Remember in discovering on the flow of water to adduce first experience and then reason.

Leonardo da Vinci

(Adduce … to bring forward in argument)

"The major problems in the world are the result of the difference between how nature works and the way people think."

Gregory Bateson

2019 SRF Workshop

Assessing Ecological Risks from Streamflow Diversions by Applying Riffle Crest Thalweg Rating Curves

Workshop Coordinators: *William Trush, Ph.D., Co-Direct HSU Rive Institute and Emily Cooper, Stream Scientist, HSU River Institute*

April 23, 2019


Use this email:
bill.trush@gmail.com

ABSTRACT. By restricting streamflow diversions to a small percentage change in ambient riffle crest thalweg (RCT) depth, the natural magnitude, duration, frequency, and timing of unregulated streamflows (Q) remain protected. We will quantitatively link stream hydraulics to stream ecosystem processes, then practically assess ecological risks from streamflow diversion during the hydrograph recession. The morning session will review field techniques for measuring riffle crests, show how basic stream channel hydraulics can be estimated from RCT-Q rating curves, then calibrate an RCT-Q rating curve from the real-time USGS gaging web-site. Real spatial and real temporal variability will then be folded-into this hydraulic RCT framework to demonstrate how stream ecosystem complexity can be quantified from a top-down strategy. The afternoon session will synthesize the morning's RCT-Q rating curves' analytical/ecological attributes, then perform a step-by-step risk analysis of spawning success of the WY2018 Pacific lamprey run in the South Fork Eel River. As time permits, additional instream and riparian ecological processes will be risk-assessed. The final hour will be reserved for discussing the application of top-down versus bottom-up strategies for instream flow diversion policies in California.

PART 1

Basic Channel Morphology

Hydraulic Units and Thalweg

RCT Survey Protocol

RCT Survey Findings Presentation

RCT-Q Rating Curves

Definition

USGS Rating Curves

RCT-Q Rating Curves from Field Data

RCT-Q Rating Curve Family

Hydraulic Controls

Riffle Crests as Weirs

Basic Hydraulic Channel Controls

Active Channel Streamflow

Protocol Estimating Hydraulic Streamflow Thresholds (Q_T)

PART 2

Proportionality of Power Functions

Bypass vs Variable Diversions

Proportionality of Power Functions

PFE and Diversions

Flow Criteria

Definition

5% RCT Flow Criteria

Significance, Success, and Risk

Thinking Flow Criteria on the River

Ecological Significance of Hydraulic Controls

Hooker Creek Watershed Connectivity

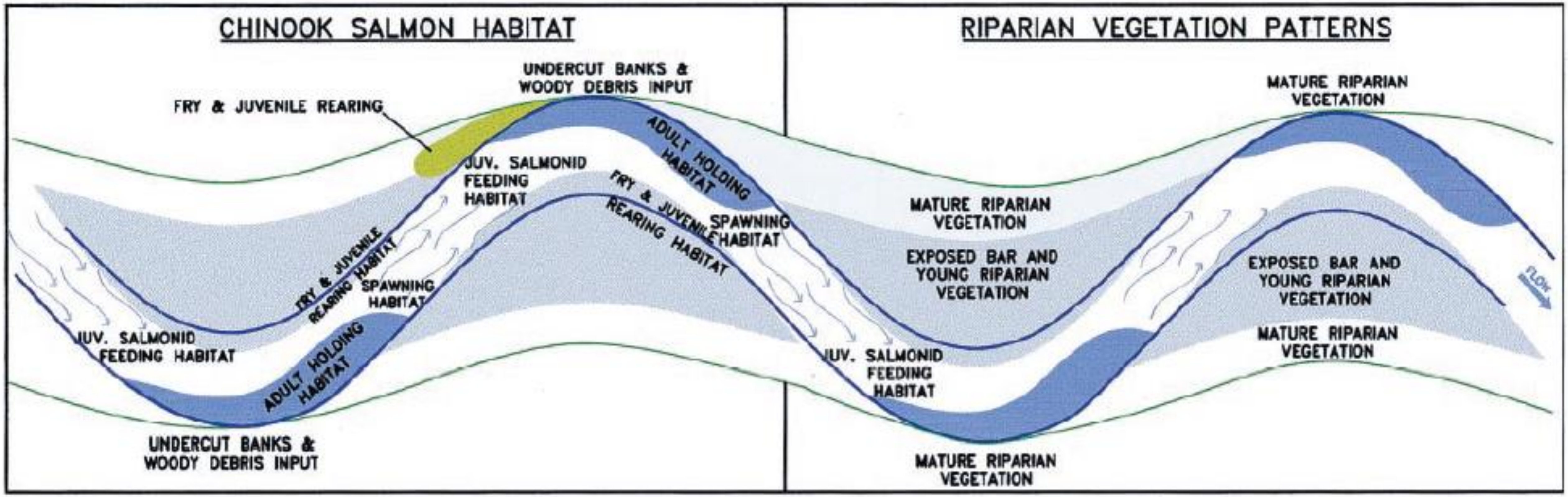
Cedar Creek Juvenile/Smolt Outmigration

Spawning Pacific Lamprey Success

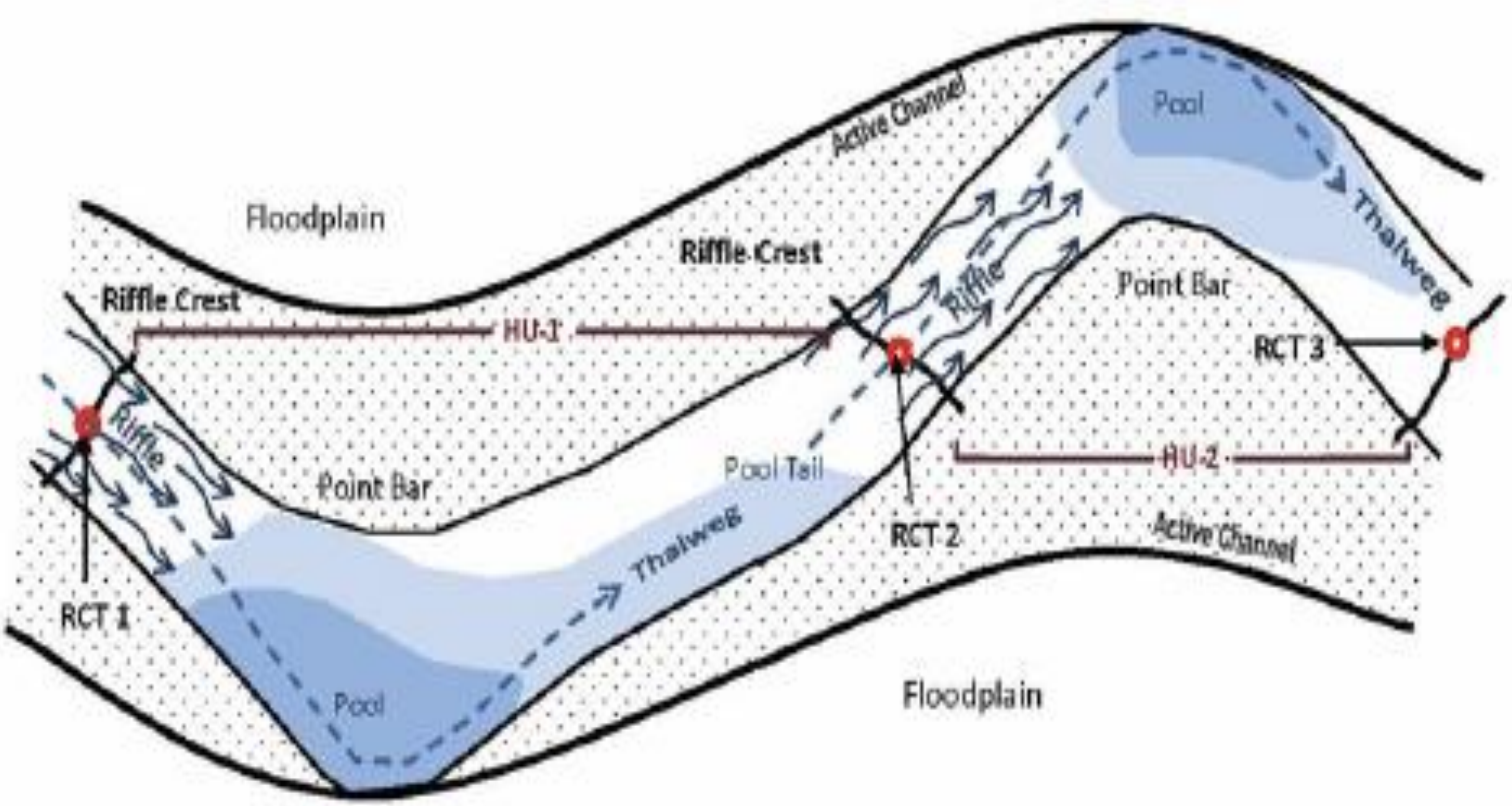
SF Eel River Section Control as Flow Criteria

Start with simple:

WHERE TO MEASURE A STREAM'S DEPTH?



Each hydraulic unit, defined by an upstream riffle and downstream pool or run, is bounded by an upper and lower riffle crest, and therefore an upper and lower RCT as well. These RCTs typically are located mid-channel, where the thalweg pathway transitions from one bank upstream toward the opposite bank downstream.

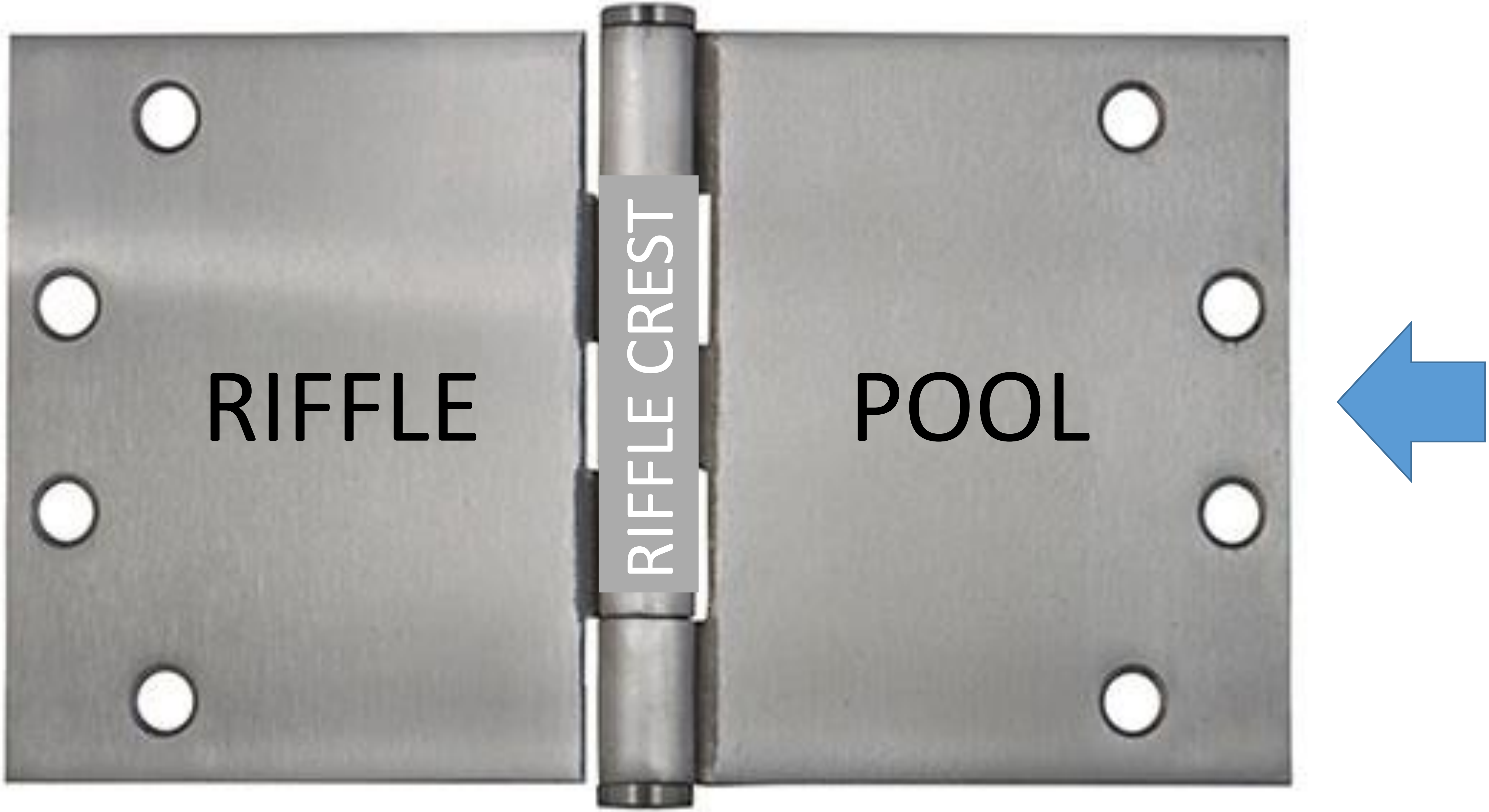

Floodplain
Active Channel
Pool
Riffle Crest
Riffle Crest
HU-1
Riffle
Point Bar
Thalweg
RCT 3
Riffle
Point Bar
Pool Tail
HU-2
Thalweg
RCT 2
Active Channel
RCT 1
Pool
Floodplain

Strategic hydraulically, riffle crest cross-sections (or ‘RCs’) and their thalwegs (i.e., the ‘riffle crest thalwegs’, or ‘RCTs’) are located at the highest channelbed thalweg elevation between an upstream pool and downstream riffle.

Two hydraulic units on Lower Arroyo Seco River, 24March2018 at 1:50 PM (777 cfs @ USGS nr Soledad gage).
(photo credit: Mason London)

The Riffle Crest (RC) is the uppermost boundary of a riffle. The lowest channelbed elevation along a stream’s cross-section spanning the riffle crest is its Riffle Crest Thalweg (RCT).

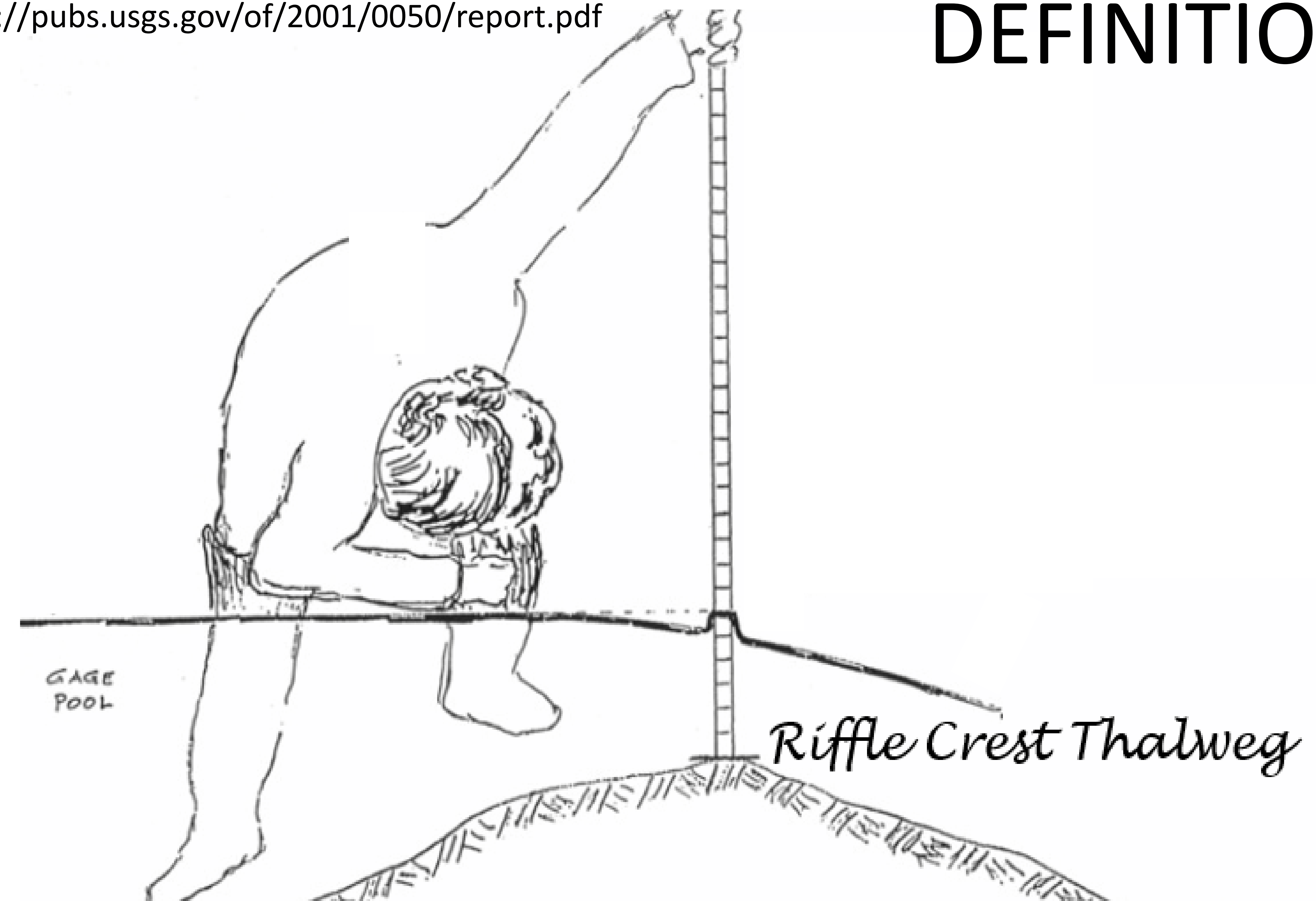

RCT


RIFFLE
RIFFLE CREST
POOL


South Fork Eel River
Miranda Reach
Blw Miranda Floodplain

U.S. Geological Survey Open-File Report 01-50
https://pubs.usgs.gov/of/2001/0050/report.pdf

DEFINITION



Measure down to hydraulic dead space.


March 8, 2019 Sullivan Gulch

EXCEEDENCE

P-Value = (n/N+1)*100

EXERCISE No.1.

EXCEEDENCE CURVE FOR RCT SURVEY

USE RCT SURVEY ON NEXT FRAME

SF Miranda

22 Sept 2016

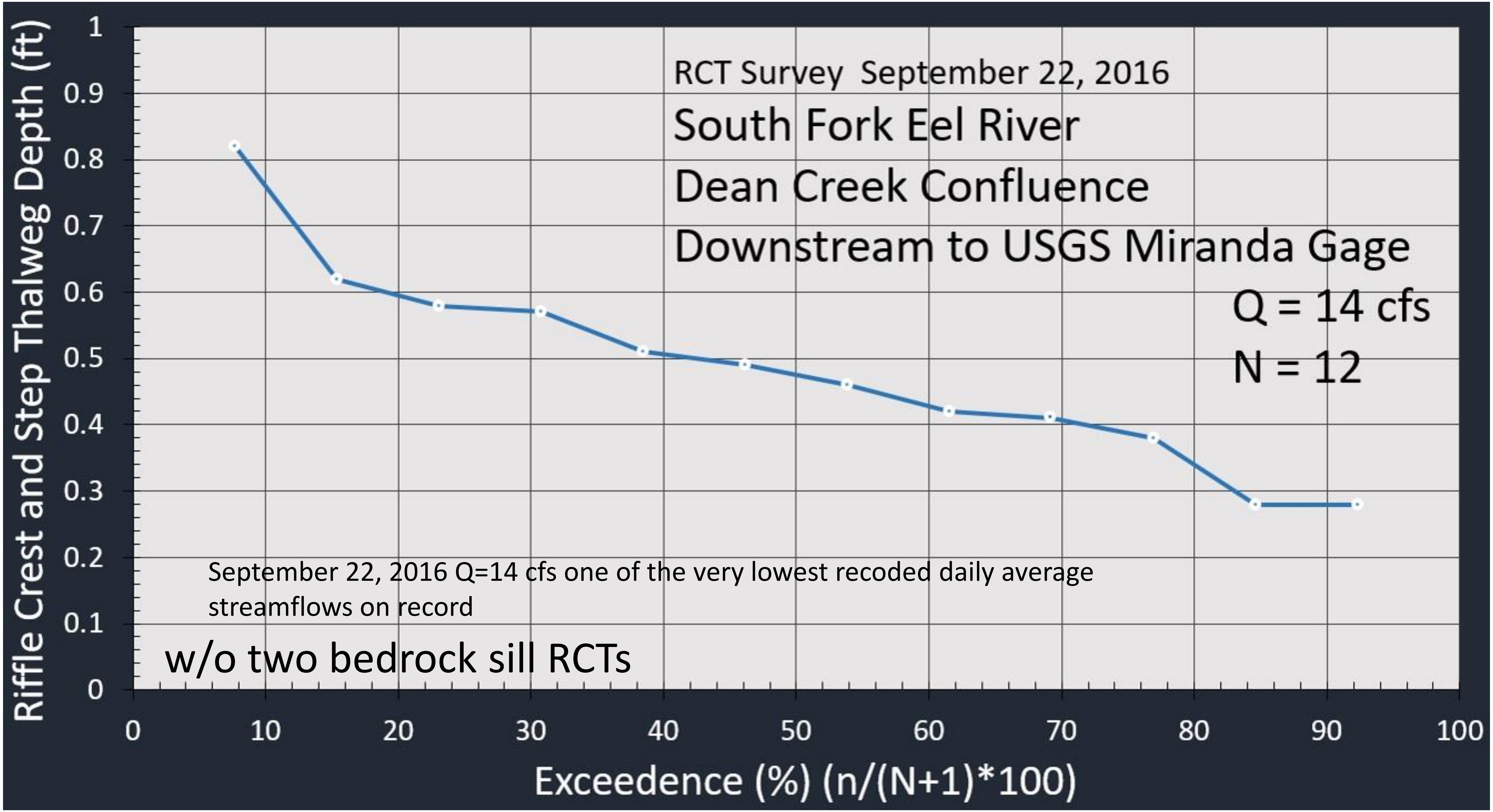
14 CFS

B. Trush
J. Ludtke

0.28
0.58
0.62
0.46
0.49
0.46
0.51
1.13 Bdrck Sill Map 4
0.57
0.38
0.28 Truck cross
0.81 Brk Sill
0.42
0.41
~~0.82~~
0.82

0.075 cfs

24 June 07 July

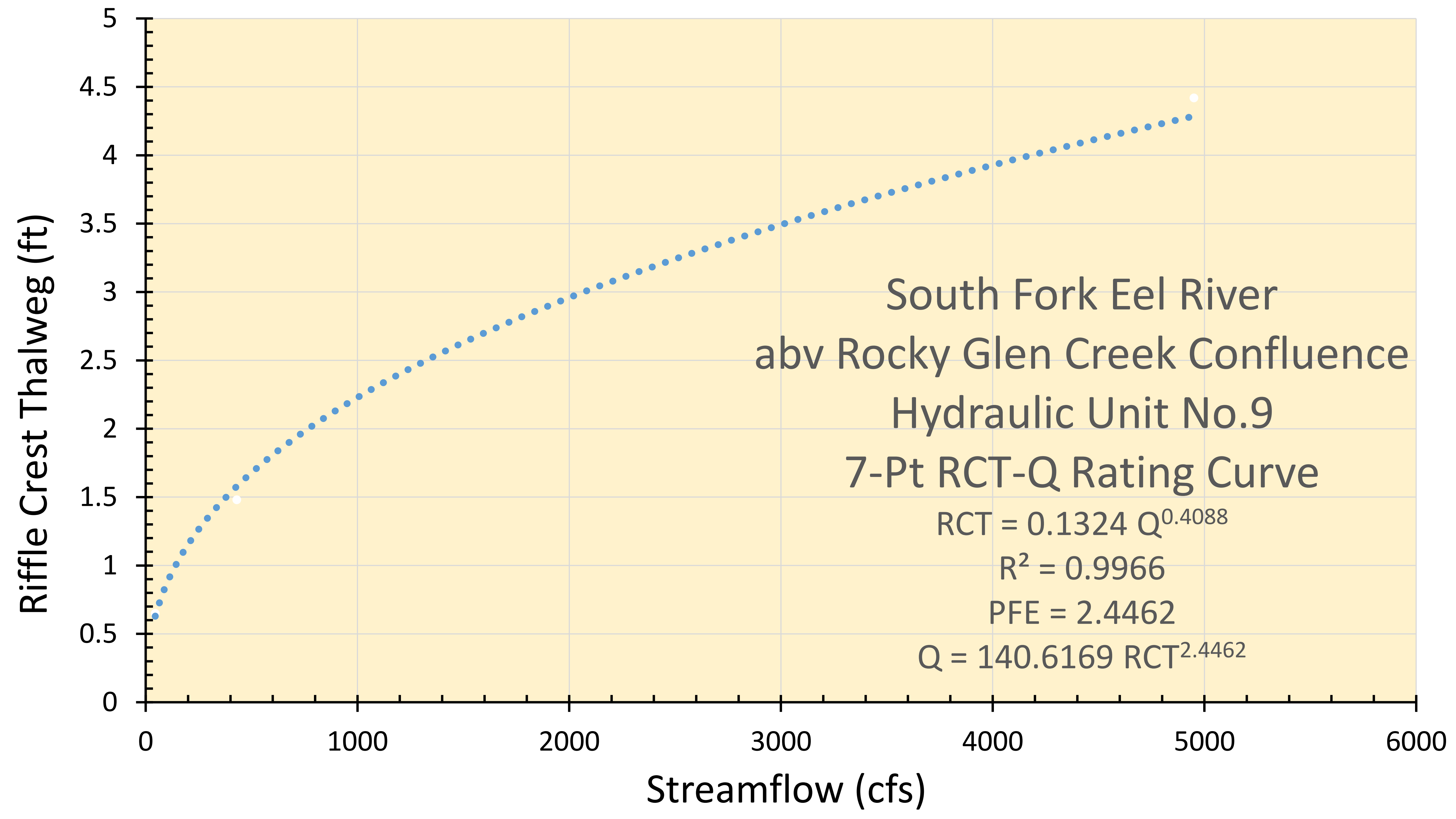

RCT Survey September 22, 2016
South Fork Eel River
Dean Creek Confluence
Downstream to USGS Miranda Gage
Q = 14 cfs
N = 12
September 22, 2016 Q=14 cfs one of the very lowest recoded daily average streamflows on record
w/o two bedrock sill RCTs
Riffle Crest and Step Thalweg Depth (ft)
Exceedence (%) (n/(N+1)*100)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50
60
70
80
90
100

Power Function

$$Y = a\,X^{b}$$

a = coefficient

b = exponent


South Fork Eel River
abv Rocky Glen Creek Confluence
Hydraulic Unit No.9
7-Pt RCT-Q Rating Curve
$RCT = 0.1324\ Q^{0.4088}$
$R^2 = 0.9966$
PFE = 2.4462
$Q = 140.6169\ RCT^{2.4462}$
Riffle Crest Thalweg (ft)
Streamflow (cfs)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
1000
2000
3000
4000
5000
6000

RCT-Q Rating Curve

$RCT = a\ Q^b$ Power Function

$RCT = 0.3194\ Q^{0.3194}$

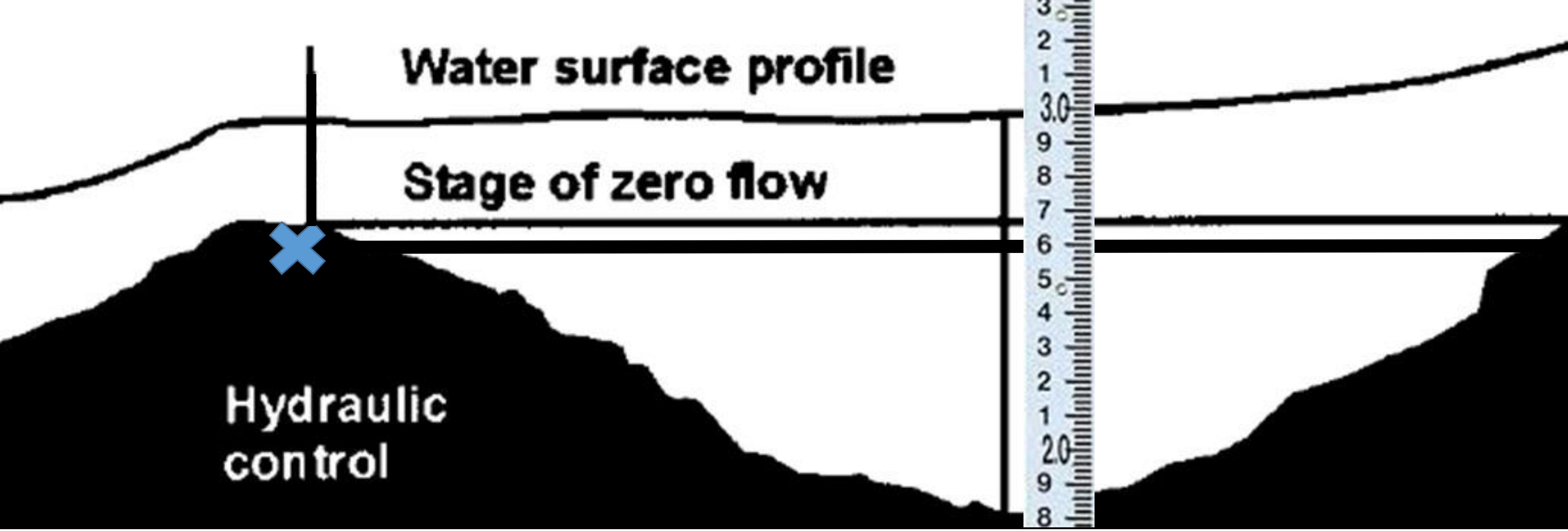
$Q = (1/a)^{(1/b)}\ RCT^{(1/b)}$

$Q = 38.6959\ RCT^{3.2031}$

$PFE = 3.2031$

USGS Realtime Web Site:

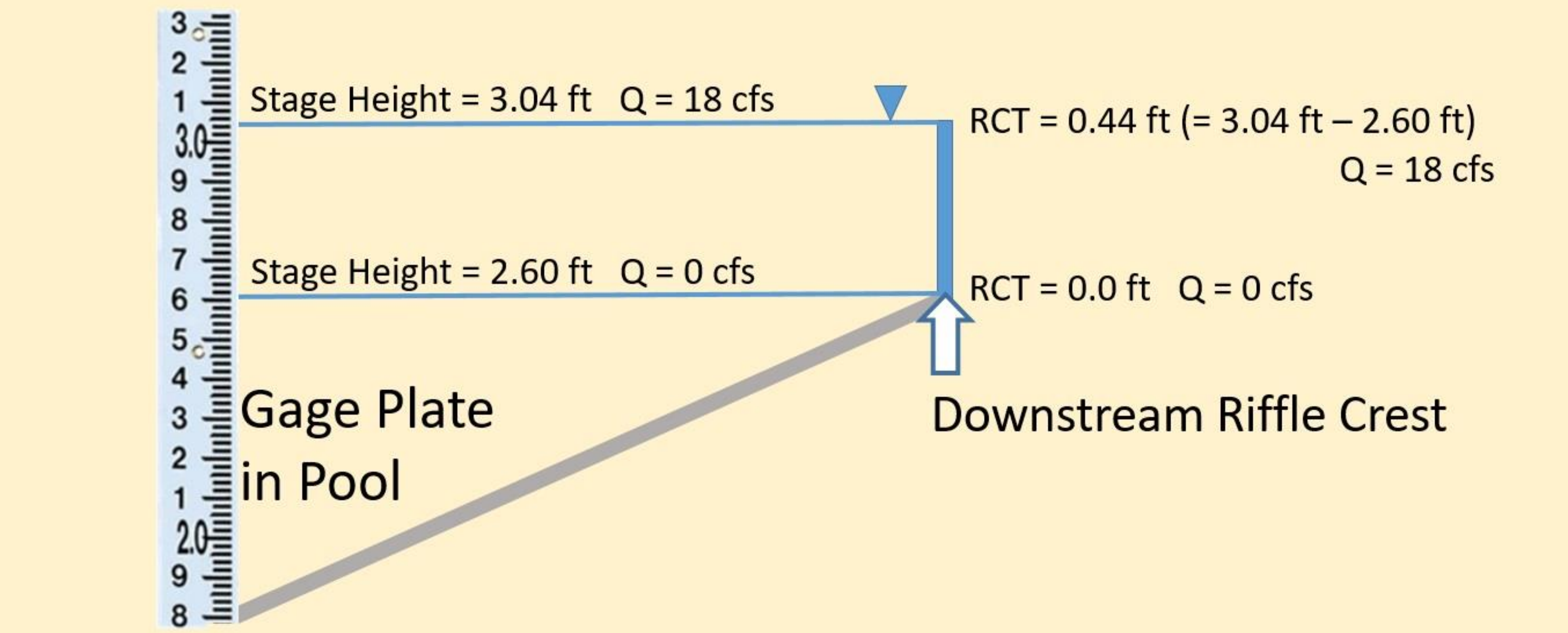
https://waterdata.usgs.gov/ca/nwis/current/?type=flow

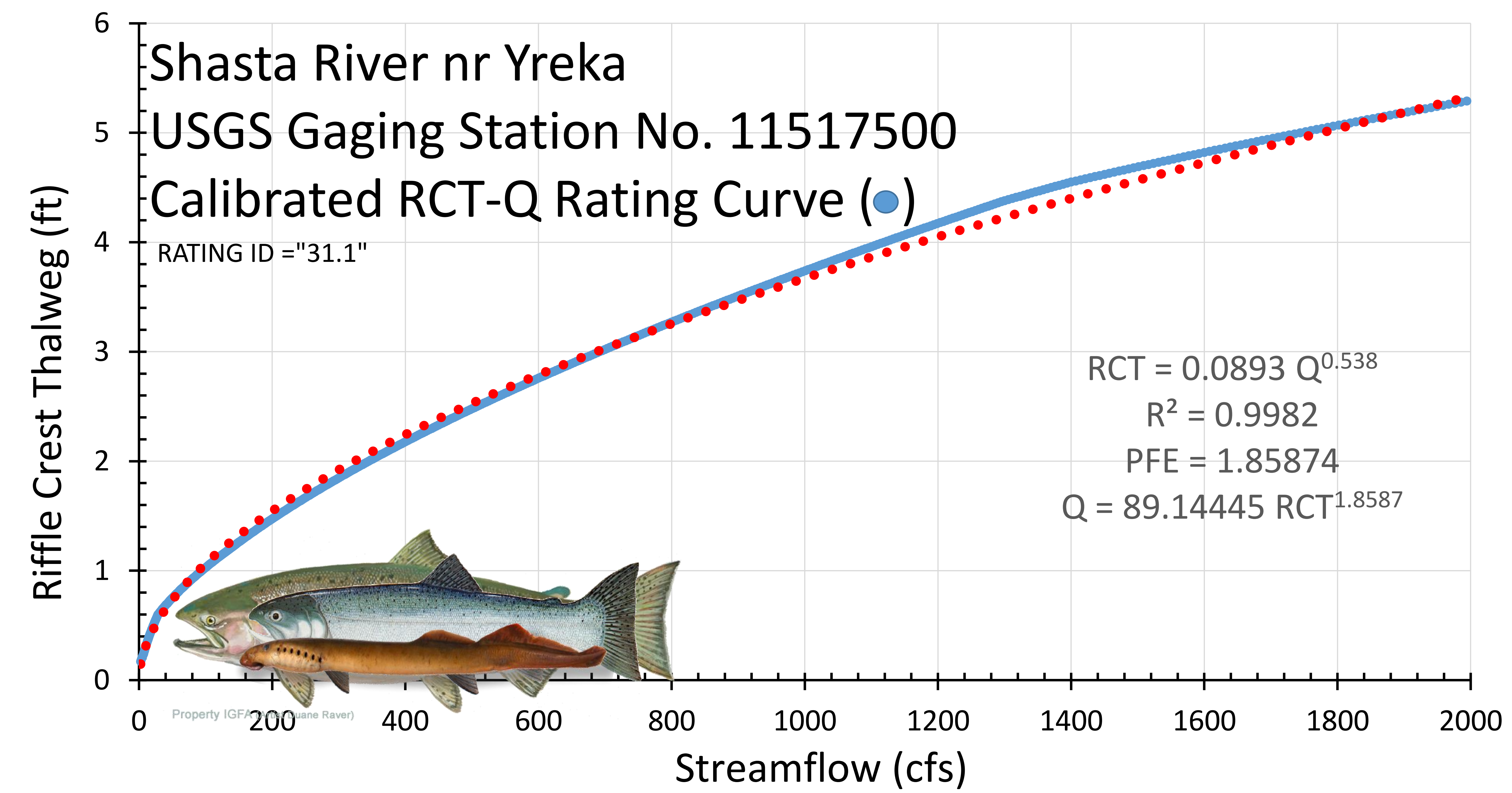


USGS Rating Curve Conversion to Riffle Crest Thalweg Rating Curve (RCT-Q Rating Curve)

https://nwis.waterdata.usgs.gov/ca/nwis/current/?type=flow

By knowing stage height at Q = 0 cfs (zero streamflow), a USGS Stage-Q Rating Curve can be calibrated as a RCT-Q Rating Curve



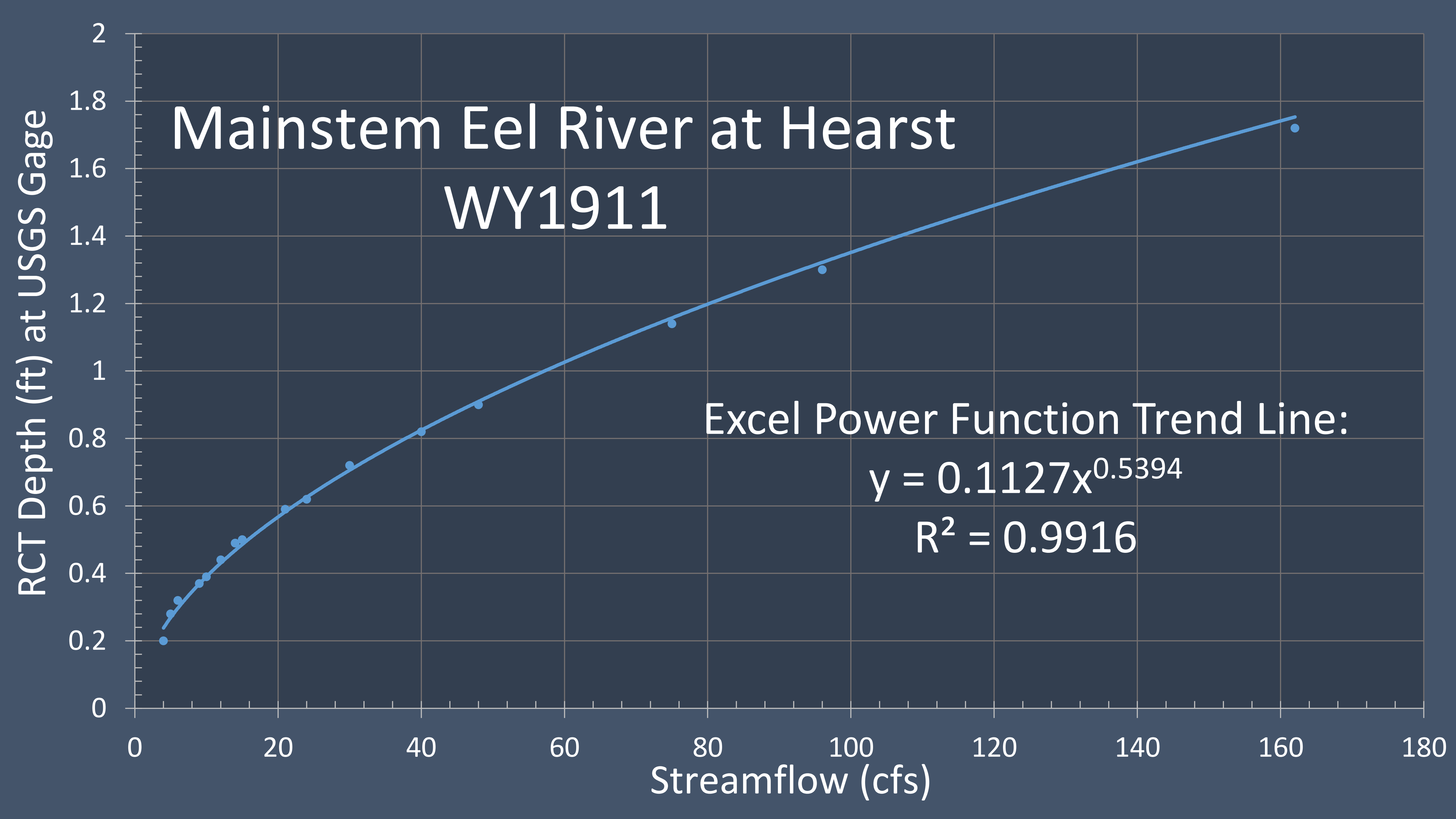

Shasta River nr Yreka
USGS Gaging Station No. 11517500
Calibrated RCT-Q Rating Curve ( )
RATING ID ="31.1"
RCT = 0.0893 Q^0.538
R² = 0.9982
PFE = 1.85874
Q = 89.14445 RCT^1.8587
Riffle Crest Thalweg (ft)
Streamflow (cfs)
0
1
2
3
4
5
6
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Property IGFA (Artist Duane Raver)

Rating tables for Salinas River near Salinas, Cal.

January 8 to December 31, 1900.

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*	*Feet.*	*Sec.-feet.*
3.60	6	4.60	65	5.60	650	7.50	3,500
3.80	10	4.80	105	5.80	850	8.00	4,750
4.00	15	.00	173	6.00	1,050	8.50	6,350
4.20	25	5.20	285	6.50	1,725	9.00	8,350
4.40	40	5.40	455	7.00	2,500	9.50	11,000

USGS Water Supply Paper No. 300



Mainstem Eel River at Hearst
WY1911
Excel Power Function Trend Line:
y = 0.1127x^0.5394
R² = 0.9916
RCT Depth (ft) at USGS Gage
Streamflow (cfs)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
20
40
60
80
100
120
140
160
180

HOW DO POWER FUNCTIONs WORK?

$RCT = 0.355\ Q^{0.306}$

$Q = 29.747\ RCT^{3.273}$

First: Choose Q = 10 cfs or RCT = 0.71817 ft

Second: 0.71817 ft * 0.95 = 0.68226 ft (decreased RCT depth by 5%)
Third: Insert 0.68226 ft into Equation Q = ……. = 8.51062 cfs
Fourth: Compute % change in Q with a 5% decrease in RCT depth:
8.51062 cfs / 10.000 = 0.85106
0.85106 * 100 = 85.11

100.00 – 85.11 = 14.99%Q

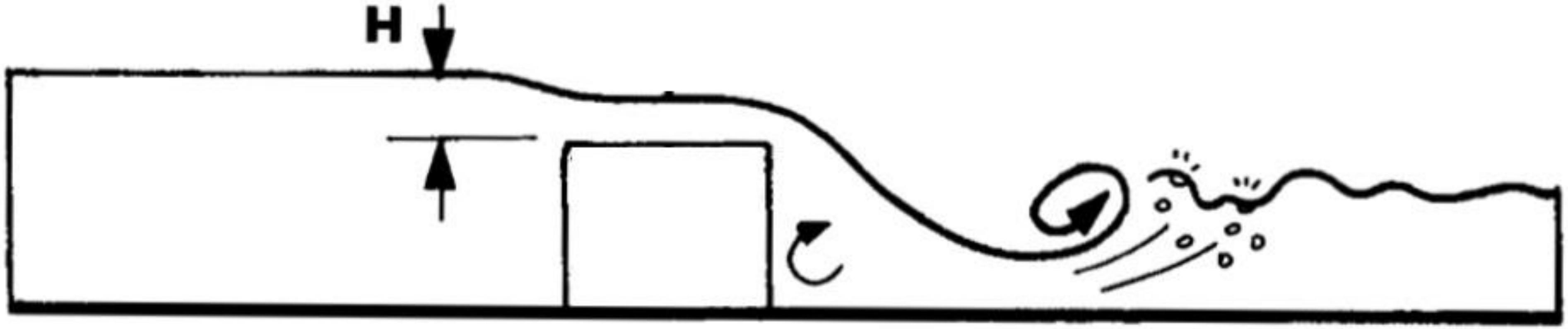
NOW, DO THE SAME CALCULATIONS FOR A DIFFERENT STREAMFLOW. WHAT %Q DO YOU GET? HINT: SHOULD BE VERY CLOSE TO 15%.

EXERCISE No.2.

Exploring How Power Functions Work

Use RCT-Q Rating Curve in Next Frame

Broad Crested Weir



Riffle Crest

Rectangular Weir

$Q = c_d \, L \, h^{3/2}$

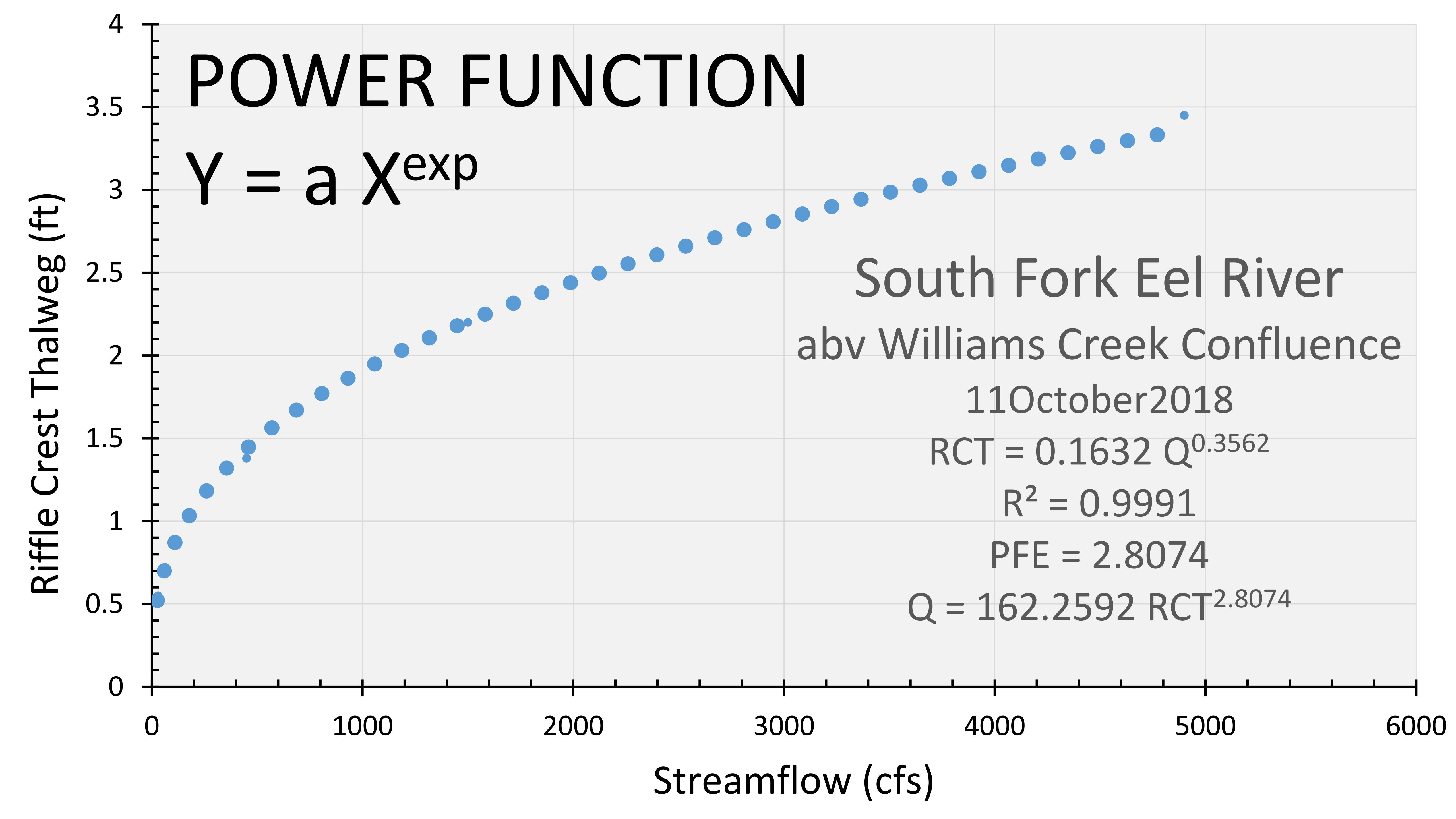
Triangular Weir

$Q = c_d \tan(\Theta/2) \, h^{5/2}$

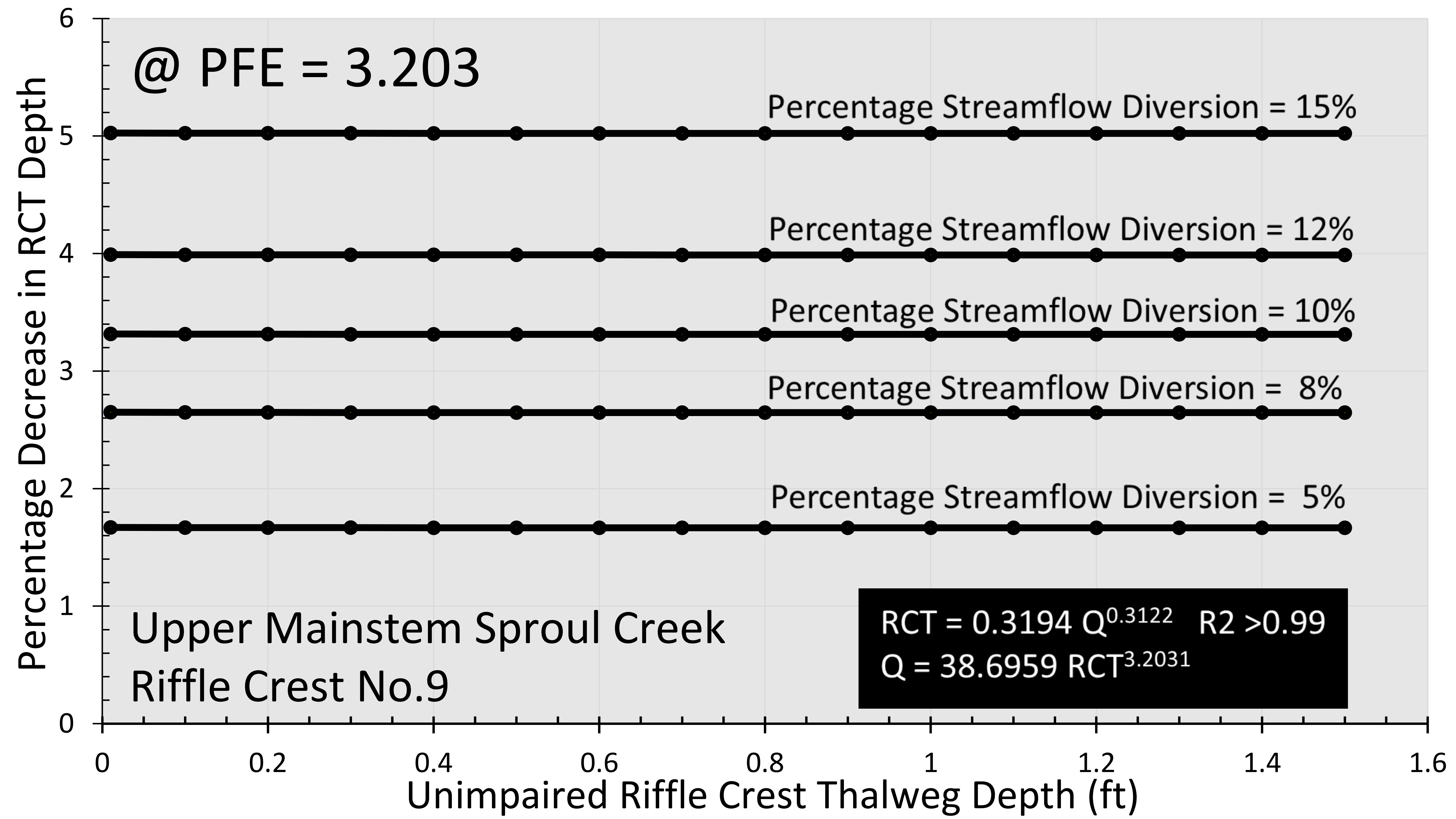
Most riffle crest cross-sections bear strong resemblance to engineered weirs. Their similarity in shape extends to their similarity in function, making riffle crest cross sections natural weir prototypes. Understanding how weirs function hydraulically does go a long way toward explaining how riffle crests function. From a hydraulic perspective, most stream channel reaches can be evaluated/investigated ecologically as a collection of unique weirs, one at each riffle crest cross section.

Riffle Crest Thalweg Rating Curves

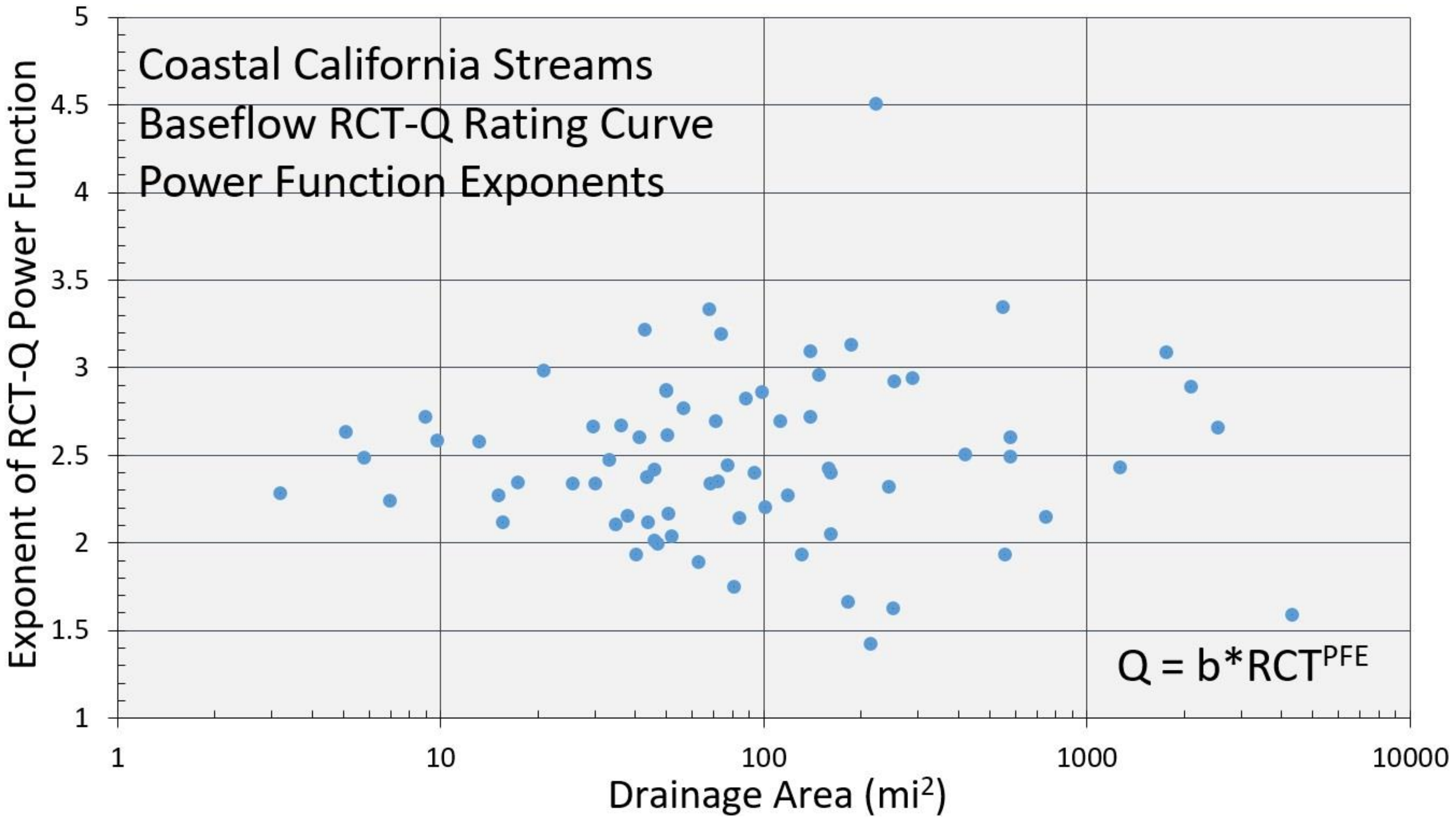
The greatest importance of the RC and RCT towards understanding how stream ecosystems work, under past and present environments, is not because of its usefulness as a universal depth measure, but because of its rate of change in depth as streamflow changes, i.e., when we think *verb* rather than *noun*.



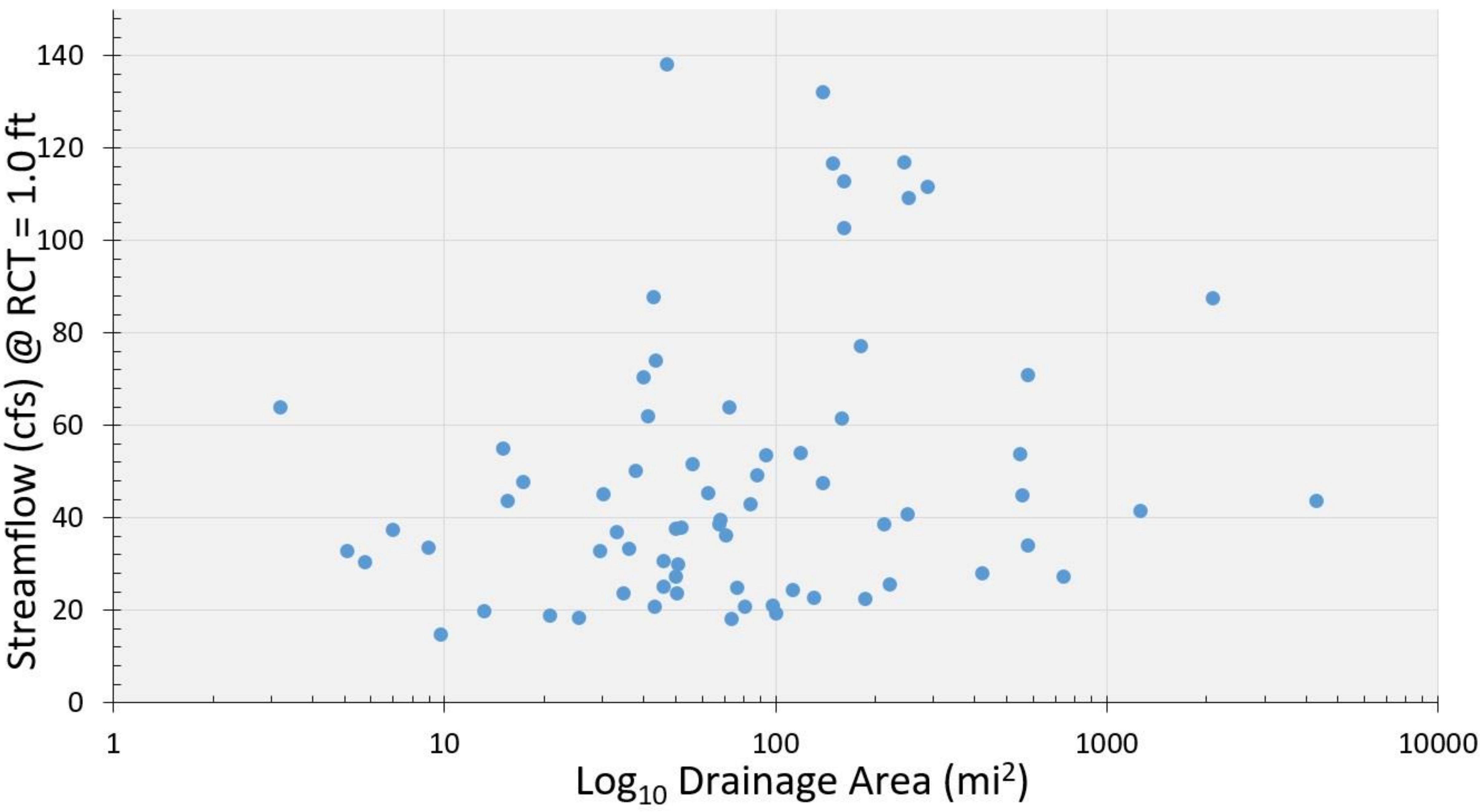
POWER FUNCTION
Y = a X^exp
South Fork Eel River
abv Williams Creek Confluence
11October2018
RCT = 0.1632 Q^0.3562
R² = 0.9991
PFE = 2.8074
Q = 162.2592 RCT^2.8074
Riffle Crest Thalweg (ft)
Streamflow (cfs)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
1000
2000
3000
4000
5000
6000



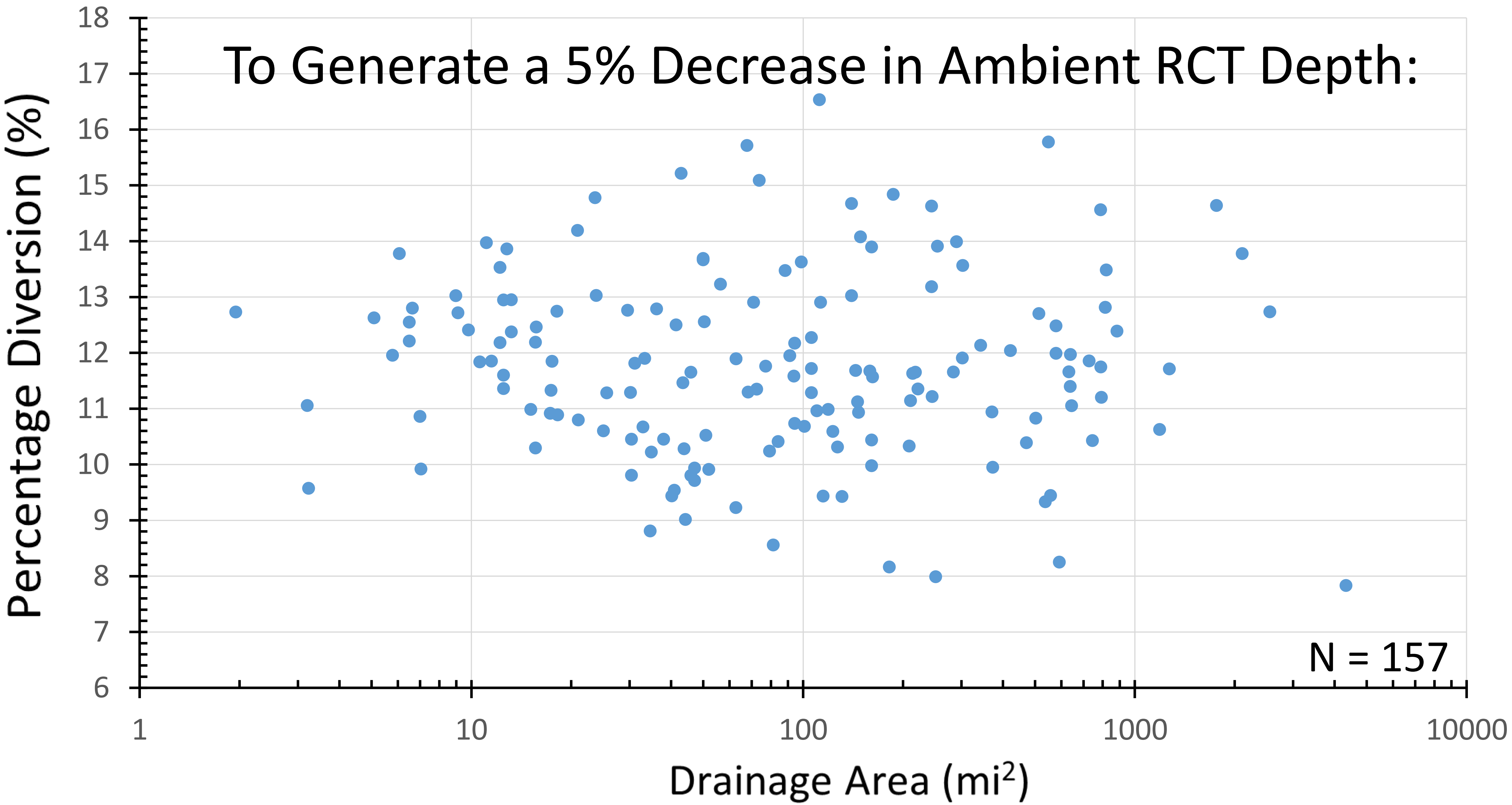
@ PFE = 3.203
Percentage Streamflow Diversion = 15%
Percentage Streamflow Diversion = 12%
Percentage Streamflow Diversion = 10%
Percentage Streamflow Diversion = 8%
Percentage Streamflow Diversion = 5%
Upper Mainstem Sproul Creek
Riffle Crest No.9
RCT = 0.3194 Q^0.3122 R2 >0.99
Q = 38.6959 RCT^3.2031
Percentage Decrease in RCT Depth
Unimpaired Riffle Crest Thalweg Depth (ft)
0
1
2
3
4
5
6
0.2
0.4
0.6
0.8
1.2
1.4
1.6



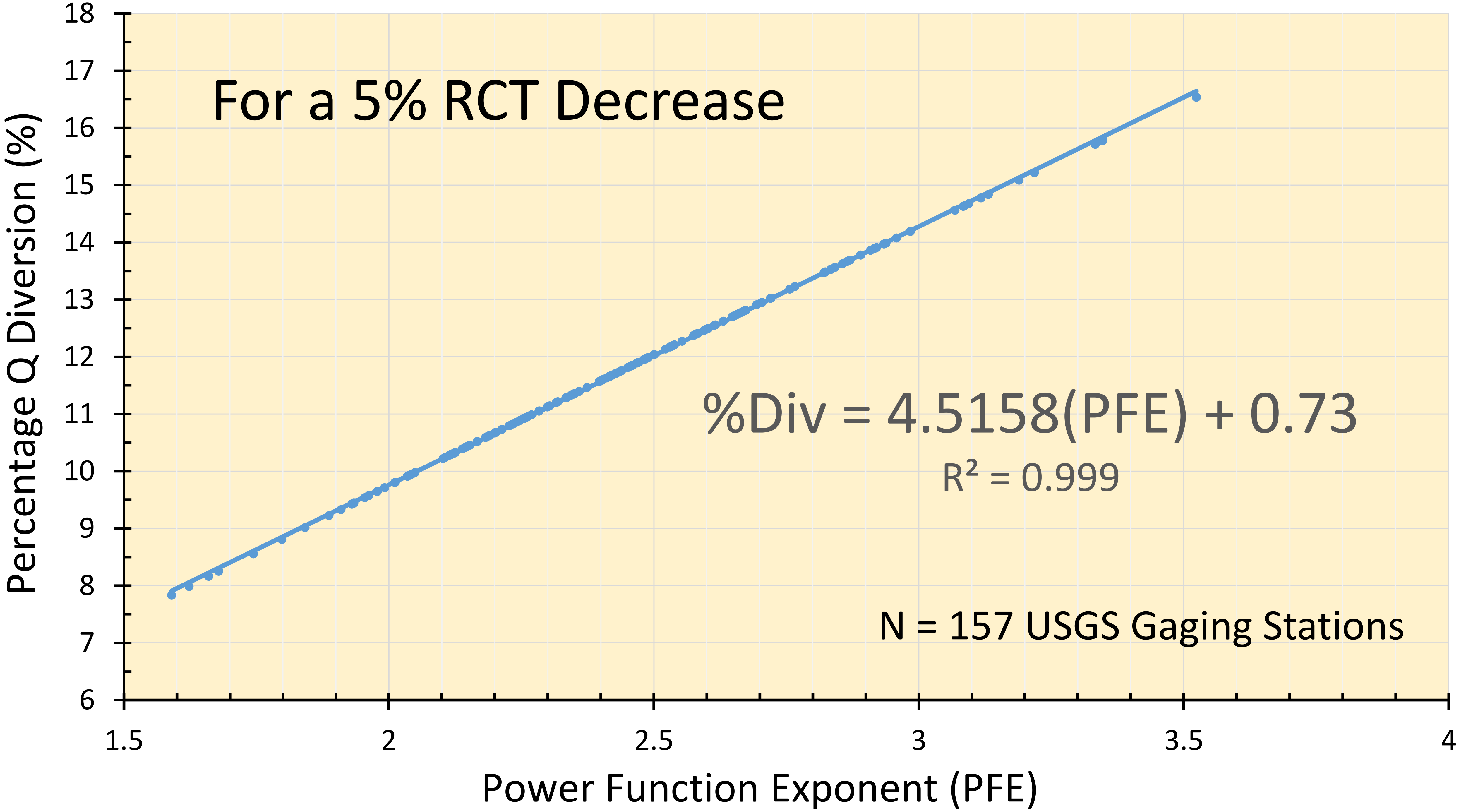
Coastal California Streams
Baseflow RCT-Q Rating Curve
Power Function Exponents
Exponent of RCT-Q Power Function
Drainage Area (mi²)
Q = b*RCT^PFE
5
4.5
4
3.5
3
2.5
2
1.5
1
1
10
100
1000
10000

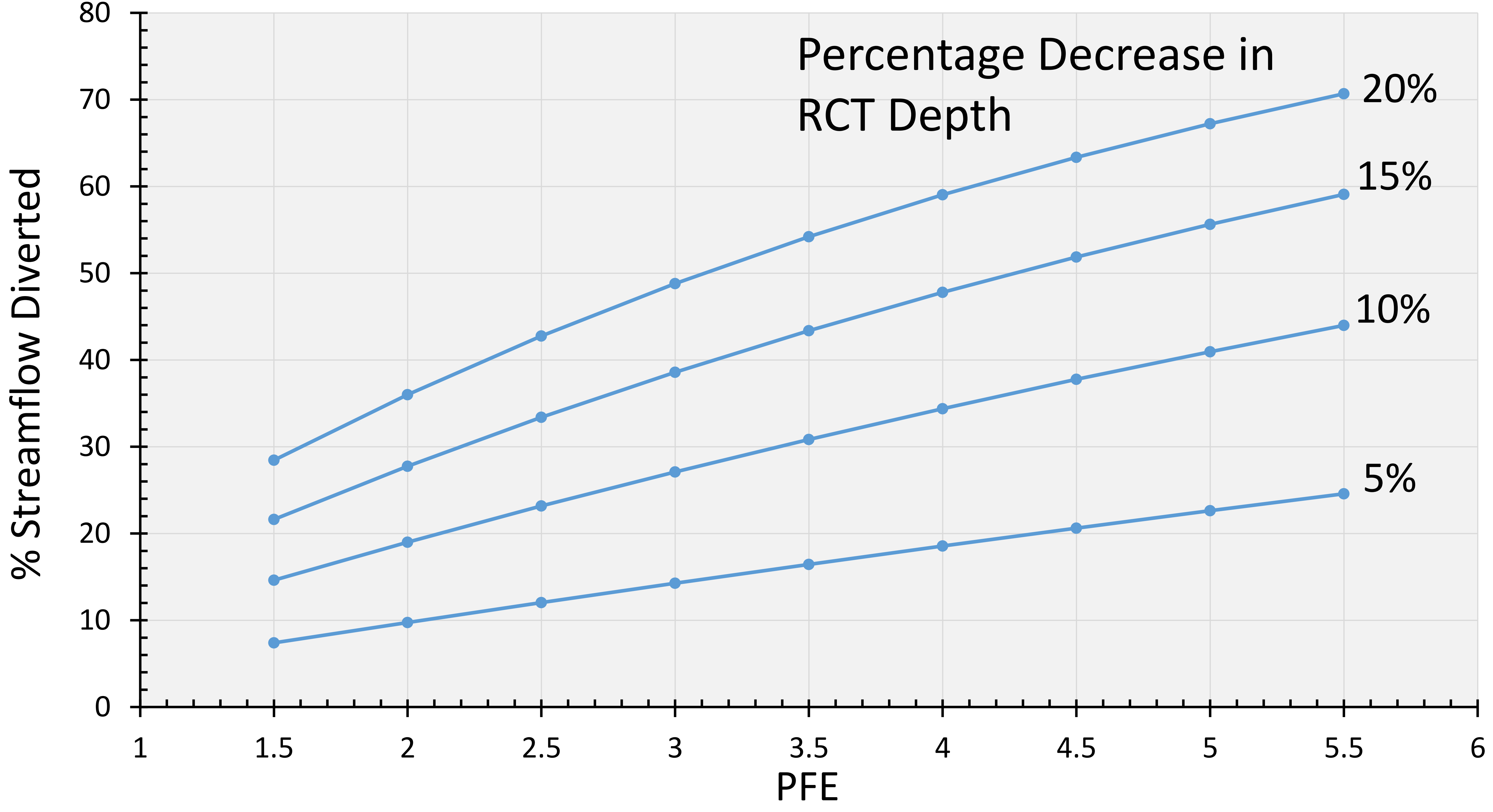


Streamflow (cfs) @ RCT = 1.0 ft
0
20
40
60
80
100
120
140
1
10
100
1000
10000
Log10 Drainage Area (mi2)

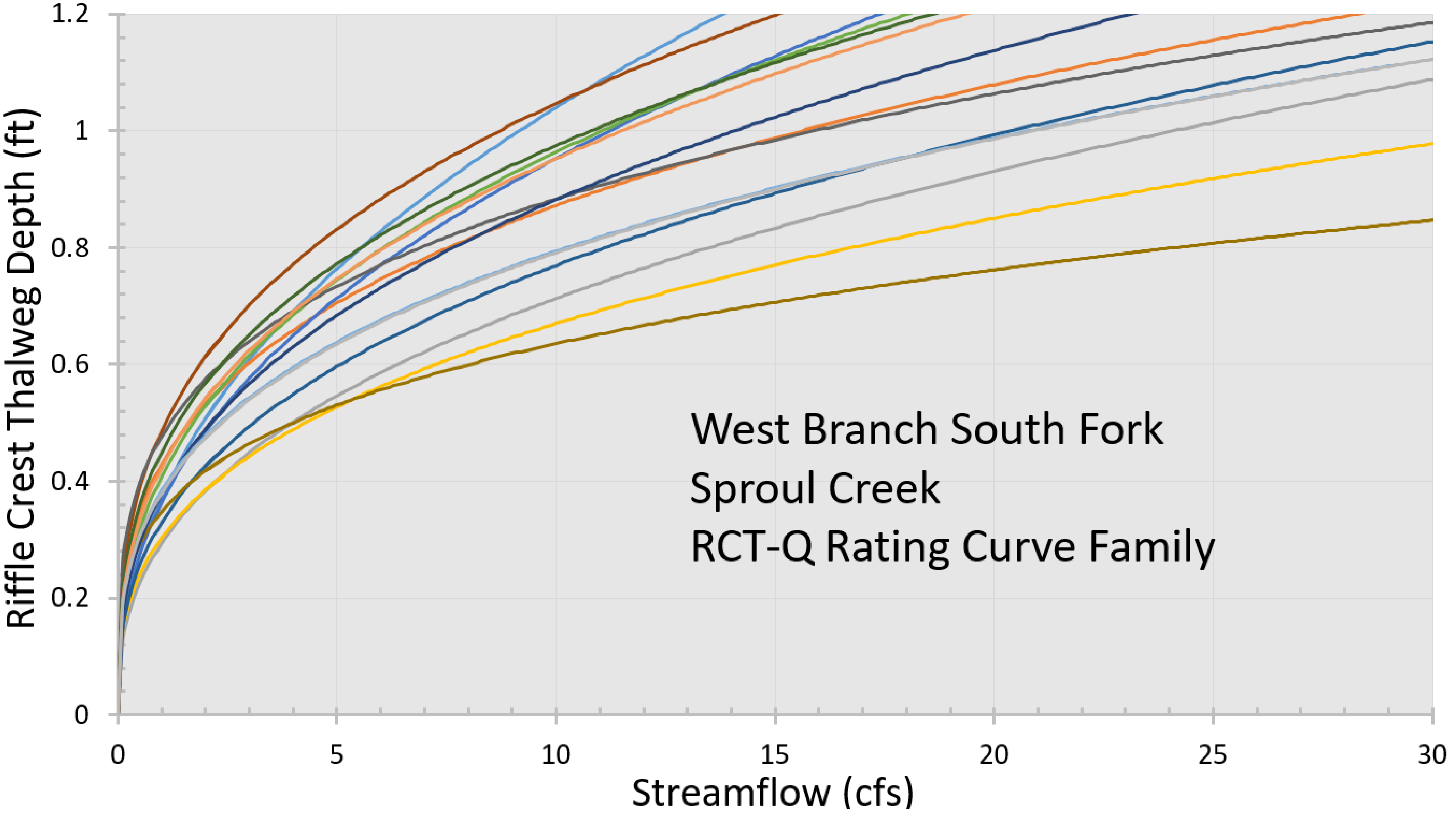


To Generate a 5% Decrease in Ambient RCT Depth:
Percentage Diversion (%)
18
17
16
15
14
13
12
11
10
9
8
7
6
1
10
100
1000
10000
Drainage Area (mi²)
N = 157


For a 5% RCT Decrease
%Div = 4.5158(PFE) + 0.73
R^2 = 0.999
N = 157 USGS Gaging Stations
Percentage Q Diversion (%)
Power Function Exponent (PFE)
6
7
8
9
10
11
12
13
14
15
16
17
18
1.5
2
2.5
3
3.5
4


Percentage Decrease in RCT Depth
20%
15%
10%
5%
% Streamflow Diverted
PFE
0
10
20
30
40
50
60
70
80
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6

RCT-Q RATING CURVE FAMILY FOR A STREAM REACH



The representative ‘Family’ of RCT-Q rating curves for a channel reach defines that stream channel’s hydraulic complexity, i.e., with ‘complexity’ expressed as a rate [a verb!].

Hydraulic Controls and RCT-Q Rating Curves

"*All there is to thinking," he said, "is seeing something noticeable which makes you see something you weren't noticing which makes you see something that isn't even visible*."

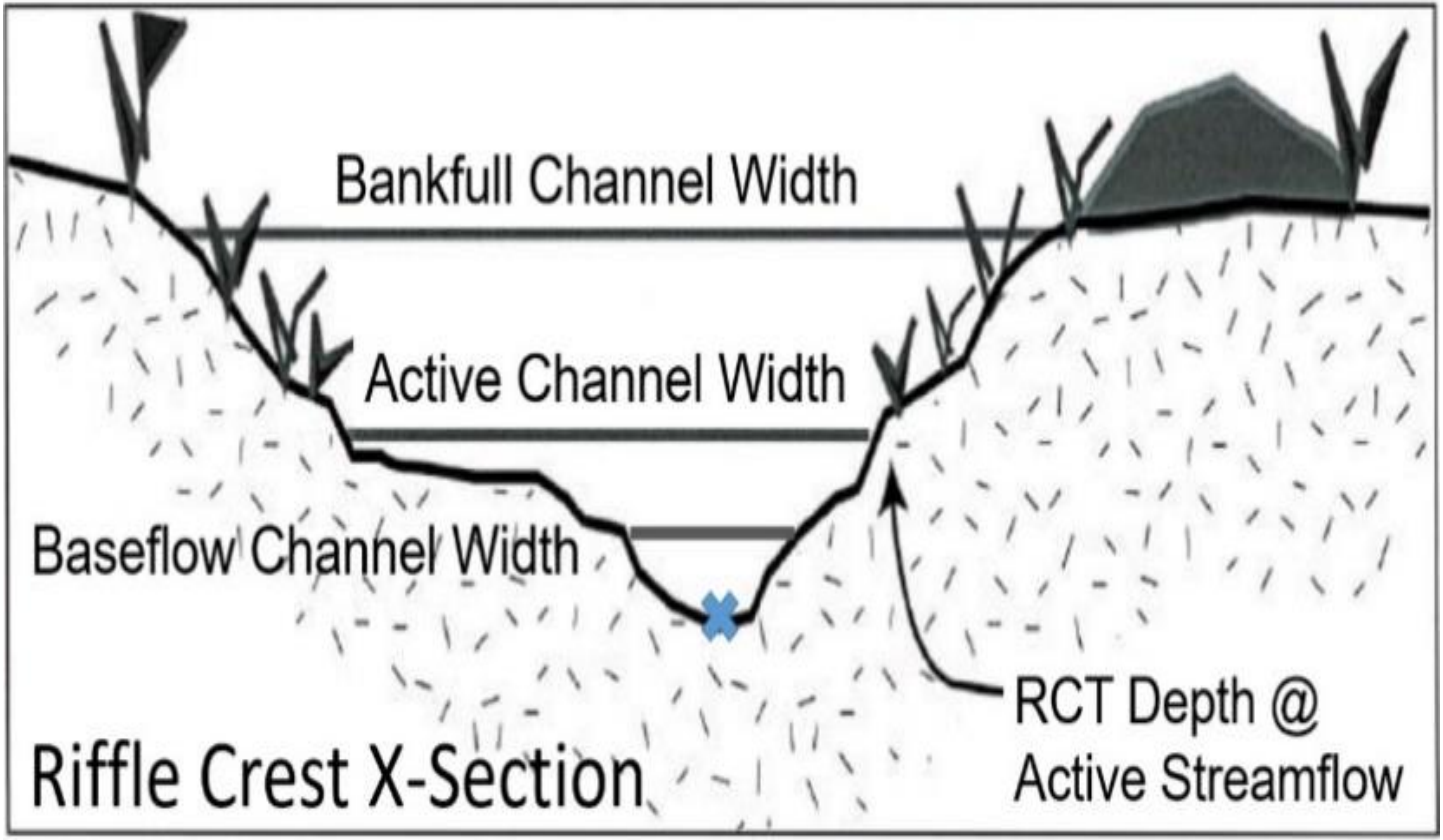
Norman Maclean in A River Runs Through It

USING RCT-Q RATING CURVES TO IDENTIFY HYDRAULIC CONTROL STREAMFLOW THRESHOLDS (Q_T)

NEED TO IDENTIFY:

Active Channel

= the onset of bankfull channel control


Bankfull Channel Width
Active Channel Width
Baseflow Channel Width
RCT Depth @
Active Streamflow
Riffle Crest X-Section

$$W_{ACT} = 8.5\ DA^{0.479}$$

For South Fork Eel River

Movie clip of inundated active channel bench (with alders) in the Lower Arroyo Seco River on 23March 2018 flowing at 1200 cfs (at USGS nr Soledad gage), slightly above estimated Q_{ACT} of 900 cfs (Photo Credit: Mason London).

Estimated active channel stage (white lines) in Lion Creek, tributary of Sespe Creek on March 29, 2014 (Photo Credit: Flickr dswphotography).

THREE BASIC HYDRAULIC CONTROLS

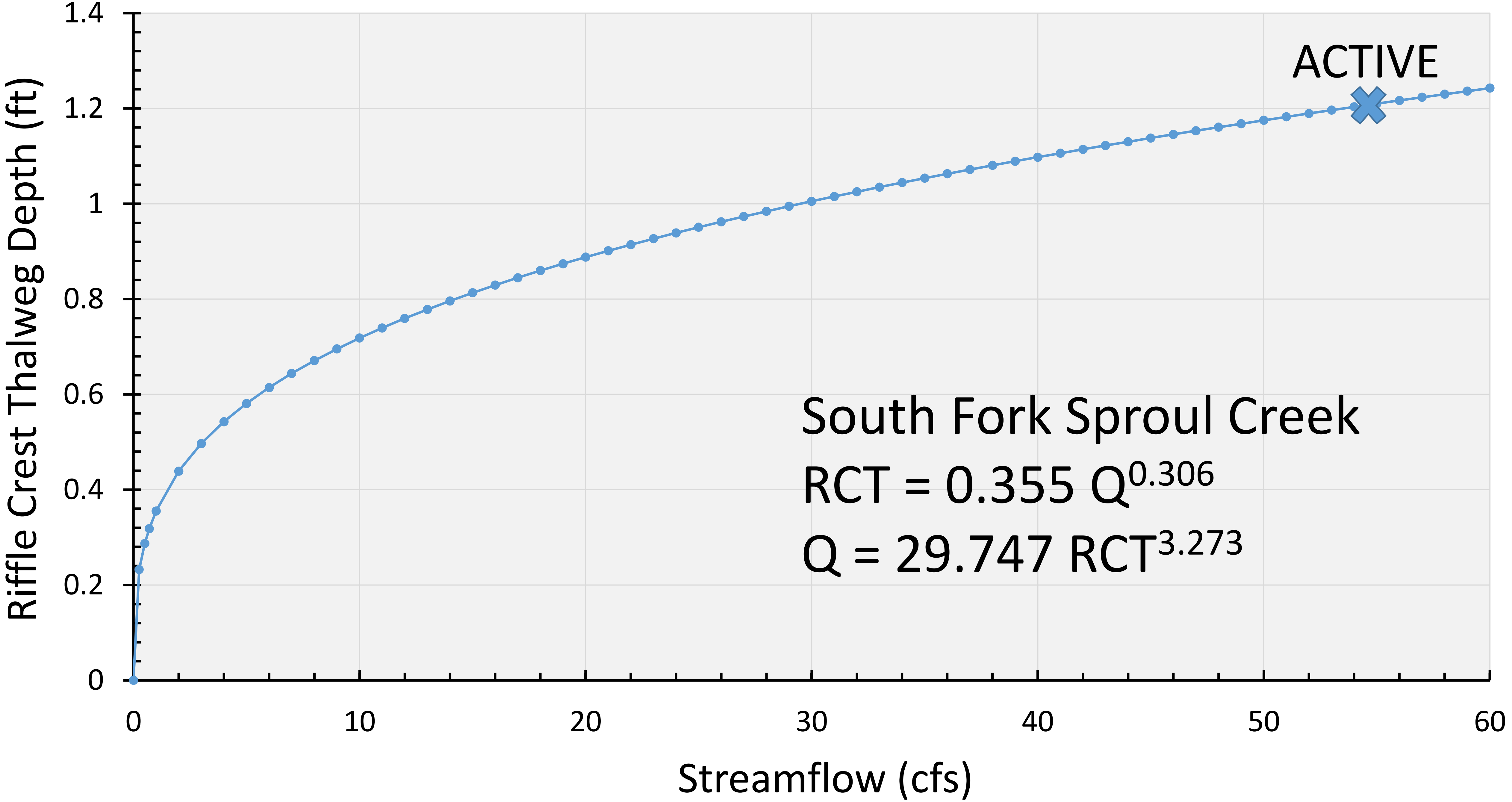
Sectional

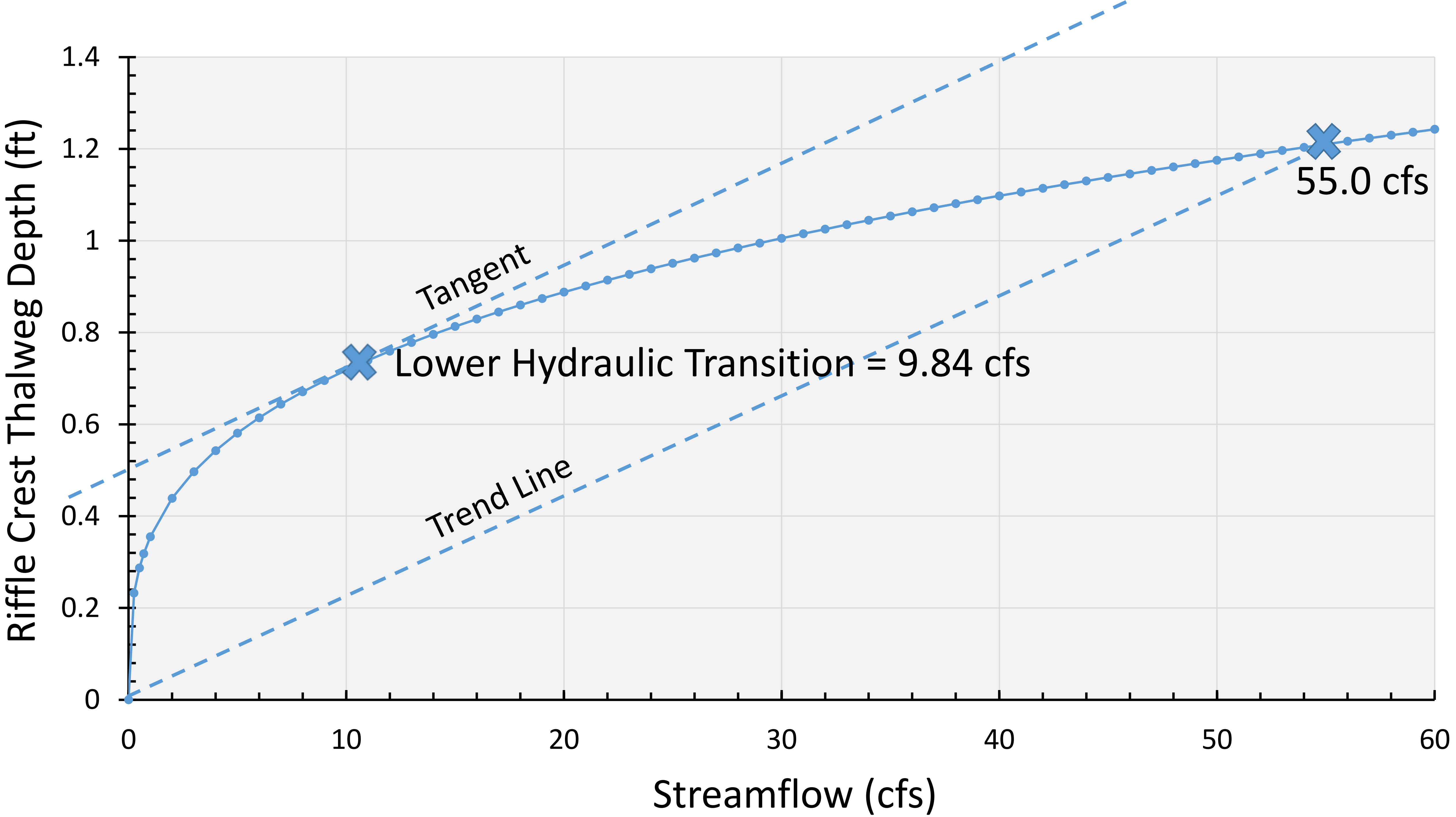
Active/Bedform

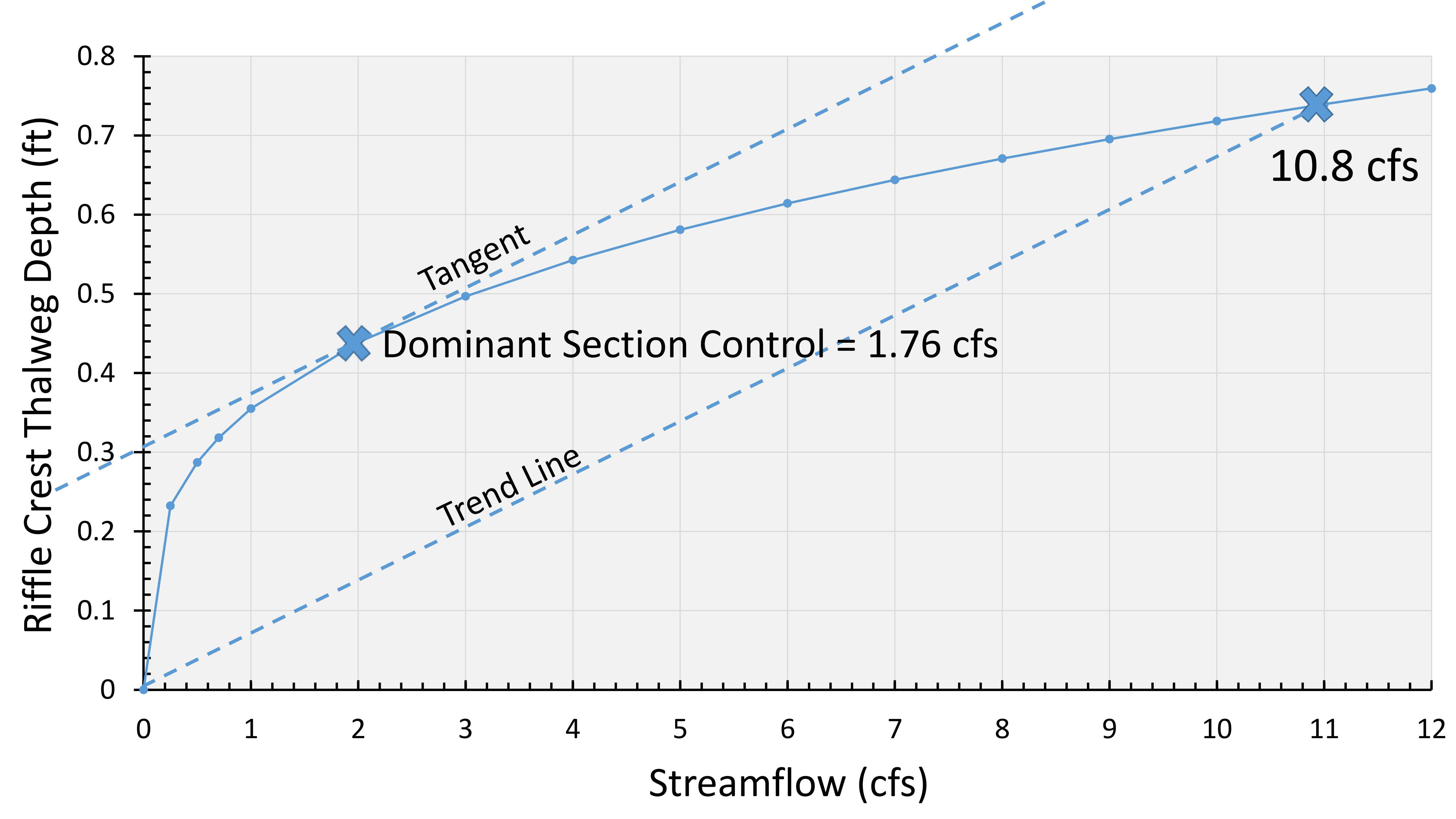
Bankfull Channel

EXERCISE No.3

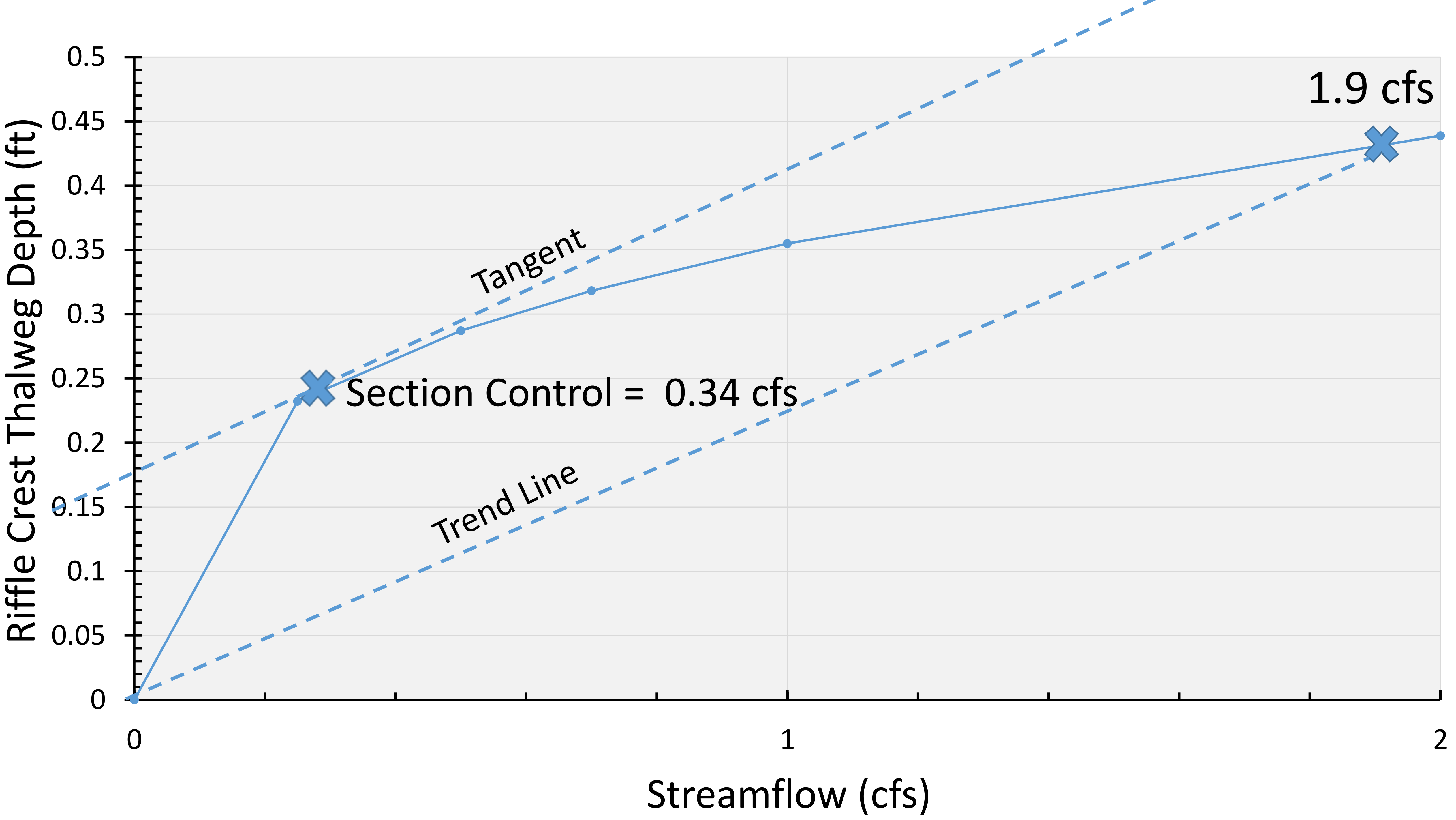
IDENTIFYING HYDRAULIC STREAMFLOW THRESHOLDS


ACTIVE
South Fork Sproul Creek
RCT = 0.355 Q^0.306
Q = 29.747 RCT^3.273
Riffle Crest Thalweg Depth (ft)
Streamflow (cfs)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
10
20
30
40
50
60

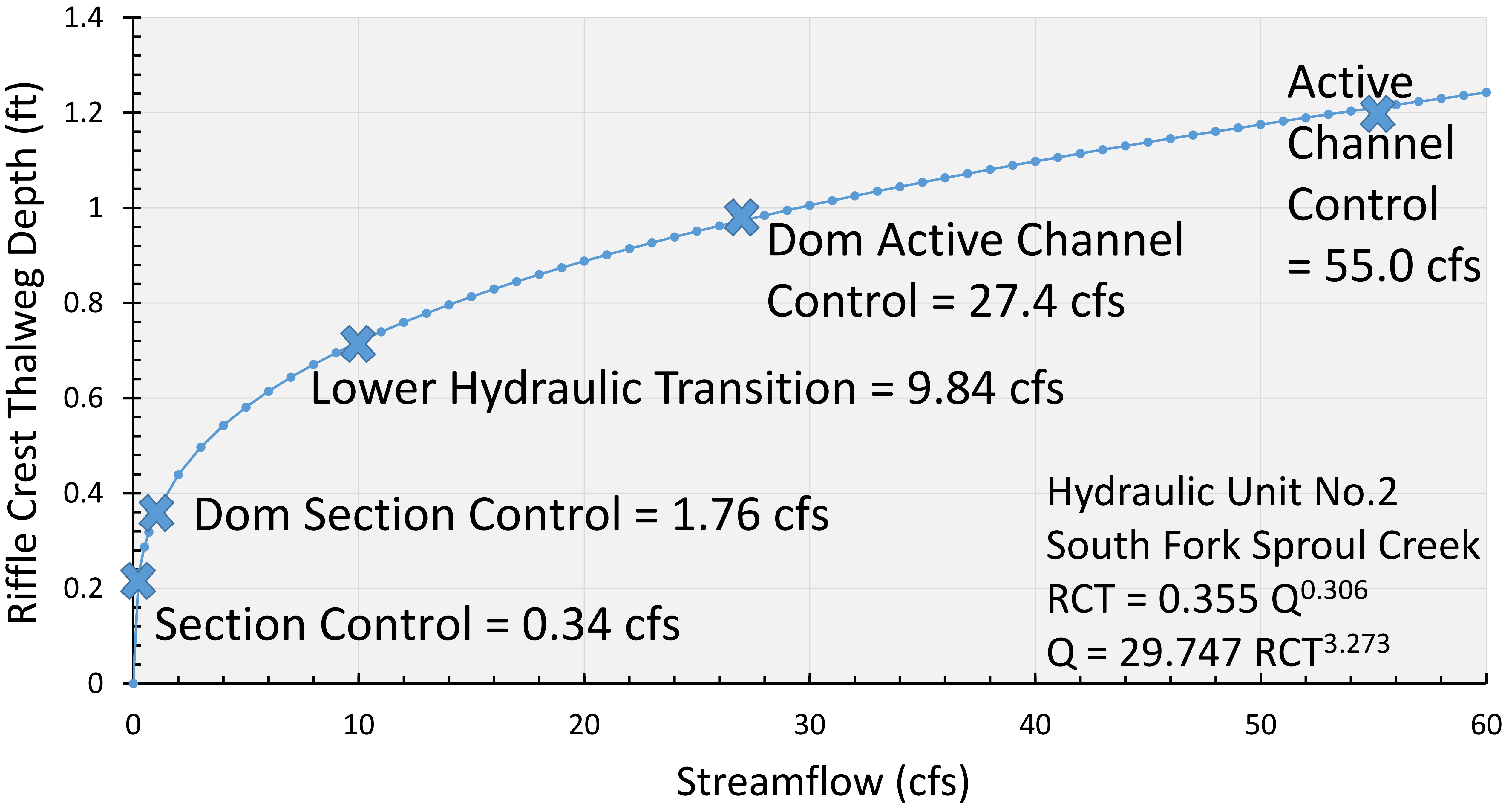

Riffle Crest Thalweg Depth (ft)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Tangent
55.0 cfs
Lower Hydraulic Transition = 9.84 cfs
Trend Line
0
10
20
30
40
50
60
Streamflow (cfs)



Riffle Crest Thalweg Depth (ft)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
9
10
11
12
Streamflow (cfs)
Tangent
Trend Line
Dominant Section Control = 1.76 cfs
10.8 cfs



1.9 cfs
Tangent
Section Control = 0.34 cfs
Trend Line
Riffle Crest Thalweg Depth (ft)
Streamflow (cfs)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2


Riffle Crest Thalweg Depth (ft)
Streamflow (cfs)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
10
20
30
40
50
60
Active
Channel
Control
= 55.0 cfs
Dom Active Channel
Control = 27.4 cfs
Lower Hydraulic Transition = 9.84 cfs
Dom Section Control = 1.76 cfs
Section Control = 0.34 cfs
Hydraulic Unit No.2
South Fork Sproul Creek
RCT = 0.355 Q^0.306
Q = 29.747 RCT^3.273

Alternatively use this ratio:

Ratio = $0.3997\ PFE^{-0.678}$

Q_{ACTIVE} = 55 cfs (in this example)

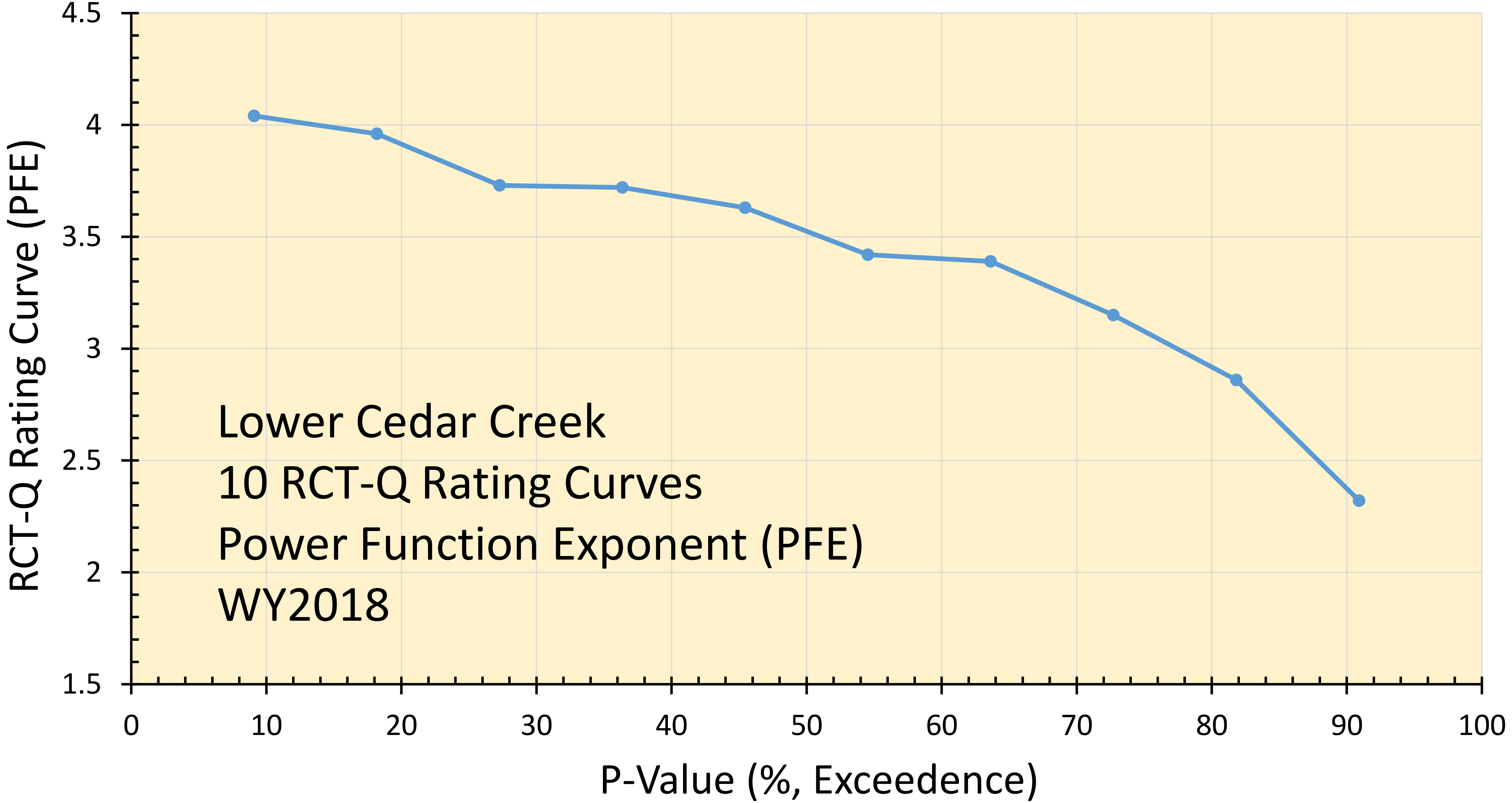
PFE = 3.2720

Ratio = 0.3997 $(1/(PFE^{0.678}))$ = 0.1789

55 cfs * 0.1789 = 9.84 cfs = Lower Hydraulic Transition Q_T

9.84 cfs * 0.1789 = 1.76 cfs = Dominant Section Control Q_T

1.76 cfs * 0.1789 = 0.32 cfs = Section Control Q_T



RCT-Q Rating Curve (PFE)
4.5
4
3.5
3
2.5
2
1.5
0
10
20
30
40
50
60
70
80
90
100
P-Value (%, Exceedence)
Lower Cedar Creek
10 RCT-Q Rating Curves
Power Function Exponent (PFE)
WY2018

SIMPLICITY IS THE ULTIMATE SOPHISTICATION

KEY CONCEPTS

Stream Ecosystem Complexity,
Top-Down Diversion Strategy,
and
Regulated vs Unregulated

HOLISTIC … relating to - or concerned with - complete systems rather than with the analysis of, treatment of, or dissection into parts.

The RCT-Q Rating Curve Family (up to the onset of channel control) physically links highly predictable thresholds in stream channel hydraulics to multiple ecological processes temporally and spatially. Unregulated annual hydrographs offer temporal complexity; the RCT-Q Rating Curve Family offers spatial complexity. Together, they largely define top-down stream ecosystem complexity. Healthy stream ecosystems require both. To use this linkage between hydraulics and ecological processes in devising a protective streamflow diversion policy, we must recognize that streamflow thresholds for most ecological processes never did exist. We created them. We have achieved only limited insight into what the key interdependent ecological processes even are, let alone how to quantify them, and even less how to manage them. Classic thresholds created include the wetted perimeter inflection, the critical riffle for fish migration, ‘optimal’ streamflow in a PHABSIM analysis, and $\%Q_{AVE}$ in the Tennant Method.

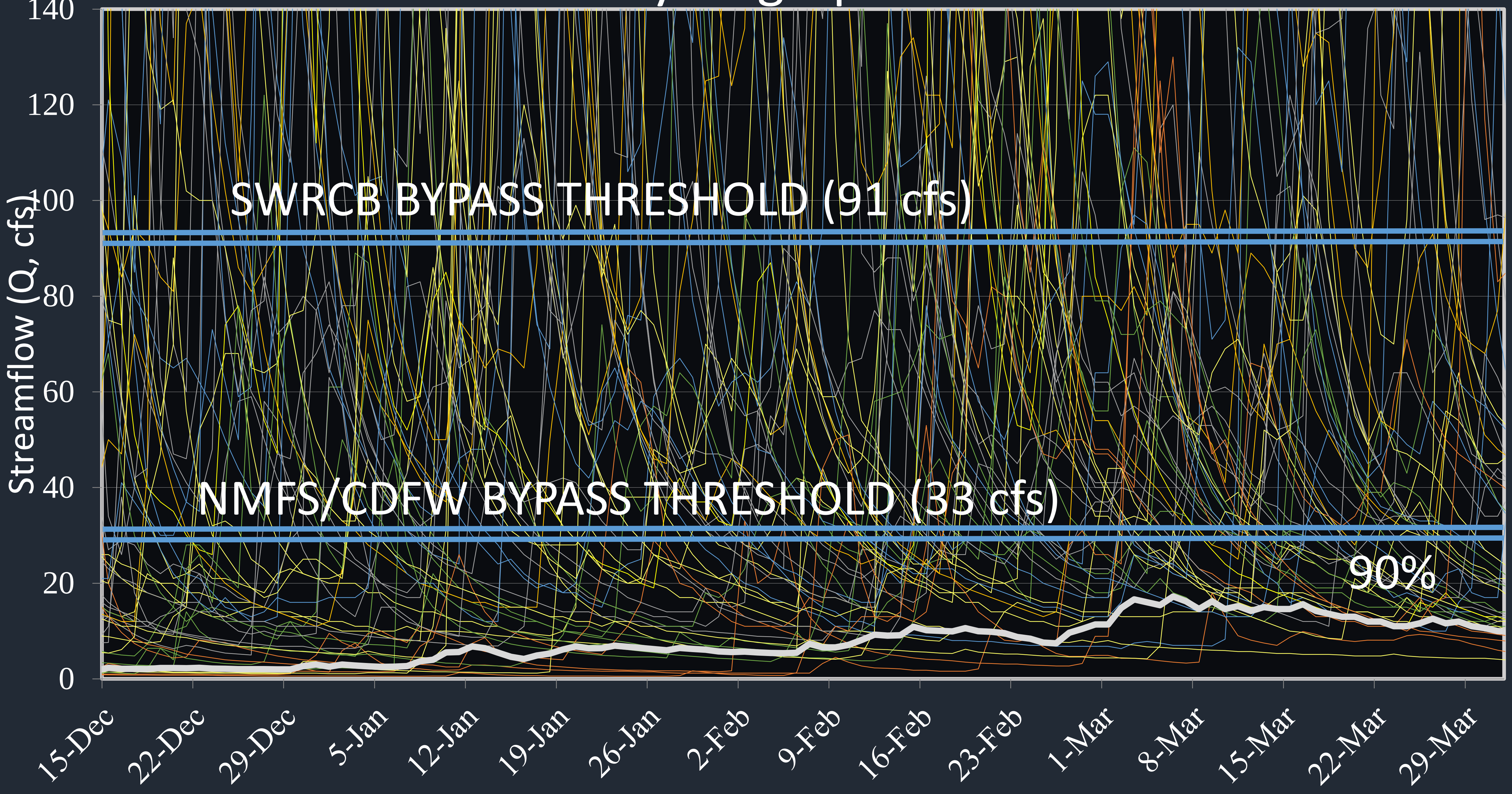



Policy for Maintaining Instream Flows in Northern California Coastal Streams

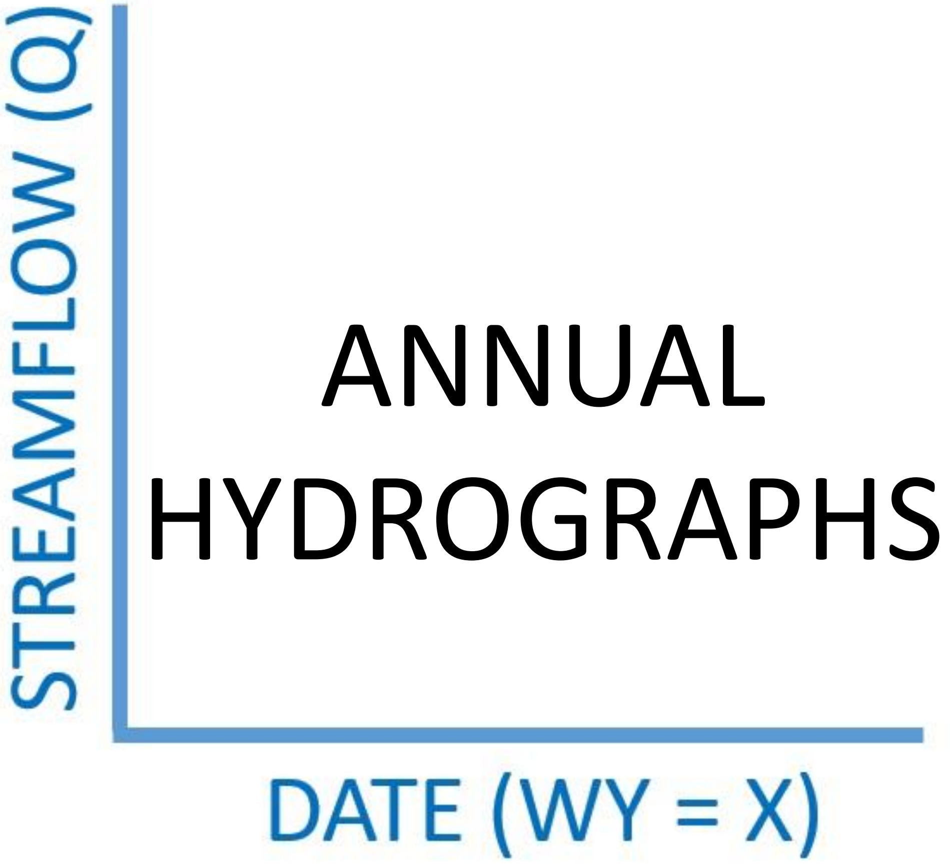
Effective February 4, 2014

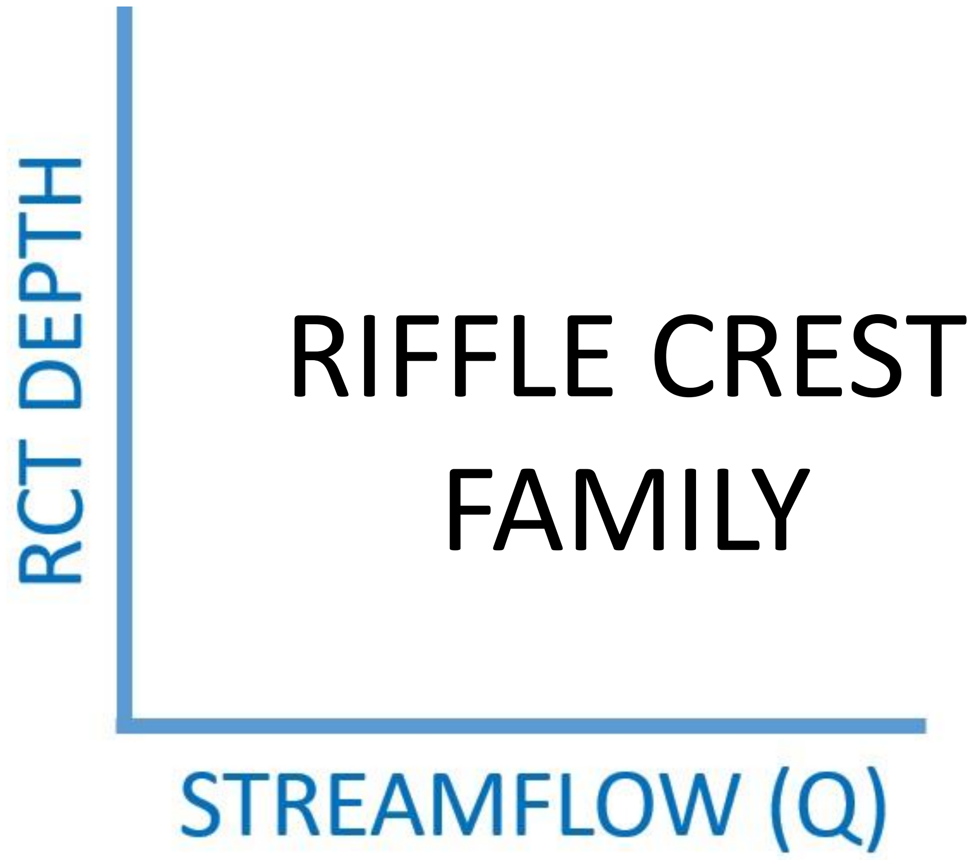
Division of Water Rights
State Water Resources Control Board
California Environmental Protection Agency

Elder Creek Annual Hydrographs WY1968 to WY2014



River Ecosystem Complexity





THINKING ‘FLOW CRITERIA’

Significance
Success
Risk

Panel Review of the CA Department of Fish and Game's Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta Review Panel

Members

Edward S. Gross, independent consultant, Oakland, CA
G. Fred Lee, G. Fred Lee and Associates, Davis, CA
Charles A. Simenstad, University of Washington, Seattle, WA
Mark Stacey, University of California, Berkeley, CA
John G. Williams, independent consultant, Davis, CA

http://www.gfredlee.com/SJR-Delta/Final_Panel_Review_DFG_BOFC_Draft.pdf

Fleenor et al. (2010) opine that nobody yet knows how to do what the legislature directed DFG to do; we agree. Given this, it is not surprising that the DFG staff assigned to write the Draft [CalFed] appeared to struggle with it. Nevertheless, as we explain below, the Delta Reform Act sets a high standard for the report, which we felt obliged to apply in reviewing.

Defining 'Flow Criteria'

1.1 Definitions

To avoid potential confusion and miscommunication, we begin with some definitions of key words or phrases in section 85084.5, as we understand and use them. The section requires that DFG develop "flow criteria" and "quantifiable biological objectives." We take flow criteria to be numerical or potentially quantifiable standards for Delta inflows or outflows. By quantifiable standards, *we mean flows sufficient to have some specified effect on biological resources that can be measured or modeled*.

“Fixity of purpose requires flexibility of method.”

H.G. Wolff

Hooker Creek Confluence and Watershed Connectivity


WHAT DO YOU SEE?
November 24, 2018 @ 3:03 PM
2110 cfs

Hooker Creek Confluence
South Fork Eel River

PHOTOS TAKEN:

November 24, 2018 @ 3:03PM

December 02, 2018 @ Noon

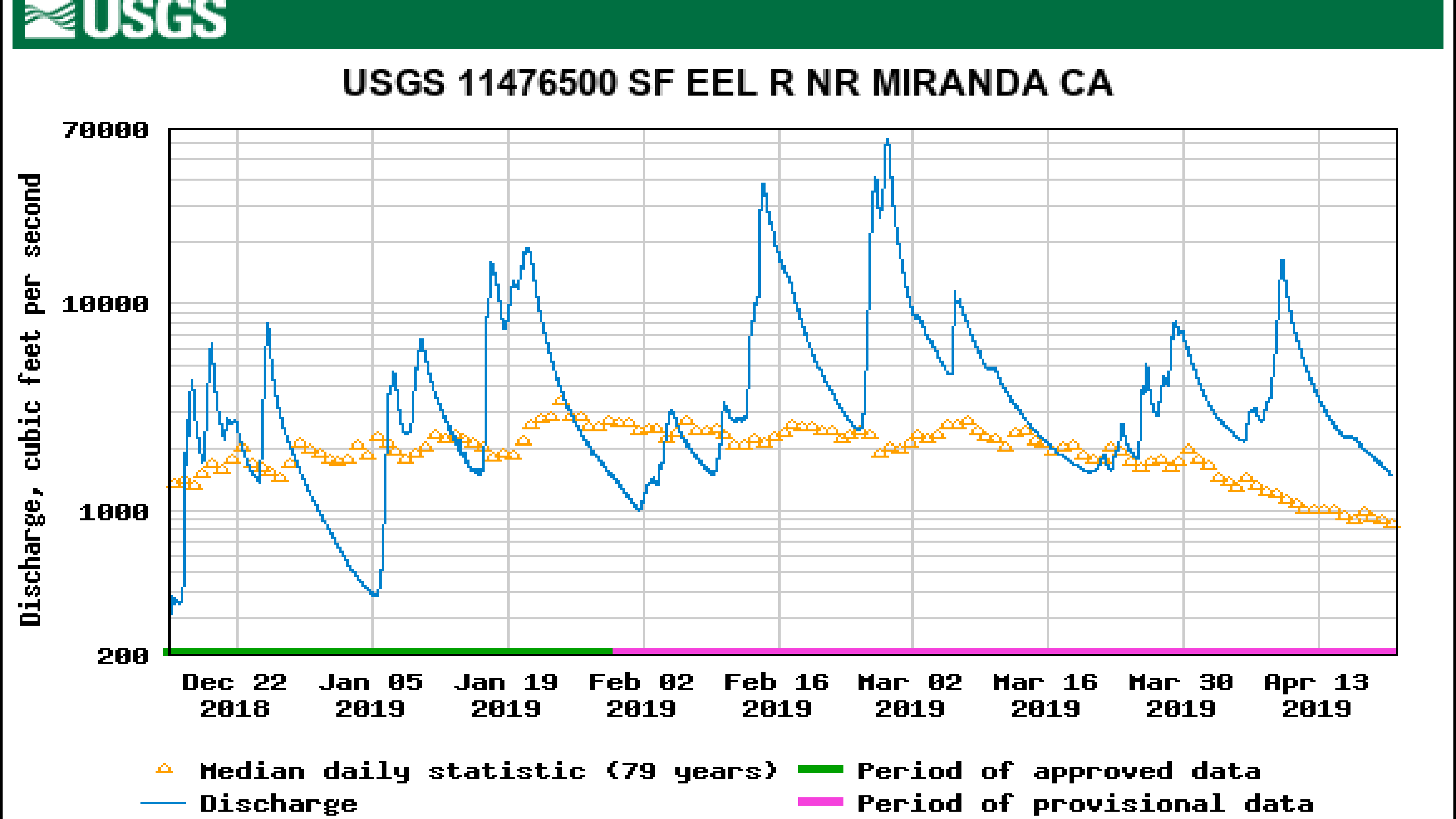
December 06, 2018 @ 11:12AM

December 18, 2018 @ 8:49AM

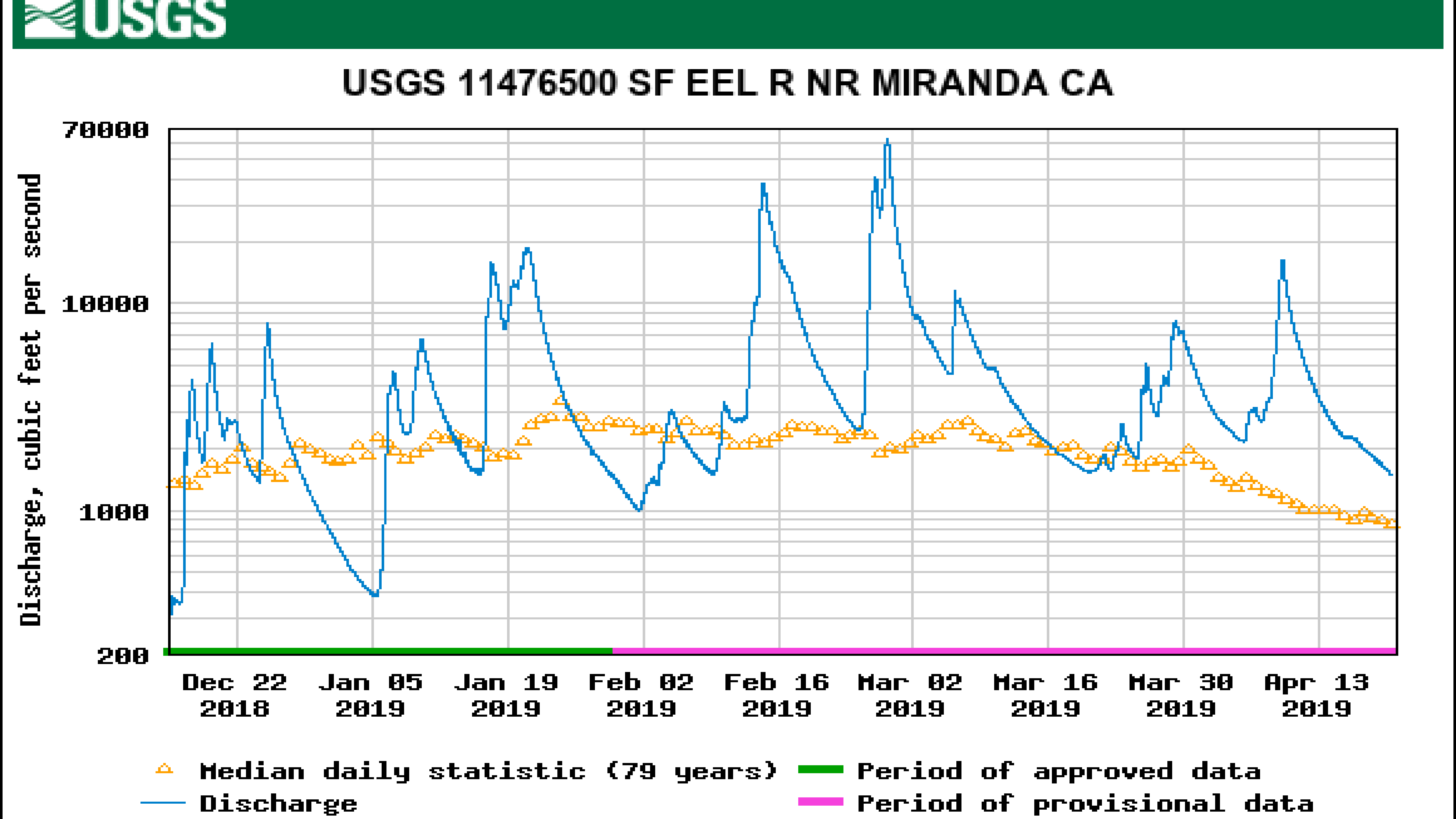
March 02, 2019 @ 10:04AM

April 12, 2019 @10:05AM

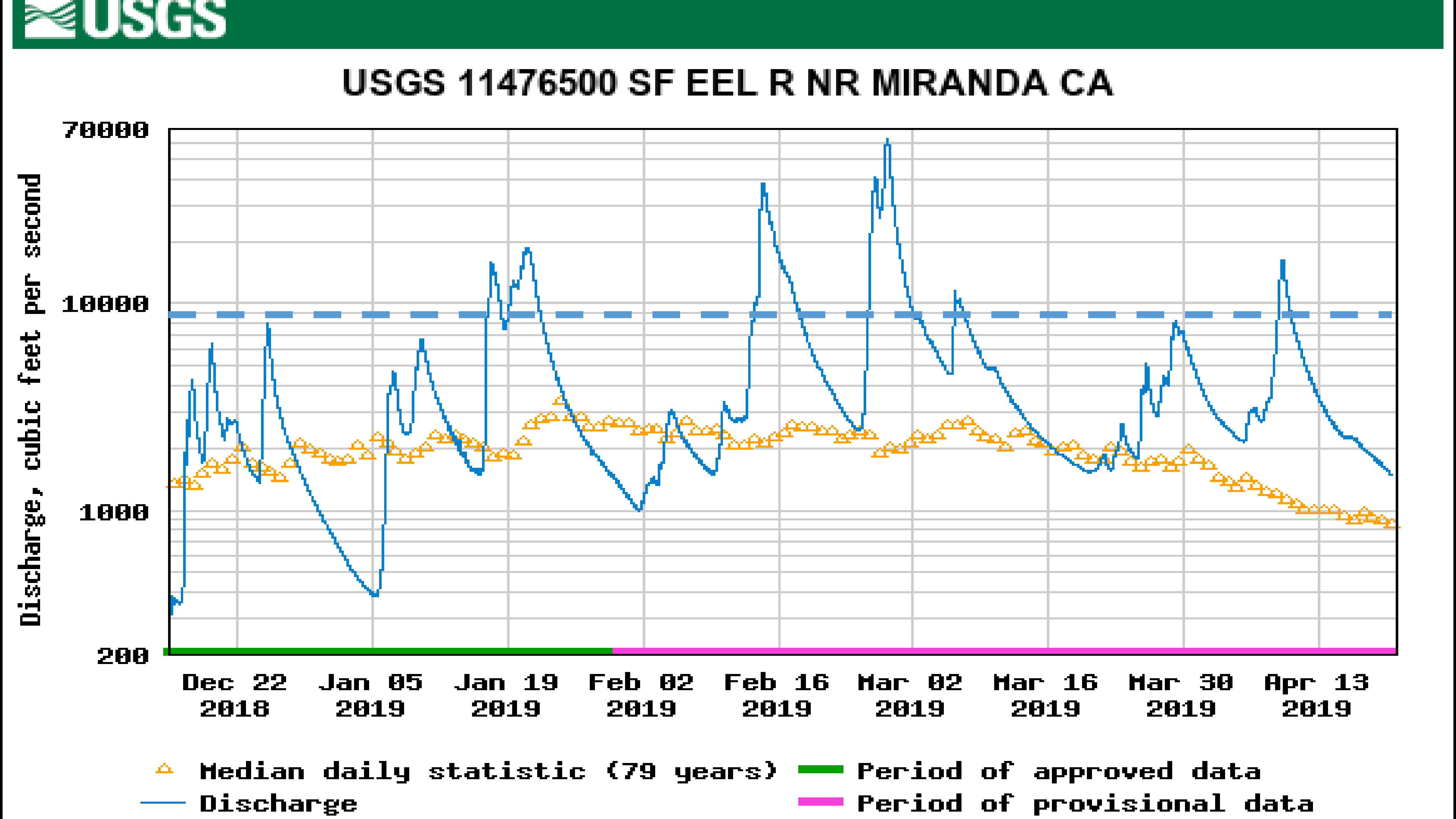
April 14, 2019 @5:37PM


USGS
USGS 11476500 SF EEL R NR MIRANDA CA
Discharge, cubic feet per second
70000
10000
1000
200
Dec 22 2018
Jan 05 2019
Jan 19 2019
Feb 02 2019
Feb 16 2019
Mar 02 2019
Mar 16 2019
Mar 30 2019
Apr 13 2019
Median daily statistic (79 years)
Discharge
Period of approved data
Period of provisional data


March 02, 2019 @ 10:04AM
8790 cfs


USGS
USGS 11476500 SF EEL R NR MIRANDA CA
Discharge, cubic feet per second
70000
10000
1000
200
Dec 22 2018
Jan 05 2019
Jan 19 2019
Feb 02 2019
Feb 16 2019
Mar 02 2019
Mar 16 2019
Mar 30 2019
Apr 13 2019
Median daily statistic (79 years)
Discharge
Period of approved data
Period of provisional data

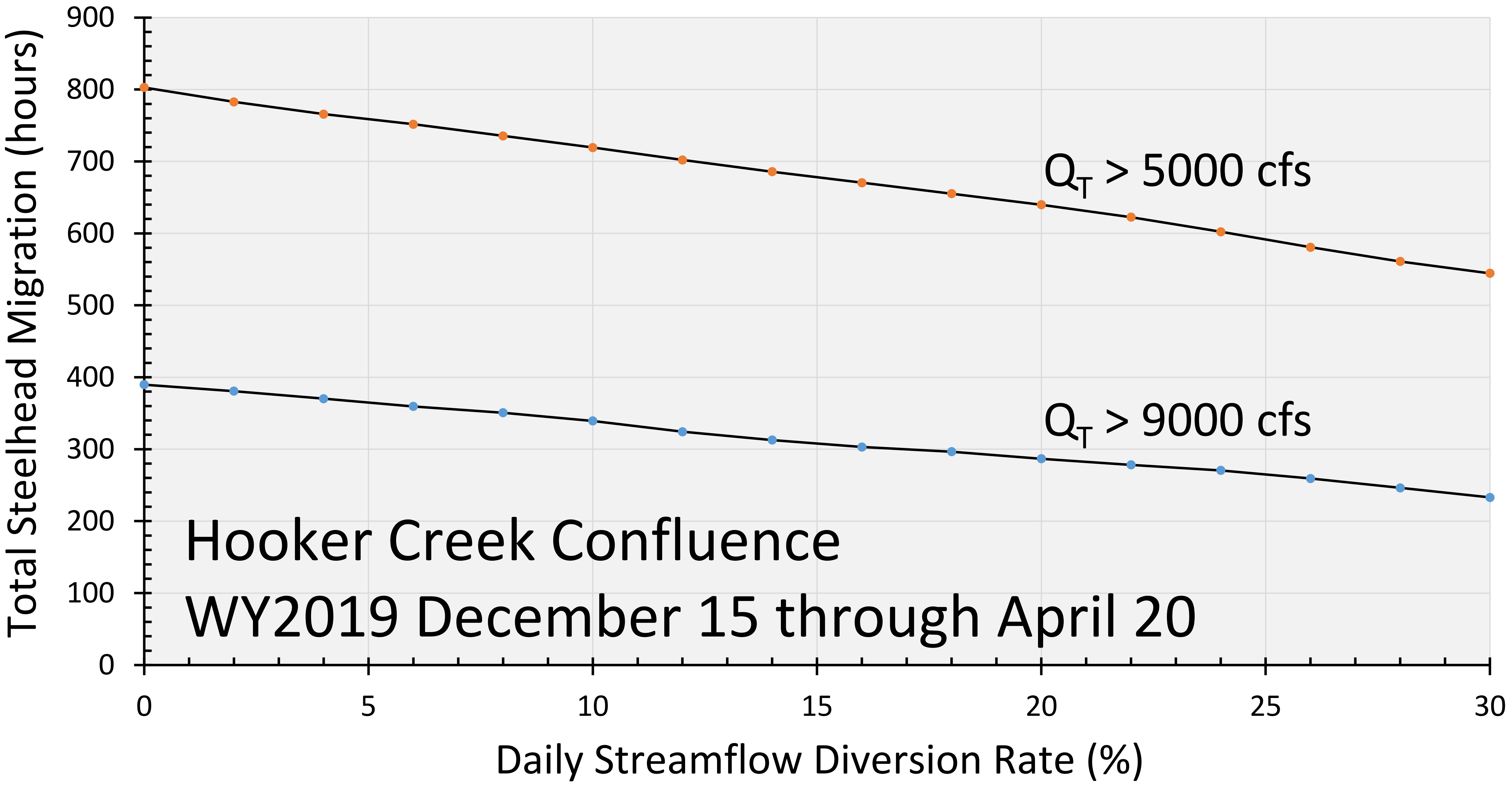

March 02, 2019 @ 10:04AM 8790 cfs



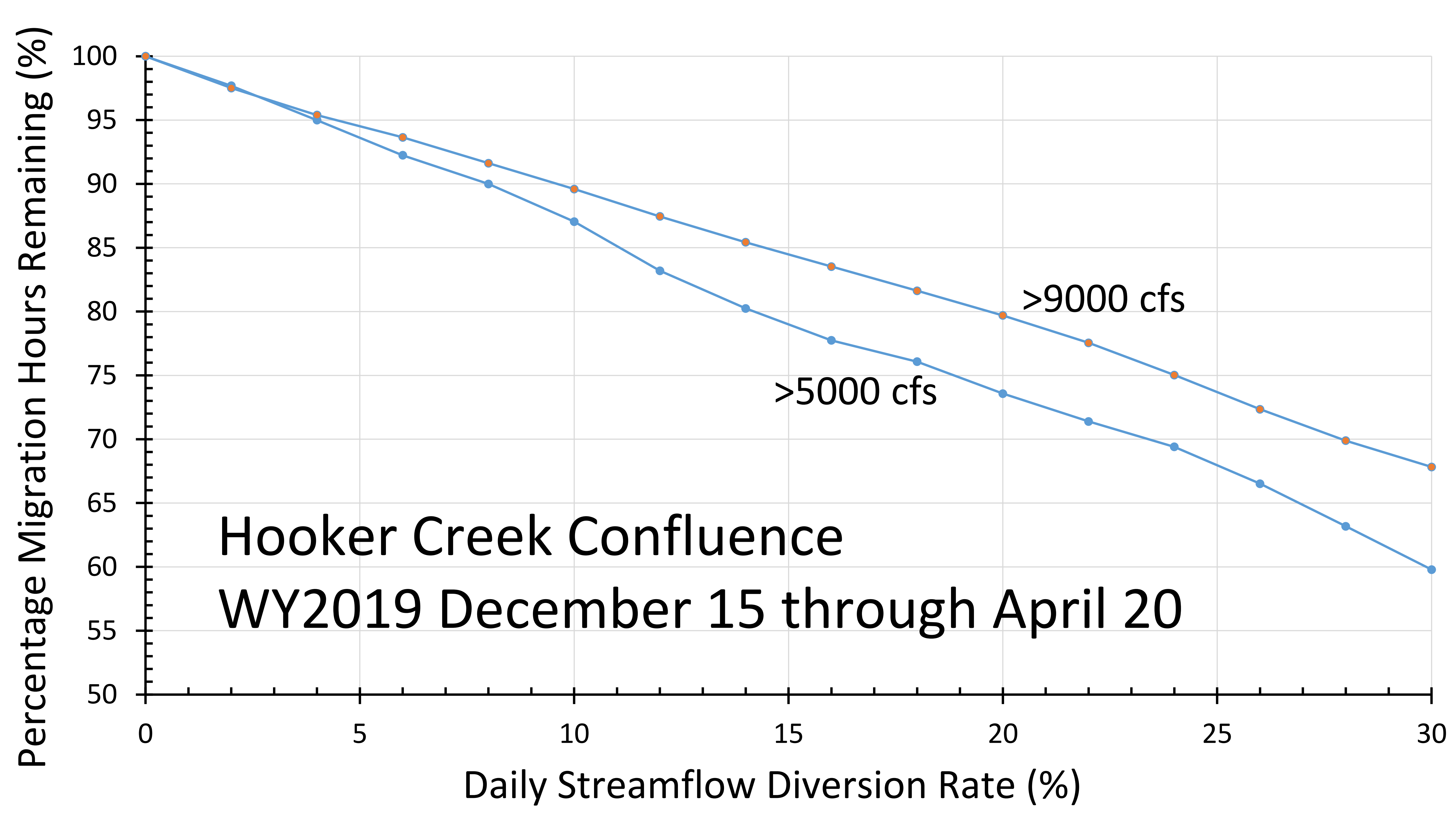
USGS
USGS 11476500 SF EEL R NR MIRANDA CA
Discharge, cubic feet per second
70000
10000
1000
200
Dec 22 2018
Jan 05 2019
Jan 19 2019
Feb 02 2019
Feb 16 2019
Mar 02 2019
Mar 16 2019
Mar 30 2019
Apr 13 2019
Median daily statistic (79 years)
Discharge
Period of approved data
Period of provisional data

TWO STREAMFLOW THRESHOLDS (Q_T) DERIVED FROM PHOTOGRAPHS:

For Steelhead Spawning in Hooker Creek:
9000 cfs Adult Steelhead Easy Access to Hooker Creek
5000 cfs Adult Steelhead Difficult Access to Hooker Creek



Total Steelhead Migration (hours)
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
Daily Streamflow Diversion Rate (%)
Q_T > 5000 cfs
Q_T > 9000 cfs
Hooker Creek Confluence
WY2019 December 15 through April 20



Percentage Migration Hours Remaining (%)
100
95
90
85
80
75
70
65
60
55
50
0
5
10
15
20
25
30
Daily Streamflow Diversion Rate (%)
>9000 cfs
>5000 cfs
Hooker Creek Confluence
WY2019 December 15 through April 20

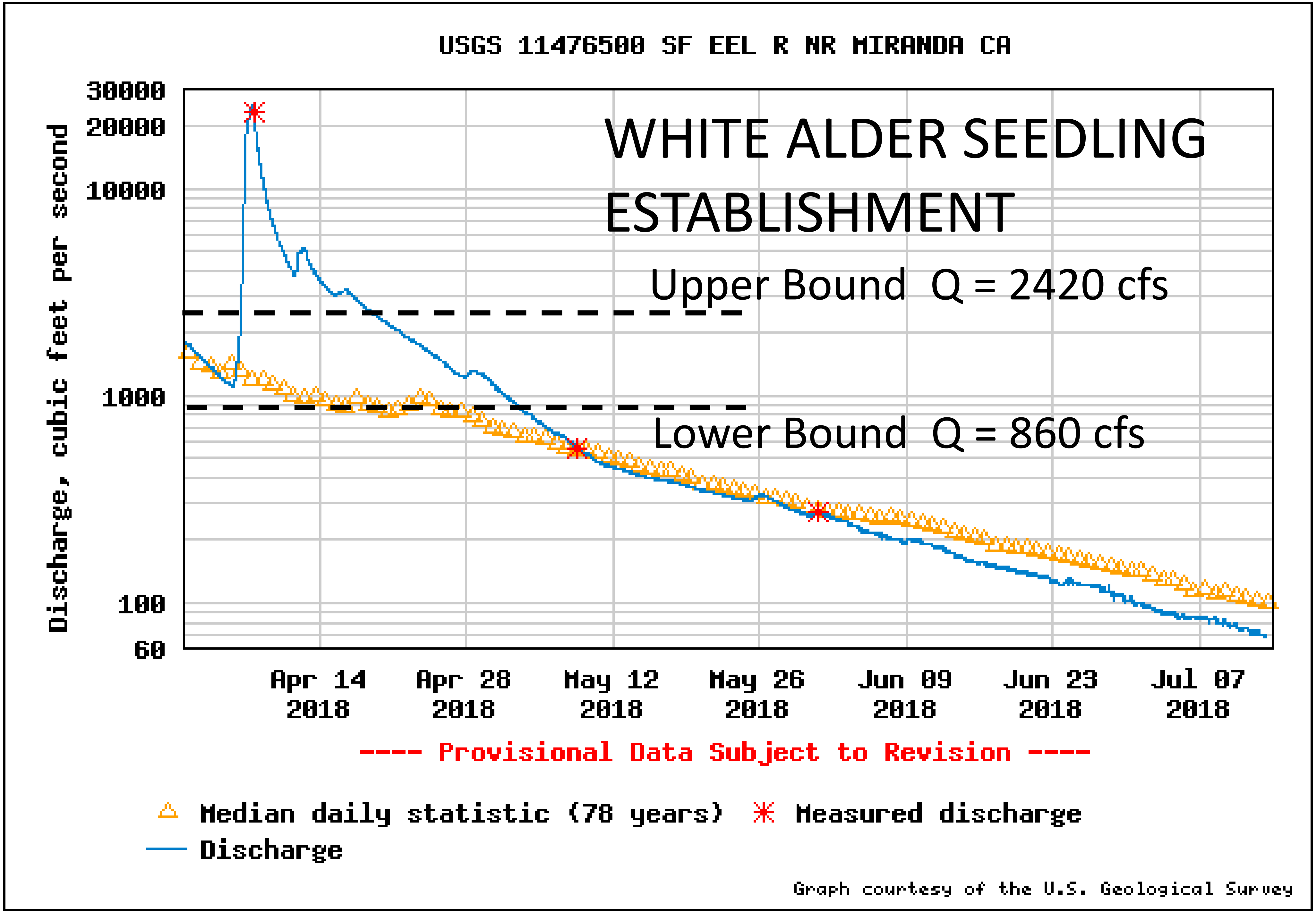
HOW CAN THIS HOOKER CREEK SPAWNING ‘FLOW CRITERION’ BE EXPANDED?

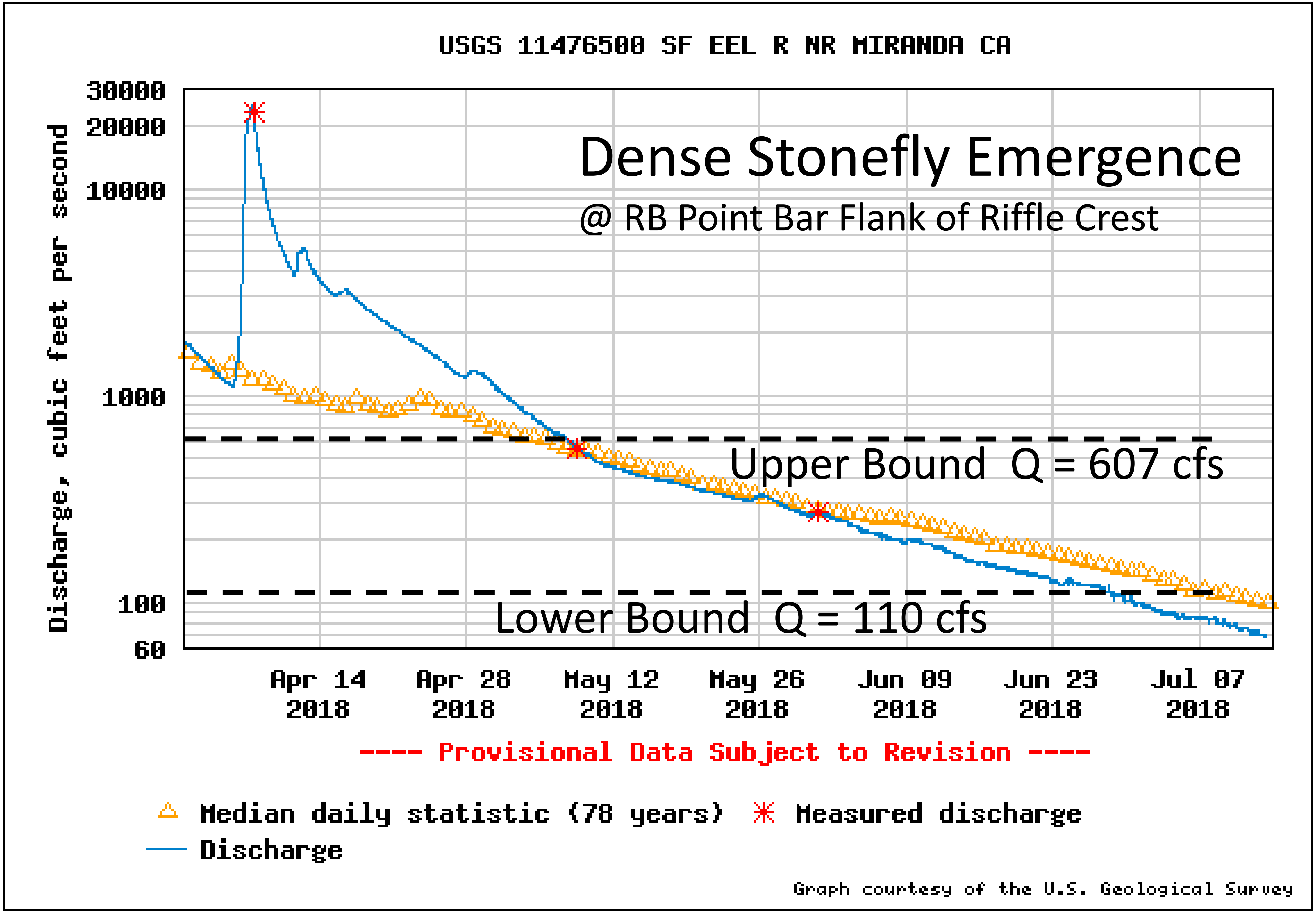
USING RCT-Q RATING CURVES TO QUANTIFY WILLOW and COTTONWOOD SEED RELEASE PERIOD

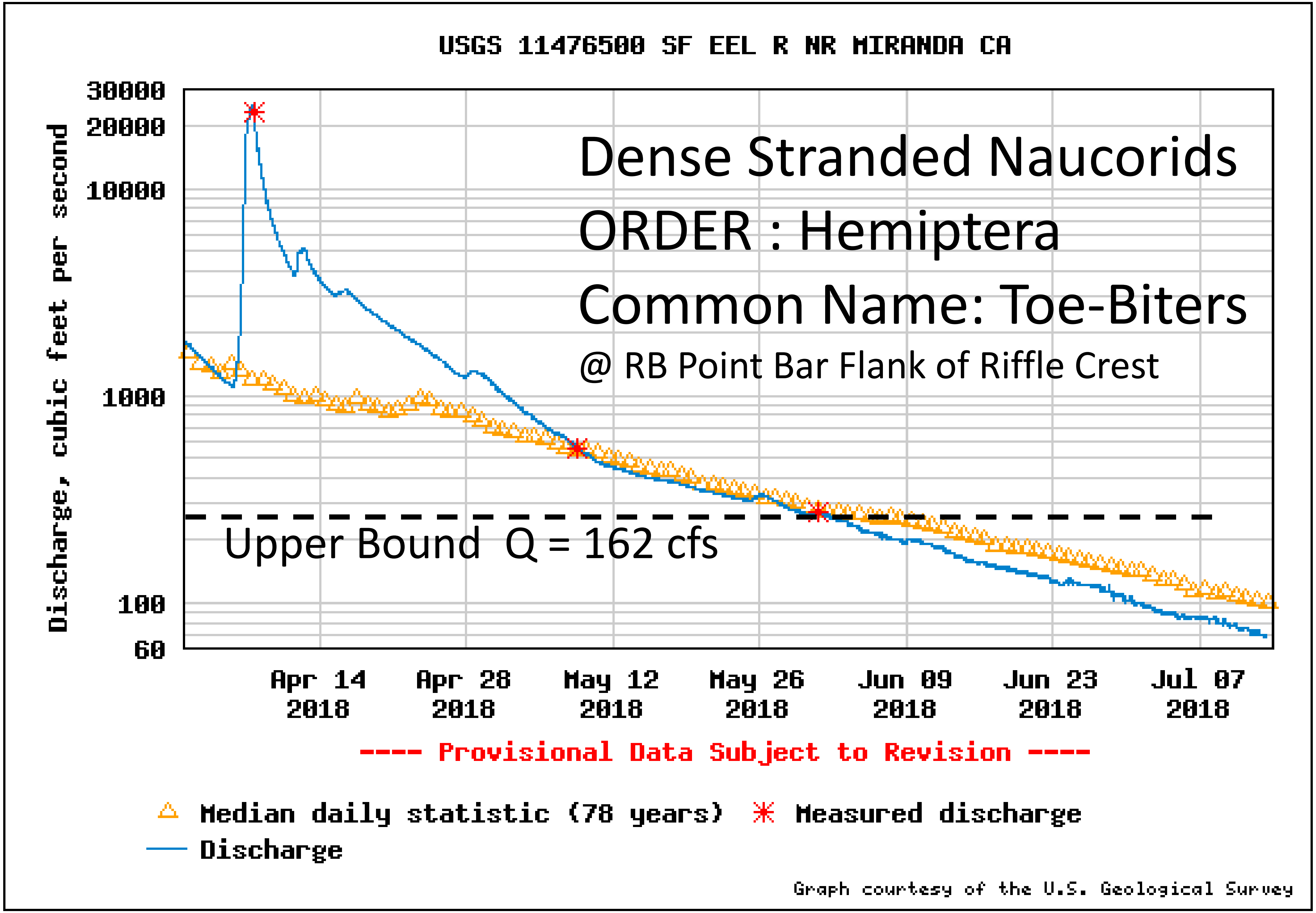

September 04, 2018 1:00 PM
Sandbar Willow
Bands
430 cfs May 13
340 cfs May 21
232 cfs June 03
TOP: 161 cfs June 14
Red Willow Band
BOTTOM: 140 cfs June 18

Talking Point 'while' standing on top of RB lateral bar: The hydraulic control determining water levels along the flank of this later bar is at the RCT … all the way down here:

(also nice view of LB Silt Band)


USGS 11476500 SF EEL R NR MIRANDA CA
WHITE ALDER SEEDLING ESTABLISHMENT
Upper Bound Q = 2420 cfs
Lower Bound Q = 860 cfs
Discharge, cubic feet per second
30000
20000
10000
1000
100
60
Apr 14 2018
Apr 28 2018
May 12 2018
May 26 2018
Jun 09 2018
Jun 23 2018
Jul 07 2018
---- Provisional Data Subject to Revision ----
Median daily statistic (78 years)
Measured discharge
Discharge
Graph courtesy of the U.S. Geological Survey

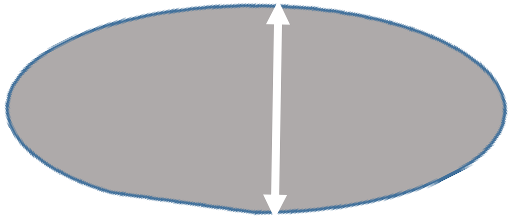

USGS 11476500 SF EEL R NR MIRANDA CA
Dense Stonefly Emergence
@ RB Point Bar Flank of Riffle Crest
Upper Bound Q = 607 cfs
Lower Bound Q = 110 cfs
Discharge, cubic feet per second
30000
20000
10000
1000
100
60
Apr 14 2018
Apr 28 2018
May 12 2018
May 26 2018
Jun 09 2018
Jun 23 2018
Jul 07 2018
---- Provisional Data Subject to Revision ----
Median daily statistic (78 years)
Measured discharge
Discharge
Graph courtesy of the U.S. Geological Survey



USGS 11476500 SF EEL R NR MIRANDA CA
Dense Stranded Naucorids
ORDER : Hemiptera
Common Name: Toe-Biters
@ RB Point Bar Flank of Riffle Crest
Upper Bound Q = 162 cfs
Discharge, cubic feet per second
30000
20000
10000
1000
100
60
Apr 14 2018
Apr 28 2018
May 12 2018
May 26 2018
Jun 09 2018
Jun 23 2018
Jul 07 2018
---- Provisional Data Subject to Revision ----
Median daily statistic (78 years)
Measured discharge
Discharge
Graph courtesy of the U.S. Geological Survey

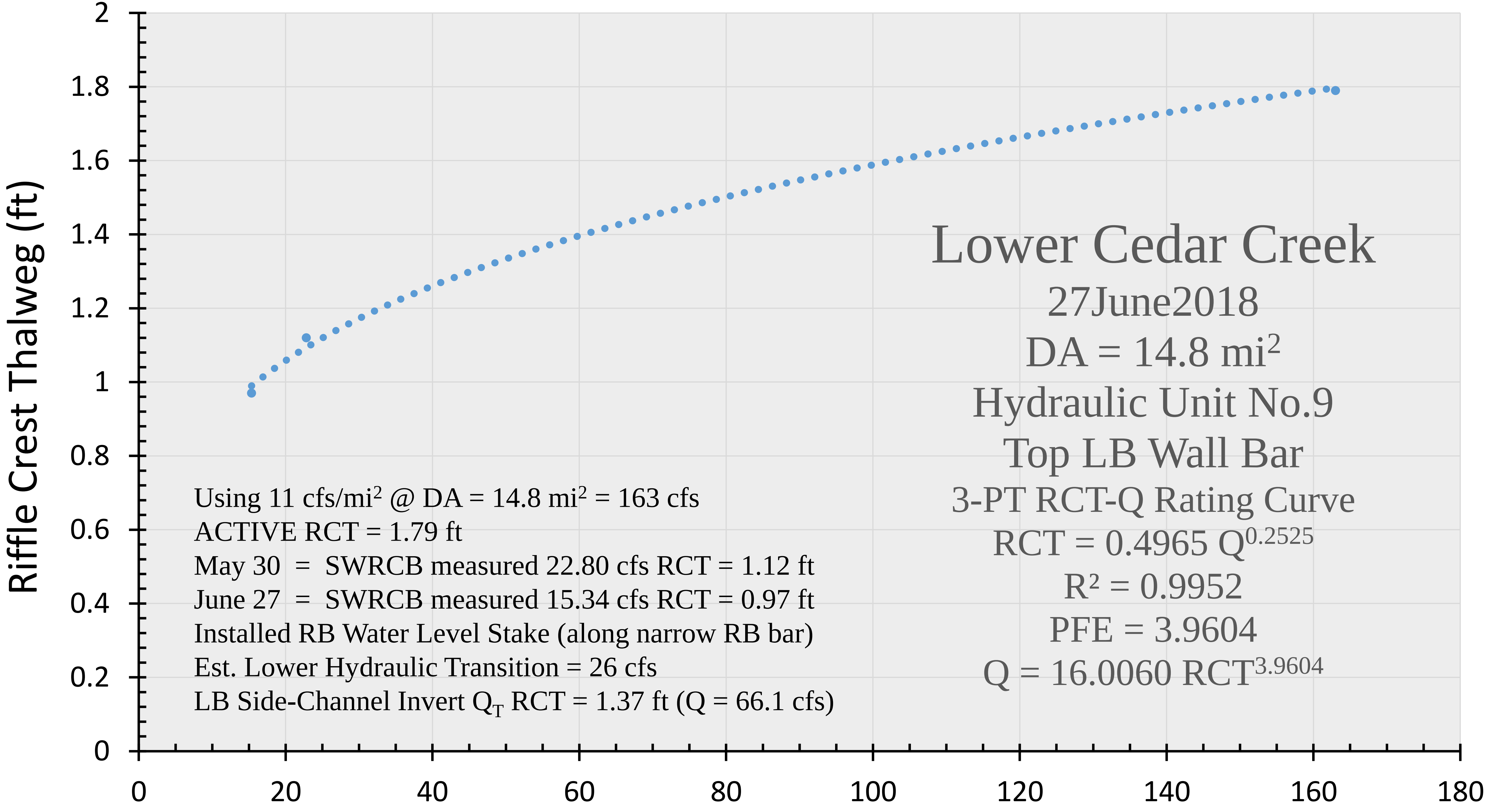
Upper Streamflow Threshold = Smooth Turbulent Flow

Lower Streamflow Threshold = Inundated D_{84} depth for optimal rock surface area utilized by benthic macroinvertebrates

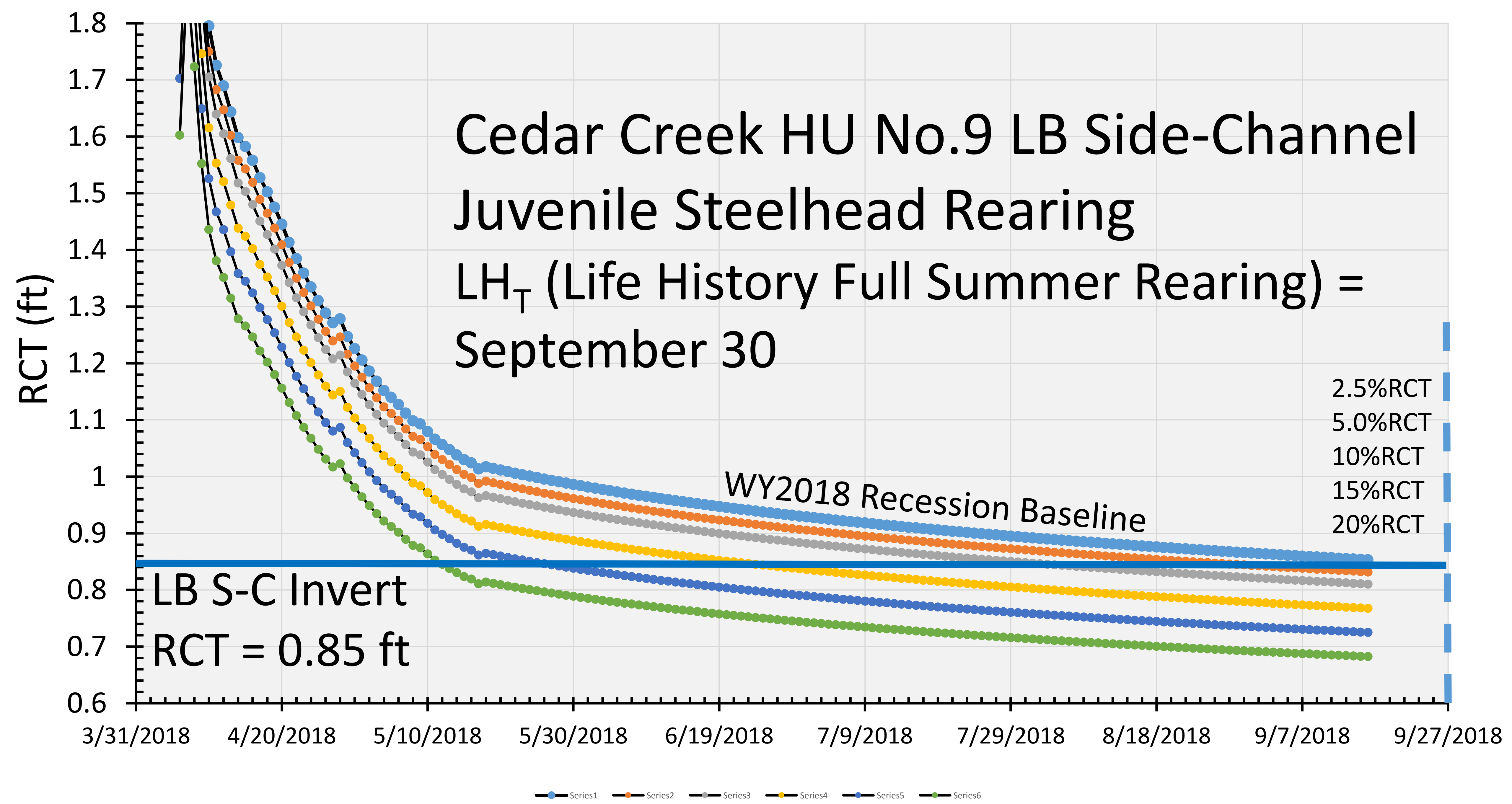


D_{84} Secondary Axis

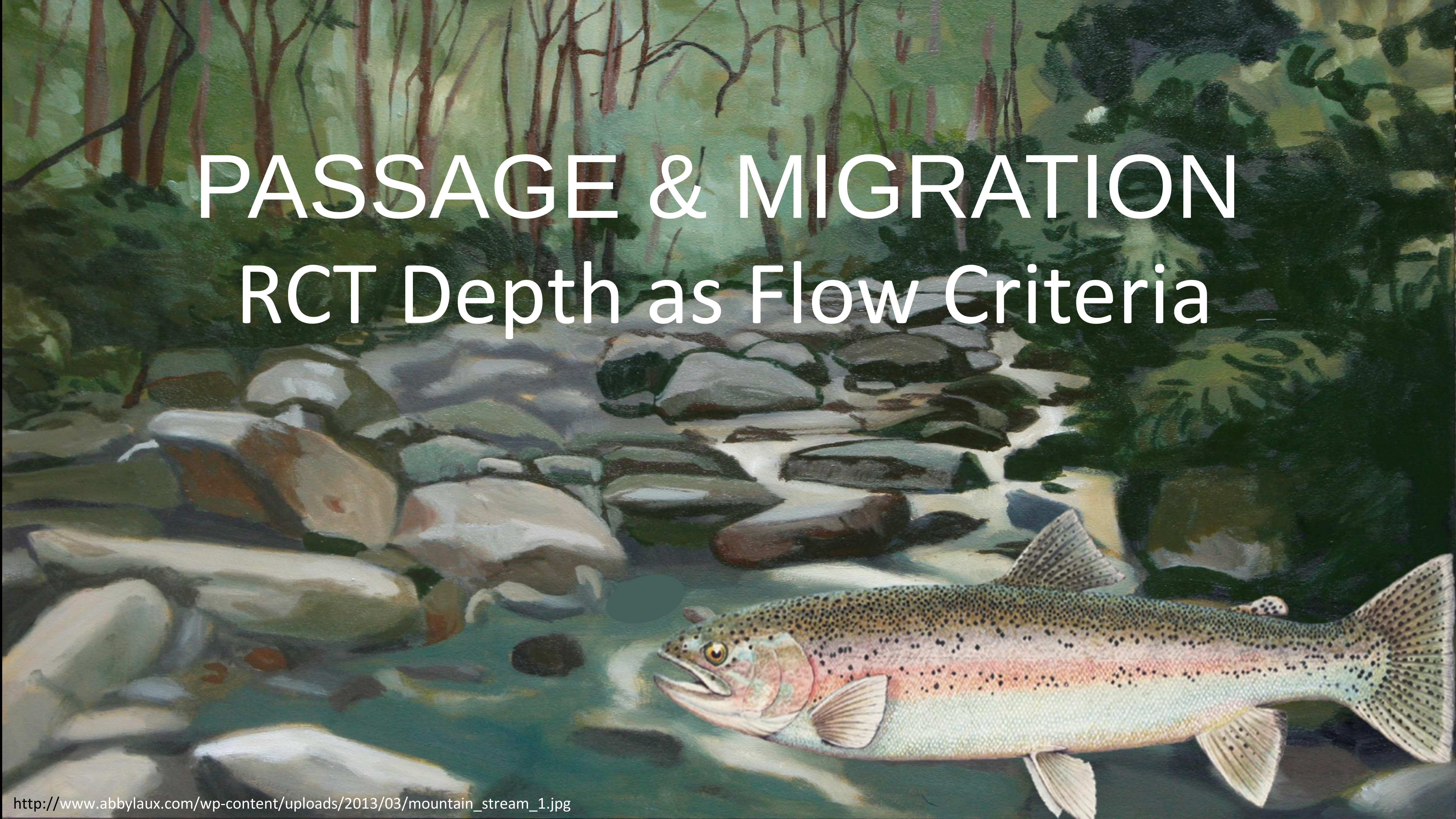
RISK TO SUMMERTIME JUVENILE STEELHEAD REARING IN CEDAR CREEK



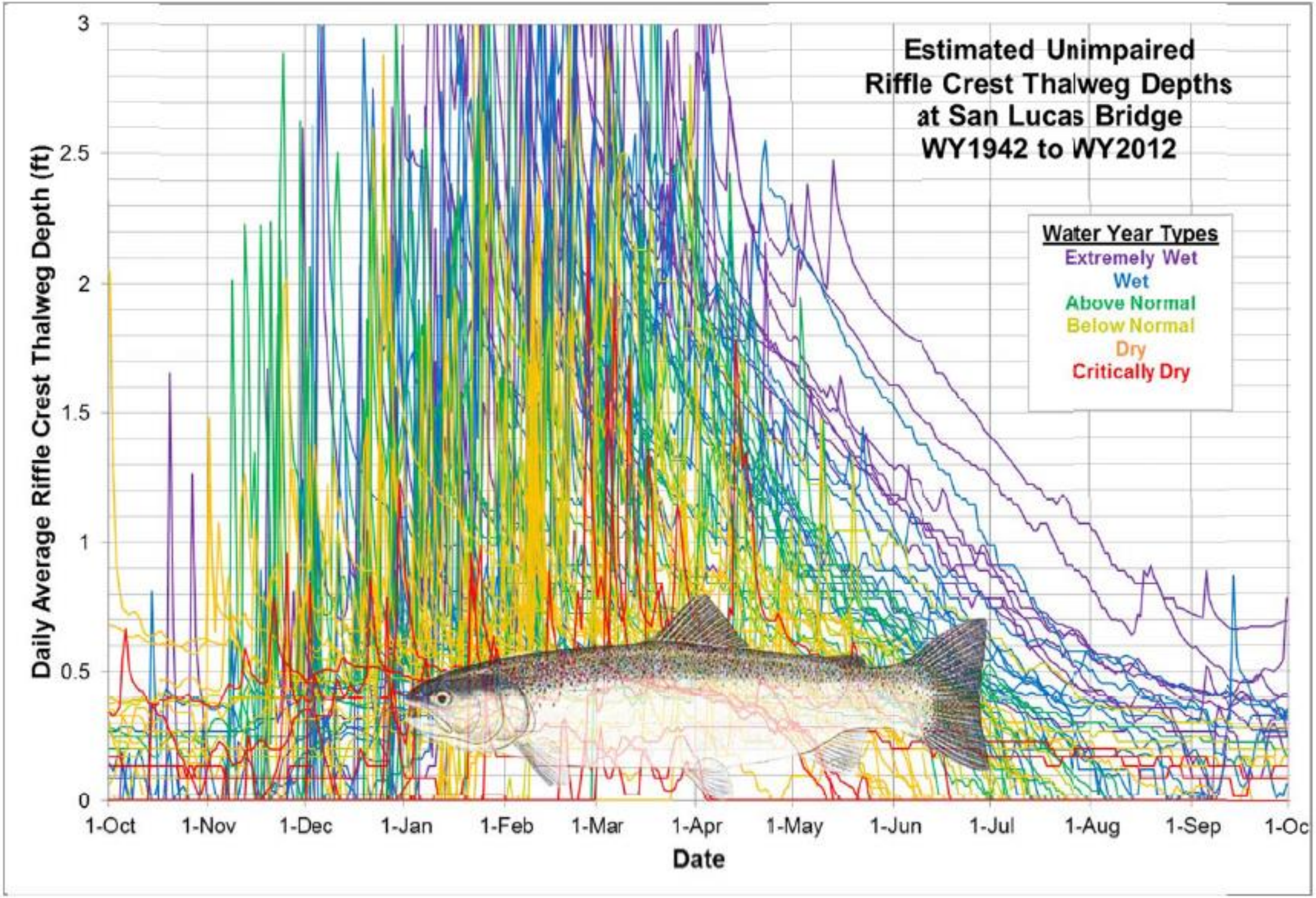
Lower Cedar Creek
27June2018
DA = 14.8 mi^2
Hydraulic Unit No.9
Top LB Wall Bar
3-PT RCT-Q Rating Curve
RCT = 0.4965 $Q^{0.2525}$
R^2 = 0.9952
PFE = 3.9604
Q = 16.0060 $RCT^{3.9604}$
Using 11 cfs/mi^2 @ DA = 14.8 mi^2 = 163 cfs
ACTIVE RCT = 1.79 ft
May 30 = SWRCB measured 22.80 cfs RCT = 1.12 ft
June 27 = SWRCB measured 15.34 cfs RCT = 0.97 ft
Installed RB Water Level Stake (along narrow RB bar)
Est. Lower Hydraulic Transition = 26 cfs
LB Side-Channel Invert Q_T RCT = 1.37 ft (Q = 66.1 cfs)
Riffle Crest Thalweg (ft)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
20
40
60
80
100
120
140
160
180



Cedar Creek HU No.9 LB Side-Channel
Juvenile Steelhead Rearing
LH_T (Life History Full Summer Rearing) =
September 30
RCT (ft)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
3/31/2018
4/20/2018
5/10/2018
5/30/2018
6/19/2018
7/9/2018
7/29/2018
8/18/2018
9/7/2018
9/27/2018
2.5%RCT
5.0%RCT
10%RCT
15%RCT
20%RCT
WY2018 Recession Baseline
LB S-C Invert
RCT = 0.85 ft
Series1
Series2
Series3
Series4
Series5
Series6

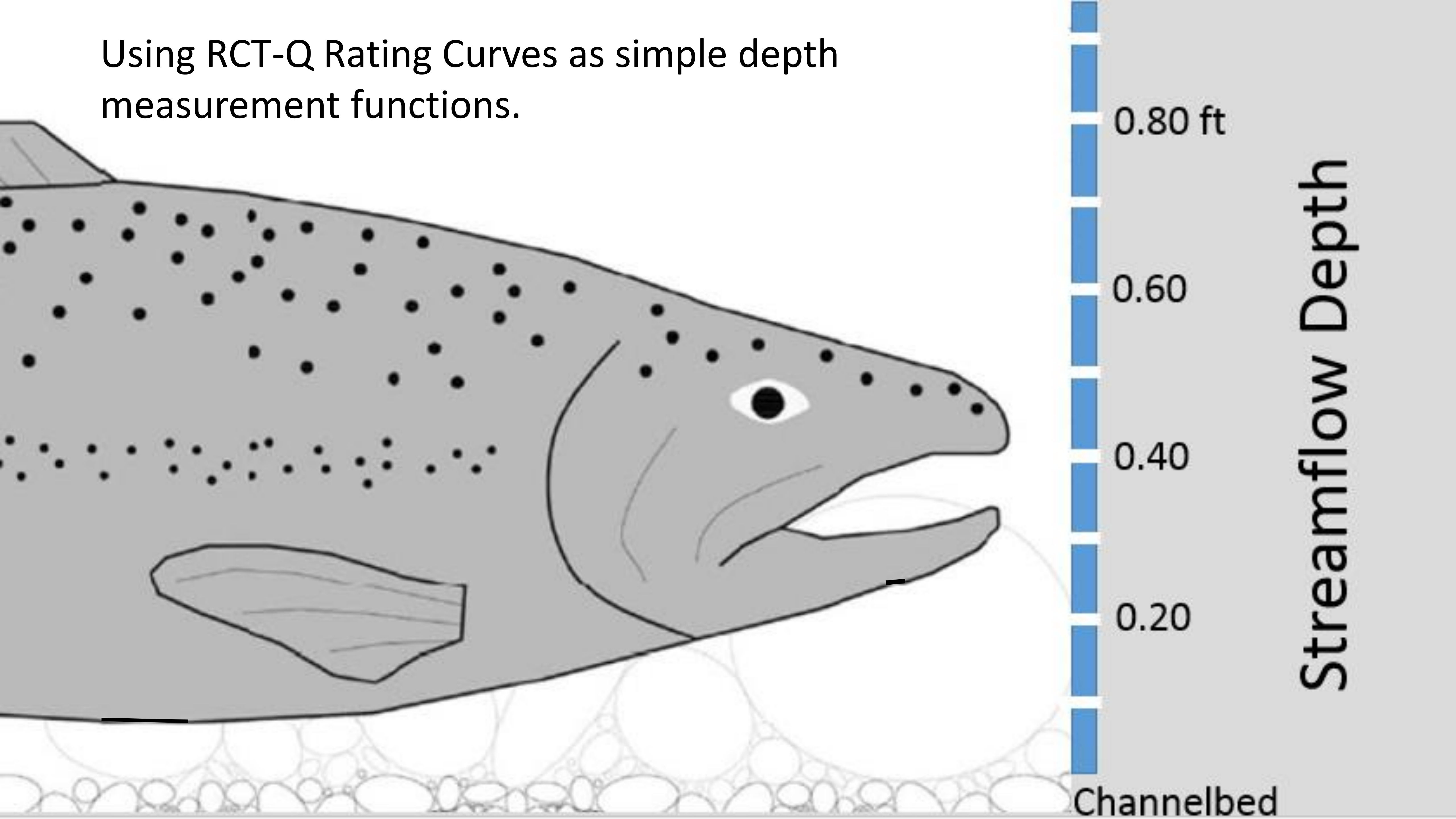


http://www.abbylaux.com/wp-content/uploads/2013/03/mountain_stream_1.jpg



Estimated Unimpaired
Riffle Crest Thalweg Depths
at San Lucas Bridge
WY1942 to WY2012
Water Year Types
Extremely Wet
Wet
Above Normal
Below Normal
Dry
Critically Dry
Daily Average Riffle Crest Thalweg Depth (ft)
3
2.5
2
1.5
1
0.5
0
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oc
Date

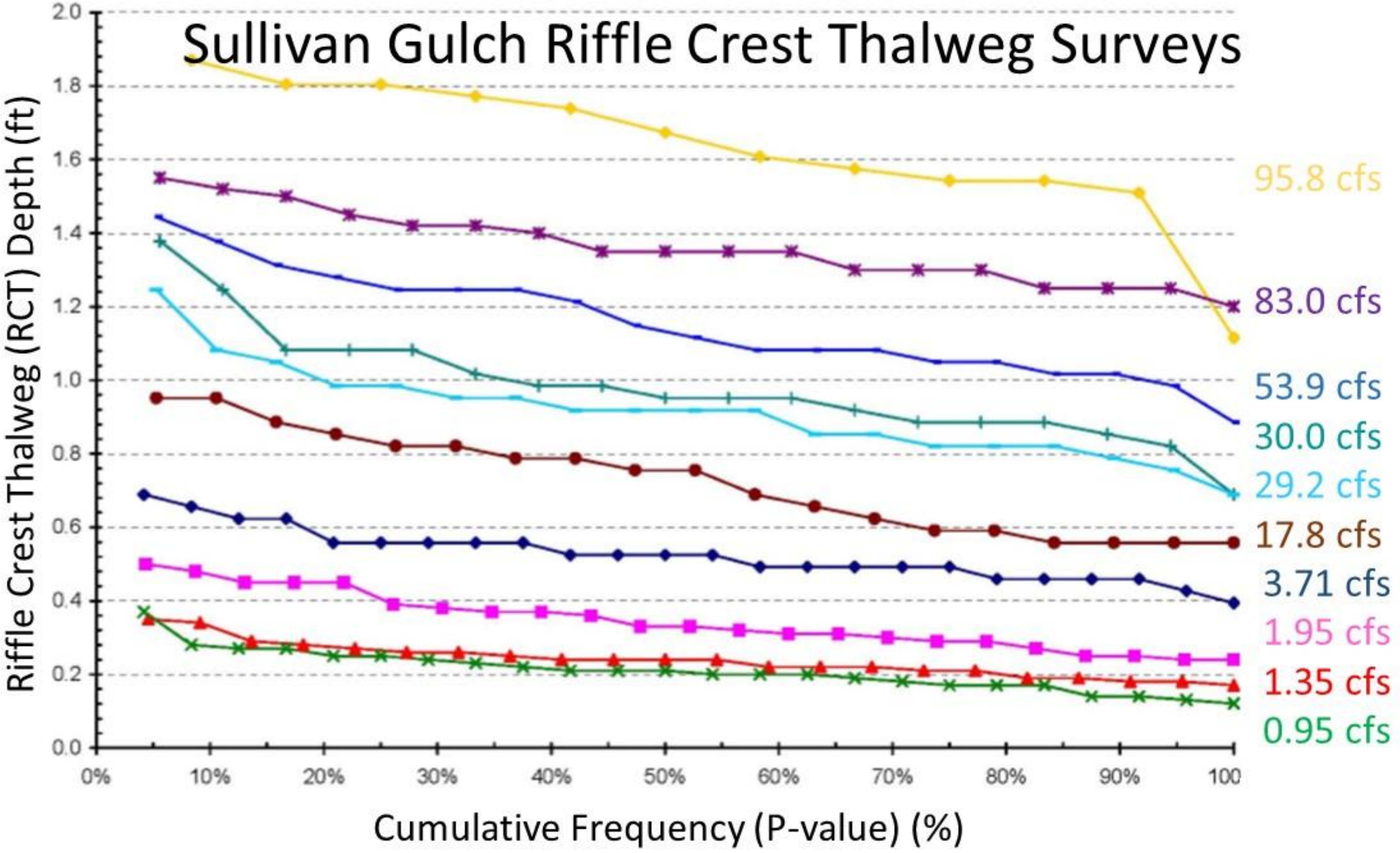
Using RCT-Q Rating Curves as simple depth measurement functions.




26 lb Chinook Salmon
Q_T = Full-Throttle
Q_T = Passage
Q_T = Struggle


CRAIN

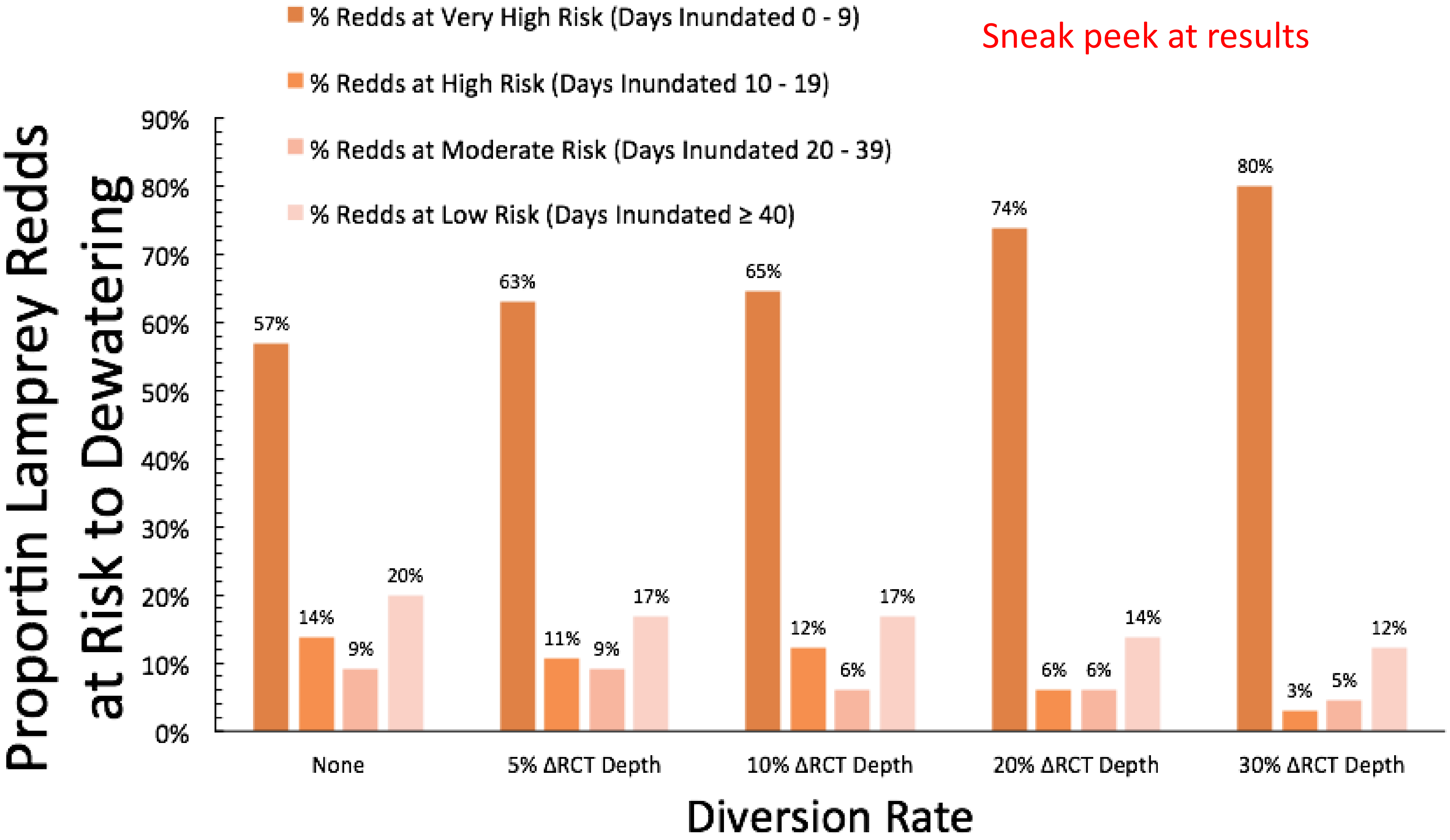
March 8, 2019 Sullivan Gulch



Sullivan Gulch Riffle Crest Thalweg Surveys
Riffle Crest Thalweg (RCT) Depth (ft)
Cumulative Frequency (P-value) (%)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100
95.8 cfs
83.0 cfs
53.9 cfs
30.0 cfs
29.2 cfs
17.8 cfs
3.71 cfs
1.95 cfs
1.35 cfs
0.95 cfs


Adult Lamprey
Spawning
Success
See Emily Cooper’s Presentation on Thursday

Sneak peek at results



Use Q_T Thresholds to Assess But Not Prescribe Instream Flows in Unregulated Streams

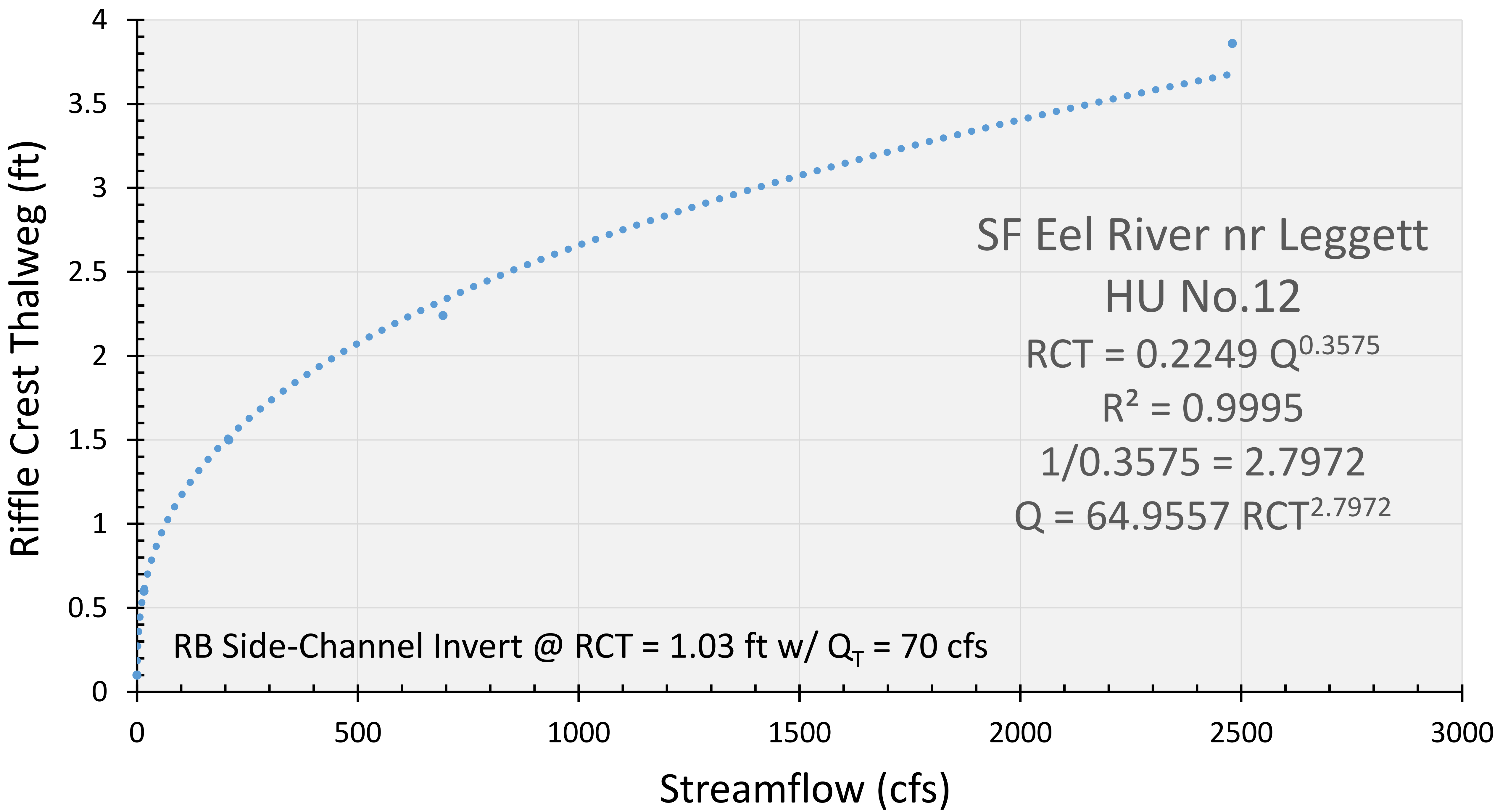
Assessing Chinook Juvenile/Smolt Out-Migration in the Upper South Fork Eel River


SF Eel River
Leggett Mainstem
Hydraulic Unit No.12
August 27, 2018
RCT = 0.51 ft


0.51 ft S-C Invert down to
present water surface

LOOKING DOWNSTREAM
FROM LB S-C INVERT

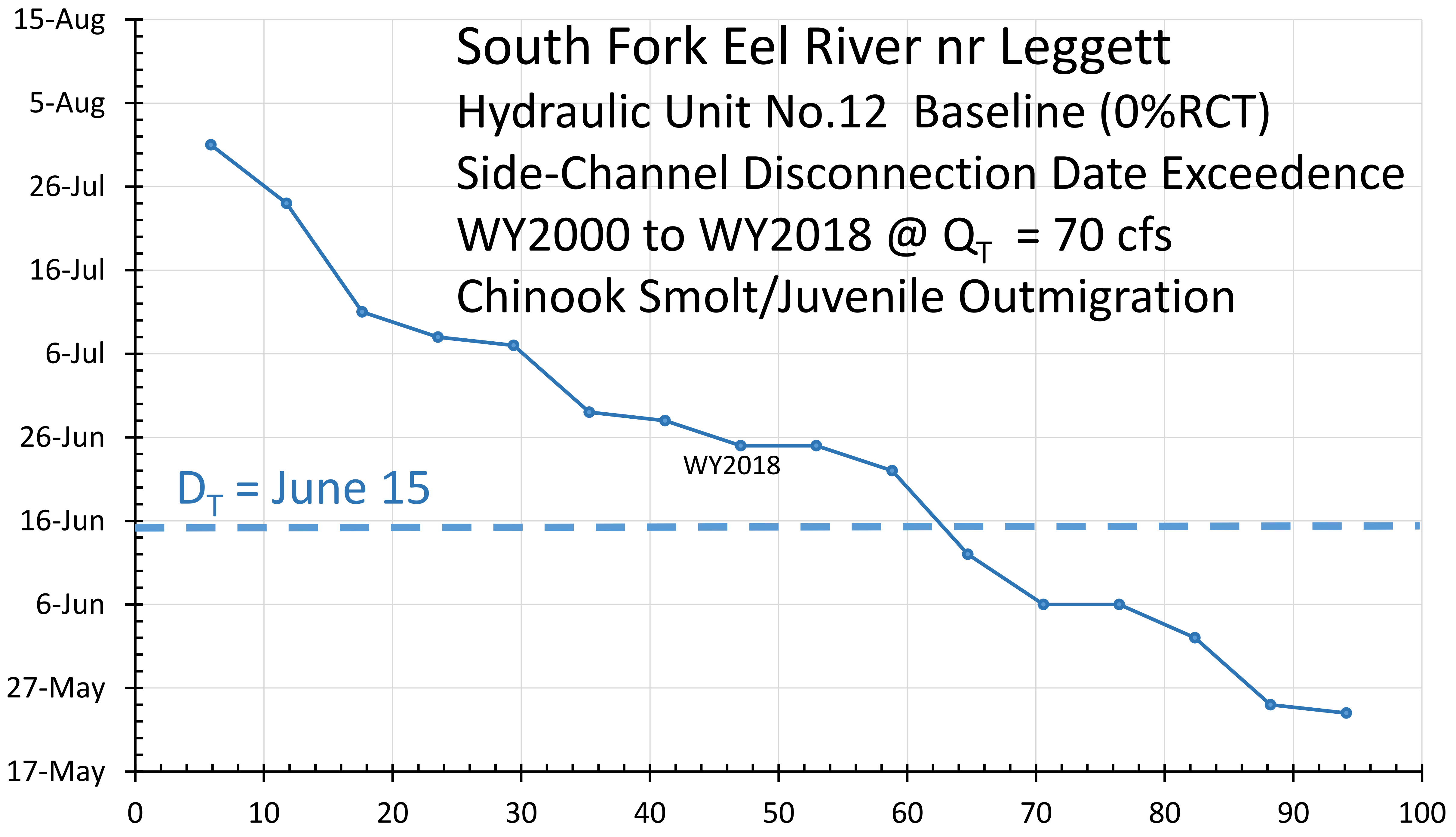

Monday, August 27, 2018 11:57 AM



SF Eel River nr Leggett
HU No.12
RCT = 0.2249 Q^0.3575
R² = 0.9995
1/0.3575 = 2.7972
Q = 64.9557 RCT^2.7972
RB Side-Channel Invert @ RCT = 1.03 ft w/ QT = 70 cfs
Riffle Crest Thalweg (ft)
Streamflow (cfs)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
500
1000
1500
2000
2500
3000

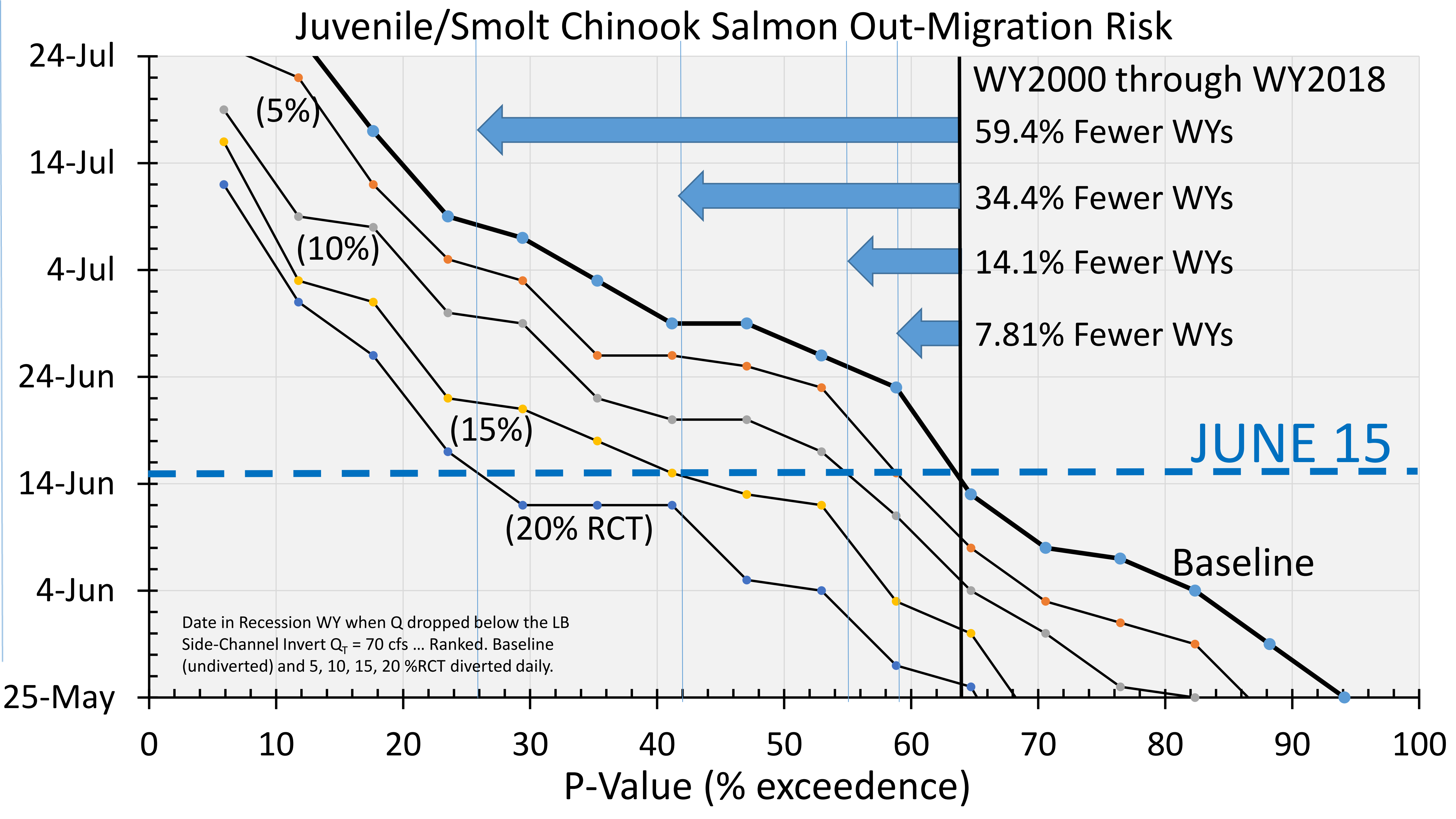
USGS	11475800	2018-06-24 10:00	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 10:15	PDT	74.2	A	5.84	A
USGS	11475800	2018-06-24 10:30	PDT	72.9	A	5.83	A
USGS	11475800	2018-06-24 10:45	PDT	72.9	A	5.83	A
USGS	11475800	2018-06-24 11:00	PDT	72.9	A	5.83	A
USGS	11475800	2018-06-24 11:15	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 11:30	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 11:45	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 12:00	PDT	72.9	A	5.83	A
USGS	11475800	2018-06-24 12:15	PDT	74.2	A	5.84	A
USGS	11475800	2018-06-24 12:30	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 12:45	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 13:00	PDT	72.9	A	5.83	A
USGS	11475800	2018-06-24 13:15	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 13:30	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 13:45	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 14:00	PDT	70.4	A	5.81	A
USGS	11475800	2018-06-24 14:15	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 14:30	PDT	70.4	A	5.81	A
USGS	11475800	2018-06-24 14:45	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 15:00	PDT	70.4	A	5.81	A
USGS	11475800	2018-06-24 15:15	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 15:30	PDT	69.2	A	5.80	A
USGS	11475800	2018-06-24 15:45	PDT	70.4	A	5.81	A
USGS	11475800	2018-06-24 16:00	PDT	70.4	A	5.81	A
USGS	11475800	2018-06-24 16:15	PDT	71.7	A	5.82	A
USGS	11475800	2018-06-24 16:30	PDT	70.4	A	5.81	A
USGS	11475800	2018-06-24 16:45	PDT	70.4	A	5.81	A
USGS	11475800	2018-06-24 17:00	PDT	69.2	A	5.80	A
USGS	11475800	2018-06-24 17:15	PDT	70.4	A	5.81	A
USGS	11475800	2018-06-24 17:30	PDT	69.2	A	5.80	A
USGS	11475800	2018-06-24 17:45	PDT	68.0	A	5.79	A
USGS	11475800	2018-06-24 18:00	PDT	69.2	A	5.80	A
USGS	11475800	2018-06-24 18:15	PDT	68.0	A	5.79	A
USGS	11475800	2018-06-24 18:30	PDT	69.2	A	5.80	A
USGS	11475800	2018-06-24 18:45	PDT	69.2	A	5.80	A
USGS	11475800	2018-06-24 19:00	PDT	68.0	A	5.79	A
USGS	11475800	2018-06-24 19:15	PDT	68.0	A	5.79	A
USGS	11475800	2018-06-24 19:30	PDT	68.0	A	5.79	A
USGS	11475800	2018-06-24 19:45	PDT	69.2	A	5.80	A

JUNE 24 @ 5:30PM

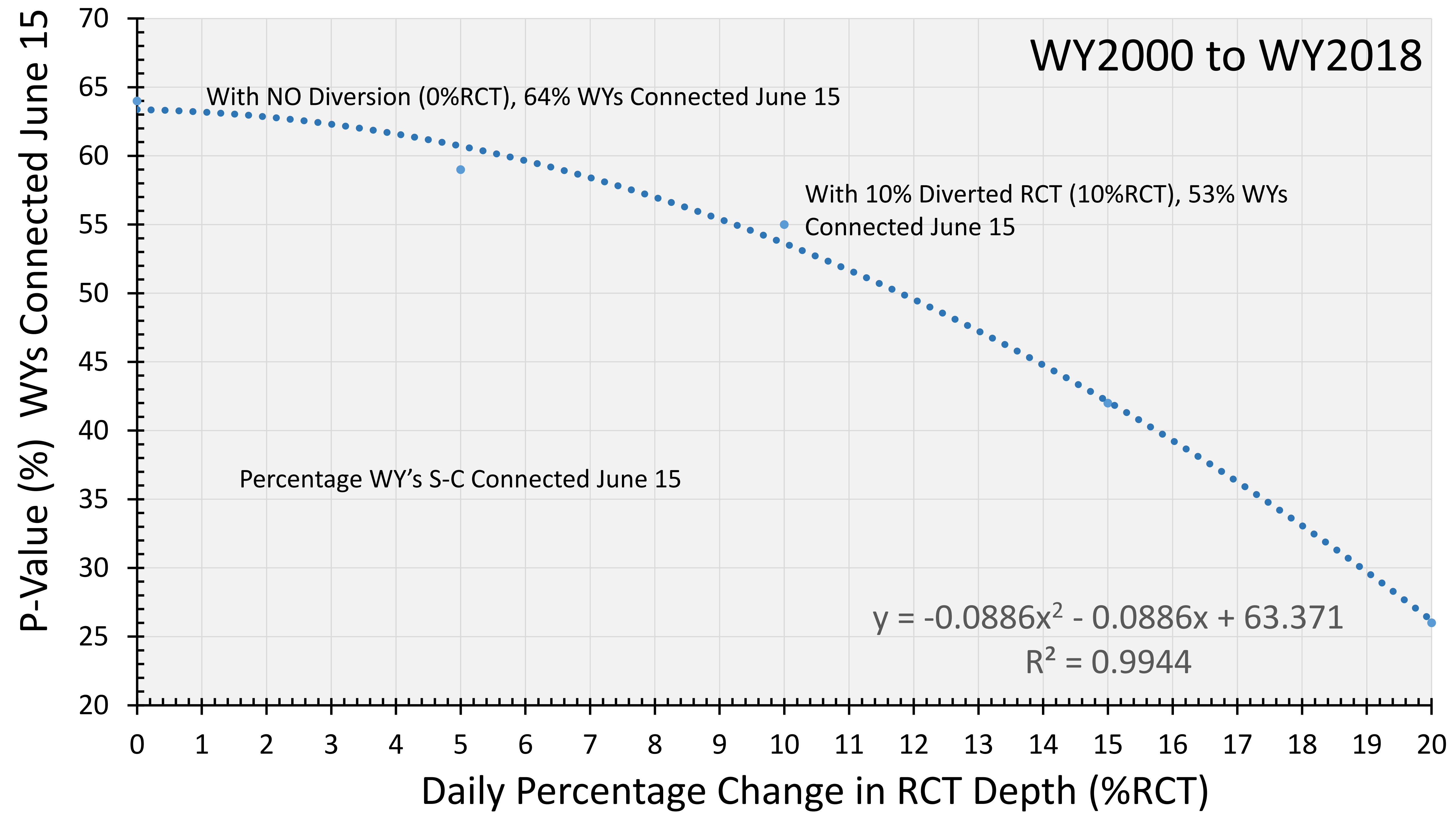


South Fork Eel River nr Leggett
Hydraulic Unit No.12 Baseline (0%RCT)
Side-Channel Disconnection Date Exceedence
WY2000 to WY2018 @ Q_T = 70 cfs
Chinook Smolt/Juvenile Outmigration
D_T = June 15
WY2018
15-Aug
5-Aug
26-Jul
16-Jul
6-Jul
26-Jun
16-Jun
6-Jun
27-May
17-May
0
10
20
30
40
50
60
70
80
90
100

RANKING AND EXCEEDENCE (P-Value, %) ESSENTIAL TO ESTABLISHING A BASELINE FOR EVALUATING RISK !!!!!!!!!!!!!!!!!!!!!



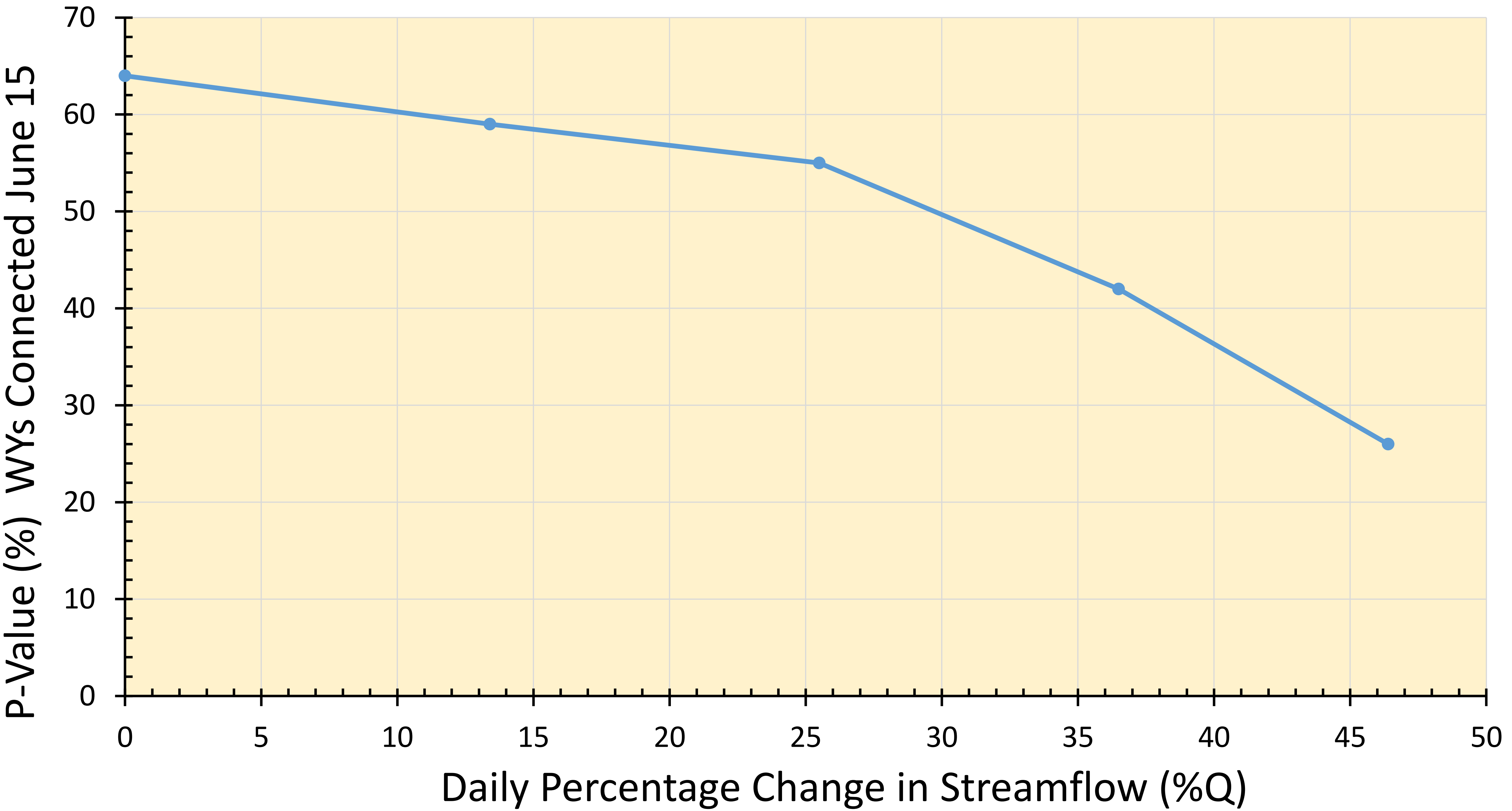
Juvenile/Smolt Chinook Salmon Out-Migration Risk
WY2000 through WY2018
59.4% Fewer WYs
34.4% Fewer WYs
14.1% Fewer WYs
7.81% Fewer WYs
(5%)
(10%)
(15%)
(20% RCT)
JUNE 15
Baseline
Date in Recession WY when Q dropped below the LB Side-Channel Invert Q_T = 70 cfs … Ranked. Baseline (undiverted) and 5, 10, 15, 20 %RCT diverted daily.
24-Jul
14-Jul
4-Jul
24-Jun
14-Jun
4-Jun
25-May
0
10
20
30
40
50
60
70
80
90
100
P-Value (% exceedence)



WY2000 to WY2018
With NO Diversion (0%RCT), 64% WYs Connected June 15
With 10% Diverted RCT (10%RCT), 53% WYs Connected June 15
Percentage WY's S-C Connected June 15
y = -0.0886x2 - 0.0886x + 63.371
R2 = 0.9944
P-Value (%) WYs Connected June 15
Daily Percentage Change in RCT Depth (%RCT)
70
65
60
55
50
45
40
35
30
25
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Convert %Changes in RCT Depth to %Q Change:

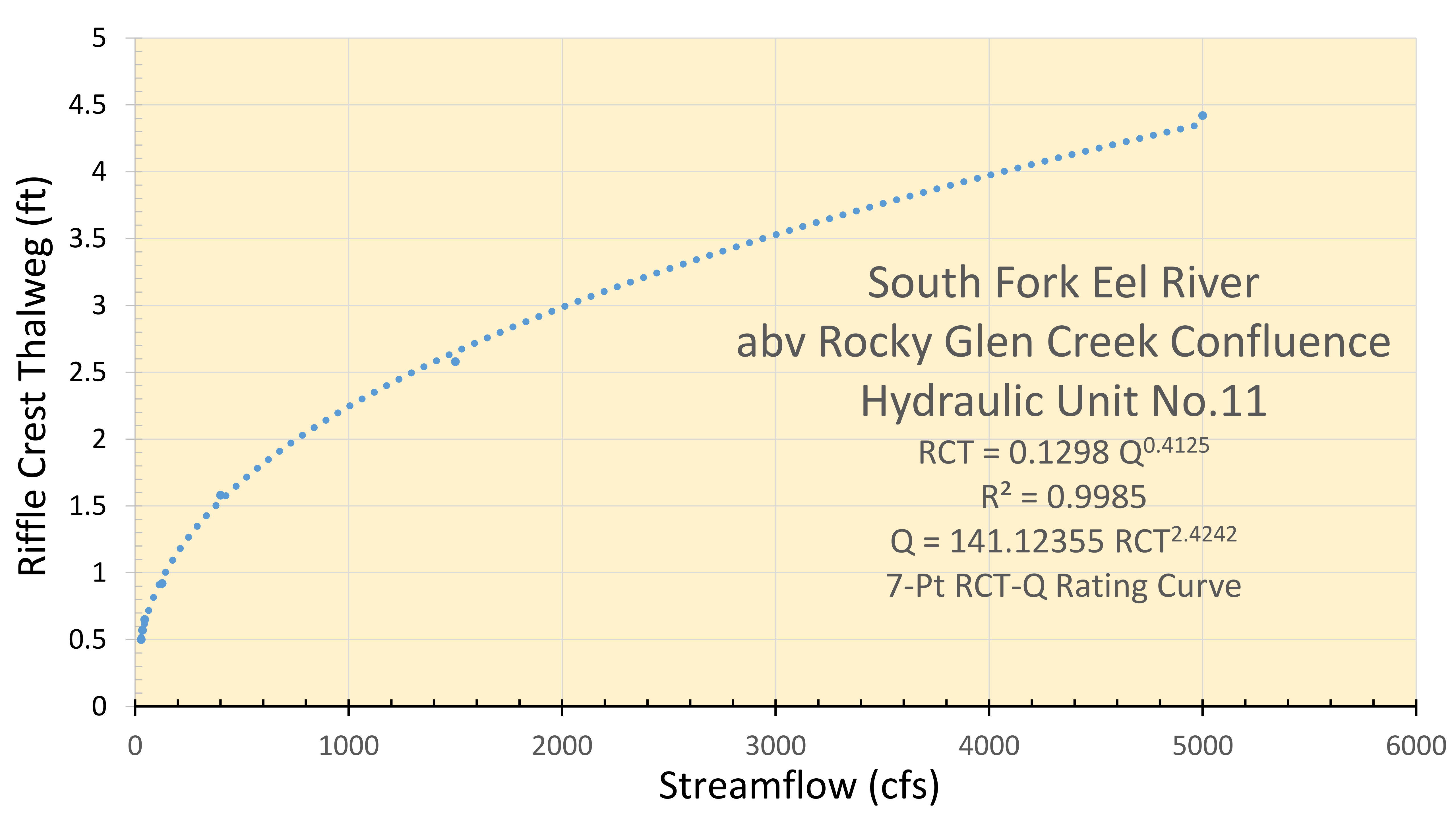
5%RCT	13.4%Q
10%RCT	25.5%Q
15%RCT	36.5%Q
20%RCT	46.4%Q



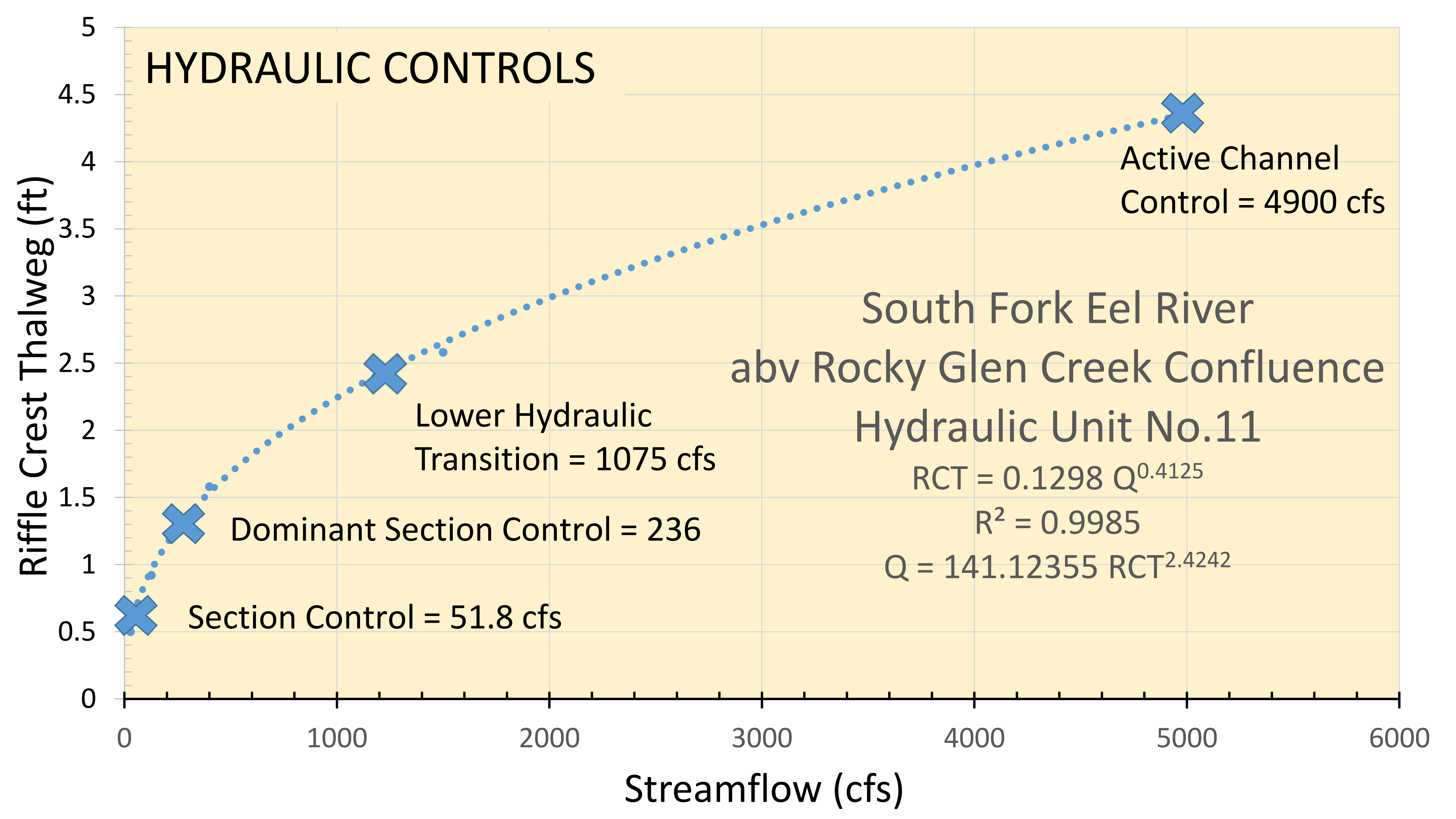
P-Value (%) WYs Connected June 15
Daily Percentage Change in Streamflow (%Q)
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
50

ADVANCEMENT OF SECTION CONTROL WITH DIVERSIONS ON THE SOUTH FORK EEL RIVER NR MIRANDA

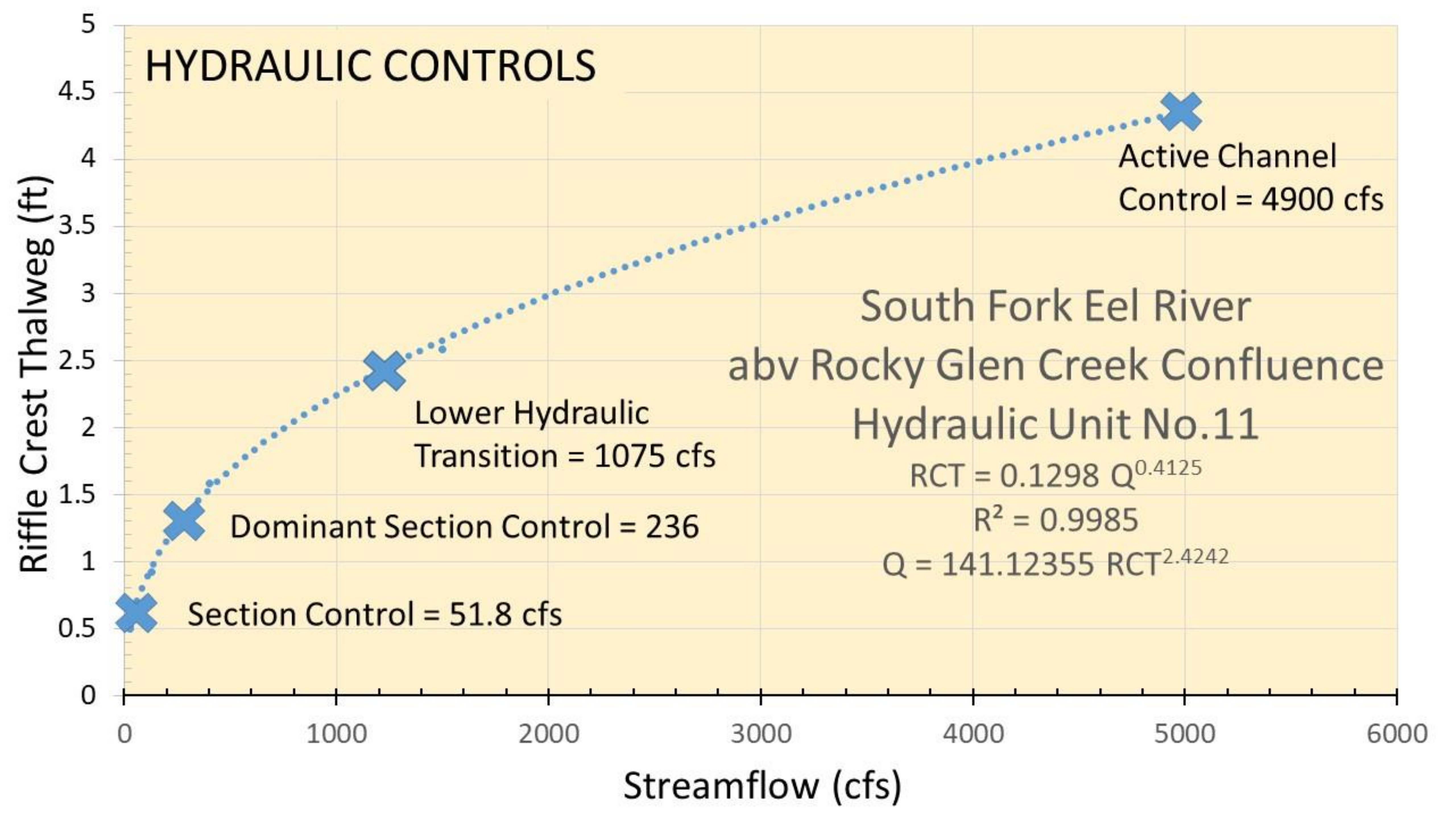
When the mainstem's streamflow drops below Q_T Section Control (= 51.8 cfs) at the Rocky Glen Creek Confluence during the summer recession, the mainstem channel loses its most of its velocity. Juvenile salmonids already experiencing less than good temperatures must ether move to the upstream pool entrance for feeding (increasing exposure to predators) or assume a nomadic strategy for locating prey in an almost lentic environment. Water quality sharply declines. Basically, the mainstem loses its Mojo. A diversion strategy should not greatly accelerate (advance) the date section control occurs in the summer recession hydrograph. This is a risk assessment modeled at Q diversion rates from 2.5% to 20%.

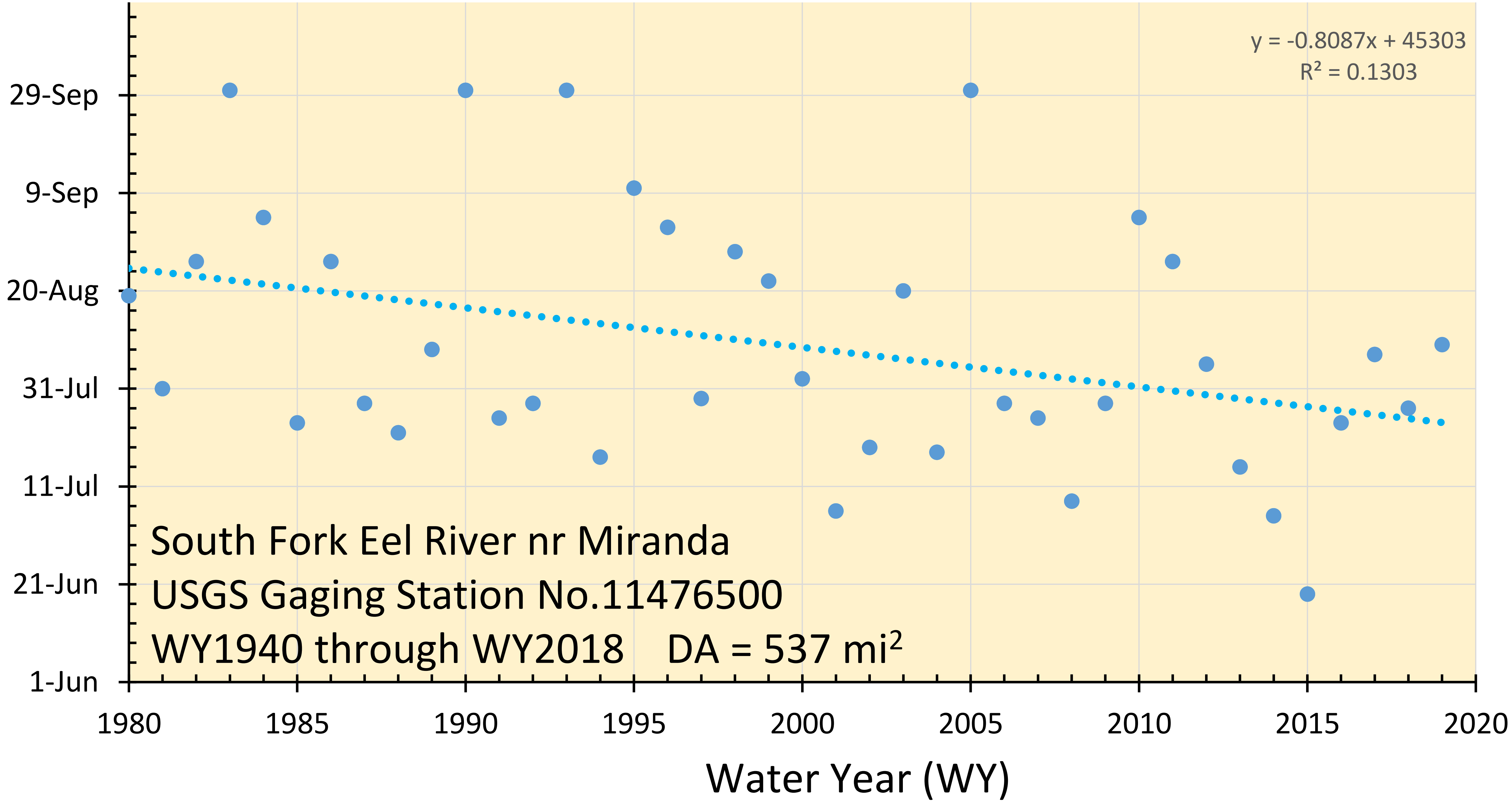

South Fork Eel River
abv Rocky Glen Creek Confluence
Hydraulic Unit No.11
RCT = 0.1298 Q0.4125
R² = 0.9985
Q = 141.12355 RCT2.4242
7-Pt RCT-Q Rating Curve
Riffle Crest Thalweg (ft)
Streamflow (cfs)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
1000
2000
3000
4000
5000
6000

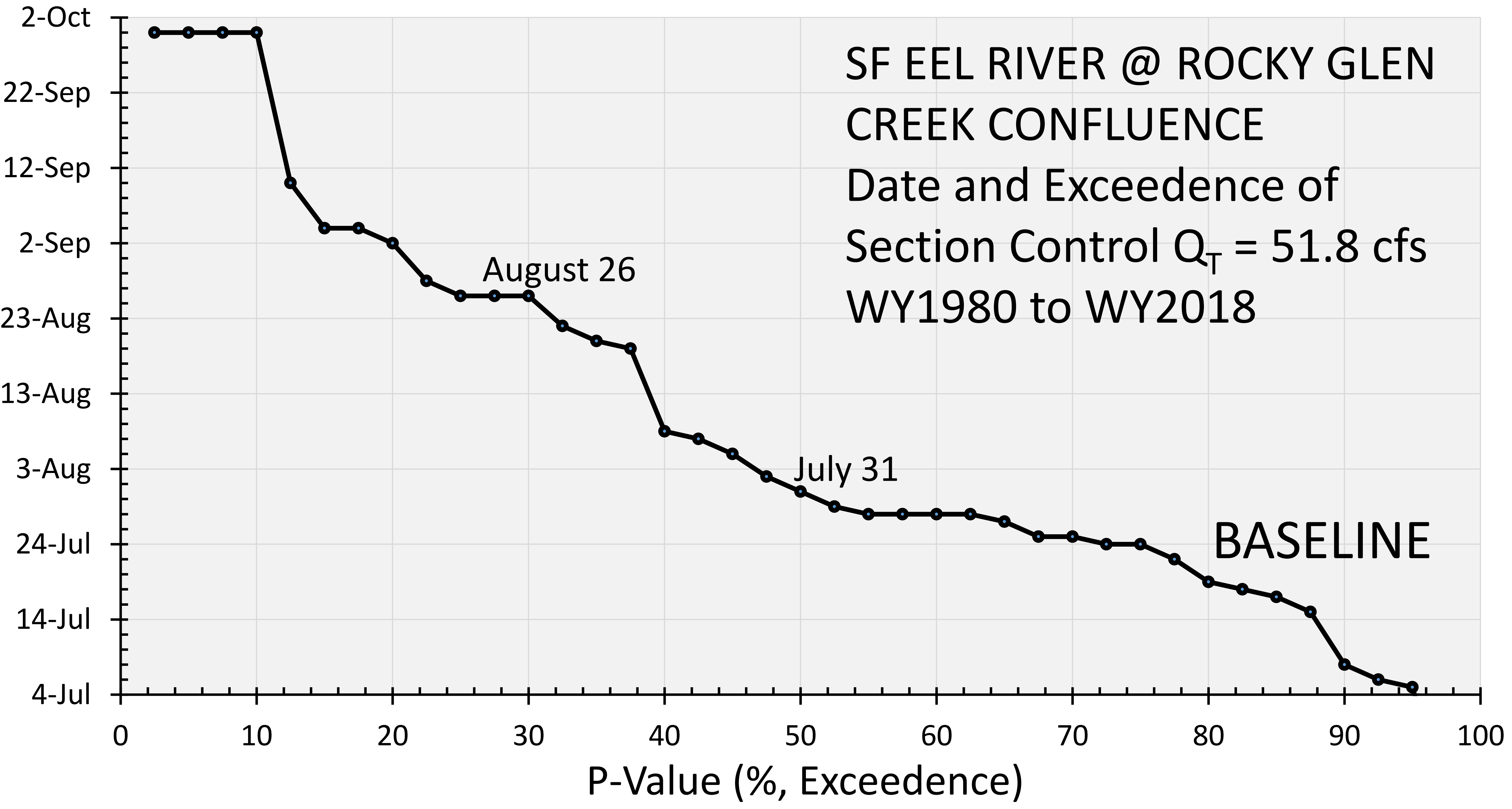

Looking Downstream At Rocky Glen Creek Riffle
Crest under Section Control
August 9, 2018 USGS Gage Miranda = 38.1 cfs

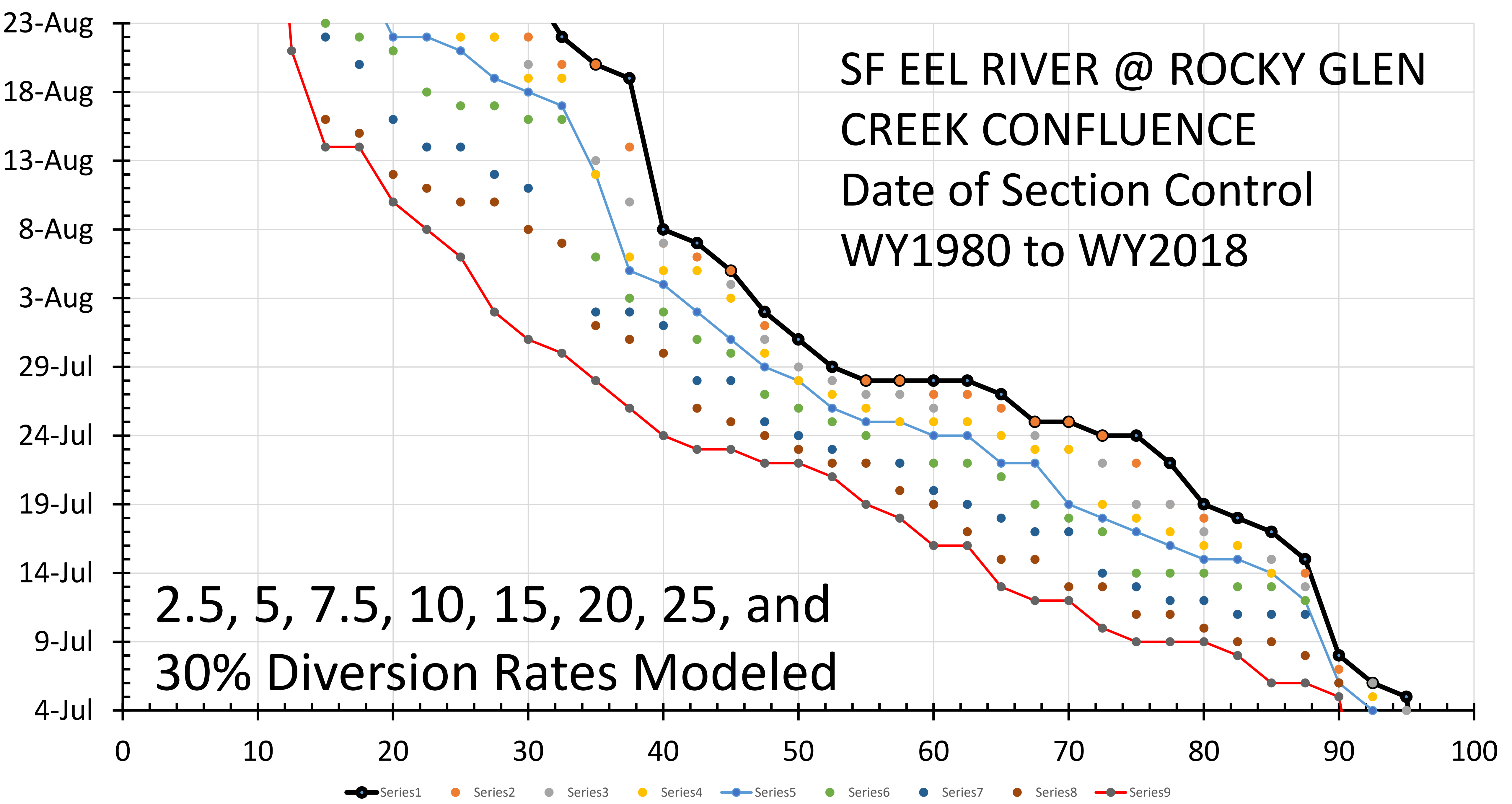


HYDRAULIC CONTROLS
Active Channel Control = 4900 cfs
South Fork Eel River
abv Rocky Glen Creek Confluence
Hydraulic Unit No.11
RCT = 0.1298 Q^0.4125
R² = 0.9985
Q = 141.12355 RCT^2.4242
Lower Hydraulic Transition = 1075 cfs
Dominant Section Control = 236
Section Control = 51.8 cfs
Riffle Crest Thalweg (ft)
Streamflow (cfs)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
1000
2000
3000
4000
5000
6000

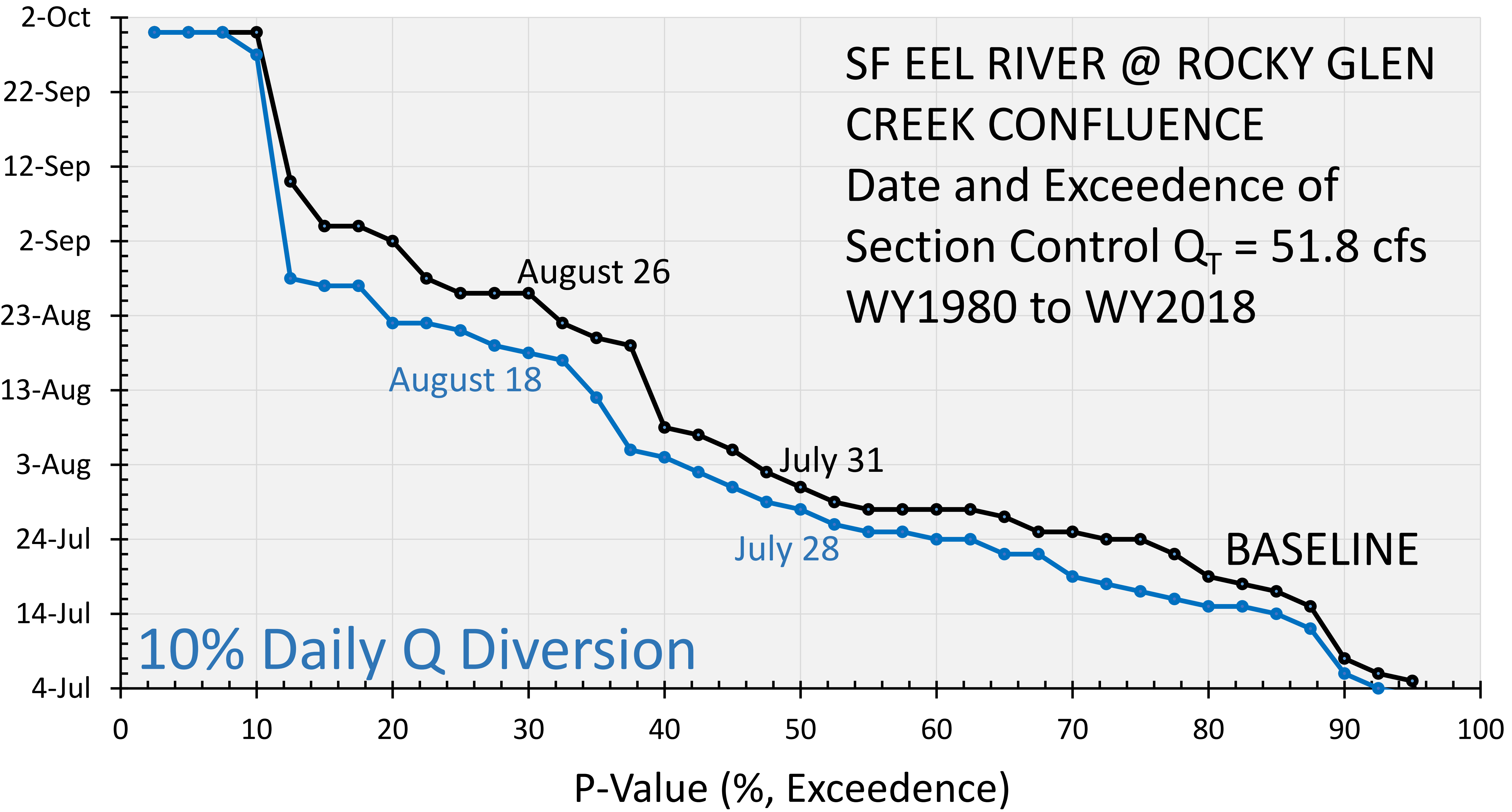

HYDRAULIC CONTROLS
Active Channel
Control = 4900 cfs
South Fork Eel River
abv Rocky Glen Creek Confluence
Hydraulic Unit No.11
RCT = 0.1298 Q^0.4125
R² = 0.9985
Q = 141.12355 RCT^2.4242
Lower Hydraulic
Transition = 1075 cfs
Dominant Section Control = 236
Section Control = 51.8 cfs
Riffle Crest Thalweg (ft)
Streamflow (cfs)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
1000
2000
3000
4000
5000
6000


y = -0.8087x + 45303
R² = 0.1303
29-Sep
9-Sep
20-Aug
31-Jul
11-Jul
21-Jun
1-Jun
South Fork Eel River nr Miranda
USGS Gaging Station No.11476500
WY1940 through WY2018 DA = 537 mi²
1980
1985
1990
1995
2000
2005
2010
2015
2020
Water Year (WY)

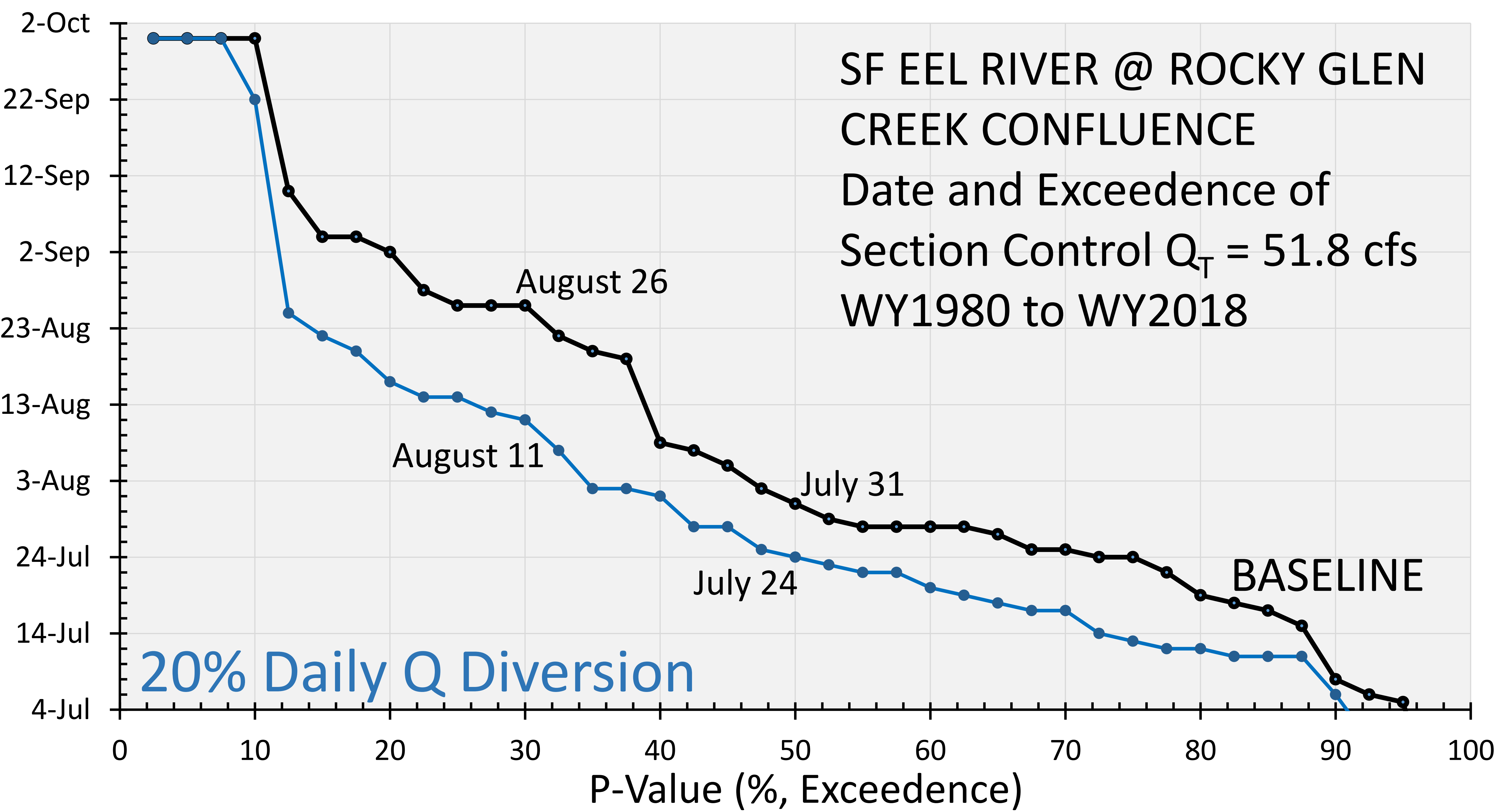

SF EEL RIVER @ ROCKY GLEN CREEK CONFLUENCE
Date and Exceedence of Section Control Q_T = 51.8 cfs
WY1980 to WY2018
BASELINE
August 26
July 31
2-Oct
22-Sep
12-Sep
2-Sep
23-Aug
13-Aug
3-Aug
24-Jul
14-Jul
4-Jul
0
10
20
30
40
50
60
70
80
90
100
P-Value (%, Exceedence)



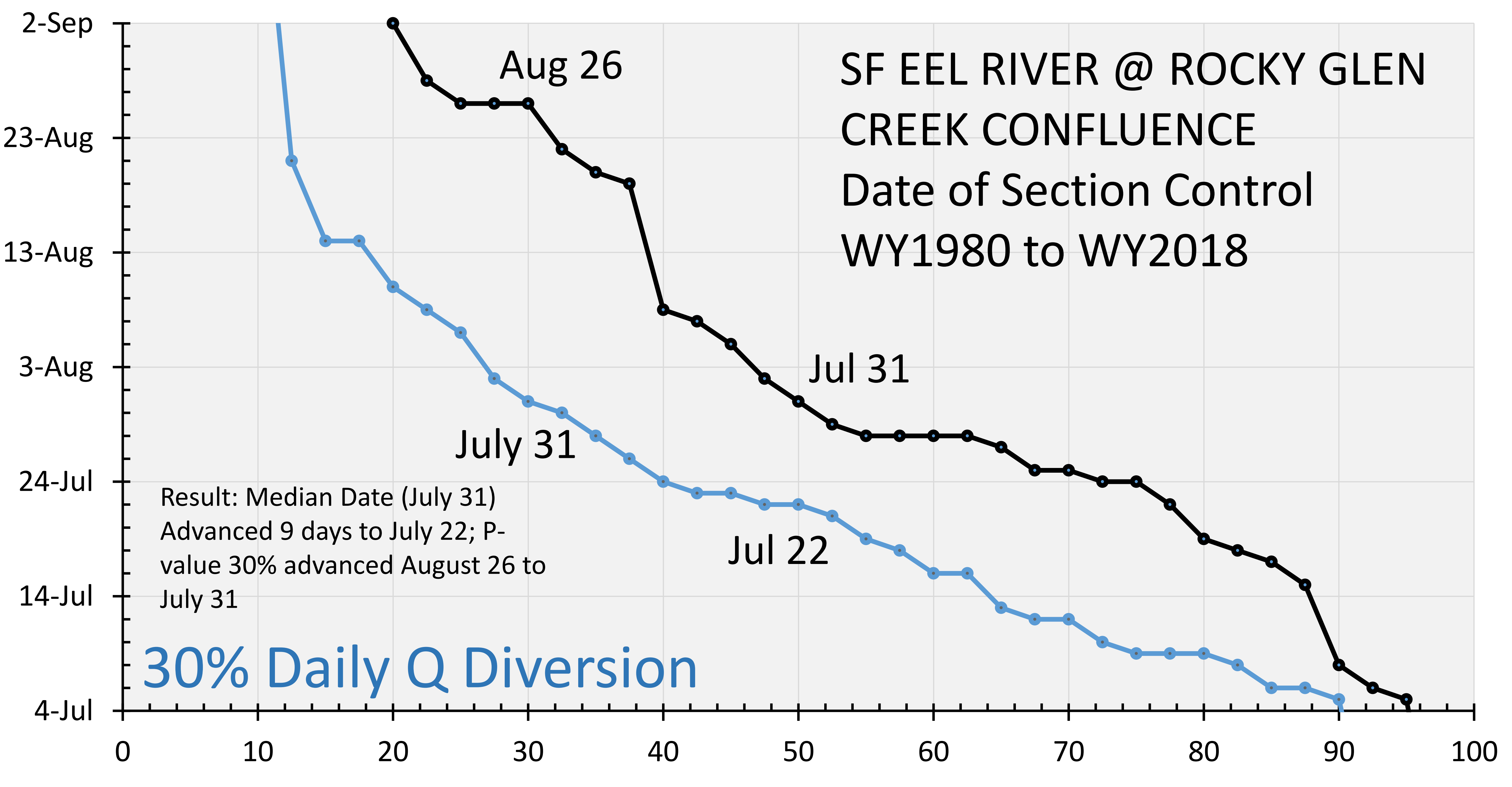
SF EEL RIVER @ ROCKY GLEN CREEK CONFLUENCE
Date of Section Control
WY1980 to WY2018
2.5, 5, 7.5, 10, 15, 20, 25, and 30% Diversion Rates Modeled
23-Aug
18-Aug
13-Aug
8-Aug
3-Aug
29-Jul
24-Jul
19-Jul
14-Jul
9-Jul
4-Jul
0
10
20
30
40
50
60
70
80
90
100
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Series9



SF EEL RIVER @ ROCKY GLEN CREEK CONFLUENCE
Date and Exceedence of Section Control Q_T = 51.8 cfs
WY1980 to WY2018
August 26
August 18
July 31
July 28
BASELINE
10% Daily Q Diversion
2-Oct
22-Sep
12-Sep
2-Sep
23-Aug
13-Aug
3-Aug
24-Jul
14-Jul
4-Jul
0
10
20
30
40
50
60
70
80
90
100
P-Value (%, Exceedence)



SF EEL RIVER @ ROCKY GLEN CREEK CONFLUENCE
Date and Exceedence of Section Control Q_T = 51.8 cfs
WY1980 to WY2018
August 26
August 11
July 31
July 24
BASELINE
20% Daily Q Diversion
2-Oct
22-Sep
12-Sep
2-Sep
23-Aug
13-Aug
3-Aug
24-Jul
14-Jul
4-Jul
0
10
20
30
40
50
60
70
80
90
100
P-Value (%, Exceedence)


SF EEL RIVER @ ROCKY GLEN CREEK CONFLUENCE
Date of Section Control
WY1980 to WY2018
Aug 26
Jul 31
July 31
Jul 22
Result: Median Date (July 31) Advanced 9 days to July 22; P-value 30% advanced August 26 to July 31
30% Daily Q Diversion
2-Sep
23-Aug
13-Aug
3-Aug
24-Jul
14-Jul
4-Jul
0
10
20
30
40
50
60
70
80
90
100

Most cumulative diversion impacts are gradual. This is a typical example of one. However, note the wetter WYs (P-value = 30%) experience greater risk (greater advancement in Q_T Date) at higher diversion rates than median WYs (P-value = 50%). Slowing the river down by a month could incur major impacts on water quality (e.g., What would be algal response that in turn could impact lamprey ammocoete summer survival?).

Riffle Crest Thalweg Rating Curves

The greatest importance of the RC and RCT towards understanding how stream ecosystems work is not because of its usefulness as a function for streamflow depth, but because of its rate of change in depth as streamflow changes, i.e., when we think *verb* rather than *noun*.

SUMMERTIME TADPOLE REARING IN THE SOUTH FORK EEL RIVER

Estimated 400 to 500 FYLF tadpoles present
July 29, 2018


However by August 9, 2018 almost all tadpoles had disappeared due to : (next frame)
JULY 29, 2018

Significance
Success
Risk