APPENDIX E.9.3

2019 AEMP Hydrometric Monitoring Report

Environmental Applications Group

MEMORANDUM

To: Connor Devereaux
Environmental Superintendent, Baffinland Iron Mines Corporation

Date: March 26, 2020

From: Andrew Rees, Ph.D.
Senior Environmental Scientist

Re: 2019 AEMP Hydrometric Monitoring Program

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1 Introduction

The 2019 iteration of the Mary River Project (Project) Hydrometric Monitoring Program, a component study of the Project's Aquatic Effects Monitoring Plan (AEMP, Baffinland, 2015), was initiated in June during the spring melt period, also known as the freshet. Station identifiers, names, period of records, drainage areas, and locations for the seven monitoring stations are summarized in Table 1.1. The locations of the monitoring stations are shown on Figure 1.

Table 1.1 2019 Hydrometric Monitoring Program Stations

Station ID	Station Name	Period of Record	Drainage Area (km^2)	Coordinates (UTM)	
				Easting	Northing
H01	Phillips Creek Tributary	2006-2008, 2011-2019	250	532831	7946247
H02	Tom River near outlet to Mary Lake	2006-2008, 2010-2019	210	555712	7915514
H04	Camp Lake Tributary (CLT-2)	2006-2008, 2010-2019	8.3	557639	7915579
H05	Camp Lake Tributary (CLT-1)	2006-2008, 2010-2019	5.3	558906	7915079
H06	Mary River	2006-2008, 2010-2019	240	563922	7912984
H07	Mary River Tributary F	2006-2008 2010, 2011, 2017-2019	14.7	564451	7913194
H11	Sheardown Lake Tributary (SDLT-1)	2011-2019	3.6	560503	7913545

A site visit was conducted in June 2019 by Environmental Applications Group (EAG) to initiate the 2019 monitoring program. Additional station visits were made by Baffinland Iron Mines Corporation's (Baffinland) environmental staff during August, and September and by EAG staff in August. The stations were decommissioned for winter by Baffinland's environmental staff in September prior to freeze-up.

2 Stage-Discharge Measurements

Water level or stage was measured at each station relative to at least two benchmarks. The benchmarks are rock bolts drilled into bedrock and have been maintained throughout the life of each station. Benchmark and water level surveys were conducted during each site visit and water level was referenced to a local datum. A pressure transducer / data logger (Seametrics PT2X, which record water level and temperature at 15-minute intervals) were installed in a stilling well at each station. The dataloggers were downloaded and checked for proper operation during each site visit and the data logger water level data were related to the local datum at the end of the season using the survey data.

Where flows permitted safe access to a watercourse's channel, a Hach FH950 wading current meter was used to measure stream velocity. Discharge was estimated from the current meter velocity using the area-velocity technique (mid-section method) per the Water Survey of Canada (WSC) guidelines (WSC, 1999). Whenever possible, the stream was divided into a minimum of 20 sections to measure depth and velocity with the objective of having less than 5% of the flow in each section. At least two cross sections of depth and velocity were measured during each site visit. Velocity was recorded at 0.6 of the stream depths as the stream depth was less than or equal to 0.75 m during each measurement.

Where higher flows prevented the use of the wading current meter, dilution gauging was utilized to estimate discharge. The dilution gauging was conducted using Rhodamine WT as a tracer. The fluorescence of the Rhodamine WT was measured in-situ and recorded using a handheld fluorometer (YSI with 6130 Rhodamine Sensor). Two-point calibration of the fluorometer was conducted in the field using a known concentration of Rhodamine WT solution and stream water. For estimating discharge, Rhodamine WT was added upstream of the station as an instantaneous release of a known volume. The fluorescence was recorded at a sufficient distance downstream to allowed for complete mixing of the tracer. At least two measurements were performed during each site visit. The discharge was estimated using the integration method.

The stage-discharge data obtained in 2019 were compared to the existing rating curves, which were last evaluated in the 2018 Hydrometric Monitoring Program Summary (EAG, 2019). Rating curves for each station, inclusive of the data collected in 2019, are presented in Figures 2 to 8. A discussion and an interpretation of the fit of the 2019 data to the rating curves is provided in the following sections:

- **H01 (Phillip's Creek Tributary)** - A stage-discharge measurement was recorded at H01 during mid to high flow conditions in June using dilution gauging and during lower flow conditions in August using a wading current meter and the area velocity technique The 2019 measurements are consistent with the existing rating curve presented in Figure 2. As such, no update to the rating curve was required and the existing curve developed in 2007 was used for the development of the 2019 streamflow record.
- **H02 (Tom River)** - A stage-discharge measurement was recorded at H02 during mid to high flow conditions in June visit using dilution gauging and during low flow conditions in August using a wading current meter and the area velocity technique. The measurements are consistent with the rating curve which was updated in 2012 (Figure 3). The flow measurements obtained since the 2012 update are a good fit with the rating curve and the 2012 rating curve was used for the development of the 2019 flow record.
- **H04 (Camp Lake Tributary CLT-2)** - Stage-discharge measurements were recorded at H04 during June, August, and September using a wading current meter and the area-velocity technique. The measurements are consistent with the rating curve that was updated in 2013 (Figure 4). Measurements during higher flow conditions (greater than 0.7 m^3/s) are recommended for future programs to further validate the 2013 rating curve update. The 2013 rating curve was used for the development of the 2019 flow record.
- **H05 (Camp Lake Tributary CLT-1)** – Stage-discharge measurements were recorded at H05 during June, August, and September using a wading current meter and the area-velocity technique. The measurements are consistent with the existing rating curve developed in 2007 (Figure 5). The existing rating curve was used for the development of the 2019 flow record.
- **H06 (Mary River)** – A stage-discharge measurement was recorded at H06 during the June visit using dilution gauging and is consistent with the existing rating curve developed in 2007 (Figure 6). The existing rating curve was used for the development of the 2019 flow record.

- **H07 (Mary River Tributary F)** – A stage-discharge measurement was recorded at H07 during the June visit using dilution gauging and is consistent with the existing rating curve. Additional measurements were made in August and September during low flow conditions using a wading current meter and the area-velocity technique. The low flow measurements are not consistent with existing curve developed in 2007 (Figure 7). Flow of similar magnitude has not been measured since 2006 and 2007 (prior to the re-installation of the station in 2017). Since that time, it is possible that the downstream control or the stream cross section geometry (which define the rating curve relationship) have shifted. This can occur naturally over time due to scour and the movement of sediment in the channel. The existing rating curve is not considered accurate for low flows based on the difference between the 2019 low flow measurements and the flow estimated from the existing rating. As such, a potential shift in the rating curve is proposed based on the flow measured in 2019 and general channel geometry and is shown on Figure 7. The shifted rating curve was used to estimate low flows and the existing curve was used to estimate mid to high flows in the 2019 flow record. The lower flows (less than ~1.0 m3/s) are considered provisional until additional data can be collected to continue to validate the potential shift in the rating curve.
- **H11 (Sheardown Lake Tributary SDLT-1)** – Stage-discharge measurements were recorded at H11 during June, August, and September and were consistent with the rating curve updated in 2014 (Figure 8). There remains some uncertainty around the higher stage-discharge conditions and as such, higher flow measurements should be obtained in the future to validate the high flow rating curve. The 2014 rating curve was used for the development of the 2019 flow record.

3 Streamflow Hydrographs

Streamflow records were developed for each station by applying the water level records to the corresponding rating curves. The discharge hydrographs for H01, H02, H04, H05, H06, H07, and H11 are presented in Figures 9 to 15.

The discharge records from all stations were converted to equivalent unit runoff (discharge per unit area) and are presented along with daily precipitation for comparison purposes on Figure 16. The 2019 records of unit runoff generally agree well with each other, exhibiting similar timing and magnitude of runoff events and similar patterns to previous years. It appears that the initial freshet period was not captured at all of the stations in 2019 due to an earlier melt at lower elevation stations (H04, H05, and H11) than in past years. The bulk of the freshet period was captured at the H02, H06, and H07 stations. A strong diurnal melt pattern is evident through the end of June and first half of July at these stations as they have higher elevation catchments. The snowmelt at lower elevations and the corresponding peak of freshet flows at the stations with smaller and lower elevation catchment likely occurred prior to the installation of the stations. Similar unit runoff is evident at all stations throughout the end of July and in August, which suggests that the precipitation was generally consistent throughout the region.

The estimated mean monthly discharge and unit runoff for each station in 2019 are summarized in Table 3.1.

Table 3.1 Summary of 2019 Mean Monthly Estimated Discharge and Unit Runoff

STATION	Drainage Area (km^2)	Estimated Mean Monthly Discharge (m^3/s)				Period of Record
		June	July	August	September	
H01	250	14.4	7.6	4.4	2.6	June 15 to September 20
H02	210	22.2	7.2	4.4	4.0	June 17 to September 22
H04	8.3	0.30	0.21	0.11	0.09	June 14 to September 21
H05	5.3	0.11	0.13	0.06	0.04	June 14 to September 21
H06	240	23.6	9.3	4.9	3.2	June 16 to September 20
H07	14.7	1.70	0.60	0.26	0.14	June 16 to September 20
H11	3.6	0.069	0.088	0.052	0.031	June 13 to September 21

STATION	Drainage Area (km^2)	Estimated Mean Monthly Unit Runoff ($l/s/km^2$)				Period of Record
		June	July	August	September	
H01	250	57	31	17	10	June 15 to September 20
H02	210	106	34	21	19	June 17 to September 22
H04	8.3	36	26	13	10	June 14 to September 21
H05	5.3	20	25	11	7	June 14 to September 21
H06	240	98	39	20	13	June 16 to September 20
H07	14.7	116	41	17	10	June 16 to September 20
H11	3.6	19	24	14	8	June 13 to September 21

The H05 station has been used since 2014 to provide a comparison of general flow conditions from year to year. The H05 station has been used for this purpose because it is positioned near the mine, has a relatively small drainage area, and has had a reliable rating curve and record of flow since 2006. A summary of flows at H05 from 2006 to 2019 is shown on Figure 16. The total annual runoff recorded in 2019 at the H05 station was less than the average from 2006 to 2018 for concurrent periods of record. The flow measured in 2019 was lower than normal in June and early July, due to the initial part of freshet occurring prior to the re-installation of the station (and/or being less than normal) and was also lower than normal in summer months. The flow volume measured during summer 2019 (mid-July to mid-August) was lower than the 2006-2019 average and close to the 2006-2019 median.

4 Summary and Recommendations

The 2019 iteration of the Project's Hydrometric Monitoring Program allowed for the continued monitoring of streamflow at hydrometric stations identified in the Project's AEMP (Baffinland, 2015). The data collected confirmed that the rating curves at all stations except H07 continue to be applicable. It is recommended that future hydrometric monitoring include more low flow measurements at H07 and additional high flow measurements at H04 and H11 to further validate the rating curves. Low flow conditions at H07 tend to occur in late July and August between rainfall events. Site visits should be targeted during forecasted dry periods and made at least 7 to 10 days following a measurable rainfall event.

Peak flows at H04 and H11 tend to occur over a shorter time period than at other stations due to their relatively small watershed size. As such, the flow monitoring program needs to be adjusted to be accommodate rapidly changing flow conditions at these sites. Precipitation events of greater than 4 mm per day result in an appreciable increase in flow at these sites. However, precipitation events that last for more than one day, with cumulative precipitation over 10 mm result in much higher flow, especially earlier in the summer (mid-July to mid-August) before the active layer fully develops. Site visits to H04 and H11 should be made following any precipitation event that lasts more than one day and/or results total precipitation approaching or greater than 10 mm. Such high flow conditions should be targeted and measured as often as possible at these stations.

5 References

Baffinland Iron Mines Corporation (Baffinland), 2015. Aquatic Effects Monitoring Plan – Rev. 1. October 30, 2015.

Environmental Applications Group (EAG), 2019. Memorandum to William Bowden and Connor Devereaux, Baffinland Iron Mines Corporation. Re: 2018 AEMP Hydrometric Monitoring Program. March 13. North Bay, Ontario.

Water Survey of Canada (WSC), 1999. Hydrometric Technician Career Development Program. Lesson Package No. 10.1 – Principles of Discharge Measurement. Environment Canada, Fredericton, NB.

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Copy to:

Christopher Murray, Environmental and Regulatory Compliance Manager, Baffinland

Attachments:

Figure 1	2019 Hydrometric Monitoring Program Stations
Figure 2	H01 - Phillip's Creek Tributary Rating Curve
Figure 3	H02 - Tom River Rating Curve
Figure 4	H04 - Camp Lake Tributary (CLT-2) Rating Curve
Figure 5	H05 - Camp Lake Tributary (CLT-1) Rating Curve
Figure 6	H06 - Mary River Rating Curve
Figure 7	H07 - Mary River Tributary F Rating Curve
Figure 8	H11 - Sheardown Lake Tributary (SLDT-1) Rating Curve
Figure 9	H01 – Phillip's Creek Tributary 2019 Streamflow Record
Figure 10	H02 - Tom River 2019 Streamflow Record
Figure 11	H04 - Camp Lake Tributary (CLT-2) 2019 Streamflow Record
Figure 12	H05 - Camp Lake Tributary (CLT-1) 2019 Streamflow Record
Figure 13	H06 - Mary River 2019 Streamflow Record
Figure 14	H07 – Mary River Tributary F 2019 Streamflow Record
Figure 15	H11 - Sheardown Lake Tributary (SLDT-1) 2019 Streamflow Record
Figure 16	2019 Comparison of Unit Runoff
Figure 17	H05 – Camp Lake Tributary (CLT-1) Measured Streamflow Hydrographs 2006-2019

Environmental Applications Group

Attachments

March 26, 2020

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H01
H02
H04
H05
H06
H07
H11

Phillips Creek
KM 97 BORROW SOURCE
OPEN BURN LOCATION
Camp Lake
WASTE MANAGEMENT BUILDING
HAZARDOUS WASTE BERM
SITE SERVICES SHOP
HELICOPTER PAD
AERODROME
QMR2
WAREHOUSE
AIRSTRIP
ORE HAUL TRUCK PAD
SNOW STOCKPILE
LAYDOWN 2
Sheardown Lake NW
SNOW STOCKPILE
LANDFILL
SNOW STOCKPILE
Sheardown Lake SE
EMULSION PLANT
EFFLUENT DISCHARGE LOCATION
WASTE ROCK FACILITY WATER TREATMENT PLANT
SURFACE WATER MANAGEMENT POND
WASTE ROCK FACILITY
MS-08 DISCHARGE LINE
110 KM LAYDOWN AREA
ULTIMATE DEPOSIT 1 PIT LIMITS
HAUL ROAD
QUARRY D1Q1
ACTIVE MINING AREA
QUARRY D1Q2
EXPLOSIVE MAGAZINE
Mary River Tributary F
Mary River

0 2.5 5 10 Km

LEGEND

- Borrow Area
- Quarry Area
- Project Development Area
- Commercial Lease Boundary
- Current Infrastructure
- Hydrometric Monitoring Station

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2019 Hydrometric Monitoring Program Stations

Projection: NAD 1983 UTM ZONE 17N.
Base Map: © 2019 Digital Global, Inc.
Imagery and Infrastructure are representative as of August 2019.

0 100 200 400 600 800 Meters
Scale 1:30,000

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Baffinland

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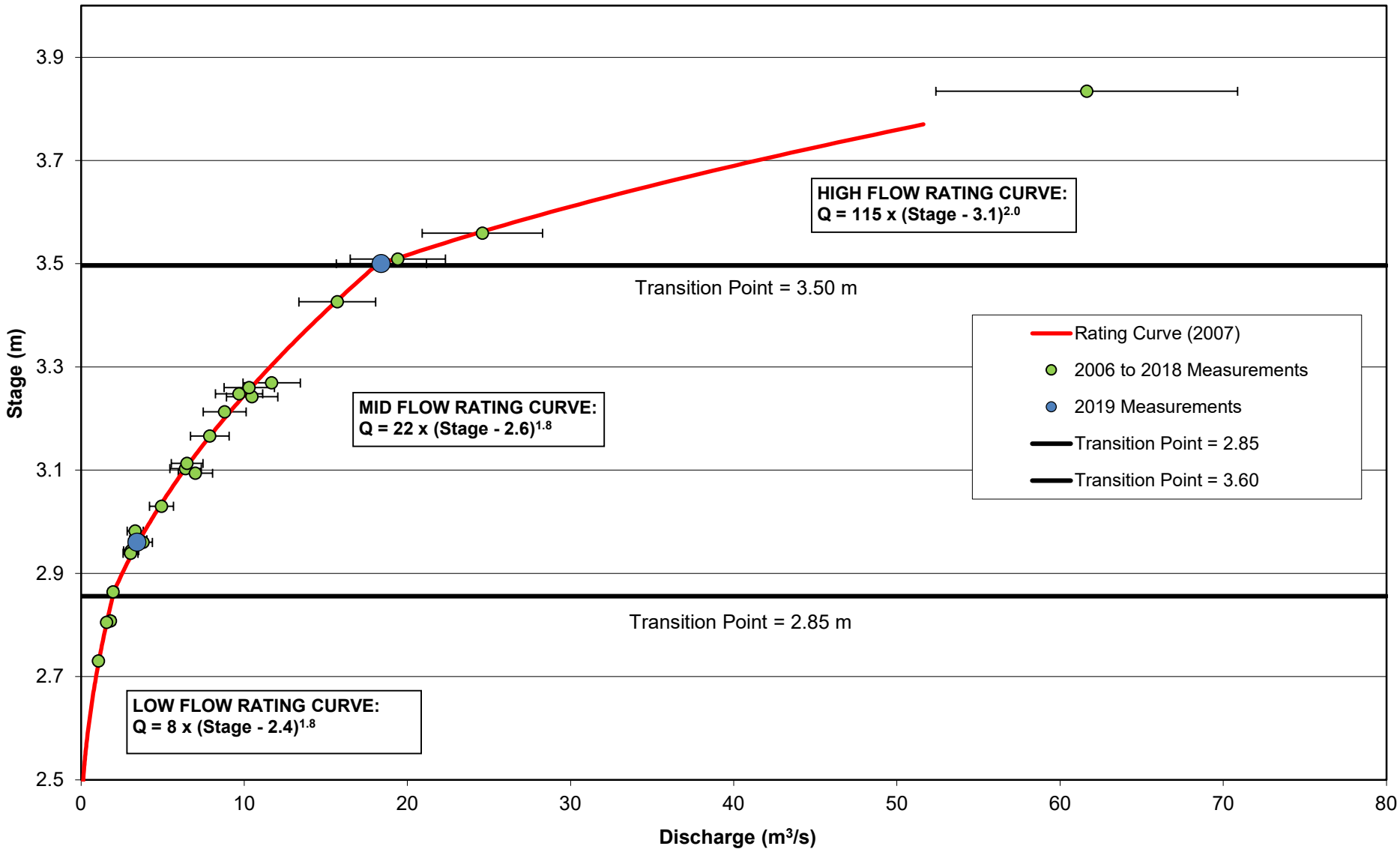
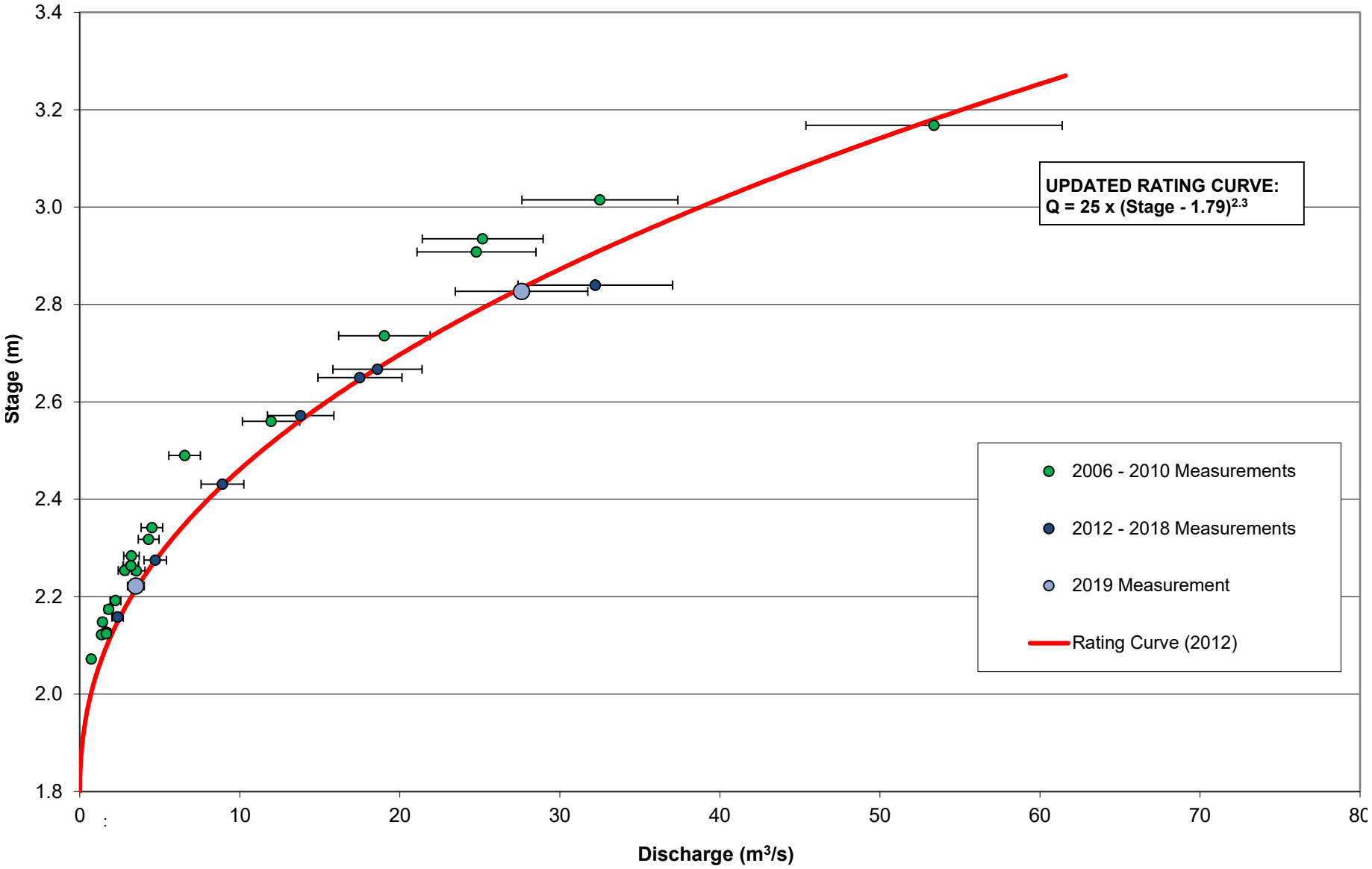
SAVED: C:\Users\katie.mcguire\Documents\4 - Maps\Reporting\1_Annual\Hydrometric\BM_Fig 1 MineSite.mxd, 24-Mar-20



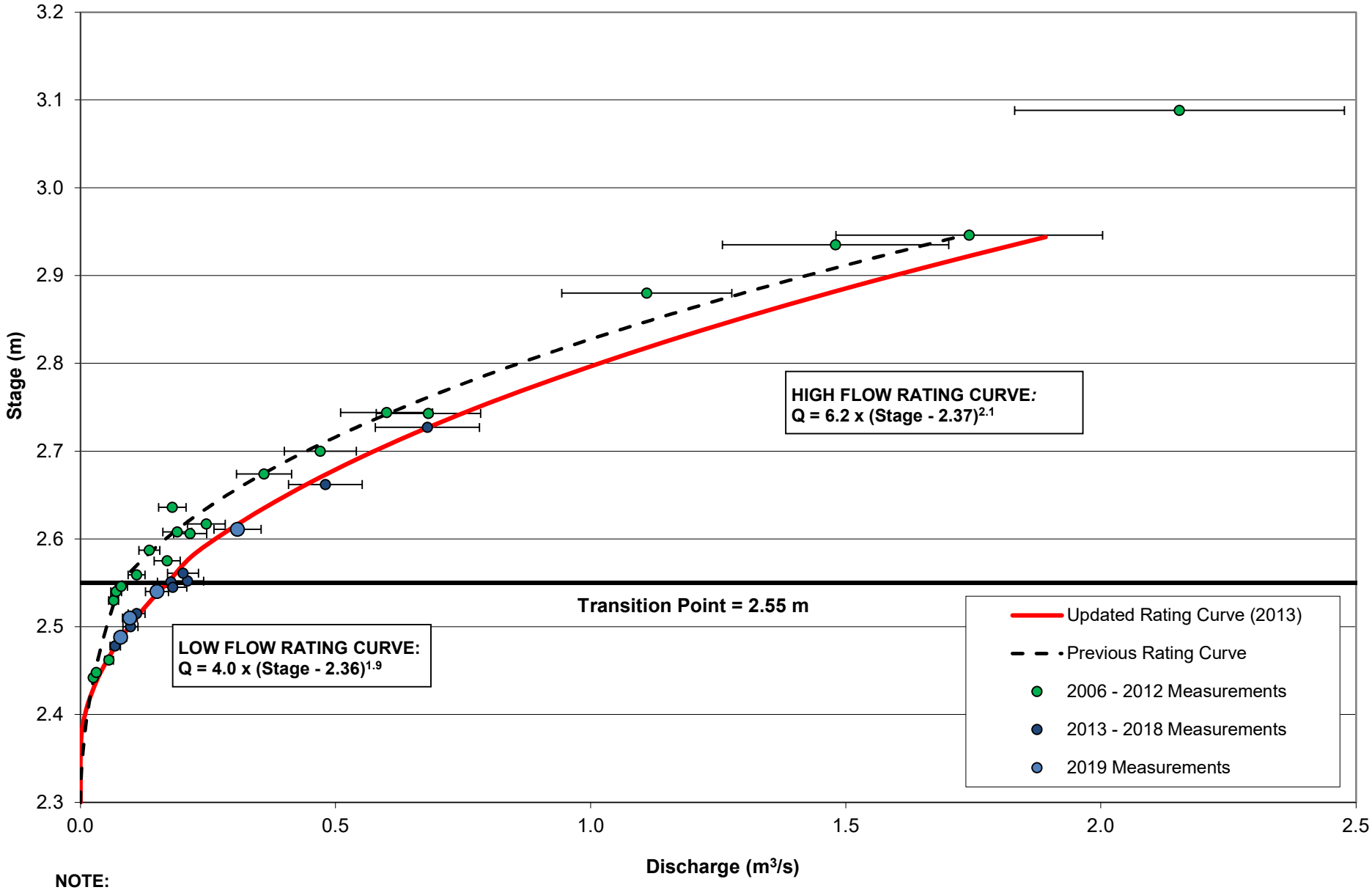
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2019

Figure 2 H01 - Philips Creek Tributary Rating Curve



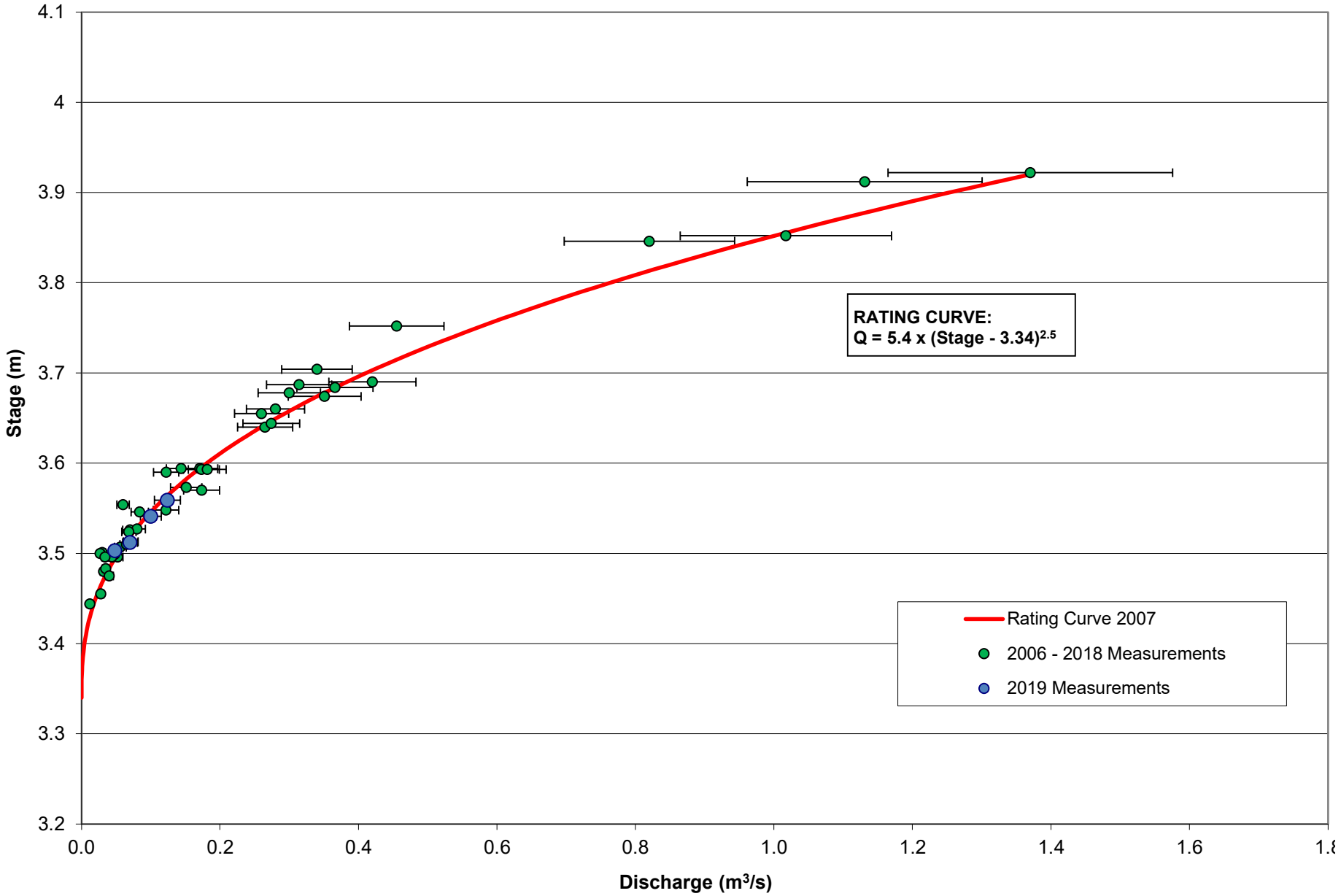
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2019

Figure 3 H02 - Tom River Rating Curve



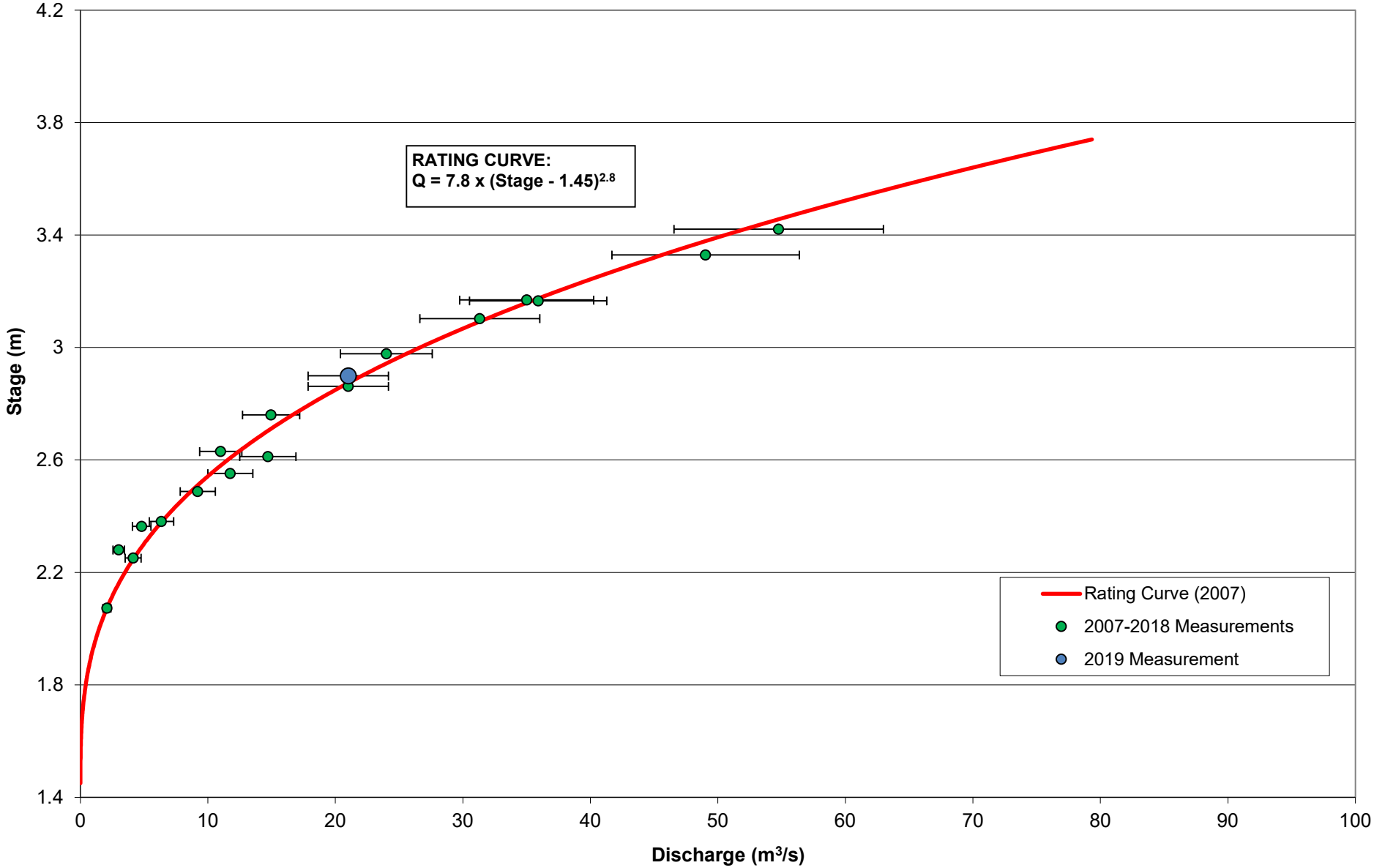
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2019

Figure 4 H04 - Camp Lake Tributary (CLT-2) Rating Curve



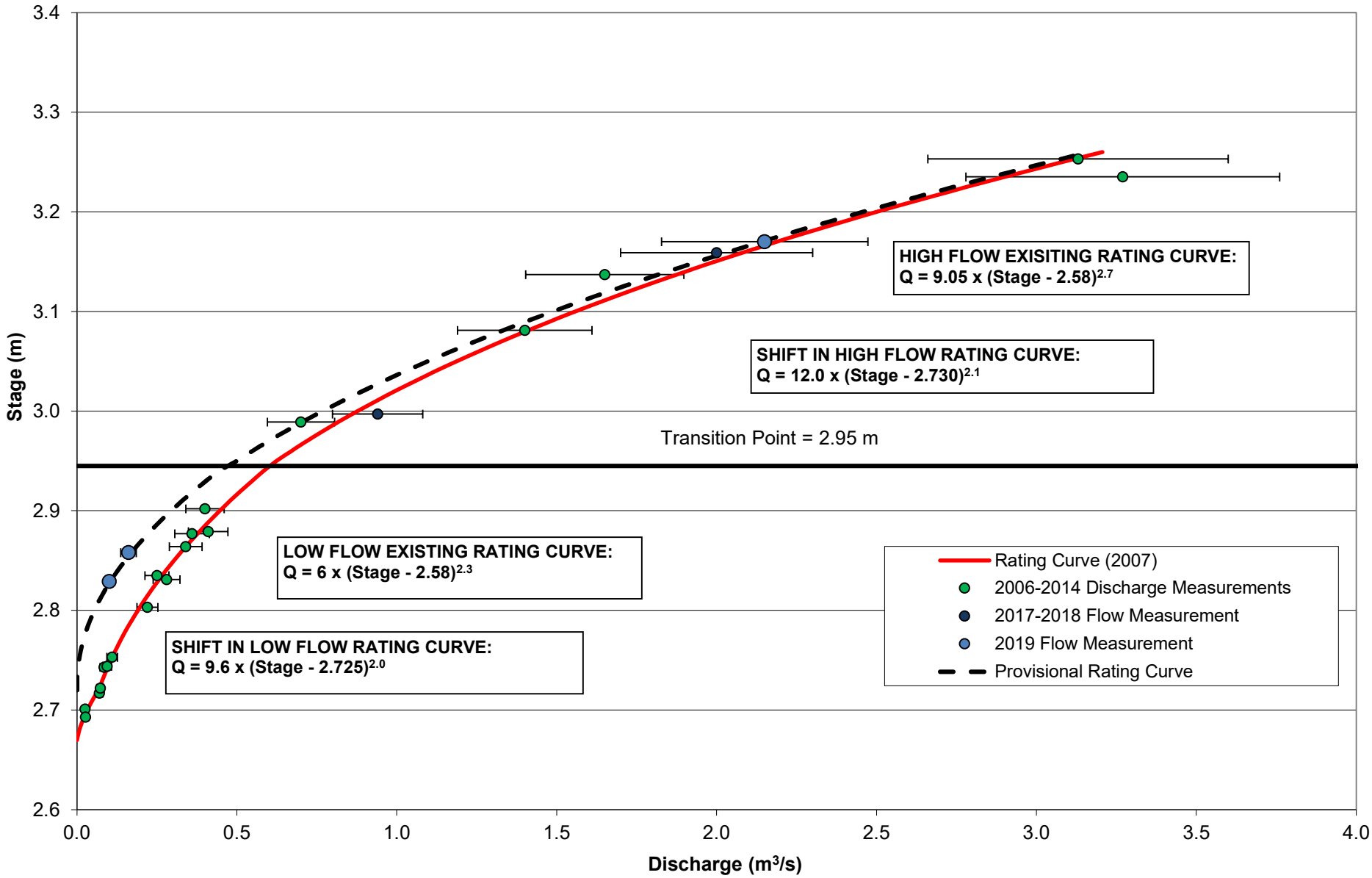
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2019

Figure 5 H05 - Camp Lake Tributary (CLT-1) Rating Curve



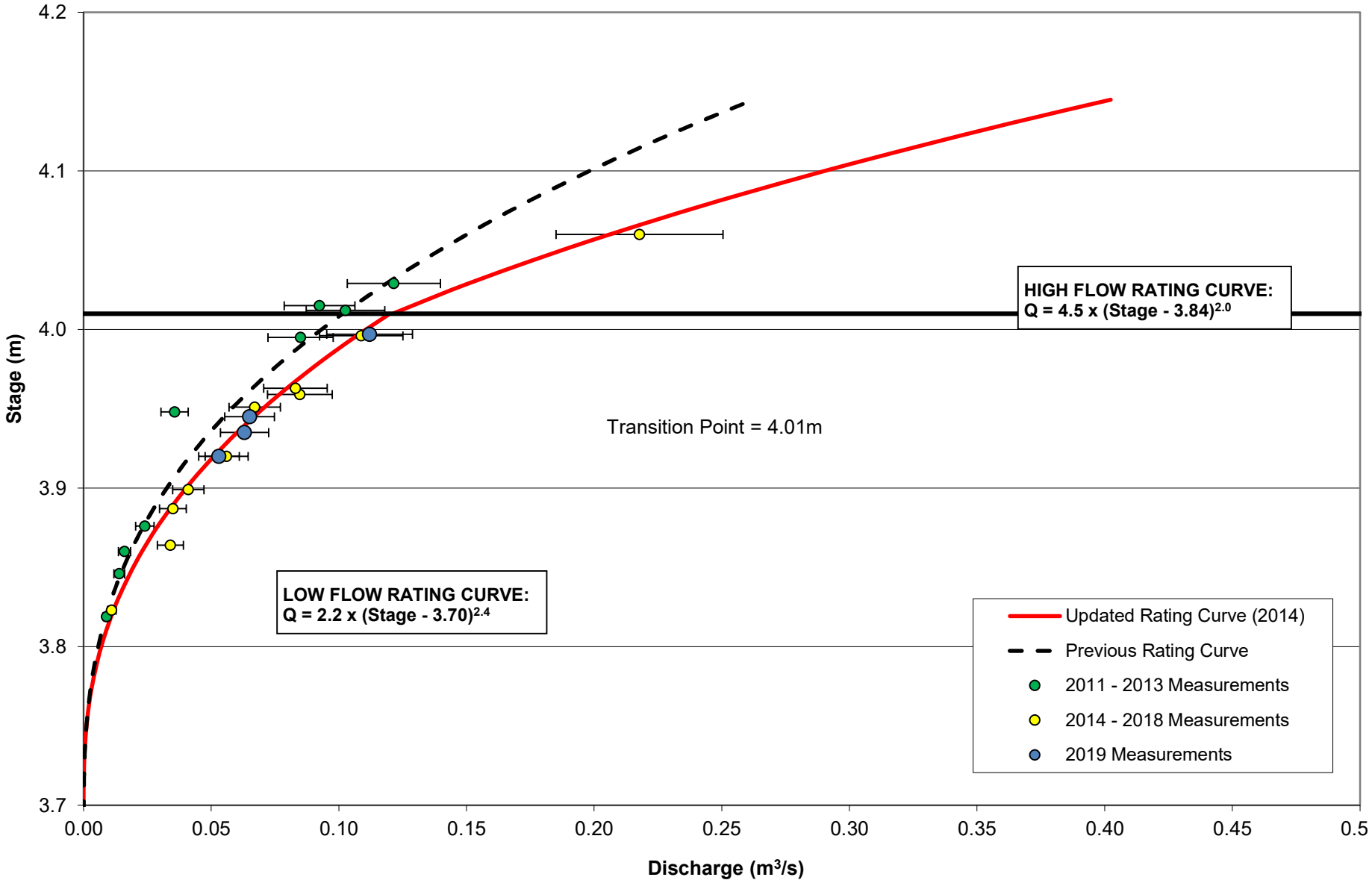
NOTES:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2019

Figure 6 H06 - Mary River Rating Curve



NOTES:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2019

Figure 7 H07 - Mary River Tributary F Rating Curve



NOTE:
1. UPDATED RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2019

Figure 8 H11 - Sheardown Lake Tributary (SDLT-1) Rating Curve

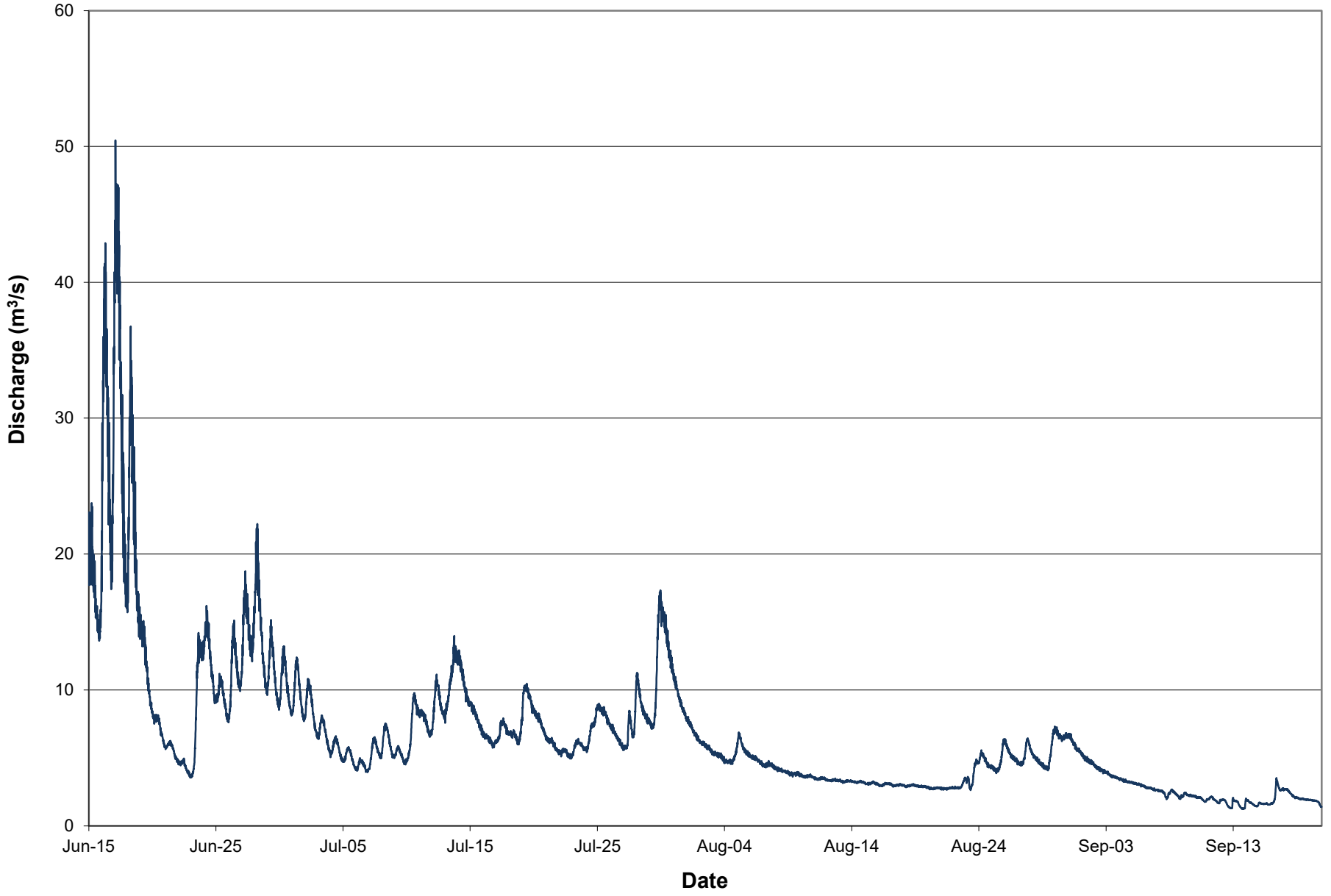


Figure 9 **H01 - Philips Creek Tributary 2019 Streamflow Record**

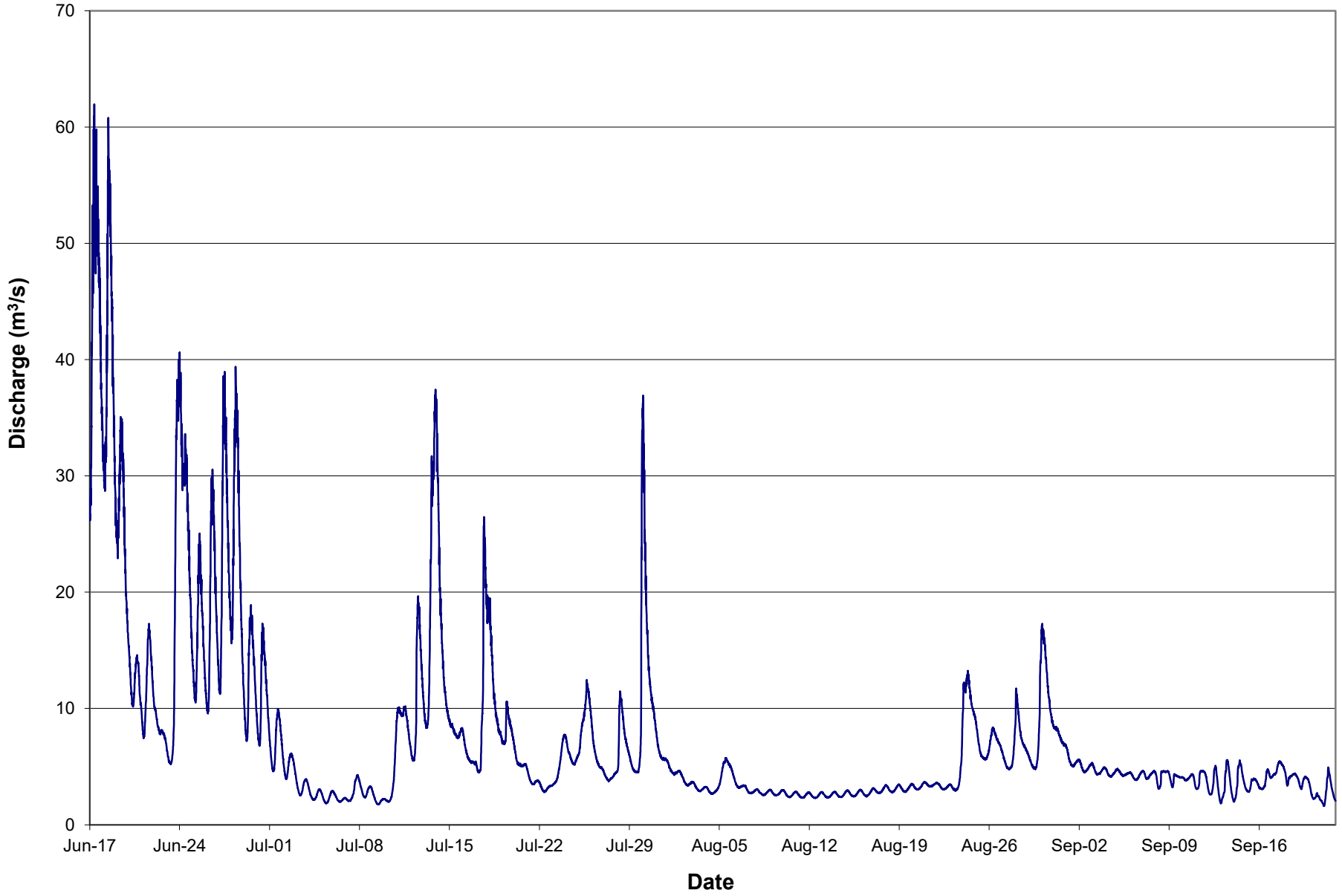


Figure 10 **H02 - Tom River 2019 Streamflow Record**

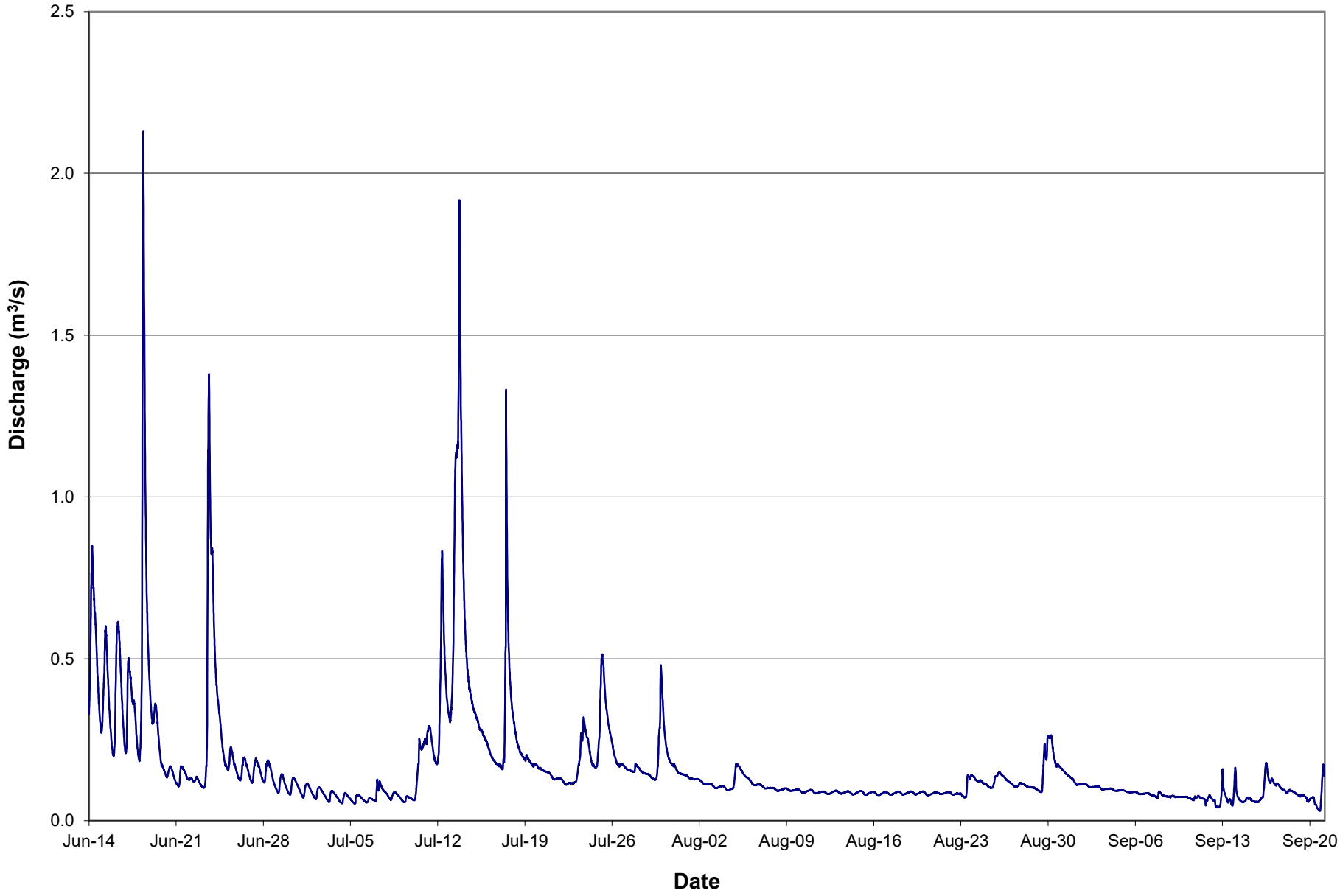


Figure 11 **H04 - Camp Lake Tributary (CLT-2) 2019 Flow Record**

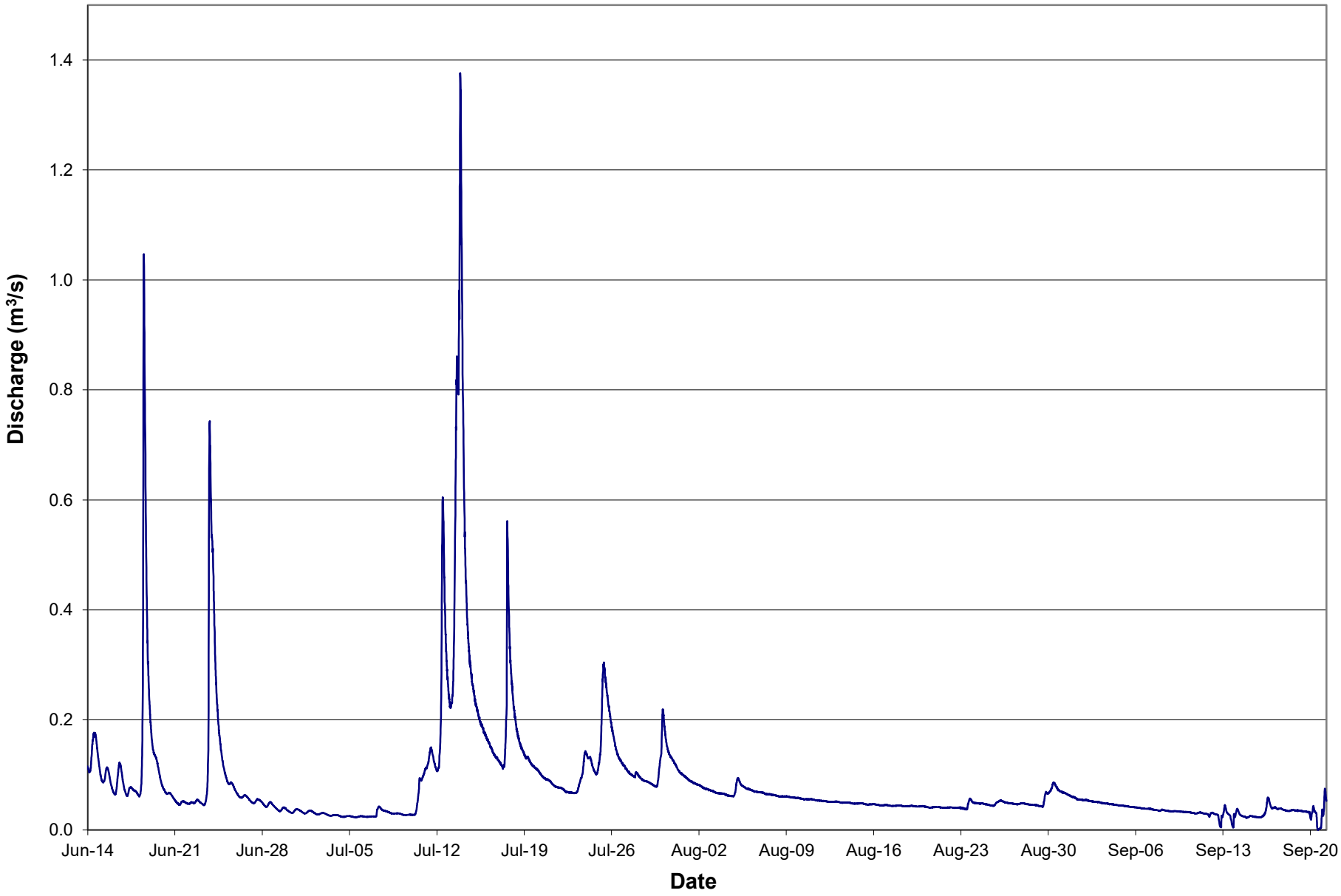


Figure 12 H05 - Camp Lake Tributary (CLT-1) 2019 Flow Record

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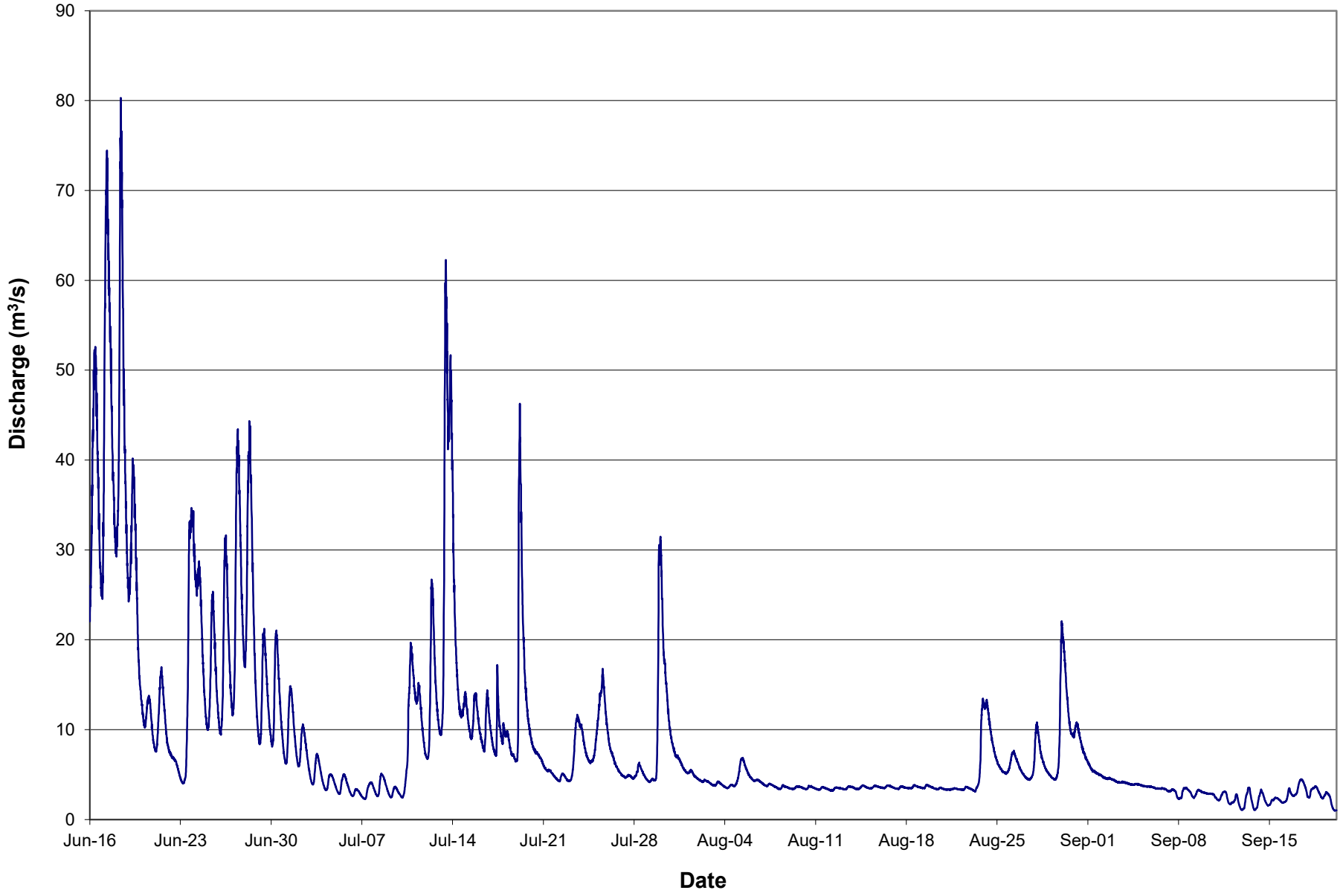
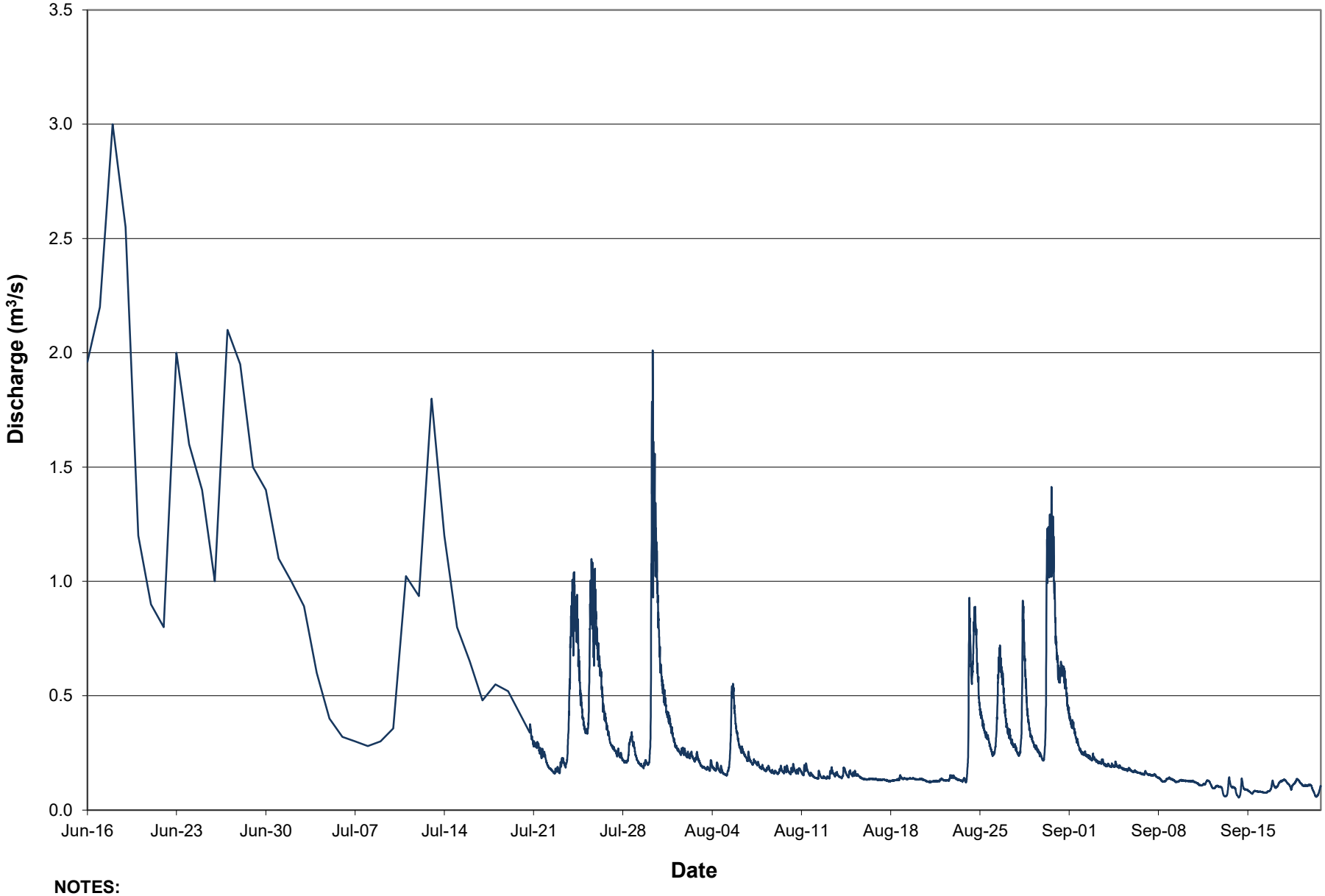


Figure 13 H06 - Mary River 2019 Flow Record



NOTES:
1. DATA FROM JUNE 16 TO JULY 20 PRESENTED AS DAILY AVERAGE FLOW DUE TO ISSUE WITH SENSOR DATA PROCESSING
2. FLOWS OF LESS THAN 1 M³/S ARE CONSIEDERED PROVISIONAL

Figure 14 H07 - Mary River Tributary F 2019 Flow Record

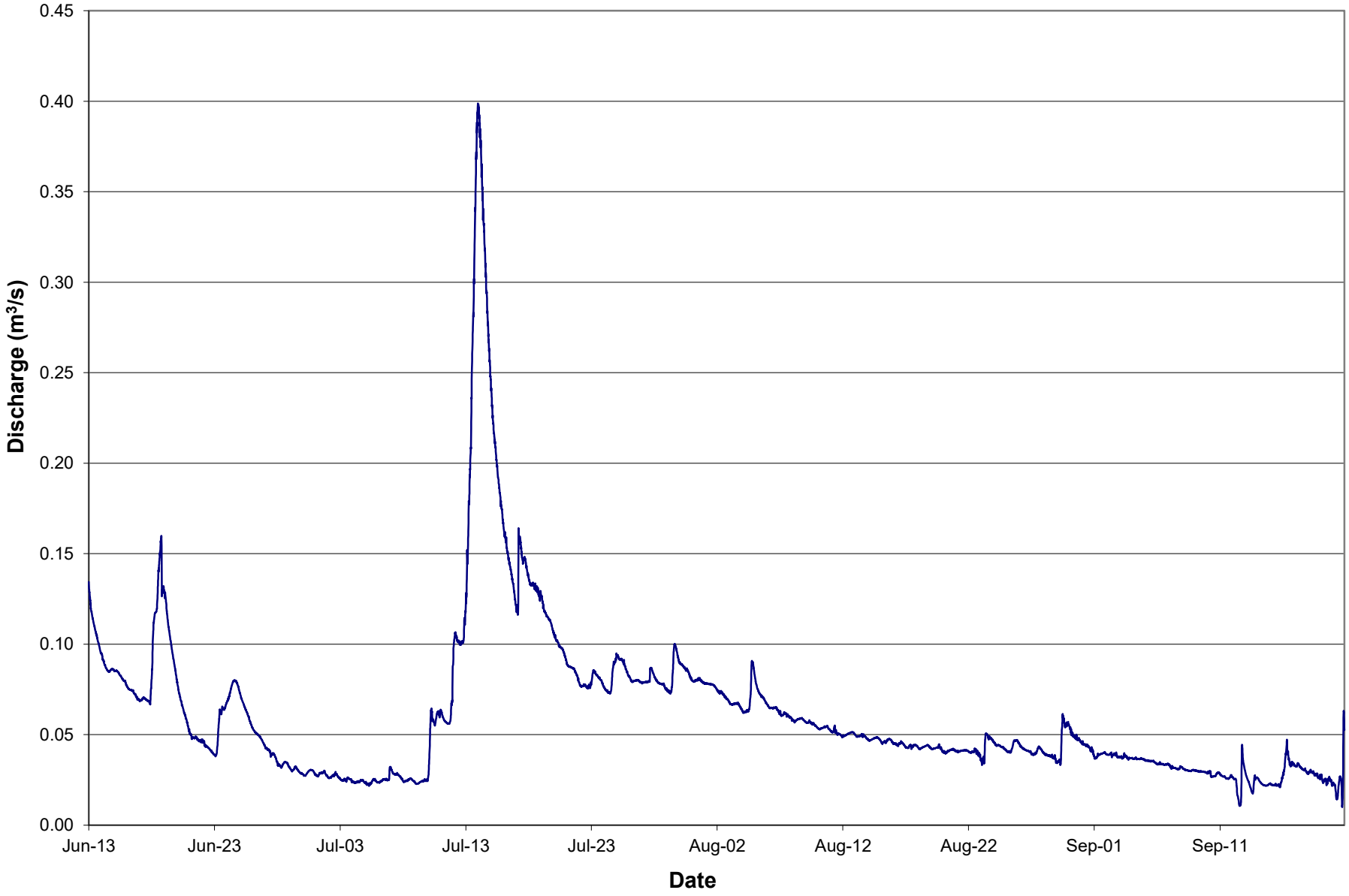


Figure 15 H11 - Sheardown Lake Tributary (SDLT-1) 2019 Streamflow Record

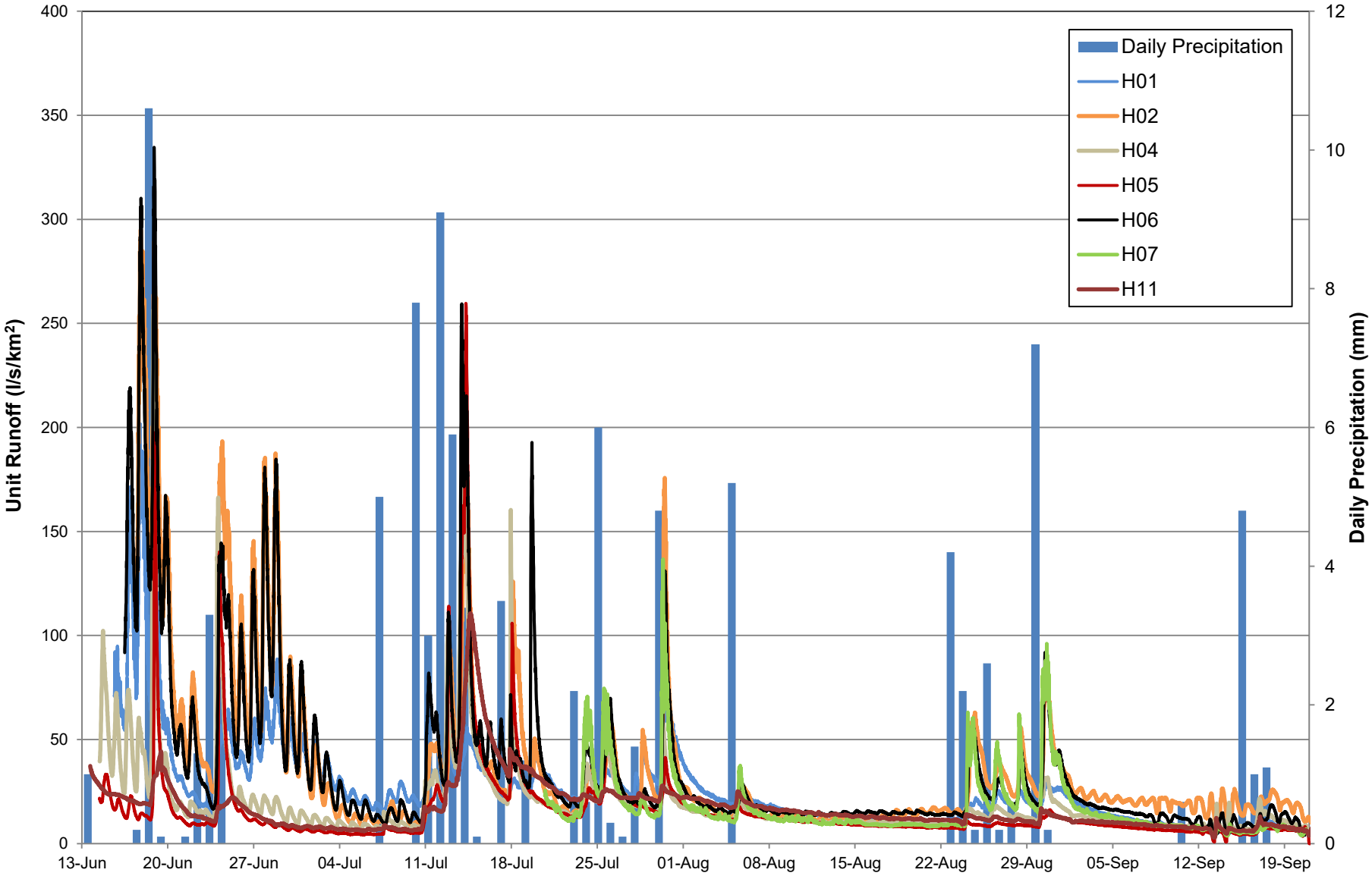


Figure 16 2019 Comparison of Unit Runoff

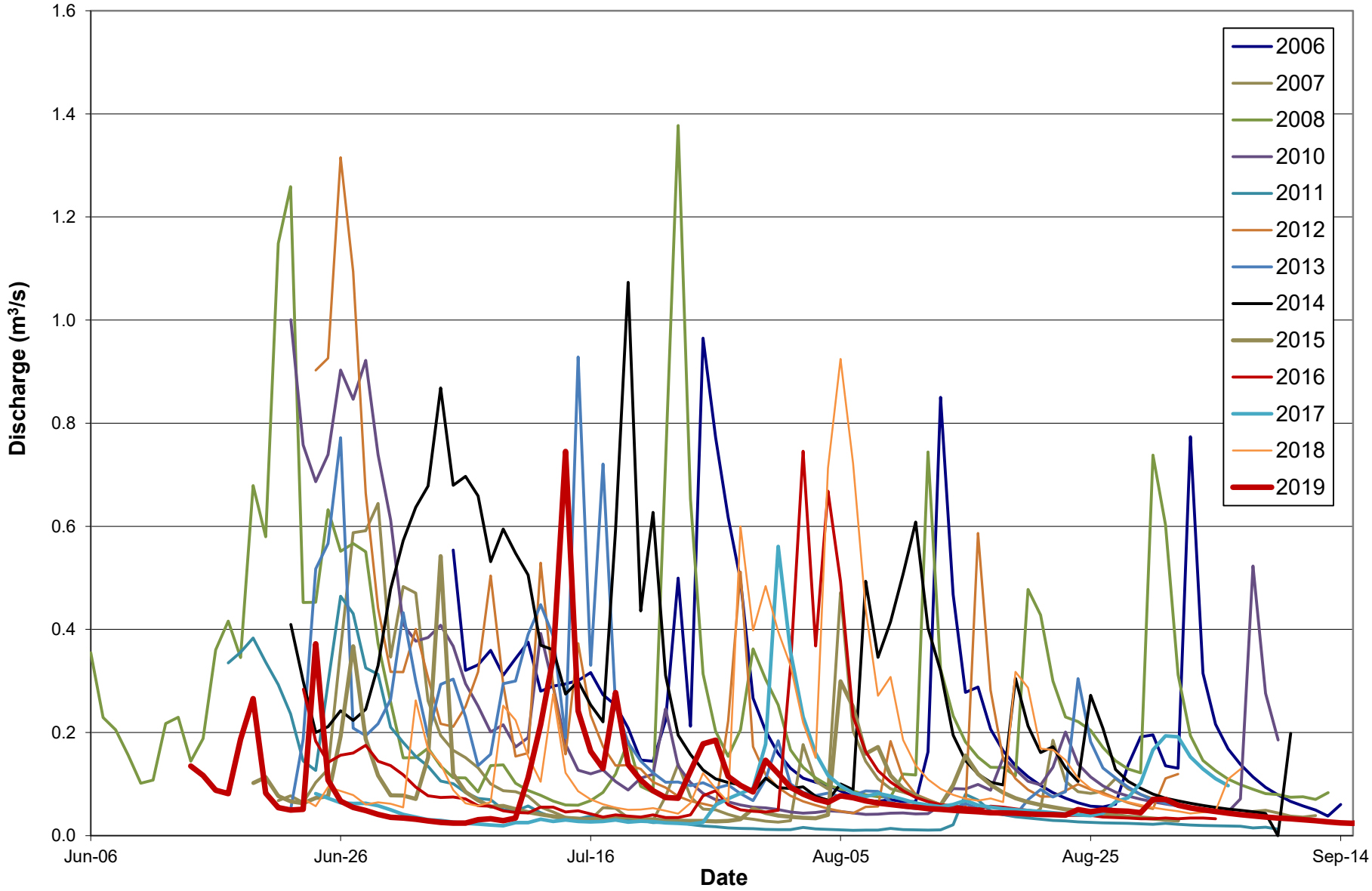


Figure 17 **H05 - Camp Lake Tributary (CLT-1) Measured Streamflow Hydrographs 2006 - 2019**