Regional Curves of Hydraulic Geometry for Wadeable Streams in Marin and Sonoma Counties San Francisco Bay Area

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Background

- Funded in 2009 under EPA 2100 Grant for $30k and managed by SFEP
- Project Goals:
  - Update original Leopold curve for SF Bay Area for Marin and Sonoma for area/width/depth
  - Assess major factors (i.e. precip, geology, % urbanization) impact channels
  - Collected and analyzed 58 data points
- Phase I report analyzes for several variables
- [Hopefully] a Phase II to further stratify and analyze data

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The Hydraulic Geometry of Stream Channels and Some Physiographic

The Virtual Luna Leopold Project

On February 23, 2006, Luna Leopold died at the age of 90. Luna was a vital force, a man of extraordinary creativity and originality, whose passion about science and the natural world permeated all he did. He wrote with a clarity, simplicity, and insightfulness that inspired generations of researchers. Nearly all of Luna's papers precede the time when publishing houses make pdf's available. In order to avoid Luna's seminal papers becoming “classics” (papers often cited but never read), we have created a web page where the majority of Luna's papers have been scanned and made available on line as pdf's. Luna assisted with this work, reviewing the publication list and helping us find originals of papers.

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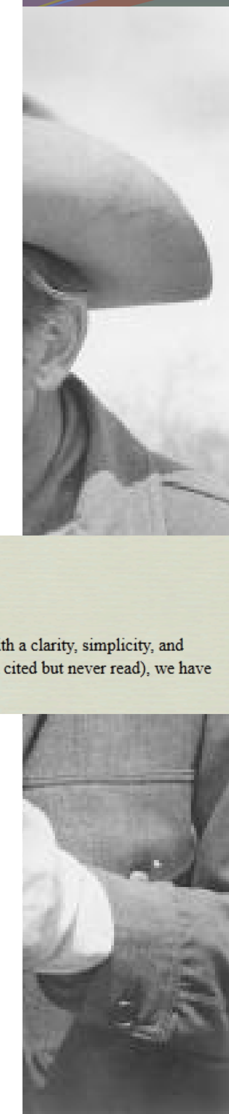
GEOLOGICAL SURVEY PROFESSIONAL PAPER 252

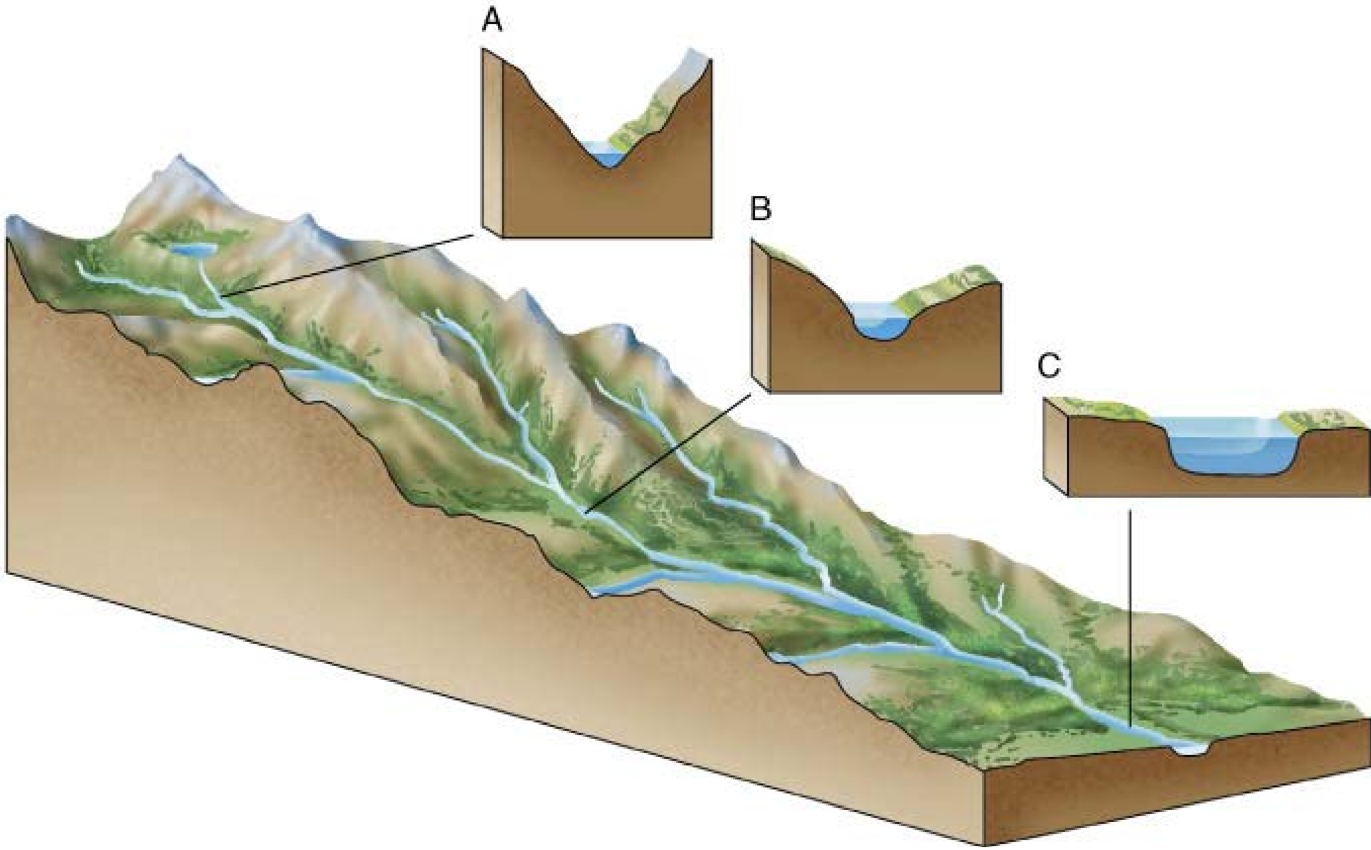
Quantitative measurement of some of the hydraulic factors that help to determine the shape of natural stream channels: depth, width, velocity, and suspended load, and how they vary with discharge as simple power functions. Their interrelations are described by the term “hydraulic geometry.”

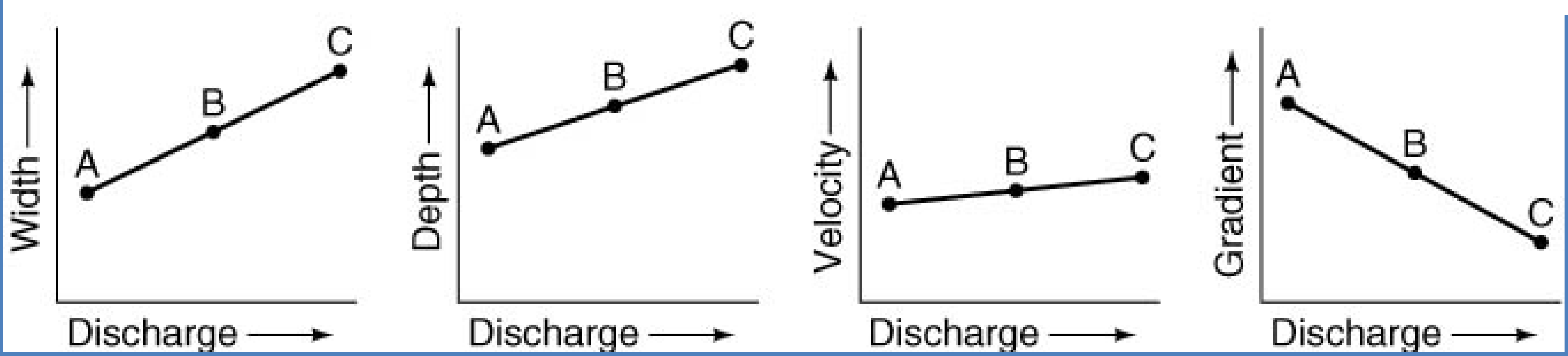
For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C[redacted]ents (paper cover)
Price 40 cents



Major Downstream Trends

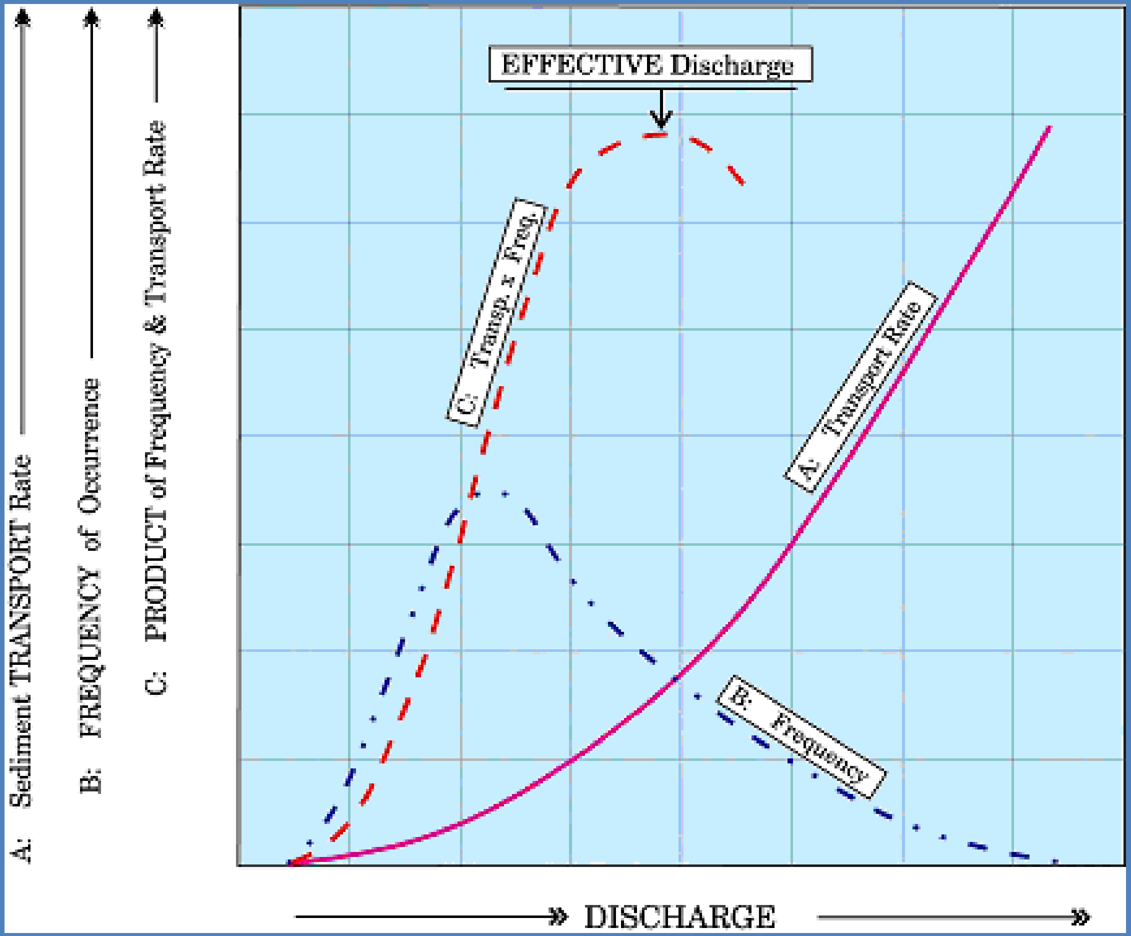
- discharge ↑
- width ↑
- depth ↑
- velocity ↑
- gradient ↓
- grain size ↓





Bankfull or Effective Flow

- For alluvial rivers - "author of their own geometry"
- "The flow that over time forms the equilibrium channel dimensions"
- ~ 1.5 yr RI flow
- Must be found from bankfull indicators in field

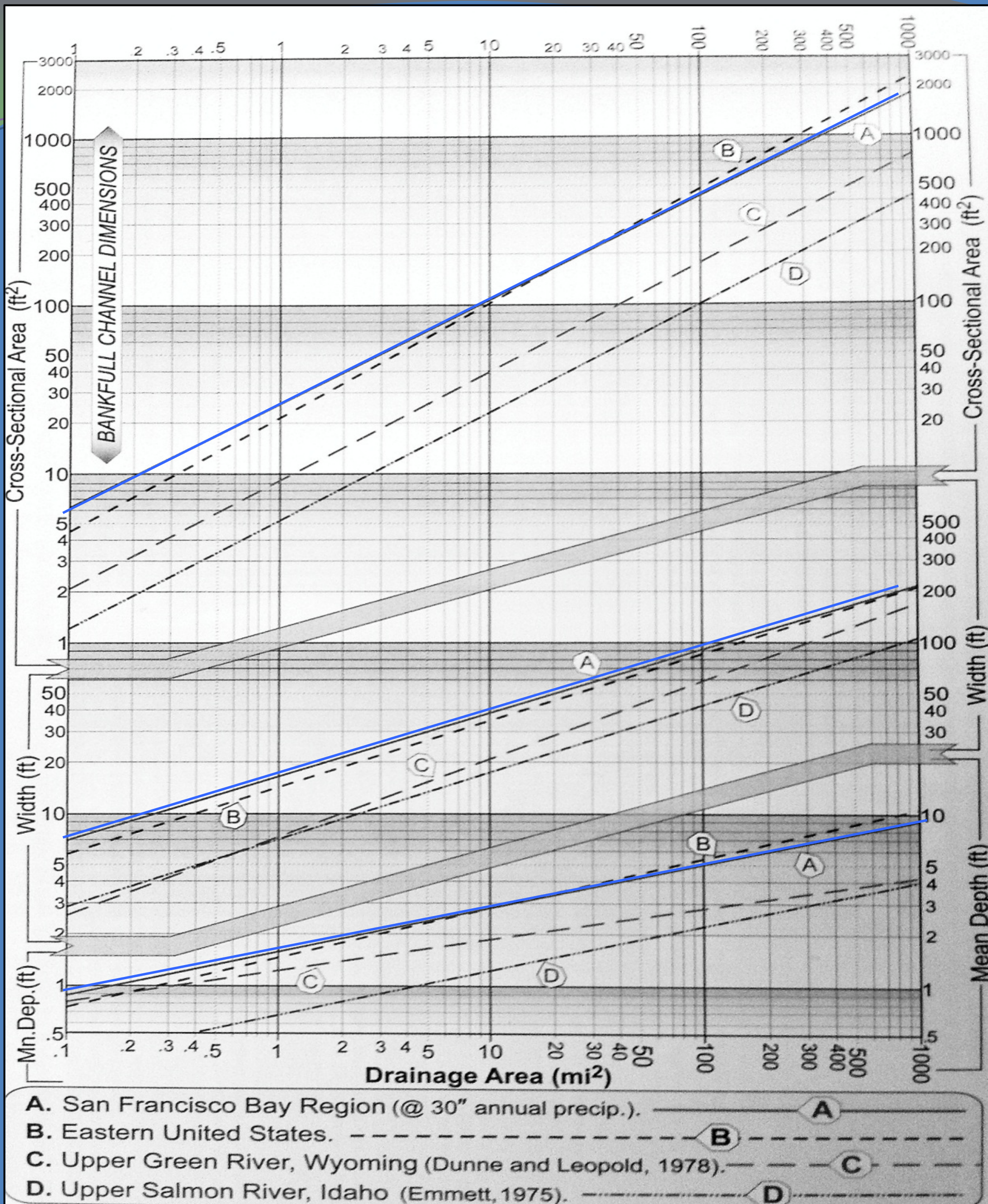


Hydraulic Geometry and Creek Restoration

- Channel parameters described with power functions using Q as the sole independent variable: BFw = aQ^b BFd = cQ^f BFv = kQ^m

- An important design tool used in many restoration project designs – regional curves are plots of "stable" or "equilibrium" sites

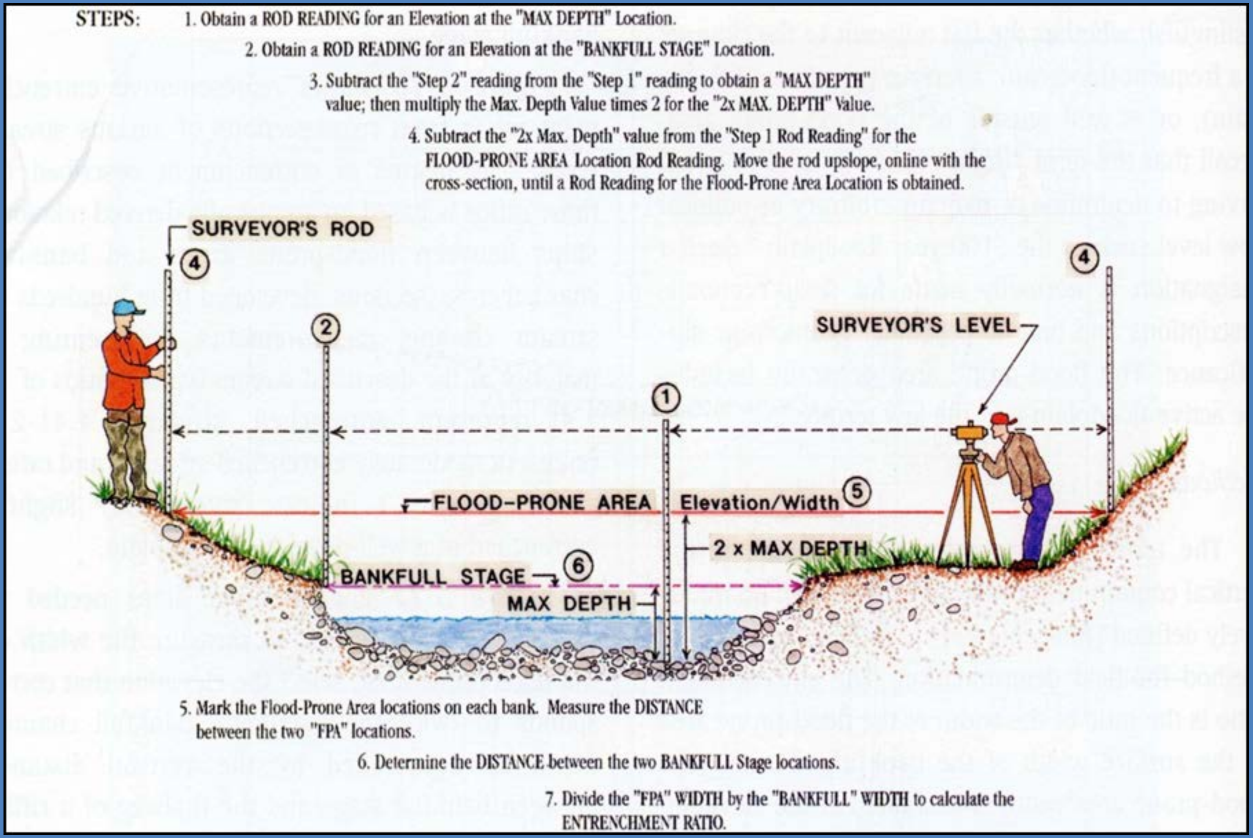
- Plots of field sites are "regional curves"



- 1978 - One curve for SF Bay Region at 30" MAP (curve A)
- Data points not plotted
- Assumed 1.5 RI and plotted A, W and D from gaging records at USGS gage sites
- Best done as local dataset (our project)

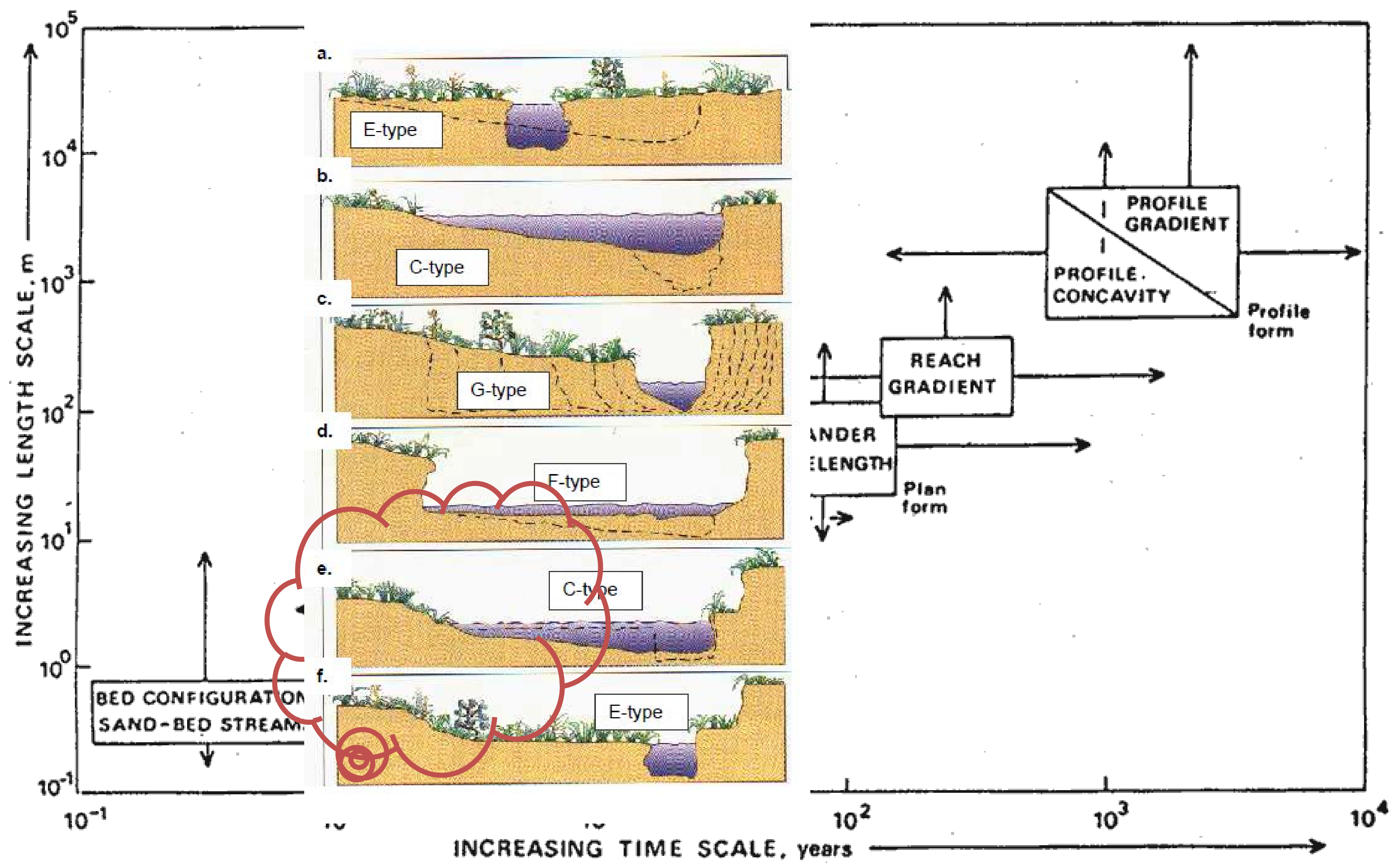
Finding bankfull elev...textbooks

- Finding bankfull elevation is not always easy
- A depositional feature not always present
- Most Bay Area streams are incising



Finding bankfull in the real world…

Adjustments in the Fluvial System



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Hydraulic Geometry: A Geomorphic Design Tool for Tidal Marsh Channel Evolution in Wetland Restoration Projects

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Michelle K. Orr[1]
Nicholas J. Garrity[1]

Abstract

Empirical hydraulic geometry relationships for tidal marsh channels are a practical geomorphically based design tool that can assist in the planning of tidal wetland restoration projects. This study provides hydraulic geometry relationships for predicting the depth, width, and cross-sectional area of mature tidal channels as functions of contributing marsh area or tidal prism. The relationships are based on data from San Francisco Bay coastal salt marshes ranging in size from 2 to 5,700 ha. These hydraulic geometry relationships refine and expand on earlier relationships. Relationships for mature marshes can be used to predict the direction and rate of evolution of a channel in an immature or perturbed marsh system. Channel evolution data for three youthful tidal channels, ages 4 to 13 years, suggest that the channels are converging on their predicted equilibrium morphology. Two channels are eroding in response to significant increases in upstream tidal prism. They have enlarged first by deepening, in one case after 13 years to beyond the predicted equilibrium depth, and then widening through slumping of the channel banks. The third channel, a new one forming in a depositional mudflat, is converging on its equilibrium morphology after 13 years but will likely take several decades to equilibrate.

Key words: hydraulic geometry, restoration, salt marsh, San Francisco Bay, tidal channel.

Introduction

Since at least the 17th century observers have noted how the depth and width of tidal marsh channels are affected by anthropogenic alterations in the upstream tidal prism or volume of water exchanged upstream of a point during a tidal cycle. This understanding was stated perceptively in 1637 by ship owners in the town of Cley in Norfolk, England, who were petitioning to have newly installed dikes on tidal marshes upstream of the shipping channel in their harbor removed.

> The banke of earth . . . taketh away . . . the indraught of water 80 rodds and upwards in breadth and one myle at least in length [an area larger than 65 ha] . . . so that what sylt or mudd the flood tide bringeth in doth settle and remaine in the navigable channel . . . through want of the ebb tide which formely overflowed the aforesaid 80 rodds of ground in breadth and one myle in length (Cozens-Hardy 1927).

Intrinsic in this description is a concept that there is an equilibrium form of a tidal channel for a given-sized marsh with a particular tidal range within an estuary that is relatively stable over long periods of time. This form is the expression of a dynamic equilibrium between erosional and depositional processes.

It was not until the 1960s that scientists (Myrick & Leopold 1963) attempted to systematize an understanding of the relationship between tidal flows and channel geometry of tidal marsh channels using equations of hydraulic geometry, as had been done for alluvial rivers and canals 30 years before. These equations relate channel cross-sectional geometry to discharge according to the power functions: $W = aQ^b$, $D = cQ^f$, and $v = kQ^m$, where W is the width, Q is the characteristic discharge, D is the average depth, and v is the characteristic velocity. By continuity of flow the sum of the constants a, c, and k and the sum of the exponents b, f, and m are both equal to 1. Various researchers have measured flow and channel cross-sectional parameters and then calculated the exponential parameters for downstream changes in hydraulic geometry. (See Allen 2000 for a succinct de-

Marin Field Sites

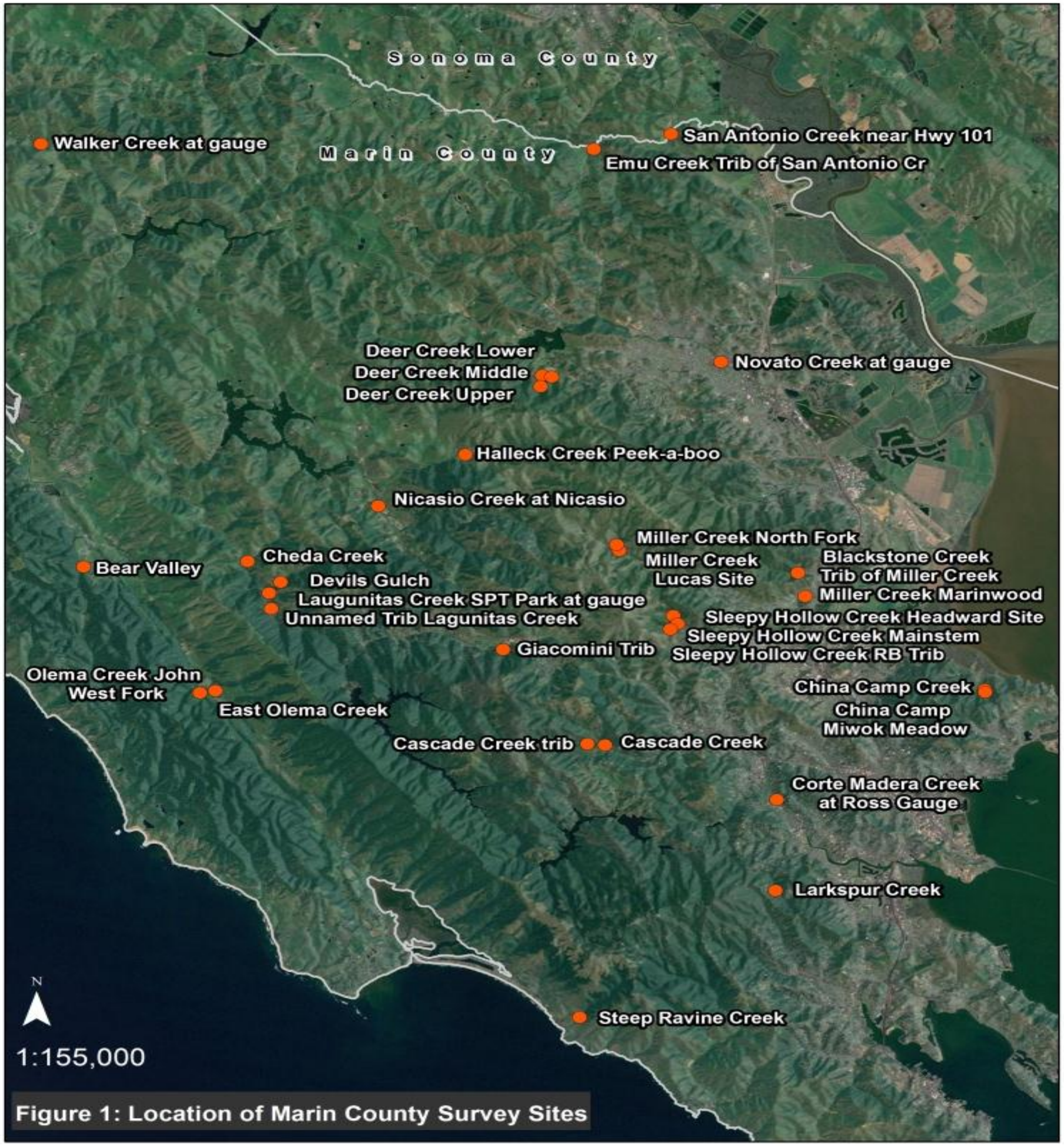


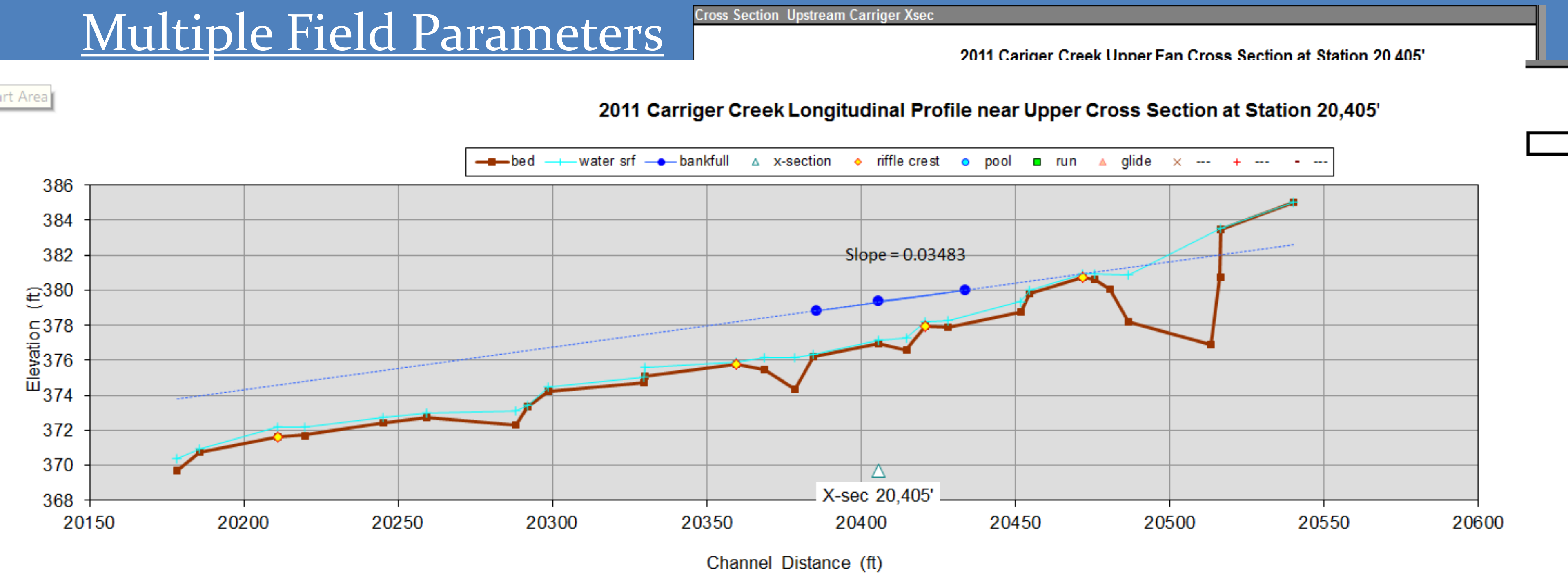
Figure 1: Location of Marin County Survey Sites

Sonoma County Sites

Figure 2: Location of Sonoma County Survey Sites

Data Collection and Analysis

Multiple Field Parameters



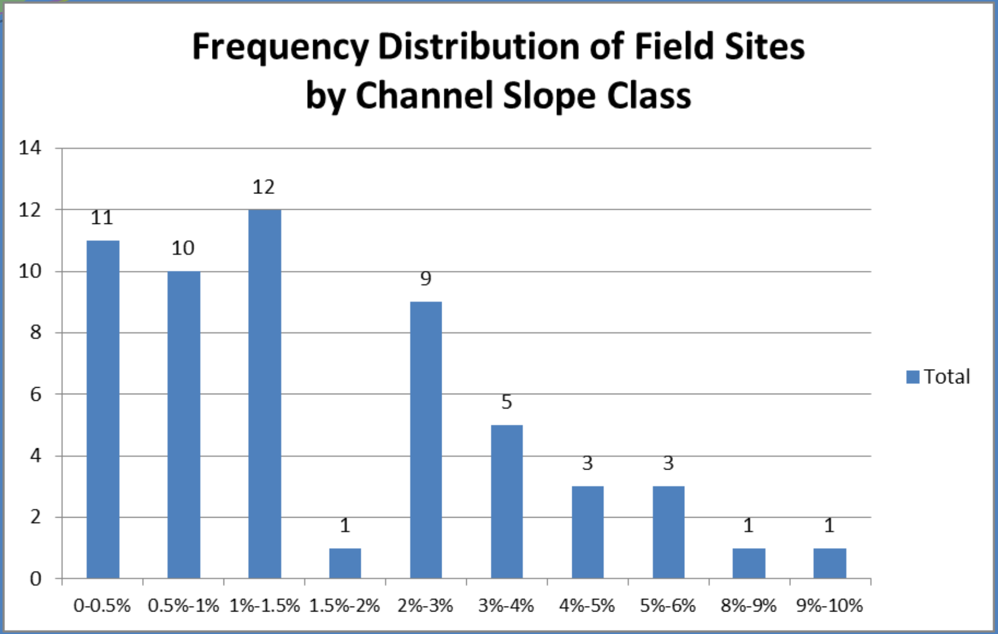
	slope (%)	slope ratio	length (ft)	length ratio	pool-pool spacing (ft)	p-p ratio
reach	---	---	20539.9 (748.4 channel widths	---	---	---
riffle	-4.15 (0 - -2.48)	---	-81.5 (-148.8 - -43.7)	---	---	---
pool	---	---	---	---	---	---

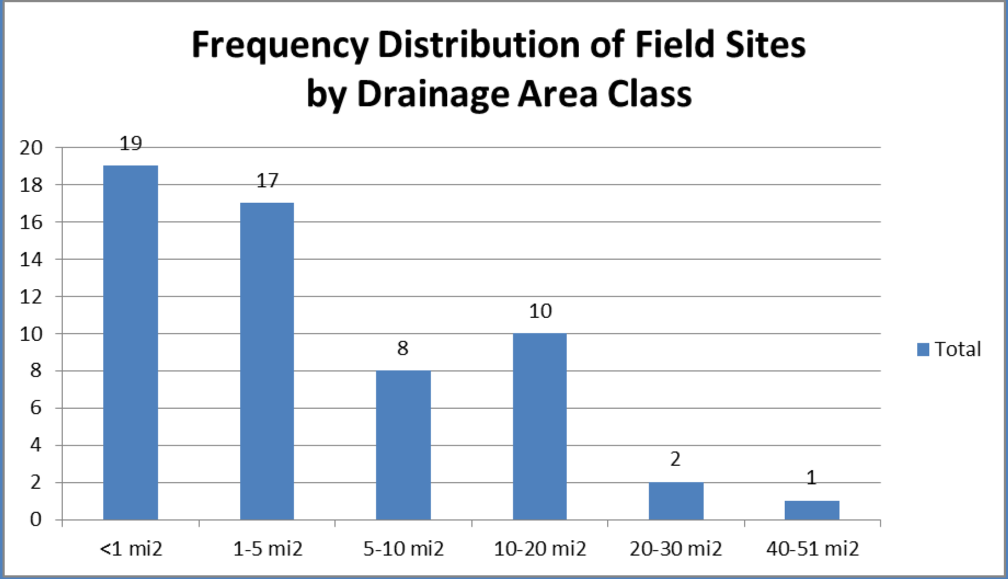
- BF flow, area, velocity, W/D ratio, SS many more

Results…

- Over 20 different graphs and tables in the report
- Showing only a few today
- New analysis of the required floodplain width and chanelized network length

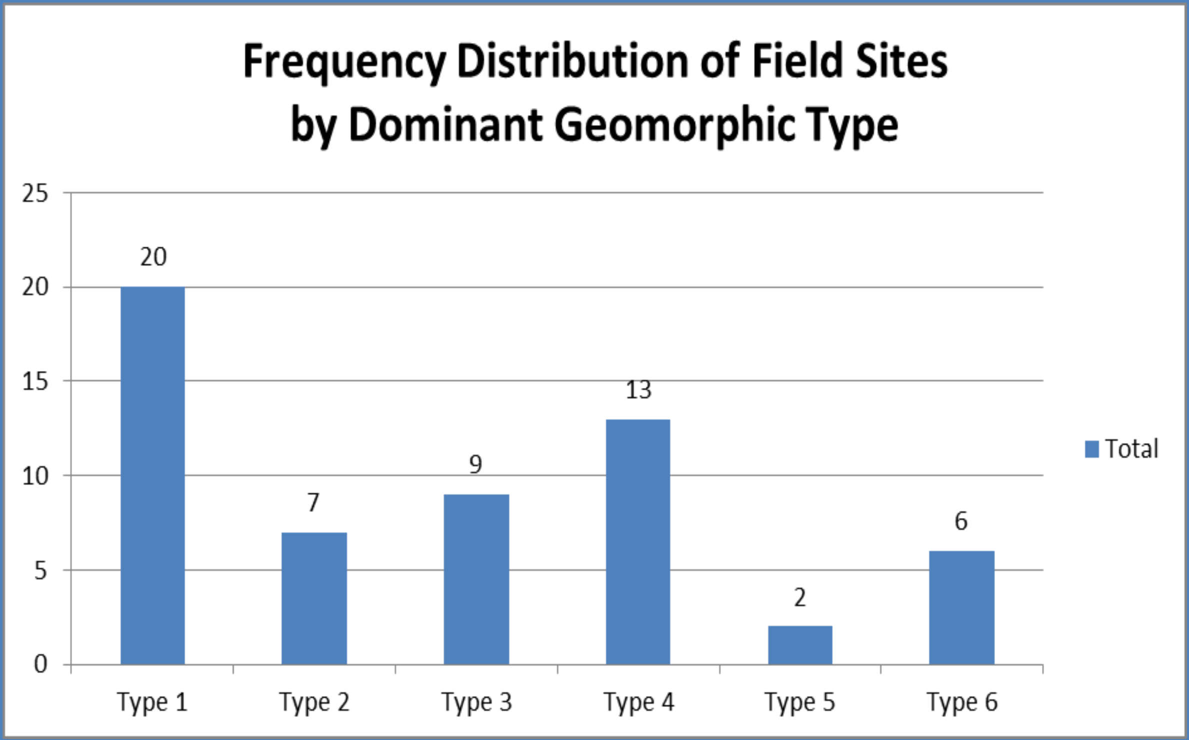
Slope and DA Frequency Plots





- 14 sites > 3% slope – fills in data gap for steeper streams
- Fills in data gap for smaller streams

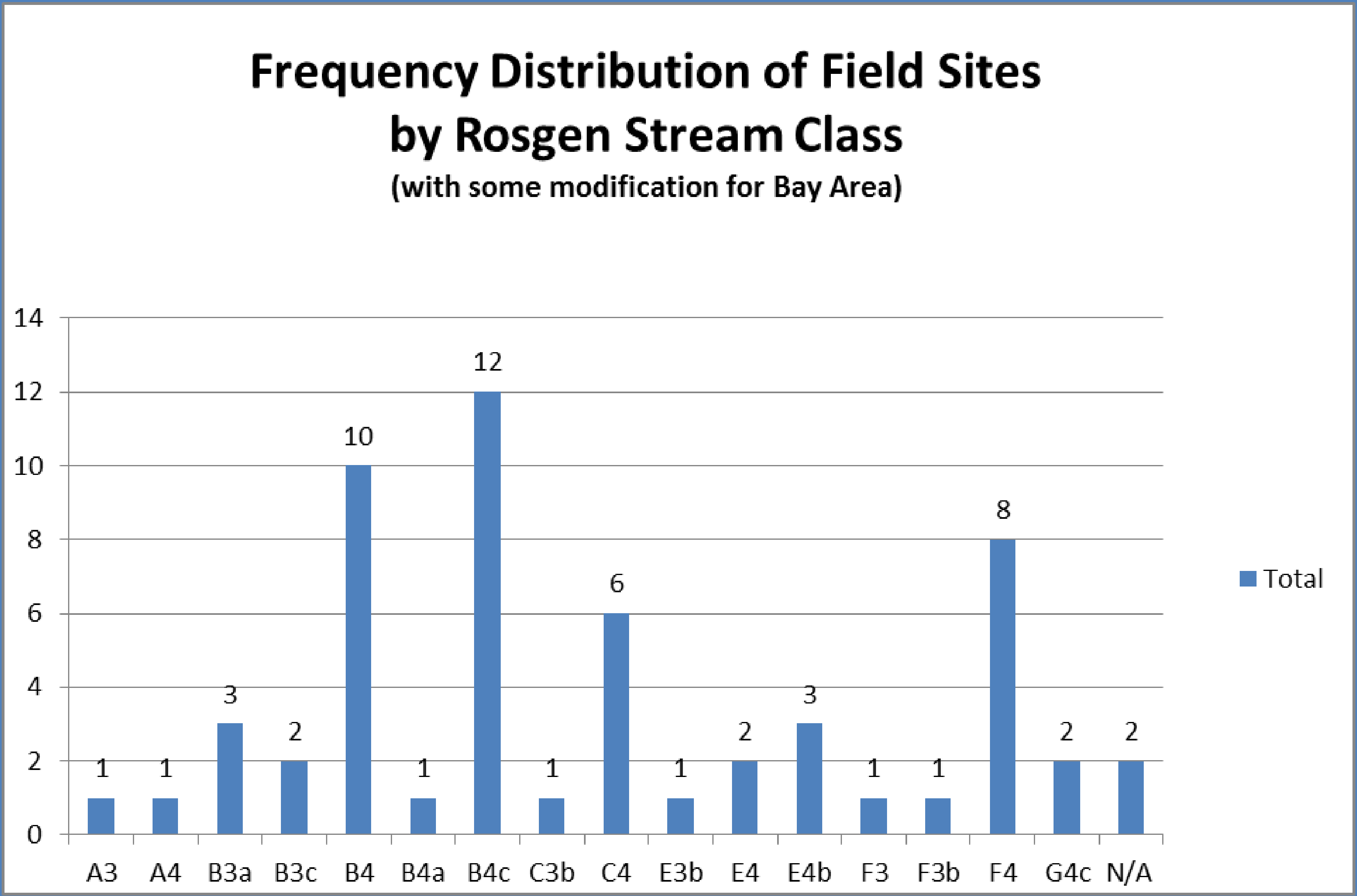
Dominant Geomorphic Setting



Types

1. Wide alluvial valley
2. Narrow predominantly alluvial valley
3. Moderately wide alluvial valley
4. Alluvial fan*
5. Narrow, predominantly colluvial valley or canyon
6. Steep, mostly bedrock confined canyon
7. Plain, often uplands transitional to tidelands

Rosgen Classification

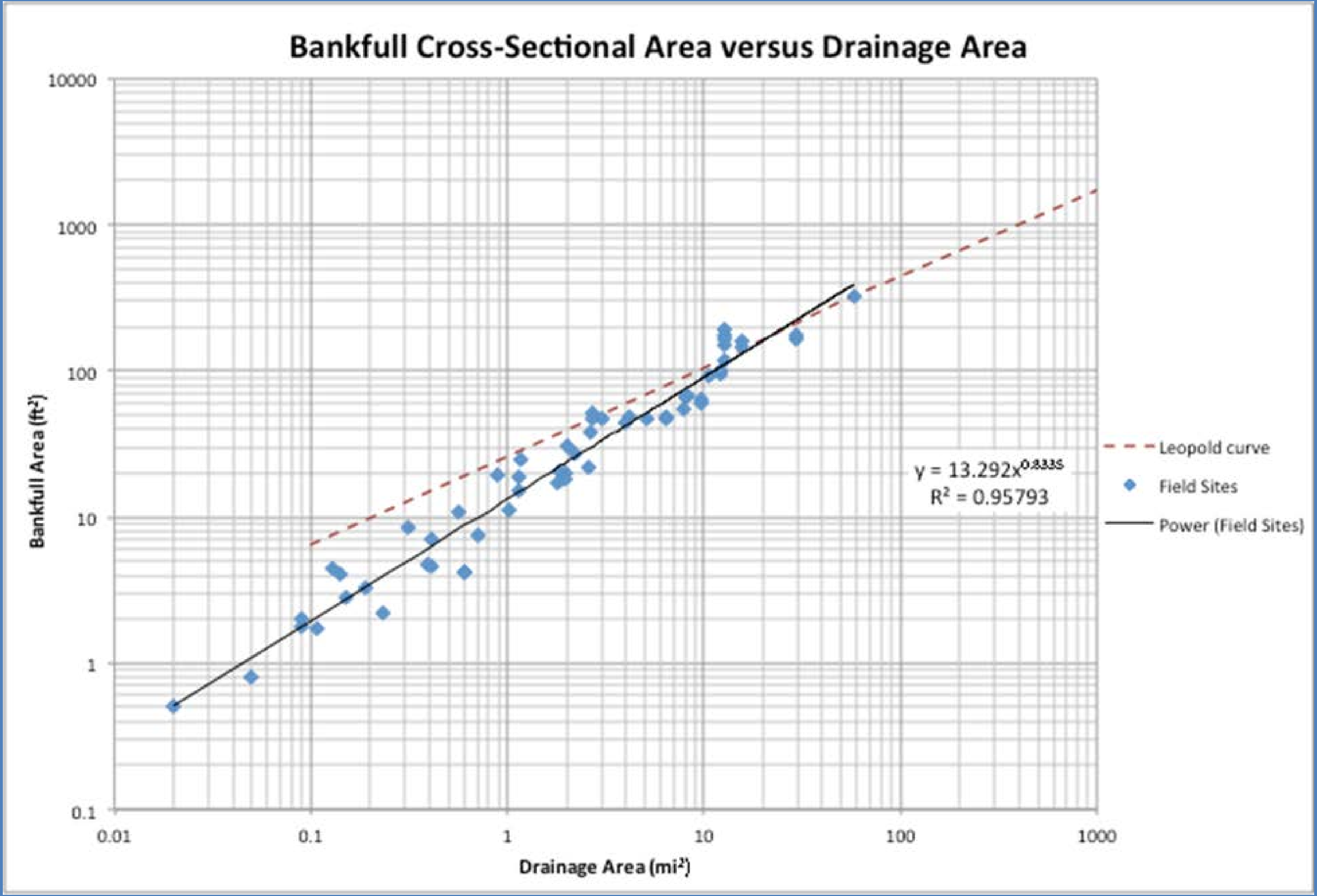


USGS Gage Sites

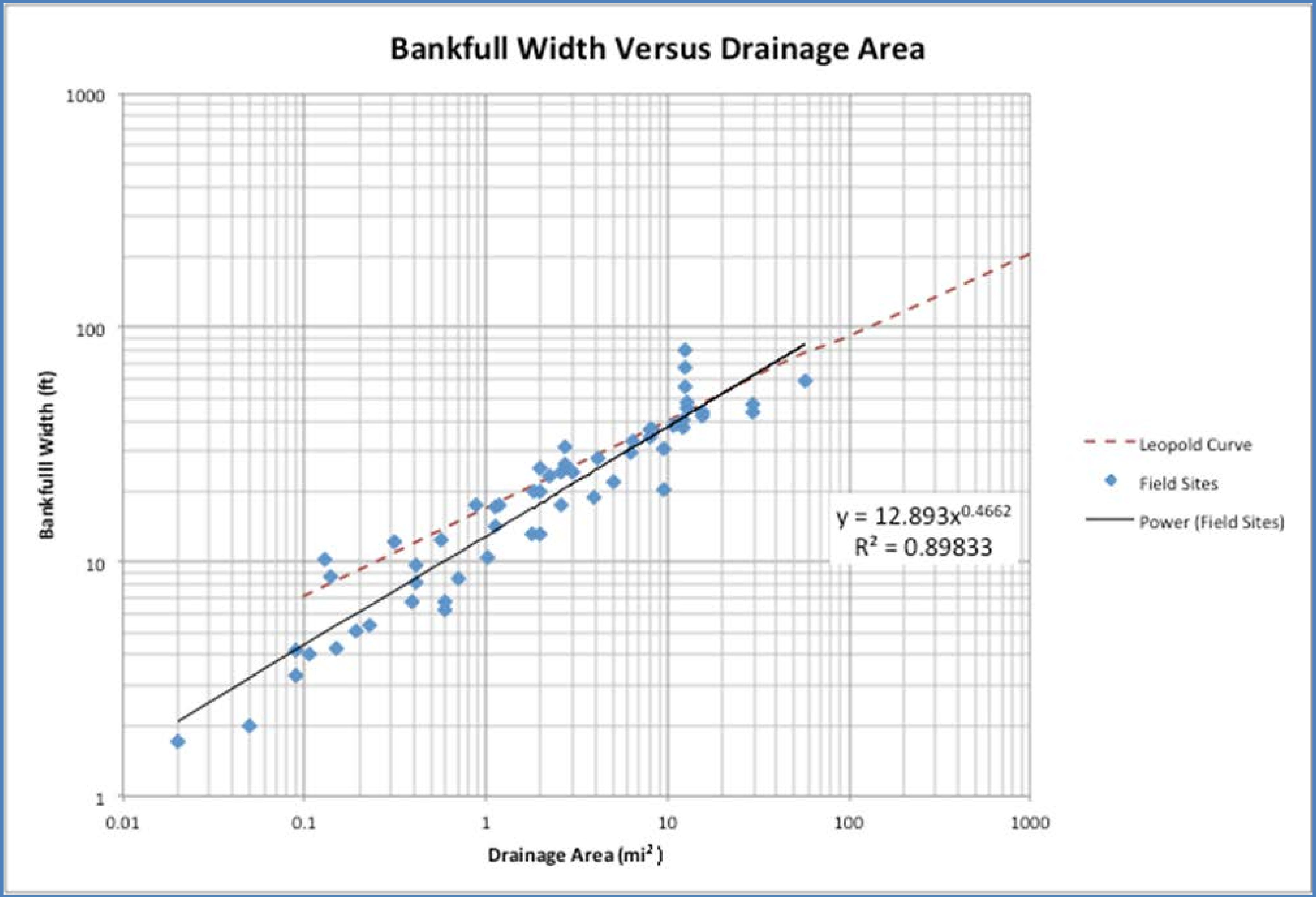
Site	Bankfull Discharge (cfs)	Reservoir Upstream	Approximate Recurrence Interval (years)
Corte Madera Creek at Ross Gage Site 11460000	953	Yes	1.3
Lagunitas Creek at Samuel P. Taylor Park, Gage Site 1146400	842	Yes	1.1
Novato Creek at Novato, Gage Site 11459500	303	Yes	1.2
Sonoma Creek at Agua Caliente, Gage Site 11458500	3139	No	1.2
Walker Creek near Marshall, Gage Site 11460750	1065	Yes	1.5

Note: Recurrence intervals were determined from a flood frequency analysis of Peak Annual flows from USGS data.

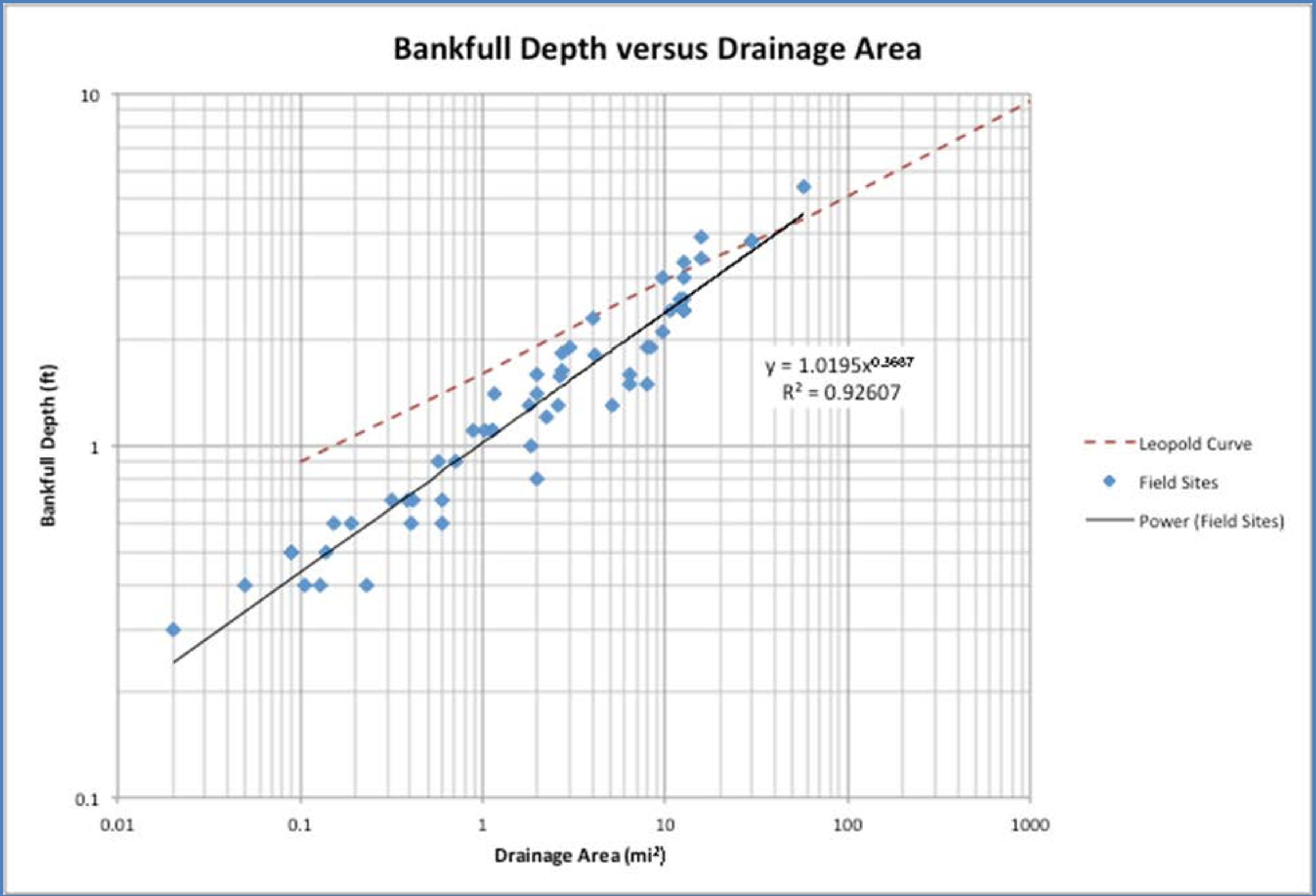
Regional Curve – X-Sectional Area



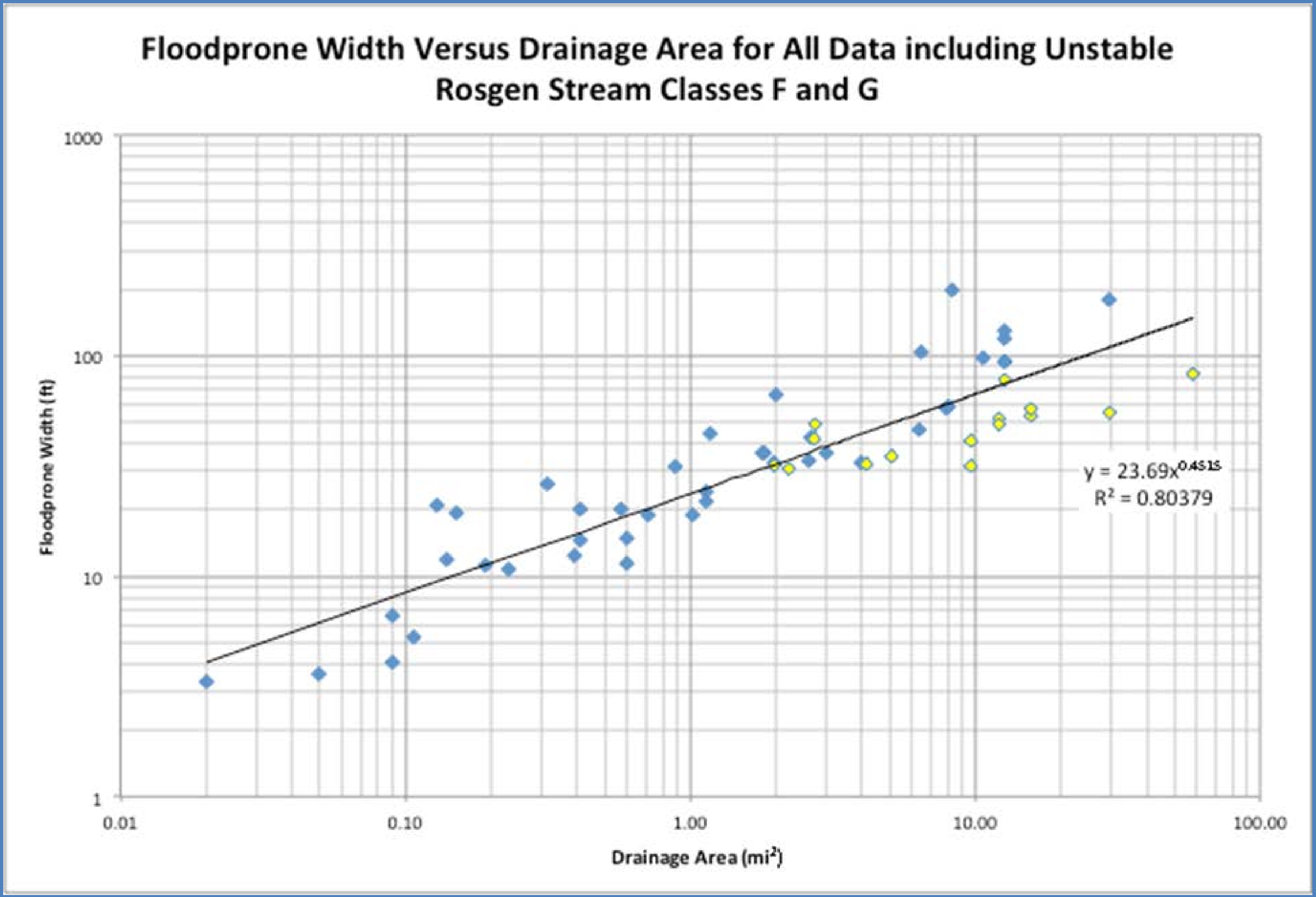
Regional Curve – Bankfull Width



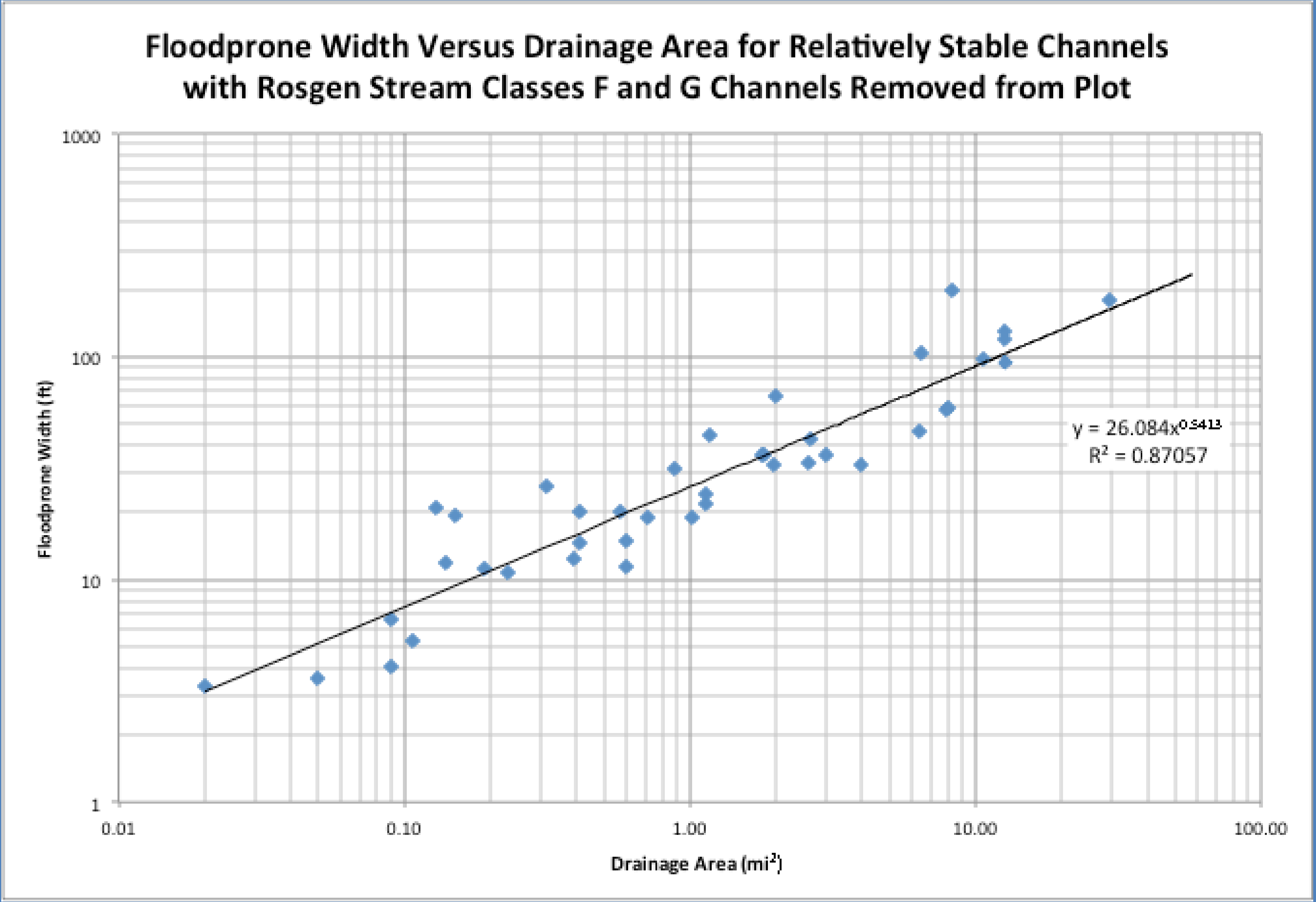
Regional Curve – Bankfull Depth



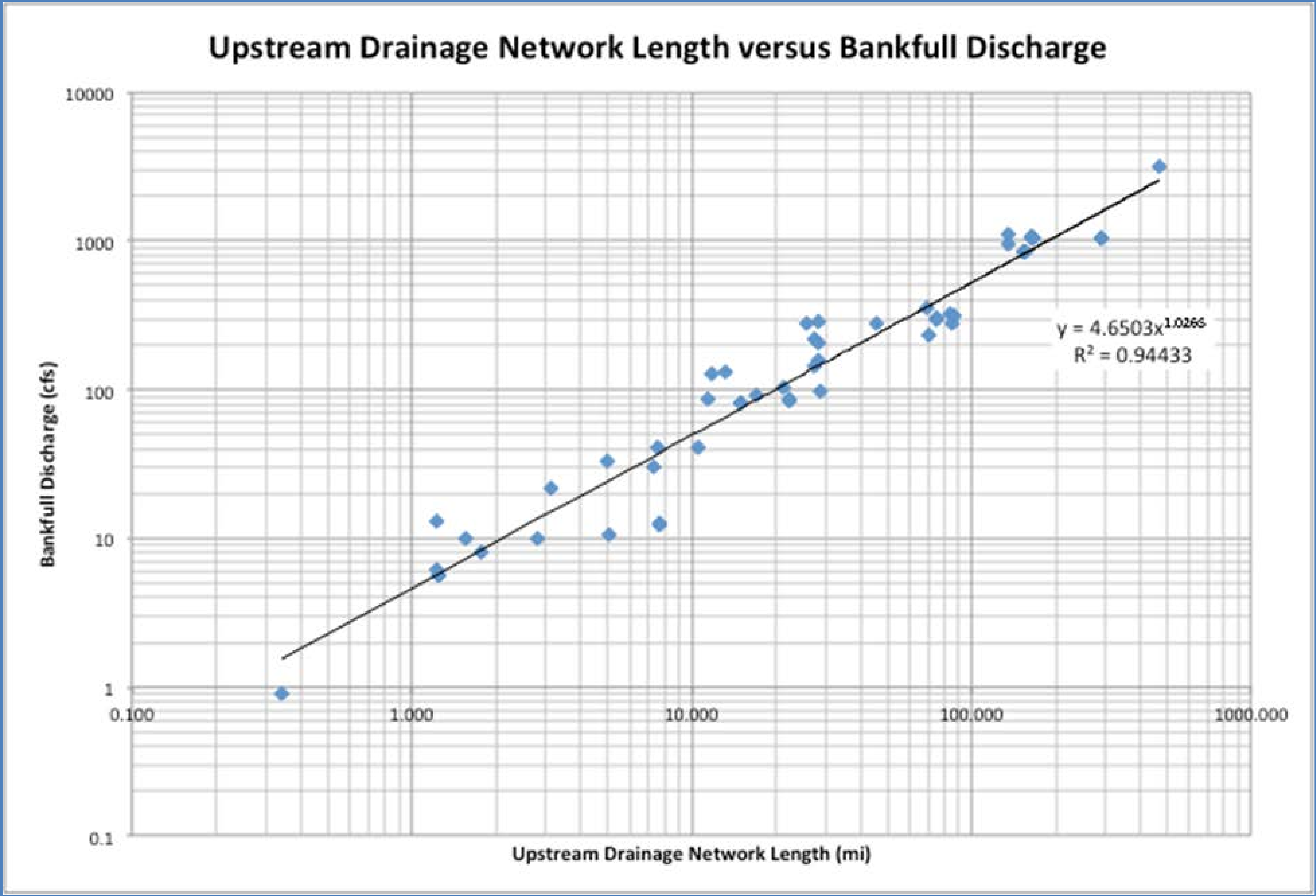
Regional Curve – Flood-Prone Width

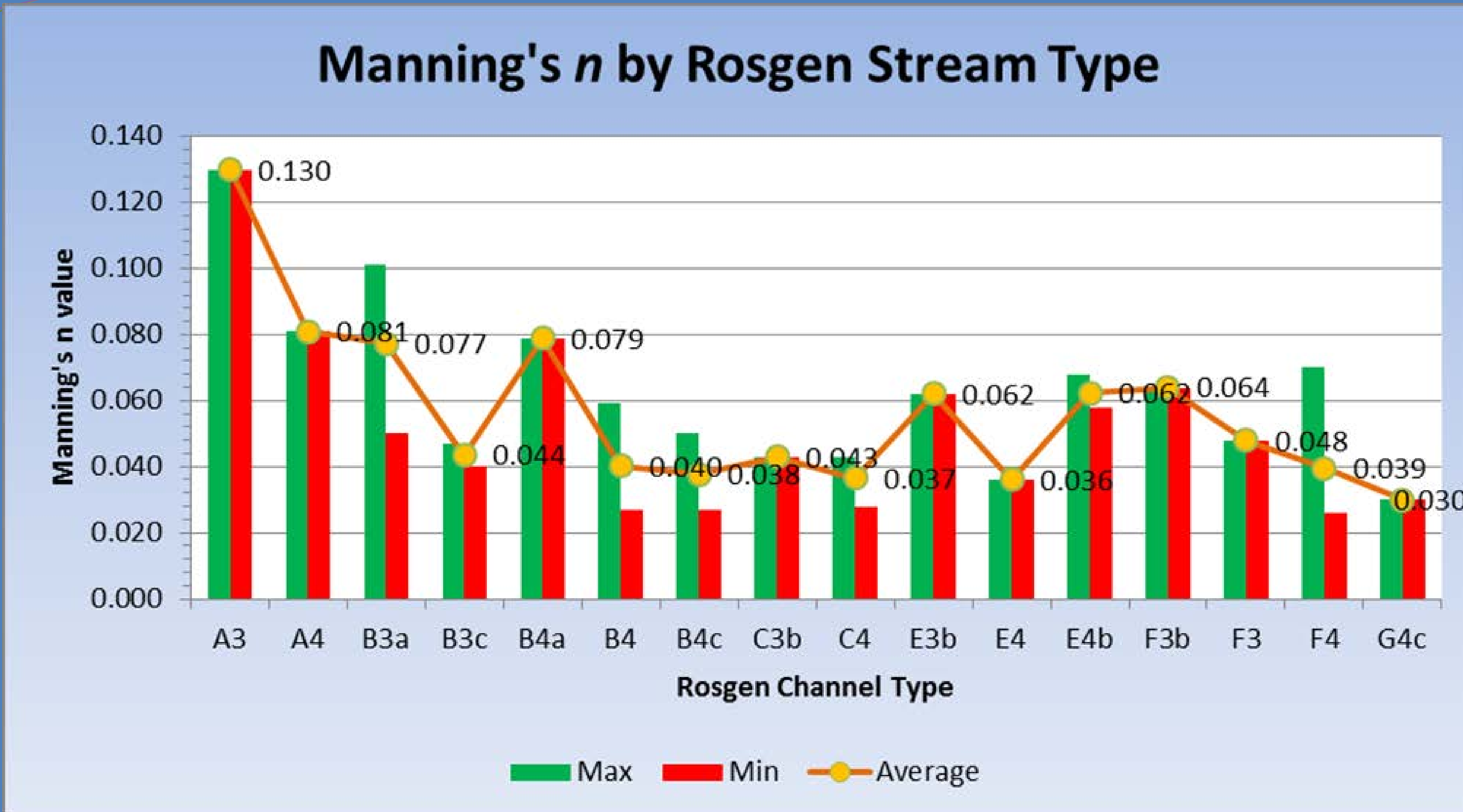


Regional Curve – Flood-Prone Width



Degree of Channelization





Manning's n by Rosgen Stream Type
Manning's n value
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0.130
0.081
0.077
0.079
0.044
0.040
0.038
0.043
0.037
0.062
0.036
0.062
0.064
0.048
0.039
0.030
A3
A4
B3a
B3c
B4a
B4
B4c
C3b
C4
E3b
E4
E4b
F3b
F3
F4
G4c
Rosgen Channel Type
Max
Min
Average

Next Steps

Looking for Phase II funding to:

- Perform more field survey at focus sites
- Statistical data analysis and segregation
- Look for riparian signature on floodplain (part of SFEI team) – focus on required floodplain width
- Assess water quality impacts of sediment production from channel erosion
- Prepare a formal methods and procedures guidance document
- Publish findings and prepare presentations of findings and use regional curves for creek restoration design and watershed analyses

Big Thanks To…

- Judy Kelly, Jennifer Krebs, Paula Trigueros and James Muller of SFEP
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- A.L. Riley of the RWQCB