Massachusetts Rivers & Roads Training

Using Fluvial Geomorphology (FGM) to Reduce Conflicts Between Transportation Assets and Rivers

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massDOT
Massachusetts Department of Transportation

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Agenda

- Why FGM?
- Introduction to Rivers and Roads Training
- Curriculum samples


Green River
Green River Road - Colrain MA
J. MacBroom, 2011

Flood Bench at Retaining Wall Repair
Route 9, Westfield Brook - Cummington, MA
MMI, 2017

Large Wood Deflector at Retaining Wall Repair
Route 9, Westfield Brook - Cummington, MA
MMI, 2017


Roaring Brook
US Route 4 in Killington, VT
Photo by Lars Gange & Mansfield Heliflight, August 31, 2011)

FGM Training Overview

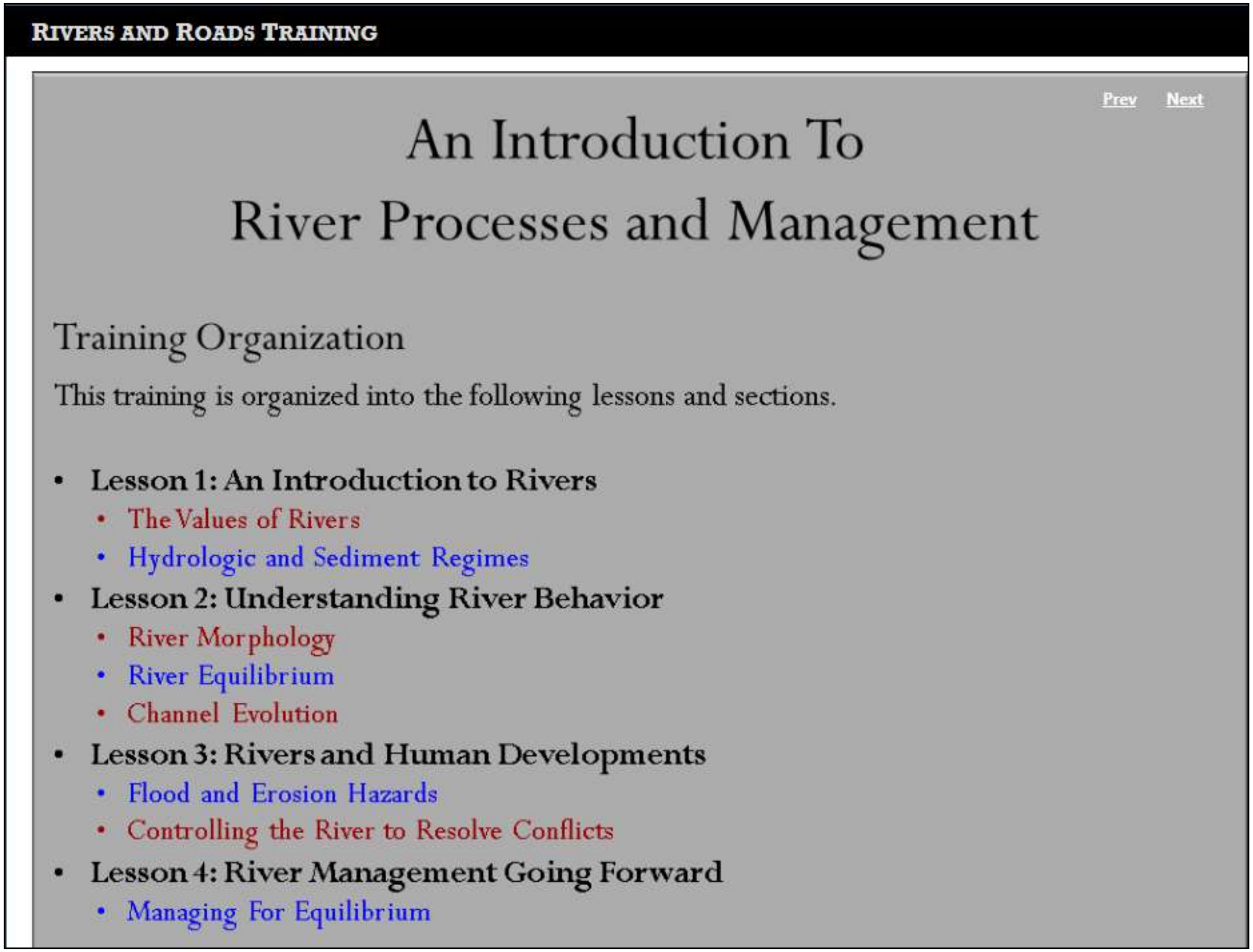
- Tier 1: Online Course to Introduce the fundamentals of FGM
- Tier 2: One-Day Course for Advance understanding of FGM
  - Tier 2A: Classroom session that includes a flume exercise
  - Tier 2B: One-day field trip
- Tier 3: One-Day Subject Matter Courses to Enable project implementation

(VTANR, FEA, MMI, 2015)

Problem: The Importance of River Morphology Is Not Understood

Tier 1 Overview

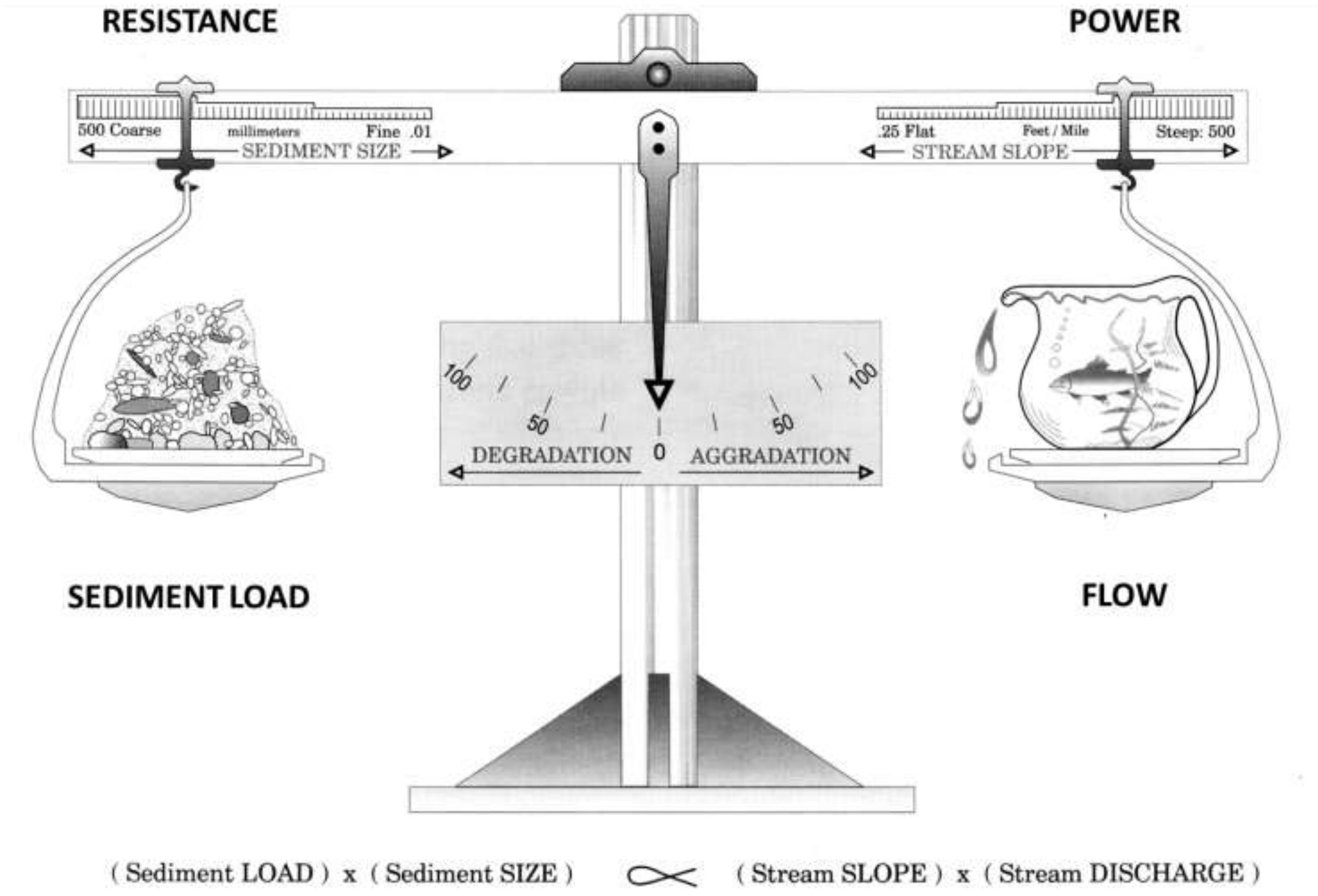
- Goal: Introduce the fundamentals of FGM
- Attendees
  - Anyone with a remote connection to work around rivers and roads
  - Project Development: Bridge & Bridge Project Management, Project Management, Hydraulics, District Projects, Geotechnical, Landscape Design, Environmental
  - Highway Design
  - Construction: Resident Engineers & Inspectors on projects in or near rivers & streams
  - Operations & Maintenance: Staff responsible for working or overseeing work in rivers & streams (culvert replacements, bank stabilizations, etc.)
  - Baystate Roads
- Format: Online only, 2 hour session



(VTANR, 2015)

Tier One (Online): Awareness
(https://anrweb.vt.gov/DEC/RoadsTraining/Default.aspx)

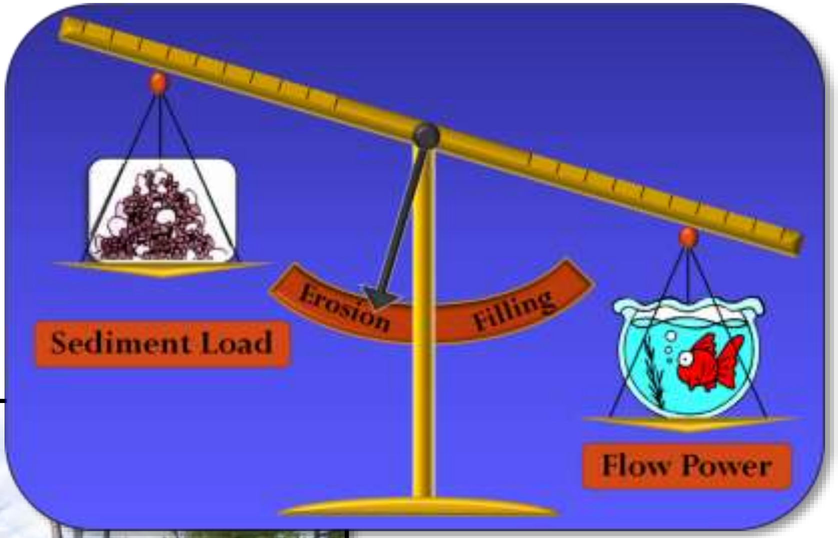
Dynamic Equilibrium



(Lane, 1955; Rosgen and Silvey, 1996)

Dynamic Equilibrium

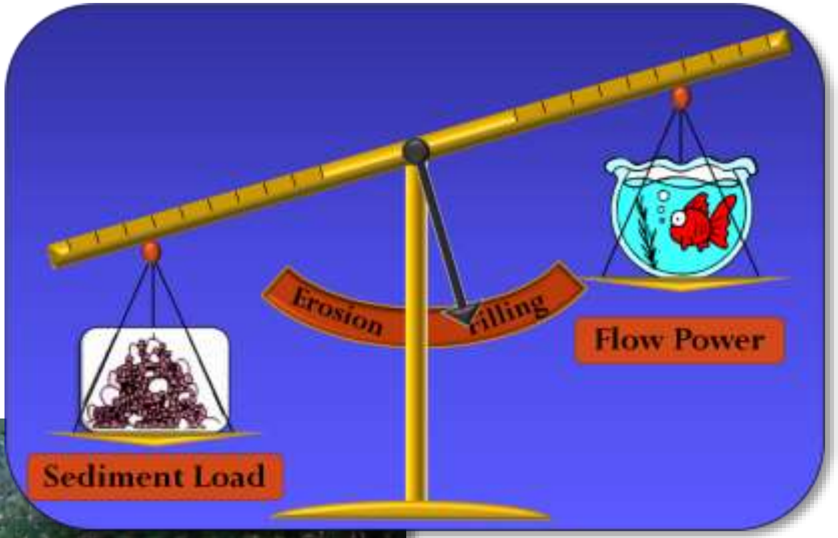
When the **flow power** is greater than what is necessary to transport the sediment load, the channel **degrades** or erodes, becoming larger.



(ANR, 2018)

Dynamic Equilibrium

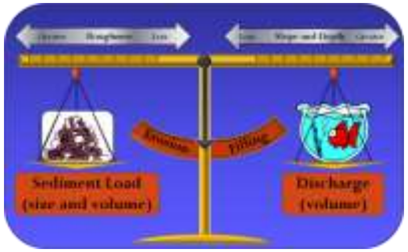
When the **flow power** is less than what is necessary to transport the sediment load, the channel **aggrades** or fills in.

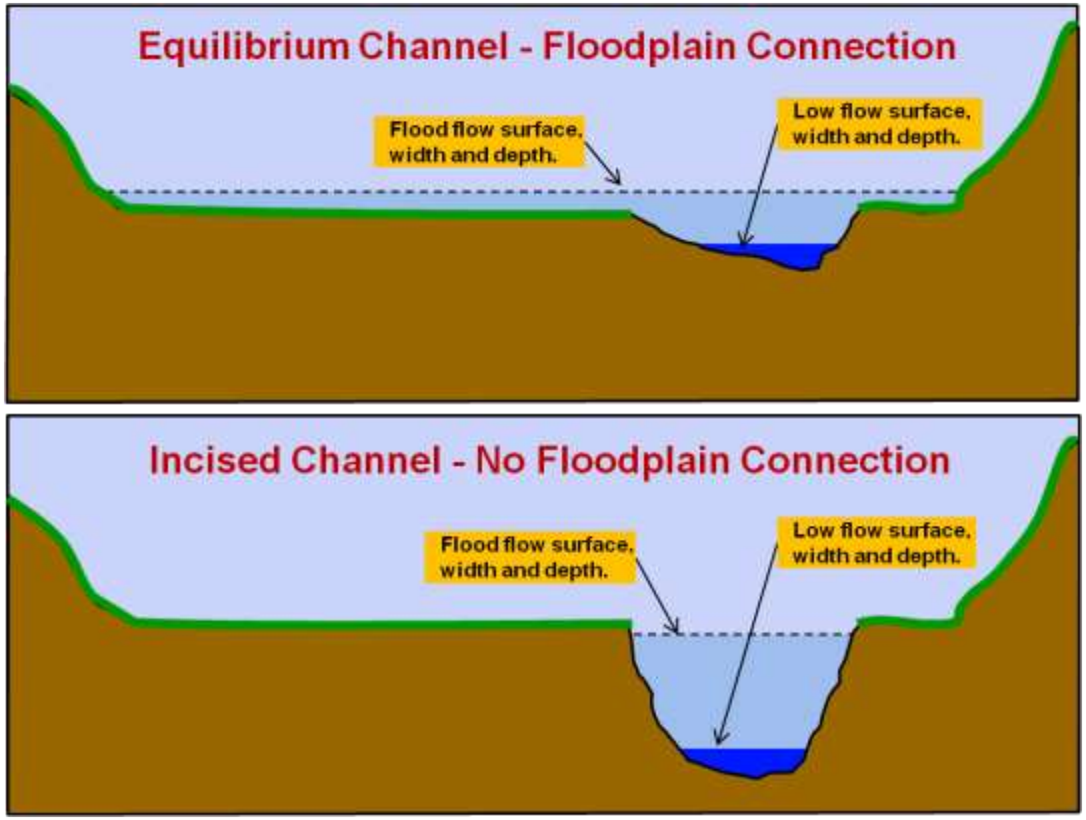


(ANR, 2018)

Dynamic Equilibrium

Where rivers are well connected to floodplains, high flows are able to spread out across those floodplains thereby reducing the flow **depth and power** in the channel during high flow events.





(ANR, 2018)

Dynamic Equilibrium

Questions:

What factors determine how much power the flow contains?

Click For Answer Click For Answer Click For Answer Click For Answer

What is the term used to describe the condition in which the flow power is just great enough to transport all of the sediment without excessive erosion or deposition?

Click For Answer

Confinement

Confinement = Valley Width / Channel Width

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

(VTANR, 2009)

NATURAL

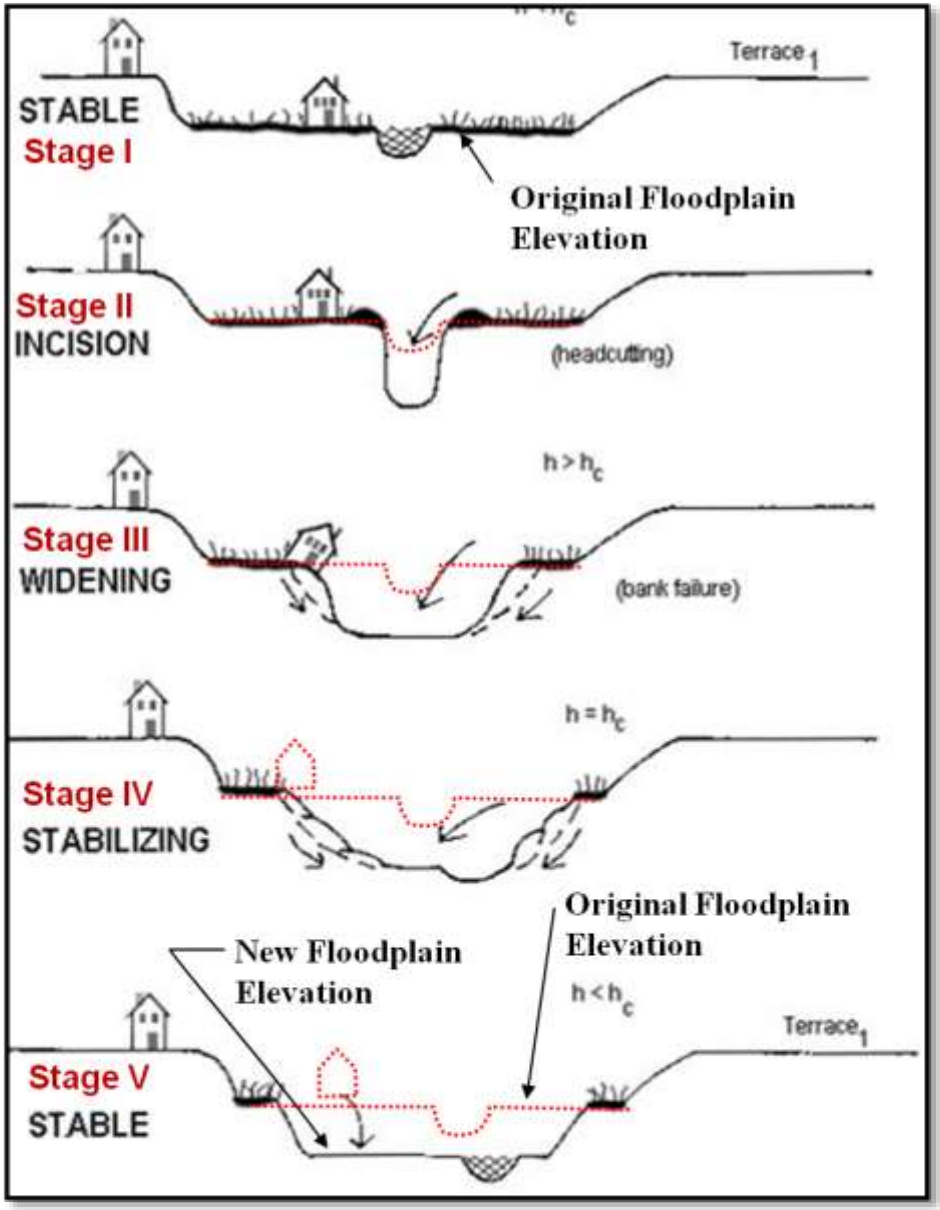
- Valley wall
- Terraces
- Alluvial fan (local)
- Natural bank levee
- Confluences

ARTIFICIAL

- Embankment fill
- Berm or levee


(MacBroom, 2011)

Channel Evolution



(Schumm, 1977)

Channel Evolution

- Look for erosion faces (i.e., nickpoints) and aggradation areas in post-flood assessment.
- Is the project area upstream or downstream of a primary nickpoint?
- Are precursor nickpoints evident on an over steepened reach?
- Is the channel in stages I or V indicating likely stability, or is the channel in stages II, III, or IV indicating likely down-cutting and widening?

(Schumm et al., 1984)

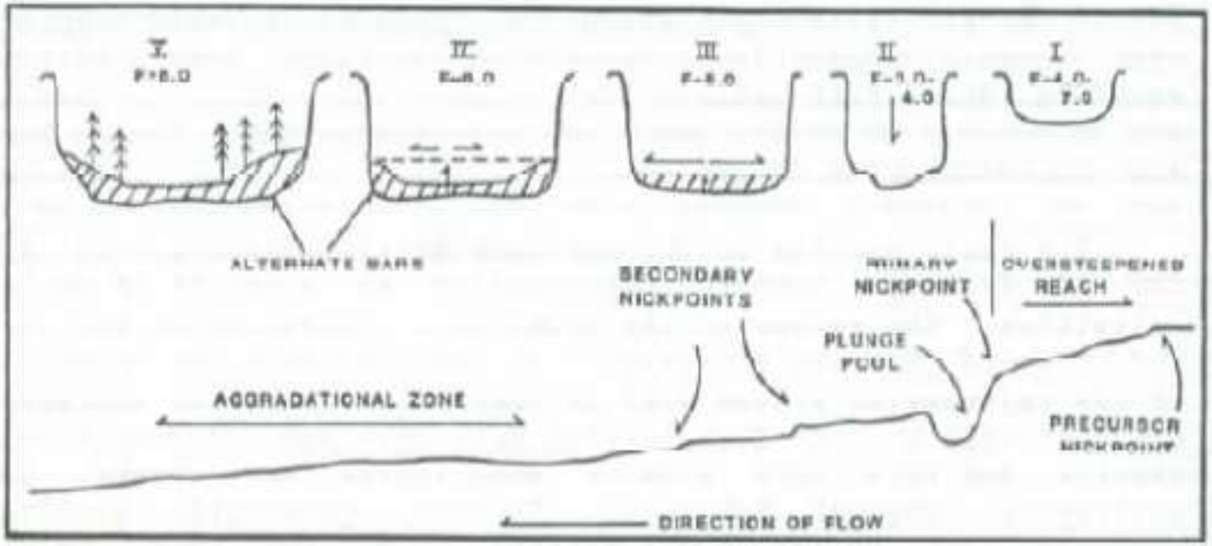
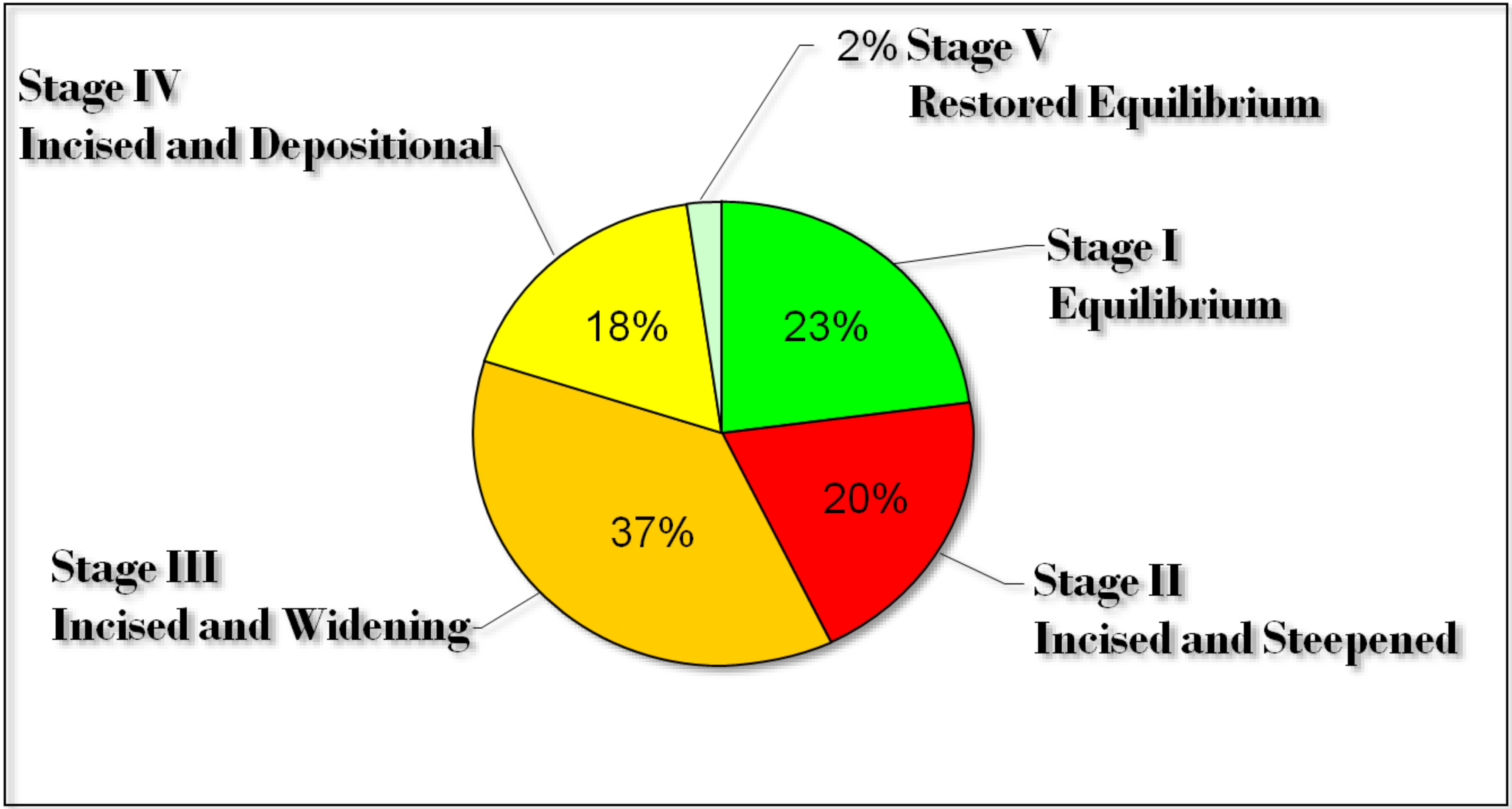


Figure 6-7. Schematic longitudinal profile of an active channel showing identifiable features. Schematic cross section profiles corresponding to reaches on the longitudinal profile show the evolution of the reaches from Type I to Type V. Typical width-depth (F) values are shown. Size of the arrows indicate the relative importance and direction of the dominant processes, degration, aggradation and lateral bank erosion.

Channel Evolution



Channel Evolution

Questions:

What is the long term process that a river which has been destabilized by sudden and major watershed and/or channel changes goes through to reach a new equilibrium condition?

Click For Answer

What are the consequences of channel evolution?

Click For Answer

Click For Answer

Click For Answer

Channel Adjustments

Using Lane's Balance and The Channel Evolution *M*odel to Predict Channel Adjustments

Tier 2 Overview

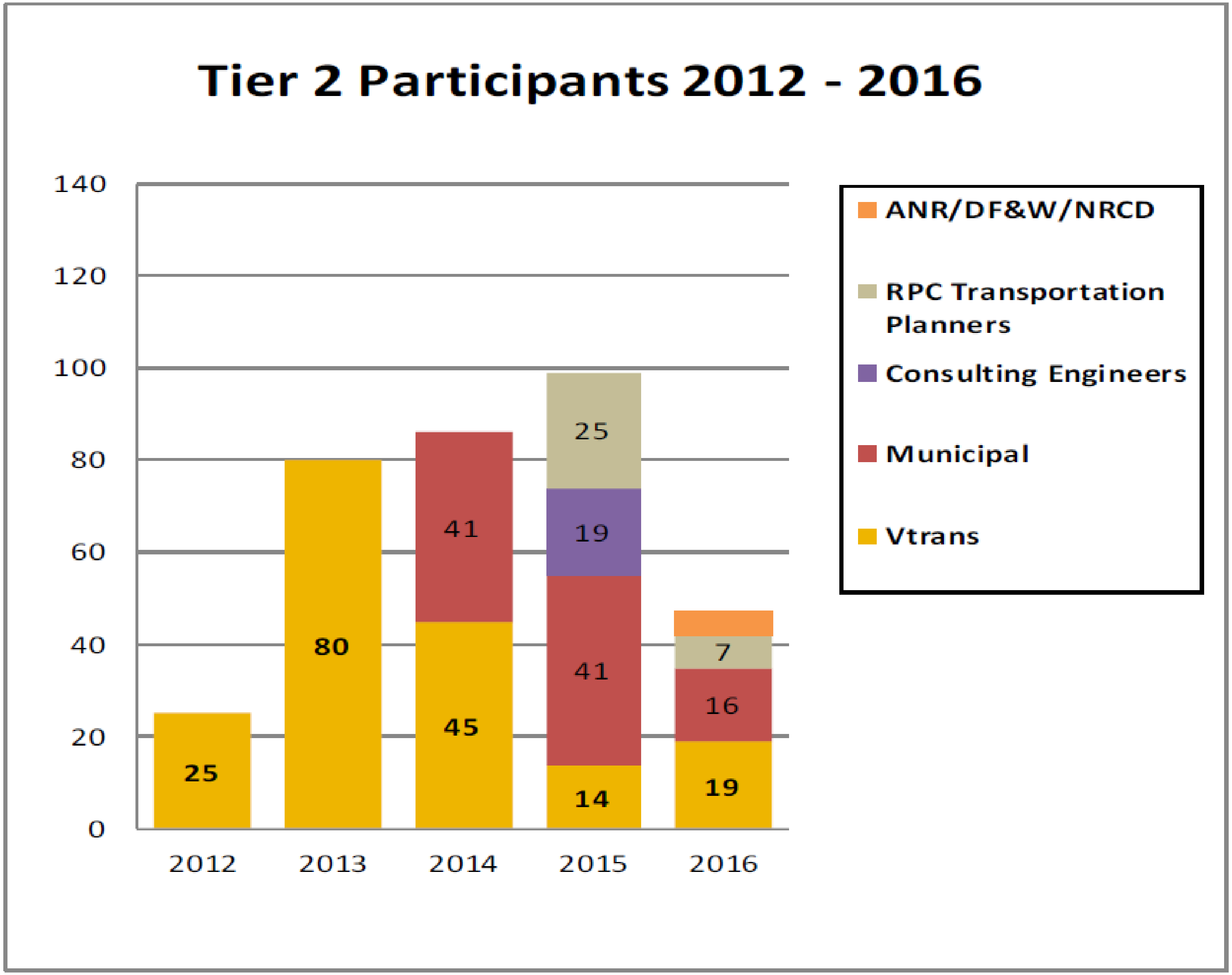
- Goal: Advance understanding of FGM for designers, project managers, technical staff, and construction & maintenance staff overseeing river work.
- Attendees generally same as Tier 1.
- Format
  - Tier 2A - One-day classroom session that includes a flume exercise
  - Tier 2B - One-day field trip

1. River equilibrium
2. Floodplain connectivity
3. Unstable river beds and banks
4. Straightened rivers cause unstable channels
5. River dynamics and equilibrium look messy
6. Forecasting adjustments and evolution
7. Determining the existing channel morphology
8. Determining the expected channel morphology
9. Flood recovery exercise – see it, walk it, build it

(Adapted from VTANR, 2015)

Tier 2: Classroom , flume, field – See it, walk it, build it.

(VTANR, 2015)



Tier 2 Participants 2012 - 2016
140
120
100
80
60
40
20
0
25
80
41
45
25
19
41
14
7
16
19
2012
2013
2014
2015
2016
ANR/DF&W/NRCD
RPC Transportation Planners
Consulting Engineers
Municipal
Vtrans

(VTANR, 2015)

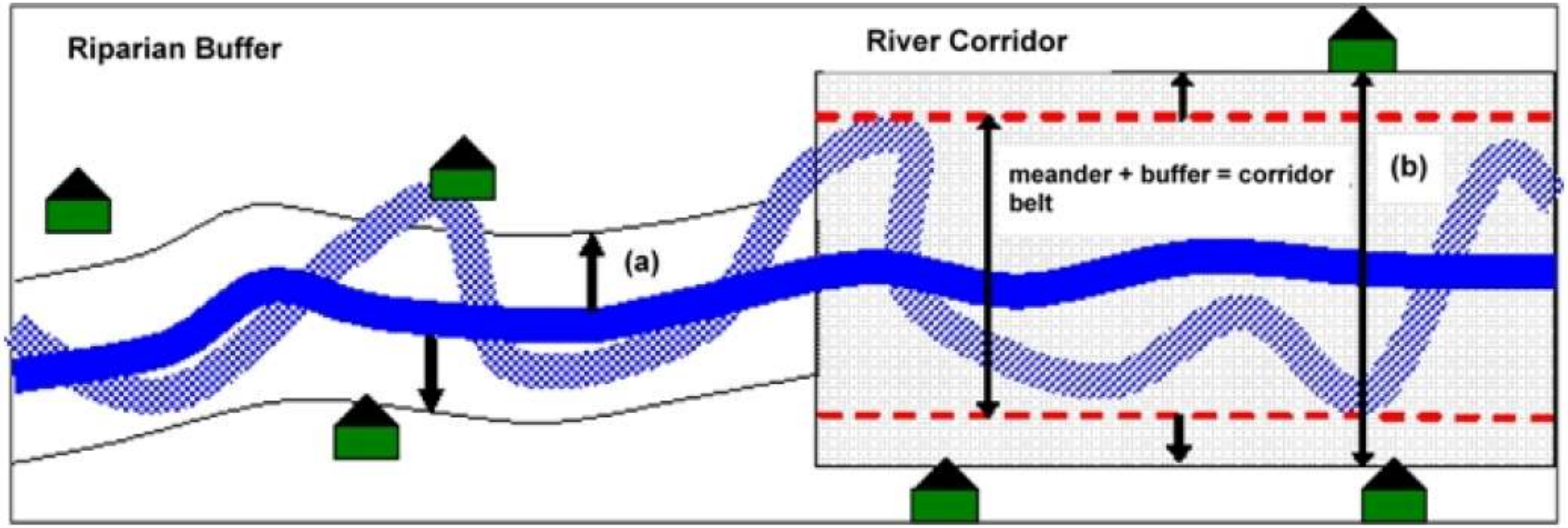
Measuring Success –
One Contractor's Comment after a flume presentation

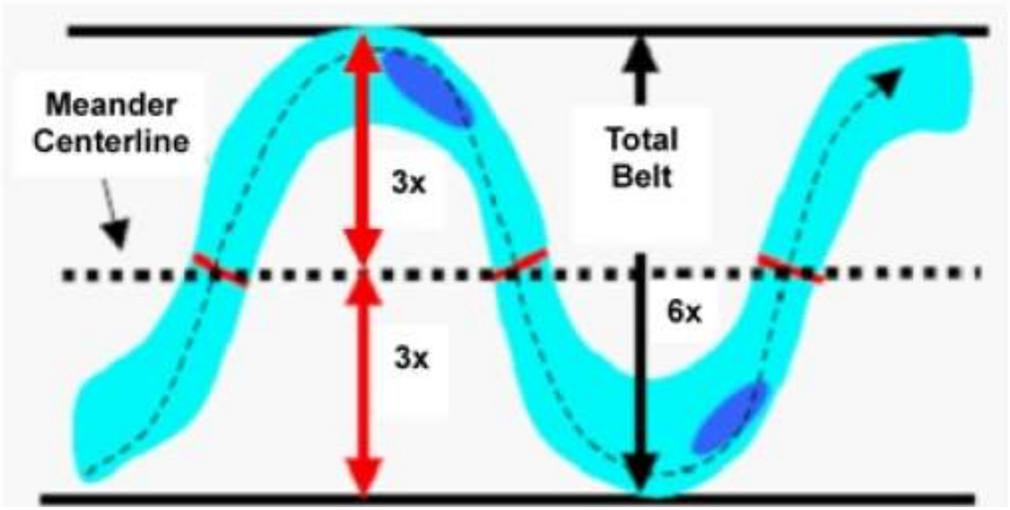
"This stuff is culture changing, you've got to get this out to all the operators in the state."

- Craig Mosher

(VTANR, 2015)

River Corridor





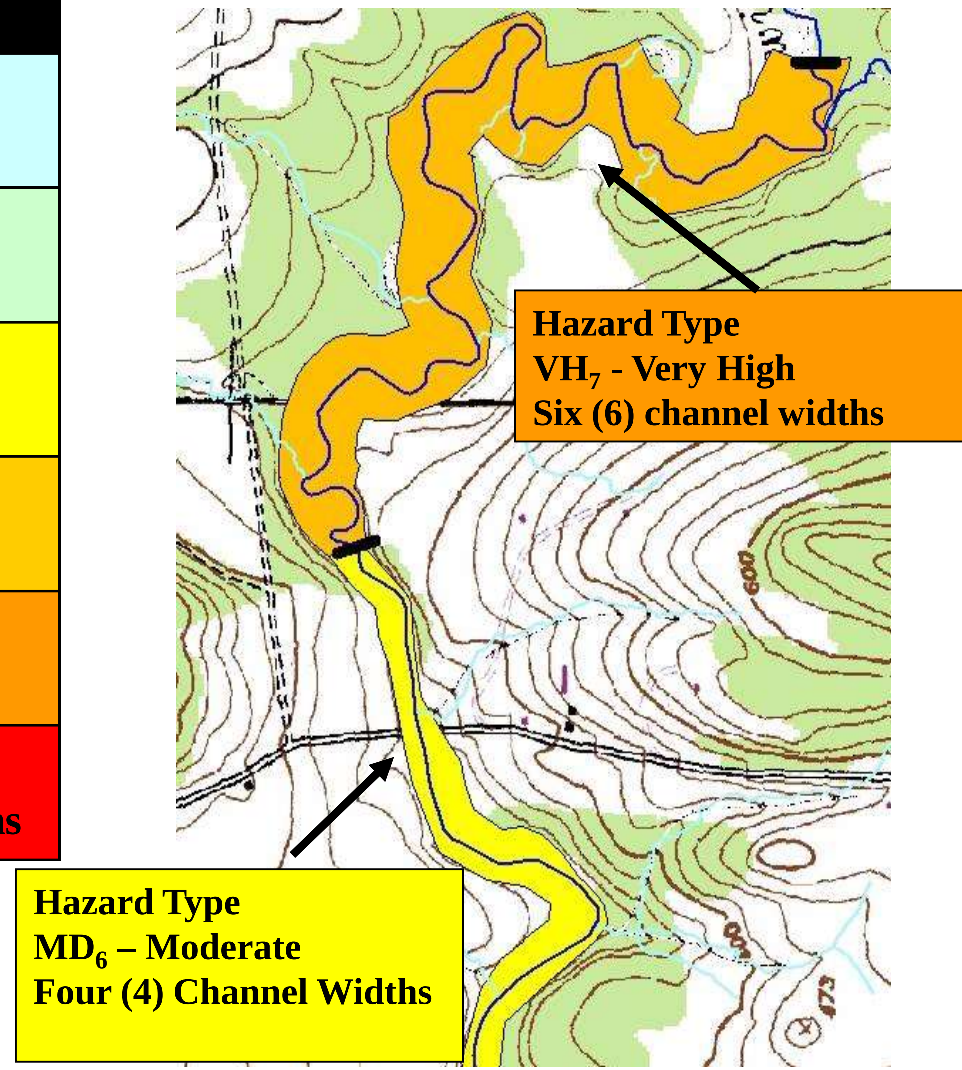
Geographical and human constraints that may justify alternate meander belt widths and locations, include:

1) Public infrastructure for which there is a long-term public commitment to protect (armor) against fluvial adjustments may shift corridor laterally;
2) Steeper streams (>2% slope), confined to narrow valleys with less erodible boundaries, where corridors of 1 to 4 times channel width are recommended based on stream type and specific valley characteristics, and
3) Very High to Extremely sensitive stream types that may require corridors > 6 channel widths.

(Kline and Cahoon, 2010)

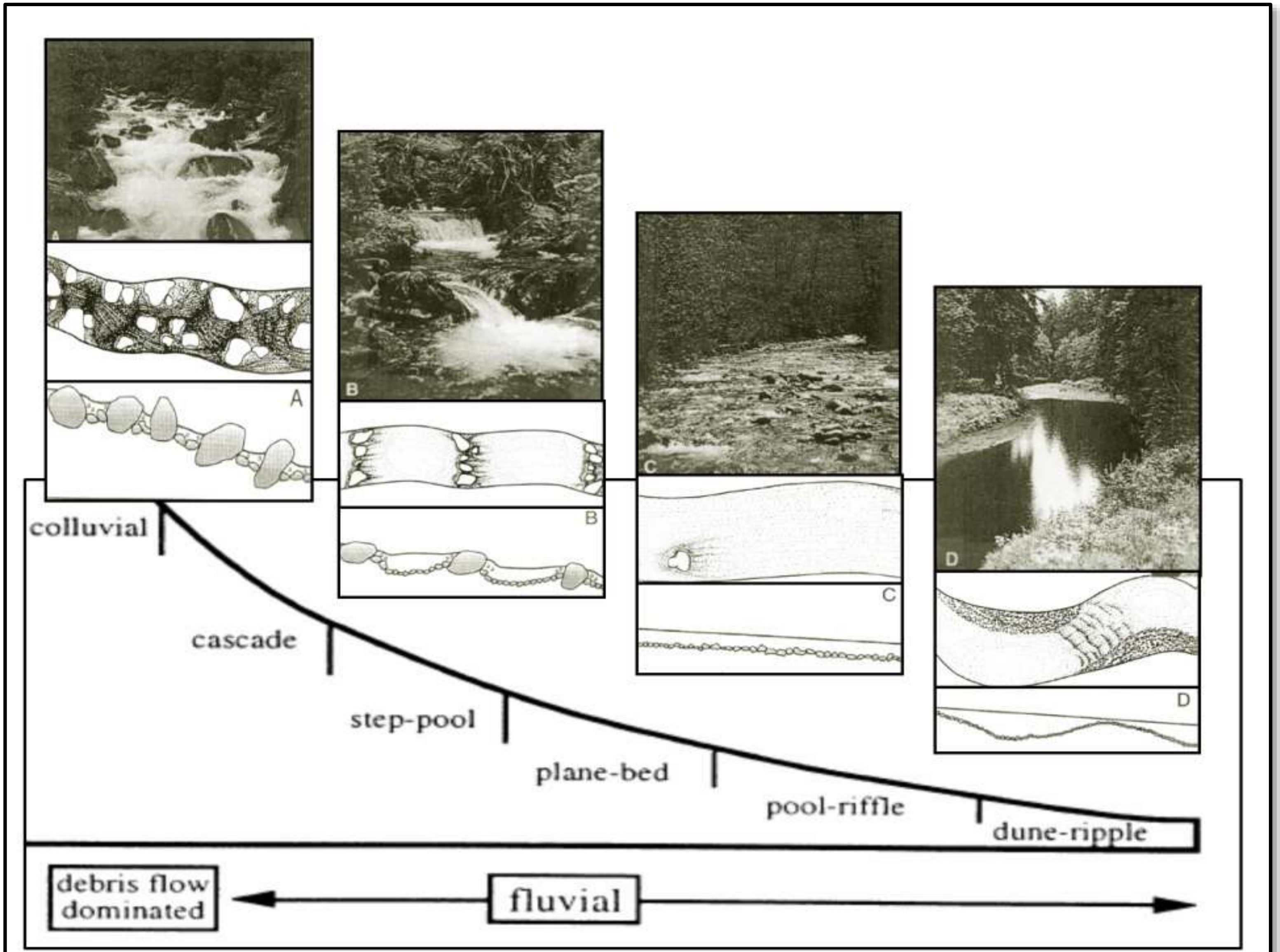
Belt Width Based on Channel Sensitivity

Very Low (VL)	**Reference channel width**
Low (LW)	**Reference channel width**
Moderate (MD)	**4 channel widths**
High (HI)	**6 channel widths**
Very High (VH)	**6 channel widths** **8+ channel widths – E streams**
Extreme (EX)	**6 channel widths** **8+ channel widths – D&E streams**



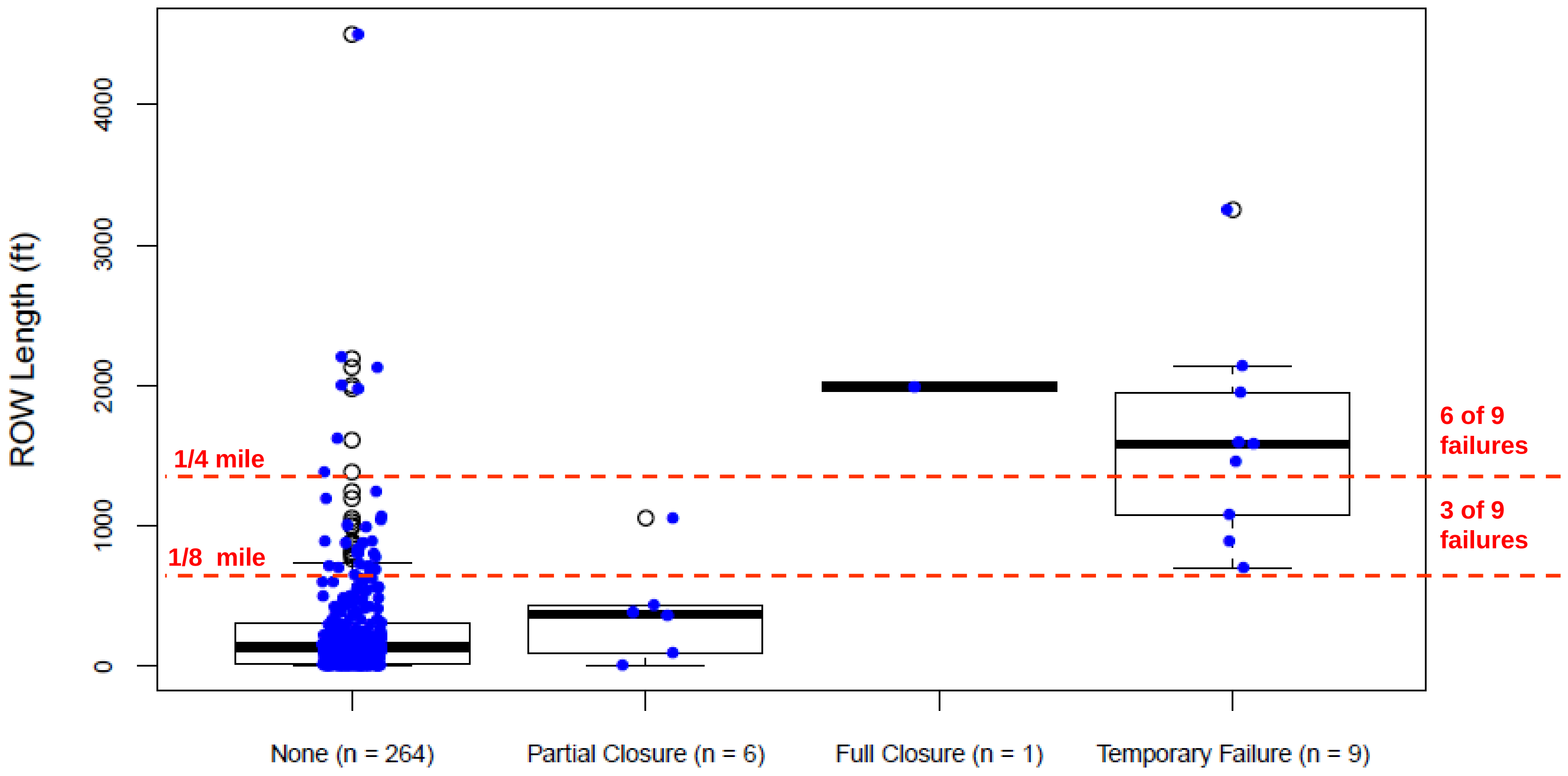
(VTANR, 2013)

Channel Classification



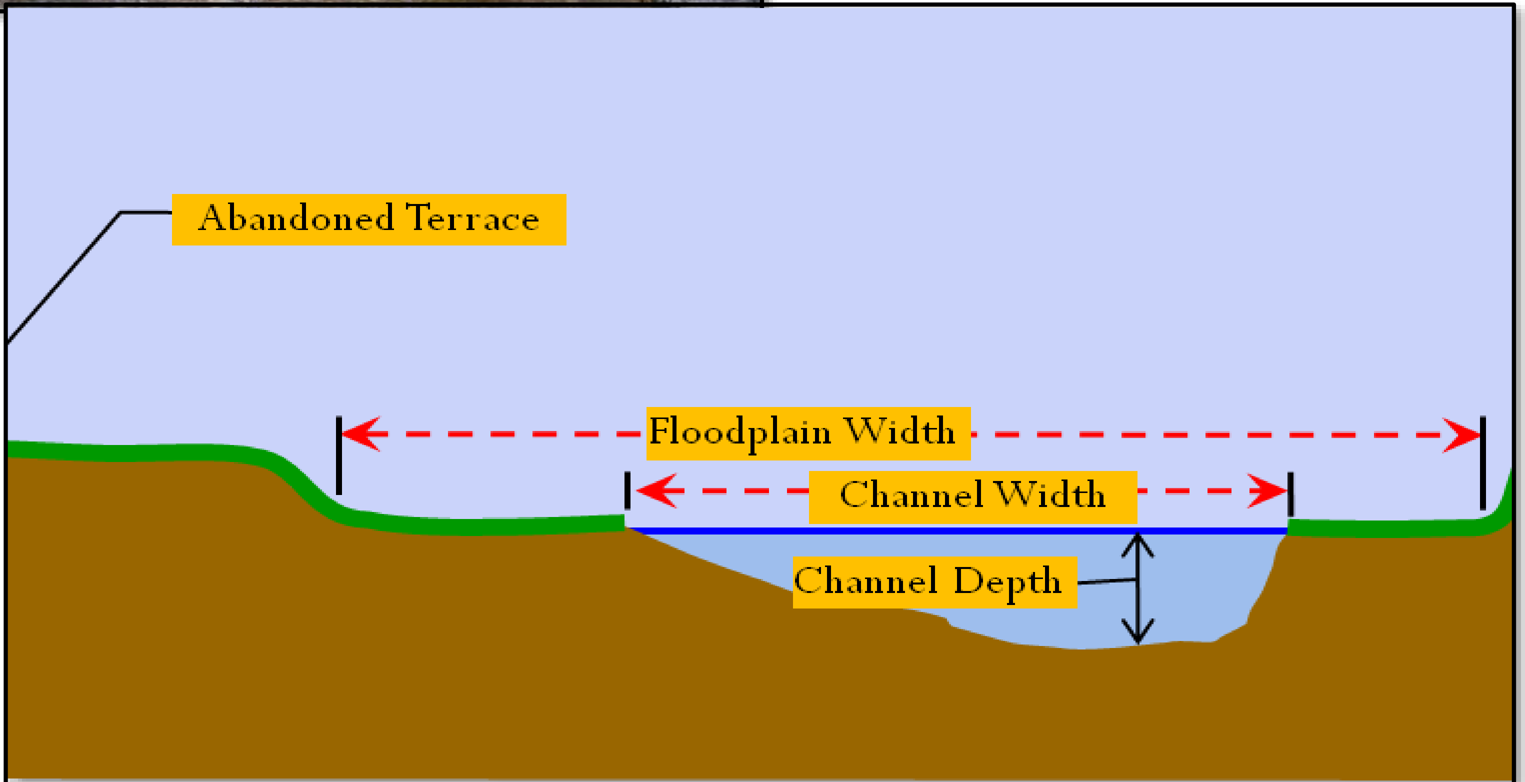
Montgomery and Buffington (1998)

Road Vulnerability

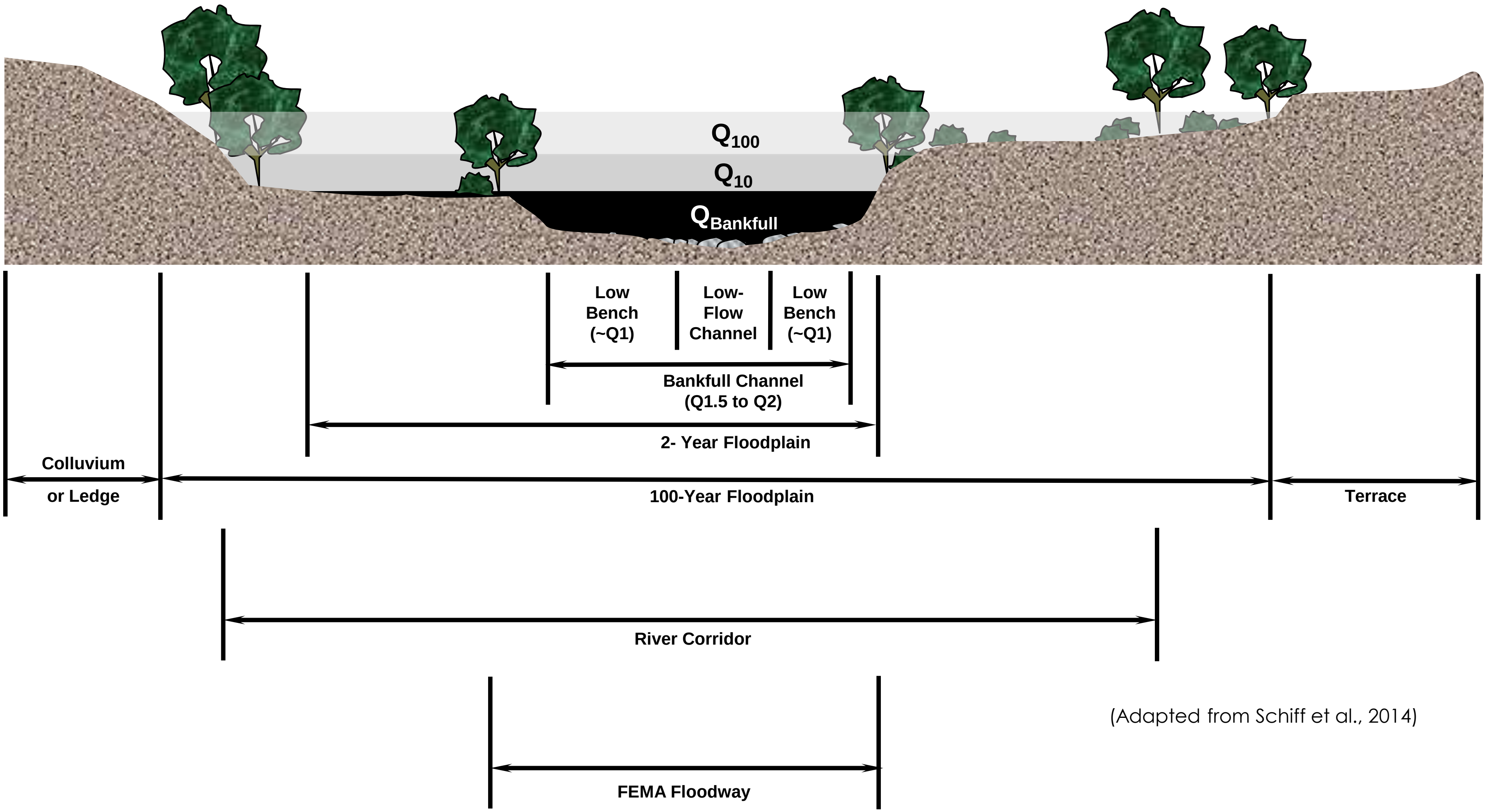


(FEA, 2017)

The Cross Section



Channel/Floodplain Cross Section



(Adapted from Schiff et al., 2014)

Tier 3 Overview

- Goal: Enable designers and construction managers to implement projects
- Attendees: Same as Tier 2 plus those regularly involved in river & stream related projects.
- Format: 1 full day in classroom for each of the four topic areas. Review questions in each section and final design project and presentation

1. Sediment and Wood
2. Channel Stabilization
3. Floodplain Restoration
4. Bridges and Culverts

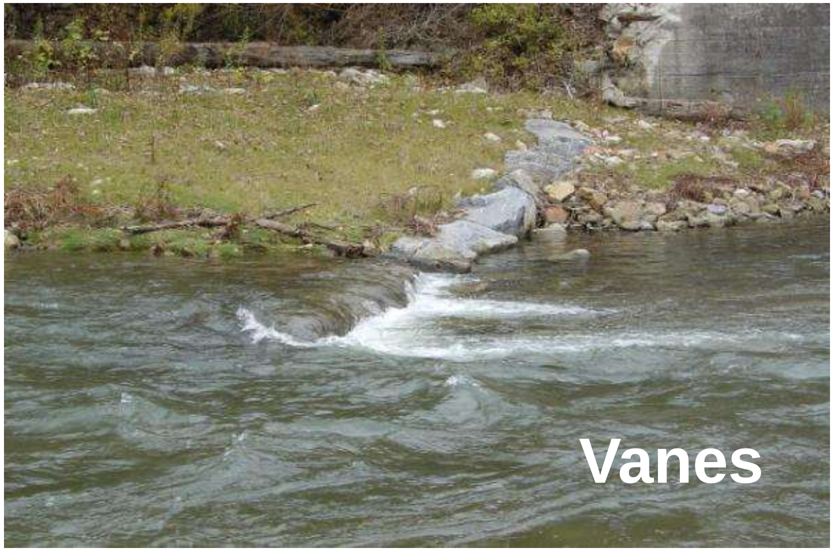
Tier 3 – Classroom, design example

(VTANR, 2015)

Bed Stabilization Objectives

1. Maintain or re-establish vertical stability over the reach to prevent unnatural raising or lowering of channel bed.
2. Re-connect as much floodplain as possible given site constraints.
3. Maintain or improve instream habitat.
4. Protect water quality.

Control Project Examples: Vanes, Riffles, Strainers



Broad Street Hollow (J. MacBroom, 2015)

Plymco Dam Channel Restoration (J. MacBroom, 2015)

Boquet River , Willsboro, NY (E. Fitzgerald, 2015)

Grade Control Design: Bed Armor Performance Standards

(MMI, 2014)

(Fitzgerald Environmental, 2015)

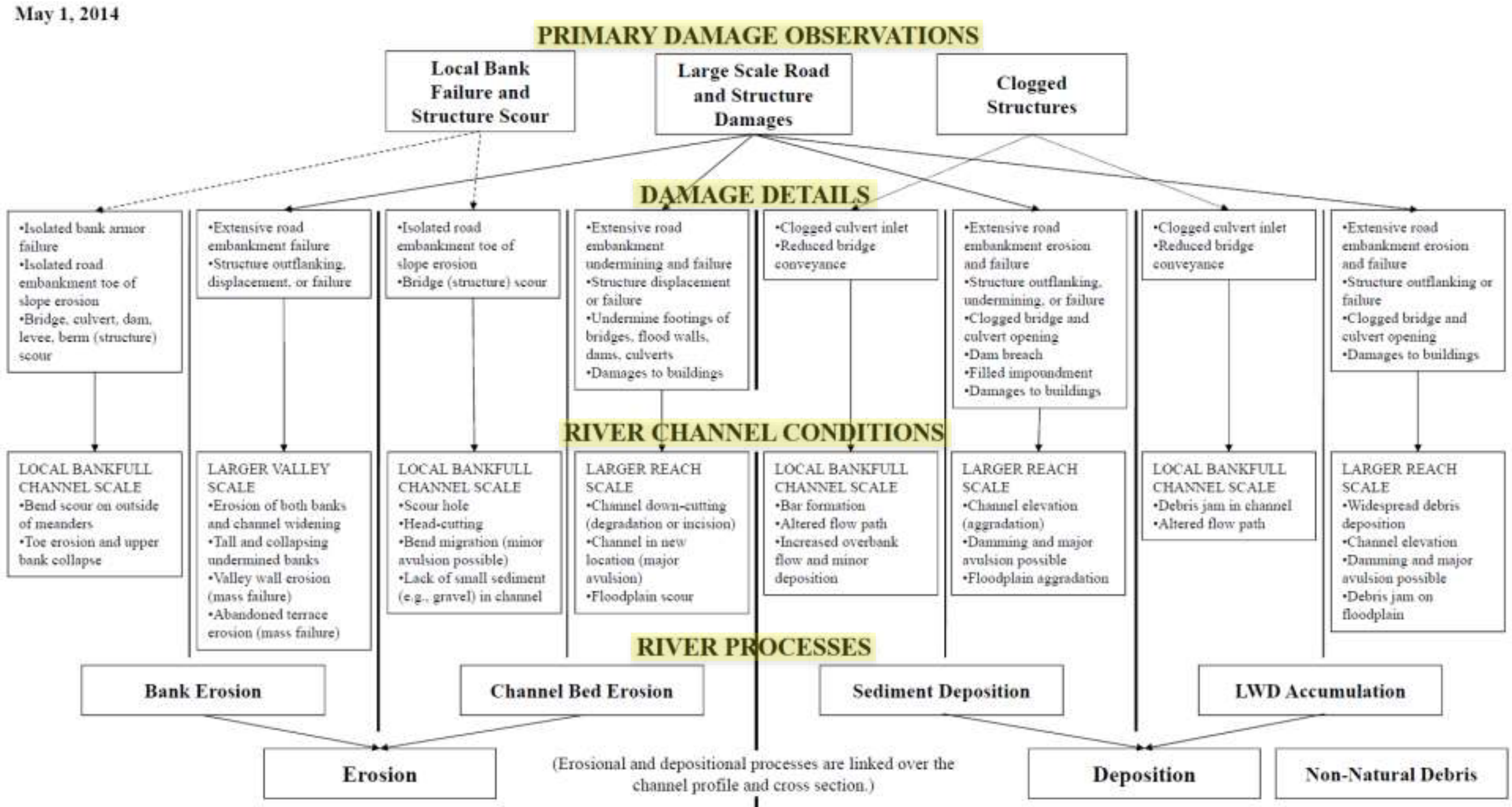
Vermont Standard River Management Principals and Practices

- Halt channel downcutting.
- Halt horizontal channel migration threatening infrastructure and unmovable habitable buildings. (Avoid horizontal channel migration along opposite bank of threatened infrastructure.)
- Provide aquatic organism passage and continuous surface flow.
- Create final channel dimensions and cross sections similar to adjacent channel

Project Example

Failure of the Vermont Route 100 road embankment due to erosion during Tropical Storm Irene
Pittsfield, VT
Mansfield Heliflight, 2011

Problem Identification

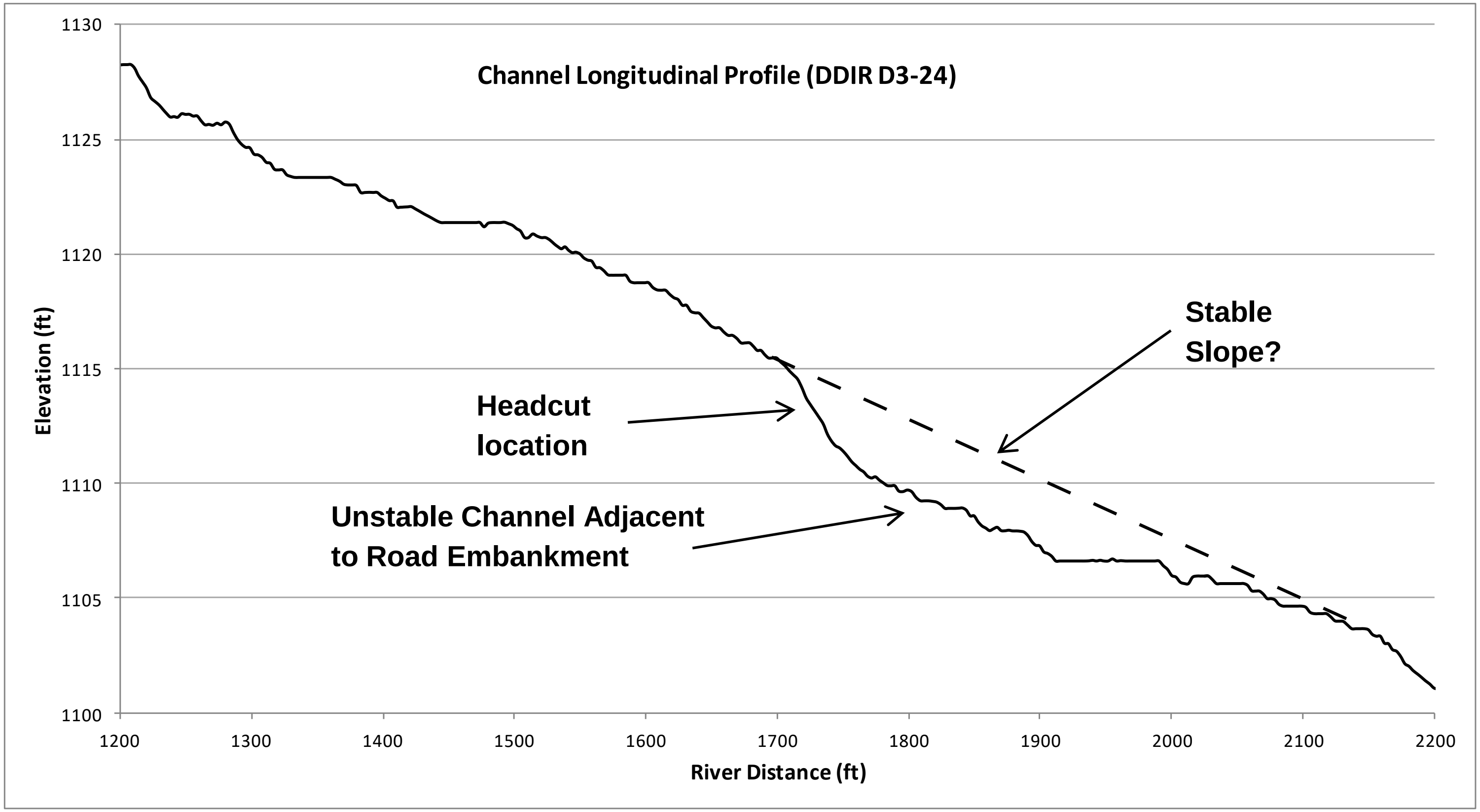


APPLICABLE GUIDING DESIGN PRINCIPLES BASED ON DAMAGES (1 = MOST IMPORTANT)

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

(Schiff et al., 2014)

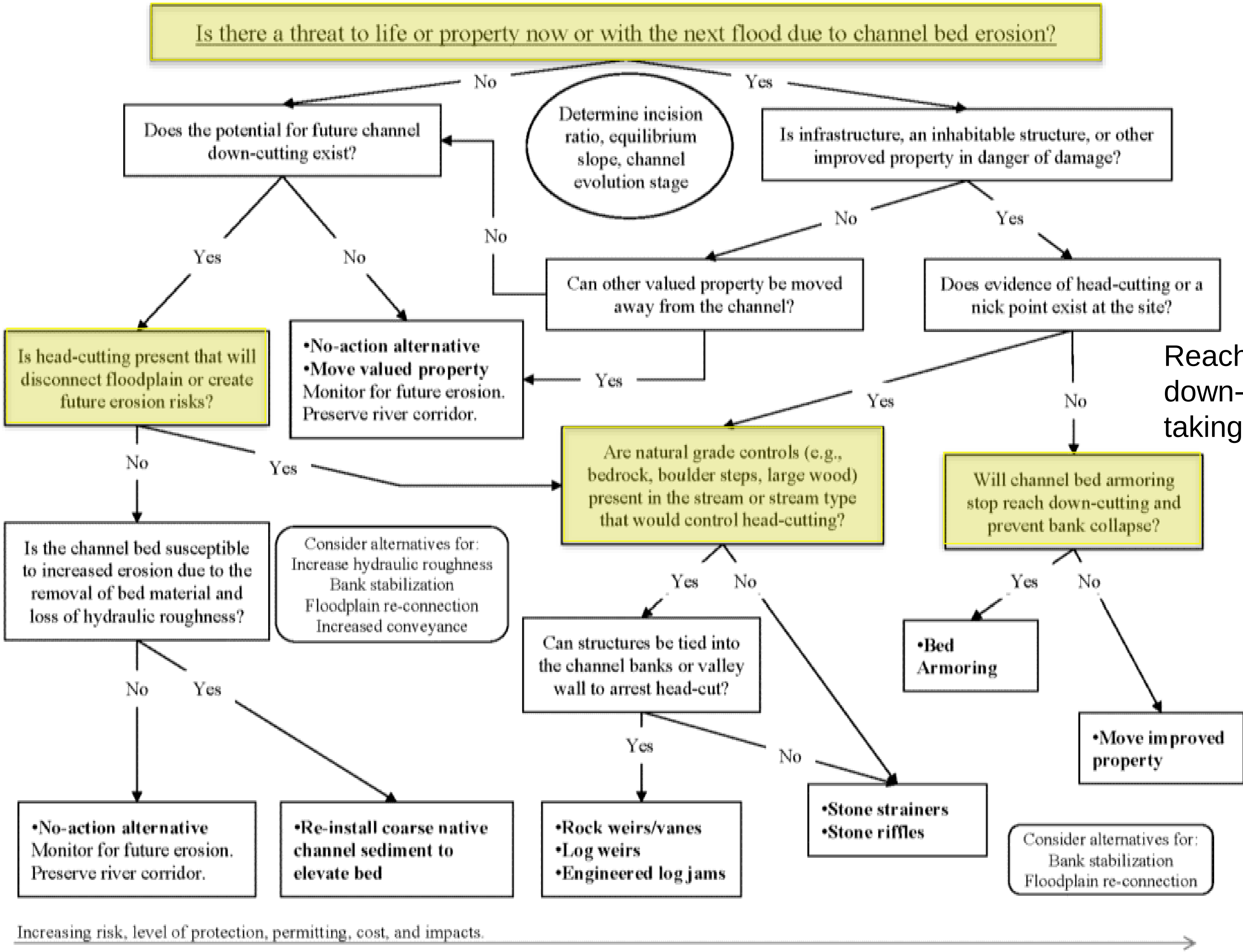
Project Example



(FEA & MMI, 2012)

Project Example

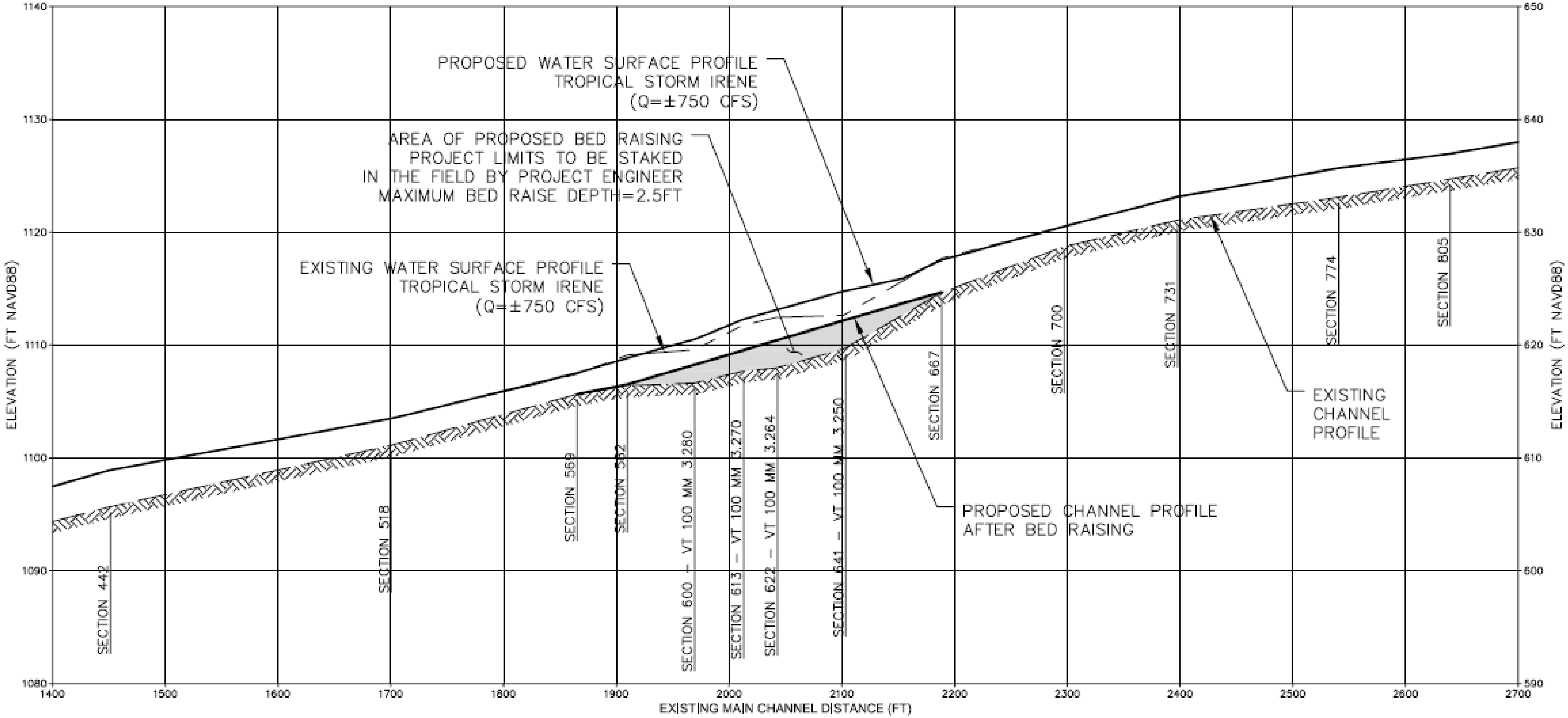
Bed Erosion Alternatives Analysis Review



Reach scale down-cutting is taking place

(Schiff et al., 2014)

Grade Control Project Example: Bed Armor

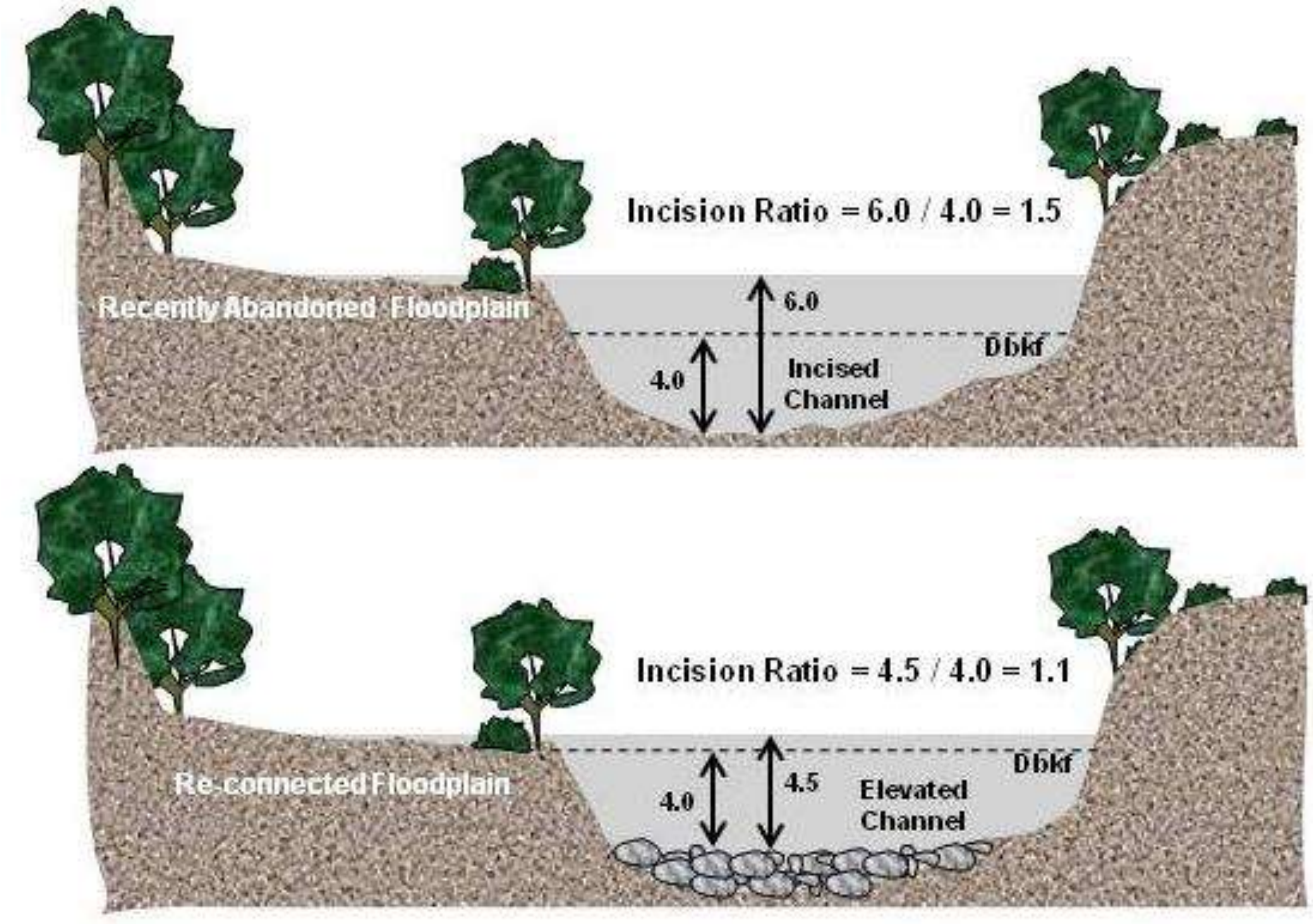


(MMI and FEA, 2013)

Grade Control Project Example: Bed Armor

(R. Schiff & E. Fitzgerald, 2012-13)

Grade Control Project Example: Bed Armor



(Milone & MacBroom, Inc. and Fitzgerald Environmental, 2013)

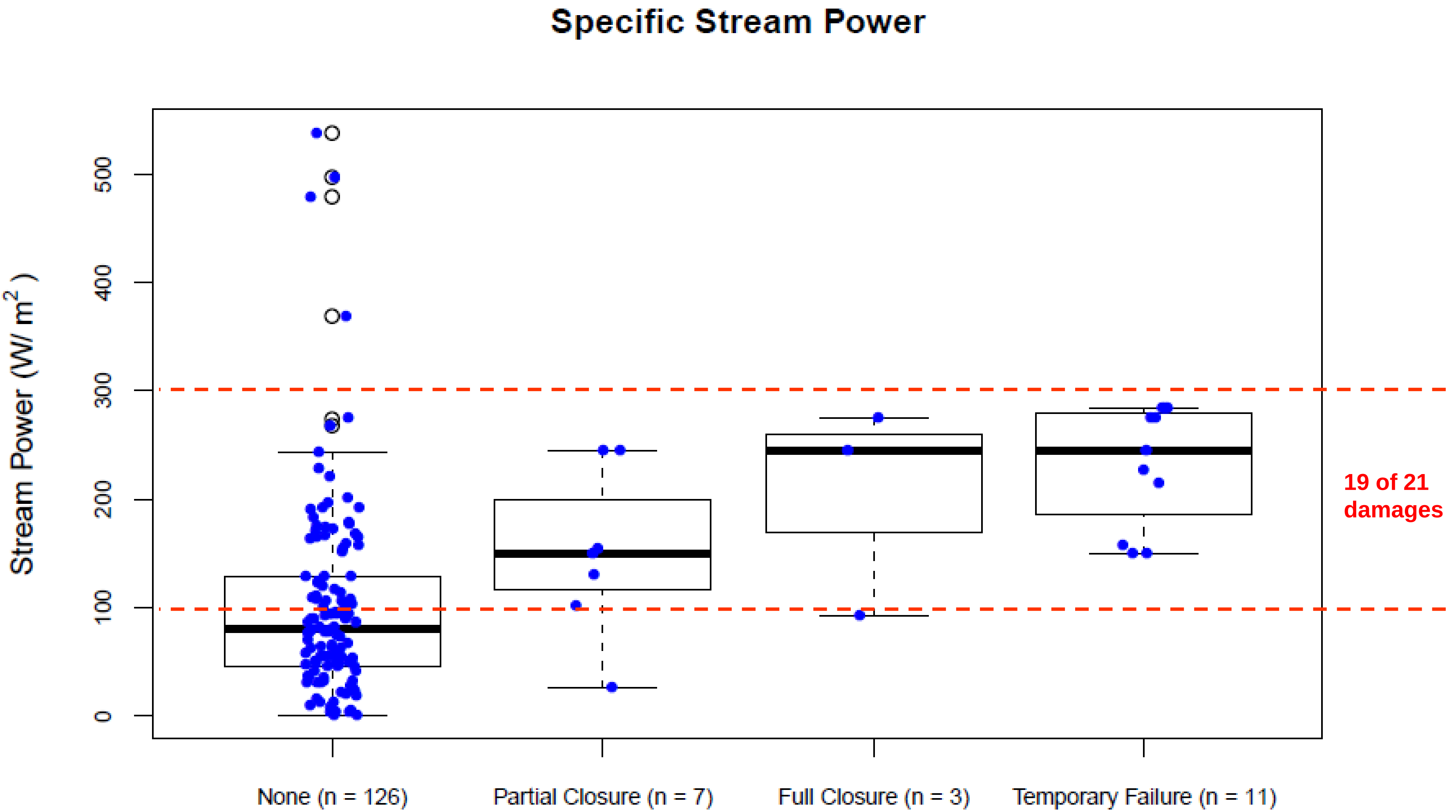
Thank You

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

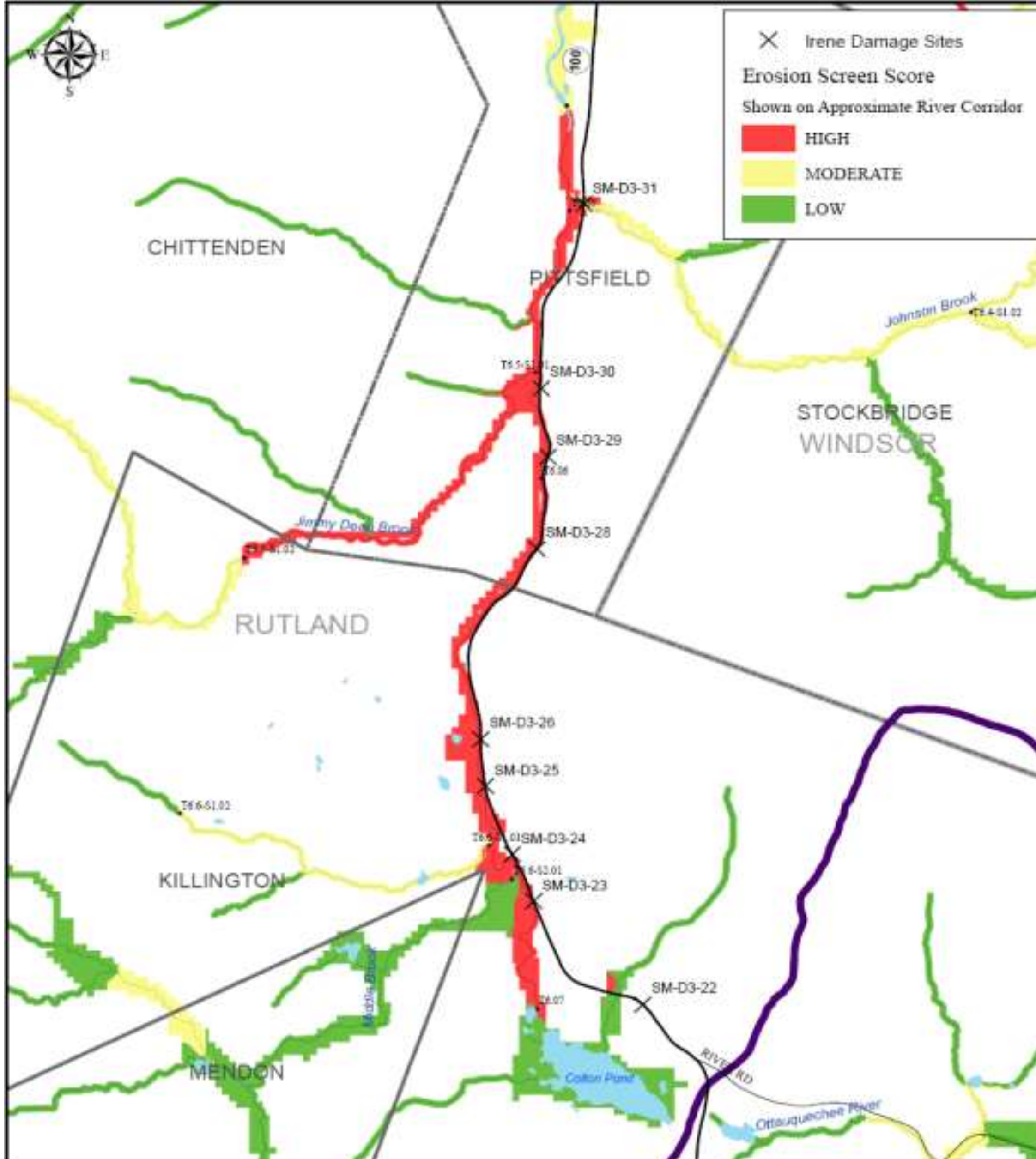
Extra Slides

Green River
Hinesburg Road near the Deer Park
Bridge
J. MacBroom, 2011

Road Vulnerability



(FEA, 2017)



Engineering, Landscape Architecture and Environmental Science

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RIVER CORRIDOR FLOOD SENSITIVITY SCREEN

RESULTS

0 0.125 0.25 0.5 Miles

DATE: February 2014

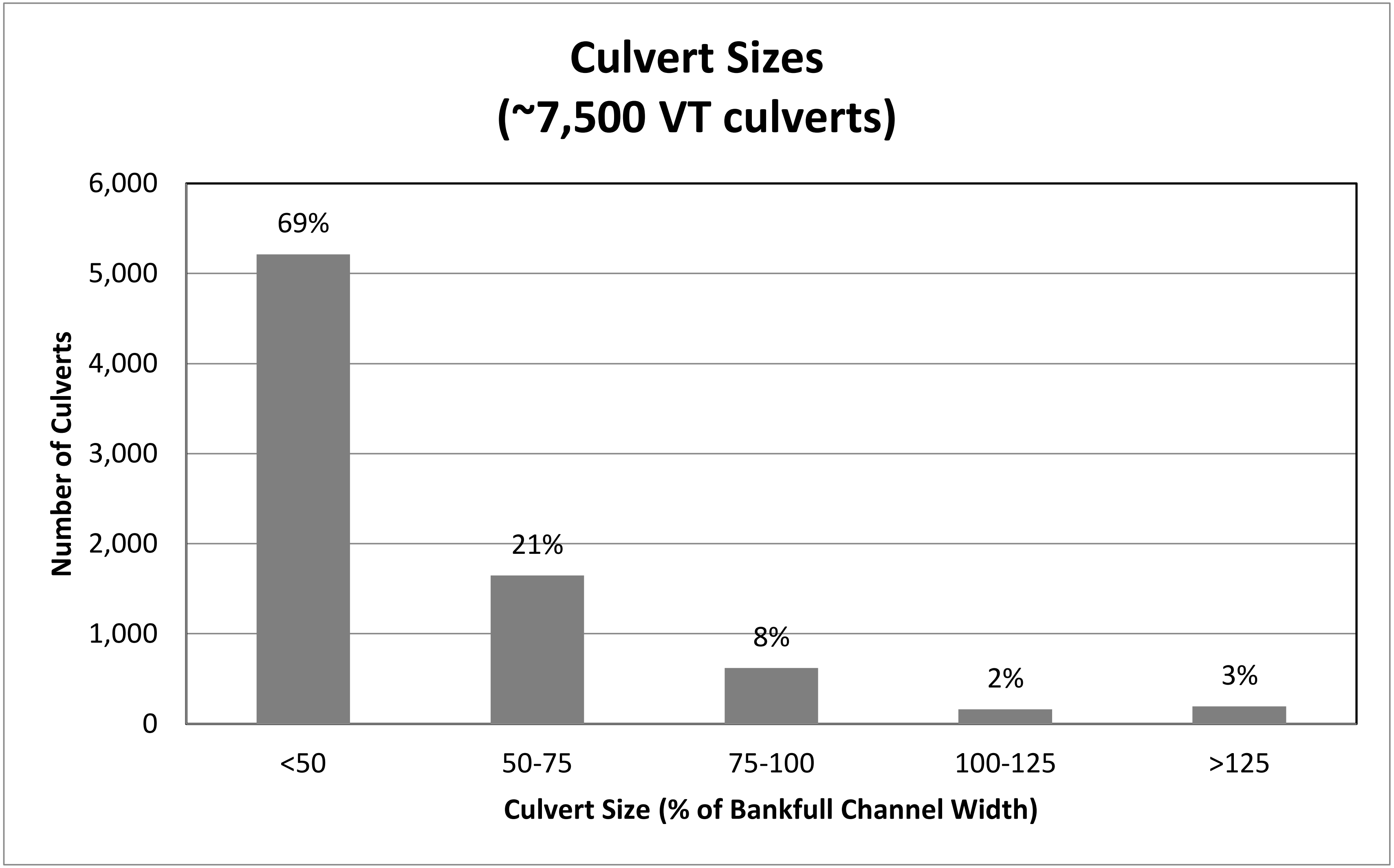
SCALE: see scale bar

SHEET: **Figure 1**

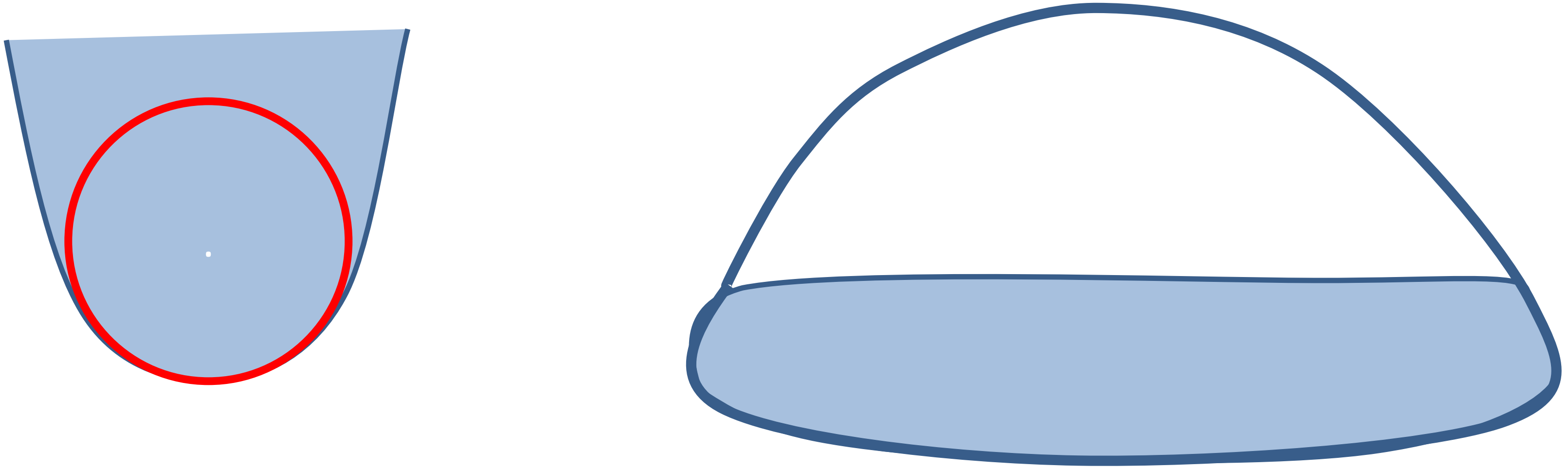
Culvert Replacement Design Example

(MMI, 2015)

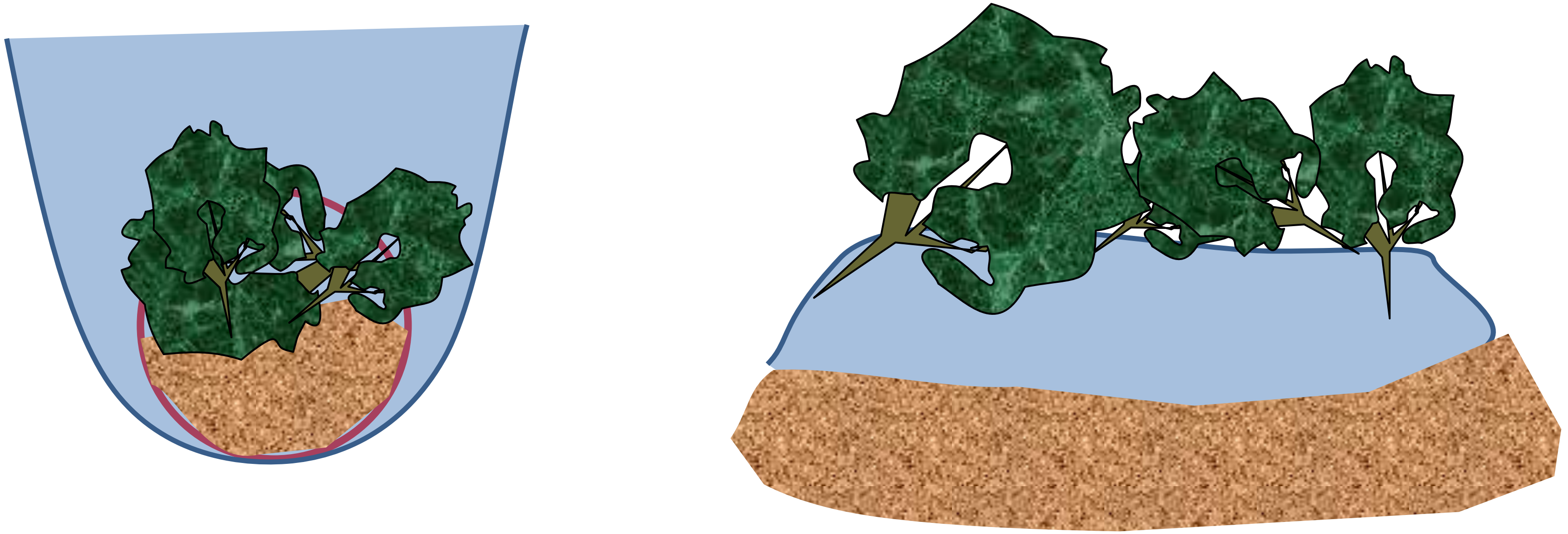
Undersized Culverts



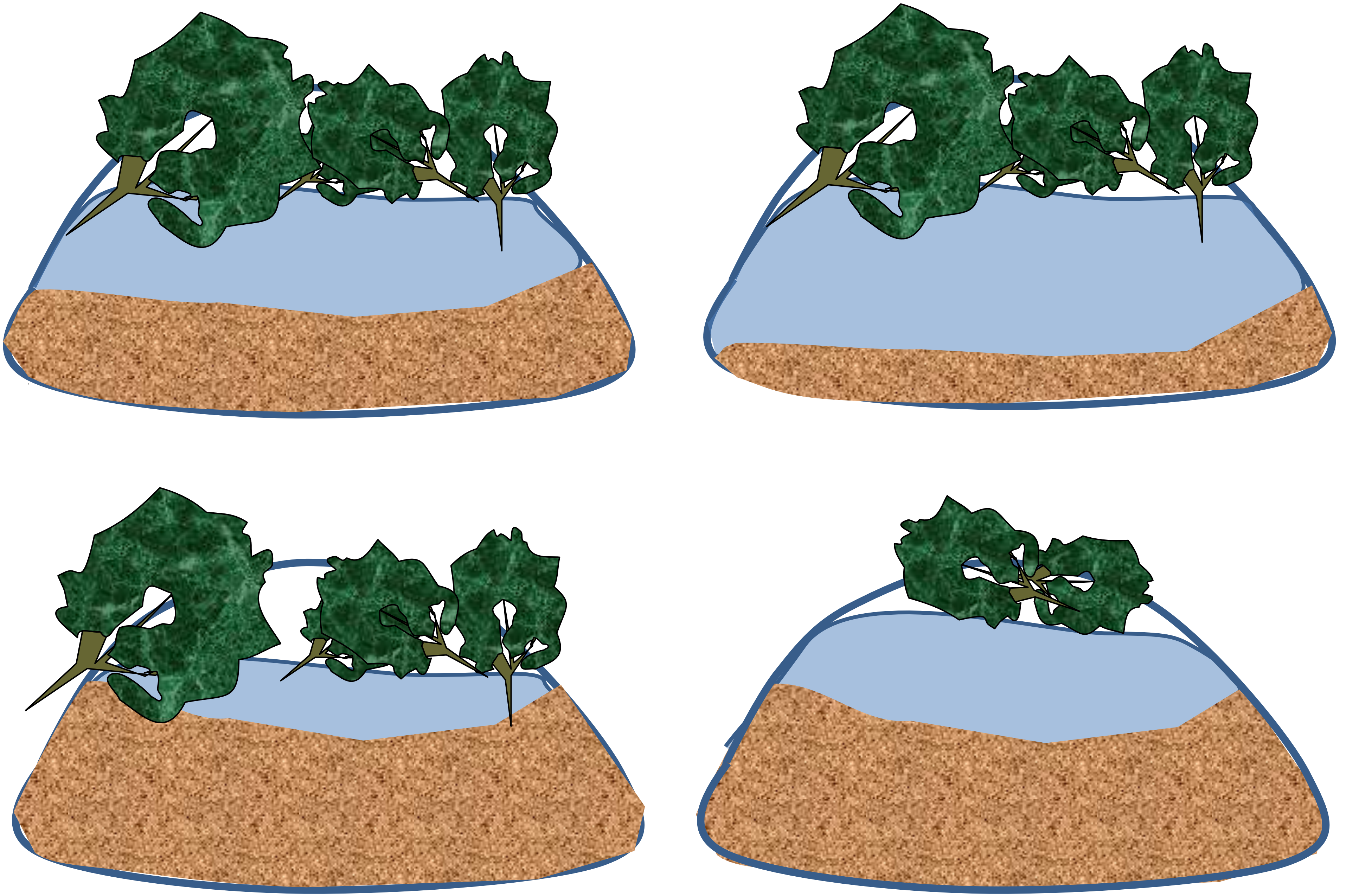
The Clear Flow Fairy Tale



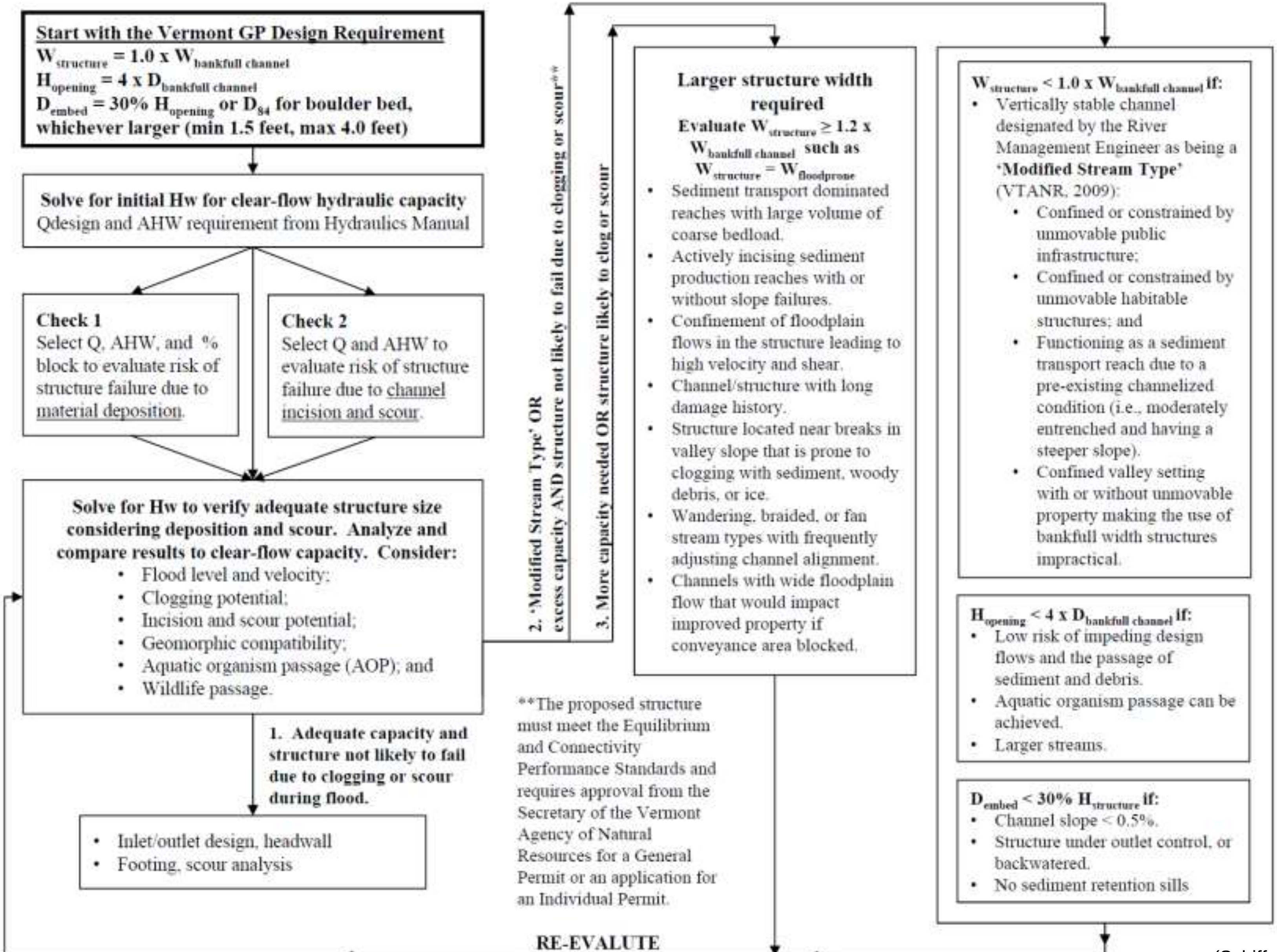
The Large Wood and Sediment Reality



The Scary Part of Reality



Recent VT Design Guidance & State Standards



(Schiff et al., 2014)

Grade Control: Common Mistakes

- Not considering stream velocity and power to determine which grade control practice is most appropriate.
- Use of undersized rocks for weirs that are susceptible to erosion during flooding.
- Not providing proper bank and bed tie-in for weirs and riffles.
- Improper spacing of stone weirs and riffles.
- Bed armor depth is too shallow and susceptible to undermining.
- Unstable banks are left unprotected with potential for the channel to roll off and outflank armoring.
- The transition between bed armoring and the channel bed is too steep at downstream limits creating abrupt changes in the longitudinal profile that may block aquatic organism passage or form upstream travelling erosion faces (i.e., head cuts) in future floods
- Uneven dispersal of native sediments along channel cross-sectional area

(Schiff et al., 2014)