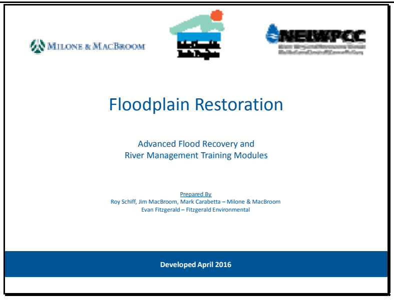
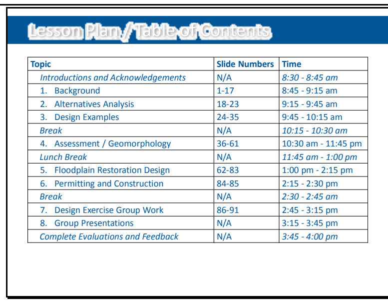
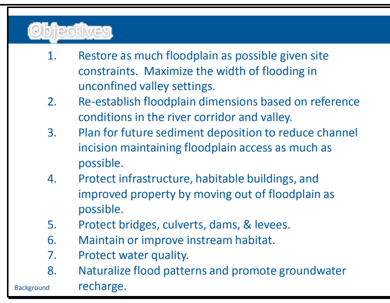
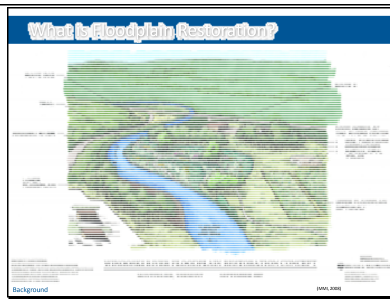
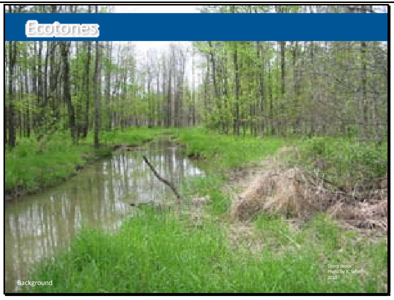
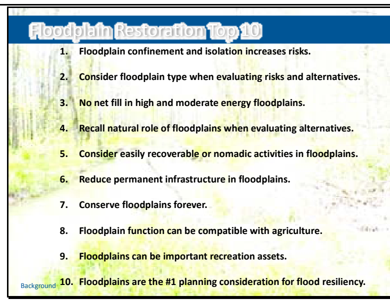
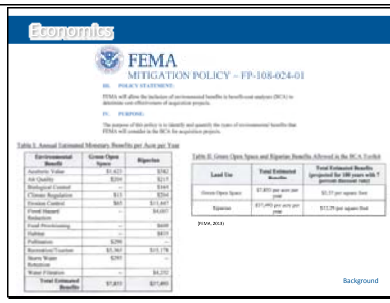
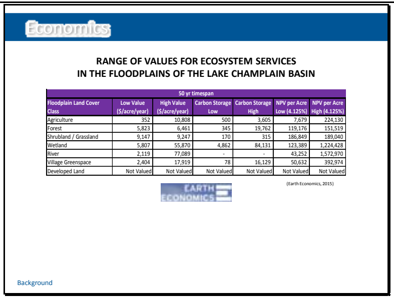
<table>
<tr>
<td>Slide 1</td>
<td>
</td>
<td>Goals: This practice reduces flood and erosion risks by providing space in the valley for water, sediment, debris, and ice to be stored. Over long periods of time (e.g., 50 to 100 years), sediment and debris may be eroded from floodplains and transported downstream to another floodplain or the basin outlet. The presence of a floodplain allows floodwaters to spread out and move slower that reduces erosion hazards. 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 Shayne for Tier 2.</td>
</tr>
<tr>
<td>Slide 2</td>
<td>
</td>
<td>Review lesson plan and slide ranges that serves as table of contents.</td>
</tr>
</table>

Slide 3		Floodplain restoration improves the connection between a river channel and adjacent lands that were once prone to regular flooding but no longer are. This practice reduces flood and erosion risks by providing space in the valley for water, sediment, debris, and ice to be stored. The presence of a floodplain allows floodwaters to spread out and move slower that reduces erosion hazards.
Slide 4		• Removing a berm adjacent to a river channel that allows floodwaters to spill onto the recently abandoned floodplain • Removing historic dredge spoils from past flood events • Removing a natural post-flood sediment levee deposit on the edge of the river channel that allows floodwaters to spill onto the recently abandoned floodplain • Lowering the elevation of the floodplain • Raising the elevation of the channel bed such as through natural bed stabilization or bed armoring • Creating a new channel in the floodplain with some filling of the historic channel • Creating a bench, floodplain restoration but at a smaller scale, that are low-lying areas in or immediately adjacent to a channel. (<1 acre) • Reconnecting abandoned flood paths (chutes).

Slide 5		• Floodplains buffer transitioning systems and geography such as river to lake – sediment and nutrient sink (ecotones) • Floodplain forest on Thorp Brook on the edge of Lake Champlain • Like rivers, everyone should have a favorite floodplain.
Slide 6		• Store flood waters, sediment and debris during large floods • Winooski River during Irene flood at the snow mobile bridge
Slide 7		• We live, farm, and recreate in floodplains, yet storage of water, sediment, debris, and ice naturally occur on floodplains. Humans are less nomadic and thus we will have conflicts.

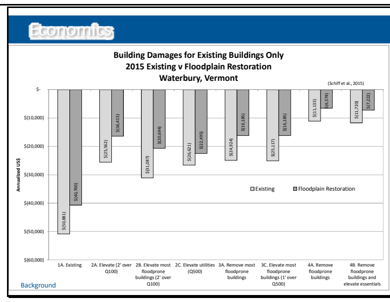
<table>
<tr>
<td>Slide 8</td>
<td>
</td>
<td>Some key points about floodplain restoration work.</td>
</tr>
<tr>
<td>Slide 9</td>
<td>
</td>
<td>Floodplain restoration is growing in popularity as it is a nonstructural, cost-effective method to reduce future flood risks over the long term. FEMA now considers an annual benefit of $37,493 per acre of riparian lands per year for ecosystem services such as flood hazard reduction, erosion control, and recreation (FEMA, 2013a, b).
A recent study in Pierce County, Washington showed that the monetary value of a functioning floodplain for services such as avoiding flood damages is $32 million to $433 million over a 50-year period (EE, 2013).</td>
</tr>
</table>

Slide 10

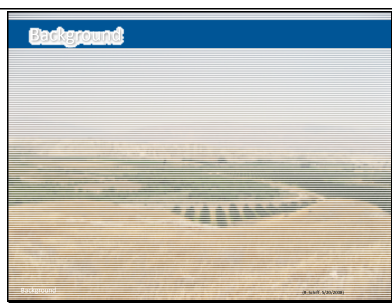


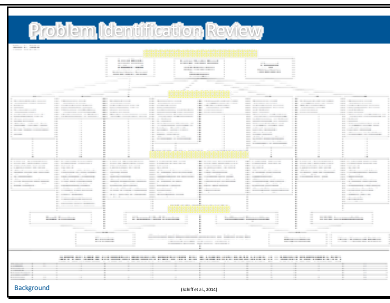
- Floodplains carry out important functions that are typically not accounted for, but that is changing.
- $ / ac / yr in Champlain basin prepared by earth economics.
- Developed land doesn't have an ecosystem service value – this land is calculated separately through tax revenue, insurance, damage modeling, etc.
- This needs to be considered in cost benefit analysis.

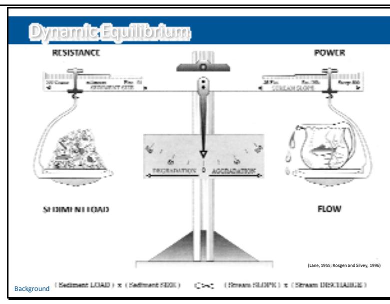
Slide 11

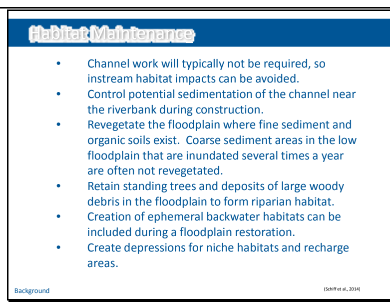


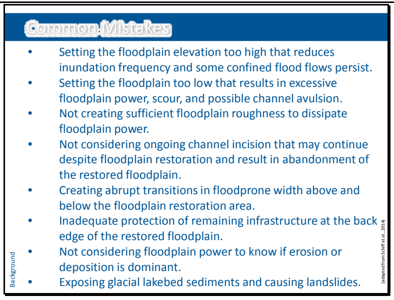
- The proposed floodplain restoration over 37 acres decreases existing annualized building damages from $51,000 to $41,000 (~20% damage reduction).
- The proposed floodplain restoration reduces annual damages across all flood mitigation activities, and improves the effectiveness of each mitigation approach.
- Floodplain restoration in conjunction with removing floodprone properties (4A) leads to the lowest building damages.
- Floodplain restoration leads to a reduction of $2.6 million dollars in simulated damages for a single modeled Tropical Storm Irene flood event.
- The recommended alternative consists of floodplain restoration in three previously identified locations – two on state lands in Waterbury and one on a private parcel in Duxbury. An alternative consisting of floodplain restoration in just the two Waterbury locations was investigated and yielded more limited damage reduction benefits so was dropped from the analysis.

Slide 12		• Economic importance of floodplains is clear following events such as Katrina, Irene, and Sandy.
Slide 13		• Floodplains are vital for life, and are largely responsible for agriculture and human civilization. • The first seeds are said to be planted in the Jordan River valley floodplain.

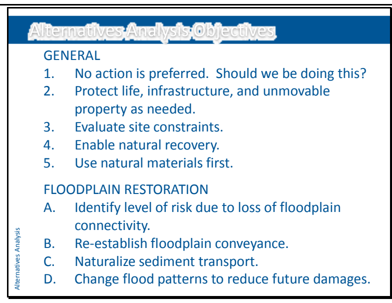
Slide 14	 	• This table is from the Vermont Standard River Management Principles and Practices (Schiff et al., 2014) (http://www.anr.state.vt.us/dec/waterq/rivers/docs/SRMPP_1.3.pdf). • See large-format handout for easier viewing. • Quick review as attendees should be familiar with this document or should review it on own. • Link observed damages to river channel conditions to river processes. • What is ultimately driving damages?

Slide 15	
	
		• Balance between sediment and water is key…really power versus resistance. Fundamental to all channel and bank stability.
		• Define terms as needed. Power = gamma*Q*S and is the ability to do work due to the flow. Slope = rise of run, and changes with sinuosity and length. Sediment size and amount resists power.
		• SRMPP language linked to GP language and understands that channels approach this equilibrium at different rates.
		    ◦ For channels in equilibrium, human activity cannot initiate vertical movement of the channel at the reach scale that would create a departure from equilibrium.
		    ◦ For channels out of equilibrium, human activity cannot cause further departure in the dimensions and profile associated with its equilibrium form and its natural stream processes.
		    ◦ For channels out of equilibrium, human activity cannot block the return of the

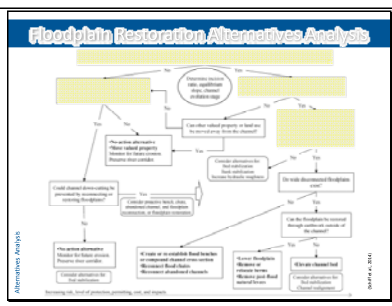
		predicted equilibrium state preventing future attainment of the most stable channel (unless defined as an emergency measure required to address a threat to life, public health, and safety or address the threat of severe damage to an improved property). • Floodplain connectivity influences this balance. • Floodplain restoration meets all of the VT Performance Standards by providing more space for river processes to take place.
Slide 16		• Summary of habitat maintenance recommendations to keep in mind as we work through alternatives analysis and design. • Seek out embankment removals that are the highest return per impact.

<table>
<tr>
<td>Slide 17</td>
<td>
</td>
<td>

- Summary of common mistakes during floodplain restoration to keep in mind as we work through alternatives analysis and design.

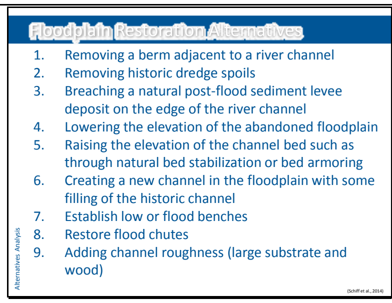
</td>
</tr>
<tr>
<td>Slide 18</td>
<td>
</td>
<td>

- Review list of general and practice-specific alternatives analysis objectives (presented in SRMPP).
- Question 2 is key. If you do not meet this, it is likely you do not need to do any work.
- Big return for buck in floodplain restoration. Analogous to dam removal.

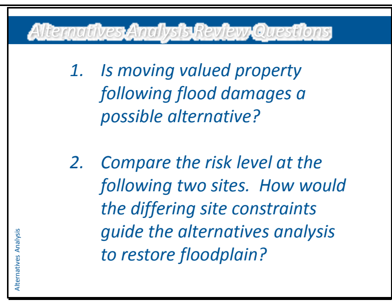
</td>
</tr>
<tr>
<td>Slide 19</td>
<td>
</td>
<td>

- Review the chart that is from SRMPP.
- Key questions highlighted.
- Minimize work / impact / cost where possible.

</td>
</tr>
</table>

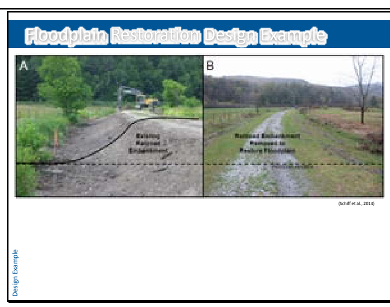
<table>
<tr>
<td>Slide 20</td>
<td>
</td>
<td>

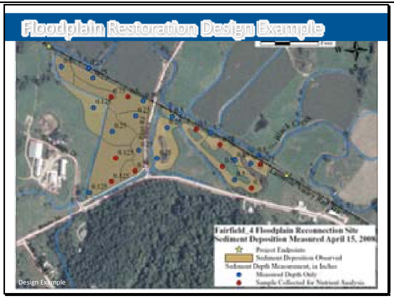
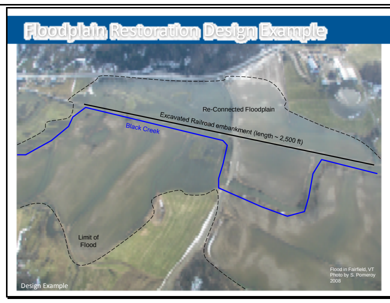
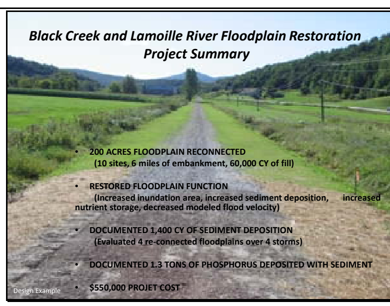
Perform alternatives analysis to consider floodplain restoration.
If time allows, evaluate residual risk in dangerous settings using sediment transport modeling during future storms.
Note that FEMA uses the elimination of immediate threats during a future 5-year flood as the limit for Public Assistance funding.
Benches are just smaller scale floodplains adjacent to the channels.
Flood chutes are flood flow paths that cut off a meander bend during high water or when the channel is clogged with sediment and debris (VTANR, 2009).

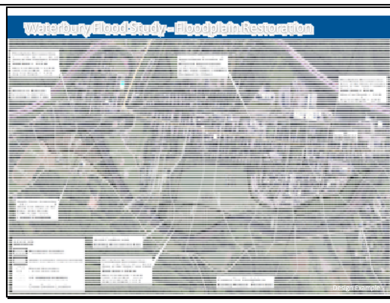
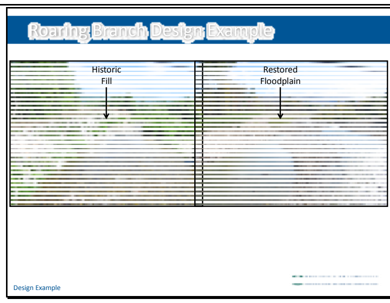
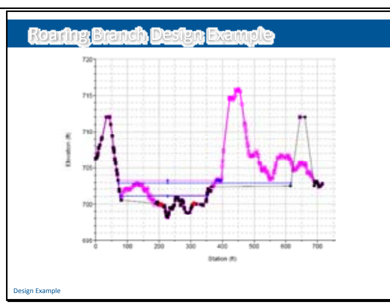
</td>
</tr>
<tr>
<td>Slide 21</td>
<td>
</td>
<td>ANSWERS:

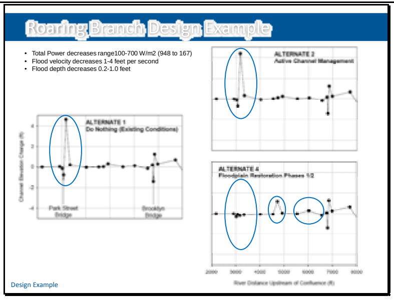
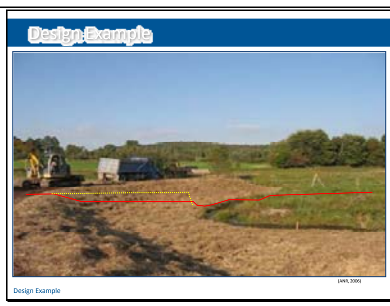
Definitely. Get out of the way wherever possible. It is the safest and cheapest approach in the long run.
Inquire about property, public safety, infrastructure, and how aggressive one would be to restore conveyance to a channel. How would these settings influence design?

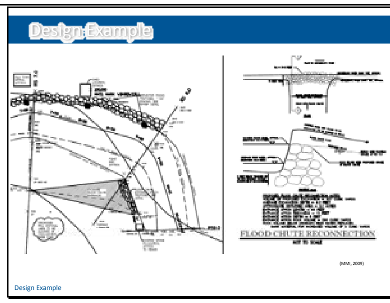
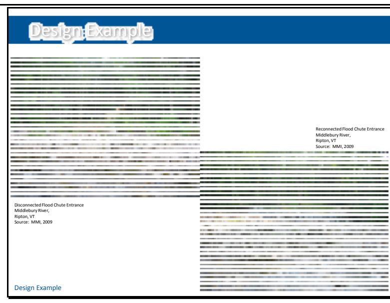
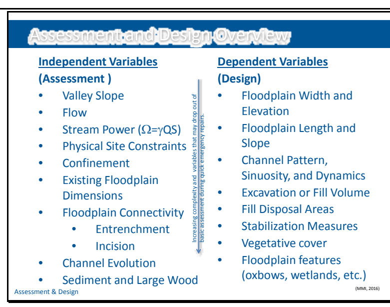
</td>
</tr>
</table>

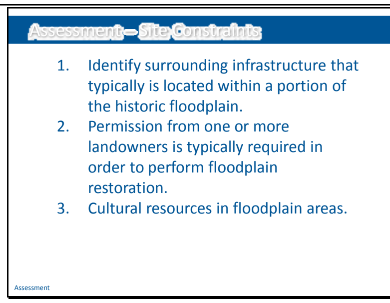
Slide 22		• Roaring Branch, Bennington, VT • High risk. Unnatural confinement. Lots of surrounding infrastructure. Bridges clogged. Houses in danger. Restore any floodplain as possible.
Slide 23		• Browns River, Jericho, VT • Low risk. Minimal surrounding infrastructure. Floodplain connected.
Slide 24		• Simple form of floodplain restoration where return per linear foot of work is high. • Impacts minimized. • Former ST J and Lamoille County Railroad embankment along Black Creek in Bakersfield, VT • Conversion to rail trail under way

<table>
<tr>
<td>Slide 25</td>
<td>
</td>
<td>• Sediment deposition with P following rail embankment removal.
• Nutrients into plants rather than the lake.
• Sample monitoring at Fairfield, VT site along Black Creek.</td>
</tr>
<tr>
<td>Slide 26</td>
<td>
</td>
<td>• Continuing flooding, but now with less road damage and shorter inundation periods.
• Naturalize flooding.</td>
</tr>
<tr>
<td>Slide 27</td>
<td>
</td>
<td>• Project summary notes.</td>
</tr>
</table>

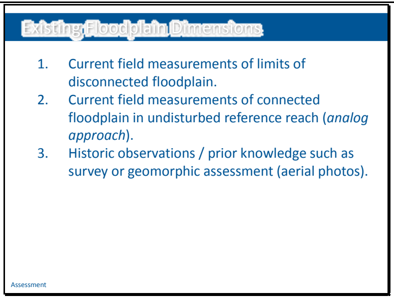
Slide 28		• Flood study was about how to minimize flood levels and impacts in floodprone Waterbury Village, VT. • Proposal is for floodplain restoration in hatched areas. • Recall economic benefit.
Slide 29		• Create space for storage of water, sediment, ice, and to facilitate nutrient uptake. • Lots of areas where historic fill was informally placed to confine the river in hazardous areas.
Slide 30		• RAS XS View from modeling. • Pink berm removed to open up floodplain.

Slide 31		• Change sediment transport during floods. Change to process is key. • Distribute load to improve water quality and reduce infrastructure conflicts.
Slide 32		• Dig up historical photos and maps to understand if your problem is recurring. • This location had numerous avulsions in the past century.
Slide 33		• Fix incised channel setting by lowering flood bench (yellow to red line). • Wanzer Brook in Fairfield, VT

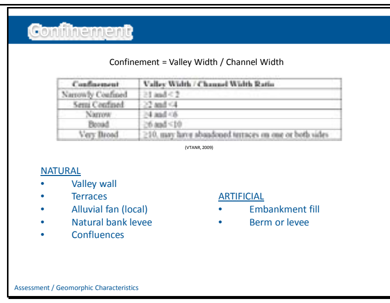
Slide 34		• Flood chute reconnection on the Middlebury River in Ripton, VT to relieve pressure at Village Center. • Removed bank material in incised setting to reconnect chute at the 10-year flood.
Slide 35		• Upper left is start of construction. • Bottom right is post-construction. • Chute reconnected to reduce flood risks to road and Village.
Slide 36		• 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 37		• The extent of the restored floodplain is often limited by the need to protect remaining property from damages. If floodplain restoration is to take place near existing infrastructure, both lateral and vertical stabilization techniques are usually required to protect property adjacent to the new floodplain. • Wells, old disposal sites, sewage leach fields, etc. • Past views of floodplain restoration were dominated by the belief that providing space for the river was not a good use of the land. With a long history of extensive damages in floodplains and the growing recognition of the risk reduction benefits of a naturally functioning floodplain, this practice is now socially more acceptable. Nevertheless, floodplain restoration often requires project outreach prior to design to reach agreements with landowners of what the floodplain restoration will look like. These agreements can include land donations, an easement donation, land purchase, purchase of a river corridor easement, and barter of land for construction services or fill.

Slide 38		• Power lines crossing the restored floodplain of the Roaring Branch in Bennington, VT.
Slide 39		• Call before you dig! • Utility crossings at risk also during flood and recovery. • Identify exposed and buried utilities such as the sewer lines in the photos that often cross the floodplain. • Have plans in field with operators showing bridge and culvert foundation depths.

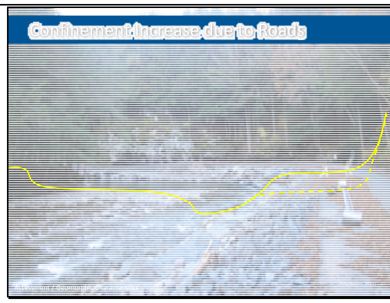
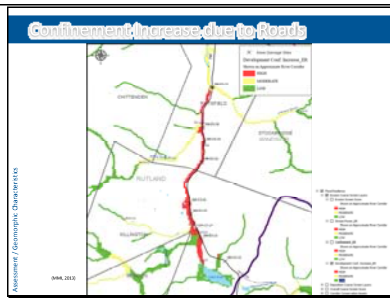
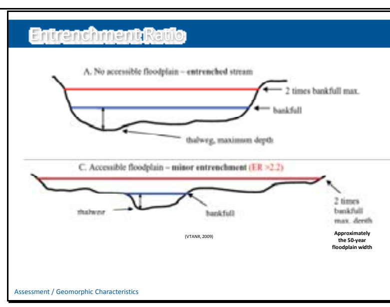
<table>
<tr>
<td>Slide 40</td>
<td>
</td>
<td>

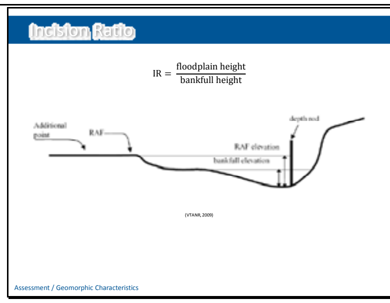
Review empirical, analog, and analytical approaches to getting dimensions.
Be sure to compare results from multiple methods to bracket answer since not exact science and local variability common.
Link to valley and channel slope.

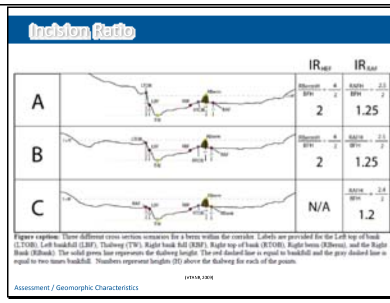
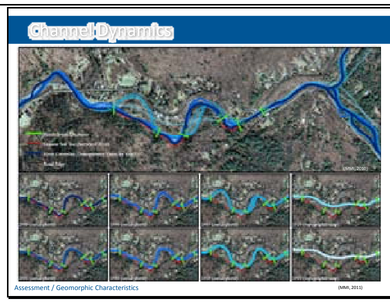
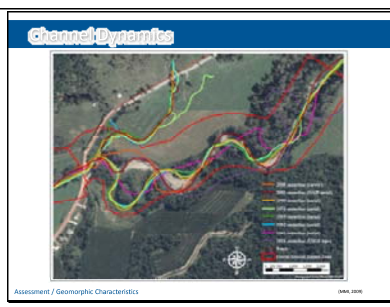
</td>
</tr>
<tr>
<td>Slide 41</td>
<td>
</td>
<td>

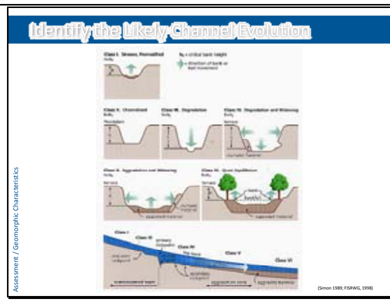
Quick review as covered in Tier 2. Does everyone get this?
The confinement ratio, the width of the valley divided by the bankfull width of the channel, indicates the extent that a river can adjust its planform over geologic timescales and the extent that a river depends on a hydrologically active floodplain to dissipate energy.
A confinement ratio larger than 6 indicates a broad valley setting where an alluvial river should be connected to a large floodplain. A ratio less than 4 indicates a narrow valley setting where a channel may or may not be connected to a smaller floodplain (<u>VTANR, 2009</u>).
The level of confinement often guides planning for floodplain restoration.
Can be locally variable and drive erosion damages.
Compare reference v existing conditions as encroachments change confinement and river processes.
Confinement can vary by reach or even locally. Scale is important relative to damage area and recovery.

</td>
</tr>
</table>

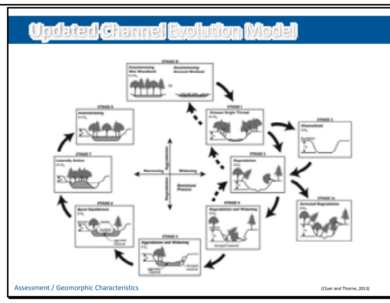
Slide 42		• The are between the dotted line and the solid line shows an example of an encroachment that changes confinement. • These spots are often prone to erosion damages. • Site info: County Road 47 on Neversink River. S-turn site • Armoring projects into river making problem worse due to more confinement.
Slide 43		• Map shows three levels of increase in confinement: <10% green, 10-25 yellow, >25 red • Increase in confinement is linked to damages as seen by Irene damage sites. • Increase in confinement is driving erosion potential along VT100 in Killington and Pittsfield. • In narrow valleys road fill is increasing risks of damages.
Slide 44		• Quick review as covered in Tier 2. Does everyone get this? • The entrenchment ratio quantifies the lateral extent that a large flood can spread out on the floodplain. • The entrenchment ratio is the floodprone width (the width at a stage twice the maximum bankfull depth) divided by the bankfull channel width. • Channels with high entrenchment ratios (>2.0) should have broad floodplains while channels in confining valleys with low entrenchment ratios (< 1.4) have small floodplains. • Entrenchment ratio can be used in

		conjunction with the confinement ratio (and the incision ratio) to plan for and design floodplain restoration. • Help understand amount of floodplain that naturally exists. Compare reference to local condition. • Rule of thumb: Entrenchment Ratio = 50-year floodplain width / bankfull channel width • More entrenched channels tend to have more erosive force in the channel and thus more resistive bedforms.
Slide 45		• The incision ratio is an indication of the vertical connectivity between a channel and floodplain that results from the current level of channel downcutting. • The incision ratio is the height of the recently developed (or abandoned) floodplain divided by the maximum bankfull depth. The ratio identifies which features will be inundated during a bankfull flood. • An incision ratio of 1.0 to 1.2 indicates that the bankfull flow can access the floodplain while a larger ratio indicates that the floodplain is only accessed by larger floods. • Incision ratio is a more local and current indicator of floodplain access.

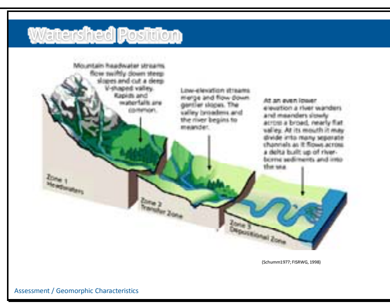
Slide 46		• Builds on Tier 2 introduction of definition. • The presence of berms and natural sediment levees elevates the incision ratio by isolating the floodplain from the channel. • Careful evaluation of the existing and proposed incision ratio takes place when designing the elevation for a floodplain restoration.
Slide 47		• What is channel trajectory? This is an important design consideration as channel moves through floodplain in meander belt. • Remeandering from past straightening or modification very common. • What is the stable reference for both channel and adjacent floodplain. • 100 years on Stony Clove Creek, Catskill Mountains, NY
Slide 48		• Meander belt width captures most likely channel location in floodplain (outer red line). • 100 years of Tyler Branch in Enosburg, VT.

<table>
<tr>
<td>Slide 49</td>
<td>
</td>
<td>

- Quick review as covered in Tier 2. Does everyone get this?
- Temporal change trajectory illustrated by channel evolution models (CEMs).
- Most actively adjusting are CEM 2, 3, and 4.
- Heraclitus : you could not step into the same river twice.
- This plot has recently been upgraded.

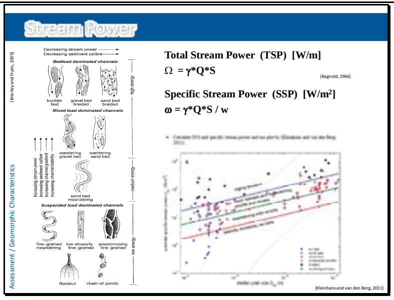
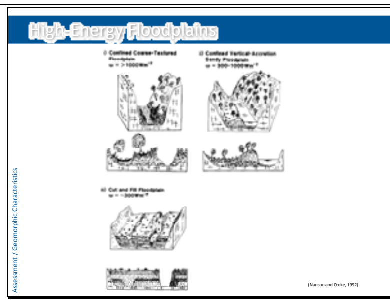
</td>
</tr>
<tr>
<td>Slide 50</td>
<td>
</td>
<td>

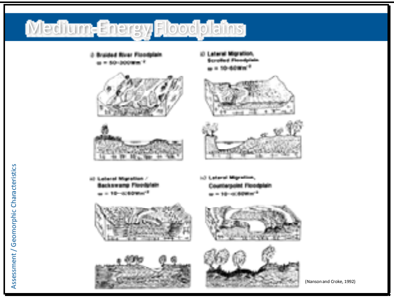
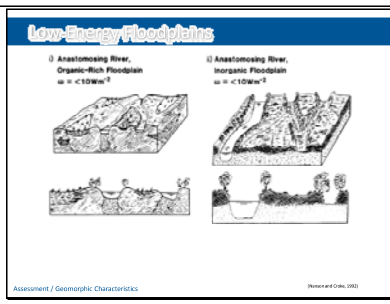
- This is a recent upgrade to CEM that includes habitat and ecosystem benefits
- Notice additional steps that tend to fit altered channels better than the original models. See stage 3s.
- Note state 7 could simulate high sediment load event.

</td>
</tr>
<tr>
<td>Slide 51</td>
<td>
</td>
<td>

- Different zones have different levels of floodplains, and they serve different functions.
- Valley slope can be a proxy for the amount of floodplain.

</td>
</tr>
</table>

Slide 52		The rate of energy dissipation against the bed and banks per unit downstream length. Gamma = specific weight = density x gravity Q = discharge S = channel slope
Slide 53		• When dealing with floodplain restoration, one must understand floodplain processes for proper alternatives analysis. • Confined and steep valleys have more power to do work. • The rate of energy dissipation against the bed and banks per unit downstream length.
Slide 54		• Confined flood flows lead to high energy. • Encroachment makes condition more erosive and risky.

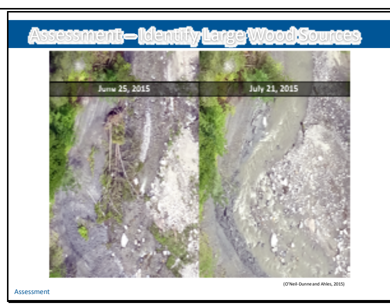
Slide 55		• The rate of energy dissipation against the bed and banks per unit downstream length.
Slide 56		• Medium energy floodplain converted to a high-energy floodplain via confinement • Contain water, sediment and debris.
Slide 57		• The rate of energy dissipation against the bed and banks per unit downstream length.

<table>
<tr>
<td>Slide 58</td>
<td>
</td>
<td>

Convert low-energy floodplain to medium energy floodplain due to confinement
Contain water, ice, sediment, nutrients

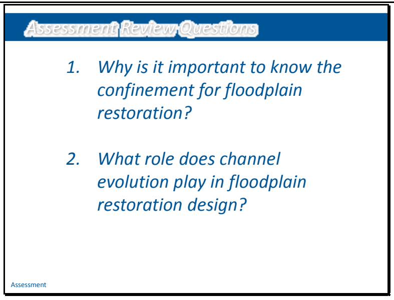
</td>
</tr>
<tr>
<td>Slide 59</td>
<td>
</td>
<td>

Identification of upstream sediment sources is important to understand the context of channel-floodplain interaction.
Are there sources that will enter the project site during the next flood?
See the photo of a perennial source of sediment on Fulmer Creek in German Flatts, NY.
See the photo of the low to moderate source of sediment and wood from an actively eroding bank on the Roaring Branch in Bennington, VT.

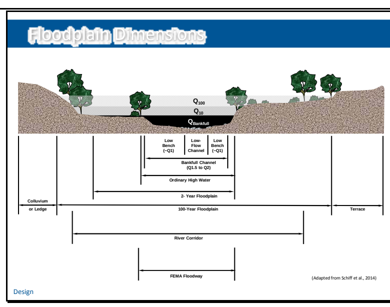
</td>
</tr>
<tr>
<td>Slide 60</td>
<td>
</td>
<td>

Is a lot of wood incident on the channel and floodplain?
Great Brook in Plainfield, VT aerial wood survey completed by UVM.

</td>
</tr>
</table>

<table>
<tr>
<td>Slide 61</td>
<td>
</td>
<td>

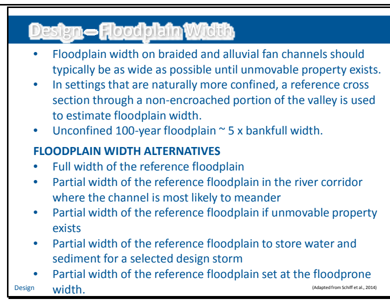
- The level of confinement often guides planning for floodplain restoration. The confinement ratio, the width of the valley divided by the bankfull width of the channel, indicates the extent that a river can adjust its planform over geologic timescales and the extent that a river depends on a hydrologically active floodplain to dissipate energy. A confinement ratio larger than 6 indicates a broad valley setting where an alluvial river should be connected to a large floodplain. A ratio less than 4 indicates a narrow valley setting where a channel may or may not be connected to a smaller floodplain (VTANR, 2009).
- Channel evolution indicates the likely channel trajectory in the floodplain. The designer must know if the channel will be stable, prone to incising, or prone to widening. This dictates how the floodplain will work in the future. Most actively adjusting are CEM 2, 3, and 4, and thus need to account for future conditions and possibly use stabilization where infrastructure exists.

</td>
</tr>
<tr>
<td>Slide 62</td>
<td>
</td>
<td>

- Floodplain width is typically obtained by a combination of field observation, geomorphic assessment, and GIS mapping.
- Key for understanding how much flood flow must get through structure.
- Compound channel / floodplain cross section
- Note boundaries of the river corridor and floodway not located at edges of floodplain.
- Corridors first delineated as approximation and second refined

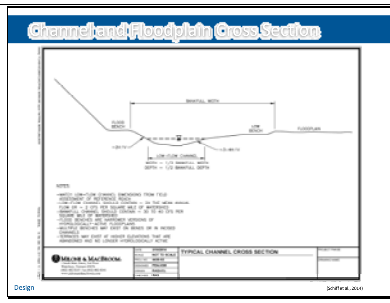
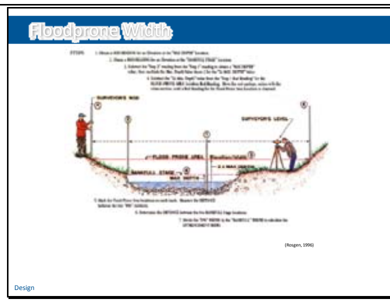
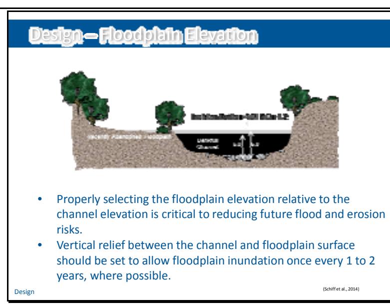
</td>
</tr>
</table>

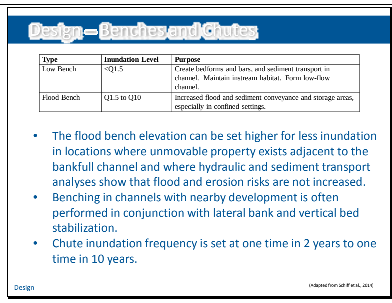
		with field data collection. This is area where river needs to move to reach a most stable state. Some erosion and deposition can take place outside. • Regulatory areas are not the only consideration when reducing flood risks. • Observe remnants of compound cross section. • Bankfull and ordinary high water are often similar. OHW is the vegetation line or shelving that defines Army Corps jurisdiction. Bankfull is typically 1.5 to 3 yr flood level, linked to break in top of bank slope in non-incised channel, or point bars or shelves in incised channels.
Slide 63		• Check the FEMA floodplain (red) and the river corridor (yellow) if it exists.

<table>
<tr>
<td>Slide 64</td>
<td>
</td>
<td>

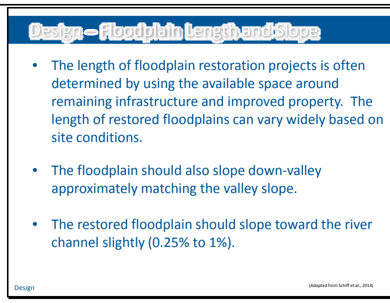
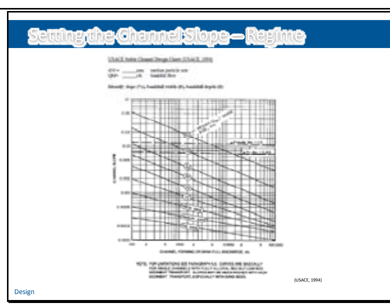
The target floodplain width can be on the order of hundreds to thousands of feet.
Set width so energy grade line is about equal to valley slope.
The target bench width is typically on the order of 10 to 100 feet and should be based on a reference bench width obtained by a combination of field observation and geomorphic assessment.
For partial width floodplain restoration, an analysis to verify that the selected floodplain width will reduce flood and erosion risks should be performed.
Field observations, computations, hydraulic modeling, and sediment transport analysis of the existing and proposed floodplain and channel can be used to predict changes.
Hydraulic geometry regression equations that provide a relationship between drainage area and bankfull channel width can be used for approximate design of benches.
If the flood chute is utilizing a historic flow path, the channel width may remain the same. If the width needs to be adjusted, the bankfull channel width is the maximum width of the chute.

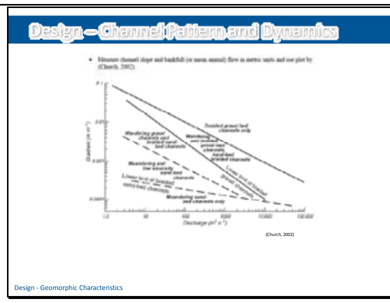
</td>
</tr>
</table>

Slide 65		• Typical section showing low bench, flood bench, and floodplain. • Note that dimensions shown are initial guides, and are often refined in non-emergency design.
Slide 66		• Quick review as covered in Tier 2. Does everyone get this? • Floodprone width is width at 2x maximum bankfull depth. • Rule of thumb is width of the 100-year floodplain is 5x the bankfull width, but often cannot get that so use floodprone width or some portion for floodplain width. • River corridor is a good approximation of floodprone width. • Often constrained in developed setting where damages take place.
Slide 67		• The target incision ratio is 1.0 to 1.2 for natural floodplain access. • The incision ratio must explicitly be evaluated and designed for each method of floodplain restoration. • Higher incision ratios mean a channel and floodplain are less connected and downstream flood risks may remain due to confined high velocity flows during a flood. • When restoration of a portion of a floodplain that contains unmovable infrastructure such as a road embankment takes place, the floodplain elevation may have to be set at higher than natural levels (e.g.,

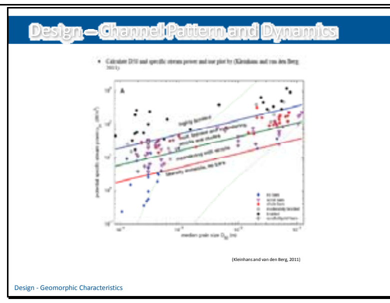
<table>
<tr>
<td></td>
<td></td>
<td>the 10-year flood).
• Hydraulic modeling and sediment transport analysis are needed to verify that this compromise both protects infrastructure and reduces future flood risks.</td>
</tr>
<tr>
<td>Slide 68</td>
<td>
</td>
<td>• If a bench is created on both sides of a channel with nearby floodprone property, the bench furthest from the property is typically set approximately 1 foot lower than the bench near the property to encourage the river to move away from the property.

• The elevation of surrounding property such as a house or a roadway that is prone to flooding is often considered when setting the entrance elevation to a flood chute so that water flows down the flood chute before it would inundate the improved property.
• When structures or infrastructure exist in the river corridor and flood risks remain high, a rigid surface may be desired on a flood bench or chute to prevent excessive erosion. Creation of a flood bench with a stone armor surface would be suitable through a bridge or along a road embankment where the floodplain remains filled. The rigid bench surface would allow some flood flows to spread out while also providing for some vertical resistance to erosion. The entrance to a flood chute may also be armored in dynamic channel settings to reduce the likelihood of outflanking and avulsion. A rigid bench or chute may be considered in</td>
</tr>
</table>

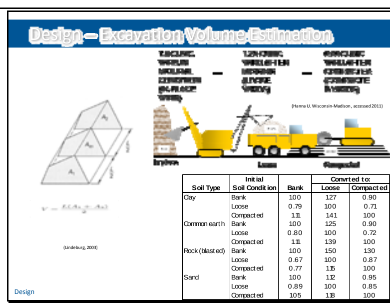
		combination or in place of a deep stone key to reduce the chance of erosion and undermining.
Slide 69		• Length and slope are secondary design elements, but important for safety and proper drainage.
Slide 70		• Use regime equation or plot as a first prediction since it is quick. • Floodplain slope to match, but vary around, channel slope. • Compare to local observations. • Alternative is to use equilibrium sediment slope S = (5* D_{50})/(γαμμα*d).

<table>
<tr>
<td>Slide 71</td>
<td>
</td>
<td>

- Church plot: slope (m/m = ft/ft) v. flow (m^3/sec)
- Identify if the channel is likely braiding, wandering, single-thread meandering. Pattern dictates dynamics.
- Substrate explicitly included in this empirical predictor that has shown good results in east coast US river channel projects.
- Note metric units for application.
- Supersedes Leopold and Wolman (1955) earlier plot.

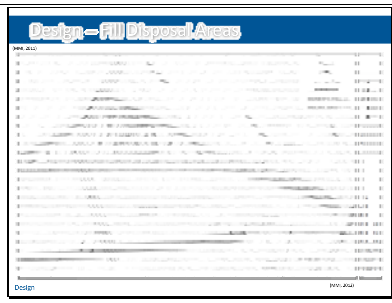
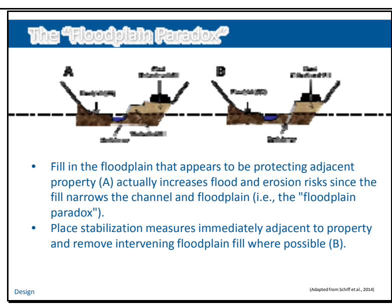
</td>
</tr>
<tr>
<td>Slide 72</td>
<td>
</td>
<td>

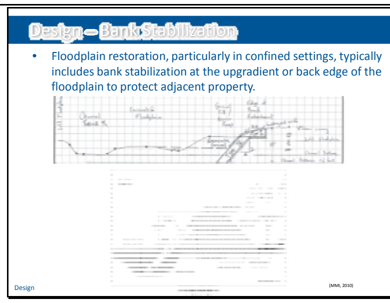
- Kleinhans plot: specific stream power (w/m^2) v. D_{50} (m)
- Specific stream power = gamma*Q*S/w
- Identify potential for mobile bed features.
- Works well based on past projects in region.
- Fines to 4 inches (gravel).

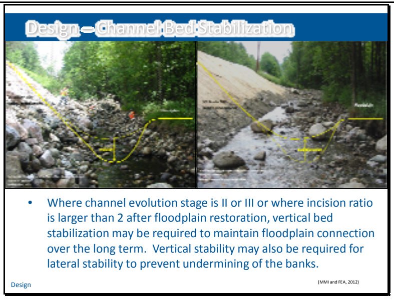
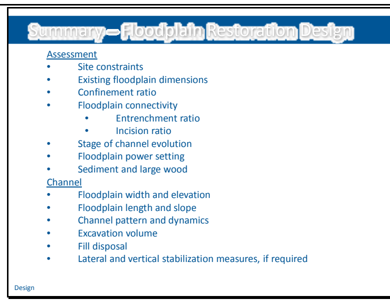
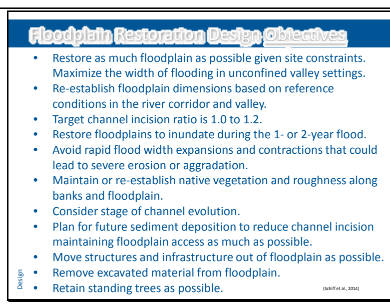
</td>
</tr>
<tr>
<td>Slide 73</td>
<td>
</td>
<td>

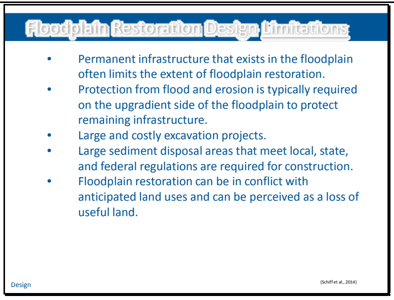
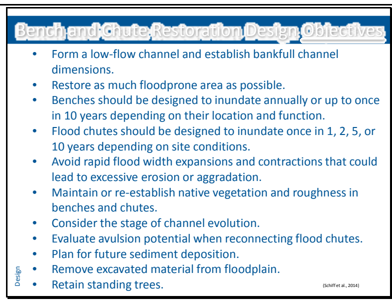
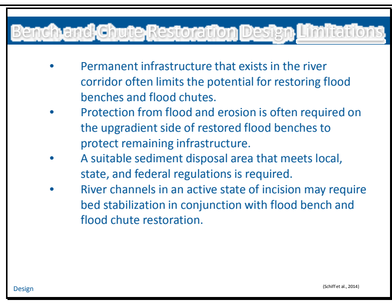
- Consider consolidation in your sediment volume estimates.
- Consolidation accounting can lead to changes in cost on the order of $100,000’s for large deposition events. (250,000 CY *$10/CY * 0.1 = $250,000)
- Agree upon consolidation factor at START of project after observing early excavations, transports, 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.

</td>
</tr>
</table>

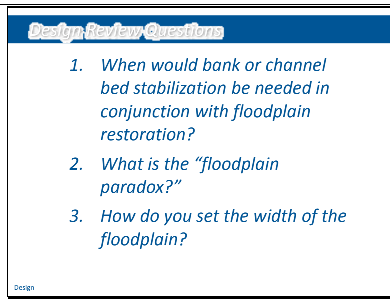
Slide 74		• Fill areas outside of floodplain and river corridor. • Perform pile survey to verify volume in piles with agreed upon consolidation. • Since floodplain excavation can lead to large sediment removal amounts, need to plan for this ahead. • Fill disposal pile on back edge of restored floodplain on the Roaring Branch in Bennington, VT.
Slide 75		• Placing lateral stabilization practices such as stone armoring along a road embankment rather than in the floodplain with adjacent fill reduces flood and erosion risks. • Fill in the floodplain that appears to be protecting adjacent property actually increases flood and erosion risks since the fill narrows the channel and floodplain (i.e., the "floodplain paradox"). • The floodplain fill confines flows increasing velocity that leads to more erosion and channel downcutting. If the floodplain were wider and lower, it would inundate more frequently, so flows would spread out, velocity would be lower, and erosion potential

		would be lower.
Slide 76		● Locate bank stabilization immediately adjacent to existing infrastructure and design the elements to resist the highest instantaneous shear stress that occurs during the design flood. This approach allows for the widest possible floodplain with the existing infrastructure in place. ● This approach is compatible with flood bench restoration. ● Sketch plan is along Route 100 in Killington, VT where the Tweed River washed out the road during Irene. ● Detail is of the Roaring Branch berm on the back of the floodplain near the hazardous waste site and neighborhoods.

<table>
<tr>
<td>Slide 77</td>
<td>
</td>
<td>• This is an aggressive alternative only to be used around unmovable infrastructure where floodplain connection can be restored and reduce risks.</td>
</tr>
<tr>
<td>Slide 78</td>
<td>
</td>
<td>• Summary for future design use.</td>
</tr>
<tr>
<td>Slide 79</td>
<td>
</td>
<td>• Summary of key objectives to focus on during design for future reference.</td>
</tr>
</table>

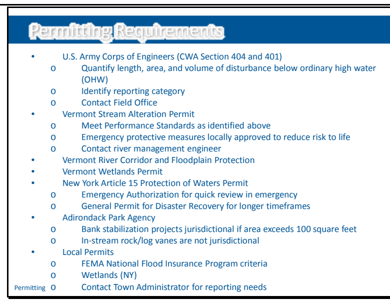
<table>
<tr>
<td>Slide 80</td>
<td>
</td>
<td>• Summary of key objectives to focus on during design for future reference.</td>
</tr>
<tr>
<td>Slide 81</td>
<td>
</td>
<td>• Summary of key objectives to focus on during design for future reference.</td>
</tr>
<tr>
<td>Slide 82</td>
<td>
</td>
<td>• Summary of key objectives to focus on during design for future reference.</td>
</tr>
</table>

Slide 83

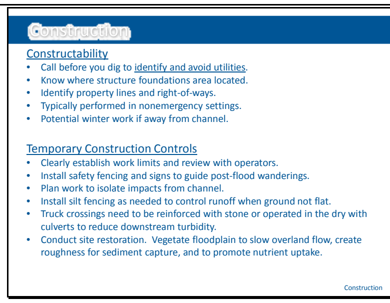


ANSWERS:

- Bank stabilization is often needed in confined settings where adjacent property exists that cannot be moved. 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.
- Fill in the floodplain that appears to be protecting adjacent property actually increases flood and erosion risks since the fill narrows the channel and floodplain leading to high flood velocities and more erosion.
- 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. Reference floodplain width is typically obtained by a combination of field observation, geomorphic assessment, and GIS mapping. Observations of all available space. Full floodplain. Check confinement, entrenchment, and incision to investigate possible connectivity. For benches typically grabbing available space that can reduce encroachment and achieve bankfull channel width.

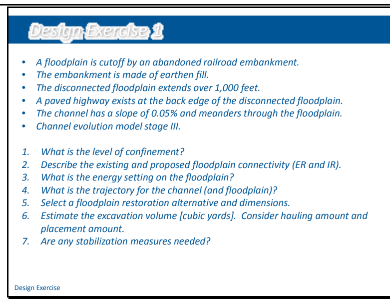
<table>
<tr>
<td>Slide 84</td>
<td>
</td>
<td>

This is a list of some initial permit requirements.
NFIP requirements can be in conflict with floodplain restoration at times (e.g., tree planting, etc.)

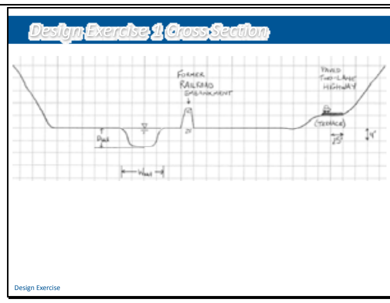
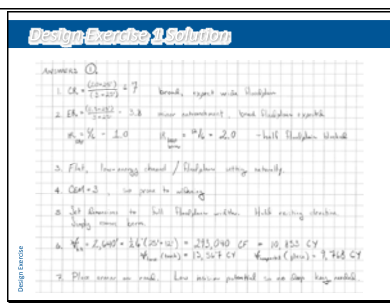
</td>
</tr>
<tr>
<td>Slide 85</td>
<td>
</td>
<td>

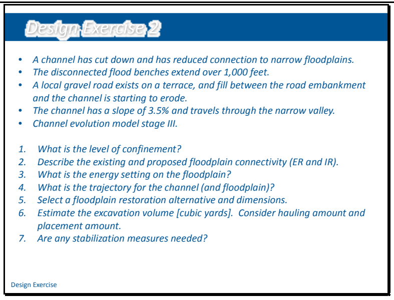
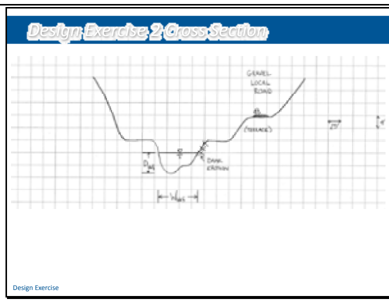
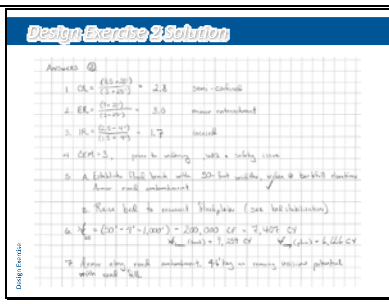
This is a list of some construction items.
Floodplain restoration projects are straightforward from a constructability point of view and have a high likelihood of successfully reducing flood risks over the long term since the practice does not rely on structural elements to properly function. As soon as the floodplain is widened and lowered, the risks for inundation and erosion decrease.
Floodplain restoration that takes place by removal of berms or lowering floodplains tends to be low-risk construction activities since work is taking place outside of the river channel. When floodplain restoration takes place by elevating the riverbed, the impacts of the project increase since work is mostly taking place in the river channel.

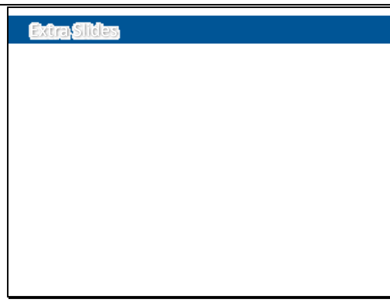
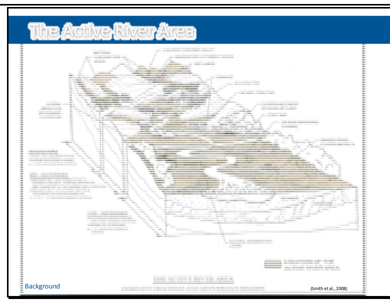
</td>
</tr>
</table>

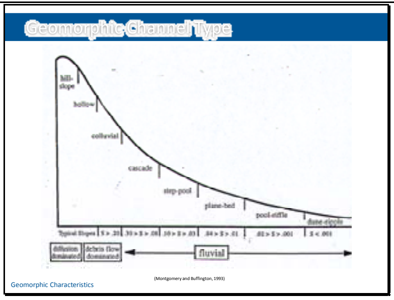
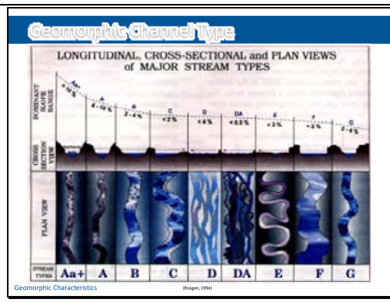
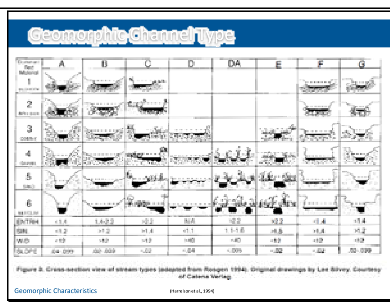
<table>
<tr>
<td>Slide 86</td>
<td>
</td>
<td>

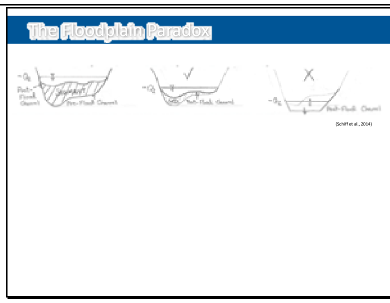
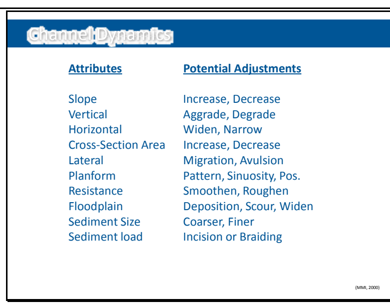
This is a lower risk example where floodplain is easily connected with a little bit of road protection. (20 minutes group work, 5-minute presentation)
See cross sections and solution notes on following slides.

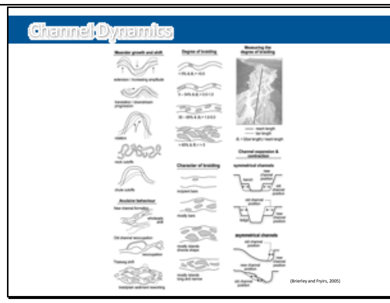
</td>
</tr>
<tr>
<td>Slide 87</td>
<td>
</td>
<td></td>
</tr>
<tr>
<td>Slide 88</td>
<td>
</td>
<td></td>
</tr>
</table>

<table>
<tr>
<td>Slide 89</td>
<td>
</td>
<td>This is a higher risk, confined example where flood benches can be re-established and armor can be placed along the road. (20 minutes group work, 5-minute presentation)
See cross sections and solution notes on following slides.</td>
</tr>
<tr>
<td>Slide 90</td>
<td>
</td>
<td></td>
</tr>
<tr>
<td>Slide 91</td>
<td>
</td>
<td></td>
</tr>
</table>

Slide 92		
Slide 93		• Most of the landscape directly or indirectly influences the river • Meander belt, floodplain, riparian areas, terraces, material contribution zones • Recall the entire valley was likely carved by ice and the river • Hydrology, sediment transport, organic material transport and processing, connectivity, water quality, thermal regime, energy transport • Moving down the watershed the floodplain becomes wider. Confinement reduces, yet connectivity to floodplain should increase.

Slide 94		• Quick review as covered in Tier 2. Does everyone get this? • Slope can help with initial prediction of channel pattern and dominant process.
Slide 95		• Quick review as covered in Tier 2. Does everyone get this? • If you are going to modify channel, have vision of channel type and trajectory. • Need target, and that typically comes initially from channel classification. • Use to organize observations and verify design.
Slide 96		• Quick review as covered in Tier 2. Does everyone get this? • Relationship between substrate, slope, and type. • Keep synchronized or you will see large adjustments post debris removal. • Ideally a vision of the channel exists for before flood, design/construction, and expected channel type (reference condition). • How much is the likely reference condition inhibited by the post-flood conditions? • Due to climate change, the channel type could take on a new form than predicted by common classification

		systems.
Slide 97		
Slide 98		

Slide 99		Dynamics = channel adjustment. Expected processes.
Slide 100		• 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.