TECHNICAL MEMORANDUM

Date:	March 1, 2017
To:	Brain Lockwood, PVWMA
From:	Jesse Barker, MS, PE; Chris Hammersmark, PhD, PE
Project:	15-1031 – College Lake Hydrologic Monitoring for Water Year 2016
Subject:	Hydrologic Monitoring Results Summary

1 INTRODUCTION

cbec was hired by Pajaro Valley Water Management Agency (PVWMA) to perform hydrologic monitoring of components the College Lake system in Watsonville, California, during the water year of 2016. This monitoring effort builds upon a monitoring effort that was initiated by cbec in 2012 (as documented in cbec, 2014), with some gages that have been maintained by PVWMA previously. The monitoring program included the installation and maintenance of several water level gages within creek channels in the College Lake area, as well as flow measurements at select monitoring sites in order to develop rating curves in order to estimate hydrographs. Monitoring of the lake water level also allows the estimation of change in storage levels within the lake through time.

2 METHODS

Gaging was performed at six different locations representing the main inputs and outputs to and from College Lake. Gage locations are listed in Table 1 and also shown in Figure 1. Four of the locations were previously installed and monitored through cbec's previous project for the Resource Conservation District of Santa Cruz County (cbec, 2014), and one location (Gage #1 - Pump House) has been monitored previously by PVWMA. The Paulsen Creek[1] Gage (Gage #6 on Figure 1) was added to the monitoring program in this round of monitoring.

New In-Situ Rugged TROLL 100 gages were installed at all sites except the Pump House site received a new Aqua TROLL 200. Both types of gages record pressure and water temperatures. Pressure readings were converted to water depth estimates using a correction from a barometric gage located at the pump house. Staff plates were also installed at all gaging locations. Staff plates were referenced to the North American Vertical Datum of 1988 (NAVD88). Elevations were corrected based on the NGS benchmark GU4185 on the North West sidewalk of the Highway 152 Bridge over Corralitos Creek. All

[1] Paulsen Creek (formerly un-named) is fed by the small neighborhood watershed upstream. It is the smallest gaged contributor to College Lake but typically has small flows year-round.

gages were installed in November, 2015 except the Paulsen Creek gage, which was installed in December, 2015.

Discharge measurements were taken at various levels of stage to construct stage/discharge rating curves at the Casserly, Fairgrounds, Pinto, and Paulsen Creek gaging locations. Discharge measurements were collected using a Sontek FlowTracker acoustic Doppler velocimeter. Channels were discretized into 10-20 horizontal bins (depending on the channel size). Discharge was estimated for each bin based on water depth and water velocities measured at 0.6 times the water depth. Discharge for each bin was then summed to produce the total discharge for the channel. Discharge measurements were not taken at the Pump House or Salsipuedes gages due to bidirectional flow that occurs at these locations, precluding the development of a deterministic stage discharge relationship.

Table 1 – Gaging locations and staff plate elevations

Gage Number	Location Name	Northing*	Easting*	Staff Plate Datum Elevation, ft**
0	Baro Logger	1,803,304.64	6,198,178.38	NA
1	Pump House	1,803,304.64	6,198,178.38	43.17
2	Casserly Creek	1,808,989.26	6,197,583.86	64.18
3	Salsipuedes Creek	1,802,144.98	6,198,267.85	58.01
4	Fairgrounds Creek	1,807,671.81	6,200,153.80	84.54
5	Pinto Creek	1,802,714.37	6,196,411.50	70.55
6	Paulsen Creek	1,808,632.59	6,193,798.87	63.53

**Coordinates are in California State Plane Zone 3 feet. Elevations are in NAVD88 feet.*

***Elevation is referenced to 0' reading on associated staff plates*

Lake storage was estimated using water levels measured at the Pump House and a hypsometric curve (Figure 2) for the lake. Using a mass balance approach, the lake storage and upstream inflows were differenced to produce an estimate for unaccounted discharge/input to College Lake.

3 RESULTS

Monitoring started on November 6th, 2015 and lasted until the most recent download conducted on the 13th of October, 2016. The lake area received an estimated 26.7 inches of precipitation during the 2016 water year (CIMIS Gage #111, located near the intersection of Green Valley Road and Holohan Road). Table 2 shows a list of the most significant storms with the associated lake storage and Casserly Creek discharge.

Discharge measurements were made at a range of flows at Casserly, Fairgrounds, Pinto, and Paulsen Creeks. Discharges were measured on six different dates ranging from dry/low flow conditions to average flows and all the way up to flood stages. When discharge measurements were conducted on days with flood flows, a series of discharge measurements were taken typically during the recession limb of the hydrograph. Measuring discharge was limited by accessibility and safety which made measurements in the highest flows unfeasible at some sites.

Table 2 – Storm data with associated flows and lake storage

Start Date	Duration, days	Precipitation, in	Casserly Creek Discharge for Duration Shown, AF	Max College Lake Storage, AF*
12/10/2015	1	0.71	9.7	88.9
12/13/2015	1	0.73	16.8	146.2
12/21/2015	1	0.83	47.5	152.2
1/5/2016	2	2.45	180.3	681.7
1/18/2016	2	2.37	573.1	2171.4
1/22/2016	2	1.42	254.1	2720.0
2/17/2016	1	0.63	17.9	1608.8
3/5/2016	3	5.35	902.9	3157.3
3/11/2016	1	0.56	116.8	2367.1
3/13/2016	1	1.72	464.7	3371.5

**Lake storage represents the maximum during the period of the storm.*

3.1 Monitoring Challenges

There were some issues and challenges faced in the monitoring. The Fairgrounds Creek gage was disturbed initially by equipment yard activity at the location of the install. The gage was re-installed but again dislodged during high flows prior to January 18th, 2016 when it was re-installed at its current location.

The gage located at the Pump House was inadvertently removed from the water and therefore no data were recorded for the period from December 18th, 2015 to February 16th, 2016. Luckily, staff plate observations (Kittleson, 2016), storm statistics (CIMIS Gage #111, 2016) and Salsipuedes Creek gage data were used to create a reasonable approximation of stage at the Pump House during this period (Figure 3).

The Casserly Creek gage also experienced some problems. First, during larger storm events, Casserly Creek experienced significant out of bank flows (Figure 4). This meant that the current location of the gage was not able to capture the full magnitude of flows coming from the Casserly Creek watershed. Additionally, as College Lake approached its maximum storage levels, the gage on Casserly Creek, as well as the gage on Paulsen Creek, experienced backwatering which temporarily affected the stage/discharge relationships. Finally, as flows travel under the Paulsen Road Bridge, the channel widens significantly and the area is characterized by the deposition of sediment and debris. This sediment is typically cleared in the late summer or early fall, based upon review of the stage records for Casserly Creek. The gage is within the effected, back watered area this sediment/debris deposition creates (Figure 5). The buildup and clearing of the sediment affected the water level at the gage which dropped by almost one foot following clearing. This provides challenges for developing a hydrograph at the low end of the rating curve.

3.2 Stage Discharge Relationships

Because of the changing nature of channel conditions on Casserly Creek, a suite of stage/discharge rating curves were used depending on stage and channel conditions. Table 3 describes how the equations were applied and Figure 6 shows the three rating curve lines along with the measurements.

Table 3 – Casserly Creek stage/discharge rating curves

Condition	Stage, NAVD88 ft	Rating Curve Equation
Low Flows with Sediment Removed	65.4 to 66.16	Q = 24.326 * h - 1599.1
Medium Flows with Sediment Removed	66.16 to 68.0	$Q = 25.333 * h^2 - 3{,}340.673 * h + 110{,}137.875$
Low and Medium Flows with Sediment Buildup	66.5 to 68.0	$Q = 5.154 * h^2 - 611.646 * h + 17{,}872.02$
High Flows	≥ 68.0	Q = 83.749 * h - 5,579.123

**Values in equations have been truncated.*

A more traditional approach was used to develop the stage/discharge relationships for Fairgrounds, Paulsen, and Pinto Creeks (Figure 7). Fairgrounds and Paulsen Creeks used quadratic best fit lines. Pinto creek used two linear, best fit lines to create the stage discharge curve. All stage plots and resulting hydrographs are provided in Appendix A – Stage Plots and Hydrographs.

3.3 Water Budget for College Lake

Total storage in the lake was estimated based on the gaged water surface elevation at the Pump House and the hypsometric curve previously developed by cbec (2014) (Figure 8). The maximum storage for the 2016 water year, approximately 3371 acre-feet, occurred on March 14th, 2016. Discharge volumes were computed for each gaged tributary to College Lake using the measured stage and the corresponding stage/discharge relationship. Additional inflow to College Lake, primarily backflow from Corralitos Creek upstream through Salsipuedes Creek, was calculated via mass balance. Some of the additional inflow to College Lake may have also been out of bank flows from Casserly Creek. Because of the issues with the Fairgrounds Creek gage, the mass balance calculations began on the 18th of January, 2016.

A majority of the water coming into College Lake was from Casserly Creek (67.3%). Other sources (i.e. out of bank flows, upstream flow from Corralitos Creek, direct runoff and rainfall) accounted for the second largest amount (25.1%). It is difficult to say how much of this water was coming from Corralitos or out of bank flow from Casserly but is nonetheless a significant portion of the inflow. Pinto, Paulsen, and Fairgrounds Creeks account for the remaining 7.6%. Pinto Creek flows were only counted when flow was towards the lake (i.e., stage at Salsipuedes Gage was greater than the weir elevation [59.627 ft] and greater than the stage at the pump house).

4 RECOMMENDATIONS

cbec recommends that monitoring continue in the College Lake system. The monitoring infrastructure is already in place, and the data are a valuable resource for planning efforts. Specifically, we recommend that an additional gage be installed upstream of the existing gage on Casserly Creek. As outlined in this report, the current gage location experiences backwater conditions from the lake, changing water levels due to sediment buildup/clearing downstream of the Paulsen Road Bridge, and out of bank flows. The new gage should be located upstream of the location where flows typically overtop the banks but downstream of the agricultural access bridge. Both Casserly Creek gages should be left in place to correlate stage/discharge rating curves for lower flows. It is also recommended that flow monitoring continue on Casserly Creek for larger storm events (i.e., > 130 cfs) to further improve stage/discharge rating curves and more accurate water accounting.

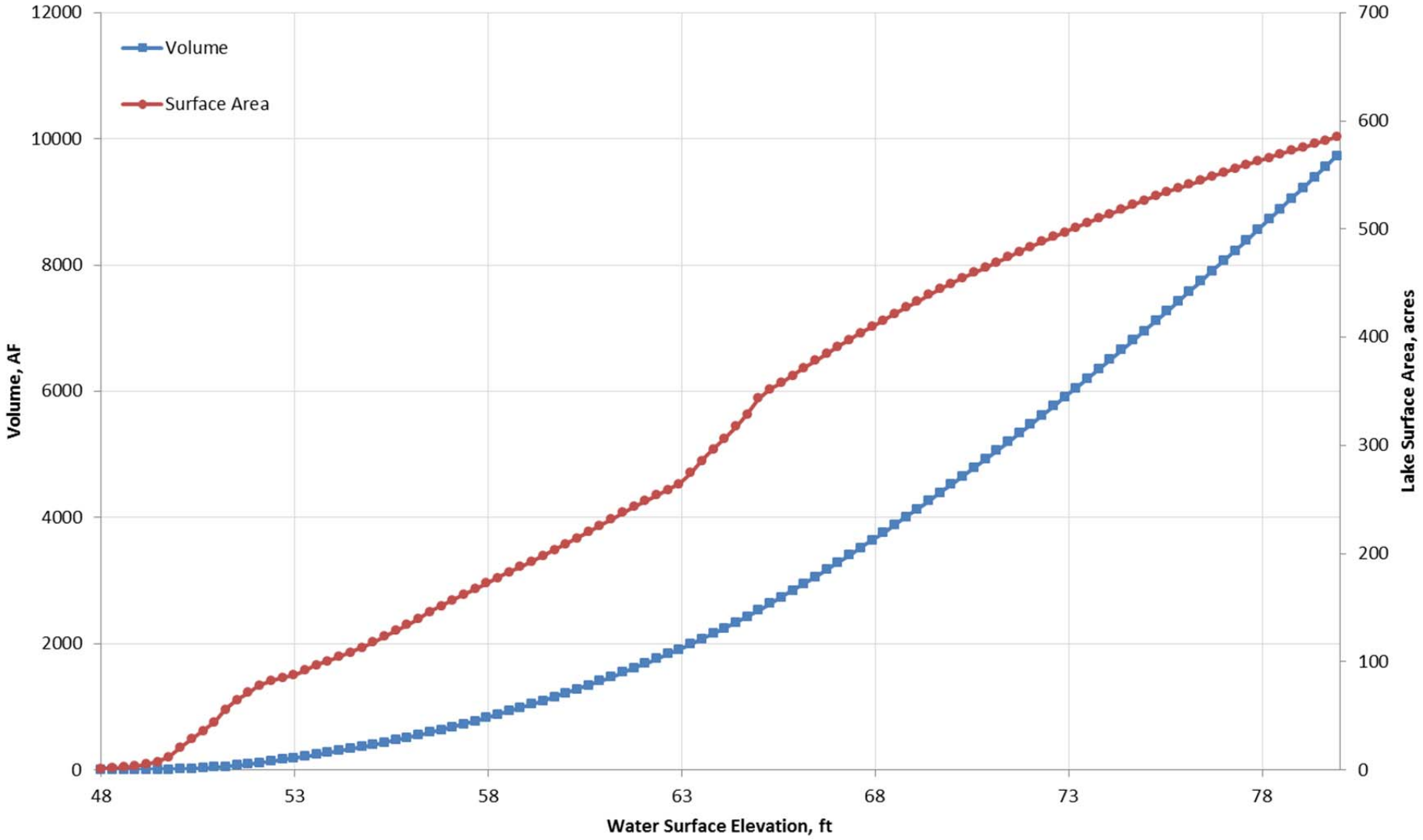
5 REFERENCES

California Irrigation Management Information System (CIMIS). 2016. California Department of Water Resources – Gage Number 111, Green Valley Road, Monterey Bay, Santa Cruz County. http://wwwcimis.water.ca.gov/WSNReportCriteria.aspx. accessed October X, 2016.

cbec, inc. November, 2014. College Lake Multi-Objective Management Project Final Report. Prepared for Resource Conservation District of Santa Cruz County, with assistance from Mike Podlech and Gary Kittleson. submitted November 14, 2014.

Kittleson, Gary. 2016. Kittleson Environmental Consulting – Provided College Lake staff plate readings recorded during bird surveys. Santa Cruz, California.

Notes:	cbec eco engineering	**Figure 1 – Gaging sites**	
		College Lake Hydrologic Monitoring for Water Year 2016	
		Project No. 15-1031	Created By: JRB

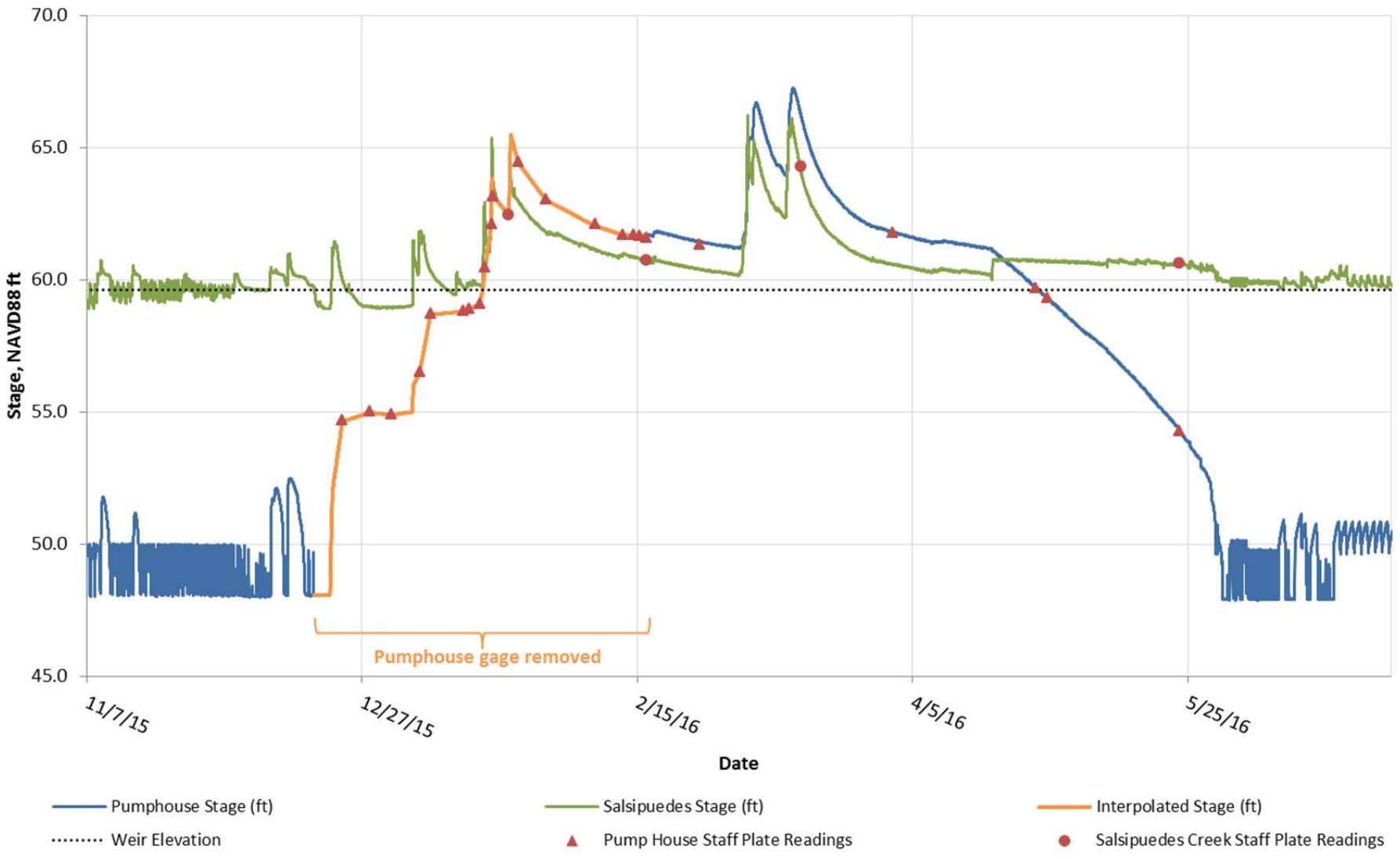


Notes:
Source: cbec, 2014.

Figure 2 – College Lake hypsometric curve

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB



Notes:

Figure 3 – Stage at pump house and Salsipuedes Creek

College Lake Hydrologic Monitoring for Water Year 2016

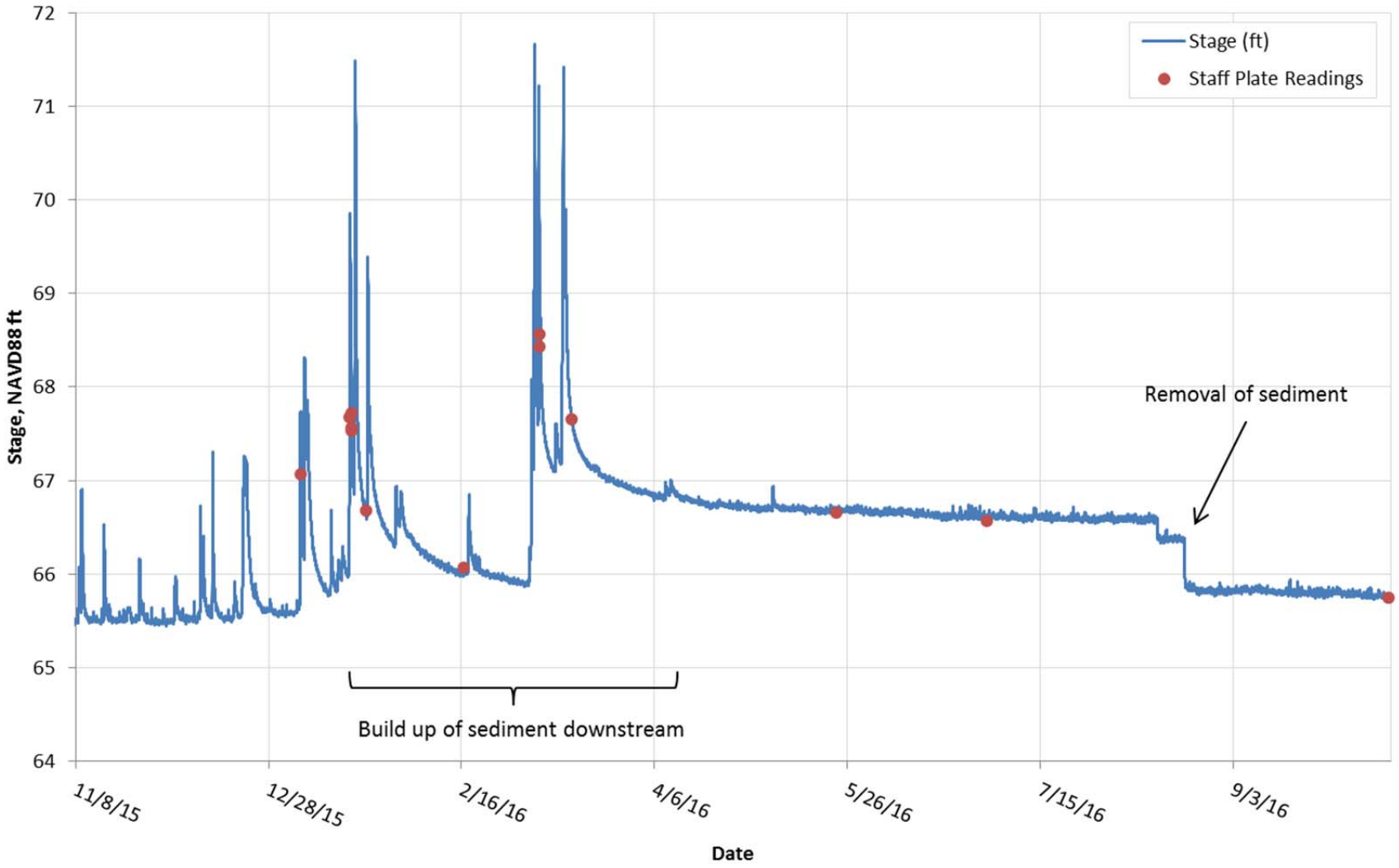
Project No. 15-1031 | Created By: JRB

Notes:
Photo credit: Jesse Barker

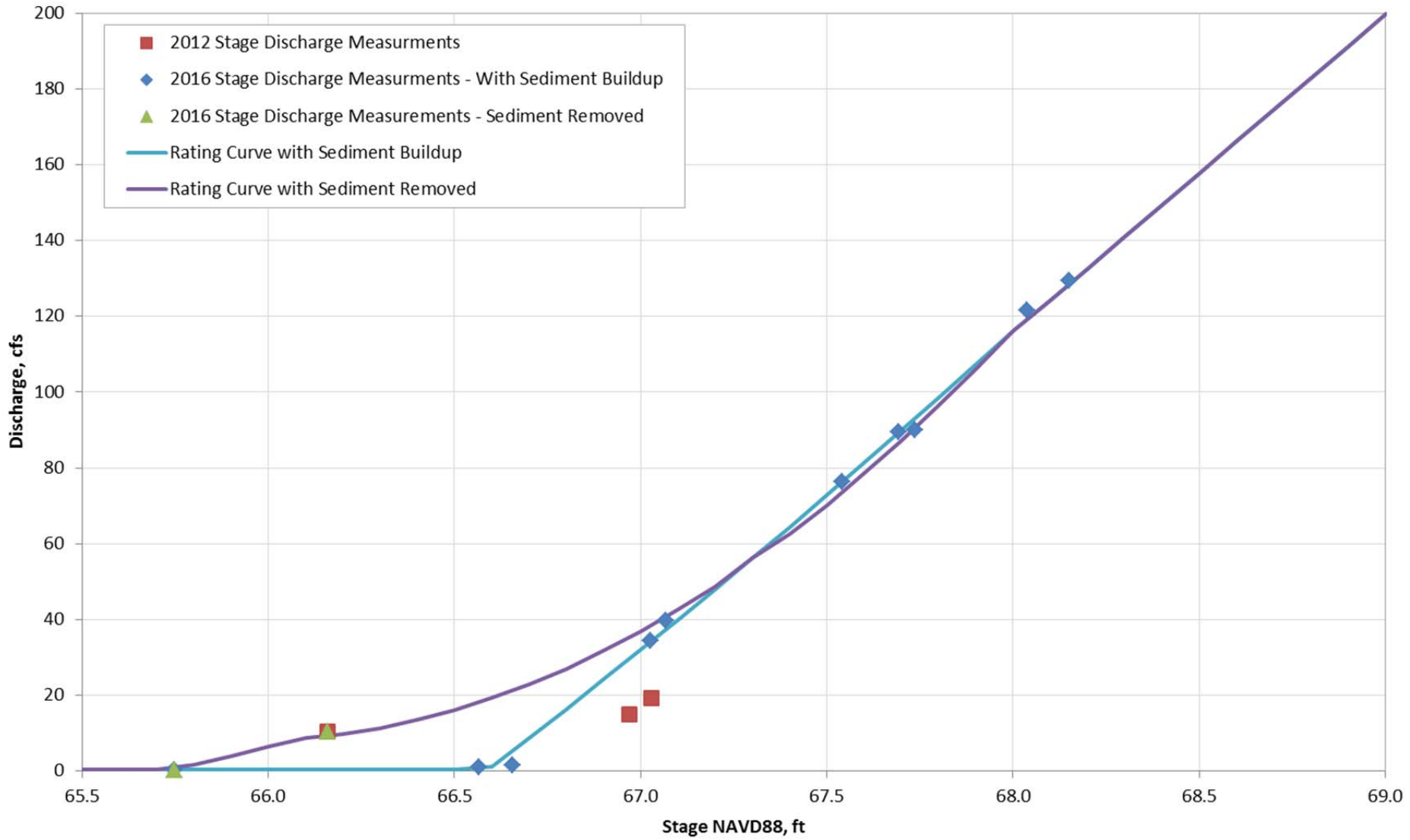
Figure 4 – Out of bank flows at Casserly Creek

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB



Notes:		**Figure 5 – Measured stage at Casserly Creek**	
		College Lake Hydrologic Monitoring for Water Year 2016	
		Project No. 15-1031	Created By: JRB

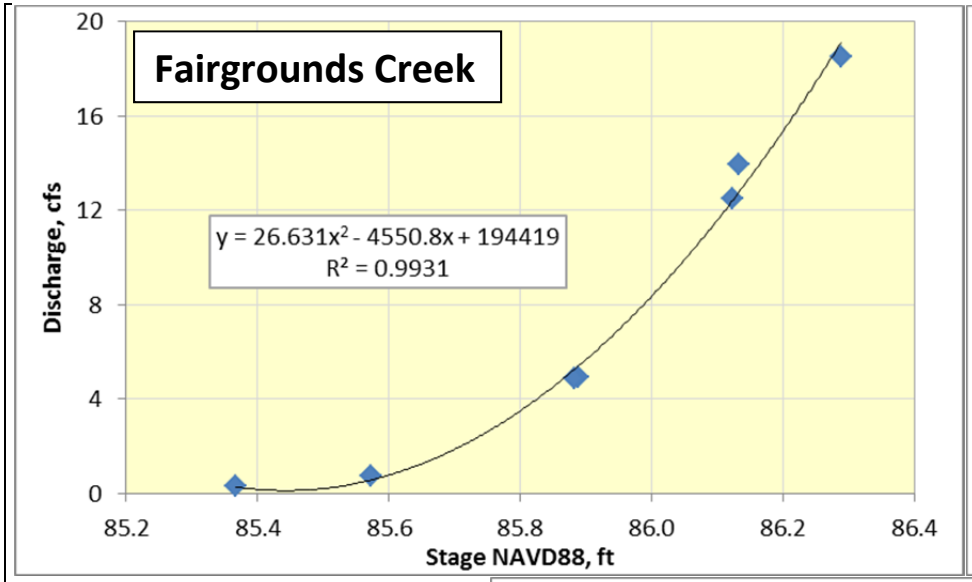


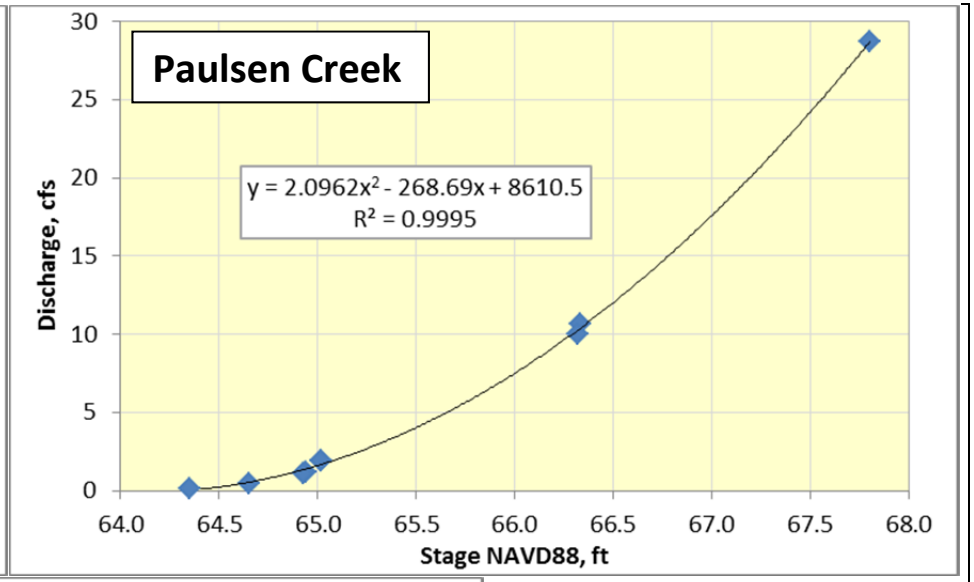
Notes:

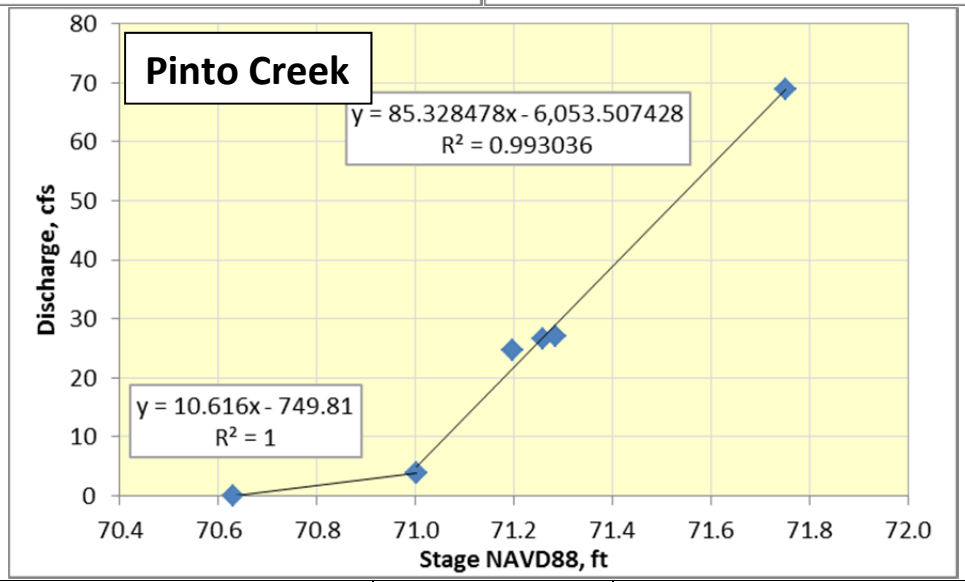
Figure 6 – Stage/discharge curve for Casserly Creek

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB





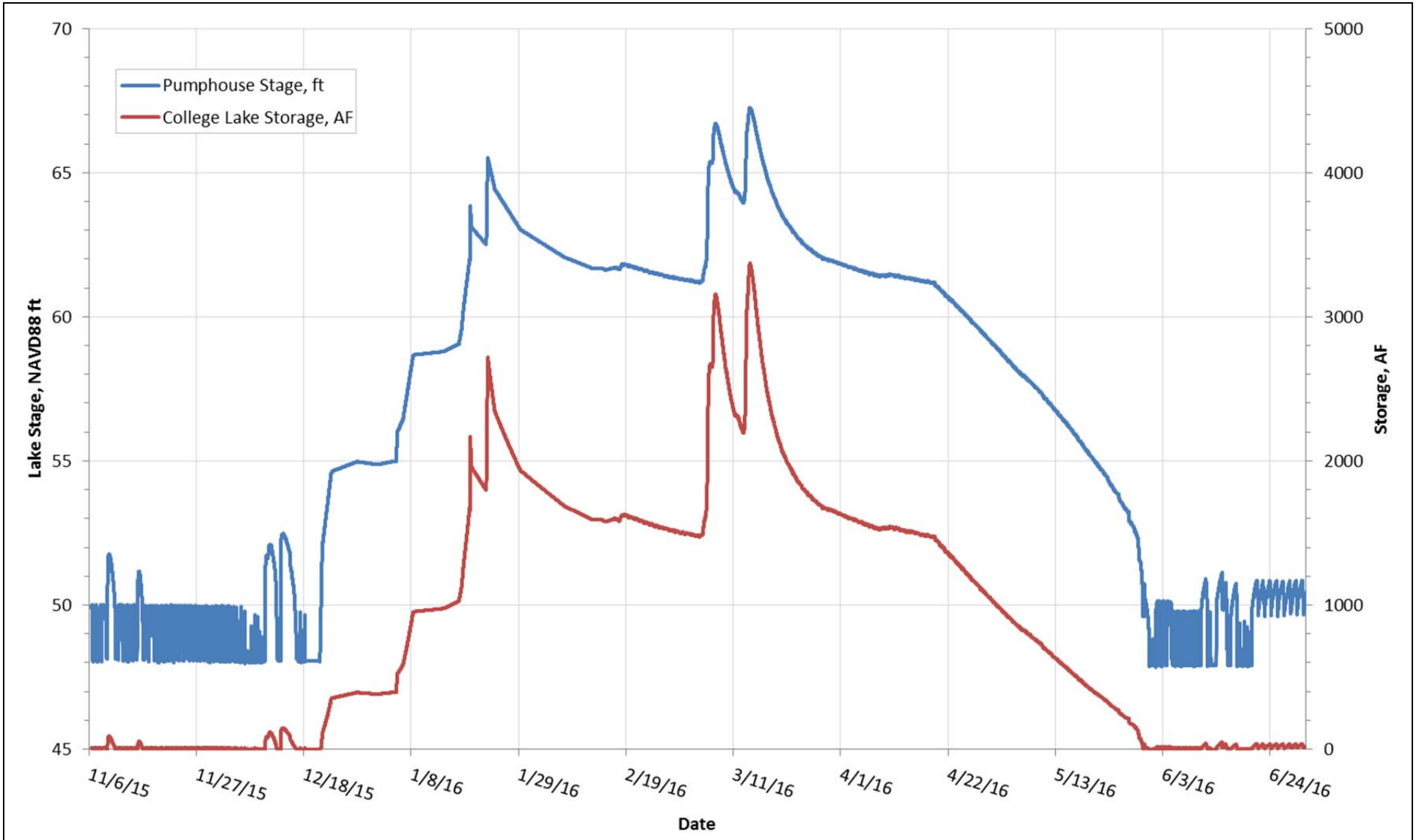


Notes:

Figure 7 – Stage/discharge curves for Fairgrounds, Paulsen, and Pinto Creeks

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031	Created By: JRB

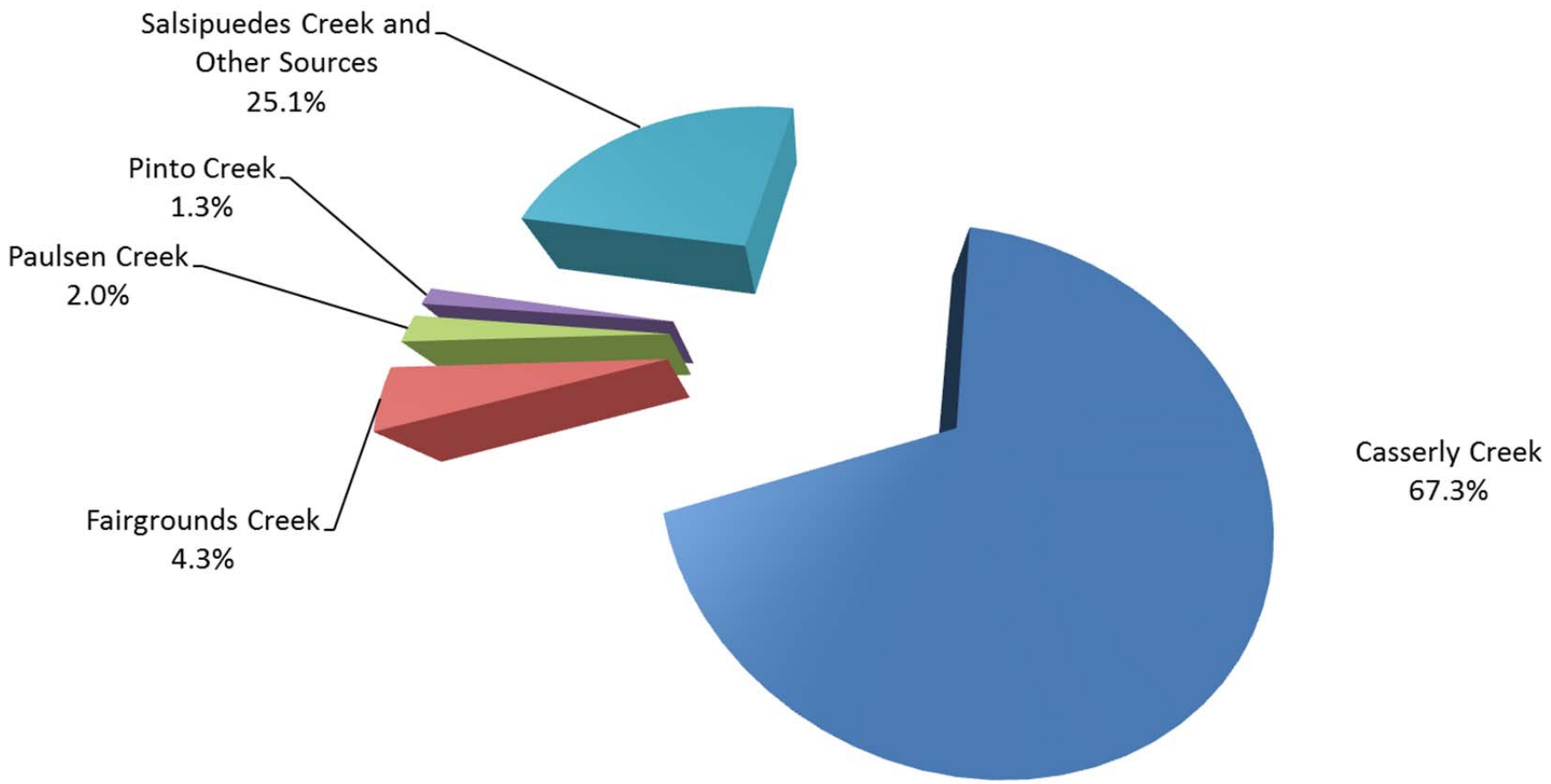


Notes:

Figure 8 – Pump House stage and estimated storage

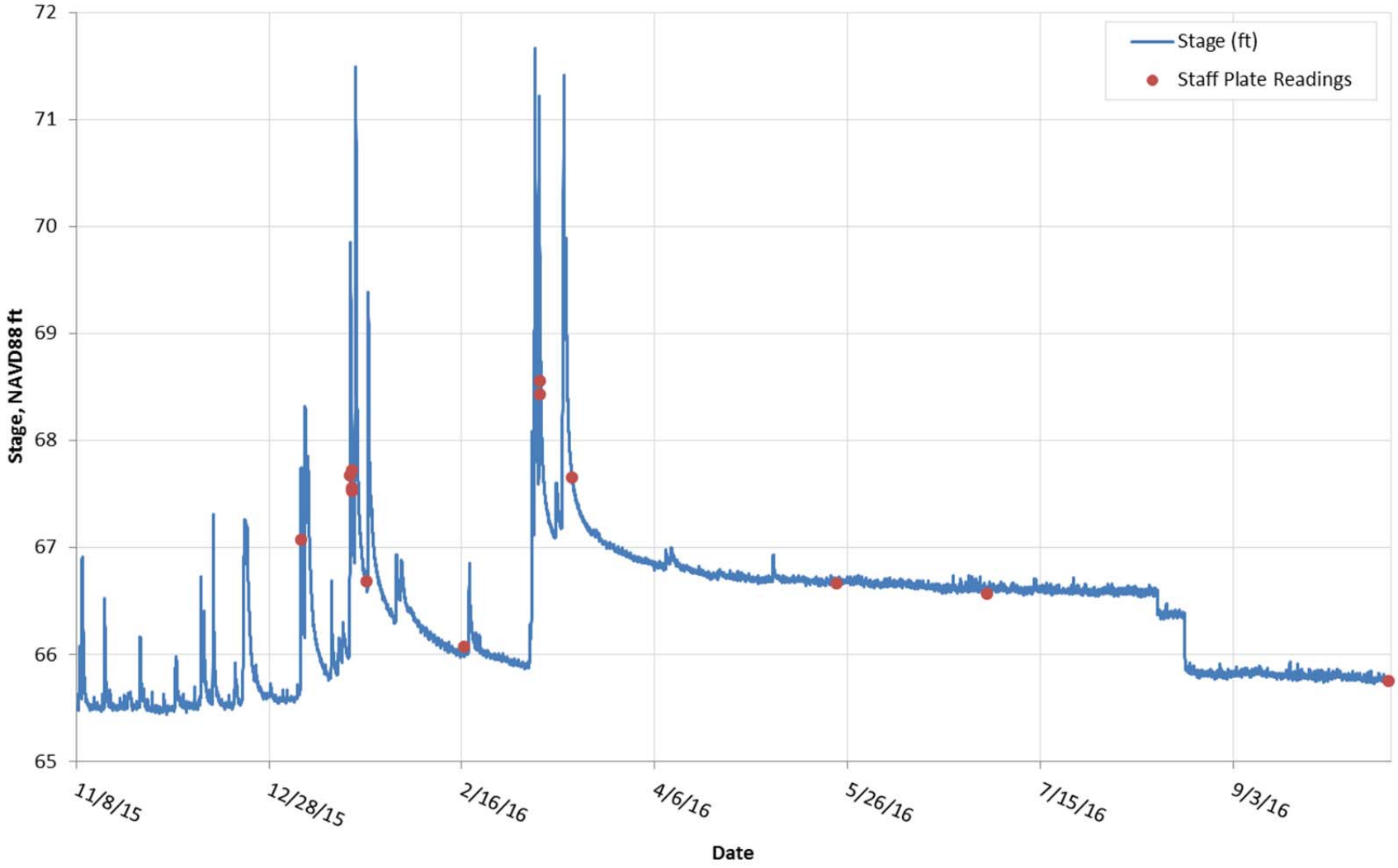
College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB



Notes:		**Figure 9 – Inflow sources to College Lake**	
		College Lake Hydrologic Monitoring for Water Year 2016	
		Project No. 15-1031	Created By: JRB

APPENDIX A – STAGE PLOTS AND HYDROGRAPHS

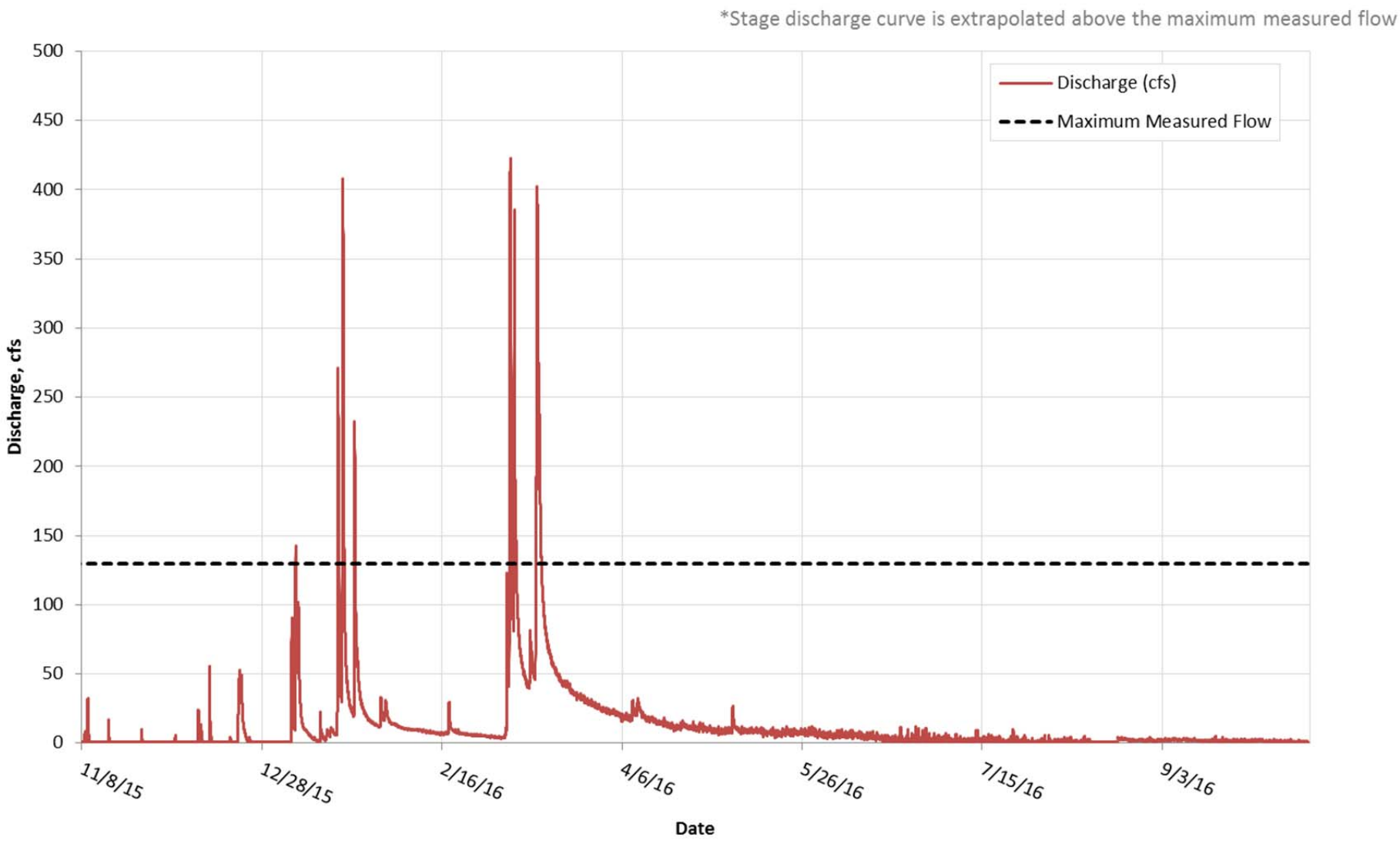


Notes:

Figure 0-1 – Casserly Creek Stage

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB

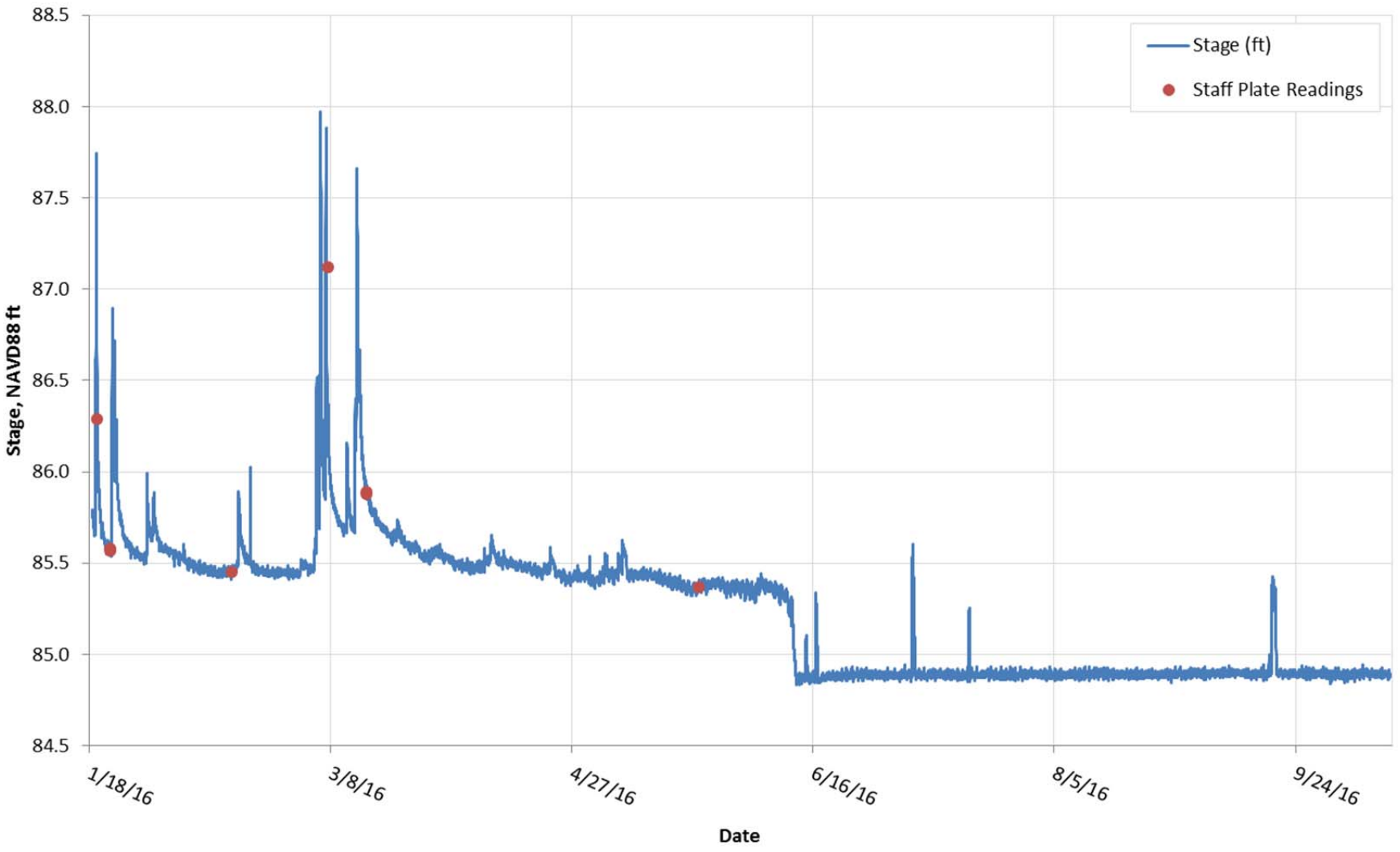


Notes:

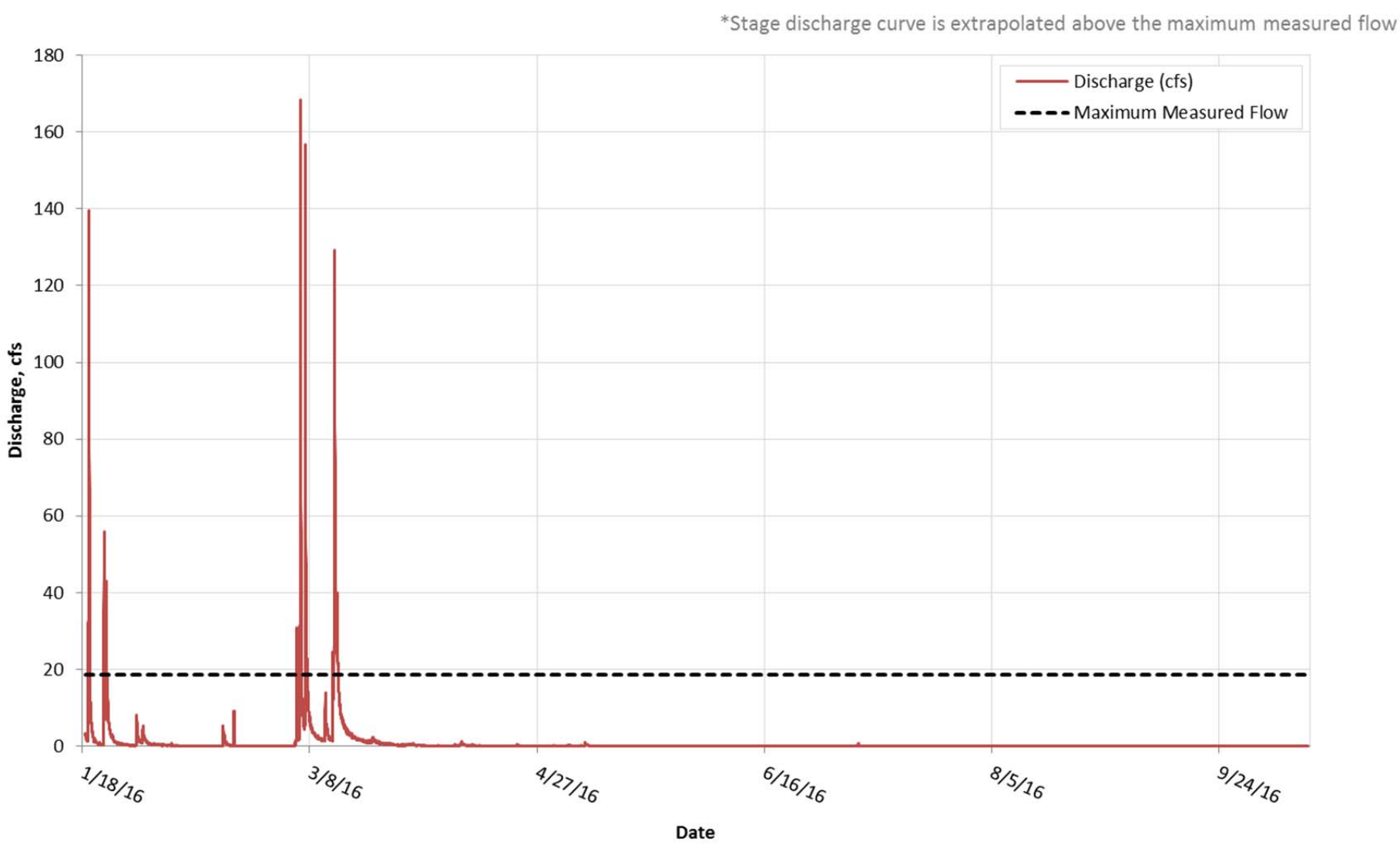
Figure 0-2 – Casserly Creek Discharge

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB



Notes:		**Figure 0-3 – Fairgrounds Creek Stage**	
		College Lake Hydrologic Monitoring for Water Year 2016	
		Project No. 15-1031	Created By: JRB

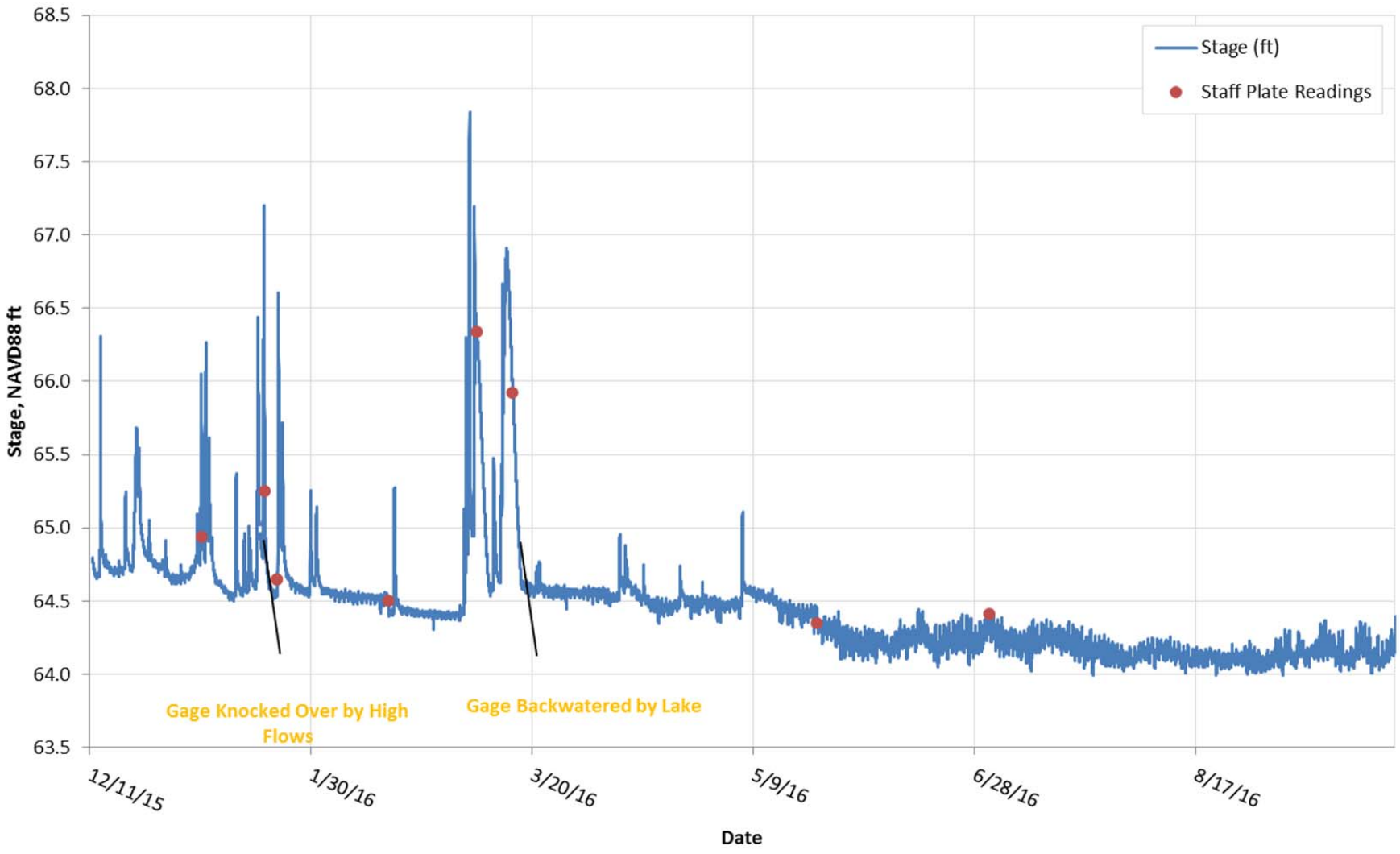


Notes:

Figure 0-4 – Fairgrounds Creek Discharge

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB

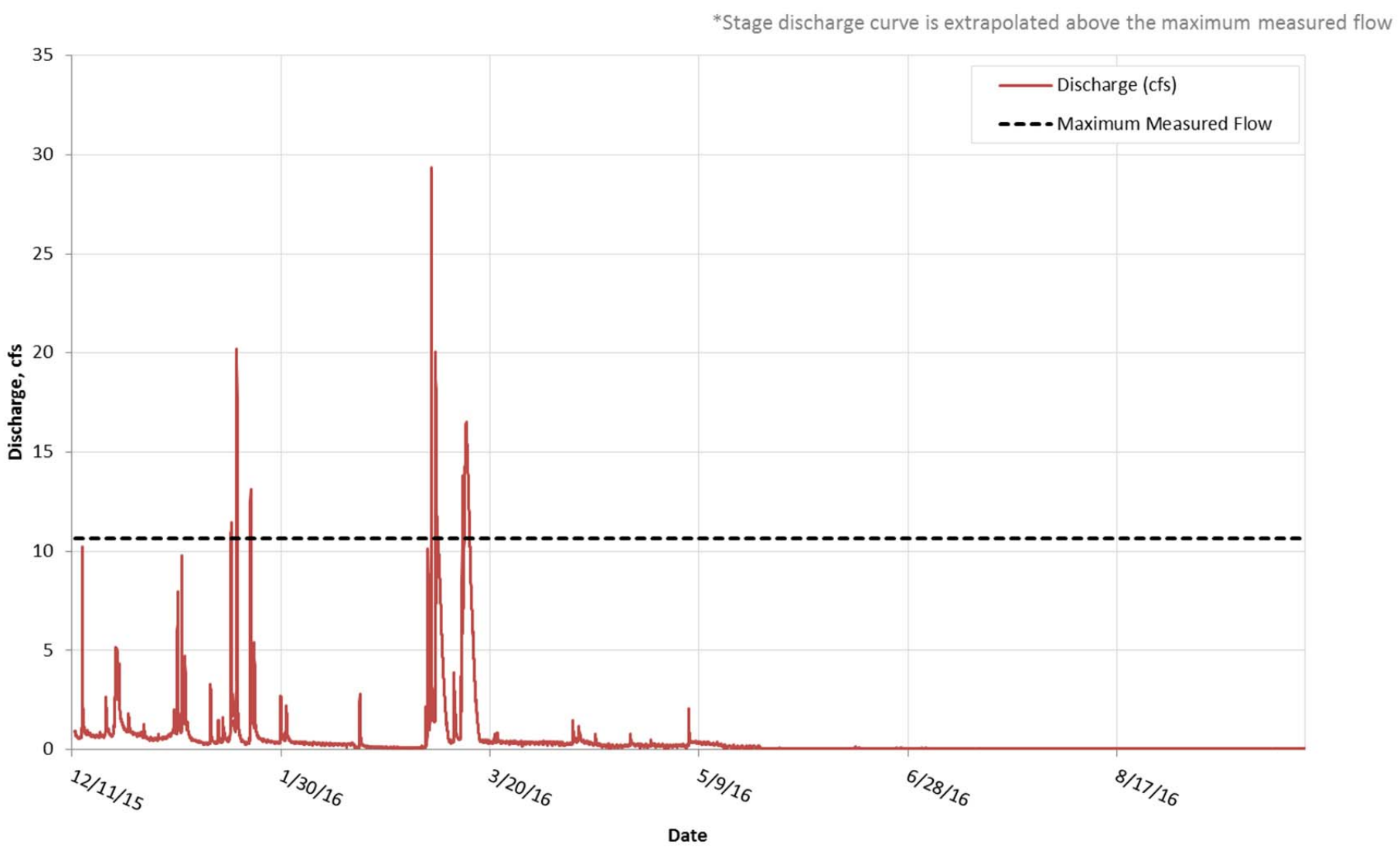


Notes:

Figure 0-5 – Paulsen Creek Stage

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB

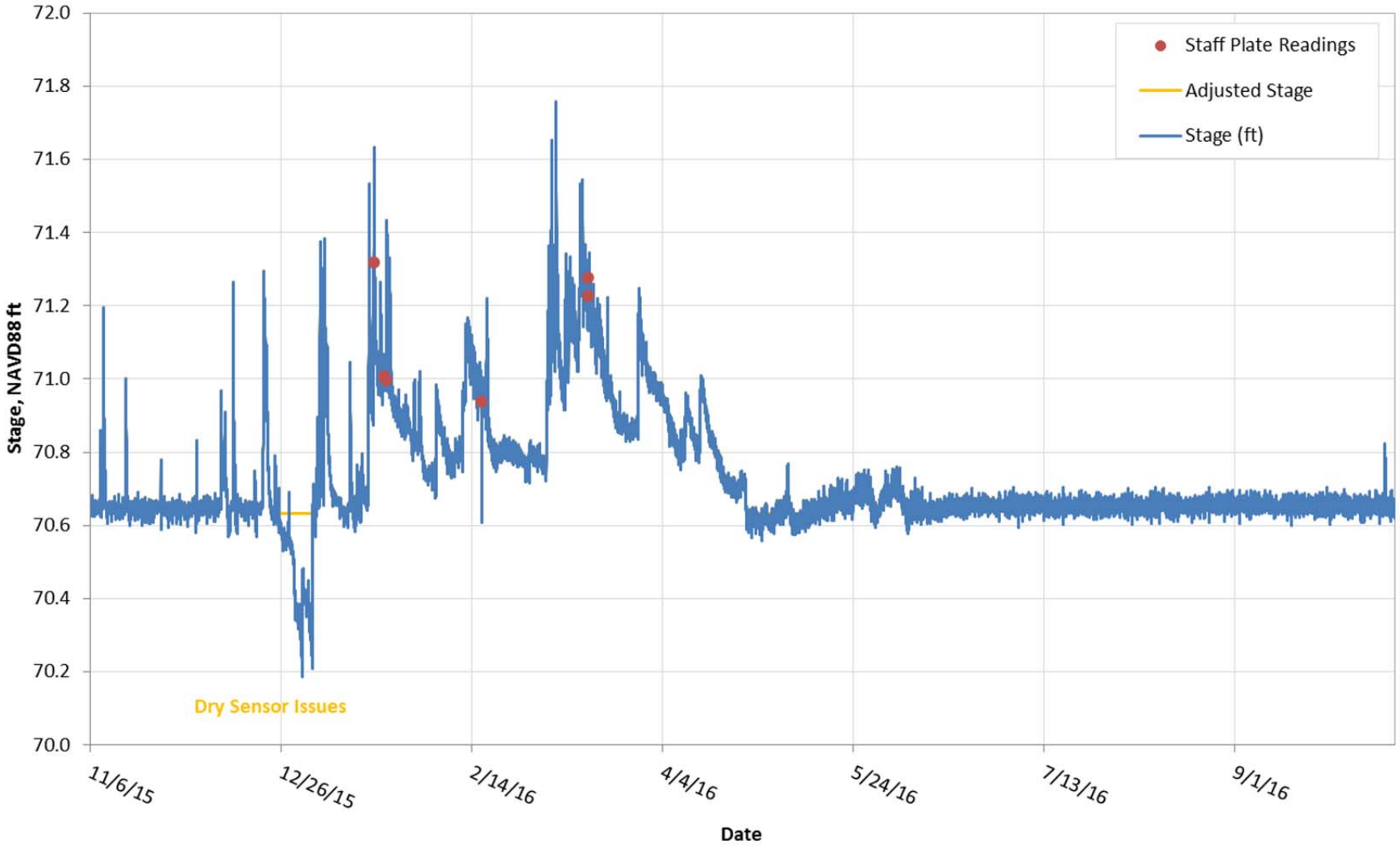


Notes:

Figure 0-6 – Paulsen Creek Discharge

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB

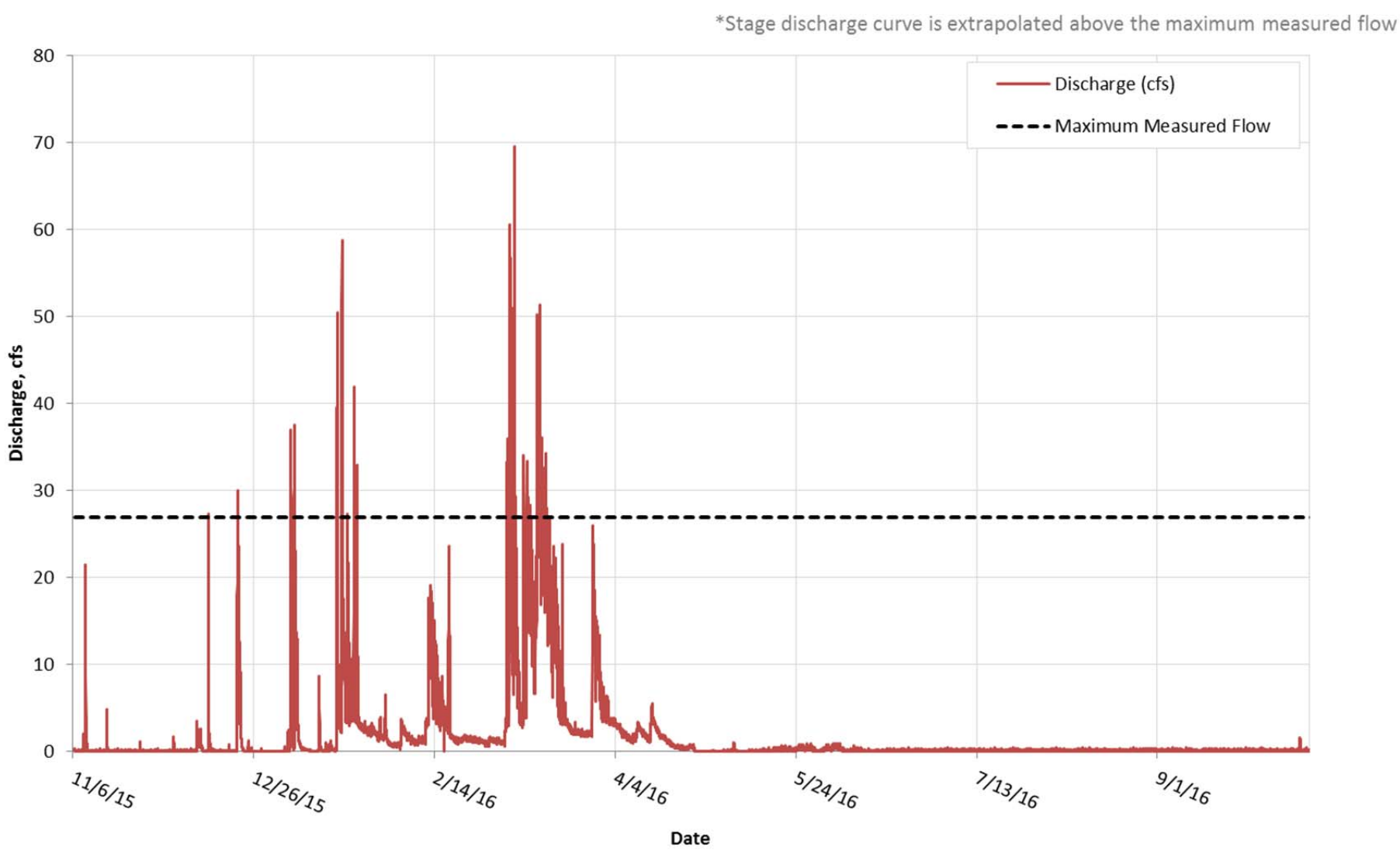


Notes:

Figure 0-7 – Pinto Creek Stage

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB

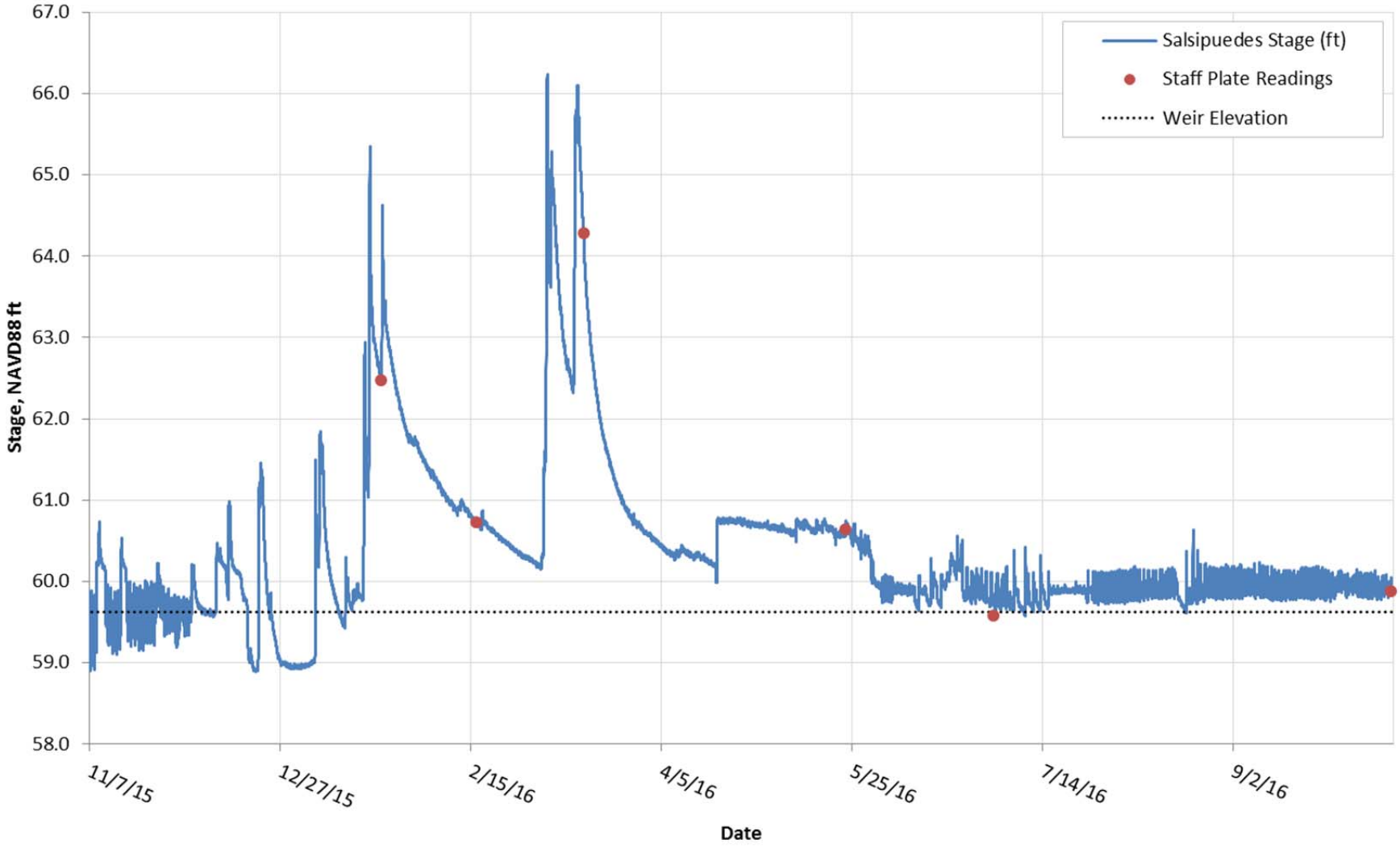


Notes:

Figure 0-8 – Pinto Creek Discharge

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB

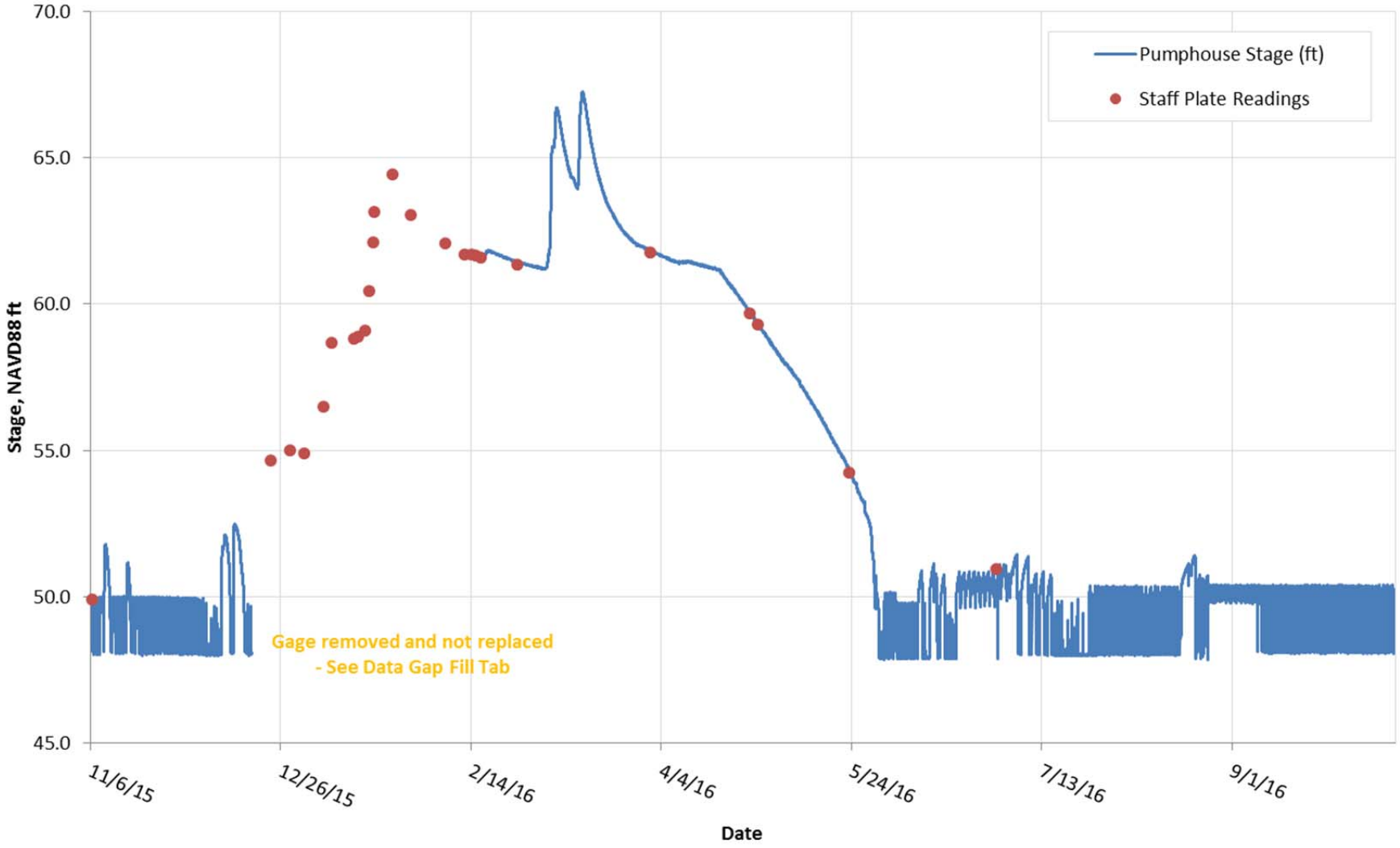


Notes:

Figure 0-9 – Salsipuedes Creek Stage

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031	Created By: JRB



Notes:

Figure 0-10 – Pump House Stage

College Lake Hydrologic Monitoring for Water Year 2016

Project No. 15-1031 | Created By: JRB