A Seasonally Oscillating Hydrograph for Salmon Population and Salmon Habitat Management

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July 2023

Key Goals in presenting to the TRRP's Flow Work Group

1) Explain rationale for Seasonally Oscillating Hydrograph

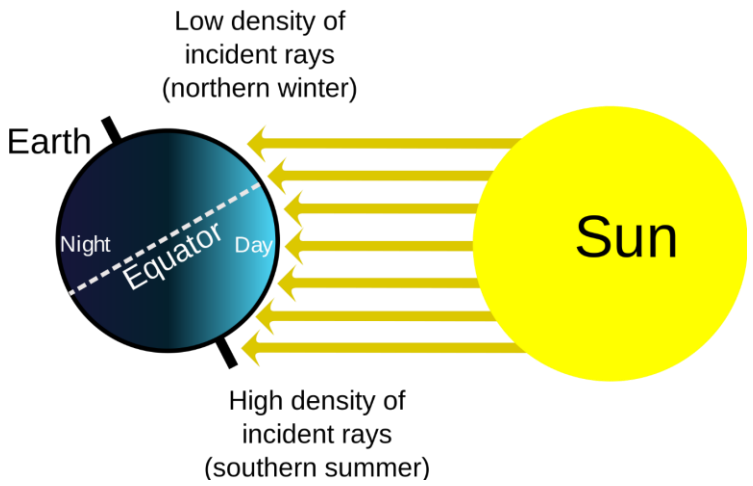
2) Define what a SOH could look like for the Trinity River.

3) Explain how a SOH would require changes to physical habitat restoration strategies.

4) Questions for the Flow Work Group.

The Astronomical Seasons

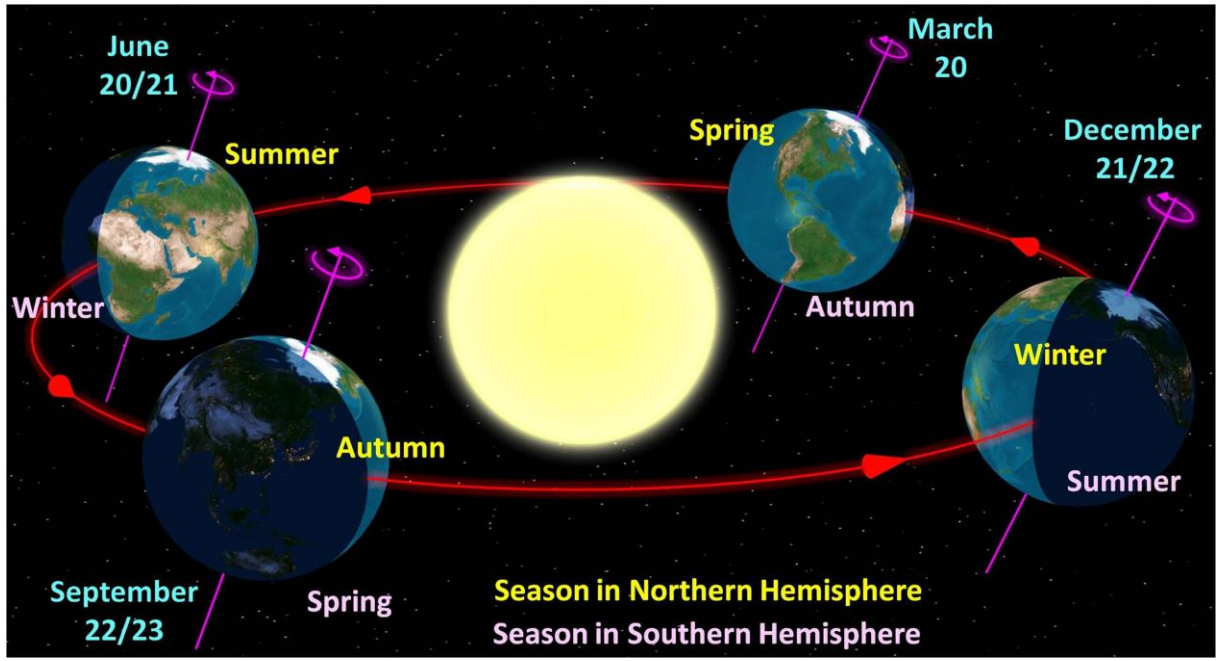
A Day is ...



Earth has a ~23° tilt

Stellar day (aligned with non-sun stars) is 23 hours 56 min 4 sec

A Year is …



One year is ~365.2422 days

Earth moves ~1 degree around the sun every day.

Figure by Rhcastilhos - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=1577426

The Astronomical Seasons in the Northern Hemisphere

Life forms across the planet have evolved under daily and yearly daylength oscillations.

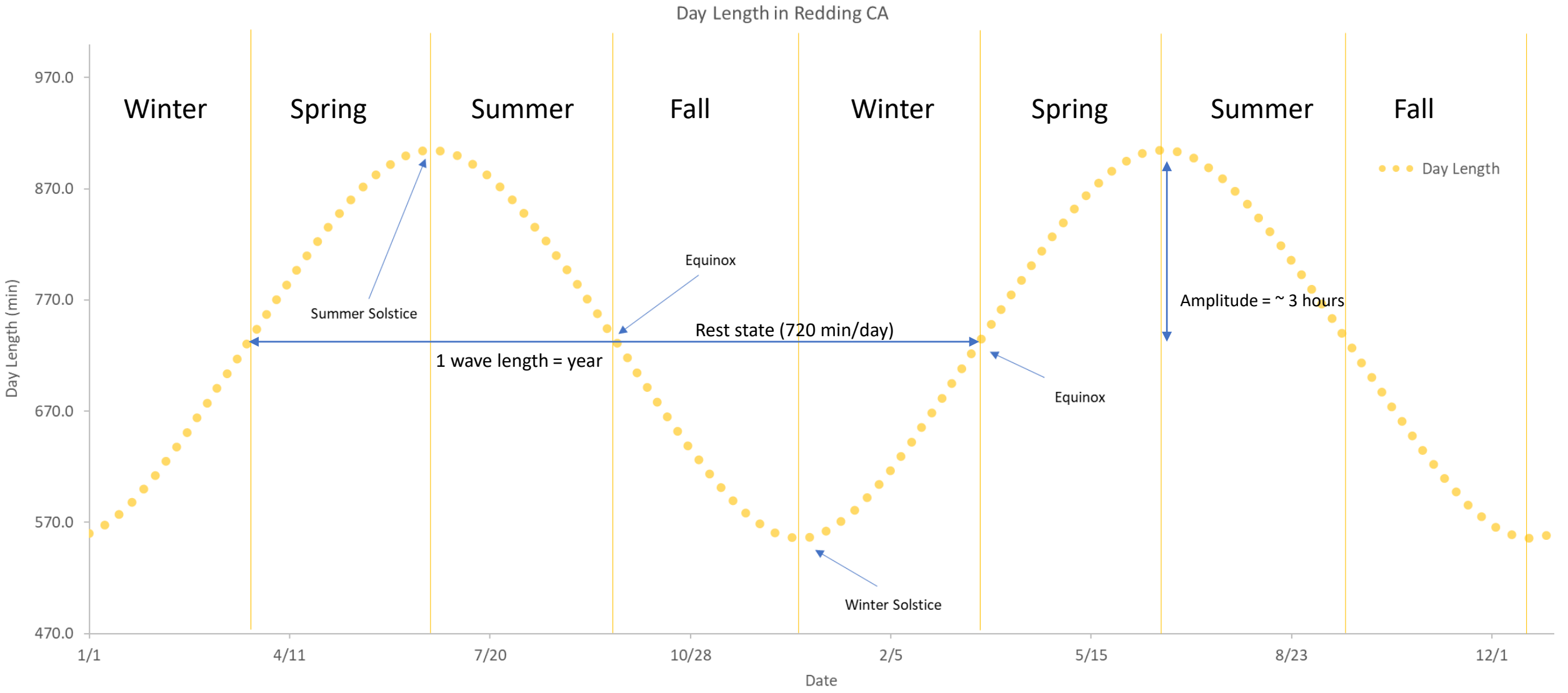
Spring
March 16 –June 19

Autumn
September 26 –December 20

Winter
December 21 – March 15

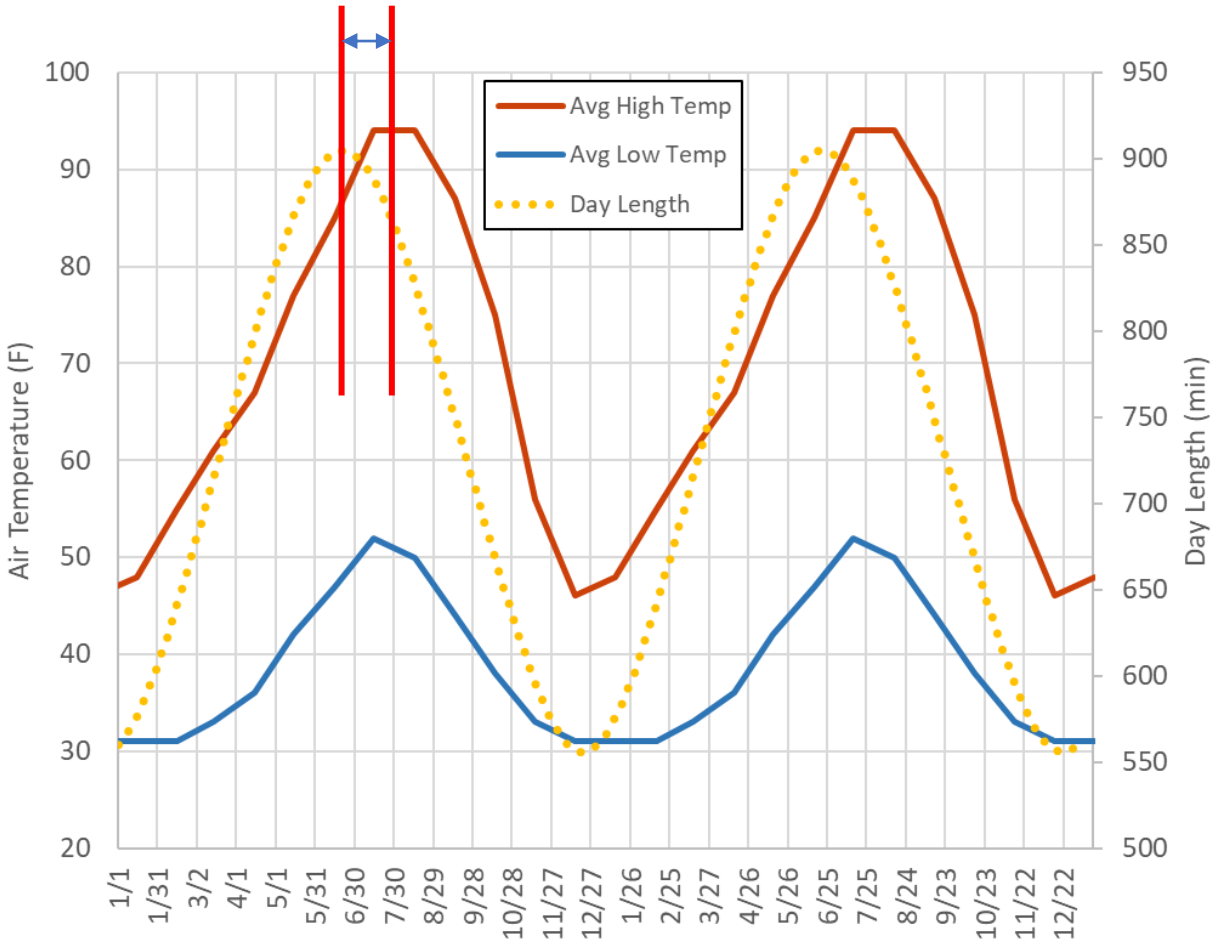
Summer
June 20 – September 25

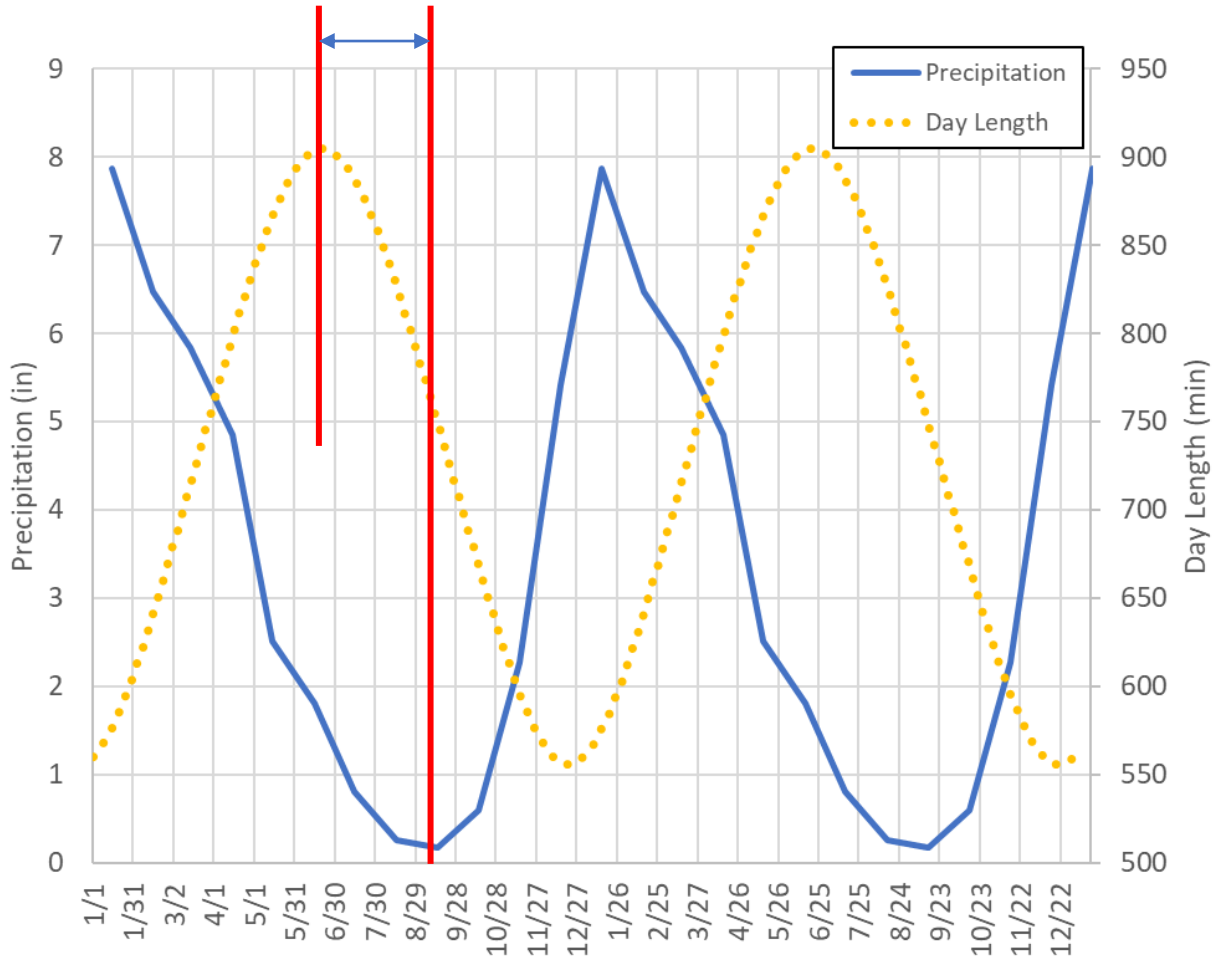
The Astronomical Seasons in Redding, CA (40° N latitude)



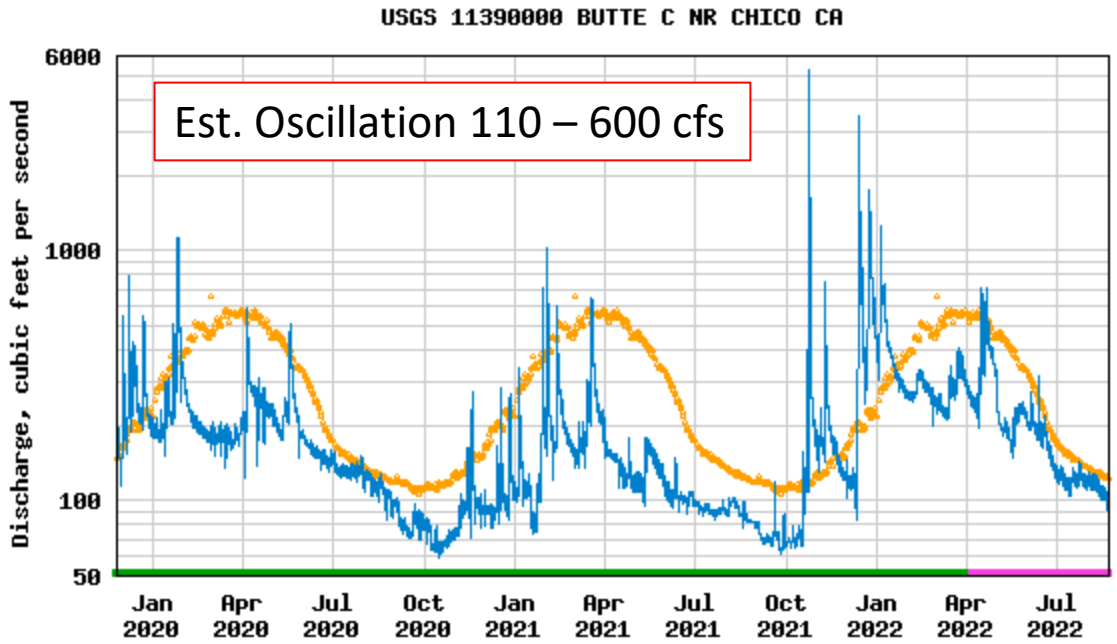
Day length is continuous wave (… -> Summer solstice -> vernal equinox -> winter solstice -> autumnal equinox -> …)

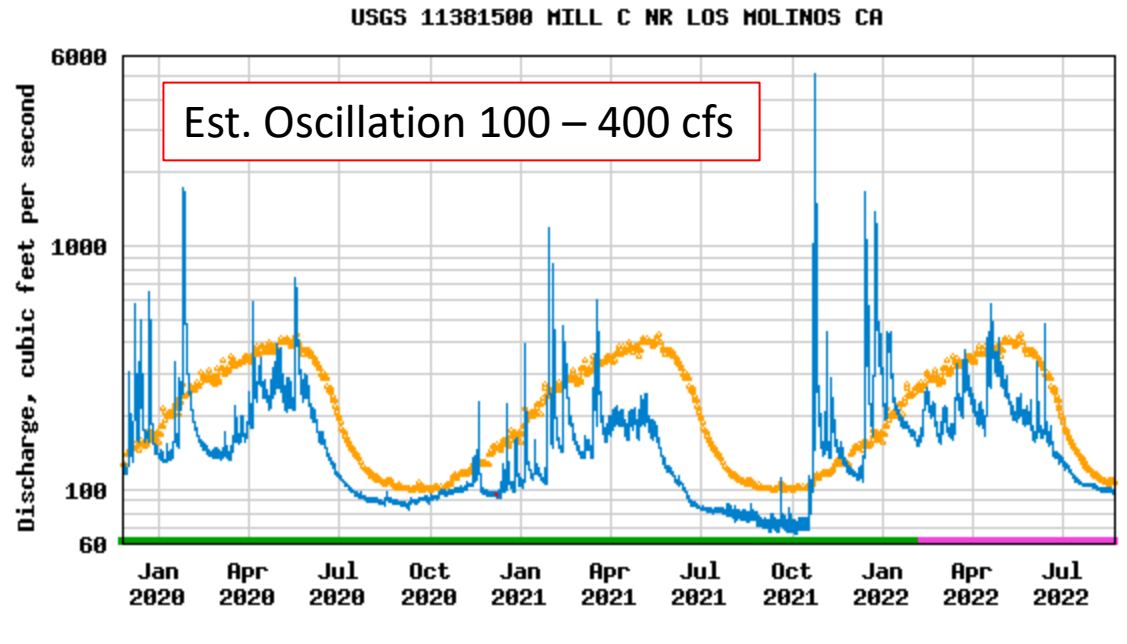
Seasonal Lag

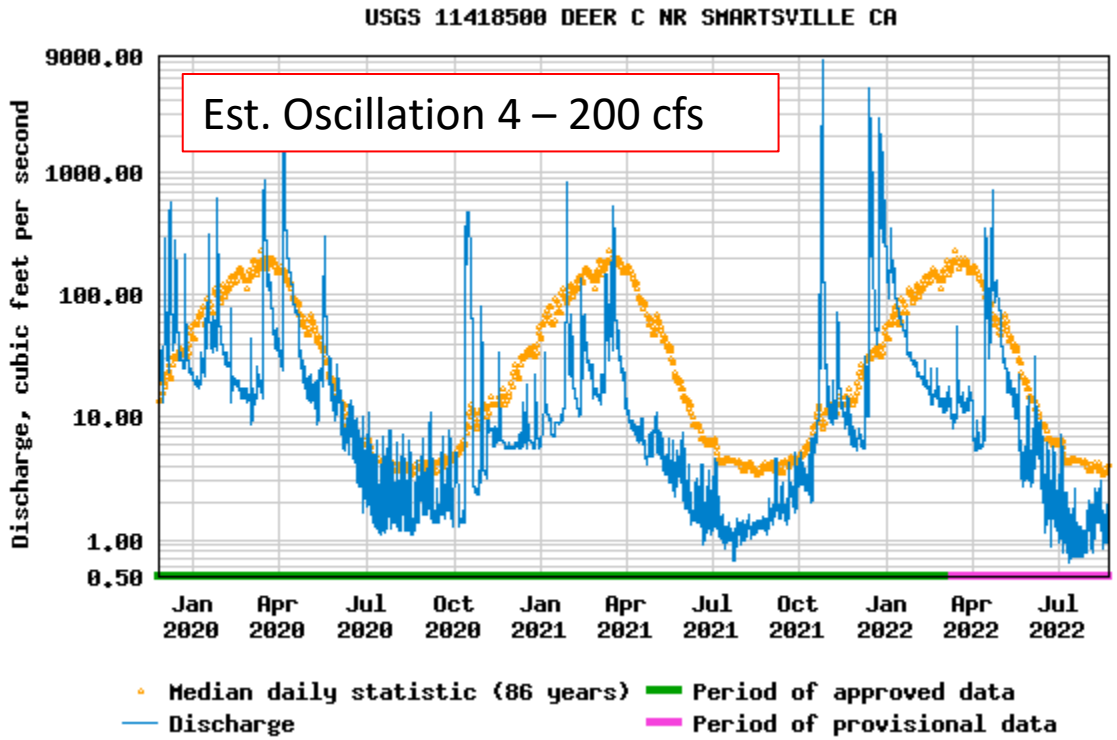


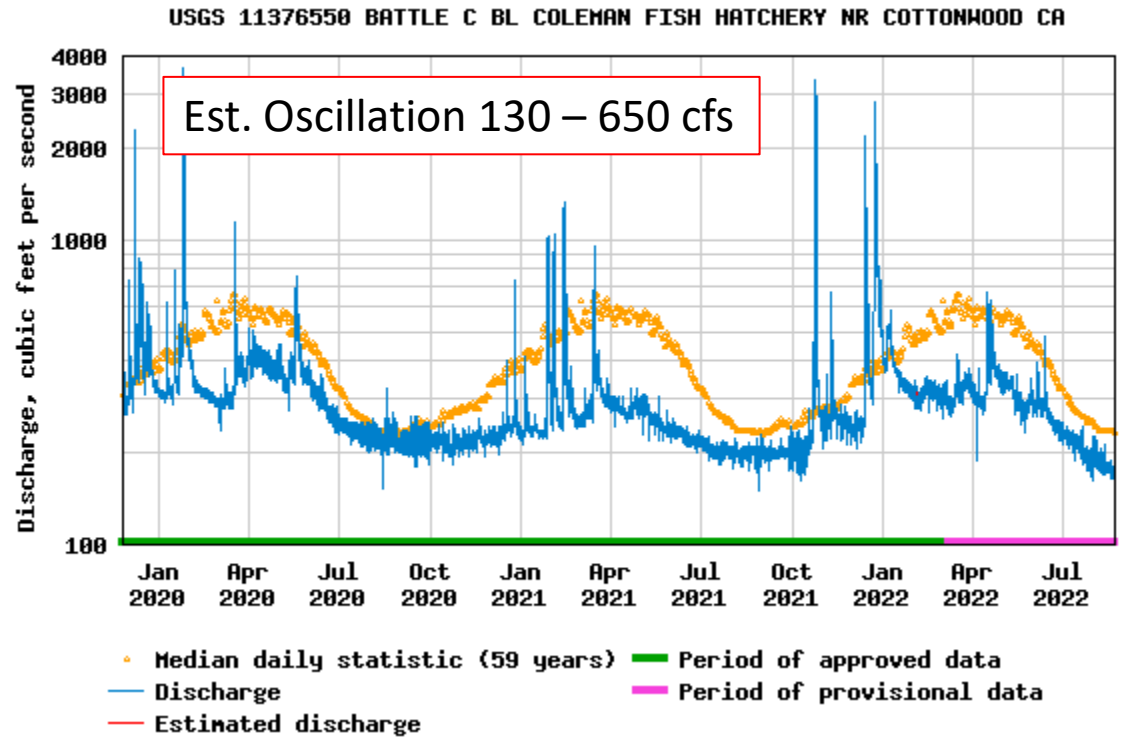


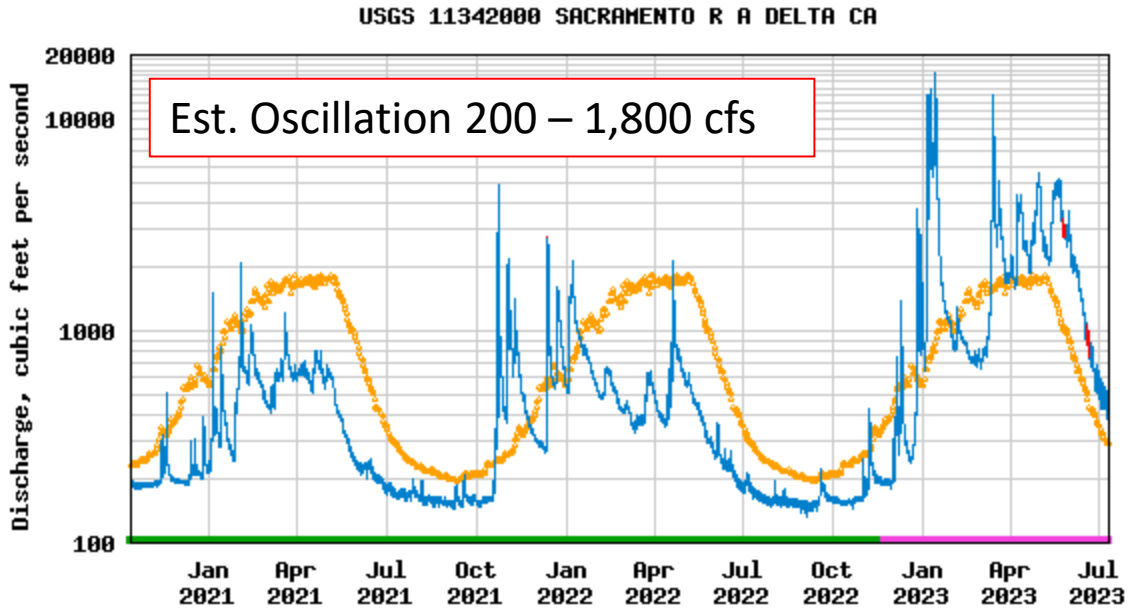
Weaverville air temps and precipitation compared to daylengths.
Air temperature (positively correlated) and precip (negatively correlated) are also a seasonal waves.

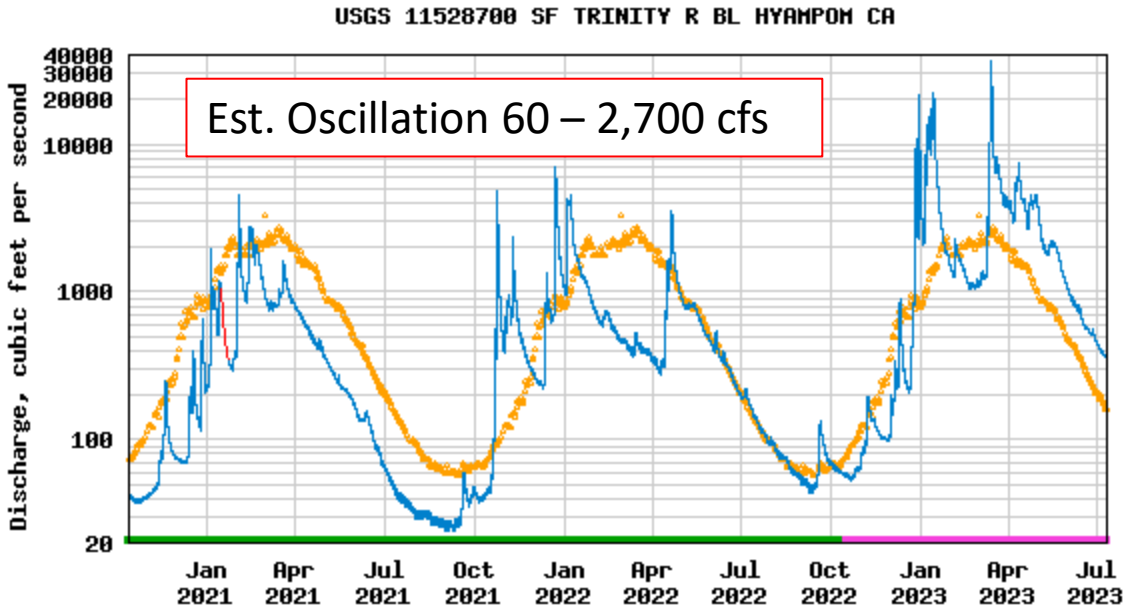

USGS 11390000 BUTTE C NR CHICO CA
Est. Oscillation 110 – 600 cfs
Discharge, cubic feet per second
6000
1000
100
50
Jan 2020
Apr 2020
Jul 2020
Oct 2020
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022

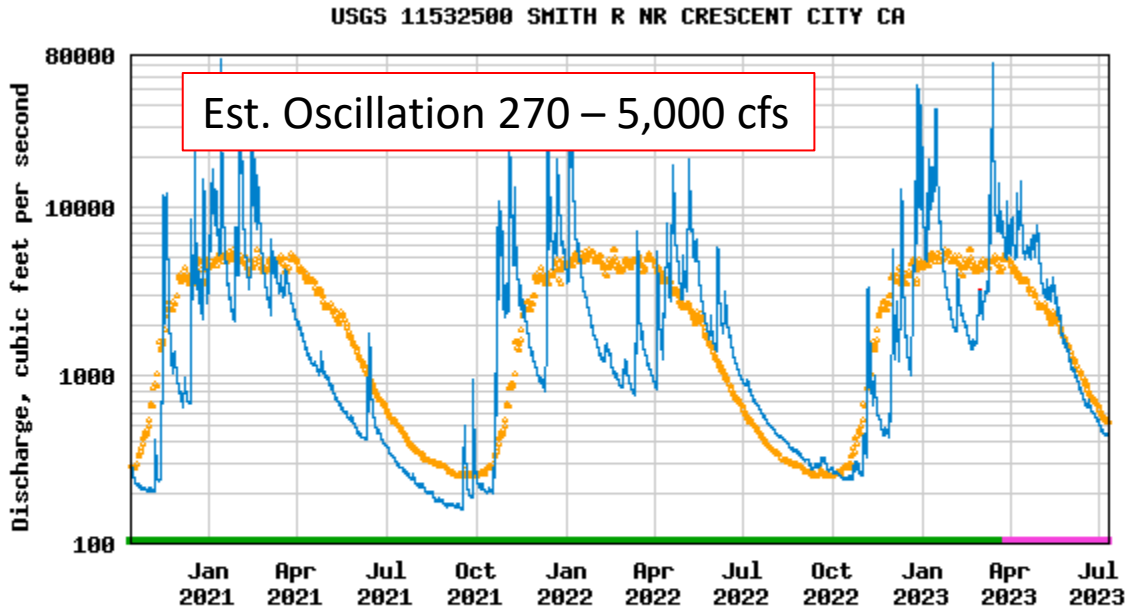

USGS 11381500 MILL C NR LOS MOLINOS CA
Est. Oscillation 100 – 400 cfs
Discharge, cubic feet per second
6000
1000
100
60
Jan 2020
Apr 2020
Jul 2020
Oct 2020
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022

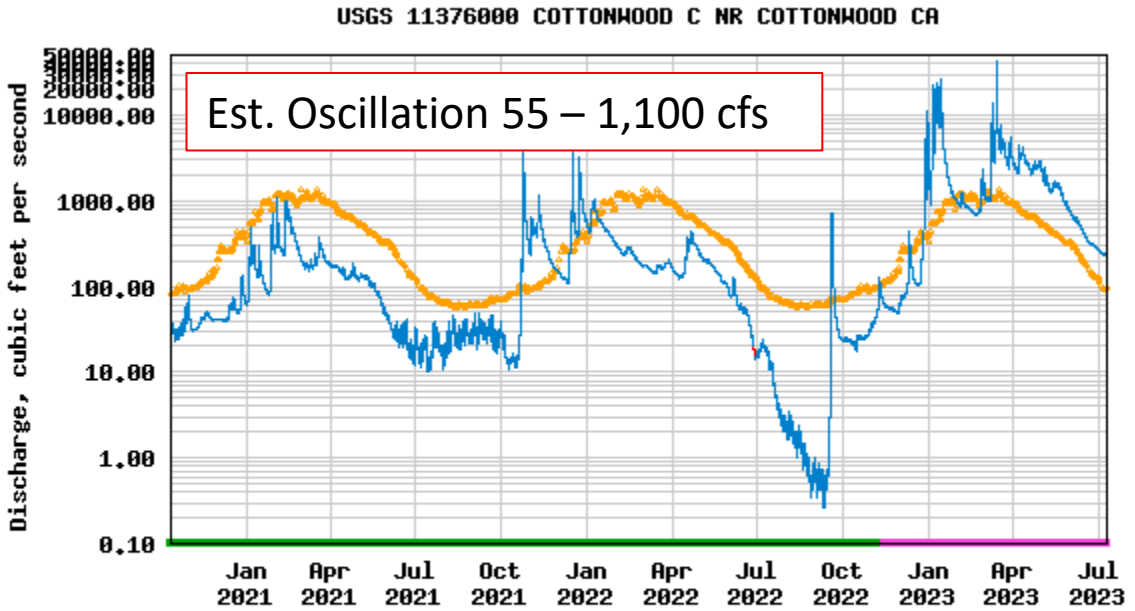

USGS 11418500 DEER C NR SMARTSVILLE CA
Est. Oscillation 4 – 200 cfs
Discharge, cubic feet per second
9000.00
1000.00
100.00
10.00
1.00
0.50
Jan 2020
Apr 2020
Jul 2020
Oct 2020
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022
Median daily statistic (86 years)
Discharge
Period of approved data
Period of provisional data


USGS 11376550 BATTLE C BL COLEMAN FISH HATCHERY NR COTTONWOOD CA
Est. Oscillation 130 – 650 cfs
Discharge, cubic feet per second
4000
3000
2000
1000
100
Jan 2020
Apr 2020
Jul 2020
Oct 2020
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022
Median daily statistic (59 years)
Discharge
Estimated discharge
Period of approved data
Period of provisional data



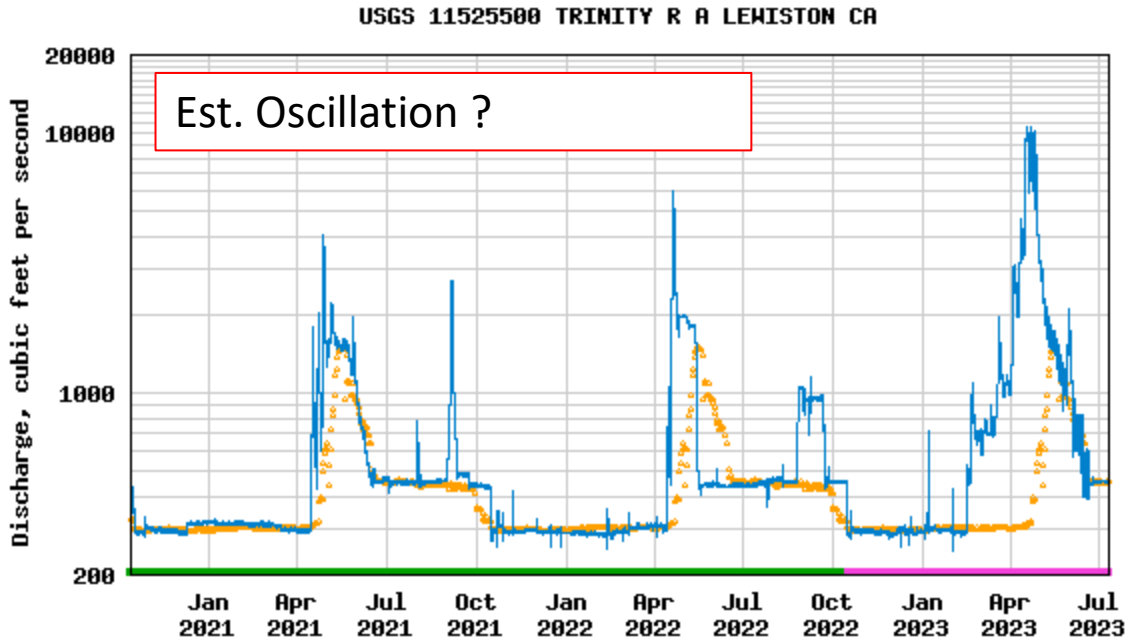


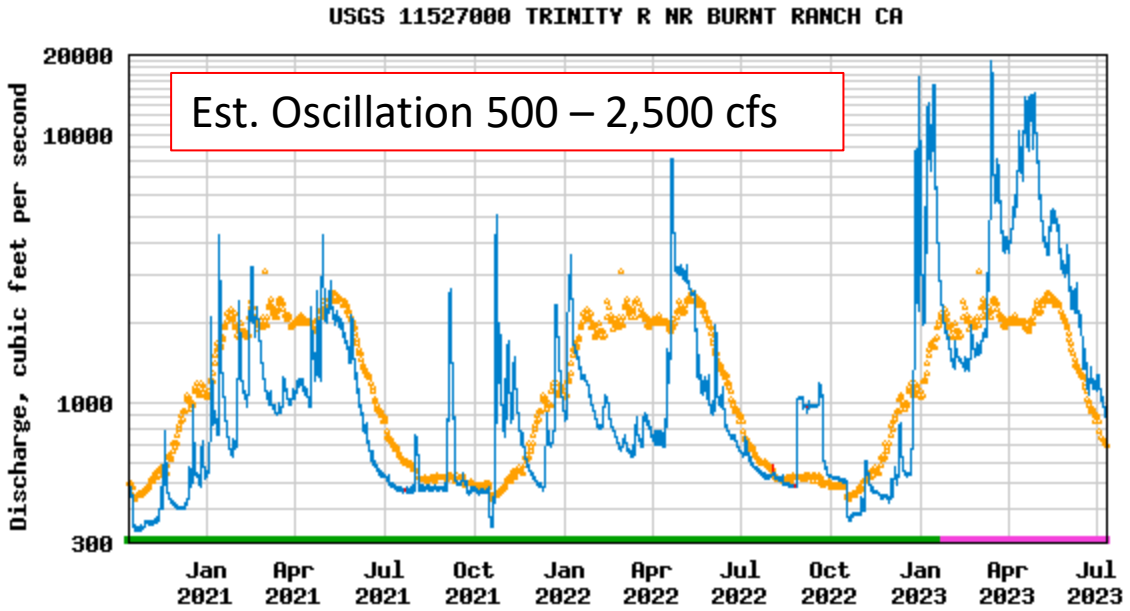


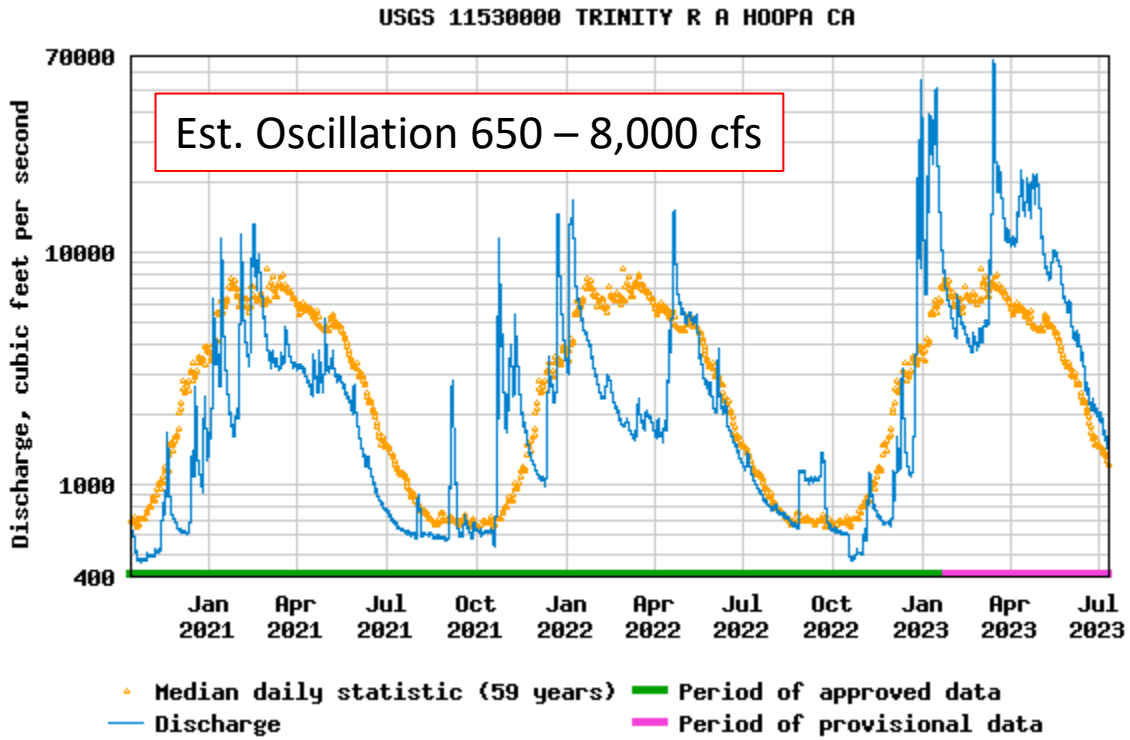


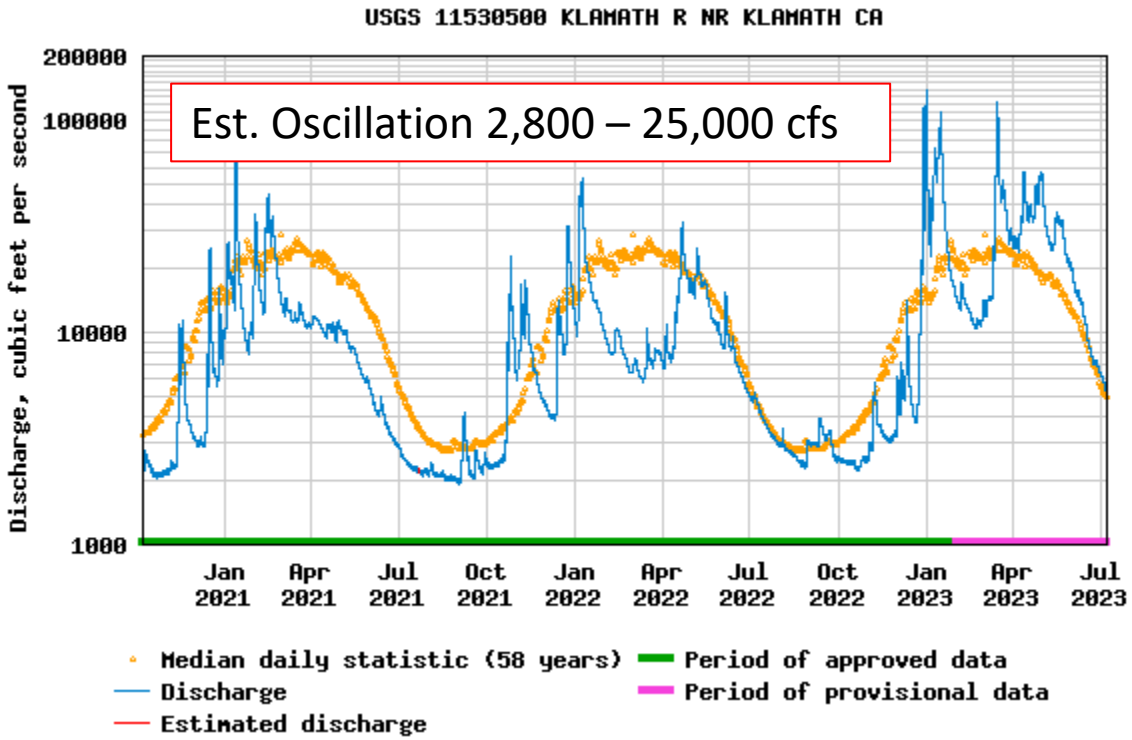
Median daily statistic (91 years)
Discharge
Estimated discharge
Period of approved data
Period of provisional data

Median daily statistic (82 years)
Discharge
Estimated discharge
Period of approved data
Period of provisional data

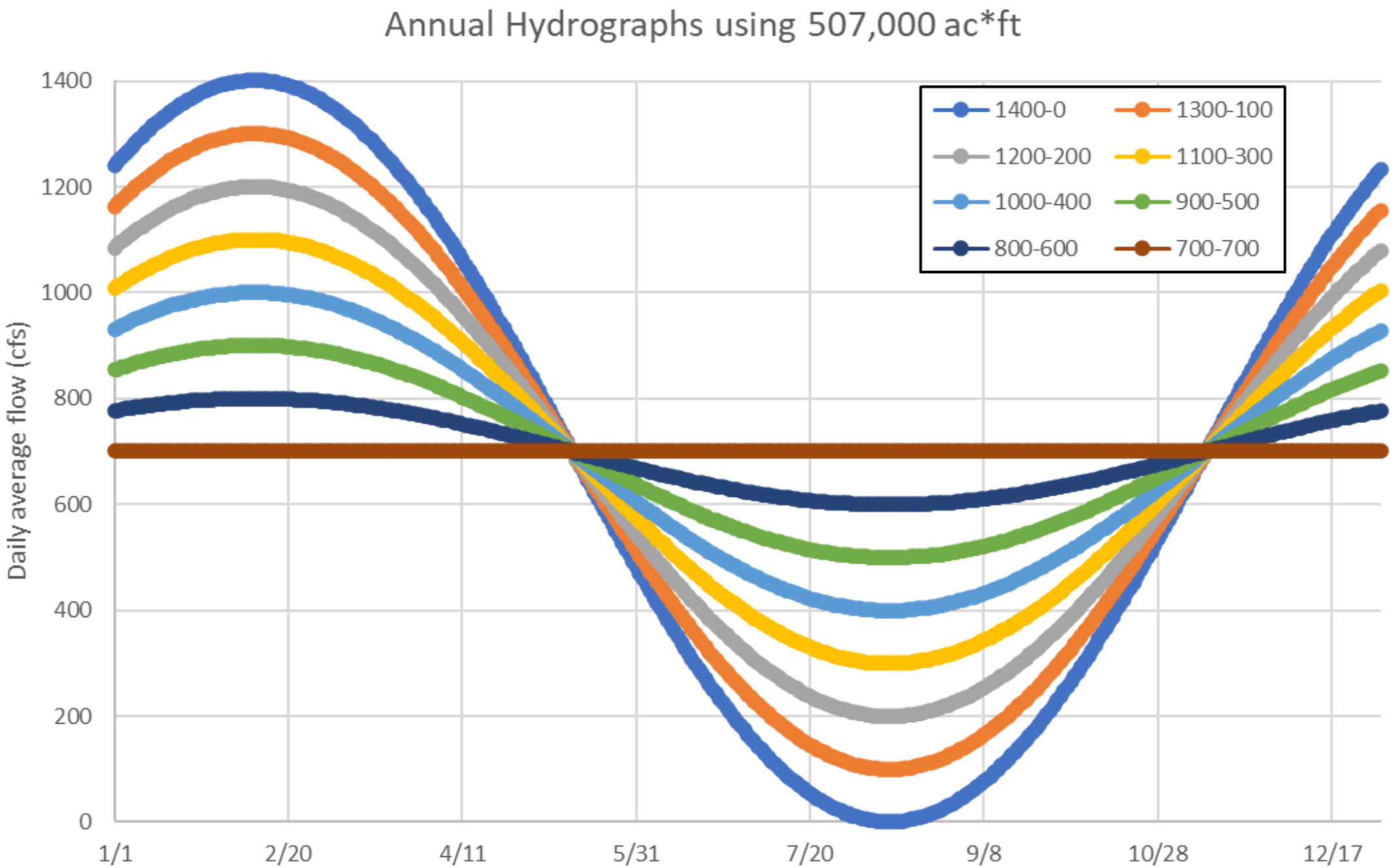

USGS 11525500 TRINITY R A LEWISTON CA
Est. Oscillation ?
Discharge, cubic feet per second
20000
10000
1000
200
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022
Oct 2022
Jan 2023
Apr 2023
Jul 2023


USGS 11527000 TRINITY R NR BURNT RANCH CA
Est. Oscillation 500 – 2,500 cfs
Discharge, cubic feet per second
20000
10000
1000
300
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022
Oct 2022
Jan 2023
Apr 2023
Jul 2023


USGS 11530000 TRINITY R A HOOPA CA
Est. Oscillation 650 – 8,000 cfs
Discharge, cubic feet per second
70000
10000
1000
400
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022
Oct 2022
Jan 2023
Apr 2023
Jul 2023
Median daily statistic (59 years)
Discharge
Period of approved data
Period of provisional data


USGS 11530500 KLAMATH R NR KLAMATH CA
Est. Oscillation 2,800 – 25,000 cfs
Discharge, cubic feet per second
200000
100000
10000
1000
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Jan 2022
Apr 2022
Jul 2022
Oct 2022
Jan 2023
Apr 2023
Jul 2023
Median daily statistic (58 years)
Discharge
Estimated discharge
Period of approved data
Period of provisional data

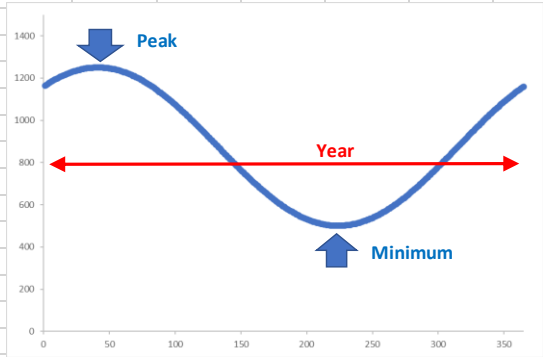
Variable Amplitudes



Total Acre*ft of Water Required for a Range of Seasonally Oscillating Hydrographs

Peak Daily Average Flow (cfs)	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200
2,500	905,322																								
2,450	887,223	905,322																							
2,400	869,123	887,223	905,322																						
2,350	851,024	869,123	887,223	905,322																					
2,300	832,925	851,024	869,123	887,223	905,322																				
2,250	814,826	832,925	851,024	869,123	887,223	905,322																			
2,200	796,726	814,826	832,925	851,024	869,123	887,223	905,322																		
2,150	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322																	
2,100	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322																
2,050	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322															
2,000	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322														
1,950	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322													
1,900	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322												
1,850	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322											
1,800	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322										
1,750	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322									
1,700	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322								
1,650	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322							
1,600	579,536	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322						
1,550	561,437	579,536	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322					
1,500	543,337	561,437	579,536	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322				
1,450	525,238	543,337	561,437	579,536	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322			
1,400	507,139	525,238	543,337	561,437	579,536	597,635	615,734	633,834	651,933	670,032	**688,131**	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322		
1,350	489,040	507,139	525,238	543,337	561,437	579,536	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322	
1,300	470,941	489,040	507,139	525,238	543,337	561,437	579,536	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223	905,322
1,250	452,841	470,941	489,040	507,139	525,238	543,337	561,437	579,536	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123	887,223
1,200	434,742	452,841	470,941	489,040	507,139	525,238	543,337	561,437	579,536	**597,635**	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	851,024	869,123
1,150	416,643	434,742	452,841	470,941	489,040	507,139	525,238	543,337	561,437	579,536	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726	814,826	832,925	
1,100	398,544	416,643	434,742	452,841	470,941	489,040	507,139	525,238	543,337	561,437	579,536	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528	778,627	796,726		
1,050	380,445	398,544	416,643	434,742	452,841	470,941	489,040	507,139	525,238	543,337	561,437	579,536	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330	742,429	760,528			
1,000	362,345	380,445	398,544	416,643	434,742	452,841	470,941	489,040	**507,139**	525,238	543,337	561,437	579,536	597,635	615,734	633,834	651,933	670,032	688,131	706,230	724,330				
950	344,246	362,345	380,445	398,544	416,643	434,742	452,841	470,941	489,040	507,139	525,238	543,337	561,437	579,536	597,635	615,734	633,834	651,933	670,032	688,131					
900	326,147	344,246	362,345	380,445	398,544	416,643	434,742	452,841	470,941	489,040	507,139	525,238	543,337	561,437	579,536	597,635	615,734	633,834	651,933						
850	308,048	326,147	344,246	362,345	380,445	398,544	416,643	434,742	452,841	470,941	489,040	507,139	525,238	543,337	561,437	579,536	597,635	615,734			Ext Wet				
800	289,948	308,048	326,147	344,246	362,345	380,445	398,544	**416,643**	434,742	452,841	470,941	489,040	507,139	525,238	543,337	561,437	579,536								
750	271,849	289,948	308,048	326,147	344,246	362,345	380,445	398,544	416,643	434,742	452,841	470,941	489,040	507,139	525,238	543,337			Wet						
700	253,750	271,849	289,948	308,048	326,147	344,246	**362,345**	380,445	398,544	416,643	434,742	452,841	470,941	489,040	507,139										
650	235,651	253,750	271,849	289,948	308,048	326,147	344,246	362,345	380,445	398,544	416,643	434,742	452,841	470,941											
600	217,552	235,651	253,750	271,849	289,948	308,048	326,147	344,246	362,345	380,445	398,544	416,643	434,742			Normal									
550	199,452	217,551	235,651	253,750	271,849	289,948	308,048	326,147	344,246	362,345	380,445	398,544													
500	181,353	199,452	217,551	235,650	253,750	271,849	289,948	308,048	326,147	344,246	362,345			Dry											
450	163,254	181,353	199,452	217,552	235,650	253,750	271,849	289,948	308,048	326,147															
400	145,155	163,254	181,353	199,452	217,552	235,650	253,750	271,849	289,948			Crit Dry													
350	127,055	145,155	163,254	181,353	199,452	217,552	235,650	253,750																	
300	108,956	127,055	**145,155**	163,254	181,353	199,452	217,552																		
250	90,857	108,956	127,055	145,155	163,254	181,353																			
200	72,758	90,857	108,956	127,055	145,155																				
150	54,659	72,758	90,857	108,956		Clear Creek																			
100	36,559	54,659	72,397																						
50	18,460	36,198																							

Minimum Daily Average Flow (cfs)



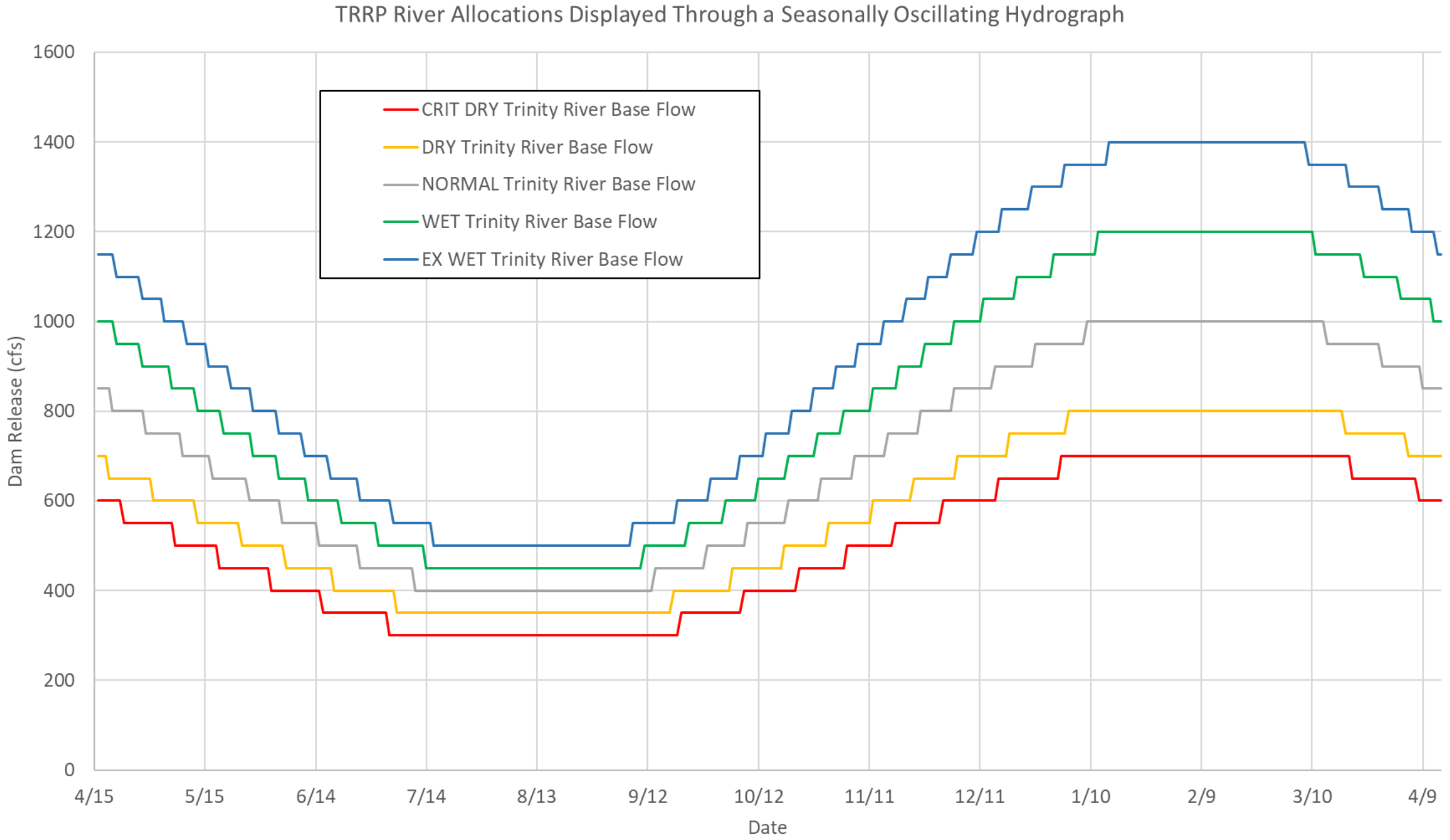
Not all ROD Volume shown, as some water is reserved for pulse flows.

Water Year SOH and Pulse Flow Volumes

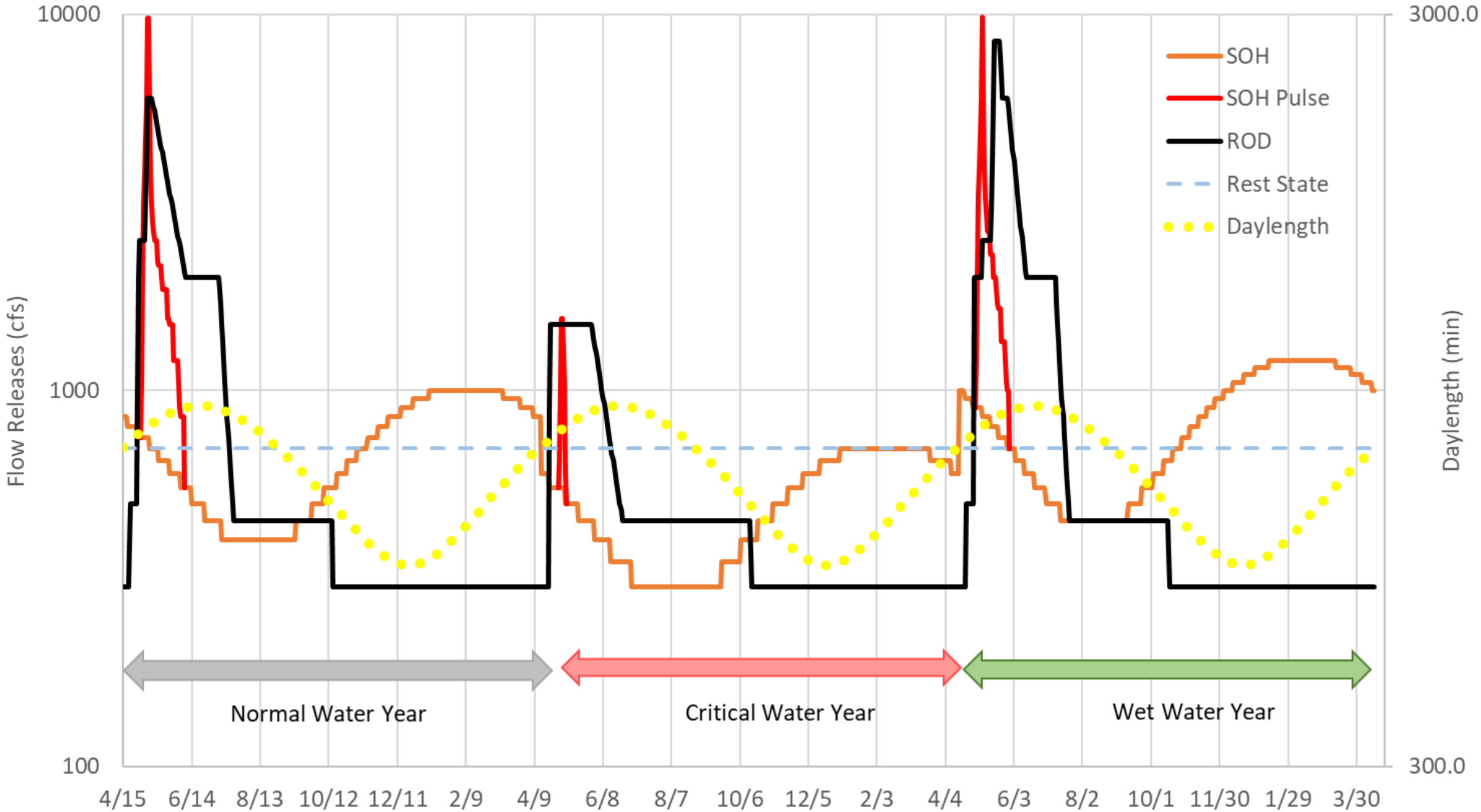
Water Year Designation	ROD Volume Allocation	SOH Lowest Flow (cfs)	SOH Highest Flow (cfs)	SOH Volume (acre*ft)	Pulse(s) Volume (acre*ft)	Total Volume (acre*ft)
Critical	369,000	300	700	361,984	7,016	369,000
Dry	453,000	350	800	426,232	36,768	463,000
Normal	647,000	400	1,000	506,778	140,222	647,000
Wet	701,000	450	1,200	597,225	103,775	701,000
Ext Wet	815,000	500	1,400	687,770	127,230	815,000

The pulse volumes to be shaped and timed through the normal TRRP/TMC process.

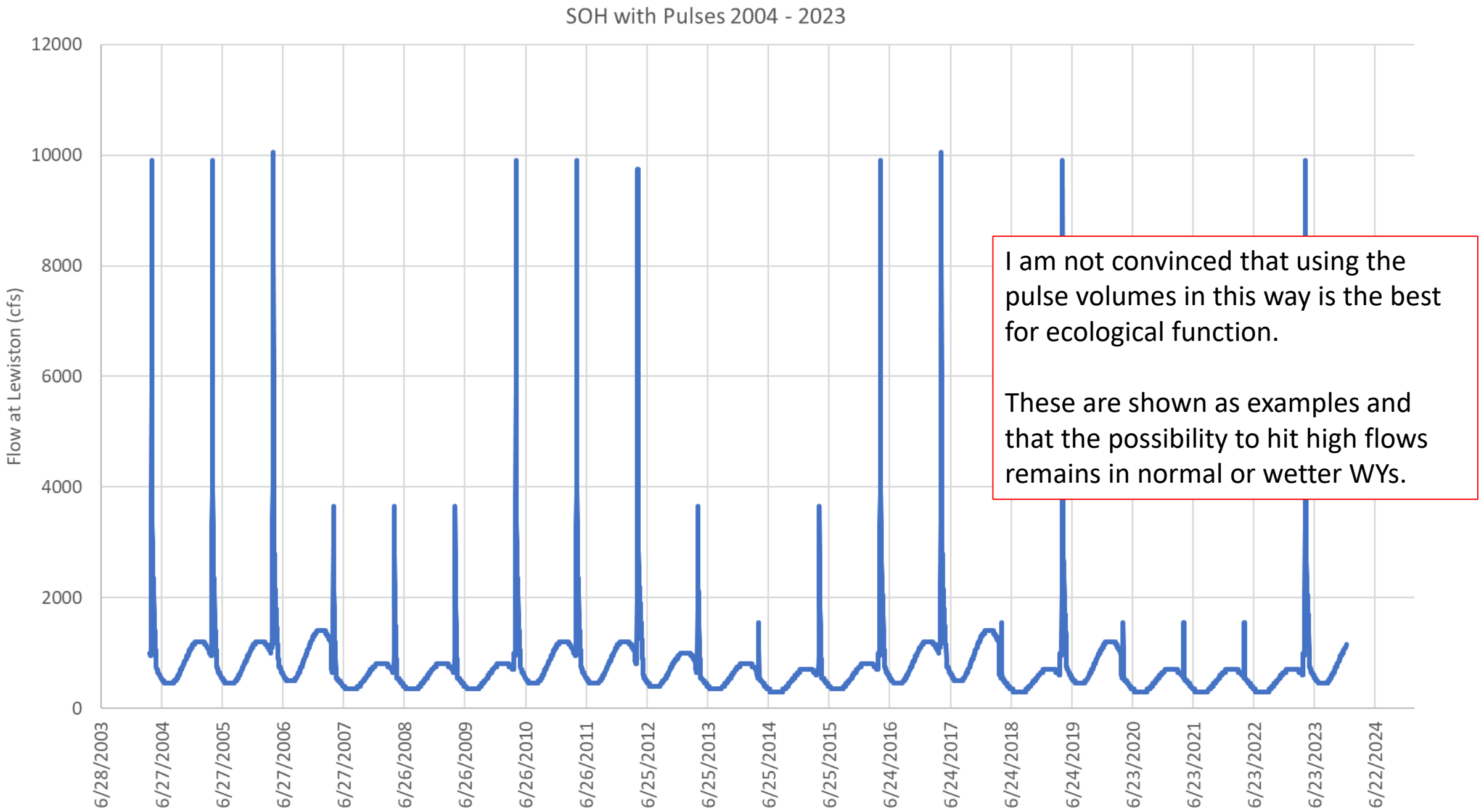
SOH for the Trinity River



SOH compared to TRRP ROD Hydrograph



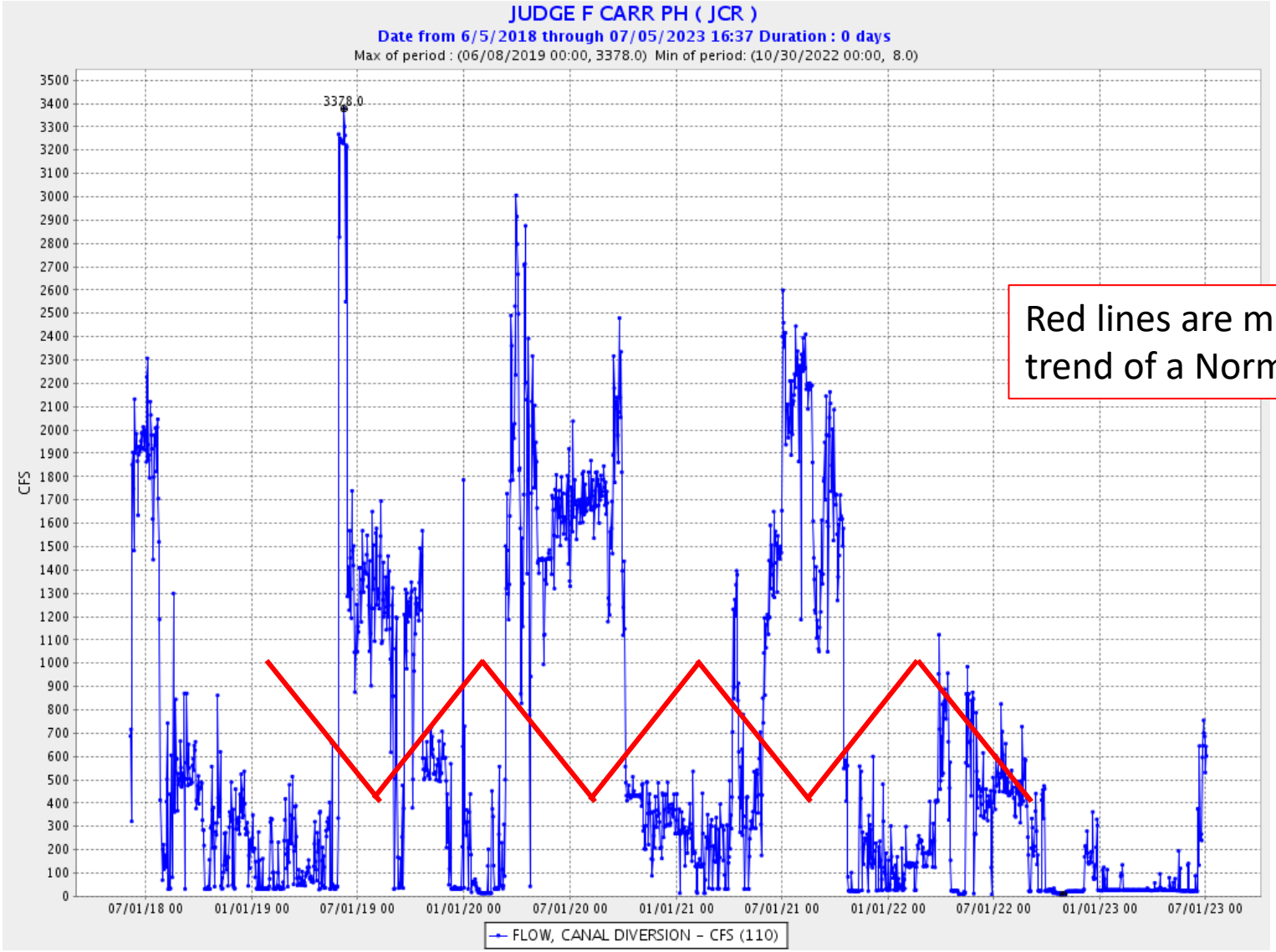
Retrospective look at river releases with a SOH and generic pulses



I am not convinced that using the pulse volumes in this way is the best for ecological function.

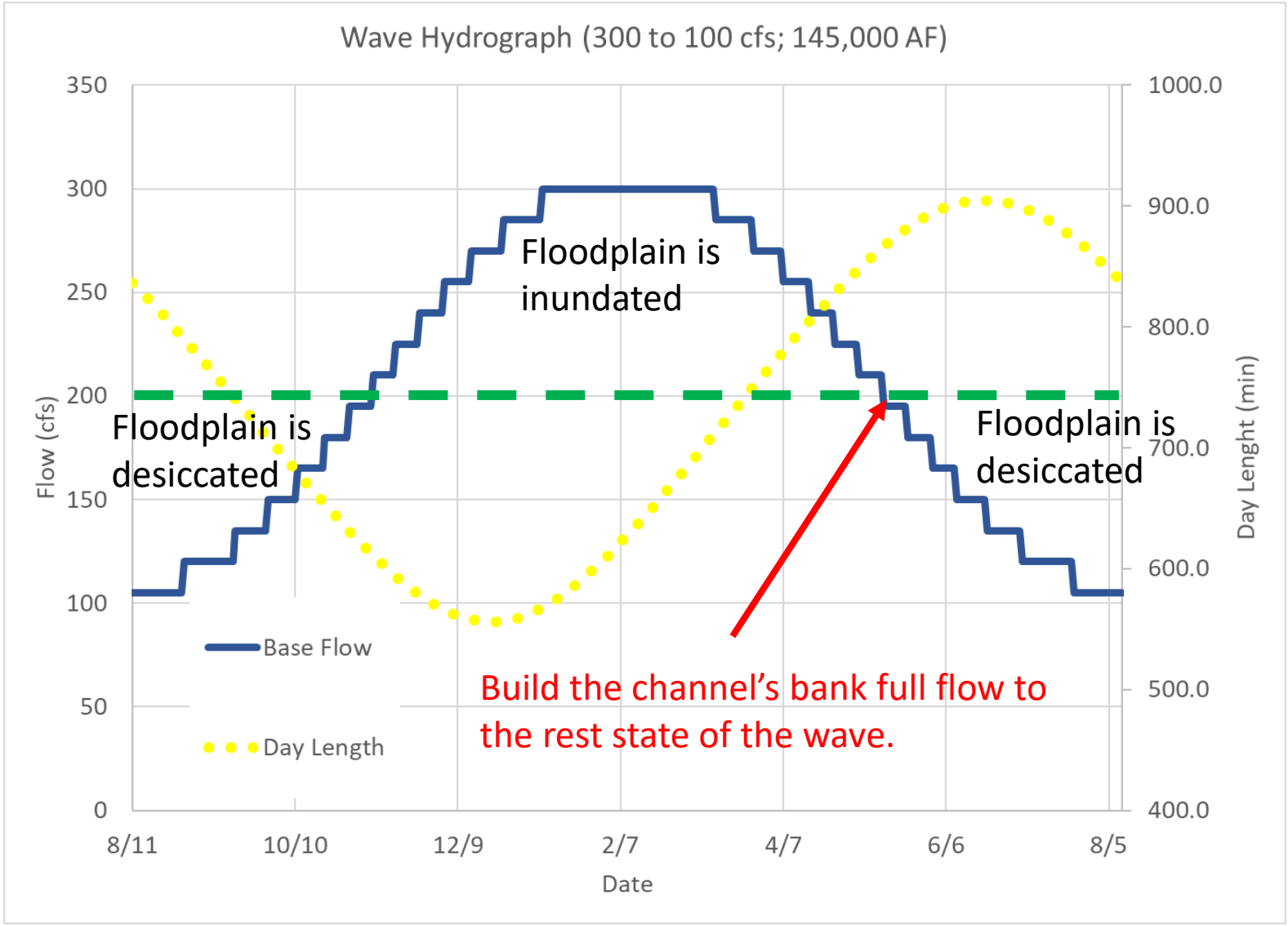
These are shown as examples and that the possibility to hit high flows remains in normal or wetter WYs.

Water temperature management and Power Generation



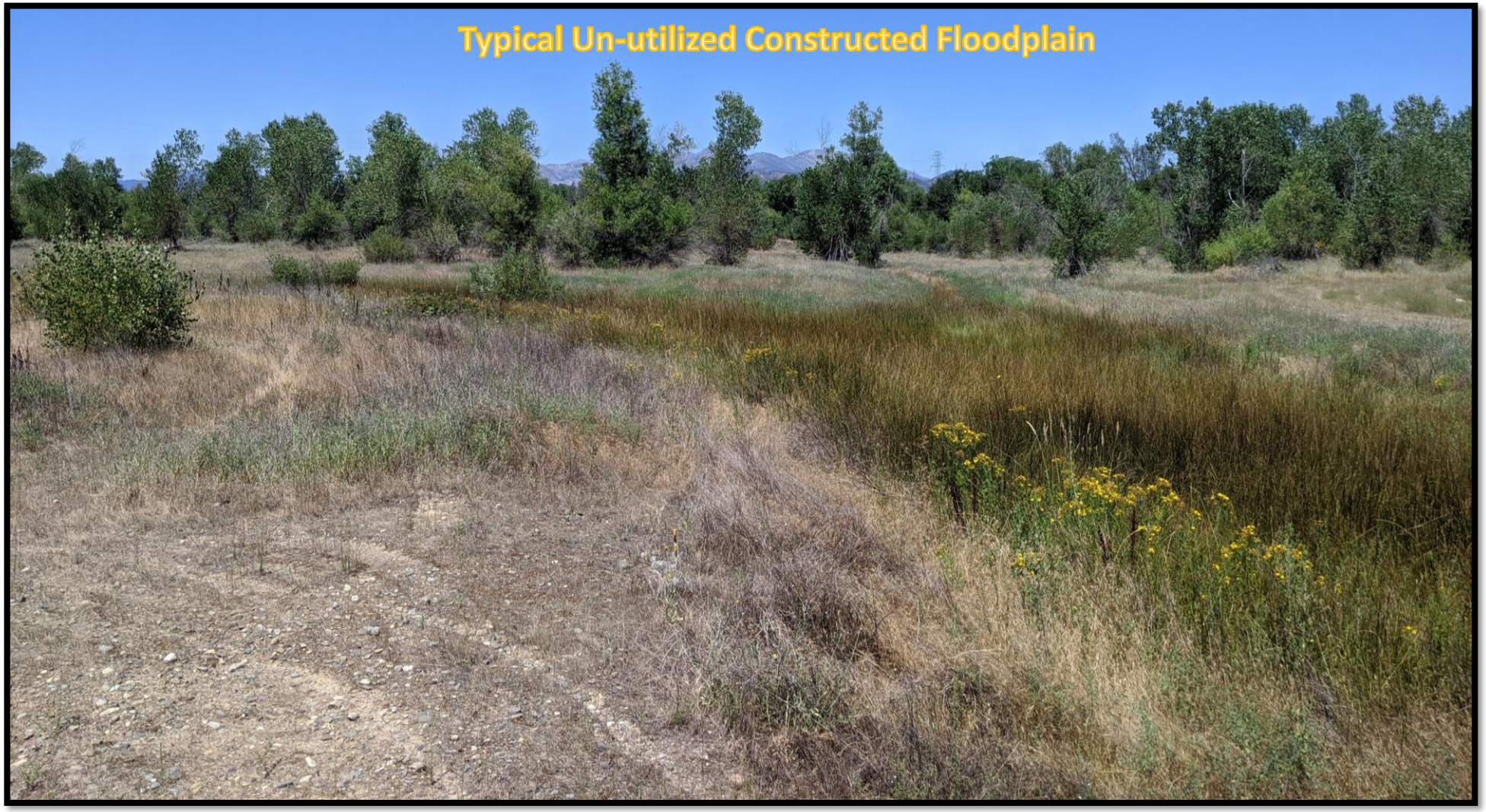
Red lines are meant to show general trend of a Normal WY SOH.

Altering channel capacity to SOH rest state



Intra-annual variation is more important and inter-annual variation

Relationships between Hydrograph and Channel Geometry



LCCFRP Phase 2A/Gold Dredge @ 200 cfs, south floodplain.

Relationships between Hydrograph and Channel Geometry

LCCFRP Phase 2A/Gold Dredge @ 200 cfs, following 2020 gravel augmentations.

Relationships between Hydrograph and Channel Geometry

Gold Dredge Area
200 cfs

Gold Dredge Area (with gravel augmentations)
840 cfs in Mid-May

Seasonally Oscillating Hydrograph - Features

- Normal WY rest state flows (700 cfs) should define the bank-full goal for restoration efforts.
- Each WY type provides variable low flows. May help reduce riparian berm development.
- Cottonwood seed dispersal (May 15) occurs when the SOH drops below the rest state (normal year).
- Low flow periods will allow riparian vegetation to grow into the river channel. These areas will inundate this vegetation in the high flow periods (i.e., formation of prime fish habitat).
- Maintains conditions for high power generation potential at Trinity Dam. SOH and trans-basin deliveries are opposite waves.
- Relatively easy to implement for operators. Base flows change at 25 cfs increments, with flow changes every 6 to 79 days (exclusive of pulses).
- Utilizing ROD volumes late in the WY will leave more storage in the reservoir across the summer, potentially improving water temperature in the fall.
- Reduce or remove opportunity for redd dewatering, as flows gradually increase through the fall.
- The spatial distribution of spawning habitat changes through spawning season, reducing redd superimposition.
- Requires use of ROD volumes within 365 days of the WY determination on April 15 (i.e., crosses Oct 1-Sept 30 Water Years).

Questions for Flow Work Group

I recommend that the TRRP to include day lengths and a SOH as fundamental components of future baseflows/dam releases.

a) What is the best date to select for the lowest/highest flow? What is the Seasonal Offset?
   - Currently lowest flow day is set to August 11.

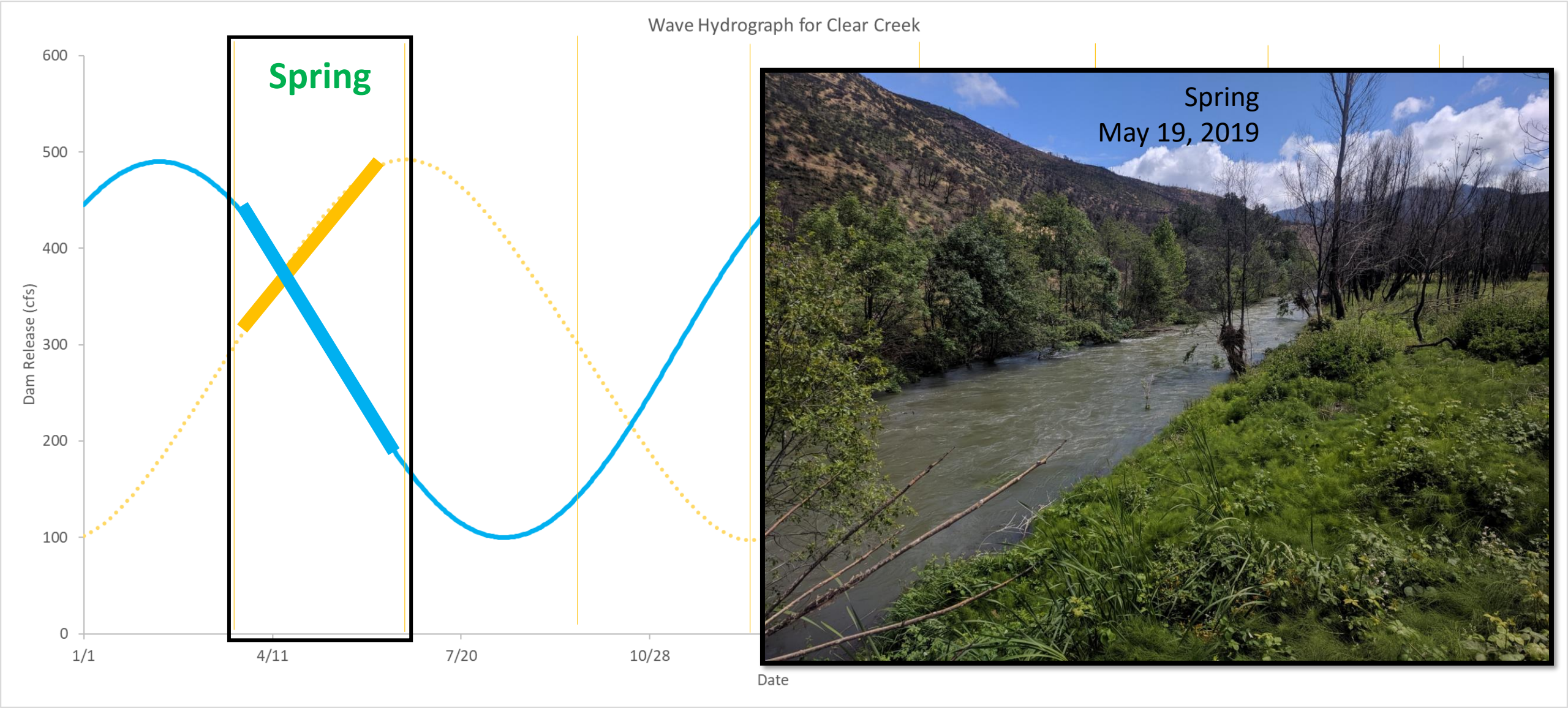
b) What is the lowest flow that we should aim for in the various water year types?
   - Currently 300 cfs in Crit WY and increases at 50 cfs increments, up to 500 in Ex Wet WY.

c) What is the best wave shape?
   - Currently based on a sine wave geometry, with 50 cfs increments.

d) What % of total ROD volume should go to SOH vs pulses? How should the pulse volumes be utilized to best meet biological and physical objectives?

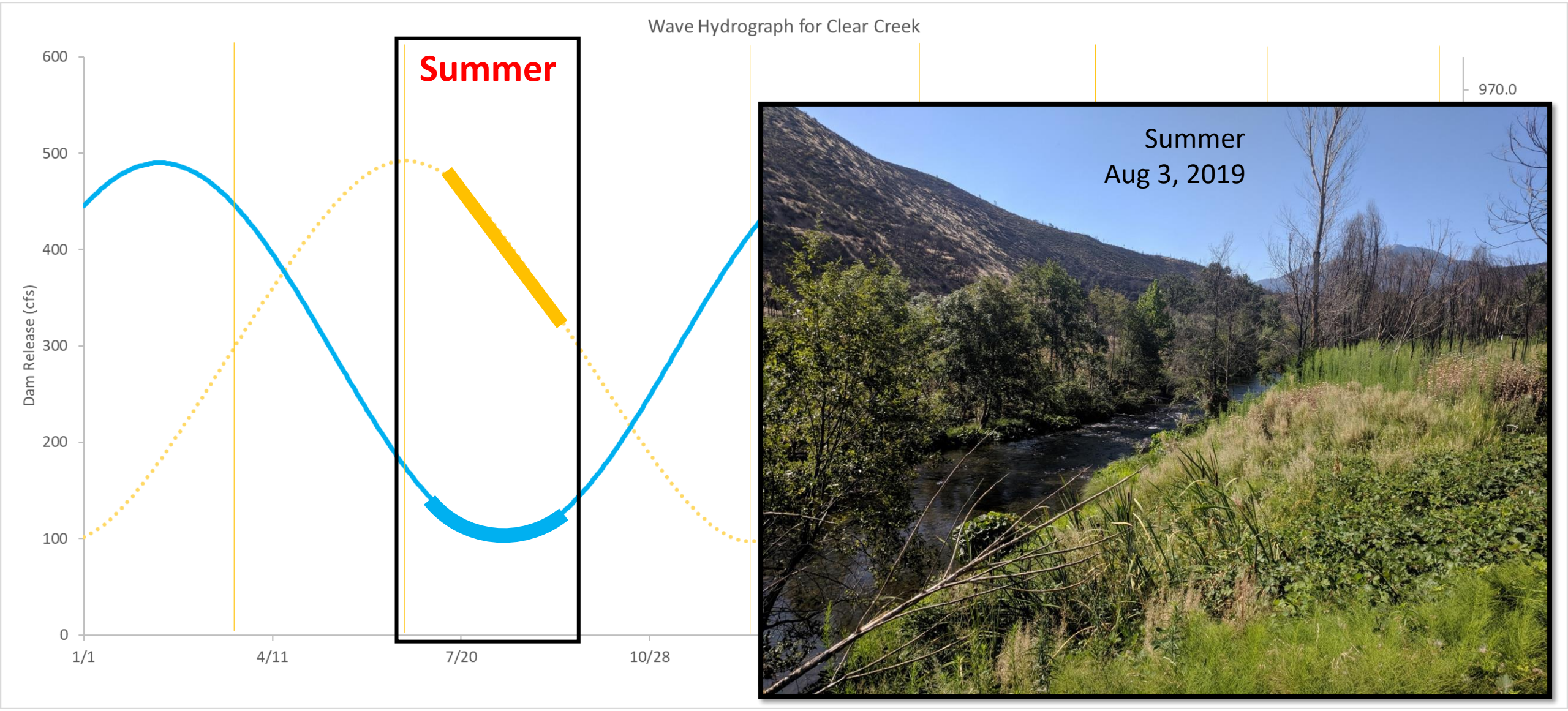
e) What are your key criticisms of the SOH?

Astronomical Seasons and Relationships to Flow



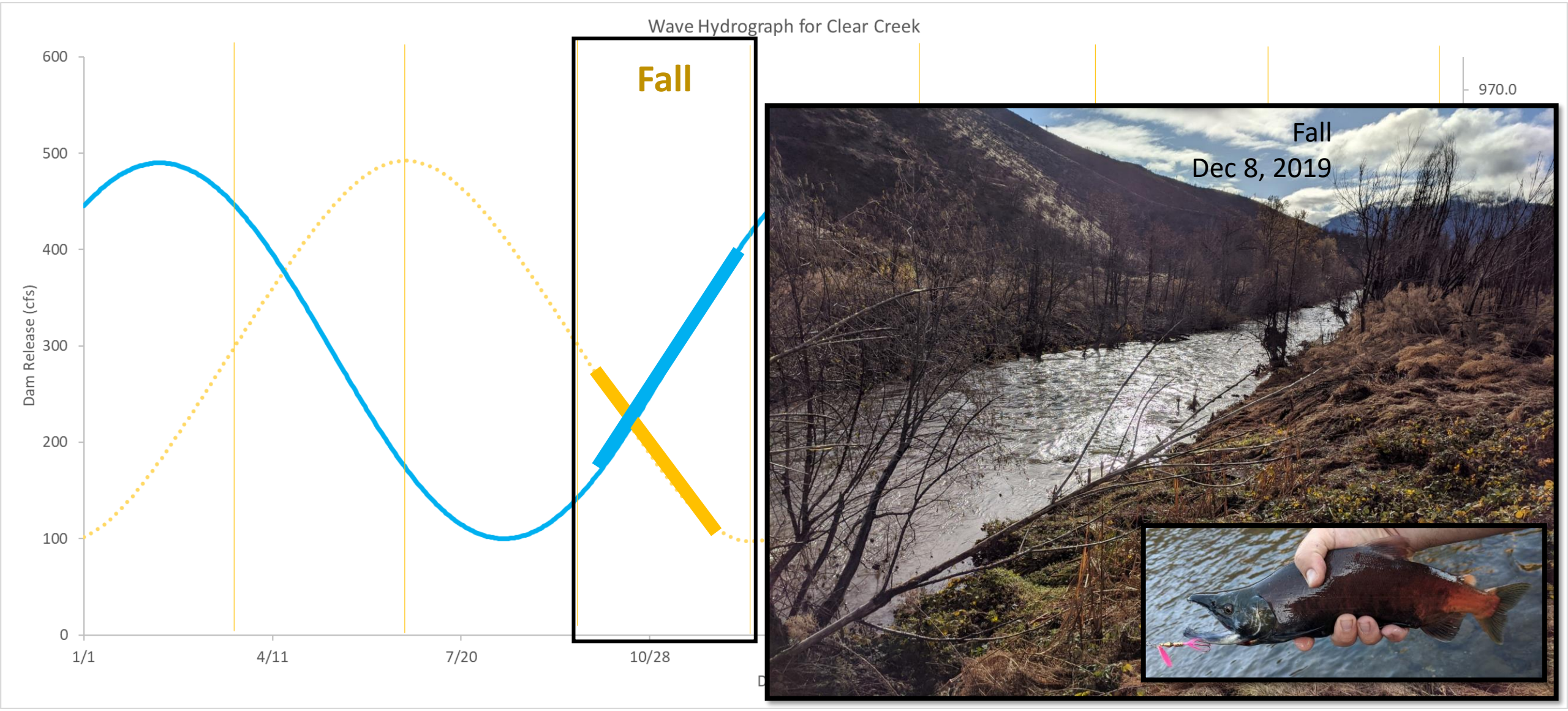
Spring: Increasingly long days and rapidly decreasing flow.

Astronomical Seasons and Relationships to Flow



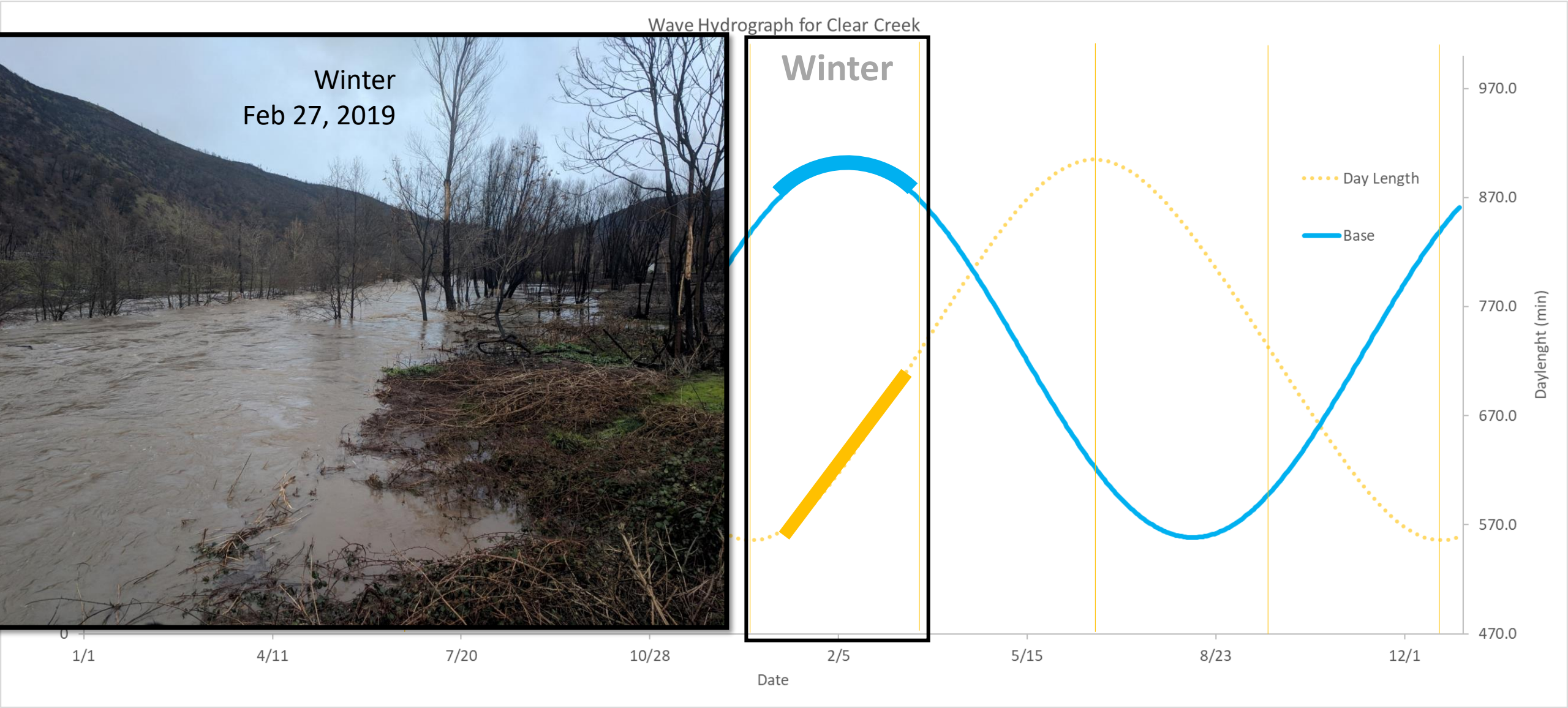
Summer: Longest days that rapidly shorten and steady, lowest flows.

Astronomical Seasons and Relationships to Flow



Fall: Rapidly increasing flow and decreasingly short days.

Astronomical Seasons and Relationships to Flow



Winter: Shortest days that continually increase in length and steady high flows.