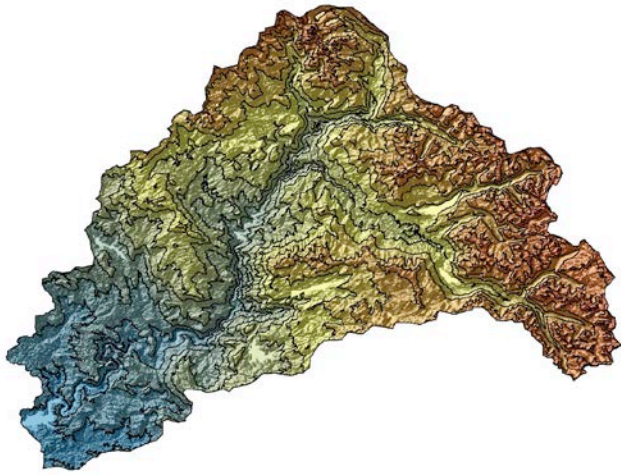
NASA Airborne Snow Observatory Factsheet

Background

Over two-thirds of the San Joaquin River runoff (the amount of water from melting snow and rain) is derived from snowpack. As such, accurately estimating how much runoff will result from the watershed's snowpack is critical to understanding runoff into Millerton Reservoir. The more accurate the runoff prediction, the more accurately agencies can manage the available water supply for environmental flows in early spring or irrigation water in late spring and summer.

For over 70 years, runoff forecasts have relied upon manual snow course measurements and historic relationships between these stations and watershed production. Over the most recent 30 years, snow course measurements have been augmented with automated snow stations (or "snow pillows") that relay snowpack conditions to scientists. Despite substantial effort and expense, this existing network is limited by the watershed's high elevation topography, accessibility and maintenance challenges, and a changing climate that are skewing predictability. Fortunately, there is a new method available for predicting the water content of Sierra snowpack that reduces seasonal runoff forecasts to less than a two-percent error: NASA's Airborne Snow Observatory (ASO).



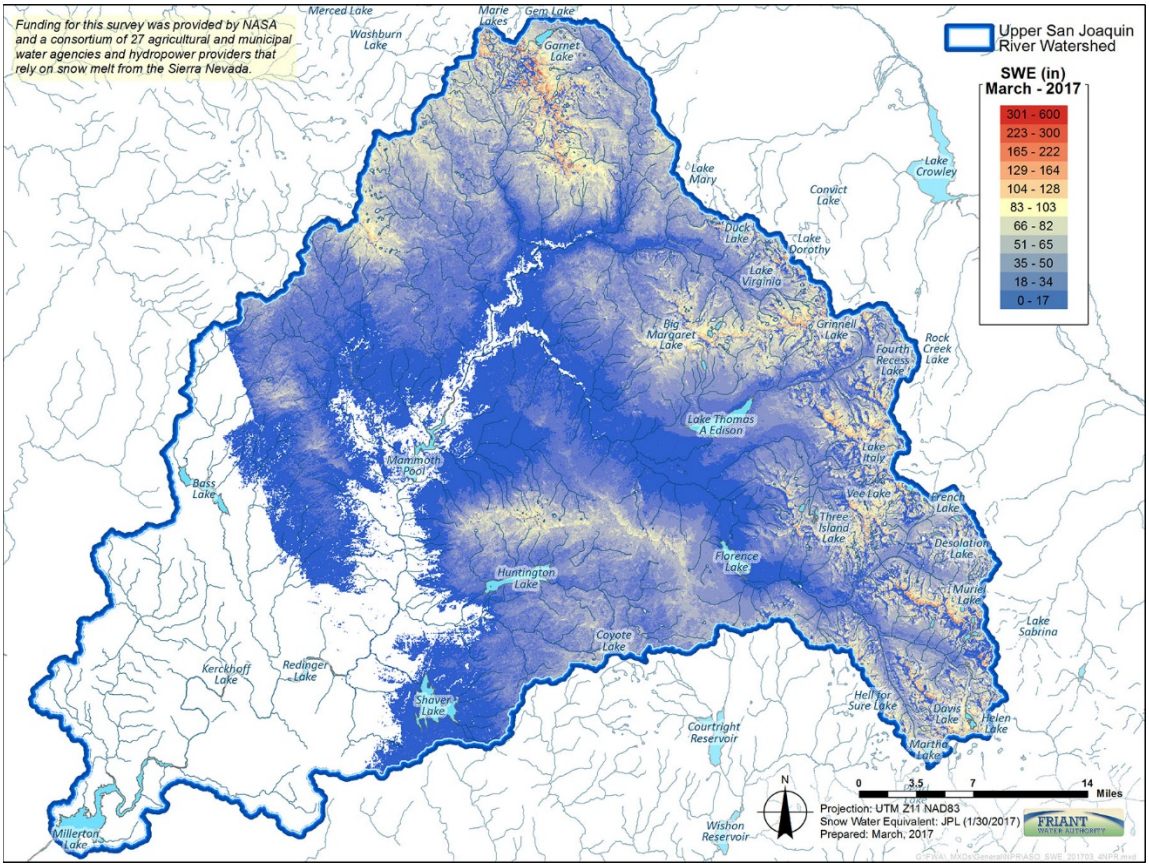
The San Joaquin Watershed is one of the highest elevation watersheds in California, with almost half of the terrain above 7,500' elevation and two-thirds of the runoff derived from snowpack. Snow courses and snow pillow are distributed between elevations of 6,800' and 11,400', with a substantial amount of the winter snowpack above the highest ground-based sensor.

ASO Data

Instead of examining the San Joaquin snowpack through widely scattered point measurements, ASO provides a watershed-wide, high-resolution snapshot and serves as a 21st Century tool to address the demands of modern water management.

Airborne Snow Observatory data is derived from two aircraft-mounted sensors — a LIDAR (Light Imaging Detecting And Ranging) instrument measures the surface elevation of the snow covered topography using a precise scanning laser, and a hyperspectral camera that measures snow reflectance at several points in the visible and near-infrared spectrum — combined with snowpack modeling to integrate the measurements. Snow density data is provided by existing ground-based sensors, and when combined with measurements of snowpack thickness produce snow water equivalent (SWE) estimates. An aircraft fitted with these sensors can image the entire watershed over the course of two to three days versus weeks of data collecting on foot. A state-of-the-art computer produces high-resolution maps of snow depth and SWE within two to

three days of flight completion. The hyperspectral data tracks snow albedo (reflectance) to help predict melt and runoff timing. Data can be subdivided by elevation band or sub-basin, giving greater detail for managing smaller reservoirs in the upper basin. The quick turn-around of information gives water operators the upper hand for managing water resources within the basin in nearly real-time fashion.



ASO produces snow water equivalent measures through a combination of LIDAR and ground-based snow density measures. The resolution is extremely fine detailed, capturing features and trends across the landscape that cannot be discerned from a handful of station or snow course measures.

ASO Plan for the San Joaquin Watershed

2017 marks the first year of a long-range ASO plan led by Friant Water Authority and sponsored by a consortium of partners including water users, environmental interests and agencies including the California Department of Water Resources, US Department of Agriculture – Agricultural Research Service, and the US Bureau of Reclamation. To demonstrate the value of this tool and test various ways to integrate the data into water supply forecasting and water management operations, a pilot study will take place from 2017 through 2019.

Over this three-year period, five to seven flights are planned annually, starting in January and continuing through May (or longer when the snowpack persists into summer). Additional flights may be added as conditions warrant such as after a significant storm event or when there are critical reservoir operational questions.

Beyond three years, an ambitious proposal is being developed by a consortium to secure funding for ASO measurements of the entire Sierra Nevada. Such a plan would have broad-based benefits addressing flood management; maximizing diversion for groundwater recharge and irrigation demand (by minimizing spills); environmental flows; wildlife fire management; forest mortality monitoring; hydropower optimization; recreation planning; marijuana interdiction; forestry; and, similar issues.

ASO Data Utilization

Traditional practices of runoff forecasting must adapt to take advantage of the richness that the ASO data provides. Water supply decision-making can forego overly conservative assumptions as trust is built in this new data product, allowing more efficient and timely use of the available water supply. There are many small but immediate benefits that will be realized from these data; transformative benefits will require multiple years of effort. The project is off to a great start, and we are fortunate to have ASO data in 2017 during one of the wettest winters on record. The following points highlight the technical tasks and adaptation strategies specific to water supply management:

Immediate Goals

- Adjust “blending” of California Department of Water Resources (DWR) and National Weather Service (NWS) runoff forecasts to inform Millerton Reservoir management and Restoration Flow Allocation.
- Comparison of ASO snowpack map with ground-based sensors, assessing how representative each station is and identifying gaps in the network.
- Partition snowpack by sub-basin to determine volume upstream of each reservoir, allowing a more complete understanding of how Southern California Edison and Pacific Gas and Electric hydropower operations will impact Millerton inflow.
- Adapt and test ASO snowpack-runoff relationship developed at Hetch Hetchy (Tuolumne watershed) by the San Francisco PUC for the Upper San Joaquin River watershed.
- DWR Bulletin 120 water supply forecasts will adjust or “nudge” their forecasts based on ASO data.
- NWS Ensemble Streamflow Prediction (ESP) forecasts will adjust or “nudge” their snowmelt depletion curves based on ASO data.
- Extend period of snowpack measurement past May 1 (when the last snow course measurements occurs) and past when snow pillows typically read zero or become unreliable, thus producing a more accurate estimate of runoff during the critical time of reservoir filling.

Three-year Goals

- Transfer of DWR Bulletin 120 water supply forecast from Excel-based regression to grid-based PRMS model (Precipitation Runoff Management System) for the Upper San Joaquin.
- Development of alternative runoff forecast model based on ISNOBAL model (image snowcover energy and mass balance), integrate ISNOBAL with DWR PRMS model.

- Development of experimental instance of NWS ESP model for the San Joaquin using ASO snowpack in place of modeled snowpack.
- Method development for integration of snow albedo into runoff timing forecasts.
- Report to USBR Central Valley Operations the value of ASO data and how data was integrated into operations at Millerton Reservoir.

Long-term Goals

- Develop platform for rapid sharing of ASO data and modeling results with partners.
- Model and track the effect of changing forest structure and tree mortality on snowpack evolution.
- Integrate ASO data into California-wide flood operations.
- Revise snow course locations and ground-based station locations based on ASO data.
- Reduce ASO program costs through economies of scale in aircraft utilization, data processing, modeling, and runoff forecasting.

References and Links

"Talking Points for the NASA Airborne Snow Observatory flights for the San Joaquin River Basin," Friant Water Authority

"NASA Airborne Snow Observatory, San Joaquin River Watershed Update," South Valley Water Association

Further background on NASA ASO:
https://www.youtube.com/watch?v=NERyUXWNgpE

New York Times article:
https://www.nytimes.com/interactive/2017/03/22/us/california-measuring-snowpack.html?_r=0

LA Times article:
http://www.latimes.com/local/lanow/la-me-ln-snowex-snowpack-forecast-study-20170611-htmlstory.html