Sediment Yield and Transport Analyses for the Goose Creek Restoration Project

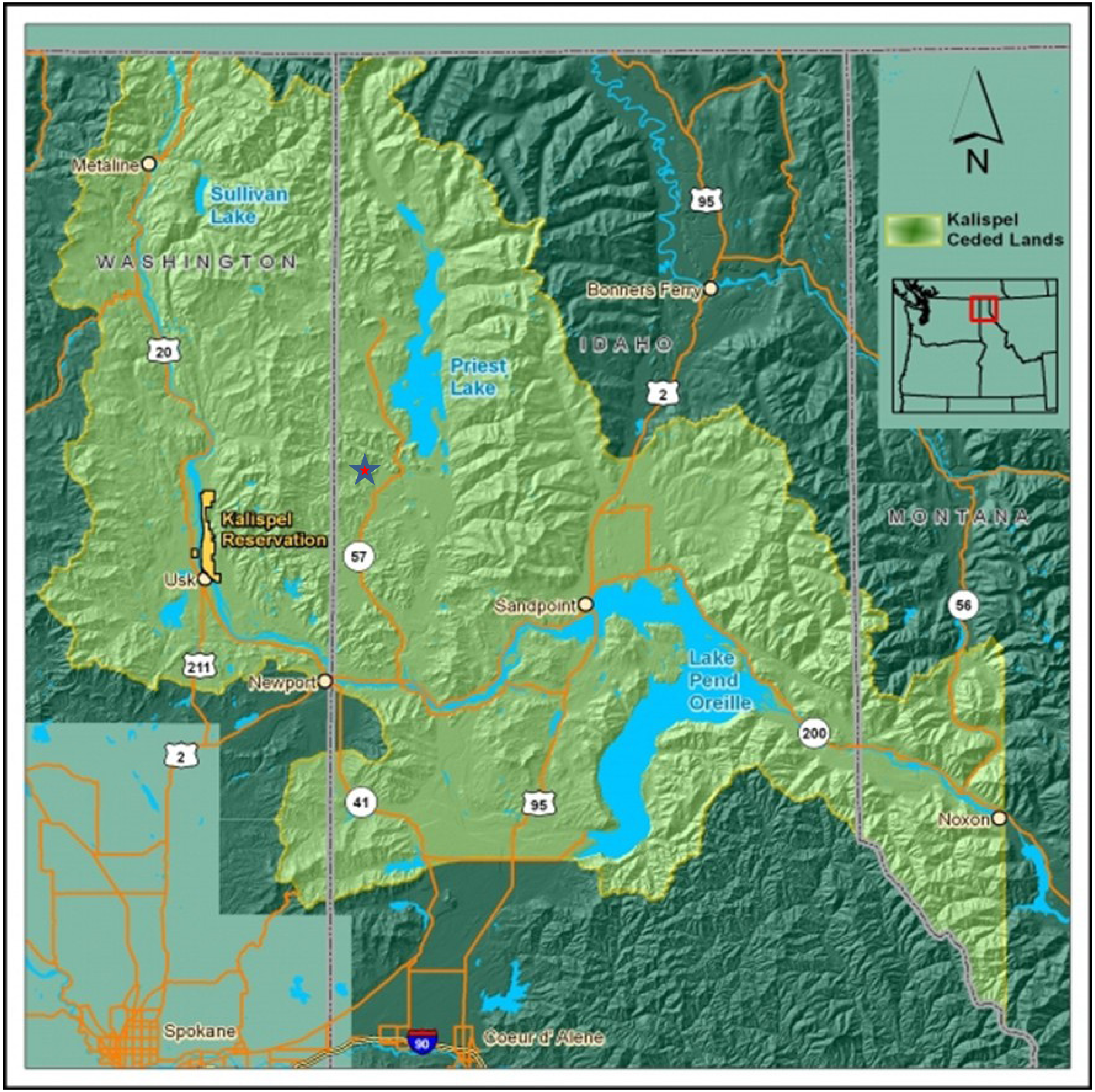
Eric Berntsen
Kalispel Natural Resources Department

Eric’s talk

- Project background and watershed overview
- Overview of river restoration principles and the importance of quantifying sediment
- Q & A

Project background

- Tribe purchased 773 acres in Bonner County, Idaho to offset wetland impacts from the construction and operation of Albeni Falls Dam
- 22 square mile drainage area originates in Pend Oreille County, Washington and is mostly forested with limited agriculture
- Target species include westslope cutthroat trout, bald eagle, and yellow warbler



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Newport
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Spokane
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Priest Lake
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Bonners Ferry
IDAHO
2
Sandpoint
Lake Pend Oreille
95
200
90
Coeur d' Alene
MONTANA
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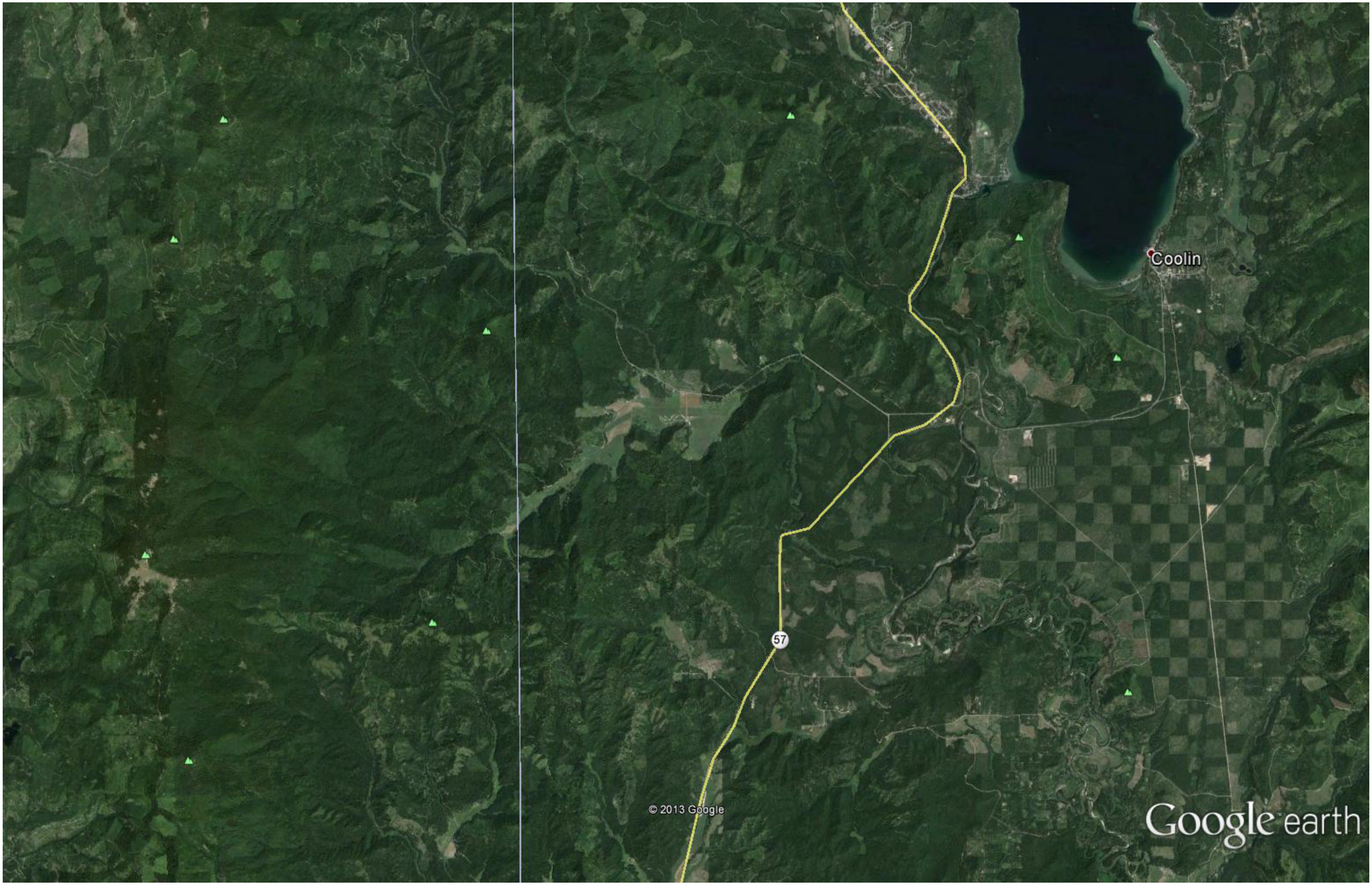
Noxon

Upper W. Branch Priest River
Blanc Creek
MEADOWS
BIG
Goose Creek
Goose Creek
KALISPEL TRIBAL PROPERTY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(from fishandgame.idaho.gov)


RELEASE

River restoration principles

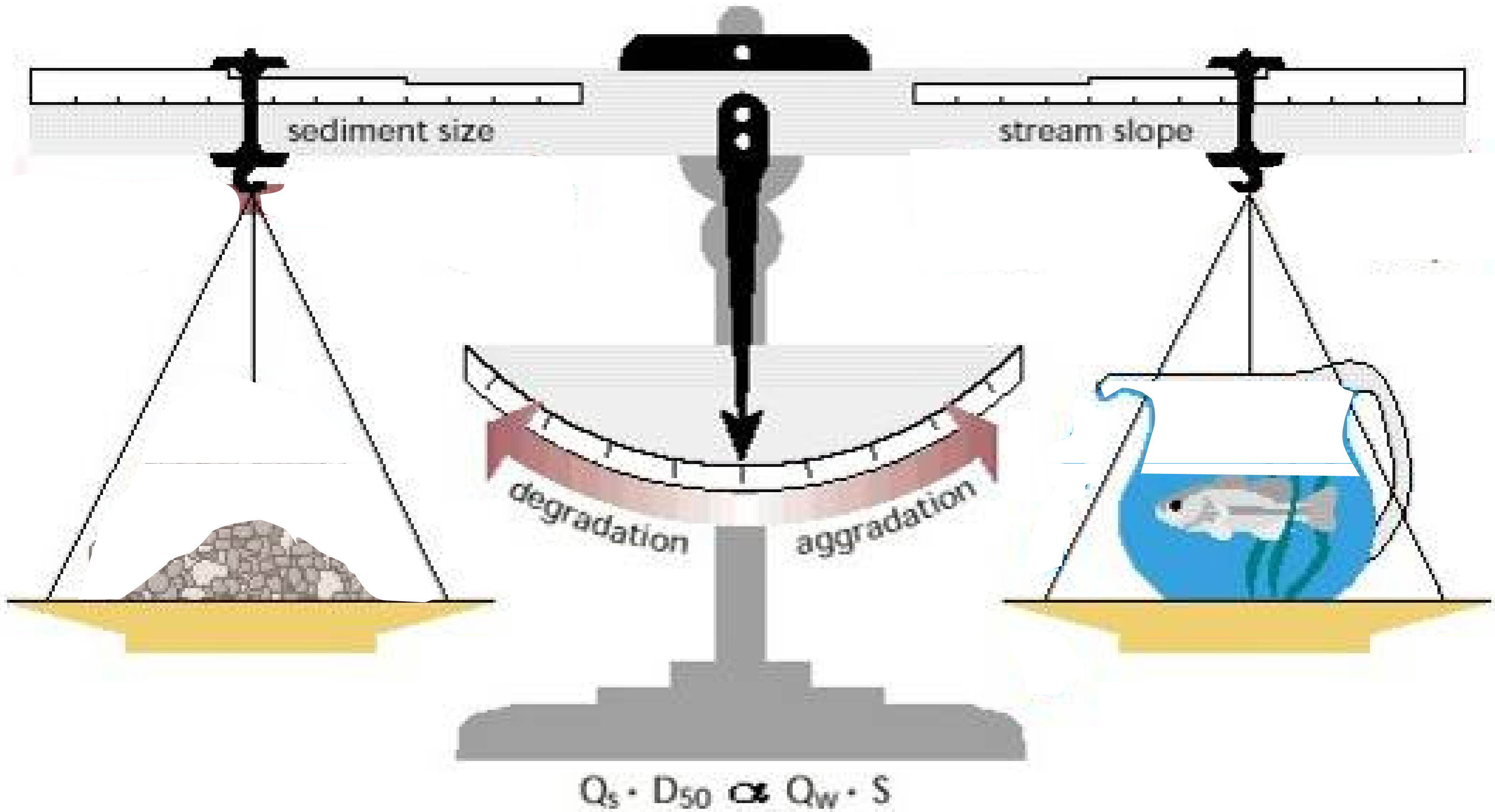
(from Beechie et al. 2010)

- Identify root causes of habitat and ecosystem change;
- Taylor restoration actions to local potential;
- Match the scale of restoration to the scale of physical and biological processes; and
- Be explicit about expected outcomes, including recovery time.

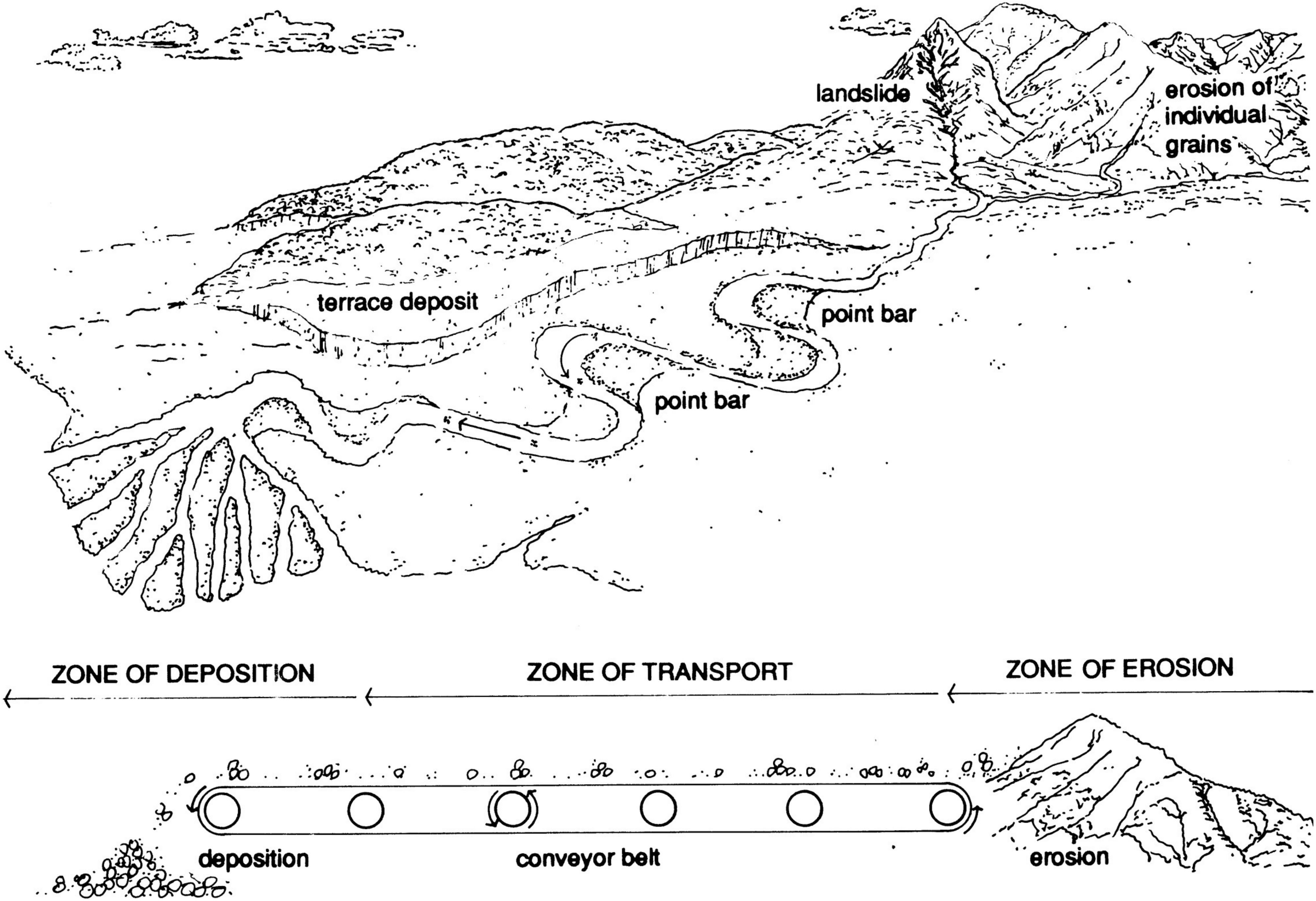
Identify root causes

- Major portions of channel have been straightened in the last 20 years, soil compacted
  - Sediment transport capacity increased
  - Widespread channel incision and widening
  - Simplification of aquatic and riparian habitat

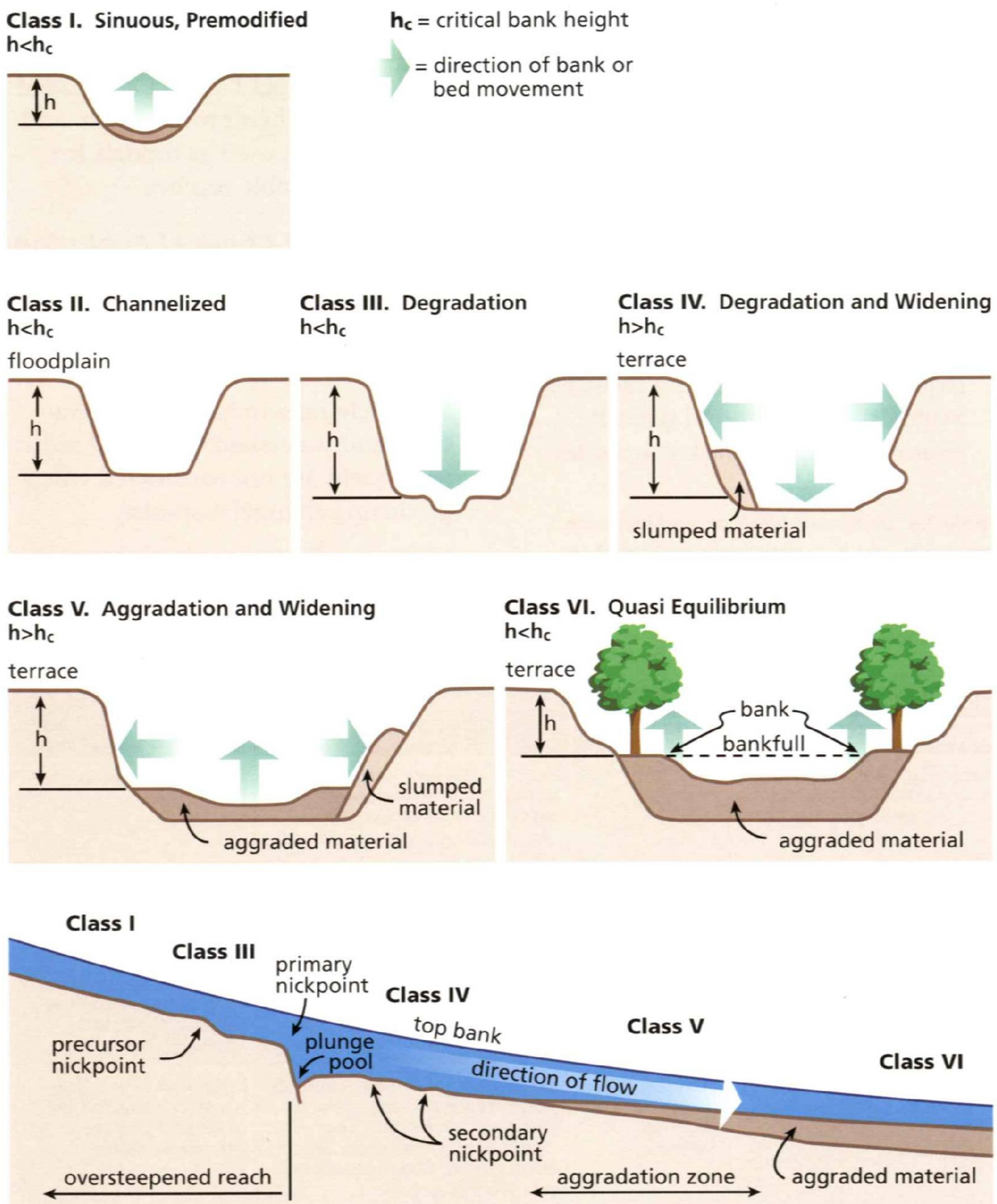
Lane's Diagram by Rosgen (1996)
c/o Chris Bowles, cbec



Over time channel geometry (width, depth, gradient) adjusts to be in equilibrium with flow and sediment regime.



(Kondolf 1997)



(Simon 1989)
(Schumm 1977)

Identify root causes (cont'd)

- Destruction of riparian habitat
  - Accelerated bank erosion
  - Increased stream temperatures
  - Loss of a habitat creation and management superhero *(hint:think Oregon State University mascot)*


(Pollock et al. 2012)

NOAA Technical Memorandum NMFS-NWFSC-120

Working with Beaver to Restore Salmon Habitat in the Bridge Creek Intensively Monitored Watershed

Design Rationale and Hypotheses

Michael M. Pollock, Joseph M. Wheaton,[1] Nick Bouwes,[2]
Carol Volk,[3] Nicholas Weber,[2] and Chris E. Jordan

Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, Washington 98112

[1]Utah State University
Watershed Sciences Department
5210 Old Main Hill
Logan, Utah 84322

[2]Eco Logical Research, Inc.
456 South 100 West
Logan, Utah 84321

[3]South Fork Research, Inc.
44842 Southeast 145 Street
North Bend, Washington 98045

October 2012

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Restoration actions

- Possibly mimic the actions of beaver by installing check dams to aggrade the channel and reconnect with the floodplain.

Question: How long will it take to reconnect?

Answer: 42?

Actually, we don't know until we calculate sediment yield

How long will it take the channel to reconnect?

\# of years to reconnect = V_c/Q_s

Where V_c = volume of incised channel (cubic yards)

Q_s = average annual sediment yield (cubic yards per year)

How long will it take the channel to reconnect?

- Based on field measurements, V_c = 1.1E+04 cubic yards

- Average annual sediment yield was estimated using four methods.
  1. Ursic and Douglass 1978
  2. Patric et al. 1984
  3. SCS Sediment Yield Maps
  4. PSIAC

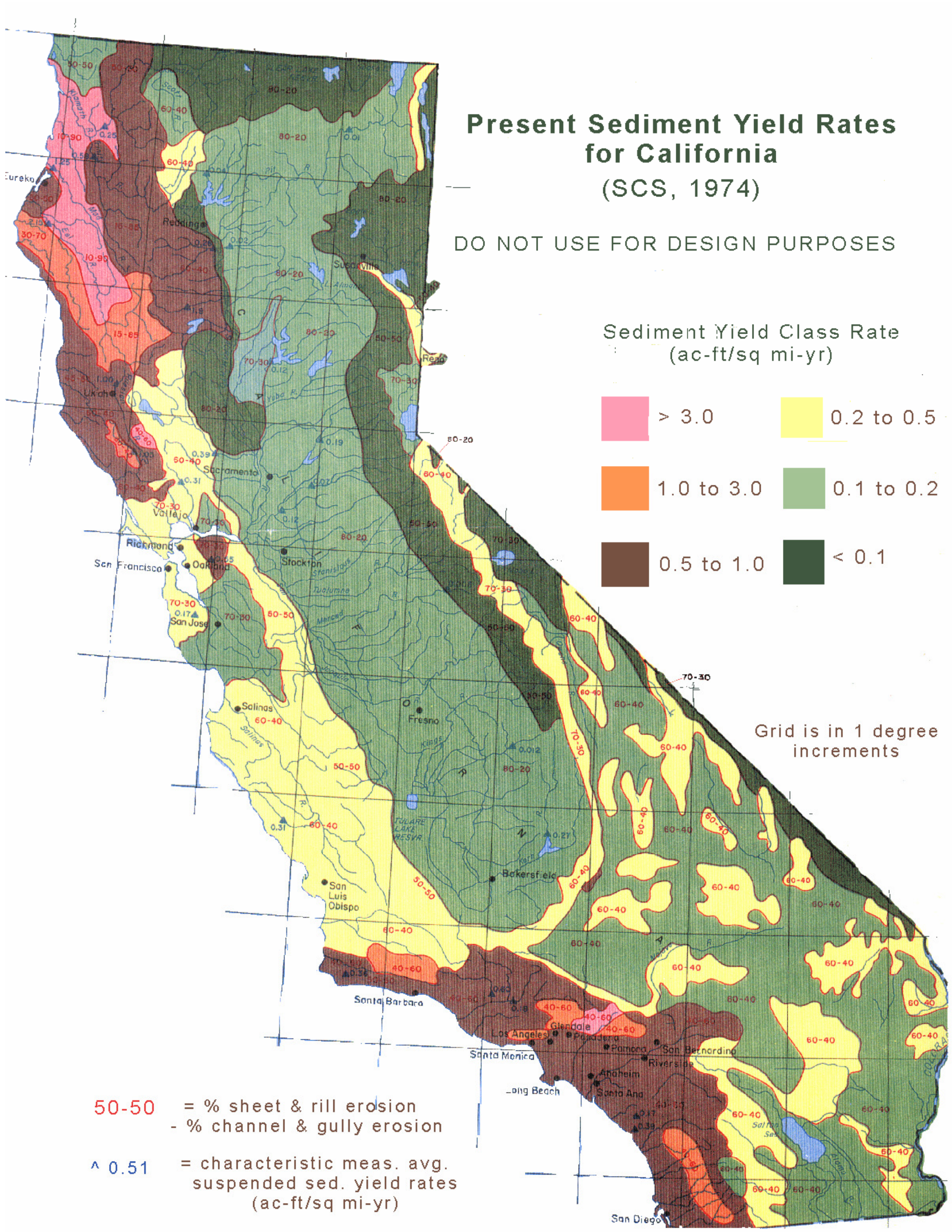
Sediment Yield

1. 0.007 tons of sediment per acre-inch of streamflow per year from western forested areas (*what's the annual streamflow?*)

2. 0.25 tons per acre annually from minimally disturbed forested areas

Sediment Yield (cont'd)

3.



Sediment Yield (cont'd)

4.

Table A.1.1. Factors Affecting Sediment Yield in the Pacific Southwest.

Sediment Yield Levels	A SURFACE GEOLOGY (10)*	B SOILS (10)	C CLIMATE (10)	D RUNOFF (10)	E TOPOGRAPHY (20)	F GROUND COVER (10)	G LAND USE (10)	H UPLAND EROSION (25)	I CHANNEL EROSION & SEDIMENT TRANSPORT (25)
High	a. Marine shales and related mud-stones and silt-stones.	a. Fine textured easily dispersed; saline-alkaline; high shrink-swell characteristics b. Single grain silts and fine sands	a. Storms of several days' duration with short periods of intense rain-fall. b. Frequent intense convective storms c. Freeze-thaw occurrence	a. High peak flows per unit area b. Large volume of flow per unit area	a. Steep upland slopes (in excess of 30%) High relief; little or no floodplain development	Ground cover does not exceed 20% a. Vegetation sparse; little or no litter b. No rock in surface soil	a. More than 50% cultivated b. Almost all of area intensively grazed c. All of area re-cently burned	a. More than 50% of the area char-acterized by rill and gully or landslide erosion	a. Eroding banks con-tinuously or at frequent intervals with large depths and long flow duration b. Active headcuts and degradation in trib-utary channels
**									
Moderate	(5) a. Rocks of medium hardness b. Moderately weathered c. Moderately fractured	(5) a. Medium textured soil b. Occasional rock fragments c. Caliche layers	(5) a. Storms of moder-ate duration and intensity b. Infrequent con-vective storms	(5) a. Moderate peak flows b. Moderate volume of flow per unit area	(10) a. Moderate upland slopes (less than 20%) b. Moderate fan or floodplain develop-ment	(10) Cover not exceed-ing 40% a. Noticeable litter b. If trees present understory not well developed	(0) a. Less than 25% cultivated b. 50% or less re-cently logged c. Less than 50% in-tensively grazed d. Ordinary road and other construction	(10) a. About 25% of the area character-ized by rill and gully or land-slide erosion b. Wind erosion with deposition in stream channels	(10) a. Moderate flow depths, medium flow duration with occasionally eroding banks or bed
**									
Low	(0) a. Massive, hard formations	(0) a. High percentage of rock fragments b. Aggregated clays c. High in organic matter	(0) a. Humid climate with rainfall of low intensity b. Precipitation in form of snow c. Arid climate, low intensity storms d. Arid climate; rare convective storms	(0) a. Low peak flows per unit area b. Low volume of runoff per unit area c. Rare runoff events	(0) a. Gentle upland slopes (less than 5%) b. Extensive alluvial plains	(-10) a. Area completely protected by veg-etation, rock fragments, litter. Little opportunity for rainfall to reach erodible material	(-10) a. No cultivation b. No recent logging c. Low intensity grazing	(0) a. No apparent signs of erosion	(0) a. Wide shallow channels with flat gradients, short flow duration b. Channels in massive rock, large boulders or well vegetated c. Artificially controlled channels

* THE NUMBERS IN SPECIFIC BOXES INDICATE VALUES TO BE ASSIGNED APPROPRIATE CHARACTERISTICS.
THE SMALL LETTERS, a, b, c, REFER TO INDEPENDENT CHARACTERISTICS TO WHICH FULL VALUE MAY BE ASSIGNED.

** IF EXPERIENCE SO INDICATES, INTERPOLATION BETWEEN THE 3 SEDIMENT YIELD LEVELS MAY BE MADE.

Sediment Yield (cont'd)

Use of the Rating Chart of Factors Affecting Sediment Yield in the Pacific Southwest

The following is a summary of the sediment yield classification presented for this methodology.

Classification	Rating	Sediment Yield AF/sq. mi.
1	> 100	3.0
2	75 - 100	1.0 - 3.0
3	50 - 75	0.5 - 1.0
4	25 - 50	0.2 - 0.5
5	0 - 25	< 0.2

In most instances, high values for the A through G factors should correspond to high values for the H and/or I factors.

An example of the use of the rating chart is as follows:

A watershed of 15 square miles in western Colorado has the following characteristics and sediment yield levels:

Factors	Sediment Yield Levels	Rating
A Surface geology	Marine Shales	10
B Soils	Easily dispersed, high shrink-swell characteristics	10
C Climate	Infrequent convective storms, freeze-thaw occurrence	7
D Runoff	High peak flows; low volumes	5
E Topography	Moderate slopes	10
F Ground cover	Sparse, little or no litter	10
G Land use	Intensively grazed	10
H Upland erosion	More than 50% rill and gully erosion	25
I Channel erosion	Occasionally eroding banks and bed but short flow duration	5
	TOTAL	92

This total rating of 92 would indicate that the sediment yield is in Classification 2. This compares with a sediment yield of 1.96 acre-feet per square mile as the average of a number of measurements in this area.

Average annual streamflow

- Created a mean daily flow record for Goose Creek using 58 years of daily flow data and annual peak discharges from two nearby USGS flow gages on the Priest River
- 1.5 yr discharge assumed to approximate bankfull discharge in Northern Idaho/Eastern Washington (Castro 1997)
- Used USGS regression equation to calculate 1.5 yr discharge for Goose Creek

Average annual streamflow (cont'd)

- $Q_{dGC} = Q_{1.5GC} * (Q_{dPR} / Q_{1.5PR})$

Where Q_{dGC} = Goose Creek daily discharge (cfs)
$Q_{1.5GC}$ = Goose Creek 1.5 year discharge (cfs)
Q_{dPR} = Priest River daily discharge (cfs)
$Q_{1.5PR}$ = Priest River 1.5 year discharge (cfs)

(Based on Biedenharn et al. 2000)

Average annual streamflow (cont'd)

- Used GeoTools (Bledsoe et al. 2007) to calculate mean annual flow
- Estimated average annual streamflow = 36 cfs
- 36 cfs = 3E+05 acre-in/year

How long will it take the channel to reconnect?

Sediment Yield Method	Average Annual Sediment Yield (tons/yr)
1. Ursic and Douglass 1978	2.2E+03
2. Patric et al. 1984	3.5E+03
3. SCS Sediment Yield Maps	7.9E+03
4. PSIAC	1.1E+04
Average	6.4E+03

How long will it take the channel to reconnect?

- Assuming density of sediment is 110 lbs/cf, 6.4E+03 tons/yr = 4.3E+03 cy/yr
- years to reconnect = 1.1E+04 cy/4.3E+03 cy/yr
- years to reconnect = 2.5 yrs

Taylor restoration actions

- Target plan forms of new channel need to reflect the historic channel pattern and current discharge and sediment regime (Kondolf et al. 2001)
  - Historic channel pattern – sinuous channel (>1.5), low width to depth ratio (approx. 6), slope of 0.0016 to 0.0019 ft/ft.
  - Variety of methods used to analyze discharge and sediment regime

Discharge and sediment regime

- Channel forming discharge
- Sediment transport

Channel forming discharge
(see Doyle et al. 2007)

- Specific return interval discharge
- Bankfull discharge
- Effective discharge

Specific return interval discharge

- Discharge of a given return interval (e.g., 1.5 yr, 2 yr, etc.)

- Castro (1997) suggested 1.5 yr return interval is most appropriate for Northern Idaho/Eastern Washington

Specific return interval discharge (cont'd)

- Goose Creek 1.5 yr discharge determined using
  - USGS Regression Equation
  - By prorating drainage areas from Priest River gages
  - Mean daily flow record from Goose Creek

Bankfull discharge

- Determined from channel hydraulics
- Mannings n determined using Jarrett's equation
- Discharge determined using Gauckler-Manning Equation

Gauckler-Manning Equation

$$Q_b = (1.49/n)*A_b*R_b^{2/3}*S^{1/2}$$

where Q_b = bankfull discharge (cfs)

n = Manning's roughness coefficient

A_b = bankfull area (sf)

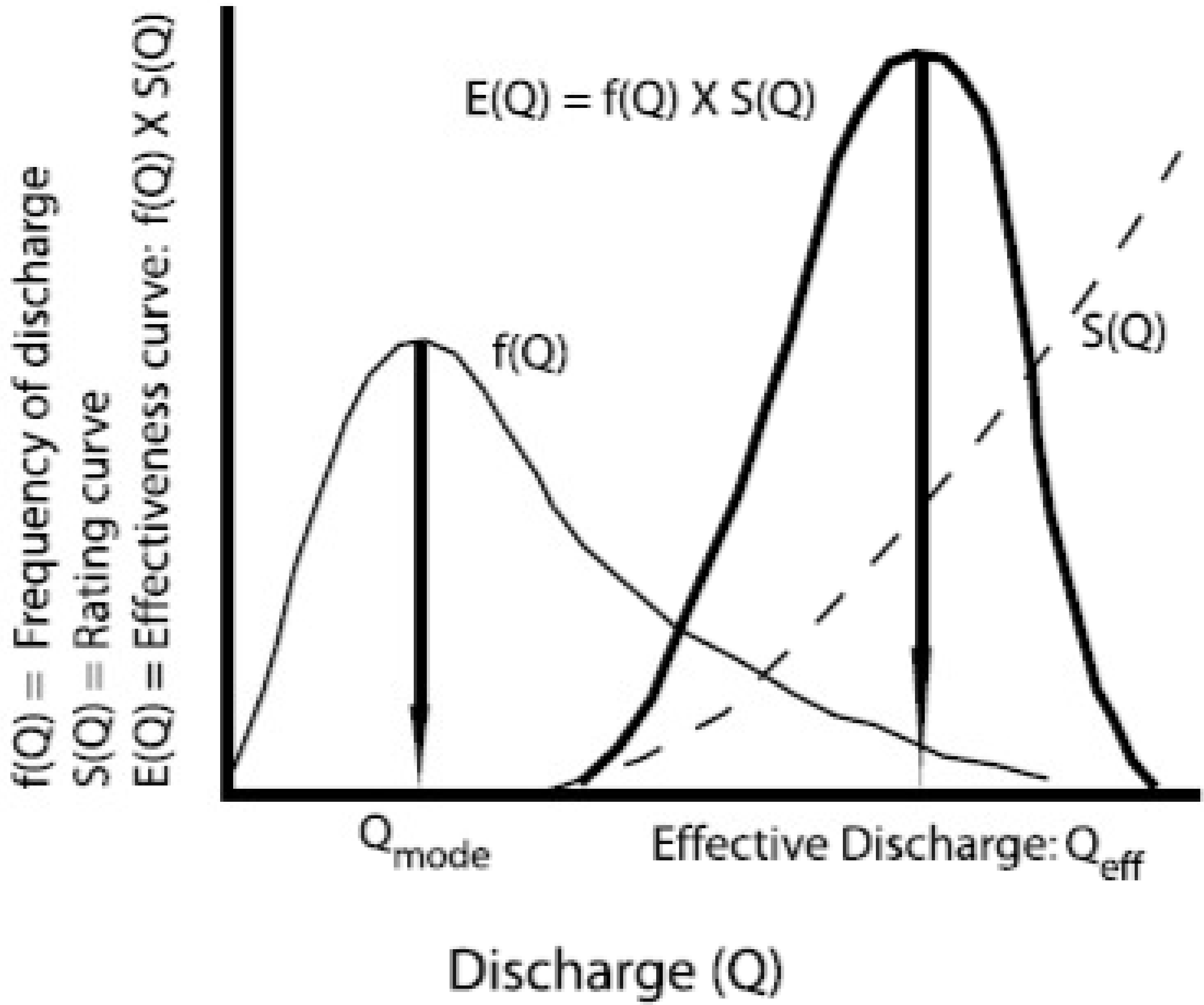
R_b = bankfull hydraulic radius (ft)

S = channel slope (ft/ft)

Effective discharge

- The discharge or range of discharges which, over time, transports the greatest quantity of sediment.

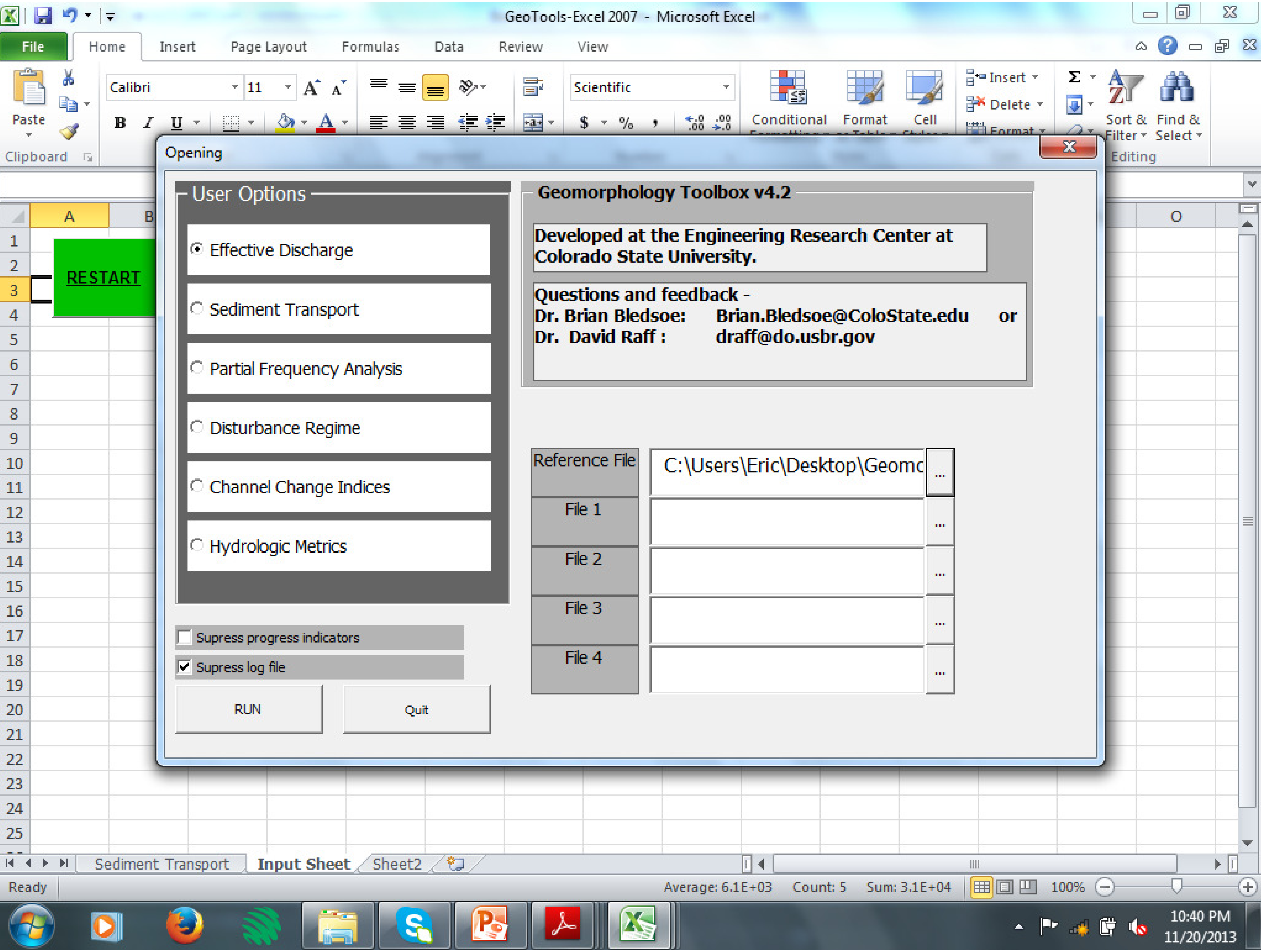
- Computed by finding the maximum of the curve resulting from multiplying the flow frequency curve times a sediment discharge rating curve



(Doyle et al. 2007)

Effective discharge

- Used GeoTools with mean annual flow record for Goose Creek developed earlier
- Used arithmetic binning of discharges based on the research of Soar and Thorne (2001)
- Used Yang's Sand equation (Yang 1996) to determine sediment rating curve



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Effective Discharge
Sediment Transport
Partial Frequency Analysis
Disturbance Regime
Channel Change Indices
Hydrologic Metrics
Supress progress indicators
Supress log file
RUN
Quit
Geomorphology Toolbox v4.2
Developed at the Engineering Research Center at Colorado State University.
Questions and feedback -
Dr. Brian Bledsoe: Brian.Bledsoe@ColoState.edu or
Dr. David Raff : draff@do.usbr.gov
Reference File
C:\Users\Eric\Desktop\Geomc
File 1
File 2
File 3
File 4
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Sheet2
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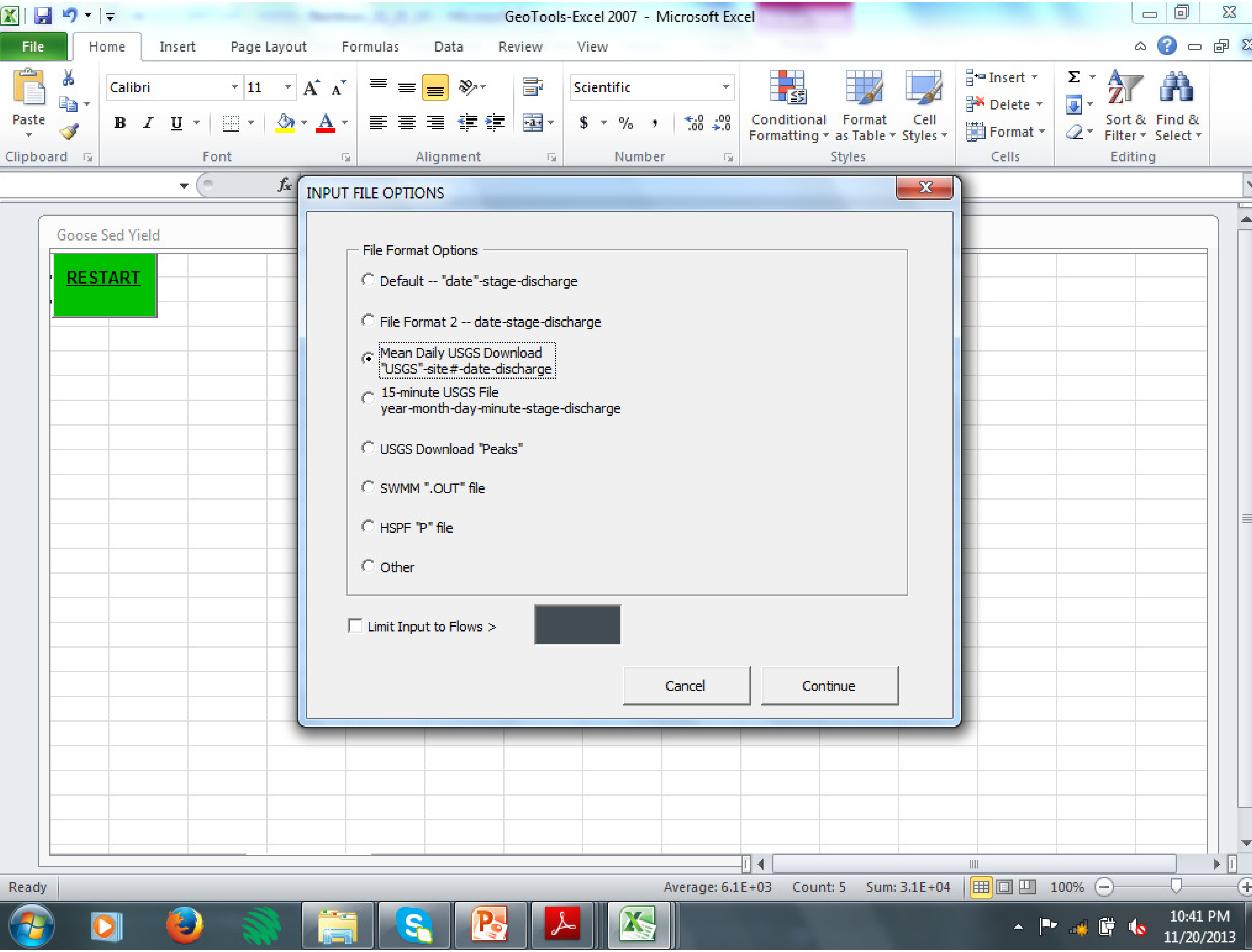
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Mean Daily USGS Download
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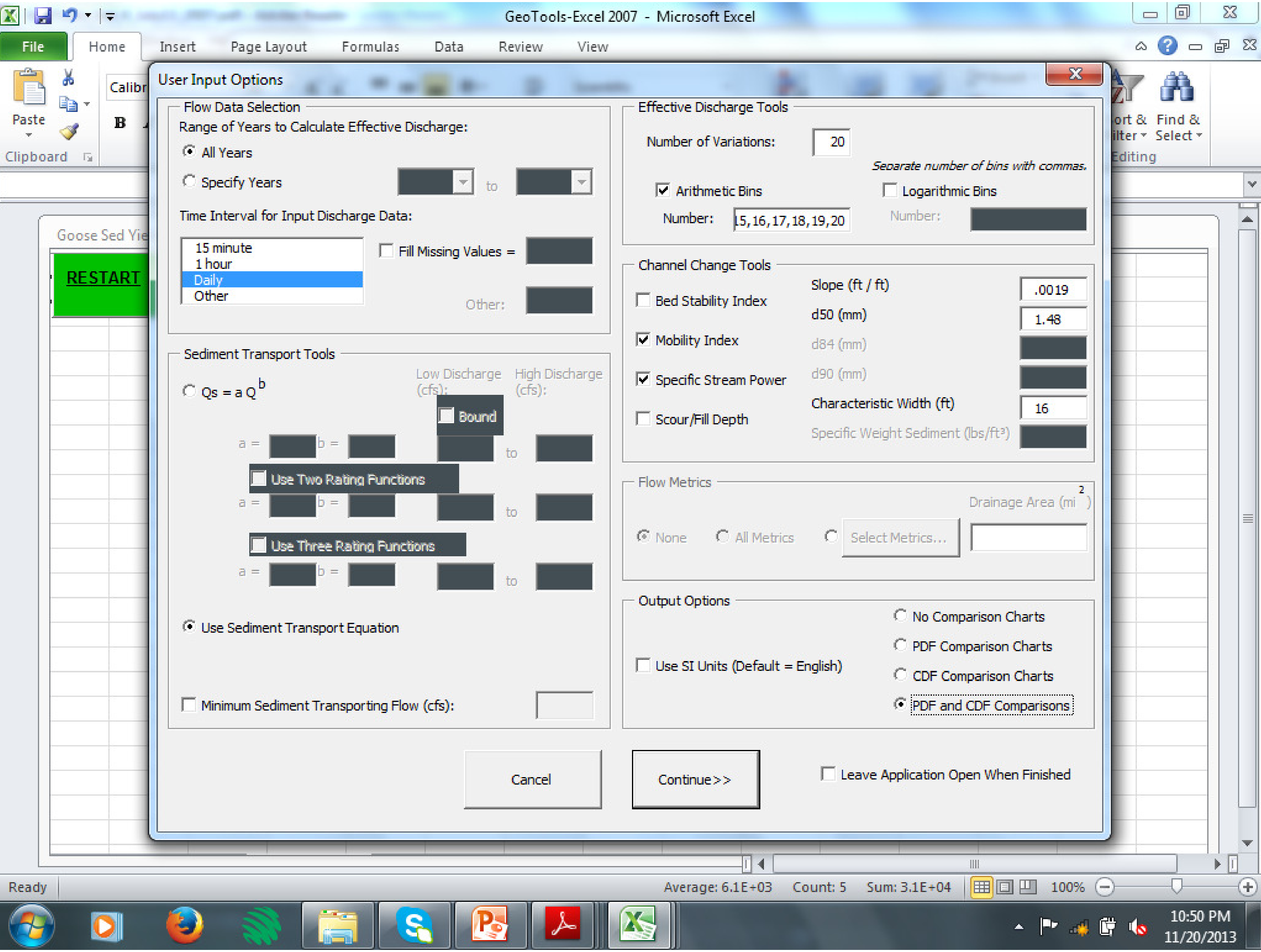
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Sediment Transport Tools
Qs = a Q^b
Low Discharge (cfs):
High Discharge (cfs):
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a =
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to
Use Two Rating Functions
Use Three Rating Functions
Use Sediment Transport Equation
Minimum Sediment Transporting Flow (cfs):
Effective Discharge Tools
Number of Variations:
20
Separate number of bins with commas.
Arithmetic Bins
Logarithmic Bins
Number:
15,16,17,18,19,20
Channel Change Tools
Bed Stability Index
Mobility Index
Specific Stream Power
Scour/Fill Depth
Slope (ft / ft)
.0019
d50 (mm)
1.48
d84 (mm)
d90 (mm)
Characteristic Width (ft)
16
Specific Weight Sediment (lbs/ft³)
Flow Metrics
Drainage Area (mi²)
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All Metrics
Select Metrics...
Output Options
Use SI Units (Default = English)
No Comparison Charts
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CDF Comparison Charts
PDF and CDF Comparisons
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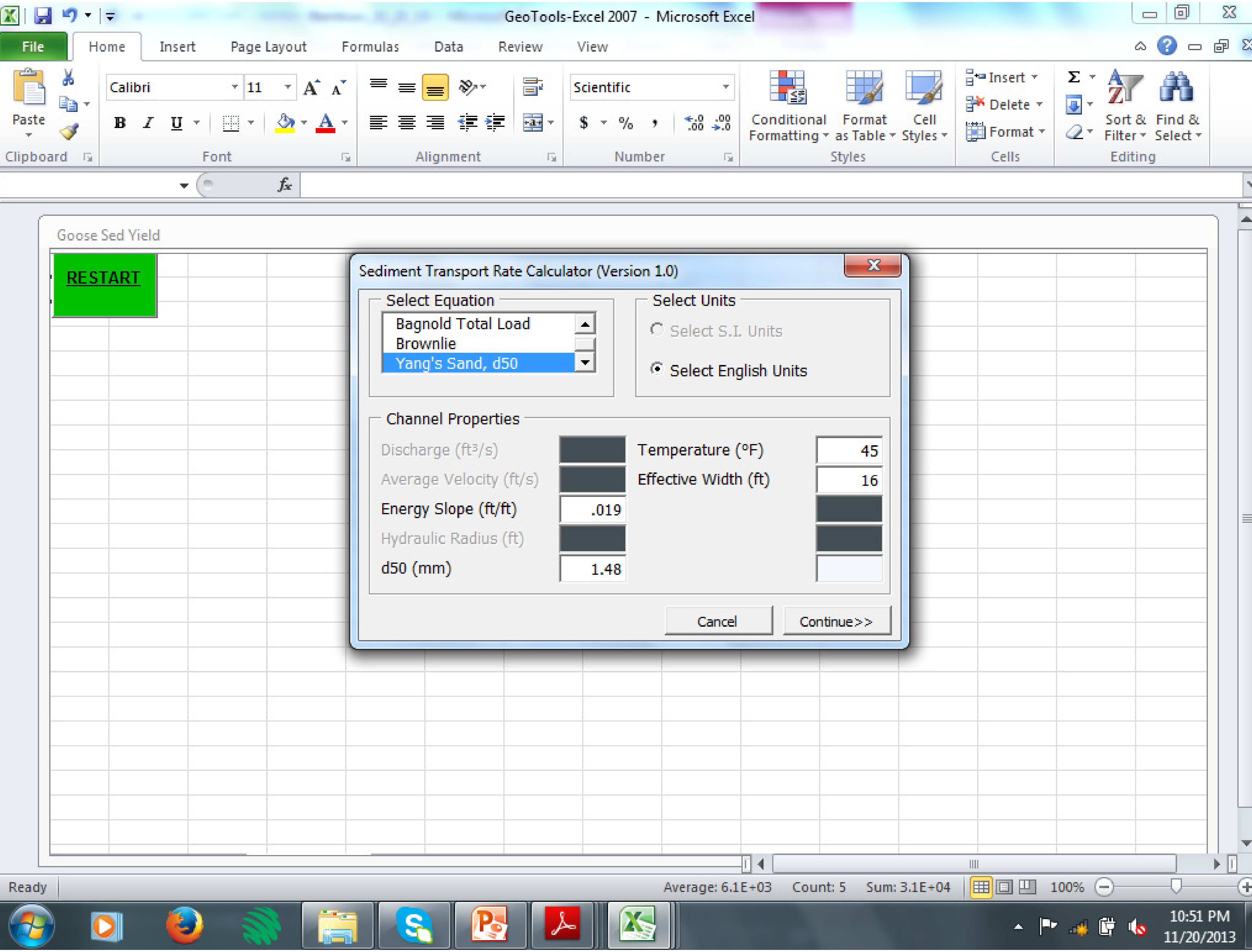
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Yang's Sand, d50
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Select English Units
Channel Properties
Discharge (ft³/s)
Average Velocity (ft/s)
Energy Slope (ft/ft)
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Hydraulic Radius (ft)
d50 (mm)
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Temperature (°F)
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Effective Width (ft)
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Cancel
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Ready
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Sum: 3.1E+04
100%
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Channel forming discharge

- 1.5 yr discharge = 146 cfs
- Bankfull discharge = 143 cfs
- Effective discharge = 21 cfs
- Ratio of bankfull to effective discharge consistent with values reported in Soar and Thorne 2001 for sand bed channels)

Sediment Transport

- Sediment competence
- Sediment transport capacity
- Sediment transport rate estimates and relationship to sediment supply

Sediment Competence and Capacity

Sediment Competence

Bankfull Shear Stress	0.27 lb/ft^2
Unit Weight H_2O	62.4 lb/ft^3
Hydraulic Radius	2.3 ft
Slope	0.0019 ft/ft
Grain Diameter	20 mm

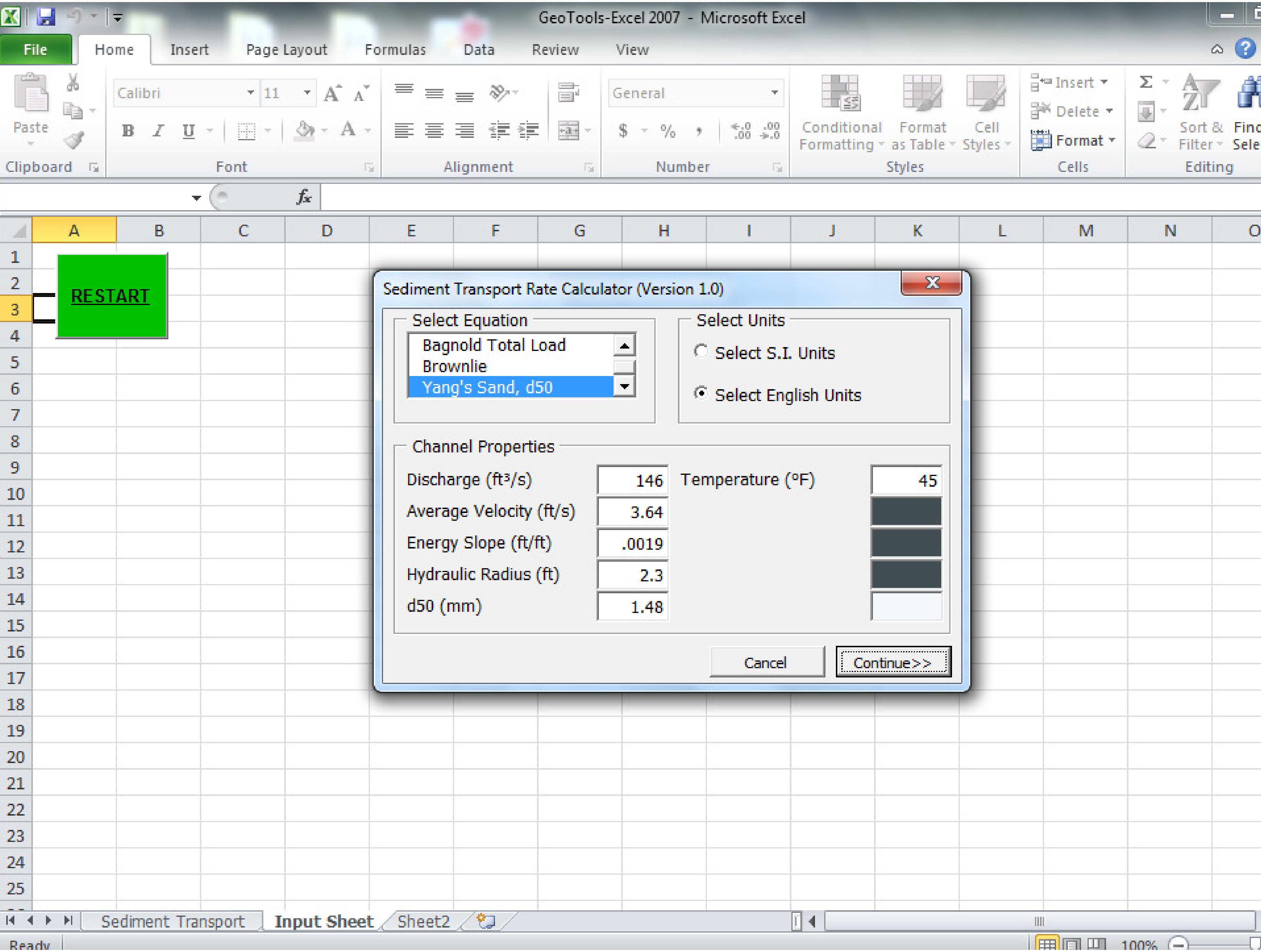
Sediment Capacity

Unit Stream Power	0.99 lb/ft/s
Bankfull Shear Stress	0.27 lb/ft^2
Mean Velocity	3.64 ft/s

Sediment Transport Rate Estimates

- Annual sediment transport rate (from effective discharge calculation in Geotools) = 3.3E+04 tons/yr

- Sediment transport rate at 1.5 yr discharge = 456 tons/day (sediment transport module in Geotools)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Yang's Sand, d50
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Select S.I. Units
Select English Units
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Temperature (°F)
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Average Velocity (ft/s)
3.64
Energy Slope (ft/ft)
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Hydraulic Radius (ft)
2.3
d50 (mm)
1.48
Cancel
Continue>>
Sediment Transport
Input Sheet
Sheet2
Ready
100%

Relationship to Sediment Supply

- Annual sediment transport rate greater than annual sediment yield (3.3E+04 tons/yr vs. 6.4E+03 tons/yr)
- Sediment yield for 1.5 yr discharge = 2900 tons/day (used relationship between annual yield and event-specific yield from MacArthur et al. 1995 and 1.5 yr yield from Simon et al. 2004)

Relationship to Sediment Supply

- Sediment transport rate at 1.5 yr discharge less than sediment yield for 1.5 yr discharge (456 tons/day vs. 2900 tons/yr)

Discharge and sediment regime

- Bankfull discharge approximately equal to 1.5 yr discharge
- Sediment supply exceeds sediment transport capacity for 1.5 yr discharge, less on annual basis
- Flows exceed flow necessary for incipient motion 98% of the time (i.e., conveyor belt is moving)

Match scale of restoration

- Need easements for farming adjacent to parcel and upstream of project
- Work with adjacent landowners and Pend Oreille and Bonner County Conservation Districts on bridge and riparian exclusion fencing
- Be involved with Colville National Forest planning efforts (culverts, logging, roads)

Be explicit about expected outcomes

- Rough estimate of the number of years to reconnect floodplain
- We hope to have beavers restablish dams…we know this isn't a typical alluvial system (lots of irregularly-flooded habitat)
- Dams will get built and get blown out under high flows, potentially causing localized erosion and flooding. It's ok…

Be explicit about expected outcomes (cont'd)

- Plantings will take a while to establish
- This isn't the Field of Dreams – "If you build it, they will come"
- We don't expect cutthroat to thrive until brook trout are eradicated

Acknowledgements

- Kalispel Tribe
- Kalispel Natural Resources Department
- Confluence Consulting


Questions?
Eric Berntsen
509-671-6466
ekberntsen@gmail.com