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Colorado River or Tributary Water— U.S. Geological Survey Update of the Accounting Surface Along the Lower Colorado River

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Introduction

The accounting-surface method was developed in the 1990s by the U.S. Geological Survey (USGS), in cooperation with the Bureau of Reclamation (Reclamation), to identify wells outside the flood plain of the lower Colorado River that yield water that will be replaced by water from the river (Wilson and Owen-Joyce, 1994; Owen-Joyce and others, 2000). Such wells need to be included in accounting for consumptive use of Colorado River water as outlined in the Consolidated Decree of the United States Supreme Court in Arizona v. California, 547 U.S.150 (2006). The method is based on the concept of a river aquifer and an accounting surface within the river aquifer (fig.1). The study area includes the valley adjacent to the lower Colorado River and parts of some adjacent valleys in Arizona, California, Nevada, and Utah and extends from the east end of Lake Mead south to the southerly international boundary with Mexico (fig. 2). Nearly 15 years have passed since the development of the original accounting surface (Wilson and Owen-Joyce, 1994; Owen-Joyce and others, 2000). Prior to the issuance of a proposed rule to define the accounting procedure, an update of the accounting surface was needed for use in the process of Decree accounting because of possible changes to the river stage at specified discharges resulting from changes to river management or the hydraulic properties of the river. In addition, the original accounting surface relied on a nonstandard datum for the drainage ditches used in Palo Verde Valley, adding an error to the elevation of the accounting surface in that area. The accounting surface was updated using a numerical model of ground-water flow (Wiele and others, 2008) in place of the hand-drawn method based on hydrologic judgment used previously.

Accounting-Surface Method

The accounting-surface method provides a uniform criterion based on the static water level in a well to determine if the well is pumping water that will be replaced by water from the river. The static water level is the level of the water in a well that is unaffected by ground-water withdrawal or the level to which water will rise in a tightly cased well under its full pressure head. 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 river. Wells that have a static water-level elevation above the accounting surface are presumed to yield water that will be replaced by water from precipitation and inflow from tributary valleys (fig. 1). Ground water in the river aquifer beneath the flood plain is considered to be Colorado River water regardless of water levels. Water pumped from wells on the flood plain is presumed to be river water and is accounted for as Colorado River water.

Generation of the Updated Accounting Surface

The accounting surface adjacent to free-flowing reaches of the river between reservoirs published by Wilson and Owen-Joyce (1994) and Owen-Joyce and others (2000) were hand-drawn based on surface-water profiles. In Parker and Palo Verde Valleys, drainage ditches or wells along the edge of the flood plain were used to define the level of the accounting surface. Adjacent to reservoirs, the accounting surface is flat, and is set to an elevation of the adjacent reservoir defined by the annual

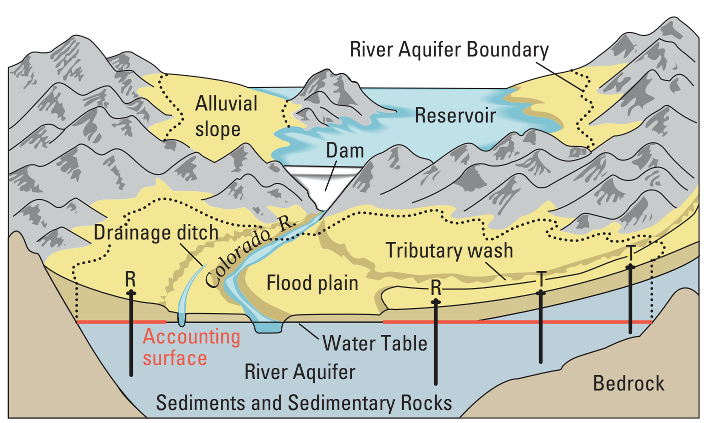

Figure 1. Schematic diagram showing the river aquifer and accounting surface. Wells labeled "R" have a static water-level elevation equal to or below the accounting surface and are presumed to yield water that will be replaced by water from the river. Wells labeled "T" have a static water-level elevation above the accounting surface and are presumed to yield water that will be replaced by water from precipitation and inflow from tributary valleys (Modified from Wilson and Owen-Joyce, 1994).

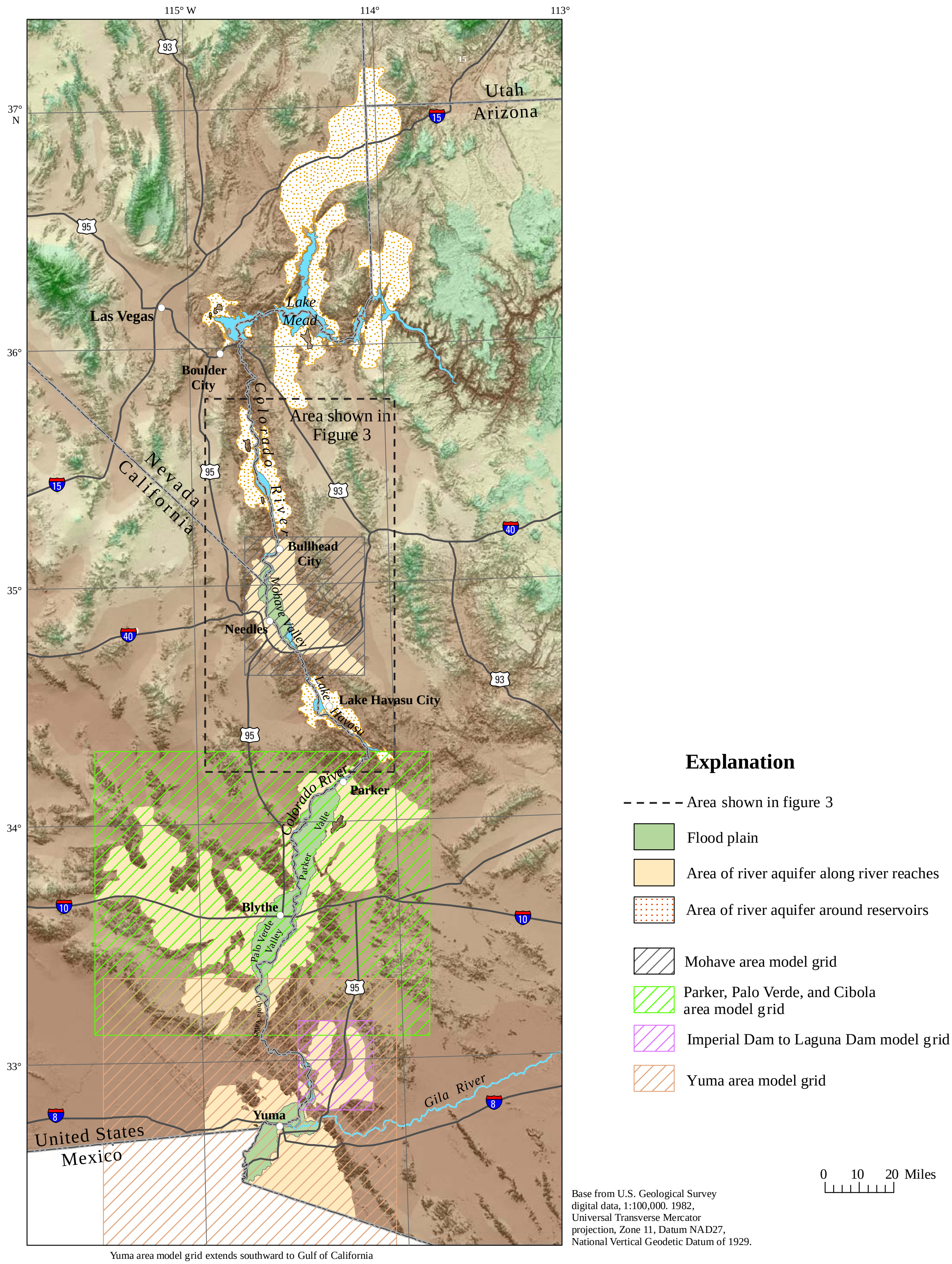

Figure 2. The lower Colorado River and areal extent of the river aquifer.

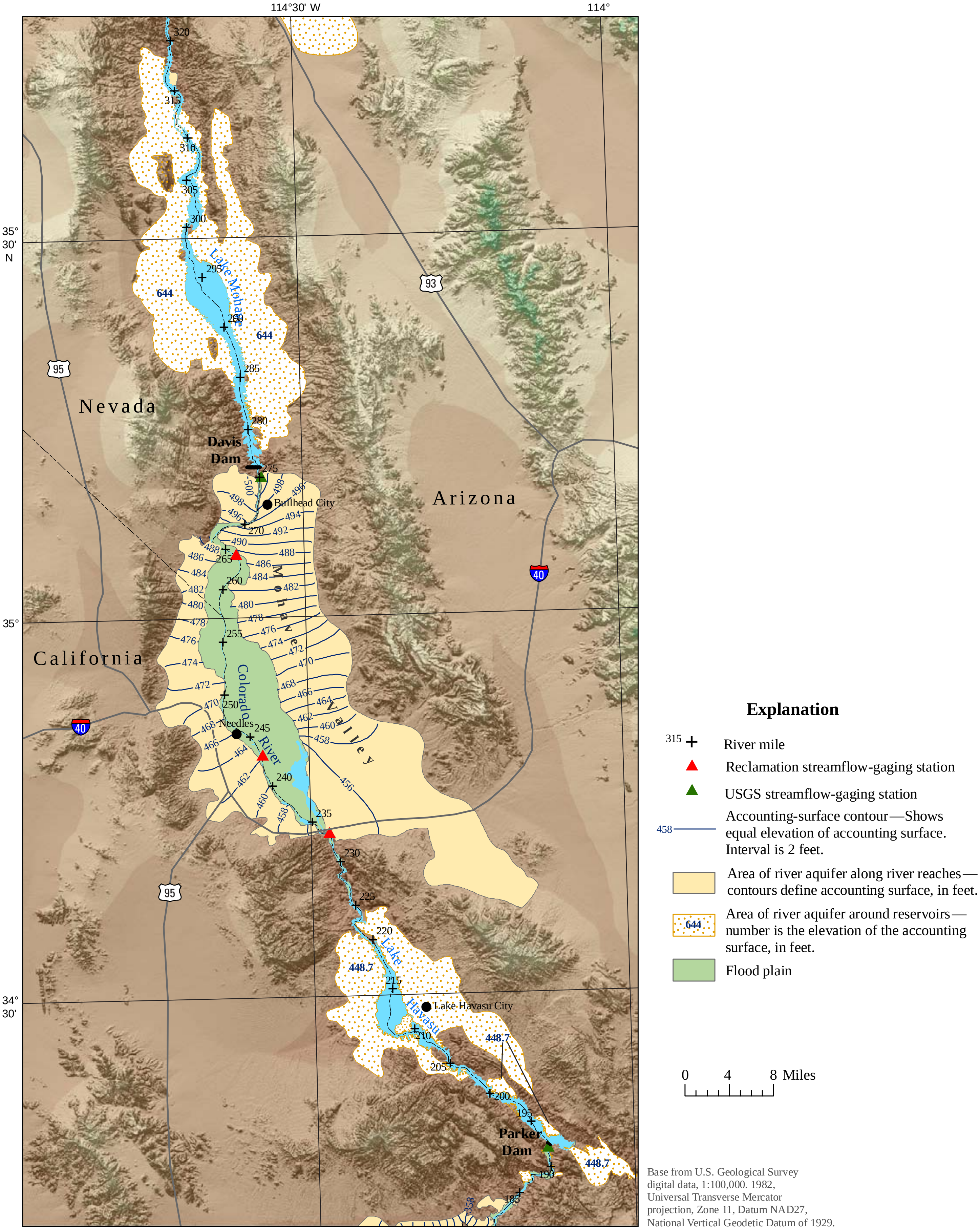

Figure 3. Accounting surface in Mohave Valley and adjacent tributary areas. Maps of the other reservoir and modeled areas can be found in Wiele and others, 2008.

high water-surface elevation used by Reclamation to operate the reservoirs under normal flow conditions.

The general strategy for updating the accounting surface was as follows:

1. The extent of the river aquifer and area over which the accounting surface was defined by Wilson and Owen-Joyce (1994) and Owen-Joyce and others (2000) were retained.

2. Water-surface profiles of the Colorado River and drainage ditches used in defining the accounting surface were updated using the most recent information available. Drainage ditches were used in Parker, Palo Verde, and Cibola Valleys in defining the accounting surface.

3. Water-surface elevations in reservoirs were updated on the basis of current operating conditions for Lakes Mead, Mohave, and Havasu.

4. Contours of the accounting surface adjacent to free-flowing reaches of the Colorado River were generated using simple steady-state ground-water models that simulate two-dimensional flow, using a constant transmissivity value, with river and drainage-ditch elevations as boundary conditions.

A calibrated and documented step-backwater model of the Colorado River that could be used to relate specified discharge values to water-surface elevations was not available for the study area, and development of such a model was beyond the scope of this study. Instead, the water-surface profile was defined by data from streamflow gaging stations operated by Reclamation, the International Boundary and Water Commission (IBWC), and the USGS, and modified by additional water-surface elevation measurements made by the USGS. Water-surface measurements were made where the linearly interpolated profile deviated significantly from the profiles used in the previous studies (Wilson and Owen-Joyce, 1994; Owen-Joyce and others, 2000).

Ground-Water Flow Models

The accounting surface was modeled with MODFLOW 2000 (Harbaugh and others, 2000) using the water-surface elevations in the Colorado River and drainage ditches as constant-head boundaries. The grid spacing in the models was 0.25 mi along model rows and columns. The lateral extents of the model grids are shown in figure 2. The path and distribution of Colorado River and drainage ditch water-surface elevations were established on the model grids using the RIVGRID program (Leake and Claar, 1999). The water-surface elevations defined by RIVGRID were then incorporated into the models as nodes with a constant head.

Areas of the river aquifer adjacent to the Colorado River for which the accounting surface was modeled include (1) Mohave Valley; (2) Parker, Palo Verde, and Cibola Valley; (3) Imperial Dam to Laguna Dam; and (4) the Yuma area. Each area was modeled with a single horizontal layer of cells of thickness 500 ft and hydraulic conductivity 39.2 ft/day; however, the model predictions of the accounting surface are independent of thickness and hydraulic conductivity. Tests were carried out by varying hydraulic conductivity and thickness to verify that computed head distributions were independent of these parameters.

Updated Accounting Surface

The accounting surface around reservoirs was updated using a reservoir elevation specified by Reclamation. The accounting surface in the river aquifer around Lake Mead is set at the maximum possible lake elevation of 1205.4 ft. This is the same elevation used for the original accounting surface. The accounting surface is set at 644.0 ft in the river aquifer around Lake Mohave, and at 448.7 ft in the river aquifer around Lake Havasu, the current high monthly target elevations for these reservoirs. These elevations are slightly different from the high monthly target elevation used for the original accounting surface. In the river aquifer between the major reservoirs, ground-water flow models with boundary conditions set by Colorado River and drainage ditch water-surface elevations were used to contour the accounting surface. The models computed water-level elevations over the entire river aquifer; however, only contours in the river aquifer where the accounting surface exists are shown for modeled areas (fig. 3). The development and application of computer models will make further updating of the accounting surface, if necessary, a straightforward task.

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