# Forecasting Daily Streamflow to Maintain a Critical Minimum Streamflow Target

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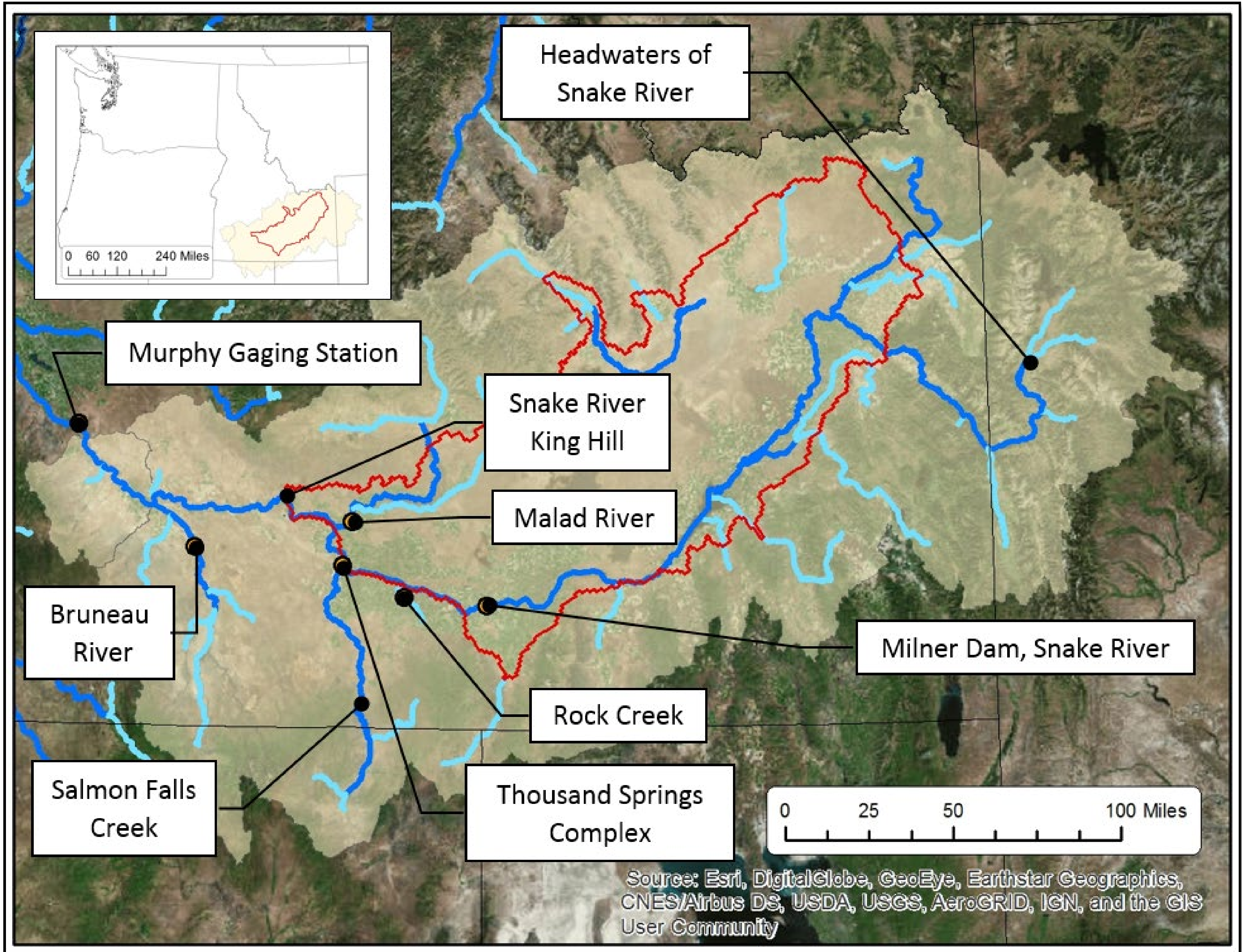
# Agenda

1. **Where** we are forecasting
2. **Why** we are forecasting
3. **What** we are forecasting
4. **How** we are forecasting
5. **Performance** of the forecast tool

# **Where** are we forecasting?



# Why are we forecasting?

- Snake River Basin Adjudication and the Swan Falls Agreement
- Provide Idaho Power Company with a baseflow in the river for hydropower generation.

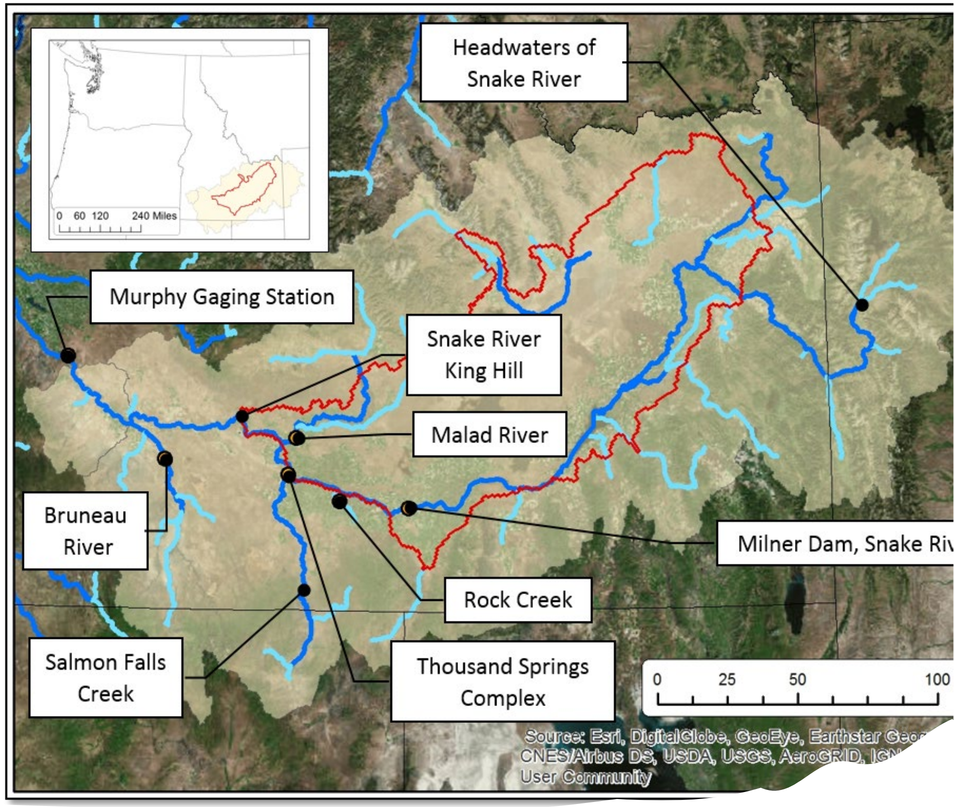
## Overview of the Swan Falls Settlement

### Brief History:

The Swan Falls Settlement resolved an ongoing controversy over how to balance water uses for agriculture and water needs for hydropower generation in the Snake River Basin. In the late 1970s, a group of Idaho Power Company's ratepayers initiated a lawsuit against the Company, contending that it had failed to adequately protect its water rights for hydropower generation at the Swan Falls Dam. As a result of the Company's alleged failure to protest junior water uses upstream from Swan Falls Dam, the ratepayers claimed, the Company had less water for power generation, resulting in higher electricity rates for its customers. Idaho Power Company, in its initial response, maintained that all of its water rights for hydropower generation were subordinated as a result of the subordination condition on its rights at the Hells Canyon Complex. The Idaho Supreme Court, however, decided the issue in favor of the ratepayers, holding that the subordination at Hells Canyon did not extend upstream to the Swan Falls water rights.

Following the decision, Idaho Power Company initiated a lawsuit against the holders of approximately 7,500 water rights upstream from its Swan Falls facility, seeking curtailment of those rights based on their junior priority relative to the Company's hydropower rights. Given the catastrophic consequences that such curtailment would have had on agriculture in southern Idaho, the State, through the Governor and the Attorney General, entered into negotiations with Idaho Power Company to resolve the litigation.

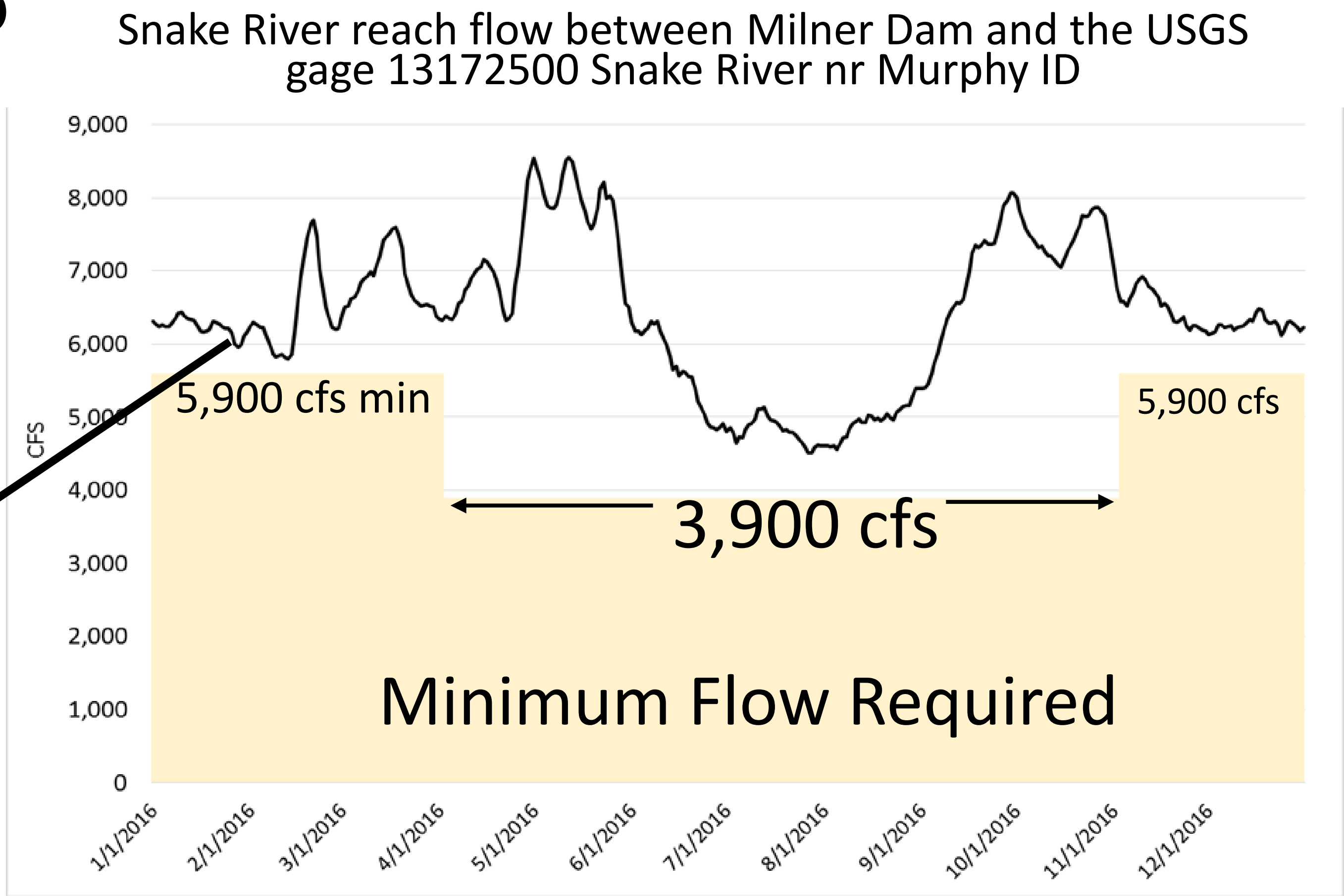
The State's primary interests were to protect existing water uses, and to ensure that the State would control the allocation of water between hydropower and other uses. The interest of the Idaho Power Company was to maintain adequate water levels in the Snake River for hydropower generation at its Swan Falls facility. The minimum stream flow right held by the State at the Murphy Gage (located approximately 4 miles downstream of the Swan Falls facility) for 3,300 cfs at the time of the negotiations, while Idaho Power Company's hydropower




# Nearly all Snake River flow below Milner is from aquifer discharge at Thousand Springs


**Challenge** - maintain a minimum streamflow in the Snake River

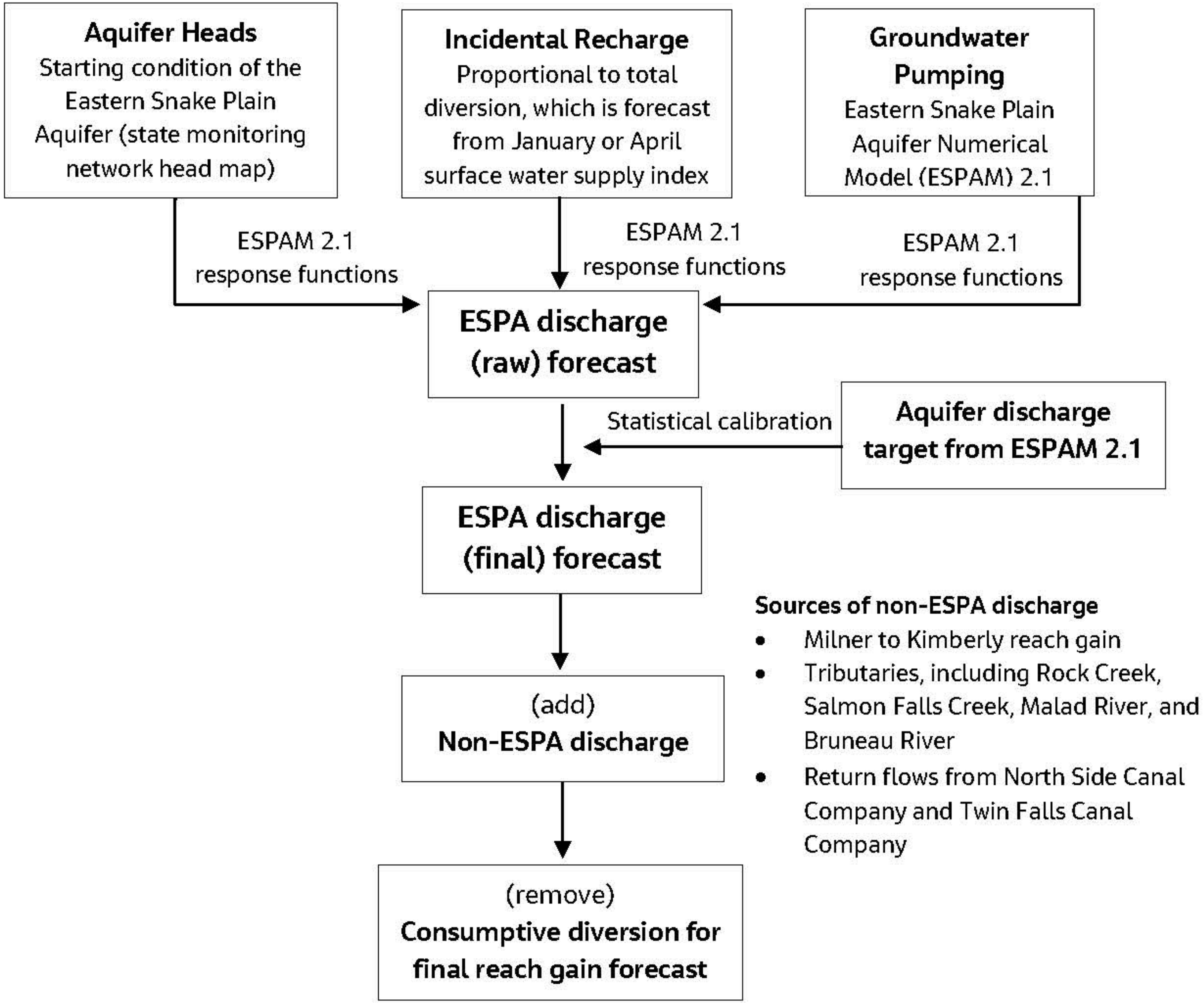
# What are we forecasting?



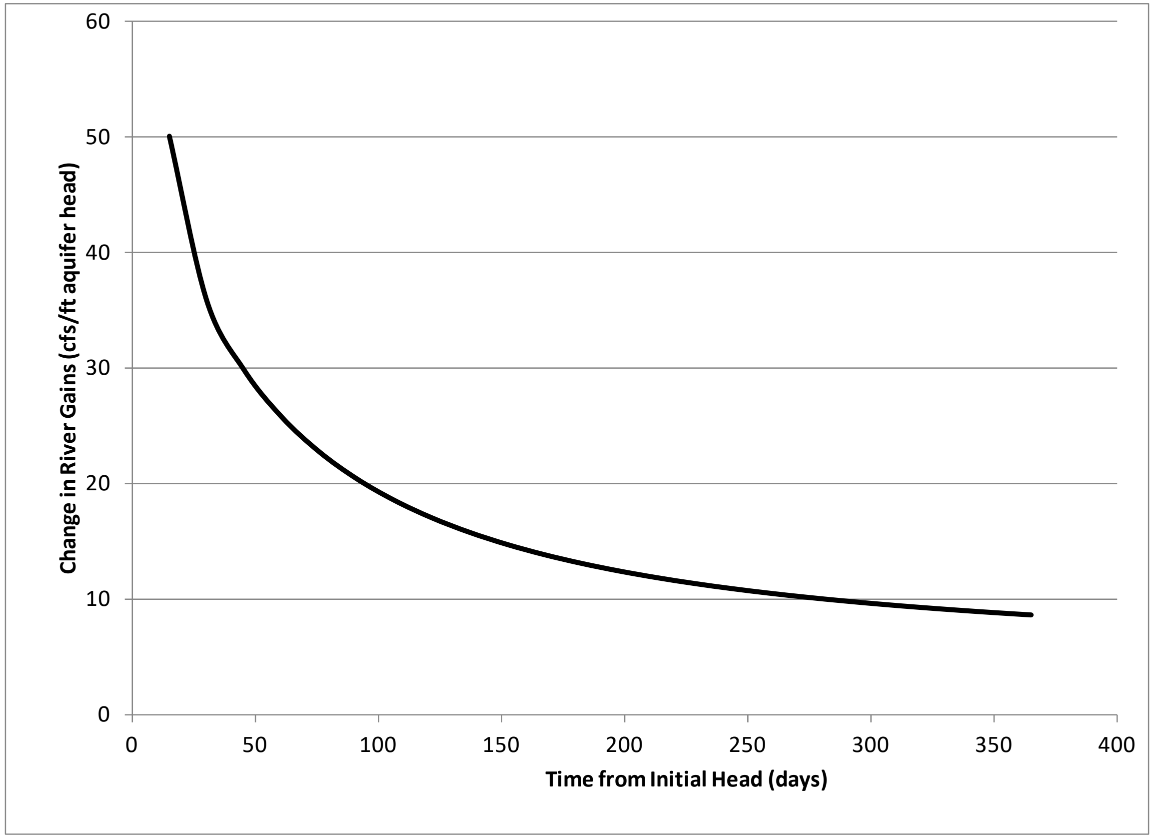

Snake River Flow $_{\text{(Milner to Murphy)}} = Q_{Murphy} - QMi_{lner} = QES_{PA} + Qno_{nESPA} \_ \; QDi_{\text{vET}}$

# How we are forecasting

**Challenge:** develop a groundwater discharge forecast without having to run a numerical model simulation (ESPAM 2.1)



Snake River Flow response to 1 foot head change – about 10 cfs after 180 days




**Response Functions:**

- Mathematical descriptions of cause and effect

**FOR EXAMPLE**

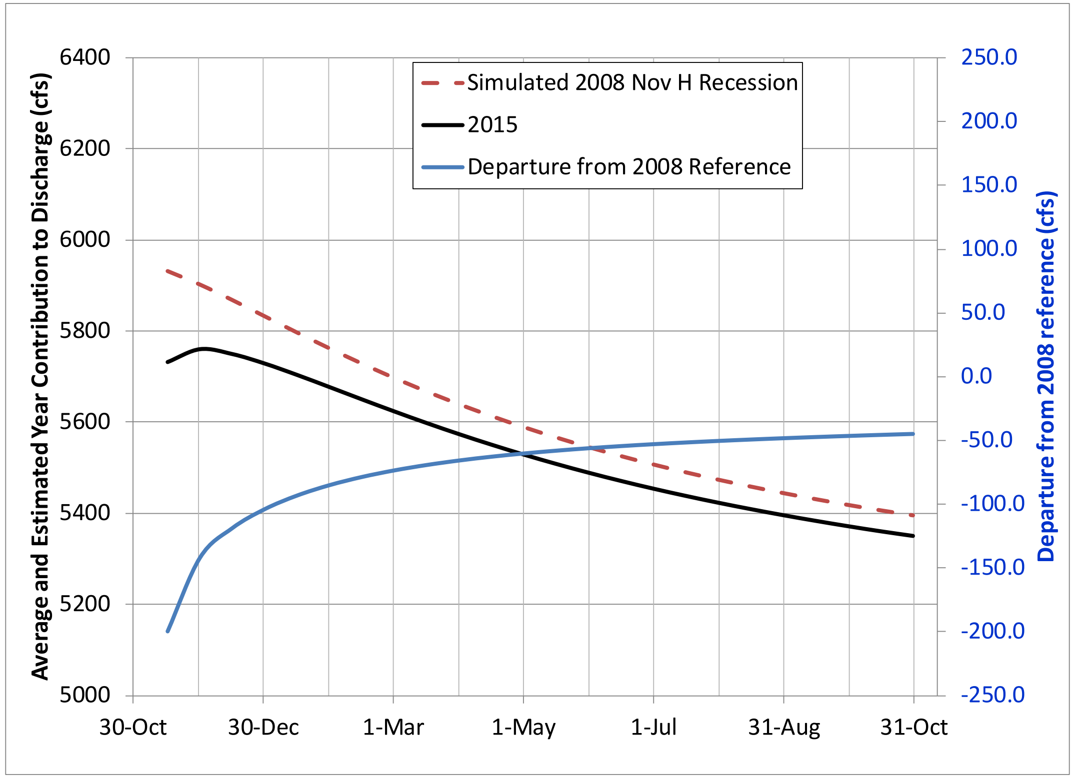
A curve describing stream depletion over time, resulting from a unit stress

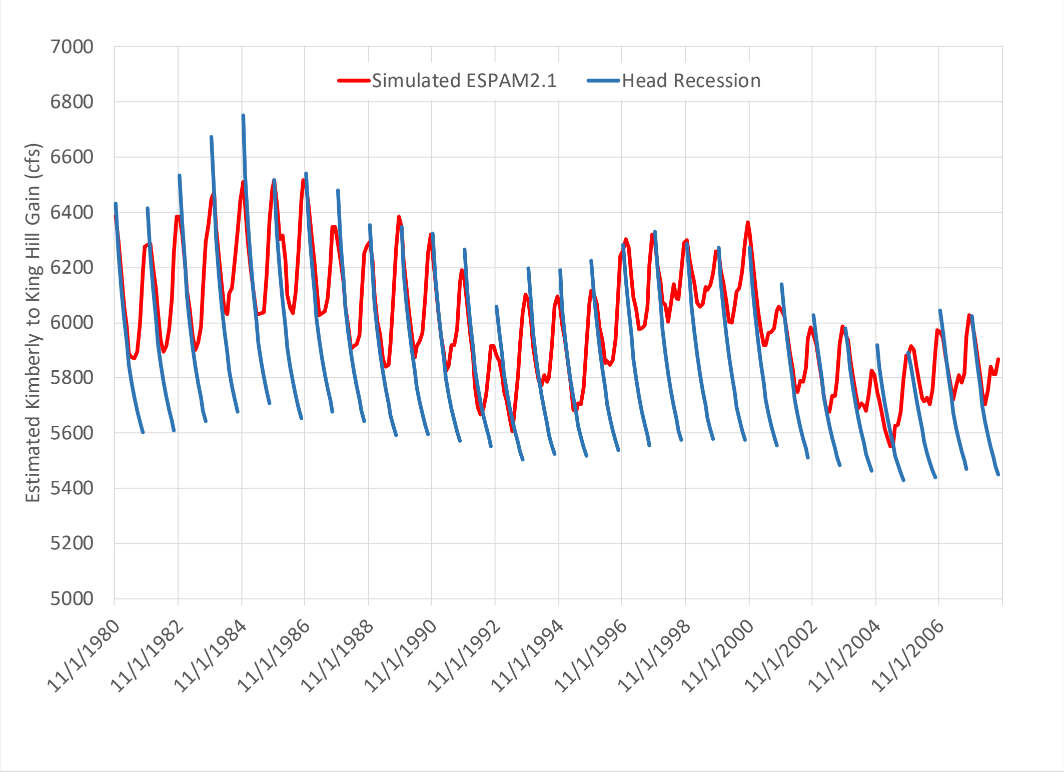
- Multiply the response function curve by the magnitude of the stress
- Aquifer properties govern the shape of the response function.

# **Head Response Functions** – An early project challenge

# Starting Heads

- Generate starting heads surface using DWR measurements.
- Use head response functions to calculate associated Snake River reach gains.



# Predict Irrigation Diversions

**Where?**

- North Side Canal Company
- American Falls Reservoir District #2
- Big Wood Canal Company

**Potential Predictor Variables**

- Basin-averaged snow-water-equivalent (SWE)
- Surface water supply index (SWSI)
- Reservoir storage

Linear regression models with autocorrelated residuals plus AIC lead to the following:

**Summary of regression models to predict upcoming irrigation-season diversion.**

**All models were fit to annual values for calendar years 1981-2014 (n = 34 years)**

| Irrigation Entity ID and Name | Predictors in model | Maximum lag of autoregressive terms | Nash-Sutcliffe Efficiency |
|---|---|---|---|
| IESW032 Northside | SWSI, reservoir storage | 1 | 0.48 |
| IESW058 AFRD2 | SWSI | 1 | 0.51 |
| IESW059 Big Wood Canal Co. | SWSI | 1 | 0.90 |

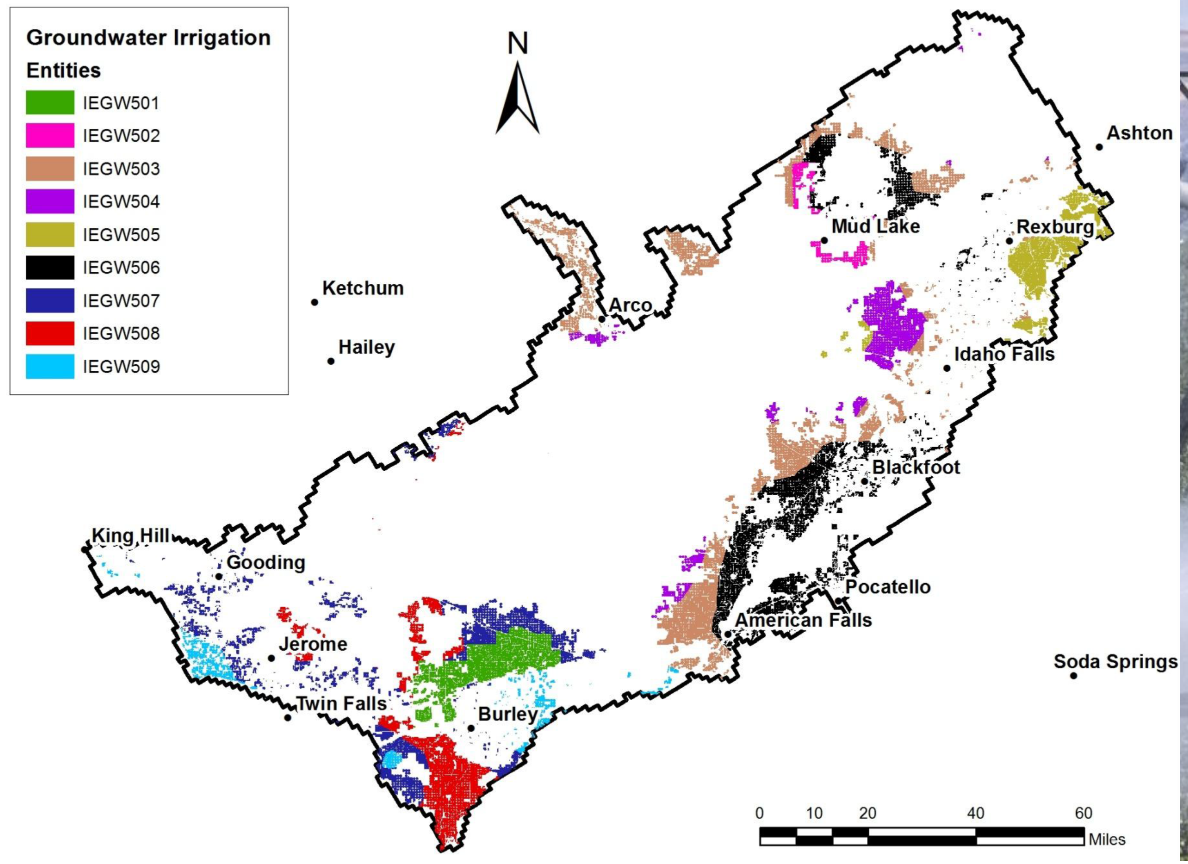
# Calculate recharge from irrigation diversions

Tool uses recharge from irrigation algorithms directly from DWR's ESPAM 2.1

# Managed Recharge Component

Tool calculates Snake River discharge from managed aquifer recharge

- Southwest Irrigation District
- Milner Good Main Canal
- Milner Gooding – Shoshone
- Milner Gooding – Milepost 31
- Northside Canal Company Main Canal including Wilson Lake
- Twin Falls Canal Company – Murtaugh Canal
- Big Wood Canal Company – Richfield



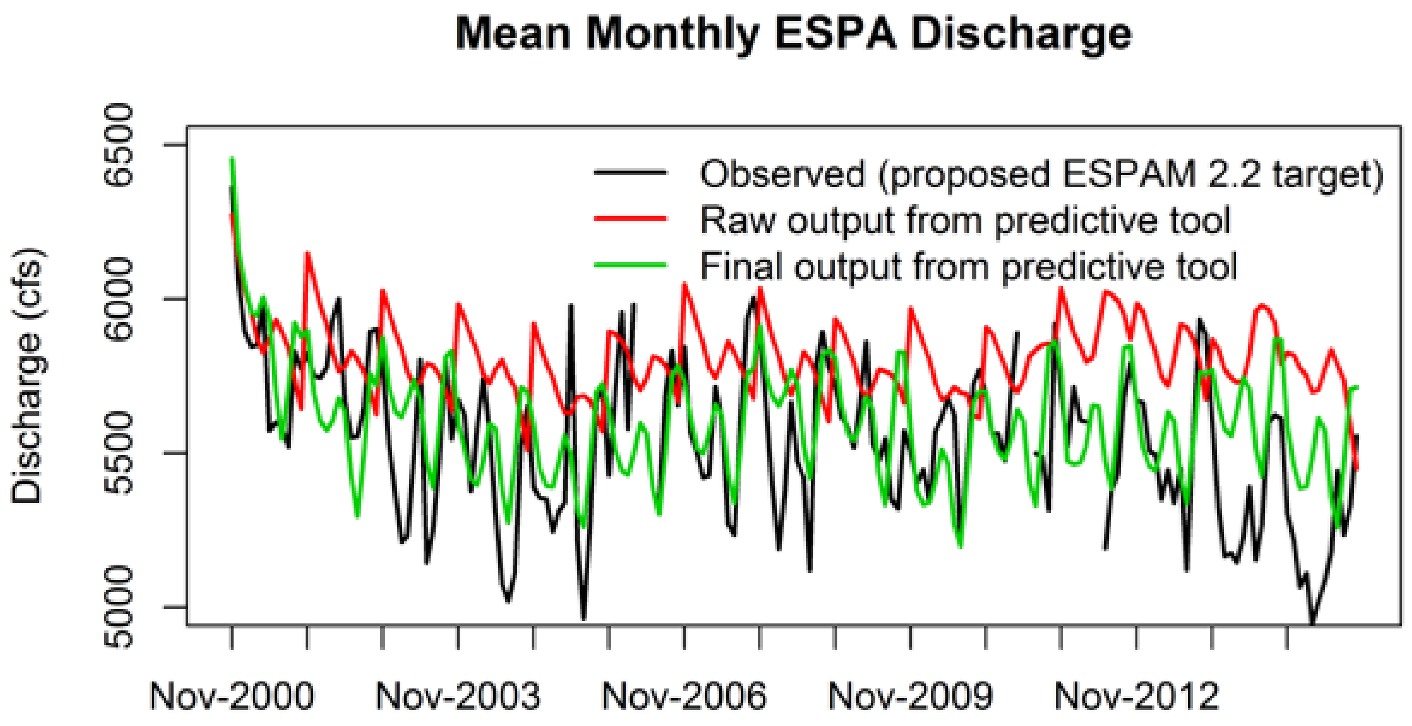

# Pumping Component

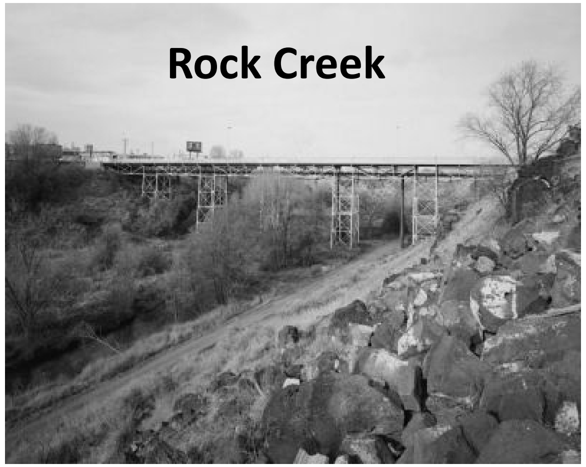
- Groundwater Pumping is based on average pumping 2001-2010 for four groundwater entities in ESPAM
  - IEGW501
  - IEGW507
  - IEGW508
  - IEGW509

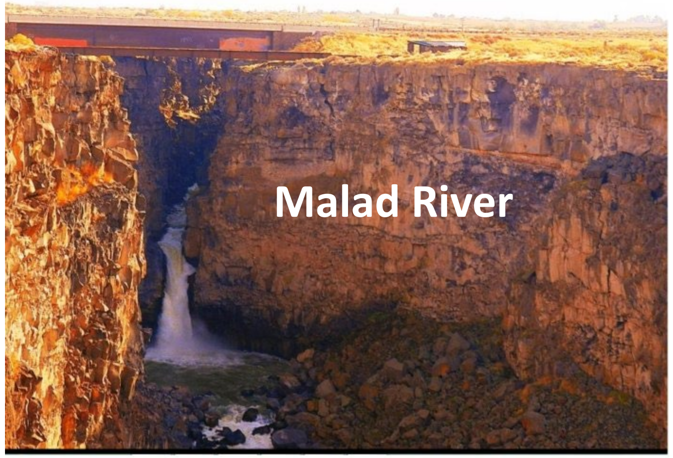
# First Phase Results: Aquifer Discharge and Cross Validation Calibration

**<u>Leave-one-out cross-validation</u>**

- Re-fit the best model (per AICc) to a sample of 14 of the 15 irrigation years in the calibration period.
- Predict monthly values for the 15th year.
- Repeated for all 15 different 14-year samples.
- **Greatly improved the model compared to observed data.**

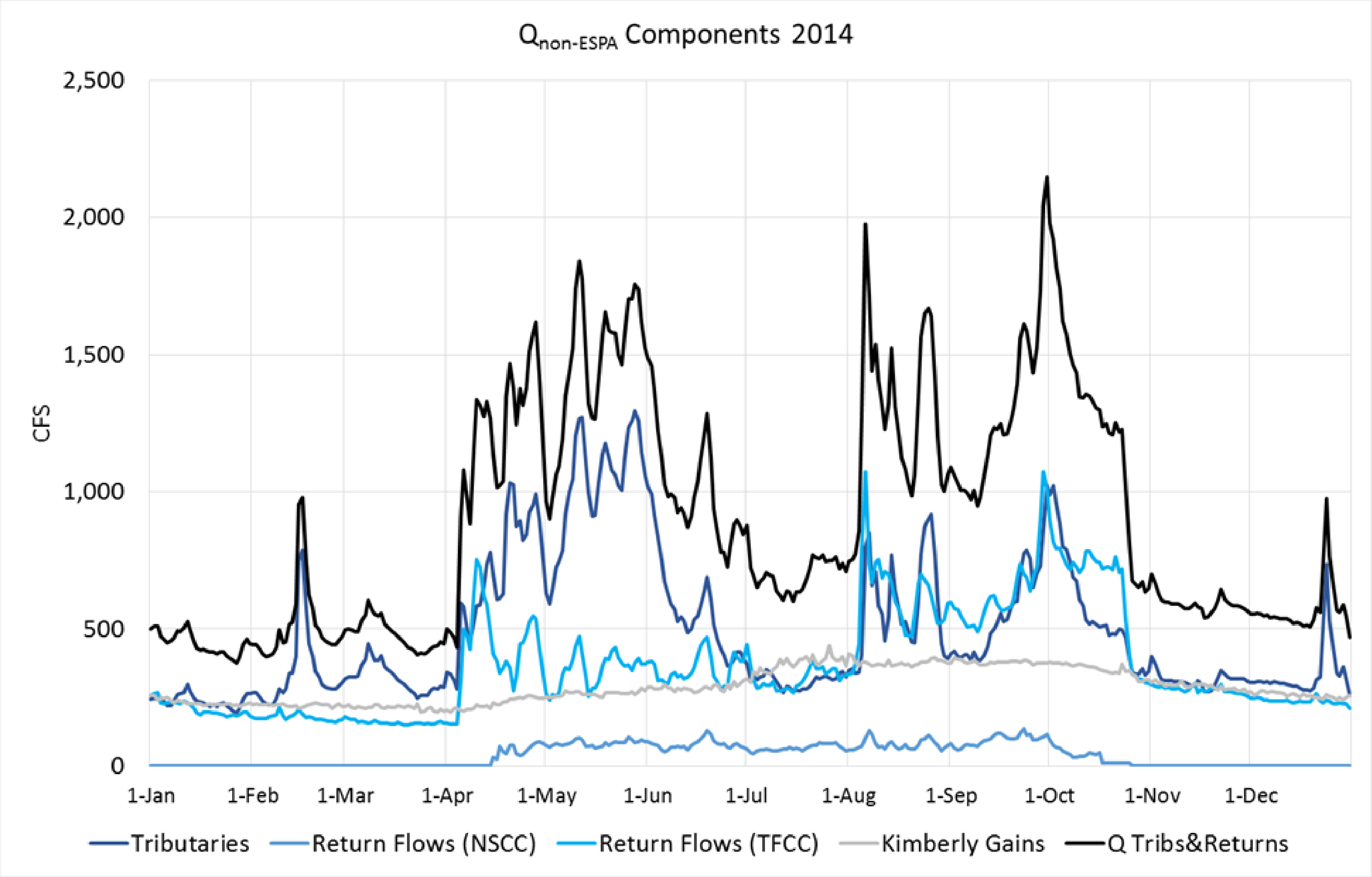






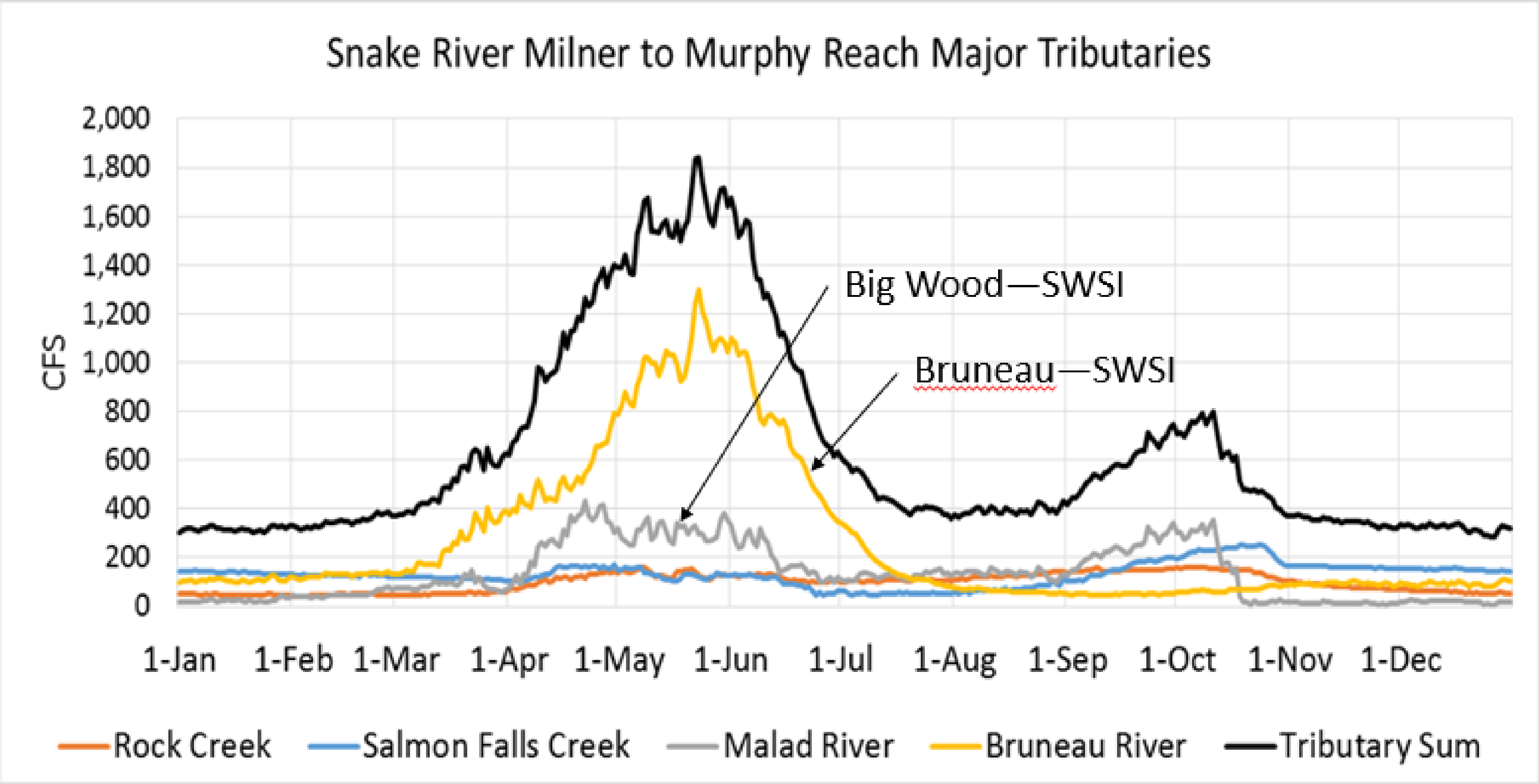

# Estimating the Surface Water Component to Snake River Influx

# Estimation of non-ESPA Reach Gains



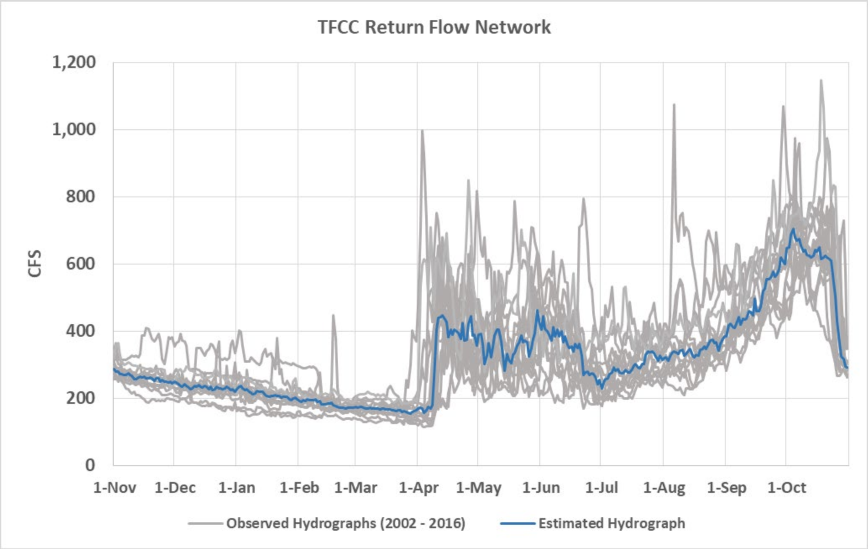
# Tributary Inflow

Median annual hydrographs for the major tributaries for the period 1993-2016

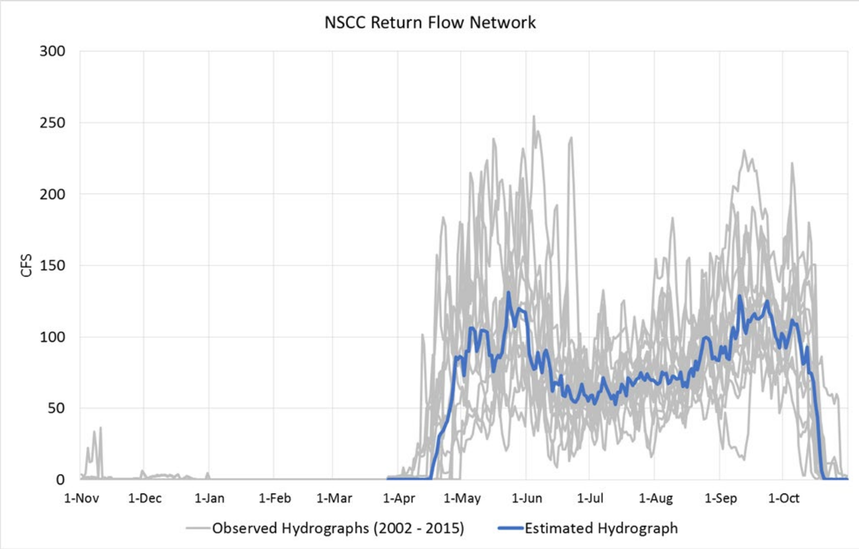


# Components used in the SFFT

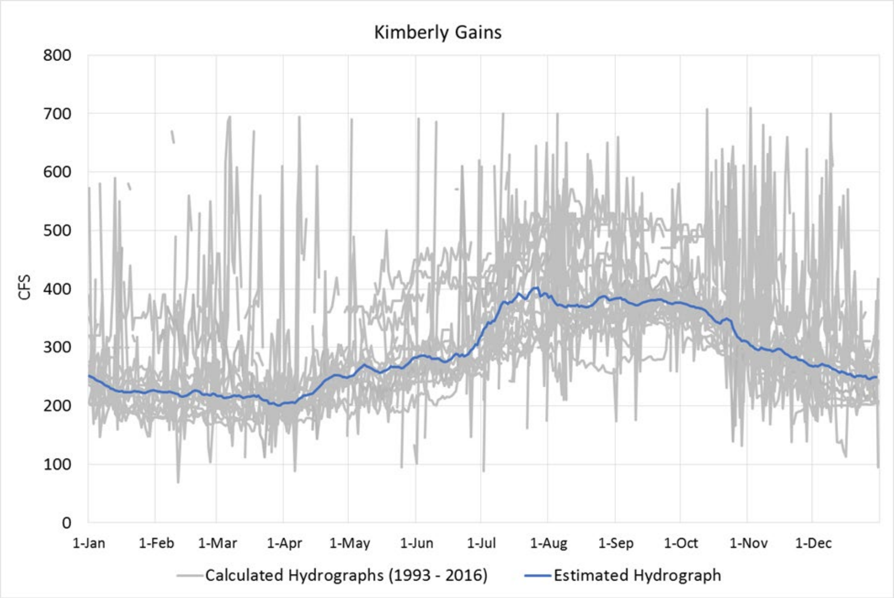
- Twin Falls Canal Co.
- Northside Canal Co.
- Kimberly Gains




Twin Falls Canal Company Returns

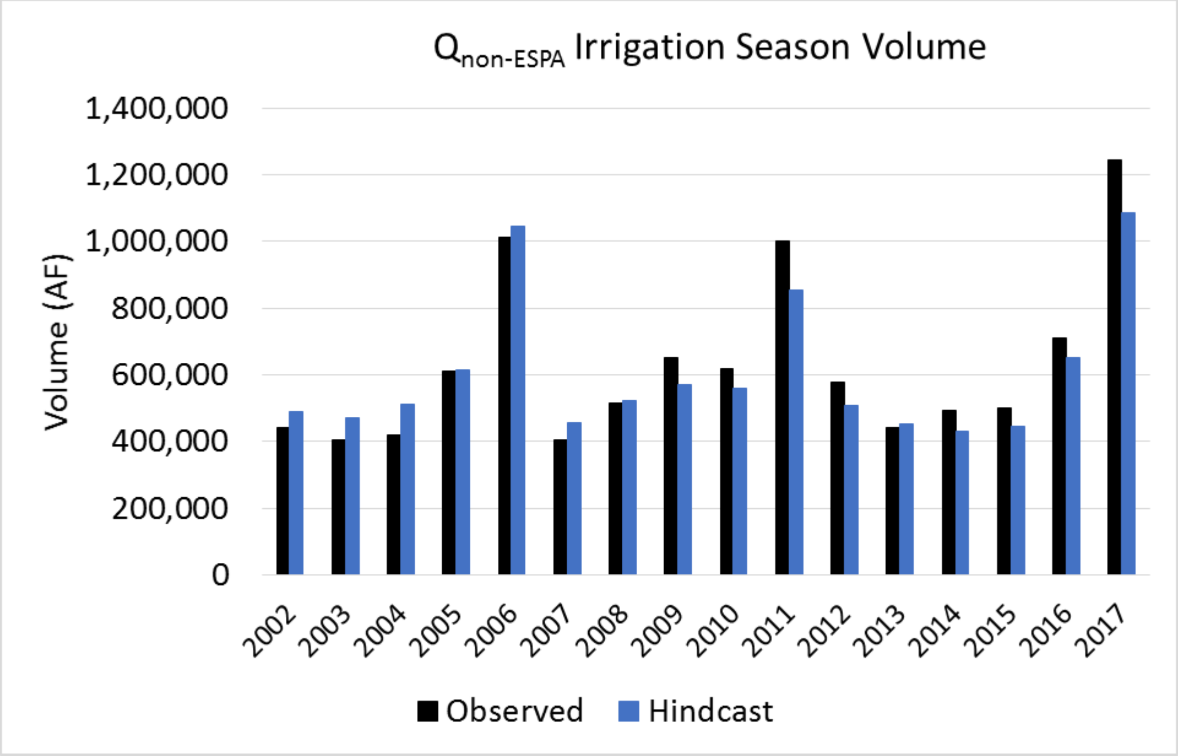


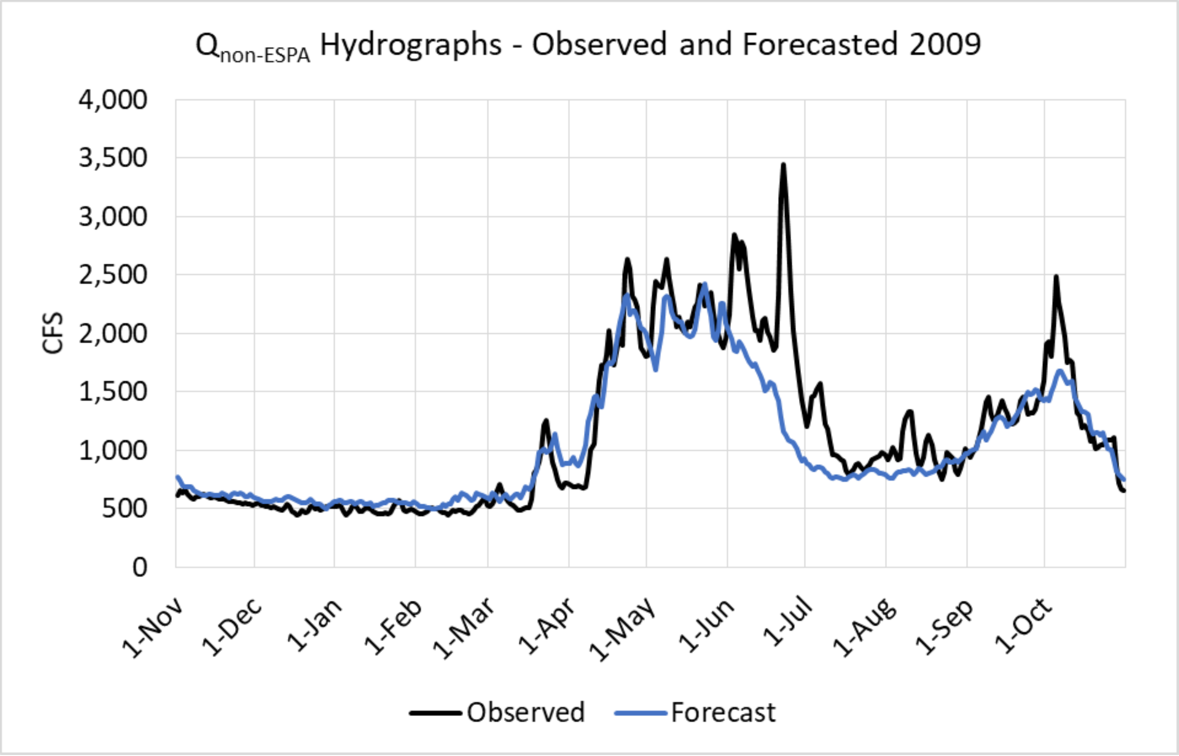

Northside Canal Company Returns




Kimberly

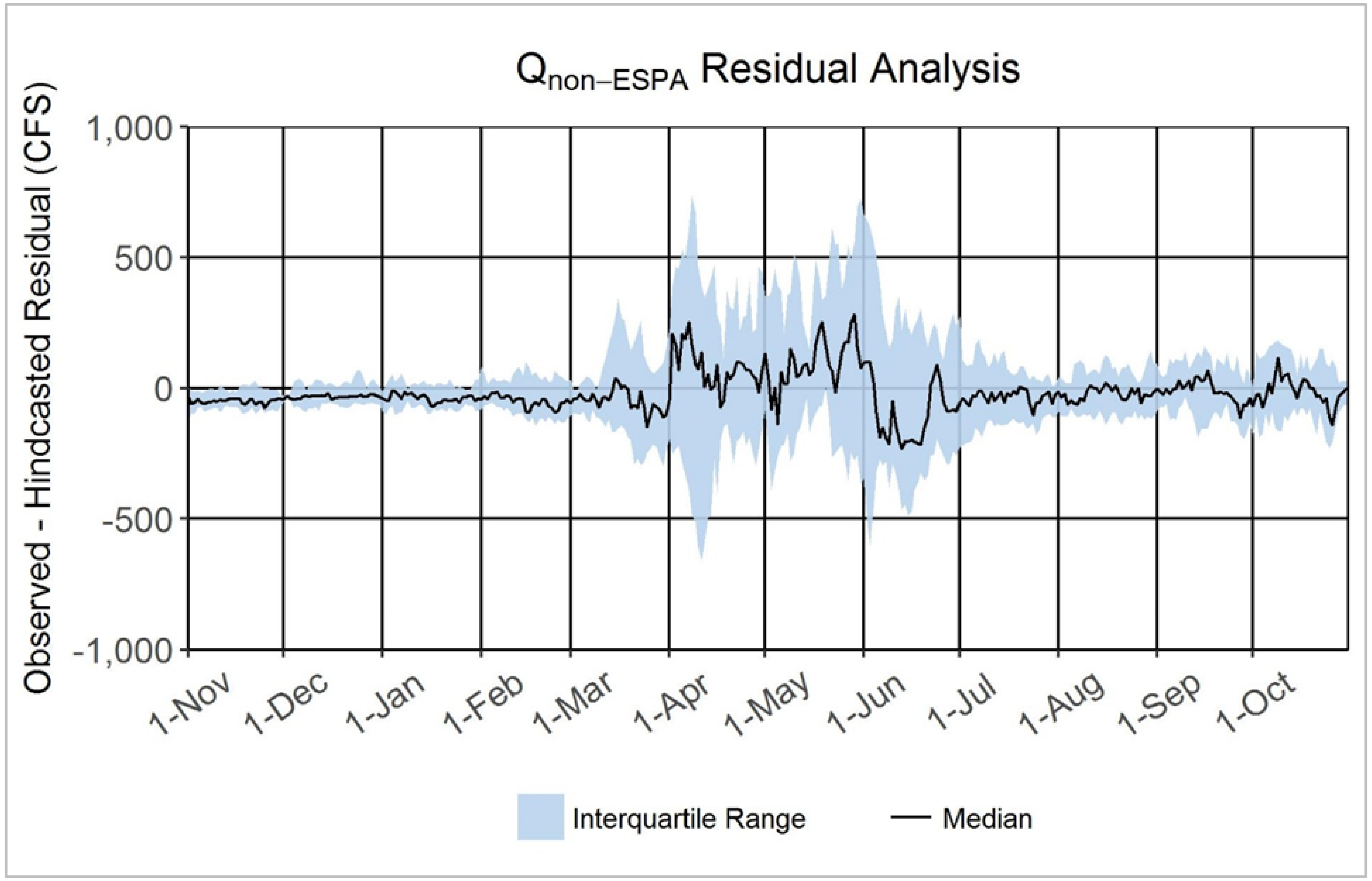
# Non-aquifer reach gain results - Hindcast of Observed and Forecast values



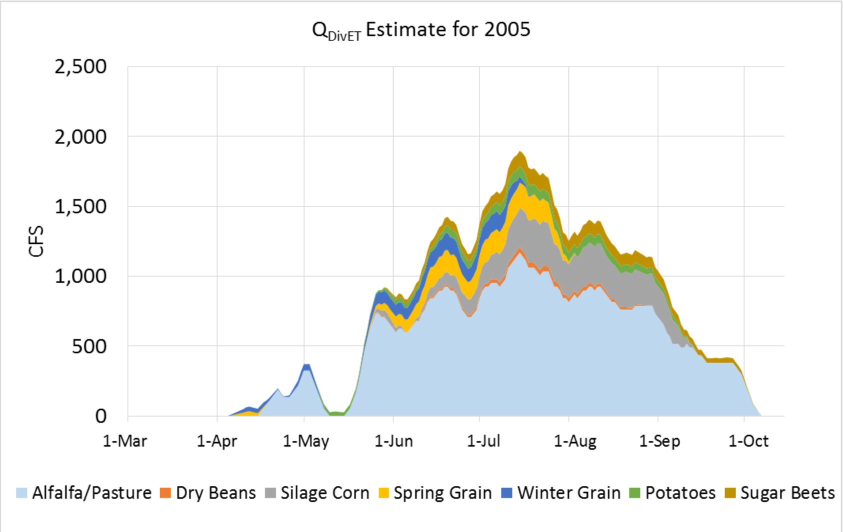



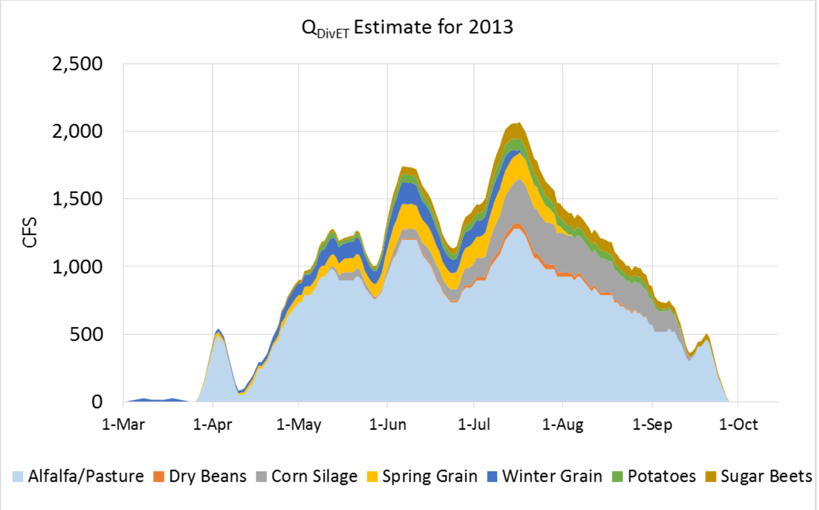
# Estimation of non-ESPA Reach Gains

- Hindcast of Observed and Forecast values in 2009



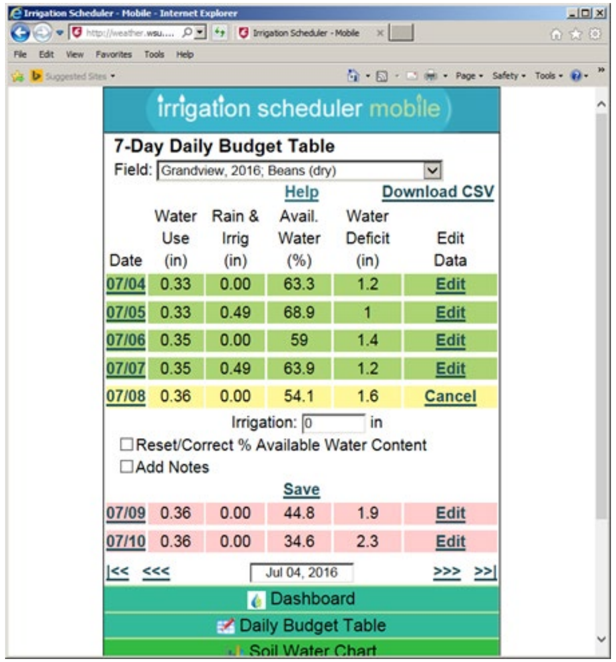
# Removing Consumptive Diversion



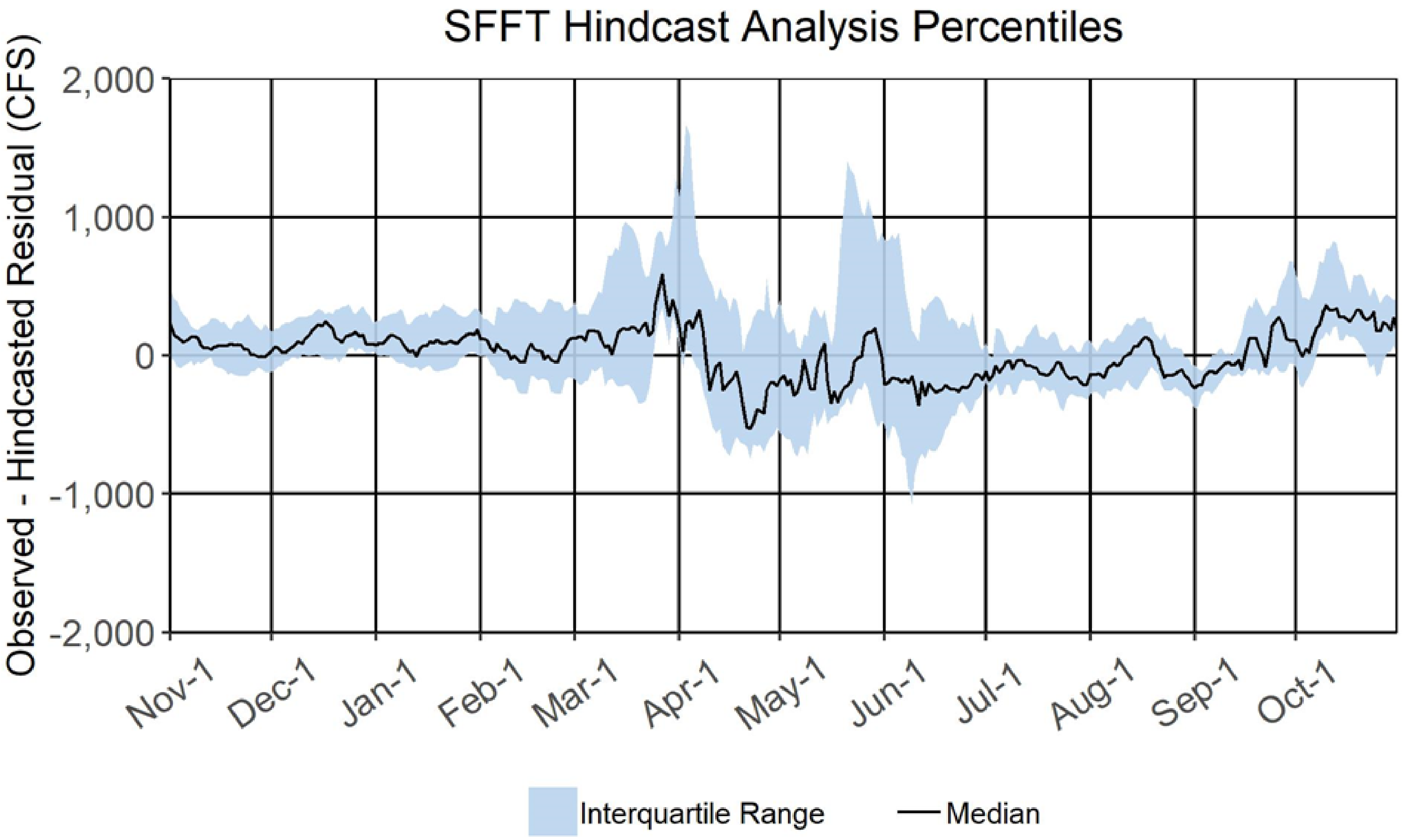




The acreage and percent crop mix within the BID and WD02 for the period from 2010 to 2014.

| Crop Type | 2010 | 2011 | 2012 | 2013 | 2014 | Average |
|---|---|---|---|---|---|---|
| Alfalfa/Pasture | 73,400 (60%) | 65,800 (53%) | 65,600 (55%) | 58,400 (49%) | 69,100 (56%) | 54% |
| Beans, Dry | 4,400 (4%) | 1,400 (1%) | 2,900 (2%) | 2,300 (2%) | 1,200 (1%) | 2% |
| Corn, Silage | 16,100 (13%) | 18,100 (15%) | 20,000 (17%) | 21,900 (18%) | 16,400 (13%) | 13% |
| Grain, Spring | 13,100 (11%) | 14,300 (12%) | 9,800 (8%) | 10,800 (9%) | 11,300 (9%) | 10% |
| Grain, Winter | 7,300 (6%) | 12,300 (10%) | 9,200 (8%) | 10,300 (8%) | 9,000 (7%) | 8% |
| Potatoes | 4,400 (4%) | 6,100 (5%) | 6,200 (5%) | 6,300 (5%) | 5,800 (5%) | 5% |



# Forecast Tool Performance



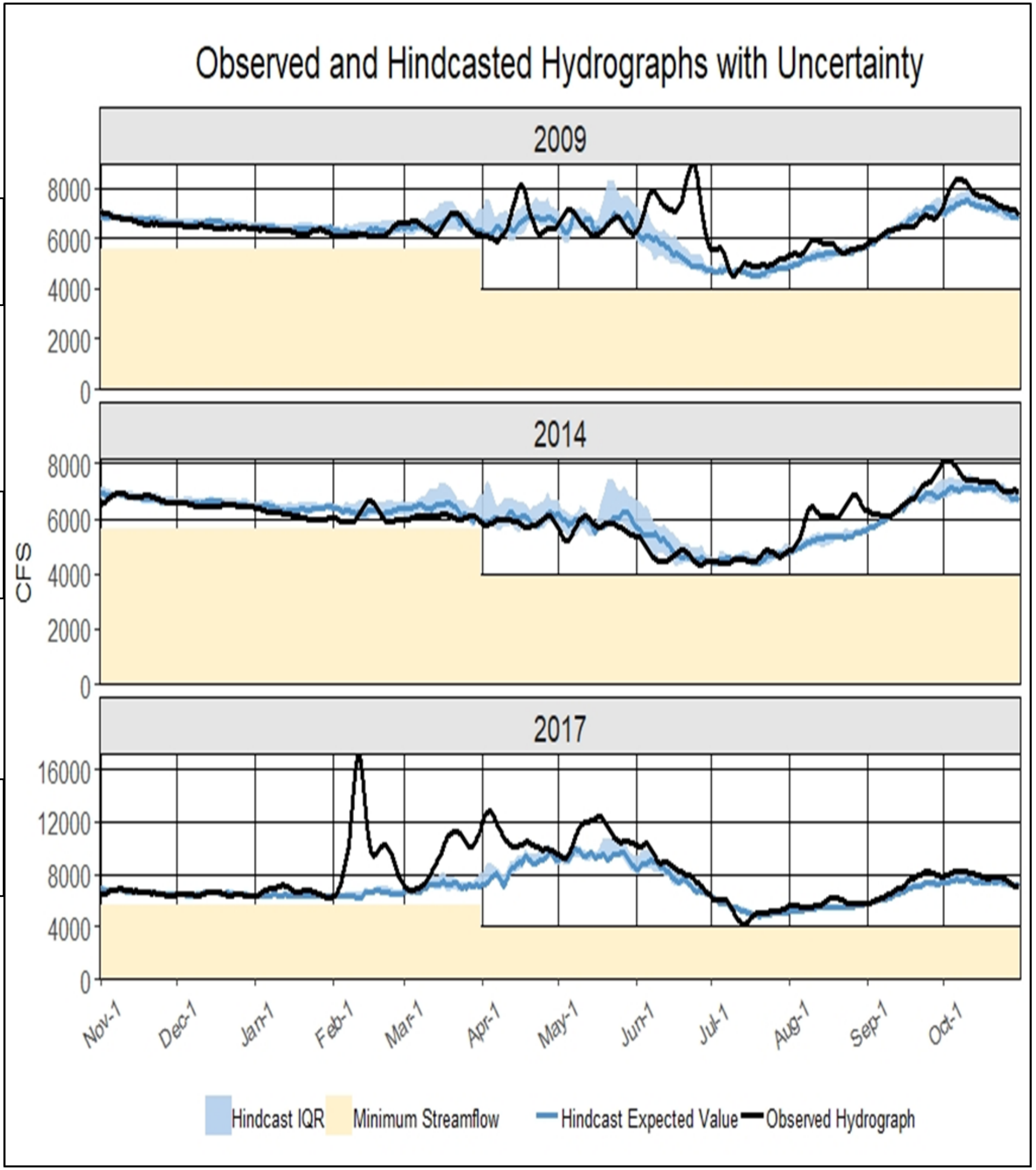
# Forecast Tool Performance

Observed and hindcasted Snake River hydrographs

**Avg. water year (2009)**

**Dry water year (2014)**

**wet water year (2017)**



# Pocket Slides

# 1. Project Goals & Project Team

1.2 Project Team

Supported by staff at IDWR

Sean Vincent—Managed the Project

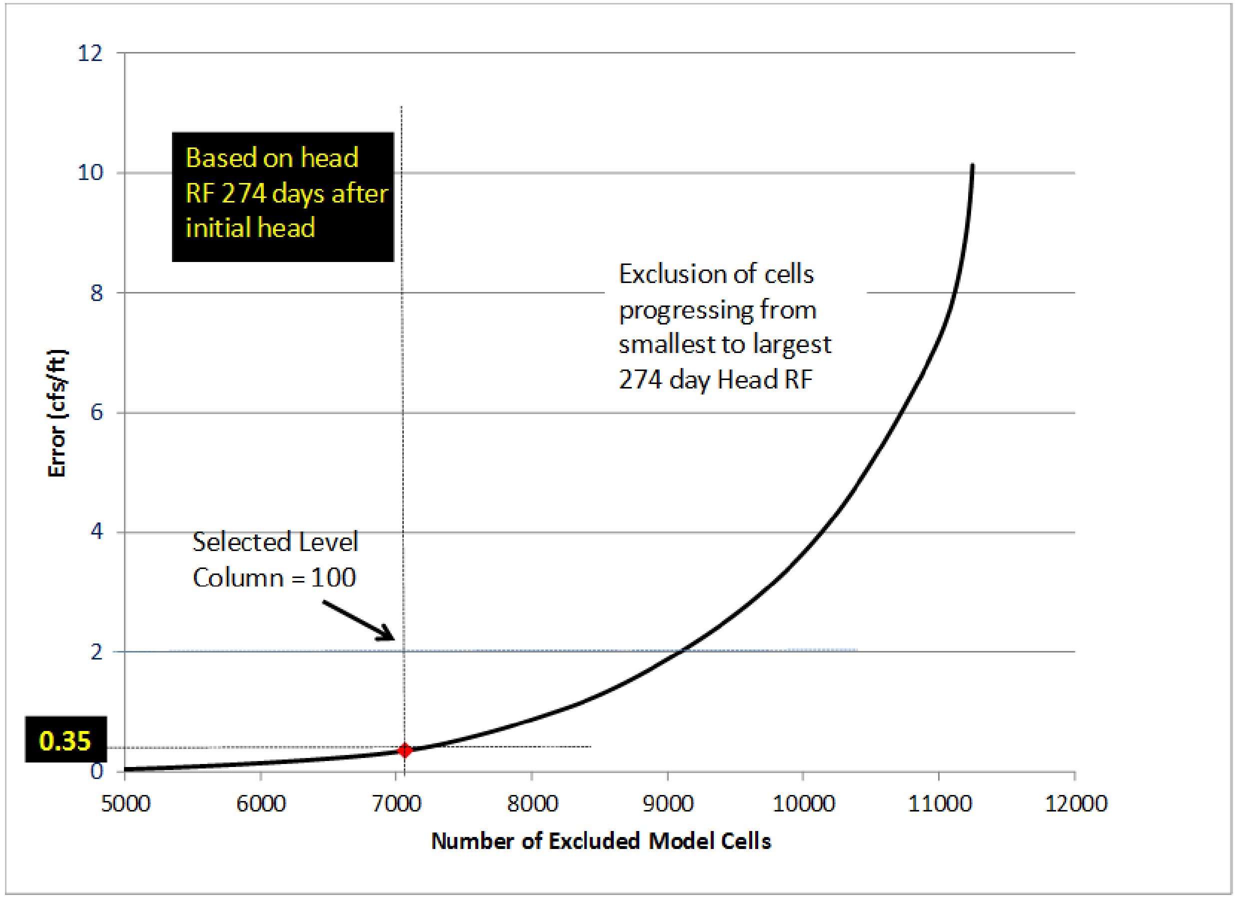
David Hoekema—Calculated Historic Consumptive Diversions

Dan Stanaway—Calculated Return Flow Estimates

Jenifer Sukow & Mike McVay, Wesley Hipke, Liz Cresto, and Allan Wylie provided insight & data

# 3.1. Aquifer Discharge Forecast Methods & Procedures

- Starting Heads Limited to the first 100 columns of ESPAM



# 3.1. Aquifer Discharge Forecast Methods & Procedures

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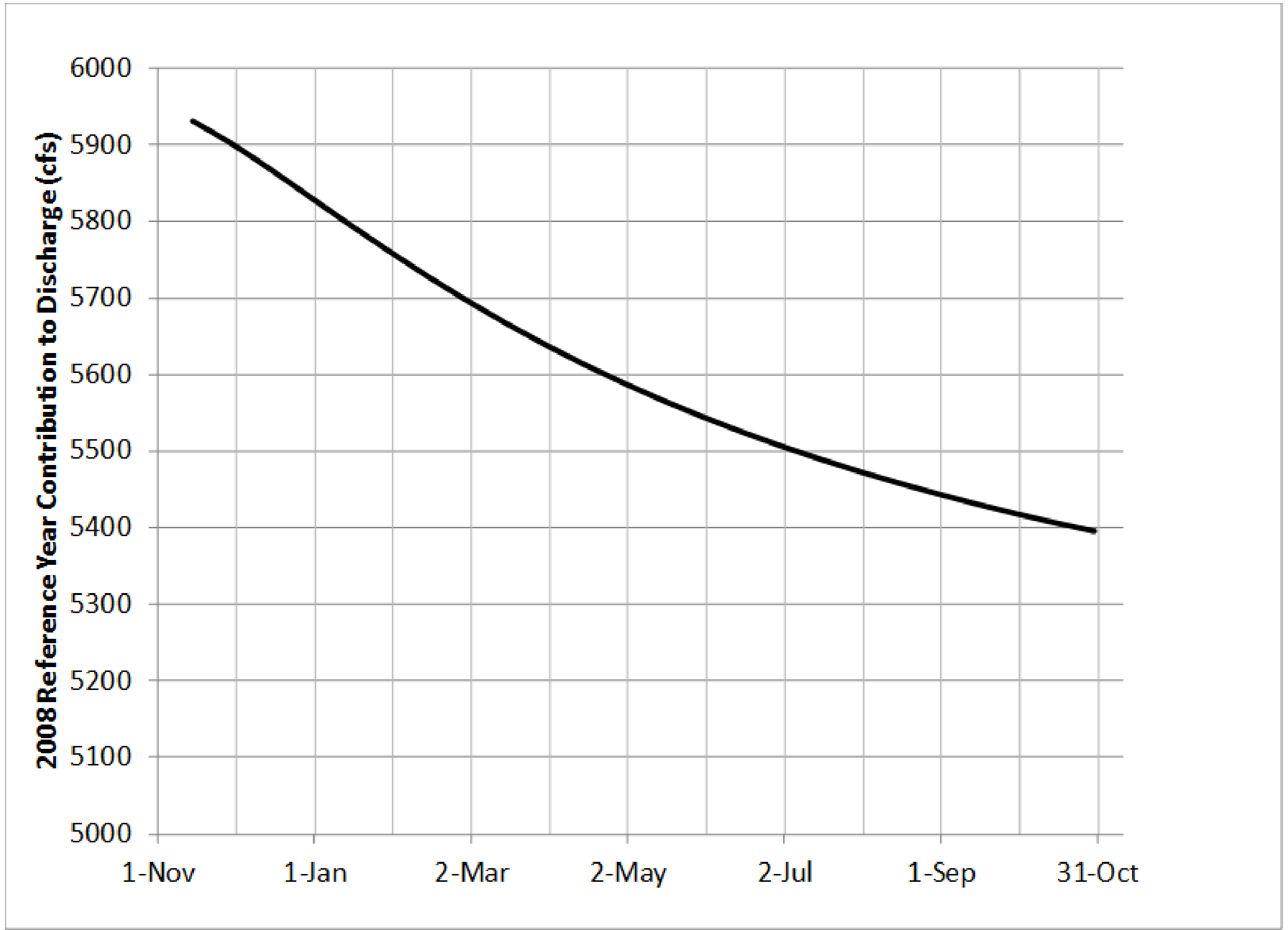


Figure 3-4. Simulated Snake River reach gains between Kimberly to King Hill resulting from November 2008 ESPAM 2.1 simulated heads with no subsequent aquifer recharge or discharge.
Dates shown after January 1 are in 2009

$$y(t) = \alpha + \sum_{i=1}^{m} \beta_i x_i(t) + \sum_{j=1}^{p} \phi_j \left[ y(t-j) - \left( \alpha + \sum_{i=1}^{m} \beta_i x_i(t-j) \right) \right] + \varepsilon,$$