Memo

Water & Earth Technologies, Inc.
Water Resources and Environmental Consulting

Date: January 30, 2008

To: Kevin Stewart and Chad Kudym

From: Markus Ritsch

Subject: **2008 Annual ALERT Data Analysis Summary Report**

I. Executive Summary

The Urban Drainage and Flood Control District (District) operates a flood detection network consisting of remote monitoring stations that report hydrologic information using the Automated Local Evaluation in Real-Time (ALERT) radio protocol. Rainfall, water level, and weather data are processed in real-time to support flood mitigation activities within the District.

In 2008, Water & Earth Technologies, Inc. (WET) provided monthly analysis of the District's ALERT database for quality assurance and control. ALERT data received by the District's ALERT 2 base station were analyzed to quantify the performance of individual stations, to assess the general health of the telemetry system, to estimate hourly radio traffic loading rates, and to calculate rainfall timer and event reporting characteristics.

The monitoring network is fully operational during the "flood season" which extends from April 1 through September 30. Many of the District's stream and rain stations are winterized beginning in October. Portions of the network, mostly weather stations, are operational year-round.

II. ALERT Data Source

Raw ALERT data records were extracted from the Nova Star 4.0 base station (ALERT 2) and analyzed for the period January 1 through December 31, 2008.

III. General System-Wide Reporting Summary

A total of 3,161,860 individual ALERT data reports were received by the base station decoder and analyzed for the year (Table 1). The reports were tabulated from the NovaStar monthly received data logs (RecDataLog). The total does not include reports from "unknown" sensors, i.e. sensors that are not defined in the database.

In previous years, the system had a consistent base load of approximately 160,000 reports per month. In 2008, the monthly base load increased to approximately 210,000 reports. The total number of reports in 2008 was greater than 2007.

Table 1. Monthly Distribution of ALERT Data Reports

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2006	193,406	158,525	175,112	196,823	189,737	194,975	193,304	212,475	189,640	193,871	164,044	161,131	2,225,049
2007	164,551	161,869	191,094	208,964	242,905	212,431	211,404	213,458	192,610	218,744	194,229	201,675	2,413,934
2008	221,176	218,689	246,487	253,827	289,334	287,100	277,303	301,916	271,014	274,395	255,380	265,239	3,161,860

Shading in light yellow denotes peak month of reporting.

IV. Flood Season Reporting Summary

The distribution of ALERT reports received during the flood season (April through September) is shown (Table 2). The vast majority of reports (73%) come from atmospheric sensors (wind, temperature, relative humidity, and barometric pressure). Reports from water level sensors account for 12% of the total and 5% of the total reports come from precipitation sensors.

Table 2. Distribution of Reports among Sensor Groups (period April 1 through September 30)

Sensor Group	Reports	Percent
Wind Gust	282,074	17%
Temperature	237,729	14%
Relative Humidity	235,465	14%
Water Level	195,564	12%
Wind Direction	118,545	7%
Wind Speed Average & Azimuth	102,328	6%
Barometric Pressure	97,617	6%
Wind Speed Average	97,347	6%
Precipitation	90,513	5%
Solar Radiation	52,324	3%
Battery Voltage HSE	37,462	2%
Battery Voltage Analog	21,793	1%
Fuel Temperature	20,283	1%
Fuel Moisture	20,230	1%
Battery Voltage Digital	19,938	1%
Soil Moisture	12,452	1%
Hayman Precipitation	7,877	0%
Repeater Pass List	3,655	0%
Hayman Battery	3,538	0%
Repeater Status Report	2,877	0%
12Hr Status Report	2,448	0%
Battery	2,244	0%
Precipitation - Test	1,451	0%
Longmont Flow Gage	1,165	0%
Hayman Stage	488	0%
Handar 585 ALARM Status	363	0%
Battery Voltage	264	0%
Precipitation-ASCII	6	0%
Solar Power	4	0%
Precipitation-Old	2	0%
Precipitation-Test	1	0%
Total	**1,668,047**	**100%**

A. Radio Traffic Loading

The system-wide radio traffic loading during the **2007** "flood season" was approximately 6,915 reports per day with an average hourly loading of about 288 reports. The system-wide radio traffic loading during the **2008** "flood season" was approximately 9,202 reports per day with an average hourly loading of about 383 reports. The daily traffic load increased by approximately 100 reports per hour in 2008.

The specific hours of highest radio traffic loading as received by the base station were determined and are shown (Table 3). Reports received at the base station differ from total ALERT radio traffic because reports lost to contention are not included. The actual traffic loading is typically higher than the reports received at the base.

One large storm period is evident on August 16 from approximately 10:00 AM to noon.

Table 3. Hours of Peak Radio Traffic Loading

Occurrence of Peak Loading (hour beginning)	Reports Per Hour (received at base)
August 16, 2008 10:00 AM	1,486
August 16, 2008 11:00 AM	1,380
August 8, 2008 8:00 PM	1,170
August 15, 2008 3:00 AM	1,093
September 11, 2008 8:00 PM	1,092

The peak hour of radio traffic occurred on August 16 from 10:00 AM to 11:00 AM. During this hour, 1,486 ALERT reports were received at the base station. The actual radio traffic loading may have been as high as 1,700-1,800 reports when contentious and "unknown" reports are considered.

Peak and hourly average data reception rates are shown for the year (Figure 1).

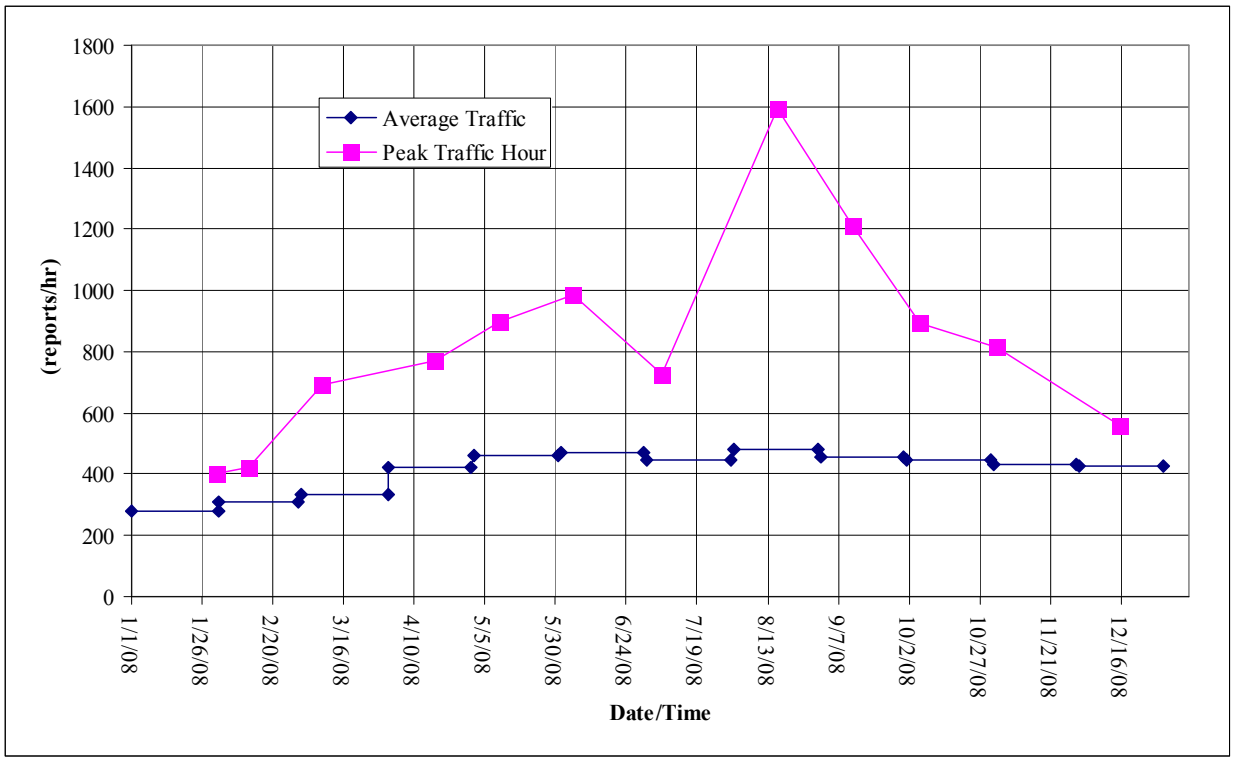


Figure 1. Peak and Hourly Average Data Reception Rates (reports received at base station)

B. Distribution of Reports during Heavy Traffic Period

During non-rain periods and over the long-term, the radio traffic is dominated by reports from meteorological sensors (Table 2), specifically wind sensors. The distribution of ALERT reports during a peak traffic period, however, looks quite different. The peak hours of radio traffic are typically dominated by reports from precipitation and water level sensors.

The peak period of traffic occurred on August 16 from 10:00 AM to 12:00 PM. The ALERT data for the 2-hour period was examined more closely to characterize the distribution of sensor reports (Table 4). Approximately 77% of the total reports received during the 2-hour period came from rain and water level sensors

Table 4. Distribution of Reports during the Peak Traffic Period

Sensor Group	Reports	Percent
Rain Sensors	1,224	43%
Water Level Sensors	978	34%
Meteorologic Sensors	412	14%
Other	252	9%
Total	**2,866**	**100%**

V. Rain Sensor Monthly Timer Reporting Summary

Non-incrementing timer reports from rain sensors were analyzed. The analysis assumes that all rain sensors have a 12-hour timer reporting interval. A summary showing those rain sensors with the worst timer reporting characteristics for each month of 2008 are shown (Table 5). Sensors having poor timer performance in multiple months are shaded with unique colors. A summary showing those rain sensors with the worst timer reporting characteristics for each month of the previous year, 2007, are also shown (Table 6).

Table 5. Monthly Summary of Sensors with Poor Timer Performance (2008)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct*	Nov*	Dec
750	1330	2310	1810	1810	1810	1810	1600	1330	2340	1500	410
4470	1460	1710	540	310	1710	4560	410	1340	2250	1530	2190
4560	2330	2350	310	540	4470	2350	1350	1360	2230	1620	4470
4240	4170	2240	850	850	1500	2250	2190	1370	2240	600	4560
4510	4470	2250	1710	1710	4290	4200	4820	2310	2310	610	140
				900	540	4240	4830	1030	2360	1320	4510

* - Many stations are taken out-of-service for the winter beginning in October which influences timer performance.

Table 6. Monthly Summary of Sensors with Poor Timer Performance (2007)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct*	Nov*	Dec*
2190	1660	1350	1710	1600	1600	1600	4130	1540	840	1520	2820
140	2190	110	540	540	110	1660	4560	1700	920	4200	2730
4150	140	2190	1600	1710	950	4140	4240	740	310	4140	4470
4060	4170	1370	1350	4080	1710	1350	4570	1360	110	4470	4520
4470	4150	620	710	4060	540	1710	1710	1660	820	4560	4850
4530	4530	840	4330	4150	4530	4530	4080	1480	2850	4850	4570

Over the past two years, the sensors with the worst timer performance were:

- Shop Creek (ID1710)
- Little Narrows (ID 4470)
- Parker/Mississippi (ID 540)
- Englewood Dam (ID1600)

VI. Rain Sensor Event Reporting Summary

A. District-Wide Total Tip Count Statistics

The incrementing rainfall reports from all 1-mm rain sensors were quantified to determine the District-wide mean total tip count (Table 7). The annual average precipitation experienced District-wide in 2008 was lower than 2007. The month experiencing the highest precipitation in 2008 was August, followed by May.

Table 7. Monthly Summary of District-Wide Mean Total 1-mm Tip Count

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
2006	4.62	5.92	18.39	20.47	19.44	13.75	74.03	46.89	24.17	41.13	5.04	16.45	24.19
2007	11.56	5.40	29.75	65.03	68.30	15.87	36.20	46.38	22.13	29.50	6.54	11.29	29.00
2008	4.05	7.38	12.26	20.57	54.82	26.06	16.43	90.20	37.54	19.59	2.82	9.24	25.08

Shading in yellow denotes peak month of reporting.

B. Incrementing Tip Reporting Summary

The incrementing tip reports received from the District's rain sensors were analyzed for each month of the year (Table 8). The system-wide reception rate of incrementing tip reports for the year was approximately 90 percent. A total of 38,860 incrementing reports were received and a total of 43,307 were expected.

Table 8. Monthly Incrementing Tip Reports Received from All Rain Sensors

Month	Received	Expected	Reception Rate (%)
January	239	247	96.76%
February	757	790	95.82%
March	1,794	1,888	95.02%
April	2,967	3,168	93.66%
May	7,764	8,442	91.97%
June	3,438	3,804	90.38%
July	2,260	2,398	94.25%
August	11,623	13,439	86.49%
September	4,756	5,519	86.18%
October	2,451	2,762	88.74%
November	198	203	97.54%
December	613	647	94.74%
TOTAL	**38,860**	**43,307**	**89.73%**

As would be expected, the month of August had a relatively poor reception rate for incrementing reports due to the high volume of radio traffic. Of greater interest may be the fact that September also showed an equally poor reception rate for the month but the volume of traffic was much lower than August. It seems that the reception rate is certainly a function of total traffic loading but it is also a function of other variables, such as storm type, intensity, and extent.

C. Rain Sensor Event Performance

The rain sensors with the worst event reporting characteristics for each month of the current year, 2008, are shown (Table 9). Sensors identified as having poor event reporting performance characteristics in multiple months are shaded with unique colors. The rain sensors with the worst event reporting characteristics for each month of the previous year, 2007, are also shown (Table 10).

Table 9. Monthly Summary of Sensors with Poor Event Performance (2008)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1640	4520	2930	1710	1600	1600	1660	1600	870	840	4840	2730
2190	4820	540	1600	2320	2750	4820	1100	1350	860	700	700
750	4530	2730	540	4150	2710	4080	1660	4090	700	2820	2190
4570	4470	2210	700	1710	310	2340	870	1050	970	1550	4130
2990	4810	110	110	4710	4090	2330	1710	2370	2190	--	970
--	700	1350	840	1350	4170	4060	410	120	2820	--	

Table 10. Monthly Summary of Sensors with Poor Event Performance (2007)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2320	1330	540	1350	860	1710	2370	1350	1810	1710	1920	4470
2190	4080	310	310	4710	1350	150	2310	520	860	4790	4790
4710	1640	4470	1100	1810	310	1700	540	1360	540	1700	4230
4090	4050	850	860	1350	1700	1350	1300	1700	850	4180	4270
4820	4180	4570	540	400	210	850	1920	1710	900	4770	4010
				4570	110	2340	840	1350	1100	1810	4520

Over the past two years, the sensors with the worst timer performance were:

- Chatfield COE (ID 1350)
- Shop Creek (ID1710)
- Parker/Mississippi (ID 540)
- Toll Gate at 6th Avenue (ID 700)
- Englewood Dam (ID1600)

VII. General Observations for the Year

A. Timer and Event Reporting

The following rain sensors had poor **timer** and poor **event** reporting characteristics for multiple months throughout the past two years.

- Shop Creek (ID1710)
- Parker/Mississippi (ID 540)
- Englewood Dam (ID1600)

The rain timer reporting characteristics for the entire network are graphically/spatially shown below for the period April 1 to September 30.

B. "Flood Season" Statistics

1. Rainfall accumulation

The rain sensors recording the highest accumulated precipitation during the "flood season" were:

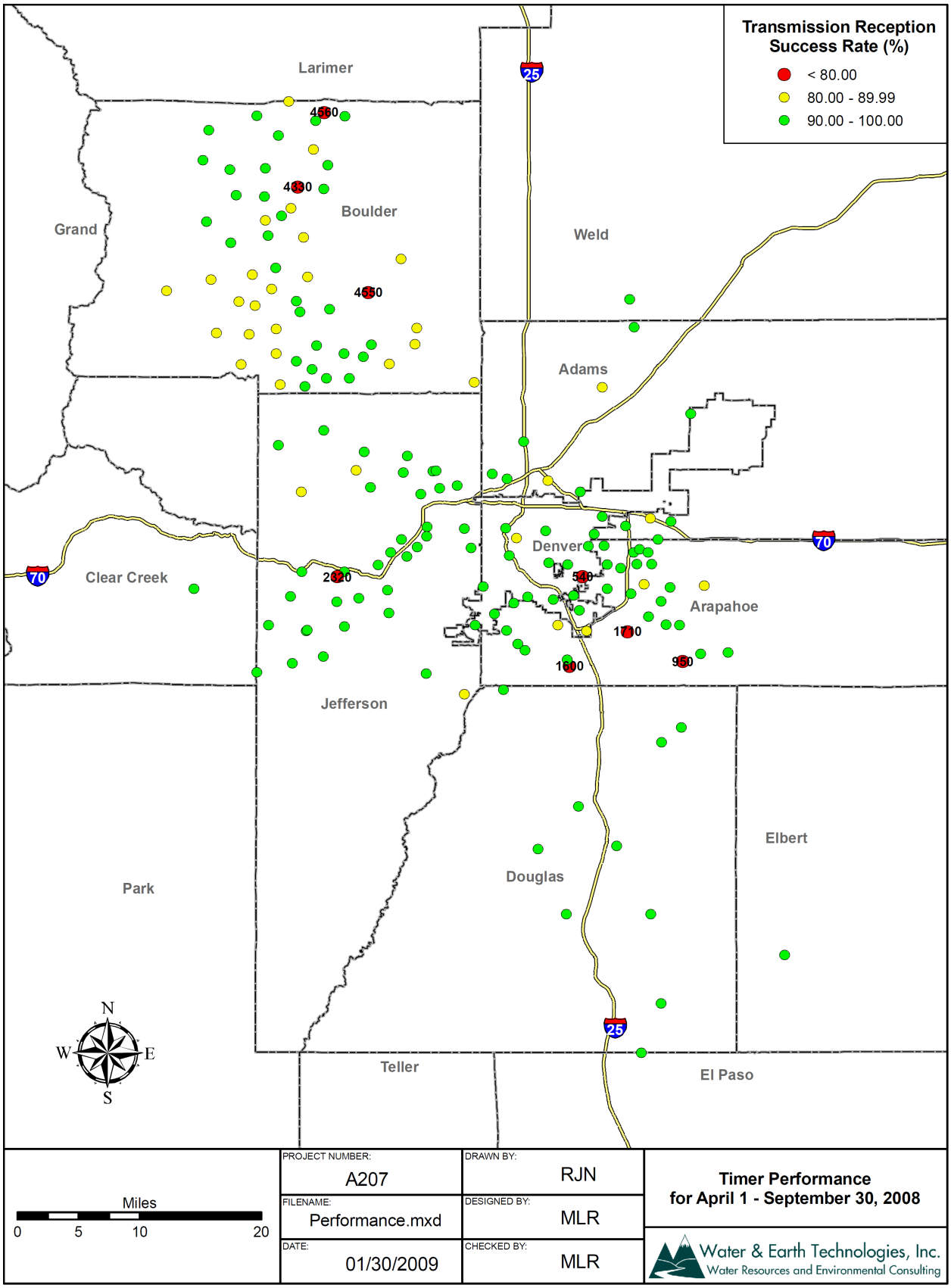
- Expo Park (ID 420) with 26.8 inches
- Aurora Town Hall (ID 920) with 25.3 inches
- Temple Pond at DTC (ID 630) with 17.9 inches and
- Powers Park (ID 1500) with 18.9 inches.

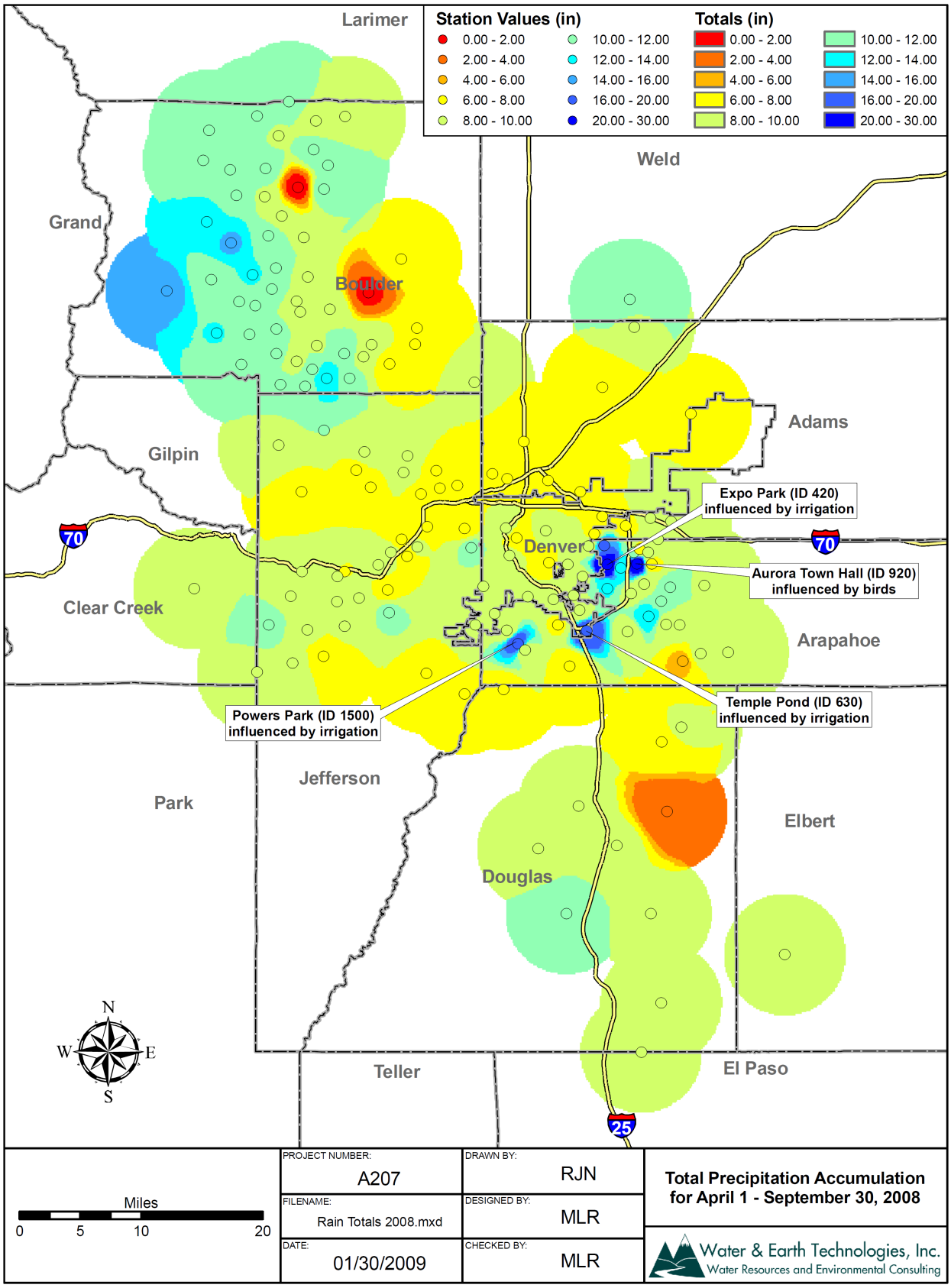
Expo Park, Temple Pond and Powers Park are all influenced by irrigation throughout the year. Aurora Town Hall had a problem with a new sensor that recorded rainfall when birds walked on the sensor pad.

The rain sensors recording the highest accumulated precipitation for the "flood season" that were not influenced by irrigation sprinklers were:

- Ward C-1 (ID 4710) with 14.4 inches,
- Gold Lake (ID 4180) with 14.0 inches,
- Mission Viejo Park (ID 760) with 13.9 inches,
- Red Garden (ID 4030) with 13.8 inches.

The average accumulated precipitation during the "flood season" was 9.07 inches. A graphical representation of the total accumulated precipitation for the "flood season" is shown below.


Transmission Reception Success Rate (%)
< 80.00
80.00 - 89.99
90.00 - 100.00
Larimer
Boulder
Grand
Weld
Adams
Denver
Arapahoe
Clear Creek
Jefferson
Park
Douglas
Elbert
Teller
El Paso
4560
4330
4550
2320
540
1710
1600
950
25
70
N
S
E
W
Miles
0
5
10
20
PROJECT NUMBER:
A207
DRAWN BY:
RJN
FILENAME:
Performance.mxd
DESIGNED BY:
MLR
DATE:
01/30/2009
CHECKED BY:
MLR
Timer Performance
for April 1 - September 30, 2008
Water & Earth Technologies, Inc.
Water Resources and Environmental Consulting


Station Values (in)
0.00 - 2.00
2.00 - 4.00
4.00 - 6.00
6.00 - 8.00
8.00 - 10.00
10.00 - 12.00
12.00 - 14.00
14.00 - 16.00
16.00 - 20.00
20.00 - 30.00
Totals (in)
0.00 - 2.00
2.00 - 4.00
4.00 - 6.00
6.00 - 8.00
8.00 - 10.00
10.00 - 12.00
12.00 - 14.00
14.00 - 16.00
16.00 - 20.00
20.00 - 30.00
Larimer
Weld
Grand
Boulder
Adams
Gilpin
Expo Park (ID 420) influenced by irrigation
Denver
Aurora Town Hall (ID 920) influenced by birds
Clear Creek
Arapahoe
Powers Park (ID 1500) influenced by irrigation
Temple Pond (ID 630) influenced by irrigation
Jefferson
Park
Elbert
Douglas
Teller
El Paso
70
25
N
W
E
S
Miles
0
5
10
20
PROJECT NUMBER: A207
DRAWN BY: RJN
FILENAME: Rain Totals 2008.mxd
DESIGNED BY: MLR
DATE: 01/30/2009
CHECKED BY: MLR
Total Precipitation Accumulation for April 1 - September 30, 2008
Water & Earth Technologies, Inc.
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