The Role of Channel Armoring with Gabions on Channel Adjustments on the Zealand River, New Hampshire

Douglas M. Thompson, Leah S. Puklin and Anna E. Marshall

Connecticut College
Gabion?
Rock-filled wire-mesh basket

1 m
1 m
1 m
Project Construction
1960-1963

Gabion walls

4.5 km long reach
1,724 m
4,870 m$^3$ of fill
Gabion deflectors

53 m
Channel bulldozing
8,600 m³

Gabion sills
405 m
What is the long-term impact (50 years) of extensive channel stabilization in an area with few other human impacts?
White Mountains National Forest, NH

- Drainage area: 35.7 km²
- Average slope: 0.022

Study reach: 4.5 km
2014 Longitudinal Profile Resurvey
2014 Cross-sectional Surveys

Pebble Counts
The general damage and recommendations for repair or improvement are as follows:

**Walls #22** - 1 meter high wall on 2 x 1 x .5 apron. Water was 2' high at end of wall. Boulders left in the stream channel as "natural sills" were barriers to stream flow. The last 50' of the wall dropped. Height of wall should be increased to 2 meters high on 2 x 1 x .5 apron.

**#23** - Water peaked over top of 2 meter high wall on 2 x 1 x .5 apron; water action on back and front side of wall scoured base, and 30' of wall sagged. Increase channel capacity and add 30' of 1/2 meter gabions to top of sagged portion. At end of Wall #23, an approximate 8 ton boulder, used as a key at end of wall was washed out. This will require placement of 20' of additional wall, tied to Sill #23a.

**#24** - 2 meter high wall set on foundation of large boulders. Water was 2' over top of this wall, and caused wash to slope and streambed. The wall sagged and will require additional height of 1 meter. Construction above this wall should be removed. (This "point" of land was left for aesthetics in 1962.)

**#25** - 1 meter high wall on 2 x 1 x .5 apron. Water peaked over top of wall; uprooted trees blocked the channel and caused subsequent damage to Wall #27. Increase height of wall extend around point and place sill to reduce velocity.

**#27** - 1 meter high wall on 3 x 1 x .5 apron. Due to uprooted trees, under - design, and flowage from old channel, this was the trouble spot on the river. Water peaked over wall, undermining back side. 60' of wall dropped into created "hole". This will have to be rebuilt and increased to 3 meter height; should be extended around curve in the river with allowance for flowage from old channel.

**Fish Improvements** - Two "T" design hangers, using 2 x 1 x 1 meter gabions placed in center of stream to create fishing holes, were lost. Streams of this velocity should not be listed for any fish improvements of this type.

**Sills #23a** - East bank washed; needs 15 - 16' additional length, anchored securely into bank.

**#25a** - Same as above.

**#25c** - Add to height of wingwall; water washed over and behind present wingwall.

**Relocation** - 60' of Seattle gabions that were added in June 1963 to increase height of existing sill moved 15 - 20' downstream. The base of the sill (Macassare gabions) is still functional.

**Damages Summary**

Sills - From wall 11 downstream 14 sills were breached and of those remaining, most are worn to some degree. Some sills were breached before the June 30 storm and it is likely that annual floods would have eventually worn out these sills. The unstable cobble size rubble in the stream groats on the baskets during each storm. One 30-year flood will breach most sills. For example, the State Highway Dept. installed sills in the Ammonoosuc River during 1971 and these were breached during the June 30 flood.

**Walls**

The total length of wall damaged is 963 feet. Past surveys indicate that some sections had been damaged before, but the June 30 flood did most of the present damage.

The most successful walls were those where the river had plenty of room or which banded into the river's present hydrologic configuration. Where walls were installed to channel flow away from a developing meander they were frequently undercut or overtopped. Many sections settled, but gabions are designed to do this without breaking up.

Walls 11 and 21 are the most heavily damaged. These walls were exposed to the full force of the river and its bedload of cobbles during storms. Gabion baskets do not have enough strength for this type of location. Deflectors could be used as a means of keeping the force of the river away from the wall, but these baskets would have to be rebuilt every ten years. A better choice may have been to place the baskets on a sloping wall and to have faced the wall with more resistance material such as concrete or metal panels.

The flood water also went over wall 25 similar to wall 11 and 21, but the baskets are intact. The angle of impact was less here and perhaps this is why 25 did not break up.

**Recommended Actions**

The minimum repairs should be made as listed below. This is a pilot project and should be left to stand the test of time. There is no justification for restoring the project to its original condition. Gabions are designed to settle, therefore, appearance is not a criteria for repair. Furthermore, resource or facility values are not a significant factor. There are many natural areas of streambed erosion on the forest which are not considered serious from a resource point. Eroding banks on the Earland River do no more damage than eroding banks on the Swift River. Finally, no facilities are being threatened by the river.
EVALUATING A BANK STABILIZATION PROJECT 25 YEARS AFTER COMPLETION

Randy S. Ferrin and Janice W. Staats

ABSTRACT: Zealand River, a feedhead tributary to the Connecticut River, drains a steep basin in the White Mountain National Forest of northern New Hampshire. A severe flood in October, 1959 caused considerable bank damage, aggradation, and channel change. Following a stream condition survey in 1960, gabions and riprap were prescribed for restoration of the stream channel. Besides repairing back damage, the objectives of the project were (1) to study techniques of gabion and riprap placement, and (2) to evaluate the effectiveness and durability of these techniques. Installation of riprap walls, gabion walls, and gabion sills in 2.5 miles of river was made from 1961 to 1963. In 1974 an assessment of the gabions was made because of the damages caused by the June, 1973 flood. In 1980, the gabions, riprap, and streambanks were inspected and mapped to ascertain their condition. The gabions walls failed at high energy points in the river or where the channel was too constricted. Gabion sills were obliterated by the river's massive bedload movement. Even 25 years after placement, the remaining gabion walls still do not fit the character of the surrounding landscape, while the riprap is natural appearing. Effectiveness and durability of the gabions and riprap are evaluated. Recommendations for future management of the structures are made.

INTRODUCTION

The Zealand River drains a 8810 acre watershed in the White Mountains of northern New Hampshire. Entirely within the White Mountain National Forest, the river joins the Ammonoosuc River, a Connecticut River tributary, near Twin Mountain, NH. Besides being a major tributary, the NZR is also a learning experience because it is a mix of resource opportunities including timber management, hiking trails, wildlife, camping, recreation, boating, and a backcountry area. The Zealand Valley receives over 9,0000 recreation visitor days per year. The White Mountain National Forest is a popular and heavily visited area. Approximately 60 million people live within a day's drive of the forest. Total yearly visits approach six million people. Scenery and the mix of recreational opportunities provide the attraction.

The stream receives an average annual precipitation of 45 inches, well-distributed throughout the year. The mean annual flow for the Zealand River is calculated to be 2.27 cubic feet per second (using the method described in Dinkman, 1978). The 2, 10, and 100 year recurrence interval flood flows are predicted at 3590, 1930, and 1250 cfs, respectively (using the method described in LeBlanc, 1983). A summary of other historical events, including floods, is given in Table 1. Table 2 summarizes the effectiveness of the walls where the gabion structures were obliterated or the 30 gabion walls, only 2 were still effective. Jahren had reduced effectiveness for, example, flow was going over, or around, the structures. In two locations, topped gabion wall sections were obstructing flow, and were threatening to pull more sections of wall into the river. The gabion structures continue to dominate the view in many segments of the project area, even though trees and shrubs have vegetated approximately 1100 linear feet of the top surface of the gabion walls, and the rocks and wire of the gabion baskets have taken on a weathered appearance.

CONCLUSIONS

As Stuart (1974) observed, gabion walls which were installed to redirect flow away from a developing meander were frequently undercut or overtopped. The most successful walls were those in relatively straight stretches where the channel capacity was not constrained. A river with such a large bedload is difficult to tam with gabion structures. In the early years of this project, damage to structures was usually inflicted on those structures exposed to the full force of the river at bends. Now, even in some straight channel sections, damage is occurring due to constantly shifting rubble bars which direct the flow into the walls. Settling or trapping of structures was nearly always initiated with some type of damage to the apron. Settling did not significantly reduce the effectiveness of the structure but totally nearly always reduced their effectiveness. Sills were effective for only a short time on a stream system with such a large amount of bedload movement. It would be difficult to justify their use again in a similar situation. Gravels are massive and abrasive and likewise would be difficult to justify again on a scenic mountainous stream. Riprap proved to be effective in protecting banks from further damage while maintaining a natural appearance. However, banks upstream that were not treated with riprap had healed naturally over the life of the project.

As stated in the introduction, the overall objective of the project was to contain and flow, trap bedload, and minimize further bank damage. The project was successful in protecting streambanks and reducing the number of high water channels but failed in...
1999 Revetment Design

Zealand River Streambank Stabilization  CROSS-SECTION VIEW  Site #2

Present Condition

FR 16
(0' w.m.)

5' Tall
2
Bank

Cobble Bar

Foiled Gabion

50 feet

1 inch = 10 feet

Work Sequence:
- Dismantle gabions and remove wire.
- Put rock revetment on bank near road.
- Put rock/roothed revetment along streambank.

Finished Condition

Cobble Bar

3' boulder

roothed

Cobble backfill (4'-min)

Potor log 16' dia.

3' boulder

15 feet

50 feet

Prepared by:
Steve Jones
Fec Tech 0  6/30/94

1 inch = 10 feet
### 2014 Gabion Assessment

**Doug Thompson  Connecticut College  860-439-5016  Zealand River, NH**

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**Diagram:**

- Failed
- Damaged
- Intact
Failed

<50% Full

>50% Broken Wires
Failed
Tilting >30°
Failed

>150% Elongation
Failed
Tilting >30°
>150% Bulging
Failed

<50% Full
Tilting >30°

Damaged

Tilting 10°- 30°
50-90% Full
5-50% Broken Wires
110-150% Elongation,
110-150% Bulging
57.6% of the full length of remaining walls were intact
# Gabion Wall Classification

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Upper Reach

d$_{16} = 26$ mm

d$_{50} = 142$ mm

d$_{84} = 455$ mm
Upper Reach

wire from failed sills?
Middle Reach

d_{16} = 24-45 mm

d_{50} = 71-104 mm

d_{84} = 194-223 mm
Middle Reach

damaged sills
Historic Photograph Replication
Middle Reach
Middle Reach

exposed aprons
Middle Reach
Middle Reach

2.5 m degradation?
Middle Reach
Gabion Wall 13a

damaged wall
damaged wall
Channel Narrowing = Increased Stream Power
Middle Reach

scour hole
Historic Photograph Replication
Middle Reach
Gabion Wall 13a
Lower Reach

\[ d_{16} = 4-46 \text{ mm} \]
\[ d_{50} = 37-97 \text{ mm} \]
\[ d_{84} = 91-194 \text{ mm} \]
Lower Reach

Overflow channel

Avulsion & Widening
Lower Reach
Gabion Wall 23

avulsion
designed path
Lower Reach

overflow channel

avulsion & widening

widenning?

avulsion & widening
widening & aggradation
aggradation
Continuing Concerns
Increased Stream Power
tree growth on wall

tree growth on apron
Lower Reach
Gabion Wall 25

attached fallen trees
Conclusions

• All gabion sills failed, increasing chance of degradation

• Gabion walls narrowed flow and increased localized sediment transport capacity

• Bed scour undermined walls, toppling walls into channel and increasing channel narrowing and shear stress

• Increased sediment supply created local avulsions and channel widening, especially in the lower reach

• Channel has little chance for stabilizing in the near future
Acknowledgements

Funding was supplied by Connecticut College. The U.S. Forest Service graciously allowed access to all the data on this historic project. Kimberly Hoffman, Sushil Bhattarai and Sailesh Tiwari helped with preliminary fieldwork at the site.