Methods, data, and analysis of slug tests of monitoring wells in the Lower Walker River Basin

By Kip K. Allander and Lindsay R. Burt

Contents

Introduction 3

Site 6

Procedures 6

Analysis 11

Hydraulic Property Estimates 11

References Cited 12

Appendix A 12

Appendix B 12

Figures

Figure 1. Location of wells slug tested in the Lower Walker River Basin. 5

Tables

Table 1. Site information and hydraulic conductivity results from 19 wells in the Lower Walker River Basin. 9

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Introduction

Walker Lake has been declining at a rate of about 1.6 feet per year since 1917 resulting in total dissolved solids concentrations increasing to the point where the lakes fishery and ecosystem health are being threatened. Uncertainties in the water budget in the Lower Walker River Basin led the U.S. Geological Survey in cooperation with the U.S. Bureau of Reclamation to undertake a study to revise the water budget of Walker Lake. The study was initiated in 2004 and a revised water budget is scheduled to be published in 2009.

Developing a better understanding of the ground-water system in the Lower Walker River Basin is a critical component of this study. To understand how ground-water interacts with Walker Lake it is necessary to understand ground-water levels and aquifer properties in the alluvial aquifers adjacent to Walker Lake. It is planned to conduct a series of aquifer tests in the alluvial aquifers of the Lower Walker River Basin. Planned tests are 1) slug tests of monitor wells installed as part of this study, 2) analysis of historic slug test data (1979) on monitor wells installed on the Hawthorne Army Ammunition Depot, 3) a multiple well aquifer test on the Walker River Indian Reservation, and 4) a single well aquifer test on the Double Springs flowing well. This paper documents the methods, data, analysis, and results of slug tests from monitor wells installed as part of this study.

Slug tests were performed on 19 monitor wells in the Lower Walker River basin (**Figure 1**). A majority of these tests were for wells that were located along both banks of the Lower Walker River downstream of the Walker River at Wabuska streamgage (10301500). These wells were tested to estimate properties of the local aquifer system. The local aquifer is an alluvial aquifer system with material originating from stream and lake alluvial processes. The tests were conducted September 17—21, 2007.

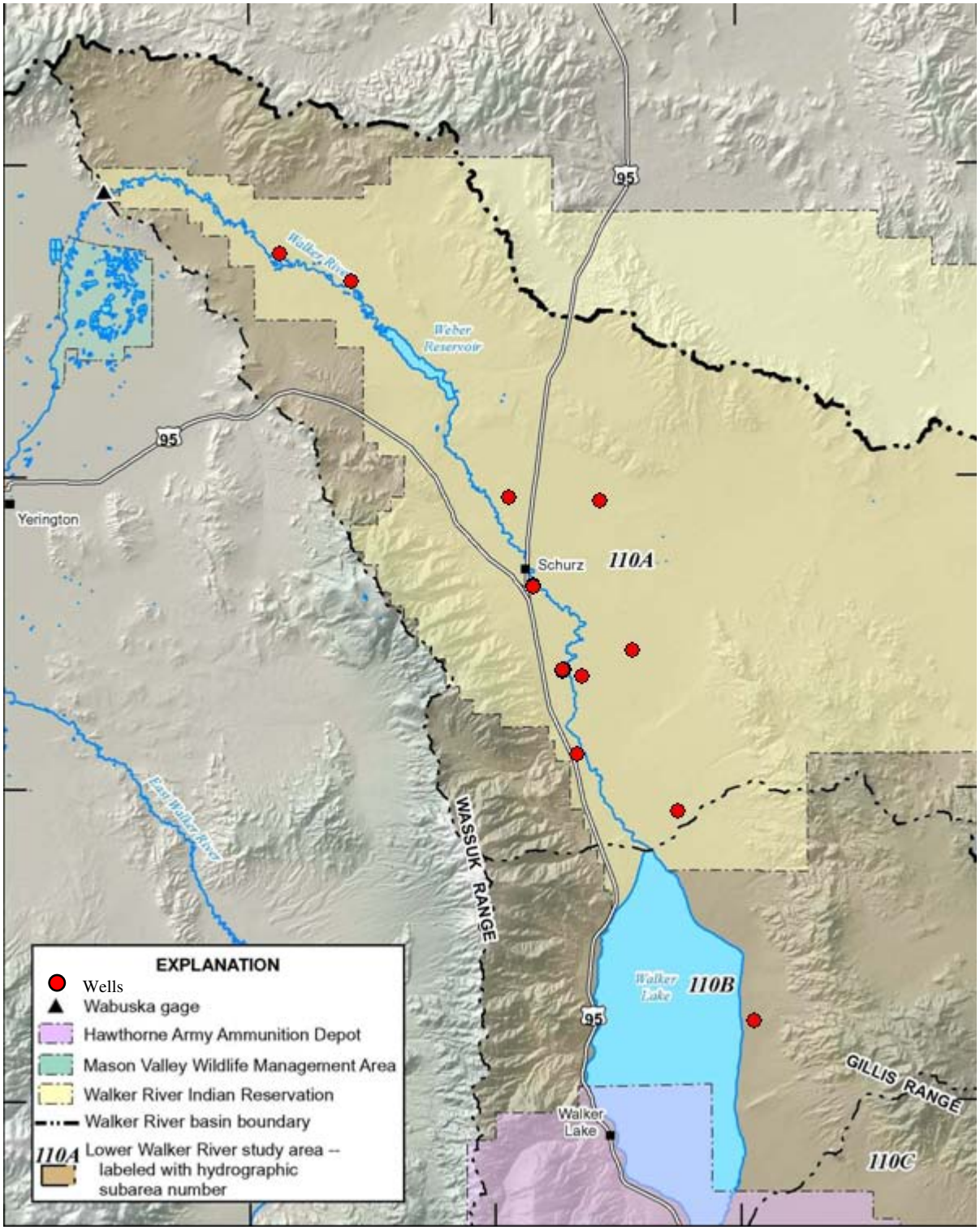

Figure 1. Location of wells tested in the Lower Walker River Basin.

Site

All wells were 2-inch diameter PVC monitor wells installed by the USGS as part of the Walker River Basin project since the winter of 2005. Several of these monitor wells were established in pairs as deep and shallow wells within the same borehole separated by a grout seal between their screened intervals. Screened interval lengths ranged between 5 and 10 ft. Wells were completed between 9 and 250 ft below land surface. The deepest wells were located on an alluvial fan deposit of the east shore of Walker Lake. Aquifer material surrounding the screened intervals of the wells ranged from silty clay to gravel, with various degrees of sorting (**Table 1**). All wells were developed after their construction.

Procedures

The first step was the measurement of depth to water and sounding of well depth. Depth to water was measured using an electric tape and measurement was verified with a second measurement. The depth of the well was then sounded using the electric tape in order to ensure that the screened interval was free and clear of silt, dirt, or debris. An Instrumentation Northwest Inc. PS9105 0-15 PSIG pressure transducer was then lowered to between 10 and 15 feet below the water surface when height of water column was sufficient. Otherwise, the pressure transducer was placed at about 1 ft above the bottom of the screen interval or higher in attempt to get at least a 7 ft column of water above the transducer. If there was less than 7 ft of water in the well, a liquid slug was used to displace the water level instead of using a solid slug. The length of the pressure transducer cable was calculated by adding the depth to water to the height of the water column above the pressure transducer and recorded. This was done at the beginning and end of each well test to document the overall change in position of the pressure transducer in the well. The pressure transducer was monitored using a Campbell Scientific CR10X data logger connected to a laptop PC. All data were observed on the PC in real time and downloaded from the CR10X to the laptop following each test.

Two different procedures were used to cause rapid displacement of water level in the well tests. The primary and preferred displacement procedure used a solid slug that was rapidly lowered into water column and after water level equilibrated, raised out of the water column. The secondary displacement procedure used a known volume of liquid (liquid slug) that was rapidly poured into the well. This secondary procedure was used when the height of the water column was insufficient for use of the solid slug, or when the solid slug did not fit down the inside of the well casing. The liquid slug procedure was also used as a follow up to the solid slug procedures so that the two procedures could be compared. The solid slug procedure utilized a 62 inch long by 1 inch diameter (O.D.) sealed galvanized steel pipe that was suspended using a steel engineers tape. The solid slug was rapidly submerged into the water to produce a falling head test (Halford and Kuniansky, 2002). After the water-level stabilized, the solid slug was rapidly removed from the water to produce a rising head test. The rising and falling head tests were repeated one more time to ensure a good data set and repeatability of results. The solid slug was then removed and a liquid slug was introduced.

Liquid slug tests were performed as follows: For wells in which the solid slug could not be used, three separate liquid slug tests were performed for each well. The liquid slug was rapidly poured into the well casing. The time it took for the pours and the drainage down the inside of the wells to occur was recorded for each test. Liquid slug volumes of 1, 2, and 4 Liters were used as the displacement volumes. When the liquid slug procedure was used as a follow-up to the solid slug procedure, only one test using a 1 Liter slug volume was done.

The pressure transducer recorded at sampling intervals that were implemented based on anticipated water level response and then was adjusted based on initial test results. Water levels were measured with a resolution of 0.01 ft and at period of 0.0125, 0.5, or 1 second intervals, depending on the length of time it took for the water level to stabilize after displacement.

Rough estimates of hydraulic conductivity values were evaluated in the field at each site to ensure that data was good and reasonable for each of the tests. The field results were obtained by using an abbreviated method of the final analytical method used in the office. The field data was analyzed in the office using a spreadsheet developed by Halford and Kuniansky (2002). The primary method used by this spreadsheet was the High-K Bower and Rice Model which Butler and others (2003), modified from Bower and Rice (1976; KGS method). Field data and all relevant well construction data were entered into the spreadsheets, and the data was then compiled in a summary table (**Table 1**).

Table 1. Site information and hydraulic conductivity results from 19 wells in the Lower Walker River Basin.

[Locations of wells are incorporated into Site ID as follows: Siteid is Latitude (DDMMSS) followed by longitude (DDDMMSS) followed by a well sequence number (0x) and are referenced to NAD83: DDMMSSDDDMMSS0x.]

Well Name	Site ID	Date	water level (DTW), Feet	Top of Screen, Feet	Base of Screen, Feet	Avg Displace-ment, Feet	Theoretical Displace-ment, Feet	Slug Test Type	Aquifer Material	K, Feet/ Day
CowCamp LBDS	390610118554201	9/20/2007	5.8	20.0	25.0	1.00	1.29	Solid	Medium Sand	30
CowCamp LBUS	390610118554301	9/20/2007	6.1	9.0	14.0	0.75	1.29	Solid	Coarse Sand	60
East Lake Deep	384234118390802	9/18/2007	88.4	298.0	308.0	1.48	1.51	Solid	Silty Clay	0.3
East Lake Shallow	384234118390801	9/18/2007	90.9	229.0	239.0	1.33	1.51	Solid	Silty Clay	4
Greasewood	385423118440801	9/18/2007	25.8	25.0	35.0	0.85	3.80	Liquid	Coarse Sand	30
Lateral 2A LBDS	385628118481302	9/19/2007	11.4	45.0	50.0	0.95	1.29	Solid	Coarse Sand	200
Lateral 2A LBUS	385628118481301	9/19/2007	11.3	13.8	18.8	0.74	1.29	Solid	Coarse Sand	200
Later 2A RB	385625118481501	9/19/2007	20.6	24.2	29.2	2.48	3.80	Liquid	Medium Sand	10
Powerline LB	385345118470001	9/19/2007	21.7	29.0	34.0	1.38	1.29	Solid	Fine Sand	1
Powerline RBDS	385344118470301	9/19/2007	16	15.0	20.0	1.46	3.80	Liquid	Sandy Clay	9
Powerline RBUS	385345118470401	9/19/2007	16.51	19.0	24.0	1.82	3.80	Liquid	Fine Sand	30
Rabbitbrush	385333118461601	9/19/2007	30.6	34.0	44.0	2.24	3.80	Liquid	Silty Sand	8
Schurz NE deep	385908118453202	9/17/2007	74.1	140.0	160.0	2.53	4.45	Liquid	Sandy Clay	0.4
Schurz NE Shallow	385908118453201	9/17/2007	74.1	80.0	100.0	0.86	6.36	Liquid	Sandy Clay	4
Schurz NW	385915118491301	9/17/2007	79	135.0	145.0	1.46	5.73	Liquid	Gravel	10
Tamarisk	385103118462801	9/19/2007	5.6	30.0	35.0	1.38	1.29	Solid	Gravelly Clay	1
Transmission Deep	384917118421602	9/18/2007	125	240.0	250.0	1.09	1.51	Solid	Gravel	4
Transmission Shallow	384917118421601	9/18/2007	126	159.0	169.0	1.11	1.51	Solid	Silty Clay	8
Willow LBUS	390700118584001	9/20/2007	4.2	9.0	14.0	0.78	1.29	Solid	Coarse Sand	80

Analysis

Inserting or extracting the solid slug took place in less than one second, making the assumption of instantaneous water displacement reasonable for the solid slug tests. The falling-head test that were initiated using the liquid slug method yielded substantial differences between the theoretical and observed displacements, due mainly to the length of time it took to make the displacement. These liquid pour tests showed substantially lower displacement than the theoretical displacement (**Table 1**).

Pouring the water down the well using a graduated cylinder and a metal funnel took 3 to 53 seconds, depending on the volume introduced. These times dropped below twenty seconds with practice, but were still far from instantaneous. The water took another 4 to 31 seconds, depending on the depth to water, to completely drain down the inside of the well casing. Despite the slow delivery time, the liquid slug tests and solid slug tests had remarkable similar results.

Hydraulic Property Estimates

Hydraulic conductivity values ranged between 0.3 and 200 ft/d with a median value of 9 ft/d (**Table 1**). Aquifer material surrounding the screened intervals of the wells were obtained from the respective well driller's reports, which only provided general descriptions of the lithology. Two of the sites listed gravel as the material at the depth of the screens, yet the hydraulic conductivity from the slug tests was less than 12 ft/d. Conversely, a site with silty-clay listed as the aquifer material had a hydraulic conductivity value higher than the extreme maximum of 6 ft/d for silt or loess (Domenico and Schwartz , 1990). **Table 1** lists the aquifer material as described in the drill logs, but hydraulic conductivities outside the plausible range of the material should not be interpreted as bad data. The aquifer material is likely not exactly as described, but instead a mixture of gravel, sand, and silt that the drillers probably were unable to accurately assess from drill cuttings rising out of the hole during well

construction (wells were constructed using hydraulic rotary method). Aquifer materials with lithologies of medium to coarse sand had hydraulic conductivity values between 11 and 220 ft/d, which are within the expected range for sand (1-300 ft/d; Dominco and Schwartz, 1990). The two sites with aquifer material of fine sand had hydraulic conductivities that were substantially different from each other (1.2 and 33 ft/d). Sites listed as silty, sandy, or gravelly clay had an average hydraulic conductivity of 4 ft/d.

References Cited

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Domenico, P.A. and Schwartz, F.W., 1990, Physical and Chemical Hydrogeology: New York, John Wiley and Sons, 824 p.

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Appendix A

Aquifer test summary, September, 2007

Appendix B

Aquifer test spreadsheets and data