Statistical Evaluation of Trinity River WY 2009 – 2013 Bed Mobility and Scour Monitoring

With supplemental bed mobility and scour information

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Historical Geomorphic Monitoring Objective based on Flow Study and ROD

- Evaluate geomorphic relationships on alluvial bars as a function of peak flow events between Lewiston Dam and the North Fork Trinity River.
  - Bed mobility and scour monitoring has been conducted since 1991.
  - Monitoring specifically conducted to evaluate management objectives for ROD releases starting in 2006.
    - Surface bed mobility in Normal years (6,000 cfs)
    - Begin bed surface scour (scour>1D_{84} thick in Wet years (8,500 cfs)
    - Cause deeper scour in Extremely Wet years (scour>2D_{84} thick 11,000 cfs)
  - Historically monitored at rehabilitation projects, then…
  - Coordinated under IAP framework in 2009 under GRTS sampling scheme, alongside fisheries and riparian vegetation monitoring.

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Question posed to us by TRRP staff (2015)

- We've been painting and monitoring tracer rocks and scour since 1991…
- CAN WE DEVELOP A PREDICTIVE TOOL TO ESTIMATE BED MOBILITY AND SCOUR, RATHER THAN PAINT ROCKS EVERY YEAR?
  - Hydraulic Modeling using new bathymetry and SRH2-D model
  - Statistical Modeling using 2009-2013 data
  - To be integrated into Decision Support System (DSS)

Bed Mobility and Scour: TRFE objectives

TRFE MANAGEMENT OBJECTIVES

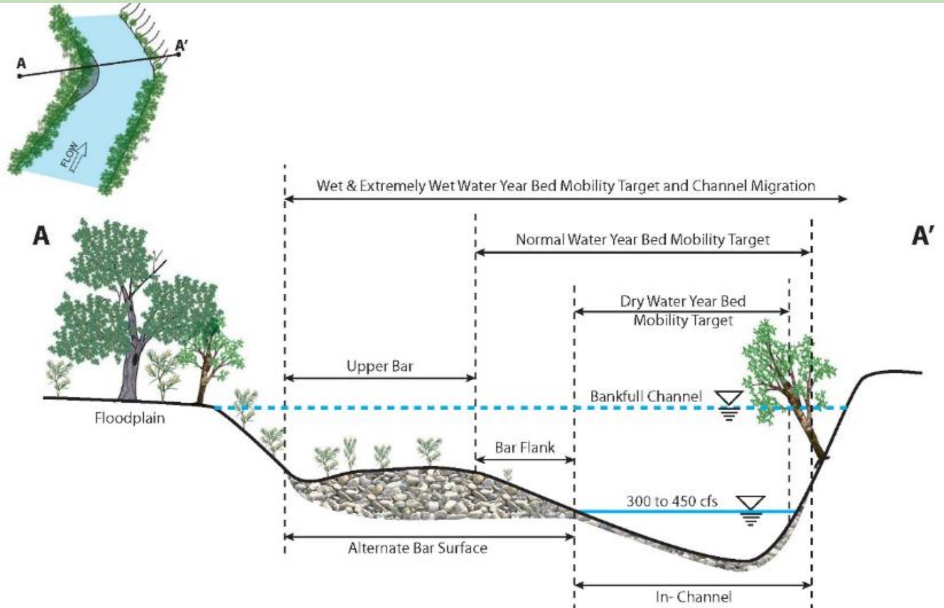
- Mobilization of matrix surface particles (D_{84}) on alternate bar surfaces during Normal and wetter water years >6,000 cfs)
- Mobilization of subsurface particles (≥ $1D_{84}$ depth) during Wet and Extremely Wet years
- Mobilization of subsurface particles (≥$2D_{84}$ depth) during Extremely Wet years

PURPOSE

- Prevent detrimental riparian encroachment of active bars to preserve healthy alluvial river attributes
- Maintain complex channel morphology
- Scour fine sediments
- Restoration of disturbance regime

Empirical observations → Statistical model

SRH 2-D hydraulic model → Numerical model



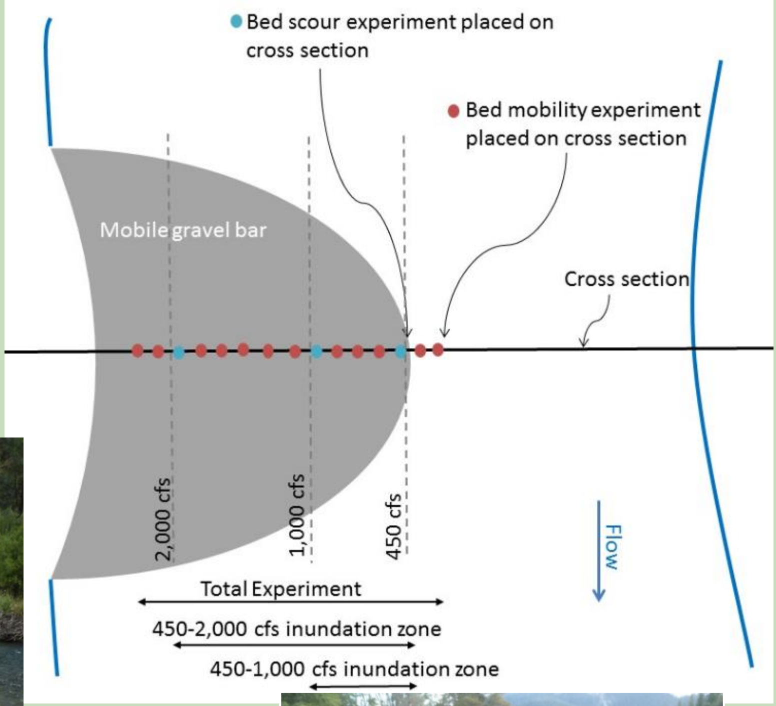
Part 1: Statistical Modeling

- Determine if a statistical model can be used to predict bed mobility and scour during the annual spring ROD release (winter high flows excluded).
- Data used are from annual monitoring conducted from 2009 – 2013.

Water year	Water year type	Maximum daily average ROD release at USGS Trinity River at Lewiston (cfs)	Number of sites with bed mobility experiment results	Number of sites with bed scour experiment results
2009	Dry	4,410	8	3
2010	Normal	6,440	12	14
2011	Wet[1]	11,600	35	36
2012	Normal	6,080	32	36
2013	Dry	4,420	24	25
		TOTAL	**111**	**114**

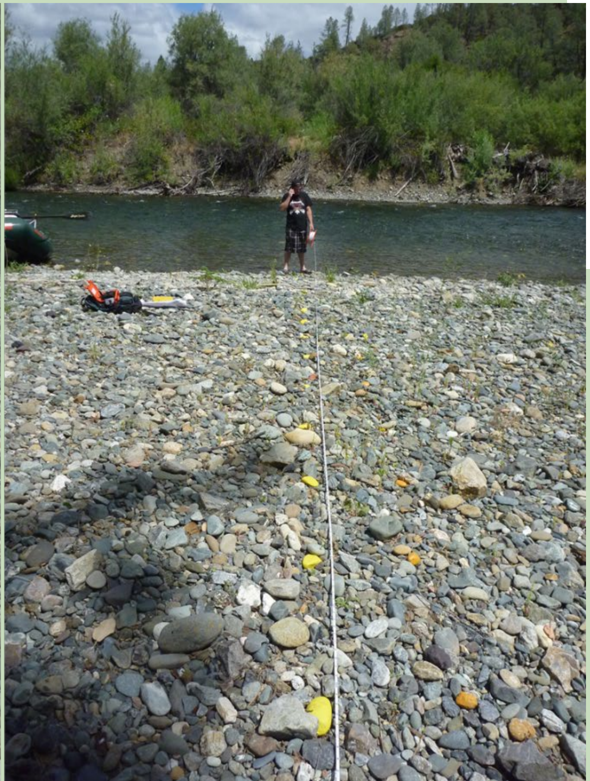
2009-2014 Empirical Observations

- Tracer Rocks → bed mobility
- Scour Cores → bed scour
- Scour Chains → bed scour



Before high flow

After high flow



Predictor Variables used in statistical analysis

Variable	Independent or dependent
Bed mobility in a given inundation zone on bar	Dependent
Bed scour at a particular location on bar	Dependent
Maximum daily average flow at monitoring site	Independent
Maximum instantaneous peak flow at monitoring site	Independent
Average shear stress over the experiment	Independent
Computed Shields parameter over the inundation zone	Independent

Metrics chosen for Dependent variables:

- Probability of a site's inundation zone having > 80% bed mobility
- Probability of a site's inundation zone having > 1D_{84} scour

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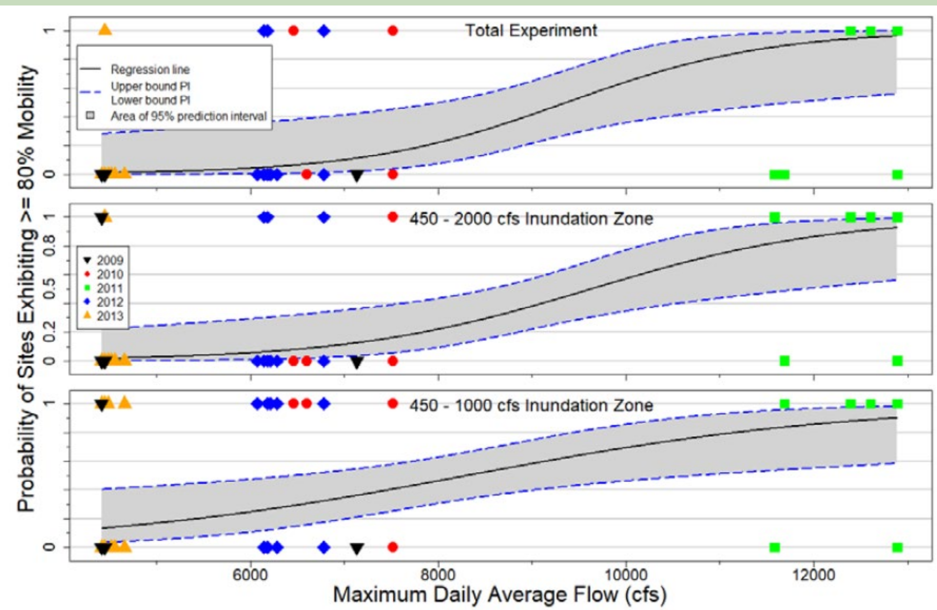
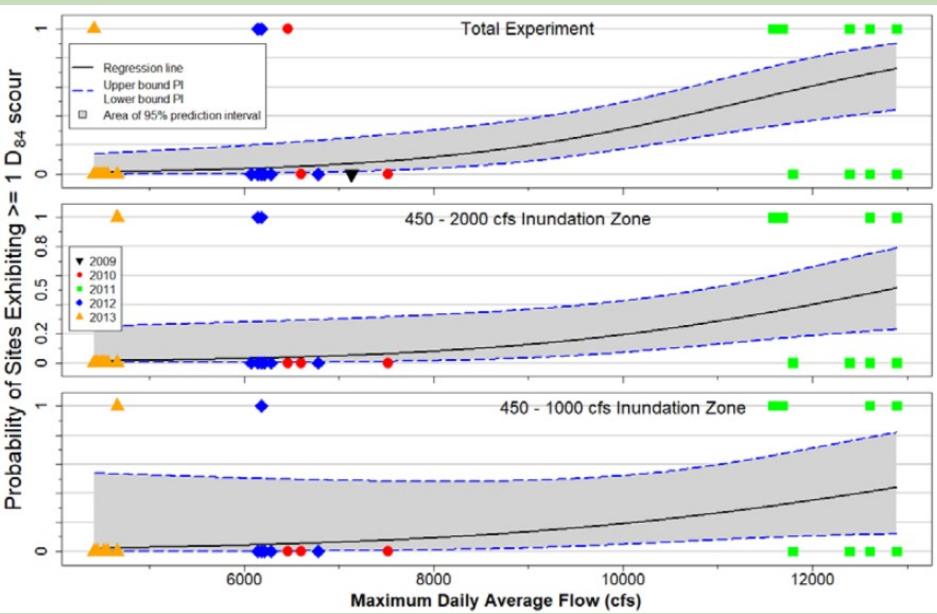
Statistical model based on 2009-2013 field data

Bed Mobility of bars >80% of tracers



Bed Scour of sites >1D84



- Bed Mobility, Scour ≥ $1D_{84}$
- Only predicts where bed mobility and scour monitoring has occurred (active bars)
- Subdivided by reaches and by inundation zone, but…
- Not spatially explicit beyond reaches and inundation zones

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Tabular results: Bed Mobility (>80% of area)

Flow	Inundation zone	Predicted probability of a site with >80% mobility	Lower confidence interval	Upper confidence interval
4,410 cfs	total experiment	0.022	0.001	0.320
	450 to 2,000 cfs	0.033	0.003	0.257
	450 to 1,000 cfs	0.188	0.064	0.439
6,000 cfs	total experiment	0.065	0.008	0.382
	450 to 2,000 cfs	0.079	0.016	0.319
	450 to 1,000 cfs	0.292	0.145	0.500
8,500 cfs	total experiment	0.283	0.117	0.542
	450 to 2,000 cfs	0.272	0.133	0.475
	450 to 1,000 cfs	0.506	0.342	0.669
10,000 cfs	total experiment	0.530	0.294	0.753
	450 to 2,000 cfs	0.474	0.287	0.668
	450 to 1,000 cfs	0.639	0.432	0.805
11,500 cfs	total experiment	0.763	0.419	0.935
	450 to 2,000 cfs	0.685	0.406	0.874
	450 to 1,000 cfs	0.754	0.494	0.906
12,000 cfs	total experiment	0.894	0.493	0.987
	450 to 2,000 cfs	0.831	0.485	0.962
	450 to 1,000 cfs	0.835	0.539	0.957

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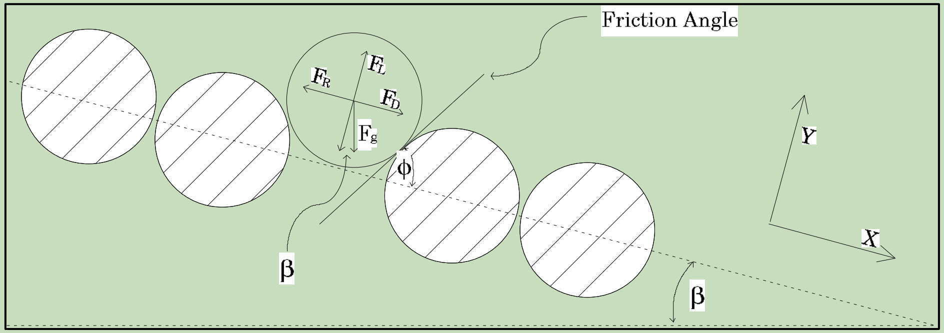
Tabular results: Bed Scour >1D_{84}

Flow[1]	Inundation zone	Predicted probability of a site with scour > 1.0 D_{84}	Lower confidence interval	Upper confidence interval
4,410 cfs	total experiment	0.024	0.003	0.169
	450 to 2,000 cfs	0.021	0.001	0.267
	450 to 1,000 cfs	0.032	0.001	0.520
6,000 cfs	total experiment	0.049	0.010	0.218
	450 to 2,000 cfs	0.038	0.004	0.290
	450 to 1,000 cfs	0.052	0.003	0.497
8,500 cfs	total experiment	0.142	0.053	0.328
	450 to 2,000 cfs	0.093	0.020	0.342
	450 to 1,000 cfs	0.107	0.015	0.482
10,000 cfs	total experiment	0.249	0.126	0.432
	450 to 2,000 cfs	0.156	0.050	0.393
	450 to 1,000 cfs	0.161	0.035	0.501
11,500 cfs	total experiment	0.398	0.237	0.586
	450 to 2,000 cfs	0.248	0.105	0.481
	450 to 1,000 cfs	0.235	0.068	0.563
12,000 cfs	total experiment	0.557	0.340	0.755
	450 to 2,000 cfs	0.361	0.169	0.612
	450 to 1,000 cfs	0.321	0.099	0.670

Part 2: Numerical Modeling

Numerical Model Assumptions

- Use 2-D hydraulic models to predict boundary shear stress (force to move particle)
- Use bed mobility model to predict dimensionless critical shear stress to move D_{84} (force resisting movement)
- If ratio of force moving particle/force resisting movement is greater than 1, then movement
- If ratio of force moving particle/force resisting movement is greater than ~1. 5, then moderate scour
- If ratio of force moving particle/force resisting movement is greater than ~2, then deeper scour



Shields parameter ~ $\frac{\text{mobility force}}{\text{grain resisting force}}$ ⇒ $\tau*_{D_i} = \frac{\tau_b}{(\rho_s - \rho_w)gD_i}$

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Computational Process

SRH-2D model mesh output (coordinates and boundary shear stress)

X, Y, Pascals

Substrate D_{84} map (grain size)

D_{84} (meters)

Active bar map (Exposed/Mobile gravel locations)

Polygons X, Y

Filtered Analysis Data (X,Y, Pascals, meters)

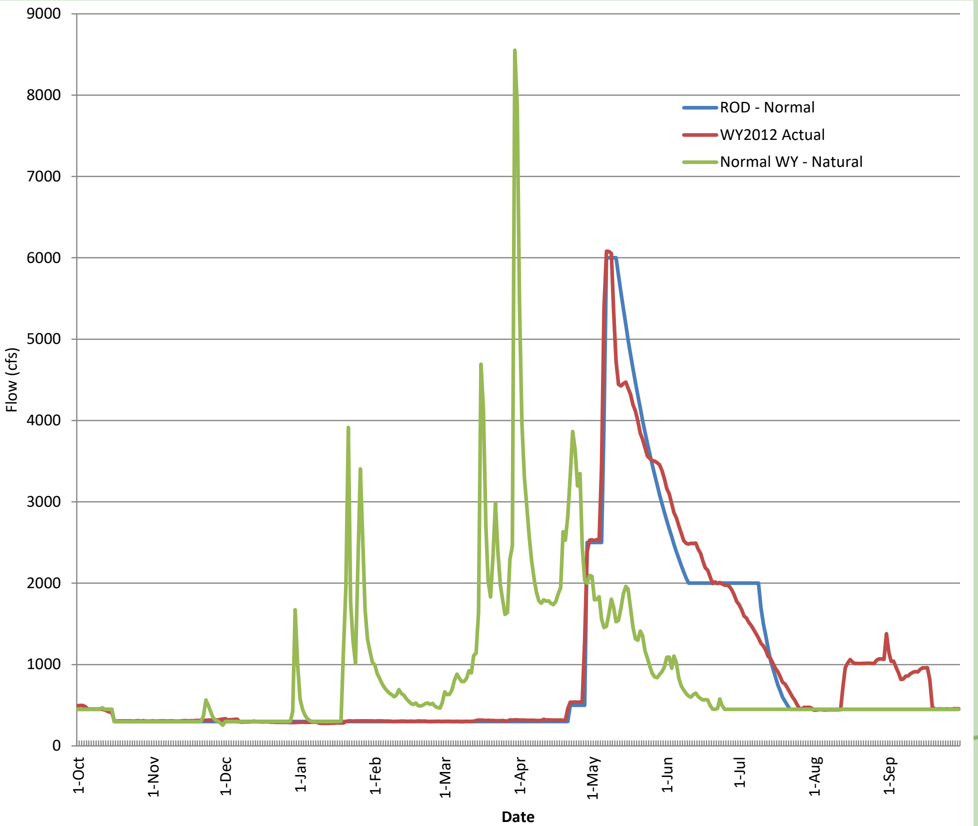
Excel Computations

$$\frac{\text{Boundary Shear Stress}}{\text{Critical Shields Parameter}*(1800)*(9.81)*(D_{84})} \geq 1.0\text{, then mobility/scour}$$

Export results to ArcView

SRH 2-D hydraulic model: Hydrology and Shear Stress

- Uses shear stress output from SRH 2-D model for peak ROD flows.
- Analyses performed to date for 40 miles: Q_{peak}=6,000 cfs and Q_{peak}=8,500 cfs
- Assume no tributary accretion, but could be added



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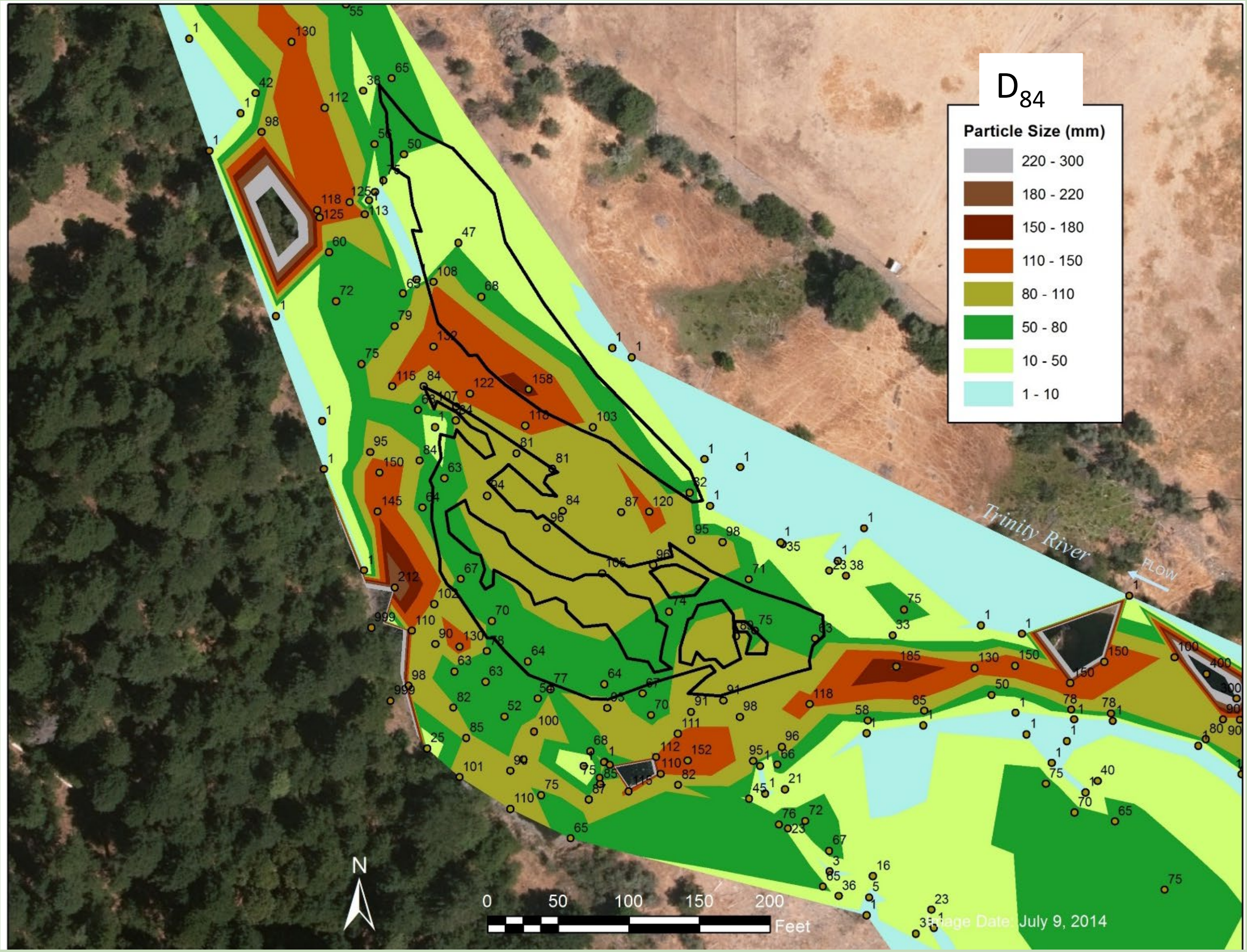
D_{84} grain size contour map (USFWS, YT, HVT) and Active Bar Map overlay



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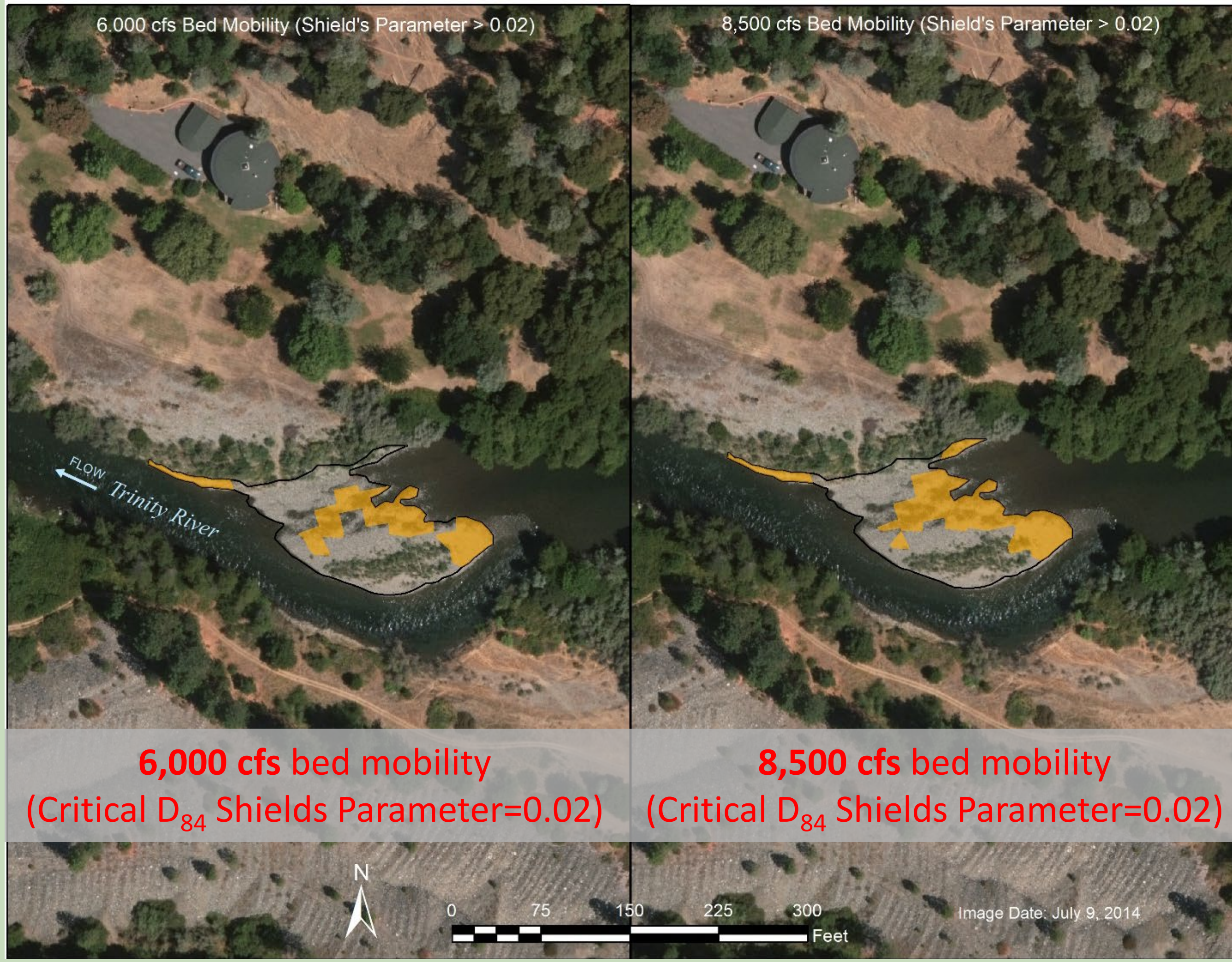
Bed Mobility Model Output: 6,000 cfs and 8,500 cfs on mid-channel bar

Predicted D_{84} Bed Mobility

Predicted $>1D_{84}$ Bed Scour

Predicted $>2D_{84}$ Bed Scour



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Bed Scour and Mobility Numerical Model Output: Example Comparison of Results for Active Bars

Total Active Bar Area (sq ft)	Peak Flow	Predicted Active Bar area mobilized by peak flow, D84 Shields parameter>0.02 (sq ft)	Percent of total Active Bar area mobilized by peak flow	Predicted Active Bar area with shallow scour (>1D84) by peak flow, D84 Shields parameter>0.025 (sq ft)	Percent of total Active Bar area scoured by peak flow	Predicted Active Bar area with deeper scour (>2D84) by peak flow, D84 Shields parameter>0.030 (sq ft)	Percent of total Active Bar area scoured by peak flow
33,480	6,000 cfs	16,229	48.5%	5,828	17.4%	3,297	9.8%
33,480	8,500 cfs	20,169	60.2%	9,090	27.2%	5,617	16.8%

- Model predicts bed mobility objective are partially met during Normal year release (6,000 cfs) and shallow bed scour objective not met for Wet year (8,500 cfs) release
- Portion of bar area mobilized increases by 24% between 6,000 and 8,500 cfs
- Portion of bar area with shallow scour increases by 56% between 6,000 and 8,500 cfs
- Portion of bar area with deeper scour increases by 70% between 6,000 and 8,500 cfs
- Critical Shields parameter values used needs further review/calibration/discussion

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SUMMARY: Potential flow management deliberations-Empirical Model

- While we had a lot of data to use, confidence intervals were still very wide in predictions, so lots of uncertainty
- 2009-2013 data set is outdated, so probably would need caveats to use now (but could be a no-cost supplement to numerical modeling results)
- Could use empirical bed mobility and scour data to "calibrate" bed mobility model, thereby improving future numerical model predictions of bed mobility and scour
- What about original question (can we use statistical or numerical model to address bed mobility and scour rather than painting rocks?)
- Can be easily added to Decision Support System

SUMMARY: Potential flow management deliberations- Numerical Model

- Systemic predictions of bed mobility and scour (need topo, model, and grain size mapping)
- Evaluation of TRFE and ROD management objectives for specific water year types
- Comparisons of predictions for different peak flow alternatives
- Easy sensitivity analyses of assumptions (critical Shields parameter)
- Predictions can be analyzed by:
    - Geomorphic reaches (e.g., Lewiston Dam to Rush Creek backwater)
    - Geomorphic feature (e.g., pool tails, point bars, mid-channel bars)
    - Inundation zone (e.g., 450 cfs-2,000 cfs inundation zone on active bars)
    - Mesohabitat boundaries (e.g., pool tails, riffles)
    - Fish habitat suitability boundaries (e.g., Chinook spawning habitat)
    - Riparian vegetation patches (e.g., initiating seedlings along low flow channel margins)
    - Groupings of all the above
- Can be easily added to Decision Support System

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Questions?