Johnson Screens

A brand of
Aqseptence Group

# Water Well Screens and Well Efficiencies Designing an Efficient Well

Efficiency in any system is defined as the ratio of the effective output to the total input. In machines, it is determined by comparing the effective work to the energy expended in producing it. The importance of efficiency has increased mainly from the rising prices of fossil fuels. This has caused a much greater awareness of the importance of efficiency in products we use every day, such as cars, furnaces and air conditioners, to name a few.

**Greater awareness of well efficiency can reduce pumping costs**

Efficiency has always been a major concern in the water well industry, but in the past, this concern has focused only on pumping equipment. Pump efficiencies can be easily calculated and most pump manufacturers make this information available to their customers. Well efficiency, on the other hand, is rarely calculated even though it plays a large role in pumping costs.

Well efficiency has been ignored because it is difficult to quantify. Many variables affect well efficiency, including the drilling procedure, screen design, filter pack size and development methods.

Well efficiency can be more important than pump efficiency in reducing pumping costs. There are thousands of irrigation wells operating today that have efficiencies as low as 35 to 50 percent. If these had been properly designed and constructed, they could have been operating at efficiencies of 80 percent or better. Unfortunately, the major emphasis was placed on comparing the efficiencies of pumps which may vary by only a few percentage points.

# Observation Wells

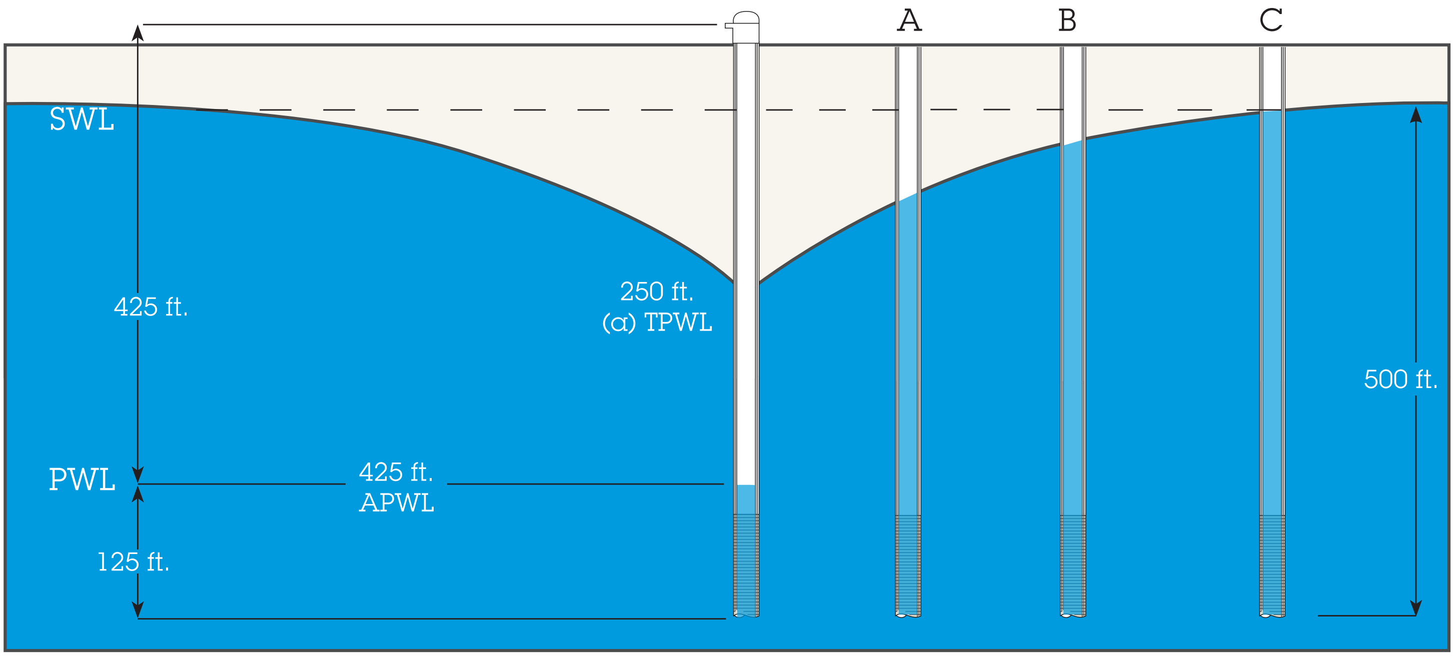



**Figure 1:** When a pump is turned on, lower pressure in the vicinity of the well causes water to flow toward it from the surrounding formation. The difference between the pumping water level in the well and the static water level is called drawdown. Since this diminishes with distance from the well, a cone shape is produced called the cone of depression.

# Operating a Well

## The principles of efficient well operation

Before well efficiency can be explained, it is important to understand how a well operates. In any non-pumping well, the water will stand at the static water level (SWL). When the pump is turned on, it creates lower pressure in the vicinity of the well. For example, in Figure 1, 500 ft. of water (head) exists in observation well "C" and only 125 ft. of head exists in the pumping well at the point of maximum pressure reduction. Thus, the water flows toward the region of lower pressure. When a well is pumped, the SWL inside the casing drops to the pumping water level (PWL). The decrease in the PWL depends on the pumping rate. The difference between the static water level and the pumping water level is called drawdown. The drawdown is greatest within the well casing itself and becomes less as the distance from the well increases. When shown in a line drawing, the drawdown is cone-shaped and is called the cone of depression.

The shape of the cone of depression is dependent on the permeability (hydraulic conductivity) of the formation, how easily the water can flow through the formation. If the formation is coarse grained, the water will flow easily toward the well. The head required to move water through this type of formation is small, causing little drawdown. The cone of depression, however, will extend relatively far from the well (Figure 2). If the formation material is very fine or contains much silt or clay, it will have a much lower permeability. This requires more head to move the water and causes greater drawdown in the well. In this case, the cone of depression does not extend as far from the well (Figure 3).

## The pumping test

The shape of the cone of depression can actually be measured during a properly conducted pumping test. A minimum of one observation well is required to secure the necessary data. During a pumping test, the well is pumped for several hours or days, at a constant pumping rate, to determine drawdown in the pumped well and the observation wells. This information is plotted and the shape of the cone of depression is determined. The pumping water level is obtained and the theoretical drawdown is calculated.

## Efficiency calculation

In an actual field situation, the pumping water level inside the well casing (actual) is rarely equal to that just outside the casing (theoretical) due to head losses through screens, gravel packs, etc. Well efficiency is then calculated by dividing the theoretical drawdown obtained graphically by the actual drawdown measured in the well. For example, in Figure 1, the cone of depression at point (a) is 250 ft. deep, so the theoretical drawdown is 200 ft. (250 ft. - 50 ft. SWL). The actual drawdown is 375 ft., the PWL 425 ft. - 50 ft. SWL.

The efficiency of the well can thus be calculated as follows:

$$\frac{\textbf{Theoretical drawdown}}{\textbf{Actual drawdown}} = \textbf{Well Efficiency}$$

$$\textbf{Example: } \frac{\textbf{200 ft.}}{\textbf{375 ft.}} = \textbf{53\%}$$

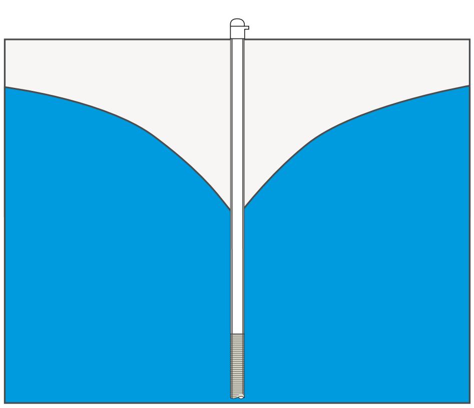


**Figure 2:** Water moves easily through highly permeable formations resulting in a flat cone of depression extending relatively far from the well.

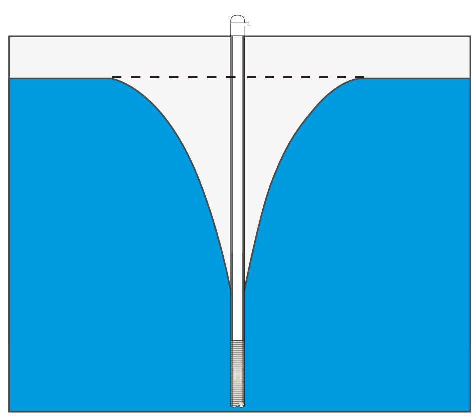


**Figure 3:** Wells in low permeability formations have greater drawdown and the cone of depression does not extend as far from the well.

# Inefficiency Causes

There are several factors that singly or collectively result in inefficient wells.

### Drilling Process

In any drilling procedure, the permeability around the borehole is reduced. Compaction and clay smearing occur in the cable tool drilling method. Drilling fluid infiltration plugs the aquifer when the direct rotary method is used and silty and dirty water often clog the aquifer in the reverse rotary drilling method.

When the permeability is reduced, more pressure (head) is required to move water into the well. This extra pressure increases drawdown and results in an inefficient well.

### Development

There are two basic reasons for development. First, the material that plugged the aquifer during the drilling process must be removed. Second, the smaller particles in the natural formation must be removed to increase the permeability near the borehole.

Several development methods are used, depending on the equipment available to the driller and the type of formation. One of the less effective – but commonly used – methods is over-pumping the well. Here, water flows in one direction only – toward the well. The flow velocities are generally not fast enough to remove much of the fine material plugging the formation.

During over-pumping, a surging action can be created by periodically shutting off the pump and allowing the water in the pump column to flow back into the well. This is more effective than over-pumping. However, water will re-enter the most permeable parts of the formation or those that have been least damaged during well construction. The portion of the formation that requires the most active development is largely excluded.

Another form of development is the surge block method. The surge block is a solid tool constructed with a slightly smaller outside dimension than the inside diameter of the casing and/or well screen and is generally used with a cable tool rig.

Because of the up and down motion with this type of machine, the up stroke draws water and fines into the screen by suction and the down stroke forces water out into the formation. Since it is somewhat difficult to adapt this type of tool to rotary drilling machines, the surge block method is not used as widely as it once was.

The most efficient form of development is the use of high velocity water jetting in sandy formation. In this method, water is jetted at high pressure (150 to 400+ psi) through the screen into the formation using pipe that has 2 - 4 nozzles that fit just inside the screen. Sediment within 12 in. around the screen can be disturbed by the jetting and fine material is put into suspension.

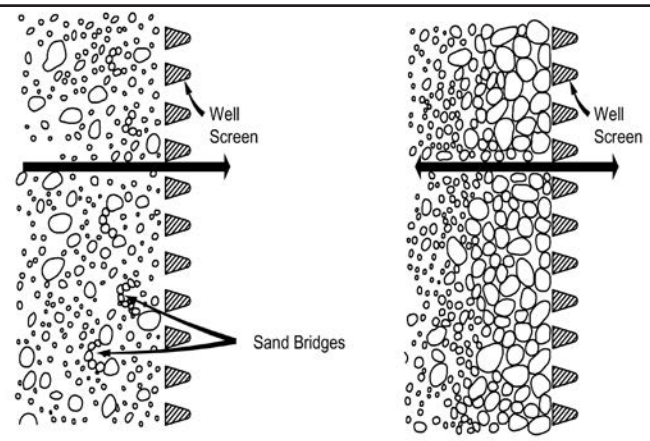
To remove this fine suspended material, the well should be air lift pumped simultaneously with the jetting procedure. The pumping rate should be substantially greater than the rate at which water is injected into the well by the jetting tool. High velocity jetting is the most successful type of development because it can be totally localized to an area of the formation that needs the development, and the fine material placed into suspension is quickly removed from the well.

### Filter Pack

A good filter pack provides a zone around the screen that is of a higher permeability than the natural formation. This allows maximum flow to the well and provides easy access to the formation for development. It is essential that the filter pack consists of well rounded, uniformly graded material and is properly sized according to samples of the natural formation.

Proper sizing assures the filter pack will physically restrict the natural formation (sand-free production), yet provide optimum permeability.

The effectiveness of developing a filter pack is not only a factor of the amount of open area in a screen, but also borehole diameter/filter pack thickness. In general, filter pack thickness should not exceed 5 in., because a thicker filter pack is difficult to develop and a filter pack of less than 2 in. is difficult to place without bridging around a screen. In fact, the recommended thickness of gravel pack is 3 to 5 in., allowing the natural formation just beyond the filter pack to be effectively developed, yet placed completely around the screen. For example, if 16 in. casing is used, the maximum borehole diameter should be 22 to 26 in.




**Effective development requires movement of fluid in both directions through screen openings (right side). Movement in only one direction (left side) does not produce the proper development effect.**

# Screen Design

Screen design is, without question, the most important factor in producing an efficient well. The well screen should be designed to serve two basic purposes: permit unobstructed entry of water into the well and allow access to the formation for development procedures. To serve these purposes, the screen should have the largest possible open area consistent with strength requirements. The openings should be uniformly arranged so that water flowing through the horizontal lenses of the formation can enter the screen directly and the entire formation can be reached during development.

The continuous slot wire-wrap screen is the dominant screen type used in the water well industry. An advantage of wire-wrap screens is the spacing of individual slots can be varied during fabrication. In fact, a single section of screen can be made with many different slot sizes, if geologic conditions require these variations in a screen's construction. Such screens enable the maximum use of the hydraulic conductivity of each stratum to allow pumping at a maximum rate and not exceeding inflow velocities through the screen of 0.1 ft./sec., resulting in laminar flow through the screen and reduced drawdown.

Well operational cost is directly related to drawdown, and continuous slot screens have the least drawdown during pumping. Low open area screens such as louvers, bridge and mill slot screens typically have less open area and might be less expensive per ft., but the long-term operational cost usually exceeds the difference in price between this type of well and a continuous slot well.

Over the life of a typical high capacity well, the operational savings might amount to 50 percent of the total operating cost or more. Each slot opening between adjacent wires is V-shaped. The V-shaped openings, designed to be non-clogging, are narrowest at the outer face and widen inwardly. Particles larger than the slot size are retained outside the screen and sand grains that pass through the opening enter the screen without becoming wedged in the slot. In screens with cut slots, the entering particles can turn or twist and become lodged in the slots, which can reduce the available intake area considerably and cause either lower yield or greater drawdown, increasing pumping costs (Figure 4).

If the screen has a smaller open area as in louvered, bridge and mill slotted pipe, the action from any development method is reduced because 95 to 97 percent of the screen is blank pipe (Figure 4 and 5). Therefore, most of the aquifer remains untouched by the development procedure.

Louver or bridge slot screens have more open area than slotted or perforated pipe. However, the slot configuration diverts the flow of incoming water (causing greater head losses through the screen) and restricts the development of the formation (Figure 5).

Continuous slot, V-shaped wire screens permit water to enter the well along the entire screen and allow maximum access to the water bearing formation so that proper development can take place (Figure 6). Low head losses through the screen and proper development guarantee the owner the most efficient well possible.

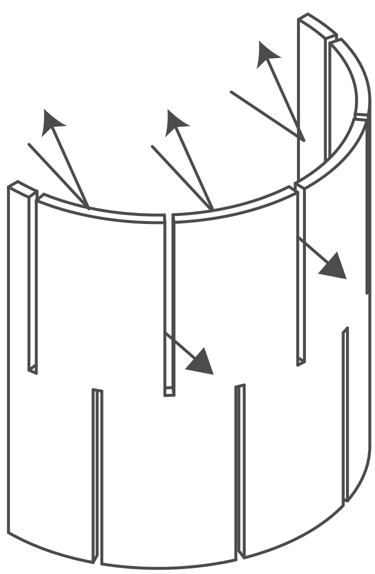


**Figure 4:** Development through slotted or perforated pipe is inadequate because severely limited open area in the pipe does not allow access to the formation.

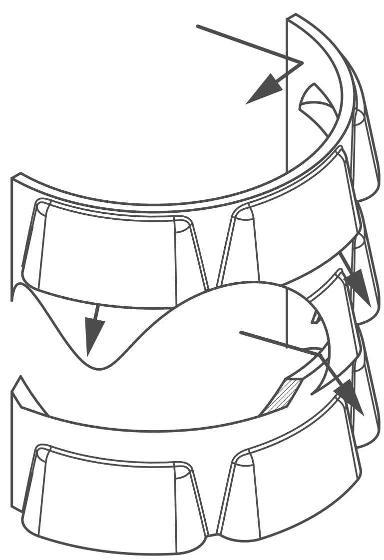


**Figure 5:** Louver or bridge slot type screens have more open area than slotted pipe, but the slot configuration diverts incoming flow and restricts development of the well.

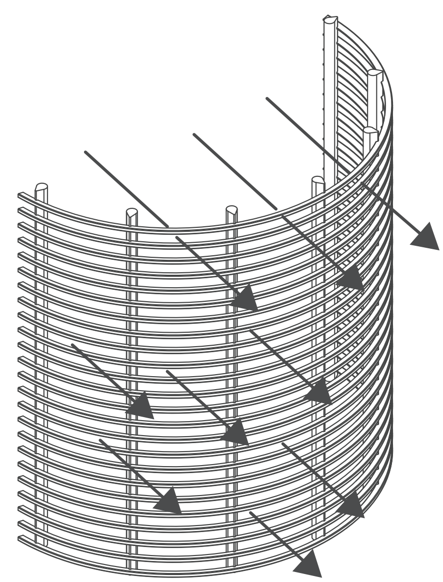


**Figure 6:** Continuous slot screens provide maximum open area and access to the formation so that development procedures are enhanced and through-screen head loss is reduced.

# Compared Cost Savings

Efficient wells will reduce operating costs over the life of the well. Efficiencies can be calculated so the cost savings can be compared. Figure 7 compares the efficiency of two wells in the same aquifer. Costs can be compared assuming an above ground head of 170 ft., diesel cost of $4.00 per gallon and overall pump efficiency of 60 percent (note that the cones of depression are the same). The inefficient well, however, requires more drawdown to produce the same volume of water, which significantly increases the pumping costs.

If these wells operated for 1,000 hours during a season, the savings would amount to $2,200 in direct fuel cost per year. If these wells operated 20 years, that savings would amount to $44,000.

While a direct savings such as this is a sufficient reason in itself for insisting on an efficient well, the savings in indirect costs could exceed the savings in power costs.

Indirect costs arise from maintenance expenses, short life span and from initial pumping costs. The principal causes of maintenance expenses and short life are corrosion, incrustation and sand pumping. A correctly designed and constructed well will reduce these destructive factors to a minimum level.

Other savings may result from reducing the initial costs of the pumping unit. The required brake horsepower for the inefficient well (Figure 7) would be: 105 BHP compared to 97 BHP for the efficient well. This may result not only in savings in engine horsepower, but also savings in the pumping assembly and length of column pipe required, etc.

The initial cost of a well is only a small part of the overall expense and operation. The extra initial investment for an efficient well will be returned many times and it all starts with the selection of the proper screen.

The type of screen and design, (diameter, length, slot size and location in the aquifer) gradation of gravel pack and borehole diameter affect the critically important ability to develop the well. Together, these determine the efficiency of the well as a hydraulic structure.

## Inefficient vs. efficient well calculation formula

### Inefficient well

$$\frac{\text{1,000 gpm x 250 tdh x .065 gal/hp hr x USD \$4.00 gal}}{\text{3,960 x .60 efficiency}} = \text{\$27.36 per hour}$$

### Efficient well

$$\frac{\text{1,000 gpm x 230 tdh x .065 gal/hp hr x USD \$4.00 gal}}{\text{3,960 x .60 efficiency}} = \text{\$25.17 per hour}$$

## Inefficient vs. Efficient Well Pumping at 1,000 GPM

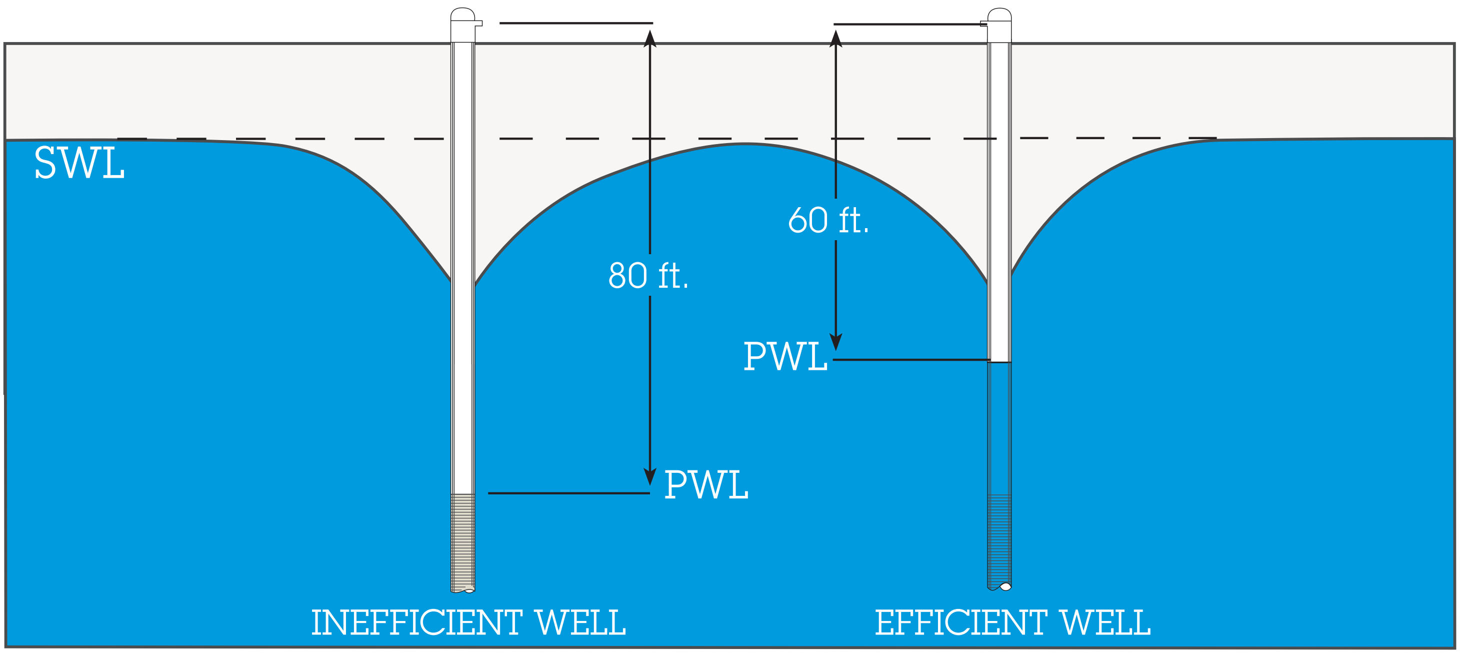



**Figure 7:** Two wells completed in the same aquifer can have nearly identical cones of depression and pump water at the same rate. The less efficient well, however, will have a lower pumping level. The extra drawdown will significantly increase the pumping costs of the well.

# The Direct Cost for Power can be Calculated by using the Following Formula

**Pump powered by an electrical motor**

$$Cph = \frac{gpm \times tdh \times 0.746 \times kwh\ cost}{3960 \times efficiency}$$

**In which**

**Cph** = cost per hour in dollars

**gpm** = rate of pumping in U.S. gallons per minute

**tdh** = total dynamic head, which includes the distance from the pump discharge down to the pumping water level plus the elevation pressure in ft. beyond the pump discharge, and the head due to friction and turbulence of flow

**0.746** = constant to convert brake horsepower to kilowatt-hours

**kwh cost** = cost per kilowatt-hour for electricity in dollars

**3960** = constant for conversion of units

**Efficiency** = pump efficiency multiplied by the efficiency of the motor

**When the pump is powered by an engine using diesel, gasoline or LP gas for fuel, the same formula is used in the following modified form:**

$$Cph = \frac{gpm \times tdh \times K \times fc}{3960 \times efficiency}$$

**In which**

**K** = fuel requirement in U.S. gallons per horsepower-hour. Assumed to be 0.065 for diesel, 0.088 for gasoline, and 0.0110 for LP gas

**fc** = fuel costs per U.S. gallon in dollars

**Aqseptence Group, Inc.**
**Water Well Screens**

North and South America
Phone +1 651 636 3900
Fax +1 651 638 3177
waterwell.johnsonscreens.us@aqseptence.com

**www.aqseptence.com**