Tidal Stream Restoration at the Lookout Slough Project

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Ecosystem Investment Partners

BEAVER CREEK HYDROLOGY

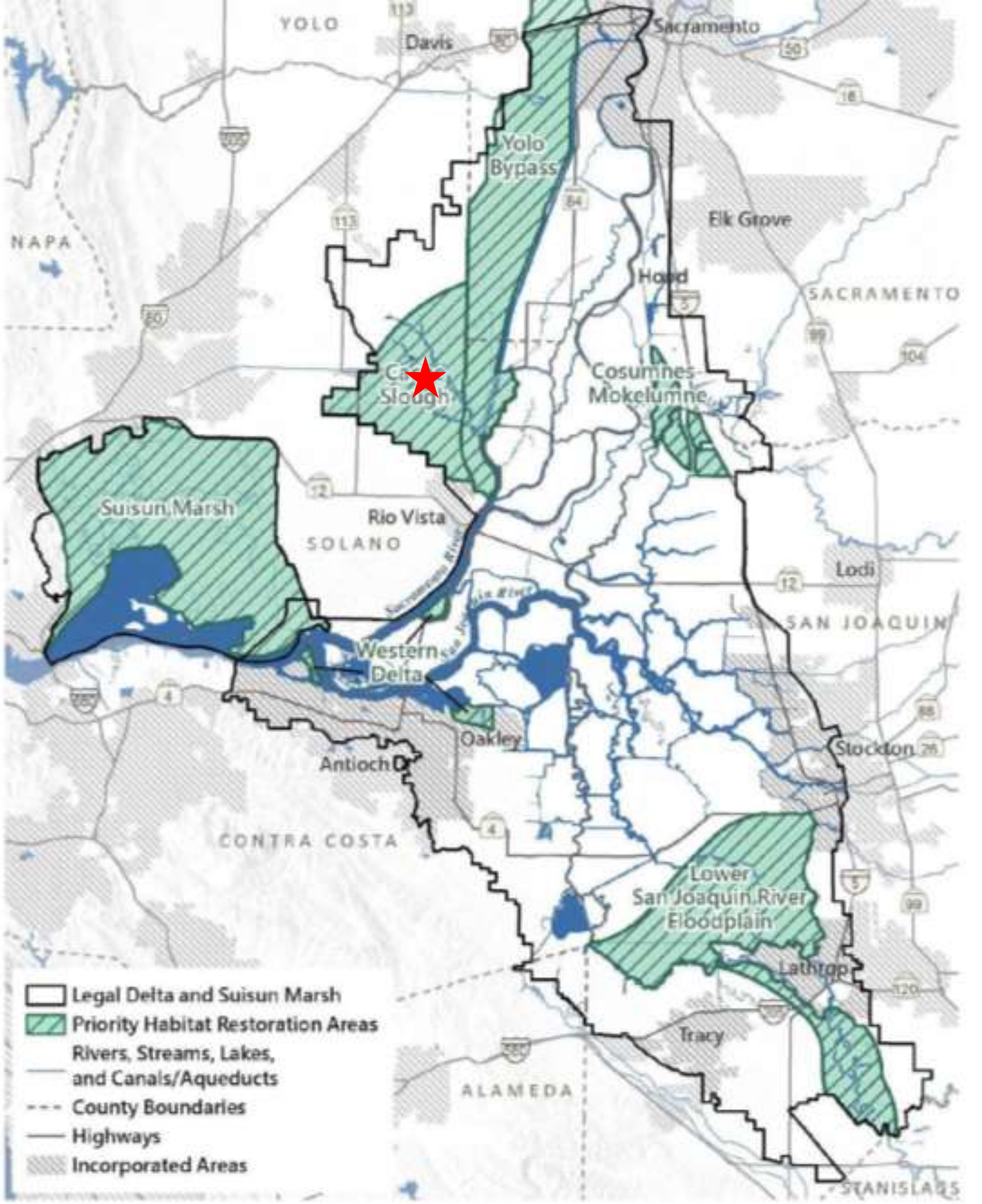
DEPARTMENT OF WATER RESOURCES • STATE OF CALIFORNIA

Presentation Overview

- Project Overview
- Tidal Channel Design Process (Typical)
- Tidal Channel Design Process (Lookout Slough)
- BANKFULL Natural Channel Design Software
- Construction Status

Goals – PPP with DWR/EIP

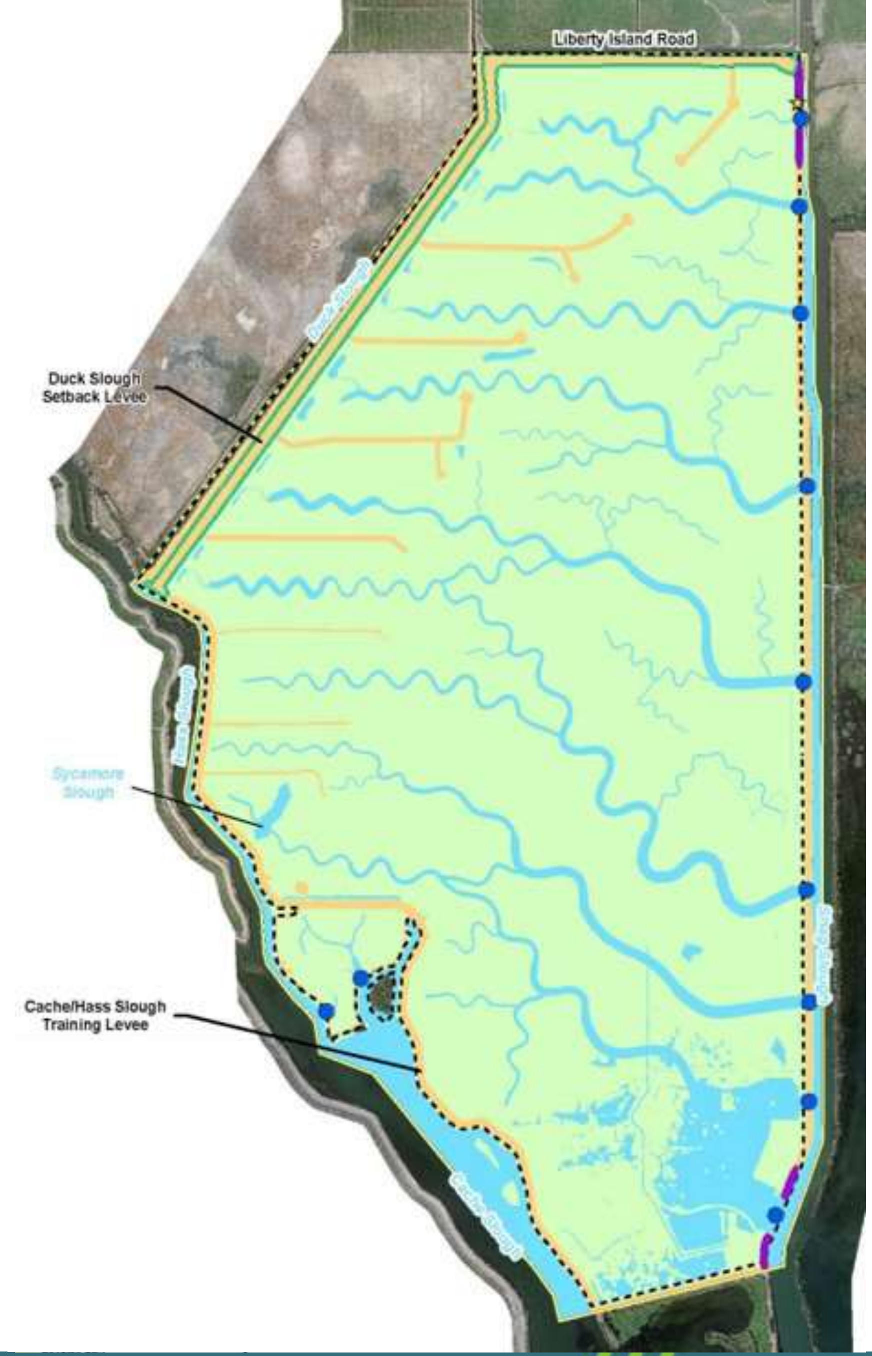
- Create habitat to support native species and improve food productivity
- Support viable populations of special-status aquatic and terrestrial species
- Provide flood storage and conveyance within the Yolo Bypass to reduce the chance of catastrophic flooding



Delta Stewardship Council (2013), *Final Delta Plan.*

I.

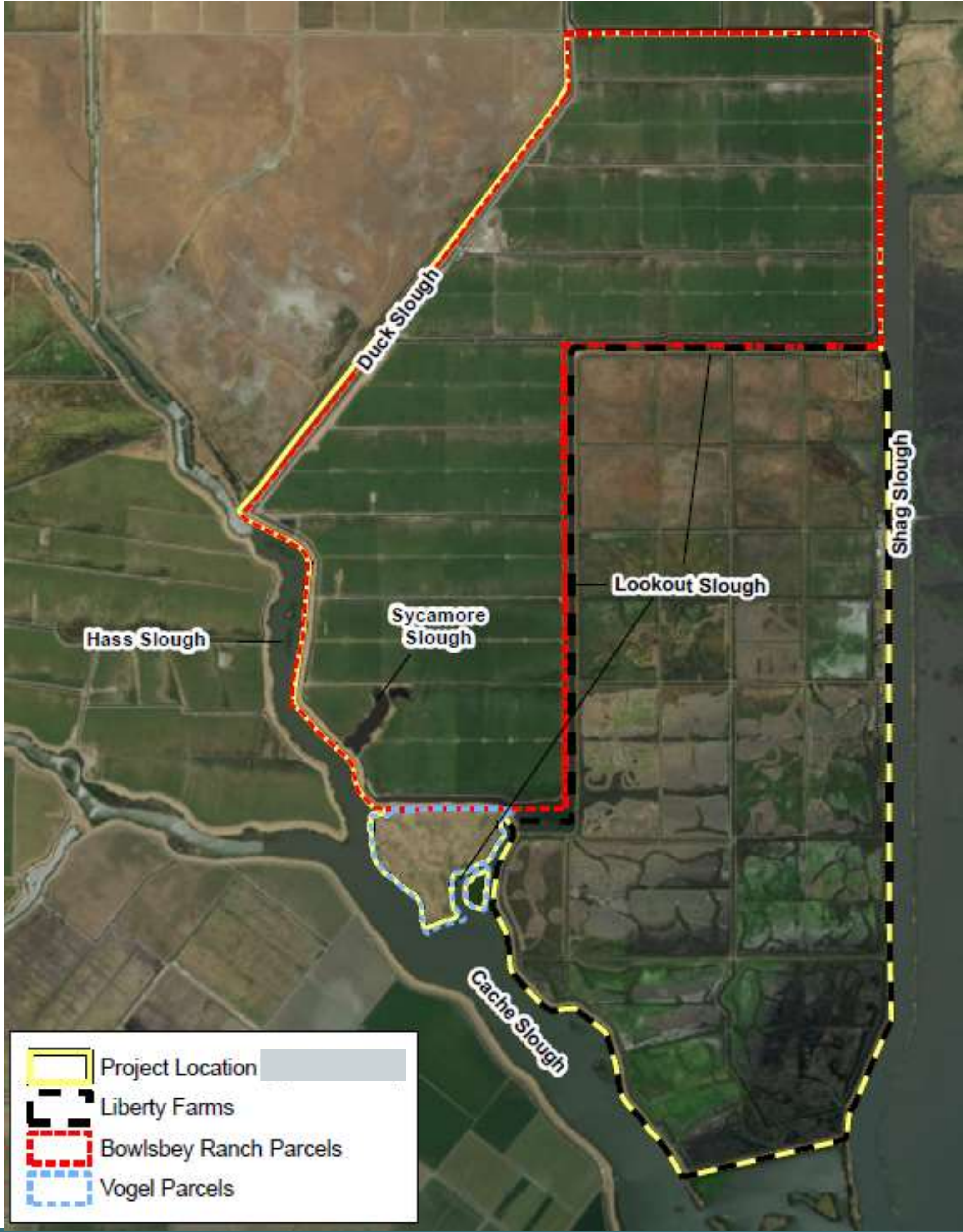
Project Overview



- Project Site Boundary (3,378 ac.)
- Project Area (3,636 ac.)
- Duck Slough Setback Levee
- Shag Slough Degrade Limits
- Boat Ramp
- Levee Breach

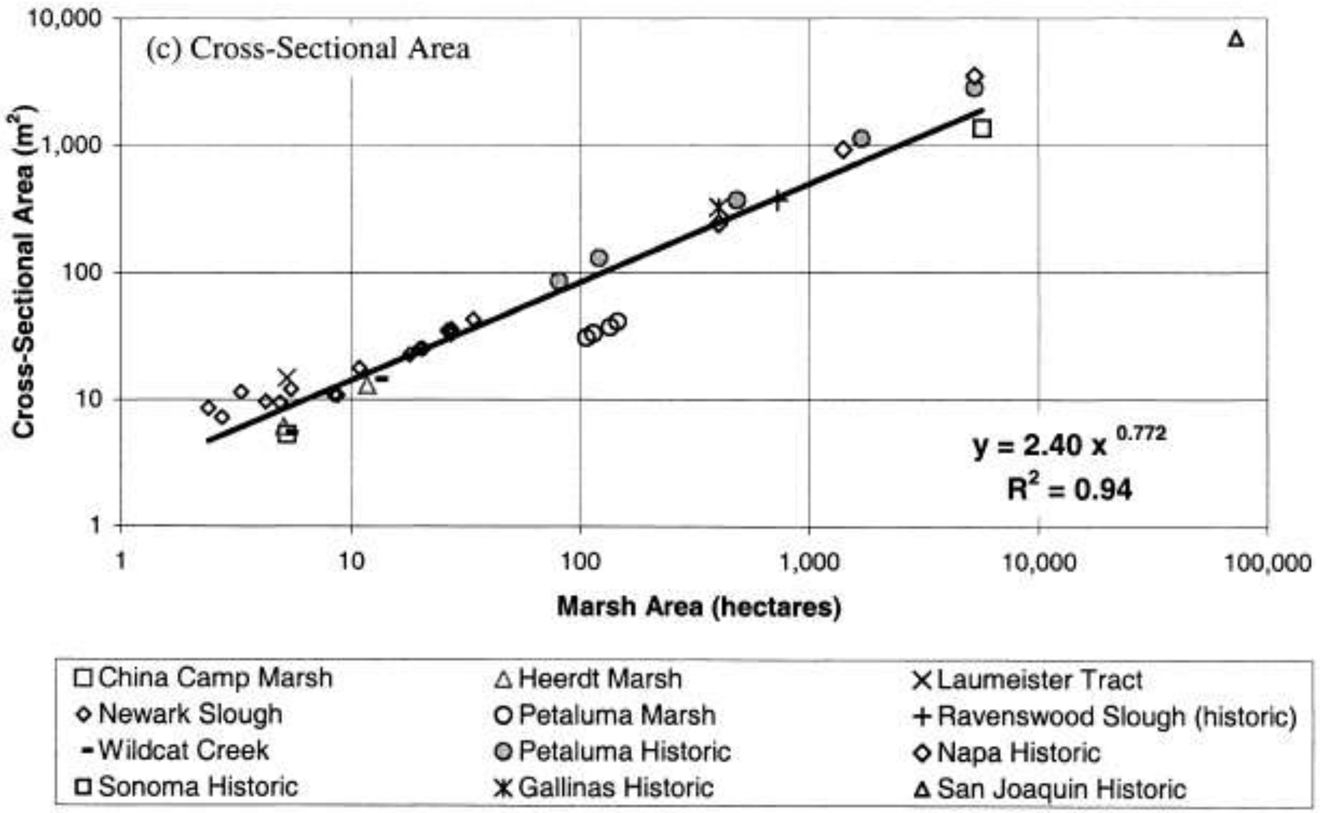
Habitat Zones by Elevation (ac. within Property Boundary/ac. within Project Area)

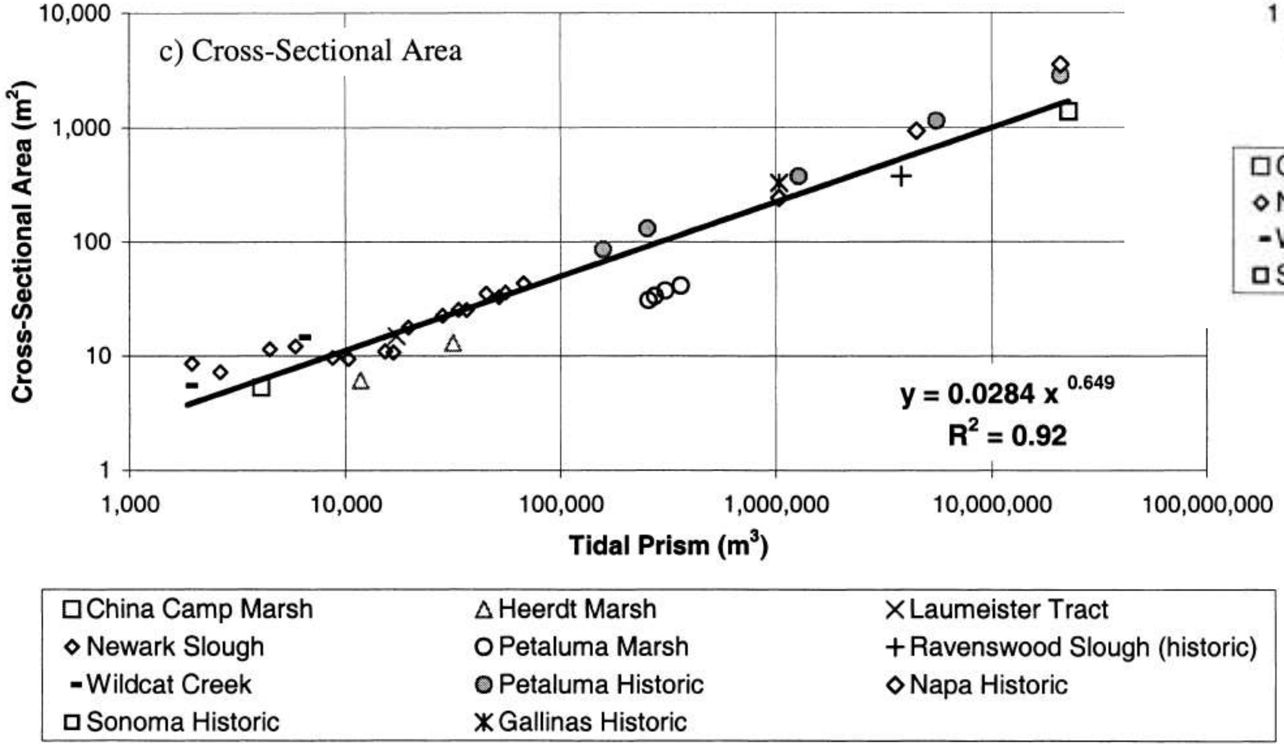
- Subtidal Habitat (2.1' and below) (445 ac./629 ac.)
- Intertidal Habitat (2.1' to 6.5') (2,720 ac./2,746 ac.)
- Upland (6.5' and above) (194 ac./234 ac.)



Credit: ESA and design team

Regression Equations

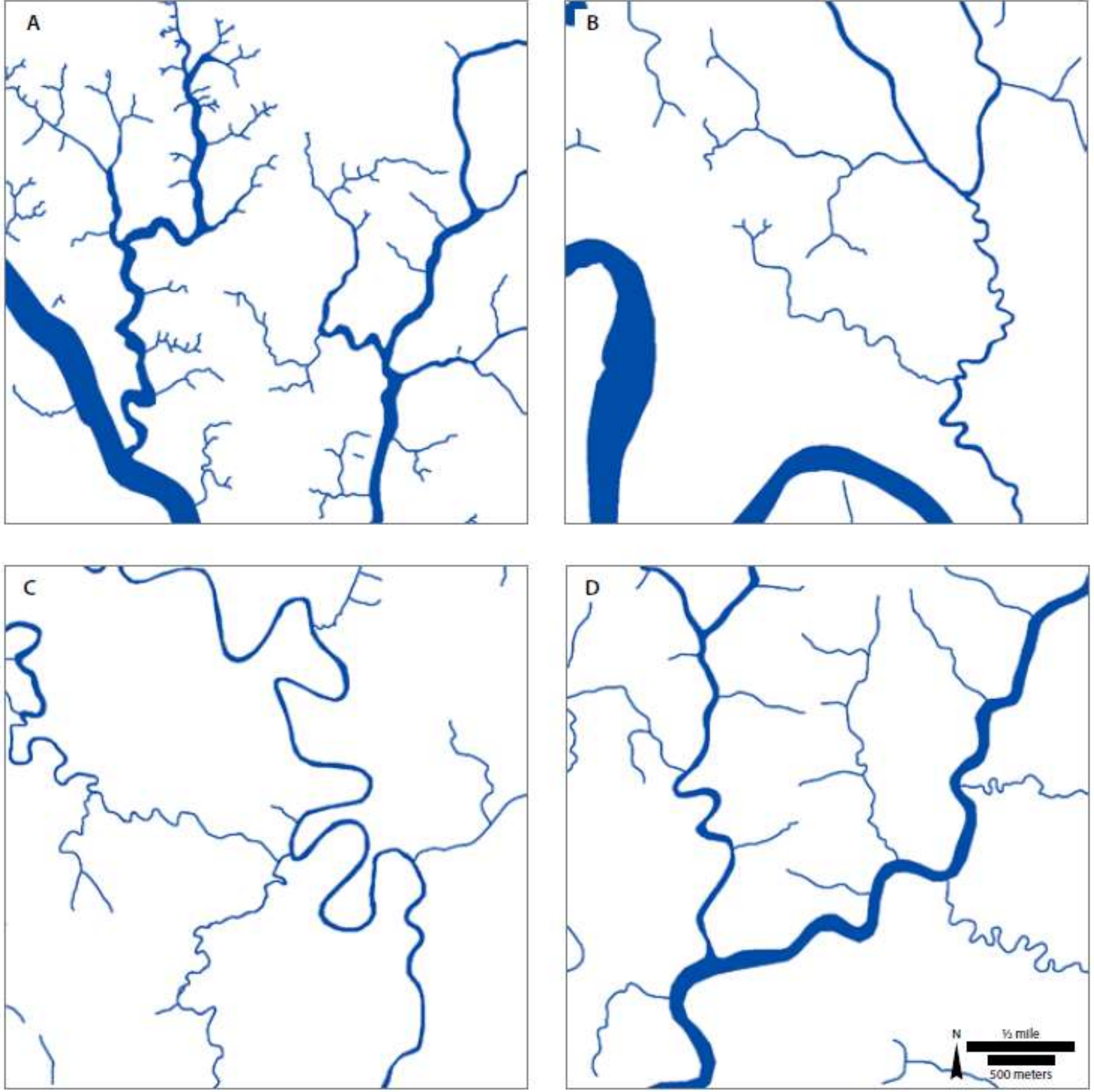




Williams, et al. (2002), *Restoration Ecology,* Vol. 10 No. 3, pp. 577-590

Reference Data

Cache Slough (A) historically had a more truncated network than sloughs found elsewhere in the Delta. Shown here is part of Venice Island (B), Whiskey Slough (C), and part of Tyler and Staten islands (D).



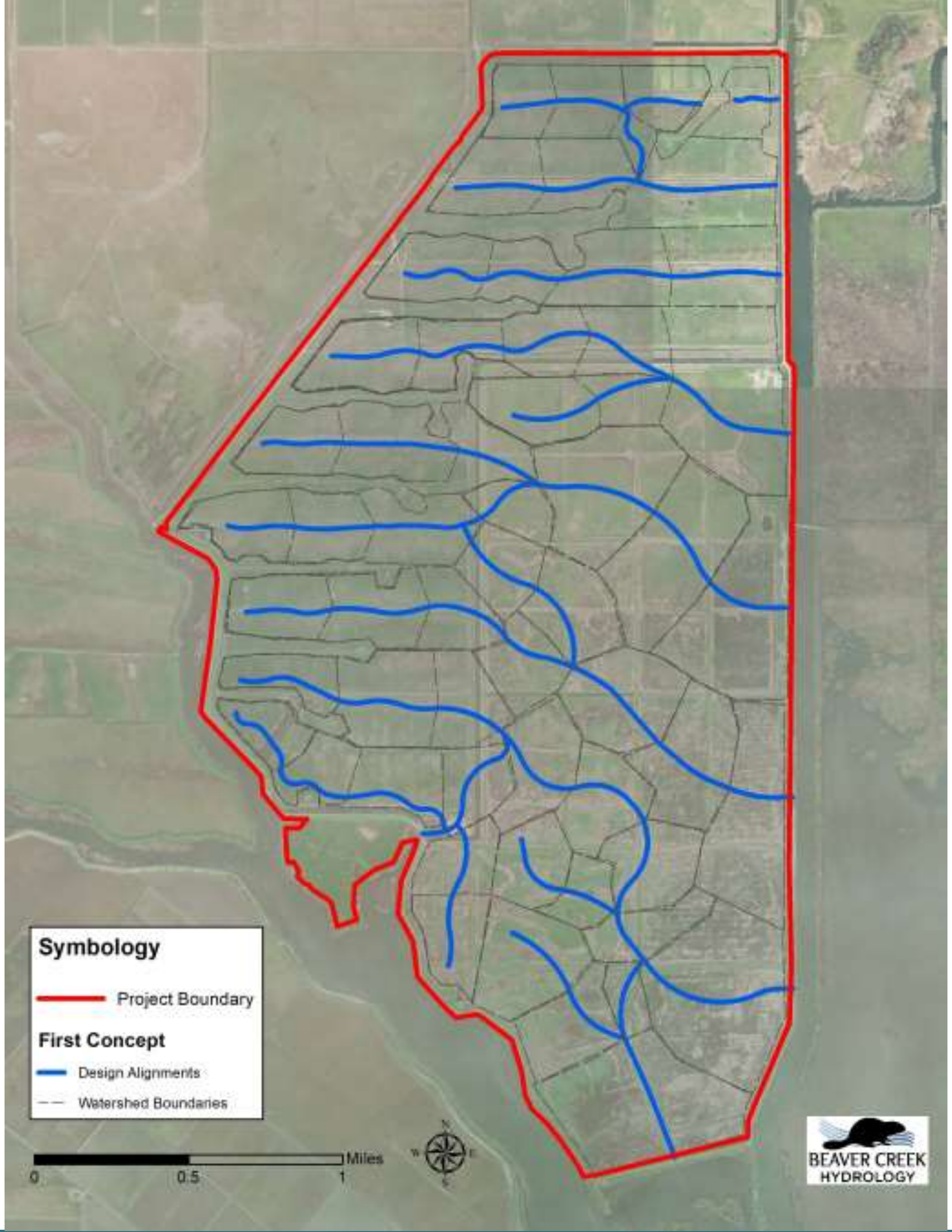
Whipple, et al. (2012), *Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process.*

Early Concept

Process

- Draw conceptual stream alignments
- Determine DA
- Iterate for stream alignments

**Conceptual plan with blue line streams created by others on design team*



Tidal Channel Design (Typical)

W4A-7

DA = 1,042 acres

Width(DA) = 317 ft

Area(DA) = 2,750 ft^2

Prism = 77mil ft^3

Width(DA) = 406 ft

Area(DA) = 3,970 ft^2

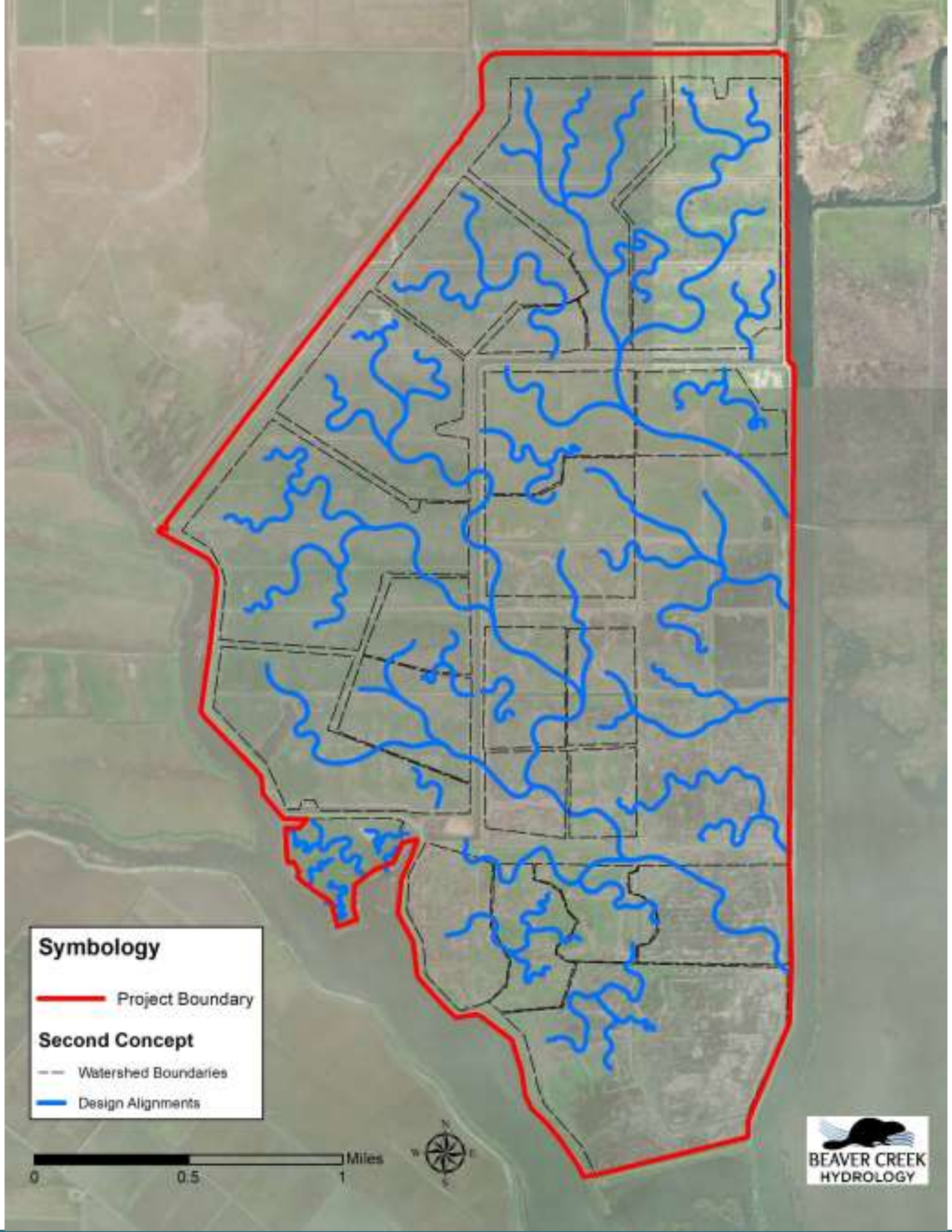
Basin Label	Area acres	Depth ft. below MHHW	Width ft.	Area sq. ft.	Tidal Prism cu. ft.	Depth ft. below MHHW	Width ft.	Area sq. ft.
W1	24.8	6.86	40	153	2,210,895	8.89	79	397
W2	274.0	11.15	152	979	18,325,672	12.90	210	1565
W2A	86.0	8.82	80	400	5,106,921	10.30	116	683
W2B	106.0	9.20	90	470	7,303,721	10.97	137	861
W2BA	30.6	7.16	45	180	2,255,330	8.92	80	402
W2BB	63.7	8.30	68	317	4,256,367	9.98	107	607
W3	184.0	10.29	122	720	12,693,762	12.10	177	1233
W3A	125.0	9.52	98	534	7,918,386	11.13	142	908
W3B	74.0	8.56	74	356	3,667,627	9.72	100	551
W3C	45.3	7.75	56	244	2,207,203	8.89	79	396
W4A-1	20.1	6.58	36	130	1,802,889	8.58	72	347
W4A-2	154.0	9.93	110	628	11,865,429	11.95	172	1180
W4A-3	317.0	11.48	165	1,096	23,074,578	13.44	233	1817
W4A-4	489.0	12.54	209	1,531	36,961,968	14.60	290	2467
W4A-5	647.0	13.26	244	1,901	52,410,769	15.52	341	3095
W4A-6	869.0	14.08	287	2,387	70,238,770	16.35	390	3743
W4A-7	1042.0	14.60	317	2,746	76,898,668	16.61	406	3970
W4B	79.0	8.67	76	375	4,846,865	10.21	113	660
W4C	117.0	9.39	95	508	7,338,429	10.98	137	864
W4D	120.0	9.44	96	518	8,194,470	11.20	145	928
W4E	123.0	9.49	98	528	11,302,720	11.85	168	1144
W4F	131.0	9.61	101	554	12,690,431	12.10	177	1233
W4G	103.0	9.15	88	460	10,262,671	11.65	160	1074
W4H	54.5	8.05	62	281	6,659,898	10.80	131	811

Second Concept

Process

- Add more complexity per reference
- Draw conceptual streams
- Determine DA
- Iterate for Streams

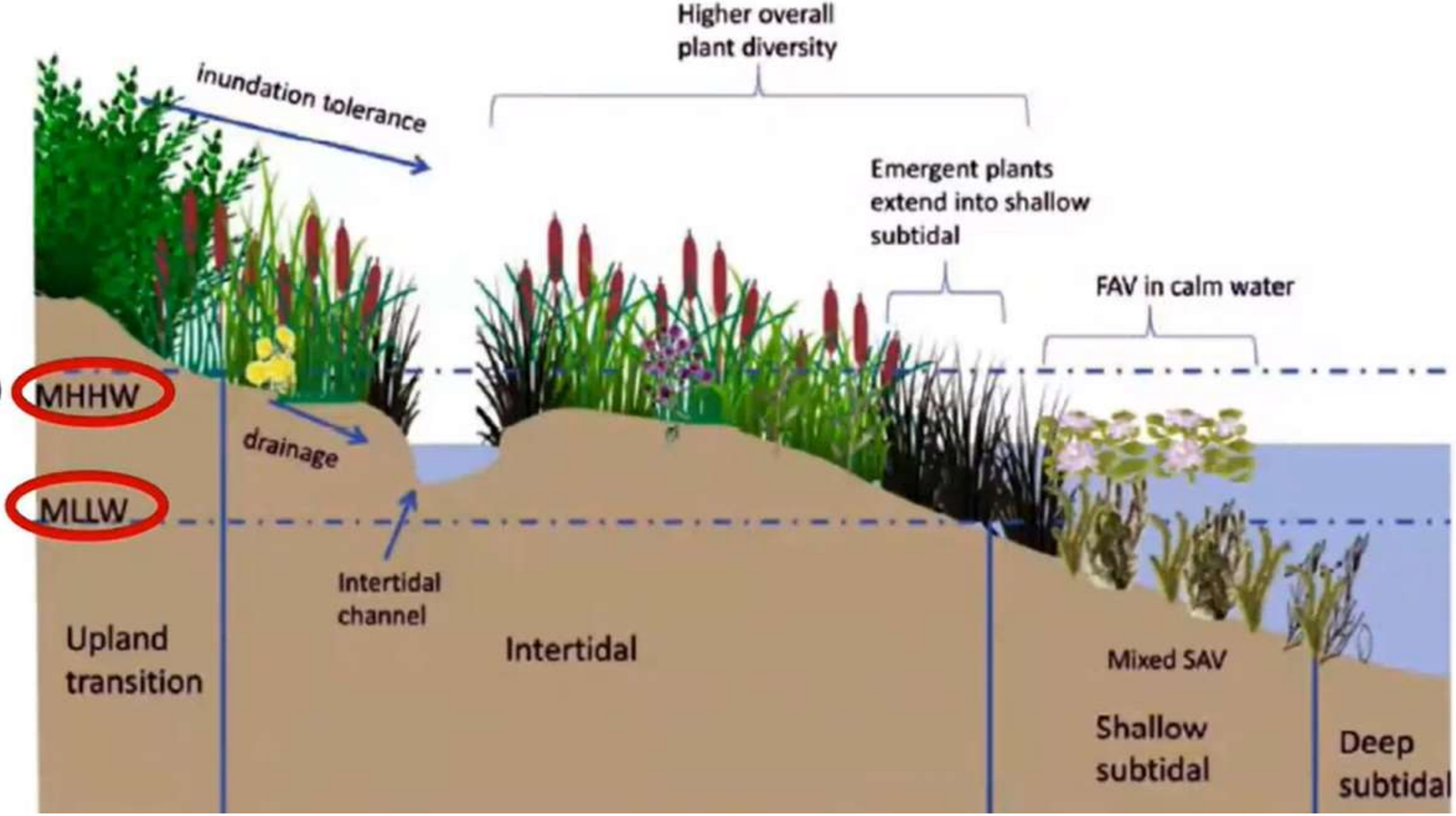
**Conceptual plan with blue line streams created by others on design team*



General Factors Controlling Vegetation Zonation in Freshwater Marshes (Sherman et al., 2017)

Approx. El. 6.5 feet (NAVD 88)

Approx. El. 2.2 feet (NAVD 88)

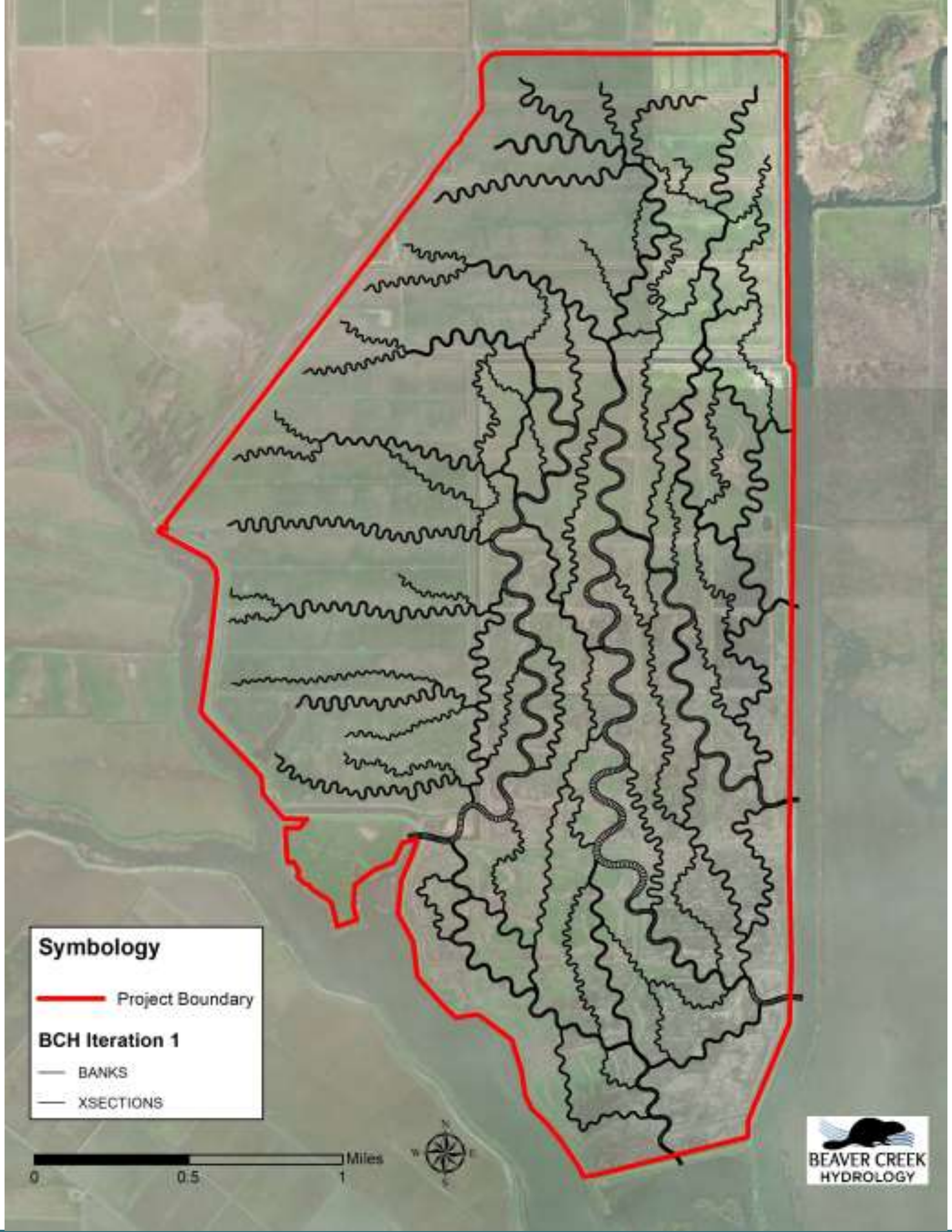


Credit: ESA and design team

BCH Iteration 1

Process

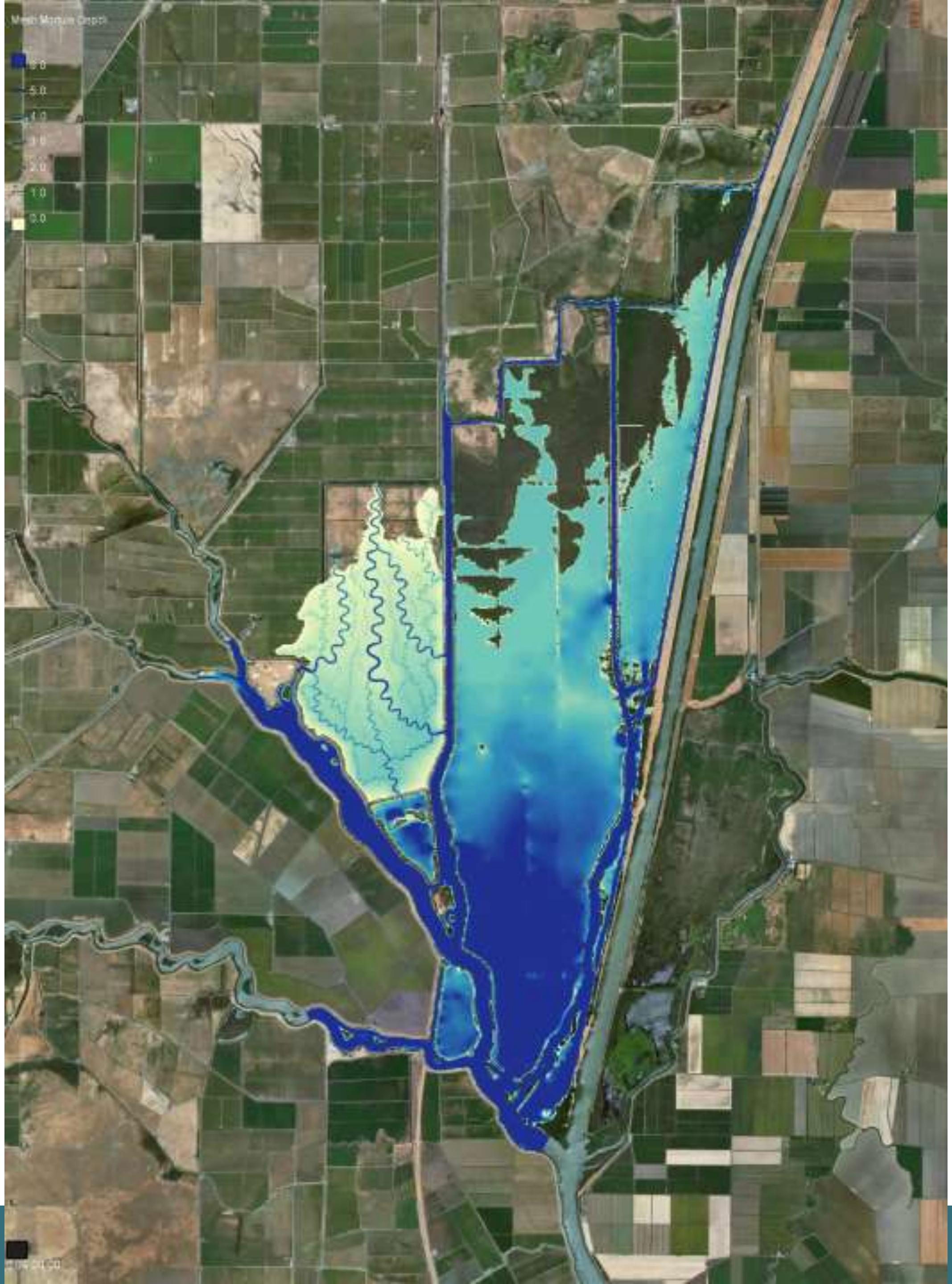
- Use the BANKFULL software to draft complex stream patterns
- Iterate based on hydraulic modeling and discharge estimates (what is DA?)
- Iterate for stream alignments
- Flood flows (north to south)



BCH Iteration 1

Process

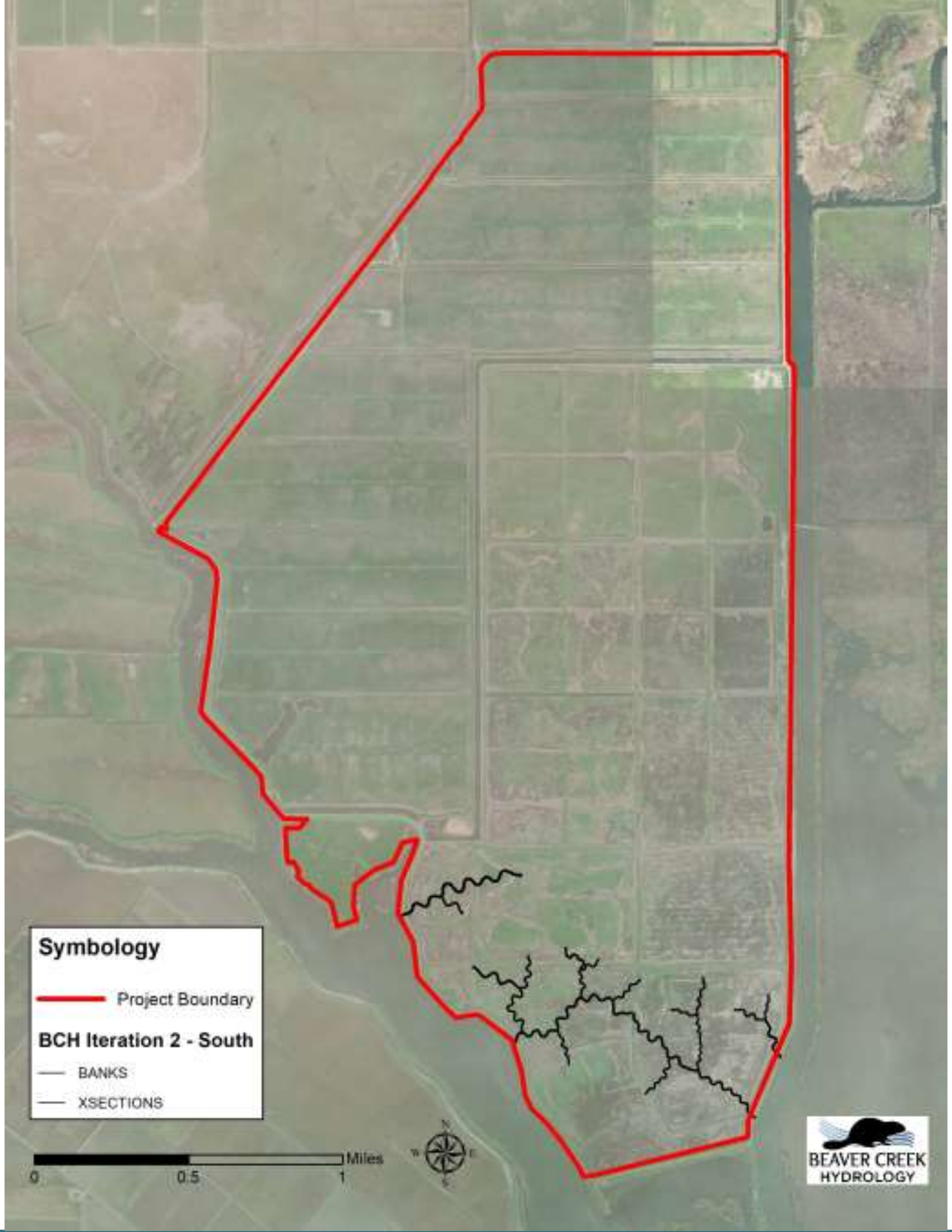
- 2D hydraulic modeling (TUFLOW) to assess offsite (upstream and downstream) impacts
- Basis of flood reduction crediting
- Basis of habitat modeling



BCH Iteration 2

Constraints considered

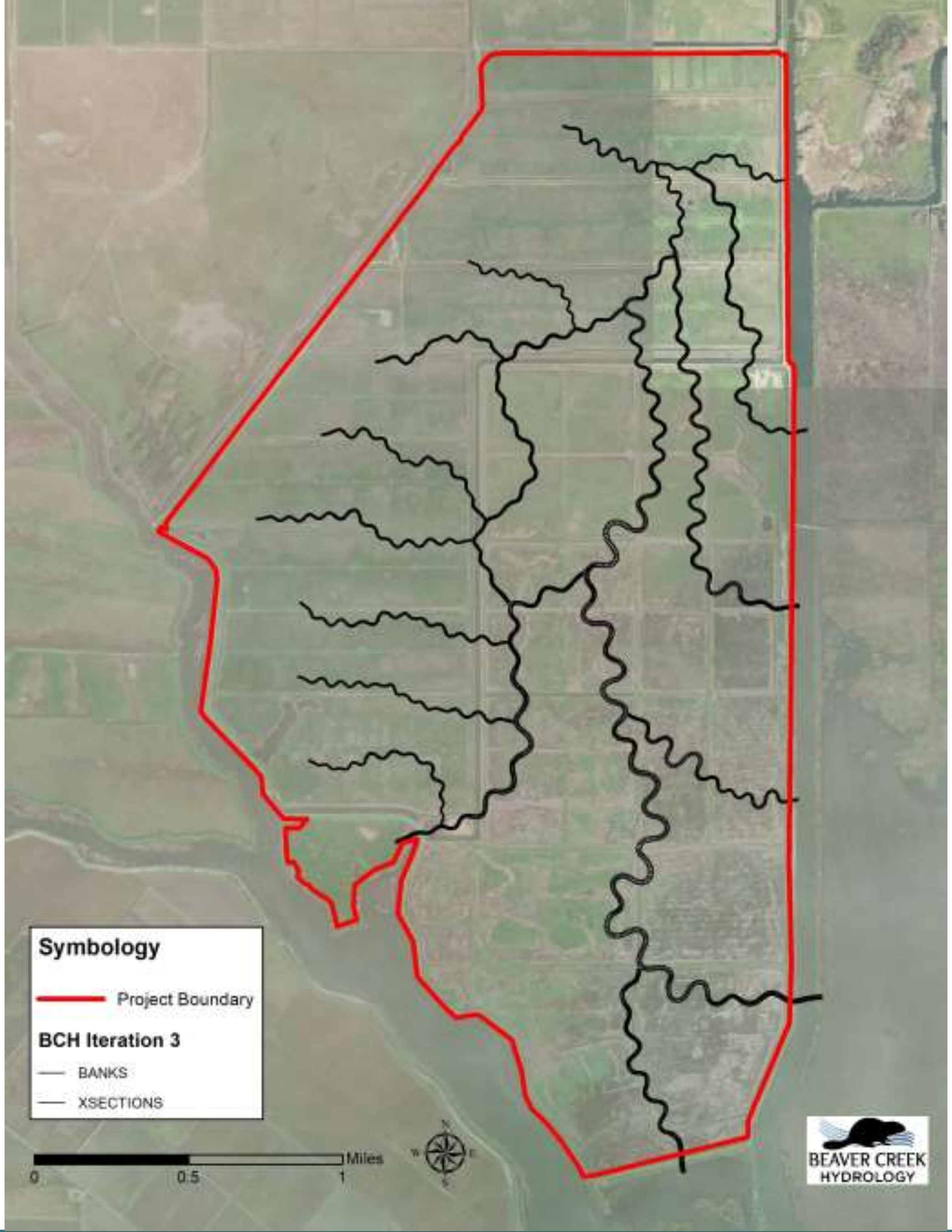
- Reassessed the southern portion only
- Alternate breach locations



BCH Iteration 3

Constraints considered

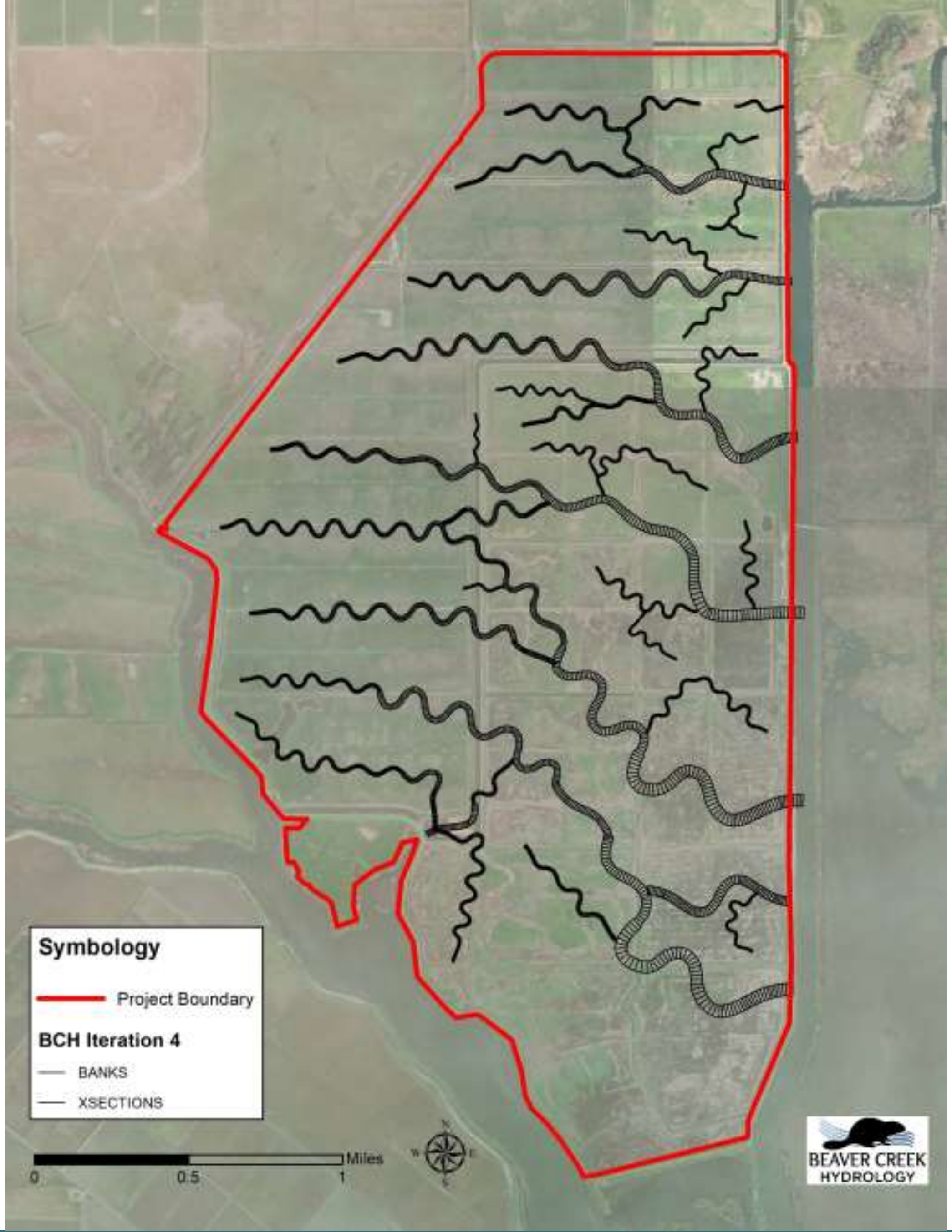
- Flood flows (north to south)
- More flood discharge to the west
- More flood discharge that does go east to southernmost two breaches (increase on site residence time during flood flows)
- Cost and schedule constraints (less complex construction)



BCH Iteration 4

Constraints considered

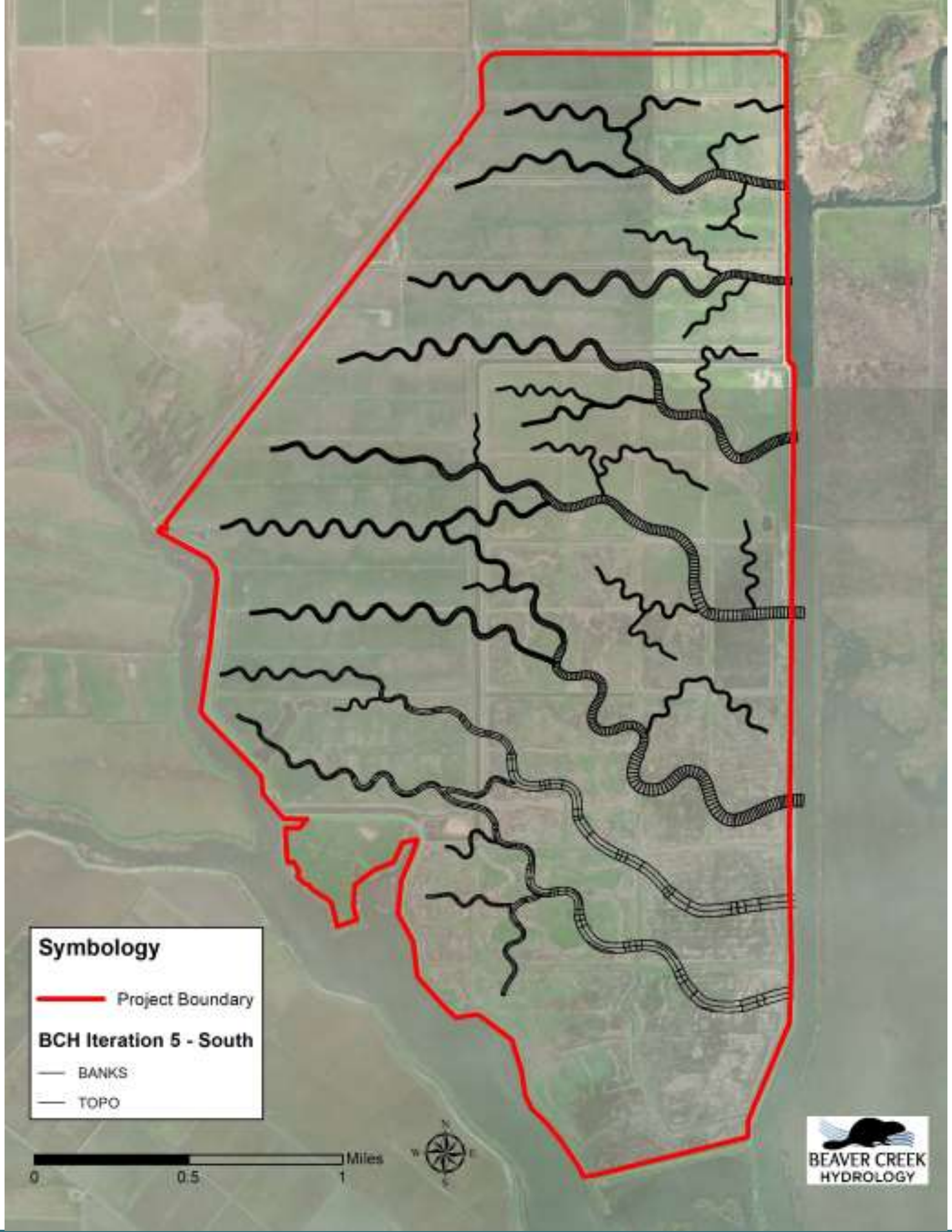
- More habitat focused (diurnal tide more than flood flows, east/west), but still handles flooding adequately
- Increased channel size near the downstream end near breaches improved hydraulic efficiency
- Drainage density near reference



BCH Iteration 5

Constraints considered

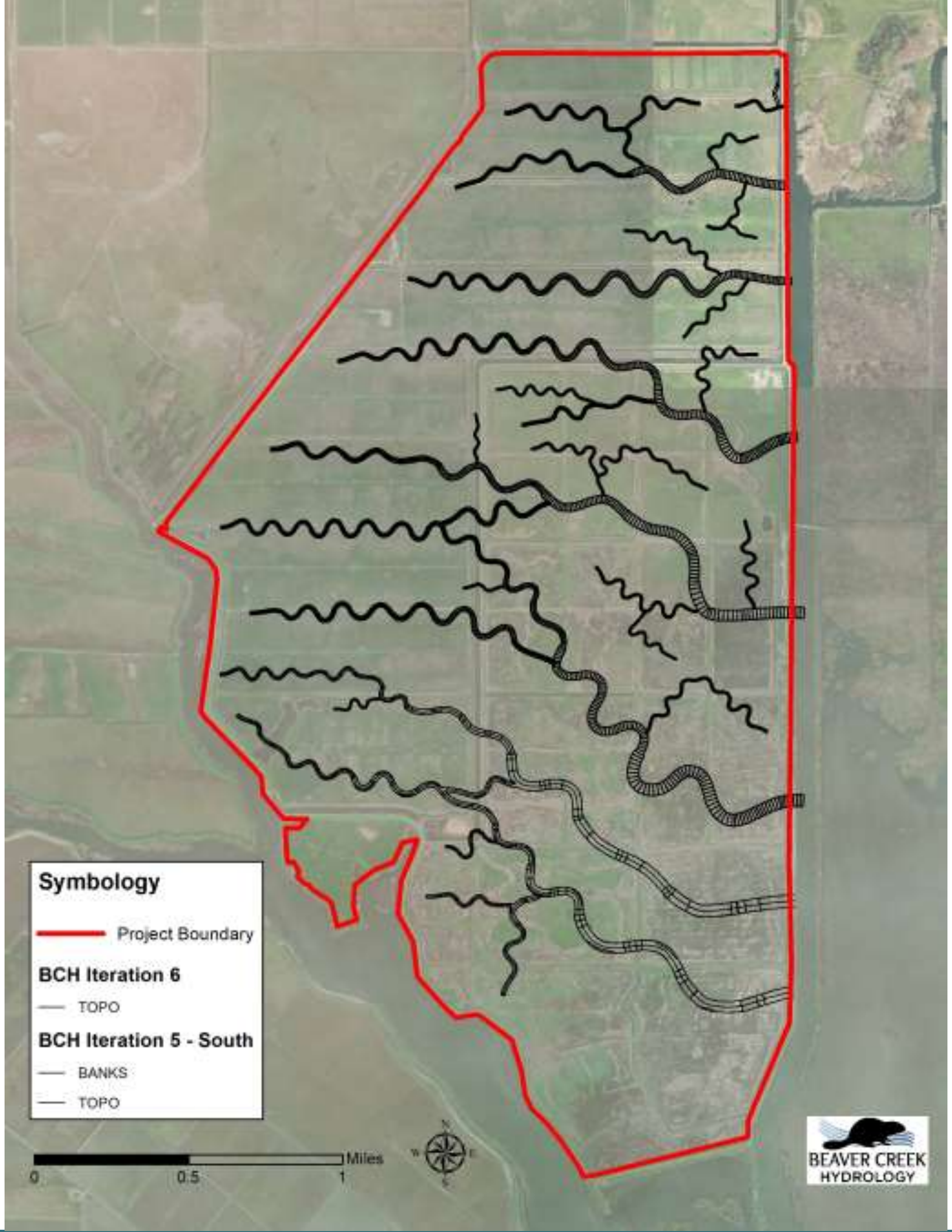
- Only changed the southern reaches
- Improve hydraulic efficiency in the southern portion of the site



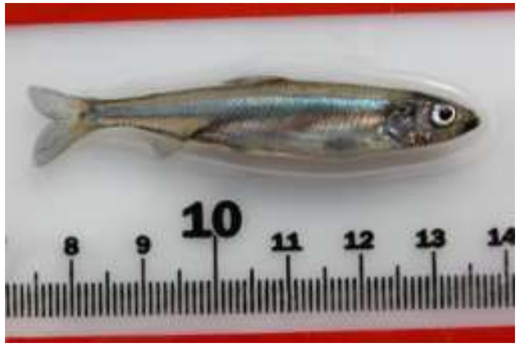
BCH Iteration 6 – FINAL

Constraints considered

- One small reach added near northeast corner of the site
- Cultural considerations
- Added public access to launch small watercraft



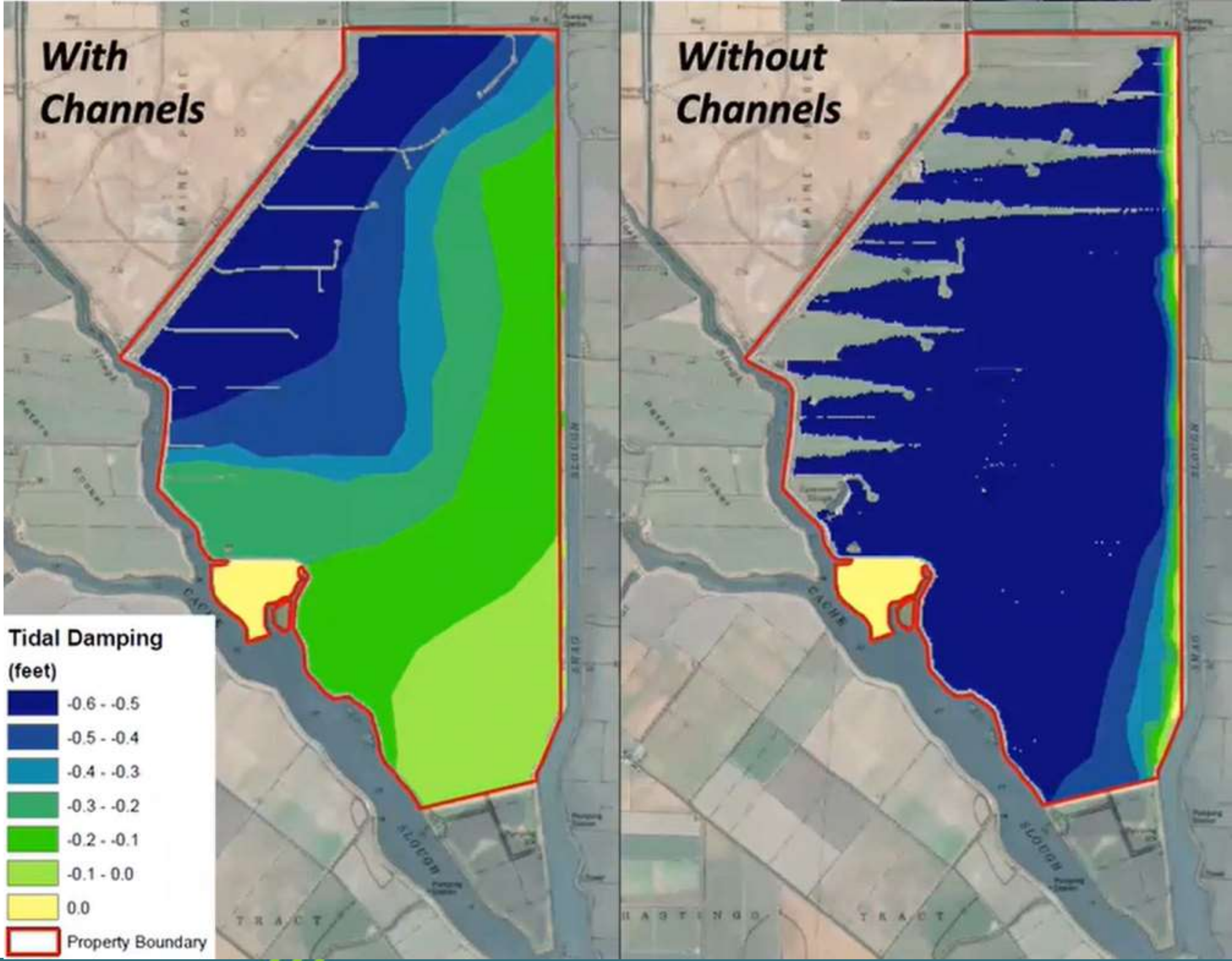
Final Design



Tidal Damping

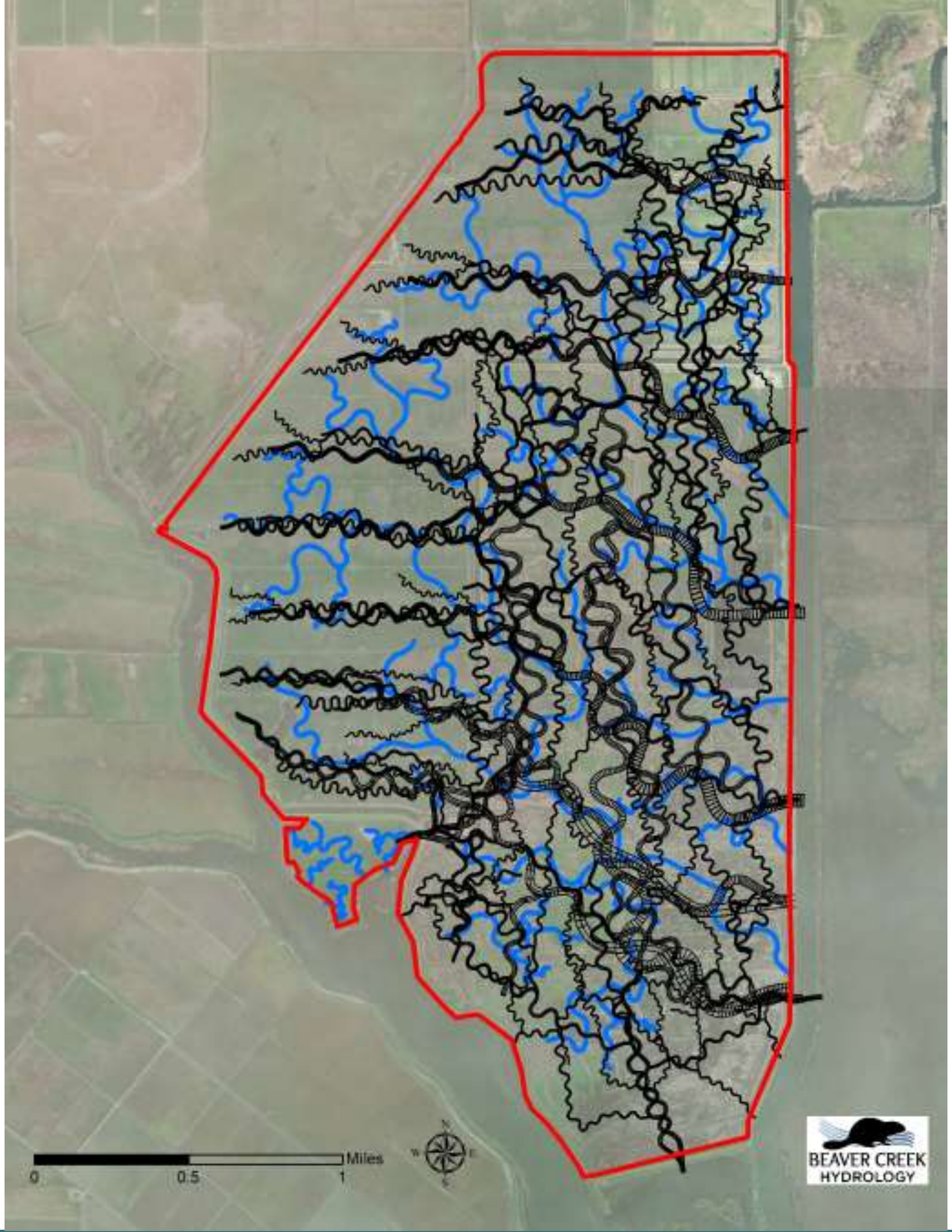
- Final grading (i.e., with channels) versus “flat-bottom” (i.e., without channels)
- Final design optimized hydrology restoration
- The entire site is wetted in normal diurnal tide

Credit: ESA and design team



Design is iterative!

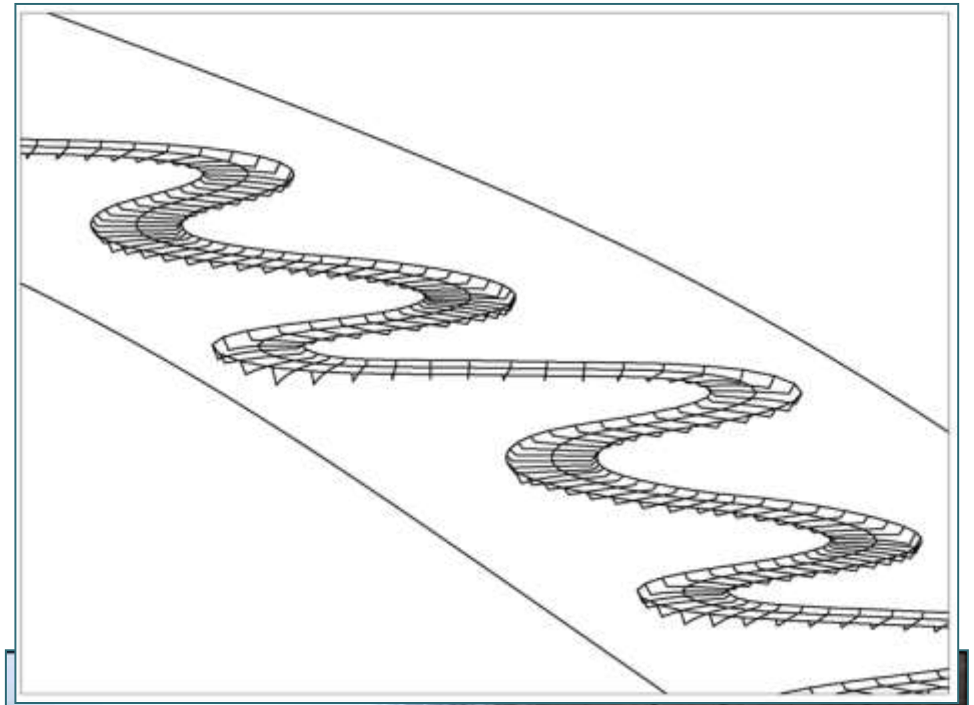
- Highly multi-disciplinary design team
- Highly multi-disciplinary regulatory environment
- Many stakeholders
- Great product!



What is BANKFULL?

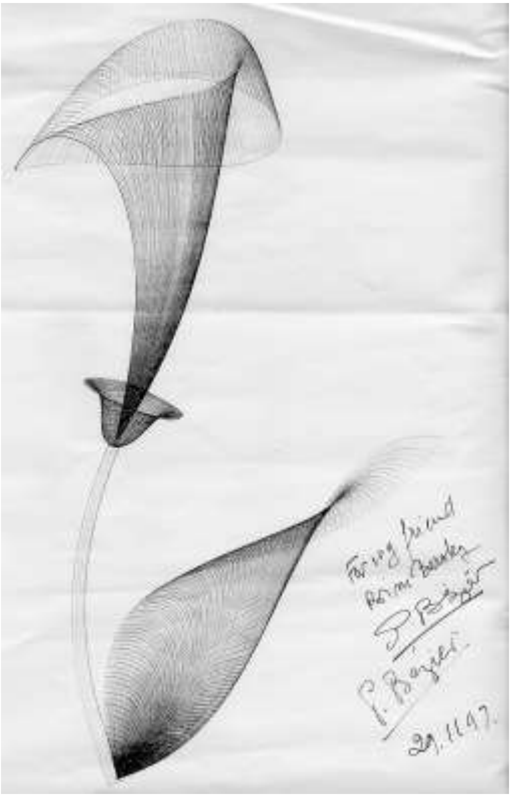
Mathematical model that generates "natural" solutions to the alluvial channel design problem.

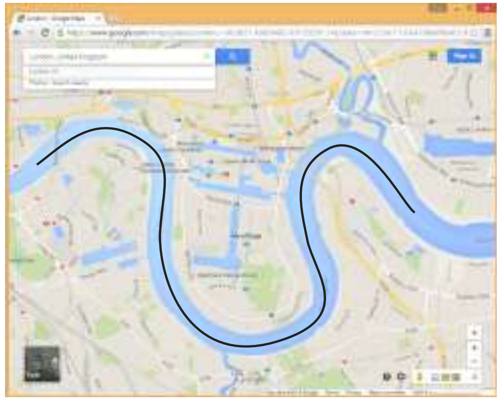
3D digital terrain mesh coupled with 2D hydraulic model and 1D sediment transport model



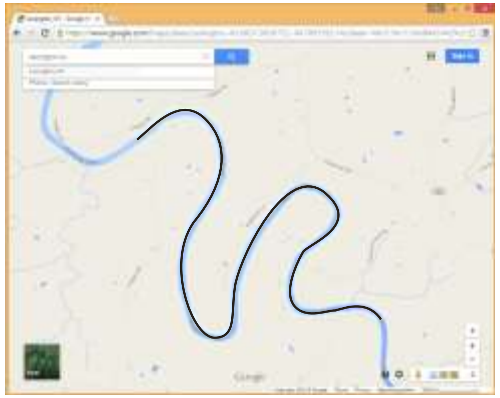
Bezier Curves

- Mathematical functions used widely by vector drawing programs
- Used to model smooth space curves
- Invented by Paul Bezier for the Rénault company
- Can fit all river patterns

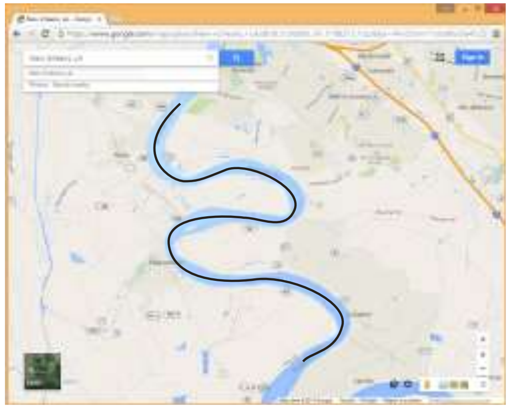




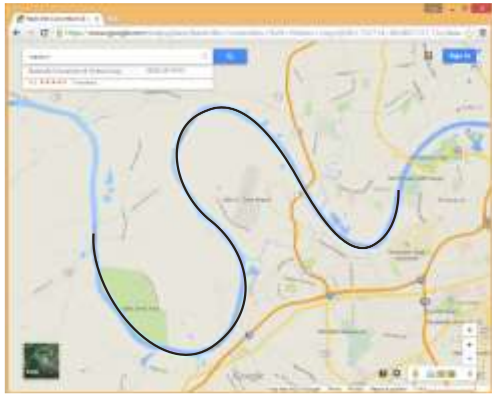
River Thames, London



Kentucky River, Frankfort

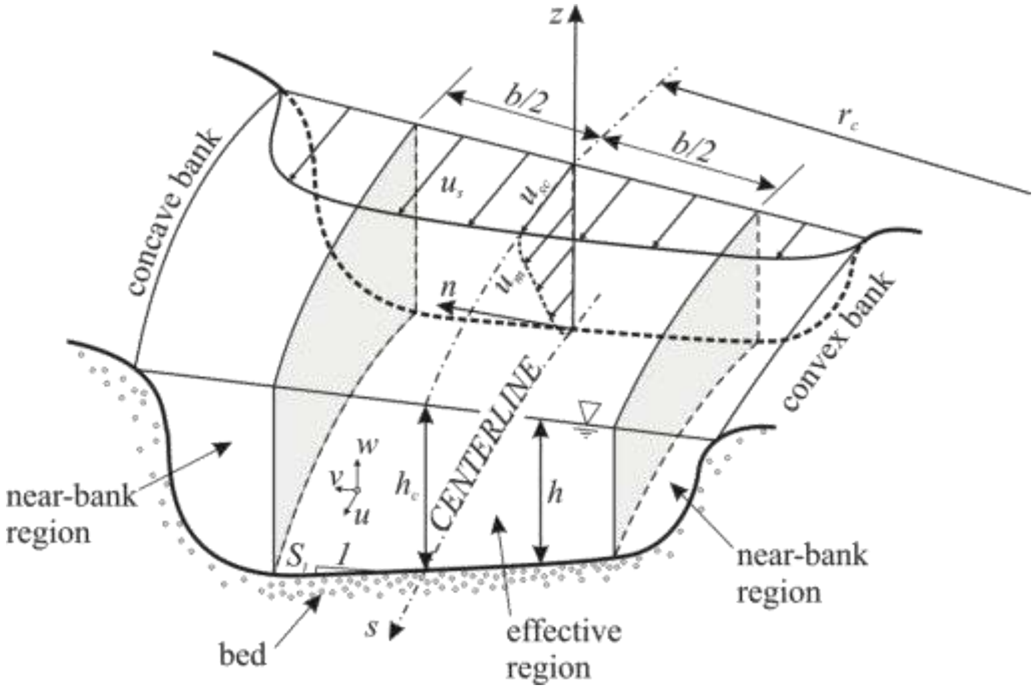


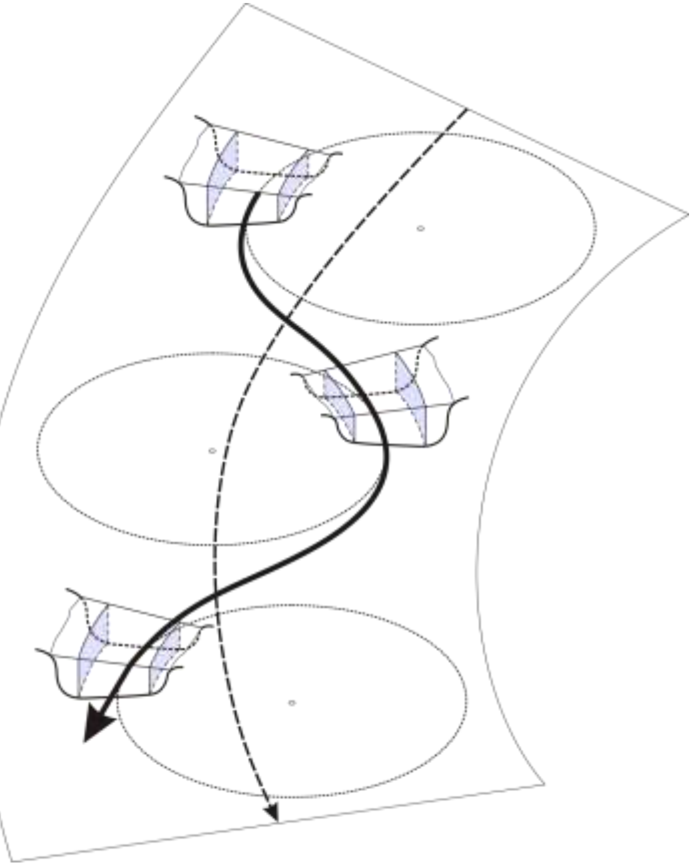
Mississippi River, Baton Rouge



Cumberland River, Nashville

Riverine Hydraulics





Equations of motion:

$$u\frac{\partial u}{\partial s}+v\frac{\partial u}{\partial n}+w\frac{\partial u}{\partial z}+\frac{uv}{r}=gS+\frac{\partial}{\partial z}\left(\varepsilon\frac{\partial u}{\partial z}\right)$$

$$u\frac{\partial v}{\partial s}-\frac{u^2}{r}=gS_r+\frac{\partial}{\partial z}\left(\varepsilon\frac{\partial v}{\partial z}\right)$$

Curvature:

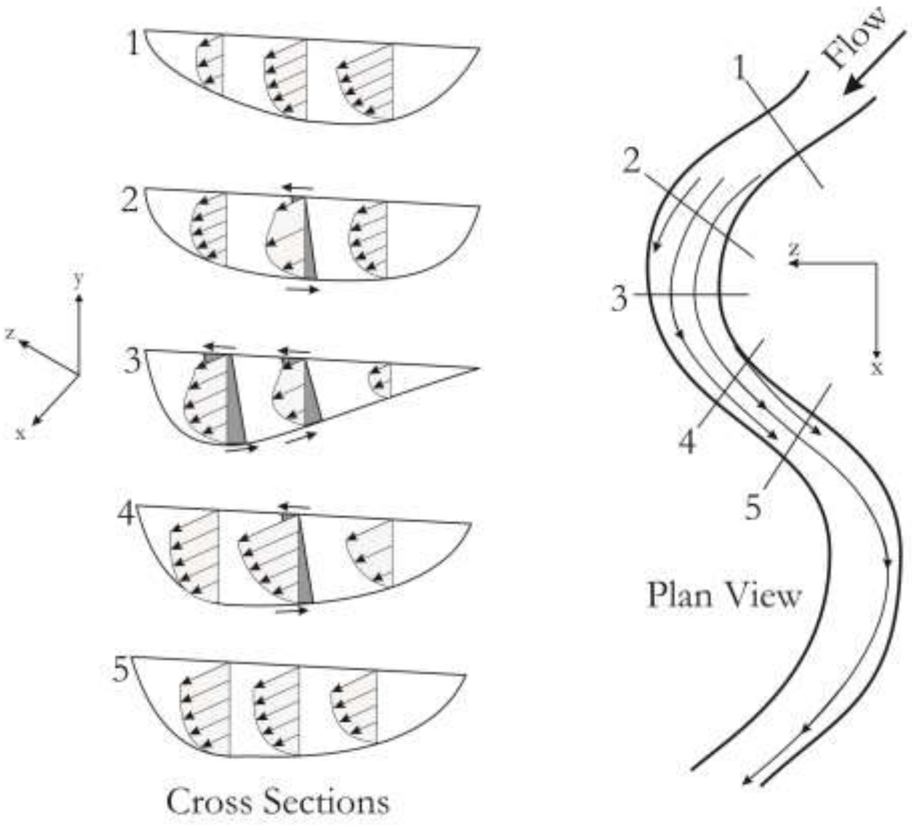
$$\frac{1}{r_c}(t)_i=\frac{|\dot{x}(t)_i\ddot{y}(t)_i-\dot{y}(t)_i\ddot{x}(t)_i|}{(\dot{x}^2(t)_i+\dot{y}^2(t)_i)^{\frac{3}{2}}}$$

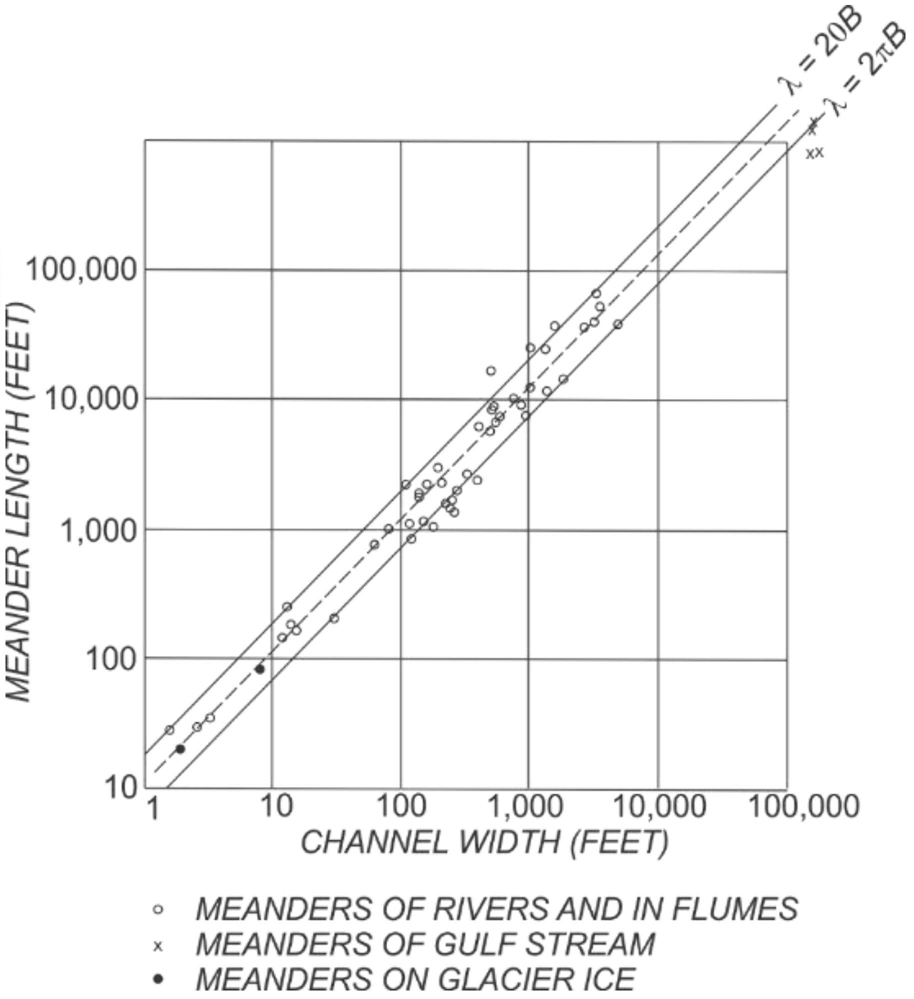
$$\dot{\boldsymbol{B}}(t)=3(1-t)^2(\boldsymbol{P}_1-\boldsymbol{P}_0)+6(1-t)t(\boldsymbol{P}_2-\boldsymbol{P}_1)+3t^2(\boldsymbol{P}_3-\boldsymbol{P}_2)$$

$$\ddot{\boldsymbol{B}}(t)=6(1-t)(\boldsymbol{P}_2-2\boldsymbol{P}_1+\boldsymbol{P}_0)+6t(\boldsymbol{P}_3-2\boldsymbol{P}_2+\boldsymbol{P}_1)$$

Riverine Hydraulics

- Secondary currents drive bed depth
- Streamwise meander length ratio λ/B



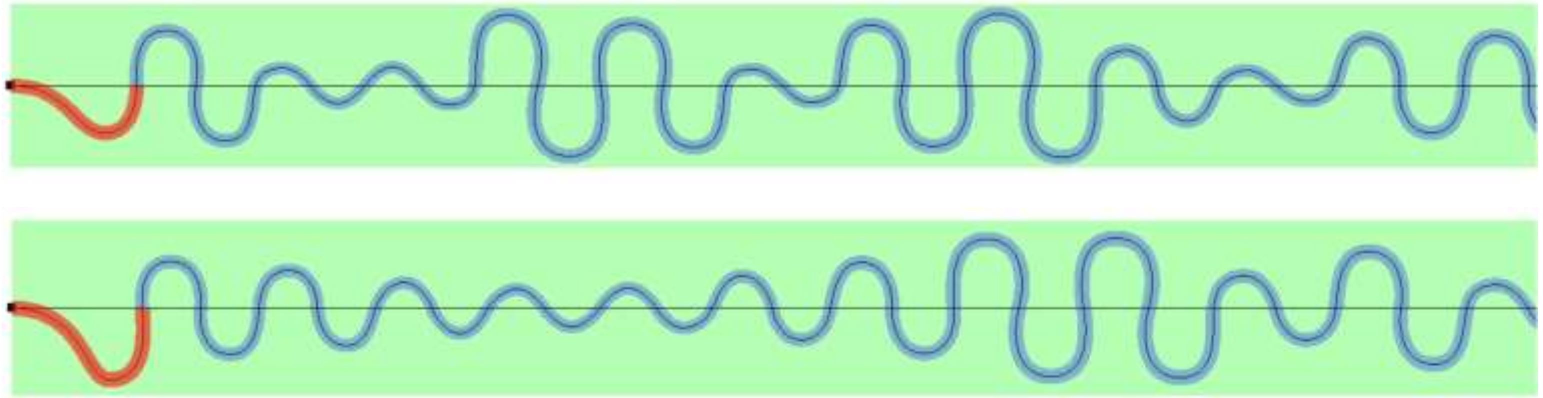


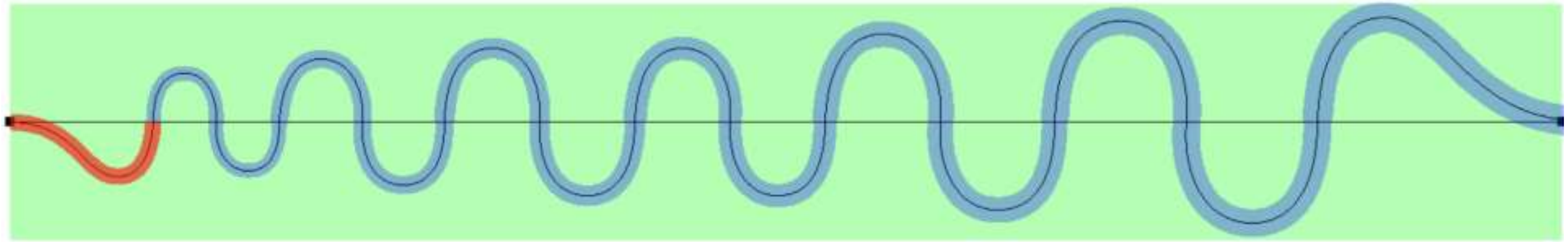
Software Features

- Effects of random variance
- Effects of gradually varied flow

Run 1

Run 2





Stream Restoration Applications

Kentucky

Tennessee

Ohio

Texas

Minnesota

California

Colorado

Status and Schedule

- Breaches have begun
- Setback levee is nearly complete
- Construction will finish 2024

THANK YOU