# STANDARD GUIDELINES FOR DESIGN AND PROPER CONSTRUCTION OF A WATER WELL

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## SITE SELECTION

Site selection should be made with consideration being given to probable water quality and volume, followed by location of a power source and then transportation of water to the desired area.

Available driller and electric logs of the surrounding area should be obtained, including oil and gas logs. (The probability of locating a successful, deep well below the Corcoran Clay may often be as high as 90%, based on research and review of existing logs.)

After the site location has been determined, specifications that follow accepted industry standards should he obtained and used as a basis for the well contract and construction. (Specifications are available from many sources, such as the Bureau of Reclamation, various governmental agencies, and geologist or engineering firms. All employ similar industry standard procedures that have- been developed and proven successful over the years.)

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* Note: These remarks were presented by the author at a District workshop in 1992. Roy can be reached at (559) 233-6131.  Last updated January 2001

## PILOT HOLE (TEST HOLE)

Pilot holes should always be drilled and water samples collected and analyzed if water quality is of a questionable nature.

A pilot hole should be drilled, samples of drill cuttings taken at 10' intervals (or at formation changes) and sieve analysis performed on the sands. An electric log of the pilot hole should then be performed to identify footage and characteristics of the producing sands with some indication of water quality. Based on a review of this information, a proper well design can be achieved.

After sands and electric log analysis, the pilot hole should be properly abandoned, if the pilot hole indicates the formation will not support a well of sufficient capacity or water quality.

A word about shallow pilot holes…. It may be necessary to drill a shallow pilot hole, analyze sands and the electric log of the proposed well site above the Corcoran Clay to determine water quality and production capacity. Water samples may be taken above the Corcoran Clay in a standard rotary test hole by installing a small diameter, 2" pipe, and pumping water samples from the target zone.

# PRE-CONSTRUCTION CRITERIA

The factors that should be considered for shallow and deep well selection design are:

1. Amount of water desired
2. Pumping cost analysis
3. Life expectancy of the well
4. Effects on land value created by a usable ground water supply.

# PRODUCING WATER FROM BELOW THE CORCORAN CLAY

Proper depth selection of a well will greatly affect producing capacity over the life of the well by as much as 1000 gpm to 1200 gpm. For instance, using an approximate value of 10 gpm water production for each one foot of producing sands below the Corcoran Clay, you can determine how many feet of producing sands should be incorporated into the final well depth, thereby constructing a well of maximum capacity, efficiency and longevity.

Therefore, for every 100' of producing sands added to the well depth, they additional productivity could be as high as 4 acre feet per day. Thus, the added footage of producing sands incorporated into the final well design may be equated as usable "water-in-the-water-bank" or "money-in-the-bank." At this point in the pre-construction decisions, consider-ation should be given as to how much of the potential producing sands should be incorporated into the well design, remem-bering that every foot of saturated sand adds value to the land.

For example, a 1200' well may initially produce a sufficient amount of water to he economically feasible. However, if there are producing sands below 1200' that can be incorporated into the well, the well would produce at a higher specific- capacity, lower pumping cost and would be able to tap more usable water. This means longer usable well life, more efficient pumping cost, and increased land value.

During the initial planning stages and continuing through the well construction, as you gain more information, is the proper time to determine well depth. If a 1200' well is completed today and at a later date a 2000' well is needed, it will be necessary to either drill a new well or go to a much greater expense to deepen the existing 1200' well.

# GRAVEL PACK

Appropriate gravel pack MUST be used and placed correctly to obtain maximum well efficiency and production. In the University of California Bulletin No. 1889, titled "Water Well and Pumps: Their Design, Construction & Maintenance," the following information is referenced:

1. Grain size distribution curves are drawn for material in each water-producing zone.
2. Grain size distribution curves are used to identify the aquifer with the finest material.
3. The 70% retained size of the finest aquifer material is selected as a basis

for design. The gravel pack to retain 70% of the aquifer material should be 4 to 6 times larger than the aquifer material. For uniform fine material, the factor should be four (4); for non-uniform coarser material, five (5); and for highly non-uniform material including fines, six (6).

The selection of gravel roundness is extremely important because it allows the use of the proper graduation to fit the finer formations and retain the maximum porosity and permeability of the gravel pack to achieve maximum well efficiency. Two suppliers who come closes to meeting the roundness criteria are "Colorado Silica" and "Heart of Texas." Both are expensive compared to less suitable gravel (due to availability and freight), but their use will pay back the added cost may times over during the life of a well.

# CASING & SCREEN

Casing and screen diameter must be adequate to allow the desired amount of water to pass without friction loss. The pump chamber casing must be large enough to allow the required size column pipe and bowl assembly to be installed freely in the well to the point of anticipated future needs.

Screen opening design should retain 80% to 90% of the gravel pack. The most commonly used perforations are louvered and continuous V slot wire-wound casing. Both are resistant to gravel pack plugging and perform efficiently with most gravel pack installations.

Millslot perforation is also frequent used, but a much higher percentage of plugging by the gravel pack occurs with millslot because the perforations are straight rather than louvered or "V" shaped. Millslot can be used in some areas, but in most instances it is unwise to use it.

Although additional slot openings can be added to compensate for plugging, millslot casing is not considered as efficient as louvered or wire-wound. A word of caution….if millslot is used exclusively in a well, it will generally result in lower well efficiency, and create greater drawdown, thereby causing higher pumping cost for the entire life of the well. However, if a combination of millslot in the lesser producing areas and continuous "V" slot wire-wound in the more productive areas is used, the combination can prove satisfactory.

# CUTTING & SETTLEMENT PITS

The drill cutting and settlement pit must be excavated to dimensions adequate to permit sufficient time for fine sands to drop out of the viscous fluid as the cuttings are discharged into the pit and to pass the full length of the pit before returning to the well bore.

If fine sands (fines) are not settled out (or removed mechanically by a de-sander) they will return to the well bore and deposit fines on the walls of the well, plugging the water passages and creating irreparable damage.

In Ground Water and Wells, published by Johnson Filtration Systems, Inc., the author suggests that a reverse rotary pit system should be three times the volume of the hole in order to properly settle solids from the drilling fluid.

EXAMPLE: A 28" diameter well bore that is 1200' deep will hold about 38,000 gallons of water. Using "Johnson's" formula a pit large enough to accommodate about 115,000 gallons is needed. A pit 70' long x 10' wide x 8' deep will hold about 42,000 gallons of water. Using two pits of this dimension will process approximately 84,000 gallons of water. The cuttings laden water will travel 70' across one pit and 70' back through the other pit before returning to the well bore. This distance allows considerable settlement time, and in most cases, will settle out fine sand.

To prevent drill hole walls from plugging, the fluid system must be maintained with a sand content of below 2% at all times. This type of plugging is often caused by less qualified contractors using poor drilling procedures or conventional rotary drilling methods. Then to compensate for this, they use a gravel pack many times coarser than the formation demands resulting in void areas between these coarse sand or gravel particles, not only large enough to pass the sand deposited on the wall into the production water, but also to large to sufficiently stabilize the sands on the drill hole wall., thereby continually passing producing fines into the water. This creates what is commonly known as a "sand pumper."

Pits of sufficient size, proper construction methods and the correct selection of gravel pack size is vital to the efficiency of a well and cannot be over emphasized.

## CONVENTIONAL ROTARY vs. REVERSE ROTARY DRILLING METHOD

In conventional mud rotary drilling, damages due to formation plugging will occur without fail because the sand laden fluids must pass by the walls to reach the surface and therefore will irreversibly plug some of the production zones, even under the best of conditions.

Knowing this, one can make the assumption that wells should be drilled by the reverse rotary method, because the efficiency of the wells drilled by the conventional rotary method usually cannot approach the efficiency of wells drilled properly by the reverse rotary method. Even though installation costs may be less expensive, it will cost much more during the entire life of the well due to the increased pumping cost.

## SAND PRODUCTION

Sand production can easily be maintained at 5-parts per million or below, if proper design and construction methods are performed. This amount of sand production will not noticeably affect pump bowl bearing life and should be the goal of all gravel packed wells. However, some agencies permit 10-parts per million, which will noticeably affect pump bowl bearing life. Therefore, a well that produces 10-part per million sand is of lesser value than a well that produces 5-parts per million sand.

## DRILLING FLUID (MUD)

Commercial drilling mud is necessary much of the time to control the Corcoran Clay, although it increases the difficulty of keeping the sand content in the drilling fluid returning to the well bore below the 2% level.

## SLOPE TEST

Deep well contracts should require an EASTMAN or TOTCO slope test to be run every 100' to the deepest anticipated pump setting depth. The well bore should not be allowed to drift more than one half degree at any point above the pump setting depth. If drift occurs, the contractor should correct it back to half a degree maximum before further advancement of the well bore.

This correction will prevent "doglegs" in the well bore and is a reasonable requirement that will greatly extend pump-bearing life, and prevent well casing breaks caused by stress created by the "doglegs." Many casing failures can be attributed to "doglegs" in the well bore.

# DRILL HOLE DIAMETER

Drill hole diameter should be at least 8" larger than the screen diameter, but not over 12" larger than the screen diameter. Drill holes can be too large, creating a gravel pack so thick that development procedures cannot reach the drill hole wall to clean it.

Again, it is pointed out that at no stage of the drilling procedure should the fluid returning to the well be allowed to contain a sand content above 2%. If the sand content goes above 2%, sand will redeposit itself on the drill hole wall and be trapped by the gravel pack (when proper size gravel pack is used) and be impossible to remove during the development process, thereby creating permanent well damage, resulting in lower well efficiencies. And, as stated above, when proper gravel pack design is used to compensate for an improperly constructed well, the result is a sand pumper.

# GRAVEL INSTALLATION

Gravel may be successfully poured slowly from the ground surface into the well annulus only on shallow wells completed above the Corcoran Clay. However, any gravel pack installed below the Corcoran Clay should be pumped through a treme pipe set to a depth at the bottom of the screen before starting gravel installation, and slowly withdrawn as gravel is pumped and fills the annulus. The gravel treme pipe should be removed one joint as a time in order to monitor gravel filling level and ensure that all areas are completely filled with the gravel.

A circulation pipe should be installed inside the well casing/screen to the bottom of the perforations, and circulation of 250 gpm of water should commence prior to gravel installation and continue during the entire gravel packing process. The fluid used to pump the gravel should be clean water because this method transports the silts and clays that are removed from the well by the scouring action of the gravel going into place. These silts and clays then enter the well screen and are pumped to the surface and settle out in the settling pit, leaving the gravel pack relatively clean and ready for the development process.

# AIRLIFT/SWABBING

Following the completion of the gravel pack procedure, the well should be airlift pumped to remove the remaining drilling fluid from the annulus in the producing zones until the water is relatively clean.

The circulation pipe should then be removed from the well and two close fitting swaps (about 5' to 6' apart with sufficient intake holes between the swaps) installed on the circulation pipe.

While the airlift pump is operating, the swabs should then be lowered and raised as fast as possible for about 30 minutes per joint of casing, starting at the top of the screen and adding a joint each 30 minutes until the bottom of the well is reached. The bottom joint should then be swabbed until the pumped water is relatively clean and this should be continued, removing one joint at a time and repeating this procedure until each joint is swabbed to the top of the screen and the final water produced is relatively clear.

The walls will then be clean enough to produce, and ready for final development by pumping and surging the well at high rates.

The mechanical swabbing will clean the thin sand layers of sand from the well bore wall that will produce small amounts of water when mechanically swabbed clean. But will remain unproductive for the entire life of the well if not mechanically swabbed clean. In most cases pump development alone will leave the weaker areas undeveloped and unproductive.

Often times, a combination of many small zones properly swabbed clean can increase the well production and efficiency (if they have not been damaged during well construction and are correctly cleaned during initial well development).

A word of caution….if only pump development is performed, these fines can remain sealed against the well bore walls for the life of the well and the thin sand layers that could have had some low flow production rates has they been properly swabbed and pumped would now make no contribution.

# PUMP DEVELOPMENT

The high capacity pump and surge development process should follow the airlift/swabbing and be started at 750 gpm to 1,500 gpm on large capacity wells, pumping at one rate until the water being pumped is relatively clear. The pumping level should be monitored during all pumping.

When the pumped water is relatively clear, the pumping rate should be raised in increments of approximately 500 gpm and the process continued at each rate until the pumped water is again relatively clear.

This procedure should be continued in 500 gpm increments until the top rate of the pumping equipment, or the top rate of well capacity, is reached and the water is relatively clear and the specific capacity (gpm per foot of drawdown) stabilized.

The pump surging process is performed next, but should not begin until the pumped water is relatively clear, because surging with dirty water can permanently damage the well.

During the pump surging process the pump should be stopped, the water allowed to flow back into the well, and then the pump restarted again, and the water pumped until it is again relatively clear. This procedure should be continued until the water no longer is dirty looking. When the water is clear the well should then be surged several times (possibly five), just bringing the water to the ground surface, then pumped until again relatively clear.

This process is continued slowly, increasing the number of back surges each time until the water remains clear after surging and the pumping level is stabilized. The well is then fully developed at that particular pumping rate, and when the specific capacity stabilizes. Many times, a well developed at 4000 gpm is capable of further development and higher capacities if higher pumping rates can be achieved. However, the special equipment required to perform higher capacity rates is often not readily available.

# PUMP TESTING

The procedure for pump testing for pump design is as follows:

1. After the well has set idle 8 to 12 hours following development, the step test should be performed by pumping at a minimum of there (3), and preferably four (4) rates, with the pumping time being three hours minimum at each rate. The highest rate should usually be at the highest

rate at which the well was developed, with drawdown and flow rates recorded at minimum 5-minute intervals during the first 30 minutes of each pumping rate, and at least 30-minute intervals for the remainder of each rate. Recovery readings should be taken at minimum 5-minute intervals for the first 30 minutes after pump shutdown, and at least 30-minute intervals for four (4) to eight (8) hours.

2. After the step test is complete, a 24-hour pump test should be run at the rate calculated for the well based on the results of the step test. It is very important that a knowledgeable individual perform the calculations to accurately project sustainable yield.

It is in the best interest of the owner to employ a capable experienced firm that is able to design and monitor the construction, the material installation, well development, and the pump testing and pump design. This should be someone independent of the well construction contractor and pump supplier, in order to provide the owner with an unbiased and impartial overseer.

# WELL EFFICIENCY EFFECTS ON PUMPING COSTS

If proper construction procedures are used, a well efficiency as high as 94% can reasonably be expected. (There is a case history of a well that is 95% efficient at 2250 gpm with a 46' drawdown.)

Based on case histories, we can assume that many new wells in the area have efficiencies near 50%. Using a 50% effective rate as a basis for comparison, a well with a 87.4' drawdown at 2250 gpm would have an additional 41.4' drawdown penalty for inefficient construction of the well.

Assuming a power rate of .075 KWH and a pumping plant efficiency of 68%, the inefficiency in the drilled well would cost $4.641 per acre foot pumped, which would be $9,299.03 for a well pumped 200 days, or $13,948.66 for a well pumped 300 days, and this additional cost occurs every year for the life of the well.

These figures do not assume any interest expense or inflation in energy costs over the 30-year life of the well, although one must assume that interest expense and inflation would greatly increase the penalty on an inefficiently constructed well.

# APPRAISAL

If you assume a water table decline of 10' per year, ;you c;an roughly project the total acre feet that can be pumped from a well (assuming and estimated value for recharge.) The test of a well should be determined by several things. Some of the most important are:

1. desired life expectancy of the well
2. appraisal value of the land
3. power cost (power/fuel cost)
4. water quality.

# FUTURE ECONOMIC CONSIDERATIONS

In designing a well consideration should be given concerning the use of top/bottom water. You can only use the bottom water if you have the original well deep enough. The water below the depth of the well has a much less value when it is not tapped by the original well; whereas, if that same water is tapped by the original well, (although possibly not immediately being pumped) has much value in the future. Although the water is available, if it is not tapped by the original well, it has no value to that particular well.

The decision on how much of the available producing aquifer to incorporate into any given well design should be based on expected well life and the affect on land appraisal value. The shallow well can be looked at as a band-aid solution, the deeper wells would be a valuable investment in that particular property.

Most shallow wells can be considered as short term and a temporary "fix" solution to a long term problem. However, in some instances and conditions they make the most economic sense (ie. getting through a drought, providing water quality is usable.) Unfortunately, in some areas such as the Westlands Water District, long term supplies are more important.

The previously discussed water sample tests taken from test holes should be one of the deciding factors in determining whether the shallow waters above the Corcoran Clay should be considered