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Evaluation of ALDOT Ditch Check Practices using Large-Scale Testing Techniques

Large-scale Channel Testing
(ASTM D 7208 – modified)
of
Evaluation of ALDOT Class I Riprap
w/8 oz. Nonwoven Filter Fabric Choker Ditch Check
over
Poorly Graded Sand

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EXECUTIVE SUMMARY

Ditch checks are used to impound stormwater runoff in channelized flow areas on construction sites. The primary purpose of ditch checks is to control erosion in earthen runoff conveyances by decreasing velocity and therefore erosive shear stresses. This occurs by creating the longest impoundment area possible by causing supercritical flow to transform into subcritical flow which results in greater depths and decreased velocity. Channelized, high flow and high velocity stormwater runoff in earthen channels typically require riprap ditch checks to impound water because of their ability to withstand the resultant forces created by the high flows while maintaining its structural integrity. Using riprap, however creates pore passages between the aggregate which easily allows water to flow through the ditch check resulting in shorter impoundment lengths.

Choking pore passages is recommended by the Alabama Department of Transportation (ALDOT) to reduce flow-through and increase impoundment length. Two flow choking methods were tested at the Auburn University Erosion and Sediment Control Testing Center to determine greatest impoundment performance: (1) ALDOT no. 4 coarse aggregate, and (2) 8 oz. nonwoven filter fabric. All tests were performed at high flow condition of 1.7 cfs for a duration of 30 minutes. A riprap installation was also tested without a choker for comparative purposes and resulted in an average impoundment length of 14.5 ft. The ALDOT no. 4 coarse aggregate choker resulted in a riprap ditch check impoundment length of 20.5 ft which was in increase of 41.1%. The 8 oz. nonwoven filter fabric choker resulted in a riprap ditch check impoundment length of 29.1 ft which was an increase of 100%. Therefore it is the recommendation of this study to use an 8 oz. nonwoven filter fabric to choke flow and to maximize impoundment length and minimize erosion.

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1 INTRODUCTION

Controlling erosion and sediment transport on construction sites has been deemed a top priority for environmental agencies such as the US Environmental Protection Agency (EPA) and the Alabama Department of Environmental Management (ADEM). Maximizing erosion and sediment control practices on construction sites has been the focus of this research study for the Alabama Department of Transportation (ALDOT). The use of ditch checks has been widely used on ALDOT construction sites and a need arose for determining the optimal practice and installation procedures for each ditch check.

Ditch checks are obstructions placed in paths of concentrated, channelized flows which impound water. This water impoundment creates subcritical, low velocity pools which reduce channel shear stress and channel erosion. Determining the most effective and feasible installation for rock ditch checks is the purpose of this report. This report evaluates rock ditch checks, with and without chokers, to determine which installation will result in the greatest impoundment, and thereby protect the earthen channel from the greatest amount of stormwater induced erosion.

2 BACKGROUND

Rock ditch checks are typically comprised of one or more classifications of aggregate which must be large enough to withstand velocities of concentrated, channelized stormwater runoff while also impounding water. The Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas, Volume 1, requires the use of ALDOT Class I Riprap with a geotextile underlay to protect the channel from undercutting and piping (*1*). The spacing of ditch checks if they are to be used to maximize performance and minimize erosion, such as riprap ditch checks, are to be no greater than the length of the ditch check's maximum pool length which protects the greatest amount of channel as shown in Figure 1.

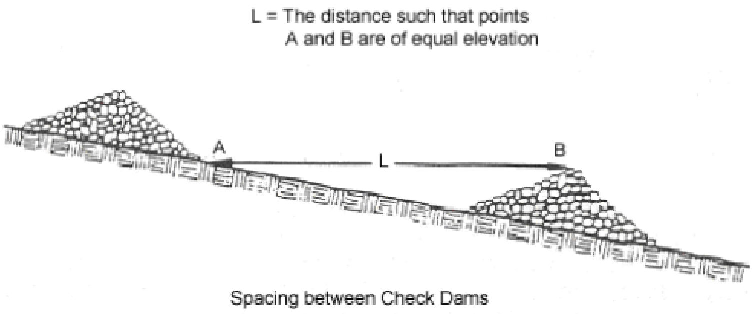


Figure 1: Alabama Handbook Recommended Ditch Check Spacing (*1*)

This spacing requirement is based upon ditch check height and channel slope. Shallower channels will allow greater ditch check spacing while steeper channels require shorter spacing for ditch checks of the same height. Also, taller ditch checks will require longer spacing when compared to shorter ditch checks used for the same longitudinal slope. This concept is shown in Figure 2. ALDOT places a minimum ditch check spacing of 100 ft (*4*).

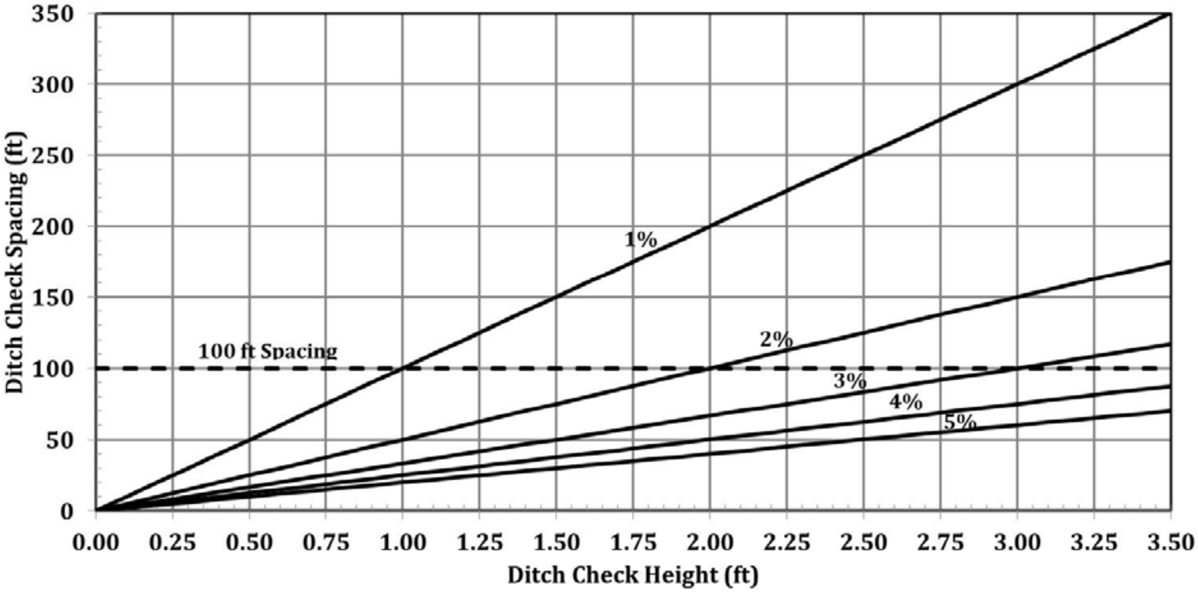


Figure 2: Ditch Check Spacing Based Upon % Long. Slope and Ditch Check Height

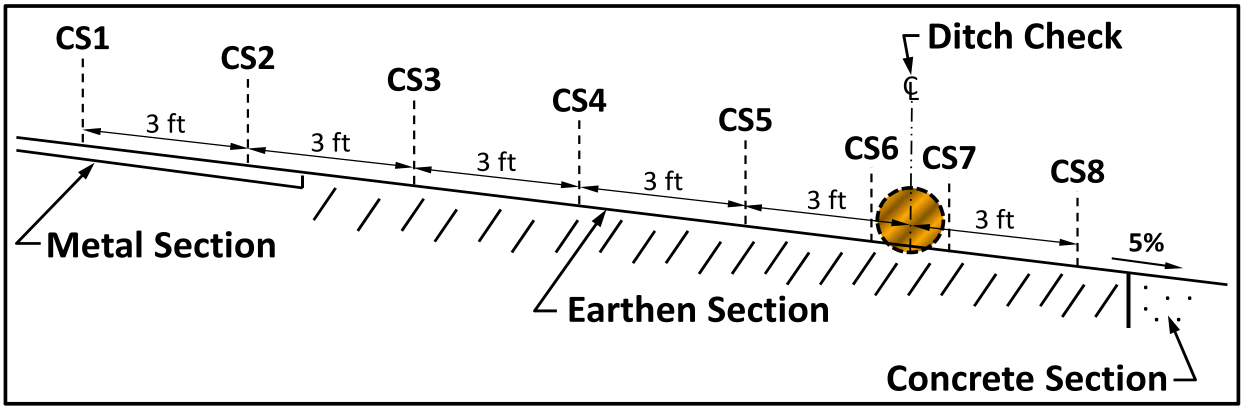
3 TESTING METHODOLOGY

All tests conducted as part of this research were performed at the Auburn University Erosion and Sediment Control Facility (AU-ESCTF) located at the National Center for Asphalt Technology (NCAT) in Opelika, AL. To properly evaluate the affect various installation configurations have on rock ditch check performance, ALDOT certified Class I riprap was used for each test.

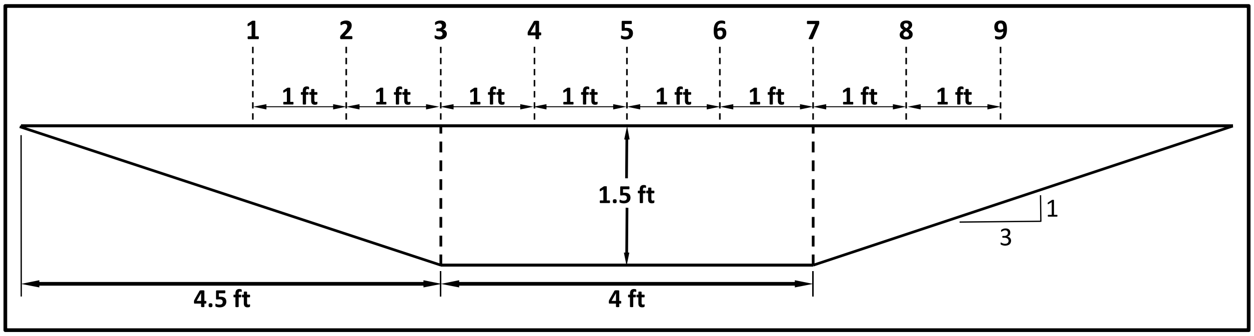
The standard test method referenced for the development of the testing methodology used in this study was ASTM D 7208-06: *Standard Test Method for Determination of Temporary Ditch Check Performance in Protecting Earthen Channels from Stormwater-Induced Erosion* (*2*).

3.1 Test Channel

The AU-ESCTF has a test channel dedicated to performance testing of ditch checks in concentrated flow applications and is shown in Figure 3(a) and (b).



(a) Elevation View



(b) Cross-Sectional View

Figure 3: Ditch Check Test Channel Dimensions and Configuration.

The ditch check testing channel has a trapezoidal cross-section with a top width of 13 ft (4 m) and a bottom width of 4 ft (1.2m) with 3H:1V side slopes. The depth of the channel is 1.5 ft (0.5 m) and is 39.5 ft (12 m) long. The channel is divided into a galvanized steel plated section 24.5 ft (7.5 m) long and an earthen section 15 ft (4.6 m) long. The longitudinal slope of the channel is 5%. The earthen section allowed for field quality installations and performance observations of the ditch checks. The metal lined portioned allowed the ditch checks to be tested regardless of channel performance.

3.1.1 Preparation of the Test Channel

Before each test, the 15 ft (4.6 m) earthen section is tilled using a rear tine tiller, hand raked, hand tamped, and then mechanically compacted using an upright rammer hammer with a compaction plate of 14 x 11.5 in. (36 x 29 cm), a blow count of 600 blows/minute and a compaction force of 2,700 lbs (1,225 kg). The soil within the earthen section was classified as a poorly graded sand using the USGS Soil Classification System. The maximum density of 123.8 lbs/ft^3 (19.44 kN/m^3) was determined by the method described in ASTM D698-07, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort* (*3*). In-place density samples were taken with a density drive hammer and thin walled Shelby tubes to verify that at least 95% compaction was achieved.

3.2 Constant Flow Test

The test for riprap ditch check installation evaluation for this study used a sustained, constant flow of 1.7 cfs (48 L/s) of clean water for a duration of 30 minutes. Prior to testing, eight level string lines were stretched across the channel at 8 cross-sectional (CS) locations (Figure 3(a): CS-1 to CS-8), six upstream and two downstream of the ditch check. The measurement points were spaced 1 ft (0.3 m) apart along each string line. These string lines were used to take erosion and deposition at each point, and water depth and velocity measurements at points 4, 5 and 6 shown in Figure 3(b) during each test.

3.3 Installation Evaluation Regime

A series of constant flow, large-scale ditch check experiments were performed to evaluate each installation configuration. These were done to comparatively analyze the three different riprap ditch check installation configurations. For each installation configuration, three replicate tests were performed, totaling 9 large-scale experiments.

3.3.1 Materials for Installations

The following is a list of materials used for the various riprap installation configurations:

- *ALDOT Class I Riprap*: consist of graded stones ranging from 10 to 100 pounds (5 to 50 kg) with not more than 10% having a weight (mass) over 100 pounds (50 kg) and at least 50% having a weight (mass) over 50 pounds (25 kg) and not over 10% having a weight (mass) under 10 pounds (5 kg) (*4*),
- *ALDOT No. 4 Coarse Aggregate*: consist of graded aggregate ranging from 1.5 in. to ⅜ in. (37.5 to 9.5 mm) with not more than 10 % greater than 1.5 in. (37.5 mm), at least 20-55% 1 in. (25 mm) and no more than 15% smaller than ¾ in. (9.5 mm) (*4*),
- *Sod Staples*: 11 gauge metal, 6 in. long x 1 in. (15 cm x 2.5 cm) wide U-shape staples or 11 gauge metal, 6 in. long x $1^{3}/_{8}$ in. (15 cm x 3.5 cm) round-top sod pin , used to secure the filter fabric underlay, and
- *Filter Fabric (FF) Underlay*: 8 oz. (225 gram), nonwoven FF, 12-20 ft (3.7-6 m) long depending on installation, 15 ft (4.6 m) wide. Extends 3 ft (1m) upstream from the upstream face of the riprap and pinned by two rows of sod staples spaced every 10 inches (25 cm) staggered on center. The fabric underlay extends 3 ft (1 m) downstream beyond the riprap. The downstream edge of FF was secured with sod staples spaced 10 in. (25 cm) apart. Also pinned longitudinally along each side and the centerline of the fabric spaced 1.5 ft (0.45 m).

3.3.2 Riprap Ditch Check Installation Tests

The channel was prepared to experimental specifications for all tests performed on the three different riprap ditch check installation configurations so direct comparisons could be made between each configuration. The following three riprap installation configurations were tested:

(1) *Riprap Ditch Check w/no Choker*: current ALDOT installation (Figure 4(a)), 8 oz. FF underlay extends beyond the toe of the rock slope 3 ft (1 m) upstream and downstream. The height of the ditch check is 18 in. (46 cm) and the base is 9 ft (2.7 m) from upstream to downstream toe of slope with rock slope being 3:1, (*5*)

(2) *Riprap Ditch Check w/ALDOT No. 4 Coarse Aggregate Choker*: installation mimics *Riprap Ditch Check w/no Choker*, however the upstream rock slope face is covered with a layer of ALDOT No. 4 coarse aggregate, as shown in Figure 4(b), and

(3) *Riprap Ditch Check w/8 oz. FF Choker*: installation uses an extra 8 ft of filter fabric. The fabric is extended 3 ft upstream of the toe of the slope, pinned and then pulled back downstream to drape over the upstream face of the riprap ditch check, where then riprap is used to secure the fabric in place as shown in Figure 4(c) and (d).

(a) Riprap ditch check w/no choker (b) Riprap ditch check w/no. 4 coarse aggregate

(c) Riprap ditch check w/8 oz. FF choker (d) 8 oz. FF choker secured w/riprap

Figure 4: Riprap Ditch Check Installation Configurations

3.4 Data Collected

Once steady-state flow conditions were achieved, water depth and velocity measurements were taken at cross-sectional measurements points, 4, 5, and 6 cross sections CS1 – CS4, CS7, and CS8 shown in Figure 3(a) and (b). These points were averaged to determine the average water depth and average velocity for each cross section. Cross sections CS5 and CS6 were not measured due to the size of the ditch check. The distance from the upstream face of the ditch check to the hydraulic jump was also recorded once steady-state conditions were achieved to determine subcritical flow length created by the installation's ability to impound water.

Using the collected data, the slope of the energy grade line (EGL) for the water profile was plotted as specified by ASTM D 7208-06. The EGL is defined by equation 1 (*7*).

$$EGL = WSE + v^2/2g \qquad \text{[EQ. 1]}$$

where,

EGL = energy grade line (ft)
WSE = water surface elevation (ft)
v = average water velocity (ft/sec)
g = gravitational constant (32.2 ft/sec^2)

The slope of the EGL for long, unimpeded, continuous flow channels should closely mimic the channel slope. When the channel is impeded (e.g., by a ditch check), the slope of the EGL within the impoundment area becomes smaller than the channel slope as ponding depths increase towards the ditch check. The potential energy built up by the subcritical flow is returned to kinetic energy as the impounded water goes under, through and/or over the ditch check. For riprap ditch checks, the flow traveling through and/or down the downstream rock slope acts as further energy dissipation and reducing water velocity through the flow transition. In addition to impounding water and reducing erosion due to shear stresses, the installation must also withstand hydrodynamic pressure fore in the front face of the ditch check and must maintain its structural integrity without a major failure.

4 RESULTS AND DISCUSSION

The following section is a summary of the results and comparisons that were made from the experiments using a 1.7 cfs constants flow rate for all large-scale tests performed. Table 4.1 shows the comparative results of the various riprap installation configurations. Table A.1, shown in the appendix summarizes the individual tests results of each test for the various installation types

Table 4.1: Comparative Results of Each Riprap Installation Configuration

Installation Type	Avg. Pool Length (ft)	% Difference(1)	% Efficiency(2)
Riprap w/No Choker	14.5	N/A	48.3%
Riprap w/No. 4 Coarse Aggregate	20.5	41.4%	68.3%
Riprap w/8 oz. FF Choker	29.1	100%	97.0%

(1) % difference w/respect to riprap w/no choker installation
(2) % efficiency refers % of spacing required for ditch check based on Figure 2 in comparison to average pool length

The Riprap w/no Choker installation (Figure 5(a)) allows flow to easily pass through the ditch check decreasing possible impoundment length when compared to the two ditch check installations with chokers. Adding ALDOT No. 4 coarse aggregate to the installation as shown in Figure 5(b) decreased the flow-through capabilities of the ditch check which therefore increased the impoundment length from 14.5 to 20.5 ft, an increase of 41.4%. Using the 8 oz. FF choker instead of the No. 4 coarse aggregate choker, as shown in Figure 5(c), further increased the pool length from 14.5 to 29.1 ft, an increase of 100%. A secondary benefit of using the filter fabric choker is that the fabric restricts flow through the ditch check and causes it to pass over and down the downstream slope of the ditch check as shown in Figure 5(d). This decreases the velocity of the water as it resumes down the ditch whereas water that flows through the ditch check finds the path of least resistance which are typically small passages which increase water velocity, creating a nozzle affect. Another secondary benefit of the FF choker is when maintenance action is required as a result of sediment accumulation in front of the upstream face of the ditch check, the FF choker can be cut away from the underlay and replaced, increasing the longevity of the ditch check.

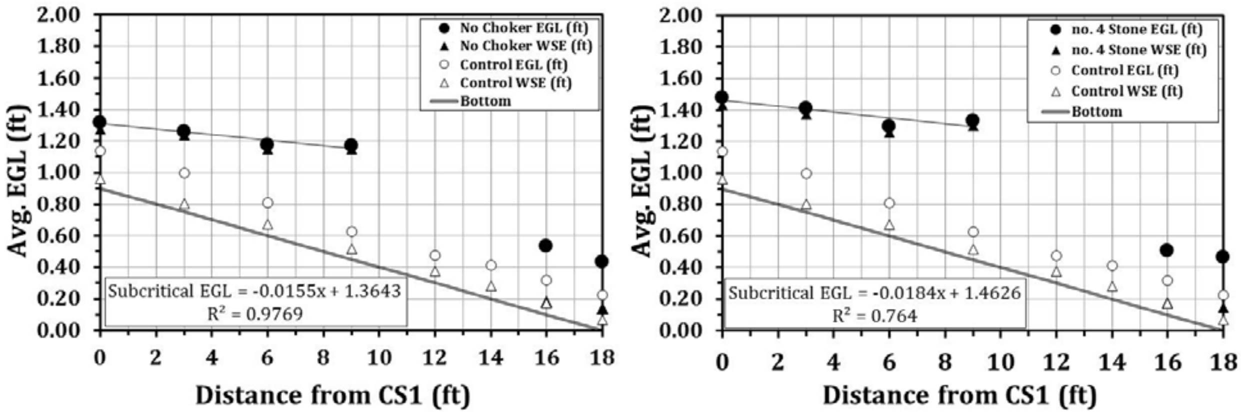
Referring back to Figure 2 and Table 1, it should be noted that the Riprap w/8 oz. FF Choker installation nearly reaches the expected ditch check impoundment length of 30 ft for an 18 in. (46 cm) tall ditch check in a 5% sloped channel. This means the ditch check was performing at nearly 100% efficiency for creating the greatest impoundment length.

(a) Riprap ditch check w/no choker (b) Riprap ditch check w/no. 4 coarse aggregate choker

(c) Riprap ditch check w/8 oz. FF choker (d) Energy dissipation w/ 8 oz. FF choker

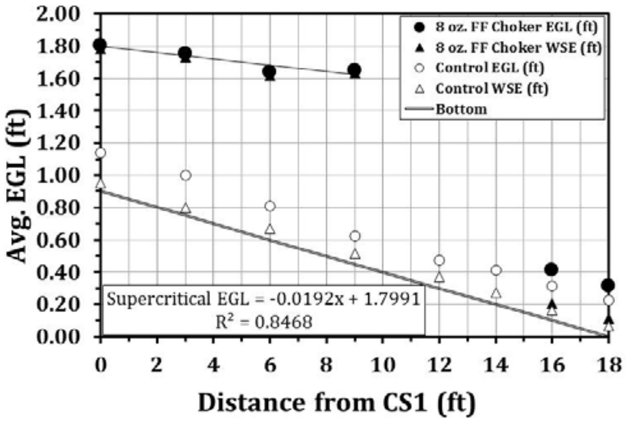
Figure 5: Average Performance of Each Riprap Ditch Check Installation

The slope of the EGLs for each installation is shown in Figure 6. The graphs depict the average EGL and WSE for all installation experimental replications. The slope of EGL will greatly decrease as flow is impounded and the transition occurs from supercritical to subcritical flow. Though this occurs for each installation, the degree of change varies based upon flow condition. Typically for shorter impoundments, flow is abruptly slowed, creating an EGL that flattens out very quickly near the upstream face of the ditch check. This flattening, in conjunction with a short impoundment length, often times creates an EGL that has a slightly smaller slope than the EGL slope of very long impoundments. Long impoundment lengths do not experience smaller EGL slopes in comparison to shorter impoundments because in these long-impoundment cases flow is affected by the slope of the channel as water flows over the structure instead of through it. When comparing the slope of the EGLs for the rip rap tests, a small increase in the slope of the EGL occurs as the impoundment pool increases for the various installations. These increases are small and still maintain a much smaller EGL slope than that of the unimpeded flow which has an EGL of approximately 0.05 slope which is the approximate slope of the channel. This trend is similar to wattle ditch check installation evaluations whereas the ditch check impoundment lengths increase, a slight increase in EGL slope was also noticed.



(a) Riprap ditch check w/no choker EGL and HGL

(b) Riprap ditch check w/no. 4 coarse aggregated choker EGL and HGL



(c) Riprap ditch check w/8 oz. FF choker EGL and HGL

Figure 6: Riprap Ditch Check Choker Comparisons

5 CONCLUSIONS

Riprap ditch checks are typically used in high flow, high velocity conditions due to their structural stability to withstand high velocity and flow forces. However, due to the large pores created by the aggregate shape, water has greater passages available for water to pass through the ditch check rather than over which results in decreased impoundment lengths. Choking these pore passages is a means to mitigate this issue and is recommended by ALDOT. ALDOT ESC 300 recommends choking with aggregate to decrease flow through. The AU-ESCTF tested both ALDOT No. 4 coarse aggregate and 8 oz. FF to determine which choker creates the longest impoundment length. The AU-ESCTF has determined that choking the ditch check with 8 oz. FF is a better means of flow impoundment and resulted in an impoundment length of 29.1 ft which was a 100% increase in flow length and a 97% impoundment efficiency in comparison to the riprap ditch check with no choker which impounded water14.5 ft at 48.3% impoundment efficiency. ALDOT No. 4 coarse aggregate impounded flow 20.5 ft which is a 50% increase in impoundment length at a 68.3% impoundment efficiency when also compared to the riprap ditch check with no choker installation.

6 RECOMMENDATIONS FOR IMPLEMENTATION

As a result of this testing effort, the research team's recommendation is to incorporate the 'Riprap Ditch Check w/8 oz. FF choker' installation into the ALDOT Standard Drawings. Based upon the results of the testing this installation resulting in a 100% increase in impoundment length in comparison to current standard installation of '*Riprap w/No Choker*', and greatly reduced flow velocities upstream of the installation. Both the increased impoundment and a reduction of velocity will maintain the integrity of an earthen channel upstream of the installation in high flow scenarios, which is a desirable outcome.

7 ACKNOWLEDGEMENTS

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8 REFERENCES

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9 APPENDIX A

Table A.1: Comparative Results of All Riprap Tests

Installation	Avg Pool Length (ft)	% Difference(1)	% Efficiency(2)	EGL Slope (ft)
No Choker	14.5	N/A	48%	0.0141
	14.5	N/A	48%	0.0165
	14.5	N/A	48%	0.0176
#4 Choker	20.5	41%	68%	0.0192
	20.8	43%	69%	0.0181
	20.7	43%	69%	0.0174
FF Choker	29.2	101%	97%	0.0190
	29.2	101%	97%	0.0193
	29.0	100%	97%	0.0194

(1) % difference w/respect to riprap w/no choker installation
(2) % efficiency refers % of spacing required for ditch check based on Figure 2 in comparison to average pool length