Greenville County Technical Specification for:

EC-07: OUTLET PROTECTION

1.0 Outlet Protection

1.1 Description

Outlet protection must be provided at all existing and newly installed outlets, within the construction site's boundary, that discharge stormwater runoff from the disturbed areas. Silt fence may not be used as outlet protection.

Outlet protection dissipates the energy of concentrated storm water flows thereby reducing erosion or scouring at storm water outlets and paved channel sections. In addition, outlet protection lowers the potential for downstream erosion. This type of protection can be achieved through a variety of techniques, including permanent turf reinforcement mats (TRMs), stone or riprap, concrete aprons, paved sections and other structural measures.

The techniques outlined in this section are not the only techniques that may be used for outlet protection design. This section only shows one method for outlet protection design as an example of the variables that need to be considered in the design. Other methods utilized that are not discussed in this Design Manual should include all graphs, charts, and calculations verifying that the protection will be able to handle the peak flow velocities and flow depths.

1.2 Design

The design of outlets for pipes and channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous lining and protection of channels or streams. Notably, pipe or channel outlets at the top of cut slopes or on slopes steeper than **10 percent** should not be protected using just outlet protection. This causes re-concentration of the flow that results in large velocities when the flow leaves the protection area. Outlet protection may be designed according to the following criteria:

1.2.1 Round Pipe Flowing Full

1. Flow Velocity:

The flow velocity at the outlet flowing at design capacity shall not exceed the permissible velocity of receiving unprotected grass-lined channels as provided in Table 1.

2. Tailwater Depth:

The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. Manning's Equation may be used to determine tailwater depth. If the tailwater depth is less than ½ the diameter of the outlet pipe, it should be classified as a Minimum Tailwater Condition. If the tailwater depth is greater than ½ the pipe diameter, it should be classified as a Maximum Tailwater Condition. Pipes which outlet onto flat areas with no defined channel may be assumed to have a Minimum Tailwater Condition.

3. Protection Length:

The required protection length, La, according to the tailwater condition, should be determined from the appropriate graphs provided in Figure 8-6 (minimum tailwater condition) and Figure 8-7 (maximum tailwater condition) in Appendix K.

4. Protection Width:

When the pipe discharges directly into a well-defined channel, the protection should extend across the channel bottom and up the channel banks to an elevation one foot above the maximum tailwater depth or to the top of the bank (whichever is less).

If the outlet discharges onto a flat area with no defined channel, the width of the protection should be determined as follows:

- The upstream end of the protection, adjacent to the outlet, should have a width three times the diameter of the outlet pipe (3D).
- For a Minimum Tailwater Condition, the downstream end of the protection should have a width equal to the pipe diameter plus the length of the apron (D + La).
- For a Maximum Tailwater Condition, the downstream end of the protection should have a width equal to the pipe diameter plus 0.4 times the length of the apron (D +0.4* La).

5. Bottom Grade: The protection shall be constructed with no slope along its length (0 percent grade) where applicable. The downstream invert elevation of the protection should be equal to the elevation of the invert of the receiving channel. There shall be no overfalling at the end of the protection.

6. Side Slopes: If the outlet discharges into a well-defined channel, the receiving side slopes of the channel should not be steeper than 3H: 1V.

7. Alignment: The protection should be located so there are no bends in the horizontal alignment.

8. Materials:

The preferred protection lining shall be with an appropriate permanent turf reinforcement matting (TRM). The shear stress and maximum velocity should be calculated to determine which type of TRM is applicable for the situation

When conditions are too severe for TRMs the protection may be lined with riprap, grouted riprap, concrete, or gabion baskets. The median size of stone for riprap may be determined for the applicable tailwater condition from Figures 8-6 and 8-7 in Appendix K.

In all cases, a non-woven geotextile filter cloth should be placed between the riprap and the underlying soil to prevent soil movement into and through the riprap.

1.2.2 Multiple Pipes Discharging at Single Point

For multiple pipe outlet scenarios; the permissible flow velocity (1), tailwater condition (2), bottom grade (5), Sideslopes (6), and Alignment (7) should be determined/designed using the same method for a single pipe as identified in Section 1.2.1.

The protection length (3) will be determined by selecting an equivalent pipe diameter which has a flow rate equal to or greater than the sum of flow rates for the multiple pipes for the given pipe outlet slope. The reference tables at the bottom of this specification provide flow rates for pipe diameters at various slopes.

The protection width (4) will be determined as described below:

When the pipe discharges directly into a well-defined channel, the protection should extend across the channel bottom and up the channel banks to an elevation one foot above the maximum tailwater depth or to the top of the bank (whichever is less).

If the outlet discharges onto a flat area with no defined channel, the width of the protection should be determined as follows:

- The upstream end of the protection, adjacent to the outlet, should have a width three times the sum of all pipe diameters of the multiple pipes 3(∑D).
- For a Minimum Tailwater Condition, the downstream end of the protection should have a width equal to the sum of all pipe diameters plus the length of the apron (∑D + La).
- For a Maximum Tailwater Condition, the downstream end of the protection should have a width equal to the sum of all pipe diameter plus 0.4 times the length of the apron (∑D +0.4* La).

1.2.3 Outlet Velocity

The flow velocity at the outlet flowing at design capacity shall not exceed the permissible velocity of receiving unprotected grass lined channels as provided in Table 1.

Table 1: Maximum Permissible Velocities for Unprotected Grass Lined Channels

Channel Slope	Lining	Velocity (ft./sec.)**
0 – 5 %	Bermuda Grass	8
	KY-31 Tall Fescue	7
	Kentucky Bluegrass	7
	Reed Canarygrass	7
	Grass-legume Mixture	5
	Lespedeza Sericea	3.5
	Small Grains	3.5
	Temporary Vegetation	3.5
5- 10 %	Bermuda Grass	7
	KY-31 Tall Fescue	6
	Kentucky Bluegrass	6
	Reed Canarygrass	6
	Grass-legume mixture	4
	Lespedeza Sericea	Not Recommended
	Small Grains	Not Recommended
	Temporary Vegetation	Not Recommended
Greater than 10%	Bermuda Grass	6
	KY-31 Tall Fescue	5
	Kentucky Bluegrass	5
	Reed Canarygrass	5
	Grass-legume mixture	Not Recommended
	Lespedeza Sericea	Not Recommended
	Small Grains	Not Recommended
	Temporary Vegetation	Not Recommended

Source: Elementary Soil and Water Engineering, Shwab et. al.

1.3 Installation

- Pipe or channel outlets at the top of cut slopes or on slopes steeper than 10% should not be protected using just outlet protection. This causes re-concentration of the flow that results in large velocities when the flow leaves the protection area.
- Follow specific standards for installation of the selected materials used for outlet protection.
- Follow all Manufacturer's installation procedures for TRMs and other manufactured products.
- A Manufacturer's Representative may be required to oversee all installation procedures and officially approve the installation of manufactured products used for outlet protection.

1.4 Inspection and Maintenance

- Periodically check all outlet protection, aprons, plunge pools and structural outlets for damage. Immediately make all needed repairs to prevent further damage.
- If any evidence of erosion or scouring is apparent, modify the design as needed to provide long term protection (keeping in mind fish passage requirements if applicable).
- Inspect outlet structures after heavy rains to see if any erosion has taken place around or below the structure.

1.5 Preventive Measures and Troubleshooting Guide:

Field Condition	Common Solutions
Riprap washes away.	Replace riprap with a larger diameter based on the pipe diameter and discharge velocity.
Apron is displaced.	Align apron with receiving water and keep it straight throughout its length. Repair damaged fabric and replace riprap that has washed away.
Scour occurs around apron or riprap.	Remove damaged TRM or riprap, fill in scoured areas, and repair damage to slopes channels or underlying filter fabric. Reinstall outlet protection.
Outlet erodes.	Stabilize TRM outlets with vegetation, replace eroded riprap; grout riprap.

Table 2: Flowrates for Concrete Pipes

Concrete Full Pipe Flow (CFS)																
n = 0.013	Pipe Size (inches)															
Slope	**15**	**18**	**24**	**27**	**30**	**36**	**42**	**48**	**54**	**60**	**66**	**72**	**78**	**84**	**90**	**96**
0.1	2.0	3.3	7.2	9.8	13.0	21	32	46	62	83	106	134	166	203	243	289
0.2	2.9	4.7	10.1	13.9	18.4	30	45	64	88	117	151	190	235	286	344	409
0.3	3.5	5.8	12.4	17.0	22.5	37	55	79	108	143	184	233	288	351	422	501
0.4	4.1	6.7	14.3	19.6	26.0	42	64	91	125	165	213	269	332	405	487	578
0.5	4.6	7.4	16.0	22.0	29.1	47	71	102	139	185	238	300	372	453	544	647
0.6	5.0	8.2	17.6	24.1	31.9	52	78	112	153	202	261	329	407	496	596	708
0.7	5.4	8.8	19.0	26.0	34.4	56	84	121	165	218	282	355	440	536	644	765
0.8	5.8	9.4	20.3	27.8	36.8	60	90	129	176	234	301	380	470	573	689	818
0.9	6.1	10.0	21.5	29.5	39.0	63	96	137	187	248	319	403	499	608	730	868
1.0	6.5	10.5	22.7	31.1	41.1	67	101	144	197	261	337	425	526	641	770	915
1.5	7.9	12.9	27.8	38.0	50.4	82	124	176	241	320	412	520	644	785	943	1120
2.0	9.2	14.9	32.1	43.9	58.2	95	143	204	279	369	476	601	743	906	1089	1293
2.5	10.2	16.7	35.9	49.1	65.0	106	160	228	312	413	532	671	831	1013	1217	1446
3.0	11.2	18.2	39.3	53.8	71.2	116	175	249	342	452	583	736	911	1109	1334	1584
3.5	12.1	19.7	42.4	58.1	76.9	125	189	269	369	489	630	794	983	1198	1440	1711
4.0	13.0	21.1	45.4	62.1	82.3	134	202	288	394	522	673	849	1051	1281	1540	1829
4.5	13.7	22.3	48.1	65.9	87.2	142	214	306	418	554	714	901	1115	1359	1633	1940
5.0	14.5	23.6	50.7	69.4	92.0	150	226	322	441	584	753	950	1175	1432	1722	2045
5.5	15.2	24.7	53.2	72.8	96.5	157	237	338	462	612	790	996	1233	1502	1806	2145
6.0	15.9	25.8	55.6	76.1	100.7	164	247	353	483	640	825	1040	1288	1569	1886	2240
6.5	16.5	26.9	57.8	79.2	104.9	171	257	367	503	666	858	1083	1340	1633	1963	2332
7.0	17.1	27.9	60.0	82.2	108.8	177	267	381	522	691	891	1124	1391	1695	2037	2420
7.5	17.7	28.8	62.1	85.0	112.6	183	276	394	540	715	922	1163	1440	1754	2109	2505
8.0	18.3	29.8	64.2	87.8	116.3	189	285	407	558	739	952	1201	1487	1812	2178	2587
8.5	18.9	30.7	66.1	90.5	119.9	195	294	420	575	761	982	1238	1533	1868	2245	2666
9.0	19.4	31.6	68.0	93.2	123.4	201	303	432	592	783	1010	1274	1577	1922	2310	2744
9.5	20.0	32.5	69.9	95.7	126.8	206	311	444	608	805	1038	1309	1620	1974	2373	2819
10.0	20.5	33.3	71.7	98.2	130.1	211	319	455	624	826	1065	1343	1662	2026	2435	2892

Table 3: Flowrates for HDPE Pipes

PVC/HDPE Full Pipe Flow (CFS)																	
n =	0.011	Pipe Size (inches)															
Slope	**12**	**15**	**18**	**24**	**27**	**30**	**36**	**42**	**48**	**54**	**60**	**66**	**72**	**78**	**84**	**90**	**96**
0.1	1.3	2.4	3.9	8.5	11.6	15.4	25.0	38	54	74	98	126	159	196	239	288	342
0.2	1.9	3.4	5.6	12.0	16.4	21.7	35.3	53	76	104	138	178	224	278	339	407	483
0.3	2.3	4.2	6.8	14.7	20.1	26.6	43.3	65	93	128	169	218	275	340	415	498	592
0.4	2.7	4.8	7.9	17.0	23.2	30.7	50.0	75	108	147	195	252	317	393	479	575	684
0.5	3.0	5.4	8.8	19.0	26.0	34.4	55.9	84	120	165	218	281	355	439	535	643	764
0.6	3.3	5.9	9.6	20.8	28.4	37.6	61.2	92	132	181	239	308	389	481	586	705	837
0.7	3.5	6.4	10.4	22.4	30.7	40.7	66.1	100	142	195	258	333	420	520	633	761	904
0.8	3.8	6.8	11.1	24.0	32.8	43.5	70.7	107	152	208	276	356	449	556	677	814	967
0.9	4.0	7.3	11.8	25.4	34.8	46.1	75.0	113	161	221	293	378	476	589	718	863	1025
1.0	4.2	7.7	12.4	26.8	36.7	48.6	79.0	119	170	233	309	398	502	621	757	910	1081
1.5	5.2	9.4	15.2	32.8	44.9	59.5	96.8	146	208	285	378	487	615	761	927	1114	1324
2.0	6.0	10.8	17.6	37.9	51.9	68.7	111.8	169	241	330	436	563	710	879	1071	1287	1528
2.5	6.7	12.1	19.7	42.4	58.0	76.9	125.0	189	269	368	488	629	794	982	1197	1439	1709
3.0	7.3	13.3	21.6	46.4	63.6	84.2	136.9	206	295	404	535	689	869	1076	1311	1576	1872
3.5	7.9	14.3	23.3	50.2	68.7	90.9	147.9	223	318	436	577	744	939	1162	1416	1702	2022
4.0	8.4	15.3	24.9	53.6	73.4	97.2	158.1	238	340	466	617	796	1004	1243	1514	1820	2162
4.5	9.0	16.2	26.4	56.9	77.9	103.1	167.7	253	361	494	655	844	1065	1318	1606	1930	2293
5.0	9.4	17.1	27.8	59.9	82.1	108.7	176.7	267	381	521	690	890	1122	1389	1693	2035	2417
5.5	9.9	18.0	29.2	62.9	86.1	114.0	185.4	280	399	547	724	933	1177	1457	1775	2134	2535
6.0	10.3	18.8	30.5	65.7	89.9	119.1	193.6	292	417	571	756	975	1229	1522	1854	2229	2647
6.5	10.8	19.5	31.7	68.3	93.6	123.9	201.5	304	434	594	787	1015	1279	1584	1930	2320	2756
7.0	11.2	20.3	32.9	70.9	97.1	128.6	209.1	315	450	617	817	1053	1328	1644	2003	2407	2860
7.5	11.6	21.0	34.1	73.4	100.5	133.1	216.5	327	466	638	845	1090	1374	1701	2073	2492	2960
8.0	11.9	21.7	35.2	75.8	103.8	137.5	223.6	337	481	659	873	1126	1419	1757	2141	2574	3057
8.5	12.3	22.3	36.3	78.2	107.0	141.7	230.4	348	496	679	900	1160	1463	1811	2207	2653	3151
9.0	12.7	23.0	37.3	80.4	110.1	145.8	237.1	358	511	699	926	1194	1506	1864	2271	2730	3242
9.5	13.0	23.6	38.4	82.6	113.1	149.8	243.6	367	525	718	951	1227	1547	1915	2333	2805	3331
10.0	13.4	24.2	39.4	84.8	116.1	153.7	249.9	377	538	737	976	1258	1587	1965	2394	2877	3418

Table 4: Flowrates for CMP Pipes

CMP Full Pipe Flow (CFS)																	
n =	0.025	Pipe Size (inches)															
Slope	**12**	**15**	**18**	**24**	**27**	**30**	**36**	**42**	**48**	**54**	**60**	**66**	**72**	**78**	**84**	**90**	**96**
0.1	0.6	1.1	1.7	3.7	5.1	6.8	11	17	24	32	43	55	70	86	105	127	150
0.2	0.8	1.5	2.4	5.3	7.2	9.6	16	23	33	46	61	78	99	122	149	179	213
0.3	1.0	1.8	3.0	6.5	8.8	11.7	19	29	41	56	74	96	121	150	182	219	260
0.4	1.2	2.1	3.5	7.5	10.2	13.5	22	33	47	65	86	111	140	173	211	253	301
0.5	1.3	2.4	3.9	8.3	11.4	15.1	25	37	53	73	96	124	156	193	236	283	336
0.6	1.4	2.6	4.2	9.1	12.5	16.6	27	41	58	79	105	136	171	212	258	310	368
0.7	1.6	2.8	4.6	9.9	13.5	17.9	29	44	63	86	114	146	185	229	279	335	398
0.8	1.7	3.0	4.9	10.6	14.4	19.1	31	47	67	92	121	157	198	244	298	358	425
0.9	1.8	3.2	5.2	11.2	15.3	20.3	33	50	71	97	129	166	209	259	316	380	451
1.0	1.9	3.4	5.5	11.8	16.1	21.4	35	52	75	103	136	175	221	273	333	400	476
1.5	2.3	4.1	6.7	14.4	19.8	26.2	43	64	92	126	166	214	270	335	408	490	582
2.0	2.6	4.8	7.7	16.7	22.8	30.2	49	74	106	145	192	248	312	387	471	566	673
2.5	2.9	5.3	8.7	18.7	25.5	33.8	55	83	118	162	215	277	349	432	527	633	752
3.0	3.2	5.8	9.5	20.4	28.0	37.0	60	91	130	178	235	303	382	473	577	693	824
3.5	3.5	6.3	10.2	22.1	30.2	40.0	65	98	140	192	254	328	413	511	623	749	890
4.0	3.7	6.7	11.0	23.6	32.3	42.8	70	105	150	205	272	350	442	547	666	801	951
4.5	3.9	7.1	11.6	25.0	34.3	45.4	74	111	159	218	288	371	468	580	707	849	1009
5.0	4.2	7.5	12.2	26.4	36.1	47.8	78	117	167	229	304	392	494	611	745	895	1063
5.5	4.4	7.9	12.8	27.7	37.9	50.2	82	123	176	240	318	411	518	641	781	939	1115
6.0	4.6	8.3	13.4	28.9	39.6	52.4	85	128	183	251	333	429	541	670	816	981	1165
6.5	4.7	8.6	14.0	30.1	41.2	54.5	89	134	191	261	346	446	563	697	849	1021	1212
7.0	4.9	8.9	14.5	31.2	42.7	56.6	92	139	198	271	359	463	584	723	881	1059	1258
7.5	5.1	9.2	15.0	32.3	44.2	58.6	95	144	205	281	372	480	605	749	912	1096	1302
8.0	5.3	9.5	15.5	33.4	45.7	60.5	98	148	212	290	384	495	625	773	942	1132	1345
8.5	5.4	9.8	16.0	34.4	47.1	62.4	101	153	218	299	396	510	644	797	971	1167	1386
9.0	5.6	10.1	16.4	35.4	48.4	64.2	104	157	225	308	407	525	662	820	999	1201	1427
9.5	5.7	10.4	16.9	36.4	49.8	65.9	107	162	231	316	419	540	681	843	1027	1234	1466
10.0	5.9	10.7	17.3	37.3	51.1	67.6	110	166	237	324	429	554	698	864	1053	1266	1504