Design criteria for instream large wood

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Precursors of this presentation

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Natural Resources Conservation Service

Part 654
National Engineering Handbook

Stream Restoration Design

Technical Supplement 14J

Use of Large Woody Material for Habitat and Bank Protection

Large wood is not for everybody

- Should address an existing habitat deficiency
- Channel stability—Goldilocks
  - Not too unstable
  - Not too stable
  - Slightly aggradational, with toe erosion primary bank erosion process
- Raw material (large wood) availability
- Site access for heavy equipment
- Conveyance should permit some LW
- Navigation, recreation
- Downstream infrastructure

If LW is for you, you must decide….

- What kind to use (species, dimensions)
- Where to get it, and how to get it to site
- What kind of structure to create
- What dimensions to use for structure and spacing between structures
- Anchoring or not
- Impact (effects) analysis
  - Conveyance
  - Sediment transport, deposition, scour
  - Habitat

Design basis

- Geomorphic analysis
- Biological analysis
- Site design
  - Professional judgment
  - Force and moment computations
  - Reach-scale flow/sediment modeling
  - Some combination

Failure definition

- Structure transported away
- Structure causes undesirable erosion or deposition
- Structure fails to provide habitat benefit

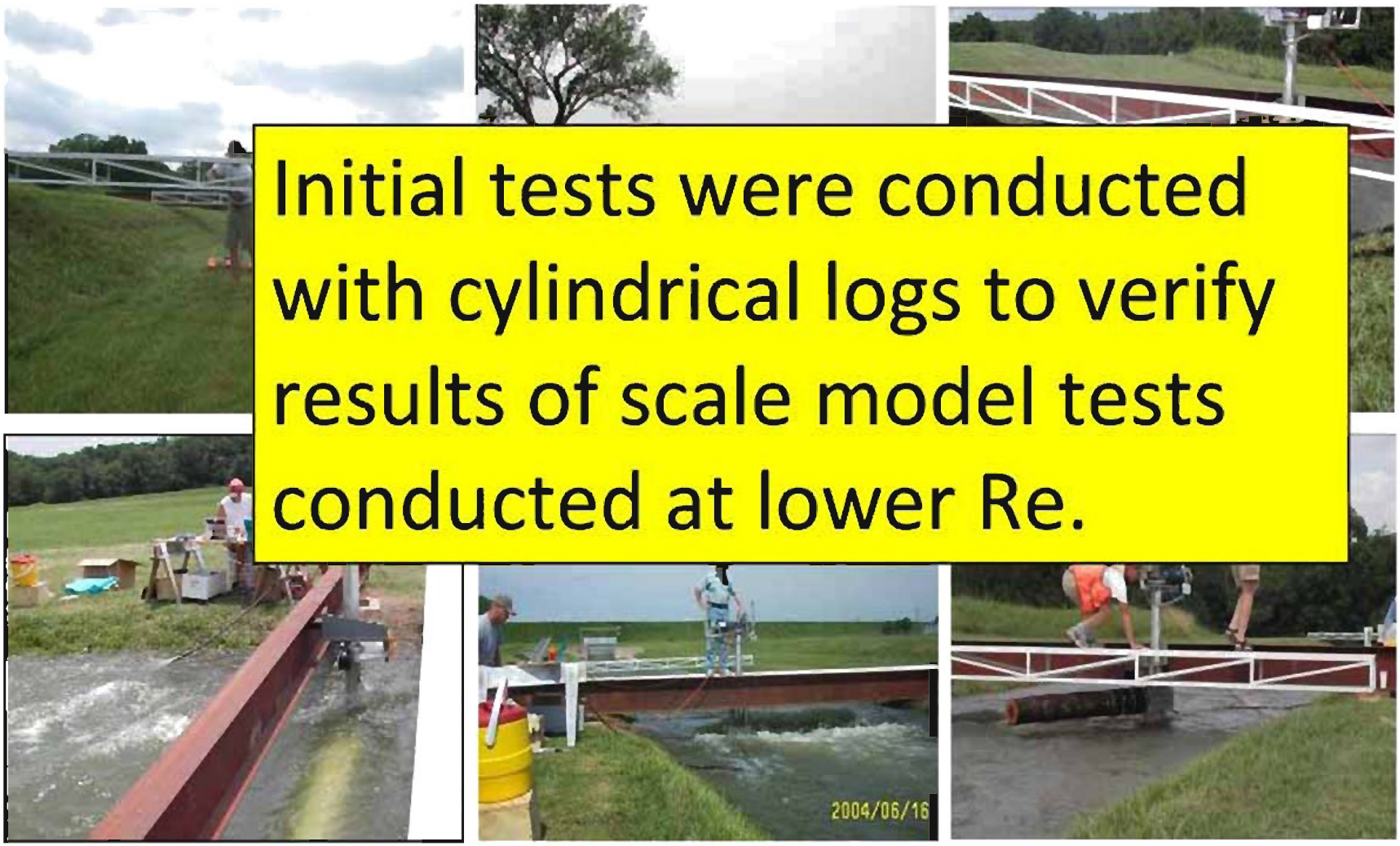
What is the design condition?

- Peak Q for design life
- Bankfull discharge—highest velocity
- Prolonged high flow
- Just barely overtopped after long dry period
  - Maximum wave drag
  - Maximum buoyant force

Based on design condition, select values for…..

- Wood density (0.4 to 0.5 x ρ_w)
- Drag coefficient (up to 6)
- Lift coefficient (-4 to 31)
- Soil strength (nil to …….)
- Safety factor (Do you feel lucky?)
- Design life for wood (very regional)

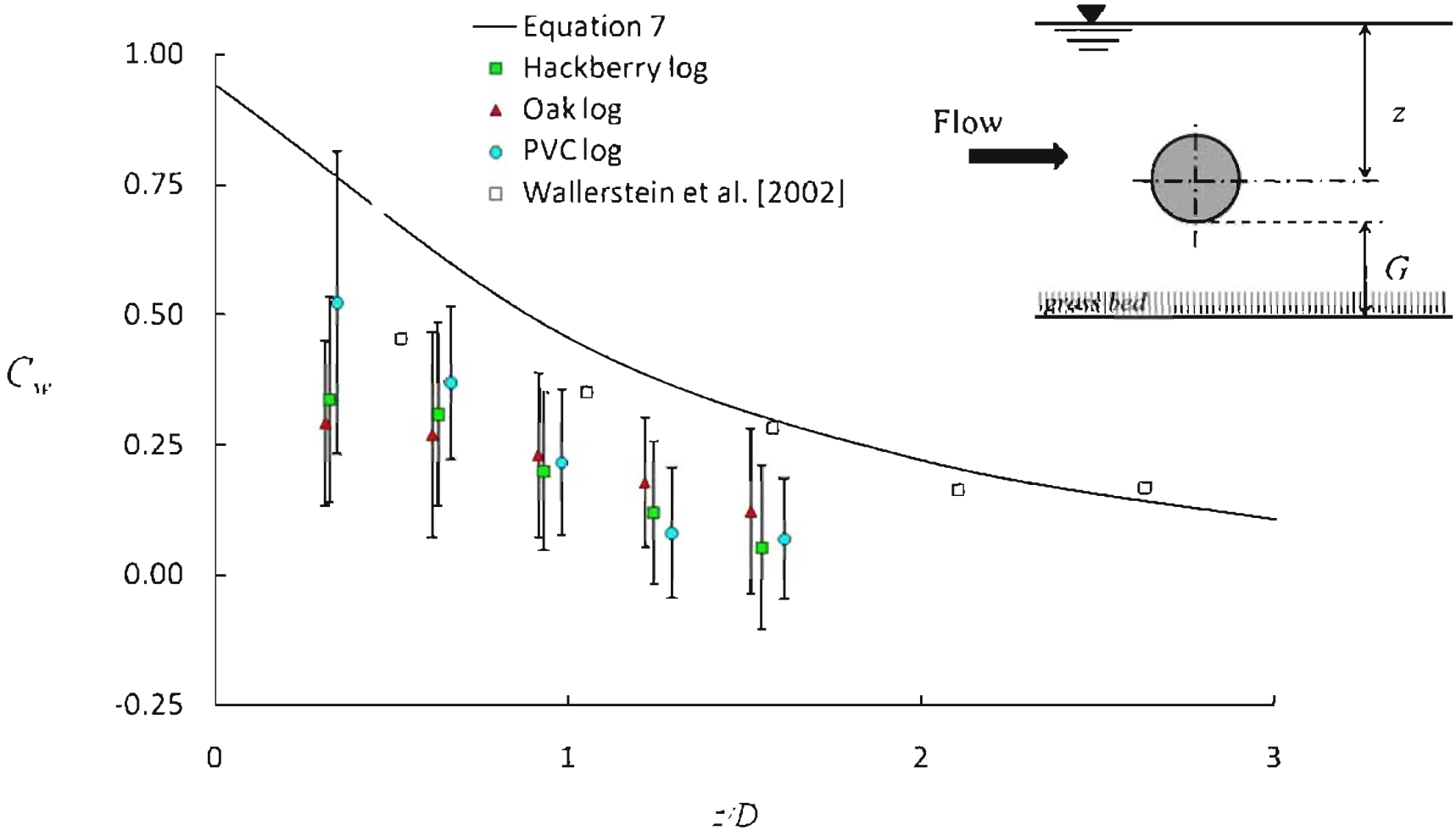
LW Tests Conducted in Stillwater, OK, Grassed Channel

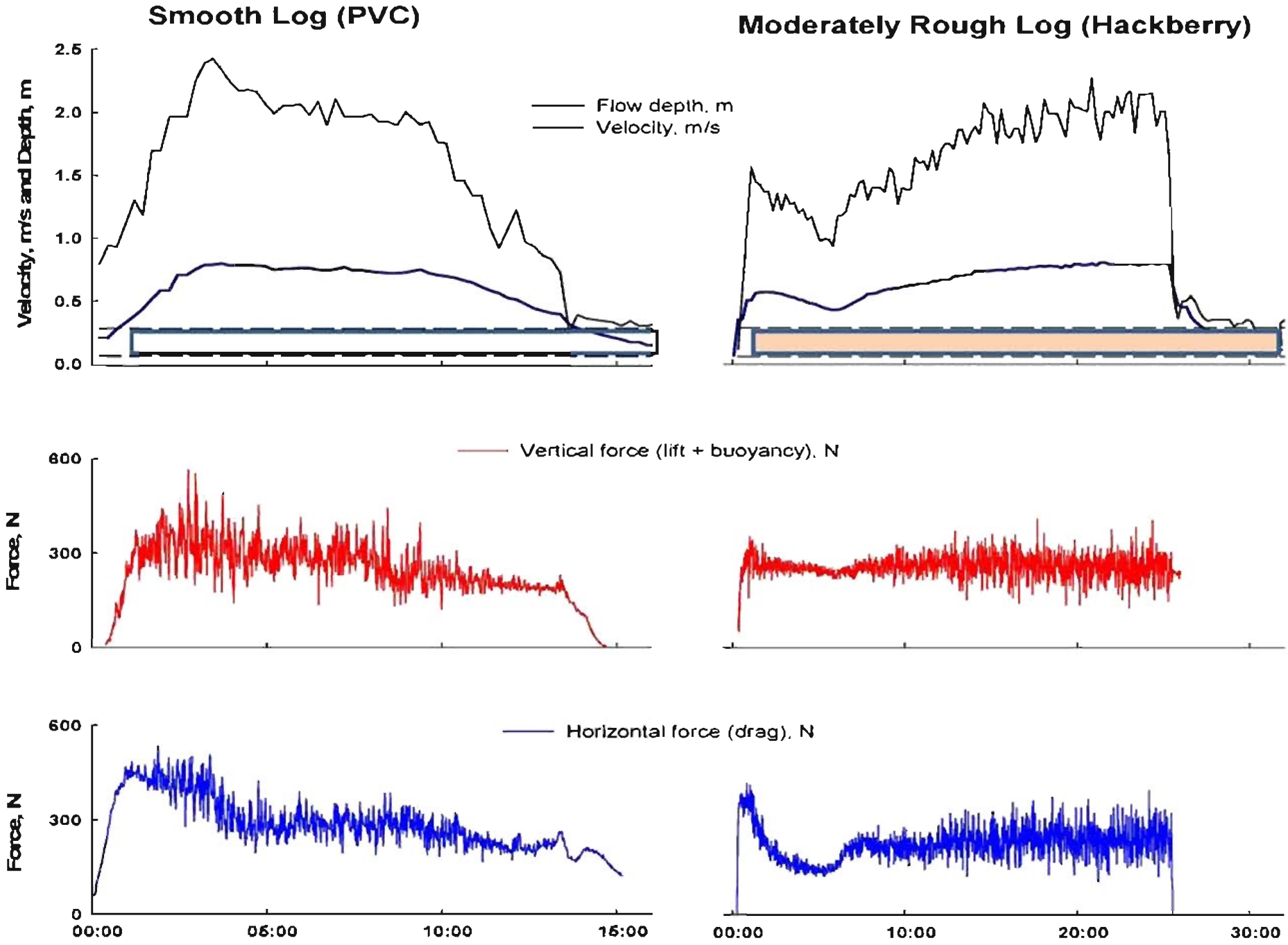


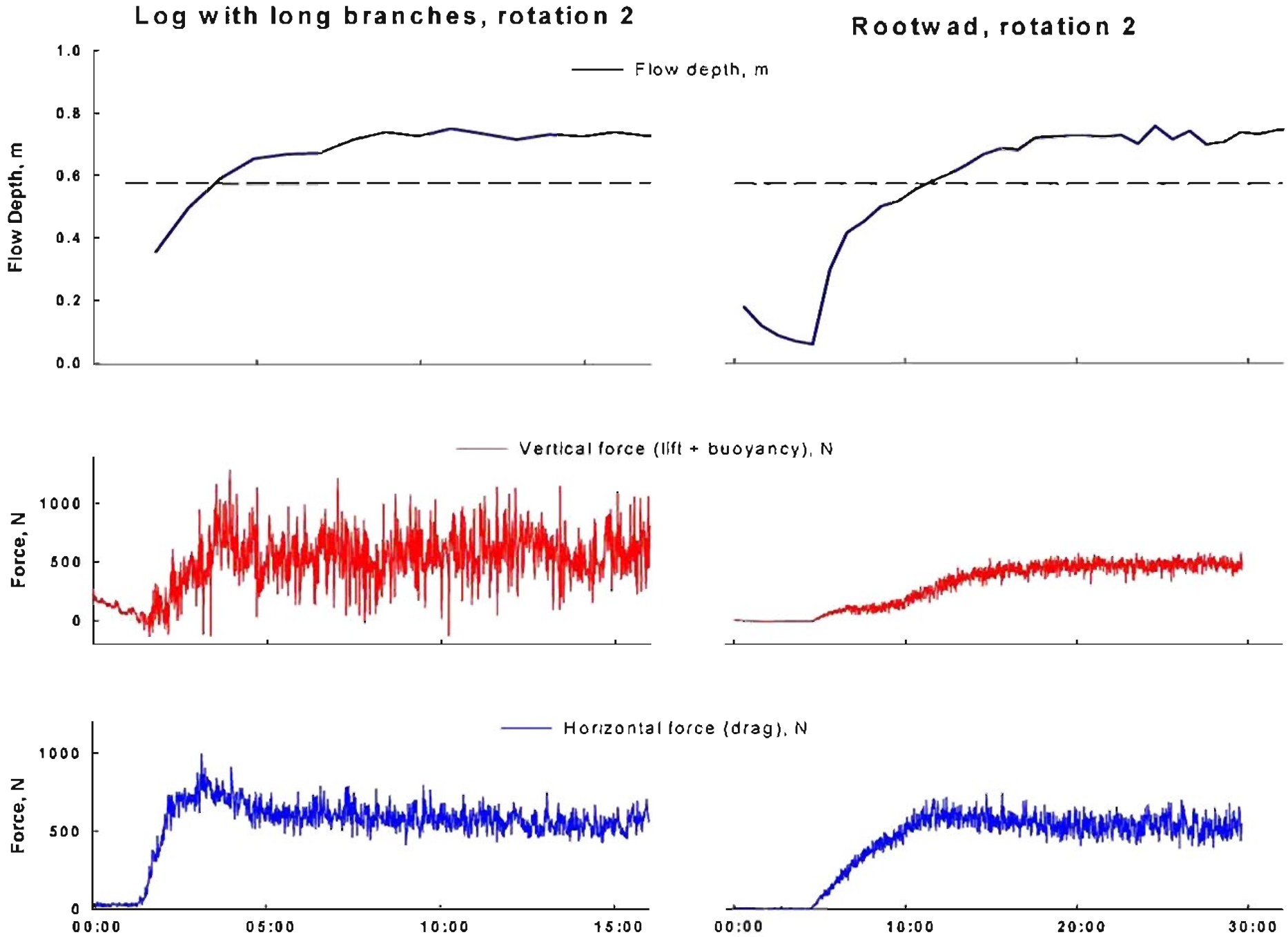
Initial tests were conducted with cylindrical logs to verify results of scale model tests conducted at lower Re.

Formation of standing wave, PVC “log”

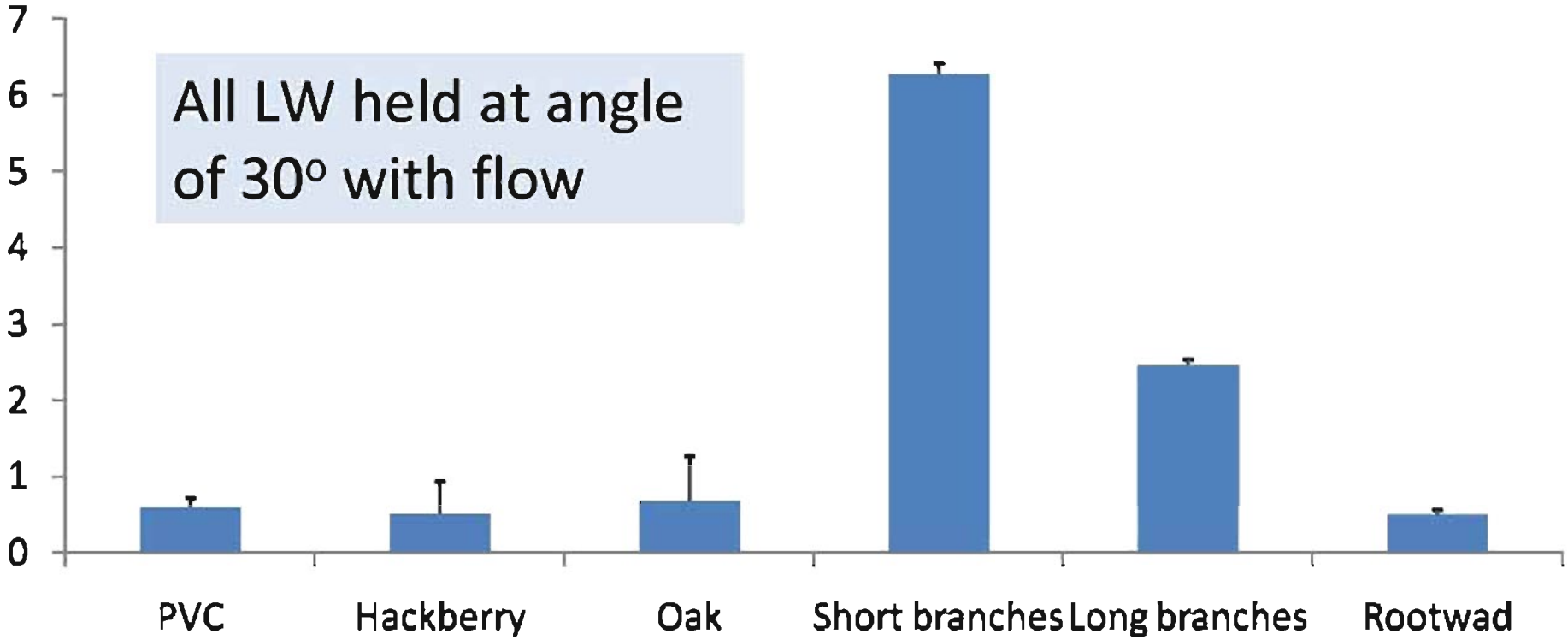
Wave drag important when flow just overtops structure




Smooth Log (PVC)
Moderately Rough Log (Hackberry)
Velocity, m/s and Depth, m
2.5
2.0
1.5
1.0
0.5
0.0
Flow depth, m
Velocity, m/s
Vertical force (lift + buoyancy), N
Force, N
600
300
0
Horizontal force (drag), N
Force, N
600
300
0
00:00
05:00
10:00
15:00
00:00
10:00
20:00
30:00

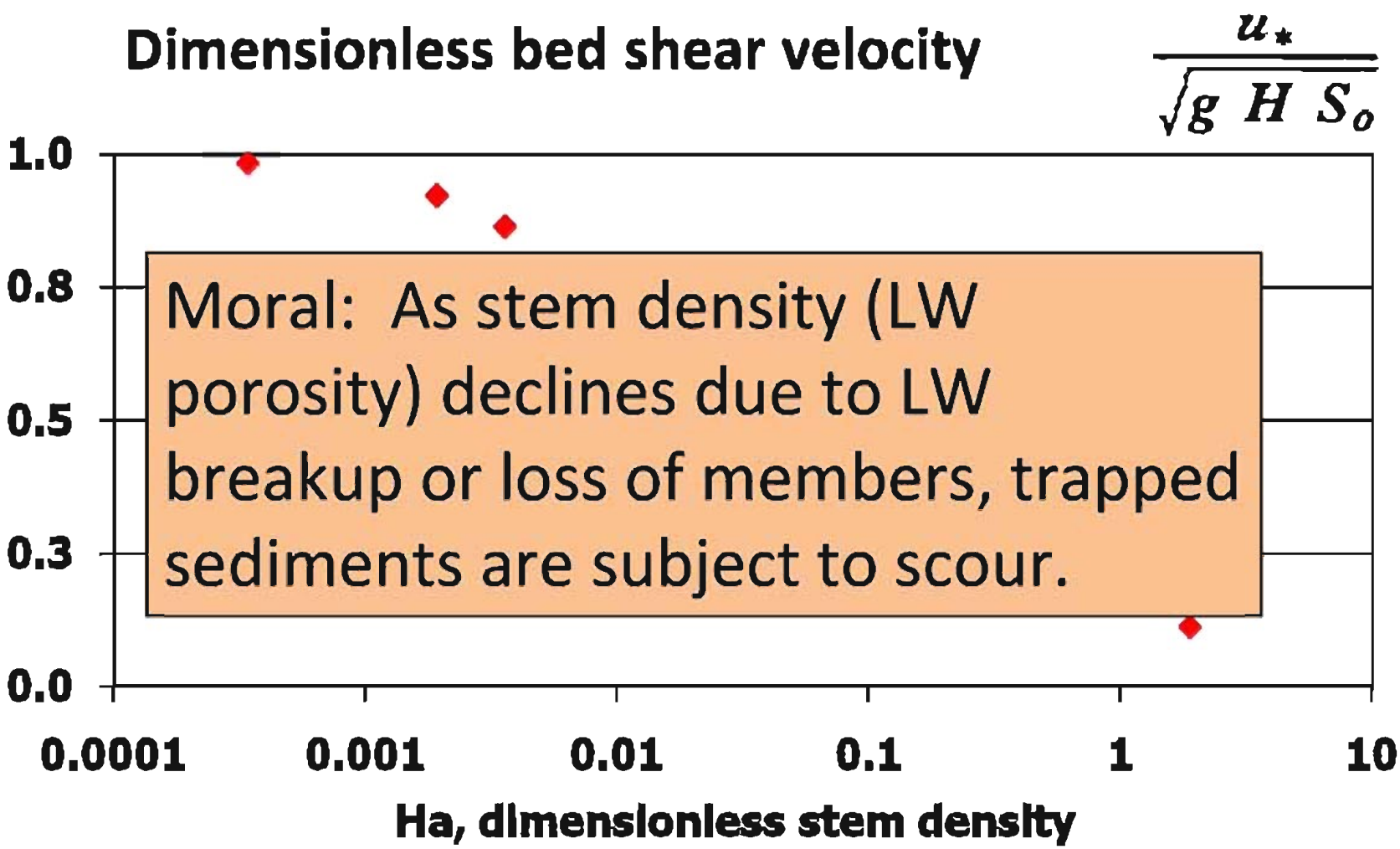

Log with long branches, rotation 2
Rootwad, rotation 2
Flow depth, m
Flow Depth, m
1.0
0.8
0.6
0.4
0.2
0.0
Vertical force (lift + buoyancy), N
Force, N
1000
500
0
Horizontal force (drag), N
Force, N
1000
500
0
00:00
05:00
10:00
15:00
00:00
10:00
20:00
30:00

Effect of LW complexity on C_D

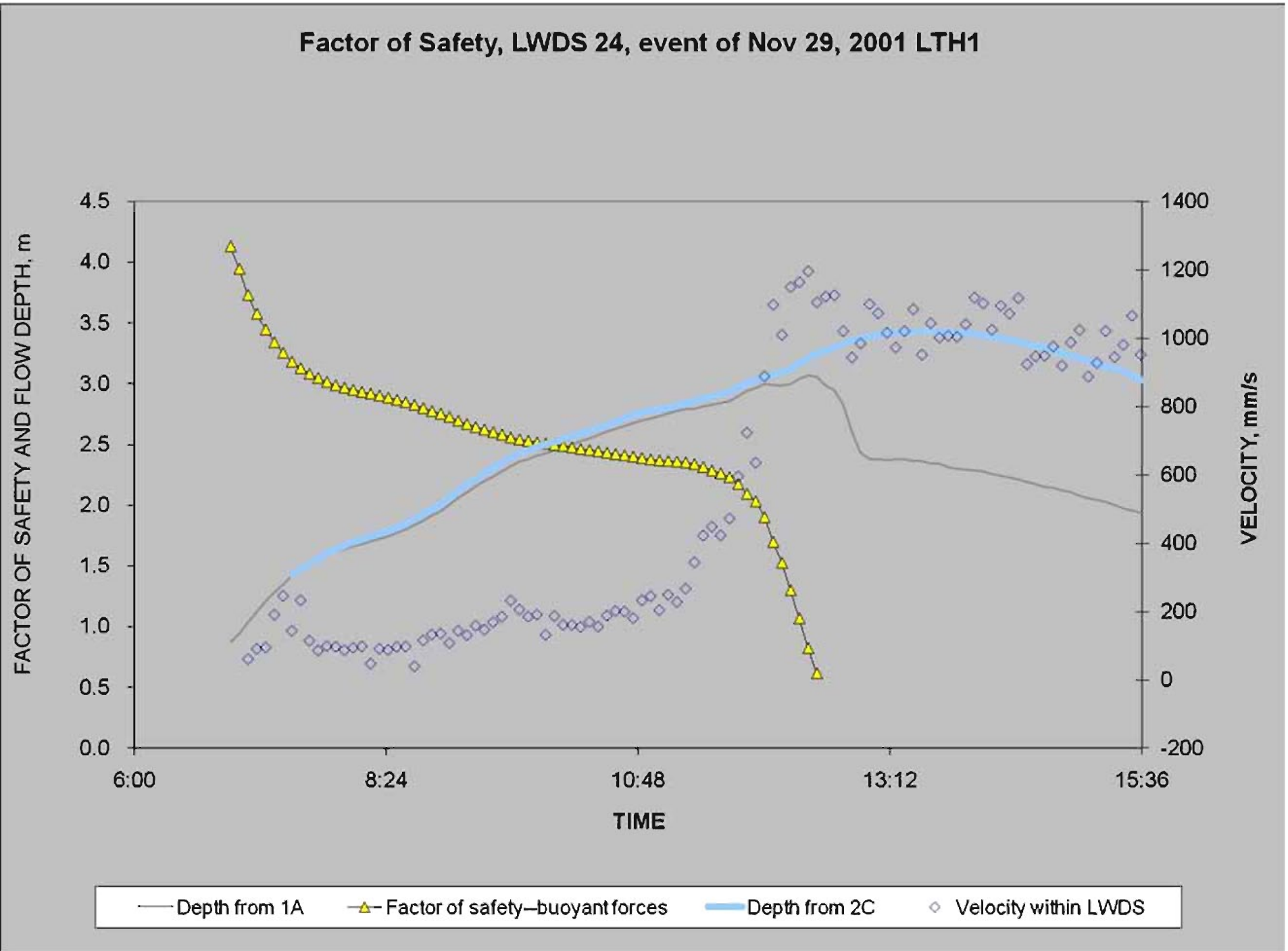


Bed shear as a Function of Stem Density

Lopez and Garcia, 1997



Moral: As stem density (LW porosity) declines due to LW breakup or loss of members, trapped sediments are subject to scour.

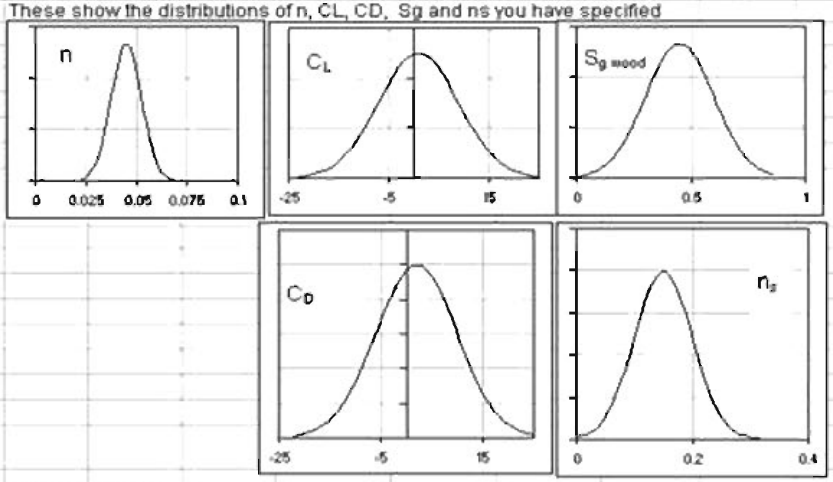

Factor of Safety, LWDS 24, event of Nov 29, 2001 LTH1
FACTOR OF SAFETY AND FLOW DEPTH, m
VELOCITY, mm/s
TIME
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1400
1200
1000
800
600
400
200
0
-200
6:00
8:24
10:48
13:12
15:36
Depth from 1A
Factor of safety–buoyant forces
Depth from 2C
Velocity within LWDS

Uncertainty analysis

Microsoft Excel - gravel bed LWS design Cd (2,8) CL (1,8).xls

	A	B	C	D	E	F	G
1	INPUT ZONE						
2	nmn	0.045		Sg wood mn	0.45		
3	nstd	0.0075		Sg wd std	0.15		
4	C_L mn	1		Ws	5.5	m	
5	C_L std	8		h_t	1.2	m	tan phi
6	C_D mn	2		Ls	13	m	tan psi
7	C_D std	8		Ls/L1	5		
8	flow width	22.14	m	angle of LWS crest with approach flow	75	deg	
9	flow depth	1.5	m	S	0.007	m/m	
10	n, mean	0.15		g	9.806	m/s^2	
11	n, std	0.1		ρ_{water}	1000	kg/m3	
12				d_{log}	0.7	m	
13				L_2	10.4		
14				L_2/h_t	0.5		
15				L_3	0.6		
16				L_1	2.6		
17	number of realizations	10001					
18							

These show the distributions of n, CL, CD, Sg and ns you have specified



19 Calculations happen below. First row calculates U, Fb, Fd, F_L and Fa for the mean n, CL, CD, Sg and n_s

20 The next 10,000 rows make the same calculation, using n, CL, CD, Sg and n_s drawn from the specified distributions.

21	Manning n	Approach velocity	lift coeff	drag coeff	spec grav wood	LWS porosity	net buoyant force	drag force	lift force	horiz force on 2 back anchors	vert force on 2 back anchors	horiz force on 2 front anchors	vert force on 2 front anchors			
22		m/s					N	N	N	N	N	N	N	N	N	kN
23	n	U	CL	CD	Sg	ns	Fb	Fd	F_L	F_{x2b}	F_{x2f}	F_{x1b}	F_{x1f}	Fa1	Fa2	design load one anchor
24	*0.05*	*2.4*	*1.0*	*2.0*	*0.5*	*0.15*	*33,260*	*81,592*	*40,796*	*-10,540*	*-11,202*	*-71,052*	*-62,854*	*94,863*	*15,381*	*47*
25	0.044	2.5	-12.571	6.18	0.274	0.066	19,263	260,872	-530,917	-710,542	113,869	449,669	397,784	600,362	719,608	360
26	0.039	2.8	8.314	12.62	0.332	0.133	35,904	699,988	461,216	-215,419	-68,463	-484,569	-428,657	646,958	226,037	323
27	0.041	2.7	5.351	9.15	0.369	0.158	40,164	446,497	260,963	-151,848	-40,477	-294,649	-260,651	393,392	157,150	197

PLOTS | Cd and CL

Ready NUM

start | Volume C... | GroupWise - ... | gravel bed L... | RRNW 2007.ppt | 96% | 3:43 PM

Summary

- LW structures will interact with river environment by
  - Accumulating or losing LW
  - Sediment scour and deposition
  - Decay
- Hydraulic behavior sensitive to stem density
- Successful design is a result of extreme good luck or careful consideration of many factors
  - Ice
  - Impacts from bedload
  - Impacts from floating debris
  - Beavers
  - Dynamic effects
- Designers must communicate risk and uncertainty to stakeholders