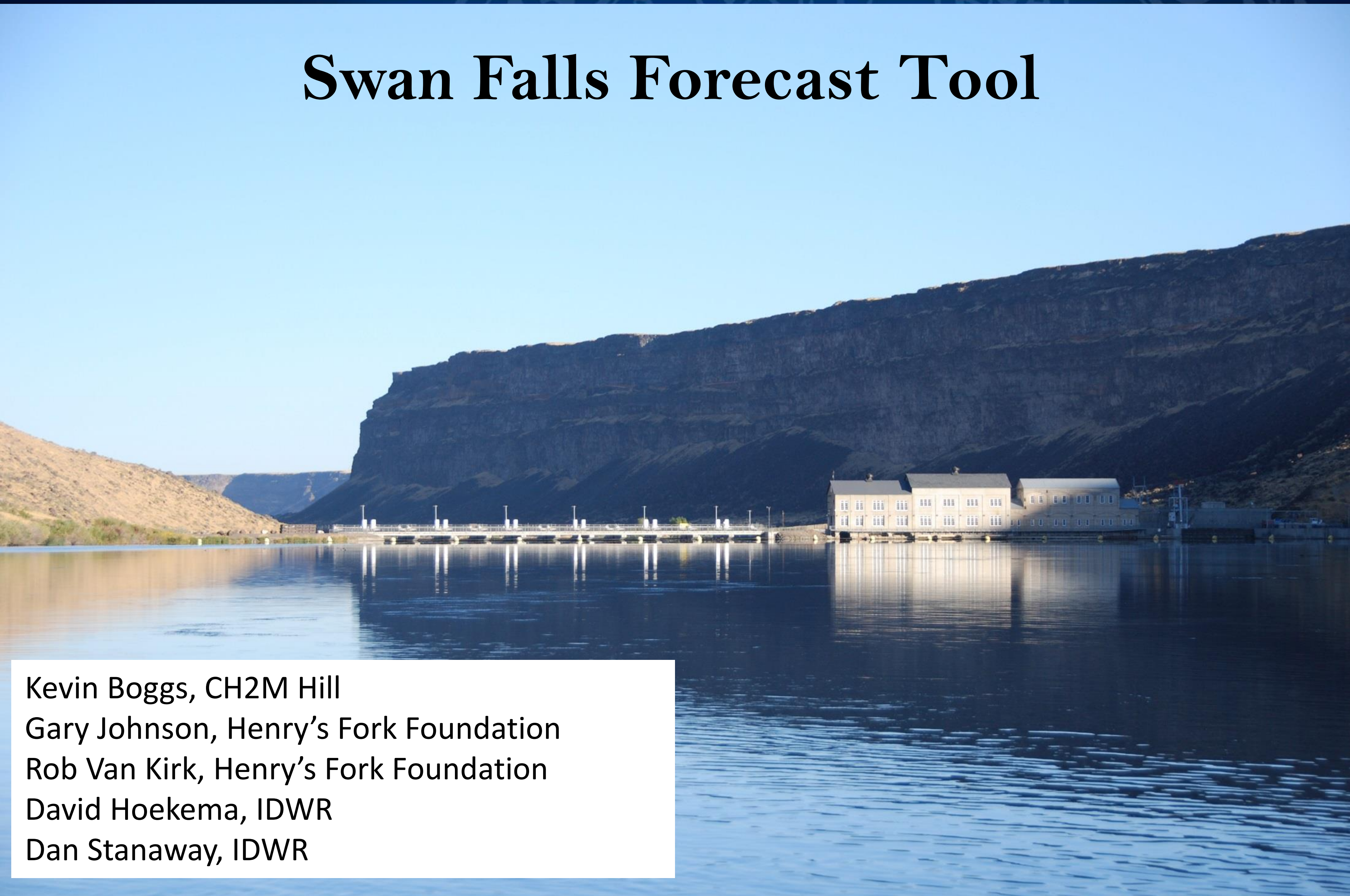
Swan Falls Forecast Tool



Kevin Boggs, CH2M Hill
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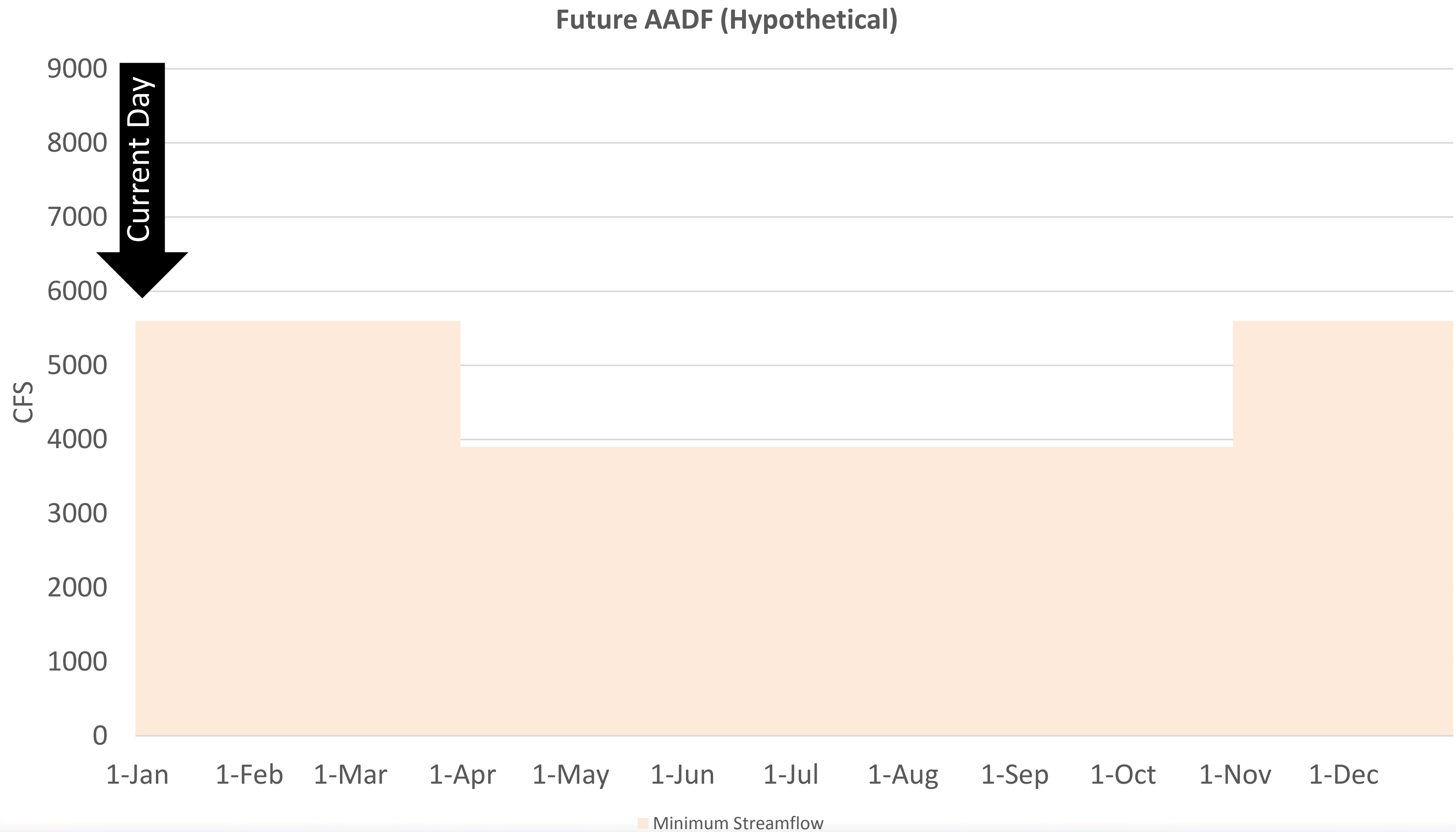
Future AADF
Minimum Streamflow

Outline

- Goals and Definitions
- Forecast Components
  1. Kimberly to King Hill ESPA Discharge
  2. Consumptive Demand
  3. Tributary and Return Flow
- Validation Results (2003 – 2016)
  – Preliminary
- January Forecast 2017
  – Preliminary

Goal: Forecast the AADF during the critical low streamflow period. Forecasts are produced twice annually, January and April.



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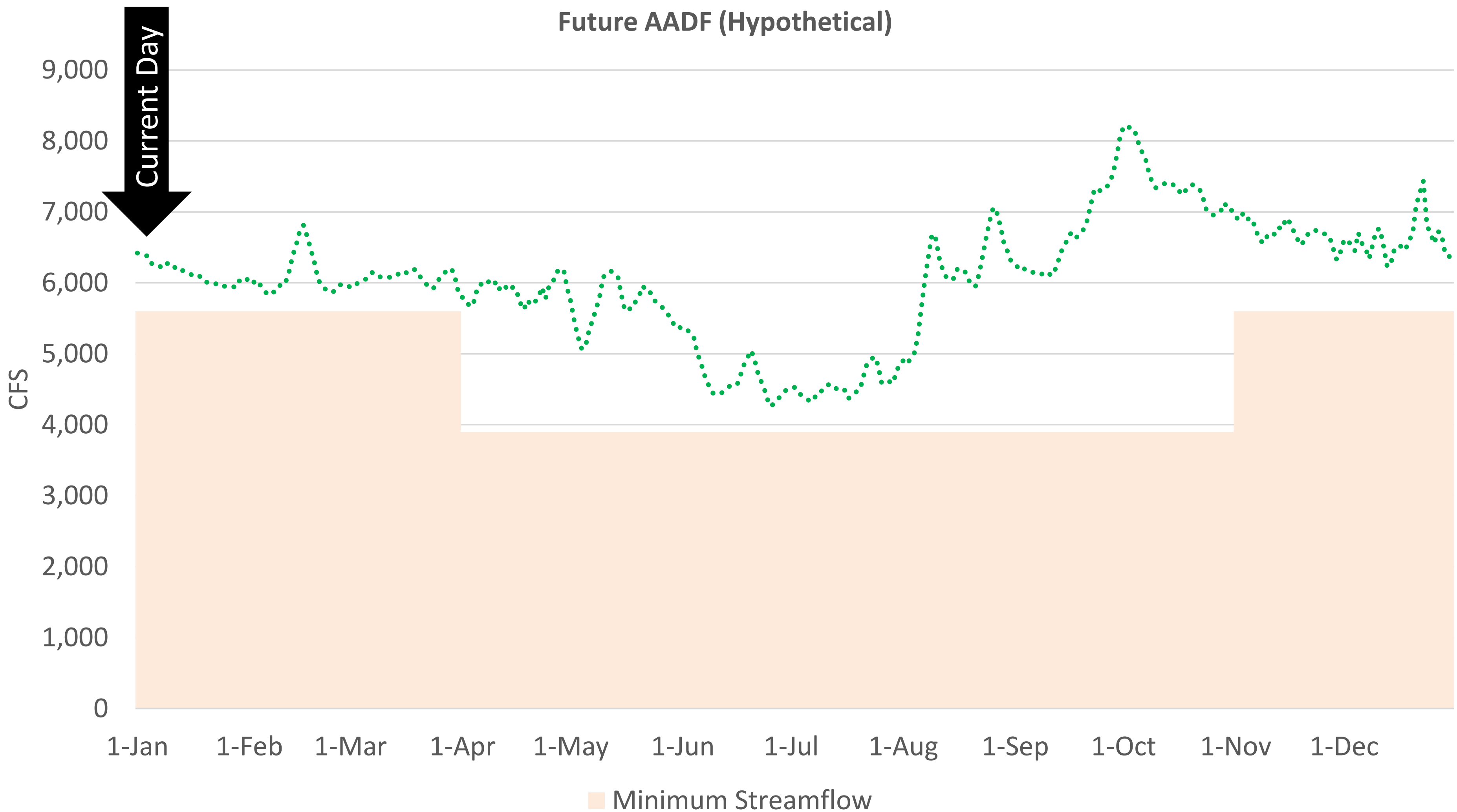

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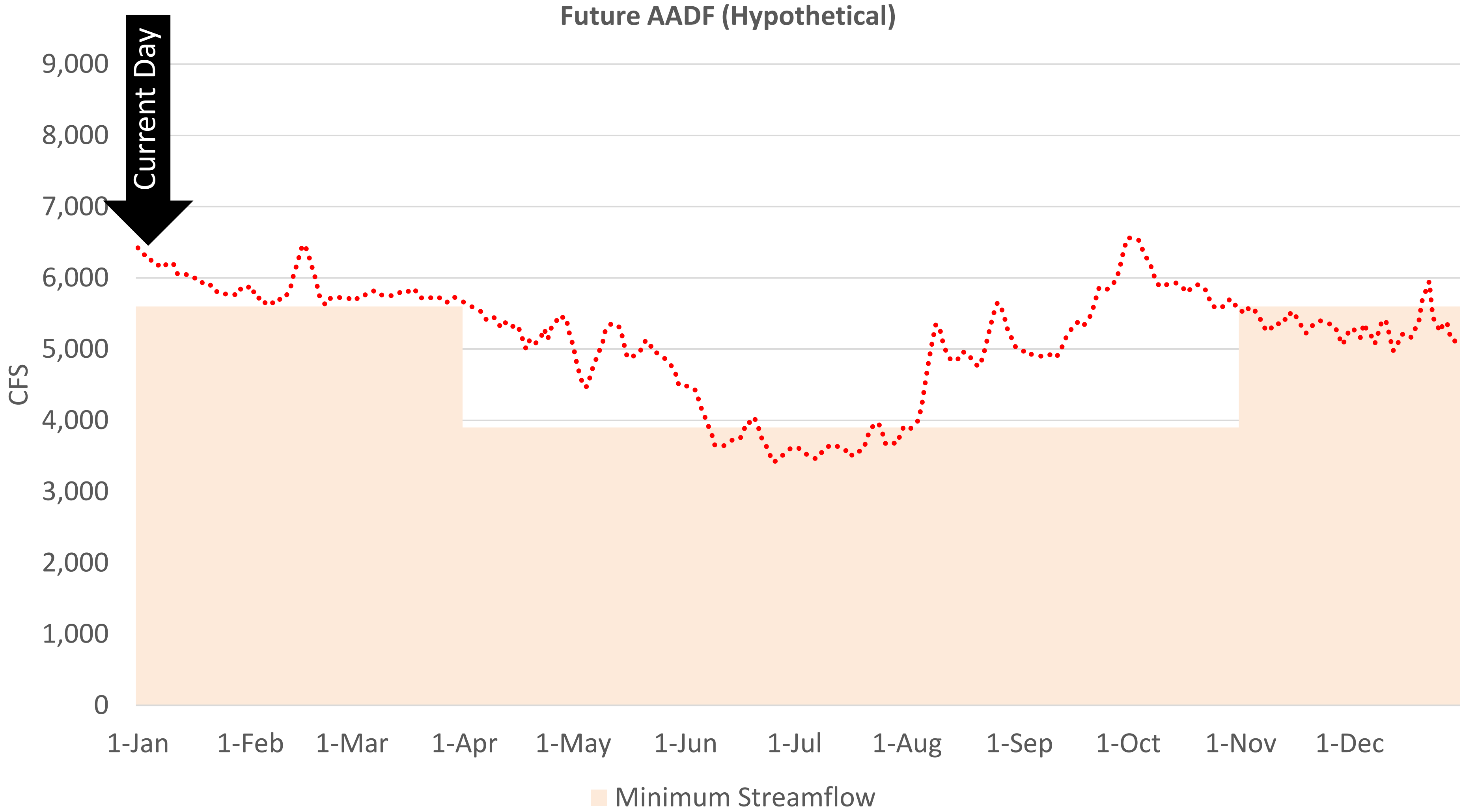

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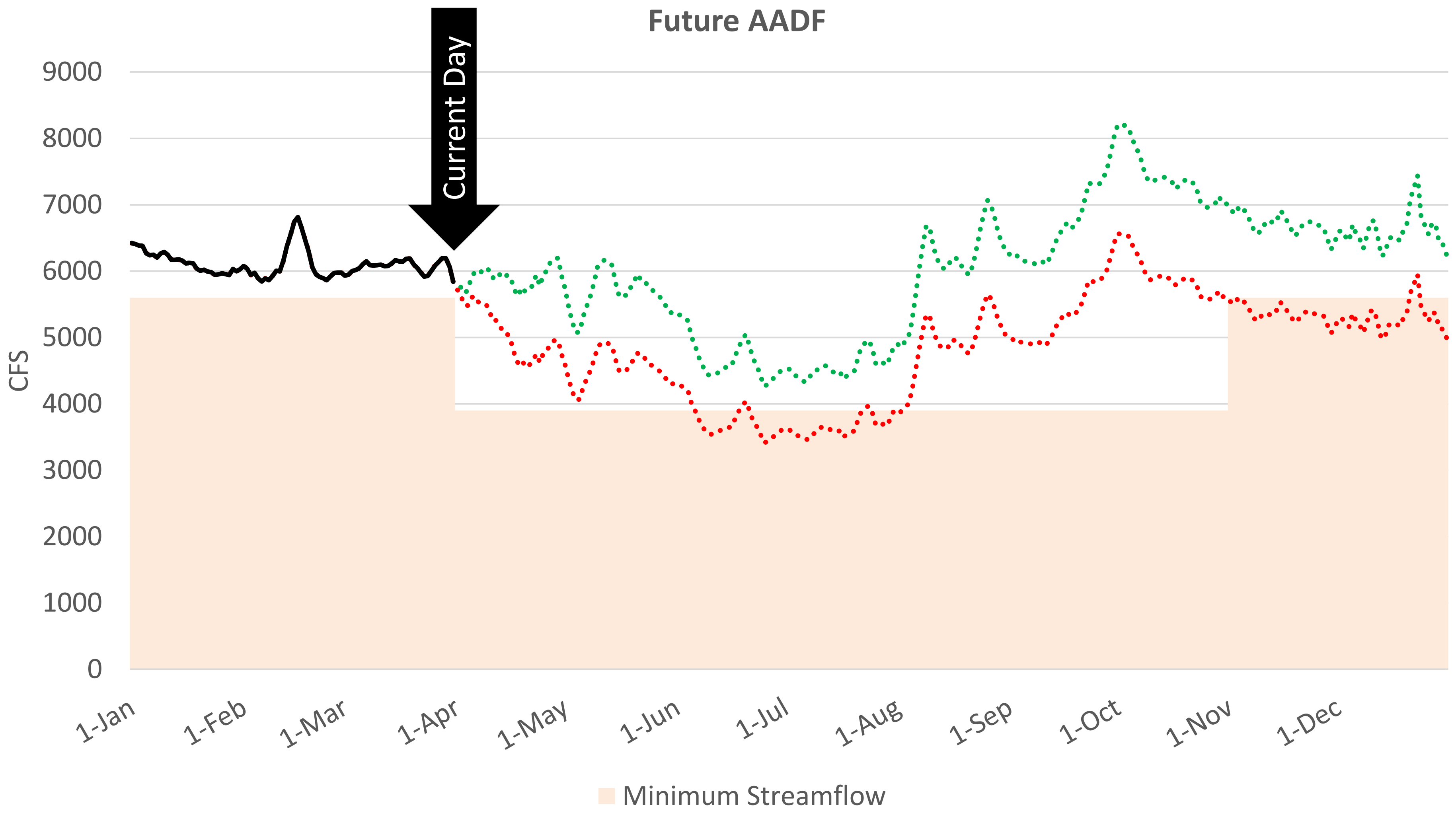

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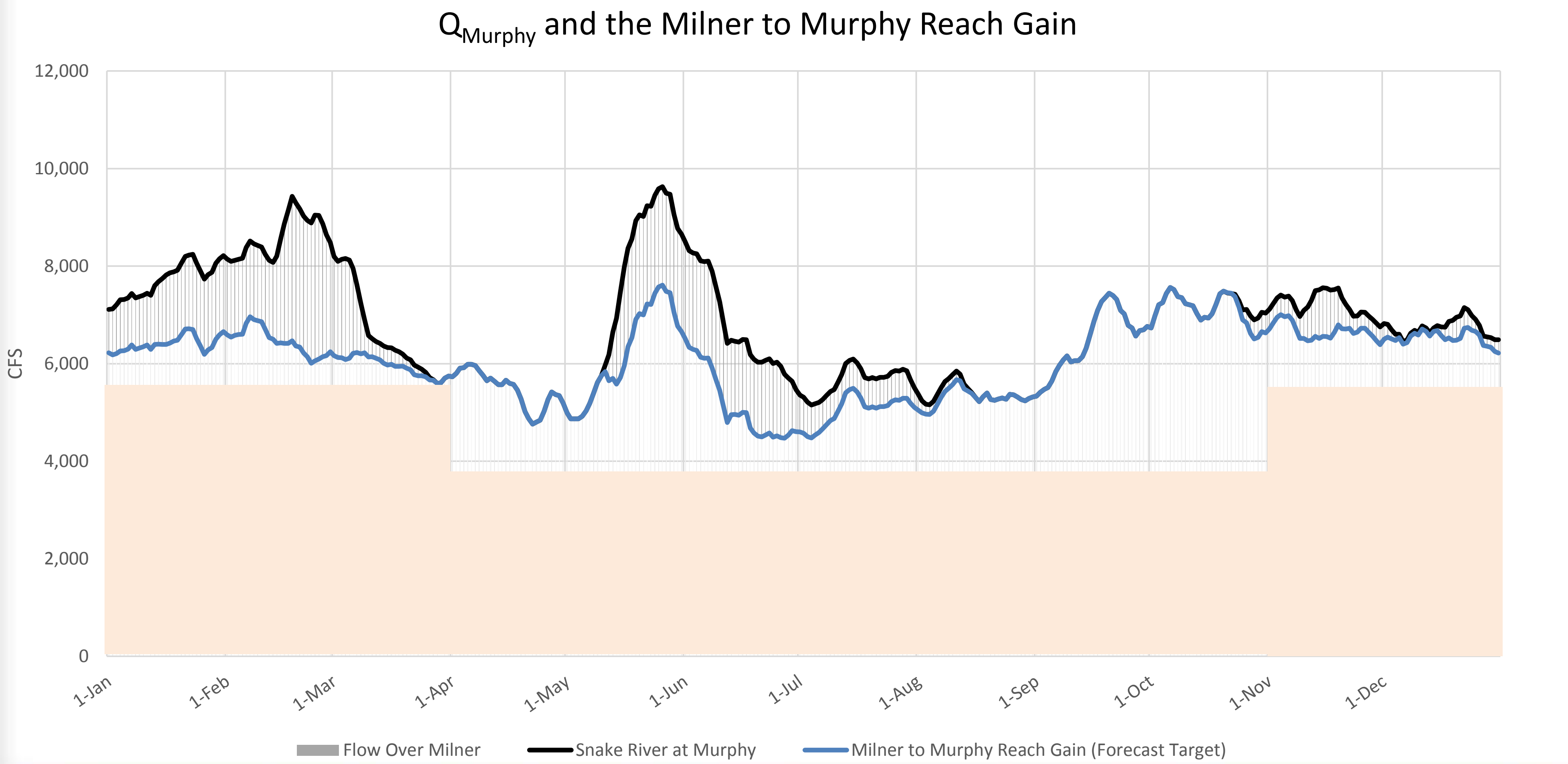
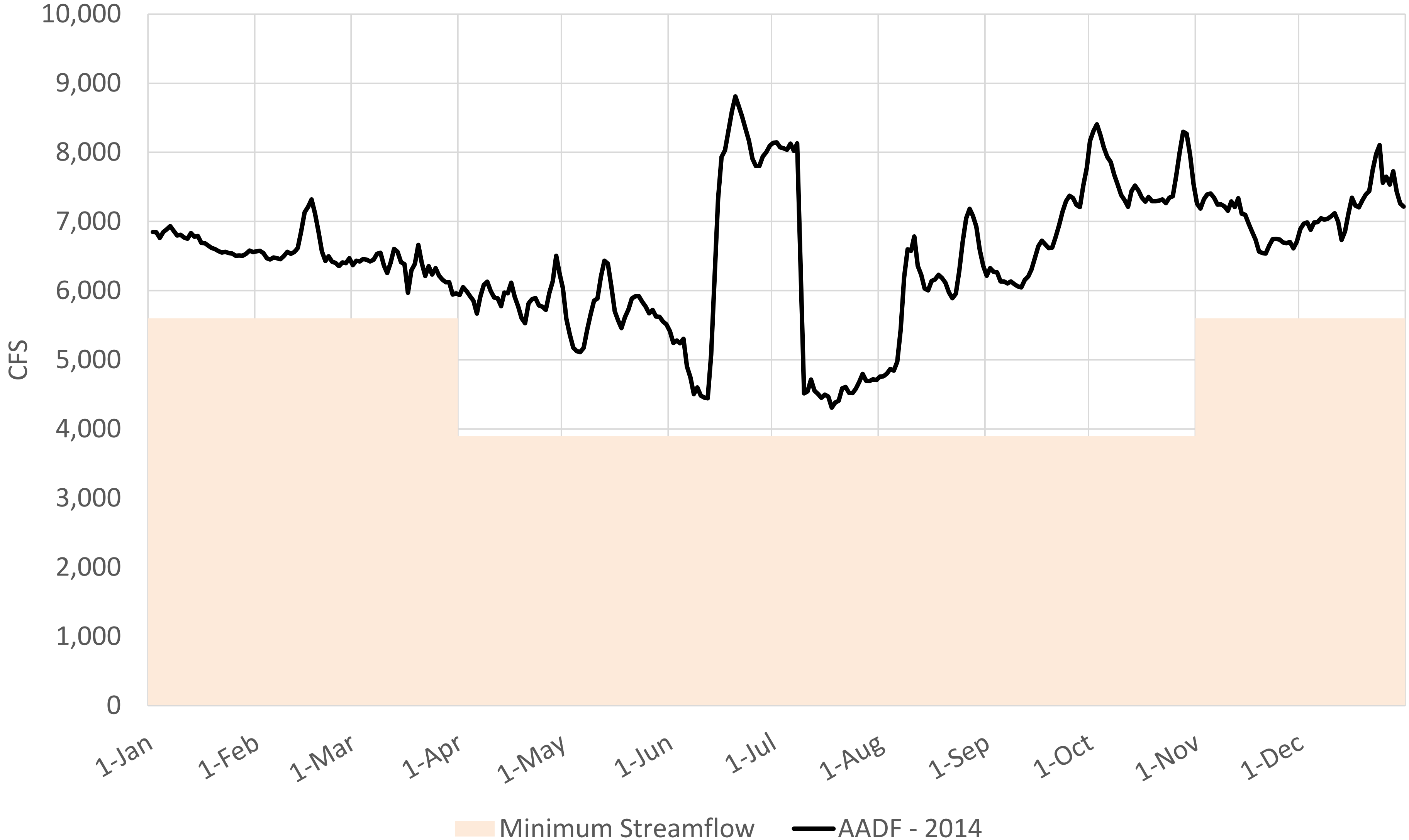
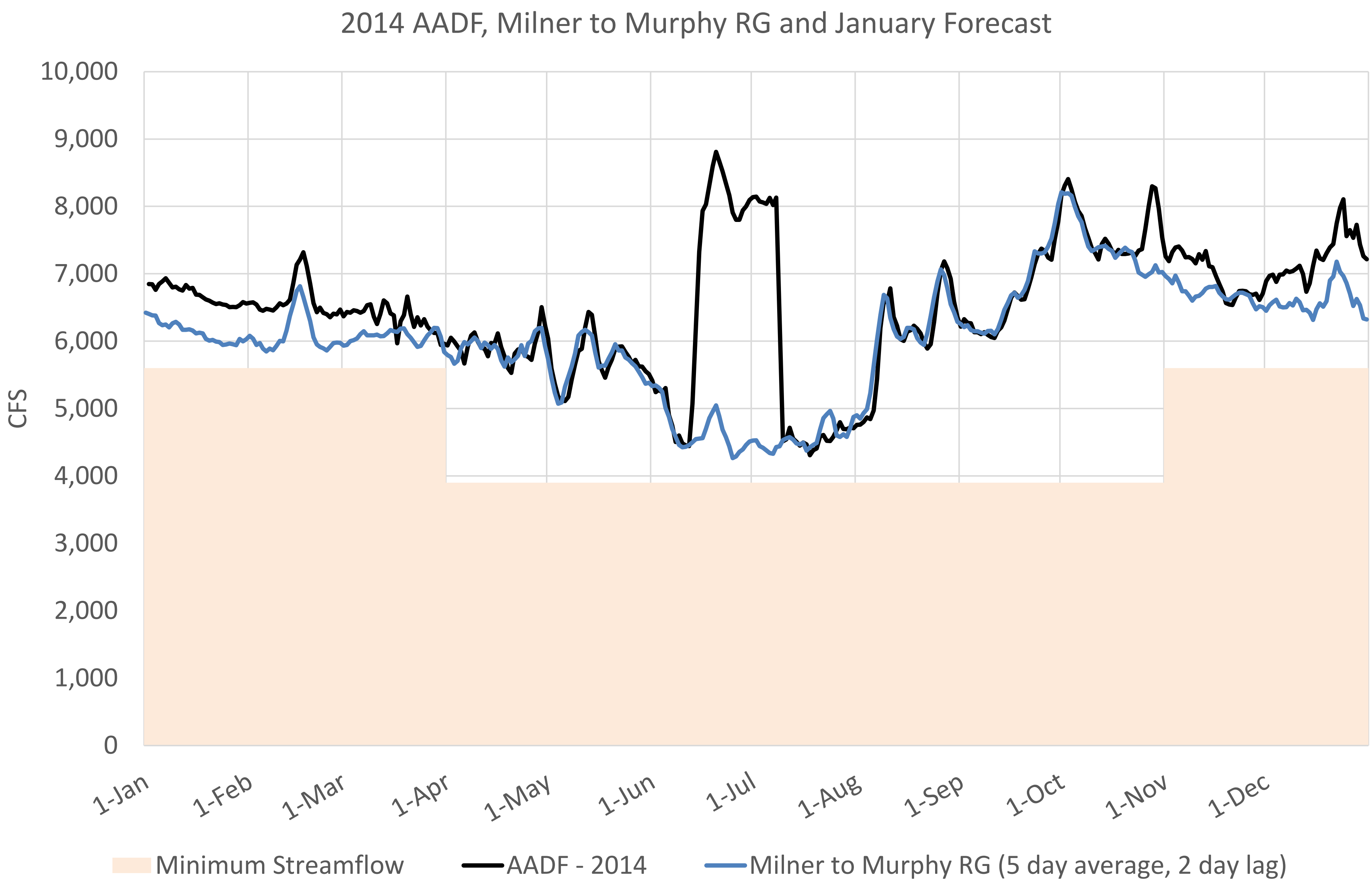
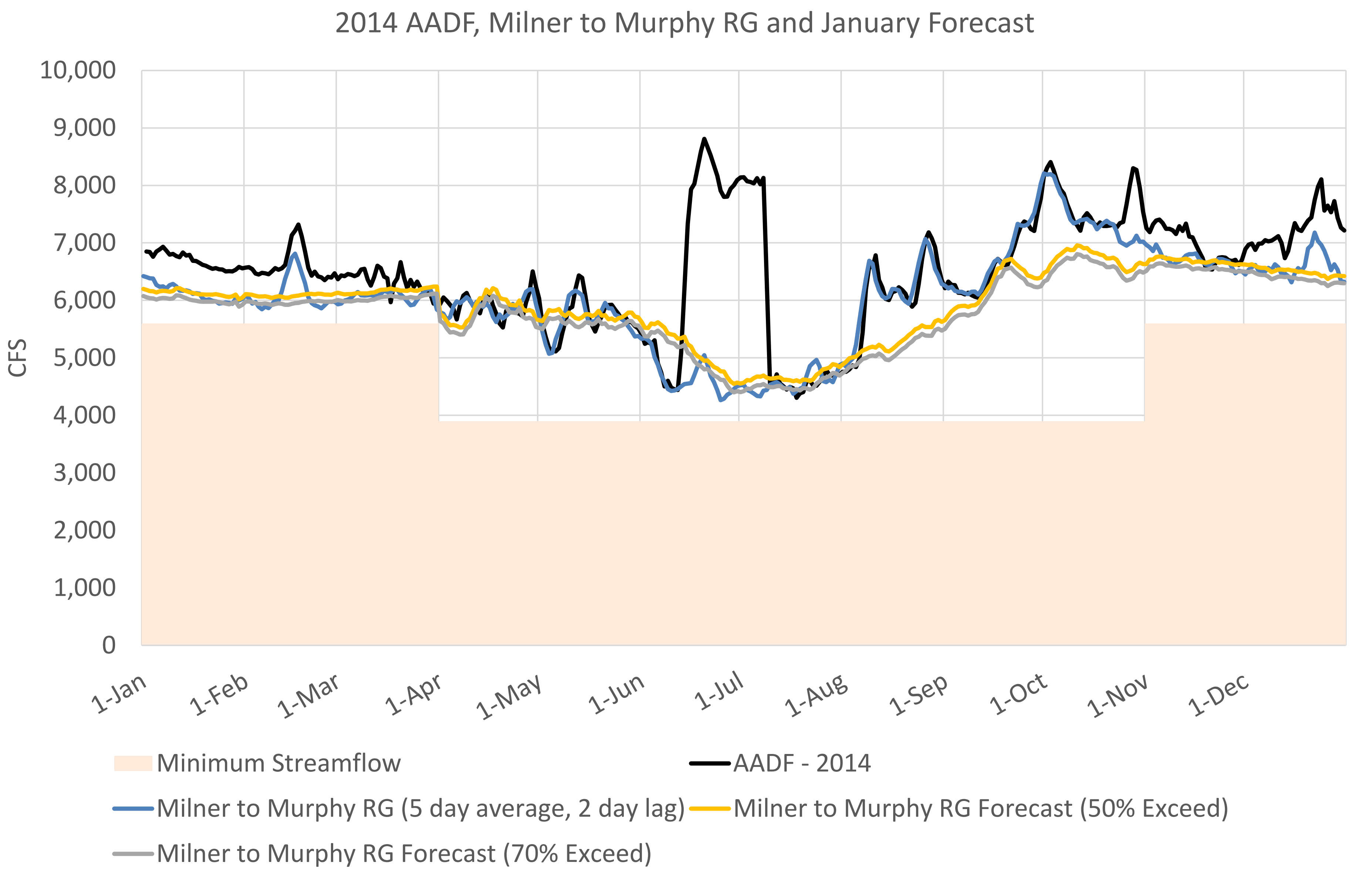
The Swan Falls Forecast Tool predicts the reach gain from Milner to Murphy. This is equivalent to the AADF when no flow is passing Milner.



2014 AADF, Milner to Murphy RG and January Forecast



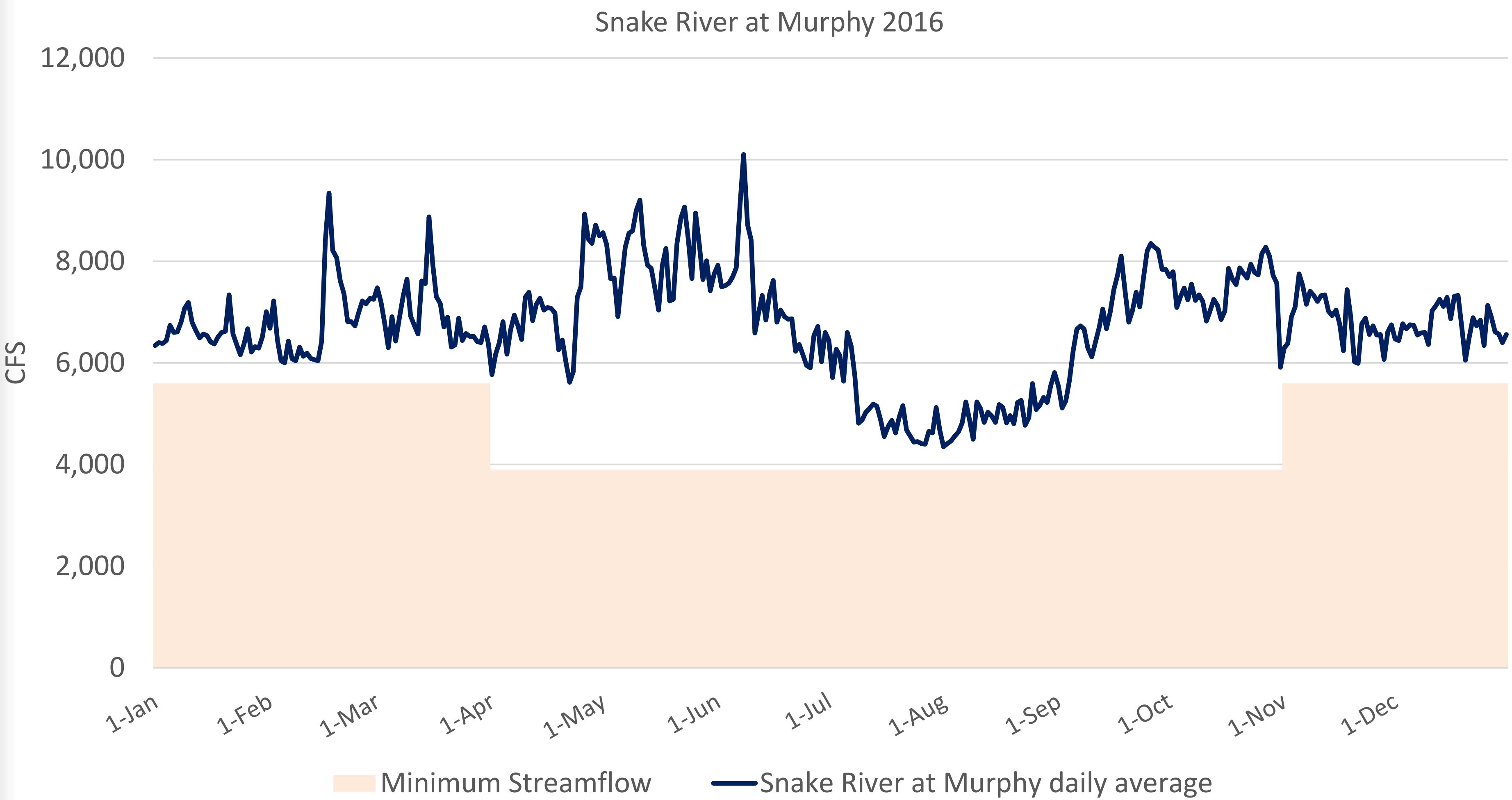

2014 AADF, Milner to Murphy RG and January Forecast
CFS
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
Minimum Streamflow
AADF - 2014
Milner to Murphy RG (5 day average, 2 day lag)


2014 AADF, Milner to Murphy RG and January Forecast
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
CFS
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
Minimum Streamflow
AADF - 2014
Milner to Murphy RG (5 day average, 2 day lag)
Milner to Murphy RG Forecast (50% Exceed)
Milner to Murphy RG Forecast (70% Exceed)

II. Forecast Components

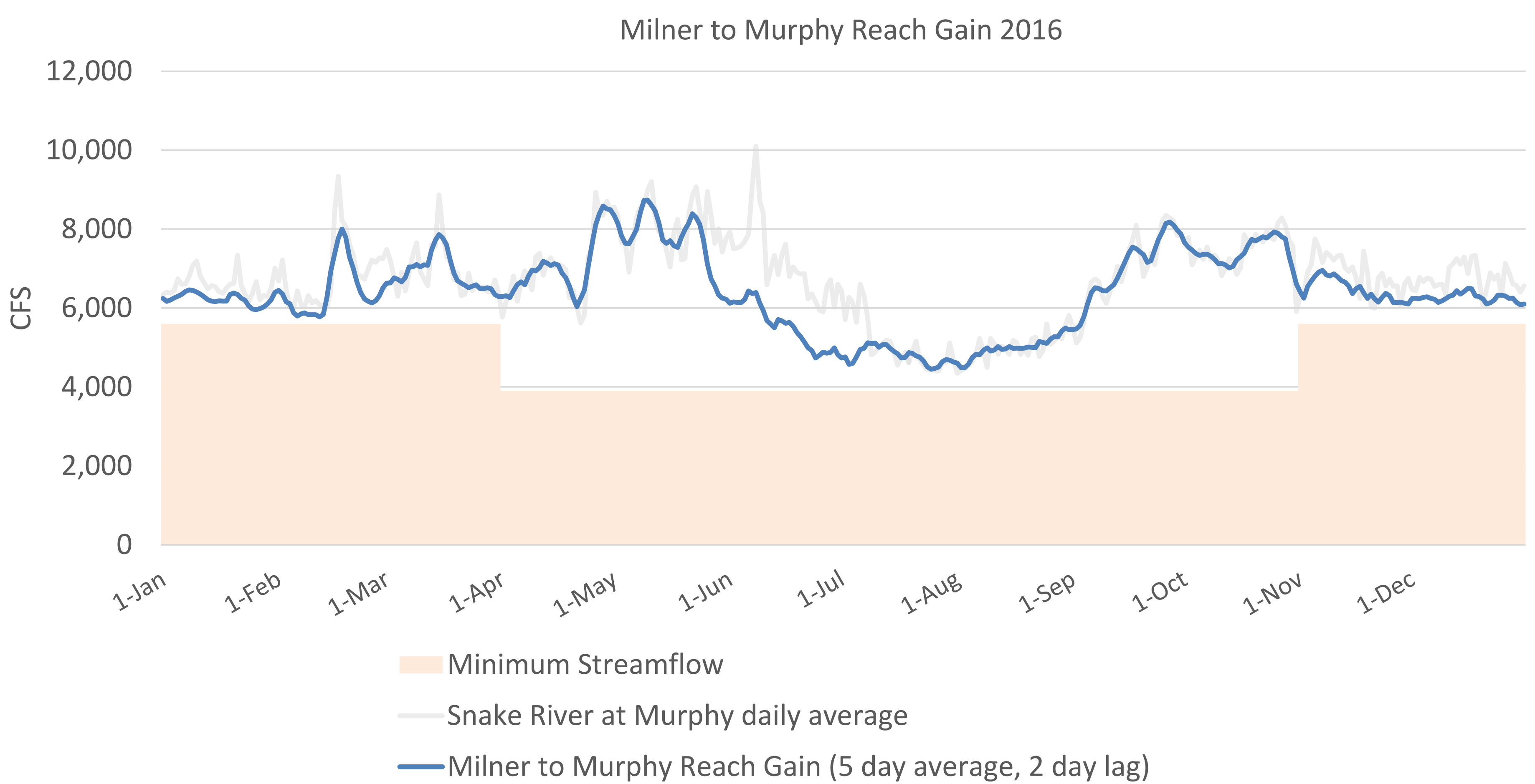
- Overview via hydrograph
- Components
  1. Kimberly to King Hill ESPA discharge
  2. Consumptive Demand
  3. Tributary and Return Flow

$$Q_{\text{Snake River at Murphy}} = Q_{\text{Snake River at Milner}} + Q_{\text{ESPA}} - ET_{\text{Crop}} + Q_{\text{Trib \& Returns}}$$

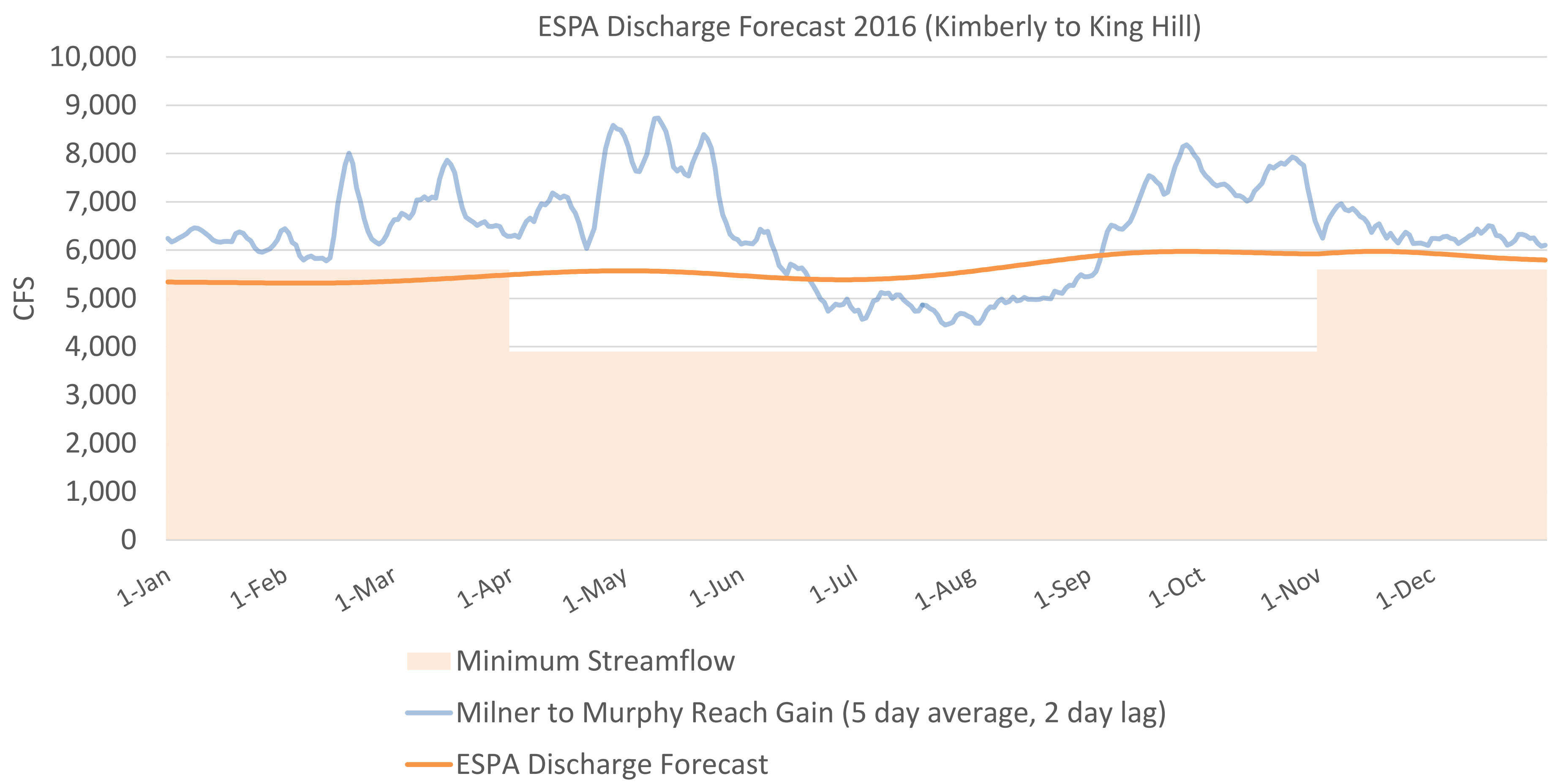


$$Q_{\text{Snake River at Murphy}} - Q_{\text{Snake River at Milner}} = Q_{ESPA} - ET_{Crop} + Q_{\text{Trib \& Returns}}$$

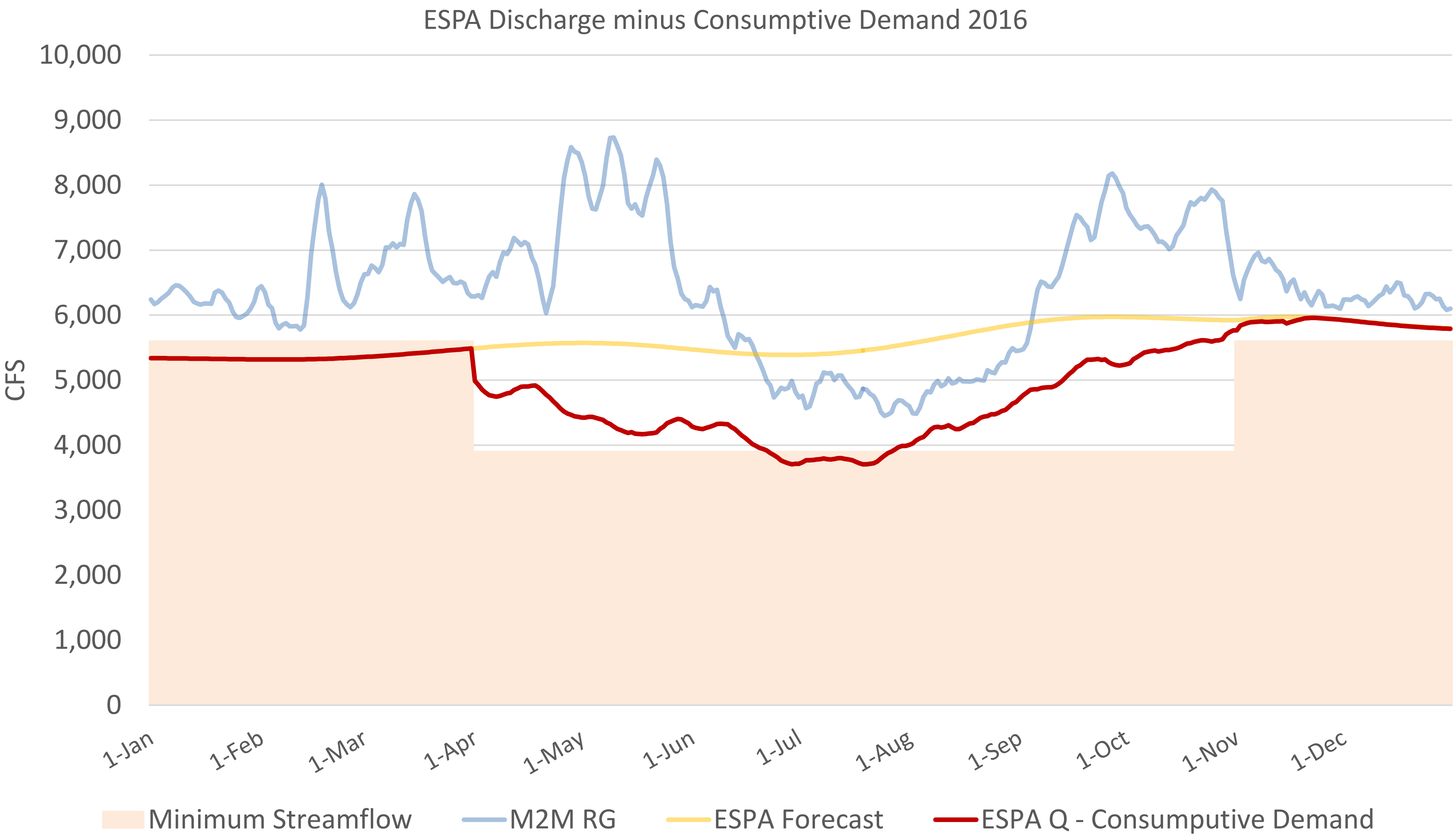
Milner to Murphy Reach Gain



Milner to Murphy Reach Gain = $Q_{ESPA} - ET_{Crop} + Q_{Trib\ \&\ Returns}$



Milner to Murphy Reach Gain = $Q_{ESPA} - ET_{Crop} + Q_{Trib\ \&\ Returns}$



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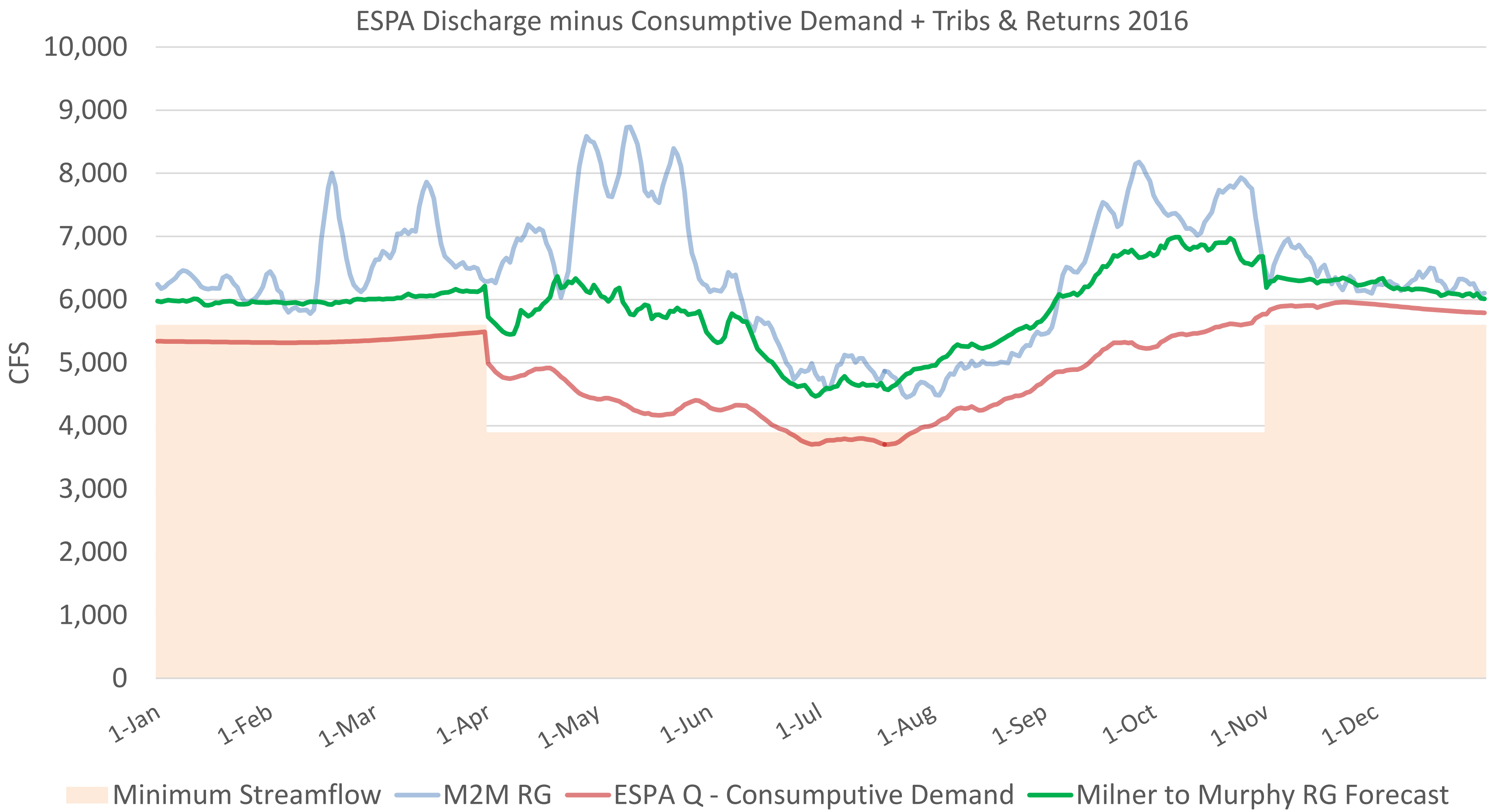


Aquifer Discharge Component to Murphy Flow

- 1a. Heads (85%)
- 1b. Recharge incidental to irrigation (9%)
- 1c. Managed recharge (0.3%)
- 1d. Pumping (5%)

→ ESPA 2.1 Response Functions → Daily ESPA discharge between Kimberly and King Hill

Response Functions

- Response functions describe proportion of a recharge or discharge event (expressed as a rate) that results in changes to the collective gains of the Kimberly to King Hill reach of the Snake River.

1a. Starting Heads

Data Entry: DWR enters depth to water data from fall synoptic for January forecast; spring synoptic for April forecast

What does the tool do? January forecast example:

1. Determines the difference in aquifer head between November 2008 and the forecast year.
2. Interpolates those measured head differences to each ESPAM2.1 model grid cell in the southwest portion of the Snake River Plain aquifer (column 100 and less).
3. Multiplies the interpolated head times a set, representing monthly timesteps, of predetermined head response functions to estimate the contribution of each cell to future discharge of the Kimberly to King Hill reach.
4. Sums the products determined in step 3 to determine the forecasted difference in gains from 2008-09.
5. Adds the values from step 4 to the simulated Kimberly to King Hill gain recession determined from November 2008 heads with no subsequent aquifer recharge and discharge to forecast the effect of the November heads on Kimberly to King Hill gains in the following 12 months.

1b. Incidental Recharge

Forecast annual diversions at 3 irrigation entities:

- Northside Canal Company (IESW032)
- American Falls Reservoir District 2 (IESW058)
- Gooding-Richfield (IESW059)

General form of statistical models that predict season-total diversion:

$$DIV_t = \alpha + \beta_1 \times SWSI_t + \beta_2 \times STOR_t + \phi[DIV_{t-1} - (\alpha + \beta_1 \times SWSI_{t-1} + \beta_2 \times STOR_{t-1})] + \varepsilon$$

DIV_t = total diversion for year t

$SWSI_t$= Surface Water Supply Index for year t at time of forecast

$STOR_t$= Reservoir storage content for year t at time of forecast

α, β_1, β_2 = regression coefficients

ϕ = first-order autocorrelation coefficient

ε = normally distributed random error

- The storage term appeared only in predictive models for Northside.
- Numerical values of coefficients varied across irrigation entities and between January and April forecasts.
- Values for ϕ ranged from 0.4 for AFRD2 April forecast to 0.7 for Northside January forecast.
- Nash-Sutcliffe model efficiencies ranged from 0.48 for AFRD2 and Northside January predictions to 0.91 for Gooding-Richfield April prediction.

1b. Incidental Recharge Continued

- Tool calculates canal seepage and the on-farm component of recharge – same process as ESPAM 2.1
- The tool multiplies aquifer recharge estimates by corresponding recharge response functions to estimate future Kimberly to King Hill reach gains.

1c. Pumping

- Used average monthly 2001 through 2010 net consumptive groundwater use (the crop irrigation requirement, or CIR) for IEGW501, 507, 508, and 509
- The tool multiplies these aquifer stresses by corresponding response functions, weighted by irrigated area in each model cell, to estimate future Kimberly to King Hill reach gains/losses.

1d. Managed Recharge

- User enters entity recharge volume in acre-feet
- The tool multiplies aquifer recharge volumes by corresponding recharge response functions to estimate future Kimberly to King Hill reach gains.

USER ENTER DATA HERE:

Enter Forecast Year	Enter the number of wells in interpolation neighborhood (between 1 and 100)	Enter desired exceedance probability (%)	Enter Consumptive Demand Category (1 through 5)	Big Wood SWSI	Snake (Heise) SWSI	Upper Snake Reservoir Storage
2017	10	70	1	(-4 to +4)	(-4 to +4)	(1000s ac-ft)
				1.8	1.8	2388

USER ENTER MANAGED AQUIFER RECHARGE (AF/MO) HERE:

	SW Irrigation District	Milner Gooding Main Canal	Milner Gooding - Shoshone	Milner Gooding - Milepost 31	Northside Main Canal Including Wilson Lake	Twin Falls Canal Co. - Murtaugh Canal	Big Wood Canal Co. - Richfield	Hold for Future Site	Hold for Future Site	TOTAL MANAGED RECHARGE
	AF/mo	AF/mo	AF/mo	AF/mo	AF/mo	AF/mo	AF/mo	AF/mo	AF/mo	AF/mo
Nov	295	0	0	15625	3119	3261	0	0	0	22299
Dec	0	0	0	0	0	0	0	0	0	0
Jan	0	0	0	0	0	0	0	0	0	0
Feb	295	0	0	15625	3119	3261	0	0	0	22299
Mar	295	0	0	15625	3119	3261	0	0	0	22299
Apr	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0

2. Consumptive Demand

Consumptive Use Assumption:
The forecast tool uses crop demand to determine consumptive use instead of calculating consumption by calculation of diversion – return. We assume that any excess diversions will return to the river and that by tracking consumptive demand we can estimate river withdrawals for agricultural use between Milner and Murphy.

Consumptive Use Model (Grandview Agrimet Station, 1993-2016)
- Two layer soil moisture model
- Crop water demand uses Reference ET & dual crop coefficient method
- Assumed crop is mature alfalfa (does capture springtime conditions)
- Assumes pivot irrigation

Consumptive Use: 5 Categorizations
- Currently the average consumptive use of the highest demand years is assumed (2007, 2012, 2013, 2015, 2016)
- Max Consumptive Use (≈1800 cfs)

3. Return Flow Components

Tributaries

- Bruneau River
  - Data record 1909 - 2017
- Malad River
  - Data record 1916 - 2017
- Salmon Falls Creek
  - Data record 1970 - 2017
- Rock Creek
  - Data record 1992 - 2017

Returns

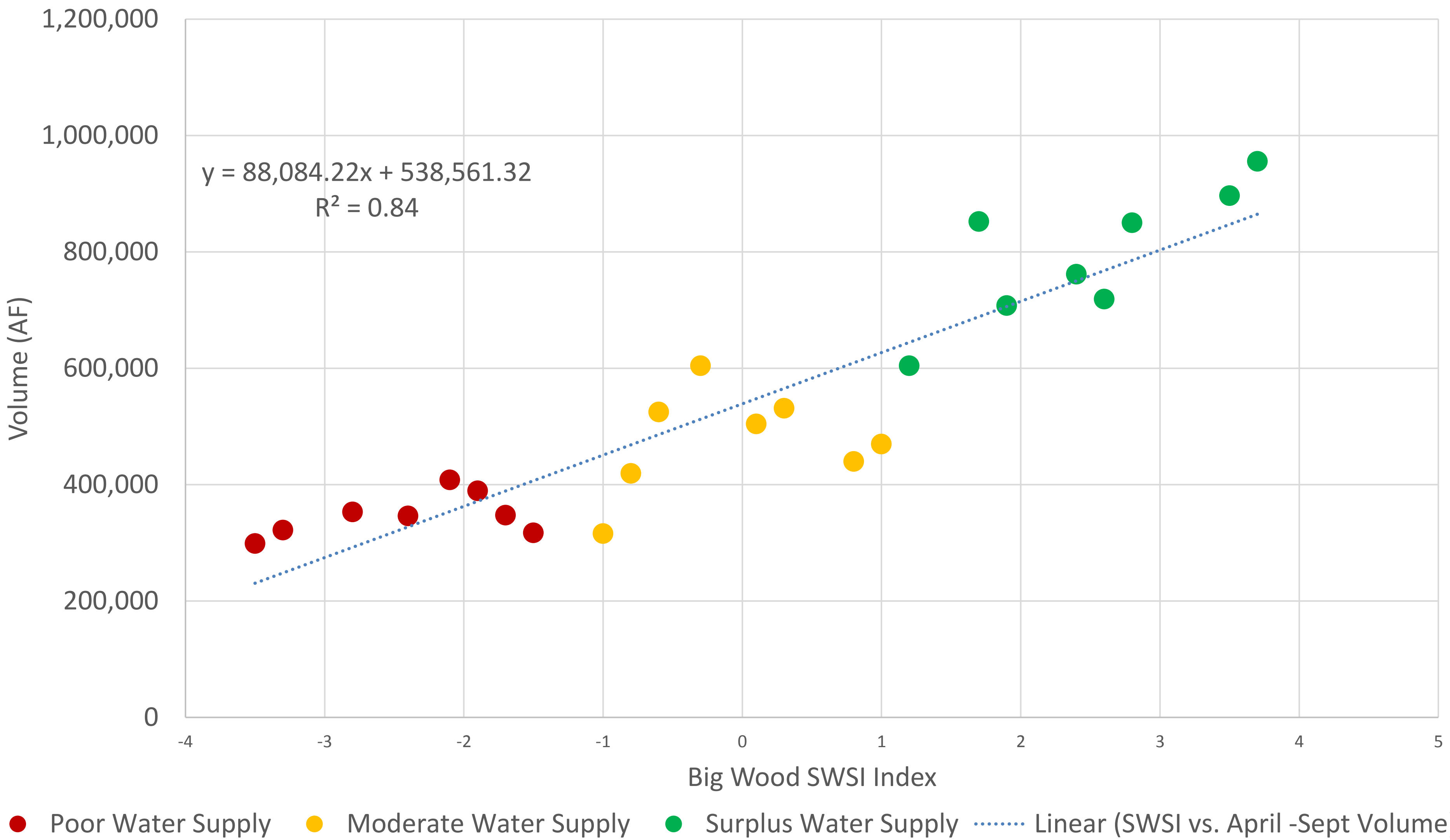
- Northside Canal Company
  - 11 sites in group
  - Data record 2002 – 2015
  - Observed and scaled data (2002 – 2007)
- Twin Falls Canal Company
  - 9 sites in group
  - Observed data (2007 – 2016), observed and scaled data (2002 – 2007), statistical data (1993 – 2002)

Milner to Kimberly Gain

- Constructed Hydrograph

Trib & Return Component = (Tribs + TFCC) + NSCC + Milner to Kimberly Gain

April - September Trib Runoff + TFCC Return Volume



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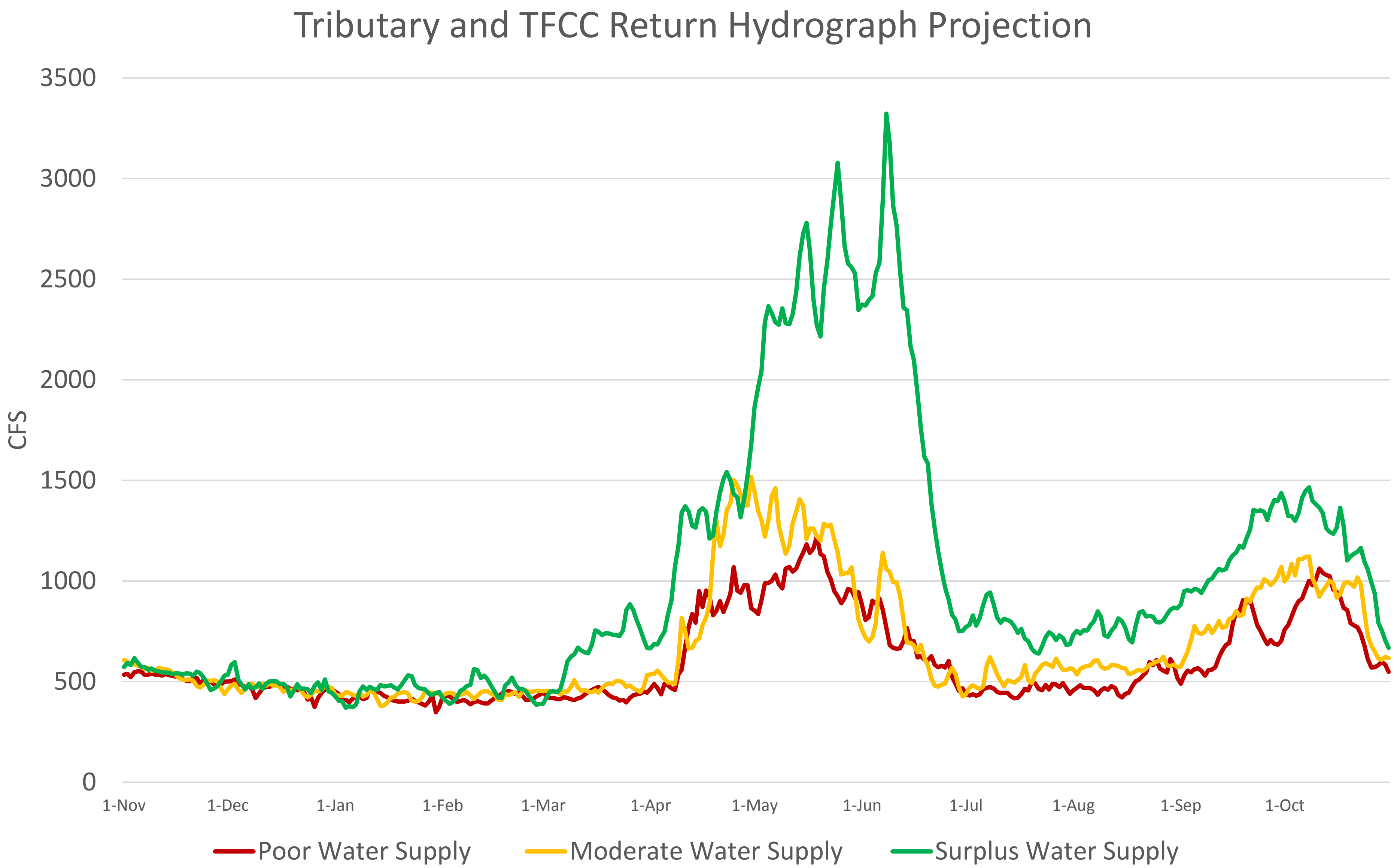

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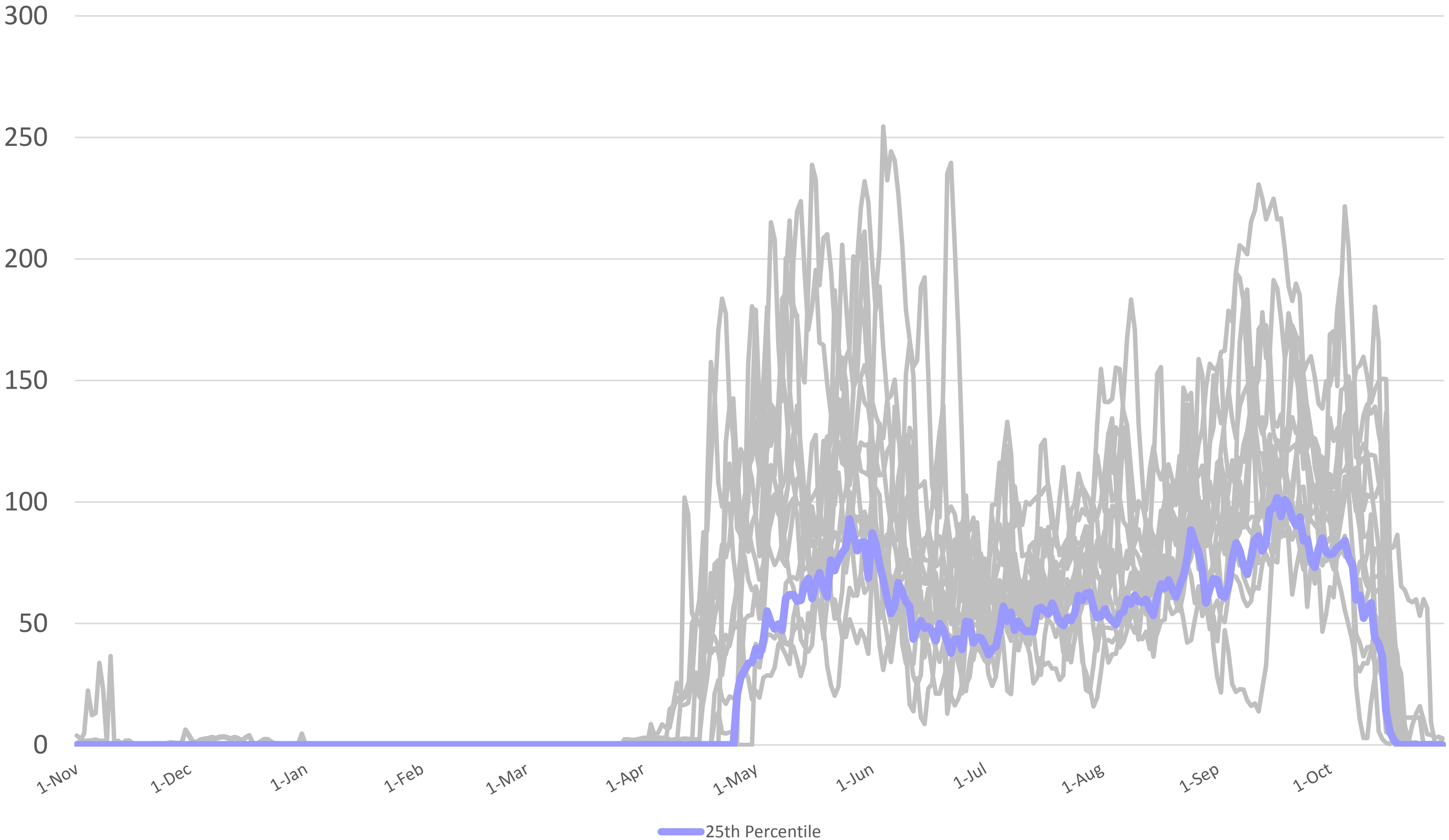
Northside Returns



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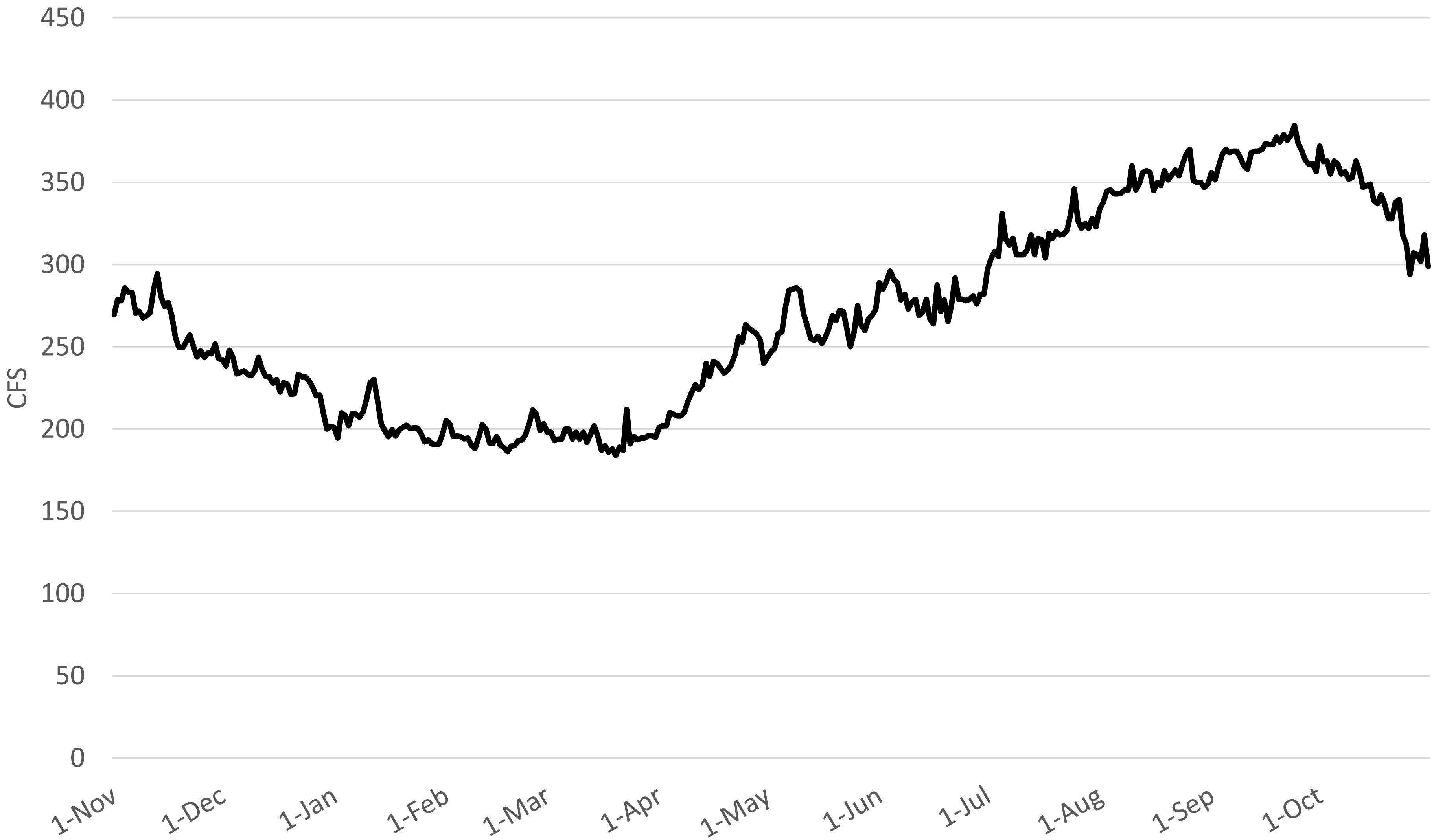
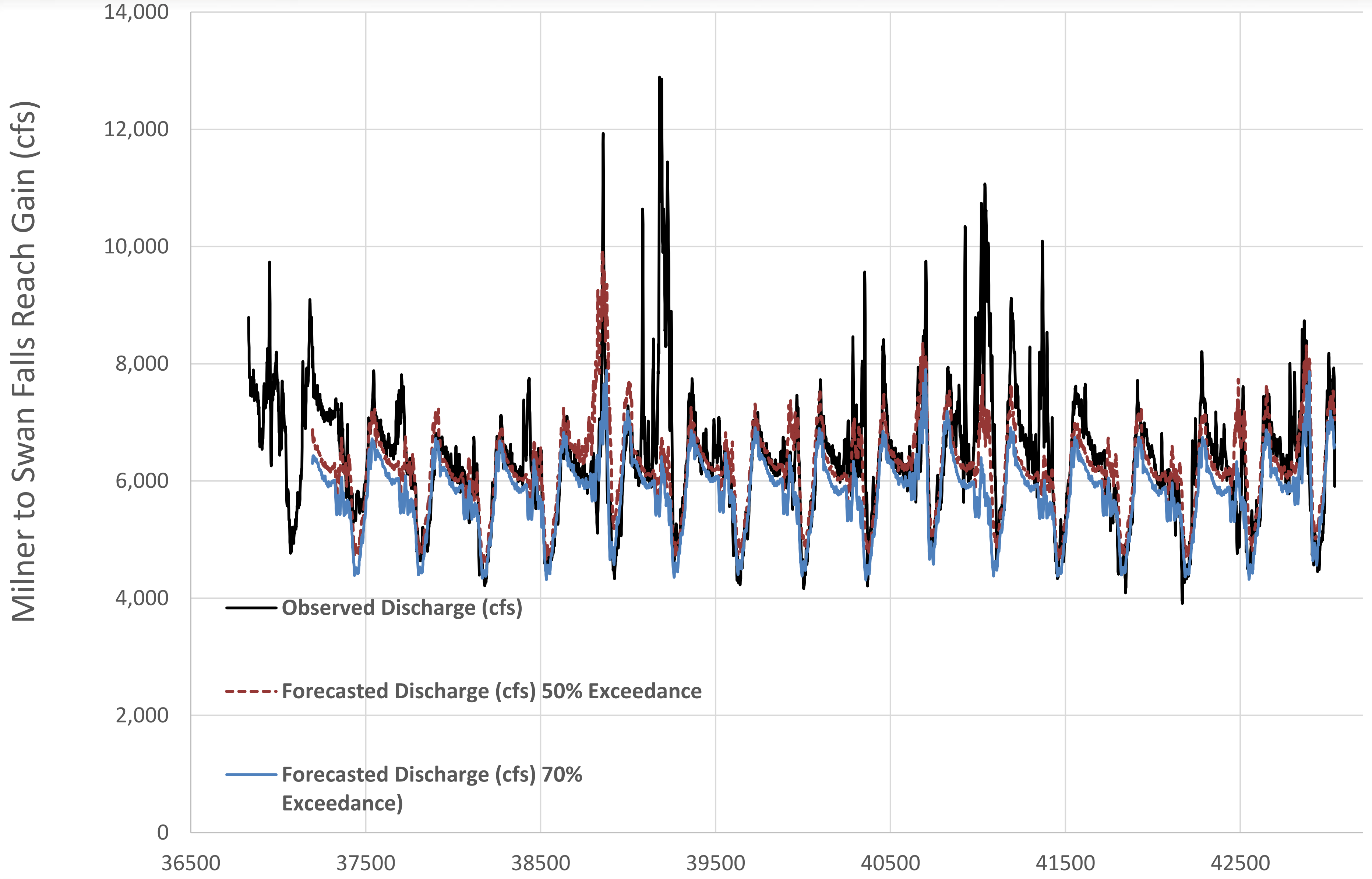
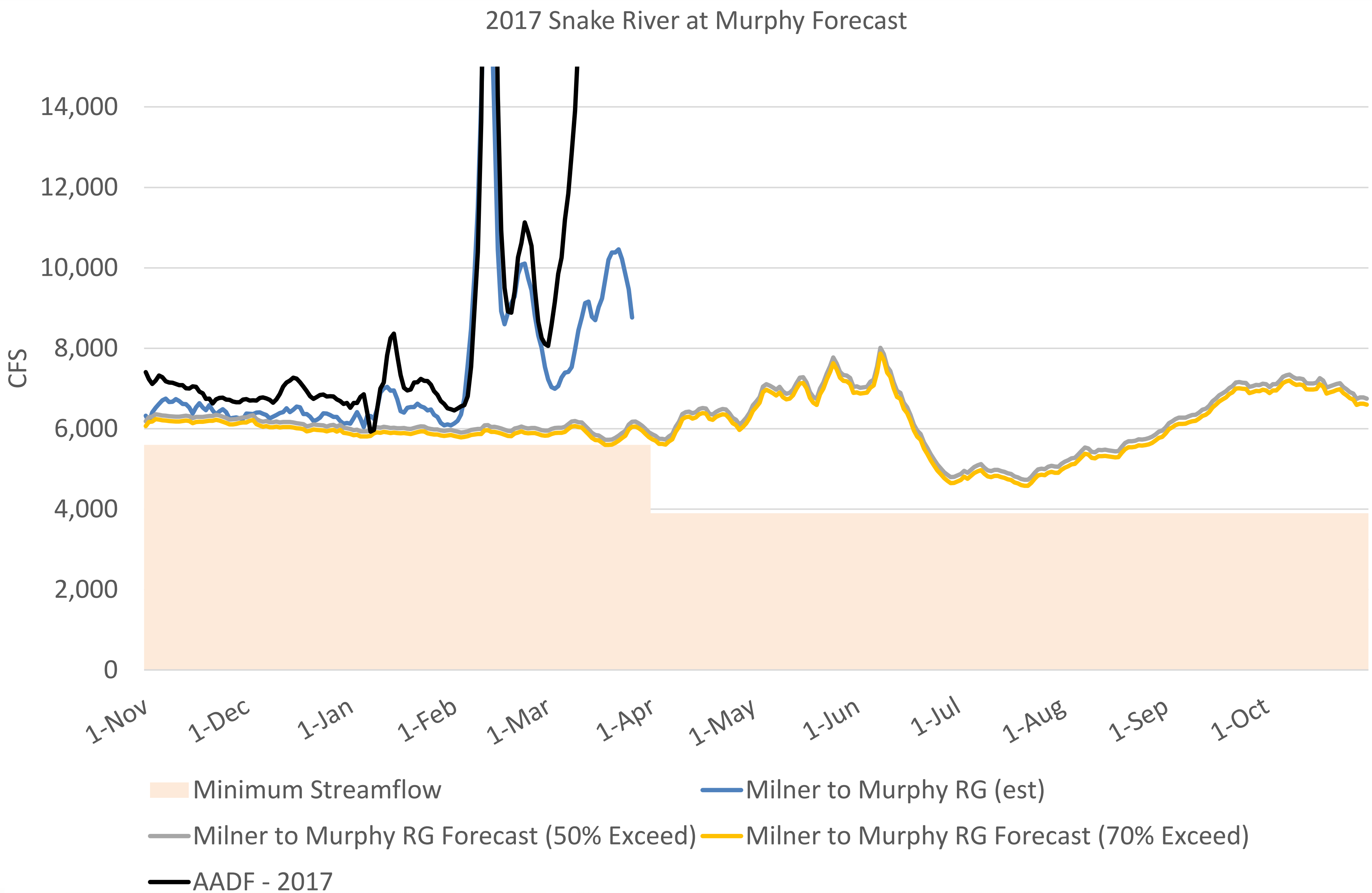
Milner to Kimberly Gain Hydrograph



Hindcast Validation




2017 Snake River at Murphy Forecast
CFS
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
Minimum Streamflow
Milner to Murphy RG (est)
Milner to Murphy RG Forecast (50% Exceed)
Milner to Murphy RG Forecast (70% Exceed)
AADF - 2017

Challenges

Technical

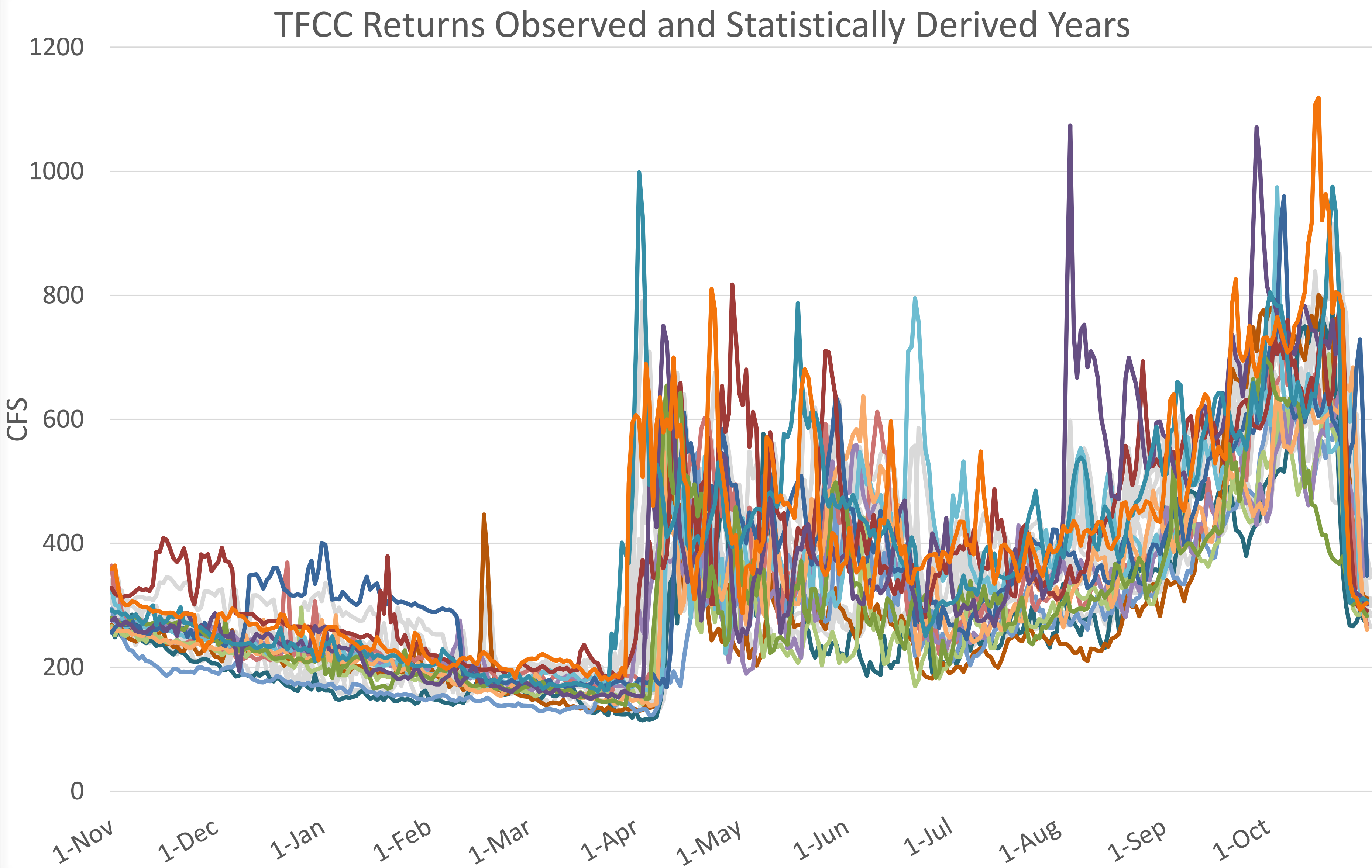
- Timing and magnitude of runoff
- Late March – early April consumptive use
  - Initiation of water demand variable
- Measured pumping data

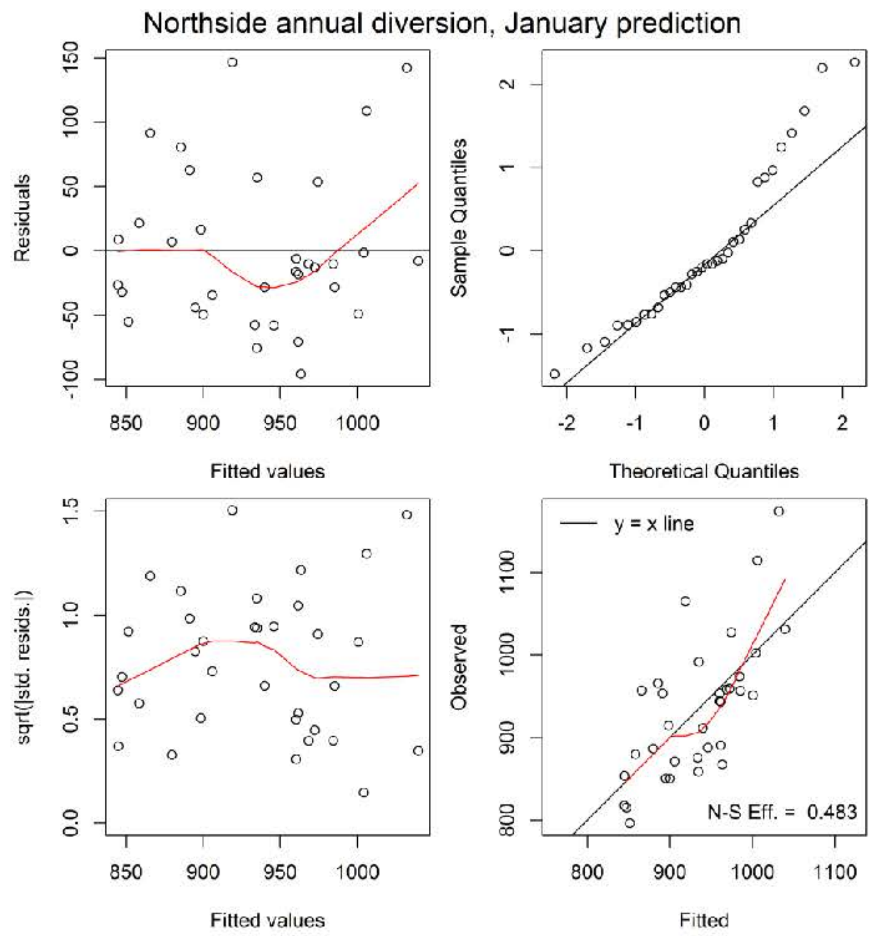
Management

- Upper Snake Reservoir Operations (not including IPCo release)
  - Flow Aug timing variable
    - 2014: 6/13 – 7/7
    - 2015: 5/12 – 6/14
    - 2016: 5/23 – 6/20

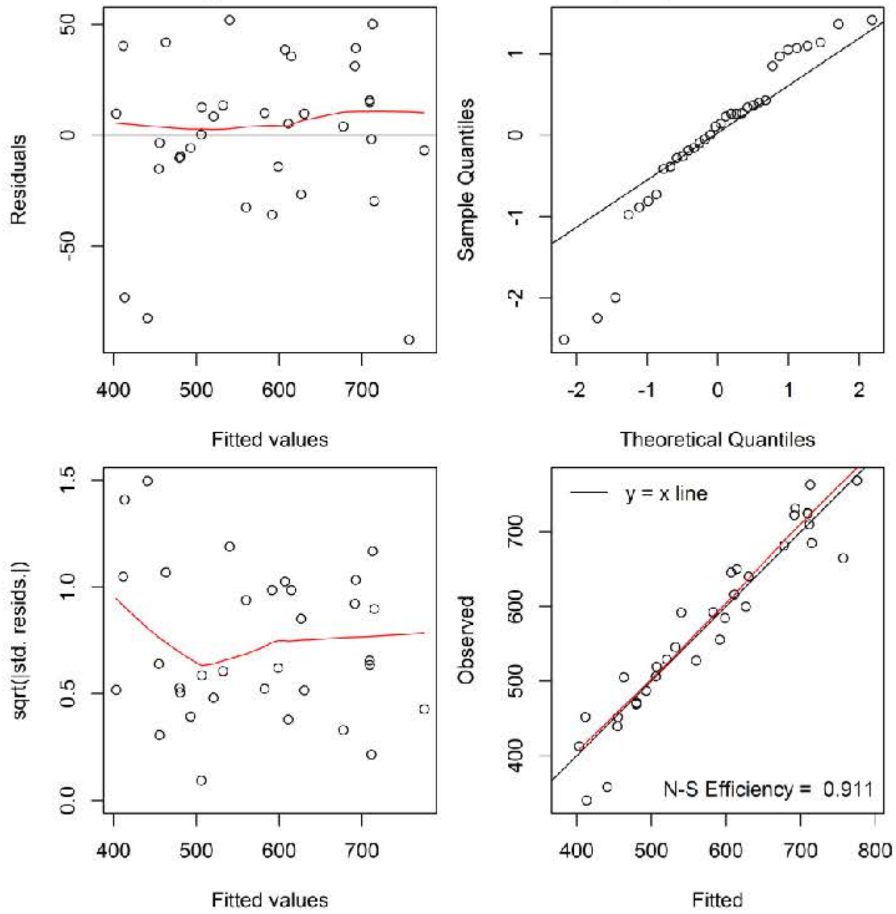
Milner to Kimberly Gain

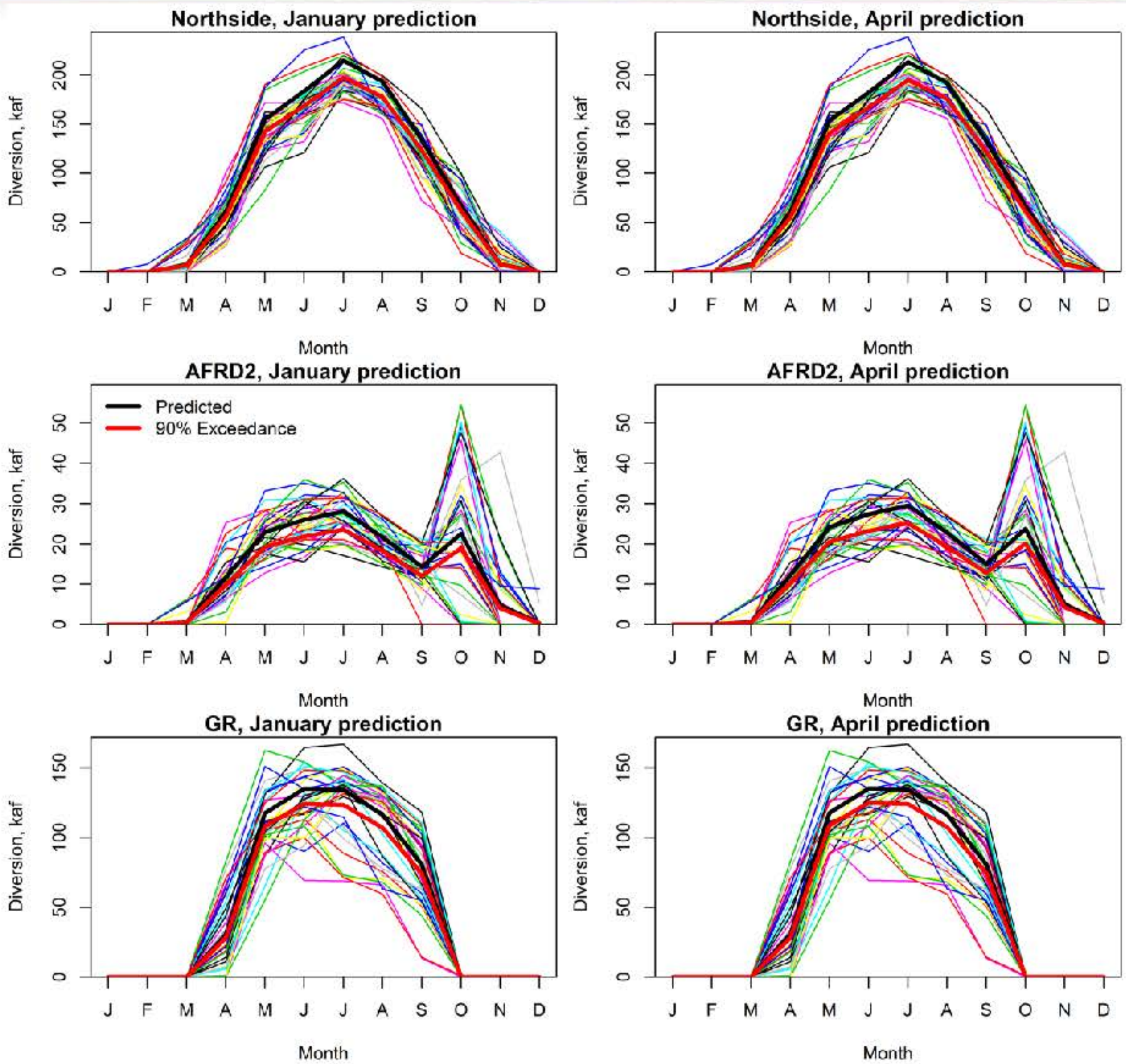
- Filtered Snake at Kimberly dataset WY1993 – 2016 to select dates with <10 cfs at Milner
- Resulted in limited daily dataset, data gap from 11/26 – 3/1
- Calculated median of Milner to Kimberly RG (5 day centered average) 1993 – 2016 to fill datagap.
- Subtracted difference of <10 cfs @Milner dataset and median dataset on 3/1 and carried offset back to Nov 1.
- Best estimate hydrograph entered into model (static values)


TFCC Returns Observed and Statistically Derived Years
CFS
1200
1000
800
600
400
200
0
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct


Northside annual diversion, January prediction
Residuals
Fitted values
Sample Quantiles
Theoretical Quantiles
sqrt(|std. resids.|)
Fitted values
y = x line
Observed
Fitted
N-S Eff. = 0.483

Gooding-Richfield Annual diversion, April prediction




Northside, January prediction
Northside, April prediction
AFRD2, January prediction
AFRD2, April prediction
GR, January prediction
GR, April prediction
Predicted
90% Exceedance
Diversion, kaf
Month
J F M A M J J A S O N D
0 50 100 150 200
0 10 20 30 40 50
0 50 100 150