WaterSMART—The Colorado River Basin Focus-Area Study

Introduction

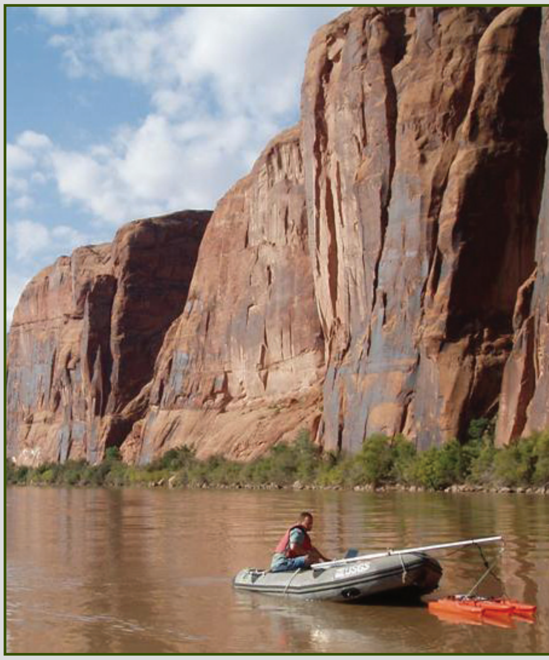
Increasing demand for the limited water resources of the United States continues to put pressure on water-resource agencies to balance the competing needs of ecosystem health with municipal, agricultural, and recreational uses. In 2007, the U.S. Geological Survey (USGS) identified a *National Water Census* as one of six pivotal future science directions for the USGS in the following decade (U.S. Geological Survey, 2007). The envisioned USGS National Water Census would evaluate large-scale effects of changes in land use and land cover, water use, and climate on water availability, water quality, and human and aquatic ecosystem health.

The passage of the SECURE (Science and Engineering to Comprehensively Understand and Responsibly Enhance) Water Act (SECURE Water Act, 2009) was a key step towards implementing the USGS National Water Census. Section 9508 of the Act authorizes a "national water availability and use assessment program" within the USGS (1) to provide a more accurate assessment of the status of the water resources of the United States; and (2) to develop the science for improved forecasts of the availability of water for future economic, energy production, and environmental uses.

The USGS WaterSMART Program

Initial funding for the USGS to begin working on the National Water Census came with the approval of the U.S. Department of the Interior's WaterSMART (Sustain and Manage America's Resources for Tomorrow) Initiative (U.S. Department of the Interior, 2010). The WaterSMART Initiative provides funding to the USGS and the Bureau of Reclamation to achieve a sustainable water strategy to meet the Nation's water needs. WaterSMART funding also allowed the USGS to begin the national Water Availability and Use Assessment, as called for under the SECURE Water Act, for the purpose of:

- providing estimates of the distribution and abundance of freshwater resources, including assessments of water use for human, environmental, and wildlife needs;
- evaluating factors affecting water availability (for example, energy development, agricultural practices, increasing population, climate change);
- estimating undeveloped potential water resources, such as saline and brackish water and wastewater; and
- developing data and information needed to forecast likely outcomes of water availability, water quality, and aquatic ecosystem health due to changes in land use and cover, natural and engineered infrastructure, water use, and climate.

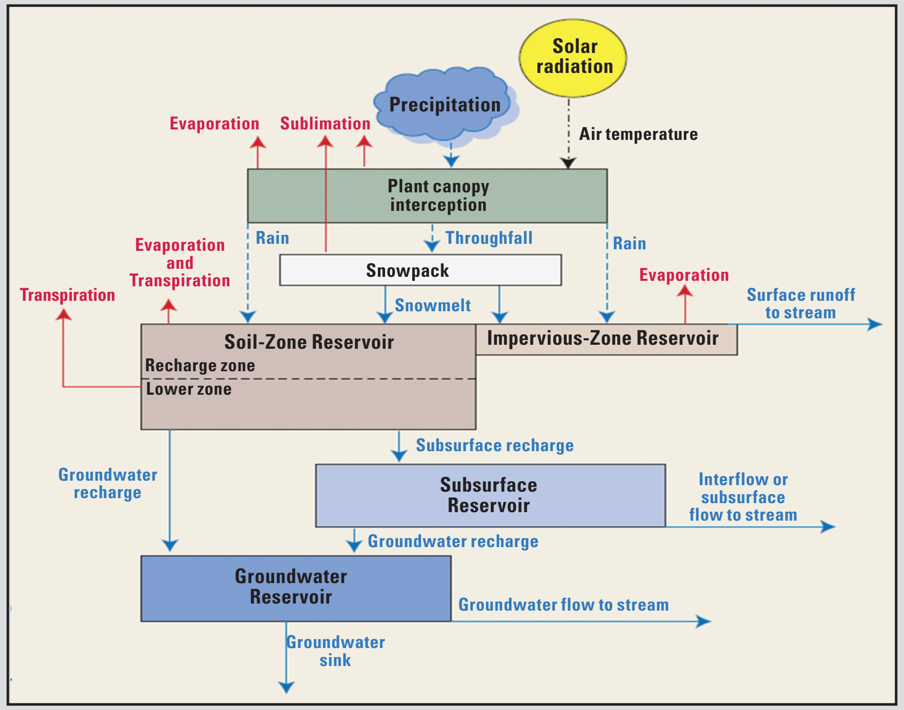


WaterSMART Focus-Area Studies

To address the goals of the DOI WaterSMART Program, while at the same time moving the USGS toward a National Water Census, the USGS proposed to start three "focus-area" studies. The locations for the three studies were chosen by the DOI: the Delaware River Basin (Del., N.J., N.Y., Pa.), the Apalachicola–Chattahoochee–Flint River Basins (Ala., Ga., Fla.), and the Colorado River Basin (Ariz., Calif., Colo., Nev., N. Mex., Utah, Wyo.). The initial plan for each of these WaterSMART Focus-Area Studies is a 3-year effort, beginning in 2012, to develop and test methods and techniques for meeting the goals of the authorizing legislation. The remaining sections of this Fact Sheet address only those activities that are proposed for the Colorado River Basin Focus-Area Study.

The Colorado River Basin WaterSMART Focus-Area Study

The Colorado River is a critical water supply for much of the Southwestern United States. The River supplies water to more than 25 million people and irrigates more than 3 million acres of cropland across seven "basin states." Increasing population, decreasing streamflows, and the uncertain effects of a changing climate urge a better understanding of water use and water availability in the Colorado River Basin.



Conceptualized water budget (from Healy and others, 2007).

In keeping with the scientific, nonregulatory mission of the USGS, water availability in the Colorado River Basin will be assessed by investigating components of a regional "water budget." A water budget is analogous to a household budget or checking account where understanding the amount entering and leaving the account indicates the balance remaining in the account for other uses. In its simplest form, a water budget can be written as follows:

Waterflow In – Waterflow Out = Change in Water Storage

The water-budget components studied in the Colorado River Basin will be those where understanding and quantification are lacking, and the USGS can contribute the largest incremental increase in scientific knowledge. In consultation with basin stakeholders, the USGS has identified three water-budget components where understanding could be improved and the USGS has relevant expertise: (1) current water use—in particular the "consumptive" use of water; (2) regional and field scale assessments of water losses from evapotranspiration and snowpack sublimation; and (3) groundwater discharge to streams, and the relative importance of the regional groundwater flow system in annual streamflow volumes. Better quantification of these components of the basin water budget will contribute to the overall assessment of water availability in the Colorado River Basin, thereby complementing ongoing work by other agencies.

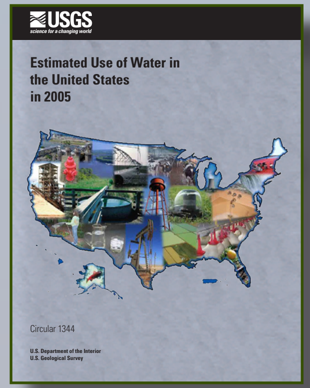
Extent of the Colorado River Basin. Upper Basin outlined in red.

***Sublimation**: means a substance transforms from a solid to a gas without passing through a liquid stage. The classic example is the disappearance of dry ice (solid carbon dioxide to gaseous carbon dioxide). In many low humidity areas, snow and ice can sublimate leaving little if any water in the soil.*

Water Use in the Colorado River Basin

Many regional stakeholders and water-supply managers in the United States have indicated an important need for water-use data to implement their management strategies, yet there is a lack of information in this area (National Research Council, 2002). What data do exist are often inconsistent and out of date. Improved and regionally consistent databases of water-use information will be one of the most essential outcomes of the National Water Census and its geographic Focus-Area Studies.

By renewing effort on quantification of water use, the USGS will be better able to describe how humans move, use, consume, and dispose of the water they withdraw, divert, or impound and to integrate that information with our understanding of natural flows in the environment. Through this integrated approach, we hope to describe how human use of water and natural flows influence one another. This effort requires that we understand the sources from which water is withdrawn (both surface water and groundwater), the demand that the water is used to satisfy, the transport of the water to the demand location (including transportation losses), the amount of water that is "consumed" in satisfying the demand, and the volume and location of water returned to the environment, either as return flows to surface water or recharge to groundwater systems. Each of these steps has a strong geospatial component: We need to know which watersheds are losing flows, which are gaining flows, and the net exchange between watersheds.



Some of the many uses of water in the United States (from Kenny and others, 2009).

To integrate water-use data with natural-flow data, the USGS will strive to improve information on the location of the points of water withdrawal, the source from which the water is withdrawn, the location of the points of demand to which the water is delivered, and the transit losses of water on the way to that location. Finally, as this information improves nationally, it will allow a mass-balance estimation of the volume of the eventual "return flows" to the environment. Owing to the large area encompassed by the Colorado River Basin, the USGS intends to work at multiple spatial and temporal scales to develop information across the entire basin, as well as demonstrate analysis and interpretive capabilities at selected subbasin scales. The Focus-Area Study will compile and integrate location information for public supply (large and very large systems, which include population served greater than 10,000) and for irrigation water uses—the two largest water uses in the Colorado River Basin. Water-use information for the industrial, mining, and thermoelectric sectors will be compiled where available to provide as complete a summary as possible for the major water uses in the Colorado River Basin.

Evapotranspiration and Snowpack Sublimation in the Colorado River Basin

Two important water-budget components that are critical to understanding water supplies in the Colorado River Basin are evapotranspiration from natural and cultivated land, and loss of water storage from the mountain snowpack through sublimation. Despite their recognized importance, evapotranspiration (ET) and sublimation remain difficult to measure and are poorly quantified for the Colorado River Basin. An improved understanding of these processes in the varied landscapes of the Colorado River Basin will improve our ability to calculate water budgets across the region.

Developing a spatially explicit estimate of ET and sublimation across the region will reduce uncertainty in the estimated water budget and allow more accurate calculation of other residual terms in the equation (for example, consumptive use from agricultural irrigation, irrigation efficiency, surface-water return flows, or groundwater recharge). Methods that use satellite-based remotely sensed data will be developed and implemented, and these regional estimates will be compared to ground-based measurements for calibration and verification. Derivative products produced during this effort (for example, land-cover distribution) also can be integrated into the assessments of water use and groundwater that are additional goals for this Focus-Area Study.

Evapotranspiration

Evapotranspiration from irrigated croplands and native vegetation (for example, riparian ecosystems) is a significant component of the water budget in the Western United States. Its quantification across the landscape is essential for estimating regional water budgets and for calculating consumptive water use on agricultural lands. The USGS Focus-Area Study will apply remote sensing techniques for calculating the surface energy balance that will provide estimates of ET across the landscape. An assessment of the entire Colorado River Basin will use MODIS (1-kilometer resolution) to provide monthly and seasonal ET estimates from 2000 to 2011. Estimates of ET for individual irrigated agricultural fields will be developed using LANDSAT thermal imagery (30-meter resolution) and will compare scenes from 2005 and 2010. This approach has many advantages over statistical interpolation between flux towers and climate stations, or estimates made from indirect proxies like consumption of electricity by irrigation pumps. The WaterSMART Colorado River Basin Focus-Area Study provides the opportunity to develop, test, and evaluate remote-sensing techniques before performing other regional or national applications. Maps and on-line datasets will be made available to the public.

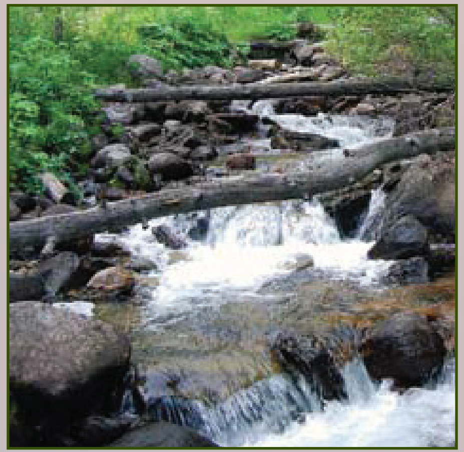
Snow-Water Assessment

Snow accumulation in high elevation settings of the Western United States is an integral component of the western regional water cycle providing water for drinking, irrigation, industry, energy production, and ecosystems. In the mountains of the Western United States, seasonal snowpacks act as a large natural water-storage reservoir providing, on average, 70 to 80 percent of annual surface-water runoff (Doesken and Judson, 1996). In the Upper Colorado River Basin, the percentage is even higher, with 85 percent of streamflow derived from melting snow (Edwards and Redmond, 2005). The quantity of water stored in seasonal snowpacks is expressed as the snow water equivalent (SWE). Springtime SWE is one of the most important data inputs to hydrologic models used to forecast runoff in the Western United States because it is the main source of water to streams during late spring and early summer (Clark and Hay, 2004; Slater and Clark, 2006). Snowpack sublimation, which is analogous to evaporation from land surfaces or water bodies, represents an important, but poorly quantified, loss of water from the snowpack (Hood and others, 1999). Sublimation represents one of the major uncertainties in runoff forecast models, and is thought to be particularly important during drought years, when water is scarce. As part of the WaterSMART Focus-Area Study in the Colorado River Basin, the USGS intends to develop regional SWE and sublimation estimates using moderate- and high-resolution gridded models and ground-based validation measurements to inform hydrologic modeling studies, water availability studies, and water-use assessments.

Groundwater Discharge to Surface Water

Groundwater is an important resource influencing water availability in the Colorado River Basin. Aquifers store water during rainfall and snowmelt (aquifer recharge), thus providing a reliable source of often high-quality water. Groundwater discharge to streams and wetlands is a critical component of regional water supply in that it supports year-round surface-water flows (baseflows) for multiple uses and sustains ecosystems and aquatic environments in the Colorado River Basin. Compared to surface water, however, groundwater storage and flow are difficult to measure, so that the groundwater components of the Colorado River Basin water budget are less well understood. The rate and spatial distribution of aquifer recharge, discharge, and use are critical for understanding long-term water availability in the basin.

In many areas, groundwater and surface water are hydraulically connected and can be considered a single resource (Winter and others, 1998). Drought, climate change, and human manipulations, such as surface-water regulation or groundwater pumping, can have major effects on the linkage between groundwater and surface water, resulting in changes in the direction and volumes of flow. Thus, the groundwater source and flow paths for discharge to streams can be an important component of the water budget and can be critical to water availability in times of small surface-water runoff. Fundamental to understanding and managing water resources in the Colorado River Basin is an understanding of groundwater discharge to surface water in the basin (Rosenberry, 2008).



Groundwater discharging to streams arrives at the stream interface via local, intermediate and regional groundwater flow paths (Freeze and Cherry, 1979; Winter and others, 1998; Stolp and others, 2010; Gardner and others, 2011) and is often a mix of water from multiple flow paths. During times of drought, surface water often has a greater component of discharge from regional groundwater flow paths with longer residence times and often differing geochemistry (Hornberger and others, 1998).

Understanding groundwater flow paths and residence times provide important information about vulnerability of water resources to natural and anthropogenic changes. Local groundwater flow systems with shorter residence times are more immediately susceptible to water-quality effects related to changing surface conditions and human activities. Conversely, discharge volumes from regional flow systems with long groundwater flow paths and residence times of possibly 1,000s of years would respond much more slowly to short-term hydrologic or climate changes and surface-related influences (Tetzlaff and Soulsby, 2008; Gardner and others, 2011). Effective management of water resources in support of ecosystem health requires an understanding of groundwater and surface-water interactions over a range of spatial and temporal scales.

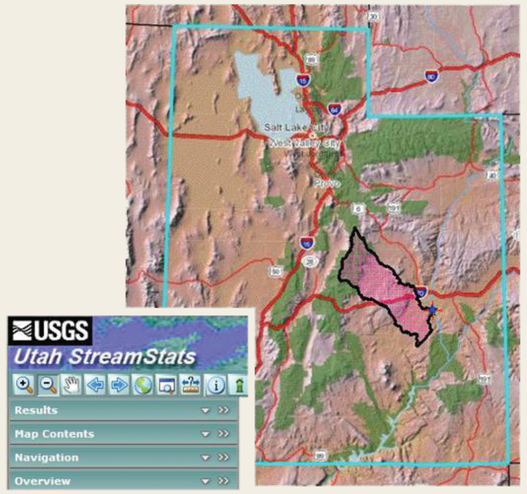
Due to the large areal extent of the Colorado River Basin, the initial groundwater investigation in the Focus-Area Study will evaluate only the groundwater systems of the Upper Colorado River Basin (UCRB). Indeed, less work has been done to understand the groundwater/surface-water interactions in the upper basin. For understanding groundwater discharge at the scale of the UCRB, two components need to be considered: (1) identifying key stream reaches where substantial groundwater discharge occurs, from what aquifers, and how discharge varies temporally and spatially; and (2) understanding the groundwater flow paths supplying water to these discharge points.

The proposed approach for the groundwater assessment in the UCRB is a hierarchical, nested approach applying multiple techniques and tracers to estimate groundwater discharge to specific stream reaches. The study will have three significant components: (1) to revise our understanding of the hydrogeologic framework controlling groundwater movement and to identify locations where local groundwater discharge is likely to be a significant source of surface water in rivers and streams; (2) to determine groundwater ages, residence times, and flow paths in selected stream reaches, which will require a geochemical reconnaissance survey of the main tributaries in areas identified as having substantial groundwater discharge to streams; and (3) to develop modeled estimates of groundwater discharge to streams and to map these discharges at a subwatershed scale across the entire UCRB.

Information Delivery

The results of the Colorado River Basin Focus-Area Study will be distributed publicly in topic-specific databases, maps, and published information products. The long-term vision for delivering water budget information from the USGS National Water Census is to develop an interactive map-based internet application that would allow user-defined queries of nationally consistent data. This application is currently (2012) under development but will await the broad application of methods and data collection activities being piloted in the WaterSMART Focus-Area Studies. The activities and methods being pursued in the Colorado River Basin and the other Focus-Area Studies will be evaluated for regional and national application and may be implemented nationwide as part of the National Water Census.

A Web application is under development as part of the USGS National Water Census, modeled on the USGS StreamStats platform, for delivering water availability information at scales that are relevant to the user.



Vision: Select a stream location where information is desired and automatically generate the contributing surface-water basin boundary.

Compile data on water-accounting components for delineated area.

Work with the online tool to construct your local water budget.

Access and analyze available trend information.

Goal: To provide detailed water budget information for any user-defined drainage basin nationwide.

Screen capture of USGS StreamStats Web interface from Utah.

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