Riparian Restoration and Flood Management:

An Exercise in Communication

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Recent legislation (SB4) requires multiple-benefit management of floodways.

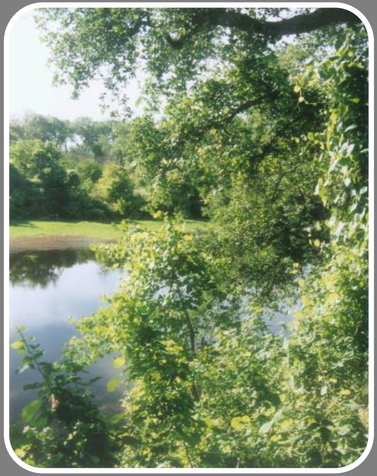
Priority management of Riparian Areas is for flood-conveyance (Public Safety) designed by civil engineers, not biologists.

Communication challenge – How to resolve?

Biologists should describe their concerns to flood-managers by using quantified descriptions for their vegetation objectives.

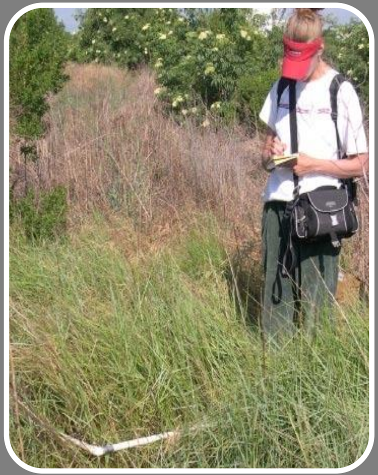
What can we learn from plant adaptations to river hydraulics?

How might we use riparian vegetation as a management tool to improve flood conveyance?



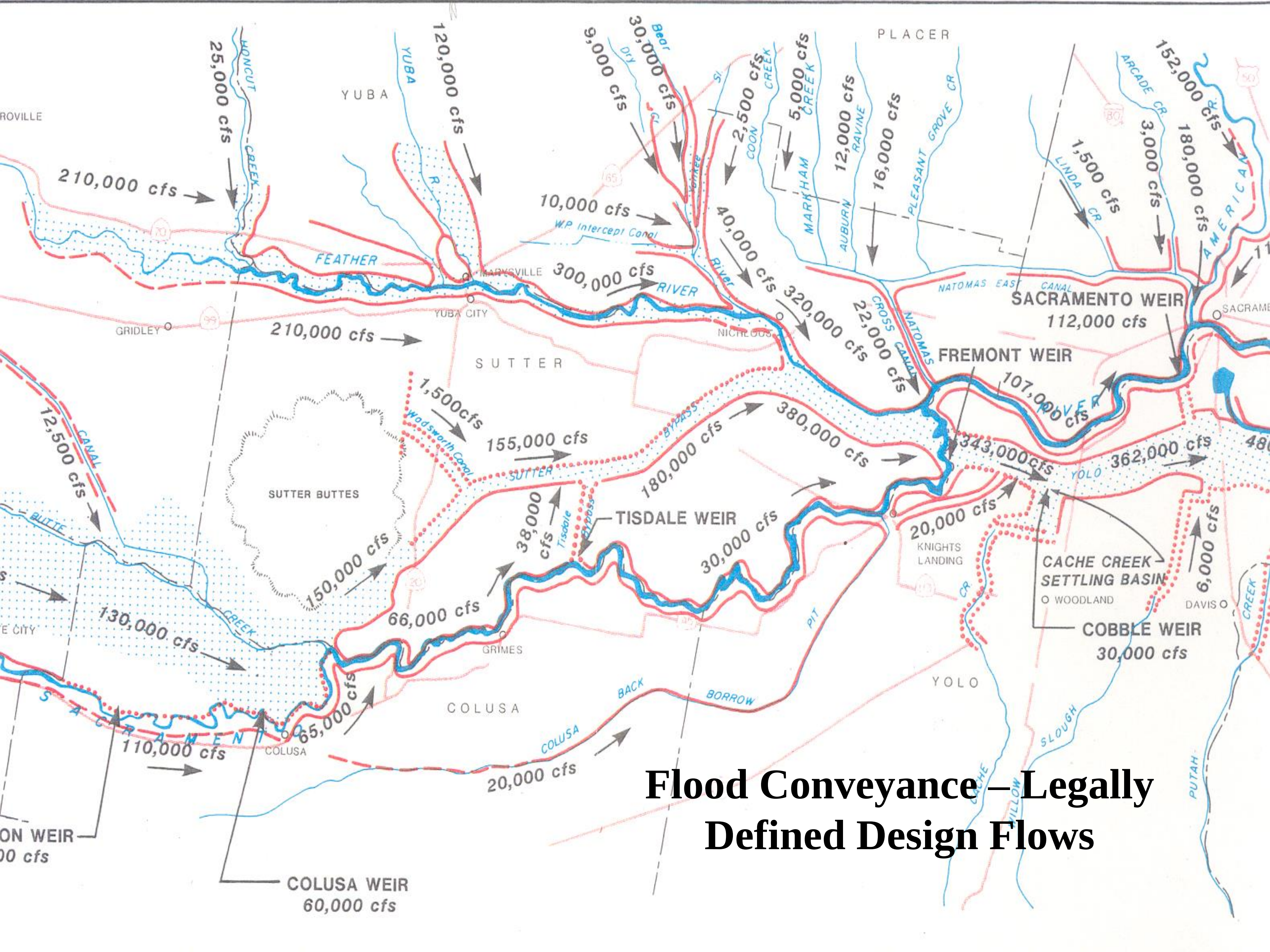
ECOLOGY

- Elucidation of the obvious

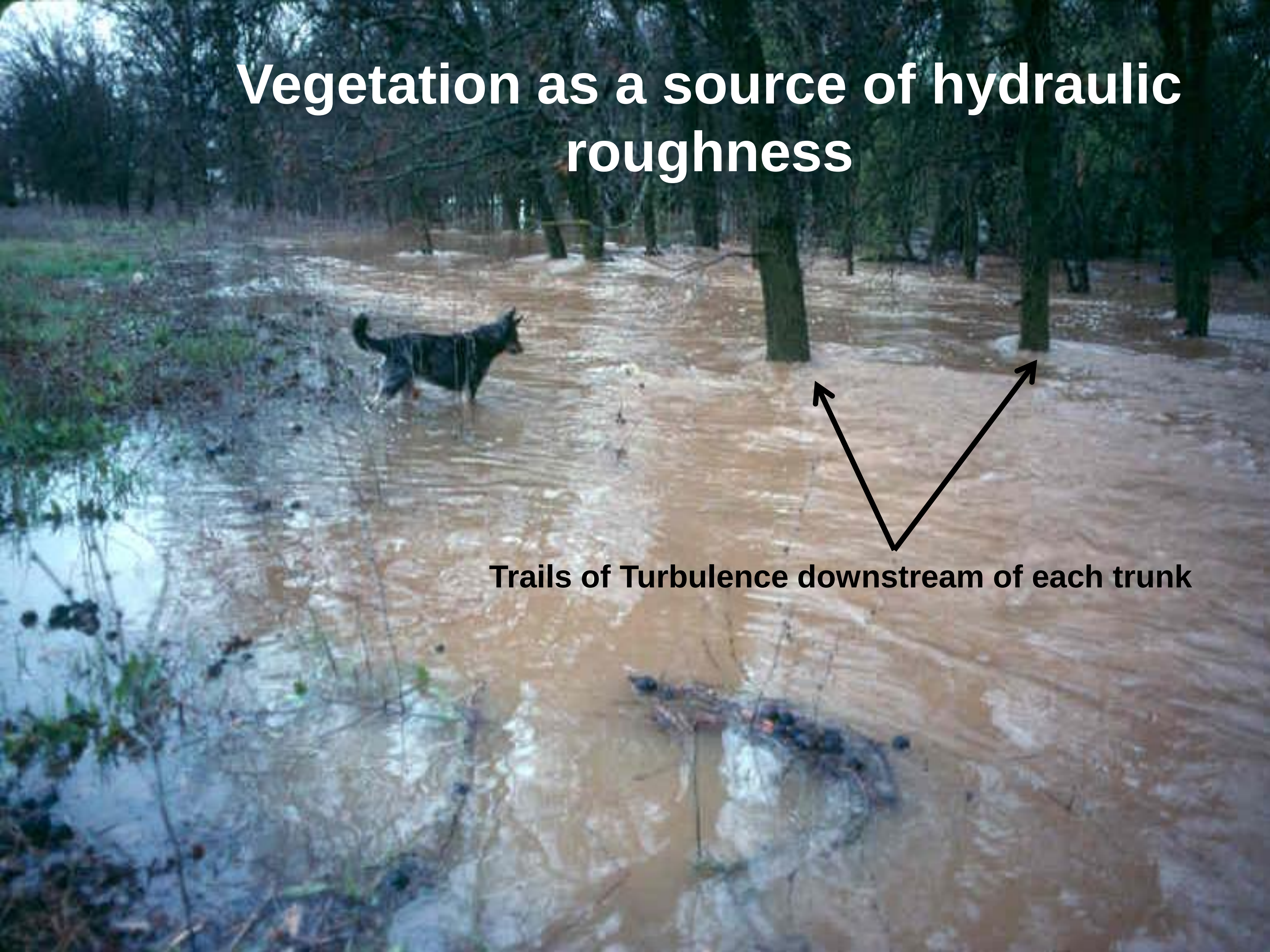


ELUCIDATION

- Quantification of ecological relationships



Flood Conveyance – Legally Defined Design Flows


Vegetation as a source of hydraulic roughness
Trails of Turbulence downstream of each trunk


Velocity = Zero at this point on Floodplain

Arundo

Stony Creek – Glenn County

Ideal plant growing conditions within the Floodway

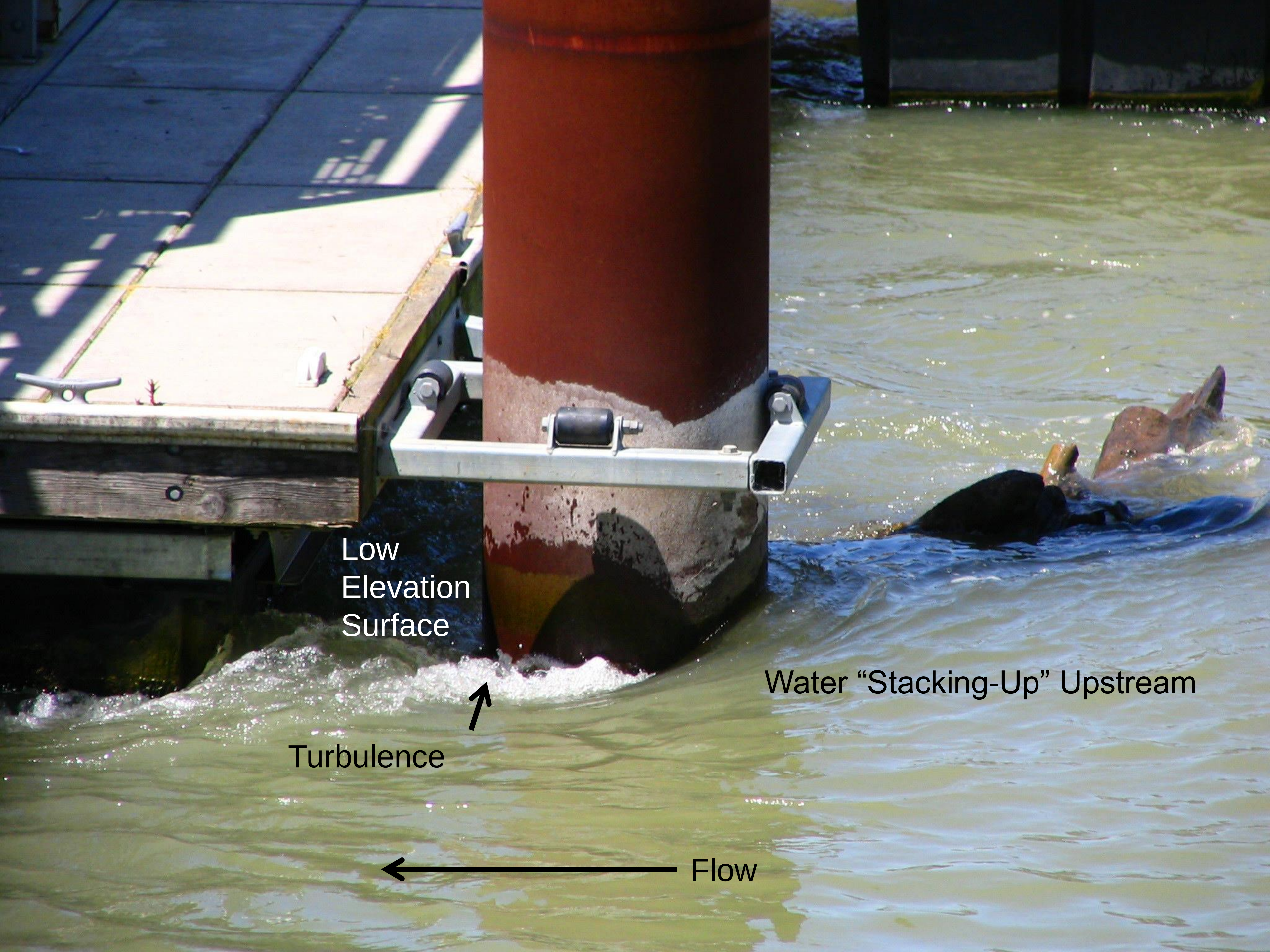
Rich, deep soils.

Soil water table within reach of plant roots

Warm, dry growing season

Disturbance regimes create complex ecological gradients that encourage biological diversity


Trails of Turbulence downstream of each trunk


Low
Elevation
Surface
Water “Stacking-Up” Upstream
Turbulence
Flow

Manning Equation
(estimates flow velocity based upon physical characteristics of the floodway)

$$U = (k_n R^{1/6}/n)\ \sqrt{(RS_f)}$$

Where U is cross-section averaged velocity, R is hydraulic radius, S_f is friction or energy slope, k_n is a unit correction factor, ***n* is Manning's coefficient – an estimate of <u>hydraulic roughness</u>, or <u>resistance to flow</u> in the floodway.**

1-D models average roughness of vegetation across each cross-section - Trees and shrubs are lumped (averaged) together

Therefore: all vegetation becomes thought of as “the same dense roughness”

With 2-D models we can apportion the vegetation with different structures and roughness values into different locations in the cross-section.

McKay, S.K. and J.C. Fischenich. March 2011. Robust prediction of Hydraulic Roughness. ERDC/CHL CHETN-VII-11.

O’Connor Lakes story

O’Connor Lakes story shows how vegetation apportioned by different roughness values across the floodplain can be used in a 2-D hydraulic model.

Objective of modeling was to generate a **FLOOD NEUTRAL** planting design


O'Connor Lakes
Project Area
Star Bend
228 acres
Feather River
Funded by:
Wildlife Conservation Board

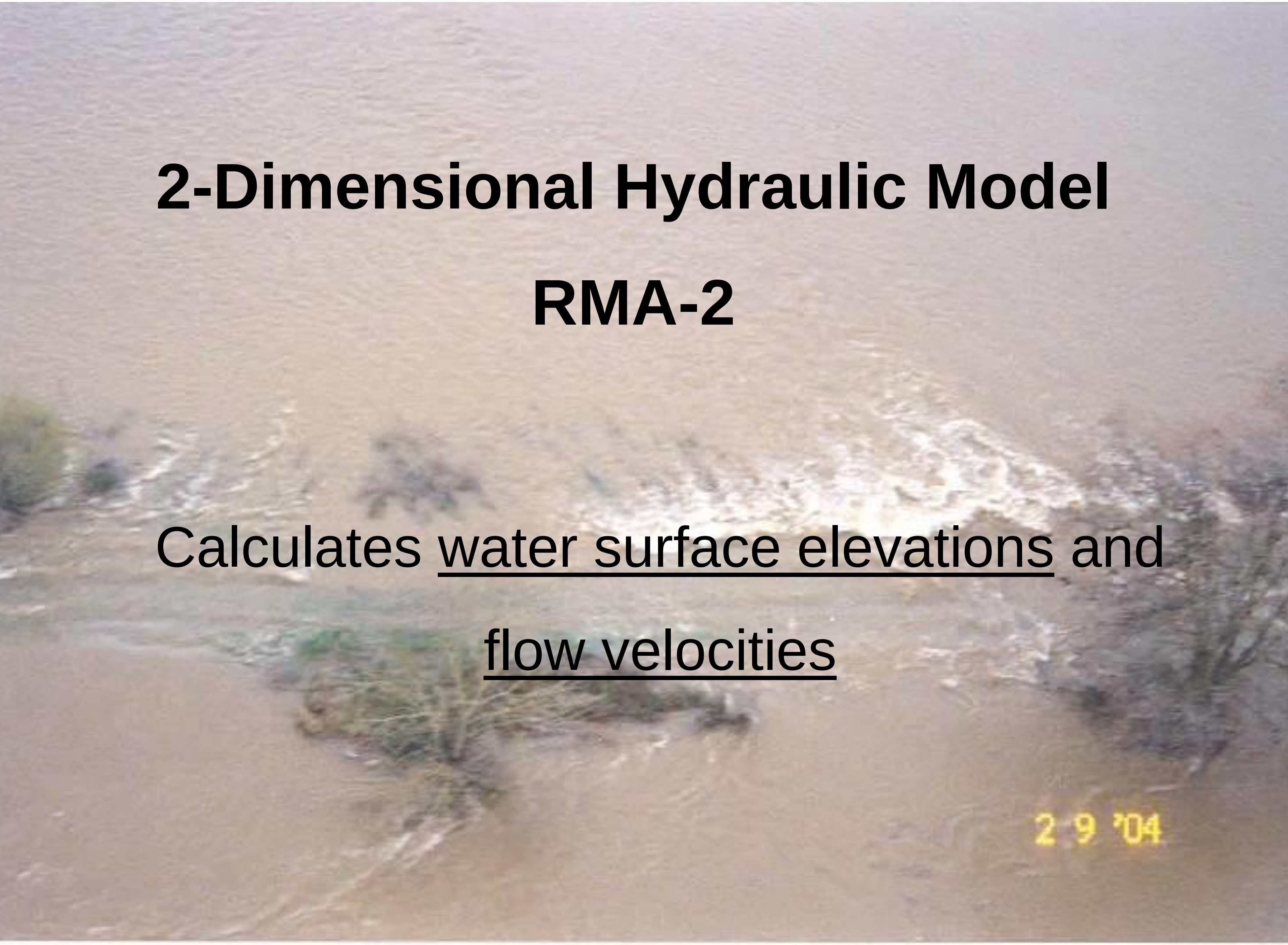

1969
No Forest Present - due to active removal


1987

2-Dimensional Hydraulic Model

RMA-2

Calculates <u>water surface elevations</u> and <u>flow velocities</u>

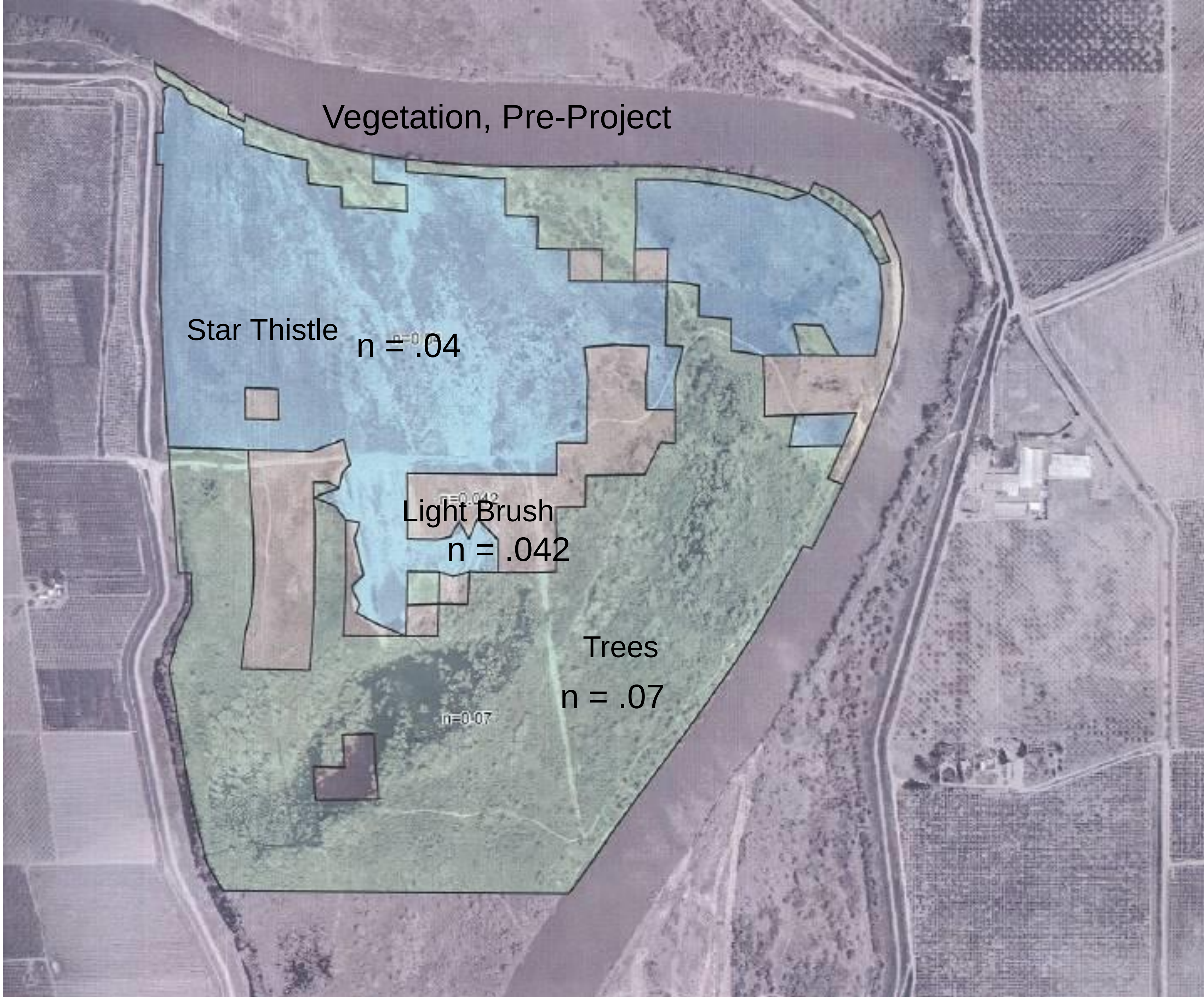


Model Calibration Study

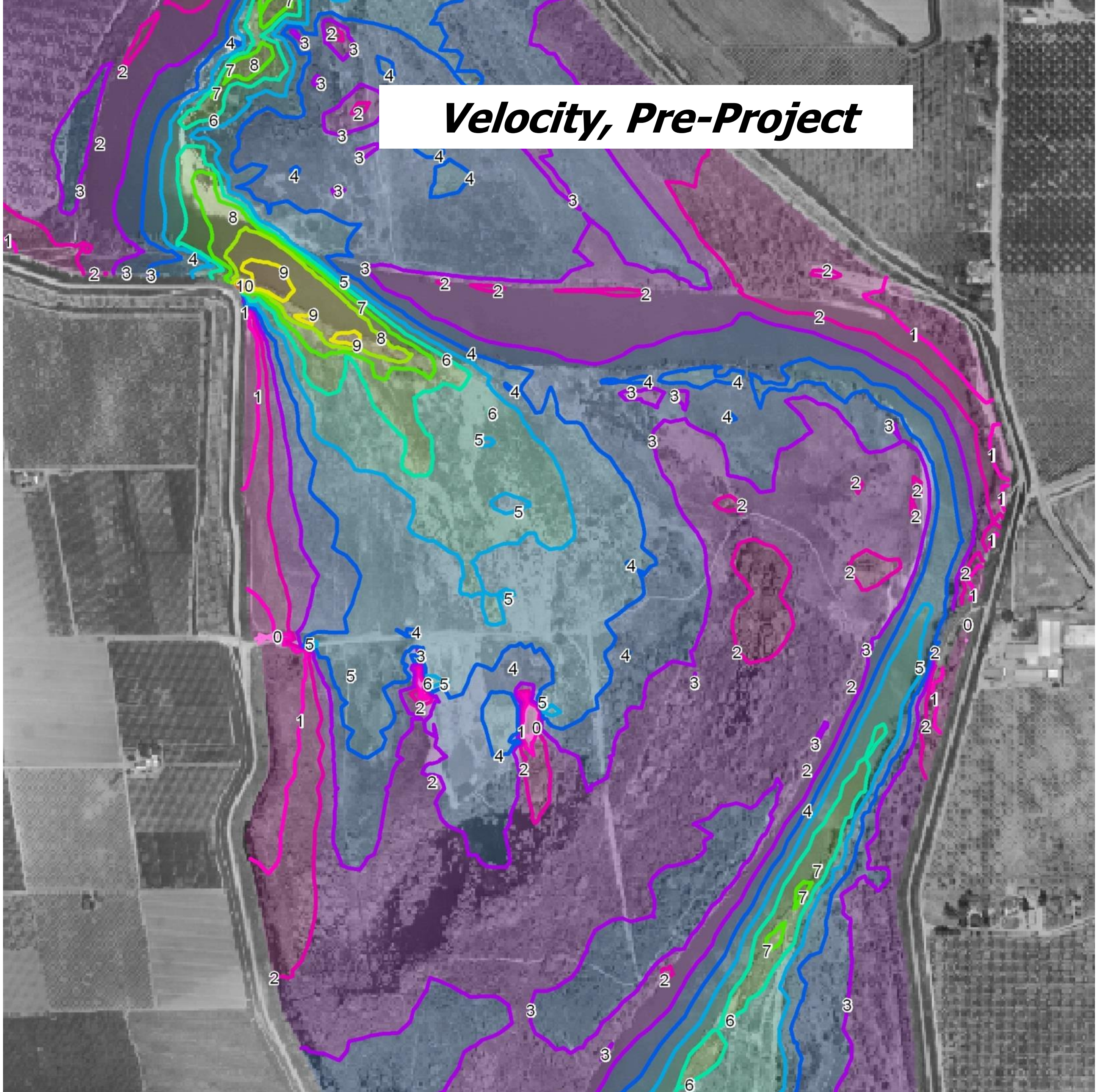
- January 1997 flood event
- 311,000 cfs at RM 23 (upstream boundary)
- Water surface elevation of 53.1 feet at RM 13 (downstream boundary) based upon high water marks staked at the peak of the flood.
- Depth of water over project area was about 14 feet
- Calibration of model involved adjusting Manning's roughness coefficient until the computed water surface elevation closely matched the high water marks.
- <u>Calibrated Manning's roughness coefficients:</u>

    0.03 to 0.08 in the overbanks

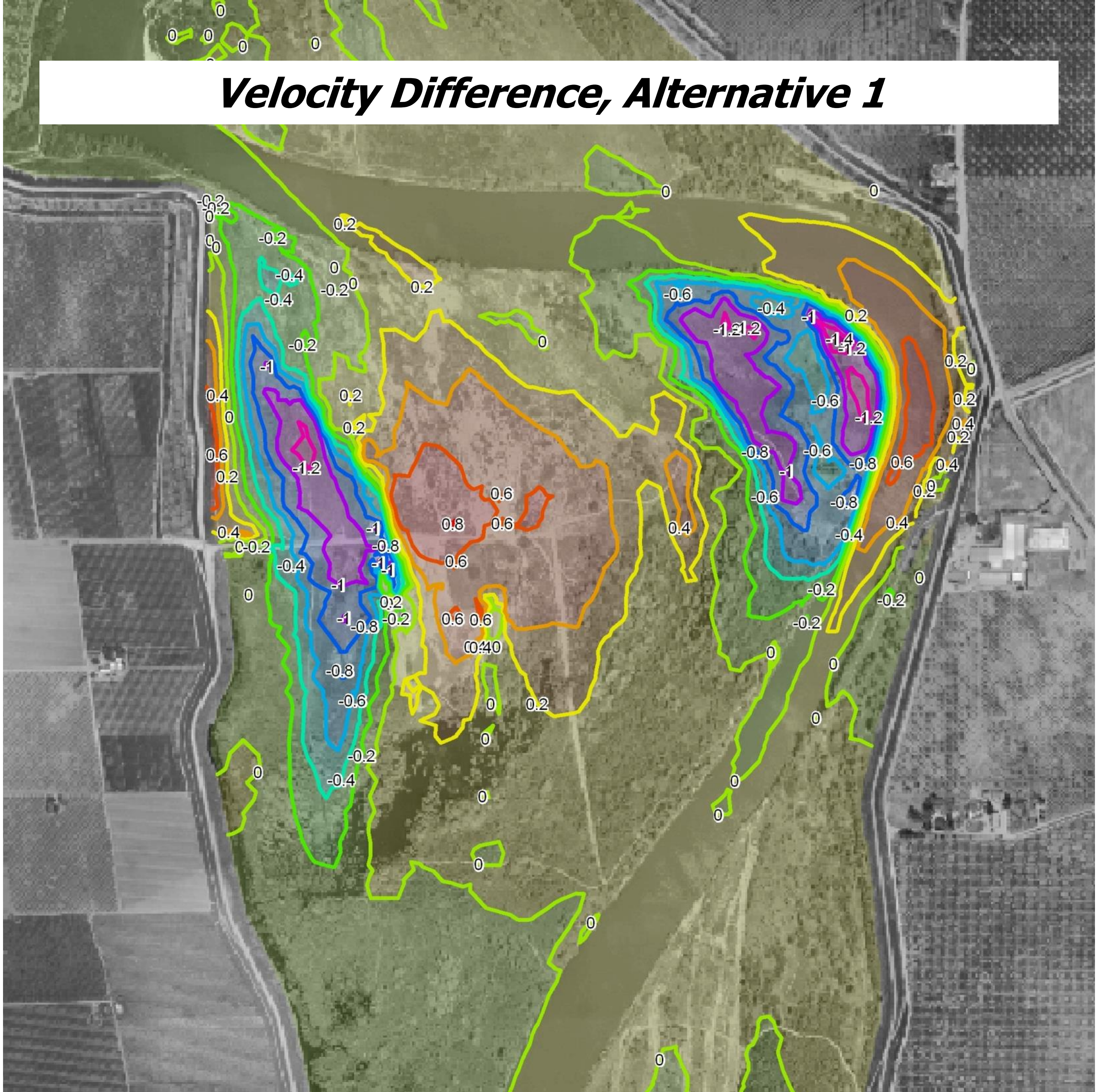
    0.025 in the channel


Vegetation, Pre-Project
Star Thistle
n = .04
Light Brush
n = .042
n=0.042
Trees
n = .07
n=0.07

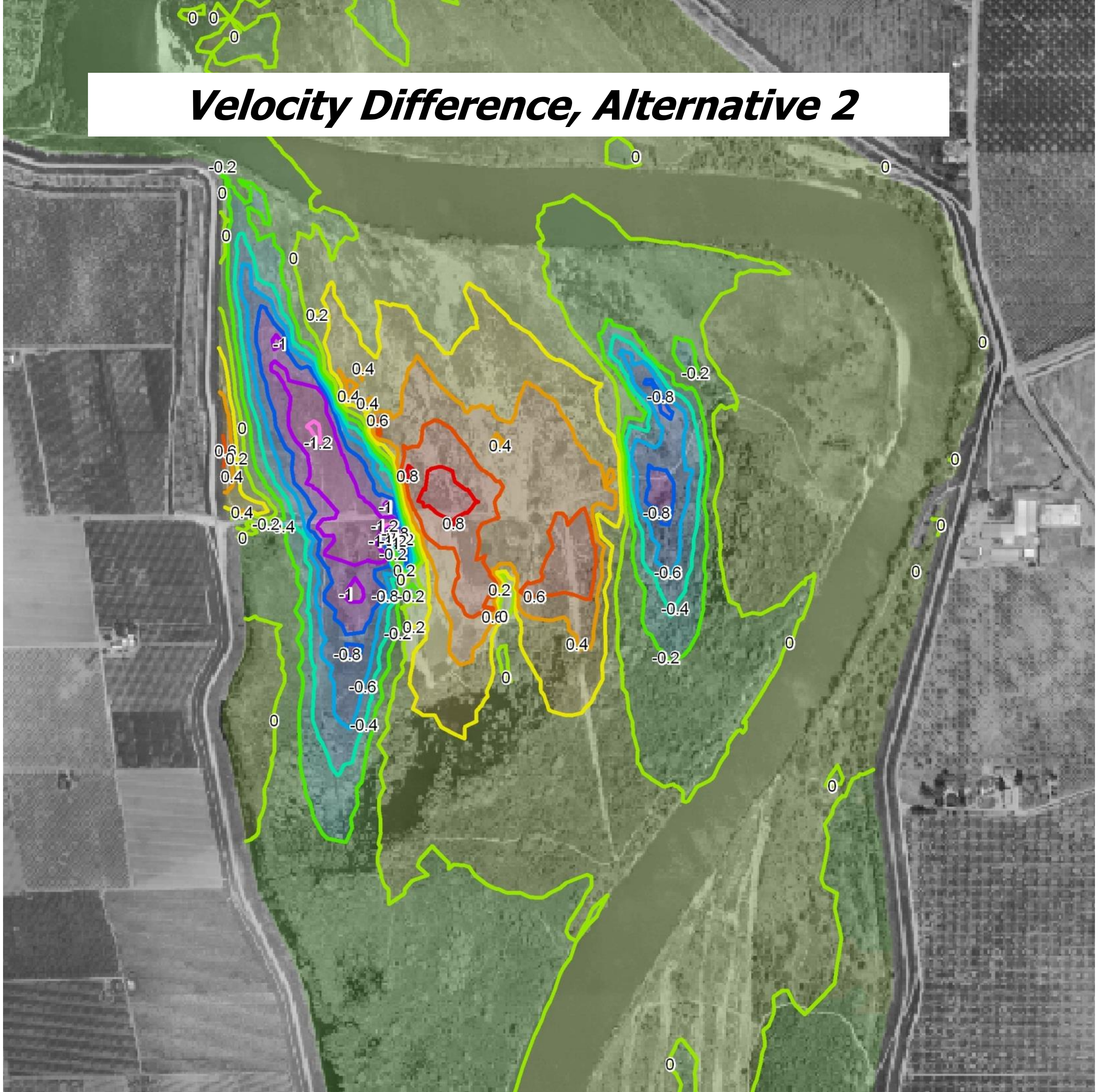
Velocity, Pre-Project



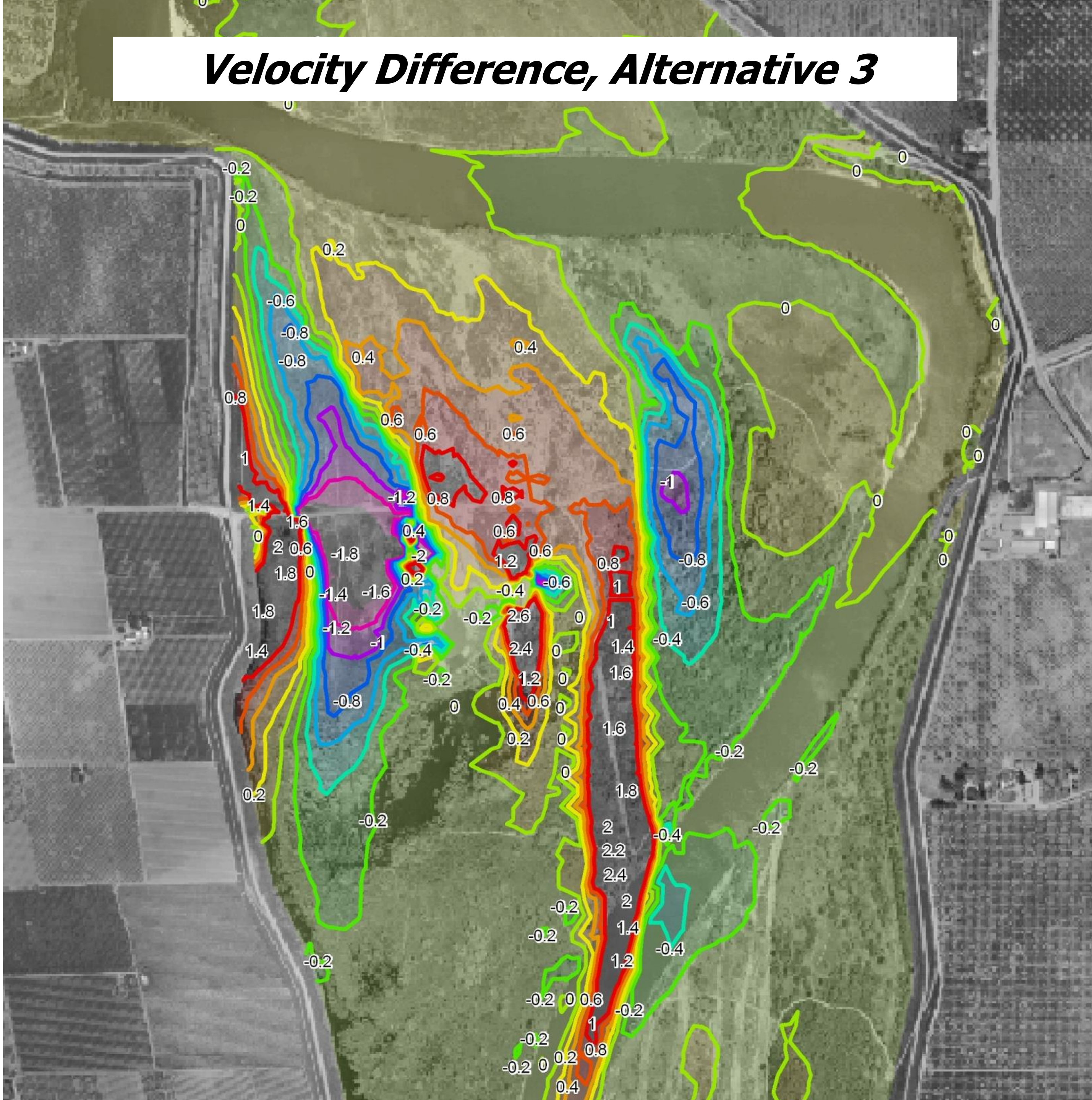
Velocity Difference, Alternative 1



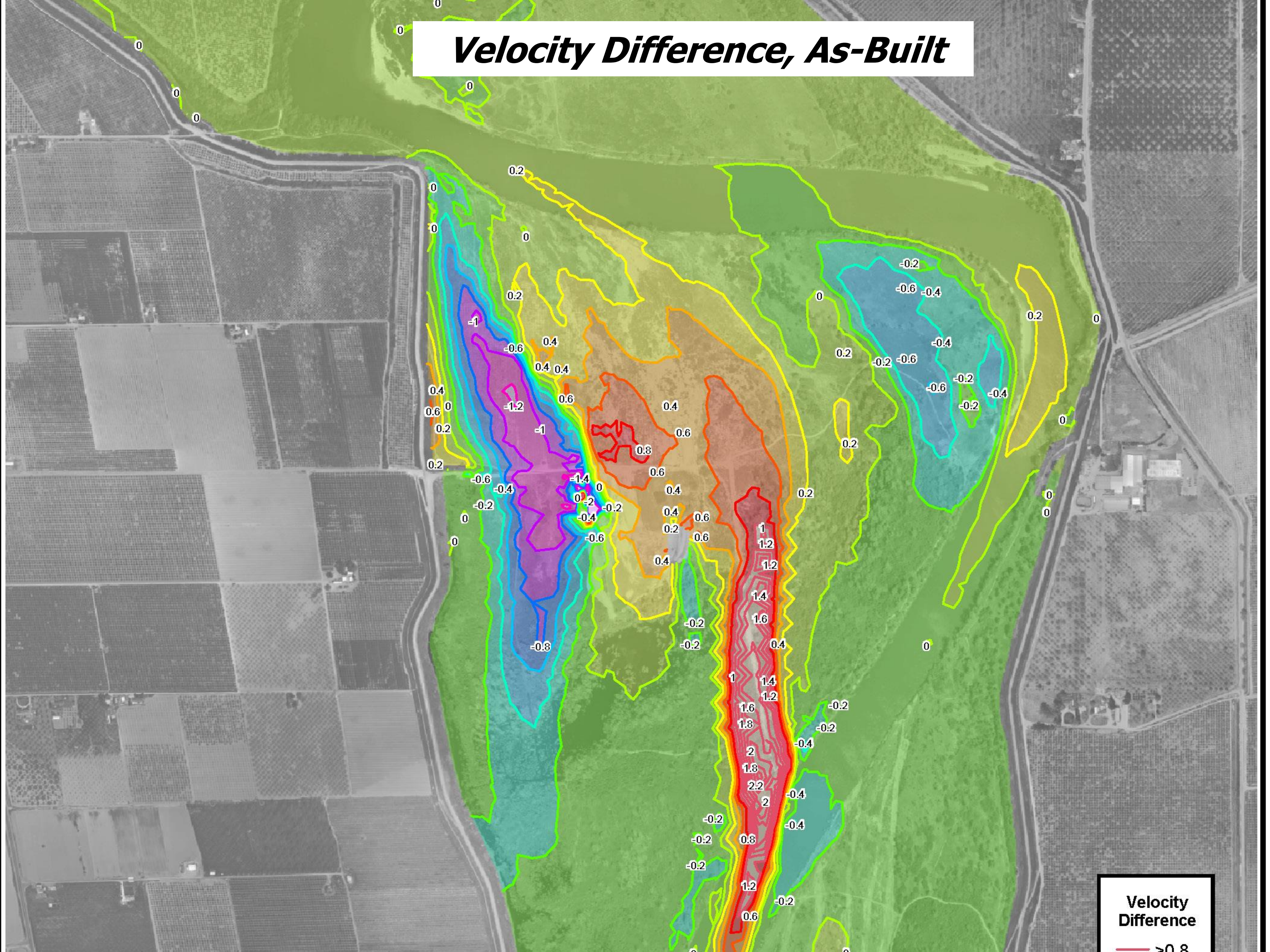
Velocity Difference, Alternative 2



Velocity Difference, Alternative 3



Velocity Difference, As-Built




Flow: about 65,000 cfs
4 January 2006


9 February 2006

Corridor Flow Depth

Sand Deposition

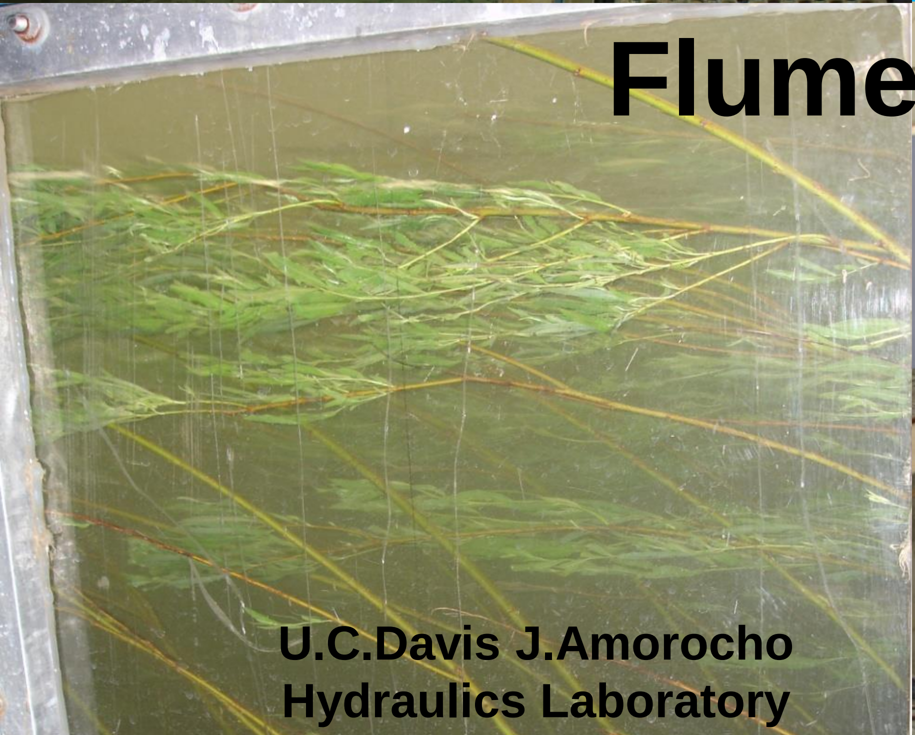
Conclusions

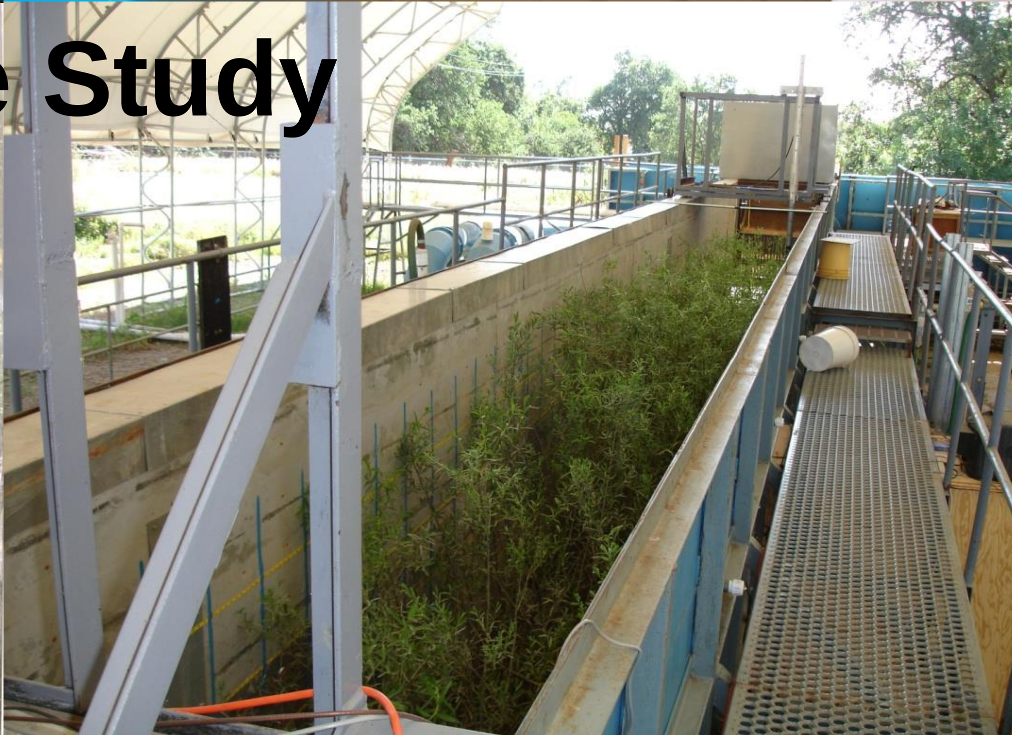
Riparian revegetation can be designed to provide quality wildlife habitat AND facilitate flow conveyance and sediment transport.

Revegetation can be used to direct flows away from flood-control structures.

Restoration can result in lower floodway maintenance costs.

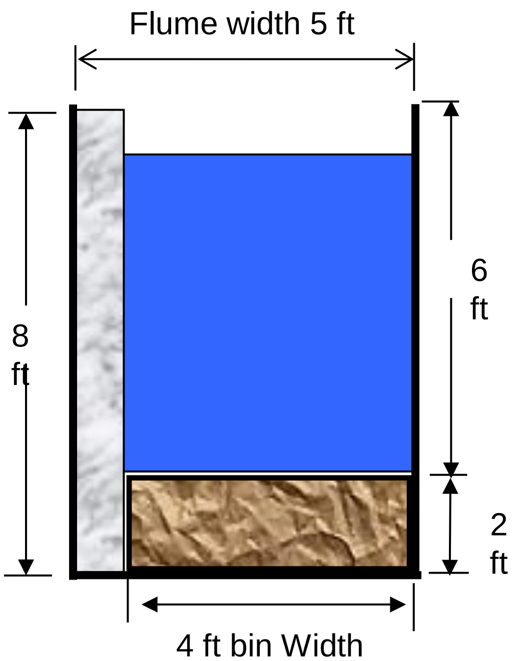
Flume Study

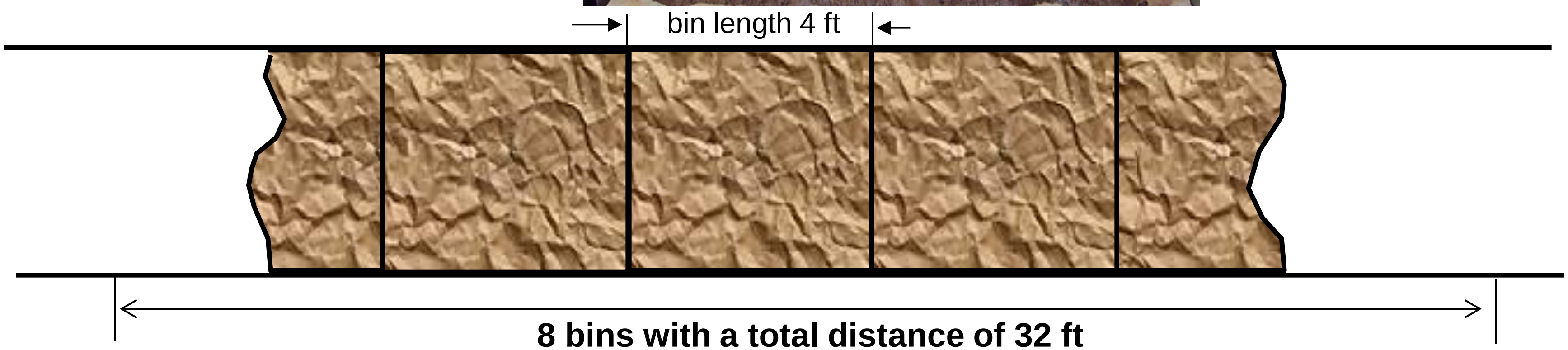




U.C.Davis J.Amorocho
Hydraulics Laboratory

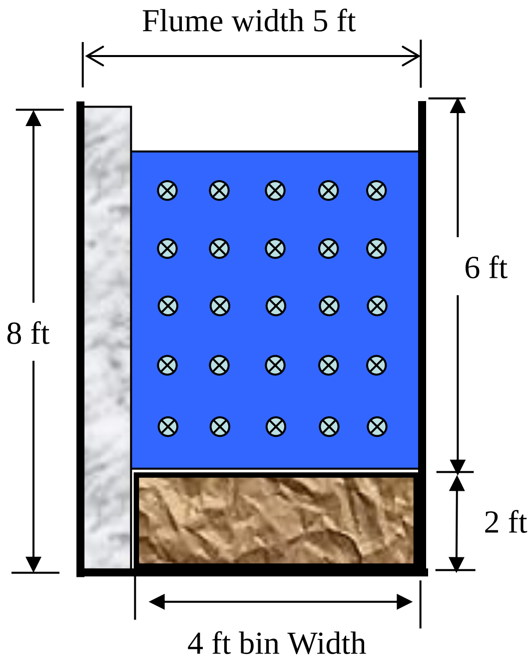
Sandbar Willow Test Configuration



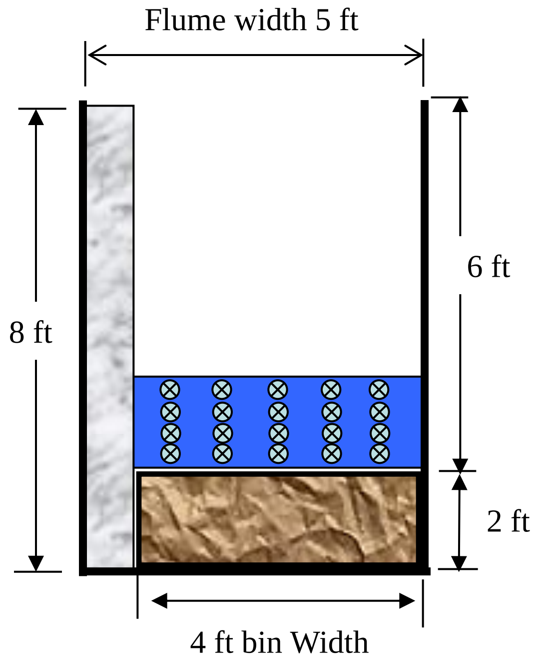


STREAMBED BARE SOIL SAMPLE PREPARATION

Velocity measurement locations in a cross-section



Water depth
higher than 2 ft



Water depth
lower than 2 ft


Sandbar Willow Stem Diameter

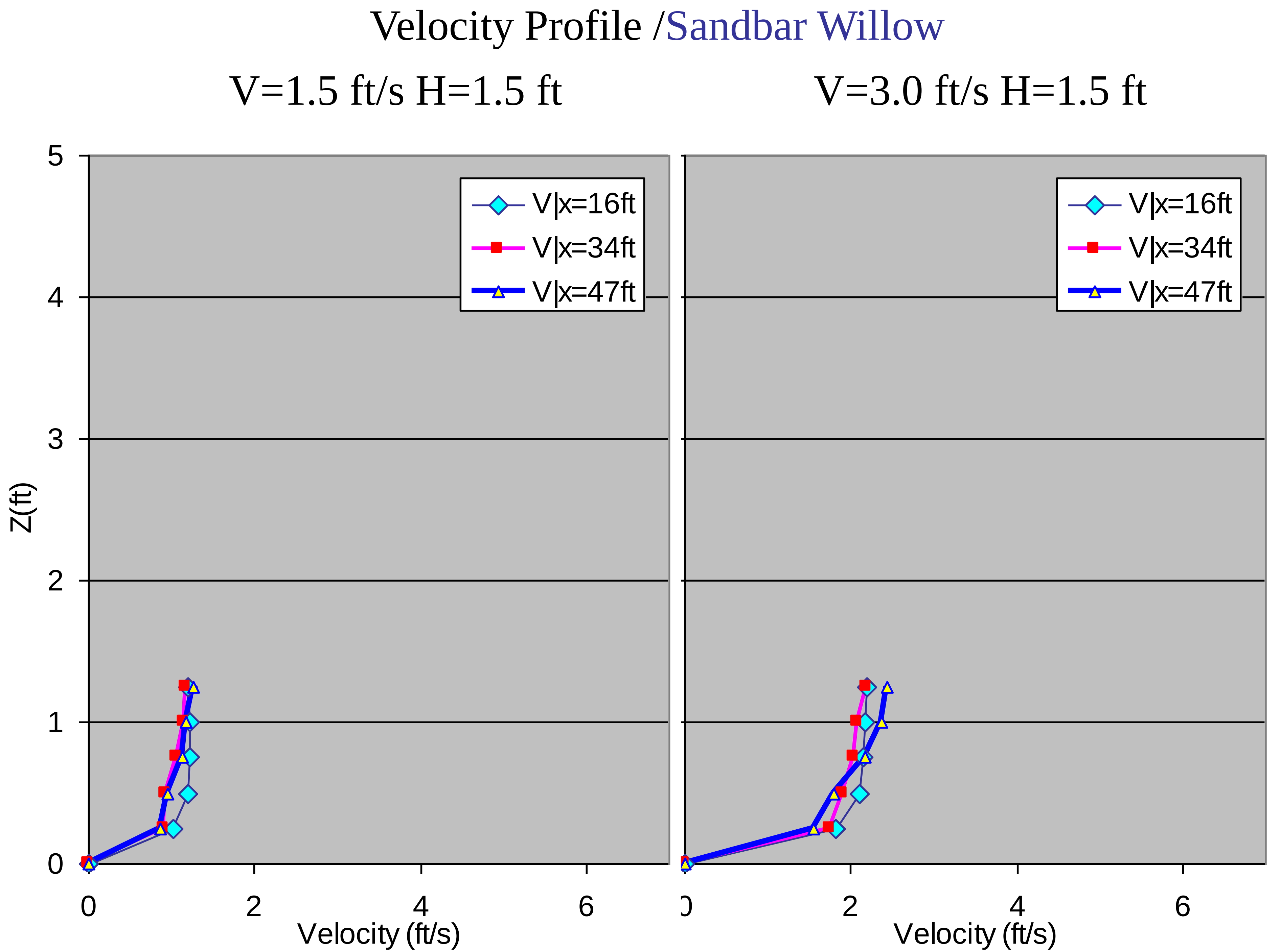

Sandbar Willow Stem Diameter

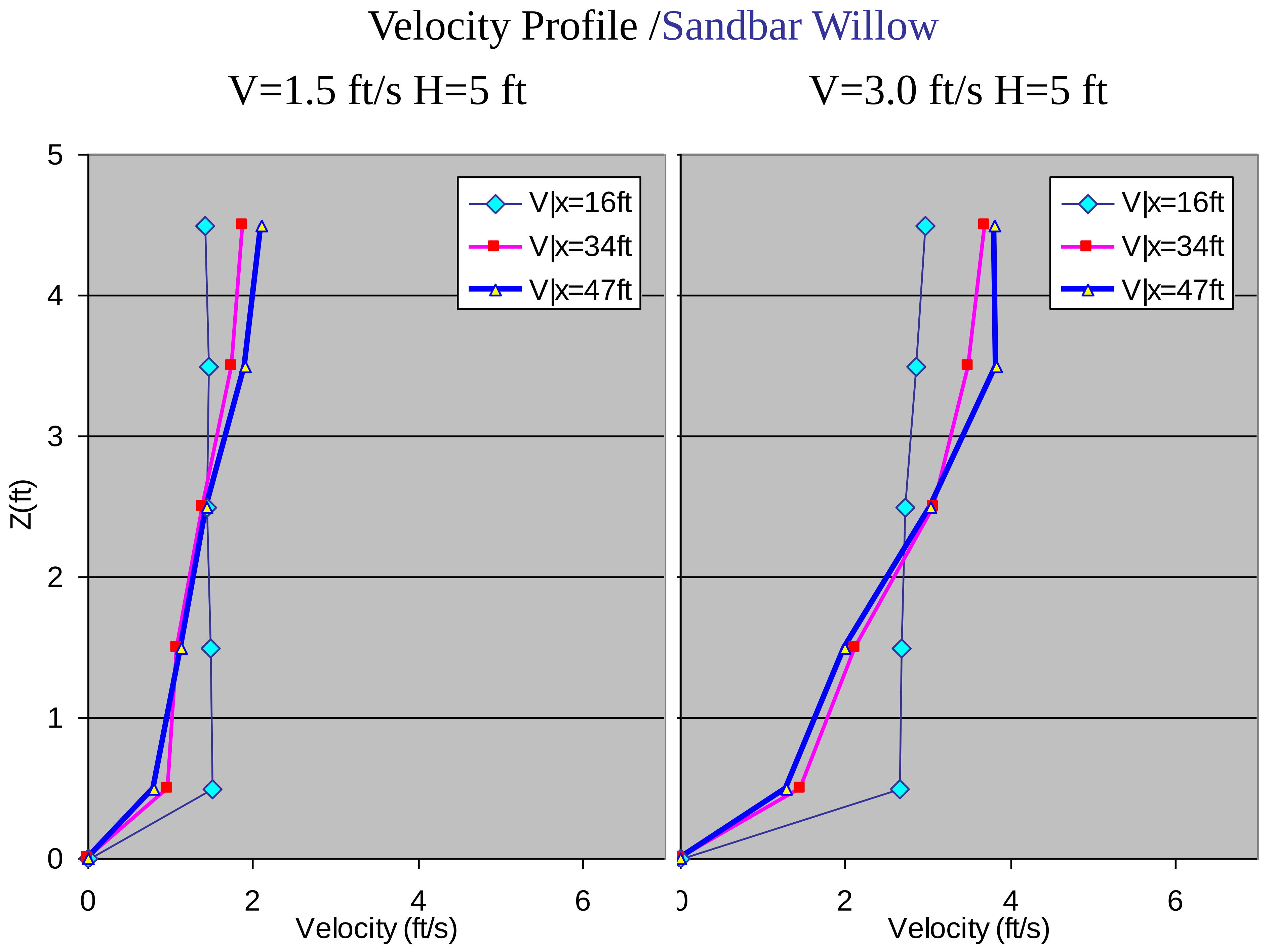
California Blackberry

California Rose

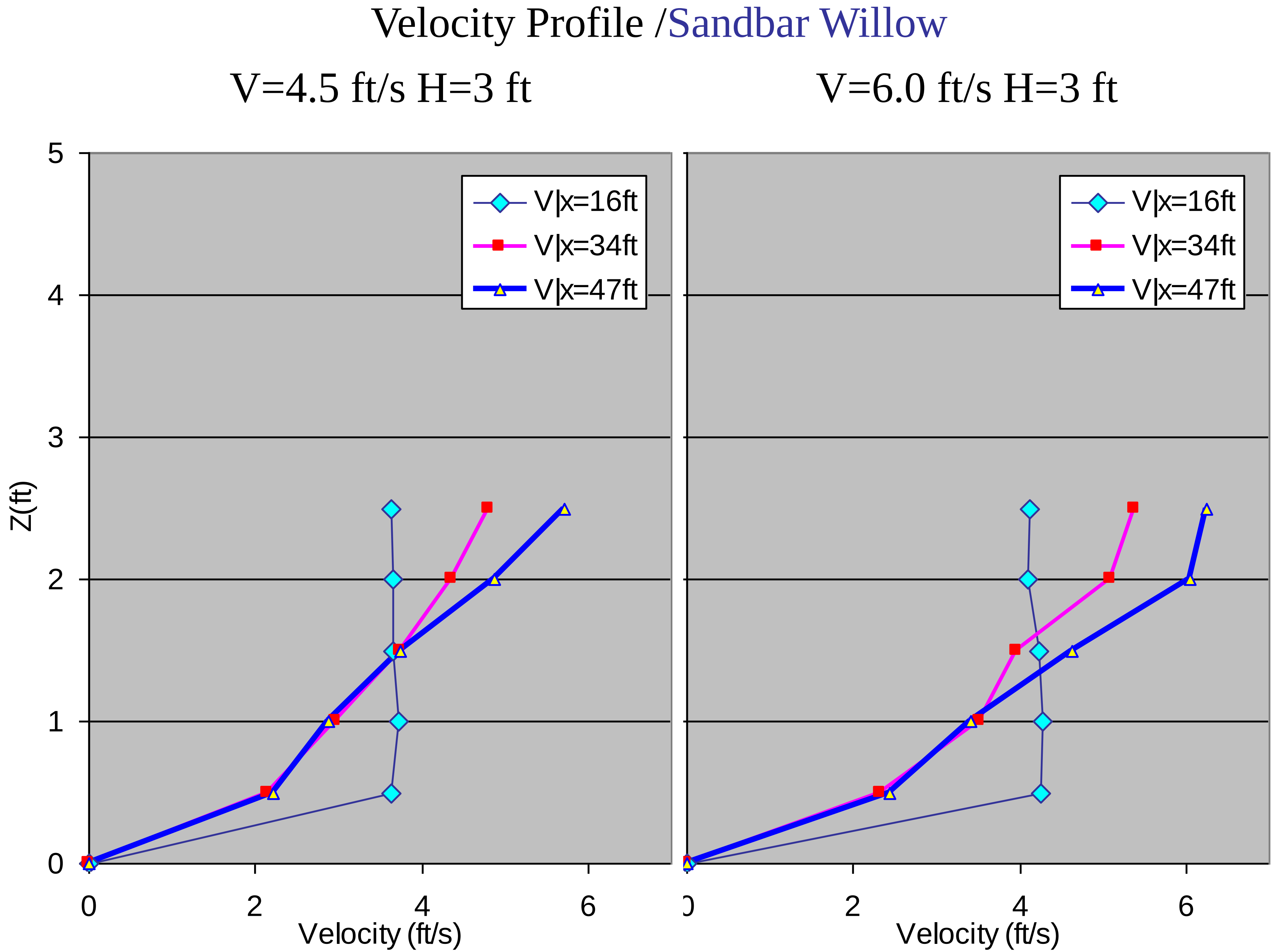

02 23 2007


07/05/02 08:30:57
07/05/09 15:57:53
11

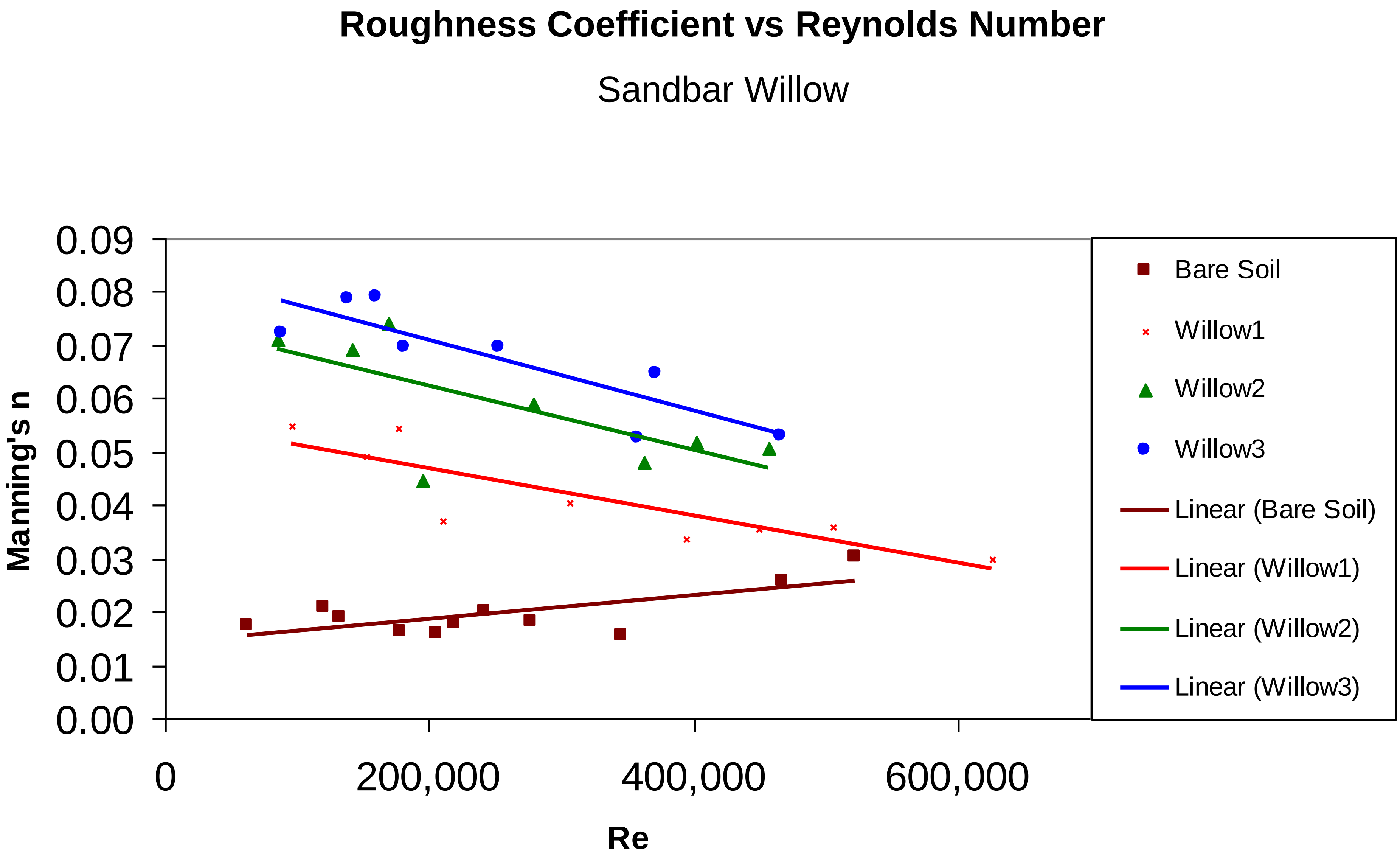

Velocity Profile /Sandbar Willow
V=1.5 ft/s H=1.5 ft
V=3.0 ft/s H=1.5 ft
V|x=16ft
V|x=34ft
V|x=47ft
Z(ft)
Velocity (ft/s)
0
1
2
3
4
5
0
2
4
6



Velocity Profile /Sandbar Willow
V=1.5 ft/s H=5 ft
V=3.0 ft/s H=5 ft
V|x=16ft
V|x=34ft
V|x=47ft
Z(ft)
Velocity (ft/s)
Velocity (ft/s)
0
1
2
3
4
5
0
2
4
6

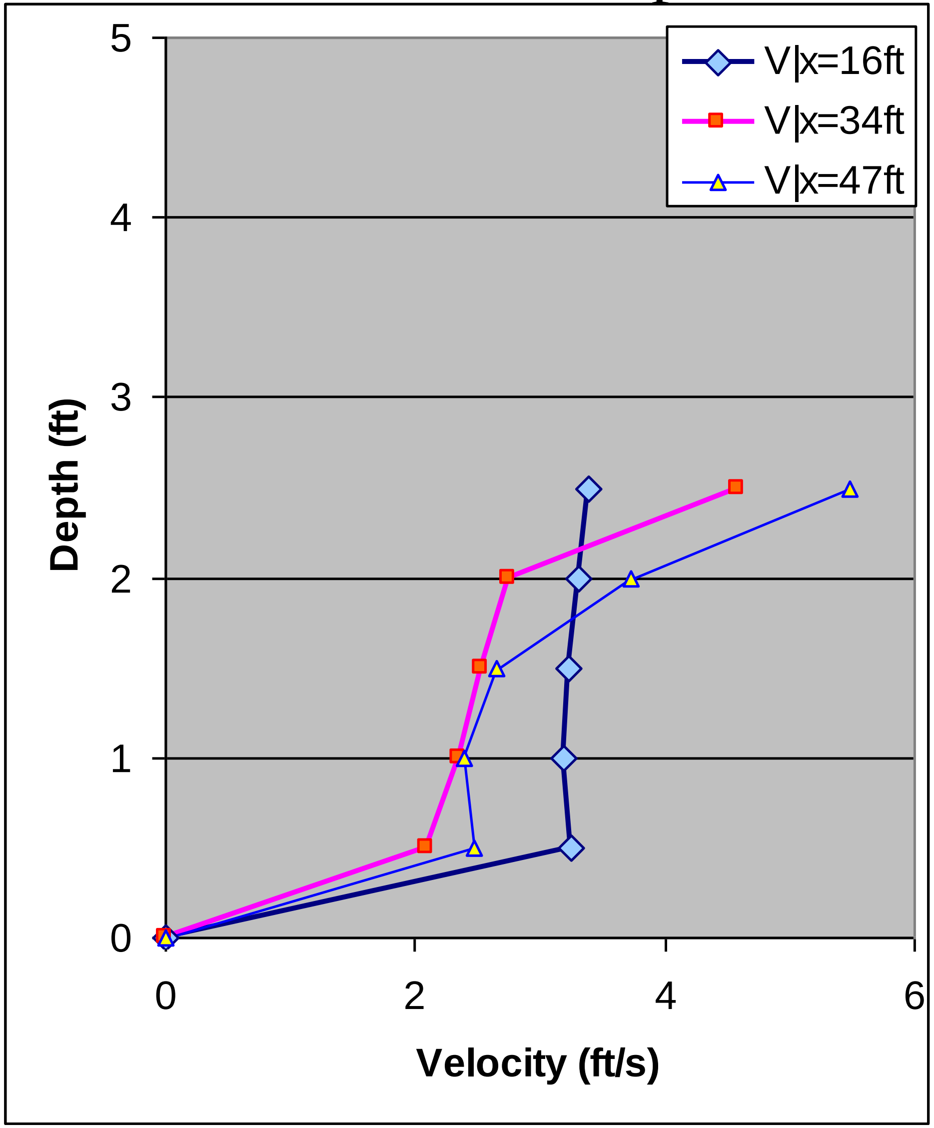


Velocity Profile /Sandbar Willow
V=4.5 ft/s H=3 ft
V=6.0 ft/s H=3 ft
V|x=16ft
V|x=34ft
V|x=47ft
Z(ft)
0
1
2
3
4
5
0
2
4
6
Velocity (ft/s)
Velocity (ft/s)

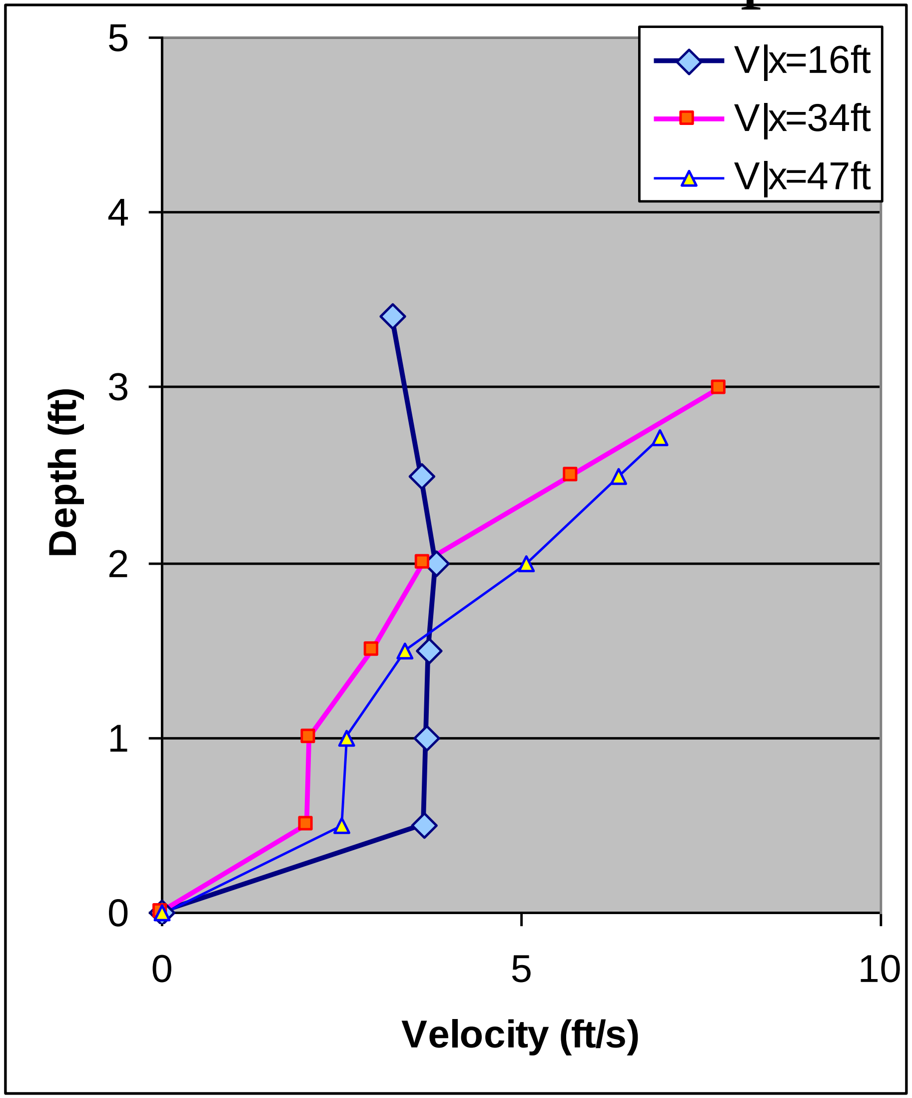

Roughness Coefficient vs Reynolds Number
Sandbar Willow
Manning's n
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
200,000
400,000
600,000
Re
Bare Soil
Willow1
Willow2
Willow3
Linear (Bare Soil)
Linear (Willow1)
Linear (Willow2)
Linear (Willow3)

Mulefat Response

4.5 ft/sec 3ft depth

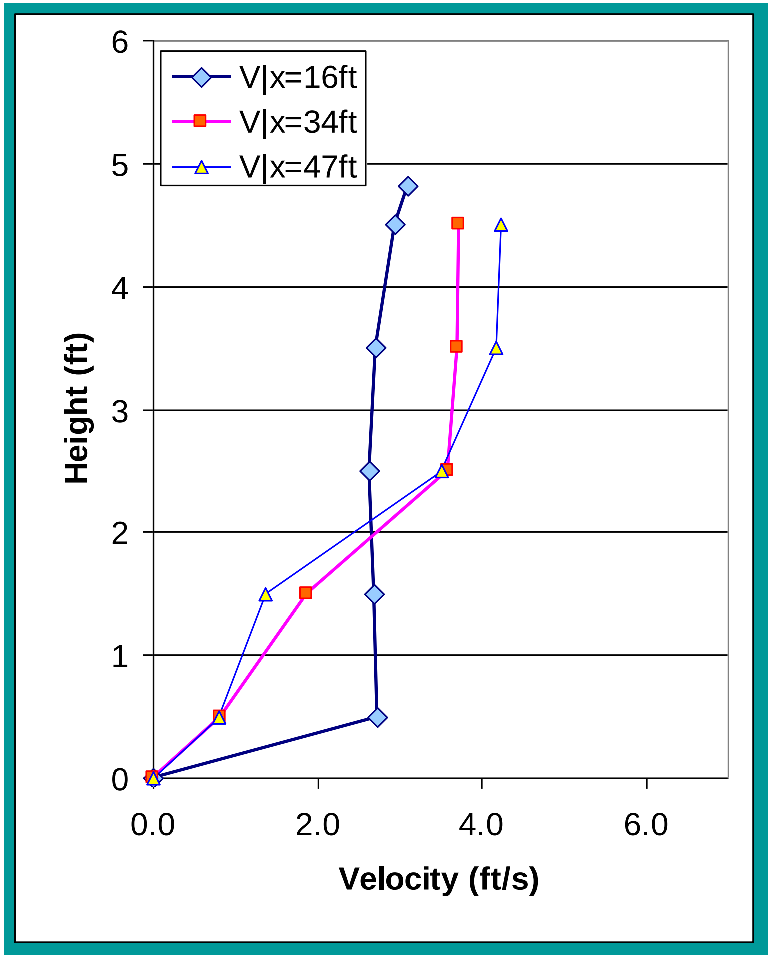


6 ft/sec 3 ft depth

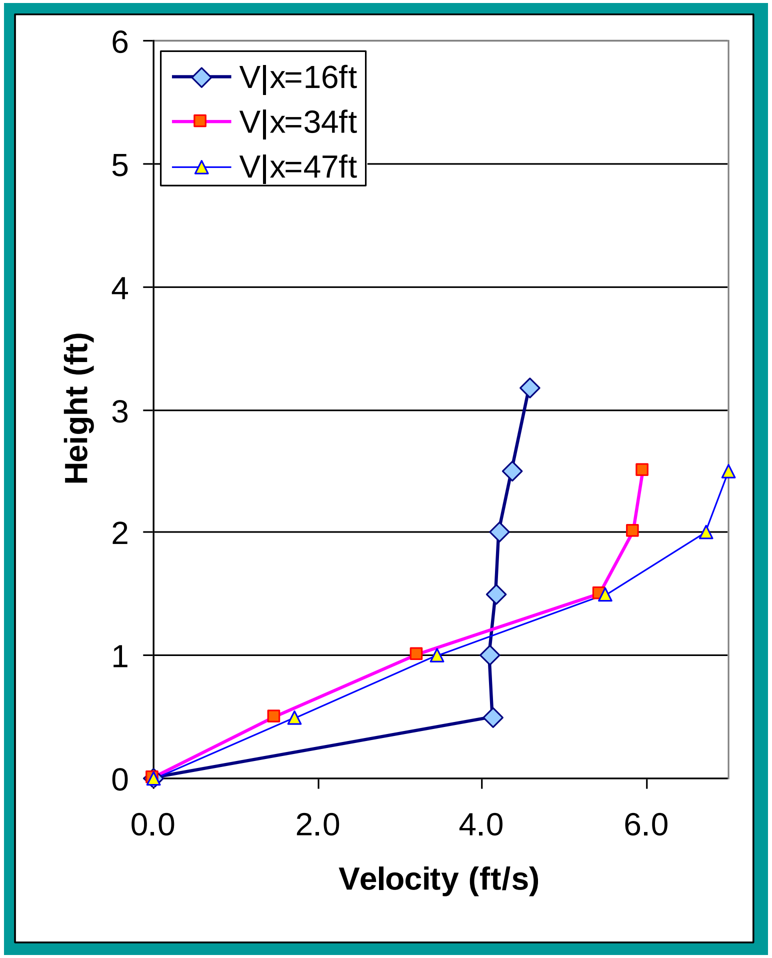


California Blackberry

Vt=3ft/s and Ht=5ft

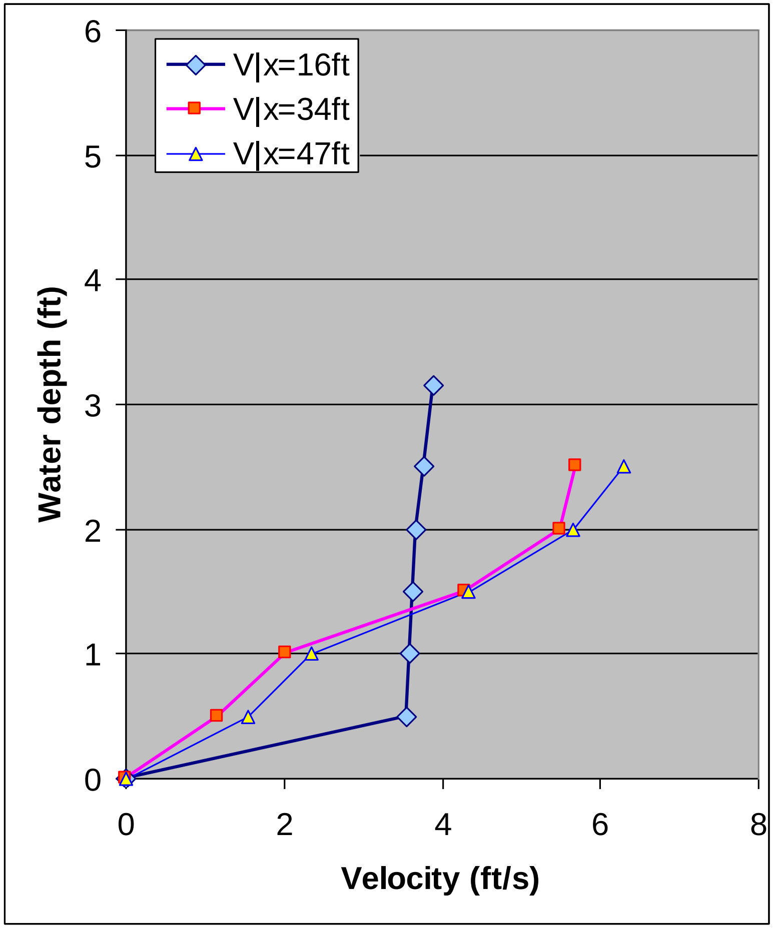


Vt=6ft/s and Ht=3.4ft

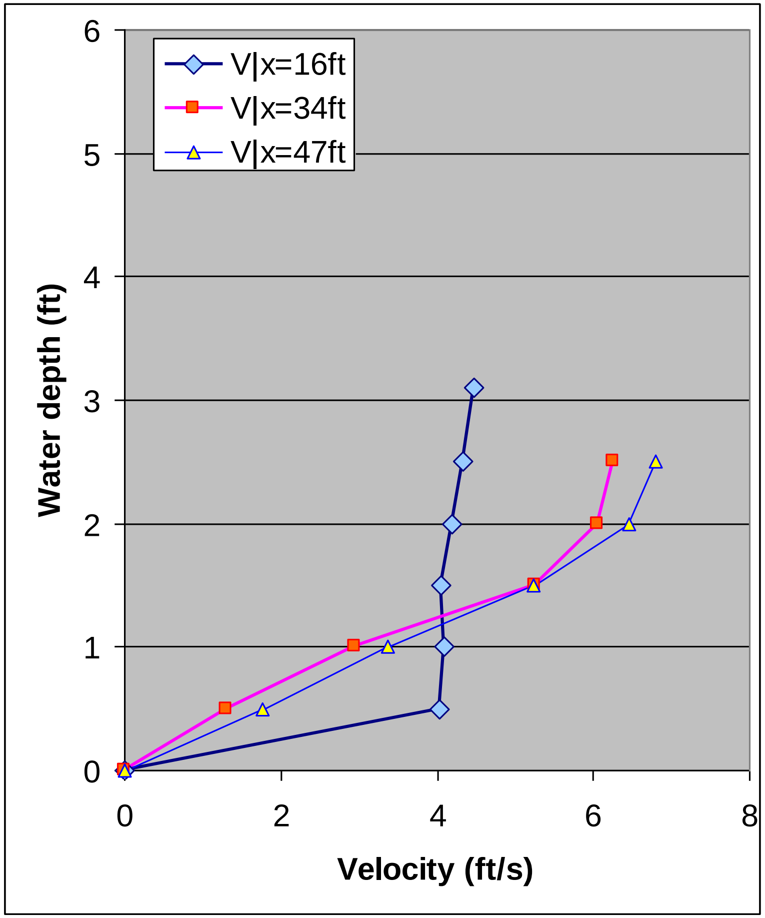


Wildrose velocity profiles

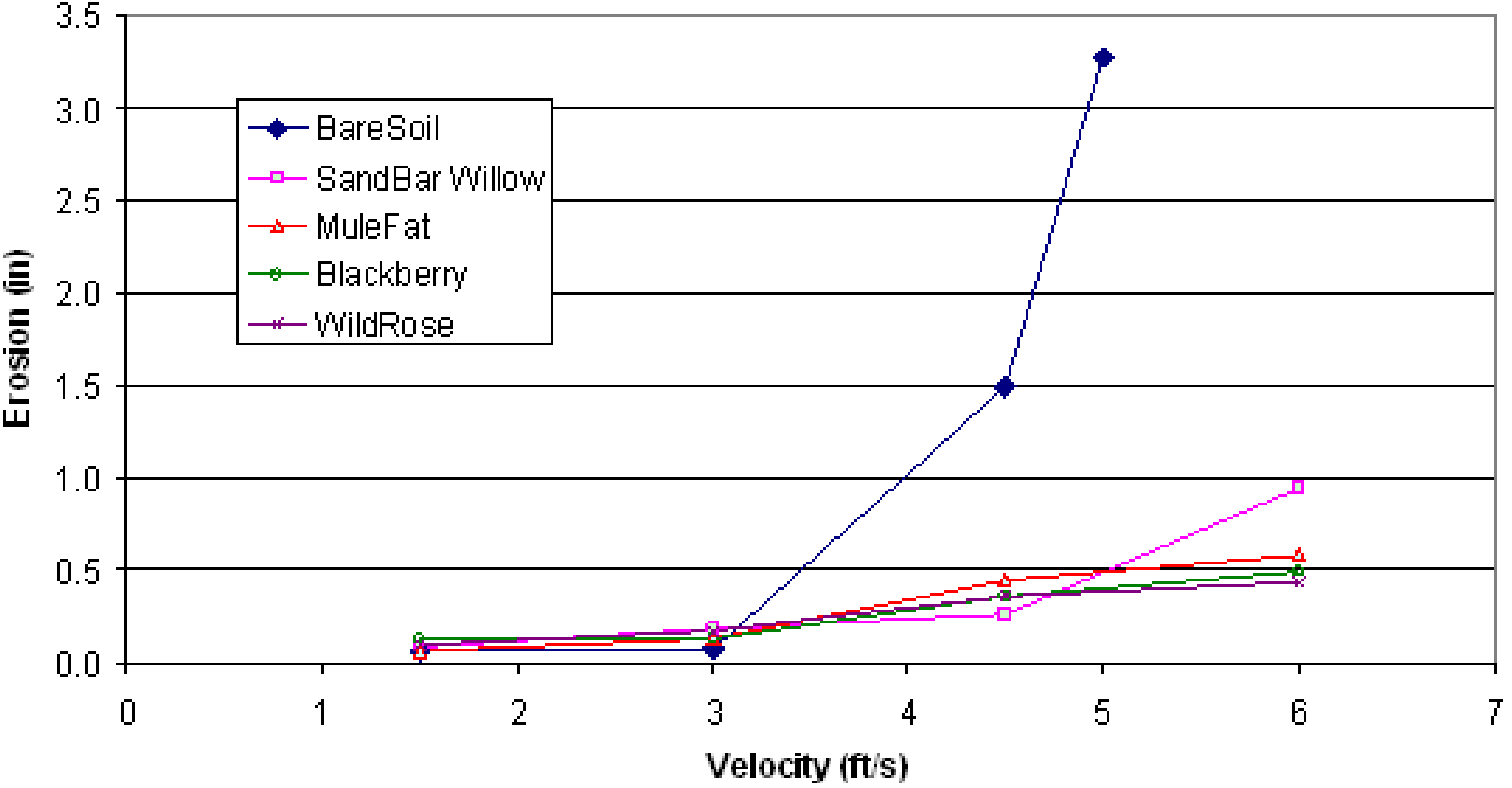
Vt=4.5ft/s and Ht=3ft depth



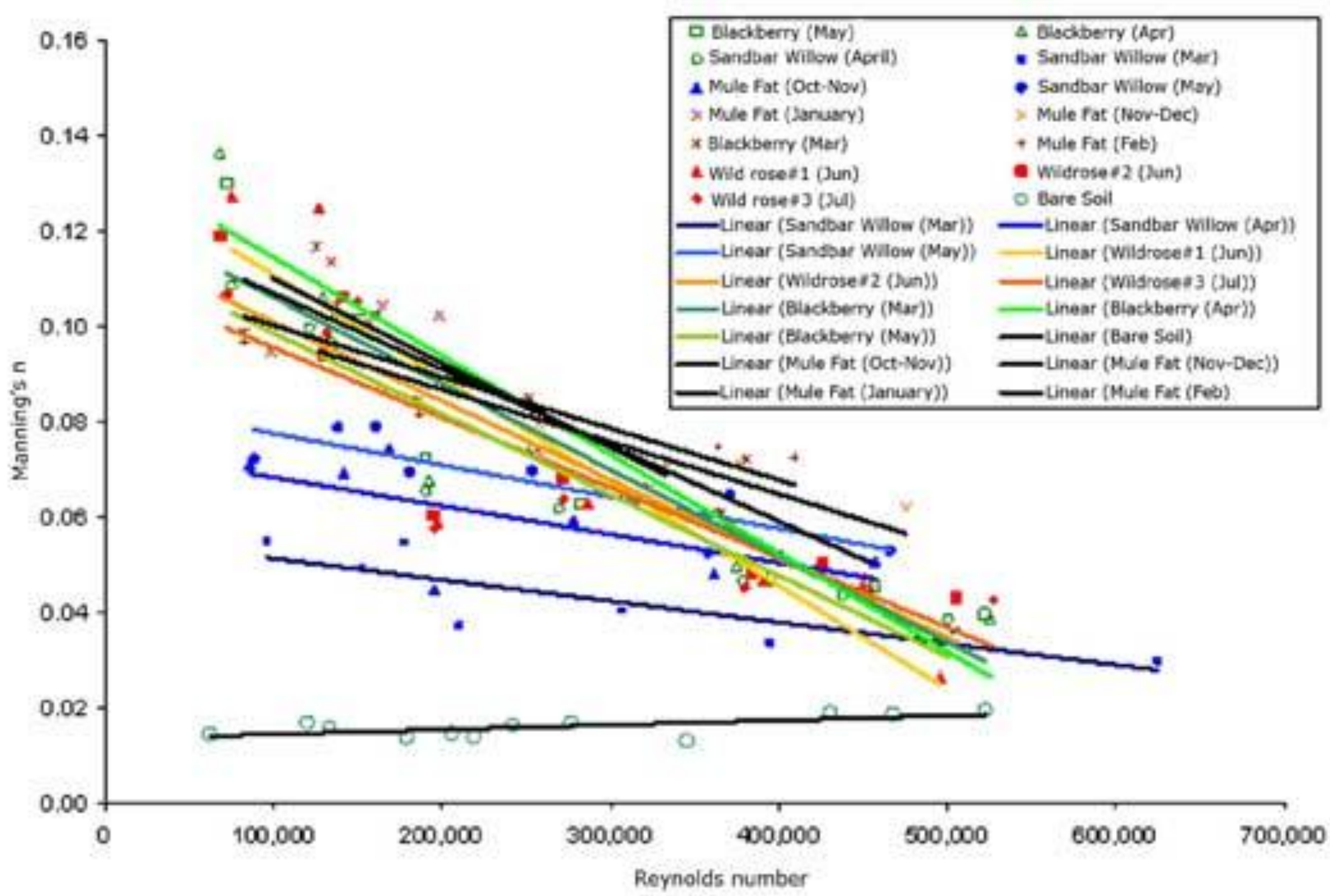
Vt=6ft/s and Ht=3.4ft depth



Soil Erosion



All Species



Blackberry (May)
Blackberry (Apr)
Sandbar Willow (April)
Sandbar Willow (Mar)
Mule Fat (Oct-Nov)
Sandbar Willow (May)
Mule Fat (January)
Mule Fat (Nov-Dec)
Blackberry (Mar)
Mule Fat (Feb)
Wild rose#1 (Jun)
Wildrose#2 (Jun)
Wild rose#3 (Jul)
Bare Soil
Linear (Sandbar Willow (Mar))
Linear (Sandbar Willow (Apr))
Linear (Sandbar Willow (May))
Linear (Wildrose#1 (Jun))
Linear (Wildrose#2 (Jun))
Linear (Wildrose#3 (Jul))
Linear (Blackberry (Mar))
Linear (Blackberry (Apr))
Linear (Blackberry (May))
Linear (Bare Soil)
Linear (Mule Fat (Oct-Nov))
Linear (Mule Fat (Nov-Dec))
Linear (Mule Fat (January))
Linear (Mule Fat (Feb))
Manning's n
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
100,000
200,000
300,000
400,000
500,000
600,000
700,000
Reynolds number

Conclusions from Flume Study

Hydraulic Roughness DECREASES with INCREASES in Velocity.

Flow Conveyance is maintained as velocity INCREASES with Flexible Stem Species.

Riparian Vegetation is Quantifiable and Predictable

Species succession over time is predictable

↓

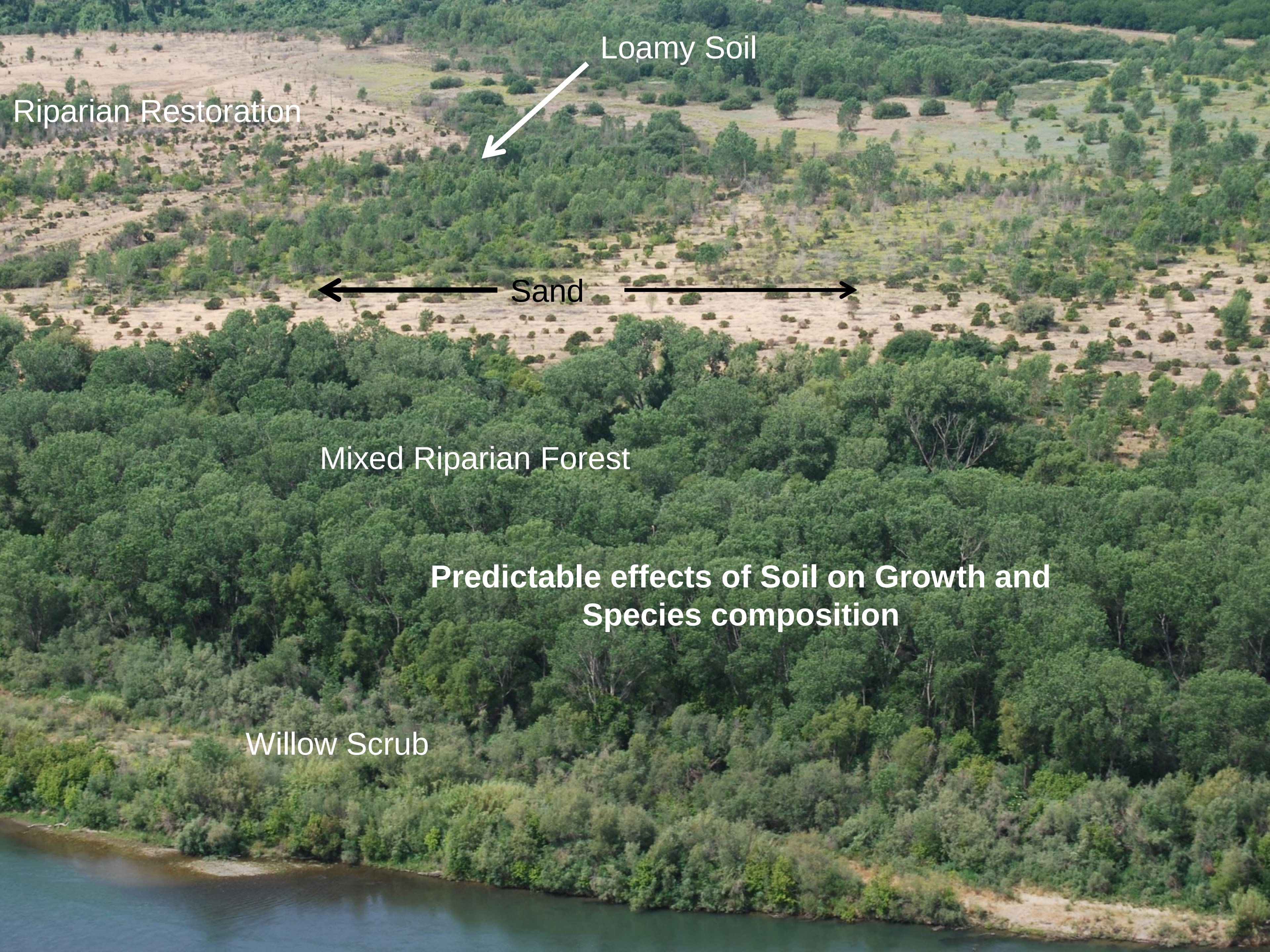
Stem density <u>decreases</u> over time

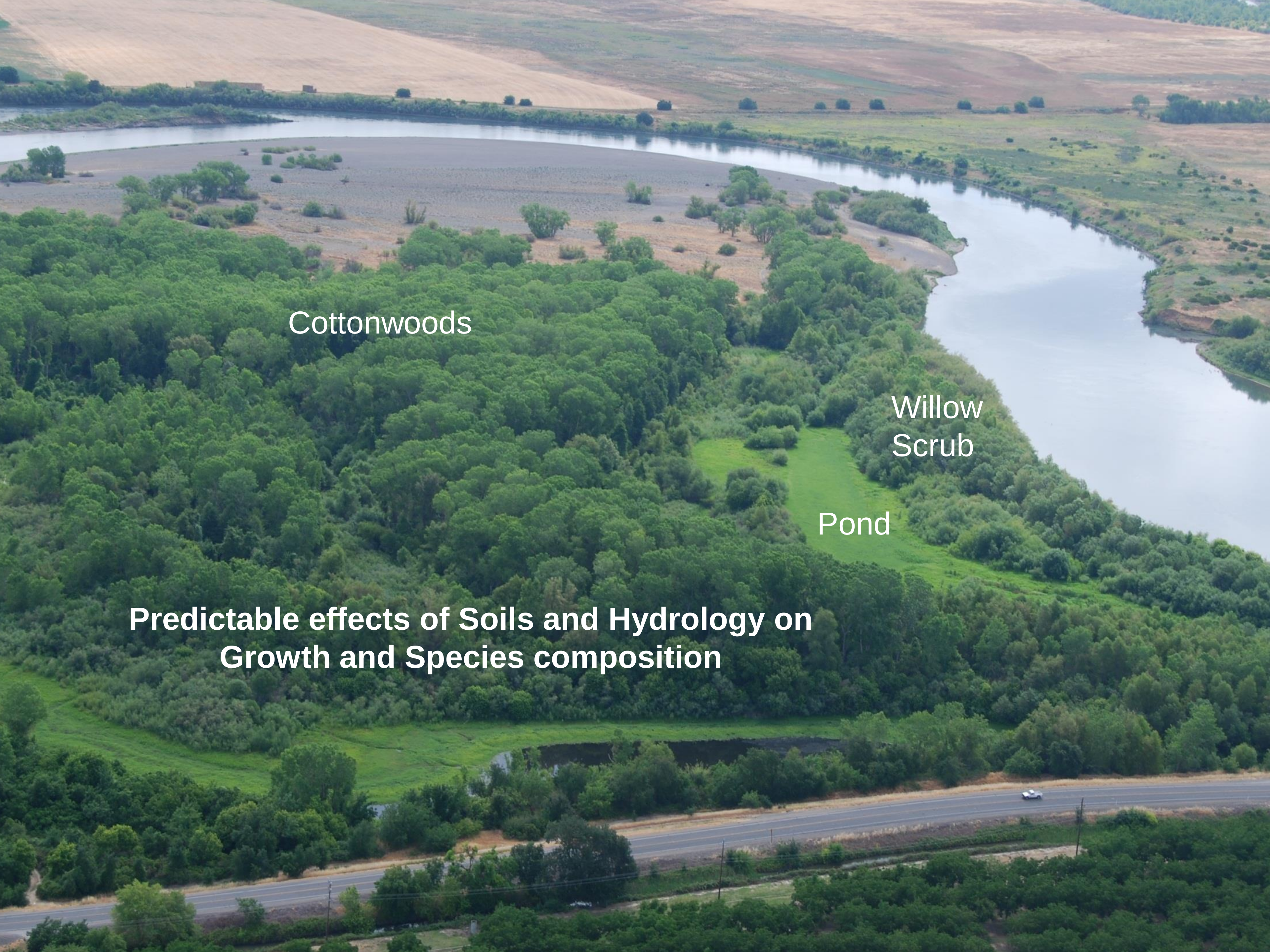
↓

Basal area (stem diameter) <u>increases</u> over time

↓

Soil texture and depth determine species composition and stem density


Loamy Soil
Riparian Restoration
Sand
Mixed Riparian Forest
Predictable effects of Soil on Growth and Species composition
Willow Scrub

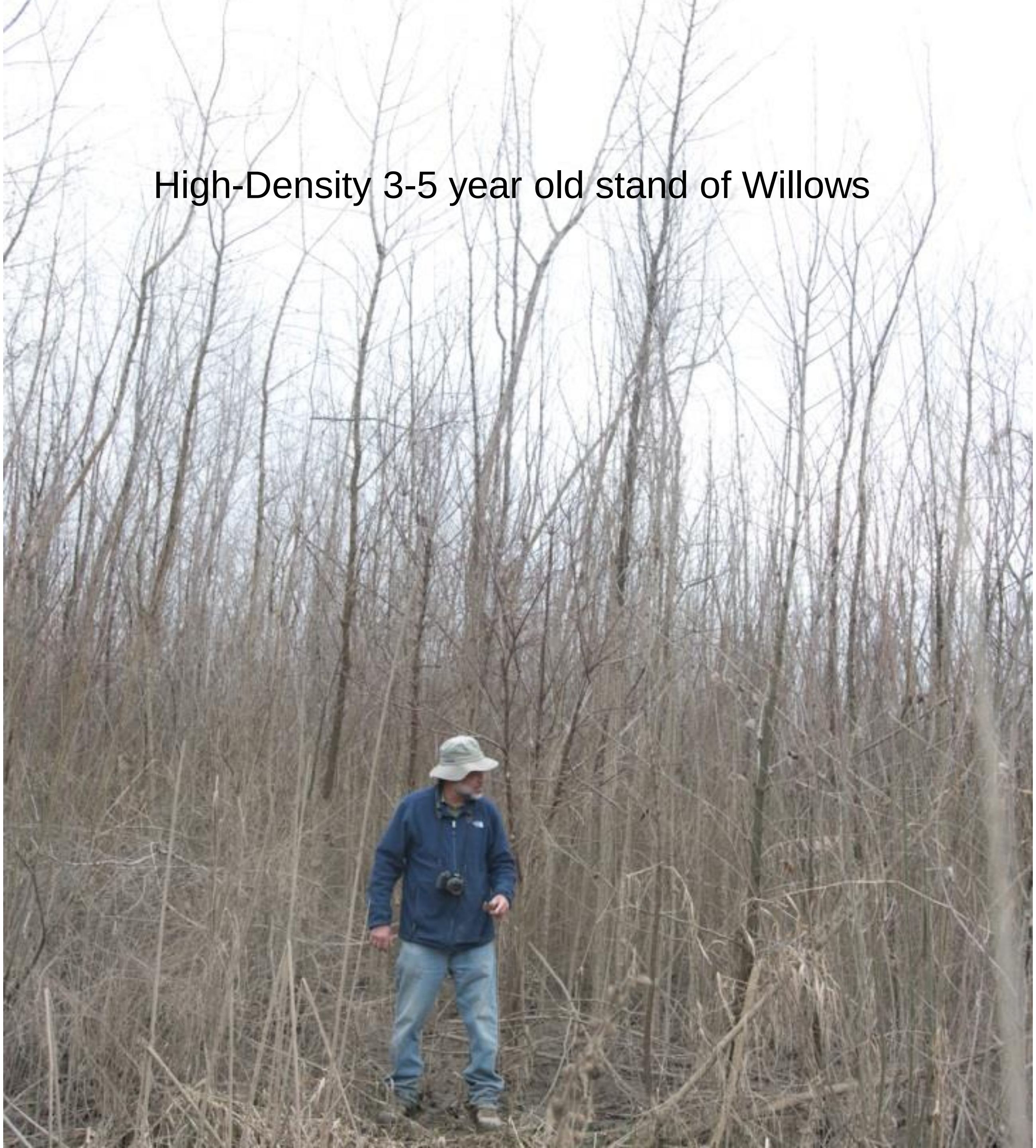

Cottonwoods
Willow
Scrub
Pond
Predictable effects of Soils and Hydrology on
Growth and Species composition

Growth and Development of Riparian Vegetation

Growth and Development of Riparian Vegetation

Willow and Cottonwood Seedlings

High-Density 3-5 year old stand of Willows



High-Density 3-5 year old stand of Willows


Growth and Development of Riparian Vegetation
Sycamore
Cottonwood
Sandbar Willow

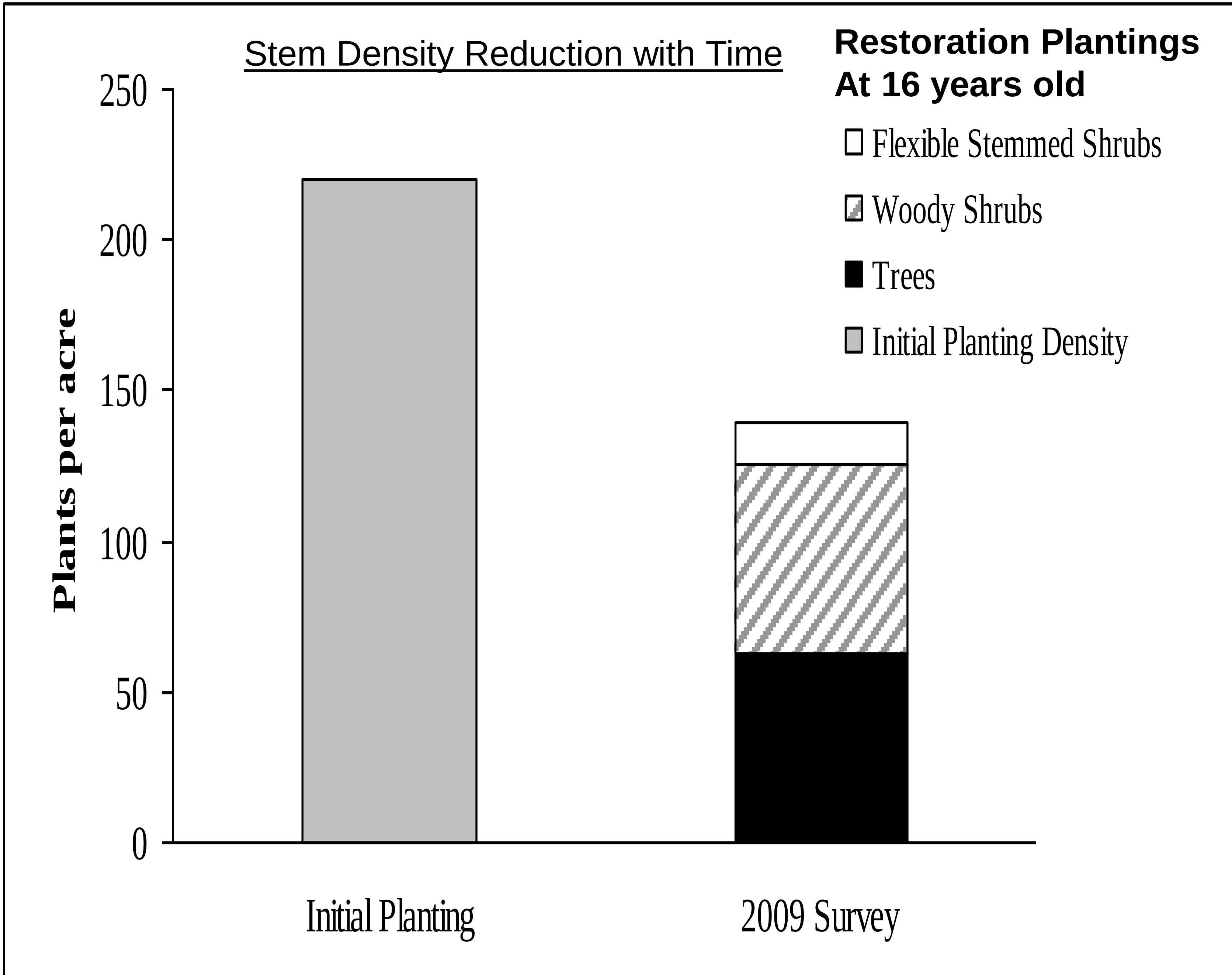

5-10 year-old stand
Growth and Development of Riparian Vegetation

Growth and Development of Riparian Vegetation


Growth and Development of Riparian Vegetation
40 – 50 year-old stand – Black Willow

Growth and Development of Riparian Vegetation

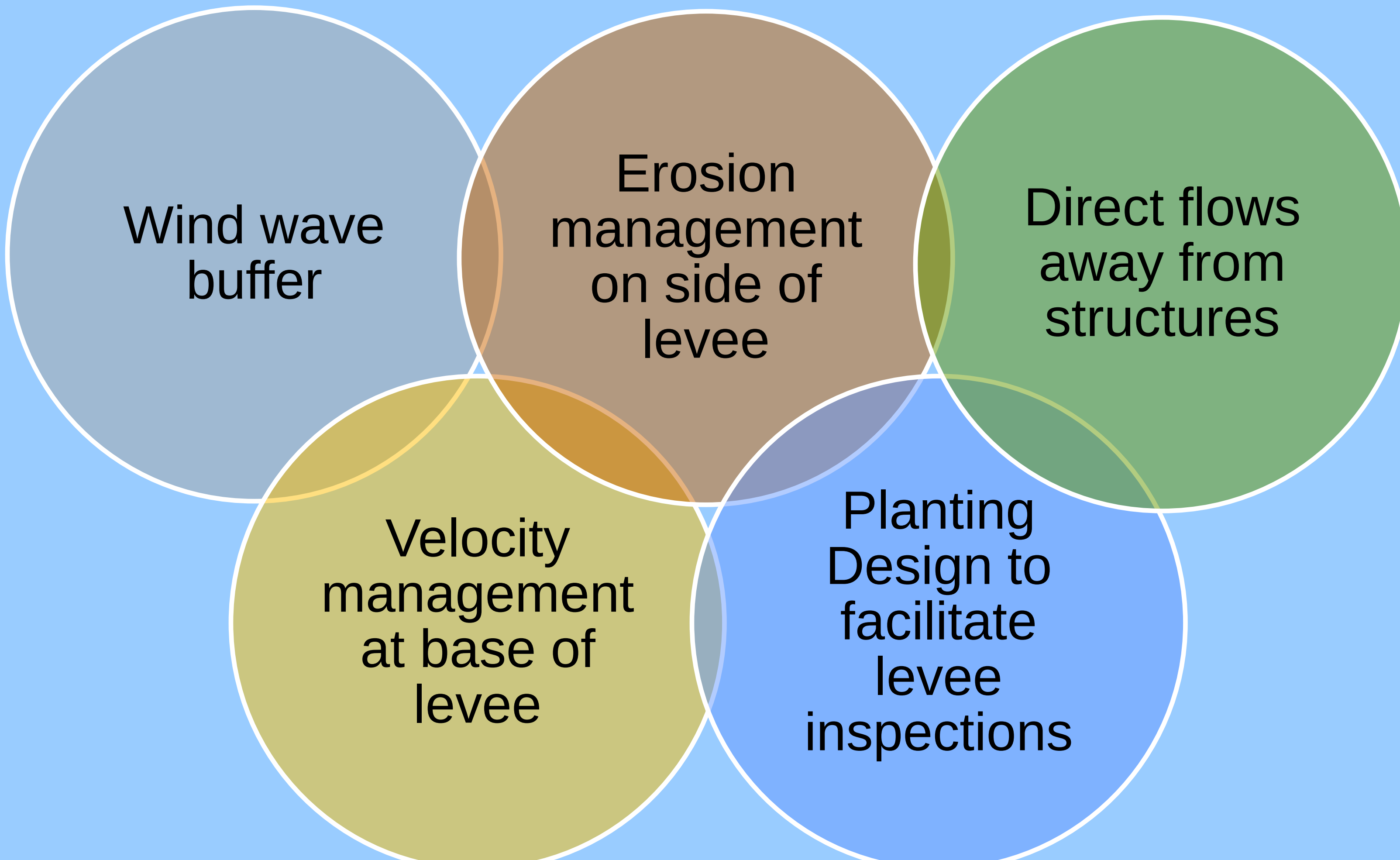
50 – 75 year-old Cottonwood


Stem Density Reduction with Time
Restoration Plantings
At 16 years old
Flexible Stemmed Shrubs
Woody Shrubs
Trees
Initial Planting Density
Plants per acre
250
200
150
100
50
0
Initial Planting
2009 Survey


10-year old Restoration Planting

16-year old
Restoration Planting

Possible Uses for Vegetation in Flood Management



Possible Uses for Vegetation in Flood Management

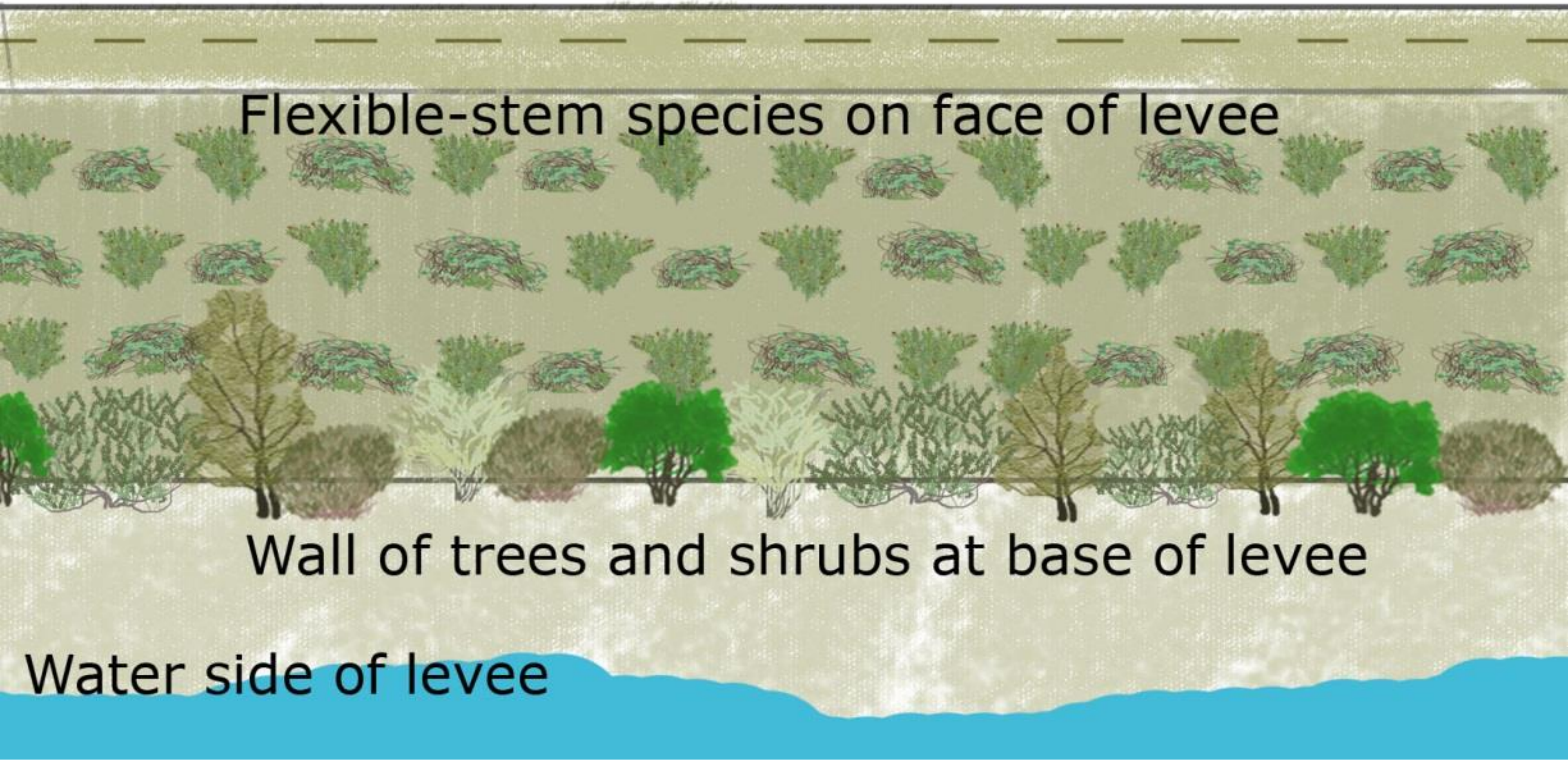

Wind-Wave Buffer


Arroyo Willow – Breakable Stem Bases


Arroyo Willow – Breakable Stem Bases

Arroyo Willow – Breakable Stem Bases

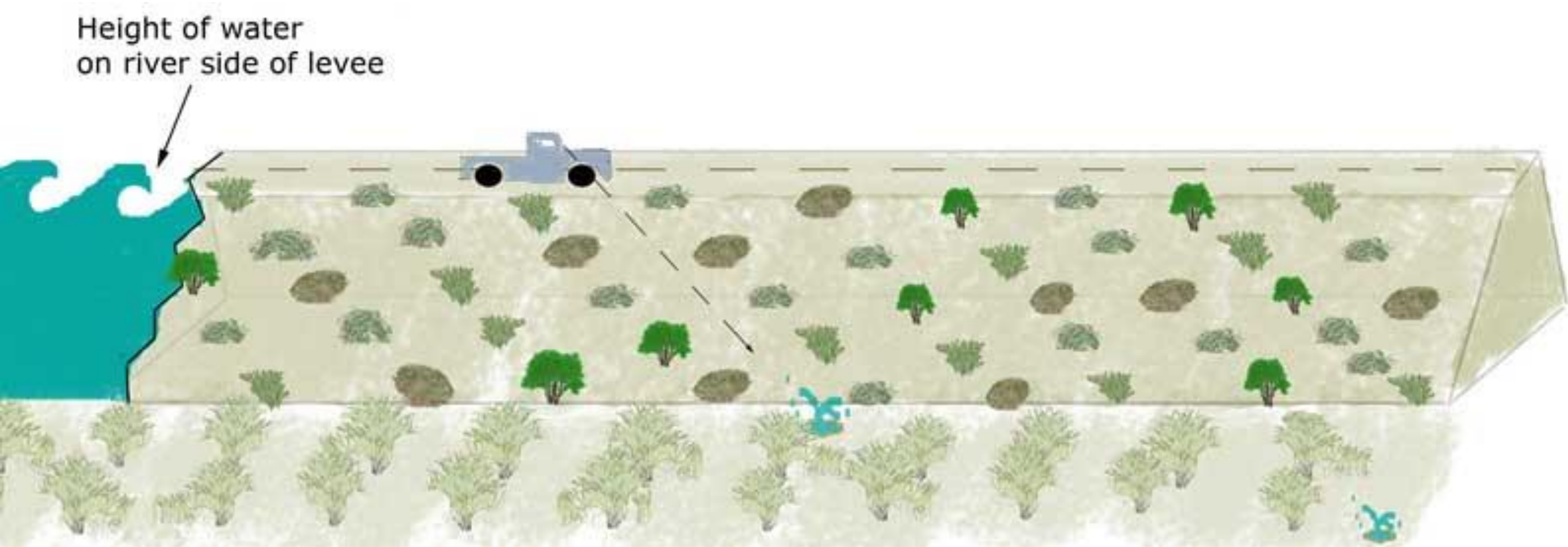
Arroyo Willow – Breakable Stem Bases


Flexible-stem species on face of levee
Wall of trees and shrubs at base of levee
Water side of levee


Levee Planting
San Joaquin River NWR

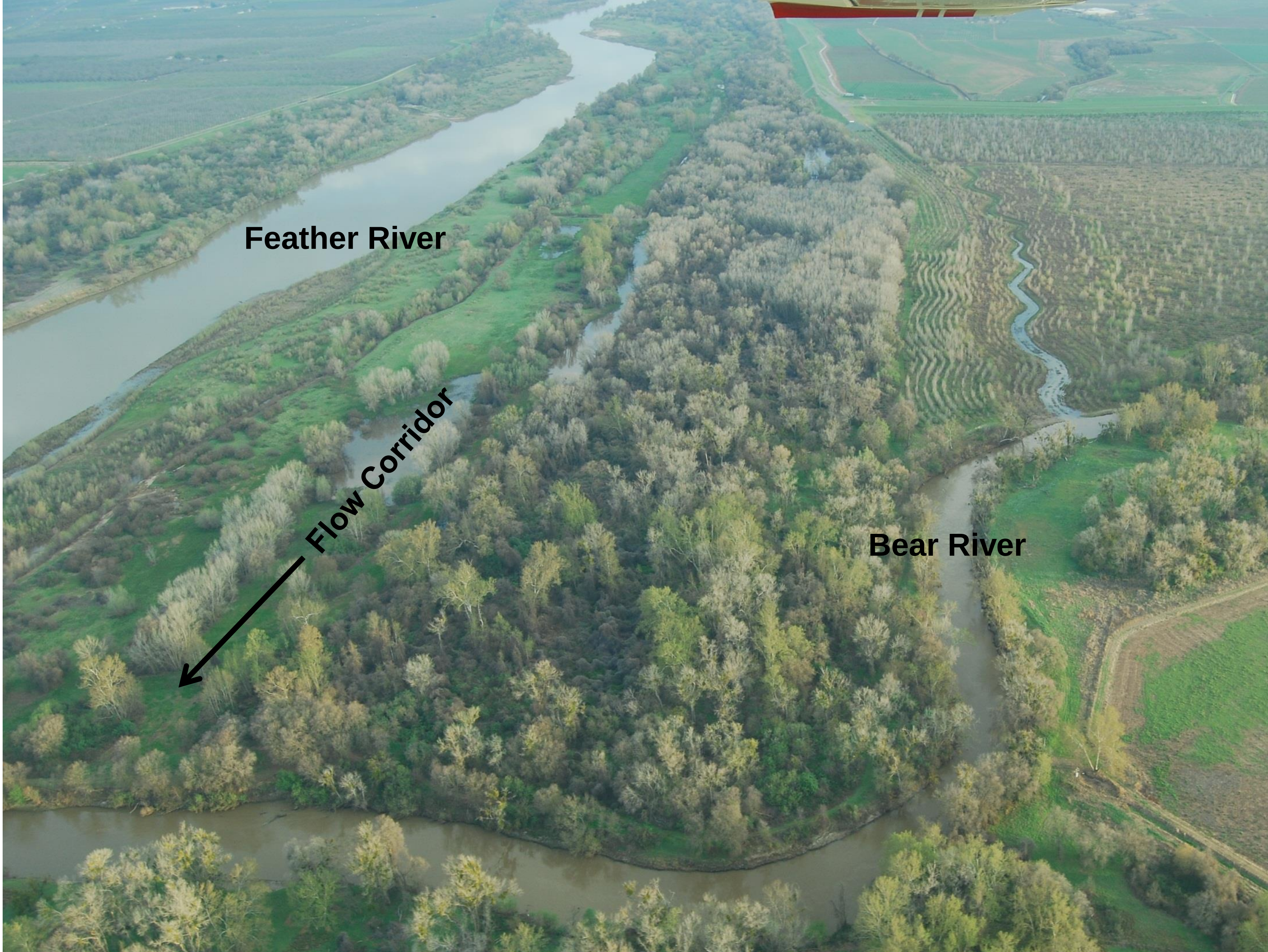
Levee Inspection

Inverted-chevron planting design



Hedgerow Planting Design for Flow Conveyance

O’Connor Lakes – Feather River


Feather River
Flow Corridor
Bear River


Current Floodway Maintenance by DWR
Feather River at Lake of the Woods Unit
Flow
Corridor
Masticated Blackberry

Summary

Low or No Cost Floodway Management

Soil texture and depth determine plant species growth/presence – e.g., not many species of woody plants can grow on sand.

Plant species follow predictable succession.

Competition for light limits growth of all species and decreases stem density.

Native plant species provide wildlife habitat.

Invasive woody species tend to be rigid – Arundo, Tamarisk, Sesbania.