Scour, Fill, and Salmon Spawning in a Northern California Coastal Stream

By Paul E. Bigelow

Objectives

1) Test a recent Scour and Fill Model
   (Haschenburger 1999)

2) Test Two Hypotheses of Salmon Adaptation to Scour

What is Scour and Fill?

- Flow increases, bed moves
- Base of the mobilized bed - scour depth
- Flow recedes, material deposited
- Depth of material deposited - fill depth

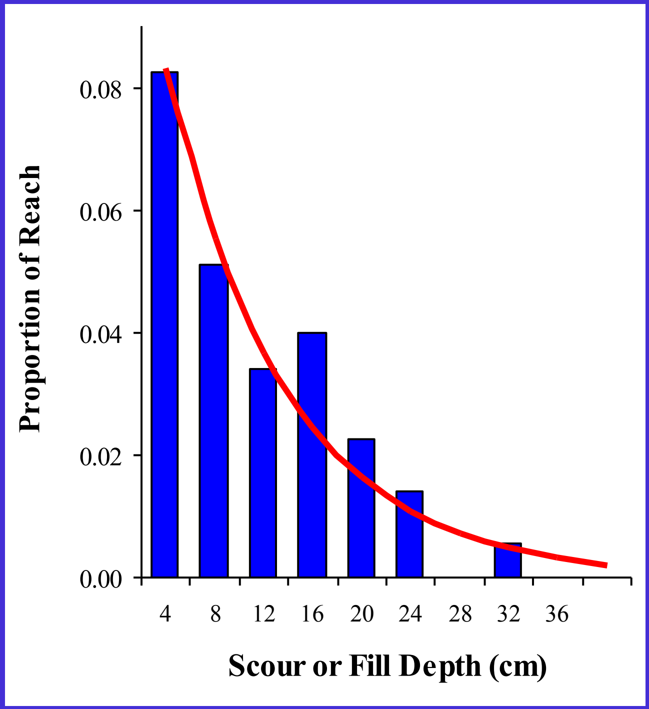
Haschenburger Model

Based on Shields Stress:

$$\tau^* = \frac{\rho_w \, R \, S}{(\rho_s - \rho_w) \, D_{50}}$$

- Ratio of tractive and gravitational forces on particle
- Average water depth **(R)**
- Water surface slope **(S)**
- Median bed surface particle size **(D_{50})**
- Density of water **(ρ_w)** and sediment **(ρ_s)**

Haschenburger Model (Cont'd)



1) Based on observed exp distribution (right skewed) of scour and fill depths
2) Measured scour and fill for a series of floods, primarily in BC
3) Plotted mean scour or fill depth against Shields stress
4) Fit a line to the plot, generated equation coefficients

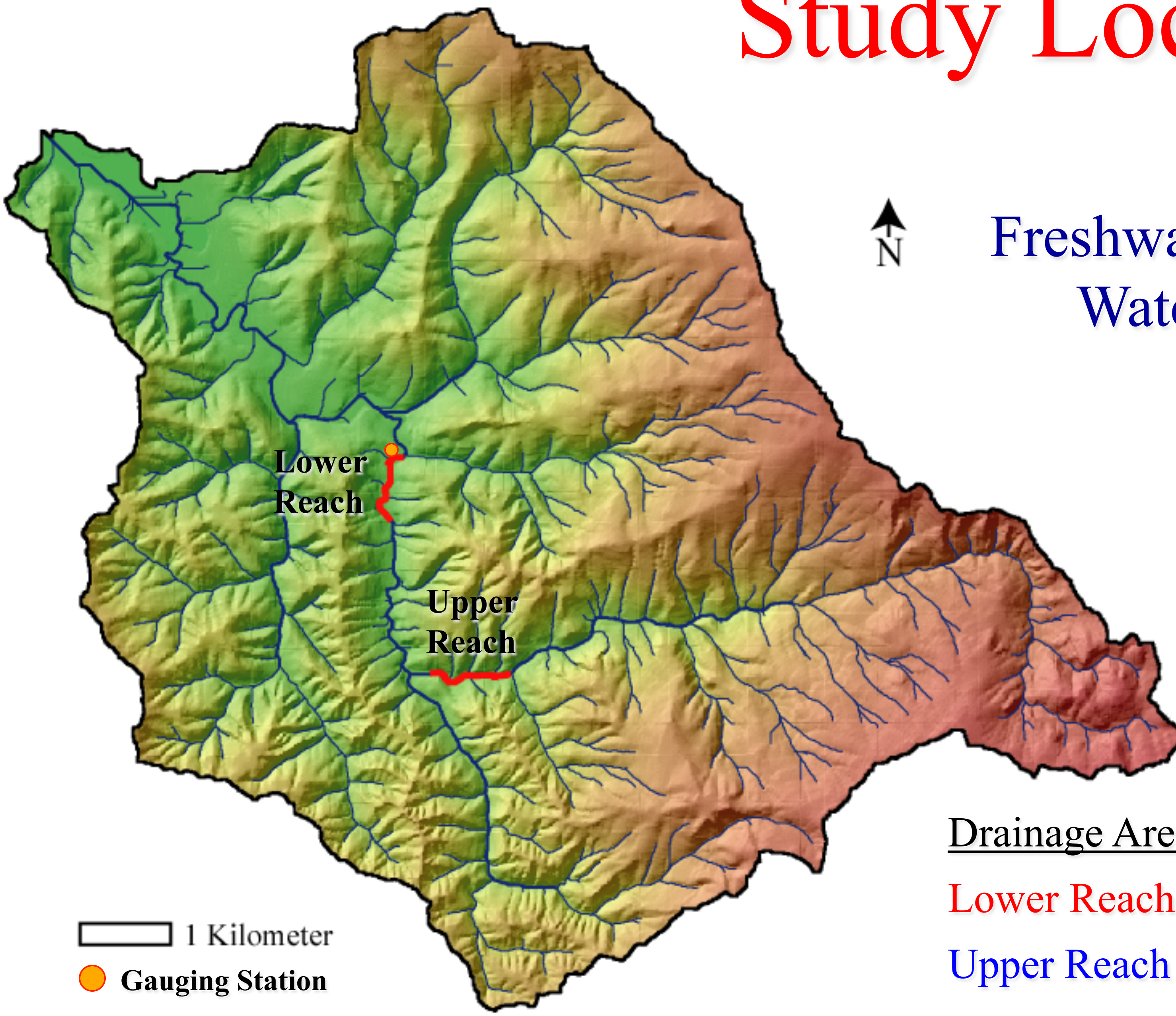
Haschenburger Model (Cont'd)

Model Equations predict reach-scale distribution of depths for a given flow:

$\theta = 3.33e^{-1.52\tau^*/\tau_r^*}$ (1/θ = mean scour or fill depth)

$f(x) = \theta e^{-\theta x}$ (proportion of reach to scour or fill to depth x)

Study Location



Freshwater Creek Watershed

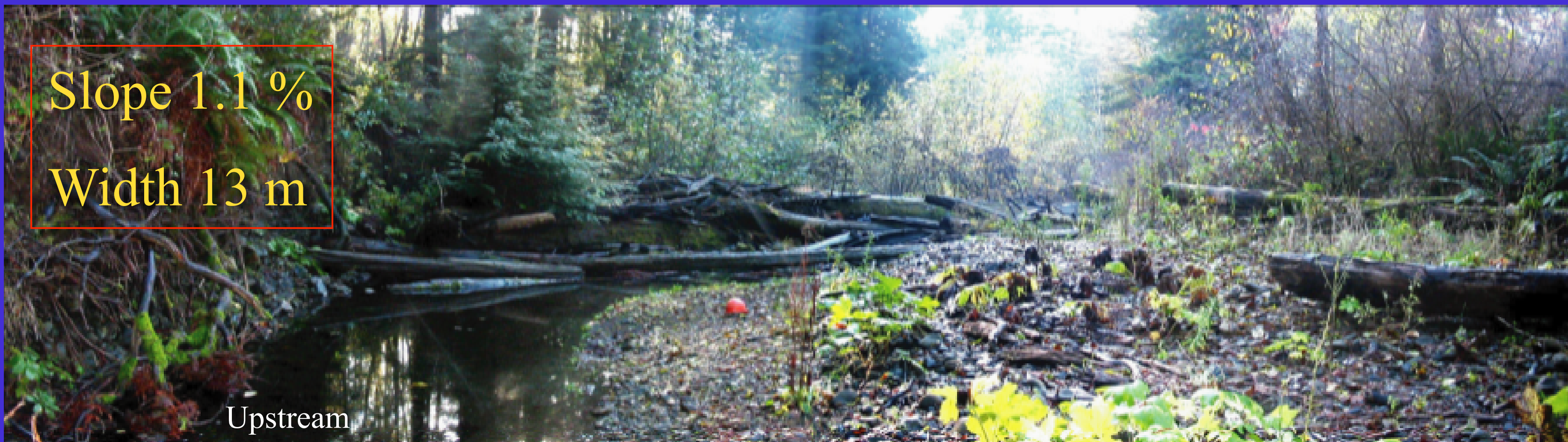
<u>Drainage Areas:</u>

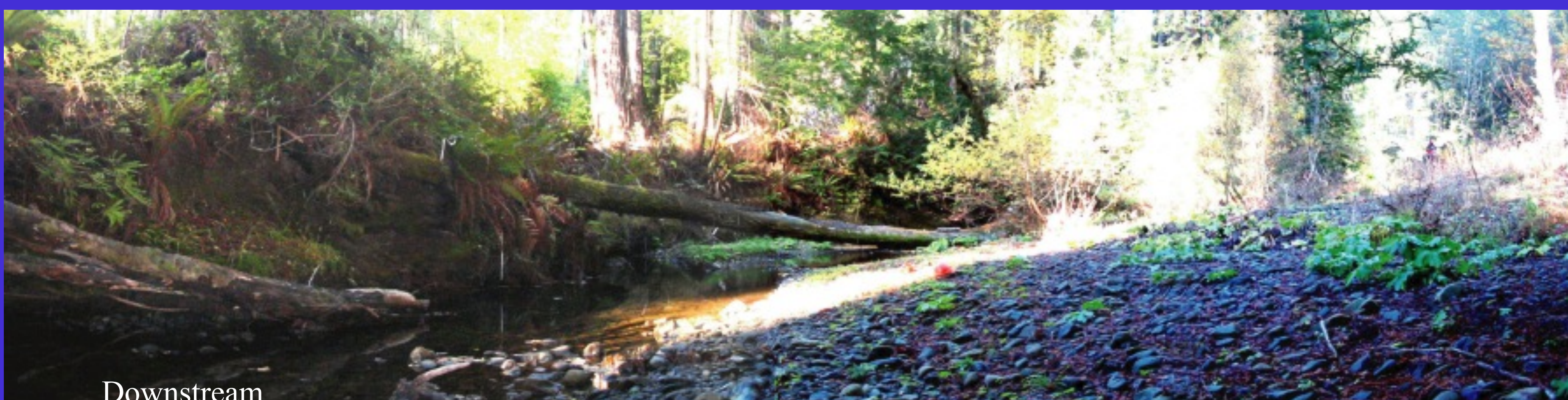
Lower Reach 34 km^2

Upper Reach 22 km^2

4th order channels

Upper Reach

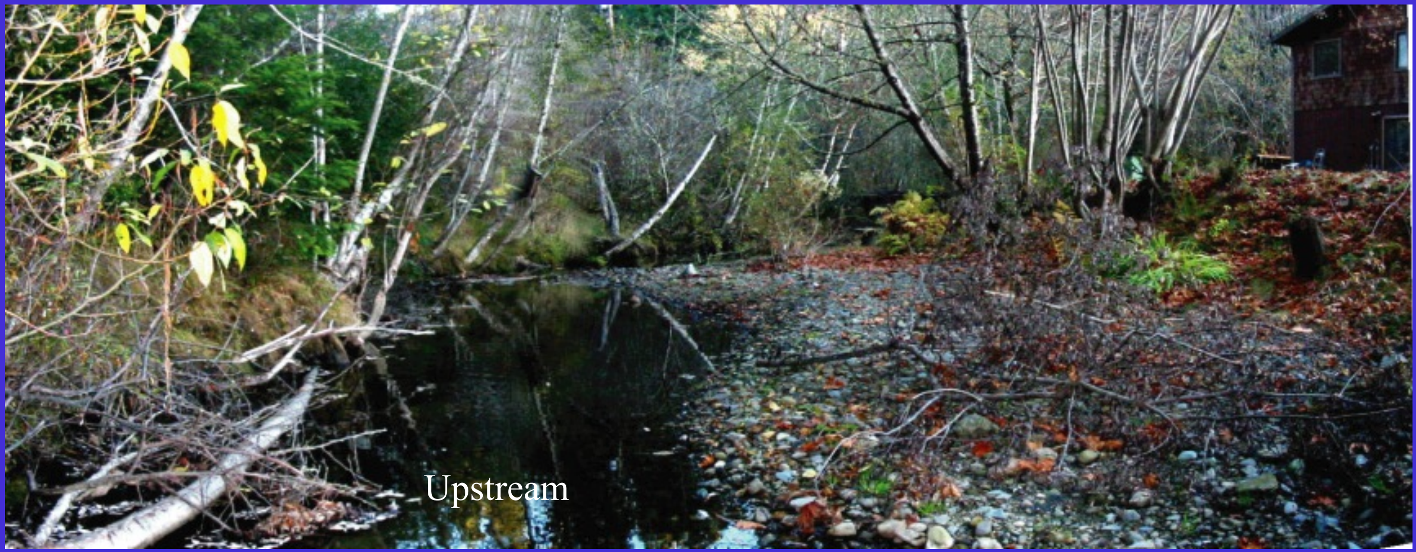




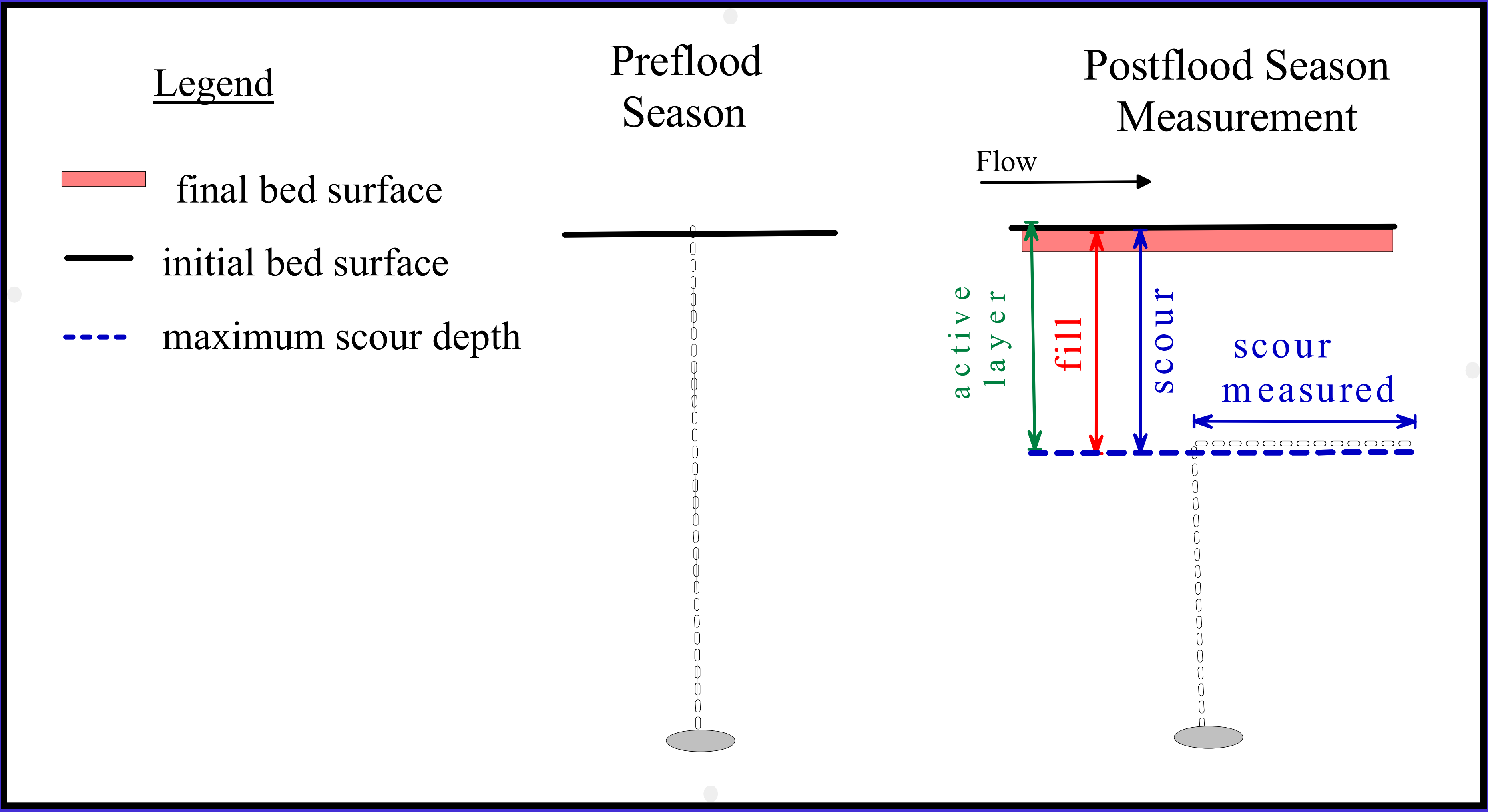
Lower Reach

Slope 0.7 %

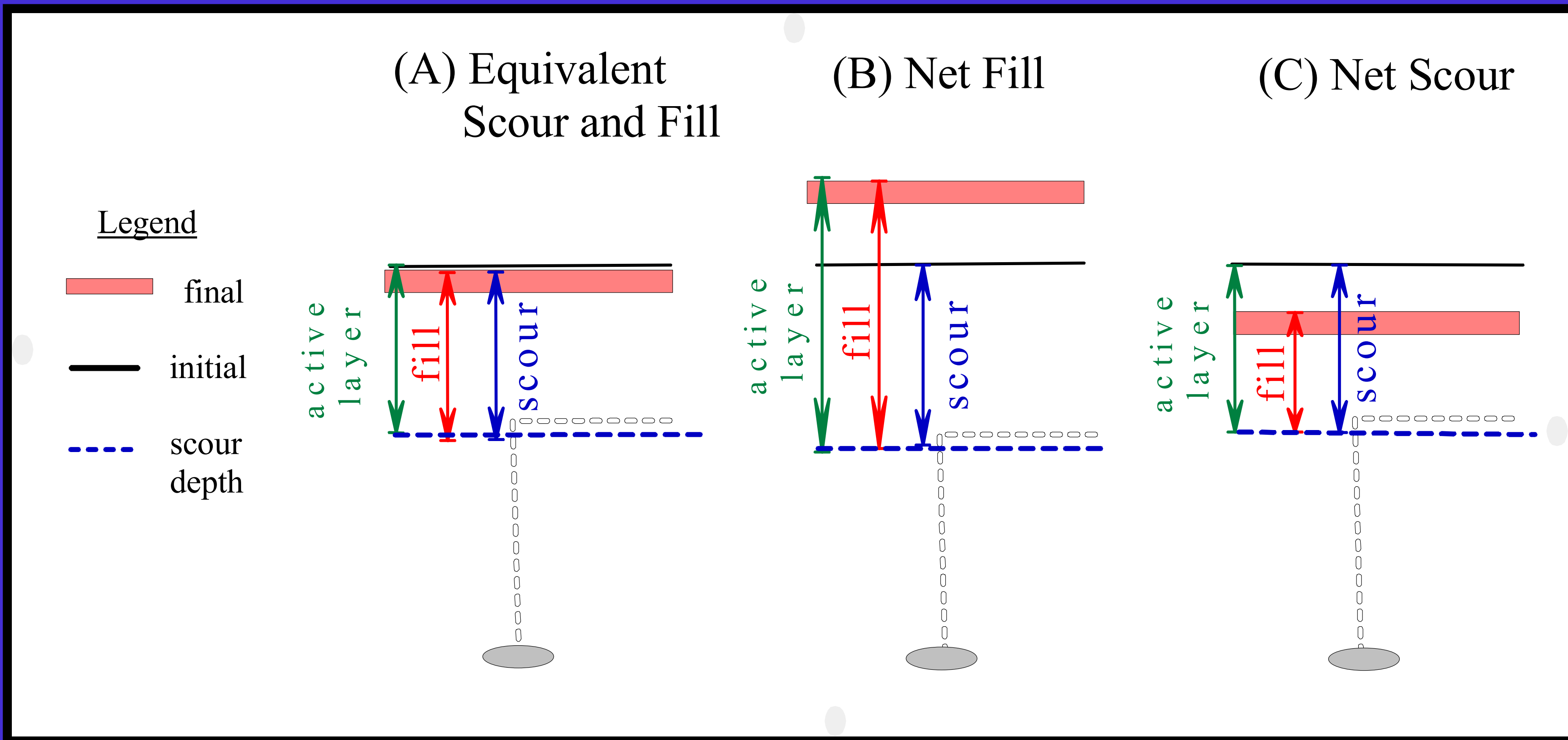
Width 12 m



Scour and Fill Measurement



Types of Scour and Fill

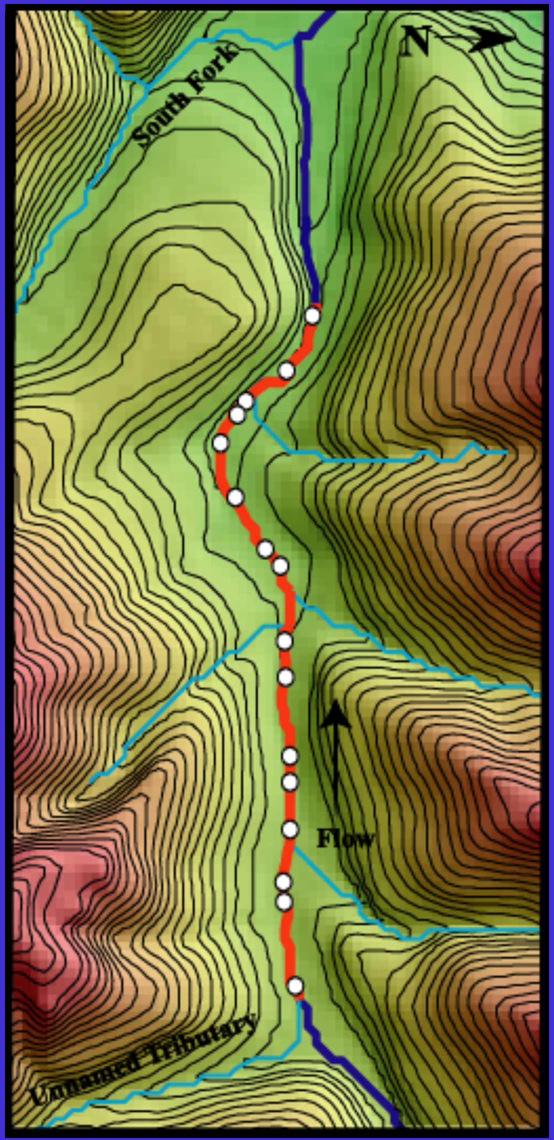


Methods - Model Testing

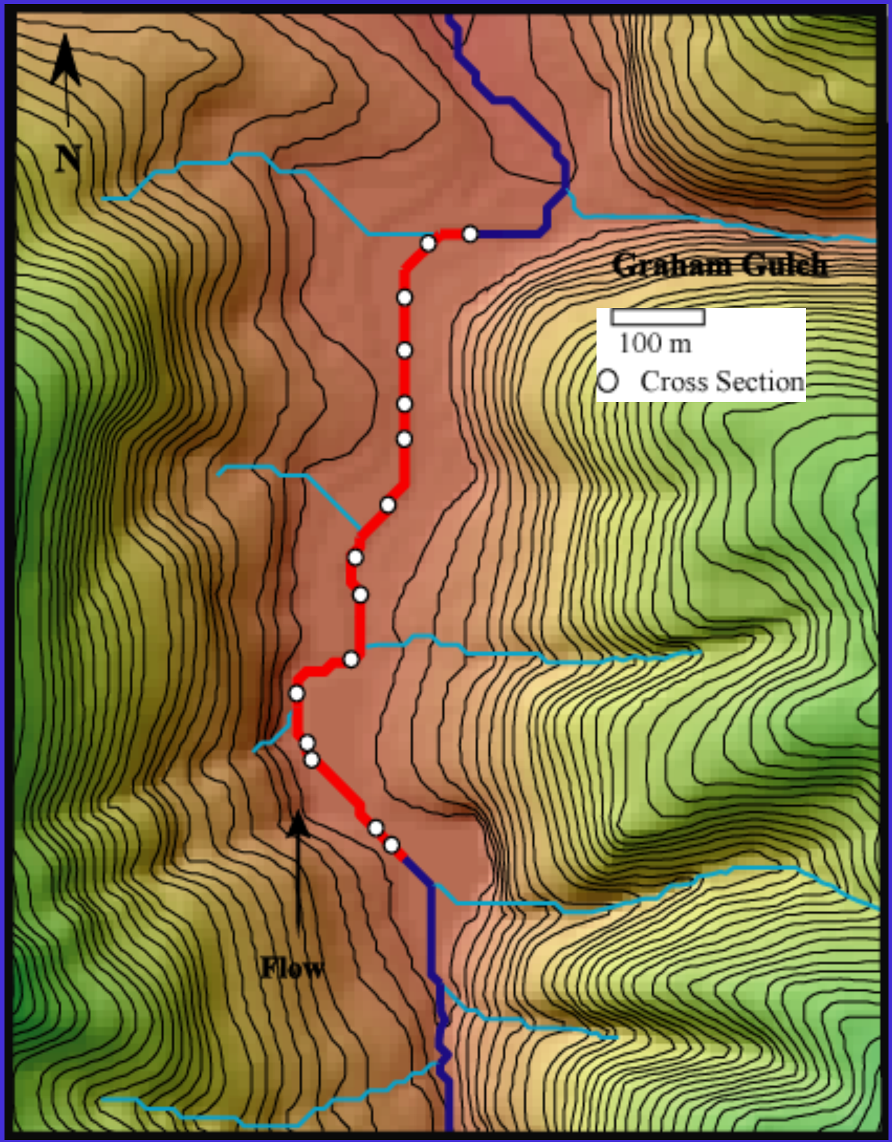
- Measure Scour & Fill on 15 - 16 cross sections in each reach (~900 m reaches)
- Install chains at 1.5-meter intervals along cross sections
  - ~5 chains per cross sections
  - 60 - 91 chains per reach

Methods - Reach Layout

Upper Reach



Lower Reach

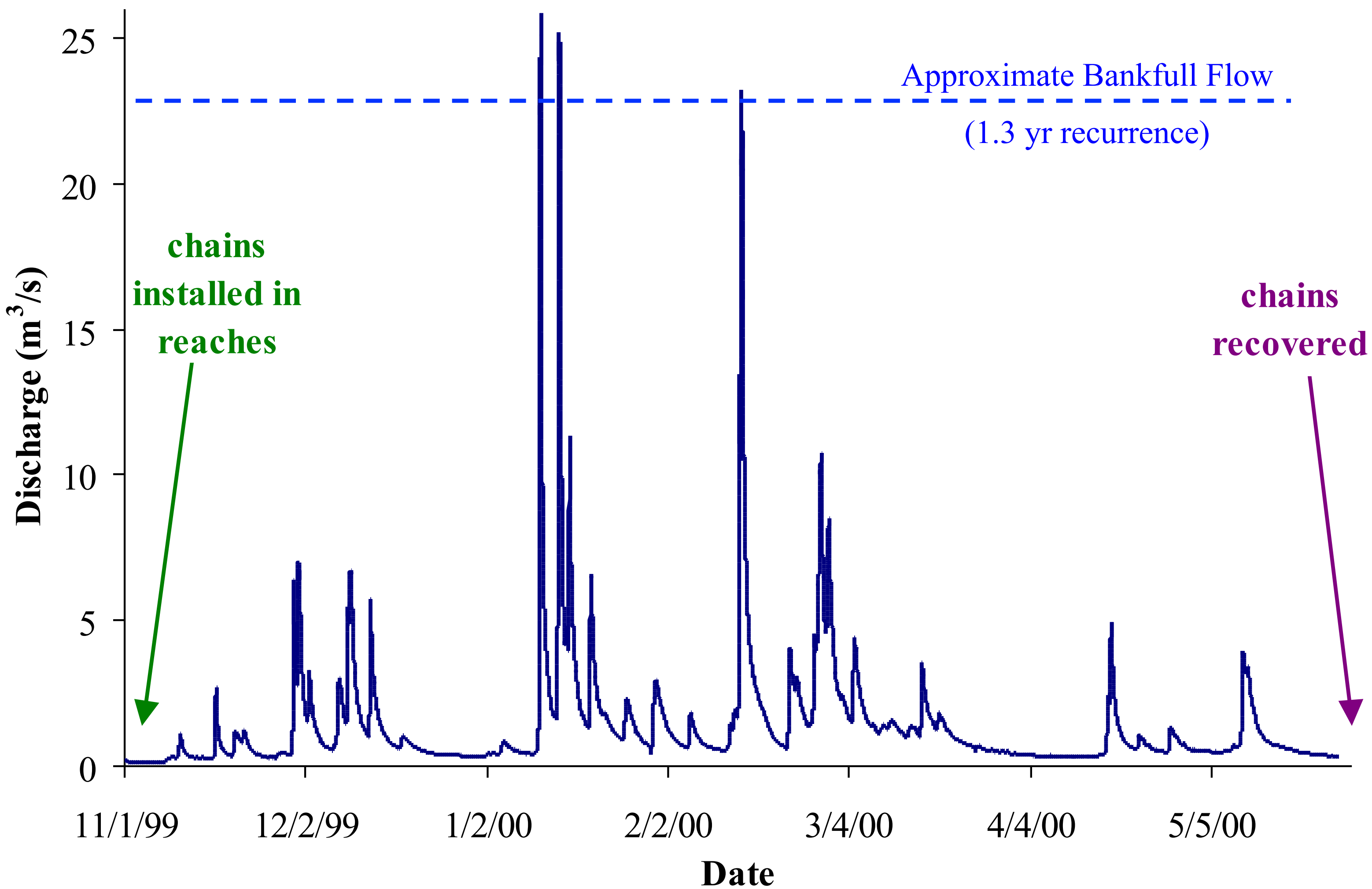


Methods - Model Testing

Collect Shields stress data necessary for model prediction:

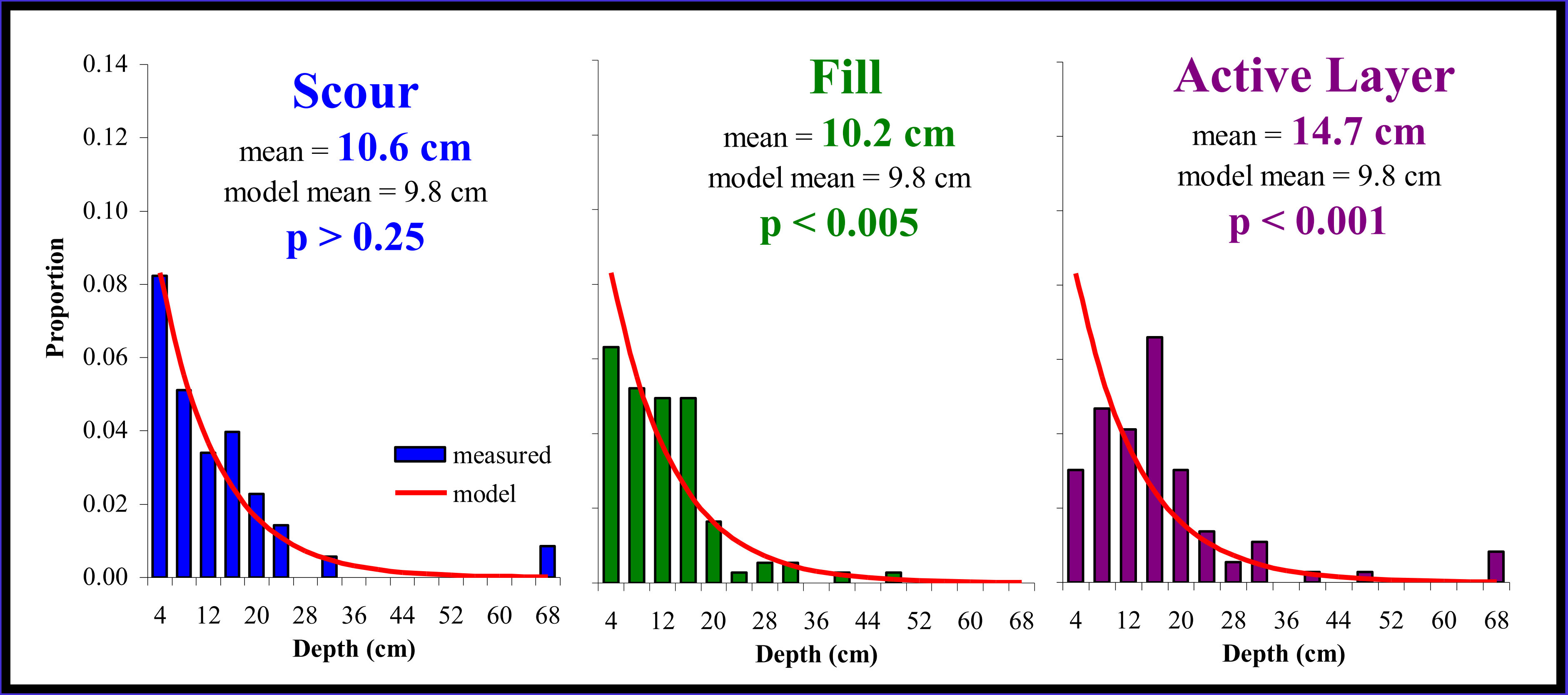
- Survey low flow water surface slope (surrogate)
- Survey peak flow water depth (flood marks)
- Estimate median particle size (pebble counts)
- Compare distributions of predicted and measured scour, fill, and active layer (Cramer-Von Mises goodness of fit)

Results - Peak Flows



Results - Model Testing

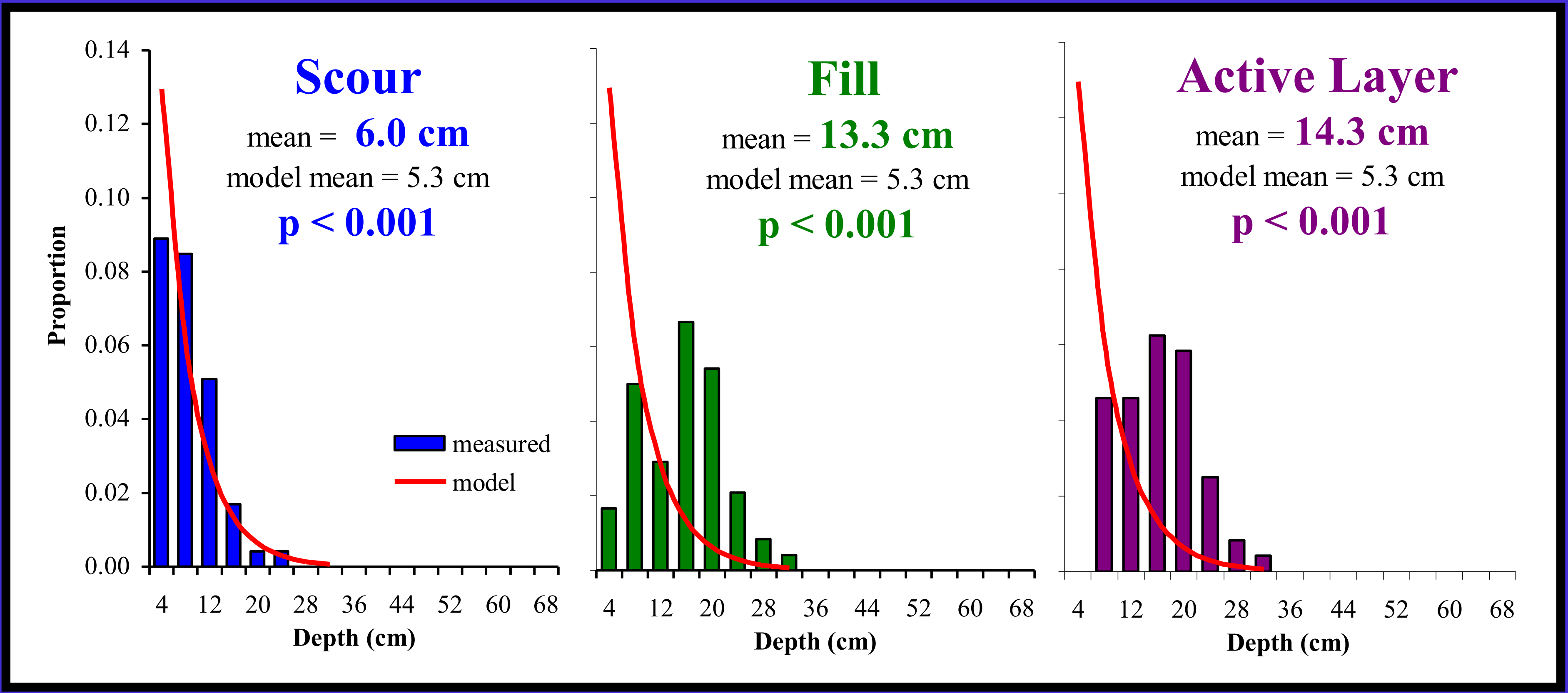
Upper Reach



n = 90 chains

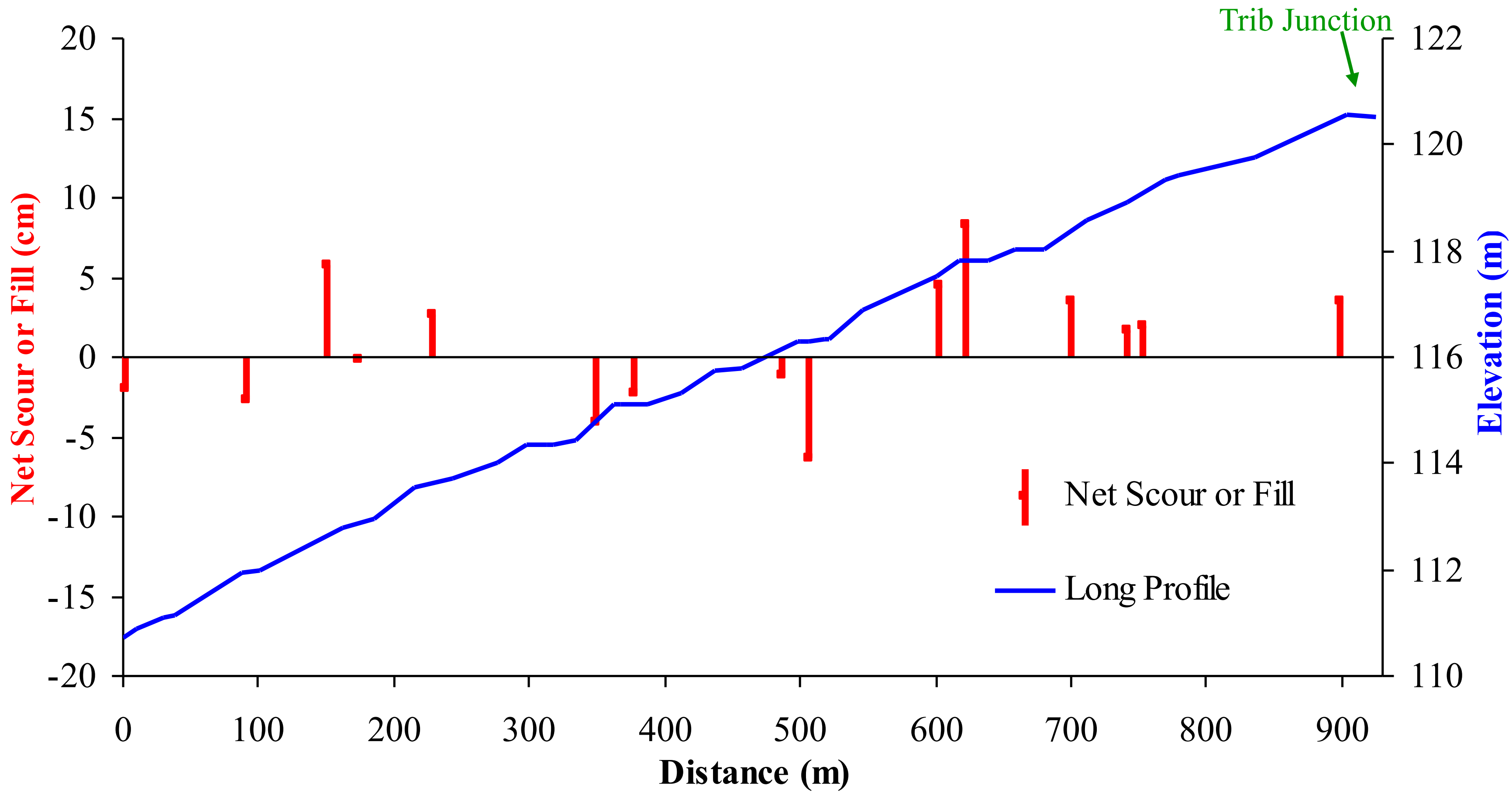
Results - Model Testing

Lower Reach

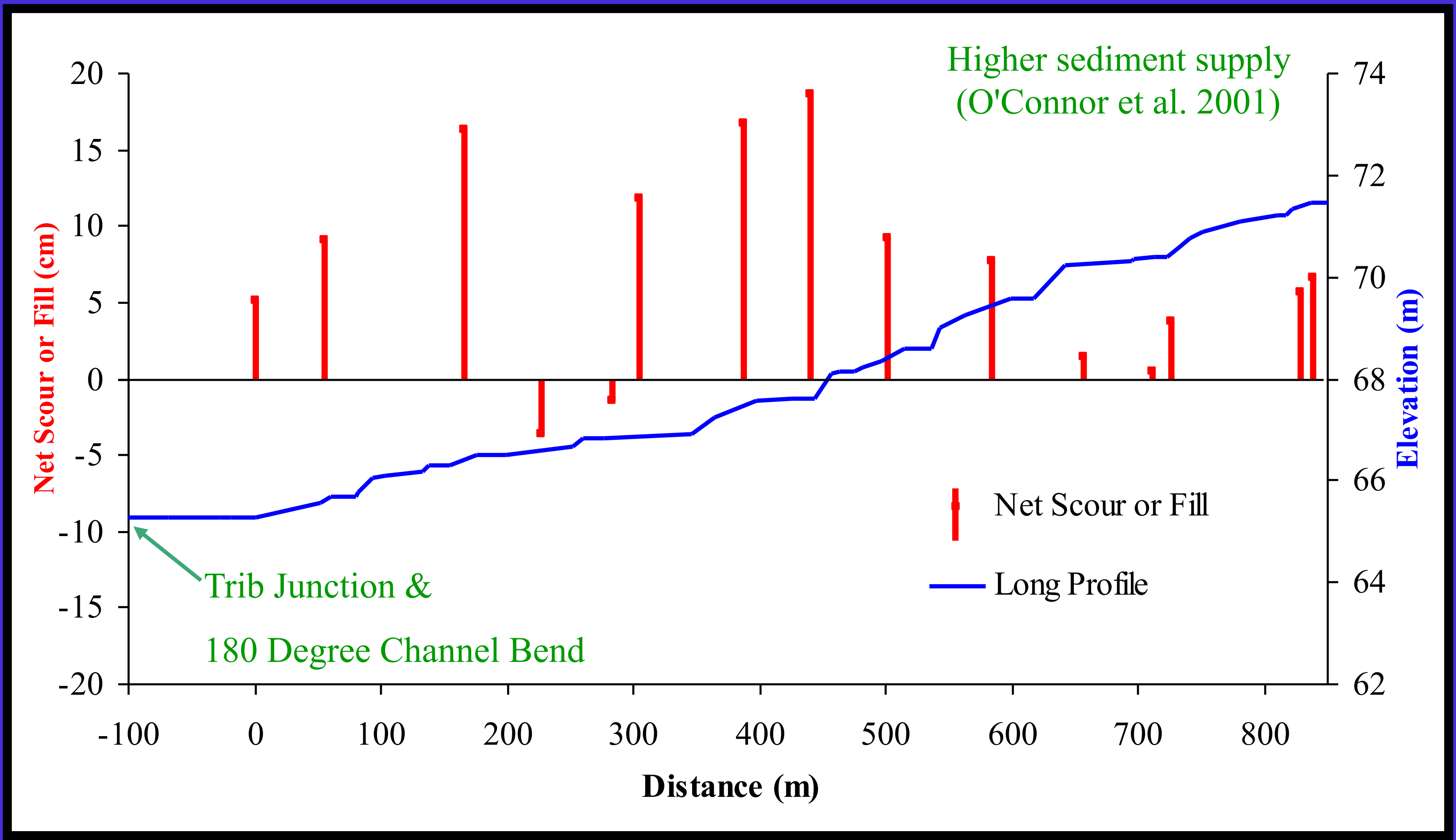


n = 61 chains

Upper Reach - Net Scour or Fill

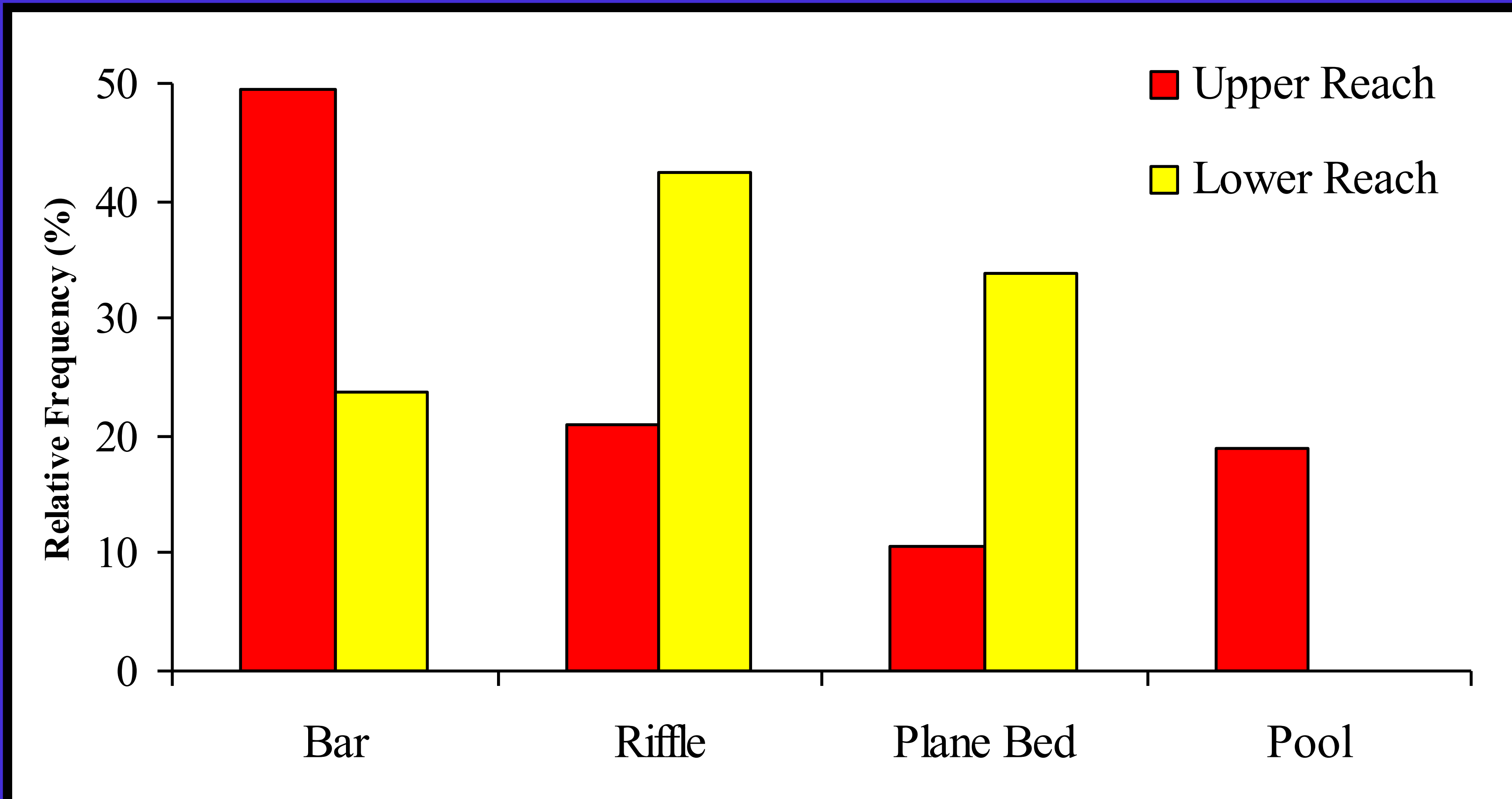


Lower Reach - Net Scour or Fill

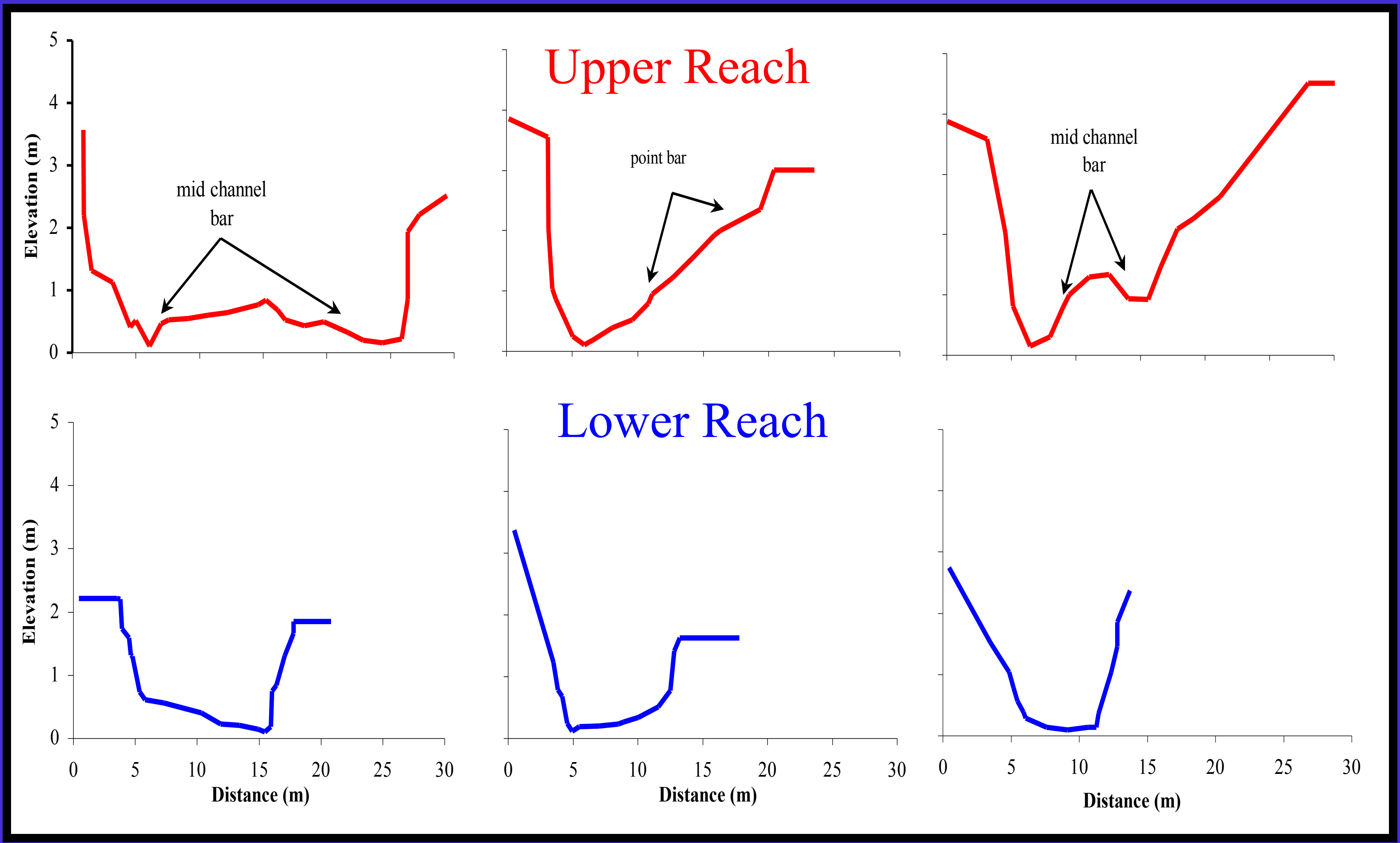


Bends and junctions: e.g. Matthai et al. 1999, Napolitano 1996; Benda et al. in press

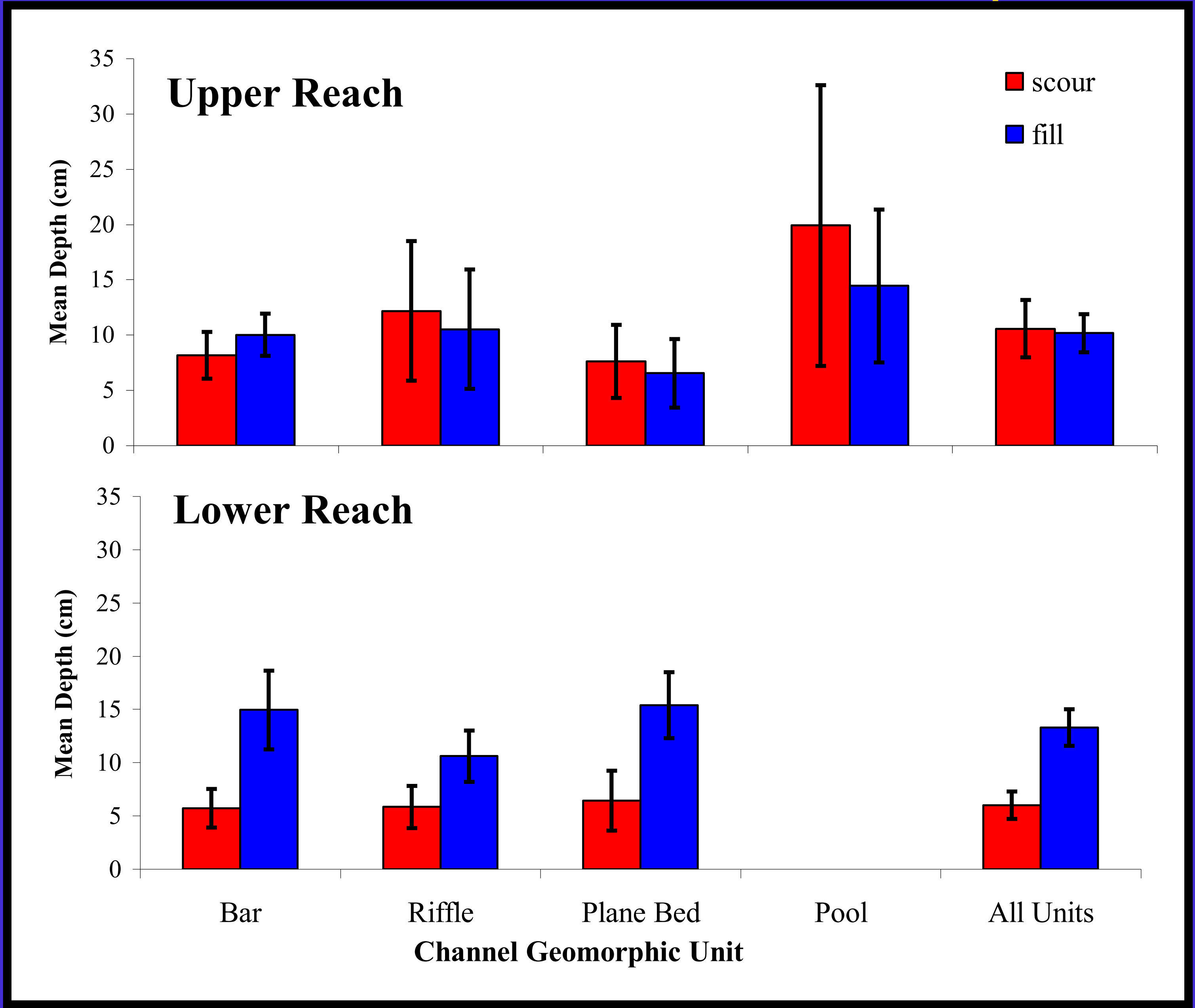
Distribution of Channel Geomorphic Units



Typical Cross Sections



Mean Scour and Fill in Channel Geomorphic Units



e.g. Shuett-Hames et al. 2000

Reasons for Differences in Predicted and Measured Scour and Fill

Scour and fill were Weakly influenced by Shields Stress and Highly influenced by:

- Location within the Channel Network (channel bends, tributary junctions)
- Channel Morphology (form roughness)
- Sediment Supply (e.g. DeVries 2000)

Reasons for Differences…

1) Model was never tested
2) Model intended for individual events
3) Model developed from stable sites
4) Differences in form roughness
5) Model developed from straight reaches
6) Model based on reach average Shields stress

Model Limitations

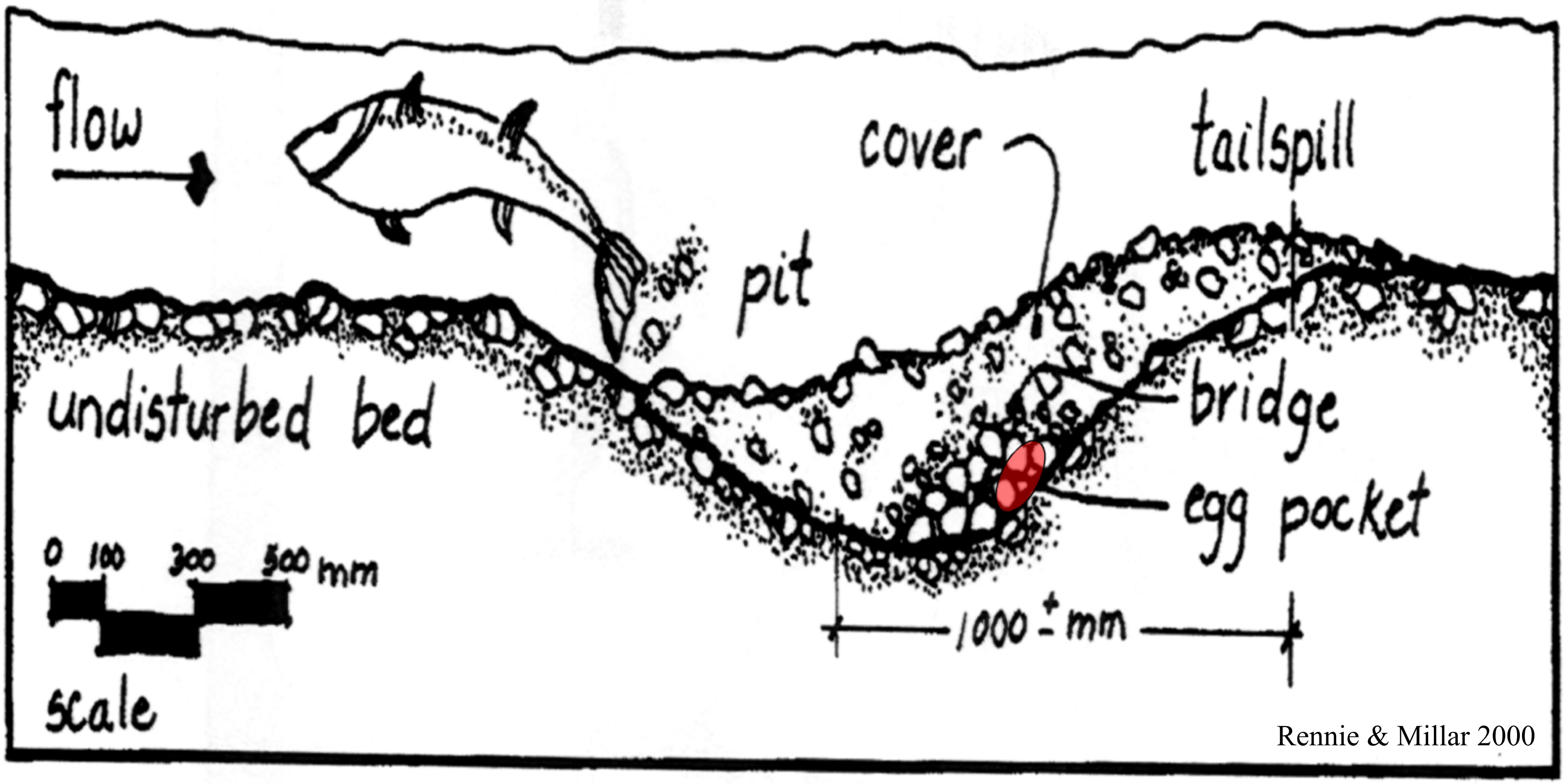
- Haschenburger Model best suited for individual floods on reaches that are:
  - Straight
  - In equilibrium between sediment supply and transport

Model Improvements

- Base Model on Shields Grain Stress which excludes form roughness
  (Parker & Peterson 1980)

- Base Model on Cumulative Distribution to avoid averaging data into bins

How Do Salmon Spawn?



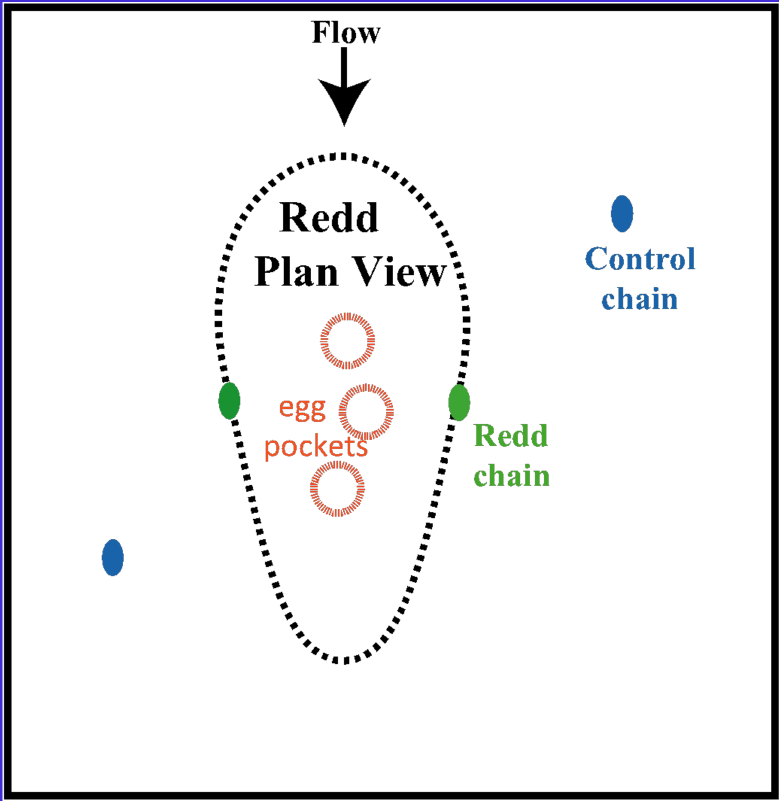
Rennie & Millar 2000

Hypothesis of Salmon Adaptation to Scour #1

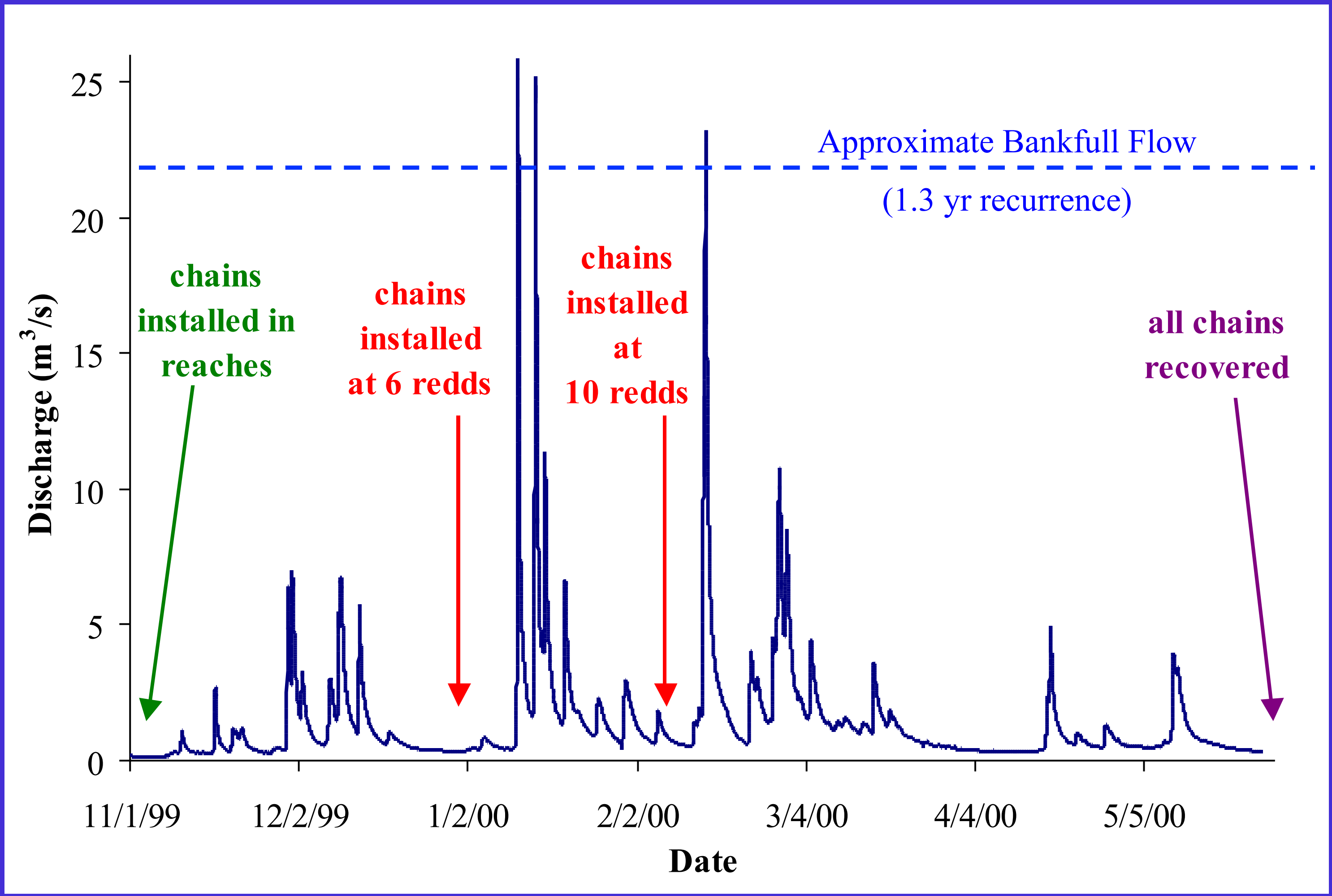
- Redd Construction Reduces Scour
  (Montgomery et al. 1996)

Methods - Hypothesis Testing
Does Redd Construction Reduces Scour?

- Install chains on both sides of a redd
- Install chains at adjacent control locations
- 16 redds total
- Compare scour depths (paired t-test)

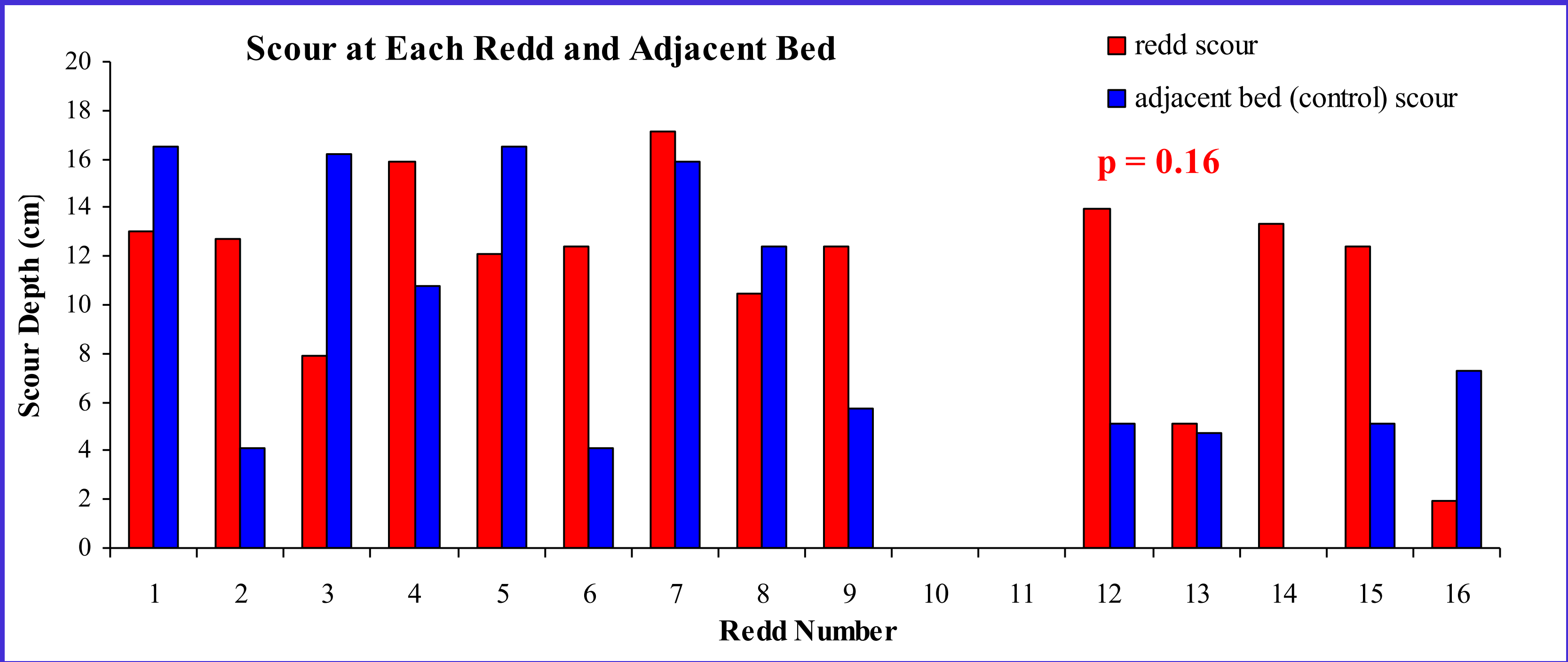


Peak Flows and Spawning



Results
Does Redd Construction Reduce Scour?

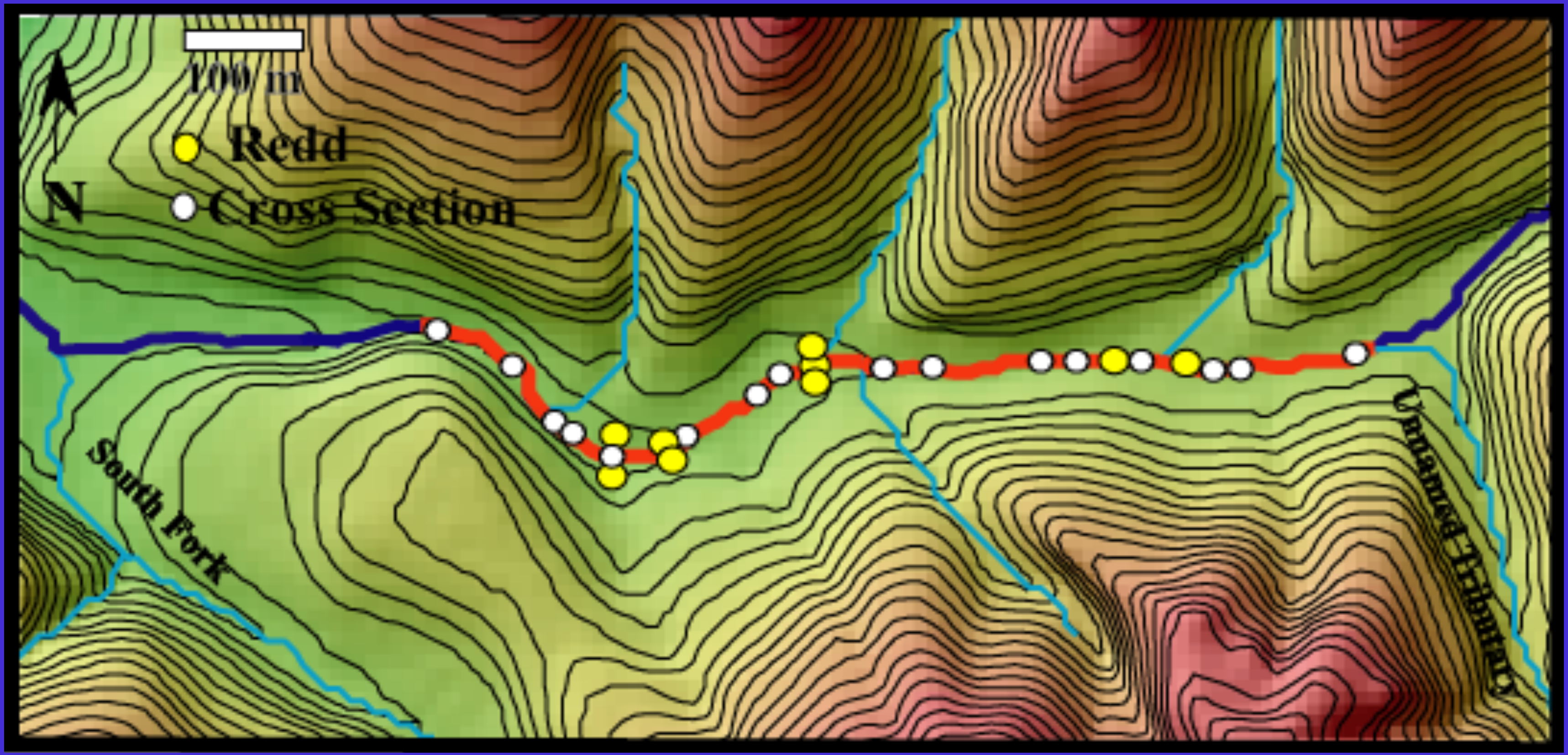
- Scour often deeper in Redds than the adjacent bed ($p = 0.16$)
- No evidence Redd construction reduces scour (e.g Rennie & Millar)
- Redd construction may increase scour by loosening the bed



Hypothesis of Salmon Adaptation to Scour #2

- Salmon Select Low Scour Areas
  (Montgomery et al. 1999; DeVries 2000)

Methods - Hypothesis Testing:
Do Salmon Select Low Scour Areas?

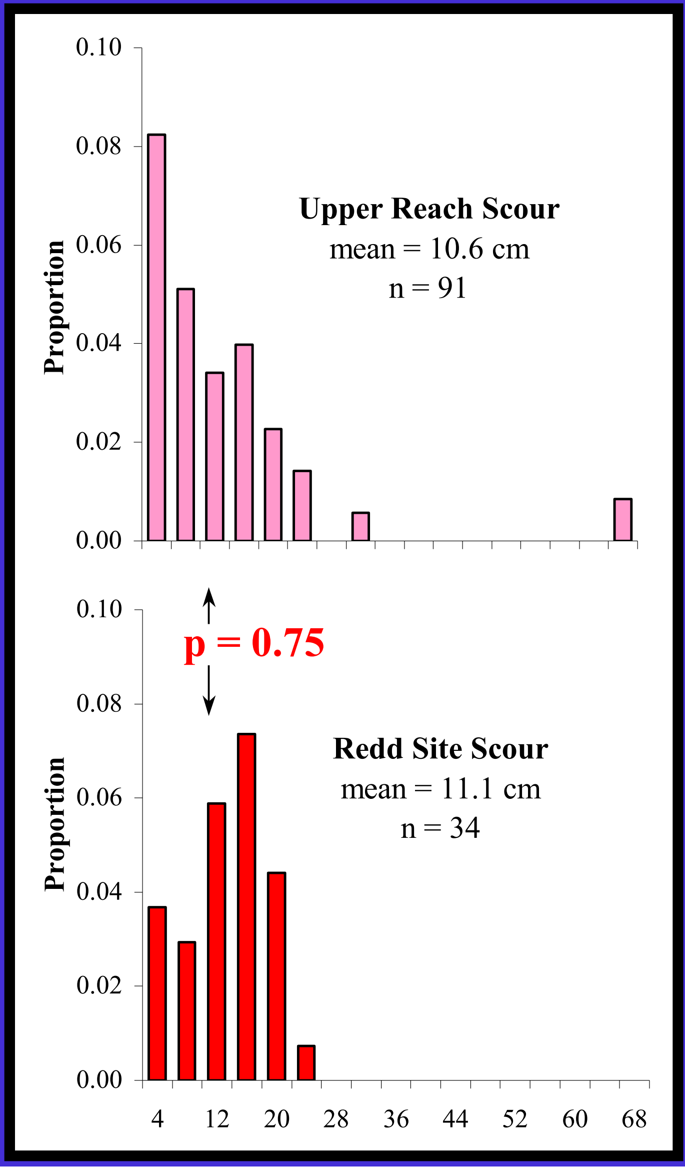


- Compare reach scour with scour at redds within the reach (t-test) (9 redds total)

Results

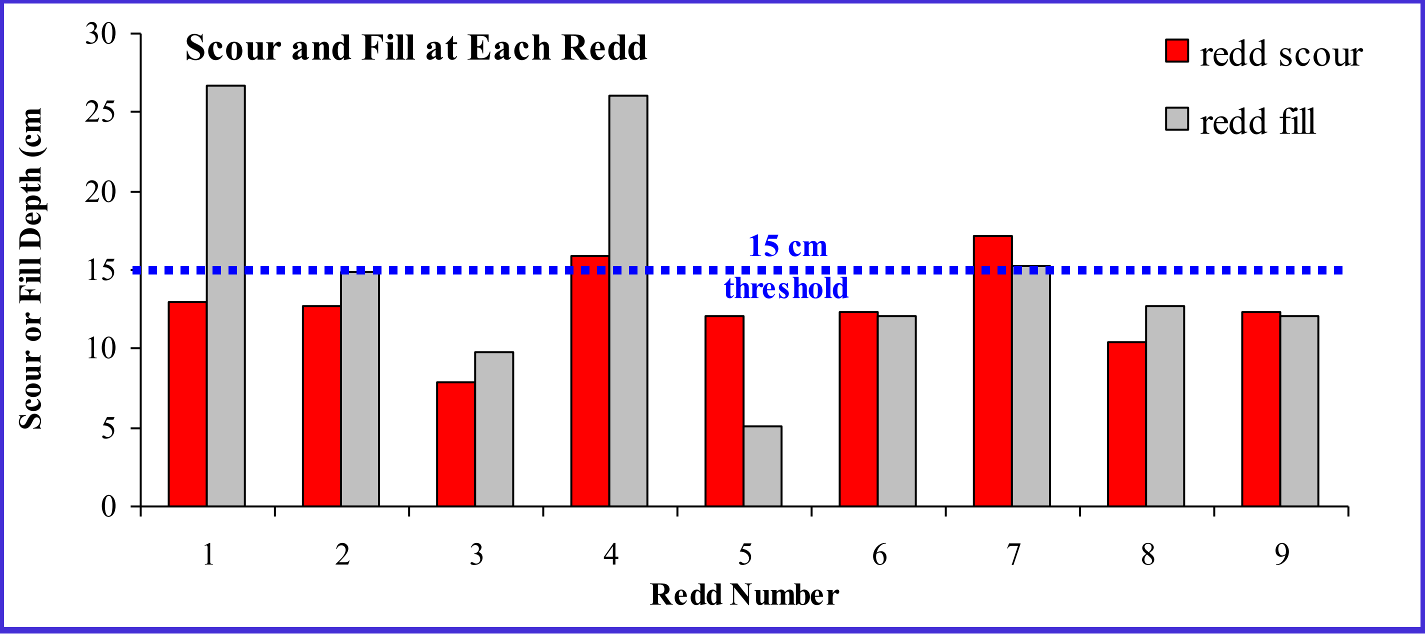
Do Salmon Select Low Scour Sites?

- Reach scour and redd scour similar (p = 0.75)
- No evidence for salmon selecting low scour areas
- Small sample size (9 redds)



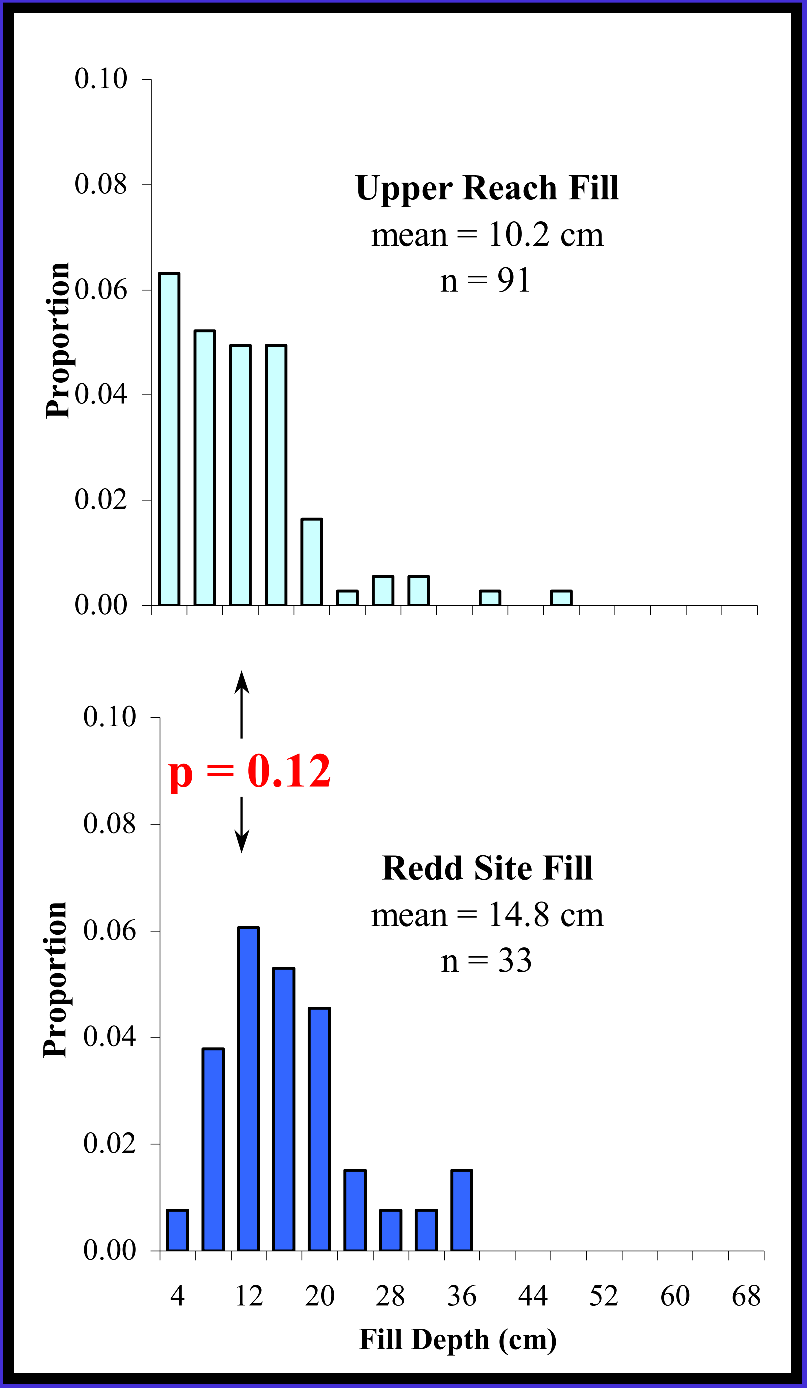
Model Application to Redds

1) Reach and Redd Scour were similar
2) Estimated egg pocket depth (15 cm)*
3) Model predicts 20% of bed scours/fills > 15 cm
4) 22% redds scoured >15 cm; 33% redds filled >15cm



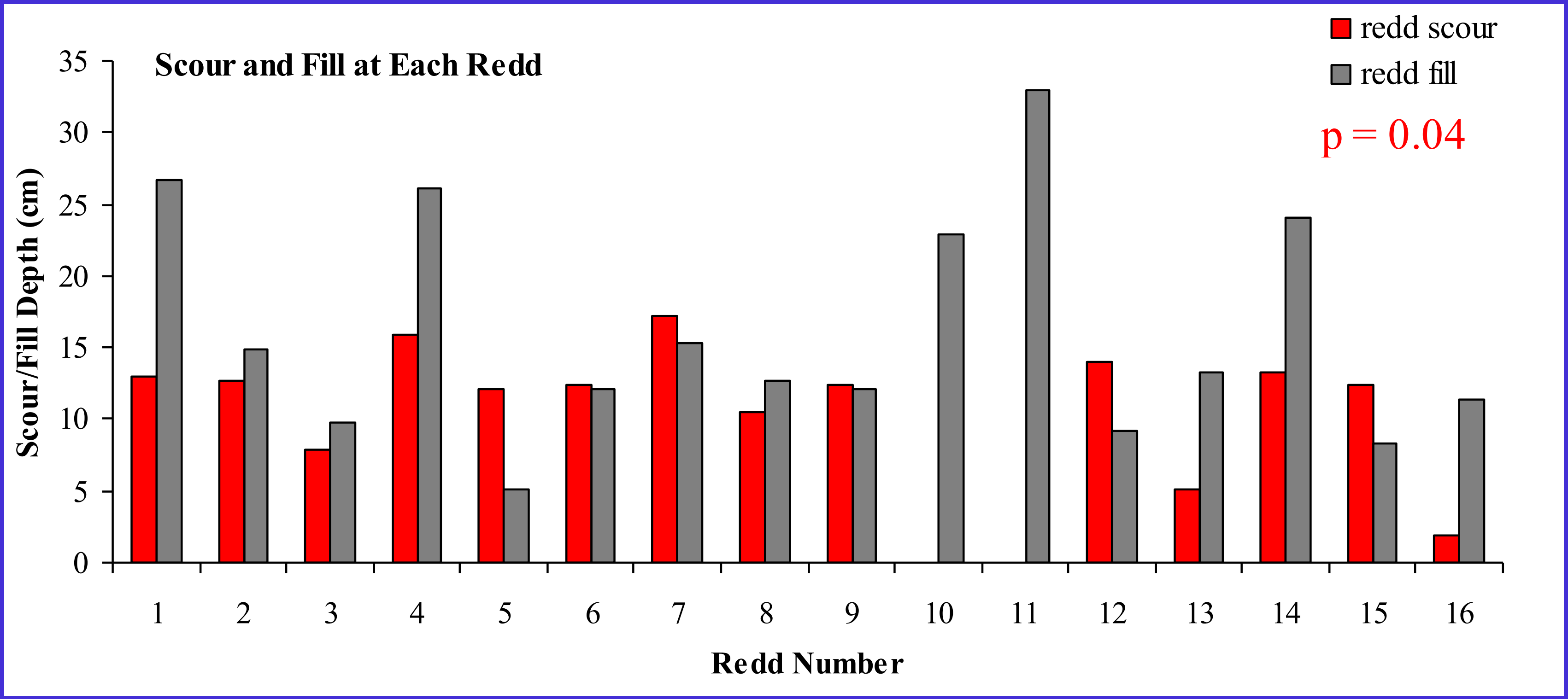
Fill Patterns at Redds

Redd fill greater than reach fill (p = 0.12)



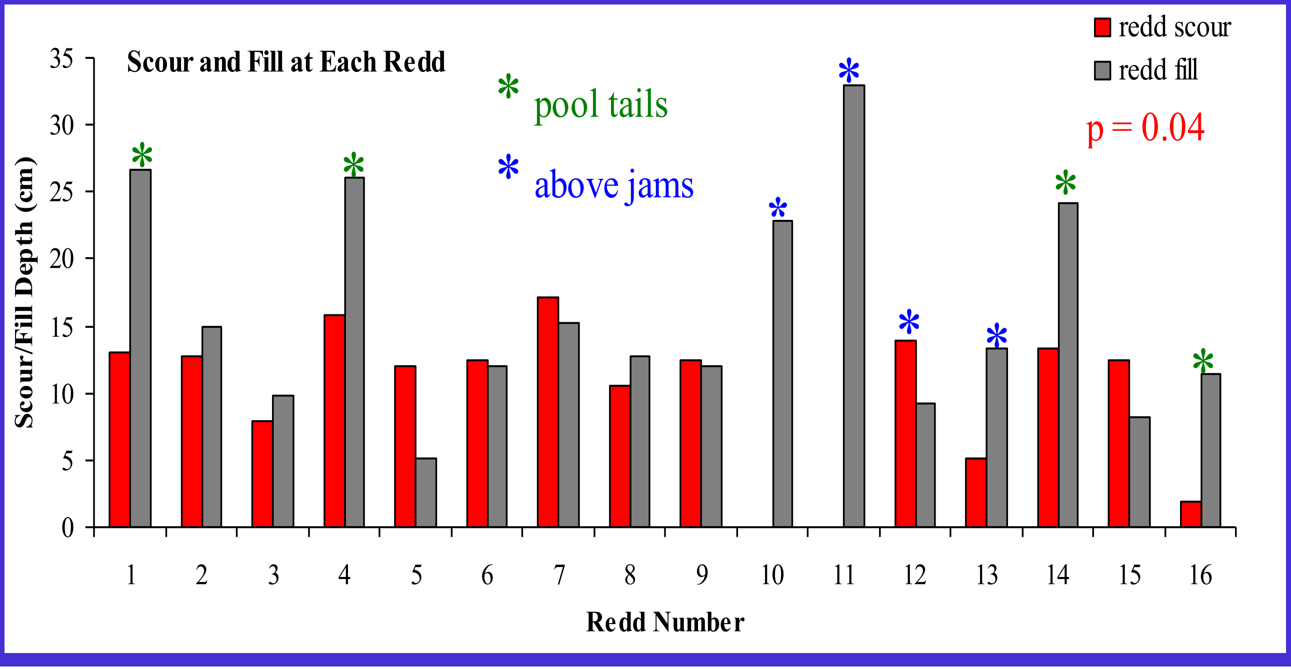
Fill Patterns at Redds

Redd fill greater than redd scour (p = 0.04)



Fill may be greater source of egg mortality than scour

Why Fill at Redd Locations?



Take Home Messages

- Scour & Fill patterns highly influenced by:
  - location within the channel network
  - sediment supply
  - channel morphology
- Haschenburger Model best suited for individual floods on reaches that are straight and in equilibrium between sediment supply and transport
- Model could be improved if based on Shields grain stress

Take Home Messages

- No evidence that redd construction reduces scour
- No evidence that salmon select low scour areas
- Small sample size (9 - 16 redds), need testing with larger sample sizes
- Redds often often located in sediment storage areas, fill may be greater source of mortality than scour