An Investigation of Potential Surficial Recharge in the Lucerne Valley Groundwater Basin, Mojave Desert, CA

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Abstract

To better understand the characteristics of recharge within the Lucerne Valley groundwater basin, a series of infiltrations tests, soil analyses and computer simulations will be conducted throughout the watershed. Previous studies have suggested that because desert valleys receive less than eight inches of precipitation per year and have deep, unsaturated zone, natural recharge cannot occur. However, gaps in the most recent water budget as well as evidence of recharge occurring at the Big Bear Area Wastewater Agency discharge site indicate that additional recharge must be occurring at some point within the valley. Studies elsewhere in the Mojave Desert have suggested that small amounts of recharge can occur as infiltration from streamflow in ephemeral channels. A similar source of recharge may exist in the Lucerne Valley as well. This research is intended to provide the Mojave Water Agency with information about the natural surficial recharge in the Lucerne Valley groundwater basin. Furthermore, this research may also provide a cost-effective method to determine potential recharge in other basins within the Mojave Water Agency's jurisdiction.

Introduction

The increasing scarcity of groundwater in semi-arid and arid environments requires better understanding of groundwater recharge to maintain a sustainable supply of water (Scanlon et al. 2006). This is especially true in areas that have growing populations, such as the Lucerne Valley in the western Mojave Desert (figure 1).

For several decades beginning in the early 1900s, water levels sharply declined in the Lucerne Valley groundwater basin due to groundwater production for agricultural purposes (Schaefer 1979; Laton et al. 2005). Since adjudication in 1996, pumping records have indicated that water levels have remained relatively constant and, in fact, have begun to rise in some locations (Laton et al. 2005). This rise suggests that modern groundwater recharge must be similar to, or exceed, the volume of groundwater production (Laton et al. 2005). While the primary source of recharge is runoff from the San Bernardino Mountains that is recharges through alluvial fan deposits, changes in precipitation volume have little effect in the water levels within the basin (Schaefer 1979; Laton et al. 2005). However, since little surface water flows into the closed basin, additional recharge into the aquifer must also be accounted for from precipitation that occurs the upper highlands as well as the surrounding desert mountains and return flow from agricultural sources (Laton et al. 2005). Additionally, it has been assumed that infiltration is limited in the Lucerne (dry) Lake due to the impermeable clay layers in the area (Laton et al. 2005). However, Fife et al. (1977; 1980) reported that desiccation fractures have developed in 60% of the Lucerne (dry) Lake. Such fissures have the potential of providing a path for groundwater recharge (Schaefer 1979; Fife et al. 1980; Knott 1992).

Statement of Purpose

The purpose of this research is to investigate the potential sources of surficial recharge into the Lucerne Valley groundwater basin both qualitatively and quantitatively using a series of infiltration tests. If significant infiltration is observed with during the infiltration tests in the Lucerne Valley, then surface recharge needs to be incorporated into the water budget analyses. If no infiltration is observed during the tests, then other sources of groundwater recharge need to be considered.

The data collected from this research is intended to provide information to the Mojave Water Agency about the nature of recharge into the Lucerne Valley groundwater basin. Such data will better enable the Mojave Water Agency to understand the recharge capabilities of the basin and potentially may help define areas for future artificial recharge sites. Additionally, this research is anticipated to define a methodical approach to better understand groundwater recharge that can be applied to other basins within the Mojave Desert.

Background and Previous Work

Groundwater Recharge in semiarid and arid environments

While the assumption that deep infiltration cannot occur in dry, hot deserts has existed for years, recent studies have shown this concept to be incorrect and that infiltration is indeed possible, even in environments where the annual loss to evapotranspiration is higher than the annual amount of precipitation (Gee et al. 2005). Precipitation can, in fact, infiltrate particularly well in permeable bare-soil areas where water can quickly percolate into the subsurface with limited loss to of evaporation (Gee et al. 2005). In the western Mojave Desert near Victorville, CA, a small amount of infiltration of intermittent flow was found to occur in the Oro Grande Wash, an ephemeral stream channel that was presumed to contribute to groundwater since the infiltration was detected below the root zone (Izbicki 2000). However, approximately fifteen to twenty kilometers to the west of the Oro Grande Wash, studies conducted at the Sheep Creek Wash indicate that while water infiltrates the surface, it does not continue below the root zone, therefore, does not contribute to the groundwater (Izbicki 2000).

Various studies have been conducted to better understand the complex nature of recharge in semiarid and arid desert environments. Groundwater recharge was modeled for the High Plains Aquifer of Texas and New Mexico, and results indicated that the estimated recharge varied over nearly two orders of magnitude (Wood and Sanford 1995). This variation in magnitude is likely due to the heterogeneity of the soil in the study area, which is commonly the most difficult factor in quantifying groundwater recharge in arid and semiarid environments (Wood and Sanford 1995). While this recharge model demonstrates that approximately 2% of the annual precipitation contributes to recharge, a large percentage of the recharge may actually result from infiltration through the playa lake basin floor and macropore recharge through the sediments surrounding the playa lakes (Wood and Sanford 1995). Similar results were obtained in the Thar Desert of the Middle East, where deep percolation of infiltrated precipitation through a thick unsaturated zone has been found to be the primary source of recharge (Athavale et al. 1998). Soil heterogeneity was found to be the attributing cause of large variations in recharge throughout the study area (Athavale et al. 1998). Athavale et al. (1998) concluded that an average of 12.5% of total annual rainfall in the Thar Desert was recharged into the aquifer.

The depth that precipitation can infiltrate is an important consideration, since evapotranspiration can remove soil moisture from shallow depths and prevent deep percolation. In the Amargosa Desert near Beatty, Nevada, surface infiltration was detected to a depth of 2 m, which was significantly deeper than the average 0.2 m infiltration depth observed in Hueco Bolson, Texas in the Chihuahuan Desert (Scanlon 1994). Scanlon (1994) also observed that the infiltration rate was much lower than the determined water potential; this difference was attributed to the upward driving forces of the liquid and isothermal vapor movement. A comparison site in Hanford, Washington in the Eastern Washington Desert was noted to have higher groundwater recharge potential, which Scanlon (1994) attributed to the coarser surficial sediments and winter snowfall.

Overall, groundwater recharge in desert environments can be several orders of magnitude less than the amounts of evapotranspiration and precipitation (Wanke et al. 2008). It has been estimated that semiarid and arid regions average recharge rates of 0.1% to 5% of the long-term average annual precipitation and that recharge generally occurs from indirect precipitation into ephemeral streams, dry rivers and lakes (Scanlon et al. 2006; Wanke et al. 2008).

Lucerne Valley groundwater basin

The Este Hydrologic Sub-basin (Figure 1) is one of 515 distinct basins recognized by the California Department of Water Resources (DWR) and managed by the Mojave Water Agency (MWA) (Mojave Basin Area Adjudication 1996; DWR, 2003). The Este Hydrologic Sub-basin includes two aquifers separated by the Helendale fault (figure 2): the Lucerne Valley Groundwater Basin and the Fifteenmile Valley Groundwater Basin (DWR 2003; Laton et al. 2005).

Figure 1 Location of the Este Hydrologic Sub-Basin relative to the state of California. (California State University, Fullerton 2005)

The Lucerne Valley groundwater basin is predominantly a single aquifer in a closed-basin system with radial flow into the Lucerne (dry) Lake. The basin is bound by the Granite Mountains and Helendale fault to the west, the Ord Mountains to the north, Fry and Cougar Buttes to the east, and the San Bernardino Mountains to the south. The sediments within the basin consist of fine- to coarse-grained

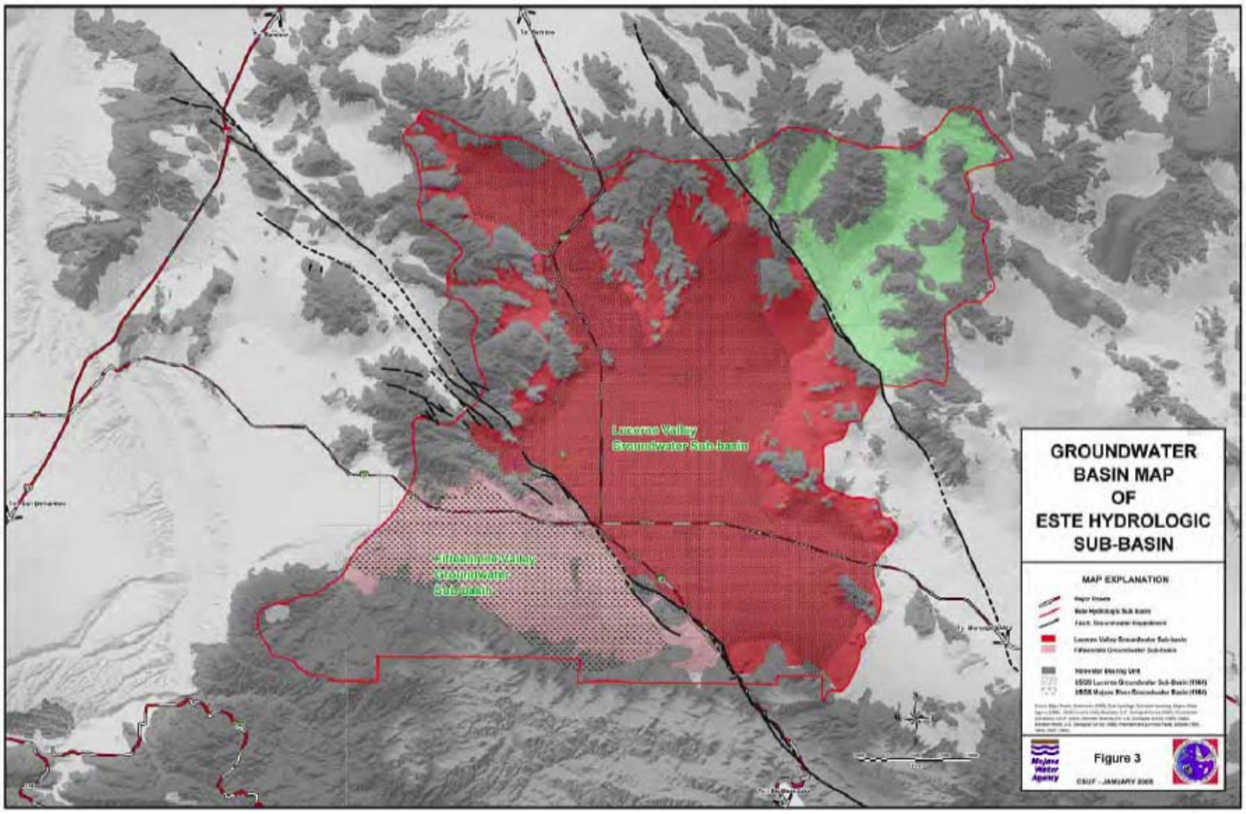

Figure 2 Groundwater Basin Map of Este Hydrologic Sub-Basin. (Laton et al. 2005)

alluvial deposits originating from erosion of the surrounding mountains (Laton et al. 2005). The Lucerne (dry) Lake is predominantly impermeable clay (Laton et al. 2005). Surface water is limited to ephemeral streams that flow during and immediately after heavy precipitation. Runoff from the nearby mountains is quickly absorbed into the basin through alluvial fan deposits with little surface water reaching the playa (Schaefer 1979; Laton et al. 2005). The majority of groundwater recharge originates from winter precipitation on the northern slopes of the San Bernardino Mountains and to a lesser extent from the mountains to the north (Schaefer 1979; Laton et al. 2005). Because precipitation in the valley averages 4 inches a year, it has been assumed that little to no recharge occurs through the valley floor (Schaefer 1979; Laton et al. 2005).

In the Lucerne Valley groundwater basin, groundwater recharge is estimated to be approximately 6,440 acre-ft per year with a 382 acre-ft surplus (Laton et al. 2005). A recent study found that while the primary source of recharge originates in the San Bernardino Mountains, changes in precipitation have little effect on the water levels within the basin (Laton et al. 2005). Since little to no surface water flows into the closed basin, additional recharge into the aquifer must also be taken into consideration. Such possible sources include the upper highlands, the surrounding desert mountains and return flow from agricultural sources (Laton et al. 2005).

Previous researchers have produced water budgets for the Lucerne Valley (DWR 1967; Goodrich 1978; Brose 1987; Laton et al. 2005); however, these budgets vary greatly from one another in predicting large deficits to a small surplus. One of the explanations for such large discrepancies between budgets is the changes in groundwater production over the past century. The most recent report estimates recharge into the Lucerne Valley groundwater basin to be approximately 6,440 acre-ft per year with a 382 acre-ft surplus (Laton et al. 2005). The most recent estimate of recharge has been based on the assumption that recharge only occurs in areas that receive an average of 8 or more inches of precipitation per year (Ganus 1973; Laton et al. 2005). Because the Lucerne Valley received less than 8 inches of precipitation per year, it has previously been assumed that recharge does not occur from the valley floor (Laton et al, 2005). Previous research has also indicated that limited recharge occurs from the Granite, Ord and Fry Mountains due to the extremely low porosity and permeability of the units and that groundwater flow across the Helendale fault is considered negligible (Schaefer 1979; Laton et al. 2005).

Previous Work

Previous work in the region includes geologic mapping as well as hydrologic and hydrogeologic investigations of the basins. Geologic maps of the area have been produced by Riley (1956), Dibblee (1964a, 1964b), the California Division of Mines and Geology (1967), Shreve (1968), Sadler (1982), and Miller and Matti (2003). Various hydrologic and hydrogeologic investigations including groundwater levels and chemistry have been conducted in the Lucerne Valley by the United States Geological Survey (USGS) Water Resources Division, DWR, and MWA (with cooperation from California State University, Fullerton, Department of Geological Sciences (Riley 1956; DWR 1967; Schaefer 1979; USGS 1994, 1996, 1998, 2000, 2002; MWA 2002; DWR 2003; Laton et al. 2005). An investigation of land subsidence in the Mojave Desert including the Este Hydrologic Sub-basin was conducted by Sneed et al

(2003). Riley (1956), Goodrich (1978), Schaefer (1979), Brose (1987), Pirnie (1990) and Stamos et al. (2001) have also investigated the hydrologic and hydrogeologic conditions within the Lucerne Valley. It was also determined that groundwater levels began to decline in the early 1900s as Lucerne Valley residences began pumping groundwater (primarily for agriculture irrigation) with the greatest declines occurring near the center of Lucerne Valley (Schaefer 1979).

Proposal (Work Plan/Methodology)

In order to investigate the surficial recharge potential within the Lucerne Valley, a series of methods will be applied: geologic mapping, infiltrations tests and soil sample analyses. Regions to be investigated include the playa (i.e.,Lucerne Dry Lake), ephemeral stream channels and the alluvial fan deposits. Reference data will be collected for evaporation rates in both desert and mountain regions as well as data for the effective evaporation depth within arid environments.

Geologic Mapping

A general geologic overview of the potential recharge areas will be produced using existing geologic maps, field reconnaissance and aerial photography.

Infiltration Test

Infiltration tests will be conducted at three primary locations throughout the valley in order to determine the infiltration potential at the surface. A single-ring, falling-head infiltrometer will be used to determine the infiltration potential in a similar method used in many similar studies (i.e., Young 1987; Bagarello et al. 2004). The infiltrometer will be constructed using a 55-gallon steel drum with the top and bottom of the drum removed. The diameter of the drum will be measured and the circular area will be calculated. The drum will be placed into the ground vertically to a depth of 6-12”. At sites with hard-packed alluvium, three shallow-depth wells will be drilled to approximately eight feet and cased with 2” PVC that is screened between five and eight feet. At sites with loose material (such as sandy ephemeral stream beds), the wells will be hand augered rather than mechanically drilled. The wells will be placed in an equilateral triangular pattern approximately four feet apart, centered on the single-ring infiltrometer. Water will quickly be placed into the drum at time equals 0 seconds (initial time, t_0) and the lapsed time will be recorded for each 1” increment of falling head in the steel drum. The area of the drum and rate at which the water infiltrates into the subsurface will be used to calculate flux, which will be used to determine the hydraulic conductivity, K. After a determined length of time in the field, the test will be repeated to determine the infiltration rate under saturated conditions.

If no water infiltrates, then we will conclude that the site has no recharge potential. A map of the region will be produced to detail the infiltration potential throughout the basin using the results from various sites.

Soil Samples

At wells that will be drilled using the drill rig, a continuous sample through the soil column will be collected using four-foot acetate liners totaling eight feet per well. At sites that will not use the drill rig, samples will be collected every six inches using the hand auger. Each sample collected will be described and labeled in the field and taken to the lab to be sieved in order to determine the grain size distribution. Using published literature, the established values of hydraulic conductivity for a specific soil type will be estimated for each soil sample. The various K-values determined from the infiltration tests and soil analyses will be plotted for all areas (playa, ephemeral stream channels and alluvial fill/fans); K distributions will be interpreted using statistical analysis, data contouring and, if applicable, computer simulations to determine the amount of rainfall necessary to produce the required volume of water to allow for infiltration in the stream channels.

Proposed Budget

Item		Dollar Amount
Salaries Faculty	R. Laton	$0
Faculty Fringe (12%)		$0
Salaries Students	750 hrs @ $20/hr	$15,000
Student Fringe (12%)		$1,800
	Salaries Total	*$16,800*
Equipment Rental*		*$500*
Travel**		*$500*
Material and Supplies***		*$250*
Foundation Overhead	25%	$4,512.50
Project Total		**$22,565.50**

* Includes; Mobil Office/Lab, computer, scanner, Geophysical Equipment
** Includes; Per Diem and Lodging
*** Includes; Paper, Ink, CD's

Time Line

January through June, 2009 –	Locate areas for field work
May through June, 2009 –	Conduct field work
June through August, 2009 –	Analyze data
	Complete all interpretations
September through December, 2009 –	Write and complete Thesis

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