



## **Technical note on rainfall in Sana'a**

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This is a technical note on data collected by the Water and Environment Centre. This note will be updated when new data are available. The latest version can be downloaded from the WEC-website at [www.wec.suye.ac](http://www.wec.suye.ac).

The rainfall monitoring program of the WEC is part of a larger research program on IWRM in Yemen. The objective of the technical note is to make data more widely available. This program is supported by Nuffic Project NPT/YE/036 "Strengthening WEC's Educational Program". Satellite analysis is provided by WaterWatch, The Netherlands.

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## **Introduction**

Integrated Water Resources Management is an approach that combines multiple disciplines to obtain a comprehensive assessment and planning towards water management. The WEC has currently 2 groups of MSc students; 14 students starting their MSc research in the second year, and 12 students following first year courses. Part of the course work involves monitoring water resources. An example rainfall monitoring program in Sana'a was started in December 2006 by WEC research staff. This program will be expanded as part of individual MSc research by the students, among other objectives, to obtain information on renewable water resources for medium size watersheds. Note that this monitoring is only a small part of the IWRM approach, and that obtaining the rainfall data is not the ultimate goal of this program. The measurements must be used as an input in comprehensive planning and evaluation of water management.

## **Methodology**

Four tipping bucket rain gauges are installed on roofs of houses with secure access. Although this is not a standard location for rain gauges, the desire to protect access to the gauges was more important than the exact height above ground level. The tipping buckets are connected to battery-operated automated data loggers, all contained in the rain gauge housing. The data logger records the exact date and time that the bucket tips, thus providing information on total rainfall depth as well as rainfall intensity. Each full bucket represents a depth of 0.2 mm (thus, this is the resolution of the measurements). Approximately once a month data are collected with a laptop, and the rain gauges are cleaned from accumulated dust. Observations on downloading and maintenance are recorded in a notebook, specifically reserved as a logbook for this monitoring program.

The four rain gauges are all installed in Sana'a to allow easy access. However, they are distributed in the city based on local knowledge of rainfall distribution, trying to cover the high and low rainfall depth areas. One of the rain gauges is installed on the roof of the WEC (# 8988), and has, in addition to a data collection function, also the function of a teaching tool. Data are downloaded with higher frequency and manual adjustment of data is applied when, due to the "show and tell" function, false readings are recorded. For this reason, careful note taking in the logbook is essential.

The distribution of the four rain gauges is shown in figure 1 overlaying a digital elevation model (DEM).

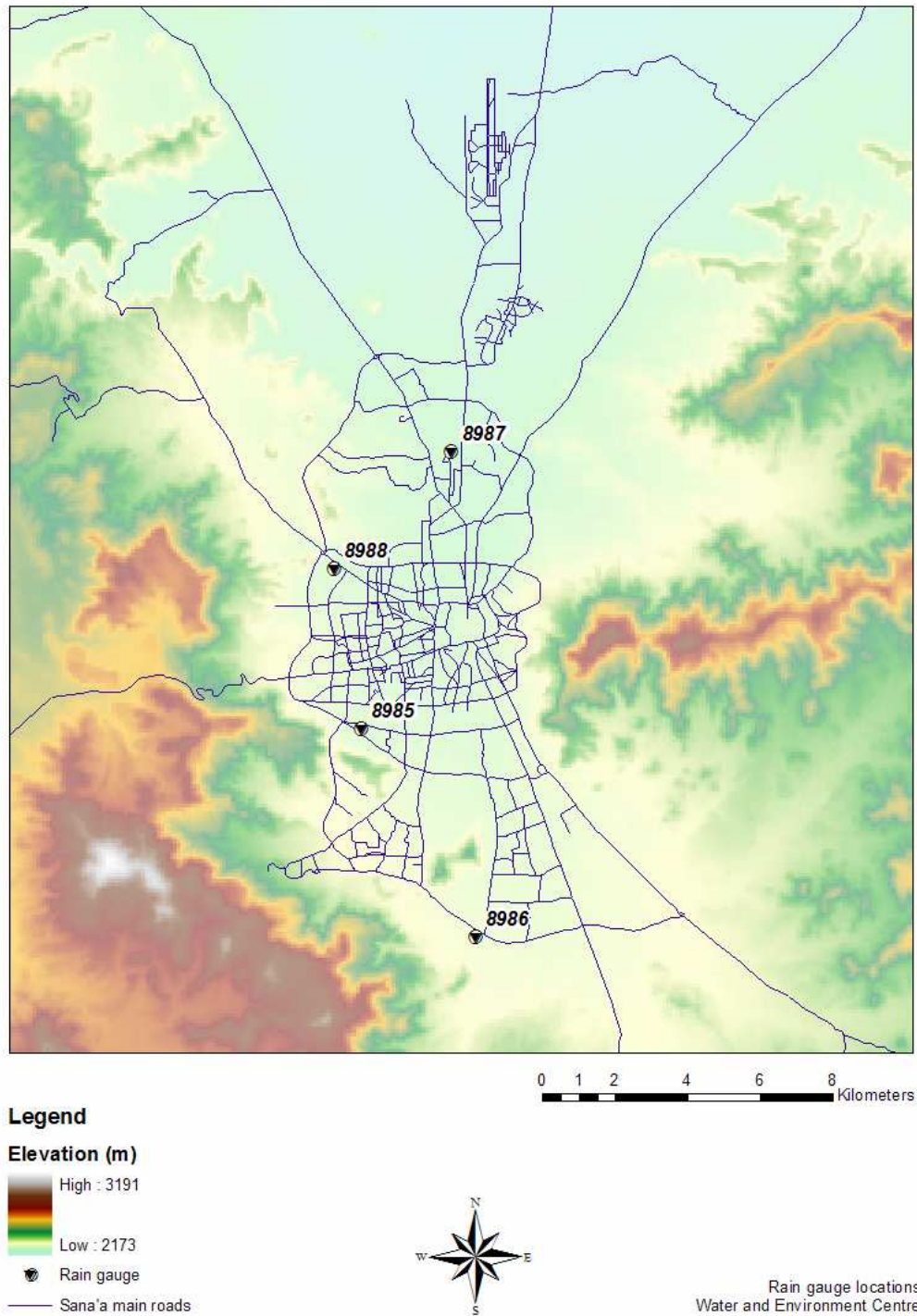


Figure 1: Location of rain gauges in Sana'a city

**Results**

Figure 2 shows the accumulated rainfall for each data logger since January 1, 2007 until July 31, 2007.

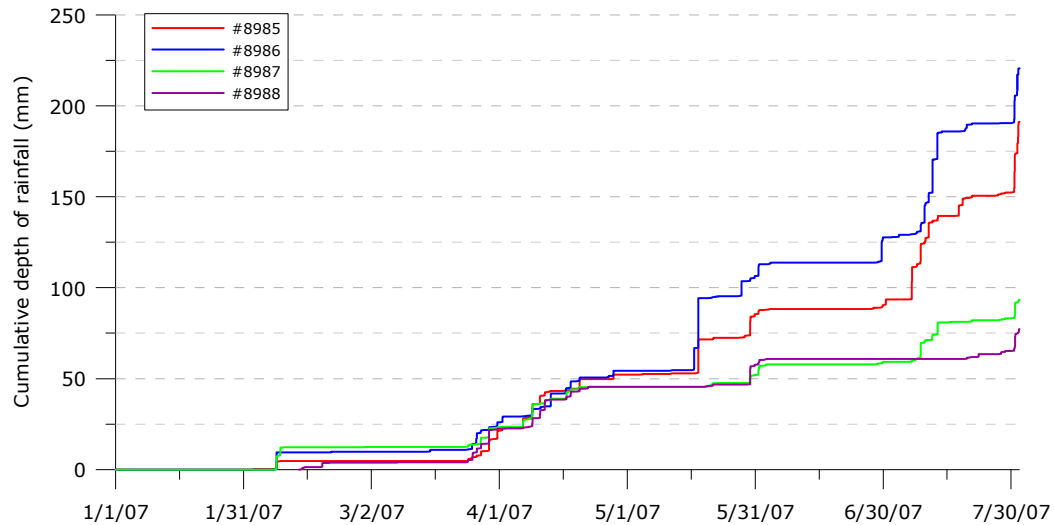


Figure 2: Cumulative rainfall depth for four locations in Sana'a

Monthly totals and year to date (YTD) totals for each of the four stations is shown in table 1.

Table 1: Monthly rainfall depth in 2007 (mm)

Month	8985	8986	8987	8988
Jan	0.0	0.0	0.0	-
Feb	4.6	9.8	12.4	3.6 <sup>+</sup>
Mar	18.2	19.4	11.2	18.6
Apr	29.4	25.2	21.8	23.2
May	35.6	58.6	11.8	14.6
Jun	5.8	14.6	2.0	5.2
Jul	98.4	93.0	34.4	16.4
YTD	192.0	220.6	93.6	81.6

One satellite that collects distributed rainfall is the Tropical Rainfall Measurement Mission (TRMM). This sensor collects 3-hour interval measurements on rainfall for the area between the latitudes 40° North and 40° South. The resolution of data collection is approximately 25 x 25 km. Although the resolution is low, the frequency and area-averaged values are sometimes preferred over single point measurements. For the Sana'a area, monthly data are extracted from the TRMM satellite information. These values are shown for 3 pixels (block with four gauges (#1), 25 km east of Sana'a (#2) and 25 km south of Sana'a (#3)) in table 2.

Table 2: TRMM rainfall depth in 2007 (mm)

Month	#1	#2	#3
Jan	15.9	14.2	17.7
Feb	5.4	11.8	19.6
Mar	25.1	19.6	32.0
Apr	56.1	34.7	71.6
May	42.8	36.4	54.5
Jun	7.8	8.0	14.8
Jul	41.5	30.3	78.2
YTD	194.6	155.0	288.4

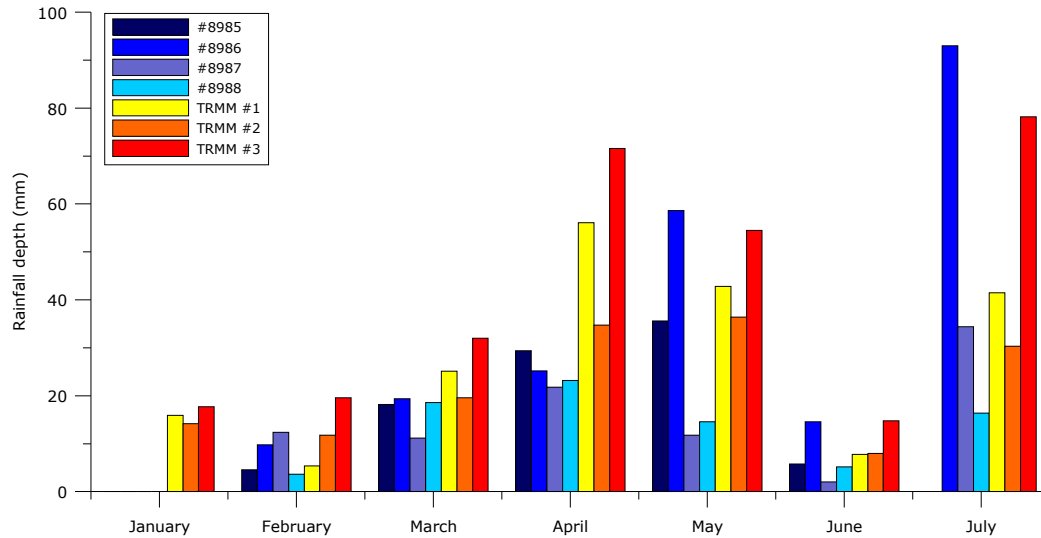


Figure 3: Comparison between four rain gauges (within yellow pixel) and 3 TRMM pixels.

Comparison with measured values shows a fair comparison. It is clear, however, that in the Sana'a area a high variability of rainfall occurs, and that an average value of a 25 x 25 km pixel could be used for water resources management on large scale, but not on local scale. When field data are lacking, however, the satellite data, available for the whole world between 40° North and 40° South, are a good alternative.

Rainfall intensity measurements are important for runoff models, preferably in combination with surface runoff measurements so that hydrographs can be created. The WEC is planning to install runoff measurement data loggers, using the same continuous measurement techniques as used for rainfall.

A few examples of rainfall intensities for 3 large storm events in Sana'a are shown in figure 4A, B and C. They represent the dates April 7, May 30 and July 29. These were dates where all four rain gauges measured a considerable amount of rainfall.

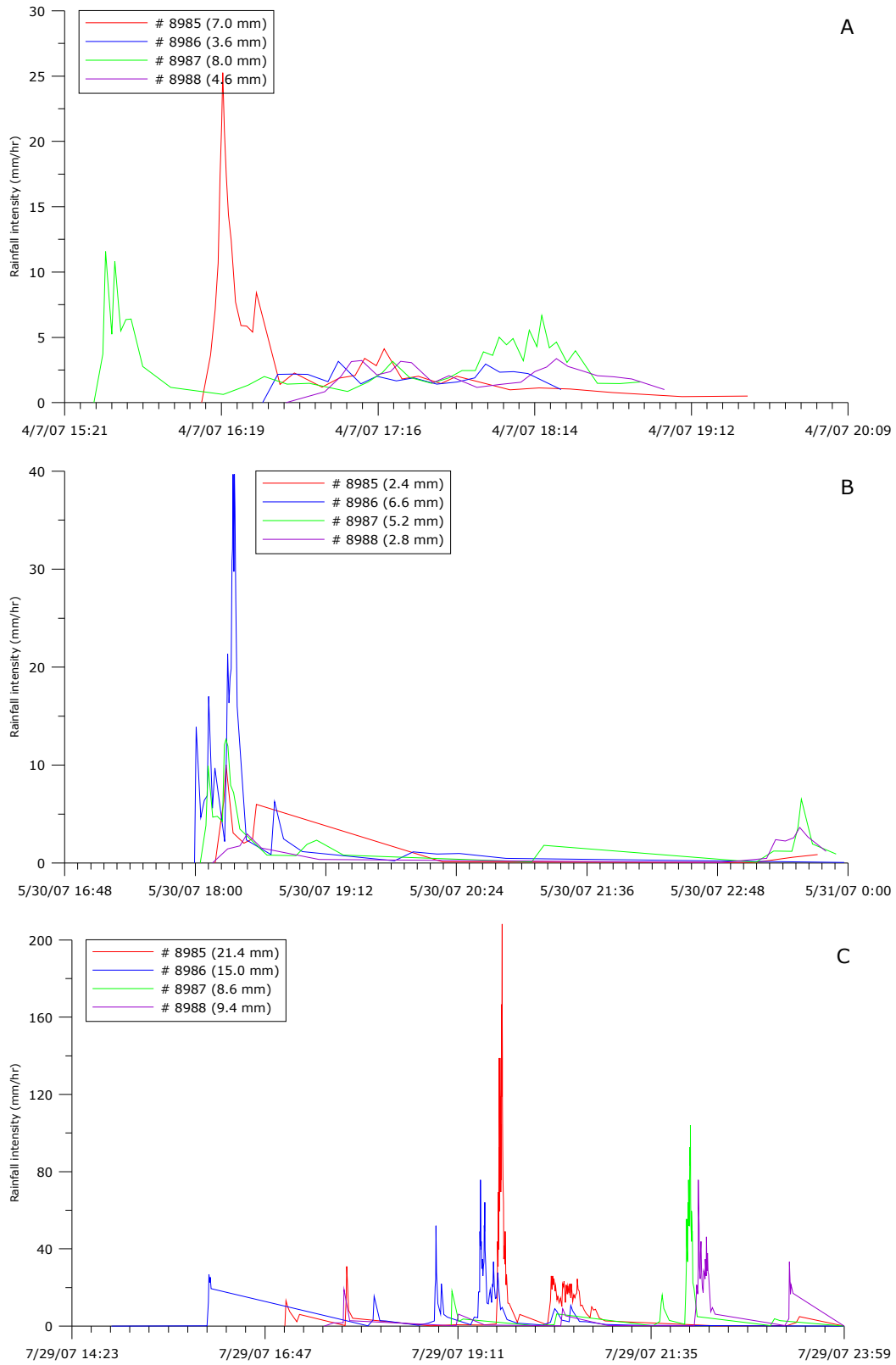


Figure 4: Rainfall intensity for three dates and four stations in Sana'a in 2007. April 7 (A), May 30 (B), July 29 (C)

These data show that rain often falls in short events with high intensity. High volume rainfall events (as the event on July 29, measured by # 8985) can reach rainfall intensity rates of over 200 mm/hr.

### **Conclusions**

Rainfall depth is higher in the south of Sana'a than in the north, with values almost double. Rain in Sana'a usually falls in short intense events. In places where no good quality rainfall data are available, TRMM data on monthly basis could be used as an alternative.



Annex 1: Daily measurements 2007

January 2007

<b>Date</b>	<b>8985</b>	<b>8986</b>	<b>8987</b>	<b>8988</b>
1/1/2007	0	0	0	-
1/2/2007	0	0	0	-
1/3/2007	0	0	0	-
1/4/2007	0	0	0	-
1/5/2007	0	0	0	-
1/6/2007	0	0	0	-
1/7/2007	0	0	0	-
1/8/2007	0	0	0	-
1/9/2007	0	0	0	-
1/10/2007	0	0	0	-
1/11/2007	0	0	0	-
1/12/2007	0	0	0	-
1/13/2007	0	0	0	-
1/14/2007	0	0	0	-
1/15/2007	0	0	0	-
1/16/2007	0	0	0	-
1/17/2007	0	0	0	-
1/18/2007	0	0	0	-
1/19/2007	0	0	0	-
1/20/2007	0	0	0	-
1/21/2007	0	0	0	-
1/22/2007	0	0	0	-
1/23/2007	0	0	0	-
1/24/2007	0	0	0	-
1/25/2007	0	0	0	-
1/26/2007	0	0	0	-
1/27/2007	0	0	0	-
1/28/2007	0	0	0	-
1/29/2007	0	0	0	-
1/30/2007	0	0	0	-
1/31/2007	0	0	0	-
<i>MONTHLY</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>-</i>

February 2007

<b>Date</b>	<b>8985</b>	<b>8986</b>	<b>8987</b>	<b>8988</b>
2/1/2007	0.2	0	0	-
2/2/2007	0	0	0	-
2/3/2007	0	0	0	-
2/4/2007	0	0	0	-
2/5/2007	0	0	0	-
2/6/2007	4.2	9.4	7.4	-
2/7/2007	0.2	0	4.6	-
2/8/2007	0	0	0.2	-
2/9/2007	0	0	0	-
2/10/2007	0	0	0	-
2/11/2007	0	0	0	0
2/12/2007	0	0	0	1
2/13/2007	0	0	0	0.4
2/14/2007	0	0	0	0
2/15/2007	0	0	0	0
2/16/2007	0	0	0	0
2/17/2007	0	0	0	2
2/18/2007	0	0	0	0
2/19/2007	0	0.4	0	0.2
2/20/2007	0	0	0	0
2/21/2007	0	0	0	0
2/22/2007	0	0	0	0
2/23/2007	0	0	0	0
2/24/2007	0	0	0	0
2/25/2007	0	0	0	0
2/26/2007	0	0	0	0
2/27/2007	0	0	0.2	0
2/28/2007	0	0	0	0
<b>MONTHLY</b>	<b>4.6</b>	<b>9.8</b>	<b>12.4</b>	<b>3.6</b>

March 2007

<b>Date</b>	<b>8985</b>	<b>8986</b>	<b>8987</b>	<b>8988</b>
3/1/2007	0	0	0	0
3/2/2007	0	0	0	0
3/3/2007	0	0	0	0
3/4/2007	0	0	0	0
3/5/2007	0	0	0	0
3/6/2007	0	0	0	0
3/7/2007	0	0	0	0.2
3/8/2007	0	0	0	0
3/9/2007	0	0	0	0
3/10/2007	0	0	0	0
3/11/2007	0	0	0	0
3/12/2007	0	0	0	0
3/13/2007	0	0	0	0
3/14/2007	0	1	0	0
3/15/2007	0	0	0	0
3/16/2007	0	0	0	0
3/17/2007	0	0	0	0
3/18/2007	0	0	0	0
3/19/2007	0	0	0	0
3/20/2007	0	0	0	0
3/21/2007	0	0	0	0
3/22/2007	0	0	0	0
3/23/2007	1.4	0.4	1.2	1.2
3/24/2007	0.8	2.8	0	4
3/25/2007	0.8	6	0.4	2.4
3/26/2007	2.4	1.6	3.6	2.4
3/27/2007	0.2	0.2	0	0.2
3/28/2007	6.2	1.6	5	7.6
3/29/2007	0.4	0.2	0.2	0.2
3/30/2007	4.6	2.4	0.6	0.4
3/31/2007	1.4	3.2	0.2	0
<i>MONTHLY</i>	<i>18.2</i>	<i>19.4</i>	<i>11.2</i>	<i>18.6</i>

April 2007

<b>Date</b>	<b>8985</b>	<b>8986</b>	<b>8987</b>	<b>8988</b>
4/1/2007	0	0	0	0.2
4/2/2007	0	0	0	0
4/3/2007	0	0	0	0
4/4/2007	0	0	0	0
4/5/2007	5.4	0.2	3.8	0.6
4/6/2007	0.8	0.2	0.4	0.4
4/7/2007	7	3.6	8	4.6
4/8/2007	0	0.2	0.2	0
4/9/2007	4.6	1	0.4	4.4
4/10/2007	2	0.4	1.6	5.6
4/11/2007	0.4	0	1	0.2
4/12/2007	0.2	7	0	0
4/13/2007	0	0	0	0
4/14/2007	0	0	0	0
4/15/2007	0.4	3	3.6	1.6
4/16/2007	0.8	3.8	1.4	2.8
4/17/2007	0	0	0	0
4/18/2007	5.4	2	1.4	1.6
4/19/2007	0	0	0	0
4/20/2007	0	0	0	1
4/21/2007	0	0	0	0.2
4/22/2007	0	0	0	0
4/23/2007	0	0	0	0
4/24/2007	0	0	0	0
4/25/2007	0	0.8	0	0
4/26/2007	2.4	3	0	0
4/27/2007	0	0	0	0
4/28/2007	0	0	0	0
4/29/2007	0	0	0	0
4/30/2007	0	0	0	0
<b>MONTHLY</b>	<b>29.4</b>	<b>25.2</b>	<b>21.8</b>	<b>23.2</b>

May 2007

<b>Date</b>	<b>8985</b>	<b>8986</b>	<b>8987</b>	<b>8988</b>
5/1/2007	0	0	0	0
5/2/2007	0	0	0	0
5/3/2007	0.4	0	0	0
5/4/2007	0	0	0	0
5/5/2007	0	0	0	0
5/6/2007	0	0	0	0
5/7/2007	0	0	0	0
5/8/2007	0	0	0	0
5/9/2007	0	0	0	0
5/10/2007	0.4	0.2	0	0
5/11/2007	0	0	0	0
5/12/2007	0	0	0	0
5/13/2007	0	0	0	0
5/14/2007	0	0	0	0
5/15/2007	0	12.2	0	0
5/16/2007	18.6	27.4	0	0
5/17/2007	0	0	0	0
5/18/2007	0	0	0.6	0.2
5/19/2007	0	0.6	1.2	0
5/20/2007	0.8	0.4	0.2	0.8
5/21/2007	0	0.2	0	0
5/22/2007	0	0	0	0
5/23/2007	0	0	0	0
5/24/2007	0	0	0	0
5/25/2007	0	0	0	0
5/26/2007	0.2	8.2	0	0
5/27/2007	1	0	0	0
5/28/2007	10.4	1.6	4	10
5/29/2007	1.4	1.2	0.4	0.8
5/30/2007	2.4	6.6	5.2	2.8
5/31/2007	0	0	0	0
<i>MONTHLY</i>	<i>35.6</i>	<i>58.6</i>	<i>11.8</i>	<i>14.6</i>

June 2007

<b>Date</b>	<b>8985</b>	<b>8986</b>	<b>8987</b>	<b>8988</b>
6/1/2007	0.2	0	0.6	0.4
6/2/2007	0.2	0.8	0	0
6/3/2007	0	0	0	0
6/4/2007	0	0	0	0
6/5/2007	0	0	0	0
6/6/2007	0	0	0	0
6/7/2007	0	0	0	0
6/8/2007	0	0	0	0
6/9/2007	0	0	0	0
6/10/2007	0	0	0	4.8
6/11/2007	0	0	0	0
6/12/2007	0	0	0	0
6/13/2007	0	0	0	0
6/14/2007	0	0	0	0
6/15/2007	0	0	0	0
6/16/2007	0	0	0	0
6/17/2007	0	0	0	0
6/18/2007	0	0	0	0
6/19/2007	0	0	0	0
6/20/2007	0	0	0	0
6/21/2007	0	0	0	0
6/22/2007	0	0	0	0
6/23/2007	0	0	0	0
6/24/2007	0	0	0	0
6/25/2007	0	0	0	0
6/26/2007	0.8	0	0	0
6/27/2007	0	0.6	0.6	0
6/28/2007	1.4	13.2	0.8	0
6/29/2007	3.2	0	0	0
6/30/2007	0	0	0	0
MONTHLY	5.8	14.6	2.0	5.2

July 2007

<b>Date</b>	<b>8985</b>	<b>8986</b>	<b>8987</b>	<b>8988</b>
7/1/2007	0	0.2	0	0
7/2/2007	0	1.2	0	0
7/3/2007	0	0.2	0	0
7/4/2007	0	0	0	0
7/5/2007	17.8	0.2	0.8	0
7/6/2007	1.6	1.2	1.2	0
7/7/2007	11.2	5	8.4	0
7/8/2007	3.2	11	1.6	0
7/9/2007	8.4	5.6	0	0
7/10/2007	1	18.2	3	0
7/11/2007	2.6	14.8	6.6	0
7/12/2007	0	0.8	0	0
7/13/2007	0	0	0	0
7/14/2007	0	0	0.4	0
7/15/2007	0	0	0	0
7/16/2007	5.8	0	0	0
7/17/2007	3.8	0.2	0	0
7/18/2007	0.4	3.4	0	0.8
7/19/2007	1.2	0.8	1	0.2
7/20/2007	0	0	0	0
7/21/2007	0	0	0	1.6
7/22/2007	0	0	0	0
7/23/2007	0	0	0	0
7/24/2007	0	0	0	0
7/25/2007	0.6	0	0	0
7/26/2007	0.6	0.2	0.4	1.2
7/27/2007	0.6	0	0.6	0.6
7/28/2007	0	0	0	0
7/29/2007	21.4	15	8.6	9.4
7/30/2007	17.4	15	1.6	2.6
7/31/2007	0.8	0	0.2	0
<b>MONTHLY</b>	<b>98.4</b>	<b>93.0</b>	<b>34.4</b>	<b>16.4</b>