Appendix G

Solutions to Well Drilling Problems

Plan for the best and be ready to take corrective actions when your plans go wrong! This section of the tutorial is designed to help you solve the problems you will encounter when you drill wells. Don't be discouraged.... use your common sense and learn what you can from the situation you are in! Common problems include:

G-1: Excessive Fluid Loss
G-2: Borehole Caving
G-3: Drill Bit Jamming
G-4: Drilling Fluid Backflow
G-5: Objects Dropped Into Well
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G-1: Excessive Fluid Loss

Large amounts of make-up water is usually required and must be immediately available at all times when drilling in permeable sand and gravel. This is important because drilling fluid sometimes suddenly flows into permeable formations which are being drilled rather than circulating back up the borehole.

If return circulation is suddenly lost, immediately switch the 3-way valve to direct the drilling fluid back to the pit through the by-pass hose (this minimizes the loss of valuable water). Then quickly pull-up the drill pipe 1-2 metres from the bottom of the borehole so that it is less likely to become jammed if the bottom portion of the hole collapses.

If drilling has been proceeding with a thick bentonite mud, the best possible action is then "to wait" (Australian, 1992). A waiting period may allow the fluid to gel in the formation and provide a seal sufficient to allow circulation to be restored. If drilling has been proceeding with water or natural mud, replace the fluid with a thick bentonite slurry, circulate it down the borehole and let it sit for a while. When ready to circulate back down the hole, hit the drill pipe rapidly with a hammer to jar loose the mud and open the pipe.

If waiting and thickening the drilling mud do not restore circulation, question why the circulation was lost. If the drilling fluid is being lost into a highly permeable saturation formation, it may be possible to construct an excellent well! Therefore, test the well yield before deciding to proceed with the steps outlined below.

If it is necessary to drill further, try adding thickening materials to the drilling mud. This may occur when extremely unstable formations or those containing open fractures are encountered. Almost any granular flake or fibrous material can be used to provide a wad to block a lost circulation zone. Local materials such as bran, husks, chaff, straw, bark, wood chips, cotton, feathers, or even fibre or wool bedding can usually be located readily and used (Australian, 1992). This material should be pushed down the hole and allowed to block the fractures.

The "gunk squeeze" method of sealing off a zone of lost circulation involves forcing a large amount of clay or cement into the zone of water loss (usually at or near the drill bit) and forcing it into the formation where it swells and fills-up any cracks (Australian, 1992). The best way is to mix a very high concentration (6 - 7 kg/L) of bentonite. Once mixed, immediately lower it into the borehole in a sealed bag or container which can be ruptured when opposite the lost circulation zone. This material can be forced into the formation by pressurizing the borehole or by pushing it with a block on the end of the drill string.

If the lost circulation zone cannot be blocked, drilling sometimes may proceed without return circulation. The cuttings are carried away into the formation cavities. It may be necessary to occasionally pump a slug of thick mud to clear the bottom of the hole (Australian, 1992).

Alternatively, casing can be placed to seal-off the problem zone. Ensure that the hole has fully penetrated the problem zone which is to be protected by the casing; Running the casing too soon may not overcome the problems for long. Finally, if none of these options work, it may be necessary to abandon the hole or to continue drilling using a air rotary drilling machine (Australian, 1992).

G-2: Borehole Caving

The main cause of borehole caving is lack of suitable drilling mud (see Section 5). This often occurs in sandy soils where drillers are not using good bentonite or polymer. The problem can be seen when fluid is circulating but cuttings are not being carried-out of the hole. If you continue to push ahead and drill, the bit can become jammed, the hole will collapse when you try to insert the casing or a huge portion of the aquifer may wash-out making it very difficult to complete a good well. The solution is to get some bentonite or polymer or, if necessary, assess the suitability of natural clays for use as drill mud (see Appendix H).

Borehole caving can also occur if the fluid level in the borehole drops significantly (see Footnote #1). Therefore, following a loss of circulation or a night time stoppage, slowly re-fill the borehole by circulating drilling fluid through the drill pipe (pouring fluid directly into the borehole may trigger caving). If caving occurs while drilling, check if cuttings are still exiting the well. If they are, stop drilling and circulate drilling fluid for a while.

Sometimes part of the borehole caves while the casing is being installed, preventing it from being inserted to the full depth of the borehole. When this occurs, the casing must be pulled out and the well re-drilled with heavier drilling fluid. When pulling the casing, no more than 12.19 m (40 ft) should be lifted into the air at any time; more than this will cause thin-walled (Schedule 40) PVC to bend and crack.

G-3: Drill Bit Jamming

The drill pipe and bit may become jammed when the drilling fluid is not allowed to thoroughly clean the borehole prior to stopping to add another joint of drilling pipe or the fluid is too thin to lift gravel from the bottom of the borehole. Therefore, if the drill bit starts to catch when drilling, stop further drilling and allow the drilling fluid to circulate and remove accumulated cuttings from the borehole. Then continue to drill at a slower rate. If it continues to catch, thicken the drilling fluid.

If the drill bit and pipe become jammed, stop drilling and circulate drilling fluid until it is freed. If circulation is blocked, try to winch the bit and pipe out of the borehole. Stop the engine and use a pipe wrench to reverse rotation (no more than 1 turn or the rod may unscrew!). Rapidly hit the drill pipe with a hammer to try and jolt the bit free.

If these actions are not successful, use lengths of drill pipe without a bit attached or Wattera tubing to "jet out" the cuttings. Attach the pipe or tubing directly to the discharge hose from the mud pump. Thicken the drilling fluid to ensure that the cuttings holding the bit can be removed. Then place tension of the stuck pipe with the drill rig winch. Once fluid starts to circulate out of the borehole, slowly push the jetting pipe/tubing down the borehole beside the jammed drill pipe until the bit is reached. When fluid starts to circulate out of the stuck pipe and/or it loosens, pull the stuck drill pipe and resume circulation of the thickened drilling fluid back down the drill pipe and bit. Remove the jetting pipe. If water freely circulates out the borehole, slowly lower the drill pipe and bit and resume drilling.

G-4: Drilling Fluid Backflow

Sometimes drilling fluid comes up through the drill pipe when you disconnect the swivel. This is caused by falling soil particles pressurizing drilling fluids at the bottom of the hole. Immediate action is required because this occurs when either the borehole is caving-in or when drill cuttings have not been cleaned well enough from the borehole. If you notice backflow of drilling fluid, immediately re-connect the drill pipe and continue circulation to clean-out the cuttings. If caving is suspected, thicken the drill mud while continuing circulation.

G-5: Objects Dropped Into Well

Unfortunately, sometimes wrenches, rocks etc are inadvertently dropped into the borehole when drilling. In addition, the LS-100 is often operated near its design limits with a high degree of structural stress on the drilling stems and tools; encountering unexpected layers of very soft sand or filter or hard rock can cause cave-ins or tool breakage and all the drill pipe can be lost in the hole.

If objects are dropped into the borehole after the final depth has been reached, it may be possible to leave them there and still complete the well. If this is not the case, it may be possible to make a "fishing" tool to set-up on the lost gear. For example, if a length of well screen falls down the borehole, it may be possible to send other sections down with a pointed tip on the end and "catch" the lost casing by cramming the pointed end hard into it. These types of "fishing" exercises require innovation and resourcefulness suitable to the circumstances - there is no single right way of doing this work. If sediment has caved in on top of the drill bit or other tools, circulation should be resumed in the hole and the fishing tool placed over the lost equipment.

If the lost tools/bit(s)/drill pipe are not critical, do not even try to retrieve them and just move over and start drilling a new hole. Even if the equipment is important, it is still best to start drilling at a new location while others try to retrieve it since considerable time can be spent on retrieval and there is a low likelihood of success.

G-6: Resistant Beds Encountered

Once a resistant bed is encountered and the rate at which the drill bit is penetrating the formation drops dramatically, a decision needs to be made whether to stop drilling or to continue. If the resistant bed is comprised of gravels, the drilling fluid may need to be thickened to lift-out the cuttings. If the resistant bed is hard granite, drilling with the LS-100 should cease. Other drilling methods should be found or drilling should be attempted at another location. *Remember, to help as many people as possible and to get the best value for donor dollars, DRILL THE EASY BOREHOLES FIRST!!* It is not worth wearing-out the equipment by grinding away for hours and hours to gain a foot or two of borehole depth.

G-7: Contaminated Soil/Water-Bearing Zones

It is sometimes necessary to drill through aquifers which contain contaminated water. In these situations, drill until a confining layer (clay or rock) is encountered. Insert the casing and then seal the annular space with a grout slurry. To avoid damaging the grout seal, let the grout cure for at least 12-24 hours prior to resuming drilling (Driscoll, 1986).

Grout is prepared by mixing 19.7 L (5.2 gal) of water with every 42.6 kg (94 lb) sack of cement (Driscoll, 1986); 5 volumes grout slurry can be made by mixing 4 volumes cement powder with 3 volumes fresh water (Australian, 1992). Alternatively, each sack of cement can be added to a clay-water suspension formed by mixing 1.36 - 2.27 kg (3-5 lbs) of bentonite with 25 L (6.5 gal) of water (Driscoll, 1986). This mixture helps hold cement particles in suspension, reduces cement shrinkage, improves the fluidity of the mixture and prevents excessive penetration of grout into these formations.

Cement grout is normally placed by just pouring it into the annulus. Alternatively, some grout could also be poured into the casing and/or the casing could be raised several feet and then pushed into the grout that accumulates at the bottom of the borehole. Place the grout in one continuous operation to form a good seal (Driscoll, 1986). Since irregularities in the size of the borehole and losses into formation may occur, the driller must be prepared to augment initial estimates of grout volume on short notice.

Where contamination is severe, follow special procedures to ensure that a very good seal around the casing is achieved (see **Appendix I**). When you finish grouting, ensure that you leave about 0.5 metres of grout in the casing (see Footnote #2).

G-8: Flowing Wells

Sometimes the water in a confined aquifer is under so much pressure that it will flow out the top of a well which is drilled into it. Special precautions and construction techniques must be used to control the water pressure and flow or serious environmental problems can result.

The free flow of excess water to waste can result in the depletion of a valuable resource and in unnecessary interference with other well supplies. Free flow from the well casing or a breakout of uncontrolled flow around the well casing can cause serious erosional and flooding problems on the owner's and adjacent properties that may be very difficult and costly to correct.

Sometimes natural flow can be brought under control by extending the well casing 1.5 - 6 m (5 - 20 ft) into the air. This can allow the pressure in the pipe to balance that within the aquifer. A spout with a tap can then be installed in the side of the casing. A hand pump can be installed at a later date if the pressure in the pipe drops over time.

G-9: Marginal Aquifer Encountered

Sometimes a very thin or relatively impermeable aquifer is encountered which must be developed to provide a reliable water supply. Ensure that the borehole penetrates the full thickness of the aquifer, extending as far below it as possible. Install the well screen adjacent to the entire aquifer thickness with solid casing installed above and below it. After developing the well, install the pump cylinder as low as possible in the well.

If a well is being completed in a fine sand/silt aquifer within 15-22 m (50 - 75 ft) of ground surface, a 20 cm (8 in) reamer bit has sometimes been used (e.g. Bolivia). This makes it possible to install a better filter pack and reduces entrance velocities and passage of fine silt, clay and sand particles into the well.

Yield can be maximized by adding a small amount of a polyphosphate to the well after it has been developed using conventional techniques. The polyphosphate helps remove clays that occur naturally in the aquifer and that were introduced in the drilling fluid (see Footnote #3).

Enough time must be allowed between introduction of the polyphosphate and development, usually overnight, so the clay masses become completely desegregated (Driscoll, 1986). After the polyphosphate solution is surged into the screen (see Footnote #4), water should be added to the well to drive the solution farther into the formation.

G-10: Casing Jamming During Installation

Sometimes it is not possible to lower the casing and well screen to the bottom of the hole. This can be due to part of the borehole collapsing, clays in the aquifer swelling and reducing the size of the borehole or the borehole being crooked resulting in the casing digging into the wall of the borehole. These problems are most common where 10 cm (4 in) schedule 40 casing is being inserted into a 15 cm (6 in) borehole. This is because the outside diameter of the casing couplers is 13 cm (5.25 in), leaving an annular space of just over a quarter inch on each side of the casing! It does not take much swelling of clays or slight deviation from vertical to result in the casing jamming.

If the casing does not slide freely into the borehole, it is not advisable to try and force the casing down. Striking it hard in an attempt to drive it may cause the screen to deform; rotating and pushing it down can cause the screen openings to become hopelessly plugged with fine materials.

To avoid these problems, minimize the amount of pull-down pressure when drilling so that the bit can run freely under its own weight. Also, casing there is no problem with casing jambing when 7.6 cm (3 in) schedule 40 casing is used. Keep in mind, however, that a 7.6 cm (3 in) casing is too small to take a 6.4 cm (2.5 in) pump cylinder or most submersible pumps. Usually, however, these issues are not a concern.

If you need to construct a 10 cm (4 in) well and the casing has jammed, the best solution is to pull the casing / screen from the borehole. This involves cutting the casing into 6-12 m (20 - 40 ft) lengths (longer than this will result in the casing bending and cracking). Slowly re-drill the borehole with a 15 cm (6 in) reamer bit or, if available, a 18 or 20 cm (7 or 8 in) bit. Concentrate on the portion of the borehole where the casing jammed. While this can take several hours, it often eliminates blockages and allows the casing to slide to the bottom of the borehole. As soon as the reaming is completed, re-glue and re-insert the casing.

If it still jams, your last resort is to try and "wash" the casing down by installing the drilling rods down inside the casing and circulating drilling fluid through a wash-down valve (see **Section 7**). Fluid is pumped down through the casing and out the bottom of the screen where it will pick-up and carry soil particles back up to the surface between the casing and the hole walls. The amount of water passing through the screen openings can be minimized by attaching a surge block to the lower end of the drill string. Be sure to secure the pipe with a rope to prevent the casing from dropping if the blockage was localized and is removed with the circulation process. Failure to do so could result in the casing dropping to the bottom of the hole without the casing extending to the surface. When the casing is finally installed to the appropriate depth, stabilize the open bottom end of the casing by pouring in 30-60 cm of coarse gravel into the well. If the casing still jams above the water bearing formation, the only other option is to obtain and install 7.6 cm (3 in) casing and well screen.

G-11: Well Stops Producing Water:
A well can suddenly no longer provide the same amount of water that it did before. If you move the pump handle and it feels OK but little or no water comes out the spout, the well may be dry. Confirm this by measuring the water level in the well and try to determine which of the following causes is responsible:

- Natural Lowering of the Water Table: Water levels in shallow dug and bored wells experience large fluctuations due to climatic conditions. The natural seasonal change in water level often will often be several metres. This is likely the cause of the drop in yield if the level of water within the well does not rise up, even several hours after pumping. All that can be done is to construct a new well, ensuring that the well casing is set far enough below the water table (ideally 5 to 10 metres) to assure an adequate water supply during the dry summer periods when the water level declines. Also, check how many people are drawing water from the

- Well Water Interference: The construction of water and sewer mains, drainage ditches and highways (road cuts) can occasionally affect ground-water levels and interfere with nearby shallow wells. In addition, the static water level in a well may be affected by large withdrawals of ground water from nearby large capacity wells or de-watering equipment for construction works (see Footnote #5). The potential for well interference depends greatly on the lithology of the producing formation and the magnitude of well usage.

- Screen Blockage: Sometimes the problem is that the well screen has plugged-up with fine sand and silt particles, with accumulated iron deposits or with growths of nuisance bacteria (naturally occurring, non-health related bacteria with can produce rotten egg smells, random slugs of iron rich water etc). This is likely the case if the water level in the well is near its original construction level but drops to the bottom of the pump cylinder as soon as the well is pumped. The well should be extensively re-developed to try and restore the efficiency of the screen and gravel pack (see **Section 10**). Unfortunately, if the problem occurred once, it will probably occur again. Be prepared to repeat the development process as needed to extend the life of the well.

G-12: Footnotes & References

[1] The drilling fluid prevents caving of the borehole because it exerts pressure against the wall. As long as the hydrostatic pressure of the fluid exceeds the earth pressures and any confining pressure in the aquifer, the hole will remain open. The pressure at any depth is equal to the weight of the drilling fluid column above that point.

[2] Before drilling out the grout plug, the effectiveness of the seal can be checked by measuring water-level change in the casing over time. In wells with a low static water level, the casing can be filled with water or drilling fluid and later checked for any water loss. If the static water level is high, the casing can be nearly emptied and any influx of water into the casing can be measured.

[3] Frequently used polyphosphates include sodium tripolyphospate [$Na_5P_3O_{10}$), sodium pyrophosphate ($Na_4P_2O_7$), tetra sodium pyrophosphate (NaP_2O_7) and sodium hexametaphosphate ($NaPO_3$) (Anderson, 1993).

[4] About 6.8 kg (15 lb) of a polyphosphate should be used for each 400 L (100 gal) of water in the screen. 0.9 kg (2 lbs) of sodium hypochlorite should also be added to every 100 gal of water in the well to control bacterial growth promoted by the presence of polyphosphates (Driscoll, 1986). Polyphosphates should be premixed before introduction into the well because they do not mix easily with cold water. Occasionally the mix water is heated to help dissolve the chemical (Driscoll, 1986). Polyphosphates should **NOT** be used in formations with thinly bedded clays and sands because these chemicals tend to make the clays near the borehole unstable, causing them to mix with the sand (Driscoll, 1986) continually passes into the borehole during pumping (Anderson, 1993).

[5] When a well is pumped, the water level in the immediate area of the well is lowered and a cone of depression develops around the well. The size and the shape of the cone will depend on the aquifer characteristics of the water-bearing formation in which the well is completed and the rate of pumping. This is likely the cause if there are two or more wells located within 100 m of each other and if water levels return to normal in both wells once pumping has stopped or within some reasonable time afterwards. Water level recovery depends on the quantity of water withdrawn from the aquifer and the length of time the wells were pumped. All that can be done is manage the rate at which water is taken from the interfering wells.

Australian Drilling Industry Training Committee Ltd (1992) Australian Drilling Manual 3rd edition", Macquarie Centre: Australian Drilling Industry Training Committee Ltd, ISBN 0-949279-20X.

Driscoll, F. (1986) Groundwater and Wells, St. Paul: Johnson Division