Sources and Accumulation of Dissolved Solids in Water Resources of the Southwest

By David W. Anning[1], Nancy J. Bauch[2], and S. J. Gerner[3]

In the Southwestern United States, the location and extent of economic and cultural activities are dependent in part on the availability and quality of water. In many areas of the Southwest (fig. 1) concentrations of dissolved solids (also referred to as total dissolved solids) limit a water supply's suitability for certain uses. In response to this water-quality issue, the U.S. Geological Survey (USGS) National Water Quality Program began a regional study in 2004 to characterize dissolved-solids conditions in the basin-fill aquifers and streams of the Southwest and to understand how natural and human factors affect the conditions. A significant part of the study included characterization of the sources and accumulation of dissolved solids in water resources in the Southwest.

The study's approach was to determine the significant dissolved-solids source areas and accumulation areas by using a mass-balance analysis of the contributions and losses of dissolved solids for river systems in hydrologic accounting units of the Southwest. Hydrologic accounting units are large river basins that were defined nationwide by the USGS and those in the Southwest have an average area of about 16,000 mi^2. Contributions to river systems in each hydrologic accounting unit included inflows, internal deliveries, and imports; and losses included outflows, internal accumulation, and exports. These six terms were quantified by using predictions from a spatially-referenced regression model of contaminant transport on watershed attributes (SPARROW). The SPARROW model also provided information about the relative importance of individual natural or human sources of dissolved solids in hydrologic accounting units.

The SPARROW model is a non-linear regression model that was used to relate the sources, land-to-water delivery, and losses of dissolved solids in a stream-reach network to reach-catchment characteristics. The model was calibrated on the basis of annual dissolved-solids load data for 315 USGS water-quality monitoring stations and basin characteristics for the associated upstream drainage areas. In the calibrated model, dissolved-solids loads in each stream reach originated from (1) deliveries from catchment sources, including 12 different geologic units, cultivated land, and pasture land, (2) deliveries in imported water from other catchments, and (3) inflow from upstream reaches. Catchment source deliveries were locally increased or decreased by catchment on the basis of values for land-to-water delivery factors—runoff depth, drainage density, and percent barren land. Instream dissolved-solids loads delivered to each reach from upstream reaches and from catchment sources were transferred to downstream reaches, minus any losses to sinks along each reach. Reach losses of dissolved-solids loads occurred as a result of streamflow infiltration or diversion and infiltration of streamflow, and were determined on the basis of the change in stream discharge along the reach and percent Quaternary basin fill within the catchment. Reach losses represent dissolved solids that were removed from the stream and can accumulate in the soils, unsaturated zone, or ground water of the catchment.

[1]USGS Arizona Water Science Center, 2255 N. Gemini Drive, Flagstaff, AZ 86001, dwanning@usgs.gov
[2]USGS Colorado Water Science Center, Denver Federal Center, Box 26046, MS-415, Lakewood, CO 80225, njbauch@usgs.gov
[3]USGS Utah Water Science Center, 2329 W. Orton Circle, Salt Lake City, UT 84119, sjgerner@usgs.gov

Significant source areas were assessed on the basis of the total amount of dissolved solids delivered from internal sources to all stream reaches within a hydrologic accounting unit, divided by the unit's area. The most significant dissolved-solids source areas in the Southwest included the Colorado headwaters, Middle Gila, Lower Bear, and Santa Ana accounting units, where deliveries from internal sources were greater than 150 tons per year per square mile (fig. 1).

Predictions from the SPARROW model were used to determine the relative significance of the various natural and human internal sources of dissolved solids in Southwest accounting units (fig. 1). Geologic units, which represent natural sources of dissolved solids, contribute about 44 percent of the total internal deliveries for all accounting units in the Southwest. Of this percentage for geologic units, about 7 percent is from crystalline and volcanic rocks, 2 percent is from eugeosynclinal rocks, 12 percent is from Tertiary sedimentary rocks, 12 percent is from Mesozoic sedimentary rocks, and 10 percent is from Paleozoic and Precambrian sedimentary rocks. Cultivated lands (44 percent) and pasture lands (12 percent) are anthropogenic sources of dissolved solids and contribute the remaining 56 percent of the total internal deliveries for all Southwest accounting units.

Significant accumulation areas were assessed on the basis accumulation rates for each accounting unit. Accumulation rates were computed as the total amount of dissolved-solids losses from all stream reaches within an accounting unit, excluding outflow and exports from the accounting unit, divided by the unit's area. The most significant dissolved-solids accumulation areas included the Salton Sea, Lower Gila-Agua Fria, Middle Gila, Lower Bear, and Great Salt Lake accounting units, where accumulation rates were greater than 150 tons per year per square mile (fig. 1). The dissolved-solids accumulation rate for the Salton Sea accounting unit, 704 tons per year per square mile, was more than twice as high as the second highest rate, 305 tons per year per square mile for the Lower Gila-Agua Fria accounting unit.

In summary, results from the SPARROW model were used to characterize the spatial distribution of annual loads of dissolved solids in streams of the Southwest, and to determine the major source and accumulation areas of dissolved solids in the Southwest. The SPARROW model results also allowed for characterization of (1) natural and human sources of dissolved solids to the streams, (2) natural and human factors that affected land-to-water transport of dissolved solids, and (3) natural and human factors affecting the losses of dissolved-solids loads from streams and subsequent accumulation in soils, unsaturated zone, and ground water.

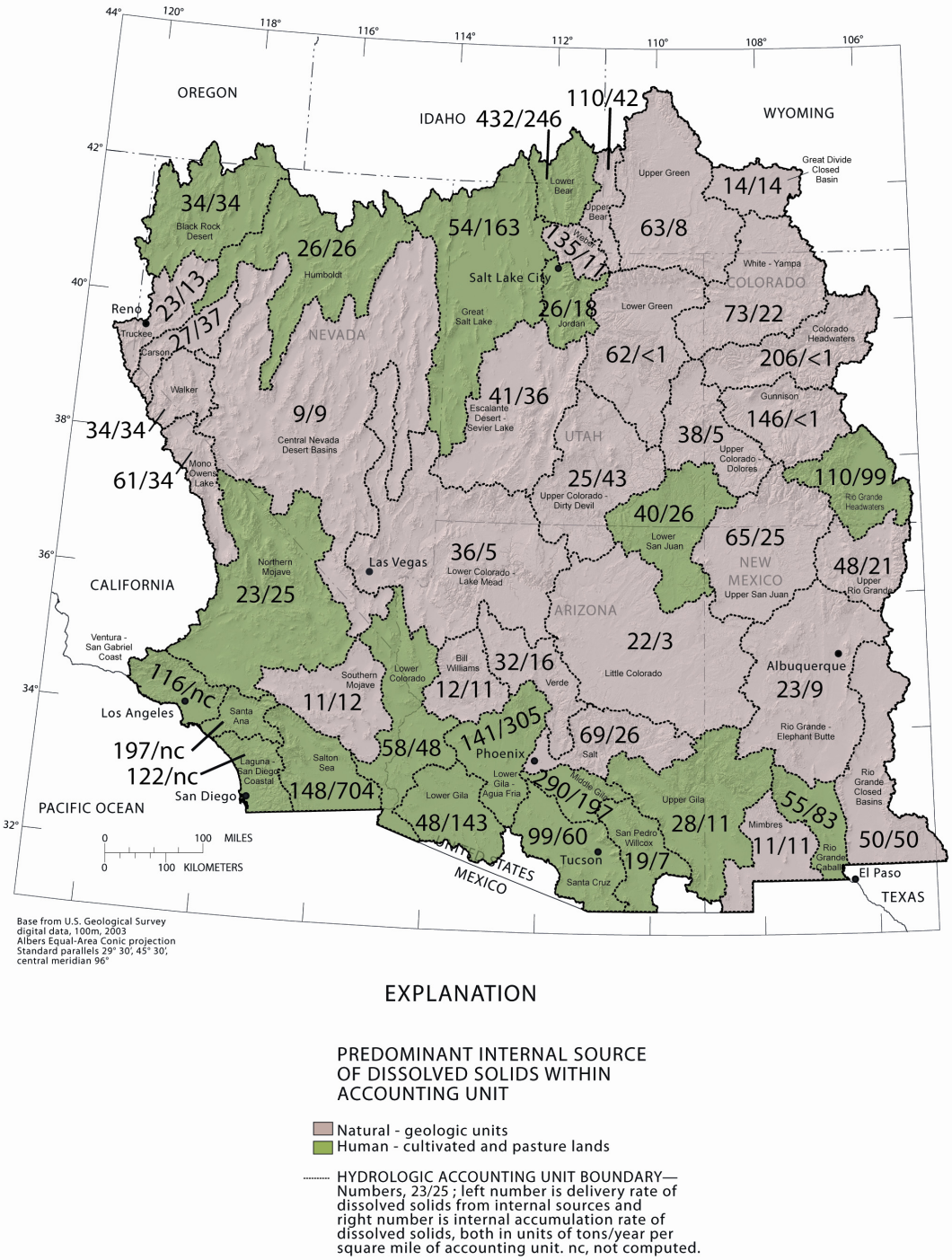

Figure 1. Delivery rate of dissolved solids from internal sources, internal accumulation rate, and predominant internal source of dissolved solids within accounting units in the Southwest.