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Managing Water in the West

Hydraulic modeling and habitat analysis of existing conditions within the San Joaquin River

U.S. Department of the Interior
Bureau of Reclamation

Project Objective

Estimate available Salmon habitat using relevant biological parameters and modeled hydraulic conditions under the current geomorphic and vegetative state of the system.

Milestone Objective

Develop an understanding of proposed methodology and present initial results from assessment of juvenile rearing habitat.

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Work Flow

1. Collect data to document the current state of the system
   - Aerial Imagery
   - LiDAR
   - Hydrographic surveys
   - Hydrology
2. Predict hydraulic conditions within each river reach
   - Build two-dimensional computational models of each reach
   - Simulate hydraulics for each flow rate stipulated in settlement
3. Estimate rearing habitat within each river reach
   - Define biologically-relevant habitat criteria
   - Calculate habitat for each set of hydraulic simulation results and habitat criteria

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Hydraulic Modeling: SRH-2D

Lai, *J. Hydr. Eng.*, 2009

- Solves the depth-averaged Navier-Stokes equations
- Produces two-dimensional (x,y) mean flow field and water depth
- Bed shear stresses calculated via Manning's Resistance equation
- Apparent (Reynolds) stresses parameterized using Boussinesq formulation and eddy viscosity
- Wetting-drying algorithm updated for each solution time step

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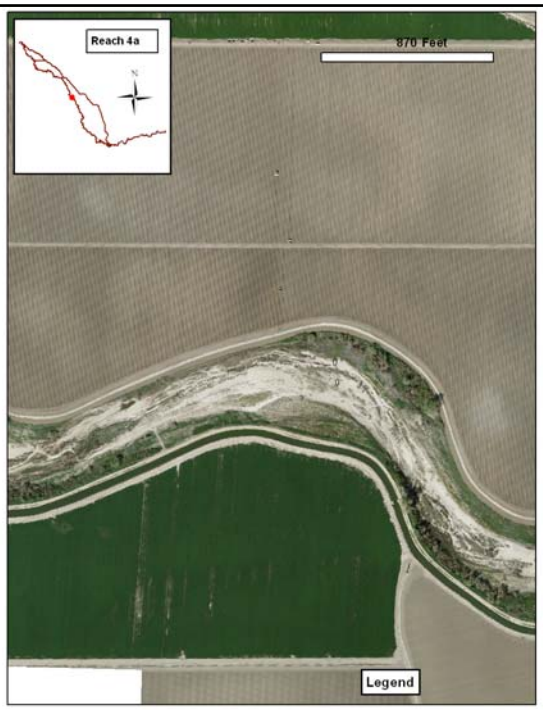
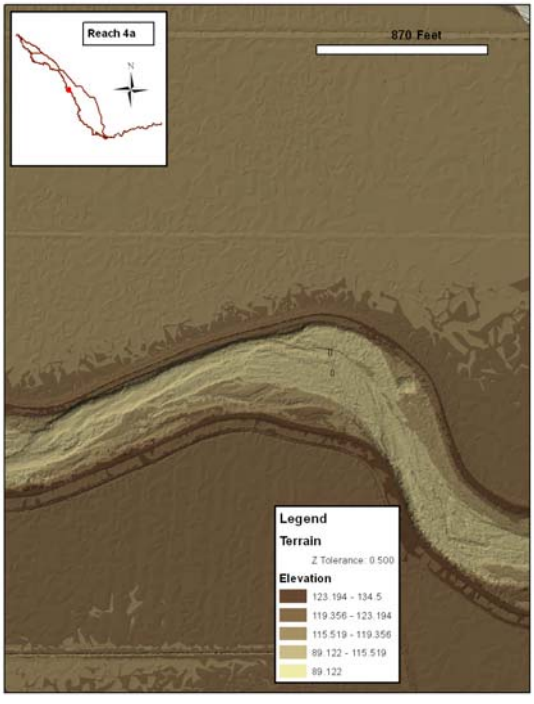
Hydraulic Modeling

Aerial Imagery



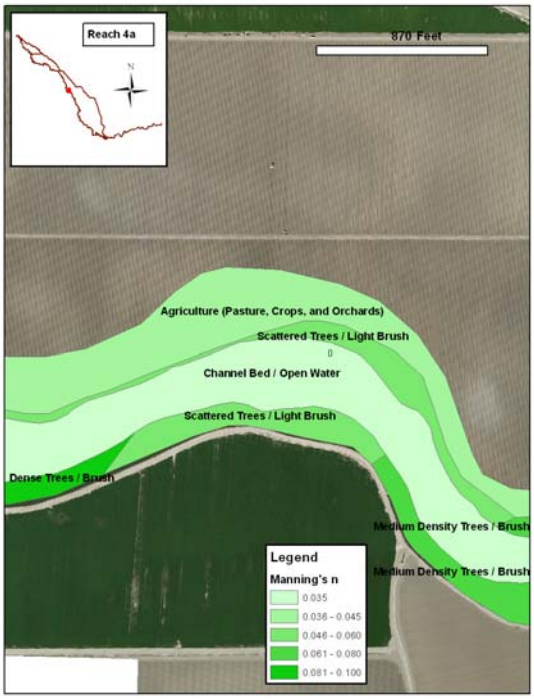
Hydraulic Modeling

Digitized Terrain



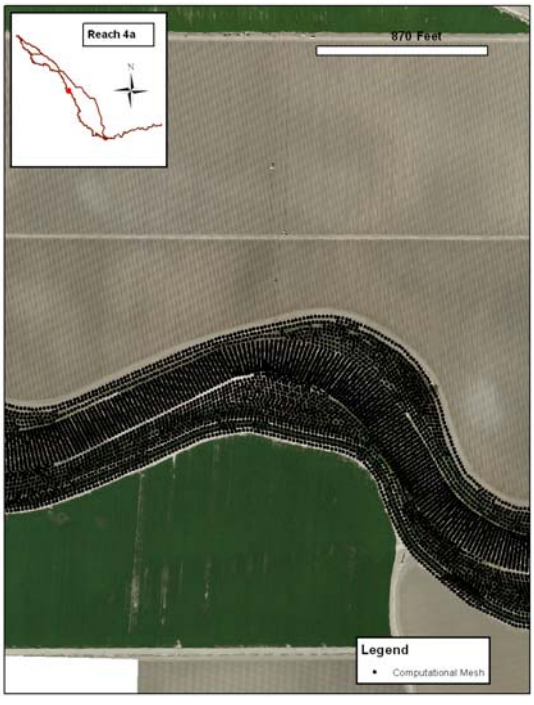
Hydraulic Modeling

Land-use classification & Manning's *n*



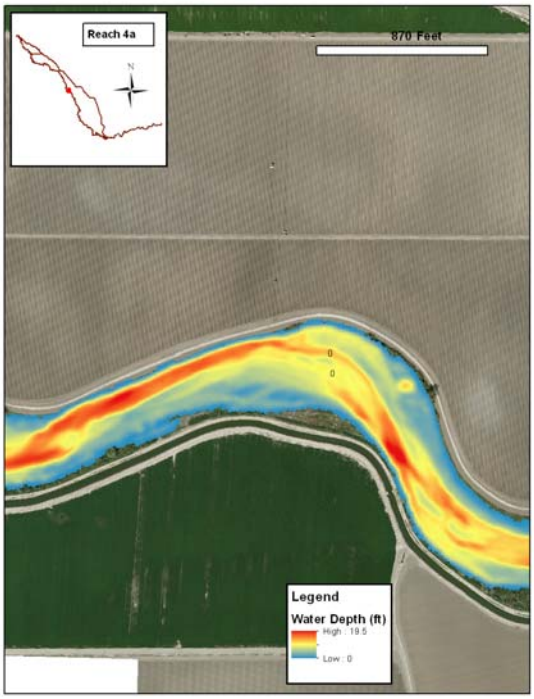
Hydraulic Modeling

Computational Grid



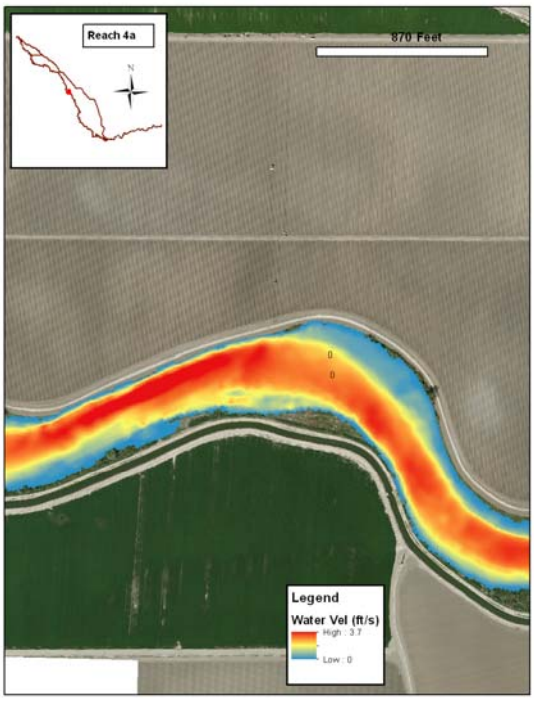
Hydraulic Modeling

Simulated Water Depth



Hydraulic Modeling

Simulated Velocity



Hydraulic Modeling Results

Computations provide spatially distributed information:

- **Area of inundation**
- **Water depth**
- **Flow velocity**

Results from hydraulic modeling of each reach, flow, and levee alignment option are used to inform habitat assessment .

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Habitat Assessment

Objective:

Map observable physical variables (e.g., depth, velocity, geomorphic & vegetative characteristics) to a quantitative metric of habitat quality for a given species

Dependency:

Need a functional relationship between physical variable and habitat quality based on field observations

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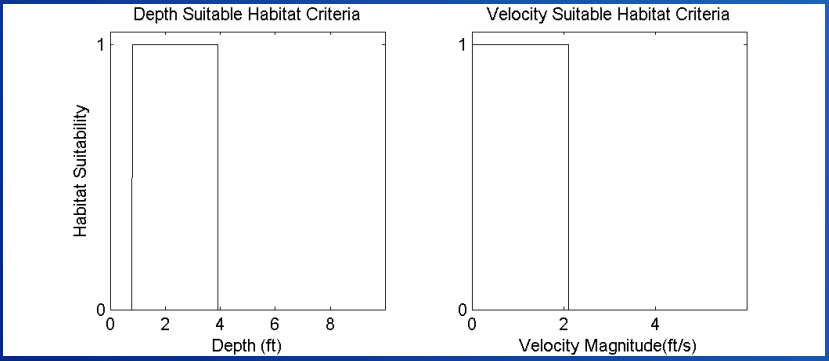
Hydraulic Suitability Habitat Criteria

Relating Depth and Velocity to Habitat Quality



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Hydraulically Suitable Habitat (HSH)

- **Map the depth suitability and velocity suitability habitat criteria (DSHC & VSHC) to each wetted element within the 2D hydraulic model solution**
- **Compute the hydraulic suitability habitat criteria:**

$$HSHC = \sqrt{(DSHC \cdot VSHC)}$$

- **Classify the HSHC distribution:**

  HSHC = 1 "hydraulically-suitable habitat"

  HSHC = 0 "non-suitable habitat"

- **Repeat for varying hydraulic and geomorphic conditions**

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Geomorphic & Vegetative Habitat Cover

Salmon need hydraulically suitable habitat to coincide with areas of cover created by geomorphic features and vegetation.

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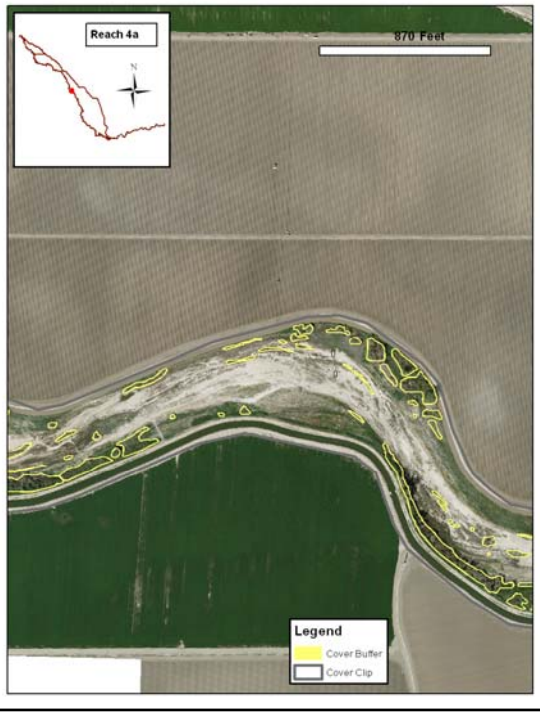
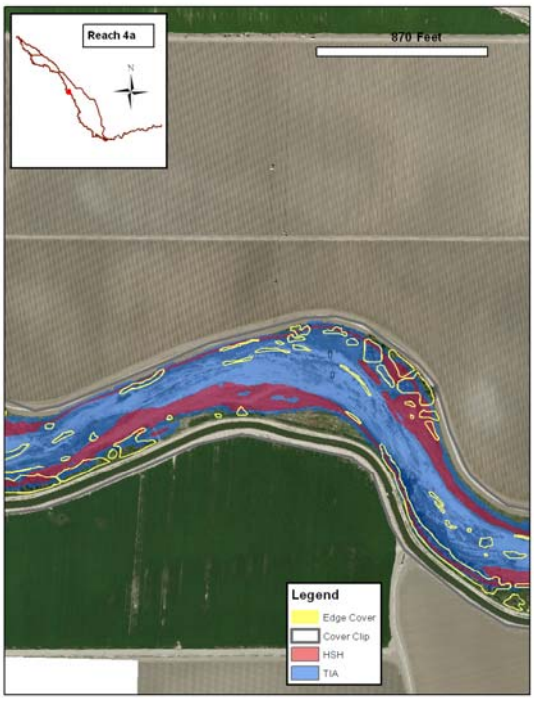
Habitat Assessment

Delineated Cover



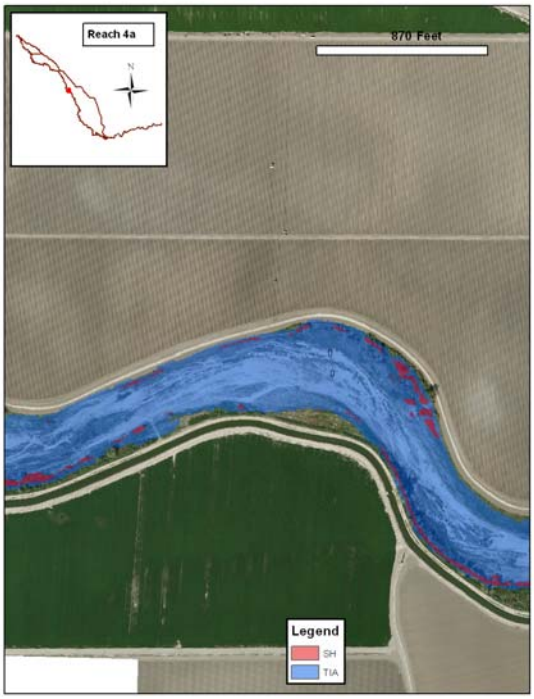
Habitat Assessment

Habitat Overlay:
- **Hydraulically suitable**
- **Cover features**



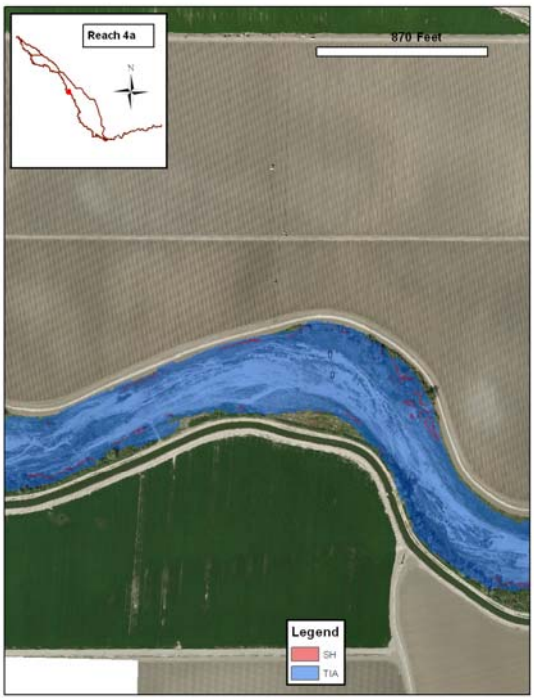
Habitat Assessment

Suitable Habitat (Full Cover)



Habitat Assessment

Suitable Habitat (Edge Cover)



"Dry" Water Year Type Results (acres)

Reach	Levee Option	TIA (ac)	HSH (ac)	Suitable Habitat (ac)	
				Full Cover	Edge Cover
1B		630	255	152	37
2A		561	299	34	27
2B	FP2	476	186		
	FP4	531	207		
	Existing	535	271		
3		431	107	72	31
4A		320	115	37	13
4B1	A	1024	526		
	B	2287	1119		
	C	3583	1820		
	D	5558	2558		
4B2		703	303	135	31
5		823	350	156	35

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"Dry" Water Year Type Results (fraction of TIA)

Reach	Levee Option	TIA (ac)	HSH (frac)	Suitable Habitat (frac)	
				Full Cover	Edge Cover
1B		630	0.40	0.24	0.06
2A		561	0.53	0.06	0.05
2B	FP2	476	0.39		
	FP4	531	0.39		
	Existing	535	0.51		
3		431	0.25	0.17	0.07
4A		320	0.36	0.12	0.04
4B1	A	1024	0.51		
	B	2287	0.49		
	C	3583	0.51		
	D	5558	0.46		
4B2		703	0.43	0.19	0.04
5		823	0.43	0.19	0.04

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"Normal" Water Year Type Results (acres)

Reach	Levee Option	TIA (ac)	HSH (ac)	Suitable Habitat (ac)	
				Full Cover	Edge Cover
1B		756	294	156	38
2A		675	305	32	25
2B	FP2	1163	456		
	FP4	1486	618		
	Existing	728	295		
3		696	236	161	25
4A		390	121	34	10
4B1	A	1124	755		
	B	2829	1897		
	C	5422	3061		
	D	7509	4318		
4B2		1033	455	125	36
5		1373	603	165	47

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"Normal" Water Year Type Results (fraction of TIA)

Reach	Levee Option	TIA (ac)	HSH (frac)	Suitable Habitat (frac)	
				Full Cover	Edge Cover
1B		756	0.39	0.21	0.05
2A		675	0.45	0.05	0.04
2B	FP2	1163	0.39		
	FP4	1486	0.42		
	Existing	728	0.41		
3		696	0.34	0.23	0.04
4A		390	0.31	0.09	0.03
4B1	A	1124	0.67		
	B	2829	0.67		
	C	5422	0.56		
	D	7509	0.58		
4B2		1033	0.44	0.12	0.03
5		1373	0.44	0.12	0.03

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"Wet" Water Year Type Results (acres)

Reach	Levee Option	TIA (ac)	HSH (ac)	Suitable Habitat (ac)	
				Full Cover	Edge Cover
1B		930	316	127	36
2A		807	309	35	27
2B	FP2	1553	945		
	FP4	1972	1174		
	Existing				
3		953	358	157	35
4A		485	127	27	7
4B1	A	1042	336		
	B	2914	2273		
	C	5996	4149		
	D	8920	5862		
4B2		1428	646	110	36
5		2192	1257	214	70

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"Wet" Water Year Type Results (fraction of TIA)

Reach	Levee Option	TIA (ac)	HSH (frac)	Suitable Habitat (frac)	
				Full Cover	Edge Cover
1B		930	0.34	0.14	0.04
2A		807	0.38	0.04	0.03
2B	FP2	1553	0.61		
	FP4	1972	0.60		
	Existing				
3		953	0.38	0.16	0.04
4A		485	0.26	0.06	0.01
4B1	A	1042	0.32		
	B	2914	0.78		
	C	5996	0.69		
	D	8920	0.66		
4B2		1428	0.45	0.08	0.03
5		2192	0.57	0.10	0.03

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TIA for Water Year Types

Reach	Levee Option	Flows (cfs)		
		Dry 1000-1500	Normal 2180-2500	Wet 3600-4500
1B		630	756	930
2A		561	675	807
2B	FP2	476	1163	1553
	FP4	531	1486	1972
	Existing	535	728	
3		431	696	953
4A		320	390	485
4B1	A	1024	1124	1042
	B	2287	2829	2914
	C	3583	5422	5996
	D	5558	7509	8920
4B2		703	1033	1428
5		823	1373	2192

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SH for Water Year Types
(Edge Cover Definition)

Reach	Levee Option	Flows (cfs)		
		Dry 1000-1500	Normal 2180-2500	Wet 3600-4500
1B		37	38	36
2A		27	25	27
2B	FP2			
	FP4			
	Existing			
3		31	25	35
4A		13	10	7
4B1	A			
	B			
	C			
	D			
4B2		31	36	36
5*		35	47	70

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Discussion

- Hydraulic modeling demonstrates that in the constrained (leveed) reaches, greater flows do not necessarily produce more habitat.
- Results of habitat assessment indicate sensitivity to how cover is defined, and suggests utility in strategic placement and modification of cover features.
- Combined analyses suggest that habitat area can be efficiently improved by increasing the coincidence of cover features with area of hydraulically-suitable conditions.

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Limitations & Uncertainties

- How well do the habitat suitability curves for depth (DHSI) and velocity (DHSI) represent the habitat dependency on hydraulic conditions within the San Joaquin system?
- How best to quantify geomorphic and vegetative cover for use in the habitat analysis?
- How would temperature modeling effect the predicted suitability of habitat?
- Currently, productivity processes and connectivity of habitat are not considered.

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