

Dissolved-solids in the Southwestern United States: Sources, Transport, and Accumulation

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Introduction

In many areas of the Southwestern United States (Southwest), high concentrations of dissolved solids degrade the suitability of a water supply for certain uses. While water naturally contains dissolved solids as a result of the weathering and dissolution of minerals in soils and geologic formations, human activities in municipal and agricultural areas also contribute to dissolved solids in water resources. In 2004, the U.S. Geological Survey (USGS) National Water Quality (NAWQA) program began a regional study to characterize dissolved-solids conditions in the basin-fill aquifers and major river systems of the Southwest, and to understand how natural and human factors affect the conditions. In particular, a primary objective of this study was to characterize regional scale sources, transport, and accumulation of dissolved solids in water resources of the Southwest. Important questions that require answers to address this objective include:

What are the main sources of dissolved solids; are they natural or human?
Which areas contribute significant loads of dissolved solids to streams?
Where are the dissolved solids transported to; do they accumulate in ground water anywhere?

Answers to these questions are needed for planning and prioritizing water resources development, protection, and improvement programs. In addition, information about the spatial distribution of sources, transport, and accumulation of dissolved solids are needed for directing and prioritizing subsequent water-quality investigations.

Approach

The sources, transport, and accumulation of dissolved-solids in water-resources of the Southwest were determined using a spatially-referenced regression on watershed attributes model (SPARROW; Smith and others, 1997). The SPARROW model related annual dissolved-solids loads in a stream reach network to the reach catchment characteristics that represented (1) sources, (2) land-to-water delivery factors, and (3) factors that affect in-stream losses. Sources of dissolved solids in the SPARROW model included several geologic units, cultivated and pasture land, and imported water. Land-to-water delivery factors included runoff depth, drainage density, and percent barren land. Factors that affect losses of dissolved solids from streams included change in discharge across the reach and percent area of the reach catchment containing Quaternary basin fill. The model was calibrated using stream load data for 315 water-quality and streamflow-monitoring stations spread throughout river systems of the Southwest. Significant source areas and accumulation areas, as well as transport through the major river systems were characterized by synthesizing the SPARROW model predictions for the 5,224 reaches in the stream network by hydrologic accounting units. Results are presented in the form of a mass balance of contributions and losses of dissolved solids in accounting unit river systems. Contributions to accounting unit streams include:

Inflow—annual load that flows in from streams of upstream accounting units
Internal delivery—annual load delivered to streams from internal sources
Import—annual load conveyed into the accounting unit from transbasin imported water

Losses of dissolved solids from the accounting unit streams include:

Outflow—annual load that flows out through streamflow to downstream accounting units;
Internal accumulation—annual load removed from streams that is retained and accumulates internally
Export—annual load conveyed out of the accounting unit through transbasin exported water

Change in storage of dissolved solids in accounting unit streams was assumed to be negligible compared to the annual contributions and losses, and therefore equal to zero. Answers to the three primary questions of this investigation and an understanding of the transport of dissolved solids from sources to areas of accumulation in the Southwest can be gained by examination of an illustration of the mass balance components and the three highest internal sources for each accounting unit (figs. 1 through 4). Results from this study are undergoing peer review and are subject to change.

Reference:
Smith, R.A., Schwarz, G.E., and Alexander, R.B., 1997, Regional interpretation of water-quality monitoring data: Water Resources Research, v. 33, no. 12, p. 2781–2798.

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Preliminary results - subject to revision

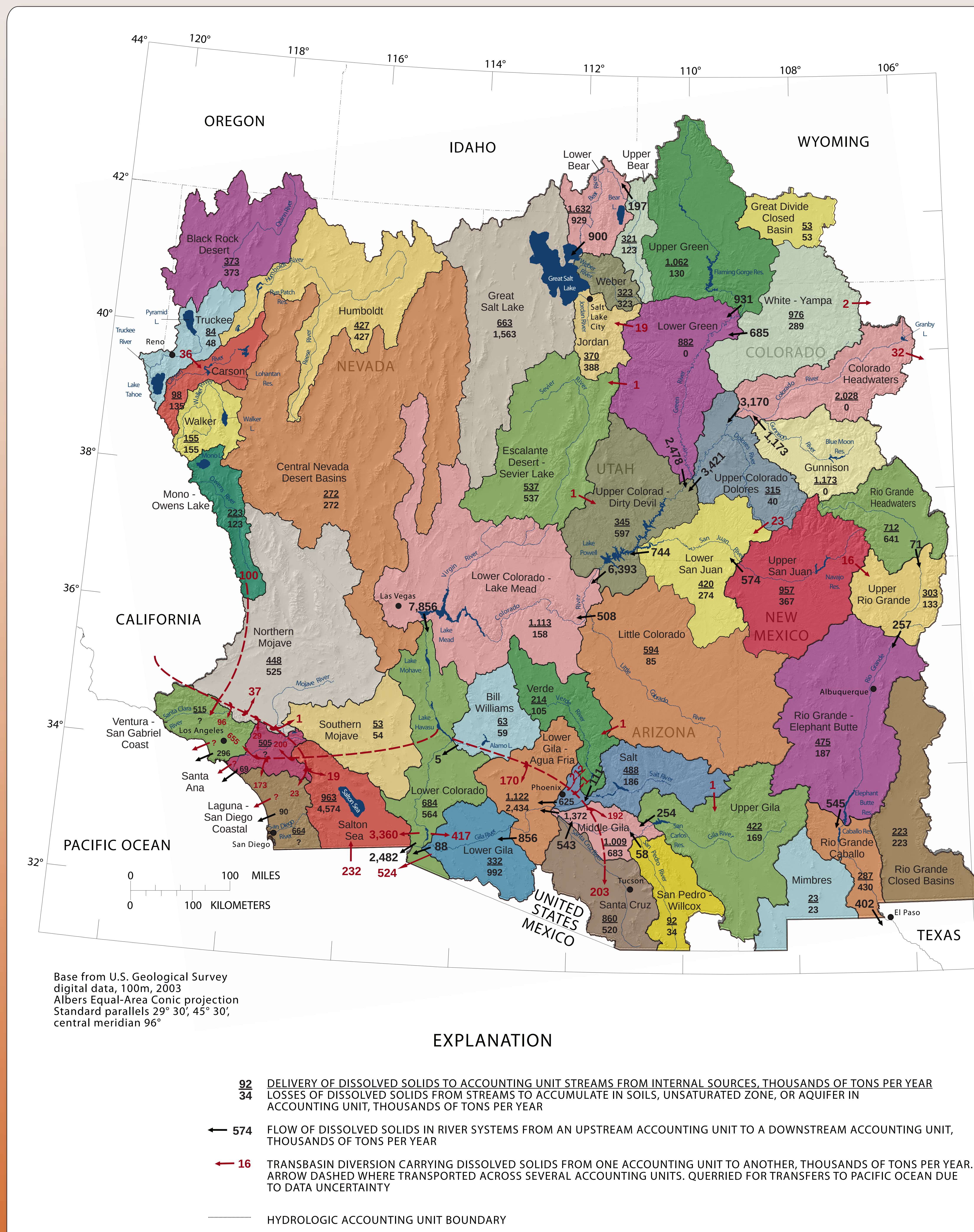


Figure 1. Internal source deliveries, transport, and losses of dissolved solids for accounting unit river systems in the Southwest

What are the main sources of dissolved solids, are they natural or human?

Predictions from the SPARROW model were used to determine the relative significance of the various natural and human internal sources of dissolved solids in accounting units of the Southwest. **Overall for river systems in the Southwest, about 56 percent of the dissolved solids load delivered to streams from internal sources originates from human sources: cultivated and pasture lands. The remaining 44 percent are from natural, geologic sources:** 3 percent from crystalline rocks such as granite, gneiss, or schist; 5 percent from volcanic rocks such as basalt or rhyolite; 2 percent from eugeosynclinal and other volcanic sedimentary rocks; 12 percent from Cenozoic sedimentary rocks; 12 percent from Mesozoic sedimentary rocks; and 10 percent from Paleozoic and Precambrian sedimentary rocks. The share of the total load delivered to streams from each source, however, varies greatly by accounting unit (fig. 2) owing to the fact that dissolved-solids sources vary spatially across the Southwest. **In 20 of the 47 accounting units, human sources—cultivated and pasture lands—account for more than 50 percent of the dissolved solids load delivered to accounting unit streams from internal sources.** Transbasin imported water, which is used for municipal and agricultural purposes, is also considered a human source of dissolved solids contributed to accounting units. In a few cases transbasin imports contribute more dissolved solids to the accounting unit than internal sources (fig. 2).

Which areas contribute significant loads of dissolved solids to streams?

Significant source areas include those where dissolved solids are released from internal sources and delivered to streams at high delivery rates. **Accounting units with the highest delivery rates to streams include the Colorado headwaters, Middle Gila, Lower Bear, and Santa Ana accounting units where delivery rates were greater than 150 (ton/yr)/mi² (fig. 3). Eight other accounting units had delivery rates greater than 100 (ton/yr)/mi². In contrast, delivery rates were low—25 (ton/yr)/mi² or less—in 11 accounting units. The Mimbres, Great Divide closed basin, Bill Williams, Central Nevada desert basins, and Southern Mohave accounting units are among those with the lowest delivery rates, less than 15 (ton/yr)/mi².** Delivery rates are greater in accounting units with (1) wetter climates, such as the Colorado headwaters, Rio Grande headwaters, and upper Bear, and (2) intensive cultivation of crops and pasture, such as the Salton Sea, Middle Gila, and Lower Bear. Delivery rates tend to be low in accounting units with drier climates and minimal cultivation of crops and pasture, such as the Central Nevada desert basins, Little Colorado, and Mimbres accounting units.

Where do dissolved solids accumulate?

In some accounting units, such as the Colorado Headwaters, most of the dissolved solids contributed to streams is transported out of the accounting unit in outflow or exports to other accounting units. In several accounting units, however, a portion of dissolved solids contributed to the streams is not transported out, but rather is retained within the accounting unit. Two mechanisms for this include (1) infiltration of stream water to the subsurface, and (2) diversion of stream water for irrigation. In each case, dissolved solids are removed from the stream and transported within infiltrating water to the soils, vadose zone, or ground water, where they accumulate. Owing to concentration through evapotranspiration, dissolved-solids concentrations in excess irrigation water that infiltrates the subsurface can be substantially high. Excess irrigation water that recharges can significantly degrade the receiving ground water.

Significant accumulation areas are those where dissolved solids transported in streams are retained internally at high accumulation rates. **The highest accumulation rate by far was that for the Salton Sea accounting unit at 704 (ton/yr)/mi², which was more than twice as large as the second highest rate, 305 (ton/yr)/mi² for the Lower Gila – Agua Fria accounting unit (fig. 4). These two accounting units and the Middle Gila, Lower Bear, and Great Salt Lake accounting units, which had accumulation rates greater than 150 (ton/yr)/mi², were amongst the most significant accumulators of dissolved solids the Southwest. Accumulation rates were low—less than 10 (ton/yr)/mi²—in 10 out of the 47 accounting units.** Accumulation rates are greater in accounting units with (1) significant inflow of dissolved solids, but closed surface drainage, such as the Great Salt Lake, (2) significant diversions for irrigation of cultivated and pasture lands, such as the Middle Gila and Lower Bear, or (3) both of the above, as is the case for the Salton Sea. Accumulation rates are smallest in accounting units that (1) lack significant inflow or imports of dissolved solids, such as the San Pedro - Willcox, (2) lack diversions for irrigation of cultivated and pasture lands, such as the Central Nevada desert basins, and/or (3) have open surface drainage to downstream accounting units, such as the Little Colorado Accounting unit.

