Memo

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

Date: January 5, 2007

To: Kevin Stewart and Chad Kudym

From: Markus Ritsch

Subject: **2006 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 to a central base station using the Automated Local Evaluation in Real-Time (ALERT) radio protocol. Rainfall, water level, and weather information is processed in real-time to support flood mitigation activities within the District.

In 2006, Water & Earth Technologies, Inc. (WET) analyzed the ALERT data received by the District each month. The monthly analysis included the quantification of general system-wide reporting characteristics, radio traffic loading, rainfall timer reporting, and rainfall event reporting.

In general the District's flood detection network functioned very well in 2006. Individual problems with stations were encountered but large-scale issues or data outages for large portions of the system were non-existent. The District's field maintenance program worked to keep the flood detection network performing at a high level.

Only two stations had reporting characteristics that were consistently poor throughout the year. These stations were: Doudy Draw (ID 4820) and El Rancho (ID 2340). The wind sensor at Squaw Mountain (ID 2189 and 2187) also showed a large number of invalid data reports throughout the year.

A summary of the various analyses performed during 2006 are provided in the following sections.

A. Change to monthly data analysis made in August

A primary concern for any large and expanding ALERT network is the degradation of data quality when radio traffic is high. Beginning in August of 2006, we realized that the monthly data analysis offers a tremendous opportunity to quantify system performance during those periods of heavy radio traffic. In August and continuing for the remainder of the year, we began to evaluate the peak hour of radio traffic. The hour containing the most ALERT reports was identified and the distribution of sensor reports within that hour was quantified as was the loss of rainfall data.

In 2007, the District will not only expand the existing network but will receive additional data reports from gages operated by Douglas County. The District in general has taken the position that the benefits provided by centralized regional data collection outweigh the degradation of District data from the additional radio traffic. This position, however, can only be maintained up to a certain point.

The District has recently completed a study to establish the channel capacity on its single input frequency. The monthly data analyses performed by WET should be used to verify the channel capacity results from the study.

B. Conclusions and recommendations

Overall, the ALERT monitoring network functioned extremely well. The District's field maintenance group also functioned well to keep the system running as required on a daily basis. The District's field maintenance program is exemplary and should be used as a blue print for other large-scale ALERT networks.

The primary issue facing the District as it contemplates expansion and the reception of additional data from Douglas County is that of channel capacity. It is our recommendation to expand the monthly data analyses in 2007 to quantify the performance of the system when it is at or exceeding channel capacity. This information will help the District to document and confirm the channel capacity so that it can be used to guide future activities.

Beginning in August of 2006, only the peak radio traffic hour was analyzed each month in terms of data loss. In 2007 we propose to analyze every hour that exceeds 700 messages per hour. Rain gage sequences will be evaluated during peak hours to specifically identify those instances where 2 or 3 sequential messages are lost from a single sensor. The loss of 3 sequential data reports forms a limit of data degradation that causes a serious problem in the evaluation of alarm threshold conditions in a timely manner to support the flood mitigation needs of emergency responders within the District.

Not only will the quantification of data degradation during peak loading (operation at or beyond channel capacity) be valuable to the District, but other regional ALERT systems facing the same issues will benefit from the information.

II. ALERT Data Source

Raw ALERT data records were extracted from the District's Nova Star 4.0 base station (ALERT 2) for the period January 1 through December 31, 2006. The extracted data records were analyzed each month to assess the performance of individual stations and the system as a whole.

III. General System-Wide Reporting Summary

A total of 2,223,043 individual data records were analyzed for the year. The distribution of records by month is shown (Table 1). The month of August had the most ALERT data reports. As would be expected, the winter months experienced fewer reports than did the spring and summer months. The system has a fairly consistent base load of approximately 160,000 reports per month throughout the year. This is due to the fact that weather stations and the stations in Boulder County are operated year-round.

Table 1. Monthly Distribution of ALERT Data Records

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
193,406	158,525	175,112	196,823	189,737	194,975	193,304	212,475	189,640	193,871	164,044	161,131	2,223,043

For the year, the vast majority of data reports came from meteorological sensors (Table 2). Wind information (gust, average speed, and direction) accounted for almost 44 percent of the total reports received for the year.

Table 2. Distribution of Reports among Sensor Groups

Sensor Group	Reports	Percent
Wind Gust	406,533	18.29%
Relative Humidity	321,988	14.48%
Temperature	303,696	13.66%
Wind Speed Average & Azimuth	230,896	10.39%
Wind Direction	198,297	8.92%
Water Level PT-HSE	167,208	7.52%
Wind Speed Average	136,455	6.14%
Precipitation	132,150	5.94%
Battery Voltage Digital	57,964	2.61%
Battery Voltage HSE	54,628	2.46%
Solar Radiation	47,244	2.13%
Water Level Float	30,837	1.39%
Water Level PT	29,726	1.34%
Barometric Pressure	27,870	1.25%
Fuel Moisture	16,825	0.76%
Fuel Temperature	16,669	0.75%
Repeater Pass List	10,850	0.49%
Hayman Precipitation	6,650	0.30%
Battery Voltage Analog	6,550	0.29%
Handar 585 ALARM Status	6,430	0.29%
Precipitation - Mean	6,321	0.28%
12Hr Status Report	2,161	0.10%
Longmont Flow Gage	1,759	0.08%
Precipitation - Test	1,217	0.05%

Soil Moisture	1,028	0.05%
Longmont Water Level PT	655	0.03%
Precipitation-ASCII	340	0.02%
Repeater ON Count	42	0.00%
Solar Power	19	0.00%
Snow (water equiv.)	16	0.00%
Repeater Battery Check	8	0.00%
Dewpoint Temperature	6	0.00%
Repeater Status Report	5	0.00%
TOTAL	**2,223,043**	**100%**

Ninety-eight percent of the received data reports were identified as “good” by the Nova Star validation process (Table 3). Roughly 2 percent of the total data reports were flagged as “bad”. Of these “bad” reports, 22,968 (58%) came from the wind sensor ID 2189 and 6,044 came from wind sensor ID 2187, both at Squaw Mountain. The reception of “bad” data reports from the Squaw Mountain sensor ID’s 2189 and 2187 has been a consistent theme throughout the entire year.

Table 3. Data Validation Summary

Records by Validation Type	**Data Type**	**Reports**	**Percent**
Good	0	2,183,475	98.22%
Questionable	1	39,568	1.78%
	Total	2,223,043	100.00%

A. Radio Traffic Loading

The system-wide radio traffic loading was approximately 6,100 reports per day with an average hourly loading of about 255 reports. The peak hour traffic loading was 1,107 reports, which occurred on August 13th, between 9:00 PM and 10:00 PM. These were reports received at the base station. The actual traffic loading was higher because contention reports are not included. A plot of monthly average and peak hourly traffic loading is provided.

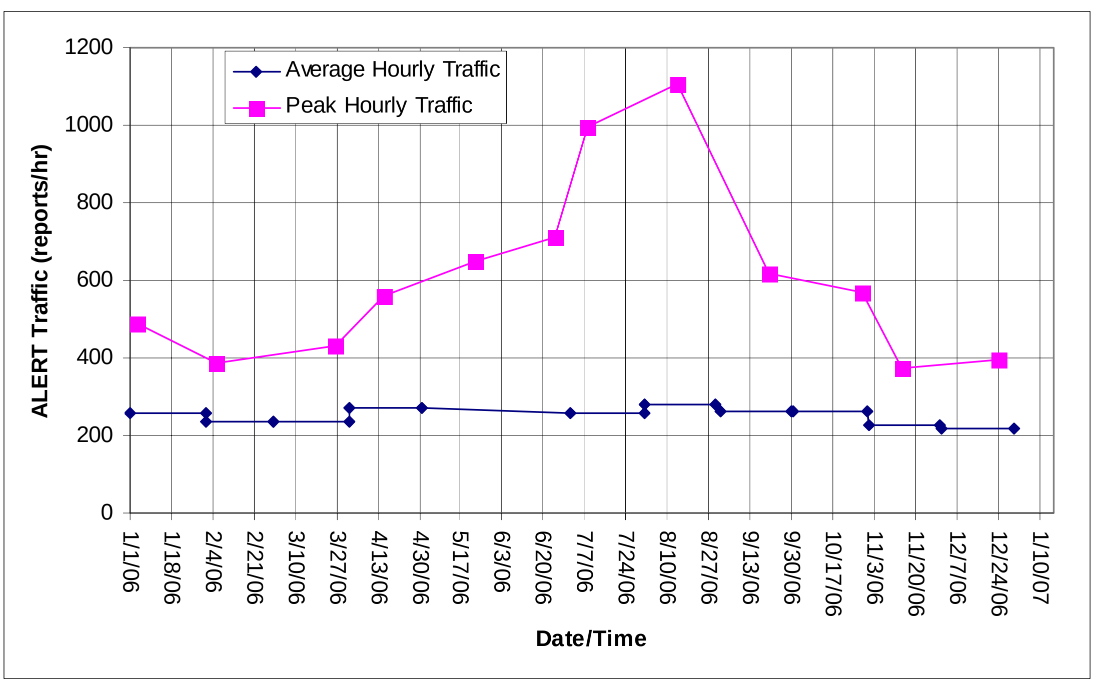

Figure 1. Radio Traffic Loading (reports received at base station)

On an average basis, the radio traffic is dominated by reports from meteorological sensors, specifically wind sensors. The distribution of ALERT reports during a peak hour, however, looks quite different. The peak hours of radio traffic are dominated by reports from precipitation sensors and water level sensors, as is shown (Table 4).

Table 4. Distribution of Reports during the Peak Hour (August 13, 2006, 9:00 PM to 10:00 PM)

Sensor Group	Total Reports	Percentage
Water Level PT-HSE	476	43%
Precipitation	347	31%
Water Level Float	64	6%
Relative Humidity	36	3%
Wind Gust	36	3%
Temperature	28	3%
Water Level PT	28	3%
Wind Direction	21	2%
Wind Speed Average	14	1%
Hayman Precipitation	13	1%
Wind Speed Average & Azimuth	13	1%
Battery Voltage Digital	8	1%
Battery Voltage HSE	7	1%
Barometric Pressure	5	0%
Solar Radiation	4	0%
Fuel Moisture	2	0%
Fuel Temperature	2	0%
Battery Voltage Analog	1	0%
Precipitation - Mean	1	0%
Repeater Pass List	1	0%
Total	**1,107**	

IV. Rain Sensor Timer Reporting Summary

The non-incrementing timer reports were analyzed for the year. The analysis assumed 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 the year are shown (Table 5). Sensors having poor timer performance in multiple months are shaded with unique colors. A developing trend can thus be identified from the color shading as the year progresses.

Those sensors showing consistently poor timer performance characteristics include: 4820, 1440, and 2340.

Table 5. Monthly Summary of Sensors with Poor Timer Performance

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1010	1460	1460	2340	1460	1460	1460	1440	1540/320	330	1460	1460
1460	1660	4820	1460	1330	4820	1440	1460	1460	1720	4080	750
1640	4240	4570	1330	540	4830	110	2340	4820	430	4830	4730
--	--	--	1610	1600	1600	4820	4820	1440	2270	4240	4850
			1600	4820	2350	4220		110	2340	4560	4750

Sensor 1460 has a 24-hour timer reporting interval so its timer performance value is actually better than reported above (see data analysis report for May, 2006).

V. Rain Sensor Event Reporting Summary

A. District-Wide Total Tip Count Statistics

The incrementing rainfall reports from all 1-mm rain sensors were quantified each month to determine the District-wide mean total tip count (Table 6). This table shows that District-wide, the month of July had the most rain followed by August and October.

Table 6. Monthly Summary of District-Wide Mean Total 1-mm Tip Count

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
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

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 7). The system-wide reception rate of incrementing tip reports for the year was approximately 90 percent. A total of 36,601 incrementing reports were received and a total of 40,599 were expected.

Table 7. Incrementing Tip Reports from Rain Sensors

Month	Received	Expected	Percent
January	294	314	93.63%
February	356	370	96.22%
March	2,447	2,667	91.75%
April	2,797	3,002	93.17%
May	2,443	2,858	85.48%
June	1,940	2,130	91.08%
July	9,575	10,999	87.05%
August	6,180	6,910	89.44%
September	3,380	3,605	93.76%
October	5,691	6,151	92.52%
November	312	368	84.78%
December	1,186	1,225	96.82%
TOTAL	**36,601**	**40,599**	**90.15%**

A summary showing those rain sensors with the worst event reporting characteristics for each month of the year are shown (Table 8). Sensors identified as having poor event reporting performance characteristics in multiple months are shaded with unique colors.

Those sensors showing consistently poor event reporting characteristics include: 4820, 2340, and 2310.

Table 8. Monthly Summary of Sensors with the Most Missed Tips

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
640	4010	4530	2190	540	4820	4820	2370	1200	1720	1440	4490
1640	4080	4170	310	1400	1350	2350	2310	4820	330	2750	4530
4490	4170	4820	4820	1100	4790	2310	220	2340	2340	4810	4790
-----	-----	-----	-----	4820	2340	750	4060	1530	4820	1640	4710
-----	-----	-----	-----	1420	2350	150	4180	110	4270	2730	4130