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LOW WATER STREAM CROSSINGS

Costel Boariu[1]

Abstract. Rivers crossing is usually on bridges and culverts for vehicle and walkways for people. These arrangements are costly. If the traffic of people and vehicles is large enough expense can be justified. For low traffic or seasonal river crossings arrangement can be achieved by simpler methods. The paper describes low water stream crossings that allow the vehicle under certain conditions and people. These arrangements are recommended when disruption is possible.

Keywords: low water crossing; fords

1. Generalities

Communication lines usually cross rivers using bridges. The amplitude of the crossing relates to the importance class of the communication lines. The flow of the river is calculated with a probability that relates to the importance class. That means that only construction falling in the A or I class are designed with the maximum flow in mind. For lower importance class constructions, the actual river flow frequently passes the values used in design. Ford crossings are submersible adjustments of the roadway (PD 003-2011). When water flow and levels reach a certain limit, these crossings are closed to traffic.

In Romanian technical literature, low water stream crossings are usually proposed in the case of forest roads. As part of the adjustments needed, the river thalweg is strengthened to endure care traffic and sometimes a way to dissipate hydraulic energy is provided.

Internationally, stream crossings are divided in 3 categories:

-unvented ford

-vented ford

-low water bridge

These types of stream crossings are usually recommended for low importance roads with little traffic. They are particularly useful for hydroelectric power plant construction sites.

2. The necessity for low water stream crossings

Country roads as well as IV and V class roads have the crossings planned for a 5% probability flow, to which a safety is added depending on the inner width of the bridge. This means that once every 20 years, the flow values can exceed the values allowed by the bridge

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section. In these cases, it is useful that planning foresees a temporary discontinuing of use and not total scrapping of the crossing. It would be then more rational to use an installation that could be temporarily decommissioned and cheaper to build.

Temporary arrangements specific to construction sites should be designed using a 10% probability. An increase in flow occurs during heavy rain periods, when construction can, and is, discontinued.

Another example of temporary works is roads that serve farming developments. Proper access during fair weather can be ensured with a very well designed low water crossing. Access during rainy periods is not necessary.

Secondary access roads can also have low water crossings, as these roads can be closed off in rainy seasons while the main roads are used.

3. Low water crossings in Romania

The standard regarding the designing of forest roads states that the crossings should be solved using the unvented ford method. No method or design criteria are further detailed. This type of crossing is usually done as a temporary solution when the main crossing is unusable (Figure 1) or sometimes as a permanent solution for small streams (Figure 2).

Figure 1: Crossing of the Arges River at Budesti

Figure 2: a) Cungrea Village (Olt) *b) Deleni Village (Iasi)*

The Arges crossing is shown after it has been taken out of use by floods. The crossings at Cungrea and Deleni are still in decent condition, but the lack of protection works downstream is apparent.

4. Designing low water crossings

4.1. Unvented fords (Figure 3)

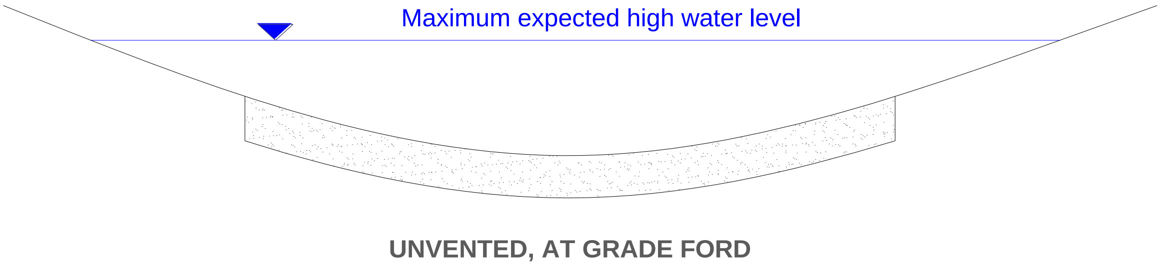


Figure 3: Unvented at grade ford

Use Manning's method for channel capacity.

$$Q = AC\sqrt{R \cdot i}\text{ , where}$$

$$C = \frac{1}{n} R^{\frac{1}{6}}\text{ , is Chezy coefficient}$$

n = Manning coefficient

Adjust Roughness Coefficient (n) as appropriate (Minea, Romanescu, 2007).

If the channel bottom and sides are made from different materials, then the Manning *n* for the bottom and sides may have different values. To simplify the computations, it becomes necessary to determine a value of *n*, designated by n_e, that may be used for the entire section. This value of n_e is referred to as the equivalent *n* for the entire cross section. Let consider a channel section that may be subdivided into *N* subareas having wetted perimeter *Pi* and Manning constant, n_i, ($i = 1, 2, \cdots, N$). By assuming that the mean flow velocity in each of the subareas is equal to the mean flow velocity in the entire section, the following equation may be derived (Horton, 1933; Einstein, 1934 apud Chaudhry)

$$n_e = \left(\frac{\sum P_i n_i^{3/2}}{\sum P_i} \right)^{2/3}$$

4.2. Vented fords with culverts (Figure 4 and 5)

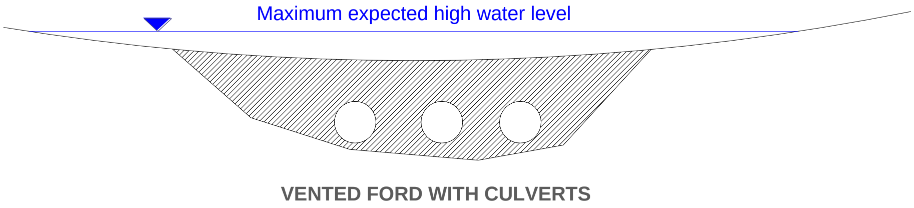


Figure 4: Vented ford with culverts

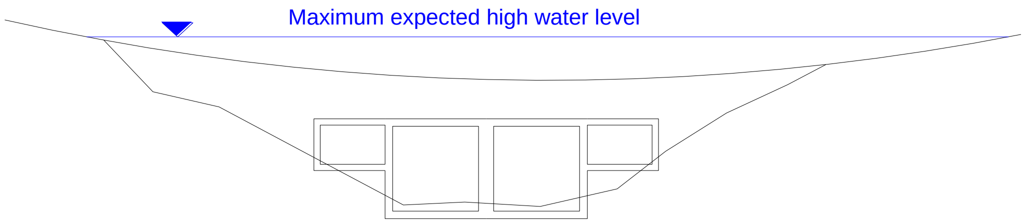


Figure 5: Vented ford with box culverts

Use pipe capacity relation plus broad crested weir formula for overflow.

4.2.1. The amount of water that passes over the road is calculated for broad crested weir

$$Q = m\sigma b\sqrt{2g}H^{3/2}$$ in which

H - weir drop
m - flow coefficient
σ – flood coefficent, depend of *h/H*
b - weir width
h – water depth downstream of the crossing

Table 1: Flow coefficient values for broad crested weirs (Kiselev, 1988)

Flow conditions	m
No hydraulic resistance	0,385
Admission shape studied on model	0,365
Baffle with round crest	0,350
Baffle with chamfer crest	0,335
Sharp crest	0,320
Unfavorable hydraulic conditions	0,300

Table 2: Flood coefficient (Kiselev, 1988)

h/H	σ	h/H	σ	h/H	σ
0,70	1	0,90	0,739	0,98	0,360
0,75	0,974	0,92	0,676	0,99	0,257
0,80	0,928	0,94	0,598	0,995	0,183
0,83	0,889	0,95	0,552	0,997	0,142
0,85	0,855	0,96	0,499	0,998	0,116
0,87	0,815	0,97	0,436	0,999	0,082

4.2.2. The amount of water that passes through the bridge section is calculated as it would through a pipe. When the pipe length is small in relation to its diameter, the flow is (Bartha et al., 2004):

$$Q = \mu A\sqrt{2gH}$$, in which

A – pipe section (bridge)
H – height difference between the water level upstream and downstream of the crossing

The flow coefficient μ depends on the shape of the pipe (circular, rectangular, etc.), the shape of the entry, and the ratio *L/D*. If $L < 50D$ the µ coefficient is taken from the following chart, otherwise, the losses are calculated as if for short pipes.

Table 3: Values for μ coefficient

Pipe entry	L (m)	*D (m)*						
		0.305	0.46	0.61	0.915	1.22	1.525	*1.83*
Skewed entry	3.05	0.86	0.89	0.91	0.92	0.93	0.94	*0.94*
	6.1	0.79	0.84	0.87	0.90	0.91	0.92	*0.93*
	9.15	0.73	0.80	0.83	0.87	0.89	0.90	*0.91*
	12.2	0.68	0.76	0.8	0.85	0.88	0.89	*0.90*
	15.25	0.65	0.73	0.77	0.83	0.86	0.88	*0.89*
Straight entry	3.05	0.80	0.81	0.80	0.79	0.77	0.76	*0.75*
	6.1	0.74	0.77	0.78	0.77	0.76	0.75	*0.74*
	9.15	0.69	0.73	0.75	0.76	0.75	0.74	*0.74*
	12.2	0.65	0.70	0.73	0.74	0.74	0.74	*0.73*
	15.25	*0.62*	*0.68*	*0.71*	*0.73*	*0.73*	*0.73*	*0.72*

4.3. Low water bridge (Figure 6)

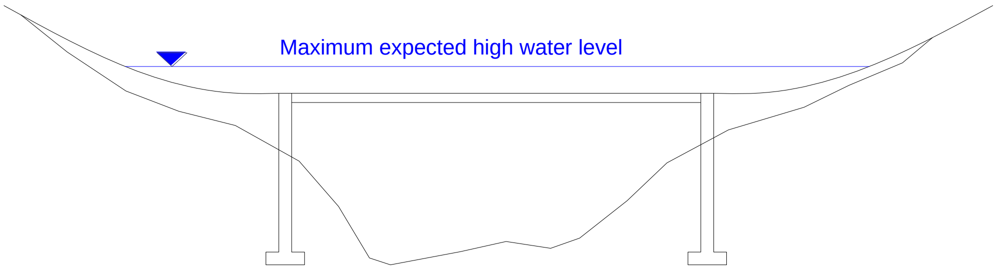


Figure 6: Low water bridge

Use Manning's method for channel capacity through the bridge, and total capacity over and under the bridge

5. Downstream protection

The construction of the crossing usually creates a concentration of hydraulic energy that needs to be dissipated.

5.1. In the unvented ford case, the reduced riverbed roughness increases the flow speed. This has to be accounted for when dimensioning protection elements downstream of the crossing. The following consolidation options exist (USDA, 2006) (Figure 7 and 8):

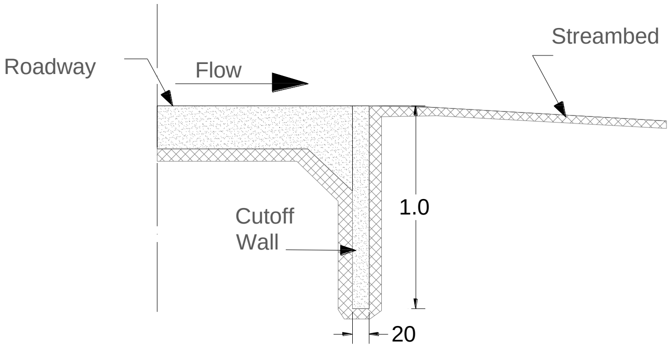


Figure 7: Downstream consolidation with cutoff wall

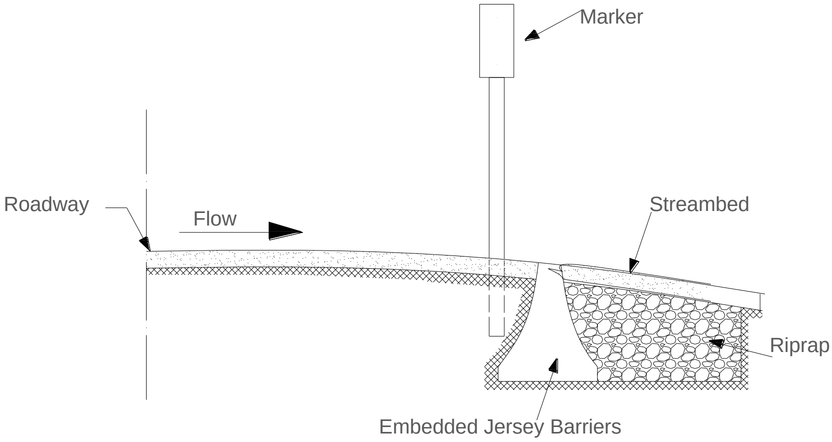
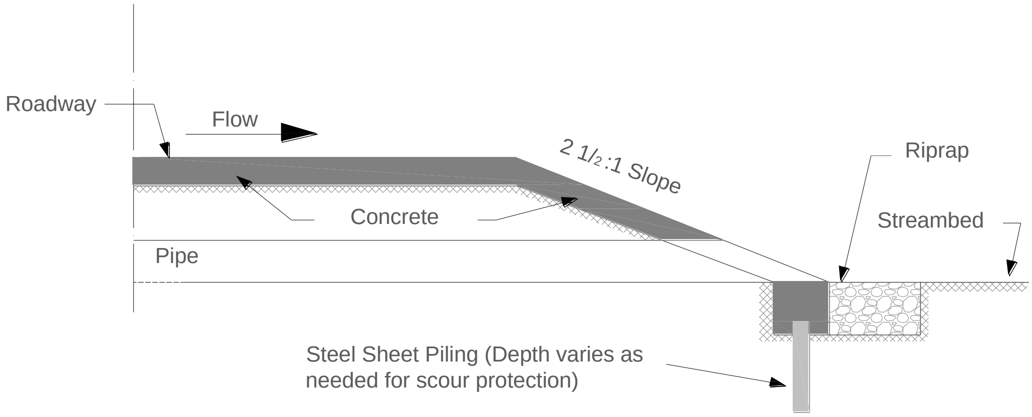


Figure 8: Downstream consolidation with precast elements

5.2. In the vented ford situation, a solution is needed to dissipate energy and pool conection. If downstream water depth is smaller than conjugate depth of contracted depth of nappe is needed construction of hydraulic energy dissipation.

The following shows possible solutions for protection and energy dissipation:



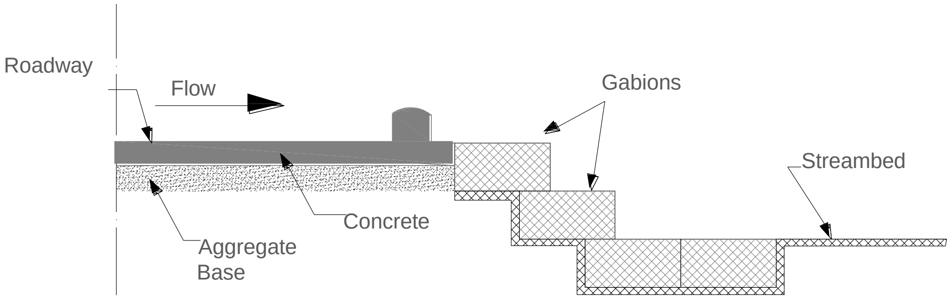


Figure 9: Downstream consolidation with steel sheet piling and gabions

5.3. In the case of low water bridges, downstream protection may or may not be necessary. Usually, the bridge itself narrows the water passageway, thus water speed it up. Depending on the flow regime, backwater can occur upstream of the crossing.

If the flow regime is fast, backwater always occurs. If the flow regime is slow and the section is narrowed enough to speed it up, backwater can occur. If the critical flow regime is not reached (due to the section being narrow enough), backwater can not occur upstream.

Identifying a situation where backwater can not occur can be done like this:

-we determine the flow regime – it has to be slow ($h>h_{cr}$; $v<v_{cr}$)

-we calculate the depth and speed of the water in the narrowed section (h_1; v_1)

Critical flow regime must be reached in order for the flow to reach maximum value through the section (Chaudhry).

In a section with A_{cr} (for $h=h_{cr}$), in which a critical regime would be reached, water speed is: $v_{cr} = \frac{Q}{A_{cr}}$

The specific energies of the two sections are:

$$E = h + \frac{\alpha v^2}{2g} \text{ (upstream section)}$$

$$E_1 = h_1 + \frac{\alpha v_1^2}{2g} \text{ (crossing section)}$$

Narrowing the section in the crossing area does not cause raise in water levels if $E_1<E$. By avoiding raise in water levels, protection is no longer needed downstream.

6. Conclusions

Crossing rivers is a rational solution in many situations. It is necessary that their implementation and design be regulated by construction standards. Various solutions which do not significantly impact the stream exist. However, safety measures must be in place to ensure safe crossing during floods.

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