United States Department of Agriculture

Planning and Design of Stream Crossings

FEATURING:

Dean Renner, PE
Stream Mechanics Engineer
(Retired) NRCS Washington

BY:

Sally Bredeweg, PE
Environmental Engineer
NRCS West National Technology Support Center

NRCS National Conservation Practice Standard

STREAM CROSSING, Code 578

DEFINITION

A stabilized area or structure constructed across a stream to provide a travel way for people, livestock, equipment, or vehicles.

USDA United States Department of Agriculture

DEFINITION

A stabilized area or structure constructed across a stream to provide a travel way for people, livestock, equipment, or vehicles.

PURPOSE

- Provide access to another land unit
- Improve water quality by reducing sediment, nutrient, organic, and inorganic loading of the stream
- Reduce streambank and streambed erosion

CONDITIONS WHERE PRACTICE APPLIES

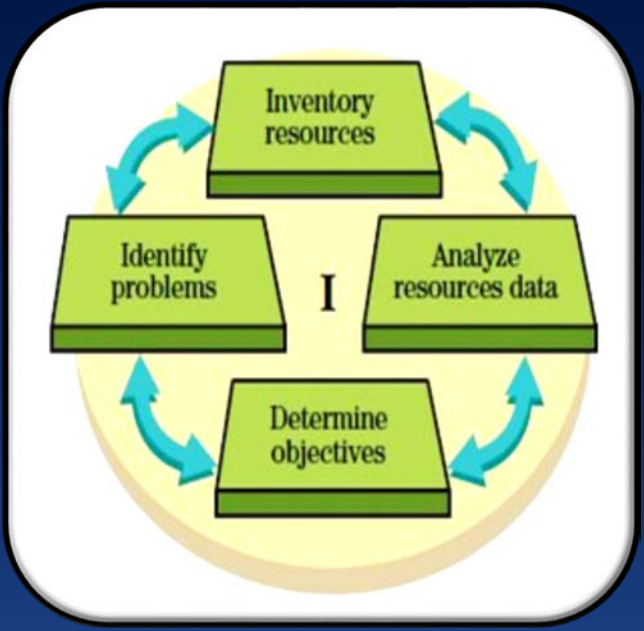
This practice applies to *all land uses* where an *intermittent or perennial* watercourse exists and a **ford**, **bridge**, or **culvert** type crossing is needed.

United States Department of Agriculture

Planning Process

The first 4 steps of conservation planning are:

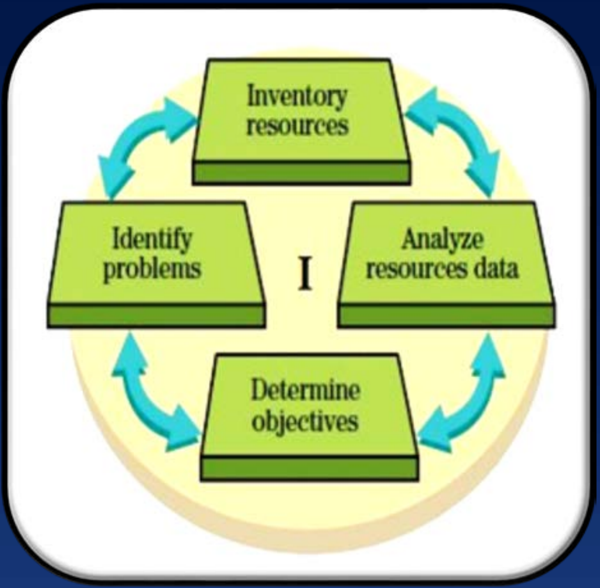
1. Inventory resources
2. Identify problems
3. Landowner objectives
4. Analyze resource data



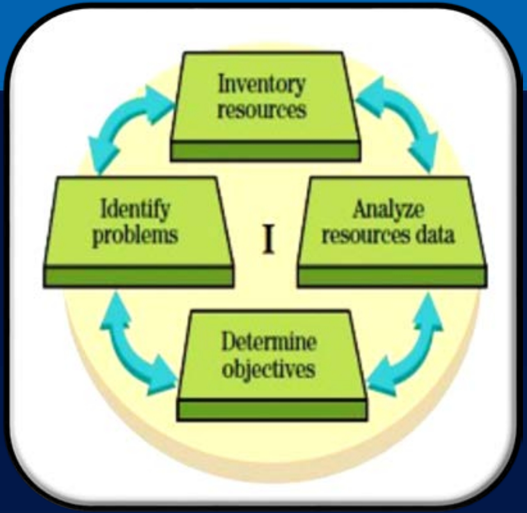
United States Department of Agriculture

NRCS Technical Specialists staff:

- Engineer
- Biologist
- Stream Mechanics Engineer
- Geologist
- Soil Scientist
- Fisheries Biologist
- Fluvial Geomorphologist
- Others………



CRITERIA (for all structures)



- Apply this standard in accordance with all local, State, Tribal, and Federal regulations, including flood plain regulations and flowage easements.
- Identify significant cultural resources or threatened or endangered species that could be affected by the implementation of the practice.

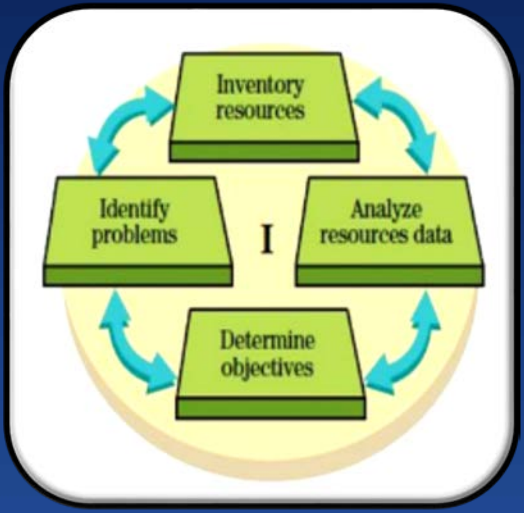
CRITERIA (continued)

For all structures

- ✓ Location
- ✓ Access Roads
- ✓ Width
- ✓ Side Slopes
- ✓ Stream Approaches
- ✓ Rock
- ✓ Fencing
- ✓ Vegetation

For specific structures

- ➢ <u>Bridge Crossings</u>
- ➢ <u>Culvert Crossings</u>
- ➢ <u>Ford Crossings</u>



CONSIDERATIONS

Read this section over each time you use this practice. This lists excellent guidance to consider for each site and structure.

PLANS AND SPECIFICATIONS

Final plans and specifications package for a stream crossing will need to address requirements for permitting agency review as well as installation and construction instructions.

OPERATION AND MAINTENANCE

Information required as a part of the practice.

USDA United States Department of Agriculture

Associated Practices for Stream Crossing

Access Road (560)

Animal Trails and Walkways (575)

Aquatic Organism Passage (396)

Channel Bed Stabilization (584)

Critical Area Planting (342)

Fence (382)

Forest Trails and Landings (655)

Heavy Use Area Protection (561)

Open Channel (582)

Structure for Water Control (587)

Stream Crossings

Dean Renner, PE
Stream Mechanics Engineer
USDA-NRCS Retired
Olympia, WA

dean.renner@wa.usda.gov

Stream Crossing Projects

- New crossings on stable stream reaches designed so there will be no impact on the stability of the stream channel.

- Replacement of existing crossings that have resulted in a stream reach that is no longer stable, designed with a new channel profile regrade and cross section that will result in a stable stream reach.

Very important to remember

- Streams transport water sediment and wood
  - Sediment can include fine grained material to boulders.
  - Wood can include vegetative material of all sizes.

Historic Culvert Designs

- Passed water and not sediment
- Created backwater at the inlets resulting in upstream sediment deposition
- Created high velocity flows exiting the culvert resulting in downstream channel scour

Historic Culverts

Historic Bridge Designs

- Constricted stream channels
- May not have sufficient clearance to pass large woody material.

A nice looking stream crossing structure
Affected stability of channel

A stream crossing with a questionable structure did not affect stability of channel

For Stream Crossings

- Stream problems are not just site limited, they may affect a fairly long reach of a stream.
- Project Planning should consider sediment continuity and channel stability first.
- Projects on existing crossings, should be considered to be stream channel restoration projects, and not road repair projects.
- Consider elimination of the existing crossing first

New Stream Crossings

Should be designed so that the calculated design stream flow velocities and shear stress do not change from before the installation of the crossing to after the installation of the proposed crossing.

- In the existing upstream reach
- In the existing downstream reach

Replacement Stream Crossings

Should be designed so that the calculated design stream flow velocities and shear stress do not change with the installation of the crossing structure:

- In the upstream reference reach
- In the downstream reference reach
- In a new channel reach constructed at the crossing

Design Approach for Stream Crossings

- This presentation will be based on the "Stream Simulation" approach for stream crossings.
- "Stream Simulation" designs have a continuous channel through the crossing structure with dimensions and characteristics similar to the adjacent natural channel.
- The concept of Stream Simulation was first introduced by the Washington (State) Department of Fish and Wildlife, and has been adopted by the USDA Forest Service.

Design Steps for New Crossings

- Gather inventory data in office.
- Collect Field Data
- Perform Hydrology Calculations
- Perform Hydraulic Analysis
- Develop Structural Design of Crossing
- For Culverts, design the Culvert Bed
- Develop the structural design for any in-stream structures for channel stabilization.

Gather Inventory Data in Office

- USGS Quad: Project Location, Map channel slope
- USGS Stream Stats: Drainage Area, Mean Annual Precipitation, Mean Basin Elevation, Location of nearest stream gage.
- Soil Survey: Soil Series, Depth, Unified Class
- Historical Projects on Same Stream

Collect Field Data

- Survey a Long Profile:
  - 20 Bankfull Widths Upstream
  - 20 Bankfull Widths Downstream
  - Start and End Profile on Riffles

- Survey Channel Cross Sections and Measure Channel widths:
  - Minimum of 6 Sections in Long Profile reach above and below crossing site.
  - At Riffle or Cross-Over locations.

Collect More Field Data

- Obtain Pebble Counts: At least one Pebble Count upstream of proposed crossing and one Pebble Count downstream of proposed crossing.
- Survey topo for the crossing Structural Design
- Perform Soils Investigation for Foundation Analysis.

Perform Hydrology Calculations

- Calculate the Hydrology at the Project Site, estimate Peak Flows for various Frequencies
- Need design flow for channel stability
  Usually Bankfull Flow (between 1-yr to 2-yr recurrence interval runoff event)
- Need design flow for structural stability
  Usually (100-yr recurrence interval runoff event)
- Use Gage Data if Available.

Bankfull Discharge

- Bankfull Discharge usually falls somewhere between and 1 yr. and 2 yr. recurrence interval.
- Bankfull Discharge is generally found to transport more sediment over time than any other flow event.
- Bankfull Discharge is determined near Stream Gages by comparing elevation discharge data with an estimated bankfull elevation.
- There have been studies made in several states relating Bankfull Discharge to recurrence interval at long term stream gages.

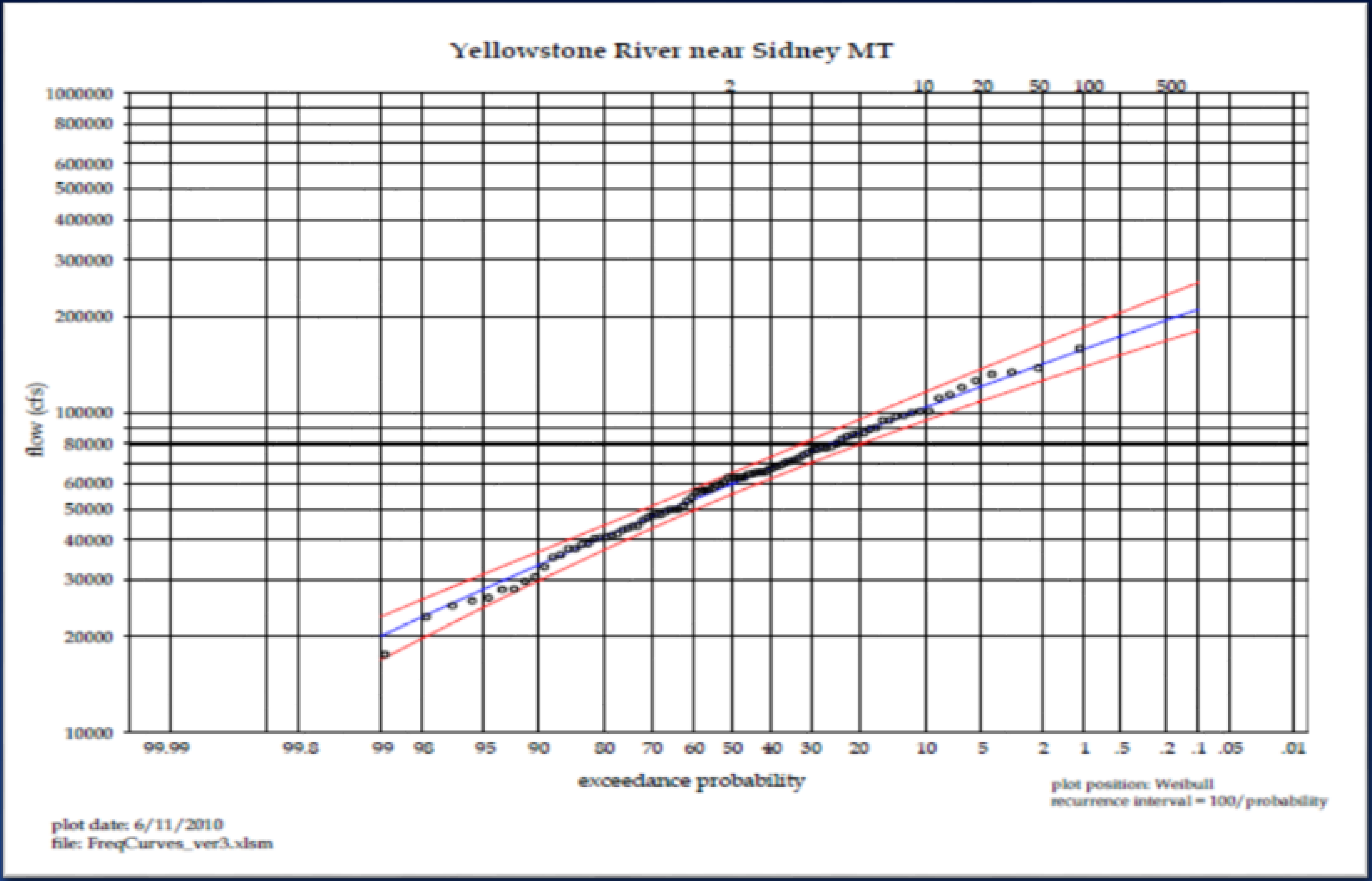
Perform Hydrology Calculations Cont.

- Usually no gage data is available at the Project Site, need to estimate Peak Flows for various Frequencies.
- NRCS Curve Number hydrology calculation methods (estimated runoff from estimated rainfall) are usually not accurate for these sites.
- USGS StreamStats using the Regression Equations for Ungaged Sites or Flow Estimates based on Nearby Streamgaging Stations (within 50% drainage area) method provide more accurate estimates.

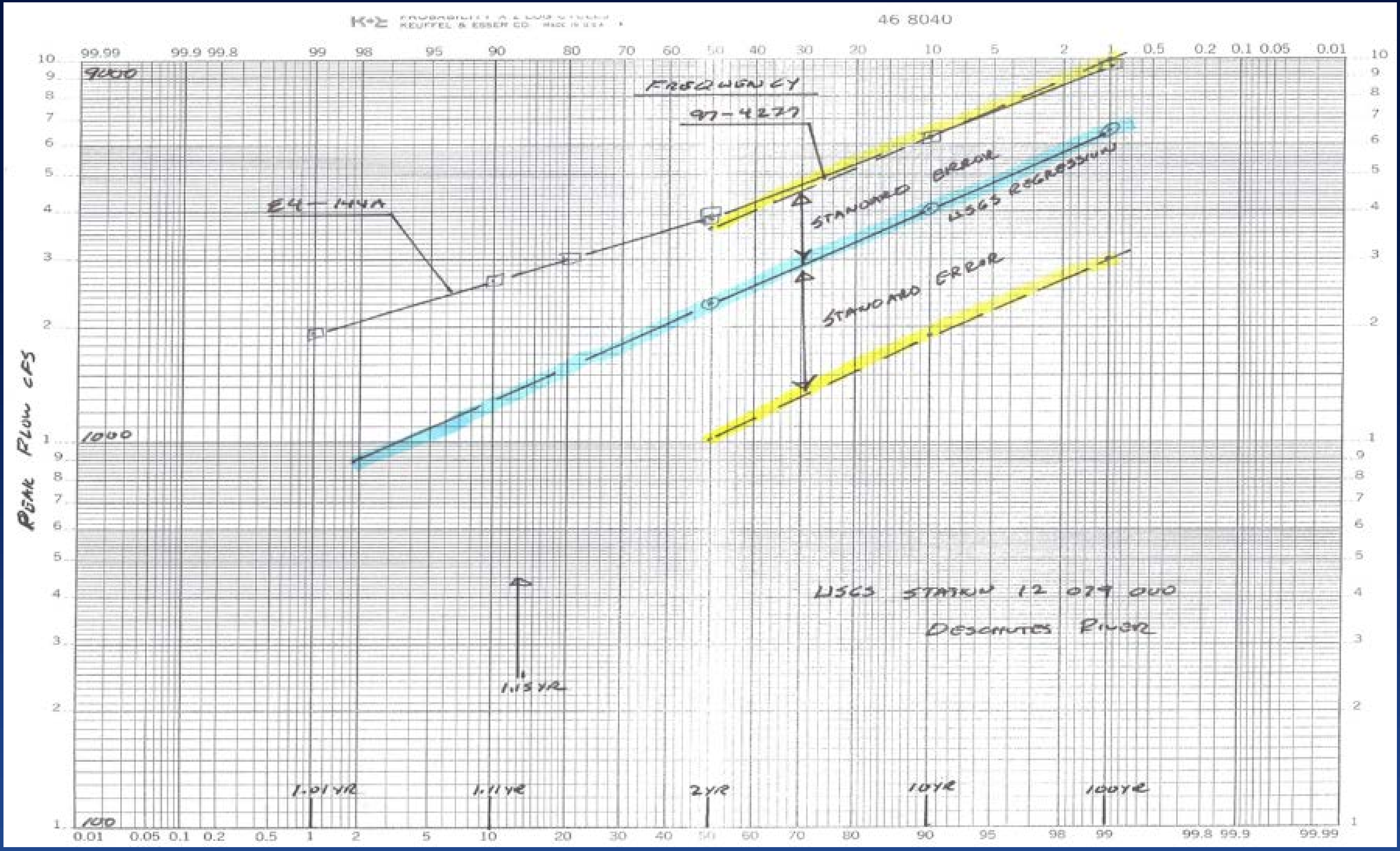
Hydrology Calculations at Ungaged Sites

- To check the error in the USGS StreamStats Methods and to estimate less than 2yr events:
  1. Estimate Discharge vs Frequency using StreamStats at the Nearest Gage
  2. Compare with a Log-Frequency Analysis (Bulletin 17-B) at the Nearest Gage.
- There may be other hydrology calculation methods for ungaged sites developed by State Agencies that may provide more accurate estimates than USGS StreamStats estimates from Regression Equations.

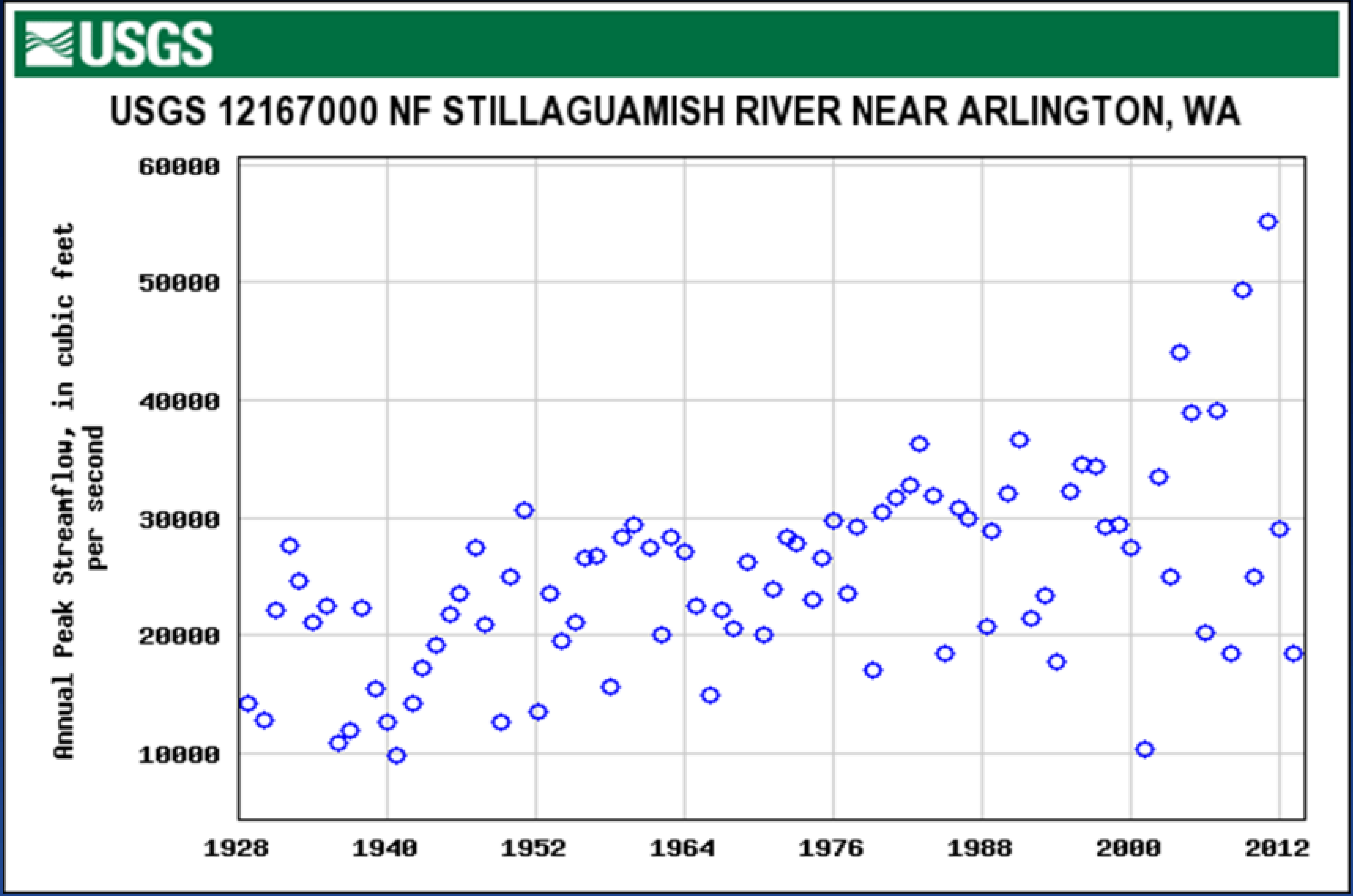
NRCS Spreadsheet for Log-Frequency Analysis (Bulletin 17-B) of gage data



Regression Equation vs Frequency Analysis of Gage Data



Another Hydrology Issue to be Aware Of



Perform Hydraulic Analysis

Hydraulics CalculationTools

- Two different methods for hydraulic calculations are recommended:

- The Reference Reach Spreadsheet (Mecklenburg 2004)
- HEC-RAS (US Army Corps of Engineers 2008)

Hydraulics Calculation Tools

Reference Reach Spreadsheet:

- The Reference Reach Spreadsheet is part of a suite of spreadsheet tools, the STREAM Modules which have been developed by the Ohio Department of Natural Resources and Ohio State University. The STREAM acronym represents Spreadsheet Tools for River Evaluation, Assessment and Monitoring.
- NRCS recognizes the Reference Reach Spreadsheet as a tool that can be used to supplement National Engineering Handbook 654 (NEH 654) Stream Restoration Design.

Hydraulics Calculation Tools

HEC-RAS:

- HEC-RAS is a program developed the US Army Corps of Engineers that calculates water surface profiles in natural gradually varied channels. HEC-RAS is used to calculate gradually varied non-uniform flow through a series of cross-sections.
- NRCS recognizes HEC-RAS as a tool that can be used to supplement National Engineering Handbook 654 (NEH 654) Stream Restoration Design.

Hydraulics Calculation Tools

The difference between the Reference Reach Spreadsheet and HEC-RAS

- The Reference Reach Spreadsheet plots the data from field surveys & calculates uniform flow at individual cross sections.

- HEC-RAS calculates gradually varied non-uniform flow through a series of cross sections.

Existing Stream Hydraulics

- The Reference Reach Spreadsheet can be used to summarize the field survey data for the longitudinal profile and the stream channel cross sections.
- Then the Reference Reach Spreadsheet can be used to estimate the Manning's "n" value at the cross sections based on a bankfull profile developed from the survey data and the estimated bankfull discharge.
- The Reference Reach Spread sheet can be used to define the hydraulic geometry of the cross sections.

Existing Stream Hydraulics

- Develop water surface profiles using HEC-RAS for the existing condition. Compare computed profiles to the bankfull indicators to determine bankfull discharge. Compare estimated bankfull discharge to the hydrology calculations.
- Super-critical flow generally does not exist in natural channels.
- Use appropriate stream discharge versus frequency values, Manning's "n" values, and bankfull frequency.

Existing Stream Hydraulics

- Remember that to evaluate the hydraulics of a crossing site that you need to estimate <u>three critical items</u>:
- The Discharge versus Frequency Relationship;
- The Frequency at which Bank Full Flow occurs;
- The Manning's "n" value for a natural stream. (Most people under-estimate the "n" value)

Also, the bankfull flow regime should be a subcritical flow profile

Existing Stream Hydraulics

When a reasonable bankfull discharge profile is obtained from the HEC-RAS analysis of the existing channel, summarize the following values from each cross section for the Bankfull Discharge and 100-year Discharge:

- Water surface elevation
- Steam flow velocity
- Channel Shear Stress
- Froude Number

Proposed Stream Hydraulics

- For a proposed bridge or culvert crossing, develop HEC-RAS water surface profiles for Bankfull Discharge and the 100-year discharge with the proposed bridge abutments.
- Remember to Utilize the four user defined cross sections for computation of energy loss due to the crossing structures that are defined in Chapter 6 of the HEC-RAS Manual

Proposed Stream Hydraulics

When a reasonable bankfull discharge profile is obtained from the HEC-RAS analysis of the proposed crossing structure over the existing channel, summarize the following values from each cross section for the Bankfull Discharge and 100-year Discharge:

- Water surface elevation
- Stream flow velocity
- Channel Shear stress
- Froude Number

Structural Design

If the Stream Hydraulics with the Proposed Crossing Structure is acceptable when compared with the Existing Stream Hydraulics then the next step is to develop the structural design of the:

- Bridge deck superstructure and abutments
- Culvert
- Bottomless Arch

Structural Design

- For culverts, design the culvert bed. If the Proposed Culvert is sized appropriately, then the bed material placed inside the culvert will be the same as that found in the existing stream.

- Develop the Structural Design for any rock or log in-stream structures for stream channel stabilization.

Design Steps for Replacement Crossings

- Gather inventory data in office
- Collect Field Data
- Perform Hydrology Calculations
- Perform Hydraulic Analysis
- Design Stream Simulation Channel Reach
  - Longitudinal Profile
  - Channel Cross Section
- Develop Structural Design of Crossing and any In-stream Structures

(Orange Font denotes a change from New Stream Crossings)

Collect Field Data-Existing Crossings

- Survey a Long Profile:
- Existing crossings involve 4 reaches:
  - Upstream Reference Reach,
  - Aggraded Channel,
  - (Existing Crossing),
  - Incised Channel, Downstream
  - Reference Reach.
- Collect Field Data similar to a New Crossing but extend the data collection through all 4 reaches.
- The field data should extend at least 20 bankfull widths through both Reference Reaches

Collect Field Data-Existing Crossings

- Survey Channel Cross Sections and Measure Bankfull Channel Widths:
  - Minimum of 6 Sections in Upstream Reference Reach and Downstream Reference Reach.
  - At Riffle or Cross-Over Locations
- Obtain Pebble Counts in Upstream Reference Reach and Downstream Reference Reach.
- Survey Topo for the Structural Design and Foundation Soils Investigation.

Proposed Stream Hydraulics-Existing Crossings

- Compute water surface profiles for the existing condition to determine water surface elevations, velocity, channel shear stress and Froude Number for the cross sections in the reference reaches.
- Develop a channel profile and cross section for the channel regrade reach based on the channel morphology of the upstream and downstream reference reach cross sections.
- Develop water surface profiles using HEC-RAS for the Downstream Reference Reach, Channel Regrade Reach, and Upstream Reference Reach.

Proposed Stream Hydraulics-Existing Crossings

- For proposed Bridges, develop water surface profiles using HEC-RAS for the channel with the channel regrade and the proposed bridge abutments. Adjust Abutment Design as needed.
- For proposed Culvert, develop water surface profiles using HEC-RAS for the channel with the channel regrade and the proposed Culvert. abutments.
- Adjust Culvert Design as needed, a bottomless arch may be evaluated as an arch-bridge.

Structural Design

If the Stream Hydraulics with the Proposed Crossing Structure to replace the Existing Structure is acceptable when compared with the Existing Stream Hydraulics then the next step is to develop the structural design of the:

- Bridge deck superstructure and abutments
- Culvert
- Bottomless Arch

Structural Design

- For culverts, design the culvert bed. If the Proposed Culvert is sized appropriately, then the bed material placed inside the culvert will be the same as that found in the existing stream.
- Develop the Structural Design for any rock or log in-stream structures for stream channel stabilization.
- Review & Approval by an Engineer with Job Approval Authority for CPS 578!