Prepared in cooperation with Playas Lakes Joint Venture

# Recharge Rates and Chemistry Beneath Playas of the High Plains Aquifer—A Literature Review and Synthesis

Circular 1333

U.S. Department of the Interior
U.S. Geological Survey

# Recharge Rates and Chemistry Beneath Playas of the High Plains Aquifer—A Literature Review and Synthesis

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## Abstract

Playas are ephemeral, closed-basin wetlands that are important zones of recharge to the High Plains (or Ogallala) aquifer and critical habitat for birds and other wildlife in the otherwise semiarid, shortgrass prairie and agricultural landscape. The ephemeral nature of playas, low regional recharge rates, and a strong reliance on ground water from the High Plains aquifer has prompted many questions regarding the contribution of recharge from playas to the regional aquifer. Considerable scientific debate has led to more than 175 publications about the potential for water to infiltrate the relatively impermeable playa floors and subsequently recharge the High Plains aquifer. Since the early 1900s, many conceptual models about recharge beneath playas have been proposed. Some early conceptual models indicate that playas are evaporative pans that do not allow recharge beneath playas, whereas other more recent models indicate that playas are effective recharge basins. A variety of data supports various aspects of these competing conceptual models.

The competing conceptual models have developed because of the sporadic nature of rainfall to the region, the large number of playas in the region (more than 66,000), a range of physical characteristics in playas, the relatively thick unsaturated zones (often greater than 100 feet) separating most playas from the regional water table, and the inherently uncertain nature of most methods used to estimate recharge. An accurate understanding of recharge rates beneath playas is important from the perspective of ground-water management and the sustainability of rural agricultural economies, particularly in light of the substantial water-level declines in the High Plains aquifer. Other environmental concerns, such as erosion and transport of sediment and contaminants from surrounding land and modification of playas to allow artificial recharge, also have made accurate understanding of recharge an important priority from the perspective of wetland function and habitat health, protecting ground-water quality, and the substantial costs associated with land and water management, conservation, and regulation.

To address these questions and concerns, the U.S. Geological Survey, in cooperation with the Playa Lakes Joint Venture, present a review and synthesis of the more than 175 publications about recharge rates and chemistry beneath playas and interplaya settings. Although a number of questions remain regarding the controls on recharge rates and chemistry beneath playas, the results from most published studies indicate that recharge rates beneath playas are substantially (1 to 2 orders of magnitude) higher than recharge rates beneath interplaya settings. The synthesis presented here supports the conceptual model that playas are important zones of recharge to the High Plains aquifer and are not strictly evaporative pans. The major findings of this synthesis yield science-based implications for the protection and management of playas and ground-water resources of the High Plains aquifer and directions for future research.

## Introduction

***Playas*** are ***ephemeral,*** closed-basin ***wetlands*** that have been hypothesized by some researchers to be important zones of ***recharge*** to the ***High Plains*** (or ***Ogallala***) ***aquifer*** (note: see ***glossary terms*** in appendix 1). Playas are critical for maintaining biodiversity (Tsai and others, 2007) and are wetlands unique to the Great Plains physiographic province (fig. 1*A*) because they are zones of recharge and do not receive ground-water discharge as do prairie potholes and many other types of wetlands. The floors of most playas are lined with relatively impermeable clay soils and are commonly separated from the regional water table by tens to hundreds of feet of ***unsaturated zone (vadose zone)***, which have generally confounded a detailed understanding of the role that playas have in recharging the High Plains aquifer.

Although numerous studies have investigated the role of playas in recharging the High Plains aquifer, relatively few have directly measured water and chemical movement beneath playas and ***interplaya*** settings. Most studies rely on indirect methods to estimate water and chemical movement beneath playas. Although results from these studies indicate that playas enhance recharge at rates higher than rates in interplaya settings (Scanlon and Goldsmith, 1997), the water fluxes beneath playas are highly variable in both space and time. No studies to date have systematically characterized all the factors that control spatial or temporal variability of water and chemical movement within and beneath playas. A more detailed understanding of these controls is needed for best management of the ground-water resources of the High Plains aquifer and of the ecosystems and wetland habitat within each playa. In 2008, the U.S. Geological Survey, in cooperation with the Playa Lakes Joint Venture, began a study to gain more understanding by reviewing and synthesizing scientific literature related to the playas of the High Plains aquifer.

The purpose of this report is to present previous information from investigations of playas in the High Plains aquifer and to synthesize the existing knowledge about the rates and chemistry of recharge beneath playas and interplaya settings. The information presented in this report is designed to inform and assist ground-water resource managers and partners, such as the Playa Lakes Joint Venture, responsible for playa management and conservation.

The Playa Lakes Joint Venture (*http://www. pljv.org/)* is a nonprofit partnership of Federal and State wildlife agencies, conservation groups, private industry, and landowners dedicated to conserving bird habitat in the Great Plains. The mission of the Playa Lakes Joint Venture is to conserve playas, other wetlands, and associated landscapes through partnerships for the benefit of birds, other wildlife, and people. There are approximately 66,000 playas throughout the southern Great Plains, most of which are located within the joint venture's boundary (fig. 1*A*) (McLachlan, 2008). Approximately 61,000 playas are on the High Plains aquifer and have the highest density in the ***southern High Plains*** (or ***Llano Estacado***) aquifer in Texas and in part of the ***central*** and ***northern High Plains aquifer*** in Kansas and Nebraska (fig. 1*B*) (Smith, 2003; LaGrange, 2005; McLachlan, 2008). The playas of the Playa Lakes Joint Venture region are essential habitat in one of the most important inland migratory corridors in North America for many waterfowl, shorebirds, and waterbirds, and for many other migratory and resident birds.

Playas are an integral component of resource management in the High Plains (Brian Slobe, photographer; published with permission).

## Summary of Major Findings and Implications

Understanding how playas affect the quantity and quality of recharge to the High Plains aquifer has important implications for the sustainability of the High Plains aquifer, human and ecosystem health, the sustainability of rural agricultural economies, and the substantial costs associated with land and water management, conservation, and regulation. The major findings of the literature synthesis are outlined in this section and yield science-based implications for assessing and managing playas and ground-water resources of the High Plains.

**Movement of recharge and chemicals to the water table follows fast and slow pathways.** Different pathways are available for recharge and chemical transport to reach the water table, and some paths are relatively faster than others. In locations that represent ***diffuse recharge*** (slow paths), estimated time of chemical transport from land surface to the water table exceeds the period of agricultural activity (more than 100 years in some locations) and imply that agricultural chemicals should not be present at the water table yet. In fact, agricultural chemicals are commonly detected in ground water. This apparent discrepancy is explained by local fast paths that may enable water and chemicals from the land surface to reach the water table in months to decades. By comparison, slow paths may enable water and chemicals from the land surface to reach the water table in centuries to millennia.

**Ground-water quality is changing with time.** Changes in water quality are occurring with time that may affect the sustainability of the High Plains aquifer. Understanding ground-water quality is important because it directly affects how water can be used. Studies show that at some local and subregional scales, particularly where pumping is intense or where environmental and topographic settings are conducive to fast-path recharge and chemical transport, water quality may be a limiting factor for some intended uses such as drinking water or irrigation water.

**The High Plains aquifer has a limited ability to naturally attenuate contaminants.** The High Plains aquifer is limited in its ability to naturally attenuate contaminants, such as nitrate ($NO_3^-$) by means of denitrification, and it generally has slow recharge rates—both of which suggest that once the aquifer is contaminated it will remain so for decades and even millennia. Denitrification rates are slow and would take between 250 to 14,000 years to lower nitrate concentrations by 1 milligram/liter (***mg/L***) as nitrogen (N) in ground water of the High Plains aquifer. Additionally, because transport times to the water table are generally long—decades to millennia along slow paths—the amount of chemical mass reaching the aquifer will most likely increase with time. These results highlight the importance of managing land use to minimize contaminants in recharge.

**Playas help recharge the High Plains aquifer.** Most playas represent fast pathways for recharge and provide an important component of recharge to the High Plains aquifer. Although the exact amount of recharge to the High Plains aquifer from any individual playa or group of playas is unknown without detailed investigation, substantial evidence in the literature shows that some portion of water that is stored seasonally in playas is able to infiltrate and eventually intercept the High Plains aquifer as recharge.

**Recharge from interplaya settings is relatively low compared with playa settings.** Interplaya settings generally represent slow paths for recharge and chemical transport because of high ***evapotranspiration*** and low precipitation rates in the southern High Plains. Reported interplaya recharge rates average 1 to 2 orders of magnitude smaller than most estimated recharge rates beneath playas.

**Playa recharge varies in space and time**. Large variations in estimated recharge rates beneath playas indicate that recharge is controlled, in part, by the spatial and temporal patterns in the physical characteristics of the playas, in climate, and in surrounding land-use practices. The physical characteristics of playas that have apparent influence on recharge rates are the drainage area, playa volume, depth of the playa floor, vertical extent of shrink-and-swell clay that lines playa floors, depth of sediment overlying clay-lined floors, unsaturated-zone sediments underlying the playa, and depth to the water table. Climate factors that affect the shrink-and-swell characteristics of the playa floors are likely to have important controls on changes in recharge with time. Some land-use practices, such as cultivation, increase sedimentation to playas and thus affect the physical characteristics that influence infiltration and recharge beneath playas. However, existing studies do not provide data to support the development of a reliable predictive model (or models) of recharge beneath any individual playa or group of playas. Future studies are needed to develop models that predict the recharge rates beneath playas.

**The terms infiltration and recharge are not equivalent but are commonly used interchangeably in the literature.** Our literature search indicates that many authors commonly use the terms ***infiltration*** and recharge interchangeably. However, the two terms are not synonymous. Infiltration of water from playa or interplaya settings into the subsurface does not necessarily guarantee that the infiltrating water will intercept the water table as recharge.

**Cost-benefit analyses of artificial recharge need to consider natural infiltration rates beneath playas.** Given the ecological importance of unmodified playa wetlands to the biodiversity of the Great Plains region and the substantial infiltration rates reported for some natural playas, cost-benefit analyses for ***artificial recharge*** need to consider any added improvements that playa modification may have on rates of infiltration and recharge that exceed the rates reported for unmodified playas. Therefore, considerations of playa modification for artificial recharge need to weigh the costs associated with the difference between the estimated recharge rate under modified playas and the recharge rate under natural playas.

**Methods used to estimate recharge have inherent and unavoidable uncertainty.** The same is true for the methods used by studies to estimate recharge beneath playas. However, these studies rarely report errors or uncertainties associated with recharge estimates. Furthermore, many studies use only a single method to estimate recharge. Recent research has shown that the use of many different methods can help constrain recharge estimates and reduce uncertainty. Thus, future studies that use as many different approaches as logistically and financially possible to estimate recharge will likely help answer important remaining questions about recharge rates and chemistry beneath playas.

**Important questions remain about the role of playas recharging the High Plains aquifer.** The existing literature does not bring data to bear on important questions that include the following:

1. What are the effects of current and future rates of sedimentation on infiltration and recharge beneath playas?
2. How much of the water that infiltrates beneath playas is lost to lateral subsurface flow and subsequent evapotranspiration before reaching the water table, and how do such processes affect the results of studies that assume that all water infiltrated beneath playas becomes recharge?
3. Are innovative and wetland-friendly approaches for ***artificial recharge*** beneath playas available?
4. How much contamination reaches the ground water beneath playas, and does playa modification that increases artificial recharge also increase transport of contaminants to the water table?
5. How important are playas for recharge to the northern High Plains aquifer, for which comparatively little research has been reported?
6. How will climate change and climate variability affect recharge beneath playas?

These and other questions may be answered using interdisciplinary studies of water and movement of chemicals through the playa-wetland system to the High Plains aquifer as recharge

**U.S. Geological Survey, Reston, Virginia: 2009**

**Reprinted from:**
Gurdak, J.J., and Roe, C.D., 2009, Recharge rates and chemistry beneath playas of the High Plains aquifer—A literature review and synthesis: U.S. Geological Survey Circular 1333, 39 p.

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