SUBSURFACE DRAINAGE

By J. David Rogers Ph.D., G.E.

Purpose: to alleviate the hydrostatic pressure induced by saturation or submergence

For example:

typical clay soil dry density, $\gamma_d = 110$ PCF (dry)

water density, $\gamma_w = 62.4$ PCF ↑ VS ↓

typical saturated soil density, $\gamma_{SAT} = 125$ PCF

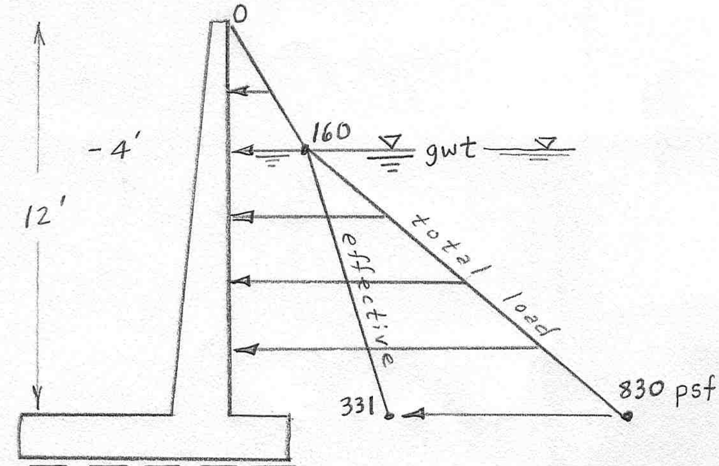
Bouyant Unit Weight $= 110 - 62.4 = 47.6$ (wet)

if $\phi = 20°$ and $K_a = .40$; Saturated Lateral Load $= 81.4$ PCF

the Unsaturated Lateral Load $= .40(110) = 44$ PCF

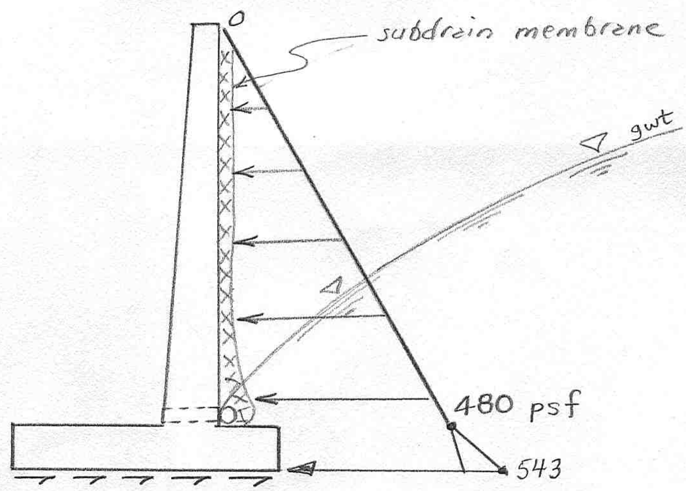
} submergence doubles the LOAD

IF NO SUBDRAINAGE



base friction = 248 PSF

WITH SUBDRAINAGE

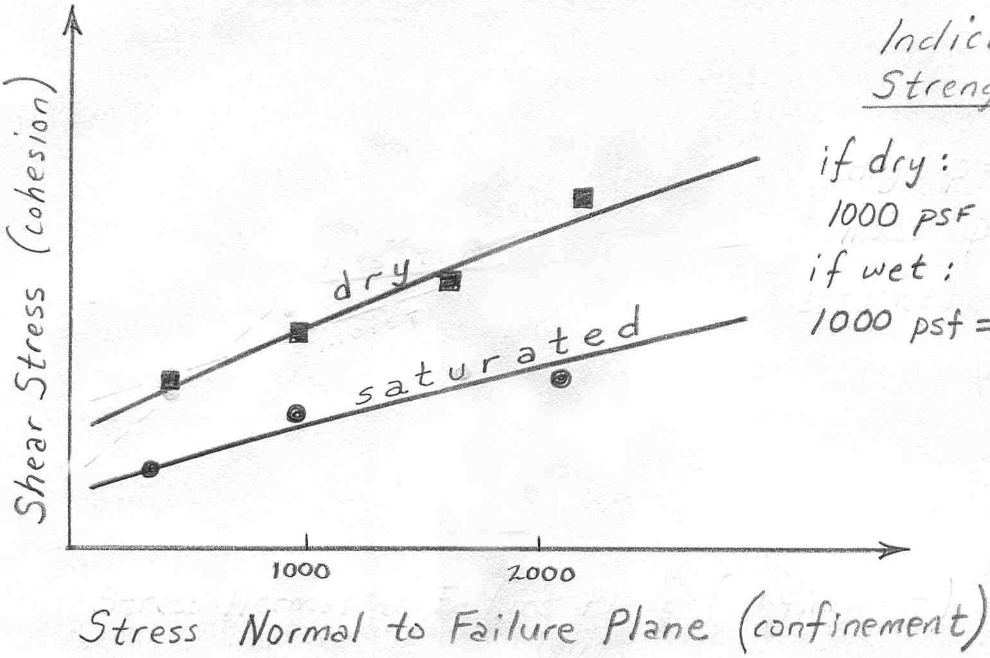


base friction = 456 PSF

∴ Through simple subdrainage, the lateral soil pressures on this wall are <u>reduced by 42%</u>, while base friction (footing with soil) is <u>increased by 184%</u>!

Saturation provides Pore Pressures which serve to lessen the effective stress, or confinement, provided by soil overburden

e.g.



Indicated Strength Parameters

if dry: $\gamma_d = 100$ pcf

$1000 \text{ psf} = \gamma_d H \Rightarrow 10$ feet

if wet:

$1000 \text{ psf} = \gamma_{bouy} H = 21$ feet

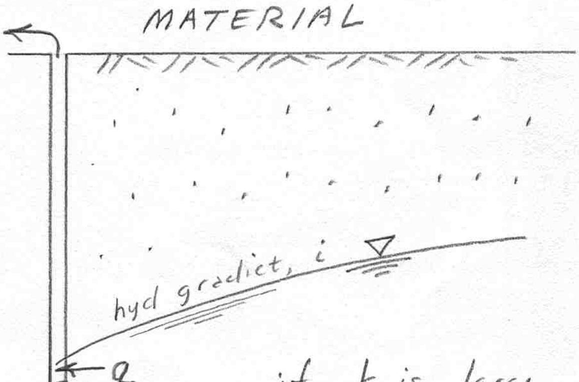
BASIC PRECEPTS OF GROUNDWATER FLOW

Darcy's Law: $Q = k i A$;

or Quantity of Flow = (permeability)(hydraulic gradient)(Cross Sectional Area of Flow)

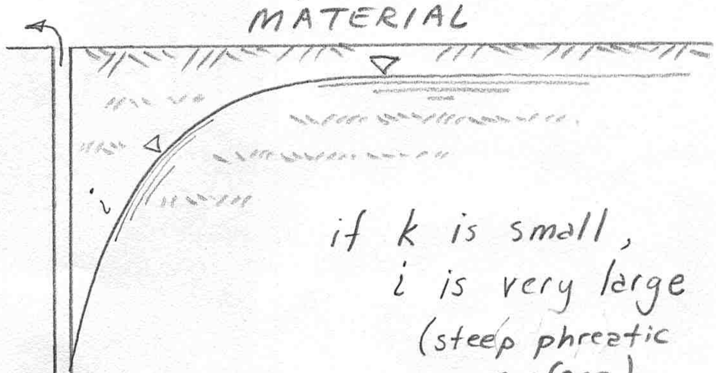
e.g. Well drawdown

IN SANDY, PERVIOUS MATERIAL



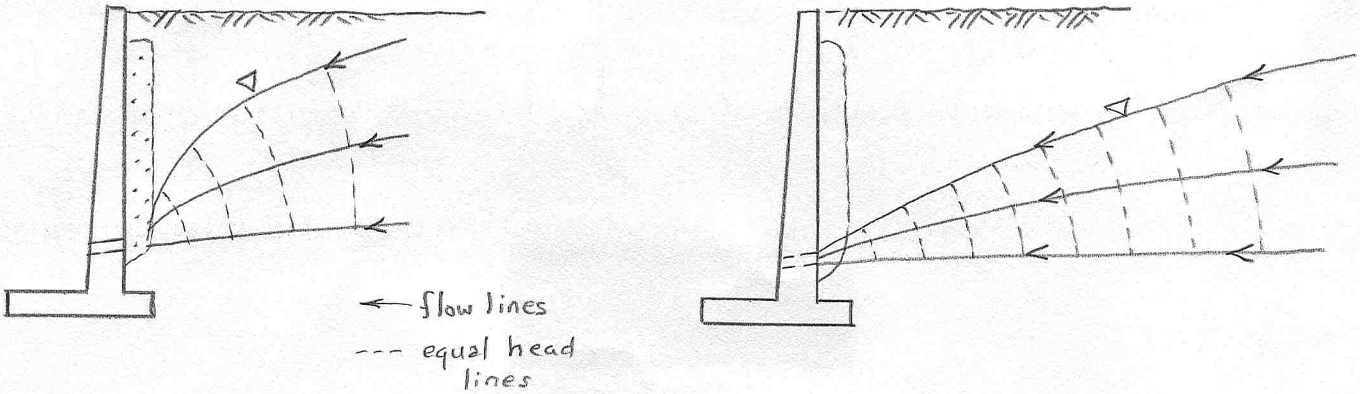
if k is large, i is small (flat phreatic surface)

IN CLAYEY, LESS PERVIOUS MATERIAL



if k is small, i is very large (steep phreatic surface)

DRAWDOWN OF WATERTABLE BY SUBDRAINS

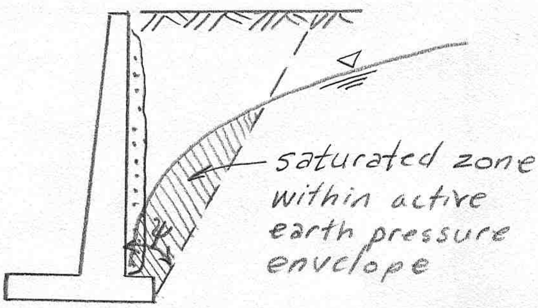


SILTY CLAYS

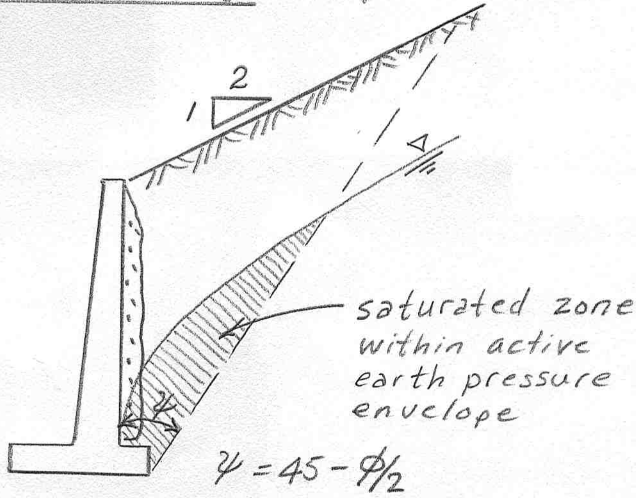
SANDY / GRAVELY MTLS

Conclusion: groundwater drawdown is most pronounced in the more pervious materials, like sands and gravels.

Be Aware that the Active Earth Pressure Zone exerting a lateral pressure on a retaining wall may be partially saturated, even if thorough subdreinage is placed behind the wall. e.g.



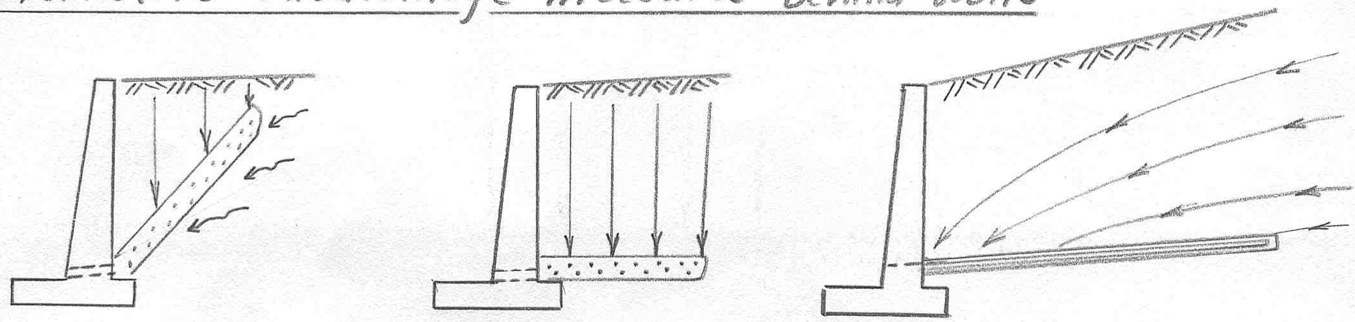
LEVEL BACKFILL



INCLINED BACKFILL

This partial saturation of the wall backfill creates an additional load on the retaining wall and reduces base friction values by 10% to 30%.

Alternative Subdrainage Measures behind walls



INCLINED DRAIN

HORIZONTAL DRAIN

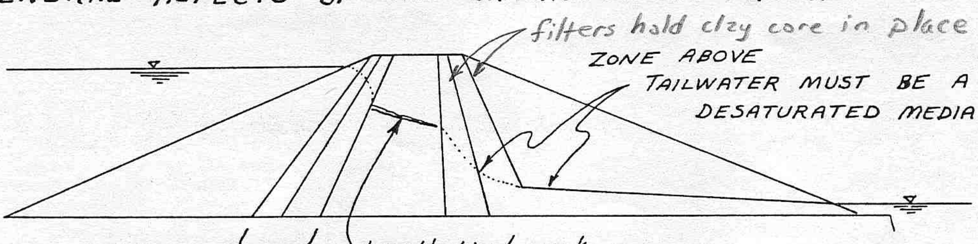
HYDRAUGER HORIZONTAL BORING

FILTER PROTECTION

In order to assure that subdrain systems are not clogged by fine soil particles, there needs to be some sort of filtration between the coarse-grained drainage material and the finer-grained ground mass.

Filter protection was originally undertaken to protect the clay core of earth dams from piping out of the embankment.

GENERAL ASPECTS OF THE CRACKSTOPPER THEORY

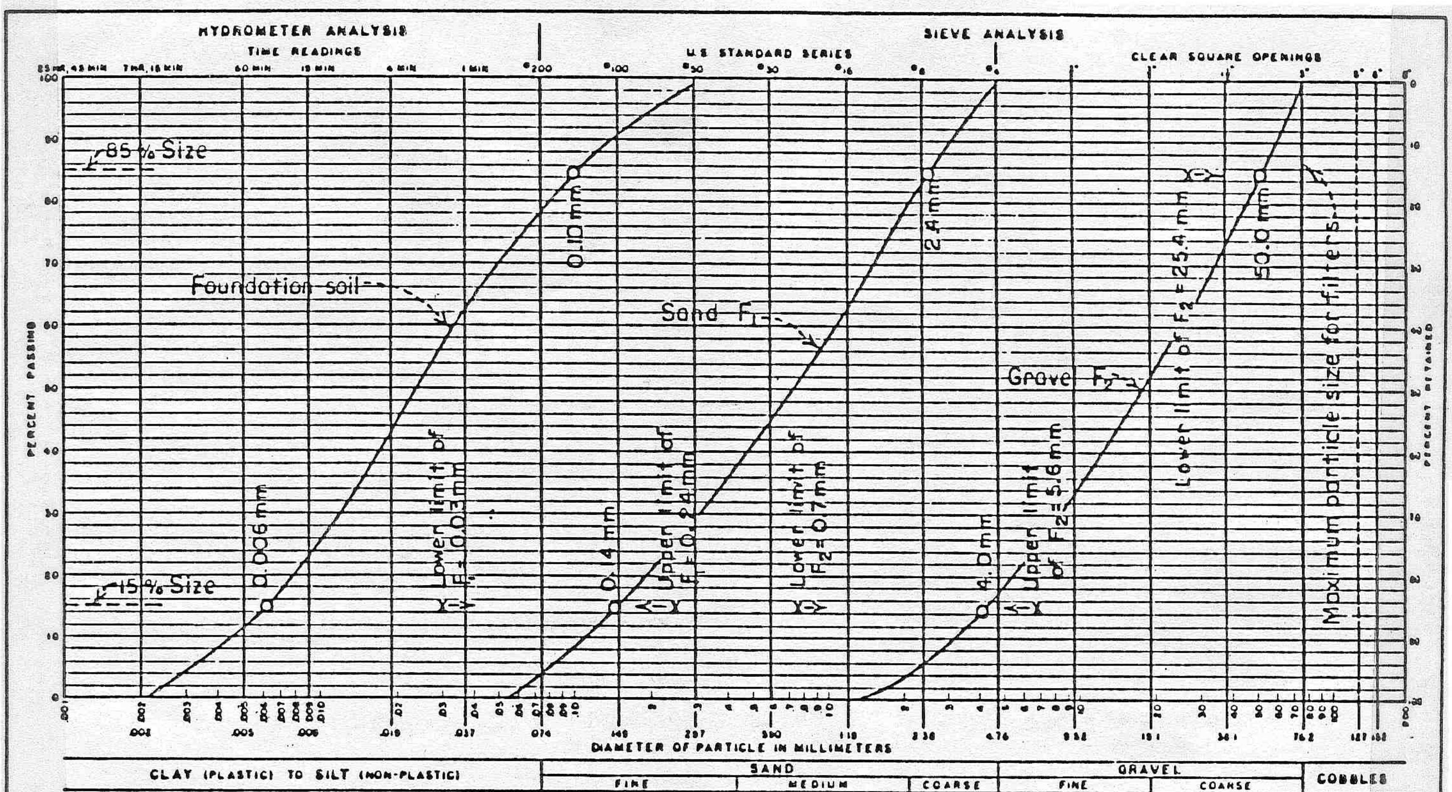


TWO ESSENTIAL ELEMENTS

1. CRACK WON'T GET LARGER
2. CRACK WILL PLUG WITH FILTER MTL.

— NO GUARANTEE OF VALIDITY —

The U.S. Army Corps of Engineers originally developed filter gradation criteria in the 1930's. These have since been refined and adopted by the U.S. Bureau of Reclamation.



Check of the Filter Gradations Against Design Criteria

For Filter F_1:

$\frac{D_{15} \text{ of } F_1}{D_{15} \text{ of Foundation}} = \frac{0.14}{0.006} = 23$; $5 < 23 < 40$, O.K.

$\frac{D_{15} \text{ of } F_1}{D_{85} \text{ of Foundation}} = \frac{0.14}{0.10} = 1.4$; $1.4 < 5$, O.K.

For Filter F_2:

$\frac{D_{15} \text{ of } F_2}{D_{15} \text{ of } F_1} = \frac{4.0}{0.14} = 29$; $5 < 29 < 40$, O.K.

$\frac{D_{15} \text{ of } F_2}{D_{85} \text{ of } F_1} = \frac{4.0}{2.4} = 1.7$; $1.7 < 5$, O.K.

D_{85} of F_2 = 50 mm; 50 mm > 25.4 mm, O.K.

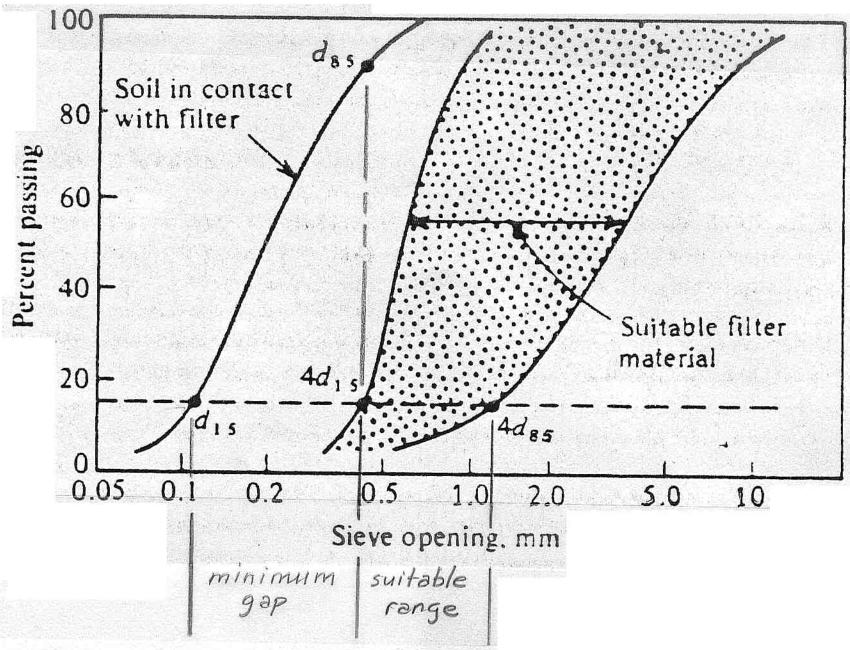
Figure 132. Typical filter design. 288–D–2877.

Basic Soil Mechanics Filter Criteria:

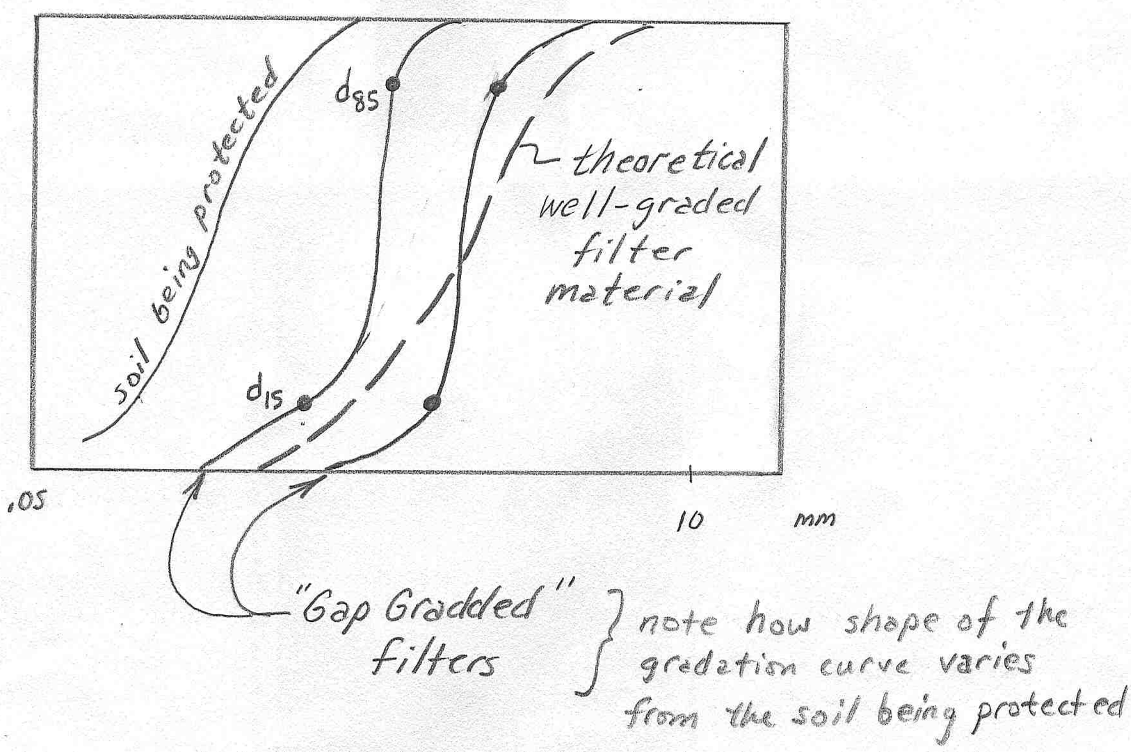
d_{15} of filter $\geq 4d_{15}$ of soil; and it must $< 4d_{85}$ of soil

For Gap Graded (uniformly sized) materials, the filter grain size curve must PARALLEL the material to be protected

The fathers of modern soil mechanics, Terzaghi and Peck, presented a somewhat simpler criterion



One aspect of these theoretical d_{15}/d_{85} relationships is so-called "gap gradation" problems, shown below:



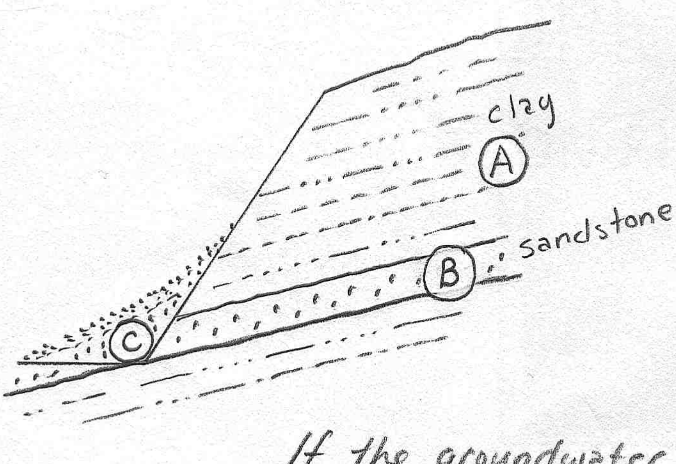
Types of Filter Materials

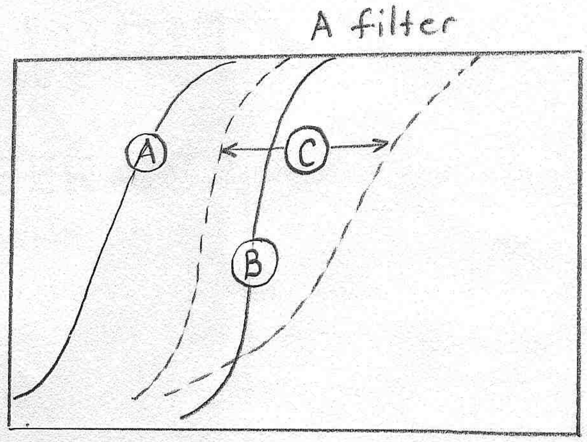
The only commercially-available subdrain filter rock mix is the CALTRANS CLASS 2 PERMEABLE MATERIAL (state Std. Specification 68-1.025). As shown on the next page, this mix is <u>NOT</u> to be confused with CLASS 2 Aggregate Base or Aggregate Subbase Materials.

CLASS 2 PERM mixes must have < 3% material passing No. 200 sieve and < 7% passing the No. 50 sieve.

However – beware of several facts:

1. Clean gravel mixes are approximately 1000 times more permeable than Class 2 Perm mixes. (see Permeability Chart on Page 8a)
2. The wrong 'Class 2' mix can be delivered to the job site without proper checking of fines content.
3. The gradation of the AQUIFER material you are trying to tap with your subdrain MAY be much different from intervening, clayey materials. e.g.





If the groundwater is coming out of the sandstone and <u>not</u> the clay, <u>match filter to the sandstone</u>.

Road Base Aggregate Mixes Versus Subdrain Aggregate Mixes

Typical Road Base Mixtures:

These Types of Road Aggregate Mixes are not applicable to subdrainage!

AGGREGATE SUBBASES (percent passing)

Sieve Size	Class 1	Class 2	Class 3
3"	100	100	100
2½"	90-100	90-100	90-100
No. 4	35-70	40-90	50-100
No. 200	0-20	0-25	0-30

AGGREGATE BASES (percent passing)

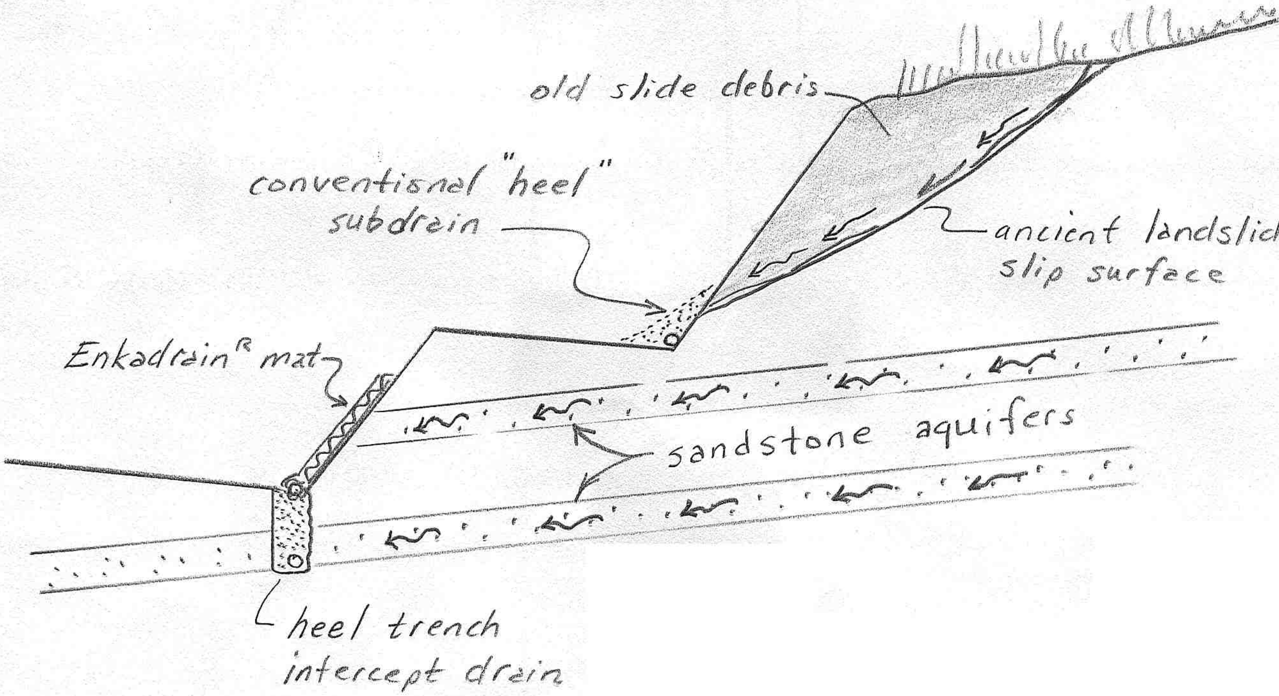
Sieve Size	1½" Maximum	¾" Maximum
2"	100	—
1½"	90-100	—
1"	—	100
¾"	50-85	90-100
No. 4	25-45	35-55
No. 30	10-25	10-30
No. 200	2-9	2-9

SUBSURFACE DRAINS (percent passing)

Sieve Size	CLASS 1 Type A	CLASS 1 Type B	CLASS 2
2"	—	100	—
1½"	—	95-100	—
1"	—	—	100
¾"	100	50-100	90-100
½"	95-100	—	—
⅜"	70-100	15-55	40-100
No. 4	0-55	0-25	25-40
No. 8	0-10	0-5	18-33
No. 30	—	—	5-15
No. 50	—	—	0-7
No. 200	0-3	0-3	0-3

Often, there is considerable confusion over the use of so-called "Class 1" or "Class 2" mixes for use in subdrainage applications. The road base mixes are most easily attainable, but not designed for percolation. As shown on the previous page, Class 2 Aggregate Subbase can be 1000 X less permeable than Class 2 Permeable mixtures. Note the percent allowed to pass the No. 200 sieve.

After excavations are opened, seepage zones and sources need to be identified and tapped with subdrains!



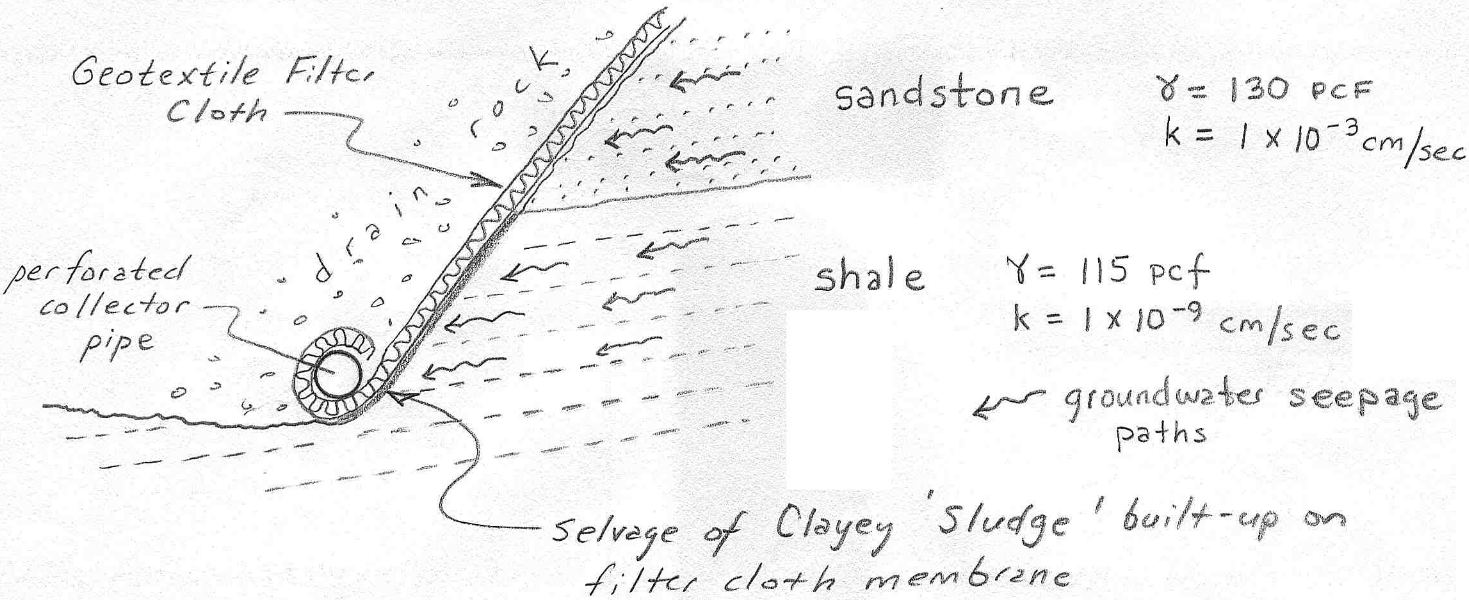
Common Groundwater Aquifers

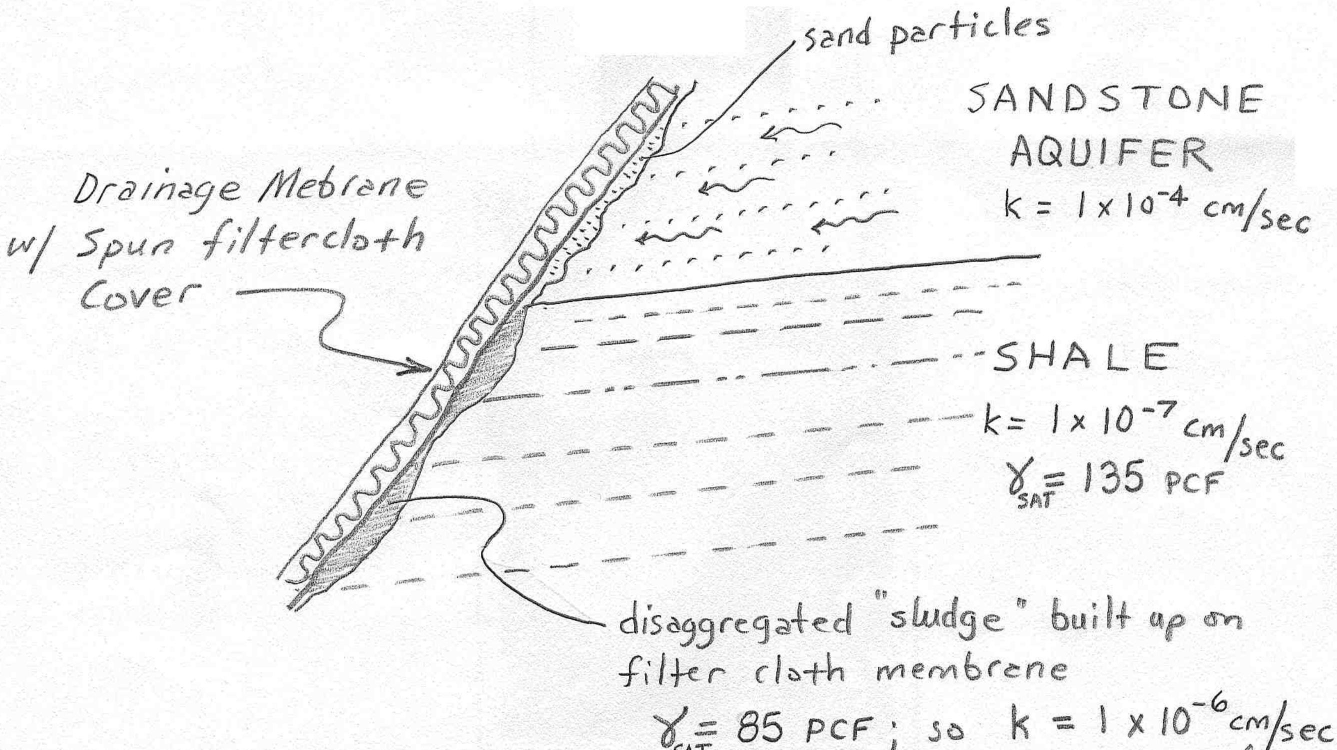
Old landslide slip surfaces
Bottom of Old Fills
Bottoms of Old Swales, Ravines, Gullies
Severely weathered, jointed bedrock
(just beneath ground surface)

Rodent burrows, decayed root tracks (usually w/i 18" of surface)
Severely fractured siltstone
sandstone
conglomerate
old pipelines, pipeline trenches, or canals
old stream channels

Why Filter Cloths Work:

Many practioners worry about the build-up of fine soil particles on the upflow side of geotextile filter clothes. This situation is sketched below:





∴ density of accumulated sludge will always be less then that of the parent material; so permeability of the sludge must be <u>greater</u> than that of from whence it came - the parent mtl.

Where Filter Cloths May Not Work

- When placed adjacent to dispersive clays, which are generally very susceptible to piping
  - high salt content, Sodium Absorption Ratio < 300
  - high gypsum concentration in soil or groundwater
- In situations where very high hydraulic gradients exist, thereby entraining excessive quantities of soil.
- In situations involving poorly graded or gap graded Cohesionless Materials; such as
  - loess
  - rock "flour" or rock dust
  - fine sands

These problems will be most accute in areas subject to rapid changes in hydraulic gradient, such as stream or canal channels.

Possible Solutions:

The designer must critically evaluate the Hydraulic Efficiency of the subdrain system being designed.

e.g. a 12" layer of crushed 3/4" x 1½" gravel with $k = 1$ cm/sec would carry the same amount of water as a drain 20 feet wide comprised of Class 2 Permeable Material ($k = 5 \times 10^{-2}$ cm/sec)!

Options:

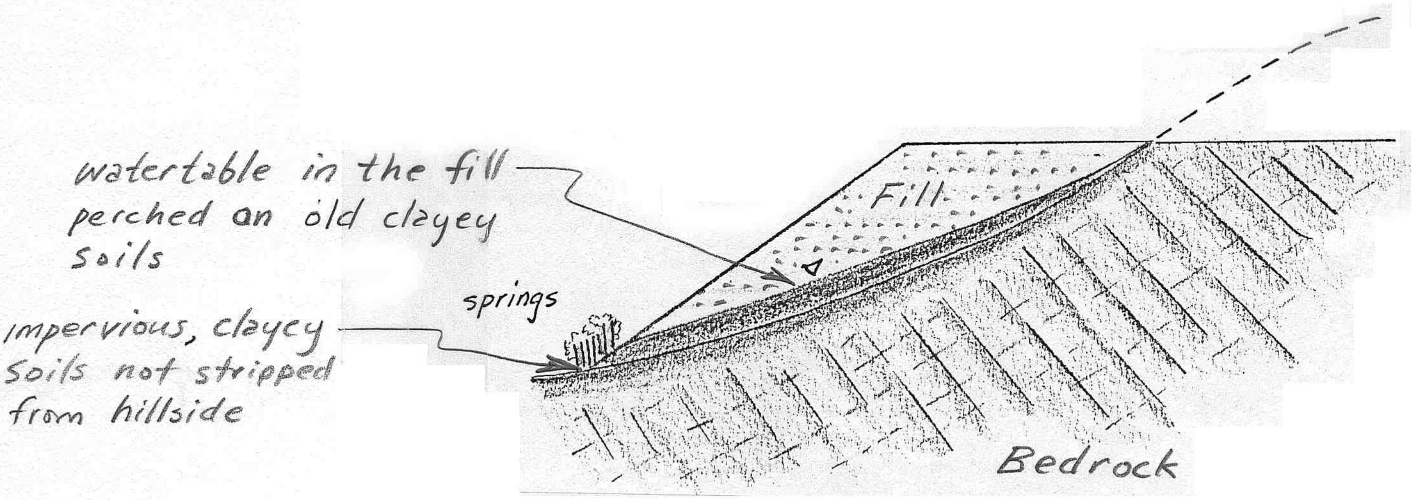
1. Construct a very pervious drain system, such as clean gravel – realizing that it will be hydraulically efficient and may take some time to plug up. An inverted filter of sorts may form as a consequence of fines infiltration.

2. Pick a geotextile with a large effective opening size (>800 microns) and hope that it passes a certain percentage of the fines (e.g. Mirafi 600X or Envirofence Woven fabrics). Monofilament cloths with large openings tend to work best in such situations

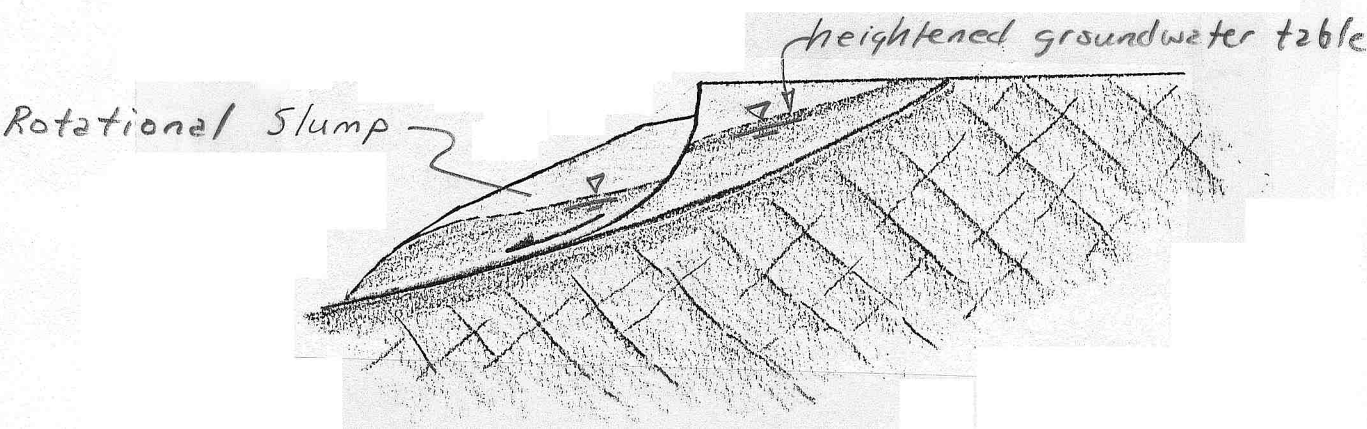
3. Add chemical flocculents (cation mixtures) to the water which will cause entrained (dispersed) particles to drop out of solution.

SUBDRAINS UNDER EMBANKMENTS

In the old pre-Grading Ordnance days, fill embankments were usually constructed by simple 'drifting' of cut soils by bulldozer over a natural hillside. This pushing of material created the now-infamous "SLIVER FILL", as shown below:

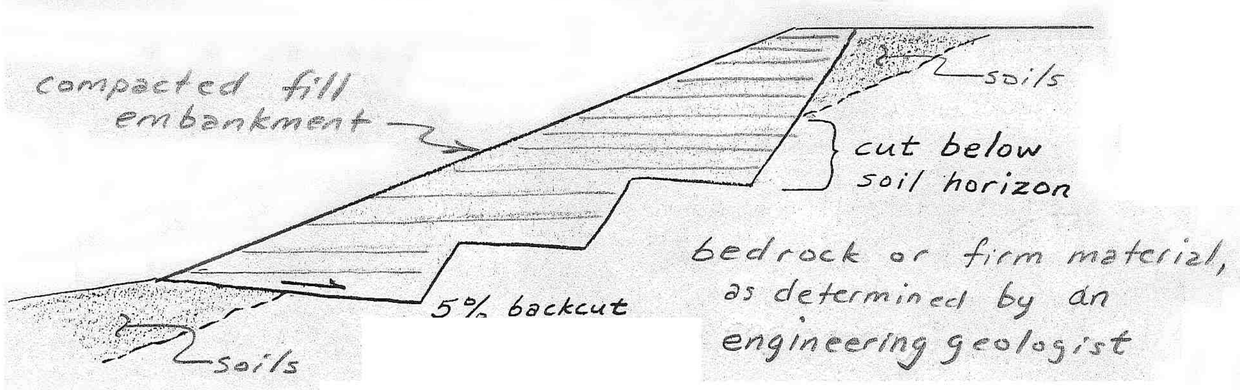


Eventually, springs at the toe of the slope are clogged with vegetation like pampass grass, and groundwater can build up in the fill like water in a bathtub. When the groundwater accumulates at a rate faster than it exits the toe of the slope, a ROTATIONAL SLUMP landslide occurs.



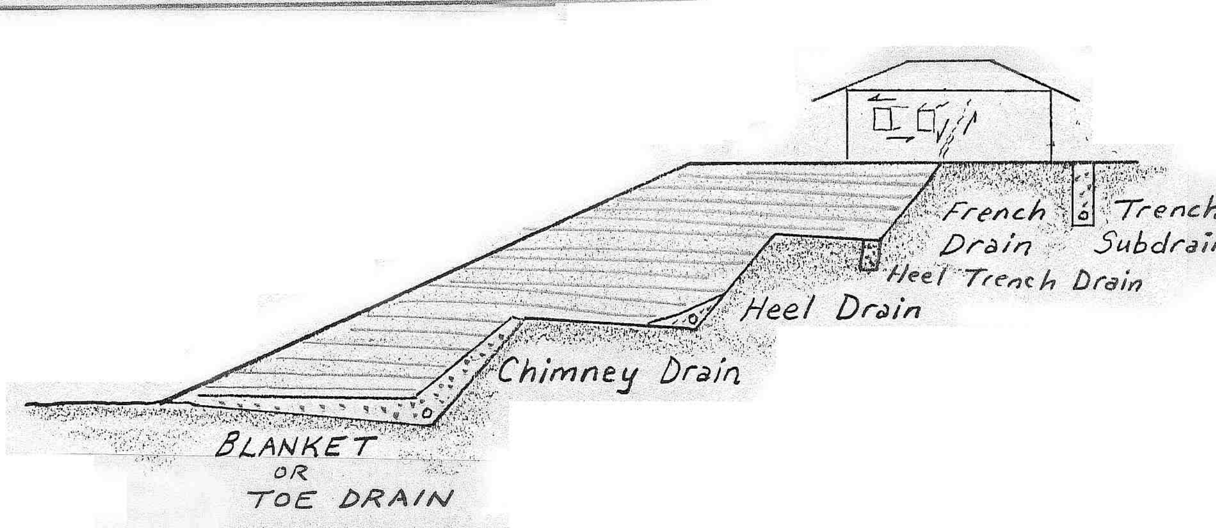
In an attempt to thwart the 'Sliver Fill' problem, stripping of surface soils and shear keys extending into bedrock or firm materials began to be required, starting with the Los Angeles Grading Ordnence in 1957 and then in Chapter 70 of the Uniform Building Code, beginning in 1964.

Shear Keys and Soils Stripping



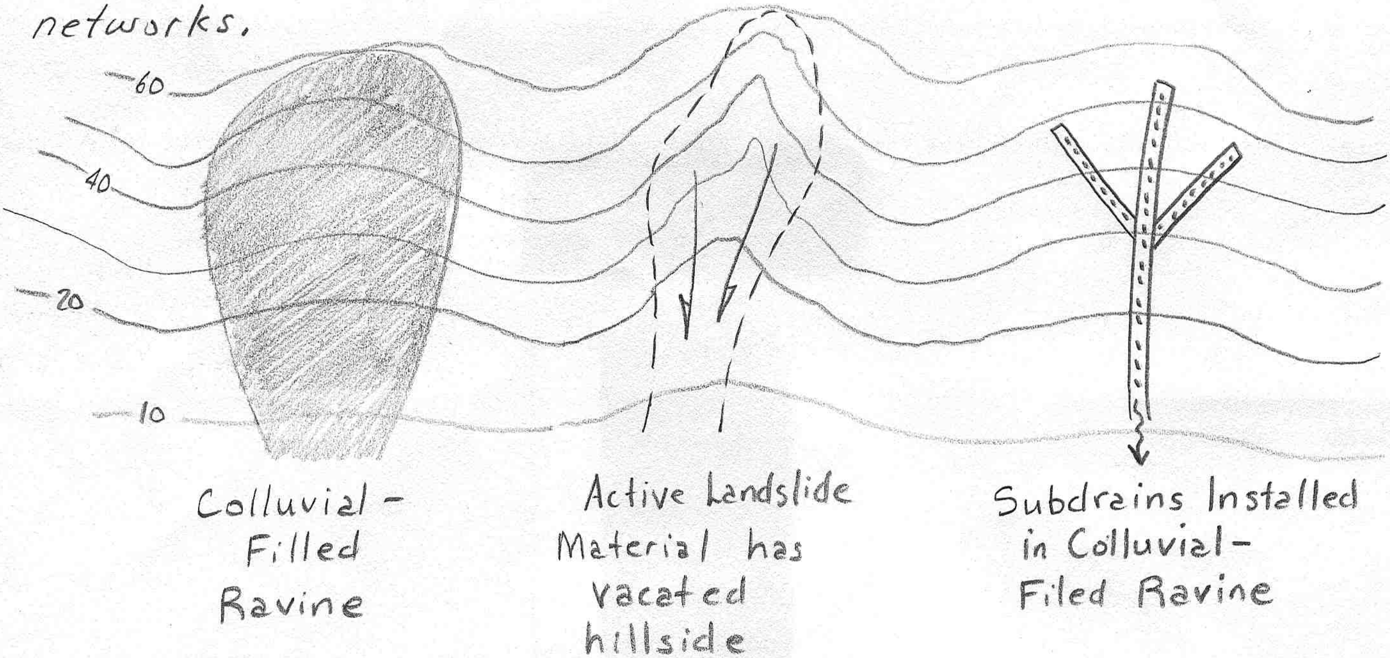
Soon, it became obvious that proper subdrainage needed to be emplaced beneath such embankments. Subdrains have many colloquial names; here are a few:

COMMON TYPES OF SUBDRAINS



TRENCH SUBDRAINS IN LANDSLIDE-PRONE AREAS

One very cost-effective manner of reducing future landslide hazards is to install trench subdrain networks.



Trench Subdrains are extremely cost effective. Proper filter protection and perforated pipe sizing need to be considered. See Standard Specifications for Continuous Trench Subdrains, attached.

<u>Beware</u>:

Many Contractors will try to use:

1. Corrugated Polyethylene Flex Pipe
2. HANCOR 1500-16 crush Perforated Drain Pipe
3. Styrene Pipe
4. Leach Line Pipe (½" holes at 6" on bottom of pipe)

These are <u>unacceptable pipes</u>, they can be crushed by the simple static weight of only a few feet of soil and they cannot be roto-rootered to effect maintainence.