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Potentiometric Surface and Hydrologic Conditions of the South Coast Aquifer, Santa Isabel Area, Puerto Rico, March–April, 2014

Pamphlet to accompany
Scientific Investigations Map 3455

U.S. Department of the Interior
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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
	Area	
square foot (ft^2)	0.0929	square meter (m^2)
	Volume	
million gallons (Mgal)	3,785	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Datum

Vertical coordinate information is referenced to local mean sea level.

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Altitude, as used in this report, refers to distance above the vertical datum.

Potentiometric Surface and Hydrologic Conditions of the South Coast Aquifer, Santa Isabel Area, Puerto Rico, March–April, 2014

By Félix A. Ramos and Alex A. Santiago

Abstract

A potentiometric surface map of the South Coast aquifer near Santa Isabel, Puerto Rico, was created from data collected during a synoptic survey of groundwater levels at 55 wells from March 31 to April 17, 2014. Measured groundwater level values ranged from −22.8 to 185.4 feet above mean sea level. During the study period, cumulative rainfall of 0.65 inch was recorded in the study area. Measurements of instantaneous streamflow at 15 locations in streams and irrigation canals, and locations of irrigation ponds, provide additional information about the hydrologic setting. Results of the study indicate a cone of depression was present near the center and eastern parts of the Santa Isabel area of southern Puerto Rico, and a small, deeper cone of depression existed west of Santa Isabel and Rio Coamo. These cones of depression represent areas where the potentiometric surface was below mean sea level. The long-term persistence of such conditions could result in seawater intrusion and an increase in concentrations of total dissolved solids within the South Coast aquifer.

Introduction

Santa Isabel is a small town located in south-central Puerto Rico with a population of 23,274 (U.S. Census Bureau, 2010). The town is bordered by the municipalities of Coamo to the north, Juana Díaz to the west, Salinas to the east, and by the Caribbean Sea to the south. The South Coast aquifer underlies the town and consists of alluvial and associated clastic deposits within the Santa Isabel area that range in thickness from 0 feet (ft) along the foothills to 3,700 ft at the coast (Rodríguez-del-Río and Gómez-Gómez, 1990). Most water-supply wells penetrate less than 200 ft below land surface. Below 250 ft, the unconsolidated deposits become finer-grained and yields to deep wells are not increased relative to shallower wells (Rodríguez-del-Río and Gómez-Gómez, 1990).

The U.S. Geological Survey (USGS) conducted a synoptic survey of the South Coast aquifer in the Santa Isabel area, in cooperation with the Puerto Rico Department of Natural and Environmental Resources, during March–April 2014. The objectives of the study were to (1) document hydrologic conditions during the extended drought of 2012–15 in the South Coast aquifer, and (2) delineate the potentiometric surface of the South Coast aquifer between the Río Descalabrado and the Río Jueyes.

Documenting extreme hydrologic conditions helps to characterize groundwater flow during a period of rainfall deficiencies, which has been as much as 35 percent below average in recent years (Torres-González and Rodríguez, 2015). The climate of the southern coastal plain of Puerto Rico is influenced by the general topography of the island, which interacts with the eastern and southern winds creating a rain-shadow effect. Along the southern coastal plain, this effect greatly reduces mean annual rainfall from north to south, changing the general landscape from forest-humid to desert-dry (Rodríguez, 2013). A potentiometric surface map of the South Coast aquifer was created as part of the investigation to identify the direction of groundwater flow in the aquifer.

Methods of Investigation

A synoptic survey of groundwater levels in 55 wells and a field reconnaissance of the hydrologic conditions in the Santa Isabel area of the South Coast aquifer were conducted from March 31 to April 17, 2014. Measurements of instantaneous streamflow were made at 15 selected sites along the Río Coamo, Río Descalabrado, Río Cañas, and the Canal de Juana Díaz to constrain the potentiometric surface. Data used to generate the potentiometric surface and the potentiometric contours are available online (U.S. Geological Survey, 2018; Ramos and Santiago, 2019)

The potentiometric surface was delineated by measuring water-level altitudes in USGS observation wells in the study area and in pumping wells that were either not operating during the survey period or shut down briefly so that water-level measurements could be made. In the latter case, measurements were made after a recovery period of 30 minutes so that drawdown in the wellbore achieved a near-static-level

representation of the aquifer at the measurement point (Rodríguez and others, 2005). The water-surface altitude was referenced to the mean sea level datum from USGS 1:20,000-scale maps for Santa Isabel, Rio Descalabrado, Coamo, and Salinas quadrangles (Doyle and Smith, 2012).

The aquifer in the study area is heterogenous, being composed of unconfined, semiconfined, and confined zones; however, well-depth and construction data are insufficient to adequately distinguish the vertical zones penetrated by the majority of wells. Thus, the potentiometric surface map is presented as a planar, two-dimensional feature, assuming hydrologic connectivity between zones of variable confinement (Prinos, 2005). The potentiometric-surface contours were delineated using water-level data, and more qualitatively informed by surface hydrologic features such as irrigation ponds, canals, drainage ditches, and saturated intermittent streams, as well as topographic settings (Rodríguez, 2013).

Hydrologic Conditions and the Estimated Potentiometric Surface

The potentiometric surface map (sheet 1) and hydrologic conditions presented herein represent dry-season conditions in the study area, which typically occur during the months of December through April (Kuniansky and others, 2004), as well as conditions during a multiyear drought. Drought conditions during 2014 were indicated by substantial rainfall deficits, relative to the 30-year moving average, starting in 2012, at multiple, long-term rainfall National Oceanic and Atmospheric Administration monitoring stations in the area overlying the South Coast aquifer (Torres-Gonzalez and Rodriguez, 2016). During March and April 2014, groundwater levels and streamflow were seasonally low, and agricultural irrigation withdrawals were assumed to be high to meet crop demands during these extremely dry conditions. The mean annual rainfall at the Santa Isabel rain gage 50106100 is 36.27 inches (in.) (National Weather Service, 2010). Two separate rainfall events (April 3 and April 9, 2014) occurred during the study period, and a total rainfall of 0.65 in. was recorded for those dates at Alomar Oeste observation well (USGS station number 175734066233300, fig. 1). Rainfall on April 3, 2014, corresponds with a 0.54-ft increase in groundwater levels at the Alomar Oeste observation well; rainfall accumulation on April 9, 2014, also corresponds with an increase in groundwater levels at this well (fig. 1).

Measured groundwater level values collected during the study period ranged from −22.8 to 185.4 feet above mean sea level. Groundwater-level data indicate that a large cone of depression was present near the center and eastern parts of the Santa Isabel area of southern Puerto Rico, and a smaller, deeper cone of depression existed west of Santa Isabel and

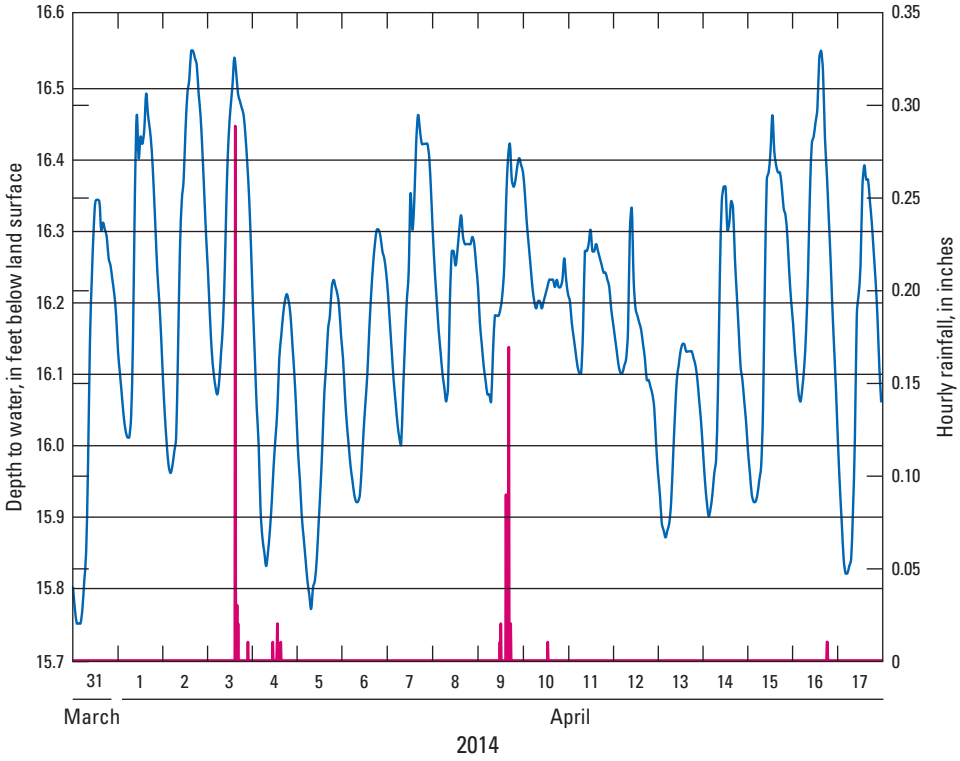

Figure 1. Groundwater levels and rainfall at Alomar Oeste observation well (station 175734066233300), Santa Isabel, Puerto Rico, March 31 to April 17, 2014.

Rio Coamo (sheet 1). These cones of depression represent areas where the potentiometric surface was below mean sea level. Long-term persistence of groundwater levels in the South Coast aquifer below sea level could lead to saline-water intrusion and an increase in concentrations of total dissolved solids in groundwater.

The potentiometric surface that represents conditions in the aquifer during March–April 2014 can be compared to that determined from data collected in March 1987 (Rodríguez-del-Río and Gómez-Gómez, 1990). The comparison of these potentiometric surfaces indicates that groundwater levels in the aquifer were about 39 ft lower on average during March–April 2014 than during March 1987. During and prior to 1987, sugarcane was the main crop harvested in the area, and farmers used furrow irrigation techniques (Rodríguez-del-Río and Gómez-Gómez, 1990). During the early 1990s, furrow irrigation was replaced by drip irrigation, which is a more efficient irrigation method. The change to drip irrigation reduced the aquifer recharge, because most of the irrigation water applied is used by the crops or returned to the atmosphere by evapotranspiration. As a result, no appreciable amounts of water are returned to the aquifer as recharge under current irrigation methods (Kuniansky and others, 2004).

Instantaneous streamflow was measured at selected sites along the Río Coamo, Río Descalabrado, Río Cañas, and the Canal de Juana Díaz and used to qualitatively constrain the potentiometric surface during the timeframe of the synoptic survey. Where streamflow was present, the potentiometric surface was assumed to intersect the streambed; where streamflow was zero, the stream was dry, and the potentiometric surface was assumed to not intersect the streambed. During the study, the Río Coamo, Río Descalabrado, and Río Jueyes were flowing along their upstream reaches, north of Puerto Rico Highway 52; flow in the downstream reaches along the south coastal plain diminished southward until it was intermittent or absent. Streamflow measured in the Canal de Juana Díaz between the Río Cañas and Río Jueyes on March 19, 2014, ranged from 20.4 to 7.3 cubic feet per second. Streamflow in the Canal de Juana Díaz decreased substantially in the reach between the Río Coamo and Río Jueyes area, most likely because of the diversion of surface water to irrigation ponds in this area.

Water diversion from the Canal de Juana Díaz replenishes 11 irrigation ponds within the study area that were in operation during the survey. These 11 irrigation ponds are used to complement and reduce continued groundwater withdrawals in the area. Irrigation ponds represent areas where recharge to the aquifer, and associated potentiometric mounding, may be occurring. This information was used to qualitatively guide placement of the potentiometric contours. The surface area of the irrigation ponds was calculated using the original engineering drawings provided by the U.S. Department of Agriculture and verified with satellite-georeferenced photographs. The corresponding areas and volumes of the irrigation ponds are summarized in table 1.

Table 1. Storage capacity of irrigation ponds in the Río Descalabrado to Río Jueyes area, Santa Isabel, Puerto Rico, March to April 2014.

[NAD 27, North American Datum of 1927; ft^2, square foot; Mgal, million gallons]

Pond name	Latitude / longitude (NAD 27)	Area (ft^2)	Volume (Mgal)
Doble A Pond	175835.80 / 662343.96	142,148.1	7.21
Doble B Pond	175837.64 / 662343.26	37,027.8	2.73
Celso Pond	175911.44 / 662319.67	94,765.4	5.12
La Guancha Pond	175955.58 / 662247.05	116,336.2	6.26
Portalatín Pond	175836.43 / 662249.21	105,755.3	6.31
La Muerta Pond	175900.63 / 662230.32	113,376.2	6.57
Cardona Pond	175936.77 / 662221.37	115,485.9	6.65
Sergio Pond	175839.86 / 662206.10	76,143.8	4.02
Grande Pond	175940.35 / 662156.14	201,349.5	14.83
Paso Seco Pond 1	180055.17 / 662441.80	140,285.9	10.33
Paso Seco Pond 2	180102.28 / 662456.53	107,326.8	7.90
Total		**1,250,001**	**77.93**

Summary and Conclusions

Groundwater-level data collected during the study period from March to April 2014 indicate that a large cone of depression, where the potentiometric surface was below mean sea level, existed near the center and eastern parts of the Santa Isabel area of southern Puerto Rico, and a small, deeper cone of depression existed west of Santa Isabel and Rio Coamo. The presence of groundwater levels in the South Coast aquifer below sea level for extended periods of time could lead to seawater intrusion and an increase in concentrations of total dissolved solids in groundwater.

Instantaneous streamflow measurements were made at selected sites along the Río Coamo, Río Descalabrado, Río Cañas, and the Canal de Juana Díaz. The Río Coamo, Río Descalabrado, and Río Jueyes were flowing along their upstream reaches north of Puerto Rico Highway 52, but flow in the downstream reaches on the south coastal plain diminished southward until it was intermittent or absent. Streamflow measured in the Canal de Juana Díaz between the Río Cañas and Río Jueyes ranged from 20.4 to 7.3 cubic feet per second. A substantial decrease in streamflow along the Canal de Juana Díaz occurred in the reach between the Río Coamo and Río Jueyes, most likely caused by the diversion of surface water to irrigation ponds in this area. These irrigation ponds are used as an alternative to continued groundwater withdrawals in the area and may provide recharge to the aquifer.

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