Stream-Smart Road Crossing Project Example for Small Stream

Planning Example: Site Selection Determination

- Year around permanent road crossing
- Road frequently floods, pipe has washed out or gravel is lost from the road surface
- Culvert is perched on both ends
- Stream has good fish habitat
- Reasonable size culvert or bridge (maximum size 10 ft), current culvert is 36” dia. metal pipe
- Stream is less than 10 ft. wide
- Stream channel has uniform cross section upstream and downstream
- Site is easily accessible and should be easy to dewater

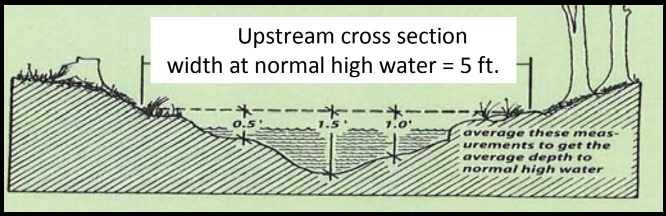
Slide 1. This document shows a detailed example of how to size a culvert stream crossing that will pass an adequate storm event to minimize the pipe from washing out and also allow for adequate fish passage. Listed are some things to consider or reasons to use in prioritizing and selecting sites to replace a culvert with an improved structure. This list is not all inclusive as there may be other site specific reasons to install an improved stream crossing. This procedure can be used for smaller streams where a typical channel cross section can be determined. A reasonable maximum size culvert or bridge opening to use this procedure for should be 10 feet. Larger or more complex sites will typically need a more detailed hydrology/hydrologic analysis to properly size crossing structures.

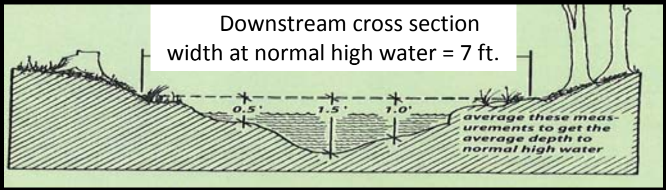
Gather Field Data

1) Determine typical channel normal high water width and average depth (take measurements upstream and downstream and average)
2) Determine stream channel profile (take points from at least 100 ft. upstream and downstream or at least to undisturbed sections of the stream)
3) Determine road height existing culvert end elevations and compare to stream channel elevation

Slide 2. It is important to obtain stream information at the crossing site specifically the channel size, stream profile, and road height. The location of any existing culvert or bridge structures in relation to the road and stream should also be obtained. The stream channel size and profile need to be obtained in unaltered or undisturbed sections of the stream in order to size and locate the pipe correctly.

Stream Channel Data





Slide 3. Two typical cross sections should be obtained in order to insure the pipe is sized correctly. Two typical cross sections are shown in this example, one upstream and one downstream.

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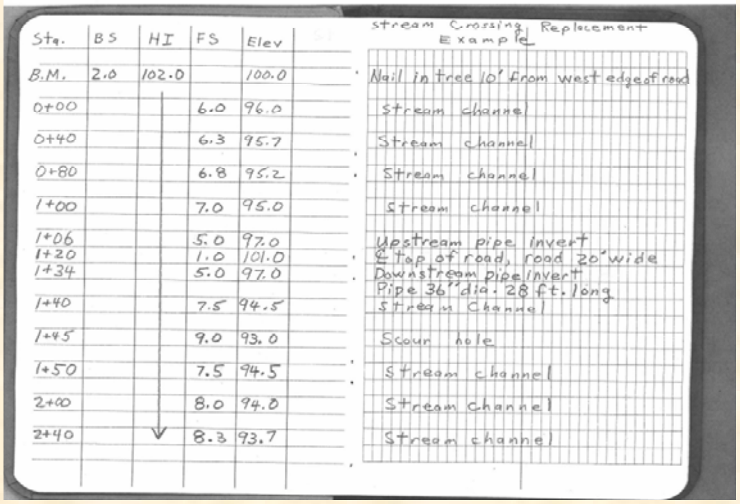
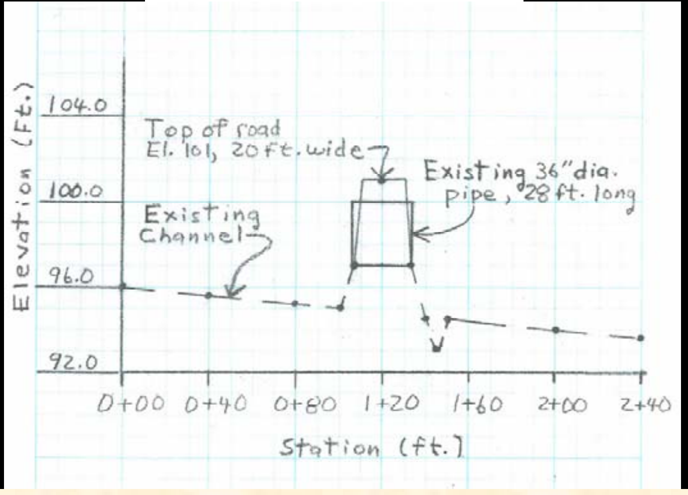
Typical Survey Notes



Sta.	BS	HI	FS	Elev	Stream Crossing Replacement Example
B.M.	2.0	102.0		100.0	Nail in tree 10' from west edge of road
0+00			6.0	96.0	Stream channel
0+40			6.3	95.7	Stream channel
0+80			6.8	95.2	Stream channel
1+00			7.0	95.0	Stream channel
1+06			5.0	97.0	Upstream pipe invert
1+20			1.0	101.0	℄ top of road, road 20' wide
1+34			5.0	97.0	Downstream pipe invert Pipe 36" dia. 28 ft. long
1+40			7.5	94.5	Stream Channel
1+45			9.0	93.0	Scour hole
1+50			7.5	94.5	Stream channel
2+00			8.0	94.0	Stream Channel
2+40			8.3	93.7	Stream channel

Slide 4. This slide shows typical field notes that are taken in determining the stream profile, road height and width, and existing pipe information. It is important to establish a bench mark in order to install the structure to the correct design elevation.

Plot of field survey notes



Slide 5. This is a plot of the field survey notes shown in the previous slide. Seeing a graphical representation of the stream channel, road and pipe help to determine the proper elevation the replacement culvert should be located and how long the pipe should be.

Sizing the Crossing Structure

- Decided to use a metal pipe structure
- Sizing determined by DEP regulations (3.0 times the cross-sectional area of stream channel or 25 year storm capacity)
- Cross sectional area of stream = width at normal high water x average depth at normal high water
- Embed pipe 20% (5% to 25% recommended for fish passage)

Slide 6. Structures are typically sized to pass a 25 year event and have an effective stream width as close to the normal high water stream width as possible. Without doing a detailed hydrology analysis the pipe size for a 25 year storm can be approximated by the area of three times the cross sectional area of the stream at the normal high water level. To obtain an adequate effective stream width a round pipe should be embedded into the stream channel bottom. Embedding the pipe 20% will provide a substantial effective stream width without a considerable reduction in the pipe opening.

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Pipe Size Determination

- Channel cross sectional area = average width x average depth
- Average width = (5 ft. + 7 ft.)/2 = 6 ft.
- Average depth = (0.5 ft. + 1.5 ft. + 1.0 ft.)/3 = 1.0 ft.
- Channel cross sectional area = 6 ft. X 1.0 ft. = 6 ft.^{2}
- Pipe size required = 3 x channel cross sectional area = 3 x 6 ft.^{2} = 18 ft.^{2}
- Note existing pipe has an opening area of 7.05 ft.^{2} (capacity approximately 2 yr. storm or slightly greater)

Slide 7. This slide shows the detailed calculations for determining the cross sectional area of the stream at normal high water and the cross sectional area needed for the pipe structure. These calculations are specifically for the average of the two cross sections shown in Slide 3. The cross sectional area of the stream at normal high water will typically pass the flow rate of a 1 to 2 year frequency storm event.

Table 2. Comparison of percent of culvert rise/diameter with embedding and corresponding cross-sectional area loss for round and pipe arch culverts. Also the effective width, in percent of diameter, with loss of area for round culverts.

A	B	C	D
Percent of rise/ diameter with embedding of culvert	% loss of flow capacity: **Pipe Arch Culvert**	% loss of flow capacity: **Round Culvert**	*Effective width (% of diameter) of round culvert with embedding*
10	8	5	60
15	14	9	71
20	20	14	80
25	26	20	87
30	33	25	92
35	39	31	95
40	45	37	98
45	51	44	99
50	57	50	100
55	63	56	
60	69	63	
65	74	69	
70	79	75	

Slide 8. This chart shows the reduction in flow capacity when the pipe is embedded. For this example a round culvert is used and will be embedded 20 %. This results in only a 14 % reduction in capacity and allowing for an effective width of 80 % of the culvert diameter at the stream channel, or an open channel bottom of 80% of the pipe diameter.

Determining culvert size

- Try 60 inch diameter pipe; effective opening area = (1 – 0.14) x 19.65 = 16.90. Too small.
- Try 66 inch diameter pipe; effective opening area = (1 - 0.14) x 23.75 = 20.43. Ok
- Effective width at channel level = 0.80 x 66 inches = 52.8 inches or 4.4 ft.
- Embedded depth = 66 inches x 0.20 = 13.2 inches, or 1.1 ft.

Table C
Culvert Diameter and Opening Sizes

Opening size (sq. ft.)	Diameter (inches)
0.20	6
0.80	12
1.25	15
1.75	18
2.40	21
3.15	24
4.90	30
7.05	36
9.60	42
12.55	48
15.90	54
19.65	60
23.75	66
28.26	72

Slide 9. This slide shows the detailed calculations for determining the pipe size needed based on the area of three times the cross sectional area of the stream at normal high water. The effective opening of the pipe is reduced by 14% since the pipe will be embedded 20% of its diameter. Using Table C it is determined a 66 diameter round culvert is needed.

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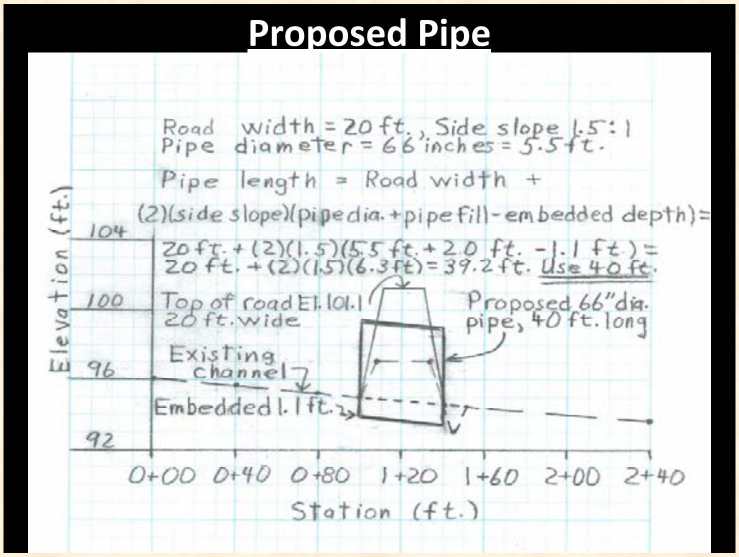
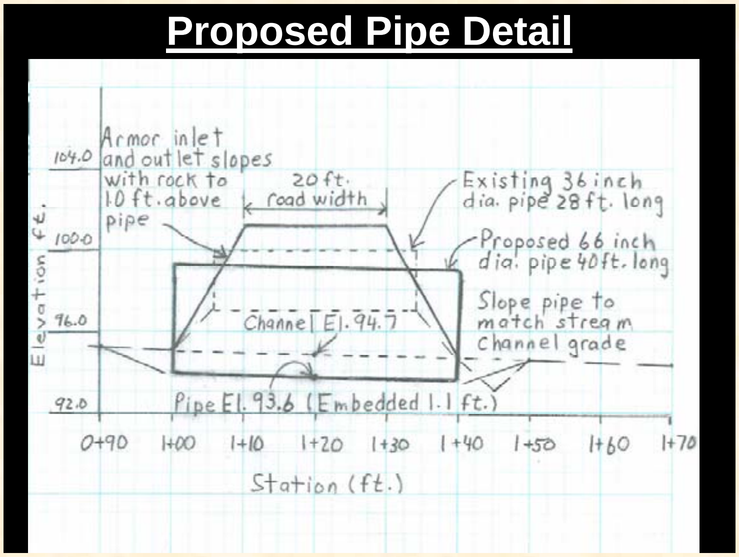
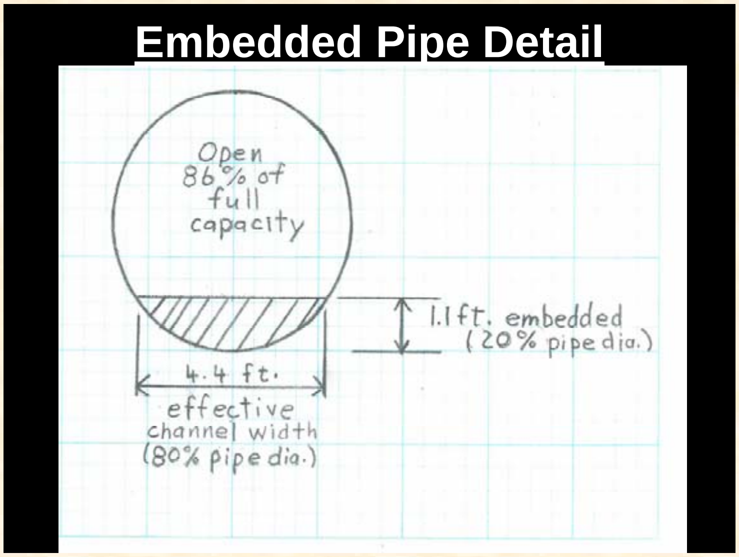


Slide 10. This slide shows a plot of the proposed pipe in relation to stream channel and road cross section. Note how much the bottom of the pipe has been lowered compared to existing 36 inch pipe. The proposed pipe is embedded 20% below the estimated original channel bottom under the road. The calculations show how the pipe length is determined taking into account the road top width, pipe diameter, and stable side slopes for the road shoulders (typically 1.5:1 or flatter).



Slide 11. This slide shows a more detailed cross section of the proposed pipe and the relation to the existing pipe. Notice how the proposed pipe has been lowered and embedded below the estimated original stream bottom. The design channel elevation at the center of the road is determined graphically by connecting a straight line between the undisturbed upstream and downstream channel elevations. The pipe is then embedded below this design channel elevation. This will help to insure the pipe does become perched in the future.



Slide 12. This slide shows a cross section of the pipe and illustrates how embedding the pipe can provide an effective stream bottom that is large percentage of the pipe diameter yet a relatively minor reduction in the effective opening of the pipe. It is preferable to add channel substrate material to embedded pipes. However, access to smaller pipes may make it impractical. If the pipe is sized large enough and embedded deep enough steam bed material should naturally accumulate in the embedded section.

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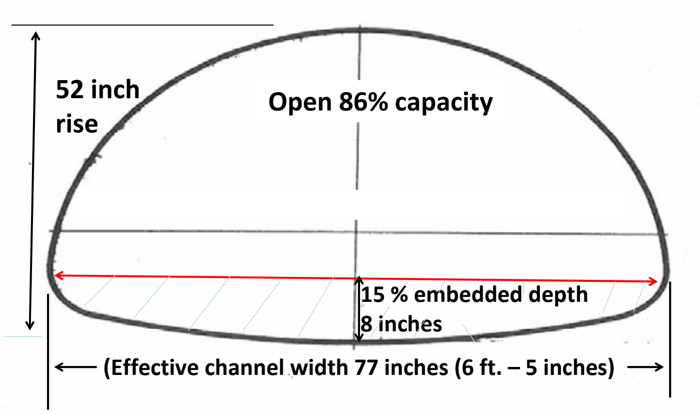
H 20 and H 25 Live Loads, Pipe-Arch

Size		Minimum Structural Thickness, Inches	Minimum Cover, Inches	Maximum Cover, Feet 2 Tons/Ft.² Corner Bearing Pressure
Round Equivalent, Inches	Span x Rise, Inches			
15	17 x 13	0.064	12	16
18	21 x 15	0.064		15
21	24 x 18	0.064		
24	28 x 20	0.064		
30	35x 24	0.064		
36	42 x 29	0.064		
42	49 x 33	0.064*		
48	57 x 38	0.064*		
54	64 x 43	0.079*		
60	71 x 47	0.109*		
66	77 x 52	0.109*		
72	83 x 57	0.138*	12	15

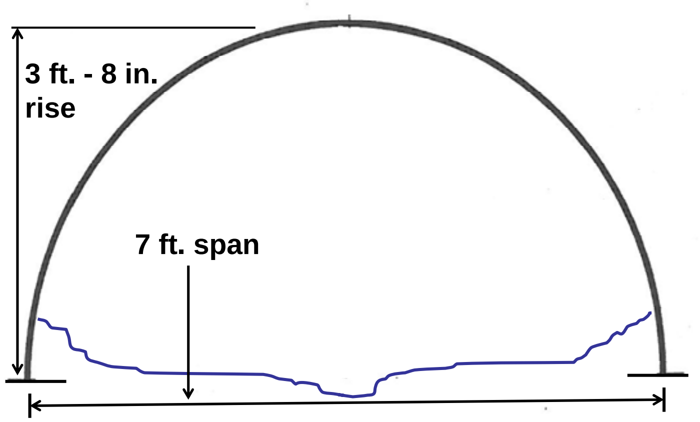
Slide 13. Another alternative to increase the effective stream bottom is to use a pipe arch with a full bottom invert. Since it is not an open bottom it is still important to embed the pipe so it does not become perched if there is any channel erosion. This chart shows the equivalent size arch culvert needed for a particular round pipe.

Full Invert Pipe Arch Option



Slide 14. This slide shows a cross section of the full bottom invert pipe arch option. This is a better approach for a "stream smart" crossing as the effective channel width of the structure exceeds the average channel width. Again adding channel substrate material is preferable especially for wider flatter openings to insure a low flow channel forms for better fish passage at low flows.

Open Bottom Arch Option



Slide 15. Another alternative is to use an open bottom arch. An open bottom structure is a better option for fish passage and stream connectivity since it does not become perched like a full bottom invert structure can if there is any stream channel erosion. The key to the installation of an open bottom structure is to make sure the footings are placed deep enough and stabilized so that they are not undermined for any anticipated channel erosion. If the structure is design wide enough and installed deep enough the channel through the structure will remain stable with low flow channels naturally forming.

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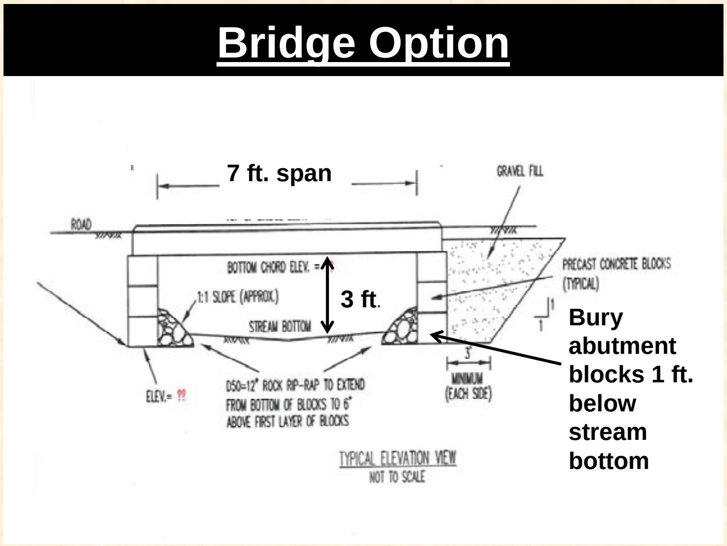

Slide 16. Another alternative is to use an open bottom bridge. The bridge option has the flexibility of multiple widths and heights and can be a cost effective option if one lane traffic is adequate. Bridges are a good option to use for sites that have a relatively low road fill. Using a bridge at low road fill sites will require abutments of a reasonable height and not require so much extra road fill that a culvert may require.

Note: A concrete box culvert with a full invert could also be used. The same sizing and embedding principles described above would still apply. Getting channel substrate material in any flat bottom structure is important for low flow passage. Open bottom box culverts are also available. Concrete box culverts are typically used for larger structures and would likely involve a more complex hydrology/hydrologic analysis.

Again it should be noted that this procedure should probably be limited to stream channels less than 10 ft. in width and where a typical cross section for the stream channel can be easily determined. Larger complex sites should use more complex hydrology and hydrologic design methods.