# Snow Survey Centennial Celebration
## 1906-2006

### The Today and Tomorrow of Snow and Water Supply Forecasting

Generating a water supply forecast is much like preparing a meal. The freshest, highest quality ingredients (input data) are a necessary but not sufficient condition for a winning dish. A variety of utensils, sharp knifes, and pots and pans of all sizes (forecast tools), all help the chef (hydrologist) transform the ingredients. While presentation (visualization) can increase a dish's appeal and make a great first impression, ultimately the proof of the pudding is in the tasting (forecast accuracy). There is no last minute spice (except perhaps a vivid color bar and slick product design) that can mask over the results of poor preparation or ingredients.

Just imagine the challenge of acquisition of data, preparation of guidance, and timely distribution of product. A network of NRCS data collection personnel throughout the Western US gather and prepare the ingredients and send them to the kitchen at the National Water and Climate Center in Portland, Oregon. Immediately, four hydrologists set upon the data, each preparing the equivalent of 150-200 different dishes simultaneously, every one of which has to be just right in its own way. These are then handed off to the NRCS state water supply specialists who have the task of whisking the plates out of the chaos of the kitchen and placing them before thousands of water users. If the product doesn't satisfy or has gone cold by the time it reaches the decision-maker (e.g., a major storm has dramatically changed basin conditions since the data was first collected), some users don't hesitate in sending it back to the kitchen with their regards.

The NRCS has done many things in recent years to improve the entire experience, from start to finish. Building on earlier newsletters' themes of the history and evolution of water supply outlooks, this week's installation highlights products that are at the cutting edge of technology of the NRCS forecasting and analysis division. These modern tools are designed to answer age old questions, such as "how wet is the basin?" or "how much water can we expect this summer?" but in quicker and easier ways that yield more accurate results. Three themes run through many of these advances:

**Visualization:** A picture speaks a thousand words and the NRCS is working hard to display data to both users and forecasters in a richly visual environment, containing maps and time series plots.

**Flexibility:** It is easy to forecast when everything goes according to plan. However, hydrologists earn their oats when the unexpected occurs. When nature throws a curve-ball, the forecaster must know how to react. The NRCS has improved the tools for handling uncertain situations.

**Automation:** An old Western sharpshooter who could hit a penny in mid-air once said "If I took time to aim, I'd miss." So too must the very personnel-limited forecast environment of the NRCS function fluidly and efficiently like a precision instrument to achieve beyond its means.

### *New GIS-based map products*

Last year, the NWCC began an extensive and growing section of real-time map-based GIS products (http://www.wcc.nrcs.usda.gov/gis/). Every day an array of maps containing information about snowpack, snow density, precipitation, and temperature are generated in a variety of contexts. All of the data behind the GIS-based maps are available in machine readable formats for any user interested in doing local-scale custom analysis.

While many users are familiar with snow data displayed as percent of normal, new maps of percentile rankings and of record highs or lows help users determine the historical significance of current conditions (Figure 1). In order to monitor the current water year, some maps show the change in conditions over the last week, others show current status with respect to the entire season. The NWCC webpage also provides fine resolution snow depth maps of every state, useful for winter recreation and other purposes such as wildlife management.

Precipitation and temperature maps using data collected at NRCS SNOTEL sites are available on the website. Precipitation and temperature data are also extracted from the Applied Climate Information System (ACIS) to create merged National Weather Service (NWS) and NRCS maps. High density maps show monthly and seasonal precipitation and the temperature maps are sufficiently detailed to see when inversions occur between NWS valley stations and NRCS stations in the mountains. I predict that multi-agency data visualizations are going to be The Next Big Thing, a welcome if overdue development.

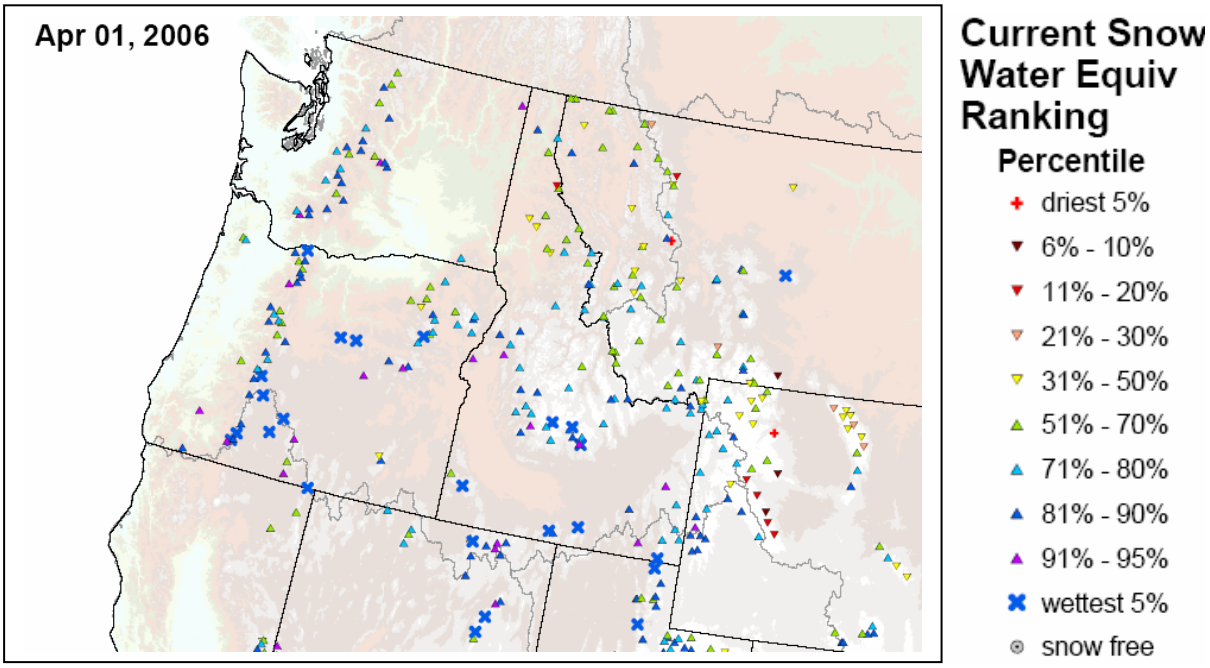


**Figure 1.** GIS depiction of the ranking percentile of the April 1 2006 snowpack.

### *Google Earth-based map products*

The NRCS recently released a 3-D visualization layer to view SNOTEL data using Google Earth (http://www.wcc.nrcs.usda.gov/snotel/earth/index.html). SNOTEL sites are color-coded by snowpack as percent of normal, and if one highlights an individual station, a new window to additional information opens including site photos and tables and charts of real-time and historical data (Figure 2). A Google Earth layer of water supply forecasts was also released earlier in the season and a layer for reservoir data is in the works. These

layers make an excellent companion to the spatial snow data served by the National Operational Hydrologic Remote Sensing Center (NOHRSC). One hydrologist excitedly remarked that the entire ensemble was better than a free helicopter ride around the watersheds. The screen shots here clearly don't do justice.

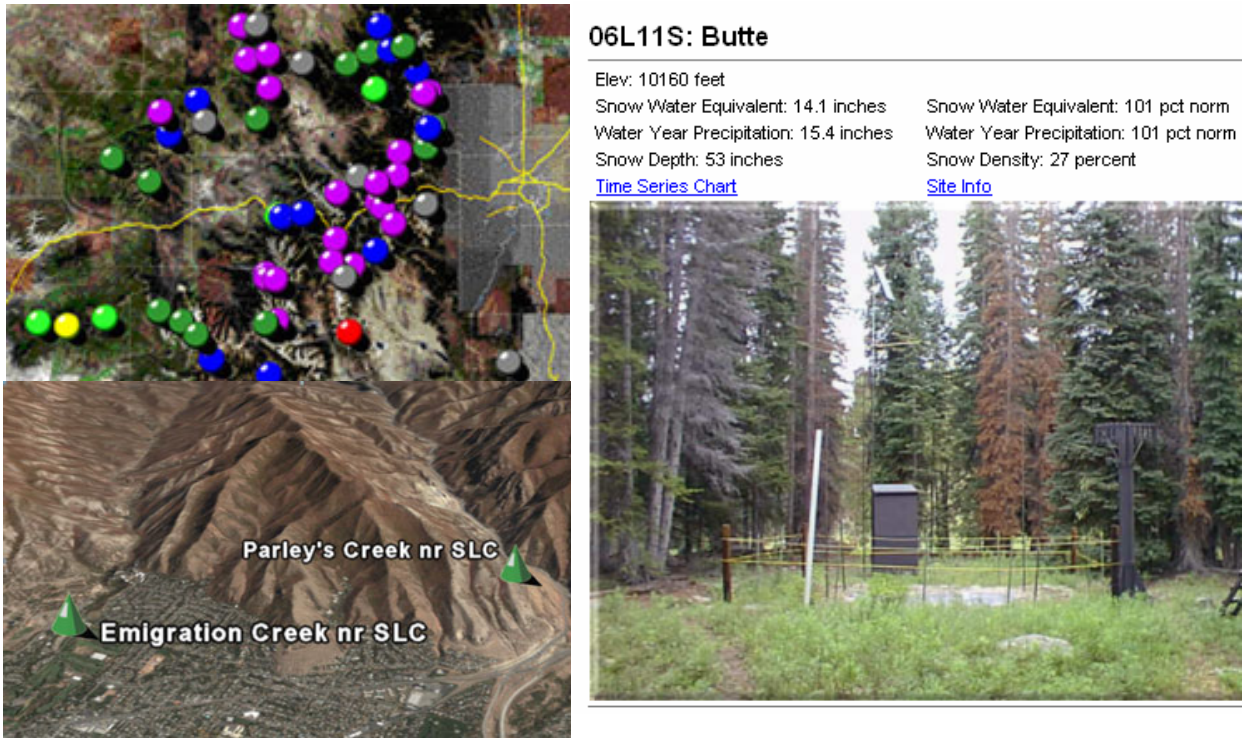


**Figure 2.** NRCS Google Earth snow (top left, right) and streamflow forecast (bottom left) products.

### *Snow Projection Tools*

Often forecasters and users ask about snow conditions: "Where are we now? How does this compare to history? What is the range of possibilities for the future?" The NRCS developed a product that answers all of these questions for daily SNOTEL data. The chart in Figure 3 shows the historical range of snowpack variability for a station in southwestern Oregon over the period of record (in gray). The 1971-2000 normal is shown as a heavy black line. The current year to date is displayed in red and, in this example, the snowpack has reached new record highs for this date. Derived using a statistical technique, the colored lines on the right side of the graph depict the range of possibilities, showing that not even the worst case scenario could bring the snowpack back to 100% of normal by mid-april. The various colored lines indicate the probability that future snow will be less than a certain amount on any given day.

This information is useful in hydrologic risk management such as determining the chances of recovery. One highly innovative NRCS office even used the projected dates for snow melt-out to do "smart scheduling" of SNOTEL site summer field maintenance, based on when sites would be accessible. While the NRCS moves towards an interactive web interface to this product, we will gladly provide this information on request.

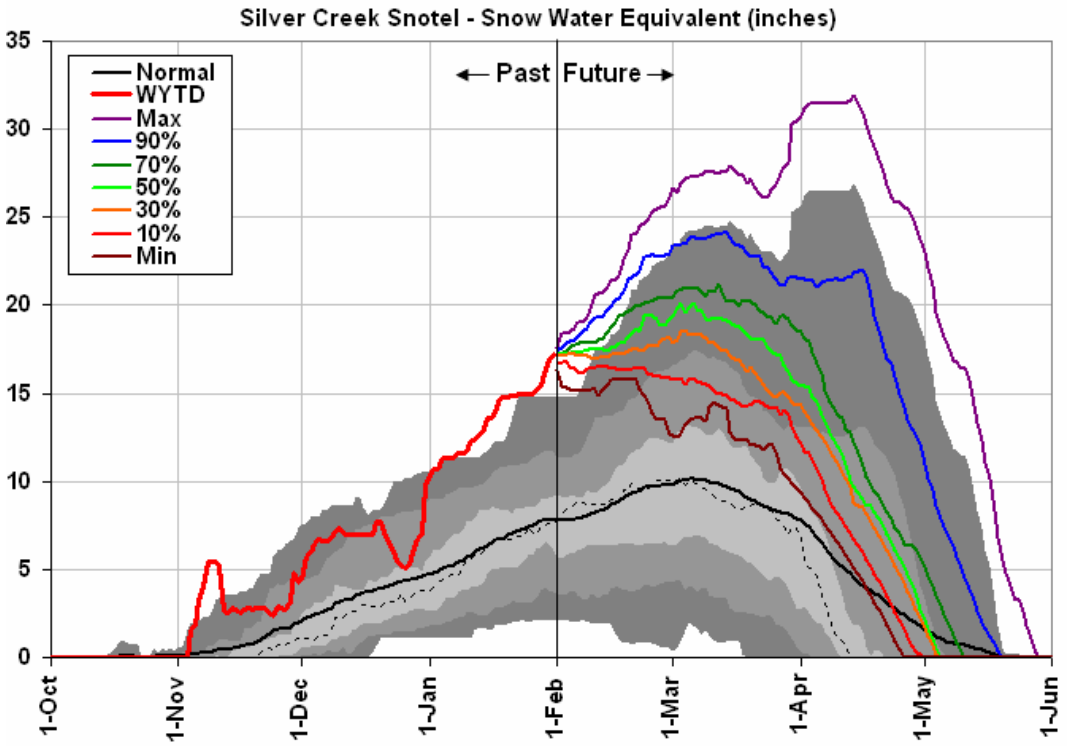


**Figure 3.** Snowpack observations to date (red, left) and future projections (colored, right) in the context of the historical range of variability (gray background).

### *Daily Forecast Updates*

While having up-to-date snowpack information is useful, ultimately, users would like to know the implications for water supplies. The most common request from users to the NWCC is for more frequent updates to the official forecasts issued once per month, i.e. "A large storm just hit our basin. What does this mean for this summer's flow? Do these storms mean that we will have enough water to irrigate?" To address these concerns, we are further taking advantage of daily SNOTEL data by developing an automated daily statistical forecast system. The current prototype system is running twice daily for 49 locations in the Intermountain West region.

Figure 4 tracks the progress of the forecasts for inflows to the Vallecito Resevoir in the San Juan basin in southern Colorado. Again, the gray background indicates the range of historical variability and the colored lines show how a forecast of April-July water volume changes throughout the season. The yellow squares show the official forecasts by comparison. As early as December, a month before the first official forecast for the season, dry conditions already indicated a diminished water supply. The graphs provide a quick look whereas a data sheet provides a wealth of additional information and diagnostics. Several users are helping the NWCC refine and improve this product. Preliminary skill evaluations for this season have been promising. The humans aren't about to pack it in just yet, but this product should help fill in some of the gaps between the official outlooks, give users an indication of the trend in water supply.

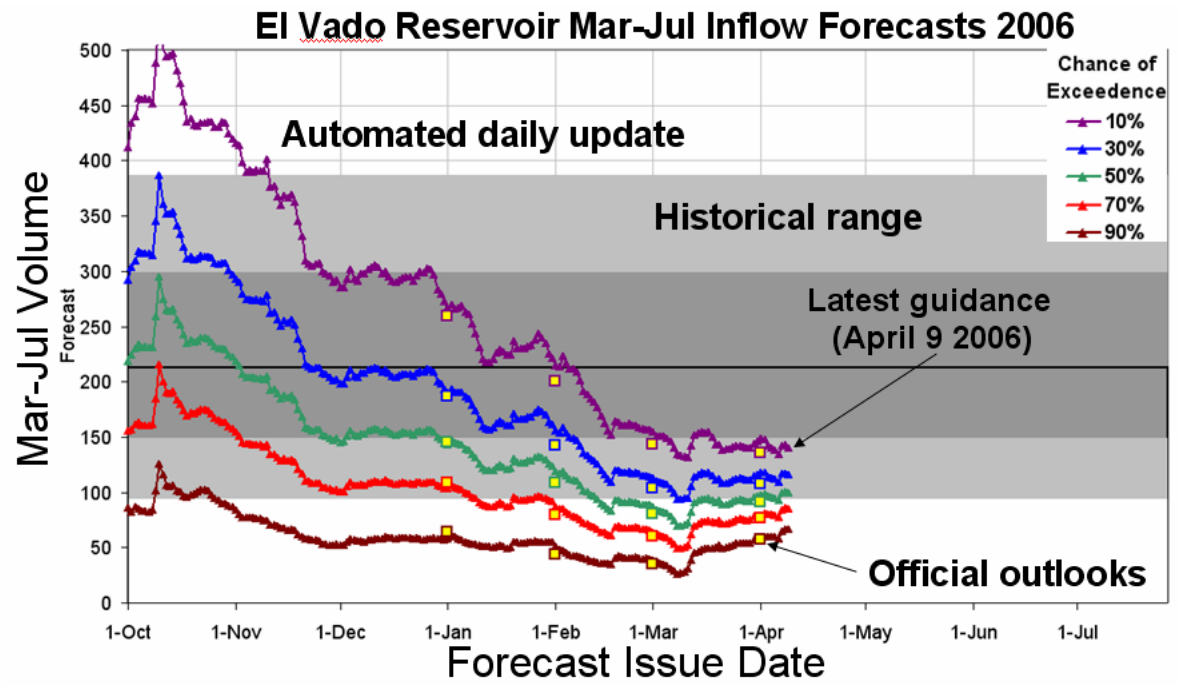


**Figure 4.** An experimental seasonal water supply outlook updated every day.

### *New Forecasting Tools*

What may not be evident to those in the dining room are all the changes happening back in the kitchen. I joined the agency in 2002, and the way that the forecasting environment has changed in that short period is nothing short of revolutionary. It would not be entirely accurate to say what we had before was the hydrologic equivalent of trying to cook a feast over a campfire because the NRCS has had a long tradition of innovation and adopting cutting edge technology from Dr. Church through to the early 1990s. When I stepped into my current position, however, visualization and interactivity were less than they could be.

Back in the day, a hydrologist would have a fixed set of statistical forecasting equations, perhaps even a couple equations per location to get a range of guidance. At forecast time, he or she would look at the numbers in a table to see if they made sense. If they didn't and he had the time, he might log into the mainframe to call up more tables of historical data, finding similar past years using the eyeballic method. Over time, the equations would get old and would need to be updated every couple years. Rumor has it that one hydrologist ate, slept and drank forecast recalibration for an entire summer and came close to updating all 150 points before going mad. They contemplated institutionalizing him, but instead promoted him to lead hydrologist a couple years later.

In a scant four years, the NRCS has started to modernize the operational forecast environment, adding the equivalent of microwave ovens, Cuisinarts and Tupperware. Using commercial-off-the-shelf spreadsheet software, an interactive forecast application has been developed that gets all of its data off the Internet, producing analysis on demand. Linked in with both the historical and realtime data, the hydrologist specifies a list of sites, the kind of analysis desired and instantly the equations are developed and the forecast produced in seconds or less. This system is even tied in to the historical published forecasts, so the hydrologist can see how the skill of this technique compares to past forecasts. The analysis is supported by a full suite of time series graphs and scatter plots that is so visually rich that the original prototype was nicknamed "The Dashboard" because it had the complexity of an airplane cockpit (the newer version is called Visual Interactive Prediction and Estimation Routines, VIPER).

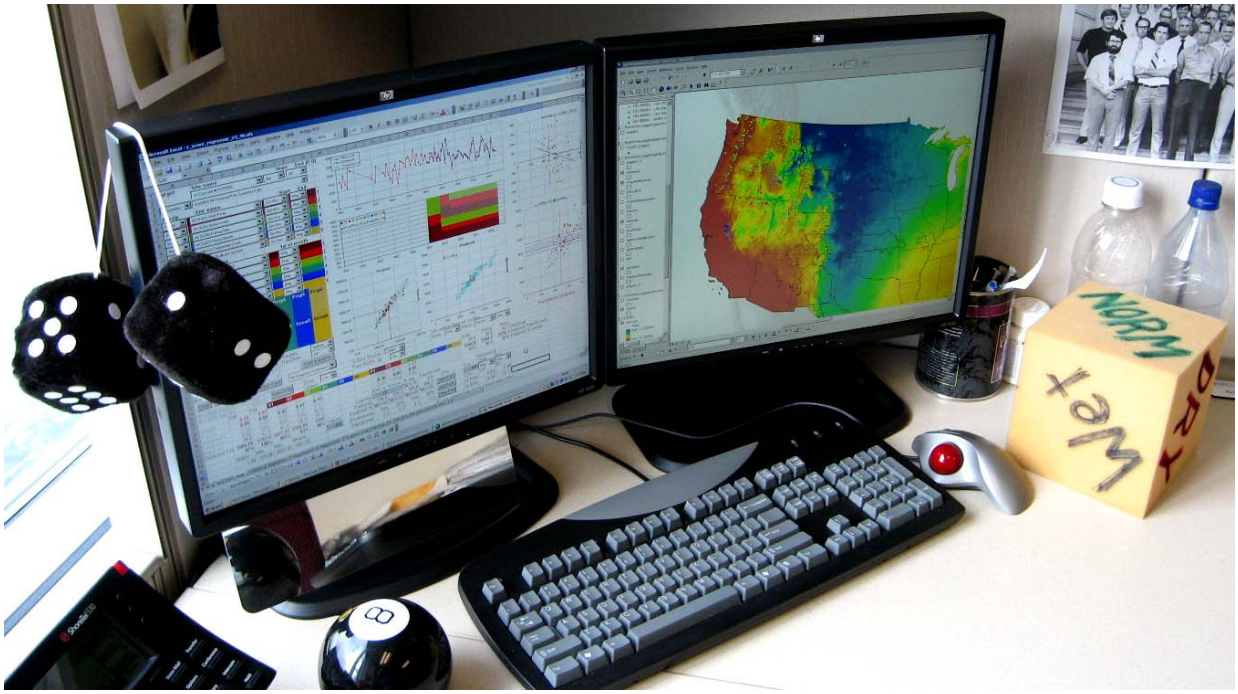


**Figure 5.** Current NRCS forecasting environment. Next year, three screens!

If the situation is unusual (e.g. one side of the basin is very wet, the other very dry), the new GIS visualization tools make that gradient evident, and the interactive forecast application allows the hydrologist to ask what happens to the forecast guidance if some sites are included or excluded from the analysis. A user calls and wants an unusual forecast, for example, the expected March (or maybe it was August?) flow for a river that is not part of the current forecast roster. Four years ago, this user would be out of luck, but now, it's a matter of changing one or two drop down boxes to get the answer. Forecast environment maintenance is now practically a non-issue: equations recalibrate themselves every time a forecast is made, always using the latest available data, never falling five to ten years out of date like they might have in the past.

The end result is a light, agile and flexible forecast system, which has the hydrologist doing less "work" and more "analysis". One can't help but believe that the users are served with timelier, more relevant and more accurate forecasts.

### *Up, Up and Away!*

In just the past few years, the NRCS has made great advances in visualization of hydrologic data. With its emphasis on flexibility, interactivity and automation, it is beginning to redefine the way forecasts are produced and users are served. Just in time, too! Times have never been harder for users, with water managers increasingly operating at the razor's edge. With increased competing demands and dwindling management options, it does not help that the climate is now more erratic than during any other period that most people have been keeping records. On the brighter side, it is especially encouraging watching university groups (historically disconnected from operations) rally to our side with suggestions for new tools and techniques.

Each day when I come in to work, I walk by a portrait of R.A. "Arch" Work outside of our director's office. Arch was the first snow survey supervisor in Oregon and was a prominent member of the program for decades, serving as perhaps as the Thomas Jefferson to the George Washington of Dr. James Church. He even played a significant role in the famous 1948 Sno-Cat expedition from California to the Columbia across the rugged crest of the Cascades (which included, among other things, a roaring tug-of-war between the Sno-

Cat and a rival machine in front of a crowd of whiskery mountaineers). I never knew Arch, but our office has innumerable documents bearing his signature, on such far ranging topics as forecast accuracy to how to build a wilderness cabin.

I sometimes catch myself looking at these images and am reminded of portraits of my immigrant ancestors at the turn of the century. From a simpler time, humble and industrious, they did more with less against long odds; maybe if I listen hard enough they'll whisper their legacy. Every picture I've seen of Arch has him with a half grin that says something like "I know something you don't know, and you're going to get a kick out of it when you find out." When I look at the picture, I see an amused, grounded optimist eager to find out how all this'll turn out.

I must confess that it has been a profound experience to take some time this year to learn more about the legendary figures of snow survey and water supply forecasting, the Churches, the Boardmans, the Clydes, the Schaefers, among many others, and tracing the arc of the program through the years. After seeing the changes in the last few years, while the challenges are far from over, the sense of reinvigoration among many in the division is palpable. These appetizers have been great; may we have patience enough to hold on for the main course yet to come!

**Figure 6**. R.A. "Arch" Work.

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