Hydrologic Forecast Development for the New CALSIM II Allocation Model (CAM)

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- Mr. Pierre Stephens

  DWR Flood management

Motivation of Project

- SWP contractors need an analysis tool to evaluate their allocation procedures for the water allocations and its associated risks in response to various September reservoir carry-over storage rules, hydrologic uncertainties, and timing of allocation decisions.

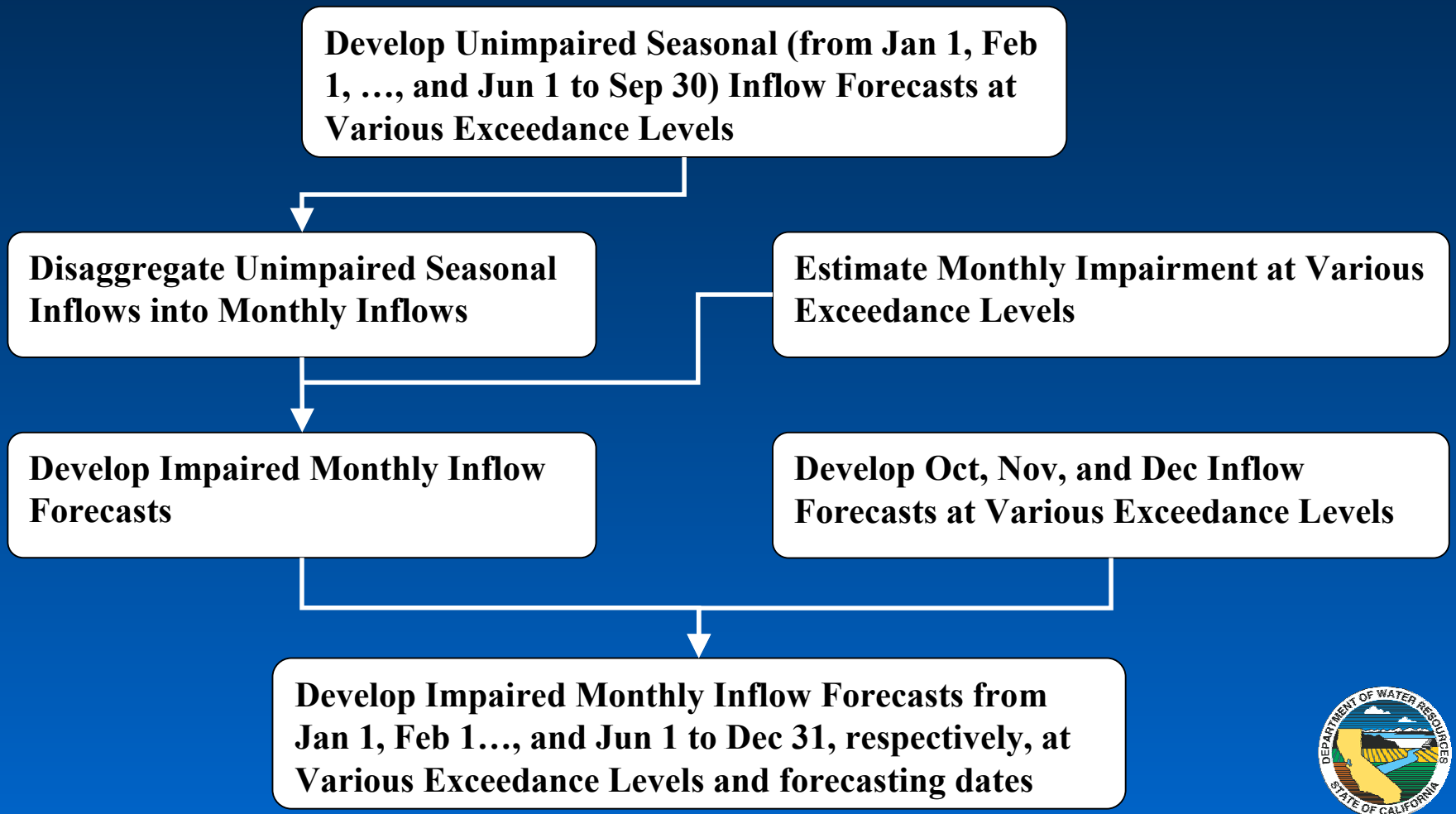
New CALSIM II Allocation Model (CAM)

- Mimic system representation used in spreadsheet models by CVO and OCO as much as possible while being consistent with CALSIM II
- Optimization model
- Allocation decision linked with CALSIM II simulation model
- One year time horizon (to end of calendar year)
- Monthly time step
- Monthly hydrologic forecasts and their monthly updates

Hydrologic Forecast Needs of CAM

Forecasting Date	Oct 1, Nov 1, Dec 1	Jan 1, Feb 1, Mar 1, Apr 1, May 1, Jun 1	Jan 1, Feb 1, Mar 1, Apr 1, May 1, Jun 1
Probability Exc.	99%, 95%, 90%, 75%, 50%, 20%	99%, 95%, 90%, 75%, 50%, 20%	99%, 95%, 90%, 75%, 50%, 20%
Impairment	Impaired Monthly Forecast	Impaired Monthly Forecast	Unimpaired Monthly Forecast
Trinity	1922-98	1922-98	
Whiskeytown	1922-98	1922-98	1922-98
Shasta	1922-98	1922-98	1922-98
Oroville	1922-98	1922-98	1922-98
Yuba	1922-98	1922-98	1922-98
Folsom	1922-98	1922-98	1922-98
Sac Accretion ab. NCP	1922-98	1922-98	
Sac Accretion bl. NCP	1922-98	1922-98	
Bear R.	1922-98	1922-98	
Stony Cr.	1922-98	1922-98	
Eastside Streams	1922-98	1922-98	
San Joaquin	1922-98	1922-98	

Impaired Monthly Inflow Forecast Derivation



Data Used in the Forecasts

- Streamflow record covering WY1922-98
- Basin average precipitation record covering WY1922-98

Seasonal Reservoir Inflow Forecasts

- Various regression models including real-space and log-space multiple linear regressions, polynomial regressions, multivariate regressions, and their combinations were evaluated for both annual and seasonal inflows.
- Various independent variables including previous water year's precipitation and runoff, water year cumulative precipitation and runoff, previous months' precipitation and runoff, future seasonal precipitation, etc. were examined by using the stepwise regression technique.

Shasta Unimpaired Seasonal Inflow Forecast Equations Based on Record of WY 1922-2001

Dependent Variable	Independent Variable	Coefficient
$LogQ_{Jan\_Sep}$	$LogP_{Jan\_Sep}$	0.7955
	$LogP_{Oct\_Dec}$	0.2682
	Constant	2.1814
$LogQ_{Feb\_Sep}$	$LogP_{Feb\_Sep}$	0.6428
	$LogP_{Oct\_Jan}$	0.3722
	Constant	2.2280
$LogQ_{Mar\_Sep}$	$LogP_{Mar\_Sep}$	0.4470
	$LogP_{Oct\_Feb}$	0.4554
	Constant	2.2954
$LogQ_{Apr\_Sep}$	$LogP_{Apr\_Sep}$	0.2219
	$LogP_{Oct\_Mar}$	0.5764
	Constant	2.2376
$LogQ_{May\_Sep}$	$LogQ_{Apr}$	0.2265
	$LogQ_{Oct\_Apr}$	0.3107
	Constant	1.4134
$LogQ_{Jun\_Sep}$	$LogQ_{May}$	0.2812
	$LogQ_{Oct\_May}$	0.2102
	Constant	1.4693

Folsom Unimpaired Seasonal Inflow Forecast Equations Based on Record of WY 1922-2001

Dependent Variable	Independent Variable	Coefficient
Q_{wy} (For Jan, Feb, Mar, Apr, and May)	P_{wy}^2	1.3454
	P_{wy}^3	-0.0066
$LogQ_{Jun\_Sep}$	$LogQ_{May}$	1.3878
	Constant	-1.2340

Note:

Q_{X_Sep} = Max(minimum of historical Q_{X_Sep} over period of record, Forecasted Q_{wy} – historical Q_{Oct_X-1})

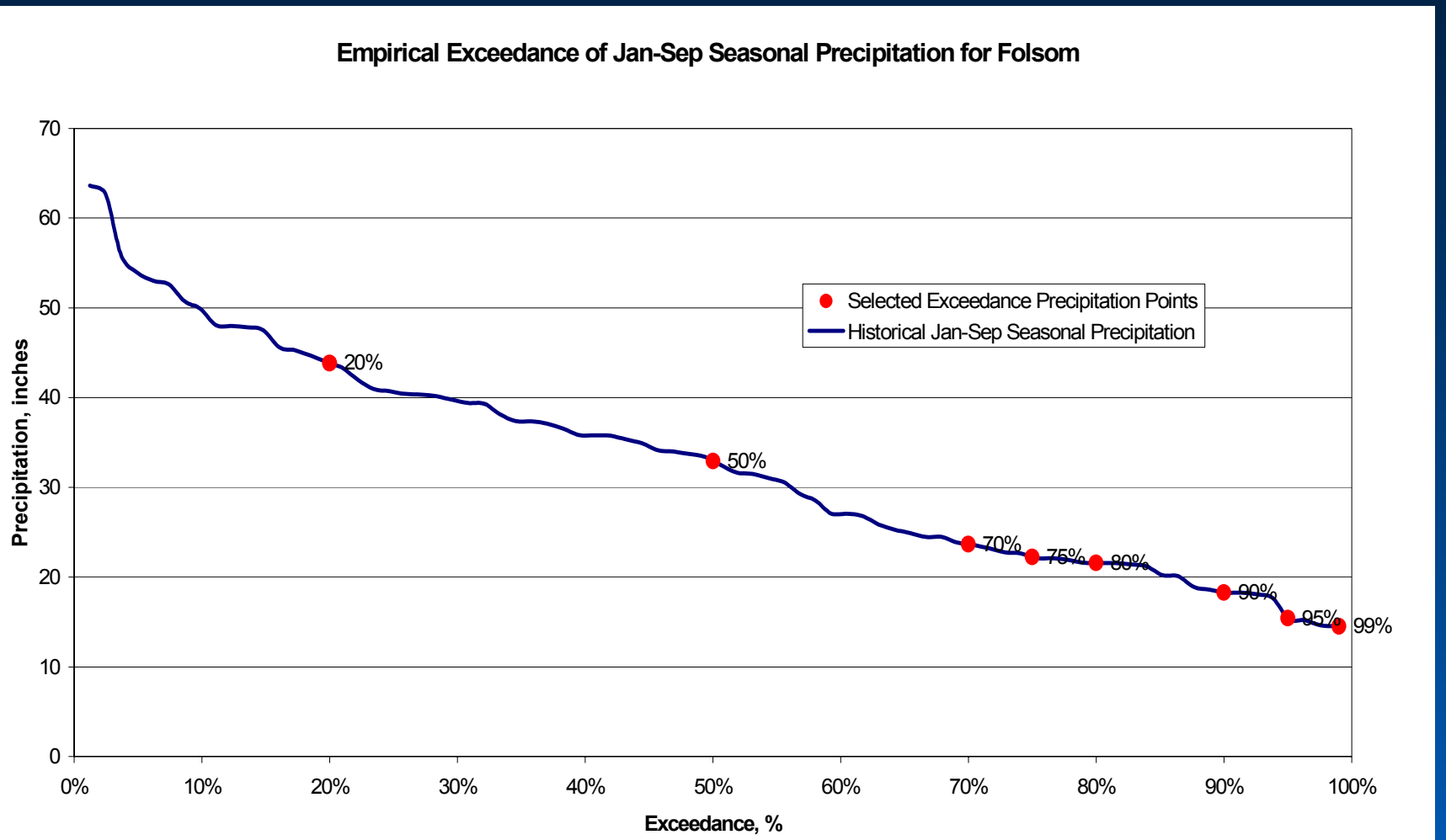
X = Jan, Feb, Mar, Apr, or May

Q_{wy} = Forecasted current water year total inflow, taf

P_{wy} = P_{Oct_X-1} + forecasted P_{X_Sep} at various exceedance levels

Estimate Seasonal Precipitation With Various Exceedance Levels

- Compute the basin average seasonal (Jan-Sep, Feb-Sep, ……, May-Sep) total precipitations from historical record.
- Determine the 99%, 95%, 90%, 75%, 50%, and 20% exceedance seasonal precipitations from the empirical frequency curves.


Empirical Exceedance of Jan-Sep Seasonal Precipitation for Folsom
Precipitation, inches
70
60
50
40
30
20
10
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Exceedance, %
Selected Exceedance Precipitation Points
Historical Jan-Sep Seasonal Precipitation
20%
50%
70%
75%
80%
90%
95%
99%

Oroville Unimpaired Seasonal Inflow Forecast Equations Based on Record of WY 1922-2001

Dependent Variable	Independent Variable	Coefficient
Q_{wy} (For Jan, Feb, Mar, Apr, and May)	Q_{wy-1}	0.0960
	P_{wy}^2	2.5375
	P_{wy}^3	-0.0138
$LogQ_{Jun\_Sep}$	$LogQ_{May}$	0.6575
	Constant	0.9936

Note:

Q_{X_Sep} = Max(minimum of historical Q_{X_Sep} over period of record, Forecasted Q_{wy} – historical Q_{Oct_X-1})

X = Jan, Feb, Mar, Apr, or May

Q_{wy} = Forecasted current water year total inflow, taf

Q_{wy-1} = Previous water year total inflow, taf

$P_{wy} = P_{Oct\_X-1}$ + forecasted P_{X_Sep} at various exceedance levels

Yuba River Unimpaired Seasonal Inflow Forecast EquationsBased on Record of WY 1922-2001

Dependent Variable	Independent Variable	Coefficient
Q_{wy} (For Jan, Feb, Mar, Apr, and May)	P_{wy}^2	0.8736
	P_{wy}^3	-0.0045
$LogQ_{Jun\_Sep}$	$LogQ_{May}$	1.1445
	Constant	-0.5320

Note:

Q_{X_Sep} = Max(minimum of historical Q_{X_Sep} over period of record, Forecasted Q_{wy} – historical Q_{Oct_X-1})

X = Jan, Feb, Mar, Apr, or May

Q_{wy} = Forecasted current water year total inflow, taf

P_{wy} = P_{Oct_X-1} + forecasted P_{X_Sep} at various exceedance levels

Trinity Unimpaired Seasonal Inflow Forecast Equations Based on Record of WY 1922-1998

Dependent Variable	Independent Variable	Coefficient	R^2
Q_{Jan_Sep}	Q_{Shasta,Jan_Sep}	0.2781	0.93
	Constant	-188.32	
Q_{Feb_Sep}	Q_{Shasta,Feb_Sep}	0.2947	0.91
	Constant	-176.88	
Q_{Mar_Sep}	Q_{Shasta,Mar_Sep}	0.3231	0.85
	Constant	-176.73	
Q_{Apr_Sep}	Q_{Shasta,Apr_Sep}	0.3808	0.81
	Constant	-206.87	
Q_{May_Sep}	Q_{Shasta,May_Sep}	0.5309	0.83
	Constant	-369.91	
Q_{Jun_Sep}	Q_{Shasta,Jun_Sep}	0.5664	0.78
	Constant	-371.00	

Whiskeytown Unimpaired Seasonal Inflow Forecast Equations Based on Record of WY 1922-1998

Dependent Variable	Independent Variable	Coefficient	R^2
Q_{Jan_Sep}	Q_{Shasta,Jan_Sep}	0.0870	0.86
	Constant	-165.79	
Q_{Feb_Sep}	Q_{Shasta,Feb_Sep}	0.0844	0.82
	Constant	-138.52	
Q_{Mar_Sep}	Q_{Shasta,Mar_Sep}	0.0766	0.80
	Constant	-101.67	
Q_{Apr_Sep}	Q_{Shasta,Apr_Sep}	0.0655	0.75
	Constant	-63.55	
Q_{May_Sep}	Q_{Shasta,May_Sep}	0.0592	0.67
	Constant	-46.73	
Q_{Jun_Sep}	Q_{May}	1.0169	0.56
	Constant	3.62	

Seasonal Inflow Monthly Disaggregation

- Several disaggregation methods such as back-cast monthly flow from annual inflow, simple regression from seasonal inflow, and multivariate regression from seasonal inflow are examined.
- The no-constant multivariate regression is adopted because it:
  - preserves the correlation between the seasonal total inflow and each individual month;
  - sums up disaggregated monthly inflows to the seasonal total inflow;
  - preserves the cross-correlation among different months' inflows.

Multivariate Regression Disaggregation

The form of multivariate regression is

$$\mathbf{Q}_{monthly} = \mathbf{B}Q_{seasonal} + \mathbf{e}$$

Where

$\mathbf{Q}_{monthly}$ is a nx1 matrix of monthly inflows;

$Q_{seasonal}$ is the seasonal total inflow;

B is a nx1 coefficient matrix;

e is a nx1 error matrix and E(**e**)=0;

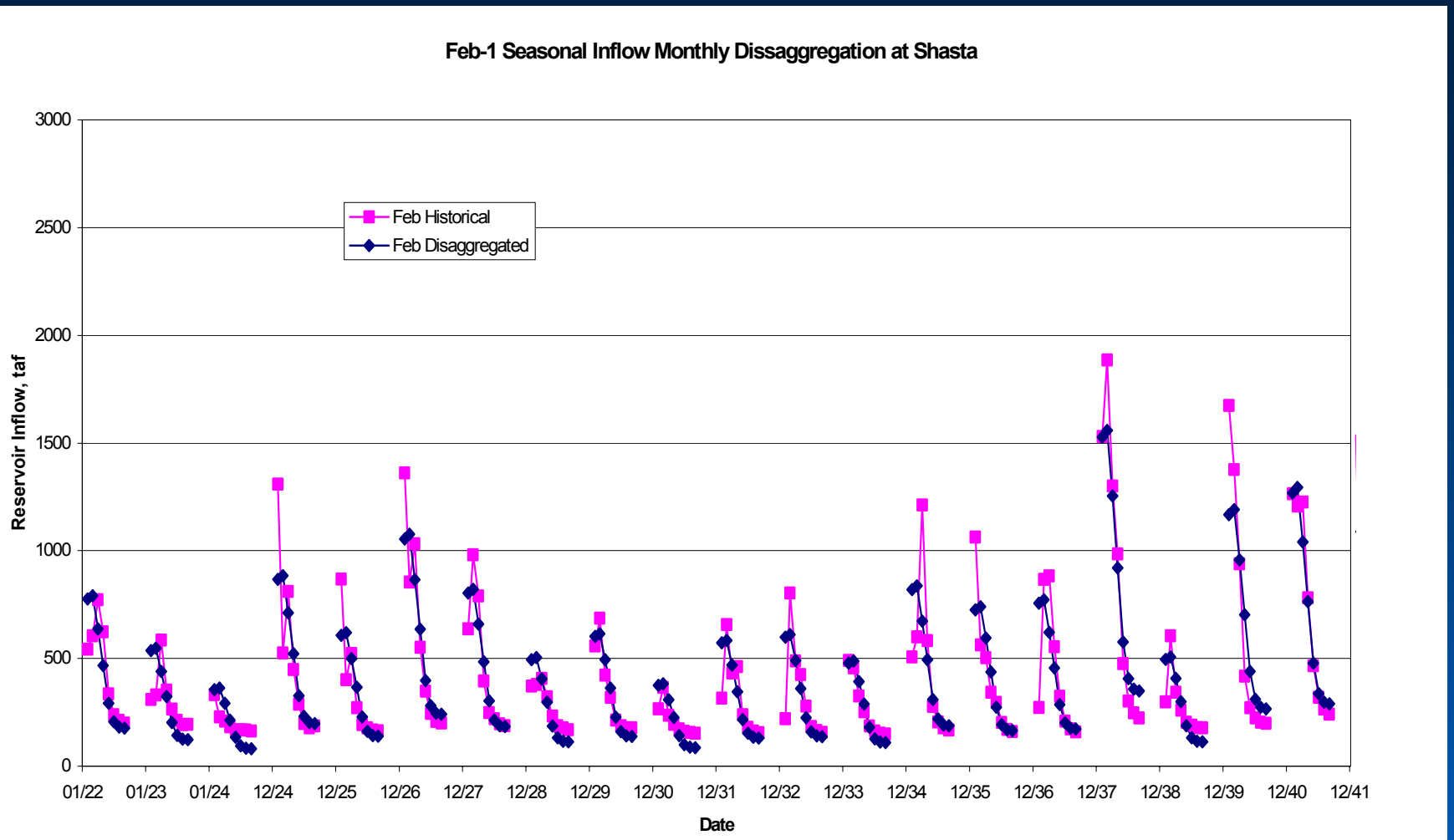
n is the number of months in the season ending at September.

Shasta Disaggregation Model

	Jan-1 Disaggregation			Feb-1 Disaggregation			Mar-1 Disaggregation		
Dep. Var.	Ind. Var	Coef.	"R^2"	Ind. Var	Coef.	"R^2"	Ind. Var	Coef.	"R^2"
Q_{Jan}	Q_{Jan_Sep}	0.1648	0.80						
Q_{Feb}		0.1833	0.88	Q_{Feb_Sep}	0.2199	0.89			
Q_{Mar}		0.1874	0.92		0.2244	0.93	Q_{Mar_Sep}	0.2877	0.94
Q_{Apr}		0.1505	0.92		0.1805	0.94		0.2315	0.95
Q_{May}		0.1106	0.95		0.1324	0.96		0.1700	0.97
Q_{Jun}		0.0694	0.95		0.0829	0.95		0.1062	0.96
Q_{Jul}		0.0490	0.96		0.0585	0.96		0.0748	0.97
Q_{Aug}		0.0430	0.94		0.0514	0.94		0.0657	0.95
Q_{Sep}		0.0420	0.93		0.0502	0.93		0.0641	0.94

Shasta Disaggregation Model (cont.)

	Apr-1 Disaggregation			May-1 Disaggregation			Jun-1 Disaggregation		
Dep. Var.	Ind. Var	Coef.	"R^2"	Ind. Var	Coef.	"R^2"	Ind. Var	Coef.	"R^2"
Q_{Jan}									
Q_{Feb}									
Q_{Mar}									
Q_{Apr}	Q_{Apr_Sep}	0.3255	0.96						
Q_{May}		0.2382	0.98	Q_{May_Sep}	0.3511	0.98			
Q_{Jun}		0.1491	0.97		0.2217	0.98	Q_{Jun_Sep}	0.3391	0.97
Q_{Jul}		0.1050	0.98		0.1558	0.99		0.2403	1.00
Q_{Aug}		0.0923	0.96		0.1373	0.97		0.2126	0.99
Q_{Sep}		0.0900	0.95		0.1341	0.96		0.2080	0.98


Feb-1 Seasonal Inflow Monthly Dissaggregation at Shasta
Feb Historical
Feb Disaggregated
Reservoir Inflow, taf
3000
2500
2000
1500
1000
500
0
01/22
01/23
01/24
12/24
12/25
12/26
12/27
12/28
12/29
12/30
12/31
12/32
12/33
12/34
12/35
12/36
12/37
12/38
12/39
12/40
12/41
Date

Summary of Unimpaired Monthly Inflow Forecast Procedure

Step 1

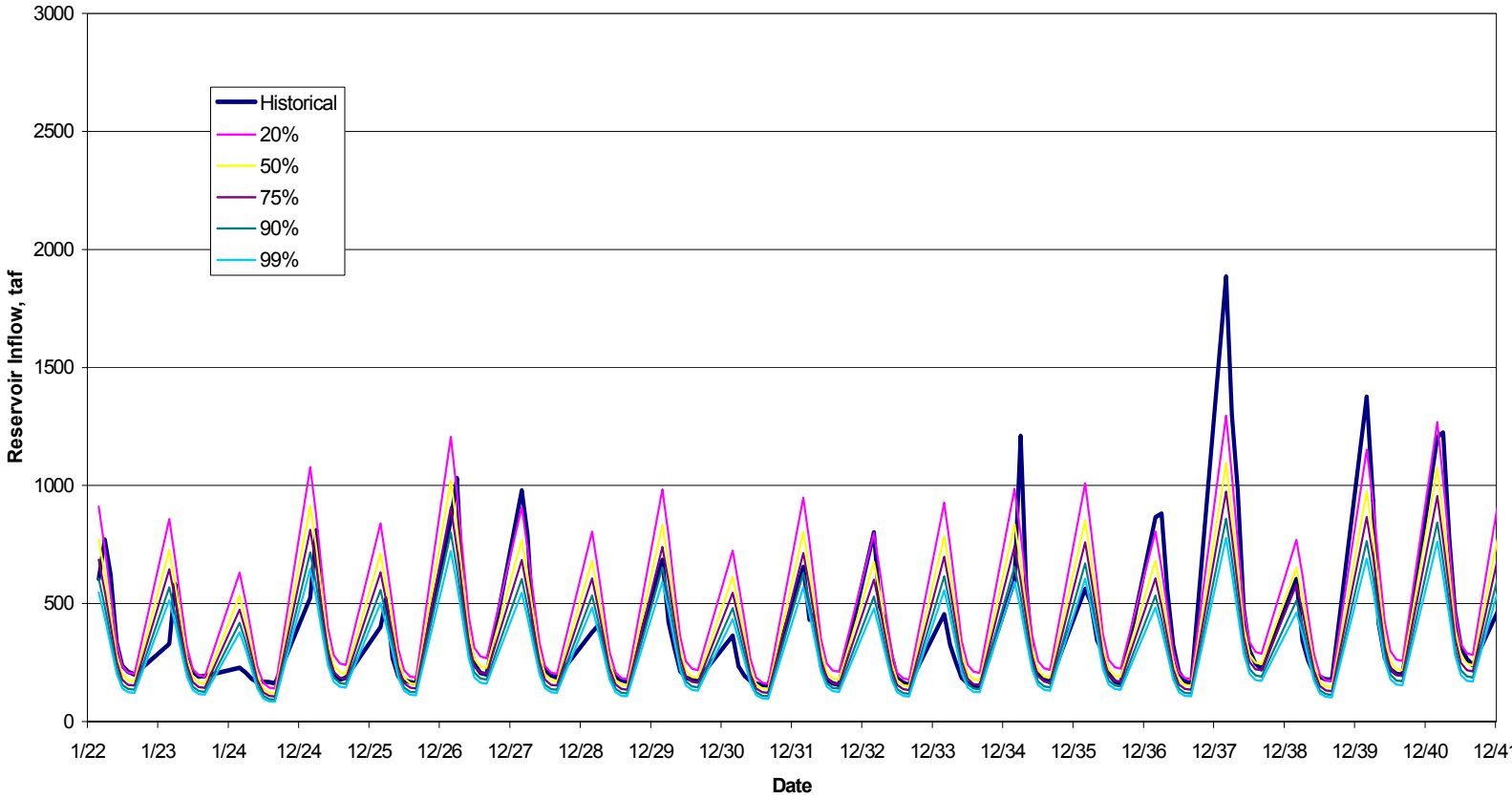
Determine empirical seasonal precipitations and/or its corresponding annual precipitation at various exceedance levels on forecasting dates of Jan1, Feb 1, …, and Jun 1.

Step 2

Make unimpaired seasonal inflow forecasts using the precipitations in step 1 and/or historical inflow record at each forecasting date using seasonal forecasting models.

Step 3

Disaggregate forecasted seasonal inflows into monthly inflows using the disaggregation models.


Mar-1 Forecasted Monthly Unimpaired Inflow to Shasta Reservoir
Reservoir Inflow, taf
3000
2500
2000
1500
1000
500
0
Historical
20%
50%
75%
90%
99%
1/22
1/23
1/24
12/24
12/25
12/26
12/27
12/28
12/29
12/30
12/31
12/32
12/33
12/34
12/35
12/36
12/37
12/38
12/39
12/40
12/41
Date

Where Our Forecast Stands?

Shasta Standard Errors* of Median Seasonal Forecasts by B120 and New Forecasting Models

Source	Jan-Sep	Feb-Sep	Mar-Sep	Apr-Sep	May-Sep	Jun-Sep
B120 Forecast**		1405	907	391	264	
New Forecast***	1552	1198	810	458	253	108

* Standard Error = $\{ \sum(Q_{Forecasted} - Q_{Measured})^2 / (n-2) \}^{0.5}$

** Based on forecasts of WY1970-01

*** Based on forecasts of WY1922-01

Shasta % Standard Errors* of Median Seasonal Forecasts by B120 and New Forecasting Models

Source	Jan-Sep	Feb-Sep	Mar-Sep	Apr-Sep	May-Sep	Jun-Sep
B120 Forecast**		35%	28%	18%	17%	
New Forecast***	34%	31%	27%	21%	17%	11%

* % Standard Error = (STE / Avg. Measured Inflow) * 100%

** Based on forecasts of WY1970-01

*** Based on forecasts of WY1922-01

Shasta Standard Errors* of Median Monthly Forecasts by B120 and New Forecasting Models

Forecast Date	Source	Feb	Mar	Apr	May	Jun	Jul	Aug+Sep
1-Feb	B120 Forecast**	504	594	244	213	148	54	71
	New Forecast***	461	414	284	189	112	50	86
1-Mar	B120 Forecast**		526	249	191	129	44	54
	New Forecast***		392	271	177	104	42	73
1-Apr	B120 Forecast**			207	156	119	42	56
	New Forecast***			249	160	96	37	70
1-May	B120 Forecast**				145	99	38	55
	New Forecast***				144	91	31	65

* Standard Error = $\{ \sum(Q_{Forecasted} - Q_{Measured})^2 / (n-2) \}^{0.5}$

** Based on forecasts of WY1970-01

*** Based on forecasts of WY1922-01

Shasta % Standard Errors* of Median Monthly Forecasts by B120 and New Forecasting Models

Forecast Date	Source	Feb	Mar	Apr	May	Jun	Jul	Aug+Sep
1-Feb	B120 Forecast**	59%	59%	38%	41%	43%	22%	16%
	New Forecast***	57%	49%	41%	37%	34%	21%	20%
1-Mar	B120 Forecast**		52%	38%	37%	38%	18%	12%
	New Forecast***		47%	39%	35%	32%	18%	17%
1-Apr	B120 Forecast**			32%	30%	35%	17%	12%
	New Forecast***			36%	31%	30%	15%	17%
1-May	B120 Forecast**				28%	29%	15%	12%
	New Forecast***				28%	28%	13%	15%

* % Standard Error = (STE / Avg. Measured Inflow) * 100%
** Based on forecasts of WY1970-01
*** Based on forecasts of WY1922-01

Folsom Standard Errors* of Median Seasonal Forecasts by B120 and New Forecasting Models

Source	Jan-Sep	Feb-Sep	Mar-Sep	Apr-Sep	May-Sep	Jun-Sep
B120 Forecast**		974	678	285	160	
New Forecast***	1023	816	625	377	276	159

* Standard Error = $\{ \sum(Q_{Forecasted} - Q_{Measured})^2 / (n-2) \}^{0.5}$

** Based on forecasts of WY1970-01

*** Based on forecasts of WY1922-01

Folsom % Standard Errors* of Median Seasonal Forecasts by B120 and New Forecasting Models

Source	Jan-Sep	Feb-Sep	Mar-Sep	Apr-Sep	May-Sep	Jun-Sep
B120 Forecast**		48%	41%	23%	19%	
New Forecast***	44%	40%	37%	29%	32%	43%

* % Standard Error = (STE / Avg. Measured Inflow) * 100%

** Based on forecasts of WY1970-01

*** Based on forecasts of WY1922-01

Folsom Standard Errors* of Median Monthly Forecasts by B120 and New Forecasting Models

Forecast Date	Source	Feb	Mar	Apr	May	Jun	Jul	Aug+Sep
1-Feb	B120 Forecast**	348	270	163	207	194	87	29
	New Forecast***	269	227	165	209	172	63	21
1-Mar	B120 Forecast**		250	180	171	164	79	28
	New Forecast***		225	166	191	163	62	21
1-Apr	B120 Forecast**			143	112	117	61	22
	New Forecast***			142	154	142	56	19
1-May	B120 Forecast**				107	77	54	20
	New Forecast***				157	119	49	18

* Standard Error = $\{ \sum(Q_{Forecasted} - Q_{Measured})^2 / (n-2) \}^{0.5}$
** Based on forecasts of WY1970-01
*** Based on forecasts of WY1922-01

Folsom % Standard Errors* of Median Monthly Forecasts by B120 and New Forecasting Models

Forecast Date	Source	Feb	Mar	Apr	May	Jun	Jul	Aug+Sep
1-Feb	B120 Forecast**	95%	60%	41%	45%	75%	117%	89%
	New Forecast***	81%	59%	38%	42%	64%	91%	71%
1-Mar	B120 Forecast**		56%	45%	37%	63%	106%	86%
	New Forecast***		58%	38%	38%	60%	90%	71%
1-Apr	B120 Forecast**			36%	24%	45%	83%	68%
	New Forecast***			32%	31%	52%	82%	65%
1-May	B120 Forecast**				23%	30%	72%	61%
	New Forecast***				32%	44%	70%	62%

* % Standard Error = (STE / Avg. Measured Inflow) * 100%
** Based on forecasts of WY1970-01
*** Based on forecasts of WY1922-01

Oroville Standard Errors* of Median Seasonal Forecasts by B120 and New Forecasting Models

Source	Jan-Sep	Feb-Sep	Mar-Sep	Apr-Sep	May-Sep	Jun-Sep
B120 Forecast**		1409	1034	435	275	
New Forecast***	1512	1143	870	484	327	151

* Standard Error = $\{ \sum(Q_{Forecasted} - Q_{Measured})^2 / (n-2) \}^{0.5}$

** Based on forecasts of WY1970-01

*** Based on forecasts of WY1922-01

Oroville % Standard Errors* of Median Seasonal Forecasts by B120 and New Forecasting Models

Source	Jan-Sep	Feb-Sep	Mar-Sep	Apr-Sep	May-Sep	Jun-Sep
B120 Forecast**		43%	38%	23%	22%	
New Forecast***	41%	35%	33%	24%	25%	22%

* % Standard Error = (STE / Avg. Measured Inflow) * 100%

** Based on forecasts of WY1970-01

*** Based on forecasts of WY1922-01

Oroville Standard Errors* of Median Monthly Forecasts by B120 and New Forecasting Models

Forecast Date	Source	Feb	Mar	Apr	May	Jun	Jul	Aug+Sep
1-Feb	B120 Forecast**	481	527	244	306	223	65	41
	New Forecast***	395	374	269	306	186	53	46
1-Mar	B120 Forecast**		500	249	265	190	66	35
	New Forecast***		371	263	272	172	52	52
1-Apr	B120 Forecast**			220	182	144	45	32
	New Forecast***			222	208	139	44	56
1-May	B120 Forecast**				165	106	42	32
	New Forecast***				196	113	42	64

* Standard Error = $\{ \sum(Q_{Forecasted} - Q_{Measured})^2 / (n-2) \}^{0.5}$
** Based on forecasts of WY1970-01
*** Based on forecasts of WY1922-01

Oroville % Standard Errors* of Median Monthly Forecasts by B120 and New Forecasting Models

Forecast Date	Source	Feb	Mar	Apr	May	Jun	Jul	Aug+Sep
1-Feb	B120 Forecast**	80%	65%	39%	51%	67%	42%	21%
	New Forecast***	70%	56%	39%	48%	56%	35%	24%
1-Mar	B120 Forecast**		62%	40%	44%	57%	42%	18%
	New Forecast***		56%	38%	43%	52%	34%	27%
1-Apr	B120 Forecast**			35%	30%	44%	29%	16%
	New Forecast***			32%	33%	42%	28%	29%
1-May	B120 Forecast**				27%	32%	27%	17%
	New Forecast***				31%	34%	27%	34%

* % Standard Error = (STE / Avg. Measured Inflow) * 100%
** Based on forecasts of WY1970-01
*** Based on forecasts of WY1922-01

Yuba Standard Errors* of Median Seasonal Forecasts by B120 and New Forecasting Models

Source	Jan-Sep	Feb-Sep	Mar-Sep	Apr-Sep	May-Sep	Jun-Sep
B120 Forecast**		725	521	240	136	
New Forecast***	775	632	488	330	249	127

* Standard Error = $\{ \sum(Q_{Forecasted} - Q_{Measured})^2 / (n-2) \}^{0.5}$

** Based on forecasts of WY1970-01

*** Based on forecasts of WY1922-01

Yuba % Standard Errors* of Median Seasonal Forecasts by B120 and New Forecasting Models

Source	Jan-Sep	Feb-Sep	Mar-Sep	Apr-Sep	May-Sep	Jun-Sep
B120 Forecast**		42%	37%	24%	20%	
New Forecast***	39%	37%	35%	30%	35%	41%

* % Standard Error = (STE / Avg. Measured Inflow) * 100%

** Based on forecasts of WY1970-01

*** Based on forecasts of WY1922-01

Yuba Standard Errors* of Median Monthly Forecasts by B120 and New Forecasting Models

Forecast Date	Source	Feb	Mar	Apr	May	Jun	Jul	Aug+Sep
1-Feb	B120 Forecast**	260	237	121	163	146	59	22
	New Forecast***	211	185	139	170	141	45	17
1-Mar	B120 Forecast**		224	144	149	117	56	17
	New Forecast***		180	143	158	133	44	17
1-Apr	B120 Forecast**			117	108	89	41	13
	New Forecast***			134	135	118	40	16
1-May	B120 Forecast**				100	57	35	13
	New Forecast***				145	104	36	16

* Standard Error = $\{ \sum(Q_{Forecasted} - Q_{Measured})^2 / (n-2) \}^{0.5}$

** Based on forecasts of WY1970-01

*** Based on forecasts of WY1922-01

Yuba % Standard Errors* of Median Monthly Forecasts by B120 and New Forecasting Models

Forecast Date	Source	Feb	Mar	Apr	May	Jun	Jul	Aug+Sep
1-Feb	B120 Forecast**	82%	61%	37%	43%	73%	96%	53%
	New Forecast***	71%	56%	38%	42%	67%	78%	40%
1-Mar	B120 Forecast**		58%	44%	39%	58%	90%	41%
	New Forecast***		54%	39%	39%	63%	77%	40%
1-Apr	B120 Forecast**			36%	29%	44%	66%	32%
	New Forecast***			37%	33%	56%	70%	37%
1-May	B120 Forecast**				27%	29%	57%	30%
	New Forecast***				36%	49%	63%	38%

* % Standard Error = (STE / Avg. Measured Inflow) * 100%
** Based on forecasts of WY1970-01
*** Based on forecasts of WY1922-01

Monthly Flow Impairment

- Basins with minor impairment or the impairment is handled directly by the model:

  Shasta, Trinity, Whiskeytown, and Sac Accretions above/below NCP
- Basins with significant impairment:

  Oroville, Folsom, and Yuba.

Impairment Above Oroville

- DWR O&M method is adopted in this study:

  $q_{R,t} = S_{t-1} - S_t$

  $q_{D,t}$ = fixed amount

  $q_{imp,t} = Q_{R,t} + Q_{D,t}$

  where

  $q_{R,t}$ is the impairment due to major reservoir operations in month t;

  $q_{D,t}$ is the impairment due to minor reservoir operations and diversions in month t;

  $q_{imp,t}$ is the basin total impairment

  S_{t-1} and S_t are previous and current months' reservoir storages

Impairment Above Oroville
(Continued)

- Exceedance levels of impairment are determined by empirical frequency curve of historical seasonal (from forecasting dates to Sept.) unimpaired inflows to Oroville Reservoir.

- Impaired inflow forecast:

$$Q_{imp,p,t} = Q_{p,t} + q_{imp,p,t}$$

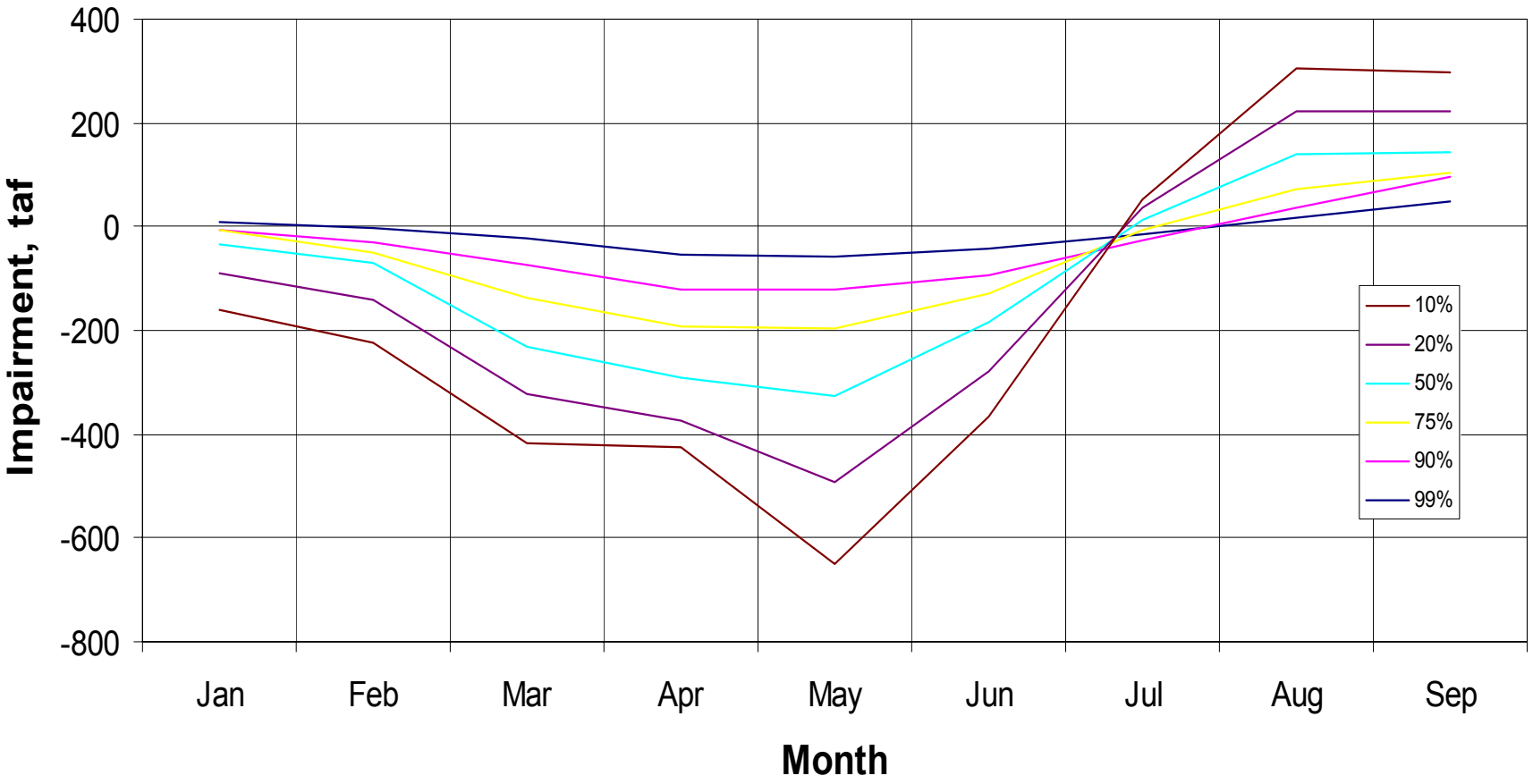
where

$Q_{imp,p,t}$ is the forecasted impaired inflow with exceedance p in month t

$Q_{p,t}$ is the forecasted unimpaired inflow with exceedance p in month t

$q_{imp,p,t}$ is the estimated impairment with exceedance p in month t.

Jan - Sep Projected Impairment Above Oroville



Impairment Above Folsom

- USBR developed a multiple regression equation to estimate the monthly impairment in their operation:

  $q_{imp,t} = f(S_{1,t},S_{1,t-1},S_{2,t},S_{2,t-1},\ldots,S_{5,t},S_{5,t-1})$

  where

  $q_{imp,t}$ is monthly impairment above Folsom in month t

  $S_{i,t},S_{i,t-1}$ are storages of reservoir i in months t and t-1

  i = 1, 2, …, and 5, representing upstream reservoirs.

- USBR regression equation can not be applied to CAM due to the limited storage record lengths of upstream reservoirs.

Impairment Above Folsom
(Continued)

- Method developed for this study:

$$q_{imp,t} = Q_{FNF,t} - Q_{Gaged,t}$$

where

$q_{imp,t}$ is the impairment above Folsom in month t

$Q_{FNF,t}$ is the full natural flow (FNF) or unimpaired inflow to Folsom in month t

$Q_{Gaged,t}$ is the computed (impaired) inflow to Folsom in month t

Impairment Above Folsom
(Continued)

- Exceedance levels of impairment are determined by empirical frequency curve of historical seasonal (from forecasting dates to Sept.) unimpaired inflows into Folsom Lake.

- Impaired inflow forecast:

$$Q_{imp,p,t} = Q_{p,t} - q_{imp,p,t}$$

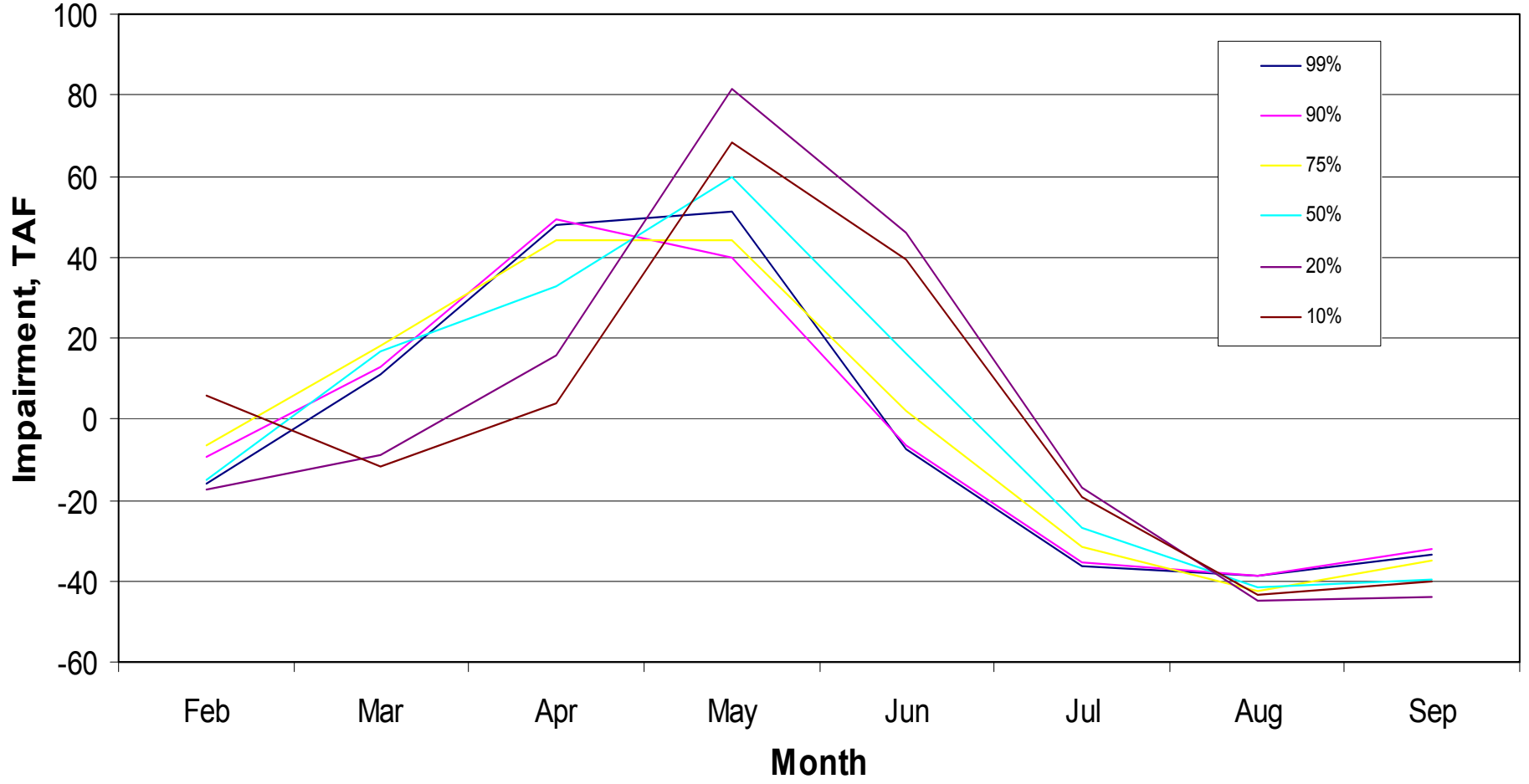
where

$Q_{imp,p,t}$ is the forecasted impaired inflow with exceedance p in month t

$Q_{p,t}$ is the forecasted unimpaired inflow with exceedance p in month t

$q_{imp,p,t}$ is the estimated impairment with exceedance p in month t

Feb - Sep Projected Impairment Above Folsom



Impairment of Yuba River

- No known impairment method is available
- Method developed for this study:

$$q_{imp,t} = Q_{FNF,t} - Q_{Gaged,t} - Q_{Dry,t}$$

where

$q_{imp,t}$ is the impairment of Yuba River in month t

$Q_{FNF,t}$ is the full natural flow (FNF) or unimpaired flow of Yuba River in month t

$Q_{Gaged,t}$ is the gaged (impaired) flow of Yuba River in month t

$Q_{Dry,t}$ is Dry Creek inflow downstream of Smartville in month t

Impairment of Yuba River
(Continued)

- Exceedance levels of impairment are determined by empirical frequency curve of historical seasonal (from forecasting dates to Sept.) unimpaired flows of Yuba River near Smartville.

- Impaired inflow forecast:

$$Q_{imp,p,t} = Q_{p,t} - q_{imp,p,t}$$

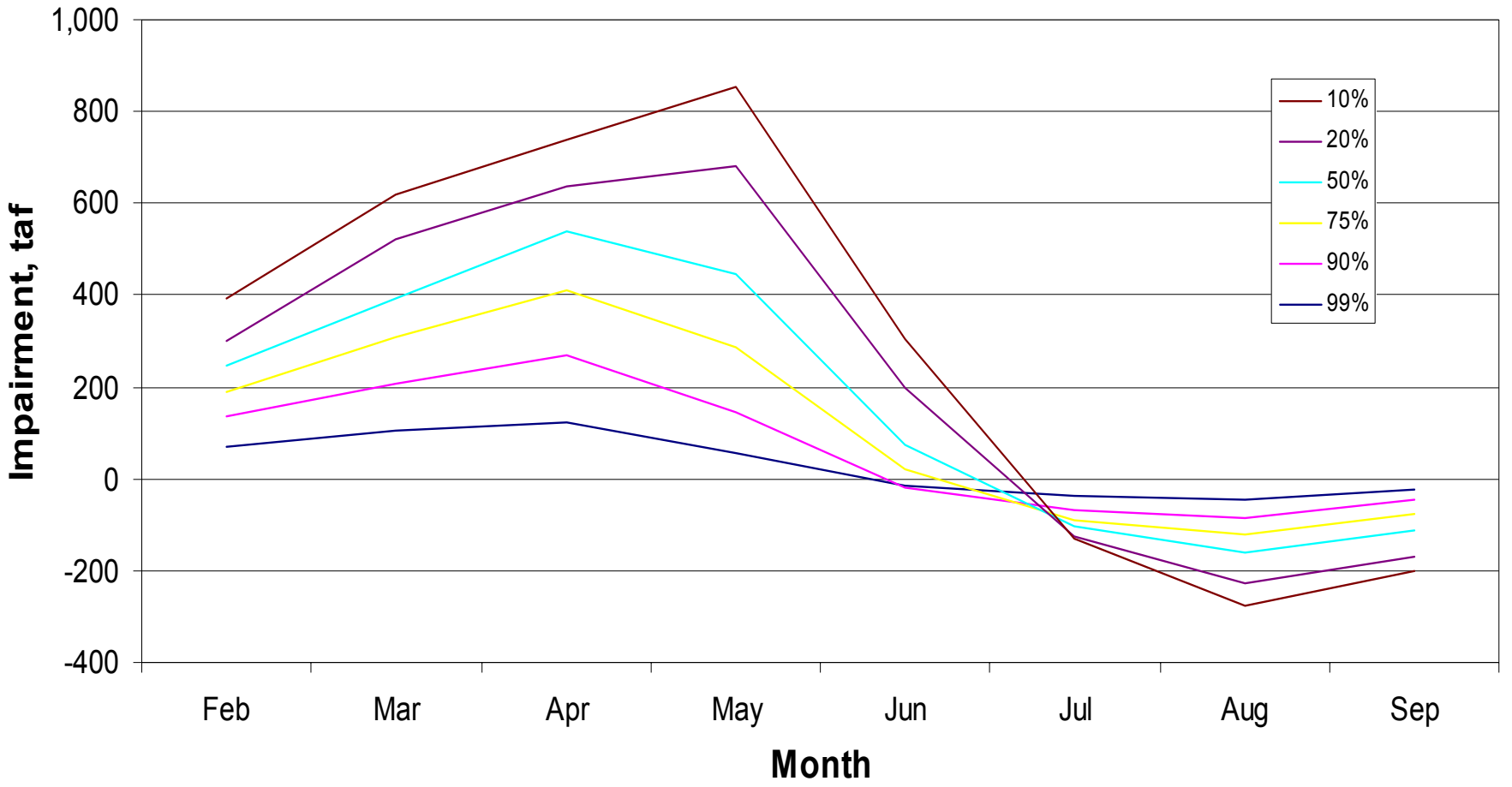
where

$Q_{imp,p,t}$ is the forecasted impaired inflow with exceedance p in month t

$Q_{p,t}$ is the forecasted unimpaired inflow with exceedance p in month t

$q_{imp,p,t}$ is the estimated impairment with exceedance p in month t

Feb - Sep Projected Impairment at Yuba River

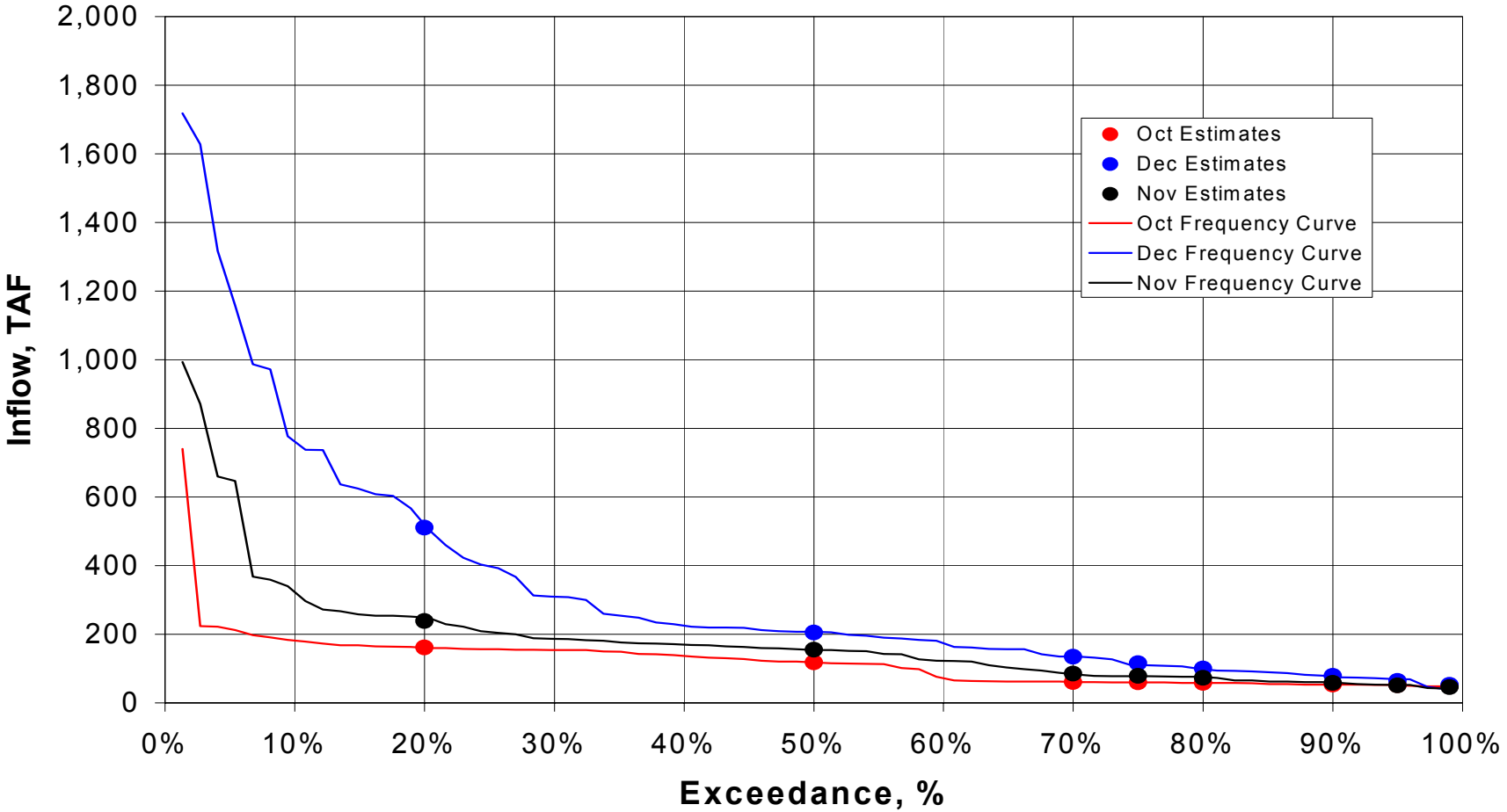


Oct, Nov, and Dec Impaired Inflow Forecast

- Current operation: Inflow estimates for Oct, Nov, and Dec at certain exceedance levels are made from empirical monthly frequency curves.
- This forecast study: The same procedure in the current operation is applied and inflow estimates are made at various (including 75%) exceedance levels CAM needs.

Oct, Nov, and Dec Oroville Impaired Inflow Estimation

(Based on WY 1922-94 gaged record)



Future Studies

- Develop forecasts for:
  - San Joaquin River
  - Eastside Streams
  - Bear River
  - Stony Creek
- Revise Forecasts for:
  - Sac Accretions Above NCP
  - Sac Accretions Above NCP

Questions?

More Information

ftp://ftpmodeling.water.ca.gov/hydro/pub/CAM/