
From: Evan Sawyer - NOAA Federal <evan.sawyer@noaa.gov>
Sent: Thursday, April 18, 2019 1:50 PM
To: Stephen Maurano - NOAA Federal
Cc: Kate Spear - NOAA Federal; Cathy Marcinkevage - NOAA Federal
Subject: Re: [EXTERNAL] Inimpaired Flow Hydrograph

Stephen, Kate,

This is really great stuff. Thanks.

I think the first figure is closest to what I was looking for and it adds some nuance to the post-dam period. I'm a little surprised by the second figure and there not being a significant difference between November and February given the first figure and what we know about Reclamation trying to build storage during that period. I haven't looked but could it be due to where or how these flows are measured/observed (flow measured lower in the river would "capture" more of the natural flow during the high flow season regardless of reservoir operations, while during the low flow season they would be more dependent on those ops.)? I think the take home message of the last figure/table is "observed" flows are overall flatter on an annual basis than what we expect under FNR (although I'm not entirely clear on the "flood free" metric).

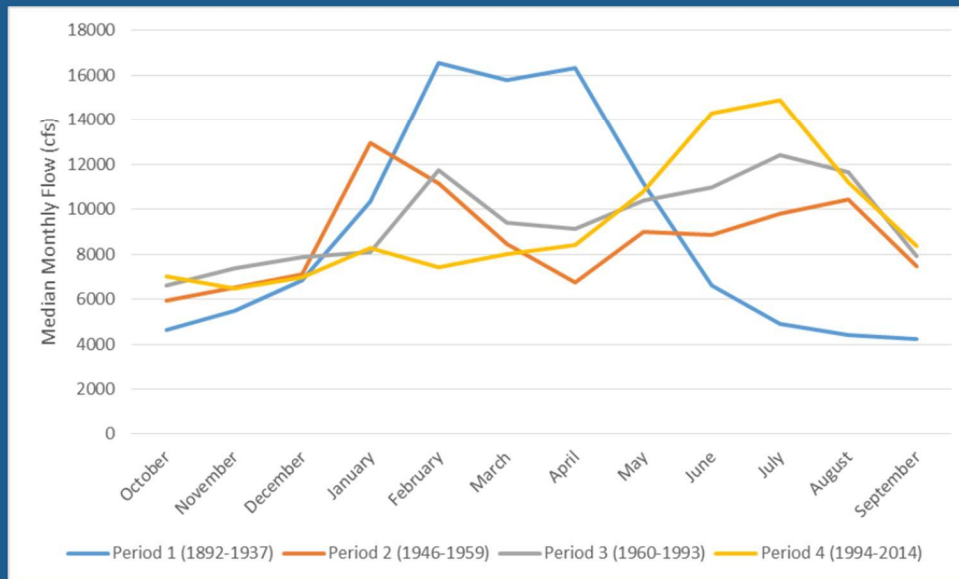
Overall, really helpful. Thank you,
Evan

On Thu, Apr 18, 2019 at 12:48 PM Stephen Maurano - NOAA Federal <stephen.maurano@noaa.gov> wrote:
Hey Evan, Thinking more about it, I searched around a little, and wonder if these might help get at your question:

[Brycen Swart's September 29, 2016 Presentation](#) It show's period 1 (predam) vs the dampened Spring flows period 2 (post dam), followed by more recent operations.

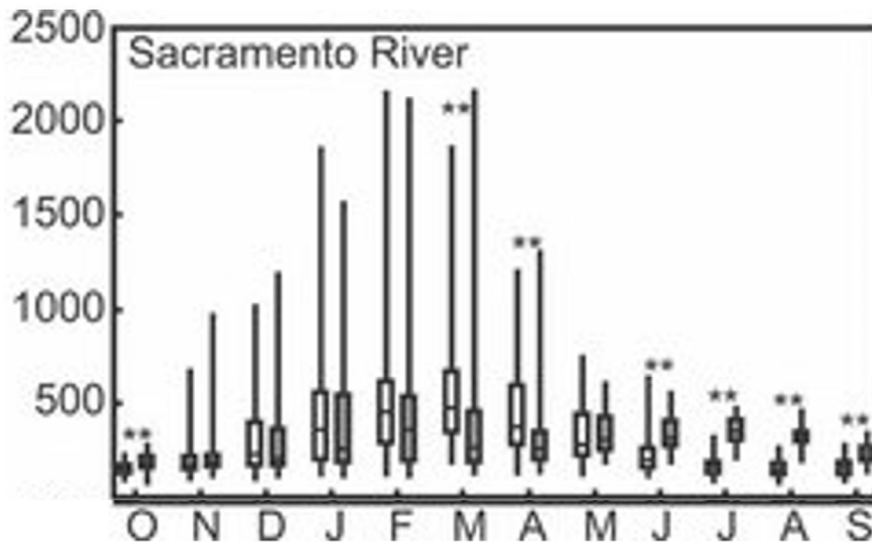
Median Monthly Flows

NRDC-48



[Larry Brown's 2009 Manuscript](#) analyzed the same location we're looking at, using the indicators of hydrologic alteration like we discussed yesterday. Basically the difference b/t monthly natural vs observed flows is significantly different in all months (except Nov-Feb). Moreover, the flow predictability has increased and the flood-free season has decreased.

Median monthly discharge for estimated full natural runoff (open bars) and observed flow (filled bars) for rivers in the Sacramento River drainage. Statistically significant differences are indicated by asterisks ($p < 0.05$, $p < 0.01$). Key to boxplots: median, horizontal line; box, 25th and 75th percentiles; whiskers, range



Effects of hydrologic infrastructure on flow regimes of California's Central Valley rivers: Implications for fish populations River Research and Applications, Volume: 26, Issue: 6, Pages: 751-765, First published: 13 July 2009, DOI: (10.1002/rra.1293)

Table IV. Values for selected hydrologic parameters calculated for estimated full natural runoff (FNR) and observed (OBS) flows

	Flow record	Annual mean daily discharge ($m^3 s^{-1}$)		Flow predictability		Constancy/predictability		Flood-free season (d)	
		FNR	OBS	FNR	OBS	FNR	OBS	FNR	OBS
Sacramento River drainage									
Sacramento River above Bend	1945-2006	351	352	0.53	0.61	0.76	0.85	70	23
Bridge near Red Bluff									
Annual mean daily discharge				Mean of daily discharge.					
Flow predictability				Ranges from 0 (low predictability) to 1 (high predictability). The sum of constancy (C), a measure of temporal invariance and contingency (M), a measure of periodicity. See Colwell (1974) for details.					
Constancy/predictability				$C/(C+M)$, the proportion of predictability due to constancy.					
Flood free season				Number of days in the longest period common to all water years when flows are at or below the 75th percentile of the FNR data record in every year.					

Likewise, [Michael Singer's 2007 publication](#) looked at the same spot and said that the annual flood volume suggests that Shasta Dam is operated to completely cut off the large flood peaks and shorten the rising limb, but a single extreme point at the lowest exceedance probability for the post-dam era points to early release operation for the largest floods.

On Thu, Apr 18, 2019 at 11:19 AM Stephen Maurano - NOAA Federal <stephen.maurano@noaa.gov> wrote:
Hi Evan,

We looked briefly at the data. At some point we'd need to confirm that the data sets Derek stitched together are fully consistent, specifically the flow (CDEC full natural flow = DWR unimpaired flow?) and station (DWR UF 6 Sacramento River near Red Bluff = CDEC SHA station Sensor 8 - esp. b/c of Paynes Creek flow additions in the former). Assuming those are consistent, below are some quick visualizations of the data. We haven't converted to cfs yet, just quickly averaged and looked at patterns -- which are pretty unremarkable (wet vs dry season & various water year types).

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1921	226	1236	1557	2123	1576	1583	931	792	541	369	281	261
1922	242	289	542	432	967	880	1067	896	511	338	263	239
1923	256	339	646	678	446	422	884	431	398	314	240	233
1924	232	250	269	306	517	286	269	263	266	246	199	191
1925	211	439	445	463	2508	789	1275	700	466	299	246	237
1926	220	274	343	437	1598	548	832	431	314	266	212	199
1927	206	858	1167	1205	2589	1345	1505	781	490	337	249	239
1928	221	633	550	722	1059	1585	1194	538	359	306	236	231
1929	215	338	381	369	647	482	526	432	350	257	200	202
1930	196	219	973	662	881	1106	575	487	324	258	198	217
1931	219	232	235	470	385	461	300	243	214	186	177	174
1932	204	213	781	548	420	845	556	608	310	215	198	184
1933	180	201	246	390	319	1117	644	552	356	218	188	180
1934	193	200	505	738	728	609	438	324	232	192	176	167
1935	197	483	400	986	732	965	1895	822	371	248	204	190
1936	219	209	282	1571	1779	780	724	482	401	247	195	186
1937	200	196	224	262	682	1441	1194	731	425	250	186	188
1938	250	1165	1908	950	2614	3185	1769	1286	632	375	282	261
1939	305	326	466	426	406	750	454	339	249	225	209	215
1940	207	212	443	1729	2577	2188	1458	581	346	275	231	246
1941	270	320	1881	2528	2339	2111	2048	1124	650	413	325	305
1942	311	321	1655	1733	2540	751	1340	990	658	382	300	280
1943	305	364	628	1687	1077	1408	1002	668	490	331	275	262
1944	290	291	295	387	694	696	485	463	378	274	229	221
1945	268	527	723	495	1416	794	629	672	453	268	235	219
1946	332	619	2161	1249	556	755	767	598	356	283	257	236
1947	256	354	421	275	624	995	618	342	480	259	228	221
1948	370	302	288	1031	343	821	1720	1151	745	338	268	273
1949	274	286	350	277	504	1937	811	584	332	234	226	217
1950	243	243	250	750	962	883	816	542	333	244	225	227
1951	665	768	1517	1263	1517	922	654	702	345	252	244	235
1952	295	520	1765	1463	1753	1429	1621	1111	575	404	305	302
1953	283	300	1271	2746	687	897	861	913	734	388	295	293
1954	308	490	442	1487	1625	1474	1445	650	437	318	308	298
1955	302	516	789	566	447	473	767	682	335	278	250	257
1956	256	414	2898	3226	1849	1200	951	1009	542	361	311	290
1957	371	325	321	423	1115	1446	817	968	459	316	278	330
1958	584	527	913	1482	4414	2085	2149	1069	731	458	362	346

1959	355	326	361	1308	1283	789	631	476	343	284	257	326
1960	288	265	300	546	1431	1216	622	615	403	270	248	254
1961	281	423	965	576	1344	1043	691	627	418	283	259	256
1962	283	425	830	477	1861	1100	772	564	382	274	251	245
1963	898	400	918	558	1360	913	2402	1033	476	347	309	286
1964	353	699	400	850	473	451	470	415	404	246	223	232
1965	263	498	2500	2089	803	593	1632	682	406	330	297	267
1966	283	725	485	1121	950	1186	913	490	337	275	254	259
1967	253	691	1279	1405	1083	1338	1544	1273	714	375	294	261
1968	303	302	437	764	1668	1061	597	500	343	306	327	301
1969	321	356	980	2549	2209	1307	1482	1072	539	361	293	329
1970	356	330	1486	4536	1369	1233	561	514	411	323	306	288
1971	343	1032	1705	1648	766	1493	1110	957	674	421	313	322
1972	370	360	512	731	760	1236	872	525	376	297	277	289
1973	381	655	818	1818	1746	1436	802	677	397	324	292	295
1974	407	2107	1846	3355	1054	2579	1849	911	595	458	362	354
1975	345	380	503	507	1452	2307	1177	1044	634	379	327	332
1976	435	379	402	371	443	625	554	391	304	258	304	295
1977	298	272	275	303	282	313	255	338	271	242	245	318
1978	282	320	969	3115	1632	2074	1459	801	441	336	281	314
1979	271	264	270	474	945	1010	667	706	271	267	232	240
1980	379	479	690	1776	2262	1520	783	592	362	309	257	309
1981	299	278	509	969	908	1227	661	468	312	273	243	244
1982	324	1546	2104	1293	1737	1687	2208	929	534	290	313	310
1983	383	542	1367	1915	2925	4677	1817	1530	853	475	341	356
1984	377	987	2569	1029	824	1069	726	615	441	314	277	293
1985	372	963	661	428	497	554	555	338	329	252	245	312
1986	330	343	551	1100	3671	2288	764	623	361	338	260	318
1987	323	275	330	463	751	1337	455	371	245	270	219	239
1988	250	279	1015	1045	473	419	426	492	354	247	201	210
1989	231	537	397	470	384	2242	903	455	288	229	223	264
1990	414	262	250	680	370	616	327	663	477	257	215	208
1991	241	244	225	247	269	981	516	439	263	208	189	191
1992	238	226	269	336	1268	921	635	353	265	244	190	212
1993	259	244	650	1573	1410	2167	1339	914	808	319	260	249
1994	311	256	447	458	653	537	382	374	244	185	159	220
1995	229	267	396	3867	1431	3904	1744	1513	693	416	333	354
1996	307	274	786	1046	2277	1527	967	1053	481	307	284	282
1997	330	495	2299	3075	1032	708	621	464	359	276	276	296
1998	375	614	667	2621	3960	2100	1541	1650	1322	562	384	381
1999	426	768	942	953	1741	1590	1113	799	513	354	321	335
2000	373	426	413	1186	2500	1793	1027	662	439	305	299	347
2001	375	337	408	533	924	1067	585	461	316	273	273	276
2002	292	558	1507	1477	810	829	650	507	331	272	280	280
2003	286	335	1920	1845	746	1015	1225	1214	490	321	283	286
2004	213	266	672	661	1372	779	516	391	265	229	188	180
2005	245	211	477	600	499	790	600	1101	441	267	215	202
2006	214	290	1207	1414	825	1379	1752	933	436	299	254	229
2007	240	288	479	325	633	517	346	299	212	209	189	191
2008	235	209	334	576	610	525	369	390	240	184	165	178
2009	199	249	244	246	664	1041	469	613	266	220	177	160
2010	263	213	292	928	836	637	734	580	485	254	215	194

2011	236	262	826	462	489	1488	942	725	565	297	222	209
2012	228	231	220	298	259	832	773	401	234	186	168	157
2013	171	382	918	392	338	415	413	245	213	165	166	164
2014	169	171	177	178	284	588	357	203	154	145	143	145
2015	179	185	942	314	720	273	219	189	159	146	141	138
2016	143	149	308	1032	562	1647	484	324	222	176	155	142
2017	322	408	758	1458	2712	1251	1256	626	346	263	222	207

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Wet	338	599	1372	1859	1848	1719	1395	962	581	367	300	296
Above Normal	318	473	808	1435	1516	1491	1057	792	455	311	266	274
Below Normal	267	343	520	823	967	952	866	577	374	263	230	227
Dry	271	389	570	539	821	956	628	479	330	251	226	230
Critical	254	247	398	452	531	584	414	376	277	214	193	202

On Wed, Apr 17, 2019 at 11:34 AM Evan Sawyer - NOAA Federal <evan.sawyer@noaa.gov> wrote:
Hey Stephen, Kate,

Attached is an excel file of unimpaired, average monthly flow at Red Bluff. Also included is a DWR report in which those flows were calculated.

I'm not totally sure how best to summarize this information (there are limitations given the format but I'm open to suggestions or ideas!) but what I'd like to describe is, generally what un-managed flows are like in the Sac River. This way I can describe how the life history adaptations are (may be) incongruent with water operations. Not sure if including [WYT](#) would be helpful or not. Also if units could be converted to cfs that would be helpful.

Take a look and let's talk,
Evan

----- Forwarded message -----

From: **Hilts, Derek** <derek_hilts@fws.gov>

Date: Wed, Apr 17, 2019 at 8:53 AM

Subject: Re: [EXTERNAL] Inimpaired Flow Hydrograph

To: Cathy Marcinkevage - NOAA Federal <cathy.marcinkevage@noaa.gov>, <Evan.Sawyer@noaa.gov>

Hi Cathy,

Here (attached) is a report DWR put out around 10 years ago with unimpaired flow estimates for WY1922-WY2003.

I pulled out the table for the Sac River near Red Bluff and added more recent years' data per documentation in the attached workbook.

I'll leave it to Evan to decide how he wants to chart the data.

Derek

Derek Hilts M.S., P.E.
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On Tue, Apr 16, 2019 at 2:33 PM Cathy Marcinkevage - NOAA Federal <cathy.marcinkevage@noaa.gov> wrote:

Hey Derek --

Have you seen, or do yo have an idea of the difficulty in generating, a hydrograph of average unimpaired flow ("full natural flow"?) for the upper Sac, say below Keswick? Evan could find that to be useful so I'm poking to find one.

Thanks -
Cathy

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