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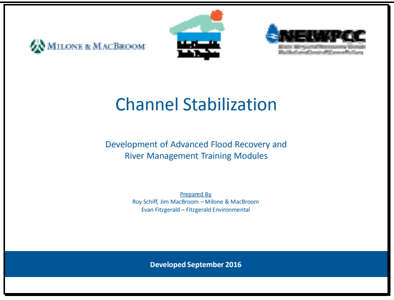
<td>
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Goals: Accelerate post flood infrastructure recovery, reduce future flood risks, and reduce river impacts.
Recall that this is Tier 3 of the Vermont Rivers and Roads Training. See if attendees have taken Tiers 1 and 2. If not direct them to Tier 1 online (http://wsmd.vt.gov/rivers/roadstraining/) and to VTDEC for Tier 2.
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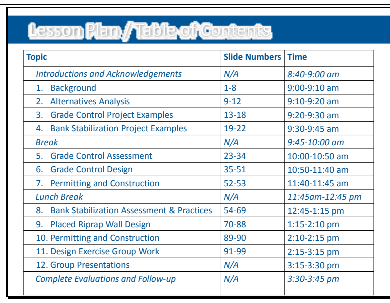
<td>Slide 2</td>
<td>
Lesson Plan / Table of Contents
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<tr><td>Introductions and Acknowledgements</td><td>N/A</td><td>8:40-9:00 am</td></tr>
<tr><td>1. Background</td><td>1-8</td><td>9:00-9:10 am</td></tr>
<tr><td>2. Alternatives Analysis</td><td>9-12</td><td>9:10-9:20 am</td></tr>
<tr><td>3. Grade Control Project Examples</td><td>13-18</td><td>9:20-9:30 am</td></tr>
<tr><td>4. Bank Stabilization Project Examples</td><td>19-22</td><td>9:30-9:45 am</td></tr>
<tr><td>Break</td><td>N/A</td><td>9:45-10:00 am</td></tr>
<tr><td>5. Grade Control Assessment</td><td>23-34</td><td>10:00-10:50 am</td></tr>
<tr><td>6. Grade Control Design</td><td>35-51</td><td>10:50-11:40 am</td></tr>
<tr><td>7. Permitting and Construction</td><td>52-53</td><td>11:40-11:45 am</td></tr>
<tr><td>Lunch Break</td><td>N/A</td><td>11:45am-12:45 pm</td></tr>
<tr><td>8. Bank Stabilization Assessment & Practices</td><td>54-69</td><td>12:45-1:15 pm</td></tr>
<tr><td>9. Placed Riprap Wall Design</td><td>70-88</td><td>1:15-2:10 pm</td></tr>
<tr><td>10. Permitting and Construction</td><td>89-90</td><td>2:10-2:15 pm</td></tr>
<tr><td>11. Design Exercise Group Work</td><td>91-99</td><td>2:15-3:15 pm</td></tr>
<tr><td>12. Group Presentations</td><td>N/A</td><td>3:15-3:30 pm</td></tr>
<tr><td>Complete Evaluations and Follow-up</td><td>N/A</td><td>3:30-3:45 pm</td></tr>
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<td>
Review lesson plan and slide ranges that serves as table of contents.
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<td>Slide 3</td>
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<td>
Set stage that this is not comprehensive on softer stabilization methods, especially where risk is lower.
This is how to minimize impacts and need for repeat work, typically at high risk sites.
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Set stage that this is not comprehensive on softer stabilization methods, especially where risk is lower.
This is how to minimize impacts and need for repeat work, typically at high risk sites.

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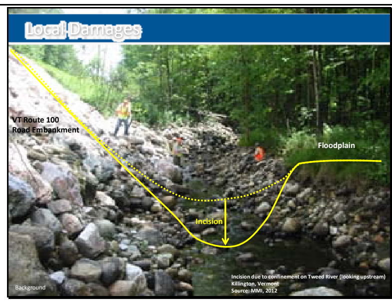

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Set stage that this is not comprehensive on softer stabilization methods, especially where risk is lower.
This is how to minimize impacts and need for repeat work, typically at high risk sites.

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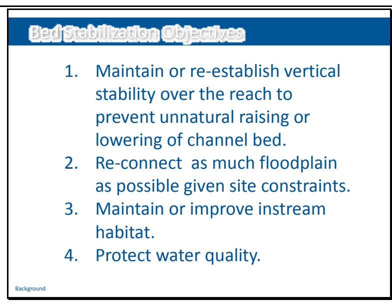

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<td>Review overarching bed stabilization objectives from Vermont Standard River Management Principals and Practices (http://www.anr.state.vt.us/dec/waterq/rivers.htm).</td>
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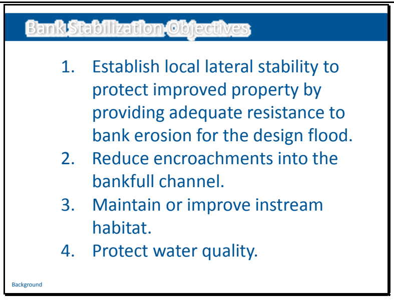
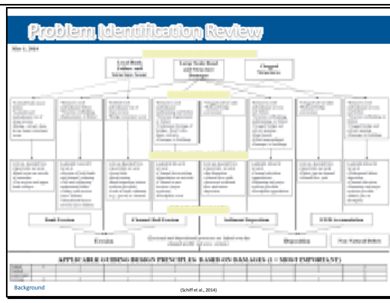
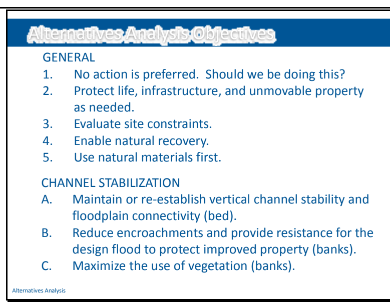
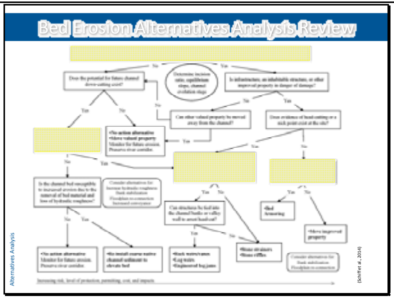
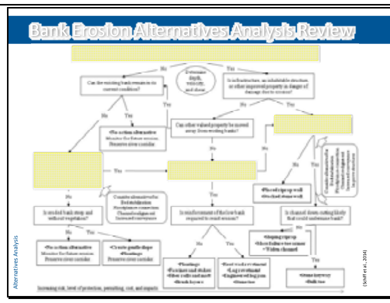
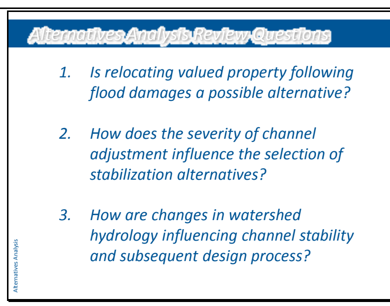
Slide 7		Review overarching bank stabilization objectives from Vermont Standard River Management Principals and Practices (http://www.anr.state.vt.us/dec/waterq/rivers.htm).
Slide 8		• This table is from the Vermont Standard River Management Principles and Practices (Schiff et al., 2014) (http://www.anr.state.vt.us/dec/waterq/rivers/docs/SRMPP_1.3.pdf). • Quick review as attendees should be familiar with this document or should review it on own. • Link observed damages to river channel conditions to river processes. • What is ultimately driving damages?
Slide 9		• Review list of general and practice-specific alternatives analysis objectives.

Slide 10		• Review the chart that is from Vermont Standard River Management Principles and Practices. • Key questions and turning points in analysis are highlighted. • Minimize work / impact / cost where possible. • Note lower risk actions.
Slide 11		• Review the chart that is from Vermont Standard River Management Principles and Practices. • Key questions and turning points in analysis are highlighted. • Minimize work / impact / cost where possible. • Note lower risk actions.
Slide 12		ANSWERS: • Definitely. Get out of the way wherever possible. It is the safest and cheapest approach in the long run. • The severity of erosion drives the selection of alternatives. First and foremost, if the erosion is not severe and/or not threatening property or infrastructure, there is no need for action and the river can be left to heal at its own pace. Where property is threatened the severity of erosion, along with the site constraints, dictates which practice is appropriate and will resist the erosion forces specific to the site; i.e., sites with lower power/erosion potential may

		call for less invasive, natural approaches such as bioengineering. • We know that climate change and upstream development are changing watershed hydrology, which in turn affects the rate and magnitude of channel adjustments caused by floods. Need to consider using conservative hydrology estimates to evaluate flood velocity, surface water elevation, etc.
Slide 13		• Next series of slides are examples of grade control practices, going from least invasive/structural to most (bed armoring). • Pictures of the South Branch Tweed River along VT Route 100 in Killington, VT. • Dozens of sites along the Vermont State Highway System called for a combination of bank stabilization and minor bed stabilization through the re-installation of native bed material that was pulled out the bed and draped along the embankment during the emergency repair work. • This work is typically done in conjunction with bank stabilization such as a placed riprap wall, and serves to reestablish roughness in the bed, restore a more natural longitudinal profile and bed features, thereby setting the river up for reforming smaller scale habitat features.

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<td>• Reconstructed riffles typically following disturbance to the channel bed during construction, such as dam removal or temporary in-stream diversions during construction. These can range from dozens of intentionally placed boulders to simply seeding the bed with a few boulders.
• Vanes or spurs do not span the entire channel and are used to deflect flow away from vulnerable banks or infrastructure, and create habitat complexity.
• Proper sizing of rock sizes requires force-resistance calculations.</td>
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<td>Slide 15</td>
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<td>• Weirs are used to set the profile of the channel, prevent incision, and create habitat features.
• Spacing along channel and configuration depends on natural channel tendencies.
• Proper sizing of rock sizes requires force-resistance calculations.
• We will get into the design of these features in more detail.</td>
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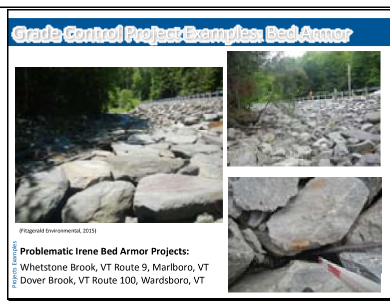
Slide 16		• Bed armor is the most extreme, invasive approach to stabilizing an incising stream. It has become more common in flood recovery work and makes good economic sense in some cases, but it requires some design work up front to avoid problems – can't just end dump Type IV rock in channel and walk away. • Numerous case studies of bed armor – good and bad – during Tropical Storm Irene recovery in Vermont. • Pictures from an example of a successful bed armor installation as part of permanent repairs along Route 100 in Killington. • Bed armor is not visible on right because it was buried beneath native substrate. Sequence is specified in the Vermont Standard River Management Principles and Practices.
Slide 17		• Many examples of aggressive bed armor projects in Vermont needing follow up work to address AOP barriers. • Projects were "successful" in preventing incision in channel and protecting the adjacent road embankment. • However rock depth and gradation (no fines) resulted in subsurface flow for many hundred feet in some cases.

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<td>Even when the flow is not subsurface through the bed armor, the downstream transition to the natural bed can be a problem for AOP if it is too abrupt. Example of AOP barrier on the Sleepers River in Danville, VT.</td>
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<td>Slide 19</td>
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Traditional post-Irene slope stabilization along 4th order channel in Pittsfield, VT.
1V:2H or 1V:1.5H slope with grubbings and seeding on upper slope above common flood levels.
Key depth depends on scour risk. Rock sizing depends on flood velocity and elevation.
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<td>Slide 20</td>
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Placed riprap wall (i.e., stacked stone wall) very common practice in Vermont for permanent Irene repairs. Gains space for a bankfull channel in confined settings.
Most common and appropriate in confined 3rd and 4th order channels where roadway occupies a large portion of the narrow valley/floodplain, and lateral space is a premium.
May not be appropriate on larger rivers due to potential instability with greater scour depths. Relatively little space gained on a large river over sloping armor approach.
Large, blocky rock at base keyed into the channel bed to a depth below
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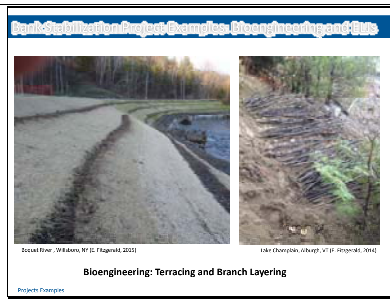
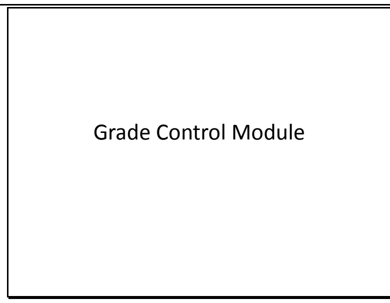
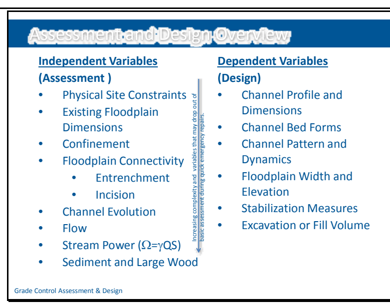
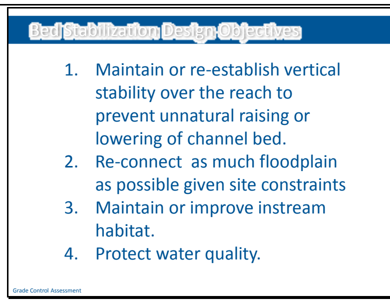
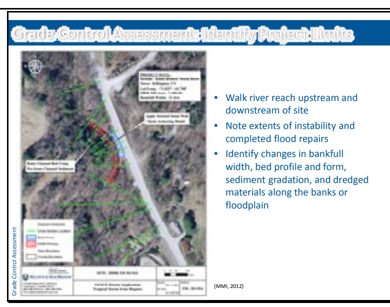
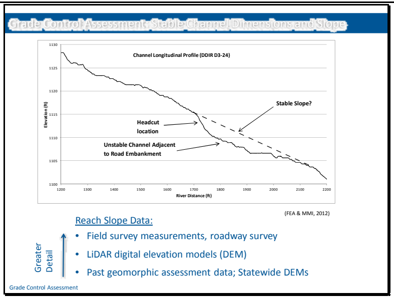
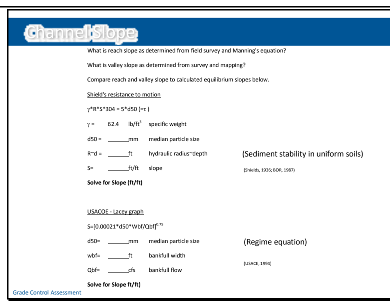
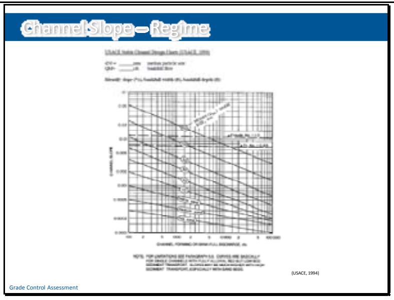
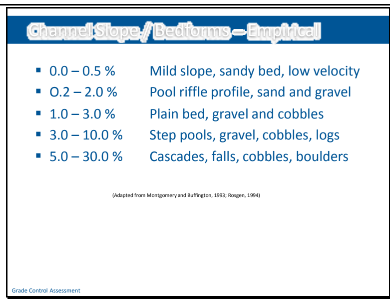
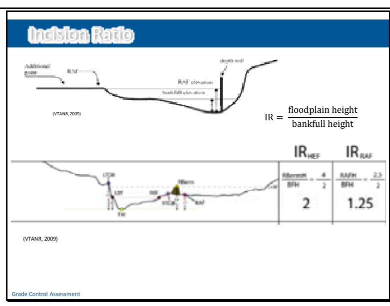
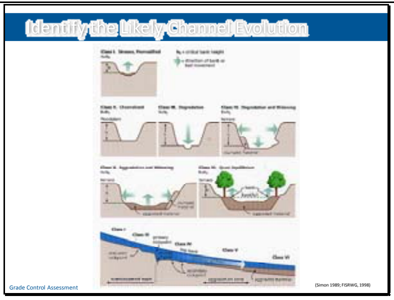
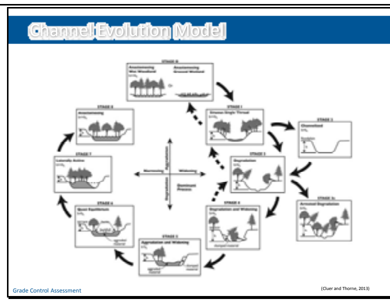
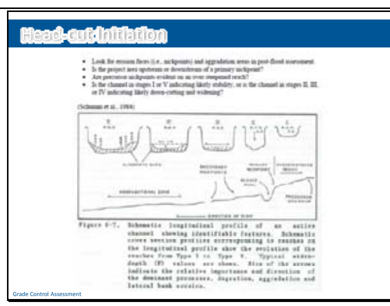
		predicted scour. • Type III or II stone above wall depending on large flood elevations and velocities. • Grubbings and seeding on slope above wall.
Slide 21		• Bioengineering describes a variety of practices that are well documented in stream restoration literature. Includes combinations of fabrics (ie, coir), plantings, and seeding. • Appropriate for lower power/energy settings or higher on banks where velocity and shear potential is lower. Bioengineering methods can fail when designers underestimated the erosion forces. • Bioengineering practices complement traditional armoring approaches by working to naturalize the banks and riparian corridor. • Engineered log jams (ELJs) are large masses of trees and soil/stones projecting from the bank. They are used to deflect flow, push the thalweg away from the bank, and create habitat complexity in the channel.

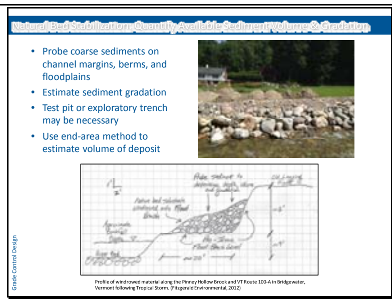
Slide 22		• Examples of bioengineering on upper banks to rapidly vegetate steep banks. • The branch layers root deep into the bank, providing a plane of root mass that “stiffens” the bank similar to a geogrid approach.
Slide 23		
Slide 24		• Understand what you are changing and what responds to that change. • Assess independent variables (before or after flood). • Design dependent variables. • Listed in order of increasing complexity to assess so some items will drop off bottom of list for emergency repairs and quick implementation. • Basic design is performed under emergency rules in high risk settings to return to existing conditions while keeping the concept of equilibrium in the design process. • Keep in mind the principal of do no harm as we enter into design

		discussion.
Slide 25		Review overarching bed stabilization objectives from Vermont Standard River Management Principals and Practices (http://www.anr.state.vt.us/dec/waterq/rivers.htm).
Slide 26		• Review bed stabilization assessment steps from Vermont Standard River Management Principals and Practices (http://www.anr.state.vt.us/dec/waterq/rivers.htm) • Need to observe reach to put the damage site characteristics into context of river adjustments • Look at changes in channel morphology through the damage site and upstream/downstream reach that may influence project site.

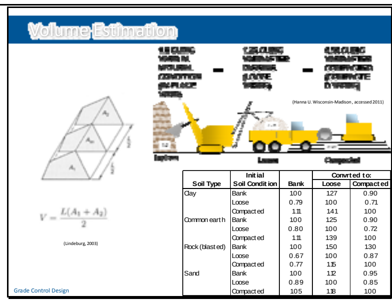
Slide 27		• Evaluate reach slope and channel dimensions. • Field survey data needed for larger projects during non-emergency work. • LiDAR is an appropriate tool to evaluate reach channel slope and dimensions but has limitations (does not penetrate water well). • Past geomorphic assessment data may be available for reach, including cross-sections and reference bankfull dimensions. • We will get into hydraulic geometry and channel sizing in more detail in the bank stabilization module. • Observe longitudinal profile to understand reach and local slope (fit site scale into reach scale appropriately).
Slide 28		• Slope is a key parameter in channel design to leave a stable channel once work is complete. • What is reference reach slope? • Use equations to determine what the slope is based on sediment size and channel dimensions. • Army Corps has handy plot for this. • Compare slope predictions from reference reach, sediment stability equation, and regime equation, and compare to current conditions. • Solve for S

Slide 29		• Use regime equation or plot as a first prediction since it is quick. • Compare to local observations.
Slide 30		• This is a guide for initial thinking to relate slope to channel type / bedforms. • The range for braided and wandering channels can be wide and overlap several of these ranges. • Caution that this list does not explicitly account for channel size.
Slide 31		• Builds on Tier 2 introduction of definition. • Incision ratio is a more local and current indicator of floodplain access. • IR = floodplain height / bankfull height. IR =1 is well-connected floodplain during bankfull flood. Higher IR is less connected. • Note change in IR due to berms.

Slide 32		• Quick review as covered in Tier 2. Does everyone get this? • Temporal change trajectory illustrated by channel evolution models (CEMs). • This model assumes that bedrock and natural bed armor is absent. • Most actively adjusting are CEM 2, 3, and 4. • This plot has recently been upgraded.
Slide 33		• This is a recent upgrade to CEM that includes habitat and ecosystem benefits • Notice additional steps that tend to fit altered channels better than the original models. See stage 3s. • Note state 7 could simulate high sediment load event.
Slide 34		• Original CEM, but also shows longitudinal profile with nickpoints. • See if nickpoints exist in the field up- or downstream of project. • Do aggradation areas exist? • Use the CEM and head-cut potential to understand how channel exists and may react to sediment removal. • Difference in scale is important as this trajectory and process can play out on tributaries and mainstem rivers. For example, Lilliesville Brook meeting the White River in Bethel where major sediment loading and then headcutting.

Slide 35		Natural bed stabilization is commonly used: • When historic flood recovery work resulted in excessive coarse sediment removal from the channel; • When natural bed armor was stripped from the channel due to excessive stream power during a flood; • In a channel that has cut down and is disconnected from its floodplain; and • When historic berms are being removed to restore floodplain connection. Need to begin by quantifying the sediment volume and gradation along the banks and windrows.

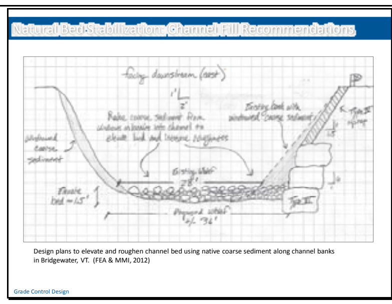
Slide 36



If the bed stabilization work involves a large volume of sediment consider the following:

- Consider consolidation in your sediment volume estimates.
- Consolidation accounting can lead to changes in cost on the order of $100,000's for large deposition events. (250,000 CY *$10/CY * 0.1 = $250,000)
- Agree upon consolidation factor at START of project after observing early excavations, transports, and compactions with contractor.
- Invest time up front in the project to agree upon consolidation factor, especially if the removal volume is over 10,000 CY.

Slide 37



Design plans to elevate and roughen channel bed using native coarse sediment along channel banks in Bridgewater, VT. (FEA & MMI, 2012)

- Example of simple sketch from Irene repairs of bed roughening in conjunction with placed riprap wall.
- In this example relief of roadway not a concern so bed elevated to maximize channel width in a confined channel setting.

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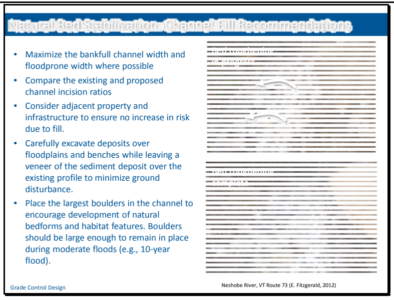
<td>
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After Irene this practice most commonly used in conjunction with bank stabilization where the coarse native bed material was stripped from the channel and placed on the bank. The pictures are from VT Route 73 in Goshen along the Neshobe River.
Objective is to regain natural channel morphology and roughness as much as possible, and reconnect floodplain while minimizing risks to adjacent infrastructure.
Evaluate reference channel morphology and incision ratio in the reach for targets.
When working with contractors be clear on what you want to see in the channel roughness – “random” boulder placement is sometimes interpreted as uniform spacing of large boulders instead of clusters of boulders that resemble natural habitat. Take contractor down the river to view natural bedforms you want as end product!
This is a corrective action for poor flood recovery and to reduce incision that typically is not performed away from floods since it would be channel/floodplain fill.

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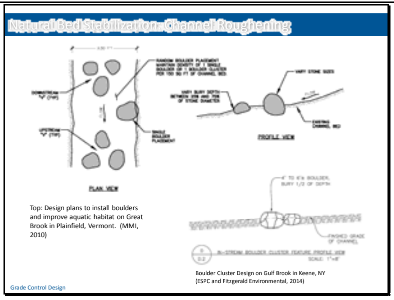
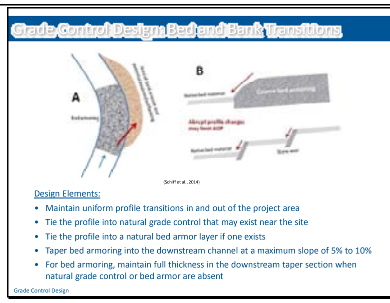
Slide 39		• Example plans of "random" boulder placement. • These example shows boulders and boulder clusters that do not have "footers" and are not imbricated. Designs should consider the channel dimensions and expected forces (i.e., velocity and shear) in determining appropriate embedded depth and cluster configuration to remain stable during design floods. • Largest boulders embedded into the channel so they will stay put in floods and recruit sediment/wood and create scour features downstream • Remember that messy looking channels have the features fish are seeking!
Slide 40		• Critical first step in evaluation/design is fitting grade control features into the reach profile. • Account for natural grade control and/or bed armor elevations/profiles in upstream and downstream areas. • Avoid common mistake of a steep transition of bed armor or weirs to in the downstream project area that might be an AOP barrier.

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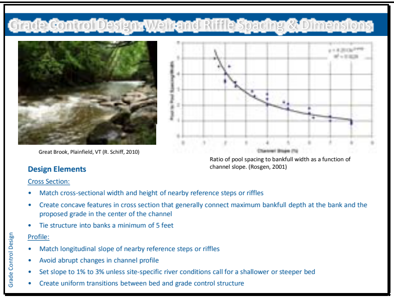
<td>
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Riffle and step features often spaced naturally in channels based on channel slope and dimensions.
Use spacing chart as a first cut guide, but observe natural spacing in the reach to confirm. Study the spacing, configuration, and rock size of natural steps/riffles to mimic in design.
Ensure proper bank ties with weirs and concavity in cross-section to concentrate low flows in center of channel. Low flow channel width is typically 1/3 to ½ bankfull width.

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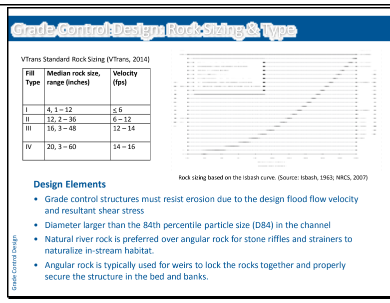
<td>
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Natural channels are instructive for immobile bed material. Observe average largest particle size at riffle heads or in steps to verify D84 or greater.
For smaller projects cursory hydraulic analysis (e.g., single uniform flow calculation) may suffice for estimating velocity and sizing rock.
For complex projects on larger rivers and with multiple grade control features hydraulic modeling may be required.
Note differences in rock shape for weirs vs. riffles or strainers.

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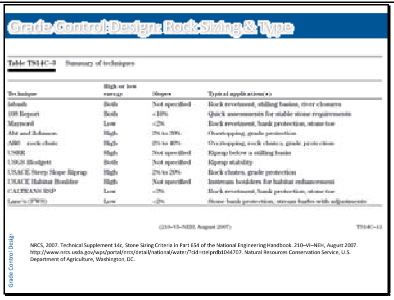
<td>
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Many rock sizing methods.
See Isbash method common and good over wide range of slopes and energy levels.
Maynord method commonly used for riffle-pool or flatter channels.
USACE steep slope method applies to many steep streams in our region.

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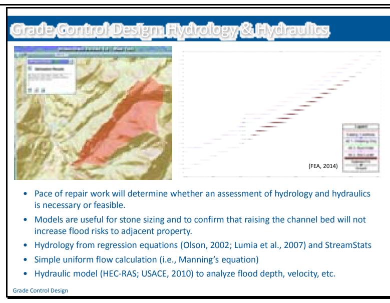
<td>Slide 44</td>
<td>
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If the project is large or complex or situated near infrastructure a full hydrology and hydraulic analysis may be required. This is usually not feasible during emergency repair work.
Watershed hydrology readily available through USGS records and Streamstats, but flows on ungaged rivers may be underestimated where watershed slope is very high or soils are impervious.
Climate change since 1970's appears to be causing increases in peak flows in the Northeast –consider adding 10% to design flows.
Return flows should be checked against high water marks at site whenever possible.
Smaller projects may only need a single velocity estimate.

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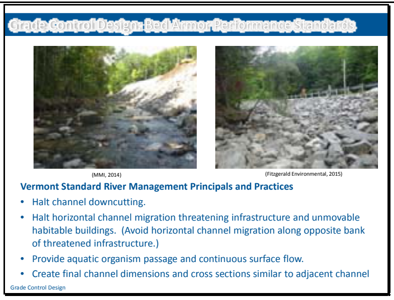
<td>
</td>
<td>Bed armor performance standards from VSRMPP.
• Naturalize channel as much as possible.
• Install rock in lifts by swapping native bed with imported rock.</td>
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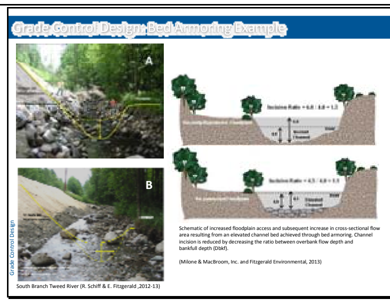
<td>Slide 46</td>
<td>
</td>
<td>• On right is schematic of elevated channel and reduced incision. Disconnected floodplain might only be inundated in large floods but after reconnection is accessed in more frequent floods (ie, 5 or 10-year flood)
• Example of reinstallation of native bed material following a bed armor install on South Branch Tweed River in Killington, VT.
• Note the bed has expected features including gravel bar on inside bend, low flow channel on outside bend, etc.</td>
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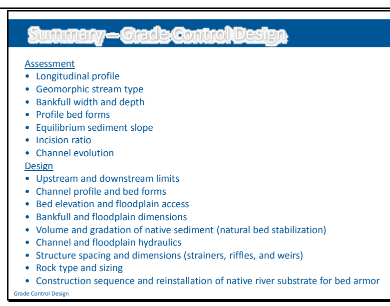
<td>Slide 47</td>
<td>
</td>
<td>• Summary / checklist for future design use.
• Mostly for future reference since we have covered throughout presentation.</td>
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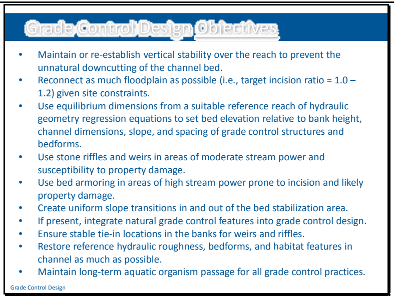
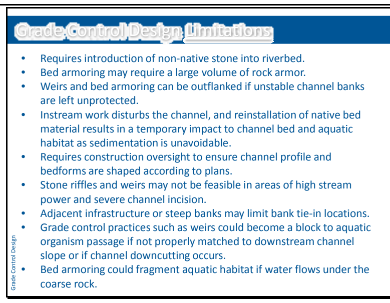
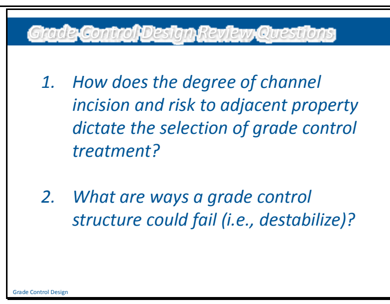
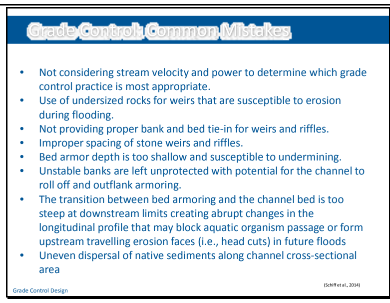
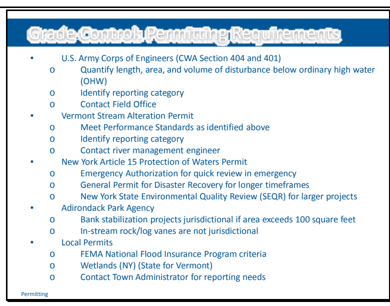
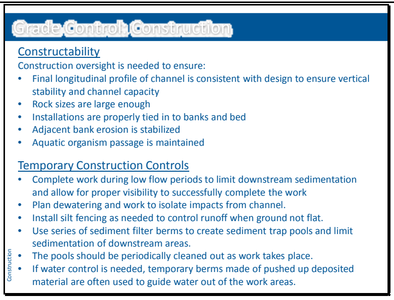
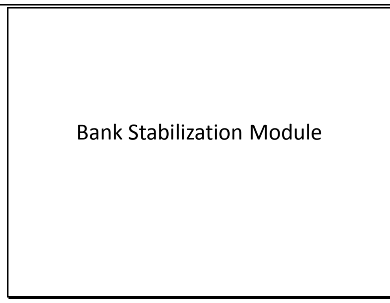
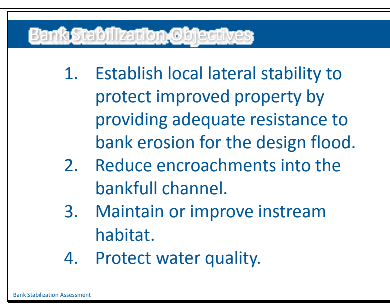
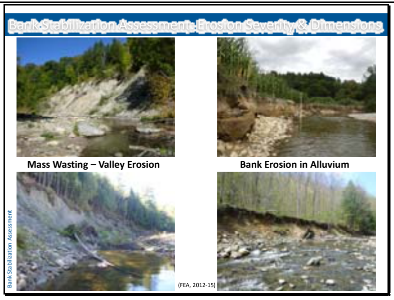
Slide 48		• Summary of key design objectives for future use. • Mostly for future reference since we have covered throughout presentation.
Slide 49		• Summary of key limitations for future design use. • Mostly for future reference since we have covered throughout presentation.
Slide 50		• The severity of erosion and risk to infrastructure drives the design process. If the erosion is not severe and/or not threatening property or infrastructure, there is no need for action and the river can be left to heal at its own pace. Deeply incised channels along infrastructure that cannot be moved (e.g., major state highway) will require the most aggressive bed stabilization measures. Discrete grade control features such as weirs may be appropriate for moderately incised channels in lower power settings. • Grade control failure: • Structures inappropriate for reach/channel setting.

		• Stream power underestimated during design. • Structures not keyed into bed/banks. • Severe lateral channel migration and/or bank erosion outflanks structure due to deposition behind grade control.
Slide 51		Follow up for answer to question #2 on previous slide. Taken from Vermont Standard River Management Principles and Practices.
Slide 52		List of common permitting requirements in VT and NY.

Slide 53		Taken from Vermont Standard River Management Principles and Practices. • Review of check list for construction oversight. • Review of temporary construction controls during the work to minimize channel impacts.
Slide 54		
Slide 55		Review overarching bank stabilization objectives from Vermont Standard River Management Principals and Practices (http://www.anr.state.vt.us/dec/waterq/rivers.htm).

Slide 56		• Understanding basics of erosion terminology and what is realistic for stabilization. • Mass wasting or valley erosion encompasses a large chunk of the valley wall. • Bank erosion encompasses alluvial or glacial deposits down in the valley and along the banks. • Helpful to know the soil parent material and the landform. Some soil types are more easily eroded (e.g., fine sandy loams) whereas others may have cohesivity properties that resist erosion (e.g., clay loams, dense till).
Slide 57		• Presence or absence of adjacent improved property drives risk and design process. • State highways and larger town roads are generally not movable; stabilization necessary. • Homes subject to repeat erosion damage could be bought out, obviating bank hardening.

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Top pictures: Adams Brook in Newfane, VT. Continued high risk of erosion due to bedload and high power channel.
Bottom left: Green River in Halifax, VT. Channel overwidened and took out bridge to house across from Town road. House was a FEMA buyout after Irene. No need to stabilize bank to protect infrastucture.
Bottom right: South Branch Tweed River along Route 100 in Killington, VT. Moderate scour along embankment toe, naturally high channel roughness. Watch erosion over time but no immediate action needed.

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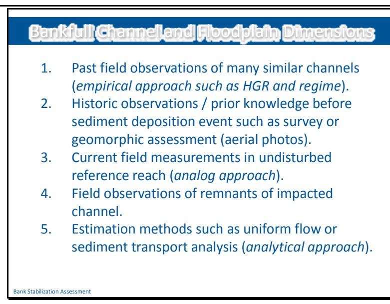
<td>
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Review empirical, analog, and analytical approaches to getting dimensions.
Simplest to complex – HGR, past info, current measurements, current observations, modeling
Be sure to compare results from multiple methods to bracket answer since not exact science and local variability common.

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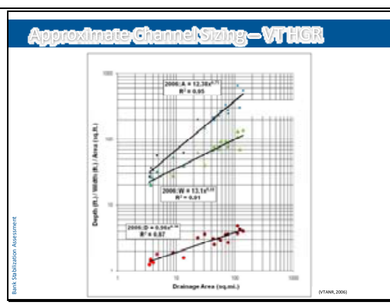
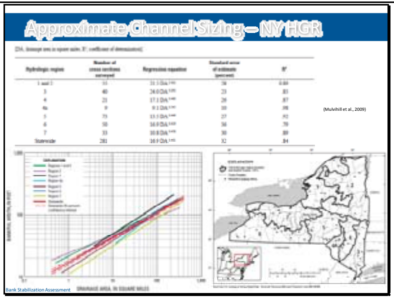
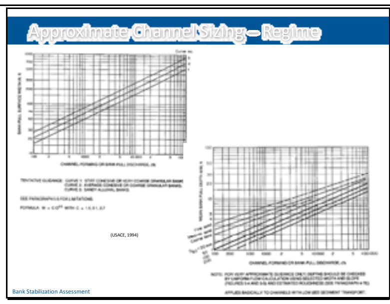
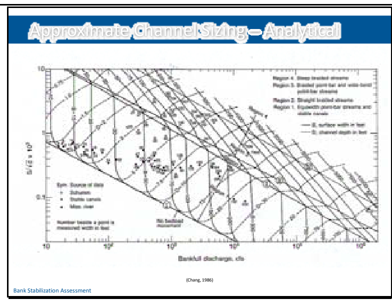
Slide 60		• Quick review as covered in Tier 2. Does everyone get this? • Note that it is difficult to ID bankfull indicators post flood so past geomorphic assessments are very helpful, if not essential in damage prone areas. • Be sure to consider bankfull relative to larger flood indicators that are typically linked to damages.
Slide 61		• Quick review as covered in Tier 2. Does everyone get this?
Slide 62		• Quick review as covered in Tier 2. Does everyone get this? • Note that there are limitations to this – disturbed channels, different geomorphic settings, etc. • HGRs are notorious for under-estimating widths on braided or wandering channels. • Consider how changes in climate may be dating these regressions – consider adding +/-10% to predicted dimensions.

Slide 63		• Many states separate regions for HGRs. • HGRs are notorious for under-estimating widths on braided or wandering channels, and overestimating widths on “slow winders” or Rosgen E-type channels. • Quick review as covered in Tier 2. Does everyone get this? • Consider how changes in climate may be dating these regressions – consider adding +/-10% to predicted dimensions. • The USGS developed an enhanced web-based streamstats application to estimate the impact of climate change scenarios on flood flows: http://ny.water.usgs.gov/maps/floodfreq-climate/
Slide 64		• Note that regime equations are based on bankfull discharge or Q2, and not drainage area. • Regime equations consider sediment grain size or bank cover since the origin was the ability for canals to convey water and not fill in. • Regime equations are more appropriate for changing hydrology as seen in region since Q is the independent variable rather than drainage area. • Can use equation or plot for width.

Slide 65		• Chang performed computer simulations for sandbed rivers and made this plot for quick reference that is often used for larger substrates as well. • What dimensions to carry water and sediment? • This is an attempt to solve the extremal hypothesis - an alternative to solving the reach scale 3-dimensional conservation laws for fluid and sediment, to provide a first order means of predicting channel dimensions in an objective and reproducible manner. • Calculate vertical axis variable, locate point on graph, read region, width, depth.
Slide 66		Clockwise from upper left: • Traditional slope stabilization: 1V:2H or 1V:1.5H slope with grubbings and seeding on upper slope above common flood levels. • Placed riprap wall common practice after Irene – we will work through design process for this practice. • Bioengineering practices complement traditional armoring approaches by working to naturalize the banks and riparian corridor. • Engineered log jams (ELJs) are large masses of trees and soil/stones projecting from the bank. They are used to deflect flow, push the thalweg away from the bank, and create habitat complexity in the channel.

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<td>Slide 67</td>
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<td>1. Bioengineering is not suitable for many sites with higher power/velocity.
2. Need to understand processes and where the site sits on the spectrum of stream power/velocity.
3. Selection of appropriate fabrics and wood species is very important for success of project.</td>
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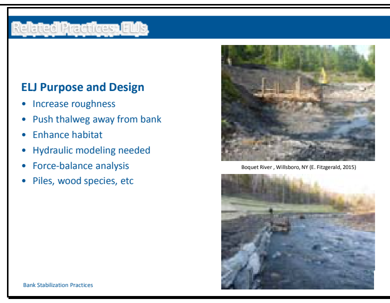
<td>
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<td>• In some settings ELJs may be as effective or more than bank hardening.
• Toe wood is a lighter option for sites with limited power and less tendency for lateral migration.
• These practices enhance habitat by creating heterogeneity in the bed.
• Typically not appropriate along highways or in high-risk areas with infrastructure.</td>
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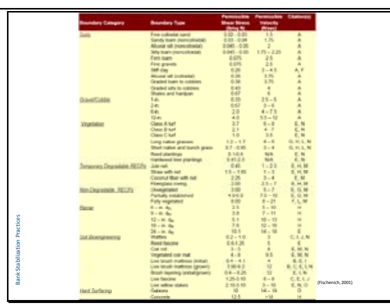
<td>
</td>
<td>• Permissible or critical velocity. Note gradient from bioengineering approaches through rock riprap.
• Note values from example.</td>
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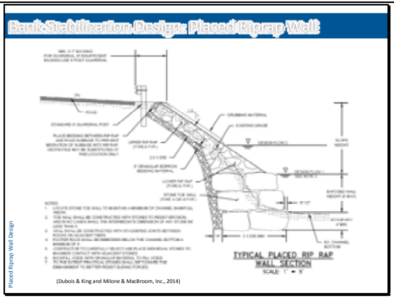
<td>
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Typical section from Post-Irene repairs on VT State Highways. Point out key features:
Blocky armor for building wall – wall height does not exceed 6ft unless a geotechnical evaluation is to be completed.
Key below channel bottom depending on scour potential.
Gravel bedding behind wall and upper riprap.
Upper riprap with grubbing/seed depending on flood elevations.

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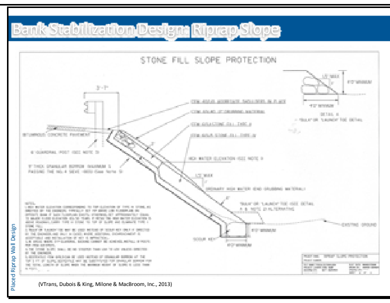
<td>
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Another typical from Irene repairs in VT.
Lower slope is Type IV stone, sometimes with a bulk toe depending on scour potential.
Upper slope very similar to placed riprap wall.
Gravel bedding instead of geotextile behind riprap, unless soils and piping are a concern.

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May requires coordination with quarry ahead of time to blast/sort appropriate rock dimensions.
Due to size there is a lot of wear and tear on dump trucks – sometimes higher trucking price.
Many loads – some trips only have 4-5 stones in truck.
Habitat note: explain to contractor not to fill voids in large rocks at bottom of wall at water interface to provide refuge for fish during high flows.

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This is key step in pre-construction layout to confirm desired channel width/dimensions will be achieved.
Common issues:

Make sure contractor knows the stake is for the face of wall in the channel vs. the top of wall (red arrow).
Spacing of stakes too wide resulting in wall face that is wavy or not smooth/uniform

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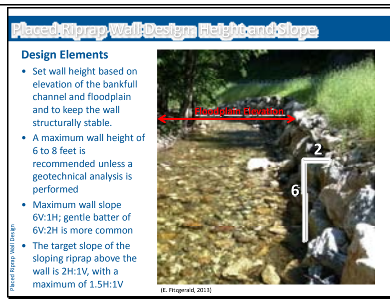
<td>
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Need to indentify floodplain or flood bench elevation opposite bank to relate to wall transitions.
Hydraulic modeling not necessary for small projects or if floodplain is wide – use adjacent floodplain +1ft for wall or upper riprap transition.
VTrans Geotechnical staff not comfortable with walls >6ft (reveal) without a geotechnical analysis.

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Example of challenging but well-built wall along a larger channel (bankfull width 50-60ft) in Mt. Holly, VT.

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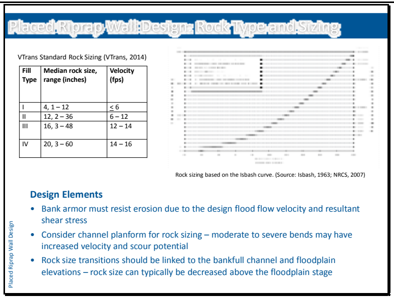
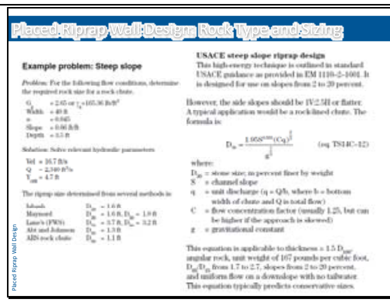


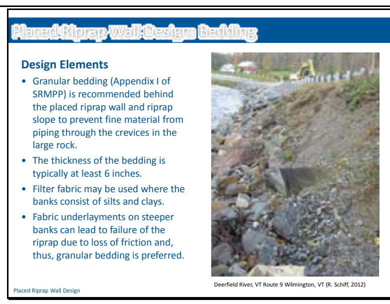
- Very useful to triangulate on sizing using multiple methods.
- If the project is large or complex or situated near infrastructure a full hydrology and hydraulic analysis may be required. This is usually not feasible during emergency repair work.
- For smaller projects cursory hydraulic analysis (e.g., single uniform flow calculation) may suffice for estimating velocity and sizing rock.

Slide 77



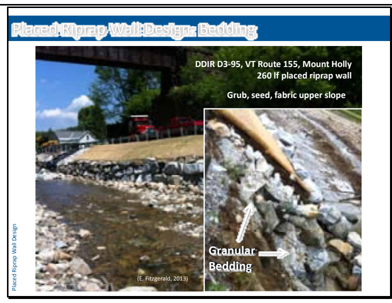
- Check several methods and range of rock size results to land on design size.
- Steep slope riprap sizing applicable to many of our high-energy channels.

Slide 78



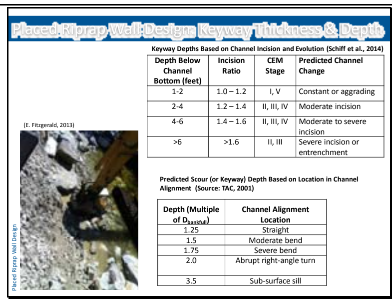
- Geotextile filter fabric traditionally used behind rip rap on river slopes, but observations after Irene that these can lead to armor failure due to slipping, shear behind/along fabric.
- Soils prone to piping may still need fabric.

Slide 79



Lower left hand picture is a nice cross-section of steep (1V:1.5H) upper riprap slope above wall with granular bedding, Type IV stone above, and grubbing, seed, erosion control blanket.

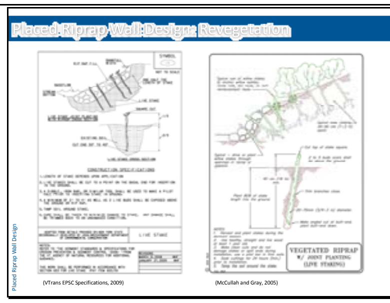
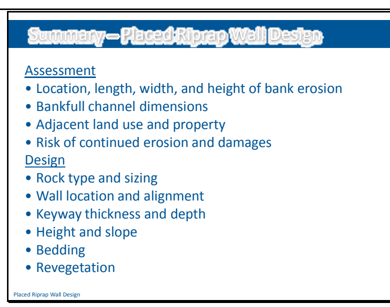
Slide 80

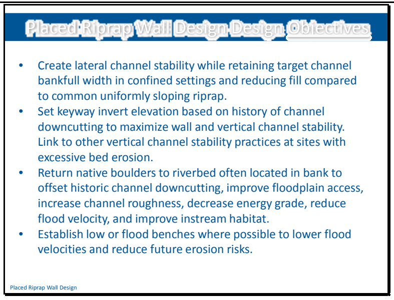
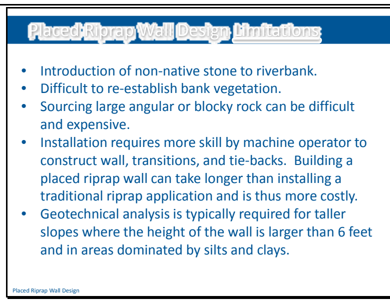


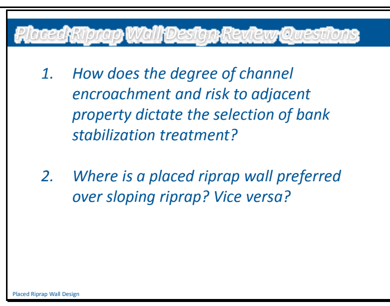
- Edge of keyway in channel should be clearly staked at appropriate intervals.
- Solid keyway is essential to stability of wall.
- Dewatering allows for better keyway installation – use native bed materials to create temporary diversion berms and work pads.

Slide 81

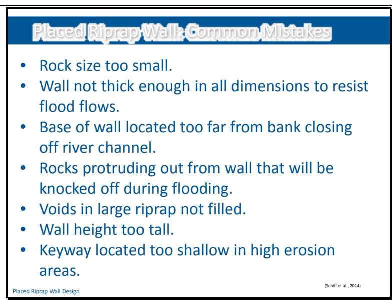
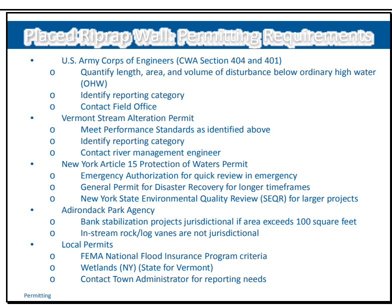
- Note dewatering and ability to see keyway depth in channel.

Slide 82		• Vegetation on upper slope serves to stabilize topsoil, filter runoff from adjacent road, and enhance near-bank habitat. • Upper slope vegetation along highways typically needs to be herbaceous for mowing and FHWA requirements. However native trees will likely volunteer over time. • If work is done in early spring or late fall, provide a conservation mix with winter rye or other fast growing seed to establish cover.
Slide 83		• Rock armor + Vegetation = Long-term Stability! • Where this approach is possible, joint plantings are good option but require planning re: time of year for plant dormancy and collection of stakes. • Higher costs - joint plantings slows the rock installation and an additional laborer is needed.
Slide 84		• Summary / checklist for future design use. • Mostly for future reference since we have covered throughout presentation.

Slide 85		• Summary of key design objectives for future use. • Mostly for future reference since we have covered throughout presentation.
Slide 86		• Summary of key limitations for future design use. • Mostly for future reference since we have covered throughout presentation.

Slide 87		• Need to put the site into the reach and confinement context.
		    • What is the natural valley/floodplain look like and to what degree is encroachment taking up this space?
		    • Is the channel/floodplain depth and velocity significantly changed at the site due to encroachment?
		    • If a severe encroachment on 3rd or 4th order stream, placed riprap wall will buy more space compared to settings on larger rivers.
		    • Adjacent property risk drives the stabilization needs: high

		risk sites require hardening to arrest of erosion; lower risk sites may be suitable for “softer” approaches.
		• Sloping riprap may be suitable in these locations:
		  • Larger rivers or wide/braided rivers where relative gain in channel width is minor with a placed riprap wall.
		  • Sites with limited machine access to base of slope.
		  • Sites with geotechnical concerns.

Slide 88		• Summary of common mistakes for future design use. • Mostly for future reference since we have covered throughout presentation.
Slide 89		List of common permitting requirements in VT and NY.

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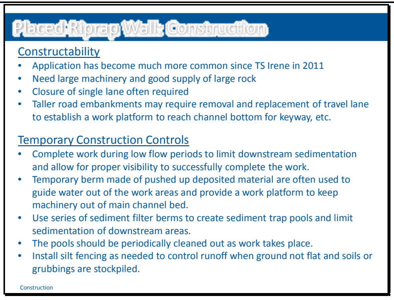
<td>
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Taken from Vermont Standard River Management Principles and Practices.
Review considerations for rock supply, traffic interruptions.
Review of temporary construction controls during the work to minimize channel impacts.

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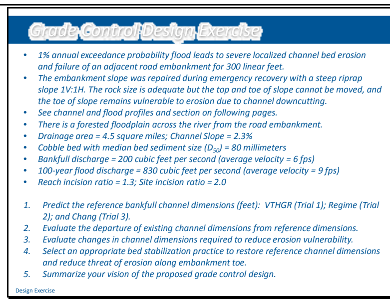
<td>
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This example is a real site along Route 100 in Killington, VT that was repaired during the permanent repair phase.
30 minutes group work, 5-minute presentation

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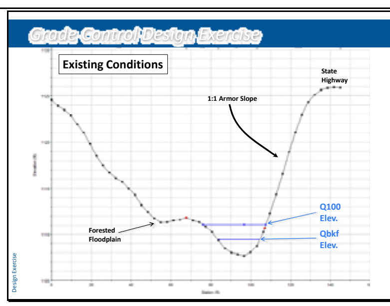
<td>
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Existing conditions cross-section of site with flood elevations based on hydraulic model.

Note forested floodplain on left bank that is currently not accessed during large floods (incised channel)
Note 1:1 riprap armor slope on highway bank

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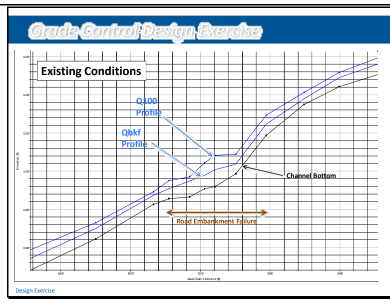
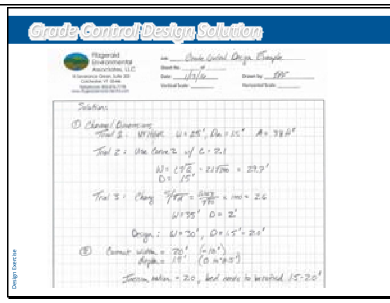
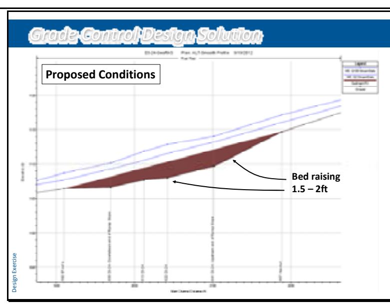
Slide 93		Longitudinal profile of site with flood profiles based on hydraulic model. 1. Note the gouge in the channel profile below the headcut 2. Note the wobble in the 100-year flood profile as it passes over the head cut, indicating significant changes in velocity and shear (i.e., super critical flow).
Slide 94		Bankfull channel dimensions: Width = 30ft (average of 25, 30, 35 from 3 trials) Depth = 1.5 – 2ft (average of 1.5, 1.5, 2 from 3 trials) Departure from reference: Width: -10ft Depth: -0.5ft Raising bed 1.5 – 2ft will achieve bankfull width of ~30ft and depth of ~2ft
Slide 95		Profile with bed raised 1.5-2.0 feet and smoothing of flood profiles.

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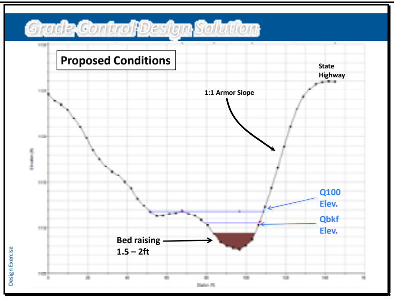
<tr>
<td>Slide 96</td>
<td>
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<td>Cross-section with bed raised 1.5-2.0 feet and restored floodplain access for large flood resulting in lower bank velocity and erosion risk.</td>
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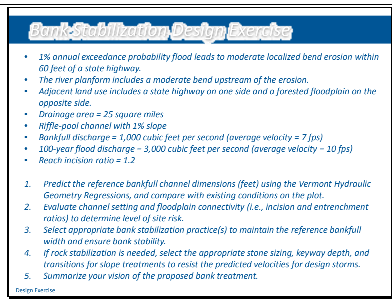
<td>Slide 97</td>
<td>
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- This is a fictitious example of a low risk bank stabilization setting.
- 30 minutes group work, 5-minute presentation

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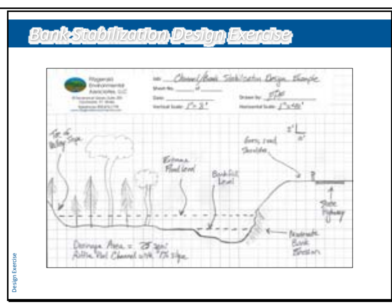
<td>Slide 98</td>
<td>
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- Road is situated 30ft from top of slope, and 60ft from eroded slope.
- Existing slope is 1V:5H with scour at toe.
- Existing bankfull width is 60ft, max depth is 3ft.
- Incision ratio 1.0-1.2.
- Entrenchment ratio is ~3.5.
- Rosgen C-type channel with 1% slope.
- Reference bankfull dimensions based on drainage area of 25 sqmi: Width = 54ft, Mean Depth = 2.5ft

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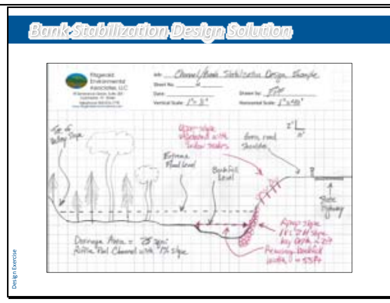
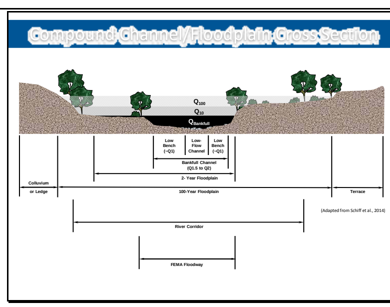
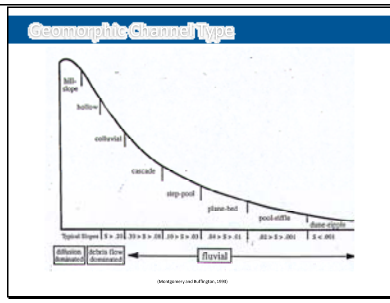
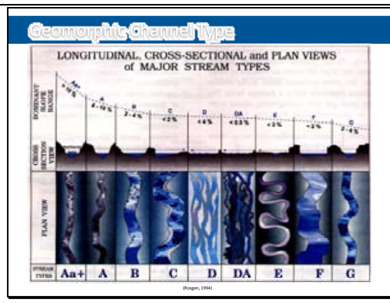
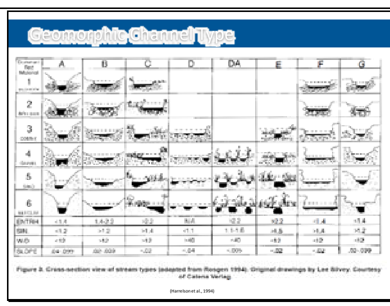
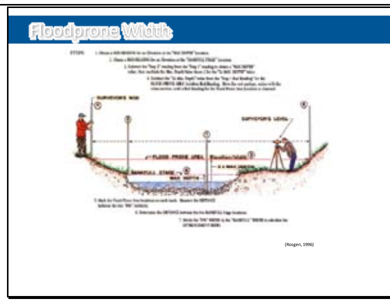
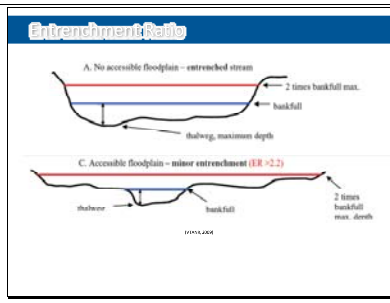
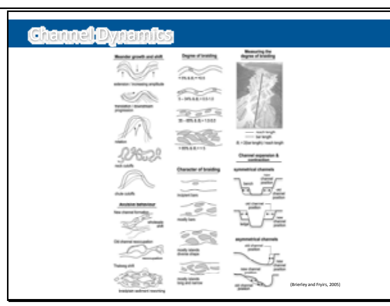
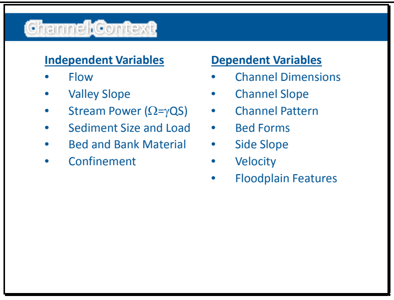
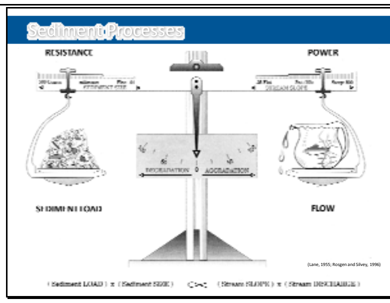
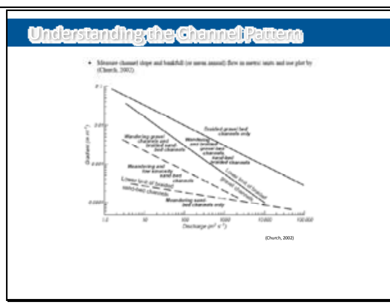
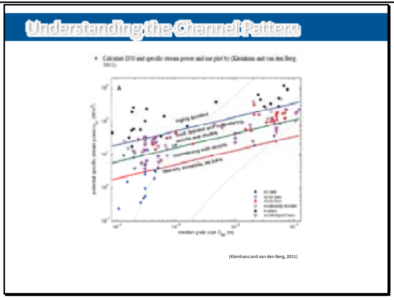
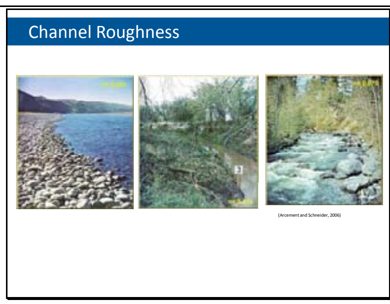
Slide 99		• May want to just monitor bank if perceived risk level is low. • Vegetation only is option. • Sloped riprap 1V:2H along low bank. • 2ft key depth given no incision, good floodplain access, and moderate channel bend. • Link top of rock to high flows or foot or two over floodplain since erosion potential lowers at this flood level. • Revegetate upper slopes with willow stakes. • Final bankfull width ~55ft which matches reference width from HGRs.
Slide 100	EXTRA SLIDES Basic Geomorphic Assessment	
Slide 101		Note boundaries of the river corridor and floodway not located at edges of floodplain. Regulatory areas are not the only consideration when reducing flood risks.

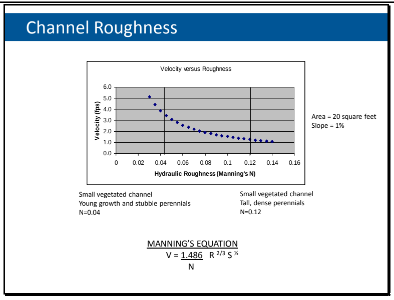
Slide 102		Slope can help with initial prediction of channel pattern and dominant process.
Slide 103		If you are going to modify channel, have vision of channel type and trajectory. Need target, and that typically comes initially from channel classification.
Slide 104		Relationship between substrate, slope, and type. Keep synchronized or you will see large adjustments post debris removal.

Slide 105		
Slide 106		Entrenchment and incision ratios key for connectivity. Shapes channel dynamics. Most of our channels are now incised and disconnected from floodplains.
Slide 107		Dynamics = channel adjustment. Expected processes.

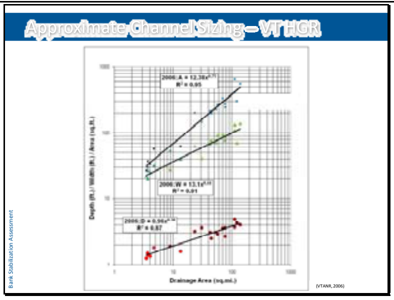
Slide 108		Understand what you are changing and what responds to that change.
Slide 109		Balance between sediment and water is key…really power and resistance. Fundamental to all channel and bank work. Manage towards the most stable equilibrium state, or at least a place where the system is not further driven from EQU. Slope changes = sinuosity, length
Slide 110		Braiding, wandering, meandering. Substrate explicitly included in this empirical predictor. Has shown good results in east coast US projects. Note metric units. Supersedes Leopold and Wolman, 1955

Slide 111		Mobile bed features? SSP = gamma*Q*S/w Works well based on our past projects. Fines to 4 inches (gravel).
Slide 112	EXTRA SLIDES Channel roughness Slides	
Slide 113		

Slide 114

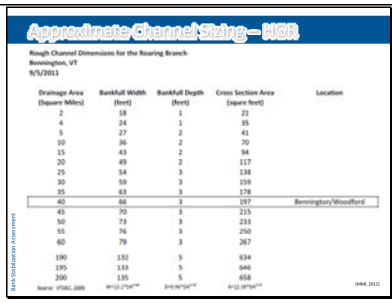


Slide 115



- Quick review as covered in Tier 2. Does everyone get this?
- Note that there are limitations to this – disturbed channels, different geomorphic settings, etc.
- HGRs are notorious for under-estimating widths on braided or wandering channels.
- Consider how changes in climate may be dating these regressions – consider adding +/-10% to predicted dimensions.

Slide 116



- Tabular for easier for quick calculations.
- Quick review as covered in Tier 2. Does everyone get this?