December 28, 2007

Kevin Stewart, P.E.
Urban Drainage and Flood Control District
Suite 156-B
2480 West 26th Avenue
Denver, CO 80211

Re: ALERT Gaging System Maintenance Agreement 07-02.05, Final Report

Dear Kevin,

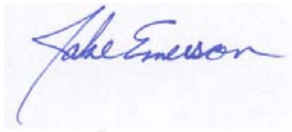
OneRain is pleased to present you with the accompanying ALERT Gaging System 2007 Final Report. The purpose of the Report is to summarize the ALERT system maintenance activities completed by OneRain in 2007 on behalf of the Urban Drainage and Flood Control District (UDFCD) under Agreement 07-02.05.

The accompanying Report includes a summary of the maintenance activities in 2007 and recommendations for future operation of the District's flood detection network. OneRain and the District implemented new QA/QC techniques this in 2006 while reducing the number of scheduled maintenance visits. Now in its second year, this program has given us indication that it is working the way we hoped. The service rate has fallen by 40%. We are getting closer to confirmation that the reduced preventive maintenance and increased predictive maintenance is helping to clearly identify issues. This clarity has helped OneRain to focus maintenance efforts better than ever before.

The Smoky Hill repeater remains an area of concern, however. OneRain will be working with the East Cherry Creek Valley Water District to find a suitable location to move this unit. Since there have been repeated issues with degradation on the output side of this repeater, there is more work to be done to address and correct this issue.

We have enjoyed this past year greatly, as we have the many preceding ones, and we look forward to our continued collaboration with the UDFCD. Please contact me with any questions.

Sincerely,



Jake Emerson, Field & Integration Services Director

cc: Ilse Gayl, Earl Weiler

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ALERT Gaging System Maintenance
Agreement 07-02.05

Annual Report
December 28, 2007

Presented To
Kevin Stewart
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Denver, Colorado

By
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EXECUTIVE SUMMARY

The purpose of this report is to summarize the ALERT system maintenance activities completed by OneRain in 2007 on behalf of the Urban Drainage and Flood Control District (UDFCD) under Agreement 07-02.05.

OneRain and the District conducted the 2007 maintenance according to the same schedule used in 2006. The number of site visits over the last two years required 80% of the field effort of previous years, and we employed some new data analysis techniques this year. This report will discuss the effects of these changes. The results continue to be positive.

Maintenance activities on the ALERT real-time monitoring network for 2007 have been completed. Table 1 outlines the maintenance activities for both the last three operating seasons for the combined UDFCD/Boulder system.

Table 1: 2005, 2006 and 2007 Maintenance Service Statistics

Year	Total # of Maintenance Records	Total # of Service Calls	OneRain Service Calls	District Service Calls
2005	810	95 (11.8%)	75 (79%)	20 (21%)
2006	696	97 (13.9%)	83 (86%)	14 (14%)
2007	653	58 (8.9%)	49 (84%)	9 (16%)

The number of unscheduled service calls decreased significantly this year. This year saw less rainfall than last which lessened the affect of any plugged tipping buckets. Any plugged funnels that we did find were discovered during routine maintenance and not by indication of underreporting during an event.

Last season the unscheduled maintenance activities were dominated by proactive battery replacement and tipping bucket rain gage maintenance. This year we spent more time on transmitter failures and reprogramming of the manufacturer-unsupported Handar units. The one major outage for the year was the loss of the Blue Mountain repeater. This site was damaged by a nearby lightning strike. OneRain's field staff replaced the unit the same day.

The following sites required the greatest number of unscheduled visits:

- Hiwan (site 2210) 4 service visits for Handar programming, sensor replacement and battery replacement
- South Platte at Mausoleum (site 1320) 4 service visits for connector repair and event criterion change to this High Sierra 3206 transmitter

- Blue Mountain Repeater (site 950) 3 visits for repeater replacement and pass list updating
- Blue Mountain Weather Station (site 140) 3 visits for sensor replacement and power system repair
- Broadway (site 4580) 3 visits for battery replacement
- Eldorado Spring (site 4380) 3 visits for transmitter replacement
- Sand Creek Park (site 1800) 3 visits to modify the PT to accommodate low flow measurement

The 23 trips to these 7 sites accounted for 40% of all unscheduled service calls for 2007. There were 9 trips attributed to the "District Service Call" category. These were primarily for pressure transducer over- or under-reporting. Two rain gages were identified by the District as having issues: Hiwan, Fairgrounds and Chatfield Dam.

MAINTENANCE ACTIVITY SUMMARY

Site Additions

Lakewood Gulch was the only new site installed this year. This site's identifier is 1560; it is a stage only site. The site is located at N 39°43'59.16", W 105° 2'16.80" (WGS84 datum). This site reports via the Blue Mountain repeater.

Figure 1: Lakewood Gulch Stage Gage

Damaged Equipment and Site Reinstallations

The Blue Mountain weather station and West repeater, which are collocated, were damaged by a nearby lightning strike in the early morning on August 24th. The image below was generated by the District, and shows the core of the storm centered over the site.

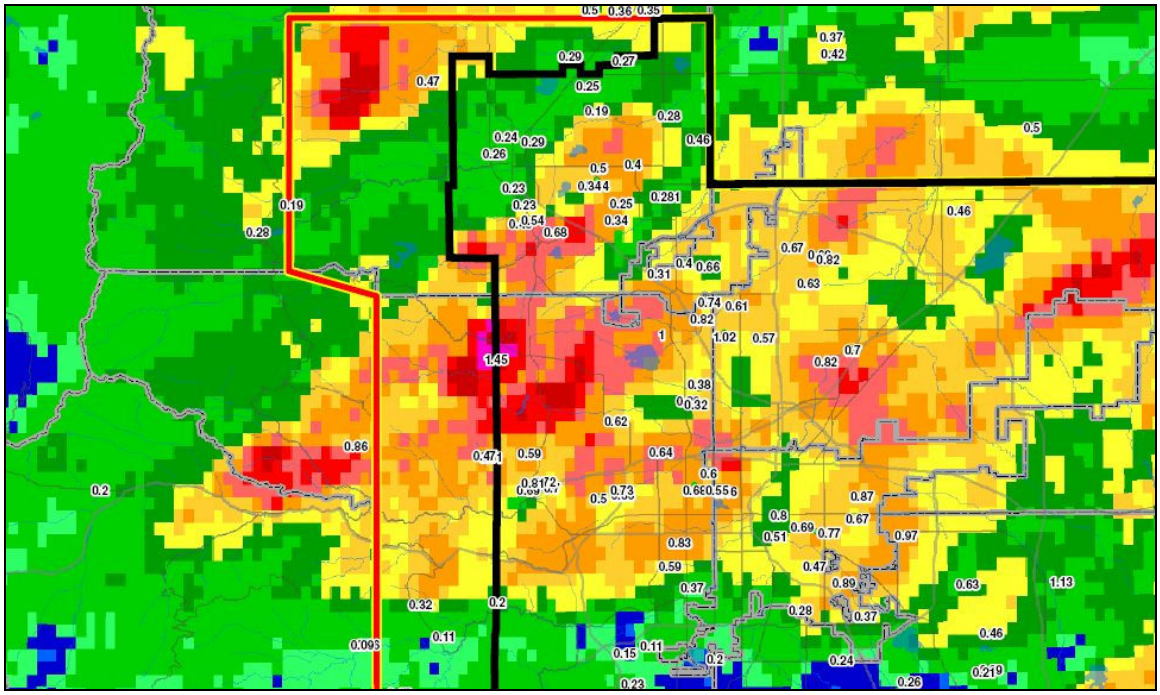


Figure 2: Radar rainfall image during the August 24th storm event

The 50386 repeater was damaged beyond repair. The site iscurrently served by an older spare unit that does not have the same capabilities of the 50386 for remote control. The Relative humidity, air temperature, fuel moisture, fuel temperature, wind sensor and the Blue Mountain weather transmitter were temporarily removed an brought to OneRain's shop for inspection and testing. The Blue Water Design / Campbell Scientific transmitter and wind sensor were found to be in working order, but the RH/AT and FM/FT sensors were damaged beyond repair. The RH/AT unit has been replaced, but the fire fuel sensor has not.

Three Handar transmitters were replaced by Blue Water Design / Campbell Scientific weather transmitters this year: Blue Mountain, Elbert and Squaw Mountain. The RH/AT sensors were also replaced to allow bring these measurements to within calibration standards.

OneRain also replaced the anemometer at the Calwood weather station, and replaced the solar panel at Diamond Hill.

Removals Requested Prior to Construction Activity

A holdover from 2004, the Castle Oaks site (2830) reinstallation is still pending. This site is scheduled for re-installation in the spring of 2008 at Bayou Gulch.

Pressure Transducer Failures or Replacements

Overall PT failures were low for the 2007 field season as compared to previous years. In 2006 OneRain replaced 14 pressure transducers. This year we only replaced two.

- Sand Creek Park (site 1800) relocated, Druck PT, having been in service for 4 months.
- Lena at Highway 6 (site 1040) Druck PT failed after having been in service for 6 years, 10 months.
- Hidden Lake (site 1300) Druck PT had to be calibrated three times in 2007. If it needs another calibration in early 2008 then it should be replaced. This sensor has been in place for 3 years, 9 months.
- Montview Park (site 400) Druck PT had to be calibrated three times in 2007. If it needs another calibration in early 2008 then it should be replaced. This sensor has been in place for 2 years, 4 months.

Miscellaneous Activity of Note

Spurious Data from Smoky Hill

There have been a large number of documented erroneous reports in the data record this year, as in previous years. OneRain has seen a marked improvement in these errors commonly referred to as “flipped bits,” but the problem still exists. The root cause of these obviously corrupted data values is not known. We also do not know the extent of the corruption of sensor identifiers, as these reports cannot be associated with a site.

OneRain conducted a test to see if we could at least parse the problem, if not isolate it. Since we have good data reception from Squaw Mountain, we recorded data from the temperature sensor at different times over several days. The most recent data are presented in the table below along with the data received at both the District and OneRain via the Smoky Hill repeater.

The table below demonstrates this issue in a three hour period.

Table 2: Data reception from the Squaw Mountain temperature sensor and the Smoky Hill repeater

Date/Time	UDD Raw Data	OR Raw Data (Repeated)	OR Raw Data (Direct)	Total count of Smoky output reports
12/28/07 09:08:00	33	33	33	4
12/28/07 08:53:00	33	33	33	18
12/28/07 08:38:00	34	34	34	26
12/28/07 08:23:00	1,539	1,539	35	25
12/28/07 08:08:00			34	24
12/28/07 07:53:00			33	21
12/28/07 07:38:00			32	33
12/28/07 07:23:00			31	20
12/28/07 07:08:00			31	20
12/28/07 06:53:00			30	13
12/28/07 06:38:00			30	19
12/28/07 06:23:00			29	9
12/28/07 06:08:00			30	8
12/28/07 05:53:00			30	10
12/28/07 05:38:00			30	22
12/28/07 05:23:00	1,054	1,054	30	10
12/28/07 05:08:00			29	15
12/28/07 04:53:00	29	29	29	11

The problem can be broken down into two scenarios: the data are being lost or corrupted at the receiving base stations, or the problem is occurring at the repeater. Since both base stations are independent, and are receiving the same erroneous data and are missing data at the same times, the first option is unlikely.

Problems at the repeater would include: a desensitized receiver due to an intermittent noise source, weakened signal strength from Squaw due to environmental changes or intermittent repeater hardware operation. The Squaw Mountain transmitter is the farthest away of all the sites reporting to Smoky Hill. Even though the path is line of sight, the signal is attenuated along this 67 kilometer (41 mile) distance. No matter which of these three problems is the cause, Squaw's reception is the canary in the coal mine.

To see if Squaw's reception is an anomaly, or if there really is some chronic problem, we looked at Smoky's reporting behavior during each 15-minute period that Squaw should report. For every 15 minute period, starting just after a Squaw temperature report, a query counted the number of reports from sensors in Smoky's pass list. Looking at a two week period, we found all of the periods where Squaw came in properly and all the 15-minute periods when it didn't. We then compared the average 15-minute report count with good Squaw reports to the average counts corresponding to bad reports.

OneRain found that there is a statistically significant difference in Smoky's output reliability between when Squaw is coming through and when it isn't. In other words, the Smoky Hill repeater's performance is periodically, and chronically, being degraded. The cause of this failure is not known. However, OneRain intends to investigate the RF environment around the repeater in the next couple of months.

The figures below provide some additional information on the intervening terrain and path characteristics between Squaw Mountain and Smoky Hill, and Smoky to the two base stations.

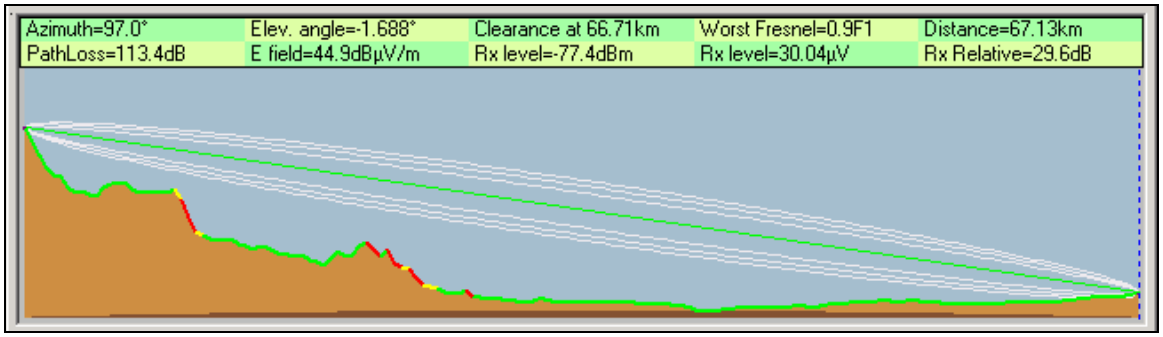


Figure 3: Radio Path from Squaw Mountain (left) to Smoky Hill (right)

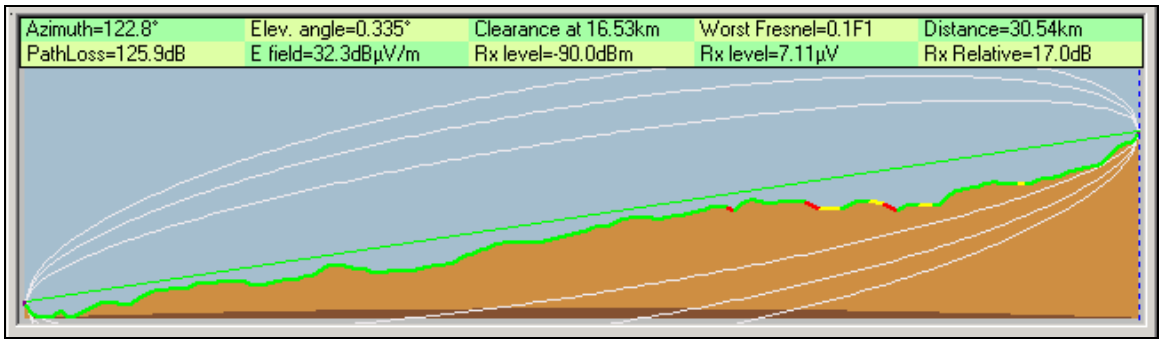


Figure 4: Radio path from UDFCD (left) to Smoky Hill (right)

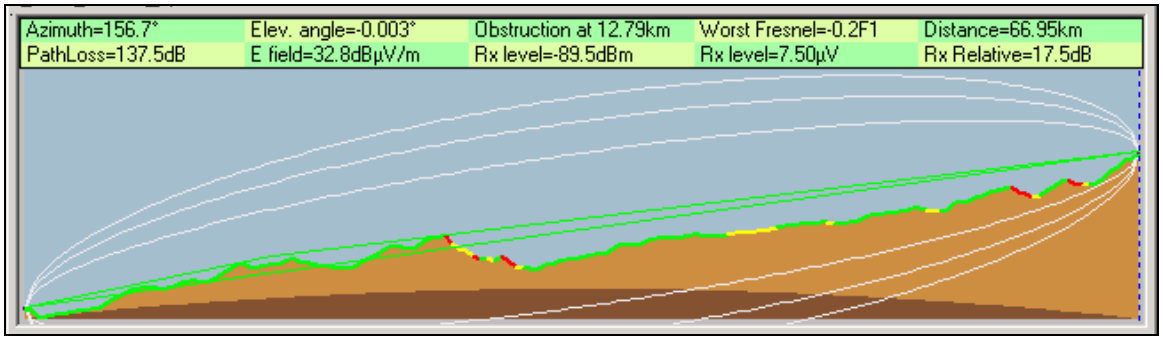


Figure 5: Radio path from OneRain's headquarters in Longmont (left) to Smoky Hill (right)

Handar 585 Transmitter Replacement

The UDFCD system includes 17 sites (not including Quincy Reservoir) that are in excess of 14 years old. These Handar 585 units are no longer supported by any manufacturer. Table 1 summarizes the older sites.

Table 3: UDFCD Sites with Equipment Older than 14 Years

Site ID	Site Name	Sensors*	Model	Purchase Date
130	Simms Street	S	585 B Rev G	1/1/1990
150	Knott Creek	P	585 B Rev G	1/1/1990
330	Van Bibber @ 93	PS	585 B Rev G	1/1/1990
750	Quincy Reservoir	PW	585 B Rev G	1/1/1991
1110	Gunbarrel	PS	585 B Rev G	1/1/1991
1630	S Platte @ Dart	E	585 C Rev G	1/1/1990
1720	Cherry Cr @ Steele	PS	585 B Rev G	1/1/1991
2230	Bear Creek @ Cub	PS	585 B Rev G	1/1/1991
2240	Cold Spring Gulch	PS	585 B Rev G	1/1/1991
2250	Rosedale	PS	585 B	1/1/1990
2260	Brook Forest	P	585 B Rev G	1/1/1991
2270	Cub Ck below Blue	PS	585 B Rev G	1/1/1991
2280	Kinney Peak	P	585 B Rev G	1/1/1991
2310	Genesee Village	P	585 B Rev J	1/1/1991
2350	Idledale	P	585 B	1/1/1991
2360	Indian Hills	P	585 B Rev G	1/1/1991
2370	Red Rocks	PS	585 B Rev G	1/1/1991

*PW = rain and weather array, E = shaft encoder, PS = rain and stage, P = rain

These units could be replaced as they fail or according to a replacement schedule.

Tipping Bucket Replacement

All of the tipping bucket rain gages have been upgraded from the freeze damage-prone tin units to cast aluminum.

FCC Licensing

To date, OneRain has received confirmation for renewed or extended licensing on all sites and call signs. As new sites are installed OneRain will keep the licenses up to date.

Smoky Hill Repeater Relocation

This remains a priority for OneRain because the RF path between our receiver and this site has been marginal. The East Cherry Creek Water and Sanitation District owns the property where this repeater is located. They have expressed a strong desire to have this station moved as well.

FUTURE AREAS OF INTEREST

The sections below outline areas that the District and OneRain have been tracking through our monthly meetings.

ALERT-2 Field Application

OneRain, with Blue Water Design LLC and Telos Services, has proposed a solution to improve the current system's performance and to build the first field application of the ALERT-2 protocol.

To improve system performance during intense rainfall events we have proposed to split the inputs to the two repeaters across two frequencies. In addition to the current 169.525MHz input to the Smoky Hill and West repeaters we would add a second input frequency. Half of the sites that report to Smoky would use 169.525, and half would use the new frequency. The same would be the case for the West repeater.

The RS-232 serial data streams from the two input frequencies would be merged into a compact message using the well established hardware and physical layer of the ALERT-2 protocol. This ALERT-2 application would operate in parallel with the operational system on a different frequency from 171.875 MHz.

East Plum Creek

This is a shared site with the USGS on Haskins Gulch. USGS technicians have replaced the sensor with a unit that is not compatible with our existing transmitter, and they have been very hesitant to make further changes. Rather than ask the USGS technicians to, again, change the configuration of this site we could "listen" to the SDI-12 data. This can be accomplished with an HSE 4015 signal converter and would be the most cost effective and least intrusive option from the USGS' perspective.

DATA ANALYSIS

This year OneRain and the District approached maintenance in a new way. By reducing the number of preventive maintenance visits we were able to reduce costs significantly. At the same time we applied new predictive maintenance techniques to improve our ability to explore the data from a maintenance perspective. Table 2 below summarizes the maintenance activity over the

course of the past five years. The "Service Rate" column is the ratio (%) of service calls to sites in the combined UDFCD/Boulder system.

Table 4: Recent Maintenance Activity Statistics

Year	Total Visits	Service Calls (OneRain/District)	Number of Sites[1]	Service Rate
2001	701	66 (30/36)	152	43%
2002	723	59 (45/14)	161	37%
2003	794	110 (86/24)	171	64%
2004	790	78 (51/27)	173	45%
2005	810	97 (76/21)	174	56%
2006	696	97 (78/19)	182	53%
2007	653	58 (49/9)	183	32%

The general trend over the past five years has been increasing service rate, until this year. In 2007 the total number of service calls fell by 40% as compared to 2006. This is due to data analysis and maintenance scheduling.

Data analysis techniques applied in 2006 and 2007 have allowed us to more clearly identify issues and their causes. This enabled us to execute project maintenance to fix these problems rather than repeatedly make partial repairs. Examples of less tractable problems include: partial solar panel and regulator failure, spurious reporting from pressure transducers, weather sensors out of calibration and transmitter reliability problems.

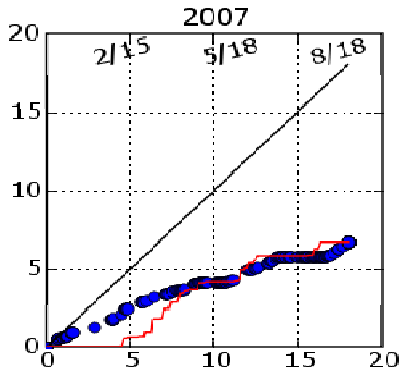
Sites with known issues have been scheduled for preventive maintenance on a more appropriate interval. Examples of known issues are plugged tipping buckets and excessive current drain from batteries.

In addition to these benefits, OneRain and District staffs have been more able to identify issues before they become problems. Both graphical and tabular data analysis tools have provided the means to quickly identify plugged tipping buckets, discharging batteries, and out-of-range weather sensors.

In addition to providing near-real time reports on sensor activity OneRain provided post-event analysis. These analyses indicated issues with both radio path reliability and clogged tipping bucket funnels. This year only one event met the criteria of 10 gages measuring more than 1 inch in 7 days. To analyze this late season event OneRain used double-mass plots.

[1] This total number of sites includes repeaters and base stations.

	Accum	#Rpts	Start	End
1600	6.69	457	03/13/07	11/01/07
630	25.349	879	03/17/07	10/12/07
1620	12.174	635	03/17/07	11/02/07
620	12.142	622	03/16/07	11/01/07
1500	25.578	1040	03/17/07	11/02/07
640	13.512	777	03/16/07	11/01/07



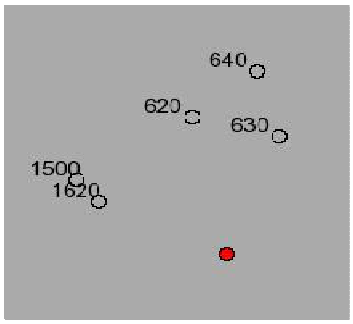
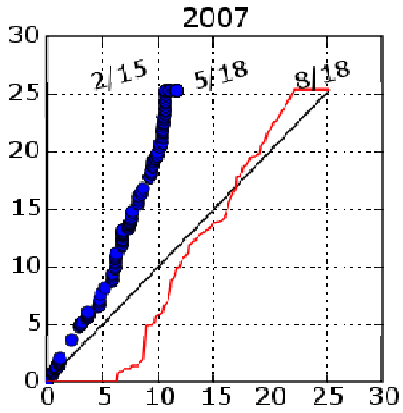


Figure 6: Double-mass plot for the Englewood Dam rain gage (affected by poor transmitter output)

	Accum	#Rpts	Start	End
630	25.349	879	03/17/07	10/12/07
640	13.512	777	03/16/07	11/01/07
620	12.142	622	03/16/07	11/01/07
1710	10.972	530	03/30/07	10/29/07
650	12.847	645	03/16/07	11/01/07
1600	6.69	457	03/13/07	11/01/07



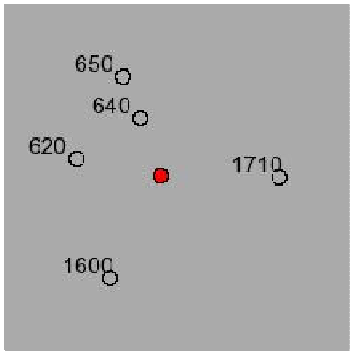


Figure 7: Double-mass plot for the Temple Pond rain gage (affected by sprinkler systems)

OneRain used these double-mass plots to identify problems with gages that would otherwise be difficult to quantify. Here, problems can be quickly targeted and then addressed with corrective maintenance.

There are still failure modes that cannot be found without direct calibration, measurement, or inspection. The challenge to optimizing maintenance is to find the minimum number of preventive maintenance visits while still catching problems. This year's activities have shown us that we have moved closer to achieving that goal.

CONCLUSION

This was a very successful in both reducing costs and improving performance. This report has not addressed the very serious RF channel contention issues. Aside from these problems the combined UDFCD / Boulder County flood detection system has performed well with no significant event going undetected. As compared to 2005 there were a high number of PT failures (10 versus 5) and the same number of radio failures this year (5 versus 5). The positive aspect of this is that these problems were caught by preventive maintenance.

Further challenges include improving methods to calibrate and validate weather sensor data, establishing statistics on the useful life of a piece of equipment, improving the detection rate of site and sensor failures, and addressing issues of traffic contention.

APPENDIX A: EQUIPMENT RECOMMENDATIONS

The items listed below are in order according to OneRain's recommendation of priority. Prices are based on recent quotations from vendors. OneRain will invoice the actual cost of each item.

1. Pressure Transducer Replacements.
   - The below listed pressure transducers would be ordered from GE Druck. The first unit would be to replace the sensor currently installed at Leyden Reservoir. The other two units would be used to replace the sensors at sites 400 and 1300 which required three calibrations this season.
   - Druck pressure transducer, 100 mV, 20 psi, 165', 1 x $900
   - Druck pressure transducer, 100 mV, 10 psi, 40', 2 x $650
   - Total Price: $2,200

2. Signal Conditioning Modules.
   - Some have been damaged by voltage surges and others are for interfacing with upgraded transmitters.
   - High Sierra Electronics 100mV to analog signal conditioning modules, five (5): 5 x $100 = $500
   - Total Price: $500

3. Transmitter Spares.
   - One High Sierra Electronics 3206 ALERT transmitter to replace the Eldorado Canyon unit.
   - One additional unit brings the spares for this transmitter type to 10%.
   - Total Price: 2 x $2,200 = $4,400

4. Handar 555F Replacement for the Hiwan weather station.
   - Replacement will retain the original enclosure and will include a new FCC-compliant radio, Blue Water Design transmitter controller (CommEngine) and, where sensors other than rain are required, a Campbell Scientific CR1000 datalogger.
   - One (1) weather station transmitters = $3,900

5. Handar 585 Replacements.
   - There are 16 rain or rain/stage transmitters still in the system. These have become increasingly unreliable, required specialized equipment to work on them which is also becoming unreliable, and the manufacturer no longer provides support. OneRain recommends replacing these units with 3206 transmitters from High Sierra Electronics.
   - The 585 transmitter at Gunbarrel is currently non-functional and non-repairable.
   - 3206 Transmitters = 16 x $2,200 = $35,200

6. Wind Sensor Replacements.
   - Vaisala sonic sensor spare = $1,700

7. Stroh Road rain and stage site installation.
   - High Sierra Electronics packaged rain and stage station
   - Druck pressure transducer, 100 mV, 10 psi, 140'
   - 12 hours of field labor, 4 hours of project management
   - Total Price: $5,500