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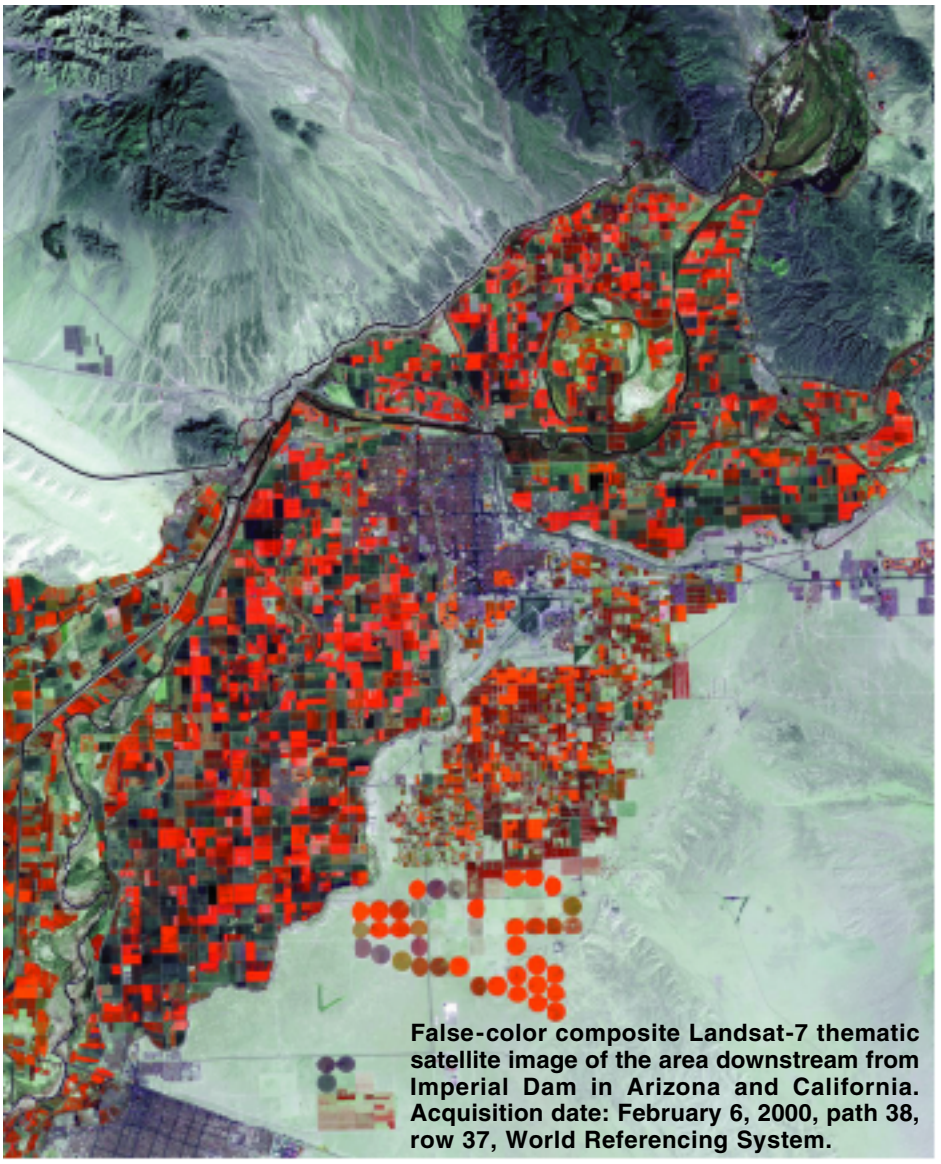
Identifying Wells Downstream from Laguna Dam that Yield Water that will be Replaced by Water from the Colorado River, Arizona and California

This report summarizes a comprehensive study and development of the method documented in Owen-Joyce and others (2000). That report and one for the area upstream from Laguna Dam (Wilson and Owen-Joyce, 1994) document the accounting-surface method to identify wells that yield water that will be replaced by water from the Colorado River.

Downstream from Laguna Dam, the Colorado River is the source for nearly all recharge to the river aquifer. The complex surface-water and ground-water system that exists in the area is, in part, the result of more than 100 years of water-resources development. Agriculture is the principal economy and is possible only with irrigation. The construction and operation of canals provides the means to divert and distribute Colorado River water to irrigate agricultural lands on the flood plains and mesas along the Colorado and Gila Rivers, in Imperial and Coachella Valleys, and in the area upstream from Dome along the Gila River. Water is withdrawn from wells for irrigation, dewatering, and domestic use. The area downstream from Laguna Dam borders additional areas of agricultural development in Mexico where Colorado River water also is diverted for irrigation.

Why Identify Wells?

In the United States, water from the mainstream in the lower Colorado River is apportioned among the States of California, Arizona, and Nevada by the Boulder Canyon Project Act of December 21, 1928, and confirmed by the U.S. Supreme Court decree, 1964, *Arizona* v, *California*, in terms of consumptive use (U.S. Congress, 1948). The decree is specific about the responsibility of the Secretary of the Interior to account for consumptive use of water from the mainstream; consumptive use is defined to include "water drawn from the mainstream by underground pumping." Accounting for the use of Colorado River water is required by the 1964 decree (U.S. Supreme Court, 1964); a report that contains records of diversions, returns, and consumptive use of water by individual water users is published annually by the Bureau of Reclamation (Bureau of Reclamation, 1965–2000). The accounting-surface method is a tool the Bureau of Reclamation can use to identify users of Colorado River water and from which to build a policy to account for consumptive use of water from wells in the river aquifer.



False-color composite Landsat-7 thematic satellite image of the area downstream from Imperial Dam in Arizona and California. Acquisition date: February 6, 2000, path 38, row 37, World Referencing System.

River Aquifer

The river and the underlying and adjacent river aquifer form a complex, hydraulically connected ground-water and surface-water flow system in the Yuma area downstream from Laguna Dam (fig. 1). The river aquifer consists of permeable sediments and sedimentary rocks that are hydraulically connected to the Colorado River so that water can move between the river and the aquifer in response to differences in water-level elevations between the river and the aquifer and withdrawal of water from the aquifer. The subsurface limit of the river aquifer is the nearly impermeable bedrock of the bottom and sides of the basins that underlie the Yuma area and adjacent valleys. Bedrock is a barrier to ground-water flow.

The principal source of water to the area downstream from Laguna Dam is the Colorado River, although much of the water does not arrive in the river channel. Water stored in upstream surface reservoirs is delivered for use downstream from Laguna Dam. Most of the water delivered at Imperial Dam is diverted from the river into the All-American Canal on the California side of the river and into the Gila Gravity Main Canal on the Arizona side (fig. 2). Millions of acre-feet of water are diverted or pumped annually from the river channel; most is transported for use in Imperial and Coachella Valleys through the All-American Canal downstream from Pilot Knob and for use in the lower Gila River Valley upstream from Dome through the Gila Gravity Main and Wellton-Mohawk Canals.

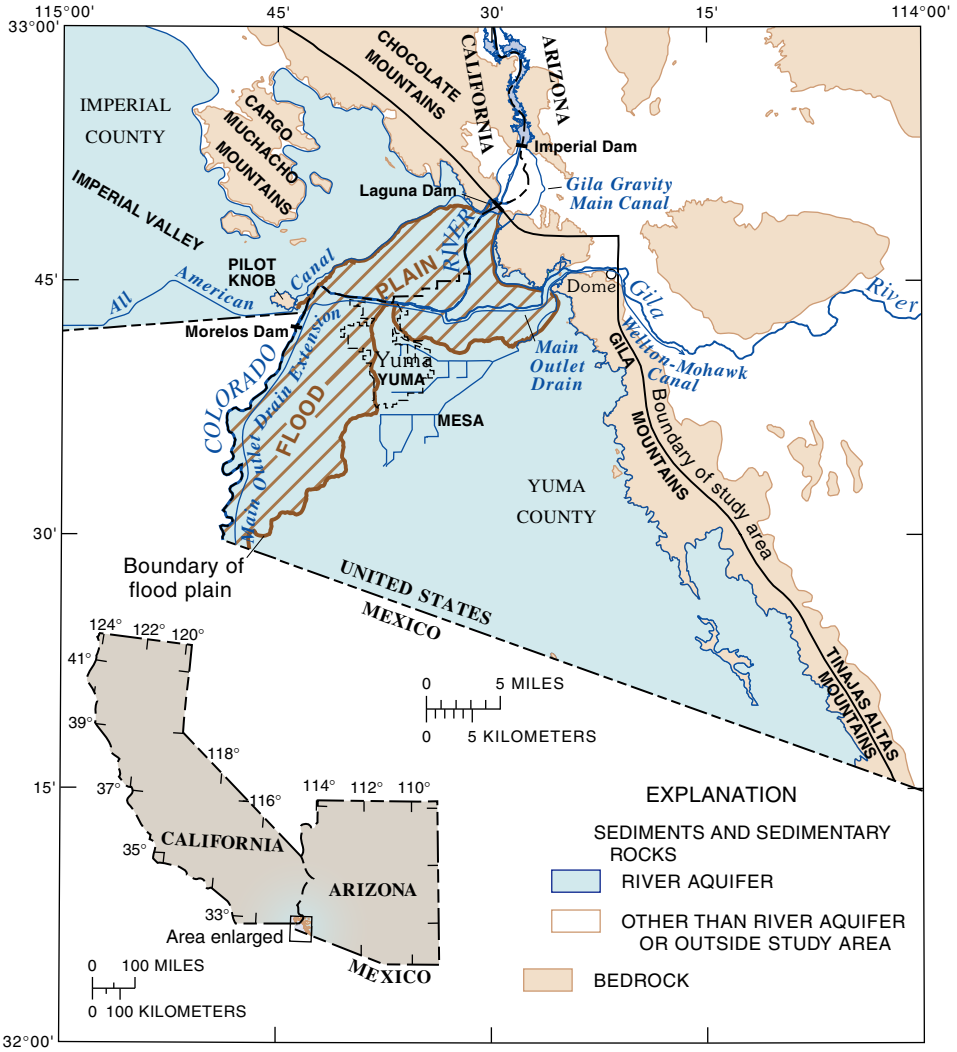


Figure 1. The lower Colorado River and the areal extent of the river aquifer downstream from Laguna Dam, Arizona and California.

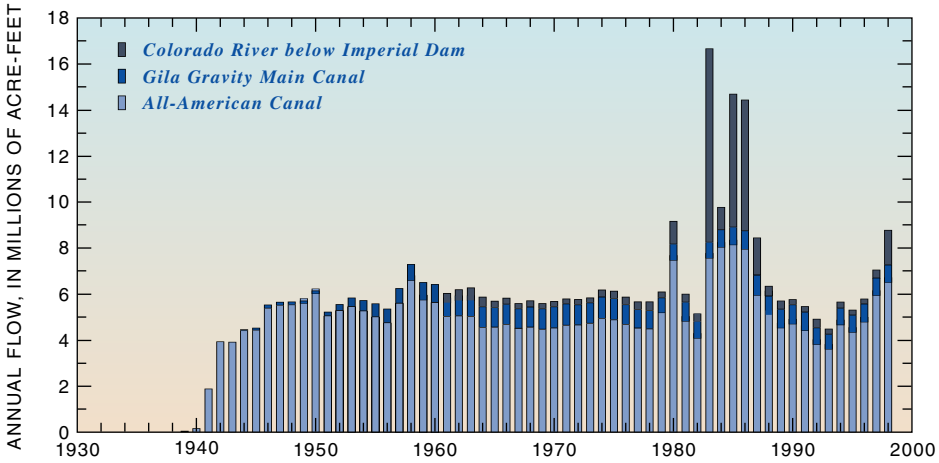


Figure 2. Annual flow in the Colorado River above Imperial Dam. This flow is the sum of flow diverted from the Colorado River into the All-American Canal near Imperial Dam, 1938–98, flow diverted into the Gila Gravity Main Canal, 1944–98, and flow in the Colorado River below Imperial Dam, 1961–98.

The rest is used for irrigation of fields adjacent to the river and for municipal use in the Yuma area. Downstream from Laguna Dam, water also is stored in the river aquifer and is pumped from wells for irrigation, municipal, and domestic use. Much of the irrigation water is transpired by vegetation or evaporates, and the remainder percolates below the root zone into the river aquifer. Some of the water in the unlined canals and in the river channel and marshes during high flows percolates through the underlying soils and sediments and recharges the river aquifer. Small quantities of runoff that originate from precipitation infiltrate the beds of washes and intermittent tributary streams; most of the infiltrated water later evaporates or is transpired leaving little to recharge the river aquifer.

Ground water flows downgradient through the river aquifer and discharges as seepage into drainage ditches or through the river banks into the river. Water moves back and forth between the surface-water and ground-water systems in response to application of water to irrigated fields and annual changes in the water-level elevation of the river. In addition to drainage ditches, dewatering wells also are used to manage ground-water levels beneath irrigated areas by withdrawing ground water for discharge to the Colorado River. Water is pumped from thousands of wells completed in the river aquifer on the flood plain, on alluvial slopes, and in tributary valleys. Agricultural development, degradation of the river channel because of reduced sediment load, and diversions upstream have caused the Colorado River to become a drain in the Yuma area. The river channel from Laguna Dam to Pilot Knob wasteway normally conveys seepage and flow from drainage ditches. Except for occasional discharge of water past Morelos Dam as a result of deliveries to Mexico in excess of treaty requirements, the channel downstream from Morelos Dam normally conveys seepage and discharge from the Main Outlet Drain Extension or is dry.

Accounting-Surface Method

The accounting-surface method was developed for the area upstream from Laguna Dam and is based on the concept of a river aquifer and an accounting surface within the river aquifer (Wilson and Owen-Joyce, 1994). This method was modified for use downstream from Laguna Dam to identify wells outside the flood plain of the lower Colorado River that yield water that will be replaced by water from the river. Use of the same method provides a uniform criterion of identification for all users pumping water from wells by determining if the static water-level elevation in the well is above or below the elevation of the accounting surface.

The accounting-surface method can be used in the area downstream from Laguna Dam outside the flood plain of the Colorado River to identify wells that are presumed to yield water that will be replaced by water from the river, and wells that are presumed to yield water that will be replaced by river water stored above river level. The identification is made by determining the static water-level elevation in the well and comparing it to the elevation of the accounting surface at the well. The accounting surface represents the elevation and slope of the unconfined static water table in the river aquifer outside the flood plain of the Colorado River that would exist if the river were the only source of water to the river aquifer. The accounting surface was generated by using water-surface profiles of the Colorado River from Laguna Dam to about the downstream limit of perennial flow at Morelos Dam and without consideration of the time required for water to travel from the river to any point of withdrawal from the river aquifer. River discharges selected for the computation of water-surface profiles are based on flow for 1998-99, which reflects average cropping patterns and agricultural drainage, neither flood nor drought conditions, and no operational activities. The accounting surface extends outward from the edges of the flood plain to the subsurface boundary of the river aquifer (fig. 3). Water pumped from wells on the flood plain, including the area downstream from Morelos Dam, is presumed to be Colorado River water.

Wells that have a static water-level elevation equal to or below the accounting surface are presumed to yield water that will be replaced by water from the Colorado River (fig. 3, wells labeled **R**). The water-table elevation in the river aquifer near a well or well field is assumed to be the same as the elevation of static water levels in the wells. Pumping water from a well completed in the river aquifer where the elevation of the static water level in the well is below the elevation of the accounting surface eventually will cause the slope of the hydraulic gradient between the river and the well to be downward toward the well. This, in turn, will result in the movement of water from the Colorado River into the river aquifer.

The modification to the accounting-surface method for use downstream from Laguna Dam is in the designation of the source of the water in wells where the static water level is above the accounting surface. Wells that have a static water-level elevation above the accounting surface are presumed to yield river water stored above river level (fig. 3, wells labeled **S**). In an area underlain by a ground-water mound, the water-level elevation in a well can remain above the accounting surface as long as river water stored above river level can move to the well to replace river water removed from storage.

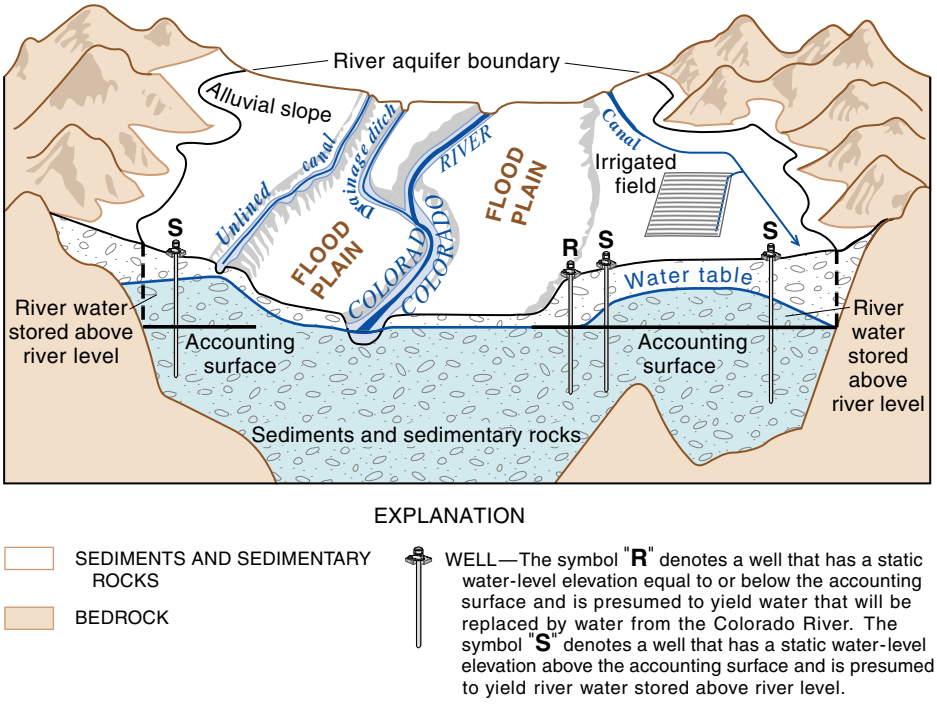


Figure 3. Schematic diagram showing the river aquifer and accounting surface.

If more water is pumped from a well than can be replaced by river water stored above river level, the static water-level elevation in the well will decline below the accounting surface and water will eventually move from the Colorado River into the river aquifer toward the well. In an area where a well has a static water level below the accounting surface but where a ground-water mound exists between that well and the river upstream from Morelos Dam, water pumped from that well is presumed to be replaced by river water stored above river level until the mound is depleted. When the mound of river water stored above river level no longer exists, water eventually will move from the Colorado River into the river aquifer toward the well and the well will be presumed to yield water that will be replaced by water from the Colorado River.

Applying the Method

Application of the accounting-surface method will require identification of all wells within the river aquifer from which water is pumped for consumptive use. Static water levels need to be measured and compared to the accounting surface for the method to be applied. The inventory of each well will include interviewing the well owner or operator to collect current ownership and historical information to enable the tracking of the driller's log. Other data to be collected during an inventory include precise locations and elevations determined by use of a Global Positioning System, and photographs of the wells to help with identification for future monitoring of static water levels. Bureau of Reclamation management responsibilities include a legal mandate to ensure that all diversions of Colorado River water, including those by wells, are authorized.

—*Sandra J. Owen-Joyce*

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