# MEMORANDUM

Date: October 24, 2022

To: Swan Falls Implementation Group

From: Swan Falls Technical Working Group

Subject: Analysis to determine if AADF would have been below the minimums at any time since 2014, but for IGWA-SWC-Cities settlement and IWRB managed recharge activities. (Question 1)

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## Methodology

The Swan Falls Technical Working Group (SFTWG) discussed the approach to providing an answer to the following question posed by the Swan Falls Implementation Group (SFIG):

1. Technical analysis to determine if the Adjusted Average Daily Flow (AADF) at the Snake River near Murphy gage would have been below the minimums at any time since 2014, but for IGWA-SWC-Cities settlement and IWRB managed recharge activities.

The SFTWG concurred that the Eastern Snake Plain Aquifer Model Version 2.2 (ESPAM 2.2) is the best available tool to estimate the contribution of the IGWA-SWC-Cities settlement and IWRB managed recharge activities conducted on the Eastern Snake Plain to flow at the Snake River near Murphy gage. The superposition version of ESPAM 2.2 was used to evaluate the response to the activities in question independently of other sources of aquifer recharge and withdrawals. The results of the superposition analysis of the effects of the activities in question were deducted from the observed flow at the Murphy gage, which reflects the cumulative effects of all ESPA stresses including the activities in question, as well as the contributions of hydrologic inputs and withdrawals occurring outside of the ESPA. Documentation for the ESPAM2.2 model, including a model calibration report, a report describing the superposition version, and a predictive uncertainty analysis report are available at https://research.idwr.idaho.gov/files/projects/espam/browse/ESPAM22_Reports/.

IDWR staff conducted the ESPAM 2.2 modeling to estimate the net change in reach gains in the Milner to King Hill reach of the Snake River resulting from aquifer enhancement activities (i.e., managed recharge and/or conservation) conducted by the Idaho Water Resources Board (IWRB), the cities and Idaho Ground Water Appropriators (IGWA). The IWRB initiated a managed recharge program in 2014 and IGWA initiated managed recharge and diversion reductions in 2016 under the IGWA-SWC Settlement Agreement, with both programs ongoing. For the model simulation, pumping reductions reported by IGWA were assumed to represent reduction in consumptive use of groundwater. Table 1 summarizes the annual recharge and aquifer water budget changes that are reflected in the ESPAM 2.2 model run.

Table 1. The yearly summary of inputs for the ESPAM 2.2 model runs in acre-feet.

| Calendar Year | IWRB* | | IGWA** | |
|---|---|---|---|---|
| | Natural Flow Recharge (AF) | Donated Storage and Cities' Recharge (AF)*** | Recharge (AF) | Conservation (AF) |
| **2014** | 36,246 | 0 | 0 | 0 |
| **2015** | 70,543 | 0 | 16,847 | 0 |
| **2016** | 75,470 | 0 | 101,814 | 146,439 |
| **2017** | 419,936 | 61,162 | 182,148 | 301,999 |
| **2018** | 354,297 | 53,771 | 124,437 | 240,725 |
| **2019** | 356,999 | 70,175 | 98,020 | 339,821 |
| **2020** | 449,823 | 67,303 | 109,276 | 254,001 |
| **2021** | 133,988 | 1,752 | 65,832 | 79,957 |
| **2022** | 95,262 | 0 | 0 | 0 |

* Differences in reported IWRB annual volumes are due to offset of reporting time frame from the calendar year. ** Differences from reported IGWA values are due to reporting time frames spanning across calendar years and missing or unknown site locations see Table 4 in Appendix A. Conversions are modeled to the extent that they reduce pumping from the 2010-2014 baseline reported by IGWA for specific groundwater points of diversion. Conversions occurring between 2010-2014 within NSGWD are not associated with specific groundwater points of diversion in IGWA's performance reports and were not included in this analysis. *** Includes 1800 to 4400 AF of City recharge in 2019, 2020, and 2021

The combined monthly impacts of aquifer enhancement activities to the reach gains were modeled with the ESPAM 2.2 each year from 2014 to 2022. The estimated monthly reach gain changes were then converted to average daily values and the daily results were subtracted from the Swan Falls Adjusted

Average Daily Flow (AADF) (https://idwr.idaho.gov/legal-actions/settlements/swan-falls/aadf-calculations). The AADF is the flow at the United States Geological Survey (USGS) Snake River near Murphy stream gage after adjustments are made to remove any fluctuations resulting from the operation of Idaho Power Company's hydropower facilities (Streamflow Measurement and Monitoring Plan can be retrieved from https://idwr.idaho.gov/wp-content/uploads/sites/2/legal/swan-falls-settlement/20140530-Swan-Falls-Measurement.pdf). In addition, daily natural flow IWRB lower valley managed recharge was added to the AADF (no lag time) since it would have passed the Snake River near Murphy gage as surface water had recharge not been conducted. This IWRB managed recharge diversion occurs in the fall, winter, and spring and so there are increases to the "AADF – 3 Day Average: Excluding Aquifer Enhancements" during these times within the annual hydrographs (Figures 1-9). Equation 1[1] summarizes the calculation that was conducted:

AADF (Excluding Aquifer Enhancements) = AADF (Observed) + Lower Valley Recharge (Observed) – ESPAM 2.2 Superposition Reach Gain (Modeled) (Equation 1)

[1] Equation 1 omits Upper Valley recharge, which the SFTWG acknowledges would also impact flow past Milner had it not been conducted. However, adding Upper Valley recharge into the surface water calculation is not as straightforward as adding Lower Valley recharge because of flow time lags and reservoir operations at American Falls. Because the analysis is interested in whether Swan Falls would have fallen below the minimums at any point during the analysis period, excluding Upper Valley recharge would not change the answer to the question since it typically occurs in times of above normal water supply and the minimum flows are not at question. However, for a full water balance accounting of what the Swan Falls AADF would have been without recharge, Upper Valley recharge would need to be accounted for, with the bulk or potentially all that water likely to pass Milner Dam had recharge not occurred.

## Discussion of Uncertainty and Variability

The SFTWG extensively discussed the uncertainty, variability, and simplifications inherent in the relatively straightforward modeling and simple additions/subtractions to the observed AADF. The SFTWG has developed the following list of drivers of uncertainty, which are at this time qualitative. If the SFIG desires that these elements are assigned a quantitative value, then the SFTWG can provide an estimate on the scope and level of effort that would be required.

The Eastern Snake Plain Aquifer Model, Version 2.2 (ESPAM2.2), like all regional groundwater flow models, is a simplified simulation of a complex natural system that is continually affected by climate variability and human activities. Uncertainty is inherent in the results of all model simulations. A predictive uncertainty analysis (Sukow, J. (May 2021). *Predictive Uncertainty Analysis Eastern Snake Plain Aquifer Model Version 2.2*) was conducted during model development to provide a general understanding of the uncertainty associated with predictions made using ESPAM2.2. The predictive uncertainty analysis included evaluations of the uncertainty of predictions of the steady state response at the Kimberly to King Hill reach to aquifer stresses applied in each of seven regions within the model boundary. Based on an aggregation of the results for the seven predictions, the estimated predictive uncertainty for a model prediction of the long-term response in the Snake River below Milner Dam to aquifer stresses distributed throughout the model domain is +/-3.6% (Table 2).

Table 2. ESPAM2.2 predictive uncertainty analyses for the Kimberly to King Hill reach

| District | Applied Stress (cubic feet per day (cfd)) | Calibrated Impact (cfd) | Post-calibration standard deviation (cfd) | Post-calibration 95% confidence interval (cfd) |
|---|---|---|---|---|
| WD33 | 5,534,425 | 144,059 | 8,469 | 16,599 |
| WD34 | 5,382,210 | 1,586,725 | 112,678 | 220,849 |
| WD100 | 14,669,608 | 24,897 | 3,466 | 6,794 |
| WD110 | 46,659,571 | 602,703 | 45,151 | 88,496 |
| WD120 | 123,918,862 | 5,201,317 | 131,761 | 258,251 |
| WD130 | 93,942,633 | 50,947,644 | 714,431 | 1,400,284 |
| WD140 | 34,852,549 | 16,208,780 | 366,955 | 719,232 |
| Sum | 324,959,857 | 74,716,125 | 1,382,911 | 2,710,506 |

Aggregate predictive uncertainty = 2,710,506/74,716,125 = 3.6%

The predictive uncertainty analysis also included evaluations of the uncertainty of predictions of the transient response in aquifer storage retention to aquifer stresses applied at each of five managed recharge sites, including the lower valley Milepost 31 and Shoshone recharge sites. The predictive uncertainty for the retention of aquifer storage at a time five years after a recharge event was +/- 7.2% for the Milepost 31 recharge site and +/- 7.6% for the Shoshone recharge site. While not directly applicable to the current analysis, these results illustrate there is generally somewhat higher predictive uncertainty in transient predictions inherent to the uncertainty in calibration of aquifer storage parameters.

As noted in the predictive uncertainty report, predictive uncertainty analyses only consider the uncertainty associated with adjustable model parameters and do not account for potential predictive error resulting from other sources such as the conceptual model, model discretization, or the values of fixed model parameters. The total uncertainty in steady state model predictions of impact to Snake River flow below Milner Dam will be somewhat greater than +/- 4%. Total uncertainty in transient model predictions is expected to be somewhat greater than +/- 8%.

1. The superposition version of ESPAM2.2 neglects non-linearity in the fully-populated model resulting from the presence of river cells that are perched during the 10-year average condition but may become hydraulically connected to the aquifer during the simulation as water levels rise in response to a simulated decrease in groundwater pumping (or other increase in net recharge). The fully-populated model is able to respond appropriately to the increase in water levels, but the superposition model cannot because the perched river cells have been converted to model cells without a river boundary. Because these river cells are located in the Heise to Shelley and Neeley to Minidoka reaches of the Snake River, the effect on predictions of impacts to the Kimberly to King Hill reach is minimal. Predicted responses to a simulated aquifer-wide curtailment of groundwater use in reaches between Kimberly and King Hill were 0.49% to 0.60% higher in the superposition simulation than in the fully populated simulation (Sukow, J. (March 2021). *Comparison of Superposition Model with Full-Populated Model for Eastern Snake Plain Aquifer Model Version 2.2*).
2. The SFTWG, with IDWR staff leading the effort, have undertaken their best efforts at correctly capturing the reported IWRB recharge volumes, IGWA-SWC agreement recharge, and pumping reduction data. Any stakeholder familiar with such large datasets over the time period and spatial application being considered here understands the challenges in correctly capturing all activities and aquifer water budget stressors. The SFTWG feels that the analysis is thorough and well-representative, but changes to input data could change analysis results. For this analysis, pumping reductions reported by IGWA were assumed to represent reductions in consumptive use of groundwater. To the extent that pumping reductions may have resulted from increases in efficiency instead of reductions in consumptive use, the analysis will overestimate the impact of IGWA's pumping reductions on aquifer stress and the resulting response in Snake River reach gains.

3. Assumptions around how surface water management would have been different had it not been for recharge are not included in this analysis. For example, only Lower Valley recharge is added back to the observed AADF as a conservative assumption. In years where Upper Valley recharge was also being conducted, it is possible that releases of natural flow past Milner Dam would have been larger, resulting in a higher AADF in the case of excluding recharge.
    a. Idaho Power and collaborative partners have been conducting cloud seeding in the Upper Snake and Henrys Fork Basins since 2008. The SFTWG acknowledges that the addition of water due to cloud seeding activities has a connection to the amount of recharge and other aquifer management that has been observed since 2014. However, the quantification and assignment of additional water from cloud seeding to specific water management activities is challenging and requires multiple analyses and models, each with their associated uncertainties. Idaho Power and IDWR are currently pursuing model improvements to conduct such analyses.

## Discussion of Results

Figures 1A through 10A summarize the results of the ESPAM 2.2 simulation of managed recharge and conservation activities and AADF surface water adjustments for calendar years 2014 through 2022. Table 1A summarizes the monthly average difference between the observed AADF and the AADF calculated to reflect no IWRB or IGWA-SWC recharge and conversion activities.

Flow Augmentation and flood control are included in the AADF calculation for IDWR purposes. These flows usually do not coincide with the AADF during the critical low flow period from June through August, except for the 2021 calendar year. Flow augmentation occurred later than usual in 2021, at the end of June, and coincided with the AADF flows during the critical low flow period. Due to this, the

Snake River at Milner flow was removed from the AADF calculation for all of 2021 so that we could determine if the AADF would have dropped below the minimum (Figure 10A).

***The analysis indicates the AADF would have remained above the Swan Falls minimum flow from 2014 to 2022 without IGWA, Cities, and IWRB activities*** (see Figures 1 through 9 and no conclusions were drawn for 2022). The exception is March 2015, when the AADF – 3 Day Average dropped below the 5,600 cubic feet per second (cfs) minimum to 5,541 cfs and 5,563 cfs on March 28$^{th}$ and 29$^{th}$, respectively. The 2015 drop below the minimum would also have occurred without the aquifer enhancement activities. The 2021 AADF analysis shows that without the reach gains resulting from aquifer enhancement activities the Snake River near Murphy flows were approximately 150 cfs above the minimum streamflow target of 3900 cfs. It is possible that given the uncertainty in the model and recharge/conservation inputs flows could be closer to the minimum threshold if not for the IGWA, Cities, and IWRB activities.

# Appendix A:

Swan Falls AADF with impacts of Aquifer Enhancement Activities

For the following Swan Falls AADF figures, the "AADF – 3 Day Average: Excluding Aquifer Enhancements" excluded aquifer enhancements and includes the natural flow that was diverted by the IWRB recharge program during the fall, winter, and spring months.

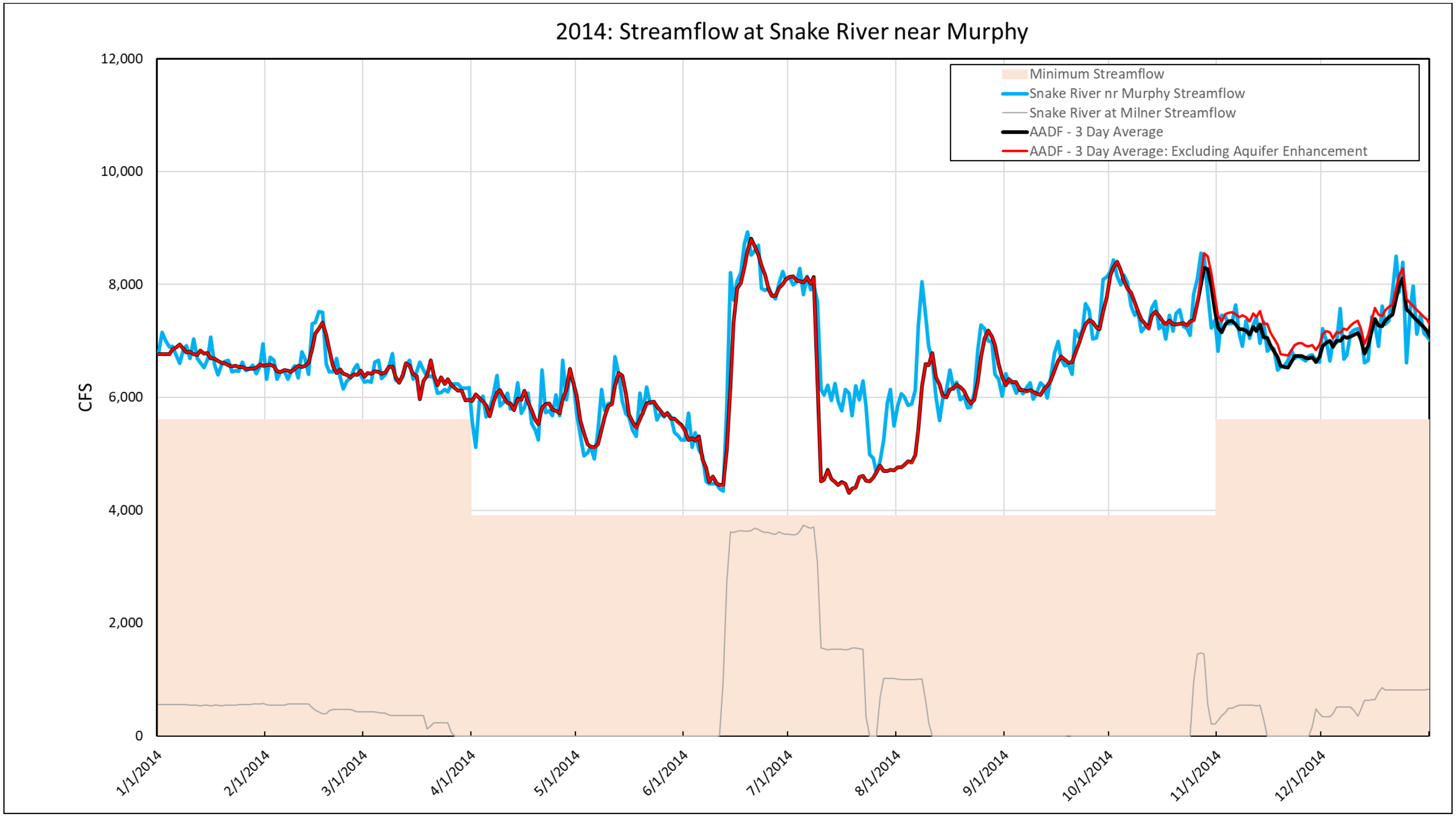


Figure 1. The impact of aquifer enhancement activities on the Swan Falls AADF calculation during the 2014 calendar year

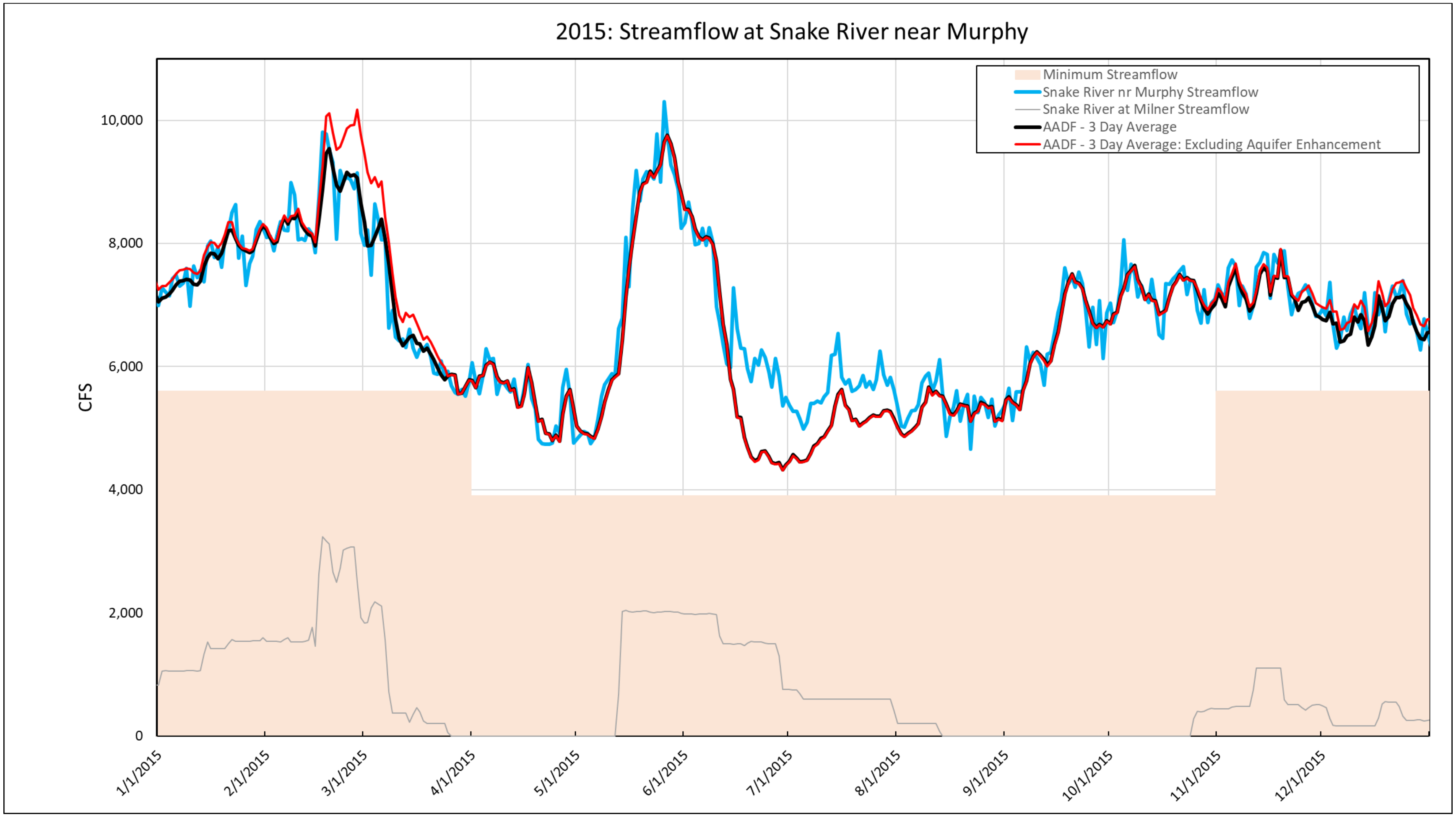


Figure 2. The impact of aquifer enhancement activities on the Swan Falls AADF calculation during the 2015 calendar year

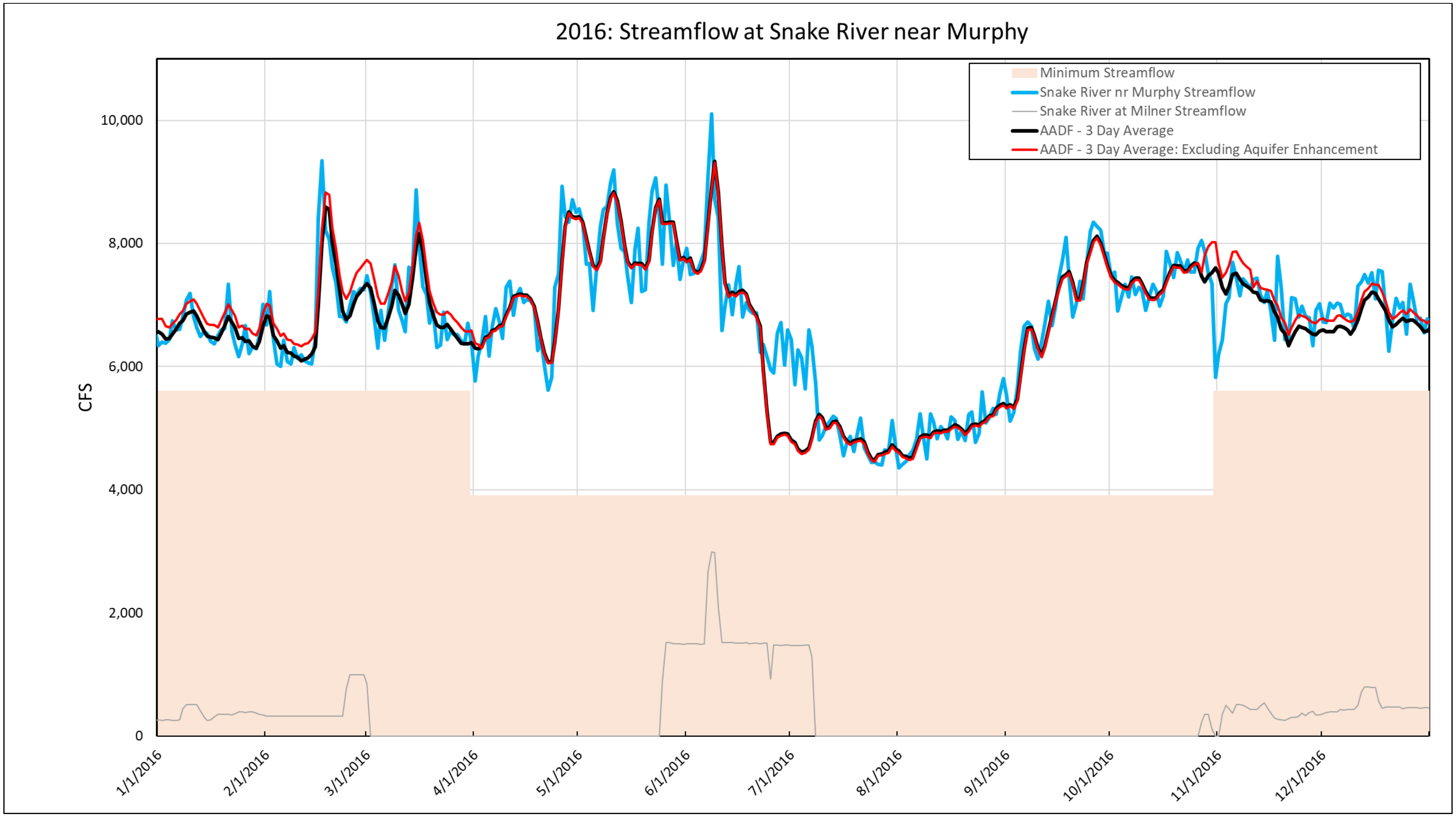


Figure 3. The impact of aquifer enhancement activities on the Swan Falls AADF calculation during the 2016 calendar year

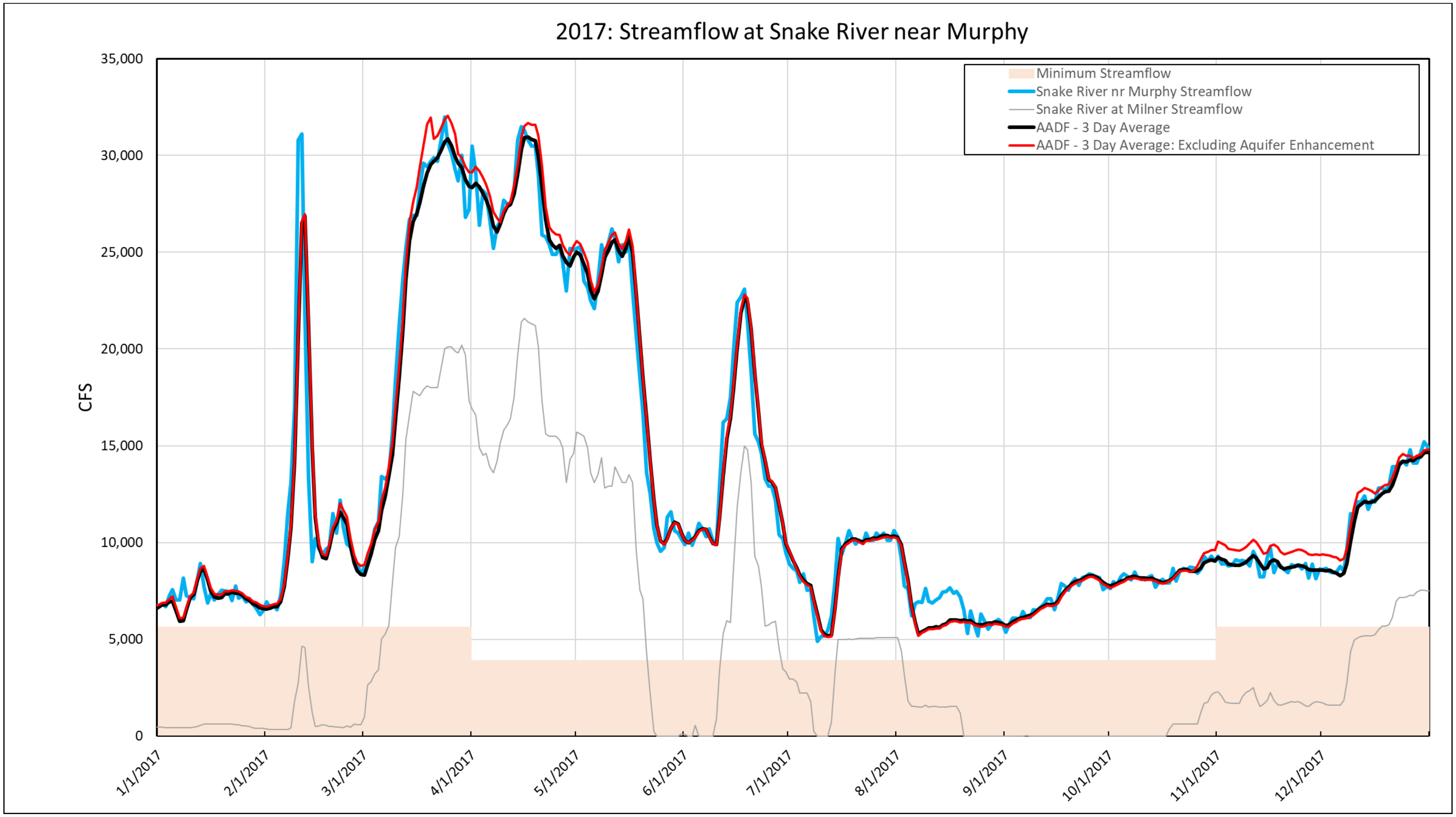

Figure 4. The impact of aquifer enhancement activities on the Swan Falls AADF calculation during the 2017 calendar year

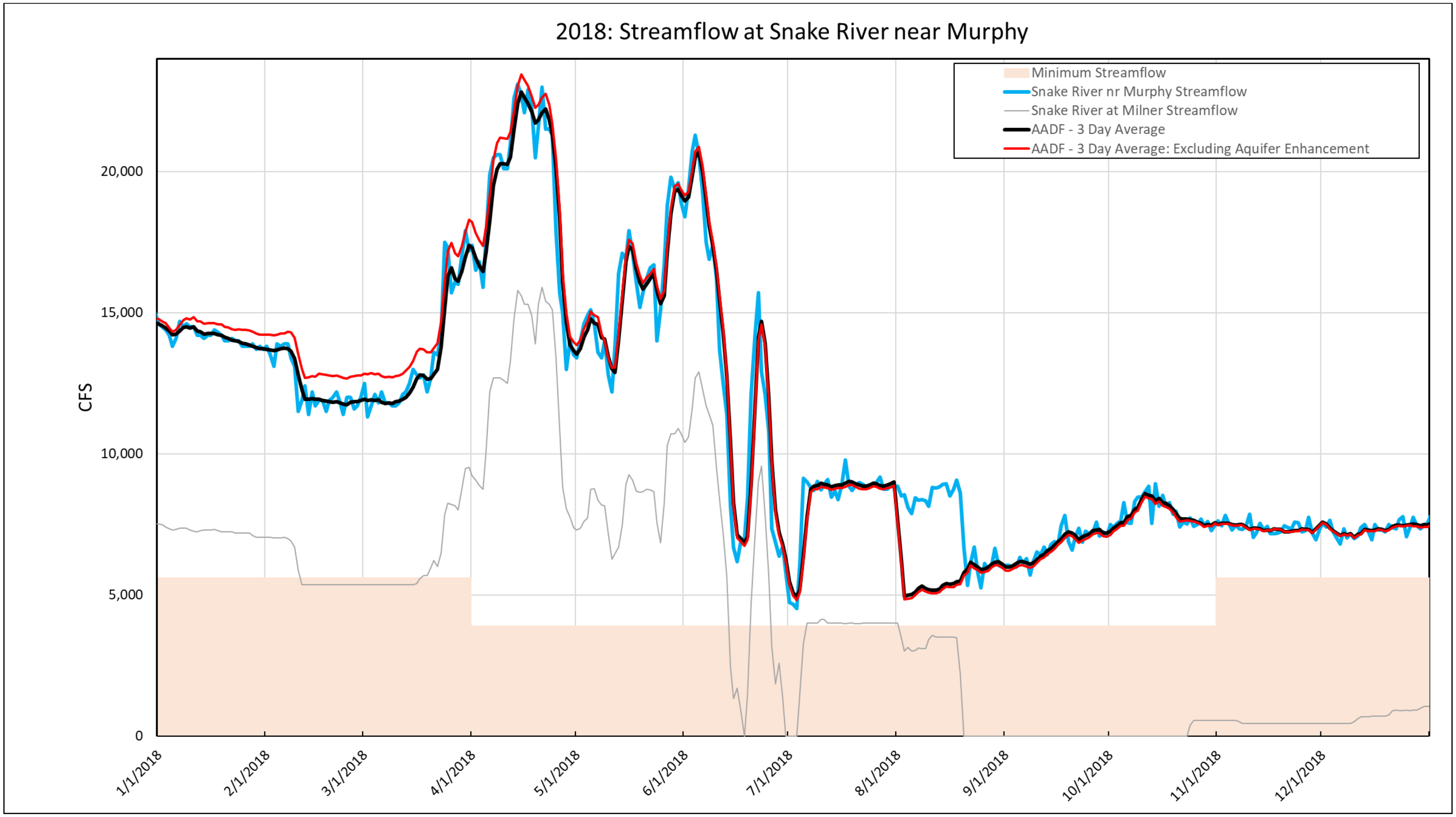

Figure 5. The impact of aquifer enhancement activities on the Swan Falls AADF calculation during the 2018 calendar year

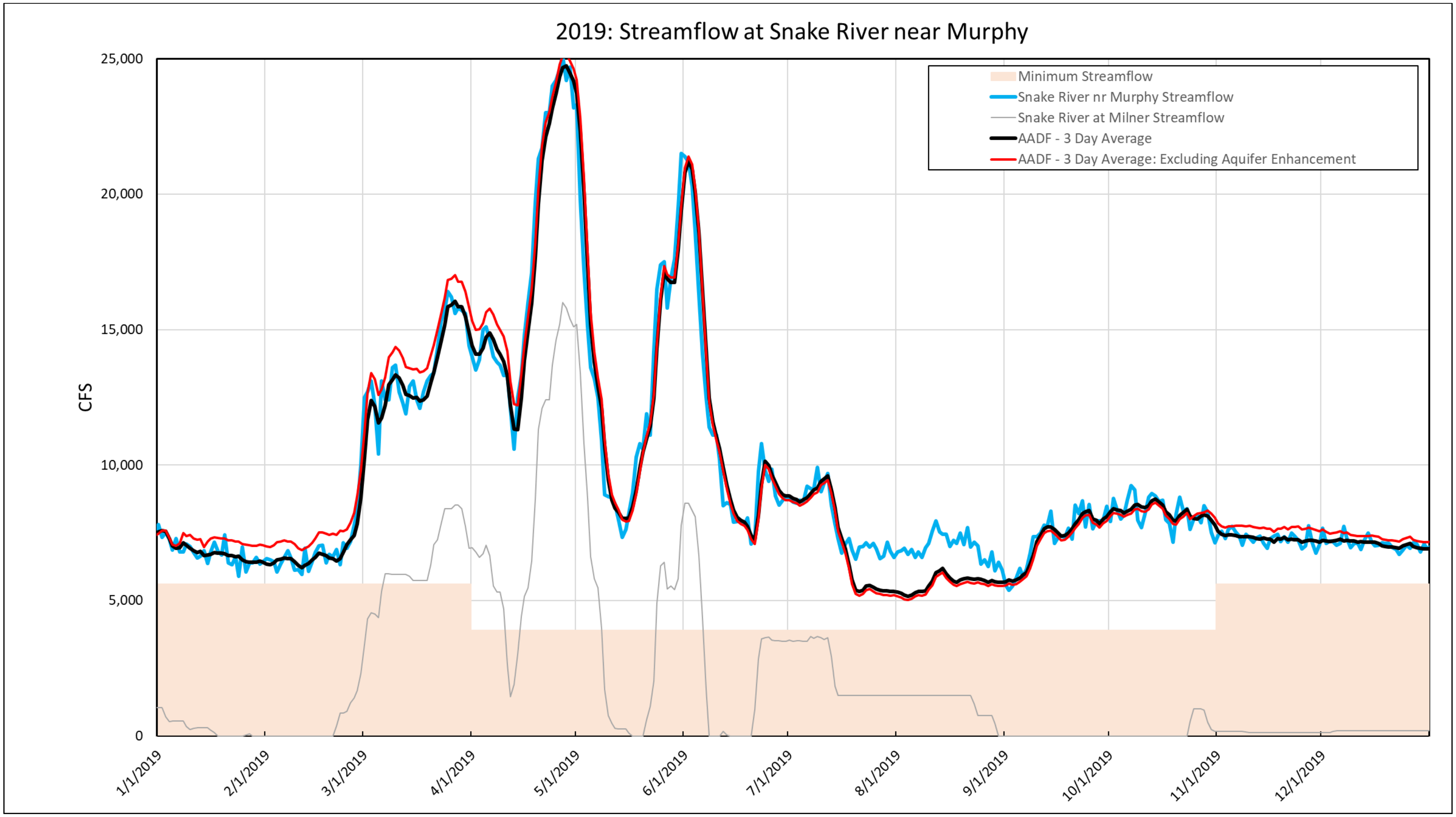


Figure 6. The impact of aquifer enhancement activities on the Swan Falls AADF calculation during the 2019 calendar year

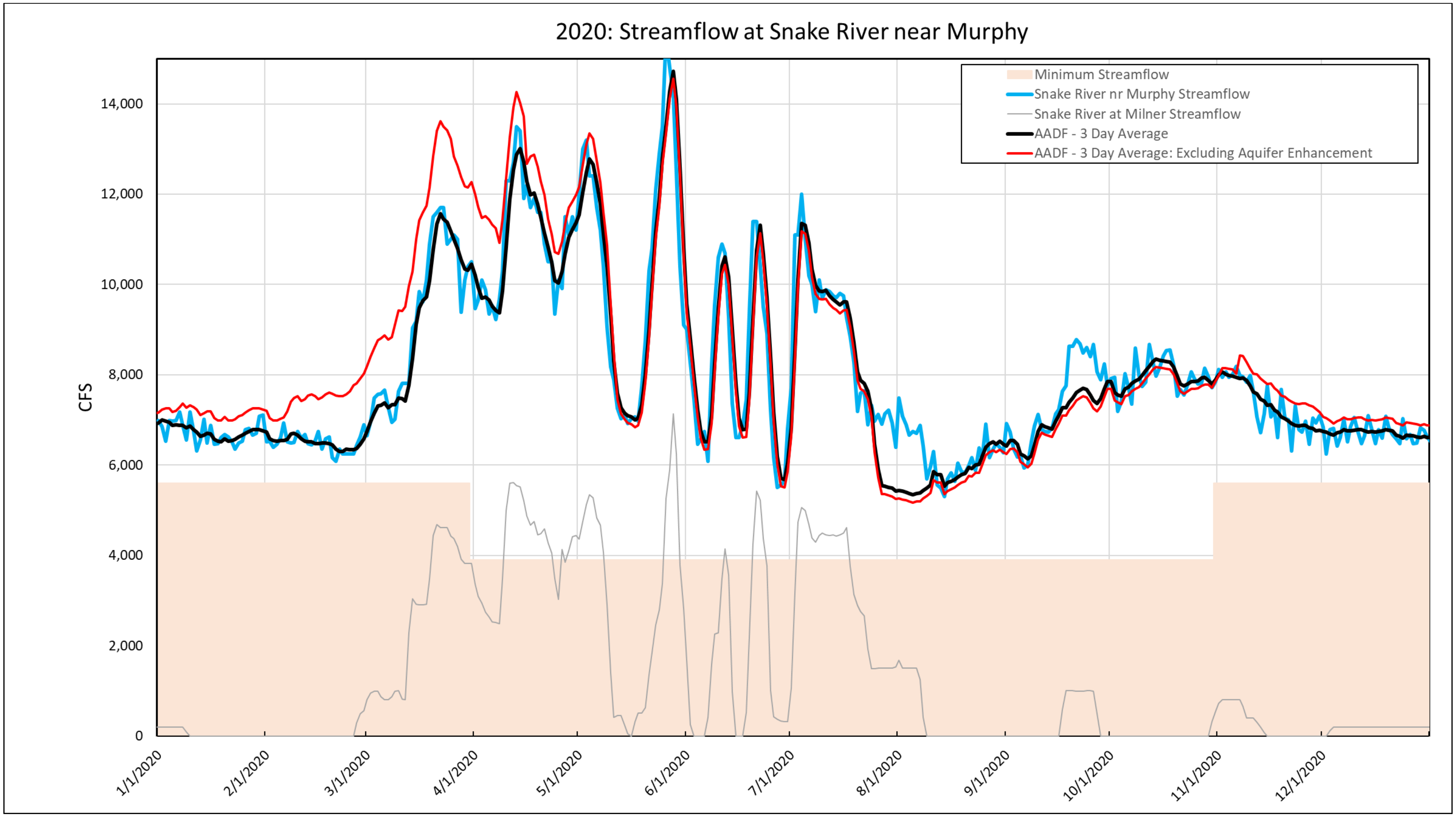

Figure 7. The impact of aquifer enhancement activities on the Swan Falls AADF calculation during the 2020 calendar year

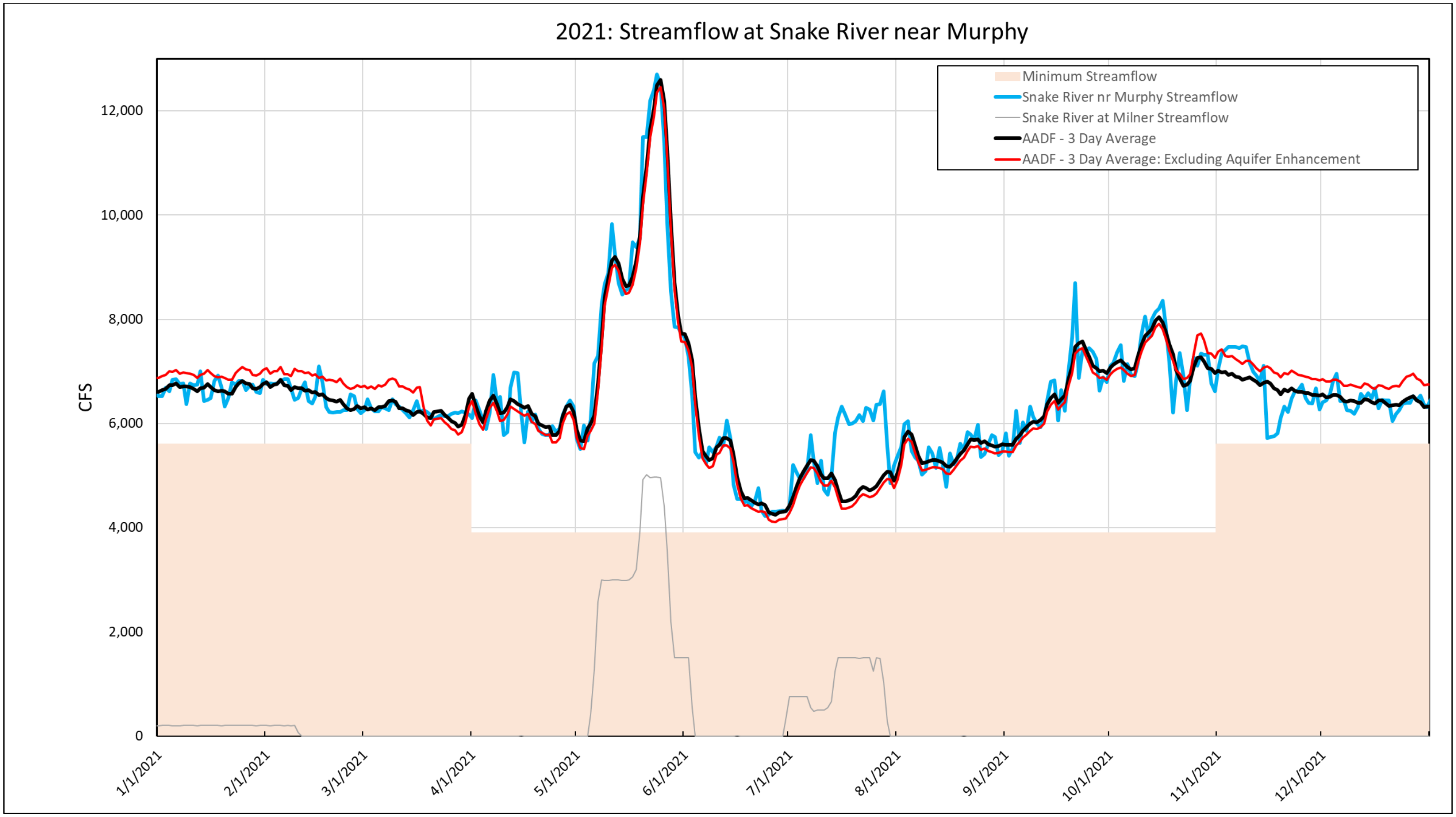


Figure 8. The impact of aquifer enhancement activities on the Swan Falls AADF calculation during the 2021 calendar year

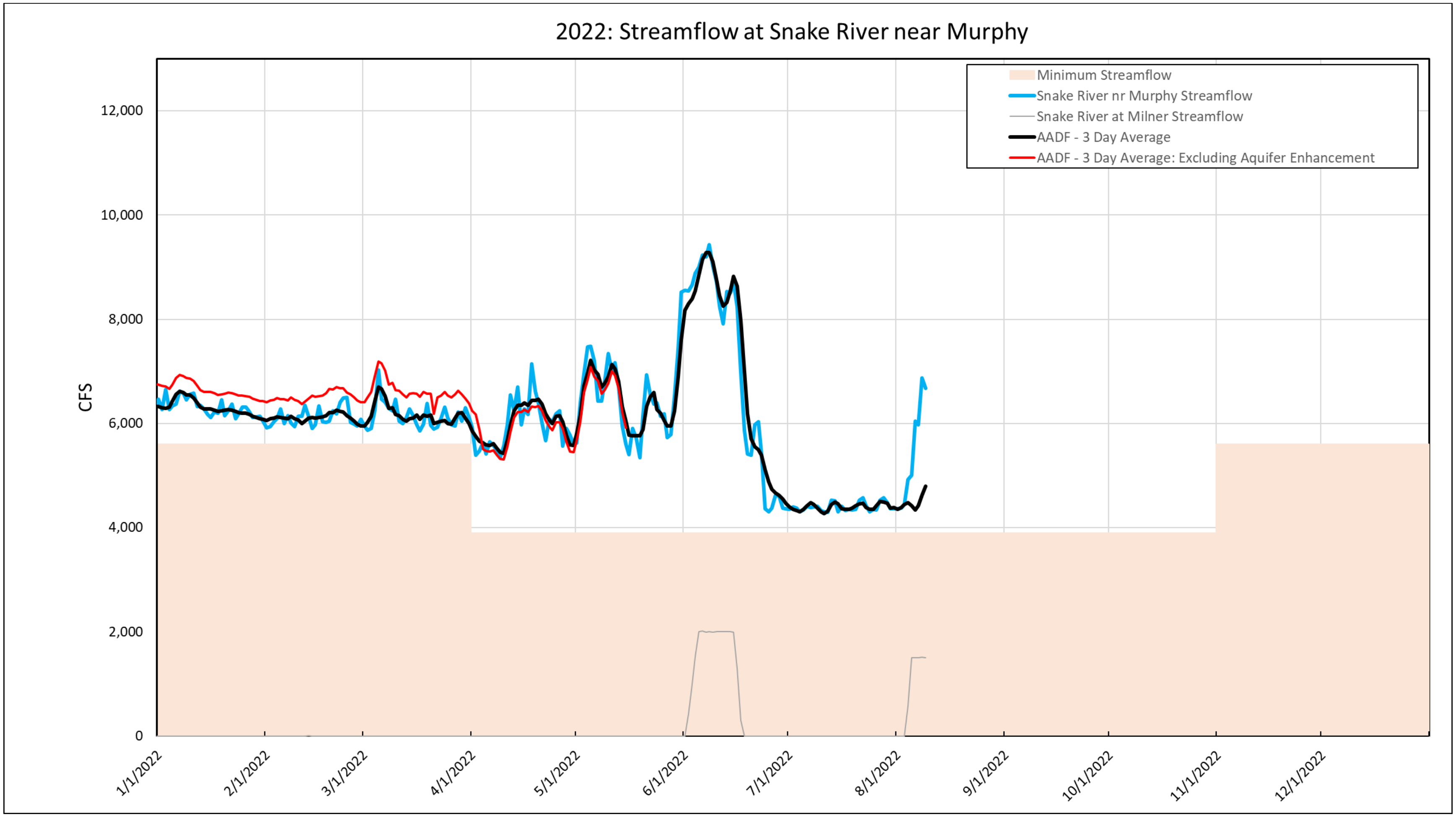

Figure 9. The impact of aquifer enhancement activities on the Swan Falls AADF calculation during the 2022 calendar year

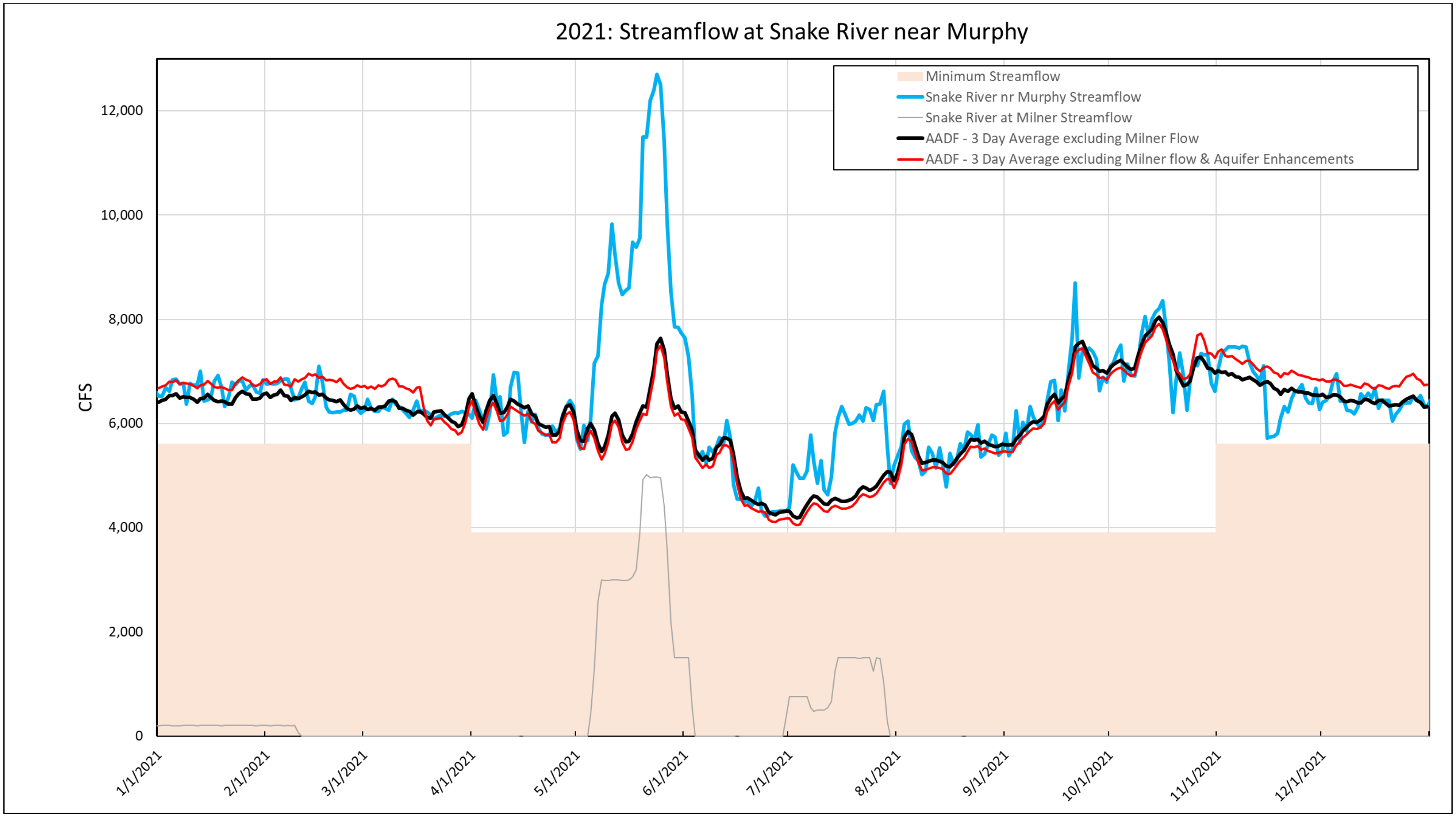


Figure 10. Figure of the AADF – 3 Day Average excluding Snake River at Milner flows and Aquifer Enhancements to removed contribution of Flow augmentation to the AADF calculation during the critical low flow period in July 2021.

Table 3. The average monthly difference (cfs) between the AADF and the AADF excluding aquifer enhancement activities for 2014 -2022. Positive values indicate that the observed AADF was higher than what would have occurred without recharge and conservation. Conversely, negative values indicate that the observed AADF was lower than what would have occurred without recharge and conservation.

| | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sept | Oct | Nov | Dec | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2014** | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 2 | -35 | -215 | -180 | -35 |
| **2015** | -131 | -341 | -344 | 8 | 10 | 11 | 12 | 12 | 12 | -2 | -84 | -225 | -87 |
| **2016** | -194 | -258 | -265 | 11 | 21 | 24 | 26 | 27 | 28 | -39 | -222 | -154 | -82 |
| **2017** | -141 | -213 | -974 | -641 | -230 | -64 | 63 | 73 | 76 | -39 | -786 | -504 | -280 |
| **2018** | -342 | -777 | -917 | -661 | -206 | -11 | 112 | 117 | 118 | 94 | 22 | 34 | -195 |
| **2019** | -416 | -737 | -1004 | -712 | -182 | 79 | 139 | 144 | 146 | 71 | -387 | -254 | -252 |
| **2020** | -432 | -965 | -1835 | -1131 | -76 | 170 | 177 | 178 | 175 | 161 | -387 | -271 | -348 |
| **2021** | -266 | -333 | -181 | 143 | 144 | 141 | 138 | 133 | 128 | -20 | -323 | -337 | -49 |
| **2022** | -338 | -404 | -452 | 78 | 124 | | | | | | | | |

Table 4. The total volume of conservation not modeled due to unknown locations or being outside the model boundary

| Calendar Year | Conservation volume with unknown location or location outside model boundary (AF) |
|---|---|
| **2016** | 804 |
| **2017** | 2470 |
| **2018** | 3062 |
| **2019** | 2597 |
| **2020** | 2038 |
| **2021** | 2234 |