Stream Depletion by a Shallow Well

By Charles Pugh

May 4, 2001
May 10, 2001

Dear ESSP Capstone Readers,

This capstone project was performed in collaboration with the California Department of Fish and Game for the purpose of implementing policy regarding water rights. The project looks at stream depletion by a shallow well and the policy behind the issue. I have selected this project to be my capstone as it addresses not only science but also the integration of a systems approach to problem solving and policy. I was drawn to this project in that it was a hands on learning experience. I was initially given guidance on basics of how to perform the project and then set loose to make the decisions myself. After the initial conference with the Department of Fish and Game and California State Department of Conservation, I performed the project independently. The project will be submitted to CDFG and State Water Resources Control Board in order to address infringement of water rights. I have chosen to be assessed in the areas of application of knowledge in the physical and/or life sciences (MLO 3) and acquisition, display, and analysis of quantitative data (MLO 5).

Thank You,

Charles Pugh
Abstract

Majors well, located next to Laguna Creek in Santa Cruz County, is a shallow well, drilled into alluvium. Developers have proposed to greatly expand biomedical research farm known as Stephenson Ranch. Stephenson Ranch would use Majors well for a primary source of water. California Department of Fish and Game is interested in examining if the well is pumping water from the stream and the possible impacts on the species that utilize the streams water. This project tested the hypothesis that Laguna Creek and Majors well are connected to the same unconfined aquifer, and that, Majors well is pumping water from Laguna Creek underflow during times of operation. Several complementary methods were used to test the hypothesis that Majors well is pumping water from Laguna creek. The work performed included a longitudinal profile survey, stream gauging, use of piezometers, a seepage bag meter test, and static and falling head tests. Results demonstrate that Laguna Creek is a naturally losing stream during the summer. During times of well operation, streamflow and head tests confirm that the well is drawing a greater than normal amount of water into the aquifer. Since Majors well is pumping water from Laguna Creek underflow the water extracted from the well could not exceed that of the diversion permit specifications and can not be utilized during summer months.

Introduction

The distribution of water as a resource is a controversial issue in the state of California. The abundance of California’s water lies in the north coast region. In recognition of the disparity between the north and the south, the central and southern regions of the state have always had challenges in water management. Regulatory efforts have focused on areas where water is scarce and population is increasing. Available water resources limit development in many areas of the central coast.

Two traditional methods for obtaining water have been to take water directly from a stream or to put a well into the ground and extract water from the aquifer underlying one’s property. Under post-1913 California water law, all forms of water extraction must be documented with the state or the county. Stringent guidelines have been set in order to assure that sufficient water is available for California.

Surface Water Policy

A riparian water right allows the owner of property that abuts a watercourse to divert water from the watershed for “reasonable and beneficial” use within the property limits
(Littleworth and Garner, 1995). The watercourse may not be altered by human means in order to
gain a riparian right, and is limited to property abutting the natural channel. Reasonable and
beneficial uses are not specifically defined, but the use must not affect the rights of other riparian
holders within the watershed. The right can not be gained or lost by use, or lack of, but is
attached to the property itself. With a riparian right, on-site water storage is acceptable for a
period not longer than 60 days and the water must be used on the property. If the diversion is not
for use within the property limits an appropriative right must be obtained from the California
State Water Resources Control Board (SWRCB). An appropriative water right would allow for
the diversion of water from the watercourse without owning property that abuts the watercourse.
Post-1913 appropriative rights allow for a specific allotment of water to be used for “reasonable
and beneficial” use in a specific location (Littleworth and Garner, 1995). If the amount of water
in the watershed is not sufficient for diversion, the appropriative right will be denied. The water
to which riparian and appropriative rights apply include (Cal. Const. Article X, 2):

- water found within a running stream or in a lake,
- water flowing in a natural channel,
- underground waters constituting a subterranean stream flowing through known and definite
  channels,
- spring waters; and,
- water in navigable and interstate streams.

Groundwater

Riparian and appropriative rights do not apply to groundwater or water that is presumed to be
percolating groundwater (Littleworth and Garner, 1995). If a well is pumping only groundwater,
then a new set of rules applies. All underground water other than underflow or underground
streams is presumed to be percolating waters (Water Codes 1200, 2500). California ground water
law follows the correlative rights and reasonable use doctrine. This doctrine allows the overlying
property owner a common right to the reasonable, beneficial use of the underlying water use on
his or her overlying land (Littleworth and Garner, 1995). Groundwater rights are not regulated
and no permit is required to drill a well and pump water from an underlying aquifer on the
premises of your own property. If a well lies in an aquifer that is fed by percolating groundwater,
use of the water on the premises would be permitted. If the water is to be transported off-site to
another location, an appropriative right for transfer of underground water must be filed with the state. If the well lies in an unconfined aquifer, which has a defined channel of flow or is attached to the stream and acts as a subterranean stream, then the water is subject to surface water law. This right to groundwater must be used for reasonable and beneficial use without harm incurred to other overlying landowners utilizing the aquifer. If an off-site well is unable to supply a sufficient quantity of water to the appropriator, the rights to the available water lay with the overlying landowners.

Stream-Aquifer interactions

Streams and aquifers are often closely related as demonstrated by Peterson and Wilson (Peterson and Wilson, 1988). In the case of an unconfined aquifer, the stream may be in direct contact with the underlying aquifer. There are four general types of stream-unconfined aquifer relationships (Figure 5):

- connected gaining streams;
- connected losing streams;
- disconnected streams with shallow water tables; and
- disconnected streams with deep water tables.

The terms connected and disconnected are used to describe the interrelation between the aquifer and the stream. The relationship between the stream and aquifer are also controlled by factors such as the ability of the stream to permeate into underlying material (hydraulic conductivity) and the geology underlying the stream. In a connected gaining stream, the stream is gaining water from the underlying aquifer. In a connected losing stream, the aquifer is in contact with the stream and pulling water from the stream. In disconnected streams, water is being pulled from the stream by the aquifer to replace lost storage capacity within the aquifer. As the distance between the stream and the aquifer increase, water pulled from the stream may increase as the aquifer tries to reach equilibrium with the stream. Again it is very important to understand that this is dependent upon the underlying geology. The geology that underlies a stream has a significant effect on how the stream and the aquifer may interact. If a clay layer lies below the streambed the aquifer percolation into the aquifer may be impeded, thus having a low hydrologic conductivity. If the underlying material is alluvium, greater hydrologic conductivity, stream
aquifer interactions may be enhanced. Thus knowing the geologic makeup of the underlying material can give great insight to the interaction occurring between the stream and the aquifer. Alluvial aquifers have a high capacity for storage and quickly recharge, even during low flow conditions. In looking at these basic principles it can be seen the stream and the aquifer may directly effect the other. If a well were to be drilled into an unconfined aquifer, it could potentially have a direct effect on the streams natural interaction with the aquifer. During well operation, the hydraulic head, decreases around the well, causing a horizontal hydraulic gradient towards the well (Freeze and Cherry, 1979). This horizontal gradient continues after pumping until the aquifer again achieves a new equilibrium.

*Laguna Creek Background*

Laguna Creek lies approximately 60 miles south of San Francisco and 10 miles west of the city of Santa Cruz (Figure 1). Laguna Creek provides water, not only for the residents of the watershed, but also for the people of Santa Cruz by way of an appropriative right for diversion held by the city of Santa Cruz. The creek drains into the Pacific Ocean and provides prime habitat for steelhead (*Oncorhynchus mykiss*). California red legged frogs (*Rana aurora draytonii*) are found within this watershed, along with tidewater gobies (*Eucyclogobius newberryi*), which reside within the watershed’s lagoon. Both of these species are listed as being both state and federally endangered species.

*Majors well*

Approximately 40 feet east of the incised channel of Laguna Creek lies a water well, referred to as “Majors well”. Many residents have wells placed in aquifers that are naturally contaminated with bituminous (asphaltic) deposits. These deposits have been found as close as 500 feet to the west of Majors well, on the other side of Laguna Creek (Figure 3). The asphalt contamination has deemed the wells useless, as the water can not be used for domestic or agricultural use. In 1985 a regional ground water study was performed and concluded that in the Majors-Laguna area, poor water quality would limit further groundwater development (Johnson, 1985). However, Majors well produces water that if free from contamination and is being used for human consumption and irrigation.
Stephenson Ranch Proposed Project

Majors well is currently being used for domestic purposes by the property owners. There has been a proposal for Majors well to supply the irrigation water for a nearby biomedical livestock operation and equestrian facility known as Stephenson Ranch. Stephenson Ranch lies less than 0.4 miles East of Laguna Creek (Figure 4). The Environmental Impact Report (EIR) for Stephenson Ranch includes a section on surface and groundwater quantity. The proposal for six 4795-gallon storage tanks on Stephenson Ranch would be supplemented by two other wells in the area along with a shared stream diversion in Laguna Creek. Within this section a diversion from Laguna Creek is addressed along with reference to Majors well and the possibility that it may be drawing water from Laguna Creek. Stephenson ranch holds an existing riparian water right permit with SWRCB, the permit allows for a surface water diversion from Laguna Creek to be taken for irrigation purposes from January 1 to May 1 with a maximum annual diversion of 26 acre feet per year. The permit is shared with another near by ranch and has another major condition, if a natural flow within Laguna Creek fall below 2.5 cubic feet per second, water diversion from the creek is prohibited. As it stands, the water being pumped from Majors well is presumed to be separate from the water in Laguna Creek. If Majors well is pumping from the creek, Stephenson ranch would be in violation of their annual allotment of water. If Majors well continues to be utilized, using water from Laguna Creek, the amount of water that would be needed to support even a small area could have a tremendous effect on Laguna Creek’s meager flow. If the well is pumping from the stream and the stream is naturally losing water into its aquifer, irrigation by means of Majors well during low flow conditions could possibly create a dry streambed. Furthermore by inhibiting a sufficient flow of water, the watersheds lagoon may fail to convert to fresh water during summer months thus changing the natural balance that the lagoon maintains. Lack of flow could possibly affect the downstream vegetation and aquifer recharge that the stream provides and maintains.

Stakeholders

Many parties have taken interest in Stephenson ranch and the proposal to use Majors well to supply the ranch with water. If Majors well is pumping water from Laguna Creek or from its underflow, Stephenson ranch could be subject to National Marine Fisheries Endangered Species Act 4-D rules. Under the new regulations, salmonid habitat, including steelhead, may not be
altered in any way that would have an effect on the population. This includes draining, diverting, or altering stream channel, ground or surface flow. Therefore being subject to these rules, Stephenson Ranch would not be allowed to utilize Majors well.

California Department of Fish and Game is interested in examining if the well is pumping water from the stream and the possible impacts on the species that utilize the streams water. These species include but are not limited to steelhead, California red legged frogs, and the tidewater goby.

The County of Santa Cruz and State Water Resources Control Board (SWRCB) are interested in the water rights aspect of the project. Stephenson Ranch already shares a riparian right with a neighboring agricultural area. This right allows them to withdraw a specific allotment of water from Laguna Creek. As it stands now, the water from Majors well is presumed to be disconnected from that of Laguna Creek. Thus the water would fall under groundwater rights and able to be used for reasonable and beneficial use, including storage within the new proposed water tanks on Stephenson Ranch.

Hypothesis

The goal of this capstone is to test the hypothesis that Laguna Creek and Majors well are connected to the same unconfined aquifer, and that Majors well is pumping water from Laguna Creek underflow.

Site Description

Laguna Creek lies approximately 60 miles south of San Francisco and 10 miles west of the city of Santa Cruz. The creek drains approximately 750 square miles of the Santa Cruz Mountains. The creek is characteristic of a single entrenched channel which meanders through the narrow valley floor. In the study area, a riparian corridor ranged from 3 to 15 feet in width (Figure 4).

Majors well is 65 feet deep and screened for water intake from 30 to 65 feet (Figure 2). The well driller's log states that the well is drilled into alluvial material (DWR No. 056786). There is controversy regarding the underlying geology surrounding Majors Well. The well driller's log states that Majors well is drilled into alluvial material (DWR No. 056786). This is confirmed by a study done by the Department of the Interior, United States Geological Survey.
(Akers and Jackson, 1977 and Clark, J.G., 1981). There is little controversy as to what material the well is drilled into, but much controversy regarding if the well lies in the same aquifer that is connected to Laguna Creek.

Methods

Sampling Methods

Several complementary methods were used to test the hypothesis that Majors well is pumping water from Laguna creek. The work performed included a longitudinal profile survey, stream gauging, piezometers, a seepage bag meter test, and static and falling head tests. All measurements were conducted around mid-day. The study area extended approximately 311 meters above the old Highway 1 bridge at Laguna creek and approximately 117 meters below the bridge (Figure 4). Access to the site was limited in that it lies on private land, all surveys were performed while hiking in the stream, without notification to landowners.

A longitudinal profile was performed in order to calculate the slope of the stream and aid in site assessment for stream discharge and other measurements.

Discharge was measured taken during summer months when stream flows were at their annual lows. Measurements were taken at five sites within the stream between June 13, 2000 and September 22, 2000 (Figure 4). Measurements were obtained during 4 days with the well being on and 3 days with the well being off. Discharge was measured to determine whether a loss or gain in discharge occurring in the stream over the study area. Poles were placed in each bank and a tape measure was stretched from one bank to the other. Velocity was measured with a Flowmate 2000 portable flowmeter. Stream depth and velocity were measured at increments of every 0.5 feet beginning from the right banks (looking down stream) wetted edge and recorded at each increment. Velocity was measured by taking 60 percent of the depth for each increment.

Discharge at each station was calculated using \( Q = \Sigma (V \times A) \) (Dunne and Leopold, 1943).

Where,
\[ Q = \text{discharge (ft}^3 \text{sec)} \]
$V = \text{velocity (ft/sec)}$

$A = \text{area (ft}^2\text{)}$

Piezometers are used to measure the hydraulic head in an area where the underlying alluvium is saturated (Lee and Cherry, 1978). My intent was to use the piezometers to measure the hydrologic gradient around the well. Miniature piezometers as described by Lee and Cherry, were placed in the streambed above, below, and next to the well (Figure 4) and were observed over timed intervals during known well operation and non-operation to test for stream drawdown (Lee and Cherry, 1978). Data was recorded during 6 days of well operation and 3 days of non-operation. At each location two piezometers were placed within the streambed. One piezometer was placed 3 inches below streambed (shallow), while the other was placed 33 inches below the streambed (deep). The two piezometers were attached to a manometer in order to detect changes in head differences between the shallow and deep piezometers. The manometer was purged of excess air, allowing the water levels of each piezometer to rise slowly in order to achieve a static level. The levels within the two tubes were measured at the beginning of a timed interval and re-measured again at the end of the timed interval. Change in the head was recorded for the specified time interval. The hydraulic gradient can be determined by finding the change in head / depth of the piezometer below the streambed (Lee and Cherry, 1978).

A falling head test was performed over timed intervals in order to measure the hydraulic conductivity of the sediment underlying the stream (Lee, 1977 and 1978). The falling head test was performed with the existing piezometers from the differential head test at the site near the well. Two piezometers were placed within the streambed, one placed 3 inches below streambed (shallow), and the other 33 inches below the streambed (deep). For the falling head test the piezometers tube was extended vertically above the stream and marked with a one-meter interval, the tube was filled with water and then stopped. The time for the water level to pass the two points was timed with a stopwatch and recorded. The test was repeated 3 times at each site. Results may be found within the appendix.

Constant head tests were performed over timed intervals in order to measure the saturated hydraulic conductivity of the sediment underlying the stream (Lee, 1977). The constant head test
was performed at the piezometer placement near the well. For the constant head test, a known amount of water was placed in a bag. A piezometers was placed within the streambed 33 inches below the streambed (deep). The piezometer tube was purged of air using a siphon. The bag was then attached to the piezometer and submerged for a known period of time. The change of volume within the bag was re-measured and recorded. Results may be found within the appendix. The Hvorslev hydraulic conductivity equation for saturated conditions was used.

\[ K_s = q \ln \left[ \frac{(L/D) + (1 + (L/D)^2)^{1/2}}{2\pi L H_c} \right] \]

Where
- \( q \) = discharge of water
- \( D \) = diameter, intake (cm)
- \( L \) = length, intake (cm)
- \( ln = 2.3 \log 10 \)
- \( H_c \) = constant piezometric head
- \( t \) = time

Using a seepage meter, flux between the aquifer and the stream could be measured (Lee and Cherry, 1978). The seepage meter was placed in the streambed adjacent to the well. Using a 5-gallon bucket with an outlet on top, the bucket is pushed, open end, into the streambed and purged of air. A known amount of water is then added to a bag, purged of air and attached to the outlet on the top of the bucket. After the timed interval, the volume of the bag is re-measured and recorded. Results may be found in the appendix. The Darcy velocity equation was used to determine seepage flux:

\[ Q = \frac{\text{volume change, cm}^3}{\text{elapsed time, min}} \]

Where
- \( Q \) = discharge (cm\(^3\)/s)

Hydraulic conductivity equation using seepage meter:

\[ K = \frac{Q}{S} \]

Where \( S \) = hydraulic gradient

\( K \) = hydraulic conductivity
Results

Stream discharge for each of the sampling sites are listed in Table 1 below. Also shown below in Table 1 is the cumulative loss for sites B through D and if the well was in operation or not. Results on September 22 were recorded during a rainy day. As discharge from site E to site D increases, it is representative of a gaining reach. As discharge from site D to site B decreases, it is representative of a losing reach.

Table 1 Stream Discharge

<table>
<thead>
<tr>
<th>Site</th>
<th>Discharge (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13-Jun</td>
</tr>
<tr>
<td>Well Loss from D to B</td>
<td></td>
</tr>
<tr>
<td>B (Downstream of well)</td>
<td>0.22</td>
</tr>
<tr>
<td>C (at well)</td>
<td>0.81</td>
</tr>
<tr>
<td>D (Upstream of Well)</td>
<td>0.92</td>
</tr>
<tr>
<td>E</td>
<td>1.03</td>
</tr>
<tr>
<td></td>
<td>0.77</td>
</tr>
</tbody>
</table>

Piezometric readings are listed below in Table 2. Values indicate the flow in cubic centimeters from the shallow piezometer to the deep piezometer. The greater the flow from the shallow piezometer to deep piezometer, the greater the amount of drawdown. When well is off, no significant difference between shallow and deep. When well in operation a significant loss in head occurs in the deep piezometer.

Table 2 Differential Head

<table>
<thead>
<tr>
<th>Site</th>
<th>Change in Head From Shallow to Deep Piez (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream</td>
<td>0.6</td>
</tr>
<tr>
<td>Near Well</td>
<td>0.7</td>
</tr>
<tr>
<td>Upstream</td>
<td>0.1</td>
</tr>
<tr>
<td>Well</td>
<td>on</td>
</tr>
</tbody>
</table>
Discussion

My hypothesis was that Majors well is pumping water from Laguna Creek. It was predicted that during times of well operation, a decrease in streamflow would occur. Streamflows show that the creek has a gaining reach, above the well, from site E to site D. From site D to site B the creek is losing. Streamflows are consistent in that, the stream is a gaining stream and then turns into a losing stream regardless of whether the pump is in operation or not. This could be attributed to the natural process of the stream or that water is being drawn down into the aquifer for recharge in order to attain its equilibrium point again. Discharge loss could also be a result of vegetation within the riparian zone pulling water during low flow conditions. Another hypothesis is that Laguna Creek could have been a gaining stream that has turned into a losing stream due to prolonged pumping. A net loss in streamflow during times of well operation suggests that Majors well is pumping a minimal amount of water from Laguna Creek. When the well is on, piezometers demonstrate (table 2) an increase in the downward hydraulic gradient, this is demonstrated by the flow of water from the shallow piezometer to the deep piezometer. These results demonstrate that the well may be pulling water from the stream into the aquifer. Duration of pumping is unknown, but can be assumed that as time of pumping increases, the cone of depression will increase. Increase of the cone of depression is shown by the flow of water from the shallow piezometer to the deep piezometer at the sites above and below the well. As the size of the cone of depression increases, the amount of water being pulled into the aquifer increases. The data from the falling head test suggests that the material underlying the streambed has a high hydraulic infiltration. The high hydraulic infiltration would tend to be representative of an area with a close stream aquifer exchange relationship.

Loss due to a leaky aquifer could demonstrate a net loss in discharge. It is quite normal for an aquifer to receive a significant amount of recharge from adjacent aquifers (Freeze and Cherry, 1979). If Majors well is drilled into a different aquifer than that underlying Laguna Creek, water from Laguna Creek may be partially fed into the adjacent aquifer where Majors well is drilled. A leak in the aquitard between the two could demonstrate a loss in flow and head during pumping.

Alternative methods for assessment
In order to make a more accurate assessment and quantification of the well-stream interactions that are occurring, a well pump test including a falling head test within the well could prove beneficial. If these tests are performed it is imperative that a log of operation be obtained prior to the tests. It would be possible to pump the well for a long period in order to draw the aquifer down to a point that a pump test could show no change during pumping. With these results, it could be determined that the well has no effect on the stream, when there is a significant effect.

A dye or tracer test could be performed, where dye could be injected into the streambed and the well would be turned on. The presence of the dye or tracer material in the pumped well water could conclude that the well is extracting water from the creek. This test is best performed where the underlying material in the stream has a high conductivity.

Looking at the chemistry of the water is another option, but has high costs involved in the process. By looking at the water chemistry of the creek and the water chemistry coming from the well, one could identify if the two are from the same source, or if the well is pumping from a different aquifer.

**Policy Discussion**

Since the results have strongly suggest that Majors well is connected to the same aquifer as Laguna Creek and that the well is pulling water from creek, the well is subject to surface water rights. Within the existing water right permit, Stephenson Ranch is allotted 26-acre feet per year. Combined extraction between the shared surface diversion and Majors well can not exceed this amount. Also, since the well would be subject to surface water rights, it’s use is limited to the existing right which allows diversion from January 1 to May 1. In addition, if the discharge of the creek falls below 2.5 cubic feet per second, no more water may be extracted from Laguna Creek. Since the creeks discharge was measured at less than one cubic foot per second and the well was in operation during summer months, loss of the shared riparian right could be mandated by the SWRCB.

In a similar case the Garrapata Water Company in Big Sur lost the right to utilize water from a well that was drilled adjacent to the incised channel of Garrapata Creek. The company was utilizing a shallow well for allocation to off-site residences. Studies determined that the aquifer in which the well was drilled was fed directly by streamflow from Garrapata Creek. The
shallow well was extracting water from the alluvium of Garrapata Creek. The suit was filed by California Department of Fish and Game and then passed to California State Water Resources Control Board. The suit is still tied up in the court system, regarding whether the company should be able to exercise their riparian right to the water and how much water should be allocated under the riparian right.

Since Majors well is drawing water from Laguna Creek, proposal to utilize the well by Stephenson Ranch is also subject to the National Marine Fisheries Endangered Species Act 4-D rules. Since the flow of water that is utilized by Steelhead, the flow of the stream may not be drained, diverted, or altered.

Final Conclusion

This study has demonstrated that Majors well is connected to Laguna Creek. During times of pumping there is a net loss in streamflow, greater than that of normal conditions.
Literature Cited


9. Page, B.M., and Holmes, D.N., 1945, Bituminous Sandstone Deposits Near Santa Cruz, Santa Cruz County, California, USGS Oil and Gas Investigations Preliminary Map 27.

Figure 1 Map showing Laguna Creek in relation to Santa Cruz and San Jose. Map by Expedia Maps, 2000.

Figure 2 Well schematic demonstrating Majors well in relation to Laguna Creek.
Figure 3 Geologic map showing bituminous in the Majors-Laguna area. Map by Page and Holmes, 1945.
Figure 4 Piezometer placement and discharge measurement stations including Stephenson Ranch. Green dots indicate location of discharge measurements. Yellow dots indicate piezometer placement.
Figure 5: General stream-aquifer interactions. From Peterson and Wilson, 1988.
Appendix

Falling head test results are listed below in table 1. The study was performed on June 21 while the well was not operating. Fall times between the deep and shallow piezometers varied by 2.25 seconds, but still demonstrates a high hydraulic infiltration.

Table 3 Falling Head Test

<table>
<thead>
<tr>
<th>Replicate</th>
<th>1 meter fall time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep (x1)</td>
<td>0.46, 0.50, 0.55</td>
</tr>
<tr>
<td>x2</td>
<td></td>
</tr>
<tr>
<td>x3</td>
<td></td>
</tr>
<tr>
<td>Shallow...</td>
<td></td>
</tr>
<tr>
<td>x2</td>
<td></td>
</tr>
<tr>
<td>x3</td>
<td></td>
</tr>
</tbody>
</table>

Expressed in cm/s

- □ Downstream
- □ At Well
- □ Upstream
Constant head test results are listed below in table 4. The test performed on June 21 was performed with the off. Loss in volume was greater on July 14, when the well was in operation. Failure to properly acquire data could be the result of the type of bag used in the field. On the first attempt the bag seemed to be too rigid, not allowing flux between the bag and the piezometer. On the second attempt the bag seemed to be too soft, thus being affected by the flow of water from the stream. Experimentation with bag types should be performed before repeating this test in the field. Result can be found in appendix.

Table 4 Constant Head Test

<table>
<thead>
<tr>
<th>Loss (c.c/hr)</th>
<th>21-Jun</th>
<th>14-Jul</th>
</tr>
</thead>
<tbody>
<tr>
<td>67.57</td>
<td></td>
<td>93.33</td>
</tr>
</tbody>
</table>

Seepage meter test results are listed below in table 5. Failure to properly acquire data may be a result of the bag type. On 6-21-00 the bag seemed to rigid to allow flux between the bag and the aquifer. On 7-14-00, the bag seemed too soft and was easily influenced by handling and flow of water over the bag while in the stream. Experimentation with bag types should be performed before trying to replicate test.

Table 5 Seepage Meter Test

<table>
<thead>
<tr>
<th>Volume (c.c)</th>
<th>1200</th>
<th>1000</th>
<th>800</th>
<th>600</th>
<th>400</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (min)</td>
<td>0</td>
<td>50</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 8/21/00
- 7/14/00