

Rock Gabion, Rip-Rap and Culvert Treatments: Successes and Failures in Post-Fire Erosion Mitigation, Schultz Fire 2010

Daniel G. Neary and Karen A. Koestner

USDA Forest Service, Rocky Mountain Research Station, 2500 Pine Knoll Drive, Flagstaff, Arizona 86001

Abstract: Following the Schultz Fire in June of 2010, several erosion mitigation efforts were undertaken to reduce the impacts of post-fire flooding expected during the 2010 monsoon. One treatment consisted of the placement of large rock rip-rap on targeted fill slopes of a high elevation forest road that contains a buried pipeline supplying water to the city of Flagstaff. Another treatment was culvert removal at 30 channel crossings on a forest road that transects the burn area at a lower elevation (Schultz Pass). On urbanized private lands below the fire, no road culverts were initially removed or upgraded. After initial post-fire flooding, a major, unarmored drainage ditch rated at a capacity of $14.2 \text{ m}^3 \text{ sec}^{-1}$ was fitted with sixteen rock-filled wire cage gabions to reduce channel incision. Rainfall began in mid-July after the wildfire and produced multiple floods that caused substantial erosion, debris flows, and channel incision. The large rip-rap on the upper elevation road failed completely. Culvert removal at channel crossings within the forest functioned satisfactorily and prevented the addition of road fill and fill-breach surges to the stormflow. Road culverts in the urban area were grossly under capacity and were either buried or bypassed. The gabions in the drainage ditch functioned for a short time but were then bypassed, causing significant channel widening and transport of additional sediment. This paper takes a forensic look at these erosion control measures and discusses the reasons for failure or success. Recommendations are made for future use of these erosion control techniques.

INTRODUCTION

The Schultz Fire burned 6,100 ha on the eastern slopes of the San Francisco Peaks of the Coconino National Forest in north-central Arizona. The fire burned between June 20th and 30th, 2010, across moderate to very steep ponderosa pine and mixed conifer watersheds. One of the Burned Area Emergency Response treatments on Coconino National Forest lands consisted of the placement of large rock armoring on targeted fill slopes of a high elevation road that was constructed for a buried water pipeline supplying the city of Flagstaff, Arizona (Robichaud et al. 2000, Neary and Koestner 2011). Other Forest treatments consisted of culvert removal at 30 channel crossings on another Forest road that transects the Schultz Fire at a lower elevation. On urbanized private lands below the Fire, no road culverts were initially removed or upgraded. A major, unarmored drainage ditch was fitted with sixteen rock-filled wire cage gabions to reduce channel incision in unconsolidated alluvial fan sediments. Rainfall beginning in mid-July after the wildfire produced a typical series of floods that caused substantial soil erosion, debris flows, and channel incision (Neary et al. 2008).

OBJECTIVES

This paper examines the effectiveness of gabion, armoring, and culvert treatments for erosion control after the Schultz Fire and discusses the reasons for failure or success. An objective is to also make recommendations for future use of these erosion control techniques.

METHODOLOGY

Rock Armoring: This treatment was done on the Waterline Road after the fire at 17 drainage crossings (Figure 1A). It consisted of placing 294 m³ of large rocks (30 to 60 cm diameter) below the road on potential water flow paths. The downhill end of each rock armoring array was anchored to the ground by large logs.

Culvert Treatments: Culverts were removed at 30 locations along the Schultz Pass Road (Forest Road 420) on Coconino National Forest lands (Figure 2A.). Low-water crossings were then graded to allow vehicle passage. A number of culverts (30) on private land were selected for comparison. They ranged in diameter from 30 to 100 cm and were left in place according to individual land owner dictates.

Rock Gabions: After the flood of July 20th, 18 rock-wire gabions were placed at roughly equal distances in an unlined ditch along Campbell Avenue in the Timberline neighborhood. The individual gabion cages were about 60 x 60 cm in cross-section and 2 to 3 m long. The drainage ditch was rated at a capacity of 14.2 m³ sec⁻¹. The ditch was constructed on a straight fall line down the alluvial fan with a gradient of 4%. Since utility lines were buried in soil on both sides of the ditch, the wing walls of the gabions were not adequately keyed into the ditch slopes. This limitation had a major impact on the performance of the gabions during a rainfall and flood flow event of July 30th. The functioning of the gabions was evaluated and photo-documented during the actual flood flow.

RESULTS

Rock Armoring: The large rock armoring on the slopes below the upper elevation Waterline Road failed completely in the storm of July 20th (Figure 1B). All of it was washed away by the high water flows and deep gully incisions in that storm and subsequent storms. At most of the armored crossings, debris flows and runoff carrying much larger rocks than the armoring rocks (30 – 60 cm diameter) crossed the road and washed out the armored sections. The erosion control treatments were simply overwhelmed by the magnitude of the flood events. The size of the armoring pad rocks was too small to process high velocity flows coming off steep, 100%+ slopes. Flood flows lower on the mountain were powerful enough to knock over 13 Mg Jersey barriers. Larger rocks (1+ m in diameter) should have been used but there was probably not enough time to organize delivery of resources of that size. This erosion control technique contributed to the post-fire erosion and did nothing to reduce it. Therefore, this treatment is not recommended in steep terrain unless adequately sized rock material can be obtained.

Culvert Removal: The low-water channel crossings on Forest Road 420 where culverts were removed functioned satisfactorily (Table 1) and prevented addition of road fill and fill-breach surges to the stormflow (Figure 2A). Some minor maintenance is required to keep the crossings trafficable after floods.

Road culverts in the urban area were grossly under capacity and most were either buried, breached, or bypassed, thus increasing the amount of sediment transported to lower elevations

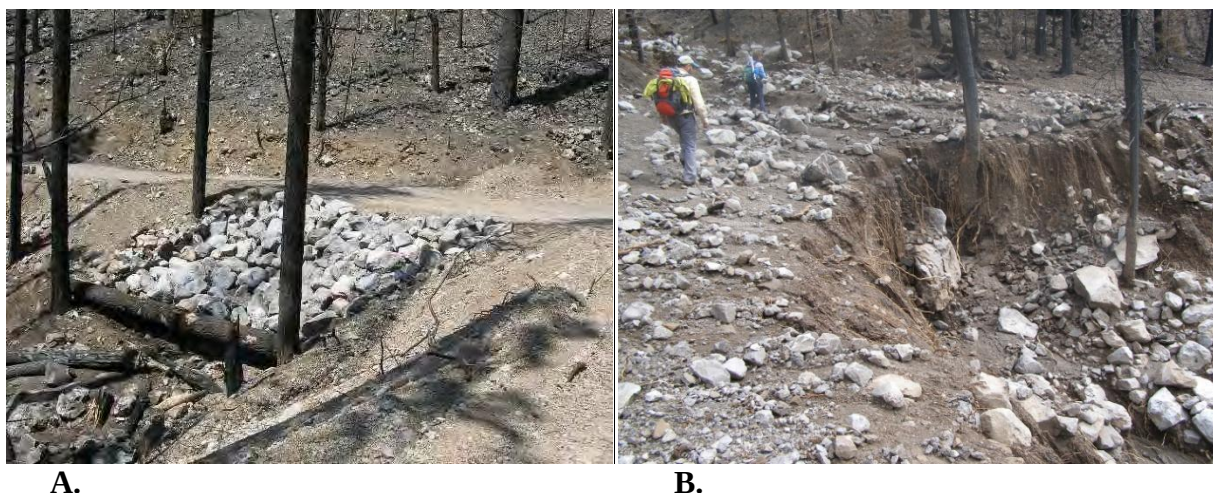


Figure 1. Rock armoring along the Waterline Road before (A) and after (B) the July 20th flood.

(Table 1, Figure 2B). In some instances, home owners replaced storm-damaged or poorly functioning culverts with larger diameter culverts only to have the same failure rate. Of the two that were successful in the private ownership area, one was designed as a concrete surfaced low-water crossing. The other had a set of four 1-m wide culverts located in a depression that followed the gradient of the alluvial fan. This set of culverts was actually installed by Coconino County on a county road. The majority of the roads in the Timberline residential area are private, thus culvert sizing has not been standardized.

Culvert removal on National Forest lands facilitated passage of flood flows from the upper slopes of the San Francisco Peaks. This treatment did not contribute to increased erosion and actually reduced potential erosion and flooding by eliminating the risk of road fill breaches. The culvert removal and low-water channel crossings treatment is recommended as a relatively inexpensive and effective means of coping with post-fire flood flows. Culverts on some private land would have performed better had been larger in diameter. However, others would have failed regardless of size due to excessive rock and woody debris. The best approach in most cases is culvert removal and construction of low-water crossings. Maintenance needs to be carried out on an as-needed basis after stormflow.

Table 1. Comparison of failure rates for culvert treatments, Schultz Fire 2010, Coconino County, Arizona.

Ownership	Location	Treatment	# of Culverts	Failure Rate
National Forest	FR 420	Culvert Removal	30	0%
Private	Timberline	Left In Place	30	93%

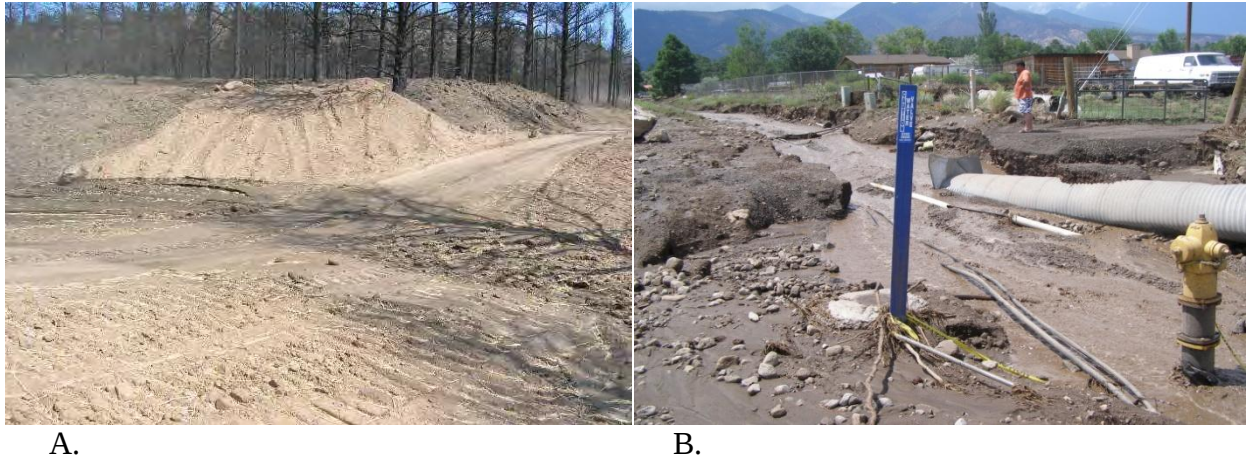


Figure 2. An example of (A) successful culvert removal and construction of low-water crossings on National Forest lands; and (B) a bypassed and breached, undersized culvert on private property, Schultz Fire, Arizona.

Rock Gabions: The gabions in the drainage ditch functioned for a short time but were then bypassed by flood flows, causing significant channel widening and transport of additional sediment (Figure 3). All of the gabions accumulated sediment on their upstream sides early in the storm event and then failed. Left side failures accounted for 56% (10). Only 11% (2) of the gabion failures occurred on the right side of the channel where the construction machinery was located (Figure 3A). An additional 33% (6) of the failures involved both sides of the gabion. The single factor contributing to the gabion failure was incomplete extension of the gabion wings into the left and right banks of the drainage ditch. The presence of phone, electricity, gas, water, and cable TV lines on both sides of the ditch restricted placement of the gabions.

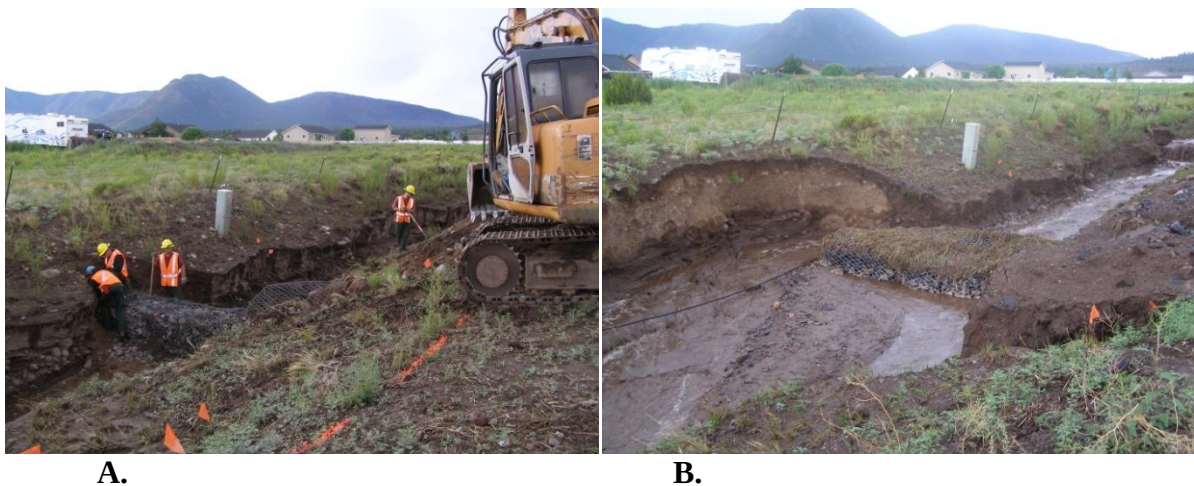


Figure 3. Gabion construction along Campbell Avenue prior to the July 30, 2010, storm (A); and results during the storm event showing gabion failure and channel widening (B).

Figure 3B shows a phone line (black pipe downstream of a junction box) that was exposed by lateral widening of the Campbell ditch at a gabion. All the gabions had to be removed after the July 20th storm to reduce further channel widening and to make room for channel armoring with concrete. One section of the channel surface that was armored with concrete functioned successfully during the July 20th event.

Gabion wire baskets can be used to reduce erosion from post-fire flood flows, but they need to be constructed correctly. Proper construction must include adequate gabion wing walls securely tied in 2 to 3 m beyond the channel slope breaks to prevent water from working around the wings. The center of the gabion should be at mid-channel and the lowest part of the structure. Channel flow velocities must also be considered. The Campbell Avenue channel has a slope of 4% so the average flow velocity was over 1 m s⁻¹ with enough velocity to maintain hyperconcentrated streamflow. High flow velocities and the potential for structure failure were reasons why the Burned Area Emergency Response team (Robichaud et al. 2000) decided to not use channel structures like gabions above the Timberline area.

SUMMARY AND CONCLUSIONS

Three different post-wildfire emergency response treatments to reduce erosion after the Schultz Fire of 2010 were evaluated. The rock armoring control treatments on the Waterline Road did not function adequately since they were simply overwhelmed by the magnitude of the flood events and washed away. Culvert removals and low-water crossings on Forest Service Road 420 worked very well, leaving the road drivable after the first Monsoon flood events. Many culverts that remained in place in the Timberline urban area were either buried, blown out, or by-passed. The rock gabions placed in the Campbell Avenue ditch failed because of improper installation and contributed to widening of the ditch and further erosion. The rock armoring along the Waterline Road has not been replaced pending redesign of the road by the City of Flagstaff. Coconino County has been successful in getting many private culverts converted to low-water crossings, and has replaced some round culverts with much higher capacity box culverts. The gabions in Campbell Avenue were removed and the ditch has been armored with lateral rock-wire cages to stabilize the banks, prevent further erosion, and protect utilities.

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