Precipitation and Water Table Measurement Comparison Study for 2010 and 2011 at Brookings, South Dakota COOP (Co-operative Observer Program) and AWDN (Automated Weather Data Network) Weather Stations. Also a Look at How 2010 Was a Record Breaking Precipitation Year

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Abstract and Introduction

First this study looked at 2010 being a record breaking precipitation year for Brookings, South Dakota. At this station during 2010, the amount of precipitation was the highest recorded since records have been kept from 1894 to present.

This study then used 2010 and 2011 COOP (Co-Operative Observer Program) and AWDN (Automated Weather Data Network) weather observations from Brookings, South Dakota and studied how the rain events during 2010 and 2011 affected the water table depth through the comparisons of daily readings, and then compared this to other observation time schedules commonly used.

Lastly, two different types of metering sticks were used in 2011 to measure water table depth.

On a near daily basis during the time of year when the evaporation pan was in service (April to October) the water table depth was measured as well as the daily amount of precipitation, evaporation and the snow depth for the entire year at the Brookings COOP station.

The 2010 and 2011 daily precipitation amounts were compared to the daily water table depth data. What was found was that the water table depth responded within hours of a rain event. This response of the water table depth and events such as melting snow, and rainfall would not have been observed if the water table had not been measured daily. The comparison was extended to show that interaction with daily details would be lost if the observations were only taken once or twice a month or only the second day after a rain event as is the current practice at other water table depth monitoring sites. It was concluded that water table depth measurements should be made daily because of the interactive dynamics that occurred between rainfall events or snow melting, and water table depths that would otherwise be lost.

The last study compared two types of sticks used to measure the water table depth during 2011. The two stick readings were compared. They were also compared for ease of use and how to handle the volume displacement associated with the dipstick.

It was concluded that daily readings be made at other stations that measure water table depth, precipitation and snow depth to determine if Brookings was or was not unique in possessing this dynamic relationship.

Objectives

1. To show the annual precipitation amounts at Brookings, South Dakota from1894 to 2010
2. To demonstrate the interactive relationship of melting snow and rainfall events at the Brookings site to the water table measurements from June 1 to October 1 of 2010 and January 1 to Nov 11 of 2011.
3. To show what the data would have looked like if the water table readings were only once a month or bi-monthly and 2 days after a rain event during 2010.
4. To compare two types of meters, on how their readings compared to each other and their ease of use.

Methods

A monitoring well was put in at the Brookings weather site October of 2009. The soil there was Vienna type soil that is well drained and does not have a water table within a depth of 60 inches during normal precipitation months and years. The weather site is located on a high landscape position with a land slope of about one percent.

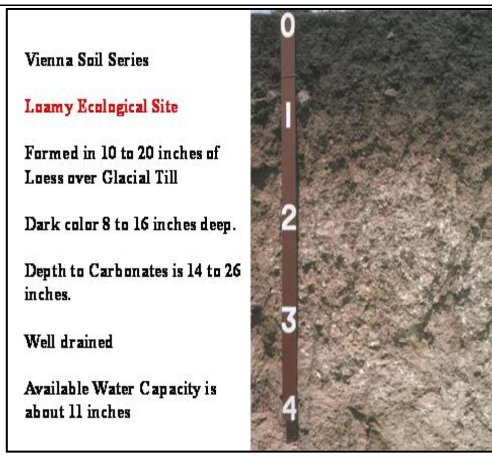

Photo 1. Shows what Vienna soil looks like at another site from the ground level to a depth of 4 feet.

Photo 2. This is what the water table monitoring well looks like at the Brookings site.

The 120 inch long 1 1/2 inch diameter PVC pipe was inserted 111 inches into the ground with a 9 inch stickup above the ground (see photo Photo 2). The bottom 36 inches of the pipe was slotted, wrapped with a woven plastic landscape fabric, and surrounded by a sand pack. The pipe from the top of the sand pack to the soil surface was sealed with Bentonite. There was also 2 inches of sand in the bottom of the pipe. This gave 109 inches of **pipe** measure inches of measurable well. Before water could come up in the well, it had to move through the soil to the sand pack and rise to equilibrium. A 10 foot long wooden dipstick with dimensions of 1/8 by 3/4 of inch was marked with one inch increments starting with 0 at the ground level and 107 inches at the bottom. This was inserted into the pipe and pulled out. The line at the top of the wet mark was the measurement recorded.

Starting April 17, 2011, an additional water table measuring device was used. It consisted of a pipe smaller than the well pipe with a washer at the end which was slightly smaller than the well diameter. The observer could hear when the washer reached the water and the number seen just above the well pipe on the small pipe was recorded. The measurements of the dipstick and pipe with the washer were compared. The advantage of the pipe over the dipstick was that it sat on top of the water and therefore did not raise the water level (up to five inches) in the well pipe like the dipstick. In addition, it could be read on rainy days. If the dipstick was already wet from rain it could not be used to find the water table depth in the well pipe that day. The advantage of the dipstick was that it was simpler to use and different users came up with the same reading with only a rounding error.. The pipe readings among different users varied by as much as 2 inches and it took time to develop a consistent technique. (My 8 year old nephew got the same number as myself and my 2 youngest daughters with the dipstick, whereas him using the pipe was comical) See Photos 3, 4 and 5.

Photo 3

Photo 4

Photo 5

Photos 3 and 4. Showed the wooden dipstick and how it was put into the well pipe. It was then pulled out and the line between the dry and wet stick was the measurement.	Photo 5. Showed the pipe meter being used. Once the top of the water is heard and/or felt, the number on the pipe meter at the top of the well pipe was recorded.

Photo 6. Precipitation can at Brookings site

Photo 7. Evaporation pan at Brookings site

The precipitation was measured with an 8 inch diameter precipitation can, and the evaporation pan was at the site, both were measured in hundredths of an inch. Snow depth and water table were measured using whole inches.

Results

The results were broken up into three parts. First, a discussion about 2010 having been a record breaking precipitation year, followed by a study that compared the daily water table depth and daily precipitation amounts and finally a comparison of the dipstick versus pipe with washer used to measure the water table.

1. 2010 a record-breaking precipitation year for Brookings

In Brookings, South Dakota 2010 was a record breaking amount of precipitation. The graph in figure1 showed the annual precipitation amounts from 1894 to 2011. The straight green line indicated the average of amount of precipitation for that time period. The red line showed the 10 year historical moving average and the blue dots were the amount of precipitation for each year. In this graph it can be seen how far above all the other years of recorded data and the average annual precipitation for the period of record that 2010 was.

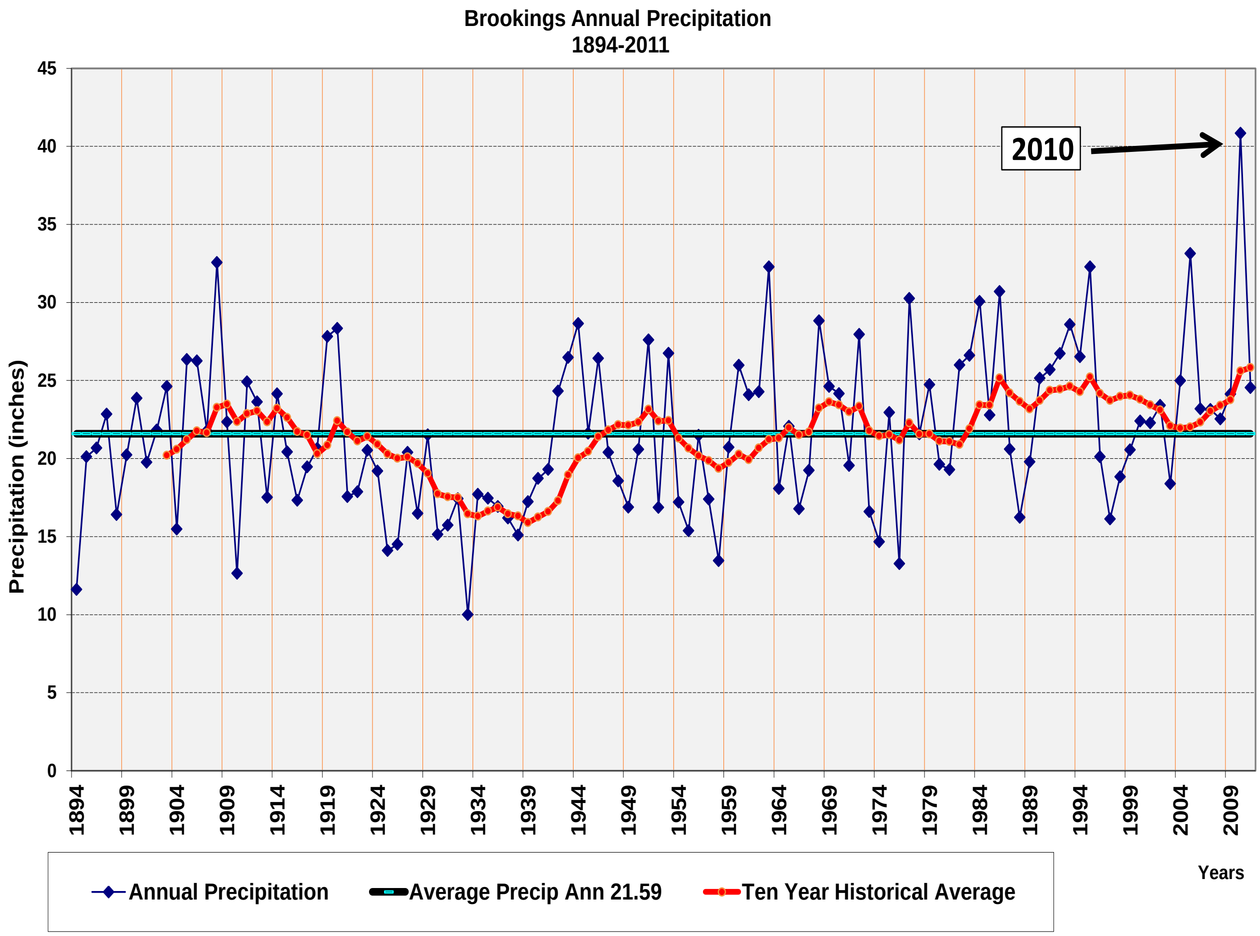

Figure 1 Annual precipitation at Brookings, South Dakota from 1984 to 2011

Rainfall patterns over the course of a year are important. Figure 2, showed the average precipitation amounts for each month of the year and the highest and lowest amount recorded for each month of the year at Brookings, South Dakota for the years 1894 to 2010.

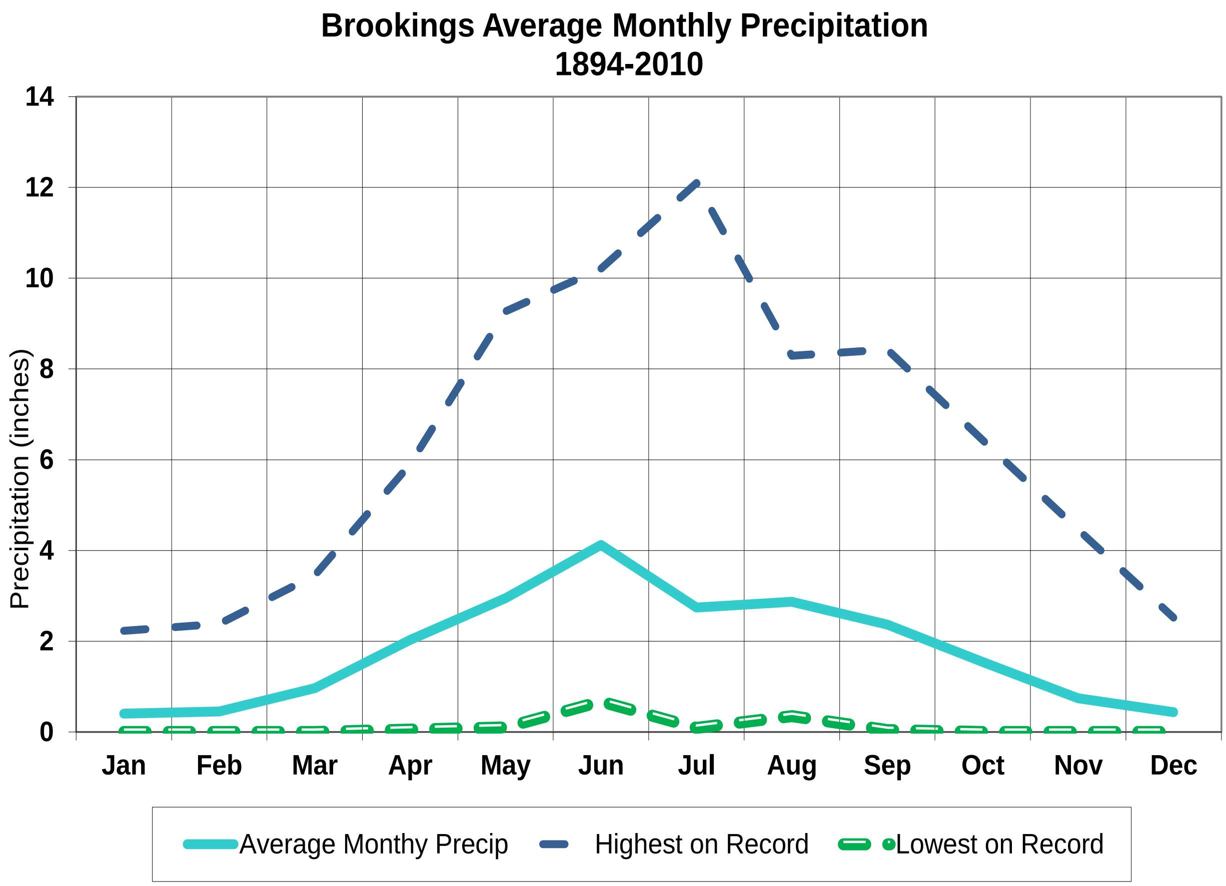

Figure 2 a graph of the average monthly precipitation for each month and the highest and lowest precipitation amount recorded for each month.

Then Figures 3 and 4 also contained the average, highest and lowest monthly precipitation amounts, However the Figure 3 graph also contained data from selected wet years from 1894 to 1990 and the record breaking year precipitation of 2010 for each month. Then figure 4 graph contained the same lines as Figure 2 plus selected wet years between 1990 and 2010.

Both figure 3 and 4 demonstrated that in the months of June, August and September 2010 had the highest precipitation amounts. In July, the year 2010 had the second highest amount of precipitation. January of 2010 and 2011 were both very wet years. Even though 2011 was above average until August, the dry spell that ended the year made it fall just a couple of inches above average for the yearly precipitation as seen in figure 4.

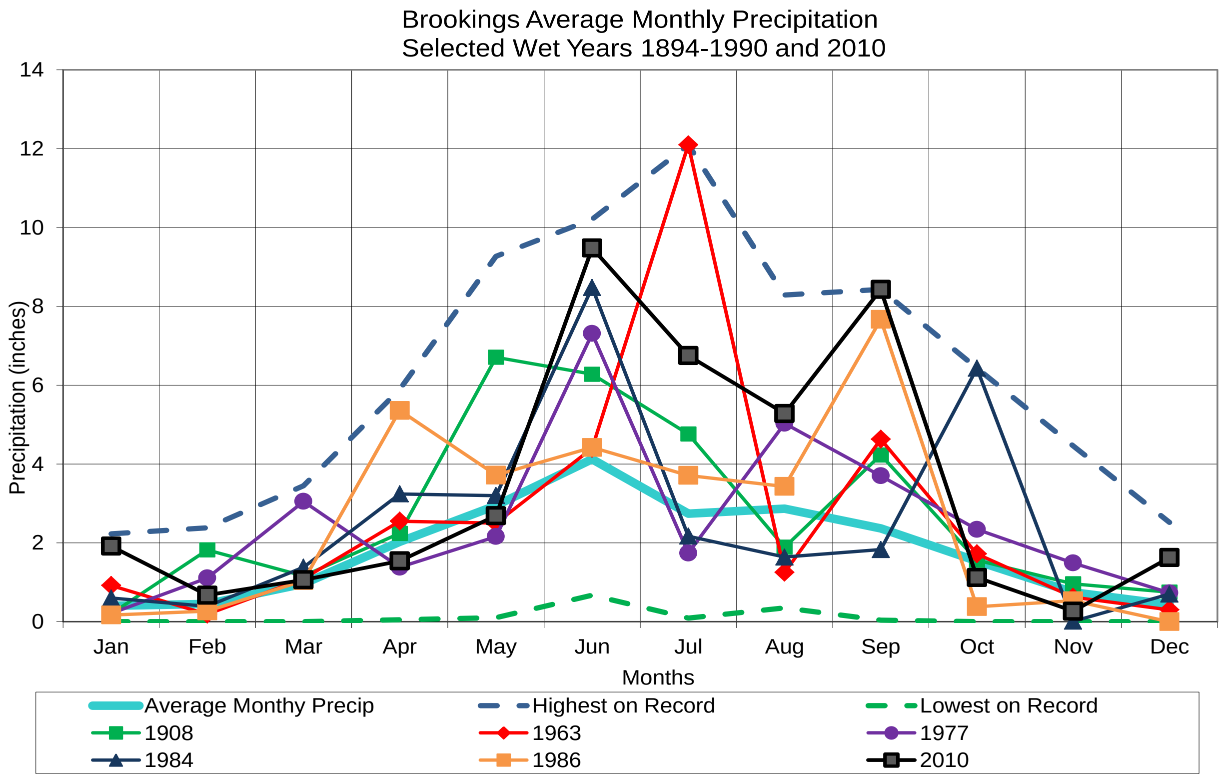

Figure 3 Selected wet years from 1894 to 1990 with the recorded breaking year of 2010

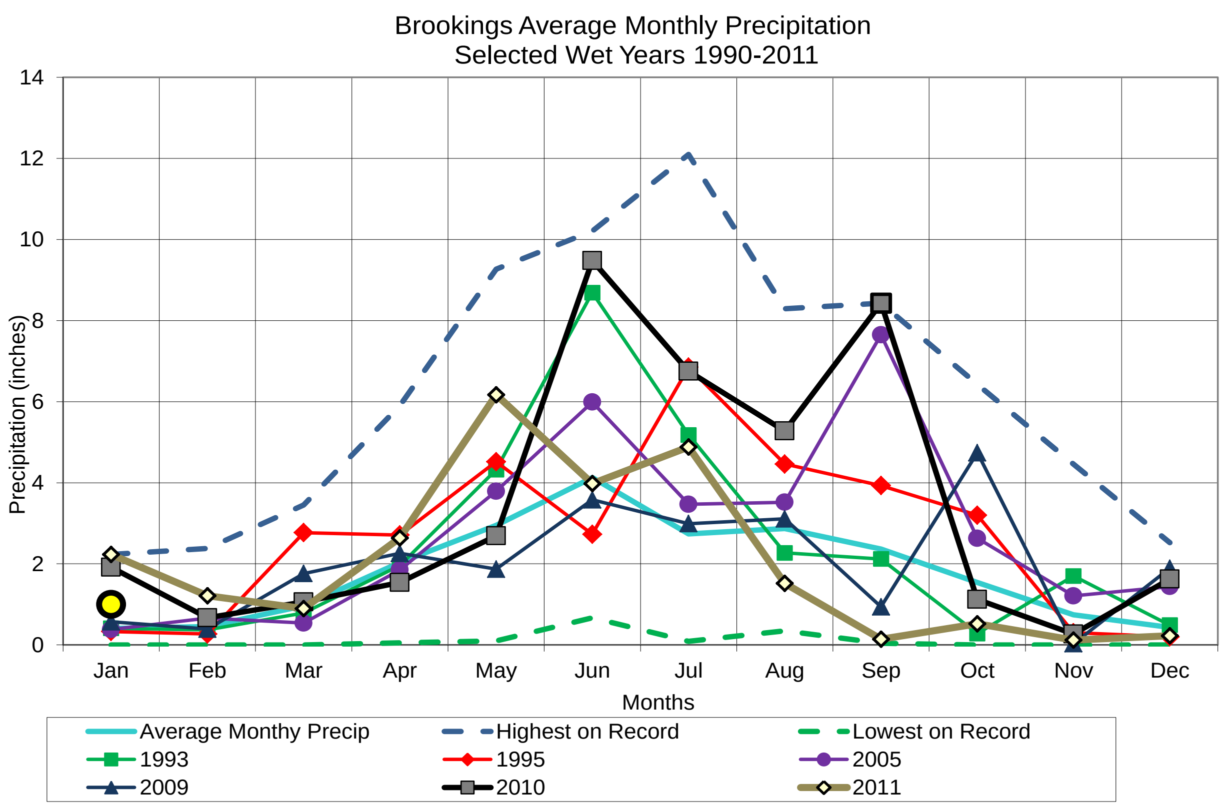

Figure 4 Selected wet years from 1990 to 2010

2. The comparison of the water table to precipitation

The combination of a higher than normal precipitation and the decision to take almost daily water table readings showed the interactive nature of rain events and melting snow with the water table depth. As seen in Figure 5, the water table depth in the black line and red dots. In 2010 the depths were read using the wooden dipstick only. The green dots with the blue line were the daily precipitation amounts in Brookings. As can be seen there was a great deal of interaction between the two sets of data. The gaps in the water table data was due to the dipstick being wet and therefore not being able to be used.

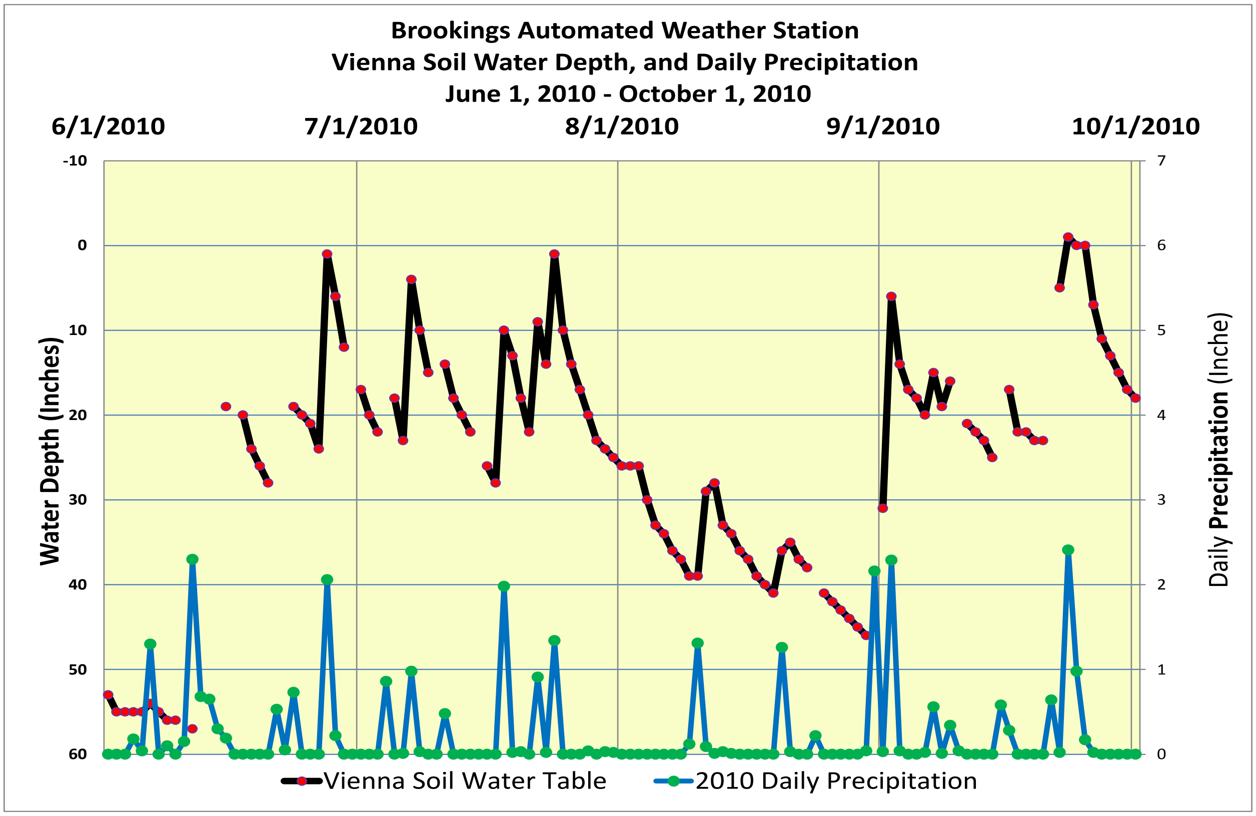

Figure 5 the daily water table depth and daily precipitation amounts at Brookings, South Dakota in 2010

The graph in figure 6 is the same as figure 5 with the addition of purple dots that represent what the data would have been if recorded bi-monthly and 2 days after a rain event only. The interactive relationship would be greatly smoothed out.

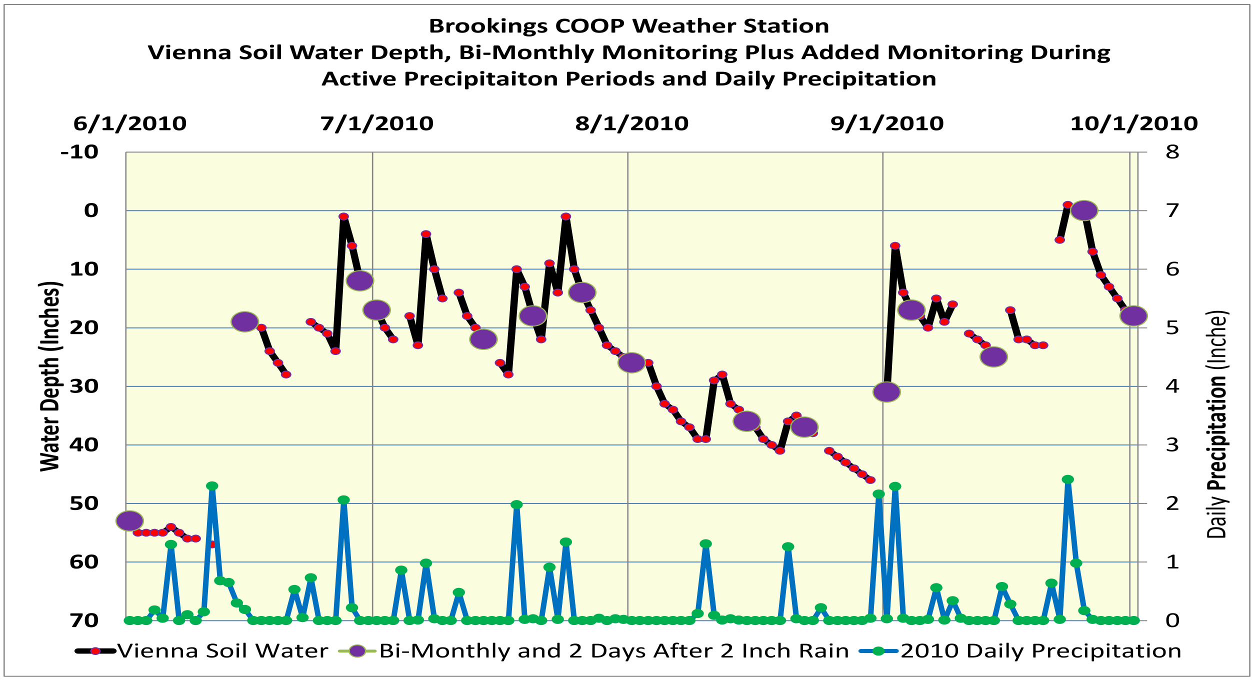

Figure 6 the daily water table and precipitation data plus what the observations of what the water table data would have looked like if only taken bi-monthly and 2 days after rain events.

The graph in figure 7 is also the same graph as in figure 5 with the addition of purple dots that represented what the data would look like if readings were taken only on the first day of the month. The results of that type of observation schedule would not show the interactive variability of the water table depth with rainfall events that the daily observations showed.

Bi-monthly and monthly schedules were commonly used at other locations.

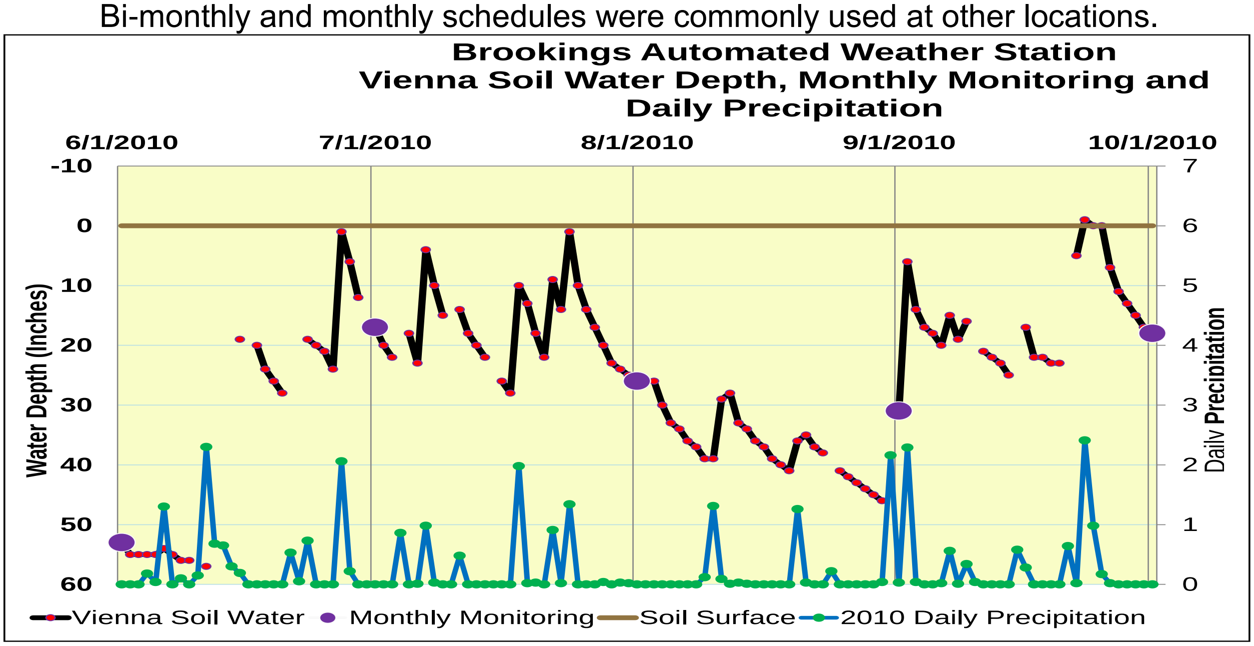

Figure 7 the daily water table and precipitation data plus what the observations of what the water table data would have looked like if only taken monthly.

3. Comparison from wooden dipstick to the pipe with washer readings

In 2011, the readings continued to be taken with the wooden dipstick. Figure 8 is a graph of the water table again using the dipstick and the daily precipitation values. The first half of 2011 was also wet and with the water table being high from the record rainfall amounts of 2010 the water table was still high and still had a very interactive relationship with rain events. But the latter half of the year had very little precipitation and as can be seen the water table dropped below the reaches of the dipstick.

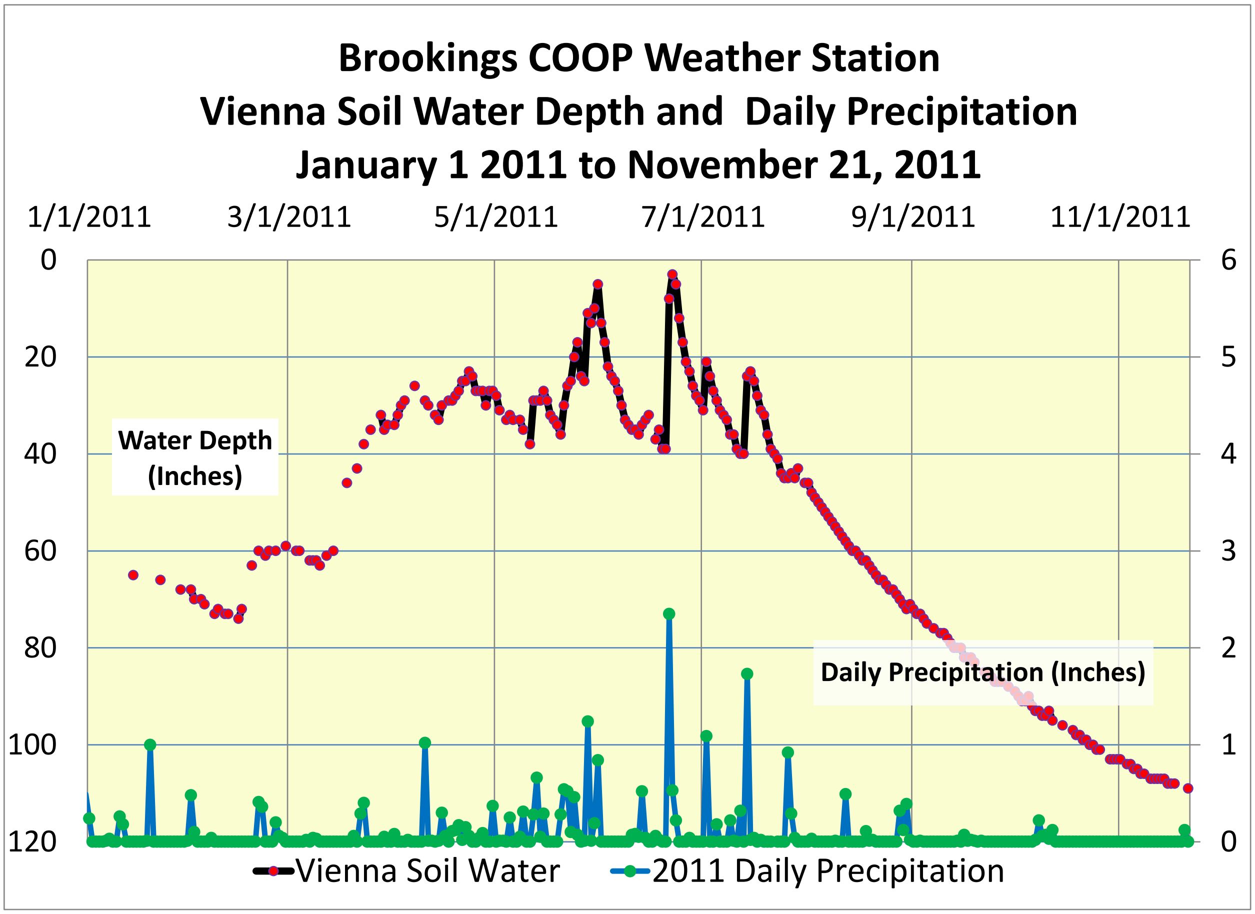

Figure 8 the daily water table depth and daily precipitation amounts at Brookings, South Dakota in 2011

Also in 2011, water table readings were taken with 2 different types of sticks. One was the wooden dipstick that was used in 2010 and the other was a pipe with a washer attached to the bottom of it. The washer had a diameter slightly smaller than the interior of the well pipe. And because 2011 started out wet and dried out after July both devises had readings for their entire usable ranges. The reason for using the pipe was to have a meter that could be used rain or shine and would not go below the top of the water table's surface and raise the level of the water in the monitoring well pipe like the dipstick did. As can be seen in figure 9 the dipstick had readings that indicated a higher water table level than the pipe the closer to the surface the water table was. The reason for this was that dipstick had volume, and that would raise the water table level in the well pipe by displacing the water and this would give a value of a water table reading closer to the surface than was actual. The pipe with a washer was used daily in addition to the dipstick so their readings could be compared. The pipe with washer would be lower into the water table monitoring well pipe till the observer heard it hit the water and/or the observer felt it push back a little. Then the observer would read the inches on the pipe with the washer at the top edge of the well pipe as seen back in photo 5.

The graph shown in figure 9 showed that the difference between the two devises was greater the higher the water table. This was because more of the dipstick was in the water in the pipe pushing the water up.

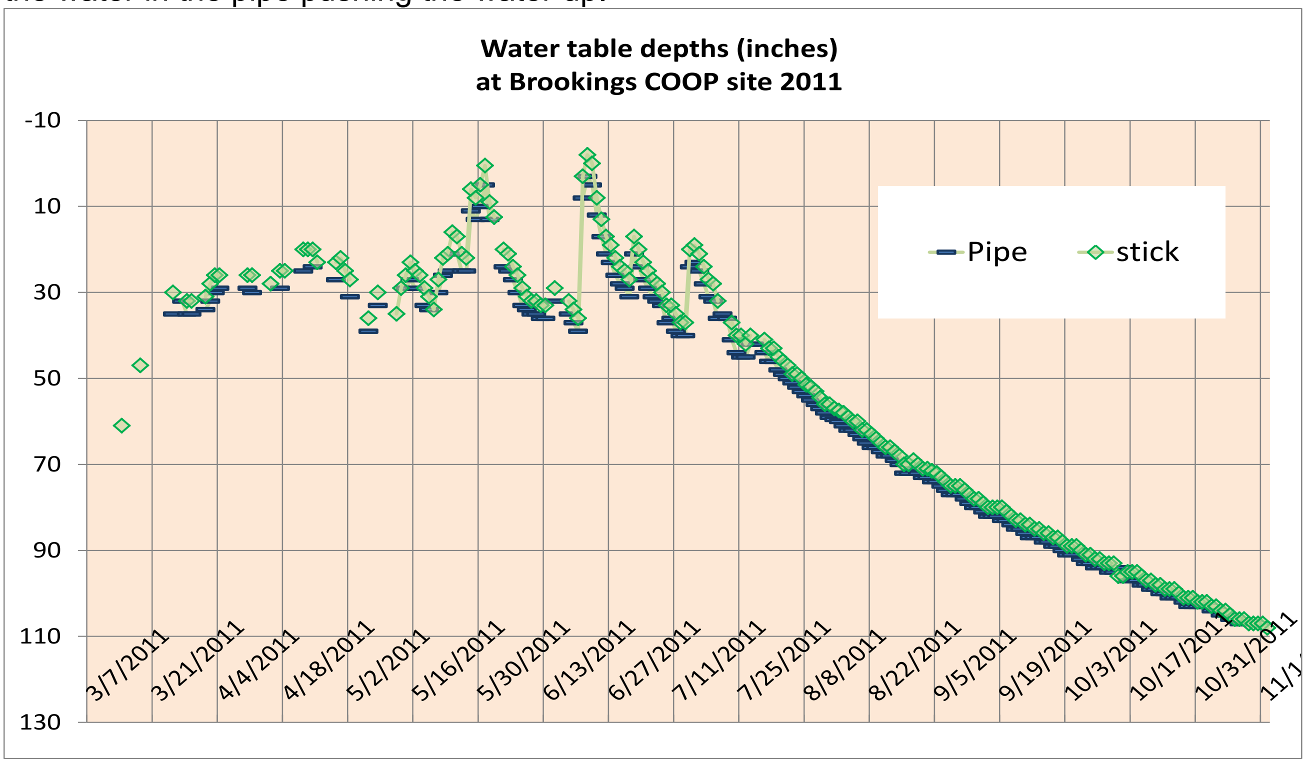

Figure 9 the comparison of the dipstick to the pipe with a washer attached to the bottom readings in 2011 from March to the middle of November.

Figure 10 and 11 are blown up portions of the graph in Figure 9. Figure 10 demonstrated the larger difference between the pipe and the stick when the water table was near the surface and the graph in figure 11 demonstrated how the two devises' readings were almost on top of each other when the water table was low.

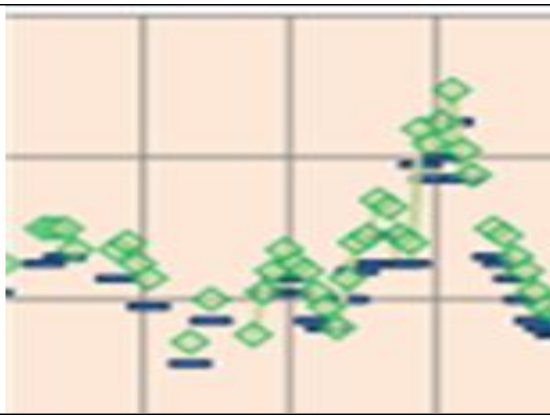	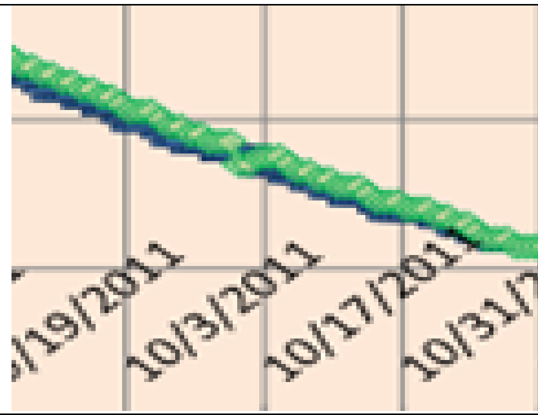
Figure 10 the difference between the dipstick and pipe readings near ground level	Figure 11 the difference between the dipstick and pipe readings near the bottom of the water table monitoring well

2011 was wet until mid-July and the first part of the year showed the quick response to rain events that was seen in 2010. Then for the rest of the year there was very little precipitation after July and the water table dropped to where the wooden dipstick and the pipe with the washer could no longer reach the water table. This meant that the two sticks could be compared over their entire usable length.

As expected the difference between the two was due to the volume of the wooden stick displacing the water and raising the water table level recorded. And the closer to ground level the greater the difference. At ground level the difference was estimated to be almost 5 inches. Using the regression equation found on the graph in figure 12.

When the dipstick and the pipe with washer were compared in a scatter plot in Figure 12 the correlation was very high with and R^2 of 99.9%. If the water table was zero with the pipe, then the dipstick should read about 5 inches **above** ground level due to the displacement of water by the wooden dipstick. Using the regression equation again from Figure 12, if the pipe recorded a water table of 107 inches below the surface the dipstick should show 106 a difference of about one inch.

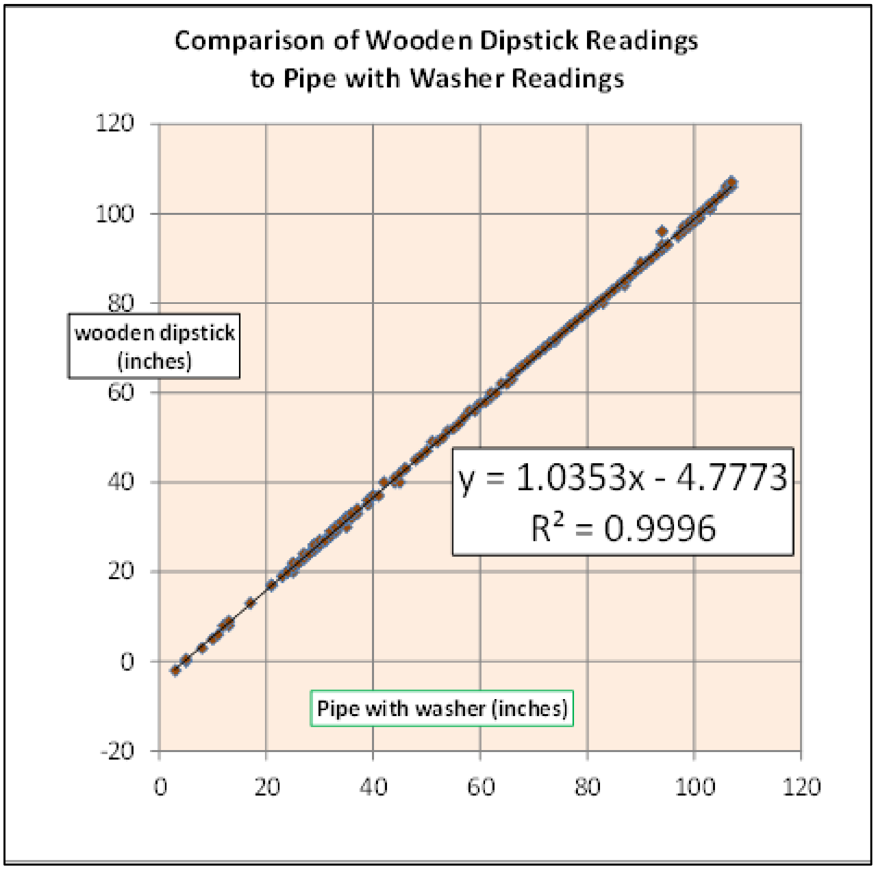

Figure 12 a scatterplot of the water table reading taken by the dipstick and the pipe with washer during 2011 at Brookings, South Dakota

In the future though, its markings should take into account the volume of the dipstick and put 0 inches where the wet line would be when the water table is at ground level. This would have both sticks read 0 at the ground level and their readings would vary the most at the bottom of the well, about 107 inches below ground level in the 10 foot water table monitoring well at the Brookings site.

Discussion and Conclusions

2010 was a record breaking precipitation year. The total amount of precipitation was the highest for the record taking time period of 1894 to 2011. Even though 2010 was the first full year of water table observations, rare high soil water tables were recorded in the soil due to the record breaking precipitation amounts in 2010. Soil interpretations can be tailored for this and similar soils based on the frequency and depth of soil water. An example would be construction activities such as home basements

The combination of a higher than normal precipitation in 2010 and the decision to take almost daily water table readings showed the interactive nature of rain events and melting snow with the water table.

In 2011, the pipe with washer and the dipstick for measuring the water table were compared. 2011 was wet until mid-July and showed the quick response like 2010. Then for the rest of the year there was very little precipitation and the water table dropped to where the sticks could no longer reach the water table. This meant that the two sticks could be compared over their entire usable lengths. As expected the difference between the two was due to the volume of the wooden stick displacing the water and raising the water table level recorded. The pipe with washer once a person had developed the technique turned out to be more accurate, but the dipstick would be easier for beginners, substitute observers and children to use. The dipstick provided a relative scale for the water table that showed it could be just as useful as the pipe with washer even though it would have to be treated as a relative scale. It has been suggested to take into consideration how much the dipstick differs from the pipe with washer and adjust were zero is on the dipstick so that when the water table is at ground level the dipstick would show a wet line at the zero mark on the stick and then mark the dipstick every inch from the zero to the bottom of the stick. This would result in both the dipstick and the pipe having the same reading of zero at ground level and they would very the most from each other at the bottom of the water table monitoring well.

Additional studies of daily water tables reading at weather stations where daily precipitation, evaporation and snow depth are measured would help confirm the relationship of water both above and below the soil surface. This would determine if Brookings was or was not unique in having this dynamic interactive relationship between rain events and the water table depth. Monitoring the water table daily would also be important in obtaining the best quality of data for future research and use in helping to forecast flooding and erosion.

Also suggested at the 2012 AMS meeting in New Orleans was that this would be a useful science educational project at schools. The monitoring wells and measuring sticks are relatively inexpensive. (Less than 100 US dollars in 2012 if one does not include the man-hours used to install the well and assemble and mark the stick and pipe). Its hands on nature would make it interesting and fun to children and demonstrate several aspects of weather and the environment. Human impact on the environment could also be observed if one well could be put near a building's downspout or the downhill side of a parking lot and another away from buildings or parking lots. An advantage of having the monitoring wells near a school is that the dipstick might be able to be stored out of the rain.

One final note, in November of 2011 the water table went below the reach of the water table monitoring well in Brookings. So in January of 2012, a 20 foot PVC pipe was installed in order to measure the water table below 107 inches. As of Feb 2012 the water table had almost reached equilibrium. It will use a gasket between 2 washers attached to a 25 foot tape measure to obtain readings.