Civil & Environmental Consultants, Inc.

2D Hydraulic Modelling of Instream Salmon Habitat

EcoStream 2018/ Sediment Sources and Modeling

Name

Presented By

Robert Stewart Ph.D.

Date August 16, 2018

CHAPTER 6

GOVERNING EQUATIONS

This chapter presents all governing equations used by SRH-2D. It provides theoretical information and is intended for reference only.

6.1 Flow Equations

Most open channel flows are relatively shallow and the effect of vertical motions is negligible. As a result, the most general flow equations, the three-dimensional Navier-Stokes equations, may be vertically averaged to obtain a set of depth-averaged two-dimensional equations, leading to the following well known 2D St. Venant equations:

$$\frac{\partial h}{\partial t}+\frac{\partial hU}{\partial x}+\frac{\partial hV}{\partial y}=e \tag{1}$$

$$\frac{\partial hU}{\partial t}+\frac{\partial hUU}{\partial x}+\frac{\partial hVU}{\partial y}=\frac{\partial hT_{xx}}{\partial x}+\frac{\partial hT_{xy}}{\partial y}-gh\frac{\partial z}{\partial x}-\frac{\tau_{bx}}{\rho}+D_{xx}+D_{xy} \tag{2}$$

$$\frac{\partial hV}{\partial t}+\frac{\partial hUV}{\partial x}+\frac{\partial hVV}{\partial y}=\frac{\partial hT_{xy}}{\partial x}+\frac{\partial hT_{yy}}{\partial y}-gh\frac{\partial z}{\partial y}-\frac{\tau_{by}}{\rho}+D_{yx}+D_{yy} \tag{3}$$

In the above, t is time, x and y are horizontal Cartesian coordinates, h is water depth, U and V are depth-averaged velocity components in x and y directions, respectively, e is excess rainfall rate, g is gravitational acceleration, T_{xx}, T_{xy}, and T_{yy} are depth-averaged turbulent stresses, $D_{xx}, D_{xy}, D_{yx}, D_{yy}$ are dispersion terms due to depth averaging, $z = z_b + h$ is water surface elevation, z_b is bed elevation, ρ is water density, and τ_{bx}, τ_{by} are the bed shear stresses (friction). Bed friction is calculated using the Manning's roughness equation as follows:

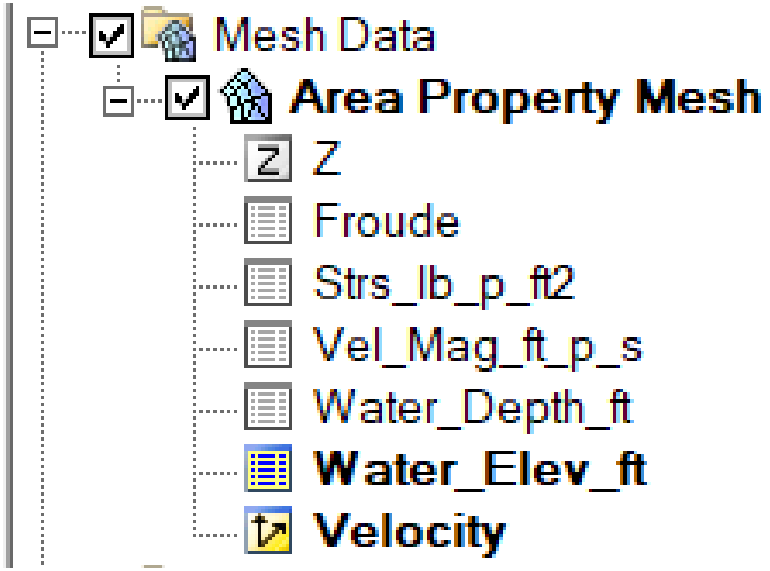
$$\begin{pmatrix}\tau_{bx}\\ \tau_{by}\end{pmatrix}=\rho C_f\begin{pmatrix}U\\ V\end{pmatrix}\sqrt{U^2+V^2}; \qquad C_f=\frac{gn^2}{h^{1/3}} \tag{4}$$

where n is the Manning's roughness coefficient.

Turbulence stresses are based on the Boussinesq equations as:

Salmon Habitat Prediction With SRH2D

- **INPUTS**
- **Topography**
- **Boundary conditions**
- **Roughness (n)**
- **Other ???**



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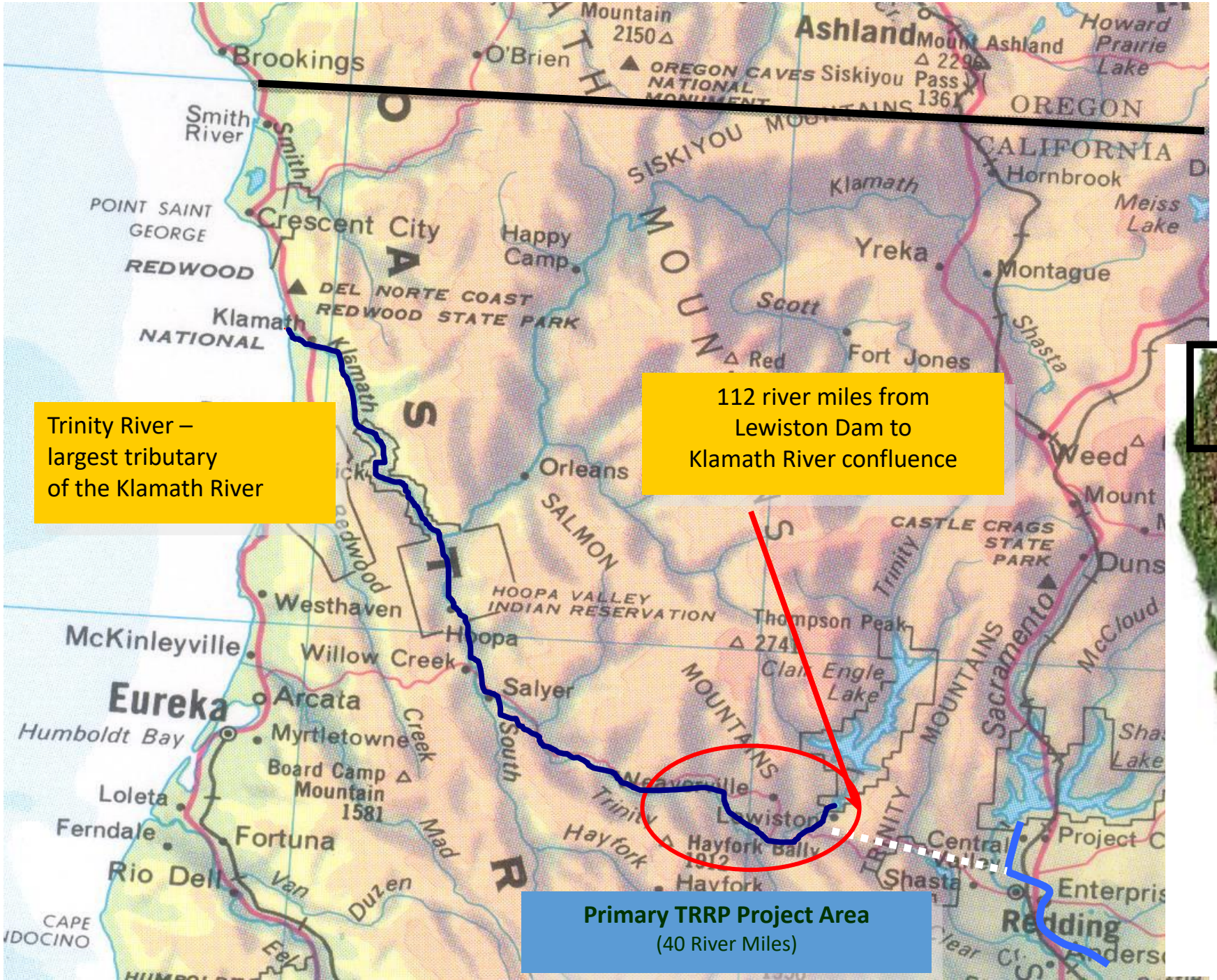
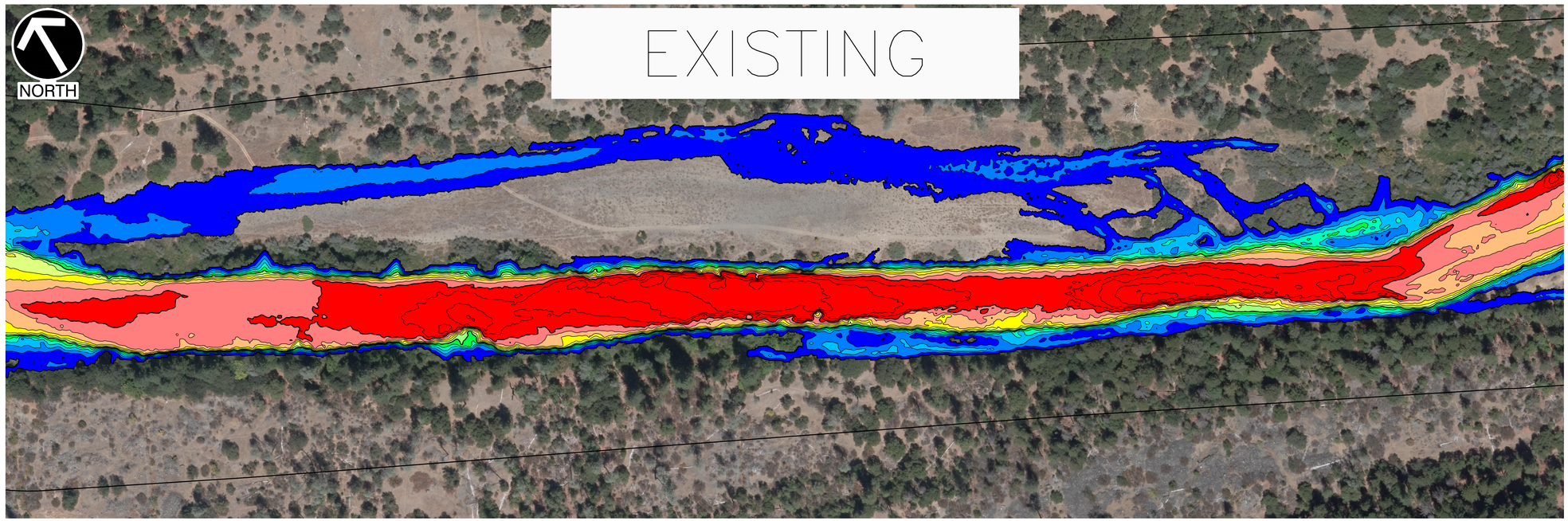

Brookings
O'Brien
Mountain 2150
Ashland
Mount Ashland
Howard Prairie Lake
OREGON CAVES NATIONAL MONUMENT
Siskiyou Pass
OREGON
CALIFORNIA
Smith River
Smith
SISKIYOU MOUNTAINS
Hornbrook
Klamath
Meiss Lake
POINT SAINT GEORGE
Crescent City
Happy Camp
Yreka
Montague
REDWOOD
DEL NORTE COAST REDWOOD STATE PARK
Klamath NATIONAL
Scott
Red
Fort Jones
Shasta
Trinity River – largest tributary of the Klamath River
112 river miles from Lewiston Dam to Klamath River confluence
Orleans
Weed
Mount
SALMON
CASTLE CRAGS STATE PARK
Dunsmuir
Redwood
Westhaven
HOOPA VALLEY INDIAN RESERVATION
Thompson Peak
McKinleyville
Hoopa
Willow Creek
Clair Engle Lake
Sacramento
McCloud
Eureka
Arcata
Salyer
Humboldt Bay
Myrtletowne
Creek
South
MOUNTAINS
Board Camp Mountain 1581
Loleta
Ferndale
Fortuna
Trinity
Hayfork
Hayfork Bally
Mad
Central
Project C
Rio Dell
Van Duzen
Shasta
Enterpris
Redding
CAPE MENDOCINO
Eel
Primary TRRP Project Area
(40 River Miles)
Sacramento

FLOW DEPTH AT 8000 CFS

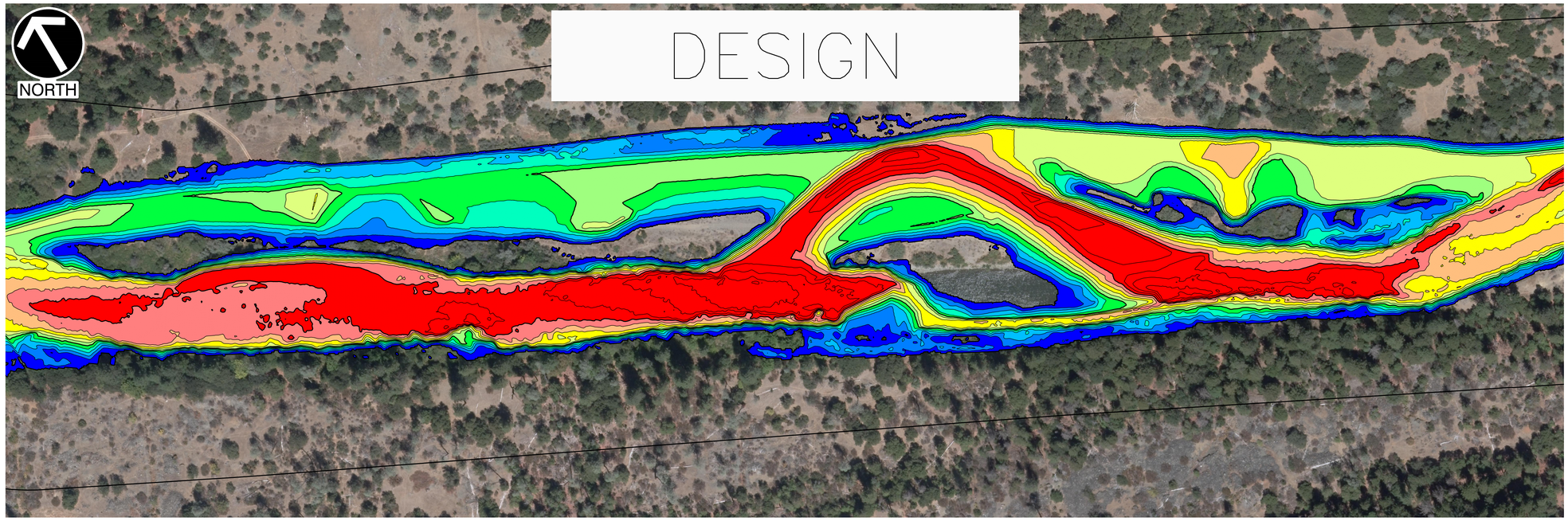
EXISTING



SCALE IN FEET

0 100 200

DESIGN

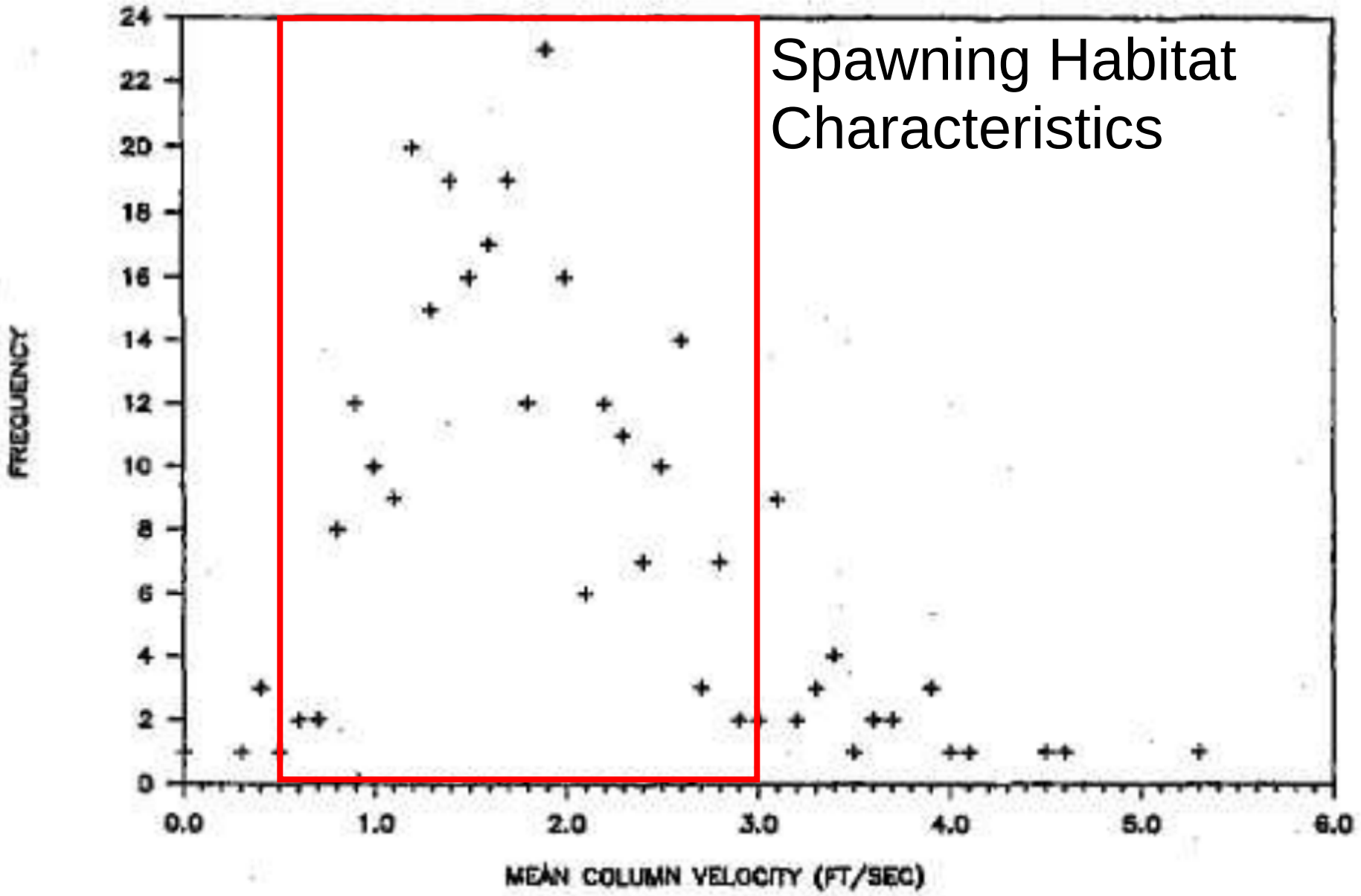


SCALE IN FEET

0 100 200

LEGEND

FLOW DEPTH
0.0 – 1.0 FT
1.0 – 2.0 FT
2.0 – 3.0 FT
3.0 – 4.0 FT
4.0 – 5.0 FT
5.0 – 6.0 FT
6.0 – 7.0 FT
7.0 – 8.0 FT
8.0 – 9.0 FT
9.0 – 10 FT
10 – 99 FT


Spawning Habitat Characteristics
FREQUENCY
0
2
4
6
8
10
12
14
16
18
20
22
24
0.0
1.0
2.0
3.0
4.0
5.0
6.0
MEAN COLUMN VELOCITY (FT/SEC)

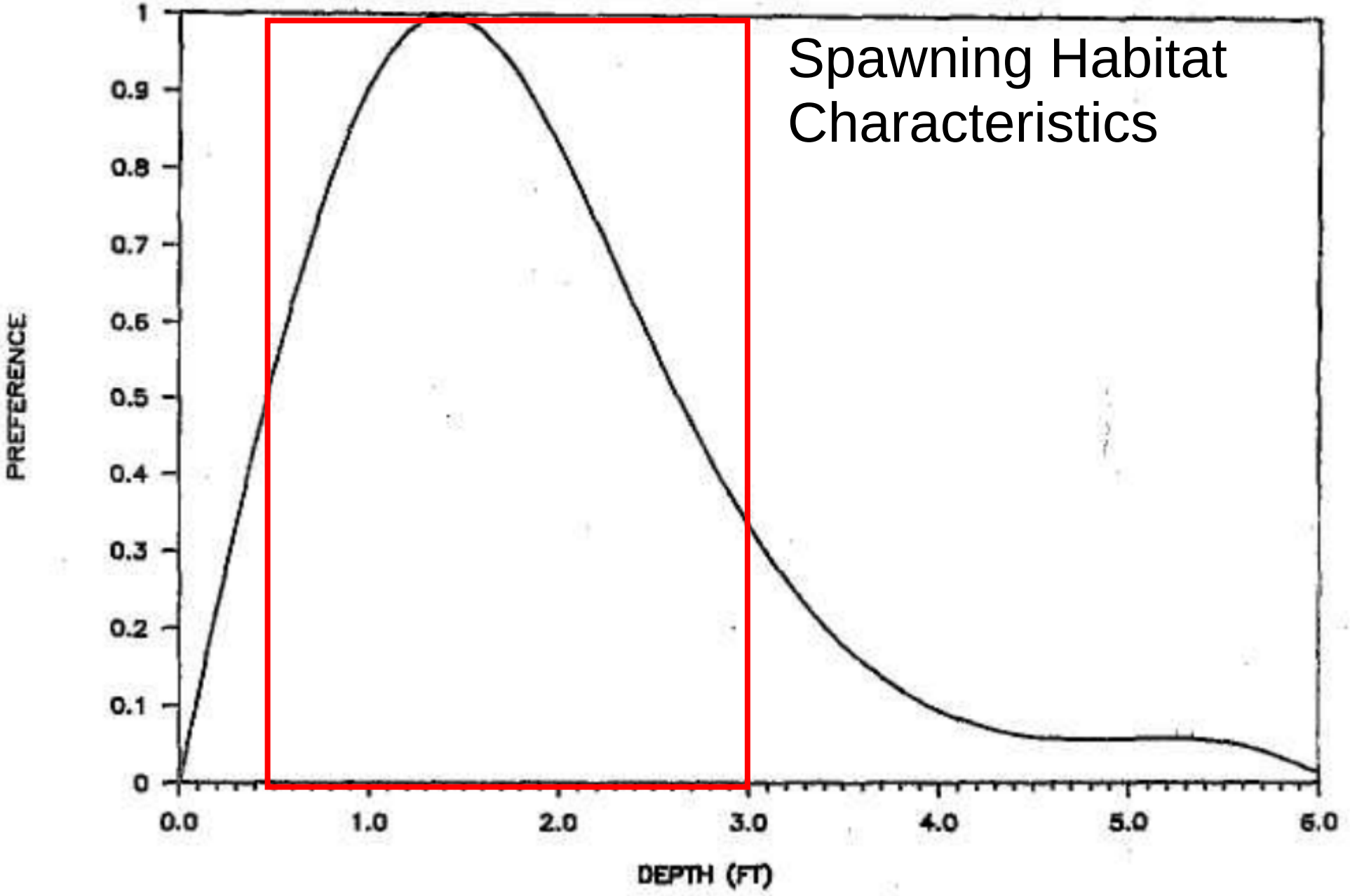
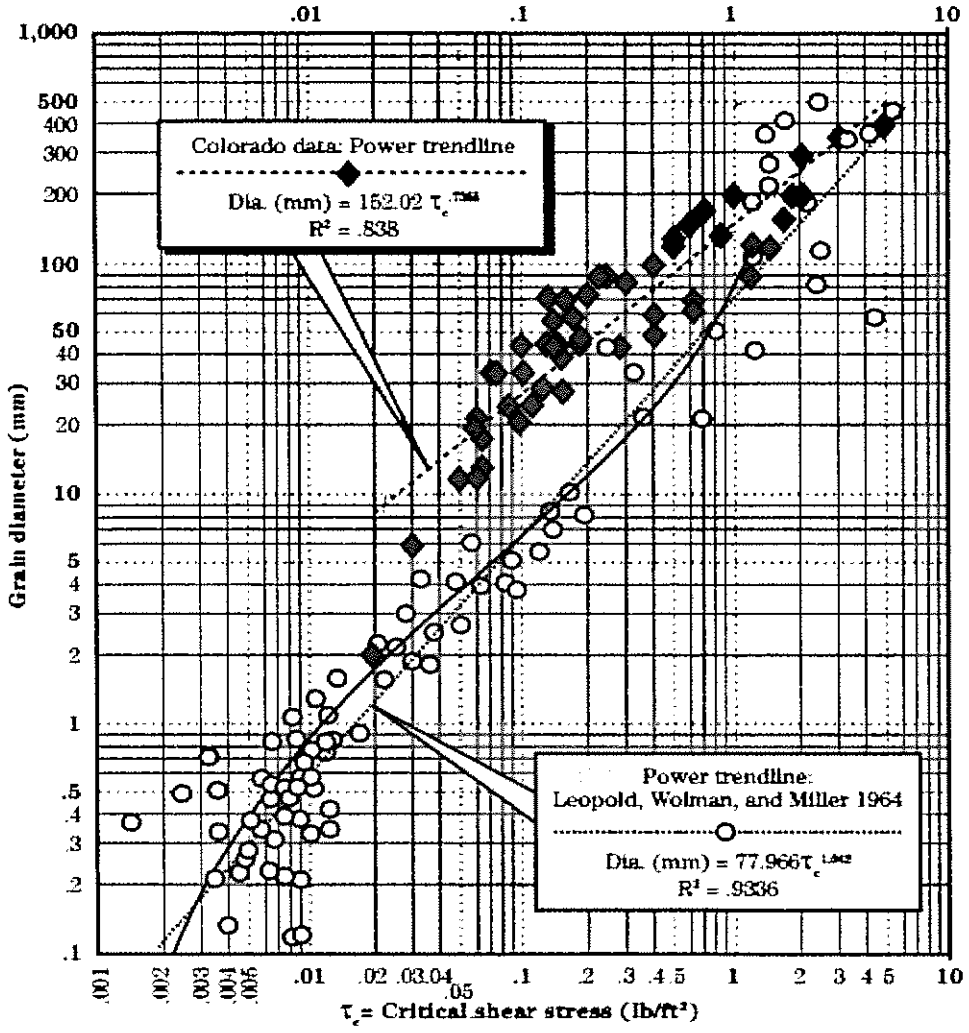
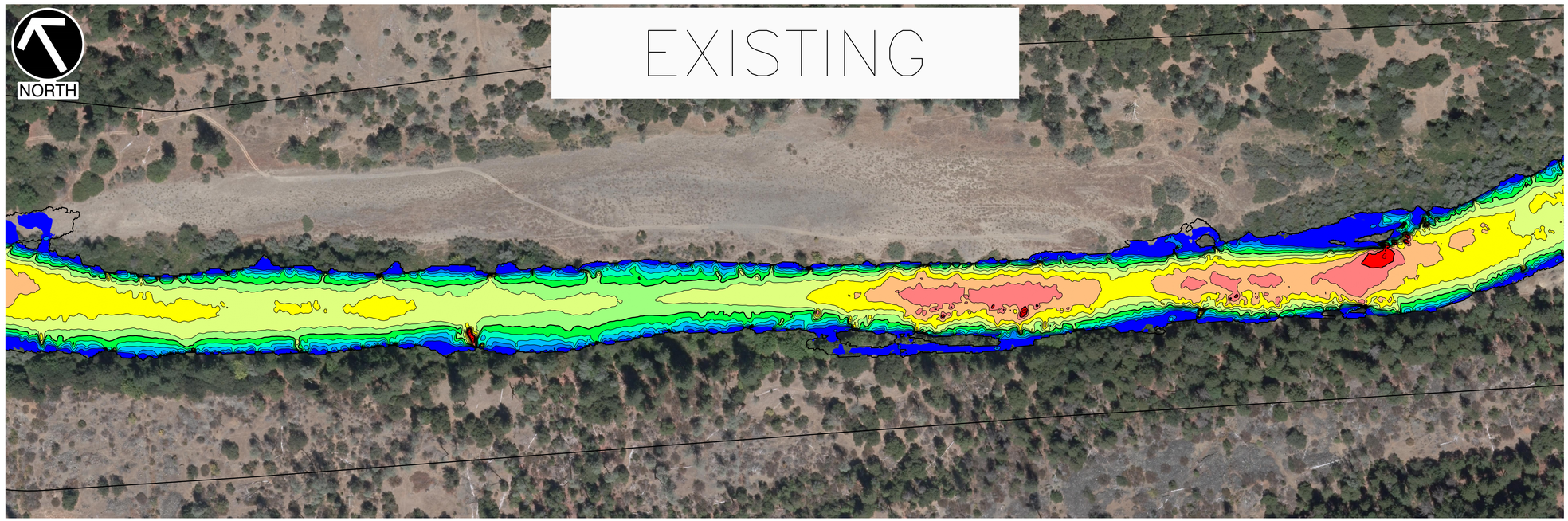

Spawning Habitat Characteristics
PREFERENCE
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
DEPTH (FT)

Figure 11–11 Relation between grain diameter for entrainment and shear stress using Shields relations



SHEAR STRESS AT 6000 CFS

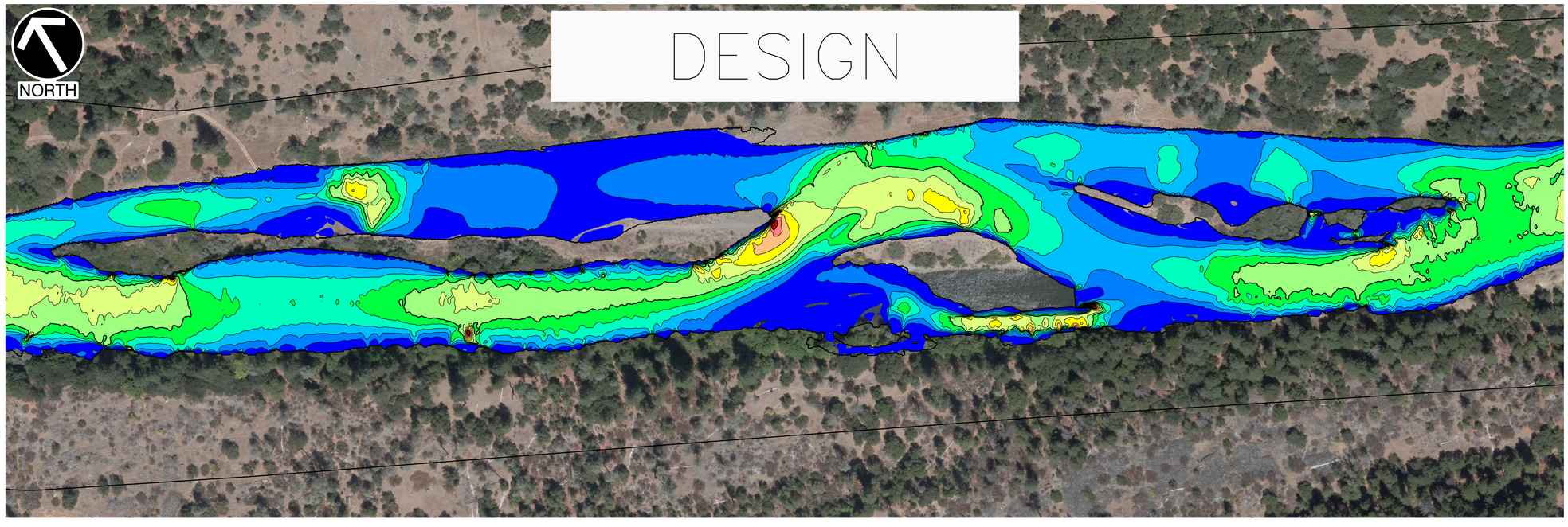
EXISTING



SCALE IN FEET

0 100 200

DESIGN



SCALE IN FEET

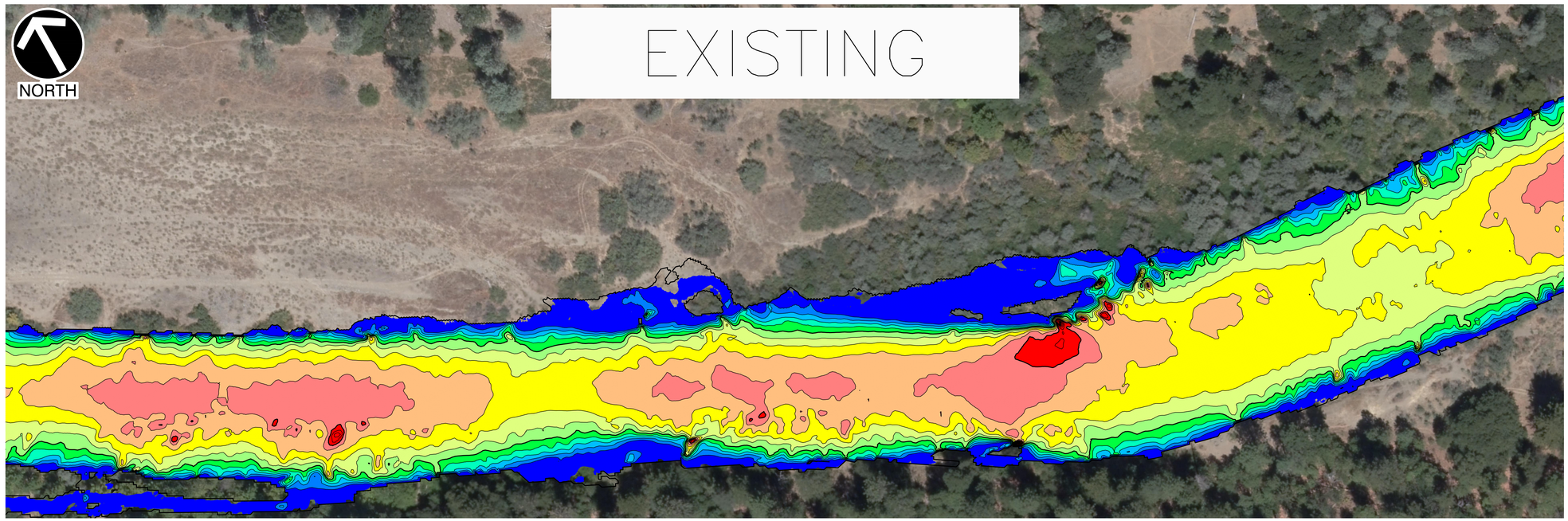
0 100 200

LEGEND

	SHEAR STRESS
	0.0 – 0.1 PSF
	0.1 – 0.2 PSF
	0.2 – 0.3 PSF
	0.3 – 0.4 PSF
	0.4 – 0.5 PSF
	0.5 – 0.6 PSF
	0.6 – 0.7 PSF
	0.7 – 0.8 PSF
	0.8 – 0.9 PSF
	0.9 – 1 PSF
	1 – 99 PSF

SHEAR STRESS AT 6000 CFS

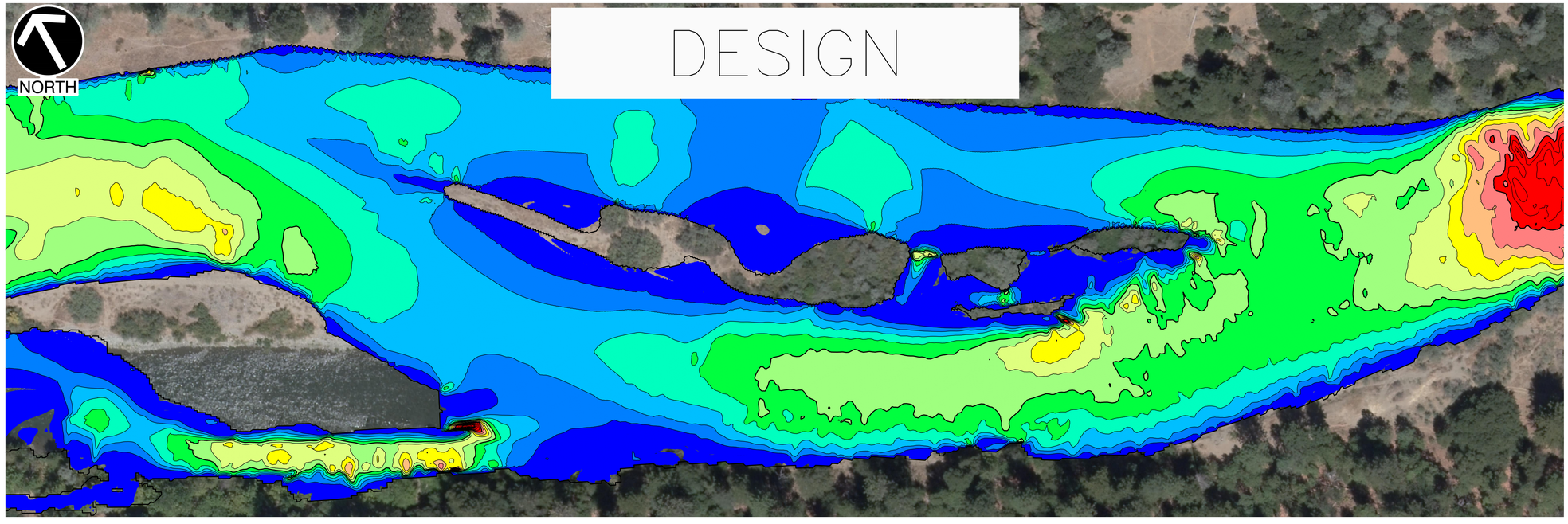
EXISTING



SCALE IN FEET

0 50 100

DESIGN



SCALE IN FEET

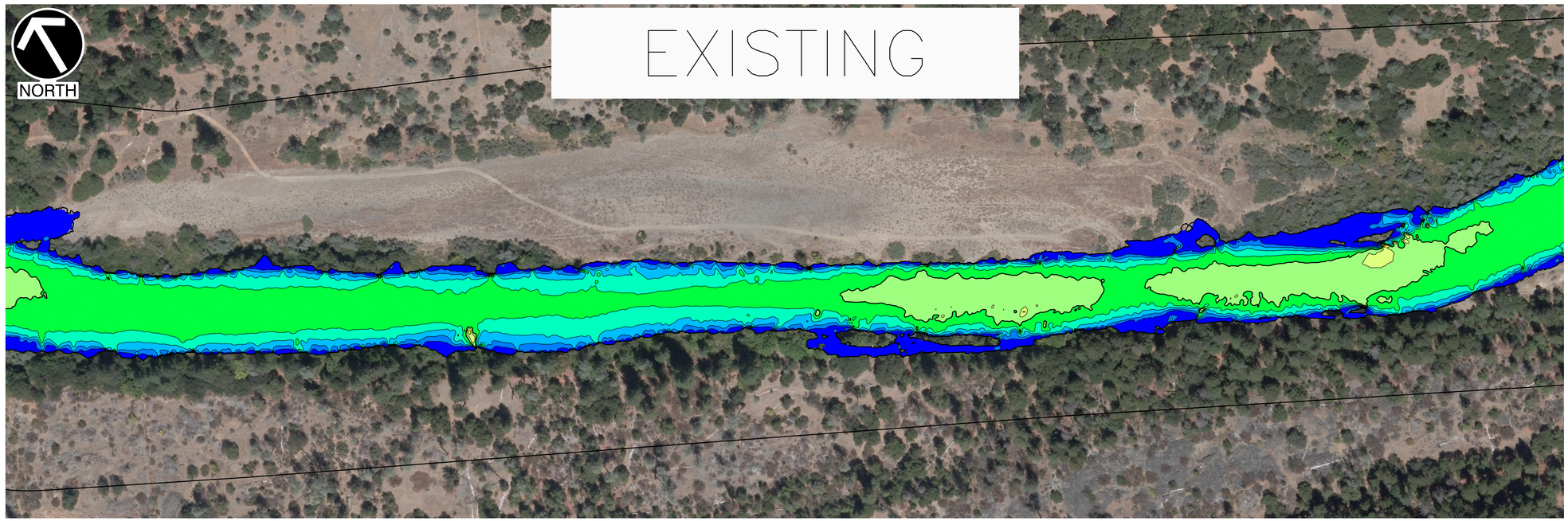
0 50 100

LEGEND

SHEAR STRESS
0.0 – 0.1 PSF
0.1 – 0.2 PSF
0.2 – 0.3 PSF
0.3 – 0.4 PSF
0.4 – 0.5 PSF
0.5 – 0.6 PSF
0.6 – 0.7 PSF
0.7 – 0.8 PSF
0.8 – 0.9 PSF
0.9 – 1 PSF
1 – 99 PSF

MOBILIZED D50 AT 6000 CFS

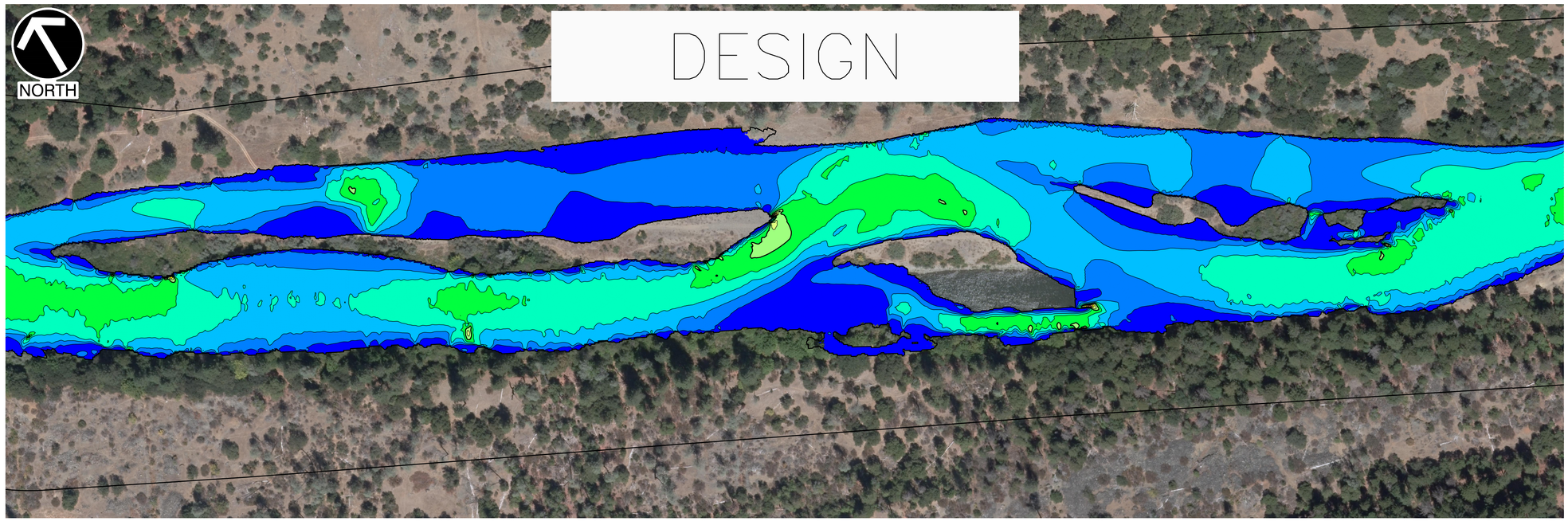
EXISTING



SCALE IN FEET

0 50 100

DESIGN

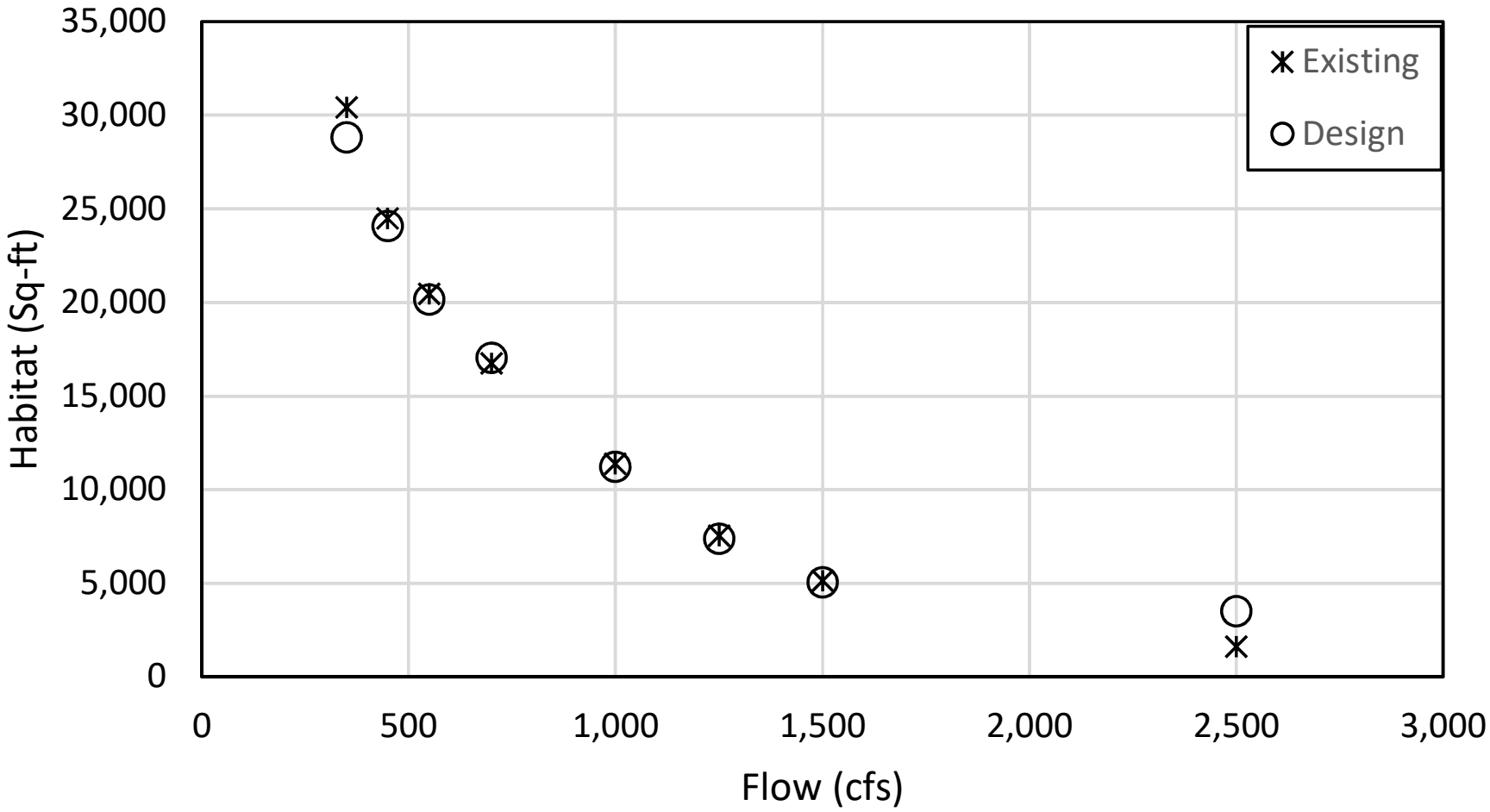


SCALE IN FEET

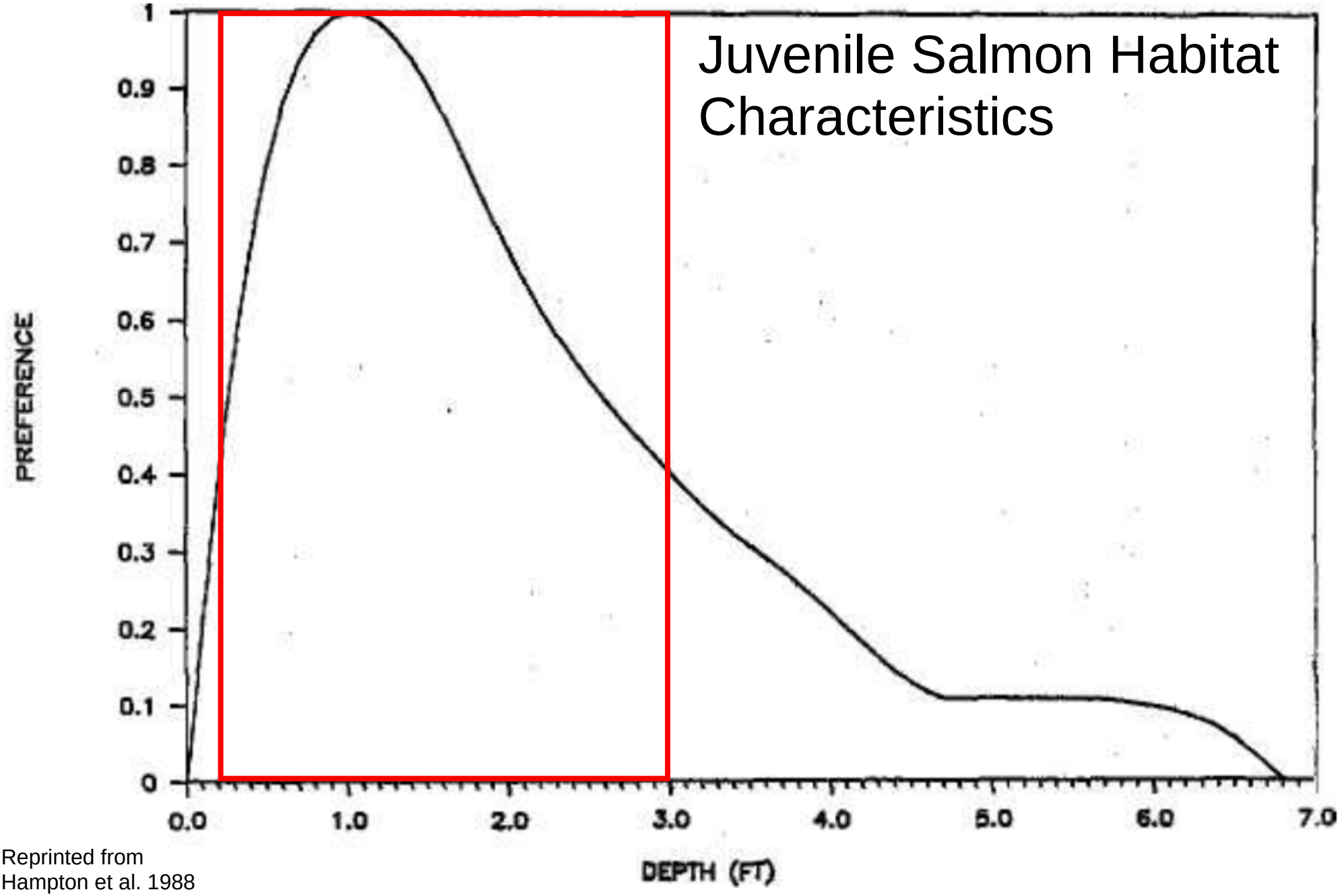
0 50 100

LEGEND

D50 INCHES
0.0 – 1.0 IN
1.0 – 2.0 IN
2.0 – 3.0 IN
3.0 – 4.0 IN
4.0 – 5.0 IN
5.0 – 6.0 IN
6.0 – 7.0 IN
7.0 – 8.0 IN
8.0 – 9.0 IN
9.0 – 10 IN
10 – 99 IN

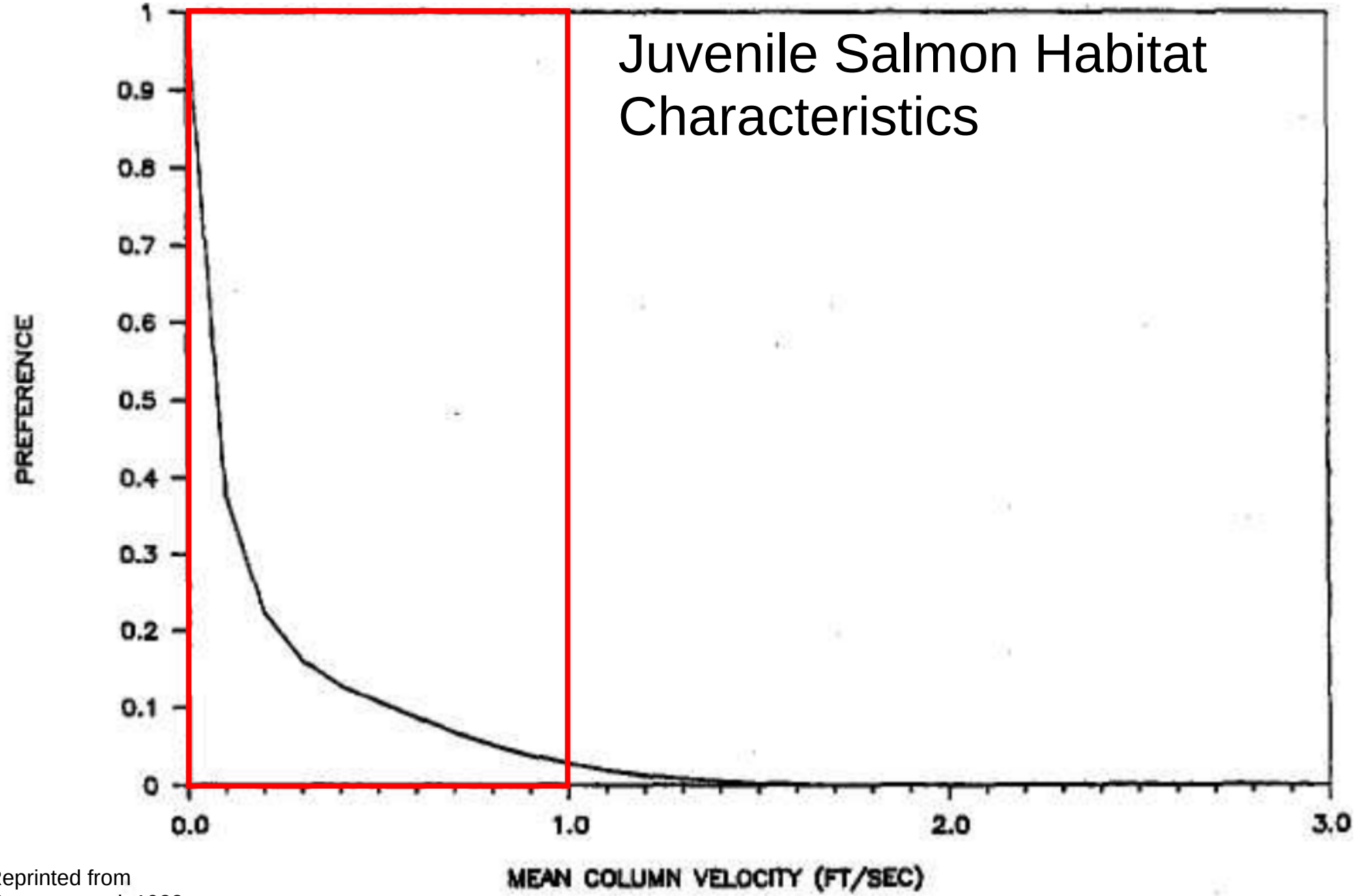

35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Habitat (Sq-ft)
0
500
1,000
1,500
2,000
2,500
3,000
Flow (cfs)
Existing
Design

Juvenile Salmon Habitat Characteristics

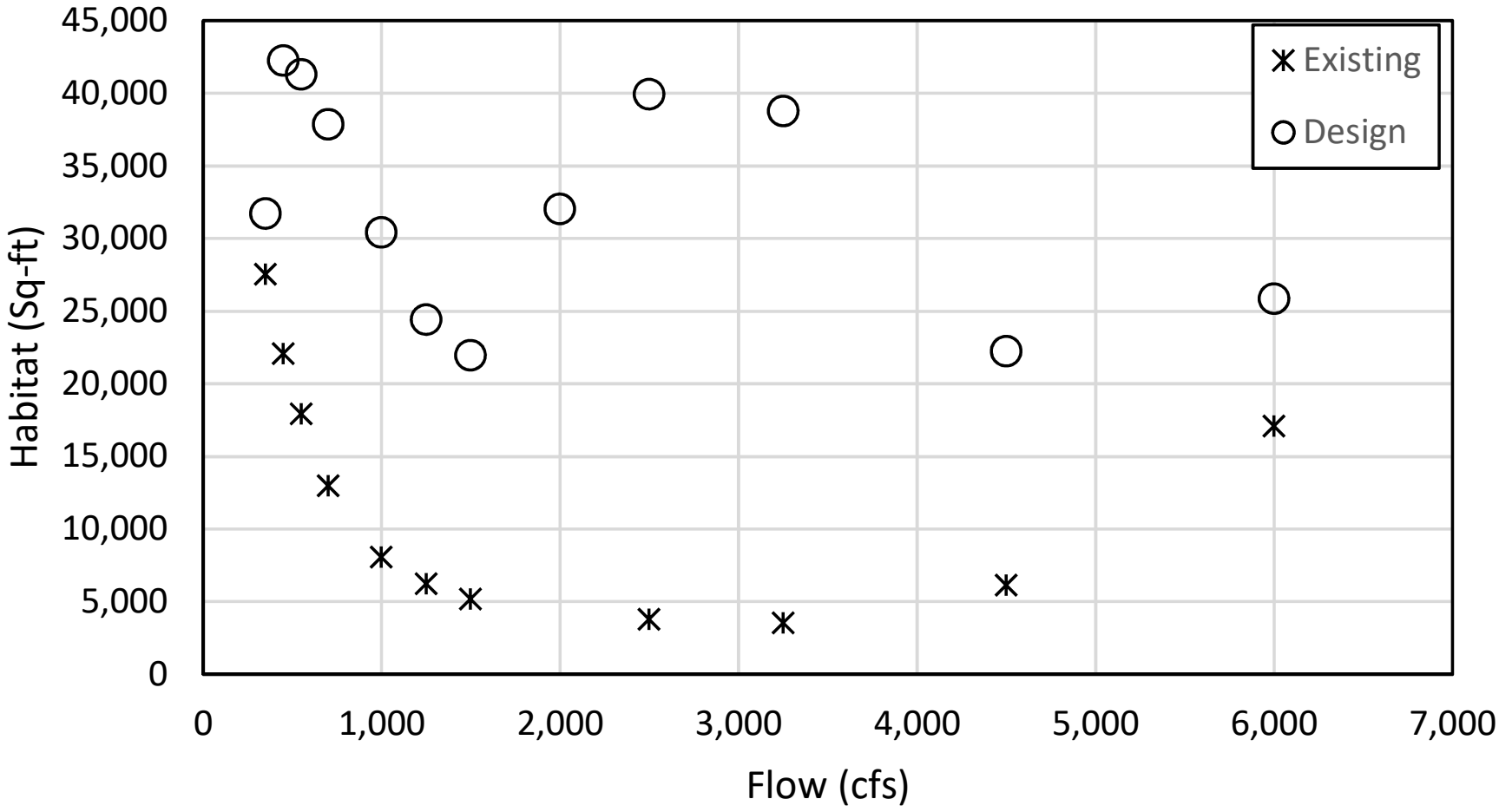


Reprinted from
Hampton et al. 1988

Juvenile Salmon Habitat Characteristics



Reprinted from
Hampton et al. 1988


45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Habitat (Sq-ft)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Flow (cfs)
Existing
Design

FRY HABITAT AT 350 CFS

FRY HABITAT AT 450 CFS

FRY HABITAT AT 550 CFS

EXISTING

SCALE IN FEET

0 50 100

DESIGN

SCALE IN FEET

0 50 100

FRY HABITAT AT 700 CFS

EXISTING

SCALE IN FEET

0 50 100

DESIGN

SCALE IN FEET

0 50 100

FRY HABITAT AT 1000 CFS

SCALE IN FEET

0 50 100

SCALE IN FEET

0 50 100

FRY HABITAT AT 1250 CFS

EXISTING

SCALE IN FEET

0 50 100

DESIGN

SCALE IN FEET

0 50 100

FRY HABITAT AT 2500 CFS

EXISTING

SCALE IN FEET

0 50 100

DESIGN

SCALE IN FEET

0 50 100

FRY HABITAT AT 3250 CFS

SCALE IN FEET

0 50 100

SCALE IN FEET

0 50 100

FRY HABITAT AT 4500 CFS

EXISTING

SCALE IN FEET

0 50 100

DESIGN

SCALE IN FEET

0 50 100

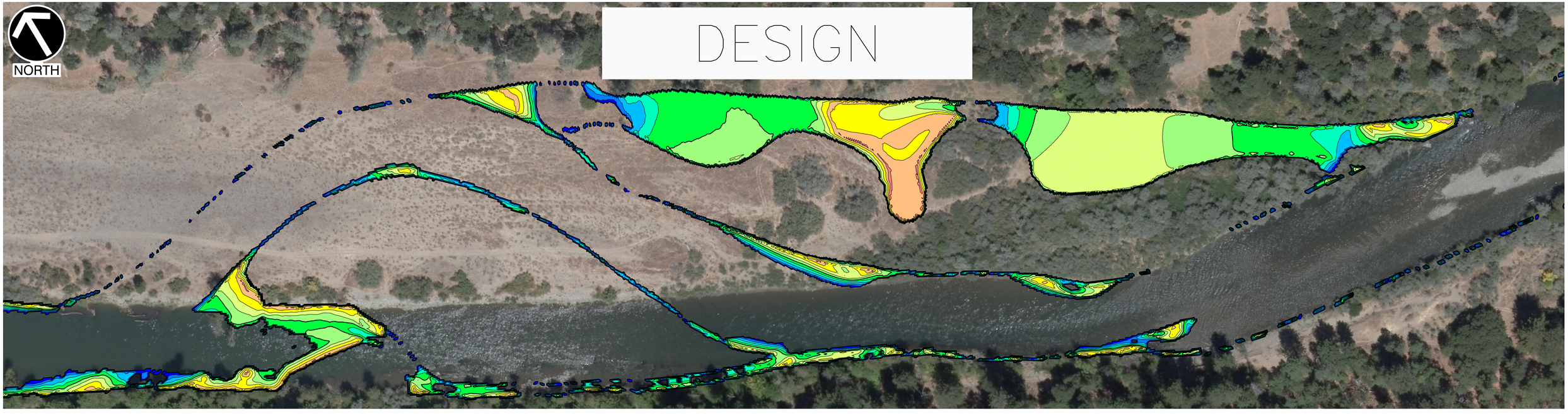
FRY HABITAT AT 700 CFS

EXISTING

SCALE IN FEET

0 50 100

DESIGN



SCALE IN FEET

0 50 100

Questions?

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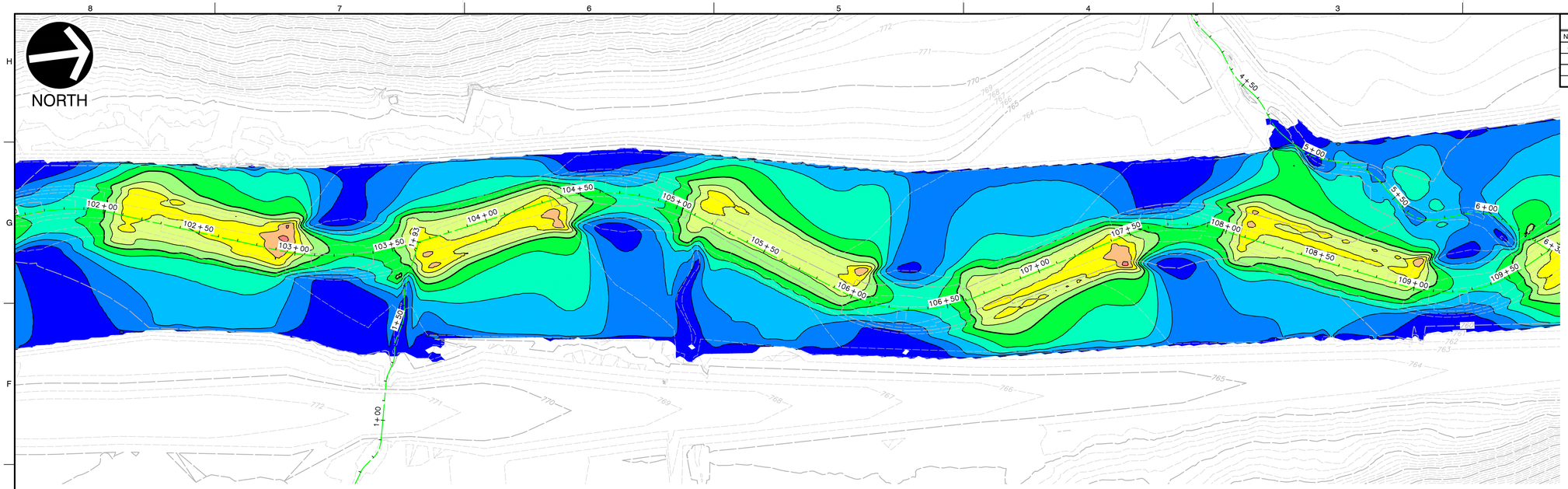
SUBMITTAL & REVISION RECORD

NO	DATE	DESCRIPTION
1	02/2016	SUBMITTED FOR PERMITS

NORTH



PLAN
SCALE IN FEET
0 20 40

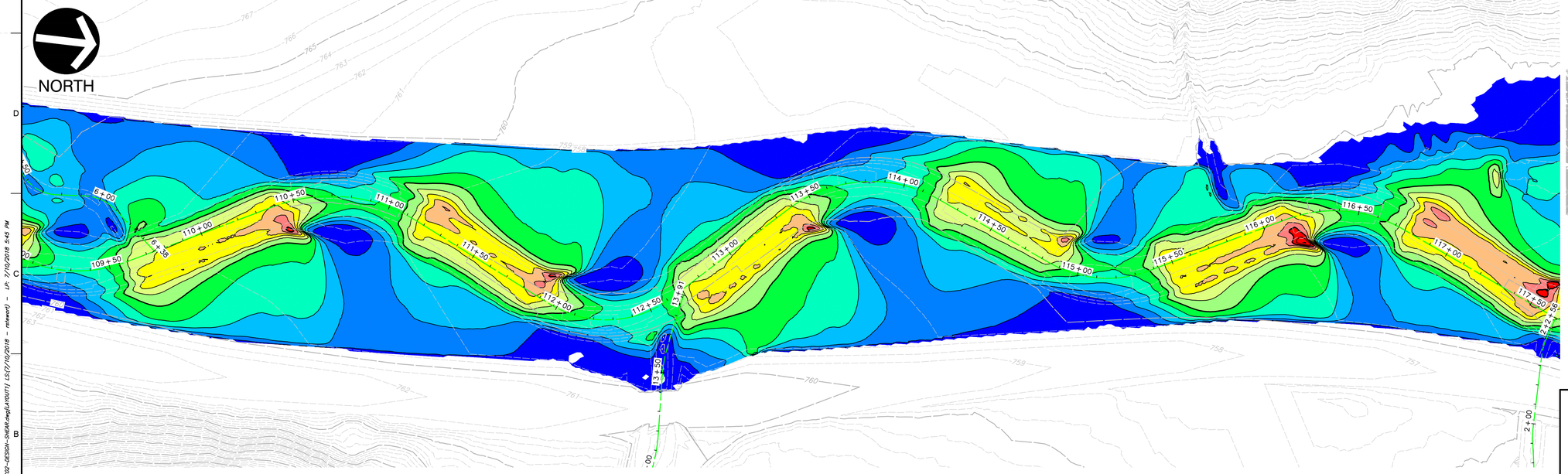
LEGEND

- 850 — PROPOSED INDEX CONTOUR
- 1030 — SHEAR STRESS INDEX CONTOUR
- PROPOSED BANKFULL
- PROPOSED STREAM CHANNEL

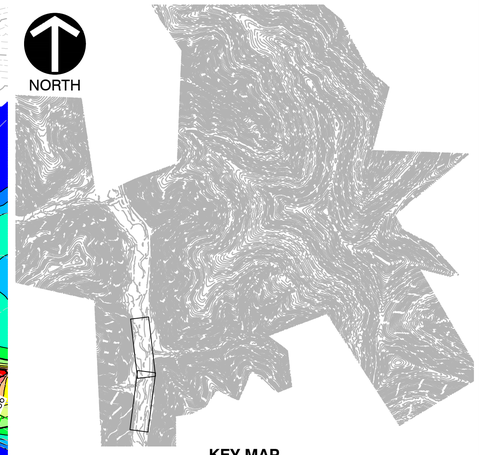
HEAT MAP LEGEND

SHEAR STRESS
0.0 – 0.2 PSF
0.2 – 0.4 PSF
0.4 – 0.6 PSF
0.6 – 0.8 PSF
0.8 – 1.0 PSF
1.0 – 1.2 PSF
1.2 – 1.4 PSF
1.4 – 1.6 PSF
1.6 – 1.8 PSF
1.8 – 2.0 PSF
2.0 – 99 PSF

NORTH



PLAN
SCALE IN FEET
0 20 40



KEY MAP
SCALE IN FEET
0 1000 2000

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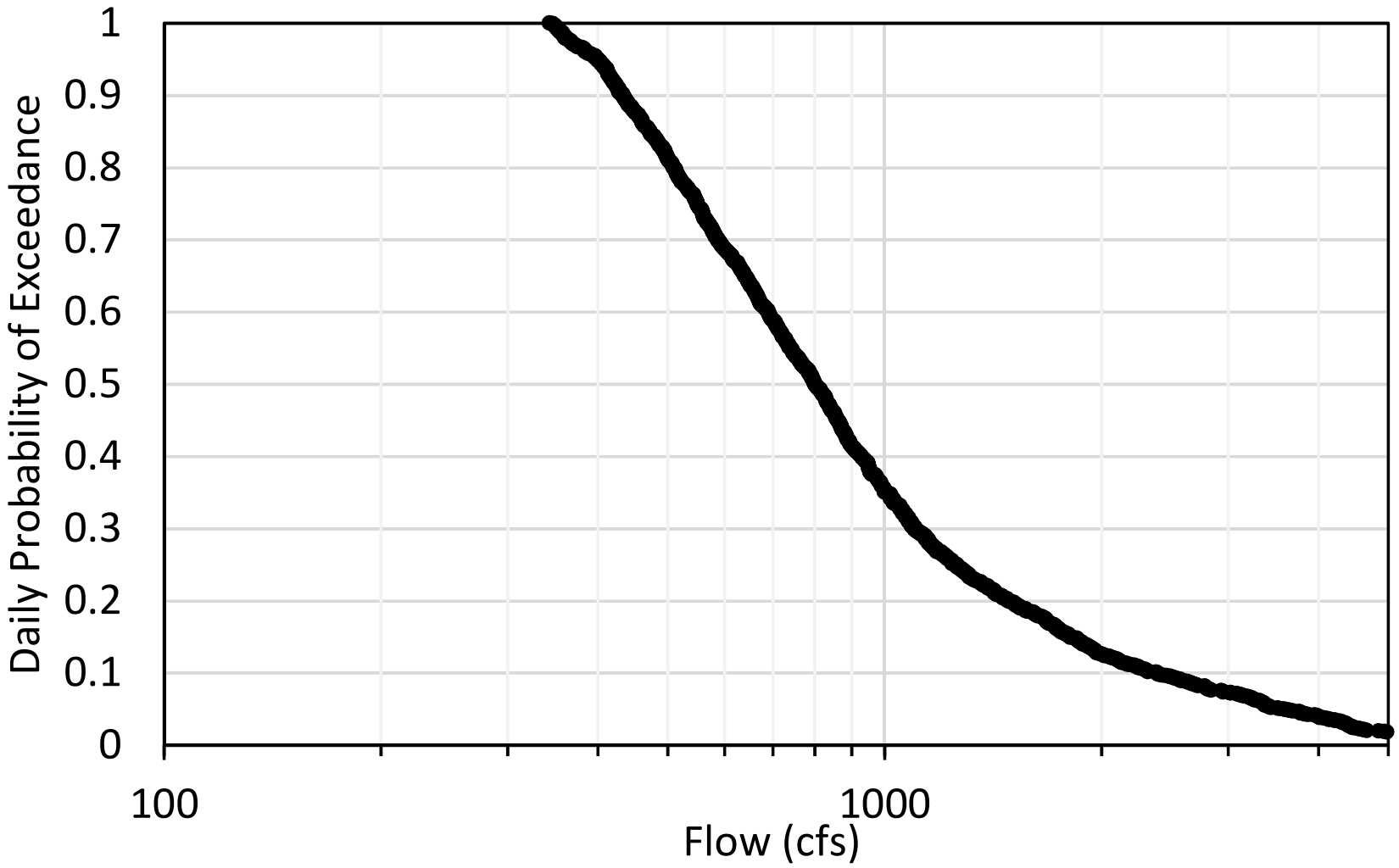
www.cecinc.com

REFERENCE

1. EXISTING TOPOGRAPHIC INFORMATION TAKEN FROM A COMBINATION OF TERRESTRIAL LIDAR SCANNING COLLECTED BY CIVIL & ENVIRONMENTAL CONSULTANTS, INC. AND AERIAL MAPPING PROVIDED BY KEDDAL AERIAL MAPPING.
2. PROPERTY LINES BASED UPON DEED DESCRIPTION AND FIELD VERIFIED BOUNDARY EVIDENCE.
3. HORIZONTAL DATUM IS WV STATE PLANE NORTH ZONE NAD '83(2011).
4. VERTICAL DATUM IS NAVD88(GEOID12B)

PRELIMINARY
NOT FOR CONSTRUCTION


Daily Probability of Exceedance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
1000
Flow (cfs)