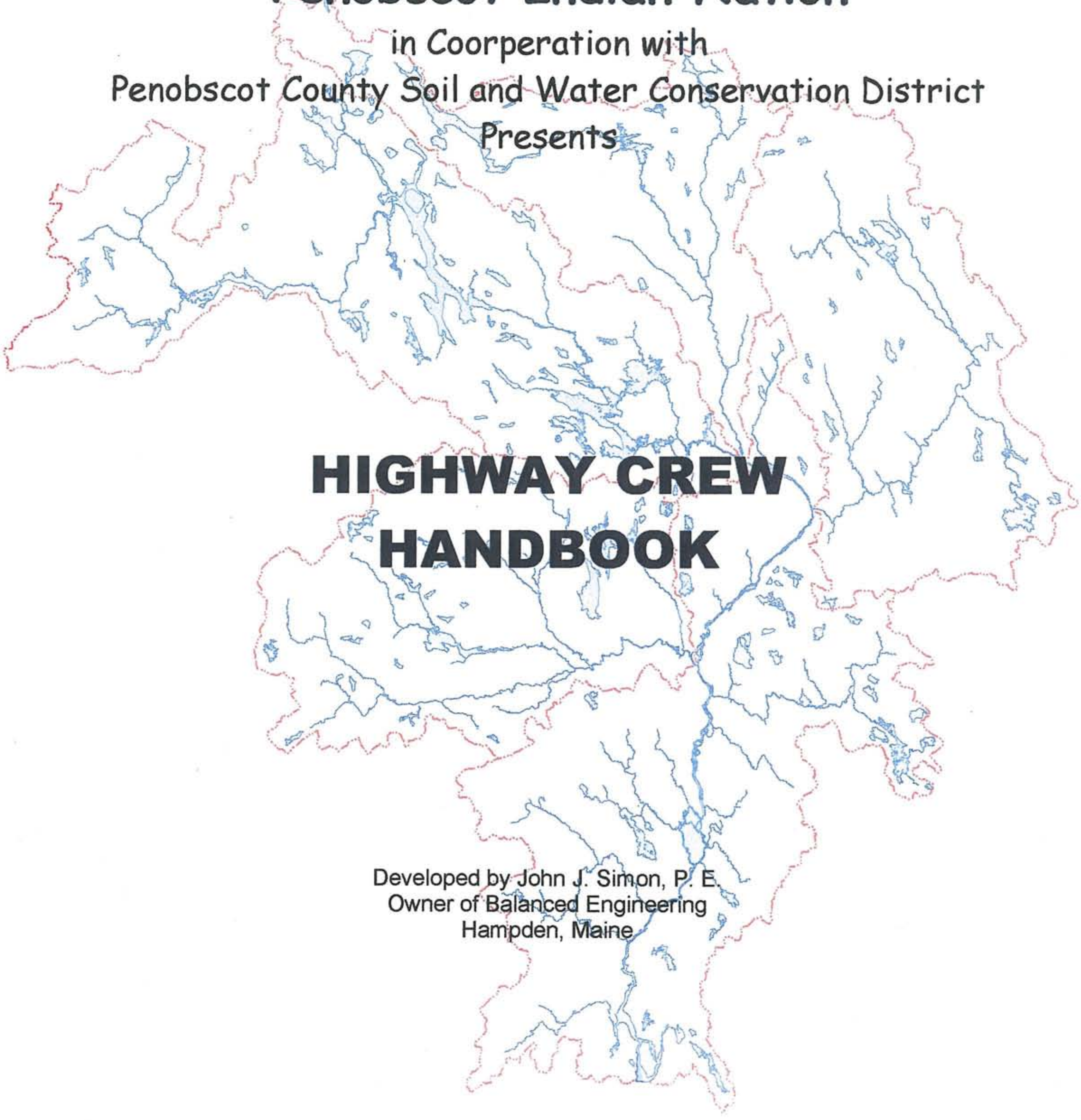
## Penobscot Indian Nation

in Coorperation with
Penobscot County Soil and Water Conservation District
Presents



# HIGHWAY CREW HANDBOOK

Developed by John J. Simon, P. E.
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This training was developed under a CWA Sec. 319 Tribal Grant awarded by the U.S. Environmental Protection Agency It has not been formally reviewed by EPA.
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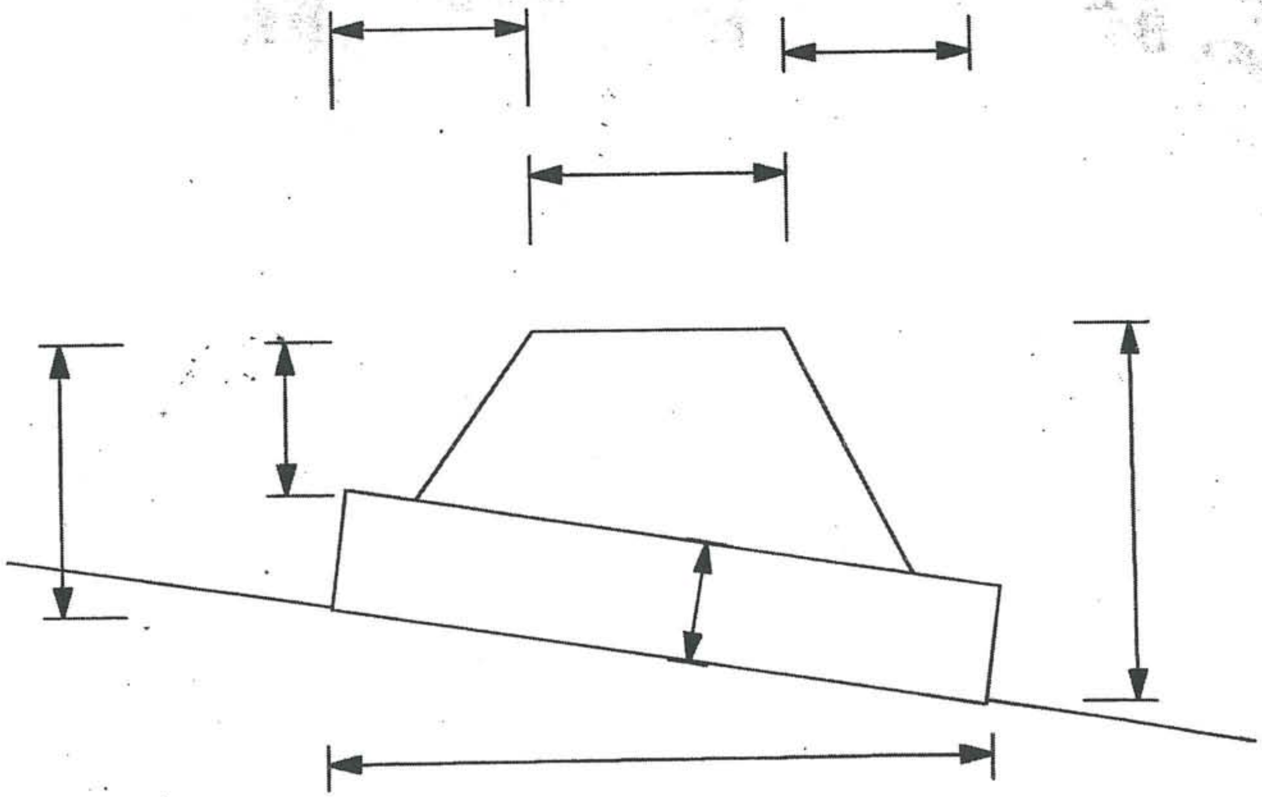
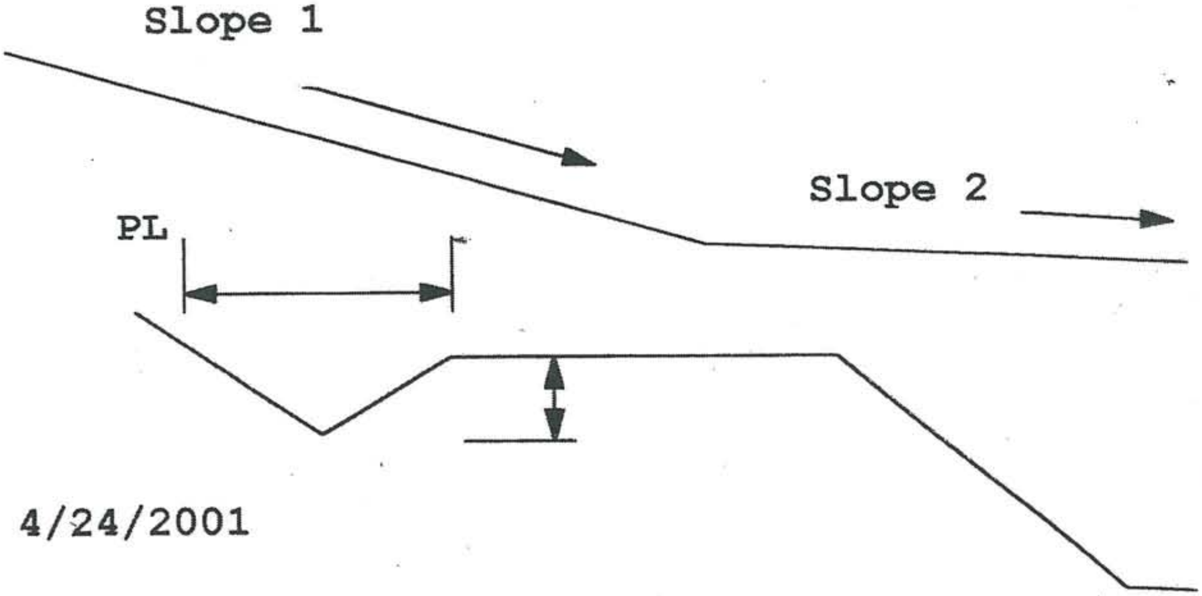
# 1 - ENVIRONMENTAL CONCERNS

## Culvert Data Needed



## Ditch Data Needed



JJS 4/24/2001

# 2 - WATERSHED ANALYSIS

# WATERSHED ANALYSIS:

## A - Watershed drainage areas:

1 - use the latest USGS topographic maps if at all possible, it is best to have a topographic map of town that shows all delineated Areas. The drainage areas of watersheds are always within each other or share boundaries so their is never any conflict with adjoining watersheds. Field examination of a watershed is always a good idea for validating decisions made while studying topographic maps in the office. Use two simple rules for delineating watershed boundary lines from any topographic map.
1 - the line is always perpendicular to the contours, except 2 - when parallel to contour lines of equal elevation(As in the location or ridges or saddles).

2 - as an alternate on small watersheds, use road maps or aerial maps combined with field observations and personal knowledge as a supplement to map studies.

3 - use the following table to estimate a culvert diameter from the acres in the watershed as obtained from 1 and or 2 above. The formula recommended by MeDOT is: diameter in inches equal to (8 + the drainage area in acres) with a minimum diameter of 12"

| Watershed drainage area (Acres) | Culvert diameter (Inches) |
|---|---|
| 4 or less | 12 |
| 7 " " | 15 |
| 10 " " | 18 |
| 13 " " | 21 |
| 16 " " | 24 |
| 22 " " | 30 |
| 28 " " | 36 |
| 34 " " | 42 |
| 40 " " | 48 |

## B - soils, average land slope, and land cover:

1 - these parameters are only necessary to quantify accurately when using a standard hydrologic models for calculating peak discharges and runoff volumes.

The drainage area and soil-cover complex of a watershed predominately govern the **VOLUME** or runoff, whereas the slope and smoothness of the land and drainage ways predominately govern the **RATE** of runoff.

The presence of ledge, hardpan, stones, cohesive soils, and vegetation limit the size of the drainage way that is scoured out by nature. The size of scoured channel for a watershed is mainly a function of land use, vegetation, geology & soils. It accurately reflects past hydrologic behavior, land use, geology, and should not be ignored.

C - drainage way or stream information:

1 - the drainage way gradient or slope downstream from a culvert is desirable to know for use in determining flow restriction, if any, at the outlet of a culvert, and to give some idea of the possibility for the need to pass fish. Steep can be considered as greater than about 8%, moderate is less than 8% but more than 2%, and flat equal to or less than 2%.

2 - the flow area of a stream <u>that appears to be kept well cleaned out</u> should be estimated for use in determining the flow area of culverts and/or channels. Most small streams keep a channel cleaned out bank-to-bank for storms somewhere around a 2 yr storm at least in Maine.

To figure the flow area of larger storms the following table can be used to give a "ball park" figure for sizing culverts and channels for small watersheds that do not warrant a hydrologic analysis. Also given is a rough estimate of <u>unit</u> flow rates for a small (less than 40 acre) wooded watershed with an average land slope of 8% and hydrologic "C" soils.

| Storm frequency frequency in Years | flow area multiplier FAM | Unit flow rate (typical) cfs/acre | | |
|---|---|---|---|---|
| | | Average | low | high |
| 2 | 1 | 1 | 0.5 | 1.5 |
| 10 | 2 | 2 | 1.0 | 3.0 |
| 50 | 3 | 3 | 1.5 | 4.5 |
| 100 | 3.5 | 4 | 2.0 | 6.0 |

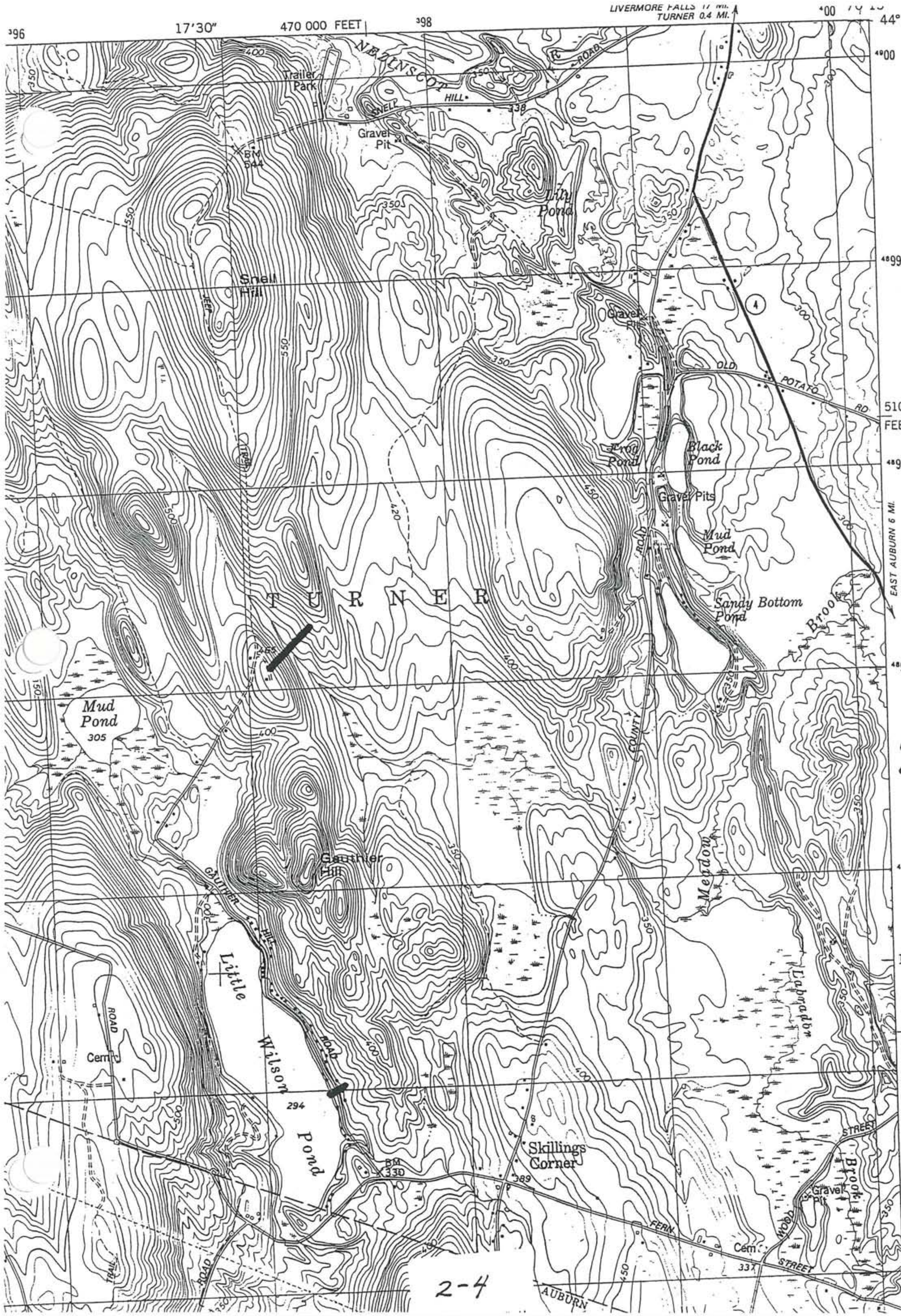
EXAMPLE: a drainage way appears to have a cleaned out flow area(FA) of about 3 square feet. Estimate the diameter of a culvert to pass a 2 yr storm, and the diameter of a culvert to pass a 50 yr storm.

Use (D) = ( 1.27 x FA x FAM)^0.5 = $\sqrt{1.27 \times FA \times FAM}$

D(2yr) = (1.27 x 3 x 1)^0.5 = 1.95 ft
= ***** use at least a 24" pipe.

D(50yr) = (1.27 x 3 x 3)^0.5 = 3.38 ft
= ***** use at least a 42" pipe.

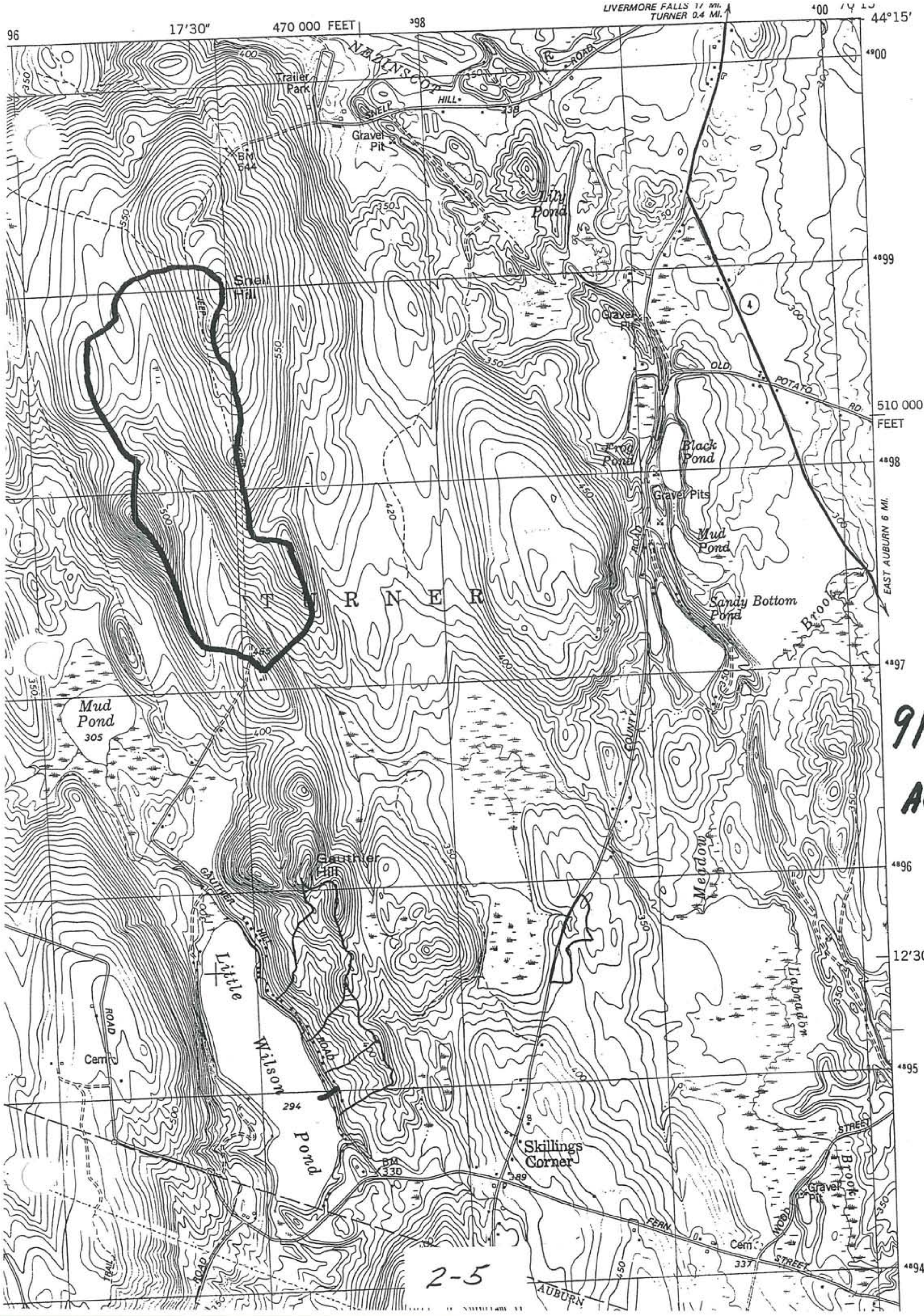
If both the drainage area and the drainage way flow area are known the culvert diameter can be determined by the above two area methods and the largest value used. If the following methods appear to be inappropriate then the assistance of an engineer trained in hydrology and hydraulics should be obtained.



2-4

91.827

AC/SI


LIVERMORE FALLS 17 MI.
TURNER 0.4 MI.
96
17'30"
470 000 FEET
398
400
44°15'
4900
NEZINSCOT R. ROAD
Trailer Park
SNELL HILL
338
Gravel Pit
BM 544
Lily Pond
550
350
4899
Snell Hill
JEEP TRAIL
4
Gravel Pit
OLD POTATO RD.
510 000 FEET
Frog Pond
Black Pond
4898
Gravel Pits
Mud Pond
EAST AUBURN 6 MI.
T U R N E R
Sandy Bottom Pond
Brook
455
4897
Mud Pond
305
420
450
COUNTY ROAD
500
400
Gauthier Hill
GAUTHIER HILL ROAD
4896
Meadow
12'30"
Little Wilson Pond
Labrador
ROAD
Cem
294
4895
Skillings Corner
BM 330
389
STREET
Brook
Gravel Pit
FERN
Cem
337
WOOD STREET
TRAIL
ROAD
AUBURN
4894

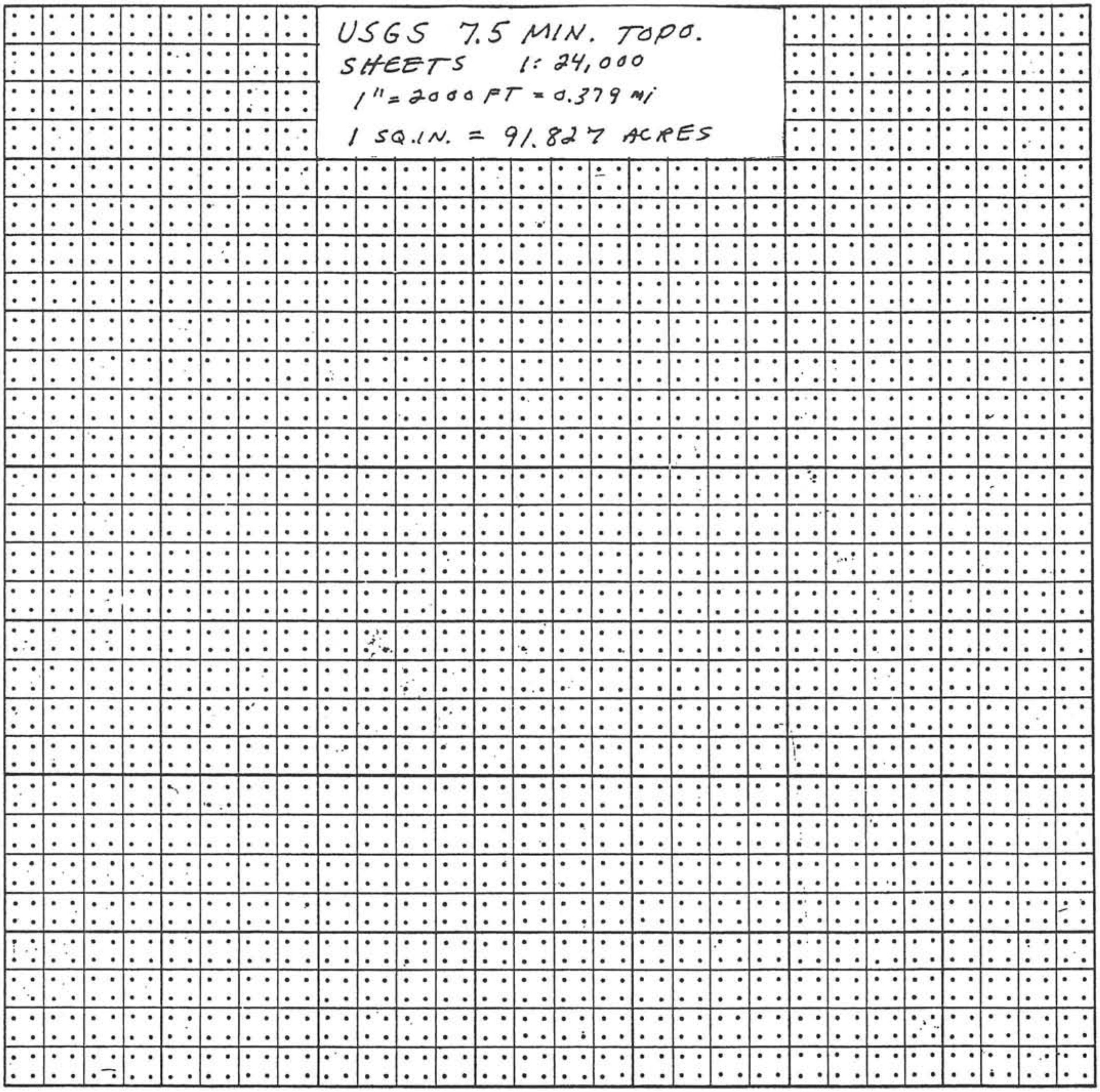
91.82

AC/SI

2-5

# ACREAGE CALCULATING GRID
## FOR ANY SCALE

1320



USGS 7.5 MIN. TOPO.
SHEETS 1: 24,000
1" = 2000 FT = 0.379 mi
1 SQ.IN. = 91.827 ACRES

( 64 dots per square inch.)

To be used for acreage determinations on maps of any scale. Place grid over area to be measured; count dots, multiply by converting factor to compute total acreage. When dots fall on area boundary, count alternate dots.

MAP SCALES AND EQUIVALENTS

| Fractional Scale | Inches Per Mile | Acres Per Square Inch | Converting Factor Each Dot Equals |
|---|---|---|---|
| 1" = 7,920" | 8.00 | 10.000 | 0.156 Acres |
| 1" = 9,600" | 6.60 | 14.692 | 0.230 Acres |
| 1" = 15,840" | 4.00 | 40.000 | 0.625 Acres |
| 1" = 20,000" | 3.168 | 63.769 | 0.996 Acres |
| 1" = 31,680" | 2.00 | 160.000 | 2.500 Acres |
| 1" = 63,360" | 1.00 | 640.000 | 10.000 Acres |
| 1" = 125,000" | 0.507 | 2,490,980 | 38.922 Acres |
| 1" = 250,000" | 0.253 | 9,963,906 | 155.686 Acres |
| 1" = 500,000" | 0.127 | 39,855,627 | 622.744 Acres |

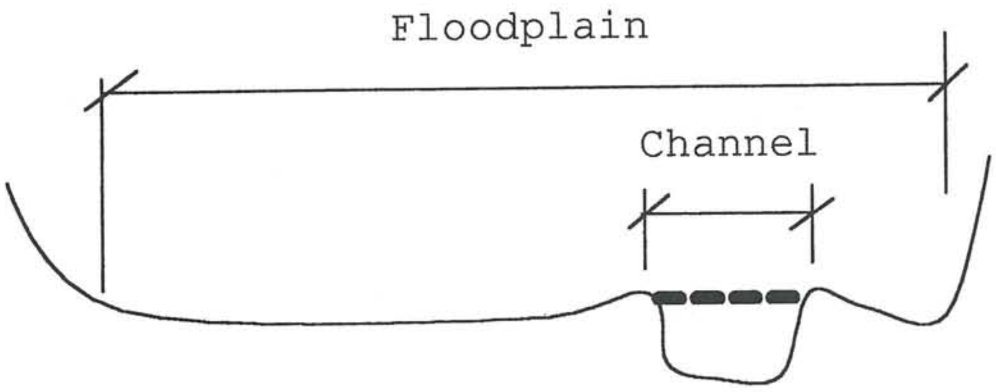
U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

1-10,359

# CHANNEL SIZE IMPLICATIONS

The channel below could belong to a large wooded watershed or a small urban watershed.



ANDY-7.KEY
JJS 11/21/98

## Understanding Map Scales

**Linear Measurements:**

**Example 1:24,000**

**Means that .....1unit on map = 24,000 units in the field.**
**Or**
**1" (inch) on map = 24,000" (inches) in the field**
**Or**
**1'(foot) on map = 24,000' (feet) in the field**

**Most map will have the scale expressed in terms of 1"(inch) = X' (feet)**

**In the above case a 1:24,000 scale Or**
**1" = 24,000" is normally expressed as:**
**1" (inch) = 2,000'(feet) ...... [ 24,000"/(12"/') ]**

**Area Measurements:**

**Example: Scale is 1:24,000 or**
**scale is 1" = 2,000' ........... used in 7.5 minute USGS topo sheets.**
**Therefore**
**1 square inch on map = 2,000 ft x 2,000 ft = 4,000,000 square feet**
**however**
**1 acre = 43,560 square feet**
**therefore**
**1 sq.in. on map = 4,000,000 sq.ft / 43560 sq.ft./acre = 91.827 acres**

## USE OF THE DOT GRID FOR AREA

## MEASUREMENTS:

**Each square inch has 64 dots. 8 dots by 8 dots. i.e. 1 sq.in. = 64.**
**However in the above,**
**1 sq.in. = 91.827 acres therefore:**

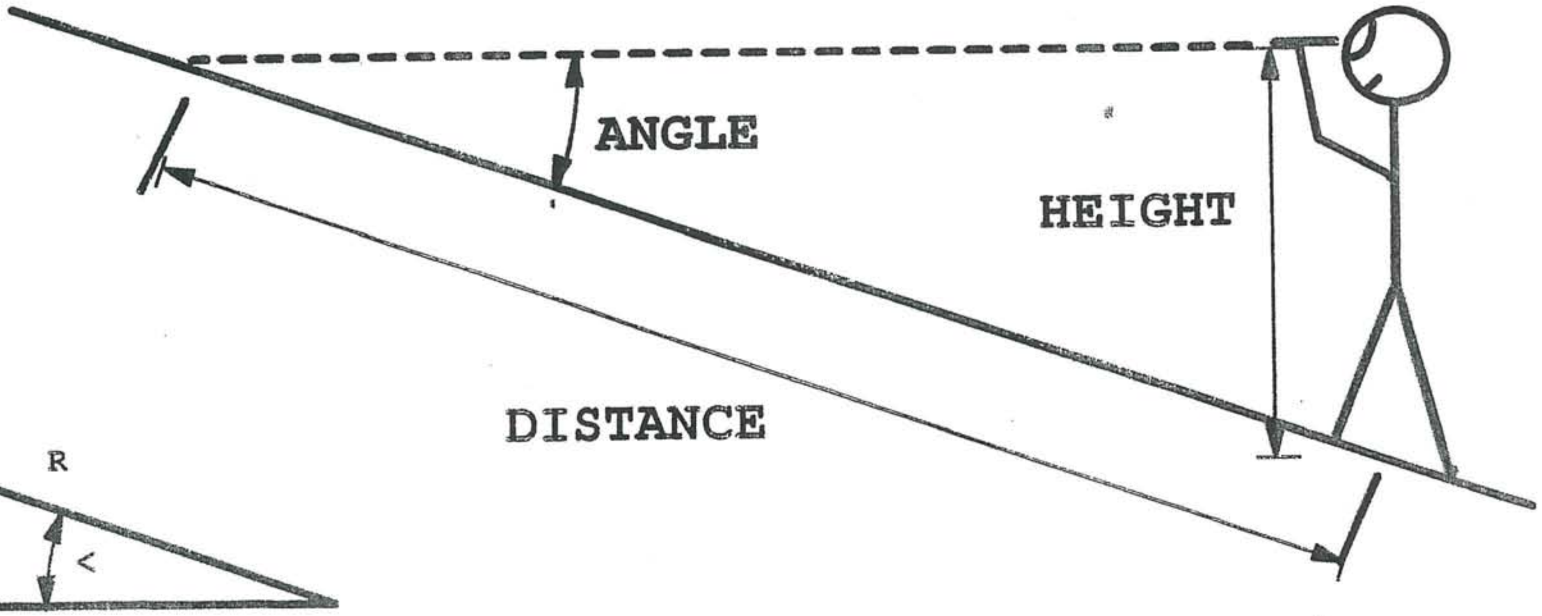
$$\frac{\text{91.827 acre/sq.in}}{\text{64 dots/sq.in.}} = \text{1.4348 acres/dot}$$

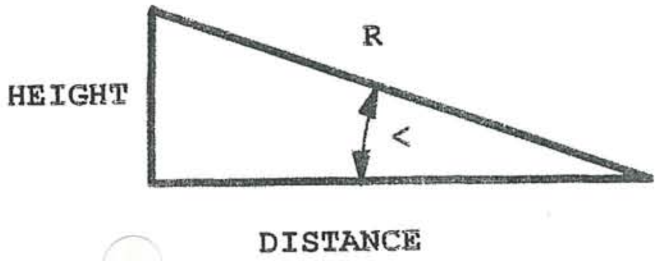
**JJS 4/18/03**

| ANGLE | SIN | TAN | <> | Z |
|---|---|---|---|---|
| 10 o | .174 | .176 | 1% | 5.7:1 |
| 20 o | .342 | .364 | 6% | 2.74:1 |
| 30 o | .500 | .577 | 13% | 1.73:1 |

**SLOPE = HEIGHT/DISTANCE = FT/FT**

**SLOPE = HEIGHT/DISTANCE X 100 = %**





TAN < = H/D (REAL SLOPE)
SIN <  H/R

# 3 - CULVERT ANALYSIS

## CULVERT & EMBANKMENT INFORMATION:

Frequent reference will be made to the handbook titled DRAINAGE, DRAINAGE, DRAINAGE, put out by the Maine Local Roads Center of MeDOT, and will subsequently be referred to as "MLRC" in this discussion.

### A - BEHAVIOR OR FAILURE MODE ANALYSIS AND REMEADIATION:

1 - Overtopping of embankment

- a - Entrance was plugged
  - I - schedule cleanout inspection and maintenance activities.
  - II - use trash fence upstream of inlet.
  - III - if beaver are reason see IF&W for trash fence design or perforated pipes.
- b - culvert has too small a capacity
  - I - install a larger pipe size - Refer to section 2 on watershed analysis to estimate an appropriate size or consult with an engineer.
  - II - install a higher capacity pipe - Consider using RCP or PE if now using CMP.
  - III - install a less restrictive inlet type - such as a flared entrance for CMP or a bell end if using RCP or PE pipe.
  - IV - install new pipe on flatter than neutral slope grade that reduces inlet turbulence, vortex development, and increases capacity.
- c - barrel has collapsed
  - I - replace pipe with proper foundation and backfill support
  - II - consider stronger pipe (heavier gage if metal) or a different type pipe.
- d - culvert was frozen full of ice
  - I - consider different pipe with less thermal conductivity. i.e. switch from metal, to PE or RCP which have much less thermal conductance.
  - II - install a small submerged companion culvert for winter low flows.
  - III - install an outlet flap valve to eliminate the "chimney effect".

2 - Road Washout @ culvert

a - overtopping for too long a time

- I - install a larger pipe. see A.1.b discussion above.
- II - improve the hydraulic behavior of inlet. see the above discussion.
- III - armor downstream slope with stone or Articulated Concrete Blocks (ACB), see Diagram #8, page 9-31 of MLRC. Use Stone with a D50 of at least 15" and a thickness of 30" minimum. See enclosed SCS work sheet which also shows the need for non-woven geotextile or gravel underlayment.
- IV - regrade roadway low spot away from culvert location. See Diagram #5, on page 9-28 of MLRC.

b - piping along outside of pipe

- I - install core material in upslope material if piping is not too far advanced.
- II - install downslope pipe drainage with tile or gravel filter.
- III - check joints for water tightness and replace pipe joints or grout.
- IV - reinstall pipe properly.

c - perforation of culvert by corrosion or damage

- I - replace pipe with pipe of similar material
- II - replace pipe with a more corrosion resistant material such as RCP or PE.
- III - consider in-situ (in-place) lining of pipe if it is still structural sound,

3 - Erosion @ Inlet

a - pipe is too short

- I - elongate pipe with more sections as needed. See Figure 5-14, page 5-38 or the MLRC manual. A length in feet = 4 times the fill height + 26 should be Sufficient for 2 lane roads.
- II - install a gabion or segmental retaining wall type headwall.

b - entrance slope not stabilized with grass sod or stone

- I - install grass, sod, or turf reinforced matting provided the slope is at least 2:1.
- II - install rip-rap lined slope for D+2' around pipe inlet.

- c - pipe on too steep a grade, thus vortexing during high flows causing slope erosion and damage to the pipe.
  - I - replace culvert and place on a flatter than neutral slope - see enclosed information sheet.
  - II - install an anti-vortex device, see enclosed sheet.

4 - Slope sloughing @ inlet

- a - pipe is too short thus the upstream embankment slope is too steep for the soil type.
  - I - elongate pipe as necessary to achieve a stable slope
  - II - install a structural headwall
- b - fill not compacted thus material is weak
  - I - replace slope fill with a well compacted material which is stronger.
- c - slope not protected from rapid drawdown related to soil texture in embankment
  - I - replace fill with stronger and denser material.
  - II - elongate pipe allowing a flatter slope.
  - III - rip-rap slope.
  - IV - use bio-engineering plantings of selected bushes.

5 - Erosion @ outlet

- a - high velocities
  - I - install a structural apron (if fish passage required) i.e. [using rock rip-rap or articulated concrete block (ACB)].
  - II - install a rock lined plunge pool. see Figure 5-25, page 5-55 of MLRC manual.
- b - erosive soils in channel banks and bed.
  - I - install a structural apron (if fish passage required) i.e. [using rock rip-rap or articulated concrete block (ACB)]
  - II - install a rock lined plunge pool - see above.
- c - surface drainage over fill
  - I - route surface drainage away from culvert to abutment area by Raising or "humping" the fill at the culvert location - see page 9-28 of MLRC.
  - II - rip-rap the downstream slope, see page9-31 of MLRC.

6 - Slope sloughing @ outlet

  a - pipe is too short thus slope is too steep

    I - elongate pipe to flatten slope to at least 2:1.
    II - install structural headwall

  b - piping of fill by seepage through embankment

    I - install an upstream core and/or anti-seep collar
    II - install downstream drainage using tile and/or gravel drain
    III - check joints for exfiltration (leakage from joints or perforations)

  c - surface drainage over fill

    I - route surface drainage away from culvert to abutment area by raising or "humping" the fill at the culvert location - see page 9-28 of MLRC.
    II - rip-rap or armor the downstream slope - see page 9-31 of MLRC.

7 - Crushed pipe

  a - corrosion of pipe wall material

    I - replace pipe and backfill properly

  b - removal of side soil support by internal piping of fill or soil entrance through leaky pipe joints.

    I - remove and replace with a new pipe having proper backfill support, water tight Joints, and a firm foundation.

B - CULVERT INSTALLATION INFORMATION:

1 - Sizing: Use the following table to determine the diameter of pipes if two or three culverts are desired to replace a single culvert.

| Diameter single | Diameter of doubles | Diameter of triples |
|---|---|---|
| 18" | 12" | 10" |
| 21 | 15 | 12 |
| 24 | 18 | 15 |
| 30 | 21 | 18 |
| 36 | 24 | 21 |
| 42 | 30 | 24 |
| 48 | 36 | 27 |
| 54 | 42 | 30 |
| 60 | 42 | 36 |
| D1 | D2 = 0.71 x D1 | D3 = 0.57 x D1 |

Culverts of 48" diameter and smaller should have at least 1 foot of cover, and culverts larger than 48" should have at least 18" of cover.

On multiple culvert installation it may be desirable to have one culvert about 6" lower than the other two to carry low flows during the winter and help to limit the ice buildup problem.

Multiple culverts should be separated by adequate room between each to operate compaction equipment. Multiple culverts make it somewhat easier to avoid siltation during installation and/or periodic replacement.

## CORRUGATED METAL UNDERDRAIN

| Diameter | Galvanized CMP (M218) | Aluminum Coated (Type II) CMP (M274) or Polymer Coated CMP (M246) | Corrugated Aluminum Alloy Pipe (M197) |
|---|---|---|---|
| Type "B" 6" | 16 ga. | 18 ga. | 18 ga. |
| Type "C" 12" | 14 ga. | 16 ga. | 14 ga. |
| 15" | 14 ga. | 16 ga. | 14 ga. |
| 18" | 14 ga. | 16 ga. | 14 ga. |
| 21" | 14 ga. | 16 ga. | 14 ga. |
| 24" | 14 ga. | 16 ga. | 14 ga. |
| 30" | 12 ga. | 14 ga. | 12 ga. |
| 36" | 12 ga. | 14 ga. | 12 ga. |

**Type "B" underdrain:**

Pure underdrain functions by itself or is on the front end of a catch basin.

**Type "C" underdrain:**

Very common design which serves as both an underdrain and a storm drain. Usually connects or drains catch basins. Pipe is typically corrugated metal or perforated plastic.

# CORRUGATED METAL CULVERTS

| Inside Diameter | Galvanized CMP (M218) | Aluminum Coated (Type II) CMP (M274) or Polymer Coated CMP (M246) | Corrugated Aluminum Alloy Pipe (M197) |
|---|---|---|---|
| 15" | 14 ga. | 16 ga. | 14 ga. |
| 18", 21", 24" | 12 ga. | 14 ga. | 14 ga. |
| 27", 30", 33" | 12 ga. | 14 ga. | 12 ga. |
| 36" | 12 ga. | 14 ga. | |
| 42" | 10 ga. | 12 ga. | 12 ga. |
| 48" | 10 ga. | 12 ga. | 12 ga. |
| 54" | 8 ga. | 10 ga. | 12 ga. |
| 60" | 8 ga. | 10 ga. | 12 ga. |

Notes:
1) Corrugations are 2 2/3" x 1/2"
2) Fill heights over 15 feet may require larger gages.
3) Metal pipe may have either spiral or annular corrugations.

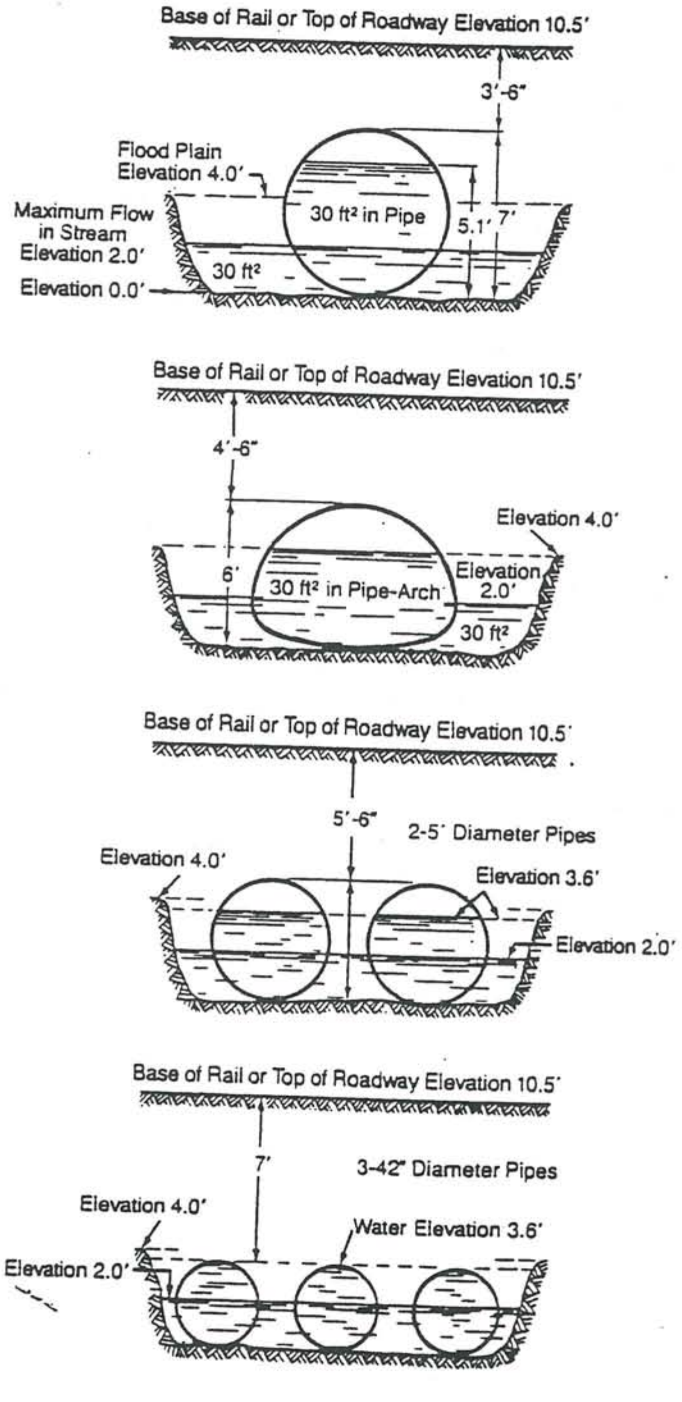


Figure 5 - 16 Single vs. Multiple Opening

Note that a single large pipe has the least amount of cover and it will cause water to back up and flood the adjacent land. A twin or triple opening offers the best solution because the water level is kept below the flood elevation and there is more gravel cover over the pipes.

7-9

2 - Hydraulics principals:

a - Sn or neutral slope is that slope on a pipe where the friction loss in the barrel and the gravity energy gained from the slope of the pipe are equal.

b - For a pipe on a slope greater than neutral slope, gravity can withdraw water from the barrel faster than gravity can force water through the opening. The length of the culvert and the culvert wall roughness are not important. However, less water normally is discharged and the danger of vortex development is greatly increased. Fish passage is also made more difficult.

c - For a pipe on a slope less than neutral slope, gravity can force water through the opening faster than gravity can pull water out of the pipe. Therefore the pipe flows full and the friction loss from the culvert barrel governs. The length of the culvert and the culvert wall roughness are important.

NOTE: If lowering the inlet of a culvert to achieve a flatter slope, especially on a steep graded stream, then be sure that a rock lined chute is provided up to the original stream bed at the inlet to prevent a "gully head" from forming and causing instability in the upstream channel in the stream above the culvert.

d - Some consideration should be given to the use of pipe arch culverts. The depth required to pass low flows is somewhat less. The discharges for equal depths at the inlet can be up to 50% more for low entrance depths. As the culverts are submerged by large flows the benefit is much less pronounced at about 10%.

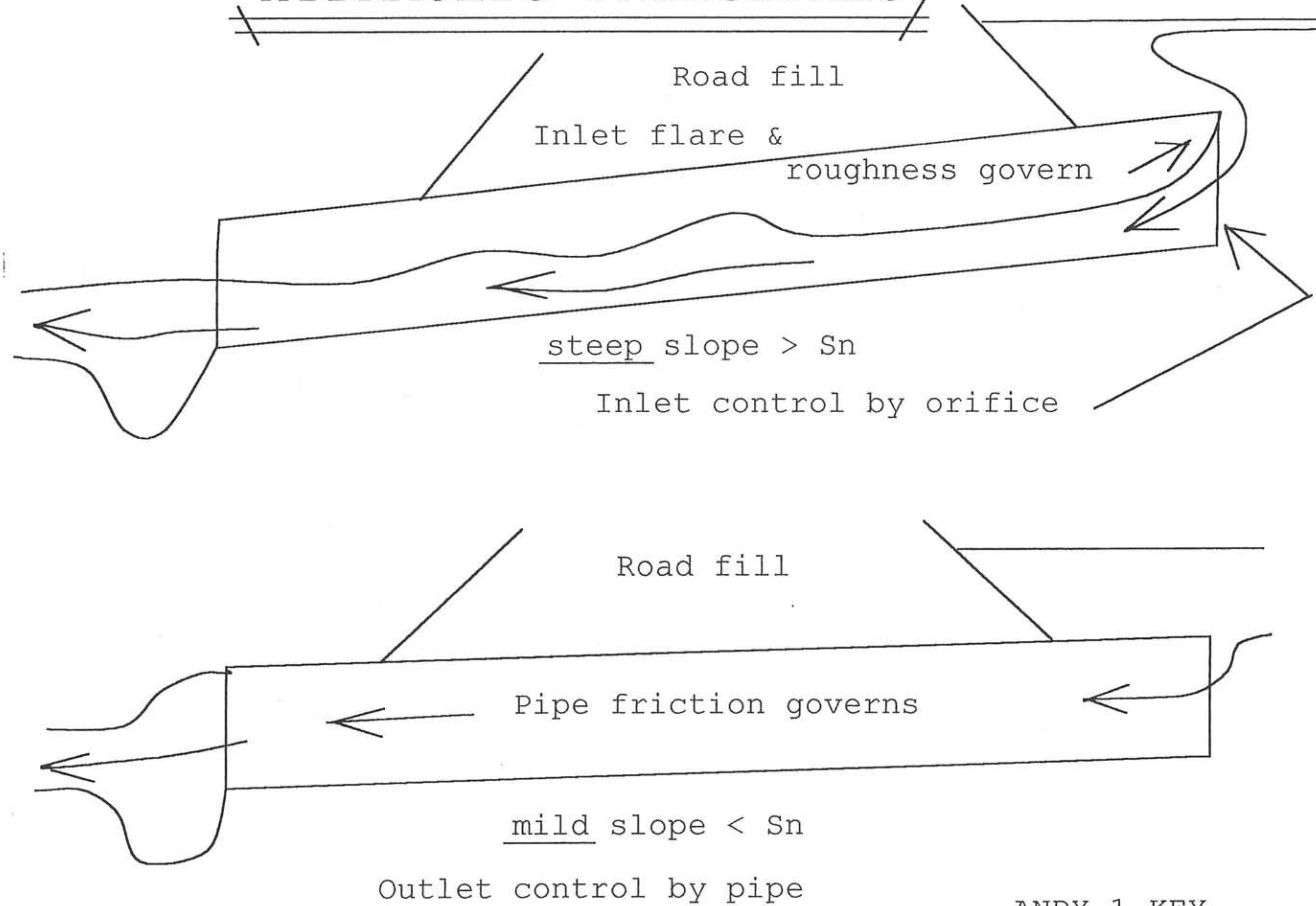
Several concerns with arches include the fact that they have less "wiggle room" to deflect laterally to transmit loads, thus increasing their chances of collapse if not properly backfilled.

Another concern is that low flows cover a more extensive portion of the lower perimeter and corrosion is likely to be present on a more extensive area, all other things being equal.

When considering the use of arch culverts spend some time and determine if the added cost is worth the perceived benefit. Any cost savings may be eliminated by the extra care needed to backfill them properly.

THIS SHEET IS LEFT BLANK FOR NOTES

# HYDRAULIC PRINCIPALS

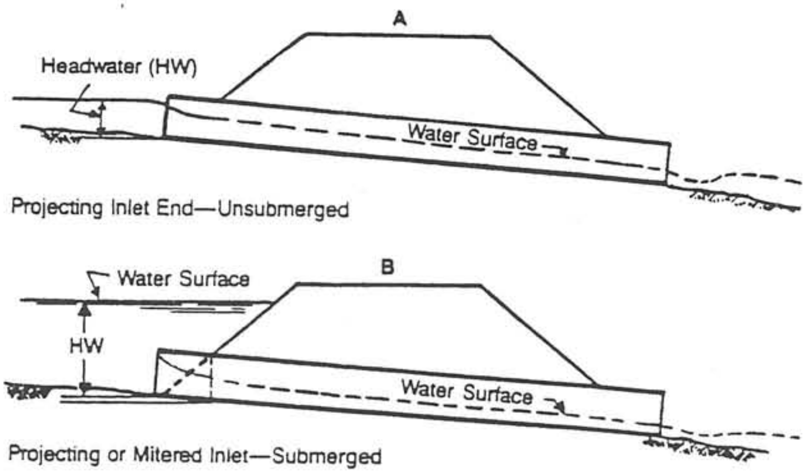


ANDY-1.KEY
JJS 11/19/98

## TWO MAJOR TYPES OF CULVERT FLOW

### Inlet control

* Pipe's capacity is controlled by conditions at inlet
* Shape of the inlet significantly affects flow
* Inlet may or may not be submerged
* Culvert is on a significant slope
* Culvert outlet is free and open (not submerged)
* There is a free water surface in the culvert barrel
* Culvert length is <u>not</u> a factor



### Outlet control

* Pipe's capacity is controlled by pressure differences between inlet and outlet ends
* Inlet is submerged
* Culvert is on mild or no slope
* Culvert outlet may or may not be submerged
* The culvert barrel may or may not be full
* Culvert length, slope, and roughness are definite factors
* Type of inlet edge affects flow

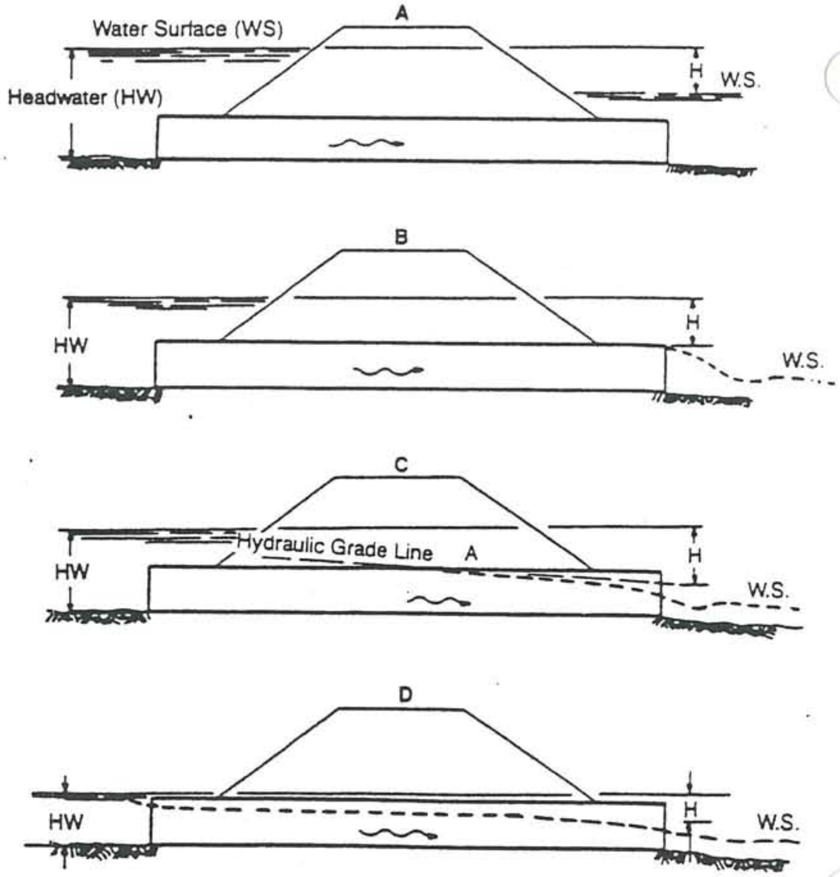
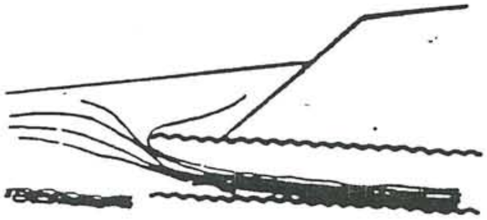
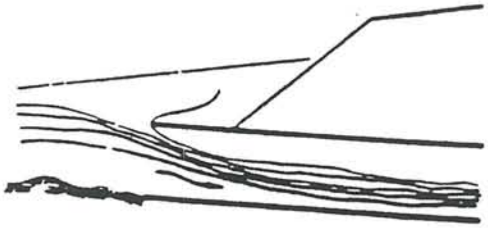


Figure 5 - 17

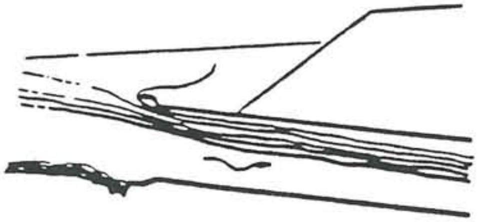
Note that in inlet control the culvert does not flow full even when the inlet is submerged. Water in the culvert barrel is shallow and much of the culvert capacity is not used. This condition is largely caused by flow restrictions or contractions as the water tries to get around the various types of culvert edges and into the barrel of the pipe. The flow line sketches in Figure 5 - 15 approximate this flow restriction graphically for three different types of pipe edges:



Corrugated Metal Pipe
(worst condition)



Square-edged Concrete Pipe
(improved flow)



Bell End of a Reinforced
Concrete Pipe
(much improved flow)

**Figure 5 - 18**
**Flow contractions for various culvert inlets.**

## PROCEDURE FOR DETERMINING CULVERT SIZE[15]

Step 1: List the design data
- 2: Estimate a first trial size
- 3: Find headwater depth, first assuming inlet control; then assuming outlet control; compare the headwaters and choose the higher.
- 4: Select culvert size which keeps headwater depth below allowable limit.
- 5: Compute outlet velocity to determine need for channel protection.

The BPR has a suggested tabulation form (Fig. 4-29) and given detailed instructions for use of inlet-control nomographs (Figs. 4-20 and 4-21) and outlet-control nomographs (Figs. 4-22 to 4-25). Table 4-12 lists Manning's values of $n$ for corrugated metal. Coefficient $k_e$. (Table 4-11) is applied to velocity head $\frac{V^2}{2g}$ for determination of head loss at entrance to a structure, such as a culvert or conduit, operating full or partly full.

## OTHER HYDRAULIC EFFECTS

Hydraulic capacity of a culvert is affected by factors other than size of opening. In order of consideration here, these include:
1. Flow conditions through culvert
2. Shape of culvert
3. Single vs. multiple opening

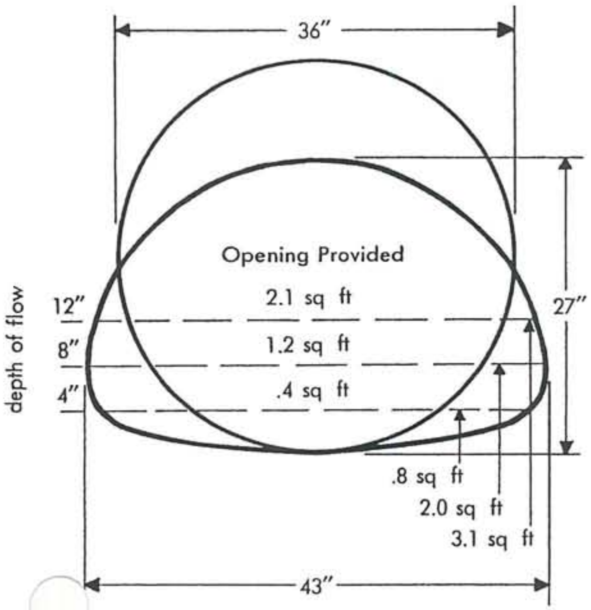


Fig. 4-30. Compa... on of waterway cross-sectional areas at equal depths of flow in steel pipe and pipe-arch. The pipe-arch handles a larger volume of water at the lower levels of flow

4. Slope of culvert
5. Length of culvert
6. Roughness of culvert interior
7. Approach channel
8. Type of culvert inlet
9. Type of culvert outlet
10. Ponding at entrance
11. Height of tailwater

### 1. Flow Conditions Through Culvert

For culverts on a steep slope, the discharge is controlled at the inlet, depending on headwater depth[12]; on mild slopes, outlet control usually exists.

For full flow with a free outlet, data are sparse, but investigators have found the hydraulic grade line to be below the crown of the pipe.

### 2. Shape of Culvert

The shape of a corrugated metal culvert—circular pipe, vertically elongated pipe, pipe-arch or arch—is generally chosen for reasons of headroom and/or strength rather than for hydraulic reasons. However, as the accompanying chart shows, a pipe-arch carries roughly 50 per cent more water at depths up to half full. See Fig. 4-30. This is advantageous in keeping the headwaters at a lower level of flow. Need for further research is indicated.

### 3. Single vs. Multiple Opening

A single culvert opening is, in general, the most satisfactory because of its greater ability to handle floating debris and driftwood. However, in many cases the greater portion of the waterway should be kept low to get the water through quickly without ponding or flooding of the land upstream. In such cases, the solution may consist of using either an arch or pipe-arch, or using a battery of two or more openings, or both. See Fig. 4-31.

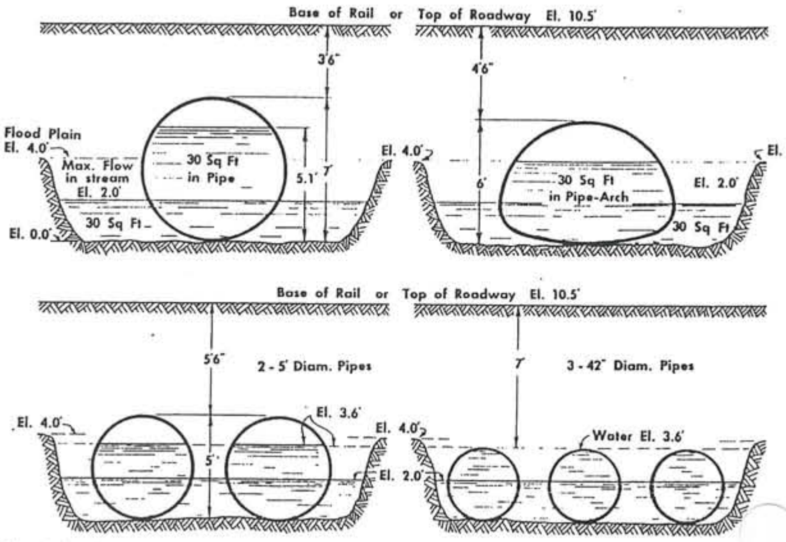


Fig. 4-31. Diagrams showing four choices of a culvert opening. For the assumed c...di-tions, a single large pipe will cause the water to back up and flood the adjacent land. A twin or triple opening, while less efficient hydraulically, offers the best solution

3 - Culvert Load carrying ability principals:

a - A firm foundation is required to prevent the foundation and also the pipe from settling and elongating into the foundation especially in the area of highest fill. When this settlement occurs the joints coming apart or open up, especially on the bottom.

b - Dense embankment fill is necessary to provide lateral support on the sides to prevent squatting during any settlement of the new fill. When the embankment settles but the foundation does not, the result is that the the culvert elongates and the joints open.

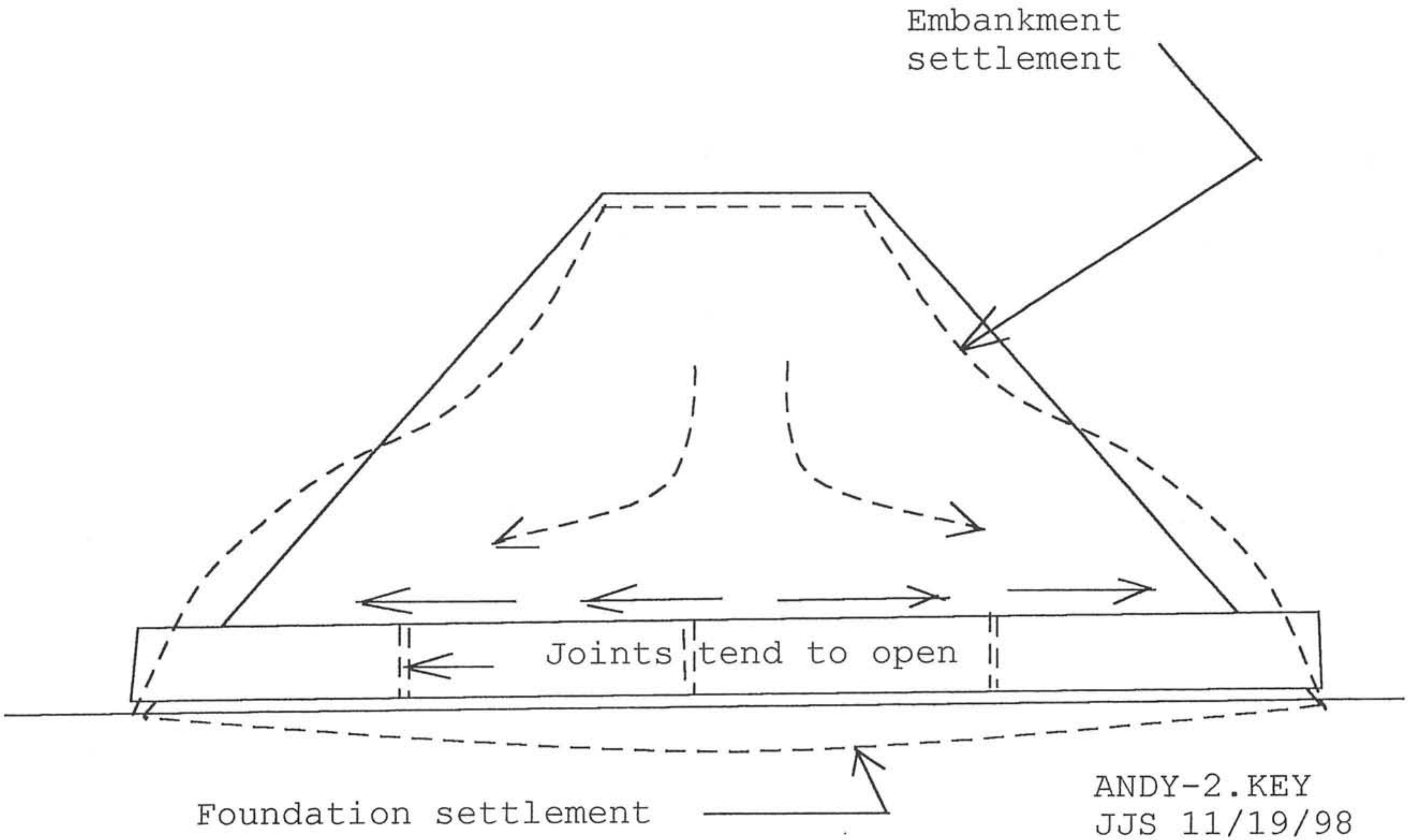
c - Rigid pipe develops load resisting strength from within it's walls and only secondarily from the backfill. A firm foundation is necessary however for reasons given above. The most common rigid pipe is RCP (reinforced concrete pipe) with class III being the most common.

d - Flexible pipes such as CMP (corrugated metal), PE (polyethylene corrugated with or without inside liner), PVC (polyvinyl chloride), and fiberglass. These pipes depend significantly on transferring the load to the soil on either side through deflection. If the sides are soft the pipe will continue to deflect until the lateral soil pressure builds up or the pipe deflects to failure.

The foundation should be properly compacted by heavy equipment and then a thin layer (1" to 2" depending on pipe diameter) of granular backfill put down on which to place the pipe. This helps preventing voids in the haunches of the pipe.

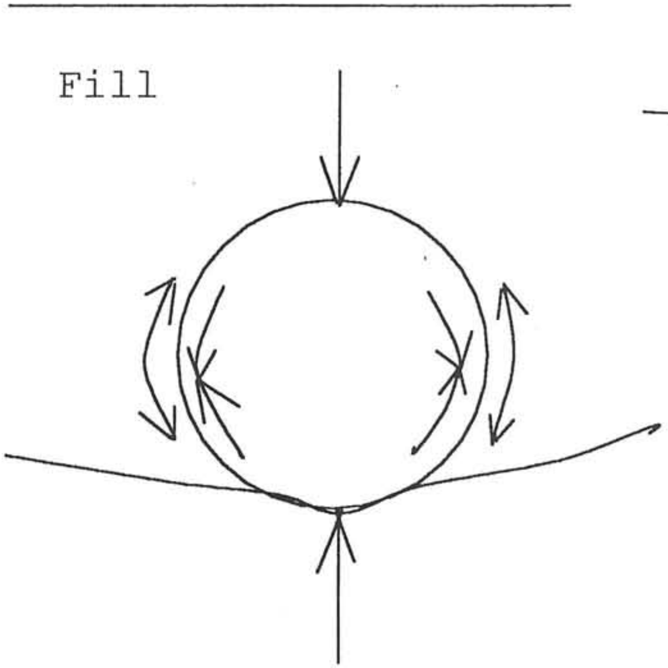
The backfill needs to be placed in 6" to 9" layers and well compacted. In lieu of compaction tests, a good rule of thumb is that the compaction equipment should not leave an indentation in excess of 1/4" to ½".

# LOAD CARRYING PRINCIPALS

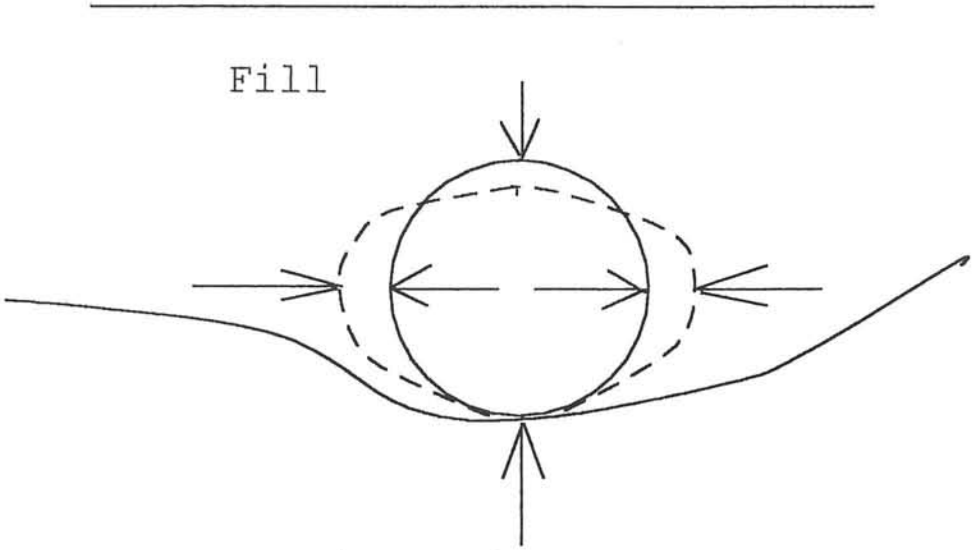


ANDY-2.KEY
JJS 11/19/98

# LOAD RESISTANCE



Rigid pipes depend on
their wall strength of
<u>most</u> of their strength.



Flexible pipes depends on
backfill density for <u>most</u>
of their strength.

ANDY-3.KEY
JJS 11/19/98

## Culvert Installation

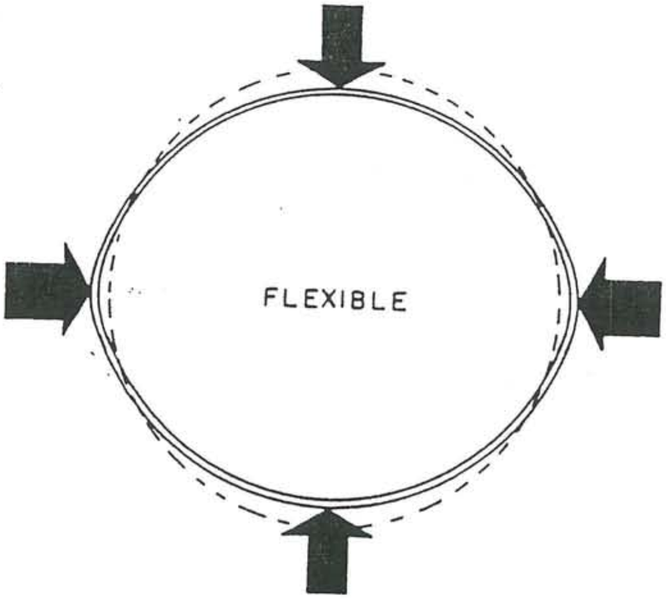
Installing a culvert is the next step after deciding on the proper location, alignment, length and grade. Deciding whether to use a rigid or a flexible culvert pipe is a crucial factor in the installation process because these two types of pipe carry the embankment and traffic loads differently. As a result of this difference, bedding requirements and backfilling treatments need to be handled differently.

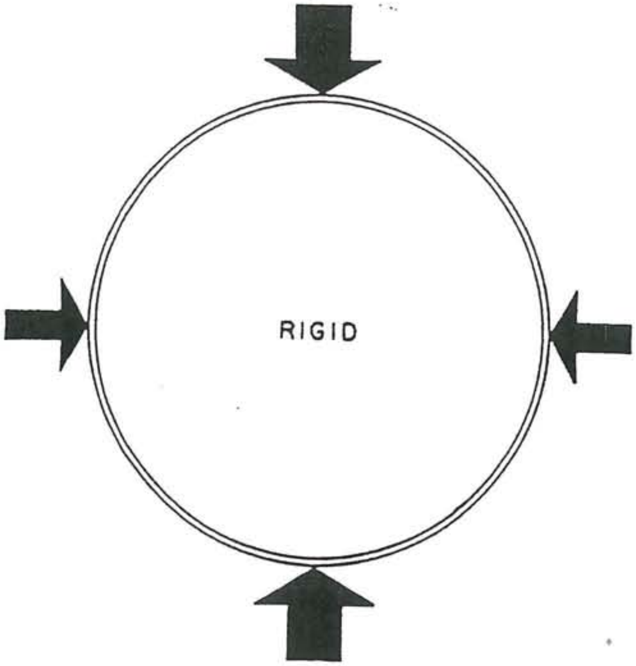
## Pipe Load Support Characteristics

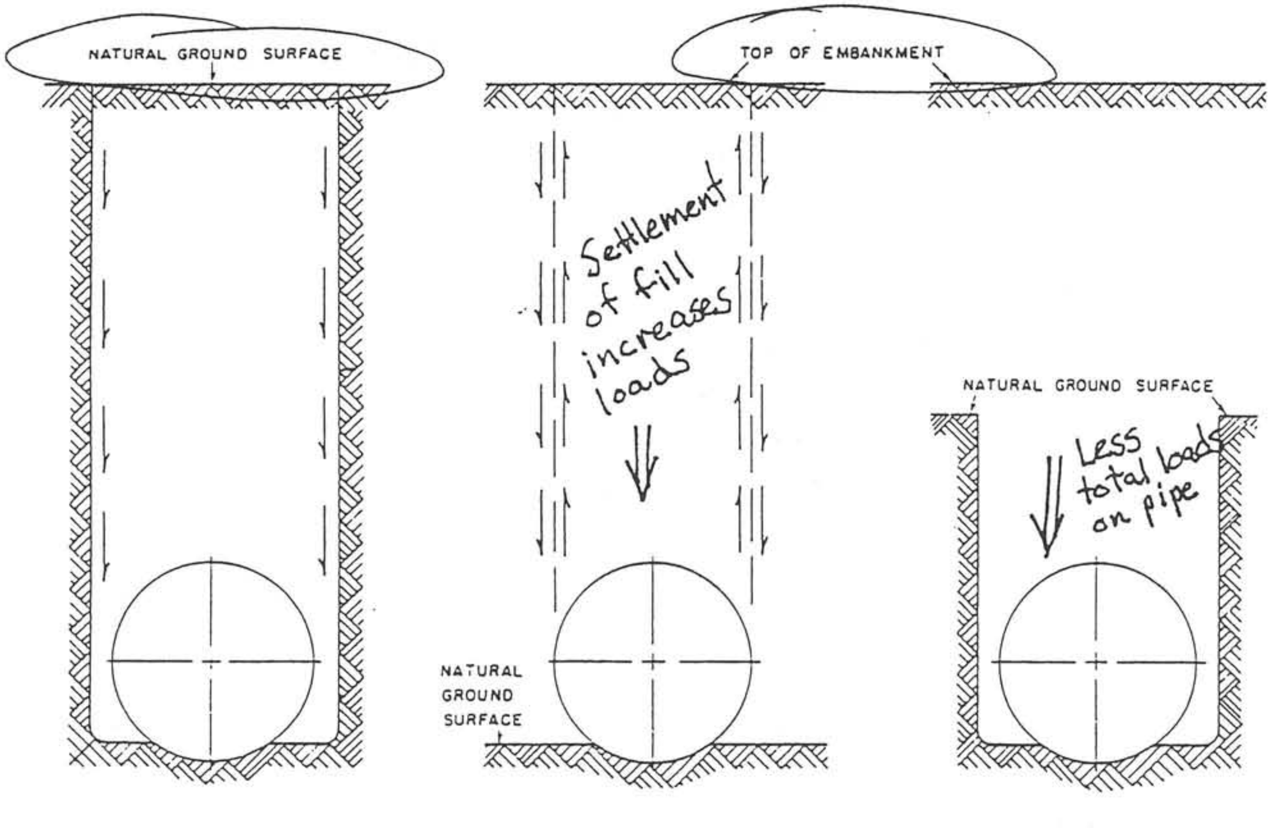
*Metal (flexible) pipe is able to support heavy earth and traffic loads because of its flexibility.* As the load is applied to the top of the pipe, it tries to flex and squat sideways. However, if the fill has been packed tightly beside the pipe, the pipe can't deform and so the load is transferred to the soil. The load-carrying ability of flexible pipe depends on the support it gets from the surrounding earth. Without this support, it would simply be deformed and not function properly or be crushed under heavy loads.

*Rigid concrete pipe, on the other hand, cannot flex and thus it cannot pass off some of the load to the earth beside it.* The structural strength of the pipe itself must be able to carry the bulk of the imposed loads. Therefore, it is extremely important that concrete pipe be given shaped, uniform support throughout its entire length to develop its maximum strength.

Note that the width of the arrows showing the load and reaction forces on the pipes are an indication of the amount of the forces being applied.







(1) TRENCH CONDUIT (2) POSITIVE PROJECTING CONDUIT (3) NEGATIVE PROJECTING CONDUIT

preferred desig

**Figure 5 - 20**
**Pipe Classification According to Construction**
**(NACE, Action Guide Vol. III-5)**

If the fill over the culvert is 10 feet or more, the culvert foundation is often "cambered", especially on a soft subgrade. Camber is simply the rise at the center of a culvert above a straight line connecting its ends. The weight of the roadbed above the pipe can cause the center portion of the pipe to settle somewhat.

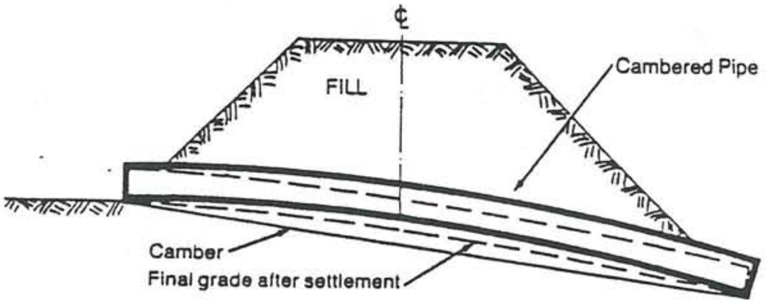


**Figure 5 - 21**
**Camber allows for settlement of a culvert under a high fill.**

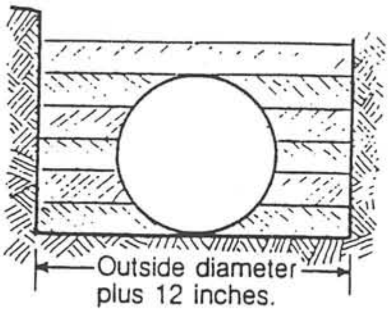
## Assembly

Proper assembly of pipe sections is necessary to avoid joint failures and the resulting wet subgrade problems. There are a variety of connecting bands for metal pipe and jointing methods for rigid pipe. Manufacturers and suppliers provide this kind of information and specific instructions for making the necessary connections. When all else fails, read the directions.

Rough handling of both flexible and rigid pipe should be avoided. Considerable unnecessary damage can be done to either type by dragging it, rolling it into the trench, banging it against rocks or other hard objects, improper stockpiling and poor lifting techniques. Normal precautions and reasonable care in handling is all that is needed to avoid damage that may appreciably shorten the service life of culvert before it has even been installed.

## Backfill

**Too much emphasis <u>cannot</u> be placed on the importance of good compaction of backfill. Poor compaction has led to more trouble with culvert installation for both flexible and rigid pipe than all other factors combined.!**(21)



Backfill materials should be moist, placed in thin layers of 6" to 8", and compacted with tampers. Compaction of the bedding material should be carried up to the mid point of the culvert or to a height sufficient to hold the culvert in place. The backfilling should continue by placing it equally in layers on both sides of the structure. The compacted layers should extend to the side of the trench or to the natural ground line.

*Granular material, free from rocks, sod or frozen earth is good for backfilling.* Rocks next to the pipe can punch through metal or damage concrete under the pressure of the backfill. Sod and frozen earth can lead to excessive settlement in the fill. Clean sand is recommended because of its high natural density. In Maine and other snow belt states, we recommend that the *excavated material* be used as the backfill in order to prevent differential heaving between the trench and adjacent road sections. At least the road and trench will move up and down together! **It's very important to minimize the differences in soil types around, above, and to the sides of any culvert.**

4 - Embankment piping resistance principals:

a - the term piping is used in reference to the removal of fine soil material in the fill by water seepage through the fill at a rate and pressure greater than the ability of the soil to resist. Dense clays and gravels are very resistant to piping, while sands and silts are very susceptible even when reasonably dense.

b - design methods meant to increase resistance to piping on a road fill include:

I - decreasing the hydraulic gradient I = h/L by either decreasing the upstream head h on the fill or increasing the length of culvert/fill.

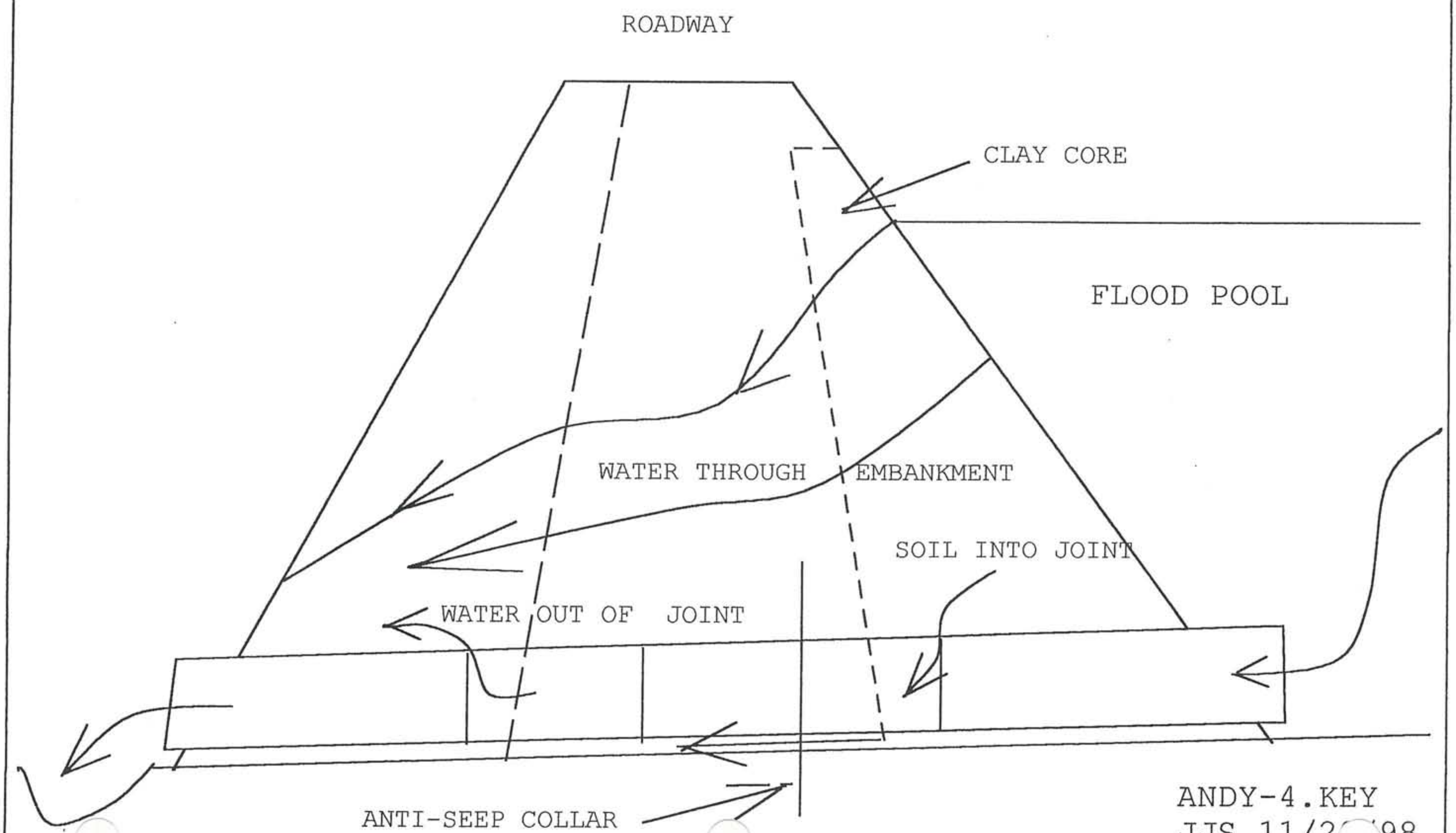
II - the placement of a seepage layer or core within the upstream shell (where pipe loads are less).

III - the use of anti-seep collars along the culvert.

IV - the use of a graded filter or embankment drain within the downstream slope. Downstream slope riprap that is placed over a thick layer of well graded gravel or quality non-woven filter fabric sometimes can serve as the filter.

V - increasing the size of the pipe so that the time that water is impounded against the fill is decreases.

# EMBANKMENT PIPING RESISTANCE



ANDY-4.KEY
JJS 11/2 98

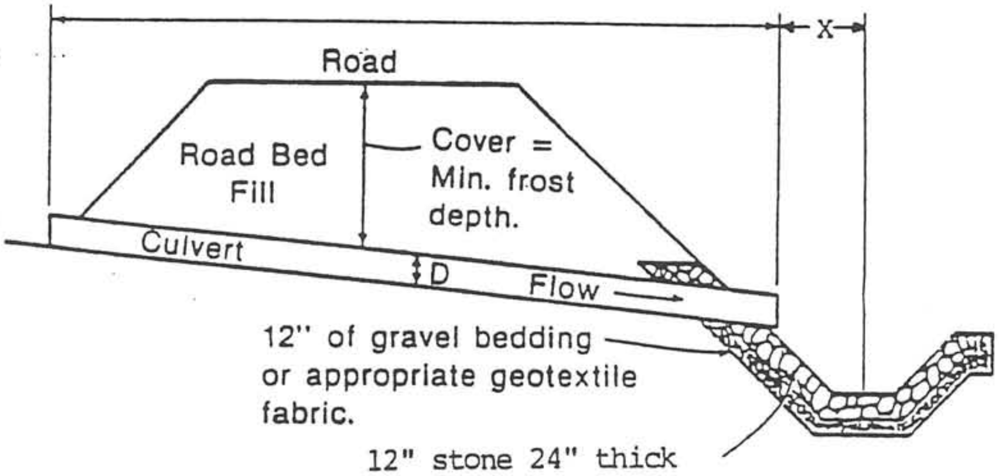
5 - Inlet & Outlet Erosion control protection measures:

- a - the culvert pipe must be long enough to have stable slopes. A length of (26 + 4 x fill height) should be ample for roads designed for two way traffic. The 26 feet represents two 11' travel ways with a 2' shoulder on each side before the 2:1 slope starts.
- b - an protected outlet is needed using either a stilling basin or apron armored with rock riprap or one of many articulated concrete block products (ACB's) such as cable concrete that are on the market.
- c - an inlet slope protected by dense vegetation, stone riprap, or a structural headwall of some type is needed for protection from erosion.

Often the culvert is located on the low spot of a road. During the winter months when snow banks are present, the water often flows to the culvert location breaks through the snowbank and discharges over the road slope at the inlet and outlet.

If your project has a culvert at the low spot of the road, consider armoring both inlet and outlet road slopes with rock riprap, an articulated concrete block product (ACB), or a permanent turf reinforcement mat (TRM)of acceptable quality.

If the culvert is not at the low point of the road and winter storms will break through the snowbanks elsewhere then the slopes can be stabilized with sod with the help of temporary erosion netting.



| PIPE SIZE | X |
|---|---|
| 12in. | 2ft. |
| 18in. | 3ft. |
| 24in. | 5ft. |
| 36in. | 7ft. |

**PLUNGE POOL**
1 "D" deep
2 "D" side
4 "D" long

Figure 5 - 25
Detail of Culvert Outlet Protection

3 -2.5

## C - SAFETY:

The following is brief discussion of how to safely perform excavations for the installation of culverts. The two predominate variables influencing excavations are soil type and excavation depth.

Of all the concerns about culvert installation and road work, safety should be # 1. Road repair work on an active road is one of the most hazardous construction activities there is. Traffic control is all important as vehicles are the main source of job site hazards. For a through discussion of all these safety issues the handbook DRAINAGE, DRAINAGE, DRAINAGE, by the Maine Local Roads Center branch of MDOT (especially chapter 10) should be referenced.

Since the installation of replacement culverts involves excavating through an existing embankment, the subject of excavation safety will be briefly covered with material from chapter 10 of the above mentioned document.

Figure 10-1 on page 3-27 shows a decision tree that represents the thought process that should occur on the part of the foreman in charge of the replacement activity. Ignoring this issue can lead to serious injury, death, and liability claims, and the citing of the foreman for Class C manslaughter if death occurs.

Page 3-28 headed "OSHA Soil Classification" gives three types of soil situation labeled TYPE A, TYPE B, and TYPE C.

Table B-1 page 3-29 should be used to select the maximum slopes allowed for the sides of excavations. Slopes must be no steeper than those values! Note 2 of that table gives the slopes that can be used in Type A soils if the excavation is "short-term" which is defined as an excavation that is to be left open for less than 24 hours. Type A soils are the stronger more cohesive clay soils and dense hardpan soils. NOTE: this open period must not have experienced any rainfall.

Chapter 10 of DRAINAGE, DRAINAGE, DRAINAGE, also states on page 2 that for temporary excavations less than 20 feet, a side slope of 1.5:1 is considered safe for all soil types regardless of classification.

## SELECTION OF PROTECTIVE SYSTEMS

The following figures are a graphic summary of the requirements contained in subpart P for excavations 20 feet or less in depth. Protective systems for use in excavations more than 20 feet in depth must be designed by a registered professional engineer in accordance with § 1926.652(b) and (c).

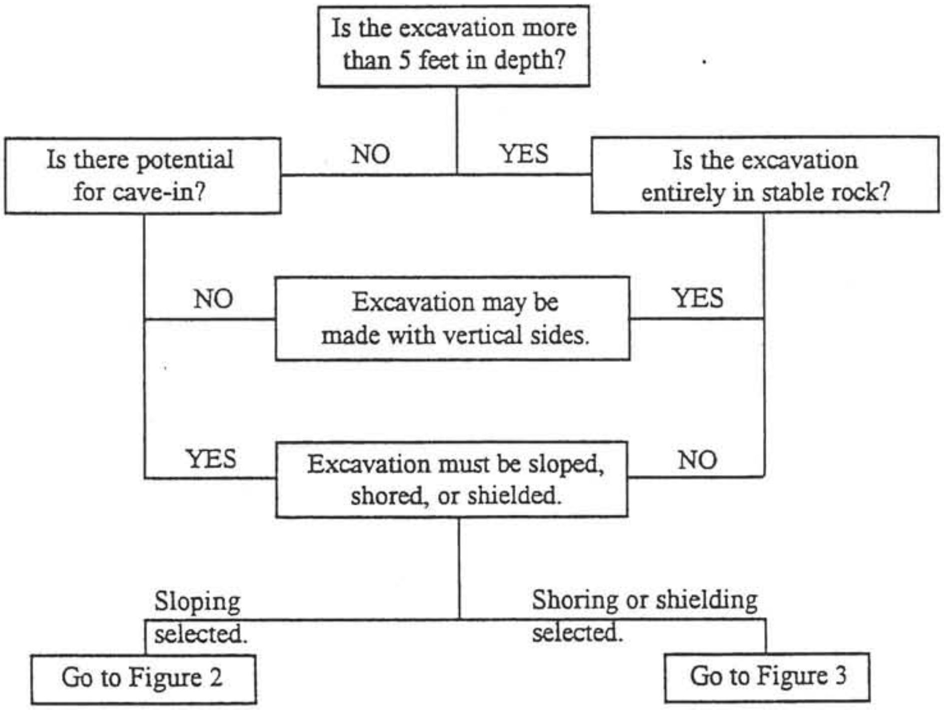


FIGURE 10 - 1
Preliminary Decisions

# *OSHA SOIL CLASSIFICATION*
## *(Appendix A to Subpart P)*

---

Type A means cohesive soils with an unconfined compressive strength of 1.5 ton per square foot [tsf] [144 kPa] or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam and, in some cases, silty clay loam and sandy clay loam. Cemented soils such as caliche and hardpan are also considered Type A. However, no soil is Type A if:

(i) The soil is fissured; or
(ii) The soil is subject to vibration from heavy traffic, pile driving, or similar effects; or
(iii) The soil has been previously disturbed; or
(iv) The soil is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical [4H:1V] or greater; or
(v) The material is subjected to other factors that would require it to be classified as a less stable material.

Type B means:

(i) Cohesive soil with an unconfined compressive strength greater than 0.5 tsf [48 kPa] but less than 1.5 tsf [144 kPa]; or
(ii) Granular cohesionless soils including: angular gravel (similar to crushed rock), silt, silt loam, sandy loam and, in some cases, silty clay loam and sandy clay loam.
(iii) Previously disturbed soils except those which would otherwise be classed as Type C soil.
(iv) Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subjected to vibration; or
(v) Dry rock that is not stable; or
(vi) Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one vertical [4H:1V], but only if the material would otherwise be classified as Type B.

Type C means:

(i) Cohesive soil with an unconfined compressive strength of 0.5 tsf [48 kPa] or less; or
(ii) Granular soils including gravel, sand, and loamy sand; or
(iii) Submerged soil or soil from which water is freely seeping; or
(iv) Submerged rock that is not stable; or
(v) Material in a sloped, layered system where the layers dip into the excavation or a slope of four horizontal to one vertical [4H:1V] or steeper.

## TABLE B - 1
## MAXIMUM ALLOWABLE SLOPES

| SOIL OR ROCK TYPE | MAXIMUM ALLOWABLE SLOPES (H:V:) [1] FOR EXCAVATIONS LESS THAN 20 FEET DEEP [3] | |
|---|---|---|
| STABLE ROCK | VERTICAL | (90°) |
| TYPE A [2] | 3/4:1 | (53°) |
| TYPE B | 1:1 | (45°) |
| TYPE C | 1 1/2:1 | (34°) |

NOTES:

1. Numbers shown in parentheses next to maximum allowable slopes are angles expressed in degrees from the horizontal. Angles have been rounded off.

2. A short-term maximum allowable slope of 1/2H:1V (63°) is allowed in excavations in Type A soil that are 12 feet (3.67 m) or less in depth. Short-term maximum allowable slopes for excavations greater than 12 feet (3.67 m) in depth shall be 3/4H:1V (53°).

3. Sloping or benching for excavations greater than 20 feet deep shall be designed by a registered professional engineer.

7(e)

D - FROST HEAVE AT CULVERTS:

The control of frost heave at culverts can be reduced by several means. Frost heaved culverts occur when the frost penetrates to below the "spring line" of the culvert, and water and frost susceptible soils are present. We will talk later about ground water depth control. For now let us look at two methods of limiting the frost penetration depth to above the "spring line" of the culvert.

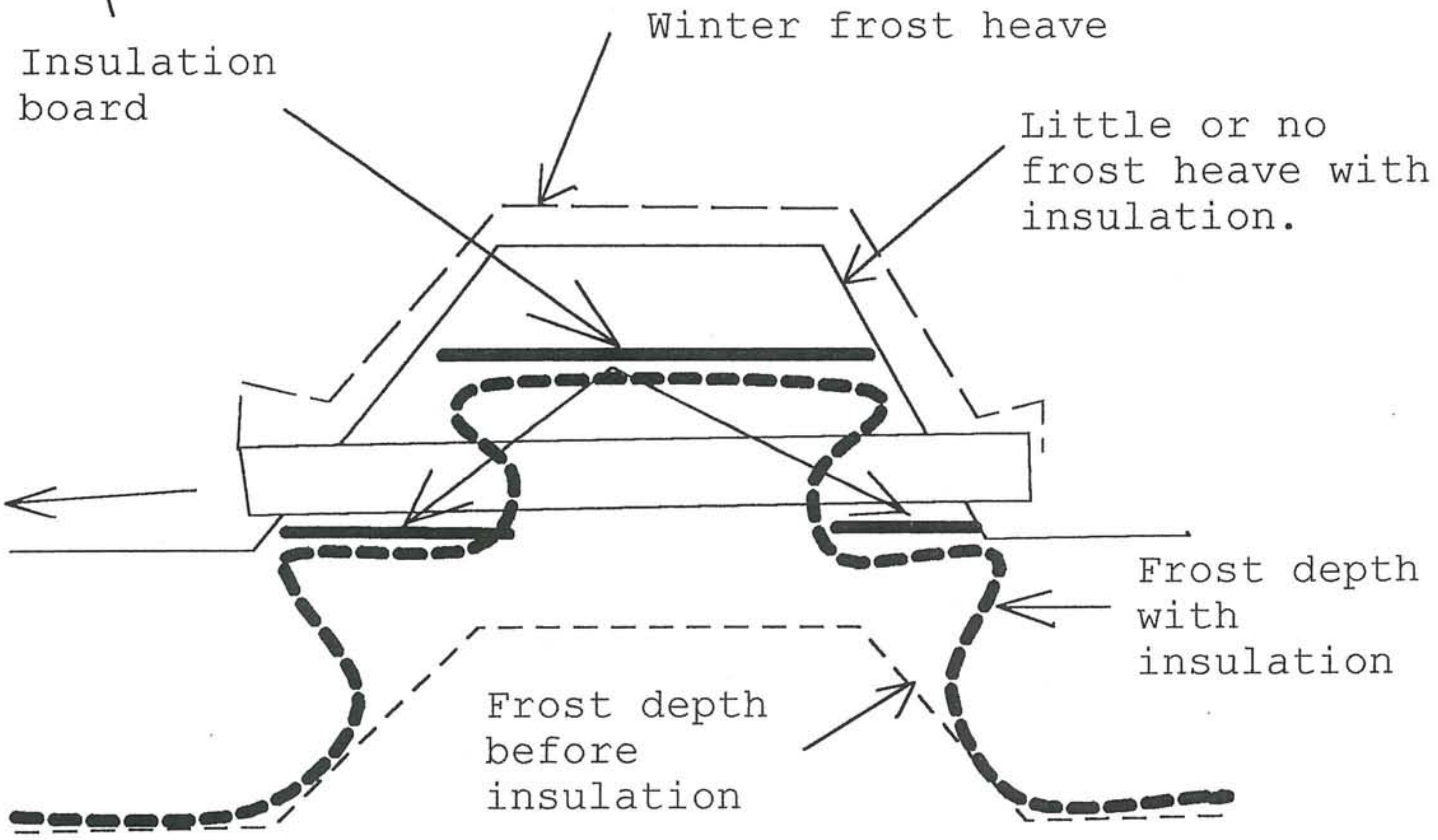
When frost penetrates below the spring line of the culvert the culvert is lifted up slightly. In the spring when the frost leaves the soil the culvert settles back - but never totally to where it started! Thus a progression continues over the years until the situation is intolerable (and grossly unsafe) and the culvert fails and is re-installed.

The first option is to install Extruded Polystyrene Insulation such as FOAMULAR by UC Industries, Inc. with a minimum compressive strength of 25 psi (3600 pounds/sq.ft.) and several inches thick. See variations in figure ANDY-9.key shown on page 3-31. There is several differences of opinion in this new field so trial and errors are inevitable and several options are possible.

The second option to limit the frost depth to above the spring line is to increase the depth of granular cover over the culvert. If possible (the depth of cover + ½ the culvert diameter) should exceed the frost depth of your area. Frost depths vary from about 4 feet to 7 feet in Maine. See figure ANDY-10.key on page 3-32. If metal pipes are used insulation board should be considered under the inlet and outlet portions to prevent the uplifting so often seen on CMPs along the highways.

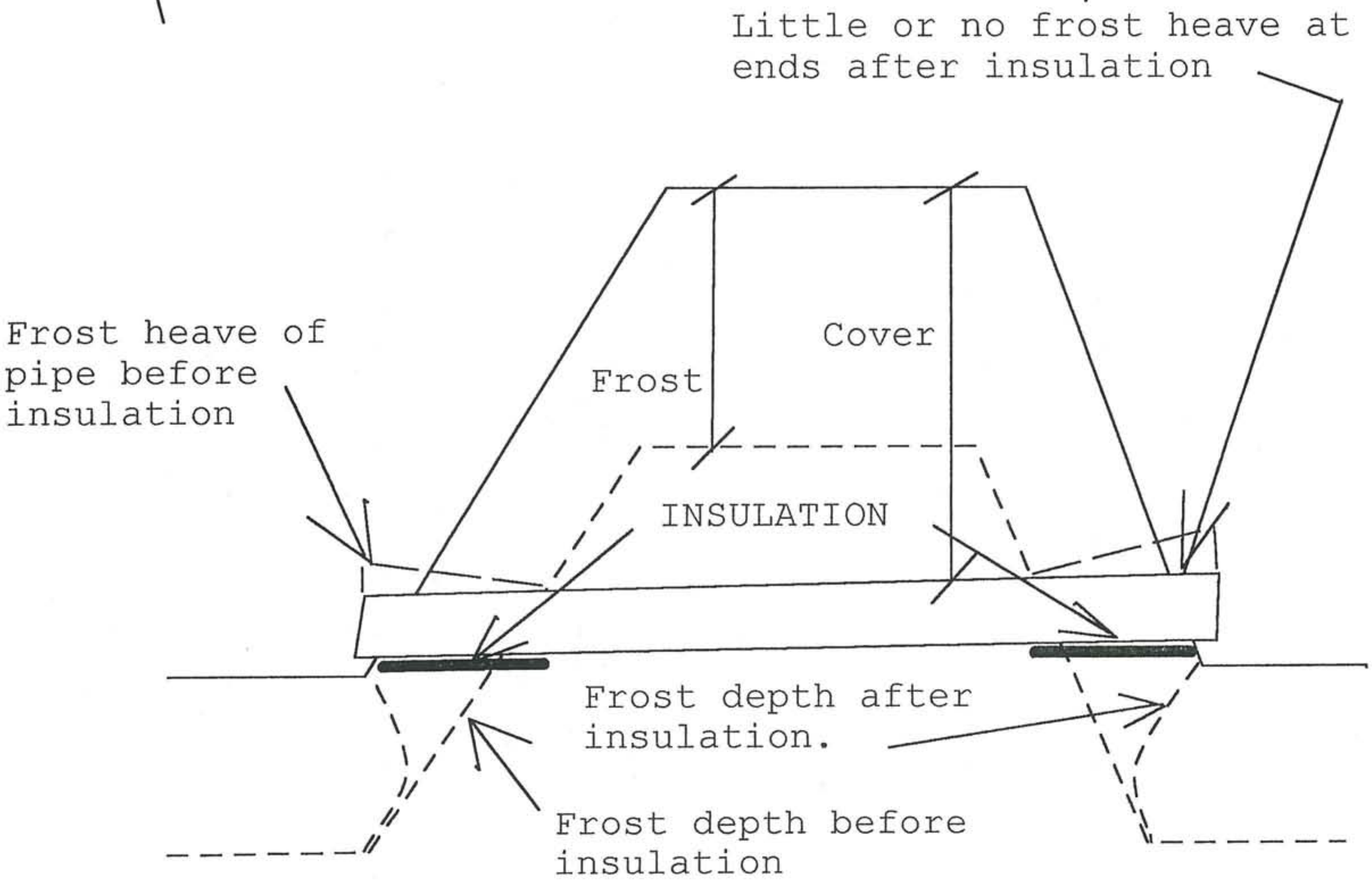
Insulation board should extend at least several feet at the minimum beyond the sides of the culvert. A more accurate design requires an engineer familiar with Thermal Soil Mechanics.

# FROST DEPTH > PIPE COVER



ANDY-9.KEY
JJS 11/22/98

# FROST DEPTH < PIPE COVER



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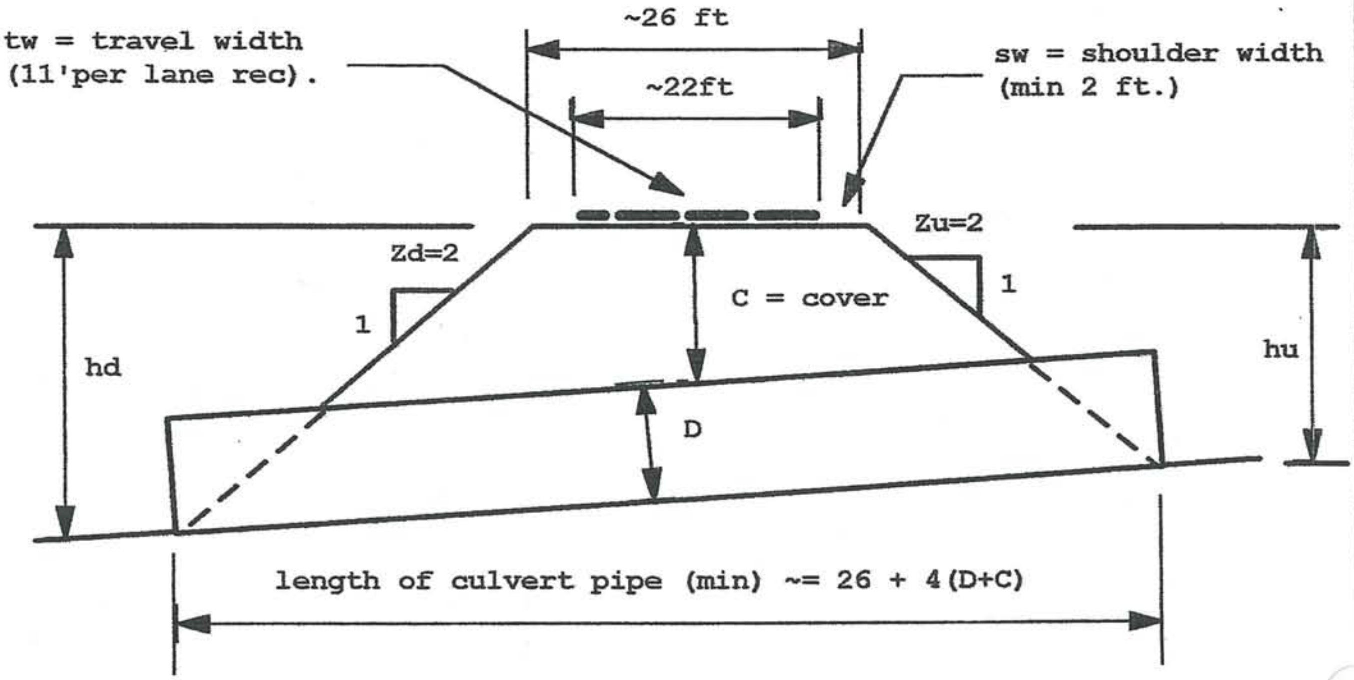
# PROPER CULVERT LENGTH



hd = height of fill at downstream toe.
hu = height of fill at upstream toe.
D = diameter of culvert.(minimum 1ft but 1.5ft recommneded min.)
C = cover over culvert at centerline of road.
Zd = downstream slope on fill. (minimum 2) or flatter.
Zu = upstream slope on fill. (minimum 2) or flatter.

RULES FOR CULVERT LENGTH:

Simplified equation(in words): Length = 26ft + four times the sum of the culvert diameter plus the pipe cover. SEE SKETCH ABOVE.

GENERAL EQUATION FOR LENGTH: LP = {tw + 2*sw + Zd*hd + Zu*hu}

Example upstream slope of 3:1 (Zu = 3)
downstream slope of 2:1 (Zd = 2)
two lane road with 12 width each (tw = 24)
upsteam fill height (hu = 7)
downstream fill height (hd = 9)
diameter of pipe (D = 3)
average cover on pipe (C = 5)
shoulder width (sw = 4)

therefore culvert length = 24+2*4 + 2*9 + 3*7 = 24+8+18+21 = 71 ft

# PIPE ANALYSIS PROCEDURE

**Determining the inlet Orifice flow amount as follows:**

1 - Select entrance type either BELL (rounded) with KE = 0.2 (see table 1)
or SHARP (cut end) with KE = 0.8 (see table 2)

2 - Select entrance/pipe diameter in feet.

3 - Select head over top of pipe at the entrance (or use top of pipe to top of road).

4 - Use the appropriate table to find the inlet ORIFICE flow in cfs.(table 1 or 2)

**Determine the culvert barrel flow amount as follows:**

5 - Select the pipe slope in percent.

6 - Select the pipe roughness value: Polyethlene or Polyvinyl chloride n = 0.010 (table 3)
or Reinforced Concrete n = 0.013 (table 4)
or Corrugated Metal n = 0.025 (table 5)

7- Use the appropriate table find the full barrel NON-PRESSURE flow in cfs. (table 3, 4, or 5)

8- Use the lesser of the values from steps 4or 7 for an approximate limiting flow value.

## DECIDING WHETHER OR NOT TO UPGRADE THE SIZE OF THE PIPE AND/OR RAISE THE ROAD GRADE.

9 - The road has overtopped within the last ________________ years.(or unknown______)

10 - What frequency of flow capacity is desired for the road before overtopping (years ______).

11 - If it is not desired to either raise the road grade or enlarge the pipe to a selected frequency, or the storm frequency capacity of the existing / replacement culvert is unknown, then riprapping the downstream road slope with stone with a D50 of 15" is recommended.

12 - If downstream riprapping is not desired or is too expensive, then determine the peak for the selected frequency storm and actually design a replacement culvert.

Note 1: The proper <u>minimum length</u> of a culvert is: + 4 times the road height at culvert
+ the width of the travel lanes + the width of the shoulders

Note 2: The upstream end of the pipe is <u>always</u> the pipe "bell". <u>**Never**</u> cut off the bell portion of the pipe being used as a culvert.

John Simon for Andy Valley SWCD 12/14/2001

| A | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 4 | | Inlet Orifice flow for culvert rating. | | | | | | |
| 5 | | | John Simon 11/30/01 | | | | | |
| 6 | | | | | | | | |
| 7 | | Orifice discharge in cu.ft. per second | | | | | | |
| 8 | | For **BELL** entrance with | | KE | 0.2 | | | |
| 9 | Culvert | | | and Co = | 0.8 | | | |
| 10 | Diameter | Depth of water above the INLET of the culvert in (feet) | | | | | | Table # 1 |
| 11 | in (feet) | 0.50 | 1.00 | 1.50 | 2.00 | 2.50 | | |
| 12 | | | | | | | | |
| 13 | 1.00 | 3.57 | 5.04 | 6.18 | 7.13 | 7.97 | | |
| 14 | | | | | | | | |
| 15 | 1.50 | 8.02 | 11.35 | 13.89 | 16.04 | 17.94 | | |
| 16 | | | | | | | | |
| 17 | 1.75 | 10.92 | 15.44 | 18.91 | 21.84 | 24.42 | | |
| 18 | | | | | | | | |
| 19 | 2.00 | 14.26 | 20.17 | 24.70 | 28.52 | 31.89 | | |
| 20 | | | | | | | | |
| 21 | 2.50 | 22.28 | 31.51 | 38.60 | 44.57 | 49.83 | | |
| 22 | | | | | | | | |
| 23 | 3.00 | 32.09 | 45.38 | 55.58 | 64.18 | 71.75 | | |
| 24 | | | | | | | | |
| 25 | 3.50 | 43.68 | 61.77 | 75.65 | 87.35 | 97.66 | | |
| 26 | | | | | | | | |
| 27 | 4.00 | 57.05 | 80.68 | 98.81 | 114.09 | 127.56 | | |
| 28 | | | | | | | | |
| 29 | 4.50 | 72.20 | 102.11 | 125.05 | 144.40 | 161.44 | | |
| 30 | | | | | | | | |
| 31 | 5.00 | 89.14 | 126.06 | 154.39 | 178.27 | 199.31 | | |
| 32 | | | | | | | Q=CoA(2gH)^0.5 | |
| 33 | | | | | | | A=piD^2/4 | |
| 34 | | | | | | | | |
| 35 | | Orifice discharge in cu.ft. per second | | | | | Q=6.3*Co*D^2*H^0.5 | |
| 36 | | For **SHARP** entrance with KE | | | 0.8 | | | |
| 37 | | | | and Co = | 0.6 | | | |
| 38 | Culvert | | | | | | | |
| 39 | Diameter | Depth of water above the INLET of the culvert in (feet) | | | | | | Table # 2 |
| 40 | in (feet) | 0.50 | 1.00 | 1.50 | 2.00 | 2.50 | | |
| 41 | | | | | | | | |
| 42 | 1.00 | 2.67 | 3.78 | 4.63 | 5.35 | 5.98 | | |
| 43 | | | | | | | | |
| 44 | 1.50 | 6.02 | 8.51 | 10.42 | 12.03 | 13.45 | | |
| 45 | | | | | | | | |
| 46 | 1.75 | 8.19 | 11.58 | 14.18 | 16.38 | 18.31 | | |
| 47 | | | | | | | | |
| 48 | 2.00 | 10.70 | 15.13 | 18.53 | 21.39 | 23.92 | | |
| 49 | | | | | | | | |
| 50 | 2.50 | 16.71 | 23.64 | 28.95 | 33.43 | 37.37 | | |
| 51 | | | | | | | | |
| 52 | 3.00 | 24.07 | 34.04 | 41.68 | 48.13 | 53.81 | | |
| 53 | | | | | | | | |
| 54 | 3.50 | 32.76 | 46.33 | 56.74 | 65.51 | 73.25 | | |
| 55 | | | | | | | | |
| 56 | 4.00 | 42.78 | 60.51 | 74.11 | 85.57 | 95.67 | | |
| 57 | | | | | | | | |
| 58 | 4.50 | 54.15 | 76.58 | 93.79 | 108.30 | 121.08 | | |
| 59 | | | | | | | | |
| 60 | 5.00 | 66.85 | 94.54 | 115.79 | 133.70 | 149.48 | | |

| A | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| **63** | | Full (non-pressure)barrel capacity of culverts. | | | | | | Table # 3 |
| **64** | | | flow in cu.ft.per second | | | | | |
| **65** | | | **PE / PVC** pipe @n= | | 0.01 | | | |
| **66** | Culvert | Slope of barrel in % (ft of drop per 100 ft.) | | | | | | |
| **67** | Diameter | | | | | | | |
| **68** | in (feet) | 0.25 | 0.50 | 1.00 | 1.50 | 2.00 | 3.00 | |
| **69** | | | | | | | | |
| **70** | 1.00 | 2.17 | 3.07 | 4.34 | 5.32 | 6.14 | 7.52 | |
| **71** | 1.50 | 6.40 | 9.05 | 12.80 | 15.67 | 18.10 | 22.17 | |
| **72** | 1.75 | 9.65 | 13.65 | 19.31 | 23.64 | 27.30 | 33.44 | |
| **73** | 2.00 | 13.78 | 19.49 | 27.56 | 33.76 | 38.98 | 47.74 | |
| **74** | 2.50 | 24.99 | 35.34 | 49.98 | 61.21 | 70.68 | 86.57 | |
| **75** | 3.00 | 40.64 | 57.47 | 81.28 | 99.55 | 114.95 | 140.78 | |
| **76** | 3.50 | 61.31 | 86.70 | 122.61 | 150.17 | 173.40 | 212.37 | |
| **77** | 4.00 | 87.53 | 123.79 | 175.07 | 214.41 | 247.58 | 303.22 | |
| **78** | 4.50 | 119.84 | 169.48 | 239.68 | 293.54 | 338.95 | 415.13 | |
| **79** | 5.00 | 158.72 | 224.46 | 317.44 | 388.78 | 448.92 | 549.82 | |
| **80** | | | | | | | | |
| **81** | | Full (non-pressure)barrel capacity of culverts. | | | | | | Table # 4 |
| **82** | | | flow in cu.ft.per second | | | | | |
| **83** | | | **RCP** pipe @n= | | 0.013 | | | |
| **84** | Culvert | Slope of barrel in % (ft of drop per 100 ft.) | | | | | | |
| **85** | Diameter | | | | | | | |
| **86** | in (feet) | 0.25 | 0.50 | 1.00 | 1.50 | 2.00 | 3.00 | |
| **87** | | | | | | | | |
| **88** | 1.00 | 1.67 | 2.36 | 3.34 | 4.09 | 4.72 | 5.78 | |
| **89** | 1.50 | 4.92 | 6.96 | 9.84 | 12.06 | 13.92 | 17.05 | |
| **90** | 1.75 | 7.43 | 10.50 | 14.85 | 18.19 | 21.00 | 25.72 | |
| **91** | 2.00 | 10.60 | 14.99 | 21.20 | 25.97 | 29.99 | 36.73 | |
| **92** | 2.50 | 19.22 | 27.19 | 38.45 | 47.09 | 54.37 | 66.59 | |
| **93** | 3.00 | 31.26 | 44.21 | 62.52 | 76.58 | 88.42 | 108.29 | |
| **94** | 3.50 | 47.16 | 66.69 | 94.32 | 115.51 | 133.38 | 163.36 | |
| **95** | 4.00 | 67.33 | 95.22 | 134.67 | 164.93 | 190.45 | 233.25 | |
| **96** | 4.50 | 92.18 | 130.37 | 184.37 | 225.80 | 260.73 | 319.33 | |
| **97** | 5.00 | 122.09 | 172.66 | 244.18 | 299.06 | 345.33 | 422.94 | |
| **98** | | | | | | | | |
| **99** | | Full (non-pressure)barrel capacity of culverts. | | | | | | Table # 5 |
| **100** | | | flow in cu.ft.per second | | | | | |
| **101** | | | **CMP** pipe @n= | | 0.025 | | | |
| **102** | Culvert | Slope of barrel in % (ft of drop per 100 ft.) | | | | | | |
| **103** | Diameter | | | | | | | |
| **104** | in (feet) | 0.25 | 0.50 | 1.00 | 1.50 | 2.00 | 3.00 | |
| **105** | | | | | | | | |
| **106** | 1.00 | 0.87 | 1.23 | 1.74 | 2.13 | 2.46 | 3.01 | |
| **107** | 1.50 | 2.56 | 3.62 | 5.12 | 6.27 | 7.24 | 8.87 | |
| **108** | 1.75 | 3.86 | 5.46 | 7.72 | 9.46 | 10.92 | 13.38 | |
| **109** | 2.00 | 5.51 | 7.80 | 11.03 | 13.50 | 15.59 | 19.10 | |
| **110** | 2.50 | 10.00 | 14.14 | 19.99 | 24.49 | 28.27 | 34.63 | |
| **111** | 3.00 | 16.26 | 22.99 | 32.51 | 39.82 | 45.98 | 56.31 | |
| **112** | 3.50 | 24.52 | 34.68 | 49.05 | 60.07 | 69.36 | 84.95 | |
| **113** | 4.00 | 35.01 | 49.52 | 70.03 | 85.76 | 99.03 | 121.29 | |
| **114** | 4.50 | 47.94 | 67.79 | 95.87 | 117.42 | 135.58 | 166.05 | |
| **115** | 5.00 | 63.49 | 89.78 | 126.98 | 155.51 | 179.57 | 219.93 | |
| **116** | | | | | | | | |

JJS 12/14/2001

# 4 - DITCH DESIGN

# DITCH DESIGN:

## A - TYPES OF ROADSIDE DRAINAGE:

The following is a list of types of road side water conveyance structures commonly used. The closed pipe system, #6, will be discussed only in concept as the design is more likely to need the attention of trained technical personnel.

1 - Grass waterways protected by temporary mulch or netting,

2 - Grass waterways reinforced with various brands of permanent Turf Reinforcement Mats (TRM's),

3 - Waterways reinforced by various brands of Articulated Concrete Block systems (ACB's),

4 - Waterways lined with rock riprap (rock should be 2.25 x the D50 thick) and have 6-12" or gravel bedding or non-woven fabric underneath (6-8 oz, AOS 50-70),

5 - Curbing with paved shoulder acting as the waterway,

6 - Curbing with paved shoulder having catch basins and outlet pipes (with or without tile).

## B - Major Design Parameters effecting design:

The use of underground drainage tile should be considered for use in helping to prevent icing of roads, frost heave, and pavement breakup. The use of tile drainage will depend on the amount of seepage at the site, especially during freezing weather, and during the spring thaw. The tile should be considered for use in supplementing the ditch types chosen except possible the stone waterways. The porous nature of the rock and gravel bedding act as an excellent drain in and of itself.

The major parameters affecting the design process including the choice of the type of ditch stabilization measure to be used are:

1 - the drainage area - governs the discharge, use discharge values given in the watershed analysis section for a selected size storm,

2 - the land slope - governs the velocity of runoff,

3 - the soil type - determines the erosion resistance of the in-place material, and

4 - the amount of land easements available - this will over ride the influences all of the above if not available.

## C - Design Tools for ditch design by HIGHWAY CREW personnel:

### 1 - **Table of roughness "n" values vs. liner type & velocity:**

| "n" | liner type | maximum allowable velocity - vx in (fps) |
|---|---|---|
| 0.02 | bare earth or concrete, | earth see table 5-2<br>concrete => 15 fps |
| 0.025 | bare earth gravelly, | earth see table 5-2 |
| | ACB's | vx = 10 to 15 fps |
| | D50 = 1 inch stone | vx = 2 fps |
| 0.04 | mowed thick grass @ 3" | see table 5-2 |
| | D50 = 4 inch stone | vx = 5.0 fps |
| 0.05 | D50 = 6 inch stone | vx = 6.5 fps |
| 0.06 | unmowed thick grass | see table 5-2 |
| | D50 = 9 inch stone | vx = 8.0 fps |
| 0.07 | D50 = 12 inch stone | vx = 9.5 fps |
| 0,06 | TRM | VX = 10-12 |

### 2 - **Table of actual flow velocities va for various conditions:**

| | slopes % | | | | |
|---|---|---|---|---|---|
| | 2 | 5 | 7 | 10 | 12 |
| "n" | va (fps) - actual velocity | | | | |
| 0.02 | 8.3 | 13.2 | 15.6 | 18.7 | 20.4 |
| 0.025 | 6.7 | 10.6 | 12.5 | 14.9 | 16.4 |
| 0.04 | 4.2 | 6.6 | 7.8 | 9.3 | 10.2 |
| 0.05 | 3.3 | 5.3 | 6.2 | 7.5 | 8.2 |
| 0.06 | 2.8 | 4.4 | 5.2 | 6.2 | 6.8 |
| 0.07 | 2.4 | 3.8 | 4.4 | 5.3 | 5.8 |

## D - Design Sequence:

step 1 - determine the discharge from the drainage area and the average flow values given in the watershed section.

step 2 - select liner & determine maximum velocity "vx",

step 3 - select design "n", & RECORD SLOPE OF WW

step 4 - enter actual velocity table with "n" & S(%) for "va".

step 5 - if va is greater than vx go back to step 2 and choose another alternative liner with a new "vx",

if va is less than vx find the top width (W) of a parabolic channel flowing 1.0 feet deep as follows:

W = 1.5 x (discharge in cfs / va fps)

NOTE: use a minimum width of 4 feet.

step 6 - draw sketch of design.

E - <u>Design Example:</u>

A ditch has a drainage area of 10 acres and has an average slope of 7% - for a 10 year storm, select a lining and determine the width of a 1 foot deep parabolic channel with the seclected liner.

Step 1 - find q10: 10 ac. x 2 cfs/ac = 20 cfs (see table page 2-3)

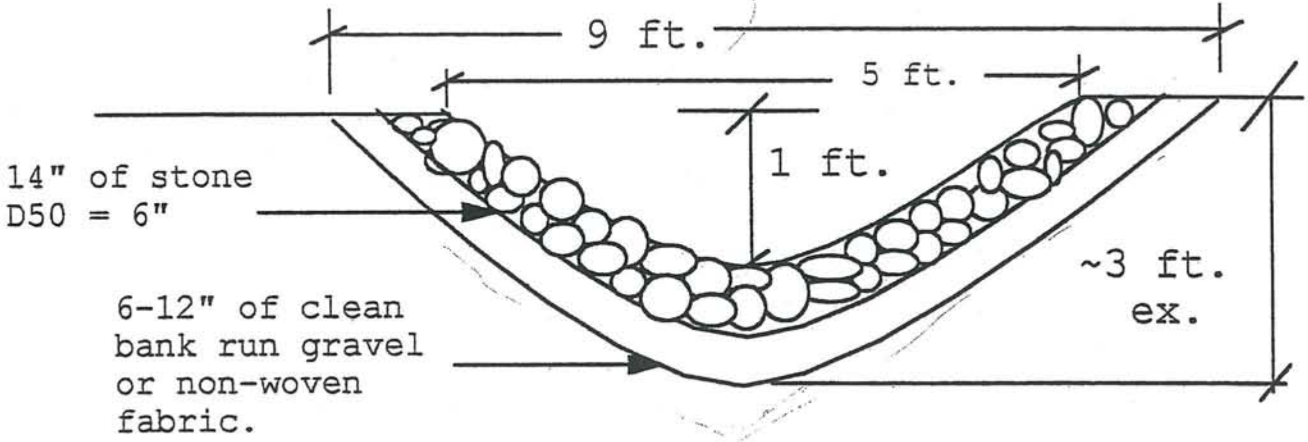
Step 2 - select 6" stone with a vx = 6.5 fps

Step 3 - determine liner "n" value from table on pg 4-3.

Step 4 - find va from table on page 4-3.

Step 5 - examine the relationship between va, and vx. i.e. the va = 6.2 is less than the 6.5 maximum allowable and the 6" stone is adequate. The width of channel is W=1.5x20/6.2 = 4.8 or 5 feet.

Step 6 - the channel flow section is 1' deep, 5' wide, stone is 14" thick (2.25x0.5), has a 6-12" gravel base, or a non-woven fabric (weight 6-8 oz./sq.yd., AOS of 50-70, and permittivity of > 50 gal/min/sq.ft.)



F - Related road ditch information:

**DRAINAGE OF GROUNDWATER:** It is desirable when solving a road ditch erosion problem that associated road base problems be enhanced if possible. Frost action is a source of severe damage to most roads. To eliminate frost action one needs to: 1 - prevent freezing temperatures (impossible in Maine without the use of insulating materials), 2 - have frost resistant road bed material to the depth of frost penetration (6 to 7 feet in many locations), or 3 - eliminate the presence of water entering the road base from cracks in the pavement or from groundwater below, see Fig 4-3 on page 4-9. It is this third option that can sometimes be effected by road ditch upgrades.

Road ditches intercepts seepage water and help keep the road base dry which increases the resistance to frost heaving damage, see Fig 5-28 on page 4-10.

Making a road ditch more that 1.5 - 2.0 feet deep is thought to require too much land and be somewhat of a hazard. Lowering the water table by using a grassed road ditch will not help much. It is often economical to install a 4 or 6 inch slotted tile drain below frost penetration depth, see DRO 15 "UNDERDRAIN" on page 4-11, for the purpose of lowering the water table under the road.

In the use of stone riprap road ditches the situation is somewhat different. The stone road ditch is as deep as a grassed ditch PLUS the additional depth of the stone (2.25 x the D50) PLUS the depth of the underlayment gravel bedding (about 1'). Thus a stone waterway using a stone D50 of 9" has the advantage of lowering the groundwater about an additional 32".

In summary a 1.5 foot deep grass road ditch lowers the groundwater about 1.5 feet. The same 1.5 foot deep stone lined road ditch, properly designed and installed, lowers the ground water a little over 4.0 feet!

**FROST SUSCEPTIBLE SOILS:** A word of caution is needed here. Looking at the values in Table 4-1 page 4-12 one can see the depth from which soil textures can theoretically draw water from below. Looks hopeless for silts and clays doesn't's it. These values assume the start of the silt and clay layer is above the frost depth.

What needs to be mentioned in this regard that modifies the whole table of values is that clays have extremely low permeability. As a result the capillary water would takes years to travel up to the freezing zone. This doesn't happen and therefore real clays are not frost susceptible.

The problem is that silt sized soil particles which are very fine grained tend to mimic clays in many respects. However they are more pervious and capable of "wicking up" substantial amounts of water in a winters time. Enough said about ground water drainage.

**Table 5 - 2. Maximum Allowable Flow Velocities for Various Types of Ditch Linings**

| Type of Lining | Maximum Velocity (ft/sec) |
|---|---|
| **Natural Soil Linings** | |
| Rip-rap sides and bottoms | 15 - 18 |
| Clean gravel | 6 - 7 |
| Silty gravel | 2 - 5 |
| Clean sand | 1 - 2 |
| Silty sand, clay | 2 - 3 |
| Clayey sand, silt | 3 - 4 |
| **Vegetative Linings** | |
| Average turf, erosion resistant soil | 4 - 5 |
| Average turf, easily eroded soil | 3 - 4 |
| Dense turf, erosion resistant soil | 6 - 8 |
| Gravel bottom, brushy sides | 4 - 5 |
| Dense weeds | 5 - 6 |
| **Paved Linings** | |
| Gravel bottom, concrete sides | 8 - 10 |
| Mortared rip-rap | 8 - 10 |
| Concrete or asphalt | 18 - 20 |

## Curbs and Gutters

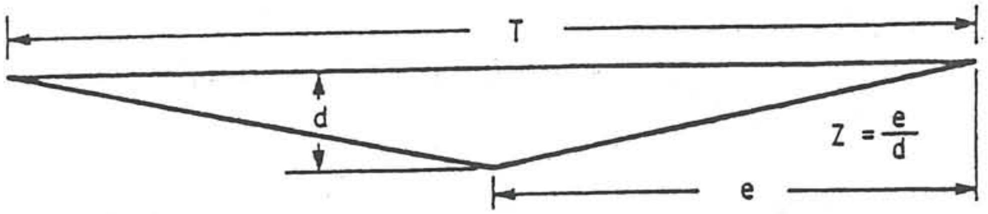
*Curbs* are often used in urban areas and occasionally on rural highways where some form of separation is needed between the road and side walks or other restricted areas. Curbs are also used to:

- provide a physical barrier for vehicles
- combine with the gutter to channel stormwater
- define the edge of the traveled way
- provide locations for stormwater inlets to underground drainage
- present an attractive appearance

*Gutters* are channels at the edges of pavement or shoulders formed by a cut or by a shallow depression or they may be part of the curb section. Gutter sections are provided on the travel side of a barrier or curb to form the principle drainage system for the roadway. A gutter section is often

**Figure 37.1 CHANNEL GEOMETRY (Virginia SWCC)**

V - Shape

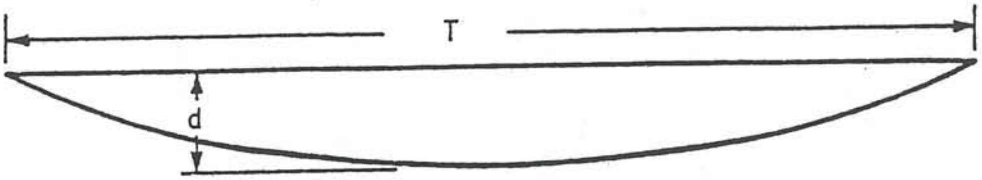


Cross-Sectional Area (A) = $Zd^2$

Top Width (T) = 2dZ

Hydraulic Radius (R) = $\frac{Zd}{2\sqrt{Z^2 + 1}}$

Parabolic Shape

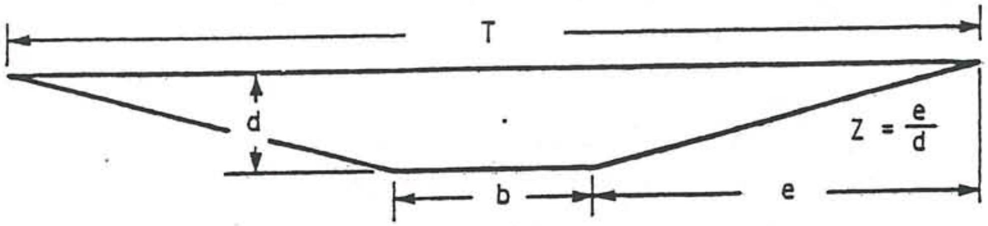


Cross-Sectional Area (A) = $\frac{2}{3}$ Td

Top Width (T) = $\frac{1.5\ A}{d}$

Hydraulic Radius = $\frac{T^2d}{1.5T^2 + 4d^2}$

Trapezoidal Shape



Cross-Sectional Area (A) = $bd + Zd^2$

Top Width (T) = b + 2dZ

Hydraulic Radius = $\frac{bd + Zd^2}{b + 2d\sqrt{Z^2 + 1}}$

If an erosion problem is in the ditch, check dams may provide a solution. Figures 5 - 26 and 5 - 27 are two inexpensive, easy-to-contruct types of check dams that would be appropriate for local road agencies to use. Figure 5 - 26 illustrates how to construct a log check dam and Figure 5 - 27 graphically shows how to turn a pile of rocks into a checkdam.

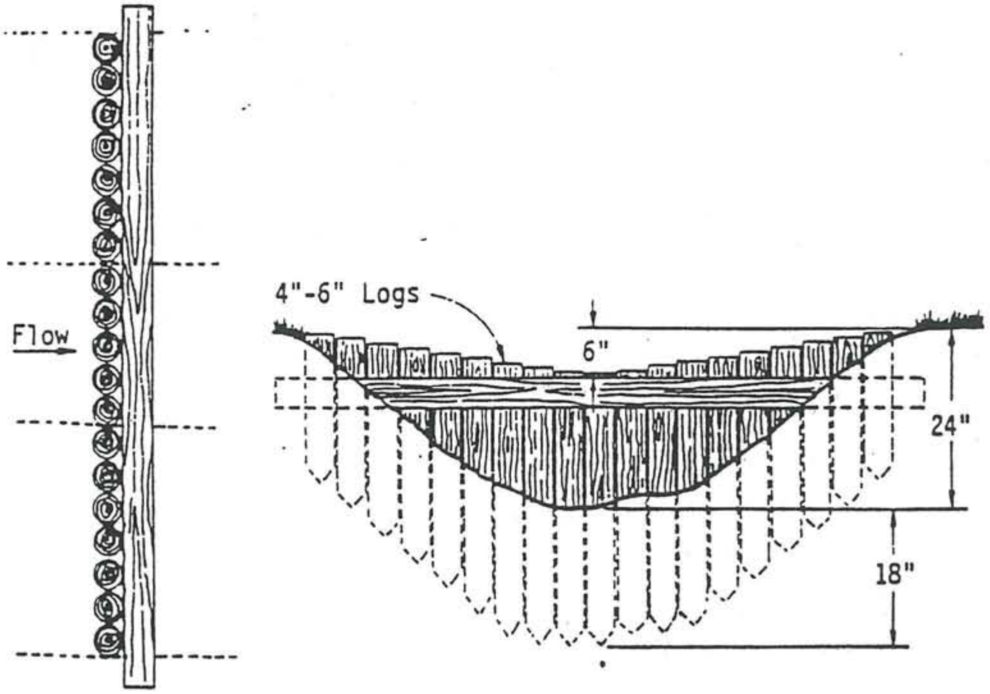


**Figure 5 - 26**
**Log Check Dam**

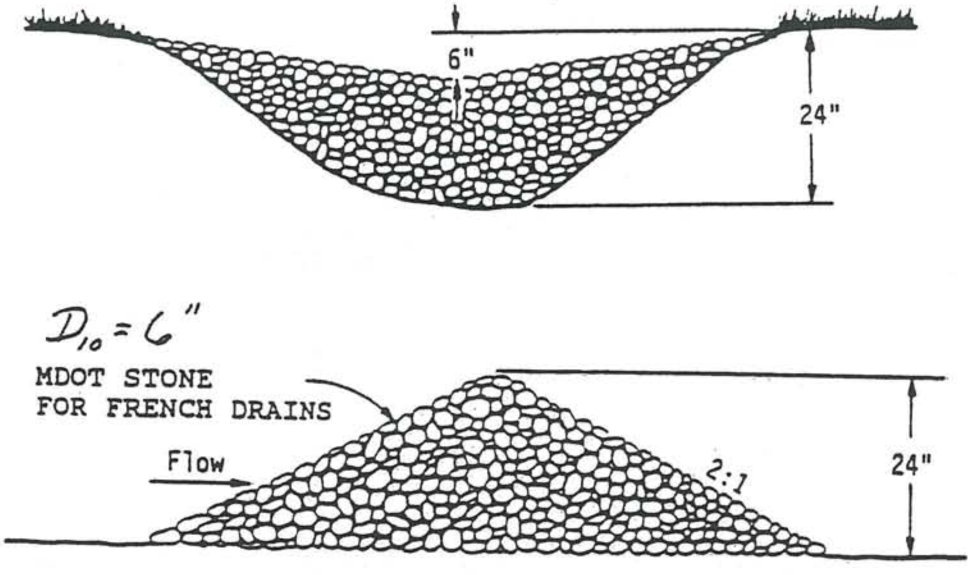


**Figure 5 - 27**
**Rock Check Dam**
**(Sketches courtesy of Virginia SWCC)**

The least expensive and most effective way of doing this is with good design and construction methods. When this is not possible, as is often the case with older roads, *maintenance crews should work toward correcting the deficiencies on a step-by-step basis.*

## HOW WATER ENTERS THE ROAD SYSTEM

The analogy is often made between a roadway and a building. The *subgrade* represents the basement, the *subbase* is the first floor and the *road surface* or pavement represents the roof. It easily follows that the entire system, roadway or house, should be built with the best materials, workmanship and design techniques available. No one part should be poorly built at the expense of the other two. It would be a waste of money.

However, this situation often happens in the case of roads and road maintenance. The part we see all the time, the road surface, often seems to get most of the attention from citizens and road officials alike. *The result is that the ''roof'' gets patched when the real problem is a ''leaky basement''.*

In real life, a roadway is exposed to more damaging attacks from water and other weather conditions than the house is. And the road structure doesn't have insulation wrapped around it and a nice warm furnace inside to protect it from freezing winters and hot summers.

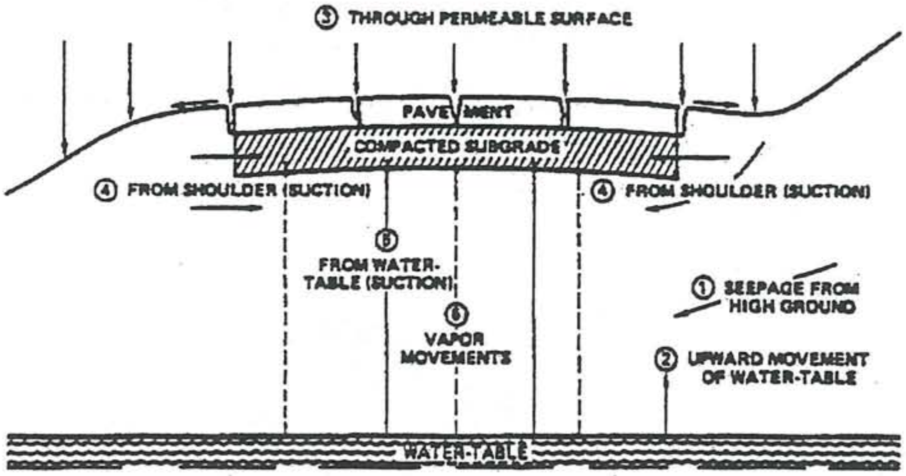


Figure 4 - 3 : Ways Moisture Gets Into the Roadbed

## Interceptor Drains

*The purpose of an interceptor drain is to cut off the movement of flowing underground water and lower the water table under the road.* Figure 5 - 28 shows a typical installation. Be sure that you put in a pipe large enough to handle the expected flow. The drain should be surrounded by crushed rock and the trench either "lined" with a nonwoven geotextile or a filter sand to keep the adjacent soils from washing in and plugging the drain. Note in the figure that the top of the trench is sealed to prevent surface water from getting in.

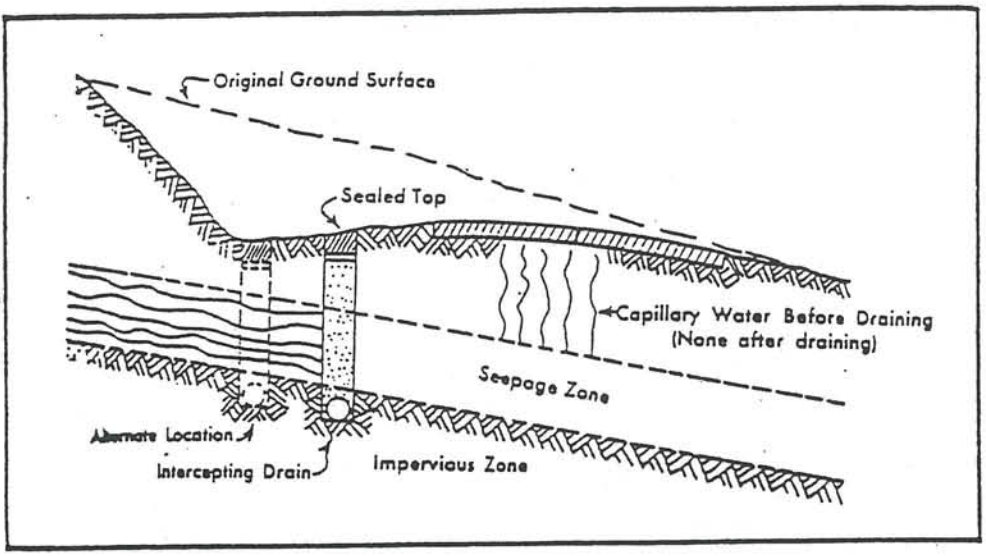
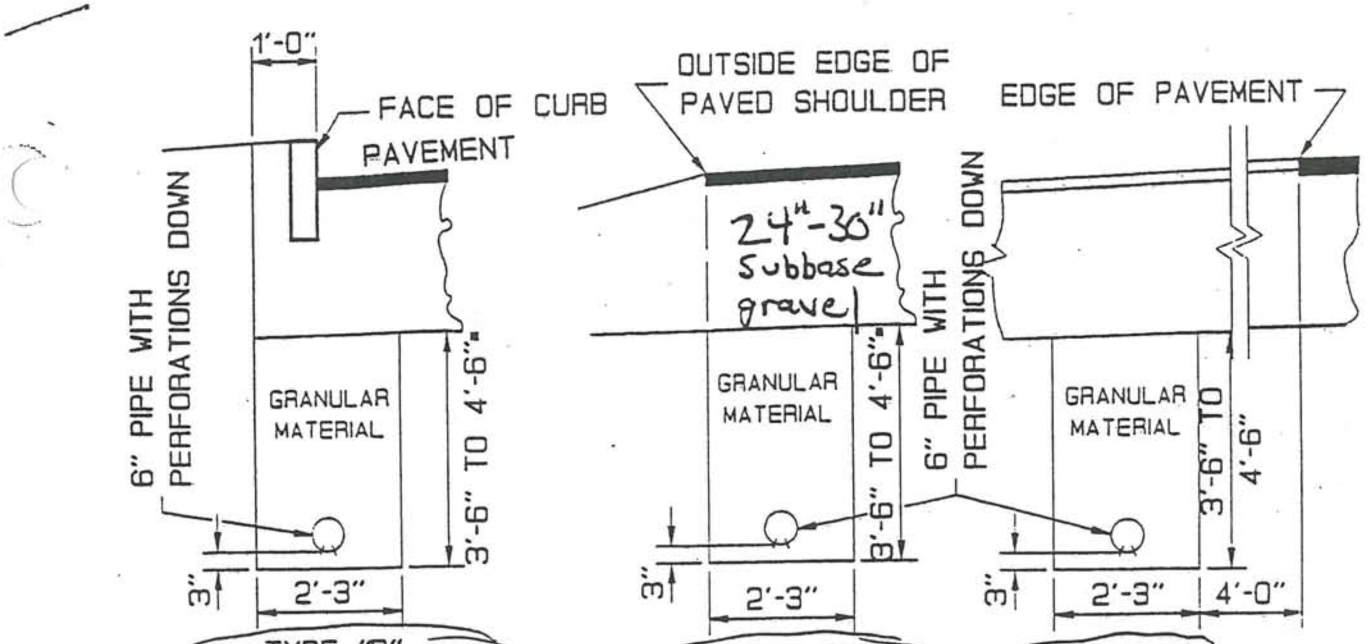


**Figure 5 - 28**
**Interceptor Drain**

Note also that the drain pipe is located in the impervious layer so the flow of water in the seepage zone is cut off completely by the subdrain. If there were no impervious layer or if the layer was much deeper than shown in the illustration, the depth of the intercepting drain would probably be made deep enough to prevent capillary action from affecting the subgrade or base.

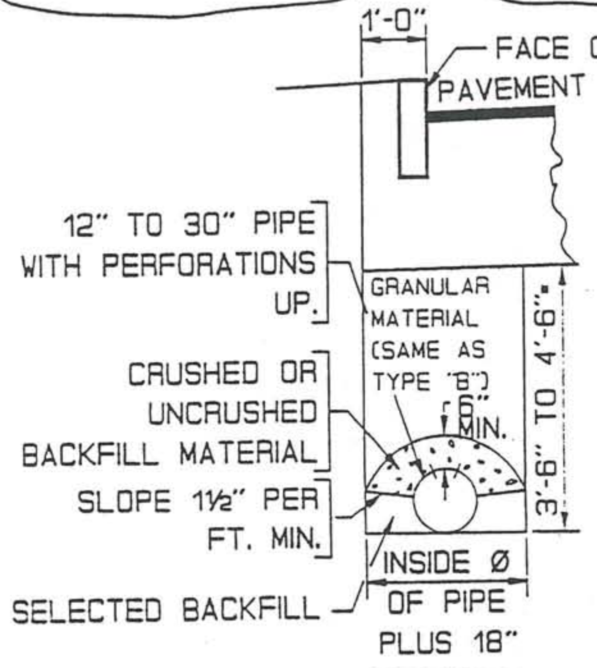
It is often difficult to predict subsurface water problems of the type shown in Figure 5 - 28 until they become evident during the construction process. A field decision to install underdrain and good judgement in putting it in place is the best solution.



TYPE "B" CURBED SHOULDER

TYPE "B" PAVED SHOULDER

TYPE "B" GRAVEL SHOULDER



TYPE "C"

NOTES

1. THE MAXIMUM VERTICAL MEASUREMENT OF DEPTH FOR PAYMENT OF STRUCTURAL ROCK EXCAVATION WILL BE TO A HORIZONTAL PLANE LOCATED 1 FOOT BELOW THE BOTTOM OF THE INVERT OF THE PIPE FOR UNDERDRAIN TYPE "B" AND UNDERDRAIN TYPE "C".

2. THE MATERIAL FOR ELBOWS, TEES & WYES FOR UNDERDRAIN TYPES "B" AND "C" SHALL BE AT LEAST AS THICK AS THE LARGEST SIZE PIPE BEING CONNECTED.

3. THE INVERT ELEVATION OF UNDERDRAIN TYPE "B" OUTLETS SHALL BE A MINIMUM OF 6 INCHES ABOVE THE FLOW LINE OF A DITCH OR THE ORIGINAL GROUND.

4. WIDTH OF THE TRENCH FOR UNDERDRAIN OUTLET WILL BE THE SAME AS THE UNDERDRAIN TRENCH.

5. NO ALLOWANCE FOR PAYMENT WILL BE MADE FOR EXCAVATING OR MATERIAL EXCAVATED BEYOND THE HORIZONTAL DIMENSIONS SHOWN FOR TYPES "A", "B", OR "C" UNDERDRAIN.

6. IN "BOX SECTIONS" THE EDGE OF TRENCH SHALL BE IN LINE WITH EDGE OF BOX SECTION.

MAINE DOT

SPEC. 605

UNDERDRAIN

DR015

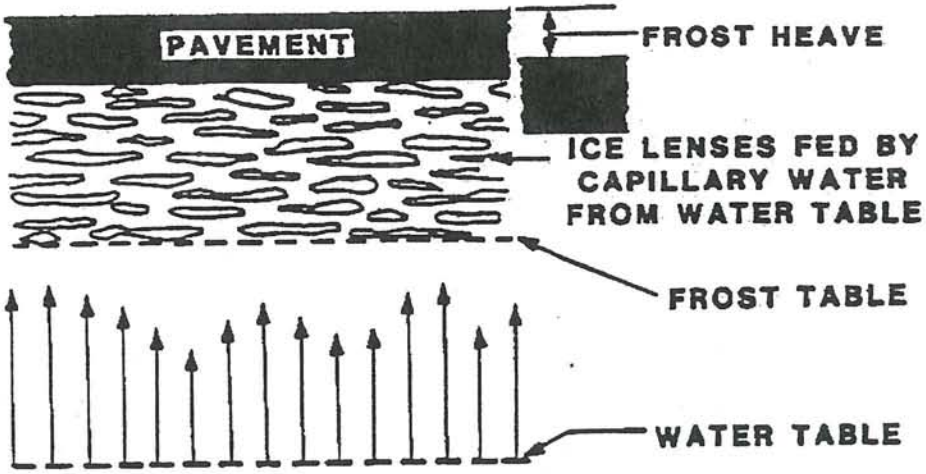
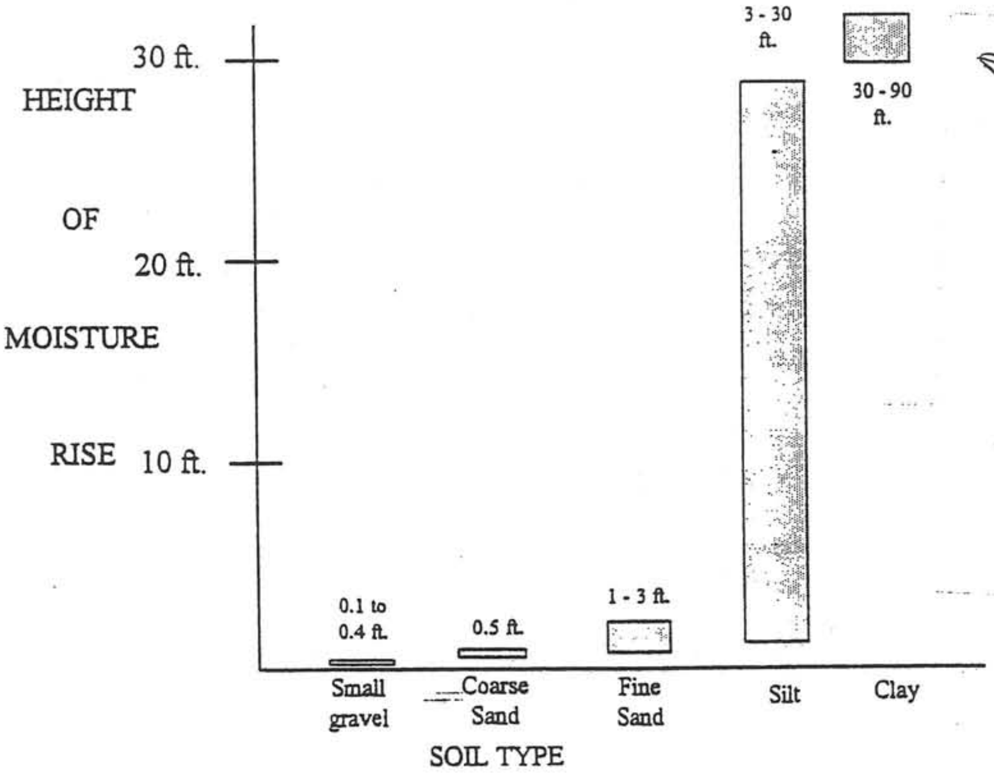


Figure 4 - 4. Ice Lense Formation and Capillary Rise in a Soil

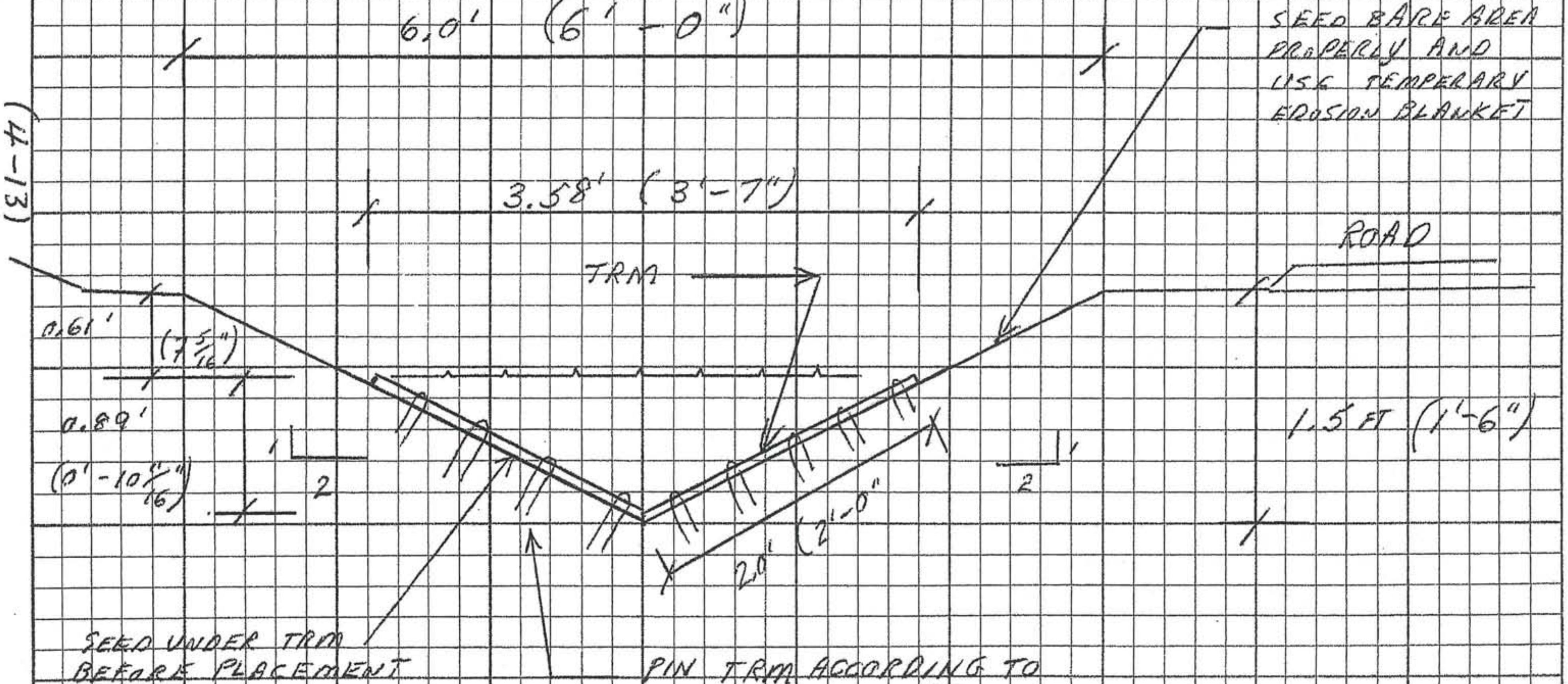
Table 4 - 1 illustrates how water can be drawn upward for considerable distances in different soil materials. *Note that the fine-grained soils are the trouble makers.*

Table 4 - 1: Height of Capillary Rise



HOWEVER!
CLAY IS IMPERVIOUS!

# TURF REINFORCEMENT MAT (TRM) DETAILS



SEED BARE AREA PROPERLY AND USE TEMPERARY EROSION BLANKET

SEED UNDER TRM BEFORE PLACEMENT OF MAT.

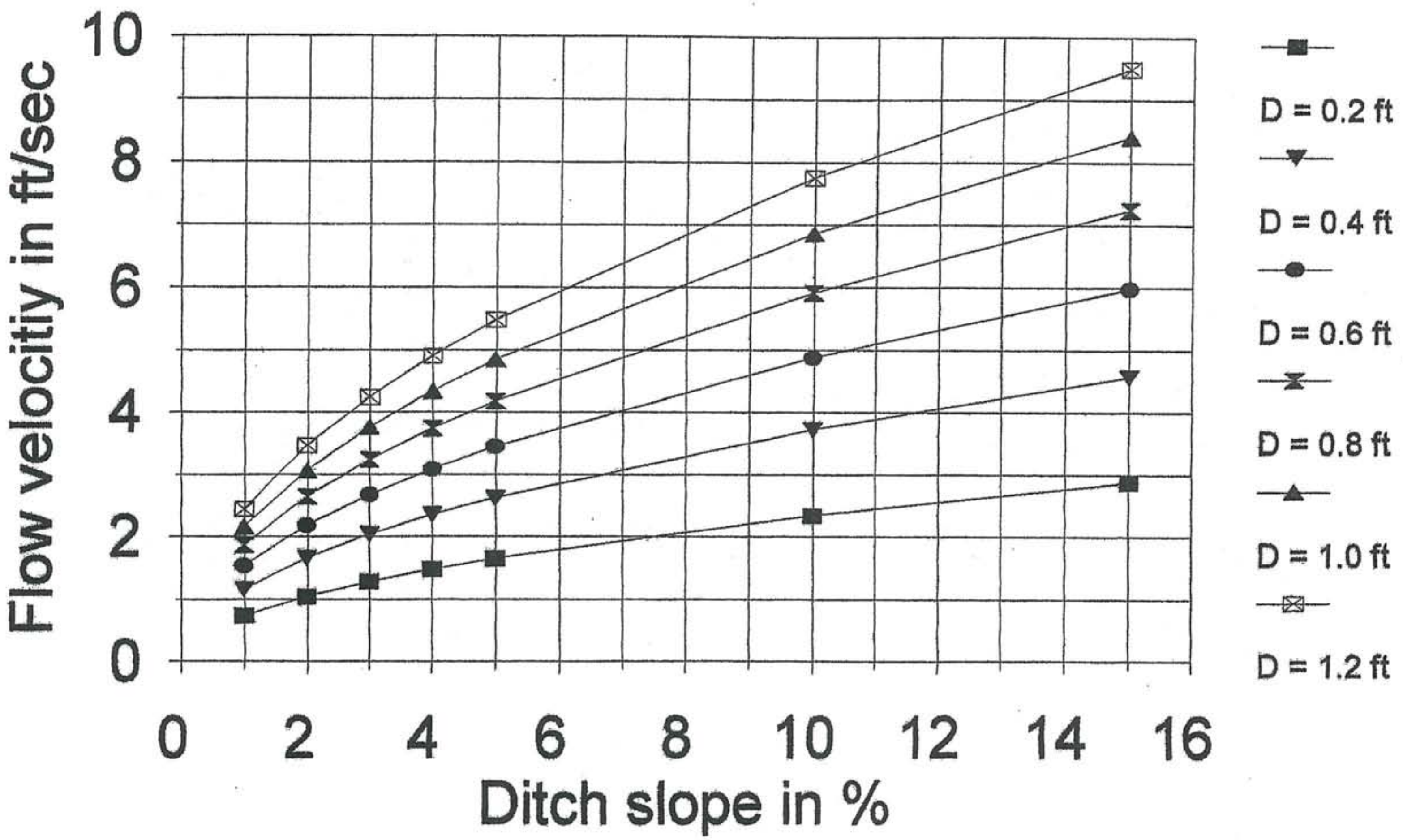
PIN TRM ACCORDING TO MANUFACTURERS RECOMMENDATIONS

BY JOHN J SIMON, P.E.
BALANCED ENGINEERING
3-18-03

| A | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3/12-13/03 Chart for V-ditch solution for use in TRM design.  by John J Simon, P.E. | | | | | | | | |
| 2 | For use in AVSWCD Road Crew Handbook | | | | | | | | |
| 3 | Z = | 2 | i.e. side slopes of 2H to 1V (2:1) | | | | | | |
| 4 | n = | 0.04 | un-mowed grass condition | | | | | | |
| 5 | | | Table of flow velocities in ft per second | | | | | | |
| 6 | | | | | flow depth in ft. | | | | |
| 7 | Slope % | 0.2 | 0.4 | 0.6 | 0.8 | 1 | 1.2 | 1.5 | |
| 8 | 1 | 0.74 | 1.18 | 1.54 | 1.87 | 2.17 | 2.45 | 2.85 | |
| 9 | 2 | 1.05 | 1.67 | 2.18 | 2.65 | 3.07 | 3.47 | 4.03 | |
| 10 | 3 | 1.29 | 2.04 | 2.68 | 3.24 | 3.76 | 4.25 | 4.93 | |
| 11 | 4 | 1.48 | 2.36 | 3.09 | 3.74 | 4.34 | 4.91 | 5.69 | |
| 12 | 5 | 1.66 | 2.64 | 3.45 | 4.19 | 4.86 | 5.48 | 6.36 | |
| 13 | 10 | 2.35 | 3.73 | 4.89 | 5.92 | 6.87 | 7.76 | 9.00 | |
| 14 | 15 | 2.88 | 4.57 | 5.98 | 7.25 | 8.41 | 9.50 | 11.02 | |
| 15 | | | | | | | | | |
| 16 | | | Taqble of discharges in cubic feet per second | | | | | | |
| 17 | | | | | flow depth in ft. | | | | |
| 18 | Slope % | 0.2 | 0.4 | 0.6 | 0.8 | 1 | 1.2 | 1.5 | |
| 19 | 1 | 0.06 | 0.38 | 1.11 | 2.40 | 4.34 | 7.06 | 12.81 | |
| 20 | 2 | 0.08 | 0.53 | 1.57 | 3.39 | 6.14 | 9.99 | 18.11 | |
| 21 | 3 | 0.10 | 0.65 | 1.93 | 4.15 | 7.52 | 12.24 | 22.19 | |
| 22 | 4 | 0.12 | 0.75 | 2.22 | 4.79 | 8.69 | 14.13 | 25.62 | |
| 23 | 5 | 0.13 | 0.84 | 2.49 | 5.36 | 9.71 | 15.80 | 28.64 | |
| 24 | 10 | 0.19 | 1.19 | 3.52 | 7.58 | 13.74 | 22.34 | 40.51 | |
| 25 | 15 | 0.23 | 1.46 | 4.31 | 9.28 | 16.82 | 27.36 | 49.61 | |
| 26 | | | | | | | | | |
| 27 | | | | | | | | | |
| 28 | n = | 0.02 | bare condition - before grass emergence | | | | | | |
| 29 | | | | | | | | | |
| 30 | | | Table of flow velocities in ft per second | | | | | | |
| 31 | | | | | flow depth in ft. | | | | |
| 32 | Slope % | 0.2 | 0.4 | 0.6 | 0.8 | 1 | 1.2 | 1.5 | |
| 33 | 1 | 1.48 | 2.36 | 3.09 | 3.74 | 4.34 | 4.91 | 5.69 | |
| 34 | 2 | 2.10 | 3.33 | 4.37 | 5.29 | 6.14 | 6.94 | 8.05 | |
| 35 | 3 | 2.57 | 4.08 | 5.35 | 6.48 | 7.52 | 8.50 | 9.86 | |
| 36 | 4 | 2.97 | 4.72 | 6.18 | 7.49 | 8.69 | 9.81 | 11.39 | |
| 37 | 5 | 3.32 | 5.27 | 6.91 | 8.37 | 9.71 | 10.97 | 12.73 | |
| 38 | 10 | 4.70 | 7.46 | 9.77 | 11.84 | 13.74 | 15.51 | 18.00 | |
| 39 | 15 | 5.75 | 9.13 | 11.97 | 14.50 | 16.82 | 19.00 | 22.05 | |
| 40 | | | | | | | | | |

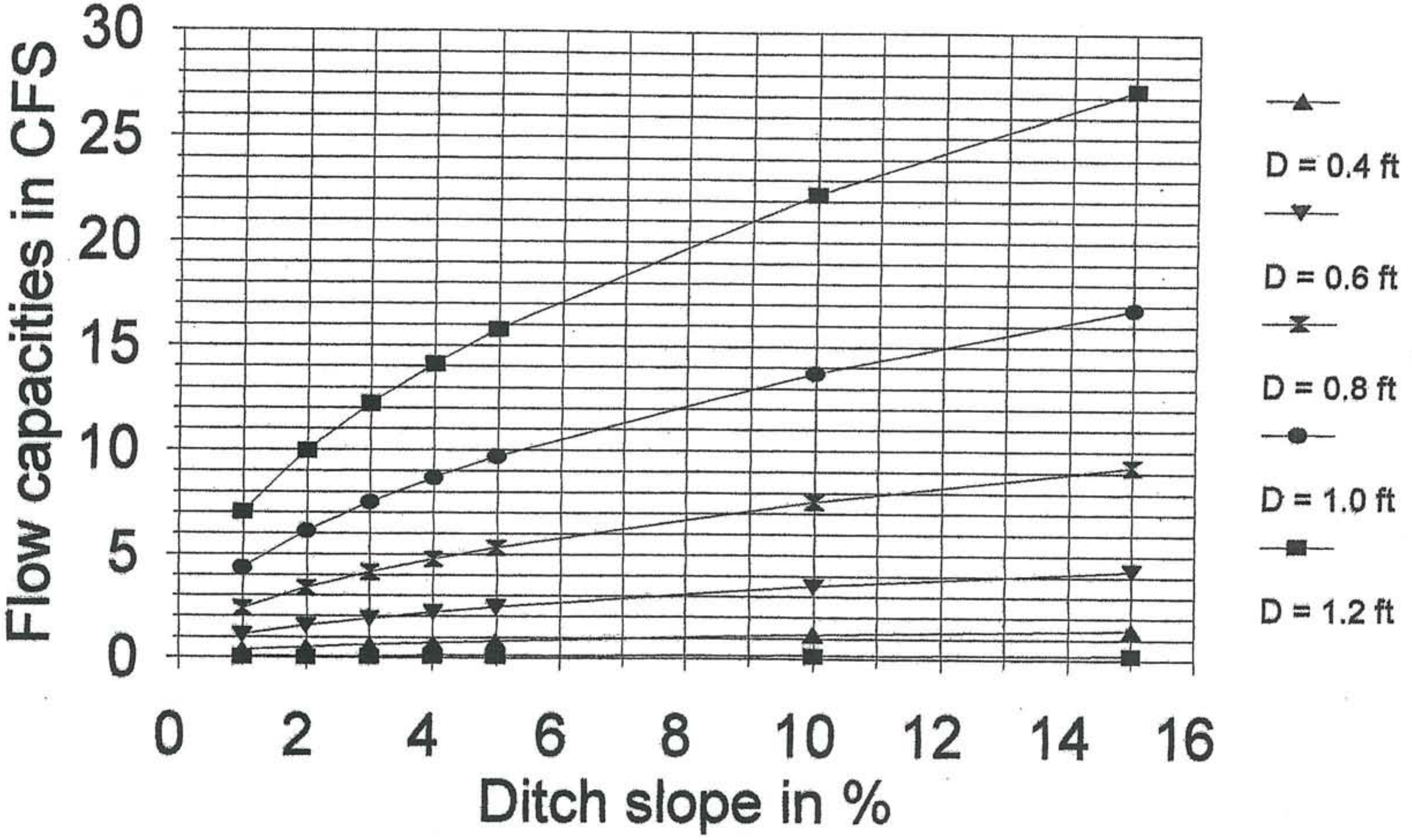
# Flow Velocities in ft per second

V ditch @ 2:1 SS, n= 0.04, by JJS 3/03



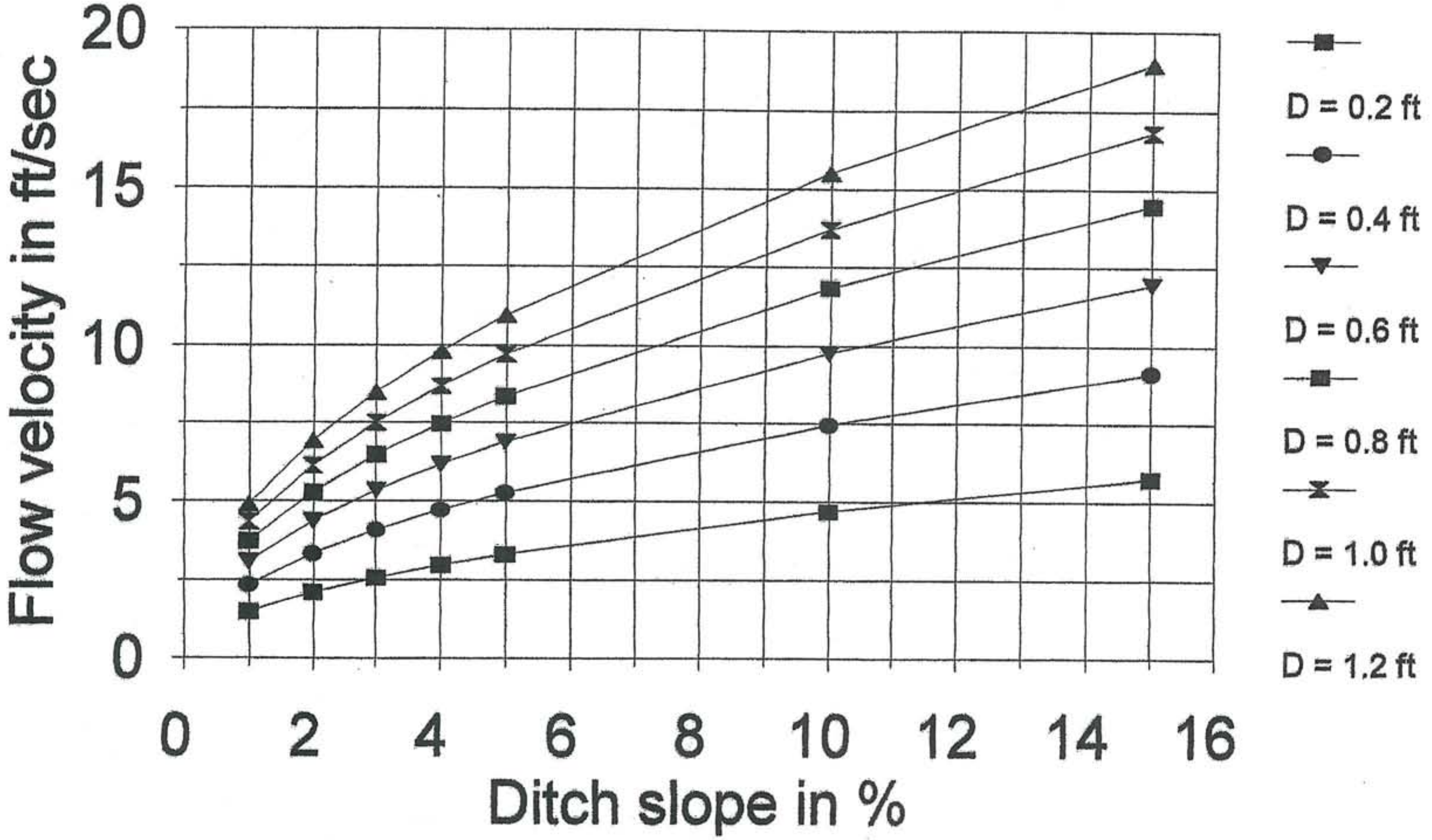
# Flow capacities in CFS

## V ditch @ 2:1 SS, n= 0.04, by JJS 3/03



## Flow Velocities in ft per second

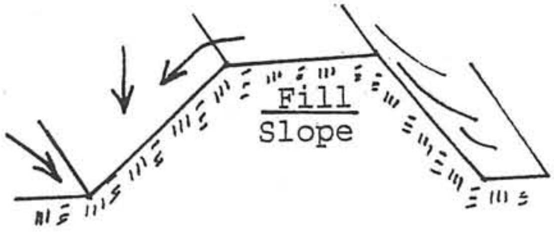
## V ditch @ 2:1 SS, n= 0.02, by JJS 3/03

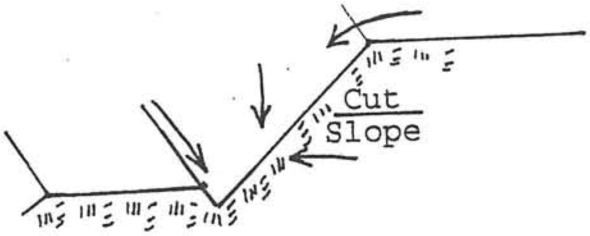


# 5 - SLOPE STABILIZATION

# SLOPE STABILIZATION:

The discussion here is meant for both upstream "cut" slopes into an existing hillside, and downstream "fill" slopes. Both need to be stable for a safe and low maintenance road.





## A - SOURCES OF INSTABILITY OR EROSION, and REMEDIAL MEASURES:

1 - Water

a - Surface flows over slope.
  I - diversions above slope with stable outlets,
  II - rock chutes over slope,
  III - stone lining of slope. Note:stone can be seeded with Crown Vetch or Birdsfoot Trefoil if desired.

b - Seepage from within slope.
  I - cutoff seepage above slope if possible - especially if seepage is along a hardpan or ledge.
  II - tile drainage across slope above area of seepage.
  III - thick layer of gravel and riprap cover.

c - flows (or wave action) along toe of slope.
  I - stone revetment (riprap). Note: stone can be seeded if desired.
  II - shrubbery - live staking or willow wattles

d - rainfall on an unprotected slope.
  I - establishment of vegetation by hydroseeding or by hand seeding.
  II - mulching using wood waste, bark, or stone.

2 - Excavations that leave a slope too steep (steeper than the angle of repose).

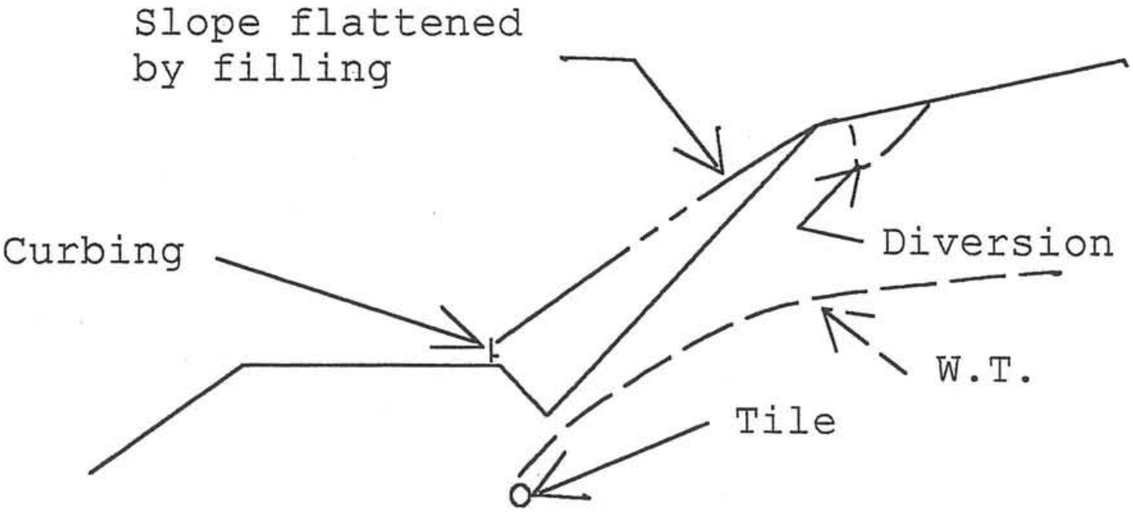
a - reduce slope to a 2:1 or flatter by excavating.

b - reduce slope to a 2:1 or flatter by filling in the lower portion. If used try leaving a top berm. Filling in road ditch and replacing with a storm underdrain which may be necessary. Or use of a curbed shoulder.

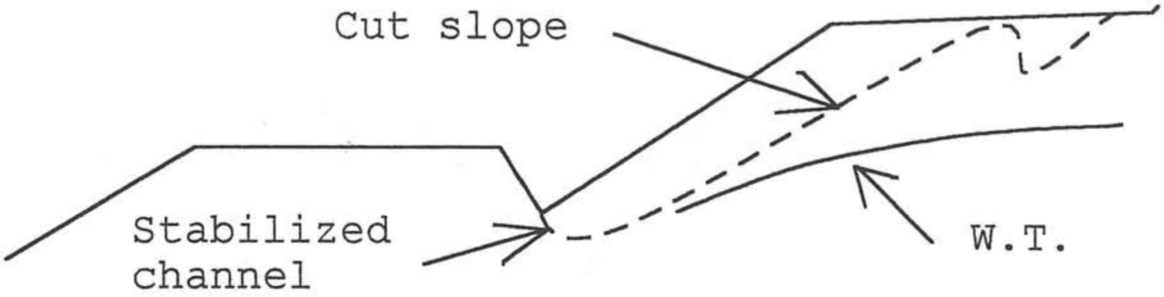
3 - Overhanging or undercut trees.

a - cut trees but leave stumps for root reinforcement and future sprouting source.

# SLOPE OPTIONS



Slope option 1 - Fill with curb & tile



Slope option 2 - cut with stable road ditch

ANDY-8.KEY
JJS 11/21/98

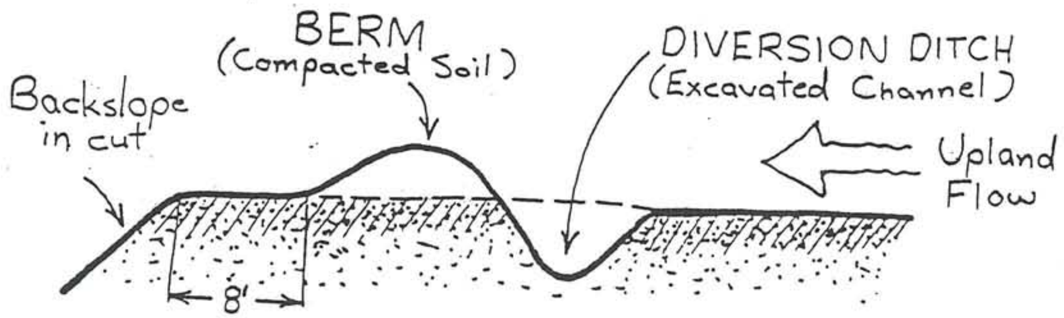


FIGURE 5 - 6
COMBINATION BERM AND DIVERSION DITCH USED AT THE TOP OF A BACKSLOPE

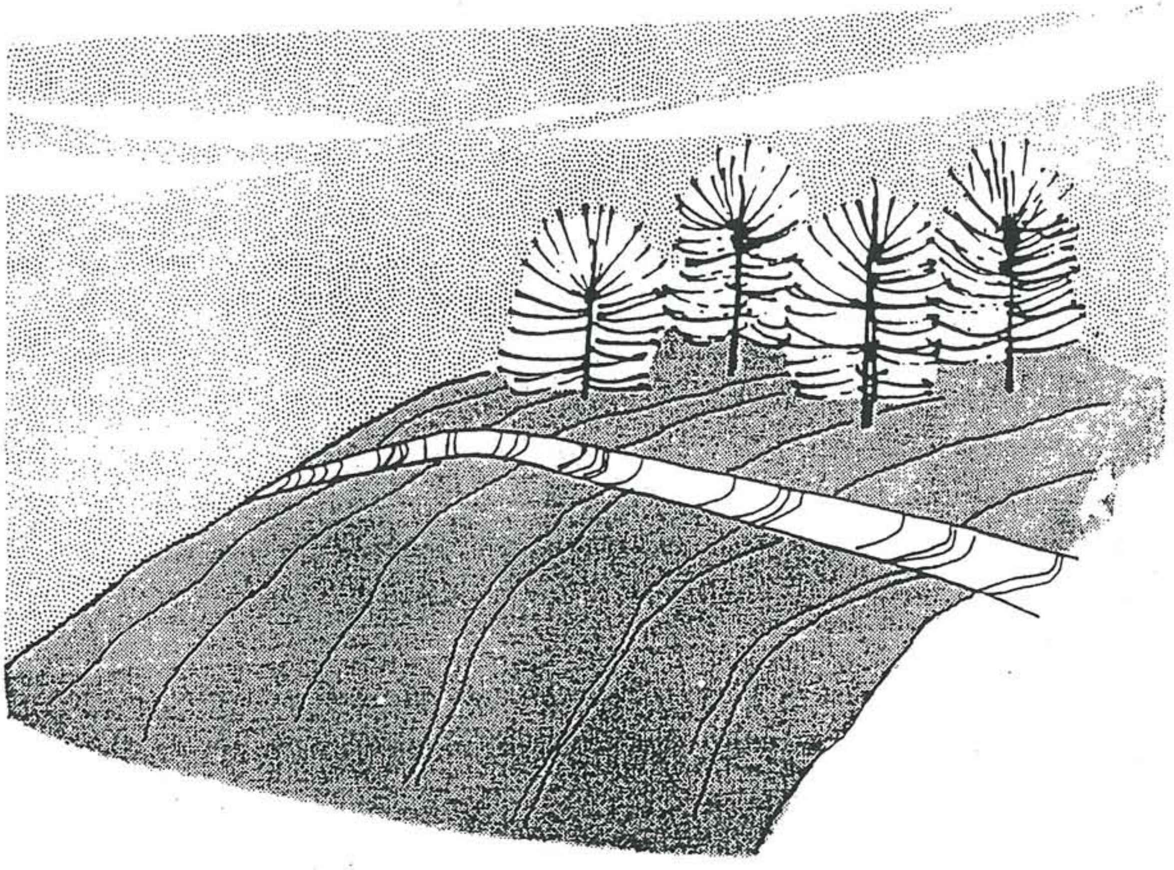
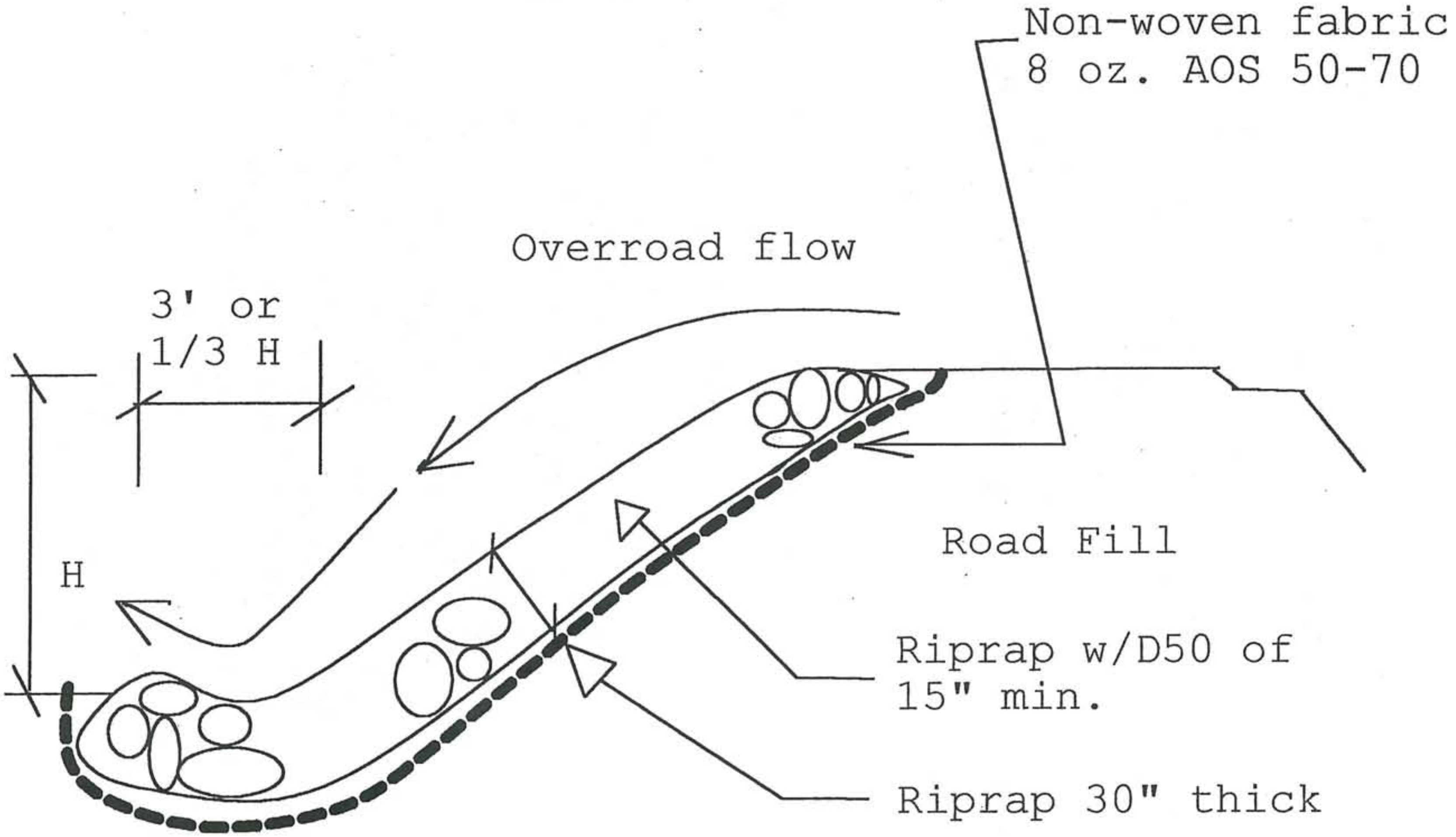


FIGURE 5 - 5
DIVERSION DITCHES CHANNEL WATER AWAY FROM SLOPES

# OVERROAD FLOW PROTECTION



ANDY-6.KEY
JJS 11/21/98

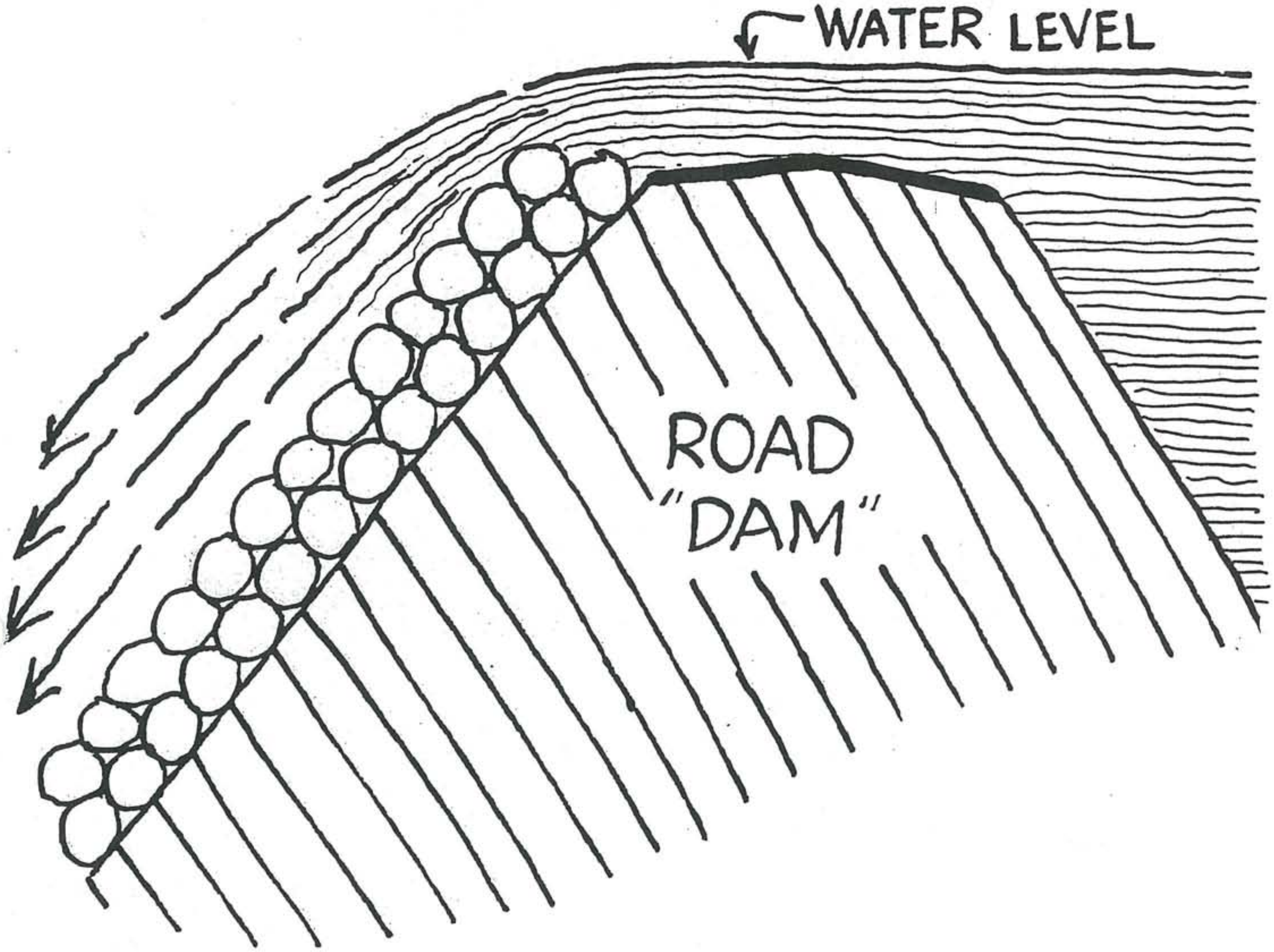


**DIAGRAM #8**

Anytime you have water flowing over a roadway fill, the fill acts as a dam, and you must consider "armoring" the down stream side of the fill. Erosion starts on the downstream end and works backwards. If you can keep this erosion from occurring, you will not lose the fill and your roadway will be useable when the water levels subside.

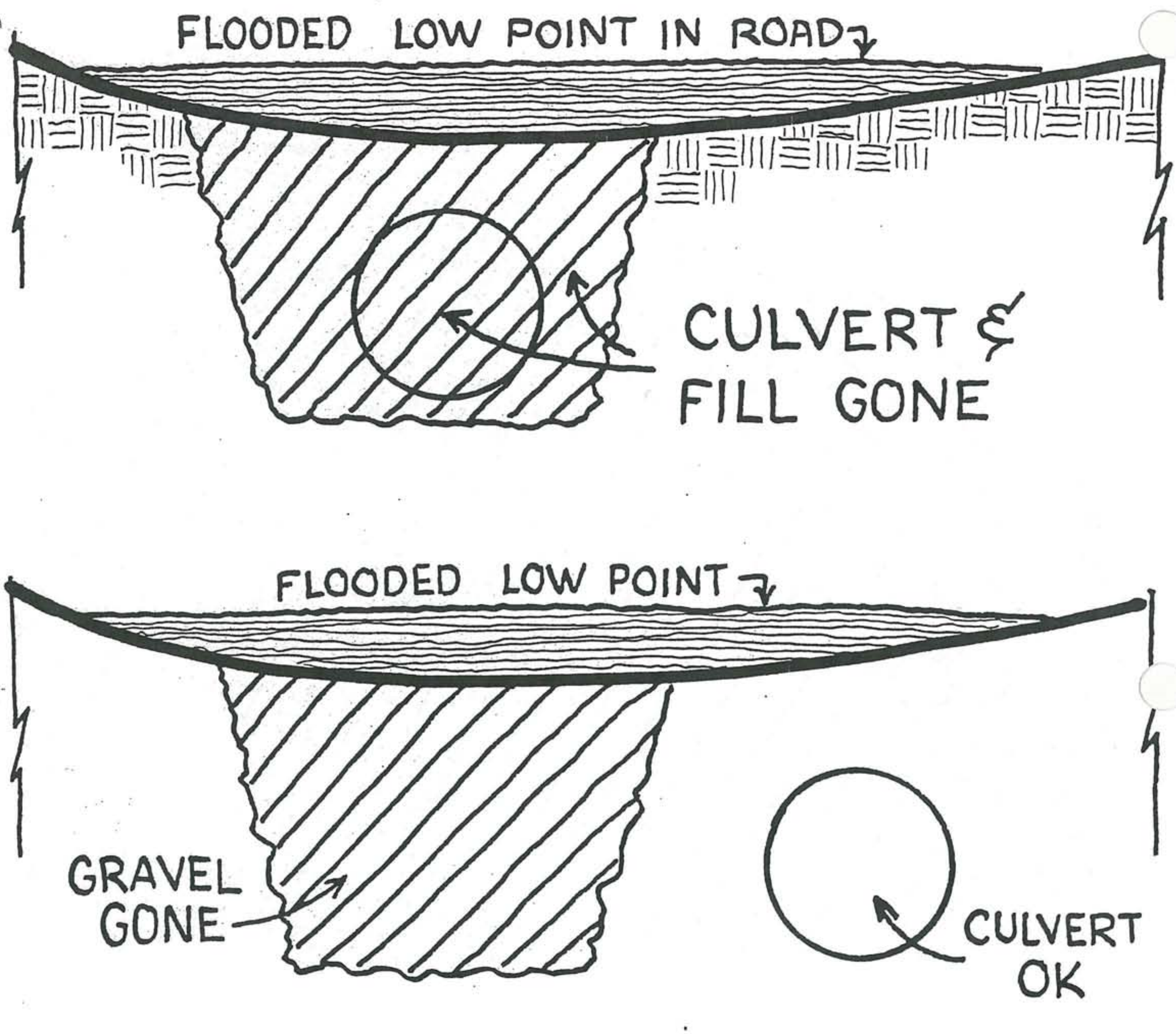


**DIAGRAM #5**

Have you ever noted that we seem to always build our roads so that the sag or low point is exactly over the river or stream where the culvert has been placed. If the culvert cannot handle a heavy flow of water and water flows over the road washing it out, we loose BOTH the fill and the culvert. In the lower example, we may lose the fill but the culvert has not been lost. *It is much easier to rebuild the fill than having to replace the culvert and the fill.* There is an added advantage to the clean-up efforts if the low point in the road is not over the culvert. The gravel is likely to end up in the nearby field or woods and not in the river or stream. Recovery of this gravel may be much easier in this situation. !

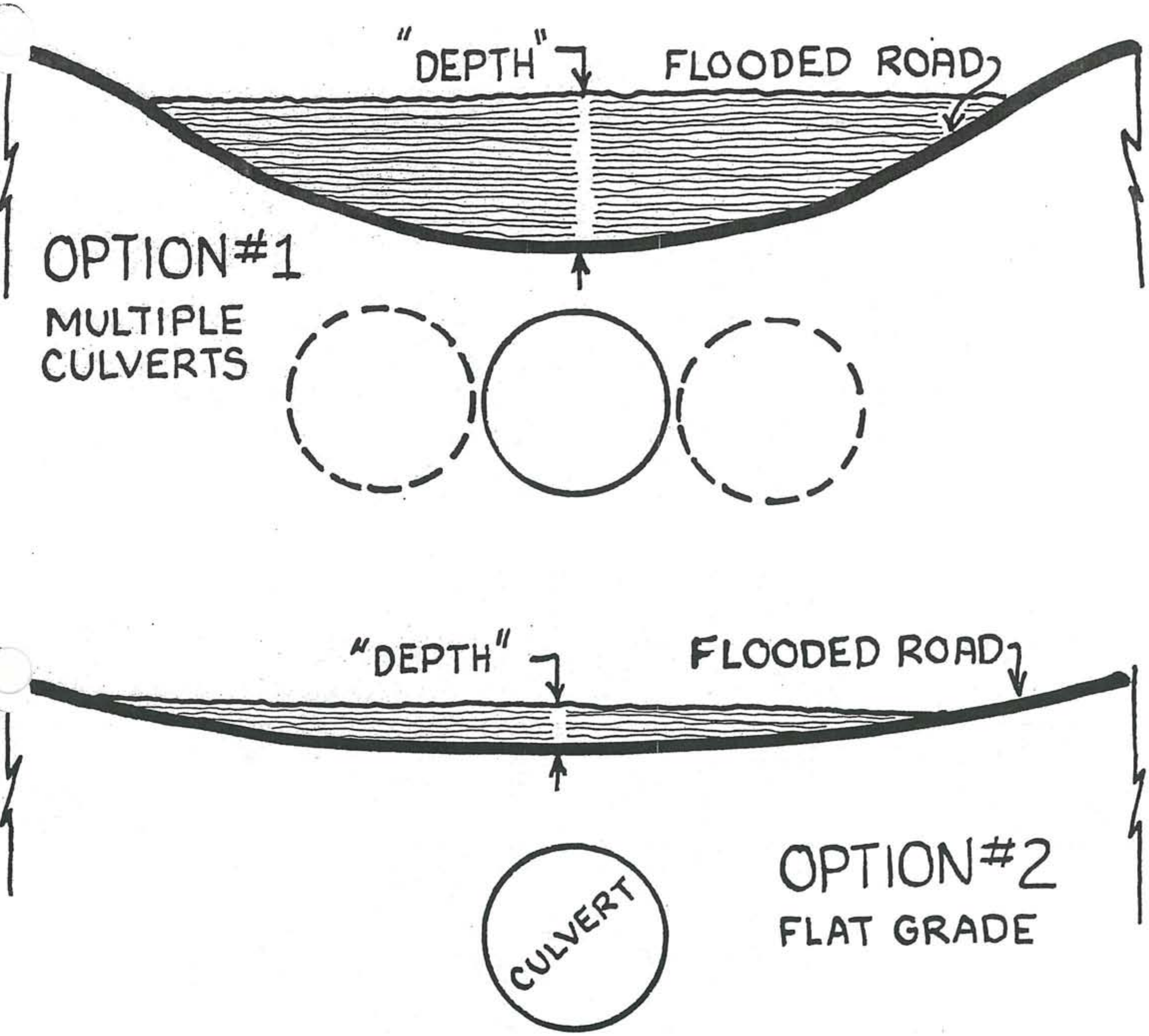


DIAGRAM #6

If a road is going to flood, you might be able to keep the flooding down to a depth that can be negotiated by emergency vehicles. If a much larger size culvert (and higher road) is too costly, you could consider two options to reduce the depth of flooding. First, you could install a series of culverts to handle the flow. Second, you could consider building a flat, zero percent grade, section of road for a distance necessary to keep the water depth over the road to an acceptable depth. (6" TO 12")

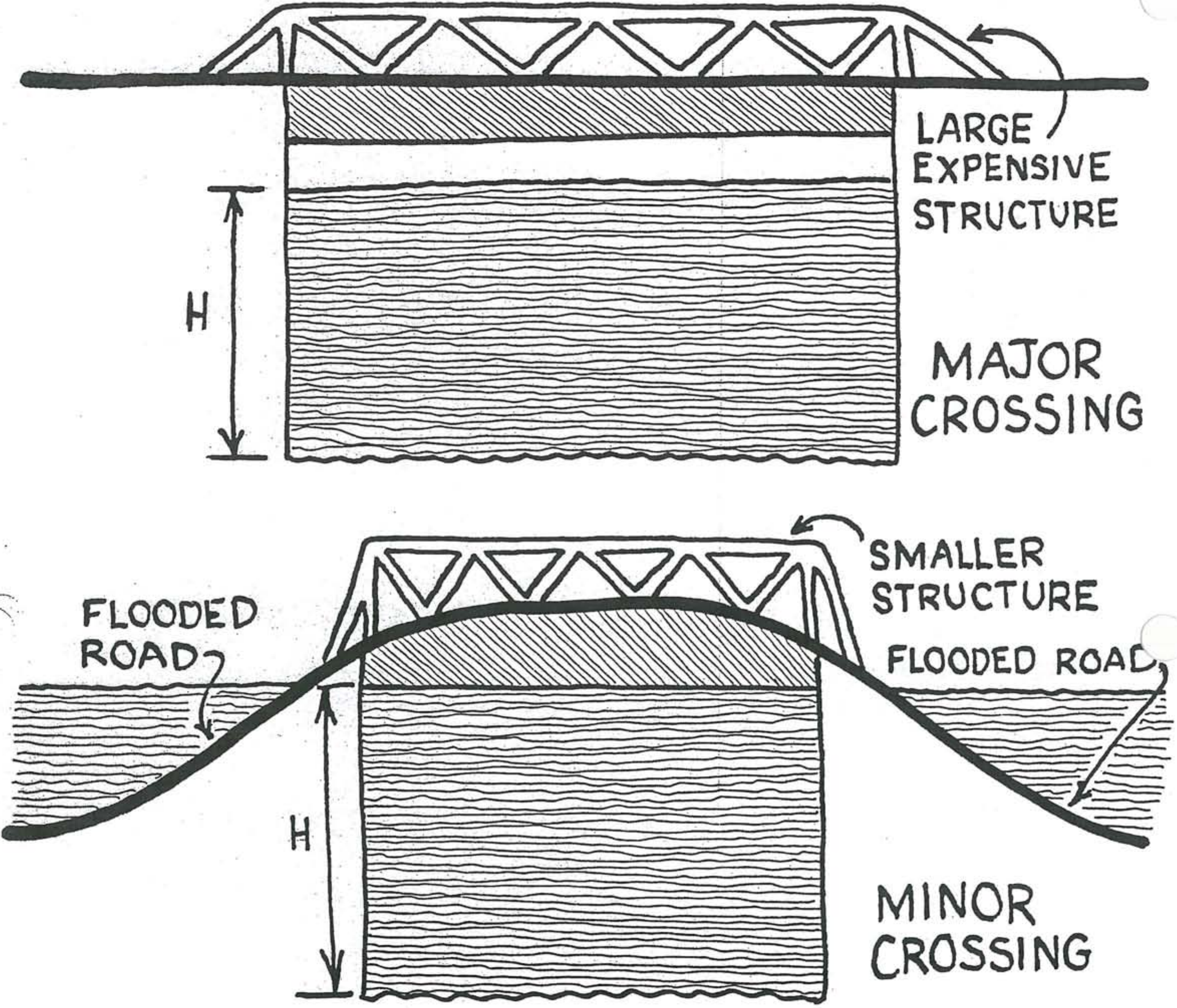
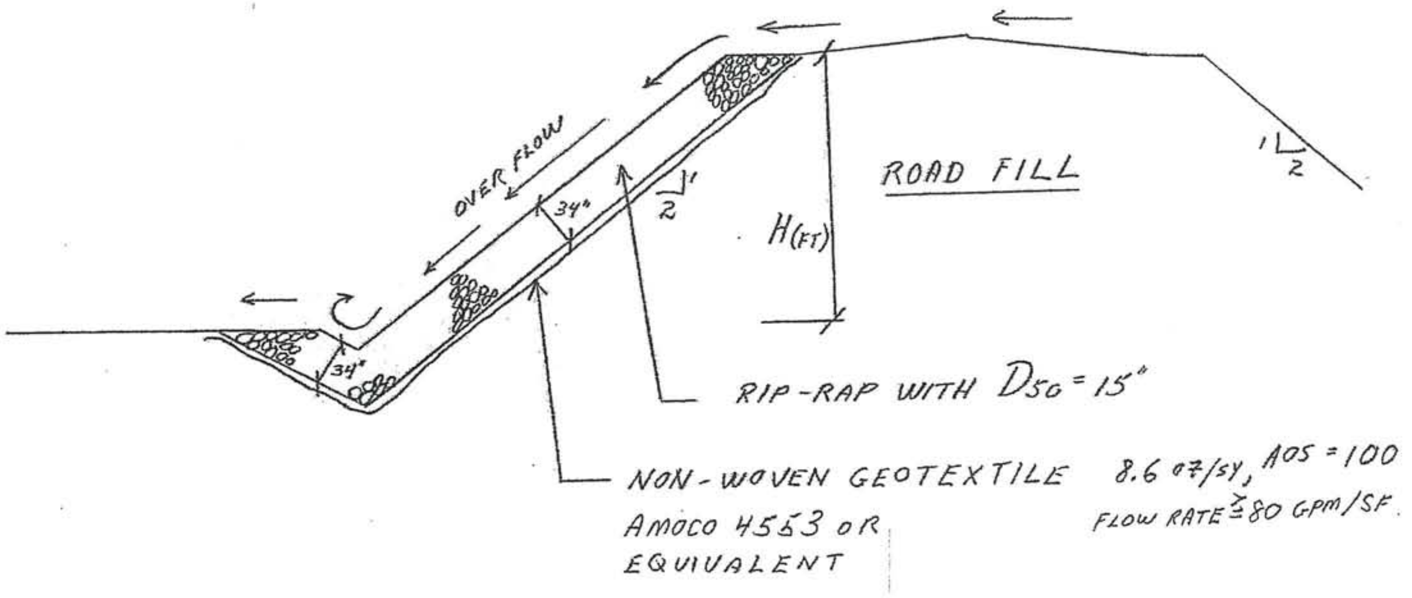


**DIAGRAM #7**

When considering a bridge OR CULVERT replacement, ask yourself how critical is this bridge to your emergency route system? If it is critical, then you must pay the cost of a larger structure that has the capacity to handle the flow. If the bridge is not on a critical route, you may want to design the bridge to be above the flood flow and allow the approaches on either side of the bridge to flood. When the flood waters subside, your bridge will still be there and your repair will be confined to just the approach fills.

| A | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 117 | | Volume of  Rip-rap for road overflow protection D50 = 15" | | | | | | Table # 6 |
| 118 | | | | | | | | |
| 119 | Height of | Volume of | | | | | | |
| 120 | road fill | rock | | | | | | |
| 121 | (feet) | cy/lin.ft. | | | | | | |
| 122 | | of road | | | | | | |
| 123 | | | | | | | | |
| 124 | 1 | 1.00 | | | | | | |
| 125 | 2 | 1.22 | | | | | | |
| 126 | 3 | 1.48 | | | | | | |
| 127 | 4 | 1.74 | | | | | | |
| 128 | 5 | 2.00 | | | | | | |
| 129 | 6 | 2.26 | | | | | | |
| 130 | 7 | 2.52 | | | | | | |
| 131 | 8 | 2.78 | | | | | | |
| 132 | 9 | 3.04 | | | | | | |
| 133 | 10 | 3.30 | | | | | | |
| 134 | 12 | 3.81 | | | | | | |
| 135 | 14 | 4.33 | | | | | | |
| 136 | 16 | 4.85 | | | | | | |
| 137 | 20 | 5.89 | | | | | | |
| 138 | | | | | | | | |
| 139 | | | | | | | | |
| 140 | | | | | | | | |



RIP-RAP WITH $D_{50}$ = 15"

NON-WOVEN GEOTEXTILE 8.6 oz/sy, AOS = 100
FLOW RATE ≥ 80 GPM/SF.
AMOCO 4553 OR
EQUIVALENT

JJS 12/14/2001

# 6 - TURNOUTS & BUFFERS

# ROAD DITCH TURNOUTS & BUFFERS:

## A - BMP DEFINITION:

### 1 - Location & Suitability:

This practice should be used on less than an acre of watershed. In addition, a spacing of more than 200 ft should be avoided if possible. If used in a situation where the drainage area exceeds one acre and the spacings exceed 200 feet then the services of an engineer is advisable.

Reference should be made to the MDOT & MDEP manuals on BMP's for Erosion & Sediment Control, and MDEP manual on storm water management, if a project is in a lake or stream watershed where water quality is an issue.

Factoring in all the considerations for locating road ditch turnouts it can be seen that good judgement is necessary. If culverts were originally located where drainage ways existed then the use of this practice would be greatly reduced. In many cases culverts were abandoned and/or combined and access to an existing drainage way lost.

### 2 - Easements:

If the receiving land is not controlled by the town with a flood easement one should be obtained before construction. If water is already entering the area and only an upgrade is planned an easement may not be required. In all cases the receiving landowner should be notified of the activity.

### 3 - BMP components:

The enclosed drawing of a Road Ditch Turnout shows the BMP to be made up of several components as described in sequence as follows.

a - <u>First</u> is a sediment trap/energy dissipator:

At the low end of the road ditch next to the shoulder a sediment trap/energy dissipator should be located which should be adjacent to the road for easy cleanout. In the sketch it shows a stone bottom. This may be undesirable for cleanout purposes. An alternate would be to increase the depth by several feet and leave the stone out of the bottom.

b - <u>Second</u> is a turnout berm:

This turnout berm should be several feet high and insures that the water does not jump over and continue down the road ditch but flows to the receiving area.

c - <u>Third</u> is a conveyance channel:

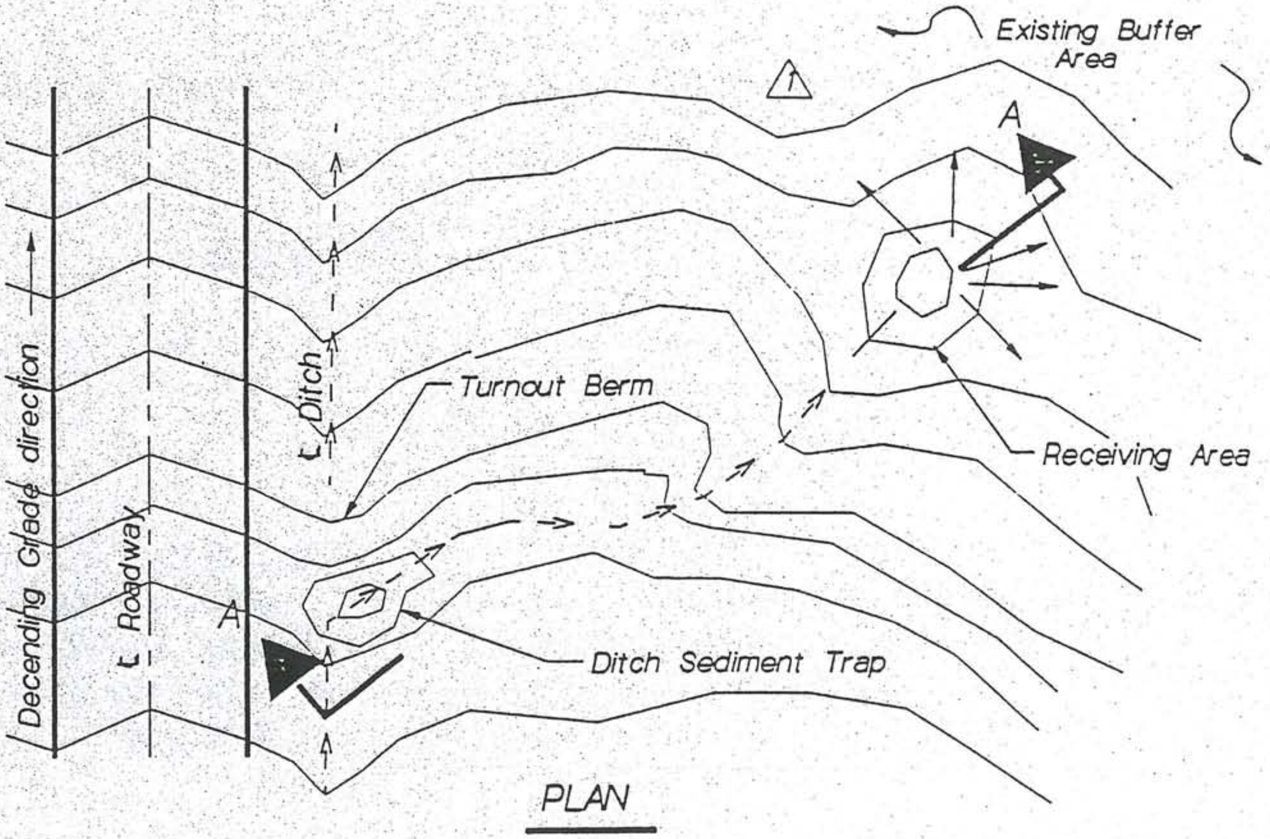
This conveyance channel down to the receiving area should be of a stable design for the soil type and use conditions anticipated.

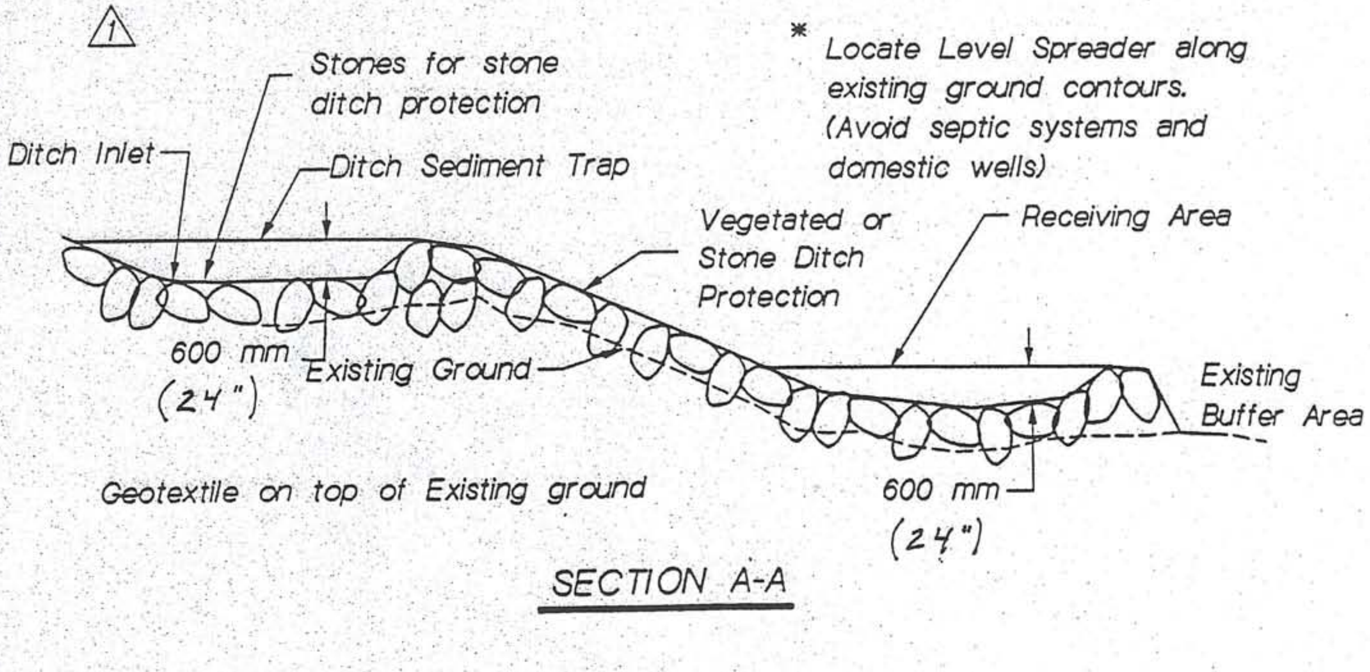
d - <u>Fourth</u> is a stone receiving area:

This stone receiving area should consist of a 2 foot deep stoned pool with a level downstream stone berm acting as a level lip spreader. The downstream stone berm of this component should be on the contour and be at least 4 ft long per cfs of design flow.

e - <u>Fifth</u> a stable well vegetated buffer/filter area:

A stable well vegetated buffer/filter area should be available downstream of the level lip to receive and treat the runoff. The receiving area should be about 1/4 acre for each acre of watershed. If a one acre maximum watershed is present an area of 0.25 acre would be needed (approximately 100' x 100').





* Locate Level Spreader along existing ground contours. (Avoid septic systems and domestic wells)

REF: Best Management Practice for Erosion and Sediment Control - Road Ditch Turnouts

Supplemental
Standard Detail

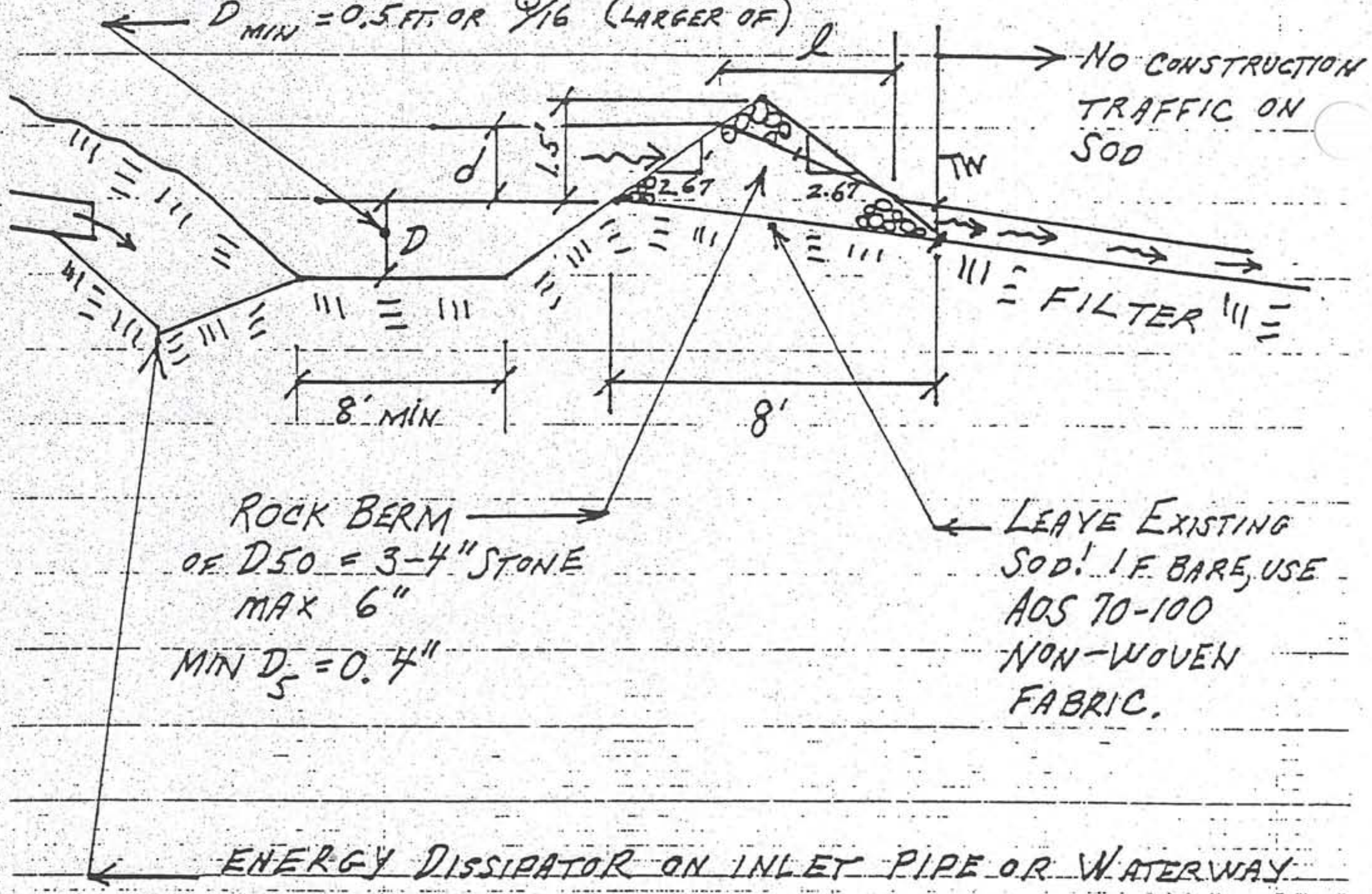
# Road Ditch Turnout

Supersedes 800(40)

1 Rev. 6/26/97

C-4

## ROCKED BERMED LEVEL LIP



ROCK BERM OF D50 = 3-4" STONE
MAX 6"
MIN $D_5$ = 0.4"

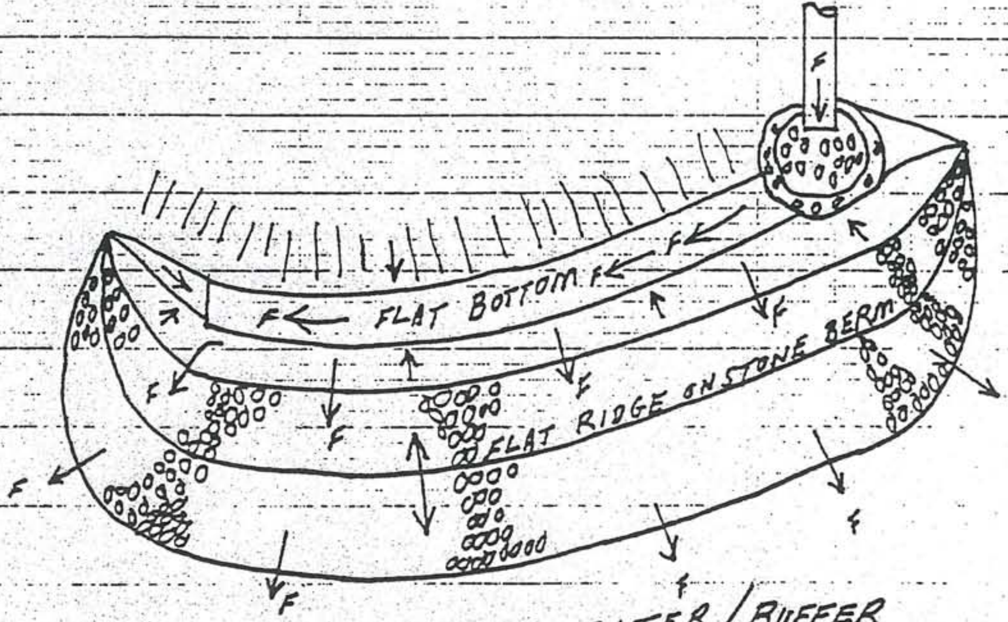
LEAVE EXISTING SOD! IF BARE, USE AOS 70-100 NON-WOVEN FABRIC.

ENERGY DISSIPATOR ON INLET PIPE OR WATERWAY

X - SECTION

LENGTH REQUIREMENTS:

1 - USE 20 FT / CFS FOR WATER QUALITY.
2 - USE 4 FT / CFS FOR EROSION CONTROL.



VEGETATED FILTER / BUFFER

PLAN VIEW

JJS 11/96

# 7 - APPENDIX

# WIRE AND SHEET METAL GAGES

## IN DECIMALS OF AN INCH

| Name of Gage | United States Standard Gage* | | The United States Steel Wire Gage | American or Brown & Sharpe Wire Gage | New Birmingham Standard Sheet & Hoop Gage | British Imperial or English Legal Standard Wire Gage | Birmingham or Stubs Iron Wire Gage | Name of Gage |
|---|---|---|---|---|---|---|---|---|
| Principal Use | Uncoated Steel Sheets and Light Plates | | Steel Wire except Music Wire | Non-Ferrous Sheets and Wire | Iron and Steel Sheets and Hoops | Wire | Strips, Bands, Hoops and Wire | Principal Use |
| Gage No. | Weight Oz. per Sq. Ft. | Approx. Thickness Inches | Thickness, Inches | | | | | Gage No. |
| 7/0's | | | .4900 | | .6666 | .500 | | 7/0's |
| 6/0's | | | .4615 | .5800 | .625 | .464 | | 6/0's |
| 5/0's | | | .4305 | .5165 | .5883 | .432 | .500 | 5/0's |
| 4/0's | | | .3938 | .4600 | .5416 | .400 | .454 | 4/0's |
| 3/0's | | | .3625 | .4096 | .500 | .372 | .425 | 3/0's |
| 2/0's | | | .3310 | .3648 | .4452 | .348 | .380 | 2/0's |
| 0 | | | .3065 | .3249 | .3964 | .324 | .340 | 0 |
| 1 | | | .2830 | .2893 | .3532 | .300 | .300 | 1 |
| 2 | | | .2625 | .2576 | .3147 | .276 | .284 | 2 |
| 3 | 160 | .2391 | .2437 | .2294 | .2804 | .252 | .259 | 3 |
| 4 | 150 | .2242 | .2253 | .2043 | .250 | .232 | .238 | 4 |
| 5 | 140 | .2092 | .2070 | .1819 | .2225 | .212 | .220 | 5 |
| 6 | 130 | .1943 | .1920 | .1620 | .1981 | .192 | .203 | 6 |
| 7 | 120 | .1793 | .1770 | .1443 | .1764 | .176 | .180 | 7 |
| 8 | 110 | .1644 | .1620 | .1285 | .1570 | .160 | .165 | 8 |
| 9 | 100 | .1495 | .1483 | .1144 | .1398 | .144 | .148 | 9 |
| 10 | 90 | .1345 | .1350 | .1019 | .1250 | .128 | .134 | 10 |
| 11 | 80 | .1196 | .1205 | .0907 | .1113 | .116 | .120 | 11 |
| 12 | 70 | .1046 | .1055 | .0808 | .0991 | .104 | .109 | 12 |
| 13 | 60 | .0897 | .0915 | .0720 | .0882 | .092 | .095 | 13 |
| 14 | 50 | .0747 | .0800 | .0641 | .0785 | .080 | .083 | 14 |
| 15 | 45 | .0673 | .0720 | .0571 | .0699 | .072 | .072 | 15 |
| 16 | 40 | .0598 | .0625 | .0508 | .0625 | .064 | .065 | 16 |
| 17 | 36 | .0538 | .0540 | .0453 | .0556 | .056 | .058 | 17 |
| 18 | 32 | .0478 | .0475 | .0403 | .0495 | .048 | .049 | 18 |
| 19 | 28 | .0418 | .0410 | .0359 | .0440 | .040 | .042 | 19 |
| 20 | 24 | .0359 | .0348 | .0320 | .0392 | .036 | .035 | 20 |
| 21 | 22 | .0329 | .0318 | .0285 | .0349 | .032 | .032 | 21 |
| 22 | 20 | .0299 | .0286 | .0253 | .0313 | .028 | .028 | 22 |
| 23 | 18 | .0269 | .0258 | .0226 | .0278 | .024 | .025 | 23 |
| 24 | 16 | .0239 | .0230 | .0201 | .0248 | .022 | .022 | 24 |
| 25 | 14 | .0209 | .0204 | .0179 | .0220 | .020 | .020 | 25 |
| 26 | 12 | .0179 | .0181 | .0159 | .0196 | .018 | .018 | 26 |
| 27 | 11 | .0164 | .0173 | .0142 | .0175 | .0164 | .016 | 27 |
| 28 | 10 | .0149 | .0162 | .0126 | .0156 | .0148 | .014 | 28 |
| 29 | 9 | .0135 | .0150 | .0113 | .0139 | .0136 | .013 | 29 |
| 30 | 8 | .0120 | .0140 | .0100 | .0123 | .0124 | .012 | 30 |
| 31 | 7 | .0105 | .0132 | .0089 | .0110 | .0116 | .010 | 31 |
| 32 | 6.5 | .0097 | .0128 | .0080 | .0098 | .0108 | .009 | 32 |
| 33 | 6 | .0090 | .0118 | .0071 | .0087 | .0100 | .008 | 33 |
| 34 | 5.5 | .0082 | .0104 | .0063 | .0077 | .0092 | .007 | 34 |
| 35 | 5 | .0075 | .0095 | .0056 | .0069 | .0084 | .005 | 35 |
| 36 | 4.5 | .0067 | .0090 | .0050 | .0061 | .0076 | .004 | 36 |
| 37 | 4.25 | .0064 | .0085 | .0045 | .0054 | .0068 | | 37 |
| 38 | 4 | .0060 | .0080 | .0040 | .0048 | .0060 | | 38 |
| 39 | | | .0075 | .0035 | .0043 | .0052 | | 39 |
| 40 | | | .0070 | .0031 | .0039 | .0048 | | 40 |

* U. S. Standard Gage is officially a weight gage, in oz. per sq. ft. as tabulated. The Approx. Thickness shown is the "Manufacturers' Standard" of the American Iron and Steel Institute, based on steel as weighing 501.81 lbs. per cu. ft. (489.6 true weight plus 2.5 percent for average over-run in area and thickness). The A.I.S.I. standard nomenclature for flat rolled carbon steel is as follows:

| Widths, Inches | Thicknesses, Inch | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.2500 and thicker | 0.2499 to 0.2031 | 0.2030 to 0.1875 | 0.1874 to 0.0568 | 0.0567 to 0.0344 | 0.0343 to 0.0255 | 0.0254 to 0.0142 | 0.0141 and thinner |
| To 3½ incl. | Bar | Bar | Strip | Strip | Strip | Strip | Sheet | Sheet |
| Over 3½ to 6 incl. | Bar | Bar | Strip | Strip | Strip | Sheet | Sheet | Sheet |
| " 6 to 12 " | Plate | Strip | Strip | Strip | Sheet | Sheet | Sheet | Sheet |
| " 12 to 32 " | Plate | Sheet | Sheet | Sheet | Sheet | Sheet | Sheet | Black Plate |
| " 32 to 48 " | Plate | Sheet | Sheet | Sheet | Sheet | Sheet | Sheet | Sheet |
| " 48 | Plate | Plate | Plate | Sheet | Sheet | Sheet | Sheet | — |

# OUTLINING WATERSHEDS:

ON TOPOGRAPHIC MAPS...

1 - THE LINE ALWAYS TRAVELS

PERPENDICULAR TO THE CONTOURS,

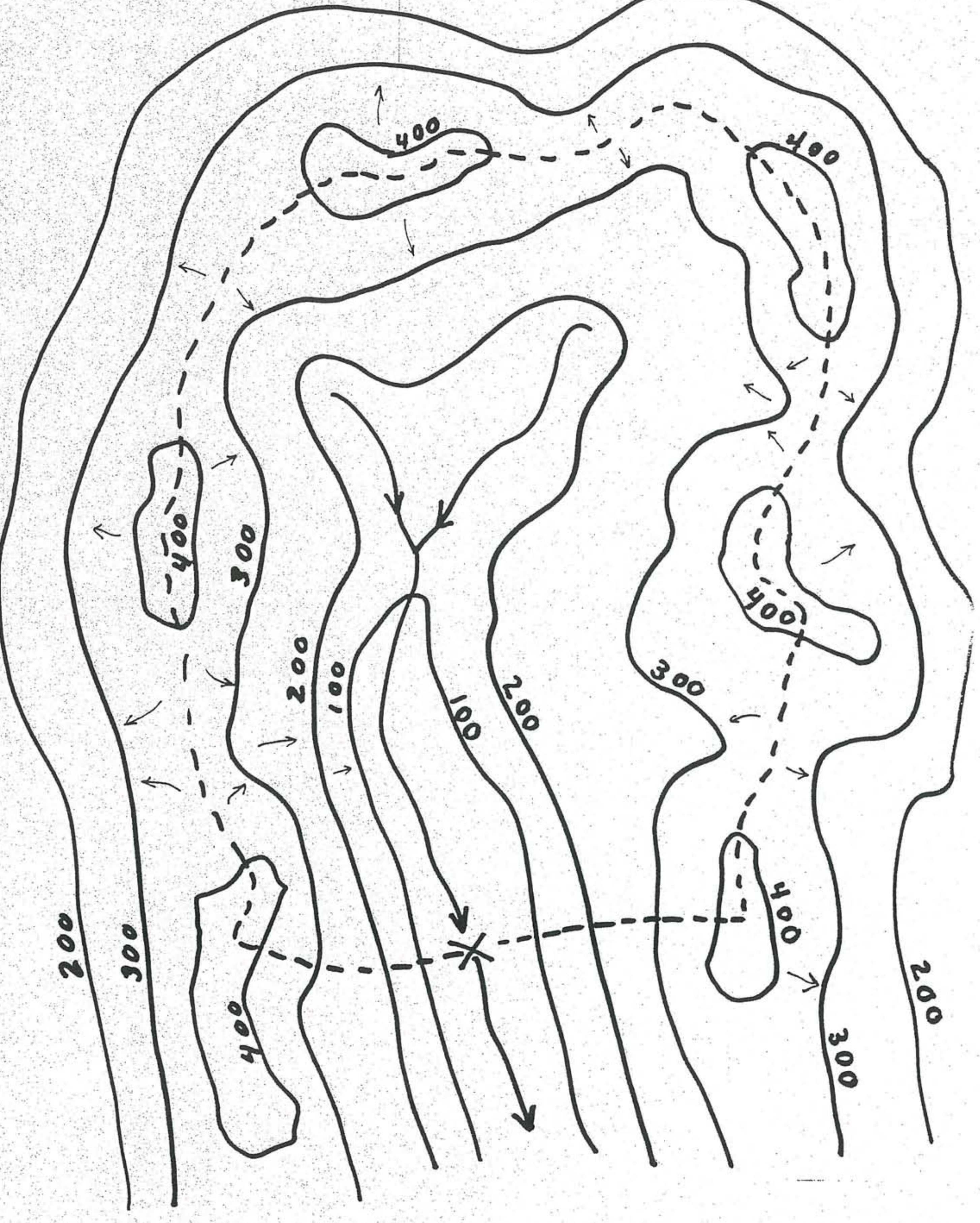
EXCEPT

2 - WHEN THE LINE TRAVELS PARALLEL

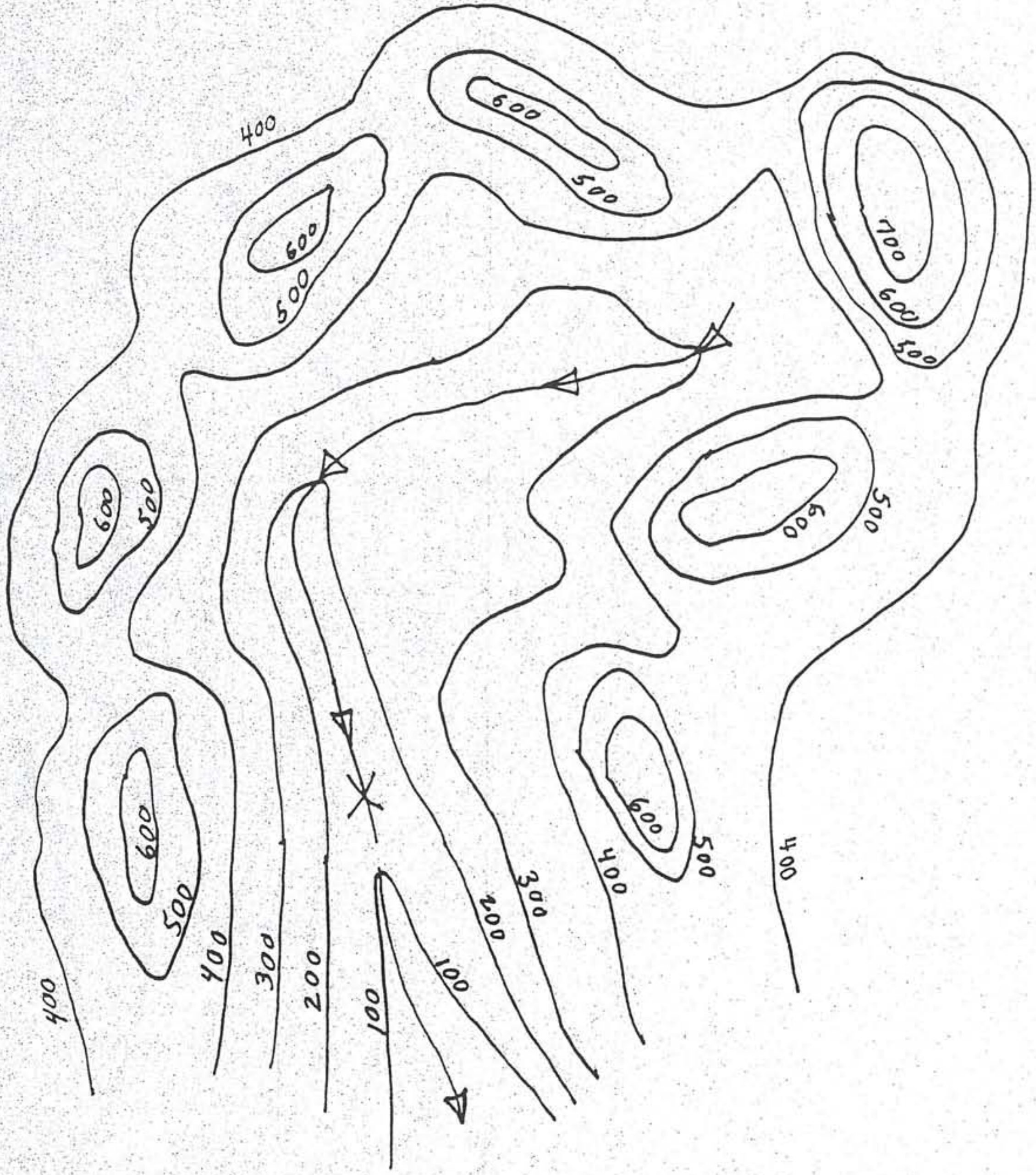
TO LINES OF <u>EQUAL</u> ELEVATION.

## NOTE:

START WATERSHED DELINEATION AT THE DESIGN POINT ON A DRAINAGE WAY AND TRAVEL UP EACH ABUTMENT UNTIL THE TWO LINES EVENTUALLY COME TOGETHER AT SOME POINT.

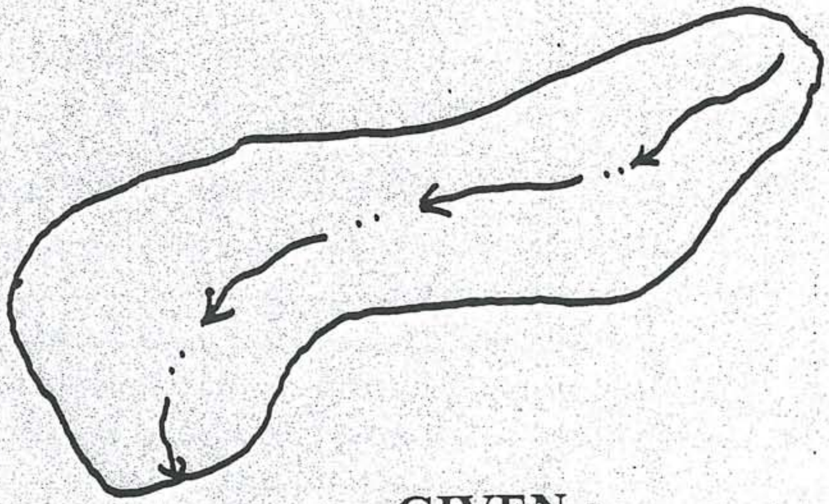

400
400
400
300
400
300
200
100
100
200
200
300
400
400
300
200

# EXAMPLE



SCALE 1:24 000 i.e. 1" = 2 000 FT

# TEST 1



## GIVEN :

SCALE, 1" = 6,000" or 1 : 6,000 or 1" = 500 ft.

Therefore 1 sq.in. = _______ sq.ft. Or _______ acres.

Hint .... 1 acre = 43,560 sq.ft.

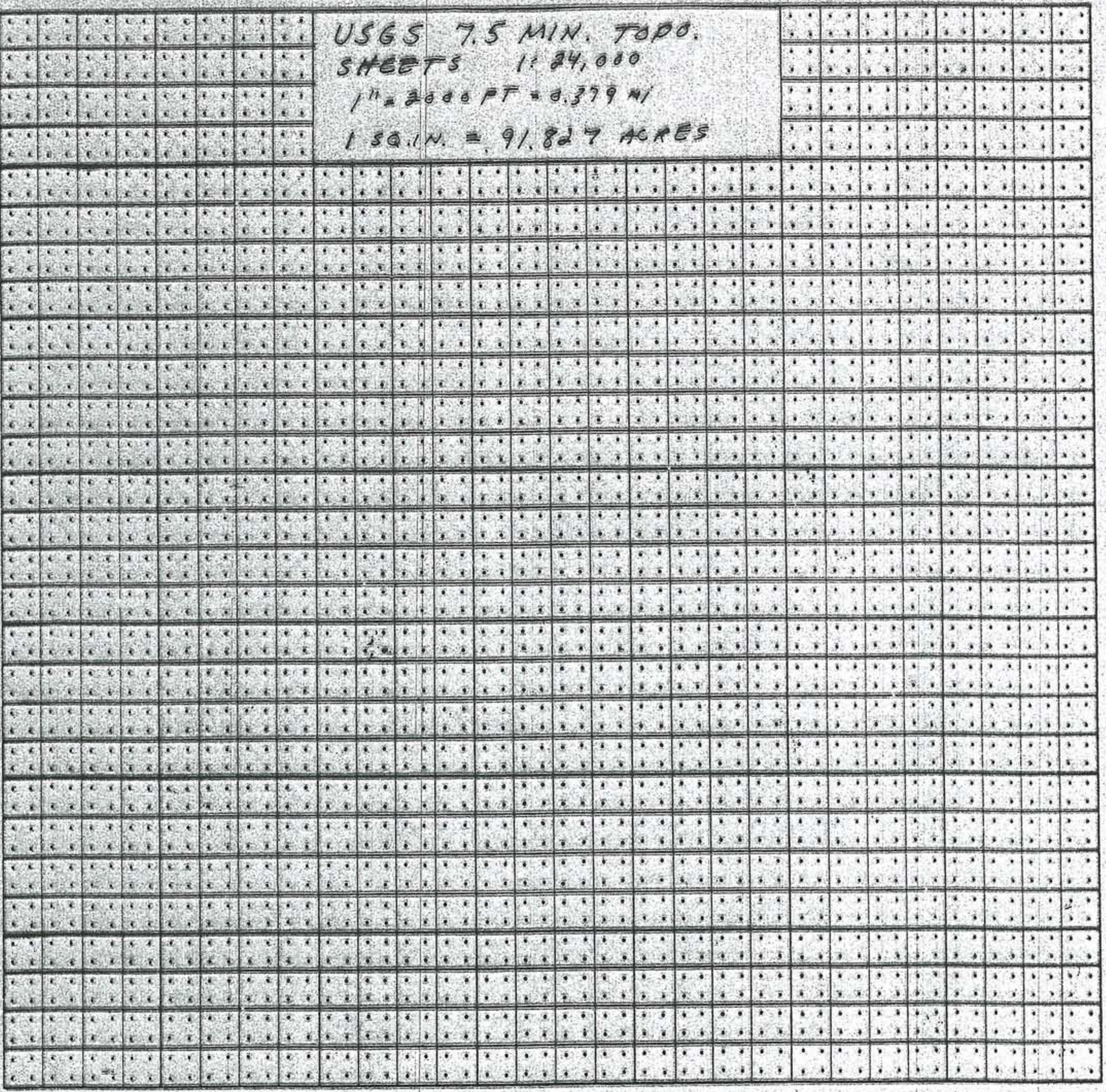
## DETERMINE :

Drainage Area of Watershed
= _____ dots
=_____ _ sq.in

Drainage Area of Watershed ? = ______ acres ?

# ACREAGE CALCULATING GRID
## FOR ANY SCALE

1320



USGS 7.5 MIN. TOPO.
SHEETS 1:24,000
1" = 2000 FT = 0.379 MI
1 SQ. IN. = 91.827 ACRES

( 64 dots per square inch. )

To be used for acreage determinations on maps of any scale. Place grid over area to be measured; count dots, multiply by converting factor to compute total acreage. When dots fall on area boundary, count alternate dots.

| MAP SCALES AND EQUIVALENTS | | | |
|---|---|---|---|
| Fractional Scale | Inches Per Mile | Acres Per Square Inch | Converting Factor Each Dot Equals |
| 1" = 7,920" | 8.00 | 10.000 | 0.156 Acres |
| 1" = 9,600" | 6.60 | 14.692 | 0.230 Acres |
| 1" = 15,840" | 4.00 | 40.000 | 0.625 Acres |
| 1" = 20,000" | 3.168 | 63.769 | 0.996 Acres |
| 1" = 31,680" | 2.00 | 160.000 | 2.500 Acres |
| 1" = 63,360" | 1.00 | 640.000 | 10.000 Acres |
| 1" = 125,000" | 0.507 | 2,490,980 | 38.922 Acres |
| 1" = 250,000" | 0.253 | 9,963,906 | 155.686 Acres |
| 1" = 500,000" | 0.127 | 39,855,627 | 622.744 Acres |

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

1-10,359

# TEST 2

## GIVEN:

Scoured flow area (FA) = 2.2 sq.ft.

## FIND:

Diameter of culvert for the 2, 10, 50, and 100 year storm.

D = ( 1.27 x FA x FAM ) ^ 0.5 SEE PG 2-3

FA in sq.ft. , D in ft.

D2 = (1.27 x 2.2 x 1) ^ 0.5 = ____ ft., use ____ inches.

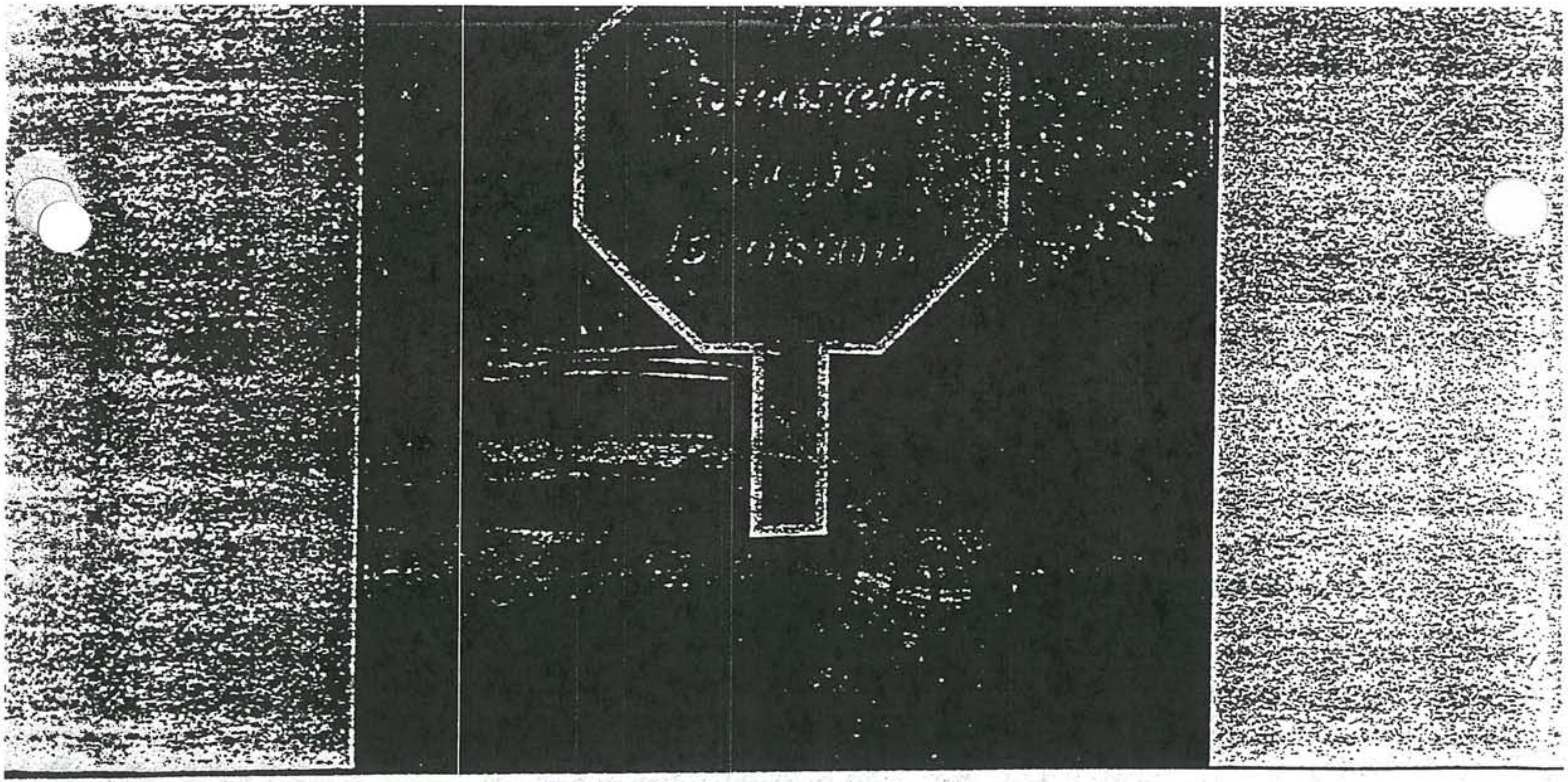
D10 = (1.27 x 2.2 x 2) ^ 0.5 = ____ ft., use ____ inches

D50 = (1.27 x 2.2 x 3) ^ 0.5 = ____ ft., use ____ inches

D100 = (1.27 x 2.2 x 4) ^ 0.5 = ____ ft., use ____ inches

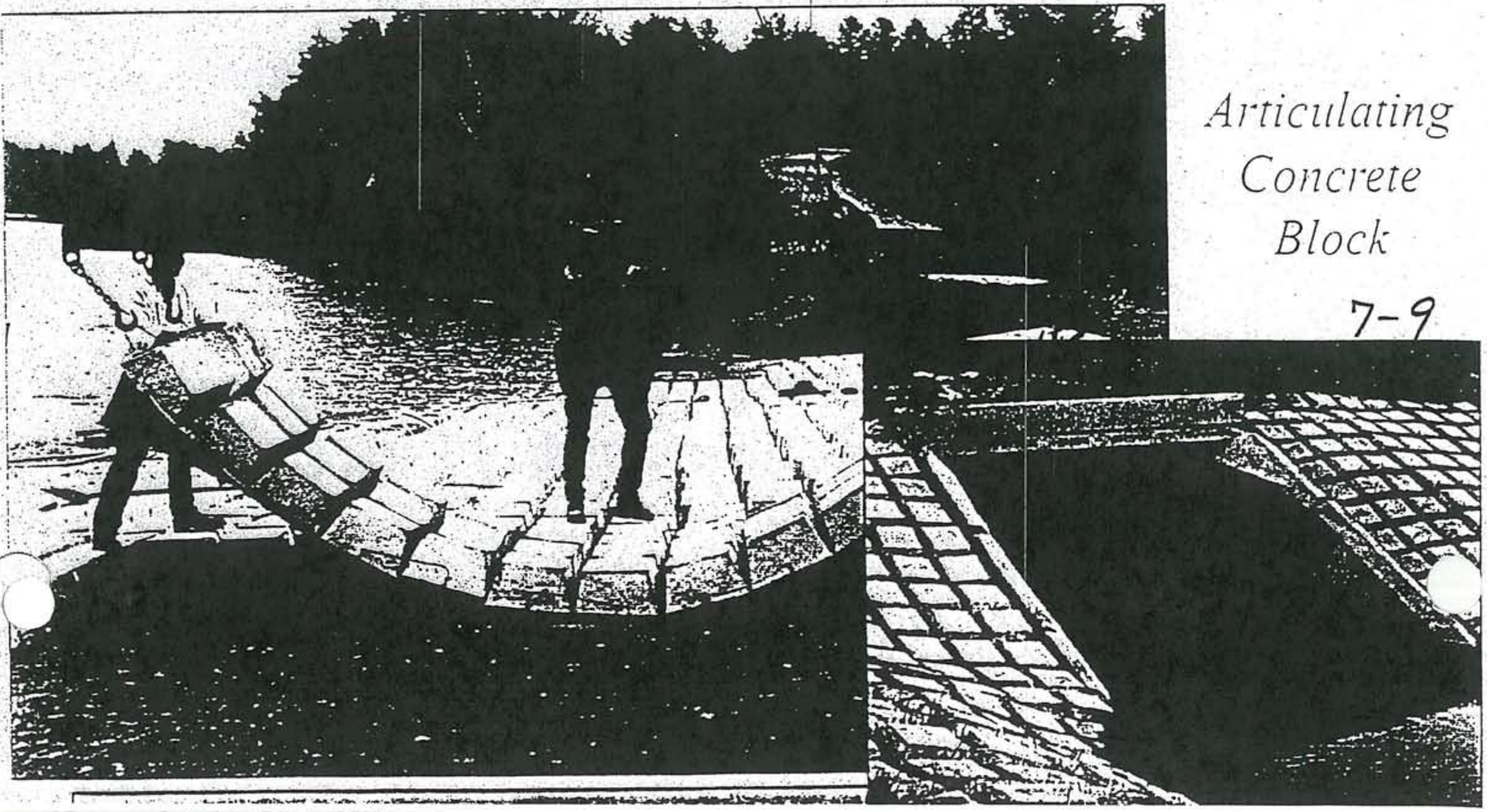
Find the diameter of three culvert pipes that would be needed to replace the single culvert for the 10 year storm. SEE PG 3-6

D10(3) = __________ inches.



# Cable Concrete

International Erosion Control Systems L.L.C.



*Articulating*
*Concrete*
*Block*

7-9

# TEST 3

## GIVEN:

DESIGN A WATERWAY FOR:

- * THE W/S IN TEST 1, FOR A 50 YR STORM
- * THAT IS ON EROSIVE SANDY SOIL,
- * HAS A 7 % SLOPE (S).

Drainage Area (AC) = 28
cfs/AC (Page 2-3) = __________
Discharge (cfs) = __________

Liner type = ____________________, vx = ________
"n" for design = __________
va (page 4-3) for "n" & S = __________ (fps)

IS va > vx ? If yes then select a new liner, "n", and vx.

If no, ... find width of 1 foot deep channel:

$$W = \frac{1.5 \text{ x discharge (cfs)}}{\text{va (fps)}} = \text{------------} =$$

| A | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | USE 10 YR STORM | | | | | |
| 2 | | | | | | | | | |
| 3 | | Ditch data for highway crew design workshop @ Norway, Me. 4/7/1999 by JJS | | | | | | | |
| 4 | | | | | | | | | |
| 5 | Ditch No. | Drainage | Channel | Soil type | Liner type | "n" used | Max. Vel. | Flow | Flow |
| 6 | | Area - Ac | grade % | | | | | Depth-ft. | Width-ft. |
| 7 | | | | | | | | | |
| 8 | 1 | 3 | 5 | sand | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | 2 | 7 | 5 | sand | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |
| 16 | 3 | 37 | 7 | clay | | | | | |
| 17 | | | | | | | | | |
| 18 | | | | | | | | | |
| 19 | | | | | | | | | |
| 20 | 4 | 51 | 12 | till | | | | | |
| 21 | | | | | | | | | |
| 22 | | | | | | | | | |
| 23 | | | | | | | | | |
| 24 | | | | | | | | | |
| 25 | | | Ditch # 1 Cross Section Below | | | | | | |
| 26 | | | | | | | | | |
| 27 | | | | | | | | | |
| 28 | | | | | | | | | |
| 29 | | | | | | | | | |
| 30 | | | | | | | | | |
| 31 | | | Ditch # 2 Cross Section Below | | | | | | |
| 32 | | | | | | | | | |
| 33 | | | | | | | | | |
| 34 | | | | | | | | | |
| 35 | | | | | | | | | |
| 36 | | | | | | | | | |
| 37 | | | Ditch # 3 Cross Section Below | | | | | | |
| 38 | | | | | | | | | |
| 39 | | | | | | | | | |
| 40 | | | | | | | | | |
| 41 | | | | | | | | | |
| 42 | | | | | | | | | |
| 43 | | | Ditch # 4 Cross Section Below | | | | | | |
| 44 | | | | | | | | | |
| 45 | | | | | | | | | |
| 46 | | | | | | | | | |
| 47 | | | | | | | | | |
| 48 | | | | | | | | | |
| 49 | | | | | | | | | |
| 50 | REMINDER: Riprap is placed in a layer that is 2.25 x D50 thick. Max. Rock is 1.5 x D50. | | | | | | | | |

SEE PG 4-3

| A | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | Culvert Data for highway crew design workshop @ Norway, Me. 4/7/99 by JJS | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | Diameter | Diameter | Capacity | <<< TABLE 1 >>> | | Diameter | Diameter | Capacity | |
| 6 | -inches- | -feet- | -cfs- | | | -inches- | -feet- | -cfs- | |
| 7 | | | | Based on 1 foot | | | | | |
| 8 | 12 | 1 | 4.63 | of depth above | | 36 | 3 | 53.79 | |
| 9 | 15 | 1.25 | 7.53 | the inlet top | | 42 | 3.5 | 76.79 | |
| 10 | 18 | 1.5 | 11.25 | and orifice flow | | 48 | 4 | 104.75 | |
| 11 | 21 | 1.75 | 15.85 | control. | | 54 | 4.5 | 137.99 | |
| 12 | 24 | 2 | 21.38 | | | 60 | 5 | 176.79 | |
| 13 | 27 | 2.25 | 27.9 | | | 72 | 6 | 272.16 | |
| 14 | 30 | 2.5 | 35.44 | | | 84 | 7 | 392.91 | |
| 15 | | | | | | | | | |
| 16 | D1(fa) = (1.27 x FA x FAM) ^ 0.5 | | | | | Storm | | FAM | |
| 17 | | | | | | Frequency | | | |
| 18 | FA = in-bank stream flow area in Sq. Ft. | | | | | 2 Year | | 1 | |
| 19 | FAM = flow area multiplier based on frequency. | | | | | 10 Year | | 2 | |
| 20 | D1=single culvert, D2=double culvert, D3=triple culve | | | | | 50 Year | | 3 | |
| 21 | | | | | | 100 Year | | 3.5 | |
| 22 | | | REMINDER | | | | | | |
| 23 | D2 = (D1^2/2)^0.5 | | or | D2 = 0.707 x D1 | | | | | |
| 24 | D3 = (D1^2/3)^0.5 | | or | D3 = 0.577 x D1 | | | | | |
| 25 | | | | | | | | | |
| 26 | | | | | | 10 Year | 10 Year | | Selected |
| 27 | DA# @ | # of dots | DA-acres | 10 year | In-Bank | Diameter | Diameter | Diameter | Diameter |
| 28 | PG. 2-5 | in WS | | peak-cfs | flow area | in inches | based on | based on | chosen |
| 29 | | from grid | | | FA(sq.ft.) | using FA | 10yr-q | MDOT | from col. |
| 30 | | | | | | | & Tbl 1 | rule 8+ac. | F,G, or H |
| 31 | 1 | | | | | | | | |
| 32 | 2 | | | | | | | | |
| 33 | 3 | | | | | | | | |
| 34 | 4 | | | | | | | | |
| 35 | 5 | | | | | | | | |
| 36 | 2,3,4 | | | | | | | | |

# TURNOUT DESIGN EXAMPLE

A turnout is receiving a flow of 5 cfs from a road ditch that is planned to be dispersed into the adjoining wooded area. Flowage easements are available. The drainage area is 0.8 acres.

**Given**:

1 - the slope of the ground from the road ditch out to level lip spreader (LLS) location is 5%.

2 - the distance out to the level lip location is 50 ft.

3 - soil is a sandy loam.

**Determine**:

1 - the liner type for the channel from the road ditch out to the level lip spreader (LLS).

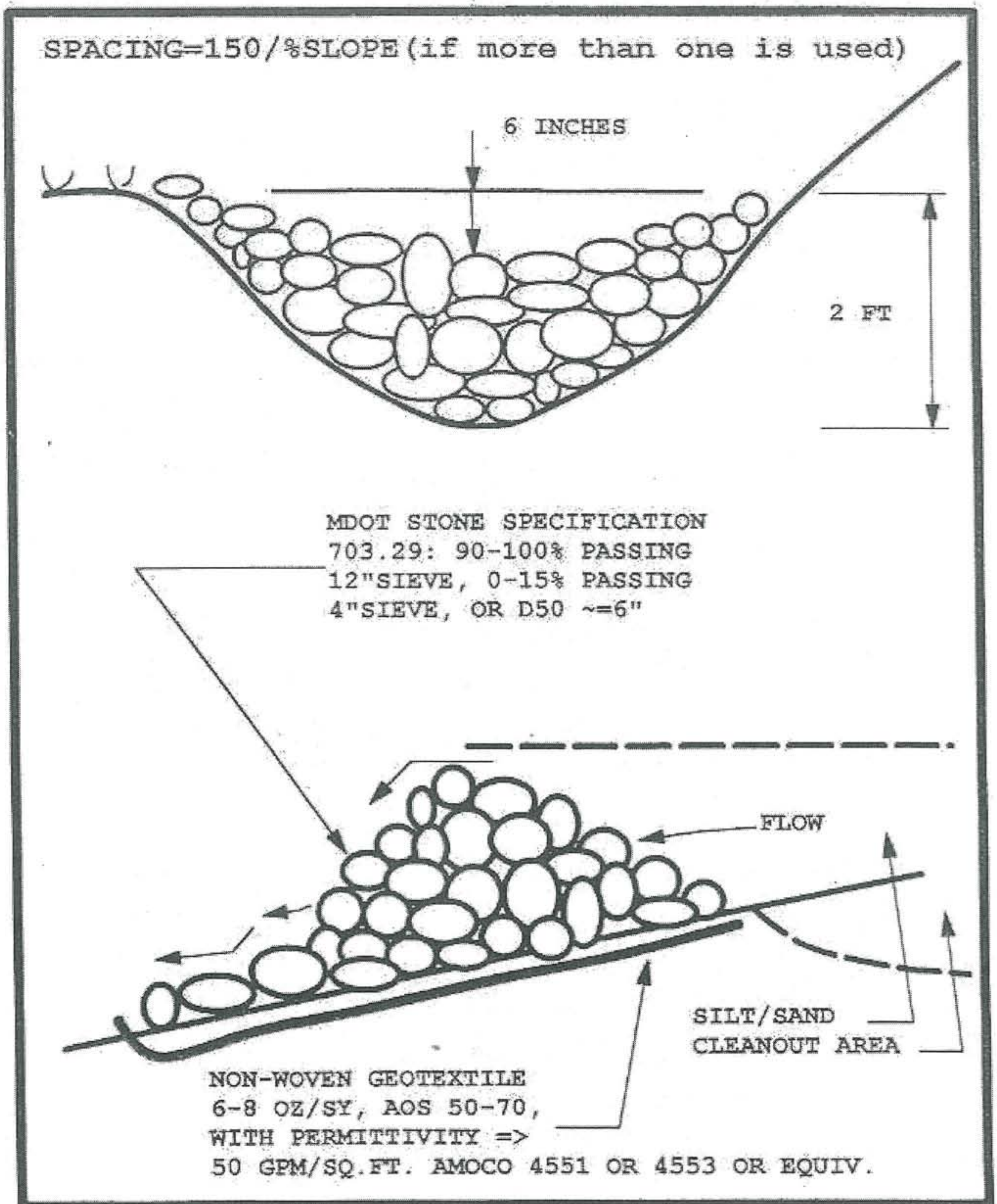
2 - the channel flow cross section.

3 - the length of the level lip spreader.

4 - the minimum area downslope from the level lip spreader that must be available.

# SKETCH SYSTEM BELOW

JJS 03/30/1999



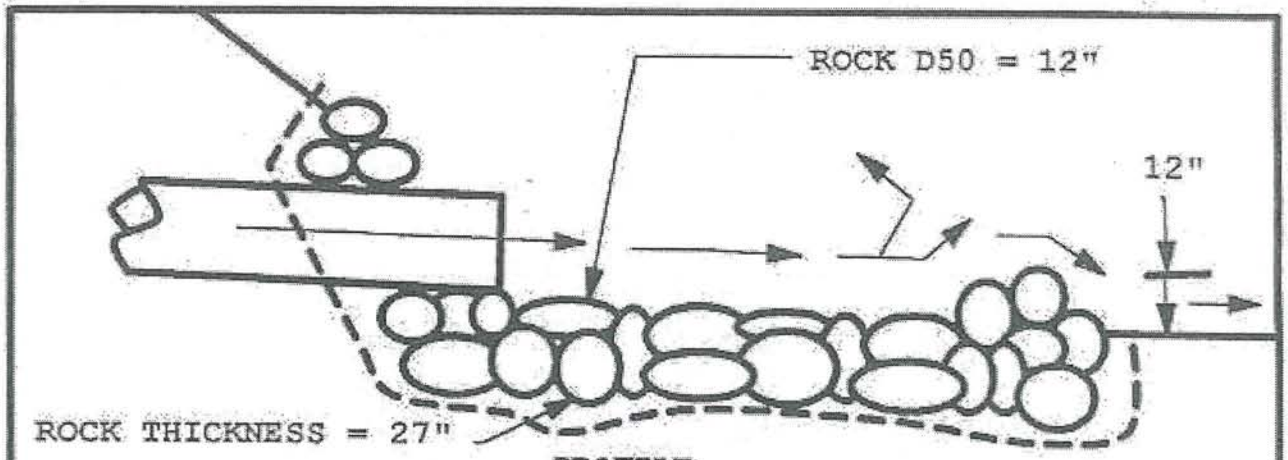
SPACING=150/%SLOPE(if more than one is used)

MDOT STONE SPECIFICATION
703.29: 90-100% PASSING
12"SIEVE, 0-15% PASSING
4"SIEVE, OR D50 ~=6"

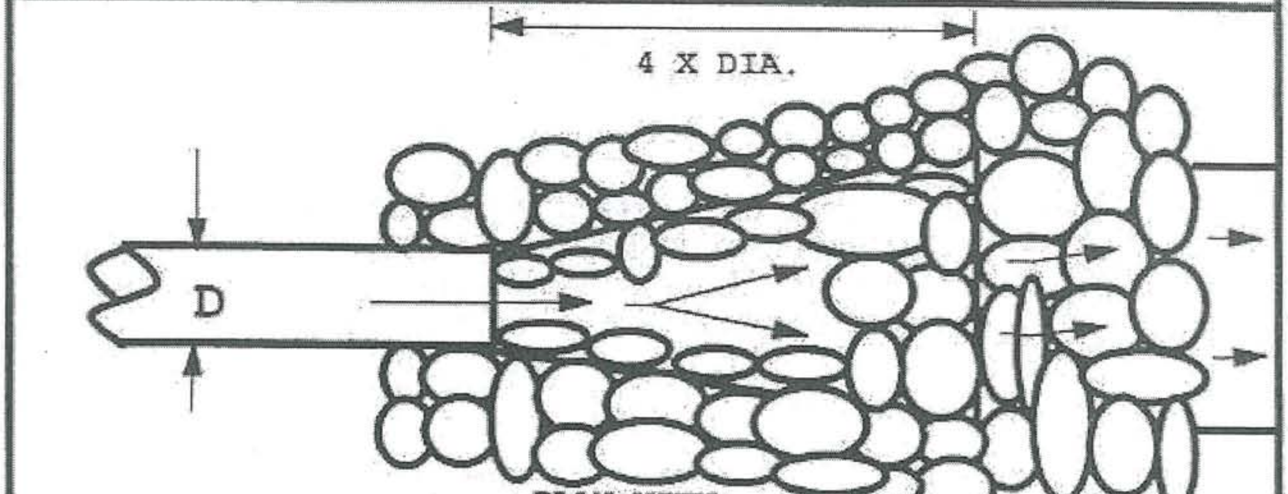
NON-WOVEN GEOTEXTILE
6-8 OZ/SY, AOS 50-70,
WITH PERMITTIVITY =>
50 GPM/SQ.FT. AMOCO 4551 OR 4553 OR EQUIV.

PERMANENT ROAD DITCH CHECK DAM

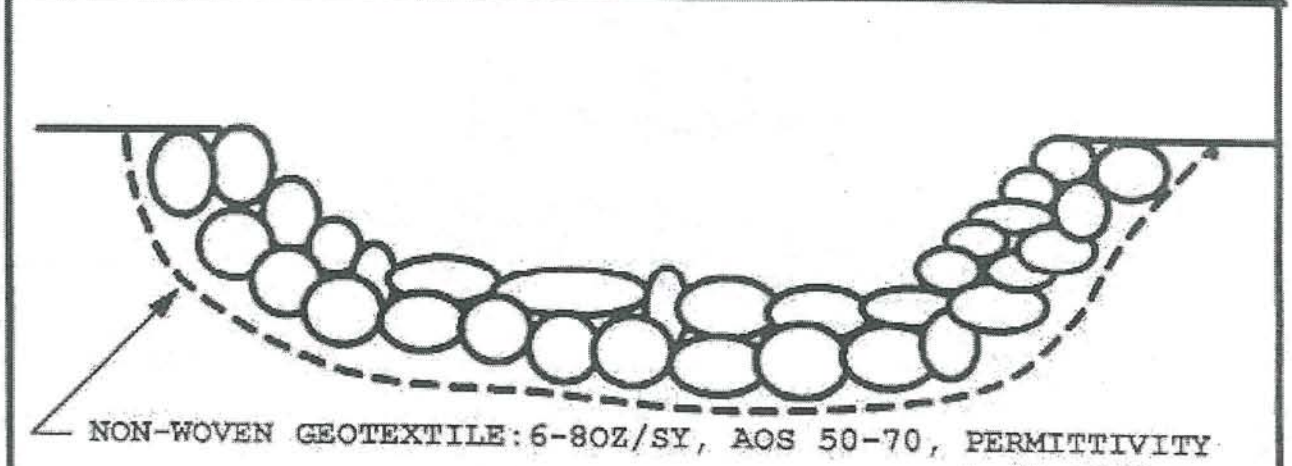
BY JOHN J. SIMON OF BALANCED ENGINEERING 10-21-1999



PROFILE



PLAN VIEW



CROSS SECTION

## ROCK APRON AT CULVERT OUTLETS

BY JOHN J. SIMON OF BALANCED EINGINEERING 10-22-1999

# 8 - GLOSSARY

# GLOSSARY

CUBIC FEET PER SECOND (cfs): A rate of flow of water passing a selected point. 1 cfs is equal to 448.8 gallons per minute or about equal to the flow from a standard 500gpm fire hose.

DRAINAGE AREA (DA): The size of a watershed or sub-watershed often expressed in acres or in square miles. i.e. There are 640 acres in a square mile.

FLOW AREA (FA): Flow area is meant as the size of an area of a valley occupied by a section devoid of vegetation that is kept scoured out by frequent flows of a magnitude less than about a 2 year storm (at least in Maine for small streams).

FLOW AREA MULTIPLIER (FAM): The flow area multiplier is a number indicating the approximate magnitude of the flow area needed for a culvert to carry a large storm of a selected return interval in relation to the 2 year storm event.

GREATER THAN (>): A symbol which indicates that a value before the symbol > is greater than the value after the symbol.

LESS THAN (<): A symbol which indicates that a value before the symbol < is less than the value after the symbol.

MANNINGS ROUGHNESS COEFFICIENT (n): A roughness coefficient used in the mannings' hydraulic formula that gives a value of roughness for the inside perimeter of a pipe or the perimeter of a flow channel.

NEUTRAL SLOPE (Sn): A term related to conduits and culverts that indicates whether the pipe barrel is likely to flow full or be limited in flow by the nature of the inlet.

A pipe on a slope greater than neutral slope (S > Sn) <u>gains</u> more gravity energy from the slope of the conduit than it <u>looses in barrel friction. Therefore it will not flow full.</u> Flow conditions are controlled at the inlet by the diameter and shape of the inlet.

A pipe on a slope less than neutral slope (S < Sn) <u>looses</u> more energy to friction along the length of the barrel than it <u>gains</u> in gravity energy from the slope of the pipe. Therefore if flows full and the barrel diameter, roughness, and length influence the capacity of the conduit. Inlet conditions do not govern here.

PERCENT PASSING (D%): A soil mechanics term indicating the percentage of a soil sample that passes a specific size of screen. A D50 of 6" indicates that 50% of the sample passes through a screen that has 6" square holes in it. A D10 of 1/4" indicates a gravelly material that has only 10% of the sample passing a grid or screen with 0.25" square holes in it.

PIPING: A term used in soil mechanics to identify the situation when seepage water through an embankment, foundation, abutment, and or along a conduit through an embankment, is strong enough to remove fine soil particles. The process continues as more and more fines removed increases the permeability which increases piping etc. until failure. Piping can also occur along conduits where the fines from the embankment are washed through the pipe joints or corroded areas of the conduit.

SOIL COVER COMPLEX NUMBER (CN): A composite number which represents the hydrologic potential for producing surface runoff from a precipitation event. The higher the number the greater percentage of rainfall ends up as surface runoff. The CN reflects the soil type and the underlying soil materials plus the type of soil cover existing which can shield the soil from rainfall and hold it in place from overland flow.

VELOCITY - MAXIMUM ALLOWABLE (Vx): The velocity in feet per second (fps) that a material should be able to withstand with out observable erosion that would create a need for repair.

VELOCITY - ACTUAL (Va): The velocity in feet per second (fps) that will actually exist given the slope, roughness, and configuration (area and perimeter) of the channel or pipe.

WATERSHED (W/S): An area of land for which all of the surface runoff from the land area flows by a selected design point on a stream or drainage way. The size of a watershed or sub-watershed is commonly referred to as a drainage area.