Final REPORT

For

2008-2009 Long-Term Characterization Test Of the Sutron Fischer Porter Rebuild

Version 4
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Prepared for
National Weather Service W/OPS22

By

SAIC
From Science to Solutions

TABLE OF CONTENTS

TABLES

FIGURES

EXECUTIVE SUMMARY

Introduction

The NWS has decided to use a Qualified Parts List (QPL) to acquire rebuild kits for the remaining F&P gauges (approximately 2500 units). A QPL specification was issued by the NWS in February 2008. In June of 2008, the Sutron Corporation delivered seven FPR kits, which were thoroughly tested in Tenney environmental chambers and in the field at the Sterling Field Support Center (SFSC) located in Sterling, VA. These units were later recommended for placement on the QPL. This report describes the year-long test which evaluated the performance of the Sutron FPR kit under field conditions.

Results

Overall, the Sutron gauges performed within the specification in 100% of the 351 daily comparisons. Also included in the functional precision was an evaluation of the FPR gauges in different types of precipitation. The Sutron kits also passed 100% of each rain, snow, and freezing rain event comparison. The greatest difference in daily accumulations collected by the FPR gauges was -0.07 inches and the RMSD for this phase of testing was calculated to be 0.0106 inches.

The characterization test also showed that each Sutron FPR kits outperformed both of the reference gauges. Additionally, a comparison of the 24-hour precipitation totals of the Sutron and reference gauges showed that the average deviation between the sensors ranged from 0.01 to 0.02 inches, which is within the specification.

The functional comparison between the Sutron gauges and the AWPAG in the DFIR showed that the FPR kits' total precipitation catches were lower than those reported by the AWPAG. However, a graph of both Sutron gauges showed similar trends, in terms of timing of precipitation, when compared to the precipitation graph of the AWPAG. Overall, the Sutron kits each met the specification in 87% of rain events, 78% of snow events, and 100% of freezing rain events when compared with the AWPAG. The variable readings that occurred in the comparison with the AWPAG were deemed to be expected, due to the lack of wind screens around the Sutron FPR kits. The unsubstantiated reports that were also seen by the Sutron kits could be explained by the high winds at the time of the event on December 24-25.

The Sutron gauges also showed similar trends when compared to the FPU gauge in the field, despite the relatively short period of time it worked properly. The Sutron gauges were within specification in 77% of the rain events compared to the FPU.

Conclusions

The long term specification compliance testing shows that the Sutron FPR kits installed in the field meet the NWS-D111-5-SP001 specifications. The Sutron kits remained within the specification (± 0.1 inch) in every 24-hour accumulation comparison (351 totals) as well as in each monthly precipitation comparison (11 totals). Additionally, the Sutron FPR kits exceeded the performance of the reference F&P gauges in the field. The Sutron gauges also showed precipitation trends similar to those seen by the AWPAG and FPU gauges.

Although one sensor experienced diurnal variations during part of the test, those variations have ceased and are therefore not considered an issue at the present time. However, the SFSC will continue to monitor the sensors. As of October 16, 2009, the Sutron FPR kits are considered compliant with the specification.

1.0 BACKGROUND

The National Weather Service (NWS) supports a Cooperative Observer Program (COOP) that includes a nationwide network of sensors that record weather information for use in the climate community. The sensors record a variety of meteorological measurements including temperature, dew point temperature, and precipitation accumulation. The COOP program currently uses a Fischer and Porter (F&P) rain gauge for measuring precipitation accumulation every 15 minutes. The current sensor uses a paper tape punch mechanism that is obsolete and the information it records can be hard to collect. Therefore, the NWS has undertaken a Fischer and Porter Rebuild Program (FPR) to replace the tape punch mechanism with a device that has digital data recording and reporting capabilities.

In 2005 – 2006, 249 upgraded F&P (FPU) gauges were deployed in the field using a conversion kit developed by Coastal Environmental technology. The upgrade kits were purchased under a competitive contract with Coastal Environmental Systems. However, the NWS has decided to use a Qualified Parts List (QPL) to acquire rebuild kits for the remaining F&P gauges (approximately 2500 units). The NWS posted a description of the QPL on FedBizOps in October 2007 and the final version of the QPL specification was issued in February 2008.

In June of 2008, the Sutron Corporation delivered seven FPR kits. Testing began immediately in an effort to determine if the Sutron kits met all the requirements of the QPL specification. The Sutron FPR kit was thoroughly tested in Tenney environmental chambers and in the field at the Sterling Field Support Center (SFSC) located in Sterling, VA, and was later recommended for placement on the QPL. This report describes the year-long test which evaluated the performance of the Sutron FPR kit under field conditions.

2.0 PURPOSE AND OBJECTIVES

The main purpose of this test was to determine if the accuracy and/or functionality of the Sutron Model NWS-0001-1 Fischer and Porter rebuild kits degraded over time. The purpose was also to show if there were differences with the FPR when compared to the current F&P gauges and an AWPAG in a 12-meter Double Fence Intercomparison Reference (DFIR). This was accomplished by analyzing sensor drift through calibration, conducting exposure tests, and performing a field demonstration to determine if the Sutron kits met the requirements of the QPL specification (*Specification NWS-D111-5-SP001, Fisher and Porter/Belfort Precipitation Gauge Rebuild Kit*) over a period of one year.

3.0 EVALUATION CRITERIA

All FPR kits were tested as set forth by the test plan and Specification NWS-D111-5-SP001. The FPR kit was required to report precipitation accumulation within ±0.10 inch of the reference F&P gauge. In addition, an assessment was performed to ensure the FPR kits do not degrade over the time of one year. All Sutron FPR kits in the field were analyzed for the purpose of the long term characterization evaluation.

4.0 TEST CONFIGURATION

4.1 Description of Sensors

The QPL testing compared the performance of rebuilt Fischer and Porter gauges (gauges that were modified with the installation of FPR kits) against the original mechanical Fischer and Porter gauge. An ASOS AWPAG located inside a 12-meter DFIR and a FPU gauge were also used as comparison sensors for the outdoor performance testing, but were not used for qualification of the kits during QPL testing.

4.1.1 Original Fischer and Porter Gauge

The original Fischer and Porter gauge (Figure 1) is a weighing gauge that records the weight of accumulated precipitation by punching a paper tape. A dial readout that displays the current amount of precipitation in the reservoir is also provided. Precipitation is collected and stored in a collection bucket. A spring balance-weighing device mechanically positions a coded disk and a dial. At a predetermined interval of 15 minutes, the code position of the disk is punched on paper tape, thereby recording the amount of accumulated precipitation to the nearest tenth of an inch. The measuring range is 0 – 19.5 inches water equivalent.[1]

Figure 1: Fischer and Porter Gauge

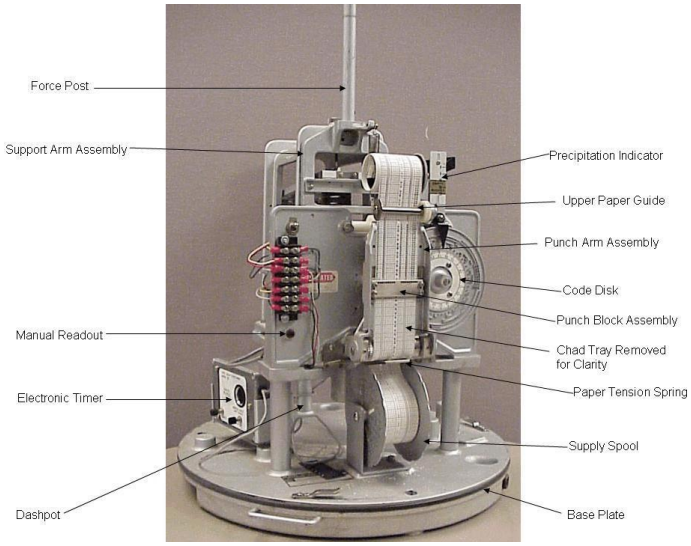


Figure 2: Fischer and Porter Components

4.1.2 Production AWPAG

A standard production ASOS AWPAG with a Tretyakov windshield located inside a 12-meter DFIR was installed in the test bed. This gauge was used during functional field testing to determine performance of the FPR kits prior to comparisons with the mechanical F&P sensor. The main purpose of using the AWPAG was to verify that precipitation occurred, and to also confirm precipitation beginning and ending times.

[1] Hoehne, Walter; Final Report – Test and Evaluation of the Fischer and Porter Precipitation Gage; U.S Department of Commerce, Environmental Science Services Administration, Weather Bureau, 1968.

4.1.3 Fischer & Porter Upgrade Gauge

Coastal Environmental Systems developed, manufactured and deployed a Fischer Porter Upgrade (FPU) unit to replace the F&P. The FPU replaces the weighing spring and paper punch mechanism of the F&P with a ZENO 3200 data acquisition system and a load cell. These modifications to the existing F&P gauge are similar to those seen in the FPR kits, thus the FPU gauge was used as an additional comparison sensor.

4.1.4 Sutron NWS-0001-1 Fischer and Porter Rebuild COTS Kits

All of the rebuild kits were designed to replace the function of the paper tape recording mechanism. In fact, the entire paper tape mechanism was removed from the gauge to make room for the new equipment. Each Sutron FPR kit was required to have the following main elements: a load cell to measure the weight inside the gauge's reservoir, a data logger computer to record and store the information, a memory card interface unit, a data display unit, a power supply unit, a battery unit, and a solar power panel. All of these devices (with the exception of the solar panel) were designed to fit inside the shell of a standard Fischer and Porter gauge. In the case of the Sutron kits, the data logger, data display, and SDI-12 memory card interface were all combined into a single unit, called the Monitor. The data logger is capable of holding 300,000 readings, and is also capable of connecting to an optional temperature sensor. Sutron gauges were installed in the new testbed at Sterling on October 16, 2008.

Figure 3: Sutron FPR Upgrade Kit

4.2 Test Location

For the purpose of this test, field-testing was conducted in the Precipitation Test Bed at the SFSC. The test bed includes all the sensors that were used in the test. (See Appendix A for a map of the test bed).

4.3 Weather Observations

The reference gauges and FPR kits were monitored by observers at the SFSC. When observers were on duty, they checked the F&P reference gauges to verify that they were still operating properly. Any issues with the gauges were reported to the Test Director immediately.

4.4 Assumptions and Limitations

- During the first half of the characterization test, the reference gauges at the SFSC failed frequently. Technicians were not able to keep either of the F&P reference gauges running properly in the field for more than a few days. Overall, insufficient amounts of data were gathered from these sensors to perform the functional comparison portion of this characterization test. Therefore, during the first half of the evaluation, the Sutron FPR gauges were only compared with the AWPAG sensor, as neither reference gauge provided usable data for evaluation purposes. Technicians were able to get both F&P gauges running properly in the field beginning on January 22, 2009. Several smaller outages were experienced again in April and June of 2009, but the gauges were promptly repaired and reinstalled in the field. Reliable data from the F&P reference gauges were gathered regularly from January through June, and a functional comparison was able to be performed on these data.

- Comparisons between the Sutron FPR gauges and the F&P reference gauges were affected by difference in measurement resolution. The F&P reference gauges measure to the nearest 0.10 inch while the Sutron FPR gauges measure to the nearest 0.01 inch. Because of measurement rounding (inherent in the reference gauges), the effective measurement uncertainty of this comparison is ±0.099 inch.

- The SFSC received a Coastal FPU gauge in February of 2009. This sensor was immediately installed in the field at Sterling and was used as a comparison gauge for this test. A second FPU gauge was installed in the field at Sterling, after the first gauge performed poorly. A functional comparison between the FPR kits and the FPU gauge in the field took place from March 1, 2009 to October 16, 2009.

- Slight diurnal variations, which were first seen during QPL testing, were also detected during the long term characterization testing. An investigation in to why these diurnal cycles were occurring was conducted in the field utilizing FPR kit #3104 (see Section 6.3).For purposes of this investigation, the load cell of #3104 was subjected to a constant force over a two week period. Findings showed that there were no issues with the load cell or with any other FPR kit components. Therefore, the meteorological data from gauge #3104 was not useable from April 7-21, 2009.

5.0 TEST METHODOLOGY

5.1 Data Collection

The vendor rebuild kits used data loggers to collect precipitation accumulation data. Data from the rebuild kits were collected approximately once every week using the media provided by the vendor. Reference gauge data were also gathered about once per week by collecting the punch tapes from each sensor. Data from the FPU gauge were collected approximately once per week using the data key provided. AWPAG data were collected continuously using the existing PC-based data acquisition system (DAS).

5.2 Evaluation Parameters

The long term characterization test consisted of testing the FPR kits in a field environment, and was performed for one year. This report includes results for the twelve month period from October 2008 to October 2009. The gauges were evaluated from meteorological and engineering standpoints.

5.2.1 Meteorological Assessment

The rebuild gauges were analyzed against each other, the mechanical F&P gauge, and the comparison sensors (AWPAG and FPU). The field-testing of these kits included a functional precision test between like rebuild kits (to determine production quality) and a functional comparison test between the rebuild kits, the mechanical F&P gauges (to verify that the rebuild kits performed as well as or better than the F&P gauge), the AWPAG in the DFIR, and the FPU gauge. The gauges report precipitation accumulation in 0.1 inch increments every 15 minutes and the data were collected once per week. All of the gauges under test caught more than 17 inches of liquid during the course of the evaluation. The gauges' collection buckets were emptied as needed, and the data were re-normalized during analysis. The following sections describe the analysis of the FPR kit performance.

5.2.1.1 Functional Precision

A comparison was made of the total catch recorded by each FPR kit (the rebuild kits were compared to each other). Differences were recorded for every report (15 minutes), and by day, week and month. The following equation was used:

Difference = FPR PA (a1) – FPR PA (a2)

where: PA = Precipitation Accumulation, a1 = Sutron kit #3104, a2 = Sutron kit #3102

A graph of the precipitation accumulation over the entire test period was produced to visually show the performance of the upgrade kits. An additional graph was created of the differences between like rebuild kits.

Also included in this evaluation was the computation of the root mean square deviation (RMSD) between the FPR kits in the field. The RMSD is a cumulative value that changes as more data are added to the long term characterization testing database.

The equation for the RMSD of the difference between simultaneous readings from two systems (Sutron FPR kits) measuring the same quantity in the same environment is:

$$C = \pm\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(X_{ai} - X_{bi}\right)^2}$$

Where: X_{ai} = *i*th measurement made by one system, X_{bi} = *i*th simultaneous measurement made by another system, N = number of samples used, and C = RMSD difference.

This equation can be found in "3.2.3 Operational Comparability (C)" of ASTM Standard, D 4430.

5.2.1.2 Functional Comparison

A reference comparison was made of the total catch recorded by each gauge. Differences were recorded for every report (15 minutes), and by day, week and month. The following equation was used:

Difference = FPR PA – Reference/Comparison Sensor PA

where: PA = Precipitation Accumulation, Reference Sensor = Mechanical F&P
Comparison Sensor = AWPAG or FPU

If the FPR kit reported more precipitation than the reference sensor, the result of the above equation was positive and if the FPR kit reported less precipitation than the reference sensor, the result was negative. The precipitation catch from the FPR kit was to be at least equal to the mechanical F&P gauge. The AWPAG located inside a DFIR and FPU were also used as comparison sensors for the characterization testing.

5.2.1.3 Unsubstantiated Reports

An unsubstantiated report occurred when the rebuild kit reported precipitation accumulation and there were no reports from the mechanical F&P gauge and the observer or a precipitation identification sensor confirmed that no precipitation occurred. These types of reports were tabulated and forwarded to the Test Director.

5.2.1.4 Observer Inspections

Observers inspected the gauges in the field and if anything out of the ordinary was found, a note was made and the information was forwarded to the Test Director.

5.2.2 Engineering Assessment

Two rebuild kits from Sutron were installed inside F&P shells in the test beds within close proximity of each other. The sensors ran continuously in all types of weather. When observers were on duty, they checked the F&P reference gauges to verify that they were still operating properly.

5.2.2.1 Installation

The majority of the FPR kits and reference gauges were installed in the field by an SFSC electronics technician and the FPR QPL Test Meteorologist. The installation procedures supplied by the manufacturer were followed and the effectiveness and clarity of the instructions as well as the installation process itself were evaluated. After installation, the gauges were field calibrated as per manufacturer instructions.

5.2.2.2 Durability

The durability of the gauges was assessed during the field testing. The gauges were monitored for the following: corrosion of parts, degradation of plastic parts, fading of the LED screens on the data loggers,

peeling paint on gauge surfaces, and parts that broke. Any durability issues noted by the test participants were photographed, documented, and forwarded to the Test Review Group (TRG). Specification requirements were taken into consideration when determining durability.

6.0 TEST RESULTS

Field tests for this final report were performed over the course of twelve months; during this time data were periodically collected from the Sutron gauges as well as the AWPAG located inside of the DFIR. Data were collected upon proper working order of the F&P reference gauges, and upon installation of the FPU gauges.

6.1 Meteorological Assessment

The following sections describe the results of the FPR kit performance. Monthly graphs of the Sutron FPR kits' performances are shown in Appendix B (Figures B-1 through B-13). Additional graphs including 24-hour precipitation amounts and precipitation differences between gauges are also included in Appendix B.

6.1.1 Functional Precision

A comparison was made of the total daily catch recorded by each FPR kit (Sutron rebuild kits were compared to each other). Analysis shows that the two Sutron gauges performed within the specification (±0.1 inch) throughout the entire testing period (Figures 4 - 7).

Figure 4: Difference between Sutron Daily Precip, October – December 2008

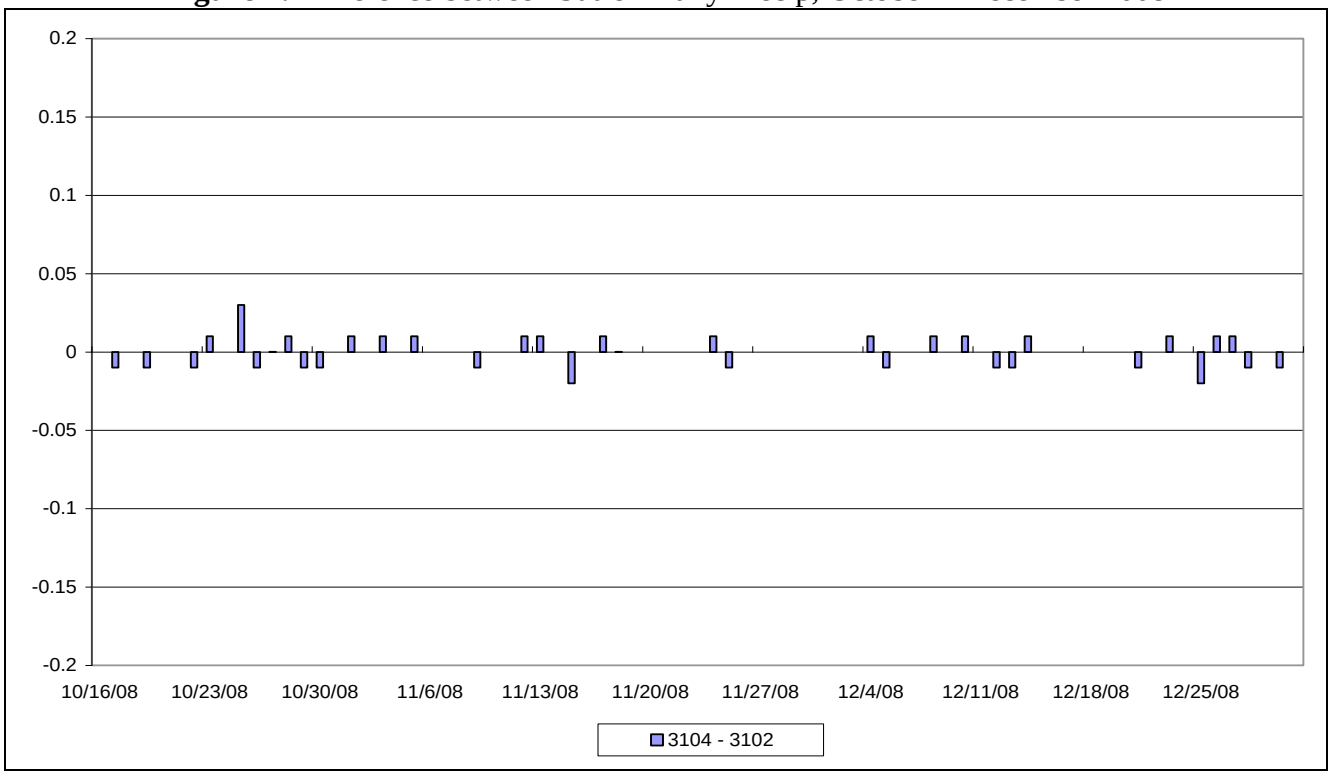


Figure 5: Difference between Sutron Daily Precip, January – March 2009

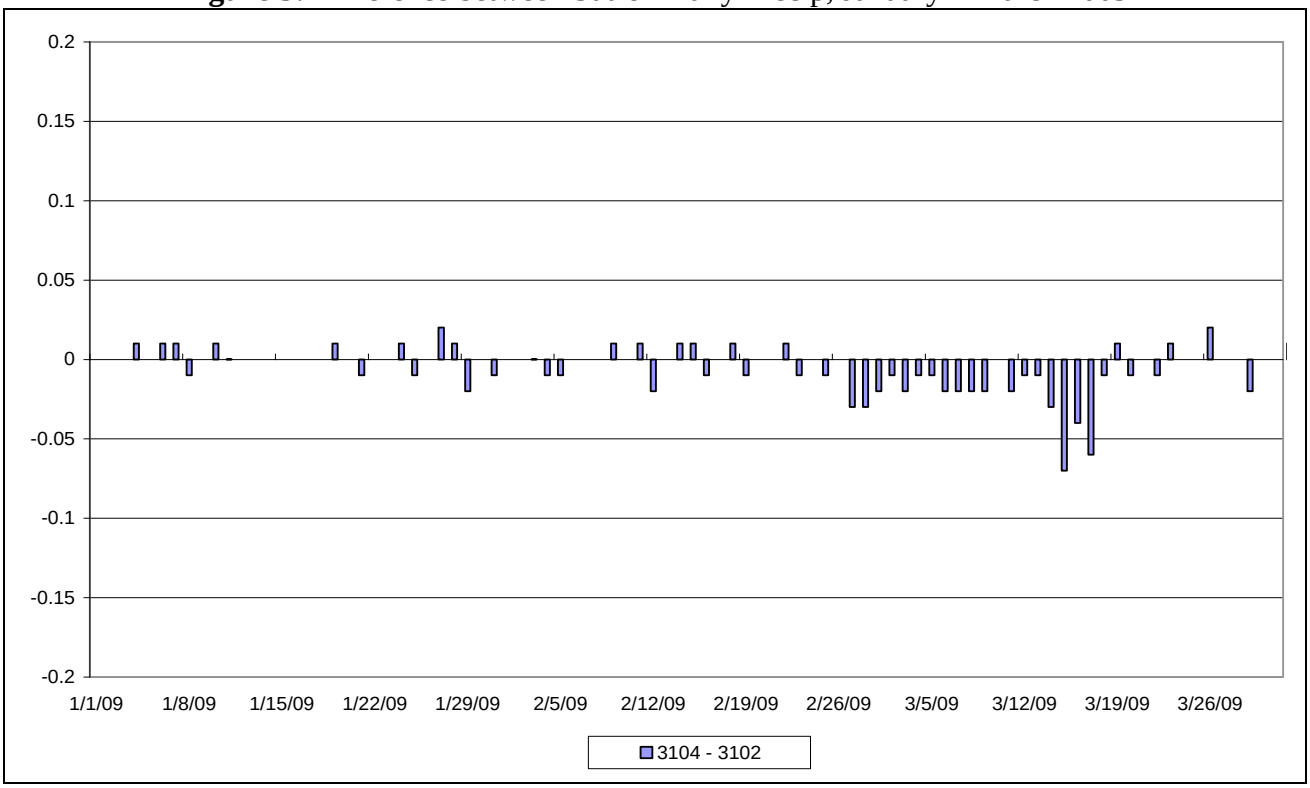


Figure 6: Difference between Sutron Daily Precip, April – June 2009

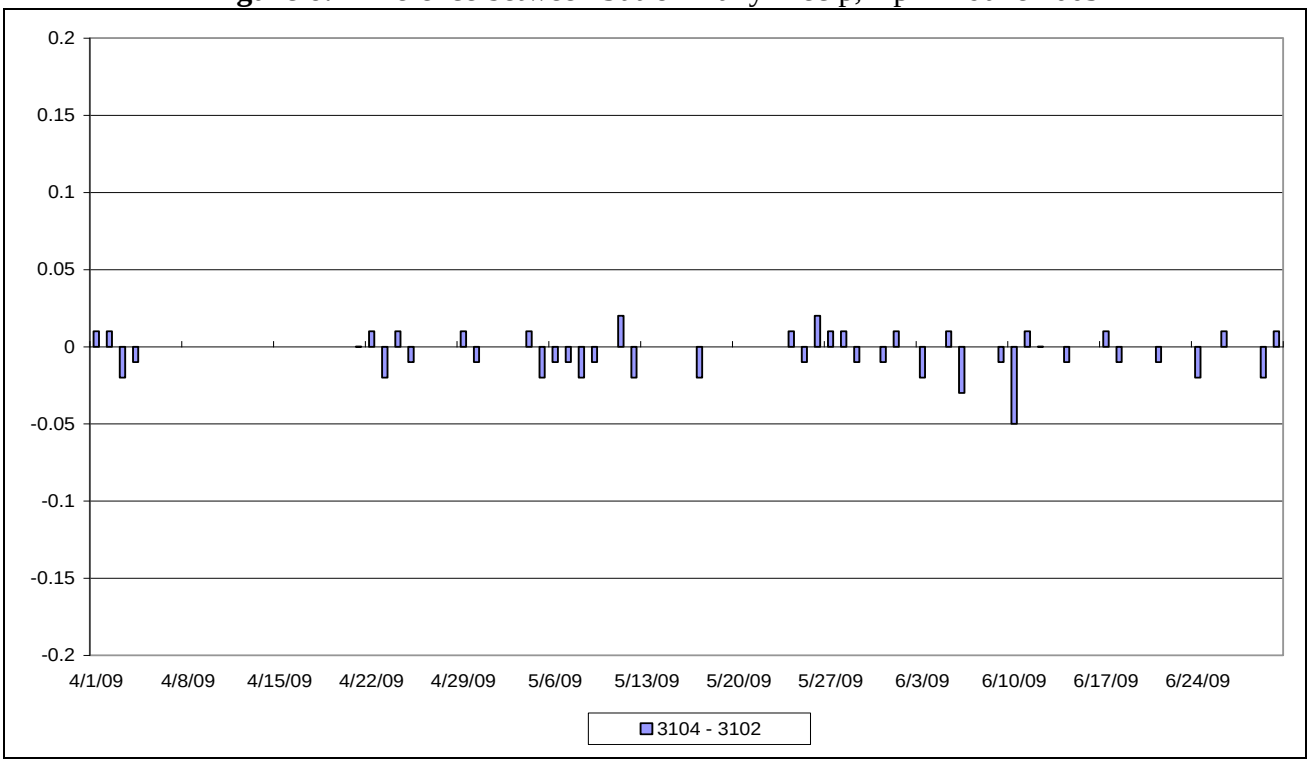
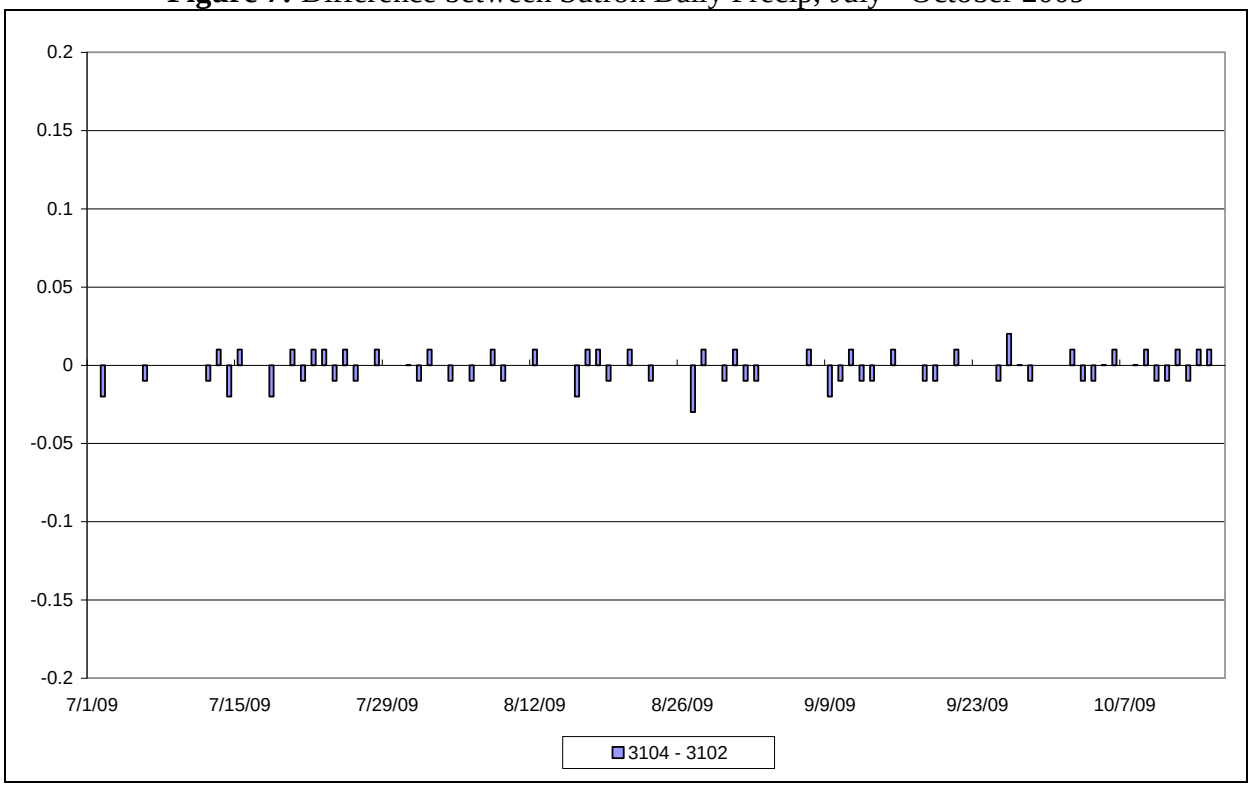


Figure 7: Difference between Sutron Daily Precip, July - October 2009



The gauges remained within the specification in each of the 351 daily accumulations that were analyzed. The greatest difference between daily accumulations collected by the FPR gauges was -0.07 inches (Table 1). Additionally, the RMSD for this phase of testing (using 15-minute accumulation periods) was calculated to be 0.0106 inches, which is within the limits set forth by the specification.

Table 1: Sutron Functional Precision

	3102 vs. 3104 (inches)
Maximum 24-hour Difference between Sutron kits	-0.07
Root Mean Square Deviation	+0.0106

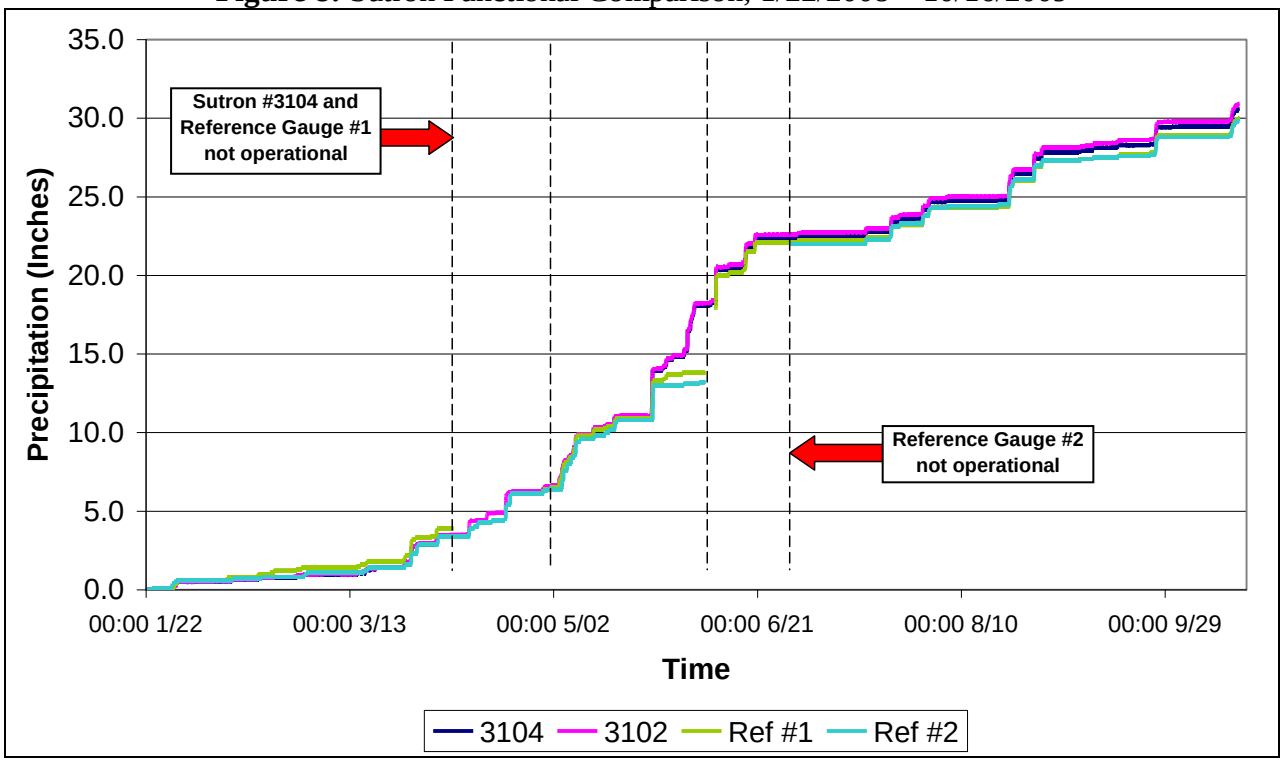
Also included in the functional precision was an evaluation of the FPR gauges in different types of precipitation. The Sutron kits compared well against each other, passing 100% of each rain, snow, and freezing rain event.

6.1.2 Functional Comparison

A reference comparison was made between the F&P gauges and Sutron FPR kits. The reference gauges at the SFSC were problematic during the first phase of the characterization test; however, technicians were able to get both F&P gauges running properly in the field beginning on January 22, 2009. Sufficient amounts of data were gathered from this point on and a functional comparison was performed.

The Sutron FPR kits performed outside the specification when compared to the reference sensors, as both FPR kits reported more precipitation than each reference sensor (Figures 8 and 9). However, the comparison between the FPR kits and the reference gauges remained within the specification during the majority of testing.

Figure 8: Sutron Functional Comparison, 1/22/2008 – 10/16/2009



Both FPR kits showed similar precipitation trends when compared to the reference sensors. The results from the Sutron FPR kits showed a positive functional comparison, by outperforming both reference gauges (Table 2). When 24-hour precipitation accumulations of the FPR and reference gauges are compared, results showed that the FPR kits caught more on a daily basis as well (see Appendix B, Figures B-19 through B-22). Overall, the Sutron FPR kits exceed the performance of the reference gauges.

Table 2: Functional Comparison with F&P Reference Gauges

Sutron vs F&P (inches)	**Sutron 3102**	**Sutron 3104**
Average 24-hour Difference vs Reference #1	+0.02	+0.02
Average 24-hour Difference vs Reference #2	+0.02	+0.01
Room Mean Square Deviation vs Reference #1	+0.1335	+0.1335
Room Mean Square Deviation vs Reference #2	+0.1490	+0.1520

A comparison of the Sutron kits and reference gauges in different precipitation types was also done (Table 3). This functional comparison showed that each Sutron gauge performed within the specification in 81%

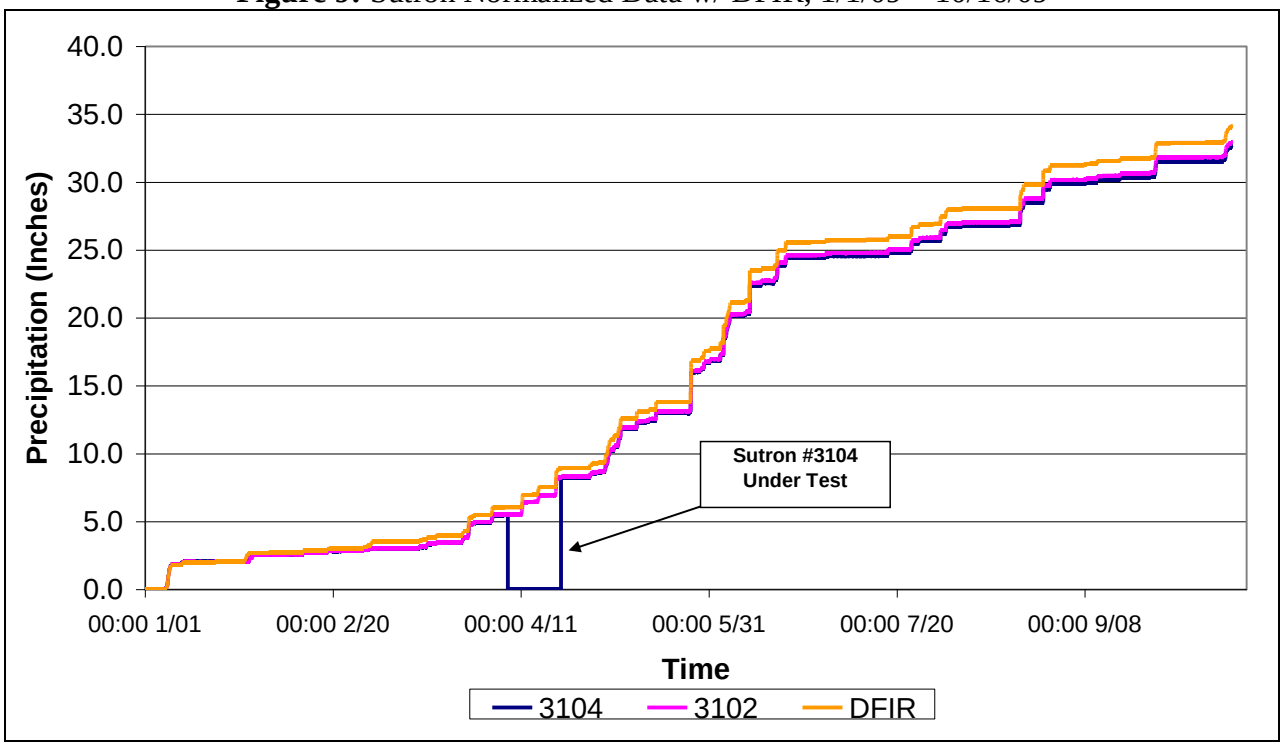
of rain events, and 60% of snow events; there were no freezing rain events analyzed with the reference gauges. The kits actually reported more precipitation totals in each of the events than the F&P reference gauges.

Table 3: Sutron Functional Comparison, Sutron FPR kits vs. Reference Gauges

	Rain	**Snow**	**Freezing Rain**
3102 vs. Ref #1 # of Periods in Specification	112	5	N/A
3104 vs. Ref #1 # of Periods in Specification	110	5	N/A
3102 vs. Ref #2 # of Periods in Specification	94	3	N/A
3104 vs. Ref #2 # of Periods in Specification	96	3	N/A
Total Number of 24-hour Periods	126	5	0

The AWPAG inside the DFIR was also used to compare precipitation amounts with the Sutron FPR kits. The Sutron gauges showed similar trends to the AWPAG in regards to timing of precipitation (Figure 9). Without any wind shields surrounding the Sutron gauges, total precipitation catches were lower than those reported by the AWPAG in the DFIR. This was expected, as the DFIR was specifically designed to reduce the negative impact of the wind on precipitation catch efficiency, thus enabling the AWPAG gauge inside the DFIR to catch more precipitation.

Figure 9: Sutron Normalized Data w/ DFIR; 1/1/09 – 10/16/09



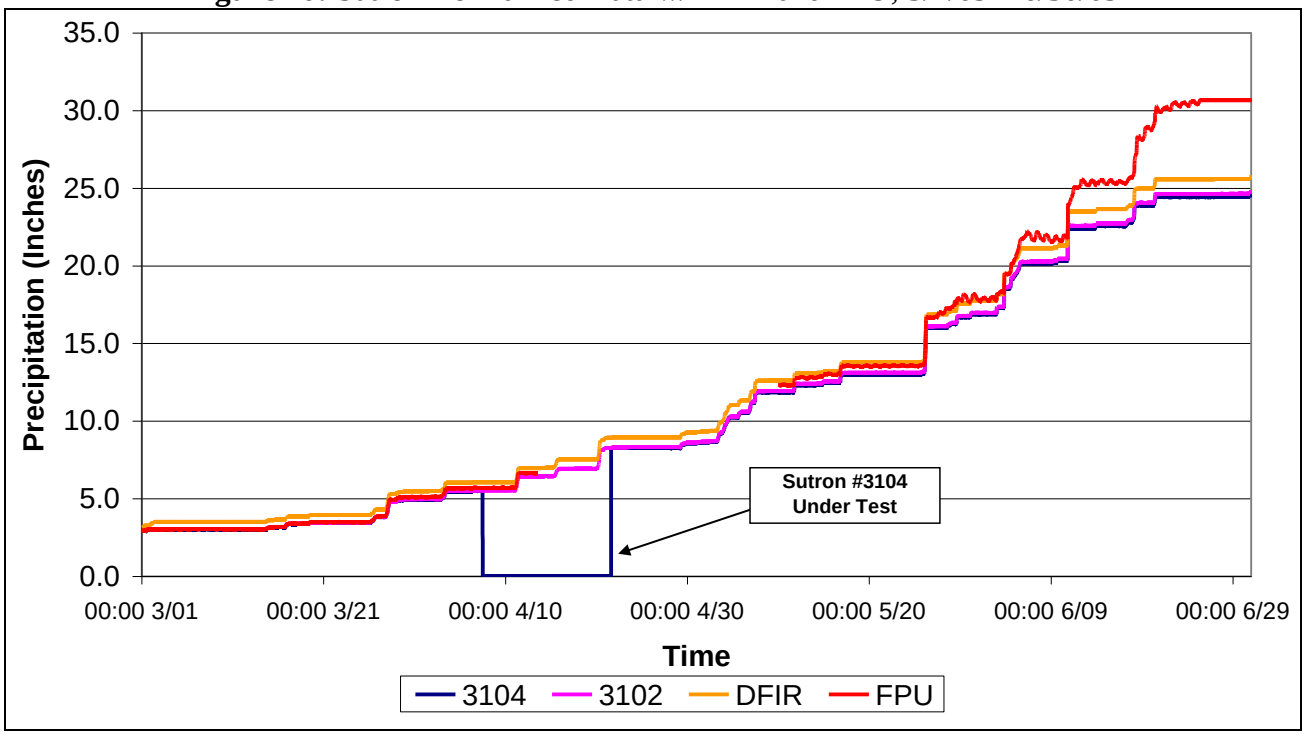
Once again the FPR kits were compared with the reference gauges in different types of precipitation (Table 4). When compared with the AWPAG, the Sutron kits each met the specification in 87% of rain events, 78% of snow events, and 100% of freezing rain events.

Table 4: Sutron Functional Comparison, Sutron FPR kits vs. AWPAG

	Rain	**Snow**	**Freezing Rain**
3102 vs. AWPAG # of Periods in Specification	131	7	1
3104 vs. AWPAG # of Periods in Specification	131	7	1
Total Number of 24-hour Periods	151	9	1

The FPR kits were also compared to the FPU gauges beginning on March 1, 2009 (Figure 10).

Figure 10: Sutron Normalized Data w/ DFIR and FPU; 3/1/09 – 6/30/09



Over time, the Sutron precipitation amounts slowly deviated from the accumulations caught by the AWPAG in the DFIR and the FPU, thus resulting in a moderate disparity in precipitation totals (Table 5). However, on an event-by-event basis, both gauges consistently showed precipitation trends similar to those shown by the AWPAG and the FPU. The FPU sensor began reporting inaccurate precipitation data beginning in late May 2009.

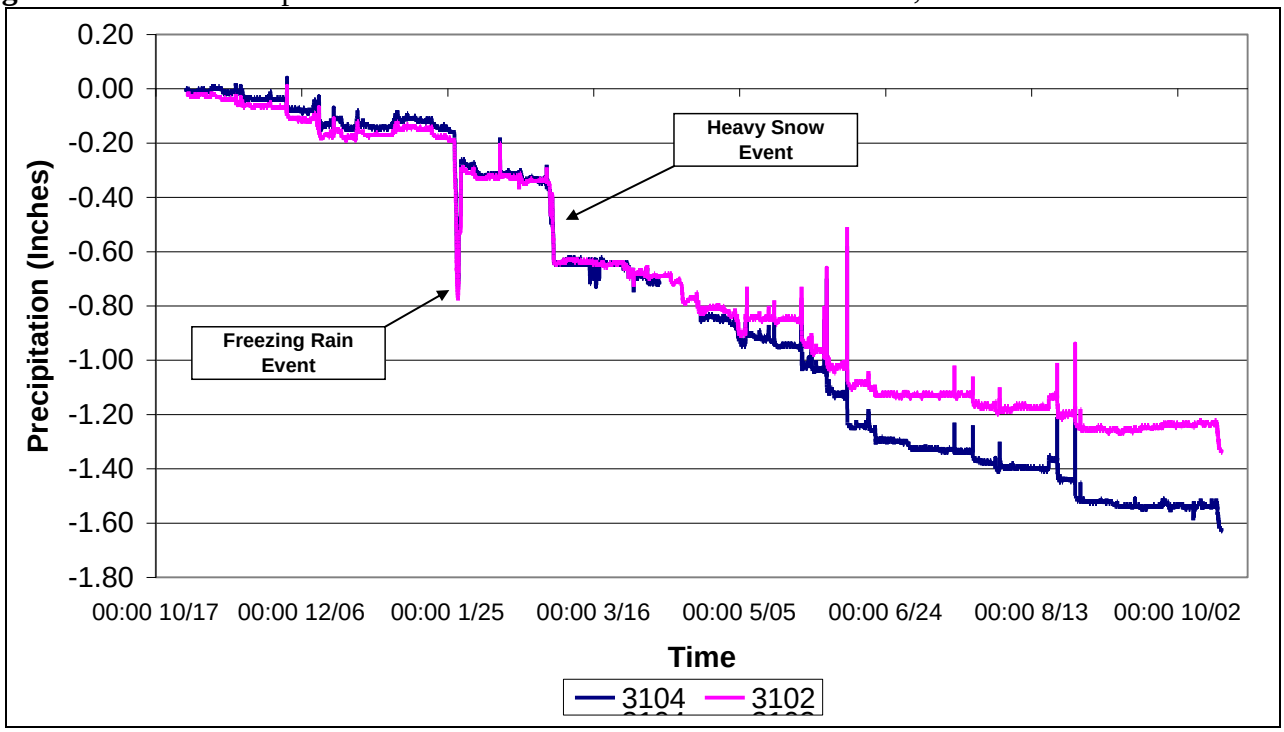
The Sutron gauges were only compared to the FPU gauge in rain events, passing 64 out of 83 total events (77%).

Table 5: Functional Comparison with AWPAG in DFIR and FPU

Sutron vs DFIR (inches)	**Sutron 3102**	**Sutron 3104**
Maximum 24-hour Accumulation Difference vs. AWPAG	-0.37	-0.35
Maximum 24-hour Accumulation Difference vs. FPU	-1.32	-1.33
Root Mean Square Deviation vs. AWPAG	+0.0319	+0.0310
Root Mean Square Deviation vs. FPU	+0.1949	+0.1952

The largest disparities between the FPR gauges and the AWPAG in the DFIR occurred during heavy and frozen precipitation events. Not only does the AWPAG record precipitation more quickly than the FPR gauges, but the AWPAG inside the DFIR has much higher catch efficiency during wind-blown snow events. The AWPAG is also equipped with an orifice heater and is able to melt any precipitation that freezes onto its orifice. Precipitation froze to the orifice of the FPR gauges during the freezing rain event of January 28, 2009 and did not fall into the collection buckets until temperatures rose above freezing the next day (Figure 11).

Figure 11: Sutron Precipitation Cumulative Deviation from the AWPAG, October 2008 – October 2009



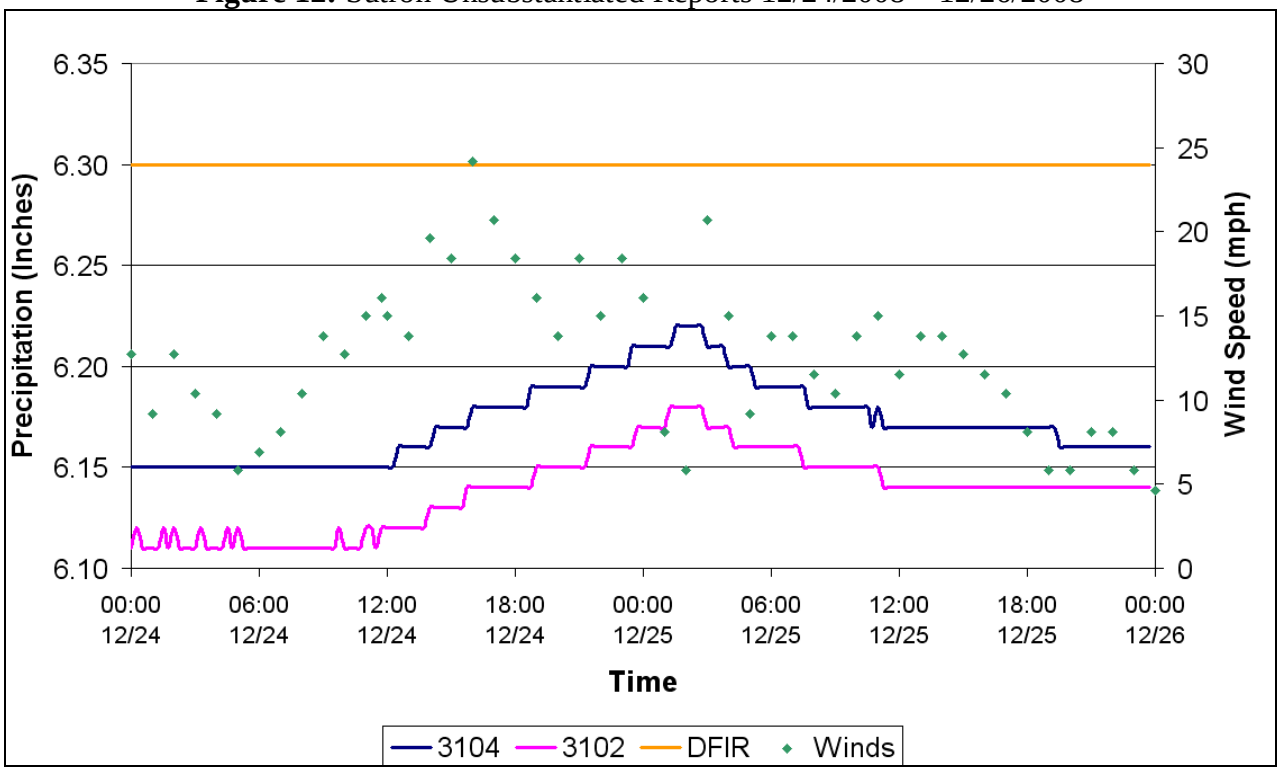
6.1.3 Unsubstantiated Reports

A twenty-four hour period of unsubstantiated reports was identified on December 24-25, 2008. During this time, there were no reports of precipitation from the AWPAG in the DFIR, yet both Sutron FPR kits reported precipitation accumulation (Figure 12). The weather observations were also checked, and showed no precipitation in the area during the time of the unsubstantiated reports. Both Sutron kits in the field began showing precipitation accumulating around 12:30PM on the 24th; these amounts slowly continued to rise until about 1:30AM on the 25th. At this time precipitation values began to decrease, and by 11:15AM on the 25th, both kits returned to values similar to where they initially stood, twenty four hours prior. The number of unsubstantiated reports is small compared to the total number of 15-minute periods collected throughout the characterization test (Table 6).

Table 6: Unsubstantiated 15-Minute Reports

	3102	**3104**
# of Unsubstantiated Reports	112	144
Total # of Reports	35,964	34,609
% of Reports Deemed Unsubstantiated	0.003%	0.004%

Figure 12: Sutron Unsubstantiated Reports 12/24/2008 – 12/26/2008



It is suspected that these unsubstantiated reports may have been caused by "wind pumping". This phenomena is created when high winds blow across the orifice of a precipitation gauge and creates a pressure differential inside the precipitation bucket, and thus an up and down force on the load cell of the FPR kit. Winds during the time of unsubstantiated reporting were reported at 8 to 24 mph, with gusts up

to 36 mph. Despite these false accumulations reported by both Sutron kits, neither unit deviated from the AWPAG in the DFIR above 0.1 inches, thus remaining compliant with the specification.

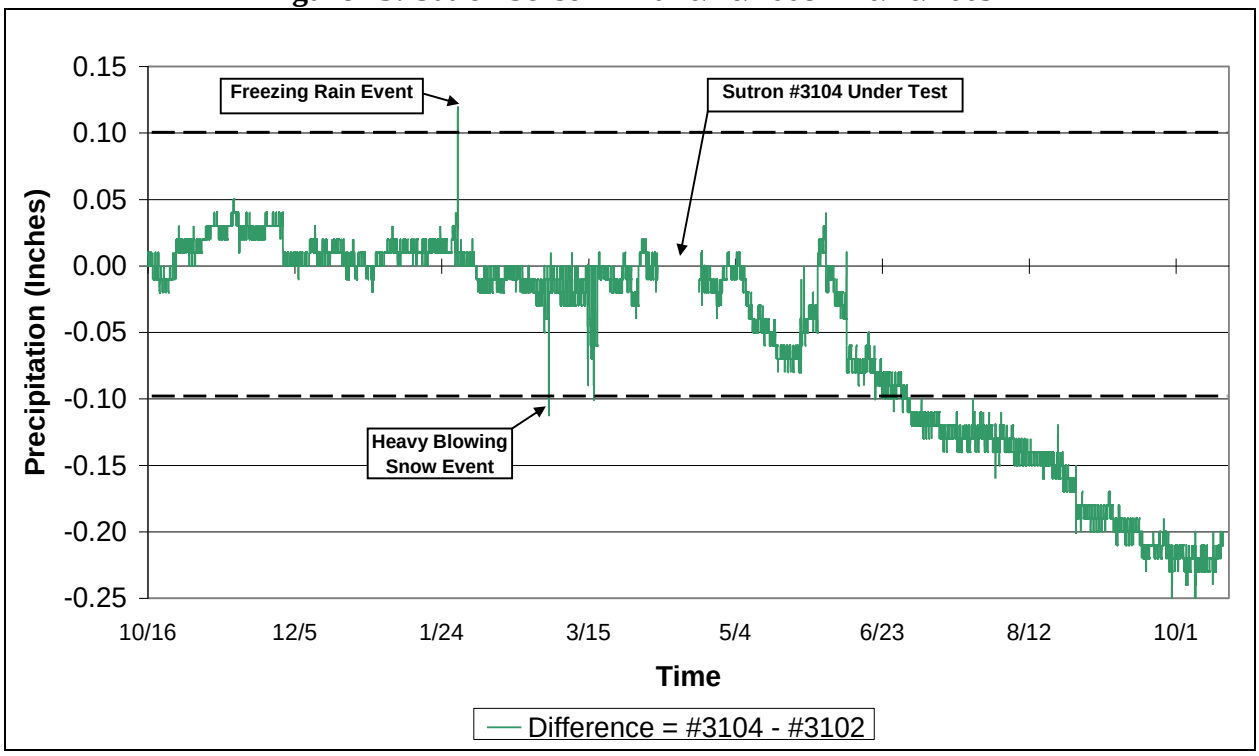
6.1.4 Observer Inspections

Both of the Sutron gauges in the field at Sterling were checked routinely and continued to collect data properly through the duration of characterization testing.

6.1.5 Sensor Drift

Over the course of one year, the Sutron units showed a slight drift in total precipitation catch. At the beginning of testing the units were normalized; at the end of the year, the gauges reported a difference in precipitation of 0.27 inches (Figure 13). This amount is outside of the specification, and should be noted when considering the long term performance of the FPR kits. However, it should also be noted that the daily and monthly accumulation totals remained within the specification throughout the long term characterization test. Overall, the deviation between the gauges averaged 0.00074 inches of drift per day. The Sutron FPR kits installed in the field met the specifications throughout 69.82% of the test

Figure 13: Sutron Sensor Drift 10/16/2008 – 10/16/2009



6.2 Engineering Assessment

The durability of the gauges was assessed during the field testing, and none of the kits monitored for the characterization test showed any degradation or failures of any components.

6.2.1 Installation

Sutron gauges were installed in the new testbed at Sterling on October 16, 2008. The installation of the kits in the field was conducted by SFSC electronic technicians and meteorologists. The installation procedures supplied by the manufacturer were followed. After installation, the gauges were field calibrated as per manufacturer instructions. The calibration procedures were determined to be straightforward and simple.

6.2.2 Durability

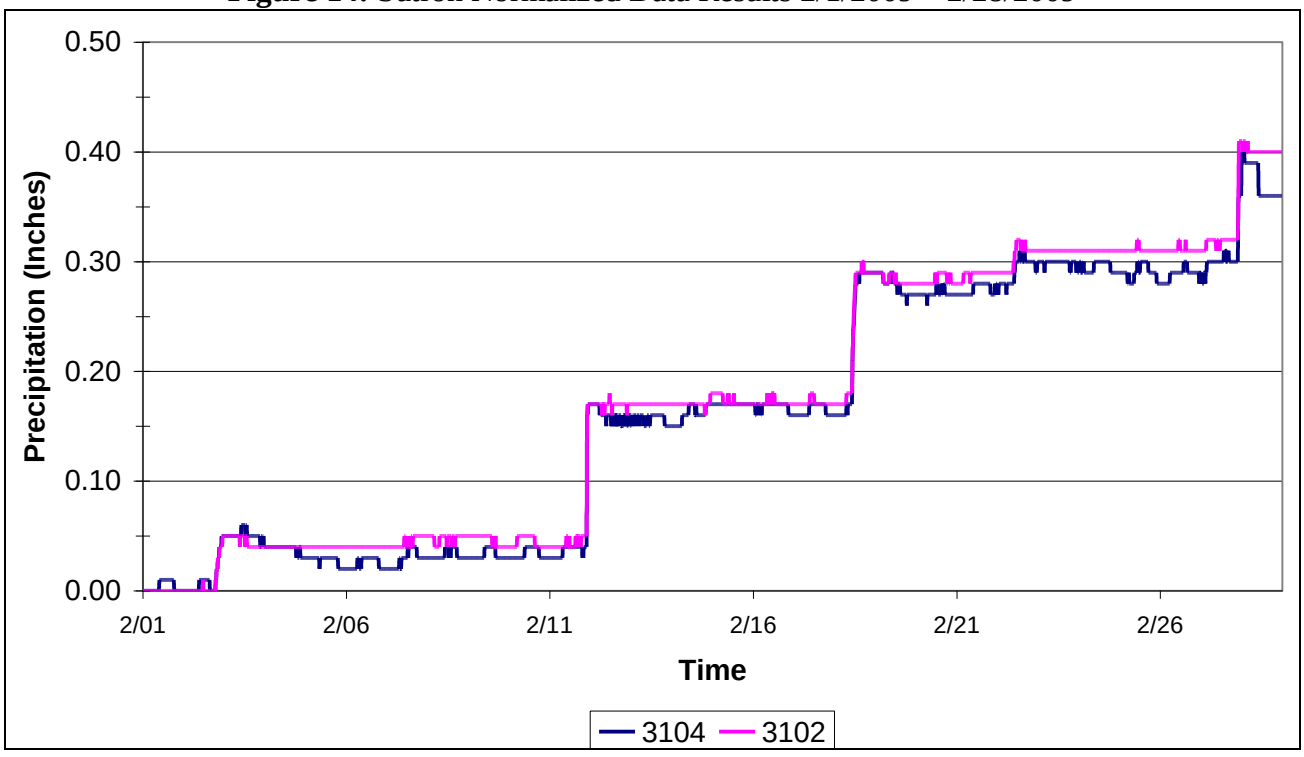
The durability of the gauges was assessed during the field testing, and none of the kits monitored for the characterization test showed any degradation or failures of any components. Slight diurnal variations, which were first seen in during QPL testing, were detected during the long term characterization testing. A case study was conducted in the field, see Section 6.3, utilizing FPR kit #3104; thus, the data from this gauge were not useable from April 7-21, 2009. Findings showed no issues with the load cell or with any other FPR kit components.

6.3 Case Studies

6.3.1 Diurnal Variation

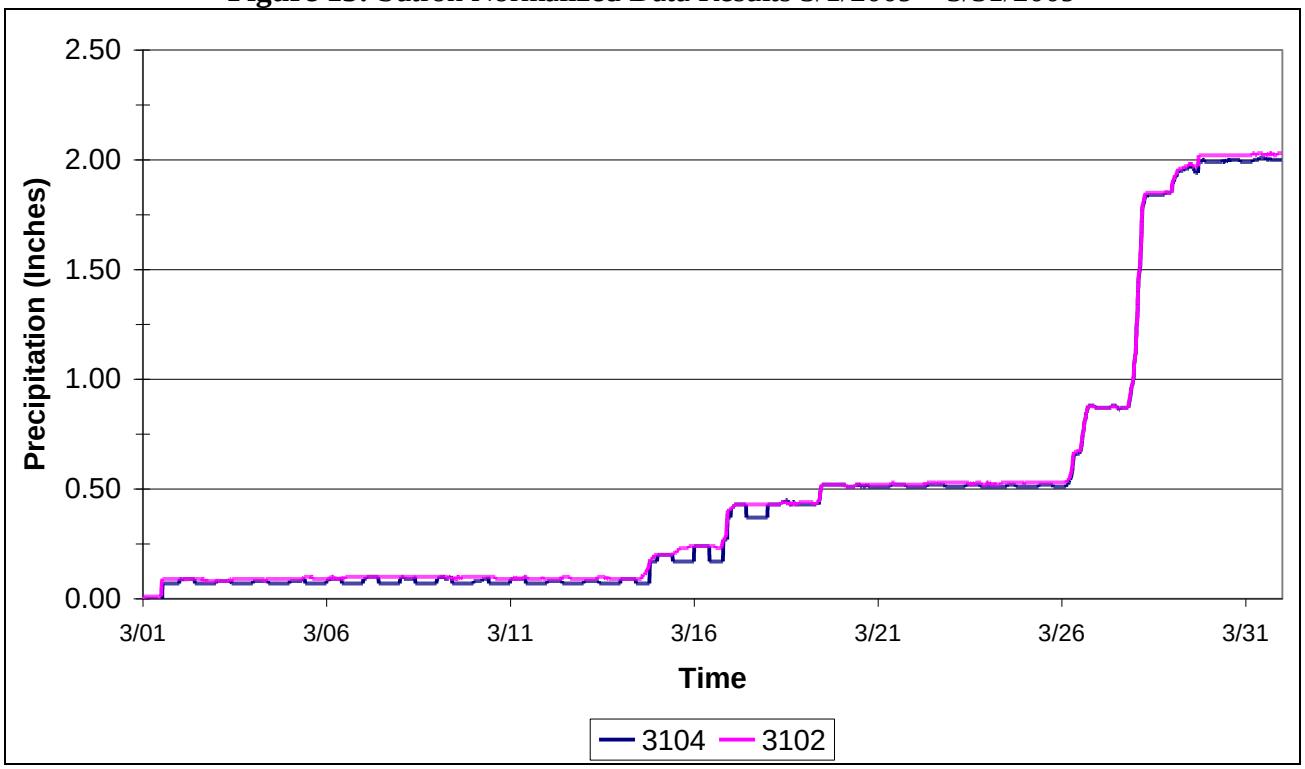
Analysis from February of 2009 shows that Sutron gauge #3104 began to experience slight diurnal variations, particularly towards the end of the month (Figure 14). The other Sutron gauge did not experience similar discrepancies.

Figure 14: Sutron Normalized Data Results 2/1/2009 – 2/28/2009



Despite the variation, both of the gauges performed within the specification during this period. Testing from March of 2009 (Figure 15) confirmed that a diurnal variation cycle continued to occur.

Figure 15: Sutron Normalized Data Results 3/1/2009 – 3/31/2009



The Sutron gauges experienced consistent differences throughout March, but performed within the specification throughout most of the month. See Section 6.3.2 for further details on time periods that were out of the specification.

A similar, if not identical, occurrence was seen in data from a different Sutron kit in July of 2008. This kit was removed from the testbed and sent back to the Sutron Corporation for additional analysis. A new Sutron FPR kit (#3104) was installed in the testbed in August of 2008. No variations occurred in any of the Sutron kits at the Sterling test facilities until the Sutron data from February and March showed these deviations once again.

Additional detailed figures also show the diurnal variations that continued to occur throughout the month of March (Figure 16 & 17). The Sutron FPR data and ambient temperature data show possible correlation between the variations and temperature.

Figure 16: Sutron Normalized Data with Temperature 3/1/2009 – 3/26/2009

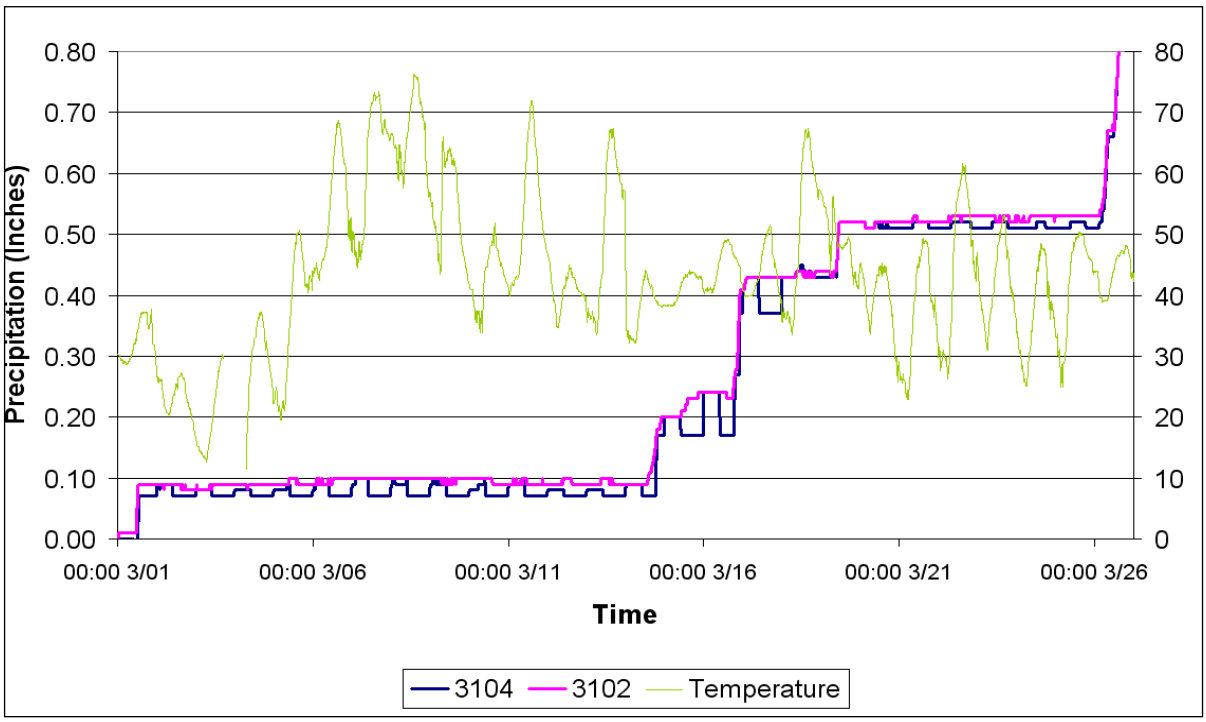
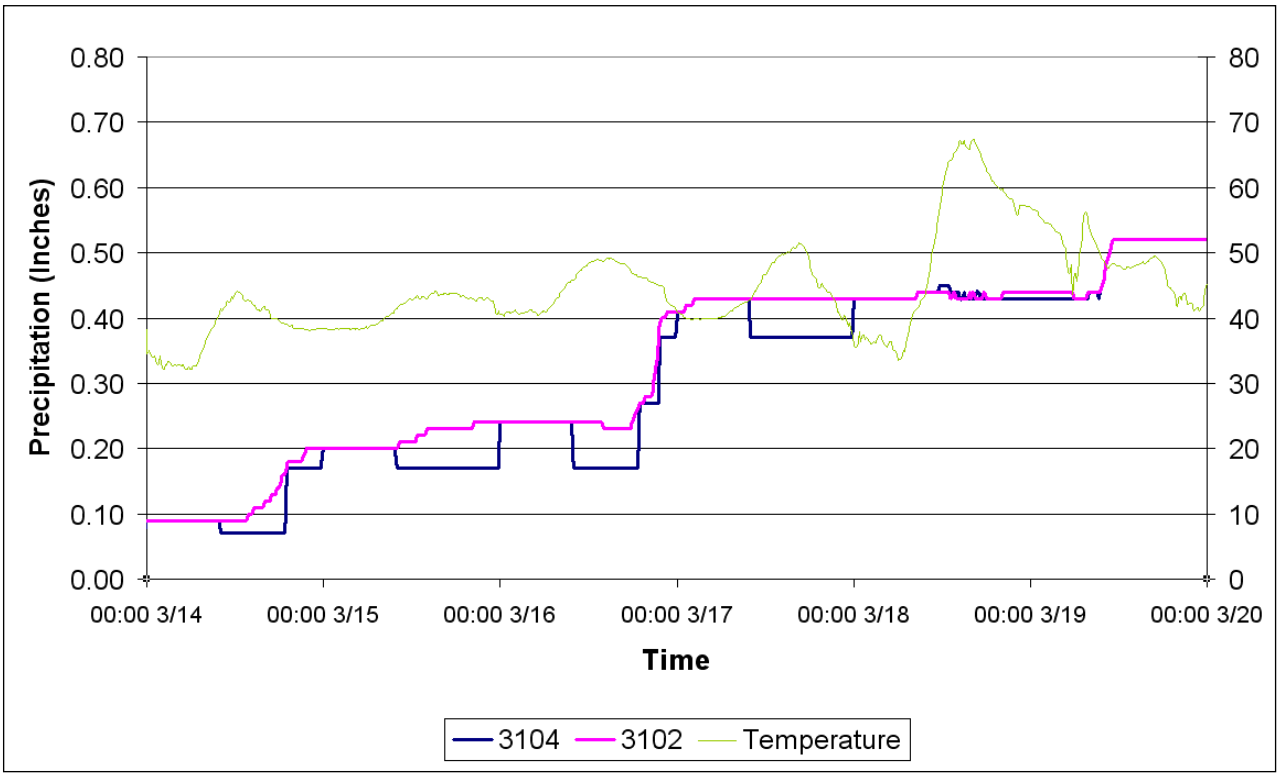


Figure 17: Sutron Normalized Data with Temperature 3/14/2009 – 3/20/2009



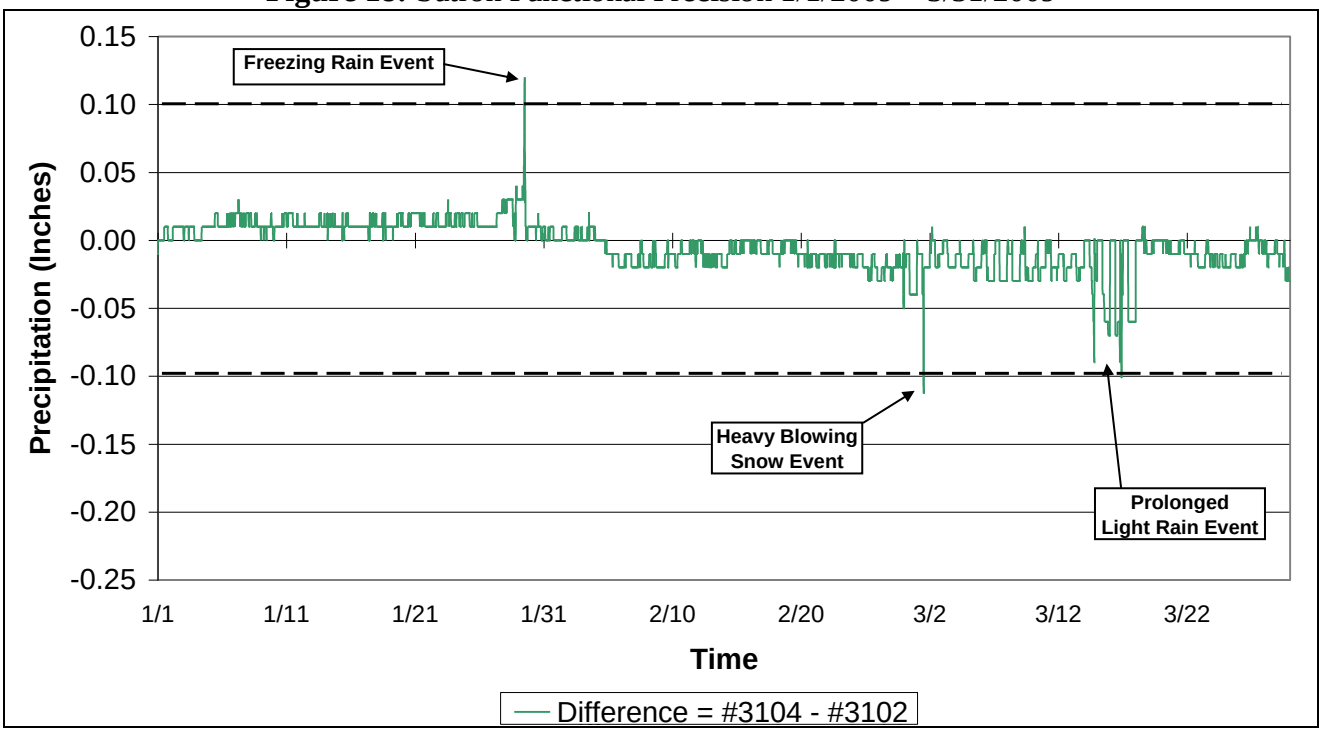
The variable readings that consistently occurred in the field can still be a cause for concern. Additionally, this issue occurred twice in the lifespan of the Sutron FPR kit; similar diurnal variations were seen in July of 2008 when these kits were first installed in the field.

The Sutron Corporation was contacted regarding this issue. It was decided that since the diurnal variation stopped, Sutron would not investigate; however, it was also decided that SFSC personnel would remain vigilant when analyzing the FPR data and would notify Sutron if the variations occurred again.

6.3.2 Functional Precision Deviations

During the first 6 months of testing, there were two occasions in which the Sutron gauges deviated by more than 0.1 inches from each other (Figure 18).

Figure 18: Sutron Functional Precision 1/1/2009 – 3/31/2009



During this time, Sutron #3104 showed a maximum difference of +0.12 inches from Sutron #3102 Additionally, Sutron gauge #3104 experienced even higher deviations as the testing period progressed, while #3102 appeared to operate normally. The overall discrepancy remained within the specification over the majority of the outdoor tests, until July 1, 2009. At this time, the gauges ventured outside of the specification, and remained that way until the end of the test.

7.0 CONCLUSIONS

The long term specification compliance testing shows that the Sutron FPR kits installed in the field meet the NWS-D111-5-SP001 specifications. The Sutron kits remained within the specification (± 0.1 inch) in every 24-hour accumulation comparison (351 totals) as well as in each monthly precipitation comparison (11 totals). Additionally, the Sutron FPR kits exceeded the performance of the reference F&P gauges in the field. The Sutron gauges also showed precipitation trends similar to those seen by the AWPAG and FPU gauges.

Overall, the Sutron gauges performed within the specification in 100% of the 351 daily comparisons. Also included in the functional precision was an evaluation of the FPR gauges in different types of precipitation. The Sutron kits also passed 100% of each rain, snow, and freezing rain event comparison. The greatest difference in daily accumulations collected by the FPR gauges was -0.07 inches and the RMSD for this phase of testing was calculated to be 0.0106 inches.

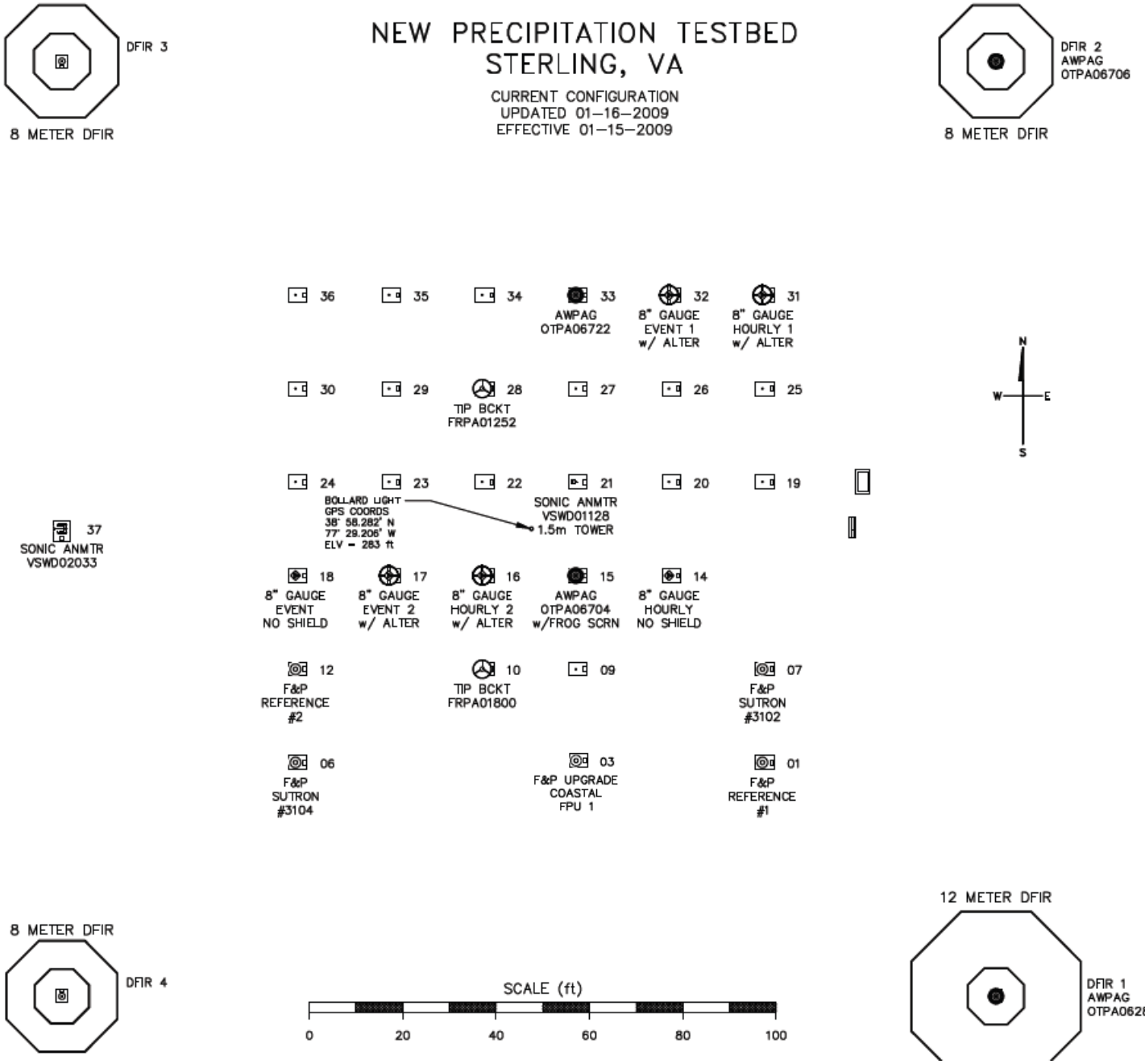
The characterization test also showed that each Sutron FPR kits outperformed both of the reference gauges. Additionally, a comparison of the 24-hour precipitation totals of the Sutron and reference gauges showed that the average deviation between the sensors ranged from 0.01 to 0.02 inches, which is within the specification.

The functional comparison between the Sutron gauges and the AWPAG in the DFIR showed that the FPR kits' total precipitation catches were lower than those reported by the AWPAG. However, a graph of both Sutron gauges showed similar trends, in terms of timing of precipitation, when compared to the precipitation graph of the AWPAG. Overall, the Sutron kits each met the specification in 87% of rain events, 78% of snow events, and 100% of freezing rain events when compared with the AWPAG. The variable readings that occurred in the comparison with the AWPAG were deemed to be expected, due to the lack of wind screens around the Sutron FPR kits. The unsubstantiated reports that were also seen by the Sutron kits could be explained by the high winds at the time of the event on December 24-25.

The Sutron gauges also showed similar trends when compared to the FPU gauge in the field, despite the relatively short period of time it worked properly. The Sutron gauges were within specification in 77% of the rain events compared to the FPU.

Although one sensor experienced diurnal variations during part of the test, those variations have ceased and are therefore not considered an issue at the present time. However, the SFSC will continue to monitor the sensors. As of October 16, 2009, the Sutron FPR kits are considered compliant with the specification.

APPENDIX A STERLING, VIRGINIA TEST BED



APPENDIX B MONTHLY PRECIPITATION TRENDS

Figure B-1: Sutron & AWPAG Normalized Data Results, October 2008

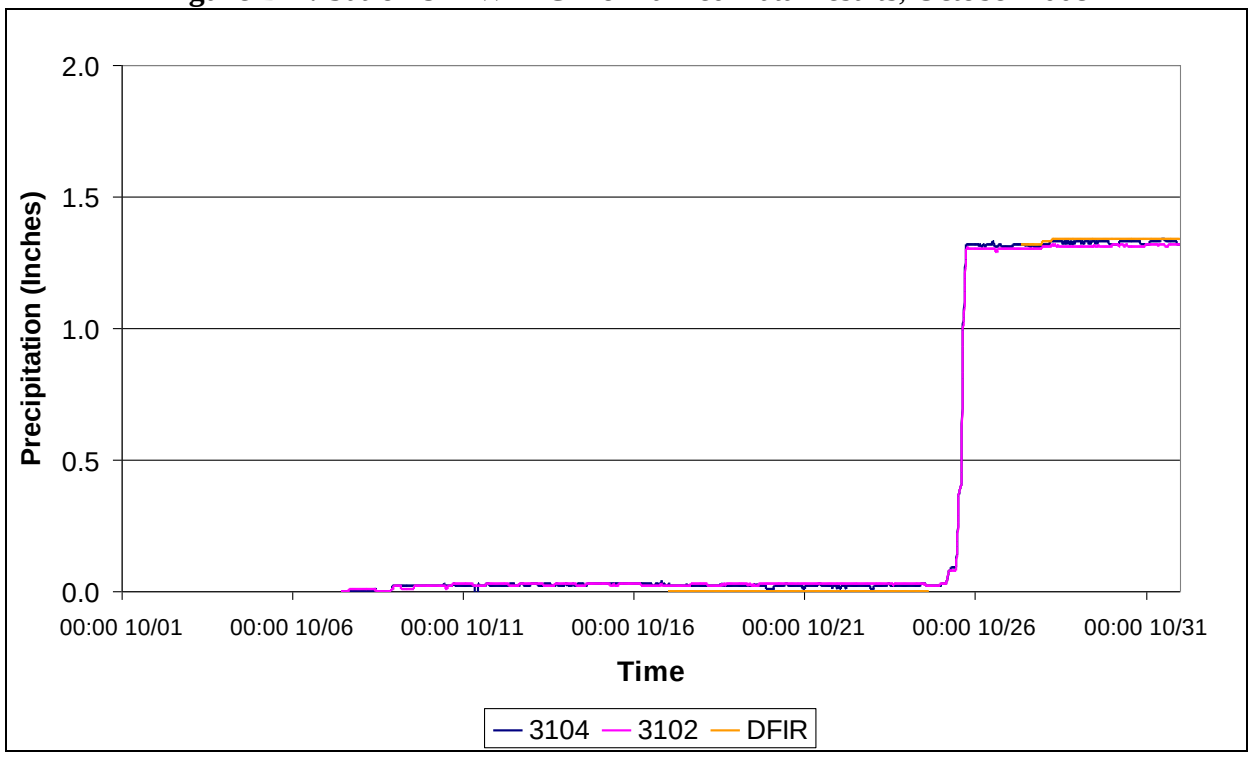


Figure B-2: Sutron & AWPAG Normalized Data Results, November 2008

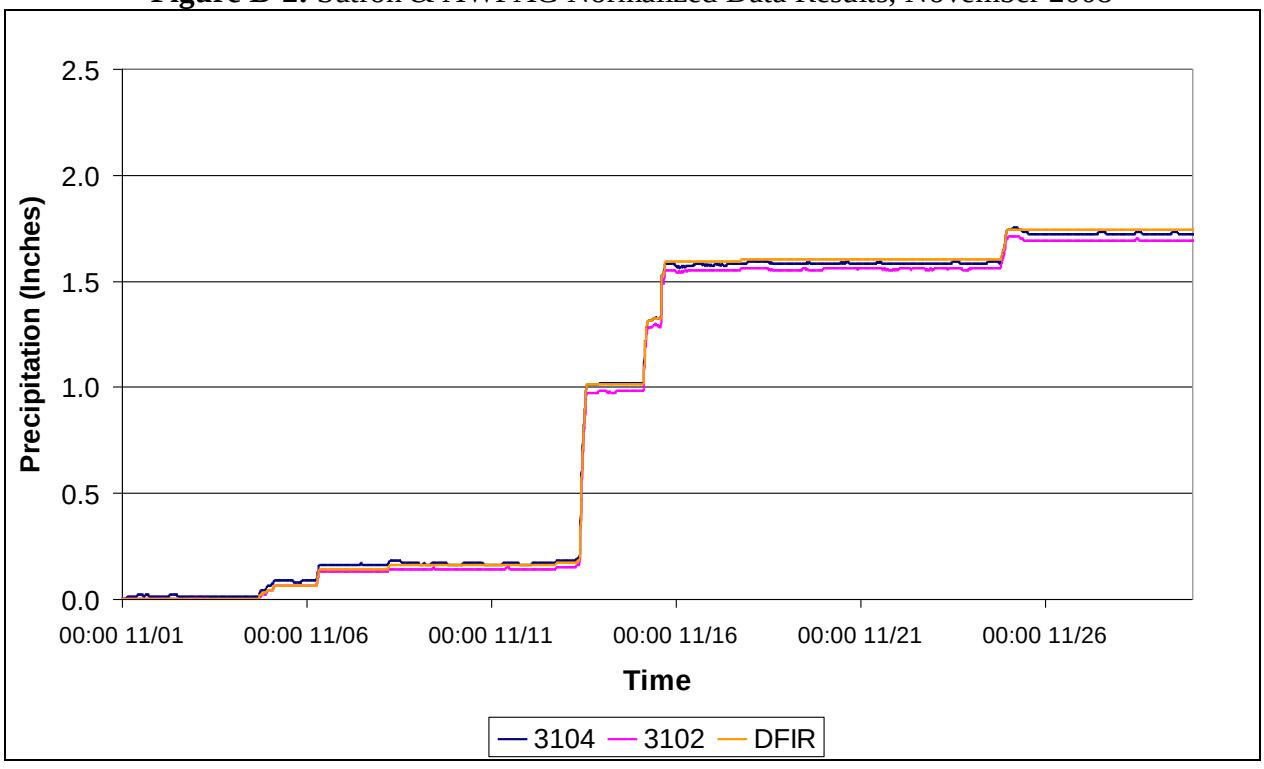


Figure B-3: Sutron & AWPAG Normalized Data Results, December 2008

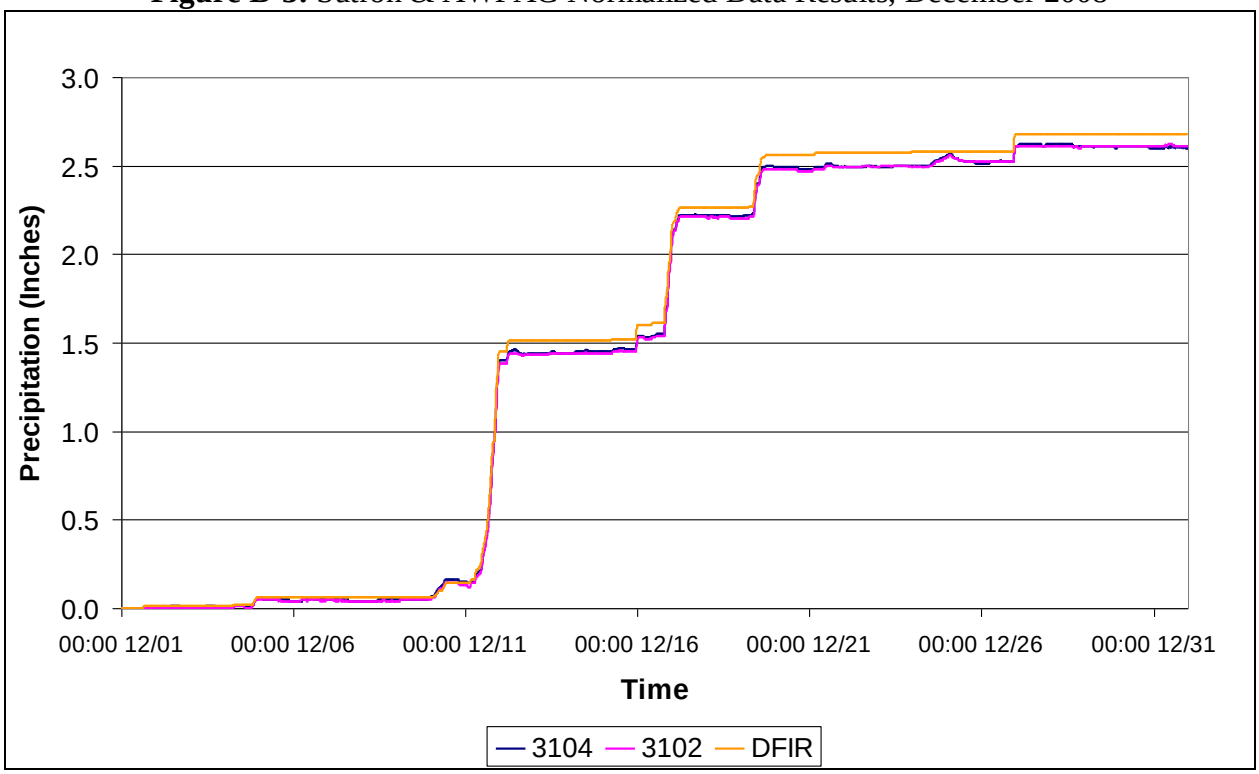


Figure B-4: Sutron & AWPAG Normalized Data Results, January 2009

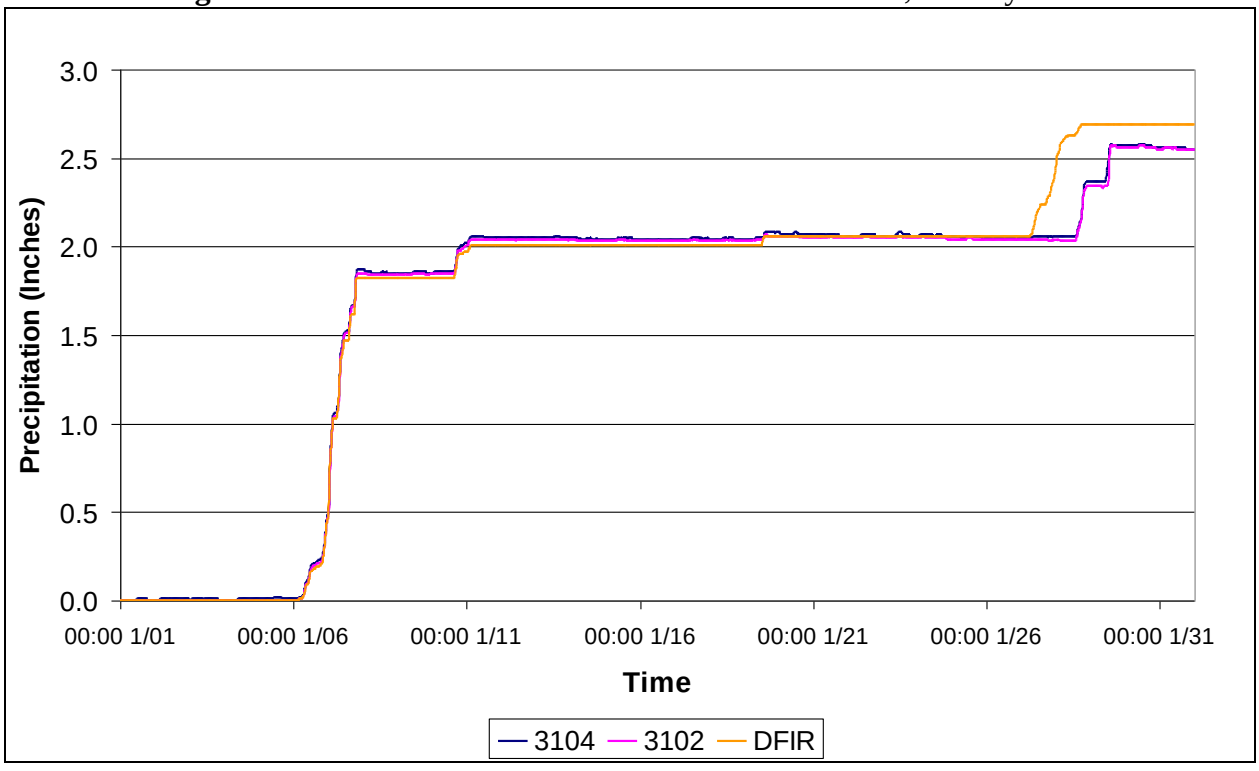


Figure B-5: Sutron & AWPAG Normalized Data Results, February 2009

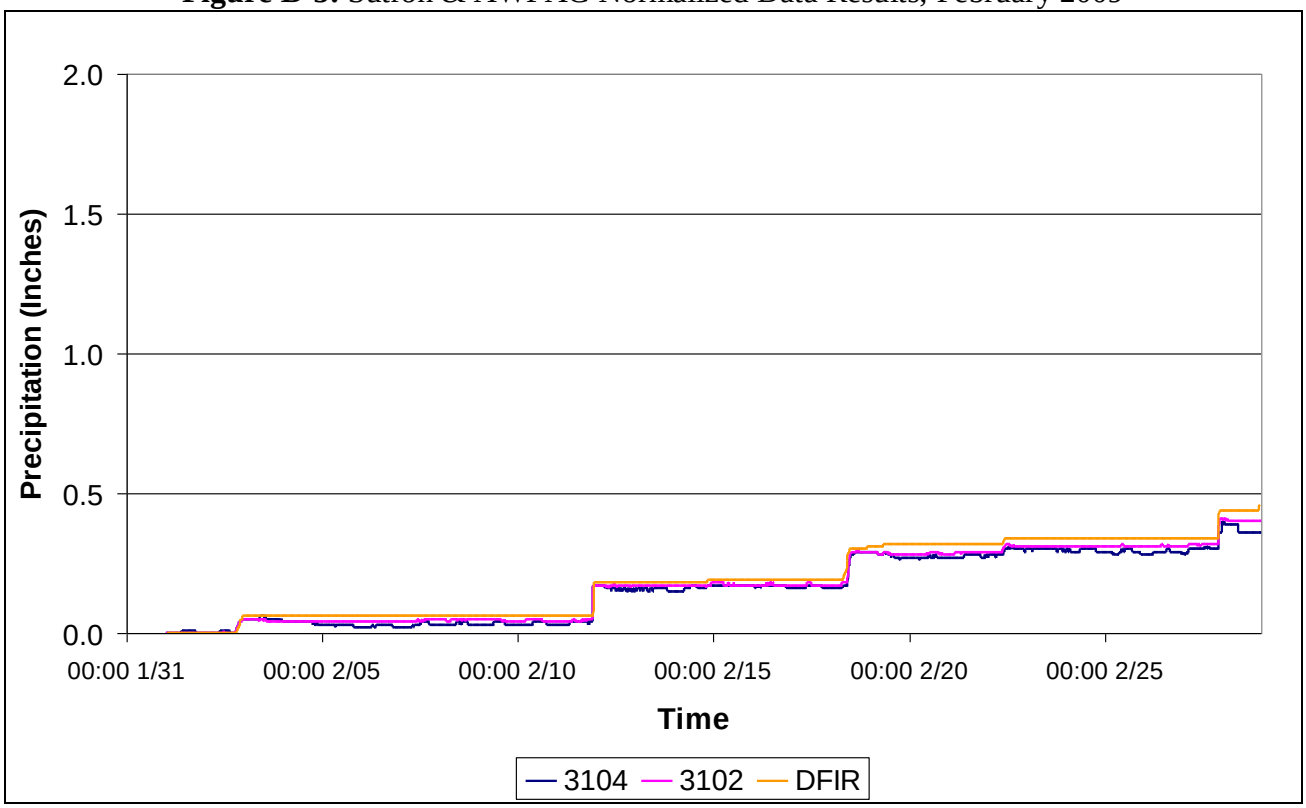


Figure B-6: Sutron & AWPAG Normalized Data Results, March 2009

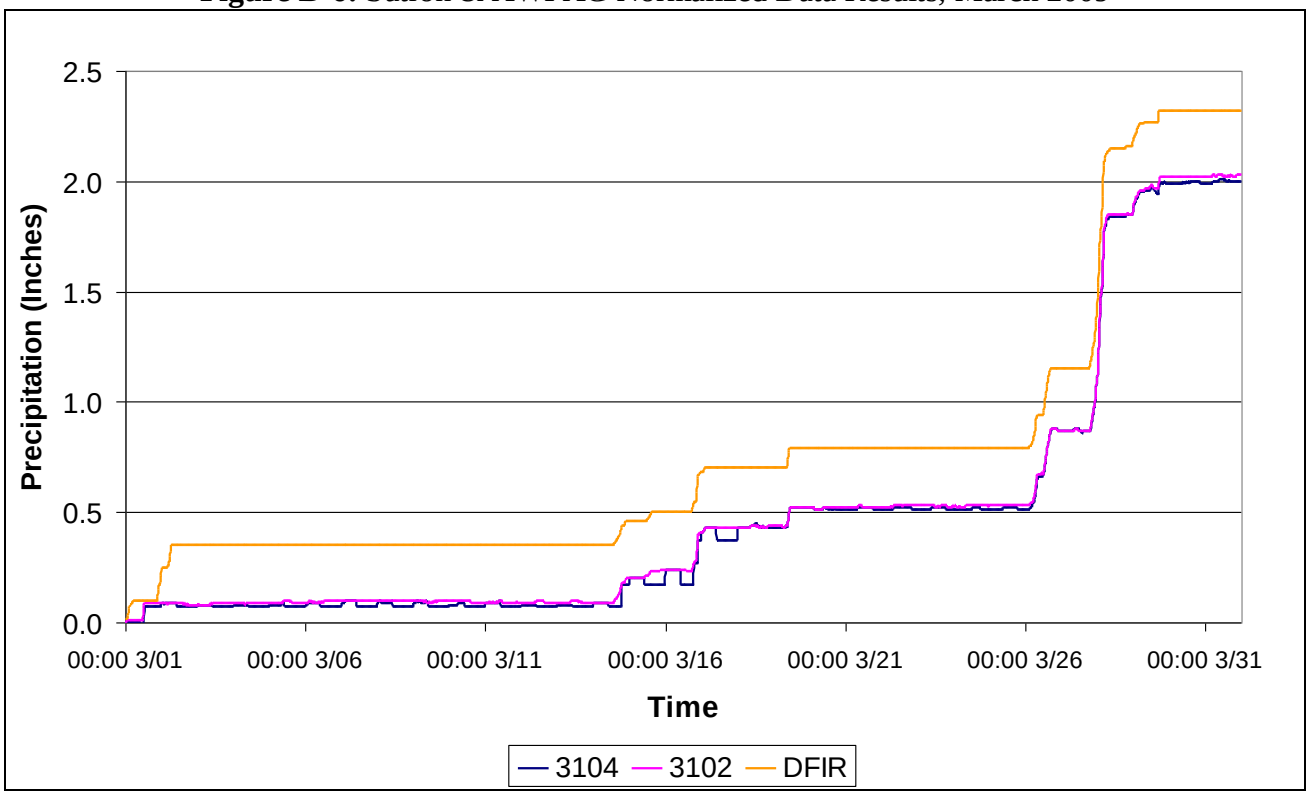


Figure B-7: Sutron & AWPAG Normalized Data Results, April 2009

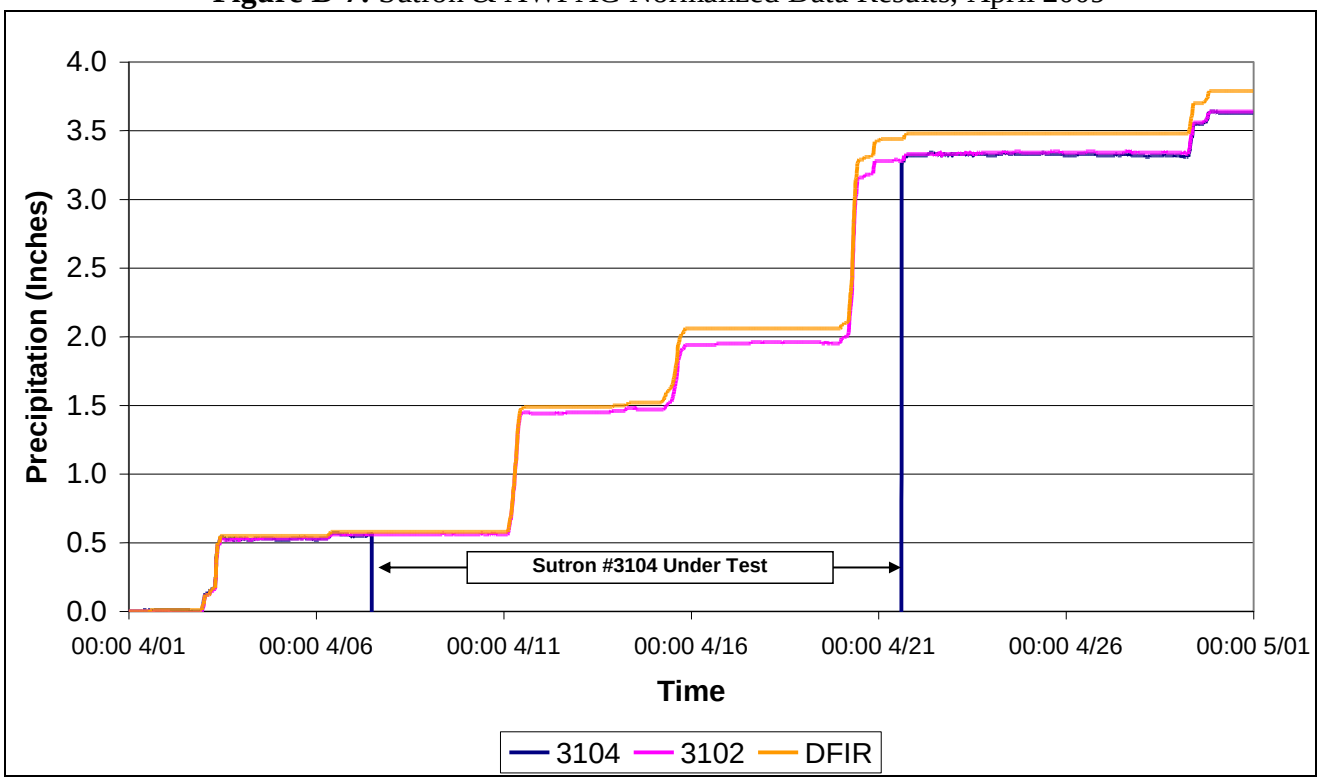


Figure B-8: Sutron & AWPAG Normalized Data Results, May 2009

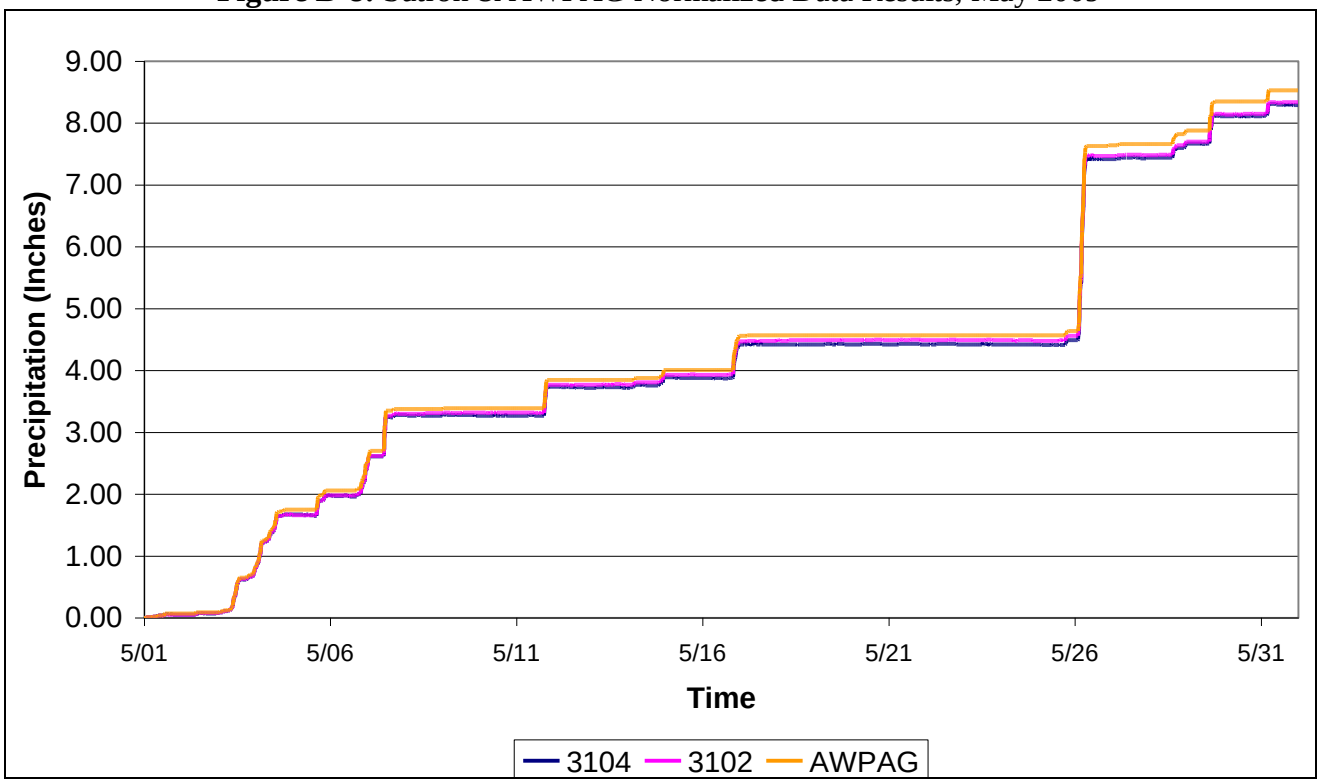


Figure B-9: Sutron & AWPAG Normalized Data Results, June 2009

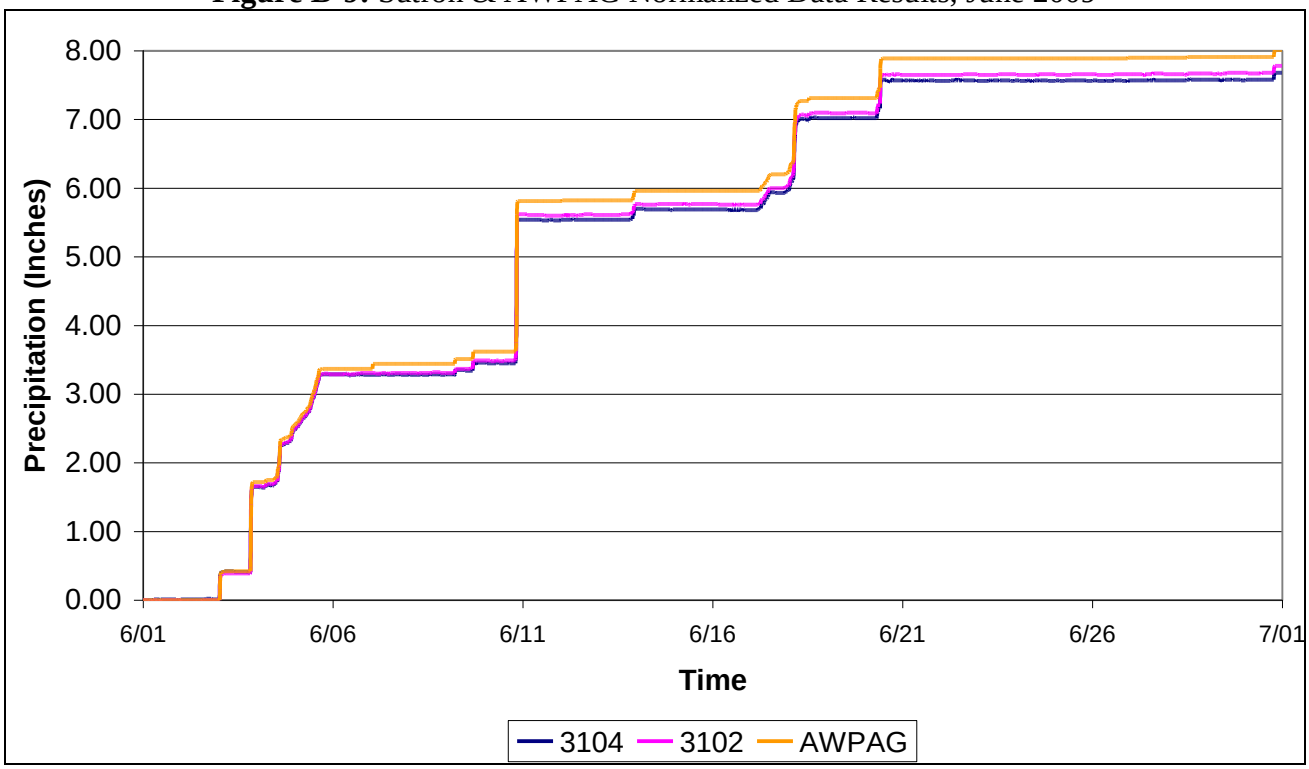


Figure B-10: Sutron & AWPAG Normalized Data Results, July 2009

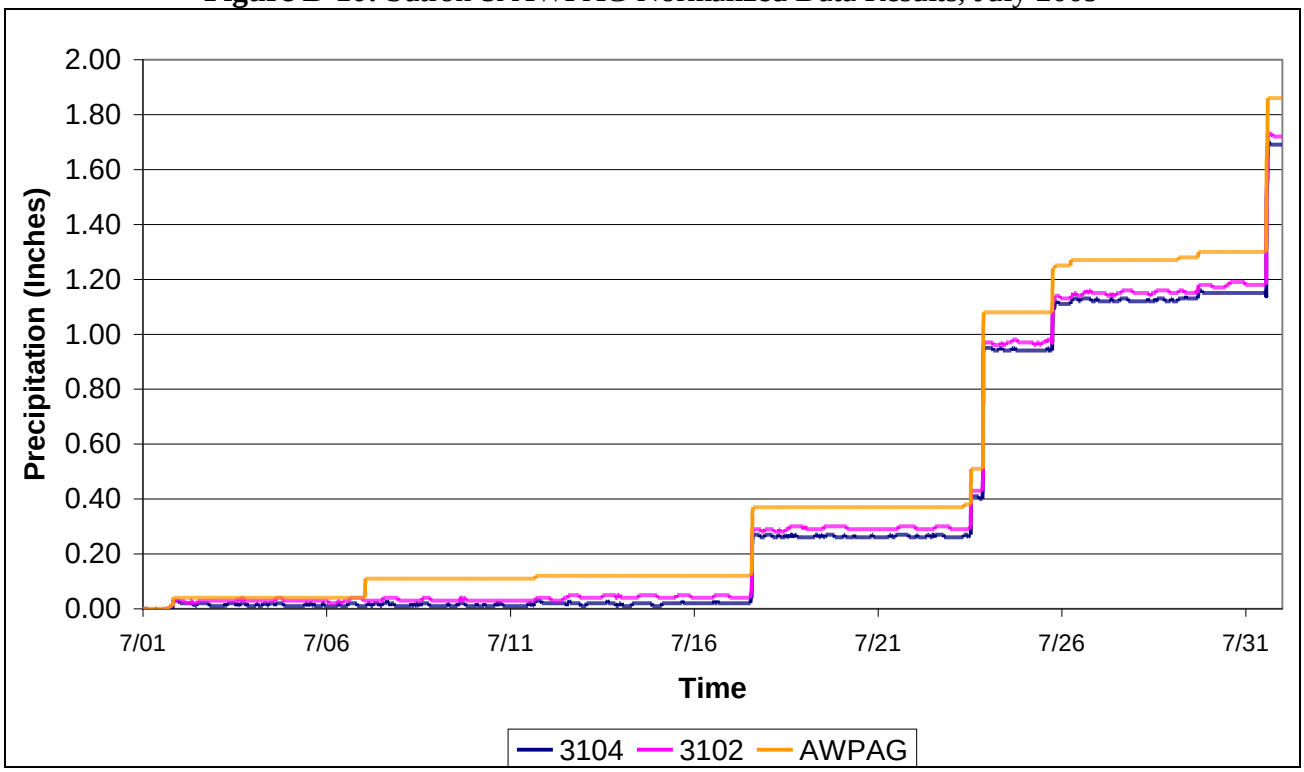


Figure B-11: Sutron & AWPAG Normalized Data Results, August 2009

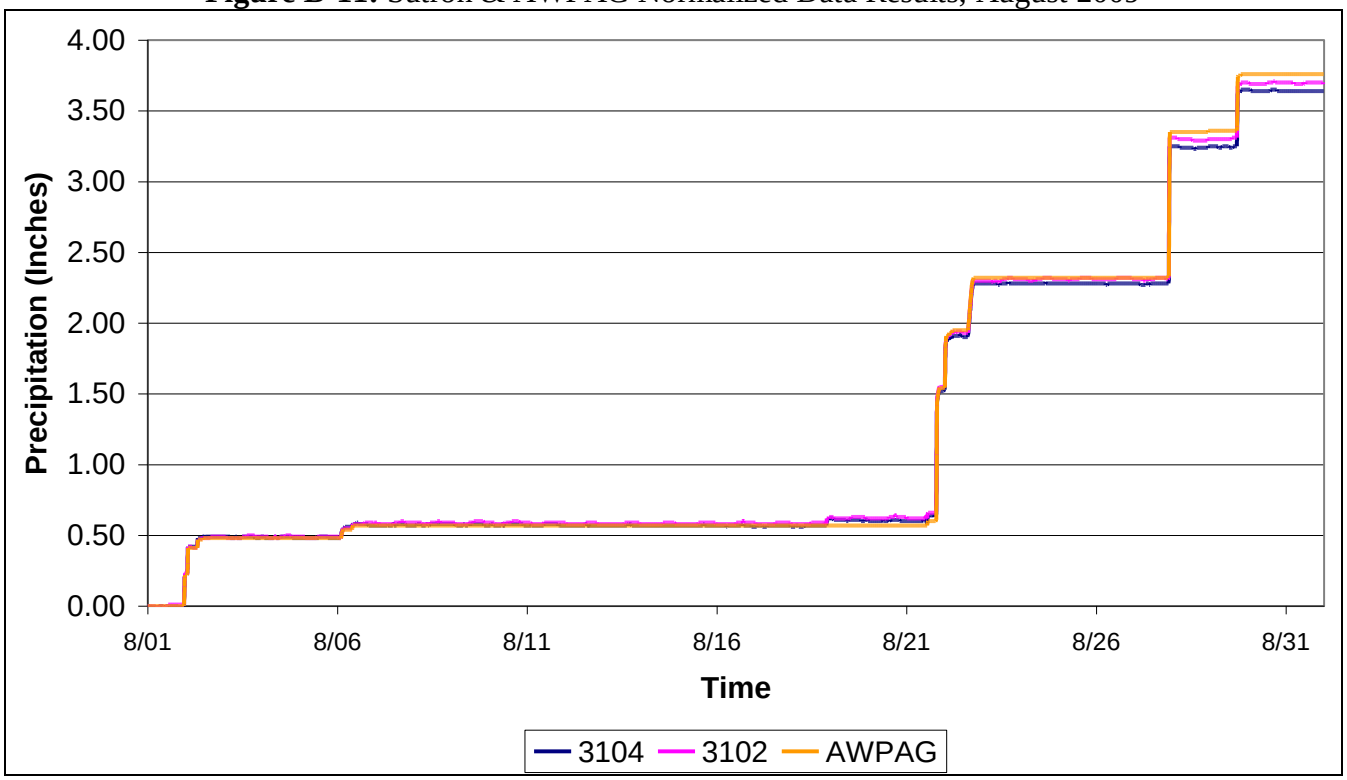


Figure B-12: Sutron & AWPAG Normalized Data Results, September 2009

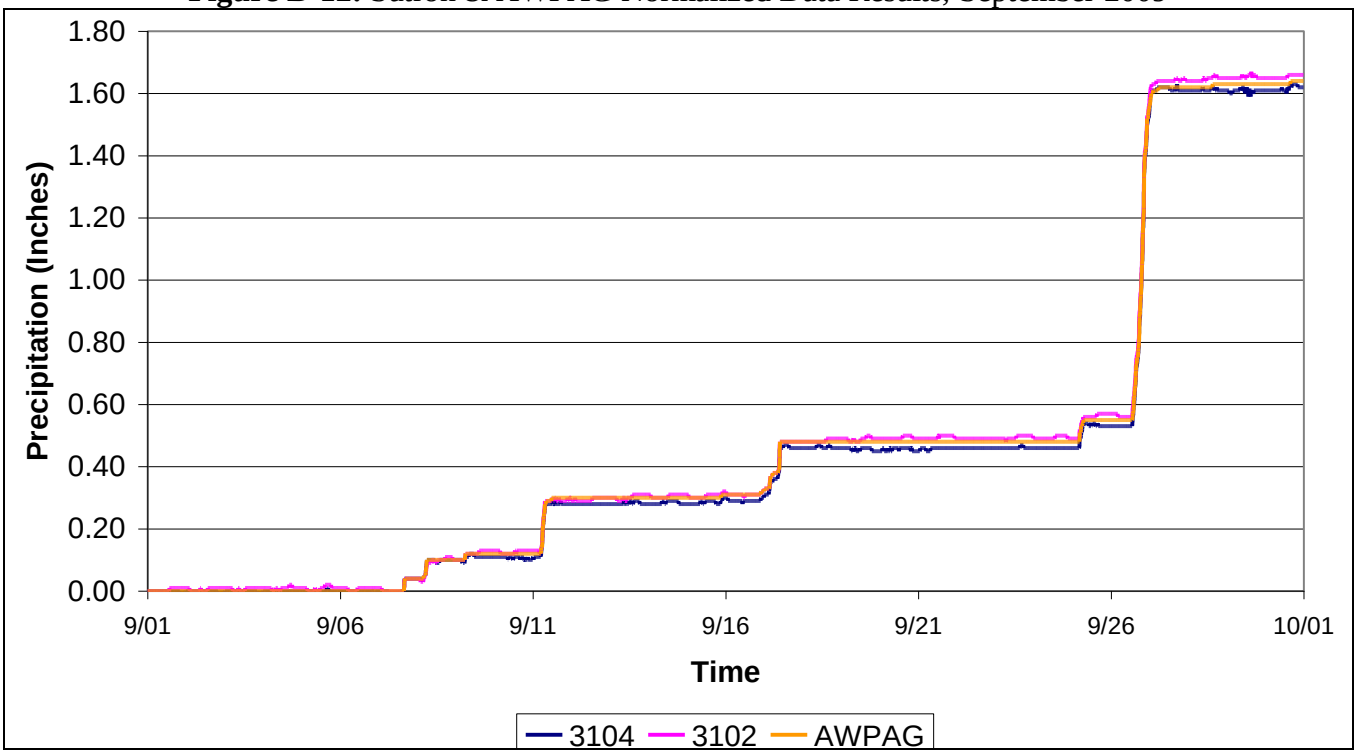


Figure B-13: Sutron & AWPAG Normalized Data Results, October 2009

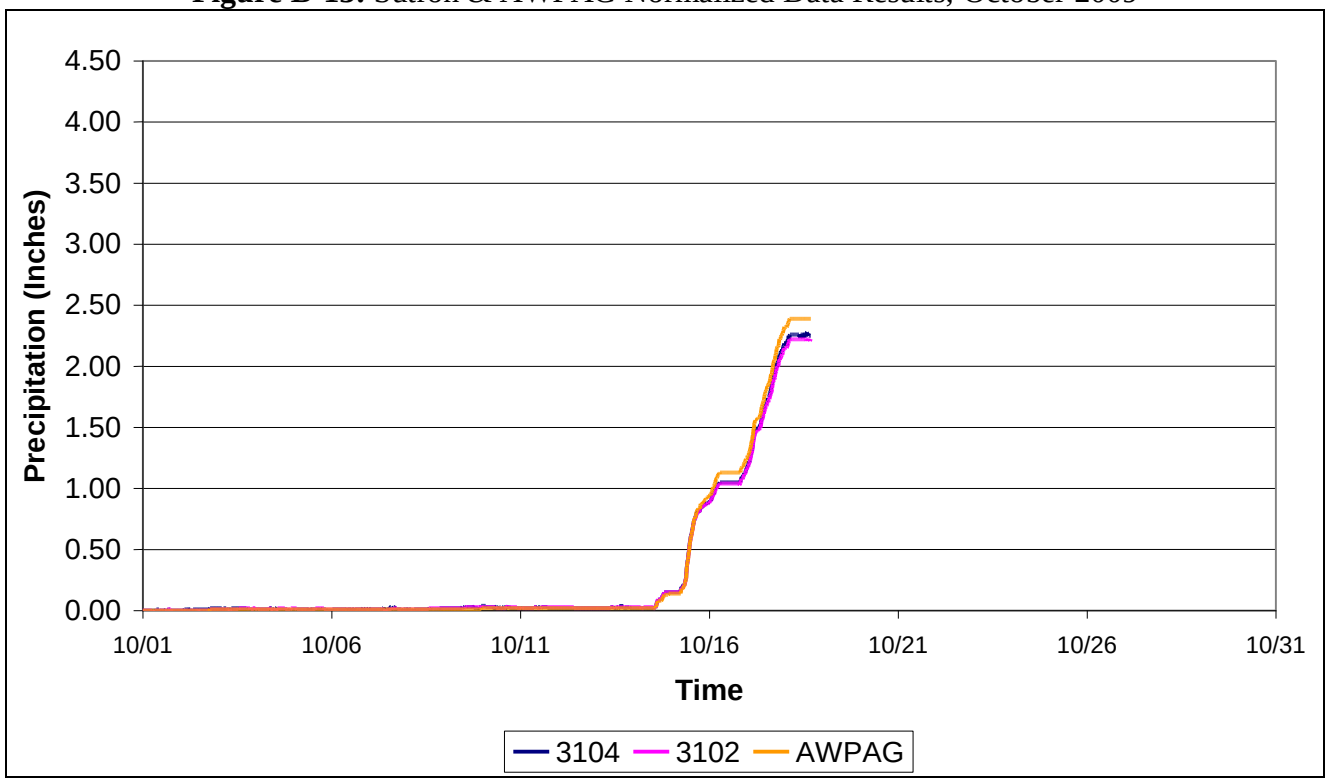


Figure B-14: Sutron & AWPAG Monthly Precipitation Totals, Oct 2008 - Oct 2009

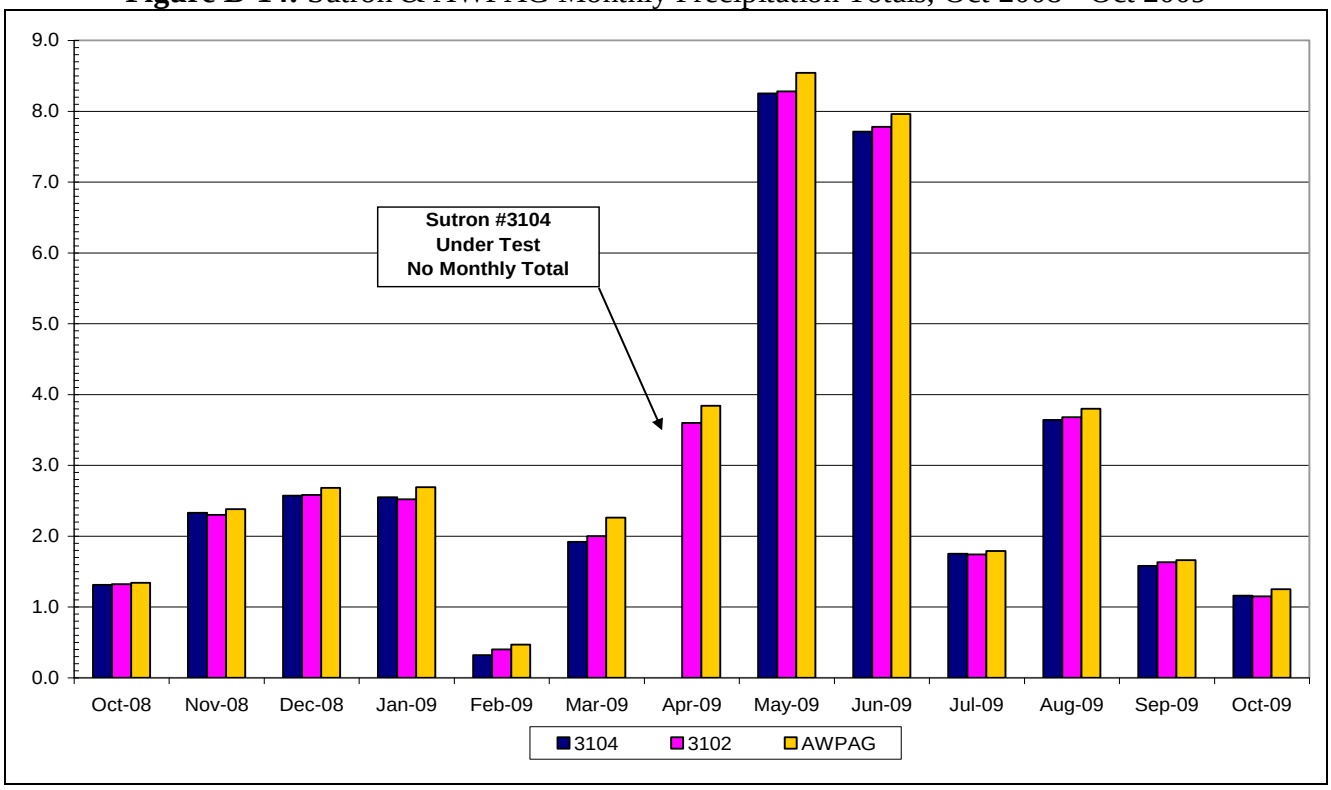


Figure B-15: Sutron Daily Precipitation Accumulations, October - December 2008

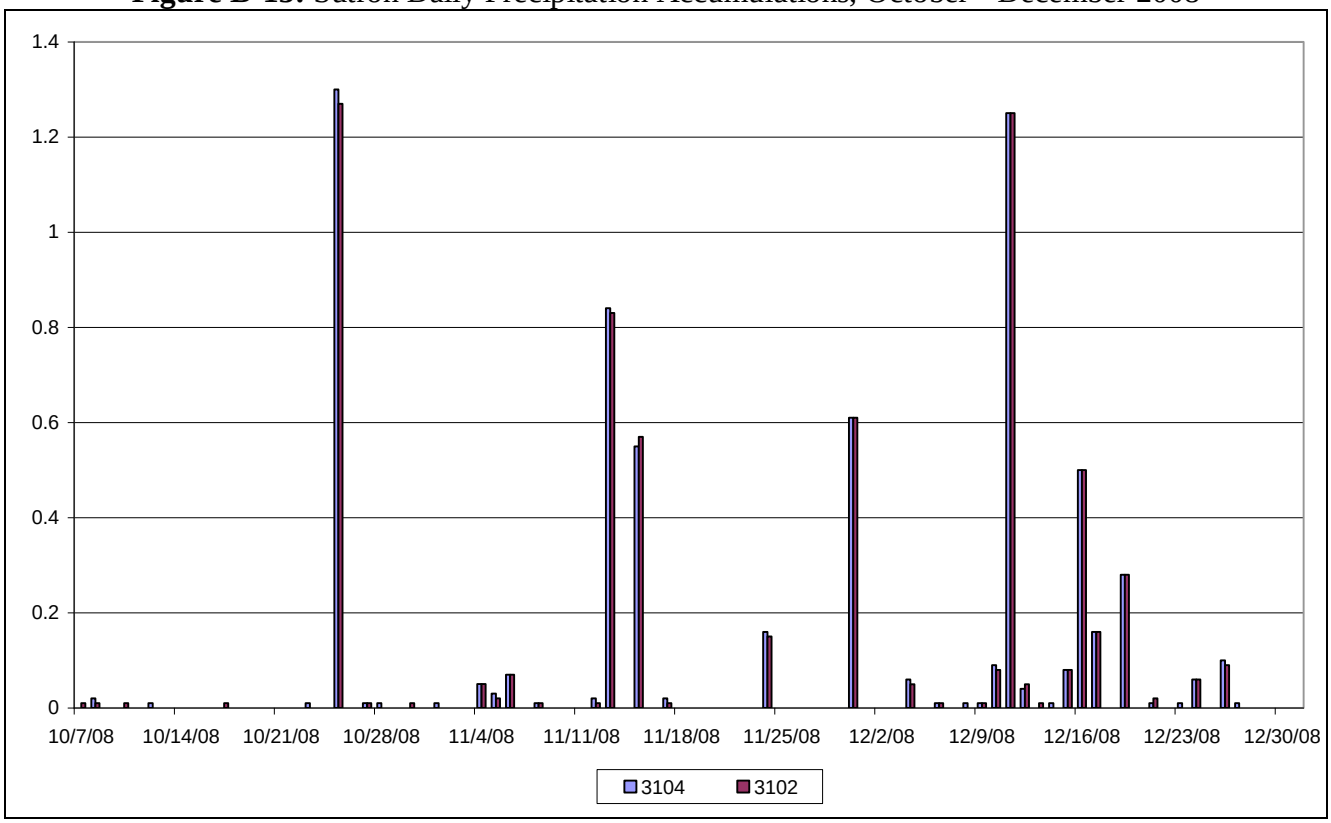


Figure B-16: Sutron Daily Precipitation Accumulations, January - March 2009

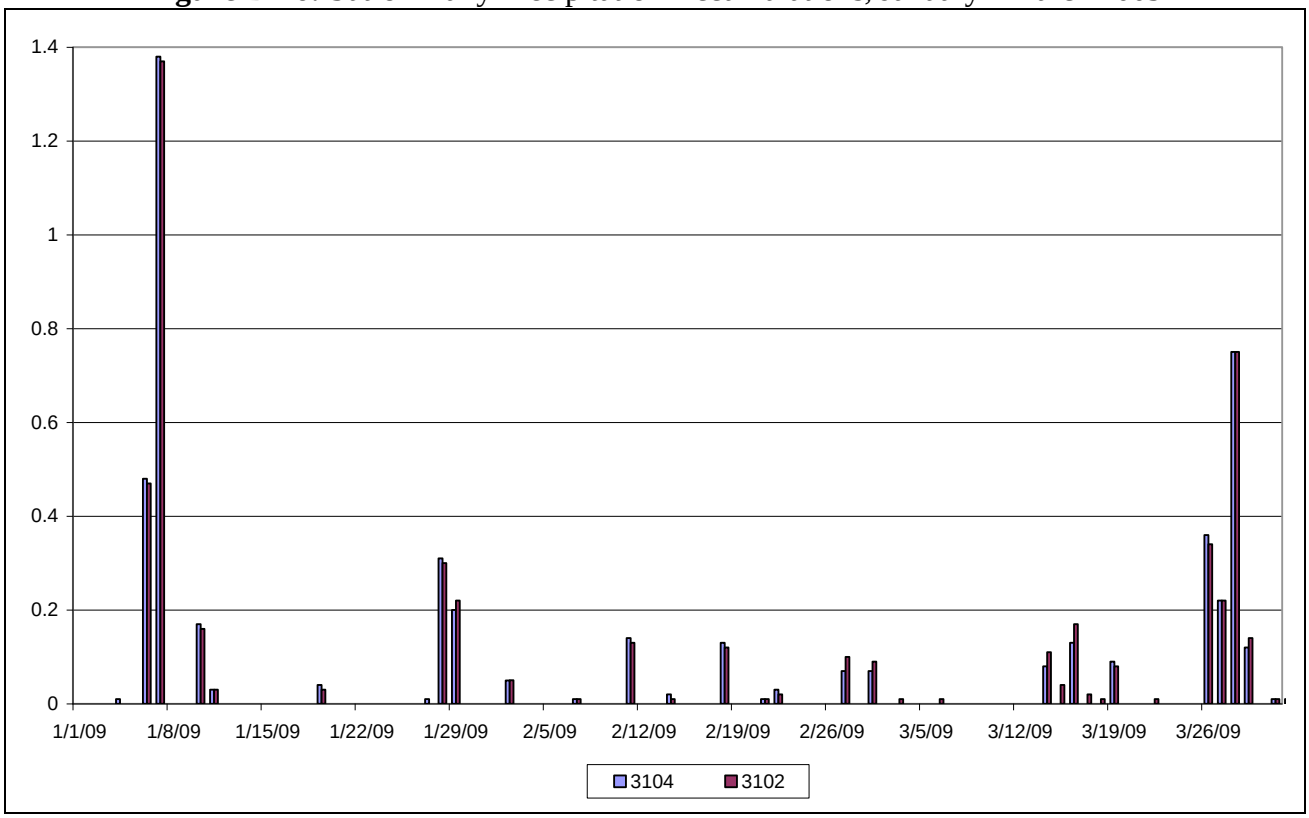


Figure B-17: Sutron Daily Precipitation Accumulations, April - June 2009

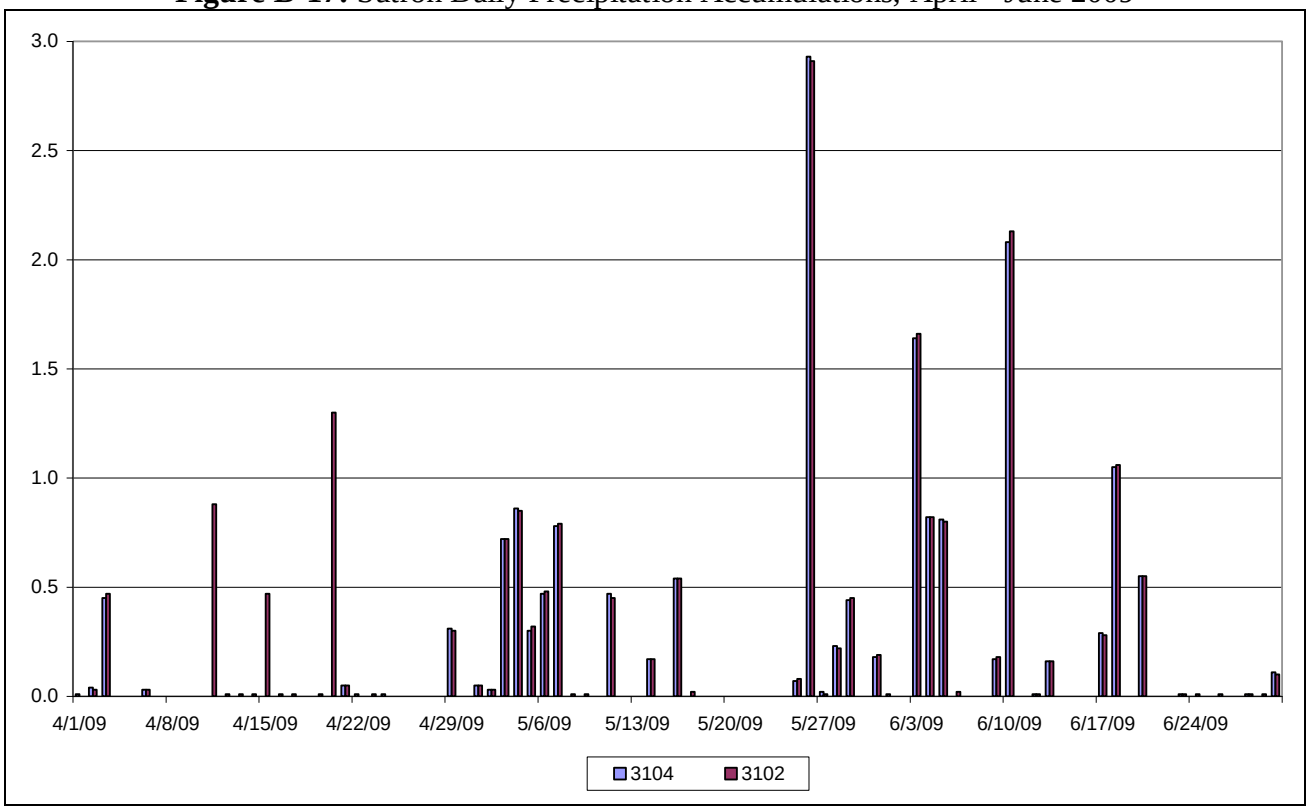


Figure B-18: Sutron Daily Precipitation Accumulations, July - October 2009

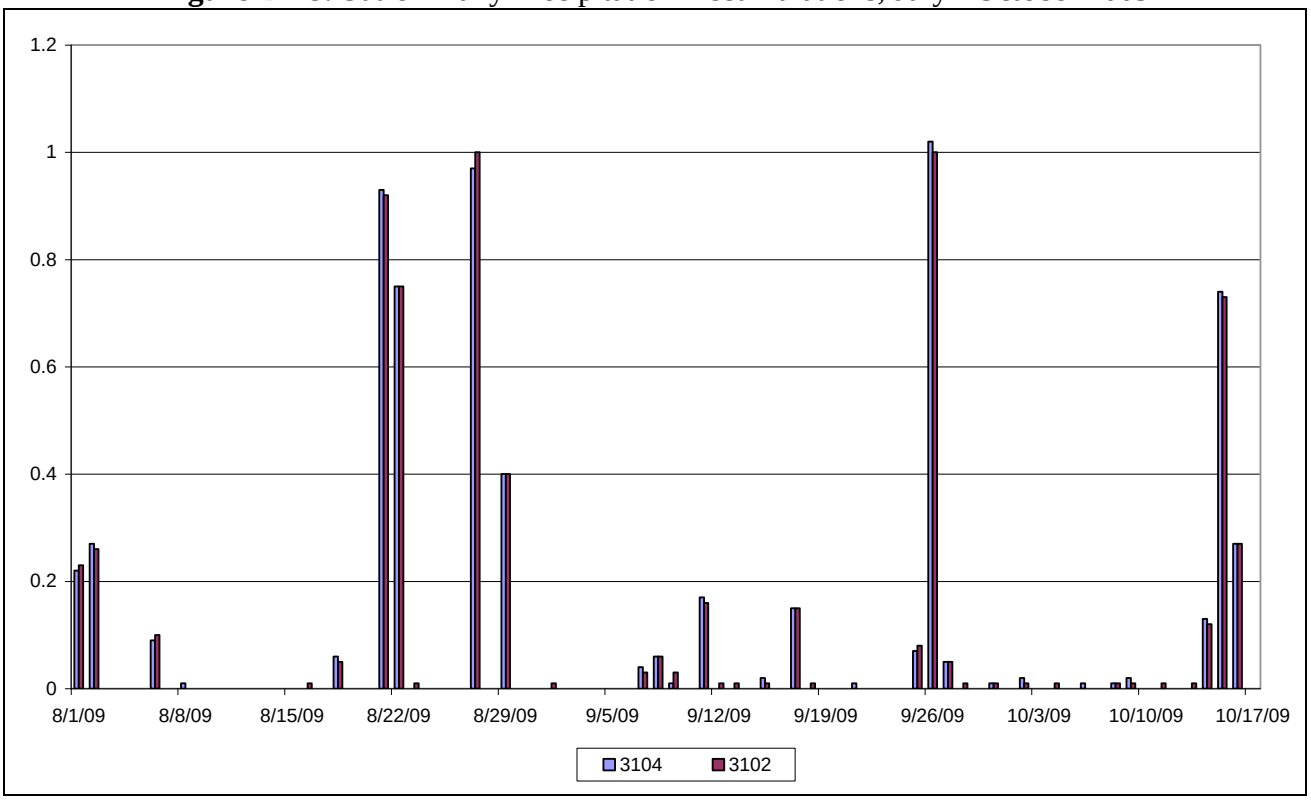


Figure B-19: Difference between Sutron and Reference #1 Daily Precip; Jan. – June 2009

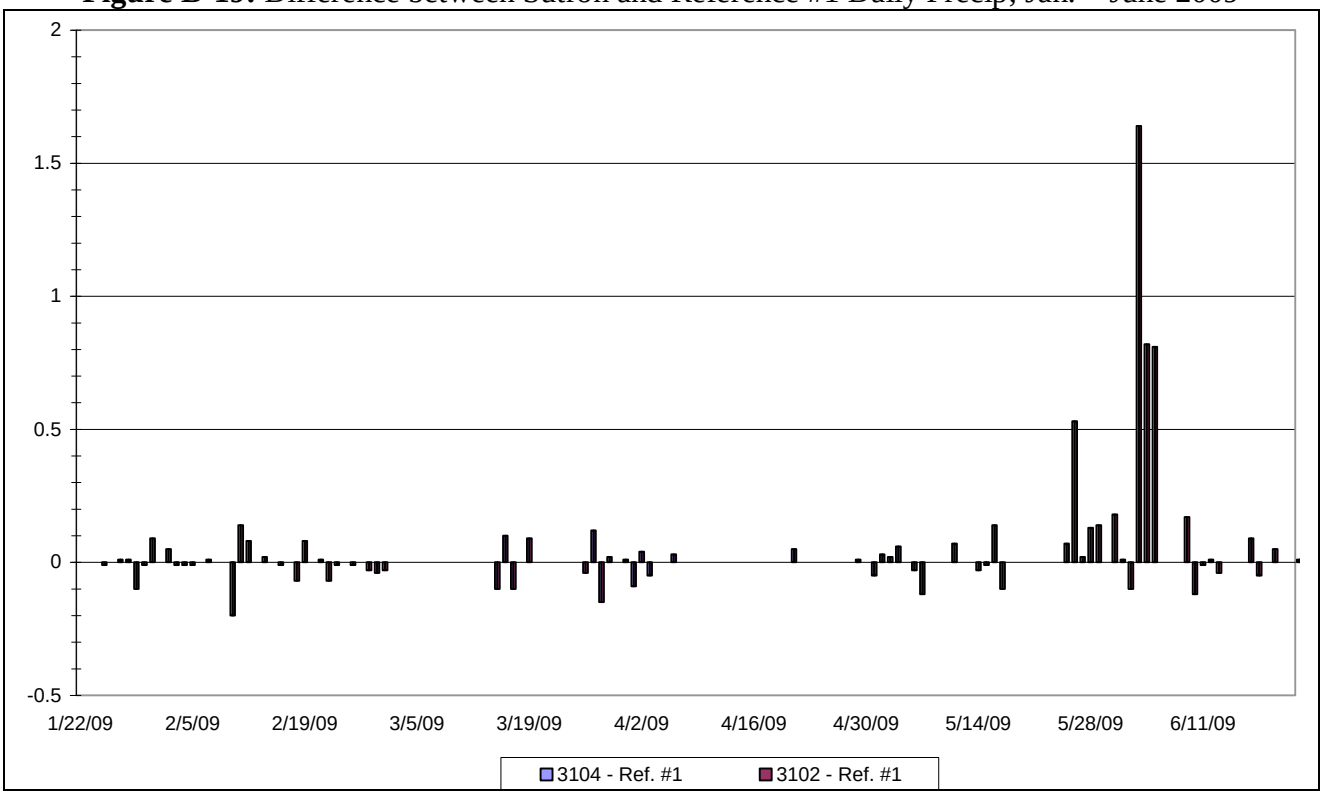


Figure B-20: Difference between Sutron and Reference #1 Daily Precip; June – Oct. 2009

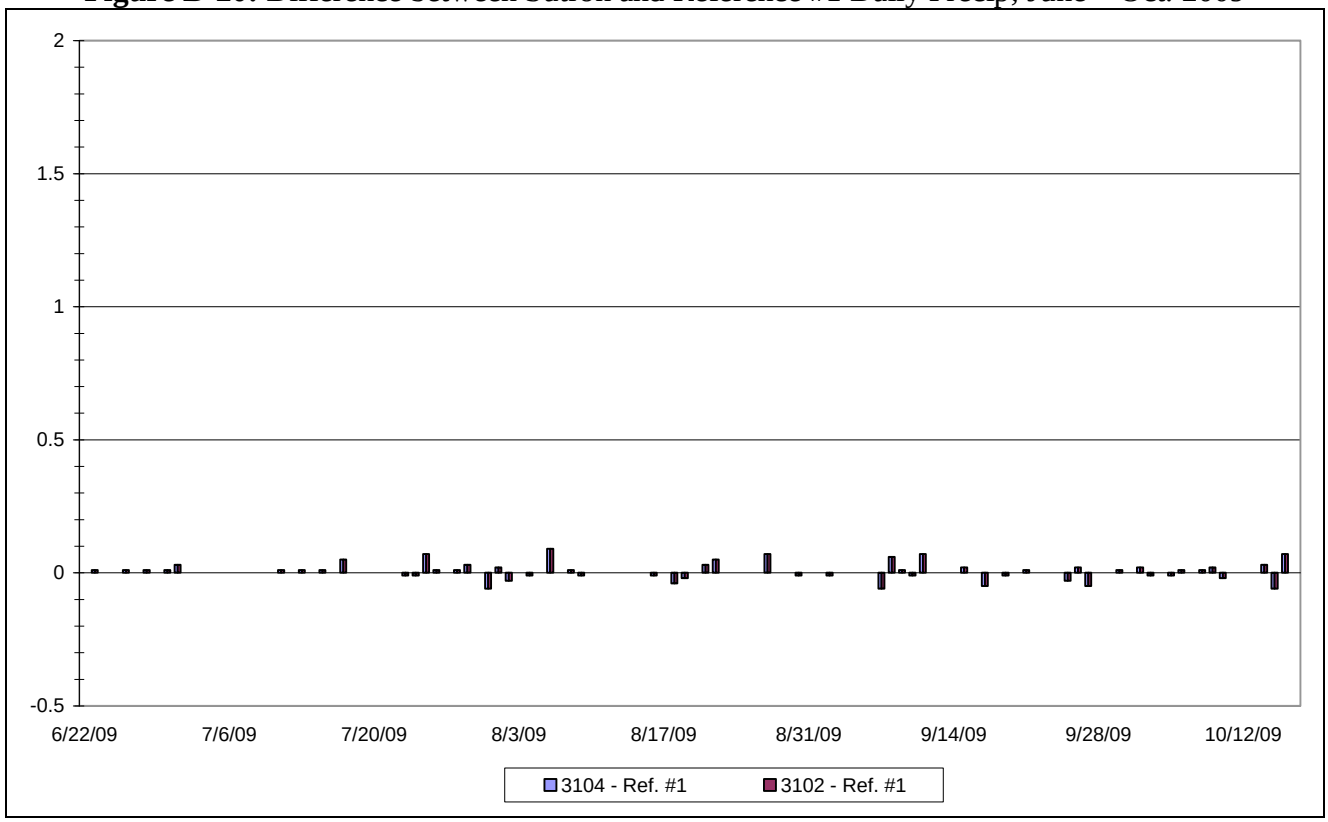


Figure B-21: Difference between Sutron and Reference #2 Daily Precip; Jan. – June 2009

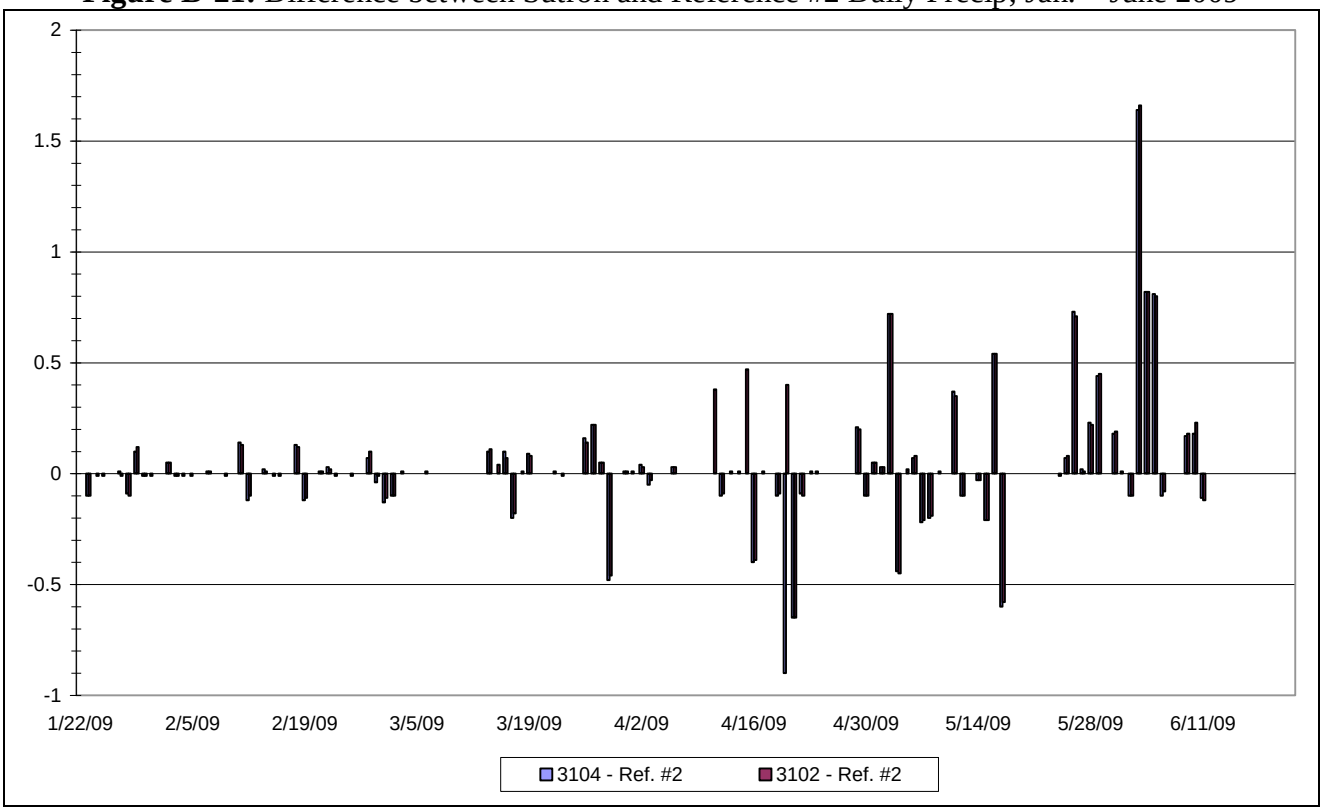


Figure B-22: Difference between Sutron and Reference #2 Daily Precip; June – Oct. 2009

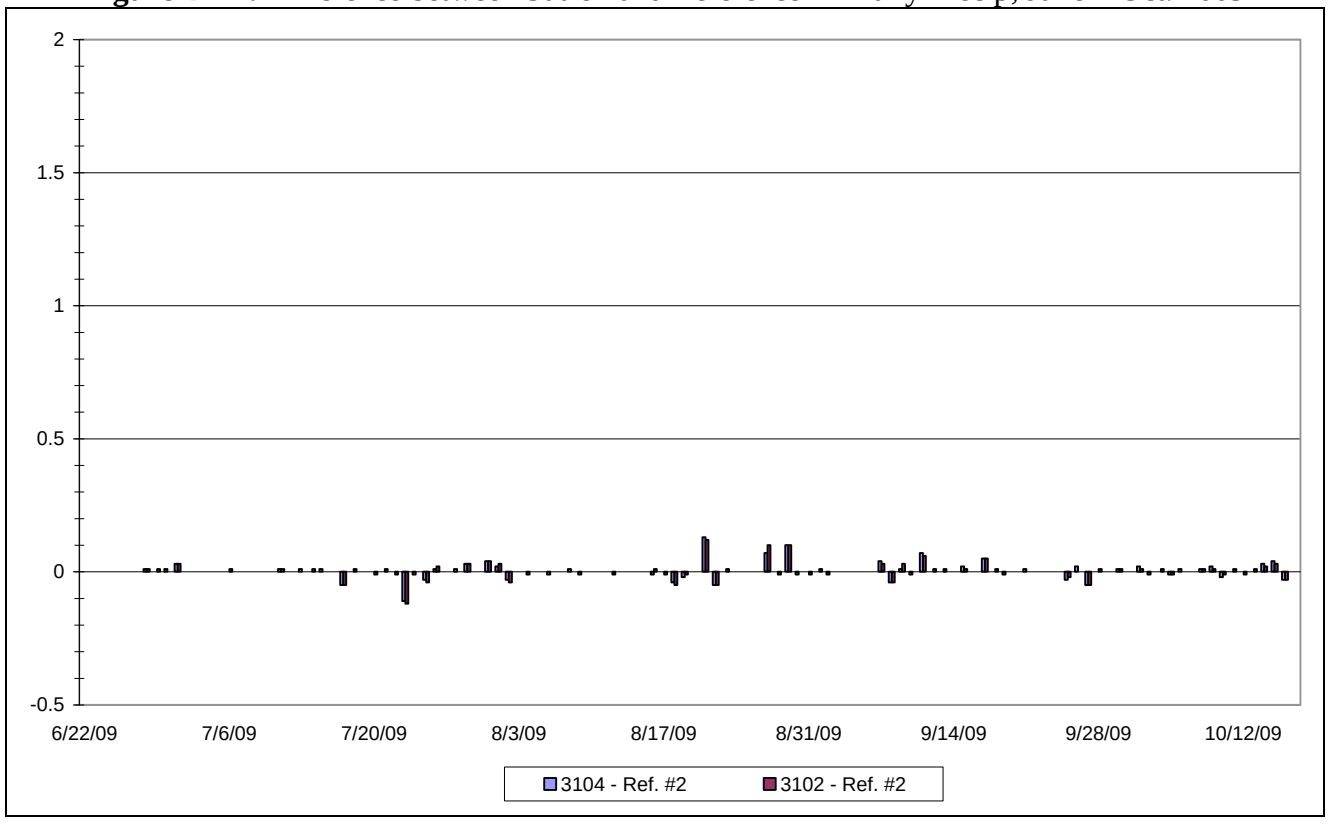


Figure B-23: Difference between Sutron and AWPAG Daily Precip, Oct. – Dec. 2008

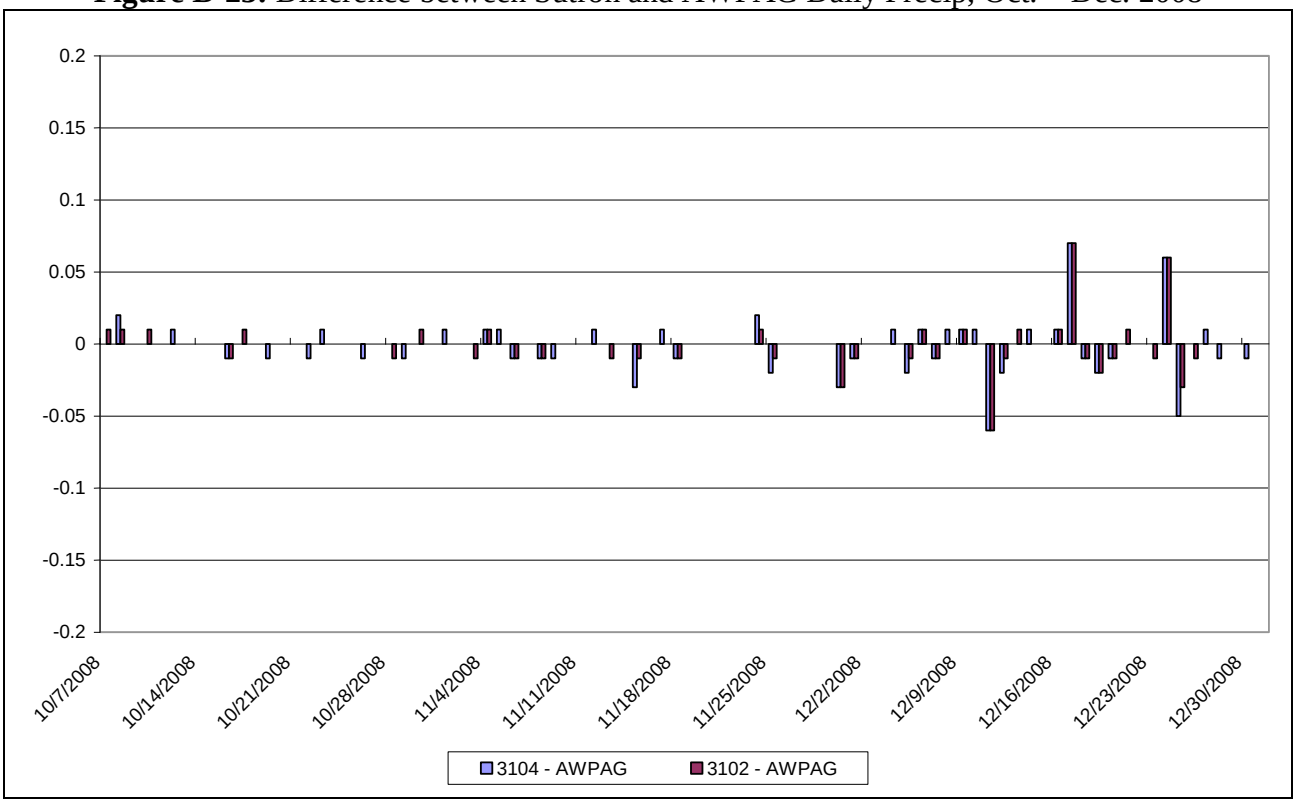


Figure B-24: Difference between Sutron and AWPAG Daily Precip, Jan. – Mar. 2009

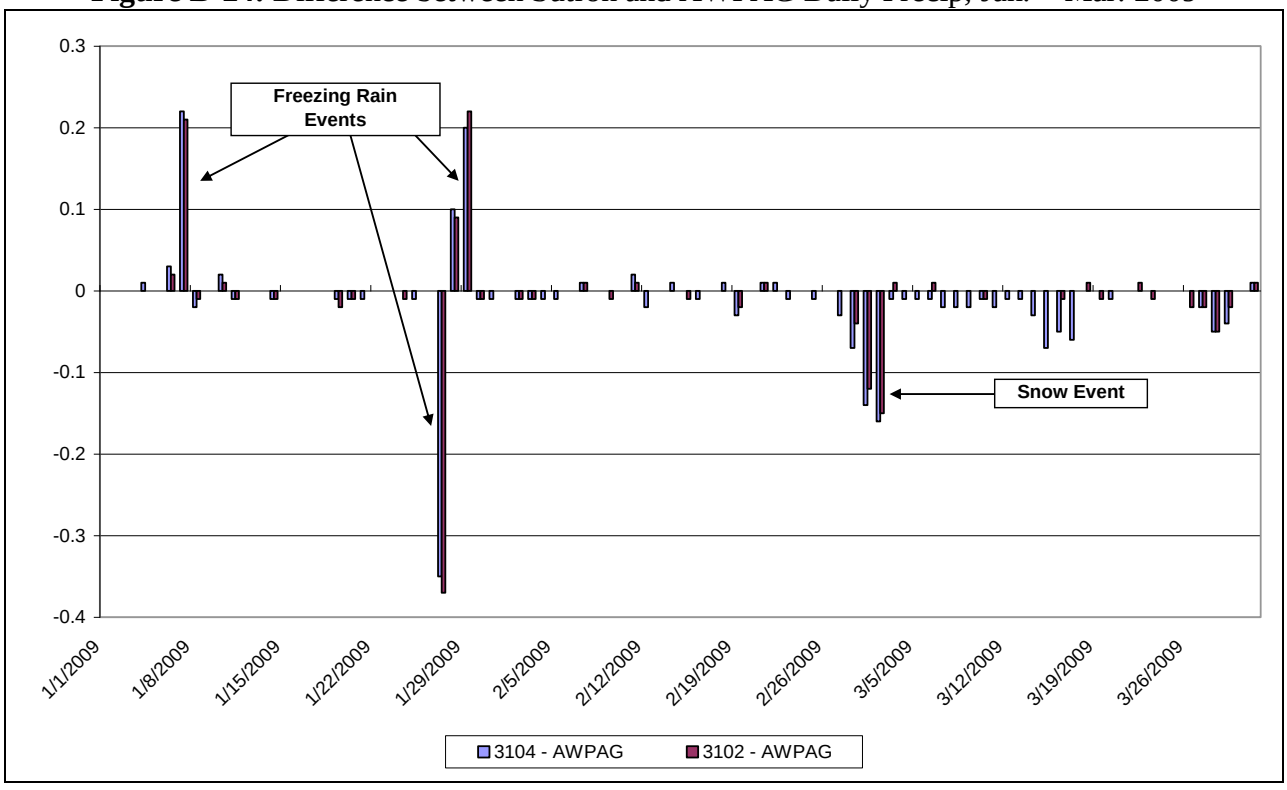


Figure B-25: Difference between Sutron and AWPAG Daily Precip, Apr. – Jun. 2009

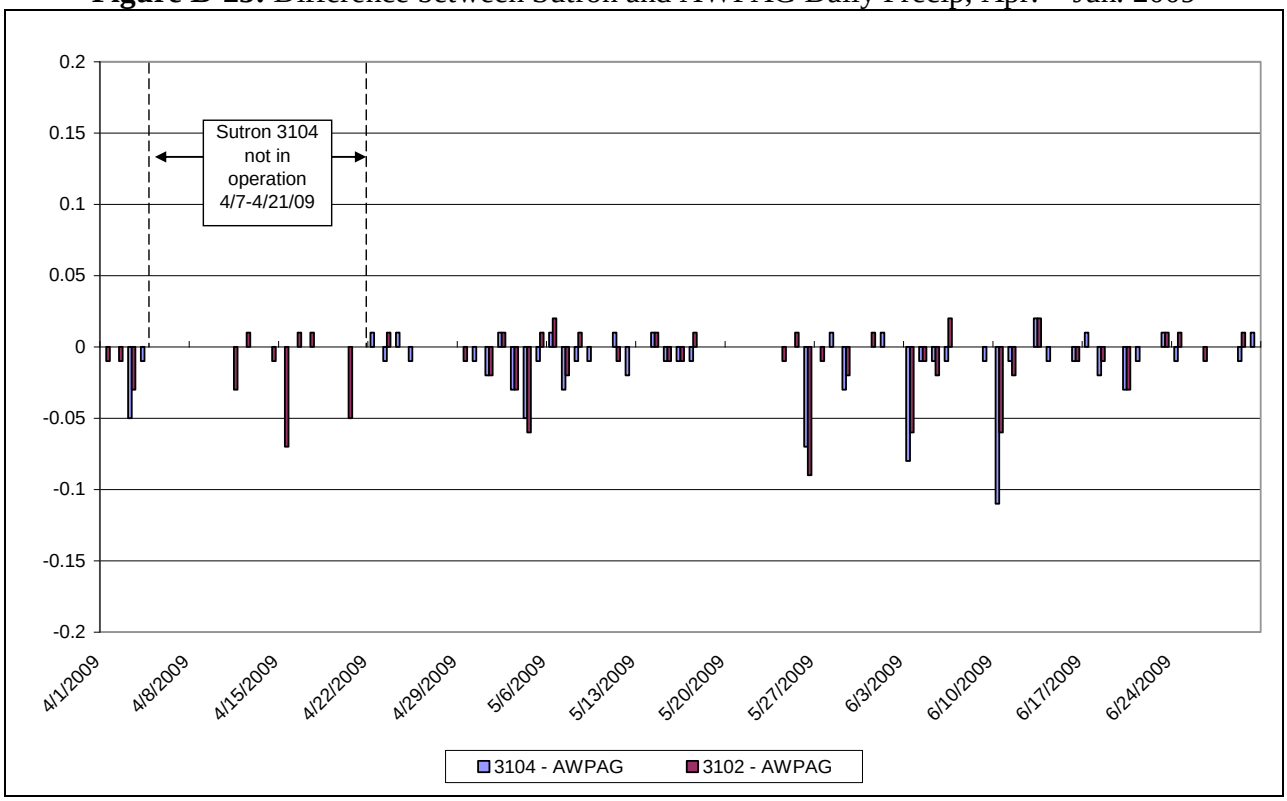


Figure B-26: Difference between Sutron and AWPAG Daily Precip, July – Oct. 2009