

A Practical Field Guide for Designing Conservation Buffers



Gary Bentrup
Res. Landscape Planner
U.S. Forest Service

September 19, 2012



Presentation Overview

- Setting the stage
- Evidence-based guidelines
 - Why was the tool developed?
- How to use the Guide
 - Structure of the guide
 - Using the references
 - Designing for multiple functions



Objectives and Outcomes

- Provide an awareness of evidence-based guidelines for buffers
- Develop a basic comfort level in using these guidelines as a design aid
- Build interest in designing for multiple functions where appropriate

Setting the stage

What is a buffer?

Areas or strips of land maintained in permanent vegetation to provide ecological, economic and/or social benefits.



Chat question

What are other similar terms do we use in addition to the word “buffer”?

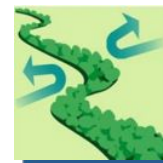
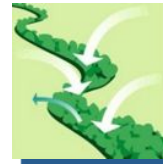


Terminology

- Buffers
- Corridors
- Greenways
- Filter strips
- Grassed waterways
- Windbreaks
- Hedgerows
- Shelterbelts
- Field margins
- Living fences
- Set-aside strips
- SMZ

Buffer Functions

- Habitat
- Source
- Sink
- Filter
- Conduit
- Barrier



Polling and Chat question

1. How many of you have planned, designed and/or implemented a buffer type of project?
2. What type of functions did you design for?



Function = Structure + Location

- Landscape Setting
- Site Location
- Configuration
- Horizontal Structure
- Vertical Structure
- Plant Community



Sources of Information

- Personal experience
- Colleagues, experts, land owners
- Grey literature
- Scientific literature

Chat question

Where did you go for information on designing and managing buffers?



Evidence-based Information



Challenges with Evidence-based Information



- Accessible
- Understandable
- Relevancy
- Not synthesized

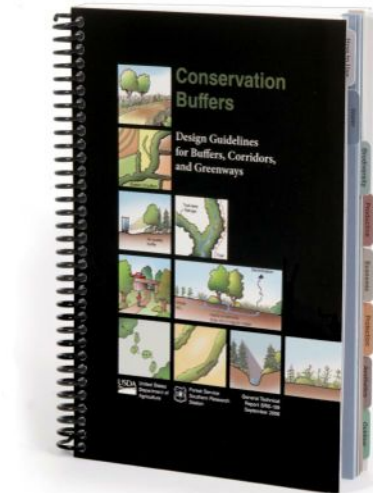
Conservation Buffer Guide

Synthesized and distilled research results from over 1,400 publications

Over 80 evidence-based design guidelines

Nationwide

Audience

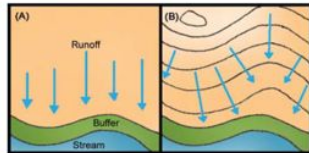


Resource Issues Covered

- ✓ Improve air & water quality
- ✓ Protect soil
- ✓ Enhance habitat
- ✓ Enhance economic productivity
- ✓ Provide recreation opportunities
- ✓ Beautify the landscape



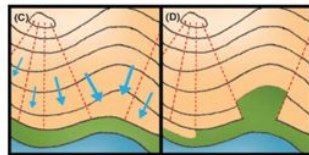
Water Quality



1.7 Variable buffer width

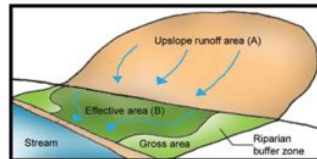
Buffers may have a fixed width where uniform runoff occurs (A). However, runoff is often nonuniform and flow is either diverging or converging due to topography, tillage practices, and other factors (B). A fixed-width buffer will be less effective in these situations.

Instead, buffer width should be variable by widening and narrowing the buffer as runoff loads and buffer site conditions vary.



Runoff areas and corresponding buffer locations to which they flow can be mapped (C). Buffer width can then be modified to account for differences in runoff loads (D). Buffers will need to be wider for upslope runoff areas that are larger and contribute greater loads.

The ratio of the upslope runoff area to buffer area can provide additional design guidance (see section 1.8).



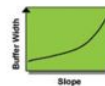
1.8 Effective buffer area ratio

The amount of runoff through an area of buffer should be low to achieve high pollutant removal. One consideration is to base the design on a ratio of upslope runoff area (A) to effective buffer area (B). Lower ratios (e.g., 20:1) can provide substantially greater pollutant removal than higher ratios (e.g., 50:1) in many cases. Note that the effective buffer area is the actual pathway that runoff travels to the stream and it may be smaller than the overall gross area of the buffer.

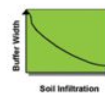
1.9 Slope and soil type adjustments

Land slope and soil type have significant impact on the ability of a buffer to remove pollutants from surface runoff.

Steeper slopes reduce performance by allowing greater pollutant transport and less time for infiltration. Steeper slopes will require wider buffers.

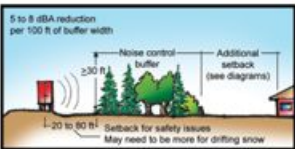


Soils with higher infiltration capacity can reduce runoff to a greater degree than soils having lower infiltration. Soils with lower infiltration capacity will require wider buffers. Finer-textured soils typically have lower infiltration than sandy soils.



Water Quality

Aesthetics and Visual



5 to 8 dBA reduction per 100 ft of buffer width

Noise control buffer

Additional setback (see diagrams)

20 to 80 ft Setback for safety reasons
May need to be more for drifting snow

6.4 Buffers for noise control

Buffers can reduce noise from roads and other sources to levels that allow normal outdoor activities to occur. A 100-foot wide planted buffer will reduce noise by 5 to 8 decibels (dBA). Using a barrier in the buffer such as a landform can significantly increase buffer effectiveness (10 to 15 dBA reduction per 100-foot wide buffer with 12-foot high landform).

Guidelines are provided below for roads. Use the diagrams on the adjacent page to estimate a setback distance from a typical 100-foot wide buffer to achieve an acceptable noise level.

Buffer Guidelines for Noise Reduction Along Roads

Moderate Speed Road (<40 mph) Plant a 20 to 50 foot wide buffer with the near edge of the buffer within 20 to 50 feet of the center of the nearest traffic lane	High Speed Road (>40 mph) Plant a 55 to 100-foot wide buffer with the near edge of the buffer within 50 to 80 feet of the center of the nearest traffic lane
--	---

Key design considerations

- Locate buffer close to the noise source while providing an appropriate setback for accidents and drifting snow.
- Evergreen species will offer year-round noise control.
- Create a dense buffer with trees and shrubs to prevent gaps.
- Select plants tolerant of air pollution and de-icing methods.
- Natural buffers will be less effective than planted buffers.
- Consider topography and use existing landforms as noise barriers where possible.

Aesthetics and Visual

Estimating setback distance from noise control buffers

Example: An outdoor recreational site near a highway needs to be located to meet the desired noise levels of 60 to 65 dBA. If a 100-foot wide tree/shrub buffer is used, the site needs to be 100 to 200 feet behind the buffer. The site can be located immediately behind the buffer if a 12-foot high landform is incorporated into the buffer.

Sound Level Decrease with Distance Due to Tree/Shrub Buffer

Sound Level Decrease with Distance Due to Tree/Shrub and Landform Buffer

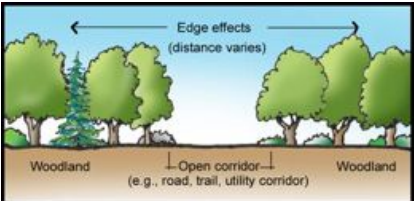
— Control - (No tree/shrub buffer - truck noise at 55 mph)
— Truck noise with 100-ft wide tree/shrub buffer
— Car noise with 100-ft wide tree/shrub buffer

— Control - (No tree/shrub buffer - truck noise at 55 mph)
— Truck noise with 100-ft wide tree/shrub buffer & 4-ft high landform
— Truck noise with 100-ft wide tree/shrub buffer & 12-ft high landform

■ 60 to 65 dBA acceptable noise levels for outdoor conversation
■ 55 to 60 dBA acceptable noise levels for daytime residential areas

Edge Effects

Aesthetics and Visual

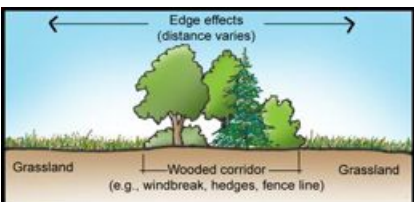


Edge effects (distance varies)

Woodland

Open corridor (e.g., road, trail, utility corridor)

Woodland



Edge effects (distance varies)

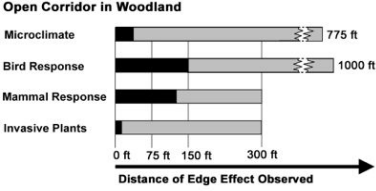
Grassland

Wooded corridor (e.g., windbreak, hedges, fence line)

Grassland

Aesthetics and Visual

Open Corridor in Woodland

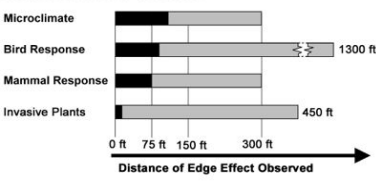


Microclimate	775 ft
Bird Response	1000 ft
Mammal Response	
Invasive Plants	

0 ft 75 ft 150 ft 300 ft

Distance of Edge Effect Observed

Wooded Corridor in Grassland



Microclimate	
Bird Response	1300 ft
Mammal Response	
Invasive Plants	450 ft

0 ft 75 ft 150 ft 300 ft

Distance of Edge Effect Observed

Minimum distance edge effect observed ■
Maximum distance edge effect observed ■



Guide Structure

Table of Contents	
Acknowledgments	ii
USING THE GUIDE	
Purpose of this Guide	1
The Guide Online	2
Limitations of this Guide	2
Landscape Design Concepts	3
Planning Conservation Buffers	5
How to Use this Guide	11
DESIGN GUIDELINES	
1. Water Quality	15
2. Biodiversity	43
3. Productive Soils	61
4. Economic Opportunities	67
5. Protection and Safety	77
6. Aesthetics and Visual Quality	89
7. Outdoor Recreation	99
Glossary	107

www.tufferguidelines.net
 Click Here

- Online version with over 1400 references
- Online slideshow with guidelines
- Additional buffer design resources

Function Table

Issue and Objectives	Buffer Functions
Water Quality	
Reduce erosion and runoff of sediment, nutrients, and other potential pollutants	Slow water runoff and enhance infiltration Trap pollutants in surface runoff
Remove pollutants from water runoff and wind	Trap pollutants in subsurface flow Stabilize soil Reduce bank erosion
Biodiversity	
Enhance terrestrial habitat	Increase habitat area Protect sensitive habitats
Enhance aquatic habitat	Restore connectivity Increase access to resources Shade stream to maintain temperature
Productive Soils	
Reduce soil erosion	Reduce water runoff energy Reduce wind energy
Increase soil productivity	Stabilize soil Improve soil quality Remove soil pollutants
Economic Opportunities	
Provide income sources	Produce marketable products
Increase economic diversity	Reduce energy consumption Increase property values
Increase economic value	Provide alternative energy sources Provide ecosystem services
Protection and Safety	
Protect from wind or snow	Reduce wind energy
Increase biological control of pests	Modify microclimate
Protect from flood waters	Enhance habitat for predators of pests
Create a safe environment	Reduce flood water levels and erosion Reduce hazards
Aesthetics and Visual Quality	
Enhance visual quality	Enhance visual interest
Control noise levels	Screen undesirable views Screen undesirable noise
Control air pollutants and odor	Filter air pollutants and odors Separate human activities
Outdoor Recreation	
Promote nature-based recreation	Increase natural area Protect natural areas
Use buffers as recreational trails	Protect soil and plant resources Provide a corridor for movement Enhance recreational experience

35 Functions

Function Table

Issue and Objectives	Buffer Functions	Protection and Safety
Water Quality		Protect from wind or snow Increase biological control of pests Protect from flood waters Create a safe environment Reduce wind energy Modify microclimate Enhance habitat for predators of pests Reduce flood water levels and erosion Reduce hazards
Reduce erosion and runoff of sediment, nutrients, and other potential pollutants	Slow water runoff and enhance infiltration	
Remove pollutants from water runoff and wind	Trap pollutants in subsurface flow	
	Stabilize soil Reduce bank erosion	
Biodiversity		Aesthetics and Visual Quality Enhance visual quality Control noise levels Control air pollutants and odor Enhance visual interest Screen undesirable views Screen undesirable noise Filter air pollutants and odors Separate human activities
Enhance terrestrial habitat	Increase habitat area	
Enhance aquatic habitat	Protect sensitive habitats Restore connectivity Increase access to resources Shade stream to maintain temperature	
Productive Soils		Outdoor Recreation Promote nature-based recreation Use buffers as recreational trails Increase natural area Protect natural areas Protect soil and plant resources Provide a corridor for movement Enhance recreational experience
Reduce soil erosion	Reduce water runoff energy	
Increase soil productivity	Reduce wind energy	
	Stabilize soil Improve soil quality Remove soil pollutants	
Economic Opportunities		
Provide income sources	Produce marketable products	
Increase economic diversity	Reduce energy consumption	
Increase economic value	Increase property values	
	Provide alternative energy sources	
	Provide ecosystem services	
Protection and Safety		

35 Functions

Protection & Safety



5. Protection and Safety

Objectives

- Protect from wind or snow
- Increase biological pest control
- Protect from flood waters
- Create a safe environment

Buffer functions

1. Reduce wind energy
2. Modify microclimate
3. Enhance habitat for predators of pests
4. Reduce flood water levels and erosion
5. Reduce hazards

Design Guidelines for Protection and Safety	Buffer Functions			
	Reduce wind energy	Modify microclimate	Enhance habitat for predators of pests	Reduce flood water levels and erosion
5.1 Managing insect pests with buffers	✓	✓	✓	✓
5.2 Plants that attract beneficial insects	✓	✓	✓	✓
5.3 Buffers and spray drift	✓	✓	✓	✓
5.4 Weed control with buffers	✓	✓	✓	✓
5.5 Buffers and road intersections	✓	✓	✓	✓
5.6 Managing shade	✓	✓	✓	✓
5.7 Managing drifting snow	✓	✓	✓	✓
5.8 Windbreaks for livestock	✓	✓	✓	✓
5.9 Flood attenuation and buffers	✓	✓	✓	✓

Protection and Safety

Protection & Safety

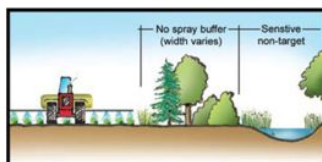
Design Guidelines for Protection and Safety	Buffer Functions				
	Reduce wind energy	Modify microclimate	Enhance habitat for predators of pests	Reduce flood water levels and erosion	Reduce hazards
5.1 Managing Insect Pests with Buffers	✓	✓	✓		
5.2 Plants that Attract Beneficial Insects		✓	✓		
5.3 Buffers and Spray Drift	✓	✓	✓		✓
5.4 Weed Control with Buffers	✓		✓		
5.5 Buffers and Road Intersections					✓
5.6 Managing Shade		✓			✓
5.7 Managing Drifting Snow	✓	✓			✓
5.8 Windbreaks for Livestock	✓	✓			
5.9 Flood Attenuation and Buffers				✓	✓

Protection & Safety

Design Guidelines for Protection and Safety	Buffer Functions				
	Reduce wind energy	Modify microclimate	Enhance habitat for predators of pests	Reduce flood water levels and erosion	Reduce hazards
5.1 Managing Insect Pests with Buffers	✓	✓	✓		
5.2 Plants that Attract Beneficial Insects		✓	✓		
5.3 Buffers and Spray Drift	✓	✓	✓		✓
5.4 Weed Control with Buffers	✓		✓		
5.5 Buffers and Road Intersections					✓
5.6 Managing Shade		✓			✓
5.7 Managing Drifting Snow	✓	✓			✓
5.8 Windbreaks for Livestock	✓	✓			
5.9 Flood Attenuation and Buffers				✓	✓

Protection & Safety

Design Guidelines for Protection and Safety	Buffer Functions				
	Reduce wind energy	Modify microclimate	Enhance habitat for preservation of pests	Reduce flood water levels and erosion	Reduce hazards
5.1 Managing Insect Pests with Buffers	✓	✓	✓		
5.2 Plants that Attract Beneficial Insects		✓	✓		
5.3 Buffers and Spray Drift	✓	✓	✓	✓	✓
5.4 Weed Control with Buffers	✓		✓		
5.5 Buffers and Road Intersections					✓
5.6 Managing Shade		✓			✓
5.7 Managing Drifting Snow	✓	✓			✓
5.8 Windbreaks for Livestock	✓	✓			
5.9 Flood Attenuation and Buffers				✓	✓



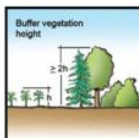
5.3 Buffers and spray drift

Buffers can help protect sensitive non-target areas from chemical spray drift. The buffer design is dependent on many variables including spray method, wind, chemical type, and the type of sensitive nontarget.

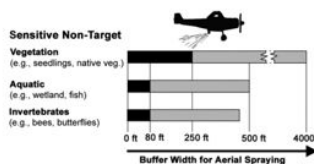
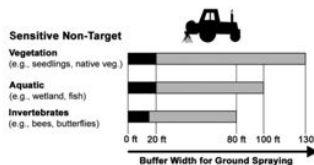
The adjacent graphs summarize recommendations for buffer widths based on spray method and the type of sensitive nontarget to be protected. Below are general design considerations.

Key design considerations

- Use vegetation with fine or needle-like leaves. Broadleaf plants capture less drift but are good for reducing wind.
- Use vegetation tolerant of the chemical being applied.
- Provide a permeable barrier (40 to 50 percent density) to allow air passage. Several rows of vegetation are better than one dense row.
- Buffer should be at least two times taller than the crop.
- Use a mixture of plant forms to ensure no gaps.
- Locate to intercept the prevailing winds and as close as possible to the spray zone.



The black bar denotes the suggested minimum recommended width while the gray bar indicates the upper end of the recommended widths based on current research. This summary should only serve as a starting point for design.



Minimum recommended width
Upper end of recommended width

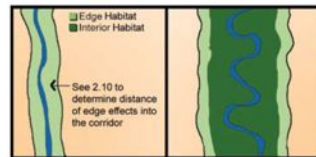
Due to the variability of chemical toxicity, these guidelines need to be used in conjunction with specific management recommendations for the particular chemical in use. Computer models are also available to help calculate spray drift potential and buffer zones.

Buffers should not be a substitute for other safety measures. Additional best management practices for chemical spraying need to be used in conjunction with buffers.

Additional Guidelines



Additional Design Guidelines that may Benefit Protection and Safety	Buffer Functions				
	Reduce wind energy	Reduce microclimate	Exclude adjacent areas for 200 ft buffer	Reduce food web energy	Reduce habitat
1.18 Allowances for bank erosion				✓	✓
2.2 Patch primer		✓	✓	✓	✓
2.9 Corridor width		✓	✓	✓	✓
2.13 Roads and wildlife crossings				✓	✓
2.14 Roadside corridors				✓	✓
3.2 Windbreaks for wind erosion	✓	✓	✓	✓	✓
3.3 Herbaceous wind barriers	✓	✓	✓	✓	✓
4.4 Windbreaks and crop yields	✓	✓	✓	✓	✓
4.5 Alley cropping	✓	✓	✓	✓	✓
4.7 Energy conservation: site	✓	✓	✓	✓	✓
4.8 Energy conservation: landscape	✓	✓	✓	✓	✓
4.9 Crop pollinator habitat	✓	✓	✓	✓	✓
6.2 Windbreaks for odor control				✓	✓
6.3 Air quality buffers	✓	✓	✓	✓	✓



2.9 Corridor width

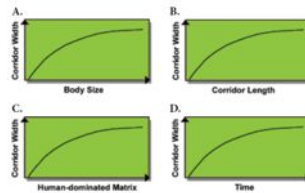
Wide corridors, both upland and riparian, provide greater habitat area with reduced edge effects, while generally promoting more opportunities for species movement. Wider riparian corridors can facilitate stream meandering, providing overall higher habitat quality and diversity.

Many studies have examined the issue of corridor width for certain species. However, many of the studies have not tested a significant range of corridor widths to adequately determine optimal corridor widths. In addition, for a given width, corridor effectiveness will vary with corridor length, habitat continuity, habitat quality, and many other factors.

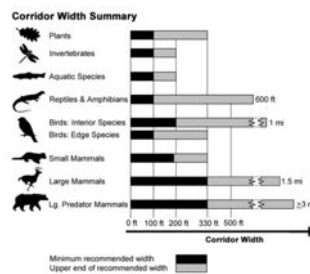
With those limitations in mind, the bar graph on the next page summarizes research on species movement through corridors. The black bar denotes the suggested minimum corridor width while the gray bar indicates the upper end of recommended widths. These ranges should be refined with a biologist.

Based on this research, some general relationships on corridor width can be inferred (see line graphs).

- A. The larger the species, the wider the corridor will need to be to facilitate movement and provide potential habitat.
- B. As the length of the corridor increases, so should the width. Shorter corridors are more likely to provide increased connectivity than long corridors.



- C. A corridor will generally need to be wider in landscapes that provide limited habitat or that are dominated by human use.
- D. Corridors that need to function for decades or centuries should be wider. Some functions that require significant time include dispersal for slow-moving organisms, gene flow, and changes to range distribution due to climate change.



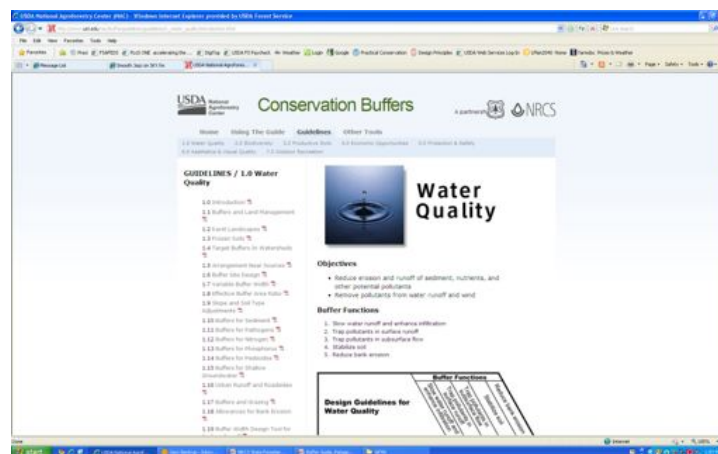
Polling question

How many of you would like to access the original scientific literature?



Over 1,400 References

www.bufferguidelines.net



References as a Resource

Minimize runoff

Use BMPs to minimize Pathogen sources, Pathogen production, Pathogen transport

Strive for zero discharge from buffer

1.11 Buffers for pathogens

Buffers can reduce pathogens in surface runoff from urban lands, pastures, manure-applied fields, and confined animal feeding operations but are generally ineffective by themselves to meet water quality standards. Buffers need to be combined with other best management practices (BMPs) to meet standards.

1.11 References

Atwill, E.R., Hou, L., Karle, B.M. [and others]. 2002. Transport of *Cryptosporidium parvum* Oocysts through vegetated buffer strips and estimated filtration efficiency. *Applied and Environmental Microbiology*, 68: 5517-5527.

Clanbey, J., Edwards, D.R., Daniel, T.C. [and others]. 1994. Effectiveness of vegetative filter strips in retaining surface-applied swine manure. *Transactions of the American Society of Agricultural Engineers*.

Google Scholar

Transport of *Cryptosporidium*

scholar.google.com/scholar?hl=en&q=Transport+of+Cryptosporidium+parvum+Oocysts+through+vegetated+buffer+strips+and+e

Web Images More...

Google

Transport of *Cryptosporidium parvum* Oocysts through vegetated buffer strips

Scholar About 117 results (0.67 sec)

Articles

Legal documents

Any time Since 2012 Since 2011

Transport of *Cryptosporidium parvum* oocysts through vegetated buffer strips and estimated filtration efficiency

ER Atwill, L Hou, BM Karle, T Harter ... - *Applied and Environmental Microbiology*, 2002 - Am Soc Microbiol

ABSTRACT **Vegetated buffer strips** were evaluated for their ability to remove waterborne *Cryptosporidium parvum* from surface and shallow subsurface flow during simulated rainfall rates of 15 or 40 mm/h for 4 min. Log₁₀ reductions for spiked *C. parvum* oocysts ranged from 1.5 to 3.5. Log₁₀ reductions for spiked *C. parvum* oocysts ranged from 1.5 to 3.5. Log₁₀ reductions for spiked *C. parvum* oocysts ranged from 1.5 to 3.5.

Cited by 64 Related articles BL Direct All 16 versions

Tool Uses

- ✓ Communication
- ✓ Reference source
- ✓ Single function design



Designing for multiple functions



How To Use This Guide

Along with other information

1. Identify resource issues of concern
2. Select the desired buffer functions for each issue
3. Use the guidelines and other information that address the desired functions
4. Prepare design plan

Identify Issues & Objectives

1. Enhance a cold-water fishery
2. Minimize loss of property



Desired Objectives

Objectives	Buffer Functions	Guidelines to Consider
Enhance cold-water fishery by a 10% increase in annual production		
Reduce loss of streamside property by 25%		

Chat question

What type of buffer functions will help achieve the desired objectives?



Desired Buffer Functions

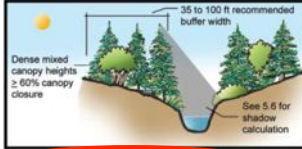
Objectives	Buffer Functions	Guidelines to Consider
Enhance cold-water fishery by a 10% increase in annual production	Shade stream to maintain temperature	
Reduce loss of streamside property by 25%	Reduce bank erosion	

Guidelines to Consider

Objectives	Buffer Functions	Guidelines to Consider
Enhance cold-water fishery by a 10% increase in annual production	Shade stream to maintain temperature	2.6, 2.11, 2.12, 1.1., 3.2, 6.5, 7.3
Reduce loss of streamside property by 25%	Reduce bank erosion	1.1, 1.4, 1.6, 1.17, 1.18, 1.22, 1.24, 2.9, 2.11

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Summary of effectiveness		
Landscape setting		
Site location and layout		
Vegetation characteristics		
Height		

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Width		
Density		
Length		
Other considerations		




2.12 Stream temperature and buffers

Buffers can help maintain cooler water temperatures in small streams if the vegetation provides adequate shade on the water surface. This can be beneficial for coldwater aquatic species and for water quality.

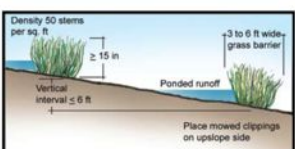
Stream shade is comprised of topographic shade provided by nearby hills, bank shade, and vegetative shade. Streams with vegetation removed usually have undesirable summer temperature increases from 5 °C to 11 °C. Aspect, channel morphology, and groundwater input may affect temperatures more than buffers.

Key design considerations

- Incorporate topography and bank shade in the design.
- Trees and shrubs provide the most shade, but unmowed or ungrazed grass buffers can provide shade on streams < 8 feet in width.
- Buffer shading effectiveness decreases as stream width increases.
- Windthrow may be common in buffers retained after timber harvest and wider buffers may be necessary.
- Buffers may need to be wider (150 to 1,000 feet) to maintain other microclimatic factors (e.g., soil temperature, humidity).

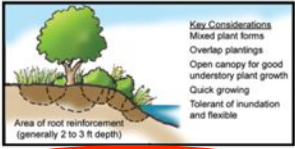


Biodiversity



1.21 Stiff-stemmed grass barriers

Grass barriers are narrow strips of tall, dense, stiff-stemmed grasses planted perpendicular to the slope. These barriers can slow and pond runoff, promoting infiltration and deposition of sediment. Used mainly where gullies would form on steep land and to slow and disperse concentrated flow.



1.22 Vegetation for bank erosion control

Herbaceous plants with shallow root systems are better for protecting banks from surface erosion. Woody species with deeper roots will be better at increasing soil cohesion and reducing mass slope failure. Select woody species that resprout from roots or from broken branches. The best approach is often a combination of plant types.

Water Quality

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Summary of effectiveness	Buffers can help maintain cooler water temperatures in small streams if the vegetation provides adequate shade on the water surface; removal of riparian vegetation often results in summer temperature increases from 5 to 11°C.	
Landscape setting	More effective on small streams. To moderate temperatures in a larger stream, buffer the network of headwater streams feeding into the larger stream. Buffers are more effective in watersheds that have a higher percentage of overall vegetative cover.	
Site location and layout	More effective near the water's edge and along west and south streambanks. Shade appears to moderate temperatures more effectively in streams with a higher width to depth ratio. Shading effectiveness decreases as stream width increases.	
Vegetation characteristics	A buffer with overstory, mid-story, and understory plants may provide the most effective shade. Narrow streams (< 8 ft) may become effectively shaded due to unassisted regrowth. Fast growing species will provide the quickest shade.	
Height	Taller vegetation consisting of large trees will provide more shade. Unmowed or ungrazed tall grass buffers may provide adequate shade on streams less than 8 ft wide.	

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Width	Recommended widths typically range from 30 to 100 ft on both sides of the stream although a 100 ft width offers a significantly higher probability of effectiveness. The final width should respond to landscape and site conditions.	
Density	Canopy closure should be > 60% to provide sufficient shade. Harvesting vegetation in the buffer seems to greatly diminish the shade effectiveness on stream temperature modification.	
Length	The rate of temperature drop once an open stream flows into a well-shaded buffer typically ranges from 1.5 to 50 C within the first 1/2 mile. Studies indicate temperature equilibrium will likely be reached within 1/2 mi on small streams.	
Other considerations	Buffers retained after timber harvest may require wider buffers due to susceptibility to windthrow. Groundwater inflow may affect stream temperatures more than buffer shade.	

Other Information

The screenshot shows the USDA PLANTS Database interface. It includes a search bar, navigation tabs like 'Home', 'About', and 'Help', and a sidebar with various search filters. The main content area displays a 'Plant of the Week' section for *HAZEL* (Asteraceae) and a 'Spotlights' section for the '2012 National Wetland Plant List'.

Soil Survey

The screenshot shows a soil survey map for Catawba County, North Carolina. A legend on the left lists soil types and their percentages of the area of interest:

Soil Type	Map Unit Name	Area In Percent of AUI	Percent of AUI
ARC	Aspen sandy loam, 0 to 20 percent clay	3.0	6.3%
C48	Ced sandy loam, 2 to 10 percent clay	3.2	16.0%
C4C	Ced sandy loam, 0 to 10 percent clay	2.2	11.4%
C4D	Ced sandy loam, 0 to 10 percent clay	0.5	2.4%
P42	Pineau clay loam, 0 to 20 percent clay, moderate eroded	3.4	18.4%
R46	Rosebud loam, 0 to 10 percent clay, moderate eroded	3.8	18.7%
W48	Wadesboro sandy loam, 10 to 20 percent clay	3.2	16.0%
Totals for Area of Interest		19.3	100.0%

USDA PLANTS Database

Other Information

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Summary of effectiveness	Buffers can help maintain cooler water temperatures in small streams if the vegetation provides adequate shade on the water surface; removal of riparian vegetation often results in summer temperature increases from 5 to 11o C.	Can substantially increase bank stability and reduce excessive bank erosion compared to streambanks without vegetation. In some situations, the forces causing bank erosion may be greater than the protective capabilities of vegetation.
Landscape setting	More effective on small streams. To moderate temperatures in a larger stream, buffer the network of headwater streams feeding into the larger stream. Buffers are more effective in watersheds that have a higher percentage of overall vegetative cover.	Buffers will be more effective on smaller streams with low discharge, particularly with small peak flood events, and along relatively stable streams. Buffers will be less effective in watersheds with increasing runoff (e.g., increasing impervious cover, channelization).
Site location and layout	More effective near the water's edge and along west and south streambanks. Shade appears to moderate temperatures more effectively in streams with a higher width to depth ratio. Shading effectiveness decreases as stream width increases.	Locate buffers on both sides of stream; stabilizing just one side can accelerate erosion on the other side. Streambanks with higher silt/clay content may hinder root density, leading to higher erosion rates. Streams with banks greater than 3 ft will be more difficult to stabilize.
Vegetation characteristics	A buffer with overstory, mid-story, and understory plants may provide the most effective shade. Narrow streams (< 8 ft) may become effectively shaded due to unassisted regrowth. Fast growing species will provide the quickest shade.	Deep-rooted vegetation is best suited for reinforcing banks against mass failure while herbaceous species with fibrous root systems provide better protection against bank scour. Root strength diminishes after 1.5 ft of soil depth for herbaceous plants and 3 ft for trees & shrubs.
Height	Taller vegetation consisting of large trees will provide more shade. Unmowed or ungrazed tall grass buffers may provide adequate shade on streams less than 8 ft wide.	On high, steep banks, large trees may increase mass failure by adding weight to the bank and creating toppling leverage. Dense shading from tall species can suppress understory growth leading to unprotected areas that are susceptible to erosion.

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Width	Recommended widths typically range from 30 to 100 ft on both sides of the stream although a 100 ft width offers a significantly higher probability of effectiveness. The final width should respond to landscape and site conditions.	Buffer width should increase as banks become higher and less stable. Include additional width to allow for erosion while the vegetation matures to the point to be effective.
Density	Canopy closure should be > 60% to provide sufficient shade. Harvesting vegetation in the buffer seems to greatly diminish the shade effectiveness on stream temperature modification.	Dense vegetation decreases flow velocities, reduces bank scour and can trap suspended sediment to rebuild the bank. High root density increases soil shear strength. Root density diminishes quickly beyond a plant's dripline so overlap plantings to achieve a dense root matrix.
Length	The rate of temperature drop once an open stream flows into a well-shaded buffer typically ranges from 1.5 to 50 C within the first 1/2 mile. Studies indicate temperature equilibrium will likely be reached within 1/2 mi on small streams.	The buffer length should probably extend the full length of the excessively eroding bank area and the ends should tie into stable sections of the bank.
Other considerations	Buffers retained after timber harvest may require wider buffers due to susceptibility to windthrow. Groundwater inflow may affect stream temperatures more than buffer shade.	In many cases, stabilization of the toe of the bank and other bioengineering techniques may be required. Reducing runoff and flood magnitude in a watershed is often necessary

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Summary of effectiveness	Buffers can help maintain cooler water temperatures in small streams if the vegetation provides adequate shade on the water surface, removal of riparian vegetation often results in summer temperature increases from 5 to 11o C.	Can substantially increase bank stability and reduce excessive bank erosion compared to streambanks without vegetation. In some situations, the forces causing bank erosion may be greater than the protective capabilities of vegetation.
Landscape setting	More effective on small streams. To moderate temperatures in a larger stream, buffer the network of headwater streams feeding into the larger stream. Buffers are more effective in watersheds that have a higher percentage of overall vegetative cover.	Buffers will be more effective on smaller streams with low discharge, particularly with small peak flood events, and along relatively stable streams. Buffers will be less effective in watersheds with increasing runoff (e.g., increasing impervious cover, channelization).
Site location and layout	More effective near the water's edge and along west and south streambanks. Shade appears to moderate temperatures more effectively in streams with a higher width to depth ratio. Shading effectiveness decreases as stream width increases.	Locate buffers on both sides of stream; stabilizing just one side can accelerate erosion on the other side. Streambanks with higher silt/clay content may hinder root density, leading to higher erosion rates. Streams with banks greater than 3 ft will be more difficult to stabilize.
Vegetation characteristics	A buffer with overstory, mid-story, and understory plants may provide the most effective shade. Narrow streams (< 8 ft) may become effectively shaded due to unassisted regrowth. Fast growing species will provide the quickest shade.	Deep-rooted vegetation is best suited for reinforcing banks against mass failure while herbaceous species with fibrous root systems provide better protection against bank scour. Root strength diminishes after 1.5 ft of soil depth for herbaceous plants and 3 ft for trees & shrubs.
Height	Taller vegetation consisting of large trees will provide more shade. Unmowed or ungrazed tall grass buffers may provide adequate shade on streams less than 8 ft wide.	On high, steep banks, large trees may increase mass failure by adding weight to the bank and creating toppling leverage. Dense shading from tall species can suppress understory growth leading to unprotected areas that are susceptible to erosion.

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Summary of effectiveness	Buffers can help maintain cooler water temperatures in small streams if the vegetation provides adequate shade on the water surface; removal of riparian vegetation often results in summer temperature increases from 5 to 11o C.	Can substantially increase bank stability and reduce excessive bank erosion compared to streambanks without vegetation. In some situations, the forces causing bank erosion may be greater than the protective capabilities of vegetation.
Landscape setting	Buffers will be more effective on smaller streams with low discharge, particularly with small peak flood events, and along relatively stable streams.	
Site location and layout	More effective near the water's edge and along west and south streambanks. Shade appears to moderate temperatures more effectively in streams with a higher width to depth ratio. Shading effectiveness decreases as stream width increases.	Locate buffers on both sides of stream; stabilizing just one side can accelerate erosion on the other side. Streambanks with higher silt/clay content may hinder root density, leading to higher erosion rates. Streams with banks greater than 3 ft will be more difficult to stabilize.
Vegetation characteristics	A buffer with overstory, mid-story, and understorey plants may provide the most effective shade. Narrow streams (< 8 ft) may become effectively shaded due to unassisted regrowth. Fast growing species will provide the quickest shade.	Deep-rooted vegetation is best suited for reinforcing banks against mass failure while herbaceous species with fibrous root systems provide better protection against bank scour. Root strength diminishes after 1.5 ft of soil depth for herbaceous plants and 3 ft for trees & shrubs.
Height	Taller vegetation consisting of large trees will provide more shade. Unmowed or ungrazed tall grass buffers may provide adequate shade on streams less than 8 ft wide.	On high, steep banks, large trees may increase mass failure by adding weight to the bank and creating toppling leverage. Dense shading from tall species can suppress understorey growth leading to unprotected areas that are susceptible to erosion.

1. Similar Design Criteria

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Summary of effectiveness	Buffers can help maintain cooler water temperatures in small streams if the vegetation provides adequate shade on the water surface; removal of riparian vegetation often results in summer temperature increases from 5 to 11o C.	Can substantially increase bank stability and reduce excessive bank erosion compared to streambanks without vegetation. In some situations, the forces causing bank erosion may be greater than the protective capabilities of vegetation.
Landscape setting	More effective on small streams. To moderate temperatures in a larger stream, buffer the network of headwater streams feeding into the larger stream. Buffers are more effective in watersheds that have a higher percentage of overall vegetative cover.	Buffers will be more effective on smaller streams with low discharge, particularly with small peak flood events, and along relatively stable streams. Buffers will be less effective in watersheds with increasing runoff (e.g., increasing impervious cover, channelization).
Site location and layout	More effective near the water's edge and along west and south streambanks. Shade appears to moderate temperatures more effectively in streams with a higher width to depth ratio. Shading effectiveness decreases as stream width increases.	Locate buffers on both sides of stream; stabilizing just one side can accelerate erosion on the other side. Streambanks with higher silt/clay content may hinder root density, leading to higher erosion rates. Streams with banks greater than 3 ft will be more difficult to stabilize.
Vegetation characteristics	A buffer with overstory, mid-story, and understorey plants may provide the most effective shade. Narrow streams (< 8 ft) may become effectively shaded due to unassisted regrowth. Fast growing species will provide the quickest shade.	Deep-rooted vegetation is best suited for reinforcing banks against mass failure while herbaceous species with fibrous root systems provide better protection against bank scour. Root strength diminishes after 1.5 ft of soil depth for herbaceous plants and 3 ft for trees & shrubs.
Height	Taller vegetation consisting of large trees will provide more shade. Unmowed or ungrazed tall grass buffers may provide adequate shade on streams less than 8 ft wide.	On high, steep banks, large trees may increase mass failure by adding weight to the bank and creating toppling leverage. Dense shading from tall species can suppress understorey growth leading to unprotected areas that are susceptible to erosion.

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Summary of effectiveness	Buffers can help maintain cooler water temperatures in small streams if the vegetation provides adequate shade on the water surface; removal of riparian vegetation often results in summer temperature increases from 5 to 11o C.	Can substantially increase bank stability and reduce excessive bank erosion compared to streambanks without vegetation. In some situations, the forces causing bank erosion may be greater than the protective capabilities of vegetation.
Landscape setting	More effective on small streams. To moderate temperatures in a larger stream, buffer the network of headwater streams feeding into the larger stream. Buffers are more effective in watersheds that have a higher percentage of overall vegetative cover.	Buffers will be more effective on smaller streams with low discharge, particularly with small peak flood events, and along relatively stable streams. Buffers will be less effective in watersheds with increasing runoff (e.g., increasing impervious cover, channelization).
Site location and layout	Vegetative shading is more effective near the water's edge and along west and south streambanks. Shade appears to moderate temperatures more effectively in streams with a higher width to depth ratio. Shading effectiveness decreases as stream width increases. Locate buffers on both sides of stream; stabilizing just one side can accelerate erosion on the other side. Streambanks with higher silt/clay content may hinder root density, leading to higher erosion rates. Streams with banks greater than 3 ft will be more difficult to stabilize.	
Vegetation characteristics	A buffer with overstory, mid-story, and understory plants may provide the most effective shade. Narrow streams (< 8 ft) may become effectively shaded due to unassisted regrowth. Fast growing species will provide the quickest shade.	Deep-rooted vegetation is best suited for reinforcing banks against mass failure while herbaceous species with fibrous root systems provide better protection against bank scour. Root strength diminishes after 1.5 ft of soil depth for herbaceous
Height	Taller vegetation consisting of large trees will provide more shade. Unmowed or ungrazed tall grass buffers may provide adequate shade on streams less than 8 ft wide.	On high, steep banks, large trees may increase mass failure by adding weight to the bank and creating toppling leverage. Dense shading from tall species can suppress understory growth leading to unprotected areas that are susceptible to erosion.

2. Different criteria but compatible

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Width	Recommended widths typically range from 30 to 100 ft on both sides of the stream although a 100 ft width offers a significantly higher probability of effectiveness. The final width should respond to landscape and site conditions.	Buffer width should increase as banks become higher and less stable. Include additional width to allow for erosion while the vegetation matures to the point to be effective.
Density	Canopy closure should be > 60% to provide sufficient shade. Harvesting vegetation in the buffer seems to greatly diminish the shade effectiveness on stream temperature modification.	Dense vegetation decreases flow velocities, reduces bank scour and can trap suspended sediment to rebuild the bank. High root density increases soil shear strength. Root density diminishes quickly beyond a plant's dripline so overlap plantings to achieve a dense root matrix.
Length	The rate of temperature drop once an open stream flows into a well-shaded buffer typically ranges from 1.5 to 5o C within the first 1/2 mile. Studies indicate temperature equilibrium will likely be reached within 1/2 mi on small streams.	The buffer length should probably extend the full length of the excessively eroding bank area and the ends should tie into stable sections of the bank.
Other considerations	Buffers retained after timber harvest may require wider buffers due to susceptibility to windthrow. Groundwater inflow may affect stream temperatures more than buffer shade.	In many cases, stabilization of the toe of the bank and other bioengineering techniques may be required. Reducing runoff and flood magnitude in a watershed is often necessary

Chat question

What criteria do you go with one has a higher requirement?



Design Element	Shade stream to maintain temperature	Reduce bank erosion
Width	Recommended widths typically range from 30 to 100 ft on both sides of the stream although a 100 ft width offers a significantly higher probability of effectiveness.	
Density	Canopy closure should be > 60% to provide sufficient shade. Harvesting vegetation in the buffer seems to greatly diminish the shade effectiveness on stream temperature modification.	Dense vegetation decreases flow velocities, reduces bank scour and can trap suspended sediment to rebuild the bank. High root density increases soil shear strength. Root density diminishes quickly beyond a plant's dripline so overlap plantings to achieve a dense root matrix.
Length	The rate of temperature drop once an open stream flows into a well-shaded buffer typically ranges from 1.5 to 5°C within the first 100 m. On larger streams, thermal equilibrium will likely be reached within 1.2 m on smaller streams.	The buffer length should probably extend the full eroding bank area and the stream should be into stable sections of the bank.
Other considerations	Buffers retained after timber harvest may require wider buffers due to susceptibility to windthrow. Groundwater inflow may affect stream temperatures more than buffer shade.	In many cases, stabilization of the toe of the bank and other bioengineering techniques may be required. Reducing runoff and flood magnitude in a watershed is often necessary.

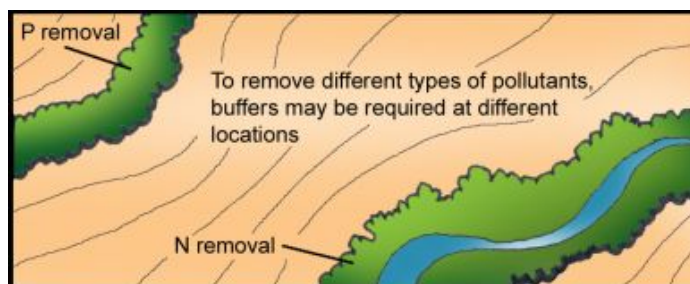
3. Stricter design criteria

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Summary of effectiveness	Buffers can help maintain cooler water temperatures in small streams if the vegetation provides adequate shade on the water surface; removal of riparian vegetation often results in summer temperature increases from 5 to 11o C.	Can substantially increase bank stability and reduce excessive bank erosion compared to streambanks without vegetation. In some situations, the forces causing bank erosion may be greater than the protective capabilities of vegetation.
Landscape setting	More effective on small streams. To moderate temperatures in a larger stream, buffer the network of headwater streams feeding into the larger stream. Buffers are more effective in watersheds that have a higher percentage of overall vegetative cover.	Buffers will be more effective on smaller streams with low discharge, particularly with small peak flood events, and along relatively stable streams. Buffers will be less effective in watersheds with increasing runoff (e.g., increasing impervious cover, channelization).
Site location and layout	More effective near the water's edge and along west and south streambanks. Shade appears to moderate temperatures more effectively in streams with a higher width to depth ratio. Shading effectiveness decreases as stream width increases.	Locate buffers on both sides of stream; stabilizing just one side can accelerate erosion on the other side. Streambanks with higher silt/clay content may hinder root density, leading to higher erosion rates. Streams with banks greater than 3 ft will be more difficult to stabilize.
Vegetation characteristics	A buffer with overstory, mid-story, and understory plants may provide the most effective shade. Narrow streams (< 8 ft) may become effectively shaded due to unassisted regrowth. Fast growing species will provide the quickest shade.	Deep-rooted vegetation is best suited for reinforcing banks against mass failure while herbaceous species with fibrous root systems provide better protection against bank scour. Root strength diminishes after 1.5 ft of soil depth for herbaceous plants and 3 ft for trees & shrubs.
Height	Taller vegetation consisting of large trees will provide more shade. Unmowed or ungrazed tall grass buffers may provide adequate shade on streams less than 8 ft wide.	On high, steep banks, large trees may increase mass failure by adding weight to the bank and creating toppling leverage. Dense shading from tall species can suppress understory growth leading to unprotected areas that are susceptible to erosion.

Design Element	Shade stream to maintain temperature	Reduce bank erosion
Summary of effectiveness	Buffers can help maintain cooler water temperatures in small streams if the vegetation provides adequate shade on the water surface; removal of riparian vegetation often results in summer temperature increases from 5 to 11o C.	Can substantially increase bank stability and reduce excessive bank erosion compared to streambanks without vegetation. In some situations, the forces causing bank erosion may be greater than the protective capabilities of vegetation.
Landscape setting	More effective on small streams. To moderate temperatures in a larger stream, buffer the network of headwater streams feeding into the larger stream. Buffers are more effective in watersheds that have a higher percentage of overall vegetative cover.	Buffers will be more effective on smaller streams with low discharge, particularly with small peak flood events, and along relatively stable streams. Buffers will be less effective in watersheds with increasing runoff (e.g., increasing impervious cover, channelization).
Site location and layout	More effective near the water's edge and along west and south streambanks. Shade appears to moderate temperatures more effectively in streams with a higher width to depth ratio. Shading effectiveness decreases as stream width increases.	Locate buffers on both sides of stream; stabilizing just one side can accelerate erosion on the other side. Streambanks with higher silt/clay content may hinder root density, leading to higher erosion rates. Streams with banks greater than 3 ft will be more difficult to stabilize.
Vegetation characteristics	A buffer with overstory, mid-story, and understory plants may provide the most effective shade. Narrow streams (< 8 ft) may become effectively shaded due to unassisted regrowth. Fast growing species will provide the quickest shade.	Deep-rooted vegetation is best suited for reinforcing banks against mass failure while herbaceous species with fibrous root systems provide better protection against bank scour. Root strength diminishes after 1.5 ft of soil depth for herbaceous plants and 3 ft for trees & shrubs.
Height	Taller vegetation consisting of trees will provide more shade but avoid trees in areas most vulnerable to mass failure. Select and maintain appropriate over-story species that will not suppress understory growth leading to unprotected areas susceptible to erosion.	

4. Compromise

Incompatible functions



Questions?

Gary Bentrup
Res. Landscape Planner
gbentrup@fs.fed.us
402-437-5178 x4018

www.unl.edu/nac

