HYDRAULIC CONDUCTIVITY OF SHALLOW SEDIMENTS IN THE VICINITY OF CATTLEMANS DETENTION BASIN, SOUTH LAKE TAHOE, CALIFORNIA

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Abstract

Cattlemans detention basin, South Lake Tahoe, California is designed to capture and reduce urban runoff and pollutants originating from developed areas before entering Cold Creek, which is tributary to Trout Creek and to Lake Tahoe. The effectiveness of the basin in reducing sediment and nutrient loads currently is being assessed with a five-year study. Hydraulic conductivity of the sediments near the detention basin is needed to estimate ground-water flow and subsurface nutrient transport. Hydraulic conductivity was estimated with slug tests in 27 monitoring wells that surround the detention basin. Each slug test was conducted by rapidly pouring water into a well, monitoring water-level changes, and analyzing the observed changes with the Bouwer and Rice method. Between 1 and 4 tests were performed on each well. A total of 24 wells were tested more than once. Of the 24 wells, the differences among the tests were within 10 percent of the average. Estimated hydraulic conductivities of basin sediments range from 0.5 to 70 feet per day with an average of 18 and a median of 15 feet per day. This range is consistent with the sandy sediments observed in the area of Cattlemans detention basin.

Introduction

Retention basins have been constructed in South Lake Tahoe, California to reduce urban runoff (fig. 1). Urban runoff is of concern in the Lake Tahoe Basin because nutrients associated with urban runoff can decrease the clarity of Lake Tahoe. Retention basins should reduce nutrient loads to Lake Tahoe by settling suspended solids and filtering runoff through surface sediments. The amount of nutrient reduction from retention basin in South Lake Tahoe is unknown because some of the nutrients could be transported by ground water.

Figure 1 belongs near here--

A cooperative study between the USGS, the El Dorado County Department of Transportation, Tahoe Engineering Unit and the California Tahoe Conservancy study was initiated in November 2000. The purpose of this five-year study is to determine if the capture of urban runoff into Cattlemans detention basin is aiding in the reduction of nutrient and contaminant loads entering nearby Cold Creek, which is tributary to Lake Tahoe. This detention basin is the focus of the 7-acre study area and is located in South Lake Tahoe, California (fig. 2).

Figure 2 belong near here---

Hydraulic conductivity of the shallow sediments near Cattlemans detention basin was estimated with slug tests so that ground-water velocities could be assessed. Ground-water direction and velocities around the detention basin affect dissolved nitrate concentrations of runoff filtering through surface sediments. Ground-water flow in the study area must be quantified to evaluate how nutrient loads to Cold Creek and Lake Tahoe are affected by Cattlemans detention basin.

Purpose and Scope

Techniques and methods used to calculate the approximate hydraulic conductivity in sediments near Cattlemans detention basin, South Lake Tahoe, California are reported. A brief description of Cattlemans detention basin and geology is provided, as well as a detailed discussion of how hydraulic conductivity was approximated for each monitoring well. A distribution of hydraulic conductivity in sediments near the detention basin also is reported.

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Description of Cattlemans Detention Basin

Cattlemans detention basin is constructed on a meadow-like flat plain that is bordered to the east by Pioneer Trail and to the north and west by Cold Creek (fig. 2). A residential area forms the southern border. Access to the basin is provided by the dead-end of Cattlemans Court.

Construction of Cattlemans detention basin began in August 2001 and was completed by October 2001. It is designed to hold a total volume of 22,000 ft^3 without surface discharge. Large boulders and concrete were used in constructing a spillway on

the west side of the detention basin to allow discharge when the capacity of the basin was breached. Flow over the spillway enters the adjacent meadow, although it is restrained by bundled straw, or a biolog, to prevent overflow from the basin directly entering Cold Creek (fig. 2).

A series of 30 monitoring wells, were installed at ground surface around the detention basin to aid in determining if nutrients are transported away from the detention basin by ground water (fig. 2). Wells were placed to the east and south of the basin where land surface elevation was higher, and between Cold Creek and the basin, as well as in the meadow west of the spillway where land surface elevation was lower. Data collected from the wells were used to estimate the direction and rate of ground-water flow from the detention basin to Cold Creek, and evaluate changes in chemistry.

Geology of Lake Tahoe and the detention basin

Lake Tahoe was formed as a result of horst and graben faulting somewhere between 7.4 and 2.6 Ma after andesitic volcanism and deformation (Gardner, and others 2000). An irregular oval in shape, Lake Tahoe stretches nearly 22 miles from north to south and 12 miles from west to east (Crippen and Pavelka, 1972). Ranked as the 12th deepest lake in the world, Lake Tahoe is one of the largest lakes in the United States (Gardner, and others 2000). The lake has an average depth of 1,000 ft (greatest depth of 1,645 ft) and a total surface area of 191 mi^2. As it is crossed by the Nevada-California state border, about 57 mi^2 of the lake is in Nevada and 134 mi^2 in California (Crippen and Pavelka, 1972).

Granitic rocks (mainly granodiorite) underlie much of the lake and the adjacent uplands. Andesitic volcanic rocks cover much of the northern and northwestern areas of

the Lake Tahoe basin, whereas granitic rocks are covered by Quatenary glacial and alluvial deposits on the southwestern and southern end (Gardner, and others 2000).

At the site of Cattlemans basin, just above the confluence of Trout and Cold Creeks, alluvium covers the granitic rocks. The alluvial deposits primarily are floodplain sediments composed of silt and sand, and stream channel sediments composed of sand and gravel with locally interbedded lacustrine silt and clay (Harrill, 1977). The alluvium ranges from 10 to 20 ft thick near the mountains (including the study area) and as much as 500 ft thick near Lake Tahoe. Prior to the detention basin construction, 4 to 5 ft of fill was placed on top of the meadow in the study area during construction of the residential area to the south. A large part of the fill was removed during the creation of the basin. It is characterized as red-brown loamy sand with some gravel and scarce cobbles. The fill overlies a layer of dark gray (nearly black) organic-rich material containing decomposing plant material. Due to the high organic content, this thin layer likely was once the old meadow surface.

Below the highly organic layer is a medium to dark gray organic silt and sand with stringers of coarse sand and fine gravel. Generally, these deposits range from 5 to 8 ft in thickness. Mica flakes are common in the silt and sand. Roots of the meadow grasses are common to a depth of 1 ft and sporadic decomposing wood pieces are found throughout the deposit.

The third category in the detention basin area is a brown to yellow-brown sand and gravel. Although the thickness of this layer is unknown, it is encountered below the meadow deposits. The yellow-brown color is the result of oxidation of iron. Granitic rock likely underlie the sand and gravel layer and is thought to have been encountered

when drilling well cc2 at a depth of about 6 ft below land surface. A cross section of the detention basin is shown in figure 3.

Figure 3 belongs near here---

Estimates of Hydraulic Conductivity

Well Construction

All wells were constructed in the same manner installed to shallow depths of less than 10 ft and deeper depths of less than 15 ft. Physical construction of the wells consisted of using nominal 2-in. schedule 40 PVC (polyvinyl chloride) pipe. Wells that were installed to a depth of 10 ft or less and those that were deeper differed slightly in construction. The former utilized a single piece of PVC pipe. Openings were cut into the pipe from 0.5 and 1.5 ft from the bottom at a width of 0.010 in. Stainless steel rivets were used to secure a cap at the bottom of the pipe. Wells deeper than 10 ft needed the attachment of a 5-ft section of flush threaded PVC to a 10-ft section of PVC with a screen. The joint was sealed with a Teflon o-ring. Two wells, cc2 and cc19D, were installed with a nominal 1-in. schedule of 40 PVC pipe due to unexpected difficulties faced during the hand-augering process.

All 2-in. monitoring wells were topped with a tightly sealed cap composed of two 0-rings in order to prevent inflow of surface runoff into the well. Each cap is lockable. The two 1-in. diameter wells also were capped, but a rubber gasket was used to seal the top of the casing instead. Table 1 summarizes the construction information of all 30 wells installed in the area of the detention basin.

Table 1. Well name, land-surface altitude, and construction data for wells in vicinity of Cattlemans detention basin, South Lake Tahoe, California

Well Name	Standard identification number	Land- surface Altitude[1] (feet)	Depth in feet below land surface		
			Bottom of well	Screened Interval	
				Top	Bottom
cc1	385432119574001	6278.84	5.6	4.1	5.1
cc2	385432119574002	6281.57	6.8	5.3	6.3
cc3S	385432119574301	6281.23	10.2	8.7	9.7
cc3D	385432119574302	6281.21	15.1	13.6	14.6
cc4	385433119574201	6279.12	10.2	8.7	9.7
cc5	385433119574202	6278.03	10.2	8.7	9.7
cc6S	385433119574301	6277.37	9.0	7.5	8.5
cc6D	385433119574302	6277.40	15.0	13.5	14.5
cc7	385433119574203	6273.29	5.0	3.5	4.5
cc8S	385432119574303	6278.13	9.2	7.7	8.7
cc8D	385432119574304	6278.15	15.0	13.5	14.5
cc9	385432119574305	6279.30	9.9	8.4	9.4
cc10	385433119574303	6276.39	10.2	8.7	9.7
cc11	385434119574401	6272.83	5.6	4.1	4.6
cc12	385434119574402	6272.64	5.1	3.6	4.6
cc13S	385434119574402	6275.14	10.2	8.7	9.7
cc13D	385434119574402	6275.69	15.2	13.7	14.7
cc14	385433119574403	6272.60	5.5	4.0	5.0
cc15	385432119574401	6278.33	10.2	8.7	9.7
cc16	385433119574404	6273.47	7.2	5.7	6.7
cc17S	385433119574501	6272.71	6.7	5.2	6.2
cc17D	385433119574502	6272.82	10.6	9.1	10.1
cc18	385433119574503	6271.93	5.1	3.6	4.6
cc19S	385433119574504	6272.19	5.6	4.1	5.1
cc19D	385433119574505	6272.11	10.0	8.5	9.5
cc20	385432119574501	6272.77	7.2	5.7	6.7
cc21	385432119574601	6272.19	5.0	3.5	4.5
cc22	385433119574701	6271.94	5.6	4.1	5.1
cc23	385433119574702	6271.08	5.4	3.9	4.9
cc24	385432119574701	6271.97	5.5	4.0	5.0

[1] Land-surface altitude referenced to pin set by El Dorado County Department of Transportation at end of Cattlemans Trail cul-de-sac. Altitude referenced to NGVD of 1929.

Wells in areas not covered by fill (in the meadow and next to stream) were installed in holes augered by hand (cc1-cc2; cc7; cc11-cc12; cc14; and cc16-cc24: fig.2). Most of the wells were installed in holes augered to depths of 5 to 7 feet, and had a

diameter of 4.5 in. Depth to ground water during installation ranged from 2 to 5 feet. Wells cc17D and cc19D were installed to depths of 10 to 11 feet below land surface next to shallower wells cc17S and cc19S.

Wells installed in the area covered by fill were installed in holes drilled using a trailer mounted hollow-stem auger (cc3-cc6; cc8-cc10; cc13; and cc15: fig. 2). Wells were installed in the approximately 7 in. augered holes to depths between 9 and 10 ft below land surface. Depth to ground water during installation of these wells was 6 to 8 ft below land surface. Deeper wells were installed to depths of 15 ft below land surface next to shallower wells 3S, 6S, 8S, and 13S. The purpose of the deeper wells was to determine if ground-water flow or chemistry changed with depth.

Wells were constructed, in order from screen to the land surface, with coarse silica sand, sand, fine sand, silica flour, native material and a cement cap (fig. 4). The top of each well was at or just slightly above land surface. With the insertion of the well into the augered hole, coarse silica sand was used to fill in the open space around the screen. Enough sand was placed in each well to reach 0.5 to 1 feet above the screen. Sequentially moving toward the land surface, fine sand, silica flour, native material and cement were added. Only a thin layer, about 0.5 ft, of the fine sand was added followed by 1 to 3 ft of the laboratory grade silica flour. Whereas a bentonite grout typically is used for this layer, the silica flour instead was used to eliminate possible reactions of the sodium-rich bentonite with the native material and with ground water. The native material was added until it reached approximately 2 ft from the land surface. To finish off the remaining 2 ft, neat cement was poured around the well cap to seal the hole.

Figure 4 belongs near here--

Method

All slug tests performed on the monitoring wells in Cattlemans detention basin were done in the same manner. Of the 30 wells, 28 were tested (all wells except wells 17S and 17D). Most wells were tested two or more times, although 3 wells were tested only once. Each test consisted of pouring 0.079 to 0.26 gal of water from a graduated cylinder rapidly into the well. This volume was sufficient to raise the water level in the well 1 to 2 ft. For most wells, either deionized water or water that had been previously pumped from the well was used for the tests. For wells near Cold Creek, water from Cold Creek was used for the tests.

The general steps of each test were to first determine the depth to water using either a steel or electric tape. In several wells, 1.05 gal of water then was pumped from the well, and the water level was allowed to recover back to its static level prior to starting the slug test. Following the removal of water from the well, a recording pressure transducer, (Global Water Instrumentation Inc. WL15-003), having a range from 0 to 3 ft was lowered and secured one foot below the water level, and was set to read continuously until the pressure readings had stabilized. After the pressure readings stabilized, the transducer was set to record every 1 to 2 s. Water then was poured as quickly as possible into the well (within 2 to 4 s) to imitate an instantaneous slug of water and the time of the slug was recorded. Water levels then were taken using either a steel or electric tape after approximately 1 min elapsed. If the water level had not returned to the initial level, a measurement was taken every 1 to 2 min thereafter until it had returned to within 0.02 ft of its static level. The time of the level's return was documented. This process was repeated until the desired number of slug tests was completed on each well.

Data from the pressure transducers were downloaded from a Personal Digital Assistant (PDA; Palm Inc., Model m105 Handheld) to an on site laptop computer using Windows XP and plotted on an x-y graph to view the quality of the pressure data. This was done to insure that the pressure transducer was recording pressure every 1 to 2 s and that the pressure transducer had not accidentally slipped from its secured position. In some instances, supplemental tests were done because the pressure transducer had not been correctly set or because it had inadvertently slipped.

Results

Each slug test was analyzed using the Bouwer and Rice method (Bouwer and Rice, 1976; Bouwer, 1989) using an EXCEL spreadsheet (Halford and Kuniansky, 2002). Pressure data from each slug test is imported directly into the spreadsheet. Other required information for analysis of each slug test includes well construction information (listed in table 1), the volume of water poured into the well, and the initial water level. Estimates of the hydraulic conductivity from slug tests of the 28 wells are summarized in table 2 and appendix A.

Estimates of hydraulic conductivity are reported only to the nearest significant figure (0.1, 1, and 10) because errors in the estimates of hydraulic conductivity were found to range from 10 to 25 percent (Bouwer and Rice, 1976) although a more recent analysis indicate errors ranging from 10 to 100 percent (Brown and others, 1995). Furthermore, the Bouwer and Rice method tends to underestimate the hydraulic conductivity (Brown and others, 1995). Pouring water as quickly as possible down the well is not exactly instantaneous as the method assumes. However, a percentage of the volume of water leaked into the sandy sediments as it was being poured into the well.

Thus for slug tests having estimated hydraulic conductivities exceeding a few feet per day, the effective volume of water used in the computation of y_o was always less than the actual volume poured into the well. The discrepancy between the effective volume and the actual volume increased with increasing hydraulic conductivity such that the largest discrepancies were recorded in wells that had estimated hydraulic conductivities that exceeded 10 feet per day. The time to pour water into the well was less than 4 s. For the well with the highest estimated hydraulic conductivity (well cc6S), the estimated rise in water level at time zero should have been 1.45 ft assuming that 0.238 gal of water was poured instantly into the well. The estimated hydraulic conductivity was no different when the rise of 1.45 ft was assumed at time zero and the next water level measurement was at 4 s. Assuming 3s instead of 4s was the next measurement, the hydraulic conductivity increased by 10 ft/day and the error was 15 percent.

Table 2. Results of slug tests in wells near Cattlemans Detention Basin, South Lake Tahoe, California.

Well Name	Date of Test	Initial Water Level Elevation (feet)	Average Displacement[2] (feet)	Estimated Hydraulic Conductivity (feet per day)	Number of slug tests
cc1	11/6/03	6275.85	1.57	1	2
cc3S	11/6/03	6272.43	1.45	2	3
cc3D	11/6/03	6272.45	1.22	10	3
cc4	11/6/03	6273.47	1.21	10	3
cc5	11/6/03	6272.33	1.19	20	3
cc6S	11/6/03	6271.5	1.02	70	4
cc6D	11/6/03	6271.53	1.05	30	3
cc7	11/6/03	6271.68	1.13	10	3
cc8S	5/27/03	6274.44	1.28	10	2
cc8D	5/27/03	6274.32	1.02	20	3
cc9	6/10/03	6272.95	0.89	40	3
	10/30/03	6271.68			1
cc10	6/9/03	6272.05	0.95	30	3
cc11	10/30/03	6270.46	1.08	2	6
cc12	6/10/03	6271.72	0.96	20	3
cc13S	5/27/03	6272.34	0.93	20	5
cc13D	5/27/03	6271.81	1.11	10	3
cc14	5/27/03	6270.91	0.88	20	3
cc15	10/30/03	6271.12	1.04	10	5
cc16	6/10/03	6271.82	1.08	5	3
cc18	11/6/03	6269.52	1.29	40	3
cc19S	11/6/03	6269.54	1.2	1	1
	6/24/03	6270.26			1
cc19D	6/24/03	6270.19	1.64	0.5	2
cc20	6/10/03	6271.11	0.93	20	1
cc21	6/10/03	6270.53	0.93	10	1
cc22	6/10/03	6269.99	1.13	40	4
cc23	11/6/03	6268.69	1.41	20	3
cc24	6/10/03	6269.58	0.93	10	1

[1] Land-surface altitude referenced to pin set by El Dorado County Department of Transportation at end of Cattlemans Court cul-de-sac. Altitude referenced to NGVD of 1929.
[2] Wells with only one slug test performed include exact displacement.

The slug test results from well cc2 are not included in the overall analysis of Cattlemans detention basin. This is because well cc2 is located at a higher elevation than all other wells and the static water level was within the screened interval of the well. When water was poured into the well, it also had to fill the gravel pack in the interval

surrounding the well above the initial water level. There is no correction within the Bouwer and Rice analysis that allows for this situation and therefore was not be included in the analysis.

Discussion

The estimated hydraulic conductivities of sediments near Cattlemans detention basin range from 0.5 to 70 ft/day (fig. 5). The distribution is slightly skewed with the majority of estimated hydraulic conductivities ranging from 3 to 30 ft/day (fig. 6). There were 4 estimates that exceeded 30 ft/day and 5 estimates that was less than 3 ft/day. The mean (average) value of hydraulic conductivity is 18 ft/d, whereas the median value is 10 ft/d. The 25-percentile is at 10 ft/d and the 75-percentile is at 20 ft/d indicating that at least half of all estimates range from 10 to 20 ft/d. The estimates of hydraulic conductivity from slug tests are consistent for sediments that are a silty to clean sand (Freeze and Cherry, 1979), and are thus consistent with the types of sediments that were encountered during augering for the monitoring wells.

Figure 5 belongs near here--
Figure 6 belongs near here--

No significant conclusions can be drawn between estimated hydraulic conductivities between the shallow and deeper wells due to a lack in number of sufficient deeper wells. With only five estimates of hydraulic conductivity of the deeper sand and gravel, there is not enough evidence to support differences in the hydraulic conductivities between the shallower meadow deposits and the deeper sand and gravel.

Summary and Conclusions

Cattlemans detention basin project, initiated in November 2000 in cooperation with the Tahoe Engineering Unit of the El Dorado County Department of Transportation, and the California Tahoe Conservancy, is a five-year study. The purpose of this study to determine if the installation of Cattlemans detention basin is aiding in the reduction of nutrients and sediments in surface flow before entering Lake Tahoe. Estimating hydraulic conductivity of the sediments near Cattlemans detention basin is important in evaluating the subsurface transport of nutrients from the detention basin to nearby Cold Creek. The purpose of this report is to describe the techniques and method used to estimate the hydraulic conductivity in the sediments and to present the results of the analysis.

A total of 30 wells were installed in the vicinity of the detention basin, ranging in depth from 5 to 15 ft, to assess the direction and rate of ground-water flow. Of these, 27 wells were tested to estimate hydraulic conductivity (23 in the shallow meadow deposits and 5 in the deeper sand and gravel). Estimates of hydraulic conductivity were determined using the Bouwer and Rice analysis of slug tests. From 0.079 to 0.26 gal of water was rapidly poured down each well and the response of the slug was recorded every 1 to 2 s using a recording pressure transducer that had a range from 0 to 3 ft.

Hydraulic conductivities of the sediments ranged from 0.5 to 70 ft/d, with more than half between 10 and 20 ft/d. The range in hydraulic conductivity is consistent with the sandy texture of the sediments encountered while augering holes for the wells. Estimates of hydraulic conductivity were reported only to the nearest significant figure because in the sandy sediments, a percentage of the water poured into the well leaked through the screen as it was poured into the well. This produced a discrepancy between

measured water-level displacement and that estimated from the volume of water poured into the well. The time to pour water into the well was less than 4 s. For the well with the highest estimated hydraulic conductivity (well cc6S), the estimated rise in water level at time zero should have been 1.45 ft assuming that 0.238 gal of water was poured instantly into the well. The estimated hydraulic conductivity was no different when the rise of 1.45 ft was assumed at time zero and the next water-level measurement was at 4 s. Assuming 3 s instead of 4 s was the next measurement, the hydraulic conductivity increased by 10 ft/day and the error was 15 percent.

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