Water Availability in CSP-Appropriate Areas

A Broad Look at Water Resources in the Southwest

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Area of Interest– from NREL

Concentrating Solar Power Prospects of the Southwest United States

Direct Normal Solar Radiation
kWh/m²/day
- 8.0 - 8.2
- 7.5 - 8.0
- 7.0 - 7.5
- 6.5 - 7.0
- 6.0 - 6.5

Transmission Lines*
- 735kV - 999kV
- 500kV - 734kV
- 345kV - 499kV
- 230kV - 344kV
- Below 230kV

*Source: POWERmap, powermap.platts.com
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Potentially sensitive environmental lands, major urban areas, water features, areas with slope > 3%, and remaining areas less than 1 sq.km were excluded to identify those areas with the greatest potential for development.

The direct normal solar resource estimates shown are derived from 10 km SUNY data, with modifications by NREL.
Scope–

- Some general thoughts regarding surface-water supplies
- Details on groundwater availability in the region including
  • Locations and types of aquifers
  • Hydrological considerations for development of groundwater supplies
  • Possible undesirable consequences of developing groundwater supplies
- Water quality will not be addressed
- Legal and economic aspects of development of water supplies will not be addressed
- Areas in northern Mexico will not be addressed
Surface Water

Surface water supplies in the region are fully allocated (if not overallocated) for most river basins in the region.

- Purchase of surface water from existing users may have advantages over development of new groundwater supplies

- Purchase of existing GW or SW water rights may be in terms of new vs. old “consumptive use,” not the actual amount of water delivered

- The area of surface-water availability is limited in comparison to the area of groundwater availability
Comparison of average consumptive water use and renewable water supplies by water-resource region of the contiguous Western United States. (Source: U.S. Geological Survey, 1984; updated using estimates of water use for 1995.)
A Regional Look at Basin and Range Hydrogeologic Areas

Classification of Hydrogeologic Areas and Hydrogeologic Flow Systems in the Basin and Range Physiographic Province, Southwestern United States

Professional Paper 1702
Ground-Water Resources Program
U.S. Department of the Interior
U.S. Geological Survey
Distribution of the water-resources development index for hydrogeologic areas in the Basin and Range Physiographic Province
Considerations for Development of Groundwater Supplies

1. Is area to be developed underlain by a productive aquifer, with acceptable water quality?

2. Is groundwater at depths that allow economical extraction?

3. What is the current state of development? Are groundwater levels stable or trending downward?

4. Is further development likely to result in undesired consequences such as subsidence or depletion of connected surface water?
Occurrence of Groundwater– Principal Aquifers
Occurrence of Groundwater
Conceptual Model of Alluvial-Basin Groundwater Flow System

Tens of miles

Un consolidated sediments

INFLOW FROM SURFACE WATER

OUTFLOW TO SURFACE WATER

UNIVERSITY OF CALIFORNIA

USGS
Occurrence of Groundwater

Conceptual Model of Carbonate-Rock Province Groundwater Flow Systems

Permeable consolidated rocks

Unconsolidated sediments

Low-permeability rocks

Fault zone

SPRINGS

ET

ET

Up to several hundred miles

Unconsolidated sediments
Occurrence of Groundwater
Conceptual Model of the Colorado Plateau Groundwater Flow Systems

Up to several hundred miles

Low-permeability rocks

SPRINGS

SPRINGS
Arizona Ground-Water Conditions Interactive Map

What is the current status of ground-water conditions in Arizona? How do conditions compare now versus before widespread development of ground-water? How far have water levels fallen, both in the past and recently? Have any wells shown rises in water levels, either in the past or recently? What are the recent trends in ground-water levels? How is ground water being used in the different basins? What are the expected population changes in these basins? Where can I go for more detailed information? The Arizona Ground-Water Conditions interactive map service website was created with funding from the USGS Water Availability and Use Program and in cooperation with the Arizona Department of Water Resources (ADWR) to address questions such as these. Ground water is an important resource in Arizona and an understanding of ground-water conditions is critical for water managers, politicians, and the general public to make informed decisions about the use and management of this resource.

Portraying the status of ground-water conditions is made more difficult than, say, river or lake conditions because of the time delay between changes in ground-water budgets (for example, changes in pumping or changes in precipitation) and the manifestation of these changes in water levels. Time scales from hours to months to many years may be required to see the effects of climate variations and human activities on ground-water conditions. Additionally, vertical and horizontal variations in subsurface soil and rock can complicate the interpretation of water-level changes from individual wells. Other complicating factors include a limited number of water-level measurements available for individual wells in a period of interest, and individual measurements that are affected by recent pumping and do not reflect a point on a trend.

In an effort to produce a reasonable interpretation of conditions of ground-water resources in the alluvial basins of Arizona on the basis of available ADWR data, an interactive map service (IMS) was created that presents different views of ground-water information. The layers of information available on the online map include:

- Wells with water-level rise (>50 ft) since 1997

This site uses popups. Please turn off any popup blockers. This site requires Adobe Acrobat Reader.
Wells with Long-Term Records
Wells with Long-Term Records

[Map of Arizona showing groundwater conditions with a focus on a specific area with a graph showing depth to groundwater levels over time.]

Graph: Depth to Groundwater Below 1 ft (m) vs Date of Measurement

- Site ID: 3240911104451
- Well Name: CG10051
- Latitude: 111.275444
- Longitude: 33.694416
- Altitude of Land Surface: 1205 (ft MSL)
- Well Depth: 124 ft

The graph shows the depth to groundwater below 1 ft for the period from December of one year to December of the next year, with observations indicating a downward trend over time.
Current Depth to Groundwater Since 2004
Water-level Changes
Trends in Recent Water Levels
See handout for links to other data resources
Consequences of Groundwater Development—Depletion of Surface Water

In an aquifer with connected surface water and/or areas where plants remove groundwater (ET), pumping will eventually deplete surface water and reduce ET.

- Main concerns relate to protecting existing surface water rights, and protecting riparian ecosystems.
- Extreme cases have involved complete elimination of perennial streamflow and/or complete loss of ET areas.
- Time scales of effects can vary from months to centuries.
- Numerical models are needed to understand the possible timing of depletion of surface water by groundwater pumping.
Depletion of Surface Water

Santa Cruz River looking south from Tucson, 1942
Depletion of Surface Water

Santa Cruz River
looking south from
Tucson, 1989
Depletion of Surface Water

- Shallow older well
- Deeper newer well

YEAR

DEPTH TO WATER BELOW LAND SURFACE, IN FEET

The timing of depletion depends on
• Aquifer diffusivity (T/S)
• Distance to connected SW features
Computation depletion by GW pumping for 50 years

Depletion of Surface Water

**EXPLANATION**

Fraction of pumping rate captured at 50 years

- **Less**
- 0.01
- 0.02
- 0.03
- 0.04
- 0.05
- 0.06
- 0.07
- 0.08
- 0.09
- More

- Major Roads
- Streamflow gaging station
- San Pedro Nation Riparian Conservation Area
Distribution of the ground-water/surface-water interactions index for predevelopment conditions of hydrogeologic areas in the Basin and Range Physiographic Province
Consequences of Groundwater Development – Land Subsidence and Earth Fissures

These are problems in many Basin and Range aquifers with unconsolidated sediments. These do not occur from groundwater pumping in sandstone and carbonate-rock aquifers.
Land Subsidence—

• Subsidence occurs from compaction of fine-grained layers (silt and clay) when water is removed by pumping

• Small amounts of subsidence can be measured with moderate water-level declines, but large declines can result in irreversible sinking of the land

• Subsidence causes the most problems in areas with human infrastructure, possibly causing damage to pipelines, roads, buildings, wells, etc.

• Subsidence is measured with conventional leveling, GPS surveys, InSAR, and extensometers

• Groundwater models can be used to predict subsidence
Land Subsidence–Areas in Basin and Range Identified by USGS
Land Subsidence—Measuring Deformation from Space using InSAR

Antelope Valley, California: October 1993 – December 1995

Compared with historical subsidence, 1930 - 1992

Contours show historical land subsidence, in meters

0 10 20 30 40 50 mm
0 10 km
Land Subsidence–Areas identified by USGS using InSAR
Land Subsidence–Areas identified by ADWR using InSAR

See ADWR web pages on land subsidence for InSAR images in these areas.
Subsidence-Related Earth Fissures

• Subsidence is an expression of vertical deformation of the sediments, but earth fissures are from components of horizontal deformation

• Subsidence-related earth fissures occur in pumped basin-fill aquifers in New Mexico, Arizona, California and Nevada

• Fissures tend to develop around the edges of the aquifers where bedrock is shallow
Concluding Thoughts

• Groundwater is more widely available than surface water in the region, but surface water that can be procured may be a good option.

• Development of groundwater supplies may lead to undesired consequences including:
  - declining water levels
  - depletion of surface water
  - land subsidence and earth fissures

• Groundwater models may be required to understand possible magnitude and timing of these effects.