Shoemaker Island Flow-Sediment-Mechanical "Proof of Concept" Experiment

Platte River Recovery and Implementation Program

Presented by:

EA Engineering, Science, and Technology, Inc., PBC

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Northern Hydrology and Engineering
Engineering - Hydrology - Geomorphology - Water Resources

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Project Team

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Shoemaker Island Flow-Sediment-Mechanical ‘Proof of Concept” Experiment

Designed to Evaluate the ability of FSM strategy to achieve Program management objectives:

1. **Improve survival of whooping cranes during migration; and**
2. **Improve least tern and piping plover production.**

Experiment Learning Objectives

Evaluate FSM management actions ability to achieve management objectives:

1. **Evaluate the relationship between peak flows (magnitude and duration) and sand bar height and area by:**
   a) **Hydrograph (shape and duration) and sand bar height and area**
      - **Direct measurements**
      - **Mobile-bed model predictions for target SDHF**

   b) **Sediment supply and frequency of sand bar occurrence**
      - **Mobile-bed model predictions for target SDHF**

   c) **Grain size and sand bar height**
      - **Mobile-bed model predictions for target SDHF**

Experiment Learning Objectives

Evaluate FSM management actions ability to achieve management objectives:

2. **Evaluate the relationship between peak flows (magnitude and duration) and riparian plant mortality.**
    - **Direct measurements**
    - **Modeling:**
        - **Bank erosion**
        - **Vertical scour**
        - **Uprooting through vegetation drag**

Experiment Learning Objectives

Evaluate FSM management actions ability to achieve management objectives:

3. **Evaluate ability of FSM management strategy to create and/or maintain habitat for whopping cranes, least terns, and piping plovers.**

PRRIP Big Questions

1. Will implementation of SDHF produce suitable tern and plover riverine nesting habitat on an annual or near-annual basis?
2. Will implementation of SDHF produce and/or maintain suitable whooping crane riverine roosting habitat on an annual or near annual basis?
3. Is sediment augmentation necessary for the creation and/or maintenance of suitable riverine tern, plover, and whooping crane habitat?
4. Are mechanical channel alterations (channel widening and flow consolidation) necessary for the creation and/or maintenance of suitable riverine tern, plover, and whooping crane habitat?

Experiment Data:

- **Flow rate, depth, velocity, and water surface elevation**
- **Turbidity**
- **Sediment Transport**
  - Suspended load, bed load, grain size distribution
- **Bed and Bar Sediment Characteristics**
  - Grain size distribution, bulk density, porosity
- **LiDAR, channel cross section and longitudinal profiles**
- **Vegetation type, density, stem diameter, height**
- **Bar/island topography and morphometry (1200 TRF elevation)**
- **Bed/Bar scour**


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Models Applied

Mobile-Bed (FaSTMECH and EFDC)

- Learning Objective 1: Sensitivity of barform frequency, area, and height to hydrograph shape, grain size and sediment supply

Fixed-Bed (FaSTMECH)

- Learning Objective 2: Riparian plant mortality:
  - Input into bank erosion model
  - Velocity predictions for uprooting estimates
  - Relation between scour depth and shear stress

Bank Erosion (BSTEM)

- Learning Objective 2: Riparian plant mortality:
  - Bank erosion estimates

2-D Models

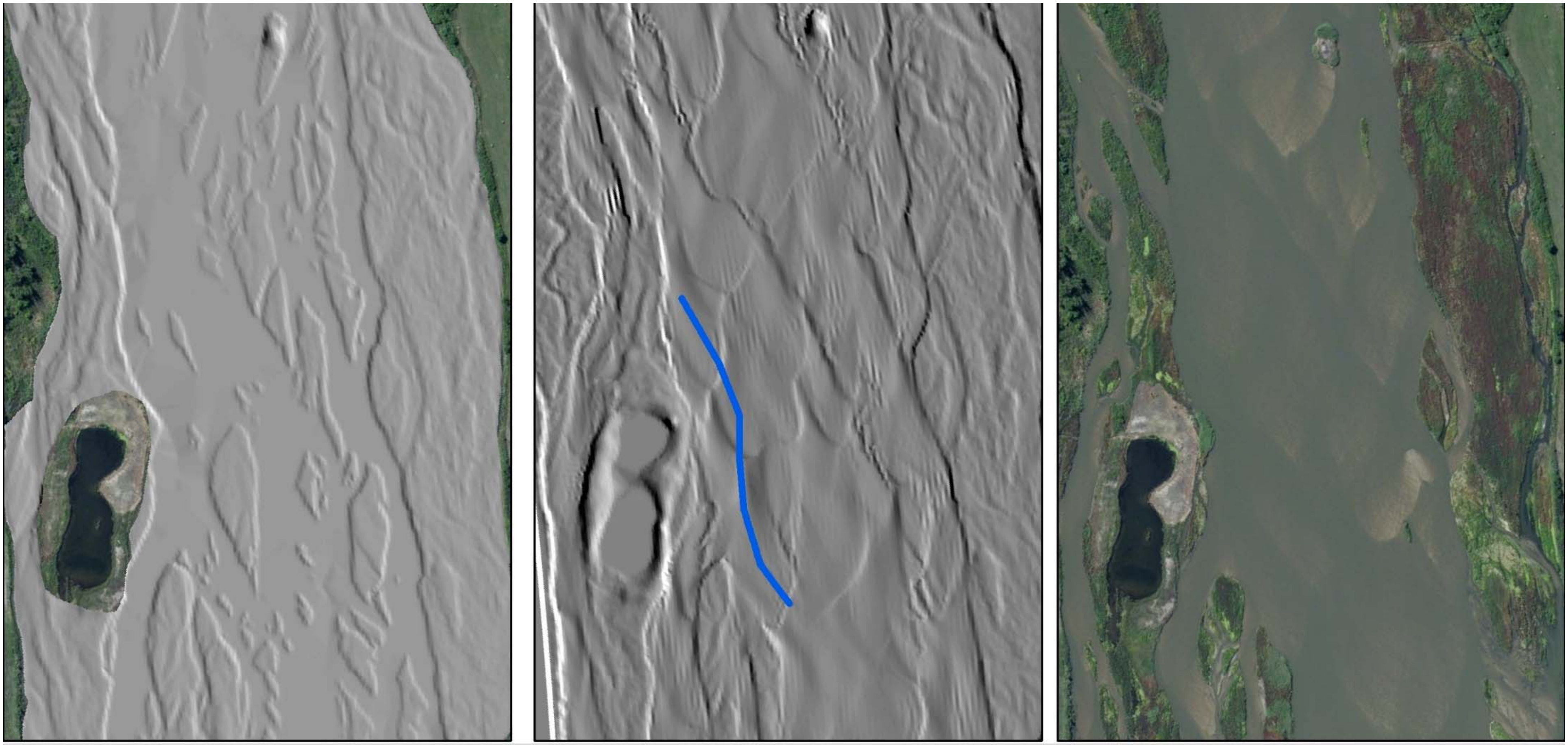
EFDC

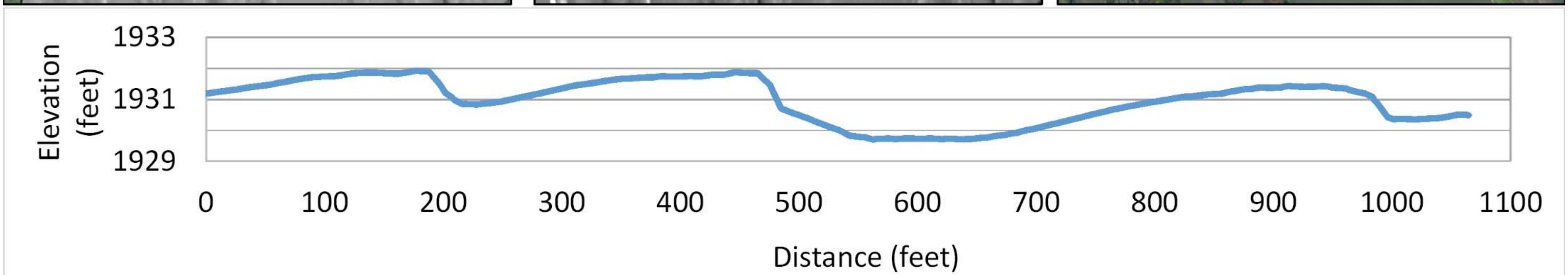
- Originally developed at the Virginia Institute of Marine Science by Dr. John Hamrick - Environmental Protection Agency (EPA) supported modeling system
- Key Differences
  - Multiple grain sizes
  - Sediment input is required at upstream boundary
  - Suspended load and bedload computed
  - Shear stress is partitioned when applying variable roughness due to vegetation
- Shoemaker application: 10 meter grid (~28,000 grid cells)

2-D Models

FaSTMECH

- Developed by Dr. Jonathan Nelson of the U.S. Geological Survey
- Key differences from EFDC
  - Efficient solver allowing for predictions over longer time frames, finer grid resolutions and longer reaches
  - Sediment input calculated at upstream boundary
  - Total load sediment transport equation
  - Single grain size
- Shoemaker application: 3 meter grid (380,000 grid cells)





Shoemaker Island Flow-Sediment-Mechanical
“Proof of Concept” Experiment

1-D Lateral Erosion (BSTEM)

- USDA Bank Stability and Toe Erosion Model (BSTEM)developed at the USDA Agricultural Research Services
  - Adjusted model parameters to matching shear stress predicted at the toe of the bank by FaSTMECH.

Experiment Learning Objectives

Evaluate FSM management actions ability to achieve management objectives:

1. **Evaluate the relationship between peak flows (magnitude and duration) and sand bar height and area by:**
   a) **Hydrograph (shape and duration) and sand bar height and area**
      - **Direct measurements**
      - **Mobile-bed model predictions for target SDHF**

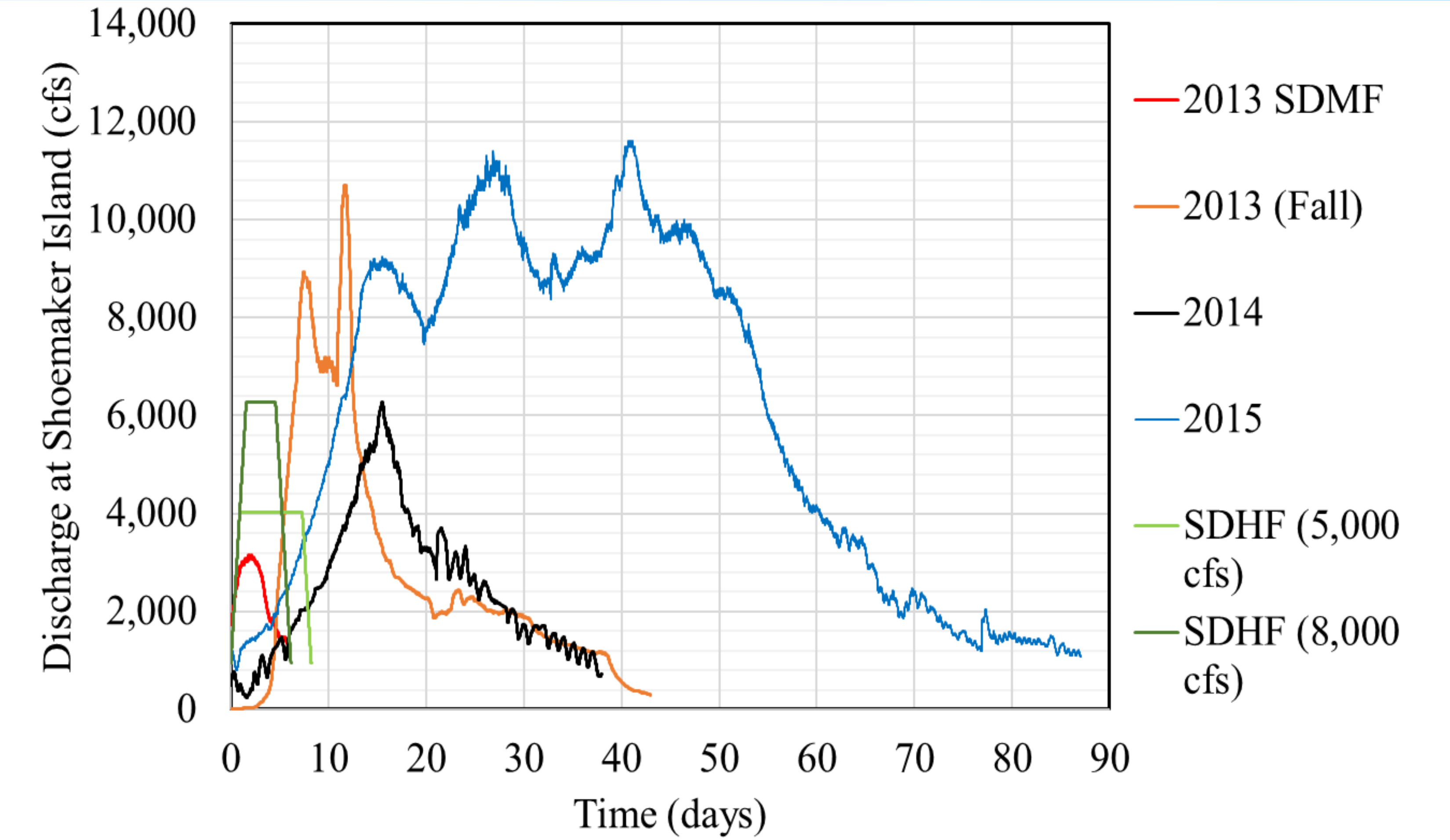
1a) Hydrograph (shape and duration) and sand bar height and area

- Three-year experiment to monitor the geomorphic response of Platte River Shoemaker Island study reach to “high flow events”

- Four discrete high flow events monitored
  - April 2013 Short Duration Medium Flow, April 2013
  - Fall 2013 High Flow, September to November 2013
  - June 2014 High Flow, June to July 2014
  - June 2015 High Flow, May to July 2015

1a) Hydrograph (shape and duration) and sand bar height and area

Hydrographs Evaluated During Study Period (2013-2015)



1a) Hydrograph (shape and duration) and sand bar height and area

Monitored Flow Events, Grand Island, NE USGS Gage

		April 2013 SDMF (12 April 2013 to 18 April 2013)		Fall 2013 High Flow (24 September 2013 to 1 November 2013)	
	Program Flow Benchmarks	Magnitude	% of Benchmark	Magnitude	% of Benchmark
Peak Instantaneous Discharge, cfs	NA	3,840	NA	10,600	NA
3-day Peak Mean Discharge, cfs	5,000 – 8,000	3,552	44%	9,700	121%
Volume, acre-feet (un-rounded, for flows above 2,000 cfs)	50,000 – 75,0000	33,743	45%	248,270	331%
Discharge Duration >2,000 cfs, days	NA	6	NA	28	NA
Discharge Duration >8,000 cfs, days	NA	0	NA	7	NA

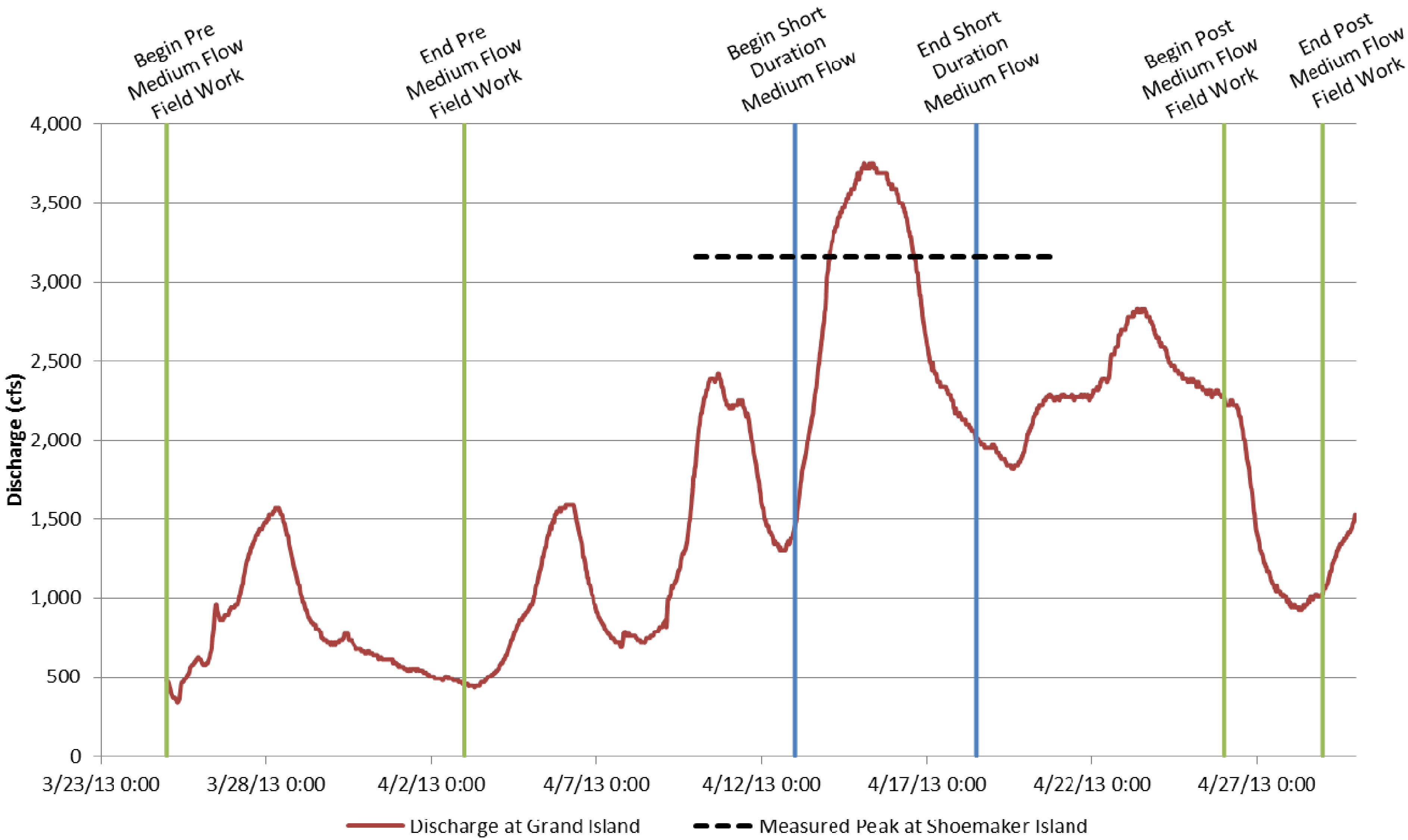
1a) Hydrograph (shape and duration) and sand bar height and area

Monitored Flow Events, Grand Island, NE USGS Gage

	Program Flow Benchmarks	June 2014 High Flow (6 June 2014 to 5 July 2014) Magnitude	June 2014 High Flow % of Benchmark	June 2015 High Flow (11 May 2015 to 20 July 2015) Magnitude	June 2015 High Flow % of Benchmark
Peak Instantaneous Discharge, cfs	NA	8,800	NA	16,100	NA
3-day Peak Mean Discharge, cfs	5,000 – 8,000	7,320	92%	15,700	196%
Volume, acre-feet (un-rounded, for flows above 2,000 cfs)	50,000 – 75,000	181,270	242%	1.231 million	1641%
Discharge Duration >2,000 cfs, days	NA	30	NA	72	NA
Discharge Duration >8,000 cfs, days	NA	1	NA	42	NA

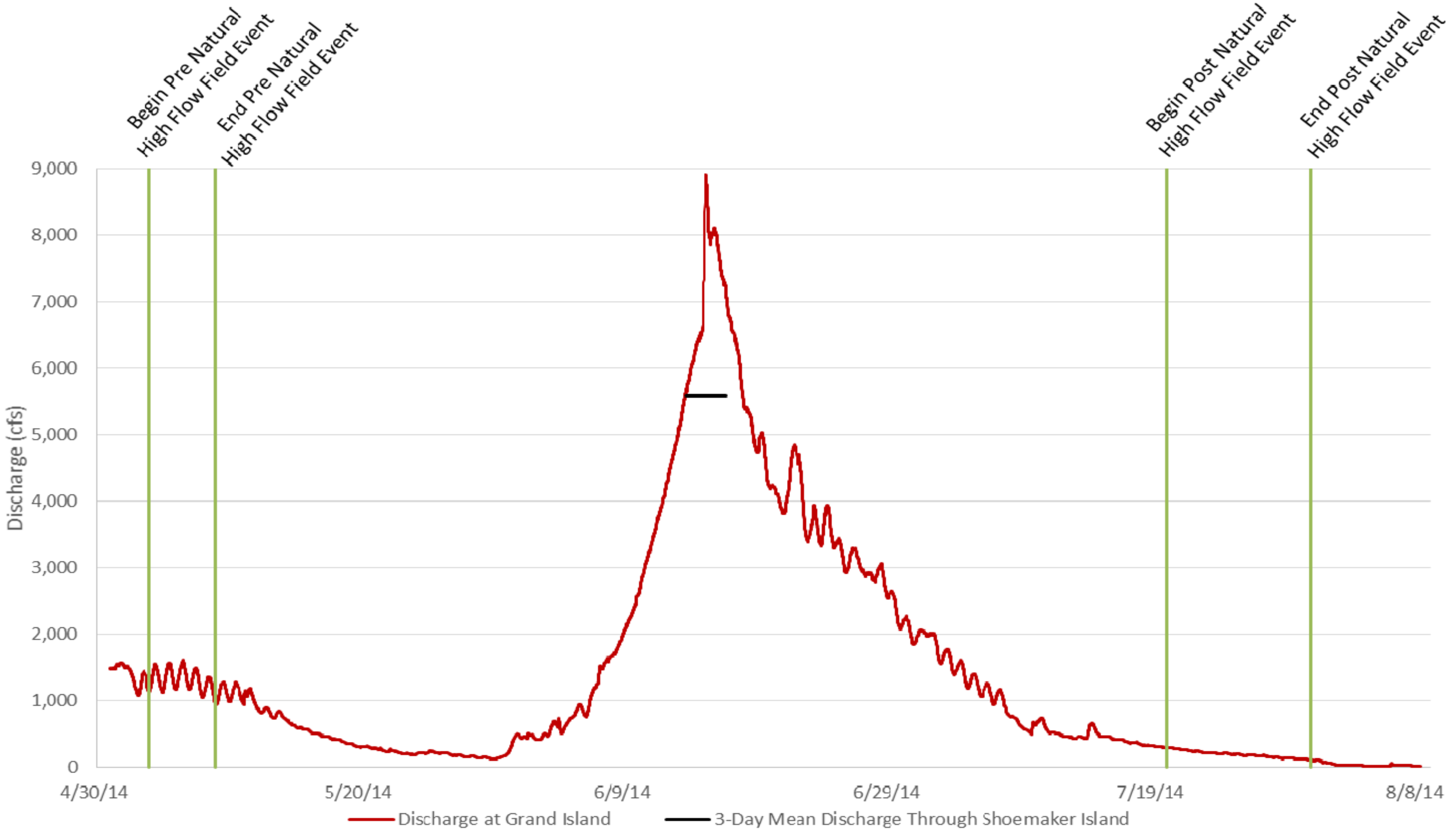
1a) Hydrograph (shape and duration) and sand bar height and area

April 2013 SDMF



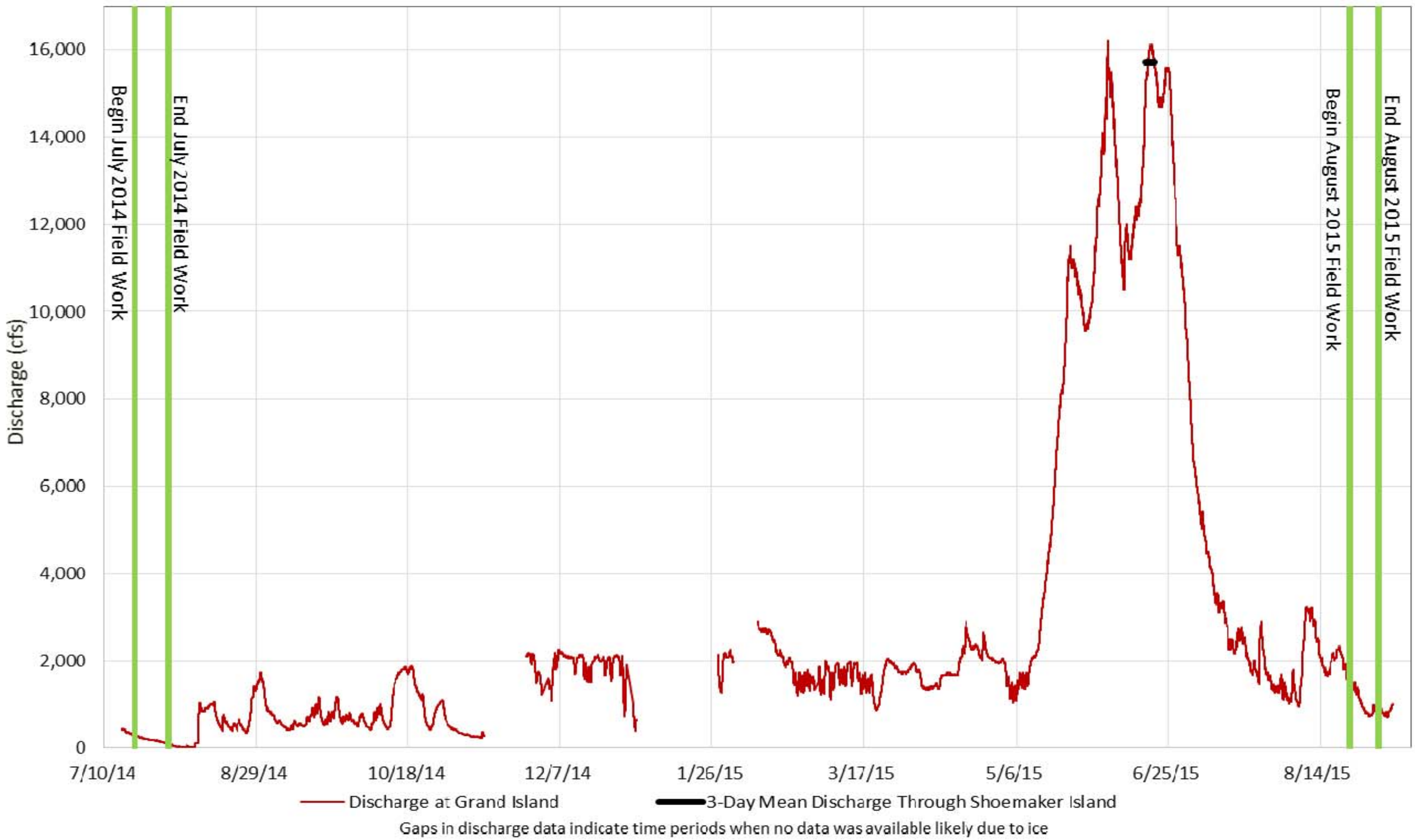
1a) Hydrograph (shape and duration) and sand bar height and area

June 2014 High Flow



1a) Hydrograph (shape and duration) and sand bar height and area

June 2015 High Flow



1a) Hydrograph (shape and duration) and sand bar height and area

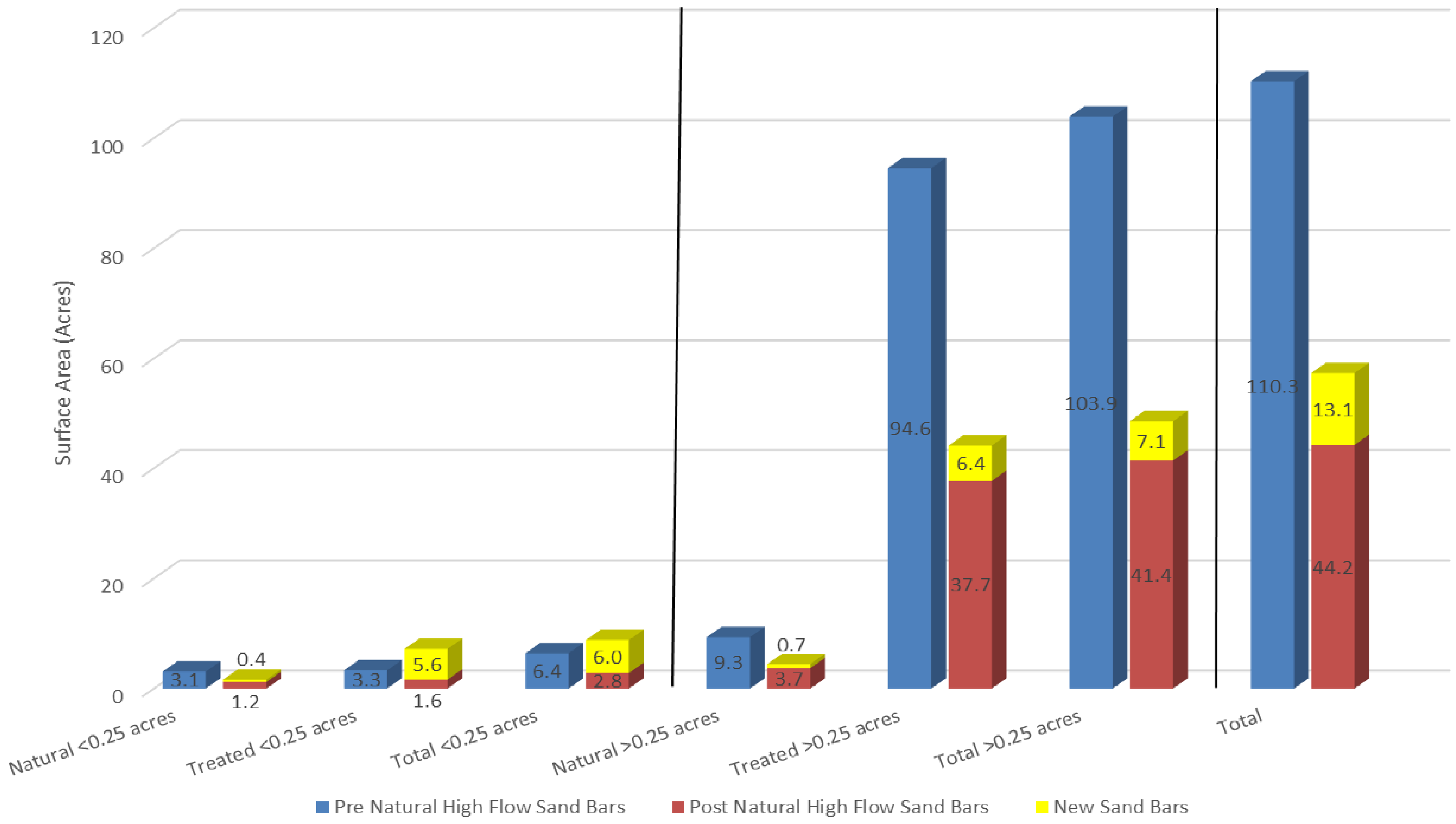
Bar Suitability for least tern and plover habitat include:

- **A sand bar is a bar whose area above 1,200 cfs TRF stage is 80% or greater bare sand.**
- **Bar area greater than 0.25 acres determined at the 1,200 cfs TRF stage.**
- **Height of sand bar is 1.5 feet or higher than the 1,200 cfs TRF stage.**

The 2013 SDMF was not of significant magnitude or duration to modify/create sand bars in the Shoemaker study reach.

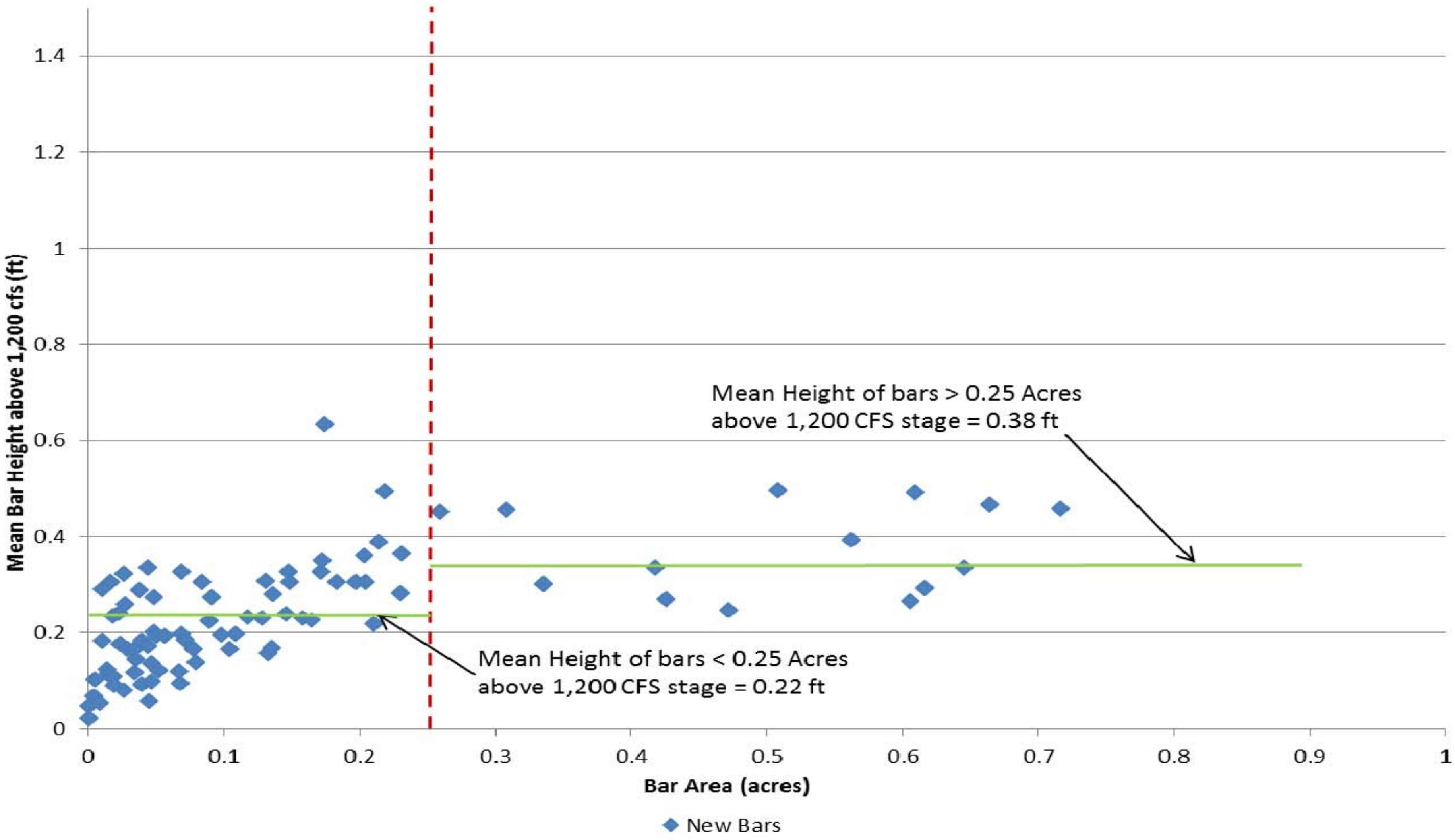
1a) Hydrograph (shape and duration) and sand bar height and area

June 2014 Post High Flow New Sand Bars



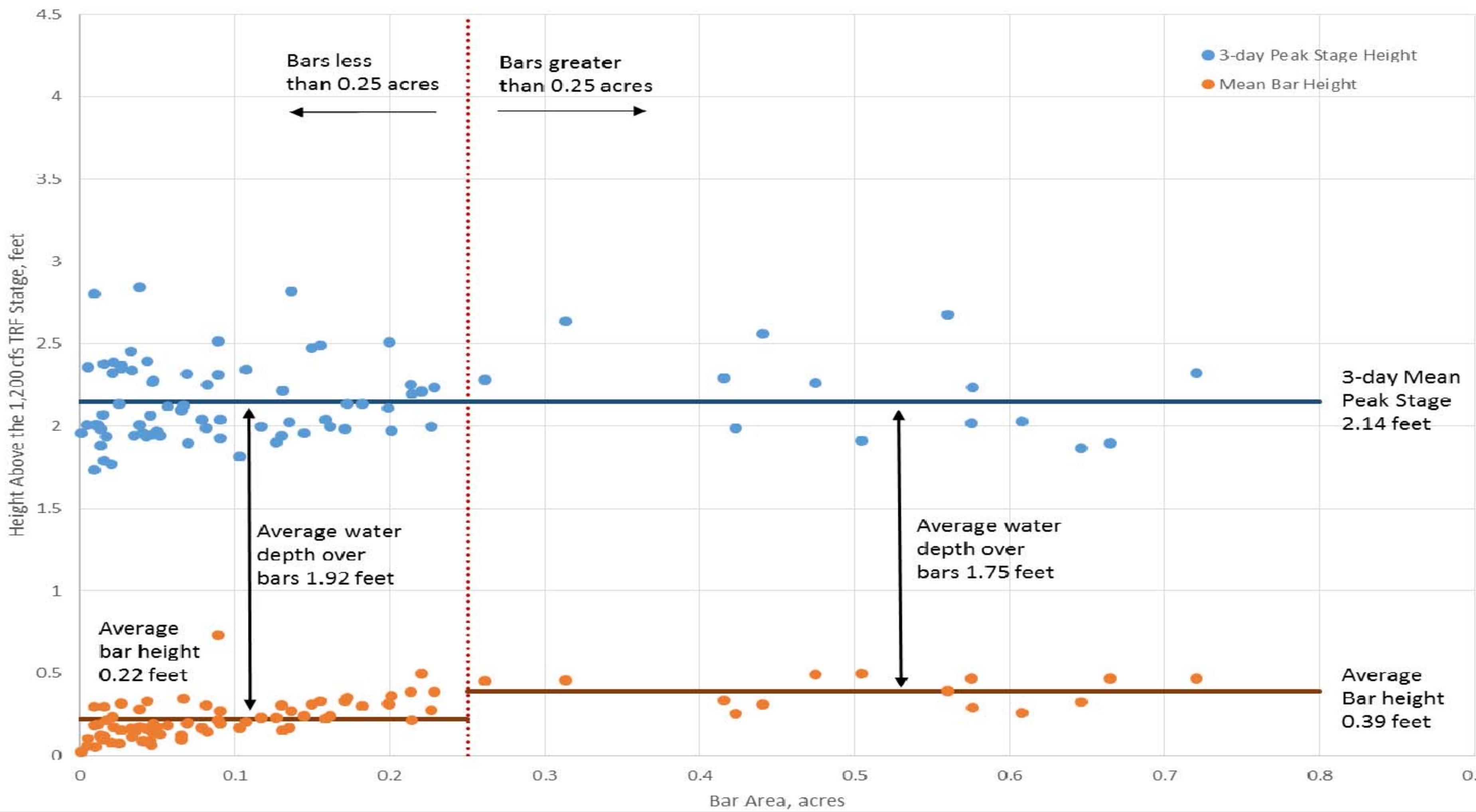
1a) Hydrograph (shape and duration) and sand bar height and area

June 2014 Post High Flow New Sand Bar Mean Height



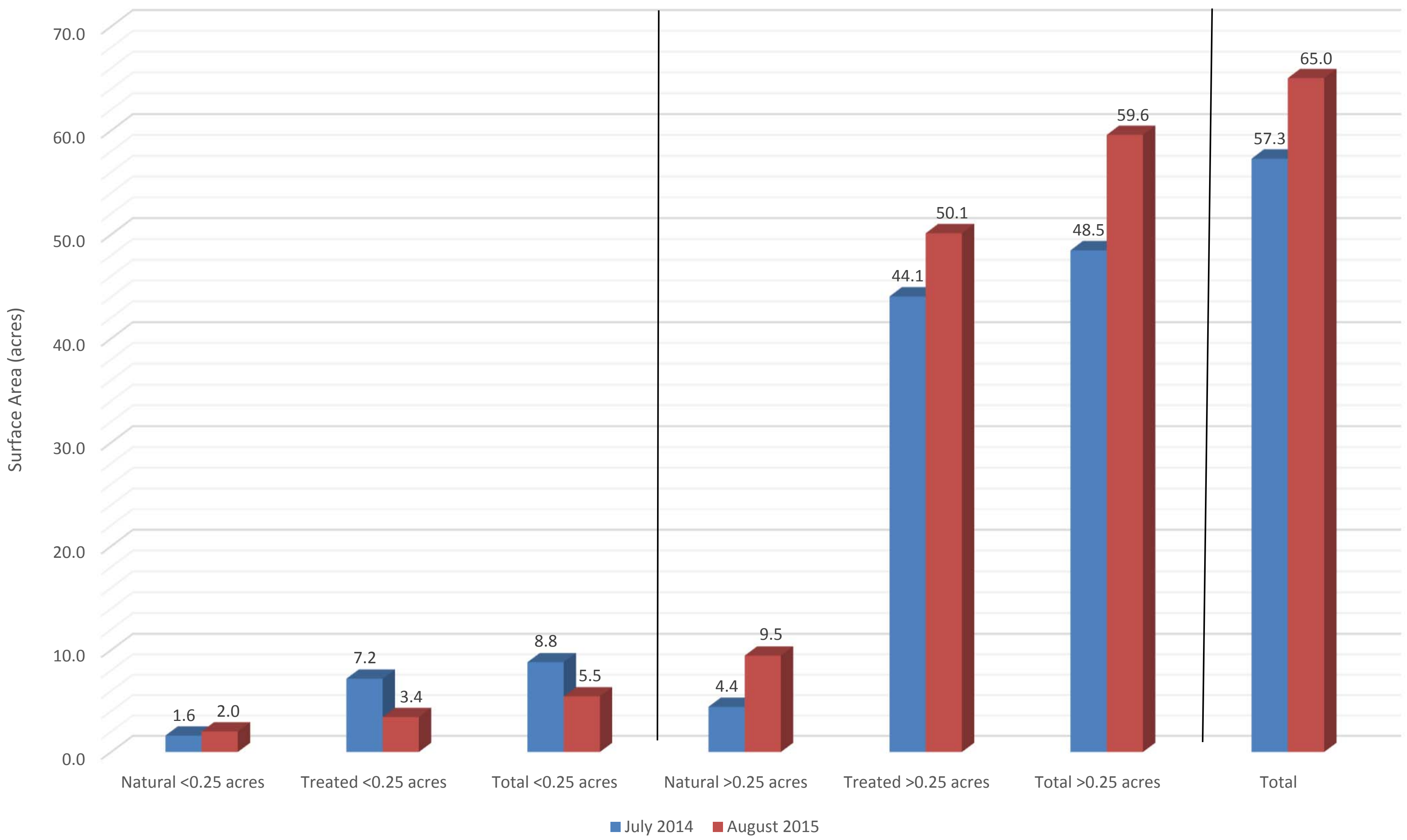
1a) Hydrograph (shape and duration) and sand bar height and area

July 2014 New Sand Bar and 3-day Peak Discharge Stage Height



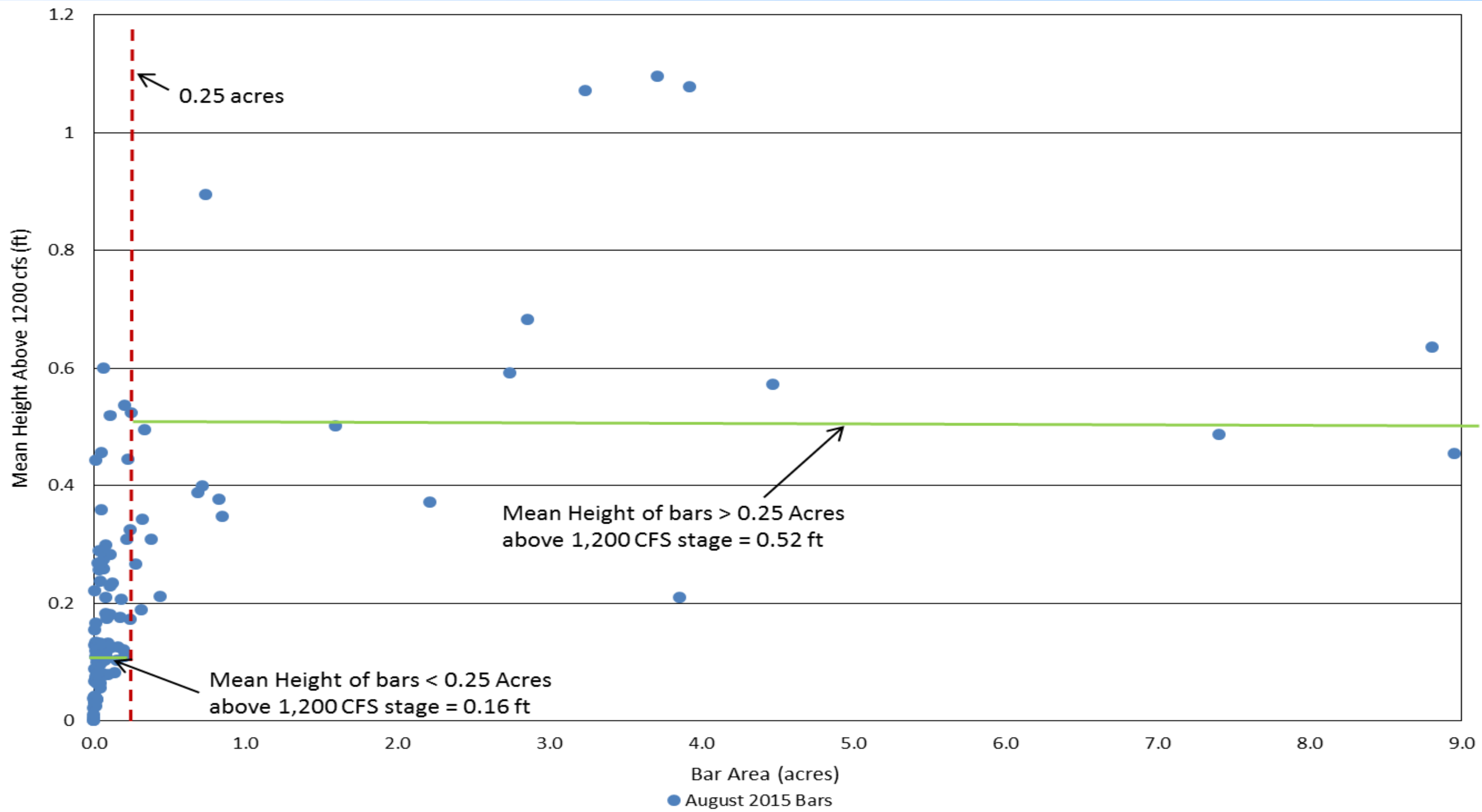
1a) Hydrograph (shape and duration) and sand bar height and area

June 2015 Post High Flow Sand Bars



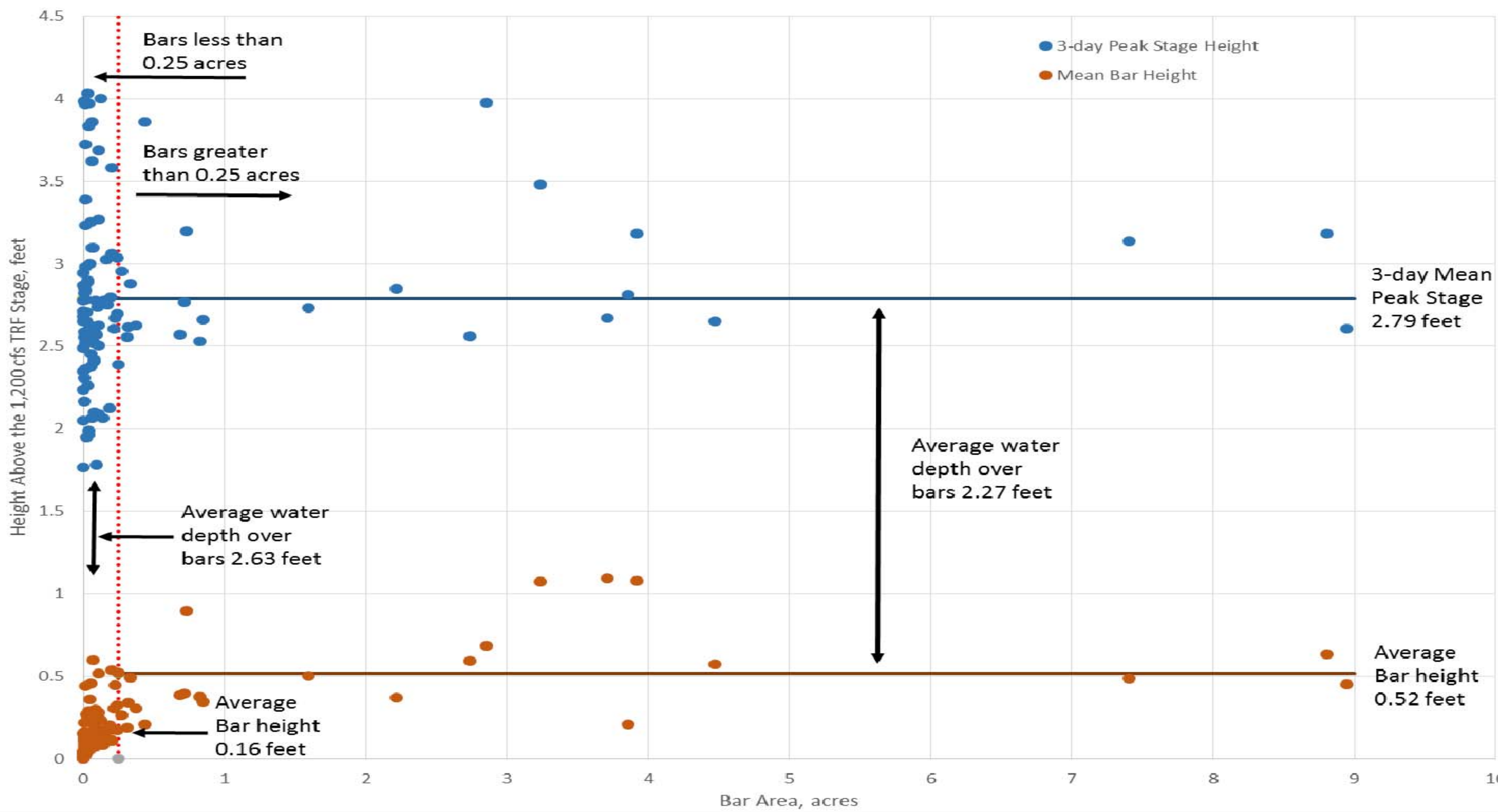
1a) Hydrograph (shape and duration) and sand bar height and area

June 2015 Post High Flow Sand Bar Mean Height

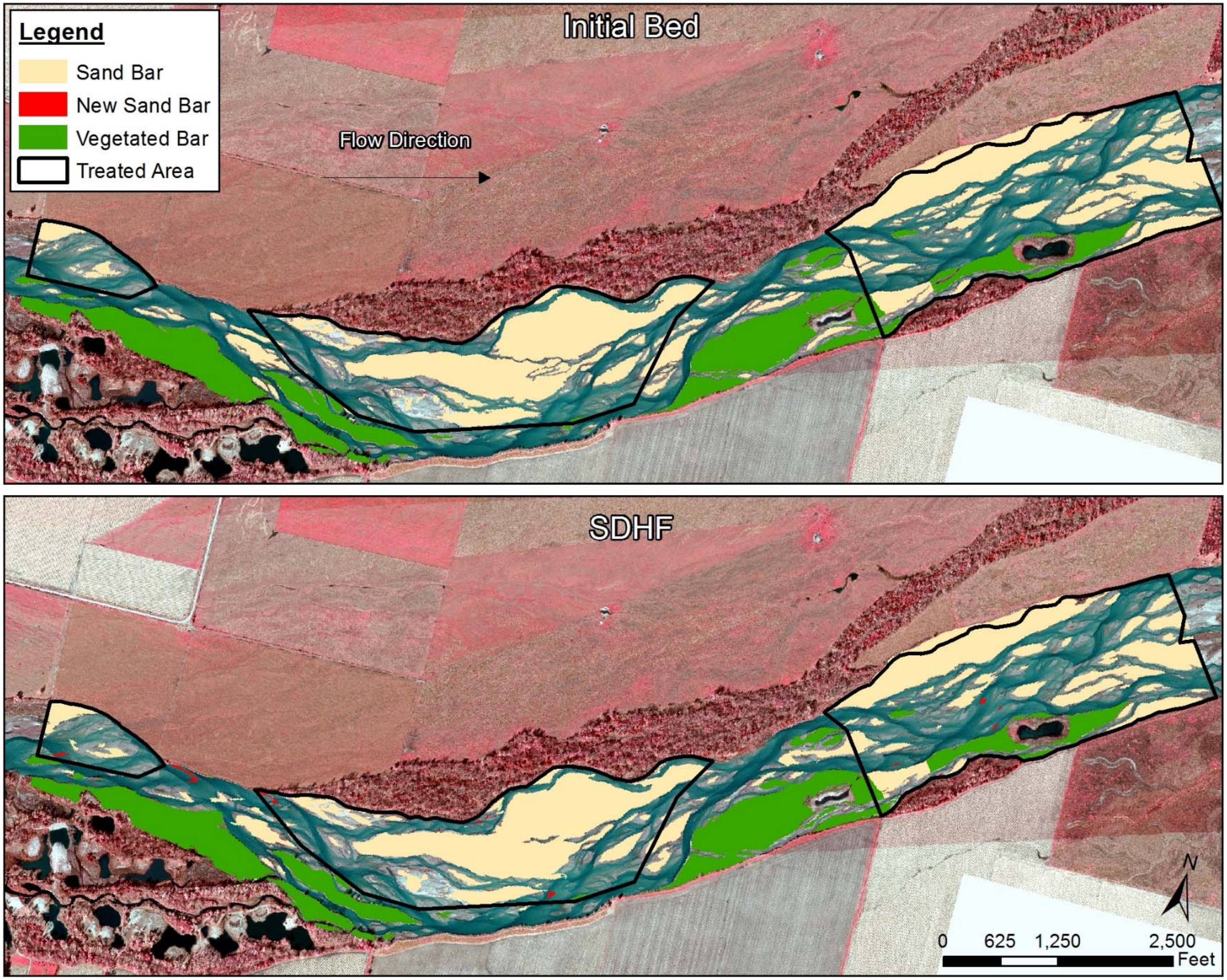


1a) Hydrograph (shape and duration) and sand bar height and area

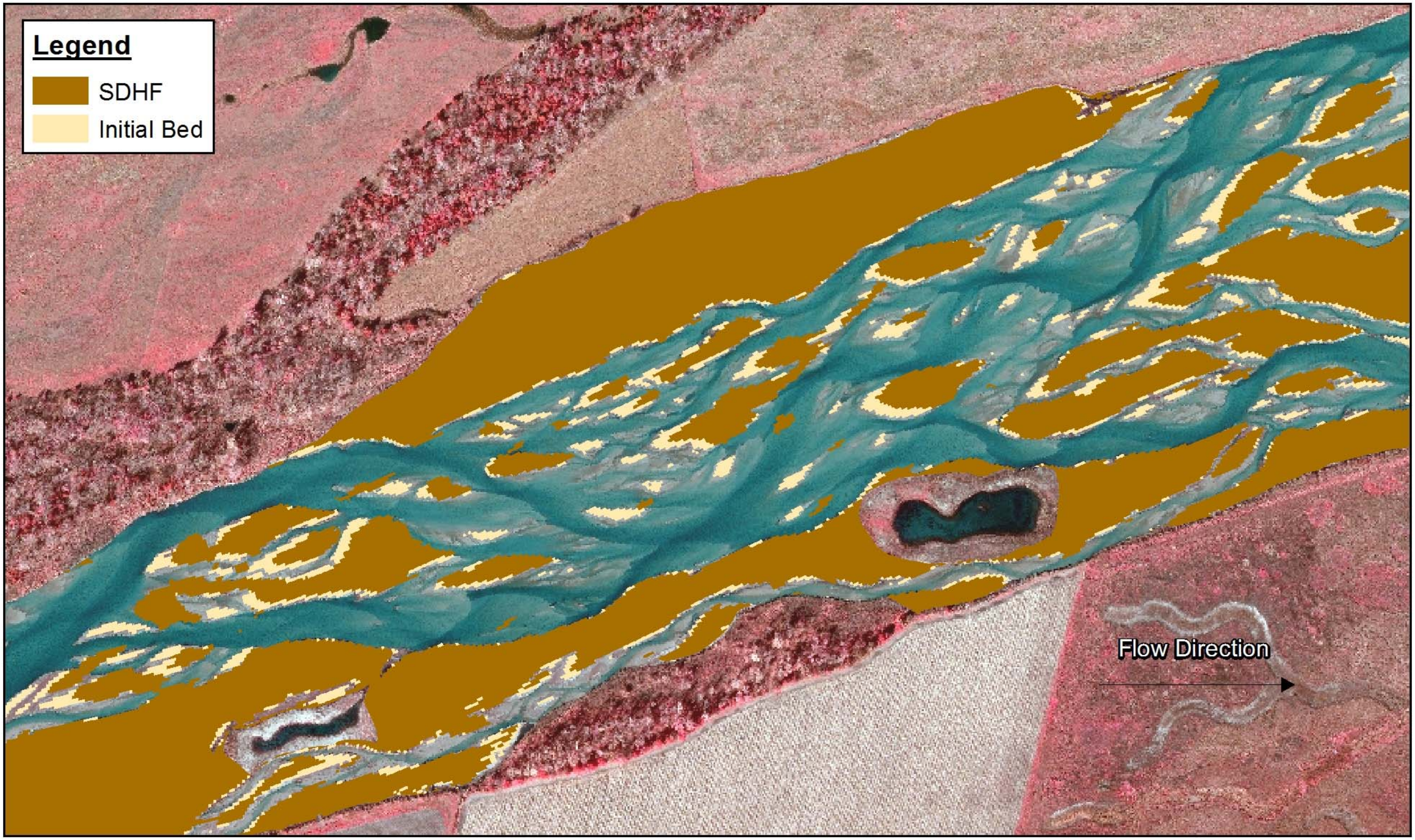
August 2015 Mean Sand Bar and 3-day Peak Discharge Stage



1a) Hydrograph (shape and duration) and sand bar height and area



1a) Hydrograph (shape and duration) and sand bar height and area



1a) Hydrograph (shape and duration) and sand bar height and area

Model Prediction Trends:

Target SDHF (5,000 – 8,000 cfs; 60,000 acre-feet)

Increase in peak flow from 5,000 cfs to 8,000 cfs:

- **More scour and fill occurs during the hydrograph with a higher peak flow and shorter duration.**

1a) Hydrograph (shape and duration) and sand bar height and area

Model Prediction Trends:

Target SDHF (5,000 – 8,000 cfs; 60,000 acre-feet)

Increase in peak flow from 5,000 cfs to 8,000 cfs:

Run	Fill (CY)	Cut (CY)	Net (CY)	
8k60k	71,552	-68,490	3,062	Fill
5k60k	60,229	-58,625	1,604	Fill

1a) Hydrograph (shape and duration) and sand bar height and area

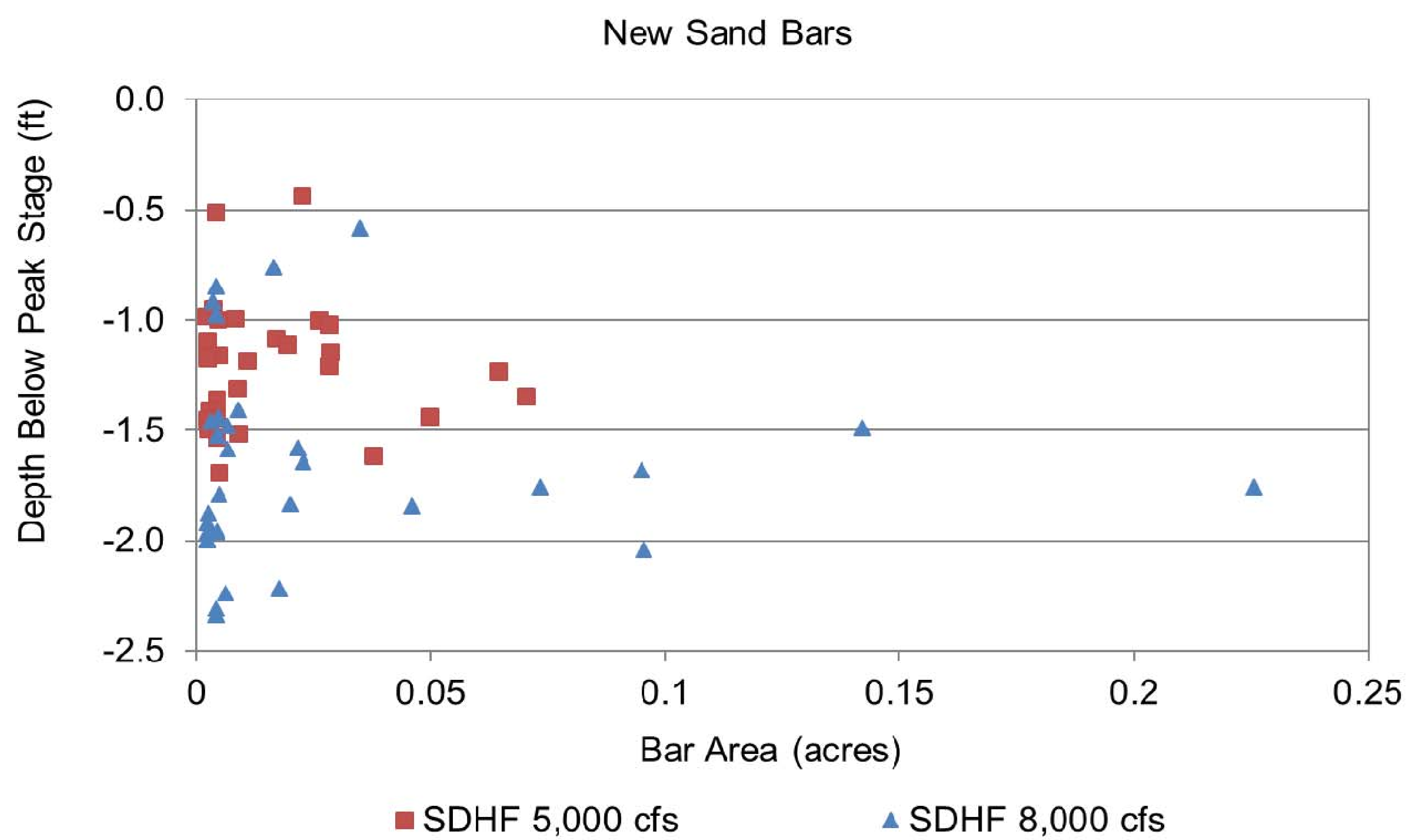
Model Prediction Trends:

Target SDHF (5,000 – 8,000 cfs; 60,000 acre-feet)

Increase in peak flow from 5,000 cfs to 8,000 cfs:

- **More scour and fill occurs during the hydrograph with a higher peak flow and shorter duration.**
- **Bars do not approach the peak stage height during SDHF**

1a) Hydrograph (shape and duration) and sand bar height and area



1a) Hydrograph (shape and duration) and sand bar height and area

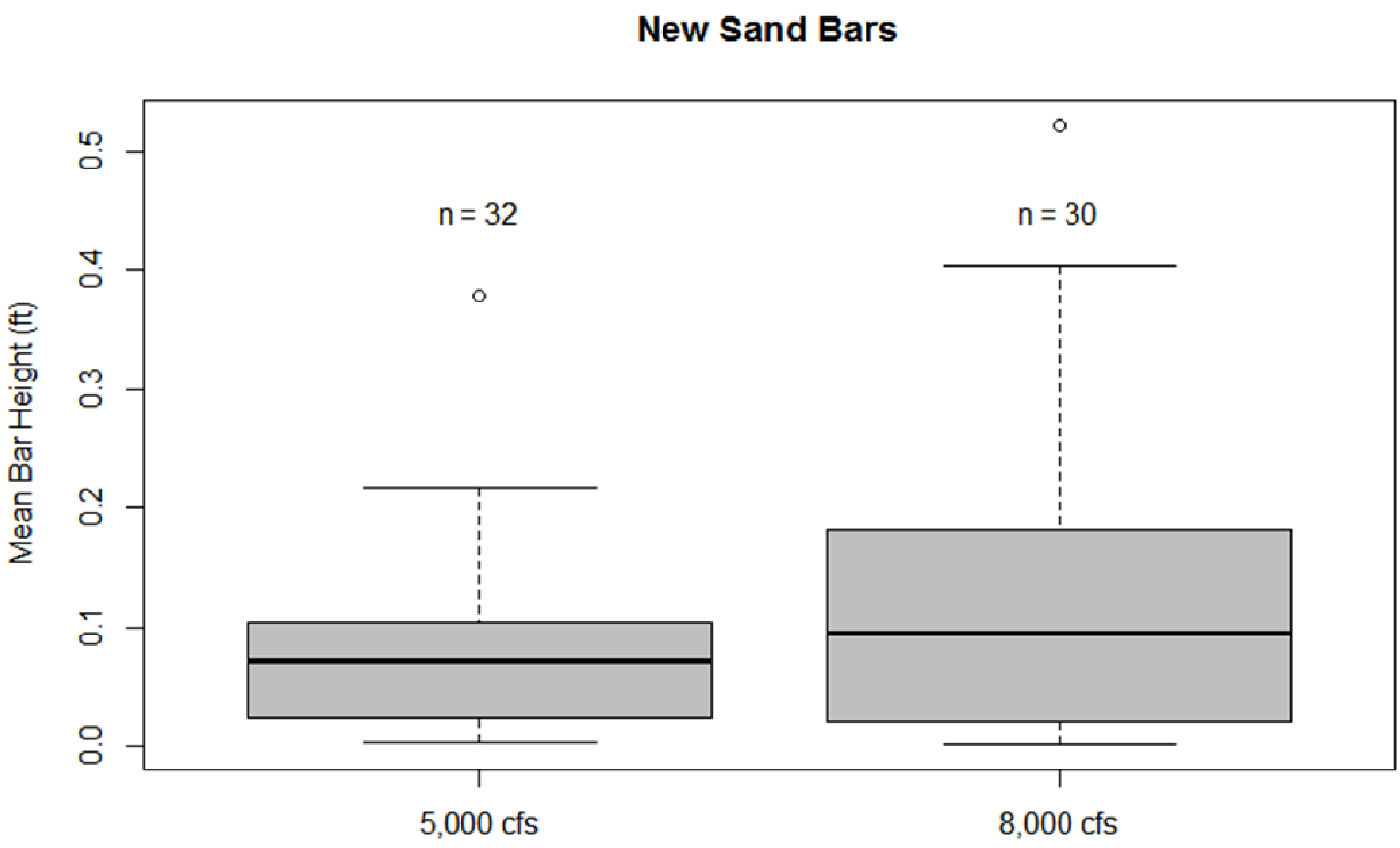
Model Prediction Trends:

Target SDHF (5,000 – 8,000 cfs; 60,000 acre-feet)

Increase in peak flow from 5,000 cfs to 8,000 cfs:

- **More scour and fill occurs during the hydrograph with a higher peak flow and shorter duration.**
- **Bars do not approach the peak stage height during SDHF**
- **No significant increase in bar area or bar height (Mann-Whitney-Wilcoxon Text)**

1a) Hydrograph (shape and duration) and sand bar height and area



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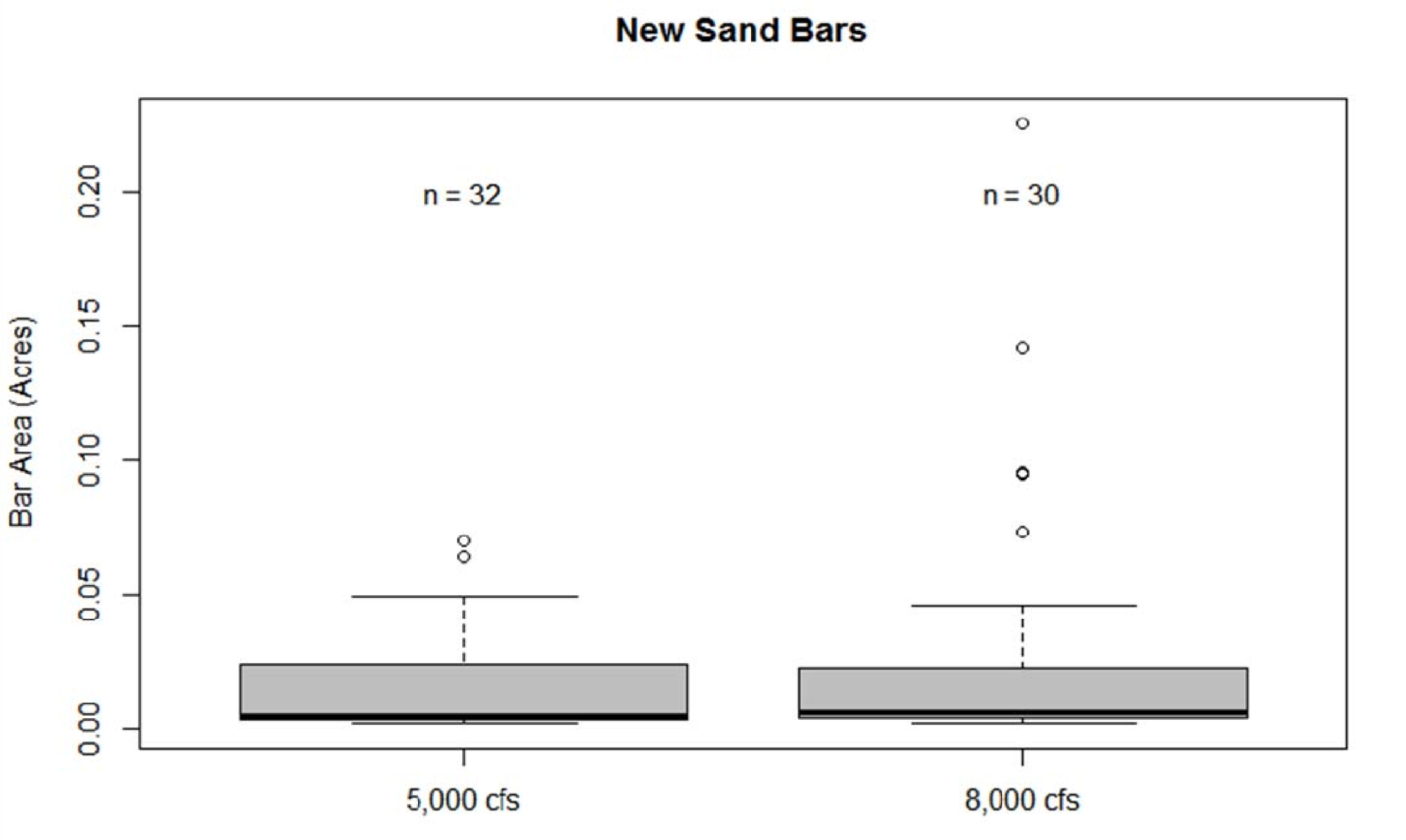


1a) Hydrograph (shape and duration) and sand bar height and area

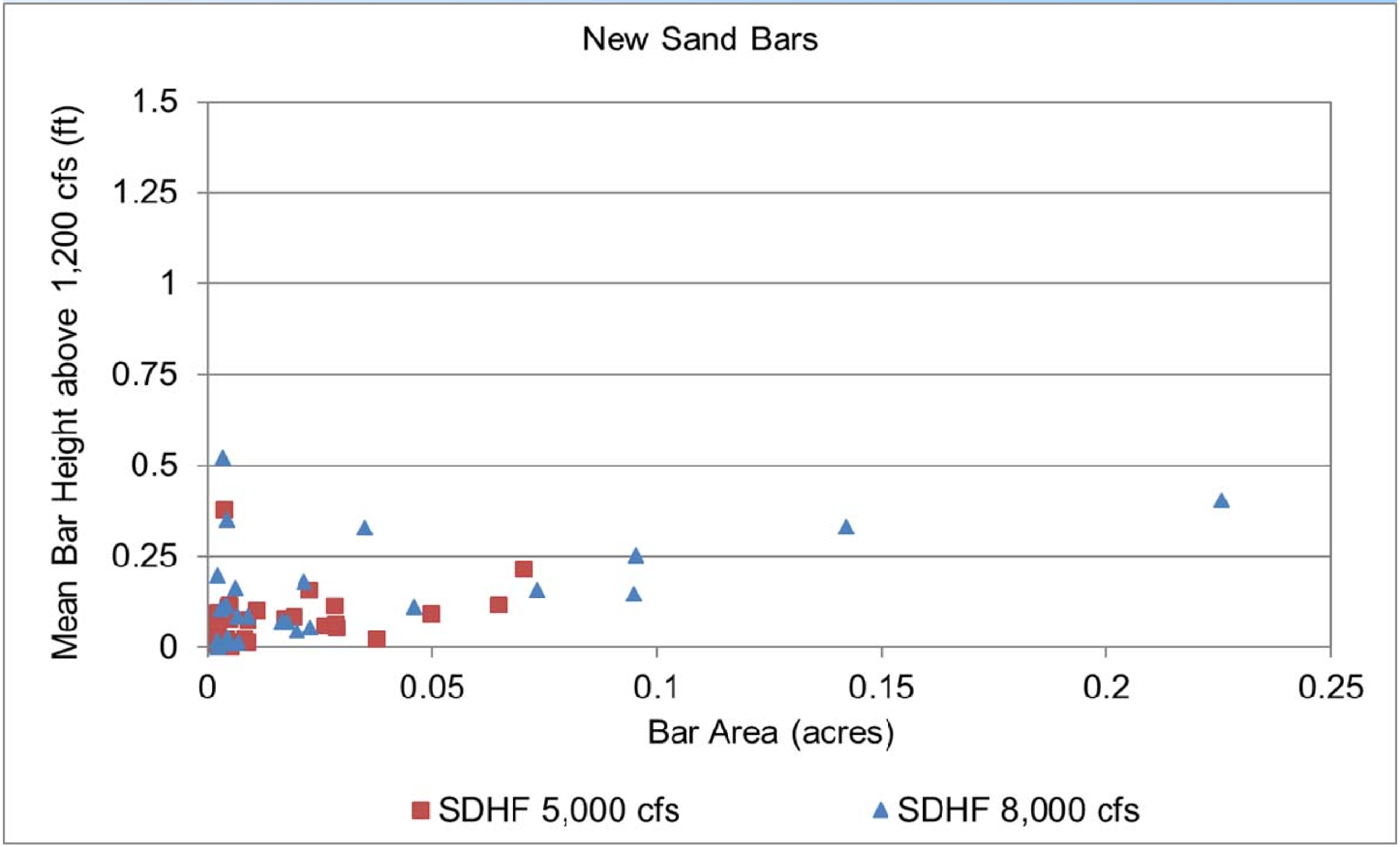
Model Prediction Trends:

Target SDHF (5,000 – 8,000 cfs; 60,000 acre-feet)

Increase in peak flow from 5,000 cfs to 8,000 cfs:

- More scour and fill occurs during the hydrograph with a higher peak flow and shorter duration.
- Bars do not approach the peak stage height during SDHF
- No significant increase in bar area or bar height (Mann-Whitney-Wilcoxon Text)
- New bars are all less than 0.25 ac and average height is less than 1.5 feet above 1,200 cfs water level

1a) Hydrograph (shape and duration) and sand bar height and area



Experiment Learning Objectives

Evaluate FSM management actions ability to achieve management objectives:

1. **Evaluate the relationship between peak flows (magnitude and duration) and sand bar height and area by:**
   b) **Sediment supply and frequency of sand bar occurrence**
      - **Mobile-bed model predictions for target SDHF**

1b) Sediment Supply and Frequency of Sand Bar Occurrence

Model Predictions Trends (In progress)

Target SDHF (8,000 cfs; 60,000 acre-feet)

Sediment supply (1/2x, 1x (Equilibrium), 2x)

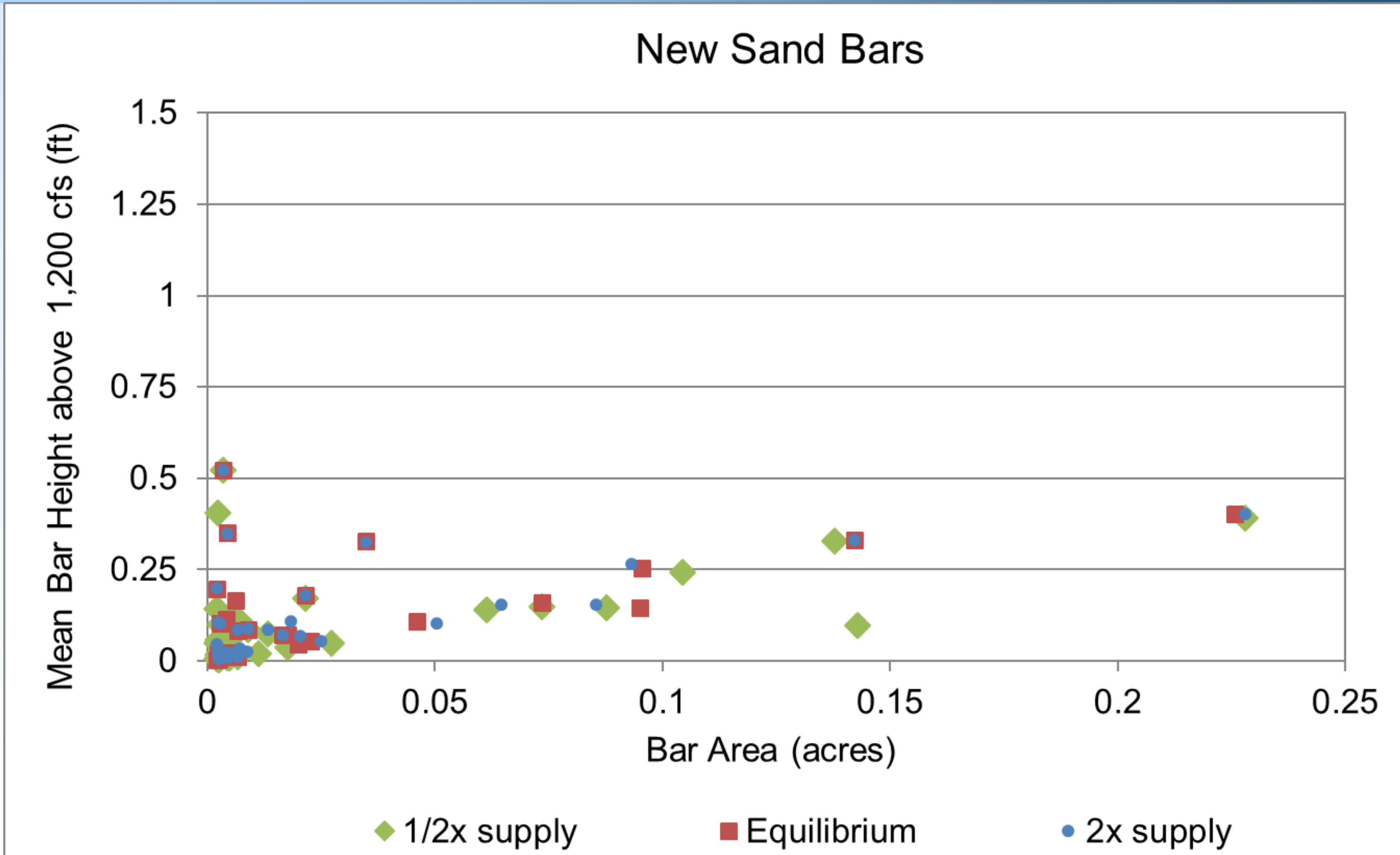
Increase in sediment supply:

- **EFDC: No change in number of new bars**
- **FM: no significant change (1 bar difference between ½ and 2x sediment supply)**

Most of the change occurs near the supply point, downstream relatively unaffected during a single SDHF event.

Longer duration or multiple events may give different results.

1b) Sediment Supply and Frequency of Sand Bar Occurrence

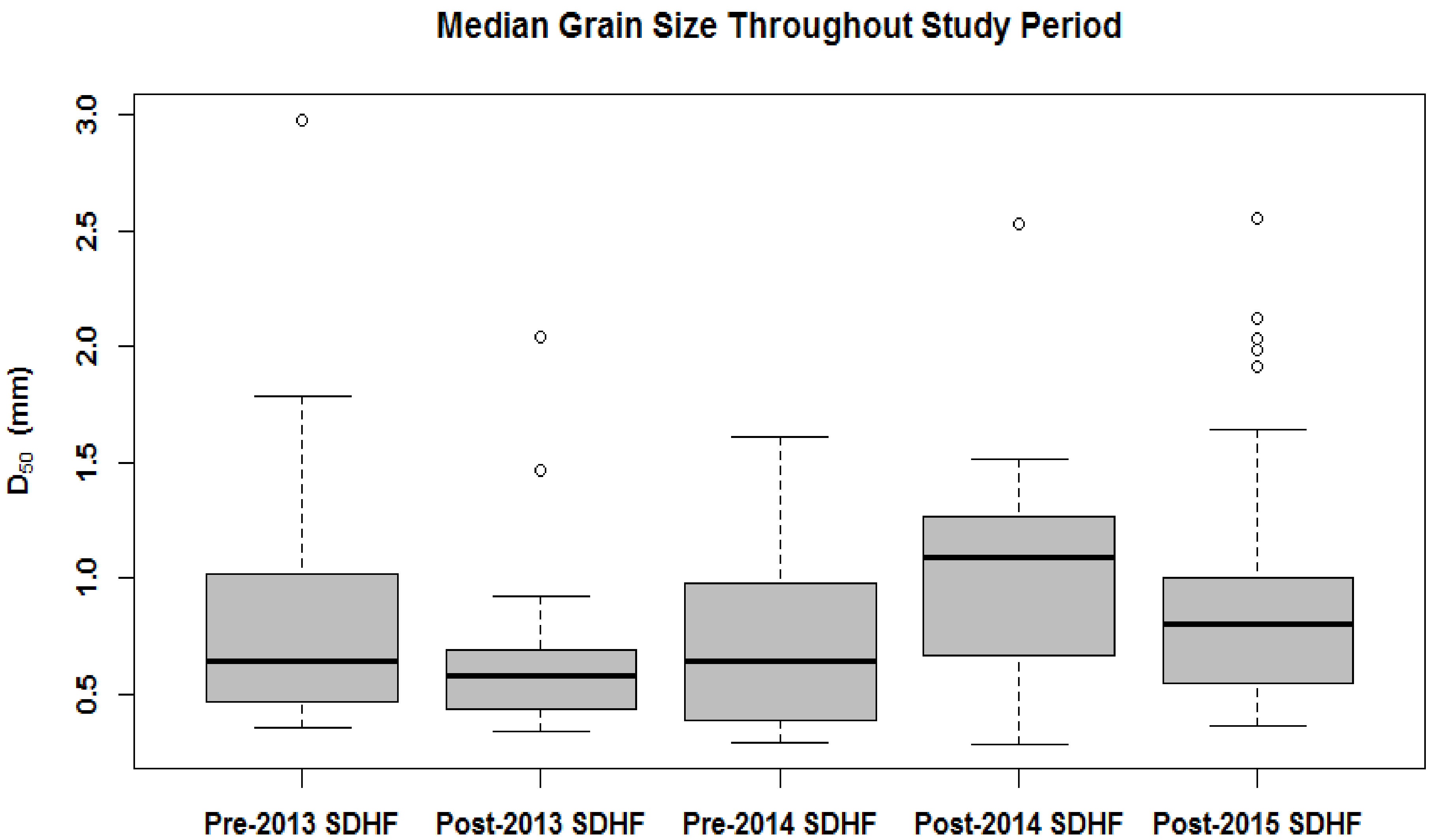


Experiment Learning Objectives

Evaluate FSM management actions ability to achieve management objectives:

1. **Evaluate the relationship between peak flows (magnitude and duration) and sand bar height and area by:**
   c) **Grain size and sand bar height**
      - **Mobile-bed model predictions for target SDHF**

1c) Grain size and sand bar height and area



1c) Grain size and sand bar height and area

Model Prediction Trends:

SDHF (8,000 cfs; 60,000 acre-feet)

Grain sizes evaluated (0.75 mm, 1 mm, 2 mm)

Increase in grain size:

- **More transport occurs when the bed is finer resulting in higher cut and fill volumes**

1c) Grain size and sand bar height and area

Model Predictions Trends:

Target SDHF (8,000 cfs; 60,000 acre-feet)

Grain sizes evaluated (0.75 mm, 1 mm, 2 mm)

Run	Fill (CY)	Cut (CY)	Net (CY)	
2 mm	56,114	-52,462	3,652	Fill
1 mm	93,586	-89,582	4,005	Fill
0.75 mm	114,398	-109,922	4,476	Fill

1c) Grain size and sand bar height and area

Model Prediction Trends:

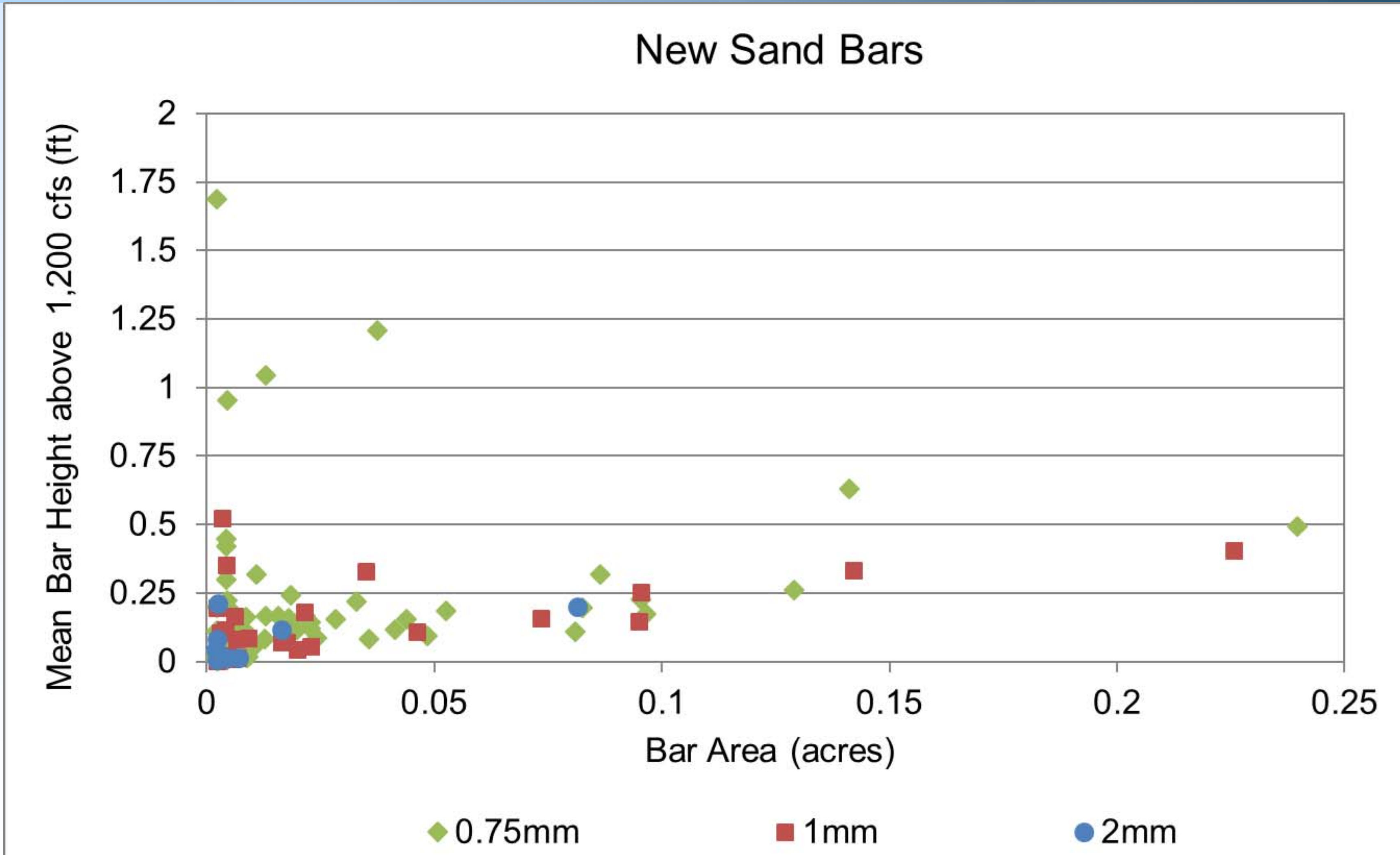
Target SDHF (5,000 – 8,000 cfs; 60,000 acre-feet)

Grain sizes evaluated (0.75 mm, 1 mm, 2 mm)

Increase in grain size:

- More transport occurs when the bed is finer resulting in higher cut and fill volumes
- More bars are created when the bed is finer.
- A few new bars are created that approach 1.5 feet or 0.25 acres at smaller grain sizes, but there is no statistical difference in bar height or bar area (Kruskal-Wallis Test)

1c) Grain size and sand bar height and area



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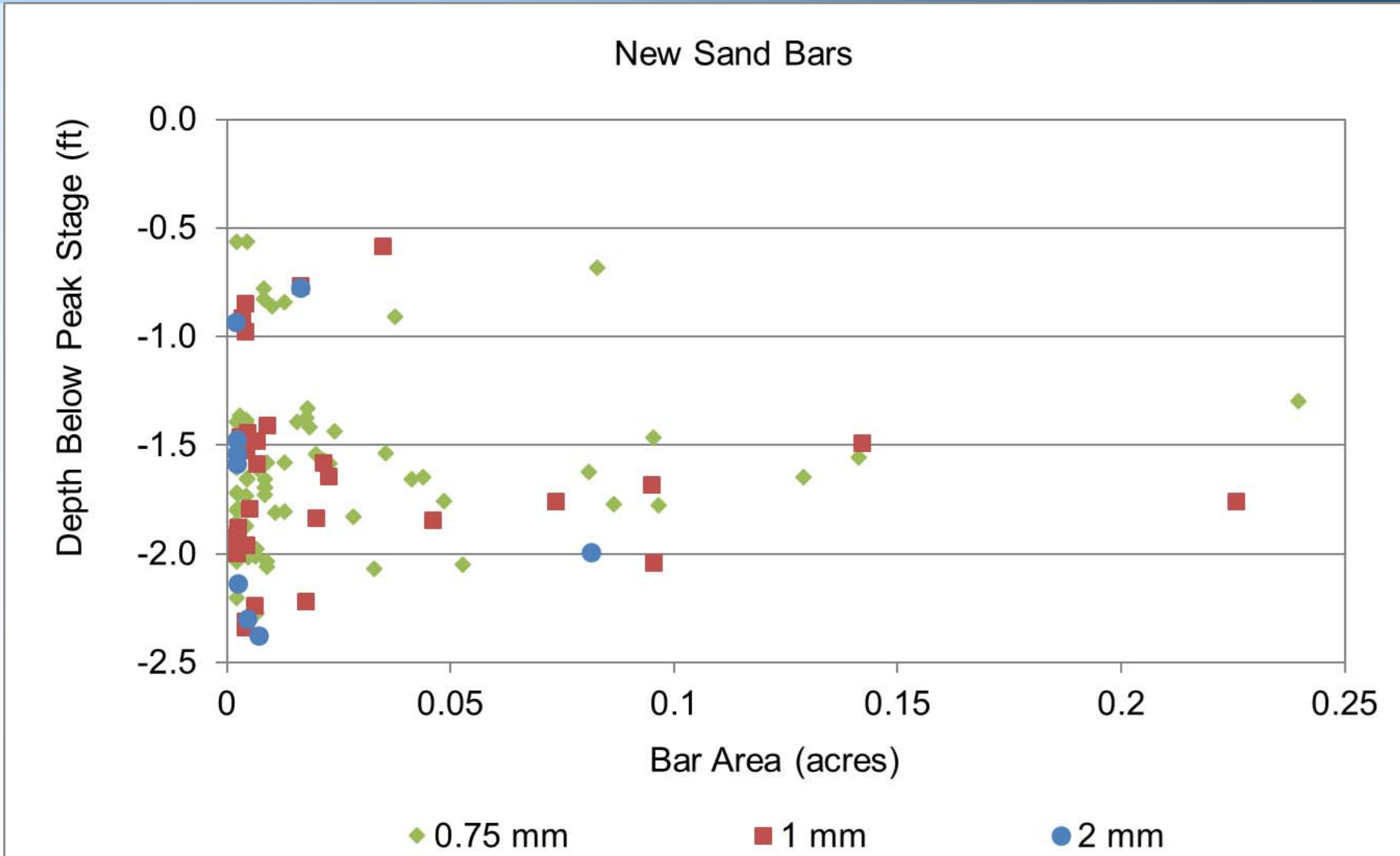

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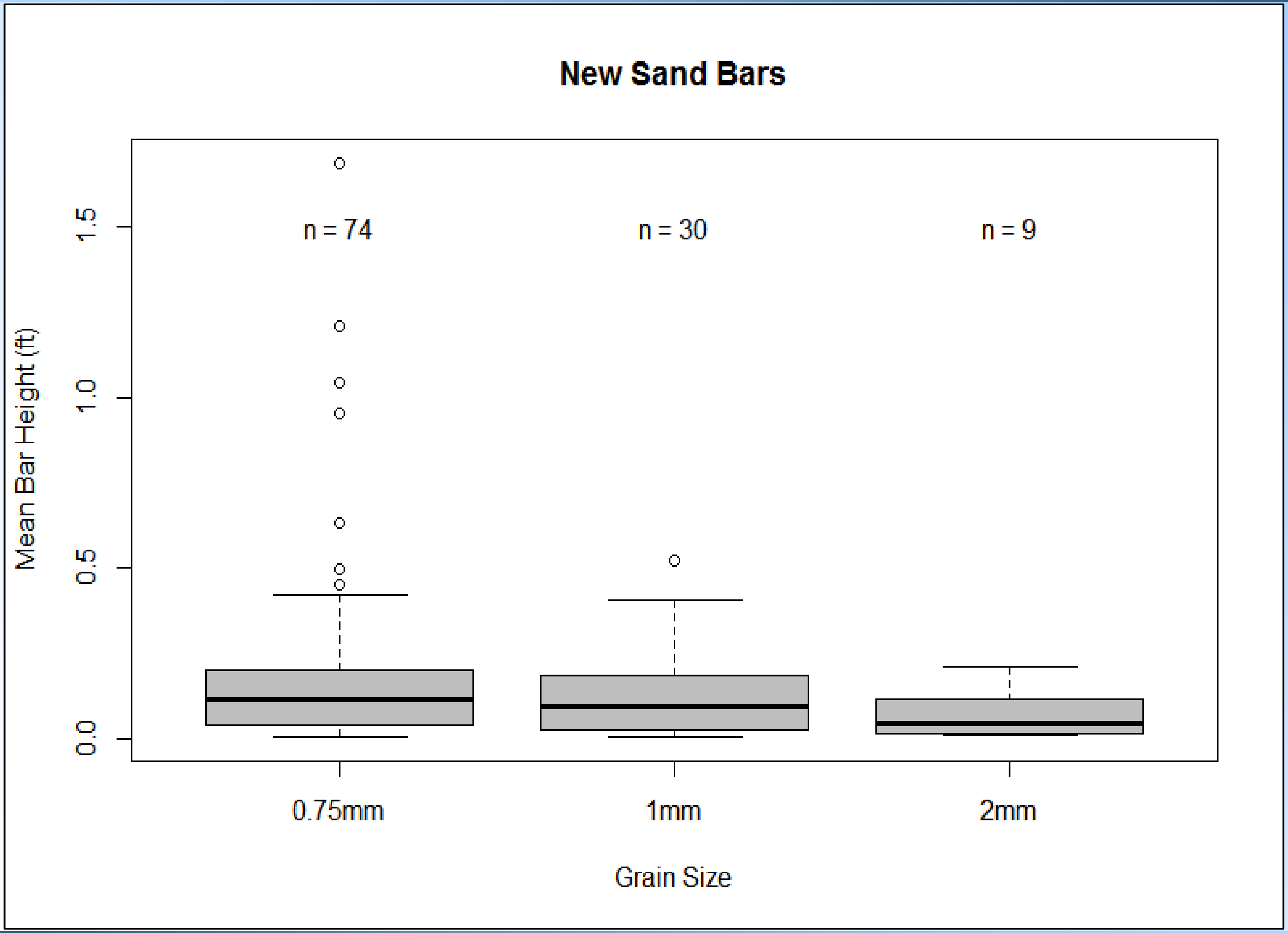

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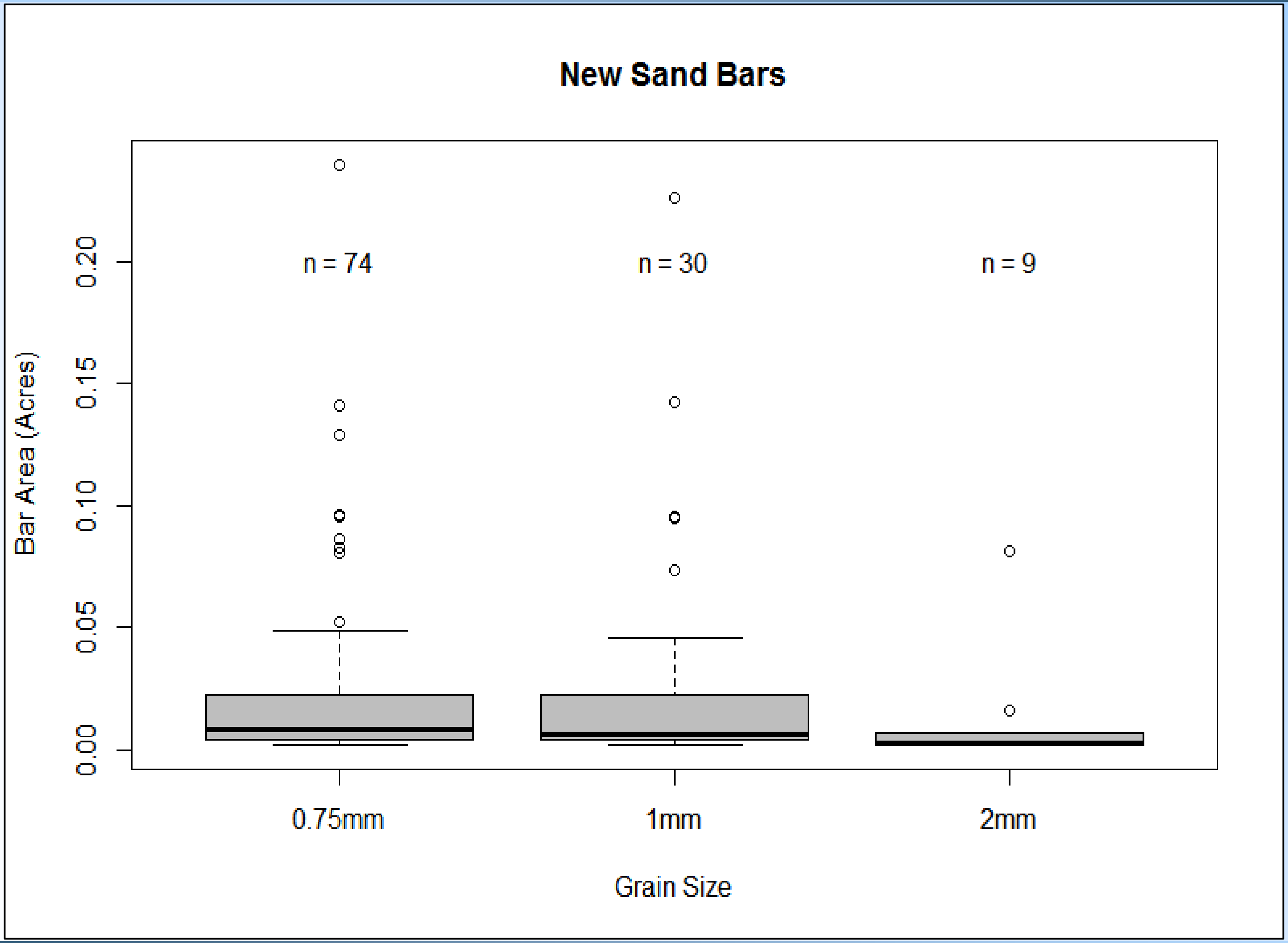


Experiment Learning Objectives

Evaluate FSM management actions ability to achieve management objectives:

2. **Evaluate the relationship between peak flows (magnitude and duration) and riparian plant mortality.**
    - **Direct measurements**
    - **Modeling:**
        - **Bank erosion**
        - **Vertical scour**
        - **Uprooting through vegetation drag**

2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality

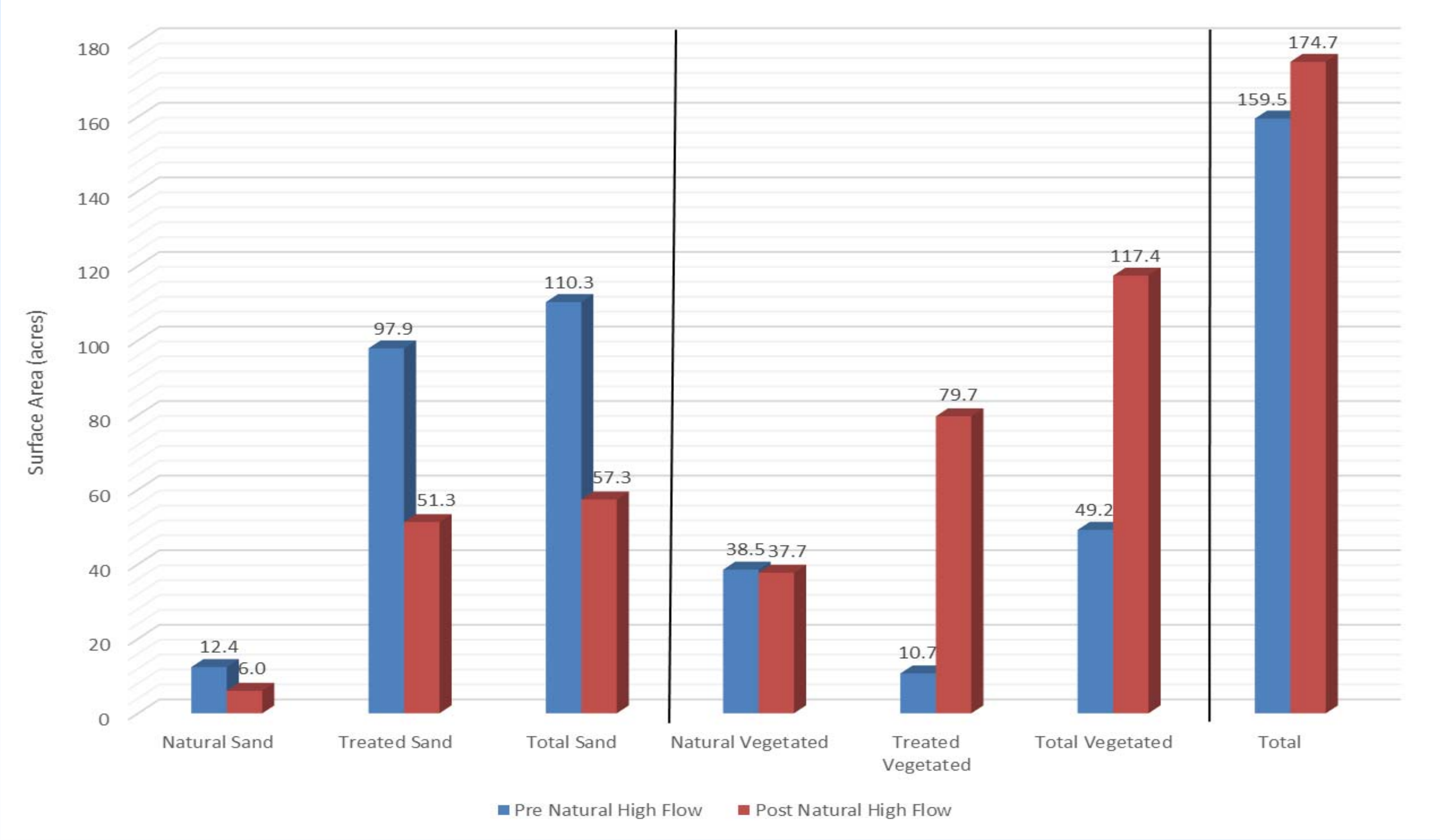
Bar Suitability for least tern and plover habitat include:

- **A sand bar is a bar whose area above 1,200 cfs TRF stage is 20% or less vegetated.**

The 2013 SDMF was not of significant magnitude or duration to modify/create or alter vegetated bars in the Shoemaker study reach.

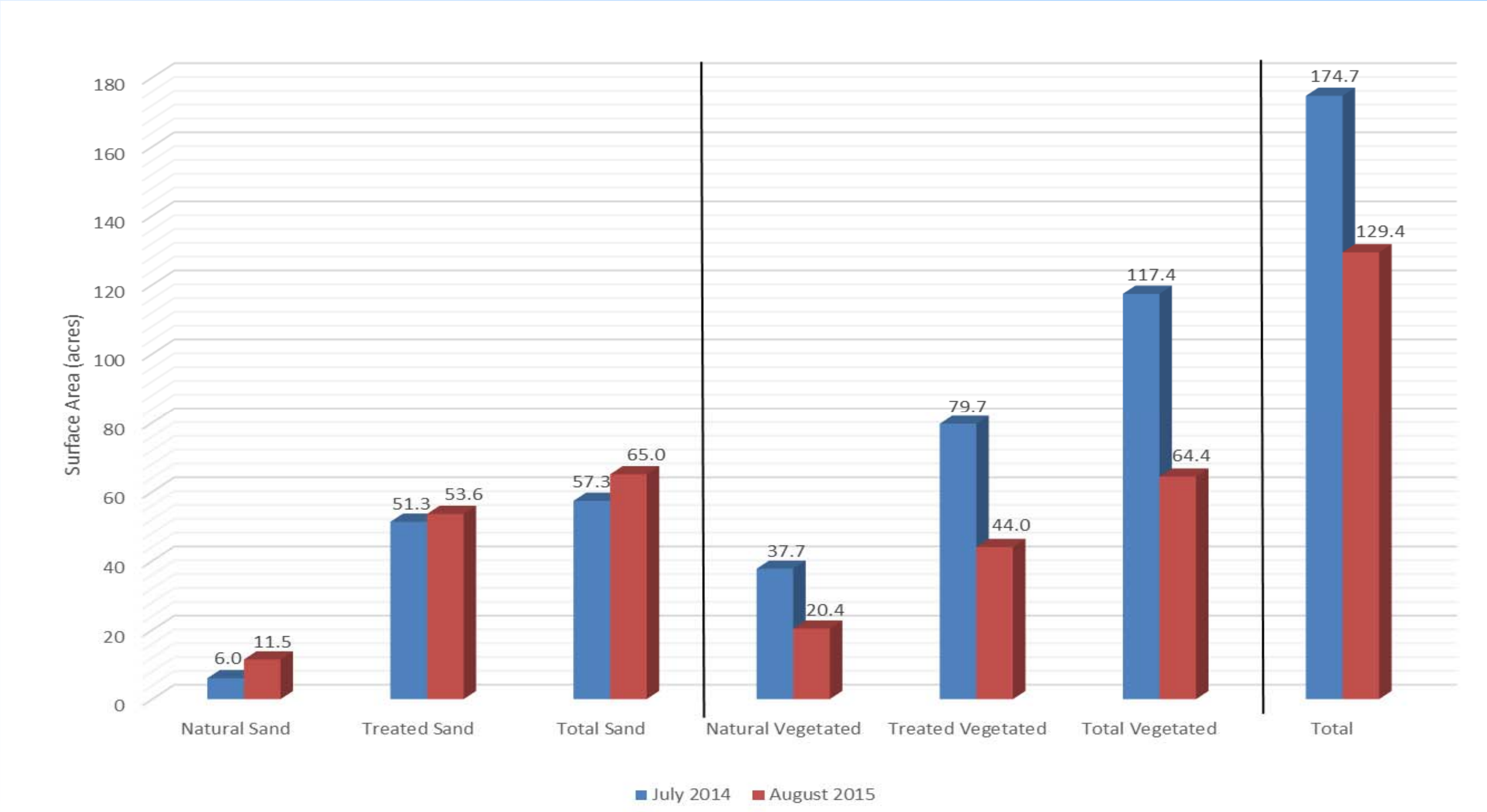
2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality

June 2014 Post High Flow Vegetated Bars



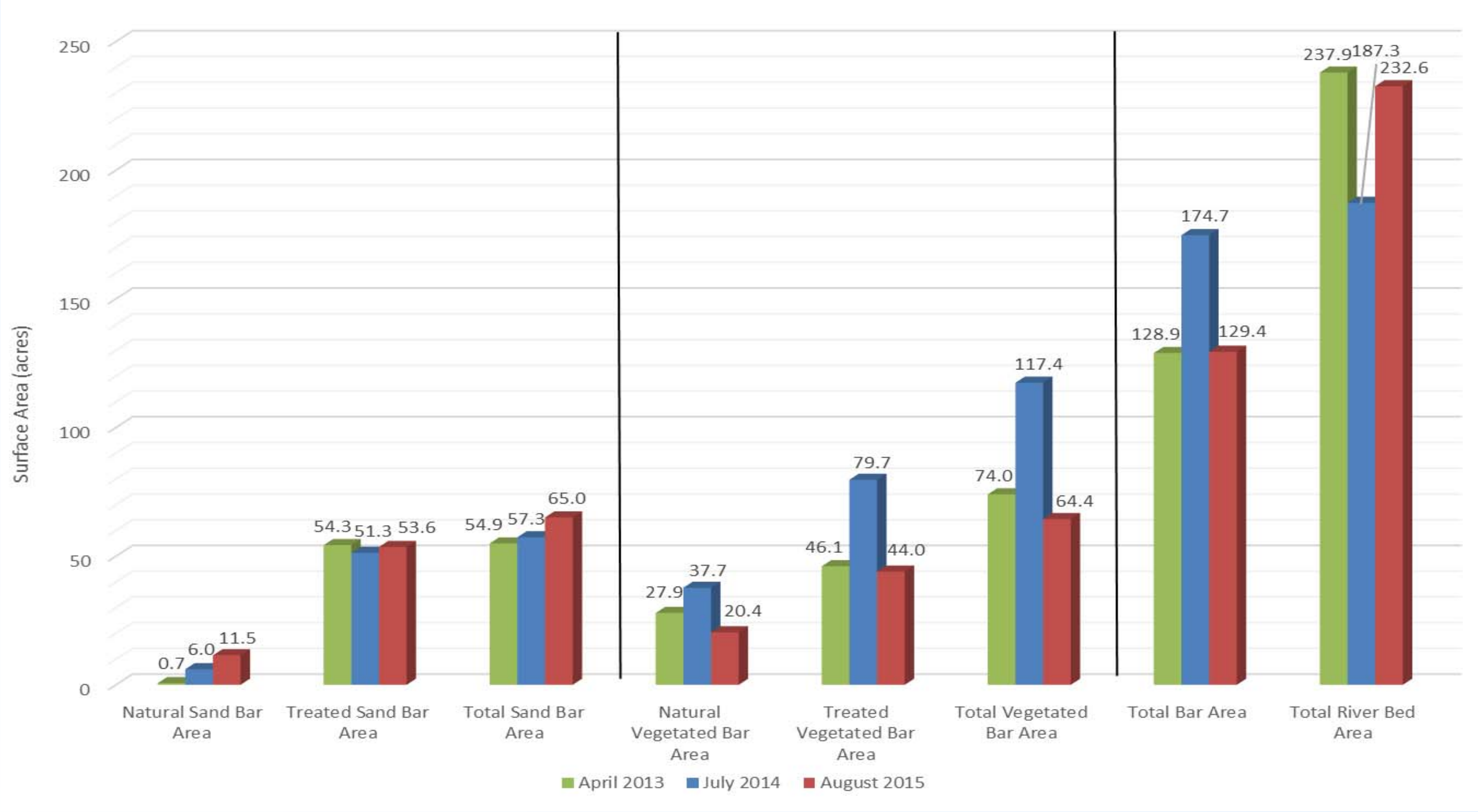
2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality

June 2015 Post High Flow Vegetated Bars



2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality

April 2013, July 2014, and August 2015 Bar/River Area

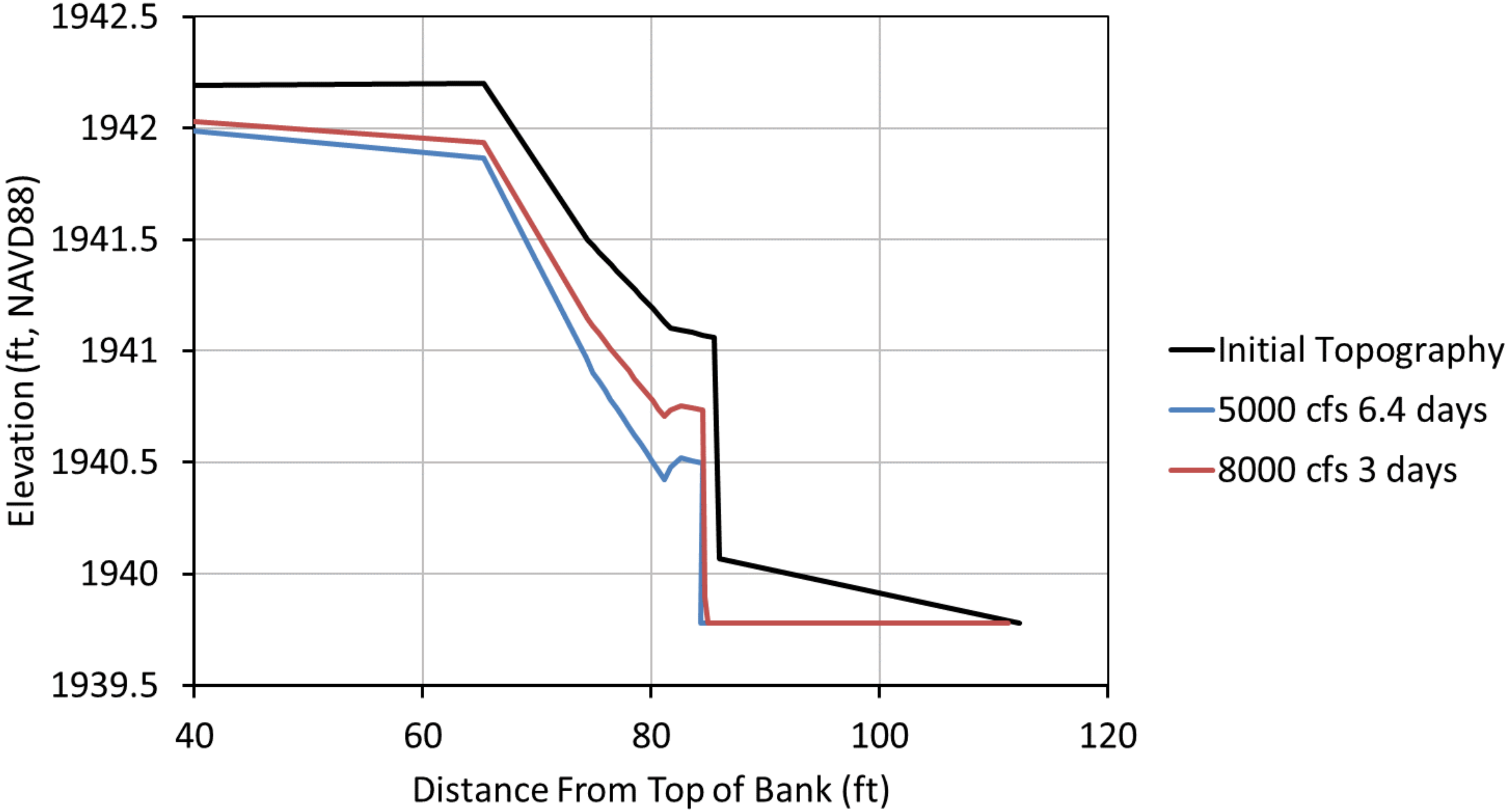


2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality

2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality

- Lateral erosion (Observed and Predicted)
  - Substantial lateral erosion of vegetated bars can occur if roots are shallow (observed and predicted).
  - Minor difference in lateral erosion for proposed hydrograph shapes of similar flow volume (8,000 cfs for 3 days ~= 5,000 cfs 6.4 days).

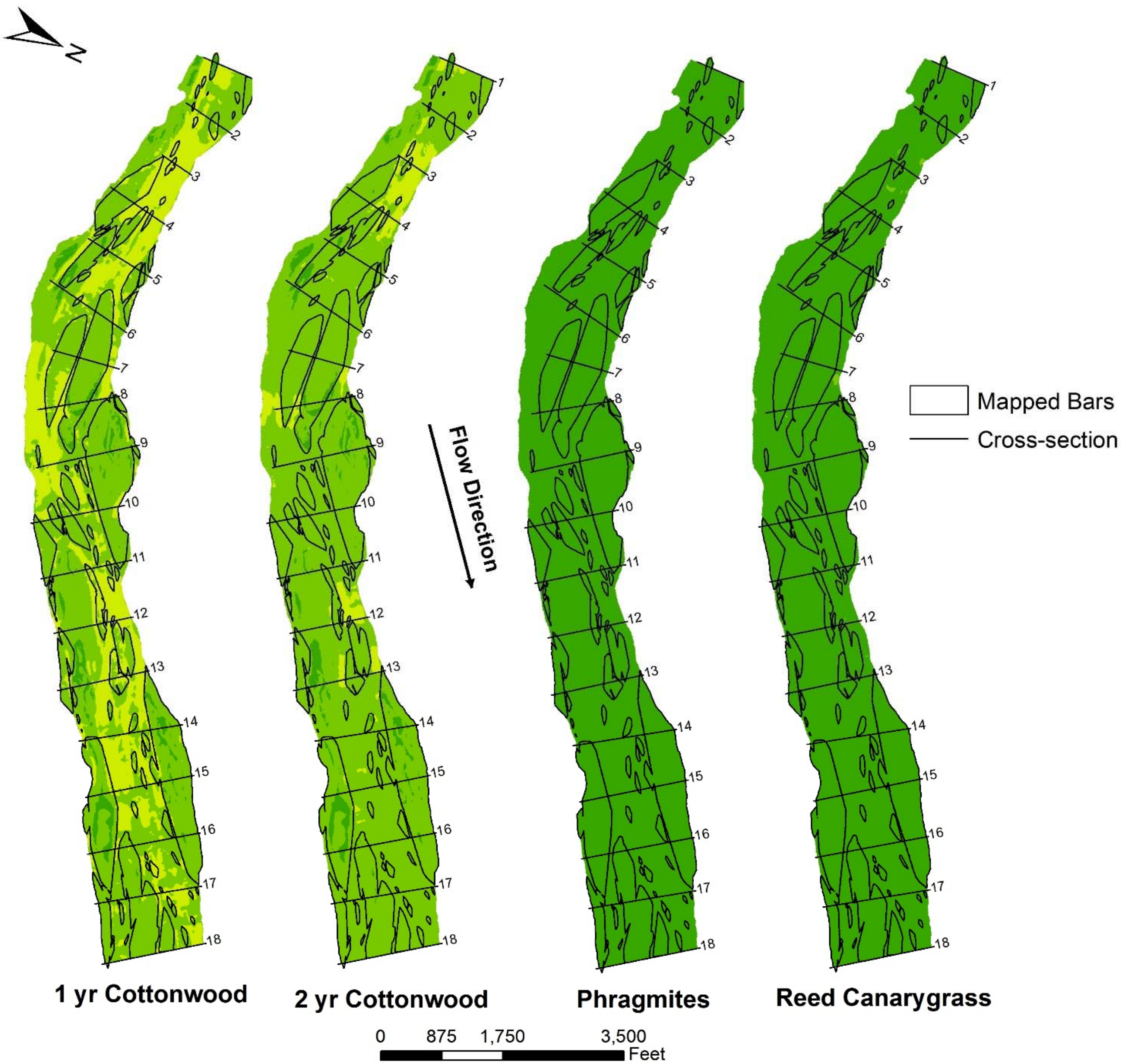
2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality



2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality

- Uprooting potential from drag forces during SDHF
  - Flow is insufficient to initiate uprooting of reed canary grass and phragmites. Some uprooting of young cottonwoods is predicted.

2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality



Velocity (feet/sec)

1-yr Cottonwood
- **< 0.007 (no uprooting)**
- 0.007 - 2.694 (uprooting initiated)
- 2.694 - 5.384
- 5.384 - 8.071
- 8.071 - 10.761
- **> 10.761 (all plants uprooted)**

2-yr Cottonwood
- **< 0.023 (no uprooting)**
- 0.023 - 3.507 (uprooting initiated)
- 3.507 - 8.15
- 8.15 - 15.262
- 15.262 - 20.341
- **> 20.341 (all plants uprooted)**

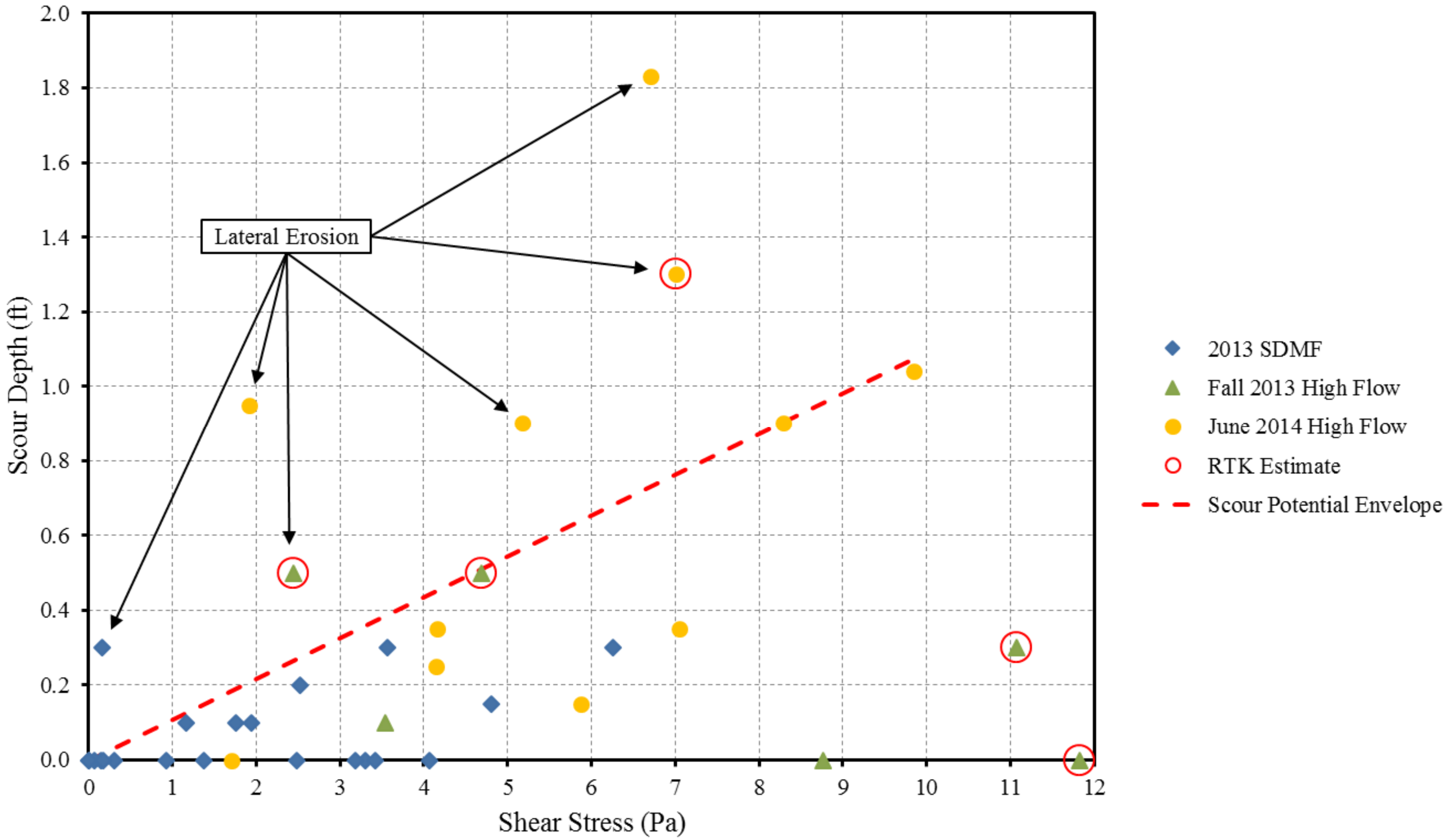
Phragmites
- **< 34.777 (no uprooting)**
- 34.777 - 43.389 (uprooting initiated)
- 43.389 - 52.001
- 52.001 - 60.614
- 60.614 - 69.226
- **> 69.226 (all plants uprooted)**

Reed Canarygrass
- **< 4.396 (no uprooting)**
- 4.396 - 10.509 (uprooting initiated)
- 10.509 - 16.617
- 16.617 - 22.73
- 22.730 - 28.839
- **> 28.839 (all plants uprooted)**

2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality

- Vertical Scour
  - Method:
    - Estimated scour potential using a relation between predicted shear stress and measured scour depth from scour chains installed throughout the project site
    - Estimated scour from mobile bed model
  - Vertical scour for SDHF is generally less than ~ 1 foot

2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality



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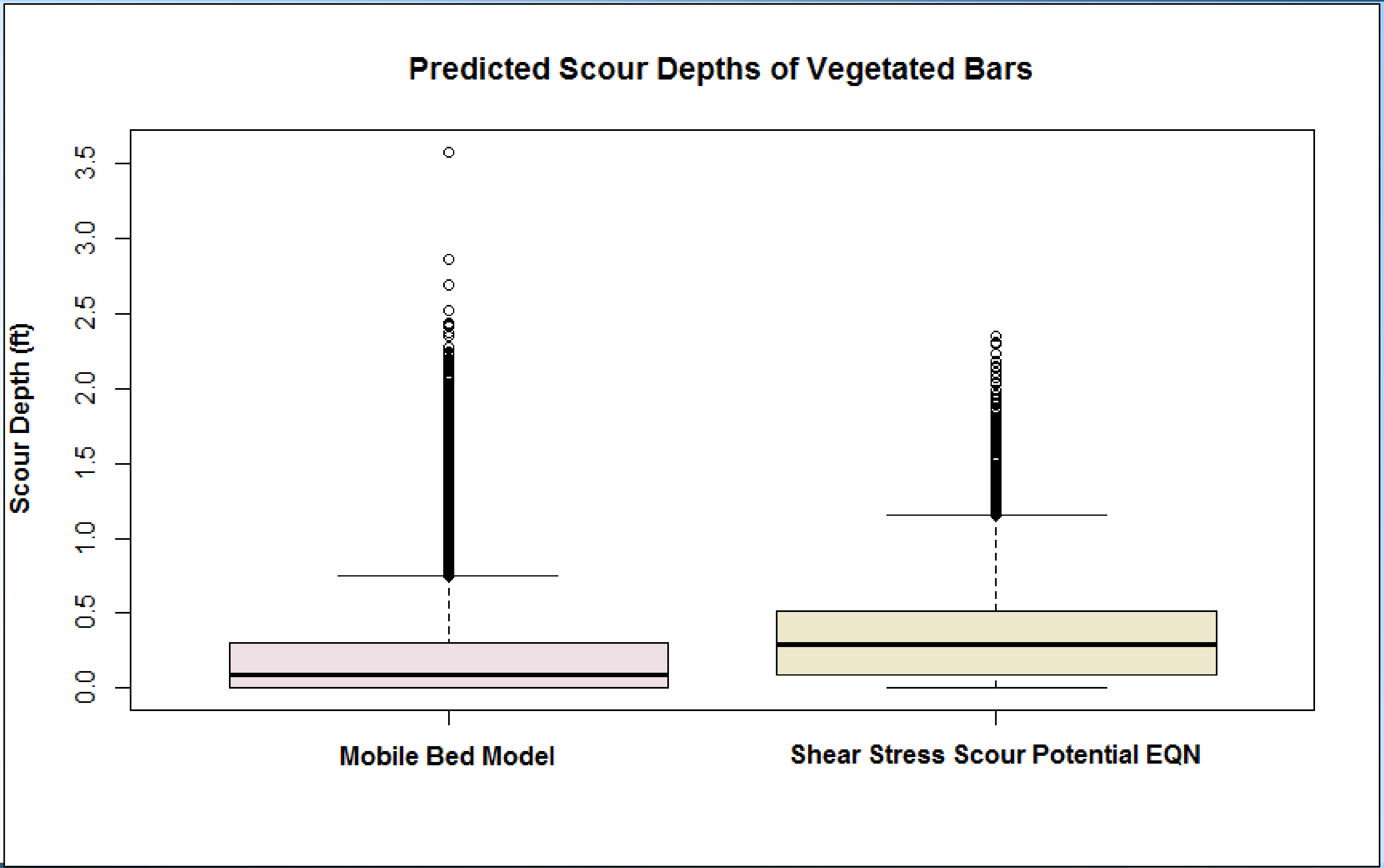
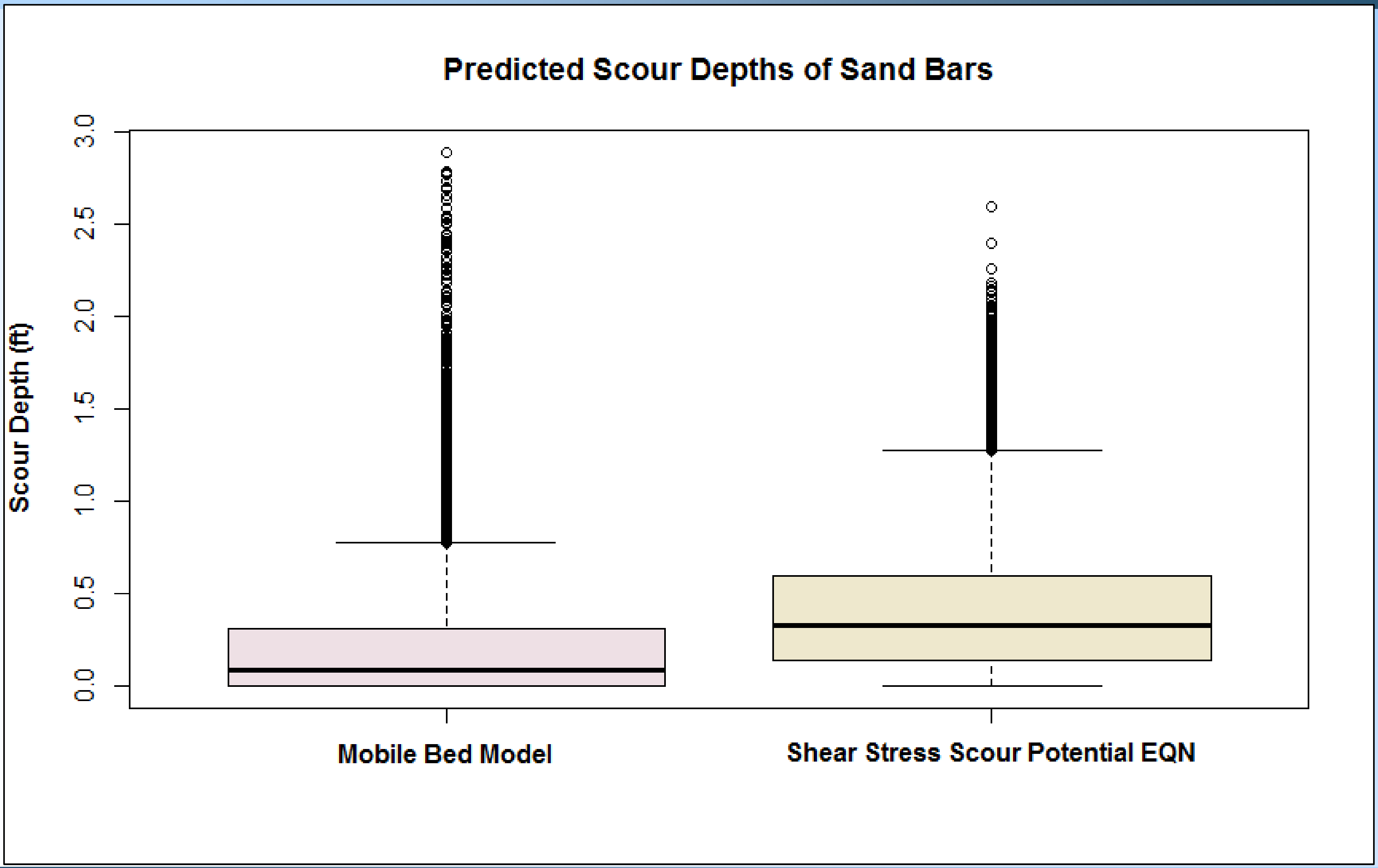


2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality



2) Peak Flows (Magnitude and Duration) and Riparian Plant Mortality

Conclusions:

- Drag forces, vertical scour and lateral erosion are expected to have a small impact on riparian plant mortality during a SDHF.
- Of the three processes, lateral erosion appears to have the highest potential for mortality.
- Observed differences in vegetation are due to:
  - Timing of the vegetation surveys
  - Timing of flow event

Experiment Learning Objectives

Evaluate FSM management actions ability to achieve management objectives:

3. **Evaluate ability of FSM management strategy to create and/or maintain habitat for whopping cranes, least terns, and piping plovers.**

3) Ability of FSM Management Strategy to Create/Maintain Habitat

June 2015 High Flow Event:

- instantaneous peak discharge of 16,100 cfs
- 3-day mean peak discharge of 15,700 cfs TRF
- TRF volume of 1.231 million acre feet (for flows over 2,000 cfs)
- peak discharge exceeded the Program-defined SDHF event of 5,000 to 8,000 cfs by 196%
- exceeded the SDHF defined volume (50,000 to 75,000 acre-feet) by 1,641%
- June 2015 high flow increased the depth of water above the 1,200 cfs TRF stage by 2.59 feet to 4.05 feet.
- June 2015 high flow was >2,000 cfs TRF for 72 days and >8,000 cfs TRF for 43 days.

3) Ability of FSM Management Strategy to Create/Maintain Habitat

June 2015 High Flow Event Sand Bars

- July 2014 survey documented:
  - 40 sand bars, >0.25 acres w/ aerial coverage of 48.5 acres
  - 103 sand bars, <0.25 acres w/ aerial coverage of 8.8 acres

- August 2015 Survey Documented:
  - 23 sand bars, >0.25 acres w/ aerial coverage of 59.6 acres
  - 87 sand bars, <0.25 acres w/ aerial coverage of 5.5 acres

- Test are the August 2015 mean sand bar heights significantly different than the July 2014 mean sand bar height?

3) Ability of FSM Management Strategy to Create/Maintain Habitat

Mean height for sand bars >0.25 acres is equal to the mean height of sand bars <0.25 acres.

Variable		n	M	SD	df	t	p
July 2014 Mean Bar Height	<0.25 acres	103	0.22	0.11	141	-5.14	0.000
	>0.25 acres	40	0.36	0.21			
August 2015 Mean Bar Height	<0.25 acres	87	0.16	0.13	108	-8.99	0.000
	>0.25 acres	23	0.52	0.28			

Mean height of sand bars >0.25 acres is significantly higher than the mean height of sand bars <0.25 acres in July 2014 and August 2015.

3) Ability of FSM Management Strategy to Create/Maintain Habitat

Mean height for sand bars <0.25 acres in July 2014 is equal to August 2015 mean sand bar height.

Variable		n	M	SD	df	t	p
Mean Height of Bars <0.25 acres	July 2014	103	0.22	0.11	188	3.6	0.000
	August 2015	87	0.16	0.13			

Mean height of sand bars <0.25 acres is significantly higher in July 2014 than August 2015.

3) Ability of FSM Management Strategy to Create/Maintain Habitat

Mean height for sand bars >0.25 acres in July 2014 is equal to August 2015 mean sand bar height.

Variable		n	M	SD	df	t	p
Mean Heigh of Bars >0.25 acres	July 2014	40	0.36	0.21	61	-2.59	0.012
	August 2015	23	0.52	0.28			

Mean height of sand bars >0.25 acres is significantly higher in August 2015 than July 2014.

3) Ability of FSM Management Strategy to Create/Maintain Habitat

Mean height for all sand bars in July 2014 is equal to August 2015 mean sand bar height.

Variable		n	M	SD	df	t	p
Mean Height of All Sand Bars	July 2014	143	0.26	0.16	251	1.13	0.259
	August 2015	110	0.23	0.23			

Mean height of sand bars July 2014 are similar to the mean height of sand bars in August 2015.

3) Ability of FSM Management Strategy to Create/Maintain Habitat

Flow Conclusion:

- Mean height of sand bars >0.25 acres increased by ~2 inches from from July 2014 to August 2015.
- Mean height of sand bars <0.25 acres decreased slightly July 2014 to August 2015.
- The June 2015 high flow did not significantly increase sand bar height to ≥1.5 ft above 1,200 cfs TRF preferred tern and plover bar height.

3) Ability of FSM Management Strategy to Create/Maintain Habitat

Sediment Load:

			Net	
	Bedload, tons	Suspended, tons	Tons	CY
2013 High flow	12,500	15,200	27,700	19,400
2013 Fall High Flow	93,300	77,000	170,000	119,000
2014 High Flow	49,500	49,800	99,300	69,000
2015 High Flow	461,000	510,000	971,000	674,000

3) Ability of FSM Management Strategy to Create/Maintain Habitat

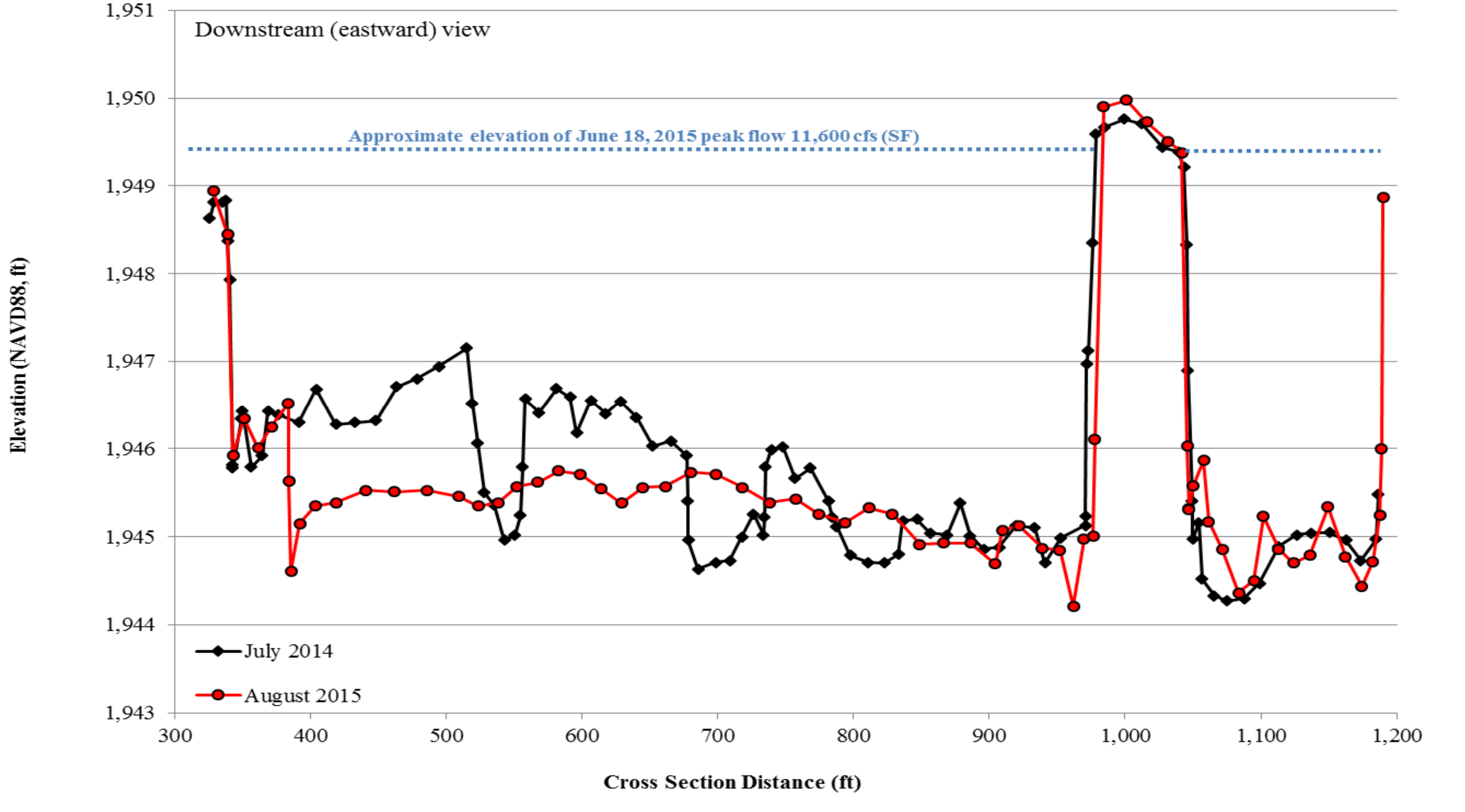
Sediment: Volume change (cubic yards) was estimated using the average end area method for the Primary (n=18) and Supplemental (n=19) Cross Sections

	Cross Sections	Cut	Fill	Net
2013 High flow	n=18	92,000	76,000	- 16,000
2013 Fall High Flow	n=18	109,000	192,000	+ 83,000
2014 High Flow	n=37	140,600	130,300	- 10,300
2015 High Flow	n=37	234,900	282,900	+ 48,000

Three year net deposition of **+ 104,700 Cubic Yards**

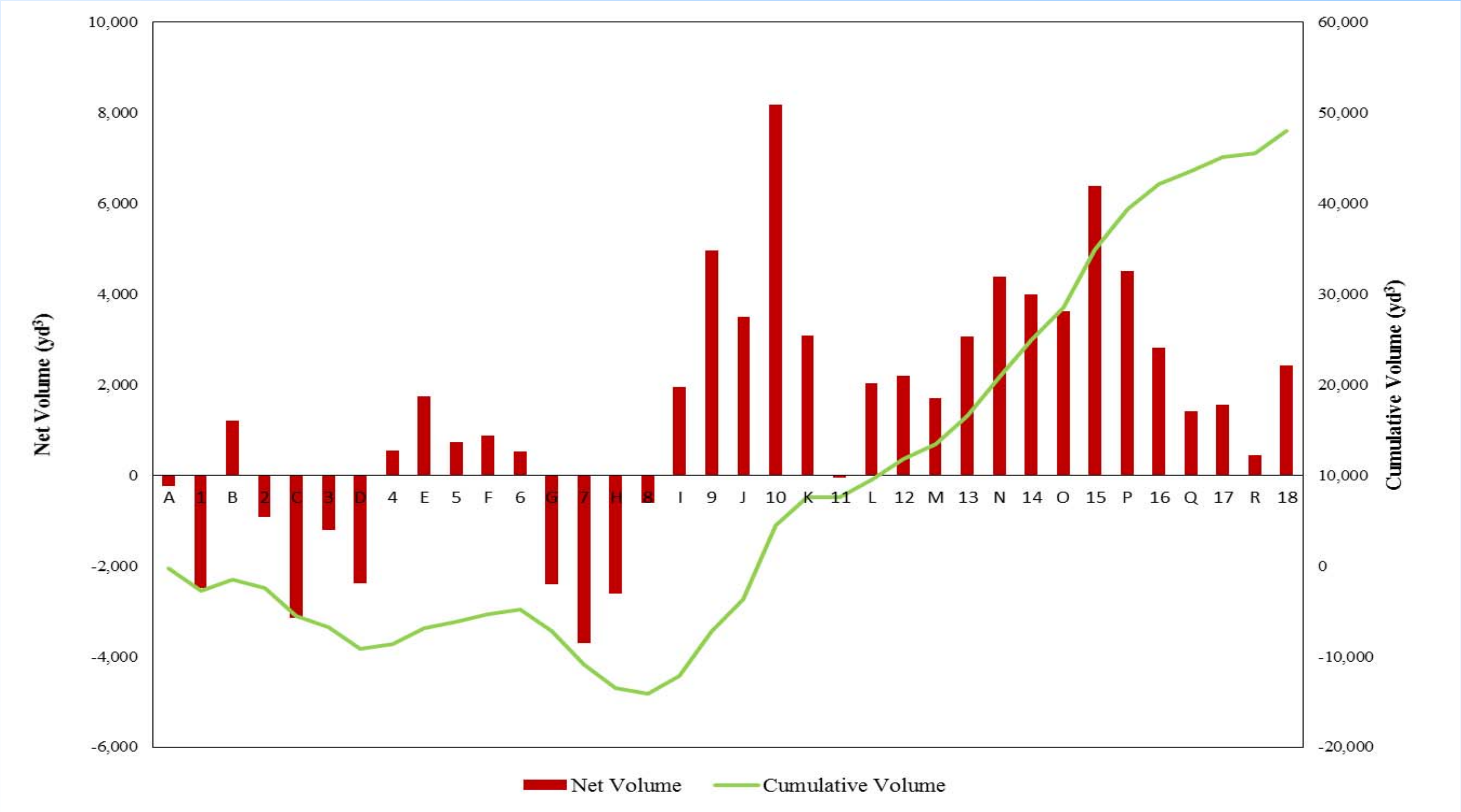
3) Ability of FSM Management Strategy to Create/Maintain Habitat

Typical Cross Section Bottom Profile – July 2014 and August 2015

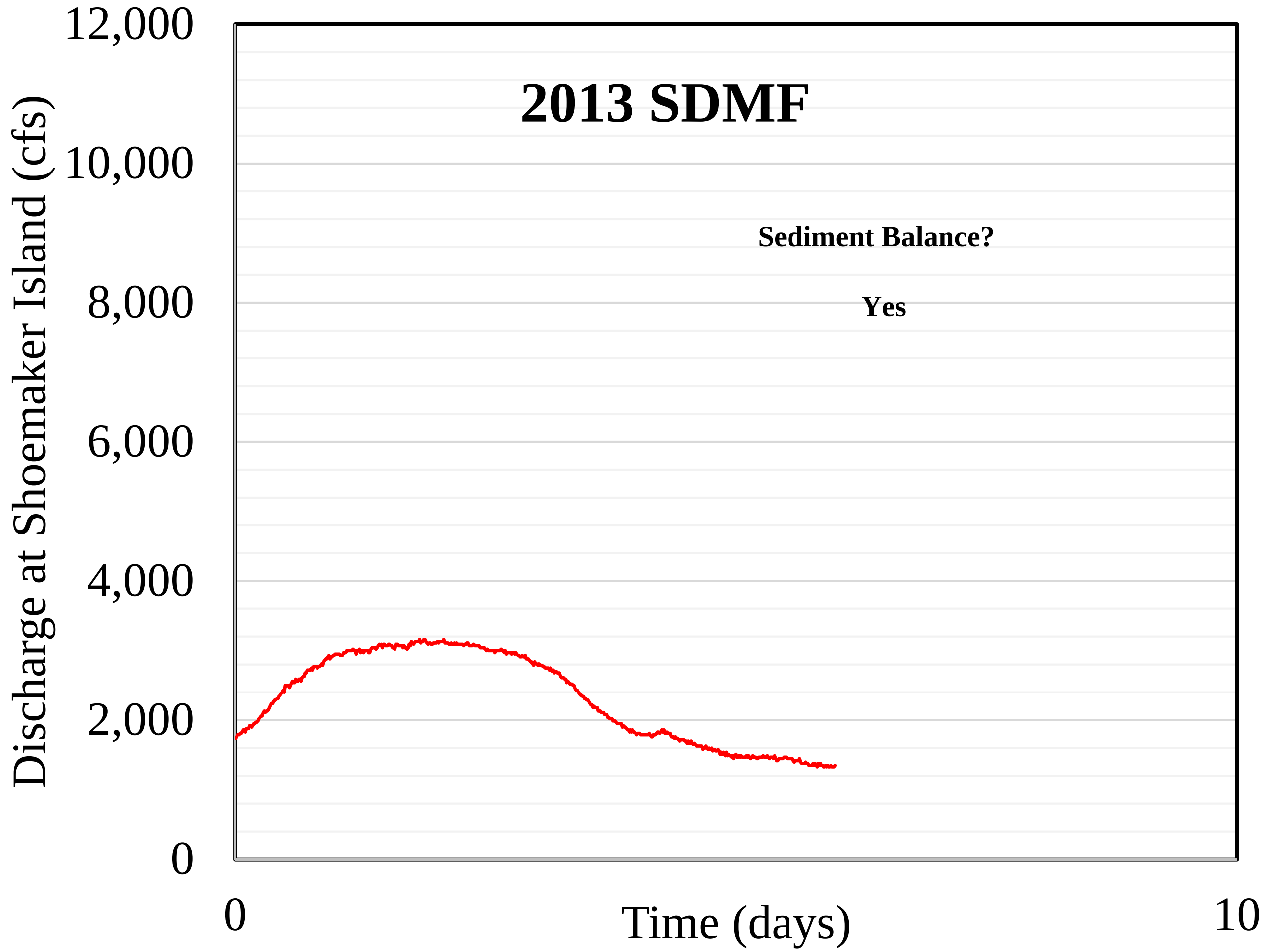


3) Ability of FSM Management Strategy to Create/Maintain Habitat

2015 Spring Flow Event Volume Change at 37 Cross Sections

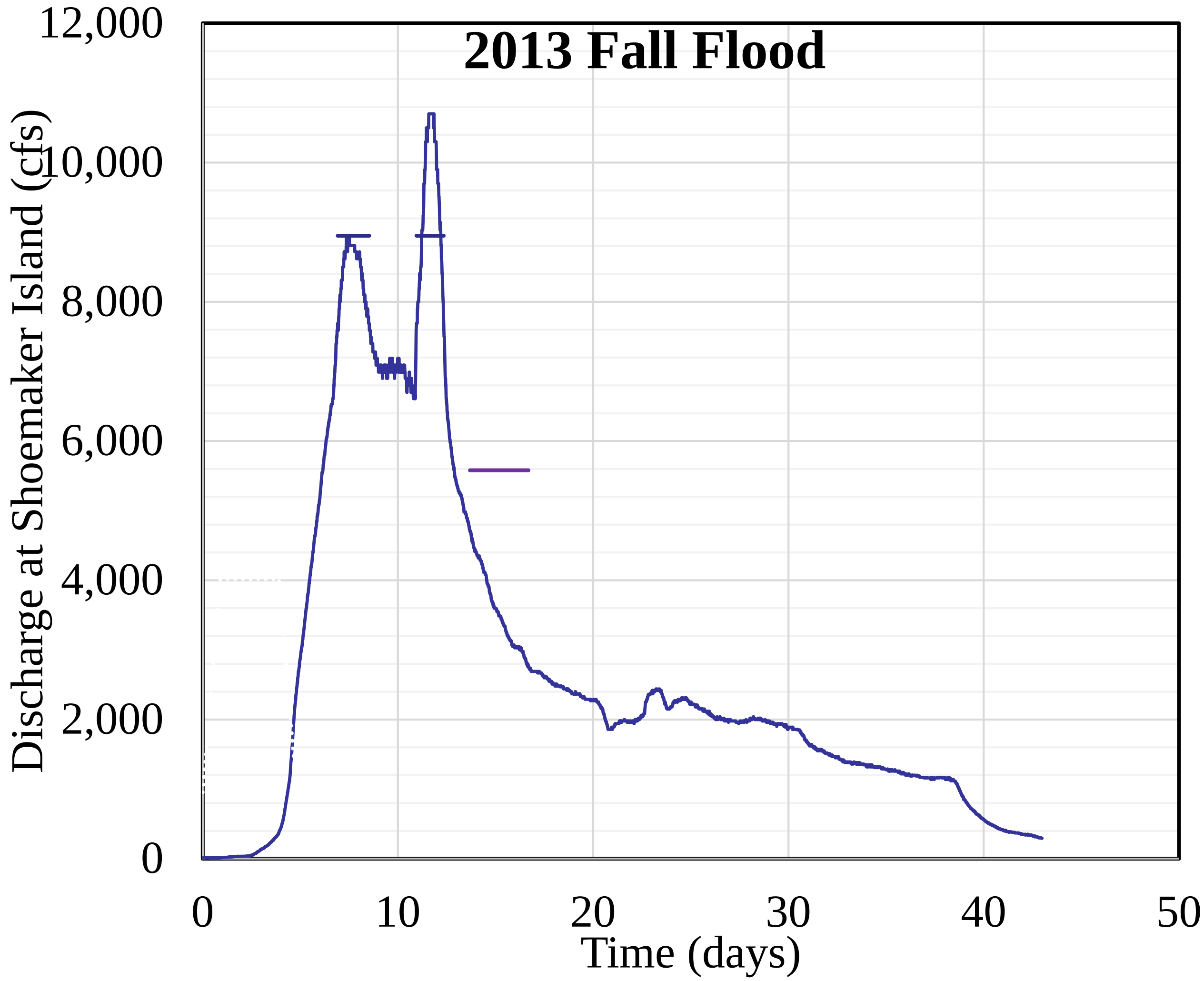


3) Ability of FSM Management Strategy to Create/Maintain Habitat



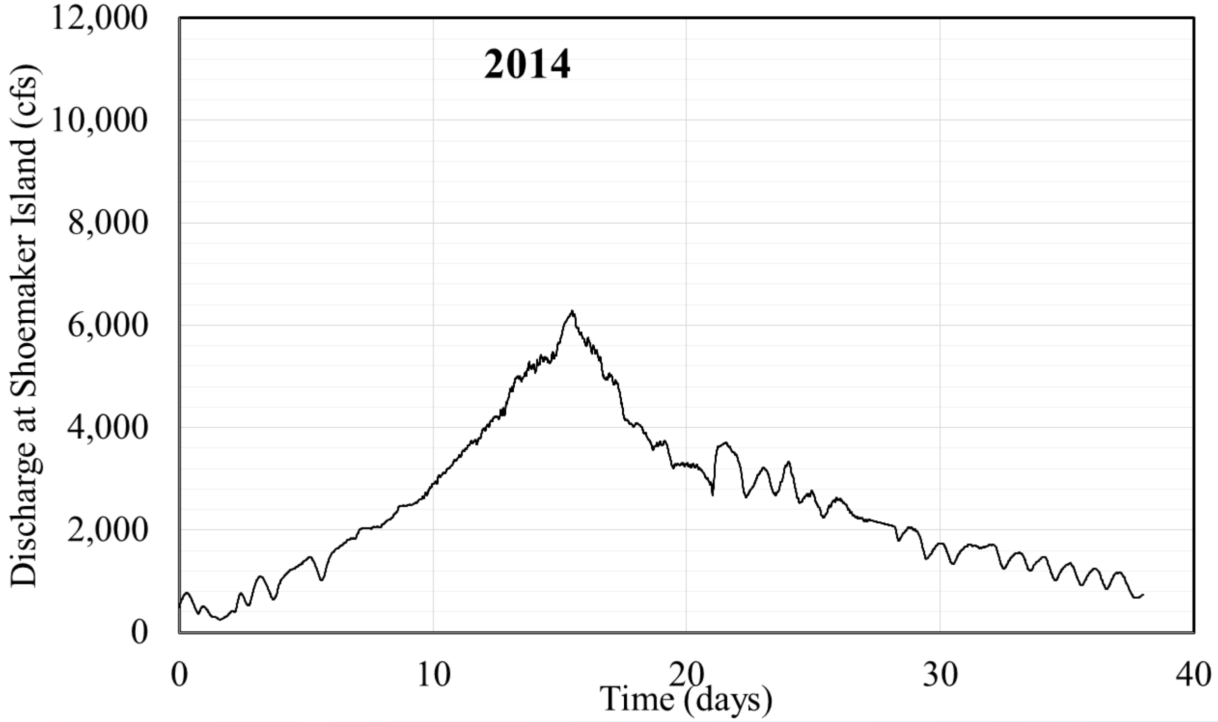
	Duration	
	4	days
Peak Magnitude		
	3,100	cfs
Total Sediment Load		
	27,200	tons
	19,400	CY
Volume Change		
	(1,600)	CY

3) Ability of FSM Management Strategy to Create/Maintain Habitat



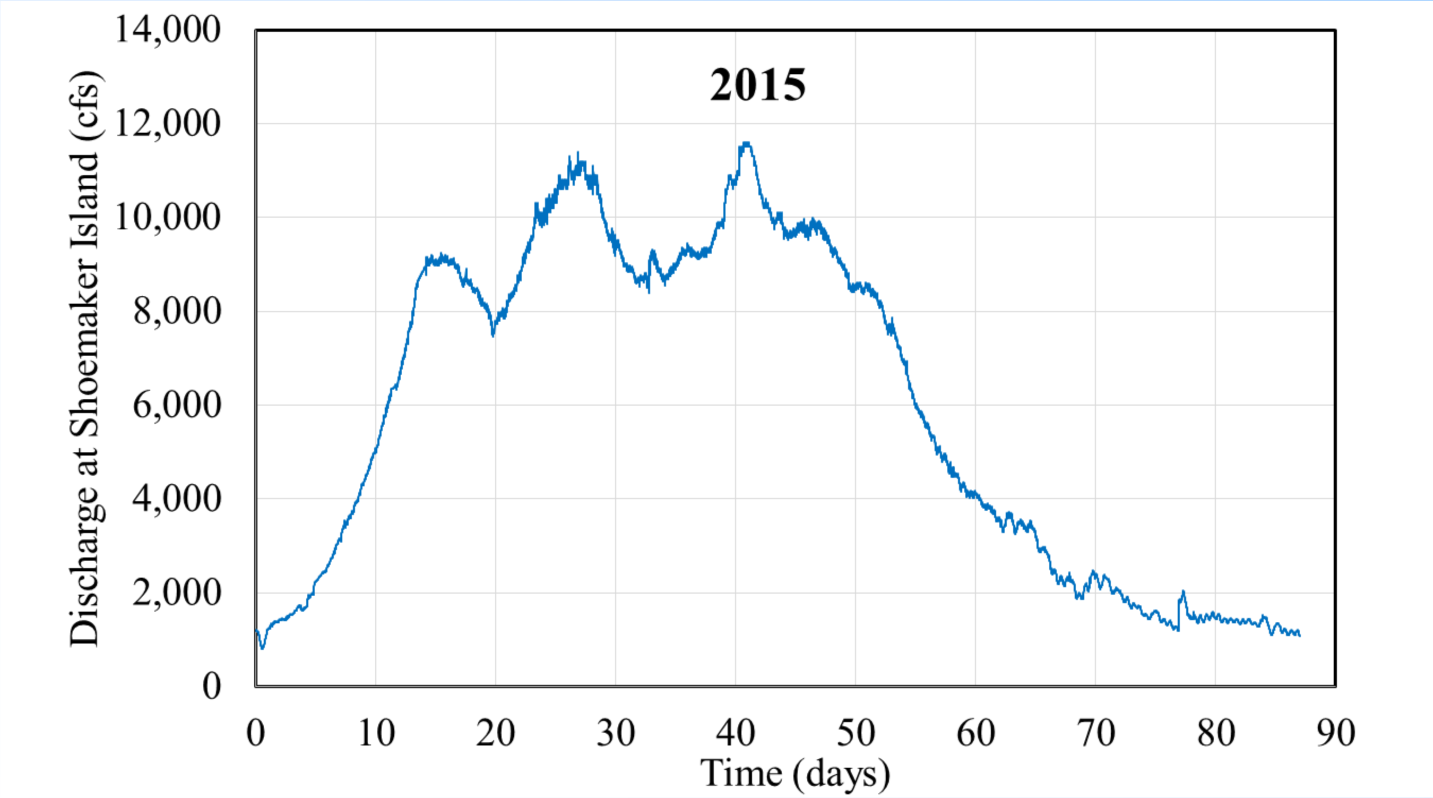
	Duration	
	16	days
Peak Magnitude		
	10,700	cfs
Total Sediment Load		
	170,000	tons
	119,000	CY
Volume Change		
	83,000	CY

3) Ability of FSM Management Strategy to Create/Maintain Habitat



Duration	
21	**days**
Peak Magnitude	
6,300	**cfs**
Total Sediment Load	
99,300	**tons**
69,000	**CY**
Volume Change	
(10,300)	**CY**

3) Ability of FSM Management Strategy to Create/Maintain Habitat



Duration	
64	days
Peak Magnitude	
11,700	cfs
Total Sediment Load	
971,000	tons
674,000	CY
Volume Change	
48,000	CY

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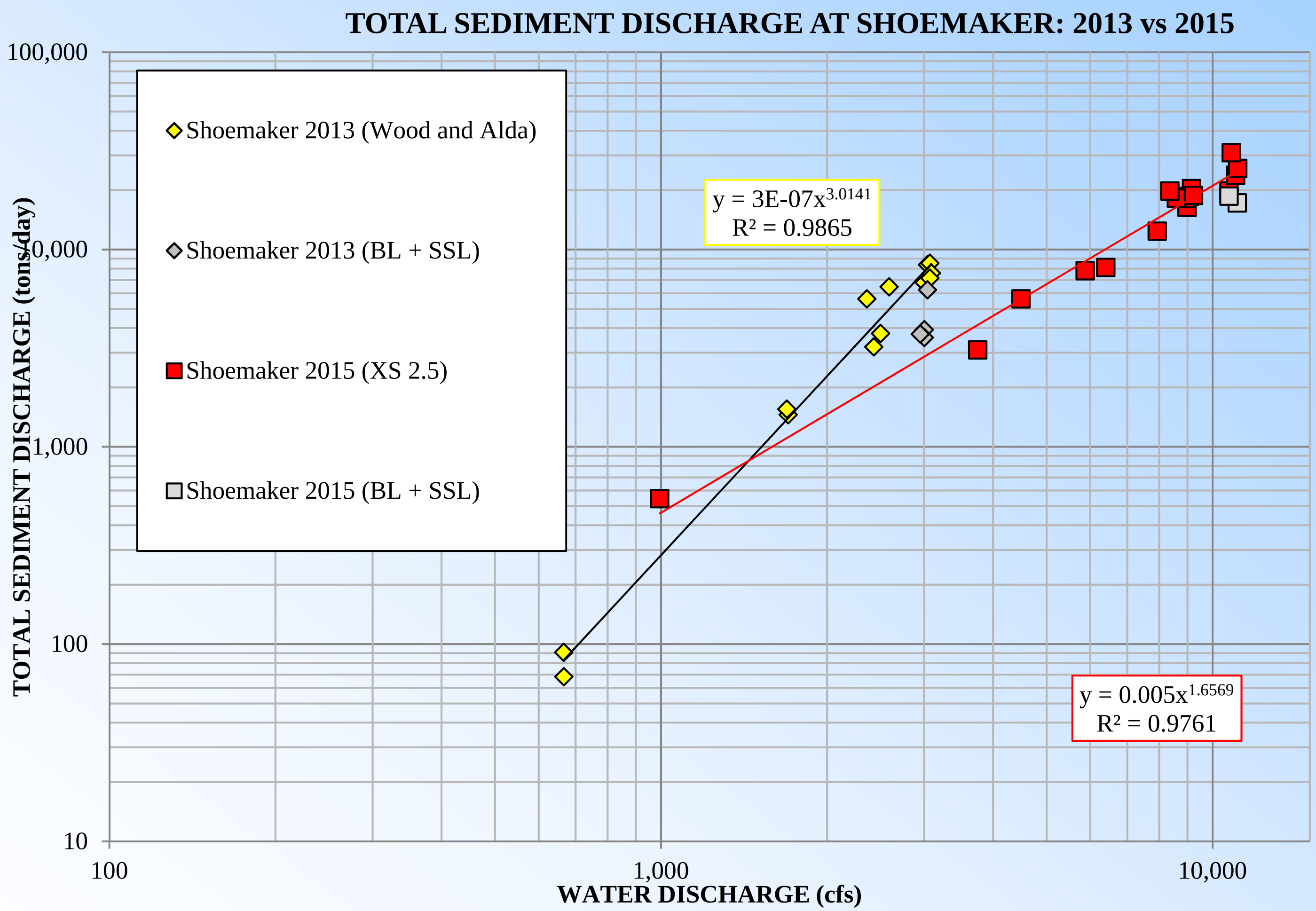


3) Ability of FSM Management Strategy to Create/Maintain Habitat

Plot Assessments designed to Document Flow impacts on cottonwood, willows, and common reed on sand bars

- Cottonwoods documented during August 2015 survey
  - 35 plots with vegetation out of 125 plots
  - 111 cottonwood stems documented in 14 plots
  - Average stem diameter 0.96 mm, stem height 120 mm (~5 in)
- Eight live sandbar willows documented in one quadrant July 2014 absent from quadrant August 2015.
- Common reeds not documented in plots during the 6 assessments.

3) Ability of FSM Management Strategy to Create/Maintain Habitat

Flow Impacts on Vegetative Plots

- **125 one meter square plots assessed**
- **Measured aerial extent and species present in plots**

			Aerial Coverage m^2		
	Plots all Sand/Water	Plots w/ Vegetation	Water/Sand	Vegetation	%Vegetation
May 2014	104	21	118.14	6.86	4.49
June 2014 High Flow					
July 2014	85	40	106.10	18.90	15.12
June 2015 High Flow					
August 2015	89	36	117.18	7.82	6.26

3) Ability of FSM Management Strategy to Create/Maintain Habitat

Height for vegetated plots with cottonwoods is equal to vegetated plots with no cottonwoods

Variable		n	M	SD	df	t	p
August 2015 Plot Heights w/ Vegetation	Cottonwood Present	14	1.00	0.53	33	0.51	0.614
	Cottonwood Absent	21	0.86	0.99			

Height of vegetated plots with cottonwoods is similar to vegetated plots with no cottonwoods

3) Ability of FSM Management Strategy to Create/Maintain Habitat

Mechanical Treatment in Shoemaker Study Reach included:

- Disking of bars/river bed
- Mowing of vegetated bars
- Herbicide treatment of bars
- Construction of nesting bars

Habitat Goal: unobstructed minimum channel widths greater than 750 feet to increase probability of whooping crane roosting

Bare sand nesting bars >0.25 acres with a height greater than 1.5 feet above the 1,200 cfs TRF stage

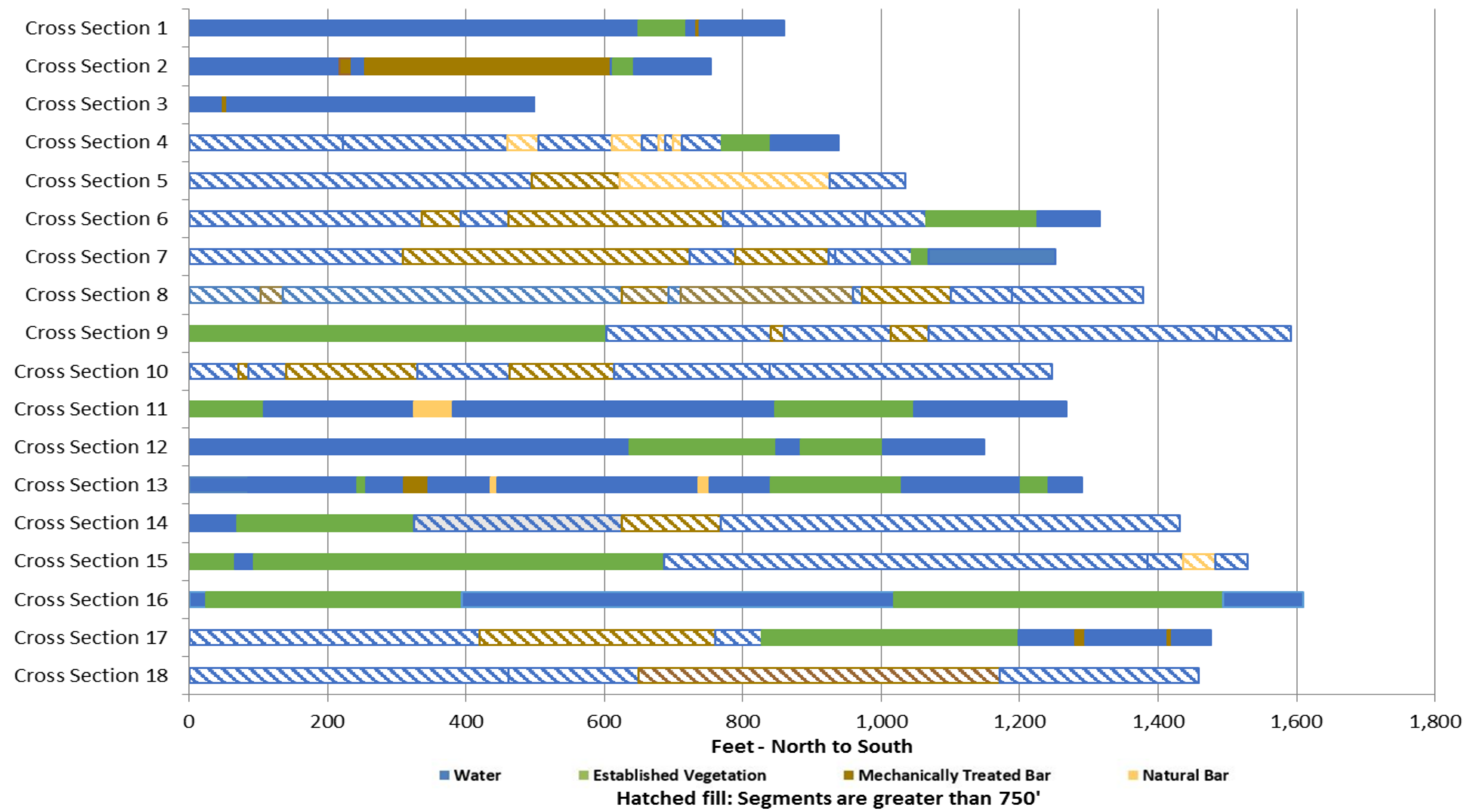
3) Ability of FSM Management Strategy to Create/Maintain Habitat

Mechanical Treatment in Shoemaker Study Reach

	April 2013		July 2014		August 2015	
	Acres	Percent	Acres	Percent	Acres	Percent
	Mechanically Treated Study Reach - 252 Acres		Mechanically Treated Study Reach – 246 Acres		Mechanically Treated Study Reach – 266 Acres	
Vegetated Bars	46.1	18%	79.7	32%	44	17%
Sand Bars	54.3	22%	51.2	21%	53.6	20%
Water/River Bed	151.6	60%	115.1	47%	168.4	63%
Total	252	100%	246	100%	266	100%
	Natural Study Reach 110 Acres		Natural Study Reach 116 Acres		Natural Study Reach 96 Acres	
Vegetated Bars	27.9	25%	37.7	33%	20.4	21%
Sand Bars	0.7	1%	6.1	5%	11.5	12%
Water/River Bed	81.4	74%	72.2	62%	64.1	67%
Total	110	100%	116	100%	96	100%

3) Ability of FSM Management Strategy to Create/Maintain Habitat

Mechanical Treatment: 2015 Unvegetated Channel Widths



3) Ability of FSM Management Strategy to Create/Maintain Habitat

Summary of Unobstructed Channel Segments Widths >750 feet,

	Natural Segments			Mechanical Treated Segements		
	May 2013	July 2014	July 2015	May 2013	July 2014	July 2015
Average	798	806	806	1,027	1,286	1,127
Minimum	771	870	769	807	786	827
Maximum	807	933	844	1,372	1,633	1,459
n	4	3	2	5	8	9

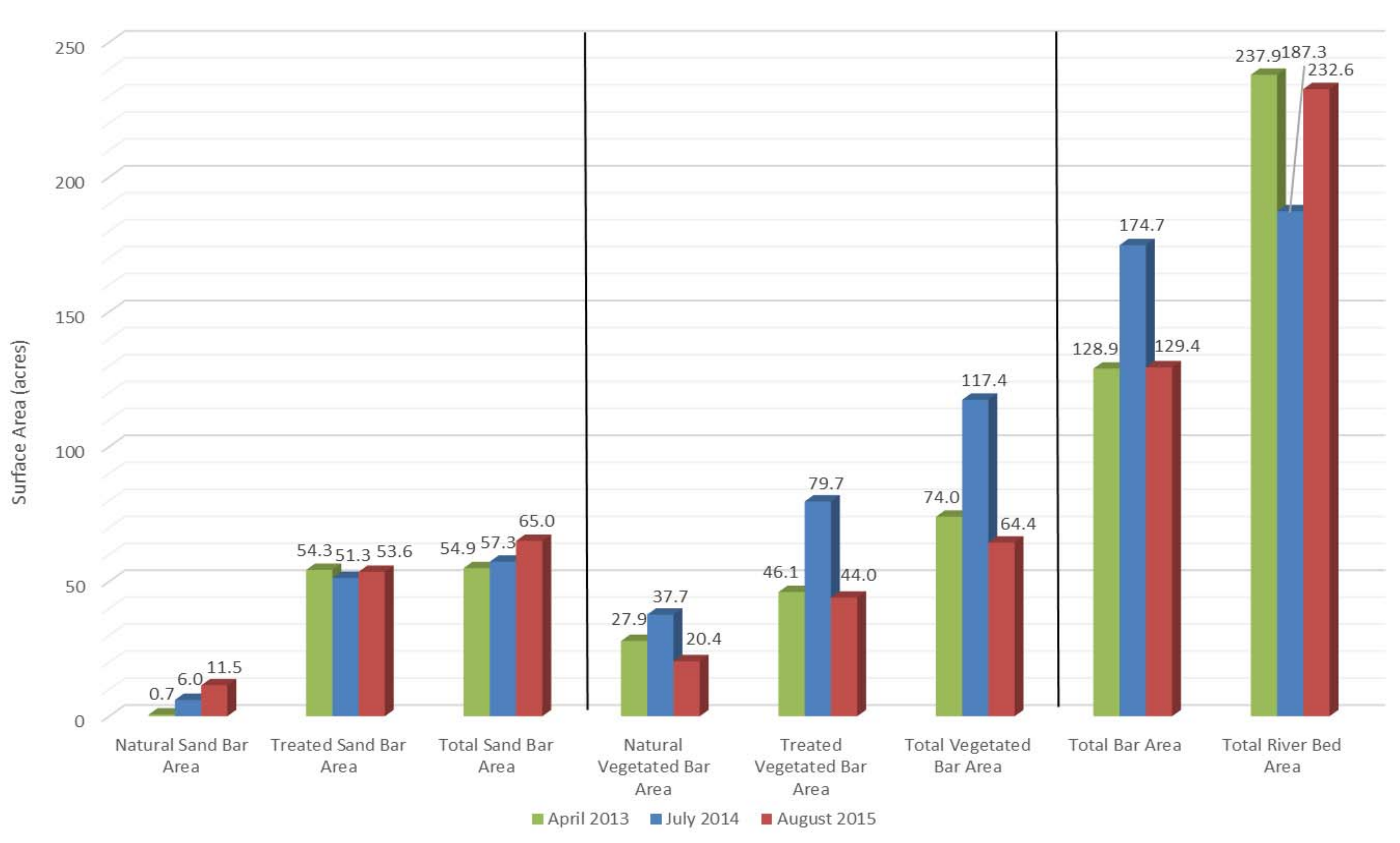
Big Questions

1. **Will implementation of SDHF produce suitable tern and plover nesting habitat on an annual or near-annual basis?**

   Conclusion: No

   - **Monitored high flow events that are substantially larger than SDHF did not increase sand bar height sufficiently to achieve biological objectives**
   - **Aerial extent of vegetation on sand bars remained proportionally similar after high flows**
   - **Model predictions of SDHF do not indicate that bars will grow to sufficient heights or areas during SDHF**

Area of all Bars surveyed – April 2013, July 2014, and August 2015



Big Questions

2. **Will implementation of SDHF produce and/or maintain suitable whooping crane riverine roosting habitat on an annual or near annual basis?**

Conclusion: No

- Vegetative assessment plots were inconclusive
- Portion of study reach subjected to mechanical treatment
- Vertical scour: limited to ~1 foot over bar surfaces
- Drag forces: some initiation of uprooting of 1-year and 2-year old cottonwoods, no initiation of uprooting for phragmites and canary reed grass.
- Lateral erosion:
  - No lateral erosion is predicted during SDHF if the rooting depth of vegetation is below the toe of the channel.
  - Lateral erosion is predicted if rooting depth is less than the toe but is not substantial for short duration flows

Big Questions

3. **Is sediment augmentation necessary for the creation and/or maintenance of suitable riverine tern, plover, and whooping crane habitat?**

Conclusion: Insufficient alone

Caveat: Sediment augmentation was not monitored or evaluated as part of the "Proof of Concept" experiment.

- Year 1 data collection suggests the reach is in equilibrium. Subsequent years produced some net cut or net fill, with total net fill by the end of 2015. Therefore, the reach does not appear to be in a sediment deficit.
- Although some bar growth was noted, target bar heights and areas were not achieved.
- Based on these observations, we hypothesize that if a reach is in a sediment deficit, adding sediment to bring the reach into a sediment balance (similar to Shoemaker), will not meet habitat goals.

Big Questions

4. **Are mechanical channel alterations necessary for the creation and/or maintenance of suitable riverine tern, plover, and whooping crane habitat?**

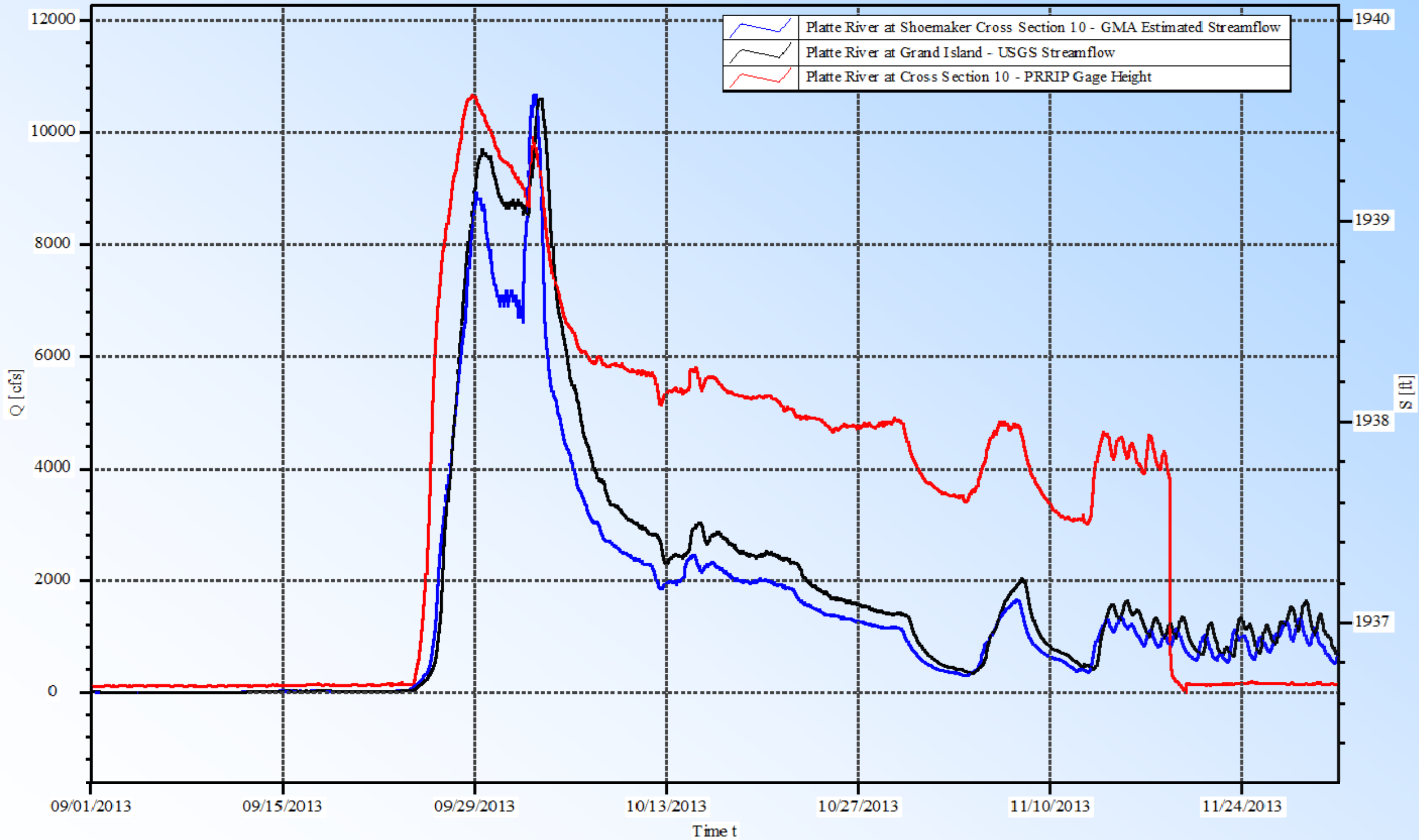
Conclusion: Yes

- **Mechanical treatment; disking, mowing, and nesting bar construction decreased vegetated areas in the Shoemaker study reach**
- **Mechanical treatment increased unobstructed vegetation widths in the Shoemaker study reach.**
- **Nesting bars were not monitored, however anecdotal evidence indicates they are highly erosive and transient.**

Questions?

1a) Hydrograph (shape and duration) and sand bar height and area

Fall 2013 High Flow

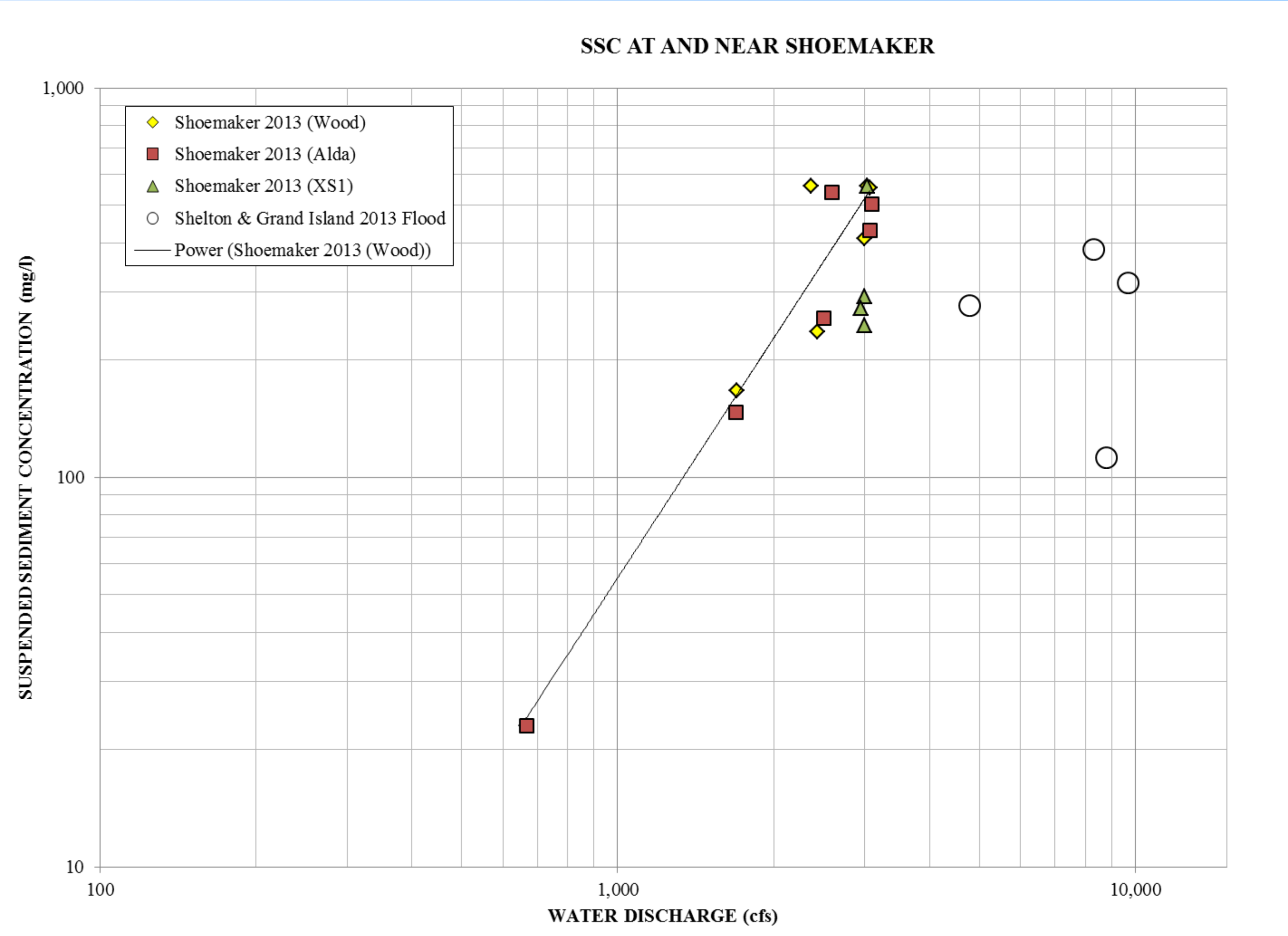


1a) Hydrograph (shape and duration) and sand bar height and area

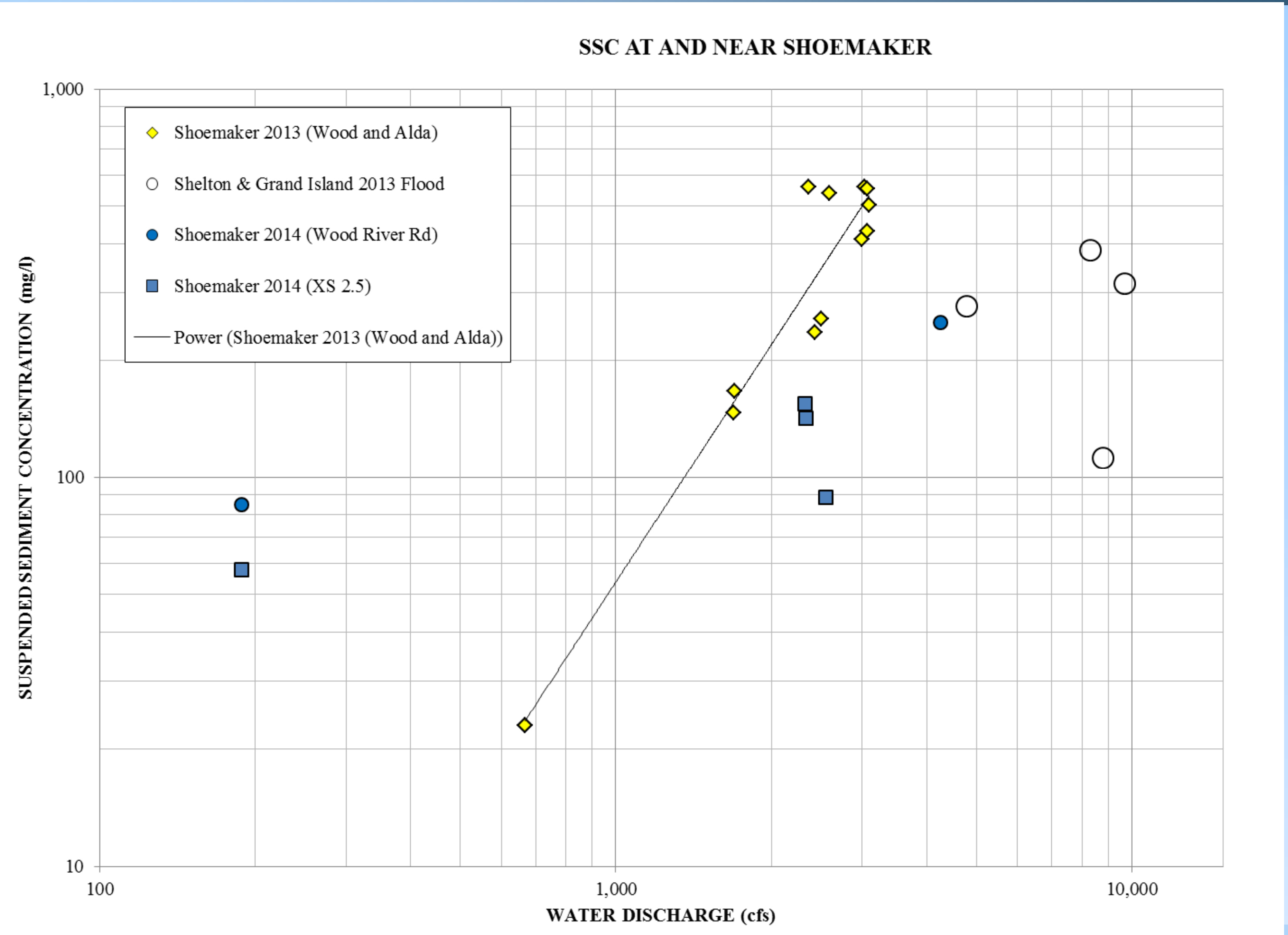
Summary of Mean Sand Bar and 3-day Peak Discharge Stage Height Above the 1,200 cfs TRF Stage, feet

			3-day Peak Stage Height	Mean Bar Height	Water Depth Over Bar
July 2014 New Sand Bars	Bars >0.25 acres	Mean	2.21	0.39	1.82
		Range	1.86 - 2.68	0.25 - 0.49	1.61 - 2.19
	Bars <0.25 acres	Mean	2.14	0.22	1.92
		Range	1.73 - 2.84	0.02 - 0.73	1.71 - 2.11
August 2015 Sand Bars	Bars >0.25 acres	Mean	2.91	0.52	2.39
		Range	2.53 - 3.98	0.19 - 1.09	2.34 - 2.89
	Bars <0.25 acres	Mean	2.76	0.16	2.6
		Range	1.76 - 4.03	0.01 - 0.60	1.75 - 3.43

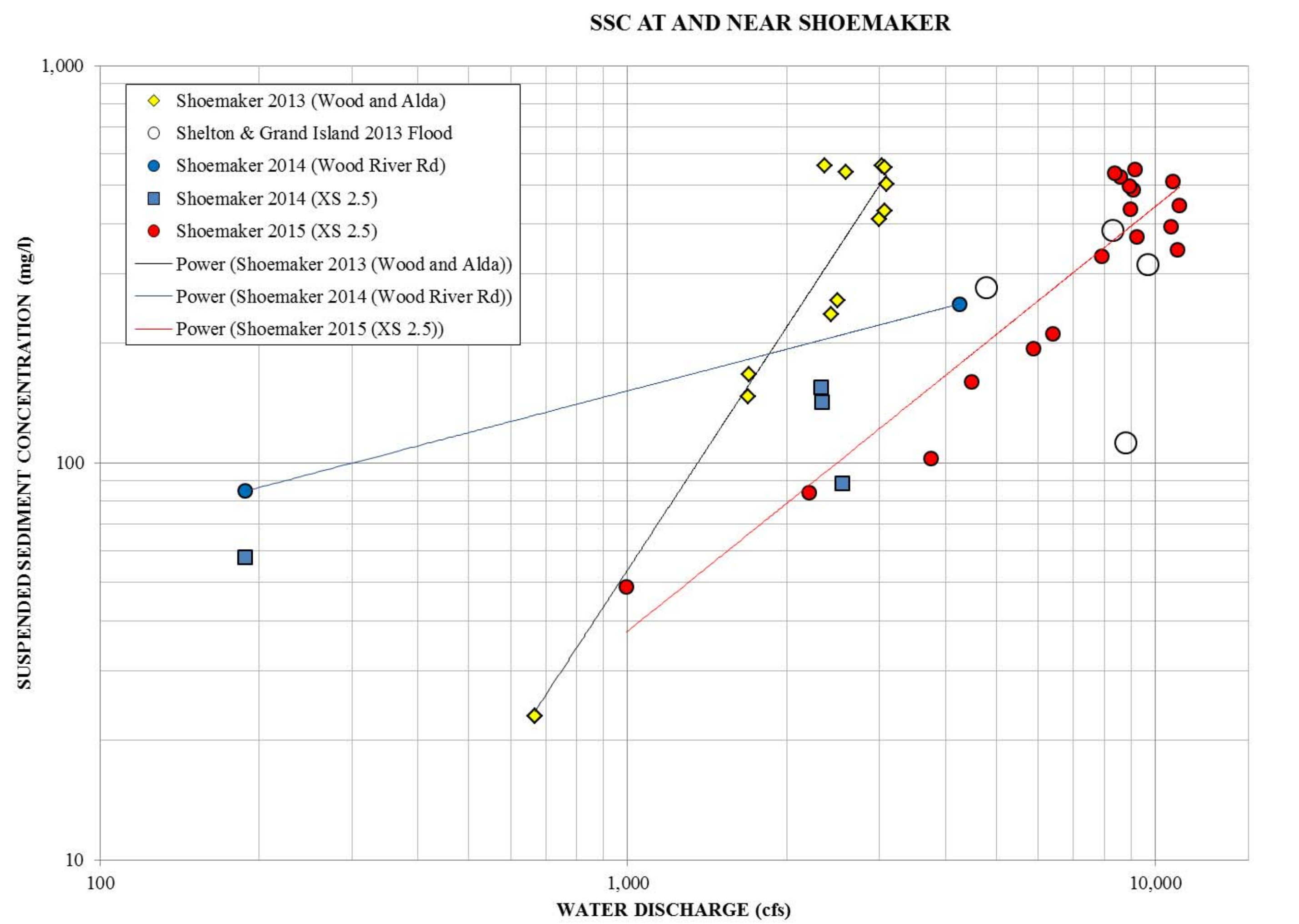
Lessons Learned



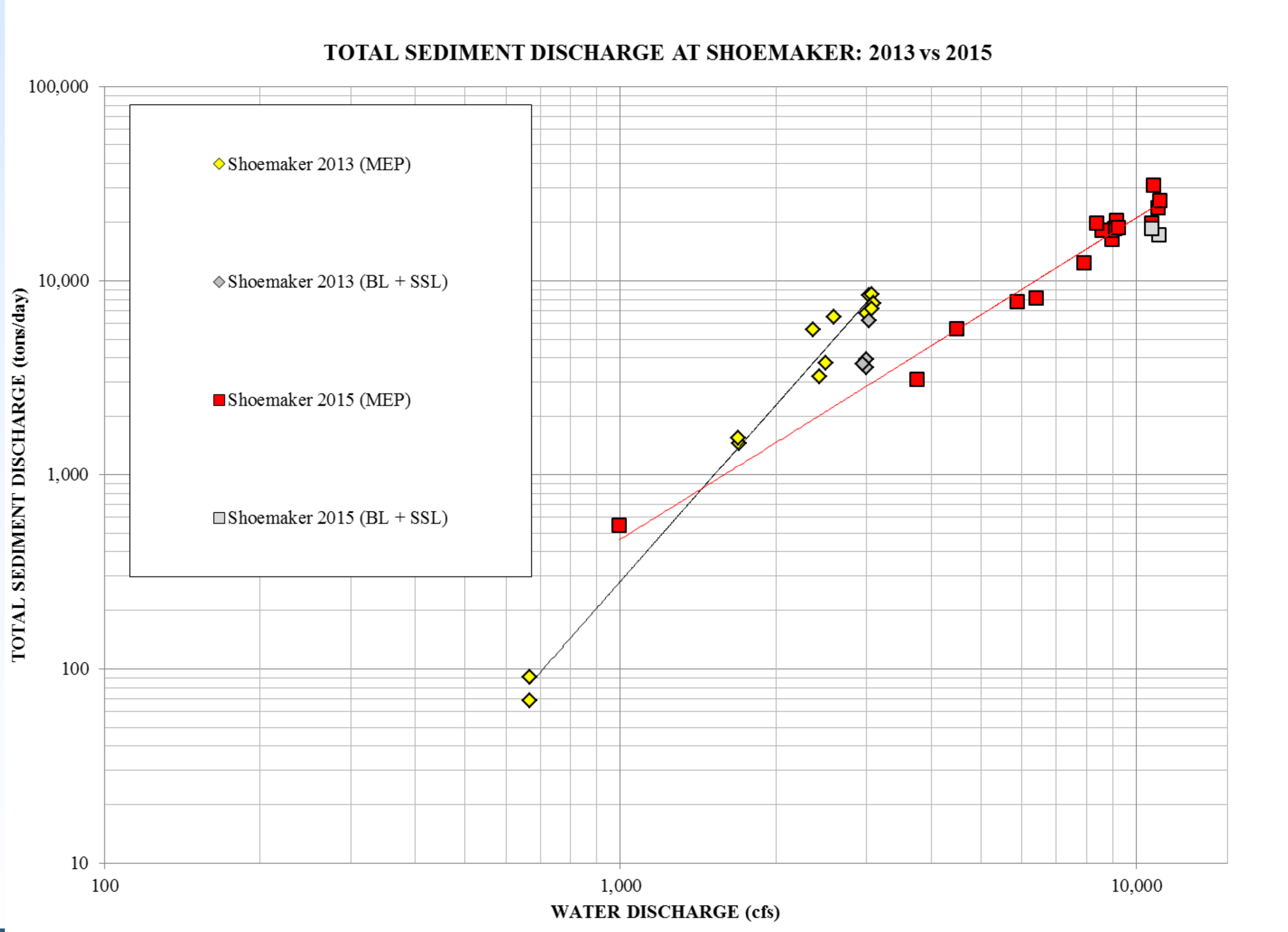
Lessons Learned



Lessons Learned



Lessons Learned



Lessons Learned