Floodplain Restoration

Advanced Flood Recovery and River Management Training Modules

Prepared By
Roy Schiff, Jim MacBroom, Mark Carabetta – Milone & MacBroom
Evan Fitzgerald – Fitzgerald Environmental

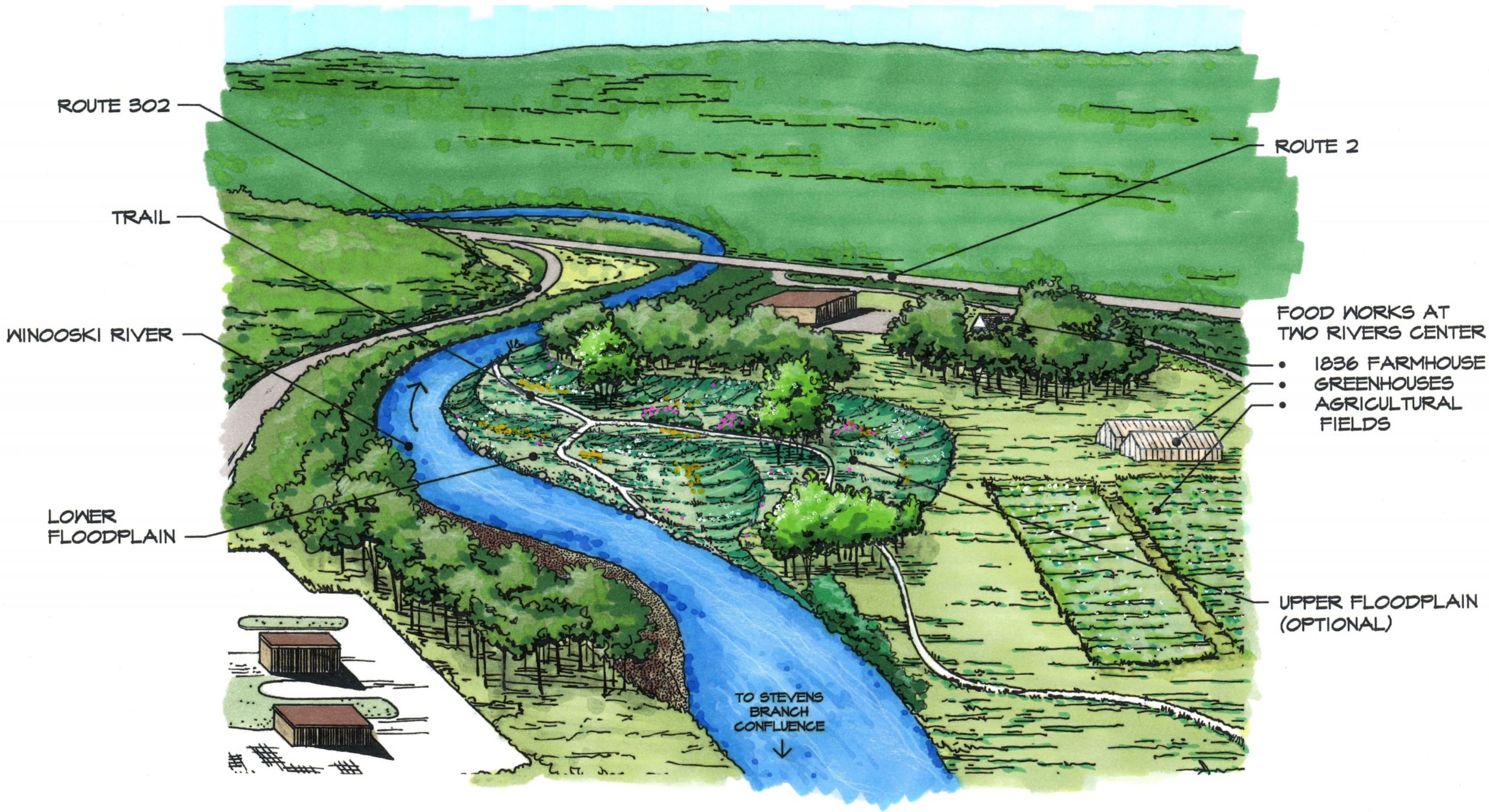
Developed April 2016

Lesson Plan / Table of Contents

Objectives

1. Restore as much floodplain as possible given site constraints. Maximize the width of flooding in unconfined valley settings.
2. Re-establish floodplain dimensions based on reference conditions in the river corridor and valley.
3. Plan for future sediment deposition to reduce channel incision maintaining floodplain access as much as possible.
4. Protect infrastructure, habitable buildings, and improved property by moving out of floodplain as possible.
5. Protect bridges, culverts, dams, & levees.
6. Maintain or improve instream habitat.
7. Protect water quality.
8. Naturalize flood patterns and promote groundwater recharge.

What is Floodplain Restoration?



PROJECT PARTNERS:
FOOD WORKS AT TWO RIVERS CENTER
VERMONT DEC RIVER MANAGEMENT PROGRAM
WINOOSKI RIVER NATURAL RESOURCE
CONSERVATION DISTRICT
FRIENDS OF THE WINOOSKI

WINOOSKI RIVER FLOODPLAIN RESTORATION CONCEPT

MONTPELIER, VERMONT SEPTEMBER 2007

Engineering, Landscape Architecture and Environmental Science
MILONE & MACBROOM
1233 Shelburne Road
South Burlington, Vermont 05403
(802) 864-1600 Fax (802) 864-1601
www.miloneandmacbroom.com

(MMI, 2008)

Ecotones

Thorp Brook
Photo by R. Schiff
2010

Background

Storage

(Lars Gange & Mansfield Heliflight, August 31, 2011)

Background

Land Use Conflicts

(Lars Gange & Mansfield Heliflight, August 31, 2011)

Background

Floodplain Restoration Top 10

1. **Floodplain confinement and isolation increases risks.**
2. **Consider floodplain type when evaluating risks and alternatives.**
3. **No net fill in high and moderate energy floodplains.**
4. **Recall natural role of floodplains when evaluating alternatives.**
5. **Consider easily recoverable or nomadic activities in floodplains.**
6. **Reduce permanent infrastructure in floodplains.**
7. **Conserve floodplains forever.**
8. **Floodplain function can be compatible with agriculture.**
9. **Floodplains can be important recreation assets.**
10. **Floodplains are the #1 planning consideration for flood resiliency.**

Economics

FEMA
MITIGATION POLICY – FP-108-024-01

III. POLICY STATEMENT:

FEMA will allow the inclusion of environmental benefits in benefit-cost analyses (BCA) to determine cost effectiveness of acquisition projects.

IV. PURPOSE:

The purpose of this policy is to identify and quantify the types of environmental benefits that FEMA will consider in the BCA for acquisition projects.

Table I: Annual Estimated Monetary Benefits per Acre per Year

Environmental Benefit	Green Open Space	Riparian
Aesthetic Value	$1,623	$582
Air Quality	$204	$215
Biological Control	--	$164
Climate Regulation	$13	$204
Erosion Control	$65	$11,447
Flood Hazard Reduction	--	$4,007
Food Provisioning	--	$609
Habitat	--	$835
Pollination	$290	--
Recreation/Tourism	$5,365	$15,178
Storm Water Retention	$293	--
Water Filtration	--	$4,252
Total Estimated Benefits	$7,853	$37,493

Table II: Green Open Space and Riparian Benefits Allowed in the BCA Toolkit

Land Use	Total Estimated Benefits	Total Estimated Benefits (projected for 100 years with 7 percent discount rate)
Green Open Space	$7,853 per acre per year	$2.57 per square foot
Riparian	$37,493 per acre per year	$12.29 per square foot

(FEMA, 2013)

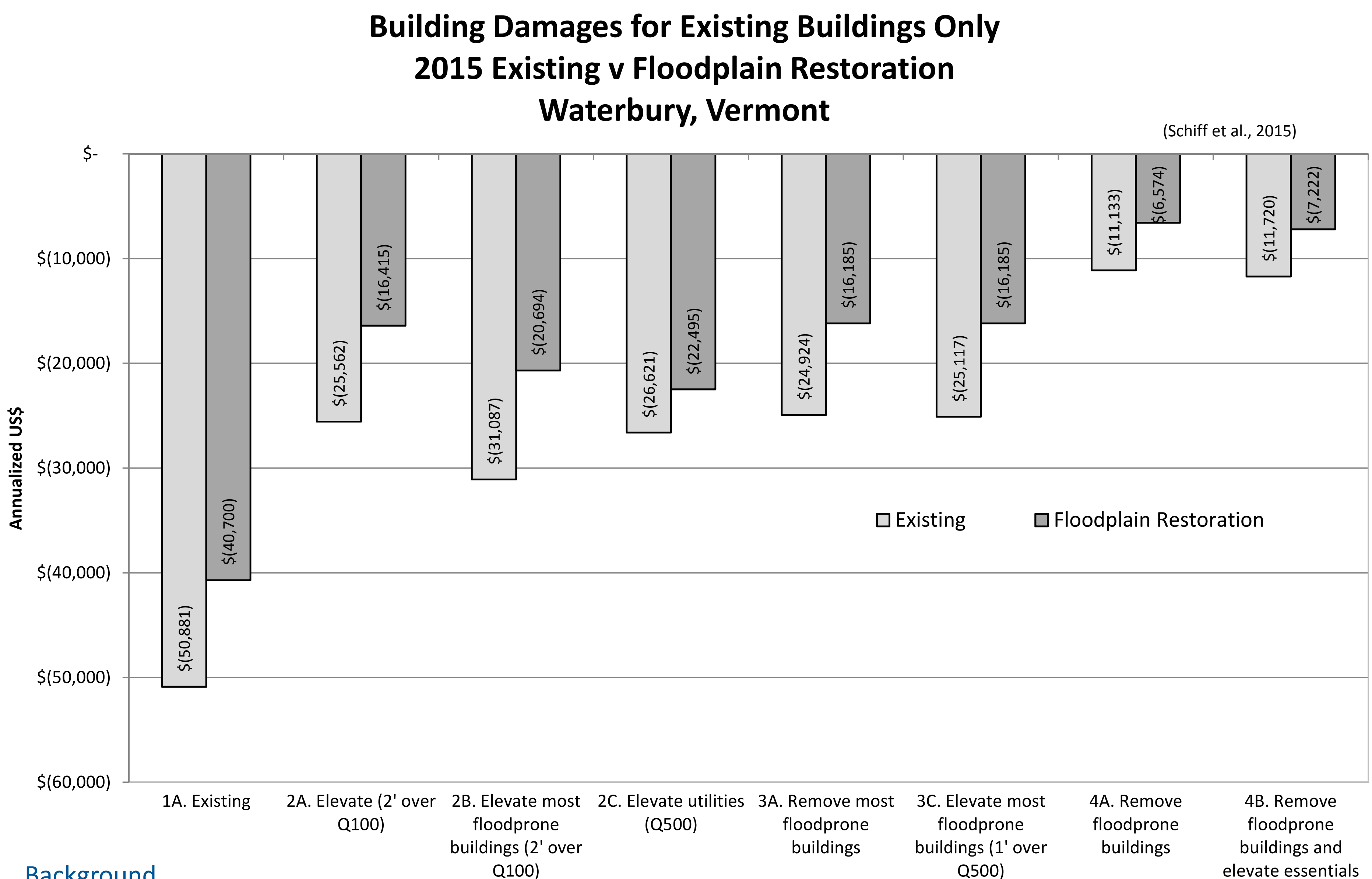
Economics

RANGE OF VALUES FOR ECOSYSTEM SERVICES IN THE FLOODPLAINS OF THE LAKE CHAMPLAIN BASIN

50 yr timespan						
Floodplain Land Cover Class	Low Value ($/acre/year)	High Value ($/acre/year)	Carbon Storage Low	Carbon Storage High	NPV per Acre Low (4.125%)	NPV per Acre High (4.125%)
Agriculture	352	10,808	500	3,605	7,679	224,130
Forest	5,823	6,461	345	19,762	119,176	151,519
Shrubland / Grassland	9,147	9,247	170	315	186,849	189,040
Wetland	5,807	55,870	4,862	84,131	123,389	1,224,428
River	2,119	77,089	-	-	43,252	1,572,970
Village Greenspace	2,404	17,919	78	16,129	50,632	392,974
Developed Land	Not Valued	Not Valued	Not Valued	Not Valued	Not Valued	Not Valued

(Earth Economics, 2015)

Economics



Background

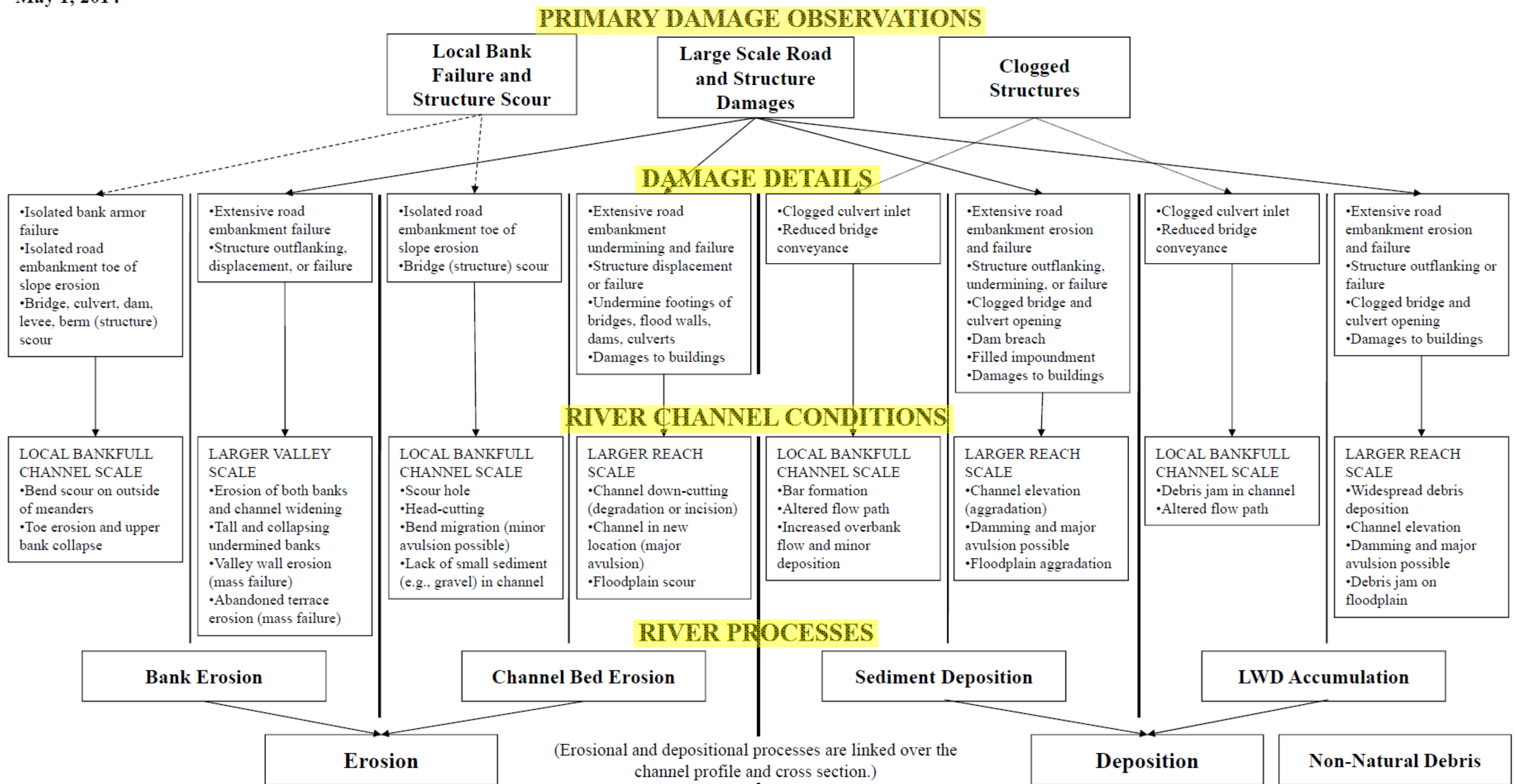
Background

(NOAA, 2005)

Background

Problem Identification Review

May 1, 2014



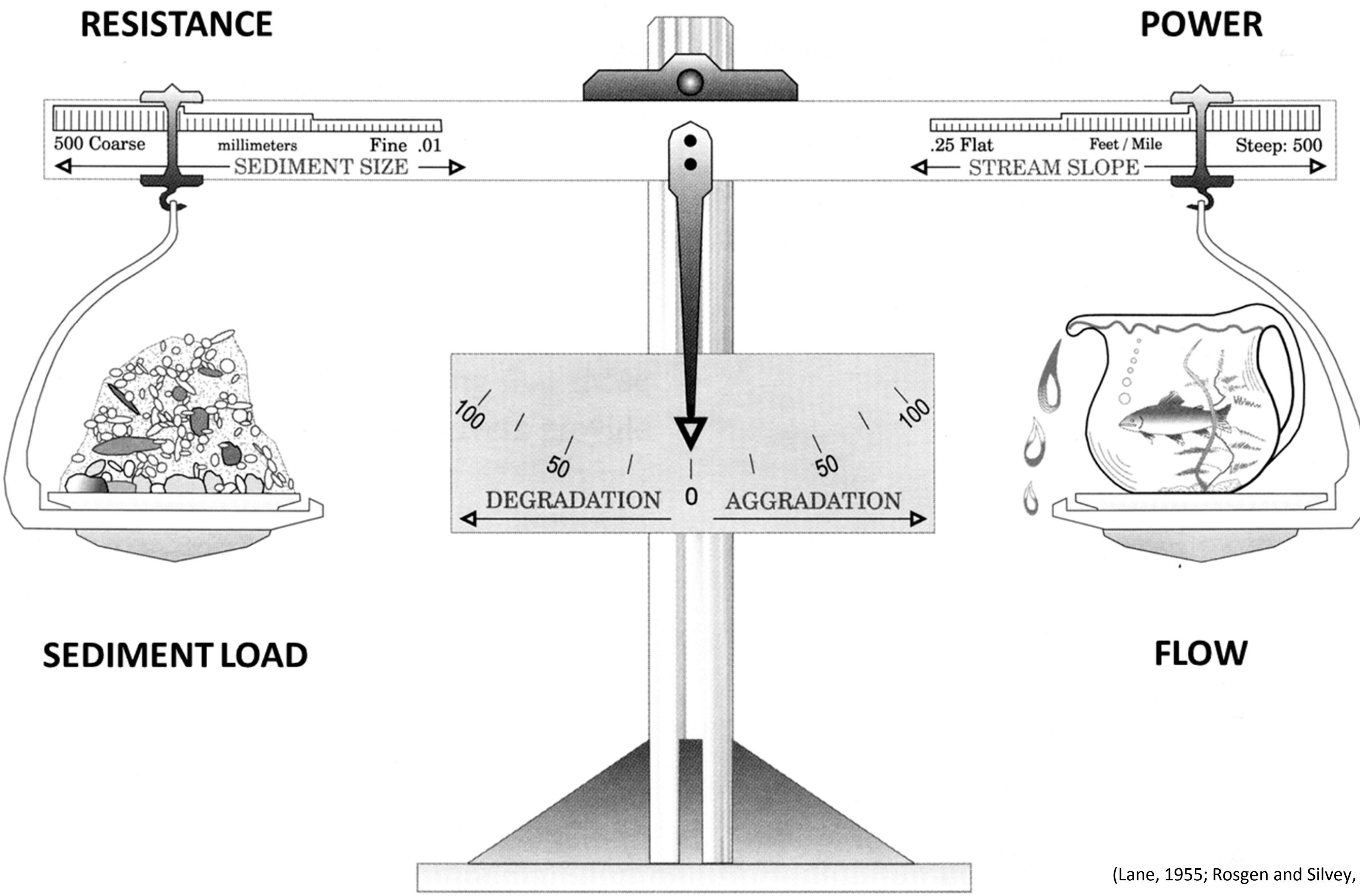
APPLICABLE GUIDING DESIGN PRINCIPLES BASED ON DAMAGES (1 = MOST IMPORTANT)

Lateral	1	1	3	3	2	3	1	3
Vertical		2	1	1	1	2	2	1
Conveyance					4	1		2
Crossing	2	3	2	2	3	4	3	4

Background

(Schiff et al., 2014)

Dynamic Equilibrium



(Lane, 1955; Rosgen and Silvey, 1996)

Background (Sediment LOAD) x (Sediment SIZE) $\propto$ (Stream SLOPE) x (Stream DISCHARGE)

Habitat Maintenance

- Channel work will typically not be required, so instream habitat impacts can be avoided.
- Control potential sedimentation of the channel near the riverbank during construction.
- Revegetate the floodplain where fine sediment and organic soils exist. Coarse sediment areas in the low floodplain that are inundated several times a year are often not revegetated.
- Retain standing trees and deposits of large woody debris in the floodplain to form riparian habitat.
- Creation of ephemeral backwater habitats can be included during a floodplain restoration.
- Create depressions for niche habitats and recharge areas.

(Schiff et al., 2014)

Common Mistakes

- Setting the floodplain elevation too high that reduces inundation frequency and some confined flood flows persist.
- Setting the floodplain too low that results in excessive floodplain power, scour, and possible channel avulsion.
- Not creating sufficient floodplain roughness to dissipate floodplain power.
- Not considering ongoing channel incision that may continue despite floodplain restoration and result in abandonment of the restored floodplain.
- Creating abrupt transitions in floodprone width above and below the floodplain restoration area.
- Inadequate protection of remaining infrastructure at the back edge of the restored floodplain.
- Not considering floodplain power to know if erosion or deposition is dominant.
- Exposing glacial lakebed sediments and causing landslides.

(adapted from Schiff et al., 2014)

Alternatives Analysis Objectives

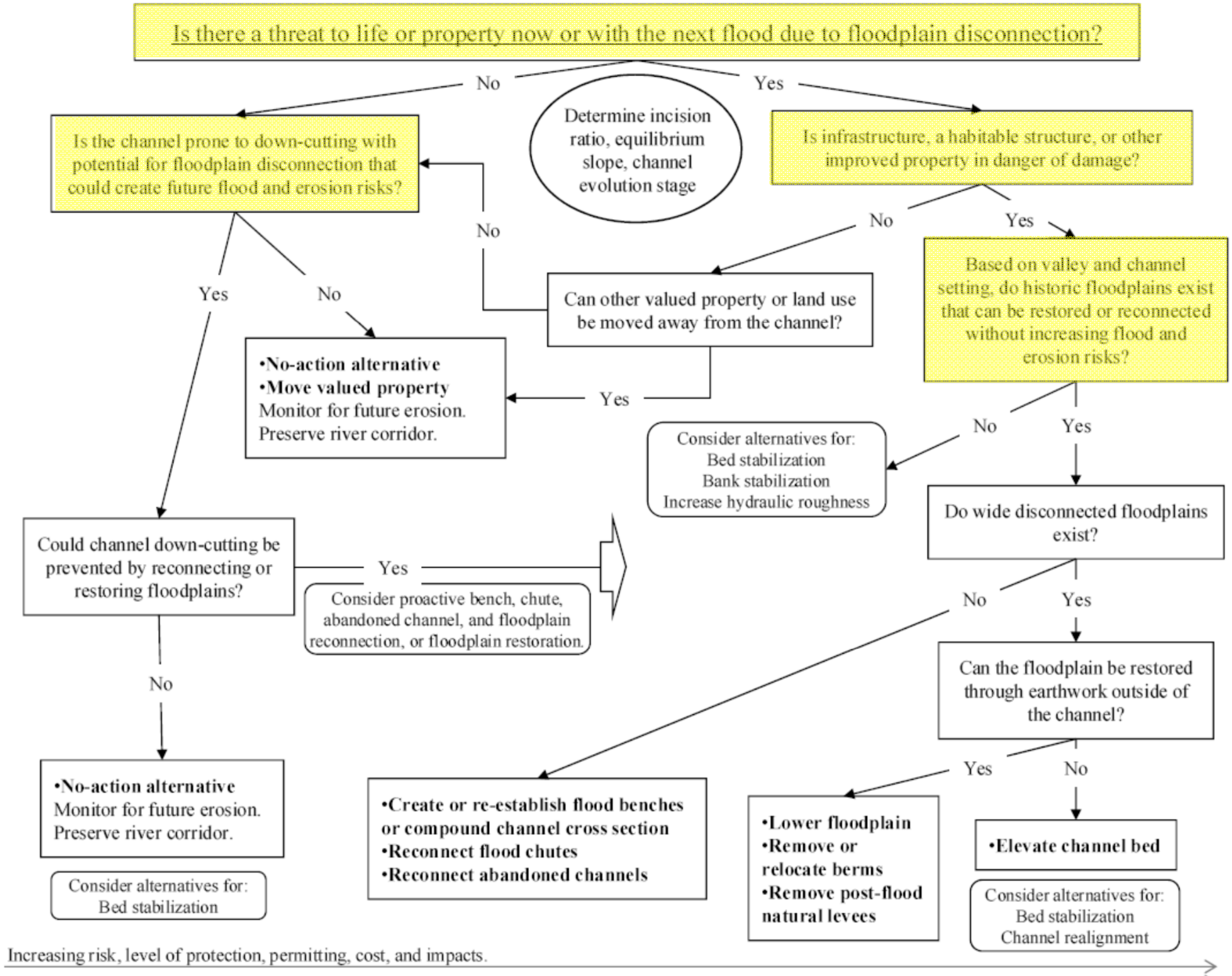
GENERAL

1. No action is preferred. Should we be doing this?
2. Protect life, infrastructure, and unmovable property as needed.
3. Evaluate site constraints.
4. Enable natural recovery.
5. Use natural materials first.

FLOODPLAIN RESTORATION

A. Identify level of risk due to loss of floodplain connectivity.
B. Re-establish floodplain conveyance.
C. Naturalize sediment transport.
D. Change flood patterns to reduce future damages.

Floodplain Restoration Alternatives Analysis



Alternatives Analysis

(Schiff et al., 2014)

Floodplain Restoration Alternatives

1. Removing a berm adjacent to a river channel
2. Removing historic dredge spoils
3. Breaching a natural post-flood sediment levee deposit on the edge of the river channel
4. Lowering the elevation of the abandoned floodplain
5. Raising the elevation of the channel bed such as through natural bed stabilization or bed armoring
6. Creating a new channel in the floodplain with some filling of the historic channel
7. Establish low or flood benches
8. Restore flood chutes
9. Adding channel roughness (large substrate and wood)

(Schiff et al., 2014)

Alternatives Analysis Review Questions

1. *Is moving valued property following flood damages a possible alternative?*

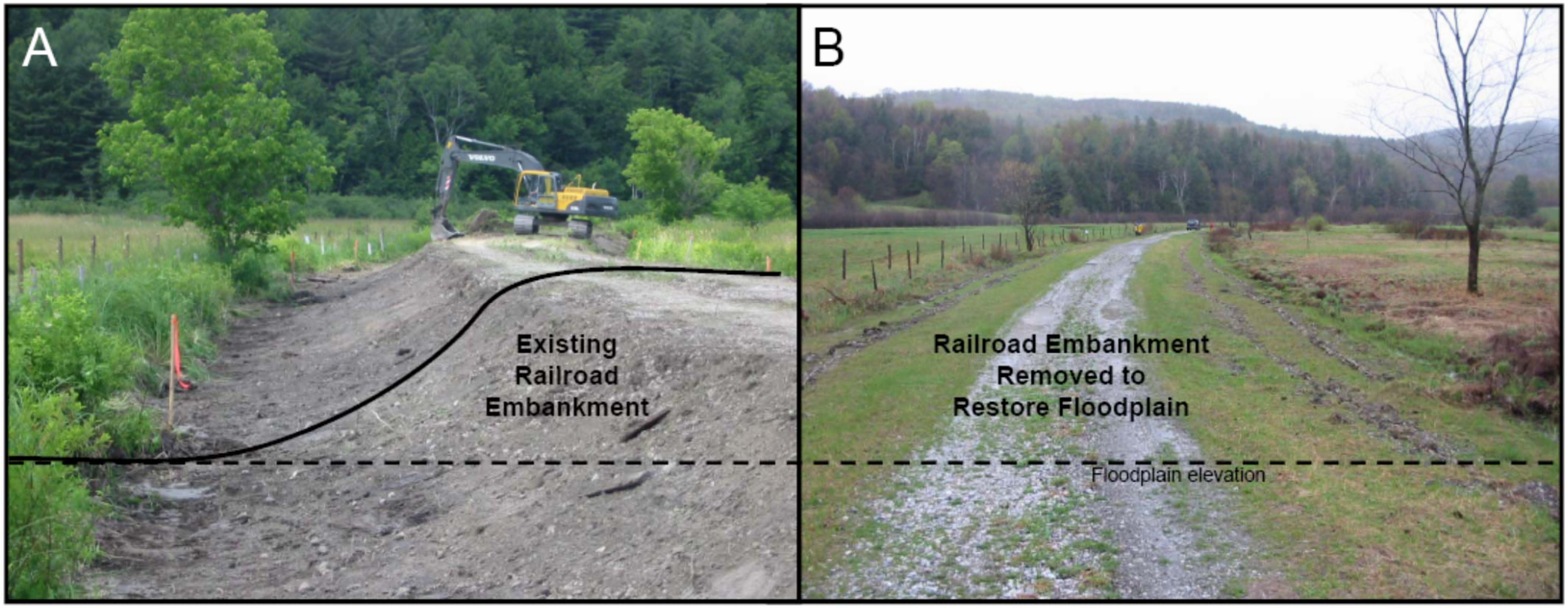
2. *Compare the risk level at the following two sites. How would the differing site constraints guide the alternatives analysis to restore floodplain?*

Alternatives Analysis Review Questions

Alternatives Analysis Review Questions

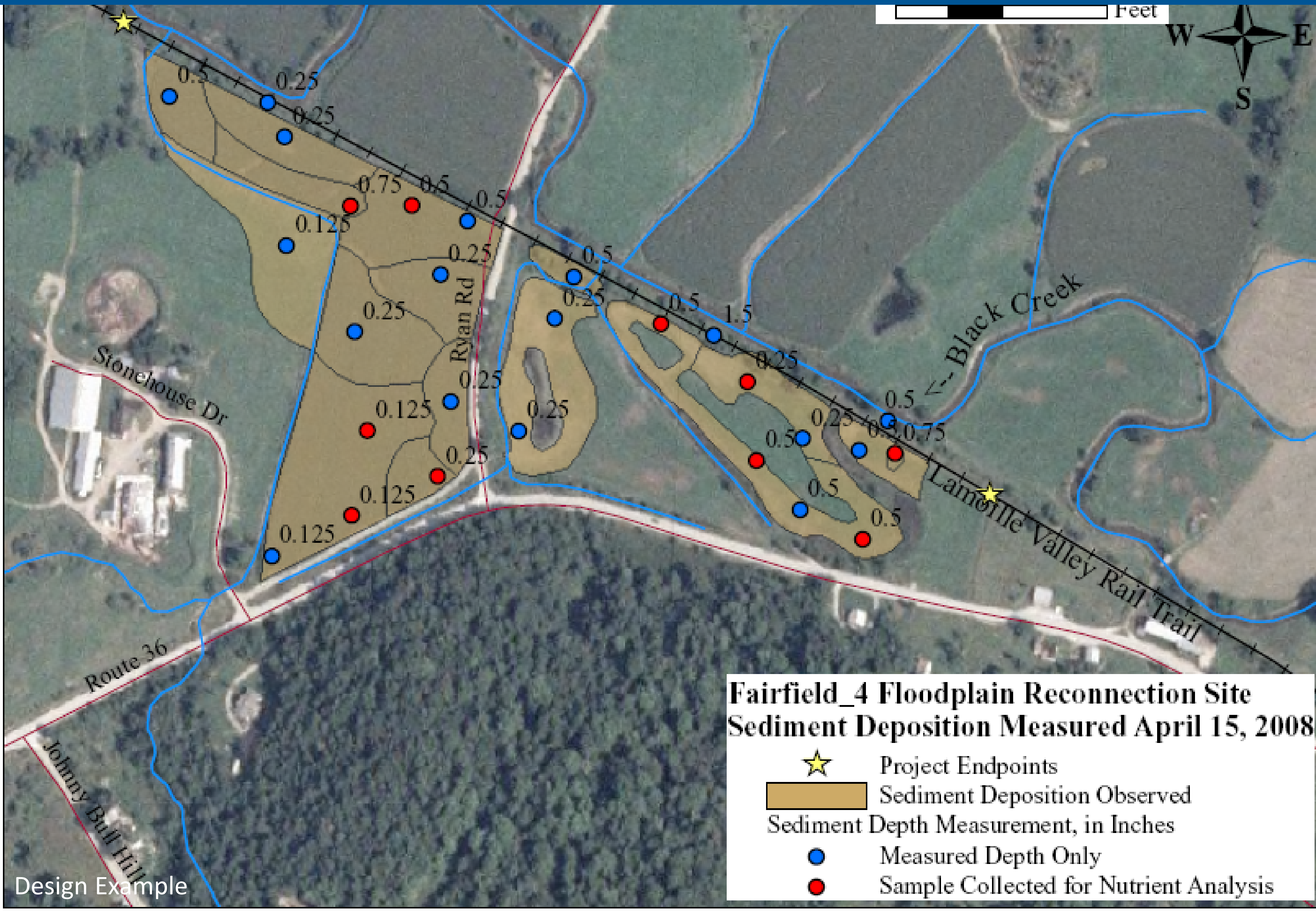
Browns River
Jericho, VT
2007

Floodplain Restoration Design Example

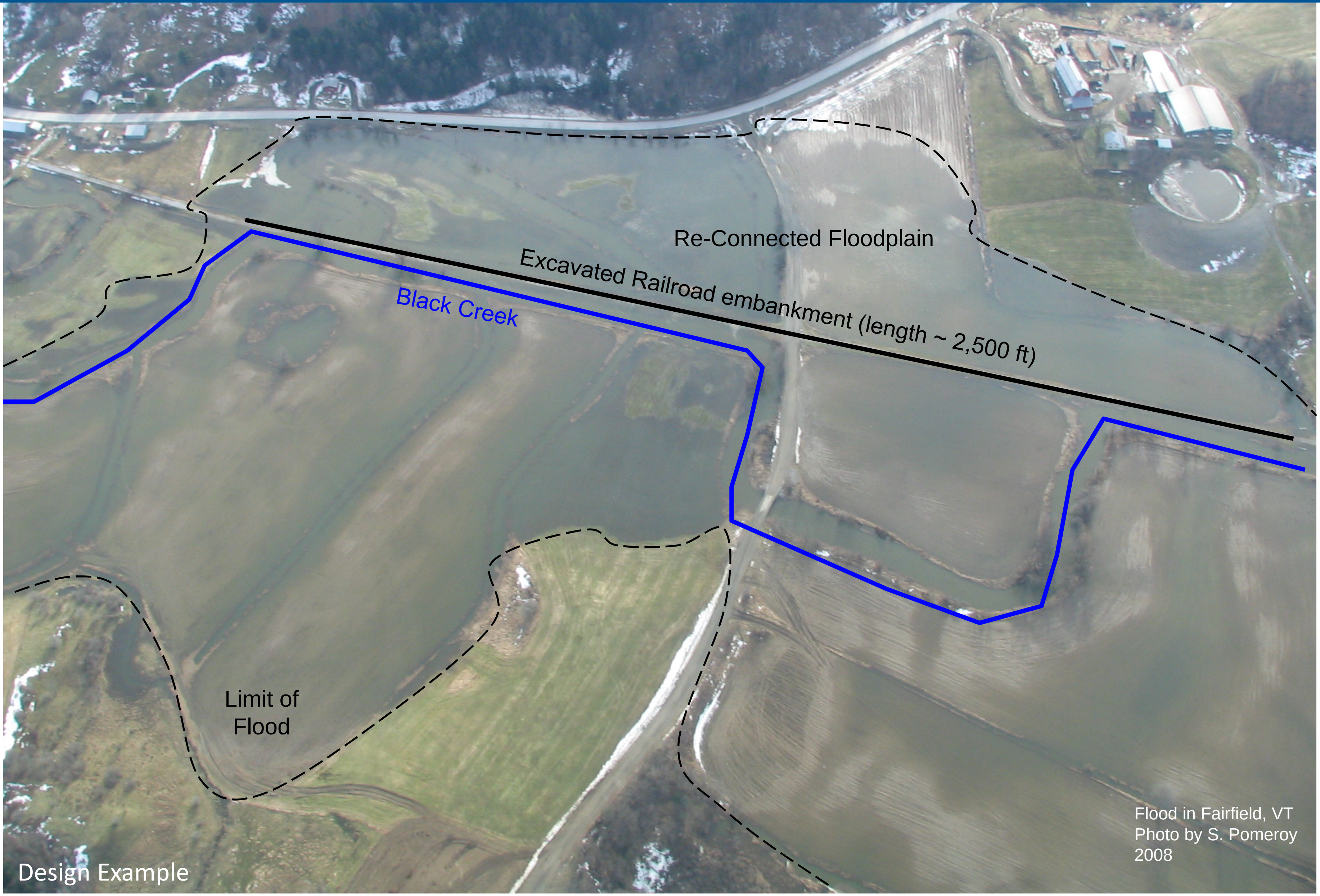


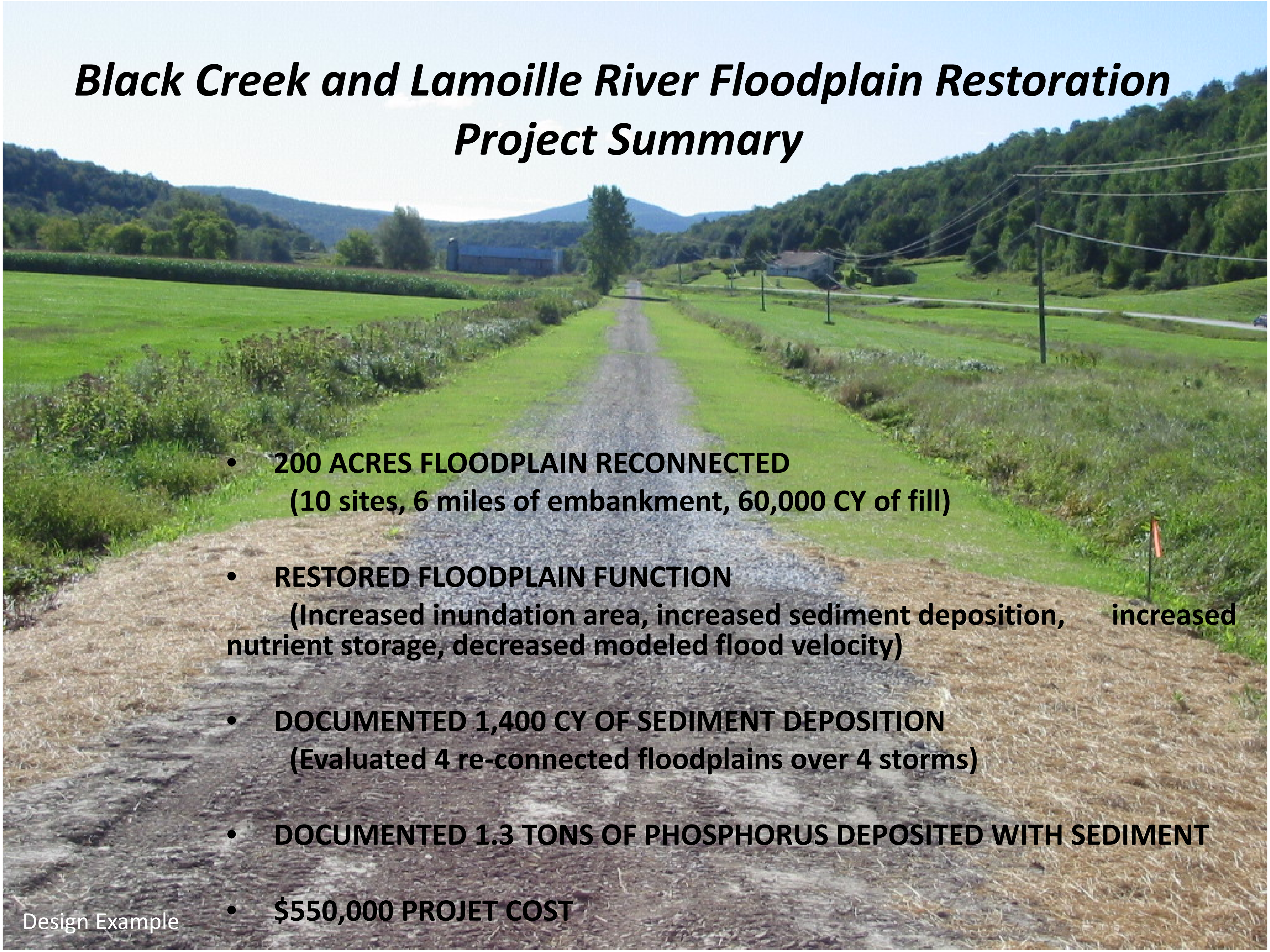
(Schiff et al., 2014)

Floodplain Restoration Design Example



Floodplain Restoration Design Example





Black Creek and Lamoille River Floodplain Restoration Project Summary

- **200 ACRES FLOODPLAIN RECONNECTED**
  (10 sites, 6 miles of embankment, 60,000 CY of fill)

- **RESTORED FLOODPLAIN FUNCTION**
  (Increased inundation area, increased sediment deposition, increased nutrient storage, decreased modeled flood velocity)

- **DOCUMENTED 1,400 CY OF SEDIMENT DEPOSITION**
  (Evaluated 4 re-connected floodplains over 4 storms)

- **DOCUMENTED 1.3 TONS OF PHOSPHORUS DEPOSITED WITH SEDIMENT**

- **$550,000 PROJET COST**

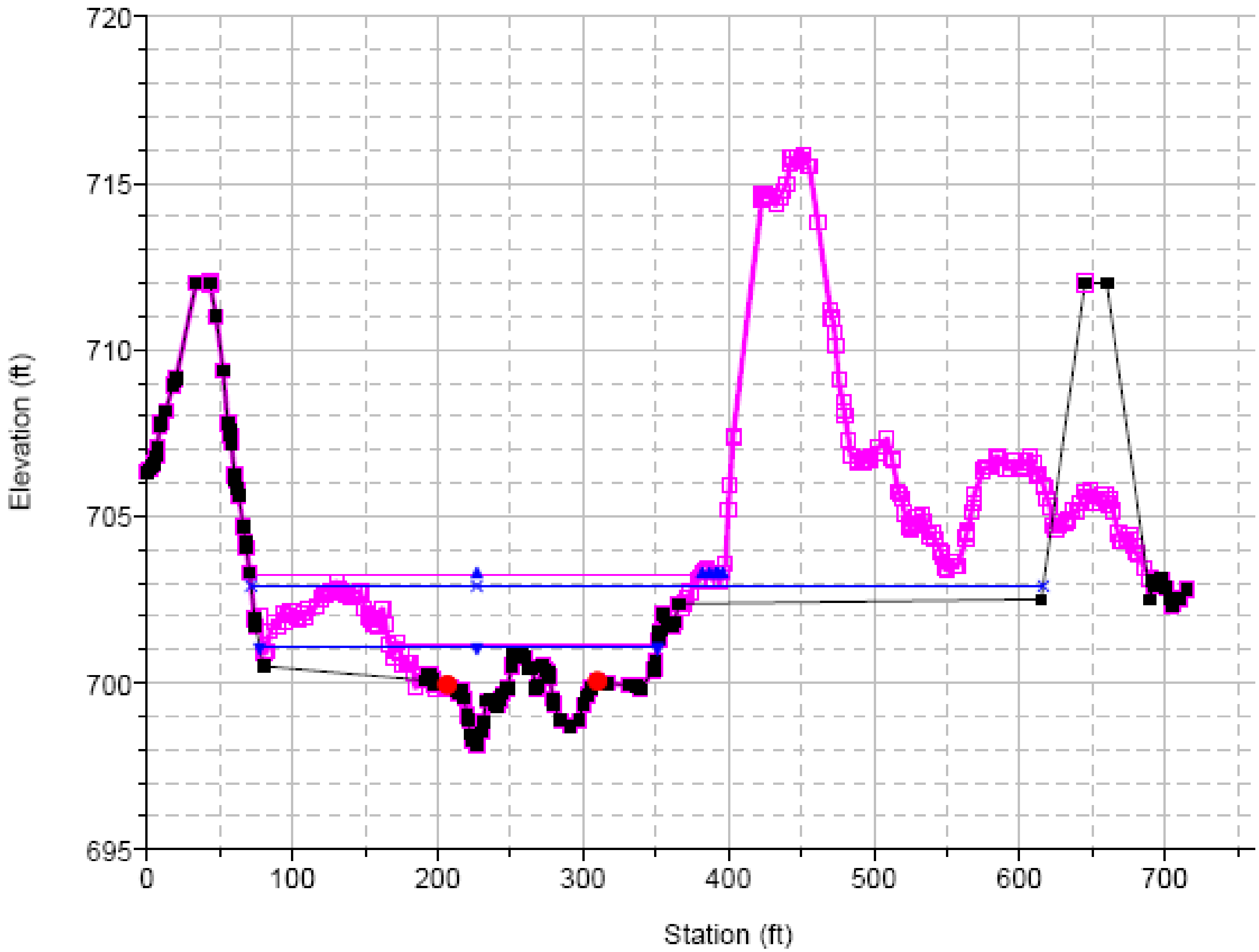
Design Example

Waterbury Flood Study - Floodplain Restoration

Roaring Branch Design Example

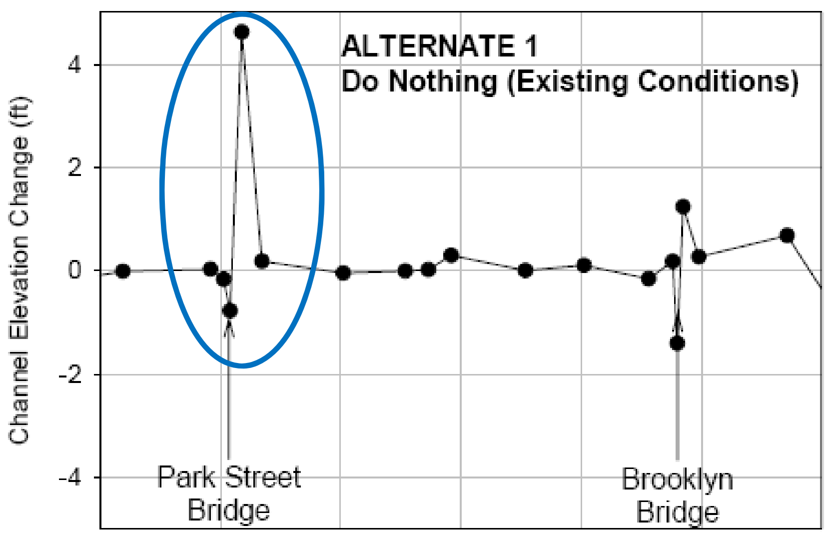
MILONE & MACBROOM

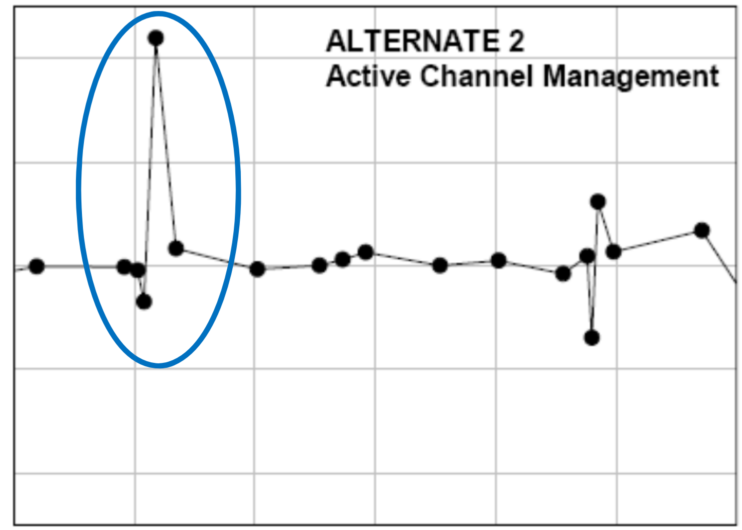
Roaring Branch Design Example

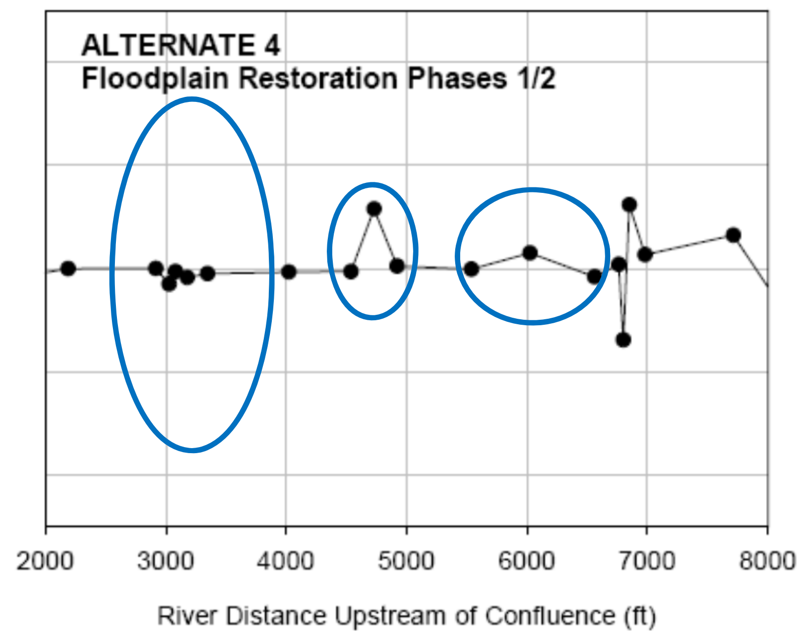


Roaring Branch Design Example

- Total Power decreases range100-700 W/m2 (948 to 167)
- Flood velocity decreases 1-4 feet per second
- Flood depth decreases 0.2-1.0 feet







Design Example

Roaring Branch Design Example

1898 Roaring Branch Flood Damage on Branch Street
Bennington, VT
Scanned Photograph Courtesy of Town of Bennington

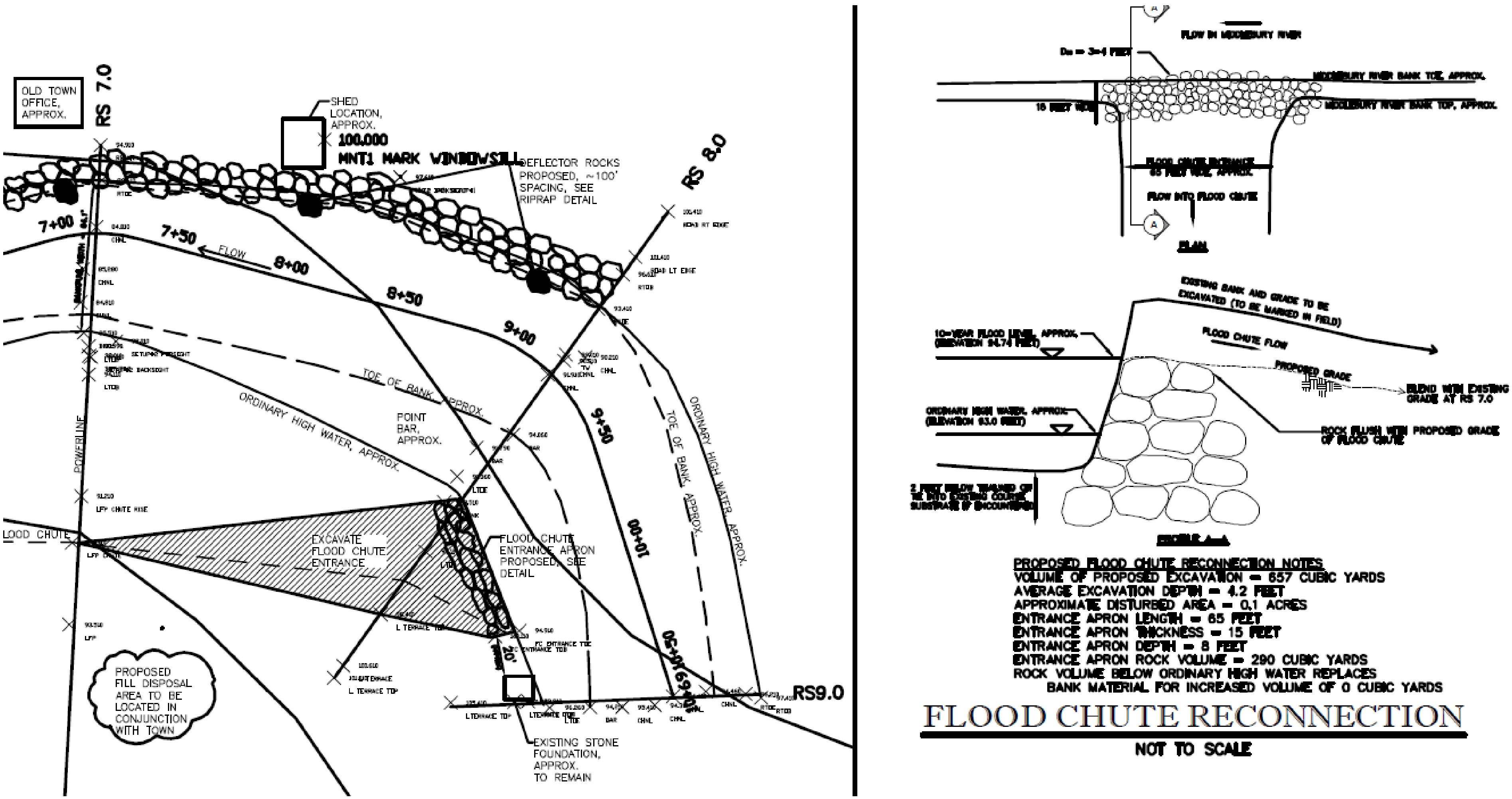
Design Example

Design Example

(ANR, 2006)

Design Example

Design Example



(MMI, 2009)

Design Example

Disconnected Flood Chute Entrance
Middlebury River,
Ripton, VT
Source: MMI, 2009

Reconnected Flood Chute Entrance
Middlebury River,
Ripton, VT
Source: MMI, 2009

Design Example

Assessment and Design Overview

Independent Variables

(Assessment)

- Valley Slope
- Flow
- Stream Power ($\Omega = \gamma QS$)
- Physical Site Constraints
- Confinement
- Existing Floodplain Dimensions
- Floodplain Connectivity
  - Entrenchment
  - Incision
- Channel Evolution
- Sediment and Large Wood

Increasing complexity and variables that may drop out of basic assessment during quick emergency repairs.

Dependent Variables

(Design)

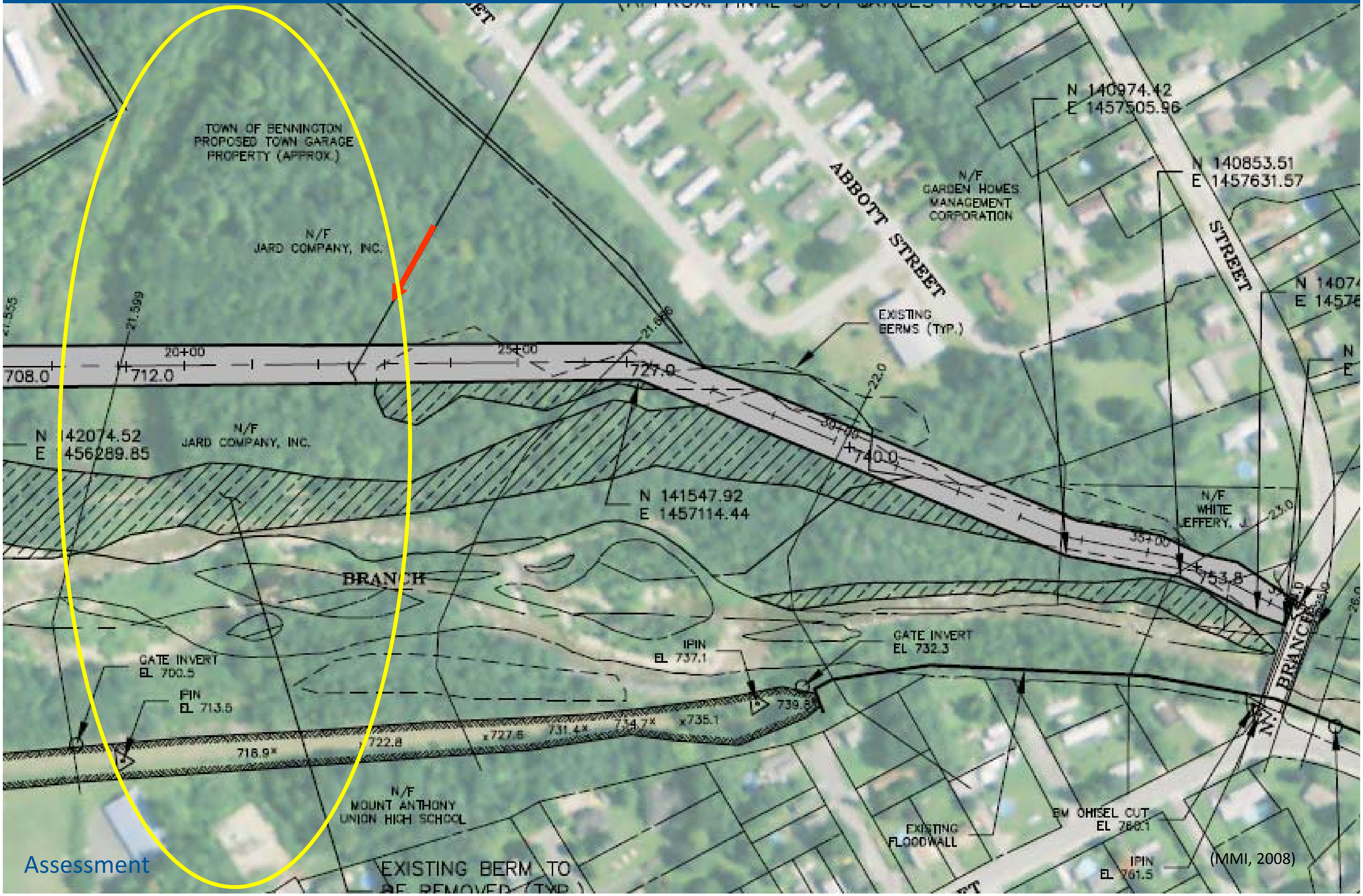
- Floodplain Width and Elevation
- Floodplain Length and Slope
- Channel Pattern, Sinuosity, and Dynamics
- Excavation or Fill Volume
- Fill Disposal Areas
- Stabilization Measures
- Vegetative cover
- Floodplain features (oxbows, wetlands, etc.)

(MMI, 2016)

Assessment – Site Constraints

1. Identify surrounding infrastructure that typically is located within a portion of the historic floodplain.
2. Permission from one or more landowners is typically required in order to perform floodplain restoration.
3. Cultural resources in floodplain areas.

Foundations and Utilities (Call Before You Dig)



Assessment

(MMI, 2008)

Foundations and Utilities (Call Before You Dig)

Existing Floodplain Dimensions

1. Current field measurements of limits of disconnected floodplain.
2. Current field measurements of connected floodplain in undisturbed reference reach (*analog approach*).
3. Historic observations / prior knowledge such as survey or geomorphic assessment (aerial photos).

Confinement

Confinement = Valley Width / Channel Width

Confinement	Valley Width / Channel Width Ratio
Narrowly Confined	$\geq$1 and < 2
Semi Confined	$\geq$2 and <4
Narrow	$\geq$4 and <6
Broad	$\geq$6 and <10
Very Broad	$\geq$10, may have abandoned terraces on one or both sides

(VTANR, 2009)

NATURAL

- Valley wall
- Terraces
- Alluvial fan (local)
- Natural bank levee
- Confluences

ARTIFICIAL

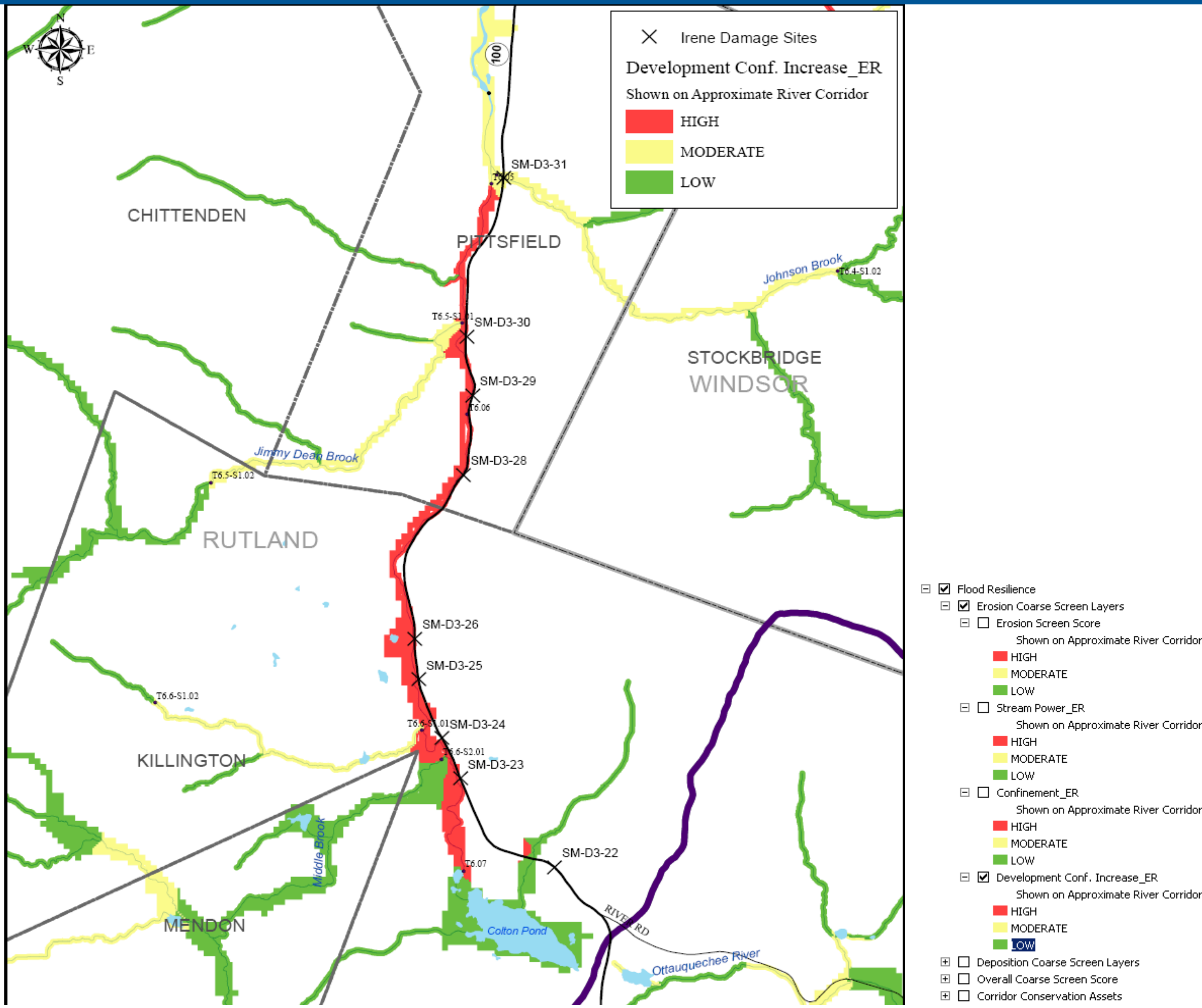
- Embankment fill
- Berm or levee

Confinement Increase due to Roads

(MacBroom, 2011)

Assessment / Geomorphic Characteristics

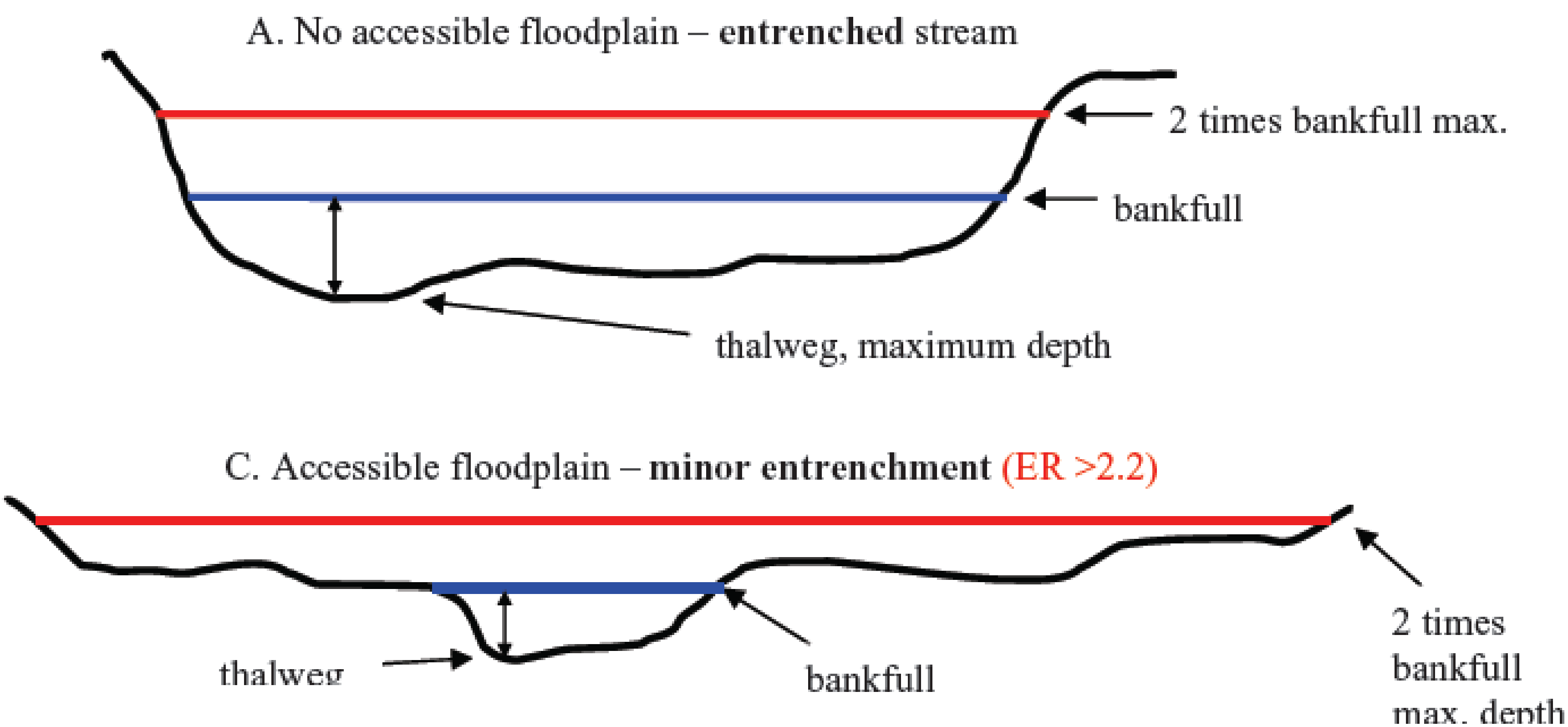
Confinement Increase due to Roads



(MMI, 2013)

Assessment / Geomorphic Characteristics

Entrenchment Ratio

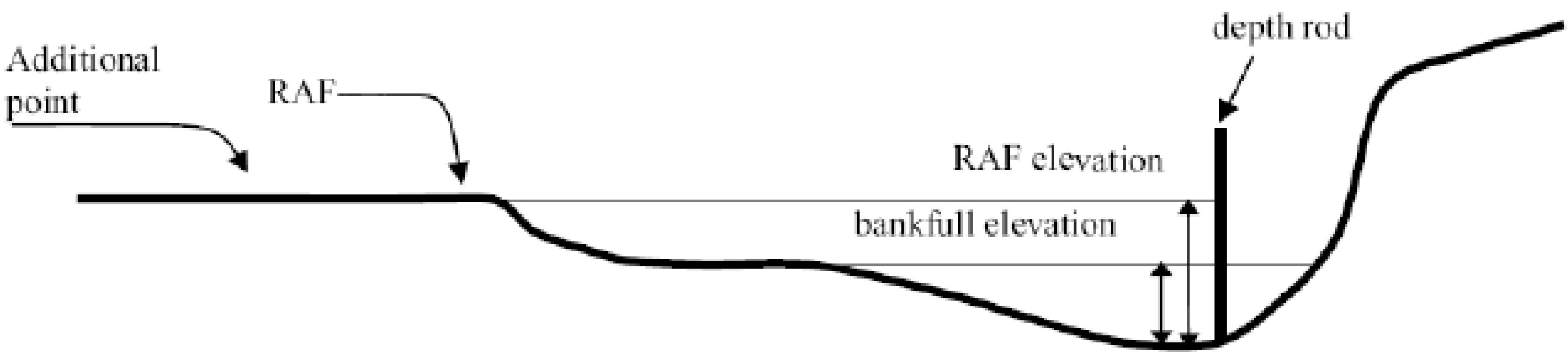


(VTANR, 2009)

Approximately the 50-year floodplain width

Incision Ratio

$$IR = \frac{\text{floodplain height}}{\text{bankfull height}}$$



(VTANR, 2009)

Incision Ratio

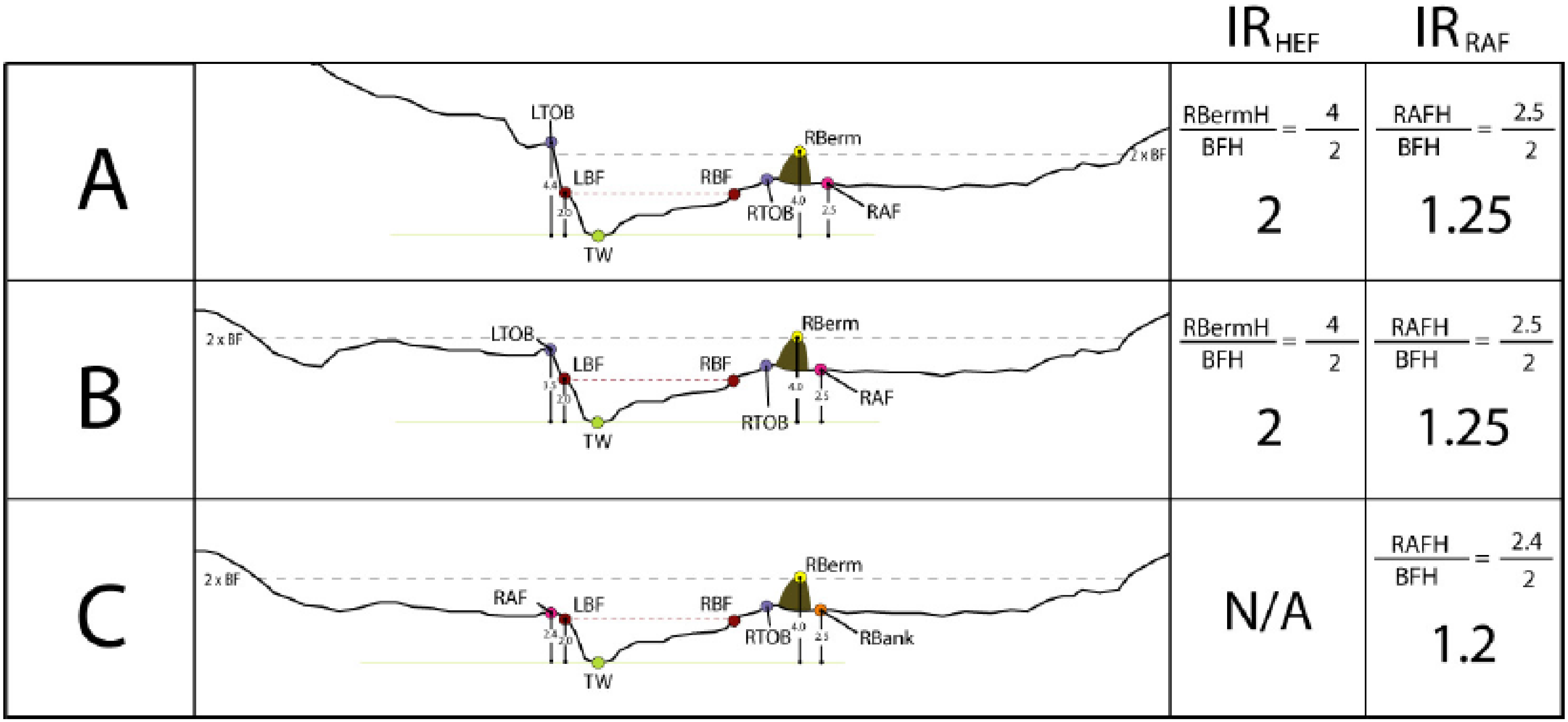
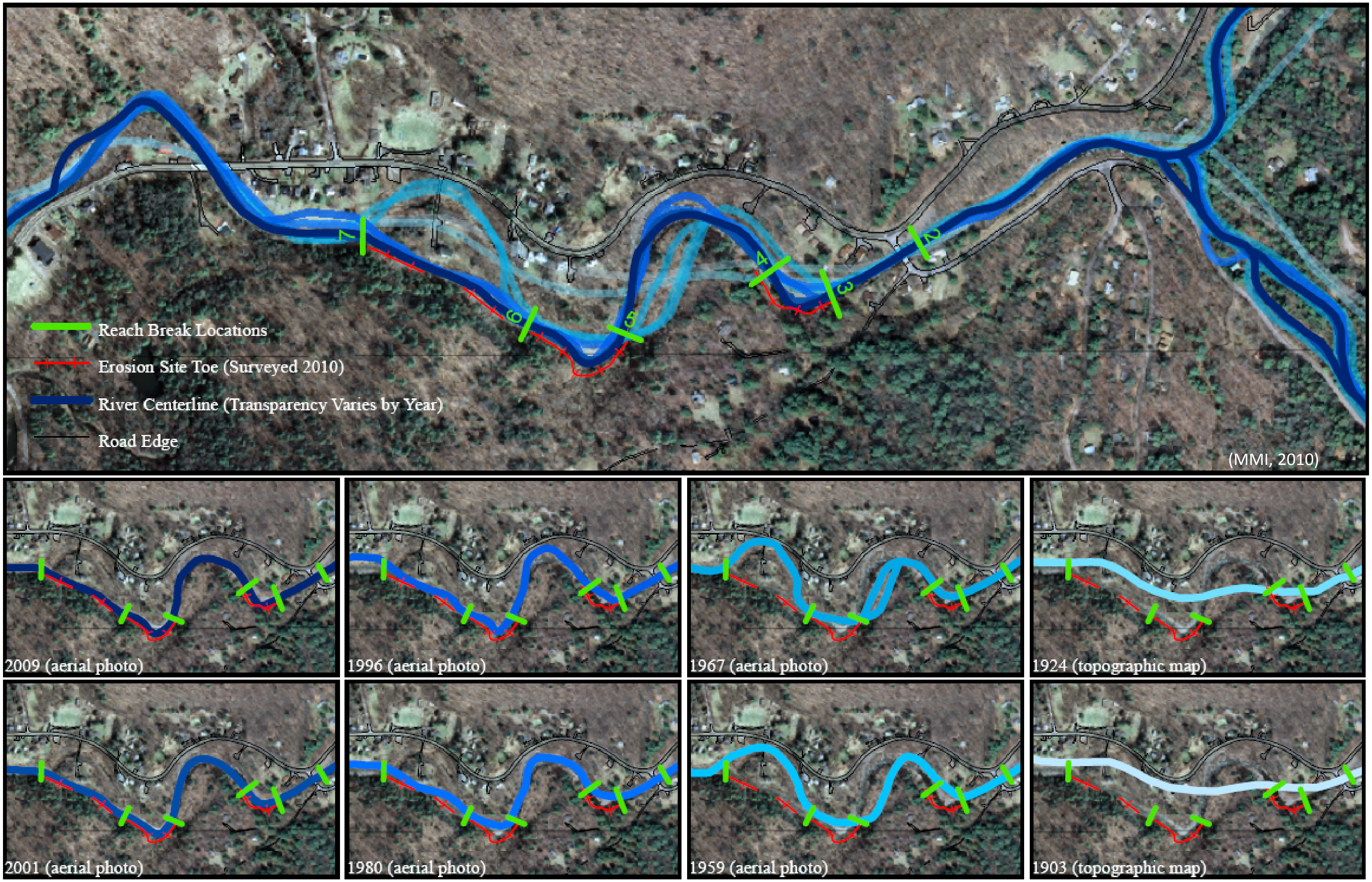


Figure caption: Three different cross section scenarios for a berm within the corridor. Labels are provided for the Left top of bank (LTOB), Left bankfull (LBF), Thalweg (TW), Right bank full (RBF), Right top of bank (RTOB), Right berm (RBerm), and the Right Bank (RBank). The solid green line represents the thalweg height. The red dashed line is equal to bankfull and the gray dashed line is equal to two times bankfull. Numbers represent heights (H) above the thalweg for each of the points.

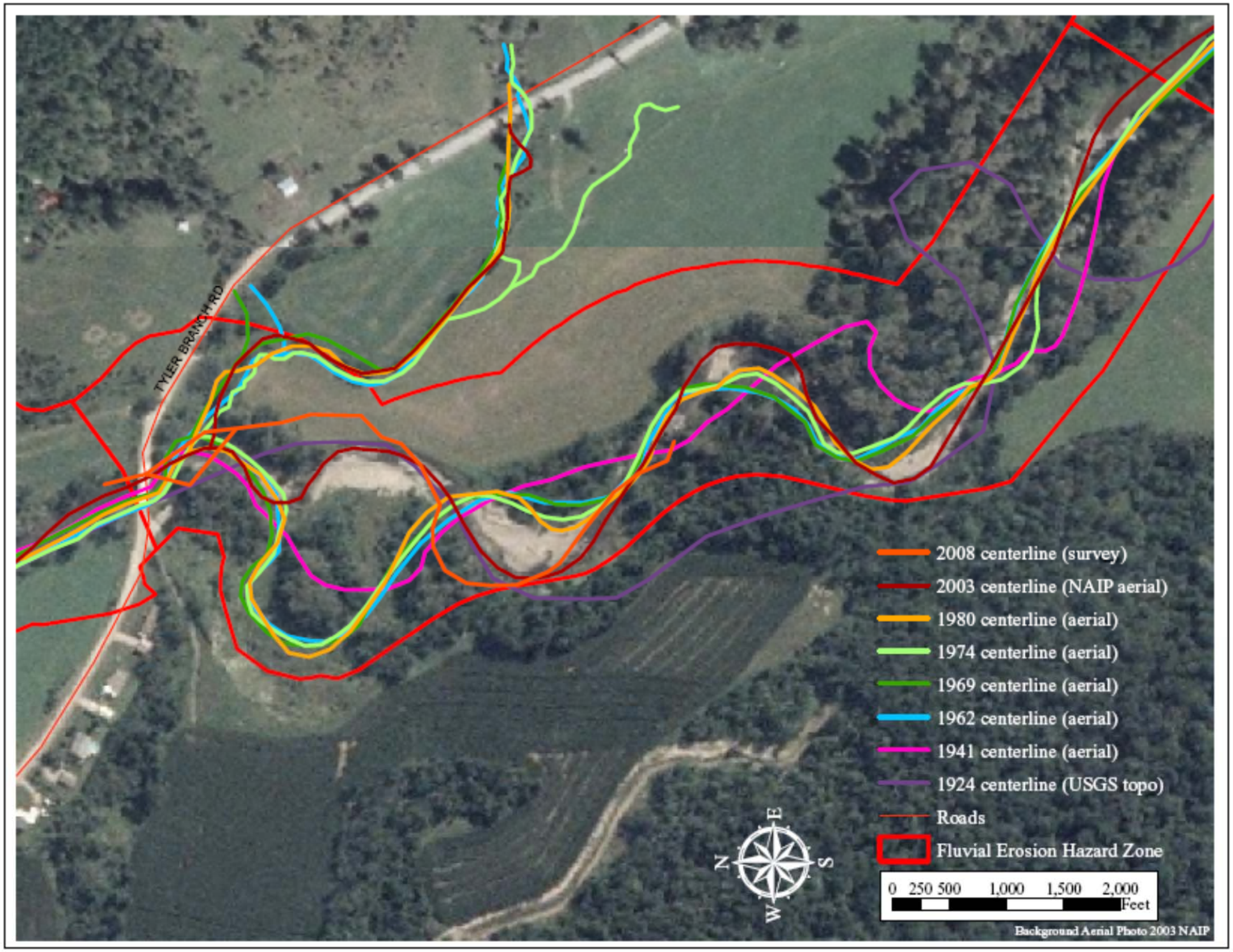
(VTANR, 2009)

Channel Dynamics



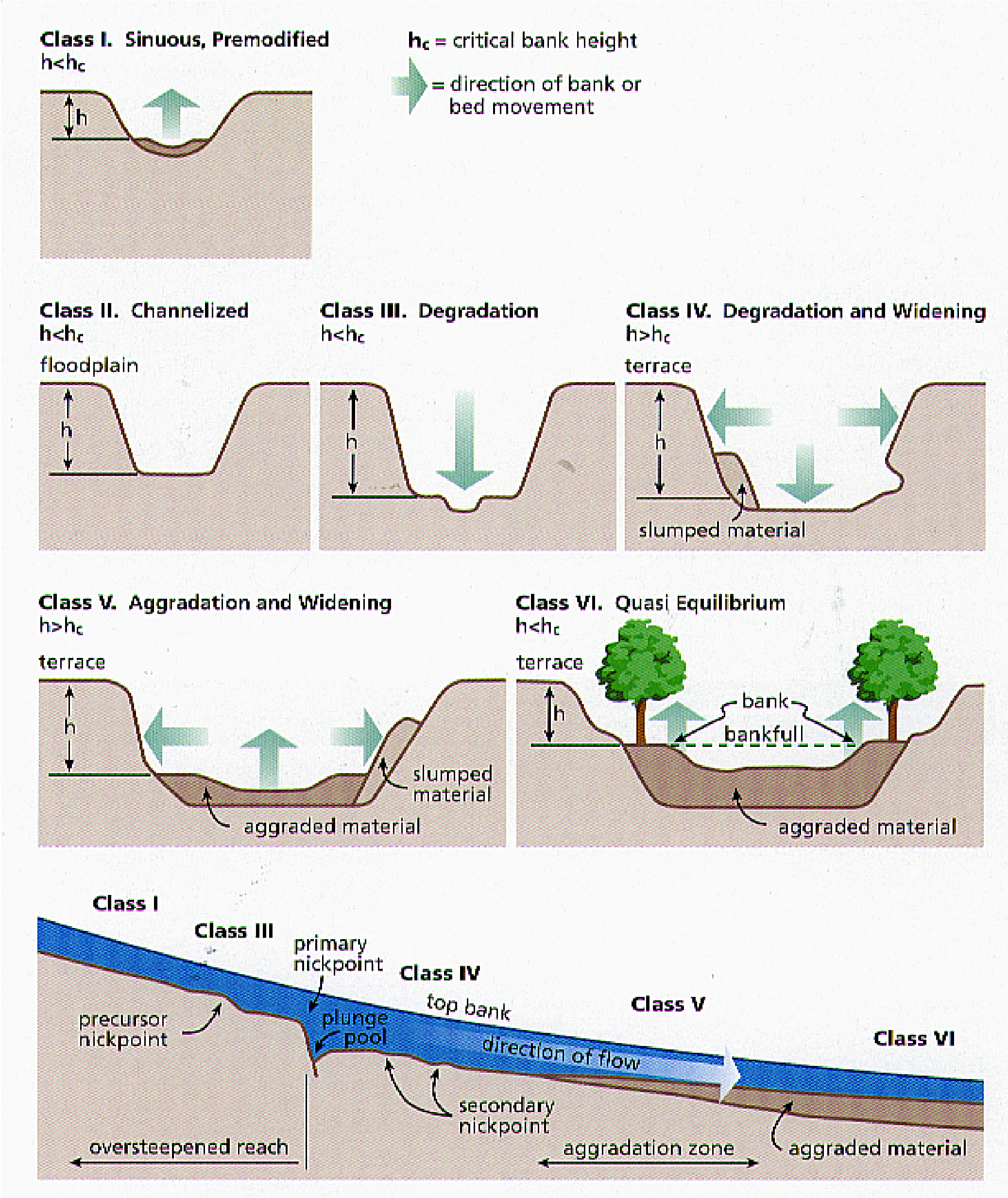
(MMI, 2011)

Channel Dynamics



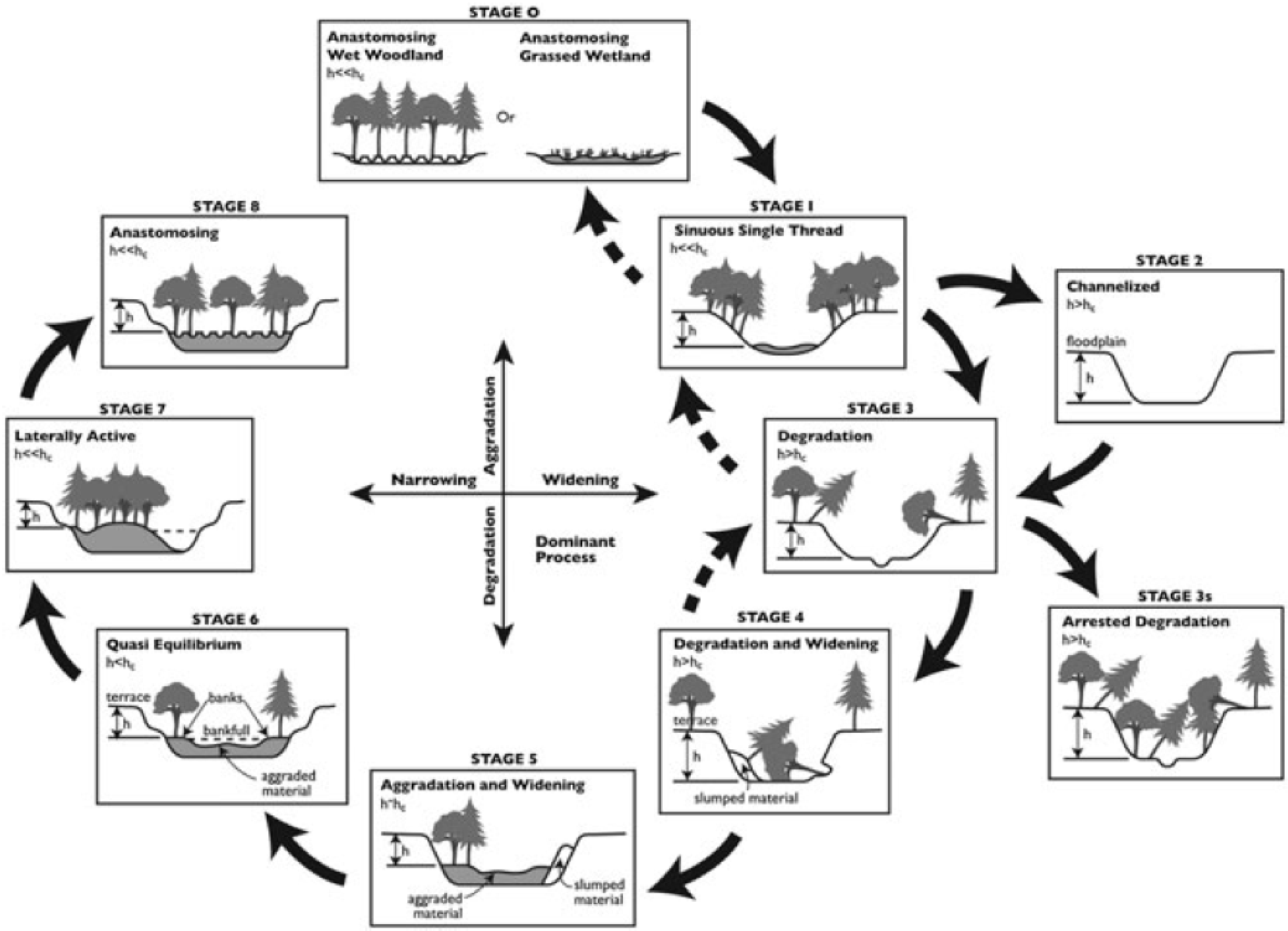
(MMI, 2009)

Identify the Likely Channel Evolution



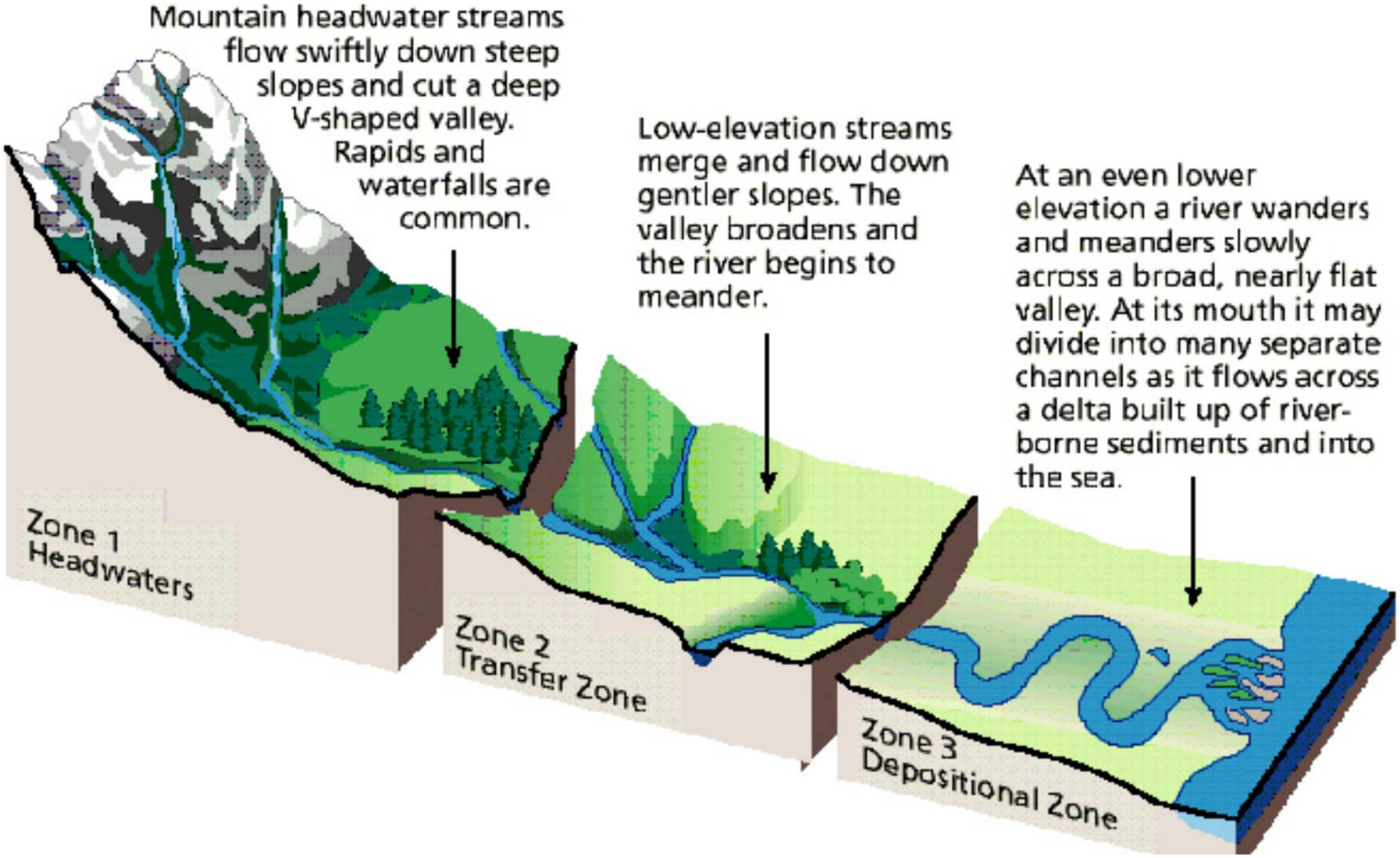
(Simon 1989; FISRWG, 1998)

Updated Channel Evolution Model



(Cluer and Thorne, 2013)

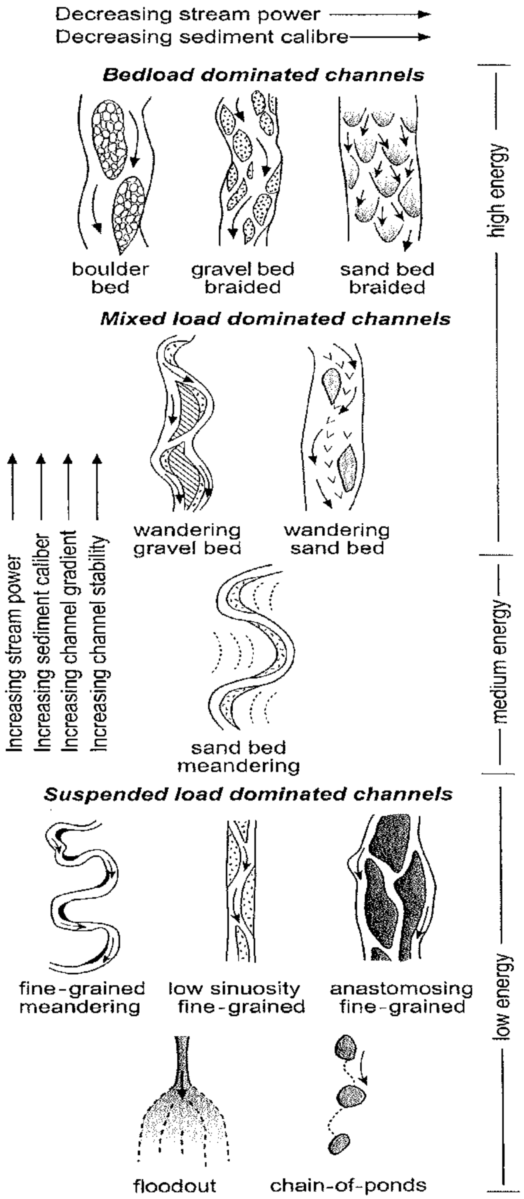
Watershed Position



(Schumm1977; FISRWG, 1998)

Stream Power

(Brierley and Fryirs, 2005)



Assessment / Geomorphic Characteristics

Total Stream Power (TSP) [W/m]

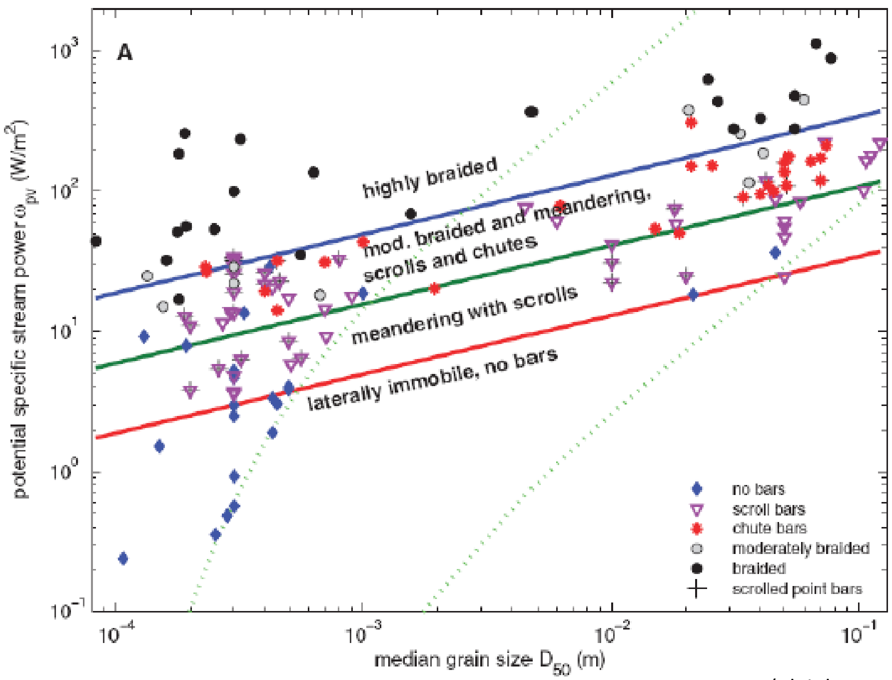
$$\Omega = \gamma * Q * S$$

(Bagnold, 1966)

Specific Stream Power (SSP) [W/m²]

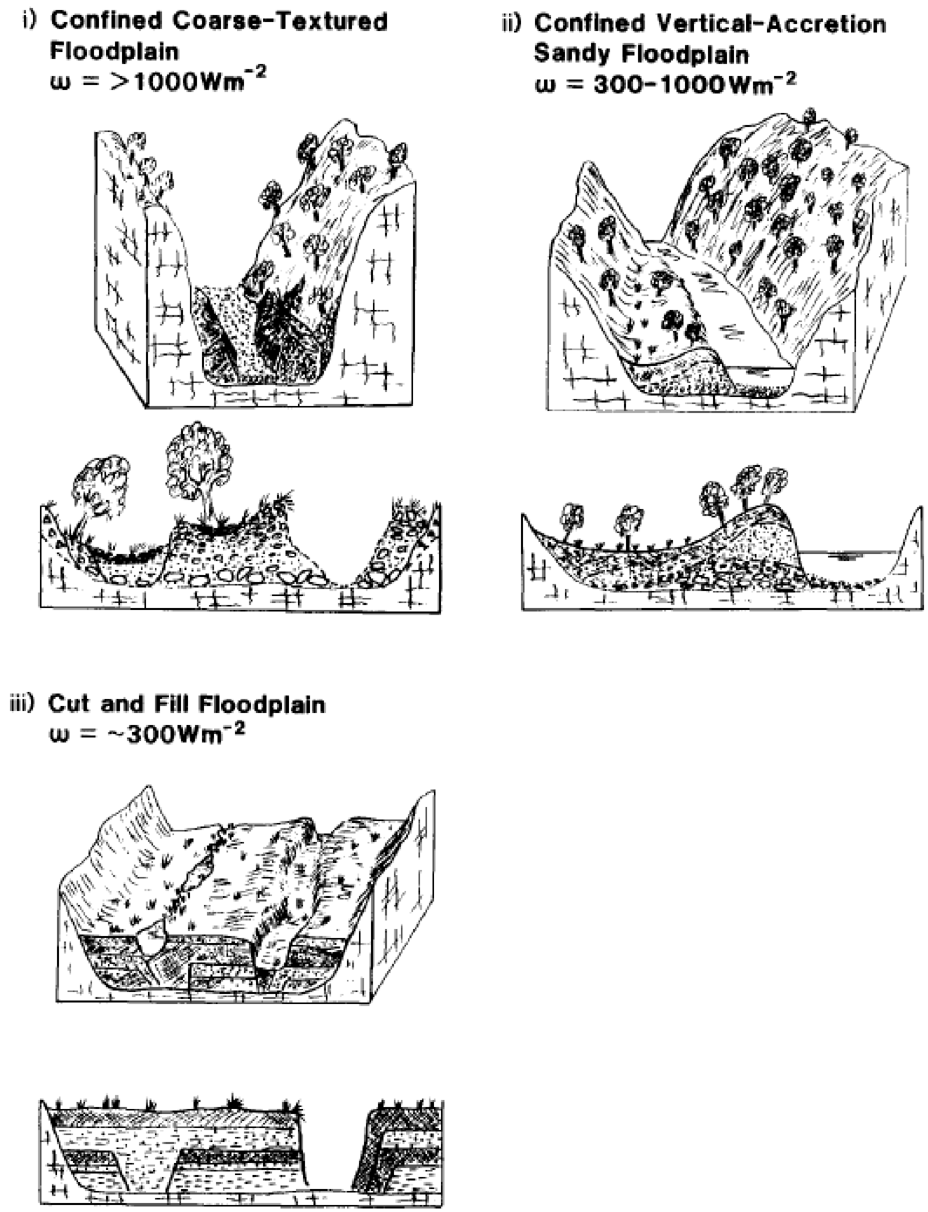
$$\omega = \gamma * Q * S / w$$

- Calculate D50 and specific stream power and use plot by (Kleinhans and van den Berg, 2011).



(Kleinhans and van den Berg, 2011)

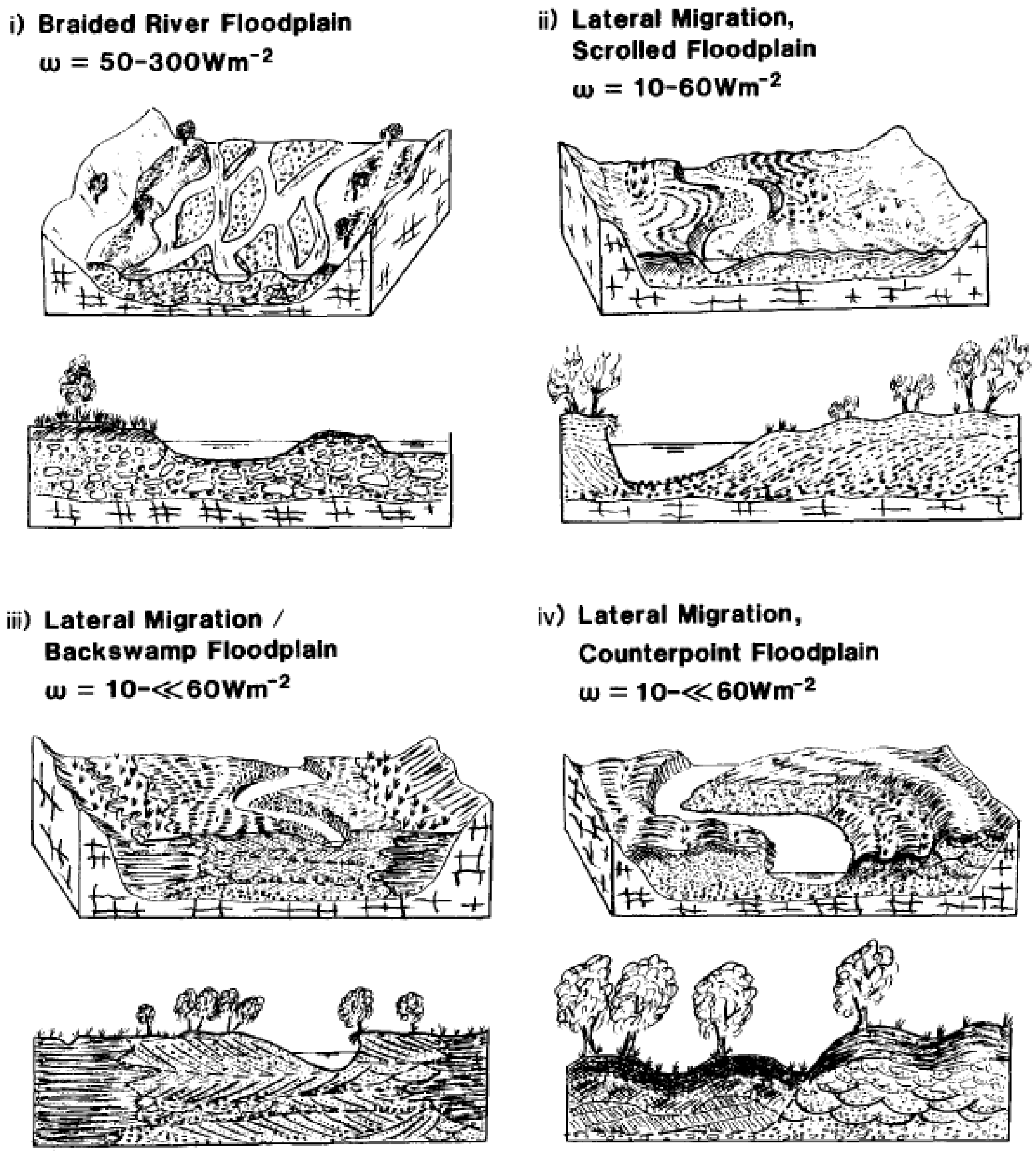
High-Energy Floodplains



(Nanson and Croke, 1992)


Assessment / Geomorphic Characteristics
Mendon Brook
Mendon, VT
9/1/2011

Medium-Energy Floodplains

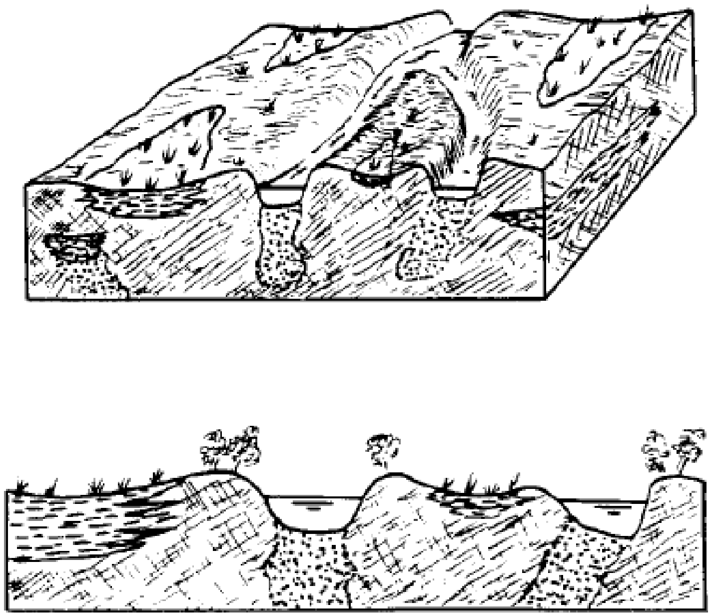


(Nanson and Croke, 1992)

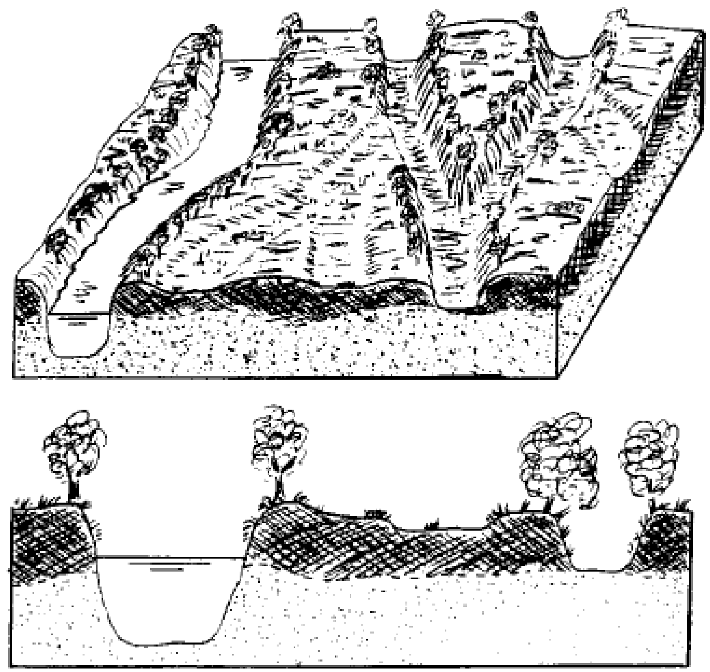

Assessment / Geomorphic Characteristics
Roaring Branch
Bennington, VT
9/1/2011

Low-Energy Floodplains

i) **Anastomosing River,**
Organic-Rich Floodplain
$\omega = <10Wm^{-2}$



ii) **Anastomosing River,**
Inorganic Floodplain
$\omega = <10Wm^{-2}$



(Nanson and Croke, 1992)

Assessment / Geomorphic Characteristics

Assessment – Identify Sediment Sources

Fulmer Creek
German Flatts, NY
(M. Carabetta, 2013)

Roaring Branch
Bennington, VT
(MMI, 2011)

Assessment – Identify Large Wood Sources

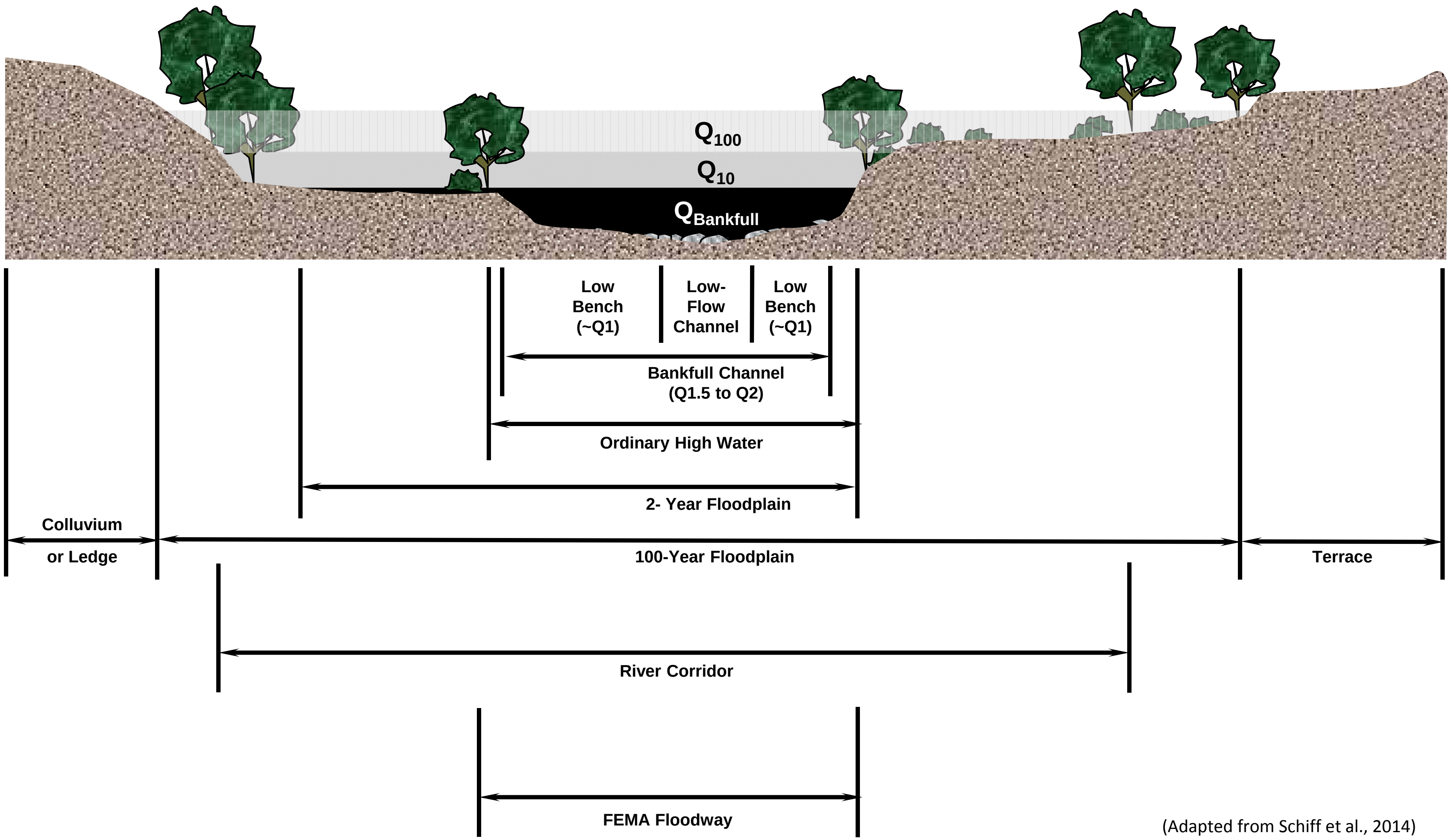
(O'Neil-Dunne and Ahles, 2015)

Assessment Review Questions

1. *Why is it important to know the confinement for floodplain restoration?*

2. *What role does channel evolution play in floodplain restoration design?*

Floodplain Dimensions



(Adapted from Schiff et al., 2014)

Design – Floodplain Dimensions

Design – Floodplain Width

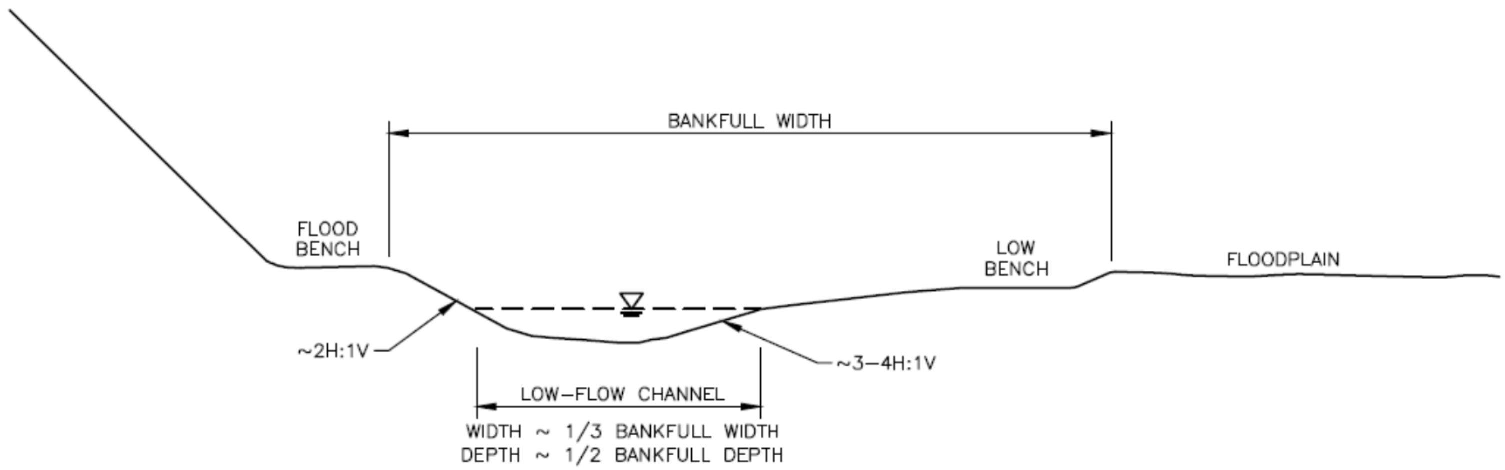
- Floodplain width on braided and alluvial fan channels should typically be as wide as possible until unmovable property exists.
- In settings that are naturally more confined, a reference cross section through a non-encroached portion of the valley is used to estimate floodplain width.
- Unconfined 100-year floodplain ~ 5 x bankfull width.

FLOODPLAIN WIDTH ALTERNATIVES

- Full width of the reference floodplain
- Partial width of the reference floodplain in the river corridor where the channel is most likely to meander
- Partial width of the reference floodplain if unmovable property exists
- Partial width of the reference floodplain to store water and sediment for a selected design storm
- Partial width of the reference floodplain set at the floodprone width.

(Adapted from Schiff et al., 2014)

Channel and Floodplain Cross Section



NOTES:

- MATCH LOW–FLOW CHANNEL DIMENSIONS FROM FIELD ASSESSMENT OF REFERENCE REACH
- LOW–FLOW CHANNEL SHOULD CONTAIN ~ 2X THE MEAN ANNUAL FLOW OR ~ 2 CFS PER SQUARE MILE OF WATERSHED
- BANKFULL CHANNEL SHOULD CONTAIN ~ 30 TO 40 CFS PER SQUARE MILE OF WATERSHED
- FLOOD BENCHES ARE NARROWER VERSIONS OF HYDROLOGICALLY–ACTIVE FLOODPLAINS
- MULTIPLE BENCHES MAY EXIST ON BENDS OR IN INCISED CHANNELS
- TERRACES MAY EXIST AT HIGHER ELEVATIONS THAT ARE ABANDONED AND NO LONGER HYDROLOGICALLY ACTIVE

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DATE	3/10/2014
SCALE	NOT TO SCALE
PROJ. NO.	4438-02
DESIGNED	FEA/JGM
DRAWN	RAD/JCL
CHECKED	RKS

TYPICAL CHANNEL CROSS SECTION

PROJECT PHASE:

DRAWING NAME:

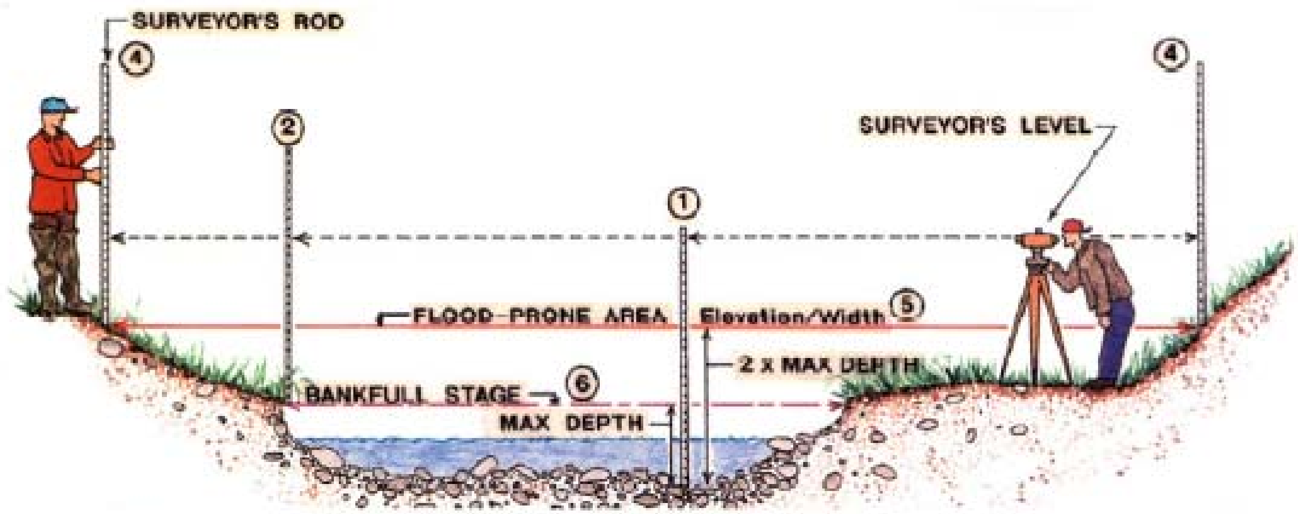
Design

(Schiff et al., 2014)

Floodprone Width

STEPS:

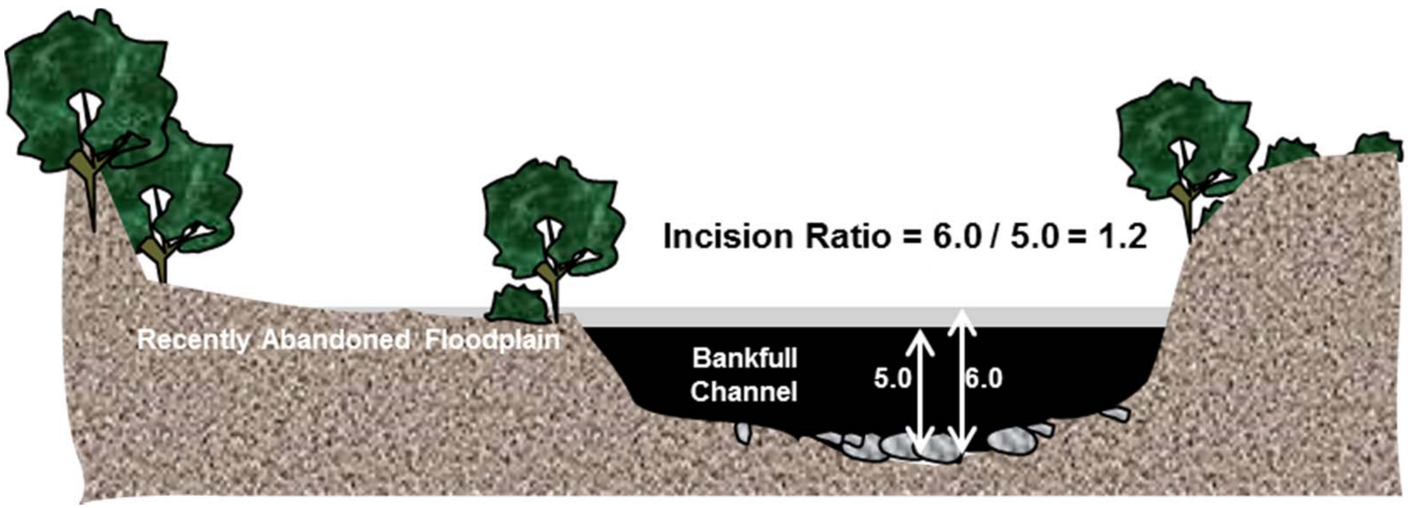
1. Obtain a ROD READING for an Elevation at the "MAX DEPTH" Location.
2. Obtain a ROD READING for an Elevation at the "BANKFULL STAGE" Location.
3. Subtract the "Step 2" reading from the "Step 1" reading to obtain a "MAX DEPTH" value; then multiply the Max. Depth Value times 2 for the "2x MAX. DEPTH" Value.
4. Subtract the "2x Max. Depth" value from the "Step 1 Rod Reading" for the FLOOD-PRONE AREA Location Rod Reading. Move the rod upslope, online with the cross-section, until a Rod Reading for the Flood-Prone Area Location is obtained.



5. Mark the Flood-Prone Area locations on each bank. Measure the DISTANCE between the two "FPA" locations.
6. Determine the DISTANCE between the two BANKFULL Stage locations.
7. Divide the "FPA" WIDTH by the "BANKFULL" WIDTH to calculate the ENTRENCHMENT RATIO.

(Rosgen, 1996)

Design – Floodplain Elevation



- Properly selecting the floodplain elevation relative to the channel elevation is critical to reducing future flood and erosion risks.
- Vertical relief between the channel and floodplain surface should be set to allow floodplain inundation once every 1 to 2 years, where possible.

(Schiff et al., 2014)

Design – Benches and Chutes

Type	Inundation Level	Purpose
Low Bench	<Q1.5	Create bedforms and bars, and sediment transport in channel. Maintain instream habitat. Form low-flow channel.
Flood Bench	Q1.5 to Q10	Increased flood and sediment conveyance and storage areas, especially in confined settings.

- The flood bench elevation can be set higher for less inundation in locations where unmovable property exists adjacent to the bankfull channel and where hydraulic and sediment transport analyses show that flood and erosion risks are not increased.
- Benching in channels with nearby development is often performed in conjunction with lateral bank and vertical bed stabilization.
- Chute inundation frequency is set at one time in 2 years to one time in 10 years.

(Adapted from Schiff et al., 2014)

Design – Floodplain Length and Slope

- The length of floodplain restoration projects is often determined by using the available space around remaining infrastructure and improved property. The length of restored floodplains can vary widely based on site conditions.

- The floodplain should also slope down-valley approximately matching the valley slope.

- The restored floodplain should slope toward the river channel slightly (0.25% to 1%).

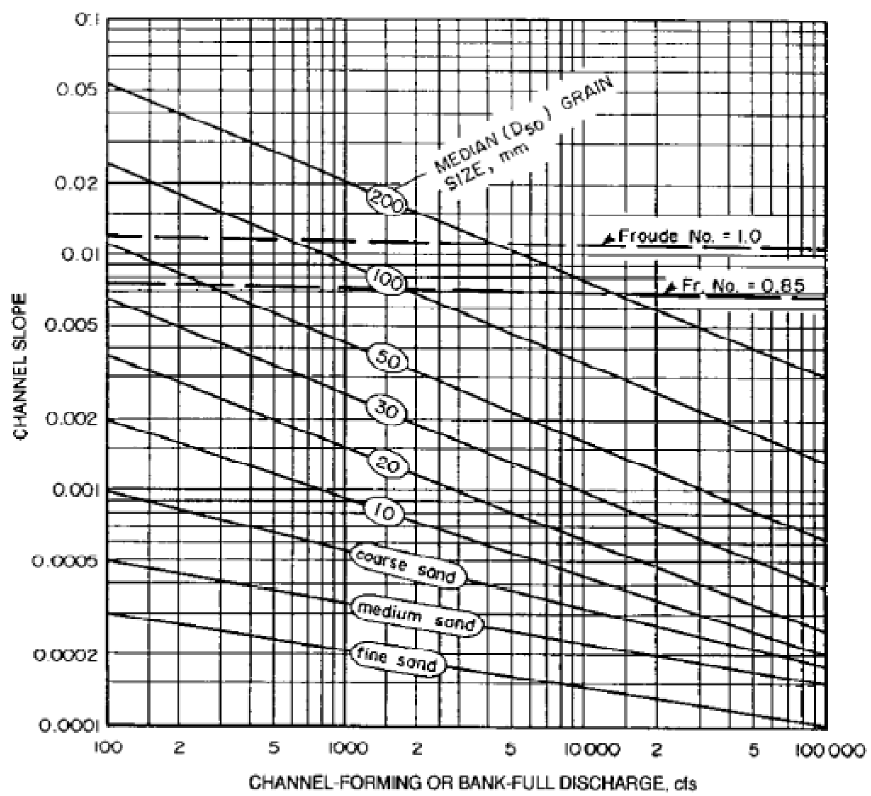
(Adapted from Schiff et al., 2014)

Setting the Channel Slope – Regime

USACE Stable Channel Design Charts (USACE, 1994)

d50 = ______mm median particle size
Qbf= ______cfs bankfull flow

Identify slope (%), bankfull width (ft), bankfull depth (ft)

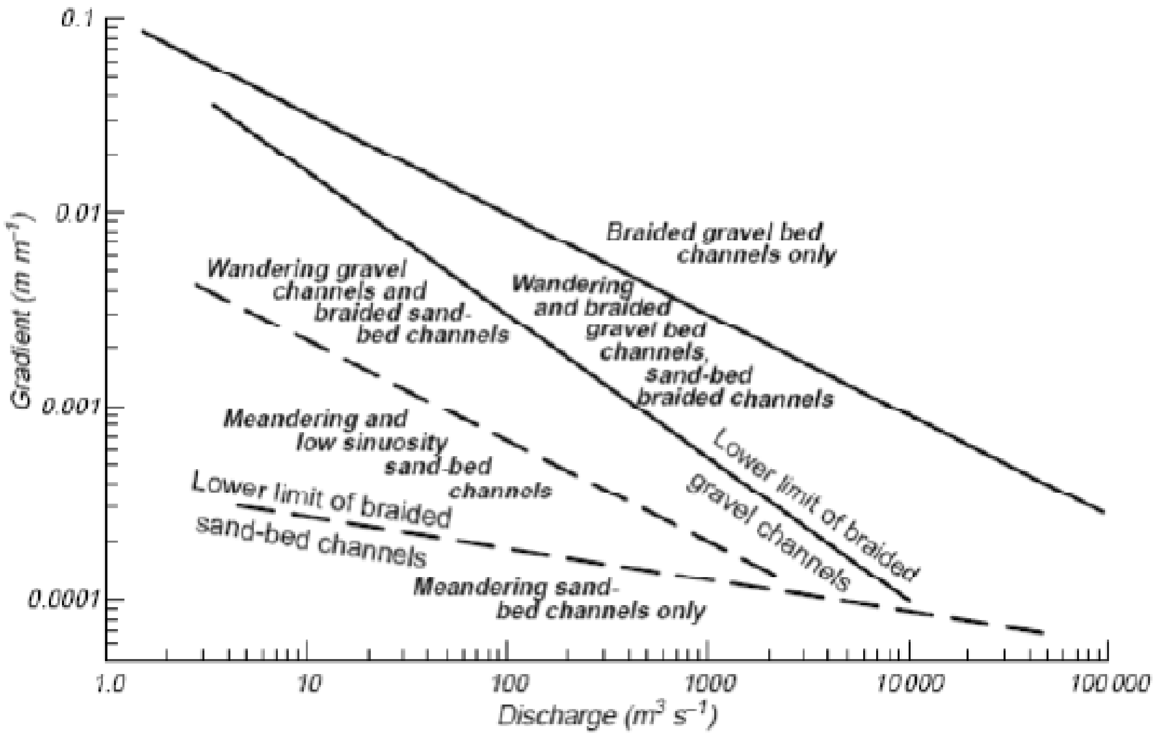


NOTE: FOR LIMITATIONS SEE PARAGRAPH 5.5. CURVES ARE BASICALLY FOR SINGLE CHANNELS WITH FULLY ALLUVIAL BED BUT LOW BED SEDIMENT TRANSPORT. SLOPES MAY BE MUCH HIGHER WITH HIGH SEDIMENT TRANSPORT, ESPECIALLY WITH SAND BEDS.

(USACE, 1994)

Design – Channel Pattern and Dynamics

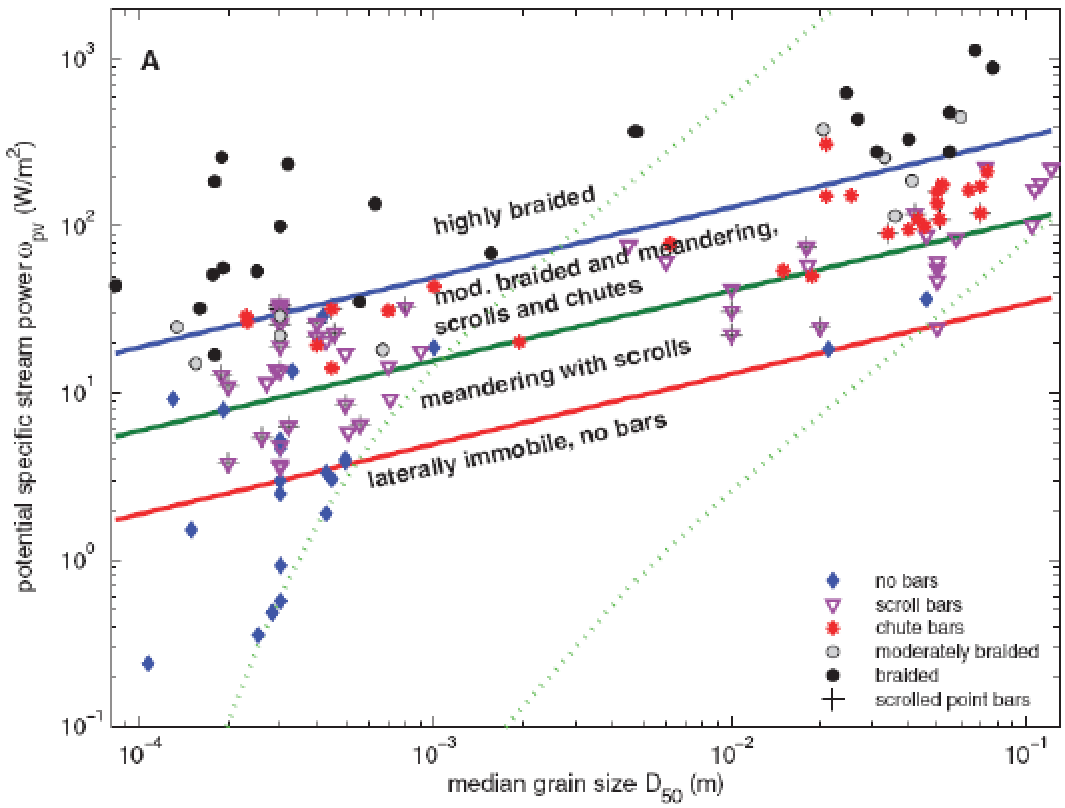
- Measure channel slope and bankfull (or mean annual) flow in metric units and use plot by (Church, 2002).



(Church, 2002)

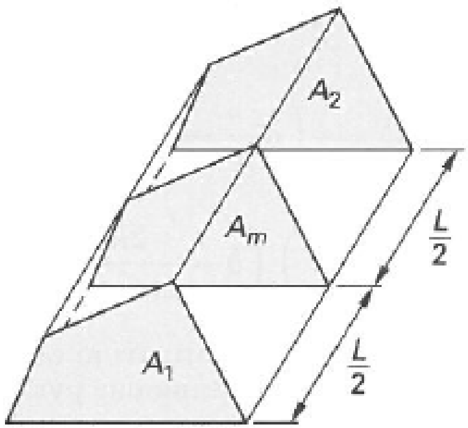
Design – Channel Pattern and Dynamics

- Calculate D50 and specific stream power and use plot by (Kleinhans and van den Berg, 2011).



(Kleinhans and van den Berg, 2011)

Design – Excavation Volume Estimation

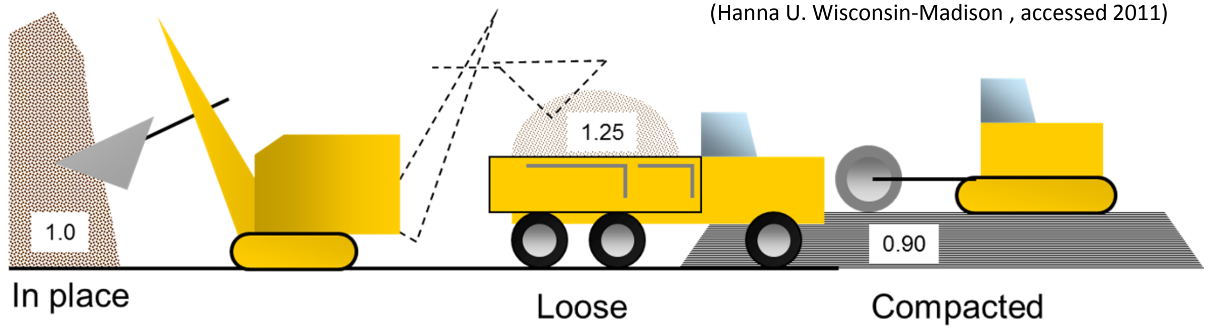


$$V = \frac{L(A_1 + A_2)}{2}$$

(Lindeburg, 2003)

1.0 CUBIC YARD IN NATURAL CONDITION (IN-PLACE YARD) = 1.25 CUBIC YARD AFTER DIGGING (LOOSE YARDS) = 0.90 CUBIC YARD AFTER COMPACTED (COMPACTED YARDS)

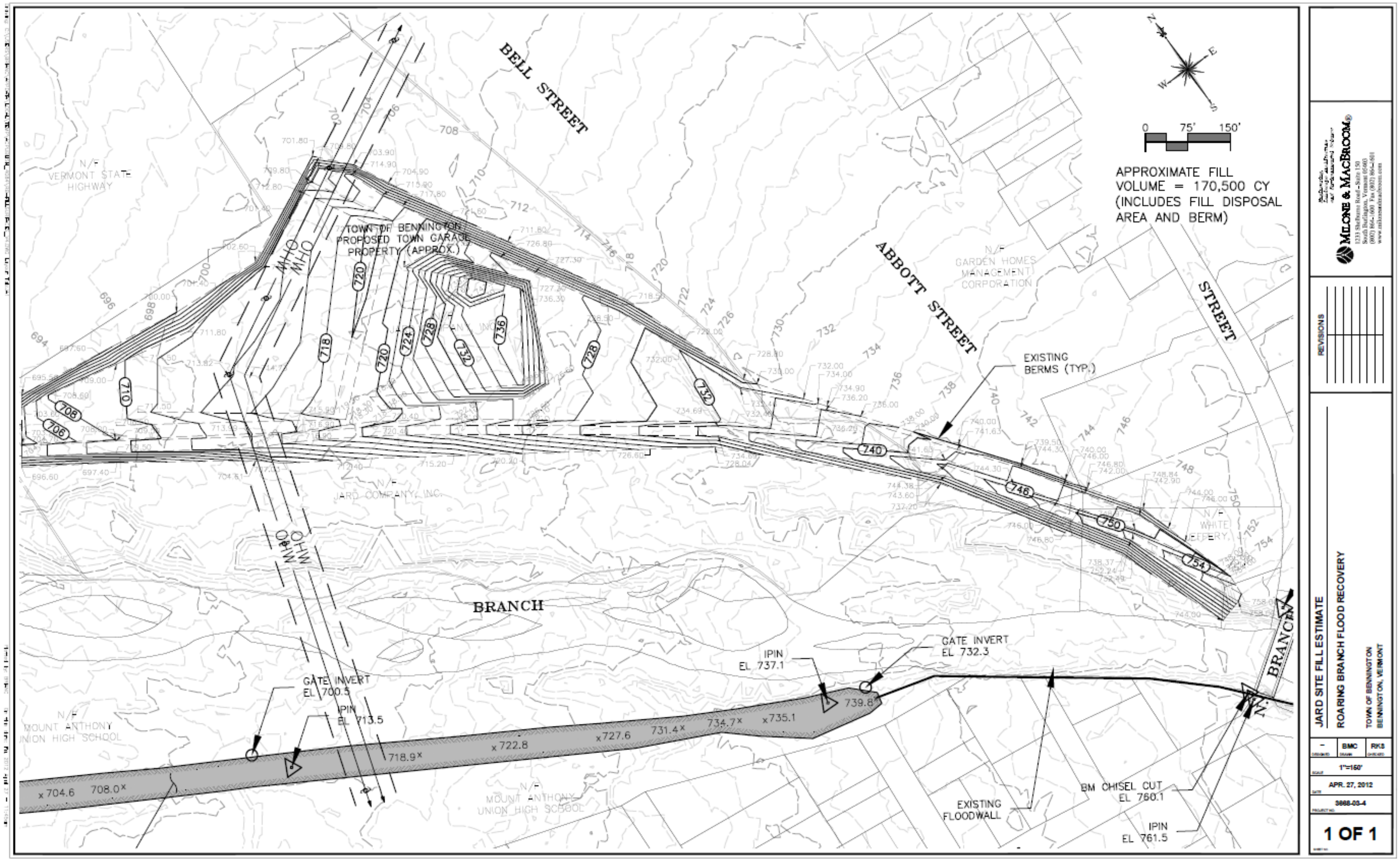
(Hanna U. Wisconsin-Madison , accessed 2011)



Soil Type	Initial Soil Condition	Bank	Convrted to: Loose	Compacted
Clay	Bank	1.00	1.27	0.90
	Loose	0.79	1.00	0.71
	Compacted	1.11	1.41	1.00
Common earth	Bank	1.00	1.25	0.90
	Loose	0.80	1.00	0.72
	Compacted	1.11	1.39	1.00
Rock (blasted)	Bank	1.00	1.50	1.30
	Loose	0.67	1.00	0.87
	Compacted	0.77	1.15	1.00
Sand	Bank	1.00	1.12	0.95
	Loose	0.89	1.00	0.85
	Compacted	1.05	1.18	1.00

Design – Fill Disposal Areas

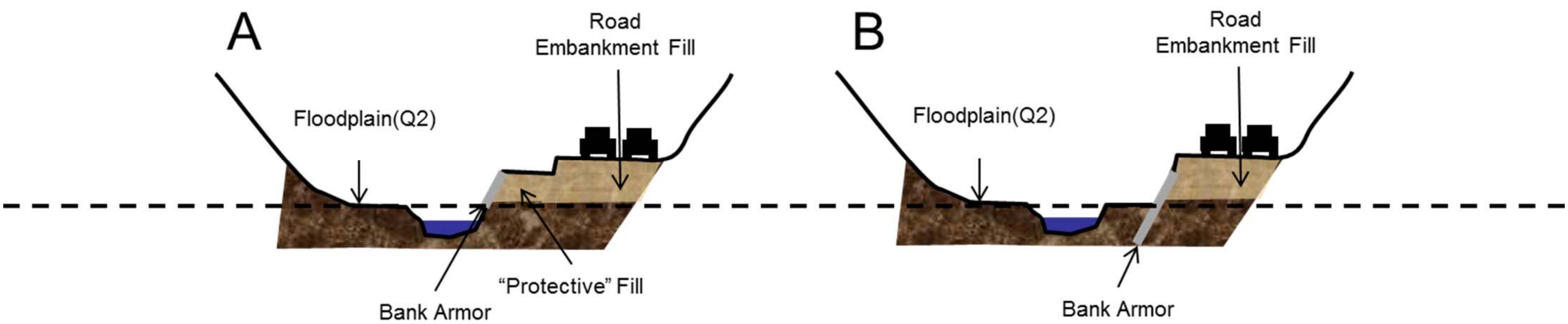
(MMI, 2011)



Design

(MMI, 2012)

The “Floodplain Paradox”

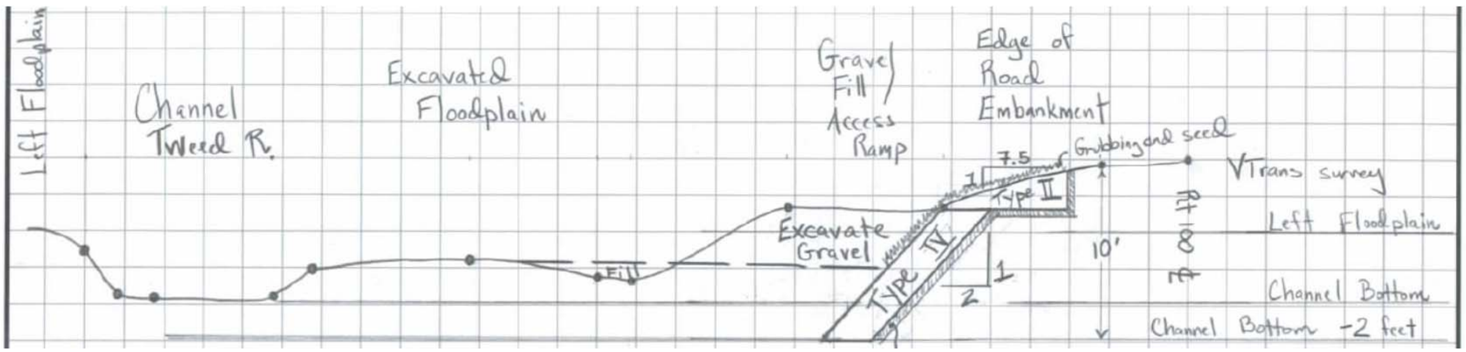


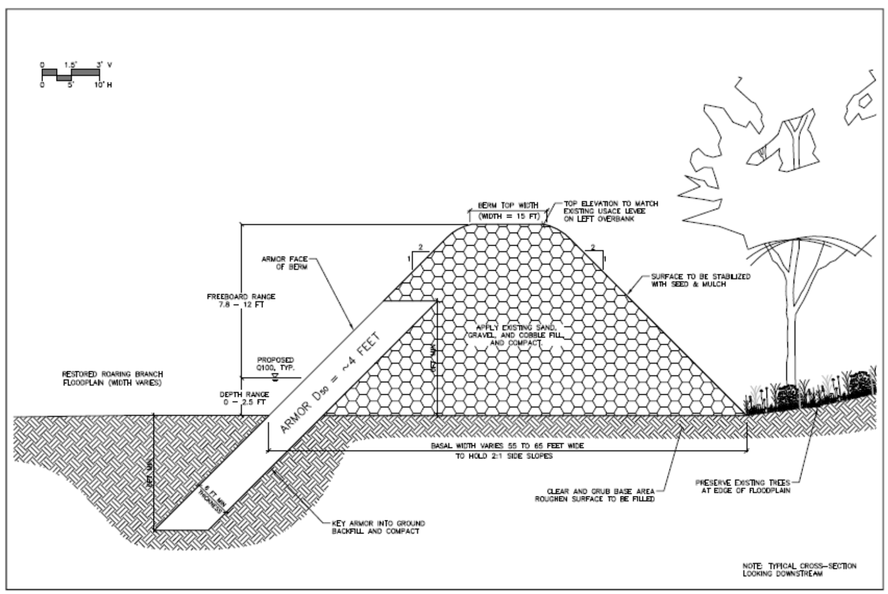
- Fill in the floodplain that appears to be protecting adjacent property (A) actually increases flood and erosion risks since the fill narrows the channel and floodplain (i.e., the "floodplain paradox").
- Place stabilization measures immediately adjacent to property and remove intervening floodplain fill where possible (B).

(Adapted from Schiff et al., 2014)

Design – Bank Stabilization

- Floodplain restoration, particularly in confined settings, typically includes bank stabilization at the upgradient or back edge of the floodplain to protect adjacent property.

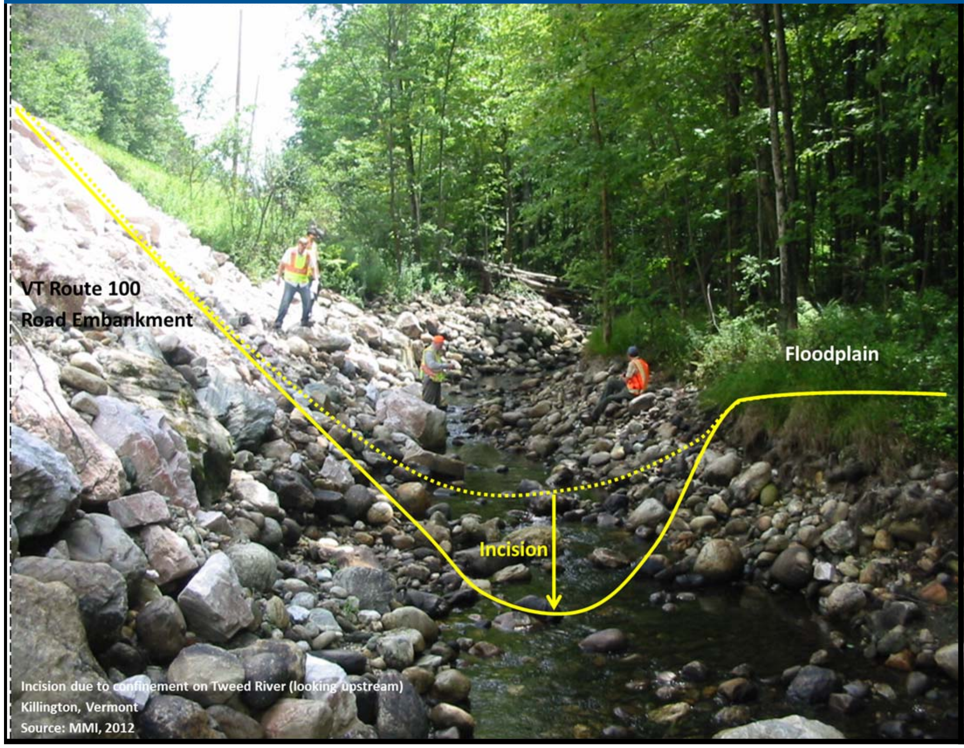




PROPOSED BERM DETAIL:
1" = 3' V : 1" = 10' H

(MMI, 2010)

Design – Channel Bed Stabilization



- Where channel evolution stage is II or III or where incision ratio is larger than 2 after floodplain restoration, vertical bed stabilization may be required to maintain floodplain connection over the long term. Vertical stability may also be required for lateral stability to prevent undermining of the banks.

(MMI and FEA, 2012)

Summary – Floodplain Restoration Design

Assessment

- Site constraints
- Existing floodplain dimensions
- Confinement ratio
- Floodplain connectivity
  - Entrenchment ratio
  - Incision ratio
- Stage of channel evolution
- Floodplain power setting
- Sediment and large wood

Channel

- Floodplain width and elevation
- Floodplain length and slope
- Channel pattern and dynamics
- Excavation volume
- Fill disposal
- Lateral and vertical stabilization measures, if required

Floodplain Restoration Design Objectives

- Restore as much floodplain as possible given site constraints. Maximize the width of flooding in unconfined valley settings.
- Re-establish floodplain dimensions based on reference conditions in the river corridor and valley.
- Target channel incision ratio is 1.0 to 1.2.
- Restore floodplains to inundate during the 1- or 2-year flood.
- Avoid rapid flood width expansions and contractions that could lead to severe erosion or aggradation.
- Maintain or re-establish native vegetation and roughness along banks and floodplain.
- Consider stage of channel evolution.
- Plan for future sediment deposition to reduce channel incision maintaining floodplain access as much as possible.
- Move structures and infrastructure out of floodplain as possible.
- Remove excavated material from floodplain.
- Retain standing trees as possible.

(Schiff et al., 2014)

Floodplain Restoration Design Limitations

- Permanent infrastructure that exists in the floodplain often limits the extent of floodplain restoration.
- Protection from flood and erosion is typically required on the upgradient side of the floodplain to protect remaining infrastructure.
- Large and costly excavation projects.
- Large sediment disposal areas that meet local, state, and federal regulations are required for construction.
- Floodplain restoration can be in conflict with anticipated land uses and can be perceived as a loss of useful land.

(Schiff et al., 2014)

Bench and Chute Restoration Design Objectives

- Form a low-flow channel and establish bankfull channel dimensions.
- Restore as much floodprone area as possible.
- Benches should be designed to inundate annually or up to once in 10 years depending on their location and function.
- Flood chutes should be designed to inundate once in 1, 2, 5, or 10 years depending on site conditions.
- Avoid rapid flood width expansions and contractions that could lead to excessive erosion or aggradation.
- Maintain or re-establish native vegetation and roughness in benches and chutes.
- Consider the stage of channel evolution.
- Evaluate avulsion potential when reconnecting flood chutes.
- Plan for future sediment deposition.
- Remove excavated material from floodplain.
- Retain standing trees.

(Schiff et al., 2014)

Bench and Chute Restoration Design Limitations

- Permanent infrastructure that exists in the river corridor often limits the potential for restoring flood benches and flood chutes.
- Protection from flood and erosion is often required on the upgradient side of restored flood benches to protect remaining infrastructure.
- A suitable sediment disposal area that meets local, state, and federal regulations is required.
- River channels in an active state of incision may require bed stabilization in conjunction with flood bench and flood chute restoration.

(Schiff et al., 2014)

Design Review Questions

1. *When would bank or channel bed stabilization be needed in conjunction with floodplain restoration?*
2. *What is the "floodplain paradox?"*
3. *How do you set the width of the floodplain?*

Permitting Requirements

- U.S. Army Corps of Engineers (CWA Section 404 and 401)
  - Quantify length, area, and volume of disturbance below ordinary high water (OHW)
  - Identify reporting category
  - Contact Field Office
- Vermont Stream Alteration Permit
  - Meet Performance Standards as identified above
  - Emergency protective measures locally approved to reduce risk to life
  - Contact river management engineer
- Vermont River Corridor and Floodplain Protection
- Vermont Wetlands Permit
- New York Article 15 Protection of Waters Permit
  - Emergency Authorization for quick review in emergency
  - General Permit for Disaster Recovery for longer timeframes
- Adirondack Park Agency
  - Bank stabilization projects jurisdictional if area exceeds 100 square feet
  - In-stream rock/log vanes are not jurisdictional
- Local Permits
  - FEMA National Flood Insurance Program criteria
  - Wetlands (NY)
  - Contact Town Administrator for reporting needs

Construction

Constructability

- Call before you dig to identify and avoid utilities.
- Know where structure foundations area located.
- Identify property lines and right-of-ways.
- Typically performed in nonemergency settings.
- Potential winter work if away from channel.

Temporary Construction Controls

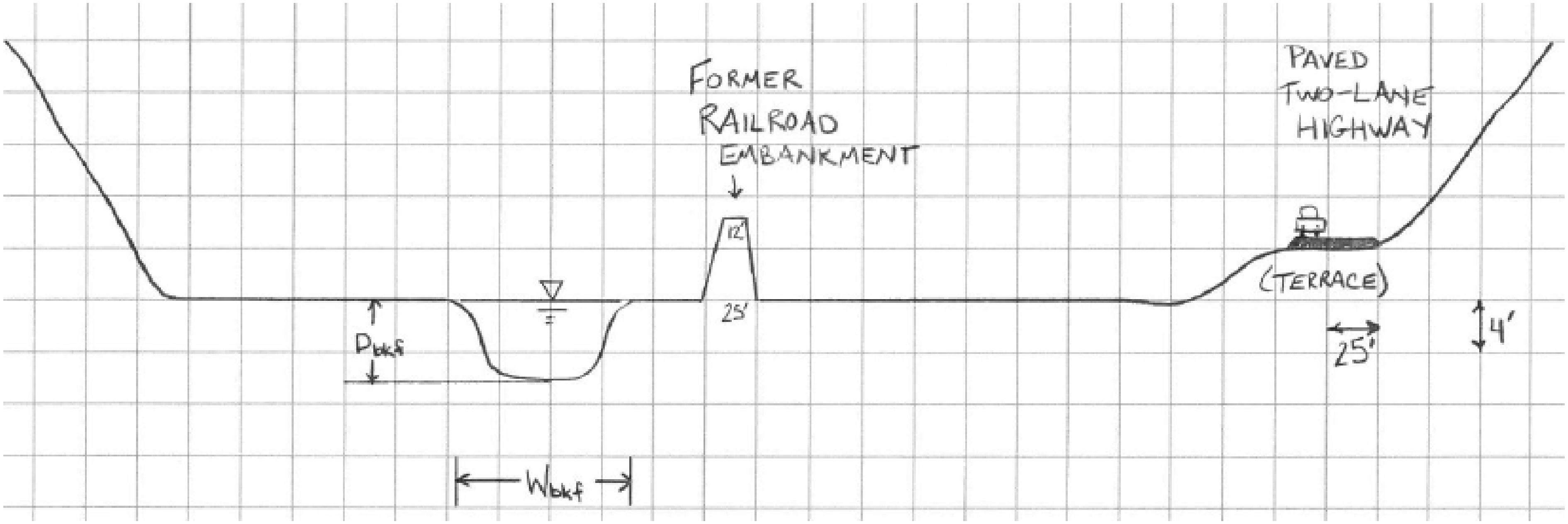
- Clearly establish work limits and review with operators.
- Install safety fencing and signs to guide post-flood wanderings.
- Plan work to isolate impacts from channel.
- Install silt fencing as needed to control runoff when ground not flat.
- Truck crossings need to be reinforced with stone or operated in the dry with culverts to reduce downstream turbidity.
- Conduct site restoration. Vegetate floodplain to slow overland flow, create roughness for sediment capture, and to promote nutrient uptake.

Design Exercise 1

- *A floodplain is cutoff by an abandoned railroad embankment.*
- *The embankment is made of earthen fill.*
- *The disconnected floodplain extends over 1,000 feet.*
- *A paved highway exists at the back edge of the disconnected floodplain.*
- *The channel has a slope of 0.05% and meanders through the floodplain.*
- *Channel evolution model stage III.*

1. *What is the level of confinement?*
2. *Describe the existing and proposed floodplain connectivity (ER and IR).*
3. *What is the energy setting on the floodplain?*
4. *What is the trajectory for the channel (and floodplain)?*
5. *Select a floodplain restoration alternative and dimensions.*
6. *Estimate the excavation volume [cubic yards]. Consider hauling amount and placement amount.*
7. *Are any stabilization measures needed?*

Design Exercise 1 Cross Section



Design Exercise 1 Solution

ANSWERS ①.

1. $CR = \frac{(20 \times 25')}{(3 \times 25')} \cong 7$ broad, expect wide floodplain

2. $ER = \frac{(11.5 \times 25')}{3 \times 25'} = 3.8$ minor entrenchment, broad floodplain expected

$IR_{RAF} = 6/6 = 1.0$ $IR_{HEF\ berm} = 12/6 = 2.0$ ~half floodplain blocked

3. Flat, low-energy channel / floodplain setting naturally.

4. CEM = 3, so prone to widening

5. Set dimensions to full floodplain width. Hold existing elevation. Simply remove berm.

6. $\forall_{fill} = 2{,}640' \times \frac{1}{2} 6' (25' + 12') = 293{,}040$ CF $= 10{,}853$ CY
$\forall_{loose}$ (truck) $= 13{,}567$ CY $\forall_{compacted}$ (place) $= 9{,}768$ CY

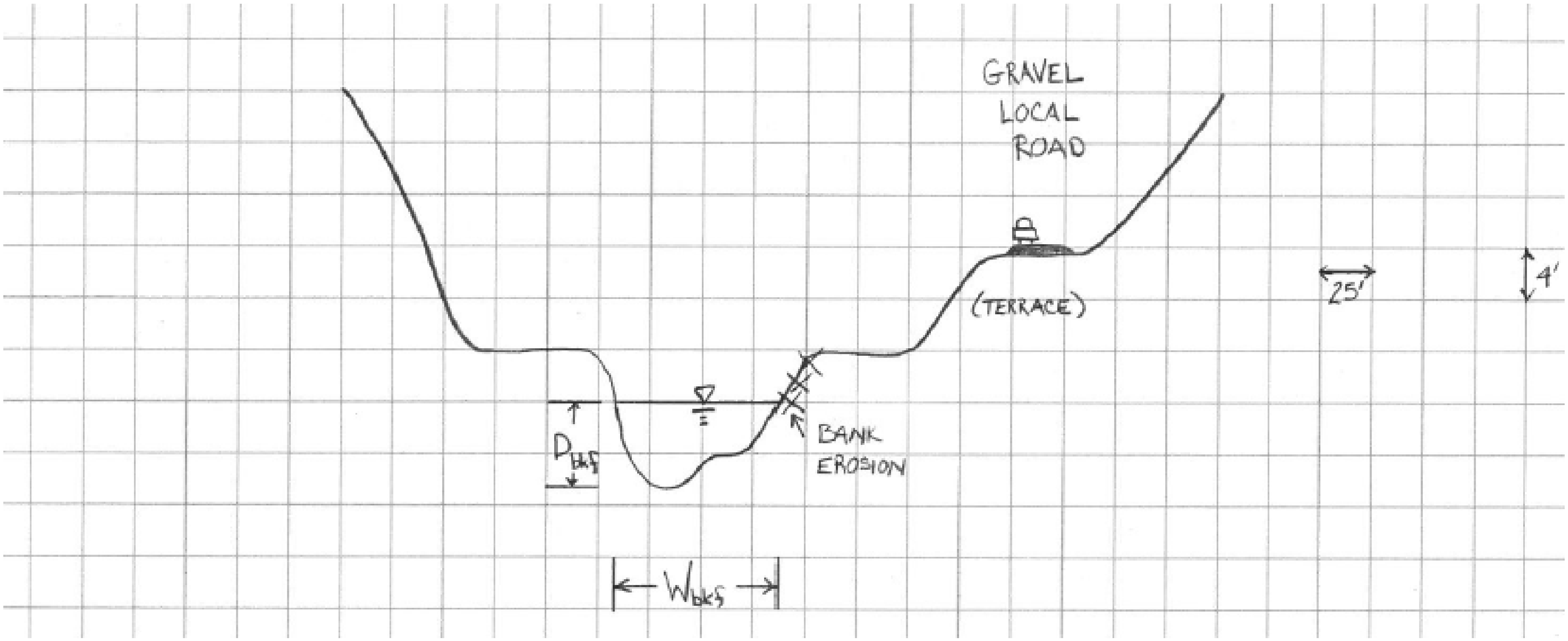
7. Place armor on road. Low incision potential so no deep key needed.

Design Exercise 2

- *A channel has cut down and has reduced connection to narrow floodplains.*
- *The disconnected flood benches extend over 1,000 feet.*
- *A local gravel road exists on a terrace, and fill between the road embankment and the channel is starting to erode.*
- *The channel has a slope of 3.5% and travels through the narrow valley.*
- *Channel evolution model stage III.*

1. *What is the level of confinement?*
2. *Describe the existing and proposed floodplain connectivity (ER and IR).*
3. *What is the energy setting on the floodplain?*
4. *What is the trajectory for the channel (and floodplain)?*
5. *Select a floodplain restoration alternative and dimensions.*
6. *Estimate the excavation volume [cubic yards]. Consider hauling amount and placement amount.*
7. *Are any stabilization measures needed?*

Design Exercise 2 Cross Section



Design Exercise 2 Solution

ANSWERS ②.

1. $CR = \frac{(8.5 \times 25')}{(3 \times 25')} = 2.8$ semi-confined

2. $ER = \frac{(9 \times 25')}{(3 \times 25')} = 3.0$ minor entrenchment

3. $IR = \frac{(2.5 \times 4')}{(1.5 \times 4')} = 1.7$ incised

4. CEM = 3, prone to widening, WQ + safety issue

5. A. Establish flood bench with 50-foot width, widen @ bankfull elevation ✓
   Armor road embankment

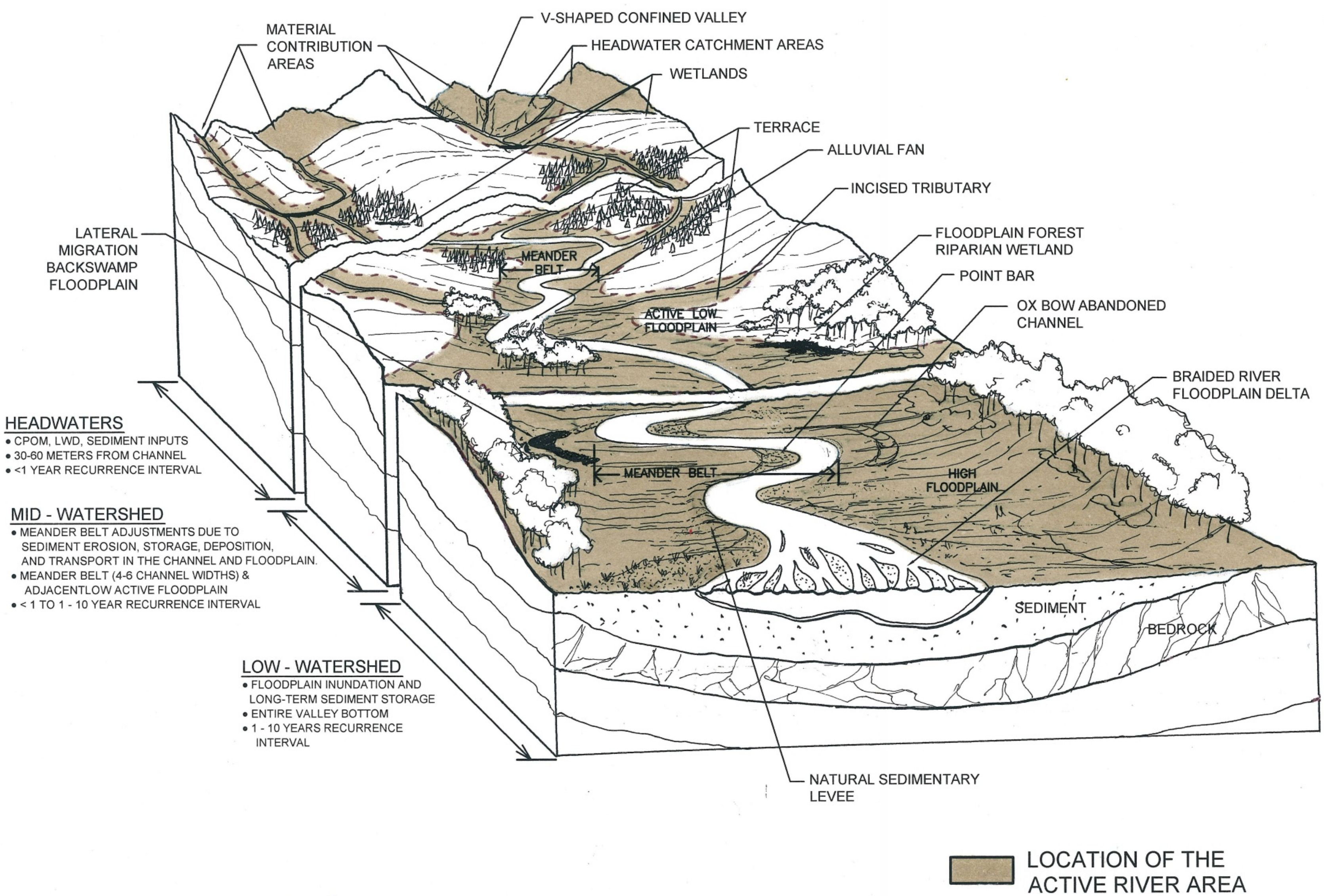
   B. Raise bed to reconnect floodplain (see bed stabilization)

6. $\forall_{fill} = (50' \times 4' \times 1{,}000') = 200{,}000\ CF = 7{,}407\ CY$
   $\forall_{loose}$ (truck) = 9,259 CY $\forall_{comp}$ (place) = 6,666 CY

7. Armor along road embankment. 4-6' key as remaing incision potential with road fill.

Extra Slides

The Active River Area

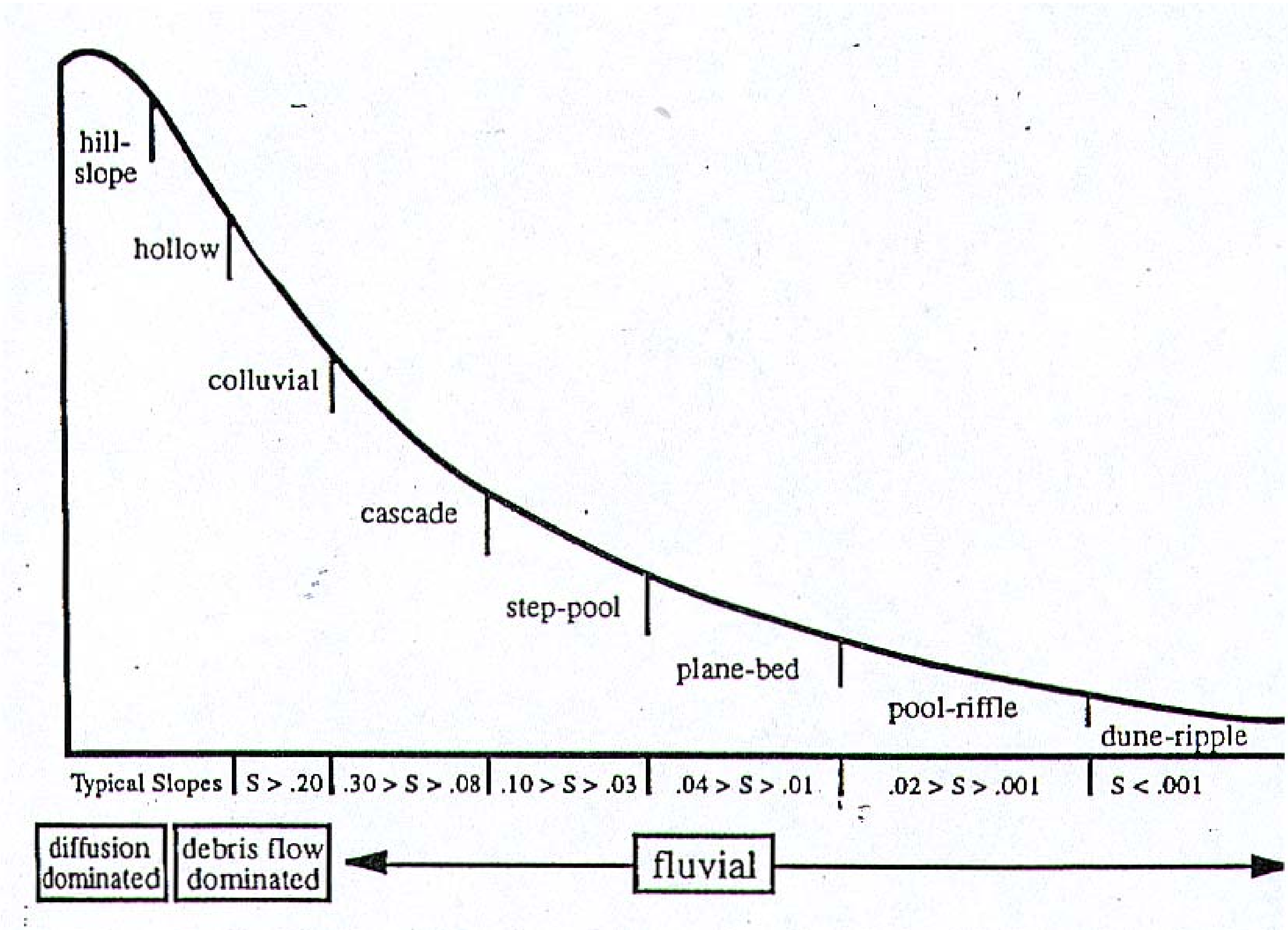


THE ACTIVE RIVER AREA

DOMINANT PROCESSES AND DISTURBANCE REGIMES

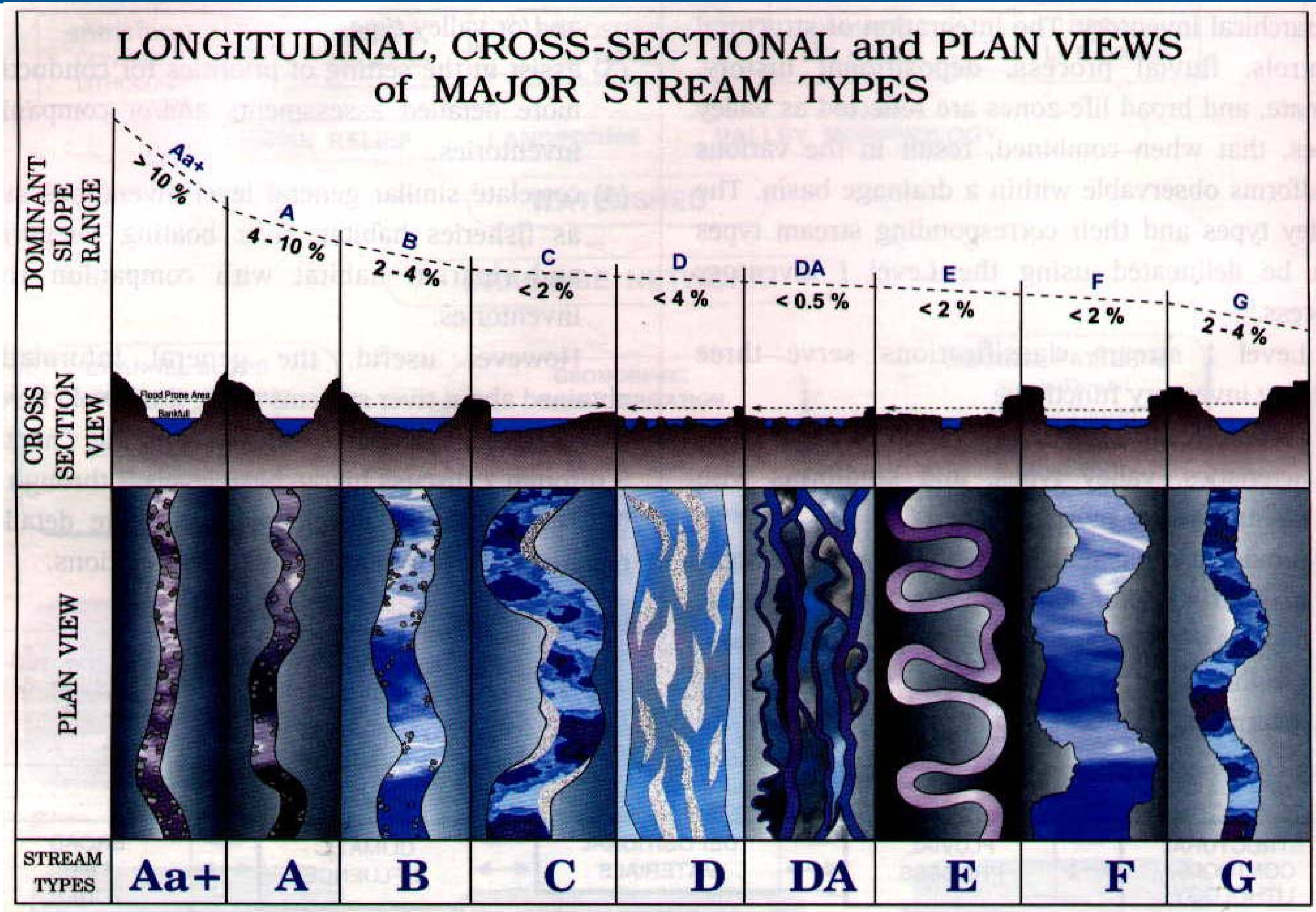
(Smith et al., 2008)

Geomorphic Channel Type



(Montgomery and Buffington, 1993)

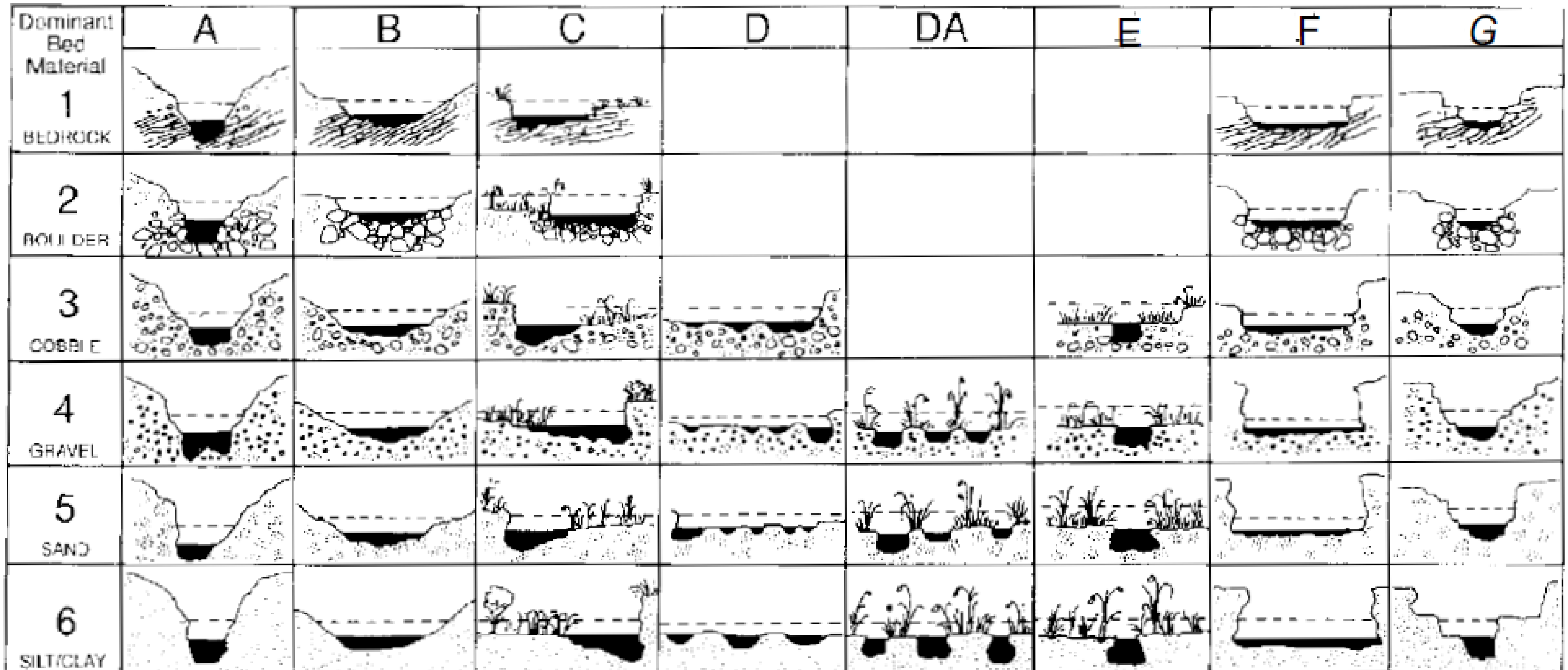
Geomorphic Channel Type



Geomorphic Characteristics

(Rosgen, 1994)

Geomorphic Channel Type



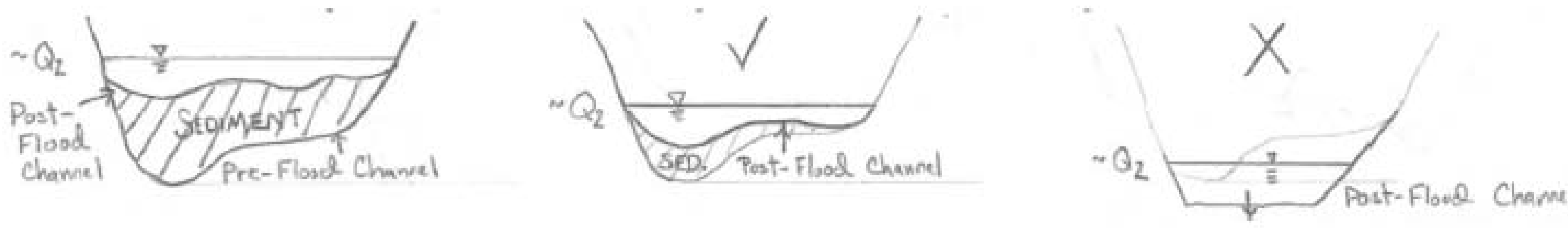
	A	B	C	D	DA	E	F	G
ENTRH.	<1.4	1.4-2.2	>2.2	N/A	>2.2	>2.2	<1.4	<1.4
SIN.	<1.2	>1.2	>1.4	<1.1	1.1-1.6	>1.5	>1.4	>1.2
W/D	<12	>12	>12	>40	<40	<12	<12	<12
SLOPE	.04-.099	.02-.039	<.02	<.04	<.005	<.02	<.02	.02-.039

Figure 3. Cross-section view of stream types (adapted from Rosgen 1994). Original drawings by Lee Silvey. Courtesy of Catena Verlag.

Geomorphic Characteristics

(Harrelson et al., 1994)

The Floodplain Paradox



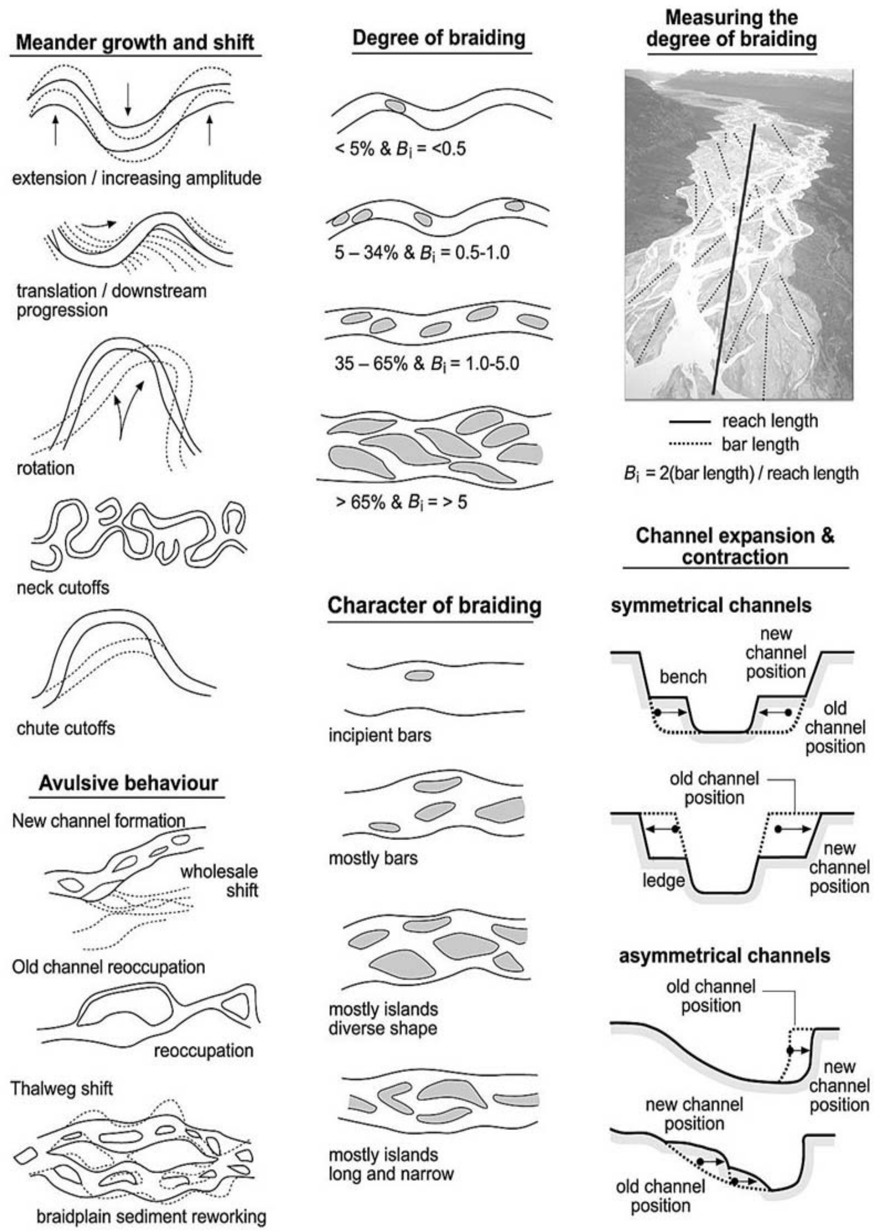
(Schiff et al., 2014)

Channel Dynamics

Attributes	**Potential Adjustments**
Slope	Increase, Decrease
Vertical	Aggrade, Degrade
Horizontal	Widen, Narrow
Cross-Section Area	Increase, Decrease
Lateral	Migration, Avulsion
Planform	Pattern, Sinuosity, Pos.
Resistance	Smoothen, Roughen
Floodplain	Deposition, Scour, Widen
Sediment Size	Coarser, Finer
Sediment load	Incision or Braiding

(MMI, 2000)

Channel Dynamics



(Brierley and Fryirs, 2005)

Bankfull Indicators / Incised Channel

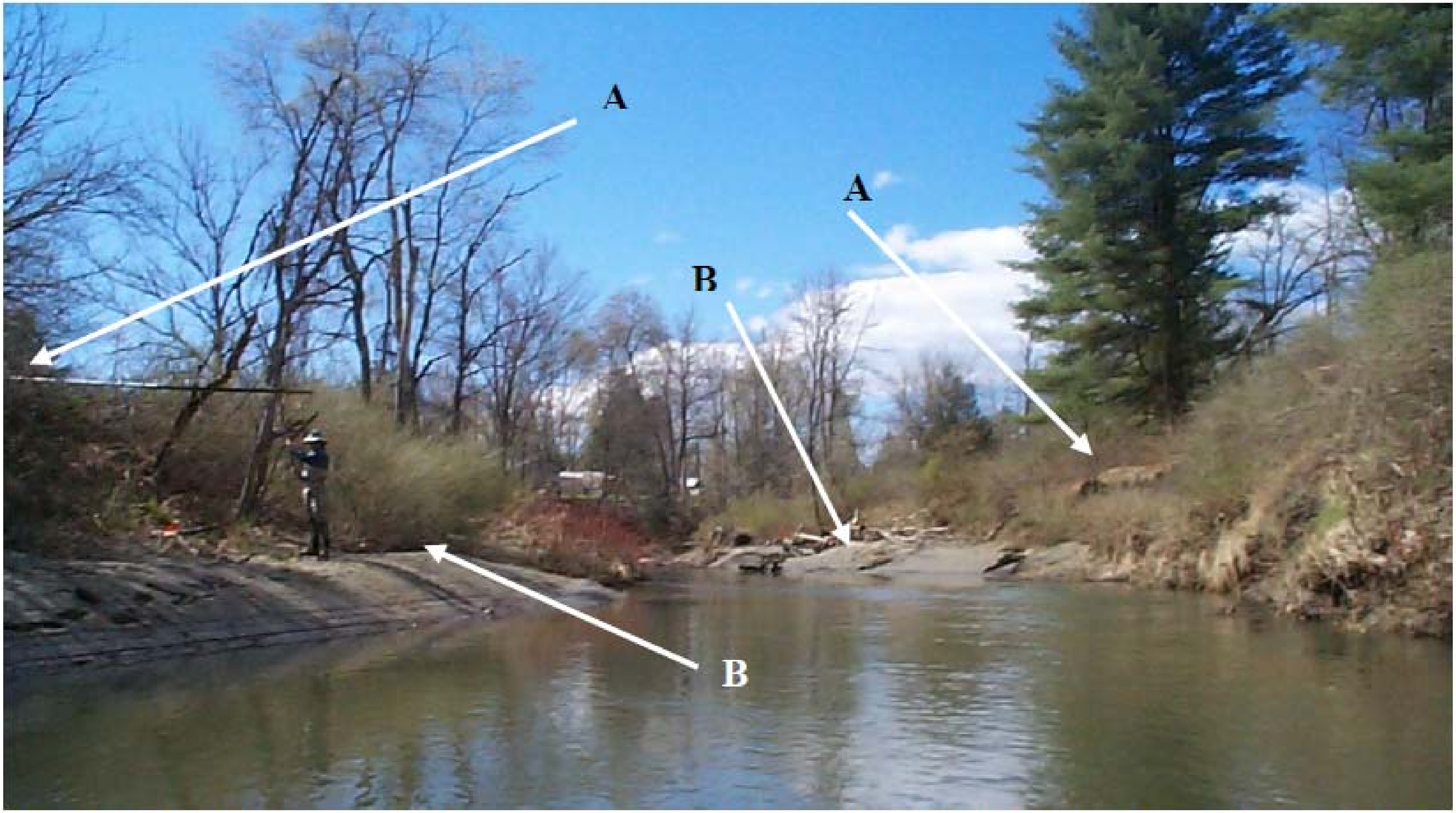


Figure 1 Embryonic active floodplain developing in incised channel. Stage IV of channel evolution.

a. Abandoned floodplain

b. Active floodplain indicating bankfull stage

(VTANR, 2009)