TECHNICAL MEMORANDUM

Date:	12/20/19
To:	Brian Lockwood and Casey Meusel; PV Water
From:	Chris Hammersmark, Chris Connor and Ben Taber; cbec eco engineering
Project:	17-1003-2 – College Lake Hydrologic Monitoring for Water Year 2018
Subject:	2018 Annual Hydrologic Monitoring Report

1 INTRODUCTION

cbec, inc. eco engineering (cbec) was hired by Pajaro Valley Water Management Agency (PV Water) to perform hydrologic monitoring of the College Lake system in Watsonville, California, during the 2018 water year (WY). This monitoring effort builds upon a monitoring effort that was initiated by cbec in 2012 (as documented in cbec, 2014), with some gages that were maintained by PV Water previously. The monitoring program included the maintenance of several water level gages within creek channels in the College Lake area, as well as flow measurements at select monitoring sites to develop new and validate existing stage-discharge rating curves to estimate hydrographs.

2 METHODS

Gaging was performed at seven different locations representing the main inputs and outputs to and from College Lake. Gage locations are listed in Table 1 and shown in Figure 1.

Pressure readings at each submerged gage were converted to water depth using a correction from a barometric gage (Gage #0) located at the College Lake Pump House. Staff plates were referenced to the North American Vertical Datum (NAVD88). Elevations were corrected based on the NGS benchmark GU4185 on the North-West sidewalk of the Highway 152 Bridge over Corralitos Creek. The water depth was then added to the gage elevation to produce the water surface elevation tied to NAVD88.

Discharge measurements were taken at various levels of stage to construct and/or update stage-discharge rating curves at the Casserly Upstream and Downstream (formerly Casserly East) gaging locations. Low and medium velocity measurements (where in-stream wading was possible) were collected using a Sontek FlowTracker acoustic Doppler velocimeter. Channels were discretized into 10 to 20 horizontal bins (depending on the channel size). Discharge was measured 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 Creek gages due to bidirectional flow that occurs at these locations, precluding the

development of a deterministic stage-discharge relationship. Discharge measurements were not collected during the 2018 water year at the Paulsen, Pinto and Fairground Creeks monitoring locations. Measurements at these sites were not collected because of the limited number of runoff events that occurred, the limited volume of inflow these creeks typically provide, and the previous data and rating curves that allow for a reasonable estimation of flow at these locations.

Table 1 – Gaging locations and staff plate elevations

Gage Number	Location Name	Northing*	Easting*	Staff Plate Datum Elevation, ft**
0	Barometric 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
7	Casserly Creek Upstream	1,810,648.60	6,197,924.09	67.95

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

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

High flow events were not measured for the 2018 WY, as no high flow events occured.

Lake Storage was estimated using water levels measured at the Pump House and a hypsometric curve (cbec, 2014) for the lake. The lake storage and upstream inflows were differenced to produce an estimate for unaccounted discharge/input to College Lake using a mass balance approach.

3 RESULTS

The monitoring period for this technical memorandum started on October 1st, 2017 and continued through May 30th, 2018. The lake area received an estimated 15.06 inches of precipitation during the 2018 water year (as recorded at City of Watsonville's Watsonville Waterworks gage; located on Freedom Blvd, near Blanca Lane). The precipitation was an estimated 66% of normal rainfall (NOAA, 2018). Table 2 shows a list of the most significant storms with the associated lake storage and Casserly Creek discharge volume. A majority of the precipitation (58%) occurred in March and April (8.62 inches) of 2018.

During the dry season, most tributary creeks (Paulsen, Fairgrounds, Pinto, Corralitos Creeks) are dry and/or not contributing significant amounts of inflow to College Lake. However, Casserly Creek conveys small amounts of flow through the dry season. The magnitude of these summer flows was not measured during the 2018 water year. The source of this dry season flow is likely agricultural return flow or baseflow discharge. Portions of Salsipuedes Creek between the College Lake weir and the confluence with Corralitos Creek remain wet throughout the year, and the water surface elvation varies with the pumping activities that allow for farming in College Lake through the summer.

Discharge measurements were made at Casserly Creek Upstream and Casserly Creek Downstream sites. Discharges were measured on two different dates at the Casserly Dowstream site with conditions ranging from low flow to medium stages (4 cfs to 202 cfs). Discharge was measured at the Casserly Upstream site at low flow stages (4 cfs).

Stage at the Pump House showed a maximum lake elevation of 62.17 ft (NAVD88) on March 24th 2018 at 4:15 am. Using this elevation, the maximum inundation extents of the lake were estimated (Figure 2). Based on the hypsometric relationships, the maximum storage and inundation area of the lake were roughly 1714 acre-feet (AF) and 277 acres respectively.

Table 2 – Storm data with associated flows and lake storage

Start Date	Duration, days	Precipitation, in	Casserly Creek Discharge Volume for Duration Shown[1], AF	Maximum College Lake Storage[2], AF
11/17/17	1	1.01	13.8	158.1
01/04/18	3	0.60	14.4	283.2
01/08/18	3	2.15	217.5	433.2
03/01/18	4	3.03	377.9	846.1
03/13/18	6	1.85	579.2	1182.3
03/21/18	3	2.15	889.2	1714.4
04/06/18	3	1.59	321.1	1626.7

Notes:

1 – The Casserly Creek discharge volume is provided because Casserly Creek is the most significant contributor of inflow to College Lake.

2 – Lake storage represents the maximum during the period of the storm.

3.1 Stage-Discharge Relationships

Casserly Creek did not experience sedimentation, nor did it appear that any channel maintenance activities occurred before the start of the water year. Therefore, the same stage discharge relation developed for the 2017 WY was applied to the 2018 WY. Table 3 provides equation tha was applied and Figure 3 shows the rating curve along with the measurements.

Table 3 – Casserly Creek stage-discharge rating curve

Condition	Stage Discharge Equation
All flows for WY 2018	$Q = 11.107 * h^2 - 1481.7 * h + 49287$

Note: Numerical values in equations have been truncated.

The same Stage/Discharge relationships presented in cbec's previous report (cbec, 2018) and shown in Figure 4, were also used to estimate hydrographs for Fairgrounds, Pinto, and Paulsen Creeks, as new flow measurements were not collected at these sites. Time series of water surface elevation and the flows estimated with the rating curves shown in Figures 3 and 4, are provided in Figures 5 through 9.

3.2 Water Budget for College Lake

Total storage in the lake was estimated based on the gaged water surface elevation at the Pump House gaged and the hypsometric curve previously developed by cbec (2014) (Figure 10). The maximum storage for the 2018 water year, approximately 1,714 AF, occurred on March 24, 2018. This maximum lake storage value was followed by one significant peak of 1,627 AF on April 8, 2018.

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.

The contribution of estimated inflow to College Lake (Figure 11) from the various sources was similar to the results from the 2016 and 2017 water year monitoring efforts (cbec, 2017; cbec, 2019). A majority of the water coming into College Lake (69%) was from Casserly Creek. Salsipuedes Creek and other sources (i.e., upstream flow from Corralitos Creek, local runoff, and direct rainfall) accounted for the second largest amount (23%). Paulsen creek accounted for 5% of inflow while Pinto and Fairgrounds Creeks accounted for the remaining 3%. Pinto Creek flows were only accounted for when flow in Salsipuedes Creek was towards the lake (i.e., stage at Salsipuedes Creek - Gage #3 was greater than the weir elevation [60.1 ft] and greater than the stage at the Pump House - Gage #1).

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 related to the proposed College Lake Integrated Resources Management Project. If PV Water wishes to reduce the resources dedicated to monitoring cbec would suggest that the gage on Pinto Creek be considered for removal. Pinto Creek only flows into College Lake during backflow events on Salsipuedes Creek. It has accounted for less than 2% of total inflow to College Lake in the past three years. However, if Pinto flows are considered relevant for discharges to Corralitos Creek then it is recommended that gaging continue. The gaging at Casserly creek should continue, as most of the inflow to College Lake occurs on Casserly Creek. If a reduction of monitoring resources is desired, the downstream gage could be discontinued, as it has been determined that the upstream gage more accurately represents the total inflow to the lake, due to the likelihood of out of bank flows occurring near Paulsen bridge.

Additionally, cbec recommends that monitoring be conducted concerning bank erosion and sediment aggradation in Casserly Creek. The accumulation of material in channel can lead to a loss of conveyance capacity in the channel and increased likelihood of out of bank flows which can impact agriculture, fish passage and vehicular accessibility via Paulsen Road. Presumably due to the sedimentation impacts on channel conveyance, channel clearing and removal of material (by unknown parties) has been observed around the Paulsen Road Bridge and is supported by previous monitoring efforts. Such channel alterations can have unanticipated ecological and hydraulic effects, therefore documentation of geomorphic changes could assist in characterizing the system and assist in better management and stewardship of the watershed.

5 REFERENCES

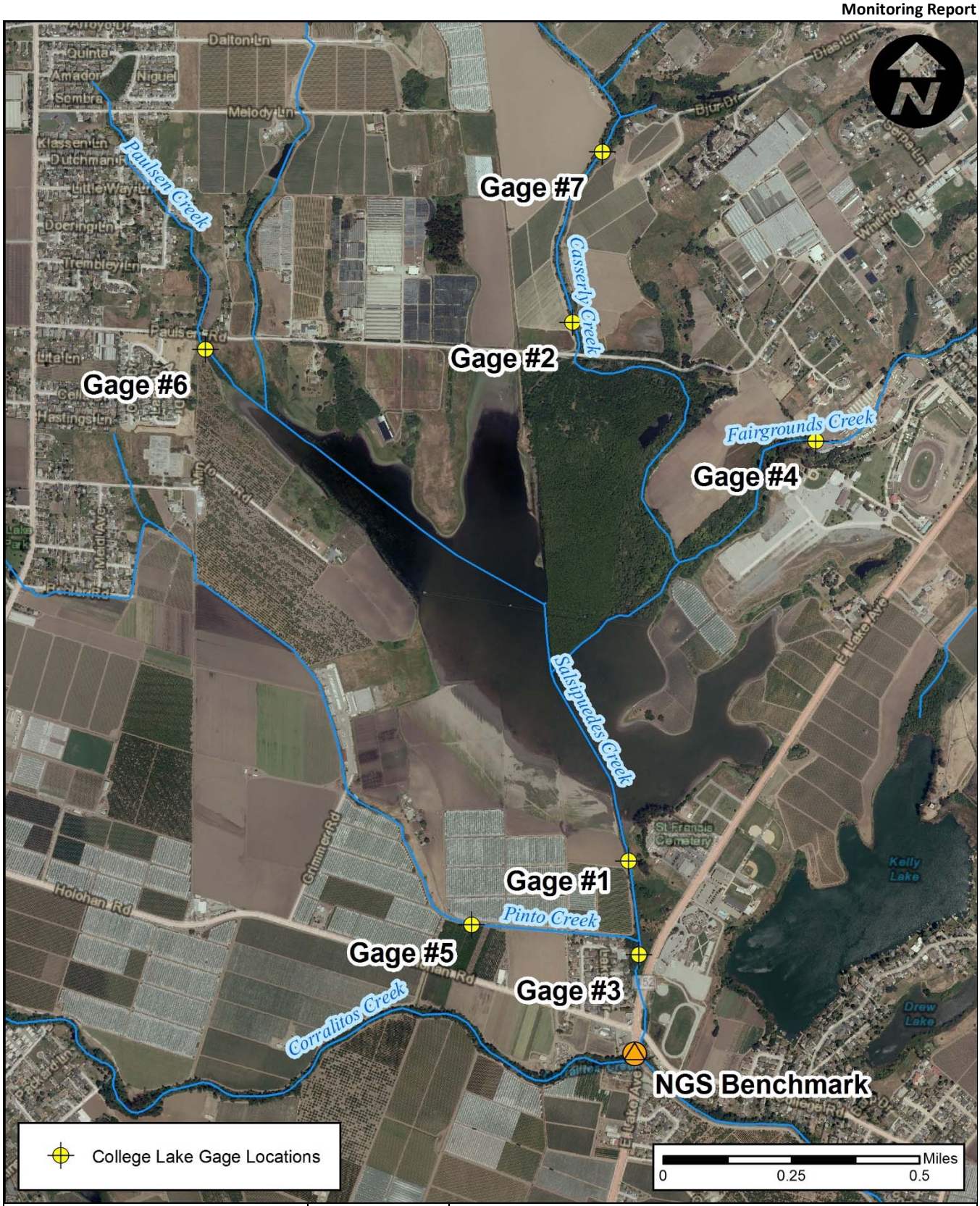
cbec, inc. 2014. College Lake Multi-Objective Management Project Final Report. Prepared for Resource Conservation District of Santa Cruz County, with assistance from Mike Podlech and Gary Kittleson. submitted November 14, 2014.

cbec, inc. 2017. Technical Memorandum - College Lake Hydrologic Monitoring for Water Year 2016 – Hydrologic Monitoring Results Summary. Prepared for PVWMA. Santa Cruz, CA.

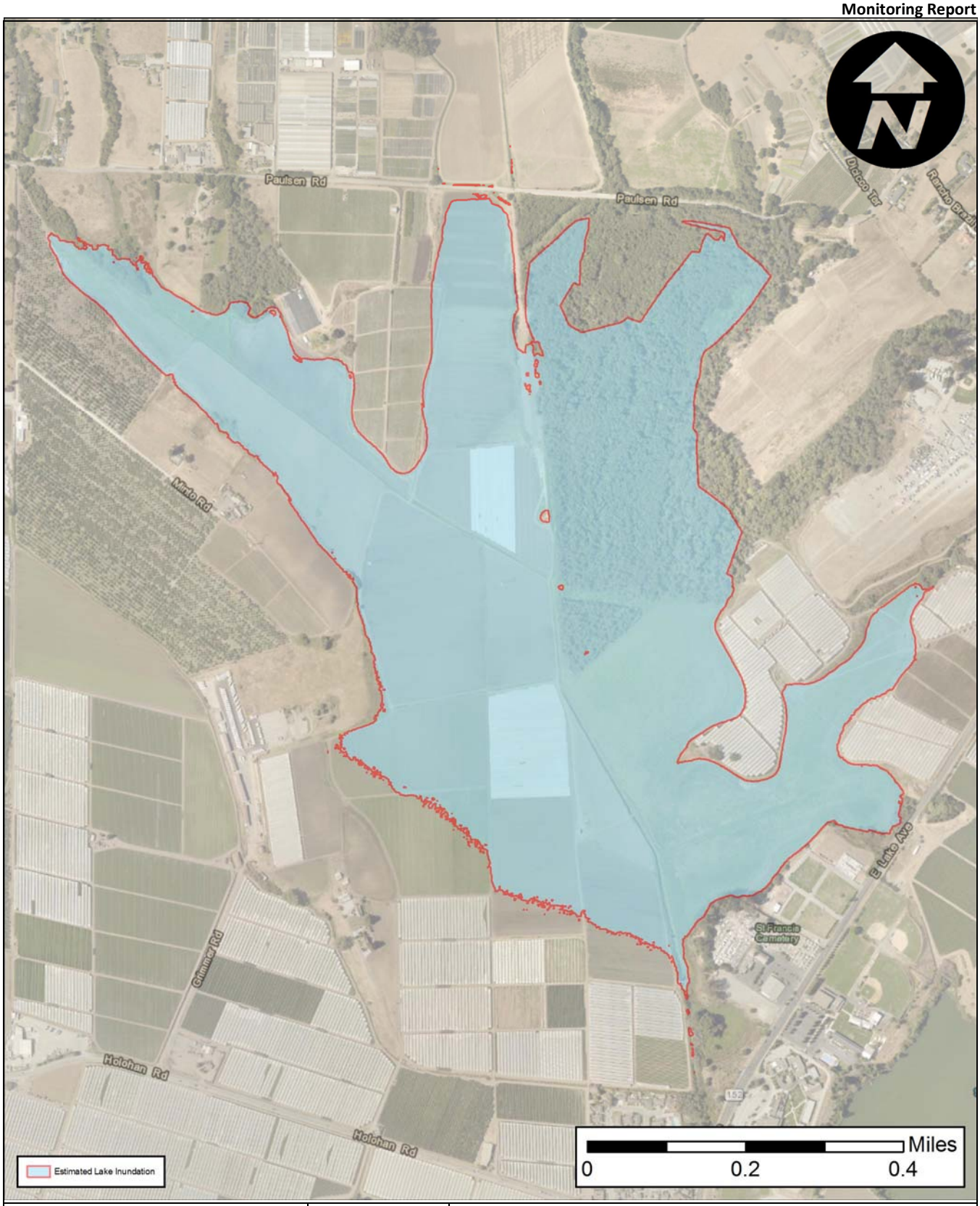
cbec, inc. 2019. Technical Memorandum - College Lake Hydrologic Monitoring for Water Year 2017. Prepared for PVWMA. Santa Cruz, CA.

NOAA – California Nevada River Forecast Center. 2017. Monthly Precipitation Summary Water Year 2017. http://www.cnrfc.noaa.gov/monthly_precip_2018.php. Accessed January 20, 2019.

(NCEI) National Centers for Environmental Information. 2018. Daily Precipitation Summary from Oct1 2017 to Oct1 2018 https://www.ncdc.noaa.gov/cdo-web/datasets#GHCND Accessed January 20, 2019.



Notes:		**Figure 1 – Gaging sites**	
		College Lake Hydrologic Monitoring for Water Year 2018	
		Project No. 17-1003-2	Created By: CMC

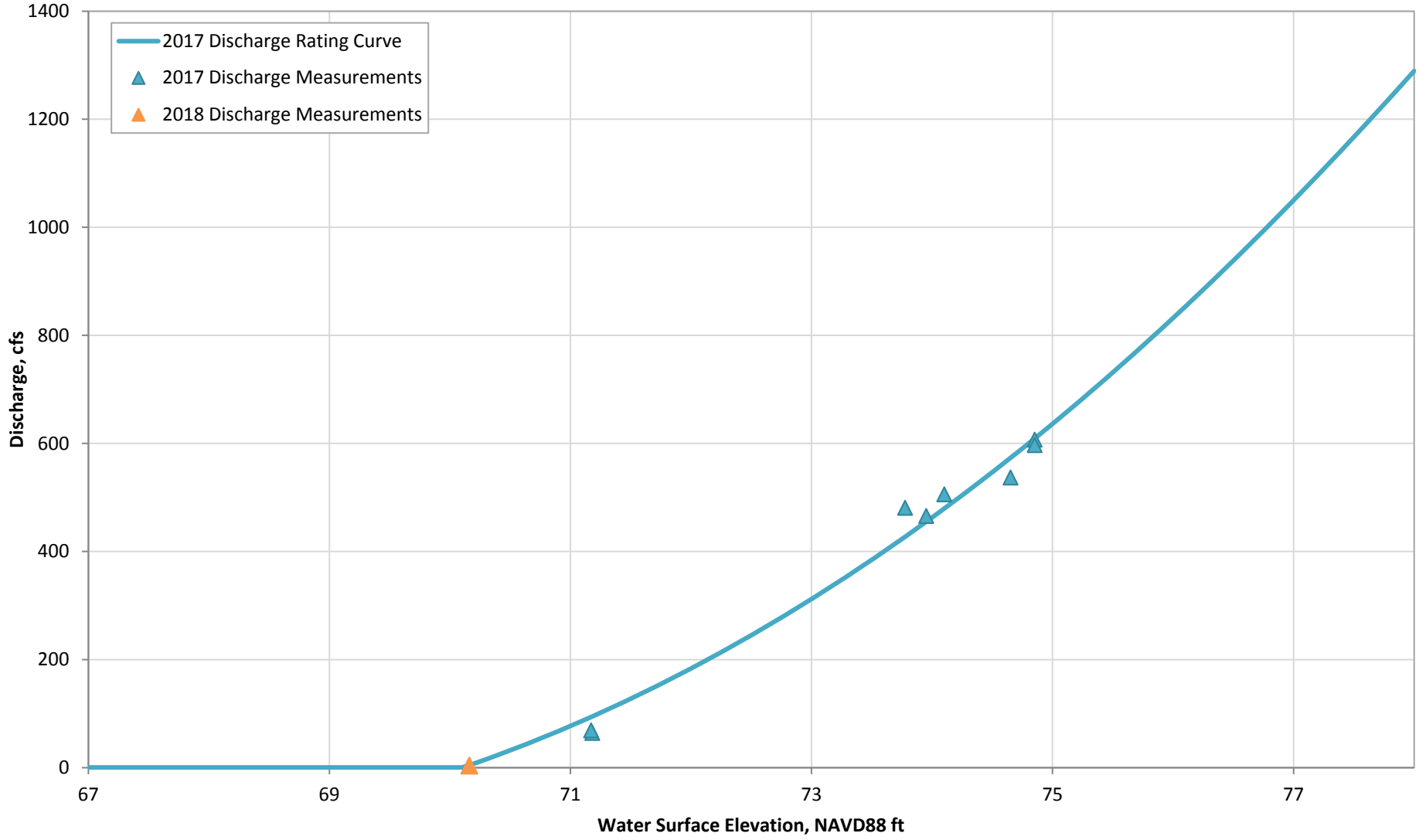


Notes:
Maximum observed water level at pump house = 62.17 ft at 3/24/2018 4:15 am. This water level was differenced with the DEM of the area to create the inundation map.

Figure 2 – Estimated maximum inundation of College Lake in WY2018

College Lake Hydrologic Monitoring for Water Year 2018

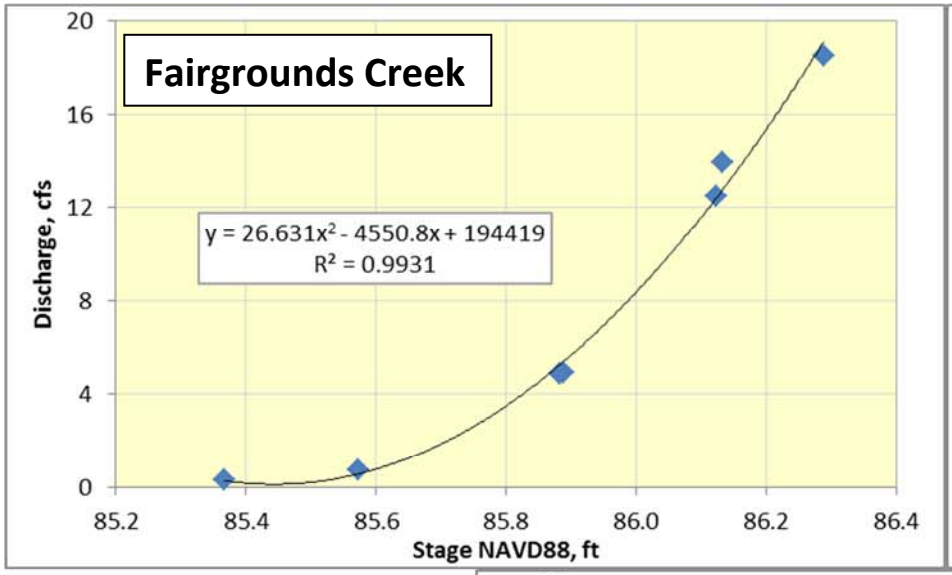
Project No. 17-1003-2 | Created By: CMC

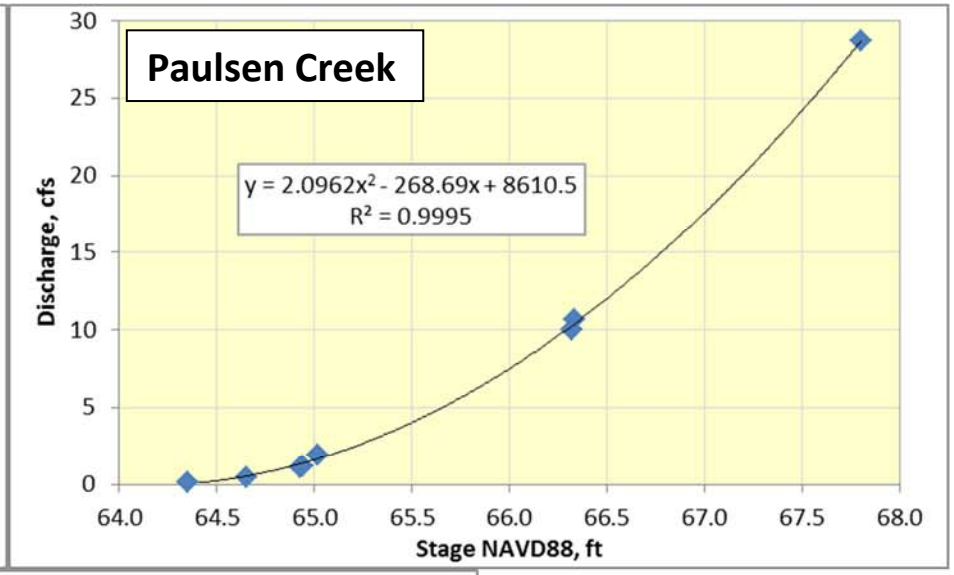


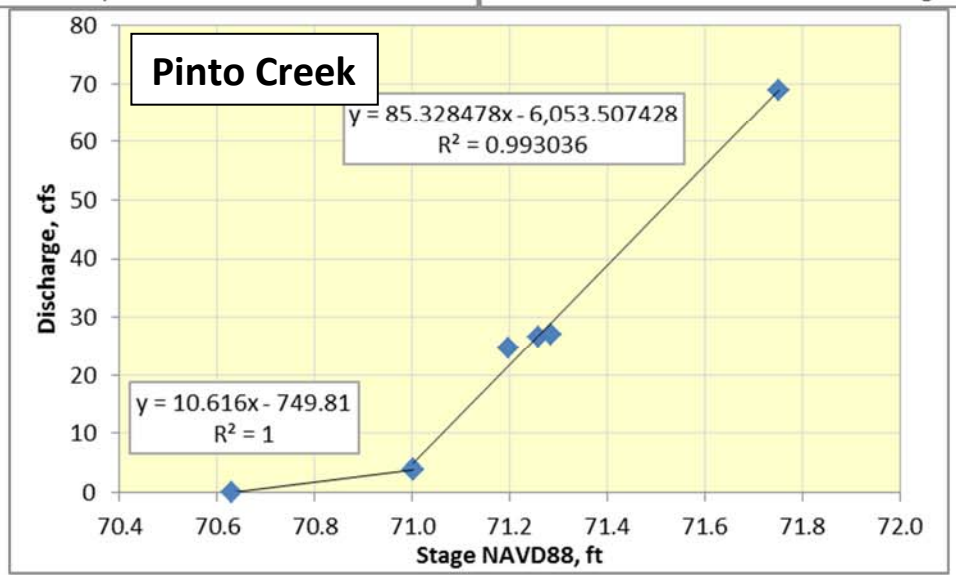
Notes:

Figure 3 – Upstream Casserly Creek Water Surface Elevation/discharge relationship

College Lake Hydrologic Monitoring for Water Year 2018





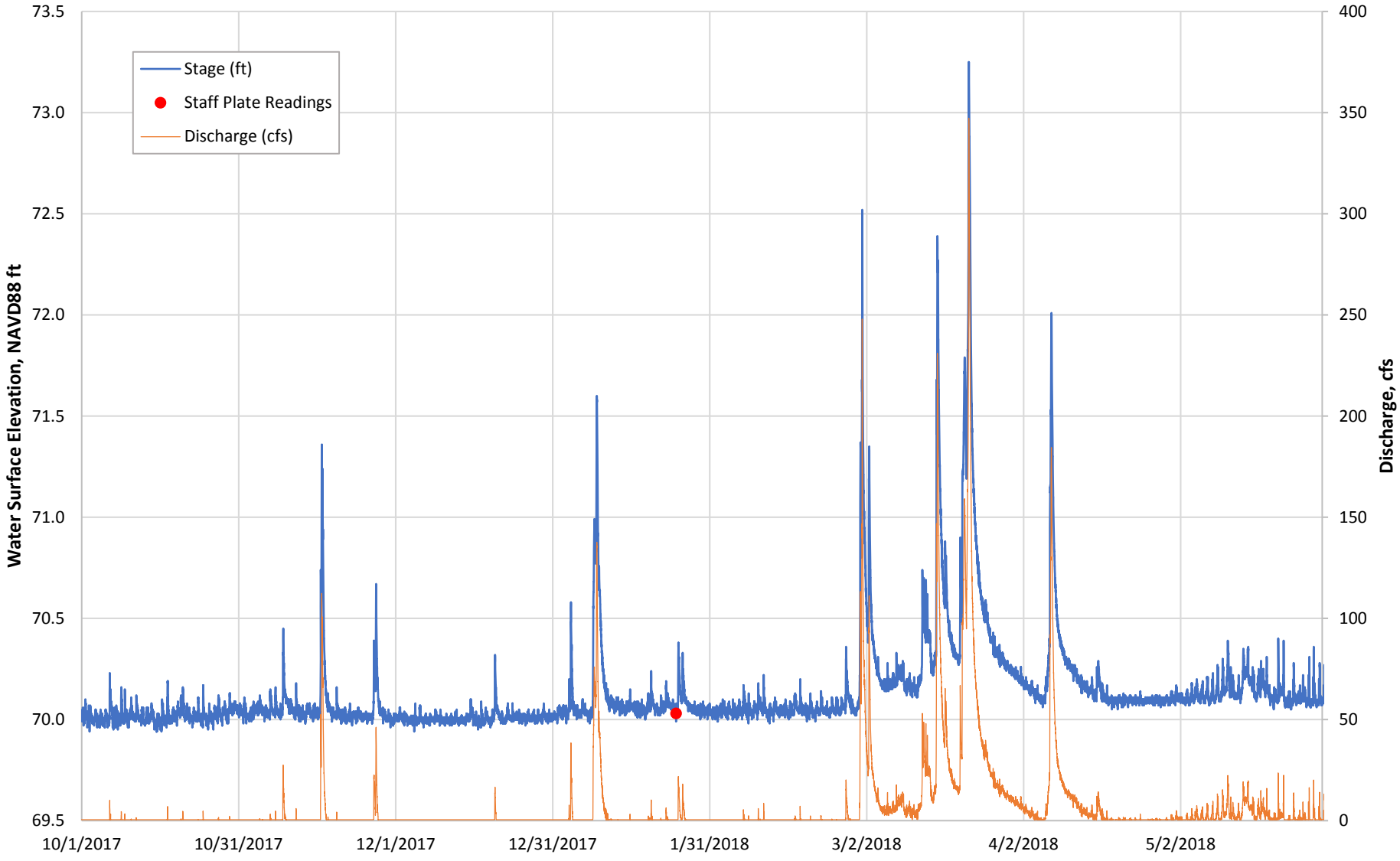


Notes:

Figure 4 – Water Surface Elevation/discharge curves for Fairgrounds, Paulsen, and Pinto Creeks

College Lake Hydrologic Monitoring for Water Year 2018

Project No. 17-1003-2 | Created By: CMC

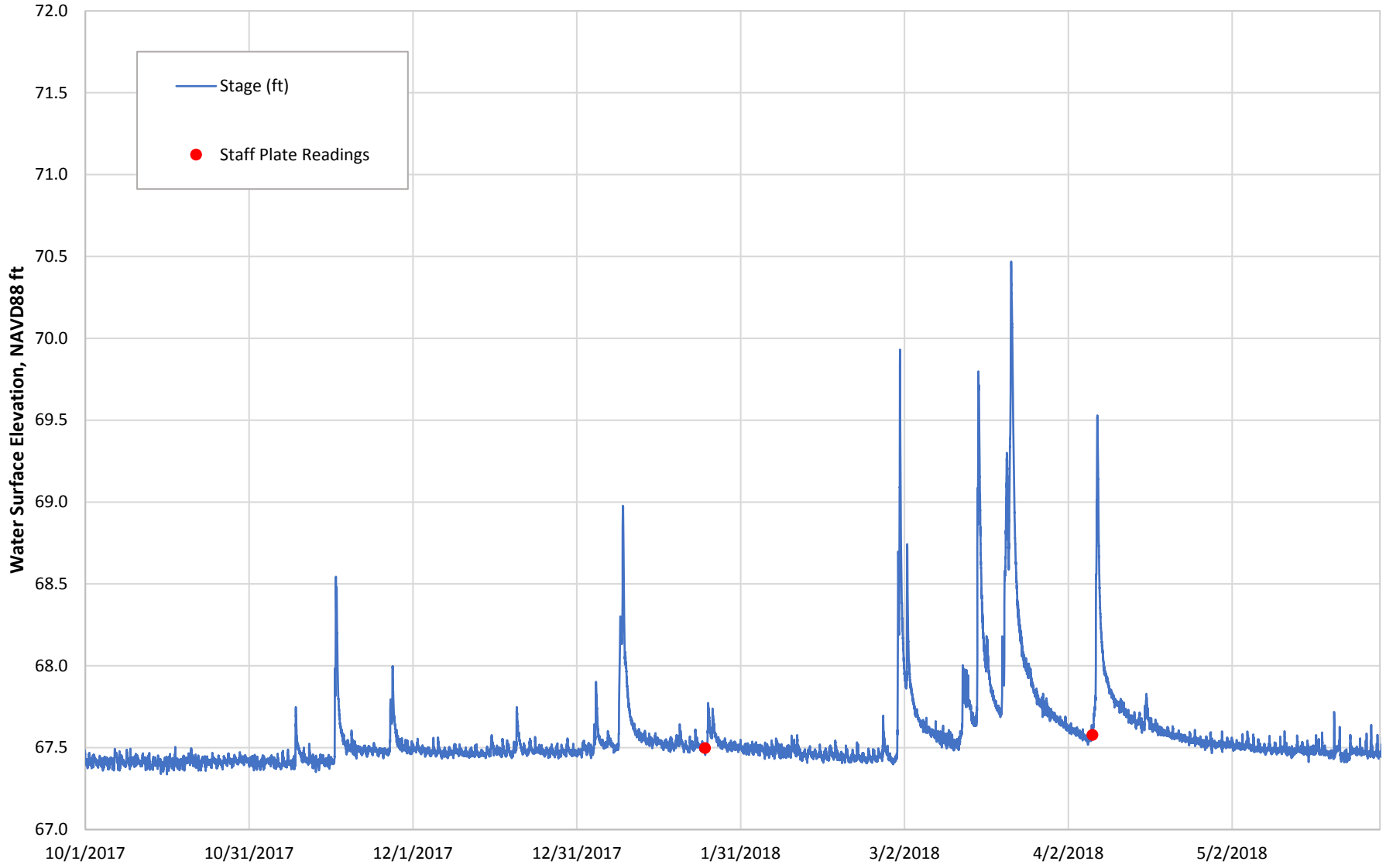


Notes:

Figure 5 – Upstream Casserly Creek Water Surface Elevation and discharge

College Lake Hydrologic Monitoring for Water Year 2018

Project No. 17-1003-2 | Created By: CMC

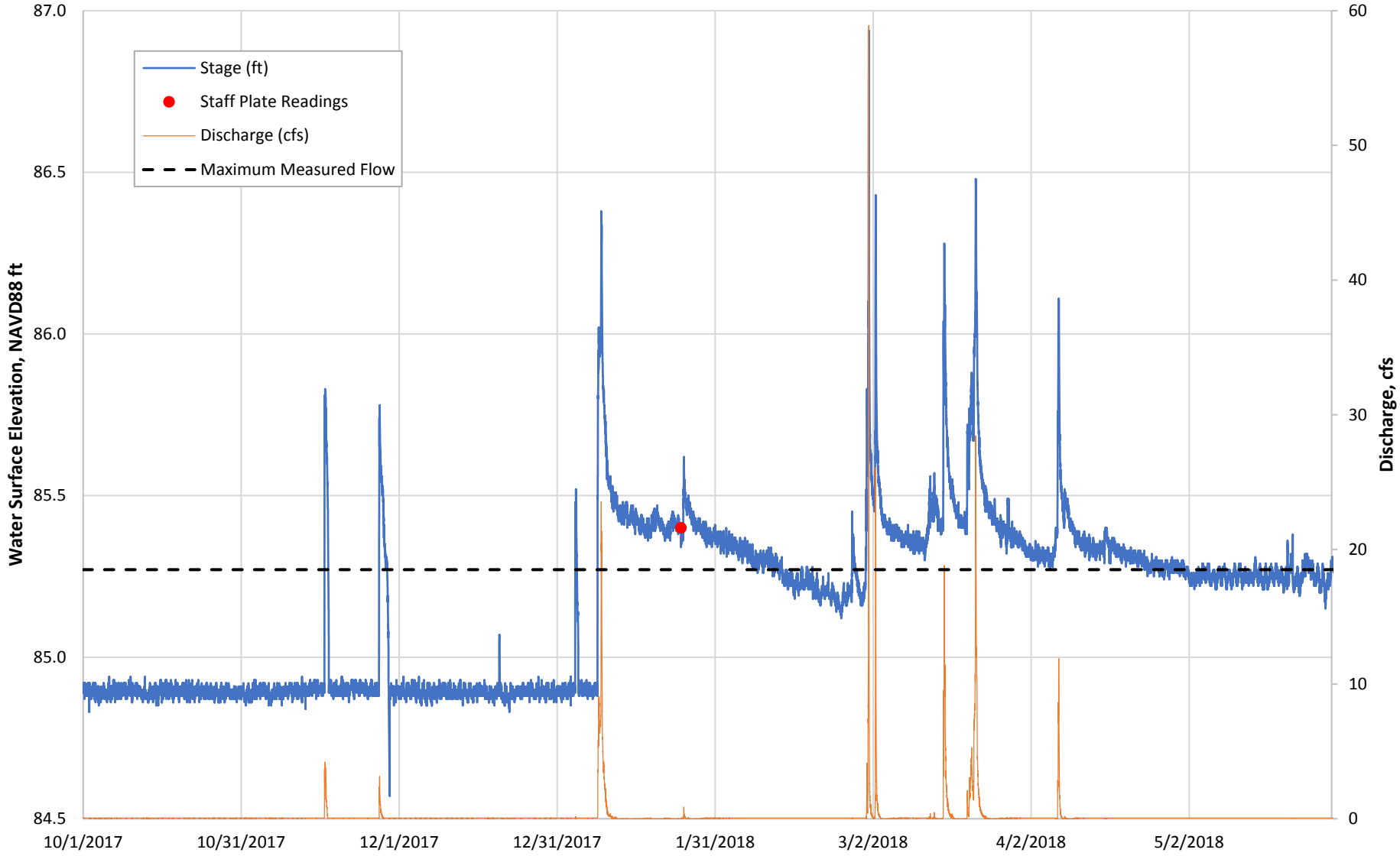


Notes:

Figure 6 – Downstream Casserly Creek Water Surface Elevation

College Lake Hydrologic Monitoring for Water Year 2018

Project No. 17-1003-2 | Created By: CMC

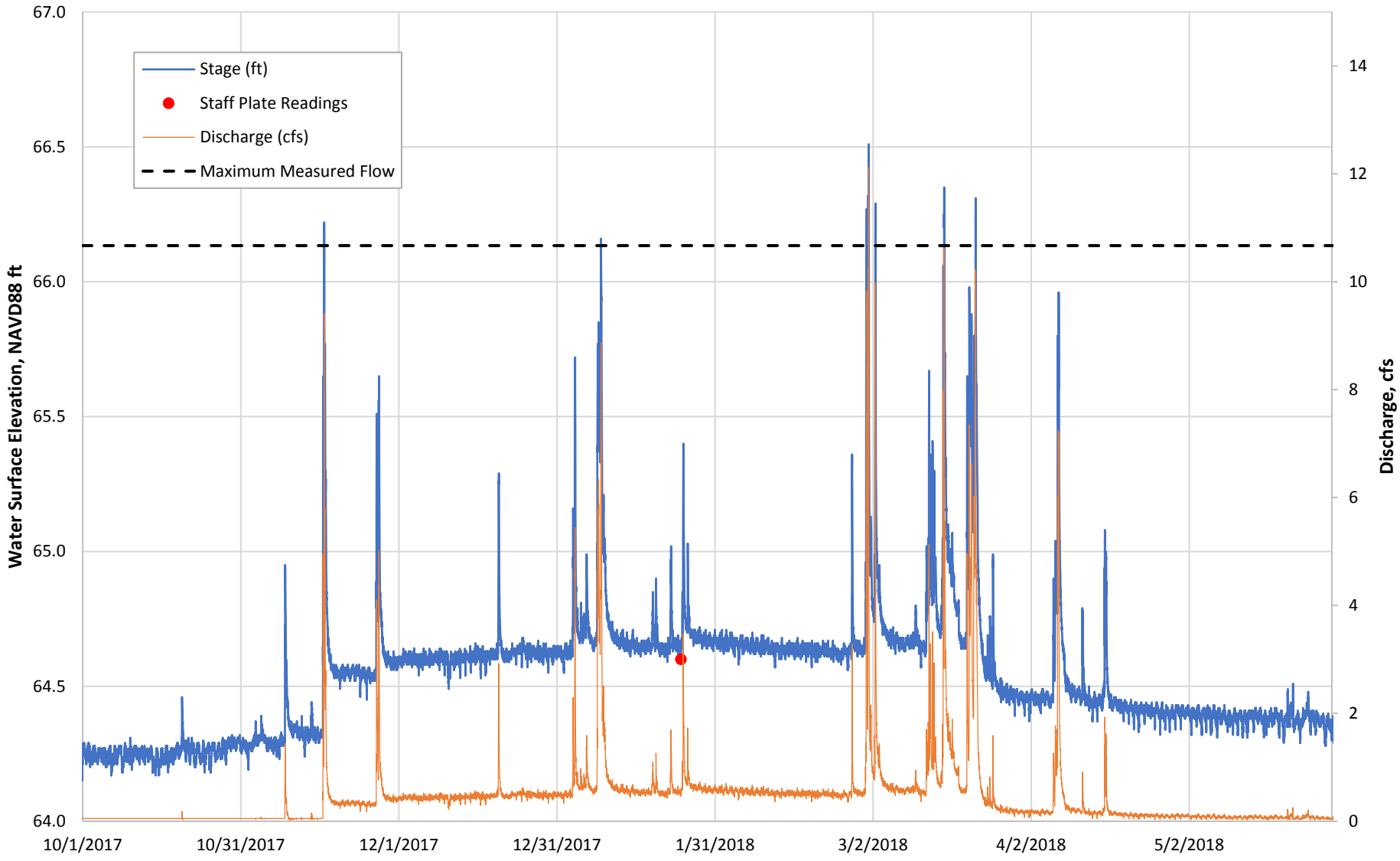


Notes:

Figure7 – Fairgrounds Creek Water Surface Elevation and discharge

College Lake Hydrologic Monitoring for Water Year 2018

Project No. 17-1003-2 | Created By: CMC

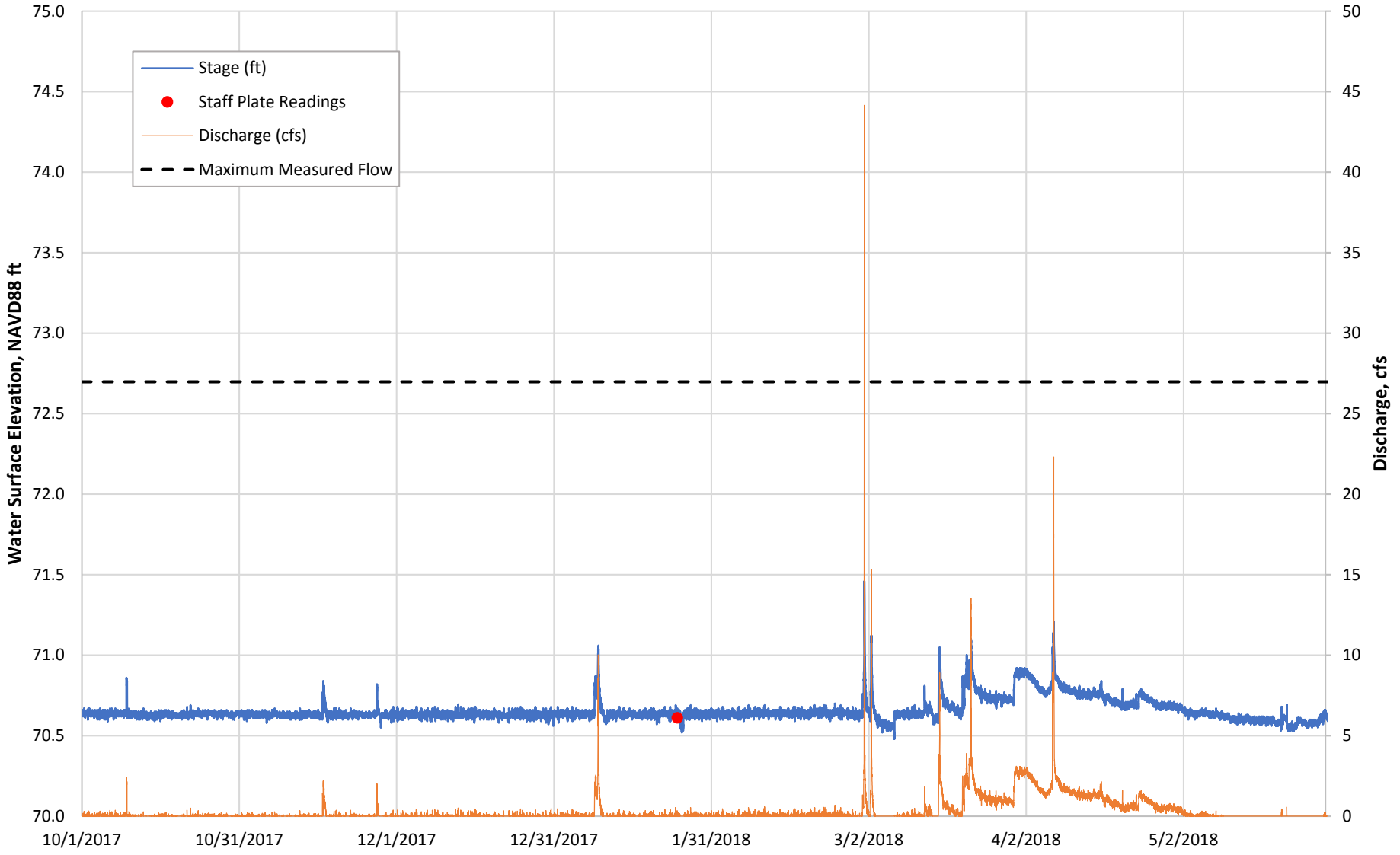


Notes:

Figure 8 – Paulsen Creek Water Surface Elevation and discharge

College Lake Hydrologic Monitoring for Water Year 2018

Project No. 17-1003-2 | Created By: CMC

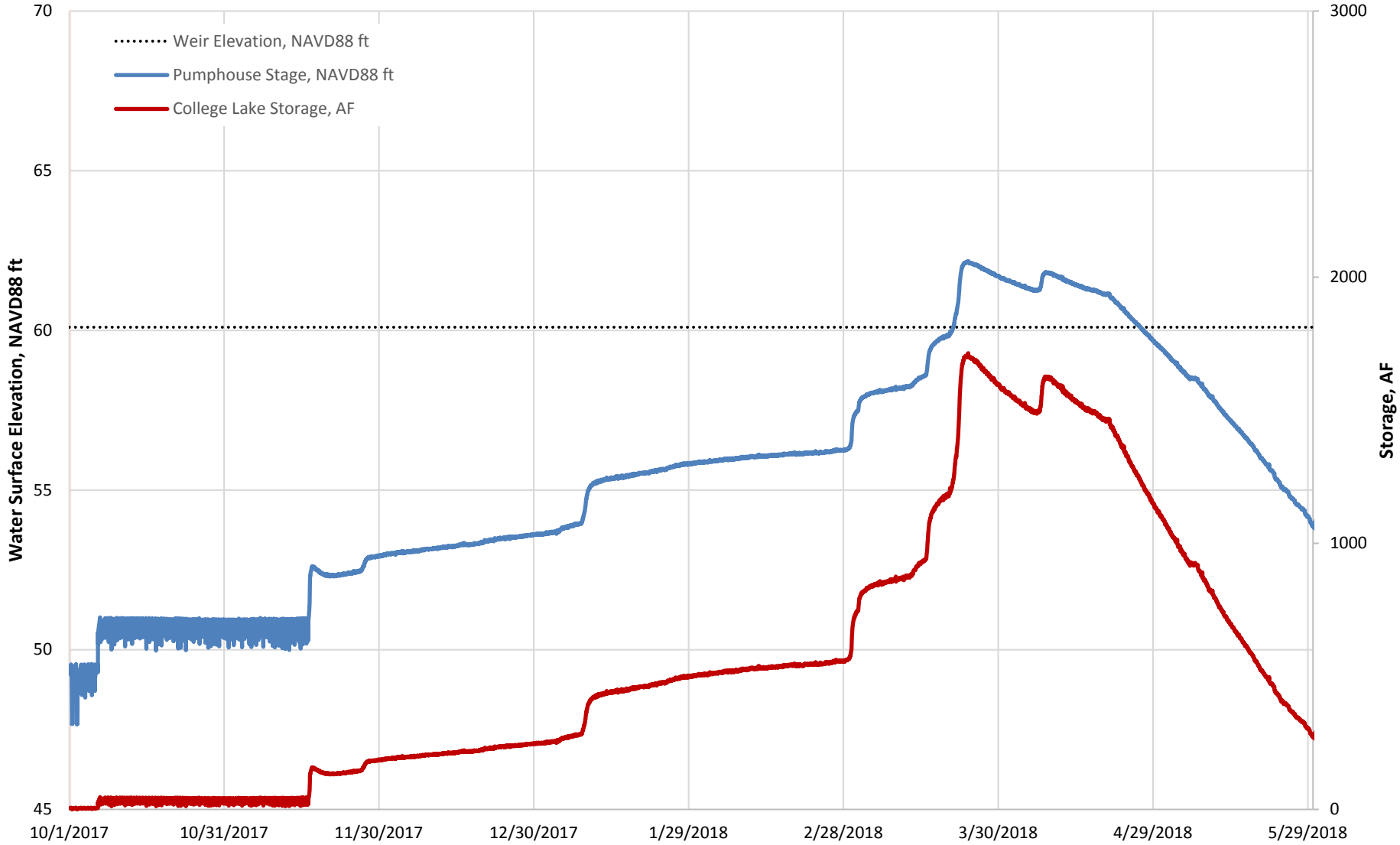


Notes:

Figure 9 – Pinto Creek Water Surface Elevation and discharge

College Lake Hydrologic Monitoring for Water Year 2018

Project No. 17-1003-2 | Created By: CMC

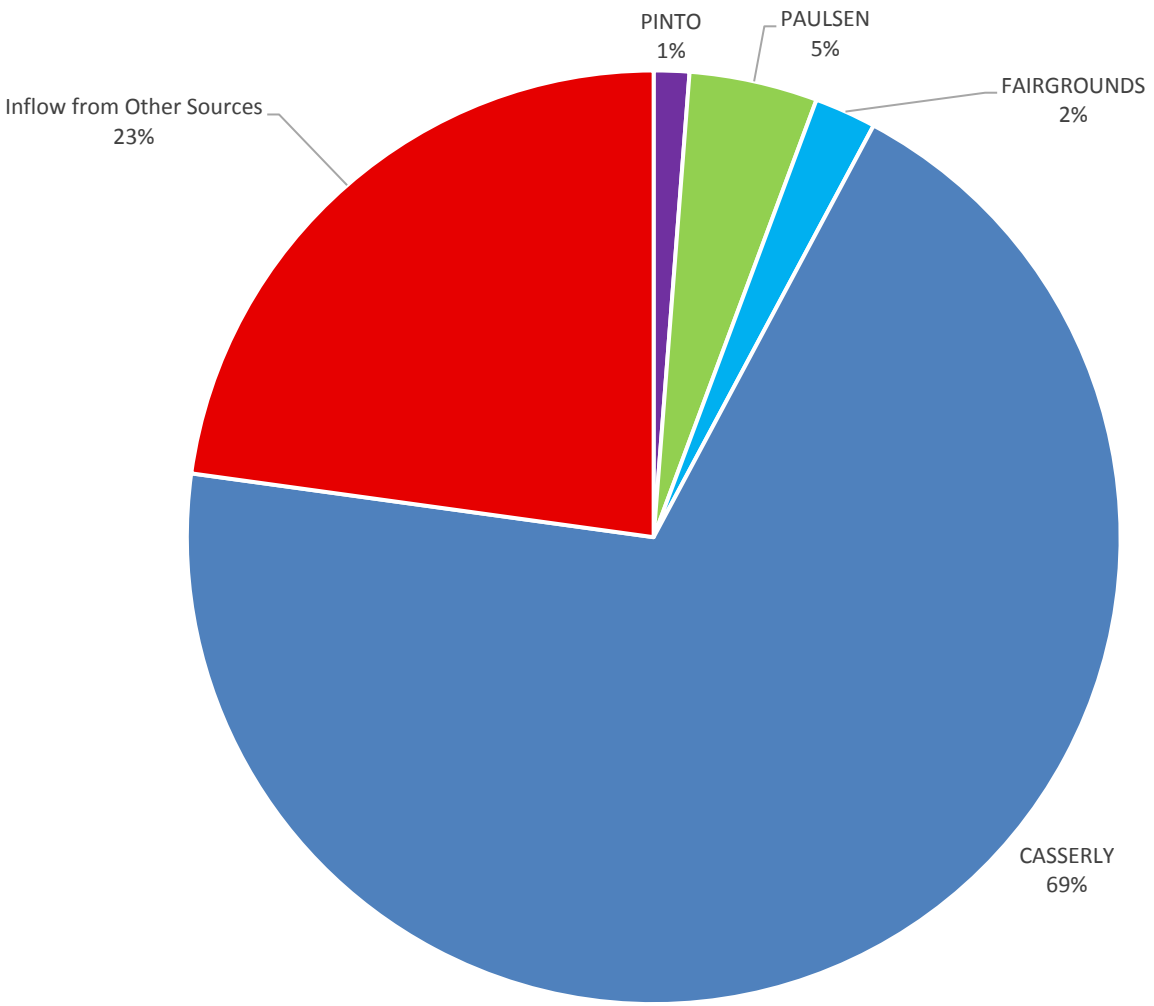


Notes:

Figure 10 – College Lake Water Surface Elevation and estimated storage at the Pump House

College Lake Hydrologic Monitoring for Water Year 2018

Project No. 17-1003-2 | Created By: CMC



Notes:		**Figure 11 – Breakdown of estimated inflows to College Lake**	
		College Lake Hydrologic Monitoring for Water Year 2018	
		Project No. 17-1003-2	Created By: CMC

APPENDIX A – FLOW MEASUREMENTS

Table 0-1 - Flow Measurements

Date and Time	Location	Flow (cfs)
3/22/18 10:30	Casserly DS	178.41
3/22/18 11:55	Casserly DS	201.57
4/6/18 11:29	Casserly DS	4.59
4/6/18 11:55	Casserly US	4.43
4/6/18 13:15	Casserly US	4.15

APPENDIX B – NGS DATASHEET

The NGS Data Sheet

See file dsdata.pdf for more information about the datasheet.

```
PROGRAM = datasheet95, VERSION = 8.12.5.2
1        National Geodetic Survey,   Retrieval Date = FEBRUARY 19, 2019
 GU4185 ***********************************************************************
 GU4185  DESIGNATION -  33 WLS RESET
 GU4185  PID         -  GU4185
 GU4185  STATE/COUNTY-  CA/SANTA CRUZ
 GU4185  COUNTRY     -  US
 GU4185  USGS QUAD   -  WATSONVILLE EAST (1995)
 GU4185
 GU4185                         *CURRENT SURVEY CONTROL
 GU4185  ______________________________________________________________________
 GU4185* NAD 83(1986) POSITION- 36 56 07.2    (N) 121 44 36.2    (W)    HD_HELD2
 GU4185* NAVD 88 ORTHO HEIGHT -    21.818 (meters)       71.58  (feet) ADJUSTED
 GU4185  ______________________________________________________________________
 GU4185  GEOID HEIGHT    -        -33.209 (meters)                     GEOID12B
 GU4185  DYNAMIC HEIGHT  -         21.801 (meters)       71.53  (feet) COMP
 GU4185  MODELED GRAVITY -    979,882.8   (mgal)                       NAVD 88
 GU4185
 GU4185  VERT ORDER      -  FIRST     CLASS II
 GU4185
 GU4185.The horizontal coordinates were established by autonomous hand held GPS
 GU4185.observations and have an estimated accuracy of +/- 10 meters.
 GU4185.
 GU4185.The orthometric height was determined by differential leveling and
 GU4185.adjusted by the NATIONAL GEODETIC SURVEY
 GU4185.in February 1993.
 GU4185
 GU4185.Significant digits in the geoid height do not necessarily reflect accuracy.
 GU4185.GEOID12B height accuracy estimate available here.
 GU4185
 GU4185.The dynamic height is computed by dividing the NAVD 88
 GU4185.geopotential number by the normal gravity value computed on the
 GU4185.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 GU4185.degrees latitude (g = 980.6199 gals.).
 GU4185
 GU4185.The modeled gravity was interpolated from observed gravity values.
 GU4185
 GU4185;                    North         East     Units  Estimated Accuracy
 GU4185;SPC CA 3     -   549,050.    1,889,230.      MT  (+/- 10 meters HH2 GPS)
 GU4185
 GU4185_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SFF1190588436(NAD 83)
 GU4185
 GU4185                           SUPERSEDED SURVEY CONTROL
 GU4185
 GU4185  NGVD 29 (10/21/93)   20.987  (m)           68.85   (f) ADJUSTED    1 2
 GU4185
 GU4185.Superseded values are not recommended for survey control.
 GU4185
 GU4185.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 GU4185.See file dsdata.pdf to determine how the superseded data were derived.
 GU4185
```

GU4185_MARKER: DB = BENCH MARK DISK
GU4185_SETTING: 38 = SET IN THE ABUTMENT OR PIER OF A LARGE BRIDGE
GU4185_SP_SET: ABUTMENT
GU4185_STAMPING: 33 WLS 1955 RESET 1965
GU4185_MARK LOGO: USGS
GU4185_MAGNETIC: N = NO MAGNETIC MATERIAL
GU4185_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
GU4185_SATELLITE: THE SITE LOCATION WAS REPORTED AS NOT SUITABLE FOR
GU4185+SATELLITE: SATELLITE OBSERVATIONS - March 27, 1990
GU4185
GU4185 HISTORY - Date Condition Report By
GU4185 HISTORY - 1965 MONUMENTED USGS
GU4185 HISTORY - 19900327 GOOD NGS
GU4185
GU4185 STATION DESCRIPTION
GU4185
GU4185'DESCRIBED BY NATIONAL GEODETIC SURVEY 1990
GU4185'3.0 KM (1.86 MI) NORTHERLY ALONG STATE HIGHWAY 152 FROM ITS JUNCTION
GU4185'WITH MAIN STREET IN WATSONVILLE, IN THE NORTHWEST ABUTMENT WALKWAY OF
GU4185'BRIDGE NUMBER 36-01 SPANNING CORRALITOS CREEK, 75.8 M (248.69 FT)
GU4185'SOUTH OF THE CENTER OF HOLOHAN ROAD, 7.4 M (24.28 FT) WEST OF THE
GU4185'CENTERLINE OF THE HIGHWAY, 2.6 M (8.53 FT) SOUTH OF THE NORTH END OF
GU4185'THE WALKWAY, 2.3 M (7.55 FT) SOUTHEAST OF UTILITY POLE NUMBER 867,
GU4185'AND 0.15 M (0.49 FT) ABOVE THE LEVEL OF THE HIGHWAY.

*** retrieval complete.
Elapsed Time = 00:00:15