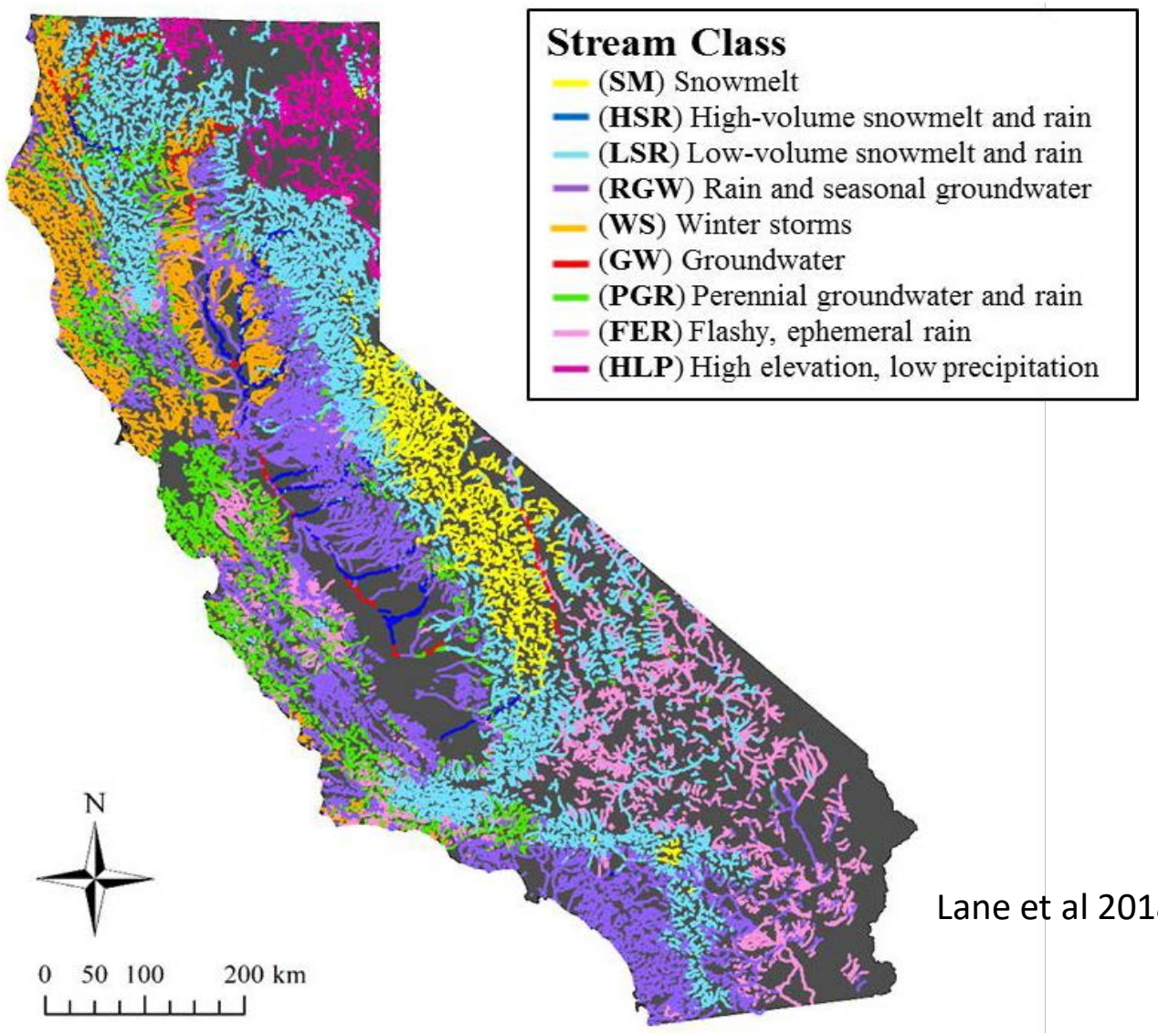
Functional Flows Calculator Technical Overview

September 11, 2018

CEFF Technical Team

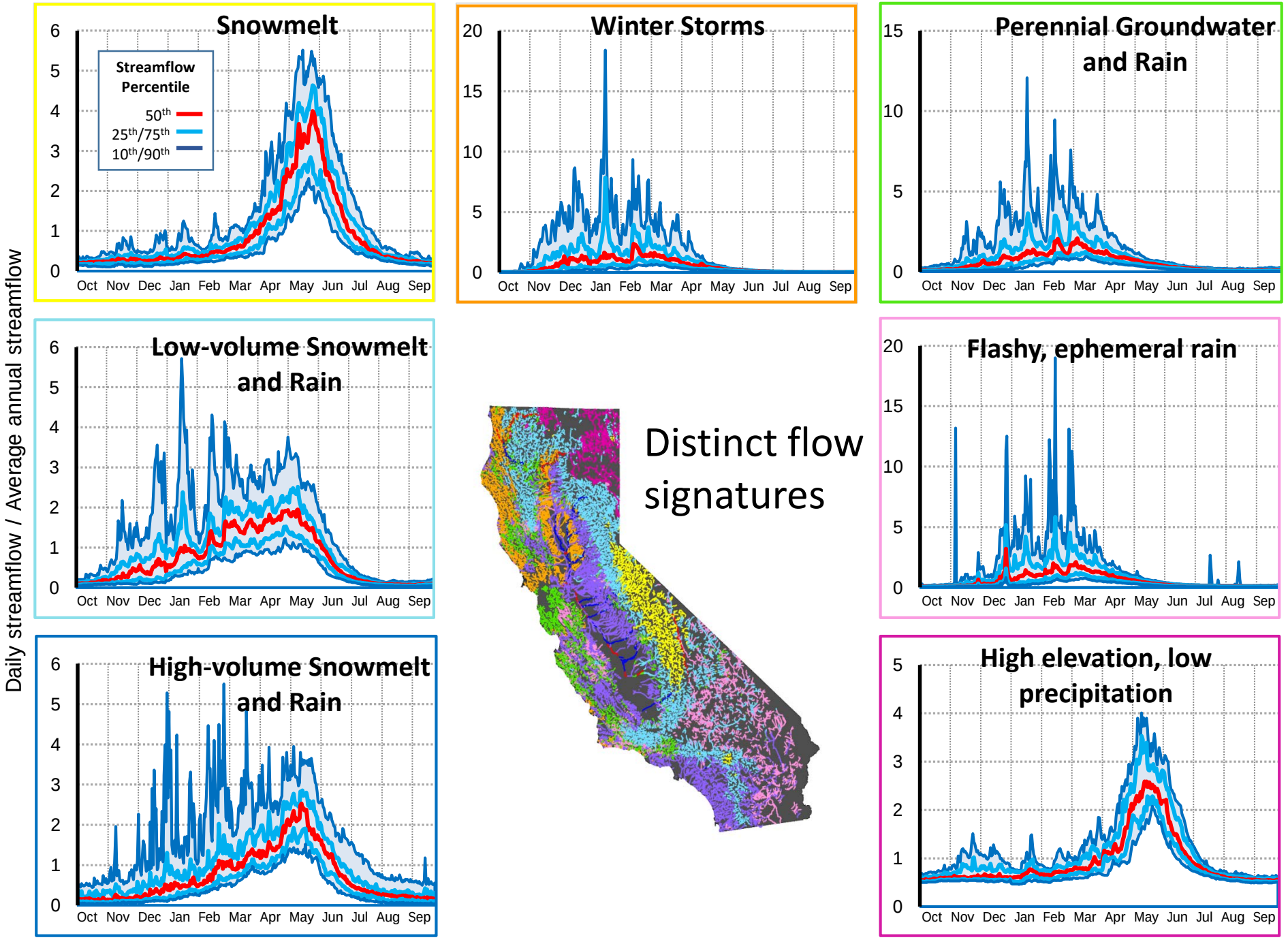
University of California
Agriculture and Natural Resources

California's hydrology is complex



Lane et al 2018. *Envr. Management.*

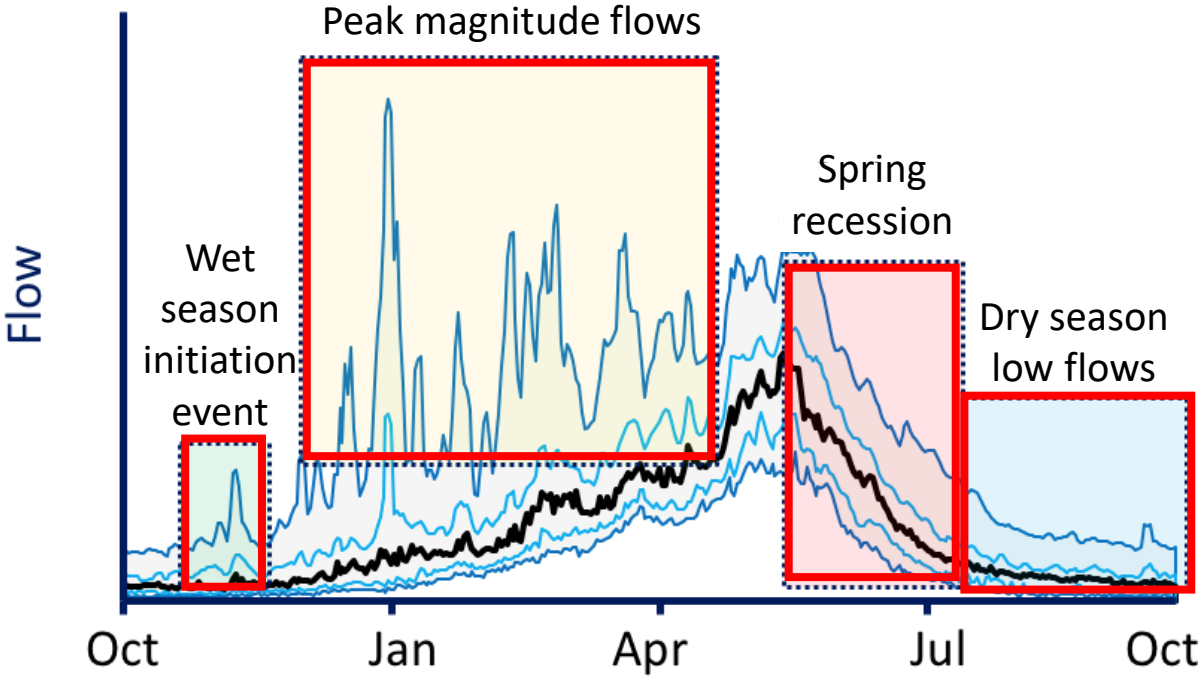
https://eflows.gitbook.io/project/website_summary#stream-classification


Daily streamflow / Average annual streamflow
Snowmelt
Streamflow Percentile
50th
25th/75th
10th/90th
Winter Storms
Perennial Groundwater and Rain
Low-volume Snowmelt and Rain
Distinct flow signatures
Flashy, ephemeral rain
High-volume Snowmelt and Rain
High elevation, low precipitation
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

Need for flow metrics

- The natural flow regime is a primary control on ecological functioning
- Flow metrics are used to link key aspects of natural and altered hydrology to ecological response to inform environmental water management
- Many flow metrics have been proposed
  - Indicators of Hydrologic Alteration (TNC 1996)
  - Hydrologic Index Tool (USGS 2006)
  - 'Statistically significant' (Olden and Poff 2003, Archfield et al 2006, Yang et al 2008)
- Appropriate selection of flow metrics remains a major challenge due to metric redundancy, limited statistical power and ecological relevance

Functional flow components



Sub-annual aspects of the natural flow regime expected to support key ecosystem functions

Constrain habitat, limiting for exotic species

Yarnell et al. 2015 *BioScience*

Conceptual Model

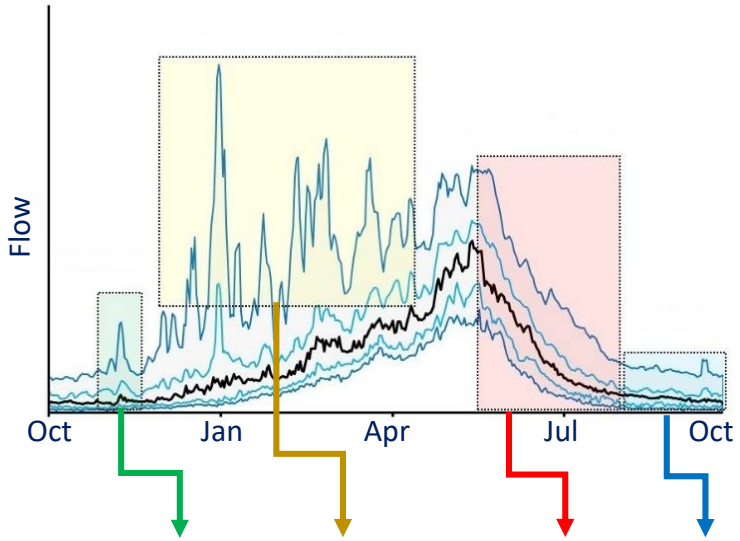
Functional Flow Components
e.g. Winter Floods, Spring Recession
Summer Baseflow

↓

Flow characteristics
e.g. Magnitude, Timing, Duration,
Frequency, Rate of Change

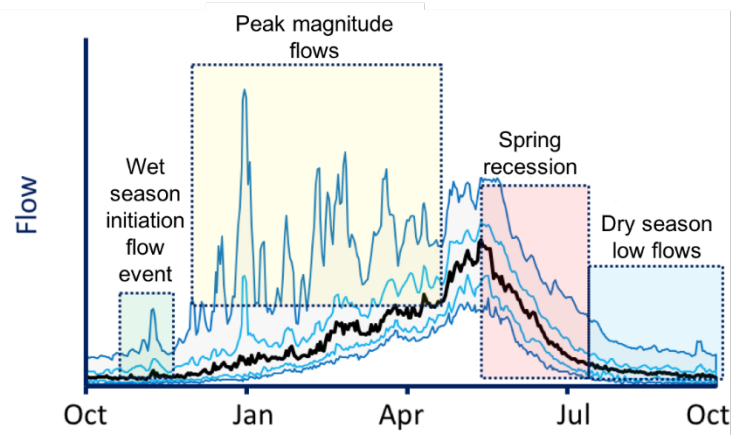
↓

Flow metrics
e.g. 5% Exceedance flow, Julian Day,
Percent decrease per day, Richards-
Baker Flashiness Index



Flow Characteristics	Wet Season Initiation	Peak Magnitude Flows	Spring Recession Flow	Dry Season Low Flows
Magnitude	X	X	X	X
Timing	X	X	X	X
Duration	X	X	X	X
Frequency		X		
Rate of Change			X	X

Functional flow metrics

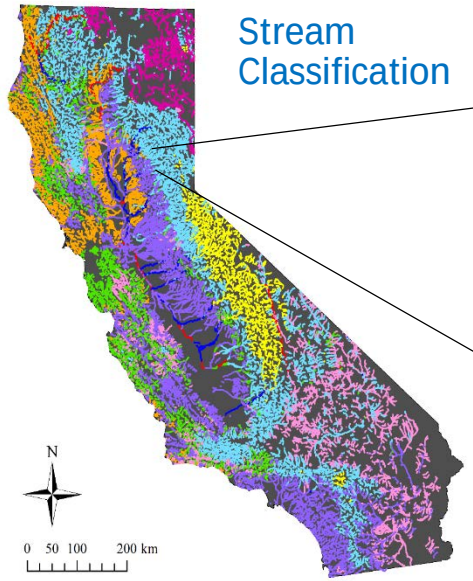


- 31 metrics
- 223 reference gauges in CA
- Annual metrics calculated for each reference Water Year (WY) on record (10 - 60 years)

Flow Component	Flow Characteristic	Units	Metric
Annual	Magnitude	cfs	average annual flow
	Rate of change	percent	coefficient of variation
Wet Season Initiation Flow Event	Magnitude	cfs	event peak magnitude
	Timing	date	event start date
	Duration	days	event duration
Peak Magnitude Flows	Timing	date	start date of wet season
	Magnitude	cfs	wet season baseflow (10P)
	Magnitude	cfs	peak magnitude: 2%, 5%, 10%, 20%
	Timing	date	event start date: 2%, 5%, 10%, 20%
	Duration	days	event duration: 2%, 5%, 10%, 20%
	Frequency	count	# of events/year: 2%, 5%, 10%, 20%
Spring Recession Flows	Magnitude	cfs	magnitude at start of spring recession
	Rate of change	percent	median daily flow percent decrease
	Timing	date	start date of spring recession
	Duration	days	from recession until dry season
Dry Season Low Flows	Magnitude	cfs	baseflow magnitude (10P)
	Timing	date	start date of dry season
	Duration	days	from dry season to start of wet season
	Frequency	count	# of no-flow days

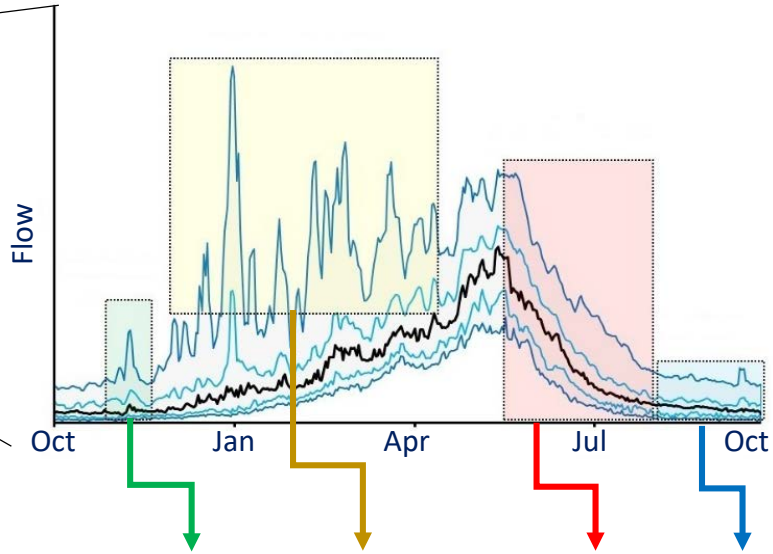
https://eflows.gitbook.io/project/website_summary#functional-flow-calculator

CEFF Tier 1



Stream Classification

Dimensionless Reference Hydrographs (DRH) for each Reference Gage



Flow Characteristics	Wet Season Initiation	Peak Magnitude Flows	Spring Recession Flow	Dry Season Low Flows
Magnitude	X	X	X	X
Timing	X	X	X	X
Duration	X	X	X	X
Frequency		X		
Rate of Change			X	X

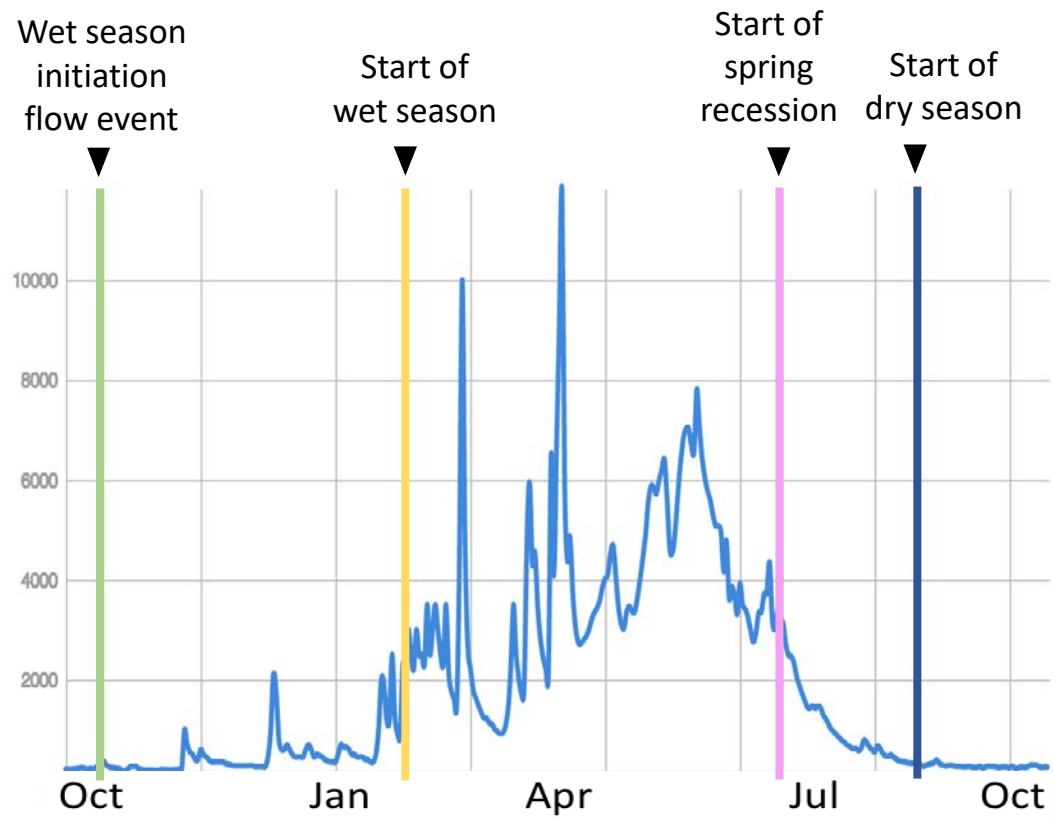
Functional Flows Metrics at Reference Gages (calculated using FFC)

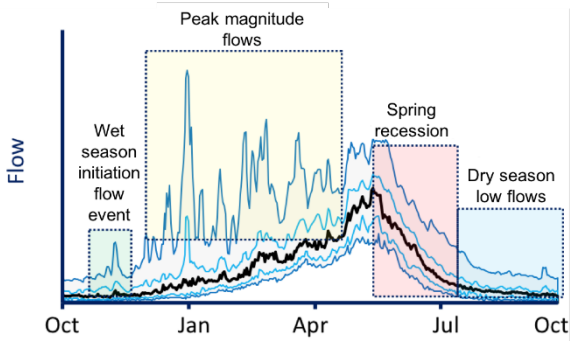
Functional flow metrics predicted for all stream reaches

Ecological Flow Criteria

Functional flow metrics

Timing metrics form foundation for all other functional flow metrics





Functional flow metrics

Wet Season Initiation Event

Initiation event timing

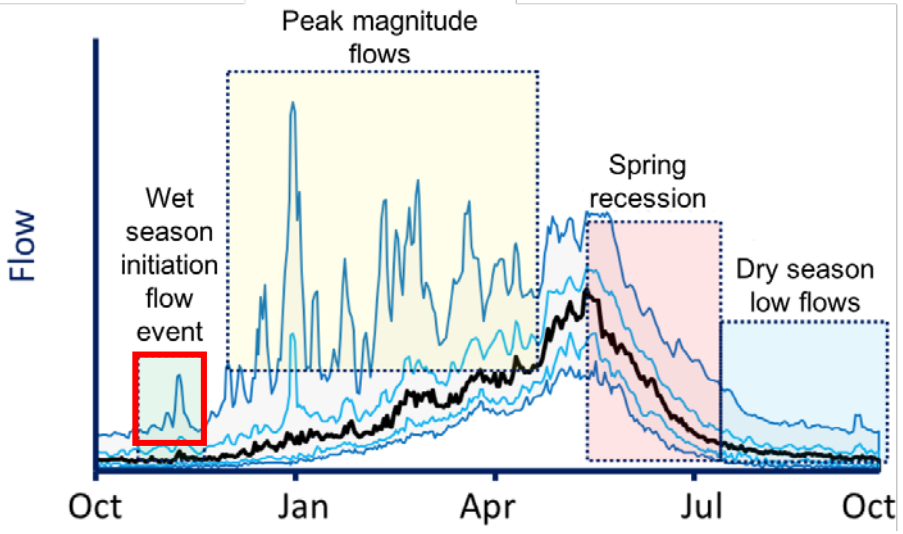
- First date from Oct 1 – Dec 15 that flow exceeds 2x previous dry season baseflow or 1 cfs, whichever is larger.

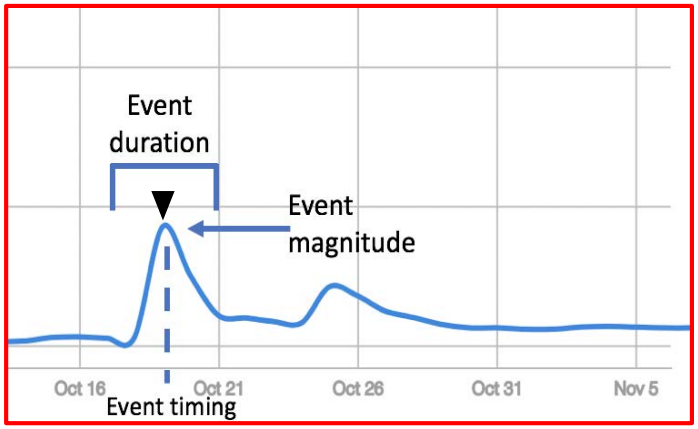
Initiation event magnitude

- Peak magnitude during initiation event.

Initiation event duration

- Number of days from the start to peak magnitude of initiation event.





Functional flow metrics

Peak Magnitude Flows

For 2%,5%,10%, and 20% exceedance flows:

High flow timing

- Date of peak flow for each high flow exceedance event

High flow magnitude

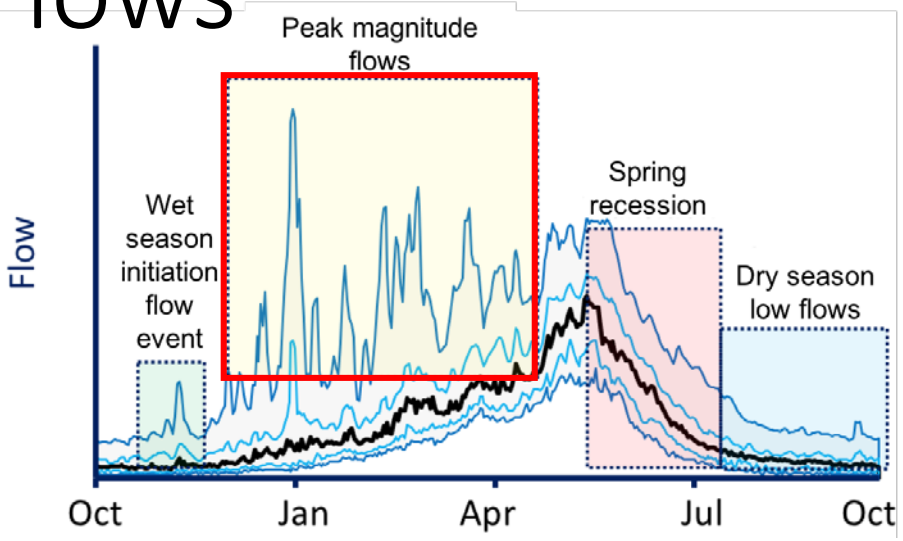
- Peak magnitude above the high flow exceedance threshold

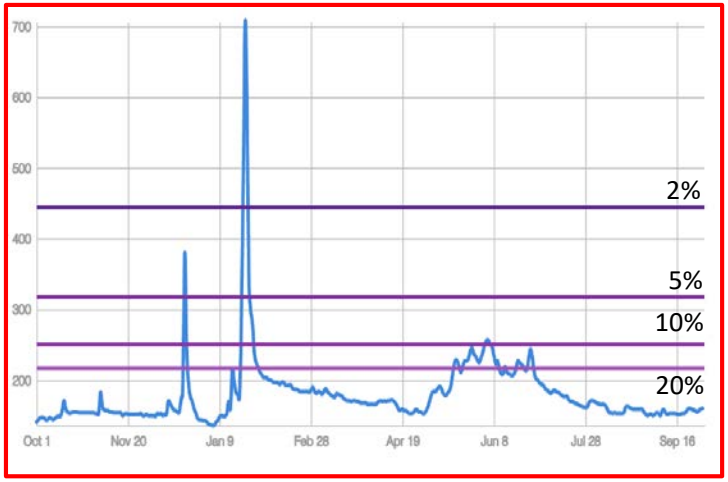
High flow duration

- Continuous duration that flow remains above threshold

High flow frequency

- Number of times threshold is exceeded per water year





Functional flow metrics

Peak Magnitude Flows

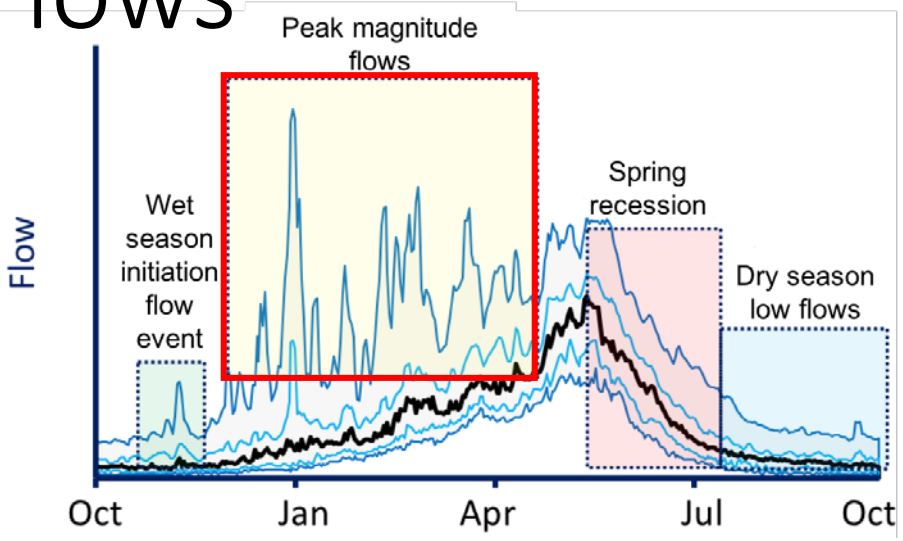
Two additional wet season metrics:

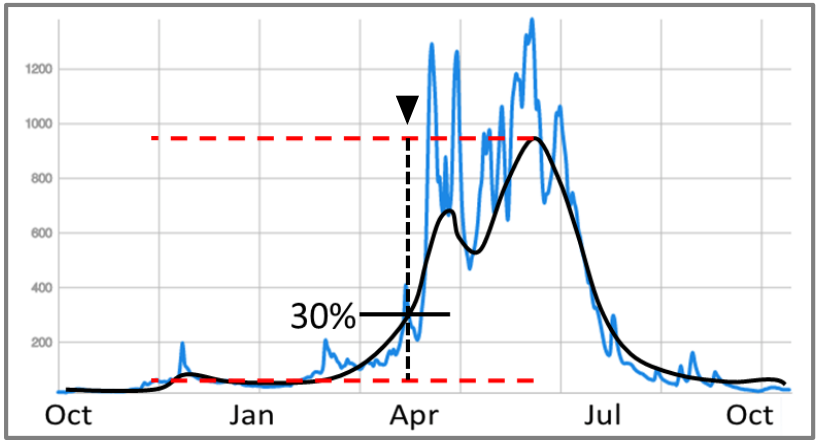
Wet season start timing

- First date flow is above 30% relative magnitude of difference between baseflow and smoothed wet season peak flow

Wet season baseflow magnitude

- 10th percentile daily flow from the start of the wet season to the start of the dry season.





Functional flow metrics

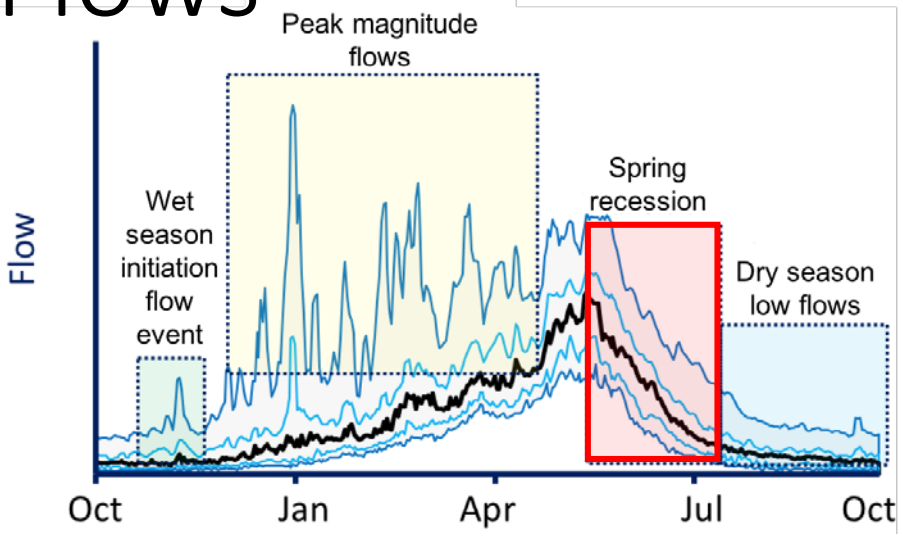
Spring Recession Flows

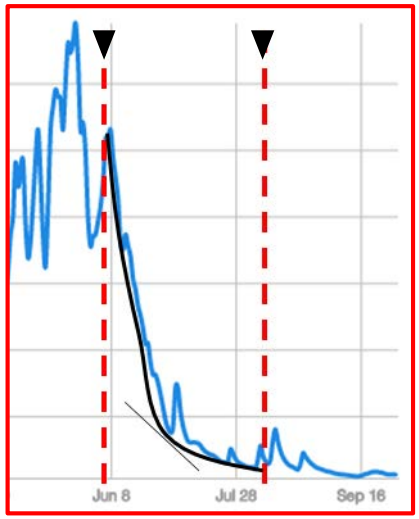
Recession start timing**
- Start of transition from wet season high flows to dry season low flows

Recession start magnitude
- Flow magnitude at start of recession.

Recession duration
- Duration from start of recession to start of dry season

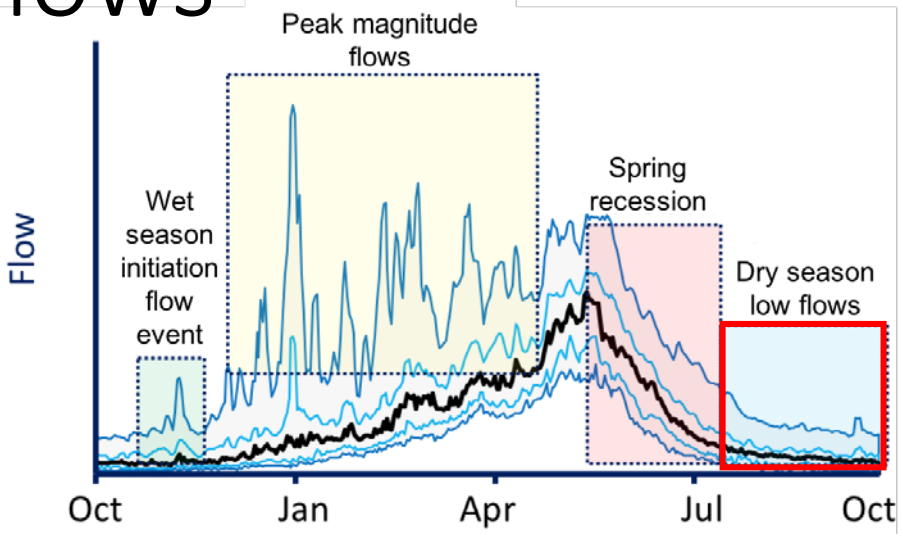
Recession rate of change
- Median daily rate of change over recession duration, considering only days with negative rate of change.





Functional flow metrics

Dry Season Low Flows



Dry season start timing

- First date from recession start to end of WY that magnitude <12.5% wet season max flow and rate of change -> zero.

Low flow magnitude

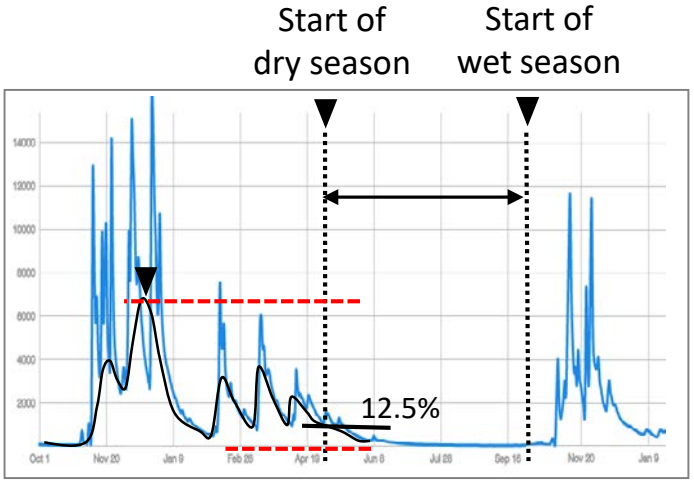
- 10th percentile daily flow from start of dry season to start of wet season.

Low flow duration

- Duration from start of dry season to start of wet season.

 # no-flow days

- Number of days with zero flow magnitude during low flow period

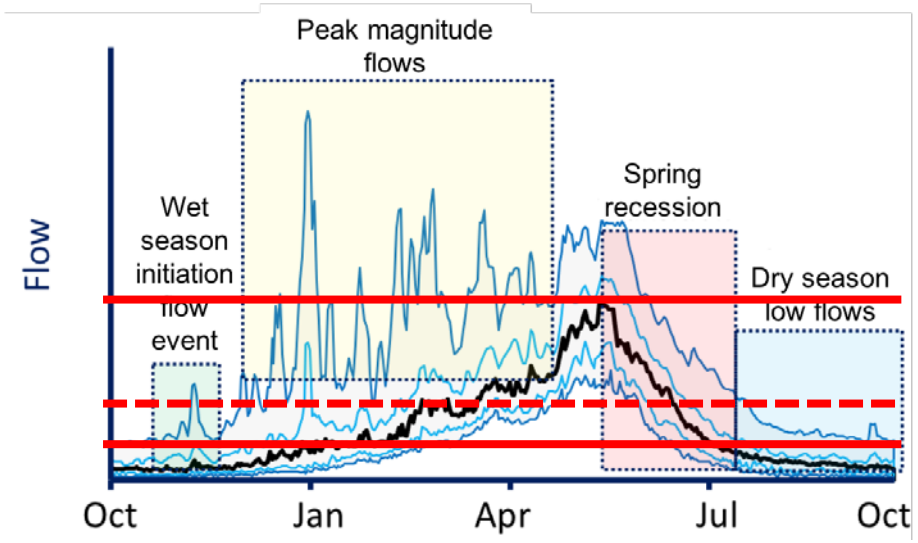


Functional flow metrics

Annual

Average annual daily flow
- Mean daily flow over WY

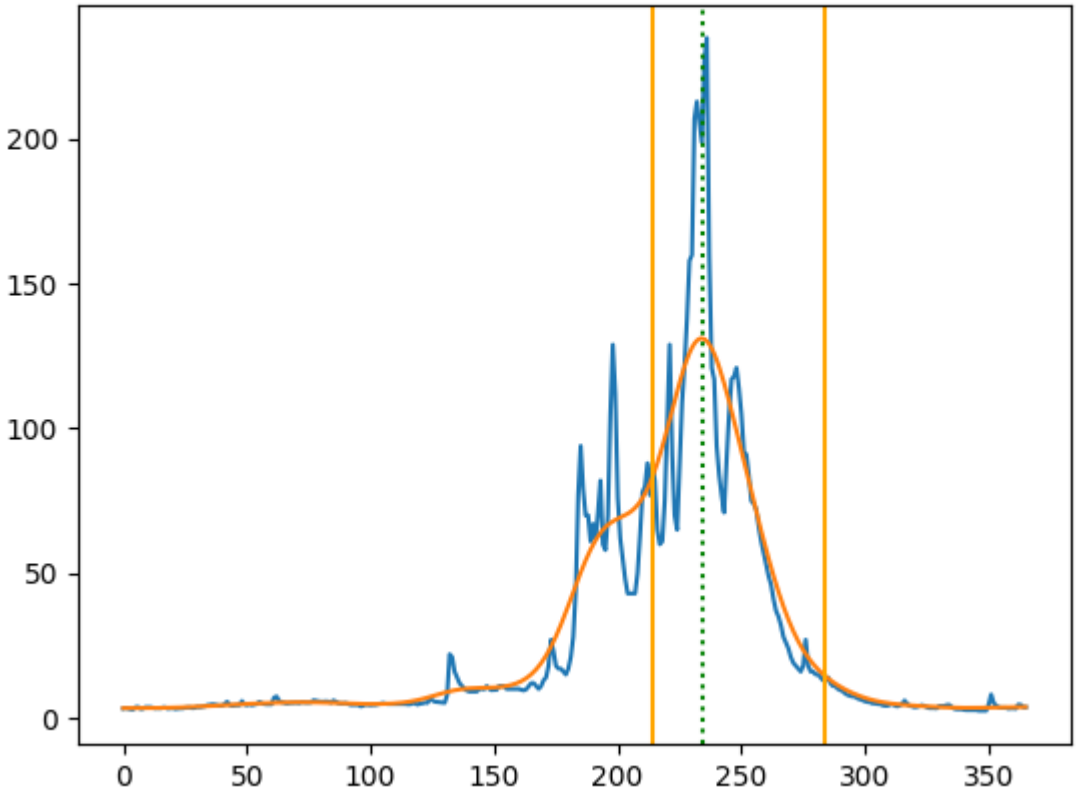
Coefficient of variation
- Standard deviation of daily flow divided by average annual flow



Detailed Methods

Identification of relevant hydrologic features using signal processing techniques

- Smoothing
- Feature detection
- Windowing

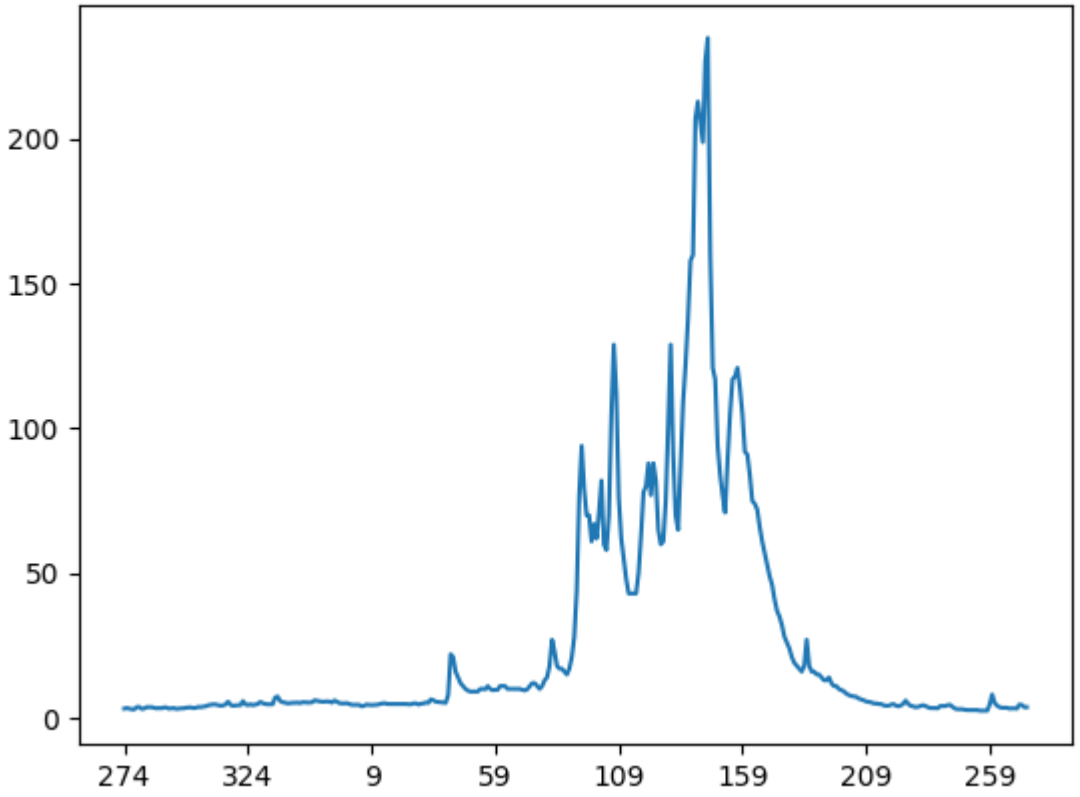


Hydrology- not calendar-driven

Detailed Methods

Example: Spring Recession Start Timing

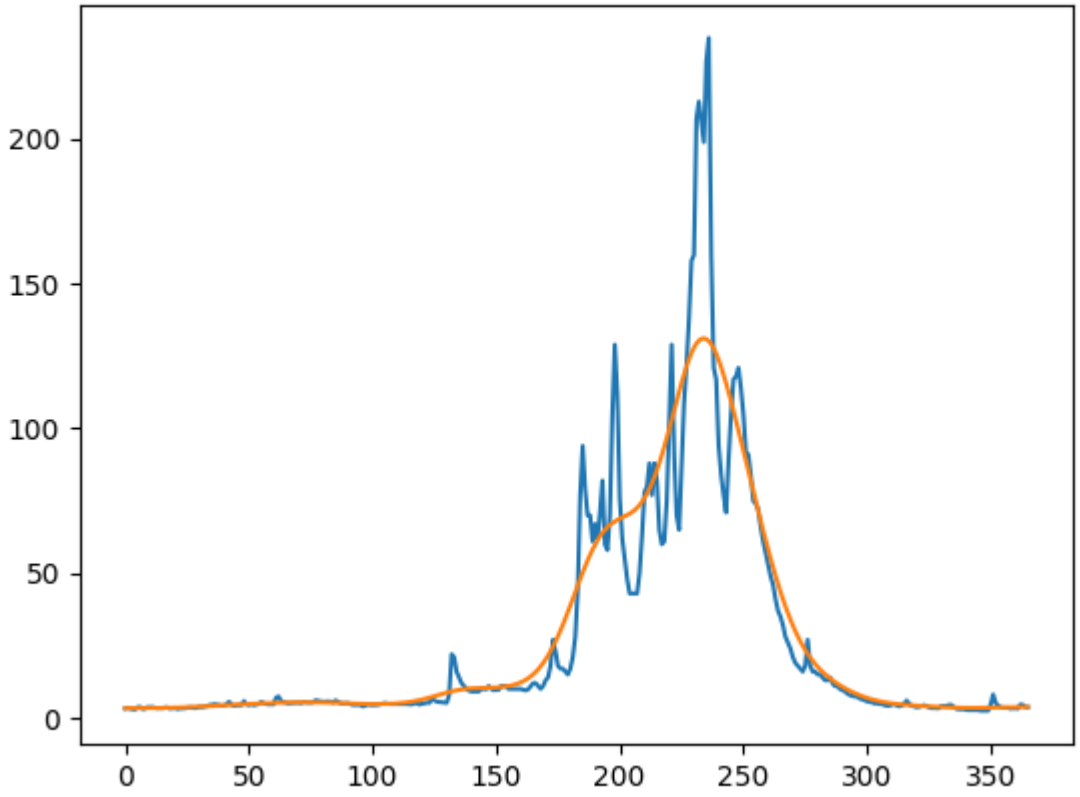
Step 1: Plot daily data by water year



Detailed Methods

Example: Spring Recession Start Timing

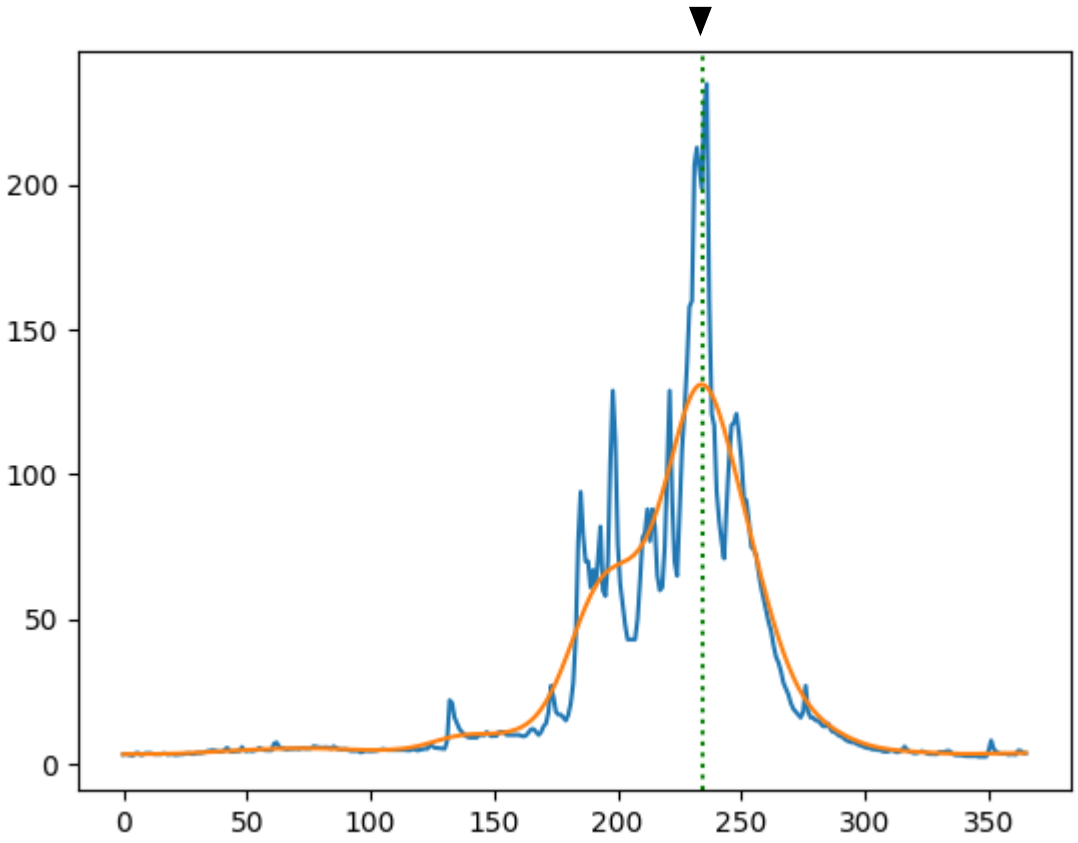
Step 2: Smooth data with Gaussian filter



Detailed Methods

Example: Spring Recession Start Timing

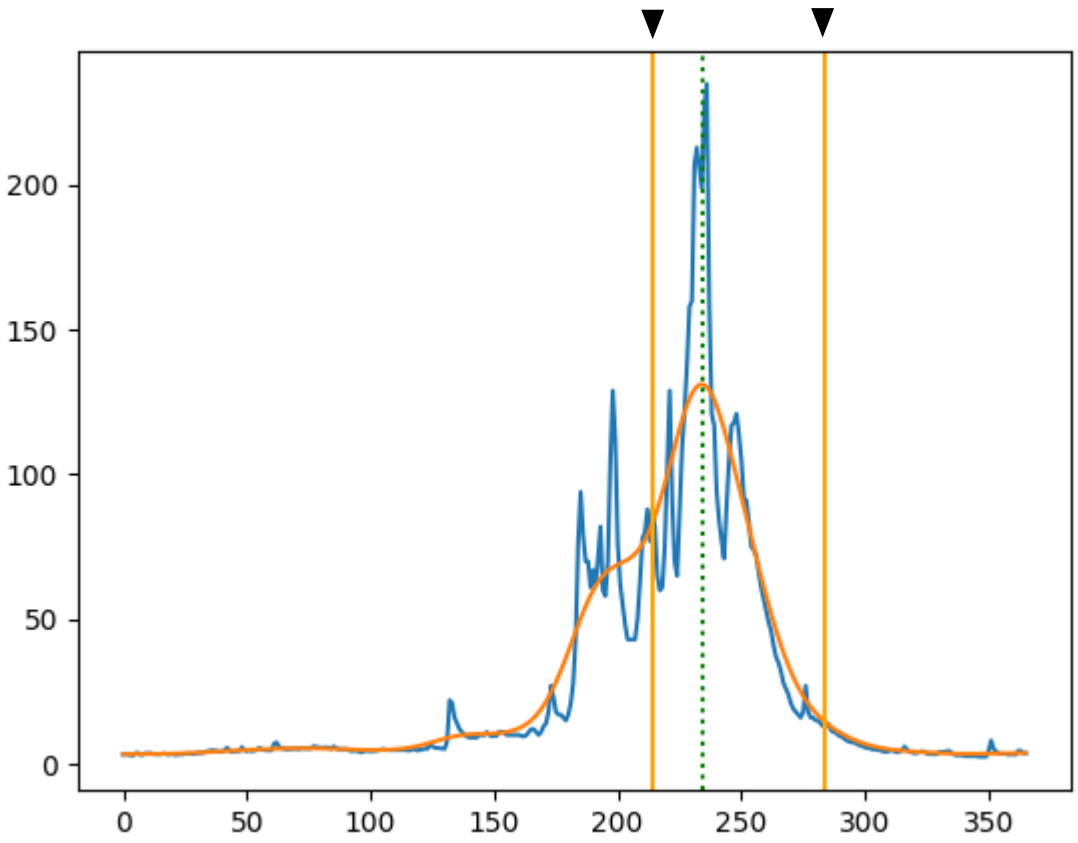
Step 3: Identify last major peak (center of mass of wet season)



Detailed Methods

Example: Spring Recession Start Timing

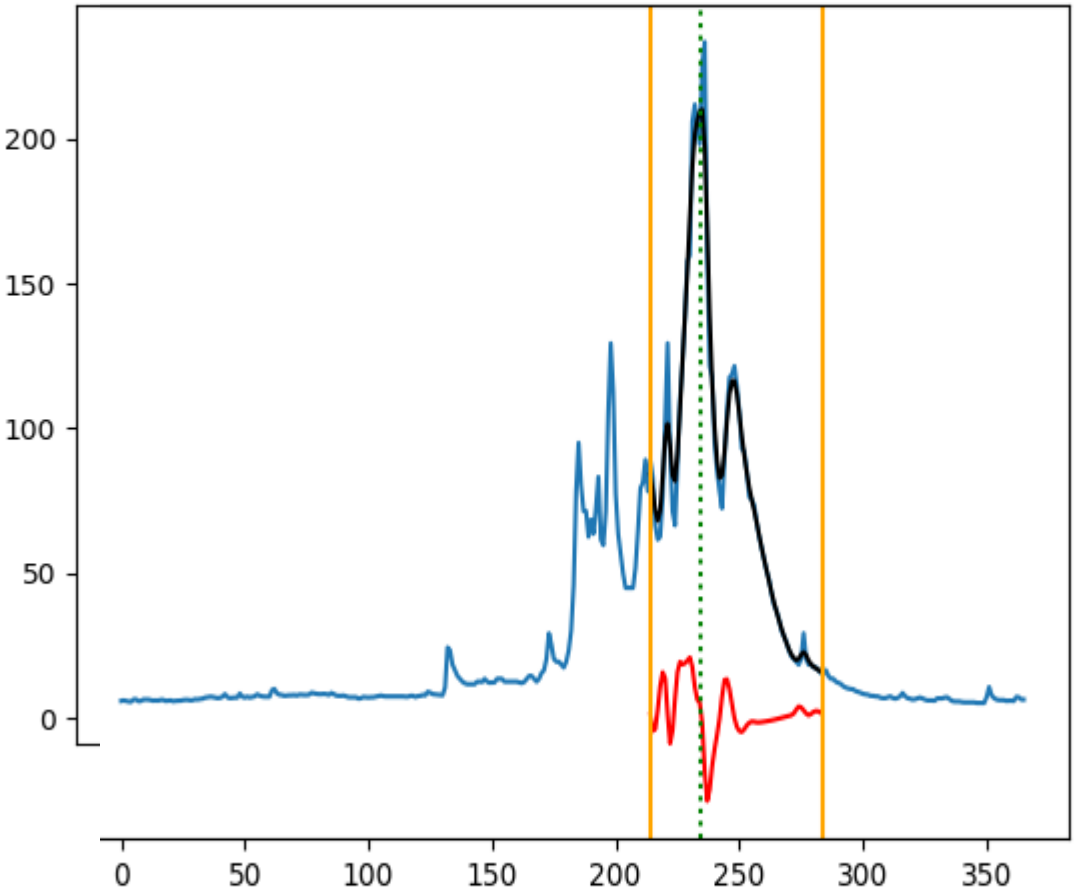
Step 4: Set dynamic search window around peak



Detailed Methods

Example: Spring Recession Start Timing

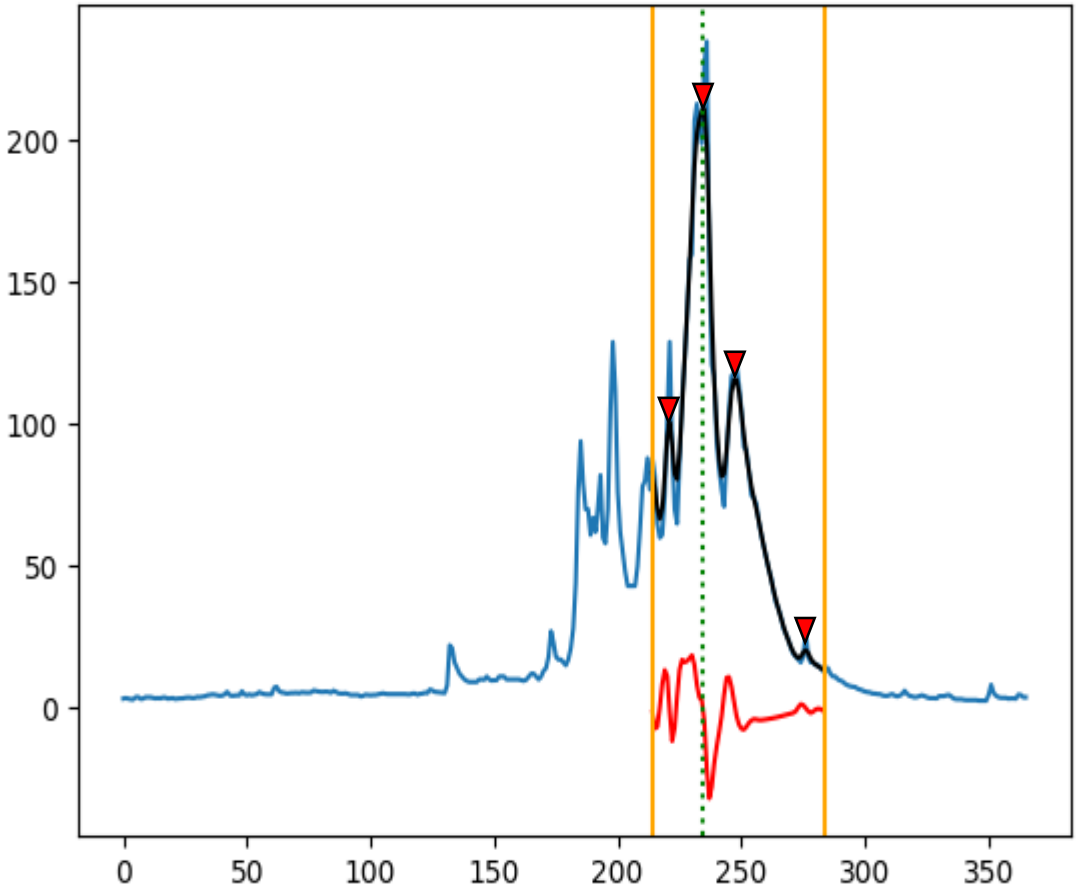
Step 5: Apply a tighter smoothing curve within window (black) and calculate its derivative (red)



Detailed Methods

Example: Spring Recession Start Timing

Step 6: Identify local peaks where derivative (red) flips from + to -

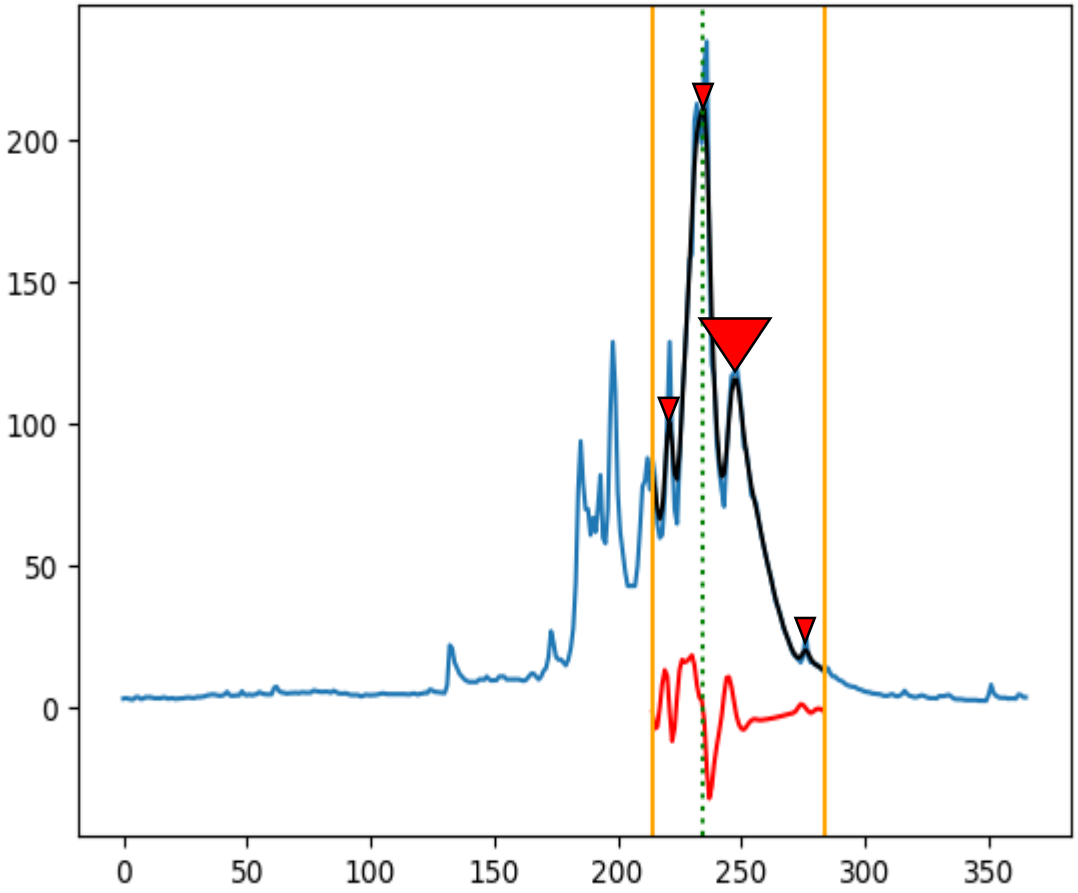


Detailed Methods

Example: Spring Recession Start Timing

Step 7: Identify last peak with sufficient:

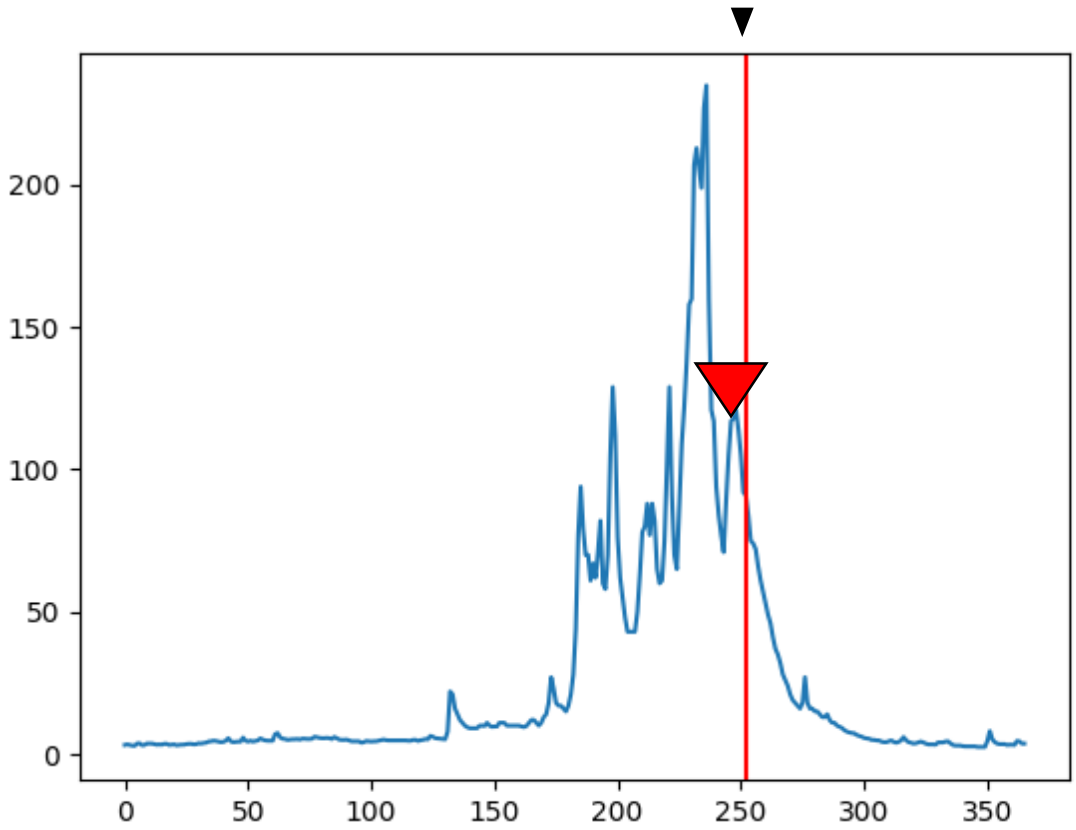
- Relative magnitude
- Duration
- Rate of change



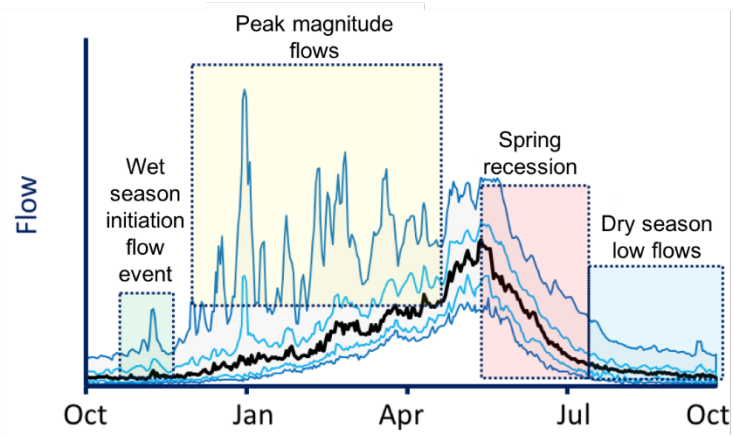
Detailed Methods

Example: Spring Recession Start Timing

Step 8: Set start date 4 days after peak flow (to remove individual storm effects)



Functional flow metrics



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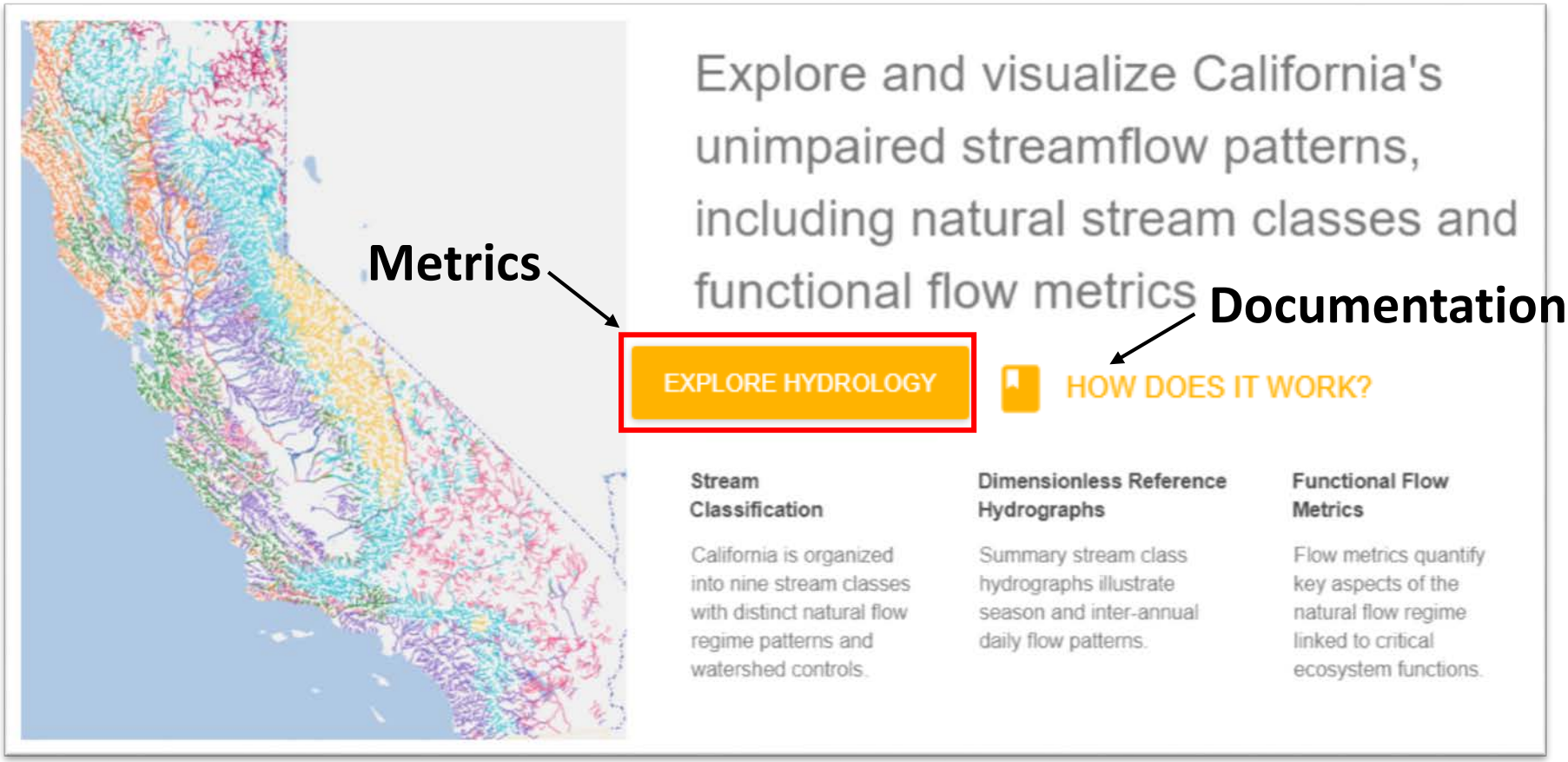
Functional Flows Calculator (FFC)



https://eflows.ucdavis.edu

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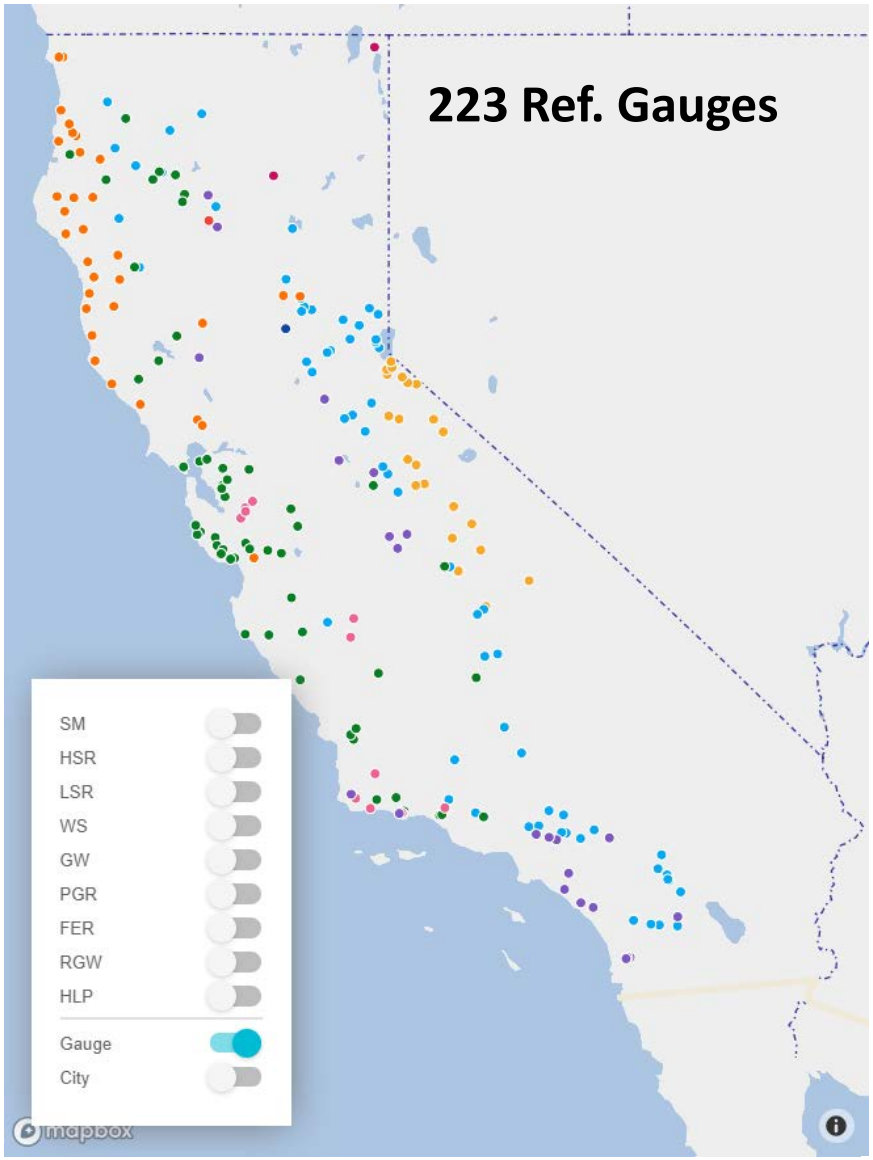

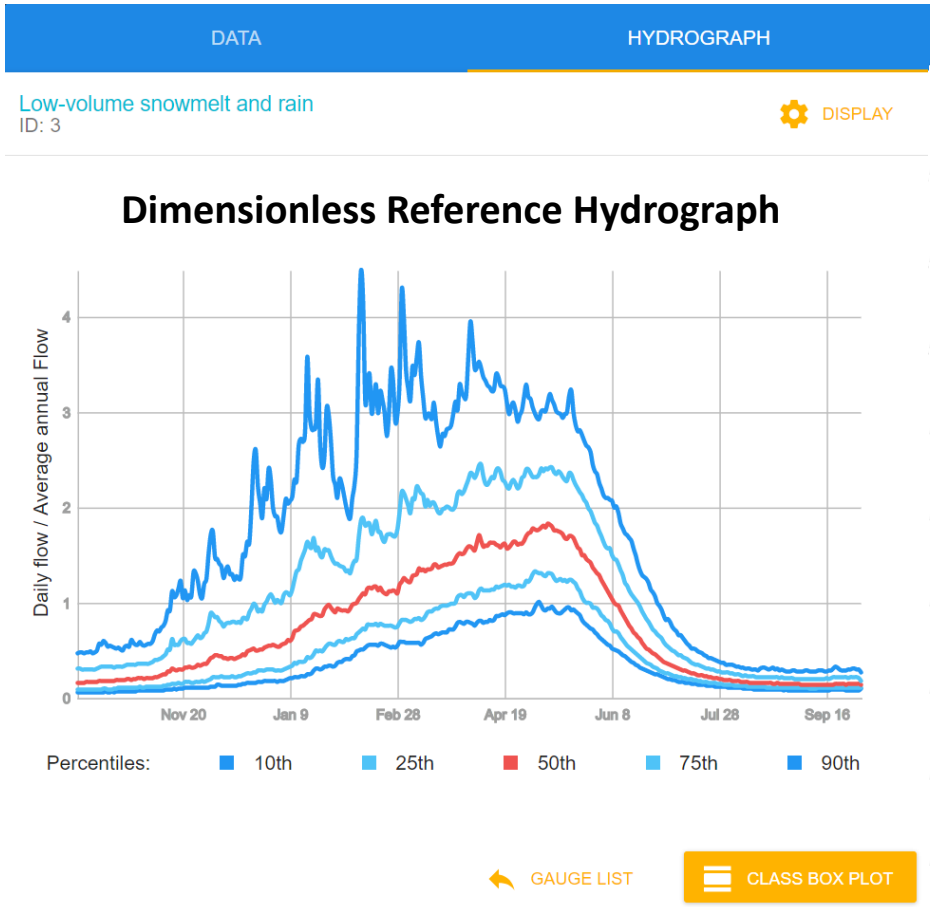

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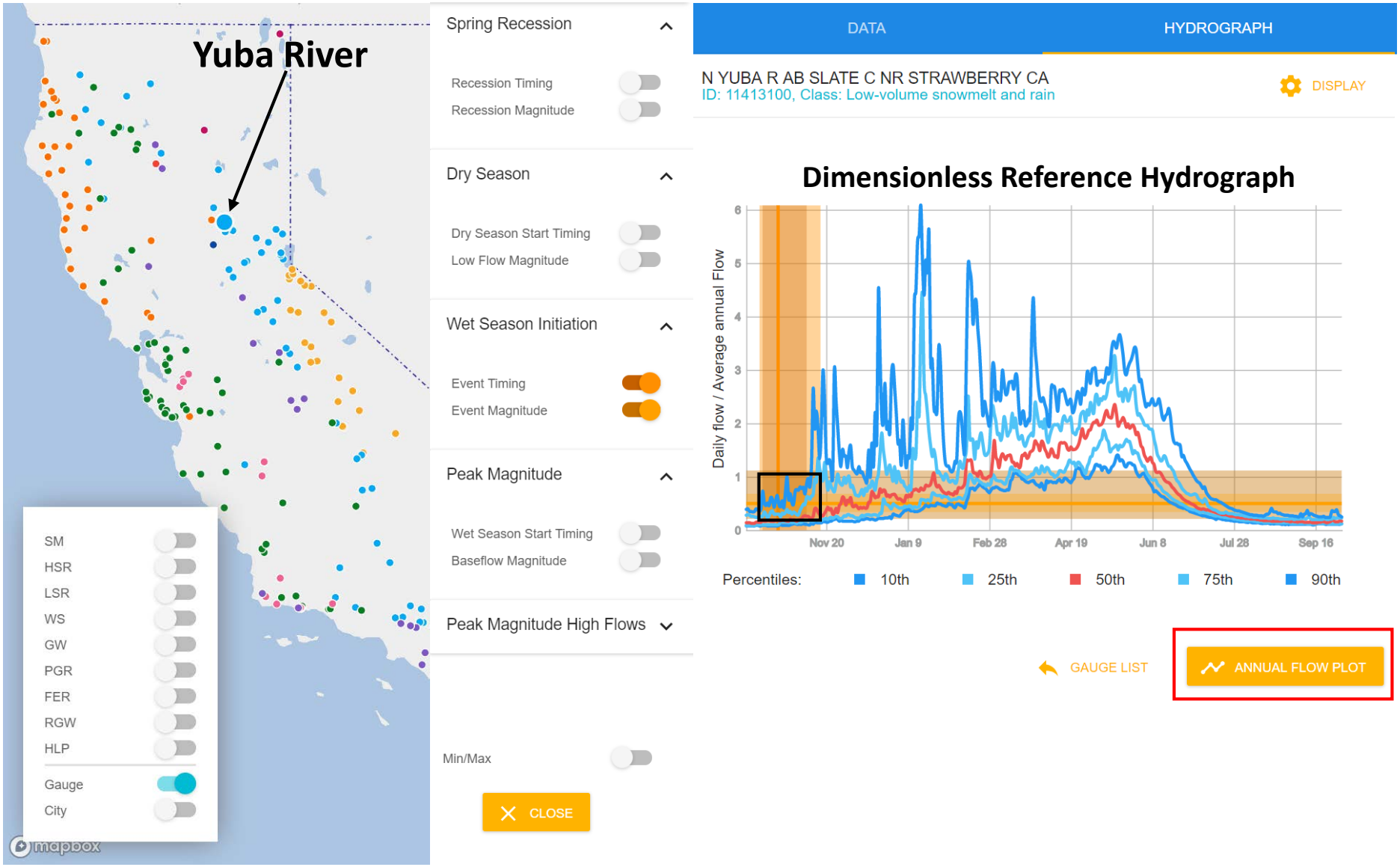
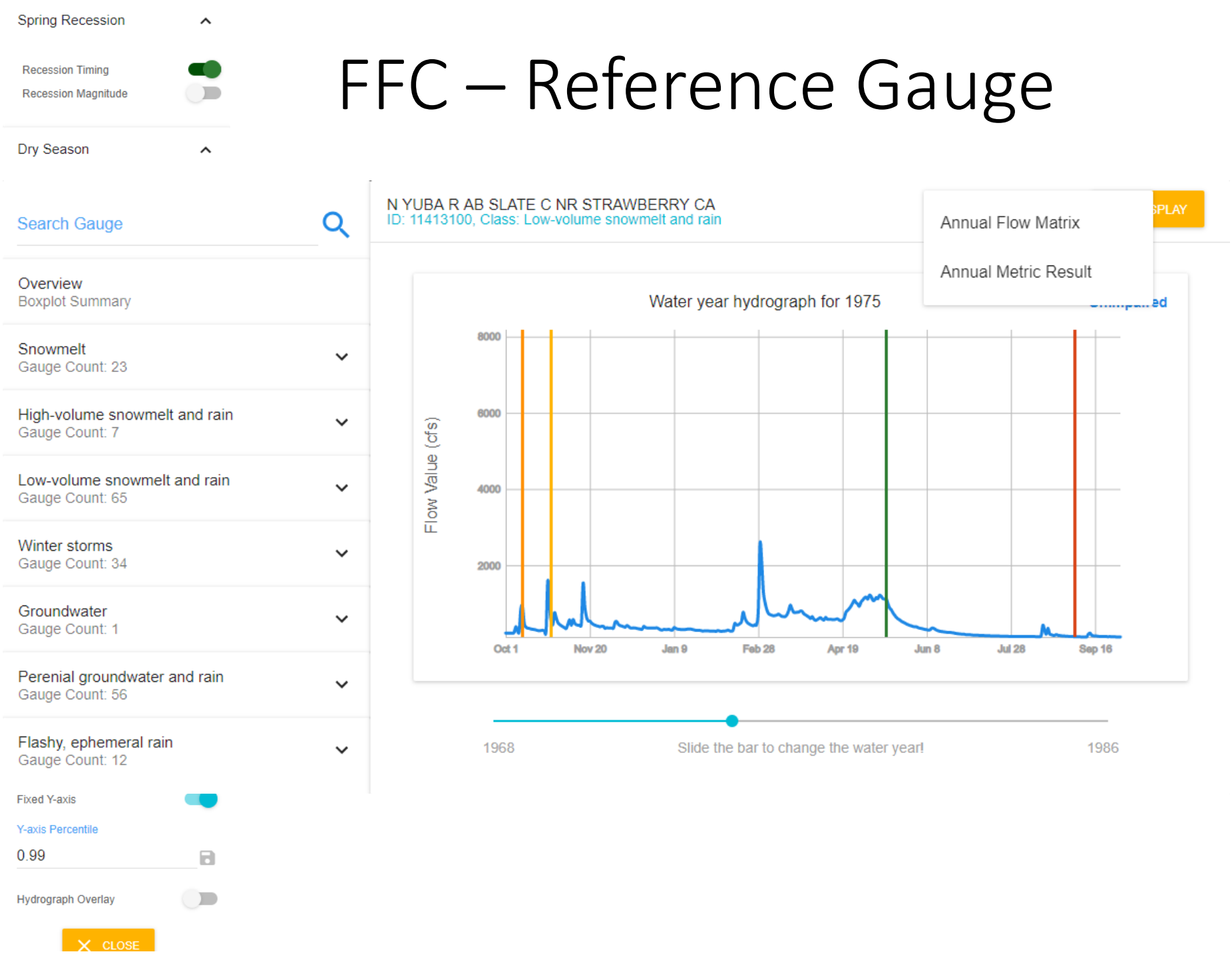
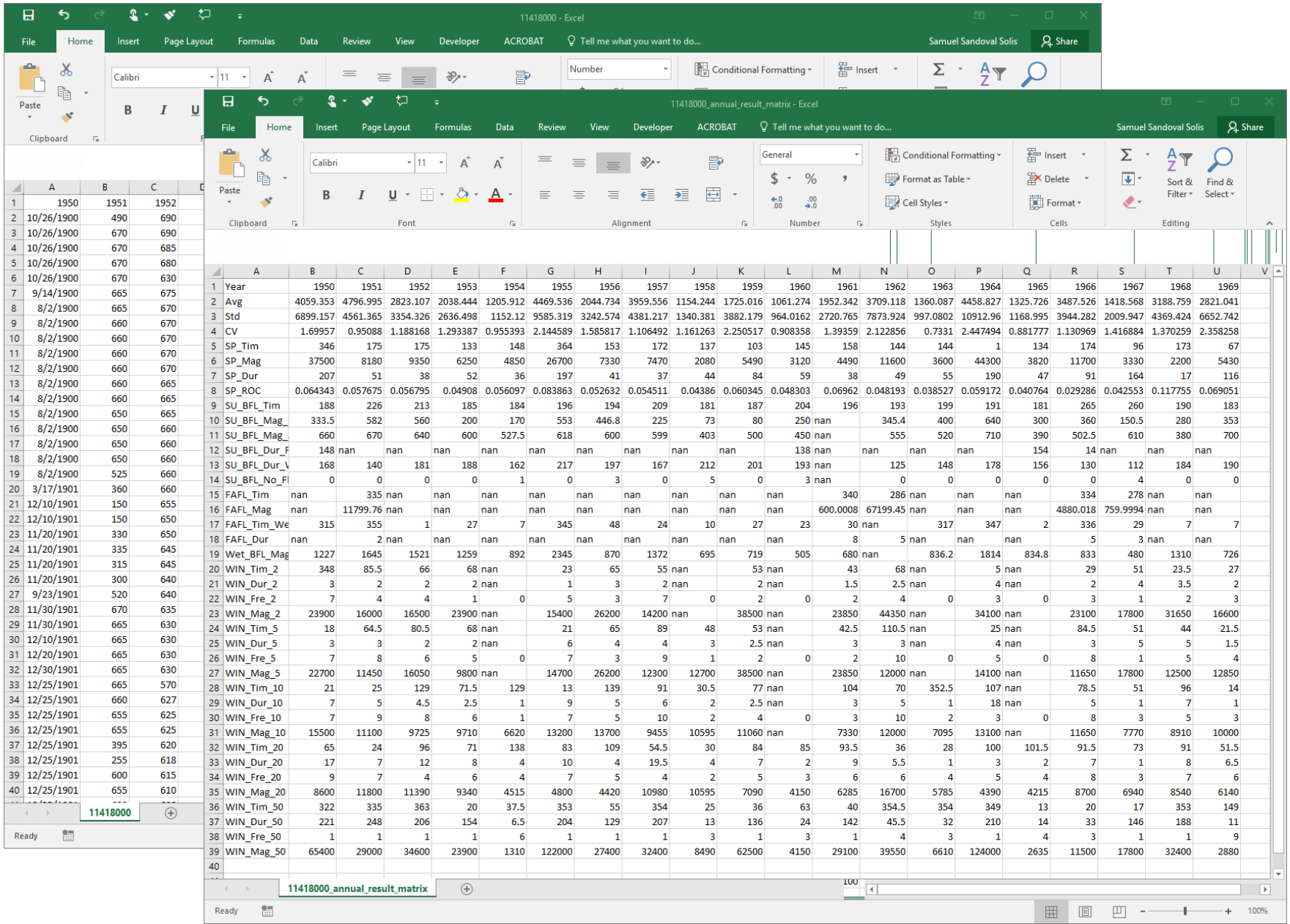


FFC – Reference Gauge



FFC – Reference Gauge Data



11418000 - Excel

	1950	1951	1952
1	10/26/1900	490	690
2	10/26/1900	670	690
3	10/26/1900	670	685
4	10/26/1900	670	680
5	10/26/1900	670	630
6	9/14/1900	665	675
7	8/2/1900	665	670
8	8/2/1900	660	670
9	8/2/1900	660	670
10	8/2/1900	660	670
11	8/2/1900	660	670
12	8/2/1900	660	665
13	8/2/1900	660	665
14	8/2/1900	650	665
15	8/2/1900	650	660
16	8/2/1900	650	660
17	8/2/1900	650	660
18	8/2/1900	525	660
19	3/17/1901	360	660
20	12/10/1901	150	655
21	12/10/1901	150	650
22	11/20/1901	330	650
23	11/20/1901	335	645
24	11/20/1901	315	645
25	11/20/1901	300	640
26	9/23/1901	520	640
27	11/30/1901	670	635
28	11/30/1901	665	630
29	12/10/1901	665	630
30	12/20/1901	665	630
31	12/30/1901	665	630
32	12/25/1901	665	570
33	12/25/1901	660	627
34	12/25/1901	655	625
35	12/25/1901	655	625
36	12/25/1901	395	620
37	12/25/1901	255	618
38	12/25/1901	600	615
39	12/25/1901	655	610

11418000_annual_result_matrix - Excel

	Year	Avg	Std	CV	SP_Tim	SP_Mag	SP_Dur	SP_ROC	SU_BFL_Tim	SU_BFL_Mag_	SU_BFL_Mag_	SU_BFL_Dur_F	SU_BFL_Dur_V	SU_BFL_No_Fl	FAFL_Tim	FAFL_Mag	FAFL_Tim_We	FAFL_Dur	Wet_BFL_Mag	WIN_Tim_2	WIN_Dur_2	WIN_Fre_2	WIN_Mag_2	WIN_Tim_5	WIN_Dur_5	WIN_Fre_5	WIN_Mag_5	WIN_Tim_10	WIN_Dur_10	WIN_Fre_10	WIN_Mag_10	WIN_Tim_20	WIN_Dur_20	WIN_Fre_20	WIN_Mag_20	WIN_Tim_50	WIN_Dur_50	WIN_Fre_50	WIN_Mag_50
1	1950	4059.353	6899.157	1.69957	346	37500	207	0.064343	188	333.5	660	148	168	0	nan	nan	315	nan	1227	348	3	7	23900	18	3	7	22700	21	7	15500	65	17	9	8600	322	221	1	65400
2	1951	4796.995	4561.365	0.95088	175	8180	51	0.057675	226	582	670	nan	140	0	335	11799.76	355	2	1645	85.5	2	4	16000	64.5	3	8	11450	25	7	11100	24	7	7	11800	335	248	1	29000
3	1952	2823.107	3354.326	1.188168	175	9350	38	0.056795	213	560	640	nan	181	0	nan	nan	1	nan	1521	66	2	4	16500	80.5	2	6	16050	129	4.5	9725	96	12	4	11390	363	206	1	34600
3	1953	2038.444	2636.498	1.293387	133	6250	52	0.04908	185	200	600	nan	188	0	nan	nan	27	nan	1259	68	2	1	23900	68	2	5	9800	71.5	2.5	9710	71	8	6	9340	20	154	1	23900
4	1954	1205.912	1152.12	0.955393	148	4850	36	0.056097	184	170	527.5	nan	162	1	nan	nan	7	nan	892	nan	nan	0	nan	nan	nan	0	nan	129	1	6620	138	4	1	4515	37.5	6.5	1	1310
5	1955	4469.536	9585.319	2.144589	364	26700	197	0.083863	196	553	618	nan	217	0	nan	nan	345	nan	2345	23	1	5	15400	21	6	7	14700	13	7	13200	83	10	7	4800	353	204	1	122000
6	1956	2044.734	3242.574	1.585817	153	7330	41	0.052632	194	446.8	600	nan	197	3	nan	nan	48	nan	870	65	3	3	26200	65	4	3	26200	139	5	13700	109	4	5	4420	55	129	1	27400
7	1957	3959.556	4381.217	1.106492	172	7470	37	0.054511	209	225	599	nan	167	0	nan	nan	24	nan	1372	55	2	7	14200	89	4	4	12300	91	6	9455	54.5	19.5	4	10980	354	207	1	32400
8	1958	1154.244	1340.381	1.161263	137	2080	44	0.04386	181	73	403	nan	212	5	nan	nan	10	nan	695	nan	nan	0	nan	48	3	1	12700	30.5	2	10595	30	4	2	10595	25	13	3	8490
9	1959	1725.016	3882.179	2.250517	103	5490	84	0.060345	187	80	500	nan	201	0	nan	nan	27	nan	719	53	2	2	38500	53	2.5	2	38500	77	2.5	11060	84	7	5	7090	36	136	1	62500
10	1960	1061.274	964.0162	0.908358	145	3120	59	0.048303	204	250	450	138	193	3	340	600.0008	23	30	505	680	43	2	23850	42.5	3	2	23850	104	3	nan	93.5	9	6	6285	40	142	3	29100
11	1961	1952.342	2720.765	1.39359	158	4490	38	0.06962	196	345.4	nan	nan	nan	nan	286	67199.45	nan	8	680	nan	1.5	4	44350	110.5	3	10	12000	70	5	7330	36	5.5	6	16700	354.5	45.5	4	39550
12	1962	3709.118	7873.924	2.122856	144	11600	49	0.048193	193	400	555	nan	125	0	nan	nan	317	5	nan	836.2	68	5	43	25	3	2	12000	352.5	1	12000	28	1	4	5785	354	32	3	6610
13	1963	1360.087	997.0802	0.7331	144	3600	55	0.038527	199	400	520	nan	148	0	nan	nan	347	nan	1814	29	4	3	34100	84.5	2	3	23100	107	1	7095	100	3	3	4390	349	210	4	124000
14	1964	4458.827	10912.96	2.447494	1	44300	190	0.059172	191	640	710	nan	178	0	nan	nan	2	nan	834.8	5	4	0	44350	25	4	0	17800	18	2	13100	101.5	7	4	4215	13	14	3	2635
15	1965	1325.726	1168.995	0.881777	134	3820	47	0.040764	181	300	390	154	156	0	nan	nan	2	nan	833	43	1.5	4	23850	42.5	3	2	23850	104	3	nan	93.5	9	6	6285	40	142	3	29100
16	1966	3487.526	3944.282	1.130969	174	11700	91	0.029286	265	360	502.5	14	130	0	nan	nan	336	5	833	29	2	3	23100	84.5	3	8	11650	78.5	5	11650	91.5	8	3	8700	20	33	3	11500
17	1967	1418.568	2009.947	1.416884	96	3330	164	0.042553	260	150.5	610	nan	112	4	278	4880.018	29	3	480	51	4	1	17800	51	1	5	17800	51	1	7770	73	1	7	6940	17	146	1	17800
18	1968	3188.759	4369.424	1.370259	173	2200	17	0.117755	190	280	380	nan	184	0	nan	nan	7	nan	1310	23.5	3.5	2	31650	44	5	5	12500	96	7	8910	91	8	7	8540	353	188	1	32400
19	1969	2821.041	6652.742	2.358258	67	5430	116	0.069051	183	353	700	nan	190	0	nan	nan	7	nan	726	27	2	3	16600	21.5	1.5	4	12850	14	1	10000	51.5	6.5	6	6140	149	11	9	2880
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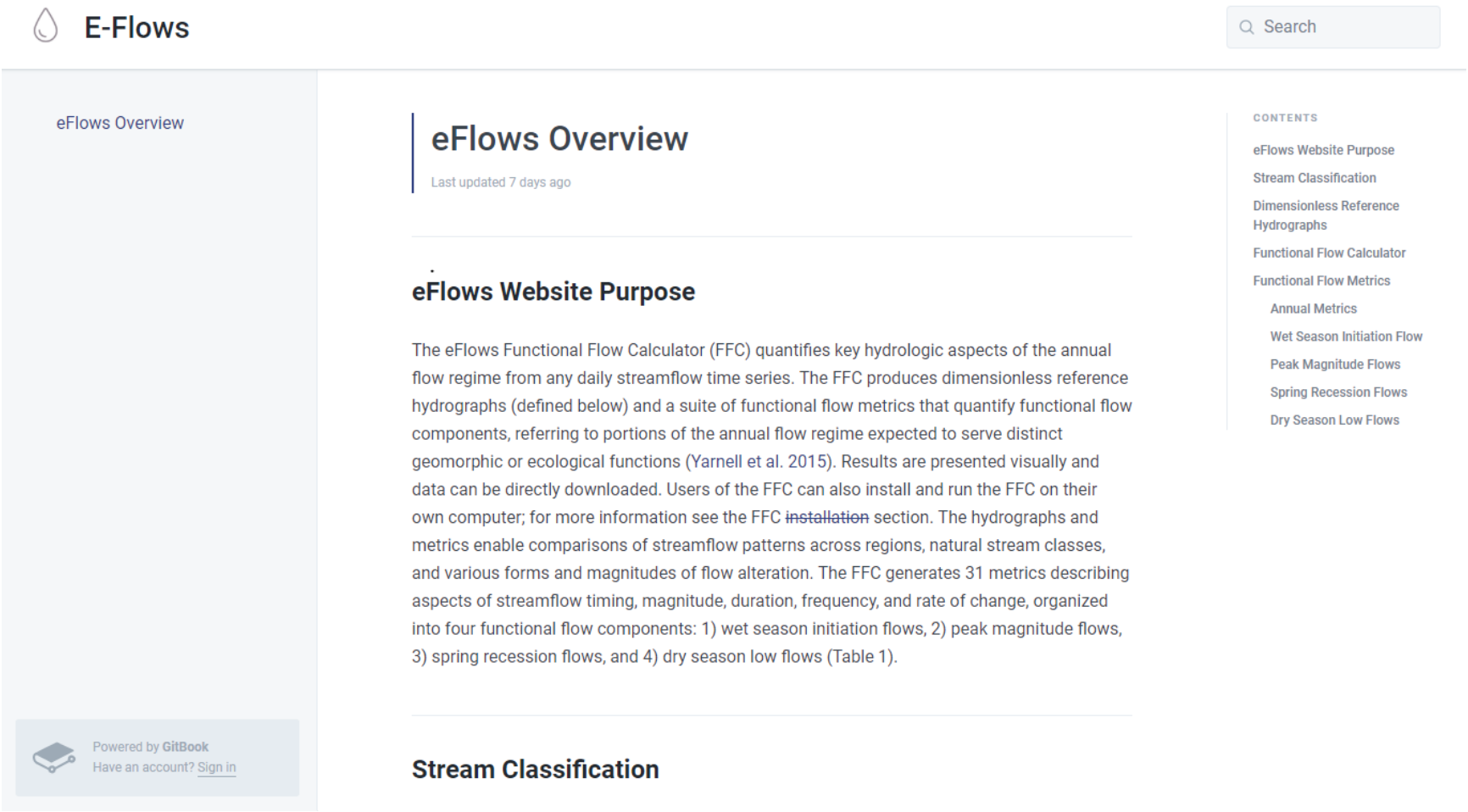
Ready

FFM - Documentation



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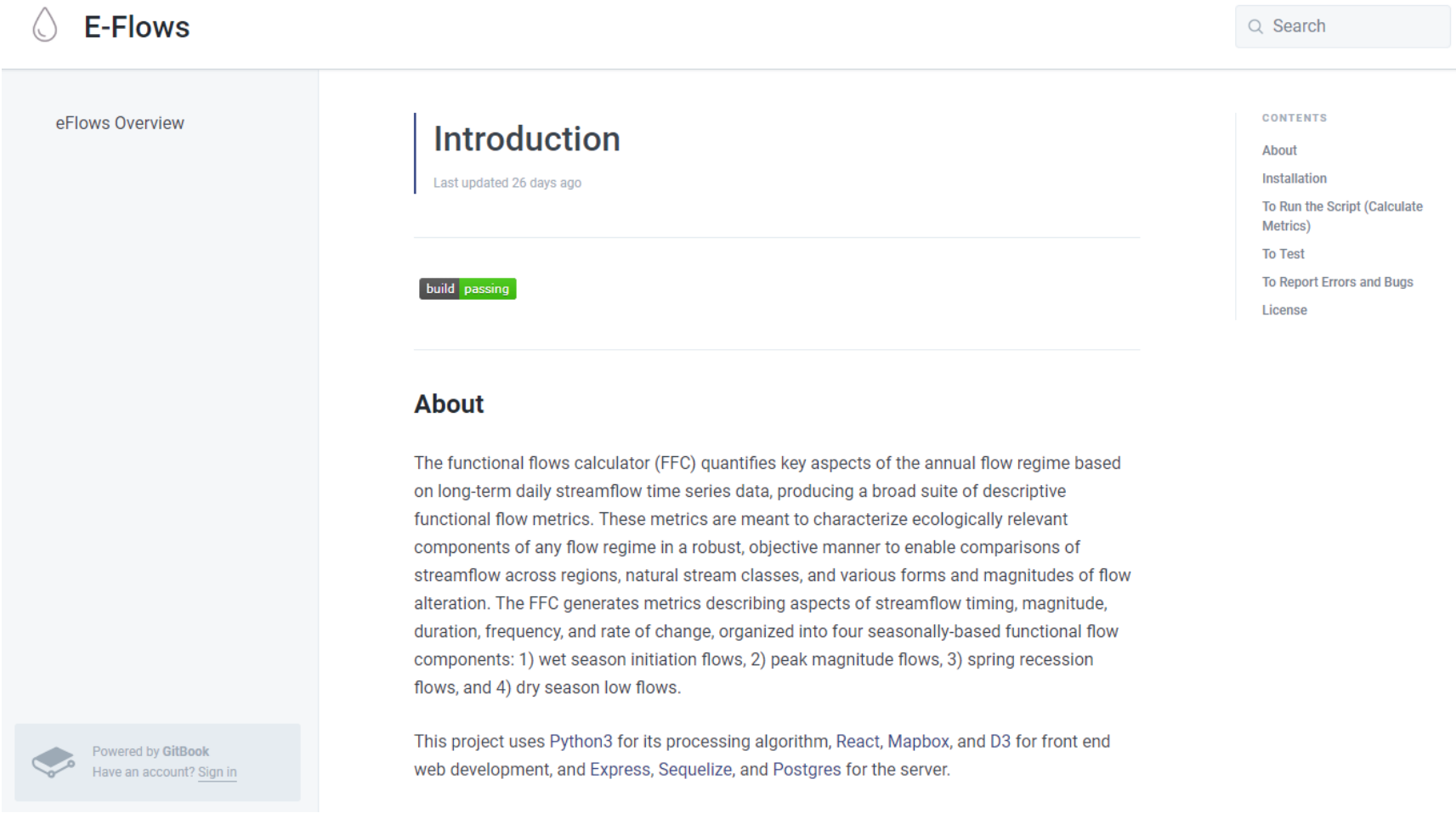
FFC - Documentation



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Thank you!


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