Stream Crossings, Culvert Crossings and Limited Access Points

Survey, Design and Installation
A well constructed crossing can serve multiple purposes and still protect the stream from direct access by livestock. This crossing provides access to another boundary, and provides an emergency water source for both boundaries.
Culvert crossings also protect the streams from direct livestock access but do not have the multiple benefits of a stream crossing. They are also more difficult to maintain.
Limited Accesses are essentially ½ of a stream crossing. They are another method of providing water to a boundary. Other sources of water should be investigated before considering a limited access point.
Stream Crossing Design
Stream Crossings

A. Site Selection Considerations

1. Location of existing crossings in field
   a) The landowner and/or livestock will generally find a good location for a crossing.

2. Channel bottom
   a) Armor is not required on the stream bottom if it is firm and stable.

3. Stream bank height
   a) A higher bank equals a longer crossings... which equals more expense.
   b) It also complicates locating the crossing because of the length of the ramps.

4. Channel slope
   a) Steep channel slopes mean higher flow velocities and will require larger base rock.
   b) Placing a crossing through an area of pooled water could result in possible sediment deposition on the crossing.

5. Surrounding topography
   a) Will a reasonable catch point be found for the 8:1 slope or can the crossing be angled to achieve a reasonable catch point.

6. Existing trees
   a) Preserve as many trees as possible to keep the stream banks stable. Also removing trees means disposing of tree and root ball somewhere. All waste material including excavated soil will be disposed of out of the floodplain.
B. **Survey Data** (print and use as a check list)

1. Cross Section of stream along centerline of planned crossing.
2. Profile of stream U/S and D/S of centerline.
3. Approximate angle of turns (if any) in crossing.
4. Stake centerline and label stakes with centerline station.
5. Do a site investigation along streambank.
6. Determine the “n” value of the stream or describe the channel in enough detail to determine “n” in office.
7. Take pictures of site to document existing conditions.
8. Draw a sketch in the field book showing:
   a) Magnetic North.
   b) TBM location and description.
   c) Stream flow direction.
   d) Centerline of crossing and direction of stationing.
   e) Existing fences or structures. (if any)
   f) Show angles on centerline (if any) and station of angle point.
   g) Planned crossing width.
   h) Location of soil borings or test pits.
My survey notekeeping format for stream crossings. Cross section data on left page. Profile data on right page aligned with the station it was taken on. Sketch on bottom of left page. Centerline station of stream is noted on sketch as well as stations with stakes set. Note that the D/S profile shot was only 45' downstream instead of the normal 50'. Brush was blocking the view at 50' so it was taken (and noted) at 45'. Also the profile shots should be taken from riffle to riffle, not in pooled or ponded water.
“n” Values

“n” is the **Channel Roughness Coefficient** used in Manning's Equation.

“n” varies from reach to reach of the stream. It is a measure of how much resistance the water flow receives from the streambed, stream shape and vegetation. Unfortunately “n” is a judgment call. You will have to try and select the best value for the stream you are working on. The next slides are some examples of guides to estimating “n”.
VI. Natural stream channels:

A. Minor streams (surface width at flood stage less than 100 ft.):
   1. Fairly regular section:
      a. Some grass and weeds, little or no brush................... 0.030–0.035
      b. Dense growth of weeds, depth of flow materially greater than weed height... 0.035–0.05
      c. Some weeds, light brush on banks.......................... 0.035–0.05
      d. Some weeds, heavy brush on banks.......................... 0.05–0.07
      e. Some weeds, dense willows on banks........................ 0.06–0.08
      f. For trees within channel, with branches submerged at high stage, increase all above values by............................ 0.01–0.02
   2. Irregular sections, with pools, slight channel meander; increase values given in 1a–e about.......................... 0.01–0.02
   3. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stage:
      a. Bottom of gravel, cobbles, and few boulders................ 0.04–0.05
      b. Bottom of cobbles, with large boulders.................... 0.05–0.07

B. Flood plains (adjacent to natural streams):
   1. Pasture, no brush:
      a. Short grass.................................................. 0.030–0.035
      b. High grass.................................................. 0.035–0.05
   2. Cultivated areas:
      a. No crop...................................................... 0.03–0.04
      b. Mature row crops........................................... 0.035–0.045
      c. Mature field crops.......................................... 0.04–0.05
   3. Heavy weeds, scattered brush................................ 0.05–0.07
   4. Light brush and trees: 10
      a. Winter....................................................... 0.05–0.06
      b. Summer..................................................... 0.06–0.08
   5. Medium to dense brush: 10
      a. Winter....................................................... 0.07–0.11
      b. Summer..................................................... 0.10–0.16
   6. Dense willows, summer, not bent over by current........... 0.15–0.20
   7. Cleared land with tree stumps, 100–150 per acre:
      a. No sprouts................................................... 0.04–0.05
      b. With heavy growth of sprouts............................. 0.06–0.08
   8. Heavy stand of timber, a few down trees, little undergrowth:
      a. Flood depth below branches................................ 0.10–0.12
      b. Flood depth reaches branches.............................. 0.12–0.16

C. Major streams (surface width at flood stage more than 100 ft.): Roughness coefficient is usually less than for minor streams of similar description on account of less effective resistance offered by irregular banks or vegetation on banks. Values of μ may be somewhat reduced. Follow recommendation in publication cited if possible. The value of μ for larger streams of most regular section, with no boulders or brush, may be in the range of........................................... 0.028–0.033
Figure B.2 Sample notes on roughness conditions.

1. Channel: bottom width 20 to 40 ft.; side slopes 1 to 1 to 3 to 1; depth range 8 to 12 ft.
   a. Bottom: small potholes and bars; average grade fairly uniform. Some small logs and roots affect low flows.
   b. Banks: some sloughing and erosion, fairly rough.
   c. Section: size fairly uniform; considerable shape changes but gradual over 200 to 400 ft.
   d. Vegetation: very little bottom; sides mostly grass and weeds with occasional patches dense brush 3 to 5 ft. high.

2. Left flood plain: less than 10% cultivated in small fields; few fences; 50 to 60% brushy with small trees; remainder scattered open areas with bunch grasses and weeds.

Notes on Roughness By: J. Doe

Section 2, _________ Creek

3. Right flood plain: at least 90% cultivated, mostly row crops and some small grain; small fields; 8 or 10 transverse fences with brushy or weedy fence rows.
Stream Crossings

C. Design Data (print and use as a checklist)

(Having this design data will get you through the design review part of a spot check)
1. Completed EE
2. Drainage area map of stream (If greater than 5 sq mi a permit is required and a copy of the letter of notification to the landowner will document this.)
3. If the stream is a designated trout stream, VGIF needs to be notified by the landowner. (Place copy of letter notification to the landowner in design file to document this.)
4. Copy of field notes. (Attach to design.)
5. Plotted cross section and profile of stream. (Virginia’s standard design sheets for stream crossings work well.)
6. Cross sectional area and wetted perimeter of channel at full flow. (Full flow defined as lowest bank elevation, for these purposes.)
7. Stream velocity calculations at full flow.
8. Copy of design package (see below), including spec’s and O&M plan, with the cover sheet signed by landowner and contractor. (At the least the signed design with a note attached to the design stating that the spec’s and O&M plan were given to the landowner.)

D. Design Package (for landowner and contractor)
1. Completed cover sheet with location map.
2. Completed plan view drawing of site.
3. Completed stream crossing design sheets.
4. Provide landowner two copies of the design, specifications and O&M plan. (One for landowner’s records and one for the contractor.)
Drainage area using planimeter

The old fashion way still works. Copy the map and outline the drainage area. Include in design for documentation.
This way is a little more modern. Again, print the drainage area map with drainage area outlined for design documentation.
The stations should be indicated at the end points and all grade changes. Station for the centerline of the stream is also shown. If using a planimeter to determine the drainage area, the scales are very important. Please note that NRCS Profile sheets are four lines to the inch horizontally and twenty lines to the inch vertically.
The centerline of crossing should be indicated on profile. The channel slope should be computed and then noted on the profile. Crossing width must be noted as well as the slope of the side slopes. Stationing should also be noted on plan view. The typical stone layer is given but can be modified by filling in different stone sizes.
Close up of the crossing design. Don't try to draw in the complete stone profile. Draw the top and bottom grade lines and reference the stone profile shown on sheet 2. Notice the scales on the upper left corner. Horizontally 1" = 8' and vertically 1" = 4'. Different scales makes it easier to distinguish the slopes.
The stream profile is a series of survey points on the bottom of the stream channel. Plot the data here and determine the average bottom grade of the stream. This data is used to determine stream velocity.

U/S Elev = 98.7
D/S Elev = 95.5
Total Distance between U/S and D/S points = 95 ft

\[
\frac{98.7 - 95.5}{95} \times 100 = 3.4\%
\]
The plan view drawing assists the contractor and landowner to understand how the crossing is positioned on the ground. It also gives fencing guidance and locations. To change the direction of the stream flow, "X" out the arrowheads on the flow lines and put one on the other end of the line.
4) Seed side slopes according to the Plant Establishment Guide for Virginia if fence runs along edge of ramp. If the fence must be installed along top of slope or the side slopes are too steep to be stable then armor the slope with 4" to 6" thick layer of VDOT #1 stone over geotextile. Side slopes must be 2:1 or flatter.

5) Ramp slopes are to be 8:1 or flatter.

This an example of how to modify the Typical Stone Layer detail on sheet 2 to show a different stone layer.
Location of Standard Stream Crossing Drawings on the NRCS Virginia WEB Page. 1) Click on the Technical Resources tab, then 2) Engineering, then 3) Standard Drawings.
When the Standard Drawing page opens...

![Virginia NRCS CADD Drawings](#)

The following files require Adobe Acrobat and Autodesk DWF Viewer. Autodesk DWF Viewer will allow you to view and print the DWF files either from your browser or from the standalone application. Microsoft Internet Explorer 5.01 or higher is required when using the browsers version of the viewer.

<table>
<thead>
<tr>
<th>Draw. #</th>
<th>Title</th>
<th>Description</th>
<th>Link Updated</th>
<th>Drawing Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>VA-SD-100</td>
<td>Virginia Cover Sheet</td>
<td>Engineering design cover sheet. To be included in all design packages.</td>
<td>01/11/2007</td>
<td>DWF, PDF, DWG</td>
</tr>
<tr>
<td>VA-SD-105</td>
<td>Virginia Cover Sheet (EWP)</td>
<td>EWP design cover sheet. To be included with all EWP design packages.</td>
<td>01/11/2007</td>
<td>DWF, PDF, DWG</td>
</tr>
<tr>
<td>VA-SD-201</td>
<td>Temporary Waste Pad</td>
<td>Temporary Waste Storage Pad design sheet.</td>
<td>01/11/2007</td>
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<tr>
<td>VA-SD-312A</td>
<td>Plan-Cross Section Sheet</td>
<td>Plan / Cross Section drawing sheet.</td>
<td>01/11/2007</td>
<td>DWF, PDF, DWG</td>
</tr>
</tbody>
</table>
Click on the icon of the format you wish to download. Drawings are in three formats; Adobe PDF, Autodesk DWF, which is a free download like Adobe Reader; and Autodesk DWG.
When determining the cross sectional area of the stream channel with a planimeter the horizontal and vertical become very important. The square inches on the paper now have more square feet of area in them. Use the following formula to compute the channel area. Planimetered sq. inches x (H scale x V scale) = area sq. ft.

Planimetered Area = 3.5 sq in
Scale: Horizontal 1” = 8’
Vertical 1” = 4’

3.5 x (8 x 4) =
3.5 x (32) =
Cross Sectional Area =112 sq ft
## Velocity Computations Worksheet

### Stream Crossing Calculations Worksheet

Velocity = \((1.49/n) \times R^{2.3} \times S^{0.5}\)

Where:
- \(n\) = Manning’s \(n\)
- \(R\) = hydraulic radius = Area/Wetted Perimeter
- \(S\) = stream slope in feet/feet (decimal form, not percent)

The area is the cross-sectional area of the stream flow. For calculations, compute the area right before the water would leave the defined channel and spill out of the low bank sides and into the floodplain. The wetted perimeter is the distance along the edge of one side of the stream bank (\(b_1\)) plus the channel width (\(cw\)) plus the distance along the edge of the other side of the stream bank (\(b_2\)). Start and stop these measurements at the same points you use to define your area (the points where water is just ready to spill into the floodplain).

Manning’s \(n\) for a stream will generally range from 0.035 to 0.05. A stream in an open field will be closer to 0.035 and a stream with heavy woody vegetation along the banks may have an \(n\) approaching 0.05. Care should be taken when selecting an \(n\) value. If you have a question contact an engineer.

**Calculations:**

1. **Selected \(n\) = 0.04**

2. Wetted Perimeter = \(b_1 + cw + b_2\) (in feet)
   
   \[
   W.P. = 4.7 + 0 + 4.7 = 9.4 \text{ feet}
   \]

3. Area = \(\text{inches squared} \times \text{feet}^2\) in \(\text{in}^2\) (determined by planimetrating your stream plot and multiplying by your scale)
   
   \[
   \text{Area} = 5.85 \text{ feet}^2
   \]

4. \(R^{2.3} = \left(\frac{A}{W.P.}\right)^{0.3} \rightarrow R^{2.3} = (\frac{5.85}{9.4})^{0.667} \rightarrow\)
   
   \[
   R^{2.3} = (0.6223)^{0.667} \rightarrow R^{2.3} = 0.7289
   \]

5. Slope = (feet of fall/length between shots)\(^{1/2}\) (This data comes from your survey)
   
   \[
   \text{Slope, } s = \left(\frac{3.2}{75}\right) \rightarrow \text{slope, } s = 0.0137 \rightarrow\]
   
   \[
   s^{0.5} = (0.0137)^{0.5} \rightarrow s^{0.5} = 0.1836 \quad \text{Note: } s^{0.5} = \sqrt{s}
   \]

6. \(V = (1.49/n) R^{0.667} S^{0.5} \rightarrow V = (1.49/0.04) (0.7289) (0.1836)\)
   
   \[
   V = (37.25) (0.7289) (0.1836) \rightarrow \text{Velocity} = 5.0 \text{ feet per second}
   \]

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**Velocity Computation Spreadsheet**

**Manning's Equation-Stream Crossing Applications**

1. Enter selected 'n' value: 0.04

2. Enter Wetted Perimeter, WP: 9.4 feet

3. Enter Area, A: 5.85 square feet

The Hydraulic Radius, R, equals (A / WP) $R = \frac{5.85}{9.4} = 0.62$

Determine the slope of the stream:

4. Enter the upstream elevation: 98.7, the downstream elevation: 95.5 and the distance between the two elevations: 95

The slope equals: 0.034 in decimal form. This is equal to: 3.37 percent

Manning's equation calculates velocity as $V = (1.49 / n) \times R^{2/3} \times S^{1/2}$

So the velocity for the conditions given above equals: 4.98 feet / second.
Excavation of the foundation of a crossing. Notice the vertical cut on the side. Think of the final excavation as forming a cup to put the base stone in. Place geotextile fabric over the cut and then place the base stone into the fabric. The fabric should extend to the top of the stone layer on the sides.
Completed crossing. All that remains to be completed is the fence installation and seeding.
This crossing was constructed on a stream with a gravel bottom. The ramps have been excavated and armored but the bottom was left as it was. Why disturb the streambed if it is not necessary? Leave it alone if you can.
Culvert Crossing Design
Culvert Crossings

D. Site Selection Considerations

1. Do you really want to “dam” this stream?
2. Drainage area
3. Q and V of watershed
4. Width of stream channel
5. Bank height
6. Emergency spillway site
7. Diameter and length of culvert needed
8. Side slopes of fill… armored or not
This is a nice single culvert crossing. The stone armor is place 1’ thick over non-woven geotextile fabric as over topping protection. Notice that the trees were left undisturbed during construction.
Crossing in fox hunting country. Notice the coops for the horses. Also notice the double spillways installed with this culvert crossing.
Same crossing from downstream. Notice that one tube is 6” lower then the other. This is required by our old permit agreement.
Again same culvert crossing. This landowner decided to use the belled double walled PE pipe. It has a “n” factor of 0.012, or VERY SLICK. This is a great product and well worth mentioning to the landowners. As always do not mention brands of pipe only types.
E. Culvert Design Data

1. Drainage area of stream
2. Plot cross section and profile of stream
3. Cross sectional area and wetted perimeter of channel at bank full flow
4. Stream velocity at bank full flow
5. Calculate culvert size based on the $Q_{2yr}$. Or Call you friendly Area Engineer.
6. Complete cover sheet
7. Complete plan view sheet
8. Complete crossing design sheet
9. Provide landowner 2 copies of design and specs
Calculating Culvert Length

Culvert length is determined by:

1. Height of fill above culverts \( FH \) (fill height) 1 ft
2. Culvert Diameter \( CD \) (culvert dia.) 2 ft
3. U/S and D/S fill slopes \( SS \) (side slope) 2:1, 2:1
4. Crossing Top Width \( TW \) (top width) 16 ft
5. Per standard.. Culverts must extend 2 ft beyond toe of slopes 4 ft

\[
(((FH+CD) \times SS) \times 2) + TW + 4' = \text{culvert length}
\]

\[
(((1+2) \times 2) \times 2) + 16 + 4 = 32' \text{ culvert length}
\]
Hydraulics Formula Program.

Culvert Flow

Mannings 'n': 0.020

Capacity = 22.7 cfs
Inlet Controls Flow

Headwater Elev (ft):
104
Inlet Elev (ft):
100

Tailwater Elev (ft):
99.1
Outlet Elev (ft):
99.1

Diameter (in): 24
Length (ft): 32

Projecting - thin edge; Ke = .92
Single culvert backfilling with gravel. Place a geotextile fabric between the subgrade and the stone. I also have geotextile fabric placed over the top of the stone and culvert to prevent the earth backfill from migrating into the stone layer. VDOT #1 size stone is also acceptable for the stone backfill.
Double culverts backfilling with gravel. Place a geotextile fabric as mentioned in the previous slide. A minimum space of 2' is to be left between the culverts. This allows the contractor to consolidate the stone backfill between the culverts. VDOT # 1 size stone is also acceptable for the stone backfill. It is also acceptable to completely backfill with stone.
Single Spillway for routing heavy flows away from culvert
Limited Access Watering Points
Limited Access Points

1. Are basically \( \frac{1}{2} \) a stream crossing
2. Use same design criteria as stream crossings
3. Should be wide...12 to 16 ft min
4. Ponds accesses should extend to a depth of 2 to 3 ft.
5. Stream accesses should have an armored bottom.