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A FARM WATER SUPPLY FROM QUICKSAND

by

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INTRODUCTION

General Statement

The plains region of Alberta is underlain by Upper Cretaceous and Tertiary strata composed mainly of silty shale and very fine-grained sandstone, the shale being by far the most predominant rock type. These strata are nearly everywhere covered by a mantle of glacial drift which is commonly 30 to 100 feet thick. The drift is composed mostly of material that has been locally derived and thus it is also fine-grained.

Such an environment is not favorable for the development of groundwater supplies. In many districts of Alberta a large proportion of the rural residents experience difficulty in obtaining a water supply, and in a few districts good wells are unknown. In several cases where studies have been made of the groundwater geology of such areas it has been found that strata of quicksand are encountered in shallow borings. A quicksand stratum carries water if it is below the water table but, in drilling, it is almost invariably "cased-off" and ignored as a source of water on the grounds that it is "dry" (unsaturated) or that the sand is too fine to control in a well.

Experience has shown that if a quicksand stratum is as much as five feet thick it can likely be developed as a suitable aquifer for small supplies of water and may provide a groundwater supply where wells have not been successful previously.

Purpose and Scope of the Report

In December of 1959 the Research Council of Alberta undertook the drilling and development of wells in a quicksand aquifer near Edmonton, Alberta, on an experimental basis. Three wells were completed and tested by pumping. Each well was completed in a different manner in order to determine the most reliable method of completion for this type of aquifer. One of the wells was wholly successful and has proven to be a suitable source of water for a dairy farm, where previously the water supply had been inadequate. The other two wells were less successful but probably adequate. The purpose of this paper is to report the results of this study in order that the possibility of obtaining a water supply from quicksand aquifers may be considered in areas where the water supply is a problem.

Acknowledgments

Mr. Walter Wedman, the owner of the land on which this and other similar work has been done, has been co-operative and helpful throughout the testing period. Independent Drilling and Exploration Limited, Edmonton, supplied equipment and competent operators for the drilling program. Mr. Frans Moens, technician, Research Council of Alberta, spent several cold winter nights conducting pumping tests on the wells. This assistance is gratefully acknowledged.

GEOLOGY AND HYDROLOGY OF QUICKSAND AQUIFERS

Occurrence of Quicksand

Bedrock

Strata composed of fine to very fine sand make up a small proportion of the nonmarine, Upper Cretaceous rocks that underlie the plains region of Alberta. The remainder of the rocks that lie within 500 or 1,000 feet of the surface are composed of silty and sandy shale and coal. The fine sand is the coarsest fraction of the sediment and the clean sand strata are the result of sorting action by waves or running water at the time the sediments were deposited. Medium- and coarse-grained sandstones are rare because particles of the necessary size were almost absent from the environment in which the sediments were deposited.

Throughout a large portion of Alberta, these fine-grained sandstone strata are the sole source of groundwater. Although they are seldom sufficiently permeable to transmit large quantities of water, they play an important role in rural water supply. For the most part the strata are consolidated and well completion is no problem. At a few places, however, these aquifers are saturated but not consolidated. In this case the usual completion techniques are not satisfactory for the sand will "quick" or "heave" into the hole, often to nearly as high as the static water level, and this will render the well useless. For this reason water-well drillers almost always "case-off" all quicksand strata encountered during drilling. This is of little consequence if a suitable aquifer is encountered at a different depth in the hole but it results in a dry-hole if no other aquifer is found. Under favorable conditions a farm water supply can be developed from a quicksand stratum in the bedrock.

Drift

Drillers' logs indicate that in many places the drift section contains strata of sorted granular material. The grains range in size from fine sand to coarse gravel, but commonly the strata are composed entirely of fine to very fine sand, and silt. The grains are rarely cemented and the strata are most commonly completely unconsolidated. Where such strata are encountered below the water table by a bore-hole, the sand heaves into the bore and is termed quicksand.

Quicksand strata are found associated with lacustrine, outwash and till deposits. A significant feature of the quicksand is the fact that it is approximately the same texture wherever it has been reported and sampled. There is a good reason why this is so, for the fact that a stratum has the characteristics of quicksand when encountered in a bore-hole is suggestive of its textural composition. The graph of grain-size analyses of typical samples is shown in figure 1. Where the texture is finer the permeability is lower and there is sufficient clay and fine silt present to bind the grains and cause partial consolidation, with the result that the stratum would behave as an impermeable layer rather than as quicksand. Where the texture is coarser it is likely that heaving will not occur unless an attempt is made to produce water from the bore-hole and, if that is the case, the material is relatively easy to cope with by the intelligent use of well screens or even slotted casing. In any case the water which occurs in the drift is usually thought to be undesirable and, though this belief is seldom true, drillers are hesitant to complete a well in this type of material.

The origin of quicksand in the drift is explained the same way as that of quicksand in bedrock. In most places sand of this texture was the coarsest material in the sediment and any sorting action would result in the deposition of a quicksand stratum.

Hydrologic Characteristics

On the basis of the mechanical analysis of samples of typical quicksand aquifers, the permeability of this material by the Hazen formula should be:

$$K = CD_{10}^2$$

where K = permeability cm./sec.

C = constant, depending upon the material; it ranges from 100 to 150

D_{10} = the effective grain size of the material, cm.

$$K = 100\,(.003 \times 2.54)^2$$

$$K = 5.8 \times 10^{-3} \text{ cm./sec.}$$

$$P = 5.8 \times 10^{-3} \times 1.79 \times 10^4 = 102 \text{ gpd./ft.}^{2}*$$

On the basis of the pumping test data the permeability of the quicksand stratum tested in this investigation is 100 gpd./ft.^{2} If the material is as uniform in different areas as postulated above, it would be reasonable to expect the permeability of the aquifer to have the same order of magnitude wherever quicksand is encountered.

In this investigation the test wells encountered quicksand in the interval from 28 to 35 feet and the water rose to a static level of 24 feet below the surface. Many shallow water-table wells show fluctuations during dry and wet seasons, but it is not likely that a confined aquifer such as this would be affected by a drought.

In drilling with percussion-type equipment the quicksand strata must be

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* gpd./ft.^{2} = gallons per day per square foot.

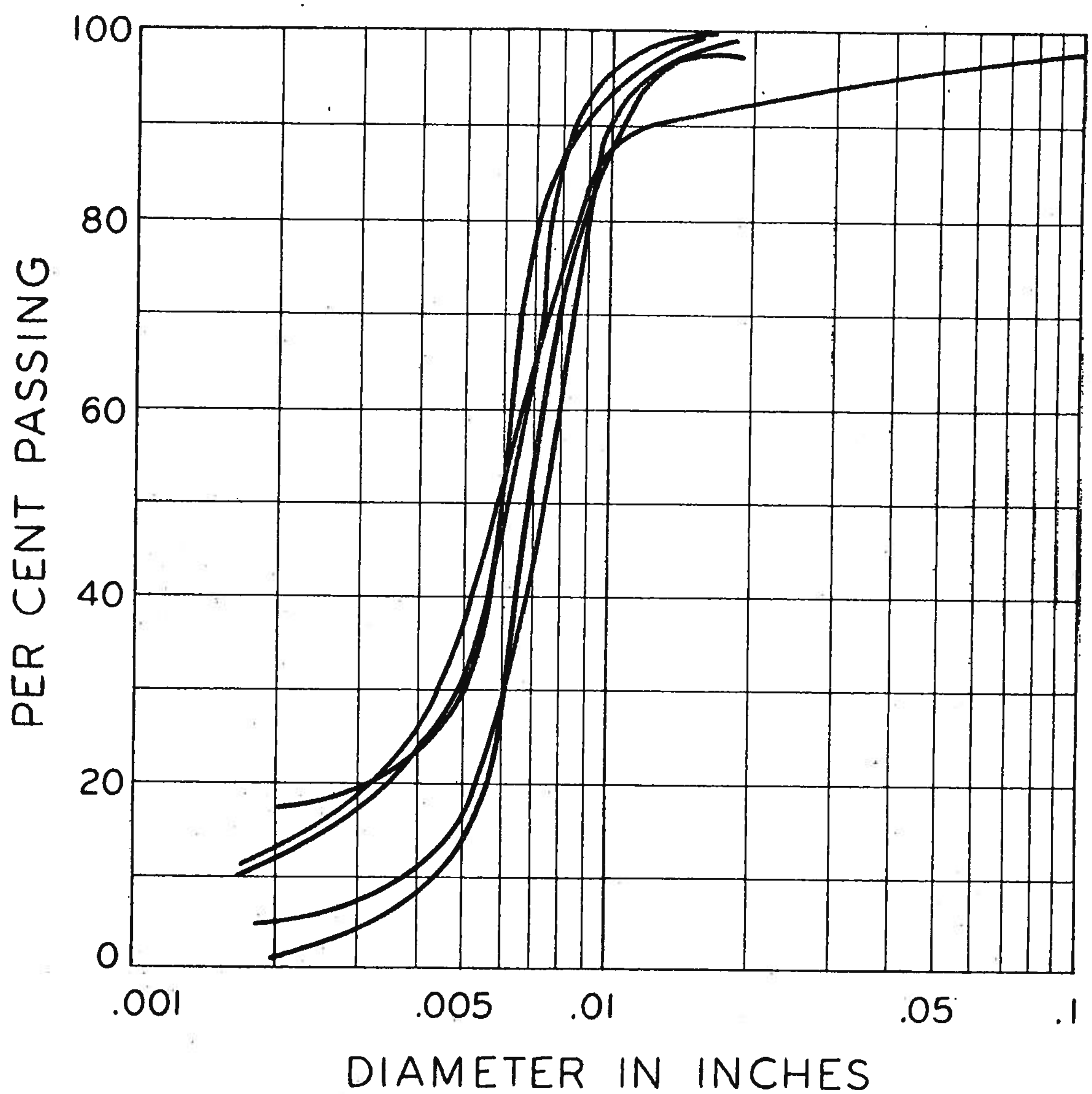

Figure 1. Size analyses of typical quicksand aquifers

"cased-off" to prevent it from "heaving" up into the hole. With rotary equipment the hole remains open if kept full of drilling mud. This is usually not difficult unless other porous horizons are also exposed by the bore, for the quicksand does not "take" water readily, either because of its low permeability or because it "muds off" very quickly. If water is withdrawn from the bore-hole either by bailing or pumping, sand moves into the bore-hole and may "heave" up as high as the static water level. The reluctance of drillers in developing this type of aquifer is easy to understand.

DEVELOPMENT PROCEDURES

Exploration

Quicksand aquifers will not likely be developed where other aquifers can be found because of the difficulties involved in construction of wells in quicksand. In some places in Alberta, however, there are no other aquifers and in such cases consideration should be given to investigation of quicksand strata. Quicksand strata in the bedrock, if present at all, are generally continuous over a considerable area. Consequently, if previous wells which have penetrated the bedrock in the surrounding district have not encountered any quicksand in the bedrock, then it is unlikely that any will be found by additional test drilling. Quicksand strata in the drift, however, are characteristically of limited areal extent and some test drilling is justified even in localities where quicksand has not been previously reported.

The following remarks refer to exploring for quicksand in the drift.

The aim of test-drilling should be to determine whether or not a quicksand stratum sufficiently thick (five feet for most farm needs) to be developed as an aquifer, exists within a certain distance from the site at which water is required. The distance might be called the economic radius and it will depend on many factors but is likely to be 400 to 600 yards for most farms. The area within a circle of 600 yards radius can be tested adequately by the proper siting of eight to twelve test-holes. Any pattern might be chosen but there should be no place in the circle more than 200 or 300 yards from a test-hole. The inference is made that if a suitable quicksand aquifer exists within the economic radius, it will be encountered by this exploration, and if a quicksand stratum does exist within the tested area but is not encountered in the test-drilling, then it is not extensive enough to be considered as an aquifer.

An exploration program may seem to be too expensive to be undertaken by most farmers. With careful planning the costs of a test-drilling program may be less than the cost of an unsuccessful well, of which any interested farmer likely has several. The cost will depend upon several factors, mainly:

(1) the cost of moving equipment to the site;
(2) the thickness of the surficial deposits;
(3) the nature of the surficial deposits;
(4) the economic radius and density of test-holes.

(1) The cost of moving equipment to the site can be quoted by the driller and will depend upon the distances from the driller's base of operations. This is a fixed cost that might be divided among two or more clients.

(2) All test-holes should be carried to the top of the bedrock surface. In most parts of Alberta this means 30 to 100 feet of drilling for each hole. Where the drift is less than 30 feet thick or over 100 feet thick, the exploration may have to be rejected altogether or modified to suit the situation.

(3) In a few districts the surficial deposits may contain abundant large boulders which makes drilling difficult and costly. This is not a common circumstance. In most instances drilling in the surficial deposits is rapid and relatively free of problems.

(4) The economic radius may vary greatly, depending on the establishment to be supplied with water and the cost of an alternate source.

A competent driller is quite capable of determining when quicksand is encountered in a hole and the thickness of the stratum, but he must be aware of the importance of this information if he is to be expected to log with accuracy. Samples of the cuttings substantiate the driller's log and should be collected. Samples of clay and till can be taken from the cuttings as they emerge from the hole. Samples of sand can be collected from the bailer if percussion tools are used or from the mud pit if rotary equipment is used.

Well Construction and Development

Two types of wells may be successful in quicksand aquifers. The gravel envelope well is the type that offers the greatest chance of success whereas the screened well without a gravel envelope is the cheaper and easier method of completion. The methods outlined in this paper are standard methods in the water-well industry and are not original with the author. The procedures and diagrams that are described in this paper have been found to be effective in the particular circumstances encountered in developing quicksand aquifers. They are included in order that persons interested in this type of work may have a ready reference and guide.

Gravel Envelope Wells

There are two methods of completing a gravel envelope well in shallow quicksand aquifers. In both methods the object is the same - to place a two- to four-inch gravel envelope or pack (the "gravel" in this case is a very coarse sand) between the water well screen and the aquifer. The purpose of the pack is to increase the effective diameter of the well and prevent the aquifer from caving into the hole.

In the pull-back method a hole 10 to 12 inches in diameter is drilled from the ground surface to the base of the quicksand aquifer. A ten-inch casing is run into this hole and sealed in the clay or shale at the base of the aquifer (figure 2-A). The

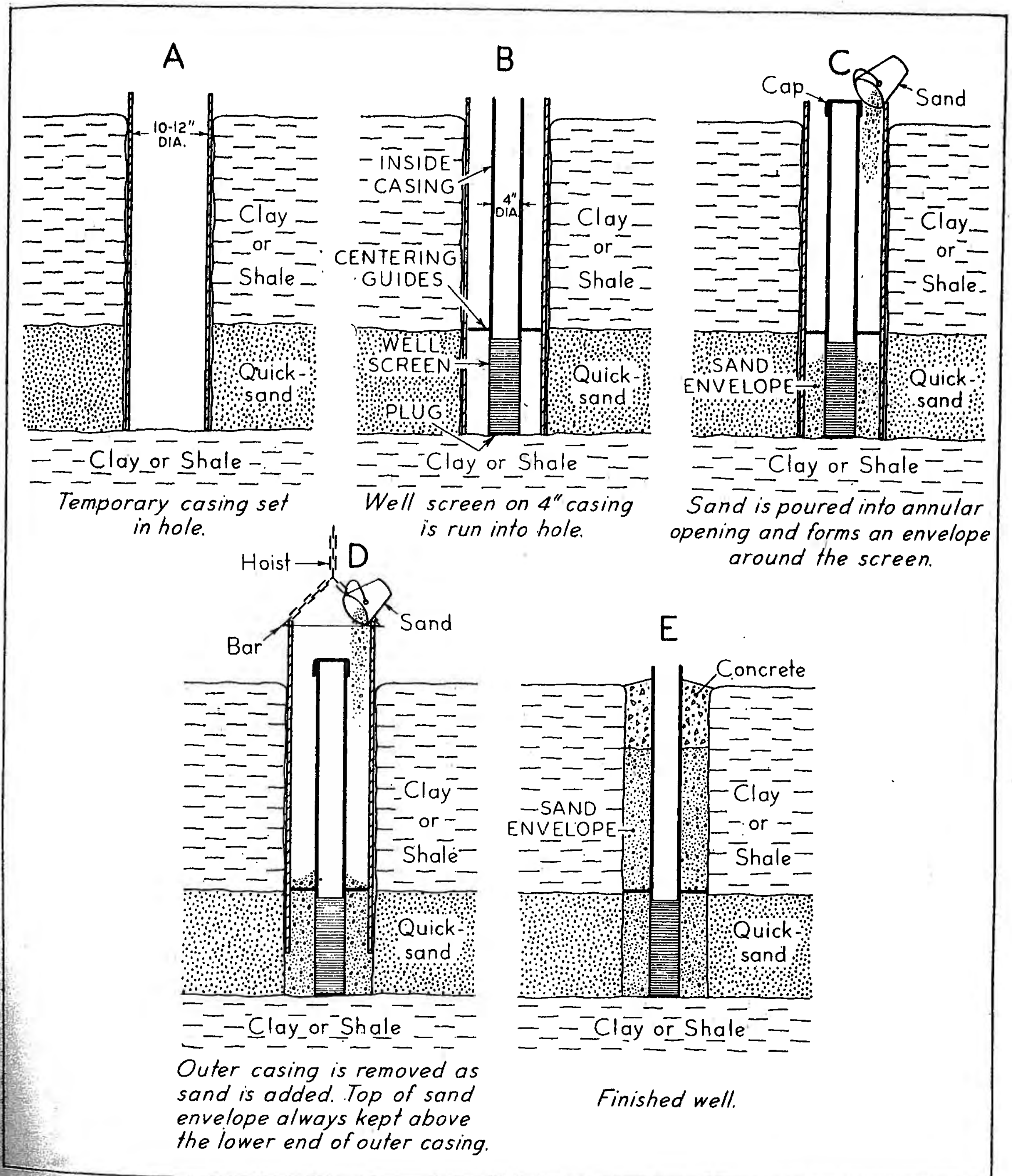

Figure 2. Construction of a gravel envelope well by the pull-back method

seal need be only tight enough to prevent extensive movement of water or sand into or out of the casing. The hole is then cleaned out and a four-inch casing with a four-inch diameter water well screen at the bottom end is run into the hole (figure 2-B). The screen should have slot openings of 0.015 to 0.030 inches. In this investigation a screen having 0.015-inch slot openings was used successfully. The length of the screen depends partly upon the amount of water required but should be at least five feet for a farm water supply. The bottom end of the screen should have a solid plug. The length of the screen and casing is such that the screen is set opposite the bottom portion of the aquifer resting on relatively solid clay or shale. The full weight of the casing should not be supported by the screen. The top of the inside (four-inch) casing should extend several inches above the ground surface. Centering guides welded onto the inside casing serve to ensure the centering of the screen in the hole. The pack is then placed around the screen. This is done by pouring the pack material into the annulus between the outer and inner casings (figure 2-C).

As the pack is added, the outside casing is pulled out of the hole. Care must be taken that the pack is always several feet higher in the hole than the bottom of the outside casing (figure 2-D). When sufficient sand has been added so that the pack extends as high as the static water level, the outside casing may be completely withdrawn. The annulus above the pack may be filled with clay, concrete or gravel; or it may be filled with pack-sand which can replace any sand that moves downward as a result of formation of a cavity near the screen. The upper 10 feet of the annulus should be filled with impervious material to ensure a sanitary well completion.

The well is then ready to be developed. Care must be taken in development that the fine fraction from the formation is not drawn into the pack and left there, for this may clog the pack and ruin it. Likely the best type of development for this well is jetting water against the inside of the screen and pumping the well sporadically. Development should continue until no fine sand or silt is produced during pumping.

The most difficult steps in this method are the withdrawal of the outside casing and the emplacement of the pack material. A cap or tin over the top of the inside casing will prevent pack material from entering this casing. A piece of pipe or board can be placed on the end of this cap and leaned against the derrick of the drill rig. This can serve as an indicator of movement of the inside casing for after the outside casing is withdrawn several feet, the inside casing is not easily observed and it must, of course, remain in place. After the outside casing has been withdrawn more than five or six feet, it becomes difficult to add pack material. It is therefore an advantage to have the top 15 or 20 feet of temporary casing in short threaded joints which can be easily removed as the end of a joint is pulled to ground level. If there is difficulty in withdrawing the outside casing, heavy jacks may be necessary to free the casing from its seat. If the top of the outside casing is above the top of the inside casing, holes can be burned in the outside casing and a bar passed through to serve as a firm purchase for a jack at each end. If the outside casing can be moved initially by this method, then the hoisting equipment on the drilling rig can usually withdraw it completely.

Another way of completing the same well is by the "flush-in" method. The value of this method lies in the fact that temporary casing is not set and the difficult steps involved in the pull-back method are not encountered.

A 10-inch hole is drilled through the aquifer and the hole is cleaned out by slow flushing. The drill-stem is carefully removed from the hole with as little agitation of the drilling fluid as possible. The hole is kept full of drilling fluid to help prevent caving (figure 3-A). This is not usually difficult because fluid loss into these formations is slight.

The screen and casing are made up as before. The screen in this case should be at least five feet long and should have a slot opening of 0.012 to 0.015 inches. Centering rings or guides are required and the bottom of the screen is fitted with a plug.

The screen and casing are run into the hole and the screen is set opposite the bottom portion of the aquifer (figure 3-B). The hole is again flushed out, by circulating water down through the casing. The water enters the annulus by passing through the screen, and then rises in the annulus to the surface (figure 3-C). If sand from the formation has entered the hole, it will be washed to the surface by the circulating water. When the water reaching the surface has cleared, one may assume the hole is clean and open at the bottom.

Pack material is then poured down the annulus between the casing and the wall of the hole while the circulation of water is maintained (figure 3-D). The coarse sand of the pack material will sink against the current of water and form an envelope around the screen. The hole around the screen is kept open by circulation, and the fine sand that may enter the hole is removed by the rising water. The rate of circulation must be adjusted to obtain the proper results, but this is simply a matter of regulating the speed of the mud pumps on the drilling rig. The position of the sand pack in the hole can be tested by means of a light pole or a heavy plumb bob. The hole can be finished and developed as for the pull-back method.

The advantages of this method are obvious. The disadvantages are that the position of the screen and the pack are not as definitely fixed with respect to one another and with respect to the aquifer as in the pull-back method.

Suitable pack material is marketed in 100-pound bags. It may also be purchased from a dealer or hand screened. The sand should consist of grains ranging in size between 0.01 and 0.1 inches.

Screened Wells

This method depends upon a well screen to hold the material from the aquifer out of the well while allowing water from the aquifer to enter the well. It is a much easier well to construct than either gravel-envelope wells mentioned above.

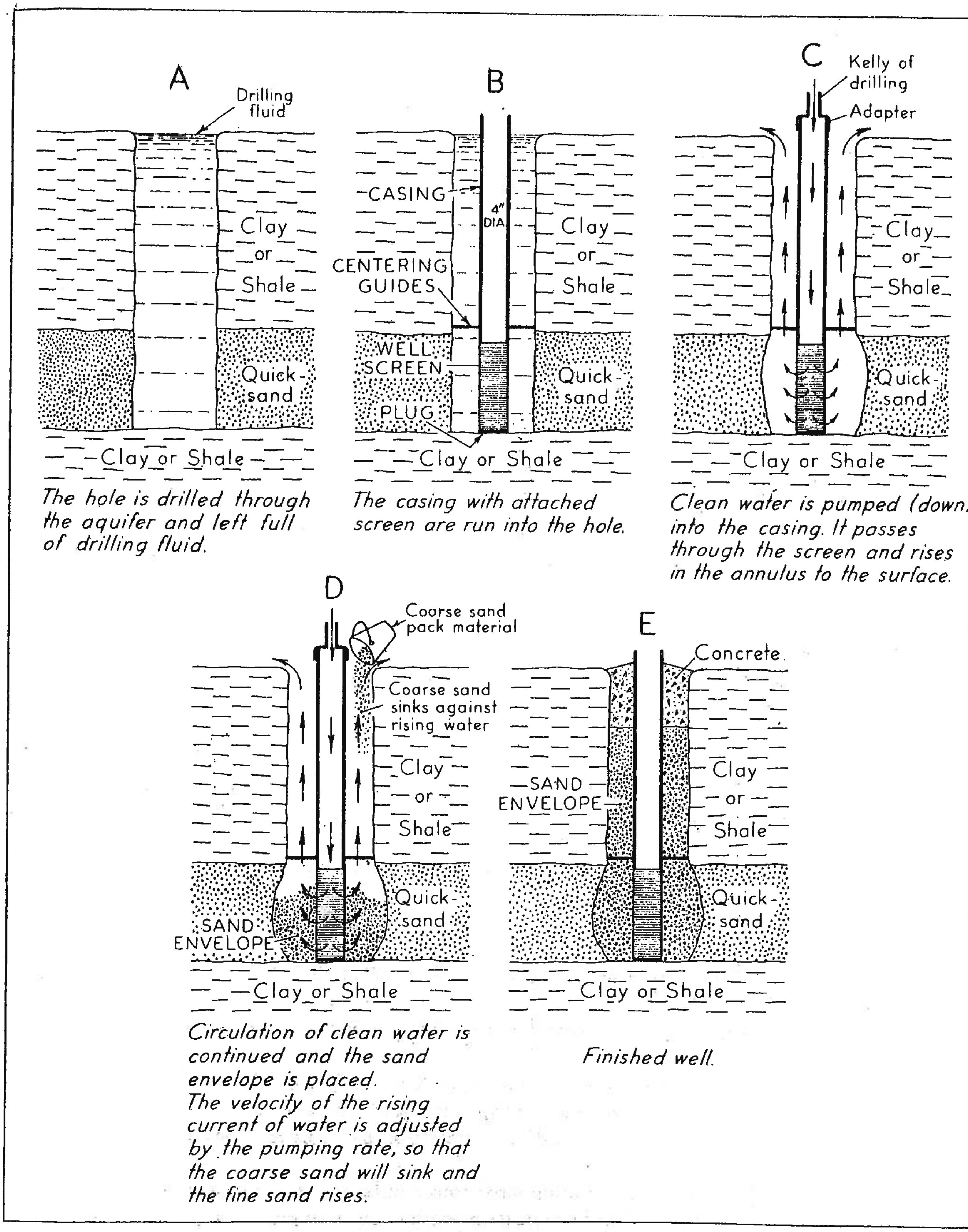

Figure 3. Construction of a gravel envelope well by the "flush-in" method

A five- or six-inch hole is drilled through the aquifer and a well screen and casing, made up as before, is run into the hole. No gravel pack is to be installed so the screen is placed directly against the aquifer. The size of the slot-openings in the screen should be such that 90 per cent or more of the sand of the aquifer will be able to pass into the screen from the formation.

The well should then be surged, flushed, and bailed alternately until no sand can be drawn through the screen into the well. The nature of the formation, the fine texture of the sand, and the relatively large screen opening make development of a natural gravel pack quite difficult for if surging, flushing, or bailing is too violent any natural pack that has developed may be destroyed and development will have to be started again. A finer screen might prevent this but experience has shown that finer screens tend to become completely plugged and impossible to develop.

The well should not be completed until testing proves it to be successful. Then the annulus can be filled with sand, clay, and cement.

Well Testing

These wells should be tested carefully before pumping equipment is installed and adjusted. The well should be pumped at a slow rate for at least 12 hours. The level of the water surface in the well should be measured periodically during this time to determine whether or not stabilization can be expected. It is most likely that even after 10 or 20 hours of pumping the water level will continue to drop very slowly. This does not indicate that the well is a failure or is likely to fail in the future. The pumping rate should be adjusted so that the water level in the well does not drop below the top of the well screen.

Samples of water can be taken every hour, and if all samples are in similar clear glass containers it is easy to ascertain whether or not sand is being produced and whether or not the condition is improving during the test. If sand is a problem, the well should be pumped sporadically at high rates, until it can be pumped continuously at a lower rate without producing sand.

CONCLUSIONS AND RECOMMENDATIONS

Quicksand aquifers may be regarded as a new source of water in Alberta.

There are many areas in Alberta where such a well would be a valuable asset to a farm. Any area in which farm water supplies have been difficult to obtain should be examined for suitable quicksand aquifers.

It is possible to develop water from quicksand strata in sufficient quantity to be suitable for a farm supply. Where a stratum of quicksand as much as five feet thick is found below the water-table, it is feasible to attempt to develop a water supply from that stratum. It is likely that any material termed quicksand by a water-well driller will fall within well-defined limits texturally, and its hydrologic properties can be anticipated. Wells may be completed in several ways but the pull-back method of installing a gravel-pack well and utilizing very coarse sand for pack material is the most reliable. It is also the most expensive method.

Investigations should be undertaken to establish criteria for the cheapest and most efficient pattern and methods of exploring for such aquifers. Some areas are undoubtedly more suited to development of quicksand wells than others, and these areas should be defined and criteria established for recognizing them. Finally, a thorough examination of the economics of farm water supplies might help to determine the "economic radius" as the term is used in this report and also might help to determine the feasibility of this method of obtaining a water supply.