Big Cypress Bayou Environmental Flows Project: Effect of Rainfall and High Flow Pulse Release on Soil Moisture

Long Term Monitoring
in Response to
Implementation of Environmental Flow Recommendations
in the Caddo Lake Watershed

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Introduction

This is the third year of a five agreement for The Caddo Lake Institute (CLI) to implement environmental flow recommendations for Big Cypress Bayou, which is the major tributary of the Caddo Lake Watershed. To support more formal operation changes for Lake O' The Pines dam following this period, the CLI has implemented priority aspects of our monitoring plan. The major tasks are: 1) establish regular fish monitoring, including coordination with USFWS on paddlefish monitoring and gravel bar utilization, to track changes versus pre-implementation baseline, and 2) use pulse flow experiments to refine high flow pulse recommendations.

The CLI has completed the first task of establishing an implementation period fish monitoring baseline. The Texas Parks and Wildlife Department led a major effort to establish and sample two sites for fish, mussel and invertebrate communities in Big Cypress Bayou and monitored fish at several sites on Little Cypress Bayou and Black Cypress Bayou (adjacent similar tributaries that serve as monitoring analysis controls). The resulting fish data is currently being analyzed relative to pre-implementation data and pre-dam data to establish fish community responses.

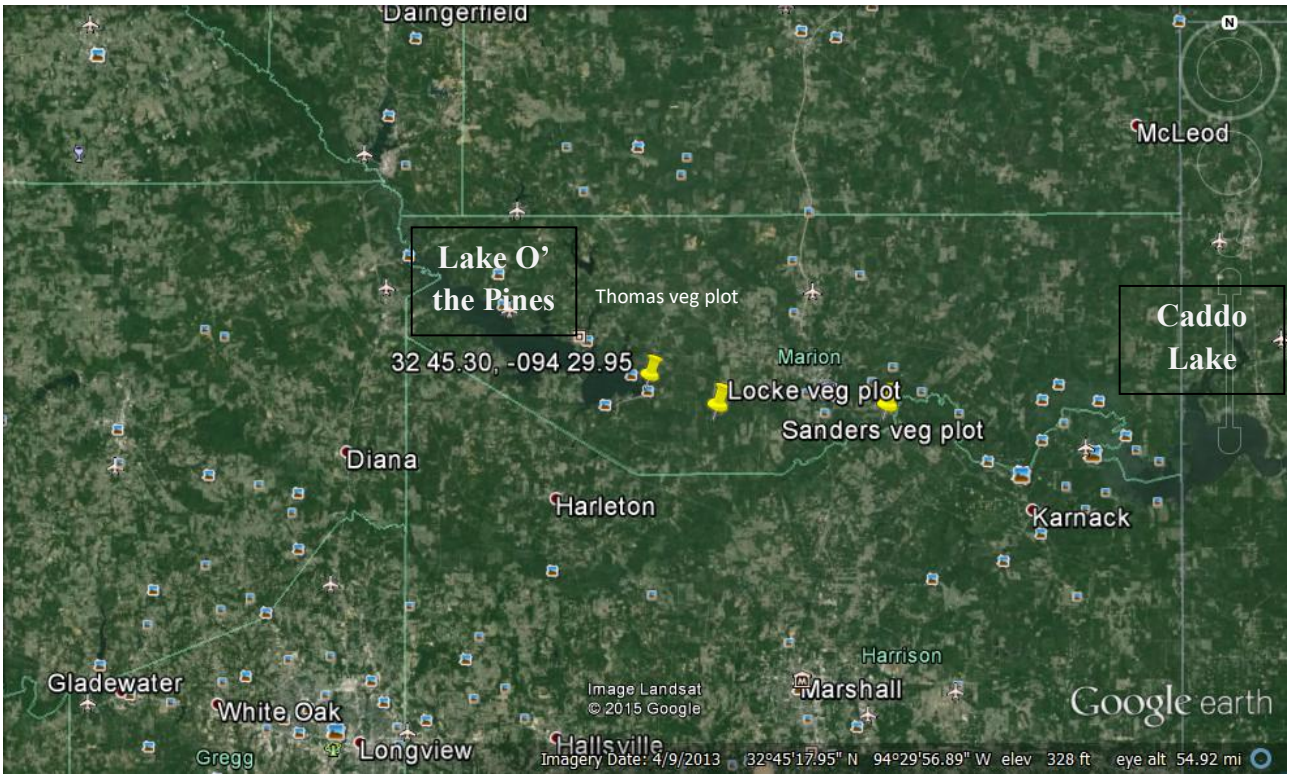
The second task of evaluating high flow pulses has been somewhat limited by hydrologic conditions. Flow pulse releases have been limited to one 3000 cfs pulse, two approximately 2000 cfs pulses, and one 1400 cfs pulse. During this time period, floodplain soil moisture and ground water levels have been monitored using soil moisture sensors and water wells.

The specific goal of this part of the Big Cypress Bayou environmental flows project was to determine the current plant community structure in the floodplain along Big Cypress Bayou and to determine if high environmental flow releases would leave the Big Cypress Bayou channel and enter the adjacent floodplain. Soil moisture, either from rainfall or from overbank flooding, is a key factor controlling the type of plant community that lives in the floodplain. The purpose of this report is to examine the effect of rainfall on soil moisture and the effect that high pulse releases from the Lake O’ the Pines have on soil moisture.

Study Sites and Plant Community Types

Three sites along Big Cypress Bayou between Jefferson and Lake O’ the Pines were selected to conduct vegetation plot surveys: Thomas (upstream site, just below the Lake O’ the Pines dam), Locke (middle site), and Sanders (lowermost site) (Figure 1).

Figure 1. Map of the Study Areas Located along Big Cypress Bayou between Lake O' the Pines and Jefferson, Texas



At each study site, four plant communities were identified and delineated:

Lower swamp (LS) – dominated by bald cypress
Upper swamp (US) – dominated by overcup oak
Seasonally flooded forest (SFF) – dominated by willow oak
Temporarily flooded forest (TFF) – dominated by water oak

During 2014 and 2015 three high pulse releases were made from the Lake O' the Pines dam. The first release occurred during January 2014, the second during April 2014, and the third during March – May 2015. This report will analyze the data from the first three high pulse releases.

Project Work Timeline

Date	Activity
5/16/12 – 5/17/12	Locate monitoring sites along Big Cypress Bayou
10/15/12 – 10/16/12	Survey monitoring sites for specific location of soil moisture and plant communities; Install monitoring well
2/3/13 – 2/7/13	Install soil moisture systems
2/16/13 - 2/28/13	Install soil moisture systems and monitoring wells
3/6/13 – 3/15/13	Install soil moisture systems and monitoring wells
4/28/13	Download soil moisture data and checked well levels

6/10/13	Download soil moisture data and checked well levels
7/25/13 – 7/30/13	Establish vegetation plots
12/17/13	Download soil moisture data and checked well levels
1/18/14 – 1/19/14	Pre-pulse release visit to all three sites and gravel bar at Sander's site
1/23/14	Check gravel bar at Sander's site
1/27/14	Check gravel bar at Sander's site
3/11/14 – 3/12/14	Downloaded soil moisture data and checked well levels
6/19/14	Downloaded soil moisture data and checked well levels
9/20/14	Downloaded soil moisture data and checked well levels
2/7/15	Downloaded soil moisture data and checked well levels
2/20/15	Downloaded soil moisture data and checked well levels
3/16/15	Downloaded soil moisture data and checked well levels
6/17/15 – 6/18/15	Downloaded soil moisture data and checked well levels
7/15/15 – 7/16/15	Checked all three sites for level of flooding due to high pulse release
8/14/15	Downloaded soil moisture data and checked well levels
12/22/15	Checked Sanders site – high release from LOP causing flooding in bald cypress slough, all soil moisture sensors underwater
4/23/16	Checked all three sites; sites were flooded
7/23/16	Checked all three sites; Sanders unit and Locke unit dead due to flooding; Thomas unit working but data file was corrupted and not useable; Water oak well at Thomas site partially pulled out of ground by felled tree
9/18/16	Installed new datalogger at Locke site
9/24/16	Updated filmware on Locke unit, recording data Installed new unit at Sanders site; updated filmware
10/22/16 – 10/23/16	Thomas site – file corrupted so no data was available; downloaded data at Sanders site and Locke site; restarted Thomas unit

Methods

Seven moisture sensors and a Watermark Model 900M monitor were installed at each study site. At the US, SFF, and TFF sites, moisture sensors were installed at both one foot and at two feet below the soil surface. At the LS site, one moisture sensor was installed at one foot below the soil surface. The sensors determined soil moisture once per hour. Water monitoring wells were dug by hand in the water oak (TFF) and bald cypress (LS) plant community types at all three study sites. Water depths were checked manually.

Rainfall

Three USGS rain gages were used during the study:

Black Cypress Bayou at US59 (USGS 07346045) – north of Jefferson
Little Cypress Bayou at US59 (USGS 07346070) – south of Jefferson
Lake O' the Pines dam (USGS 07345900) – just west of Thomas study site

The average annual rainfall for Jefferson, Texas is about 49 inches (www.usclimatedata.com). As shown in Table 1, both 2013 and 2014 were much drier than normal. Rainfall totals at the Little Cypress Bayou site were higher than the other two sites. Rainfall for the first half of 2015 has been higher than normal.

Table 1. Rainfall (inches) at the three USGS precipitation monitoring stations near the study sites. Rainfall data for 2015 is through June 25, 2015.

Year	Black Cypress Bayou	Little Cypress Bayou	Lake O' the Pines
	USGS 07346045	USGS 07346070	USGS 07345900
2013	26.82	36.58	28.45
2014	26.77	34.19	28.66
2015	18.46	35.62	35.55
Mean for 2013- 2014	26.80	35.39	28.56

Rainfall occurred on about 27% of the days with the mean rainfall on days when it rained was about 0.5 inches. The maximum rainfall measured on one day was 4.44 inches.

Soil Moisture Correlation to Rainfall

Soil moisture at all three study sites was analyzed between January 1, 2013 and February 9, 2015 and was correlated to rainfall during the same time period. Analysis of the one foot and two foot soil moisture in the water oak, willow oak, and overcup oak plant communities showed that the soil moisture was not statistically different, therefore those data were combined for this analysis. There were weak but statistically significant correlations at the Sanders and Locke sites (Table 2). When correlations were run between the plant community types located at same study site, the correlations were much higher and statistically significant (data not shown). This indicates that the soil moisture of the four plant community types is responding in a similar way to rainfall.

Table 2. Correlations between Soil Moisture and Rainfall at the Four Different Plant Communities at all Three Study Sites Combined. Correlations shown in bold are statistically significant.

Plant Community Type	Sanders	Locke	Thomas
Lower swamp - Bald cypress	-0.127	**-0.579**	-0.126
Upper swamp - Overcup oak	-0.128	**-0.506**	**-0.136**
Seasonally flooded swamp - Willow oak	**-0.152**	**-0.323**	**-0.144**
Temporarily flooded swamp - Water oak	**-0.153**	**-0.410**	**-0.139**

Soil Moisture in the Four Plant Community Types

Soil moisture was monitored at the four plant community types from January 1, 2013 – February 9, 2015 (Table 3). According to the monitoring system manufacturer, a soil moisture reading of 0 – 10 centibars means that the soil is saturated. A soil moisture reading of 10 – 30 centibars means that the soil is moderately wet. A soil moisture reading of 30 – 100 centibars means that the soil is somewhat wet. A soil moisture reading of greater than 100 means the soil is becoming increasingly dry. As predicted, the highest soil moisture was found at the bald cypress plant

community. The other three plant community types did not follow the expected soil moisture predictions. The overcup oak plant community was drier than predicted, and the water oak plant community was wetter than predicted.

Table 3. Comparison of Soil Moisture (centibars) in the Four Plant Community Types at all Sites Combined, January 1, 2013 – February 9, 2015.

Plant Community Type	Mean	Standard Deviation	Minimum	Maximum
Lower swamp - Bald cypress	102.6	29.6	54.6	148.7
Upper swamp - Overcup oak	225.1	14.1	198.6	239.0
Seasonally flooded swamp - Willow oak	197.0	17.9	170.6	216.8
Temporarily flooded swamp - Water oak	174.2	26.4	143.8	221.9

Water Well Data

As expected the BC water wells had significantly more water that the WA wells (Table 4). Also, the amount of water in the BC wells was affected by season with the winter having the largest amount of water and the summer having the least amount of water. The water levels in the wells at the Sanders site were checked just prior and during the pulse release during January 2014. The data indicate that some water did reach the BC well during the release, however water did not reach the WA well.. The USGS has now installed continuous monitoring systems in many of the wells. These data are not currently available.

Table 4. Water Depths in Monitoring Wells at the Three Study Sites, 2013-2015.

	Sanders		**Locke**		**Thomas**	
Date	**WA**	**BC**	**WA**	**BC**	**WA**	**BC**
	cm	**cm**	**cm**	**cm**	**cm**	**cm**
3/08/2013			0	67		
3/09/2013	0	75			0	61
3/15/2013	0	71	0	62	0	94
4/28/2013	0	88	0	93	0	132
6/10/2013	0	36	0	52	0	28
9/06/2013	0	0				
9/07/2013			0	0	0	0
12/17/2013	0	51	0	71	0	80
1/19/2014*	0	91	0	105	0	175
1/23/2014*	0	95				
3/11/2014	0	133				
3/12/2014			35	149	17	(underwater)

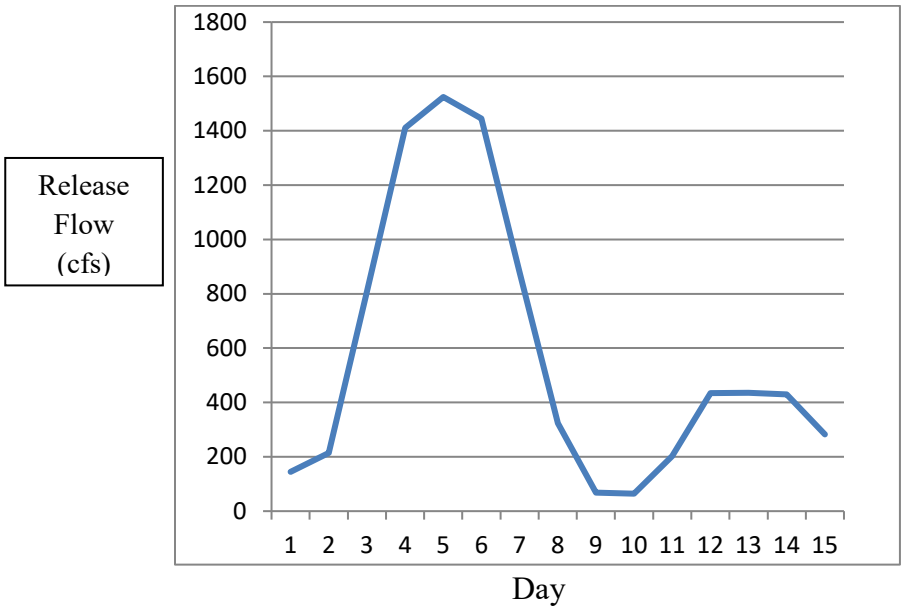
6/19/2014	0	NA	7	(underwater)	0	69.75
9/20/2014	0	NA	0	11	0	0
2/7/2015	0	NA	0	NA	0	NA
Mean	**0.0**	**71.1**	**3.8**	**67.8**	**1.5**	**71.1**

*= January 19, 2014 was day one of the high pulse release from Lake O' the Pines. January 23, 2014 was the day of the highest flow during the release period.

Effect of High Pulse Release #1 on Soil Moisture – January 2014

Beginning on January 19, 2014, the U.S. Corps of Engineers began to increase the rate of water released from the Lake O' the Pines dam (Figure 2). The release included a three day ramp up, held steady for about two days, and a ramp down that lasted three days. During the study period, the maximum flow in Big Cypress Bayou was 1,560 cfs on January 23, 2014 (day 6).

Figure 2. Release (cfs) of water from the Lake O' the Pines into Big Cypress Bayou, January 18, 2014 – February 1, 2014.



It is important to note that there was no rainfall during the study period except for a small amount of rain during the last day of the release period (Table 5).

Table 5. Rainfall (inches) at the three precipitation monitoring stations near the study sites, January 19, 2014 – February 1, 2014.

Date	Black Cypress US59 USGS 07346045	Little Cypress US59 USGS 07346070	Big Cypress Below LOP USGS 07345900
1/19/2014	0	0	0
1/20/2014	0	0	0
1/21/2014	0	0	0
1/22/2014	0	0	0
1/23/2014	0	0	0
1/24/2014	0	0	0
1/25/2014	0	0	0
1/26/2014	0	0	0
1/27/2014	0	0	0
1/28/2014	0	0	0
1/29/2014	0	0	0
1/30/2014	0	0	0
1/31/2014	0	0	0
2/1/2014	0.11	0.09	0.02

Data analysis showed that there were small but statistical significant differences between the soil moisture at the one foot and two feet depths. However, the soil moisture differences were not ecological significant, therefore the soil moisture data for the two depths were combined into one mean.

At the Thomas site, the soil moisture levels were very wet at the beginning of the release. all four vegetation types became drier during and following the release, so it seems that the release did not affect this site (Table 6).

Table 6. Soil moisture at the Thomas site in the four vegetation site-types during pre-release, release, and post-release days. The soil moisture scale is from 0 (soil is completely saturated) to a minimum of 256 (complete dryness).

Site-type	Relative Elevation	Pre-release (Day 1)	Release (Day 2-8)	Post-release (Day 9-15)	Moisture Change
Water Oak	Highest	16.0	17.3	17.7	-1.7
Willow Oak	Mid-High	3.0	6.9	9.5	-6.5
Overcup Oak	Mid-Low	3.0	6.9	9.5	-6.5
Bald Cypress	Lowest	0.0	0.0	0.9	-0.9

At the Locke site, all four vegetation types became wetter during and following the release (Table 7). The bald cypress area had the largest change in soil moisture.

Table 7. Soil moisture at the Locke site in the four vegetation site-types during pre-release, release, and post-release days. The soil moisture scale is from 0 (soil is completely saturated) to a minimum of 256 (complete dryness).

Site-type	Relative Elevation	Pre-release (Day 1)	Release (Day 2-8)	Post-release (Day 9-15)	Moisture Change
Water Oak	Highest	16.5	14.8	14.2	2.3
Willow Oak	Mid-High	16.5	15.1	14.2	2.3
Overcup Oak	Mid-Low	13.0	8.7	7.4	5.6
Bald Cypress	Lowest	40	2.8	2.8	37.2

At the Sanders site, three of the vegetation site-types became wetter, while the bald cypress site stayed fully saturated (Table 8).

Table 8. Soil moisture at the Sanders site in the four vegetation site-types during pre-release, release, and post-release days. The soil moisture scale is from 0 (soil is completely saturated) to a minimum of 256 (complete dryness).

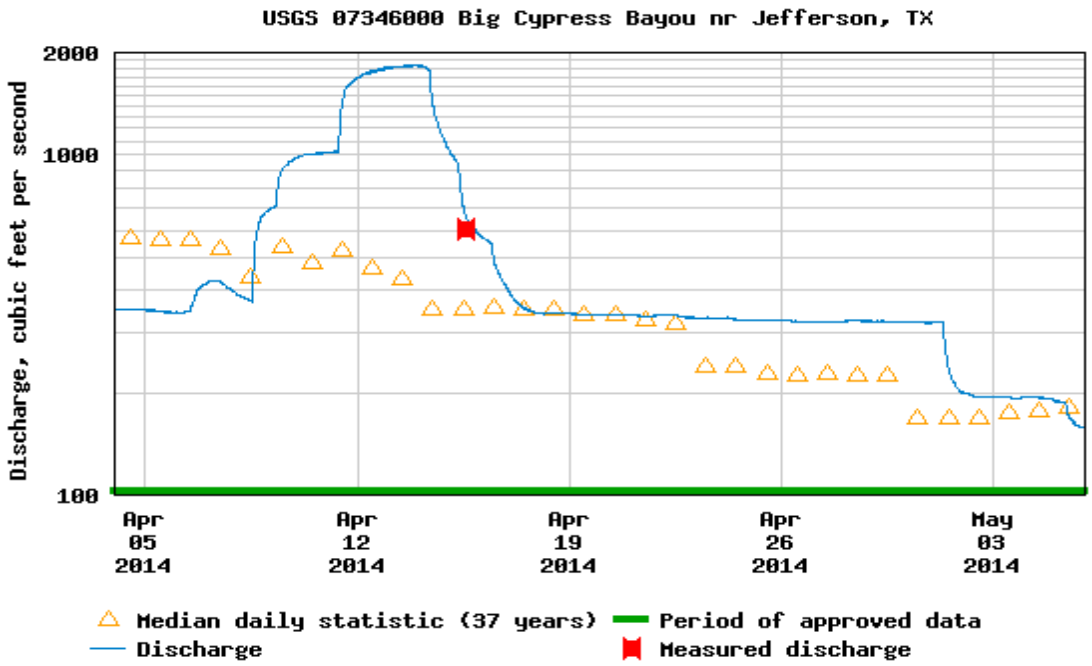
Site-type	Relative Elevation	Pre-release (Day 1)	Release (Day 2-8)	Post-release (Day 9-15)	Moisture Change
Water Oak	Highest	16.5	15.1	12.5	4.0
Willow Oak	Mid-High	12.5	11.6	9.4	3.1
Overcup Oak	Mid-Low	9.5	10.5	4.1	5.4
Bald Cypress	Lowest	0	0.07	0	0

As a summary, as expected the bald cypress site-type had the highest soil moisture and the water oak site had the lowest soil moisture. The willow oak site and the overcup oak site had relatively equal amounts of soil moisture. The release of water from Lake O' the Pines increased soil moisture at the Locke and Sanders sites, but not at the Thomas site. At this time there is no explanation for this difference.

Effect of High Pulse Release #2 on Soil Moisture – April 2014

A second high pulse release began on April 8, 2014 and ended on April 18, 2014 (Figure 3). The maximum flow during the time period was 1,800 cfs which was held for about two days.

Figure 3. Release (cfs) of water from the Lake O' the Pines into Big Cypress Bayou, April 2014



Rainfall occurred at the study sites on several days prior to the beginning of the high pulse release and occurred on the day that release flow peaked (Table 9).

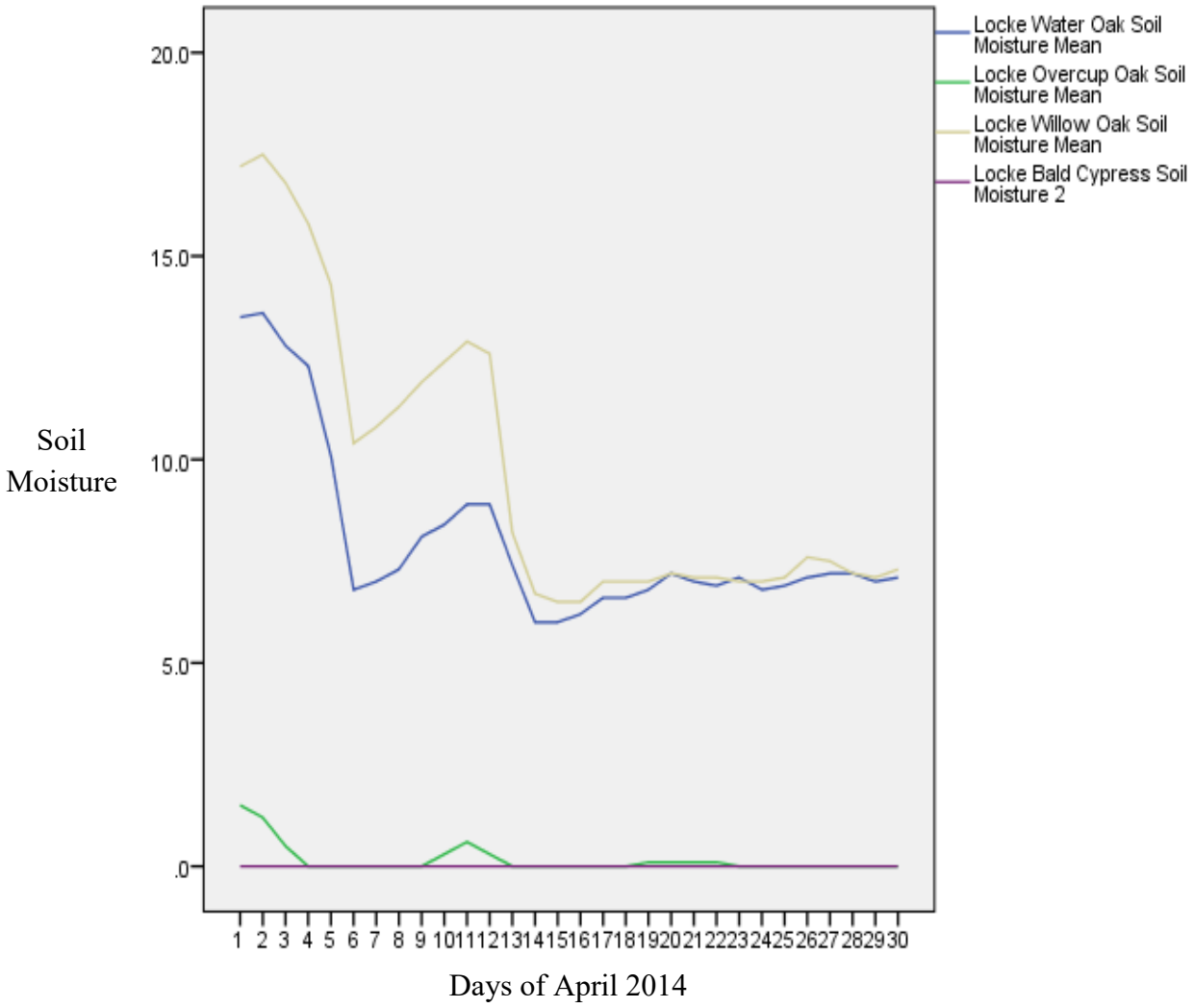
Table 9. Rainfall (inches) at the three USGS precipitation monitoring stations near the study sites, April 2014.

Date	Black Cypress US59	Little Cypress US59	Big Cypress LOP	Mean
	USGS 07346045	USGS 07346070	USGS 07345900	
4/1/2014	0	0	0	0.000
4/2/2014	0	0	0	0.000
4/3/2014	0.33	0.42	0.5	0.417
4/4/2014	0	0	0	0.000
4/5/2014	0.05	0.02	0.05	0.040
4/6/2014	1.49	1.83	1.84	1.720
4/7/2014	0.01	0.01	0	0.007
4/8/2014	0.02	0.04	0.14	0.067
4/9/2014	0	0	0	0.000
4/10/2014	0	0	0	0.000
4/11/2014	0	0	0	0.000
4/12/2014	0	0	0	0.000
4/13/2014	0	0	0	0.000
4/14/2014	0.37	0.36	0.57	0.433

4/15/2014	0	0	0	0.000
4/16/2014	0	0	0	0.000
4/17/2014	0	0	0	0.000
4/18/2014	0	0	0	0.000
4/19/2014	0	0	0	0.000
4/20/2014	0	0	0	0.000
4/21/2014	0.02	0.33	0.57	0.307
4/22/2014	0.05	0	0	0.017
4/23/2014	0	0	0	0.000
4/24/2014	0	0	0	0.000
4/25/2014	0	0	0	0.000
4/26/2014	0	0	0	0.000
4/27/2014	0	0	0	0.000
4/28/2014	0.23	0.06	0.27	0.187
4/29/2014	0	0	0	0.000
4/30/2014	0	0	0	0.000
Total	2.57	3.07	3.94	3.19

Soil moisture data for the Locke site and the Sanders site were analyzed; there was no data for the Thomas site. In general, the Locke site was wetter than the Sanders site. The plant communities were wettest to driest in the following order: bald cypress, overcup oak, water oak, willow oak (Figure 4).

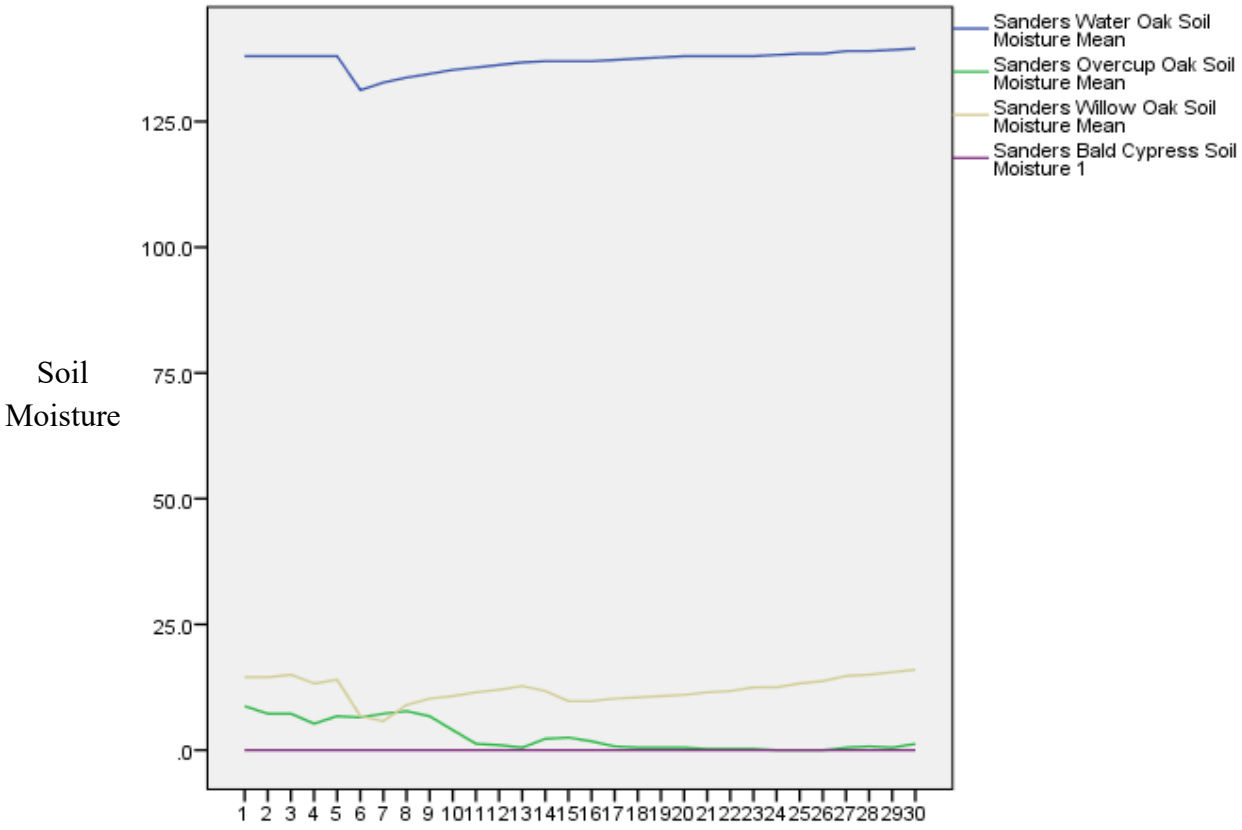
Figure 4. Soil moisture at the four plant communities types at the Locke site during the April 2014 high pulse flow release.



The bald cypress soil was completely saturated, so the pulse release had no effect on its moisture content. With the other three sites, the soil moisture increased beginning on April 11 and became maximum on April 14 which was the day of peak flow. Following April 14, these three soils became slowly drier.

At the Sanders site, the plant communities were wettest to driest in the following order: bald cypress, overcup oak, willow oak, water oak (Figure 5). The release did not have an effect on the bald cypress soil because it was completely saturated. Also, it did not have an effect on the water oak soil which slowly dried during the release period. The willow oak soil and the overcup oak soil did become slightly wetter during the release period, but the change was not significant. The water oak, willow oak, and overcup oak soils slowly dried following the release.

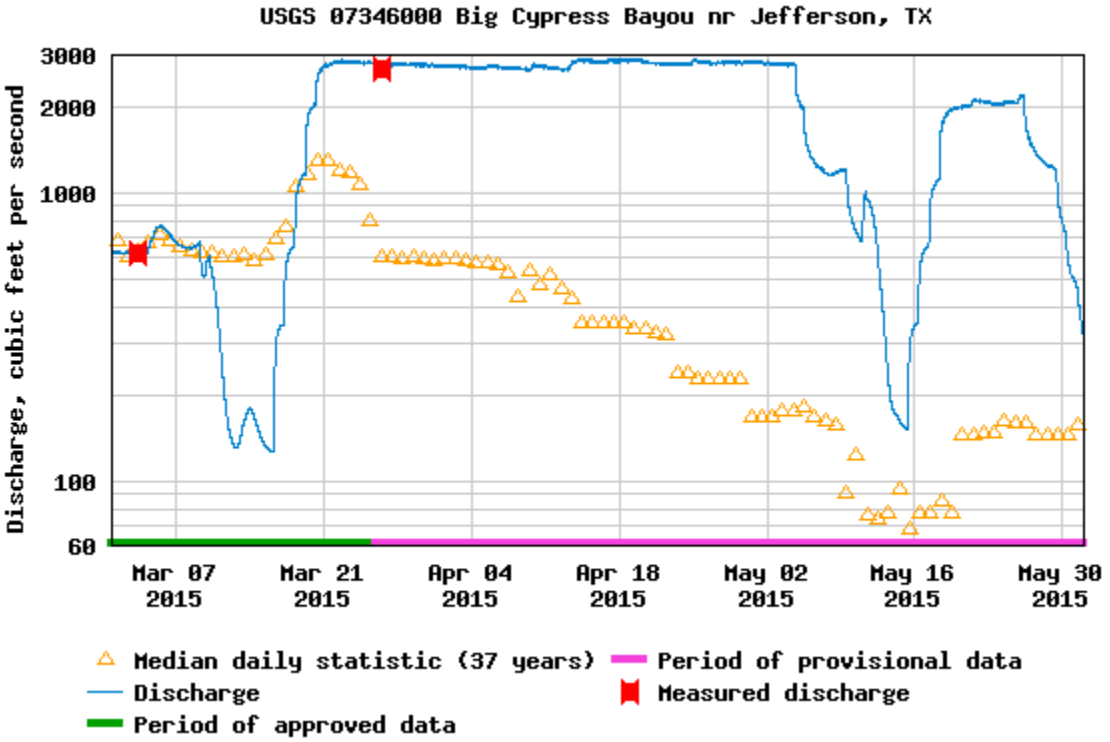
Figure 5. Soil moisture at the four plant communities types at the Sanders site during the April 2014 high pulse flow release.



Effect of High Pulse Release #3 on Soil Moisture – March - May 2015

Due to abnormally high rainfall during the late spring in the area, a high release of about 3,000 cfs occurred beginning on March 21 and continued until May 4, a total of 44 days (Figure 4).

Figure 6. Release (cfs) of water from the Lake O' the Pines into Big Cypress Bayou, March – May 2015



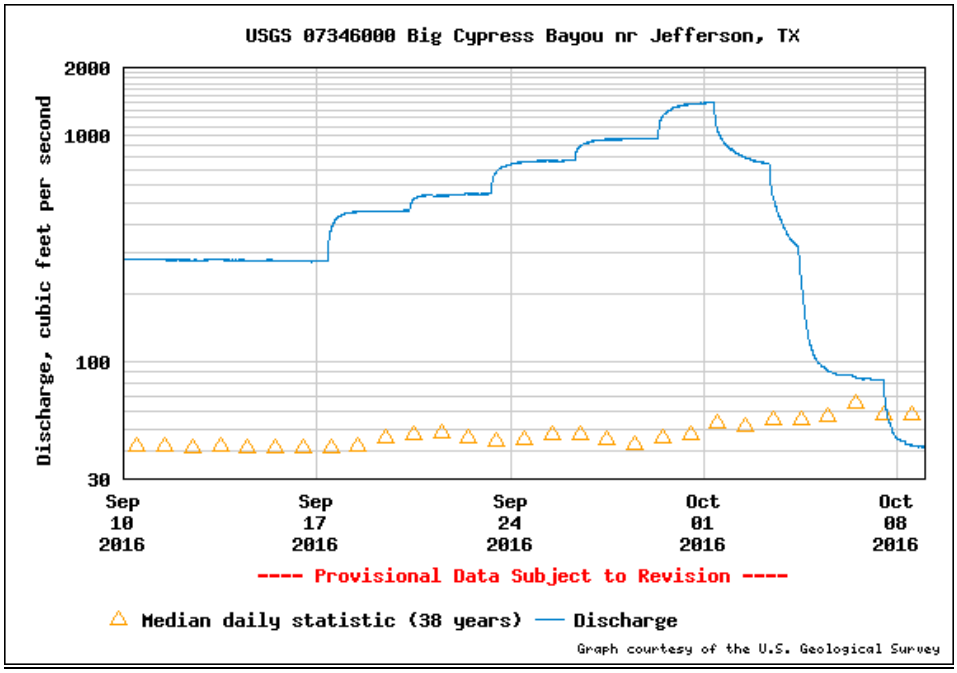
On March 16, 2015 all three sites were inundated by recent rainfall at higher than normal levels. At some point when the released exceeded 2,000 cfs, river water left the channel and entered the floodplains. All three sites were completely inundated and stayed that way through June 18, 2015. The water levels in the bald cypress sloughs were a minimum of two feet deep and were as much as seven feet deep. The data recording boxes at the Sanders and Locke sites were accessible by wading through water, however the recording box at the Thomas site was not accessible due to chest-high water in the slough. On July 16, 2015 the sites were visited and the water levels were still very high. On August 14, 2015, the sites were visited and the water levels had receded significantly. The months of June and July were very dry, so it can also be assumed that the continued flooding was due to river water and not rainwater. Thus, for a period of about three months following the end of the high pulse release, significant levels were found in the bald cypress sloughs. When the recording boxes were downloaded in August, it was found that much of the soil moisture data was corrupted, and thus cannot be used in the analysis. During the flooding period, it can be assumed that all soil moisture sensors read zero.

Effect of High Pulse Release #4 on Soil Moisture – September-October 2016

A fourth high pulse event occurred over a 20 day period from September 17, 2016 to October 7, 2016. The highest recorded discharge was 1,410 cfs which occurred on September 30, 2016. This discharge was the lowest of the four high pulse releases that have occurred during the study period. The time prior to this release had very low rainfall amounts with drought-like conditions. Recorded rainfall during this high pulse release at the three precipitation measuring stations was

Big Cypress Bayou - 0.58 inches, Little Cypress Bayou – 0.46 inches, Black Cypress Bayou – 1.13 inches.

Figure 7. Release (cfs) of water from the Lake O' the Pines into Big Cypress Bayou, September – October 2016



Soil moisture data for this high pulse release is available for the Locke site and Sanders site but not the Thomas site. As shown in Table 10 , the high pulse release of about 1,400 cfs had minimal effect on soil moisture. The soil in the bald cypress habitat was already saturated, thus no effect was seen. The soil in the water oak habitat lost moisture during the high flow period. The soil moisture in the overcup oak and the willow oak habitats became slightly wetter after a delay of about of five days.

Table 10. Daily Average Soil Moisture at the Sanders Site, September 24 – October 14, 2016

Date	Bald Cypress	Overcup Oak	Willow Oak	Water Oak	Comments
9/24	1	27	49	74	
9/25	1	27	50	77	
9/26	1	28	51	80	
9/27	1	28	51	84	
9/28	0	28	52	86	
9/29	0	29	52	89	Peak flow
9/30	0	29	52	92	Peak flow
10/1	0	28	52	94	

10/2	0	28	53	96	
10/3	0	26	54	99	
10/4	0	23	54	101	
10/5	0	11	44	103	rain
10/6	1	0	33	106	
10/7	1	0	18	109	
10/8	1	0	1	110	
10/9	1	1	2	107	
10/10	1	1	2	102	
10/11	1	0	1	100	
10/12	0	0	1	98	
10/13	0	0	1	95	
10/14	0	0	1	90	

At the Locke site, the soil moisture in the four habitats was not affected by the high pulse flow (Table 11).

Table 11. Daily Average Soil Moisture at the Locke Site, September 24 – October 14, 2016

Date	Bald Cypress	Overcup Oak	Willow Oak	Water Oak	Comment
9/24	4	4	32	53	
9/25	4	4	34	52	
9/26	4	5	36	52	
9/27	4	5	38	51	
9/28	4	5	39	50	
9/29	3	5	40	49	peak flow
9/30	3	5	40	49	peak flow
10/1	3	5	41	47	
10/2	2	5	42	44	
10/3	3	6	43	42	
10/4	2	6	44	42	
10/5	3	6	44	41	rain
10/6	2	6	46	41	
10/7		7	48	42	
10/8		7	50	43	
10/9		7	52	43	
10/10		7	54	44	
10/11		8	56	44	
10/12		8	58	45	
10/13		8	60	45	
10/14		8	62	46	

Why there was a small effect seen at the Sanders site but not the Locke site is unknown. Possible factors are small differences in the relative heights of the sites above the creek water level or soil differences that exist at the two sites.

Summary and Conclusions

The weather conditions during the past few years have limited the ability to following the environmental flow recommendations, but the results obtained so far allows for some conclusions to be drawn. During the next several years, soil moisture data and water well data will be continued to be collected and analyzed.

1. The data show that a pulse release of 2,000 cfs or less does not result in water leaving the river channel and inundating the Big Cypress Bayou floodplain below Lake O' the Pines. However, this release level causes a small but measureable increase in soil moisture in the floodplain.

2. The data show that a pulse release of 3,000 cfs results in river water leaving the channel and completely inundating the Big Cypress Bayou floodplain below Lake O' the Pines. The soil moisture in all four plant community types are fully saturated.

3. The data suggest that the soils dry out more slowly in the winter and spring months and more quickly in the summer months.

4. Detailed elevation data is needed at the three sites in order to see if small differences in elevation can account for the soil moisture differences among the three sites.

5. Soil composition and chemistry is needed at the three sites in order to see if small differences in these variable can account for the soil moisture differences among the three sites and among the four habitat types.