Case Study
Casing Path Well – An Effective Method to Deal with Cascading Water

Executive Summary

Air entrainment can be a serious problem with the potential to seriously affect a well's production capacity and the efficiency of its pumping equipment. In a typical air entrainment scenario, water enters the well from an aquifer and cascades downward when the pumping water level is below the top of the well screen. The cascading water entrains air during its freefall and causes the pump to cavitate as the mixture of air and water passes the pump impeller. Cascading water and entrained air can be controlled by using the casing path well design. This unique approach has been shown to be very effective in many areas within the Southwest.

Background

In the 1980's well owners and operators in California's San Joaquin Valley began to notice that many water wells were losing production and also pumping water with entrained air. At that time (as now), it was not uncommon to pump water from shallow, unconfined aquifers and deep, confined aquifers in the same well. During that period, as demand increased for agricultural water in the Valley there was a marked decline in ground water recharge caused by reduced rainfall. These man-made and hydrologic conditions directly resulted in the lowering of ground water levels in many areas of the Valley. As static water levels declined in the Valley, pumping water levels in many wells were lowered below the top of the well screens. Consequently, as water entered the wells it would cascade downward and in doing so, air became entrained.

Entrained Air

Entrained air occurs in a well when the pumping level is lowered such that it produces a significant difference between the water level in the well and the water level in the adjacent aquifer. When this occurs, a seepage face is created between the saturated aquifer(s) exposed to the air space between the screened section(s) of the well. As the water enters the well it cascades, i.e., falls, downward to the pumping level. As it does so, air is entrained in the water. Then, when the well is pumped, the entrained air can cause the pump to cavitate and the discharge water with air.

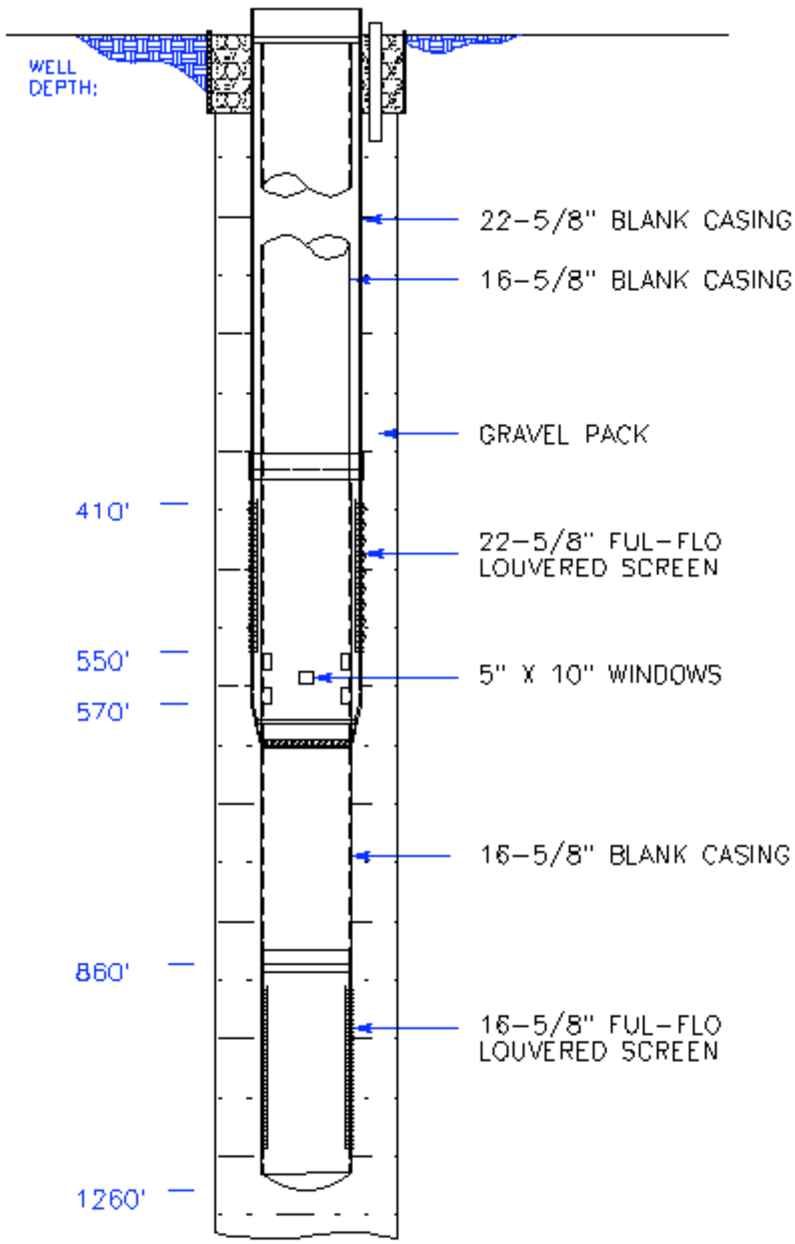
Casing Path Well Design

A casing path well is designed to allow for concurrent production from a shallow aquifer and depth aquifer. Figure 1 is a typical casing path well design showing its key components, which consist of:

1. An upper exterior casing/screen segment that is installed within the upper aquifer zone;
2. A short reducer connected to the upper segment;
3. A lower casing/screen segment that is installed within the lower aquifer zone;
4. An interior casing sized to accommodate the pump bowls; and

5. Upper and lower seals between inner and outer casings.

Figure 1 – Typical Casing Path Well Design



In the example shown above, the 22-inch diameter upper casing/screen is attached to a reducer that provides the transition piece between the 22-inch casing and 16-inch casing below it. The reducer is installed below the upper aquifer and also below the deepest anticipated setting for the pump. Both are vitally important considerations in the final design. The diameter of the inner casing should be from 4 to 6 inches smaller than the inside diameter of the outer casing to avoid "stacking" water in the chamber and to maximize the efficiency of the well. If water is unable to flow freely from the chamber into the well, it will begin to accumulate and "stack" in the chamber; if this occurs, there will be a noticeable loss of production capacity. Figure 1 shows that the bottom 20 feet of the inner casing has a number of 5"x10" portals which allow water to flow from the chamber to the inner casing. The base of the inner liner is fitted with a hard rubber perimeter band that seats in the reducer and seals the lower end of the annular chamber. A similar upper seal is installed at ground level to complete the closure of the annular chamber.

The annular space between the borehole wall and casing/screen is completed in a "conventional" manner. That is, it is filled with select gravel that is appropriately graded for the aquifers. The slot size of the well screens is then selected to retain the desired fraction of the gravel pack. A cement fill to ground level is recommended to provide sanitary protection and to preclude air from entering the upper casing through the screen.

Theory of the Casing Path Well

Figure 2 shows a laboratory setup that helps to explain how water flows from the upper aquifer into the well.

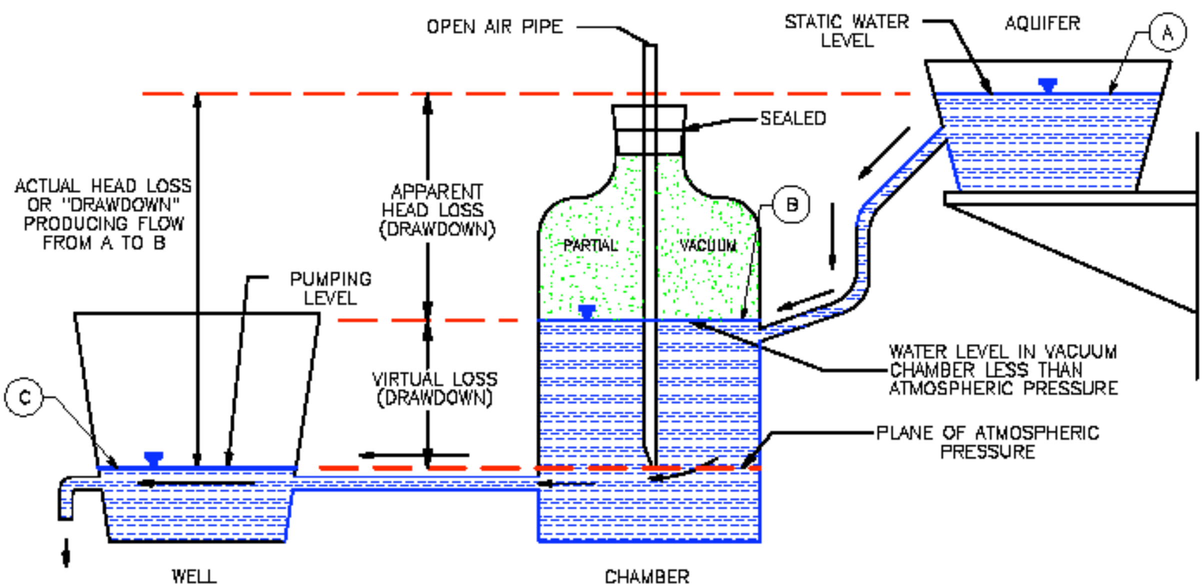


Figure 2 – Simulated Flow Path of the Casing Path Well

From the aquifer (A), water flows through gravel pack and passes through the exterior casing via the wells screen and finally into the annular space (represented above by the chamber). Note that the chamber is sealed, as would be the annular space. The sealed chamber is under a partial vacuum. When water flows from the aquifer (A) into the inner chamber, the water level (B) in the chamber appears at an elevation higher than it should be by elevation differences alone. This is shown as apparent head loss. If one were to insert a tube (open to the atmosphere) into the chamber, the water level would be measured at the pumping level in the well (C).

A unique feature of the casing path well design is the flow of water from the upper aquifer into the inner chamber. The partial vacuum created in the annular chamber provides suction that draws water from the aquifer into the well. If the partial vacuum is disrupted by opening the chamber to atmospheric pressure, the water level in the chamber will stabilize at the pumping level in the well.

Design Approach

The design approach for a casing path well differs little from that of a conventional well. In general, the basic steps are:

1. Identify the depth intervals of the upper and lower aquifers, and the depth of the confining zone above the lower aquifer. These parameters are used to define the settings of the upper screen, lower screen and reducer, respectively.
2. Estimate the anticipated well yield and maximum pump setting.
3. Select the appropriate diameter of the inner casing to accommodate the pump bowls.
4. Determine the wall thickness, strength requirements, and steel type for the casing and screen to meet the proposed design and site conditions.
5. Select the gravel pack gradation for the aquifer materials.
6. Select the slot opening for the well screen to retain the gravel.

Construction Phase

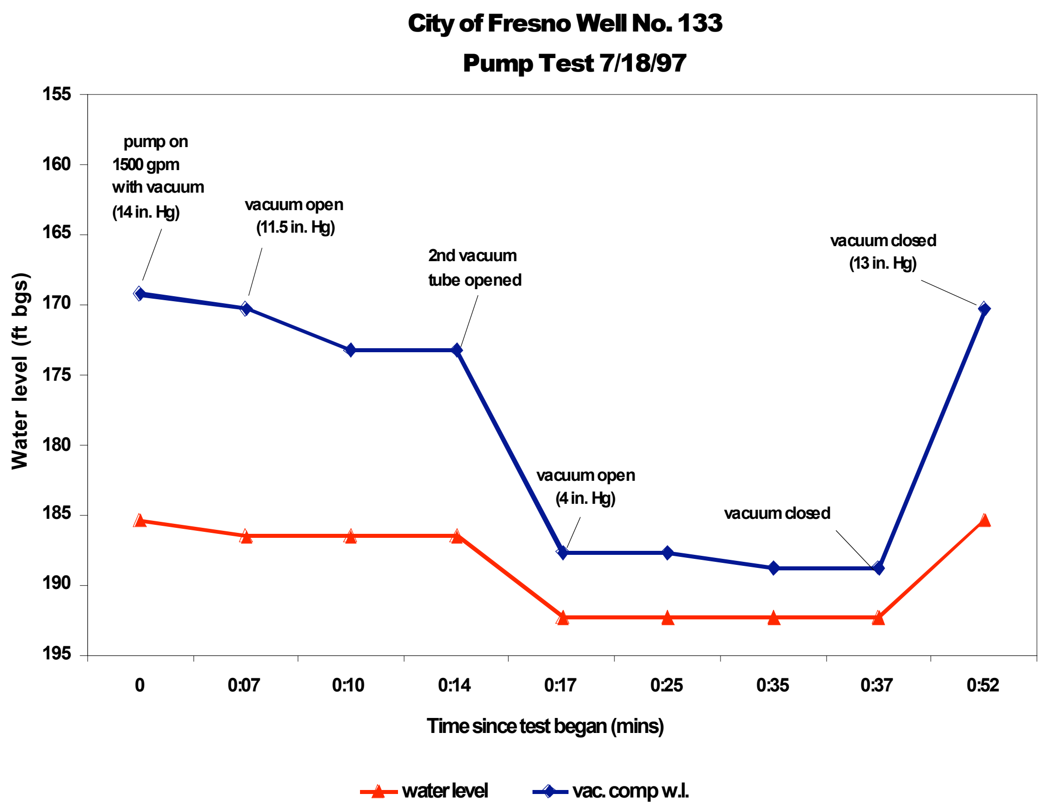
The drilling and construction methods a casing path well are essential those that apply to a conventional well. Similarly, final design decisions are generally made in the field with information obtained during the drilling of the borehole. A carefully prepared lithologic log and a suite of geophysical logs are needed to determine the thickness and depth of the upper and lower aquifers and confining zone(s). Samples collected during drilling should be analyzed to determine the gradation of the aquifer materials. The sieve results are used to finalize the gravel pack design and to select the slot size for the well screen.

Well casing and screen are installed in a conventional manner. That is, the exterior casing and screen (with reducer seating seal) are lowered into the borehole and set into place. After this is completed, the gravel pack and cement seal are placed via a construction tremie pipe. With those tasks completed, the next step is development of the well. It is important to note that the inner liner would still not have been installed.

Initial development of the well is conducted by mechanical methods, e.g., swabbing, bailing, and airlifting. This phase of development is followed by development pumping and backwashing with the test pump. When development pumping is completed, the well can be test pumped. However, some owners prefer to conduct the pumping test with the liner in place. If that is to be done, then the test pump has to be removed after development pumping. The contractor would then install the liner, seal the chamber, and conduct the pumping test. The second option makes it possible to measure the vacuum pressure and pumping rate throughout the test. These data would be useful to have for future reference.

Case Study

The City of Fresno has installed several casing path wells. Well No. 133 was pump tested in 1997 and provided some interesting results from the short-duration pumping test that was performed. Figure 3 shows the changes in vacuum pressure, production rate and water levels that were measured. The test results show the correlative relationship between these three parameters. The City reported that the wells have a history of good performance and have been shown to be effective at controlling entrained air in its wells.



Summary

Casing path wells have been successfully designed and constructed in various hydrogeologic environments throughout the Southwestern United States. This design has been shown to provide a viable approach to control entrained air in municipal, agricultural and industrial high-capacity water wells. The construction methods used for casing path wells present no unique or major challenges. Furthermore, the wells are installed using presently available technology and equipment that are standard to the water development industry. Water purveyors that currently operate casing path wells have reported that these wells have been shown to be effective, efficient and highly productive facilities.

References

“Handbook of Ground Water Development, 1990. Roscoe Moss Company.
“A Report on Casing Path Wells”, 1985. Dennis E. Williams, Ph.D.
City of Fresno, 2004. Personal communication.