# Analysis of Depletion of Water in the Lower Colorado River by Underground Pumping

A briefing for the States of Arizona, California, and Nevada
by the Non-Contract Use Technical Team

Bureau of Reclamation
U.S. Geological Survey

September 4, 2008
Las Vegas, Nevada

Results presented here are preliminary, subject to revision

# Background

The "Law of the River" recognizes that…

- Water may be diverted from the Colorado River by underground pumping, and
- The Lower Basin States are entitled to divert tributary water before it reaches the river without contracting or accounting requirements for Colorado River water.

To identify areas of ground-water tributary inflow, Reclamation and the USGS developed the "Accounting-Surface Method"

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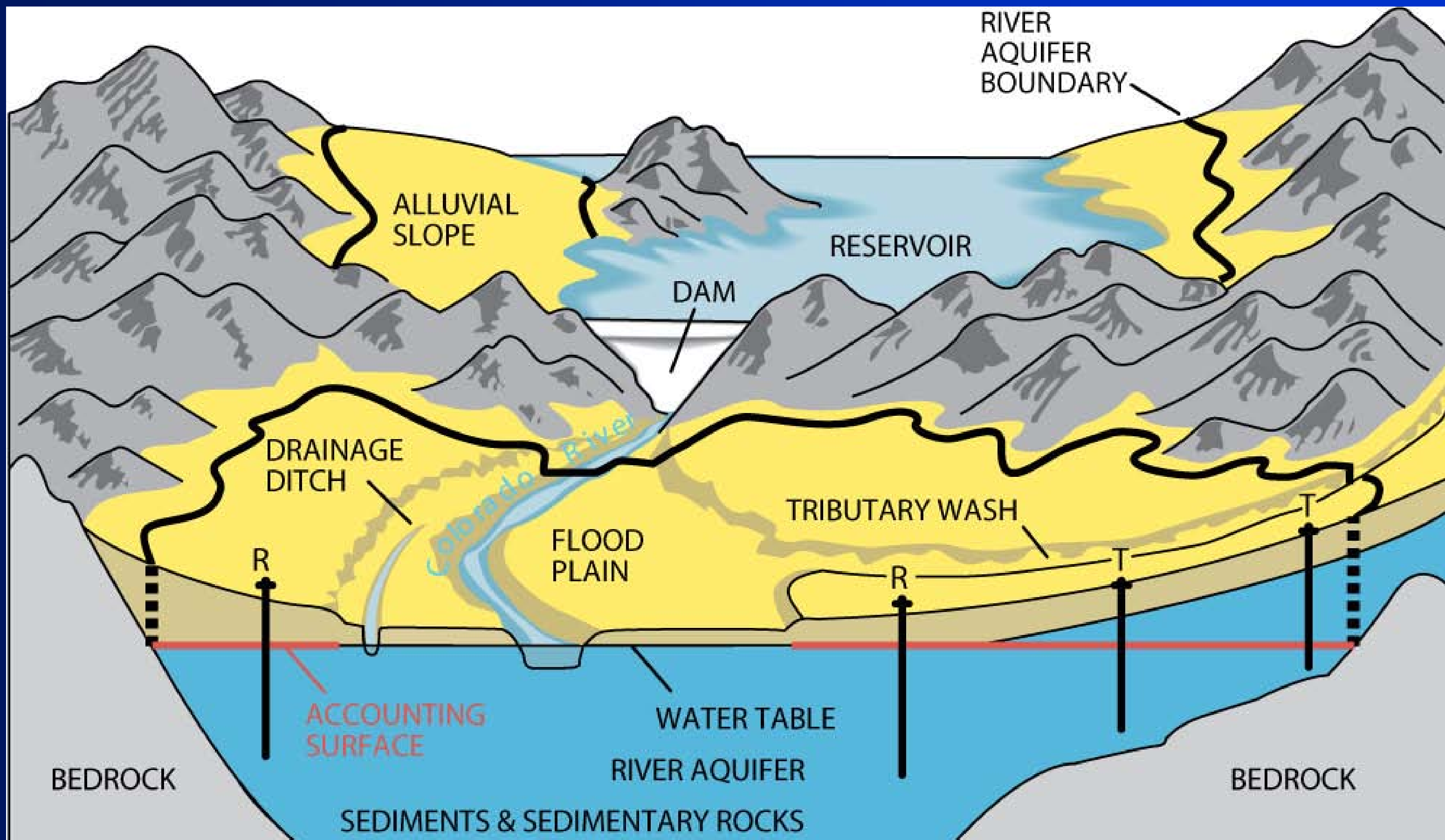
# Accounting-Surface Method

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# Need to Update the Accounting Surface

- Some of the elevations used in the PVID area were referenced to a non-standard datum

Additional benefits of updated accounting surface

- An update could be done using simple ground-water models of the river aquifer adjacent to non-reservoir reaches, eliminating the subjectivity of hand-drawn contours

- The river and drainage ditch water surface elevations were updated. The original accounting surface was developed using river-surface elevations that are now as much as 20 years old.

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# Modeling Procedure

- MODFLOW-2000 was used with a horizontal grid spacing of 0.25 mile
- Surface-water elevations in the river and drainage ditches were represented as constant-head boundaries
- The river aquifer was simulated with complex horizontal geometry but as a one-layer transmissive slab
- The Laplace equation was solved to compute the accounting surface

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0$$

Construction of model data sets was mostly automated

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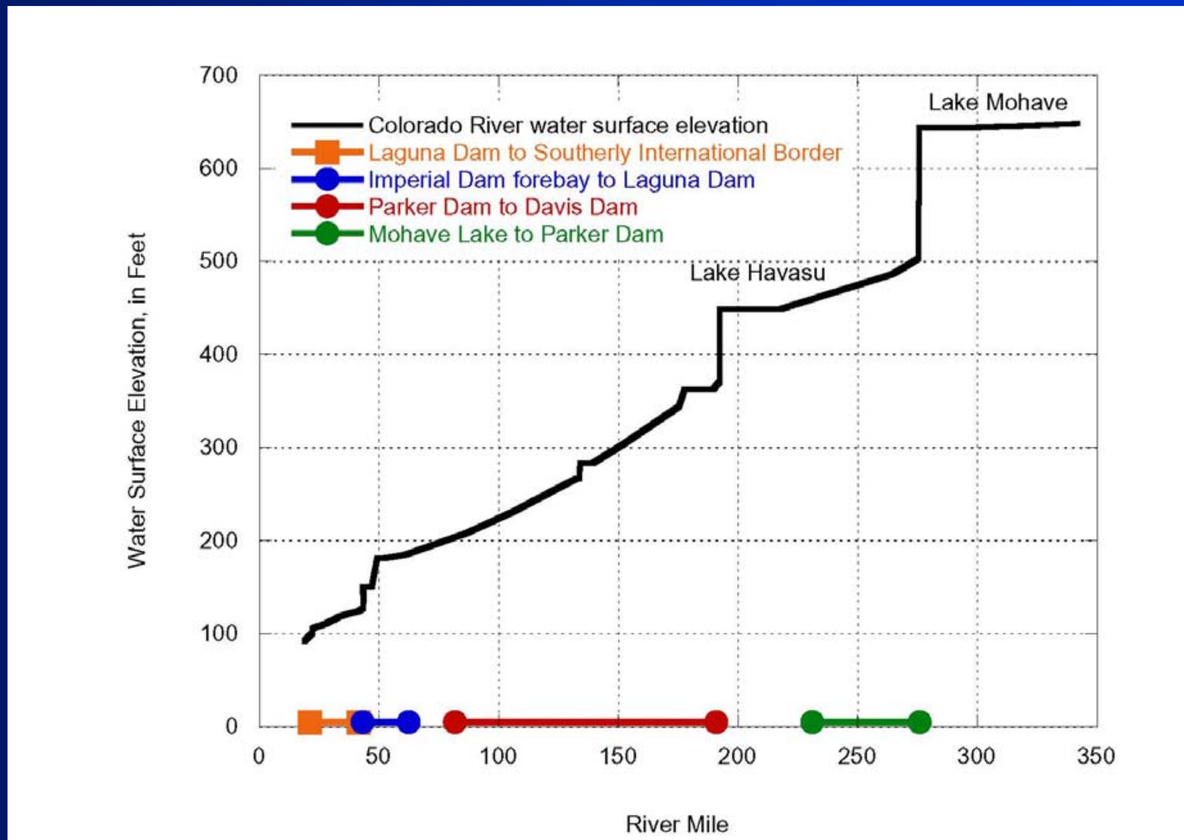
# Updated River Profile

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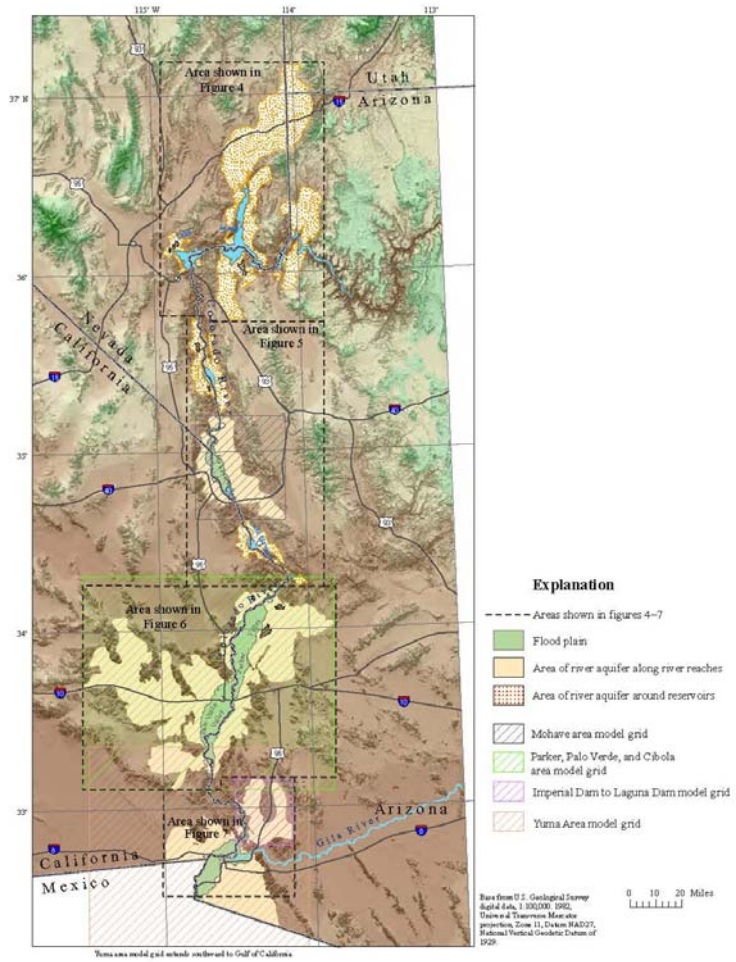


**Figure 1.** Map showing the lower Colorado River and areal extent of the river aquifer.

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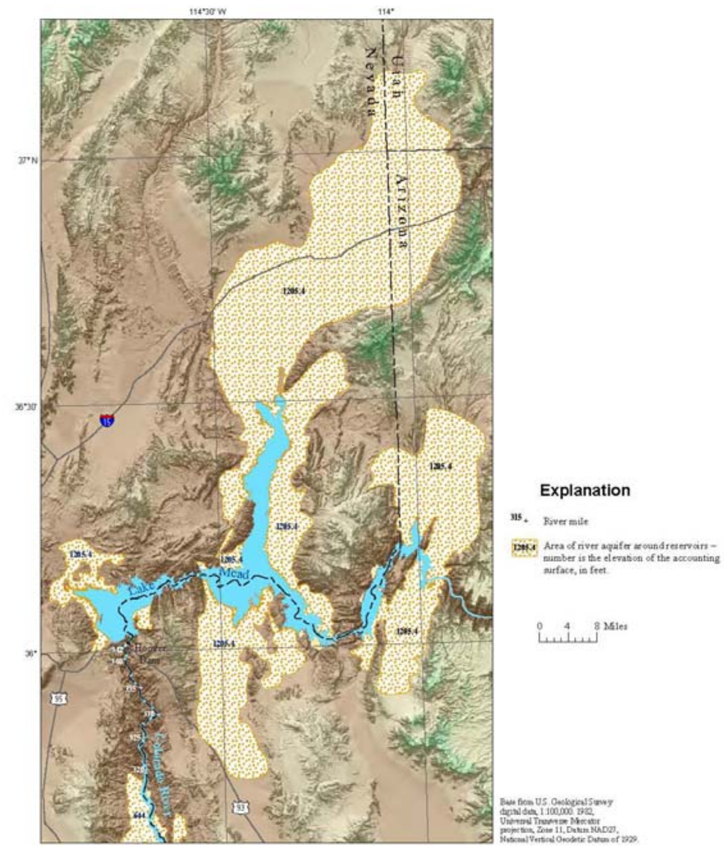


**Figure 4.** Map showing the accounting surface in the areas surrounding Lake Mead, Arizona, Utah, and Nevada.

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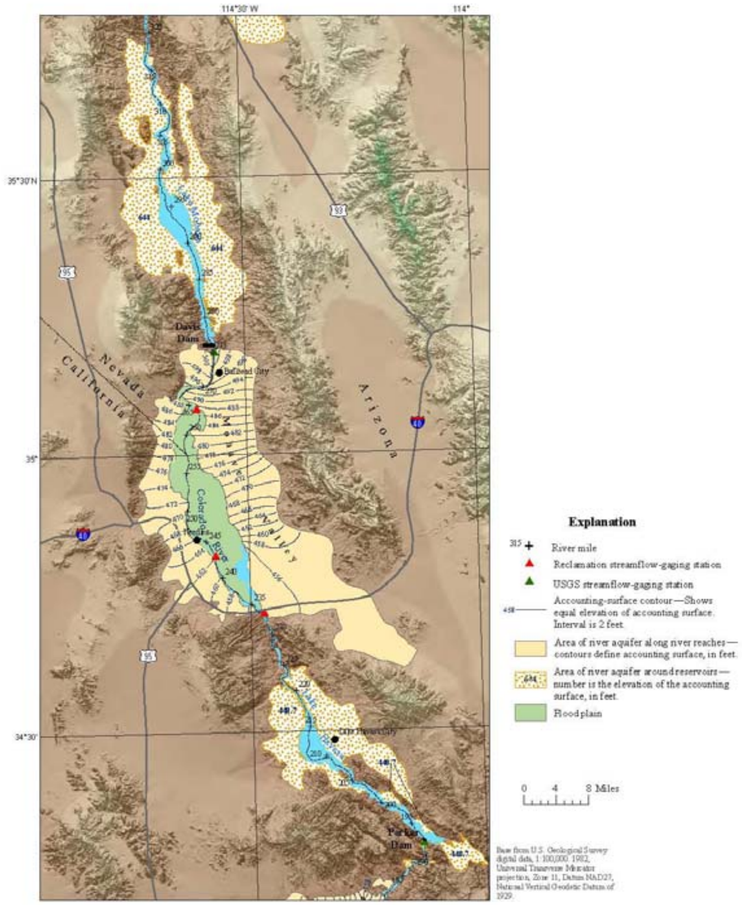


**Figure 5.** Map showing the accounting surface in Mohave Valley and adjacent tributary areas in Arizona, California, and Nevada.

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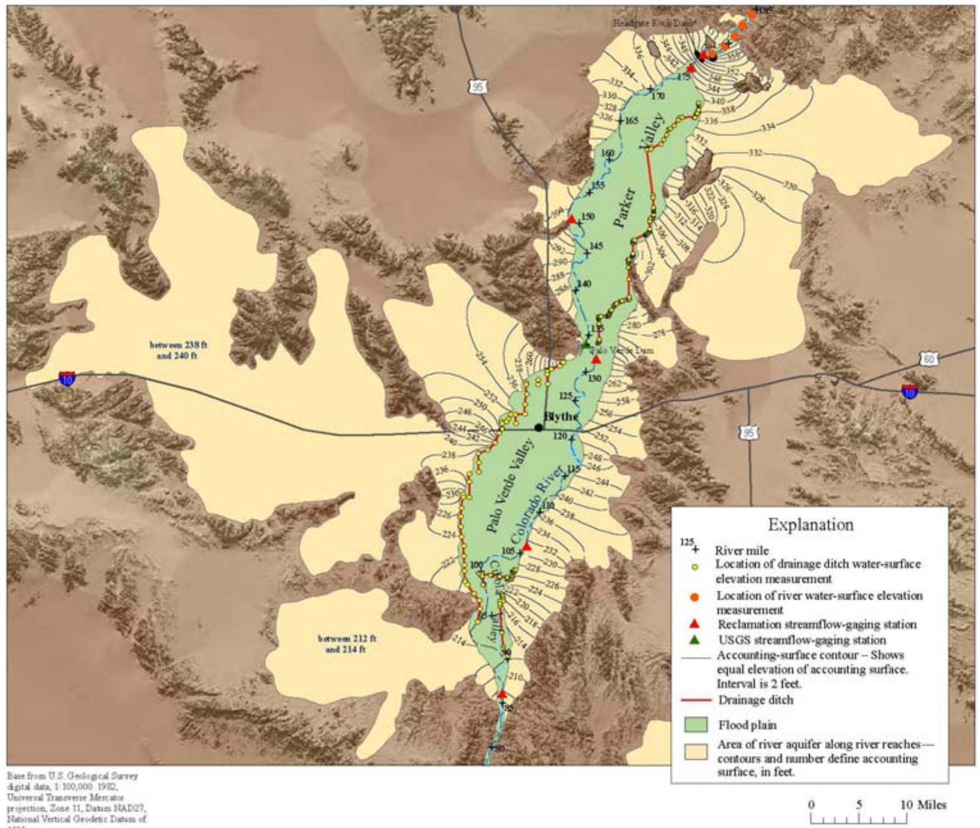


Base from U.S. Geological Survey digital data, 1:100,000 1982, Universal Transverse Mercator projection, Zone 11, Datum NAD27, National Vertical Geodetic Datum of 1929.

**Figure 6.** Map showing the accounting surface in Parker, Palo Verde, and Cibola Valleys and adjacent tributary areas in Arizona and California.

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Summary 15

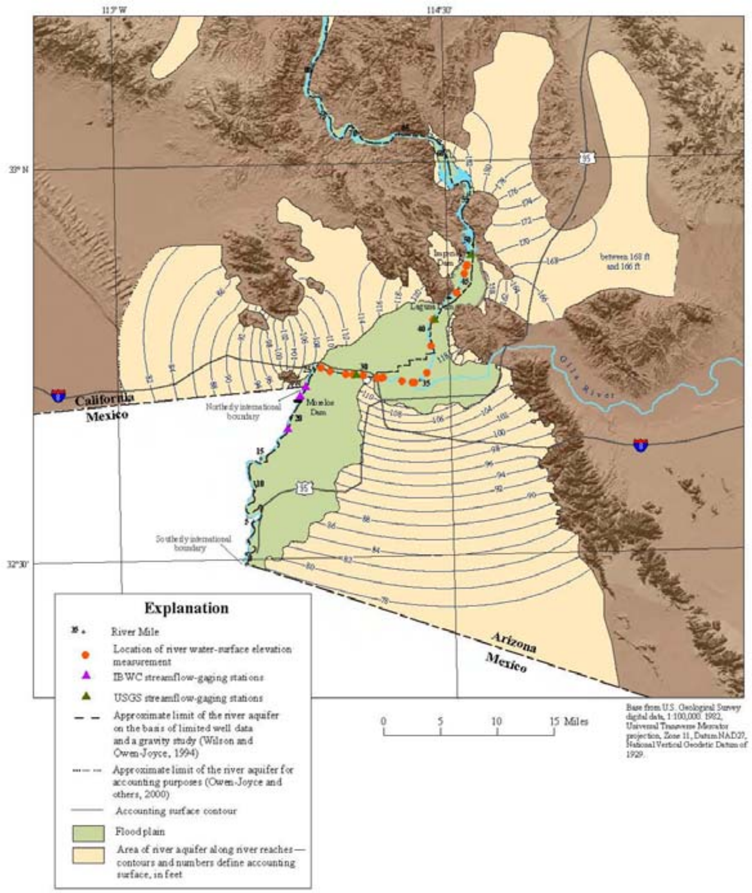


**Figure 7.** Map showing the accounting surface in the Yuma area upstream and downstream from Laguna Dam and adjacent tributary areas in Arizona and California.

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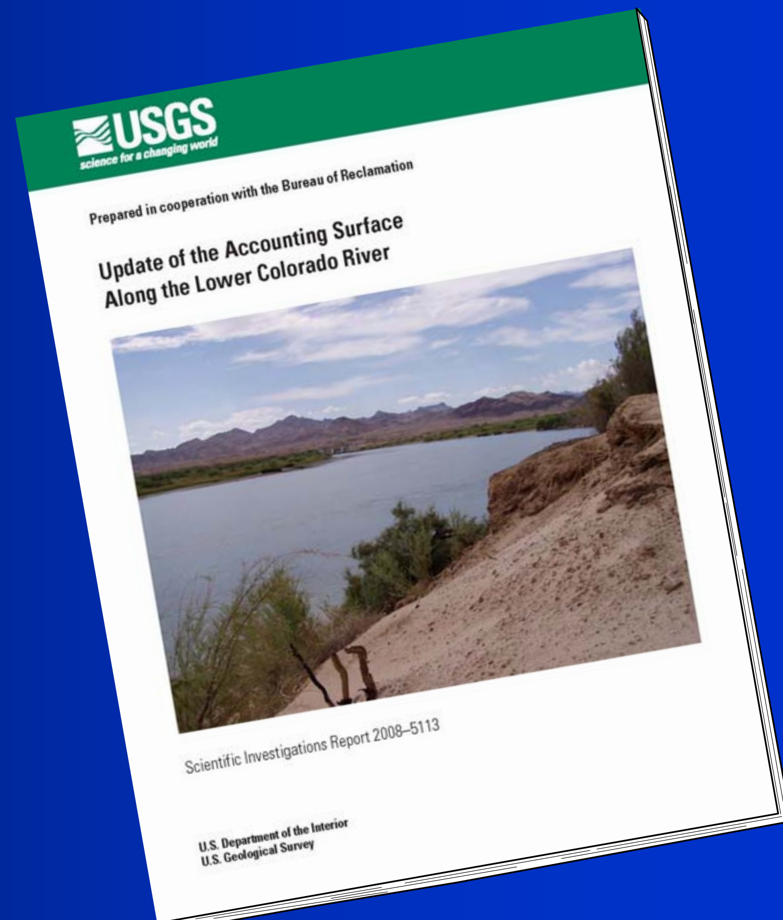
# Accounting-Surface Update

A report documenting the updated accounting surface has been published online (Wiele, Leake, Owen-Joyce, and McGuire, 2008).

http://pubs.usgs.gov/sir/2008/5113/

A hard copy version with plates will be published in early FY09.

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# Reason for Depletion Analysis

Concerns were expressed at the State level about the impacts to the depletions of the lower Colorado River with regard to the timing of well pumping and the distance that a well is located from the river.

Reclamation set up the Non-Contract Use Technical Team to design a method to evaluate the impacts of timing and distance on well depletions.

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# Non-Contract Use Technical Team

The team included the following members

- Jeff Addiego, Reclamation, Boulder City (now retired);
- Carroll Brown, Reclamation, Yuma;
- Bill Greer, Reclamation, Yuma;
- Stan Leake, USGS, Tucson;
- Sandra Owen-Joyce, USGS, Tucson;
- Ruth Thayer, Reclamation, Boulder City (Team Leader);
- Dennis Watt, Reclamation, Boulder City;
- Paul Weghorst, Reclamation, Denver (now in the private sector).

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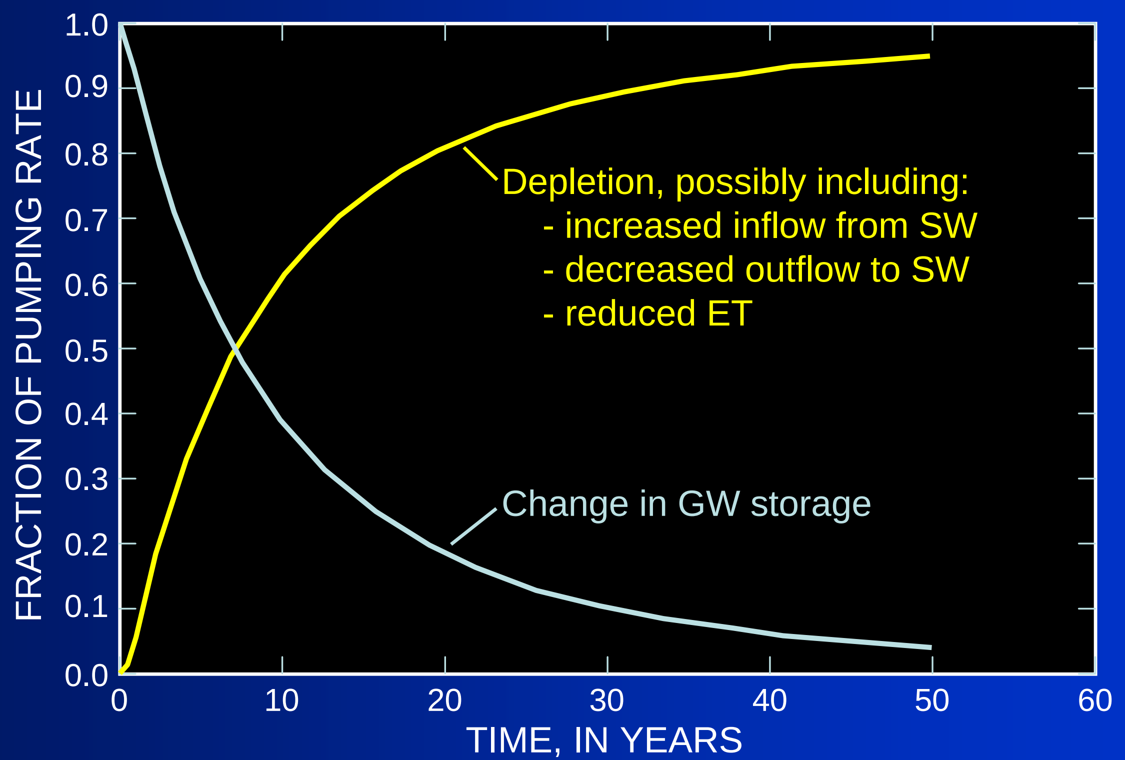
# Basics of Depletion or Capture




The timing of depends on

- Aquifer diffusivity (T/S)
- Distance to connected SW features

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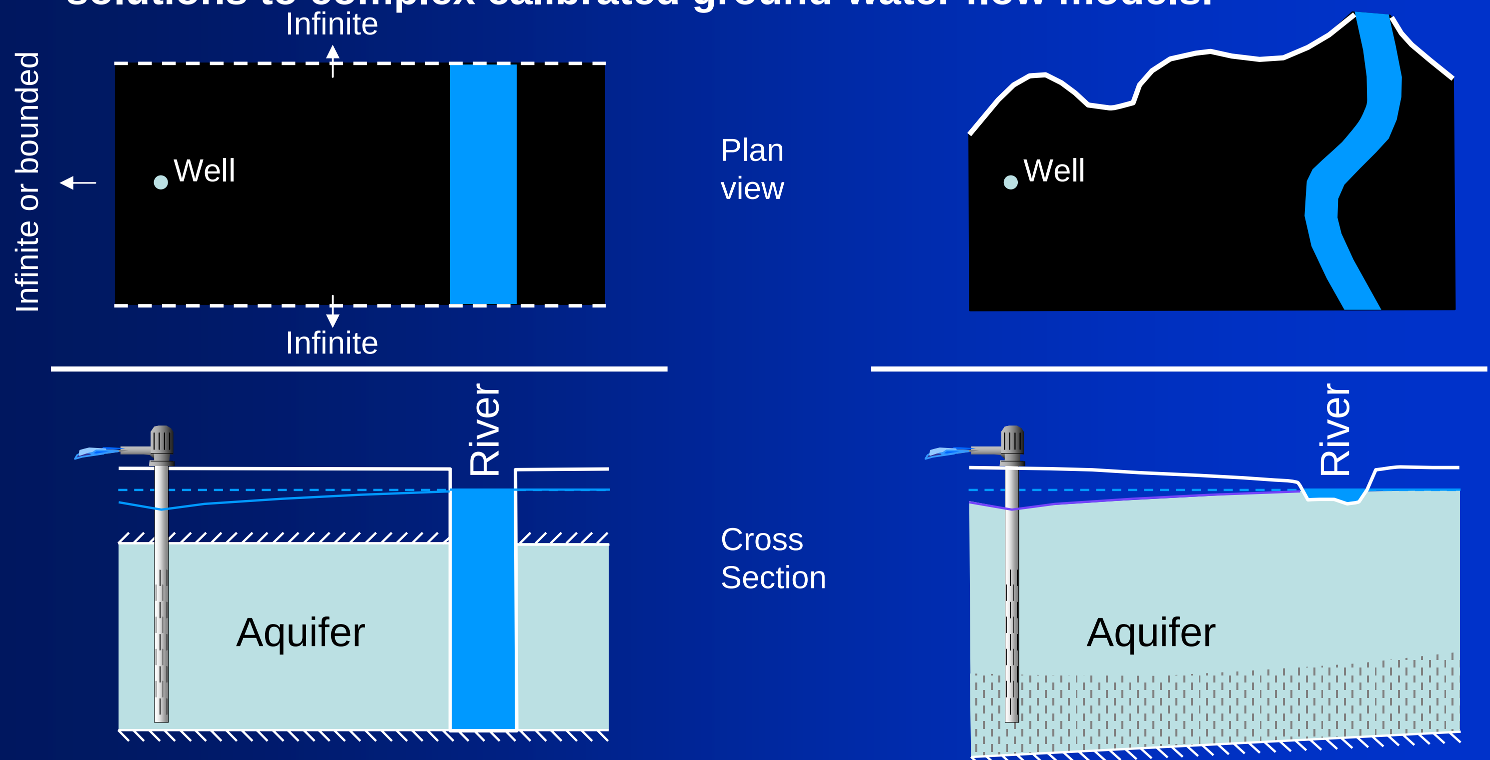
# Calculating Depletion

**Depletion can be calculated using methods ranging from simple analytical solutions to complex calibrated ground-water flow models.**




Simple analytical (Glover) solution

Complex numerical (MODFLOW) solution

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# Calculating Depletion

**Some problems in applying analytical solutions in the region are**

- **River is not straight**
- **Aquifer boundary is highly irregular with many connected side valleys**
- **River does not fully penetrate aquifer**

**Some problems in applying complex flow models are**

- **Calibrated flow models do not exist for most areas along the lower Colorado River**
- **Construction of new flow models would take more time and money than is available**

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# Calculating Depletion

An intermediate approach was taken for this study. Numerical change (superposition) models were constructed for major areas along the Lower Colorado River. Some key characteristics of the models are

- System change from pumping is simulated with MODFLOW;
- Vertical flow domain is a one-layer horizontal slab,
- Horizontal flow domain extends to the complex boundary defined by the edge of the river aquifer;
- Aquifer properties are represented with a single transmissivity and a single storage coefficient;

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# Calculating Depletion

**Key characteristics of the models (Continued)**

- **The only surface-water features represented are the river and connected reservoirs or wetlands;**
- **Surface-water features are simulated with the MODFLOW River Package, using a high riverbed conductance;**
- **Model grids are oriented in a north-south direction with uniform 0.25-mile grid spacing;**
- **The time frame selected for calculating depletion was 100 years, the same period as in Arizona's Assured Water Supply regulations.**

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# Areas Modeled


1. Detrital-Virgin
2. Lake Mohave
3. Mohave Valley
4. Parker-Palo Verde-Cibola
5. Laguna Dam
6. Yuma

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# Aquifer Properties— Transmissivity

Because transmissivity is not known over all areas, the general approach was to calculate depletion using statistically derived values from published data. The values used were

1. Average transmissivity– fiftieth percentile on a log-normal distribution of transmissivity values for area
2. Low transmissivity– fifth percentile on a log-normal distribution of transmissivity values for area

The low transmissivity provides a conservative estimate of depletion in each modeled area.

Groupings of transmissivity data were made for (a) areas between Virgin-Detrital and Yuma, (b) Yuma area, and (c) Virgin-Detrital area.

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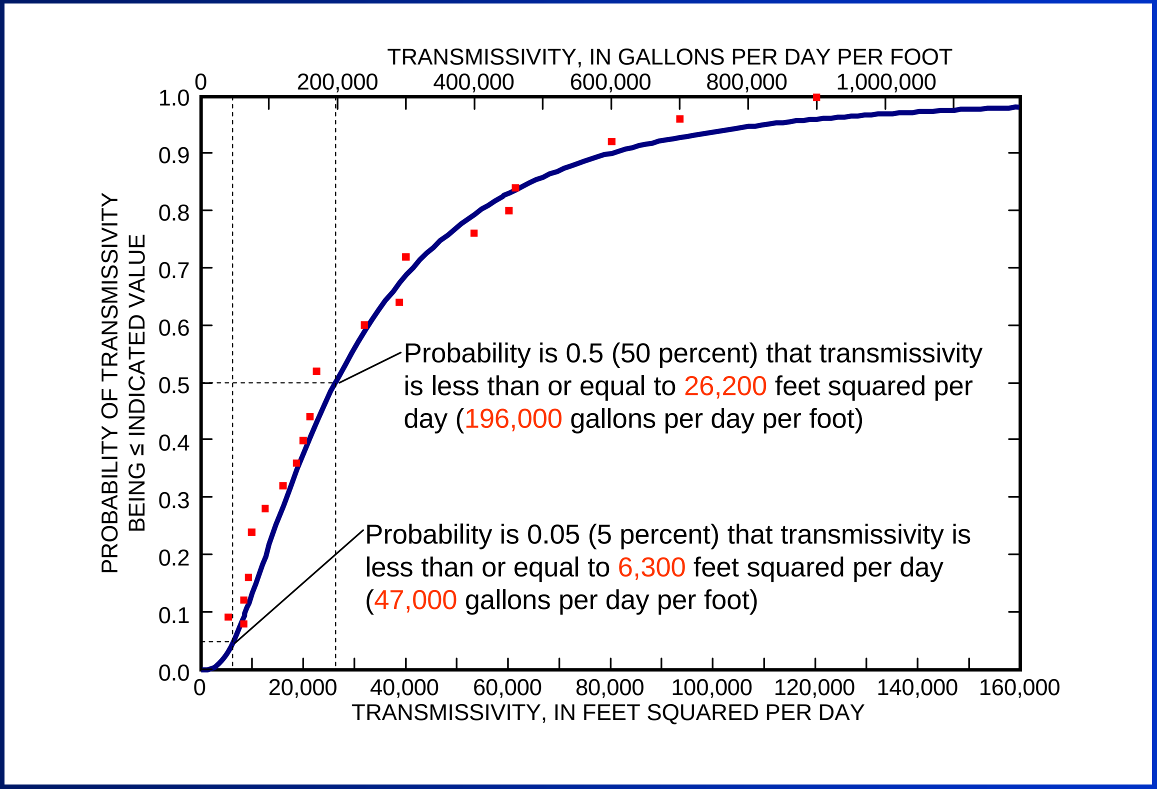
# Aquifer Properties— Transmissivity

## a) Areas between Virgin-Detrital and Yuma

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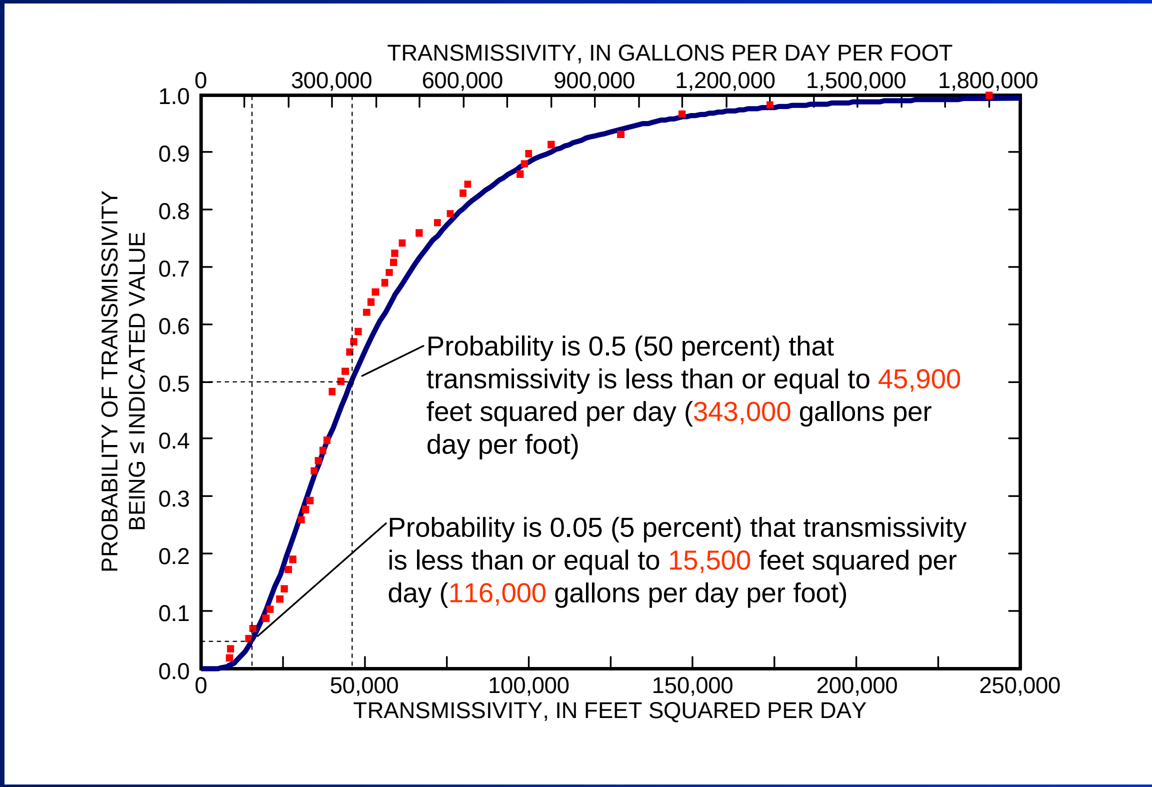
# Aquifer Properties— Transmissivity

## b) Yuma area

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# Aquifer Properties— Transmissivity

## c) Virgin-Detrital area

**Published transmissivity values are not available in USGS Professional Papers for this area. A third value of 980 $ft^2$/day (7,300 gal/day/ft) was used in addition to the values used for other areas upstream from Yuma.**

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# Aquifer Properties— Storage Coefficient

**The unique aquifer property that controls the timing of depletion is aquifer diffusivity, the ratio of transmissivity to storage coefficient (T/S). Because different transmissivity values were used, there is no need to also vary storage coefficient.**

**A storage coefficient (specific yield) of 0.2 was used for all models. This was the average of values from neutron-probe studies along the river in the Yuma area (Loeltz and Leake, 1983)**

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# Summary of Models

| Model name | Number of model rows | Number of model columns | Number of active model cells | Transmissivity values run, feet squared per day (gallons per day per foot) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 980 (7,300) | 6,300 (47,000) | 15,500 (116,000) | 26,200 (196,000) | 45,900 (343,000) |
| Detrital-Virgin | 396 | 148 | 21,025 | Yes | Yes | No | Yes | No |
| Lake Mohave | 146 | 64 | 4,103 | No | Yes | No | Yes | No |
| Mohave | 160 | 139 | 8,976 | No | Yes | No | Yes | No |
| Parker-Palo Verde-Cibola | 296 | 388 | 40,292 | No | Yes | No | Yes | No |
| Laguna Dam | 103 | 145 | 6,302 | No | Yes | No | Yes | No |
| Yuma | 374 | 340 | 59,645 | No | Yes | Yes | Yes | Yes |

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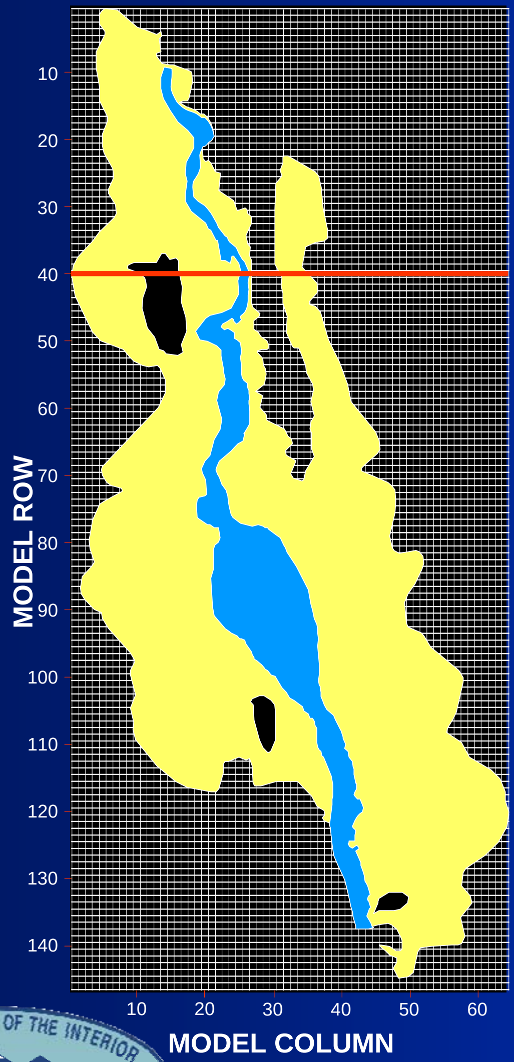
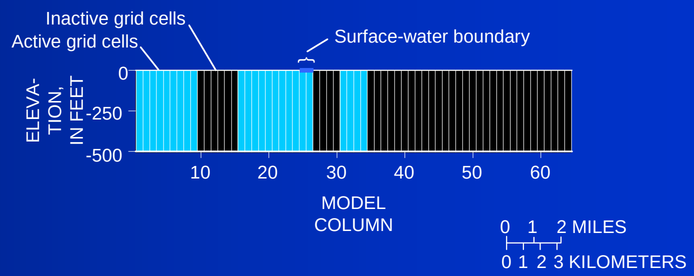
# Example Model Setup

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# Maps of Depletion at 100 years

**Approximately 250,000 model runs were made to construct the maps for six areas using different transmissivity values.**

**The following slides show these results.**

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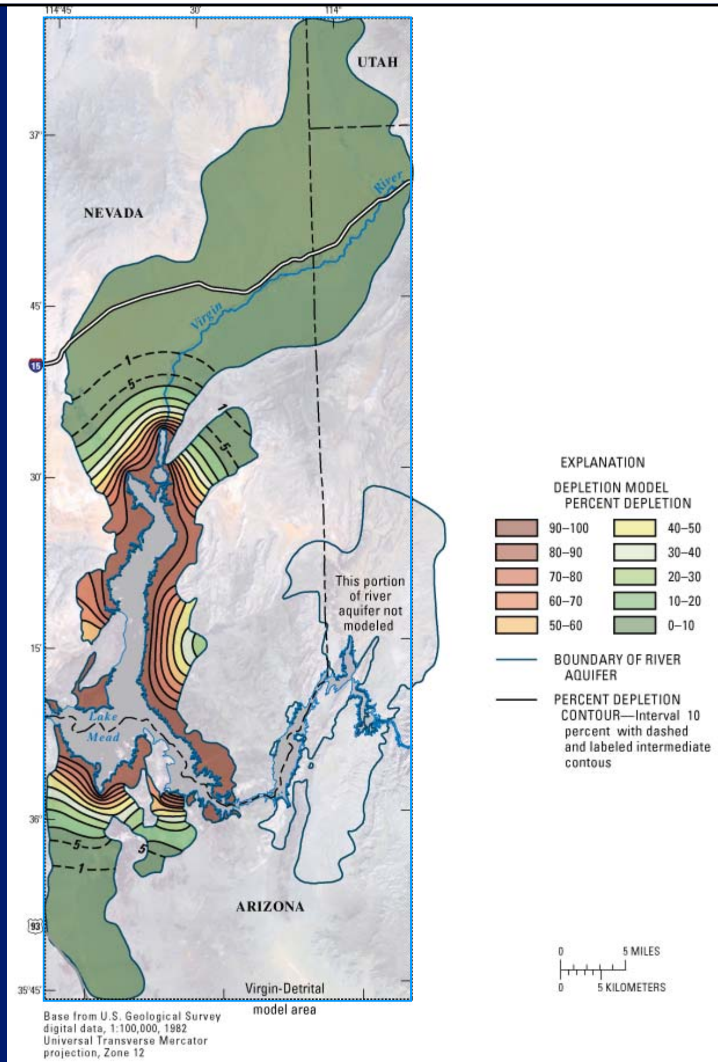
**Virgin-Detrital**
**T=980 $ft^2$/day**

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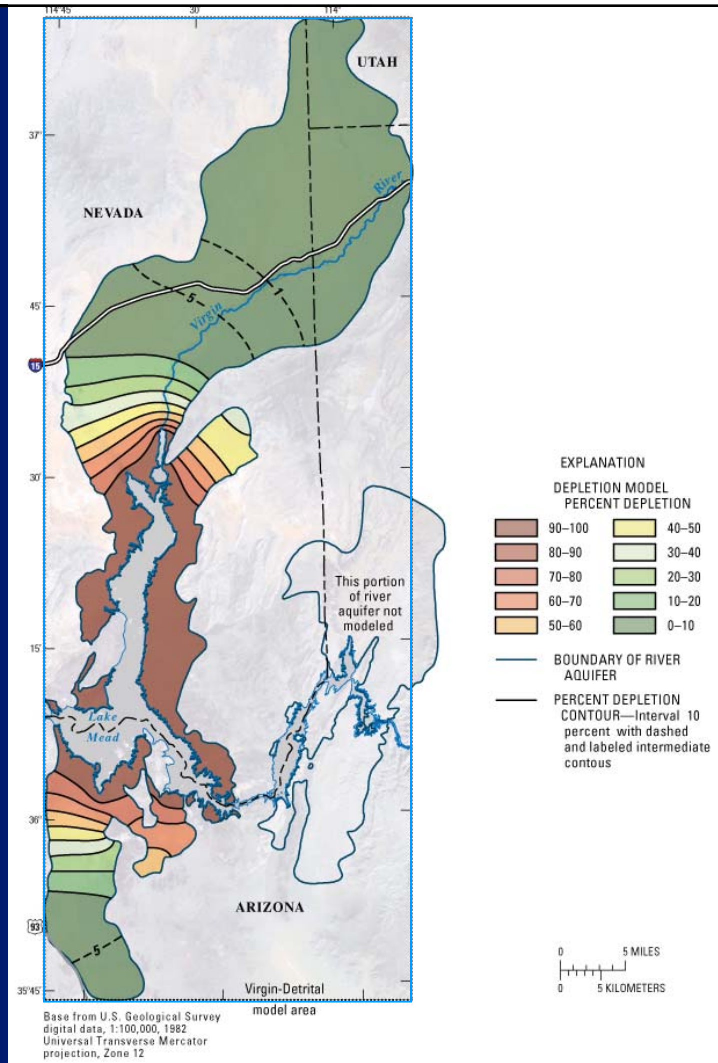


## Virgin-Detrital
## T=6,300 $ft^2$/day

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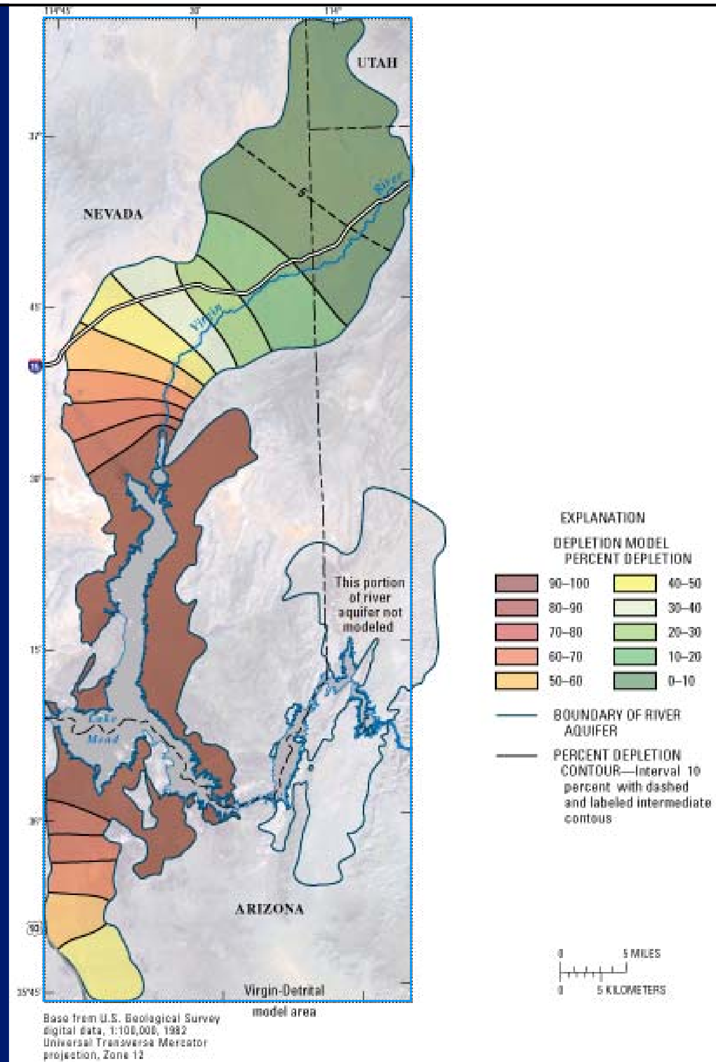


**Virgin-Detrital**
**T=26,200 $ft^2$/day**

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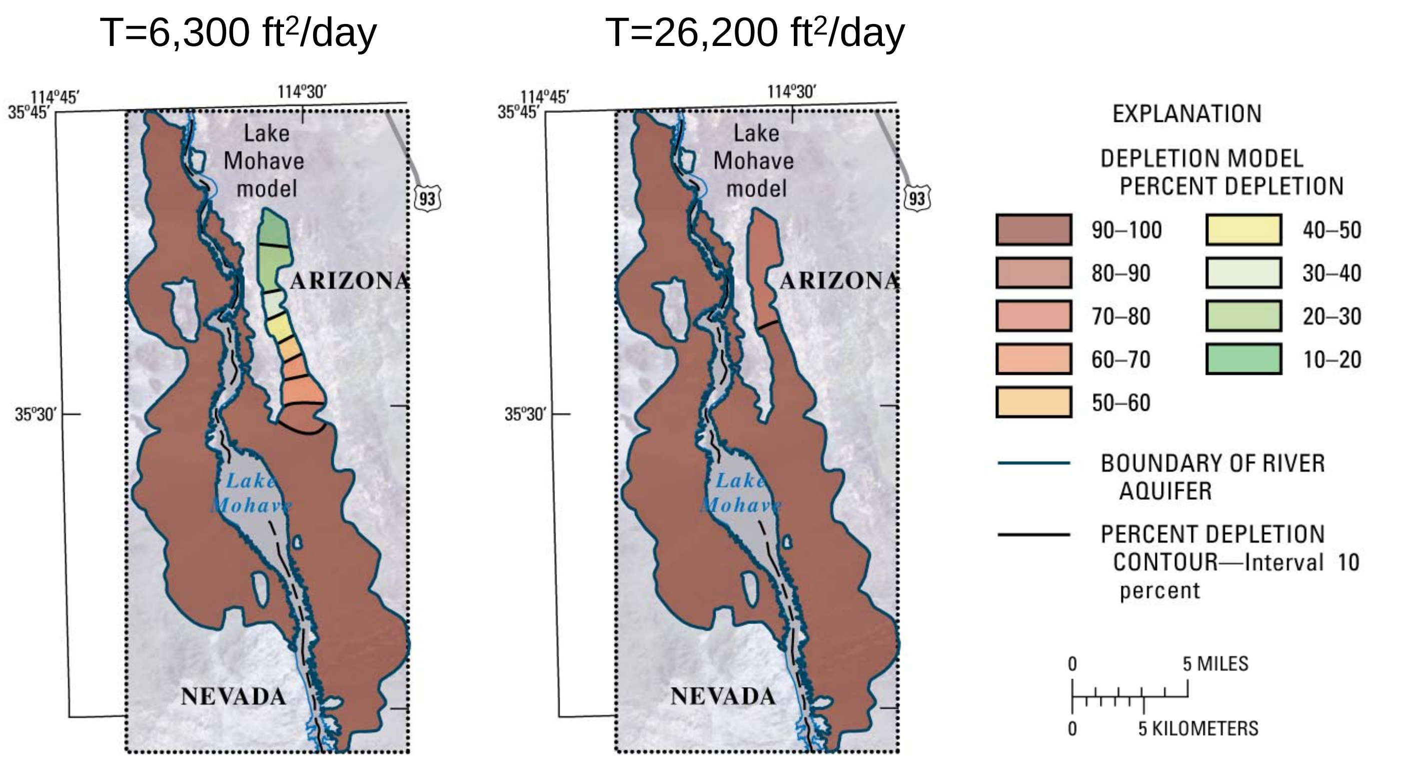
# Lake Mohave

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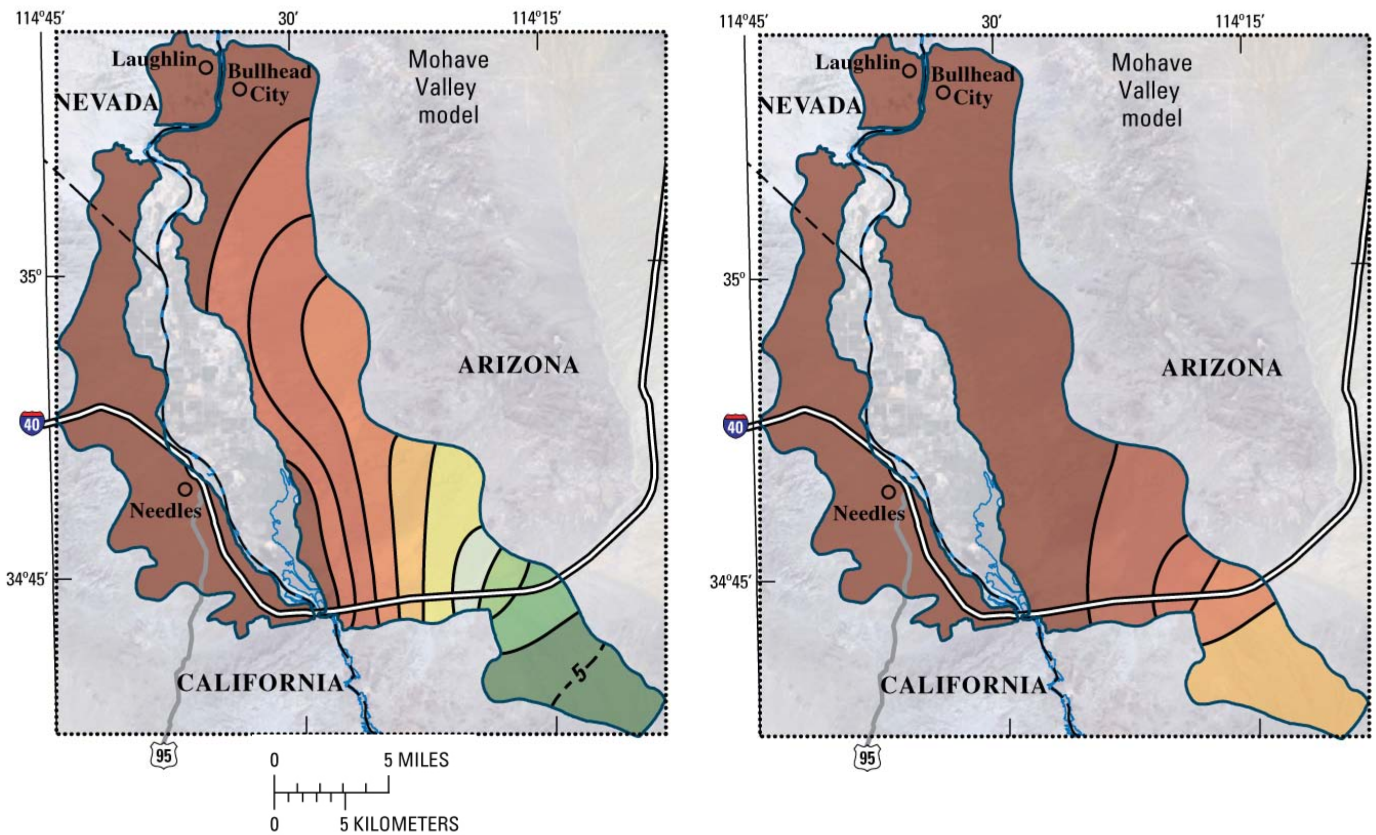
## Mohave Valley

T=6,300 $ft^2$/day T=26,200 $ft^2$/day

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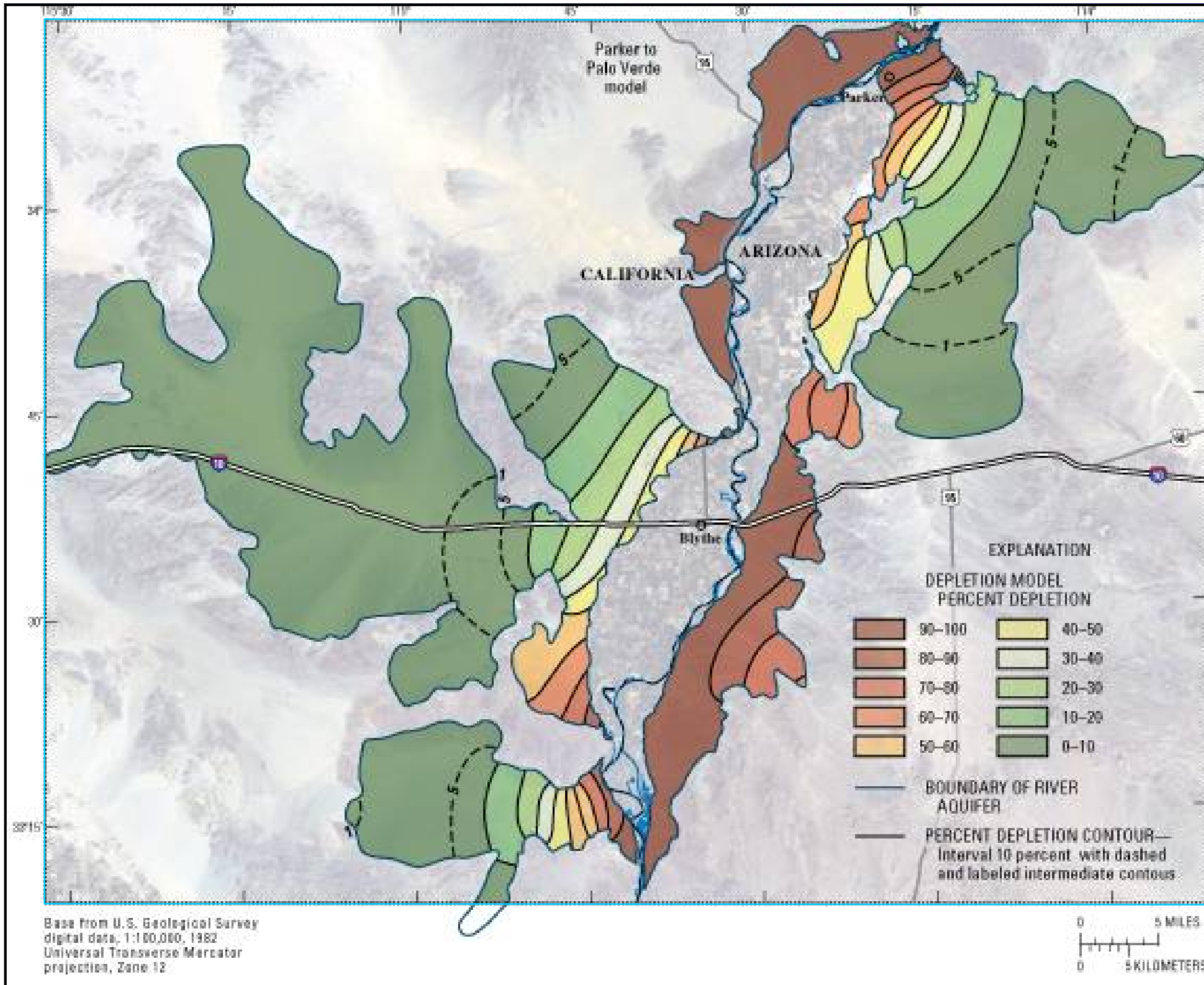


**Parker-**
**Palo Verde-**
**Cibola**
**T=6,300 ft$^2$/day**

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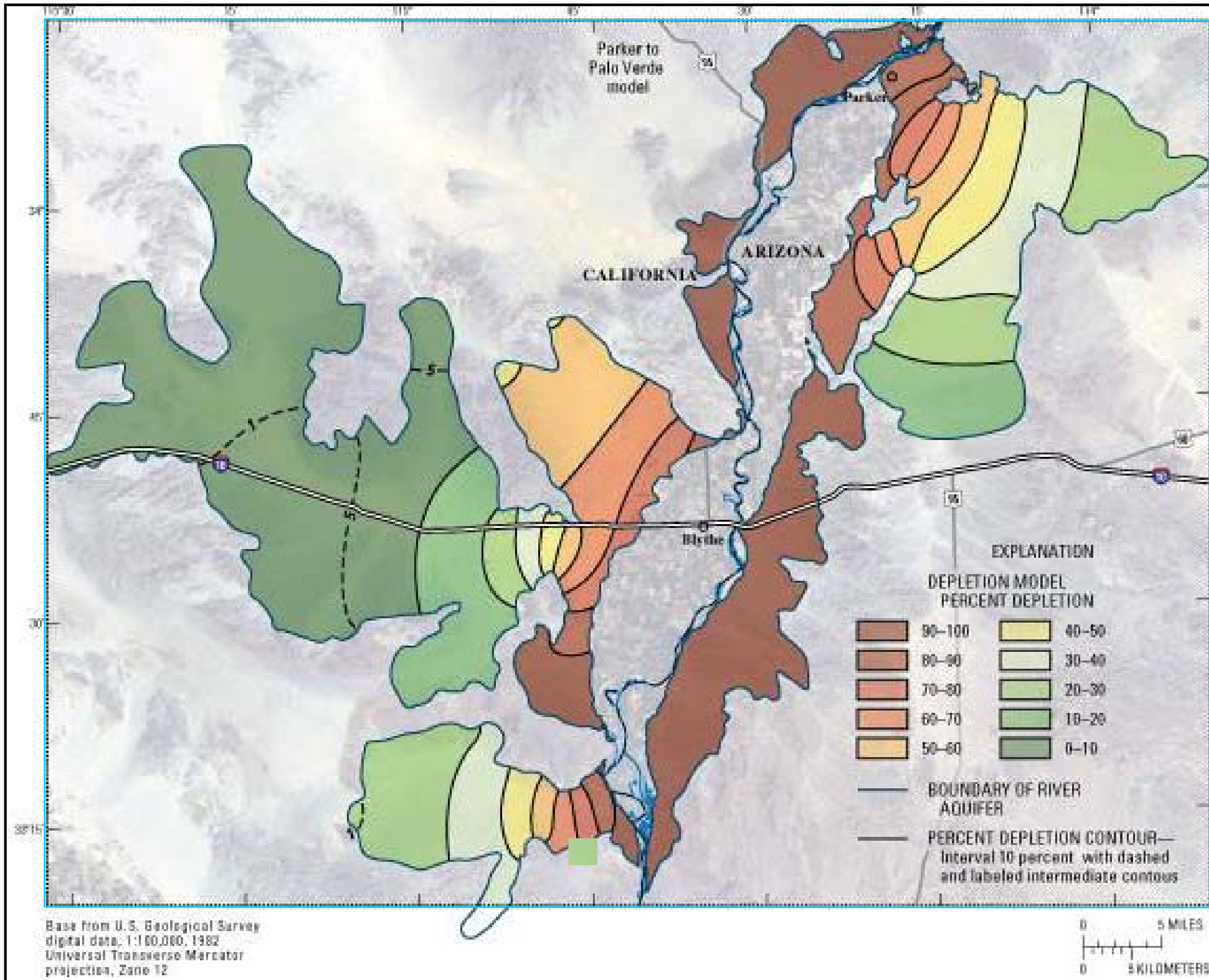


**Parker-
Palo Verde-
Cibola
T=26,200 ft$^2$/day**

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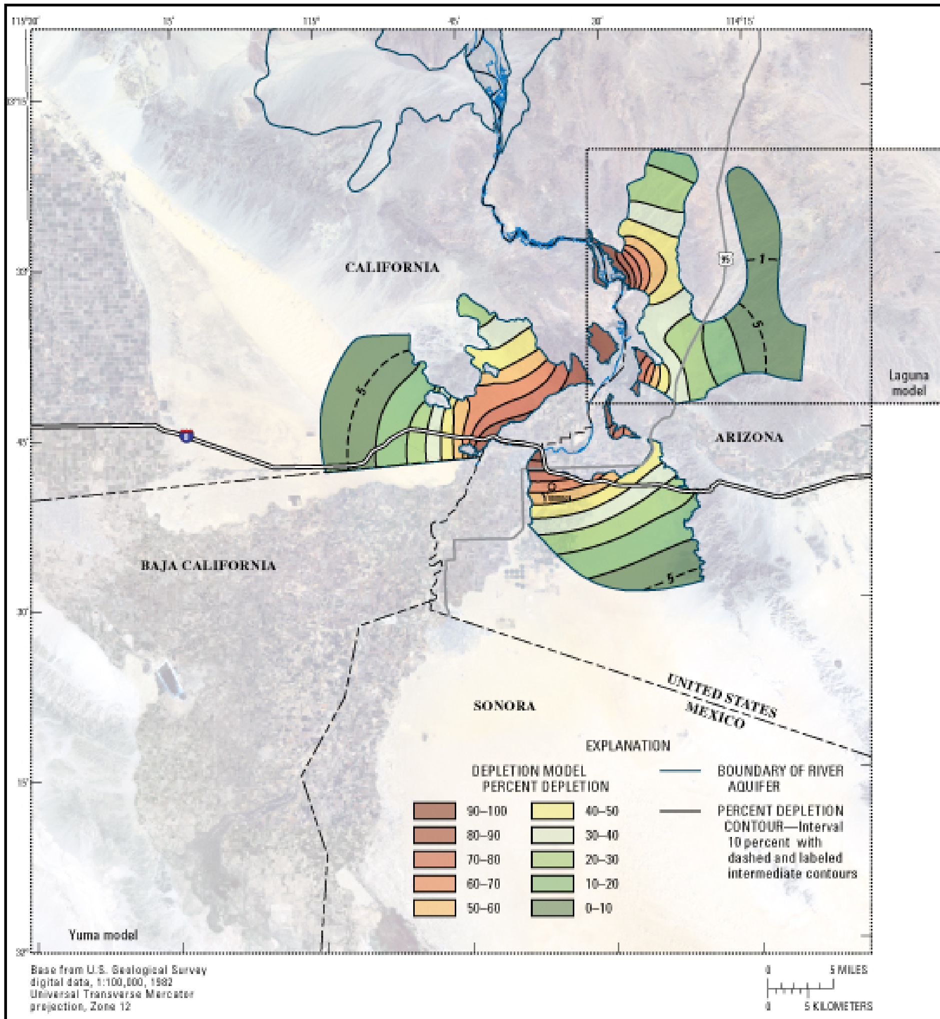


## Yuma, Laguna Dam
## T=6,300 $ft^2$/day

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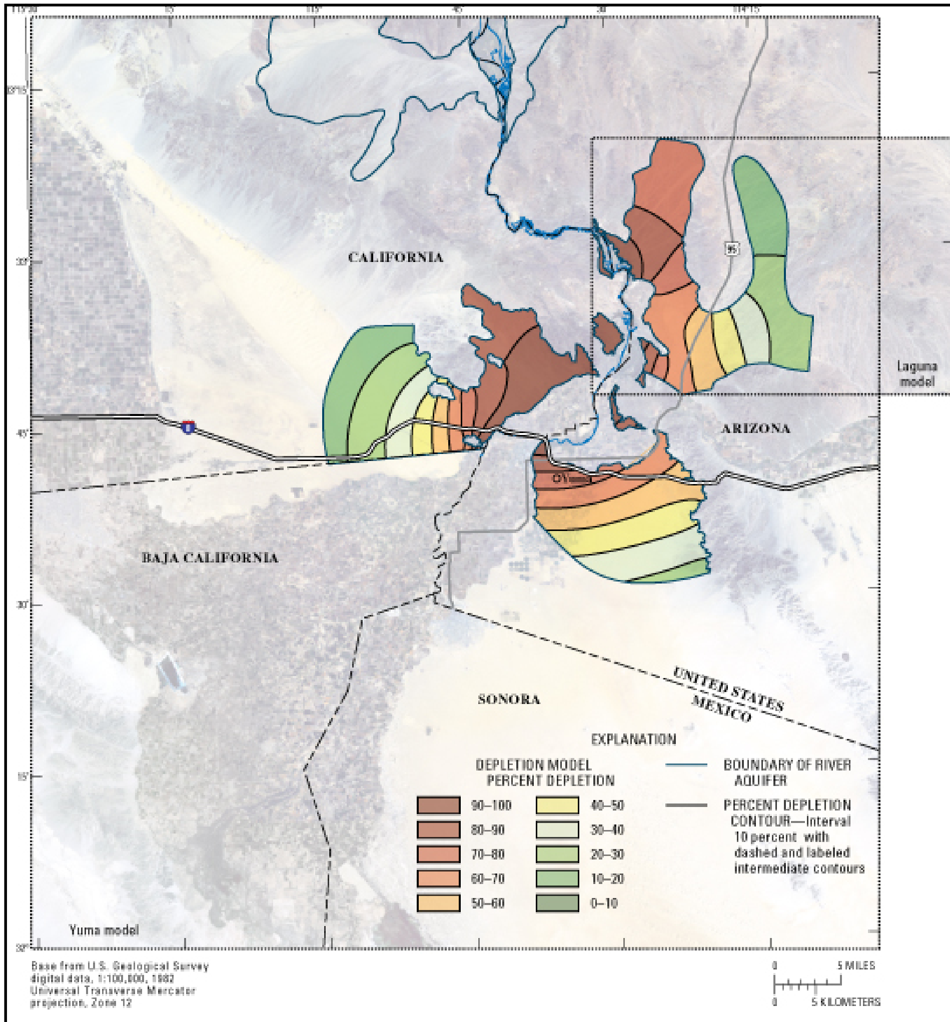


**Yuma, Laguna Dam**
**T=26,200 ft²/day**

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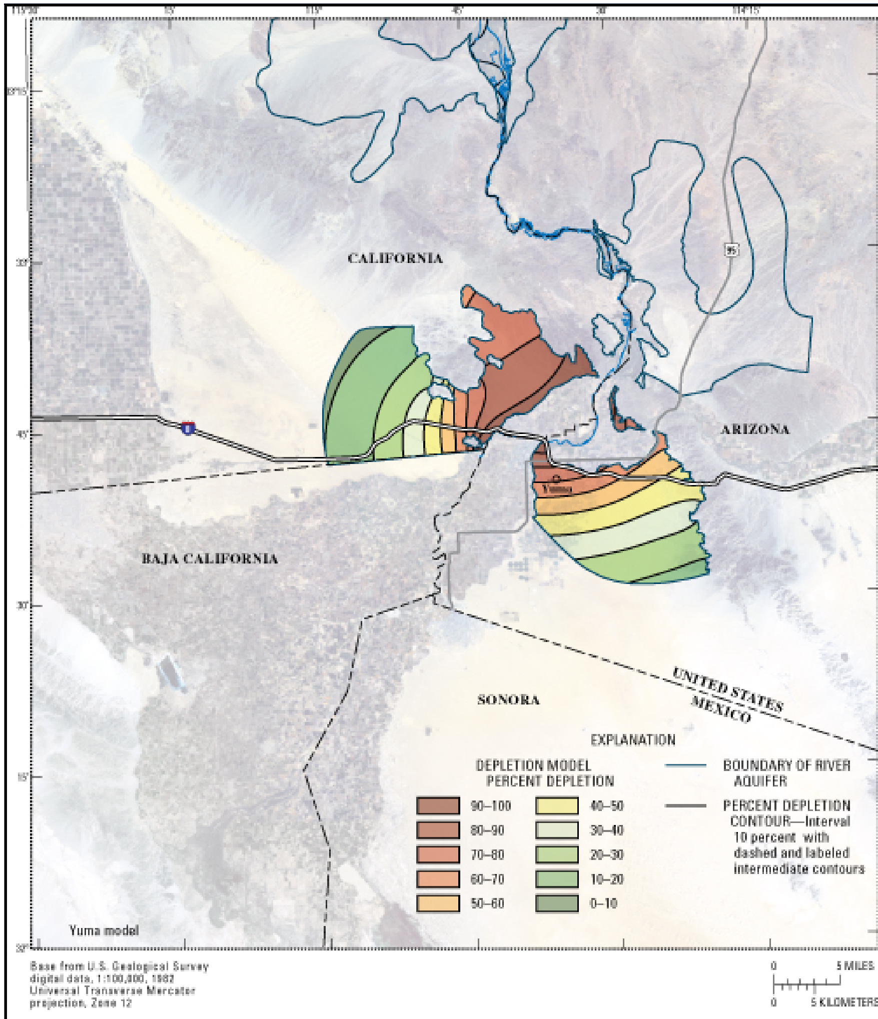


## Yuma, T=15,500 ft$^2$/day

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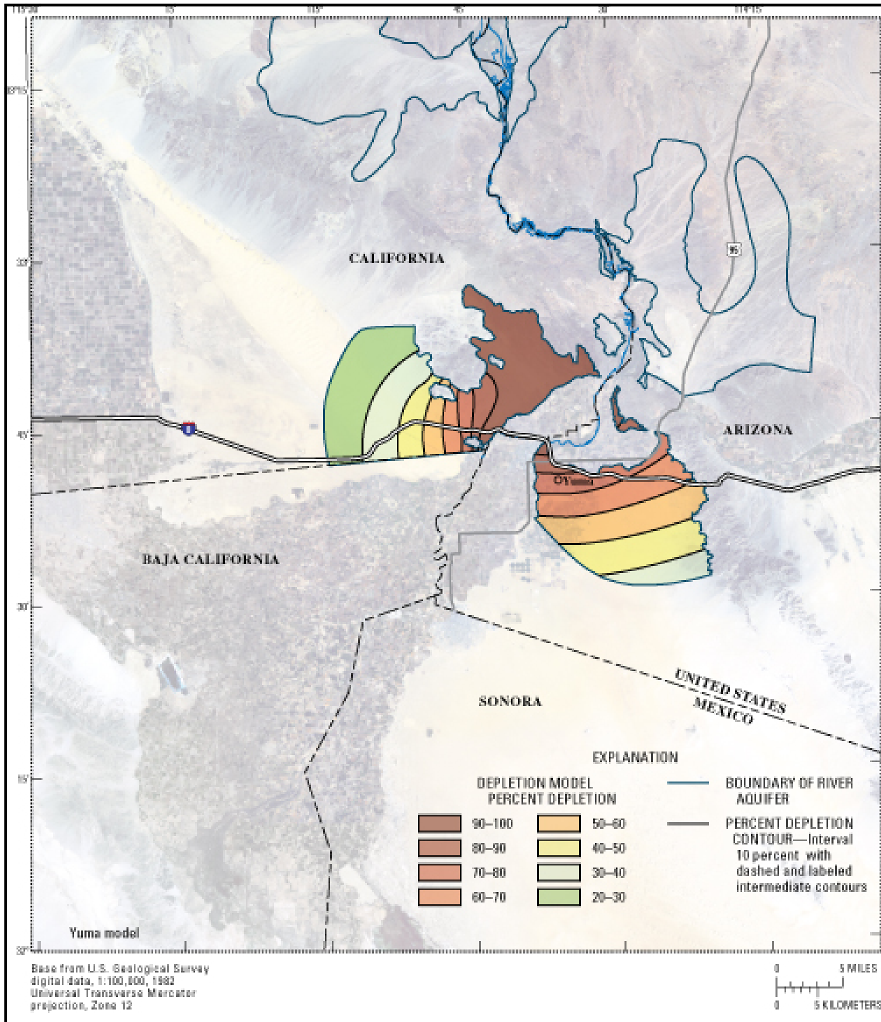
# Yuma, T=45,900 ft$^2$/day

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# General Observations and Comments

Depletion of surface water from pumping in some of the extensive side valleys for 100 years is in the range of 0-5 percent, especially with the conservative transmissivity values tested. In the main river valley adjacent to the flood plain, however, computed depletion is much higher.

In the long and large side valleys, ground-water levels are likely to be above the accounting surface where depletion in 100 years is small.

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# Questions and Comments

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