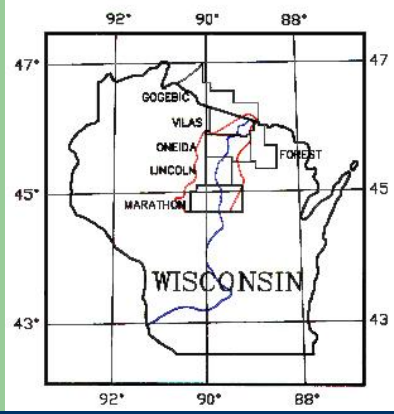
WVIC Erosion Control Methods

Summary of projects installed by WVIC

1992 - 2008



- Operate 21 storage reservoirs
  - -16 natural lake (27% storage)
  - -5 man-made (73% storage)
    - **Rainbow**
    - **Willow**
    - **Rice (Lake Nokomis)**
    - **Spirit**
    - **Eau Pleine**
- Dynamic Man-made reservoirs
  - -Less than 100 years old
  - -Fluctuate 13-27’
- Licensed by FERC (Project 2113)
  - -Issued 30 yr license in 1996
  - -Erosion control plan included
    - -Protect cultural sites
    - -Protect recreation sites
    - -Protect threatened & endangered species habitat

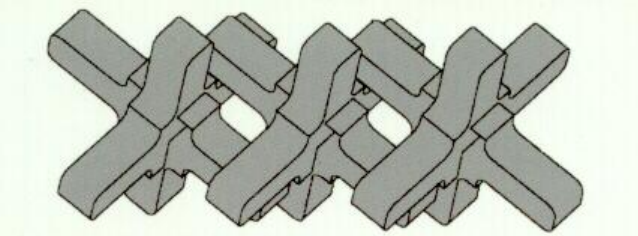
WISCONSIN RIVER RESERVOIR SYSTEM
(Darkened Water Bodies)

WVIC
WISCONSIN VALLEY IMPROVEMENT COMPANY
2301 NORTH THIRD STREET
WAUSAU, WISCONSIN 54403

Variety of Techniques Used

- A-Jacks®
- Breakwaters
- Concrete Blocks
- Deltalok®
- Fiber Rolls
- Riprap
- Rock Toe

A-Jacks®



- Engineered concrete armor units
- On a weight basis, A-Jacks are 100x more structurally stable than rock
- WVIC has installed 2 different configurations
  - 3 row design used at high energy sites &/or steep beach slope
  - Single interlocking row suitable for some sites

A combination of both configurations can be used

PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Robinson Arch Site - Triple Row	1999	100	1.2	$24.79
Rainbow Hwy J Bay - Single Row	2000	402	1.4	$14.54
Upper Rainbow - Combination	2002	279	1.7	$17.56

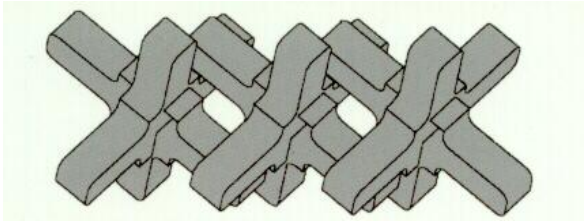
Triple Row Construction

Single Row Construction

PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Robinson Arch Site - Triple Row	1999	100	1.2	$24.79
Rainbow Hwy J Bay - Single Row	2000	402	1.4	$14.54
Upper Rainbow - Combination	2002	279	1.7	$17.56

Used in single and triple row configurations in combination with other methods & materials

A-Jacks®



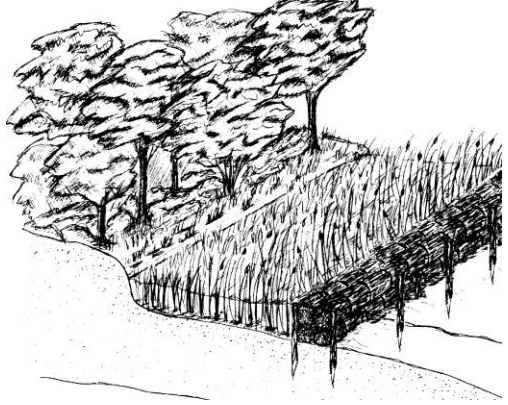
ADVANTAGES

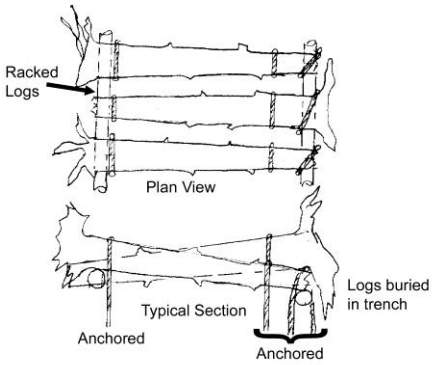
- **Can be installed without heavy equipment**
- **Can be installed without bank disturbance**
- **Can be transported to remote sites**
- **Can be installed in different configurations**
- **More structurally stable than rock**

DISADVANTAGES

- **Visually obtrusive if not vegetated**
- **Susceptible to vandalism**
- **Vulnerable to ice damage**

Breakwaters





- Placed offshore to diminish wave energy
- Can be permanent structures or temporarily placed until plants establish
- WVIC has installed several types
  - Biodegradable fiber rolls most commonly used
  - Permanent rock roll and piling
  - Branchbox
  - Anchored Log Wave Deflectors

PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Rainbow Demo - Rock Roll & Piling	1993	50	3.0	$28.25
Robinson Arch Site - Branchbox Breakwater	1999	50	2.5	$6.53
Robinson Arch Site - Log Wave Deflectors	1999	150	0.6	$4.73
Upper Rainbow - Fiber Roll	2002	320	0.6	$23.03
Rice Large Island - Fiber Roll	2004	100	0.8	$25.15

Rock Roll & Piling

Branchbox Breakwater

PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Rainbow Demo - Rock Roll & Piling	1993	50	3.0	$28.25
Robinson Arch Site - Branchbox Breakwater	1999	50	2.5	$6.53
Robinson Arch Site - Log Wave Deflectors	1999	150	0.6	$4.73
Upper Rainbow - Fiber Roll	2002	320	0.6	$23.03
Rice Large Island - Fiber Roll	2004	100	0.8	$25.15

Log Wave Deflectors

Fiber Roll Breakwaters

Breakwaters

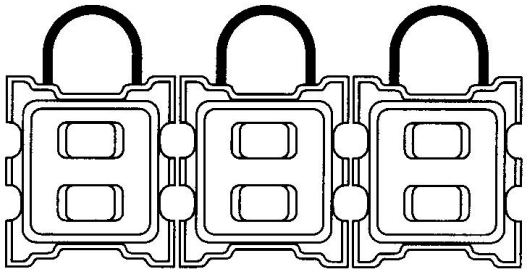
ADVANTAGES

- **Can be installed without heavy equipment**
- **Can be installed without any bank or shoreline habitat disturbance**
- **Creates protected areas for establishing emergent aquatic vegetation**
- **Can be transported to remote sites**

DISADVANTAGES

- **Placement away from the bank could present a boating hazard**
- **Can be visually obtrusive**

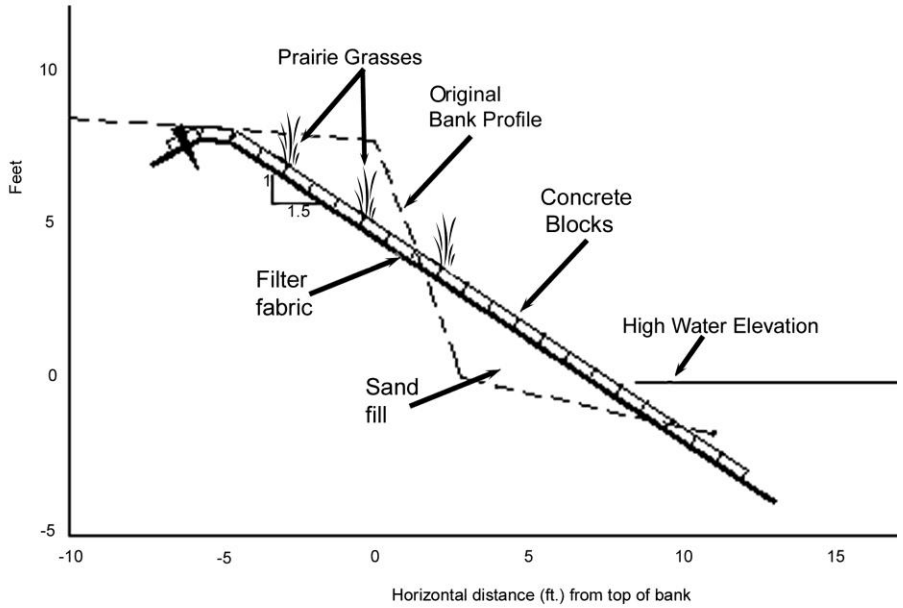
Concrete Blocks



- Many types have been patented and manufactured for erosion control
- Designed to form an interlocking, articulating revetment
- WVIC has installed three different types
  - **Armorflex®** Class 30S – 20% open, 1’x1’, 31-36lb, cabled together
  - **Terrafix®** T45 Quarry-Face, 2’x6”, 51 lb, wired together
  - **Protec®** Precast Hexagonal – 28% open, 1 ft^2 coverage, interlocking mechanism

PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Rainbow Demo - Armorflex® Revetment	1993	50	3.1	$98.33
Rainbow Demo - Terrafix® Revetment	1993	50	3.2	$78.35
Rainbow Demo - Protec® Toe	1993	50	1.4	$39.38
Rainbow Demo - Vegetated Terrafix® Toe	1998	50	3	$37.95
Rainbow Hwy J Landing - Vegetated Terrafix®	1998 2005	175 40	3.1 2.6	$44.19 $39.92

Armorflex® Revetment



Terrafix® Revetment

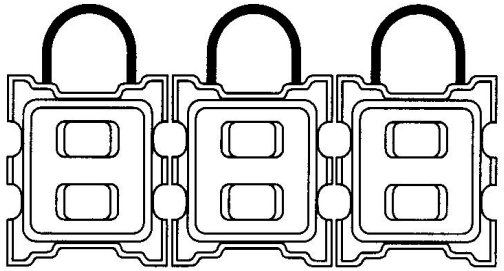
PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Rainbow Demo - Armorflex® Revetment	1993	50	3.1	$98.33
Rainbow Demo - Terrafix® Revetment	1993	50	3.2	$78.35
Rainbow Demo - Protec® Toe	1993	50	1.4	$39.38
Rainbow Demo - Vegetated Terrafix® Toe	1998	50	3	$37.95
Rainbow Hwy J Landing – Vegetated Terrafix®	1998 2005	175 40	3.1 2.6	$44.19 $39.92

Protec® Toe

Vegetated Terrafix® Toe

Vegetated Terrafix®

Concrete Blocks



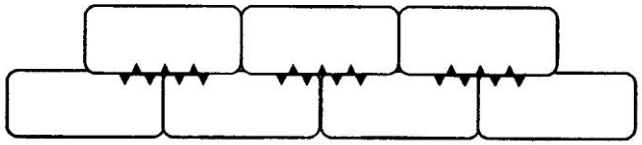
ADVANTAGES

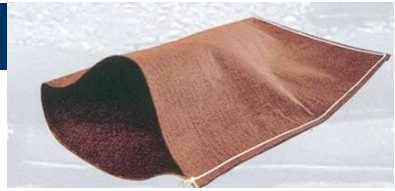
- **Provisions for vegetation**
- **Can be designed to restrict or allow human access**
- **Installations can be done by hand without the use of heavy equipment**
- **Allow ingress and egress of wildlife & waterfowl**

DISADVANTAGES

- **Fill typically needs to be added to the bank making installation at remote sites difficult**
- **Portions of the concrete block toe below the maximum water elevation are difficult to vegetate**
- **Visually obtrusive in a natural setting**

Deltalok®





- Engineered system of interlocking soil bags
- Held together with strategically placed units of high strength polypropylene

- Designed to “bridge the gap” between hard and soft armoring techniques
- WVIC has installed Deltalok® as the main bank protection as well as for maintenance and repair on several projects

PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Rainbow Hwy J Landing - Trial	2003	40	2.2	$17.04
Rice Large Island - Fill-in	2004	38	2.0	$26.31
Rainbow Hwy J Landing Repair - 3-5 layers	2005	112	1.0	$20.66
Willow Campsite #6 - 3-5 layers	2008	71	2.4	$34.04

Trial with reinforcements

Fill-in between other methods

PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Rainbow Hwy J Landing - Trial	2003	40	2.2	$17.04
Rice Large Island - Fill-in	2004	38	2.0	$26.31
Rainbow Hwy J Landing Repair - 3-5 layers	2005	112	1.0	$20.66
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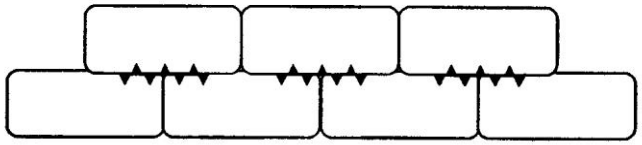
3-5 bags high with brush layering

Deltalok®



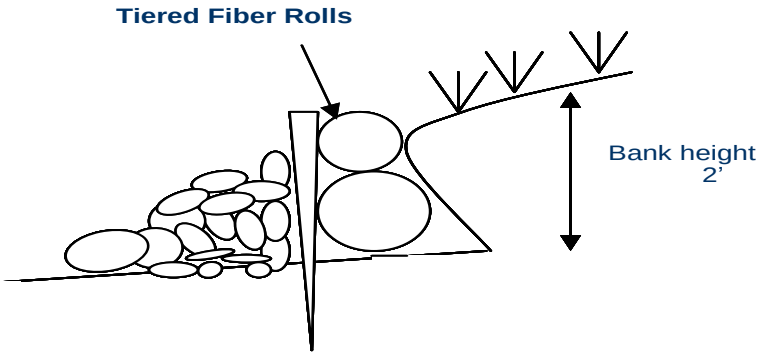
ADVANTAGES:

- **Can be installed without heavy equipment**
- **Can be installed without any bank disturbance**
- **Can be transported to remote sites more efficiently than rock**
- **Easily vegetated as a brush layer system**
- **Flexible and can be installed in different configurations depending on site**

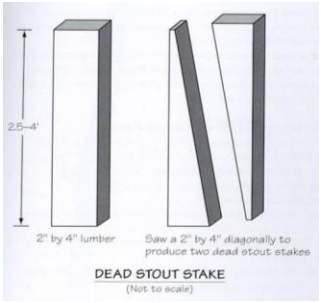
DISADVANTAGES:

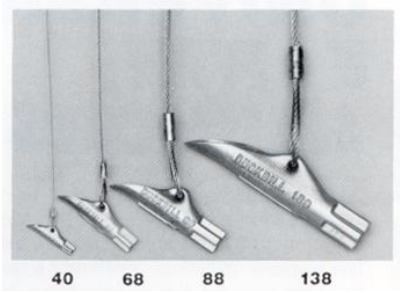
- **Labor intensive**
- **Can be damaged by ice, floating debris, animals, and human activity**

Fiber Roll Toe with Rock Armoring



- Cylindrical tubes composed of coconut husk or excelsior bound together with jute or synthetic netting
- Manufactured in different lengths, densities and diameters
- WVIC has installed several configurations of 12”, 16”, and 20” diameter rolls 1 to 3 tiers high
- Have used rock to armor rolls at higher energy sites
- 2 anchoring systems have been used
  - Wood stakes
  - Duck-bill anchors





PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Robinson Arch Site (12&16” 1-3 tiered)	1999	150	0.7	$10.15
Rainbow Hwy J Bay (12&16” 1-2 tiered)	1998-2000	1483	1.1	$12.50
Willow Dam Rec Area (1-2 tiered w/rock)	2000	120	1.5	$23.38
Rice Lg Isle (16&20” 1-2 tiered, some w/rock)	2004	128	0.6	$27.47
Willow Campsite #G2 (20” 3 terraced layers)	2008	90	1.1	$39.70

1-3 tiered with wood stakes

1-2 tiered with wood stakes & rock

PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Robinson Arch Site (12&16” 1-3 tiered)	1999	150	0.7	$10.15
Rainbow Hwy J Bay (12&16” 1-2 tiered)	1998-2000	1483	1.1	$12.50
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Willow Campsite #G2 (20” 3 terraced layers)	2008	90	1.1	$39.70

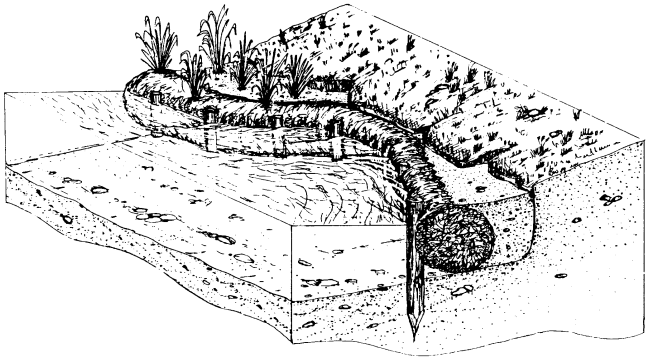
1-2 tiered 16”-20” rolls

Duckbill® anchoring system

20” rolls, 3 terraced layers

Duckbill® anchoring system

Fiber Roll Toe



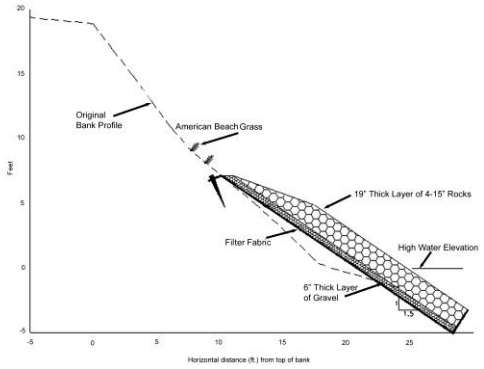
ADVANTAGES:

- **Can be installed without heavy equipment**
- **Can be installed without any bank disturbance**
- **Very flexible technique that can be installed in many different configurations**
- **Visually aesthetic and within 1-2 years blends into the existing bank and vegetation**

DISADVANTAGES:

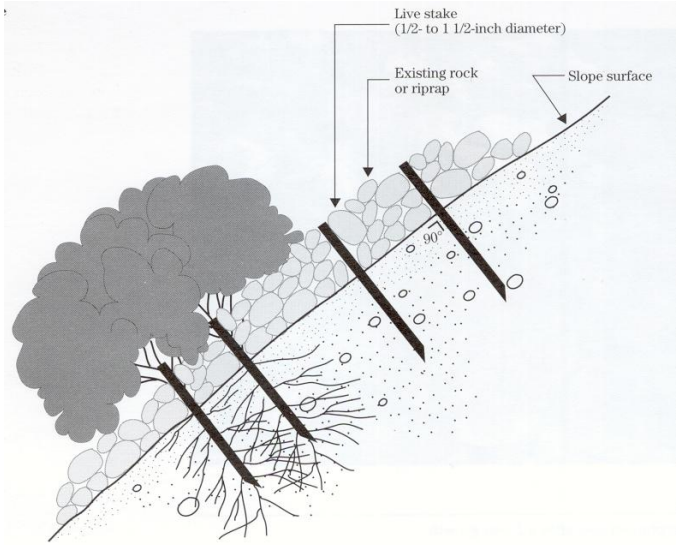
- **If not successfully vegetated shortly after installation, failure will likely occur**
- **Annual monitoring and some maintenance is typically required**
- **Susceptible to damage by animals and humans**
- **Not suited for steep bottom slopes**

Riprap

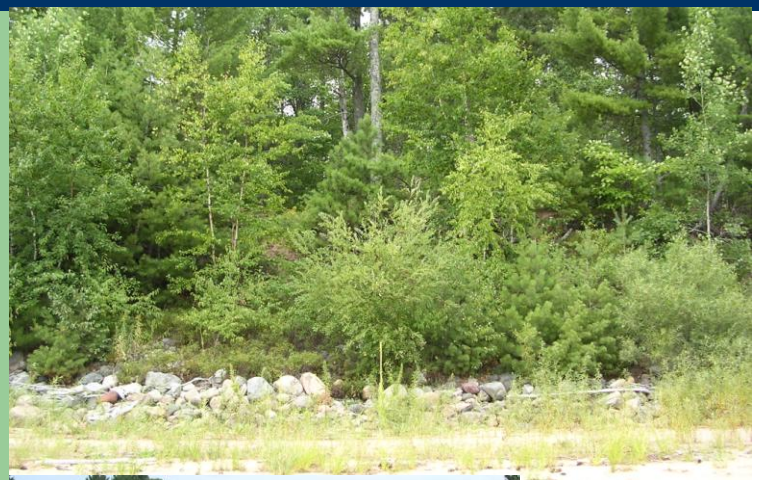


- Constructed of appropriately sized stone, placed on a natural slope or on an artificially graded shore

- WVIC includes incorporating plant materials into the rock resulting in “vegetated riprap”



PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Rainbow Demo - Riprap Revetment	1993	100	1.3	$49.21
Willow Dam Rec Area - Vegetated Riprap	2000	100	0.6	$10.00
Rainbow Hwy J Landing Repair – Vegetated Riprap	2005	55	1.1	$3.64



Riprap Revetment

Vegetated Riprap

Riprap

Advantages:

- **Provides long term stability**
- **Designed to self-adjust to eroding foundations**
- **Inert, does not depend on climatic conditions**
- **Effectively absorbs wave energy and reduces wave runup**

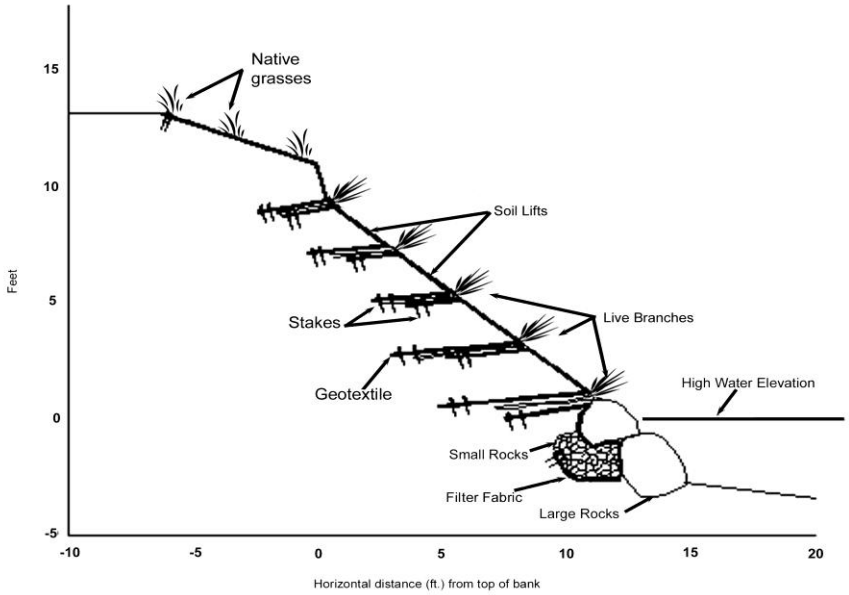
Disadvantages:

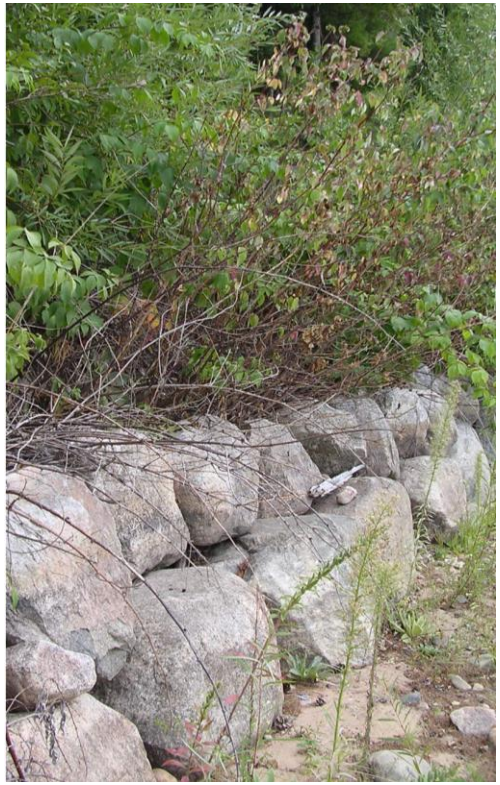
- **Cost of stone can be considerable if not locally available**
- **Large projects require heavy equipment with site access**
- **Limits beach access**

Rock Toe

- Also referred to as rock breast wall, riprap variation, or “Dutch Toe”
- Constructed of large rocks keyed into a firm foundation (reservoir bottom)
- Large rocks serve as gravity structures that resist lateral forces mainly by their weight
- The bank above can be restored in several different manners

PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Rainbow Demo - Riprap Variation	1993	100	1.0	$29.44
Rainbow Demo - Vegetated Geogrid w/Rock Toe	1998	50	5.3	$49.07
Robinson Arch Site – Fix Away from Critical Area	1999	350	2.8	$37.63
Robinson Arch Site – Critical Area Fix	1999	100	11.9	$149.76
Willow Campsite #G3 - Vegetated Fill w/Rock Toe	2006	95	1.3	$35.75
Willow Campsite #G3 - Vegetated Geogrid w/Rock Toe	2006	110	2.7	$54.13





Riprap Variation
Vegetated Geogrid with Rock Toe

PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Rainbow Demo - Riprap Variation	1993	100	1.0	$29.44
Rainbow Demo - Vegetated Geogrid w/Rock Toe	1998	50	5.3	$49.07
Robinson Arch Site – Fix Away from Critical Area	1999	350	2.8	$37.63
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Willow Campsite #G3 - Vegetated Fill w/Rock Toe	2006	95	1.3	$35.75
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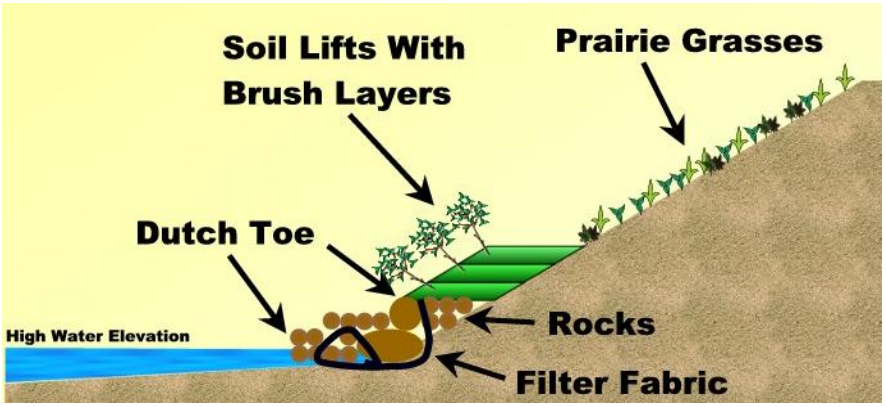
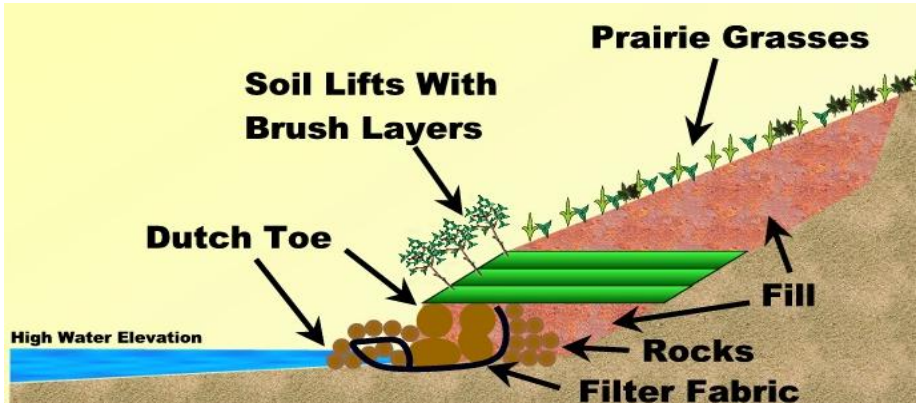


Fix Away from Critical Area



Critical Area Fix

PROJECT	YEAR	# LINEAR FT	HOURS/FT	MATERIALS COST/FT
Rainbow Demo - Riprap Variation	1993	100	1.0	$29.44
Rainbow Demo - Vegetated Geogrid w/Rock Toe	1998	50	5.3	$49.07
Robinson Arch Site – Fix Away from Critical Area	1999	350	2.8	$37.63
Robinson Arch Site – Critical Area Fix	1999	100	11.9	$149.76
Willow Campsite #G3 - Vegetated Fill w/Rock Toe	2006	95	1.3	$35.75
Willow Campsite #G3 - Vegetated Geogrid w/Rock Toe	2006	110	2.7	$54.13

Vegetated Fill with Rock Toe

Vegetated Geogrid with Rock Toe

Rock Toe

ADVANTAGES:

- **Can be installed from the bottom of the bank without any bank face disturbance**
- **Appears to be one of the most stable methods**
- **Top bank treatment can vary depending on site characteristics**

DISADVANTAGES:

- **Heavy equipment is necessary for installation**
- **Could be difficult for wildlife to traverse because of their vertical slope at the base of the toe**

Variety of Techniques Used

- A-Jacks®
- Breakwaters
- Concrete Blocks
- Deltalok®
- Fiber Rolls
- Riprap
- Rock Toe