Seven Oaks Dam High Flow Study

Phase 2 Workshop

July 25, 2019

San Bernardino Valley Municipal Water District

Agenda

- **Introduction**
- **Background / History of Partnership and High Flow Study**
- **ICF Recap of Phase 1 Report and Phase 2 Scope**
- **Science Advisor Studies**
  - Stillwater Sciences
  - Blue Octal
- **ICF Presentation of Phase 2 Report**
- **Discussion**
- **Next Steps**

Background / History of Partnership and High Flow Study

Phase 1 Report Recap

Background

- 760 acres of land were purchased to form the WSPA
- A multi-species adaptive management plan was prepared to guide management of the preserve area, resulting in the MSHMP
- The 2002 BO, BA and MSHMP: water releases to be made, coupled with diversion dikes, to create directed overbank flows for the benefit of listed species
- USACE Technical Report (2000) for the BA calls for SOD high flow releases to be synchronized with Mill Creek flood flows

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Phase 1 Report Recap

Findings

- Opportunity exists within the current SOD Water Control Manual guidelines (USACE 2003) to release 5,000 cfs
- WCM limit of 50 cfs release during rising reservoir levels effectively prevents timing releases with high-flow contributions from tributaries
- No flow releases for the purpose of habitat renewal appear to have taken place in the two decades since start of operations at SOD
- Without enhancement measures (e.g., breaching of berms, flow obstructions) no overbank flows into substantial areas of size outside of the SAR active channel are predicted to produce flood disturbance to alter successional trends and therefore satisfy the requirements of the BA/BO and MSHMP

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Phase 2 Scope of Work

- Develop three hydrographs that include a combination of SOD releases and Mill Creek flood events
- New Science Advisor Studies: Define Fluvial Disturbance Conditions
  - Stillwater Sciences: Quantification of lateral erosion and vegetation scour from historic imagery
  - Blue Octal: Quantify shear stress requirements for uprooting vegetation and fresh sand deposition
- Develop 3 structural enhancement measures to create fluvial disturbance over a range of flow conditions
- Use 2D modeling and sediment transport analysis to quantify performance
- Evaluation of non-fluvial disturbance techniques for habitat renewal
- Evaluation of treatment trade-offs and prioritize the species of interest

Science Advisor Studies

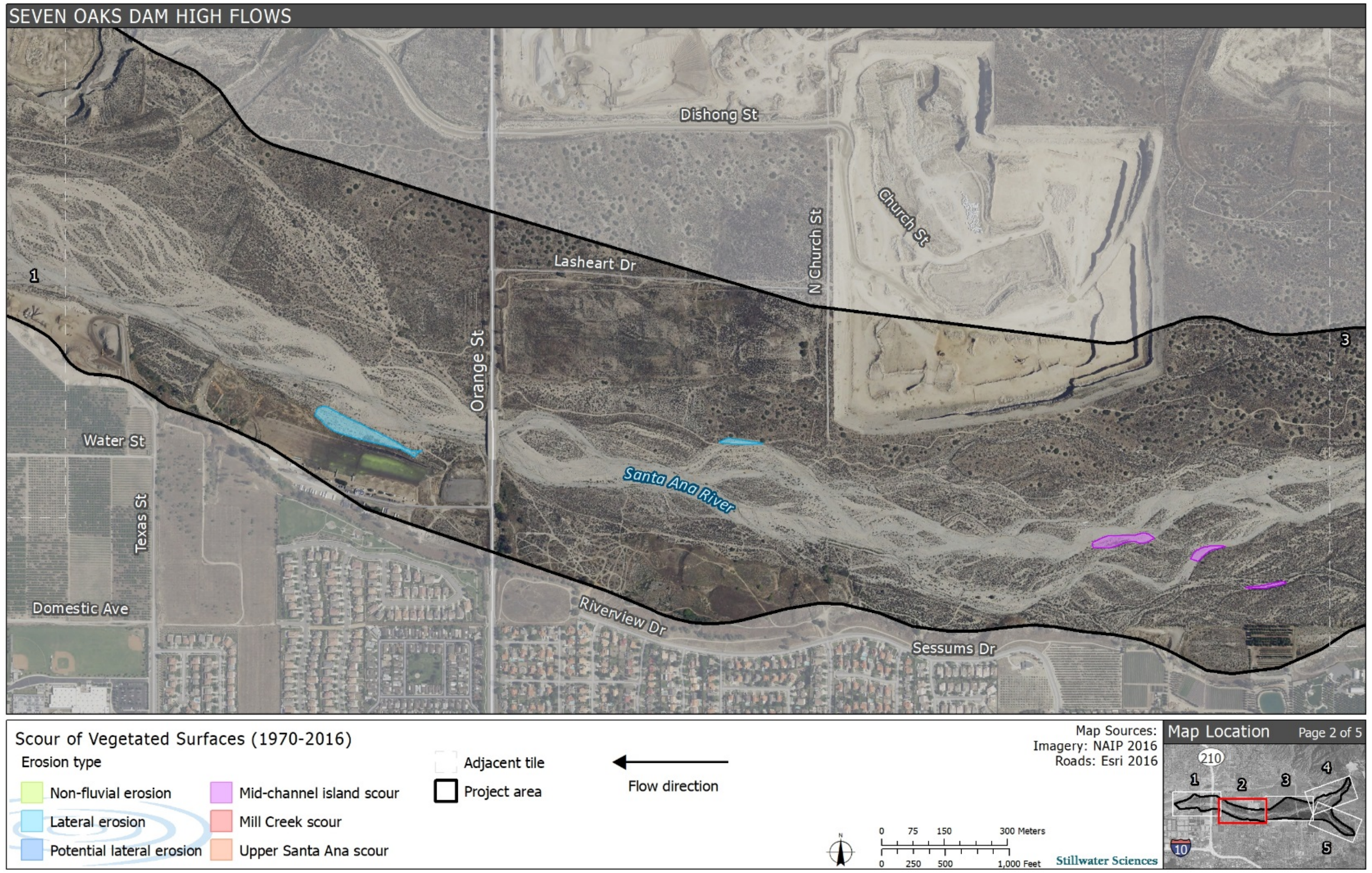
- Stillwater Sciences
- Blue Octal

Bank erosion and vegetation scour in the Upper Santa Ana River

Motivation: how do we create habitat for pioneer species in a large, arid, heavily modified, alluvial system.

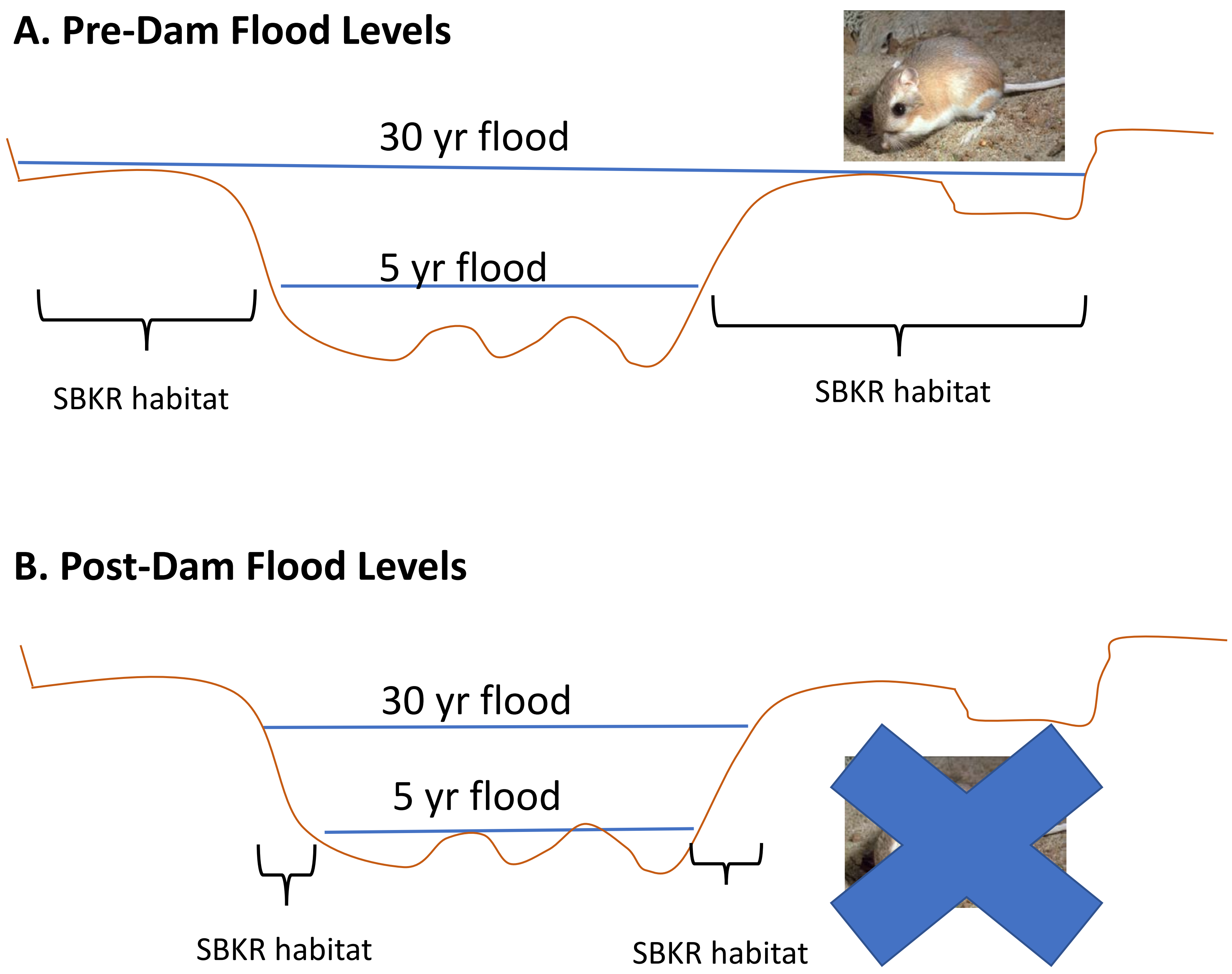
SBKR (and spineflower and woolly star) needs:

1. Relatively fresh surface, with low-ish vegetation density and few to no exotic grasses
2. But….Surfaces cannot be disturbed too frequently…perhaps every 20-30 years?
3. Speed of succession may be sped up by invasive plants.



Stillwater Sciences

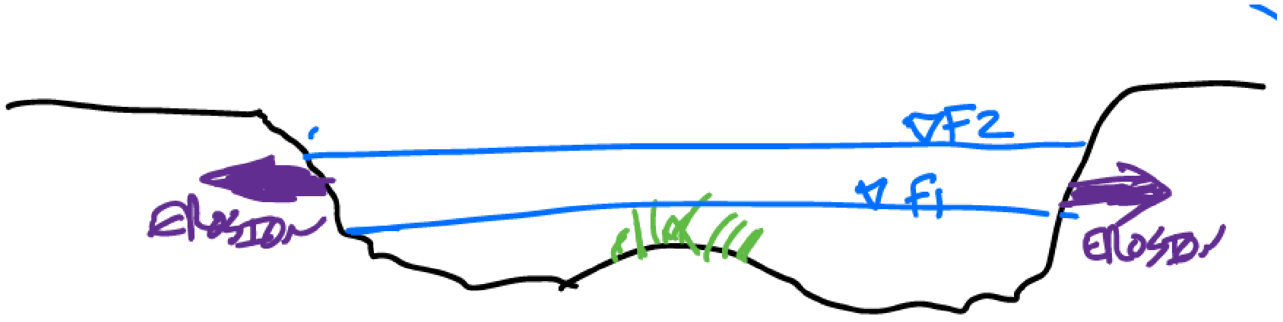
Problem statement

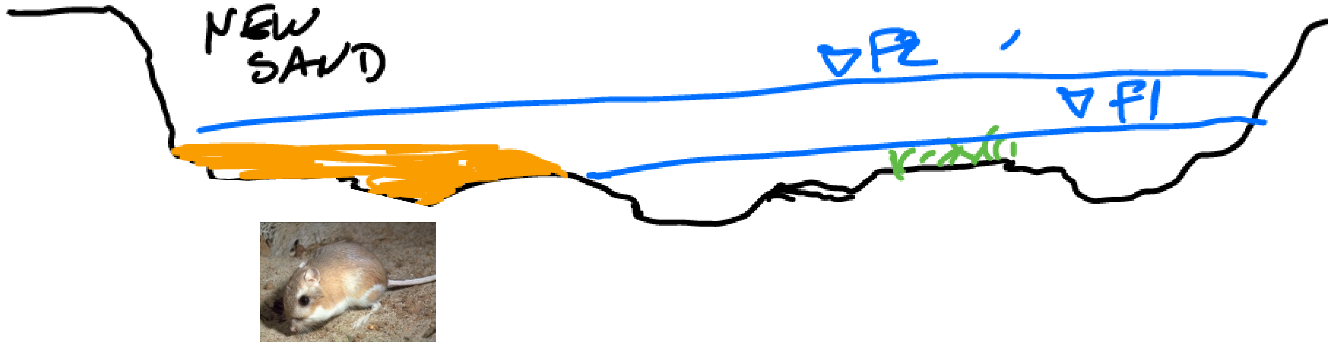


Decreased flood magnitudes due to Seven Oaks Dam have decreased the extent of habitats that are inundated sufficiently frequently to scour dense vegetation and grass growth, but not so frequently so as to continually disturb the species of interest

Source: Mike Lamb, Blue Octal Solutions

2 potential restoration strategies

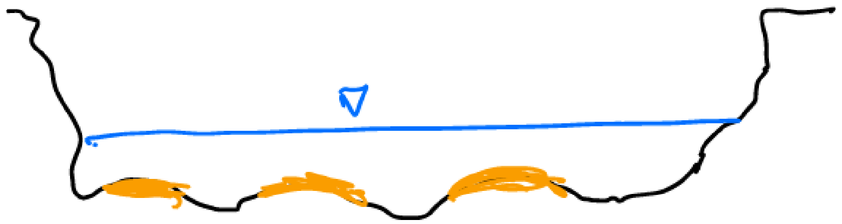




Rejuvenate potential habitat by:

1. Widening the active channel to create fresh surfaces, with low vegetation density
   - What flows are required to erode the channel banks?

Strategy 2. Scour existing vegetation in the channel

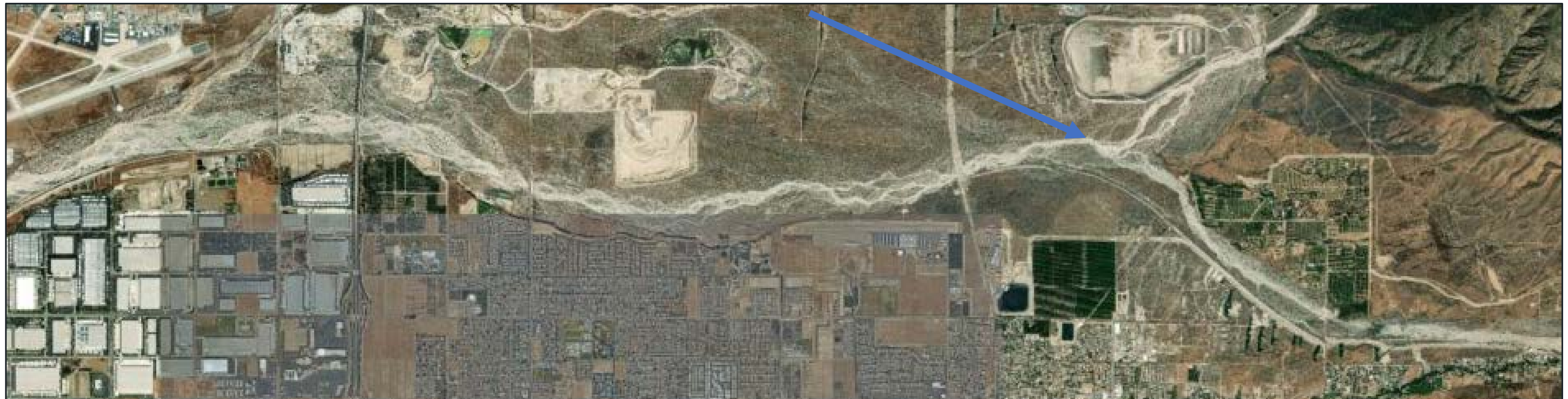


Rejuvenate habitat within the floodway

- What are the scour dynamics in the channel?

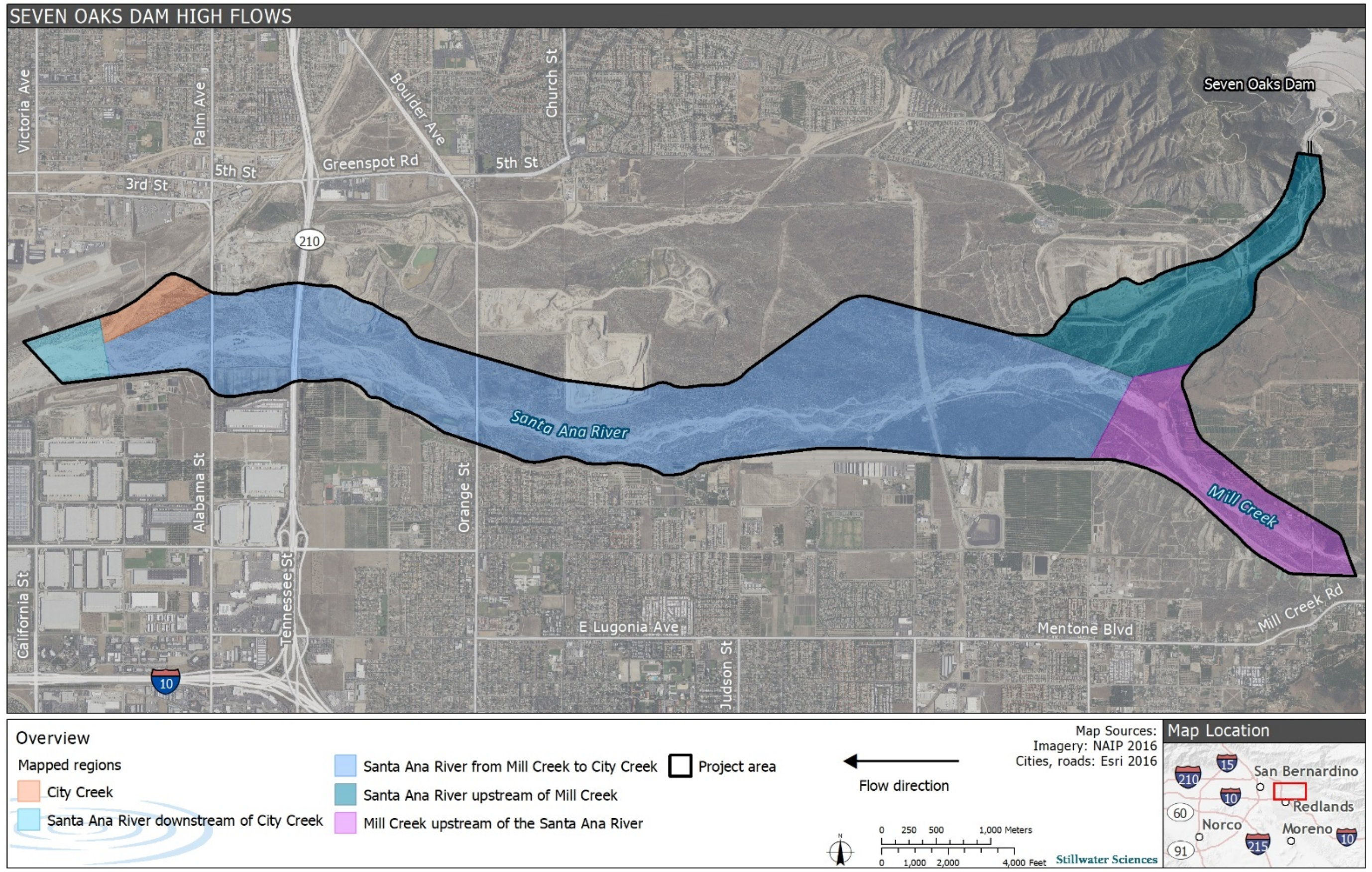
September 14, 2018

February 25, 2019

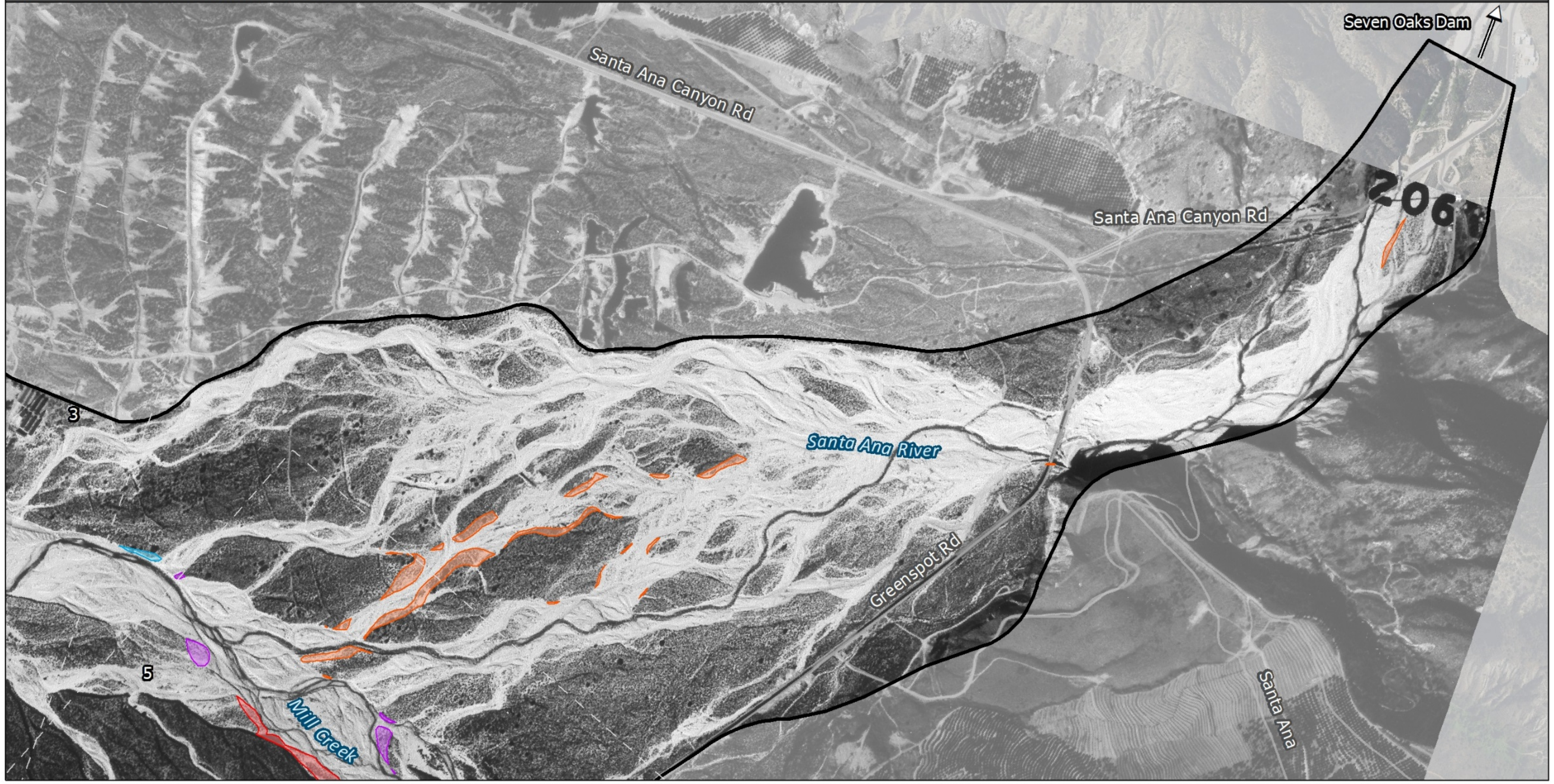


Bank Erosion Assessment Approach

1. Map surfaces based on their vegetation density from 1 (low density) to 4 high density in 1970 and 2016. Classify polygons as scoured if they had moderate to high vegetation density in 1970 and had low to sparse vegetation density in 2016.
2. We then went through and classified the scoured polygons to determine if they occurred through lateral erosion, manmade changes, or erosion of mid channel bars.



SEVEN OAKS DAM HIGH FLOWS



Scour of Vegetated Surfaces (1970-2016)

Erosion type

- Non-fluvial erosion
- Lateral erosion
- Potential lateral erosion
- Mid-channel island scour
- Mill Creek scour
- Upper Santa Ana scour
- Adjacent tile
- Project area

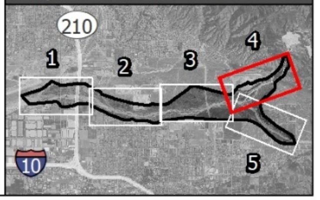
Flow direction

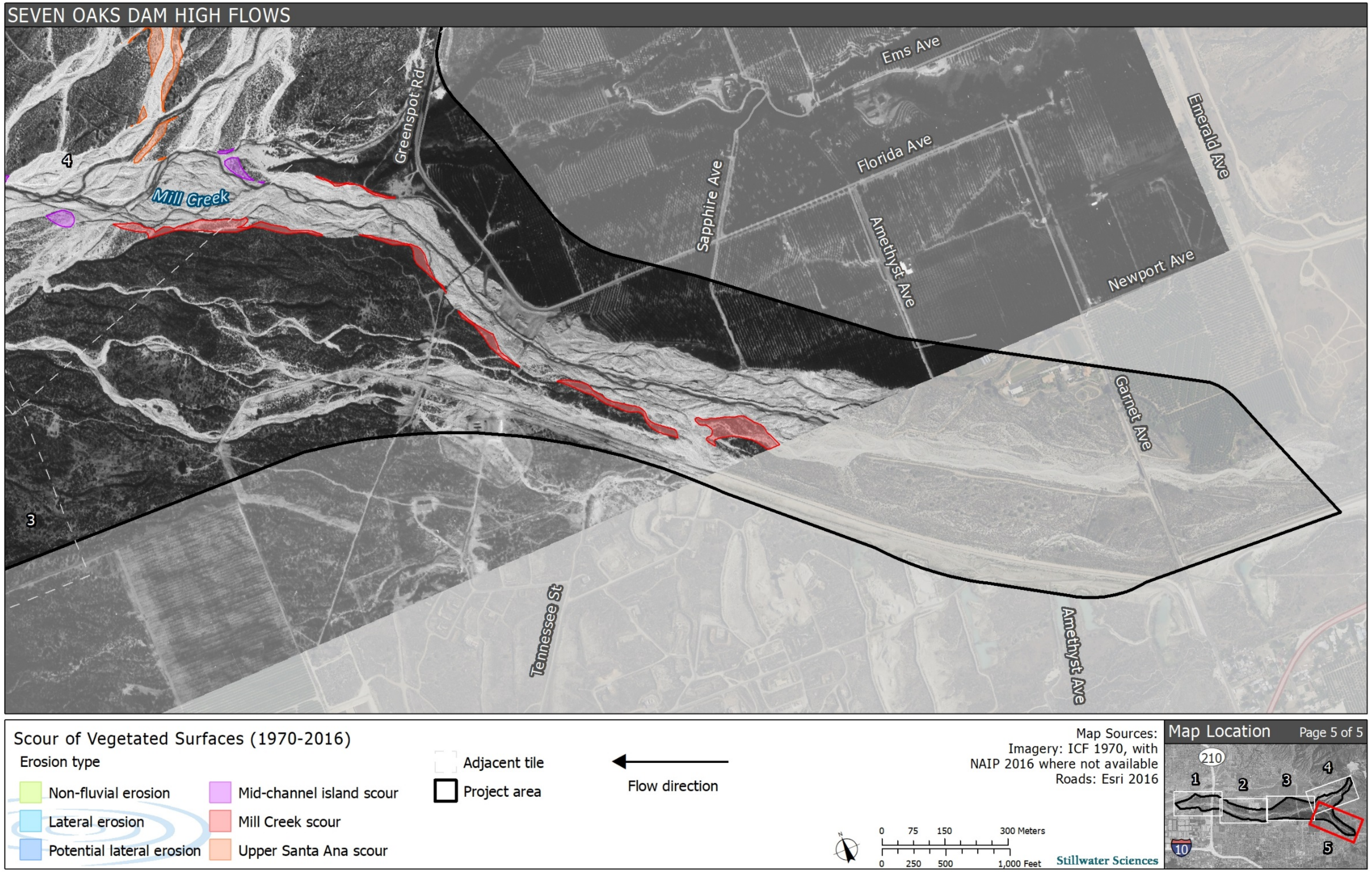
0 75 150 300 Meters
0 250 500 1,000 Feet

Map Sources:
Imagery: ICF 1970, with NAIP 2016 where not available
Roads: Esri 2016

Stillwater Sciences

Map Location




SEVEN OAKS DAM HIGH FLOWS
Ems Ave
Florida Ave
Emerald Ave
Greenspot Rd
Sapphire Ave
Amethyst Ave
Newport Ave
Mill Creek
Garnet Ave
Tennessee St
4
3
Scour of Vegetated Surfaces (1970-2016)
Erosion type
Non-fluvial erosion
Lateral erosion
Potential lateral erosion
Mid-channel island scour
Mill Creek scour
Upper Santa Ana scour
Adjacent tile
Project area
Flow direction
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NAIP 2016 where not available
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Stillwater Sciences
Map Location
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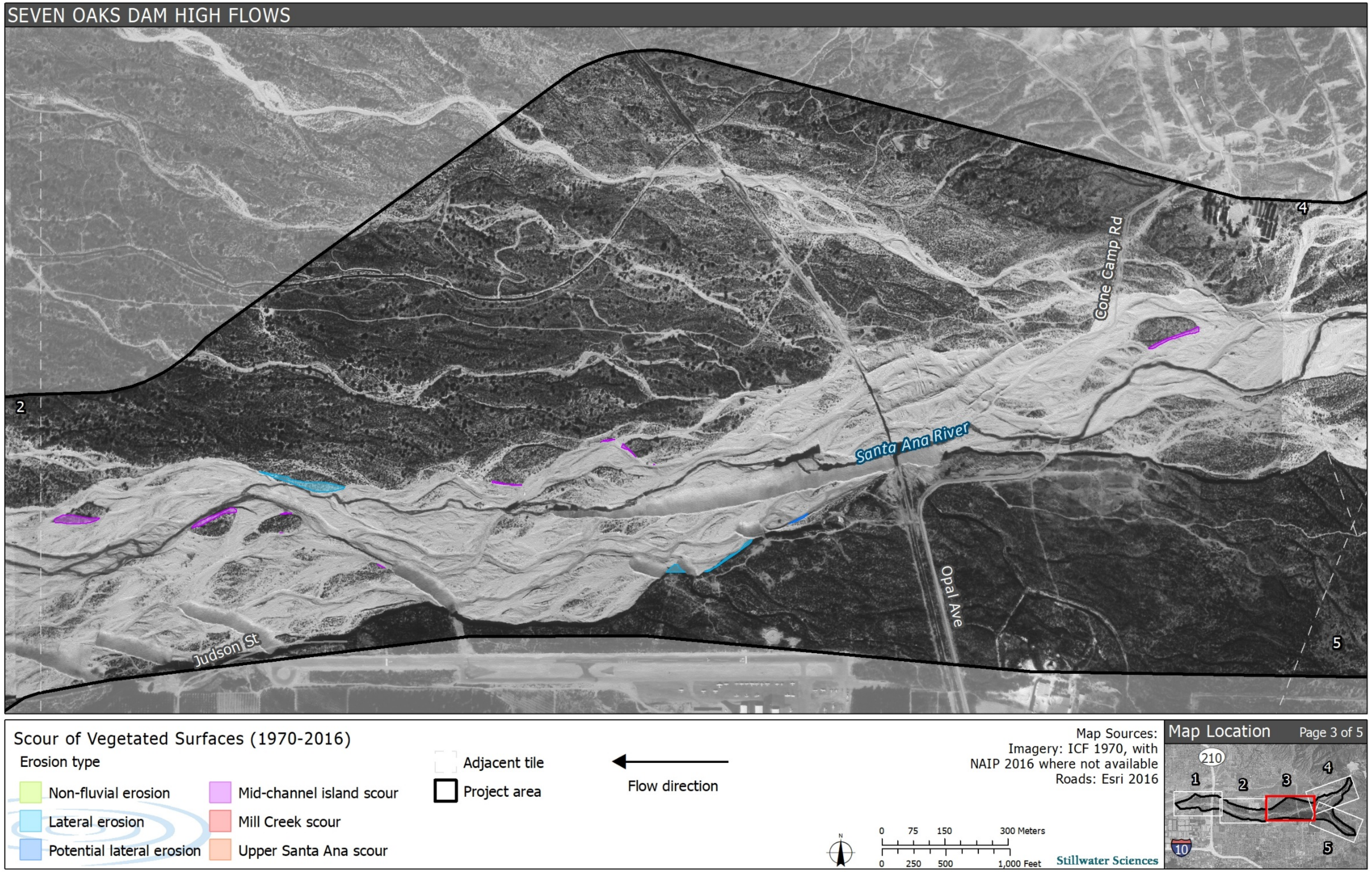
SEVEN OAKS DAM HIGH FLOWS
Cone Camp Rd
Santa Ana River
Opal Ave
Judson St
2
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Scour of Vegetated Surfaces (1970-2016)
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SEVEN OAKS DAM HIGH FLOWS

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Adjacent tile

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Flow direction

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Stillwater Sciences

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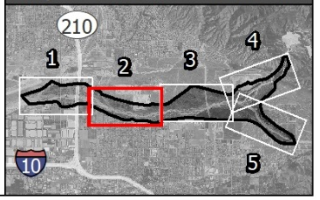

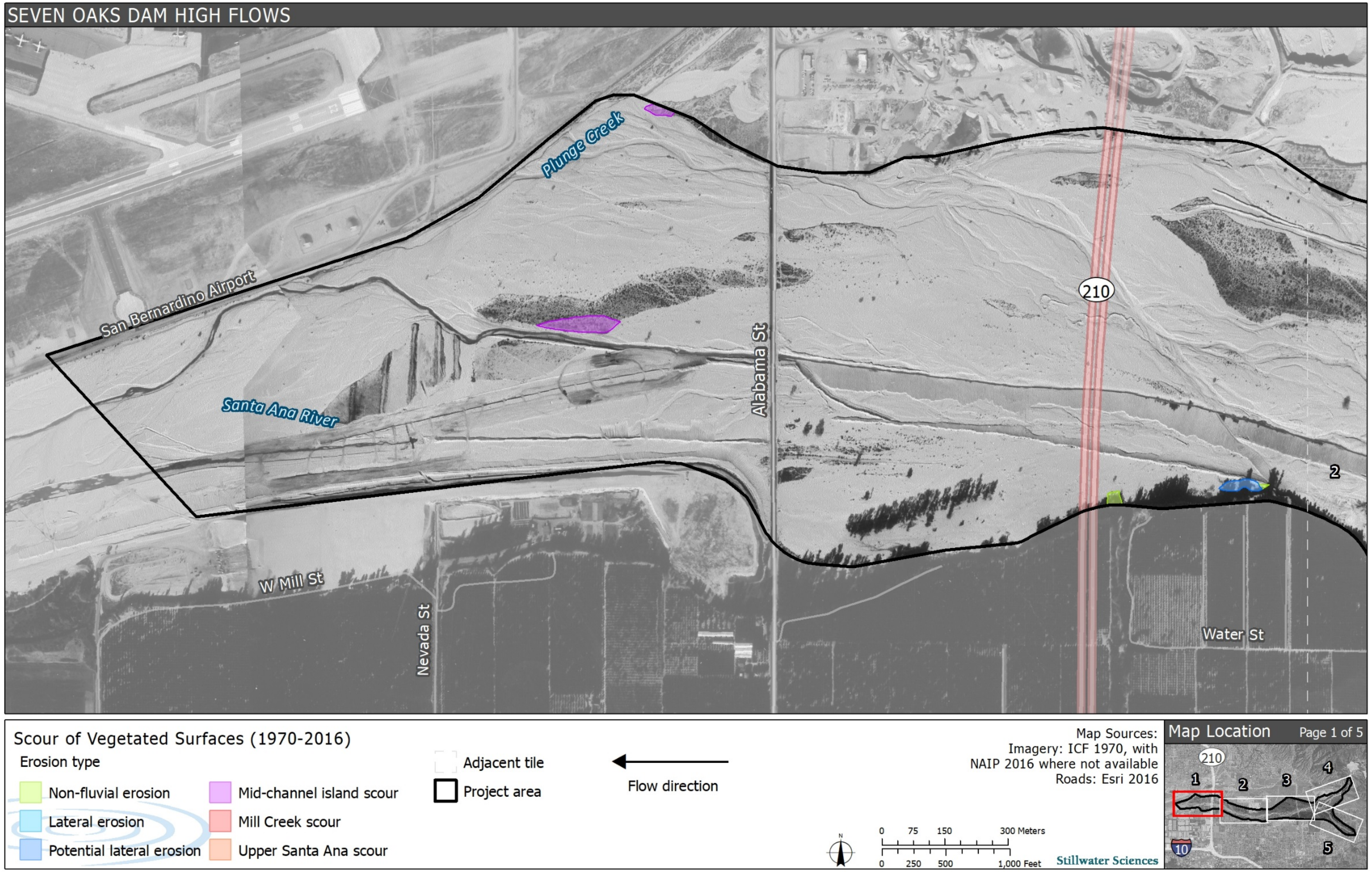
SEVEN OAKS DAM HIGH FLOWS
Plunge Creek
San Bernardino Airport
Santa Ana River
Alabama St
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W Mill St
Nevada St
Water St
Scour of Vegetated Surfaces (1970-2016)
Erosion type
Non-fluvial erosion
Lateral erosion
Potential lateral erosion
Mid-channel island scour
Mill Creek scour
Upper Santa Ana scour
Adjacent tile
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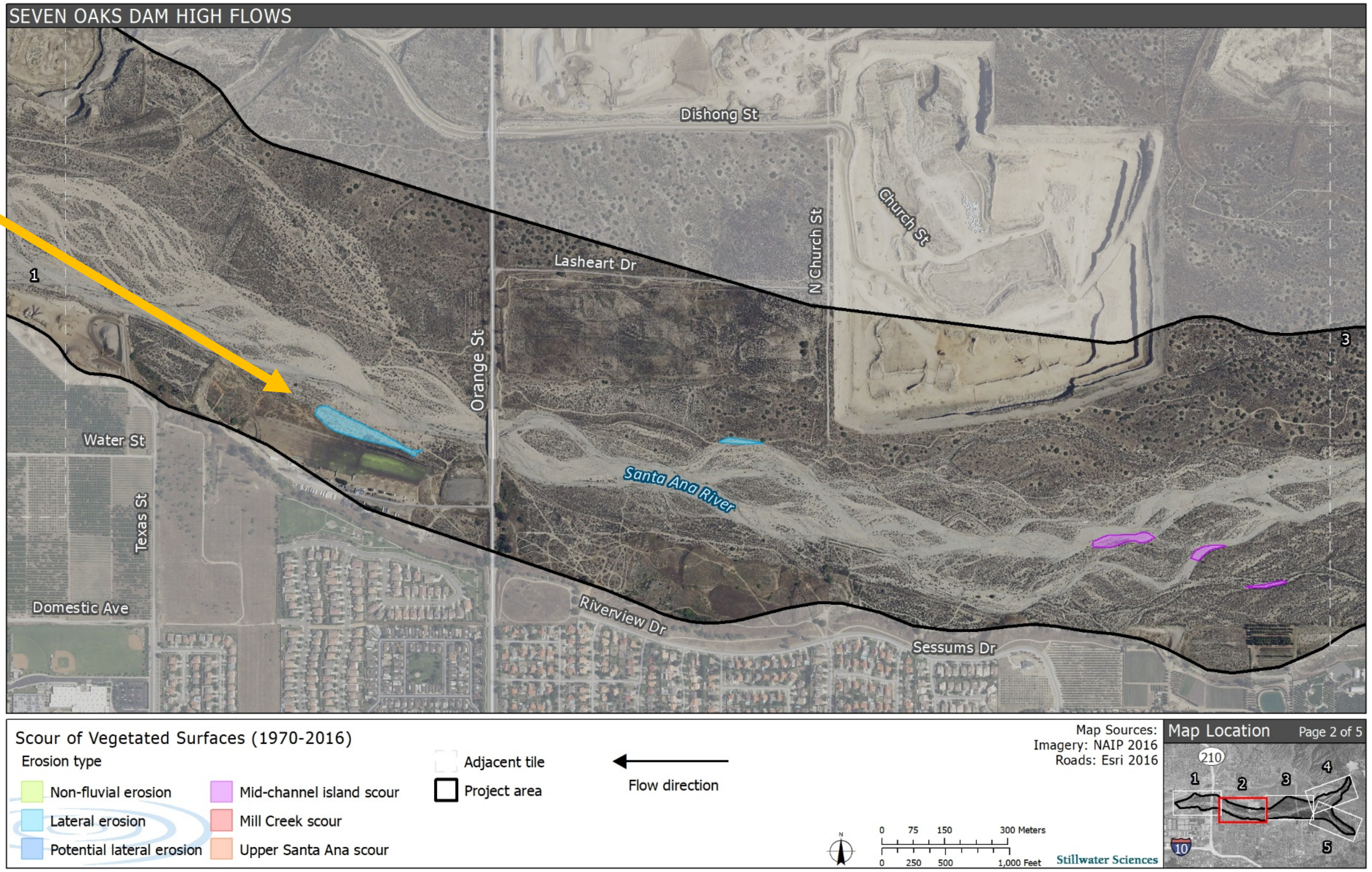
Lateral erosion summary

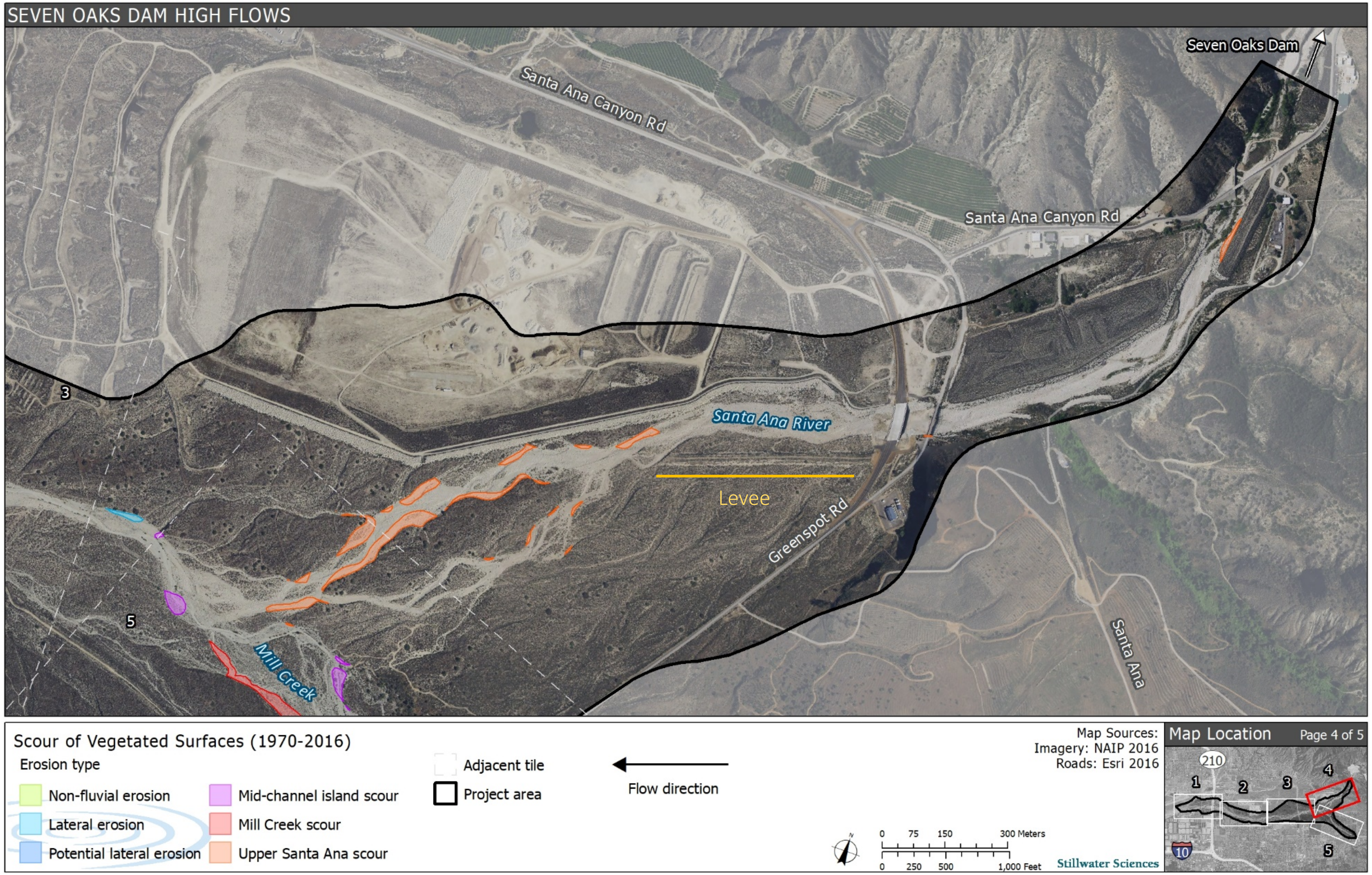
There has been only 3 acres of lateral scour between the confluence of Mill Creek and City Creek (a total mapping area of 2990 acres). The lateral position of the channel has not changed appreciably since the 1969 flood. Lateral erosion is often near structures



Scour Type	Area (acres)
Non-fluvial	0.3
Lateral Erosion	3.0
Potential lateral erosion	0.5
Mid channel island scour	4.5
Mill Creek	6.0
Upper Santa Ana	4.7

Total Mapping Area 2,990 acres

Scour upstream of Mill Creek is a response to levees concentrating flow over what was a distributary fan



Why is bank erosion so rare?

The banks are very coarse, particularly upstream with much of the sediment likely derived from debris flows. Eroding the bank therefore requires moving these large boulders.

Scour existing vegetation in the channel

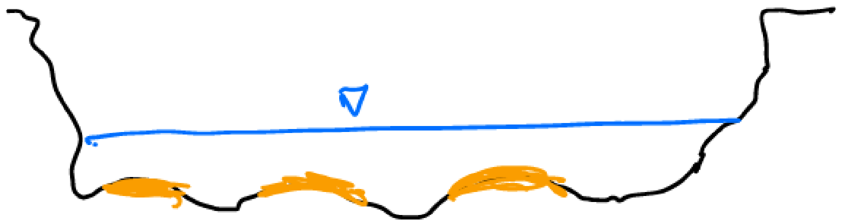
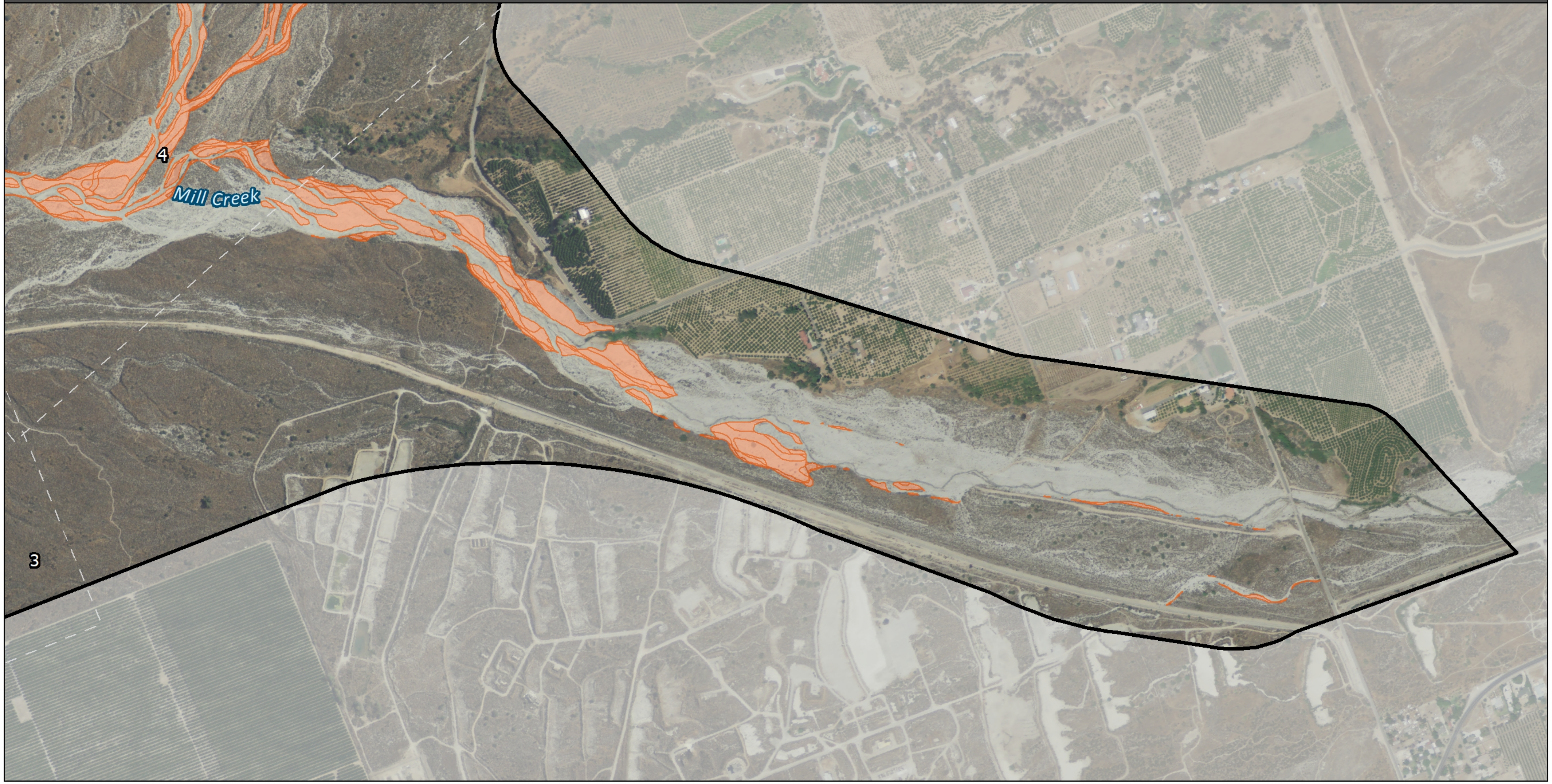


Photo year	Highest discharge at E Street gage prior to photo (cfs)	Date of highest discharge
1970 (ICF)	~25,700-40,495*	1/25/1969-2/25/1969
2008 (NAIP)	35,700	1/11/2005
2012 (NAIP)	27,800	12/22/2010*
2016 (NAIP)	6,150	11/21/2013

*Also included test releases from SOD from 3159-5003 cfs

SEVEN OAKS DAM HIGH FLOWS



Erosion (2009-2012)

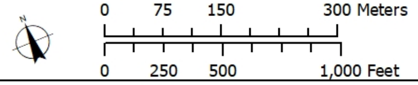
Erosion, where sparse to heavy vegetation in 2009 transitioned to low vegetation in 2012

Adjacent tile

Project area

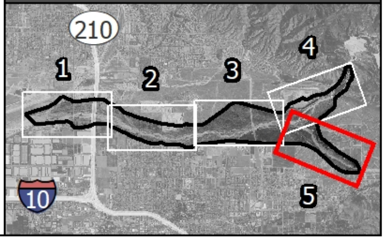
Flow direction

Map Sources:
Imagery: NAIP 2009
Roads: Esri 2016



Stillwater Sciences

Map Location



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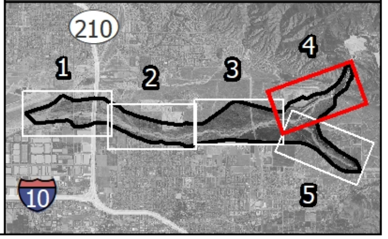

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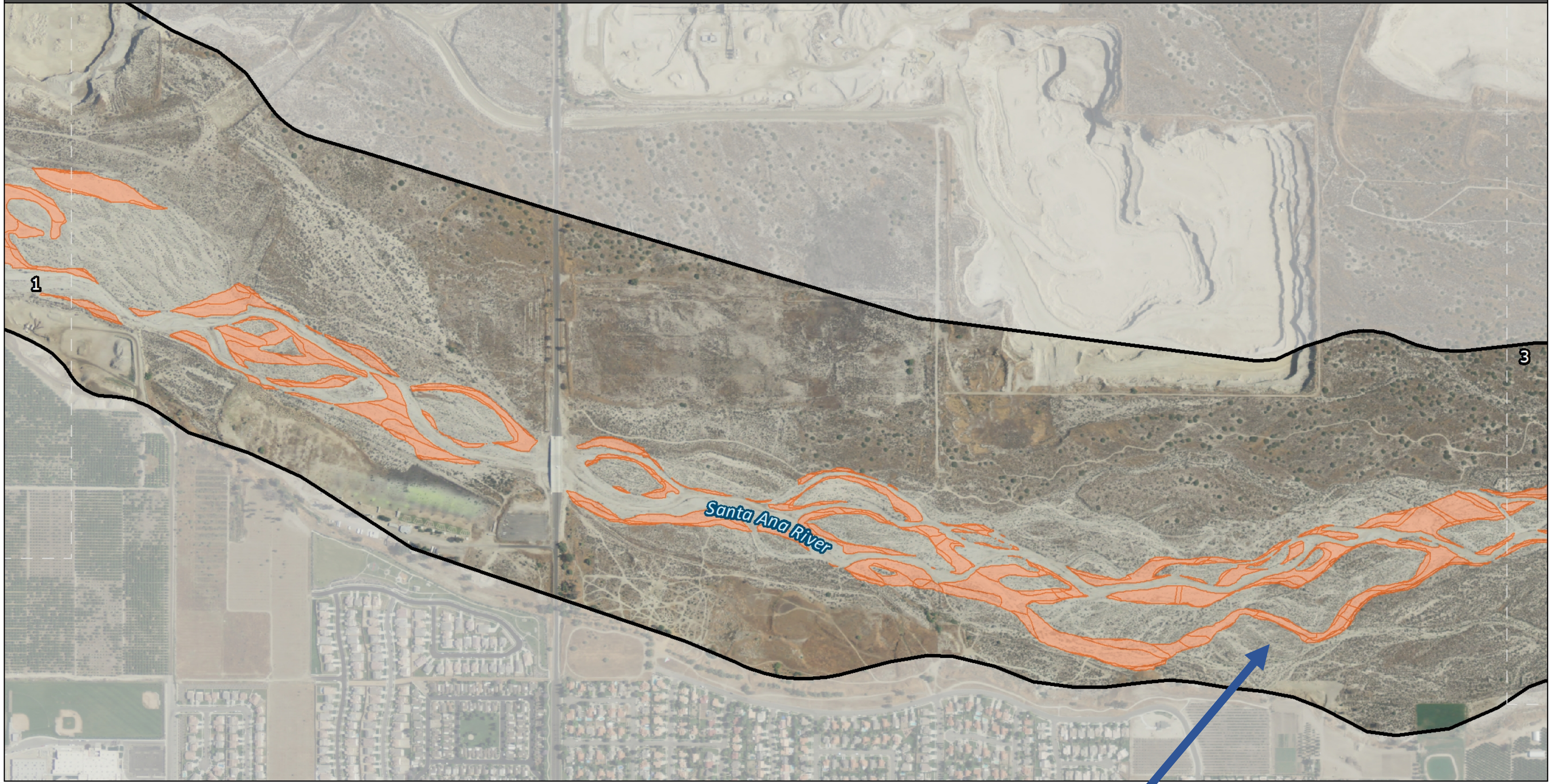

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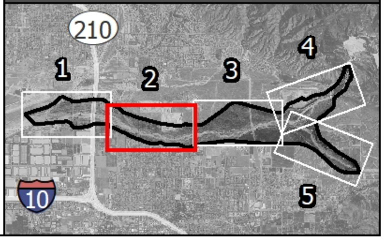

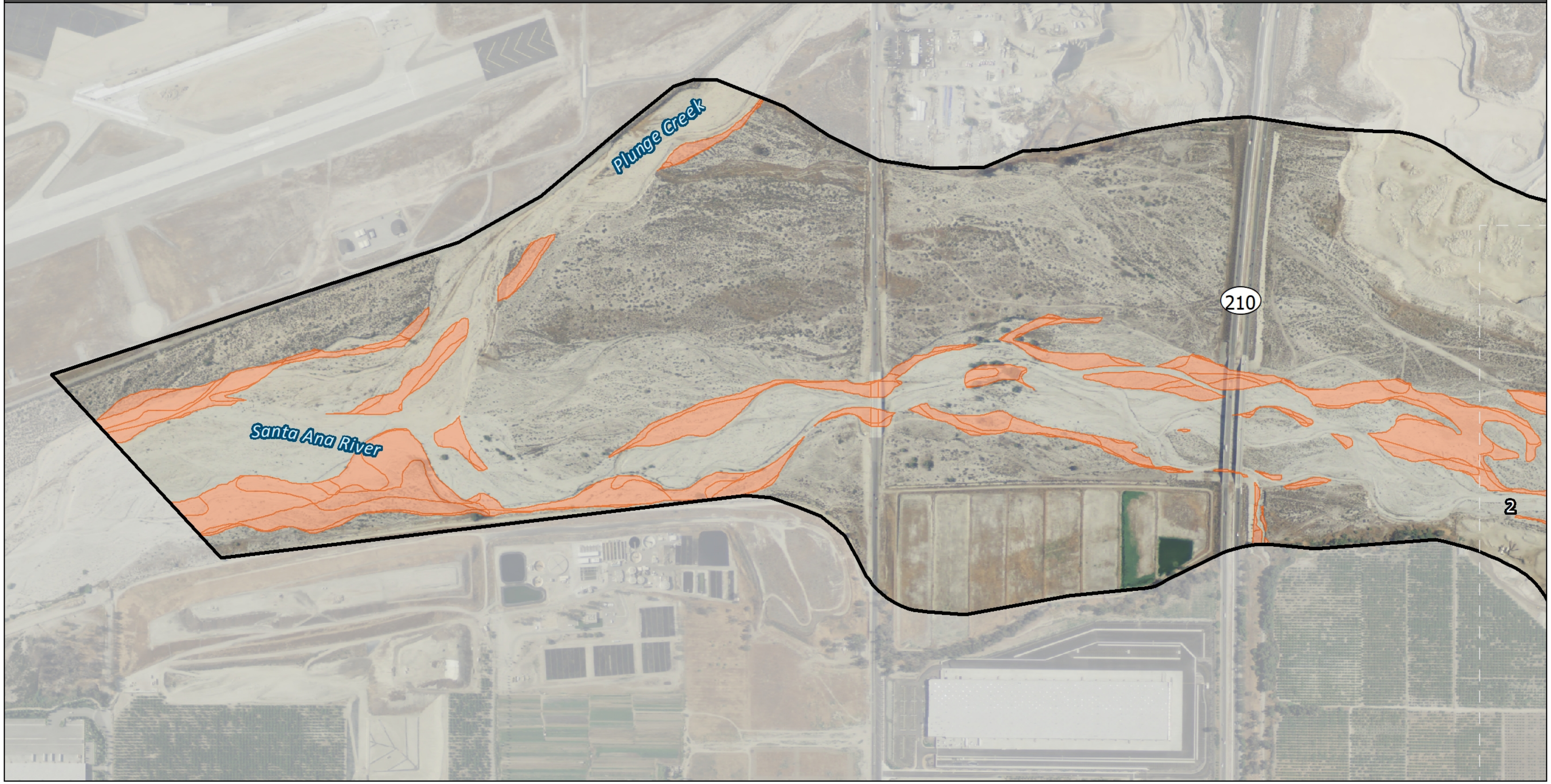

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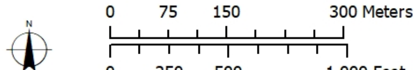

Stillwater Sciences

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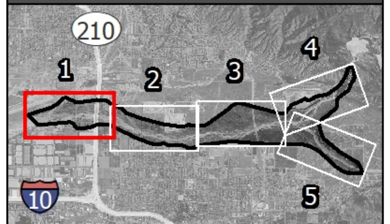

2012-2016 Changes


SEVEN OAKS DAM HIGH FLOWS
Seven Oaks Dam
Santa Ana River
Levee
Mill Creek
3
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Erosion (2012-2016)
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Flow direction
Map Sources:
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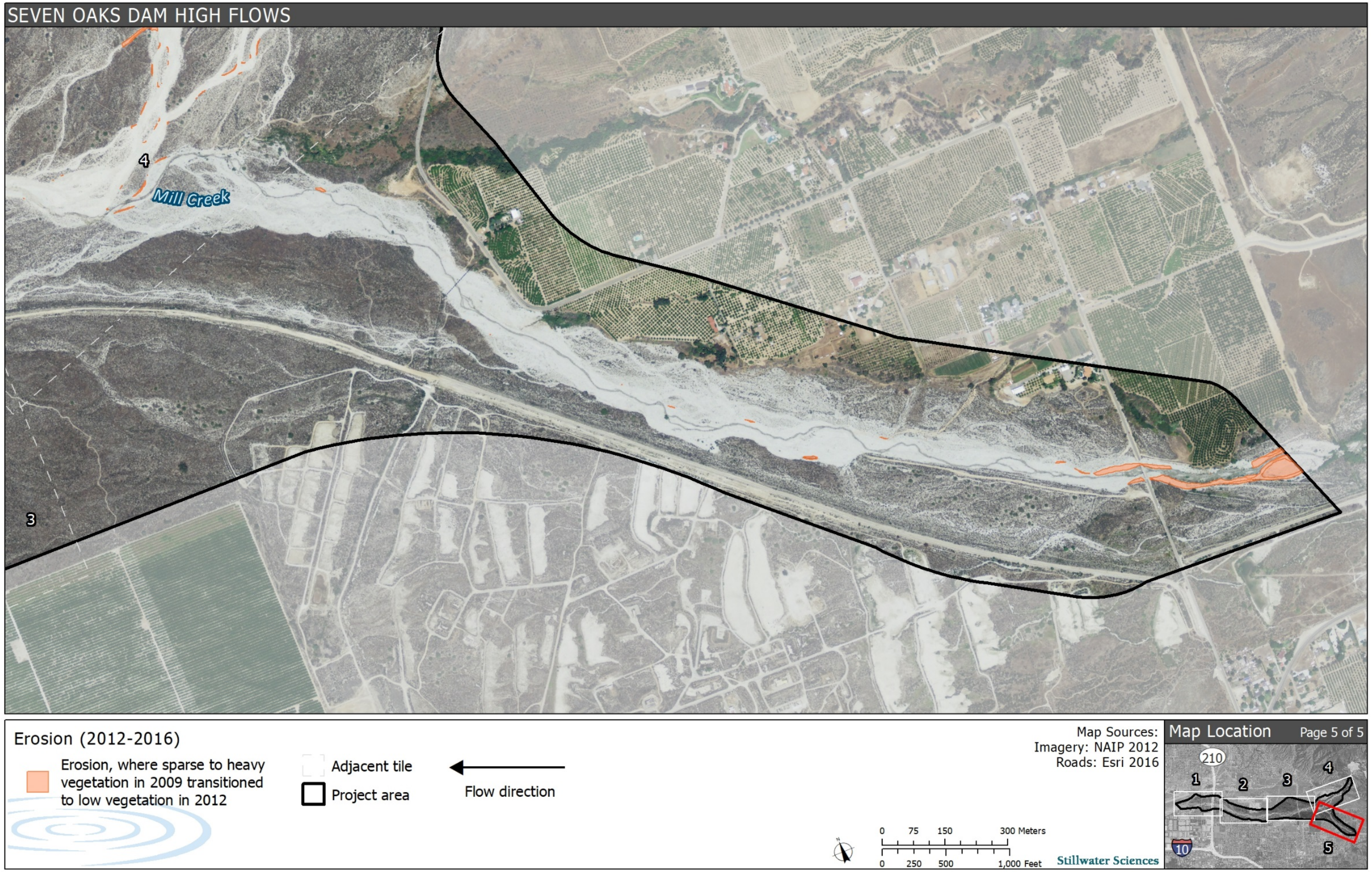
SEVEN OAKS DAM HIGH FLOWS
Mill Creek
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Erosion (2012-2016)
Erosion, where sparse to heavy vegetation in 2009 transitioned to low vegetation in 2012
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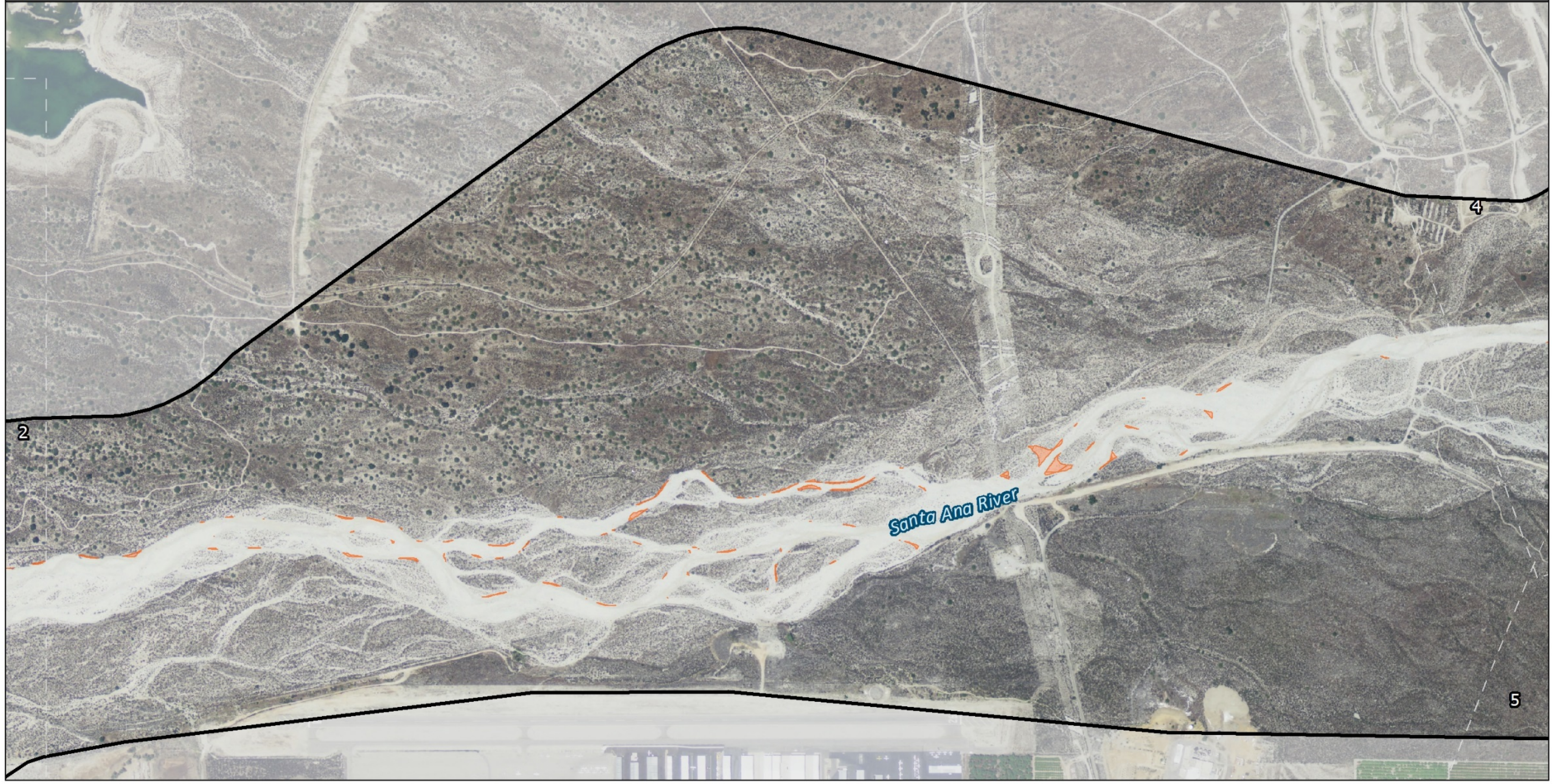
SEVEN OAKS DAM HIGH FLOWS



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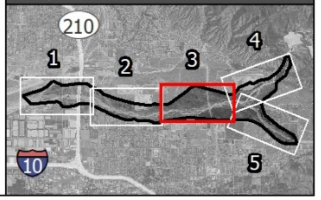

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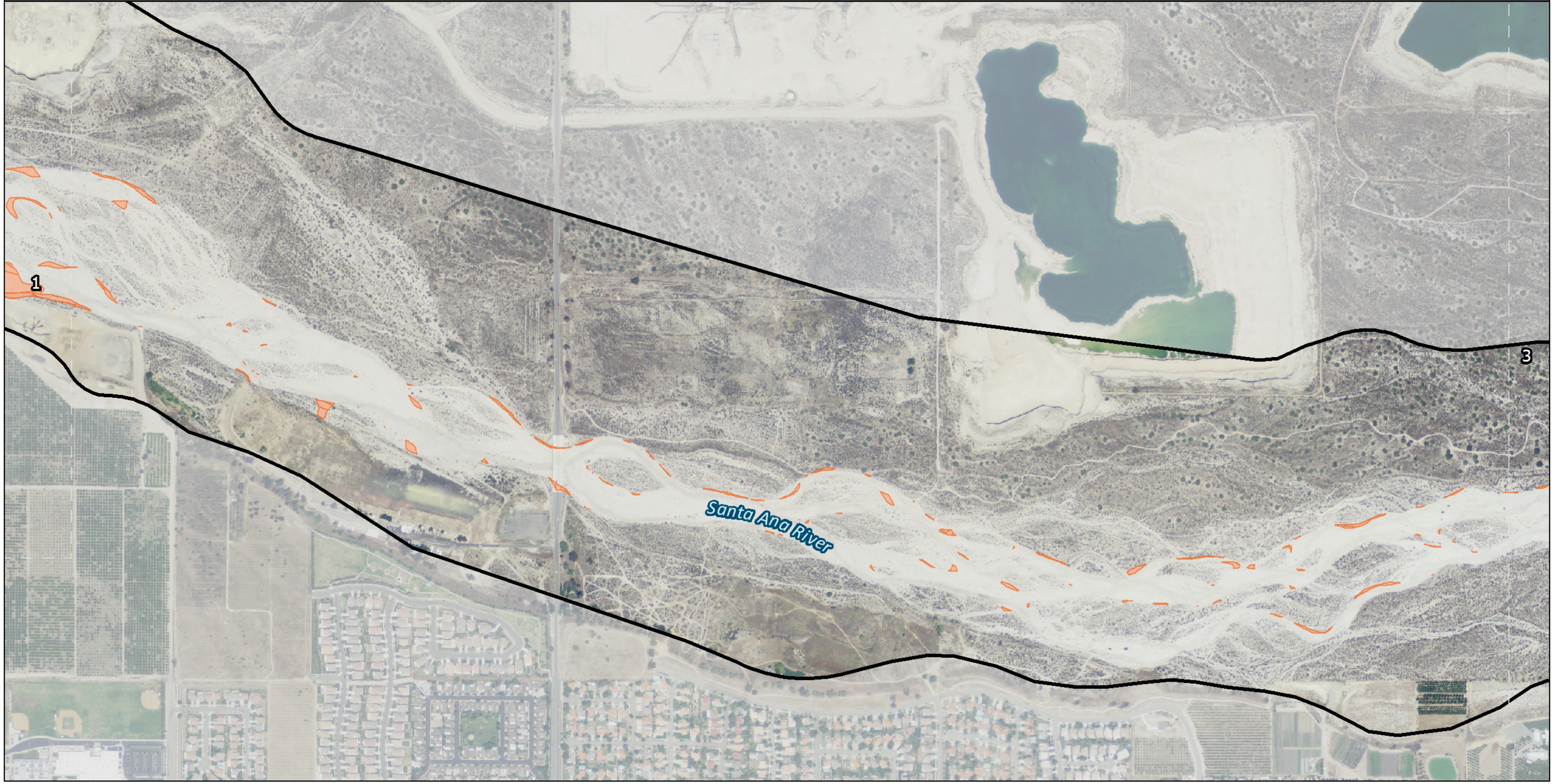

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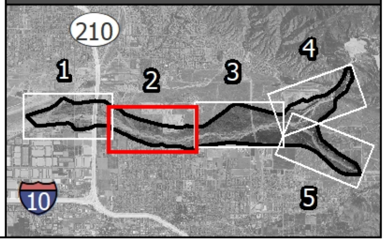

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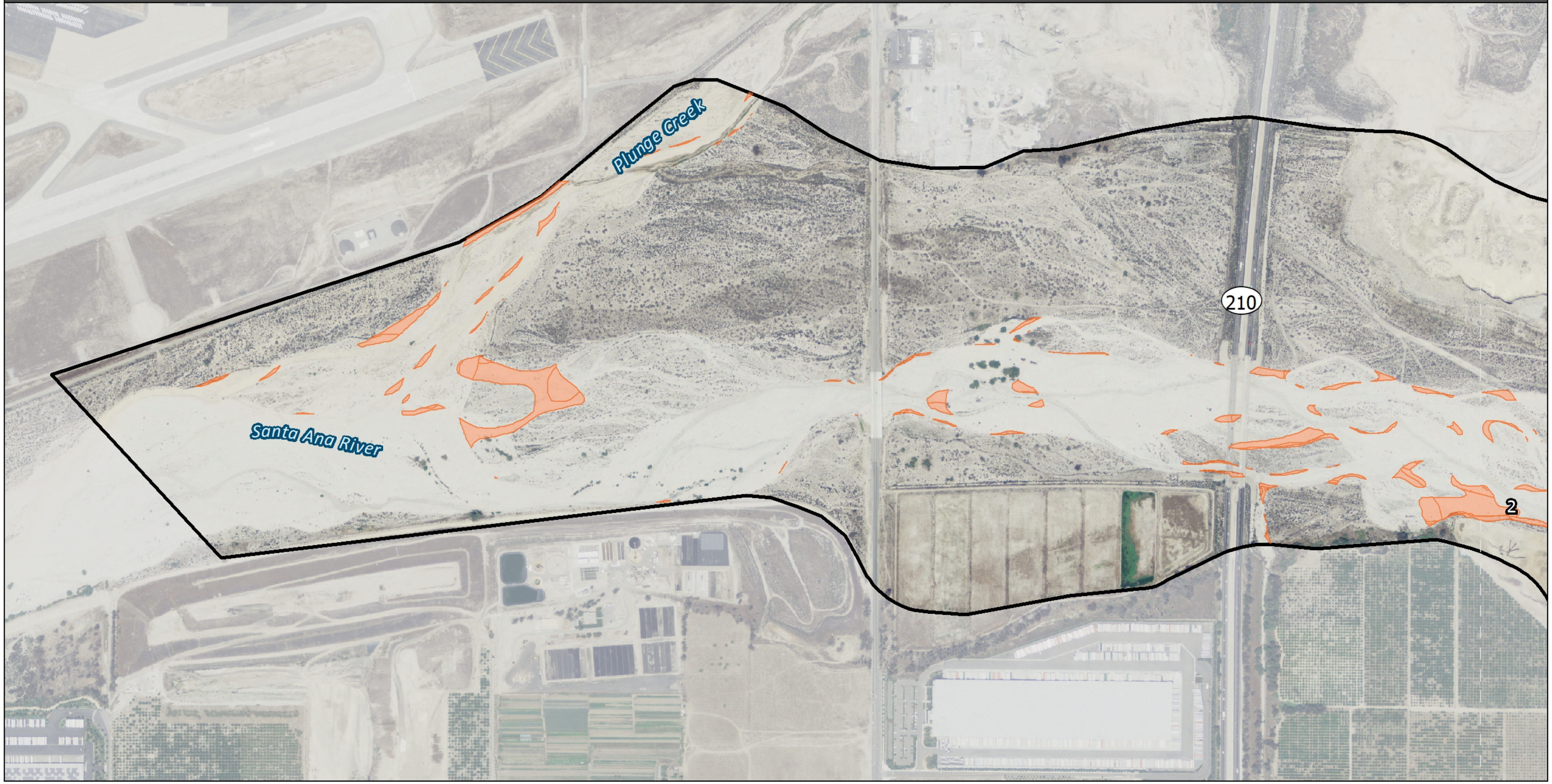

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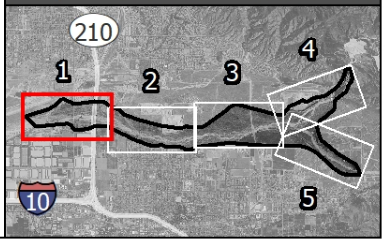


Extent (acres) of low density vegetation (i.e., recently active channel)

Year	Reach		
	Santa Ana downstream of Mill Creek	Santa Ana upstream of Mill Creek	Mill Creek
1970	2638	438	163
2009	697	115	82
2012	1125	202	88
2016	934	179	46

What surfaces were most likely to scour?

Vegetation density	Santa Ana from Mill Creek-City Creek		Santa Ana from Seven Oaks Dam to Mill Creek		Mill Creek	
	2009-2012 (acres)	2012-2016 (acres)	2009-2012 (acres)	2012-2016 (acres)	2009-2012 (acres)	2012-2016 (acres)
Sparse	429.6	29.2	60.3	0.2	26.8	4.5
Moderate	57	4.9	29.4	0.3	2.4	0.1
High	1.3	0.1	1.3	0.7	1.8	0
Total	487.9	40.1	90.9	1.2	31.0	4.5

The initial vegetation density of scoured/buried surfaces for 2009-2012 and 2012-2016 for three study reaches

From 2012-2016, 191 acres of low vegetation density had their vegetation density increase

2009 vegetation density	Area (acres)	%
Low	48	21%
Sparse-high	177	79%
Total	225	

48 acres of sparse-high vegetation density surfaces in 2012 scoured by 2016.

Summary

- This study suggests that bank erosion is rare since the 1969 flood and that channel widening due to high flows alone is unlikely to occur.
- We found that for the Santa Ana River bed scour was much greater during the 2010 floods (discharge =27800 cfs at the USGS E Street gage) than during the 2012-2016 period (maximum discharge = 6,180 cfs at the E Street gage).
- During 2012-2016 some scour occurred (generally on 2009 vegetated surfaces), although it was less than the rate of revegetation.
- The results suggest that surfaces with sparse to high vegetation density that scoured during the observed floods were more likely to revegetate than surfaces that maintained a low vegetation density through the flood (i.e., flooding higher surfaces

Upper Santa Ana River High Flows Study

Contributions to Phase II
by

Michael Lamb, PhD; Tom Ulizio; Toby Minear, PhD

Blue Octal Solutions, LLC

Presented at San Bernardino Valley Water District
July 25, 2019

Proposed Tasks

1. Literature review for critical thresholds of vegetation scour by flood flows.

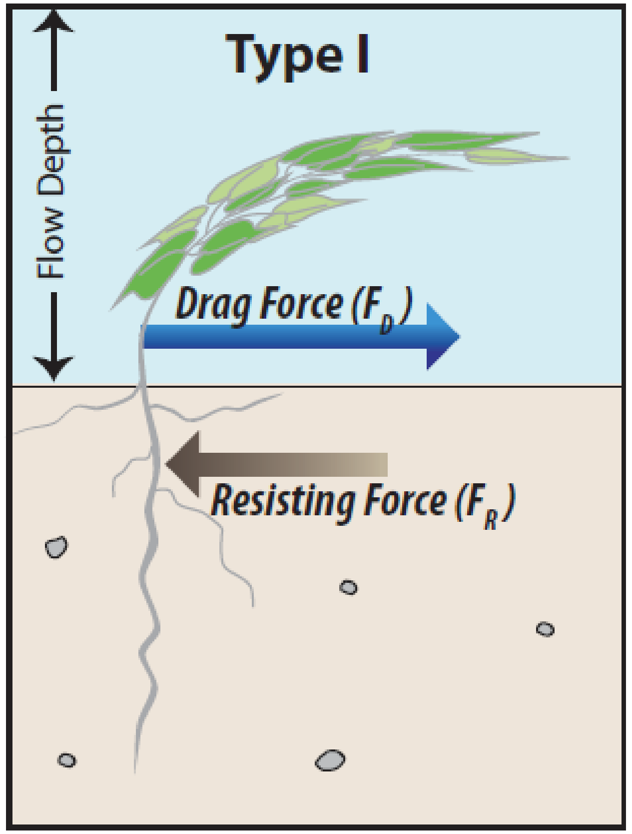
2. Field assessment of grain size distributions for threshold of sediment mobilization.

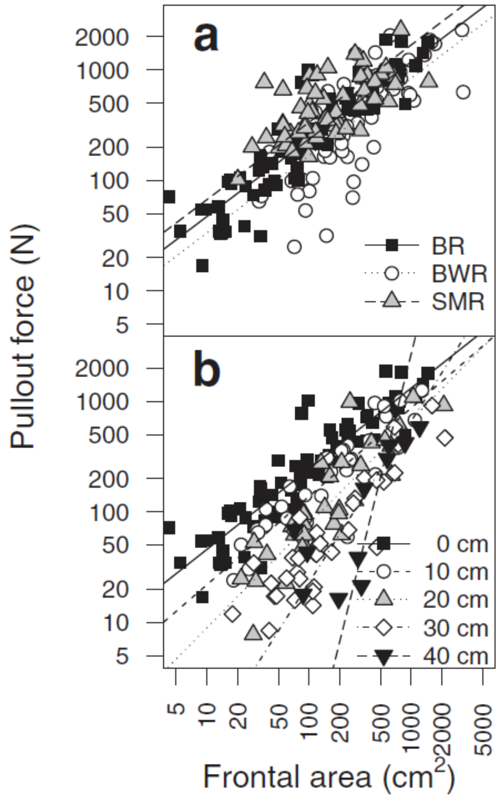
Vegetation Removal Review

- Reviewed ~20 studies on vegetation removal which used observations from natural floods, controlled floods, flume experiments, and physical uprooting measurements with force gauge, and a range of plant species.

- Studies indicate that drag forces from water is typically insufficient to overcome resisting forces of plant roots (Type I).

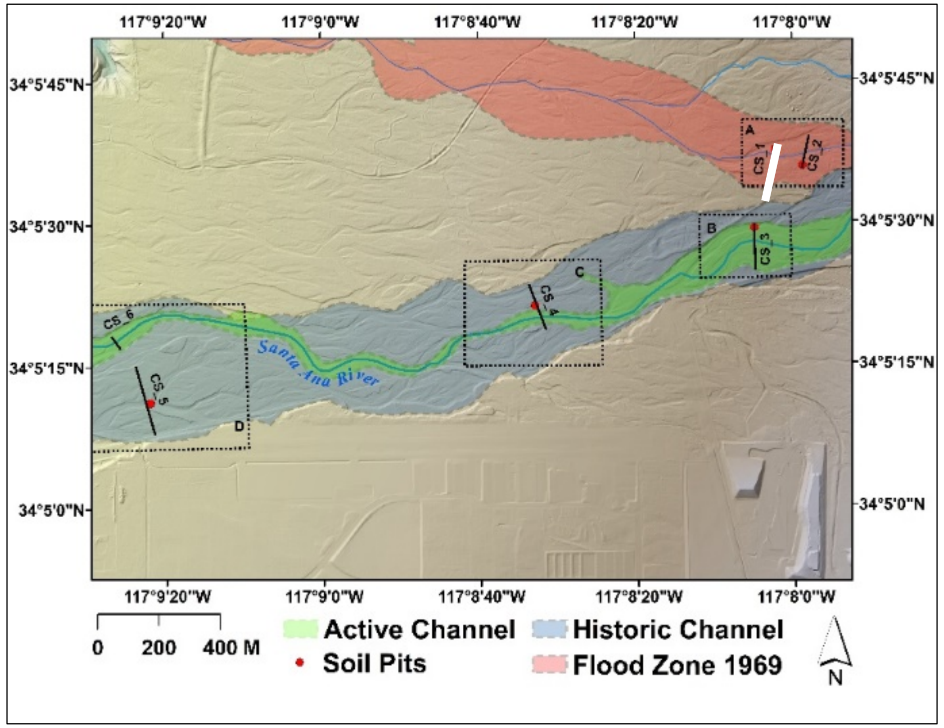
- Instead, **bed erosion or bar migration exposes roots and causes plant removal** (or burial) (Type II).





Bywater-Reyes et al. (2015)

Vegetation Removal Assessment

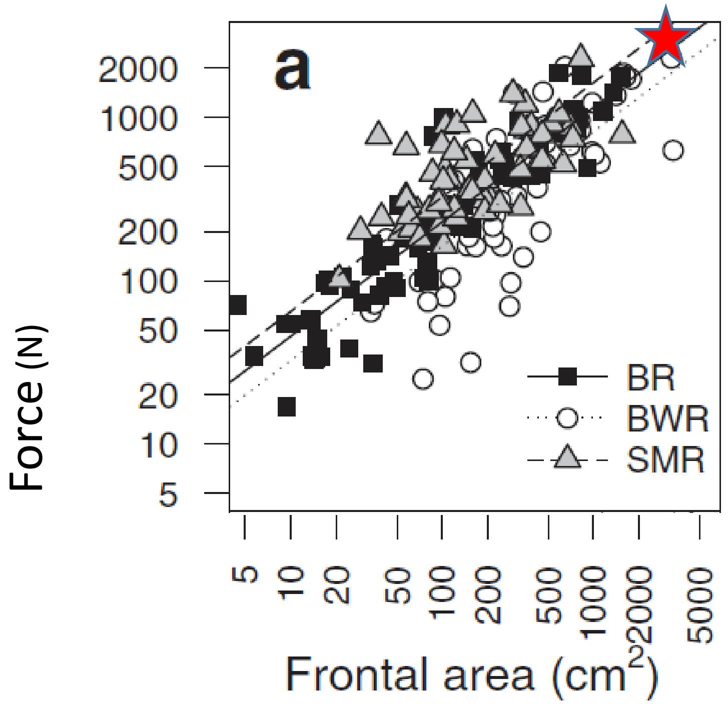


- Measured 21 plants along CS_2 (1969 flood zone), and estimated frontal area of ~ 4000 cm^2.

- Requires ~2000 N of force to uproot without bed scour (Bywater-Reyes et al., 2015).

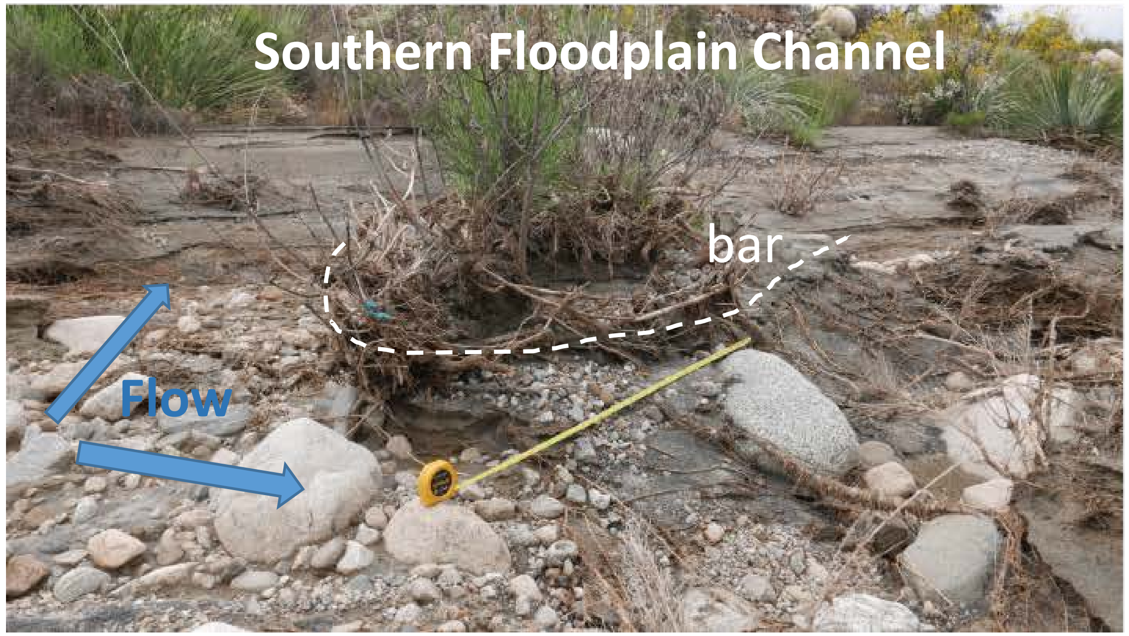
- Requires flow velocities of ~3.2 m/s given standard drag formulas for plants (Nepf, 2012).

- Patches of plants (grasses) can increase resisting forces by ~ 10-fold (Pollen and Simon, 2005).

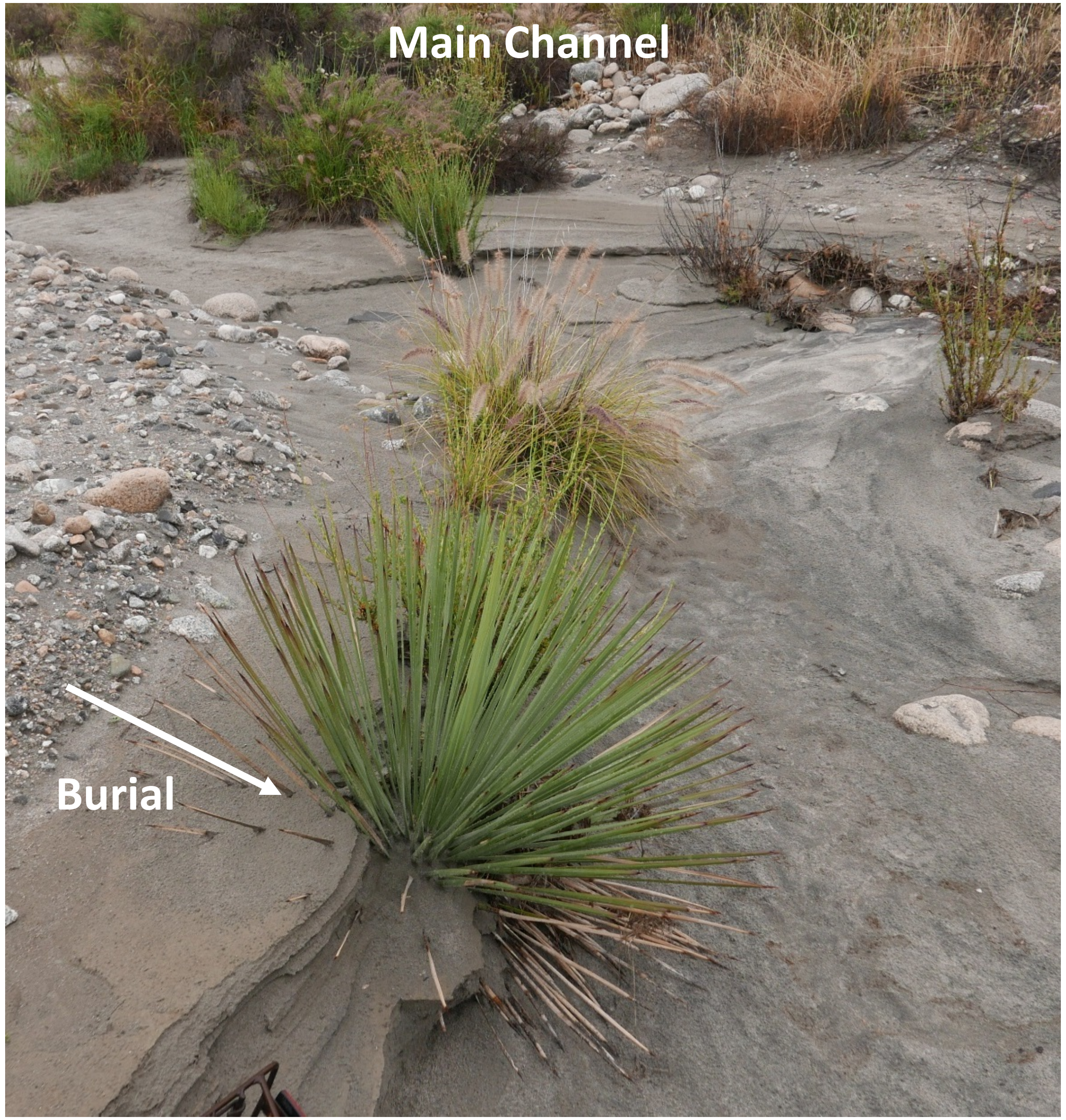


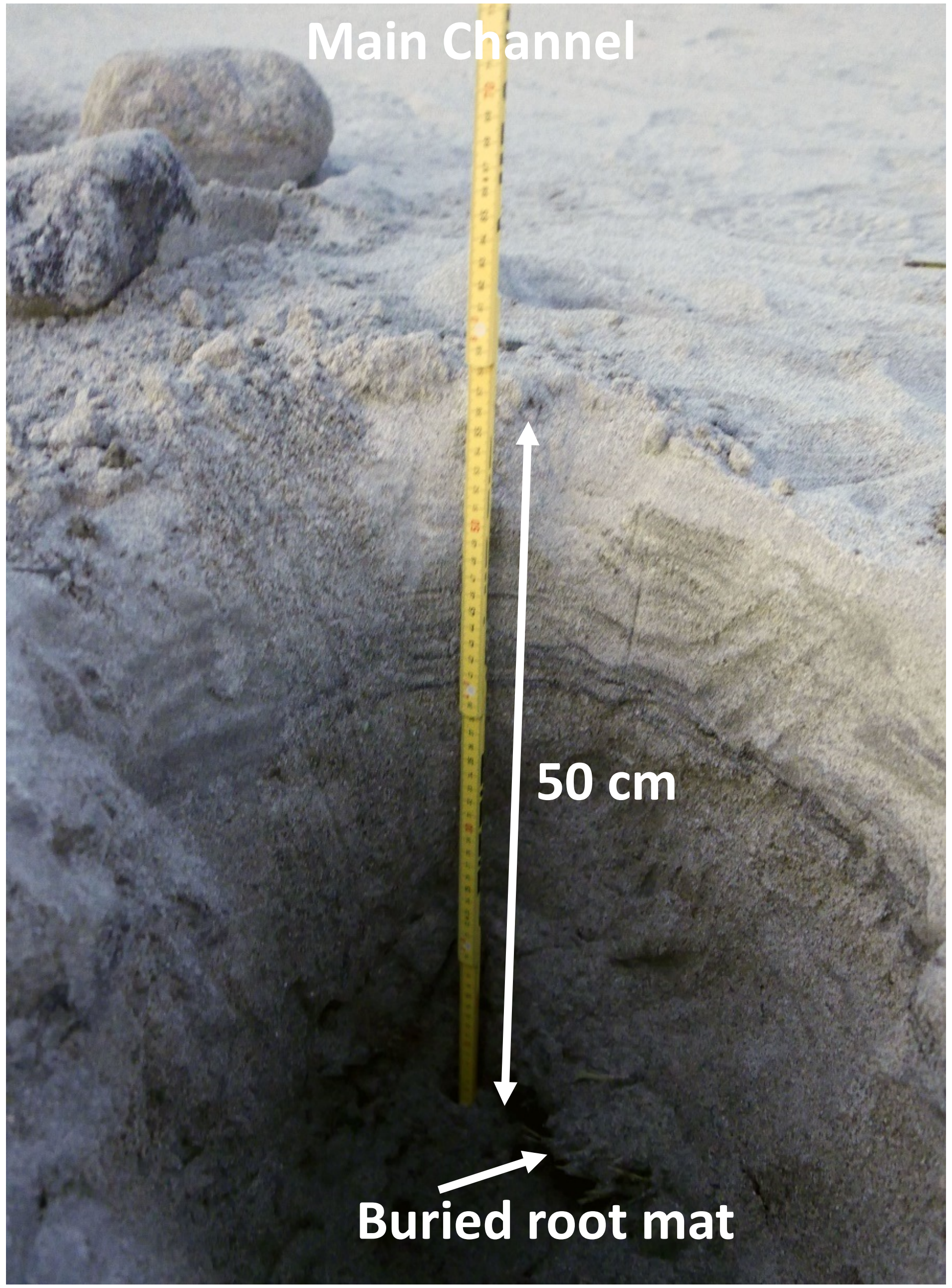
Vegetation Removal Assessment

2018/19 floods did eliminate or damage vegetation in active channel and the “southern floodplain channel” through cobble impacts and bar migration



Vegetation Removal Assessment

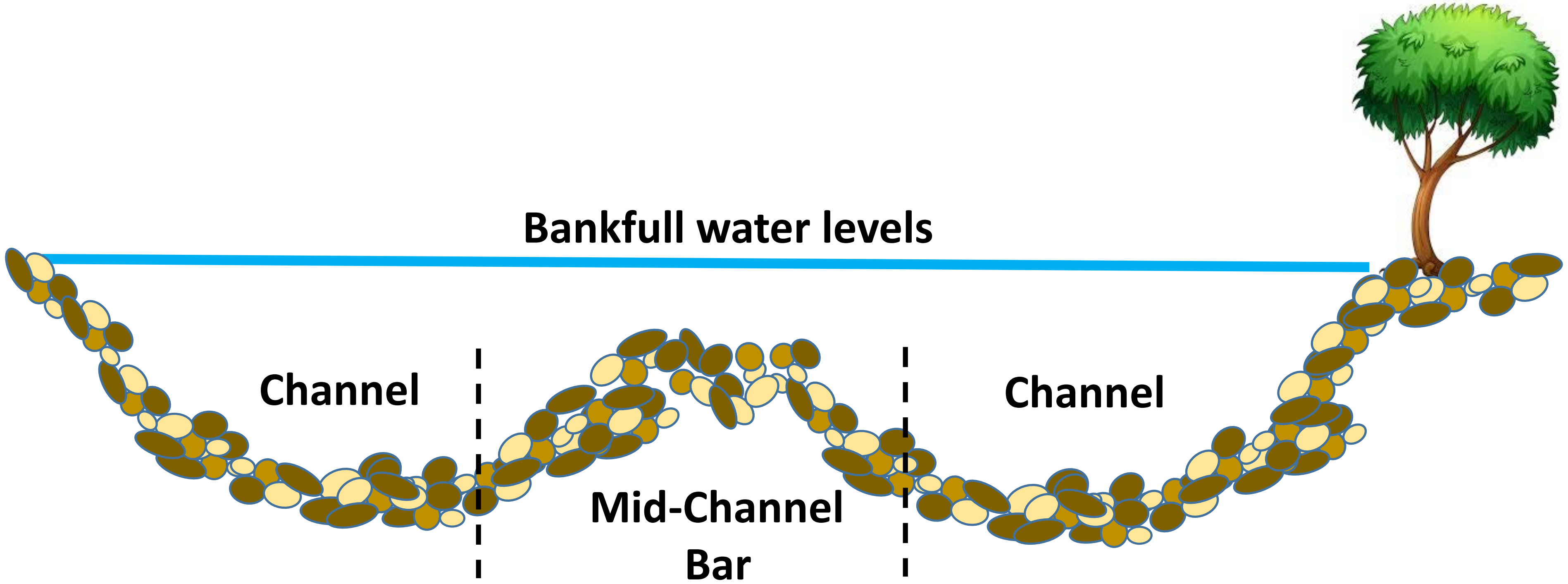




When do bars move?

- Bars form and migrate during channel bankfull conditions.

Bars form and migrate during bankfull flows



Bed stress at bankfull

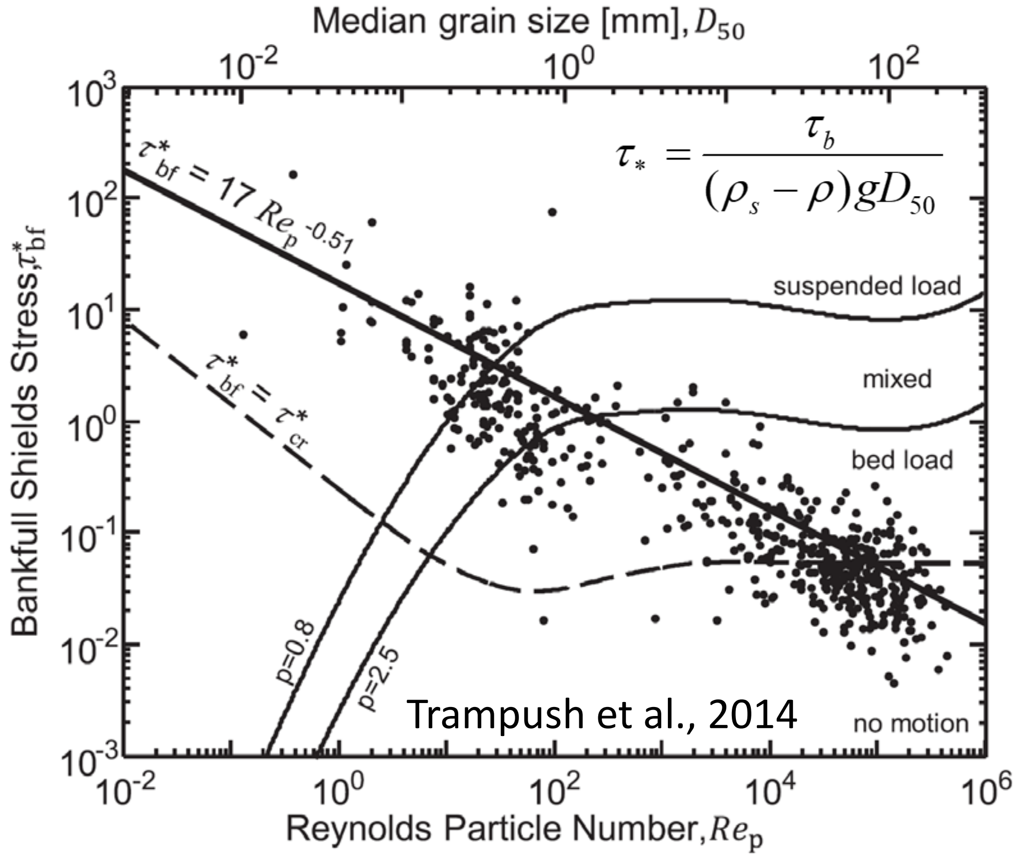
$$\tau_* = \frac{\tau_b}{(\rho_s - \rho) g D_{50}} \longrightarrow \frac{\text{Force of flow}}{\text{Particle weight}}$$

Shields number

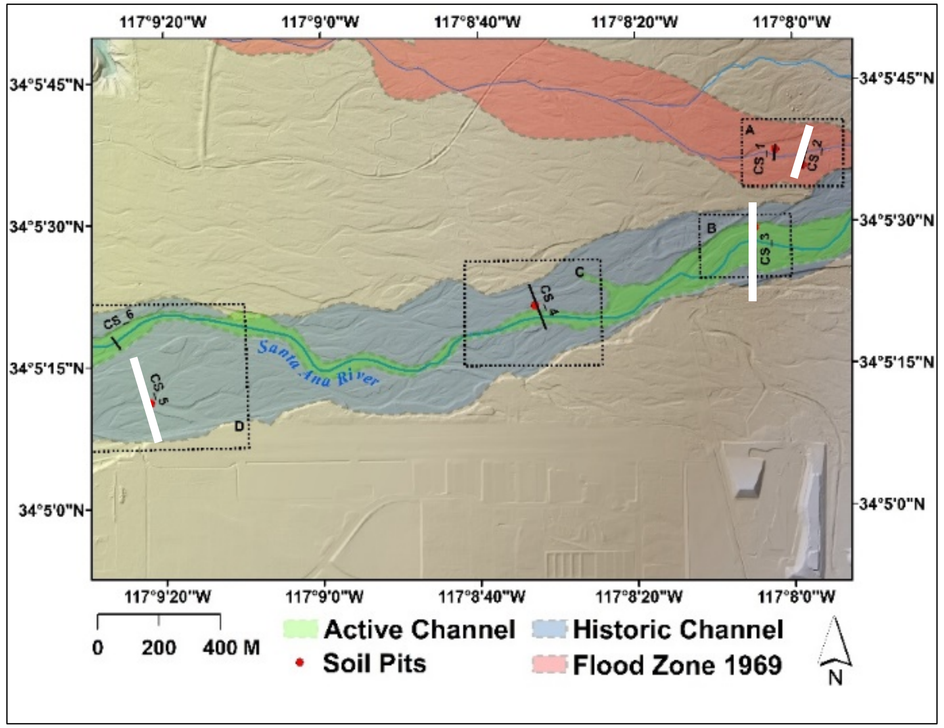
Grain size

When do bars move?

- Bars form and migrate during channel bankfull conditions.
- Global compilation shows river bankfull stresses are a function of bed grain size (Trampush et al., 2014).
- Each point is a river reach
- **Need to know bed grain size**

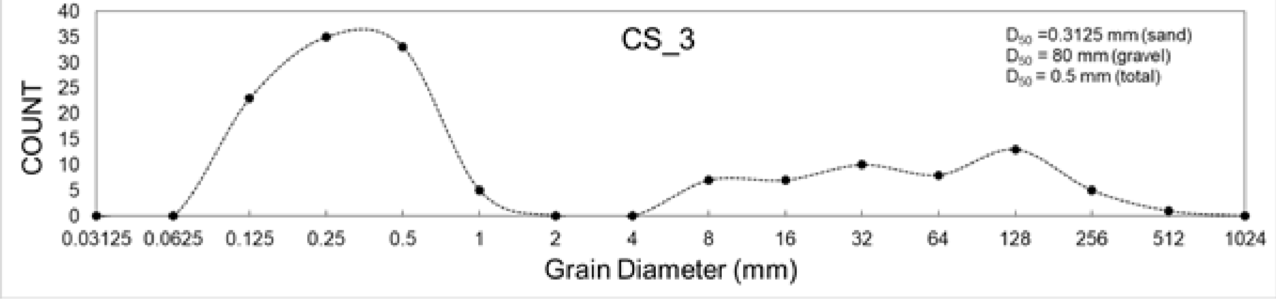


Grain size measurements

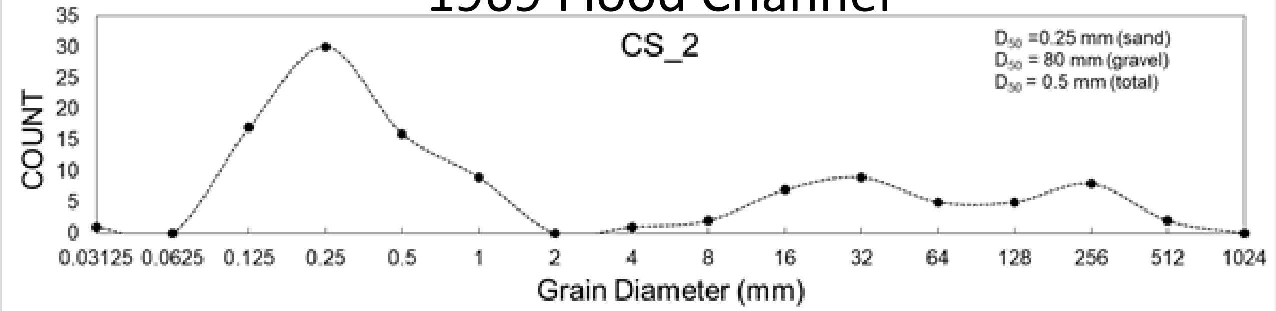


- 1-m spaced Wolman pebble count.
- 6 transects (in active channel and floodplain channels)

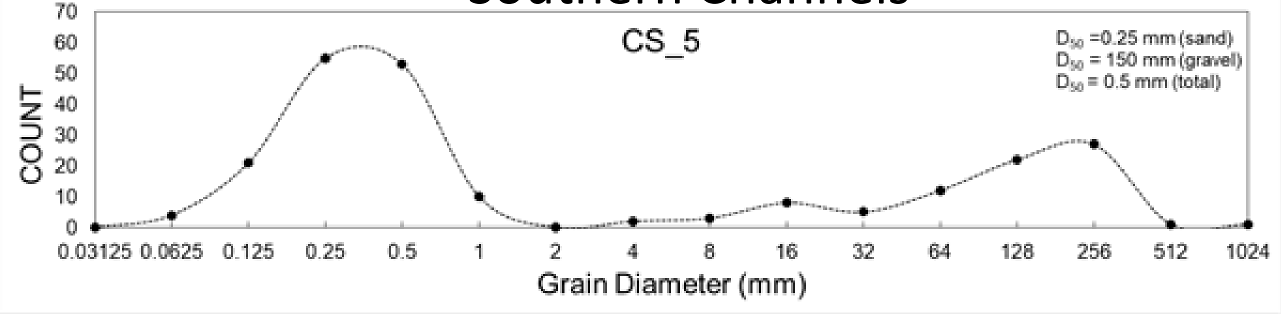
Active Channel



1969 Flood Channel



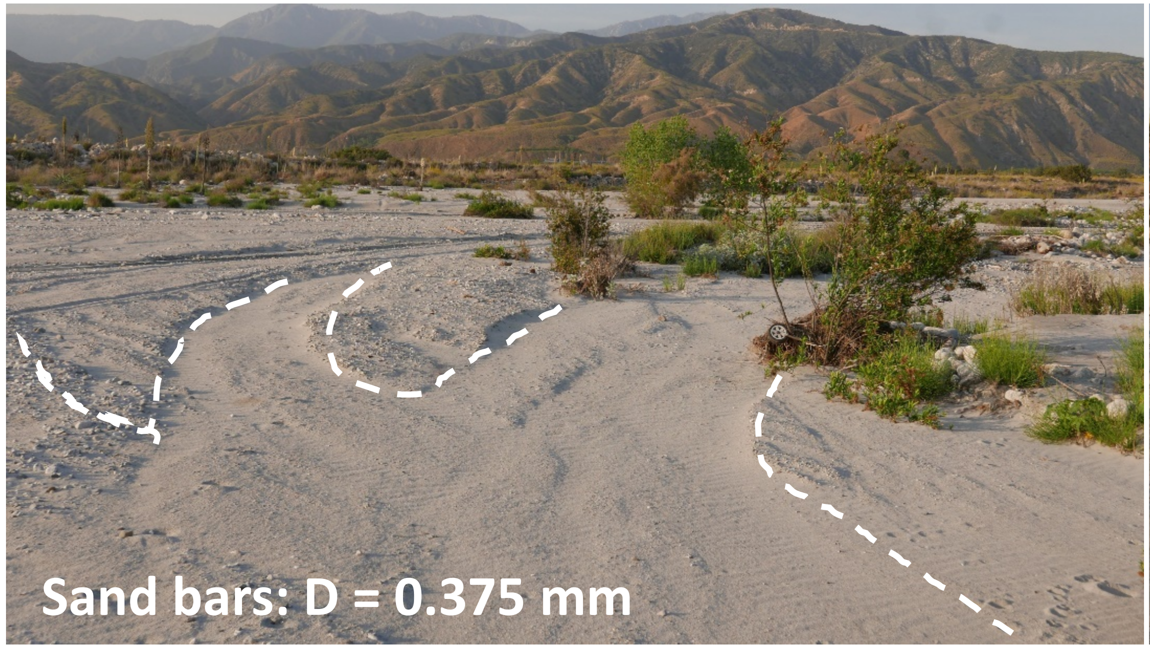
Southern Channels



Key results

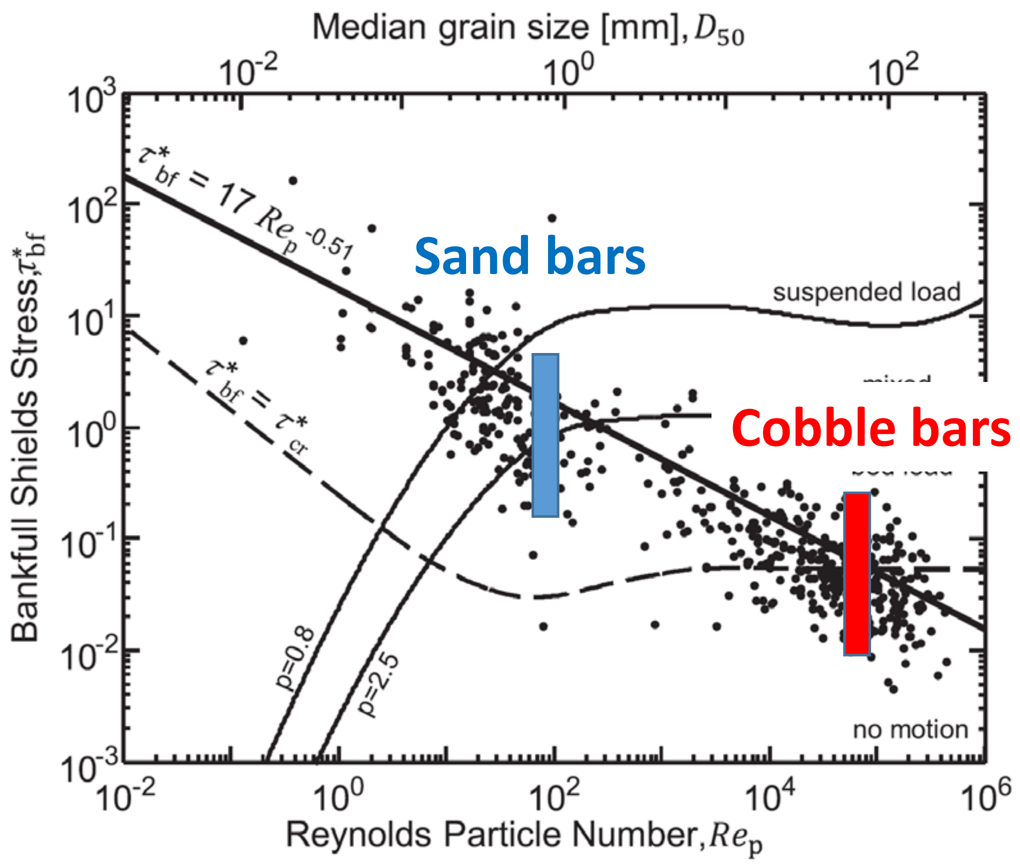
- Bimodal distribution.
- Similar sizes in active channel and older floodplain channels.
- Sediment bed is patchy: medium sand bars (*D* = 0.375 mm) and cobble bars (*D* ~ 115 mm).

When do bars move?



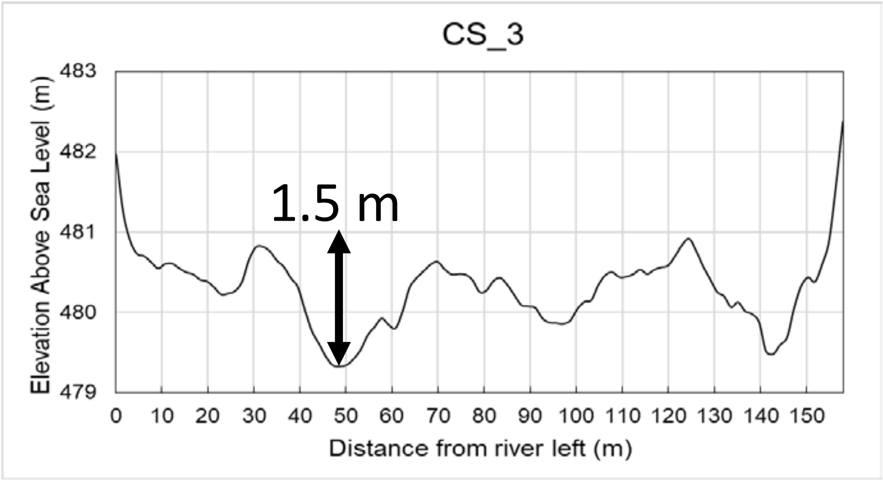
- Bankfull Shields number analysis suggests equilibrium sandy channels require bed stresses of 6-60 Pa (range represents uncertainty). Sand should be moving as mixed bed- and suspended-load during channel-bar-forming floods.

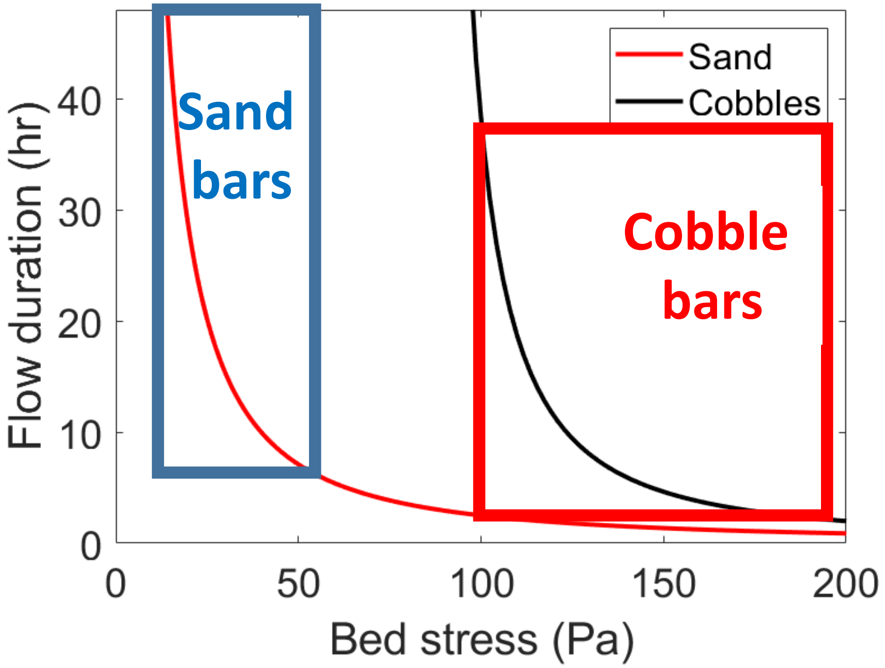
- Equilibrium cobble channels require bed stresses of 90-190 Pa (range represents uncertainty). Cobbles will be in intermittent bedload during channel-bar - forming floods.



Will bars remove vegetation?

- Bar heights are 1-2 m, on the scale of rooting depths, suggesting uprooting is likely.
- Using sediment transport calculations (see Report), we found the duration of flow needed at a given stress for significant bar migration.
- Floods must persist for many days under low sand transport stresses, and for ~ 10-20 hours under high sand transport or cobble-transport to achieve significant bar migration.
- Evidence of low vegetation density, and active plant uprooting in the active channel suggests current floods are capable of creating the desired disturbance in the active channel.





Conclusions: Vegetation and sediment thresholds

1. Plant uprooting is difficult, and most likely happens by undermining or burying plants through bar migration.

2. Bar migration likely requires bed stresses of 6 - 60 Pa to form and mobilize sand bars, and 90 -190 Pa to form and mobilize cobble bars. Range represents uncertainty.

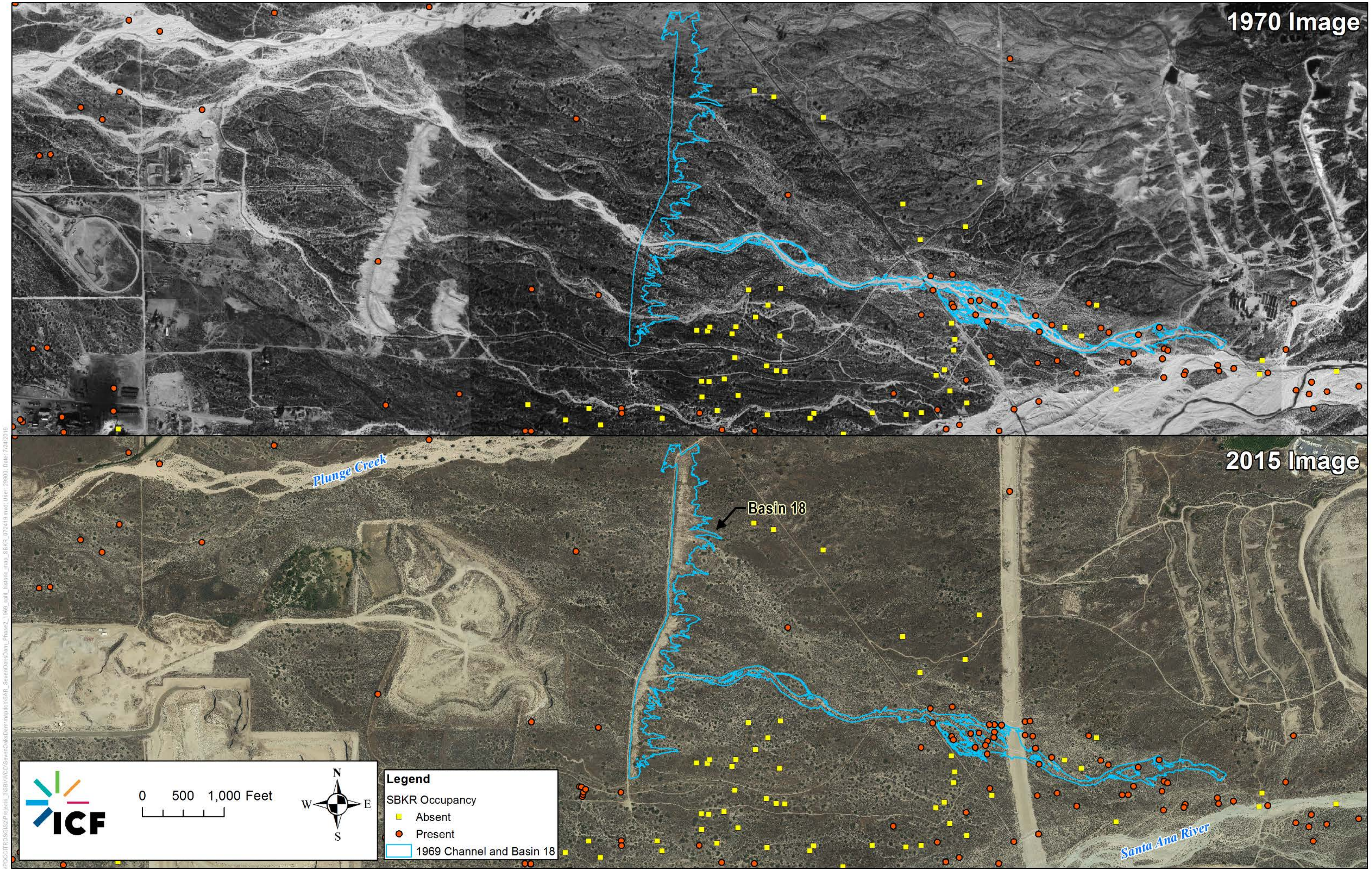
3. Flood durations need to be for tens of hours at low stresses, and ~ 10 hours at high stresses to achieve meaningful bar migration.

4. Modern channel is able to migrate bars and remove vegetation during last winters floods, and the historic imagery analysis by Stillwater Sciences suggests bar migration in the active channel since 1970. This suggests that modern floods – if routed in their entirety onto the floodplain – could achieve the desired disturbance.

5. However, it is currently unknown how much of the modern flood flows are needed to achieve the desired results. Theory presented here can be used as a guide. But, the historical events should be modeled numerically to infer the bed stresses responsible for observed disturbance to test the theoretical estimates.

Enhancement Measures Overview

Enhancement Measure 1: The 1969 Channel



Enhancement Measure 1: Overview

Enhancement Measure 1: 1969 Channel

Rock wall channel plug in relation to the active Santa Ana River and 1969 Channel

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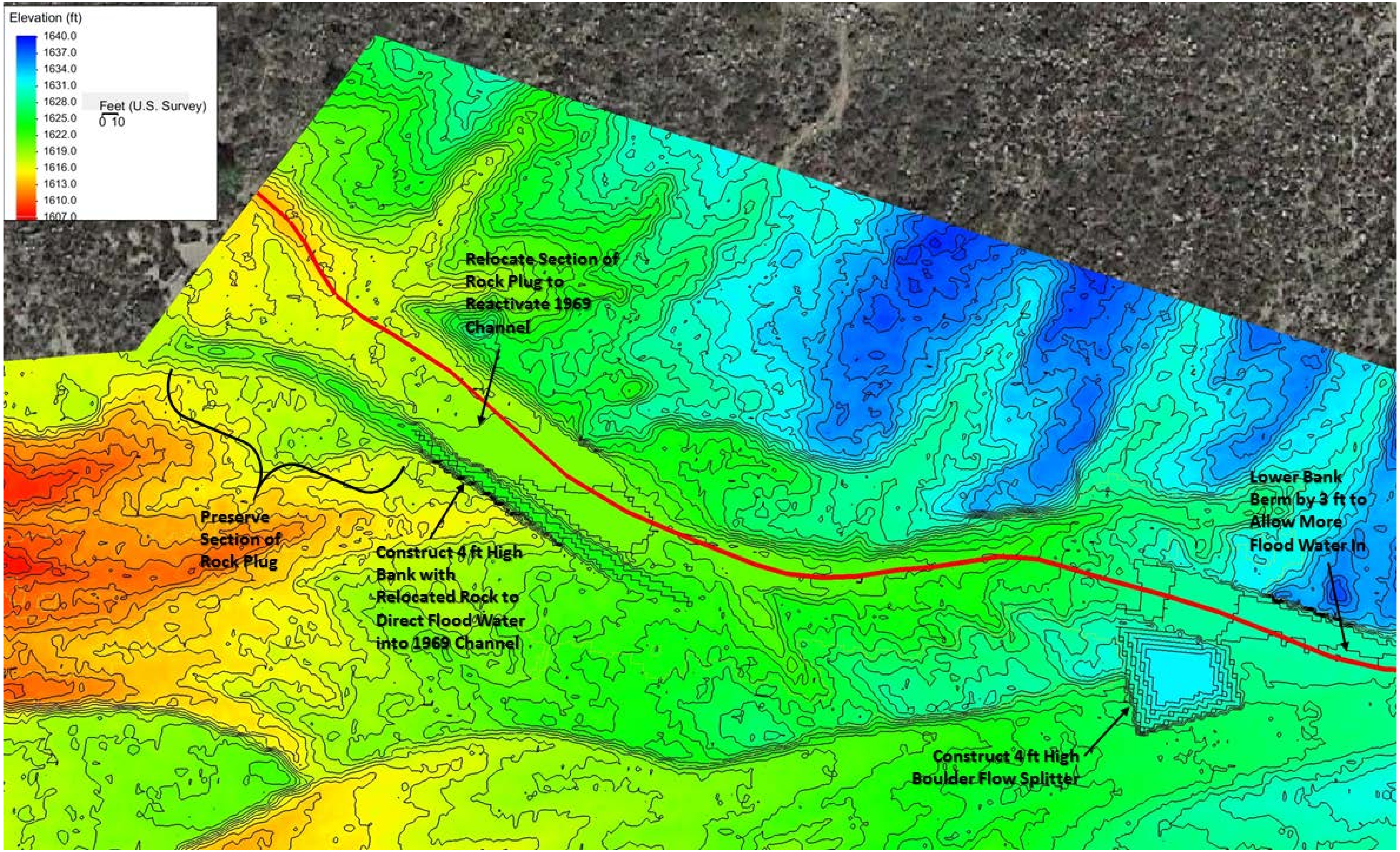
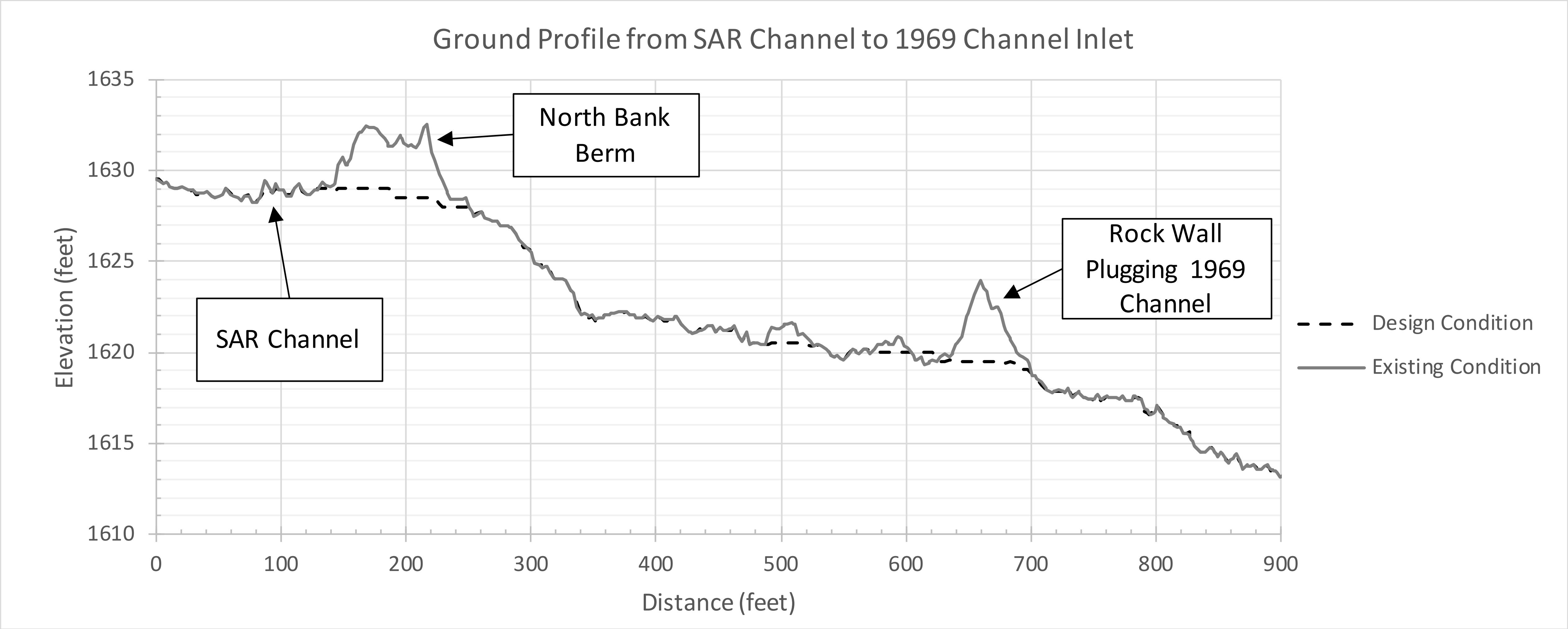
Enhancement Measure 1: 1969 Channel

View to the northwest from atop the rock wall channel plug looking down the 1969 Channel

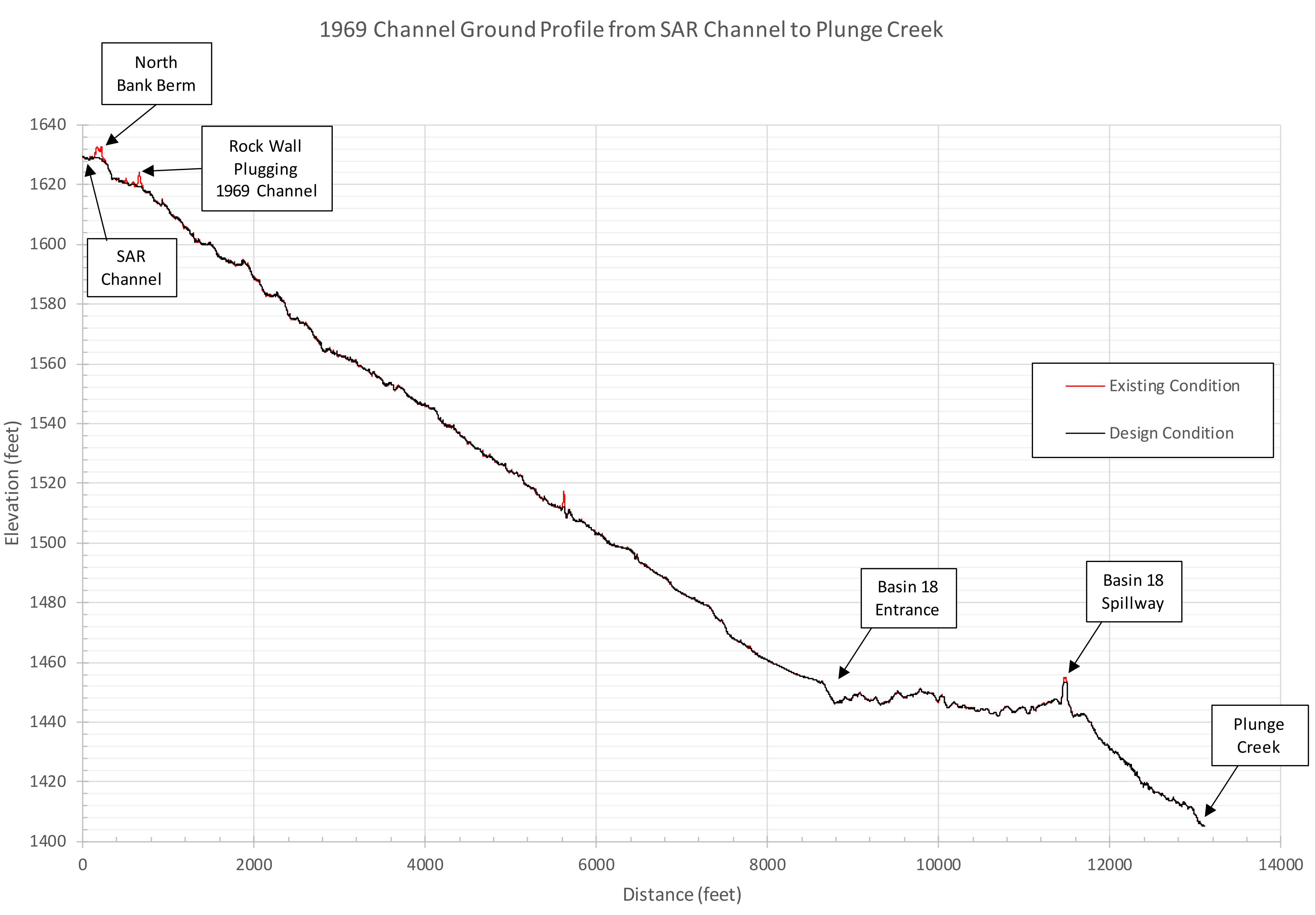
Enhancement Measure 1: 1969 Channel



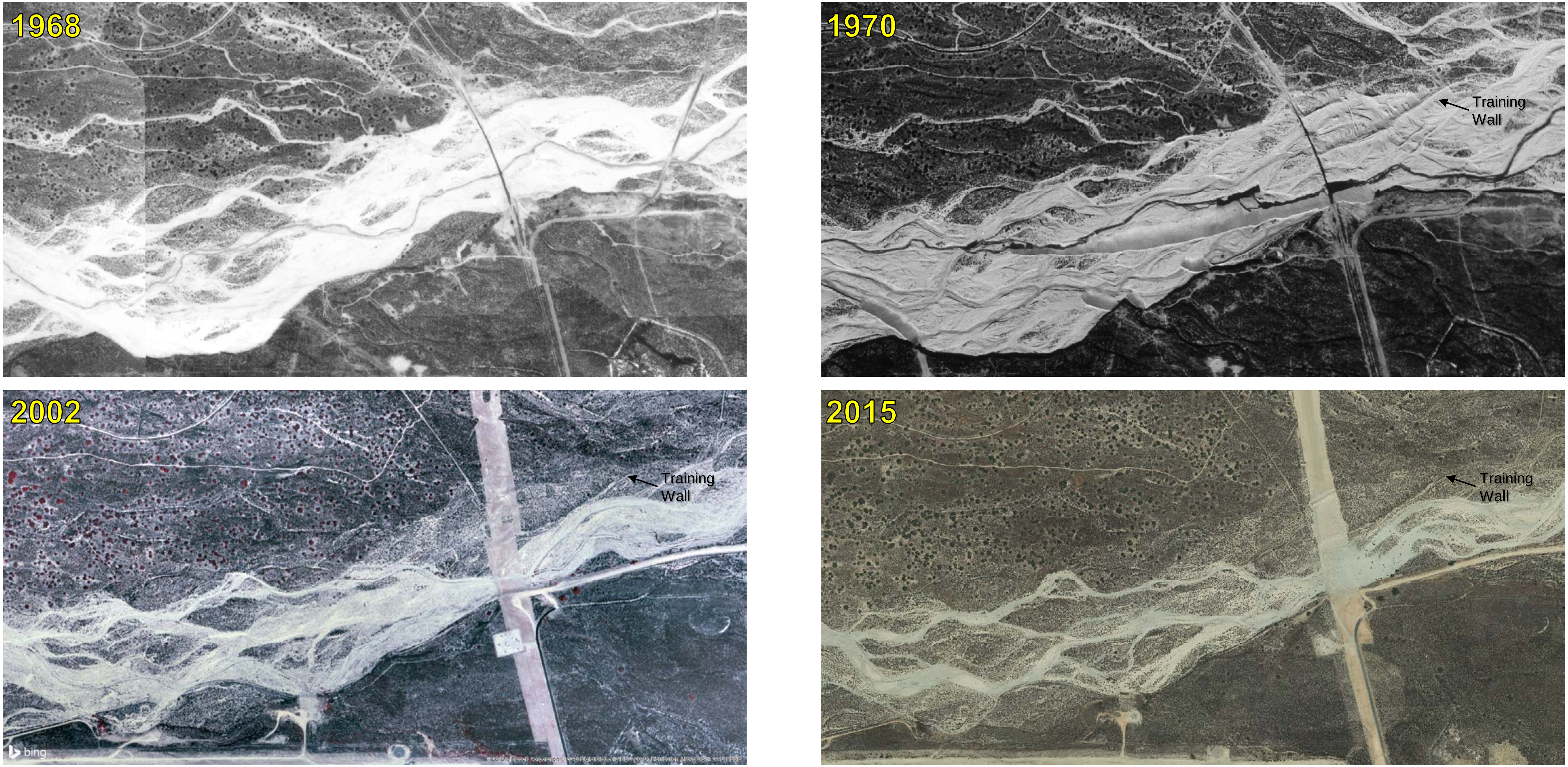
Enhancement Measure 1: 1969 Channel



Enhancement Measure 1: 1969 Channel



Enhancement Measure 2: Historic Changes



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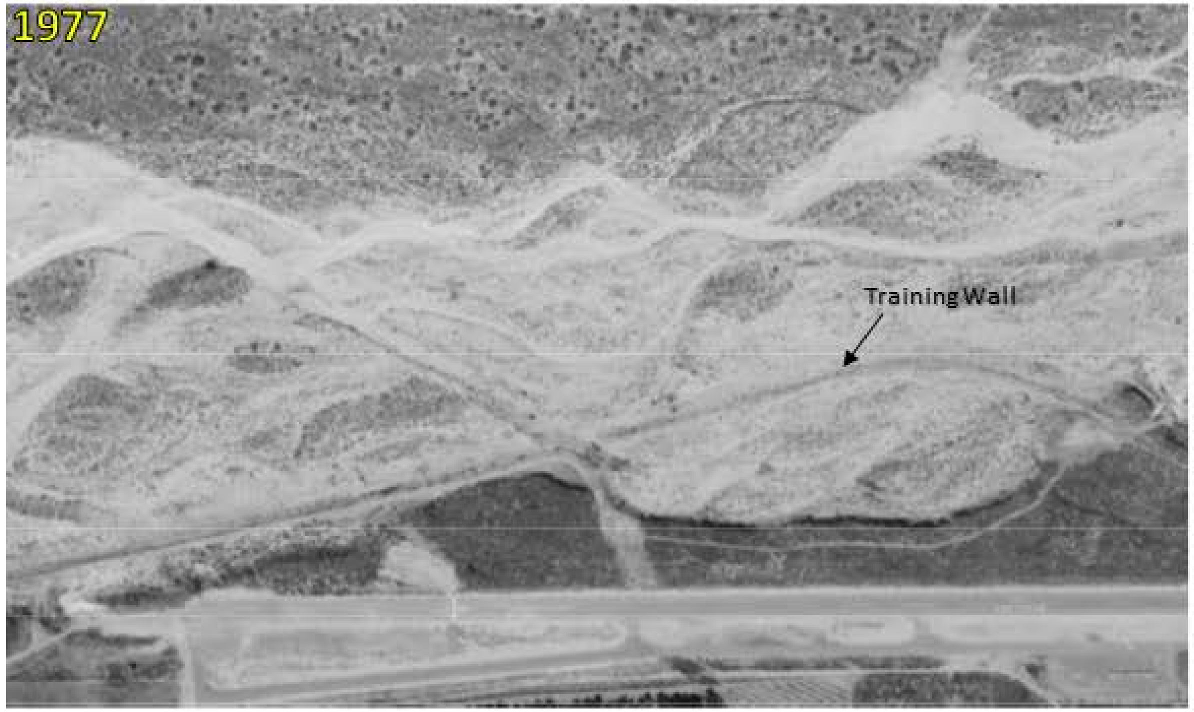
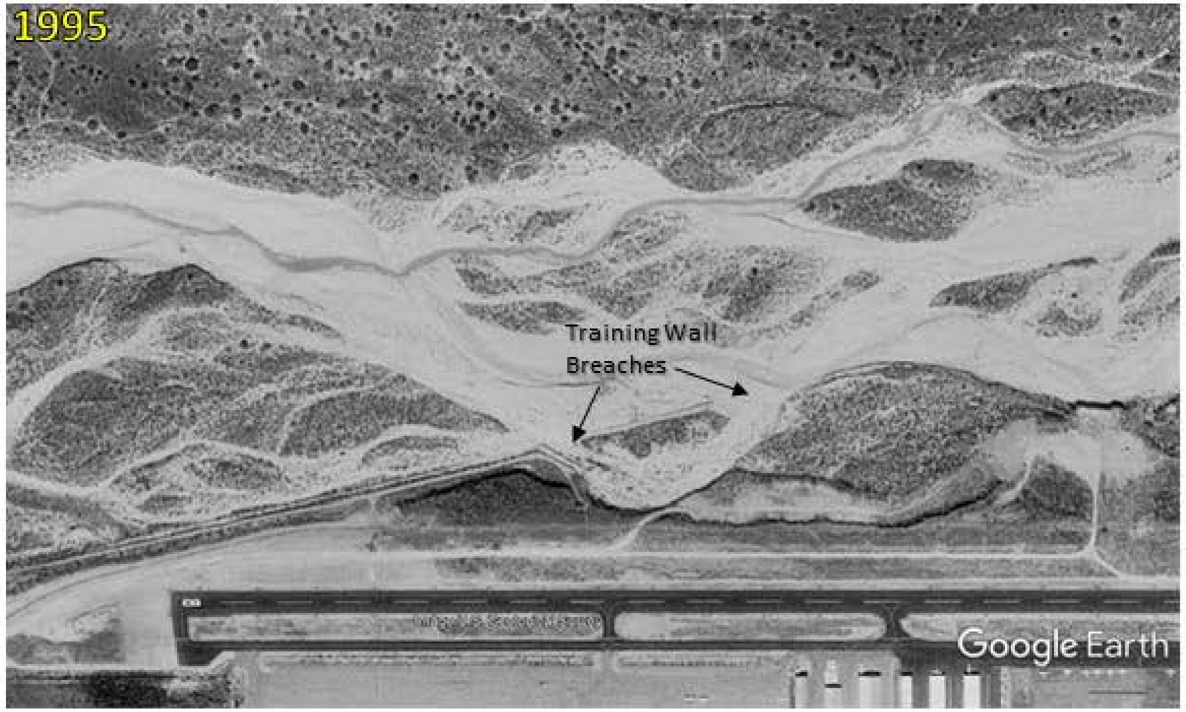
Enhancement Measure 2: Overview

Enhancement Measure 3: Historic Changes





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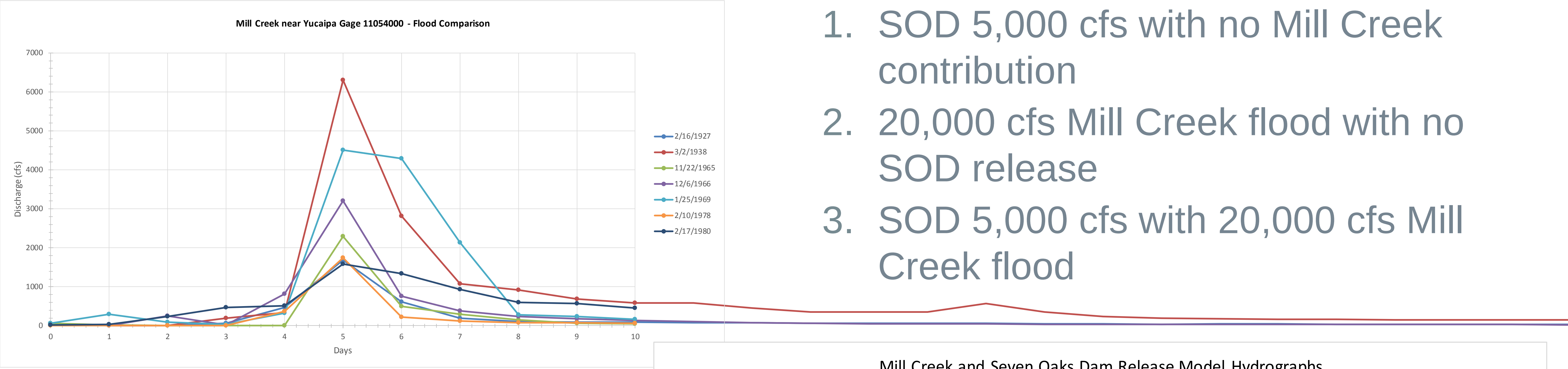
Enhancement Measure 3: Overview

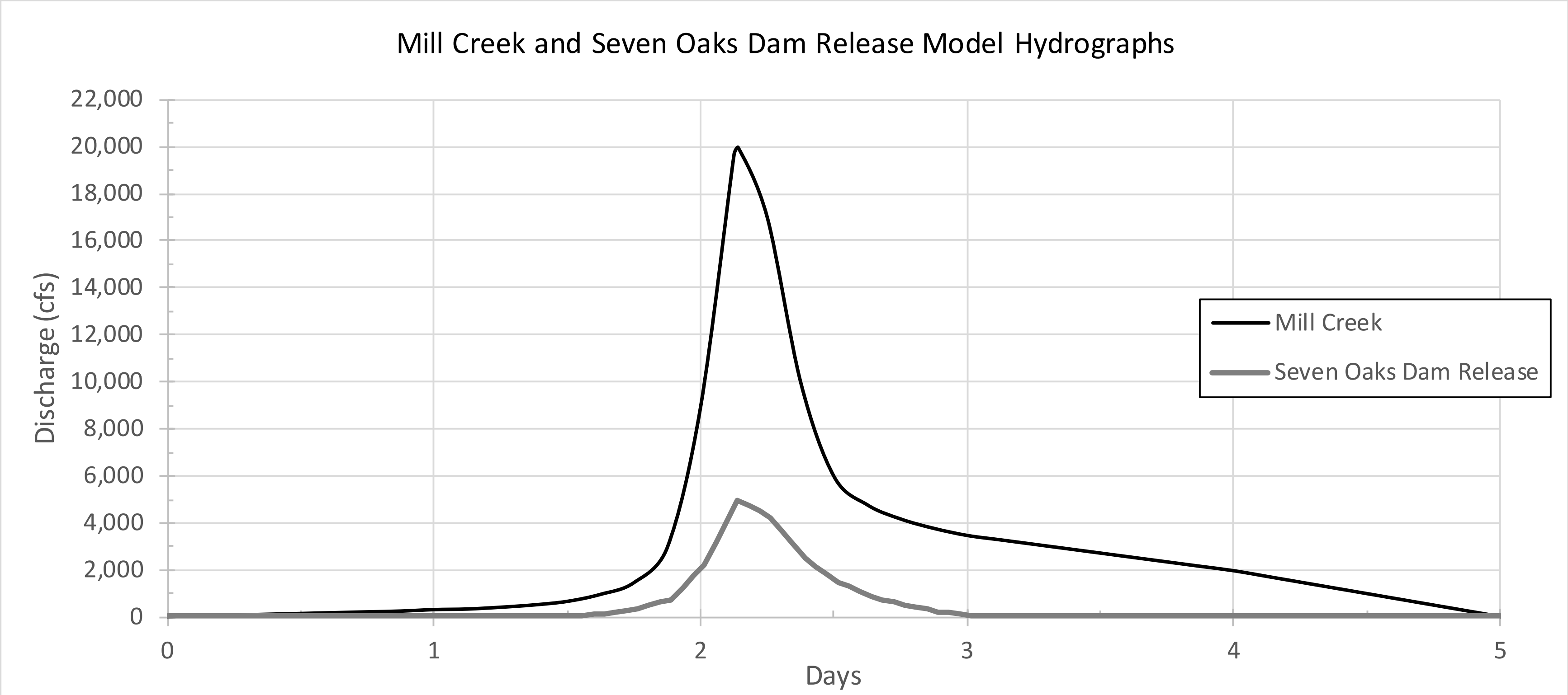
Enhancement Measures Performance Analysis

Hydrograph Scenarios



1. SOD 5,000 cfs with no Mill Creek contribution
2. 20,000 cfs Mill Creek flood with no SOD release
3. SOD 5,000 cfs with 20,000 cfs Mill Creek flood

Mill Creek rapidly reaches flood stage and peak flows typically persist for hours, not days



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Sediment Transport Analysis

2D Model Depths & Velocities

Field Measured D_{90} Sediment Sizes

Calculate Shear Stress for Sediment Transport

Bar Migration Analysis

Incipient Motion Analysis

Mode of Sediment Transport

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Shear Stress Thresholds for Sand and Cobble Bar Migration

Bar Migration Type	Shear Stress (Pa)[1]	Shear Stress (lb/ft^2)	Particle Size Class[2]
Sand Bar (low end)	6-33	0.13-0.69	medium gravel to very coarse gravel
Sand Bar (high end)	33-60	0.69-1.25	very coarse gravel to small cobble
Cobble Bar (low end)	60-90	1.25-1.88	small cobble
Cobble Bar (high end)	90-125	1.88-2.61	small cobble to large cobble
Cobble Bar (maximum)	190	3.97	large cobble

[1] Shear stress thresholds from Blue Octal 2019.

[2] Corresponding particle size classes by ICF and based on Shields curve that flattens out at a τ^*_c of 0.47 (Buffington and Montgomery 1997).

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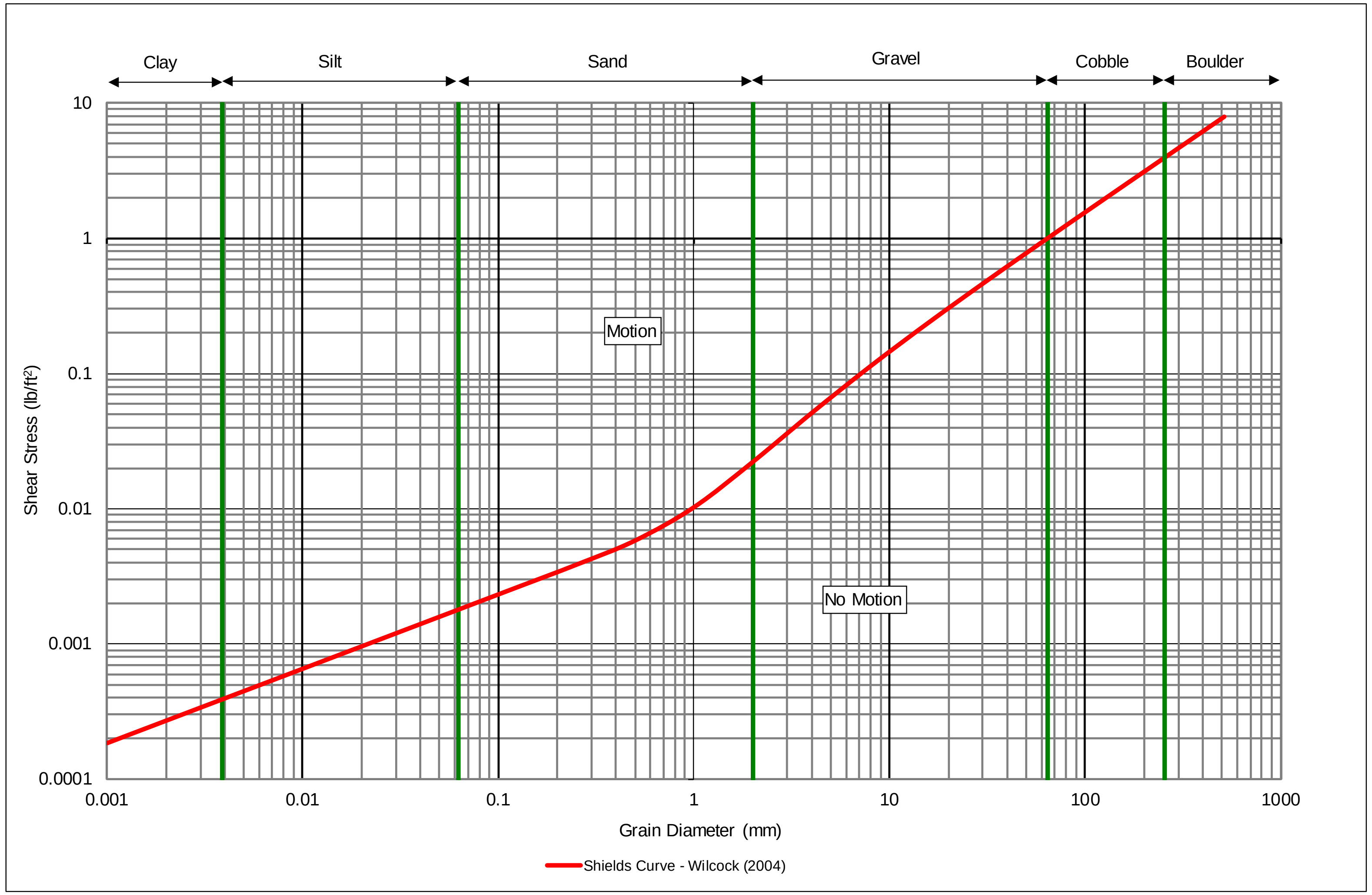
Incipient Motion and Mode of Sediment Transport Analysis



Primary Modes of Sediment Transport

Transport Mode	U_*/v_s	Rouse Number (P)
No Motion	<0.2	>12.5
Bedload	0.2-0.4	6.25-12.5
Mixed Load	0.4-2.5	1-6.25
suspended	>2.5	<1

Source: Julien 2009

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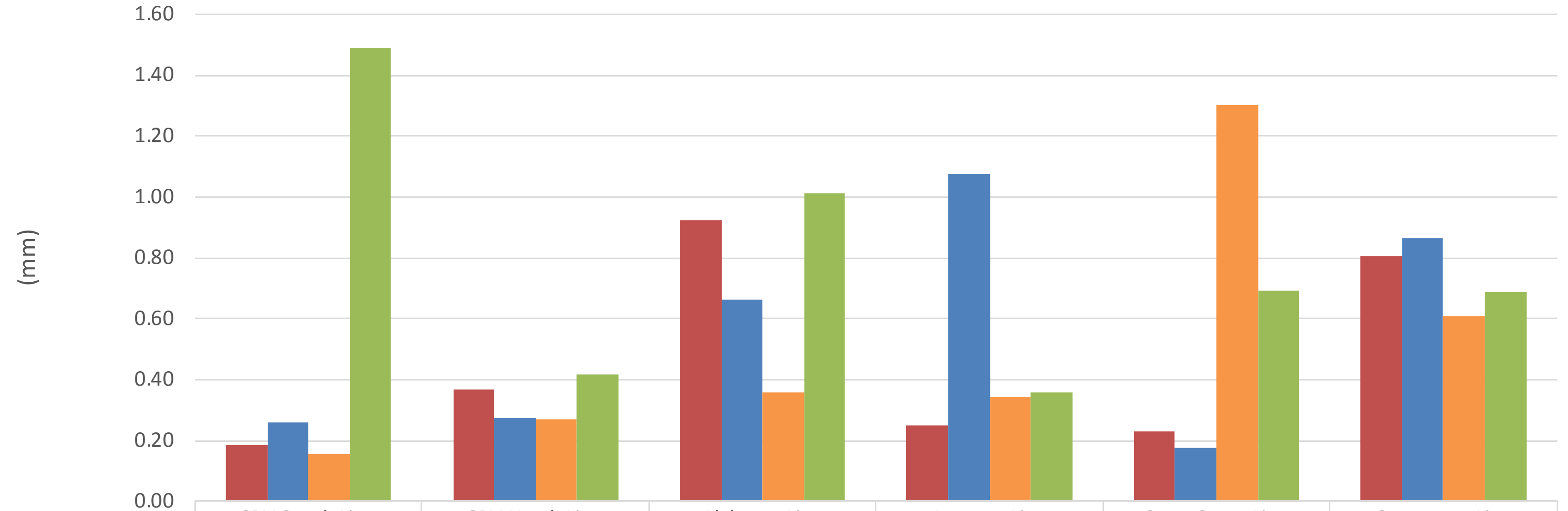
San Diego Zoo 2018 SBKR Sediment Samples

SD Zoo D_{50} Median Particle Size Same as from Blue Octal (2019) Channel Substrate Measurements



	SBV South Line	SBV North Line	Alabama Line	Amazon Line	Cone Camp Line	Greenspot Line
Transect 1 5m	0.18	0.37	0.92	0.25	0.23	0.80
Transect 1 45m	0.26	0.27	0.66	1.08	0.18	0.86
Transect 2 5m	0.16	0.27	0.36	0.34	1.30	0.61
Transect 2 45m	1.49	0.42	1.01	0.36	0.69	0.69

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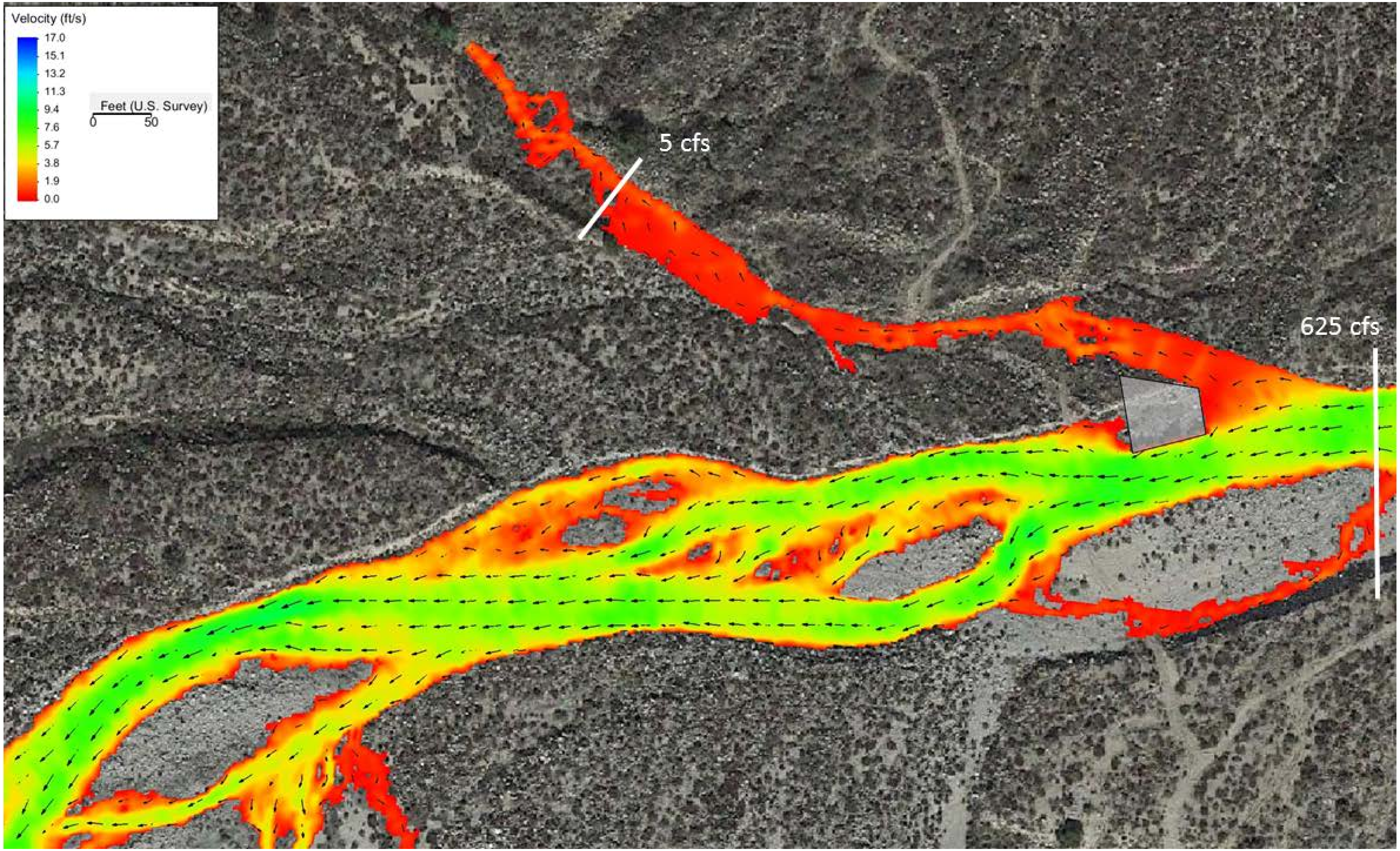
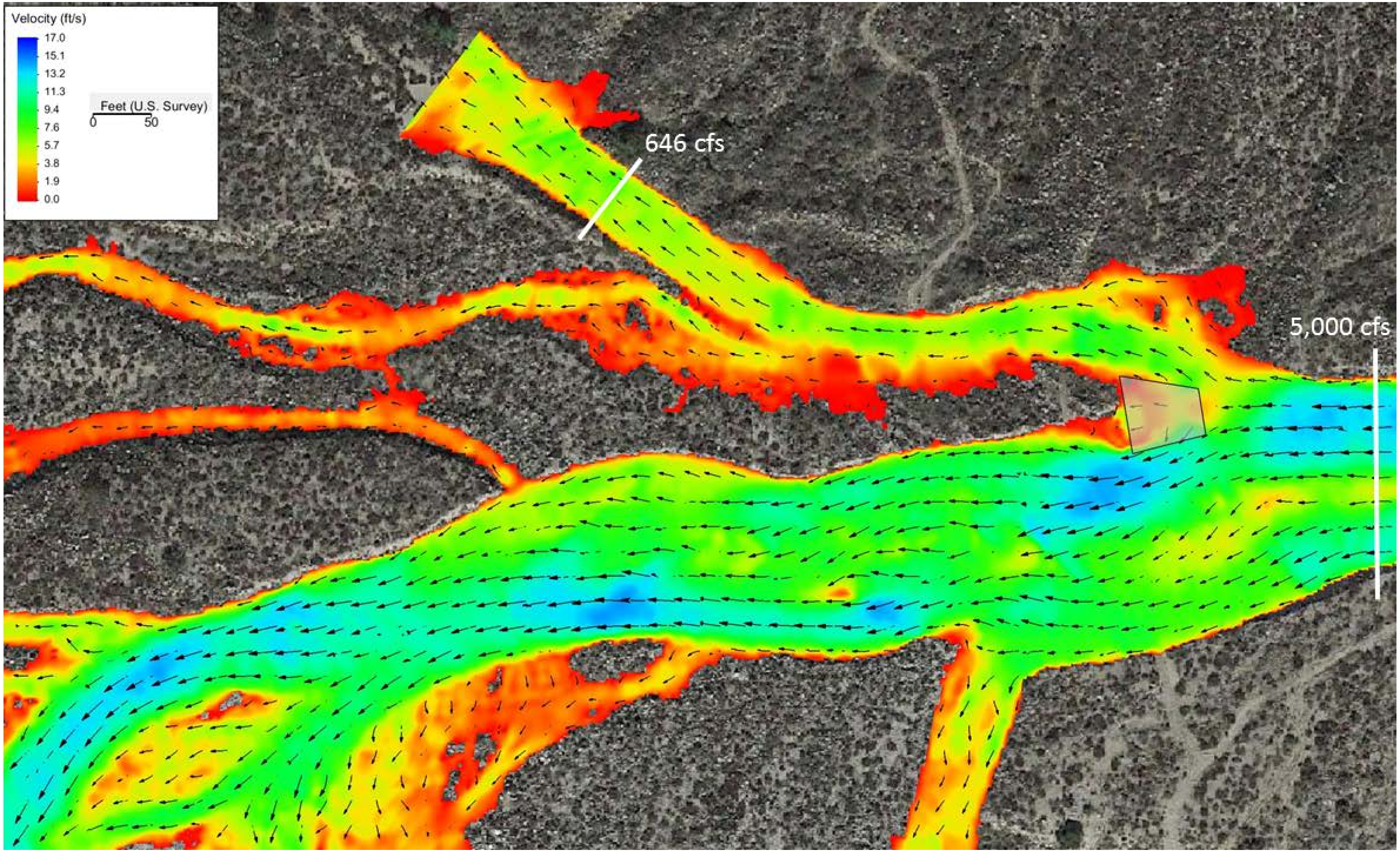
Enhancement Measure 1: Results

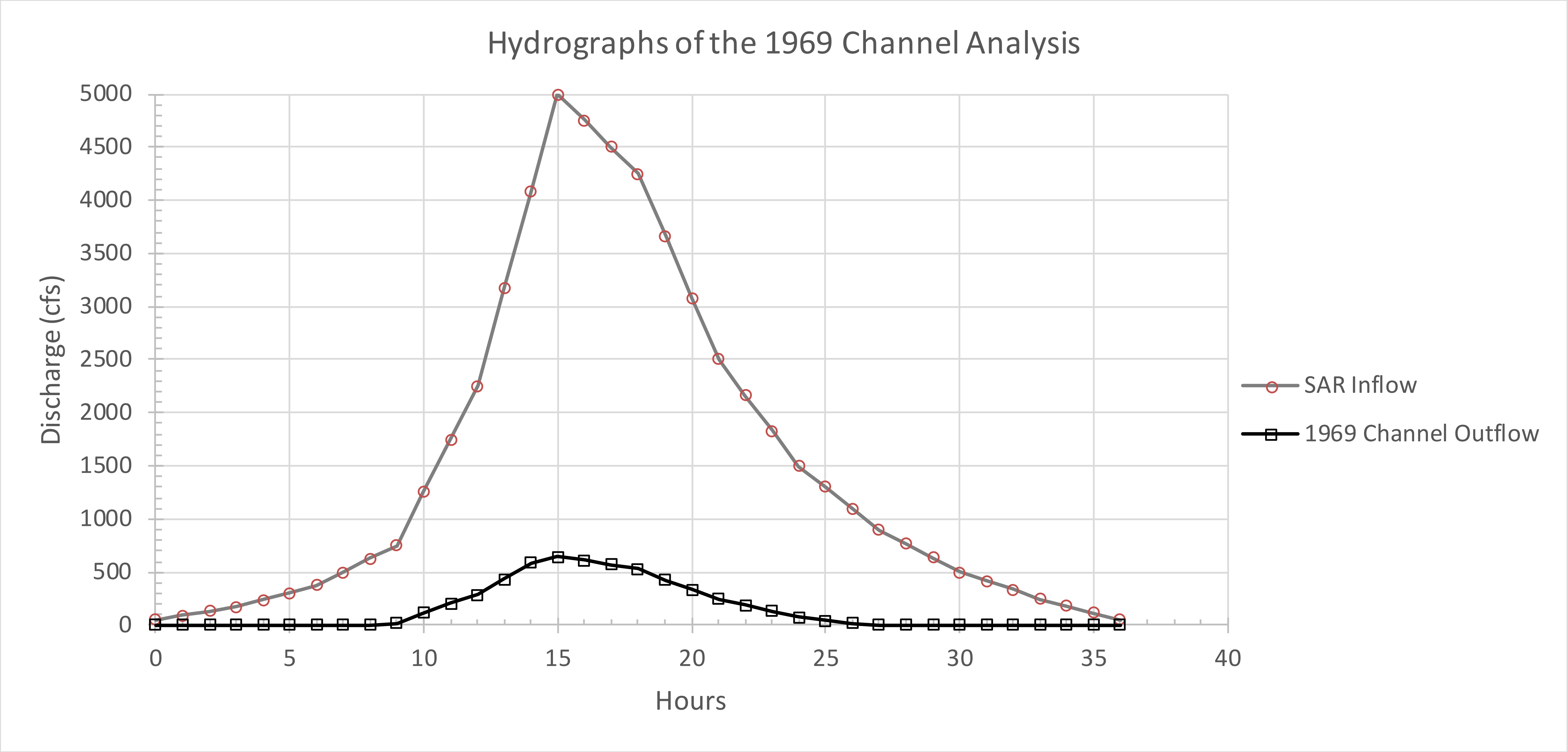


Enhancement Measure 1: Results



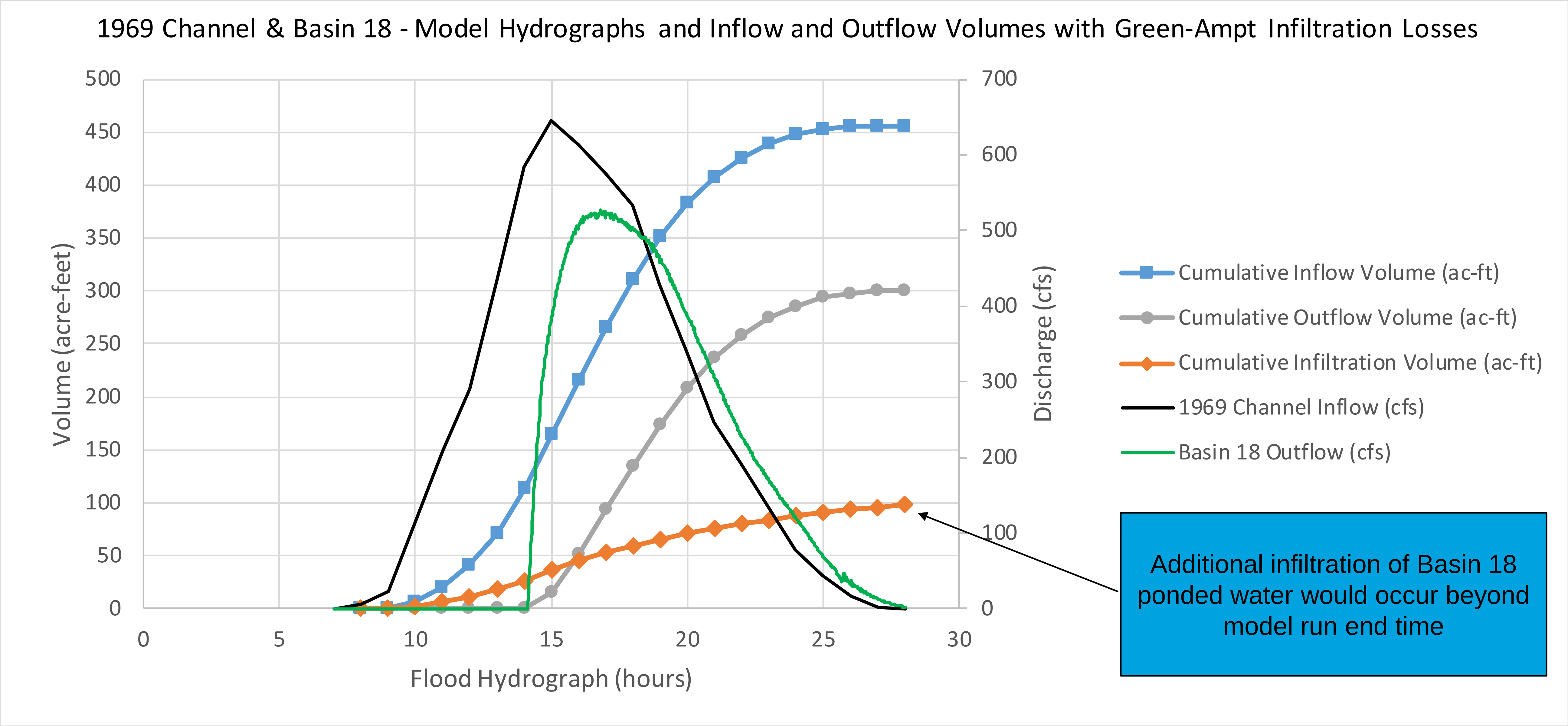
Enhancement Measure 1: Results

Amount of Water Diverted into the 1969 Channel

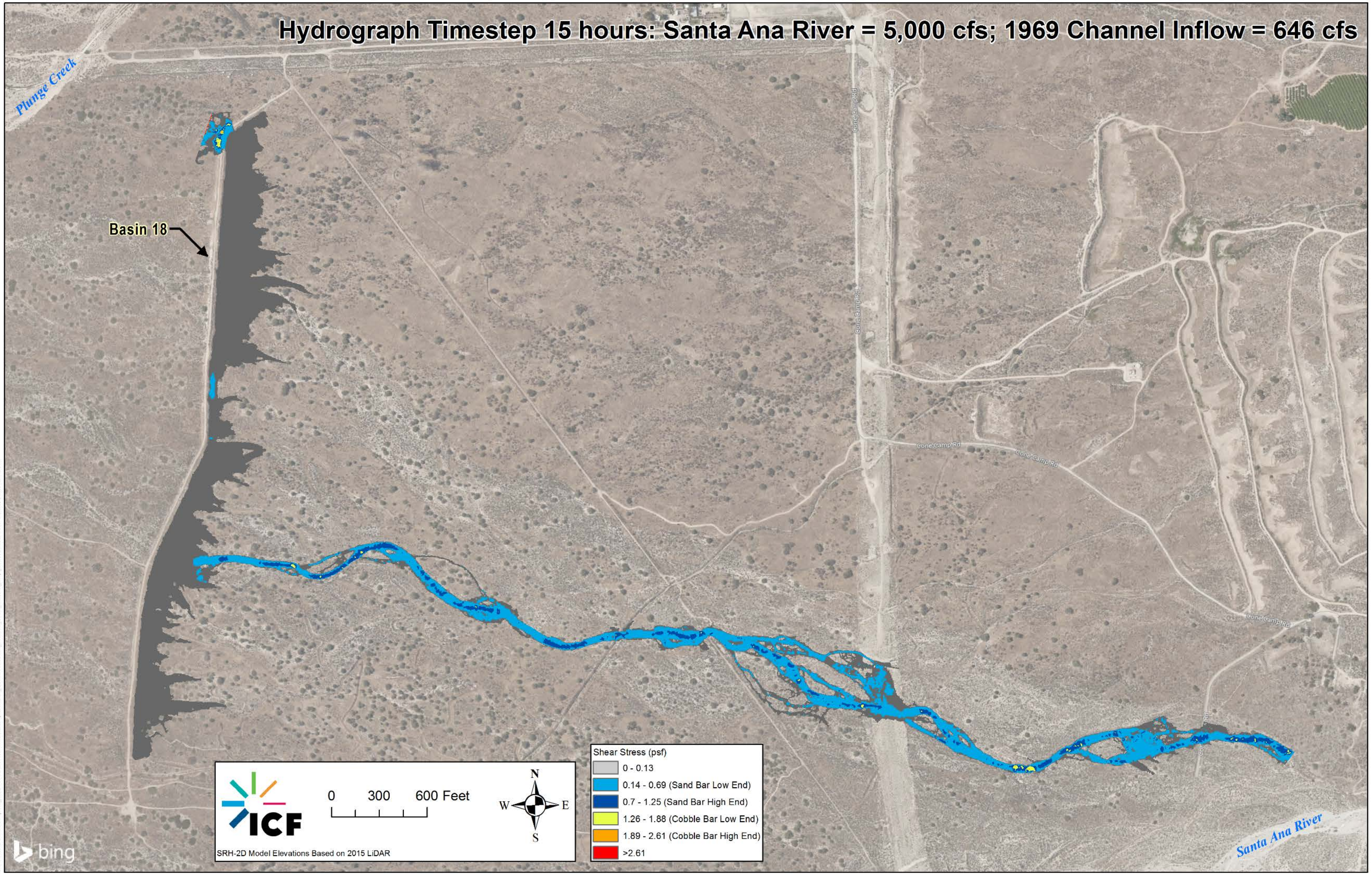


Enhancement Measure 1: Results

Infiltration Losses and Basin 18 Storage



Enhancement Measure 1: Results



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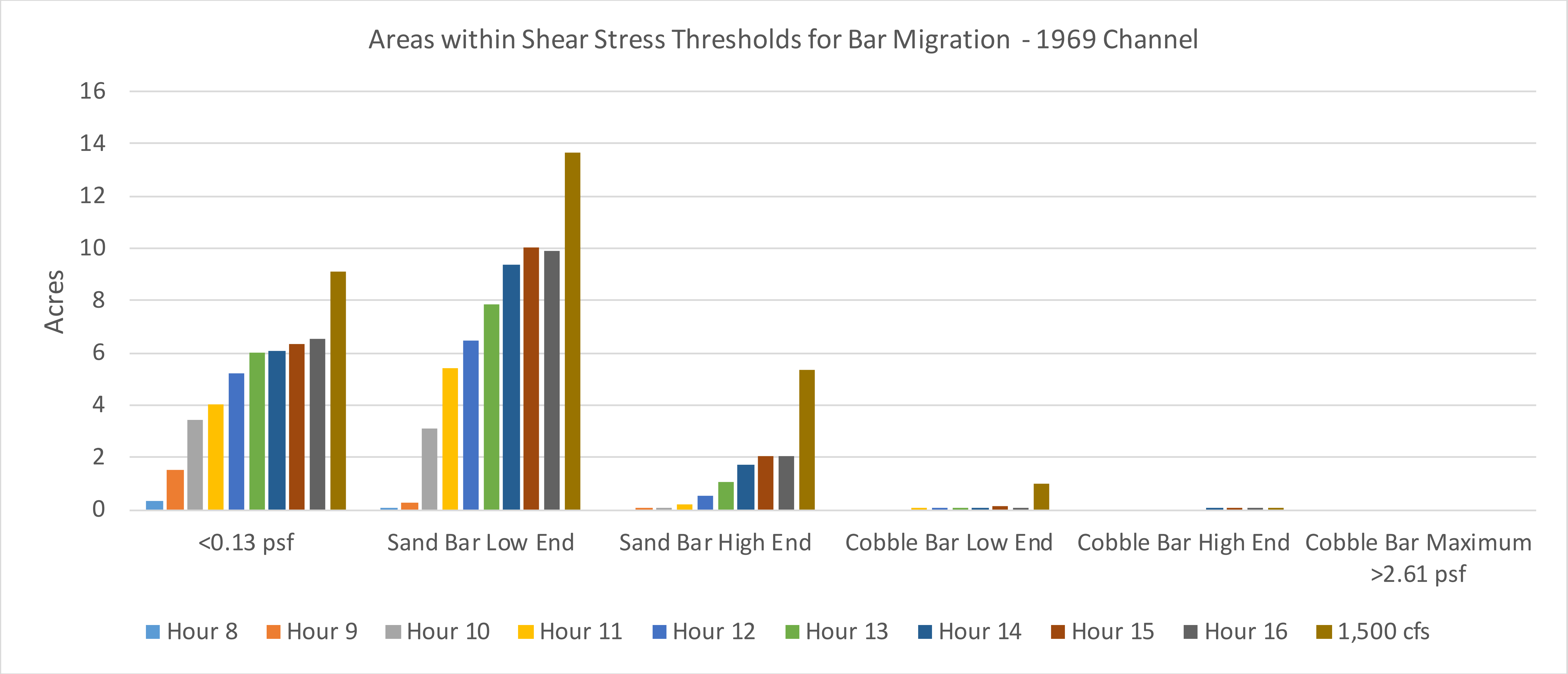
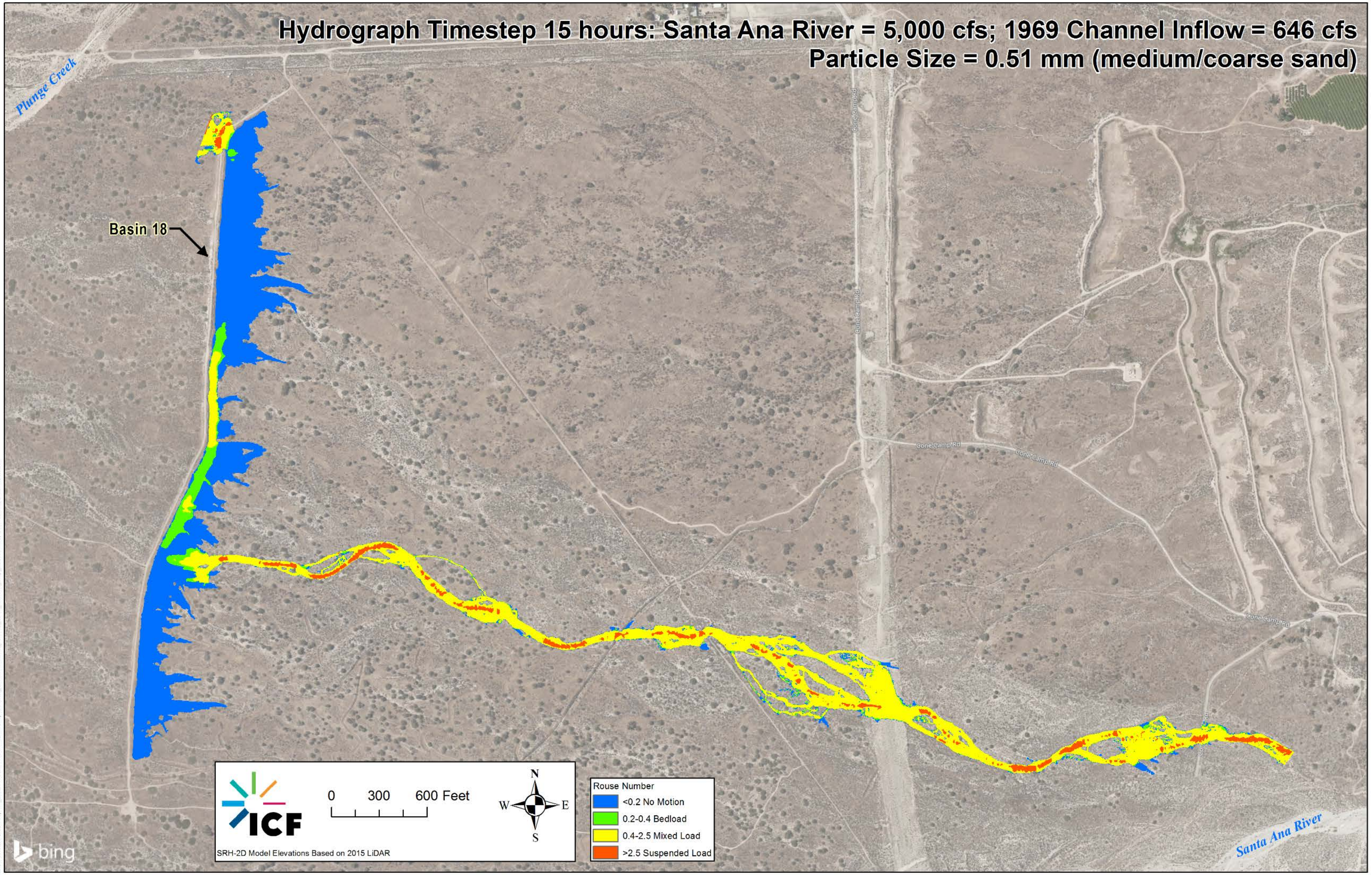
Enhancement Measure 1: Results



Enhancement Measure 1: Results



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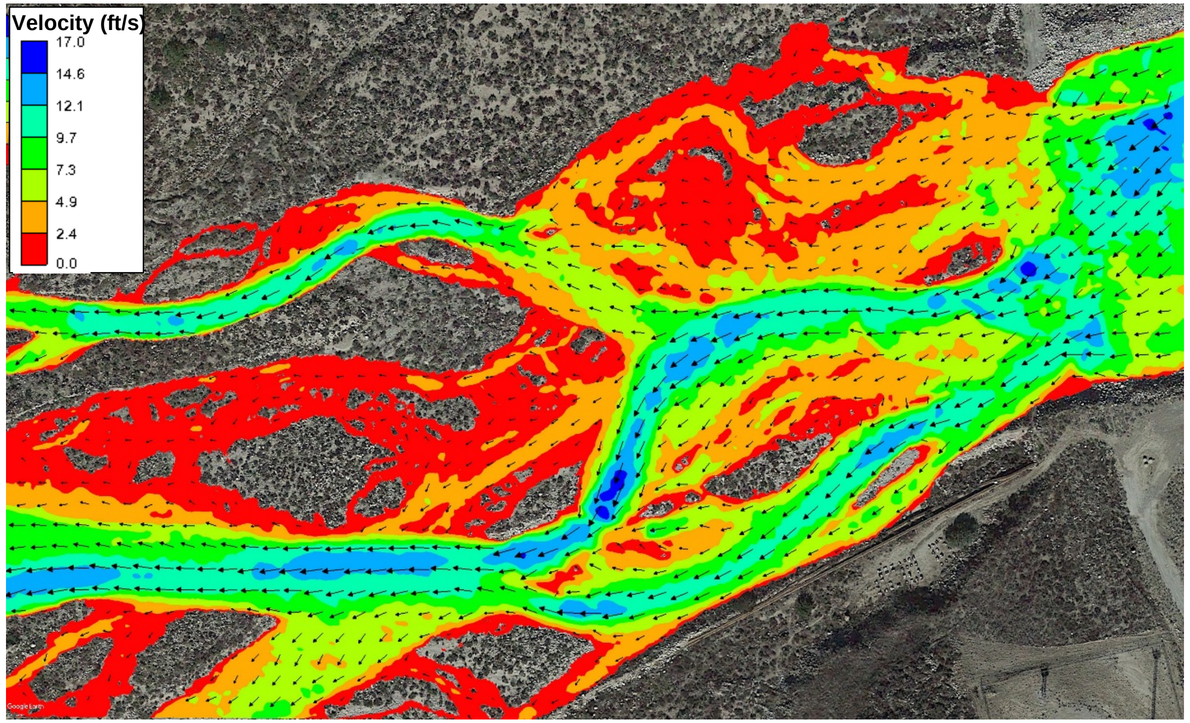
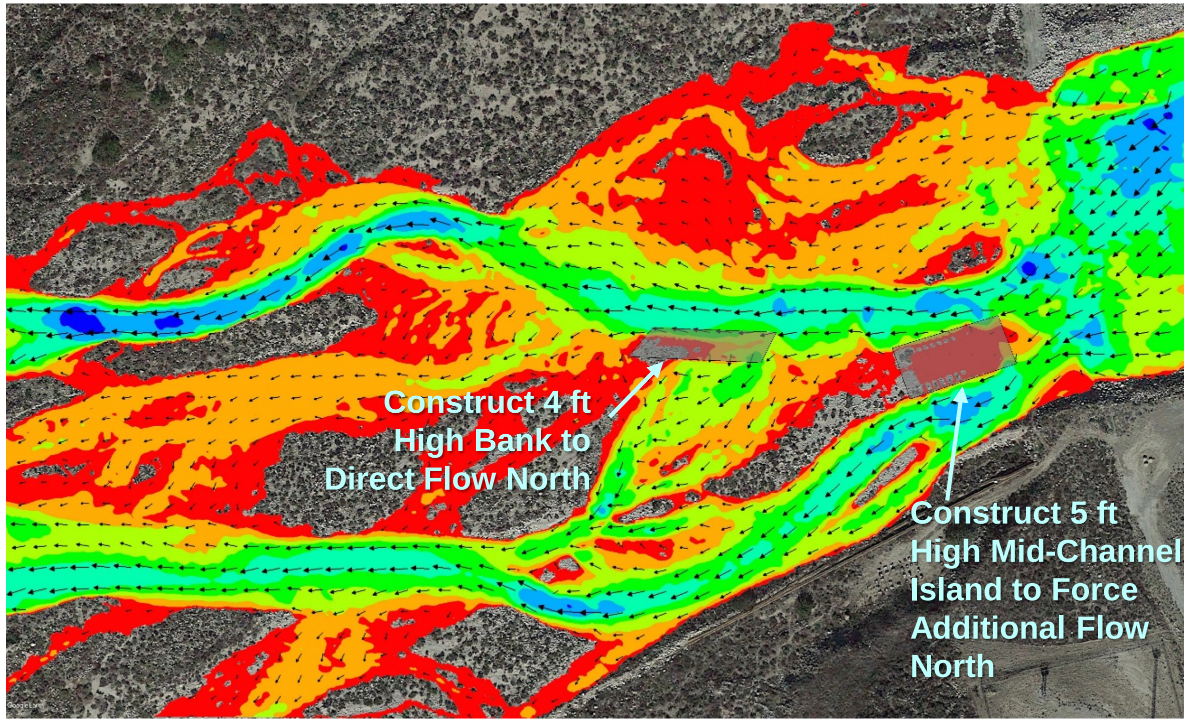
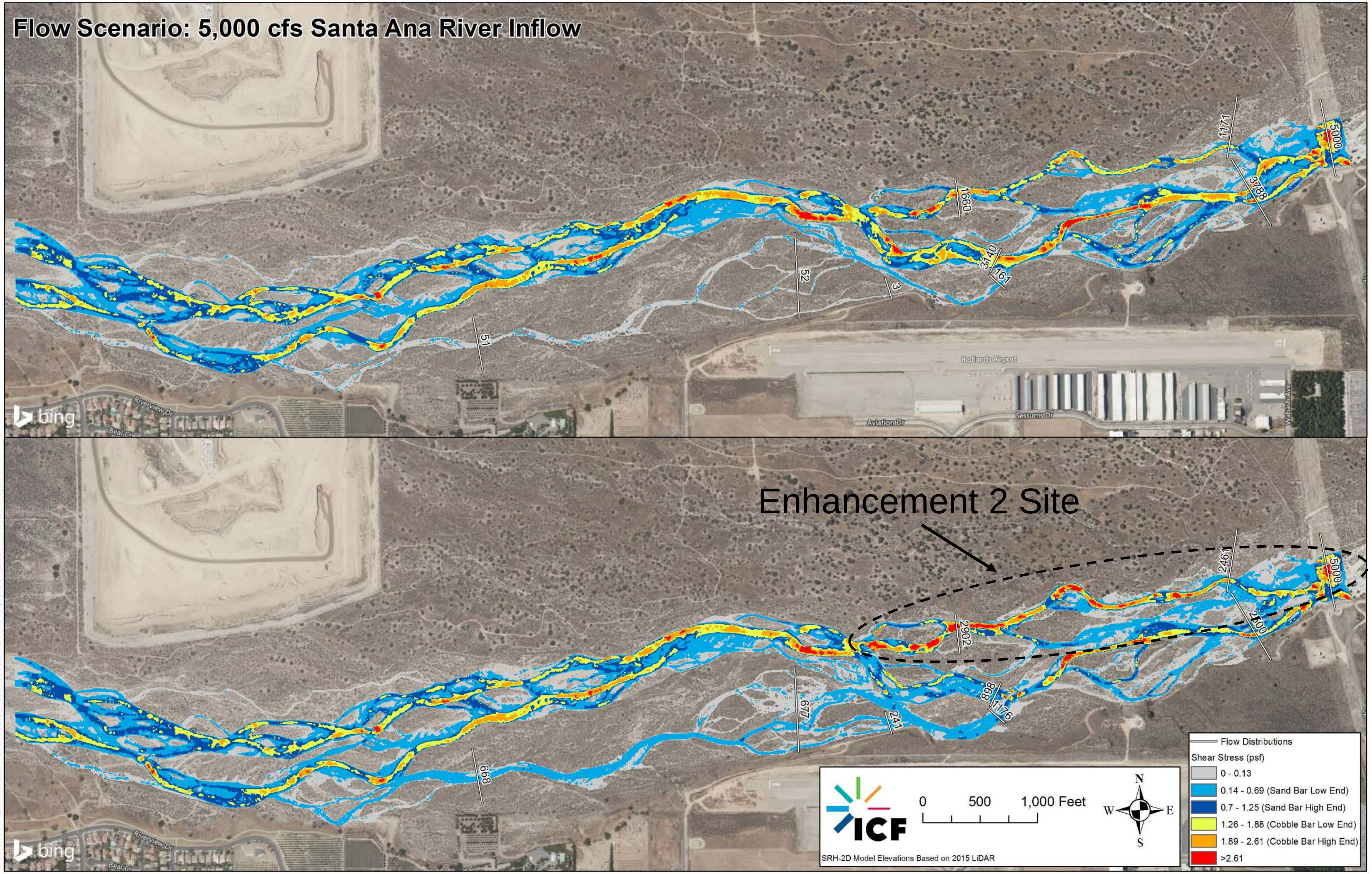
Enhancement Measure 2: Results





Enhancement Measure 2: Results



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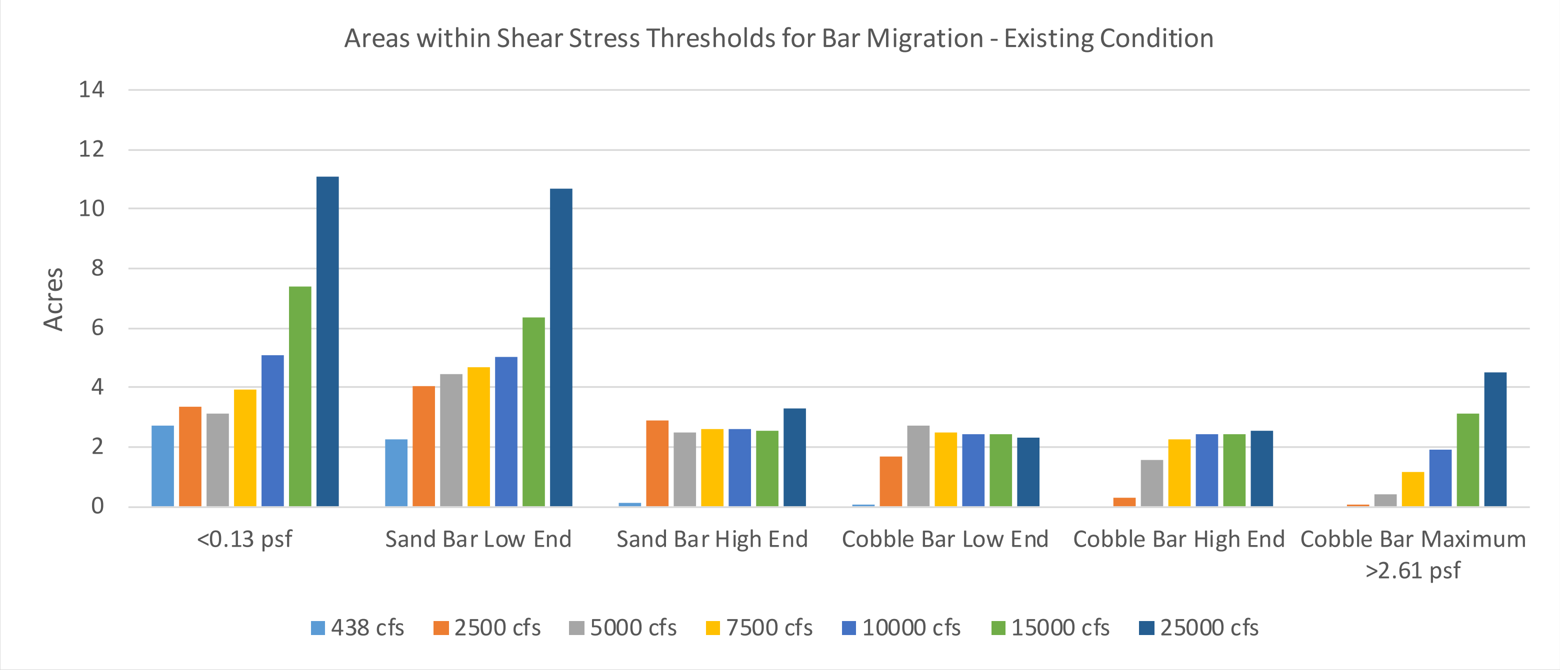
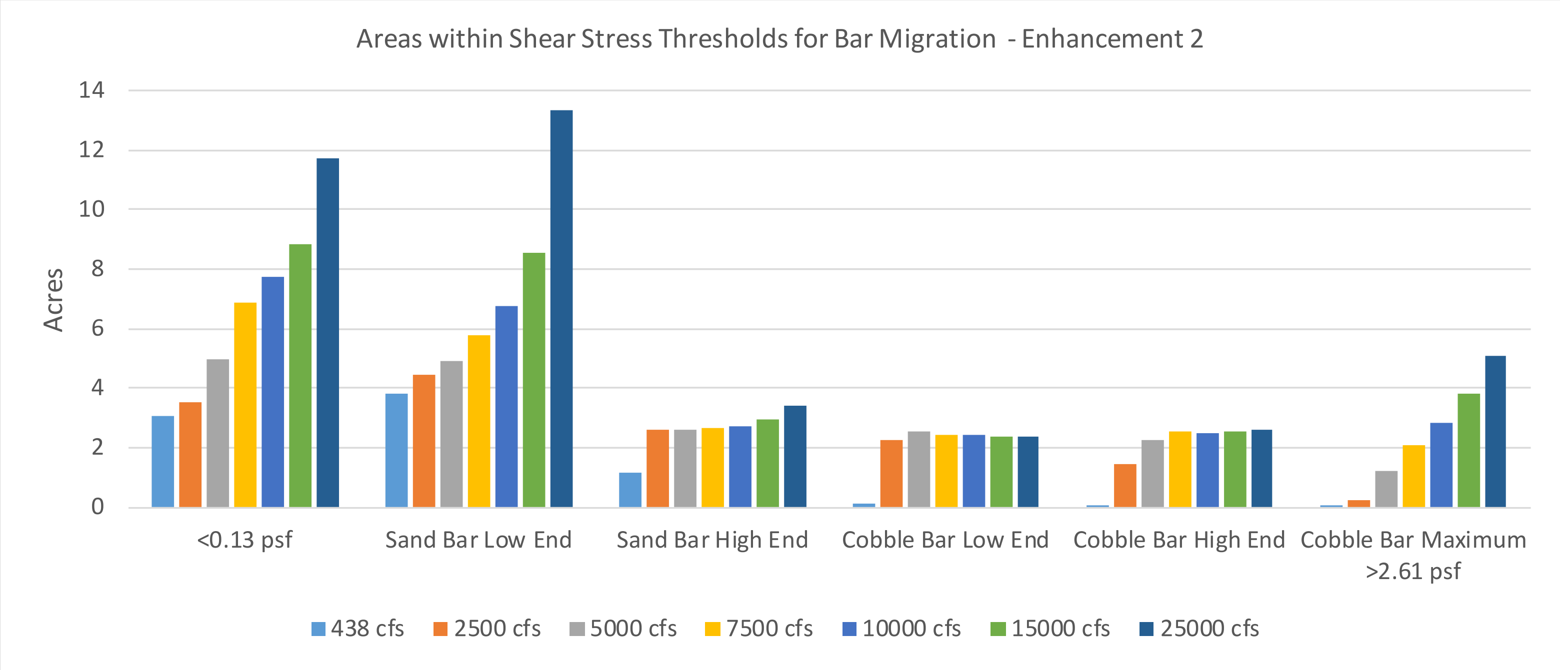
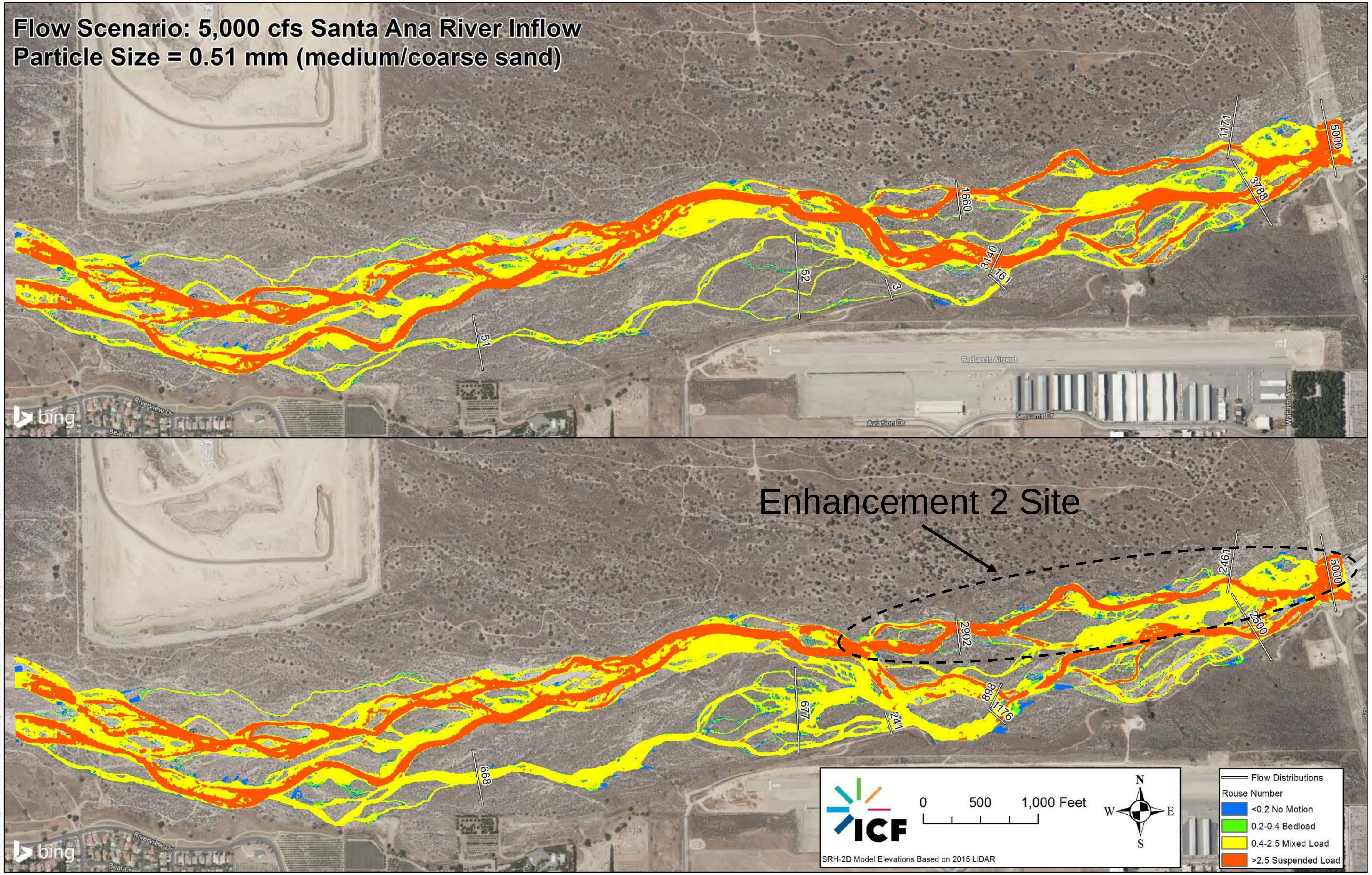
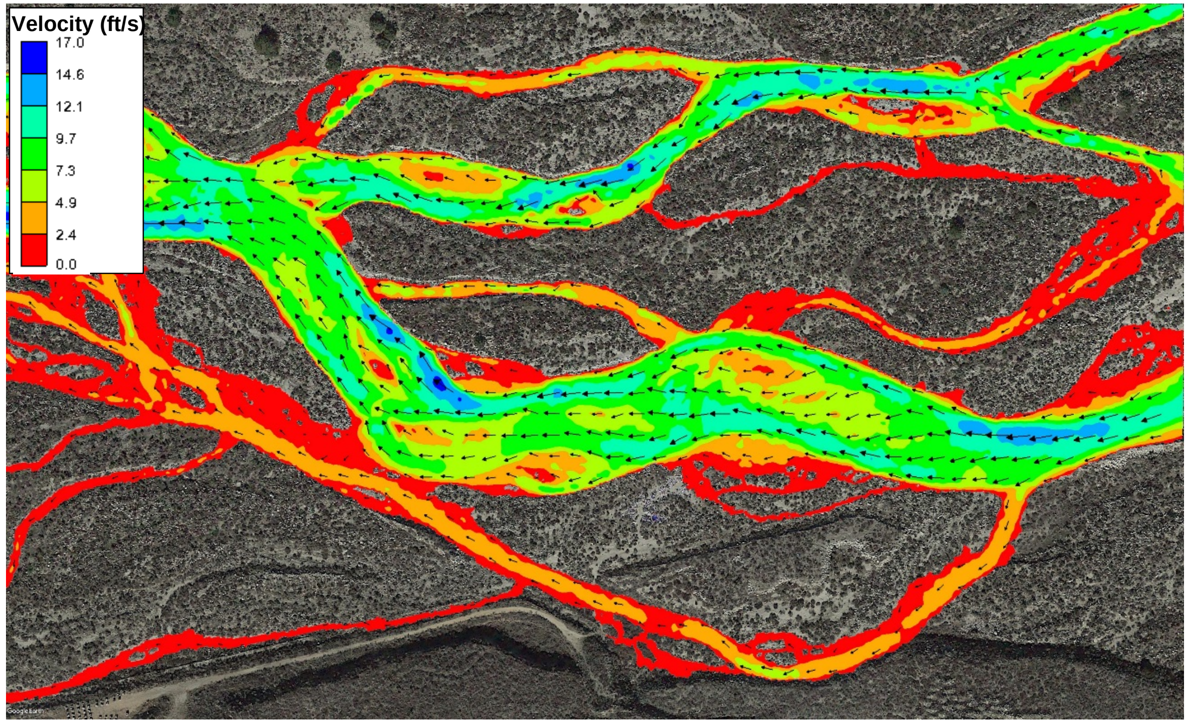


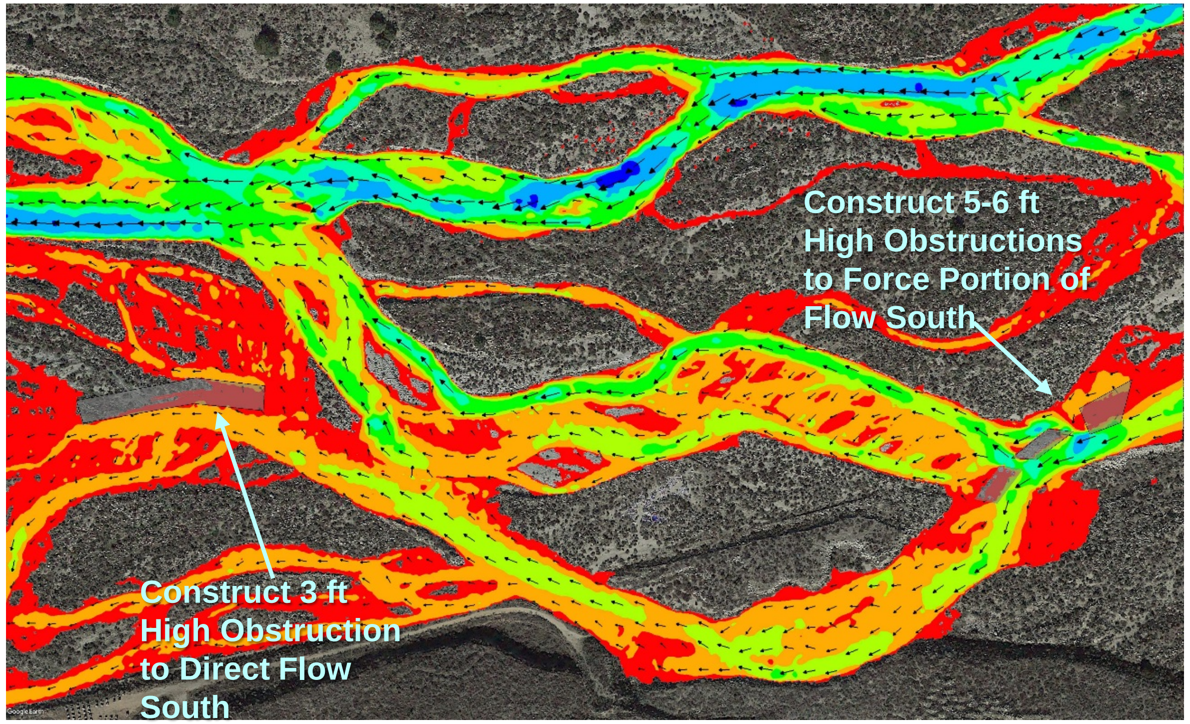


Enhancement Measure 2: Results

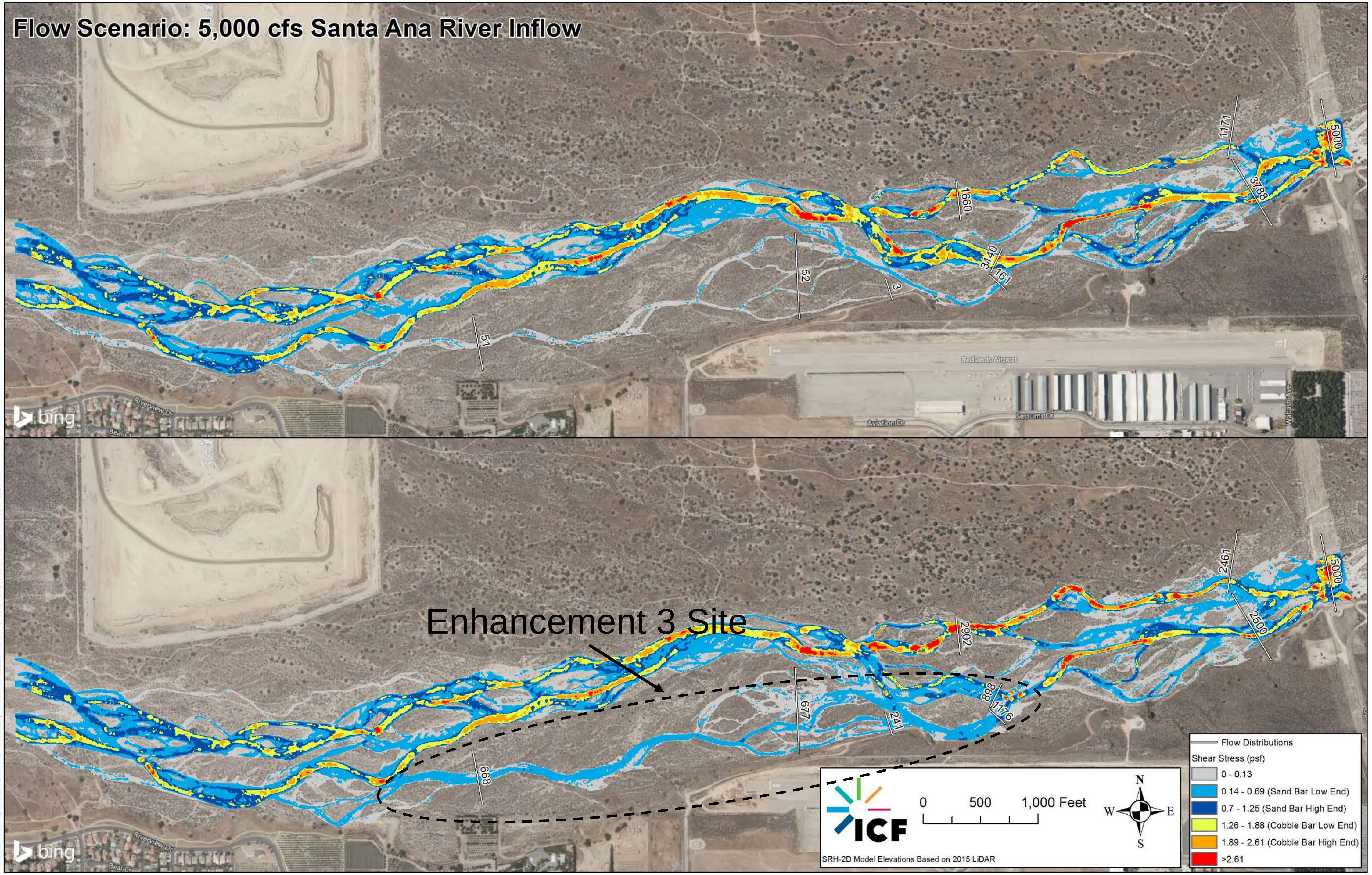


Enhancement Measure 3: Results

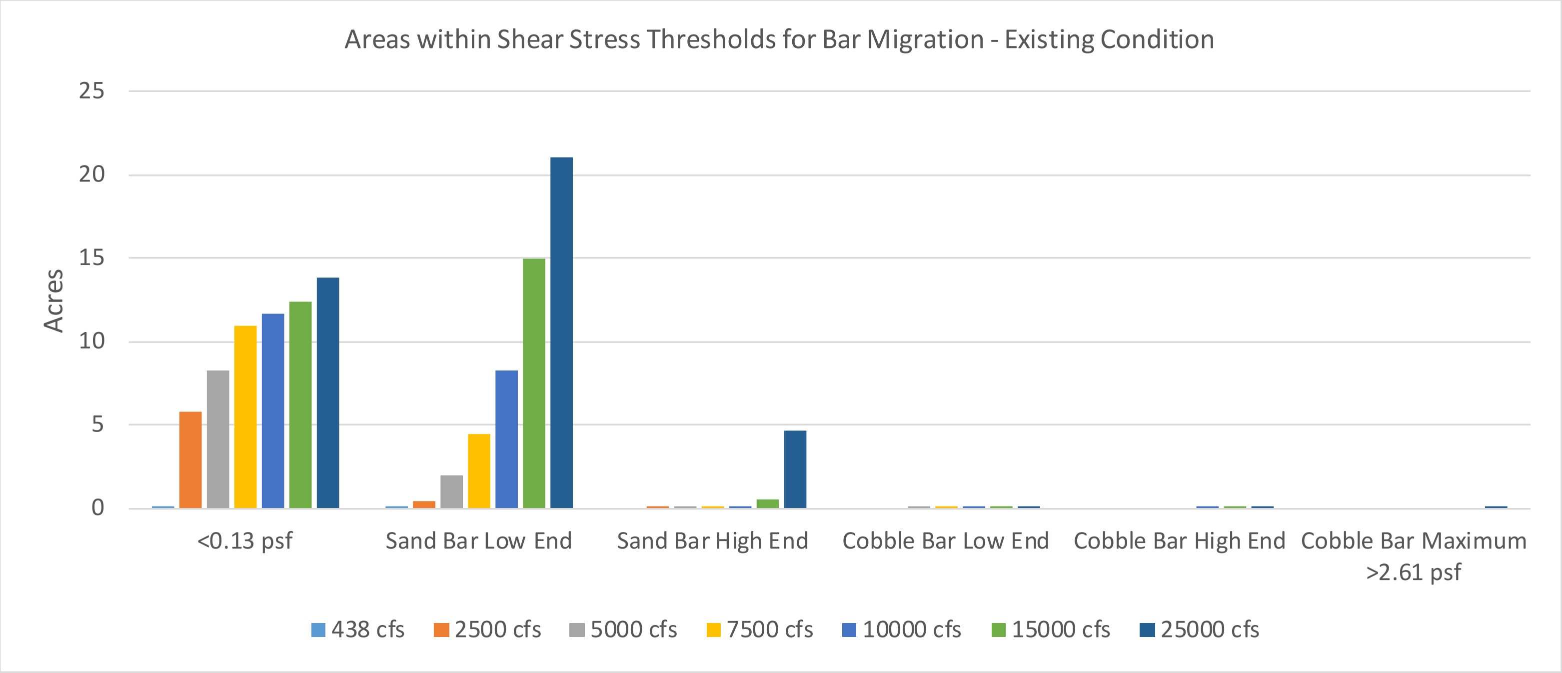


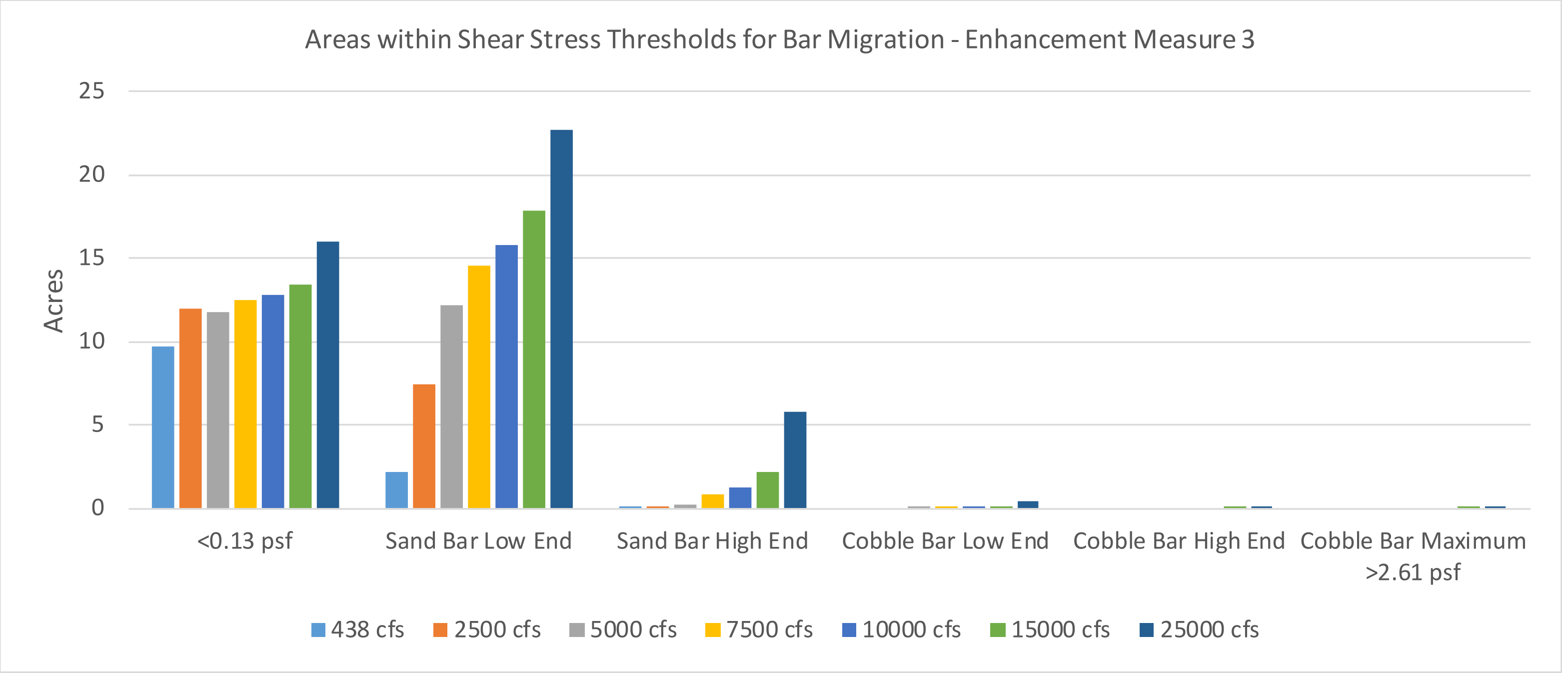


Enhancement Measure 3: Results



Enhancement Measure 3: Results





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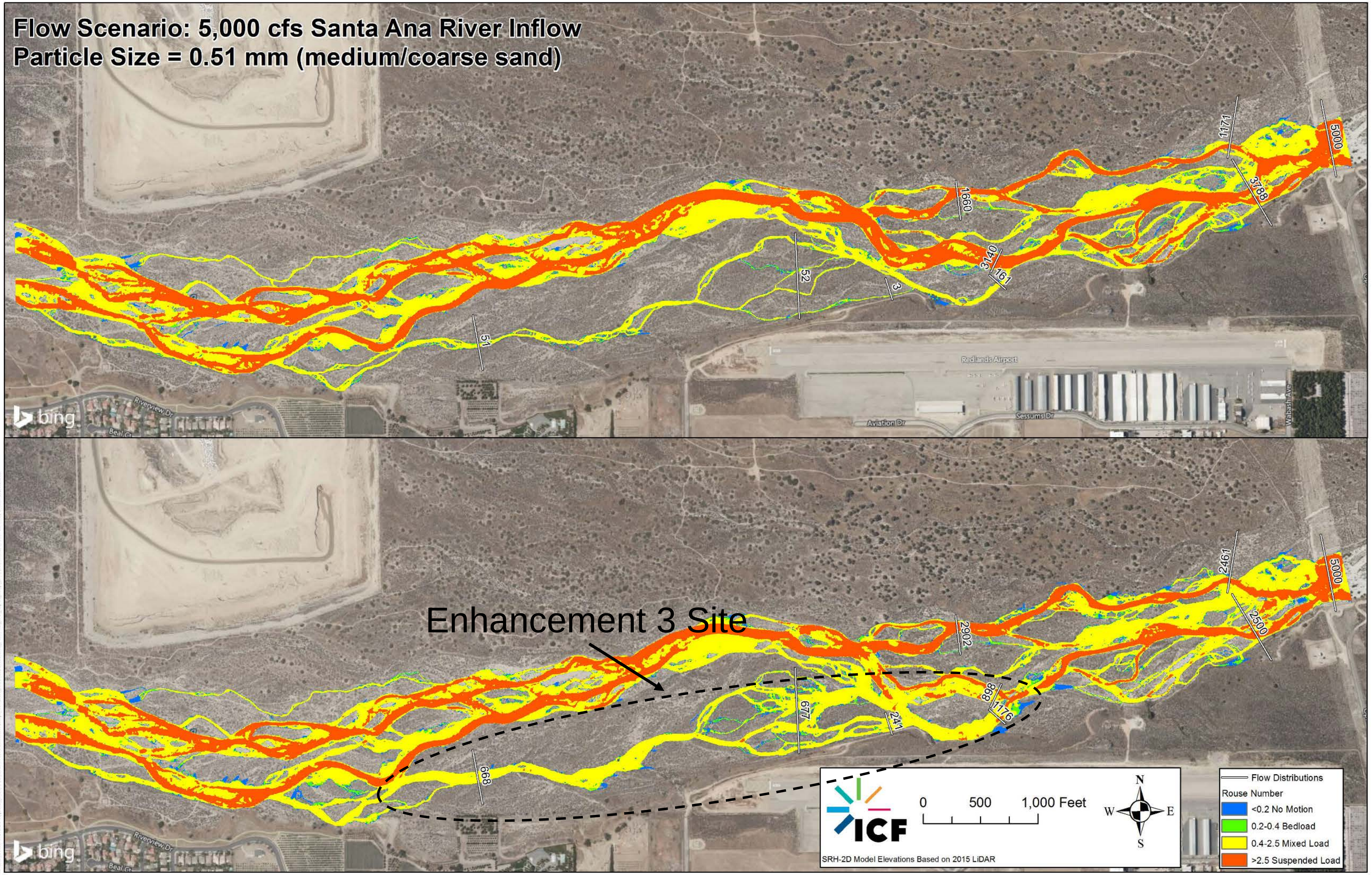
Enhancement Measure 3: Results



Enhancement Measures Comparison

Preliminary Estimate of Earthwork Required

	Area (acres)	Cut (yd^3)	Fill (yd^3)
Enhancement Measure 1	0.66	-1,166	896
Enhancement Measure 2	0.65	-470	1,650
Enhancement Measure 3	0.63	-102	2,341
Total	**1.94**	**-1,738**	**4,887**

Enhancement Measures Comparison

	Enhancement Measure 1[a]		Enhancement Measure 2		Enhancement Measure 3[b]	
	Total Acres	Increase from Existing Acres	Total Acres	Increase from Existing Acres	Total Acres	Increase from Existing Acres
<0.13 lb/ft^2	6.5	6.5	5.0	1.9	11.8	3.5
Sand Bar Low End	9.9	9.9	4.9	0.5	12.2	10.2
Sand Bar High End	2.0	2.0	2.6	0.2	0.2	0.2
Cobble Bar Low End	0.1	0.1	2.5	-0.2	0.0	0.0
Cobble Bar High End	0.0	0.0	2.3	0.7	0.0	0.0
Cobble Bar Maximum >2.61 lb/ft^2	0.0	0.0	1.2	0.8	0.0	0.0
sum of >= 0.13 lb/ft^2	**12.0**	**12.0**	**13.6**	**2.0**	**12.4**	**10.4**

[a] For time-step 16 hours on the hydrograph with a peak of 646 cfs in the 1969 Channel

[b] Enhancement Measures 2 and 3 were modeled together. Diversion of flow at Enhancement Measure 2 reduces the amount of flow at Measure 3. Without diversion of water at Measure 2, more flow would be available at Measure 3 and for a total flow of 5,000 cfs approximately 13 acres of bar migration >= 0.13 lb/ft^2 would be created.

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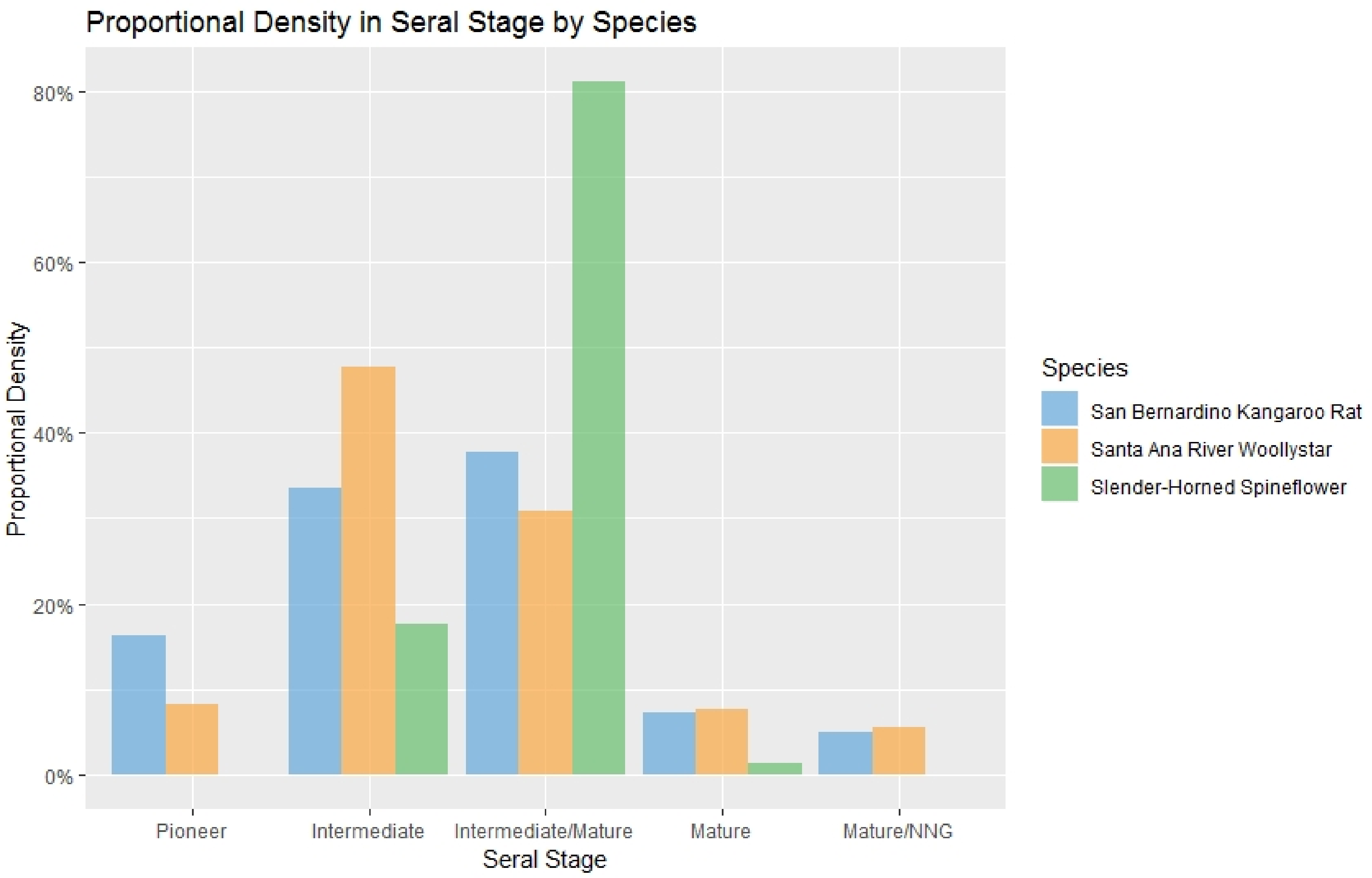
Evaluation of Mechanical Disturbance of the Floodplain

- Alternative to ecological flows from SOD
- Regenerate and maintain habitat for the species of interest

Characteristics of Appropriate Habitat

- Broad similarities between woolly star and SBKR habitat
- Spineflower are dependent on Juniper phase intermediate and mature RAFSS surfaces



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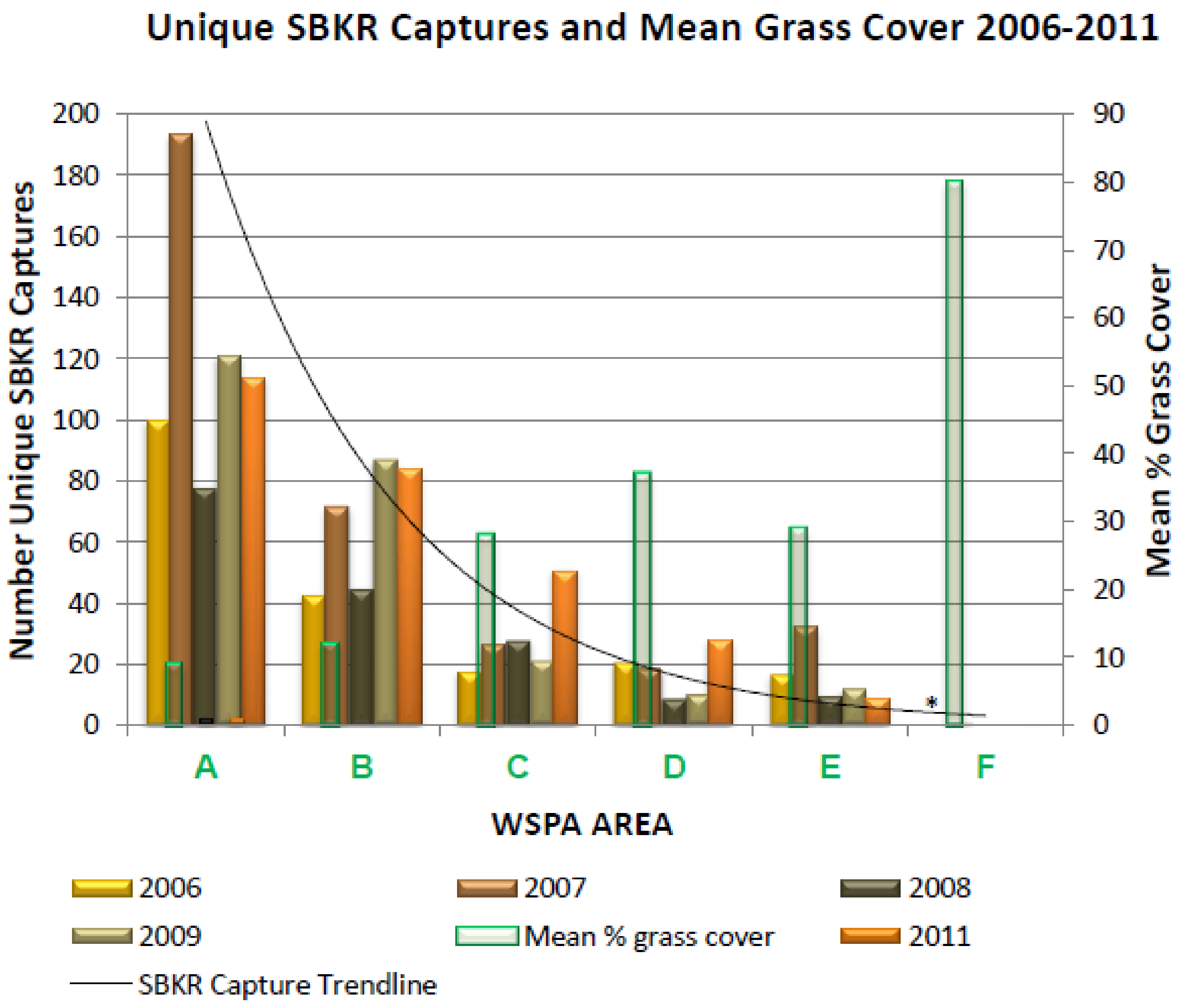
Effects of Non-native Grasses

- Exotic grasses have a negative relationship with all three species
- Common in disturbed areas
- Relationship between NNG and fines/nutrients



Proposed Mechanical Disturbance Methods

- **Sources**
  - Expert Interviews – Past disturbance accounts
  - Scientific and technical reports
  - BA/BO and MSHMP
- **Categories**
  - Manipulation of vegetation
  - Manipulation of soil substrate

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Proposed Mechanical Disturbance Methods

- **Vegetation manipulation**
  - Herbicide application
  - Mechanical vegetation removal
  - Fire
- **Substrate manipulation**
  - Cut
  - Fill
  - Hydraulic spreading

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Vegetation Manipulation - Herbicide Application

- Reduce biomass of living vegetation
- Expected to target invasive species (NNG)
- Short term, lasting 1-2 seasons
- Low impact and cost

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Vegetation Manipulation - Mechanical Removal

- Reduce biomass of living and dead vegetation (dethatch)
- May be focused, depending on techniques (ranging from hand pruning to tractor blading)
- Short term to long term, depending on technique
- High impact and cost

Vegetation Manipulation - Controlled Burn

- Reduce biomass of living and dead vegetation
- Difficult to control
- Short term to long term, depending on technique
- High impact and unknown cost
- Not considered a viable option by the MSHMP

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Substrate Manipulation - Cut

- Remove the top 20 cm of soil
- Reduce biomass of living and dead vegetation
- Long term
- High impact and cost

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Substrate Manipulation - Fill

- Add 10-30 cm of clean washed sand
- May reduce biomass of living and dead vegetation
- Long term
- High impact and cost

Substrate Manipulation – Hydraulic Spreading

- Deployed in conjunction with cut or fill
- May more closely mimic flood effects
- Long term
- High impact and cost

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Evaluation of Mechanical Disturbance of the Floodplain

- Evaluation of methods for woolly star is complete (Hernandez & Sandquist 2019)
- Evaluation for SBKR and spineflower is not complete
- Results from SD Zoo and previous disturbance can provide alternative assessment

Evaluation: Woolly Star

Disturbance	Effect	Duration
Herbicide	Positive	Short Term
Mech. Veg. Removal	Negative	Long Term
Fire	Negative	Long Term
Cut	Positive	Long Term
Fill	Positive	Long Term

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Evaluation: Spineflower

Disturbance	Effect	Duration
Herbicide	Unknown	Short Term
Mech. Veg. Removal	Unknown	Long Term
Fire	Negative	Long Term
Cut	Unknown	Long Term
Fill	Unknown	Long Term

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Evaluation: SBKR

Disturbance	Effect	Duration
Herbicide	Positive	Short Term
Mech. Veg. Removal	Negative*	Long Term
Fire	Positive	Long Term
Cut	Positive	Long Term
Fill	Positive	Long Term

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Evaluation: SBKR Habitat Model Results

Model	Variable Set	Low	Medium	High
1. Vegetation	Shrub cover	6-15%	23-35%	40-65%
	Grass cover	1-17%	22-28%	45-81%
	Forb cover	0-4%	5-9%	10-19%
2. Surface	Duff cover	2-9%	15-18%	25-30%
	Sand/bare ground	5-19%	35-40%	59-71%
	Gravel	1-8%	12-19%	27-40%
	Woody Debris	0-4%	6-13%	16-25%

Evaluation: SBKR Substrate Results

SBKR Density	Clay% (less than 0.0002 mm)	Silt% (0.002 mm to 0.05 mm)	Sand% (0.05 mm to 2 mm)	Gravel% (2 mm to 75 mm)
No SBKR	2.7-12.4	2.0-21.2	70.3-92.8	1.4-45.0
Low SBKR (0.9-3/unit effort)	2.5-6.6	0.5-17.5	76.7-97.0	2.7-50.3
High SBKR (4-9.2/unit effort)	2.4-6.6	1.2-14.6	81.9-95.6	1.0-54.9

Evaluation: SBKR Expert Consensus

- Adjacent occupied habitat is critical
- Colonization corridors are needed
- Designs should maximize edges (no parking lots)

Scale of Habitat Manipulation

- **Experimental manipulation should be as small as possible**
  - Meter scale for plant species
  - Hectare scale for SBKR
- **Habitat renewal scale specified in the 2002 BO**
  - USFWS specifies in the 2002 BO that the target treatment size is 10-20 acres every 5-10 years resulting in 200 acres of habitat being manipulated over the course of the 100-year life of the project

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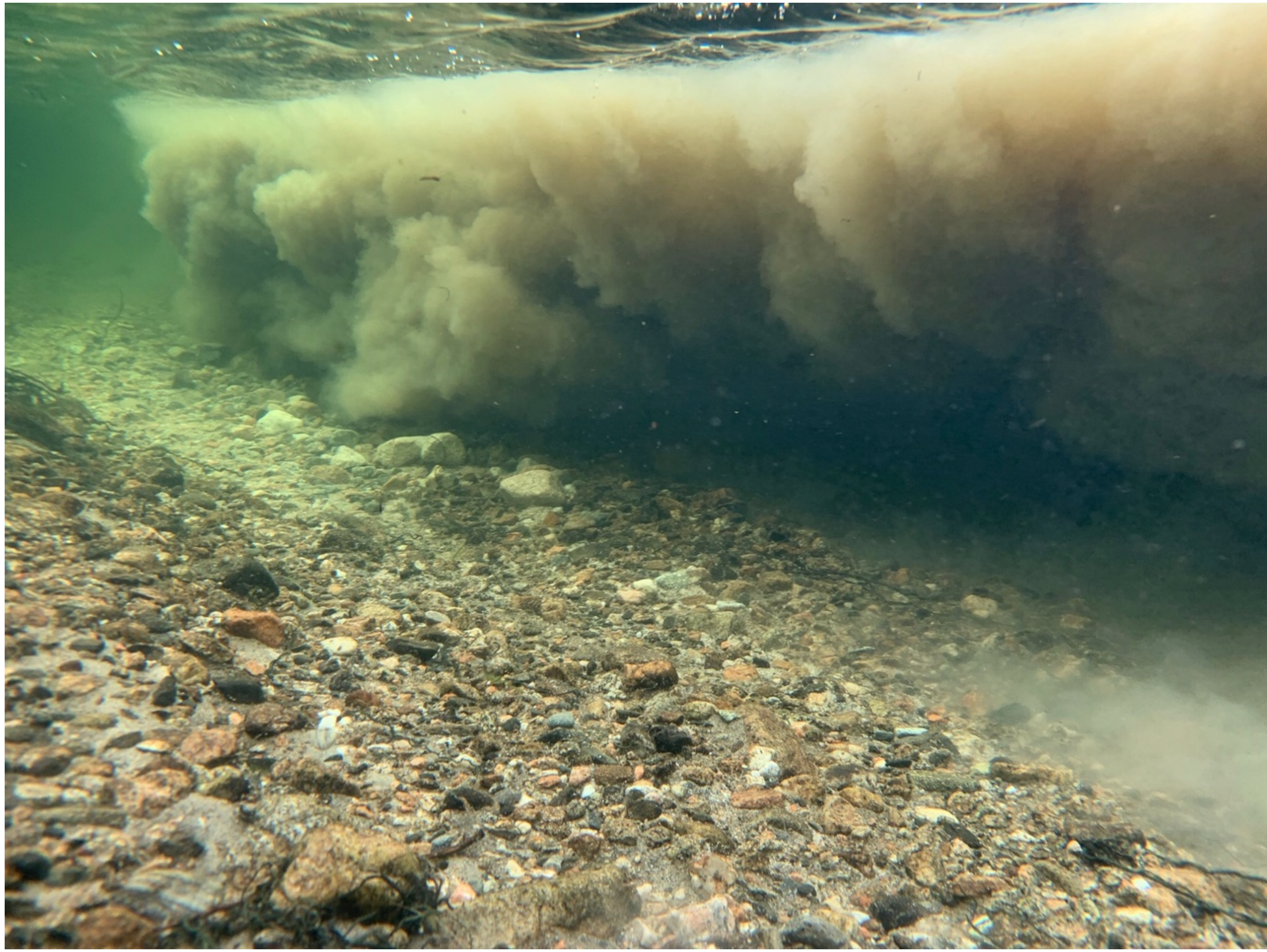
Thresholds for Implementation

- **MSHMP guidance**
  - Determine if woolly star demography metrics (growth rates), spineflower population metrics, or SBKR occupancy metrics are consistent with Baseline (≥1) or whether management/monitoring plans and schedules should be altered
  - Determine if early-intermediate RAFSS acreage is ≥ 385 acres within the WSPA or whether management/monitoring plans and schedules should be altered
- **Species trends**
  - Succession issues
  - Response times

Downstream Effects

- Primary concern is Santa Ana Sucker
- Flows emanating from SOD will carry a high fines component
- Santa Ana suckers are flood adapted (for natural floods)
- Flood disturbance should match natural flow regimes (restricted to winter releases)



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Species Priority

- All known spineflower populations should be avoided (extant and relict)
- Known extant SBKR populations should be avoided if possible (or trapped out)
- Known populations of woolly star should be avoided if possible

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Critical Features of Appropriate Habitat

- **Broad similarities between woolly star and SBKR habitat**
- **Spineflower are dependent on Juniper phase intermediate and mature RAFSS surfaces**
- **Primary driver of habitat degradation is NNG**
  - Airborn dust deposition
  - Habitat disturbance and alteration of succession
- **Likely that SBKR and woolly star will benefit from disturbance**
- **Spineflower's relationship to disturbance and succession is unknown**

Phase 2 Summary of Findings

- Creation of new habitat by lateral migration and channel widening is unlikely to occur because of the coarse texture of the boulder banks.
- Flood events must create shear stresses high enough to cause bar migration that will remove or bury vegetation. Thresholds are identified.
- Fluvial disturbance within the active channel belt occurs too frequently for successful colonization by SBKR. Recently disturbed areas should be isolated and protected for a period of ~30 years before disturbing again.
- Structural enhancement measures could be constructed to create new habitat.
- Reactivating the 1969 Channel ranks as the best opportunity.
- The water source could be SOD release, Mill Creek flood, or a combination.

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Phase 2 Summary of Findings

- Primary driver of habitat degradation is NNG
- SBKR and woolly star can probably be managed together and are disturbance oriented
- Spineflower should be managed separately and is not disturbance oriented
- Non-fluvial methods vetted for woolly star are likely to benefit SBKR at scale
- Soil manipulations (cut and fill) are the most effective

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