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FAILURE OF RIPRAP PROTECTION - PHASE II (FINAL REPORT)

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16. Abstract

Riprap rundowns are often used by the New Mexico Department of Transportation (NMDOT) to capture and drain the runoff approaching or leaving bridge decks. Rundowns are generally located at the ends of a bridge deck to transport the water down the surface of the slopes of bridge embankments. They constitute an important part of the bridge drainage system. In some occasions, riprap rundowns have also been used for drainage and erosion protection of slopes and embankments along highways in New Mexico. The NMDOT Drainage Section identified recurrent failures of the riprap rundown structures throughout the state. The poor performance and failures of the riprap rundowns in some areas have required costly maintenance repairs and reconstruction. This study is aimed at identifying and characterizing the most frequent failure modes for riprap rundowns and providing best management practice (BMP) recommendations to improve the performance of these structures. Design, materials and construction issues were considered. Selected cases of rundowns that exhibited typical problems were described in this report to illustrate the failure modes and performance problems.

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FAILURE OF RIPRAP PROTECTION – PHASE II (FINAL REPORT)

by

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Report No. NM04STR-04

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PREFACE

The research reported herein evaluates the common failure mechanisms of riprap rundowns in New Mexico and provides recommendations on how to avoid such failures in future design and construction of riprap structures. The study included wire-enclosed and non enclosed riprap rundowns. Design, materials and construction issues were considered. Selected cases of rundowns that exhibited typical problems were described in this report to illustrate the failure modes and performance problems.

NOTICE

DISCLAIMER

ABSTRACT

Riprap rundowns are often used by the New Mexico Department of Transportation (NMDOT) to capture and drain the runoff approaching or leaving bridge decks. Rundowns are generally located at the ends of a bridge deck to transport the water down the surface of the slopes of bridge embankments. They constitute an important part of the bridge drainage system. In some occasions, riprap rundowns have also been used for drainage and erosion protection of slopes and embankments along highways in New Mexico. The NMDOT Drainage Section identified recurrent failures of the riprap rundown structures throughout the state. The poor performance and failures of the riprap rundowns in some areas have required costly maintenance repairs and reconstruction. This study is aimed at identifying and characterizing the most frequent failure modes for riprap rundowns and providing best management practice (BMP) recommendations to improve the performance of these structures. Design, materials and construction issues were considered. Selected cases of rundowns that exhibited typical problems were described in this report to illustrate the failure modes and performance problems.

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The author also acknowledges the contributions of the graduate research assistant A. Saheem Ahmad during the field visits, soil testing and literature review, and the valuable assistance of David Trujillo, Jr., Jose A. Silva, and Lowe Scott during the site investigations. David Trujillo, Jr. also edited this report and provided soil samples and photographs of some of the riprap rundowns.

Special thanks go to all the Patrol Foremen who provided information and photographs of the riprap structures for this project and assisted during the site visits. Thanks also to Theodore (Ted) Barela, District 3 Project Manager, for helping with the slope measurements of two of the riprap rundowns in Albuquerque.

The author thanks especially Dr. Adrian T. Hanson, Professor of Civil and Environmental Engineering at New Mexico State University, for his enlightening discussions about the case studies described in this report and many important concepts of surface drainage, soil erosion and structure performance, for his editing of this report, and for his technical assistant during some of the site visits of this project.

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INTRODUCTION

Rundowns are surface (open) channels, often located at the ends of a bridge deck, to transport the water down the surface of the slopes or bridge abutments. They constitute an important part of the bridge drainage system. Riprap rundowns are often used by the New Mexico Department of Transportation (NMDOT) to drain the surface runoff approaching or leaving bridge decks. In other occasions, riprap rundowns are used in New Mexico for drainage and erosion protection of slopes and highway embankments. The most common type of riprap placement method for rundowns in New Mexico is the wire enclosed riprap; however, non-enclosed riprap and grouted riprap aprons are also built. Riprap grouting in rundowns and culvert outlets has often been adopted by some NMDOT maintenance crews as a remedial means after recurrent maintenance repairs of non-grouted riprap structures. The design of rundowns by NMDOT often includes a reinforced concrete flume inlet, whose geometry and size depend on the location, purpose and drainage patterns of the site. Riprap rundowns in very steep grade are not as common in other parts of the United States as they are in New Mexico.

For bridge and highway projects designed in-house, the NMDOT Drainage Section is responsible for the design of the drainage structures including rundowns. The design, materials, and construction details on these projects are in accordance with the NMDOT standard drawings (NMDOT, 2008) and standard specifications (NMDOT, 2007). Contractor-designed and built bridge and highway projects also comply with these standards and specifications. The NMDOT is concerned about the frequent failures and poor performance of the riprap protection systems, especially riprap rundowns. This project is aimed at identifying and characterizing the most frequent mechanisms of riprap rundown failure and providing best management practice (BMP) recommendations to improve the performance of these structures. Design, materials, and construction issues were considered in this study. Selected rundowns that exhibited typical performance problems were described in this report to illustrate the failure modes. The erosion problems and riprap protection failures at the outlet of small-size and medium-size culverts were studied in Phase I of this project, with emphasis on the culvert outlet failures and scour (Bandini and White, 2006).

This research project focused on studying and monitoring the performance of riprap rundowns designed and built per NMDOT specifications (sheets 515-02, 602-01, and 602-02), especially those structures located in problem areas identified by the NMDOT Drainage Section staff or District personnel. One of the tasks of this project required the construction and field testing of riprap rundowns. NMDOT District 1 was selected for the field testing because of its close vicinity to the main campus of New Mexico State University, located in Las Cruces, New Mexico. However, construction monitoring and field testing of new riprap rundowns in District 1 could not done due to the lack of maintenance funds and available maintenance personnel for this purpose, and delays in new construction projects in the District. This research project originally included monitoring the construction and performance of new riprap revetments and riprap gabion structures to be installed in two new bridges (No. 5701 and No. 5500) along highway NM 26, at mileposts 16.6 and 22.4, respectively [Control Number G3131]. According to the final design inspection meeting agenda (dated December 19, 2006), the projected construction date for this project was February 2007. Due to significant delays in the construction schedule of these bridges, the riprap structures at these locations were not installed by the contractor before the completion of this research project.

NMDOT STANDARD DRAWINGS AND SPECIFICATIONS FOR RIPRAP RUNDOWNS

The NMDOT standard drawings for wire enclosed riprap rundowns and culverts are labeled 515-02, 602-01, and 602-02 (NMDOT, 2008) (Appendix A). Note that these standard drawings do not refer to non-enclosed riprap rundowns. The current version of the standard drawing 515-02 includes two sheets, approved June 12, 2007. This standard drawing describes the materials and construction details of rundown flumes Type I for modified or pinned curb with half pipe rundown and riprap pad for erosion control (sheet 1/2) and alternative rundowns for Type I, II and III flumes, with full pipe, concrete or riprap (sheet 2/2).

The standard drawing 602-01 consists of a single sheet that describes the construction details and splicing for wire enclosed Class A riprap, including "W" wire mesh and hexagonal wire mesh. Two cross sections types are provided (Figure 1). It also provides relationships to estimate quantities (in cubic yards) per linear foot of riprap for various slope inclinations. These standard drawings call for 5-ft long (1.5-m long) steel stakes at 8-ft (2.4-m) centers and geotextile below the riprap to avoid erosion of the supporting soil. However, the type of geotextile is not specified in these drawings. These drawings were approved November 29, 2004.

The standard drawing 602-02 also consists of a single sheet that provides the standards for erosion control using wire-enclosed riprap Class A at culvert outlets. The current version was approved September 6, 2007. In all cases described in this standard drawing, non-woven geotextile Class 1 is required between the riprap and the supporting soil. (The appropriate filter material is essential to avoid large hydraulic gradients in the water that infiltrates into the soil through the geotextile; large hydraulic gradients can cause erosion and "piping" in the supporting soil and embankment.) Wire mesh, steel stakes, and splice details are also provided.

In addition to the standard drawings, NMDOT also has standard specifications for wire-enclosed and non-enclosed riprap for erosion control structures, as part of the *Standard Specifications for Highway and Bridge Construction, Section 602-Slope and Erosion Protection Structures* (NMDOT, 2007). (These standard specifications were updated in 2007; however, Section 602 remained, in essence, the same as the one in the 2000 edition concerning the subjects relevant to this research project.) These specifications include riprap material classification, based on the maximum and minimum stone volumes and the minimum stone dimension, wire

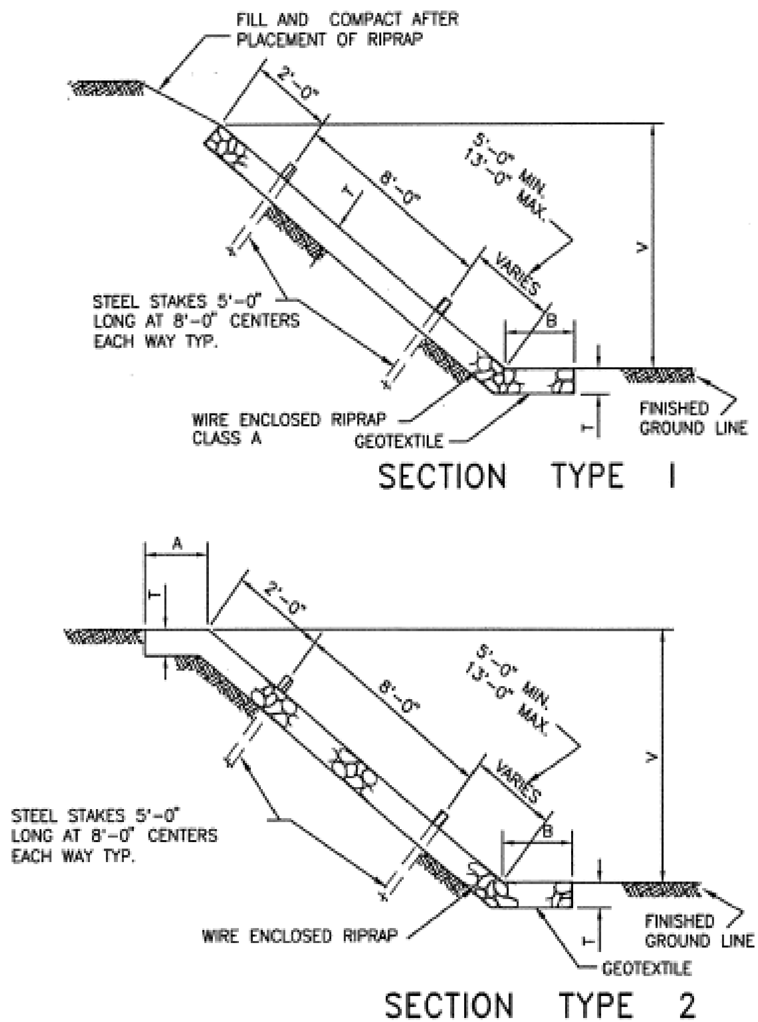


Figure 1. Typical cross sections of wire enclosed riprap rundowns according to the NMDOT Standard Drawing 602-01 "*Wire enclosed riprap Class A*" (From NMDOT, 2008) (1 ft = 0.305 m)

types and mesh opening size, steel stakes, grout, wire mesh lacing and fastening, geotextiles, and construction requirements. The standard drawings 515-02, 602-01, and 602-02 (NMDOT, 2008) call for riprap Class A and G only, depending on the particular application. The stone volume and gradation requirements for these classes are shown in Table 1. No specification on the number of fracture faces are provided for stones of riprap Classes A and G. (Classes E and F are grouted riprap.) Regardless of the riprap class, at least 80% of the stones used shall meet the specified size requirements given by Section 602 (NMDOT, 2007).

TABLE 1. Riprap Classes A and G (NMDOT, 2007).

Class	Description	Stone Volume				Minimum Dimension[a]	
		m^3		ft^3		mm	in.
		Min	Max	Min	Max		
A	Wire-enclosed riprap	0.005	0.02	1/6	2/3	100	4
G	Rock Plating[b]	-	-	-	-	100 to 200	4 to 8

- Values not applicable.
[a] Minimum size in the least dimension.
[b] 70% to 80% of the stone shall be at least 100 mm (4 in.) but not more than 200 mm (8 in.) in the smallest dimension. The remainder of the stone (20% to 30%) shall be no larger 100 mm (4 in.) in any dimension.

According to *Section 604-Soil and Drainage Geotextiles* (NMDOT, 2007), the geotextile or filter fabric for erosion control purposes shall be Class 1 or Class 2, as classified by *AASHTO M288 Standard Specification for Geotextile Specification for Highway Applications* (ASSHTO, 2006). There are three different classes of geotextiles depending on their strength: Classes 1, 2 and 3. Class 1 is the strongest and Class 3 is the weakest. (Class strength is determined based on grab strength, sewn seam strength, tear strength, puncture strength, burst strength, and elongation.) Additionally, the NMDOT specifications prohibit "the use of woven slit-film geotextiles or geotextiles made of yarns of a flat tape-like character" for erosion control or surface drainage applications. This is consistent with the recommendations of Lagasse et al.

(2006). If a woven monofilament geotextile is used for erosion control, the geotextile shall be Class 2; otherwise, the geotextile shall be Class 1 (NMDOT, 2007).

FAILURE OF RIPRAP RUNDOWNS

RIPRAP SITES AND INVESTIGATIONS

To study the performance of the riprap rundowns designed according to the current NMDOT standards and specifications, the existing riprap rundown structures in New Mexico had to be located by route and milepost. In April 2006, a communication was sent out (via e-mail) to patrol yards and maintenance personnel of the six NMDOT Districts, requesting information on location and conditions of riprap rundowns maintained by NMDOT. A second e-mail request was sent approximately six months later to those that did not respond the first time. The requests included number of sites, route and mile marker, name of reporter, structure type (e.g., wire enclosed riprap rundowns, non-enclosed riprap rundowns, riprap gabion baskets), date and time, estimated year of construction, and comments on the performance or condition of the structure.

Over 35 riprap sites were identified from the responses of 15 Patrol Yards throughout the state. These sites exhibited different levels of performance varying from good to very poor and included riprap rundowns, grouted riprap aprons and outlets, riprap blankets for erosion control, and riprap gabion baskets. Staff of the NMDOT Drainage Section and District 1 provided the location of approximately 12 additional sites with riprap rundowns and gabions built or supported on various soil types and provided technical assistance to the Principal Investigator during the site investigations. Most of the sites were visited and investigated at least once during the research project. Samples of the soil supporting selected rundowns were collected for classification purposes.

FAILURE MODES IN RIPRAP RUNDOWNS

This research project aimed at identifying and characterizing the failure modes of riprap rundowns in New Mexico, especially in bridge abutments. The study focused on factors related to design, materials, and construction that are likely to affect the performance of these drainage and erosion protection systems. The evaluation was based mainly on field observations and soil classifications, taking into account functional requirements and specifications. A failure mode is defined here as the way in which the failure of a system (or structure) occurs during service; failure is the condition in which the performance or serviceability of the riprap rundown structure is severely compromised. Failure causes are the defects or deficiencies in design, material types or quality, construction, or standard specifications, which are the underlying causes of failure or the triggers of one or more processes that lead to failure.

Non-Enclosed Riprap Rundowns

A cross section of the channel of a non-enclosed riprap rundown with geotextile is illustrated in Figure 2. The geotextile is not always used in this type of riprap rundown. In non-enclosed riprap rundowns, the common mode of failure is particle erosion. This failure mode occurs when individual riprap stones are dislodged by large hydraulic or shear forces of the runoff water in the rundown channel. The most likely causes of particle erosion in riprap rundowns include:

- Slope of embankment or road cut is very steep and the grade inclination is near the angle of repose of the riprap stones. Gravity can mobilize the riprap stones during either flow conditions or non flow conditions.
- Stone size is not large enough; consequently, insufficient resisting shear forces can be developed across the riprap layer, along the contact surface between the stones and the geotextile (if any), or along the contact surface between the stones and the supporting

soil, to counteract the action of the downward hydraulic forces plus the gravitational forces.

- Gradation of the riprap is too uniform or stones are too rounded, decreasing the effectiveness of interlocking throughout the riprap layer.
- Rundown channel is not sufficiently embedded or keyed below slope grade into the supporting soil. Embedment is necessary in riprap rundowns to form a drainage channel that can contain the flow and transport the runoff water down the slope.
- Foundation soil is highly erodible and susceptible to piping.

Failures of non-enclosed riprap rundowns are often caused by a combination of two or more of the factors indicated above. Particle erosion failure mode was also found responsible for many of the failures of non-enclosed riprap protections at culvert outlets in New Mexico (Bandini and White, 2006).

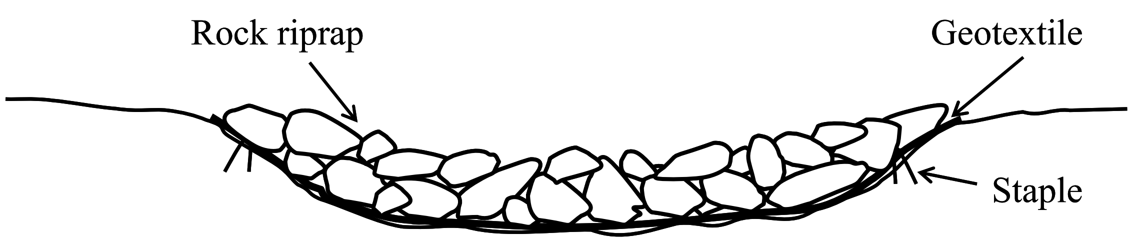


Figure 2. Typical cross section of a non-enclosed riprap rundown channel.

Wire Enclosed Riprap Rundowns

The cross section of the channel of a typical wire enclosed riprap rundown is illustrated in Figure 3. It is a common misconception that failures of riprap blankets, drainage channels or revetments are mainly due to erosion or mobilization of the riprap stones. This misconception may lead to

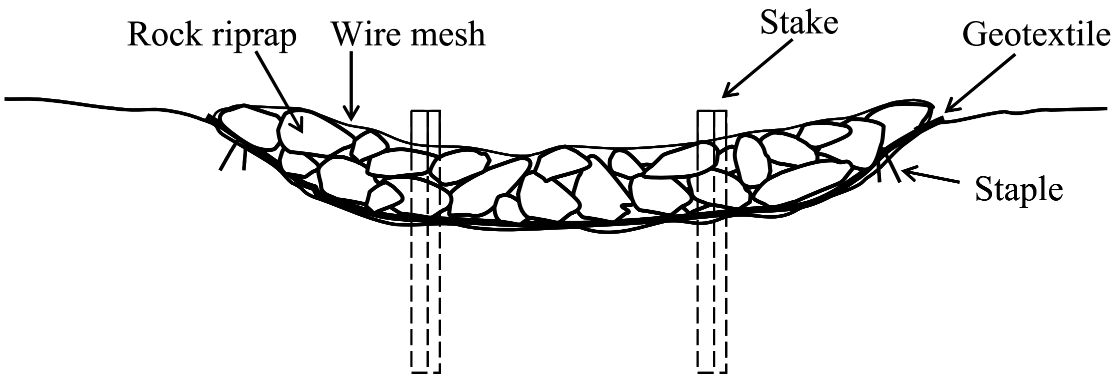


Figure 3. Typical cross section of a wire enclosed riprap rundown channel.

ignoring other potential mechanisms of failure in these structures. The two main failure modes in wire enclosed riprap rundowns identified through this project were:

(a) Partial collapse of the riprap structure resulting from erosion or instability of the supporting soil.

(b) Structure collapse or instability resulting from severe scour along the sides and/or at the end of the riprap rundown.

Several conditions can trigger these failure modes. The erosion of the supporting soil (i.e., natural or compacted soil beneath the riprap stones and geotextile) can be caused by different factors, such as:

- Inadequate filter material (geotextile) or absence of filter layer.
- High hydraulic gradients in the soil immediately below or adjacent to the riprap structure.
- Loose granular soil conditions or erodible foundation soil.
- Poorly graded riprap with large voids between stones.

The loss of foundation support is likely to be produced by a combination of two or more of these factors. During runoff, some of the water draining along the riprap rundown will infiltrate through the geotextile into the embankment or foundation soil. If the geotextile has relatively large openings or no filter material has been installed, and the soil has a relatively large permeability, high hydraulic gradients can occur. Near-surface seepage forces, with lateral and/or upward components, can be large enough to mobilize the smaller soil particles and produce small channels of faster-flowing water. This phenomenon is called “piping.” The erosion may rapidly progress to undercut the riprap structure.

If the foundation soil has little or no plasticity and the filter is not adequate, the individual particles of soil can be easily carried away by the flow, leaving large voids underneath the wire enclosed riprap mat. As the voids increase in size, the relatively heavy riprap structure progressively collapses under the lack of support. The wire mesh and splicing connections can stretch and break and the stones can get loose and be moved down toward the slope toe during heavy rain events. Dry, loose non-plastic silts and poorly graded sand and gravel mixtures with small percentages of material passing sieve No. 200 and with very low organic content are very susceptible to erosion. These soils were found in many of the sites studied in the central and southern part of New Mexico. The slopes of many bridge embankments or road cuts in this region often show little or no vegetation cover, even many years after construction.

Placing riprap so that smaller stones fill the larger voids (while maintaining the minimum size and gradation requirements) may help the fast flowing water remain in the upper part of the riprap layer. Where the natural soils or fill materials are known to be susceptible to erosion, preparing the foundation soil with a bed of well compacted fill or crushed stone can help create a stable transition infiltration zone to reduce hydraulic gradients entering the supporting soil.

The second failure mode consists of the partial collapse or instability of the riprap structure resulting from severe scour along the sides and/or at the end of the riprap rundown. This failure mode is associated to one or more of the following factors:

- Design flow is underestimated and the riprap channel is not wide enough to contain the peak flows. Consequently, the riprap channel or chute is overtopped along the sides, resulting in erosion of adjacent soil.
- Riprap structure is not sufficiently embedded or keyed into the supporting soil (as specified by standard drawings 515-02, 602-01, and 602-02). The flow is not completely contained in the riprap layer and may easily spread laterally onto the surface of the unprotected slope, causing rill erosion of the slope.
- Inadequate filter material (geotextile) or absence of filter layer. Piping and erosion of the foundation soil can quickly progress to the sides and end of the structure in erodible soils.
- Riprap structure does not extend sufficiently beyond the slope toe (i.e., the structure is too short) to allow for dissipation of energy and the transition from supercritical flow (in steep slopes) to subcritical flow (beyond the slope toe) before the end of the structure.
- Riprap channel does not follow the drainage pattern of the slope and/or make abrupt turns that are not natural drainage patterns. Water, especially in high velocity flows, does not make abrupt changes in direction. The drainage patterns are dominated by the natural or man-made gradient of the slope and the soil types.

In general, the effects of these conditions are worsened as the steepness of the slope and rundown increases.

In all the sites considered in this study, the riprap rundowns were placed or supported on dry or unsaturated soils, which is a typical condition due to the warm, semiarid climate of New Mexico. These riprap rundown structures are not expected to be underwater during service. Therefore, the failure modes and hydraulic analysis in riprap rundowns are different from those of riprap revetment and river bank protections.

STUDY OF SELECTED PERFORMANCE CASES

The NMDOT Drainage Section staff and District personnel provided the location (by route and milepost) of a number of riprap sites. All sites with riprap rundowns were visited and investigated at least once in this study. The following riprap structures were selected according to their performance, varying from good to very poor. These cases are representative of the various failure modes and performance problems recognized during the field investigations.

SITE 1: I25 AND MOUNTAIN ROAD (ALBUQUERQUE)

The site includes two wire enclosed riprap rundown structures in the east side of the northbound Frontage Road (FR2523) that runs parallel to Interstate 25 in Albuquerque, New Mexico. The site is located south of the Big I Interchange (i.e., interchange where Interstate 25 and Interstate 40 intersect). It is estimated that these riprap rundowns were built between 2001 and 2002.

The first rundown structure (No. 1) is located immediately south of Mountain Road NE. It is a section Type 2 (602-01) without flume; it was constructed using hexagonal wire mesh, steel stakes (L4"×4" angle irons), and non-woven geotextile (David Trujillo, Jr., Personal Communication, 2008). The riprap rundown was well embedded into the hill side. The structure failed after a major storm event. The extent of the damage in this rundown is shown in Figure 4. This riprap rundown was later repaired by maintenance crews by covering the collapsed riprap with relatively loose, dry reclaimed or milled asphalt pavement material (Figure 5a). This serves as a temporary repair only. Some sections of the original rundown structure still remain after the temporary repairs (Figure 5b). A storm drain at the toe of the riprap structure captures the flow (Figure 5c). The inlet of the storm drain is approximately 2.0 ft (0.61 m) below grade. The riprap pad around the inlet is no longer present; it likely was removed during the repair works.

(a) (b)

Figure 4. Wire enclosed riprap rundown No. 1 in site 1: (a) failed structure; (b) close view of the north edge showing the severe undermining and erosion of the supporting soil after a heavy rain event. Photos are courtesy of David Trujillo, Jr.

The collapse of this riprap structure was caused by the extensive erosion and piping of the supporting embankment soil due to large flow and high flow velocities at this location. The soil of this embankment is a mixture of non plastic alluvial silt, sand, gravel and cobbles. Figure 5d clearly shows a scoop-shape failure surface in the lower half of the rundown. Even though the area of the drainage basin (or catchment area) of this rundown could not be measured, the field observations and satellite images indicated that the flow could be considerable. Additionally, the slope is steep (approximately 2:1) and the riprap rundown is long.

The second rundown structure (No. 2) is located approximately 400 ft (122 m) north from the first structure. It has a section Type 2 (602-01) without flume; it was built with hexagonal

(a)

(b)

(c)

(d)

Figure 5. Wire enclosed riprap rundown No.1 in site 1: (a) upslope view of the failed structure repaired with milled asphalt material; (b) close view of the south edge, indicated with an arrow in (a); (c) storm drain at the toe of the rundown; (d) scoop-shape failure indicating piping, associated erosion, and collapse of the riprap mass (downslope view).

wire mesh, L4"×4" angle irons driven about 1 ft (0.3 m) from the edges of the rundown, and non-woven geotextile (David Trujillo, Jr., Personal Communication, 2008). The rock riprap layer is well embedded into the supporting soil (Figure 6). The embankment soil and slope are the same as in the rundown structure No. 1. The water flows to a storm drain inlet at the toe of the riprap structure. The storm drain inlet is approximately 1.5 ft (0.45 m) below grade (Figures 6b and 6d). The riprap rundown structure is in very good condition. The area of the drainage basin (or catchment area) of this rundown could not be determined, but the field observations and satellite images indicated that it is much smaller than the catchment area of the rundown No.1 in this site. Additionally, the length of the structure for rundown No. 2 is about half of the length for rundown No. 1. The combination of these factors may have contributed to its good performance.

SITE 2: NM 136 (SANTA TERESA)

In this site, a wire enclosed riprap rundown is located in the southeast side of highway NM 136 (milepost 6.2), Pete V. Domenici Highway, northwest of Santa Teresa, New Mexico. The riprap stones were grouted except in the lower part of the structure, as shown in Figure 7a. The hexagonal wire mesh was not completely covered by the shotcrete. Twenty one steel stakes (L4"×4" angle irons) were installed in the lower half of the structure only, three steel stakes in each row, spaced about 8.6 ft (2.6 m). Woven geotextile (woven slit-film type) was installed below the riprap, which is not the filter material specified for this application (NMDOT, 2007). The rundown has a flume similar to Type II (sag) according to the standard drawing 515-03 (NMDOT, 2007) (Figure 8a). The flume is approximately 4 ft (1.2 m) long and 25 ft (7.6 m) wide. The riprap rundown is 18.5 ft (5.6 m) wide and 85 ft (26 m) long.

Even though the construction and maintenance history of this riprap rundown was not available, it is likely that the shotcrete was applied after signs of severe erosion and recurrent

(a)

(b)

(c)

(d)

Figure 6. Wire enclosed riprap rundown No. 2 in site 1: (a) front view; (b) lateral view; (c) upper section of the structure (upslope view); (b) storm drain at the toe of the riprap rundown. Photos (a) and (b) are courtesy of David Trujillo, Jr.

(a) (b)

Figure 7. (a) Wire enclosed riprap rundown in highway NM 143, at milepost 6.2; (b) highly erodible soil in the area.

(a) (b)

Figure 8. Riprap rundown in highway NM 143, at milepost 6.2: (a) rundown flume; (b) rundown toe.

maintenance repairs. The soils in the area are highly erodible, very dry and relatively loose. The embankment is composed of loose poorly graded sand (SP) (non plastic medium sand). Figure 7.b shows the extensive and fast progressing erosion of the soils at this location. Wind erosion and wind-blown sand are also significant in the area. The toe of the rundown structure (not grouted) shows signs of damage, including broken wire mesh and loose riprap stones (Figure 8b). The likely mode of failure is the progressive scour and undermining of the riprap end, resulting in the loss of foundation support and partial collapse of the riprap mat. Scour occurs because the riprap does not extend far enough to allow energy dissipation, the flow is large, the slope is steep, and the soil is highly erodible.

Another wire enclosed riprap rundown previously existed in the northwest side of highway NM 136 at milepost 6.3. However, the riprap structure collapsed before 2006 due to extensive undermining and scour, and the remaining parts eventually were completely covered by fill during repairs. This riprap structure was very steep and too short (extended up to the right-of-way fence in Figure 7b), in a highly erodible and unstable soil. In addition, the geotextile used was woven slit-film type, which is not allowed for this application by the NMDOT specifications in Sections 602 and 604.

SITE 3: I25 OFF-RAMP (BROADWAY BLVD.)

The site includes three wire enclosed rundowns with reinforced concrete flume Type I (according to standard drawing 515-02), and six concrete rundowns. The wire enclosed rundowns are located in the east side of the first off-ramp (IN2215) of the southbound of Interstate 25 (between mileposts 215 and 216). [The ramp is part of the interchange between Interstate 25 and Broadway Blvd. SE (Highway NM 47) to the Isleta Pueblo.] These structures provide drainage to the two bridges over Interstate 25 and an exit ramp of the north bound of this freeway. Early satellite images, installed after the construction of the concrete rundowns but earlier than the construction of the riprap rundowns, show signs of rill erosion on the east slopes of the bridge abutments, at the ends the bridge decks, where the new riprap rundowns are now located (Figure 9).

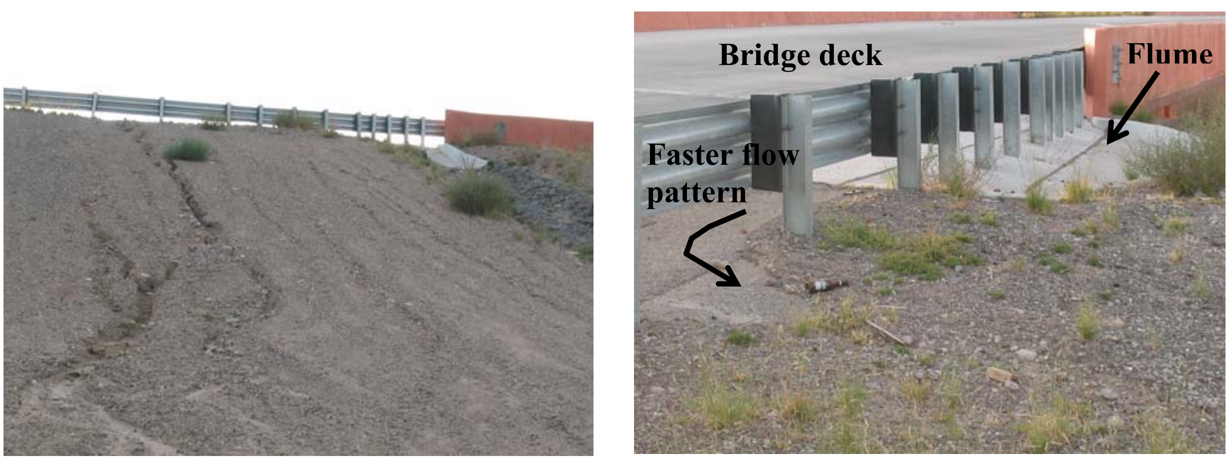
These riprap rundowns meet the NMDOT standard drawings and specifications except for the type of geotextile. A woven geotextile (woven slit-film type) was installed below the riprap, which is not the type of filter material specified for this application (NMDOT, 2007). These rundown structures have relatively small flumes and are located at the edge of the bridge decks. With these characteristics, these rundowns would perform well for relatively small flow volumes. However, if larger flows and higher flow velocities occur, the drainage at the deck ends flows past the rundown flume. At higher velocities, the water exits the bridge deck with greater momentum and energy, causing a larger radius of curvature for the drainage. At high velocities, the natural drainage pattern for the flow does not make the required right-angle turn to enter the small flume at the end of the bridge deck. Figure 10 shows signs of sediment erosion on the surface of the pavement and slope caused by runoff not captured by the rundown flume.

SITE 4: NM 599/US 285 (SANTA FE)

In this site, there are three riprap rundowns and a drop inlet structure with two 48" pipes and a wire enclosed riprap pad at the pipe outlet. They are located in the south side of highway NM 599 (Veterans' Memorial Highway), between US 285/NM 599 Interchange and Avenida Rincon, Santa Fe, New Mexico. A fourth riprap rundown is located approximately 500 ft (150 m) northwest from the Avenida Rincon bridge in highway NM 599. A first site visit was carried out in June 2006. One rundown structure is constructed with non-enclosed riprap and the others are

(a) (b)

Figure 9. Wire enclosed riprap rundown in first off-ramp (IN2215) of southbound Interstate 25: (a) rundown; (b) rill erosion on the bridge abutment.



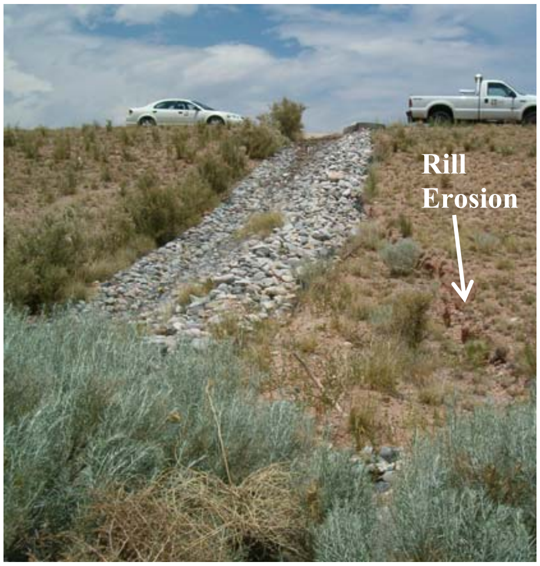
(a) (b)

Figure 10. Slope erosion next to a rundown in ramp IN2215.

wire enclosed riprap with concrete flumes. The rundown channels are about 6-ft (1.8-m) wide and the riprap layer is about 1-ft (0.3-m) thick. They all exhibit clear signs of failure (Figures 11 and 12). The riprap stones have fairly rounded edges and the filter used is woven geotextile (woven slit-film type), which is not allowed by the NMDOT specifications for erosion control applications. The rundowns are constructed in fairly steep, long slopes. The drainage channels of two of the rundowns make a 90^{o}-turn (i.e., a sharp turn forming a corner so that the channel runs almost parallel to highway NM 599) before reaching the right-of-way, as illustrated in Figure 11b. The embankment soil is a poorly graded sand/gravel mix.

Two failure modes were identified in the rundowns of this site studied in 2006. The non-enclosed riprap rundown failed because of particle erosion, mainly in the lower part of the structure, after the rundown made a sharp turn (or corner) (Figure 11b). Any runoff water that drained along the riprap rundown did not continue along the channel after the sharp turn or corner. Instead, most of the water continued further downslope with the same direction as the upper part of the rundown (following the greatest slope gradient). The lower part of the structure that ran parallel to the highway (after the sharp turn or corner) was damaged by surface runoff water along the slope and rill erosion, with help from the action of gravity. The riprap stones were mobilized and displaced downslope, destroying the riprap channel.

The wire enclosed riprap rundowns studied in 2006 failed by a combination of loss of foundation support, especially in the most upper part of the structures, near the flumes, and erosion along the sides and scour at the end of the riprap channels (Figures 12 and 13). This embankment is composed of dry, non plastic, poorly graded sand/gravel mix, which has the characteristics of erodible soils. In addition, the riprap was only partially embedded into the foundation soil. This condition may have allowed the water to migrate laterally and outside the



(a) (b)

Figure 11. Non-enclosed riprap rundown in highway NM 599 (2006 visit): (a) rill erosion from the rundown structure; (b) failure of the rundown. Photos are courtesy of Jose A. Silva.

(a) (b)

Figure 12. Wire enclosed riprap rundown in highway NM 599 (2006 visit): (a) side erosion; (b) scour at the end of the rundown.

(a) (b)

Figure 13. Failure of two wire enclosed riprap rundowns in highway NM 599 (2006).

rundown channels, causing rill erosion and scour along the sides of the rundowns. Moreover, a woven geotextile (woven slit-film type) was installed below the riprap, which is not the type of filter material allowed by the NMDOT standard specifications for erosion control applications (NMDOT, 2007). A very steep slope grade in an embankment of erodible soil caused the erosion of the supporting soil and undermining of the riprap rundown and concrete flumes (Figure 13). Widening the riprap rundown around the flume (in Figure 13b), using the appropriate geotextile, and fully embedding the riprap into the foundation soil could have prevented the erosion along the sides of the rundown. Because of the steep slope of this embankment, the riprap rundowns should have been anchored with steel stakes as specified by the NMDOT standard drawings.

This site was revisited in 2007. The conditions of the rundowns deteriorated significantly in about 18 months since the first inspection visit in 2006 (Figure 14). The rundown located at the end of the deck of the bridge over Avenida Rincon had to be reconstructed with wire enclosed riprap. Non-woven geotextile was used this time; however, no steel stakes were installed. Despite having been built a few months before the site visit in 2007, this riprap rundown already exhibited extensive damage, including severe undermining of the riprap layer and erosion of the sides with partial collapse of the structure (Figure 15a). A curb was added to the flume at the bridge end (Figure 15b) in an attempt to divert the runoff water away from the bridge abutment. Also, a short riprap gabion wall was built along the west side of the new

(a) (b)

Figure 14. Condition of riprap rundowns in highway NM 599 in 2007: (a) same structure as in Figure 11; (b) same structure as in Figure 12, 18 months later.

(a) (b)

Figure 15. Reconstructed riprap rundown in highway NM 599 (2007): (a) extensive erosion (downslope view); (b) flume with curb added.

rundown (Figure 15a). However, the curb and the gabion wall did not prevent the water from draining to the northwest side of the slope (Avenida Rincon), following the steepest gradient. Because of the pervious and erodible nature of the embankment soil and the very steep side slope (towards Avenida Rincon), high hydraulic gradients and large seepage velocities are expected. Erosion protection of the northwest slope should be incorporated into future repairs of this site.

As mentioned earlier, there is a drop inlet structure with two 48" pipes and a wire enclosed riprap pad, approximately 10-ft (3-m) long, at the pipe outlet (Figure 16a). Woven slit-film type geotextile was used as filter material underneath the riprap. The drop inlet structure drains storm water from highway NM 599 (Figure 16b). Inspections in 2006 and 2007 indicated

(a) (b)

Figure 16. Wire enclosed riprap pad at the pipe outlet in highway NM 599 (2007): (a) extensive erosion and scour around the riprap pad; (b) storm water drop inlet.

that the erosion and scour have progressed very rapidly around and towards the riprap pad. Widening the erosion protection pad in a fan-like geometry and adding energy dissipaters (riprap gabions, for example) could considerably reduce the erosion in this case.

SITE 5: NM 68 (NORTH OF ESPAÑOLA)

This site is located in the east side of highway NM 68, between mileposts 13 and 14, north of Española, New Mexico. It includes six wire enclosed riprap rundowns for erosion protection of a long road cut (Figure 17). The soil in this slope is a well graded sand with silt and gravel (SW-SM). This soil is non plastic. The riprap layer in these rundowns is fully embedded below grade. The riprap is anchored by three or more rows of steel stakes. In general, these rundowns are in good condition. The area of the drainage basin and flow for these rundowns were not determined, but satellite images show that these structures drain a series of small streams with parallel drainage pattern from the higher terrain located to the east of highway NM 68 in this site. It can be observed in the left-hand side of Figure 17a that the surface erosion is small where the slope is not protected with riprap.

SITE 6: NM 14 (CERRILLOS)

Non-enclosed Class G riprap rundowns (as rock plating) and a series of nine riprap gabion baskets were installed in 2005 for erosion protection in a new bridge in highway NM 14, between mileposts 34 and 35, just north of Cerrillos and Los Cerrillos, New Mexico. The riprap is in the west side of the bridge. The erosion protection system was not designed in-house, but it is maintained by the corresponding NMDOT maintenance patrol. The gabion baskets are 3 ft×3 ft×6 ft (approximately 0.9 m×0.9 m×1.8 m) with Class G riprap and 5ft×5ft (1.5 m×1.5 m)

(a)

(b)

(c)

(d)

Figure 17. Wire enclosed riprap rundowns in highway NM 68, between mileposts 13 and 14. Photos (c) and (d) are courtesy of Jose a. Silva.

non-enclosed riprap mats in the front and back (Figures 18a and 19a). Non-woven geotextile is installed underneath and on the sides of the gabion baskets and riprap mats (Figure 18b). The gabion baskets are spaced about 20 ft (6.1 m). A small non-enclosed Class G riprap rundown is placed upslope from the gabions (Figure 19b).

At the time of the site inspection in 2007, the rundowns were in good condition, including the one that drains the bridge deck, despite being in a very steep slope. The gabion baskets serve as energy dissipaters to account for the large change in grade elevation at the site. The gabion baskets and pads were structurally in good condition. However, there is concern for the early signs of erosion along the sides of the gabion baskets. The soil of the slope is a poorly graded sand, whose particles can be easily carried and transported down by runoff water during high flow events. In this case, increasing the length of the gabion baskets across the channel so that they are keyed at least 1.5 ft (0.5 m) into the adjacent slopes could have helped preventing the lateral erosion and potential undermining of the gabion baskets.

BEST MANAGEMENT PRACTICE RECOMMENDATIONS

The following recommendations can be drawn from the performance observations and monitoring of the riprap sites studied in this project:

- Constructing riprap rundowns with 1.5:1 slopes has been a common practice in New Mexico. It is recommended that the design and construction of riprap rundowns be limited to milder slopes (2:1 or less), especially in soils susceptible to erosion. Steep wire-enclosed riprap rundowns, with steel stakes, can perform well in soils not susceptible to erosion and when the area of the catchment basin is not significantly large.

(a) (b)

Figure 18. Riprap gabion baskets in highway NM 14, between mileposts 34 and 35.

(a) (b)

Figure 19. Riprap gabion baskets and rundown in highway NM 14.

- The riprap layer should be fully embedded or keyed in the foundation soil to prevent erosion and piping along the sides of the structure and contain the flow within the rundown channel. It is recommended including a comment in “General Notes” of standard drawings 602-01 and 602-02 in this regard.
- The riprap rundowns should be embedded into the embankment and have a channel-like cross section to contain the runoff flow. It is recommended including a typical cross section of the rundown channel (across the channel) in standard drawing 602-01. Cross sections for other structures or conditions are already shown in standard drawings 515-02 and 602-02.
- The required geotextile type is not mentioned in the standard drawing 602-01 for riprap rundowns. It is recommended that the type of geotextile (for example, “non-woven Class 1”) or a comment in the “General Notes” with a reference to the corresponding standard specifications be included in the standard drawing 602-01 for riprap rundowns.
- In addition to gradation and size, placement of the riprap stones in the riprap layer is also important for the performance of these structures. The riprap should be placed leaving a minimum of voids and filling in unacceptable voids with smaller stones. It is recommended including a comment in the NMDOT standard specifications concerning riprap stone placing.
- The rundown structure and erosion protection pads should be extended beyond the slope toe to avoid scour at the end of the structure. Including a key or footing at the end of the rundown can help prevent scour and collapse of the structure in steep slopes of erodible soils.

- Quality control of construction practice and materials, including type and placement of geotextile, gradation and quality of riprap stones, and splicing should be enforced during construction by NMDOT inspectors.
- Key factors that highly affect the performance of riprap rundowns are the drainage patterns and the slope or grade gradient of the particular site, before and after construction. Local drainage conditions must be considered in the design and construction of erosion protection systems. Rundown channels should not be designed and constructed with a sharp turn as this condition is not consistent with normal drainage patterns in steep slopes or embankments, unless the flow is fully contained.

SUMMARY AND CONCLUSIONS

Riprap rundowns are open channels to drain runoff water from bridges, highways and slopes for erosion protection. Riprap rundowns can be constructed of non-enclosed or wire enclosed riprap, with or without concrete flume. The NMDOT standard drawings for riprap rundowns are 515-02, 602-01, and 602-02 (NMDOT, 2008), and the standard specifications for riprap are included in the *Section 602-Slope and Erosion Protection Structures* of the *NMDOT Standard Specifications for Highway and Bridge Construction* (NMDOT, 2007).

This research project aimed at identifying and characterizing the modes of failure of the riprap rundowns in New Mexico and providing recommendations to avoid these failures in future projects and repairs. The investigation was carried out by conducting site visits and visual observations and monitoring of the riprap rundown structures. Sites with riprap structures with performance varying from good to very poor were considered. Soil samples from selected locations were taken for soil classification purposes. One of the tasks of this project included construction monitoring and field testing of riprap rundowns in District 1. However, this task could not be accomplished due to the lack of maintenance funds and available maintenance personnel for this purpose, and delays in the construction schedule of two new bridges (No. 5701 and No. 5500) along highway NM 26, at mileposts 16.6 and 22.4, respectively. These bridges were initially selected as the sites for investigation and testing of new riprap protection structures.

The common failure mode for non-enclosed riprap rundowns was particle erosion. This failure was generally associated with very steep rundown channels, riprap stones with rounded edges and underestimation of flow from runoff. The failure of wire enclosed riprap rundowns generally involved the partial collapse or instability of the riprap layer due to erosion and undermining of the supporting soil and/or severe rill erosion and scour along the sides and end of the riprap structure.

In this study, two common factors associated to the construction of riprap structures that showed poor performance are the insufficient embedment of the riprap layer and the use of geotextile material that is not allowed by the NMDOT standard specifications. In many of the rundown structures studied, either no filter material or a type of geotextile material not allowed by the NMDOT specifications was installed. The *NMDOT Standard Specifications for Highway and Bridge Construction* (NMDOT, 2007) specifically "prohibits the use of woven slit film geotextile or geotextiles made from yarns of a flat, tape-like character." This type of geotextile was observed in many of the riprap structures that failed or performed poorly.

The drainage patterns, soil types, runoff catchment area, and hydraulic conditions of a particular site should be taken into account when designing and constructing of riprap rundowns. Failing to consider local drainage patterns and slope gradients can lead to extensive rill erosion along the sides and scour at the end of the rundown channel, or high hydraulic gradients in the foundation soil. These effects are especially severe in erodible soils such as poorly graded sands/gravel mixtures, non plastic medium and fine sands, and non plastic sandy silts.

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2. Bandini, P., and White, K. R. (2006). Failure of Riprap Protection (Phase I). New Mexico Department of Transportation, Report NM04STR-02, Albuquerque, NM.

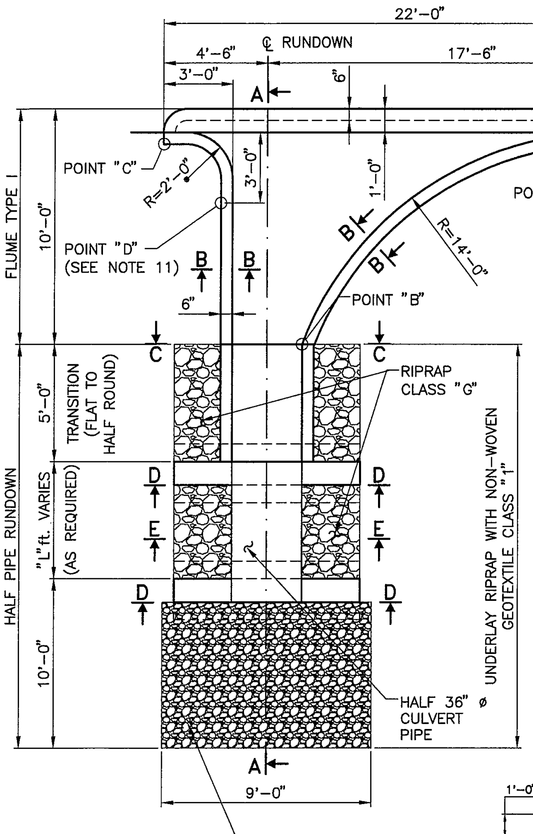
3. Lagasse, P. E., Clopper, P. E., Zevenbergen, L. W., and Ruff, J. F. (2006). Riprap Design Criteria, Recommended Specifications, and Quality Control, NCHRP Report 568. National Cooperative Highway Research Program (NCHRP), Transportation Research Board.

4. New Mexico Department of Transportation (NMDOT), Standard Specifications for Highway and Bridge Construction, 2007 Edition. http://www.nmshtd.state.nm.us/upload/images/Contracts_Unit/2007_Specs_for_Highway_and_Bridge_Construction.pdf. Accessed March 15, 2008.

5. New Mexico Department of Transportation (NMDOT), Plans, Specifications and Estimates Bureau, Standards and Specifications Unit. Active Standard Drawing Master List, 2008. http://nmshtd.state.nm.us/main.asp?secid=14793. Accessed March 15, 2008.

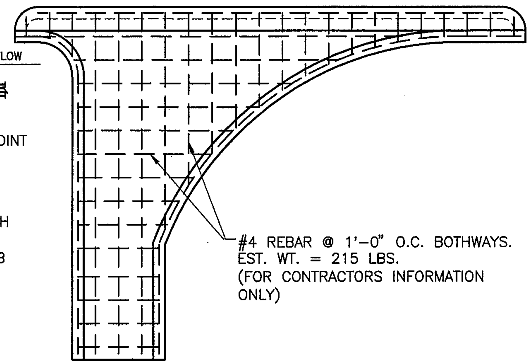
APPENDIX

NMDOT Standard Drawings 515-02 through 515-05, 602-01, and 602-02

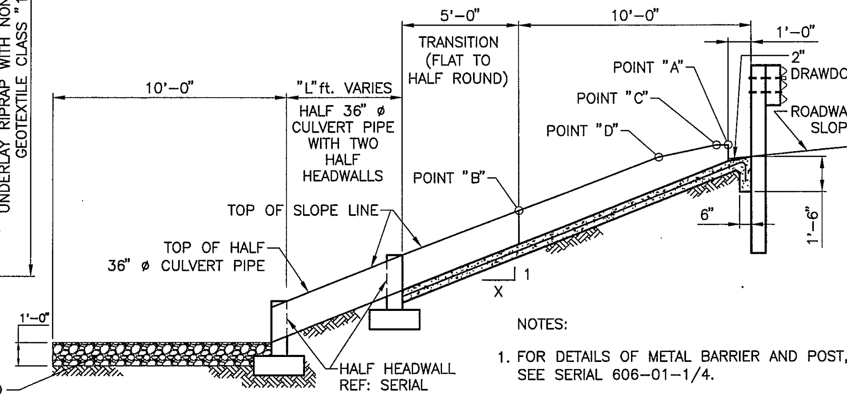


NOTE:
TRANSITION CURB FROM 6" HIGH AT POINT "A" TO 12" HIGH AT POINT "B". TRANSITION CURB FROM 6" AT POINT "C" TO 12' HIGH AT POINT "D"

PLAN



REBAR PLACING PLAN



NOTES:

1. FOR DETAILS OF METAL BARRIER AND POST, SEE SERIAL 606-01-1/4.
2. FOR "X" VALUE SEE ROADWAY PLANS.
3. SEE SERIAL 515-02-2/2 FOR ALTERNATE RUNDOWN OPTIONS OF FULL PIPE, CONCRETE AND RIPRAP.

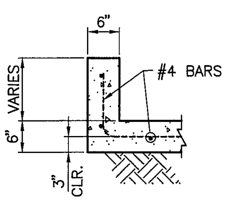
SECTION A-A

GENERAL NOTES

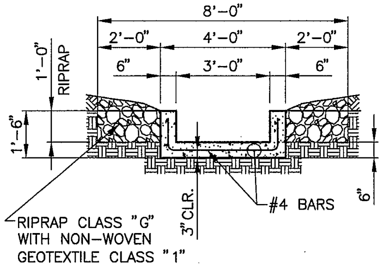
1. STRUCTURAL CAST-IN-PLACE CONCRETE SHALL BE CASS "A". CHAMFER ALL EXPOSED EDGES OF CONCRETE 3/4".
2. ALL REINFORCING BARS SHALL CONFORM TO AASHTO SPECIFICATION M31, GRADE 60.
3. FIELD CUT AND BEND REINFORCING BARS AS REQUIRED FOR THE STRUCTURE.
4. INSTALLATION AS SHOWN IS TYPICAL AND DETAILS MAY BE VARIED TO FIT LOCATION. QUANTITIES WILL BE ADJUSTED IN THE FIELD.
5. RUNDOWN FLUMES WILL BE PAID FOR UNDER THE PAY ITEMS LISTED BELOW.

ITEM	PAY UNIT
REINFORCED CONCRETE FOR MINOR STRUCTURES	CU. YD.
24" ø CULVERT PIPE	FEET
36" ø CULVERT PIPE	FEET
RIPRAP CLASS "A"	CU. YD.
RIPRAP CLASS "G"	SQ. YD.

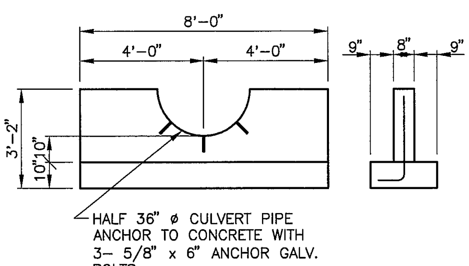
6. CONCRETE PORTION OF FLUMES OR RUNDOWNS SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE REQUIREMENTS FOR "REINFORCED CONCRETE FOR MINOR STRUCTURES – SECTION 515".
7. STEEL STAKES FOR ANCHORING RIPRAP ARE ONLY REQUIRED FOR THE RIPRAP RUNDOWN WITH CLASS "A" RIPRAP.
8. WHEN THE 24" CULVERT PIPE, OR 36" HALF PIPE EXCEEDS 50 FEET IN LENGTH, THE CONTRACTOR SHALL CONSTRUCT A HALF HEADWALL WITHOUT FOOTING AT EVEN INCREMENTS, NOT TO EXCEED 50 FEET OVER THE TOTAL LENGTH OF CULVERT PIPE. COST FOR THIS CONSTRUCTION SHALL BE PAID FOR UNDER THE APPROPRIATE ITEM FOR "REINFORCED CONCRETE FOR MINOR STRUCTURES". APPROXIMATE CONCRETE VOLUME PER HALF HEADWALL WITHOUT FOOTING = 0.67 CU. YD. APPROXIMATE REBAR WEIGHT = 70 LBS.
9. GENERAL NOTES AND ESTIMATED QUANTITIES SHALL BE USED ON STANDARDS 515-02-2/2 AND 515-03-1/1. SEE 515-04-2/2 FOR QUANTITIES.
10. THE ½" BITUMINOUS JOINT FILLER SHALL BE LOCATED BETWEEN THE RUNDOWN AND ASPHALT PAVING WHERE APPLICABLE. THE ½" BITUMINOUS JOINT FILLER SHALL BE CONSIDERED INCIDENTAL TO THE RUNDOWN FLUME.
11. WHEN POINT "D" IS WITHIN THE ROADWAY CLEAR ZONE. THE ENTIRE FLUME STRUCTURE SHALL BE SHIELDED WITH METAL BARRIER AND SHALL NOT BE CONSTRUCTED WITHIN 50' OF THE METAL BARRIER END TREATMENT HEAD OR TERMINAL CAP.
12. EXCAVATION, ANCHOR BOLTS, AND HOOK BOLTS FOR RUNDOWN SHALL BE CONSIDERED INCIDENTAL AND NO DIRECT PAYMENT WILL BE MADE THEREFORE. NON-WOVEN GEOTEXTILE SHALL BE INCLUDED IN THE UNIT BID PRICE FOR RIPRAP CLASS "A" AND RIPRAP CLASS "G".



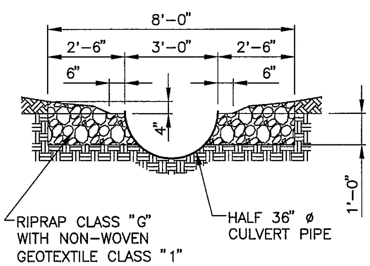
SECTION B-B



SECTION C-C



SECTION D-D



SECTION E-E

NO.	DATE	REV. BY	DESCRIPTION
1	04/23/07	TM	GENERAL REVISIONS

REVISIONS (OR CHANGE NOTICES)

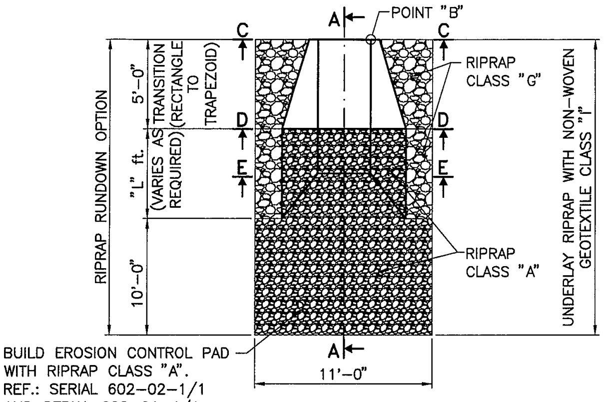
NEW MEXICO
DEPARTMENT OF TRANSPORTATION
STANDARD DRAWING

RUNDOWN FLUME TYPE I FOR MODIFIED OR PINNED CURB WITH HALF PIPE RUNDOWN

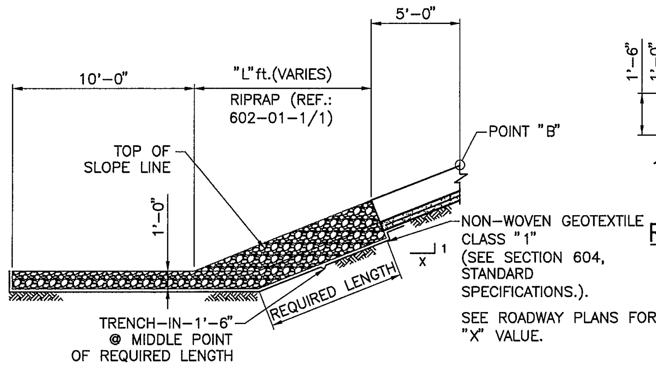
APPROVED [signature] DESIGN ENGINEER 6-12-07 DATE

DESIGNED BY____ DRAWN BY SKL CHECKED BY YML

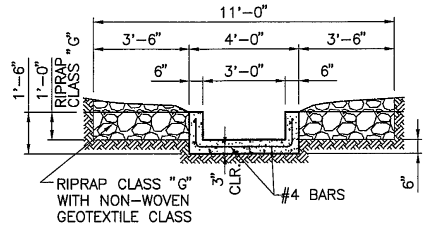
515-02-1/2



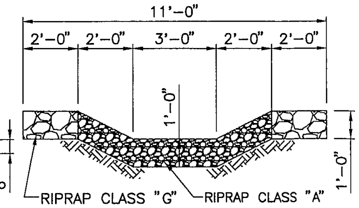
RIPRAP OPTION-PLAN



RIPRAP OPTION-SECTION A-A

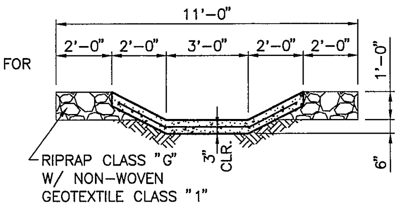


RIPRAP OPTION-SECTION C-C

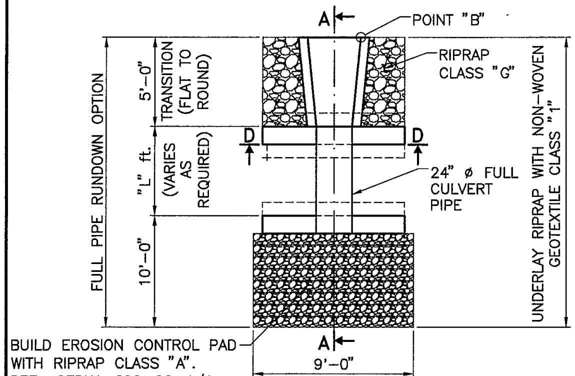


RIPRAP OPTION-SECTION E-E

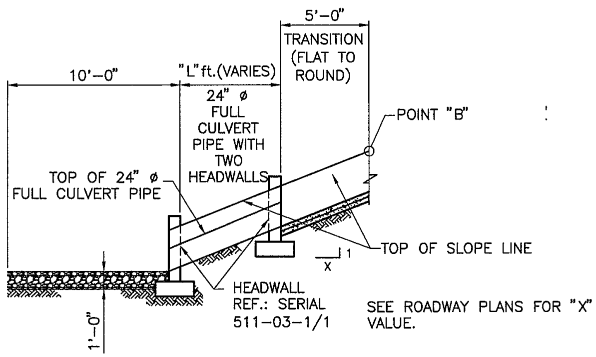
NOTE:
AFTER PLACEMENT OF RIPRAP SPREAD ENOUGH NATIVE SOIL OVER THE ENTIRE SURFACE OF THE RUNDOWN TO FILL THE VOIDS IN THE RIPRAP, THEN COMPACT THE BACKFILL SOIL AND SEED. THE COST SHALL BE INCIDENTAL TO THE RIPRAP.



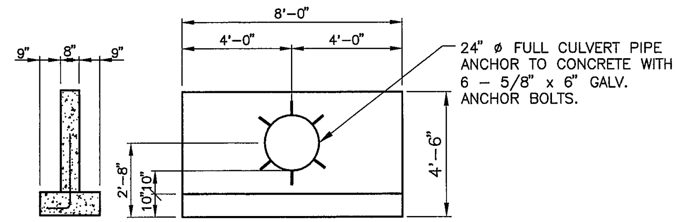
RIPRAP OPTION-SECTION D-D



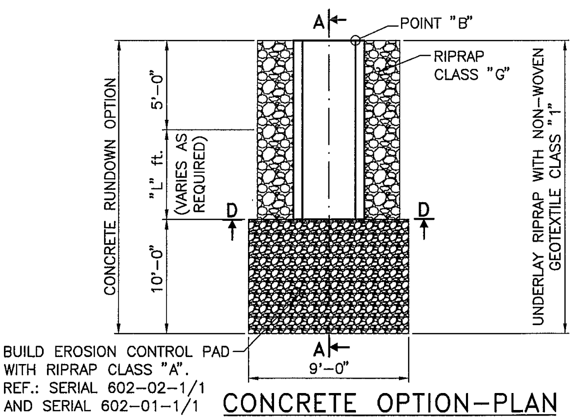
FULL PIPE OPTION-PLAN



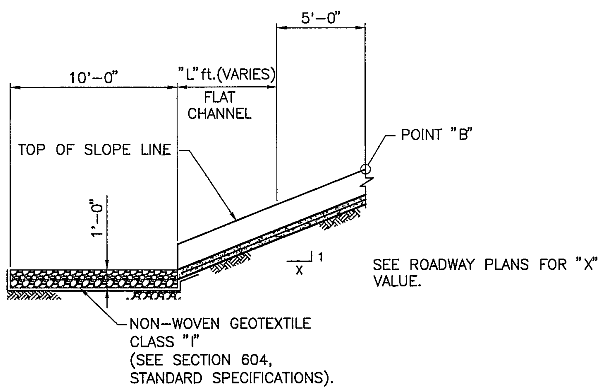
FULL PIPE OPTION-SECTION A-A



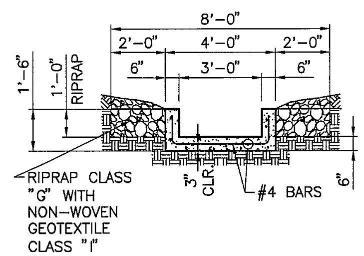
FULL PIPE OPTION-SECTION D-D



CONCRETE OPTION-PLAN



CONCRETE OPTION-SECTION A-A



CONCRETE OPTION-SECTION D-D

NO.	DATE	REV. BY	DESCRIPTION
1	04/23/07	TM	GENERAL REVISIONS

REVISIONS (OR CHANGE NOTICES)

NEW MEXICO DEPARTMENT OF TRANSPORTATION STANDARD DRAWING

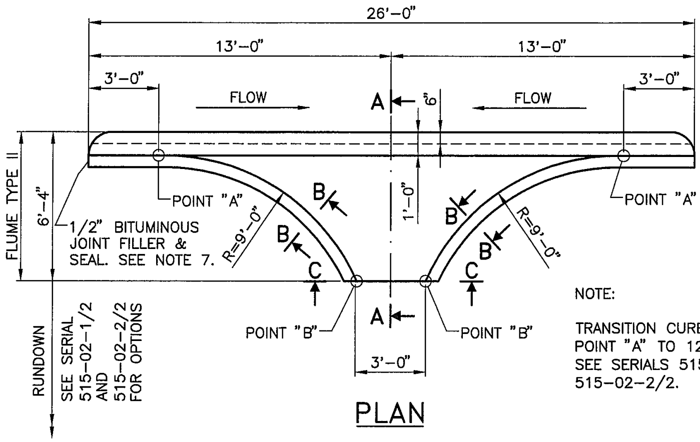
ALTERNATE RUNDOWNS FOR RUNDOWN FLUMES TYPE I, II, III FULL PIPE, CONCRETE AND RIPRAP

APPROVED [signature] DESIGN ENGINEER 6-12-07 DATE

DESIGNED BY ____ DRAWN BY SKL CHECKED BY YML

515-02-2/2

2 of 2

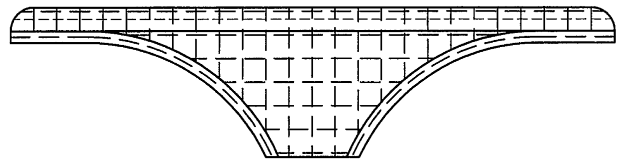


PLAN

NOTE:

TRANSITION CURB FROM 6" HIGH AT POINT "A" TO 12" HIGH AT POINT "B". SEE SERIALS 515–02–1/2 AND 515–02–2/2.

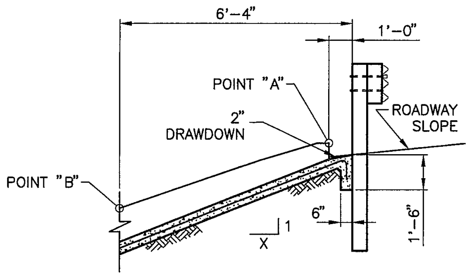
#4 REBAR @ 1'–0" O.C. BOTHWAYS EST. WT. = 385 LBS. (FOR CONTRACTORS INFORMATION ONLY).



REBAR PLACING PLAN

GENERAL NOTES

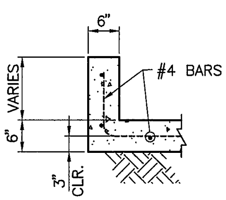
1. STRUCTURAL CAST–IN–PLACE CONCRETE SHALL BE CASS "A". CHAMFER ALL EXPOSED EDGES OF CONCRETE "A" 3/4".
2. ALL REINFORCING BARS SHALL CONFORM TO AASHTO SPECIFICATION M31, GRADE 60.
3. FIELD CUT AND BEND REINFORCING BARS AS REQUIRED FOR THE STRUCTURE.
4. INSTALLATION AS SHOWN IS TYPICAL AND DETAILS MAY BE VARIED TO FIT LOCATION. QUANTITIES WILL BE ADJUSTED IN THE FIELD.
5. RUNDOWN FLUMES WILL BE PAID FOR UNDER THE PAY ITEMS AND QUAINITIES LISTED ON SERIAL 515–04–2/2.
6. CONCRETE PORTION OF FLUMES OR RUNDOWNS SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE REQUIREMENTS FOR "REINFORCED CONCRETE FOR MINOR STRUCTURES – SECTION 515", OF THE NMDOT STANDARD SPECIFICATIONS FOR HIGHWAY AND BRIDGE CONSTRUCTION CURRENT EDITION.
7. THE ½" BITUMINOUS JOINT FILLER SHALL BE LOCATED BETWEEN THE RUNDOWN AND ASPHALT PAVING WHERE APPLICABLE. THE ½" BITUMINOUS JOINT FILLER SHALL BE CONSIDERED INCIDENTAL TO THE RUNDOWN FLUME.



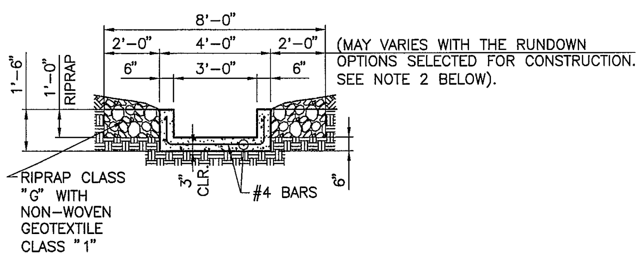
SECTION A–A

NOTE:

1. FOR DETAILS OF METAL BARRIER & POST SEE SERIAL 606–01–1/4.
2. FOR "X" VALUE, SEE ROADWAY PLANS.



SECTION B–B



SECTION C–C

NO.	DATE	REV. BY	DESCRIPTION
⚠	04/23/07	TM	GENERAL REVISIONS

REVISIONS (OR CHANGE NOTICES)

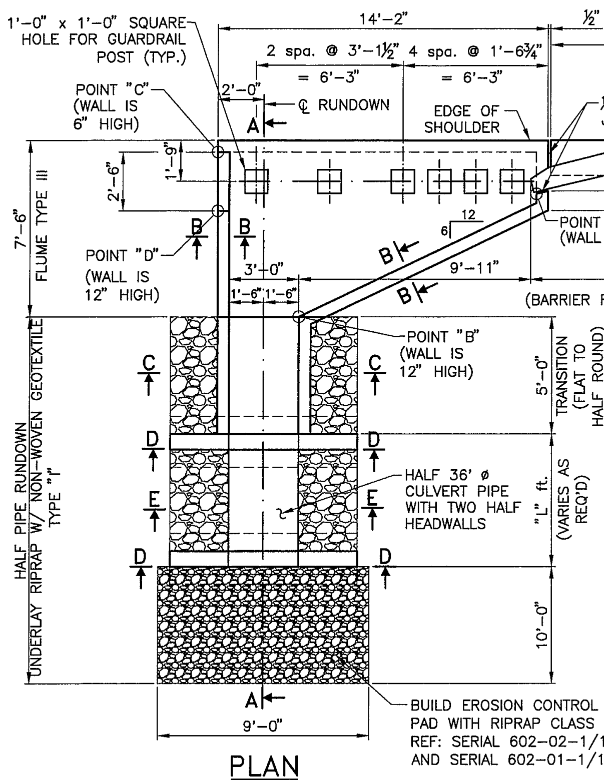
NEW MEXICO
DEPARTMENT OF TRANSPORTATION
STANDARD DRAWING

RUNDOWN FLUMES TYPE II (SAG)
FOR MODIFIED OR PINNED CURB

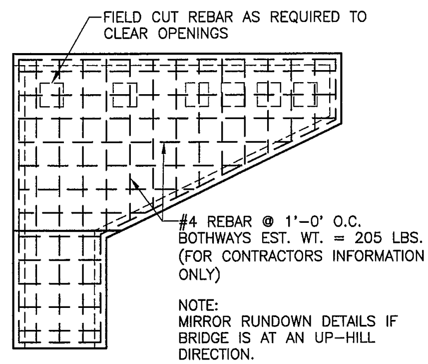
APPROVED [signature] DESIGN ENGINEER 6-12-07 DATE

DESIGNED BY ____ DRAWN BY SKL CHECKED BY YML

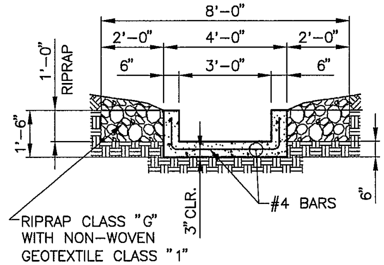
515–03–1/1 1 of 1



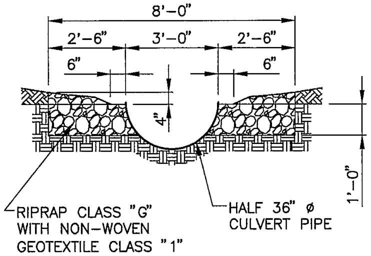
PLAN



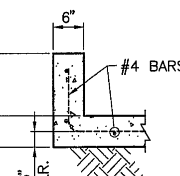
REBAR PLACING PLAN



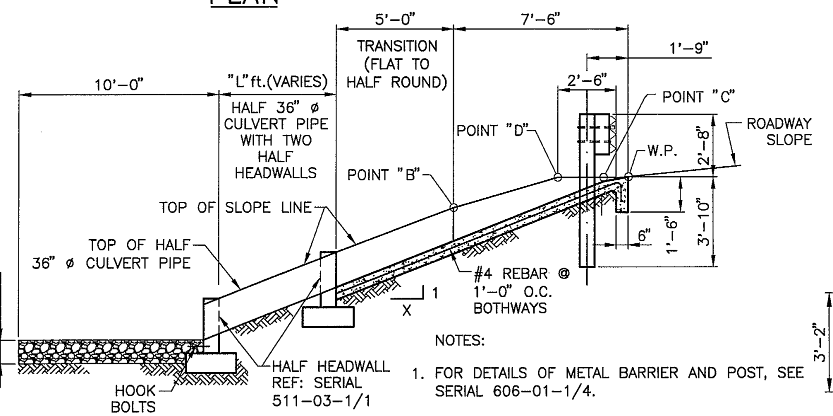
SECTION C-C



SECTION E-E



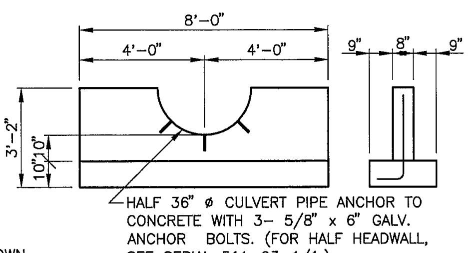
SECTION B-B



SECTION A-A

NOTES:

1. FOR DETAILS OF METAL BARRIER AND POST, SEE SERIAL 606-01-1/4.
2. FOR "X" VALUE SEE ROADWAY PLANS.
3. SEE SERIAL 515-02-2/2 FOR ALTERNATE RUNDOWN OPTIONS OF FULL PIPE, CONCRETE AND RIPRAP.



SECTION D-D

NOTE:

1. QUANTITIES FOR 36" CULVERT PIPE AND RIPRAP CLASS "A" OR "G" VARY DEPENDING UPON WHETHER THE RUNDOWN IS LOCATED AT PROTECTED OR UNPROTECTED SLOPES. SEE ROADWAY PLANS FOR QUANTITIES AND LOCATIONS.
2. REFER TO SERIAL 515-02-1/2 & 515-02-2/2 FOR RUNDOWN OPTIONS.

GENERAL NOTES

1. STRUCTURAL CAST-IN-PLACE CONCRETE SHALL BE CLASS "A". CHAMFER ALL EXPOSED EDGES OF CONCRETE 3/4".
2. ALL REINFORCING BARS SHALL CONFORM TO AASHTO SPECIFICATION M31, GRADE 60.
3. FIELD CUT AND BEND REINFORCING BARS AS REQUIRED FOR THE STRUCTURE.
4. INSTALLATION AS SHOWN IS TYPICAL AND DETAILS MAY BE VARIED TO FIT LOCATION. QUANTITIES WILL BE ADJUSTED IN THE FIELD.
5. RUNDOWN FLUMES WILL BE PAID FOR UNDER THE PAY ITEMS LISTED BELOW. SEE 515-04-2/2 FOR QUANTITIES

ITEM	PAY UNIT
REINFORCED CONCRETE FOR MINOR STRUCTURES	CU. YD.
24" CULVERT PIPE	FEET
36" CULVERT PIPE	FEET
RIPRAP CLASS "A"	CU. YD.
RIPRAP CLASS "G"	SQ. YD.

6. CONCRETE PORTION OF FLUMES OR RUNDOWNS SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE REQUIREMENTS FOR "REINFORCED CONCRETE FOR MINOR STRUCTURES - SECTION 515" OF THE NMDOT STANDARD SPECIFICATION FOR HIGHWAY AND BRIDGE CONSTRUCTION, CURRENT EDITION.
7. STEEL STAKES FOR ANCHORING RIPRAP ARE ONLY REQUIRED FOR THE RIPRAP RUNDOWN WITH CLASS "A" RIPRAP.
8. WHEN THE 24" CULVERT PIPE, OR 36" HALF PIPE EXCEEDS 50 FEET IN LENGTH, THE CONTRACTOR SHALL CONSTRUCT AHALF HEADWALL WITHOUT FOOTING AT EVEN INCREMENTS, NOT TO EXCEED 50 FEET OVER THE TOTAL LENGHT OF CULVERT PIPE. COST FOR THIS CONSTRUCTION SHALL BE PAID FOR UNDER THE APROPRIATE ITEM FOR REINFORCED CONCRETE FOR MINOR STRUCTURES. APPOXIMATE CONCRETE VOLUME PER HALF HEADWALL WITHOUT FOOTING - 0.67 CU. FT. APPROXIMATE REBAR WEIGHT = 70 LBS.
9. THE BRIDGE JOINT STRIP SEAL SHALL DRAIN WATER INTO THE RUNDOWN AS SHOWN ON THE BRIDGE PLAN DETAILS. THE ½" BITUMINOUS JOINT FILLER SHALL BE LOCATED BETWEEN THE RUNDOWN, APPROACH SLAB, AND ASPHALT PAVING WHERE APPLICABLE. THE ½" BITUMINOUS JOINT FILLER SHALL BE CONSIDERED INCIDENTAL TO THE RUNDOWN FLUME.
10. EXCAVATION ANCHOR BOLTS, AND HOOK BOLTS FOR RUNDOWN SHALL BE CONSIDERED INCIDENTAL AND ON DIRECT PAYMENT WILL BE MADE THEREFORE. NON-WOVEN GEOTEXTILE CLASS "1" SHALL BE INCLUDED IN THE UNIT BID PRICE FOR RIPRAP CLASS "A" AND RIPRAP CLASS "G".

NO.	DATE	REV. BY	DESCRIPTION
1	04/24/07	TM	GENERAL REVISIONS

REVISIONS (OR CHANGE NOTICES)

NEW MEXICO DEPARTMENT OF TRANSPORTATION STANDARD DRAWING

RUNDOWN FLUMES TYPE III FOR BRIDGES

APPROVED ______ DESIGN ENGINEER 6-12-07 DATE

DESIGNED BY____ DRAWN BY SKL CHECKED BY YML

515-04-1/2

TABLE A (FOR CONTRACTORS INFORMATION ONLY)

ESTIMATED QUANTITIES OF FLUME STRUCTURES

PAY ITEM	PAY UNIT	STRUCTURE TYPES OF FLUME		
		FLUME TYPE I (a) FOR MODIFIED OR PINNED CURBS	FLUME TYPE II (b) FOR MODIFIED OR PINNED CURBS	FLUME TYPE III (c) FOR BRIDGES
REINFORCED CONCRETE FOR MINOR STRUCTURES	CU. YD.	$0.71 + 1.71 \left(\frac{\sqrt{X^2+1}}{X}\right)$	$0.81 + 1.29 \left(\frac{\sqrt{X^2+1}}{X}\right)$	$0.38 + 1.73 \left(\frac{\sqrt{X^2+1}}{X}\right)$

(FOR THE DETAILS OF FLUME STRUCTURES, SEE SERIAL 515-02-1/2, 51-03-1/1, 515-04-1/3)

TABLE B (FOR CONTRACTORS INFORMATION ONLY)

ESTIMATED QUANTITIES OF RUNDOWN STRUCTURES

PAY ITEM	PAY UNIT	STRUCTURE TYPES OF RUNDOWN			
		HALF PIPE RUNDOWN (1)	FULL PIPE RUNDOWN (2)	CONCRETE RUNDOWN (3)	RIPRAP RUNDOWN (4)
REINFORCED CONCRETE FOR MINOR STRUCTURES	CU. YD.	$1.82 + 0.56 \left(\frac{\sqrt{X^2+1}}{X}\right)$	$2.29 + 0.51 \left(\frac{\sqrt{X^2+1}}{X}\right)$	$0.56 + 0.11(L) \left(\frac{\sqrt{X^2+1}}{X}\right)$	$0.63 \left(\frac{\sqrt{X^2+1}}{X}\right)$
36" ø CULVERT PIPE	FT.	$(0.67 + L) \left(\frac{\sqrt{X^2+1}}{X}\right)$			
24" ø CULVERT PIPE	FT.		$(0.67 + L) \left(\frac{\sqrt{X^2+1}}{X}\right)$		
RIPRAP "A"	CU. YD.	3.11	3.11	3.33	$4.07 + 0.27(L) \left(\frac{\sqrt{X^2+1}}{X}\right)$
RIPRAP "G"	SD. YD.	$(1.82 + 0.56L) \left(\frac{\sqrt{X^2+1}}{X}\right)$	$(2.5) \left(\frac{\sqrt{X^2+1}}{X}\right)$	$(2.22 + 0.44L) \left(\frac{\sqrt{X^2+1}}{X}\right)$	$3.06 + 0.43(L) \left(\frac{\sqrt{X^2+1}}{X}\right)$

(FOR THE DETAILS OF RUNDOWN STRUCTURES, SEE SERIAL 515-02-2/2)

TABLE C (FOR CONTRACTORS INFORMATION ONLY)

ESTIMATED QUANTITIES OF VARIOUS STRUCTURAL COMBINATIONS

RUNDOWN FLUME TYPE I (SEIAL 515-02-1/2)					RUNDOWN FLUME TYPE II (SEIAL 515-03-1/1)					RUNDOWN FLUME TYPE III (SEIAL 515-04-1/3)				
CONBINATION WITH RUNDOWN OPTIONS	HALF PIPE RUNDOWN	FULL PIPE RUNDOWN	CONC. RUNDOWN	RIRAP RUNDOWN	CONBINATION WITH RUNDOWN OPTIONS	HALF PIPE RUNDOWN	FULL PIPE RUNDOWN	CONC. RUNDOWN	RIRAP RUNDOWN	CONBINATION WITH RUNDOWN OPTIONS	HALF PIPE RUNDOWN	FULL PIPE RUNDOWN	CONC. RUNDOWN	RIRAP RUNDOWN
EST. QUANTITIES FROM TABLE A & B	COLUMN (a) + COLUMN (1)	COLUMN (a) + COLUMN (2)	COLUMN (a) + COLUMN (3)	COLUMN (a) + COLUMN (4)	EST. QUANTITIES FROM TABLE A & B	COLUMN (b) + COLUMN (1)	COLUMN (b) + COLUMN (2)	COLUMN (b) + COLUMN (3)	COLUMN (b) + COLUMN (4)	EST. QUANTITIES FROM TABLE A & B	COLUMN (c) + COLUMN (1)	COLUMN (c) + COLUMN (2)	COLUMN (c) + COLUMN (3)	COLUMN (c) + COLUMN (4)

NOTES

1. QUANTITIES FOR 36" OR 24" CULVERT PIPE AND RIPRAP CLASS "A" OR "G" VARY DEPENDING UPON WHETHER THE RUNDOWN IS LOCATED AT PROTECTED OR UNPROTECTED SLOPES. SEE ROADWAY PLANS FOR QUANTITIES AND LOCATIONS.
2. QUANTITIES FOR " REINFORCED CONCRETE FOR MINOR STRUCTURES " INCLUDE THE FLUME AND TWO HALF HEADWALLS OR TWO HEADWALLS WITH FOOTINGS.
3. REFER TO SERIAL 515-02-1/2 , 515-02-2/2, 515-03-1/1 AND 515-04-1/2 FOR RUNDOWN OPTIONS
4. THE ESTIMATED QUANTITY CALCULATIONS OF TABLE **A** AND TABLE **B** ARE BASED ON X:1 EMBANKMENT SLOPE SHOWN ON ROADWAY PLANS. ALSO, THE "L" VALUE IS TO BE FIGURED BY "X" VALUE OF EMBANKMENT SLOPE.
5. FOR THE UTILIZING OF TABLE **A** AND TABLE **B** TO CALCULATE ESTIMATED QUANTITIES ON SPECIFIED RUNDOWN FLUME STRUCTURES, SEE "EXAMPLE" SHOWN BELOW.

EXAMPLE : CALCULATION FOR ESTIMATED QUANTITIES OF " RUNDOWN FLUME TYPE I FOR MODIFIED OR PINNED CURB WITH HALF PIPE RUNDOWN "
SERIAL 515-02-1/2.

THE STRUCTURE IS A COMBINATION OF FLUME TYPE I AND HALF PIPE RUNDOWN, THEREFORE THE ESTIMATED QUANTITIES IS THE ADDITION OF COLUMN (a) IN TABLE **A** AND COLUMN (1) IN TABLE **B**. AS SHOWN BELOW.

ESTIMATED QUANTITIES

REINFORCED CONCRETE FOR MINOR STRUCTURES $= \left[(0.71 + 1.82) + (1.71 + 0.56)\left(\frac{\sqrt{X^2+1}}{X}\right)\right]$

$= \left[2.53 + (2.27)\left(\frac{\sqrt{X^2+1}}{X}\right)\right]$ cu. yd

36" ø CULVERT PIPE $= \left[(0.67 + L)\left(\frac{\sqrt{X^2+1}}{X}\right)\right]$ ft.

RIPRAP "A" = 3.11 cu. yd.

RIPRAP "G" $= \left[(1.85 + 0.56L)\left(\frac{\sqrt{x^2+1}}{X}\right)\right]$ sq. yd

NO.	DATE	REV. BY	DESCRIPTION

REVISIONS (OR CHANGE NOTICES)

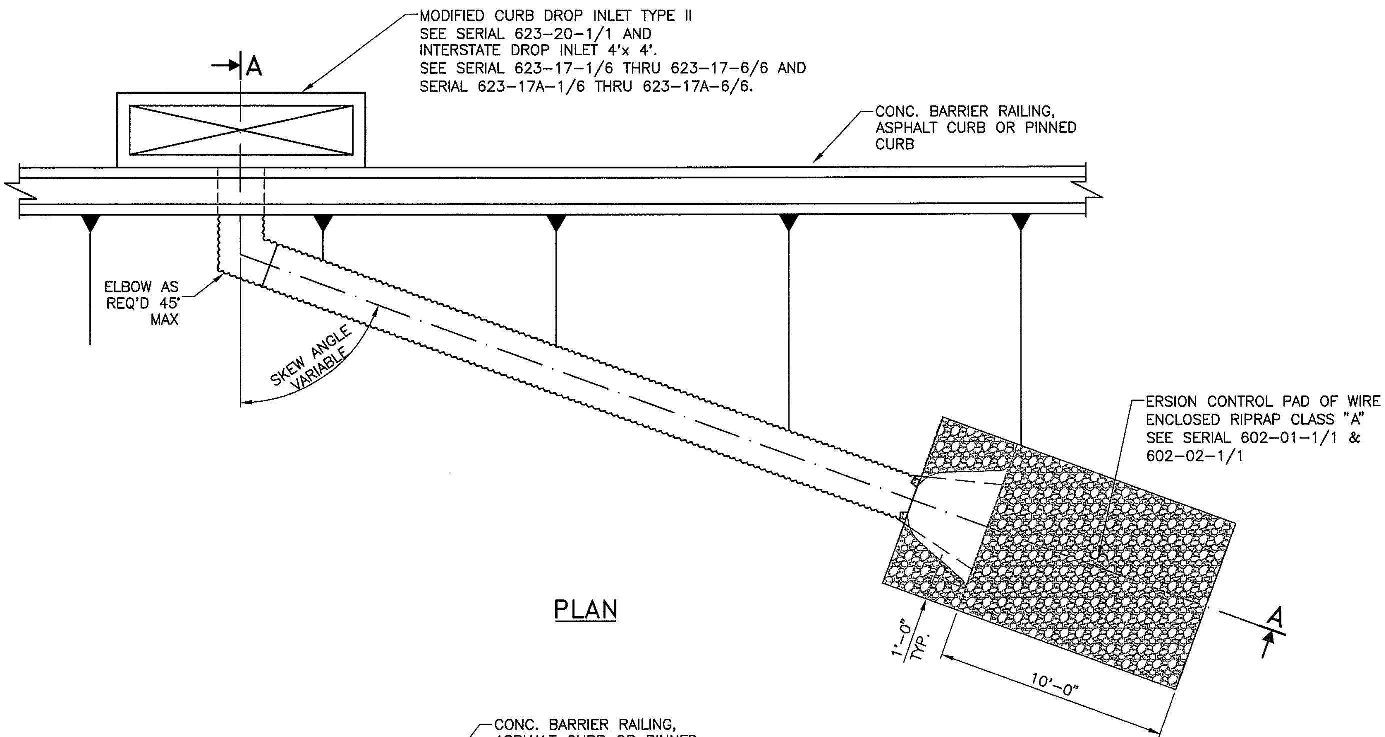
NEW MEXICO DEPARTMENT OF TRANSPORTATION STANDARD DRAWING

ESTIMATED QUATITIES FOR RUNDOWN FLUMES

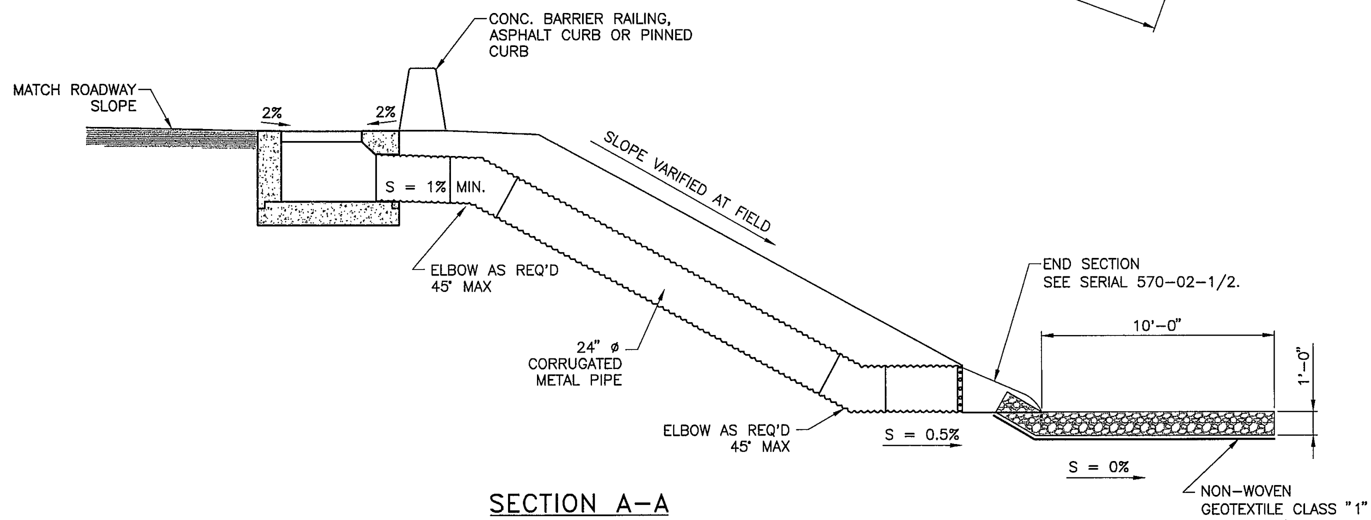
APPROVED [signature] DESIGN ENGINEER 6-12-07 DATE

DESIGNED BY YML DRAWN BY SKL CHECKED BY TM

515-04-2/2



PLAN



SECTION A-A

NOTES

1. USE 24" CORRUGATED METAL PIPE (CMP) WITH WATERTIGHT RESTRAINED JOINTS
2. THE PIPE SHALL BE EXTENDED TO THE TOE OF THE SLOPE AND MAY BE SKEWED TO MEET FIELD CONDITIONS. IN SOME CASES ADDITIONAL ELBOWS WHICH ARE NOT SHOWN SHALL BE REQUIRED AND SHALL BE CONSIDERED INCIDENTAL TO THE PIPE.
3. THE MAXIMUM DESIGN FLOW IS 12 CFS.
4. USE T = 1'-0" WIRE ENCLOSED RIPRAP CLASS A WITH NON-WOVEN GEOTEXTILE CLASS 1. THE GEOTEXTILE SHOULD BE PLACED BETWEEN THE SOIL AND THE WIRE ENCLOSED RIPRAP. USE THE DIMENSIONS SHOWN UNLESS OTHERWISE CALLED FOR IN THE CONTRACT.
5. DESIGN IS ACCORDING TO AASHTO SPECIFICATIONS AND NEW MEXICO DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS FOR HIGHWAY AND BRIDGE CONSTRUCTION LATEST EDITION.
6. A MEDIAN DROP INLET MAY BE SUBSTITUTED FOR THE MODIFIED CURB DROP INLET WHERE THE SPACING BETWEEN THE METAL BARRIER POSTS IS ADEQUATE, AND UPON APPROVAL OF THE PROJECT MANAGER.

NO.	DATE	REV. BY	DESCRIPTION
1	05/08/07	TM	GENERAL REVISIONS

REVISIONS (OR CHANGE NOTICES)

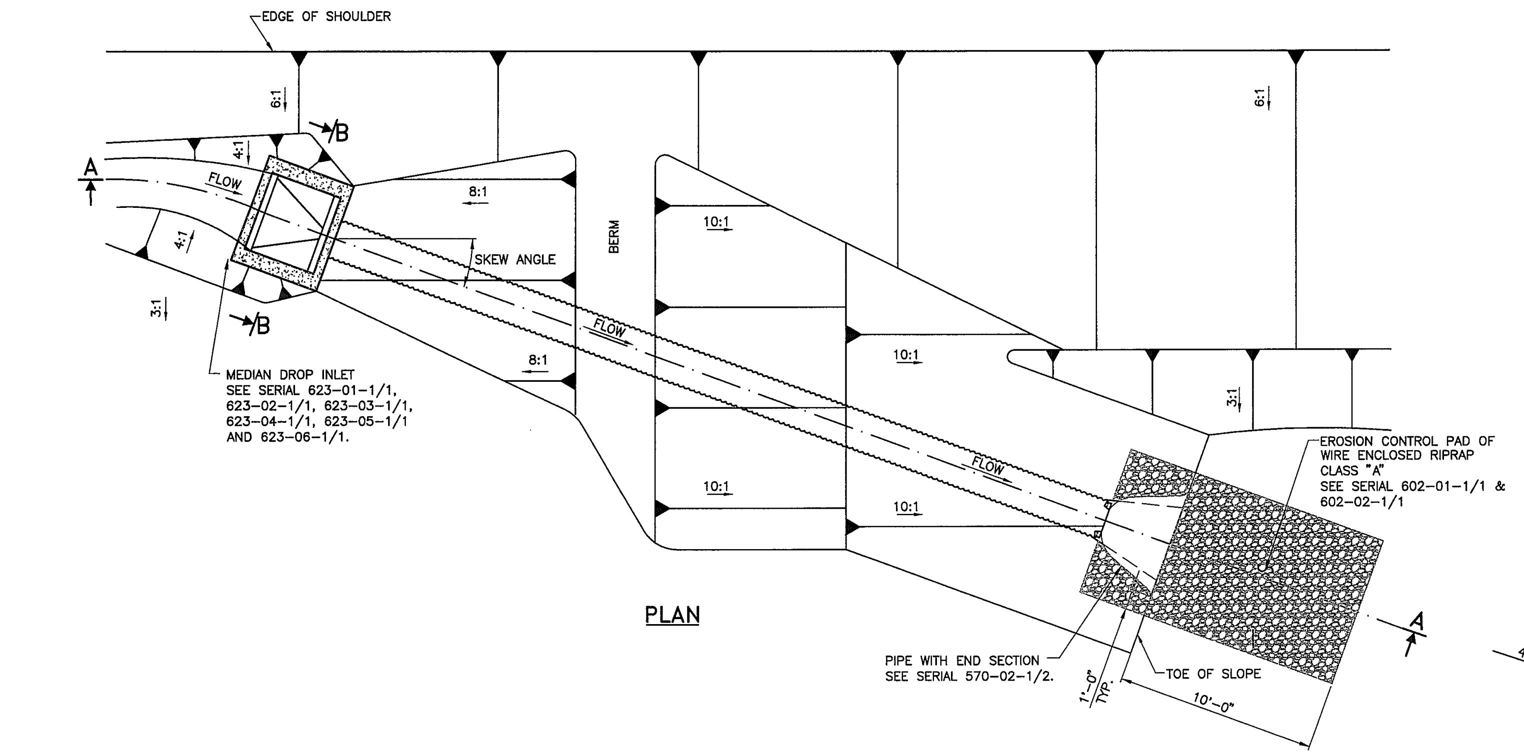
NEW MEXICO
DEPARTMENT OF TRANSPORTATION
STANDARD DRAWING

DROP INLET WITH FULL PIPE RUNDOWN FOR CWB, MODIFIED OR PINNED CURB

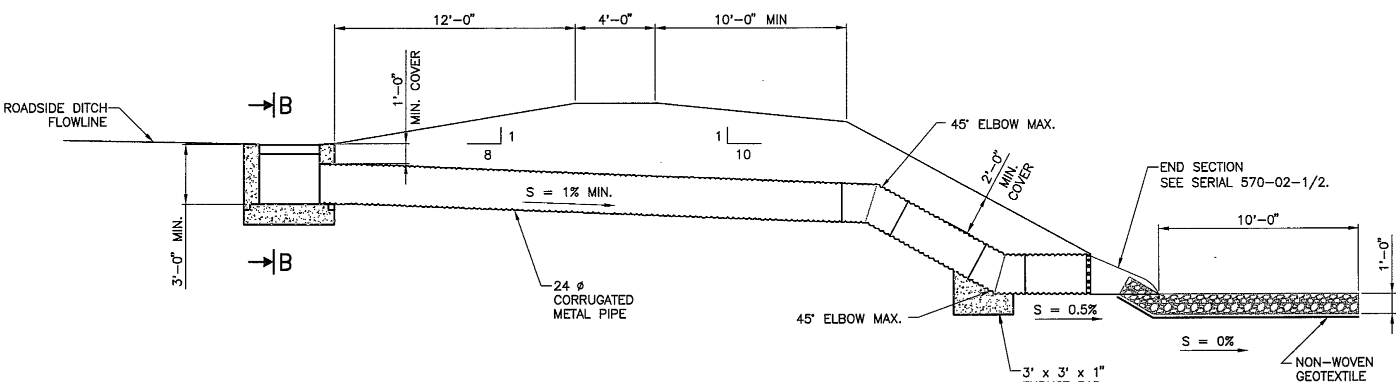
APPROVED [signature] DESIGN ENGINEER 6-12-07 DATE

DESIGNED BY ____ DRAWN BY SKL CHECKED BY YML

515-05-1/4 1 of 4



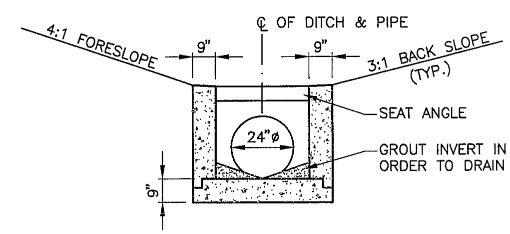
PLAN



SECTION A-A

NOTES

1. THE DROP INLET AND BERM CON BE USED INSIDE THE "CLEAR ZONE" AS DEFINED BY AASHTO ROADSIDE DESIGN GUIDE. SLOPE BLANKETS CAN BE SUBSTITUTED FOR END SECTIONS IF IN THE CLEAR ZONE.
2. USE 24" CORRUGATED METAL PIPE (CMP) WITH WATERTIGHT RESTRAINED JOINTS
3. THE PIPE SHALL BE EXTENDED TO THE TOE OF THE SLOPE AND MAY BE SKEWED TO MEET FIELD CONDITIONS. IN SOME CASES ADDITIONAL ELBOWS WHICH ARE NOT SHOWN SHALL BE REQUIRED AND SHALL BE CONSIDERED INCIDENTAL TO THE PIPE.
4. USE DIMENSIONS FOR THE MEDIAN DROP INLET AS SHOWN UNLESS OTHERWISE CALLED FOR IN THE CONTRACT.
5. THE MAXIMUM DESIGN FLOW IS 12 CFS.
6. USE T = 1'-0" WIRE ENCLOSED RIPRAP CLASS A WITH NON-WOVEN GEOTEXTILE CLASS 1. THE GEOTEXTILE SHOULD BE PLACED BETWEEN THE SOIL AND THE WIRE ENCLOSED RIPRAP. USE THE DIMENSIONS SHOWN UNLESS OTHERWISE CALLED FOR IN THE CONTRACT.
7. CONCRETE SHALL CONFORM TO SECTION 510 AND SHALL BE CLASS A. REINFORCING STEEL SHALL CONFORM TO SECTION 540 AND SHALL BE AASHTO M-31. GRADE 60.
8. DESIGN IS ACCORDING TO AASHTO SPECIFICATIONS AND NEW MEXICO DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS FOR HIGHWAY AND BRIDGE CONSTRUCTION LATEST EDITION.
6. A MEDIAN DROP INLET MAY BE SUBSTITUTED FOR THE MODIFIED CURB DROP INLET WHERE THE SPACING BETWEEN THE METAL BARRIER POSTS IS ADEQUATE, AND UPON APPROVAL OF THE PROJECT MANAGER.



SECTION B-B

NO.	DATE	REV. BY	DESCRIPTION
⚠	05/24/07	TM	GENERAL REVISIONS

REVISIONS (OR CHANGE NOTICES)

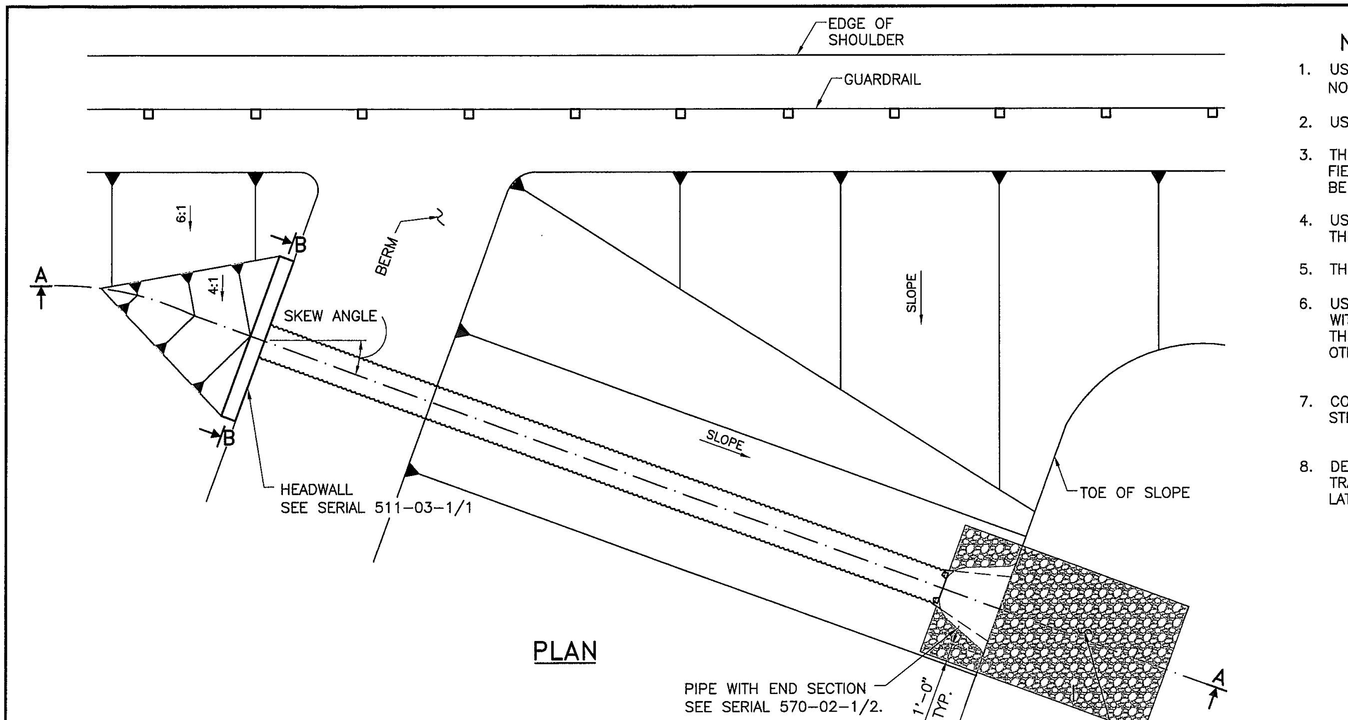
NEW MEXICO
DEPARTMENT OF TRANSPORTATION
STANDARD DRAWING

DROP INLET WITH
FULL PIPE RUNDOWN
TYPE I FOR ROADSIDE DITCH

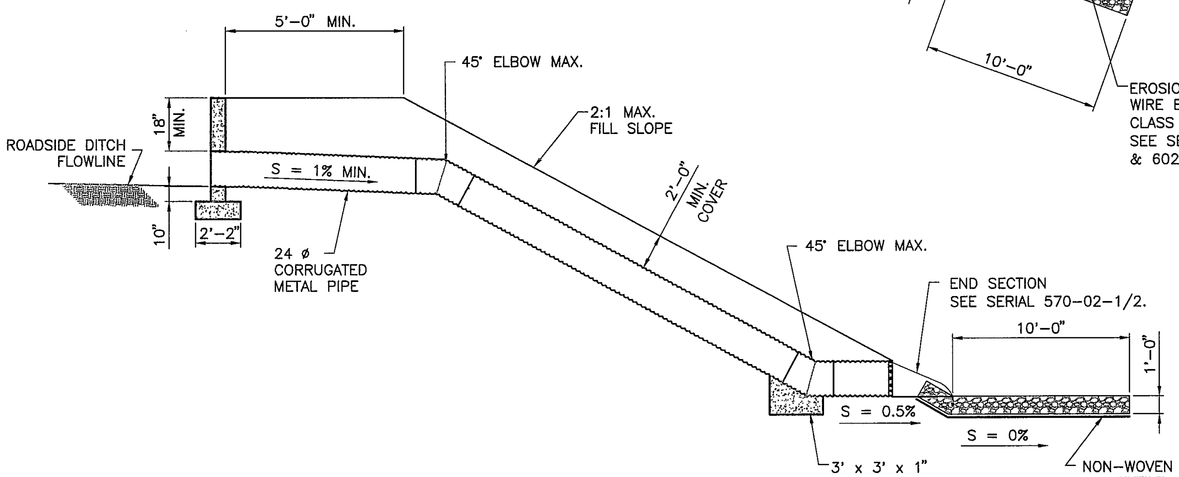
APPROVED [signature] DESIGN ENGINEER 6-12-07 DATE

DESIGNED BY____ DRAWN BY SKL CHECKED BY YML

515-05-2/4



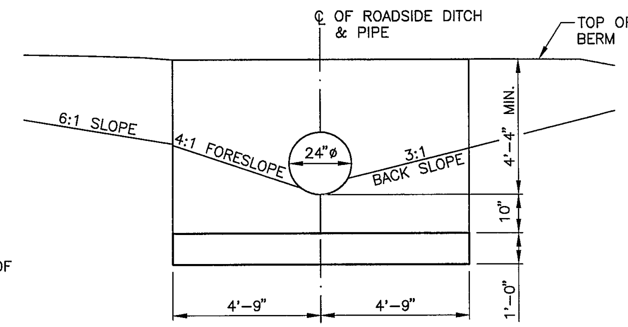
PLAN



SECTION A-A

NOTES

1. USE OUTSIDE THE "CLEAR ZONE" AS DEFINED BY AASHTO ROADSIDE DESIGN GUIDE IF NOT USED BEHIND BARRIER.
2. USE 24" CORRUGATED METAL PIPE (CMP) WITH WATERTIGHT RESTRAINED JOINTS
3. THE PIPE SHALL BE EXTENDED TO THE TOE OF THE SLOPE AND SKEWED TO MEET FIELD CONDITIONS. IN SOME CASES ADDITIONAL ELBOWS WHICH ARE NOT SHOWN SHALL BE REQUIRED AND SHALL BE CONSIDERED INCIDENTAL TO THE PIPE.
4. USE DIMENSIONS FOR THE HEADWALL AS SHOWN UNLESS OTHERWISE CALLED FOR IN THE CONTRACT.
5. THE MAXIMUM DESIGN FLOW IS 12 CFS.
6. USE T = 1'-0" WIRE ENCLOSED RIPRAP CLASS A WITH NON-WOVEN GEOTEXTILE CLASS 1. THE GEOTEXTILE SHOULD BE PLACED BETWEEN THE SOIL AND THE WIRE ENCLOSED RIPRAP. USE THE DIMENSIONS SHOWN UNLESS OTHERWISE CALLED FOR IN THE CONTRACT.
7. CONCRETE SHALL CONFORM TO SECTION 510 AND SHALL BE CLASS A. REINFORCING STEEL SHALL CONFORM TO SECTION 540 AND SHALL BE AASHTO M-31. GRADE 60.
8. DESIGN IS ACCORDING TO AASHTO SPECIFICATIONS AND NEW MEXICO DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS FOR HIGHWAY AND BRIDGE CONSTRUCTION LATEST EDITION.



SECTION B-B

TYPICAL HEADWALL
SEE SERIAL 511-03-1/1 "SINGLE PIPE"

NO.	DATE	REV. BY	DESCRIPTION
1	05/24/07	TM	GENERAL REVISIONS

REVISIONS (OR CHANGE NOTICES)

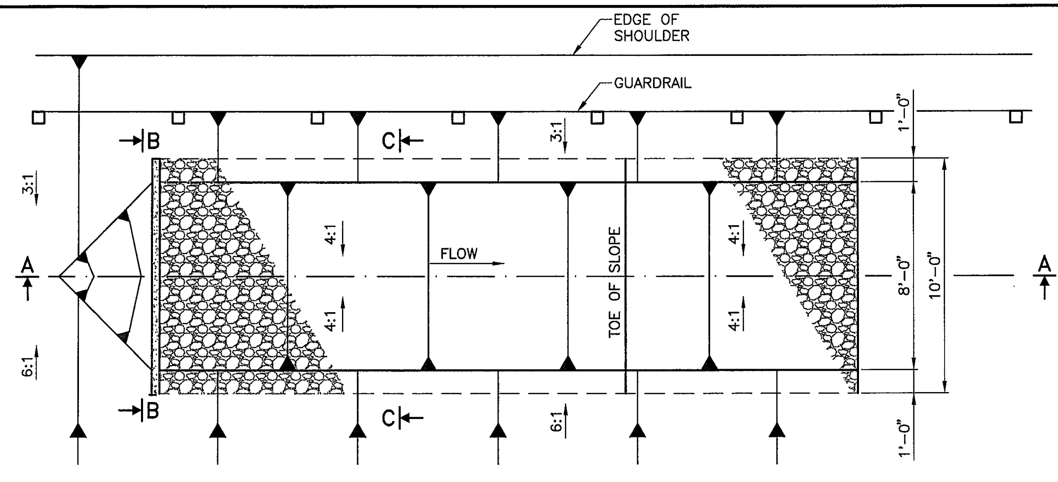
NEW MEXICO
DEPARTMENT OF TRANSPORTATION
STANDARD DRAWING

HEADWALL WITH
FULL PIPE RUNDOWN
TYPE II FOR ROADSIDE DITCH

APPROVED ______ DESIGN ENGINEER ______ 6-12-07 DATE

DESIGNED BY ____ DRAWN BY SKL CHECKED BY YML

515-05-3/4



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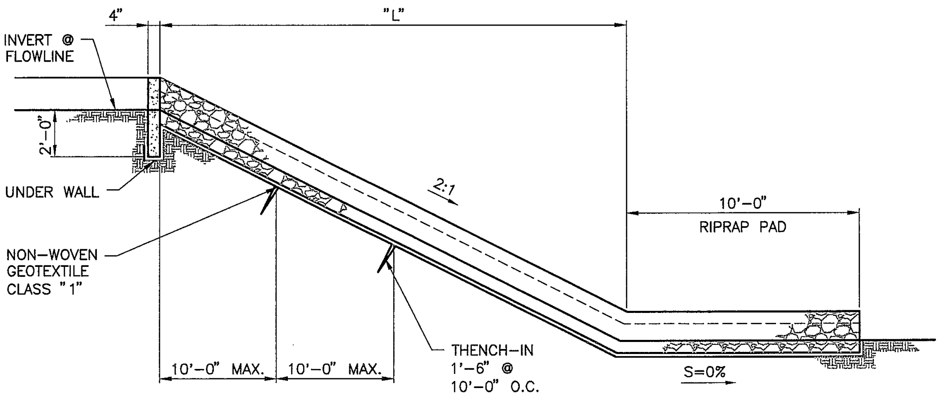
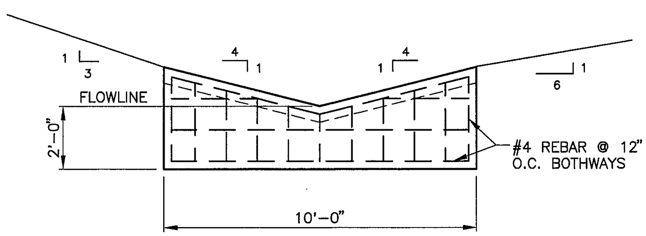
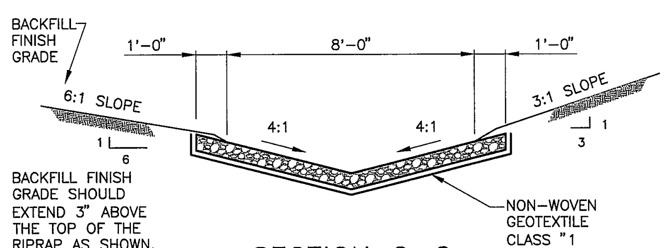


SECTION A-A



SECTION B-B



BACKFILL FINISH GRADE SHOULD EXTEND 3" ABOVE THE TOP OF THE RIPRAP AS SHOWN.

SECTION C-C

NOTES

1. THE RUNDOWN SHOULD BE EXTENDED TO THE BOTTOM OF THE SLOPE AND SKEWED TO MEET FIELD CONDITIONS.
2. THE MAXIMUM DESIGN FLOW IS 12 CFS.
3. USE T = 1'-0" CLASS A WIRE ENCLOSED RIPRAP WITH NON-WOVEN GEOTEXTILE CLASS "1". CONTRACTOR MAY SUBSTITUTE LOOSE RIPRAP AND ELIMINATE THE CUT-OFF WALL ON FLATTER SLOPE AS APPROVED BY THE PROJECT MANAGER OR AS SHOWN IN THE PLANS.
4. THE GEOTEXTILE SHOULD BE PLACED BETWEEN THE SOIL AND THE WIRE ENCLOSED RIPRAP AS SHOWN TO PREVENT PIPING AND EXTEND HALFWAY UP THE SIDE OF THE RIPRAP CHANNEL. USE THE DIMENSIONS SHOWN UNLESS OTHERWISE CALLED FOR IN THE CONTRACT.
5. THE WIRE ENCLOSED RIPRAP IS TO BE TIED VIA HOOKS TO THE CONCRETE WALL AT A MAXIMUM OF 2 FEET ON CENTER.
6. CONCRETE SHALL CONFORM TO SECTION 510 AND SHALL BE CLASS A. REINFORCING STEEL SHALL CONFORM TO SECTION 540 AND SHALL BE AASHTO M-31, GRADE 60.
7. DESIGN ACCORDING TO AASHTO SPECIFICATIONS AND NEW MEXICO DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS FOR HIGHWAY AND BRIDGE CONSTRUCTION LATEST EDITION.
8. STAKES SHALL BE PLACED 12" FROM THE EDGES OF RIPRAP.
9. AFTER PLACEMENT OF RIPRAP SPREAD ENOUGH NATIVE SOIL OVER THE ENTIRE SURFACE OF THE RUNDOWN TO FILL THE VOIDS IN THE RIPRAP THEN COMPACT THE BACKFILL SOIL AND SEED. THE COST SHALL BE INCIDENTAL TO THE RIPRAP.

NO.	DATE	REV. BY	DESCRIPTION
1	05/31/07	TM	GENERAL REVISIONS

REVISIONS (OR CHANGE NOTICES)

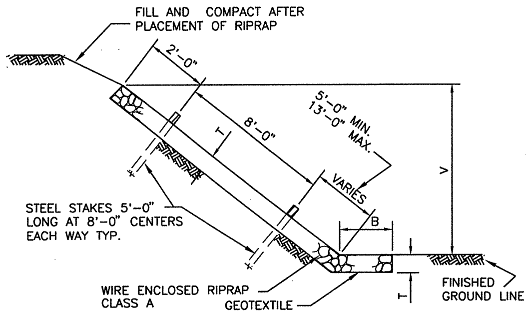
NEW MEXICO
DEPARTMENT OF TRANSPORTATION
STANDARD DRAWING

CUTOFF WALL WITH
RIPRAP RUNDOWN TYPE III
FOR ROADSIDE DITCH

APPROVED [signature] DESIGN ENGINEER 6-12-07 DATE

DESIGNED BY____ DRAWN BY SKL CHECKED BY YML

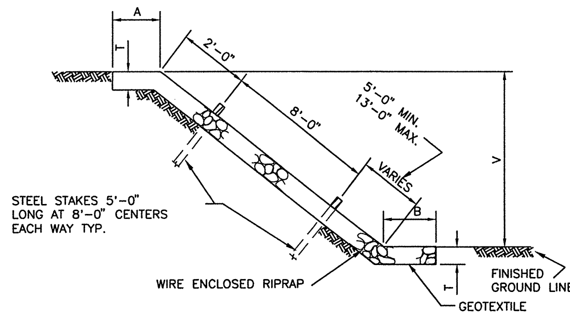
515-05-4/4



SECTION TYPE 1

QUANTITIES PER LINEAR FOOT

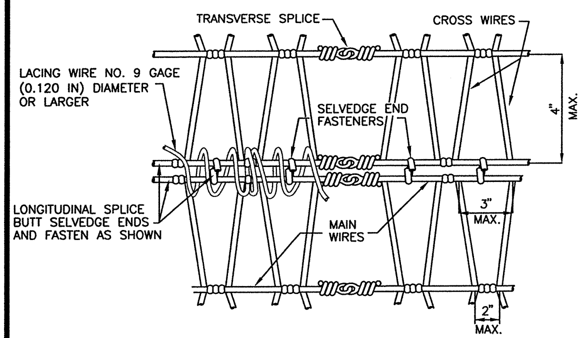
SLOPE	RIPRAP CU. YARDS
1.5 : 1	$\frac{T}{27}$(B + 1.803V + 0.303T)
1.75 : 1	$\frac{T}{27}$(B + 2.016V + 0.266T)
2 : 1	$\frac{T}{27}$(B + 2.236V + 0.236T)
3 : 1	$\frac{T}{27}$(B + 3.162V + 0.162T)
4 : 1	$\frac{T}{27}$(B + 4.123V + 0.123T)



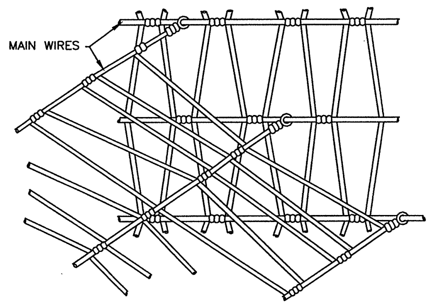
SECTION TYPE 2

QUANTITIES PER LINEAR FOOT

SLOPE	RIPRAP CU. YARDS
1 : 1	$\frac{T}{27}$(A + B + 1.414V)
1.5 : 1	$\frac{T}{27}$(A + B + 1.803V)
1.75 : 1	$\frac{T}{27}$(A + B + 2.016V)
2 : 1	$\frac{T}{27}$(A + B + 2.236V)
3 : 1	$\frac{T}{27}$(A + B + 3.162V)
4 : 1	$\frac{T}{27}$(A + B + 4.123V)

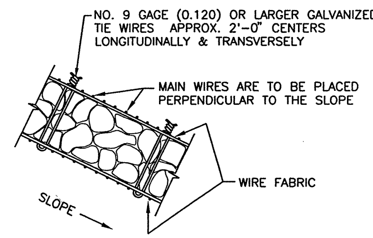


NORMAL INTERSECTION SPLICES



SKEWED INTERSECTION SPLICE

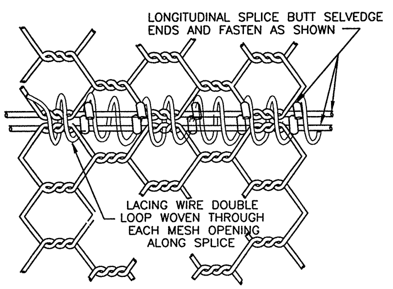
"W" MESH



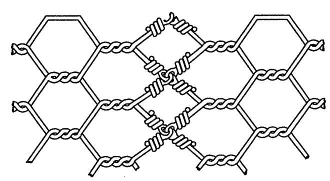
TYPICAL SECTION

GENERAL NOTES

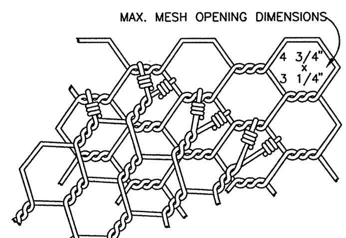
1. WIRE FABRIC FOR RIP RAP SHALL BE "W" OR HEXAGONAL MESH AND MEET THE REQUIREMENTS LISTED IN SECTION 602 OF THE STANDARD SPECIFICATIONS.
2. STEEL STAKES MAY BE RAILROAD RAILS WEIGHING NOT LESS THAN 30 LBS. PER YARD, 4" NOMINAL DIAMETER STANDARD STRENGTH GALVANIZED STEEL PIPE, OR L4"x4"x3/8" STEEL ANGLES. STEEL STAKES SHALL PROJECT 4" ABOVE TOP OF RIPRAP. STEEL STAKES ARE CONSIDERED INCIDENTAL TO THE COMPLETION OF THE WORK AND NO DIRECT MEASUREMENT OR PAYMENT WILL BE MADE THEREFOR.
3. IF LENGTH OF SLOPE IS 15 FEET OR LESS, ONLY ONE ROW OF STEEL STAKES 2 FEET FROM THE TOP EDGE OF RIPRAP WILL BE REQUIRED UNLESS OTHERWISE NOTED ON PLANS.
4. FOR DIMENSIONS A,B,V,&T SEE BRIDGE OR ROADWAY PLANS.
5. T=12" UNLESS OTHERWISE SHOWN ON PLANS, T= 18" AT BRIDGES.
6. FASTENERS FOR SPLICES AND/OR SELVEDGE END CONNECTORS MAY BE WIRE TIES, INTERLOCKING WIRE CLIPS, HOG RINGS, OR LACING WIRE. ONLY FASTENERS WHICH APPEAR ON THE DEPARTMENT'S "APPROVED PRODUCT LISTING" MAY BE USED.
7. LACING SHALL BE CONTINUOUS AS FAR AS IS PRACTICAL AND SHALL PASS THROUGH EACH MESH OPENING.
8. WHERE SPLICING IS NECESSARY, AN OVERLAP OF LACING OF AT LEAST 1 FOOT SHALL BE PROVIDED.



NORMAL INTERSECTION SPLICE



TRANSVERSE SPLICE



SKEWED INTERSECTION SPLICE

HEXAGONAL MESH

NO.	DATE	REV. BY	DESCRIPTION

REVISIONS (OR CHANGE NOTICES)

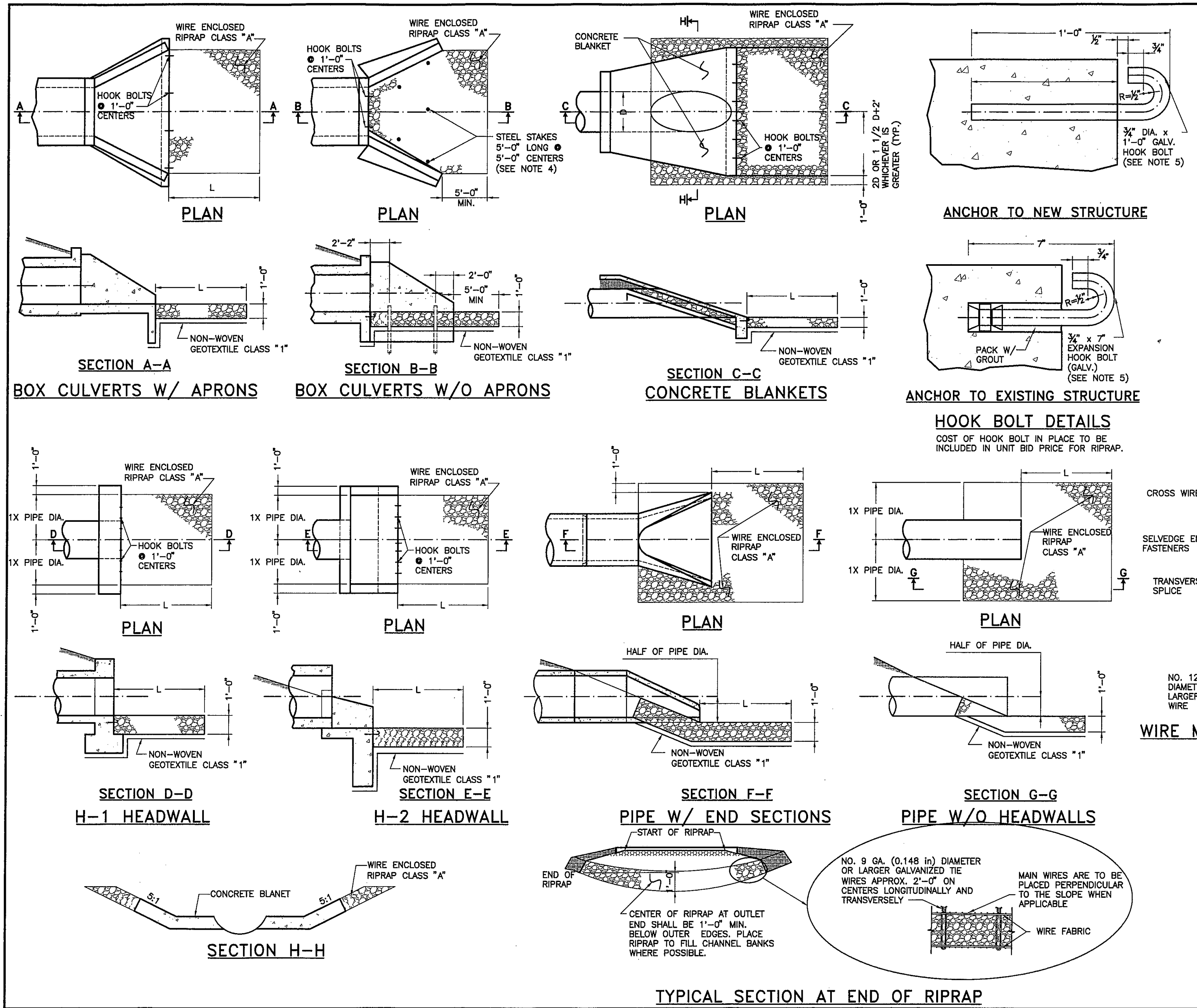
NEW MEXICO DEPARTMENT OF TRANSPORTATION STANDARD DRAWING

WIRE ENCLOSED RIPRAP CLASS A

APPROVED [signature] DESIGN ENGINEER 11-29-04 DATE

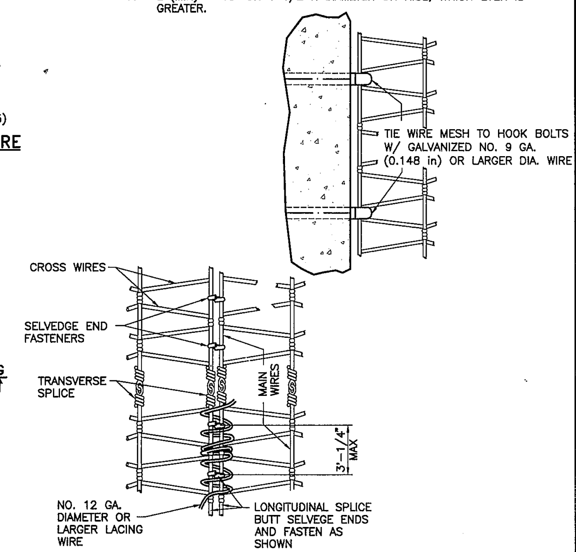
DESIGNED BY___ DRAWN BY ___ CHECKED BY ___

602-01-1/1



GENERAL NOTES

1. ALL RIPRAP SHALL BE CLASS "A" UNLESS SPECIFIED OTHERWISE IN THE PLANS. DIMENSIONS OF RIPRAP CLASS "A" SHALL BE VERIFIED IN FIELD.
2. RIPRAP ON THIS STANDARD IS SHOWN FOR SINGLE PIPES AND CULVERTS ONLY. FOR MULTIPLE PIPE AND CULVERT INSTALLATIONS, EXTEND RIPRAP BEYOND OUTLET OPENING AS SHOWN IN PLAN DETAILS AND PLACE RIPRAP BETWEEN OUTLET OPENINGS AS SHOW IN ELEVATION DETAILS.
3. SERIAL 602-02-1/1 MAY BE REFERENCED FOR DESCRIPTIONS OF WIRE MESH AND ALTERNATE PATTERNS.
4. STEEL STAKES MAY BE RAILROAD RAILS WEIGHING APPROXIMATELY 10 LBS. PER FOOT, 4 INCH NOMINAL DIAMETER STANDARD STRENGTH GALVANIZED STEEL PIPE, OR 4" x 4" x 3/8" STEEL ANGLES. STEEL STAKES SHALL PROJECT 6 INCHES ABOVE THE TOP OF RIPRAP.
5. CONTRACTOR MAY SUBSTITUTE CONCRETE CHEMICAL ANCHORS WITH HOOK GEOMETRY SHOWN, WHICH MEET REQUIREMENTS OF SECTION 522.
6. TOE-IN OR PLACE EROSION CONTROL GEOTEXTILE UNDER FOOTINGS OR CUT-OFF WALL.
7. L (MIN) = 10' OR 1 1/2 X DIAMETER OR RISE, WHICH EVER IS GREATER.



WIRE MESH ANCHOR/SPLICE DETAILS

NO.	DATE	REV. BY	DESCRIPTION
1	08/29/07	TM	GENERAL REVISIONS

REVISIONS (OR CHANGE NOTICES)

NEW MEXICO
DEPARTMENT OF TRANSPORTATION
STANDARD DRAWING

EROSION CONTROL
AT CULVERT OUTLETS

APPROVED [signature] DESIGN ENGINEER 9-6-07 DATE

DESIGNED BY TM DRAWN BY ALT CHECKED BY YML

602-02-1/1 1 of 1

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