Final Report

Prefabricated Underdrains

by

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Oct. 1972
Project 67-2 JHR 72-52

This research was sponsored by the Joint Highway Research Advisory Council of the University of Connecticut and the Connecticut Department of Transportation, and was carried out in the Civil Engineering Department of the University of Connecticut.

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SUMMARY

In 1968 the Joint Highway Research Advisory Council sponsored a program in the Civil Engineering Department at The University of Connecticut to develop a prefabricated underdrain system. The object of this research was to devise an underdrain system to reduce or eliminate some of the problems encountered in design and construction of conventional underdrains using mineral aggregate filters.

A prefabricated underdrain was developed from plastic materials and fine mesh cloth, and was tested in both the laboratory and field. Five field sites experiencing problems due to ground water were selected for testing the underdrain, and a total of 2500 lin ft of prefabricated underdrain were installed. Observations to date indicate that the system is an effective means of collecting and removing subsurface water and is much easier to install than systems using aggregate mineral filters, particularly on slopes and other hard to reach areas.

RECOMMENDATIONS

It is recommended that prefabricated underdrains be used to stablize slopes that are sloughing due to excess ground water and that these drains be used on a trial basis in other situations such as along highway cuts. In addition it is recommended that improved manufacturing techniques be developed to obtain the lowest cost drain.

DESCRIPTION OF PREFABRICATED UNDERDRAINS

General

The prefabricated drain is shown in Figure 1 and consists of a slotted pipe, a channelized vertical core inserted into the pipe slot, and a fine-mesh filter cloth enclosing the pipe and the core. The cloth retains the soil and keeps the core channels open. The ground water drains through the cloth, down the channels, into the pipe, and away from the site.

The selection of the filter cloth is based on criteria established in the 1930's for well screens (2). The openings in the screen should be just small enough to retain the coarsest 20 percent of the particles (D_{80}) in a well-graded soil and the coarsest 40 percent (D_{60}) in a uniform soil (3). The percentage of open area of the screen should be approximately the same as the porosity of the soil to prevent restriction of water flow. Well screens meeting these criteria have remained effective for many years in soils ranging from fine sand to gravel.

The filter cloth used on the prefabricated drains functions in the same way as a well screen. An advantage of using cloth as a filter as opposed to aggregate is its high permeability even with small openings. Cloth with mesh openings between 0.075 and 0.150 mm and a minimum 25 percent open area will retain most soils that can be effectively drained by gravity and will not restrict the flow of water from the soil. In addition the cloth must have sufficient strength to resist tearing and keep the fin channels open. The cloth will not clog because it is too thin to hold soil particles in a clogging position. With the initial flow of ground water into the drain, a few small soil particles next to the cloth will enter the system. These particles are smaller than the mesh openings

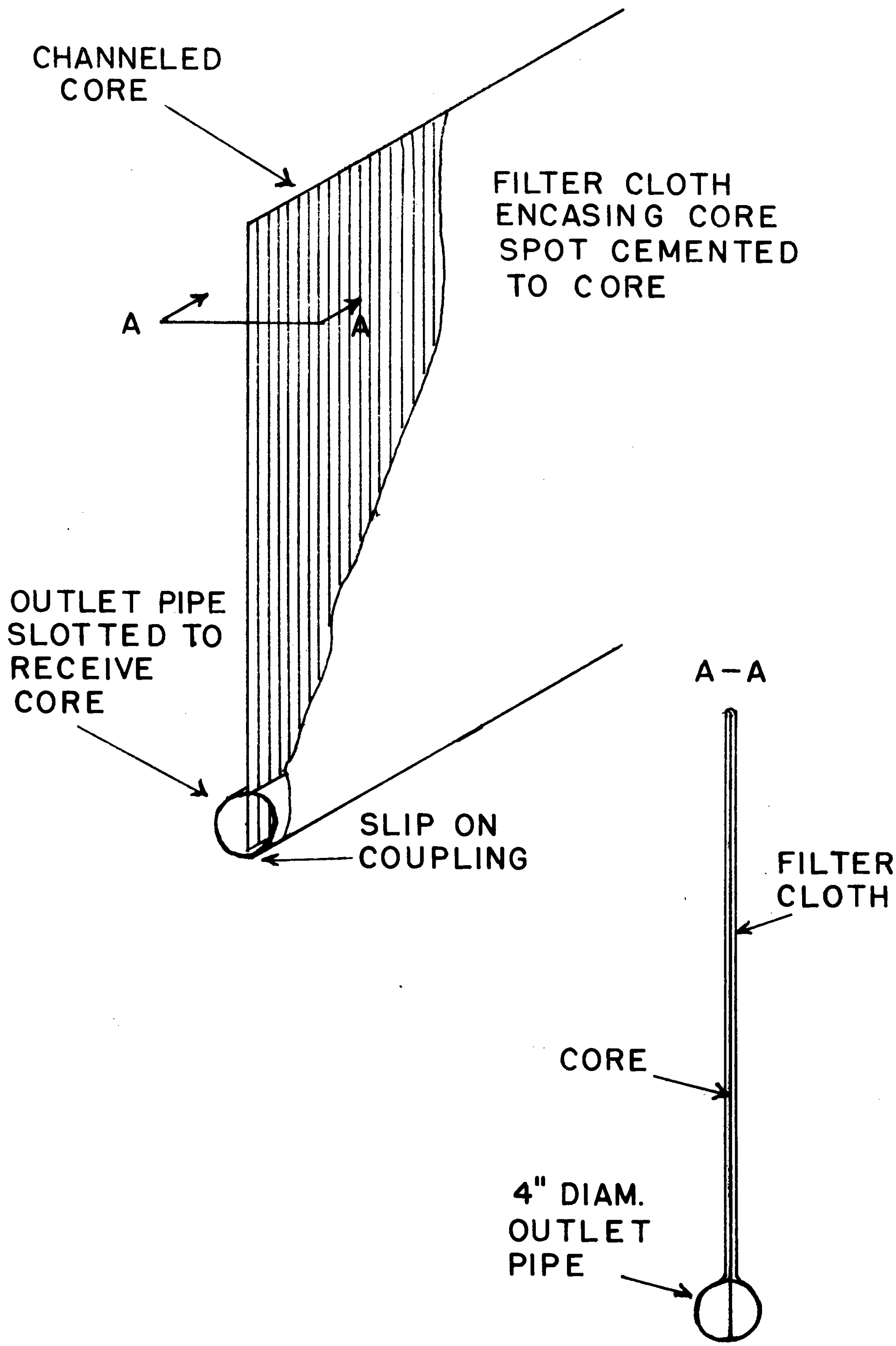

CHANNELED
CORE
FILTER CLOTH
ENCASING CORE
SPOT CEMENTED
TO CORE
A
A
OUTLET PIPE
SLOTTED TO
RECEIVE
CORE
SLIP ON
COUPLING
A – A
FILTER
CLOTH
CORE
4" DIAM.
OUTLET
PIPE

FIGURE 1

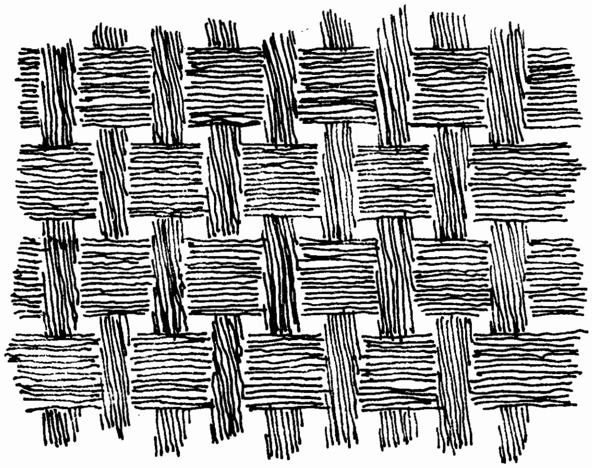
and are in a position where they cannot be filtered by the larger particles retained by the cloth. The amount of small particles that pass through the cloth with the first water flow is negligible and washes through the entire system. The loss of these small soil particles next to the cloth increases the permeability of the soil in the immediate vicinity of the drain. The fin supports the cloth and provides channels large enough to carry the water into the pipe as quickly as it flows from the soil. The channels must also be larger than the openings in the cloth so as to allow the soil particles that wash through with the initial flow of water to continue into the pipe and out of the system.

Materials Used

The materials used in the prefabricated underdrains are given as follows:

1. Filter cloth - Two types of cloth have been tested and used as filters--a nylon chiffon and a polyester butterfly (Fig. 2). Both materials have good tensile strength and resist decomposition in the ground. The chiffon has a mesh opening of 0.15 mm and a 45 percent open area. The butterfly has a mesh opening of 0.075 mm and a 15 percent open area. Long-term model tests have shown that both cloths will filter soils ranging from a fine silty sand to a glacial till with no sign of soil erosion or clogging. The butterfly cloth with 15 percent open area has adequate permeability for soils containing silt. The chiffon having a greater percent of open area is preferable for draining more permeable soil. Both cloths are more permeable than a 2-in layer of coarse gravel. The gradation of particle sizes and permeability of several soils successfully filtered by nylon chiffon cloth are shown in Figure 3. These soils, ranging from a medium sand to a

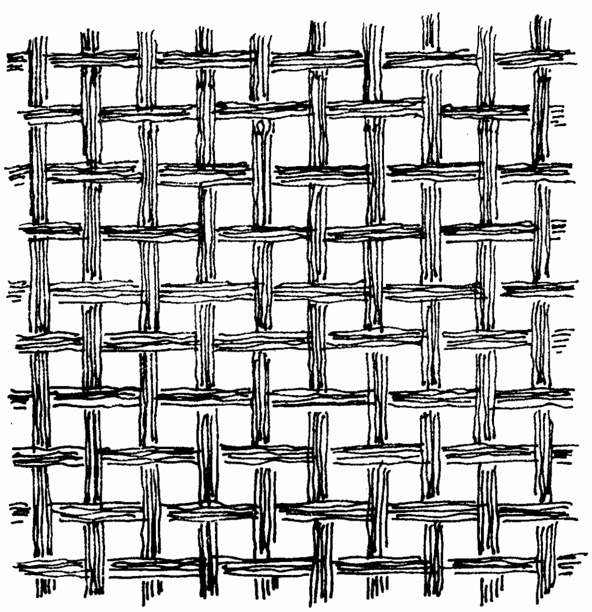
Polyester "Butterfly" Cloth



15% open area

0.075 mm openings

Nylon "Chiffon"



45% open area

0.150 mm openings

FIGURE 2

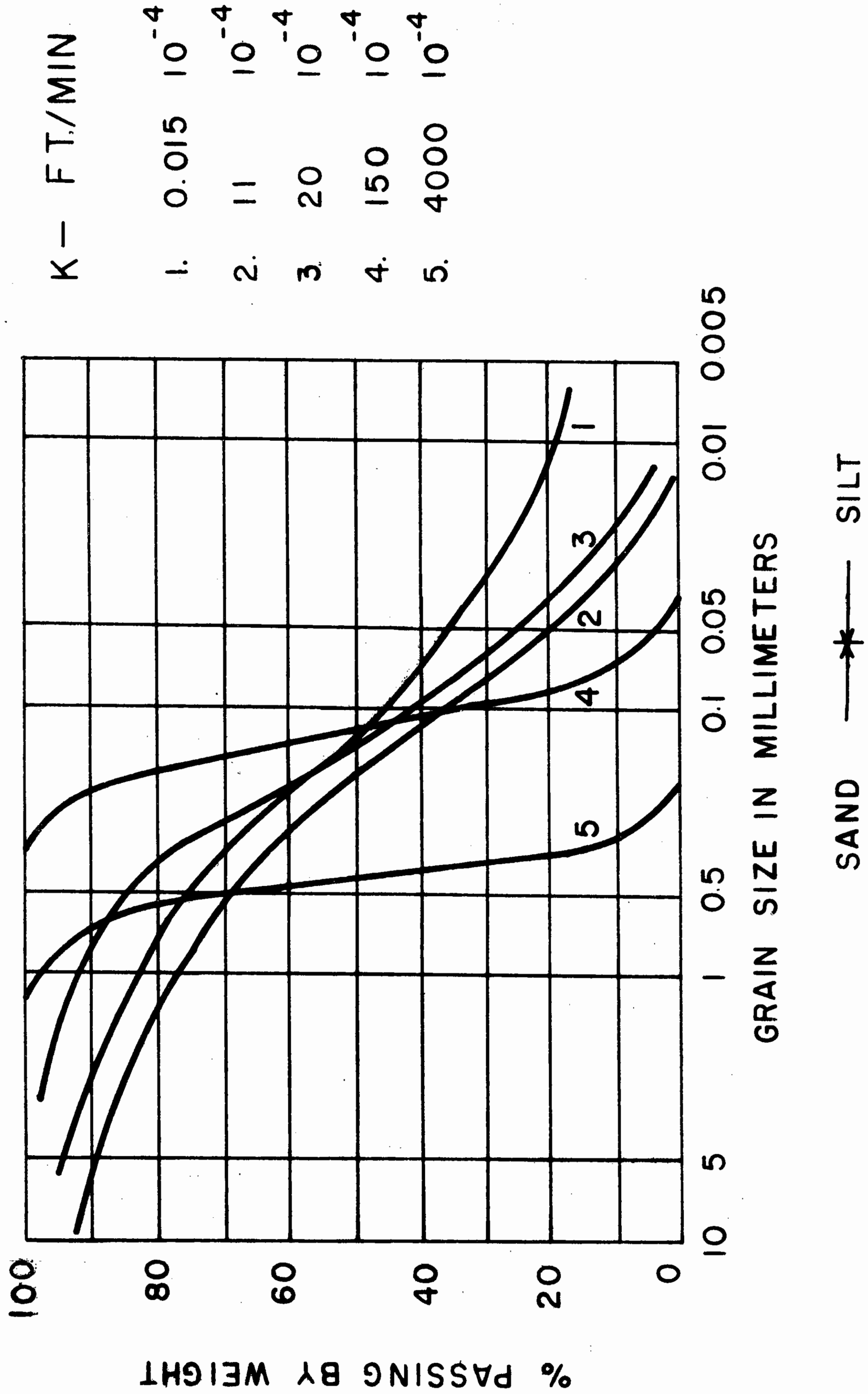

K — FT./MIN
1. 0.015 10^-4
2. 11 10^-4
3. 20 10^-4
4. 150 10^-4
5. 4000 10^-4
10
5
1
0.5
0.1
0.05
0.01
0.005
GRAIN SIZE IN MILLIMETERS
SAND
SILT
0
20
40
60
80
100
% PASSING BY WEIGHT
1
2
3
4
5

FIGURE 3

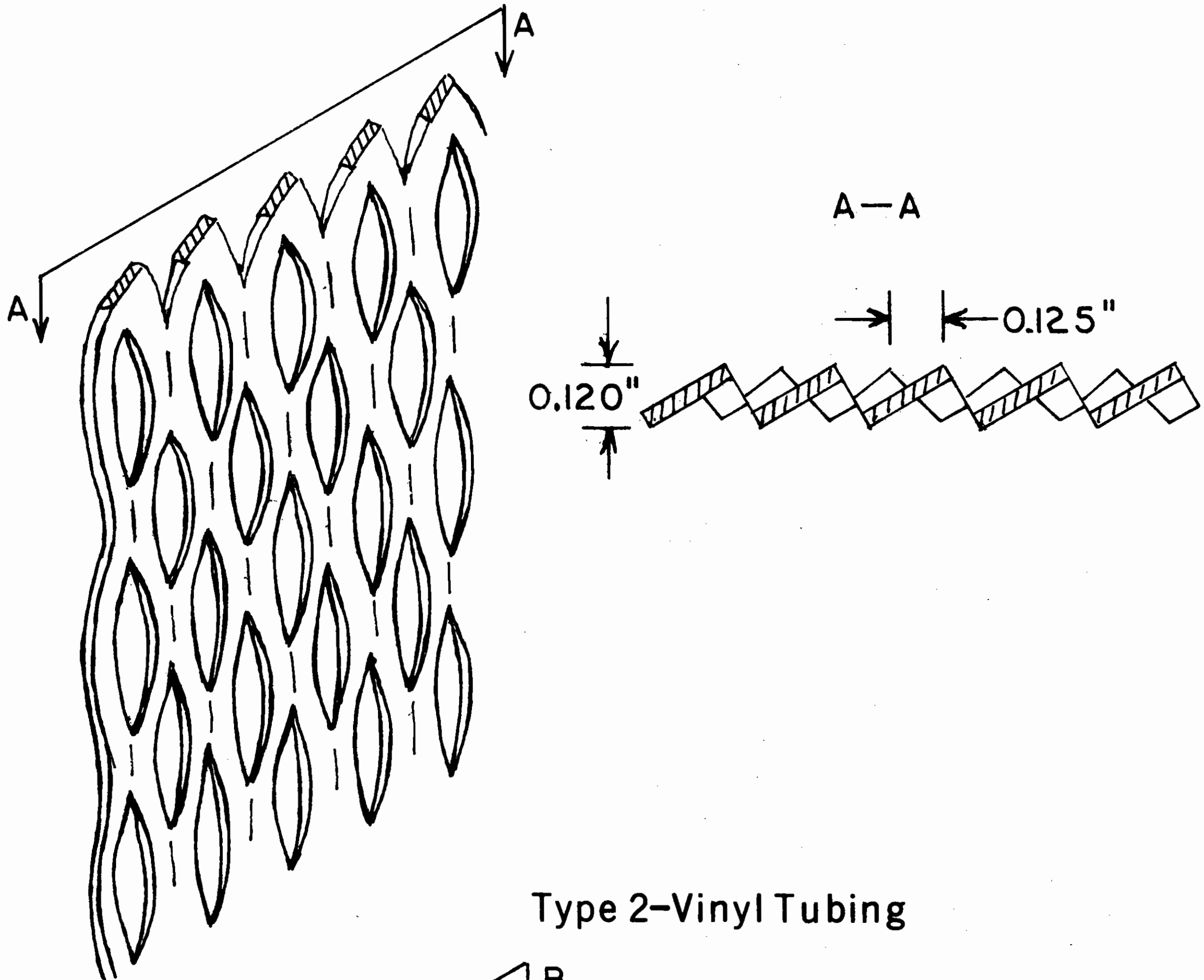
glacial till with a high percentage of silt, were tested in the laboratory under a hydraulic gradient much higher than that occurring in the field.

2. Core - The core must support the cloth and provide channels large enough to carry the water into the pipe as quickly as it flows from the soil. The following materials have been used as cores in field-test installations and are shown in Figure 4: Type 1, expanded aluminum sheet, purchased from U.S. Steel, having the commercial name Armorweave; and Type 2, vinyl tube fencing, purchased from Sears, Roebuck and Co. Aluminum core was used only to test the concept of the underdrains. It is not recommended for general use because aluminum tends to deteriorate in the ground. The core materials were tested for crushing strength and water-carrying ability. The expanded aluminum showed little deformation under a pressure of 200 lb/sq in, and the vinyl tube fencing had a crushing strength of 160 lb/sq in. Intrusion of the cloth into the channels decreases the area through which the water can flow and is a possible source of malfunction. Tests with the vinyl tube fencing showed that under an earth pressure of 4.0 kip/sq ft the cloth intruded less than 0.025 in. and that a 1-ft wide section of the drain, when vertical, could carry 2.5 gal/min. This is sufficient to drain a soil with a permeability of 5 X 10^{-2} ft/min. Tests on the expanded aluminum core showed similar flow characteristics under stress.

3. Pipe - A hard plastic pipe with a 4-in diameter and 1/8-in wall thickness has been used for the field sections. The slot was cut on a table saw. This pipe is available in 10-ft lengths from building supply companies and has a crushing strength of 0.9 kip/ft.

Underdrain sections used in the field were fabricated by inserting the vertical fin into a longitudinal slot cut in 4-in diam. (10 cm) drainpipe and enclosing both pipe and core in synthetic fine mesh cloth. Sections of

Type 1—Expanded Aluminum



Type 2—Vinyl Tubing

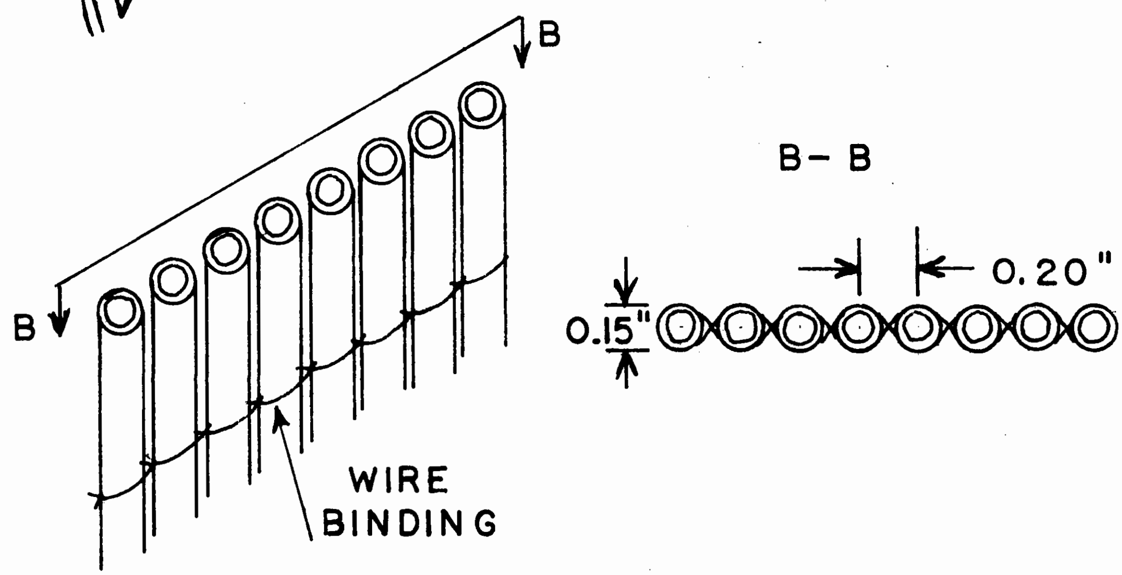


FIGURE 4

the underdrain were connected by slip couplings on the ends of the pipe.

METHODS OF INSTALLATION

The prefabricated filter fin requires no special backfill and is generally held or nailed to one side of the trench while the excavated earth is backfilled against it.

Prefabricated drains are easily installed in trenches as shown in Figure 5 or on slopes as shown in Figure 6. Drain sections 10 ft long weigh less than 20 lb and can be placed and connected with slip couplings from the ground surface. Trenches need be only wide enough to receive the drain, thereby making attractive the use of trenching machines in suitable soil.

The core is flexible enough to be pressed tightly against one face of the exposed natural soil as shown in Figure 5. In this manner the more permeable strata in the native soil can be drained quickly. The type of backfill depends on the drainage desired at the site. If most of the water enters the drain from one side, as on a slope, the native soil may be used as backfill against the opposite face. When the drain receives water from both sides, sand may be used as backfill. The use of sand as backfill is limited to soil whose permeability is greatly reduced when recompacted. This ensures that the natural drainage channels in the soil are not blocked and makes the compaction easier in a trench section. The short flow path through the sand to the core of the drain will not impede the free movement of water. For one of the trench installations in a soil containing cobbles, a piece of plywood was used to protect the pipe from the larger stones during the initial stages of backfilling and then removed.

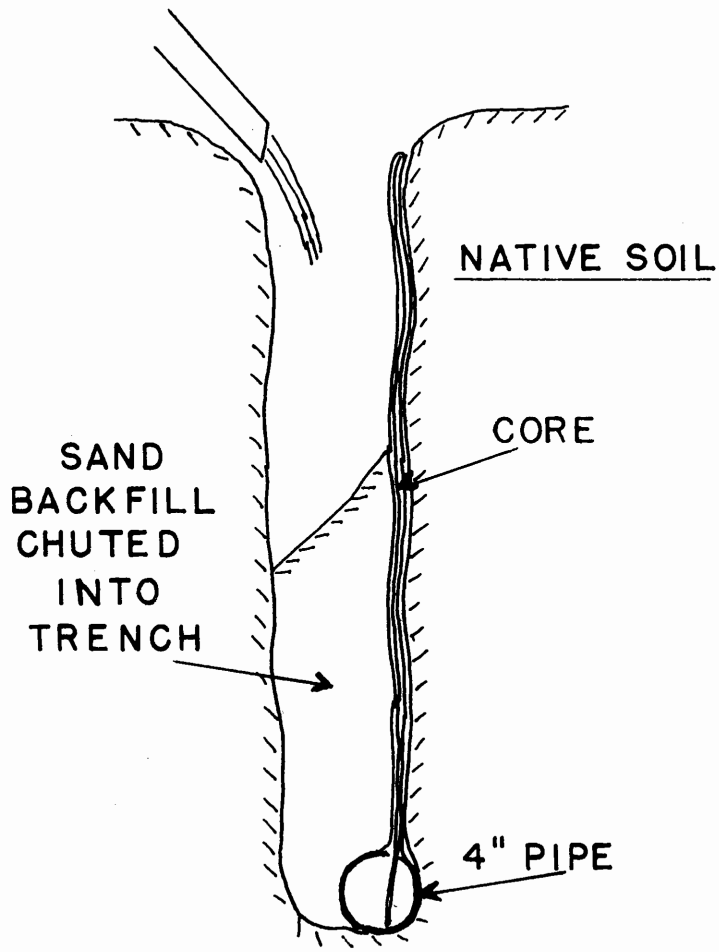


FIGURE 5

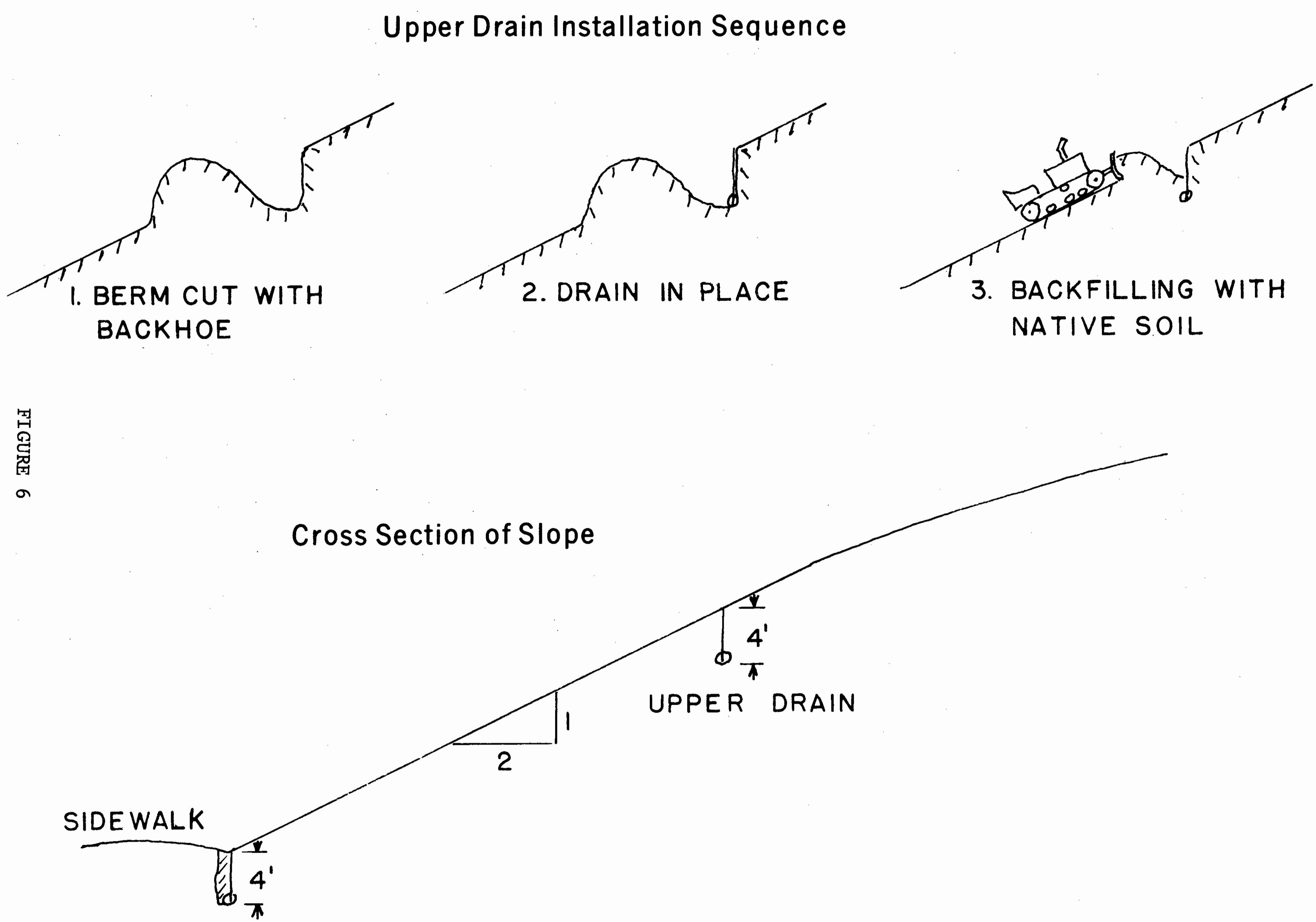

Upper Drain Installation Sequence
1. BERM CUT WITH BACKHOE
2. DRAIN IN PLACE
3. BACKFILLING WITH NATIVE SOIL
Cross Section of Slope
4'
UPPER DRAIN
1
2
SIDEWALK
4'

FIGURE 6

In earth slopes steeper than 1 or 4, installations can be made as shown in Figure 6. A bench is cut at the proper elevation to receive the drain. The drain is placed against the vertical face and the soil, removed to make the bench, is pushed back against the drain with a bulldozer.

The prefabrication of the drain sections ensures proper operation even when installed by people who are unfamiliar with filter principles. The drain sections can be fabricated in any height and length to suit the installation.

FIELD SITES

Brien McMahon Installation

The first field test of the prefabricated underdrain was the installation of 20 lin ft in the east slope of a drumlin behind Brien McMahon Residence Hall at The University of Connecticut. The primary object of this installation was to demonstrate that prefabricated underdrains would function properly in a field site. The behavior of the slope, after the drains were installed, showed that the water flow was strongly influenced by the horizontal permeability of the soil. To improve the stability of a slope the underdrains must be placed to intercept the ground water before it reaches the surface of the slope.

The backfill against the drains is concrete sand with the native material bringing the slope to grade. Further tests showed the sand backfill to be unnecessary in most installations. This test showed that the prefabricated underdrains are effective in collecting and removing ground water.

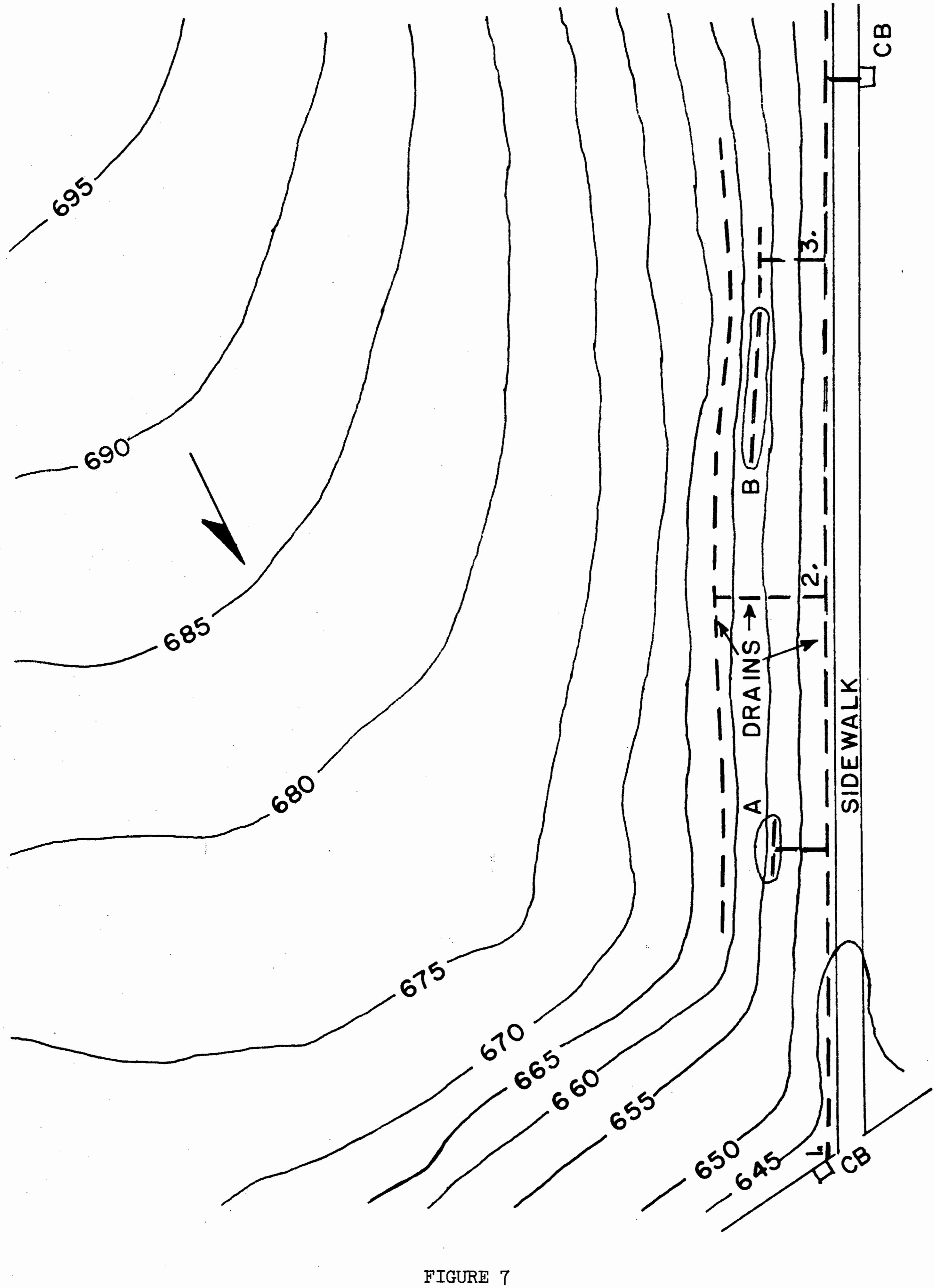
Tennis Court Slope Installation

1. Description

The slope, a plan of which is shown in Figure 7, is the northwest side of a drumlin, located on The University of Connecticut campus and was formed when the hill was cut back from a natural slope of 1 on 3.3 (17 deg) to a 1 on 2 slope to allow the placement of a sanitary line and sidewalk. The slope started sloughing after the first heavy rain, and it was a continual maintenance problem to keep the walk clear of mud in the spring and ice in the winter. The soil in its natural state is a dense, well-graded glacial till with particles varying from cobbles to clay size. Disturbed samples of the soil have a permeability of approximately 1×10^{-6} ft/min, as measured by a falling head permeameter. Slow direct shear tests showed an effective stress friction angle of 41 deg. The natural undisturbed soil is slightly cemented and contains numerous small channels parallel to the surface that seep water below the water table in an open cut.

2. Installation Procedures

In July 1969, two lines of prefabricated drains with Type 1 core and butterfly cloth were installed along the slope as shown in Figure 7. It had originally been planned to install the upper drain line by cutting a berm with a bulldozer. However, at the time of installation the slope was too wet, and a berm had to be dug by backhoe from below. Figure 6 shows a typical cross section and the method used to place the drains. A trench was dug for the lower drain and was backfilled with sand at the request of the Physical Plant, UConn., in an attempt to increase surface drainage and alleviate icing problems. In the very wet areas, the upper drain sections were partially backfilled with the backhoe



695
690
685
680
675
670
665
660
655
650
645
CB
CB
3.
2.
B
A
DRAINS
SIDEWALK

FIGURE 7

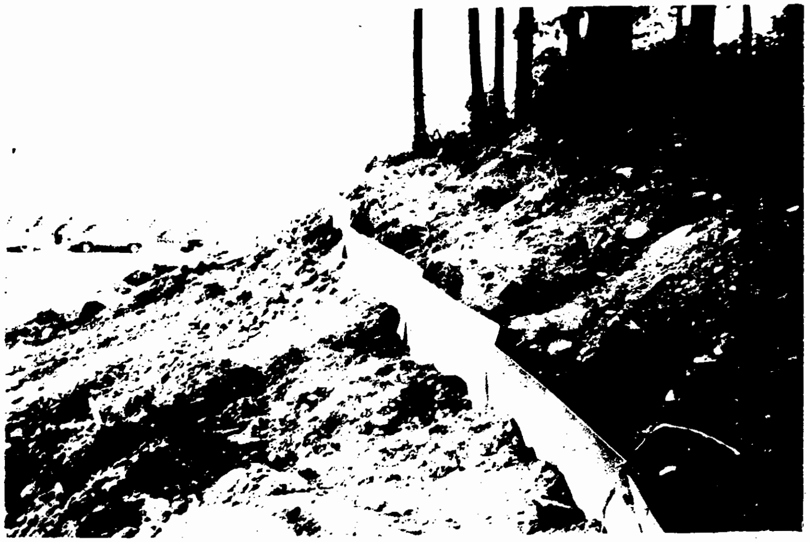


FIGURE 8

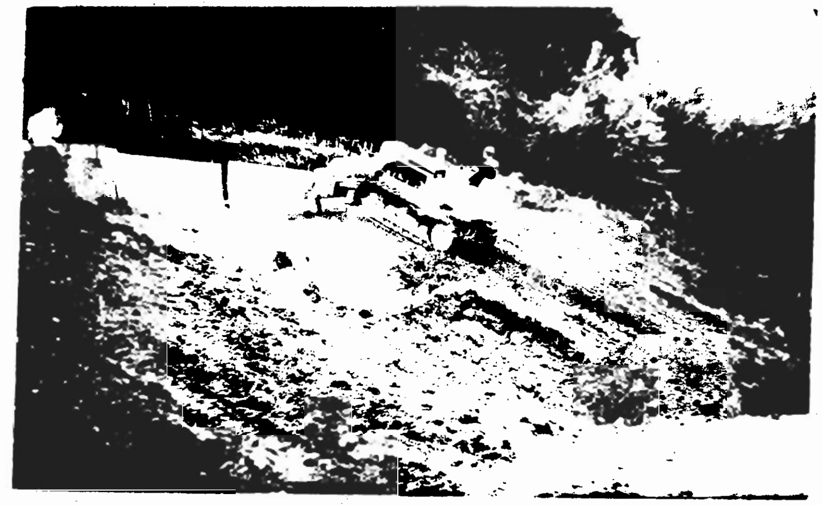


FIGURE 9

FIGURE 10

immediately after placement to prevent local sliding. Figure 8 shows the upper drain partially backfilled. Final backfilling and grading were completed by a bulldozer as shown in Figure 9. The lower trench installation is shown in Figure 10.

In the Fall of 1969, heavy rains caused surface erosion, and in two areas, marked A and B in Figure 7, the natural drainage channels were such that water was exiting under the upper drain, causing sloughing below. An additional 20 lin ft of drain were installed by hand at the south end of the area B halfway up the slope, and this portion was stabilized. In the Spring of 1970, 90 ft of drain with Type 2 core and chiffon filter cloth were installed with a backhoe and bulldozer in the remaining portion of area B, and 20 ft of drain were installed in area A. Observation pipes were installed at points marked 1, 2 and 3 in Figure 7, and the water flow in the drain pipes can be measured at these points by using calibrated probes.

3. Comments

Some piezometers were installed, but they did not reflect apparent water conditions accurately. This may be due to the nonhomogeneous permeability characteristics of the soil. The evaluation of the field installation has, therefore, been based on the overall stability of the slope and measurements of water flow out of the drains.

The slope, which was unstable over essentially its whole length, has been stabilized. Surface seeping has been almost eliminated, and the slope surface drys up within a few days after a heavy rain.

Water flow from the drains has been monitored continually since installation. The 250-ft upper drain removes water from the soil at a rate of up to 7 gal/min during rainstorms and at a rate of approximately

2 gal/min during the period following rain. Calculations, assuming a hydraulic gradient in the soil of 0.2, show the field permeability to be 1.6 X 10^{-3} ft/min. This increase of 1,000 times over the permeability from lab tests on disturbed samples may be due to the natural channels occurring in the deposit. There has been no indication of fines being removed from the soil by the drain, indicating that the cloth is filtering properly.

This installation of 710 feet was the first attempt to solve a slope stability problem by collecting the ground water with prefabricated underdrains before it seeps to the surface of the slope. The slope has weathered three winters intact.

Graphs are included for this installation showing the relation between precipitation and water flow out of the drains in Figure 11. When viewing these graphs, it should be kept in mind that the precipitation shown for the winter months was bound up in snow and ice until spring.

Route 44-A Installation

This installation was made by a maintenance crew from the Bureau of Highways, with the assistance of University personnel, on the north side of Route 44-A about 1.8 miles west of the intersection with Route 32. A plan of the installation is shown in Figure 12. The drain height varies from 3 to 5 ft. The purpose of the drain was to reduce frost heave under the pavement by controlling the ground water. This installation has experienced two winters during which the pavement showed no signs of heave. The trench was backfilled with concrete sand; a decision made by Highway Department personnel.

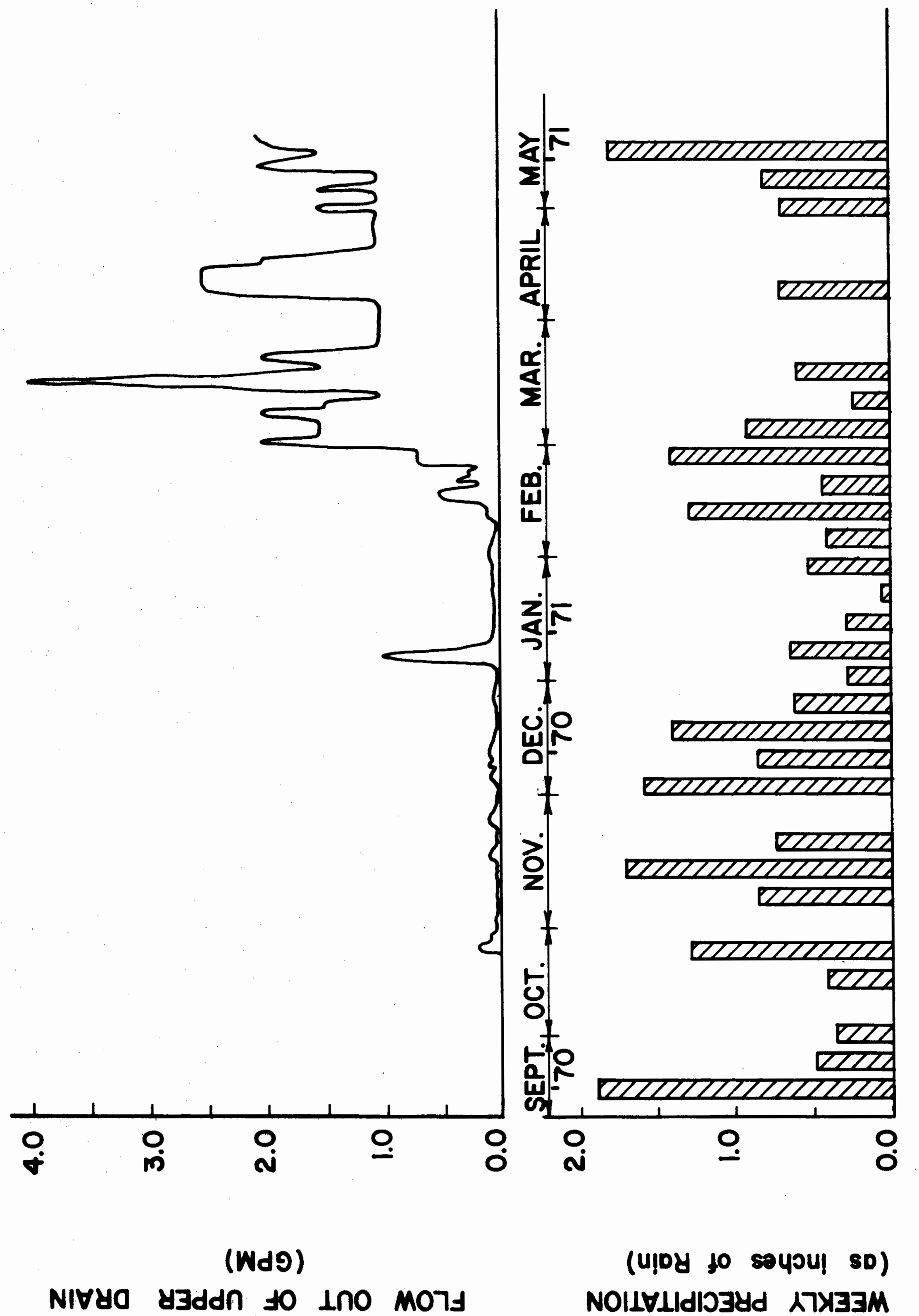

FLOW OUT OF UPPER DRAIN
(GPM)
4.0
3.0
2.0
1.0
0.0
WEEKLY PRECIPITATION
(as inches of Rain)
2.0
1.0
0.0
SEPT. '70
OCT.
NOV.
DEC. '70
JAN. '71
FEB.
MAR.
APRIL
MAY '71

FIGURE 11

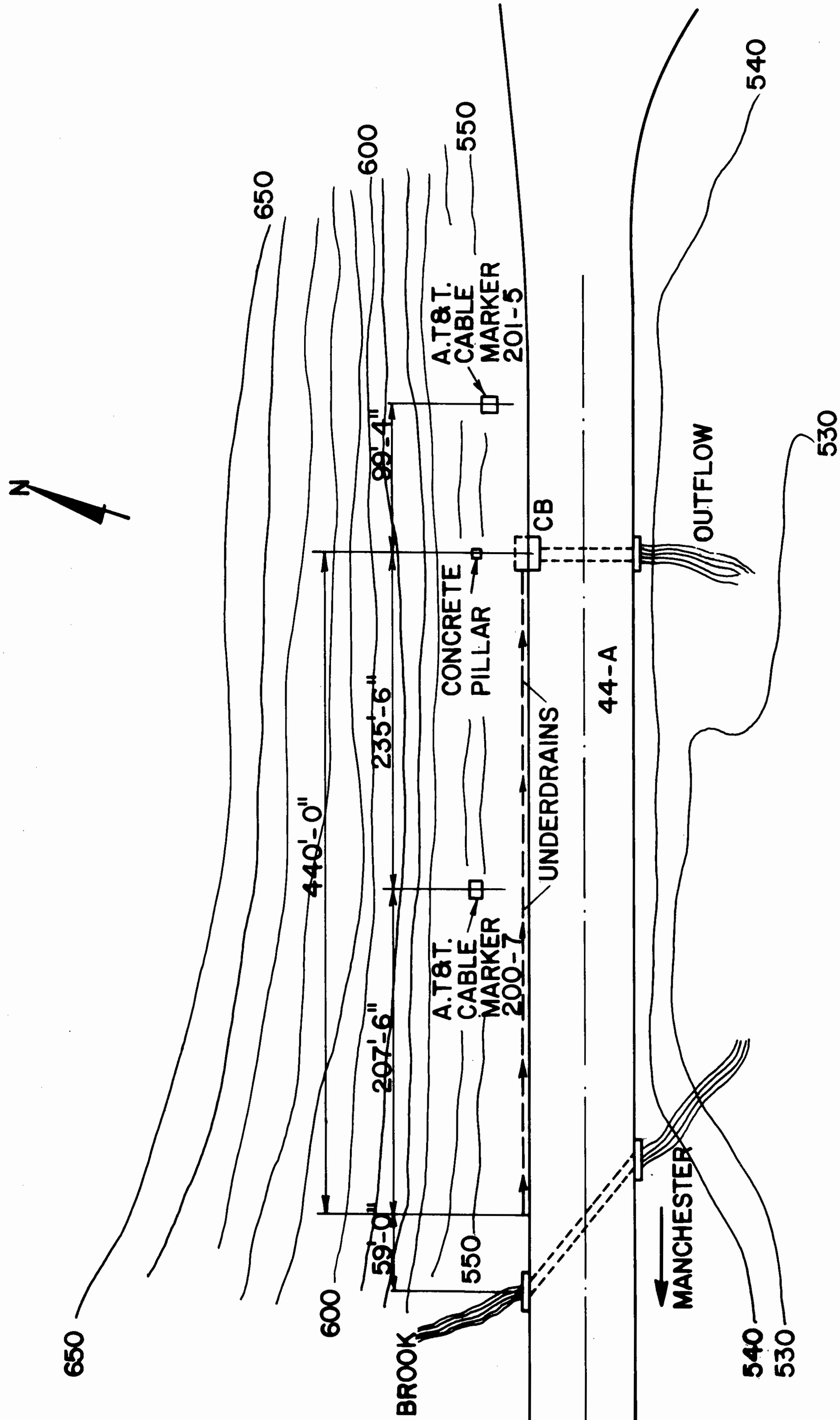

N
650
600
550
540
530
A.T.&T.
CABLE
MARKER
201-5
99'-4"
CB
OUTFLOW
CONCRETE
PILLAR
235'-6"
440'-0"
UNDERDRAINS
44-A
A.T.&T.
CABLE
MARKER
200-7
207'-6"
59'-0"
BROOK
MANCHESTER

FIGURE 12

Fellon Road Installation

This installation shown in Figure 13 was made at the owner's expense in an area intended for home construction. The purpose of this installation was to control the ground water so that houses and on site sewage disposal systems could be built. This installation was complicated by a shallow undulating bedrock surface and has not been as effective as anticipated.

Route 82 Installation

Prefabricated drains were installed in another slope, along the Route 82 extension in Haddam, Connecticut as shown in Figure 14. Two conventional underdrains using perforated pipe and select sand backfill were installed in the slope when it was originally cut. During the following Spring, water seeped out of the surface of the slope just above the higher drain, causing sloughing. A line of prefabricated underdrain 300 ft (91.4 m) long was installed, using the bench technique, to collect the water in the sloughing area. The region of the second slope installation serviced by the prefabricated underdrains has weathered one winter intact. This installation illustrated the relative ease with which the prefabricated underdrain could be installed in local trouble spots after construction.

Retaining Wall Installation

The final installation was placed to reduce the pressure behind a low (7 ft) retaining wall. The original fill behind the wall was a clayey silt that retained moisture through capillary action. The backfill remained near saturation throughout the winter and frost caused excessive movement of the wall. The drains were placed 3 ft (0.92 m) behind the wall with sand backfill between wall and drains. Water flows from these drains during heavy

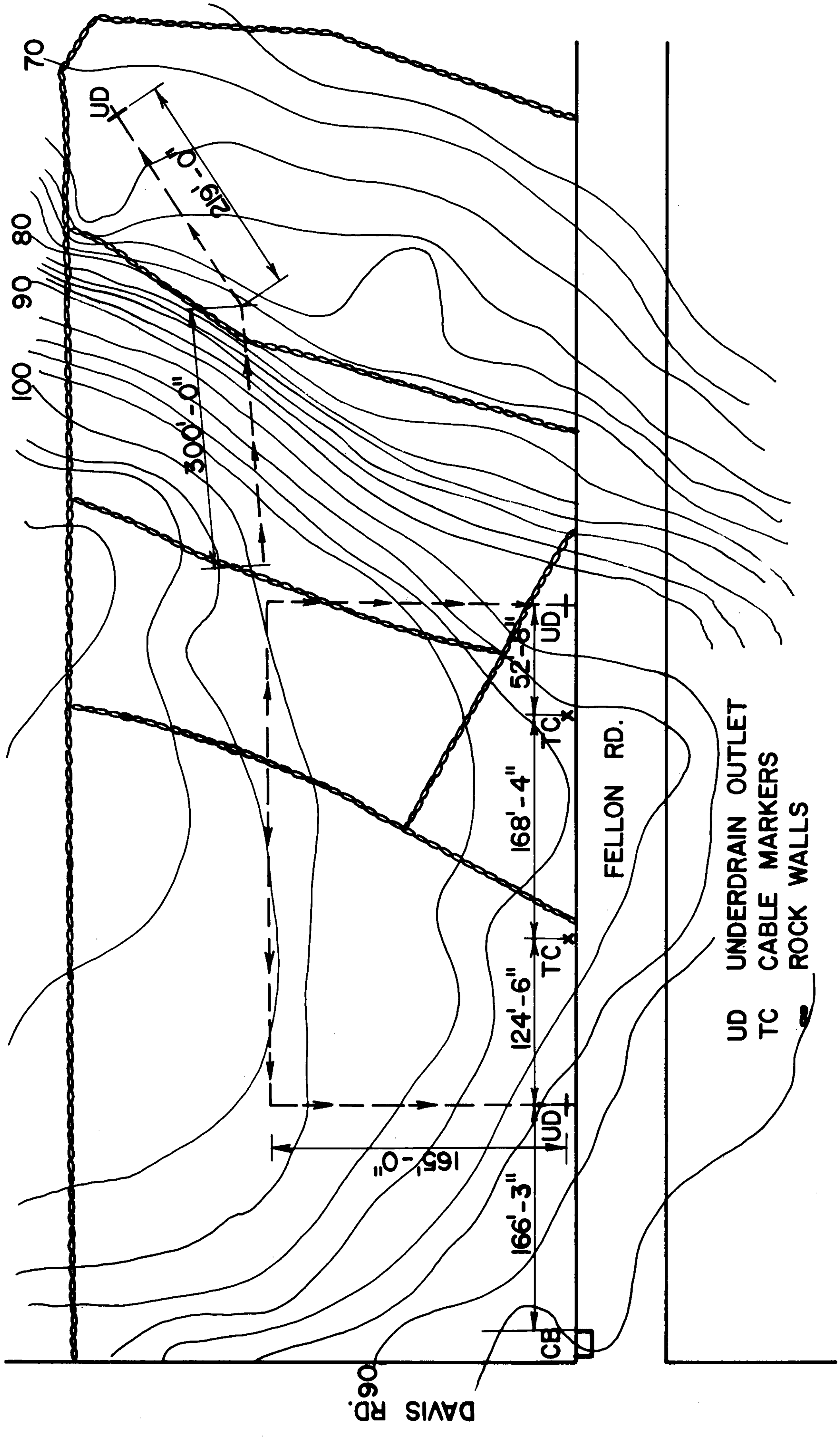
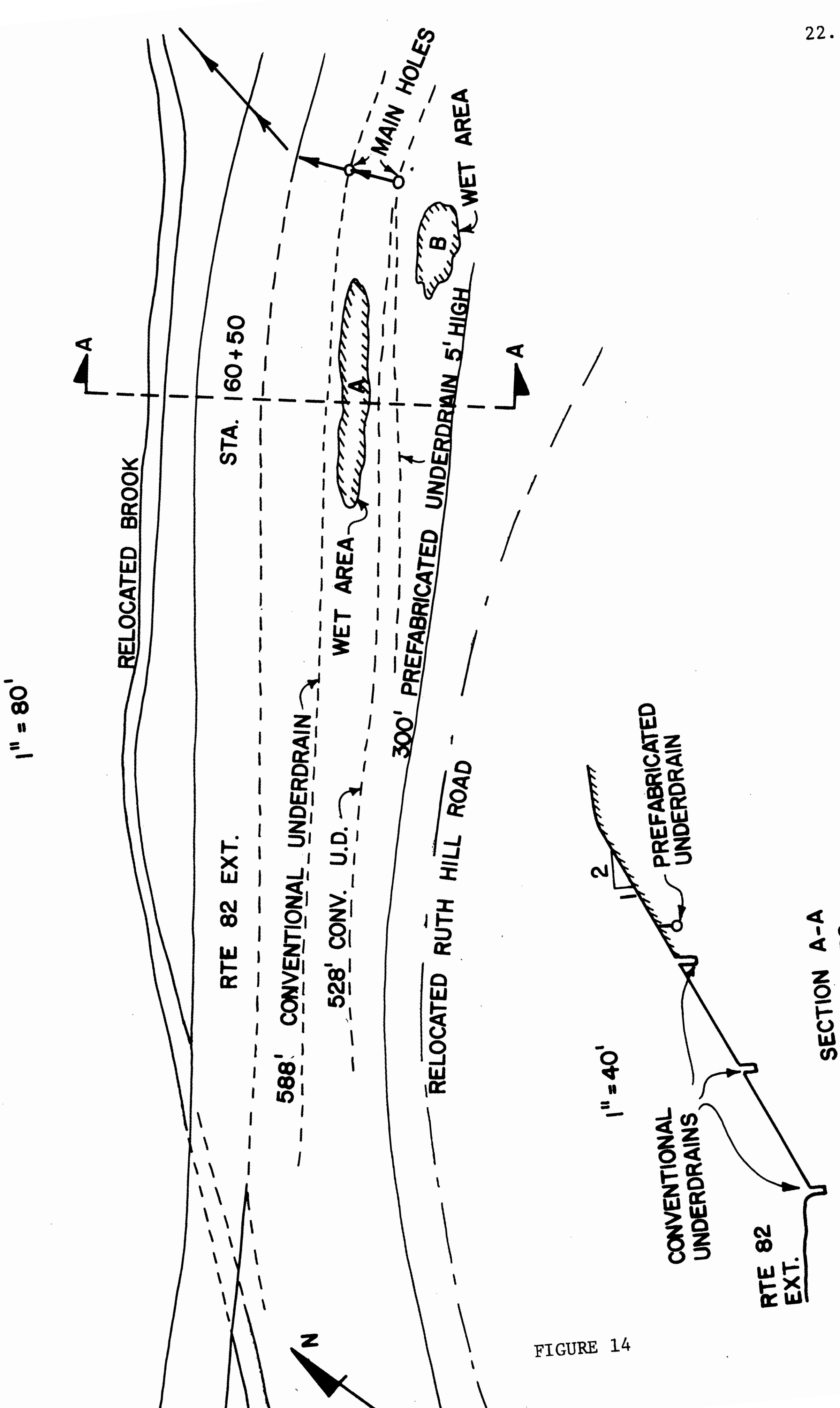

UD UNDERDRAIN OUTLET
TC CABLE MARKERS
ROCK WALLS
FELLON RD.
DAVIS RD.
70
80
90
100
90
UD
219'-0"
300'-0"
52'-8"
168'-4"
124'-6"
165'-0"
166'-3"
TC
CB

FIGURE 13



1" = 80'
RELOCATED BROOK
RTE 82 EXT.
STA. 160+50
A
A
MAIN HOLES
WET AREA
WET AREA
B
A
300' PREFABRICATED UNDERDRAIN 5' HIGH
588' CONVENTIONAL UNDERDRAIN
528' CONV. U.D.
RELOCATED RUTH HILL ROAD
N
1" = 40'
PREFABRICATED UNDERDRAIN
2
1
CONVENTIONAL UNDERDRAINS
RTE 82 EXT.
SECTION A-A
STA 60+50

FIGURE 14

rainstorms and for a short time after each rain has ceased. The flow out of the pipe occurs much faster than out of the conventional weep holes near the base of the retaining wall. This installation was made at no expense to the Highway Department.

COMPARISON OF MINERAL AGGREGATE AND PREFABRICATED UNDERDRAINS

Most subsurface drains are constructed from mineral aggregates, and a comparison with prefabricated drains is appropriate.

Filter Requirements

Tests run by Bertram in 1940 and at the U.S. Army Engineer Waterways Experiment Station (4) resulted in the development of the following criteria for mineral aggregate filters:

1. Preventing continuous movement of soil particles requires that the effective pore size (assumed to be 1/5 D_{15} of the filter) be smaller than the coarsest 15 percent (D_{85}) of the soil being drained. This is normally expressed as

$$\frac{D_{15}(\text{filter})}{D_{85}(\text{soil})} \leq 5$$

$$\frac{D_{50}(\text{filter})}{D_{50}(\text{soil})} \leq 25$$

2. Preventing restriction of water flow by the filter requires

$$\frac{D_{15}(\text{filter})}{D_{15}(\text{soil})} \geq 4 \text{ to } 5$$

Preventing movement of the filter particles into the pipe, if a perforated pipe is used to remove the water from the filter, requires

$$\frac{D_{85}(\text{filter})}{\text{pipe-opening size}} > 1$$

In the prefabricated subsurface drain, all filtration is accomplished by the cloth with openings constituting at least 25 percent of the area and having a size between 0.075 and 0.150 mm.

Design and Construction

In many situations the criteria for mineral aggregate filters must be applied with great care. The Vicksburg criteria implicitly assume well-graded soil (1). If the soil to be filtered and drained is gap-graded, the number of large particles may be insufficient to prevent movement of the smaller particles, and the filter must be designed to retain a size smaller than the coarsest 15 percent of the soil particles.

Filters placed against soil deposits, whose gradation varies from point to point, must be designed to hold the finest particles in place, and a two-phase graded mineral aggregate filter may be required to allow free drainage.

Some of the important points (1) in constructing the mineral aggregate filter are as follows:

1. Filter materials must be handled and placed with care to avoid segregation and contamination;

2. The filter must be well compacted to reduce the possibility of dropping fines of the filter through void spaces; and

3. A single improperly constructed portion of the filter can lead to failure of the drainage system.

Construction control for the prefabricated underdrain is less demanding. The prefabrication ensures that the system can be easily and correctly installed by personnel unfamiliar with filter criteria.

DISCUSSION

The prefabricated underdrains are functioning well in the field. The discharge of water from the drains is closely related to the amount of rain and the ground water conditions. A summary of observations on the field installations is shown in Table I. The soils in which these underdrains were placed are highly stratified and no theory was found adequate to predict the flows. Large flows out of the drains are observed in Spring and Fall. During the summer months when the ground water table drops, the flows stop or reduces to a trickle. The water coming from the drains is clear indicating that the soil is being filtered properly. There has been no apparent decrease in discharge due to clogging.

The soil in which these installations were made contain horizontal soil strata and lenses whose undisturbed permeability vary markedly from stratum to stratum. The soil permeability backfigured from the rate of discharge is several orders of magnitude higher than the permeability of the soil measured on disturbed samples in the laboratory. Some of the difference between the laboratory and the backfigured permeability is due to disturbance. The relatively large amounts of flow from the drains are probably due to the ability of the fin to drain the more permeable strata in the soils in which they are buried.

COSTS AND CONFIGURATIONS

The approximately 2500 ft (762 m) of prefabricated drains that have been installed to date were assembled by hand using materials available at retail stores. The retail cost of the materials is approximately \$0.30 per ft (\$1.12 per m) for a 4 inch (10 cm) hard plastic pipe, \$0.15 per sq ft (\$1.40 per sq m) for vinyl tube fencing and \$0.05 per sq ft (\$0.46 per sq m)

TABLE 1 - SUMMARY OF OBSERVATIONS ON FIELD INSTALLATIONS

Location of Underdrain Installation	Date Installed	Type of Fin	Height of Fin in feet (meter)	Type of Cloth	Soil Type	Permeability of Disturbed Samples in ft/min (cm/sec)	Total Length in feet (meters)	Max. Observed Flow gal/min (m^3/sec)	Max. Flow Rate for 1000 ft (305 m) of Equivalent Drain in gal/min (m^3/sec)
Tennis Court Slope	June 1969 June 1970	Type 1 and Type 2	4 (1.22) to 2.5 (0.76)	Butterfly Chiffon	Sand, Silt & Clay	1.5×10^{-6} (7.6×10^{-7})	710 (217)	11.2 (7.1×10^{-4}	16 (10.1×10^{-4})
Route 44-A	Aug. 1970	Type 2	2.5 (0.76) to 5 (1.52)	Chiffon	Fractured Rock to Sandy Silt	2×10^{-3} (1.0×10^{-3})	440 (134)	7.6 (4.8×10^{-4})	17 (10.7×10^{-4})
Fellon Road	Oct. 1970	Type 2	5 (1.52)	Chiffon	Sandy Silt	1.1×10^{-3} (5.6×10^{-4})	1200 (366)	12.6 (7.9×10^{-4})	10.5 (6.6×10^{-4})
Route 82 Haddam, Conn.	June 1971	Type 2	5 (1.52)	Chiffon	Silty Sand	2×10^{-4} (1.0×10^{-4})	300 (91)	3.0 (1.9×10^{-4})	10.0 (6.3×10^{-4})
Retaining Wall	Aug. 1971	Type 2	5 (1.52)	Chiffon	Clayey Silt and Sand	6.7×10^{-5} (3.4×10^{-5})	25 (7.6)	1.0 (6.3×10^{-5})	40 (25.2×10^{-4})

for nylon chiffon. This adds up to a total material cost of $1.55 per ft ($5.08 per m) for a 5 ft (1.5 m) high drain system. Mass production would certainly reduce the price of the present system considerably.

Other configurations of the drain system seem preferable to reduce assembly and shipment problems and to improve installation procedures. One such configuration is shown in Figure 15. The filter might be formed by sewing or gluing the filter cloth to both sides of a flexible fin material, made of deformed plastic sheet or a thick knitted or woven mat. The filter cloth would be left unglued from one side of the core for about a foot all along the bottom. The bottom portion of the fin material could then be wrapped around conventional perforated or slotted plastic pipe with the loose flap of cloth placed over the top of pipe allowing free flow of water into the pipe from the filter media. The flexibility of the filter media would allow easy shipment and reduce void spaces next to the trench wall after backfilling. Greater flexibility also permits easier adaption to drain installing machinery.

CONCLUSIONS

Laboratory and field tests have indicated the following:

1. A fine mesh cloth is suitable as an effective filter for a wide range of soil types;
2. A thin channelized core allows free movement of water into the outlet pipe;
3. Prefabricated underdrains are easily handled and installed in the field and allow placement where conventional drains would be difficult to construct; and
4. Prefabricated underdrains are economically competitive with conventional mineral aggregate systems.

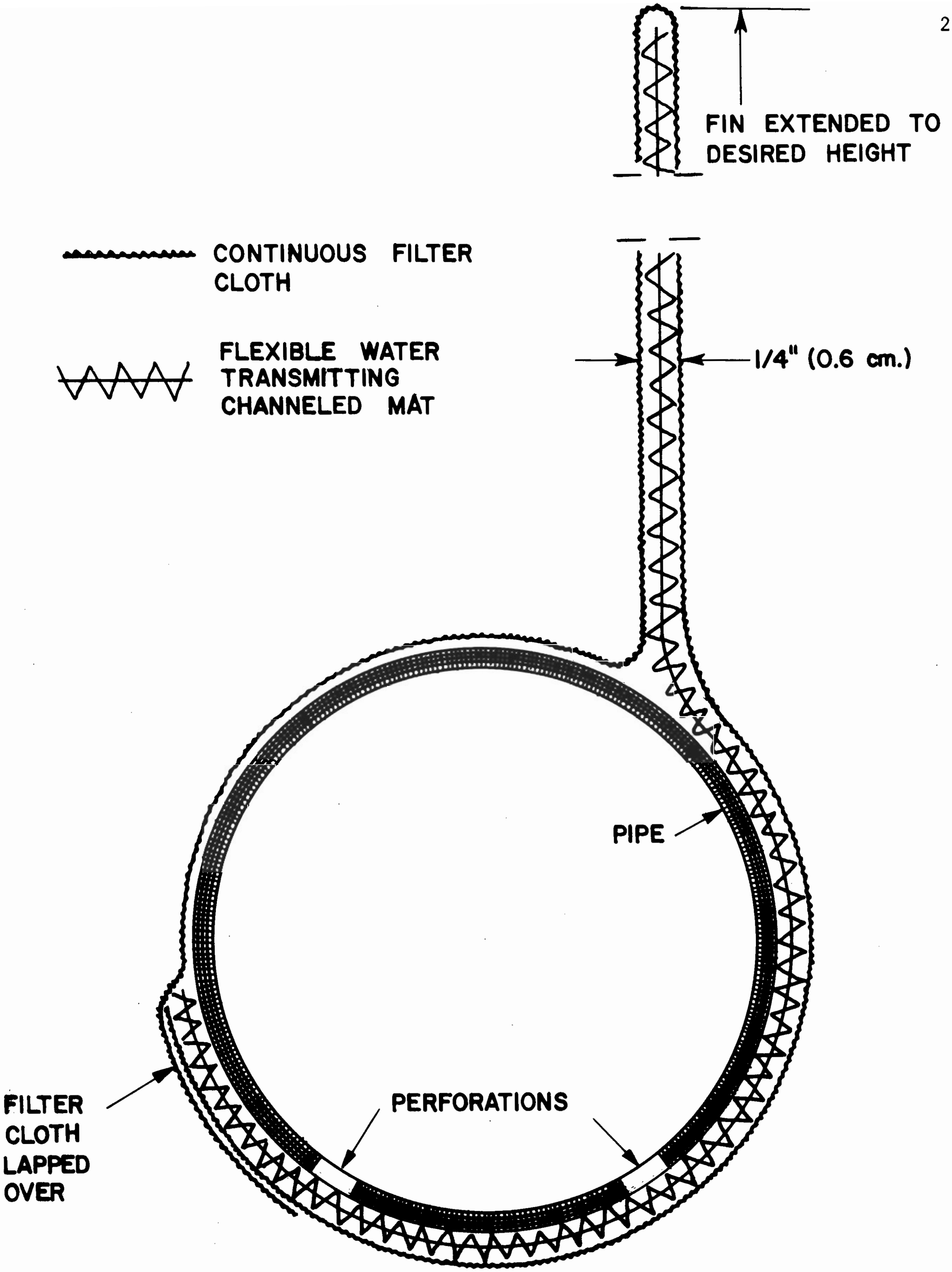

FIN EXTENDED TO DESIRED HEIGHT
CONTINUOUS FILTER CLOTH
FLEXIBLE WATER TRANSMITTING CHANNELED MAT
1/4" (0.6 cm.)
PIPE
FILTER CLOTH LAPPED OVER
PERFORATIONS

FIGURE 15

Patent Protection

The concept of the prefabricated underdrain has been patented through The University of Connecticut who has assigned the patent to the Research Corporation of New York according to their standard agreement. Research Corporation has issued a royalty free license to the Connecticut Department of Transportation. The description of the underdrain is disclosed in U.S. Patent 3,563,038, K.A. Healy and R.P. Long, Subterranean Drain.

APPENDIX - REFERENCES

1. Cedergren, H.R., Seepage, Drainage and Flow Nets, Wiley and Sons, New York, 1967, Chap. 5.

2. Tolman, C.F., Ground Water, McGraw-Hill, New York, 1937, p. 410.

3. Bennison, E.W., Ground Water, Its Development and Uses, Edward F. Johnson, Inc., St. Paul, Minn., 1947, p. 190.

4. Investigation of Filter Requirements for Underdrains, U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Miss., Tech. Memo. 183-, Nov. 1941, revised Dec. 1941.

PREVIOUS REPORTS ON PREFABRICATED UNDERDRAINS

1. Healy, K.A. and R.P. Long, "Preliminary Report, Prefabricated Underdrains", Report No. JHR 69-23, Department of Civil Engineering, University of Connecticut, Storrs, Connecticut, January 1969 (Report No. 1).

2. Healy, K.A. and R.P. Long, "Interim Report on Prefabricated Subterranean Drains", Project 67-2, JHRC PR 70-28, Department of Civil Engineering, University of Connecticut, Storrs, Connecticut, March 1970 (Report No. 2).

3. Long, R.P. and K.F. Briggs III, "Preliminary Report, Installation of Prefabricated Underdrain Along Route 44-A", Report No. JHR 70-31, Department of Civil Engineering, University of Connecticut, Storrs, Connecticut, September 1971 (Report No. 3).

4. Healy, K.A. and R.P. Long, "Field Performance of Prefabricated Underdrains", Report No. JHR 71-39, Department of Civil Engineering, University of Connecticut, Storrs, Connecticut, June 1971 (Report No. 4).

5. Healy, K.A. and R.P. Long, "Installation of Prefabricated Underdrains on Route 82 Extension, Haddam, Connecticut", Report No. JHR 71-41, Department of Civil Engineering, University of Connecticut, Storrs, Connecticut, July 1971 (Report No. 5).

APPENDIX - SPECIFICATIONS

INTRODUCTION

This appendix contains a set of specifications and typical details for the prefabricated underdrain. The research verified the concept of the underdrain, the specifications and drawings describe the type of materials used in field installations. Future manufacturing techniques will probably use other materials and core configurations.

SUGGESTED SPECIFICATIONS FOR PREFABRICATED UNDERDRAINS

1. Description - Prefabricated underdrains are units which are placed in the ground to collect and remove water while excluding soil from the system. These units are made from synthetic materials in convenient lengths, usually about 5 feet or longer, and require no special backfill in most cases. Each unit consists of a vertical fin and a pipe. The fin consists of a flexible or semi-flexible core, containing paths for the water to flow downward, covered with a fine mesh cloth.

   There are two basic types of prefabricated underdrains. One type has the semi-flexible core of the fin inserted into a plastic pipe through a longitudinal slot. The other consists of a flexible core covered with fine mesh cloth, wrapped around a perforated pipe and extending upward.

   Prefabricated underdrains shall be of the kind and size, and constructed to the dimensions and details as indicated on the plans. Outlets for prefabricated underdrains shall consist of pipe laid in a trench and refilled with earth. The size and type of outlet pipe shall be the same as the underdrain pipe.

2. Materials - The materials making up the prefabricated underdrain must be biologically nondegradable in the soil. In addition the components must satisfy the following requirements:

   a. Pipe: Sections using plastic pipe with a longitudinal slot to receive core must be able to resist a pressure of 1500 psf without crushing the core. This pipe must conform to the strength requirements per ASTM Designation D2466-65T, Schedule 40, Type II, Grade 1. The wall thickness shall not be less than 1/8 inch. Perforated pipe wrapped in drainage blanket shall conform to Article M.08.01 for the type of pipe specified.

   b. Cloth: The cloth shall be a nylon, polyester or other synthetic material having a bursting strength of 30 lb/in and must be biologically nondegradable. The fibers can be either mono- or polyfilament. The hole sizes shall be not smaller than 0.050 mm nor larger than 0.150 mm square and be reasonably uniform throughout. The porosity of the cloth shall be not less than 35 percent of the total area.

   c. Core:

      1.) Installation with maximum depth of 7 feet

      Type 1: The semi-flexible core shall consist of nondegradable material. The vertical channels in the fin must be within the dimensions shown on the drawings or must be able to transmit water at a minimum of 0.5 gallons per minute per lin ft of core under a pressure of 1500 psf. The crushing strength of the core shall not be less than 2300 psf perpendicular to the longitudinal face. The smallest core channel must have a minimum included radius of 1/16 inch to insure that a few small particles which might penetrate the cloth can continue out of the system.

Type 2: The flexible core shall have a minimum crushing strength of 2300 psf perpendicular to the longitudinal face and shall be sufficiently flexible to be bent to a 2-inch radius without kinking. The channels must be able to carry water at 0.5 gal/min per lin ft when the core is subjected to a pressure of 1500 psf. The open area inside the core under load should be 50 percent of the total in both the horizontal and vertical directions before backfilling. Channel openings must have a minimum included radius of 1/16 inch to insure that a few small particles which might penetrate the cloth can continue out of the system.

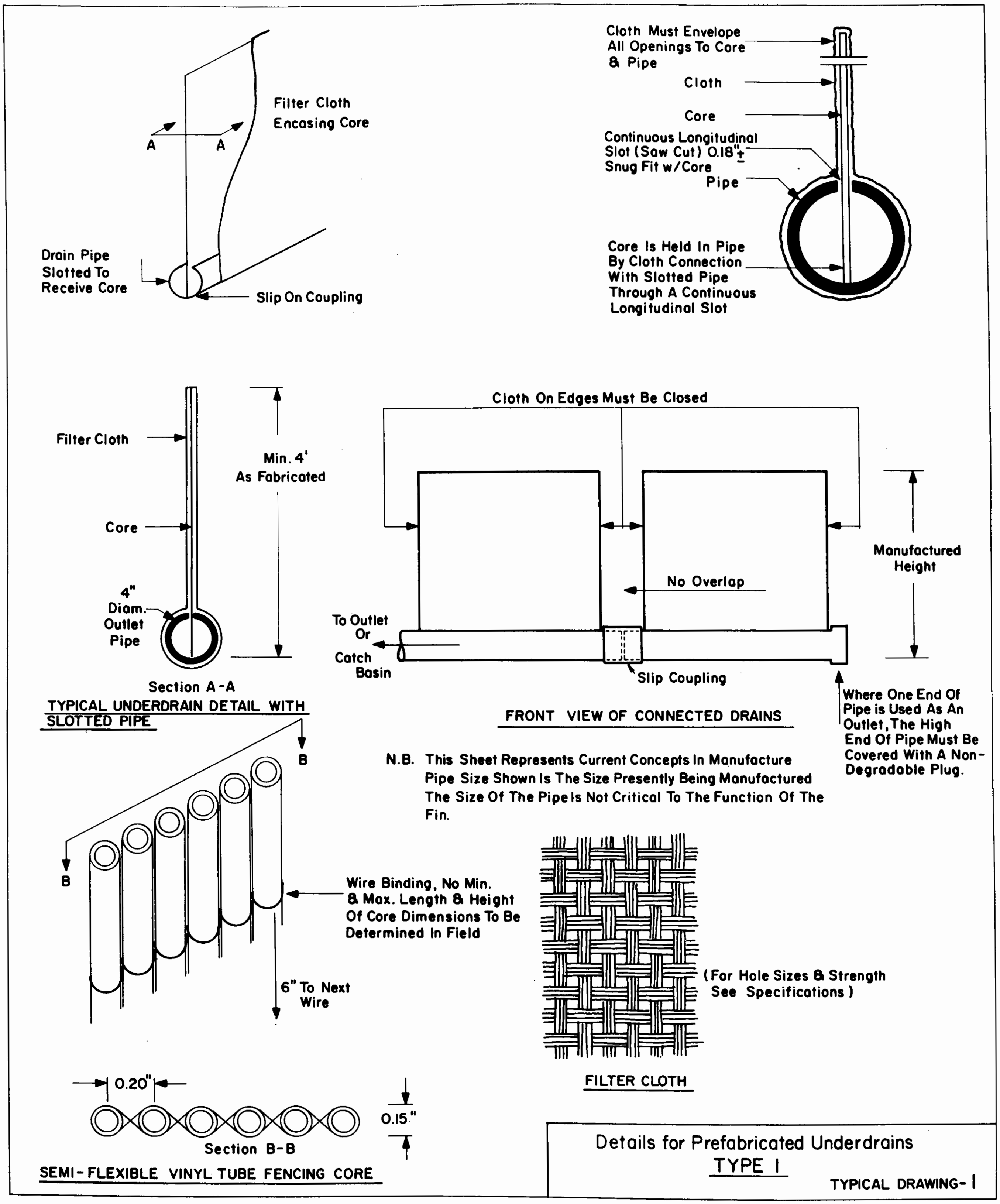
2.) Installations deeper than 7 feet

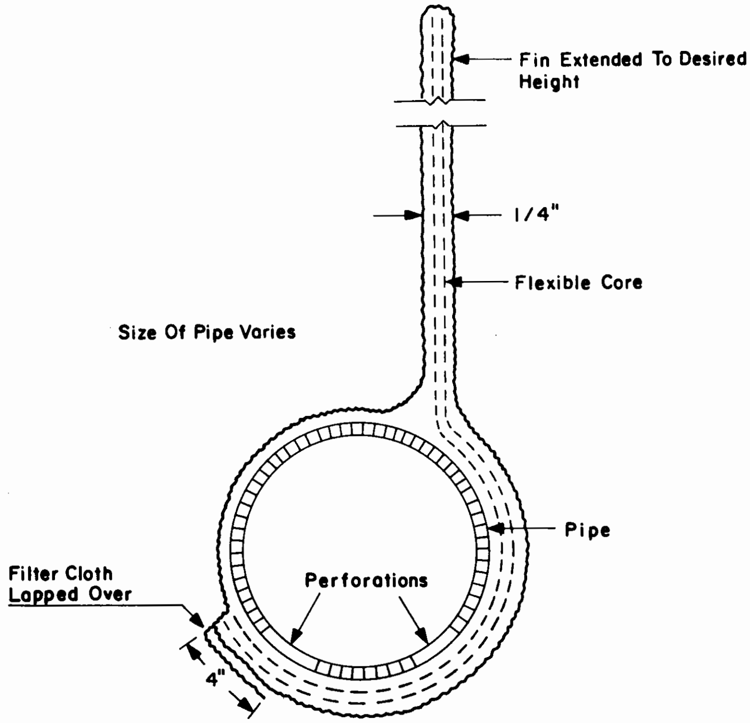
When prefabricated underdrains are to be buried deeper than 7 feet the core must be able to transmit water at the rate of 0.5 gallons per minute per lin ft under the estimated pressure from backfill and load. The minimum crushing strength of the core must be 1.5 times the estimated pressure from backfill.

d. Connections: Connections for the solid plastic pipe shall be plastic couplings conforming to ASTM Designation D2466-65T. When using perforated pipe with drainage blanket, the sealing and coupling of pipe joints shall conform to the requirements of Article M.08.01.

3. Construction Methods: The prefabricated underdrain shall be installed as shown on the drawings. The pipe shall be bedded in accordance with Article 7.51.03. The dimensions of the trench shall be as indicated on the plans or as ordered. Where bottom of the trench is unstable, sufficient unstable material shall be removed and aggregate, conforming to requirements set forth in Article M.08.03, added to stabilize the bottom of the trench.

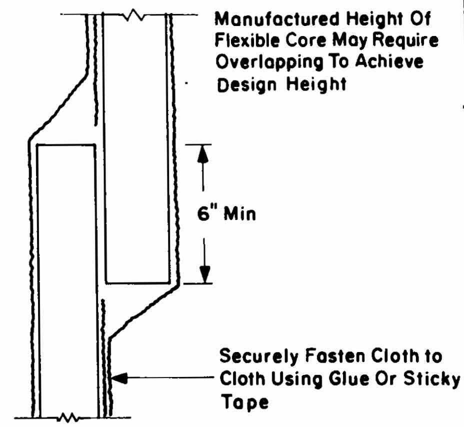
4. Basis of Payment: Prefabricated underdrains will be paid on the basis of linear feet in place, which price shall include all materials, equipment, tools, labor, handling and work incidental thereto.


Filter Cloth
Encasing Core
A
A
Drain Pipe
Slotted To
Receive Core
Slip On Coupling
Cloth Must Envelope
All Openings To Core
& Pipe
Cloth
Core
Continuous Longitudinal
Slot (Saw Cut) 0.18"±
Snug Fit w/Core
Pipe
Core Is Held In Pipe
By Cloth Connection
With Slotted Pipe
Through A Continuous
Longitudinal Slot
Filter Cloth
Min. 4'
As Fabricated
Core
4"
Diam.
Outlet
Pipe
Section A-A
TYPICAL UNDERDRAIN DETAIL WITH
SLOTTED PIPE
Cloth On Edges Must Be Closed
Manufactured
Height
No Overlap
To Outlet
Or
Catch
Basin
Slip Coupling
Where One End Of
Pipe is Used As An
Outlet, The High
End Of Pipe Must Be
Covered With A Non-
Degradable Plug.
FRONT VIEW OF CONNECTED DRAINS
N.B. This Sheet Represents Current Concepts In Manufacture
Pipe Size Shown Is The Size Presently Being Manufactured
The Size Of The Pipe Is Not Critical To The Function Of The
Fin.
B
B
Wire Binding, No Min.
& Max. Length & Height
Of Core Dimensions To Be
Determined In Field
6" To Next
Wire
(For Hole Sizes & Strength
See Specifications)
FILTER CLOTH
0.20"
0.15"
Section B-B
SEMI-FLEXIBLE VINYL TUBE FENCING CORE
Details for Prefabricated Underdrains
TYPE I
TYPICAL DRAWING-1



CONNECTION WITH PERFORATED PIPE

1. Underdrain Consists Of Flexible Fin Wrapped Around Perforated Pipe & Extended Vertically
2. Side View Of Connecting Drains Same As Shown On Typical Dwg.no.1 For Fin Extending One Manufactured Height Vertically
3. Pipe Is Same As Normally Specified Perforated Pipe

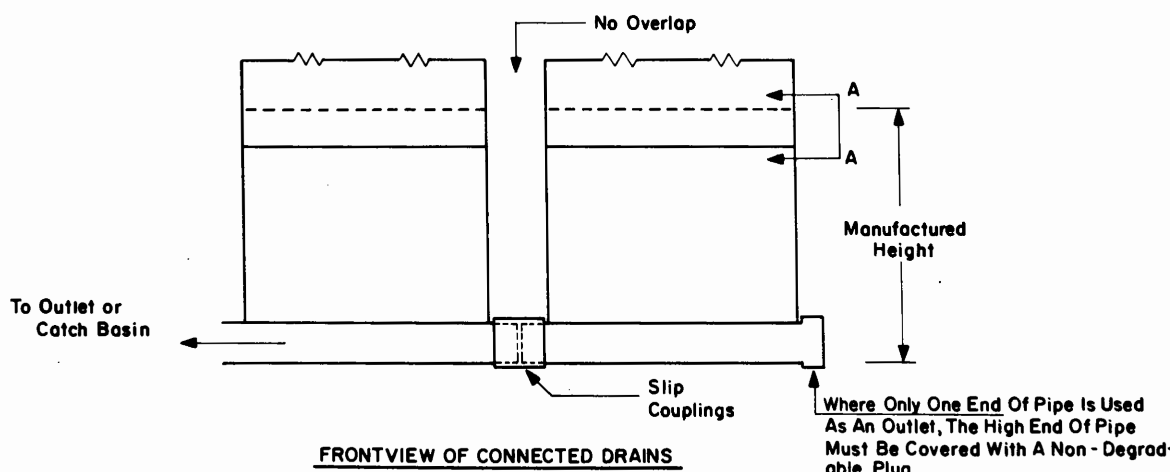


Additional Section Of Fin Without Pipe Should Be Placed To Within One Foot Of The Soil Surface

Fins Adjacent To The Vertical Location Must Overlap A Min. Of 6" To Insure Continuity Of Channels

SECTION A-A

OVERLAP OF FINS



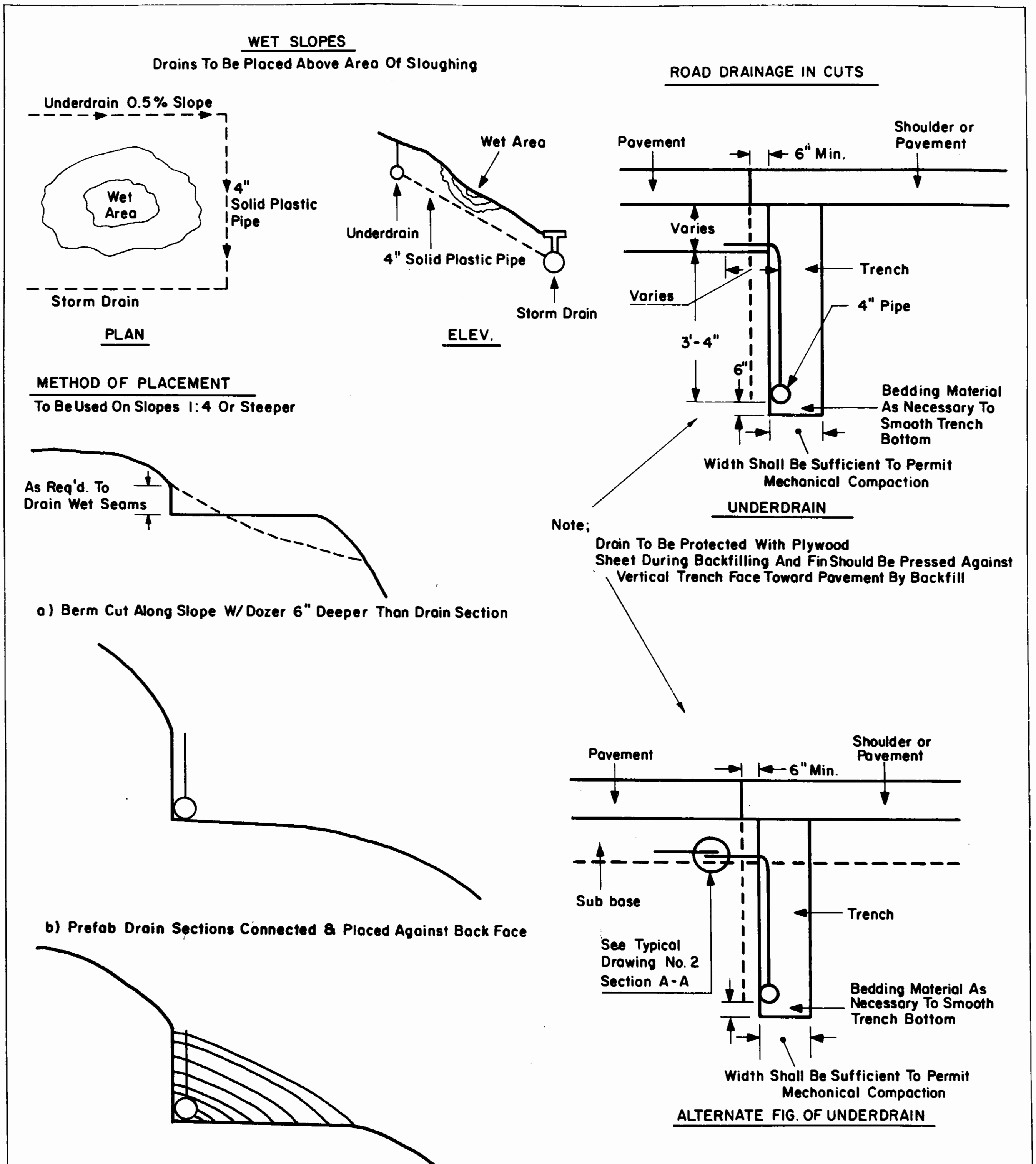
FRONTVIEW OF CONNECTED DRAINS

Design Fin Height Greater Than Manf'g. Height

Details for Prefabricated Underdrains

TYPE 2

TYPICAL DRAWING- 2



Installation Methods for Prefabricated Underdrains

DRAWING - 3