11

Horizontal Drains—Their Use in Open Pit Mine Dewatering

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INTRODUCTION

Horizontal drains are one method which may be used for open pit mine dewatering. These devices consist of horizontal holes which usually, but not necessarily, have slotted PVC screen or pipe placed in them. They are used to drain slope embankments or water-storing strata behind an impervious embankment. Further, they may be used underground to assist drainage galleries or shafts placed adjacent to an open pit. Horizontal drains are thought to have first been used in 1939 by the California Division of Highways to drain water induced slope instabilities along highway cuts. Since that time, a number of advances in the method have been made. Most notably the innovations have been in the drilling and emplacement equipment and in the perforated pipe or slotted screen inserts.

The primary purpose of this paper is to describe horizontal drains and their applications and usage in open pit mine operations. The paper begins with a description of a typical drainage system. Next, the procedures for emplacement are described and then advantages and disadvantages are outlined. A brief overview of current costs is then presented followed by a description of a case history which concludes the paper.

SYSTEM DESCRIPTION

Drain Characteristics

Slotted 1½-in. nominal diameter PVC(schedule 80 polyvinyl chloride pipe) screen with machined joints is placed inside holes approximately 4-in. in diameter. The slots vary in size with the smallest being 0.010-in. and the most typical being 0.020-in. The holes are drilled just above the toe of a bench embankment at a slight upward angle, as shown in Figure 1, and at an average length of about 500 feet. A short hole would be 300-ft in length and a long hole would be 700-ft or more in length. The most typical length is 400 to 600-ft. The slotted PVC screen which is placed inside the embankment usually has an unslotted or solid section of pipe placed at the beginning of the hole. A collection system, consisting of larger diameter plastic or steel pipe, usually runs along the toe of the bench and receives water from the solid pipe via a rubber connecting hose.

Drainage System Purpose

There are two distinct purposes for dewatering an open pit mining operation. First are the operational problems that water creates. Water tends to hamper the movement and control of the mining equipment, it increases the unit weight of the material to be removed from the pit and it can cause processing problems in the concentration plant. Second are the slope instability problems. Water reduces the effective strength in the embankment or slope materials and thus, unstable pit walls may be created. It also causes horizontal thrust forces in tension cracks, thereby reducing the factor of safety against slope failure. Horizontal drains may be used alone or in combination with other methods, such as vertical wells or drainage galleries, to lessen or eliminate the adverse affects of water.

Typical Applications

Any dewatering application in an open pit mine is usually worthy of investigation for potential horizontal drains. However, some cases are natural applications. Such a case is the condition where an alluvial sand and gravel overlies bedrock. In this case the top of the bedrock may be old topographic surface which is a relatively impermeable unconformity. Groundwater tends to flow along the interface and exit into the pit just above the contact. Drains may be collared either just above or below the contact. When they

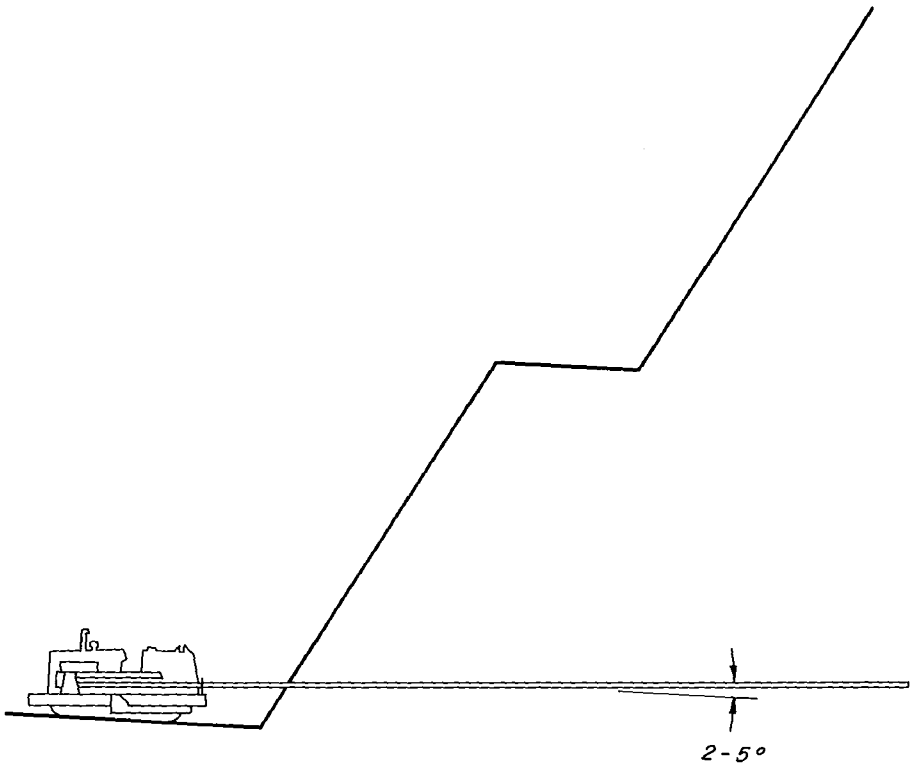

Figure 1. Horizontal Drain Emplacement.

are collared below the contact, they are angled upwards to pass through the contact at some distance inside the embankment. Another primary application would be in saturated soil or soft rock materials. In these cases, as in all cases, it is very important to be sure the source of the water is being considered and that means are taken, if possible, to lessen or eliminate the recharge. One other application that deserves special mention is the case of a water-bearing strata behind an impervious barrier in the pit slope. The water-bearing strata may be creating adverse stability affects even though it is not exposed in the pit. A very closely related condition is a water-filled tension crack located in or beyond the pit crest. Horizontal drains can serve to tap these water reservoirs and reduce their adverse affects.

EMPLACEMENT PROCEDURES

Initial Considerations

In order to arrive at the best possible horizontal drainage system, full consideration should first be made of the applicable geological and hydrological conditions. The existence of various joint systems, which act as primary water conduits, should be studied in terms of their spacial orientations, continuities, spacing and infilling materials. Usually it is best to lay out a horizontal drain, assuming that some leeway does exist in the orientation, so that it intersects as many joints as possible. The permeabilities of the various rock or soil units should also be examined. Typically, it may be more desirable to place more drains in a particular rock or soil material than another, owing to their different water flow and storage capacity characteristics.

Hole Drilling

Equipment. The first known equipment used for horizontal drains was called a "Hydrauger". It consisted of a lightweight air driven rotary drill mounted on a small frame. A hand operated ratchet level was used to advance the bit into the slope embankment. A pilot hole about 2-in. in diameter was originally drilled and then reamed to 6-in. Perforated steel pipe was then inserted by hand or with the aid of jacks. Today two commercial drilling machines are available to both perform the drilling operation and place the PVC screen. The first unit is the "Hole-Gator" which uses a hollow stem auger to bore a hole in soil or soft rock materials. The slotted screen is pushed through the hollow stem, which is then withdrawn, leaving the horizontal drain in place. The second unit is the "Aardvark" which has the ability to drill holes in soft or hard rock materials with drag, tricone or hammer bits. Once the hole is drilled to the desired depth, the bit may be dropped(usually in the case of drag or tricone bits) and the slotted screen is inserted through the rods. A unique patented locking piston allows the Aardvark to successfully place drains even under the adverse conditions where running sands are present. After screen insertion, the rods are withdrawn over the drain. The drainage system is completed by attaching a collector line to the drain to carry the water away from the slope.

Hole Sizes. The first 15-20 ft of the drain hole is usually drilled at 5-in. diameter to accomodate a solid piece of surface casing or pipe. The surface pipe is unslotted and serves to transport the water from the slotted drain to a surface collection system. Auger bits are on the order of 4-in. diameter while drag bits are 4½-in. diameter. Tricone bits vary from 3 3/4 to 4 1/4-in. in diameter. Down-hole hammer bit diameters are typically 4 1/4-in.

Drilling Rates and Hole Completion. These important factors obviously depend on the length of hole and the materials drilled. An example of what may be expected under good conditions is 900 ft of drilling in 8 hours, as has been experienced in Wyoming uranium mines, where the drains were placed in medium hard sandstones. Drilling of 200 ft of hole in 8 hours would be considered slow and/or difficult drilling conditions. The completion of a 100 ft long hole would be considered average if done in 6 hours in hard or difficult lithologies and 1 hour under soft or easy conditions. A 500 ft horizontal drain would require from 2 to 4½ days for completion depending on the rock and drilling conditions.

Drain Length

The length of the drain must be such that it reaches the desired water bearing strata. Further, it must reach that strata and effectively solve the problem for which it was originally intended. Obviously, if severe drilling difficulties are encountered, the hole may not reach the desired depth and a lessor length will have to suffice. A general rule of thumb that may be followed in the absence of a more definitive basis is that the length of the hole should vary from H/2 to H, where H is the height of the pit slope. In other words, the length of drains for a 500 ft high slope should vary from a minimum of 250 ft to a maximum of 500 ft.

Spacing

Determination of the optimum spacing could, theoretically, have a geological/hydrological basis, but in practice the spacing is usually determined by trial and error. In general, drain spacings range from 10 to 100 feet. Beyond 100 ft, they seldom provide the desired drainage, while at spacings of less than 10 ft, they may not be cost-effective. The permeability conditions obviously will have a pronounced effect on the optimum spacing. As shown in Figure 2, the draw-down curves in a direction perpendicular to the drains could vary considerably depending on the permeability. Effective drainage could only be achieved with closer spaced drains where the permeability is relatively low. The trial and error procedure generally employed consists of the following: A large spacing such as 100 ft is chosen and several drains are emplaced as shown in Figure 3. The rate of flow from the drains is measured and recorded. Then a point midway between two of the drains is selected and another drain is completed. If there is interference between the drains, i.e., if the flow on the adjacent drains lessons more than usual, then the drains may be too close. If no interference is noticed, then the spacing is again decreased by half. The procedure is continued until definite interference is noticed.

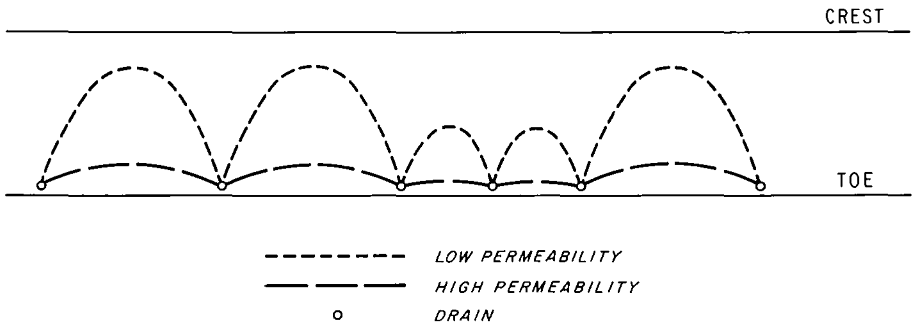

Figure 2. Draw-down Curves Between Drains.

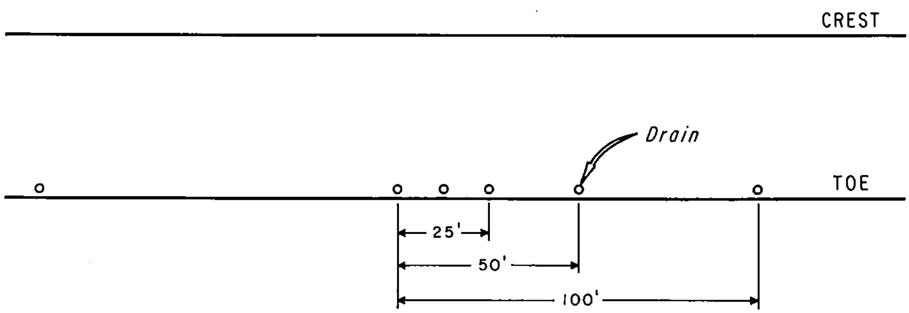

Figure 3. Horizontal Drain Spacing.

At that point the spacing is increased slightly until only slight interference takes place. The spacing would, in general, be considered optimal for that portion of the pit. Other areas, which have differing geological and hydrological conditions, may also have differing optimum drain spacings. In any case, the trial and error procedure has been found in practice to yield the best method of determining drain spacing.

Drain Performance

The completed drainage system should consist of the drains themselves, a collector system and monitoring piezometers, as shown in Figure 4, for example. The ultimate performance of the complete drainage system obviously is the success in getting rid of the water affecting pit operations and causing slope instabilities. In the shorter term, however, two methods to gauge drain performance are available. The first method involves the decrease in flow from the drains as a function of time. If the dewatering operation is successful, it should be expected that the amount of water flowing from the drains over a period of time decreases as the amount of water in the slope embankment decreases. An example of the decrease in flow that could occur is shown in Figure 5. In this case a flow of 100 gpm was initially experienced but quickly decreased to about 20 gpm after only one day. After one year the flow had decreased to about 10 gpm which was the static flow for this drain. Other drains under other conditions will have their own characteristic flow decrease

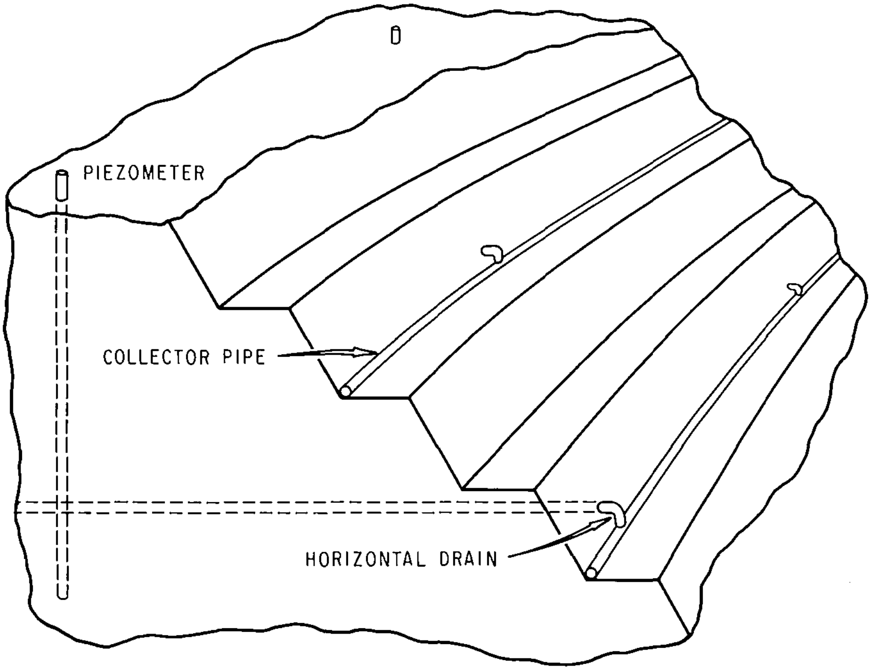

Figure 4. A Complete Horizontal Drainage System.

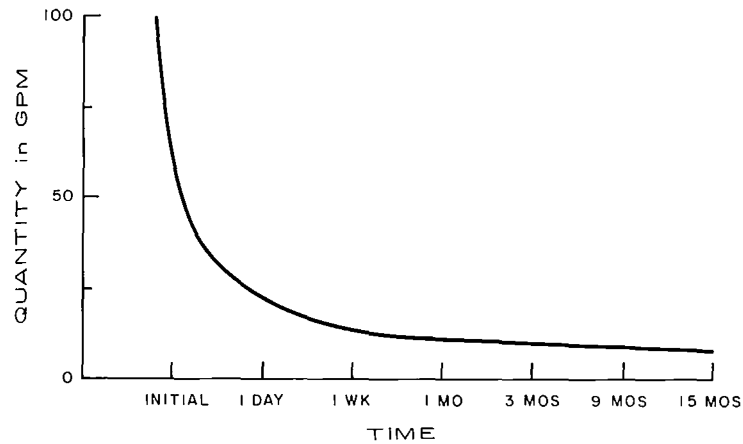

Figure 5. Horizontal Drain Flow Rate.

curves. However, they should show a marked decrease in flow rate with time, if the drains are to be considered sufficient in number and effectiveness. The second method of gauging performance is to use piezometers with which direct measurements of the water pressure in the slope may be made. As an example, consider the slope embankment shown in Figure 6. Prior to placement of the horizontal drain, the majority of the failure plane was under the phreatic surface as would be noted in the piezometer reading. After placing the drain, a distinct drop in pressure would be recorded with the piezometer, indicating the successful lowering of the groundwater below the failure plane. Use of piezometers represents a very easy and quick method to measure changes in the groundwater table. Such changes indicate whether or not a successful or unsuccessful drainage effort has been completed.

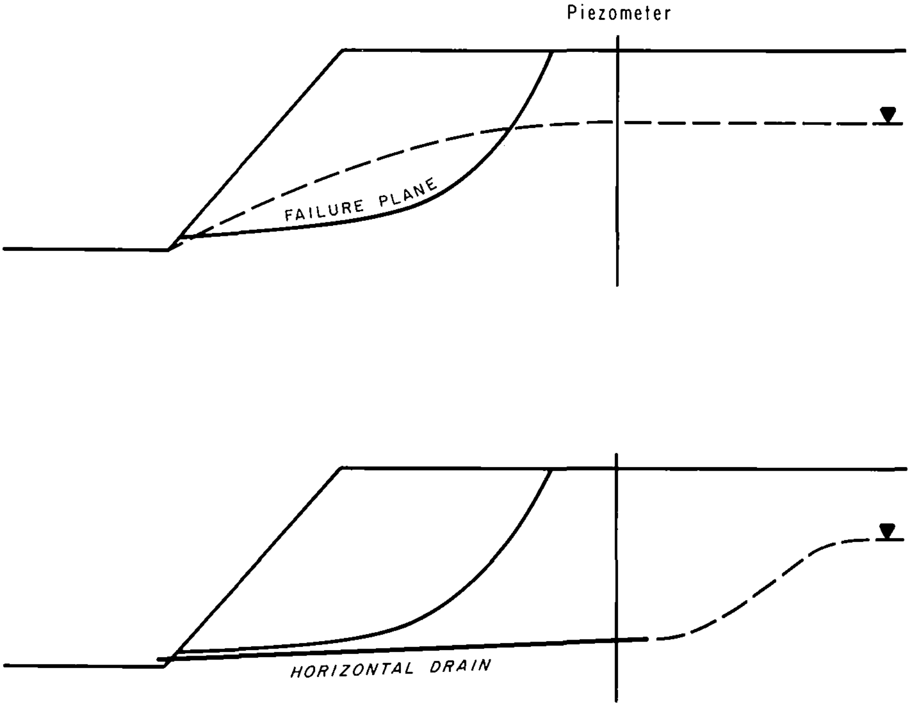

Figure 6. Groundwater Table Location Before and After Horizontal Drain Emplacement.

ADVANTAGES AND DISADVANTAGES

The advantages of horizontal drains are many and may be enumerated as follows:

1 - Drains are quick and easy to install
2 - There are no moving parts
3 - No power is required
4 - They work by gravity
5 - Little or no upkeep required
6 - Corrosion proof system
7 - They present a flexable system
8 - System life is long
9 - The relative cost is very low

Disadvantages are few, but may be listed as follows:

1 - Usually an existing slope is required. However, the drains have been installed from underground galleries and from inside vertical shafts.

2 - The water flows by gravity to the lowest point in the system and, therefore, usually at least one pump is required to remove the water from the pit.

COSTS - 1979

The costs of a drainage system will obviously vary with the geological and hydrological conditions. However, some ranges of figures may be specified:

	Cost Per Linear Foot	
Typical Drain	Soft Rock	Hard Rock
Minimum	$3.00	$4.50
Maximum	$6.50	$12.00
Average	$4.25	$7.00
Underground (Overhead)	$16.00	$20.00

CASE HISTORY

General Background

The Yerington Pit is located approximately 2 miles west of Yerington, Nevada and is in an open pit disseminated copper mine. An alluvial blanket more than 300 ft thick covers the underlying rock, which is predominately quartz monzonite. The contact forms a relatively impermeable barrier causing water to flow along old stream channels into the west end of the pit, just above the alluvial-bedrock interface. In 18 years of mining, vertical wells had been the primary dewatering tool and in most cases were successful. However, the seepage water above the alluvial-bedrock contact had not been successfully removed, even though considerable effort had been expended in drilling and pumping numerous vertical wells. The great interest in dewatering in the west end of the pit was brought about by four adverse factors: (1) the water was a hindrance to mine equipment operation; (2) the wet material represented additional weight to be hauled by truck; (3) screens in the mill became plugged when wet ore was processed and (4) slope stability problems were aggravated by water pressure affects. In 1971, the use of horizontal drains was tried as an alternative method of dewatering.

Procedures

The procedures used to implement the horizontal drainage system may be numerated in order as follows:

1 - Geologic and seismic survey data were initially used to determine the shape of the alluvial-bedrock contact, specifically, the old stream channel locations.

2 - Drain holes, which would intersect these channels and intercept a maximum amount of water, were planned.

3 - An Aardvark was used to drill some 33 holes complete with 1½-in. diameter PVC screens. The holes were inclined upward at 2-3°. They had optimum spacings of approximately 75 ft and had lengths which averaged approximately 300 feet. In the alluvium, the lengths ranged from 230-400 ft while in the bedrock, lengths were in some cases only 100 ft, but up to a maximum of 520 feet. An emplacement rate of 300 ft per day of completed system was achieved.

4 - A collection system was constructed which would pipe the water from the individual drains to one central pump station, where the water was removed from the pit.

Results

The end results of the project were that the visible saturated zone and related seepage were completely eliminated. Further, the movement of a two bench failure which had developed in the alluvium, due to adverse water pressures, was completely stopped within the first two days the drains were operational. Mining equipment operation and efficiency improved and down-time in the mill due to screen plugging was essentially eliminated.

Costs

Two different contractual agreements were used during the drain emplacement project. The first was an equipment lease basis and the second was a complete contract basis. The resulting direct drain costs were $2.94 per linear foot for the equipment lease basis and $4.85 per linear foot for the contract basis. Operator costs for the equipment lease basis probably added approximately $1.50 to the cost, for a total of $4.44 per linear foot.

Summary

The case history presents the results of a complete horizontal drainage project. Costs were probably higher at the time(1971) than they perhaps should have been, but the project had been approached on a research basis. The success is attested to by the immediate results which were produced and the fact that, on another pushback in 1972 in the same area of the pit, mine management again successfully used horizontal drains to dewater. Costs during the second phase were reduced approximately 50¢ a linear foot. A series of photographs dipicting various aspects of the case history is presented in Figures 7 through 13.

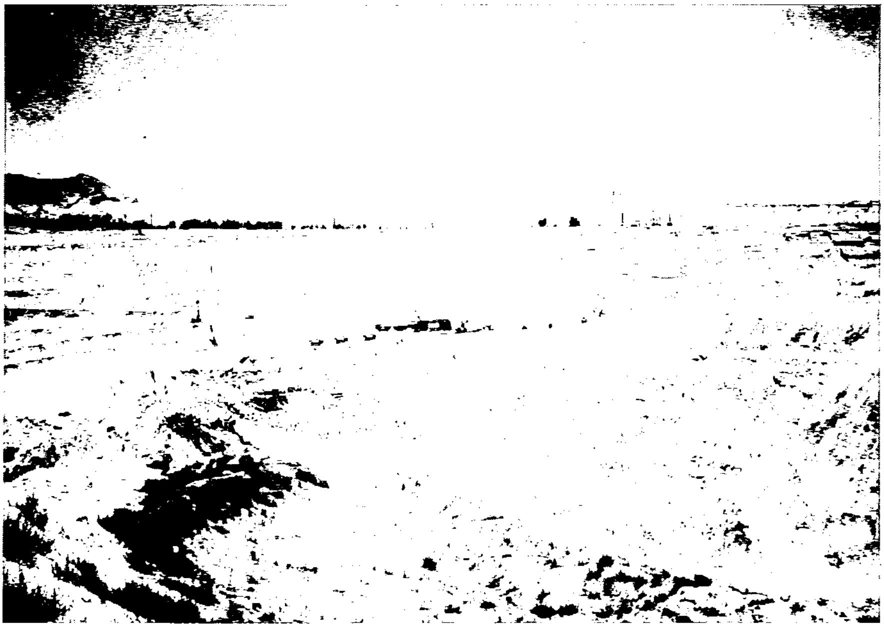

Figure 7. West End of Yerington Pit Showing Saturated Zone Immediately Behind Mining Equipment.

Figure 8. Aardvark Drilling Drainage Hole.

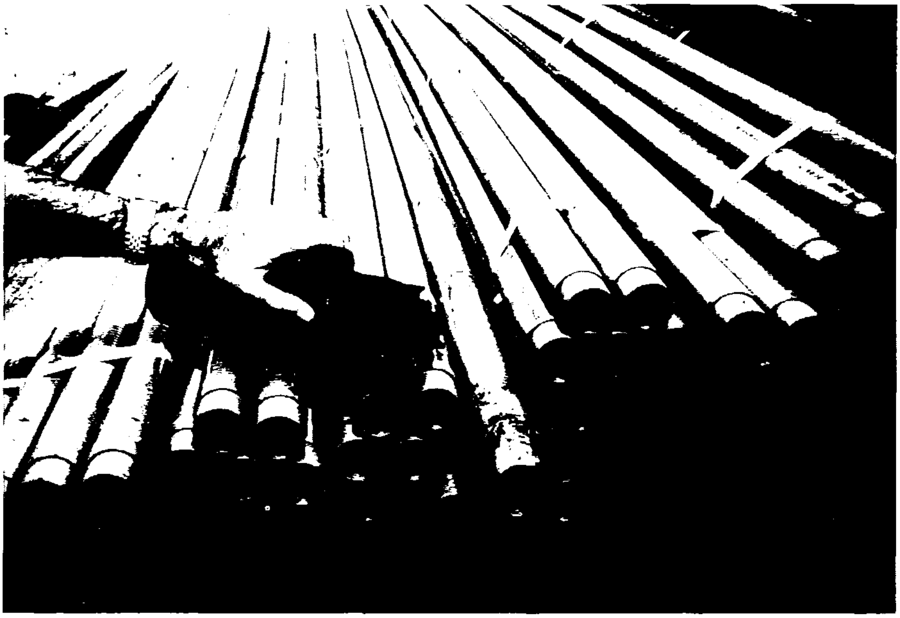

Figure 9. Tricone Bit and PVC Screen.

Figure 10. Completed Horizontal Drain.

Figure 11. Horizontal Drain, Rubber Connecting Pipe and Water Collector System.

Figure 12. Water Collection System Dischargimg to Pump Sump Intake.

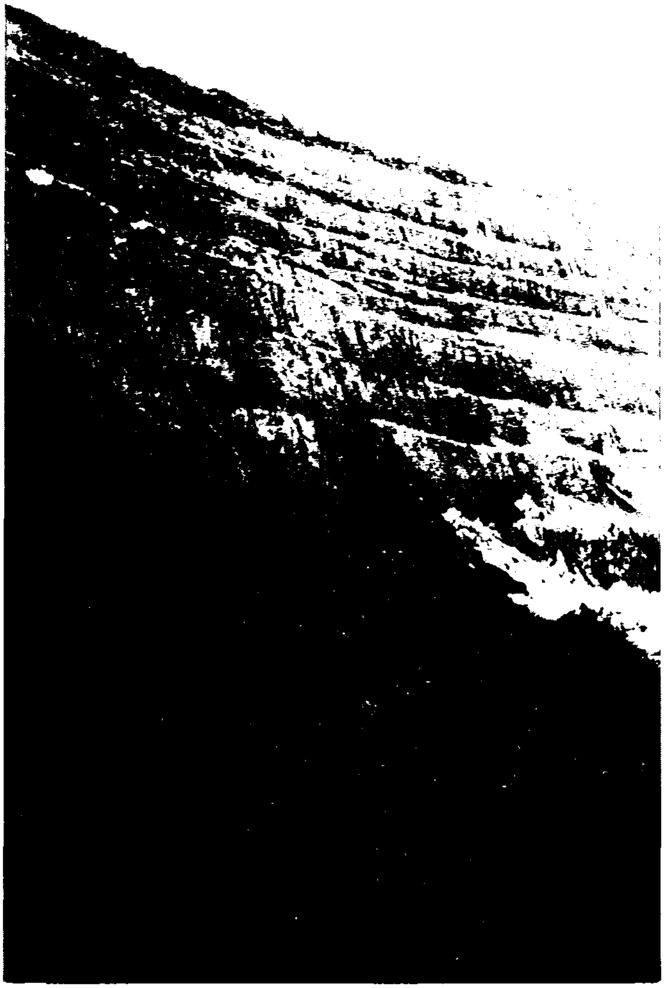

Figure 13. Slope Failure Whose Further Displacement
Was Stopped By Horizontal Drainage System.