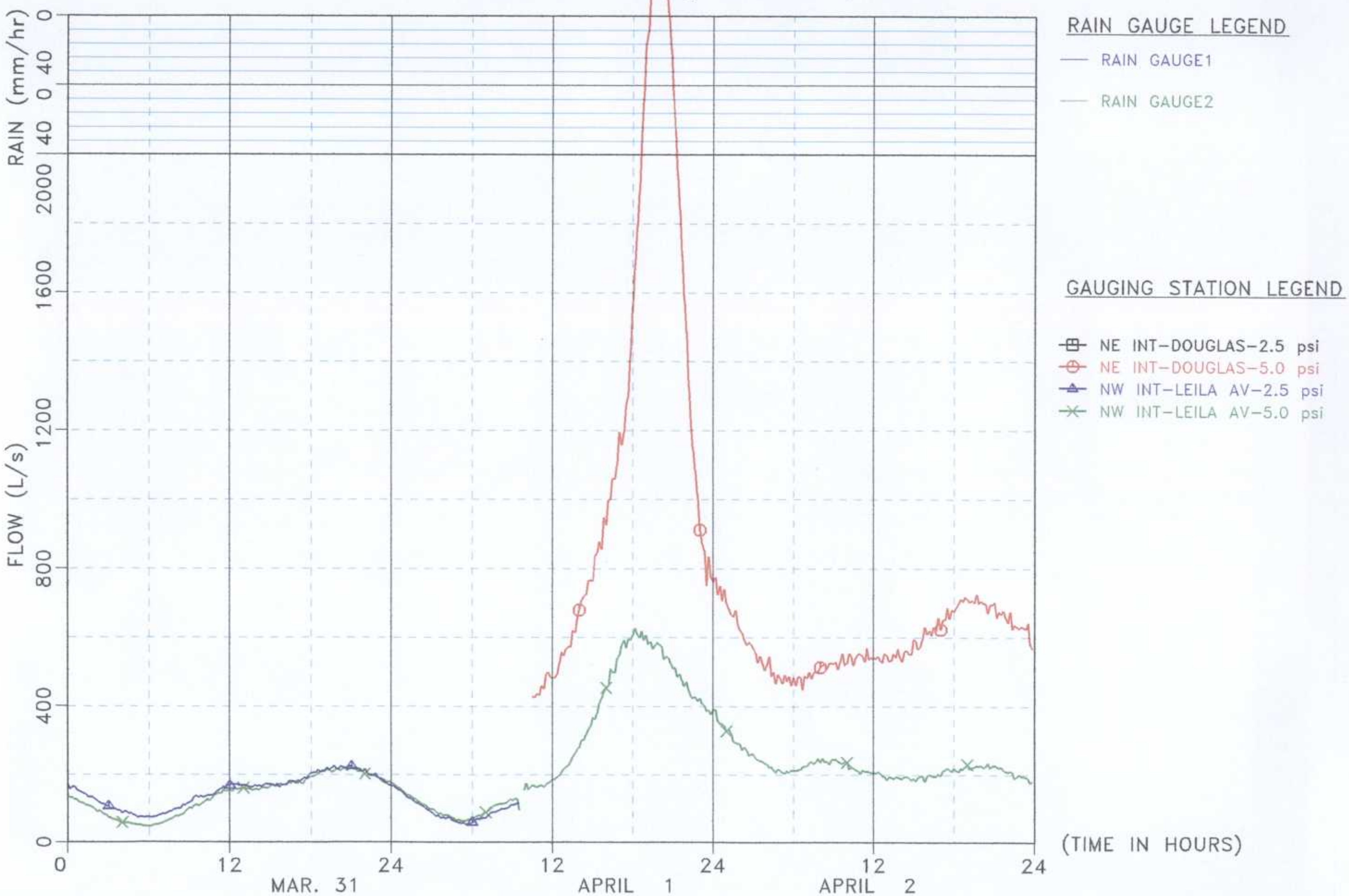

CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1996 EVENTS
31 mm EVENT OF Tuesday JULY 16 , 1996
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
15
16
17
18
19
20
JULY
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi

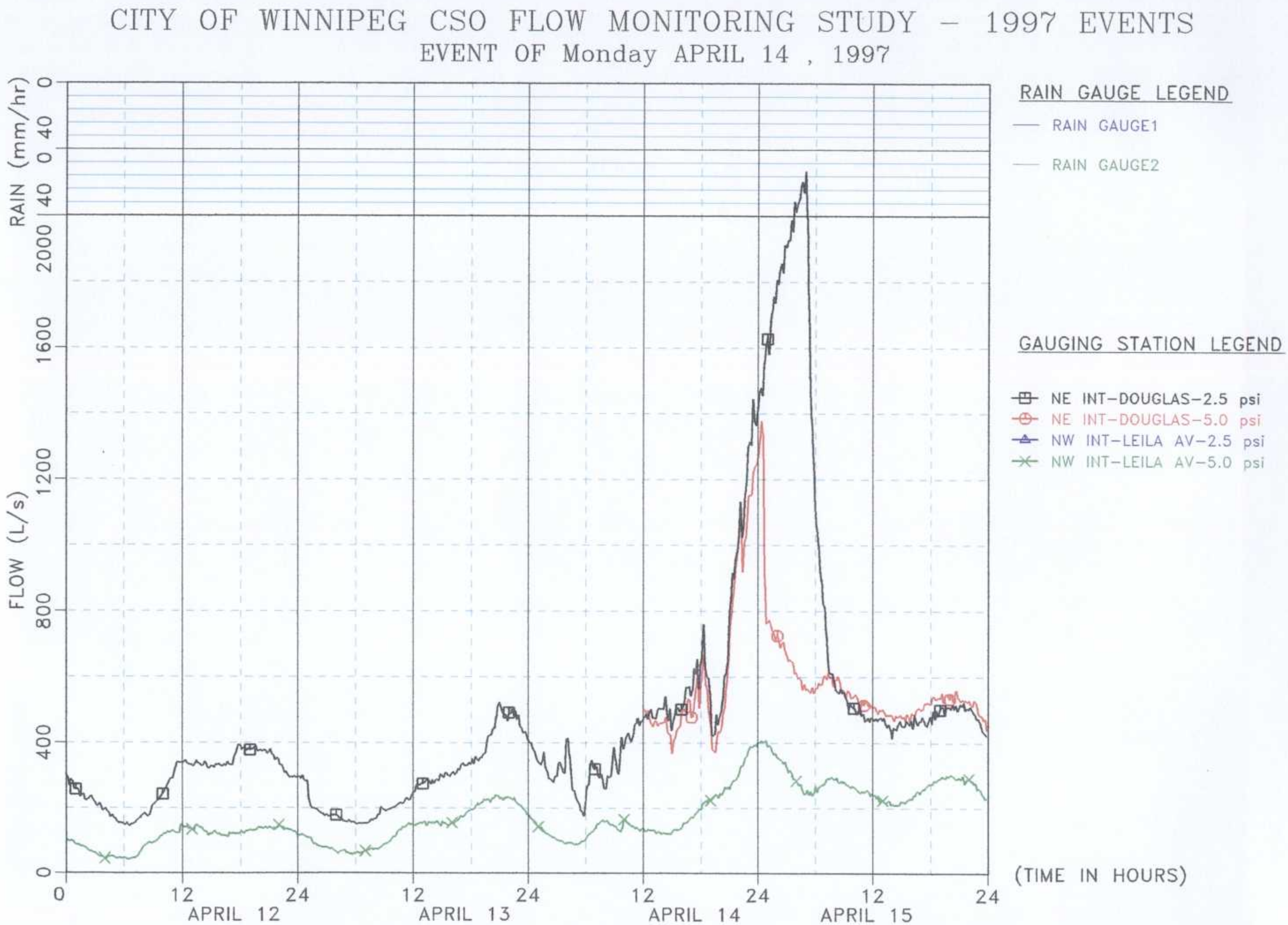
1997 EVENT PLOTS

FULL SCALE = 2000 l/s

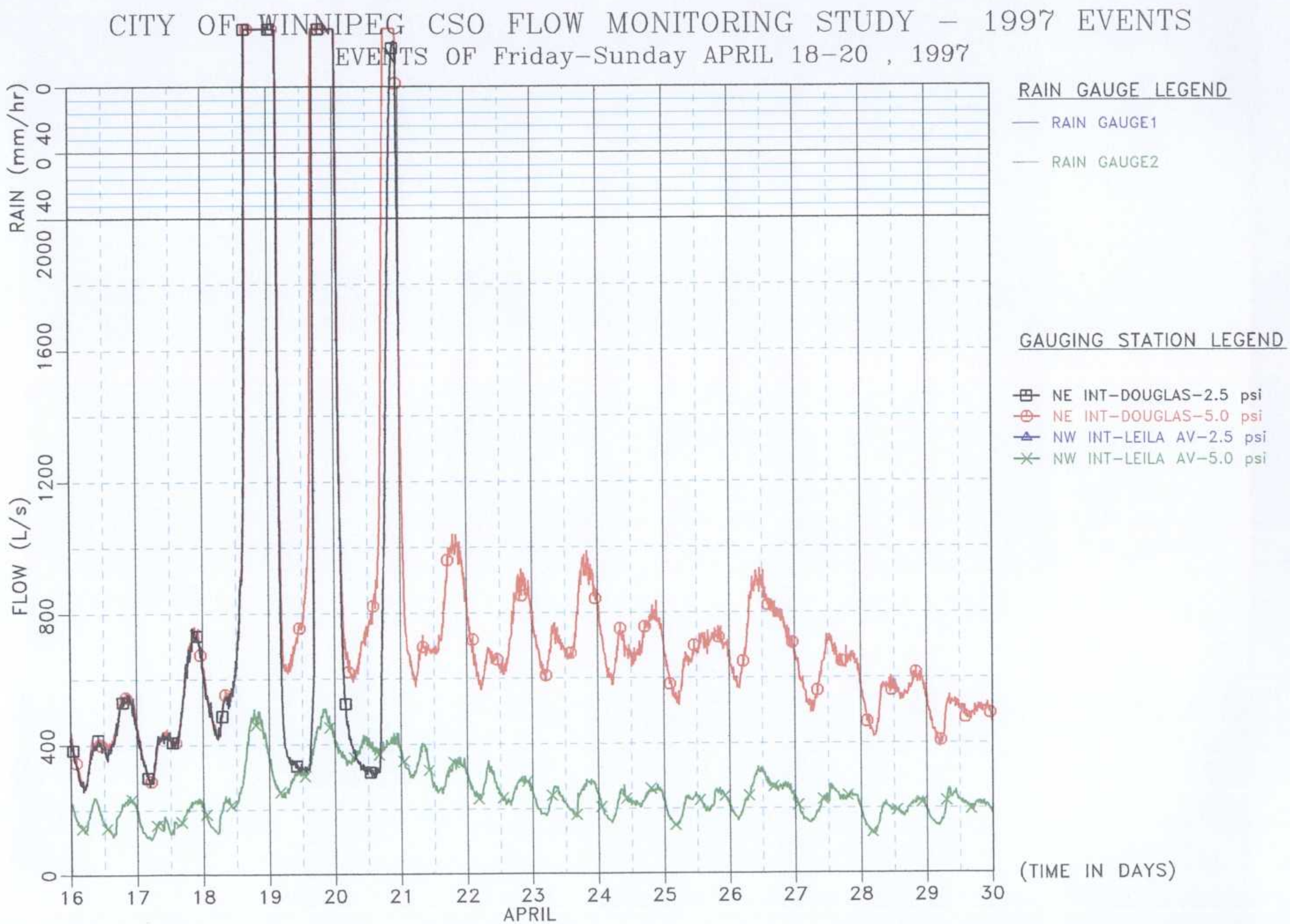
CITY OF WINNIPEG CSO FLOW MONITORING STUDY – 1997 EVENTS

EVENT OF Sunday APRIL 1 , 1997

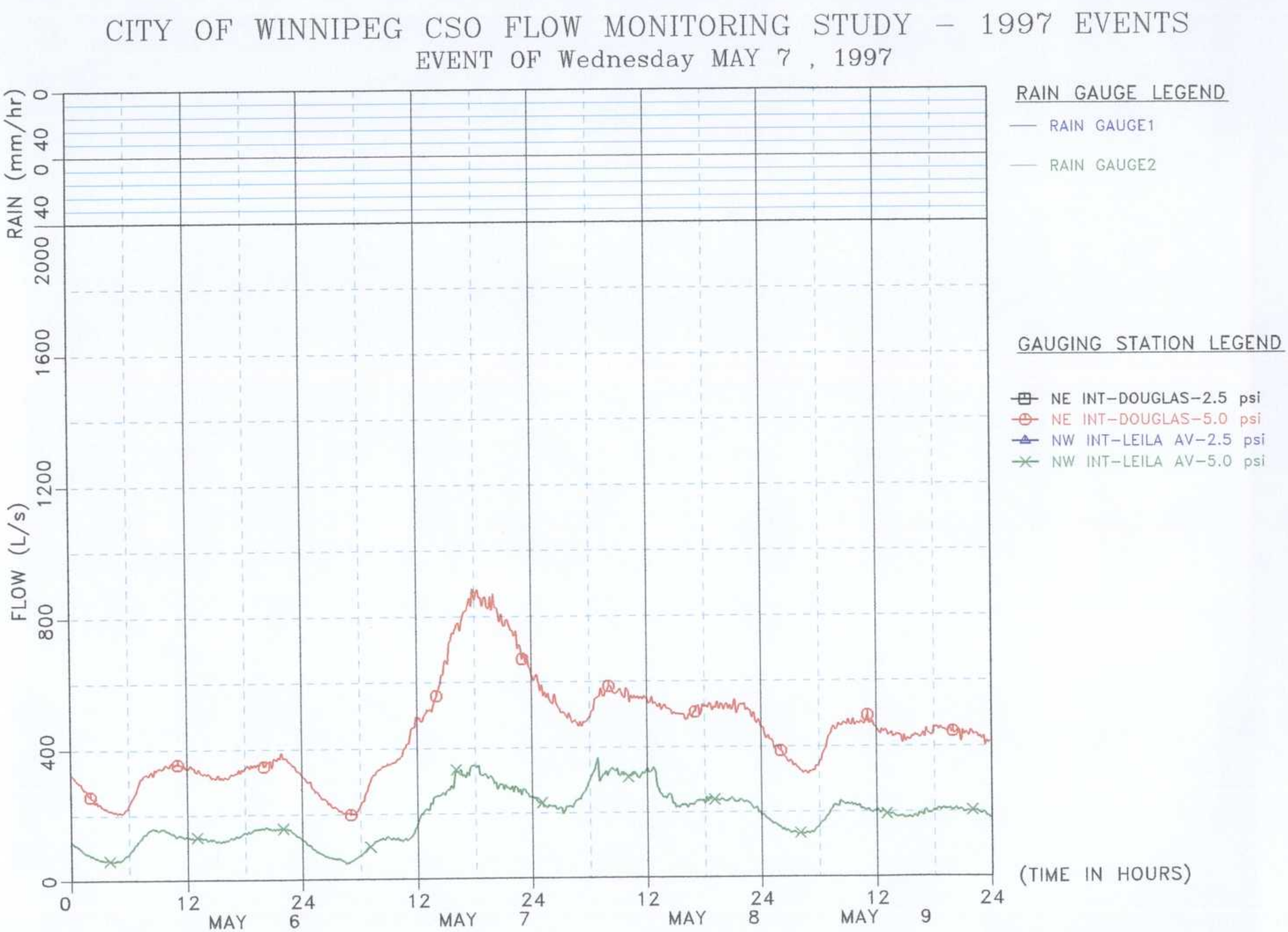




CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1997 EVENTS
EVENT OF Monday APRIL 14 , 1997
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
2000
1600
1200
800
400
0
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN HOURS)
0
12
24
12
24
12
24
12
24
APRIL 12
APRIL 13
APRIL 14
APRIL 15

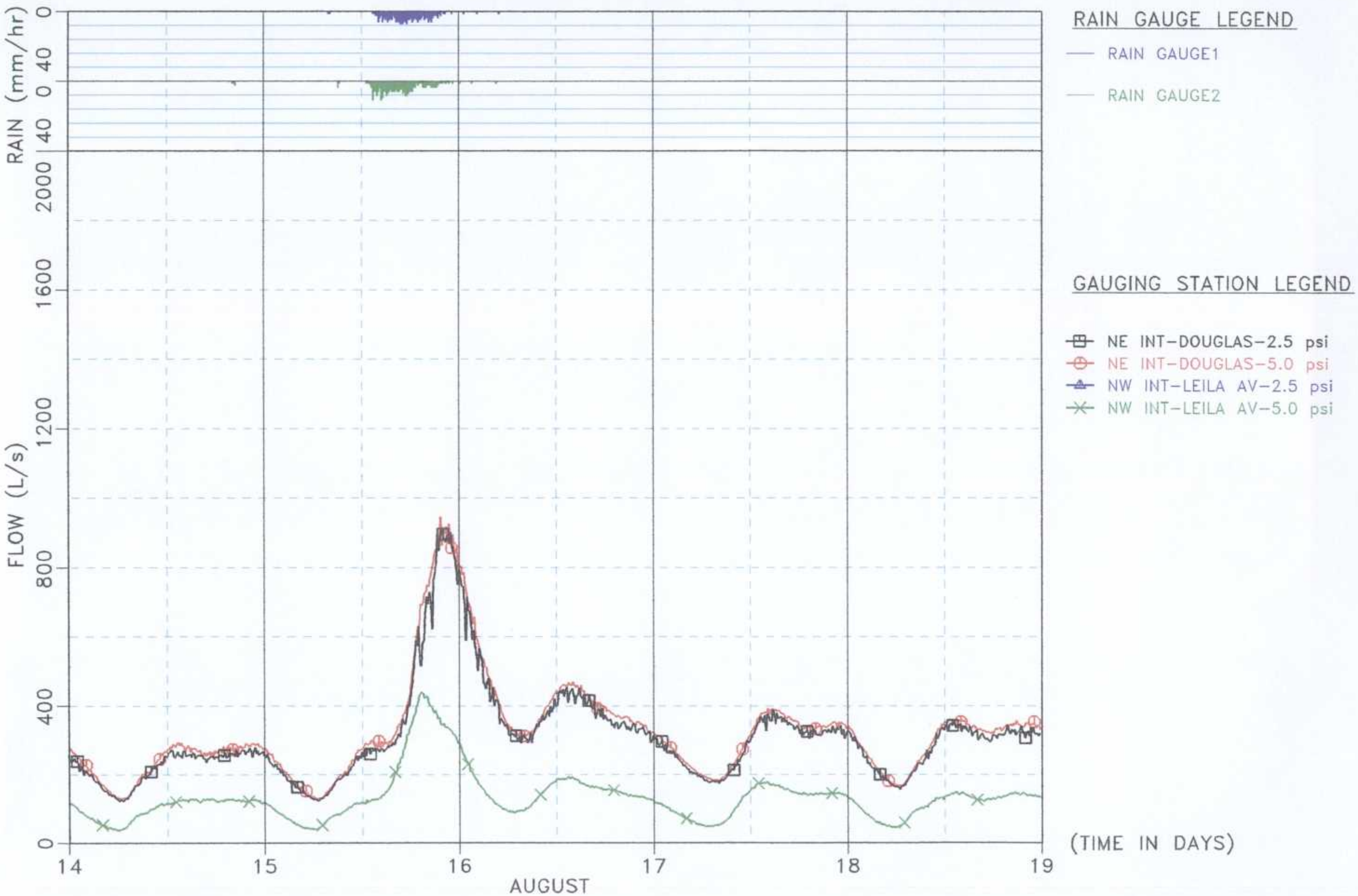


CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1997 EVENTS
EVENTS OF Friday-Sunday APRIL 18-20 , 1997
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
2000
1600
1200
800
400
0
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
APRIL
(TIME IN DAYS)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi


CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1997 EVENTS
EVENT OF Wednesday MAY 7 , 1997
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
2000
1600
1200
800
400
0
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN HOURS)
0
12
24
12
24
12
24
12
24
MAY 6
MAY 7
MAY 8
MAY 9

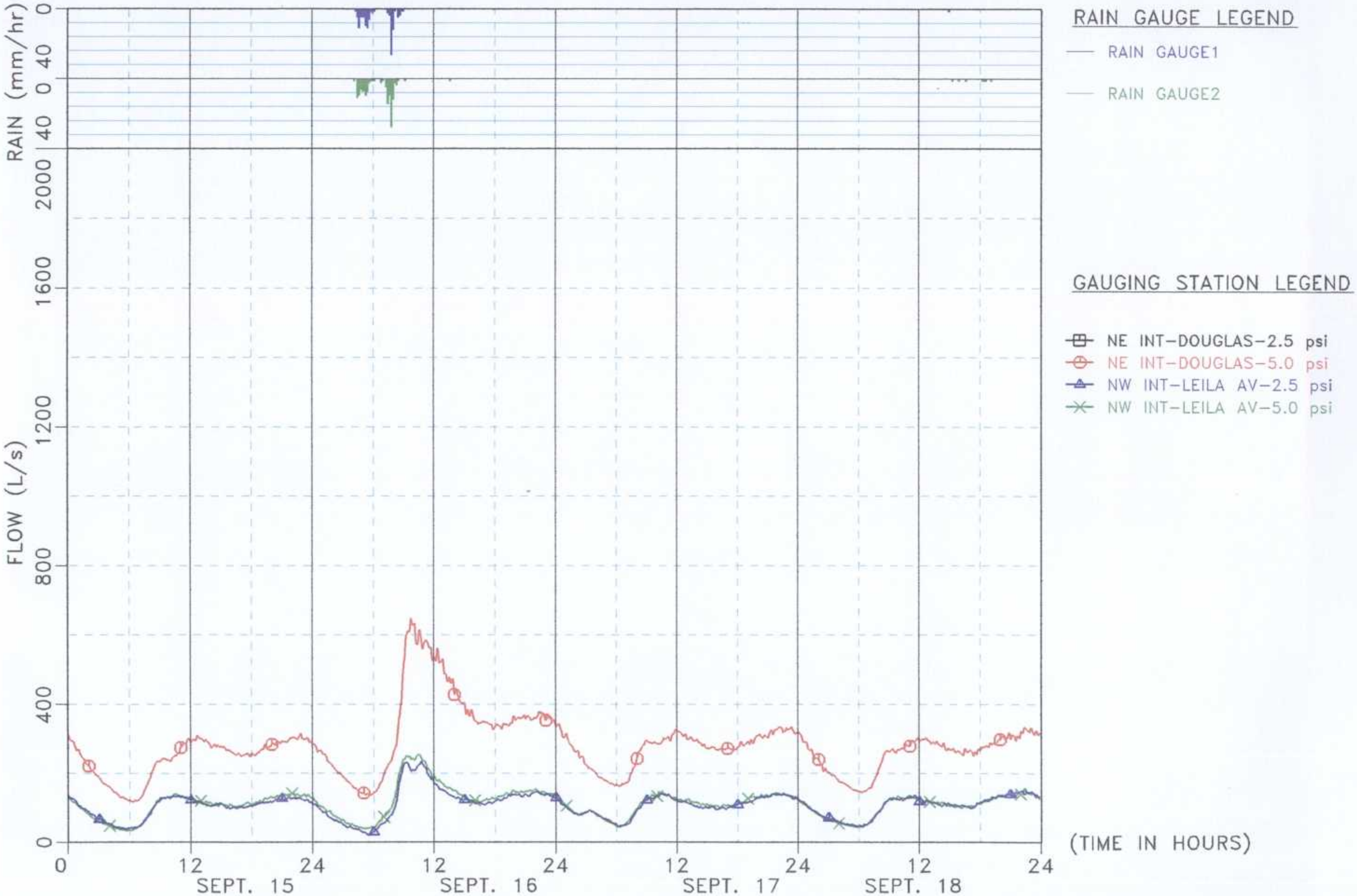
CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1997 EVENTS

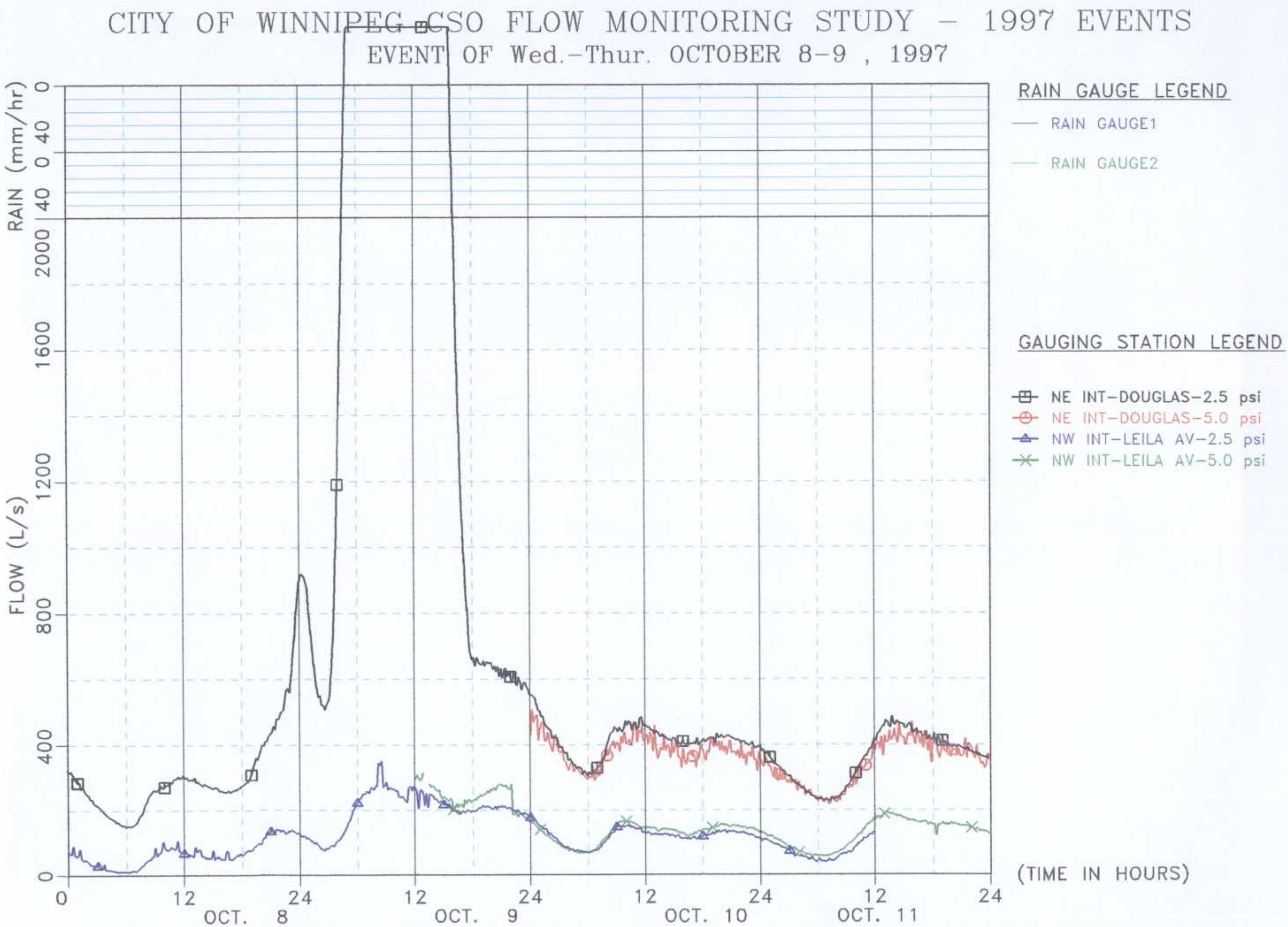
42 mm EVENT OF Friday AUGUST 15 , 1997



CITY OF WINNIPEG CSO FLOW MONITORING STUDY – 1997 EVENTS

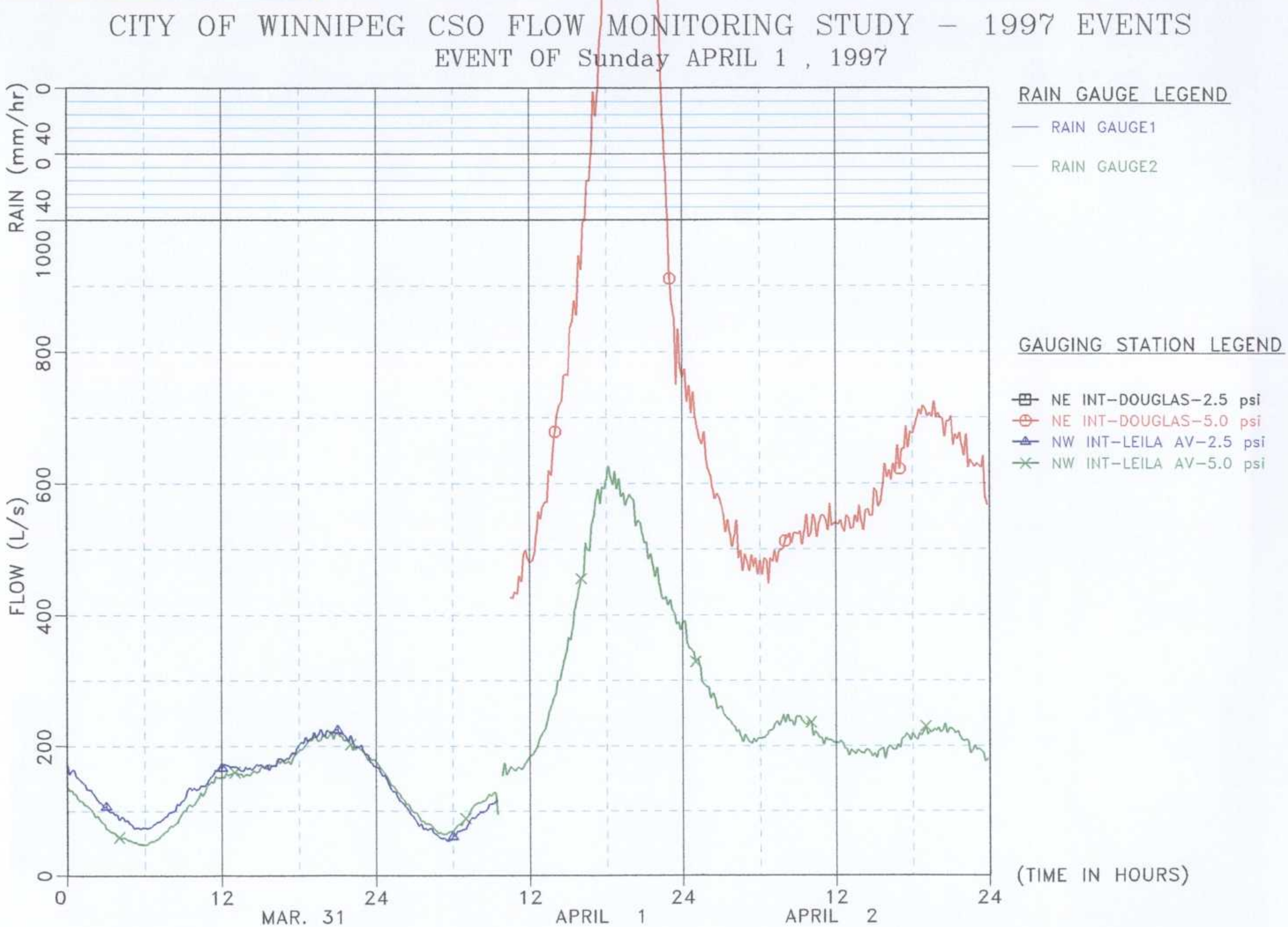
22 mm EVENT OF Tuesday SEPTEMBER 16 , 1997

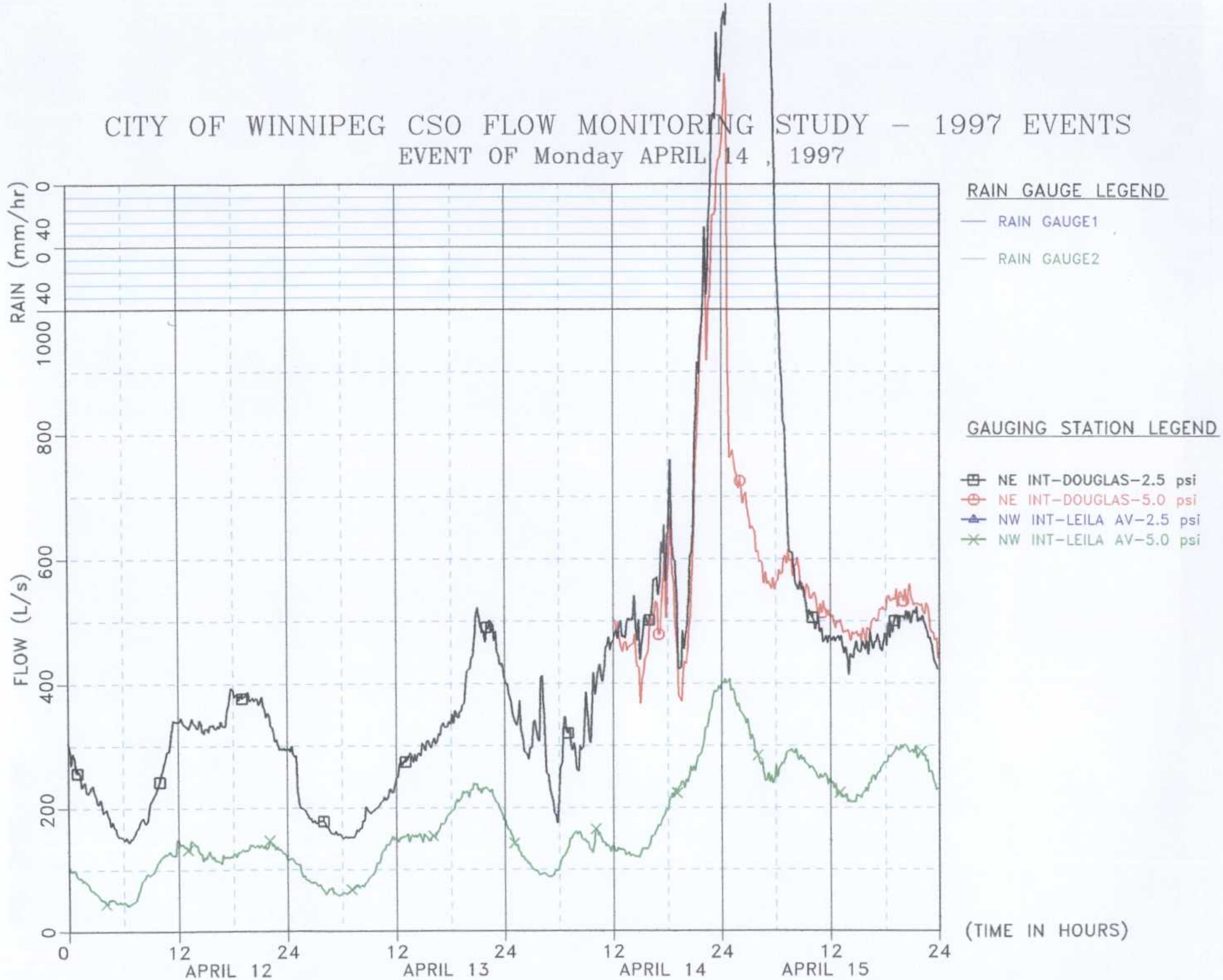




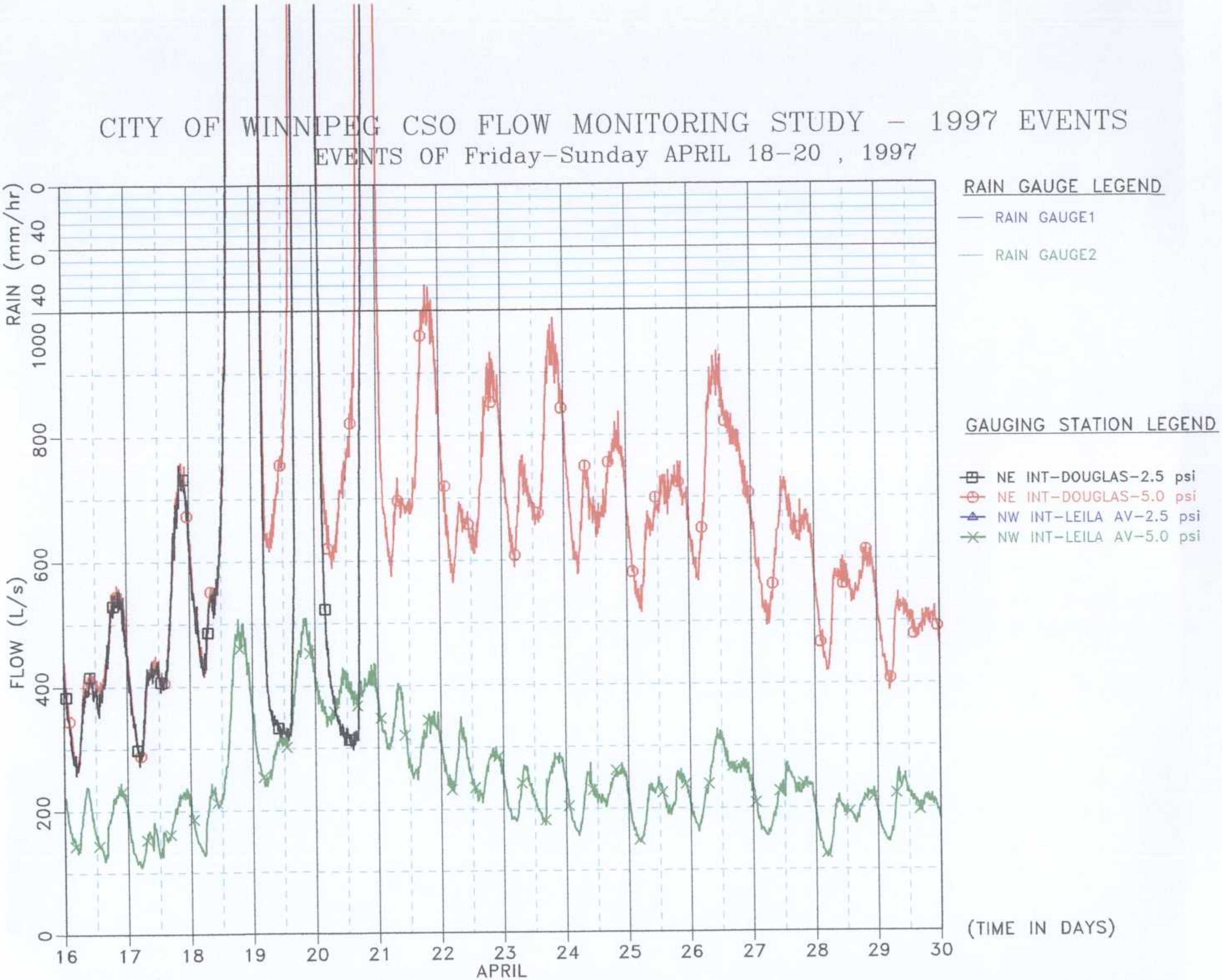
CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1997 EVENTS
EVENT OF Wed.-Thur. OCTOBER 8-9 , 1997
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
2000
1600
1200
800
400
0
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
0
12
24
12
24
12
24
12
24
OCT. 8
OCT. 9
OCT. 10
OCT. 11
(TIME IN HOURS)

1997 EVENTS
FULL SCALE = 1000 l/s

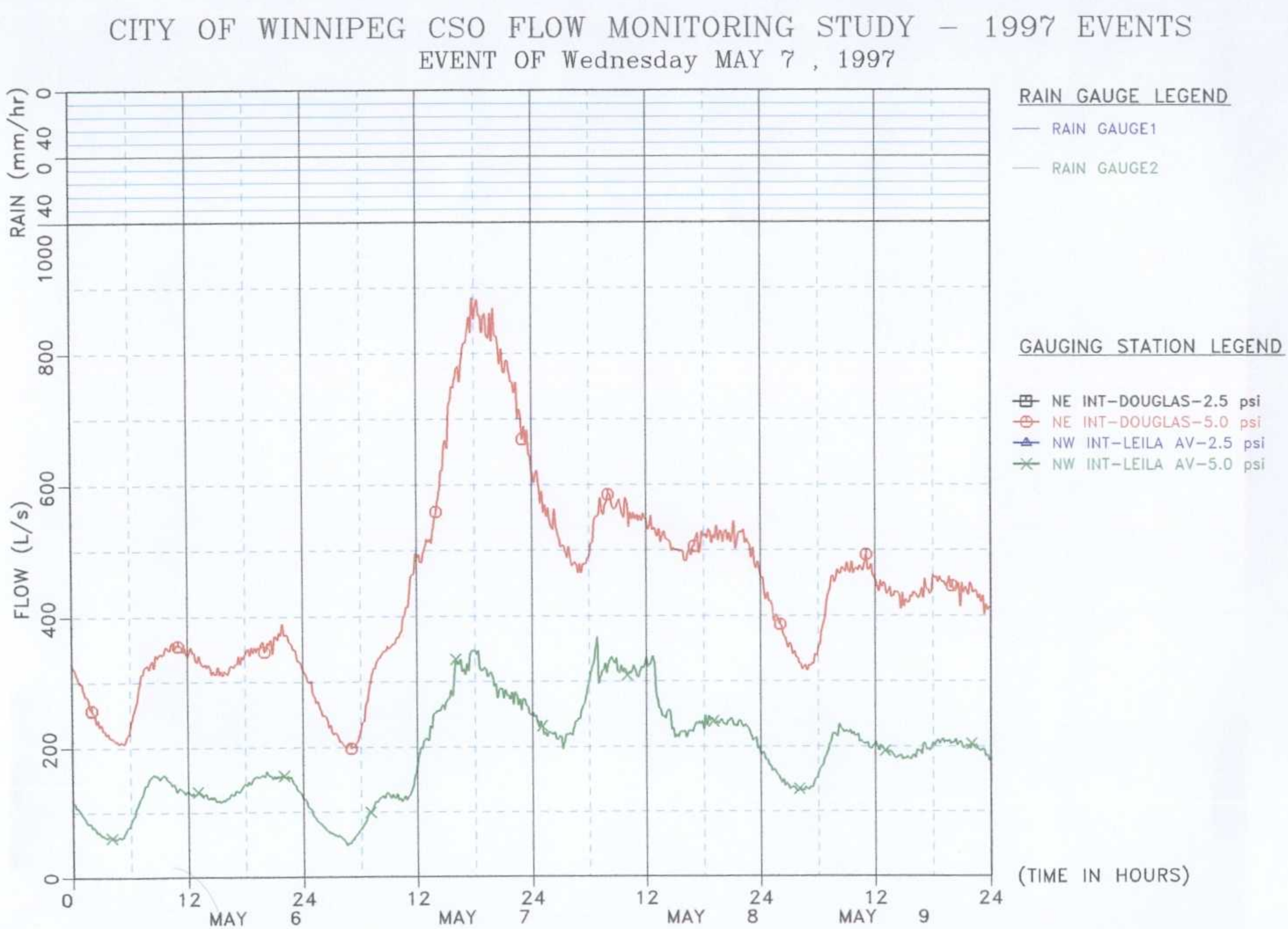




CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1997 EVENTS
EVENT OF Monday APRIL 14 , 1997
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
0
12
24
12
24
12
24
12
24
APRIL 12
APRIL 13
APRIL 14
APRIL 15
(TIME IN HOURS)



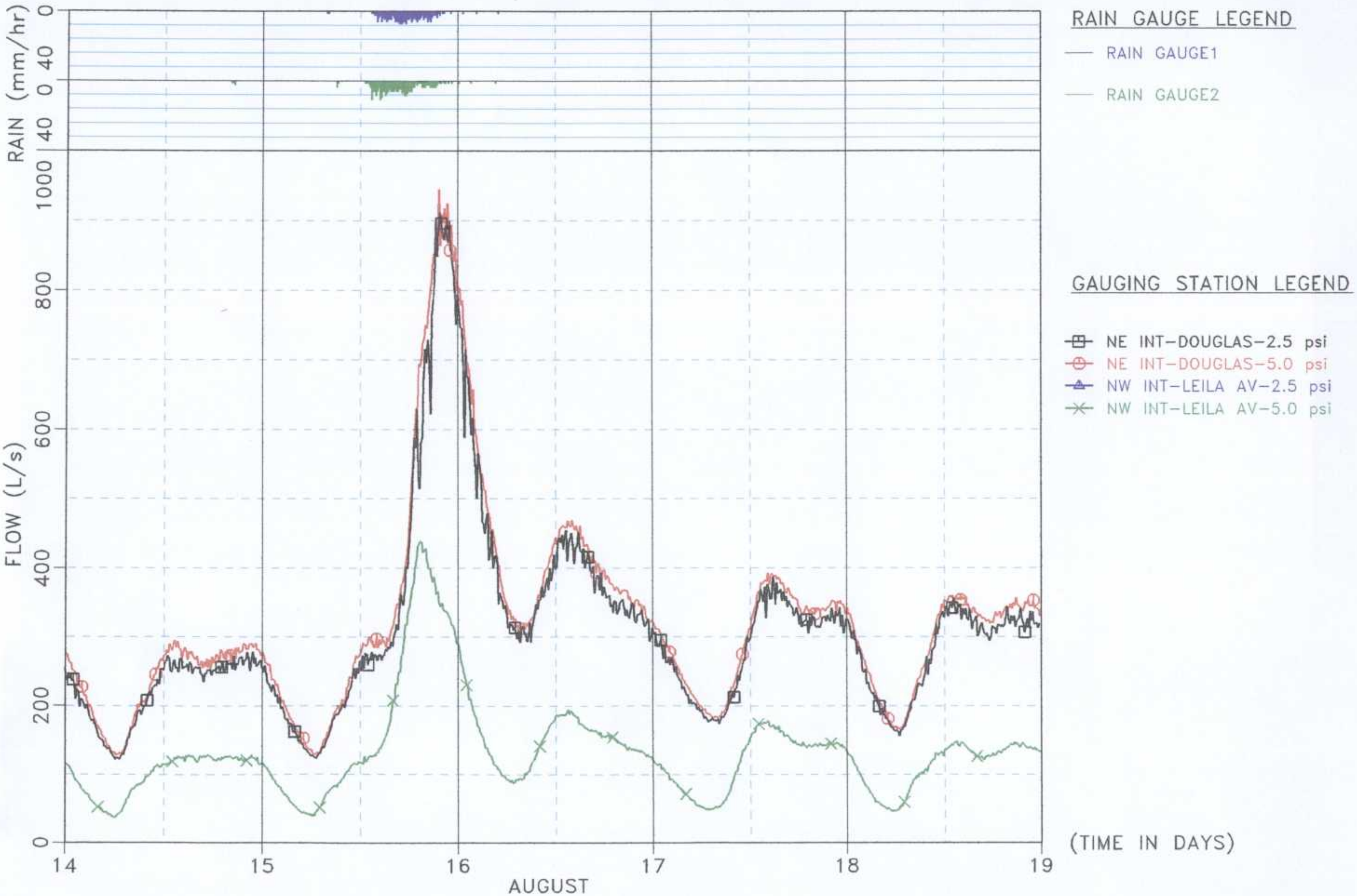
CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1997 EVENTS
EVENTS OF Friday-Sunday APRIL 18-20 , 1997
RAIN (mm/hr)
FLOW (L/s)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN DAYS)
APRIL



CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1997 EVENTS
EVENT OF Wednesday MAY 7 , 1997
RAIN (mm/hr)
0
40
0
40
FLOW (L/s)
1000
800
600
400
200
0
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
0
12
24
12
24
12
24
12
24
MAY 6
MAY 7
MAY 8
MAY 9
(TIME IN HOURS)

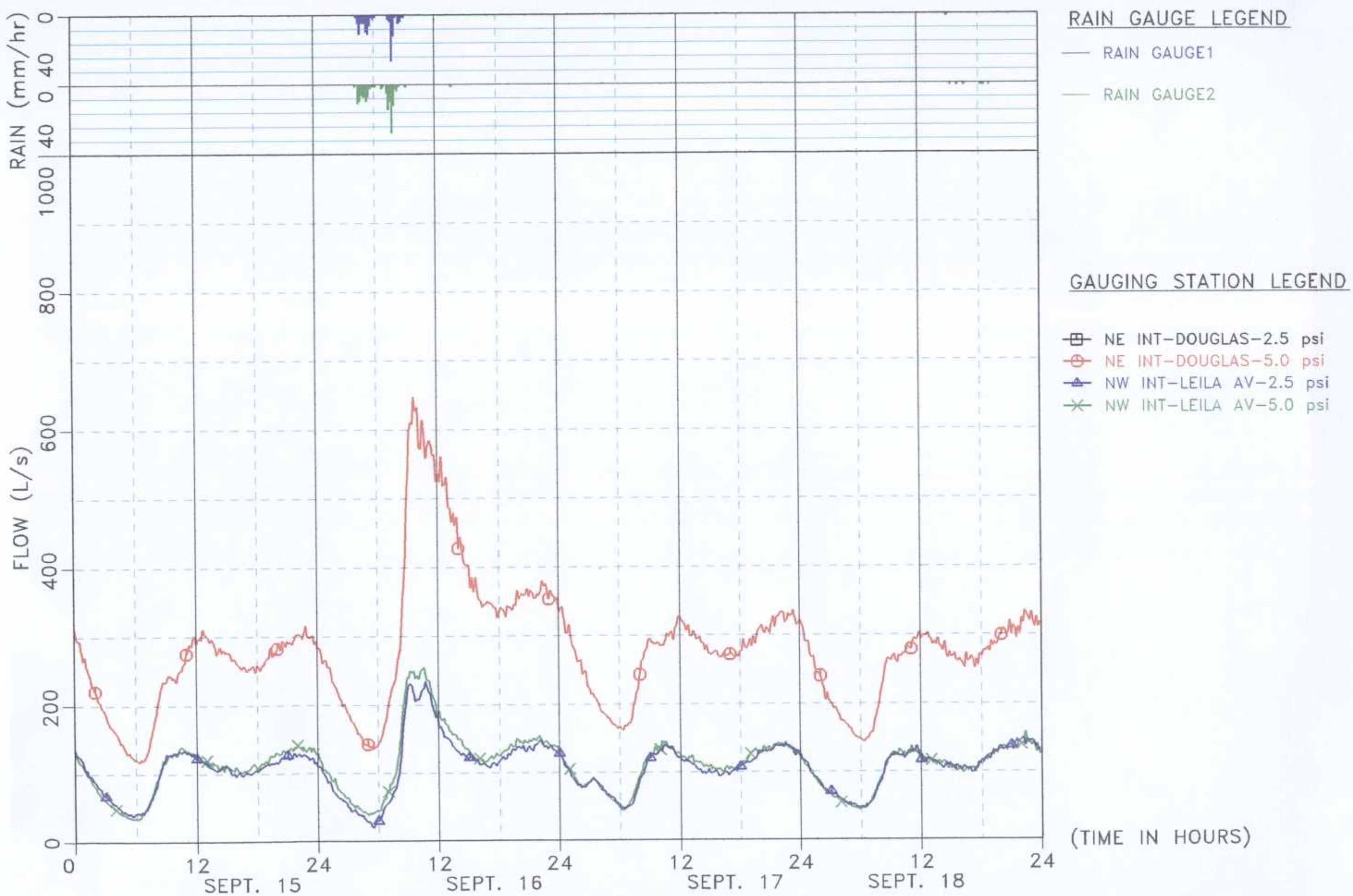
CITY OF WINNIPEG CSO FLOW MONITORING STUDY – 1997 EVENTS

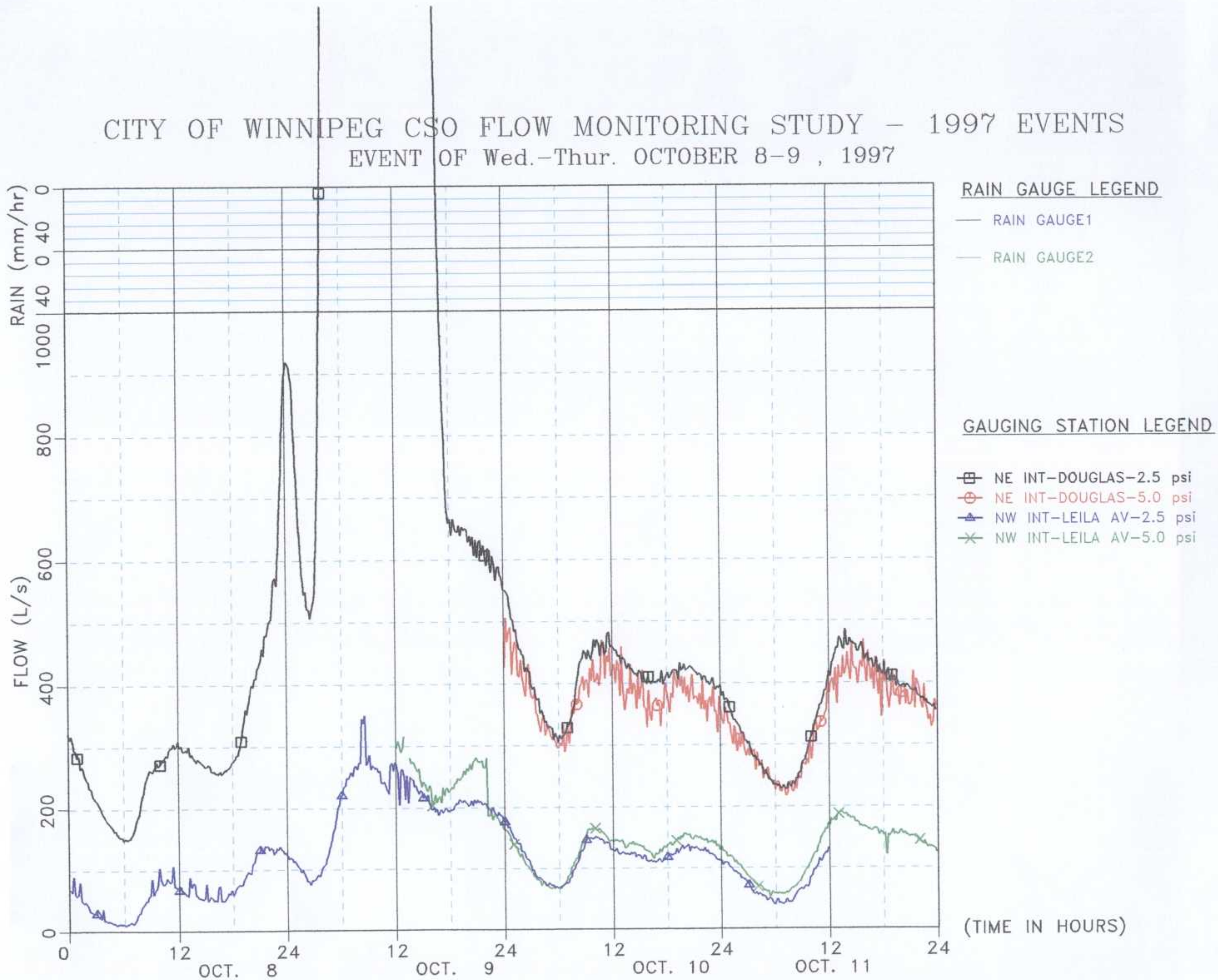
42 mm EVENT OF Friday AUGUST 15 , 1997



CITY OF WINNIPEG CSO FLOW MONITORING STUDY – 1997 EVENTS

22 mm EVENT OF Tuesday SEPTEMBER 16 , 1997





CITY OF WINNIPEG CSO FLOW MONITORING STUDY - 1997 EVENTS
EVENT OF Wed.-Thur. OCTOBER 8-9 , 1997
RAIN (mm/hr)
FLOW (L/s)
RAIN GAUGE LEGEND
RAIN GAUGE1
RAIN GAUGE2
GAUGING STATION LEGEND
NE INT-DOUGLAS-2.5 psi
NE INT-DOUGLAS-5.0 psi
NW INT-LEILA AV-2.5 psi
NW INT-LEILA AV-5.0 psi
(TIME IN HOURS)
OCT. 8
OCT. 9
OCT. 10
OCT. 11