How to Drill a Water Well

NMSU Seminar:

Wells, Pumps, Etc…

Overview

- Planning for the Well
- Preplanning
- Preliminary Design
- Drilling the Well
- Well Development
- Well Testing & Monitoring
- Preventive Maintenance

Planning for the Well:

- Obtain approved drilling permit from OSE
- Selection of a well driller:
  - Well driller is responsible for design and construction.
  - There are many ways to cheapen well – do NOT select driller on the basis of price alone.
  - Getting the best well possible can easily pay off in yield, efficiency, and the life of the well.
  - Bad design & construction can lead to:
    - Sand Pumping
    - High Fuel Consumption
    - Low Yield – Doesn't give the amount of water that you need
    - Short Life
- To obtain the most efficient Irrigation Well follow these Steps:
  - Preplanning and test drill if possible
  - Design
  - Drilling and Construction
  - Well Development
  - Testing, Maintenance, Treating
  - Record Keeping

Preplanning:

Factors to consider when designing the well:

- Aquifer characteristics:
  - Hydraulic Conductivity
  - Water Quality – may determine what material to use
- Anticipated well Depth & Diameter – Depends on Pumping Rate
- Screen Length, Type, and Slot Opening Size
- Gravel Pack Size
- Development Methods/Techniques

Learn as much as possible: Neighbors, Drillers, OSE, Literature

Test Drill if Possible:

- Samples of cuttings are collected and analyzed for size at each depth
- Info used to determine screen length, slot opening size, gravel pack size

Preliminary Design:

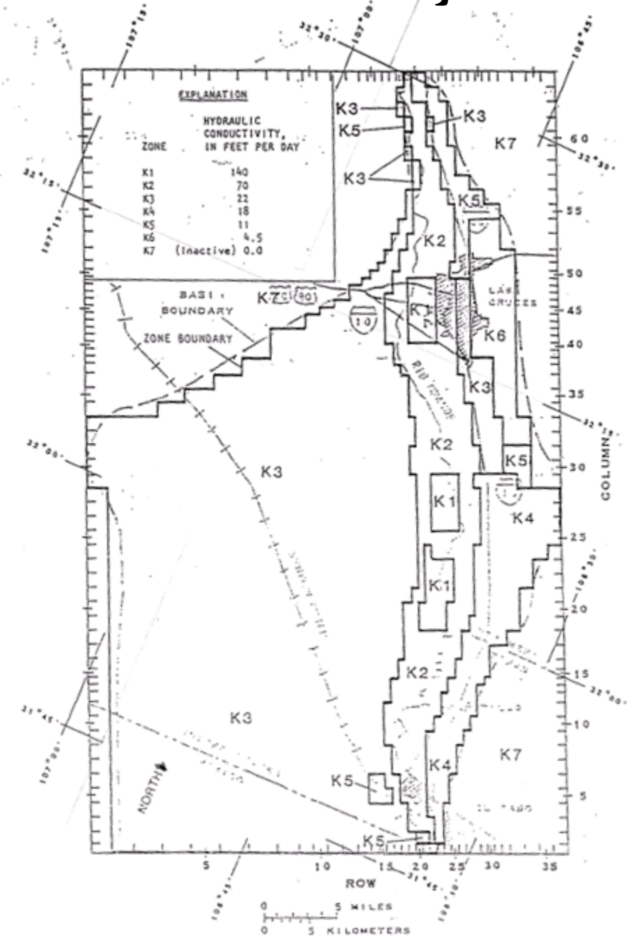
Procedure:

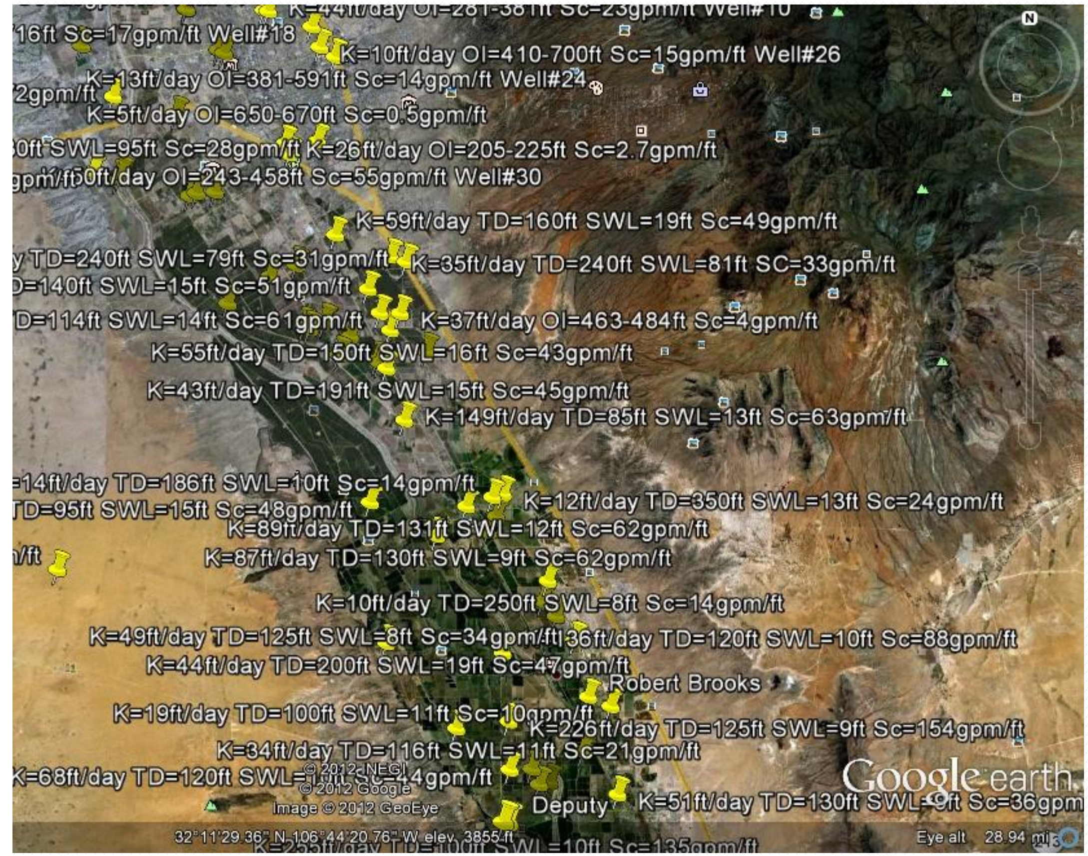
- Estimate K and S from nearby well or other sources
- Decide on well diameter
  - Pump diameter
  - Required flow
- Calculate optimum screen length & well depth
  - Use an annual cost estimate
  - Check design
- Gravel Pack Design
  - Prevents the sand in the formation from entering the well
  - Fine Sands present in aquifer – Design for the worst

Aquifer Characteristics:

Determine Hydraulic Conductivity:

- K = ?? ft/day





Well Diameter Required:

- Well diameter:
  - Two sizes larger than the pump bowl size
  - Depends on Required Pumping Rate
  - Screen may be smaller than casing diameter

Table 13.1. Recommended Well Diameters for Various Pumping Rates*

Anticipated Well Yield gpm	Anticipated Well Yield m^3/day	Nominal Size of Pump Bowls in	Nominal Size of Pump Bowls mm	Optimum Size of Well Casing† in	Optimum Size of Well Casing† mm	Smallest Size of Well Casing† in	Smallest Size of Well Casing† mm
Less than 100	Less than 545	4	102	6 ID	152 ID	5 ID	127 ID
75 to 175	409 to 954	5	127	8 ID	203 ID	6 ID	152 ID
150 to 350	818 to 1,910	6	152	10 ID	254 ID	8 ID	203 ID
300 to 700	1,640 to 3,820	8	203	12 ID	305 ID	10 ID	254 ID
500 to 1,000	2,730 to 5,450	10	254	14 OD	356 OD	12 ID	305 ID
800 to 1,800	4,360 to 9,810	12	305	16 OD	406 OD	14 OD	356 OD
1,200 to 3,000	6,540 to 16,400	14	356	20 OD	508 OD	16 OD	406 OD
2,000 to 3,800	10,900 to 20,700	16	406	24 OD	610 OD	20 OD	508 OD
3,000 to 6,000	16,400 to 32,700	20	508	30 OD	762 OD	24 OD	610 OD

*For specific pump information, the well-design engineer should contact a pump supplier, providing the anticipated yield, the head conditions, and the required pump efficiency.
†The size of the well casing is based on the outer diameter of the bowls for vertical turbine pumps, and on the diameter of either the pump bowls or the motor for submersible pumps.

Table 13.2. Maximum Discharge Rates for Certain Diameters of Standard-Weight Casing, Based on an Uphole Velocity of 5 ft/sec (1.5 m/sec)

Casing Size in	Casing Size mm*	Maximum Discharge gpm	Maximum Discharge m^3/day
4	102	200	1,090
5	127	310	1,690
6	152	450	2,450
8	203	780	4,250
10	254	1,230	6,700
12	305	1,760	9,590
14	337	2,150	11,700
16	387	2,850	15,500
18	438	3,640	19,800
20	489	4,540	24,700
24	591	6,620	36,100

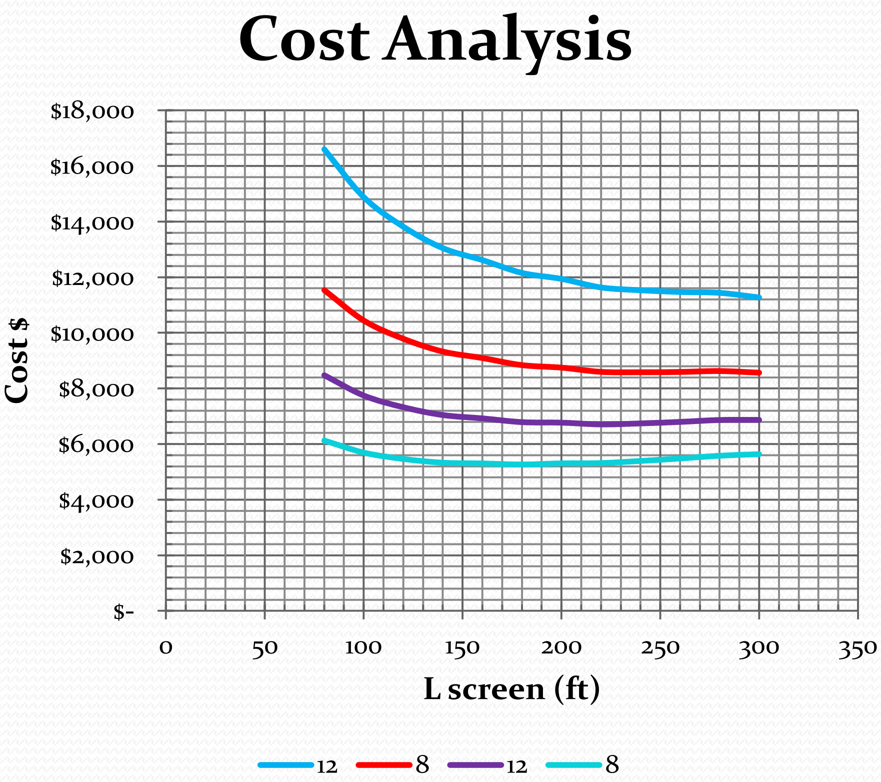
*Actual inside diameter

Screen Length & Well Depth:

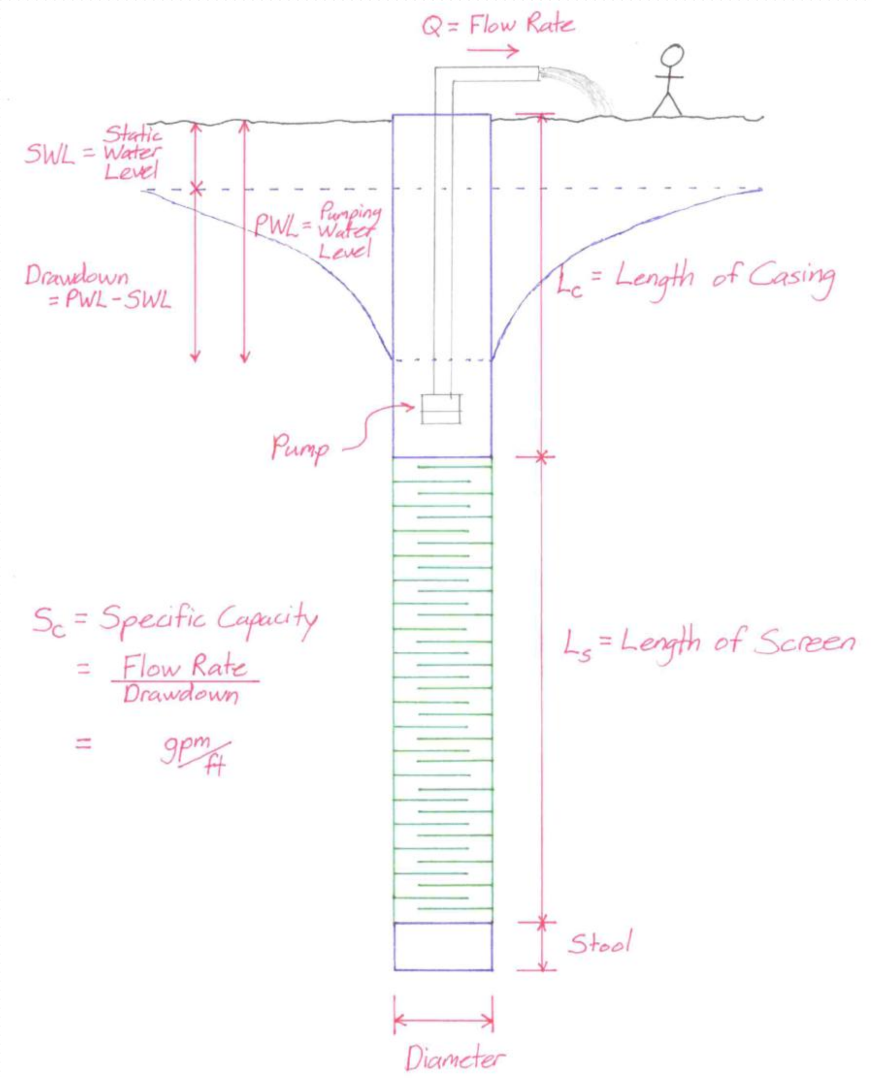
- Screen Length:
  - Cost Analysis – Cheapest pumping in the Long Run
  - Depends on Required Pumping Rate & Aquifer Characteristics
  - Located on the bottom of the Well – below PWL
- Casing Length:
  - The Pumping Level should stay above the uppermost well Screen. Otherwise the following problems will occur:
    - Cascading
    - Entrained Air
    - Accelerated Corrosion
    - Incrustation
- Well Depth = Screen Length + Casing Length

Screen Length:

- Screen Length Cost Analysis depends on:
  - Irrigation Schedule
  - Depends on Pumping Rate & Aquifer Characteristics
  - Powering Source:
    - Diesel Engine
    - Electric Motor
    - Etc…



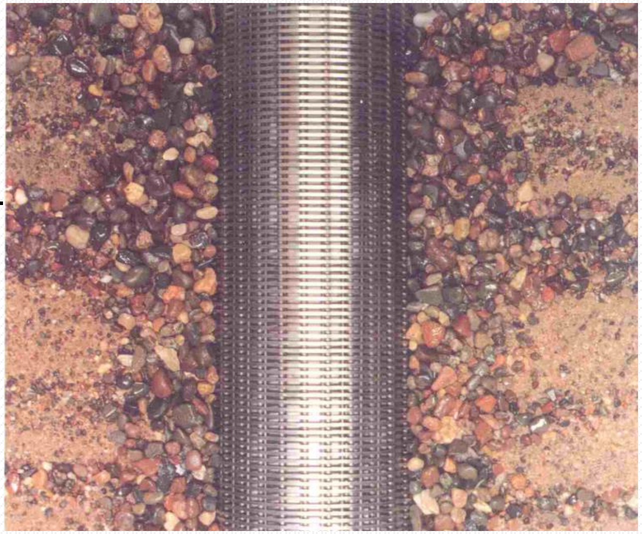
General Well Layout:



Gravel Pack:

- Purpose of Gravel Pack:
  - Stabilize the Formation
  - Prevent finer material from entering screen -- Retain the formation particles
  - Increase the permeability of the zone immediately surrounding the well
- Gravel Pack needed?
  - Need sieve analysis
  - Known presence of fine sands
  - Assume it is required
  - If design is pending – then design for the worst case: Finer material
  - Best to be conservative

    to avoid sand pumping
  - Controlling factor is the size of the Gravel Pack – NOT so much the thickness



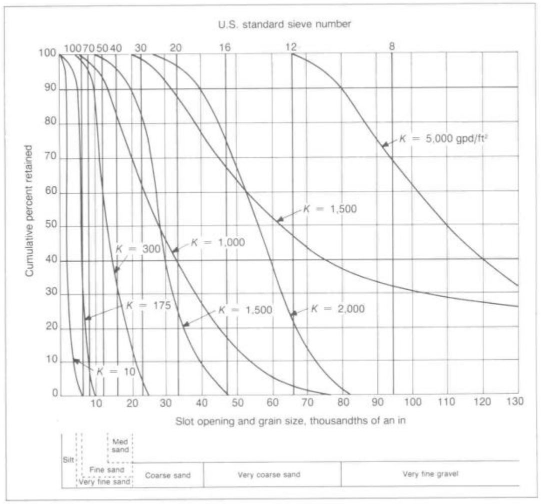
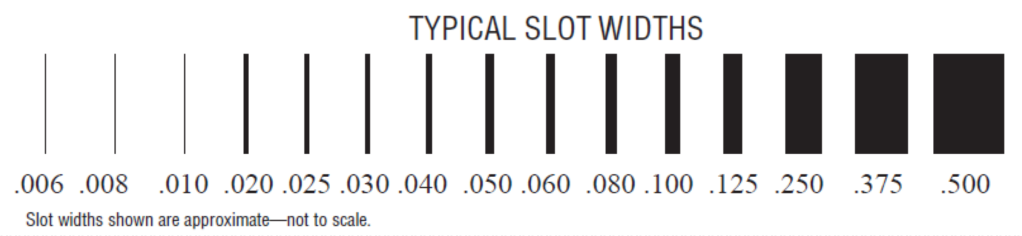


Figure 13.4. Hydraulic conductivity can be estimated on the basis of grain-size-distribution curves.

Screen Slot Openings:

- Opening Size:



- Small enough to retain 90% of the Gravel Pack
- The size of the slots in the Well Screen are based on the size of the Gravel Pack.
- The slots must be large enough to let the water enter freely into the well, but yet small enough to prevent sand pumping after the well is developed.

Screen Open Area:

- Enough area should be provided so that water enters the well slower than 0.1 ft/sec = 1.2 in/sec

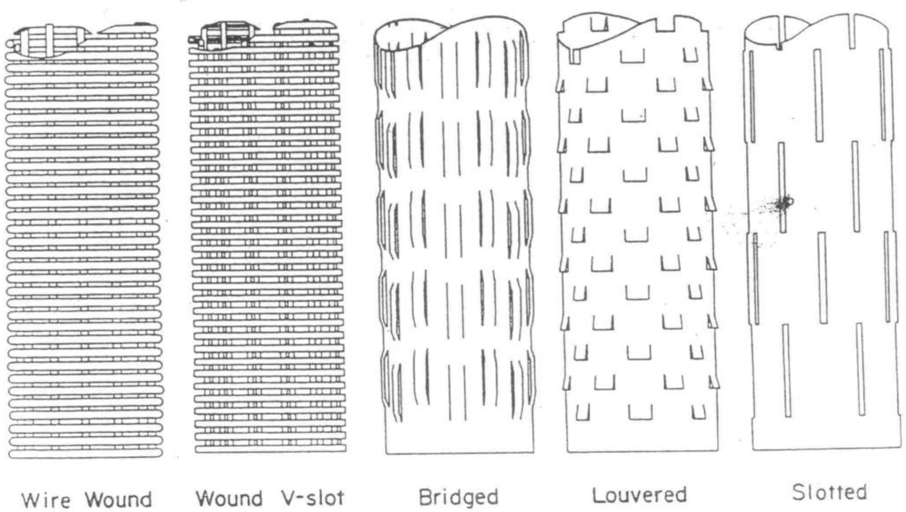
- Entrance velocities lower than 0.1 ft/sec will result in:
  - Negligible friction loss through the screen
  - Minimized rate of incrustation
  - Minimized rate of corrosion
  - Long Well Life

- Open Area depends on Screen Type

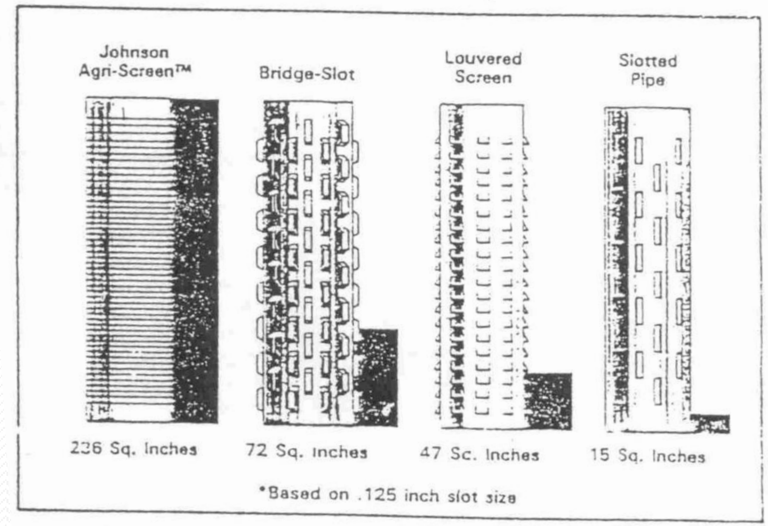
Screen Types & Area Comparison:

- More Open Area – Is Better
- Measured in sq.in. / ft-screen

Figure 10 - Types of Well Screen Slots



Agri-Screen™ has more open area...



Johnson Agri-Screen™ has between 3 and 16 times the open area than other conventional well screens.

Screen Types:

- Open Area depends on Screen Type:

Well Construction Material:

- Selection of Material is based on:
  - Water Quality
  - Corrosion Resistance – Chemical & Electrochemical
  - Acid Treatments are anticipated if incrustation is a problem
  - Well Depth – Collapse Strength
  - Cost

- Most Common Well Materials include:
  - PVC – Corrosion Resistant, Low Collapse Strength
  - Low Carbon Steel – Not Corrosion Resistant
  - Galvanized – Can significantly prolong screen life compared to LCS
  - Stainless Steel – Excellent Corrosion Resistance
  - For MAXIMUM WELL LIFE: the higher cost of the more corrosion resistant material is always justified.

- Note:
  - Combining different metals will cause electrochemical corrosion; whereby material is removed from the metal that is lowest in electric potential
  - Torch cut slot openings in LCS also cause electrochemical corrosion

Drilling the Well

Drilling the Well includes:

- Boring the correct size hole for the well
- Setting the casing & screen
- Placing the gravel pack

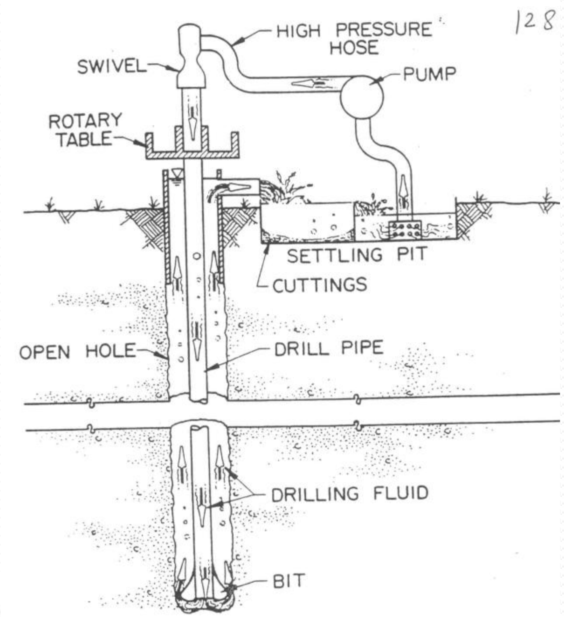
Most Common drilling methods in the LRG Basin:

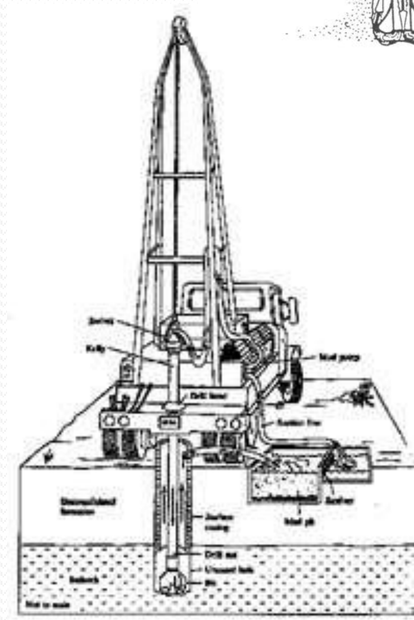
- Mud Rotary
- Reverse Rotary or Reverse Circulation
- Cable Tool
- Auger / Boring

Mud Rotary Drilling

- A rotating drill bit cuts the borehole and loosens the formation material.
- Drilling fluid is circulated down through the hollow drilling pipe and flushing out the drill bit.
- The drilling fluid cleans the bit face, it also cools and lubricates the bit, forms a filter cake and stabilizes the hole
- The drilling fluid flows upward in the well bore carrying up the material cut by the bit
- The cuttings are carried to the surface and settle out on a pit or the mud is cleaned on a machine
- The drilling mud is recirculated back

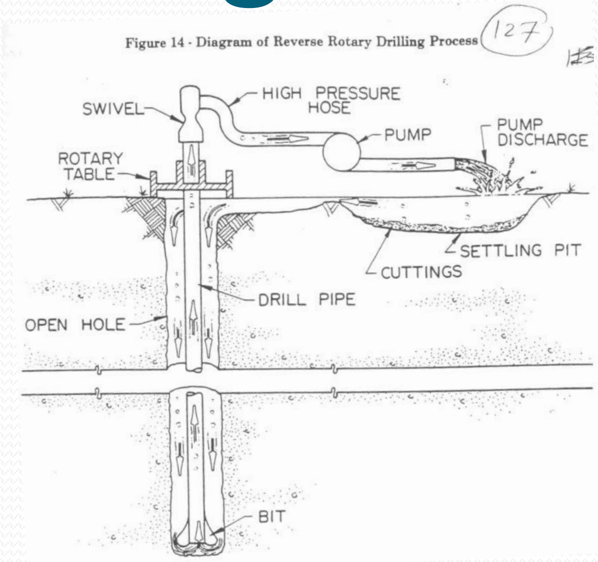
Figure 13 - Diagram of Rotary Drilling Process

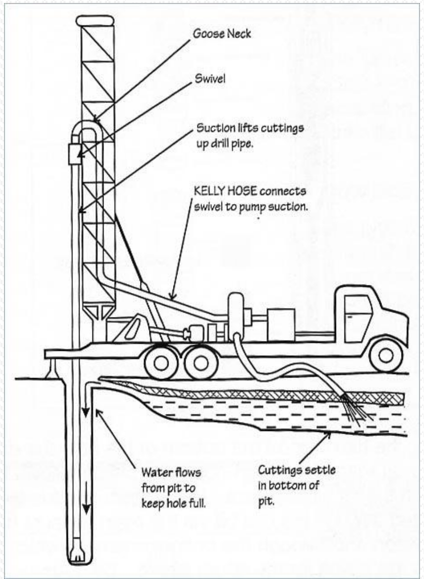




Reverse Circulation Drilling

- Same as Mud Rotary but the flow of the drilling fluid is reversed
- The drilling fluid is pumped upward through the hollow drill pipe into a pit where the cuttings settle.
- The drilling fluid returns by gravity to the borehole.
- The drilling fluid is thinner, however large quantities of water are needed to drill in permeable materials.
- The borehole must be maintained full to prevent collapse

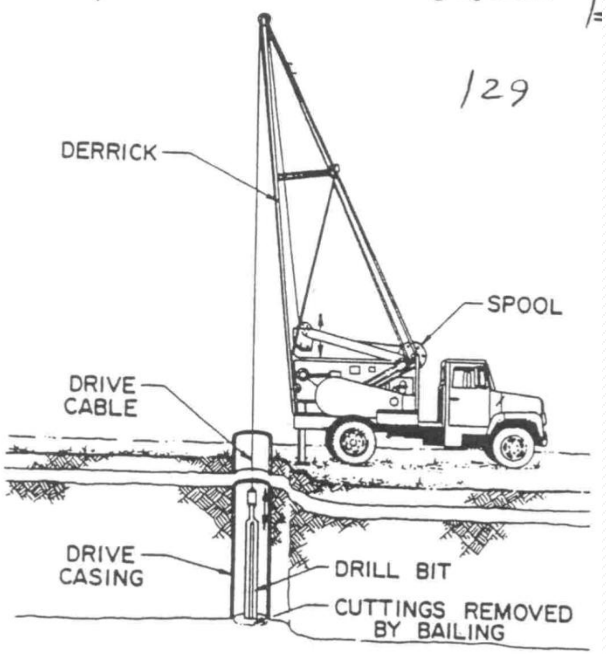




Cable Tool Drilling

- Involves lifting and dropping a heavy bit attached to a cable.
- The drilling is achieved by the chiseling or crushing of material by the impact of the drill bit.
- The cuttings are removed by a bailer
- The casing must be driven or forced down into the hole as the drilling proceeds
- Much slower drilling process compared to rotary drilling

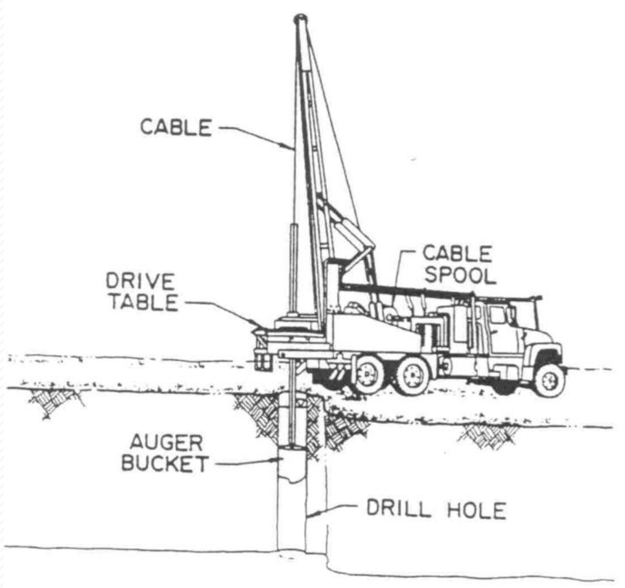
Figure 15 - Cable Tool Drilling System



Auger/Boring Drilling

- A power auger is turned to bore the hole.
- Cuttings are removed by pulling and emptying the auger or by the screw action of the auger flight itself.
- Casing is advanced with the tools and lowered as the hole deepens.
- Fast drilling but only used in shallow unconsolidated formations.

Figure 16 - Auger Bucket Drilling System



Well Development = Cleaning

- Meaning – to clean the drilling mud, clay and fine sand from the aquifer formation around the well screen
- Development will improve the performance and reduce sand pumping of almost any well
- Failure to develop a well may reduce its potential yield by 50% or more
- Purpose of developing:
  - Repair damage done to the formation during well construction
  - Increase the permeability of the formation around the well
  - Stabilize the sand formation around the screen or gravel pack in order to get sand-free water
- SHOULD be done by DRILLER:
  - As soon as possible after construction is completed
  - Your pump should NOT be used in the development process – high sand contents will seriously damage the pump

Well Development Methods

Common Development Methods Include:

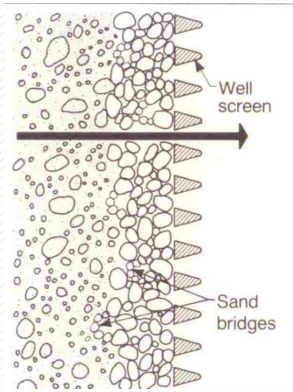
- Overpumping
- Backwashing or Rawhiding
- Surging
- Air Lifting: Surging & Pumping
- Double Packer Air Lifting
- High-Velocity Jetting

Overpumping

- Pumping at a higher rate than the well will be pumped when put into service.

- Not efficient in cleaning long screens

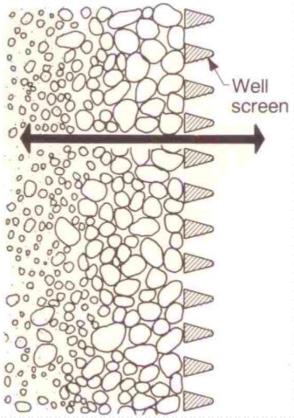
- Water flows in only one direction – Inwards
  - Leaves bridged conditions, i.e. only partially stabilized formation
  - Sand will enter the well when the bridges become unstable



- Drillers sometimes use wells pump operated at a higher speed
  - Sand pumping will cause excessive wear on the pump
  - It will reduce the pumps operating efficiency

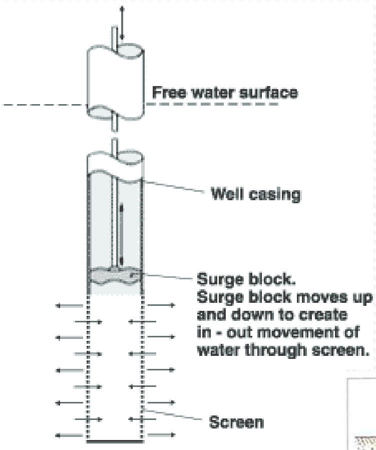
Backwashing or Rawhiding:

- The pump is started and as soon as the water is lifted to the surface the pump is shot off
- The water in the pump column pipe then falls back into the well creating a backwash action
- The backflow breaks down the bridging between particles, but in many cases the surging effect is not vigorous enough to obtain maximum results
- Not efficient in cleaning long screens
- Drillers sometimes use wells pump operated at a higher speed
  - Sand pumping will cause excessive wear on the pump
  - It will reduce the pumps operating efficiency



Surging

- Forces water to flow into and out of the screen.
- Operates a surge block up and down the casing like a piston in a cylinder
- Sediments entering the well should be removed frequently
- Effectiveness is concentrated in the upper part of the screen



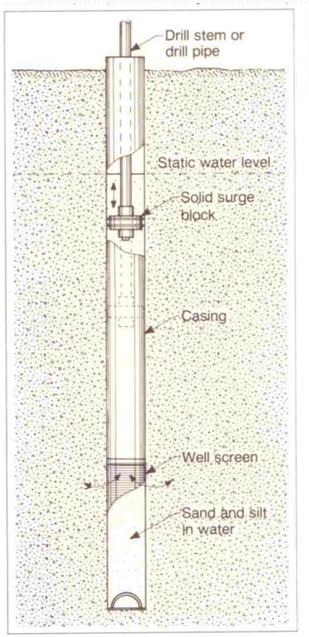


Figure 15.7. For certain types of formations, a surge block is an effective tool for well development. On the downstroke, water is forced outward into the formation; water, silt, and fine sand are then pulled into the well screen during the upstroke.

Air Lifting: Surging & Pumping

- Air Lift Pumping
  - Is used to remove sediments from the well and pumped until the water is sand free
  - Accomplished by forcing large volumes of compressed air through an air line inside the well
- Air Surging
  - To initiate surging, the air valve is opened quickly. This tends to drive the water outward through the well screen openings.
  - As the water reaches the top of the casing, the air supply is shut off, allowing the aerated water column to fall
  - Ordinarily a brief but forceful head of water will shoot from the casing
- Alternating Air Surging – Air Pumping – Periods of No Pumping, creates a more effective cycle
- The cycle is repeated at different levels in the well screen until the water is relatively free of sand

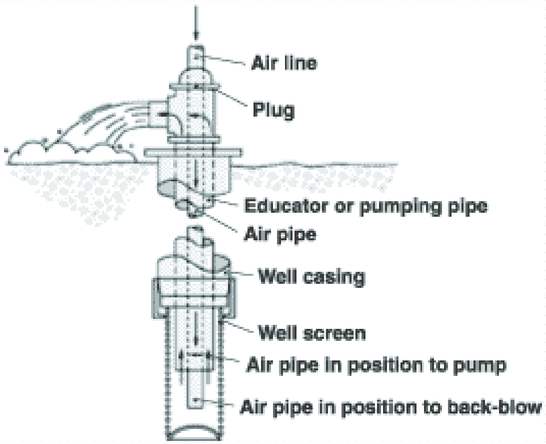
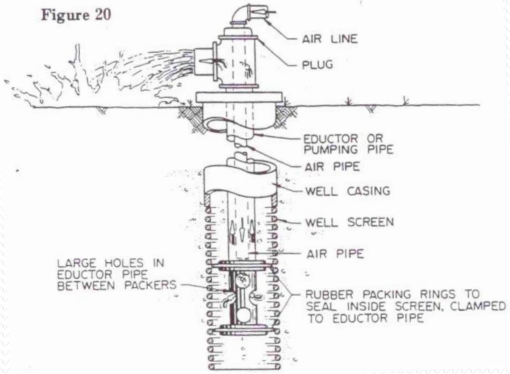


Figure 15.15. During air-lift development, brief but powerful spurts of water will be ejected from the top of the casing. *(Test Drilling Services)*

Double Packer Air Lifting

- Same as Air Lift Pumping & Surging but concentrated on a small zone of screen and formation that is isolated between the packers
- After each zone is developed by surging & air lift pumping, the tool is lowered to the next section
- The double surge-block can also be raised and dropped rapidly to produce the required turbulence in and near the screen
- Very effective in long screens because it can concentrate the development energy on short sections of the aquifer

Figure 20



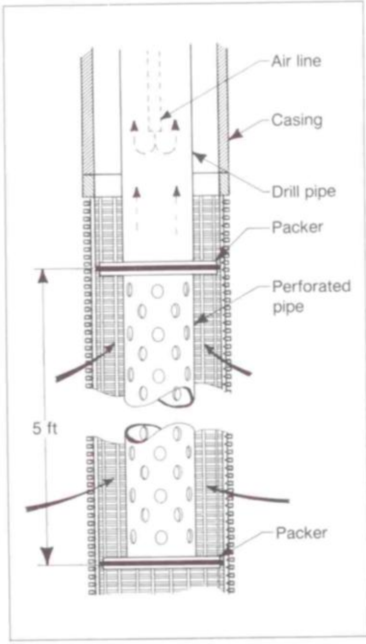


Figure 15.16. Isolation tools are used to focus the energy of air bursts on a specific part of the aquifer and to remove sediment by air lifting.

High-Velocity Jetting

- The most powerful and effective method of well development – often the most costly
- Water is jetted at high velocity inside the well so that the streams of water shoot out through the screen openings and gravel pack into the formation to loosen and break down the drilling mud and stabilize the formation surrounding the well
- The jetting tool is rotated and moved up and down inside the screen
- Very effective in long screens because it can concentrate the development energy on short sections of the aquifer
- The effectiveness depends on the open area and slot configuration of the screen and the thoroughness of the jetting operation

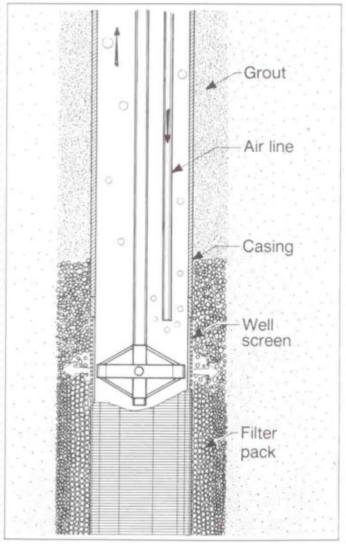


Figure 15.19. The jetting tool and drop pipe are separate from the air line so that jetting and air-lift pumping can be done simultaneously.

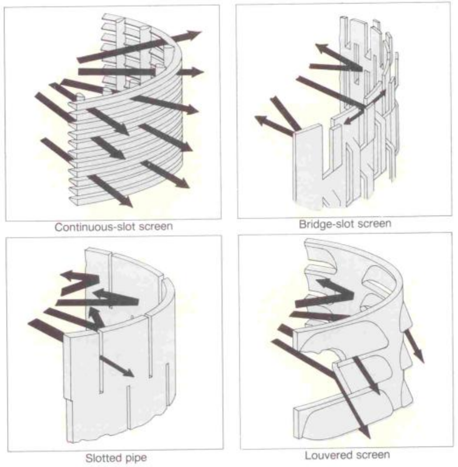


Figure 15.18. The open area of the screen and the configuration of the slot openings are important factors controlling the effectiveness of development procedures using water jetting.

Development Method Comparison

- Certain Development Methods exert more powerful cleaning forces on the formation than others, thus:
  - Are better able to remove the drilling fluid
  - Create a zone of high porosity or hydraulic conductivity around the screen
- Experiment of 10 wells in same uniform aquifer:
  - Drilled with bentonite and polymer
  - Three types of well screens were used
  - Developed in 3 Stages:
    1. Overpumping
    2. Mechanical Surging
    3. Jetting
- As the open area of the screen is increased, the enhanced effectiveness of the development causes a corresponding increase in specific capacity

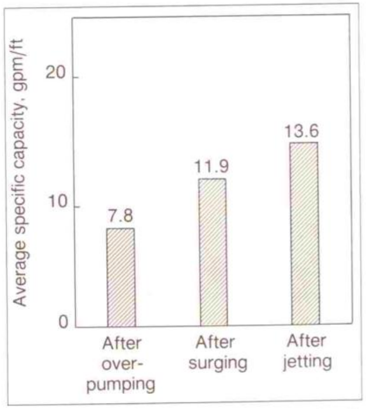


Figure 15.20. Average specific capacities of wells drilled with bentonite, after various development methods. Individual specific capacities were measured when no more sediment could be dislodged from the formation by a particular development method. *(Werner et al., 1980)*

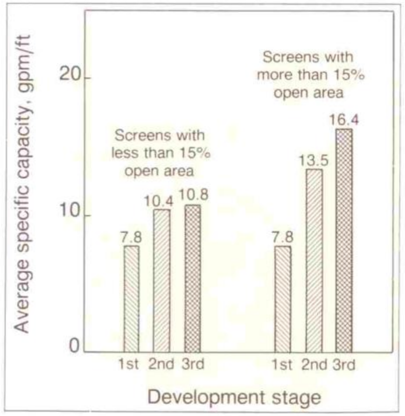
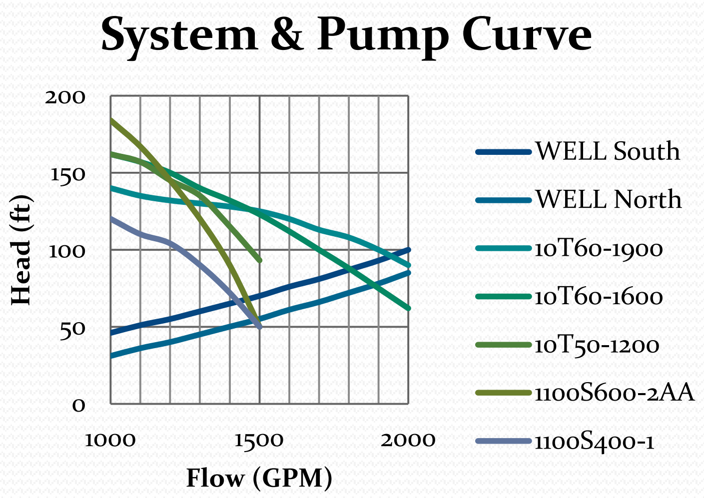


Figure 15.21. Open area of the well screen controls the effectiveness of various development methods for wells drilled with bentonite. In general, development is most effective when the screen open area is the largest. *(Werner et al., 1980; Driscoll et al., 1980a)*

Well Testing

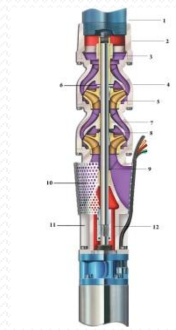
- Testing the well helps determine:
  - The Actual Operating Characteristics of the Well
  - The Specific Capacity – gpm/ft
  - The correct Pump Size
  - The Size of the Power Unit Required



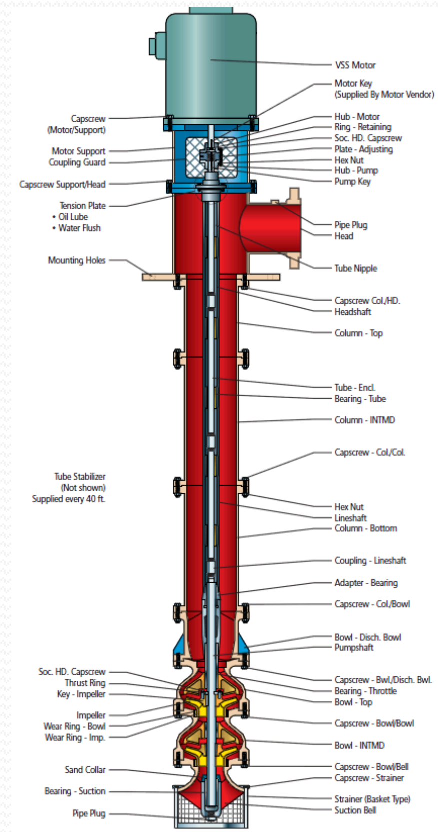
- Well Testing is achieved by monitoring the Flow Rate & Water Level inside the well as it is pumped

Pump?

- Submersible Turbine Pump
  - Cheaper
  - Easy installation
  - No maintenance required



- Turbine Pump
  - More expensive
  - Expert installation required
  - Maintenance required on:
    - Oil lubed pumps
    - Engine Power Units
  - Easy maintenance & access to the electric motor



Pump Selection & Design:

- Test the well
- Establish well characteristic curve
- Decide on pumping rate
- Design the pump
- Check adequate motor cooling for submersibles
  - V >= 0.5ft/sec
- Contract the pump purchase and installation

Well Monitoring

- Obtain a complete set of specifications from the driller when the well is finished. Includes information like:
  - Total Depth
  - Screened Intervals
  - Screen Type & Opening Size
  - Screen & Casing Materials
  - Pumping Test
- Monitor and record on a regular basis:
  - Pumping Rate – gpm
  - Static Water Level, Pumping Water Level & Drawdown
  - Specific Capacity
  - Sand Pumping if any
- Changes in Well Performance can help detect problems early on so that corrective action can be taken to restore the performance

Preventive Maintenance

- Preventive Maintenance can help increase the useful life of a well
- Well Monitoring & Performance Records are very helpful in determining the required treatment
- Preventive Maintenance may include:
  - Acid treatments to counteract mineral incrustation and iron bacteria if any
  - Annual chlorination is an excellent safety precaution
- Well Rehabilitation:
  - Recommended when the yield has reduced significantly
  - May warrant application of Acid Treatment & Redevelopment

THANK YOU !!!

Questions ???

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