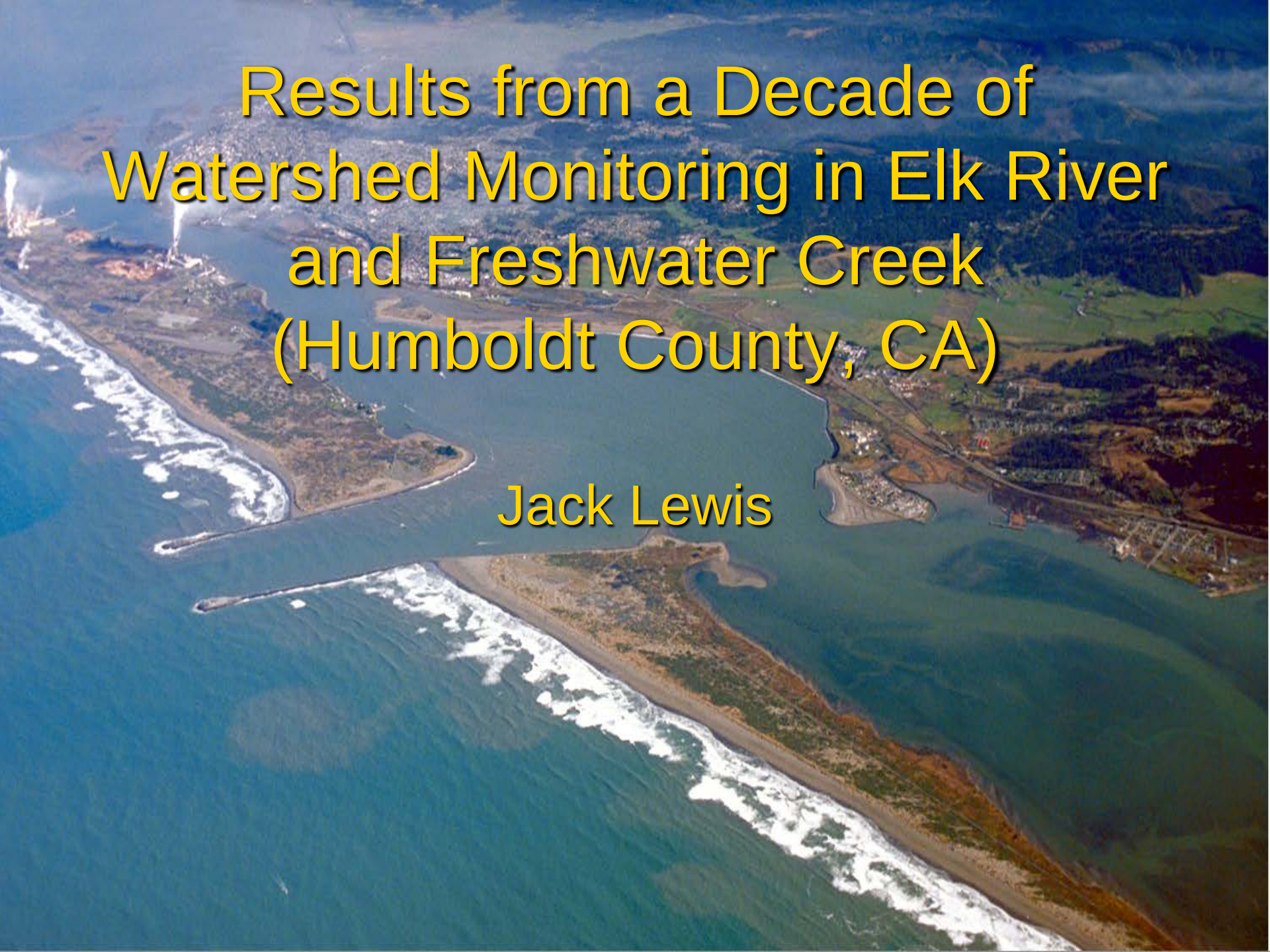
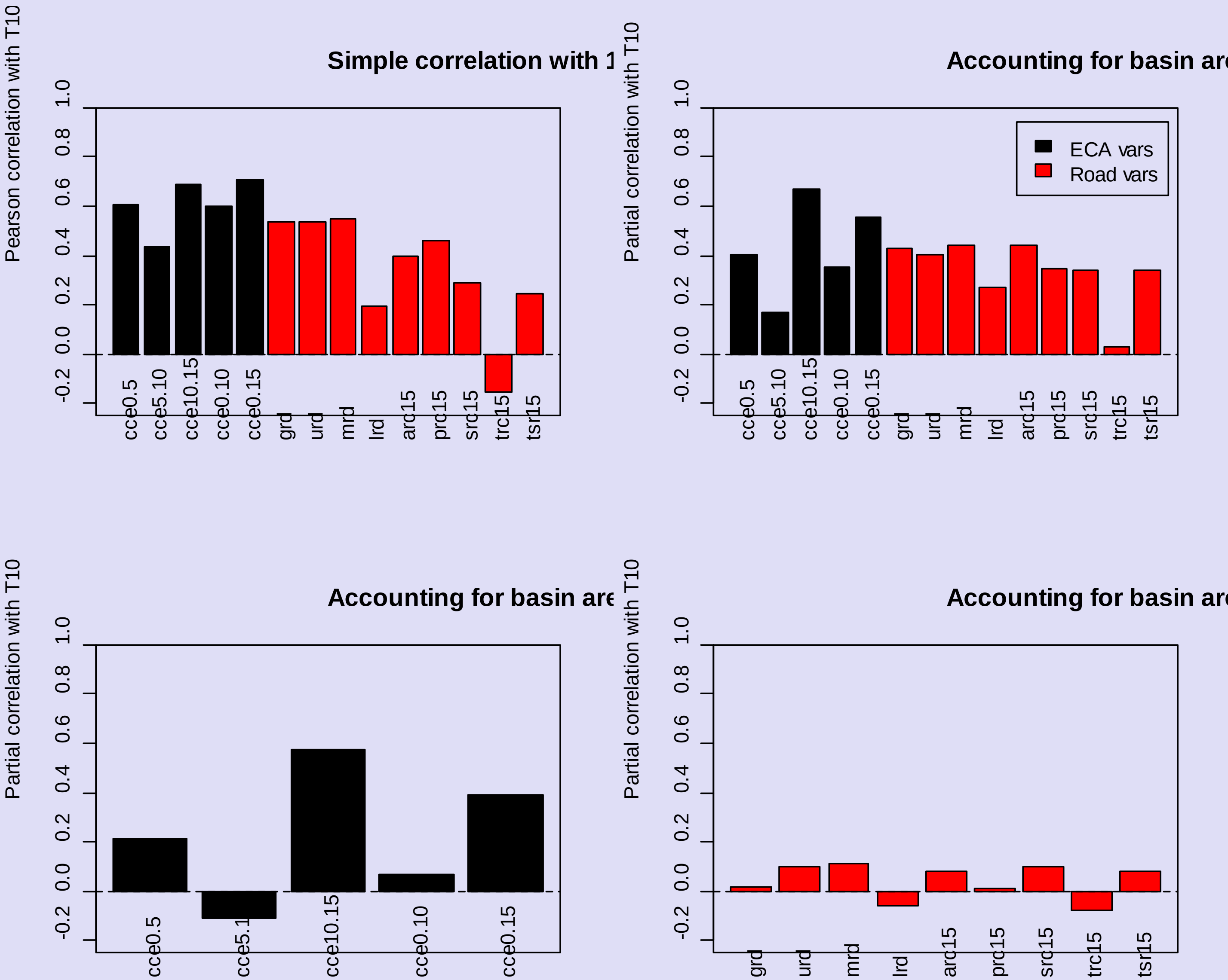


Results from a Decade of Watershed Monitoring in Elk River and Freshwater Creek (Humboldt County, CA)

Jack Lewis



Simple correlation with 1
Pearson correlation with T10
Accounting for basin ar
Partial correlation with T10
ECA vars
Road vars
Accounting for basin are
Accounting for basin ar
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
cce0.5
cce5.10
cce10.15
cce0.10
cce0.15
grd
urd
mrd
lrd
arc15
prc15
src15
trc15
tsr15

Humboldt Redwood
COMPANY, LLC

P.O. Box 712
Scotia, CA 95565
Phone (707) 764-4392
www.HRCLLC.com

Trends in Sediment-Related Water Quality After a Decade of Forest Management Implementing an Aquatic Habitat Conservation Plan

Sullivan et al, 2012

From the HRC report

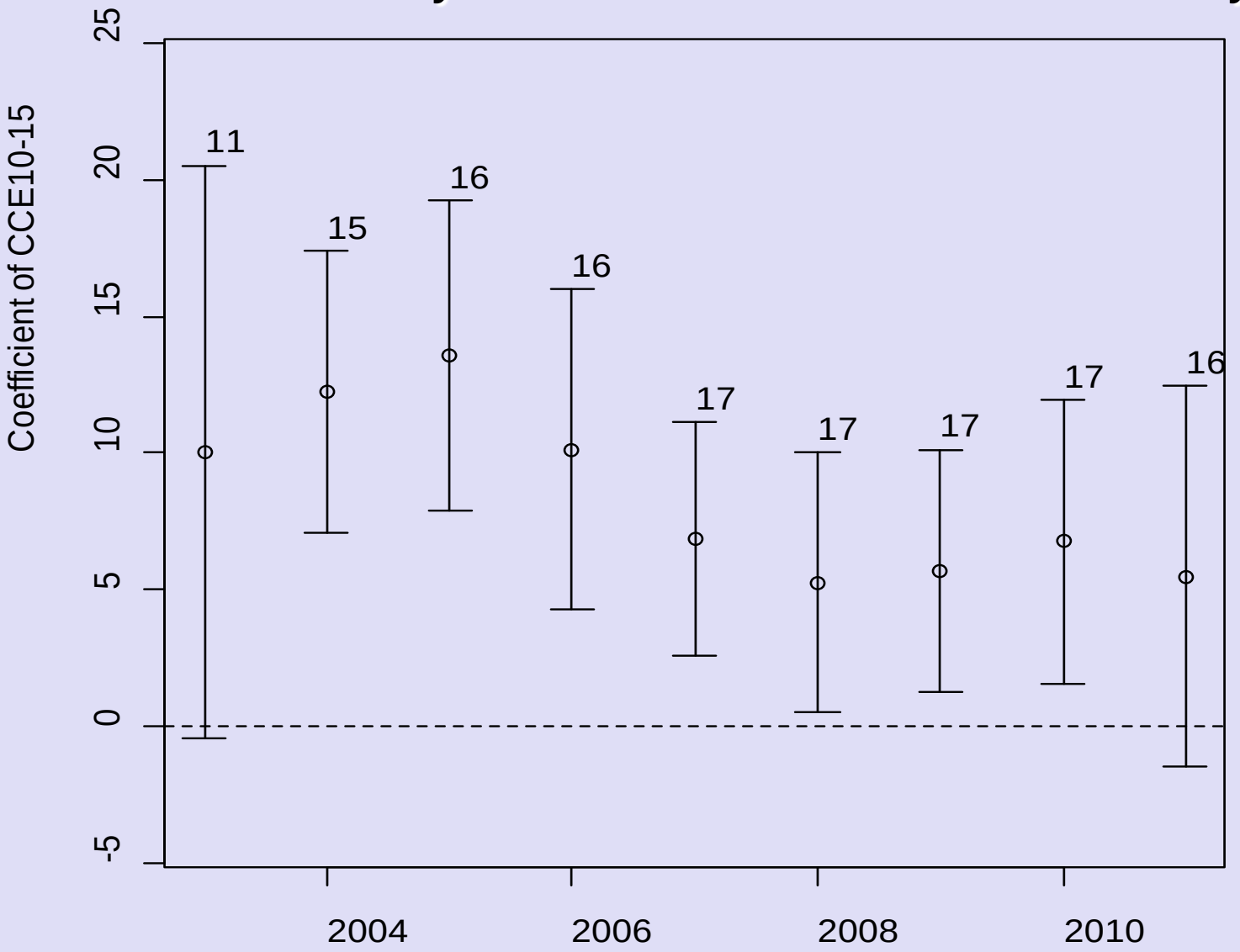
- “The findings reported by Klein *et al.*(2012) that concluded that the previous 10-15 year harvest rate had a positive and highly statistically significant effect on the turbidity 10% exceedance in 2005 were confirmed.”
- “In all other individual years [besides 2005] in the period from 2003 to 2011, and for all data grouped for the entire period, the statistical analysis found the opposite effect, with *a decreasing trend in turbidity with harvest rate*.”

From HRC Report

Table 16. Summary of results of fitting normal linear models of turbidity 10% exceedance with basin area and 10-15 year historic harvest rate. Reported p-values correspond to the statistical test for 10-15 year historical clearcut equivalent area as a significant predictor of 10% (or log 10%) exceedance. R-square values correspond to the full model with basin area and 10-15 year historical clearcut equivalent area.

Year	Log transformed?	P Value	R^2
2003	log	0.362	0.213
2004	log	0.037	0.491
2005	untransformed	0.015	0.714
2006	log	0.105	0.575
2007	log	0.130	0.386
2008	log	0.284	0.268
2009	log	0.214	0.225
2010	untransformed	0.313	0.519
2011	log	0.421	0.272

Effect of 10-15 year harvest rate on 10% Turbidity



Fixed and mixed effects models

Simple regression (e.g. 10% turbidity vs harvest rate)

$y = \beta_0+\beta_1 x+\varepsilon$ $\quad \varepsilon \sim N(0,\sigma^2)$ residual error

Fixed effects model with a categorical variable (site)

$y = \beta_0+\beta_1 x+\beta_{2i}+\varepsilon$ $\quad \varepsilon \sim N(0,\sigma^2)$

Mixed effects model: 2 fixed, 1 random (site)

$y = \beta_0+\beta_1 x+b_i+\varepsilon$ $\quad \varepsilon \sim N(0,\sigma^2),\ b_i \sim N(0,\delta^2)$

Mixed effects model: 2 fixed, 2 random (site and year)

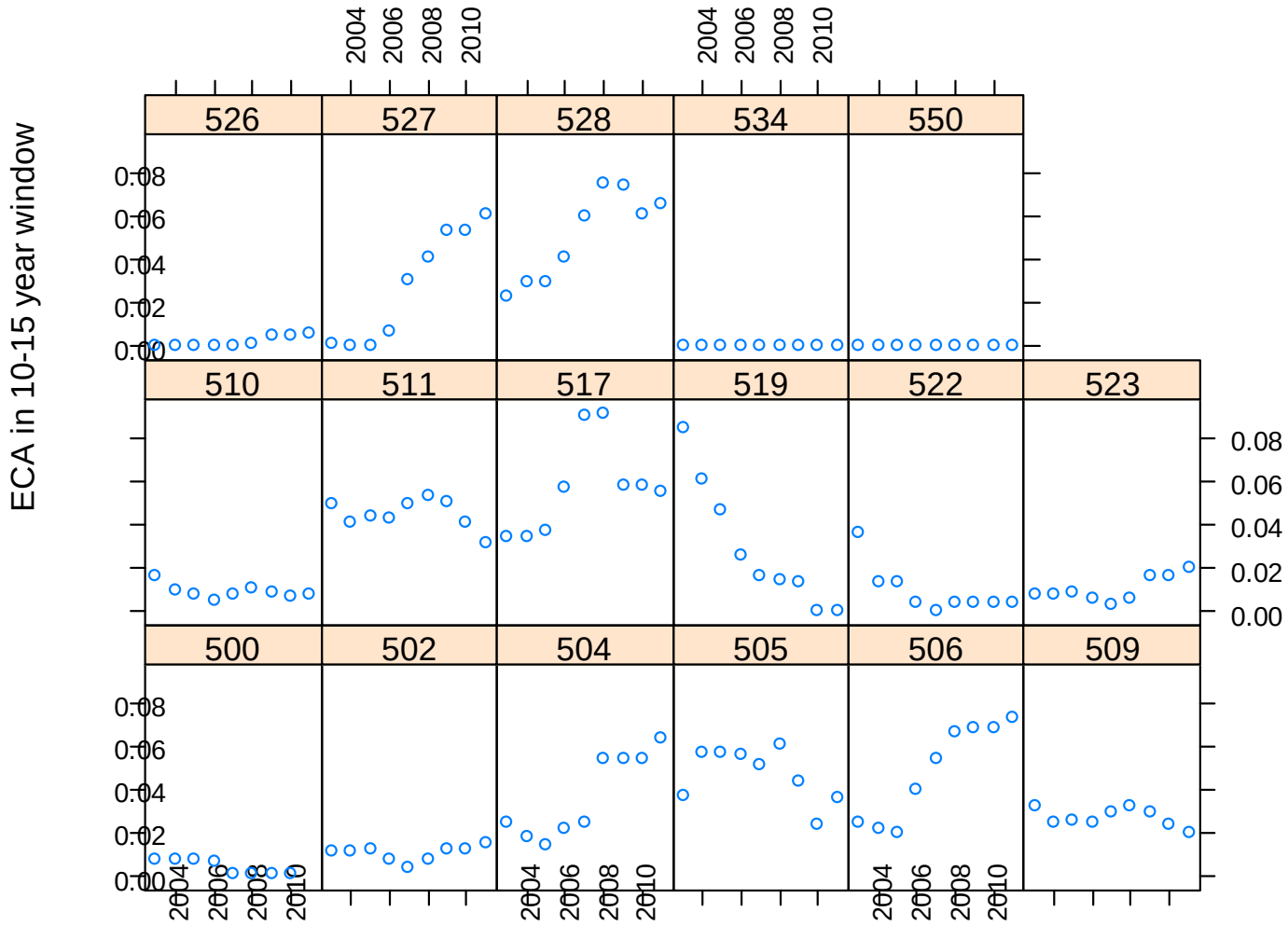
$y = \beta_0+\beta_1 x+b_{1i}+b_{2i}+\varepsilon$ $\quad \varepsilon \sim N(0,\sigma^2),\ b_{hi} \sim N(0,\delta_h^2)$

Mixed-effects model statistics for 10% exceedence turbidity

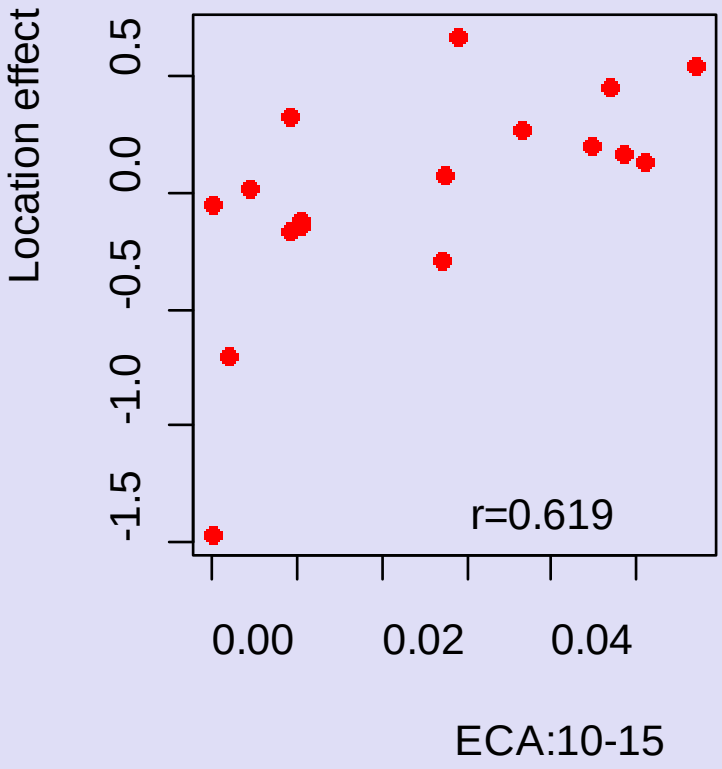
Model	Term	Estimate	Std Error	DF	t	Pr > |t|
Sullivan	Intercept	3.632	0.1947	8	18.65	<0.0001
Sullivan	Area	0.0103	0.0046	116	2.24	0.0272
Sullivan	CCE10-15	-3.270	1.3527	116	-2.42	0.0172
Lewis repro	Intercept	3.627	0.1951	139	18.60	<0.0000
Lewis repro	Area	0.0104	0.0046	139	2.27	0.0249
Lewis repro	CCE10-15	-3.286	1.3563	139	-2.42	0.0167
Lewis alt*	Intercept	3.398	0.1369	139	24.82	<0.0001
Lewis alt	Area	0.0096	0.0014	139	6.75	<0.0001
Lewis alt	CCE10-15	7.039	1.7514	139	4.02	0.0001

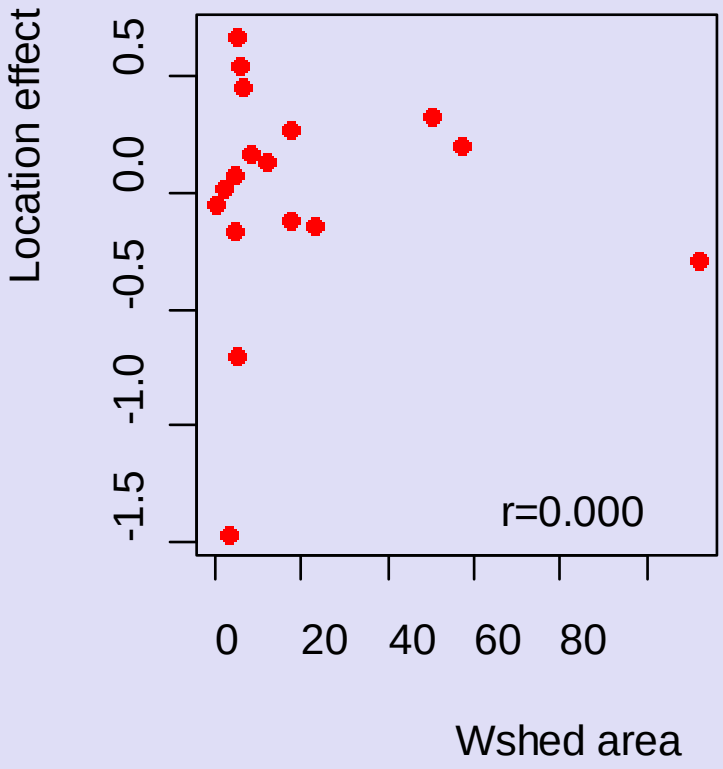
*Lewis alt model omits the “Site” random effect (retains “Year”)

Harvest rate in 10-15 yr window by site and year



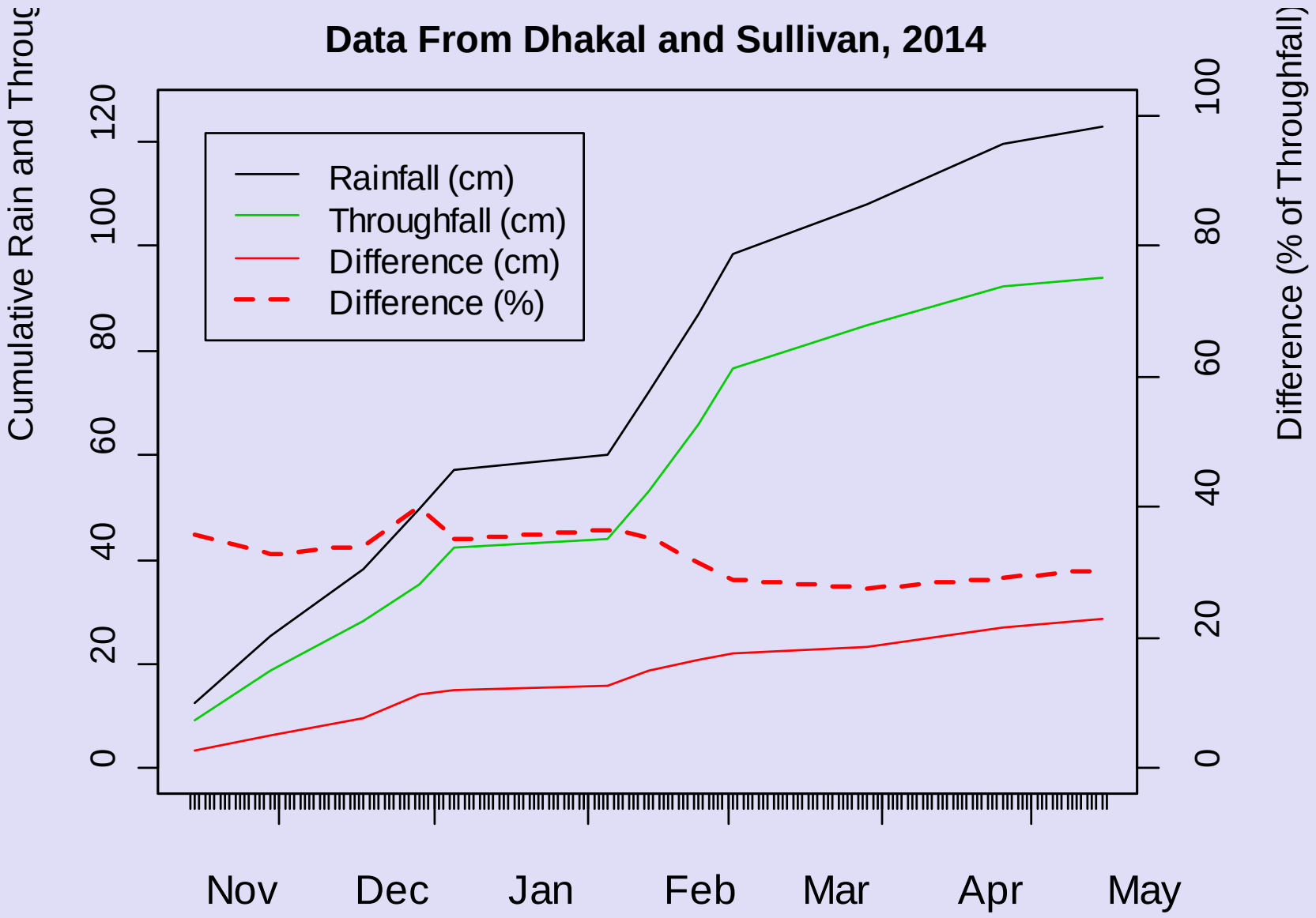
Correlations of location effect with 10-15 year harvest rate and basin area

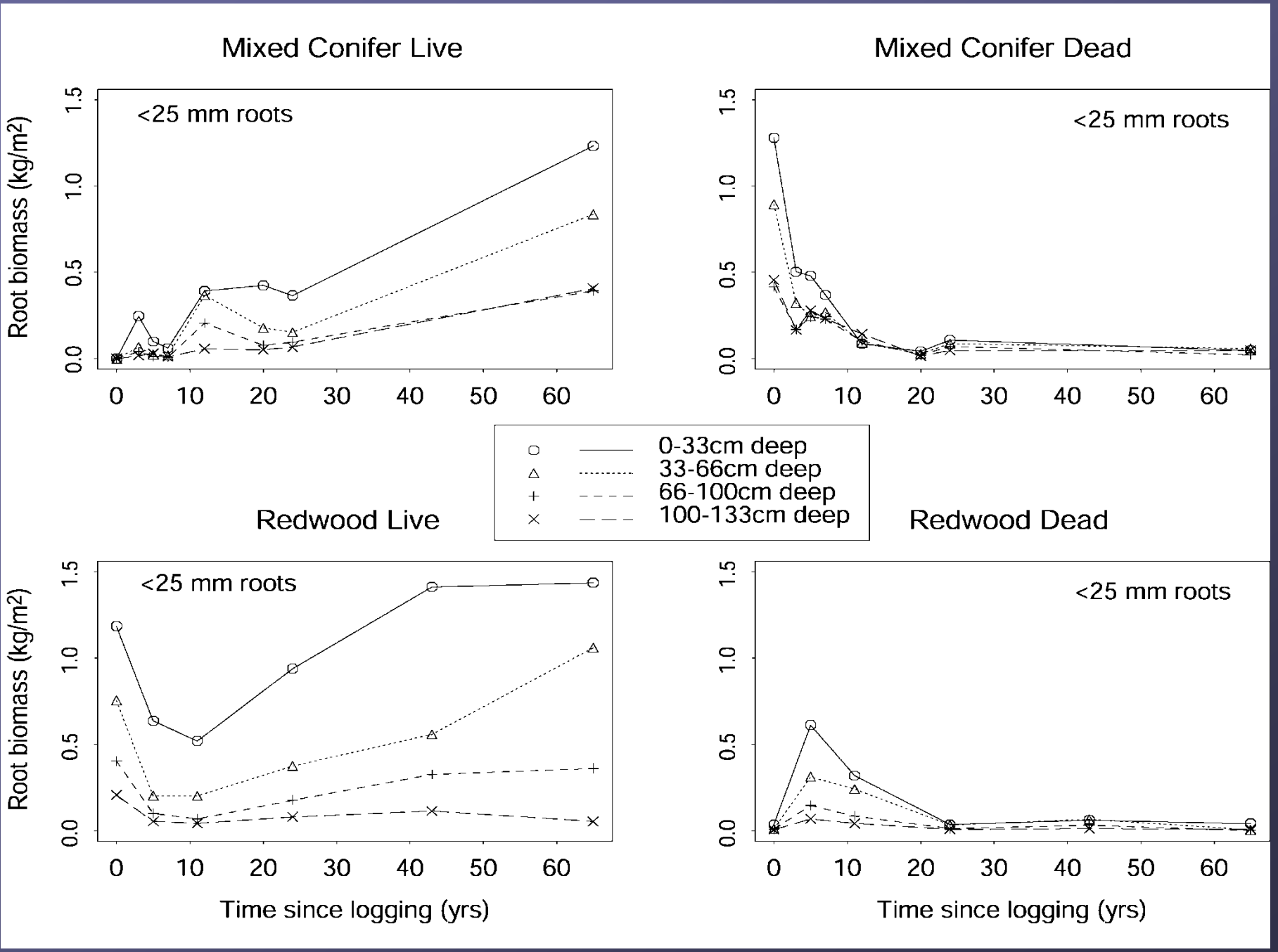


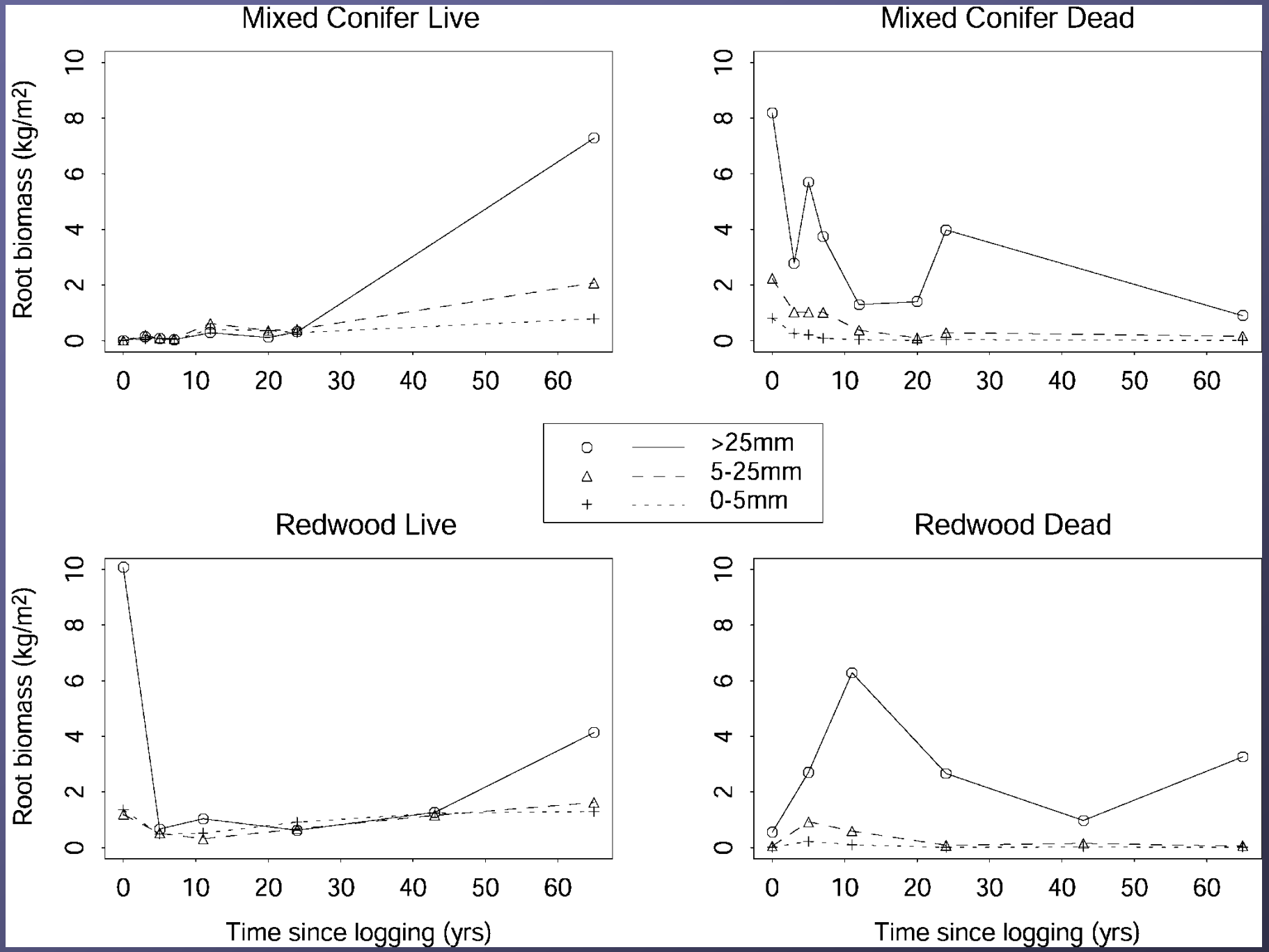


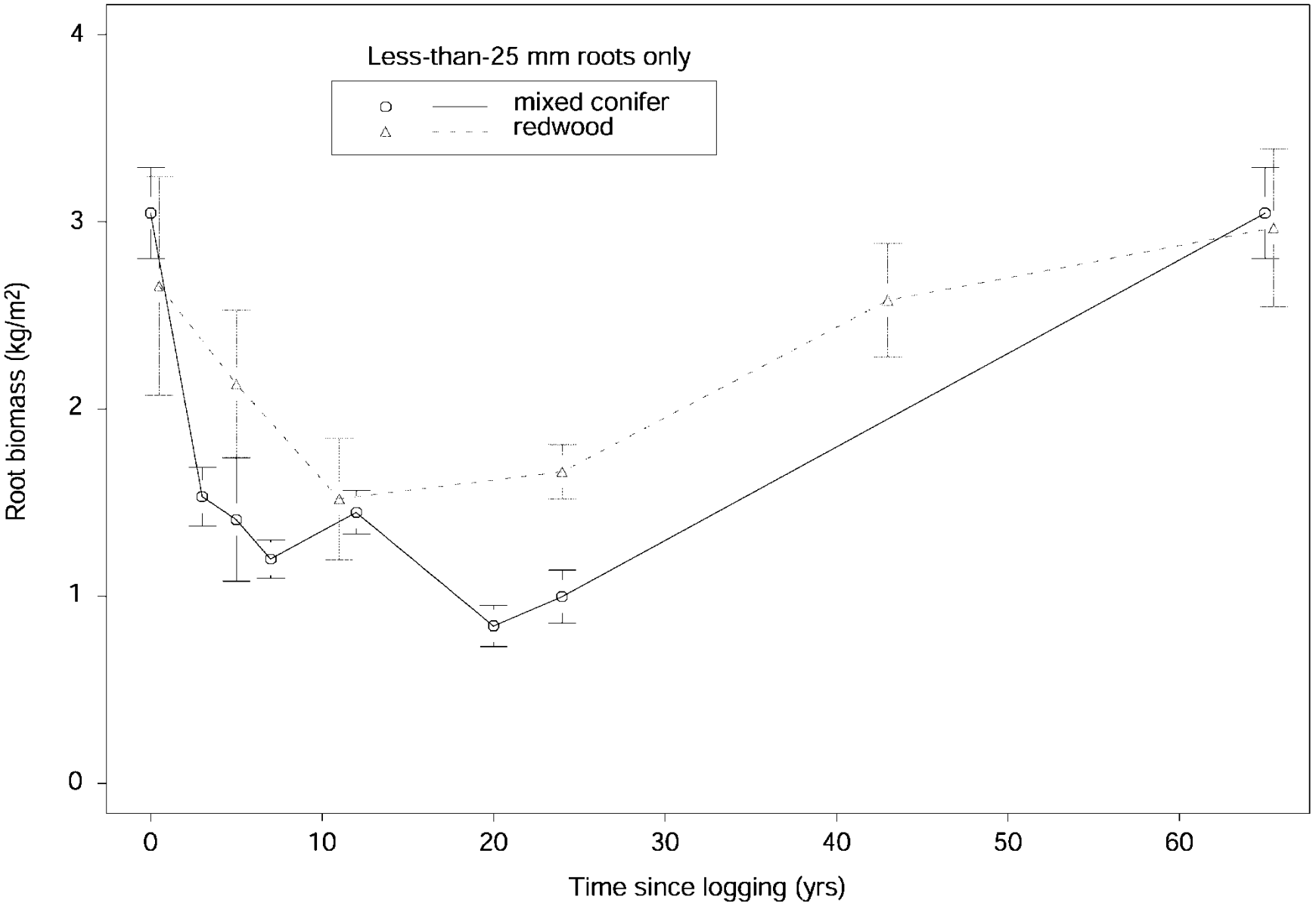
Effect of 10-15 year harvest rate: 4 years at a time

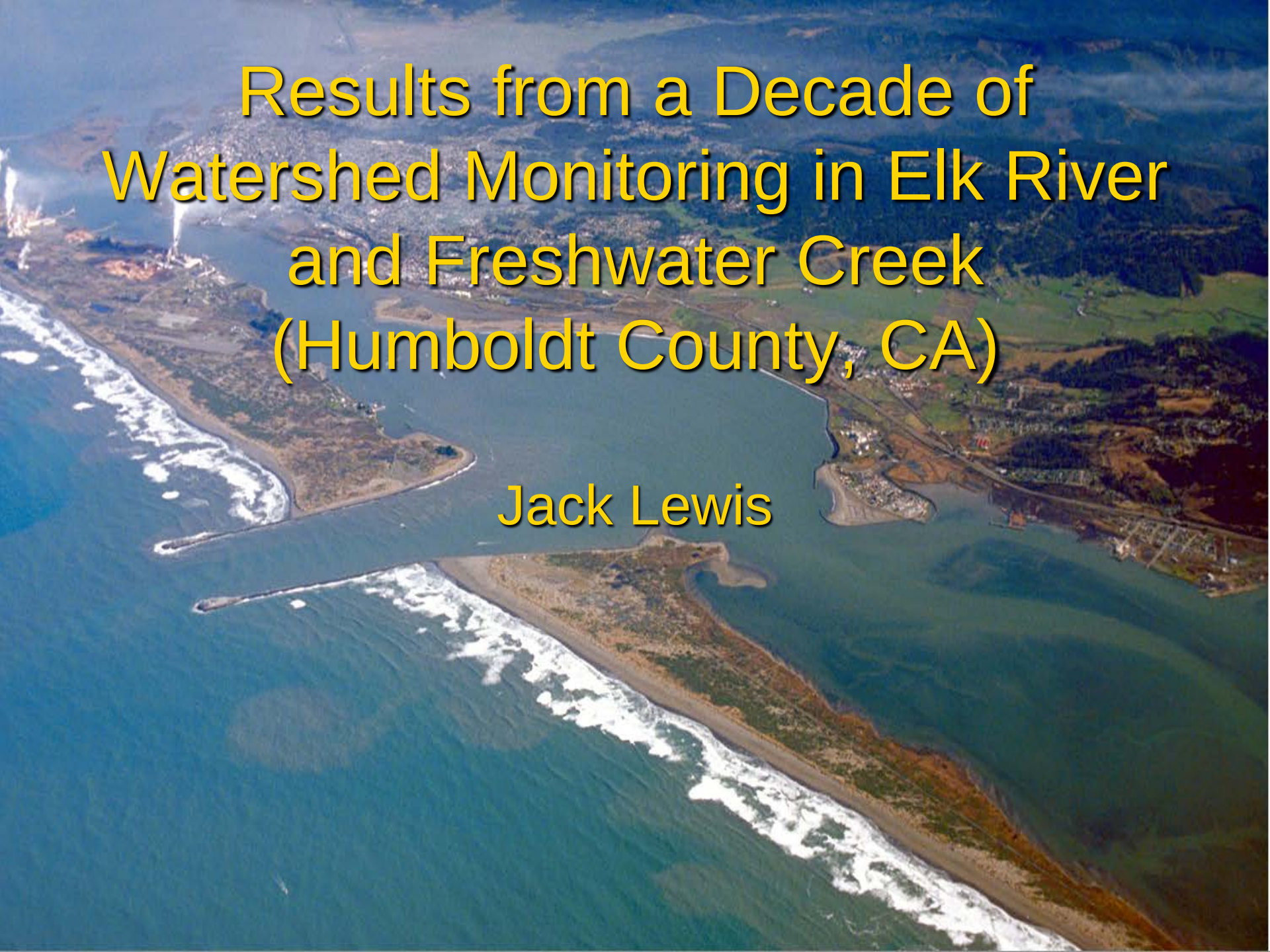
Years	Coefficient	p-value
2003-2006	11.5	0.0005
2004-2007	9.6	0.0003
2005-2008	7.4	0.0030
2006-2009	6.3	0.0077
2007-2010	6.0	0.0085
2008-2011	5.6	0.0304


Data From Dhakal and Sullivan, 2014
Cumulative Rain and Throug
Difference (% of Throughfall)
Rainfall (cm)
Throughfall (cm)
Difference (cm)
Difference (%)
0
20
40
60
80
100
120
0
20
40
60
80
100
Nov
Dec
Jan
Feb
Mar
Apr
May


Mixed Conifer Live
Mixed Conifer Dead
<25 mm roots
<25 mm roots
Root biomass (kg/m²)
0.0
0.5
1.0
1.5
0
10
20
30
40
50
60
0-33cm deep
33-66cm deep
66-100cm deep
100-133cm deep
Redwood Live
Redwood Dead
<25 mm roots
<25 mm roots
Root biomass (kg/m²)
Time since logging (yrs)
Time since logging (yrs)


Mixed Conifer Live
Mixed Conifer Dead
Redwood Live
Redwood Dead
Root biomass (kg/m2)
Time since logging (yrs)
0
2
4
6
8
10
0
10
20
30
40
50
60
>25mm
5-25mm
0-5mm


Less-than-25 mm roots only
mixed conifer
redwood
Root biomass (kg/m²)
Time since logging (yrs)
0
1
2
3
4
0
10
20
30
40
50
60



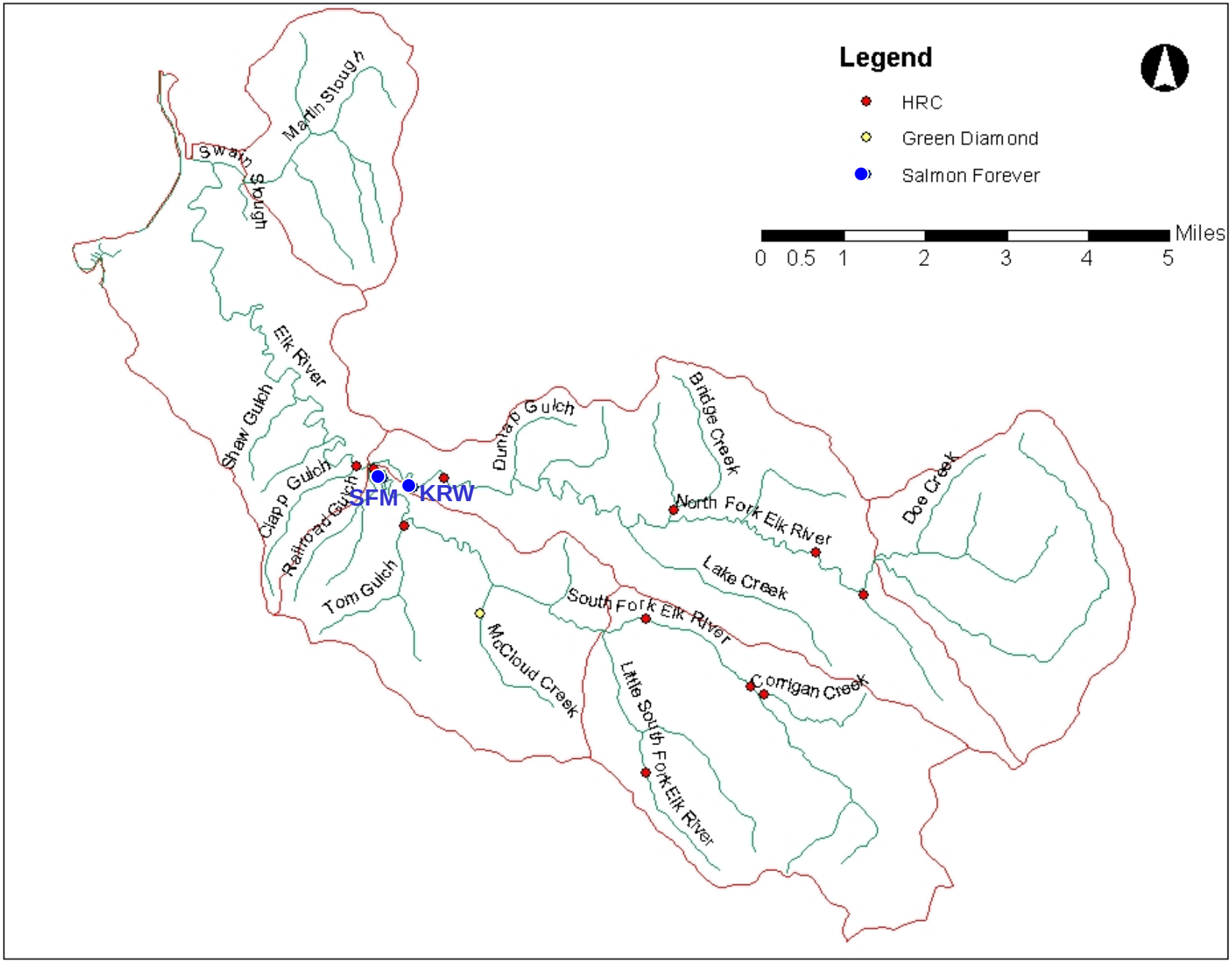
Results from a Decade of Watershed Monitoring in Elk River and Freshwater Creek (Humboldt County, CA)

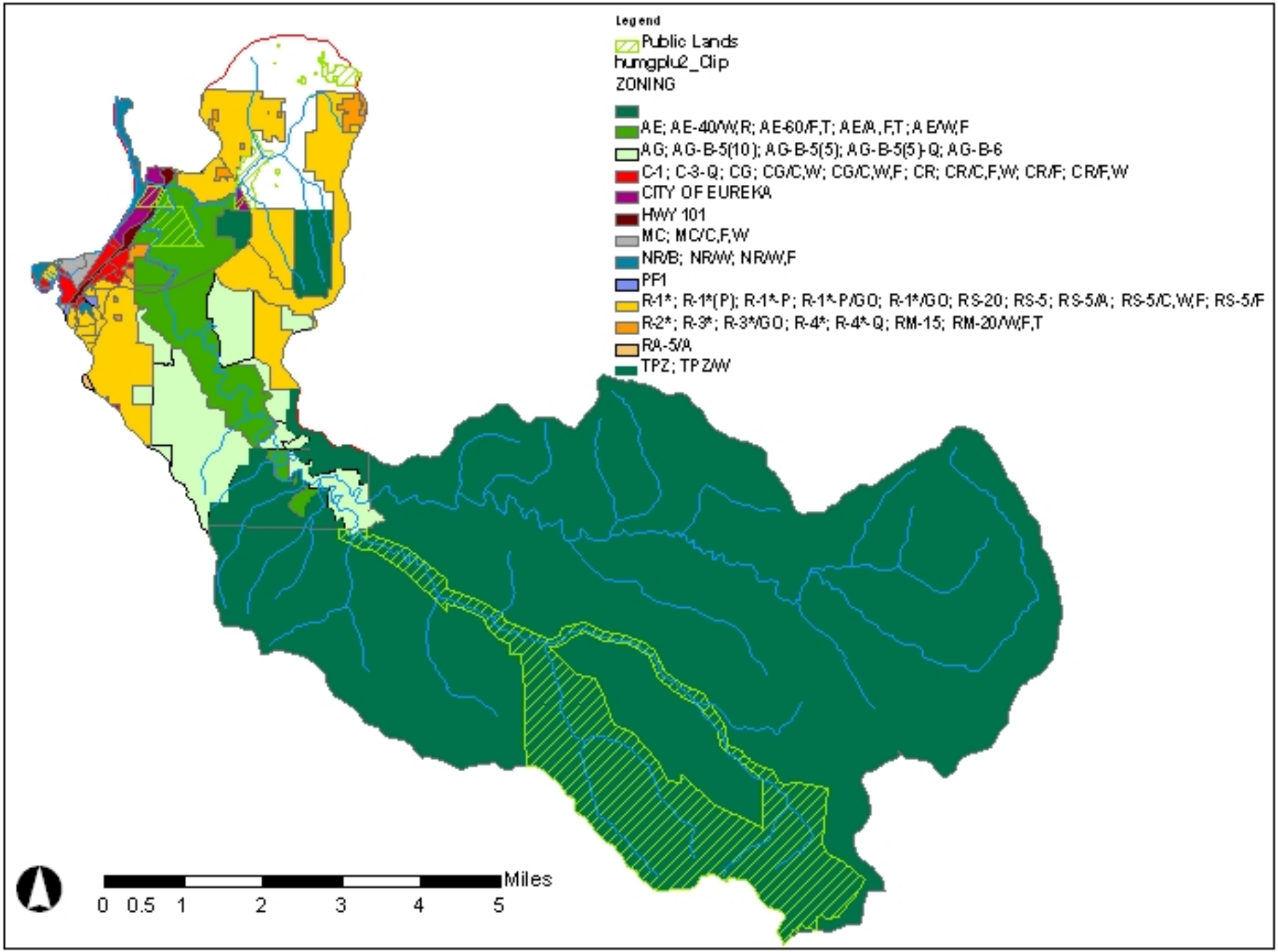
Jack Lewis

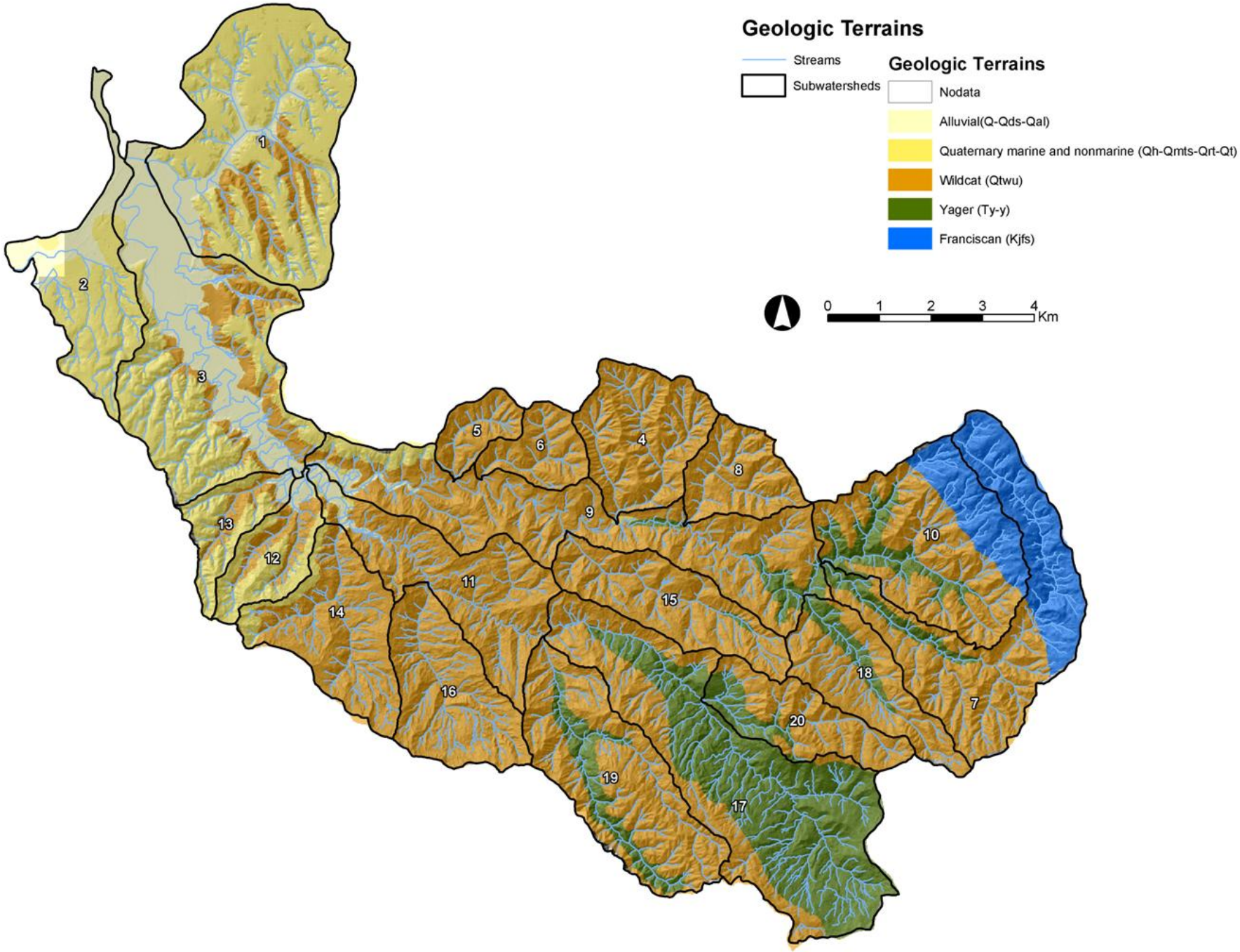

Arcata
Jacoby
Creek
Eureka
Freshwater Creek/
Ryan Slough
Elk River
Salmon
Creek

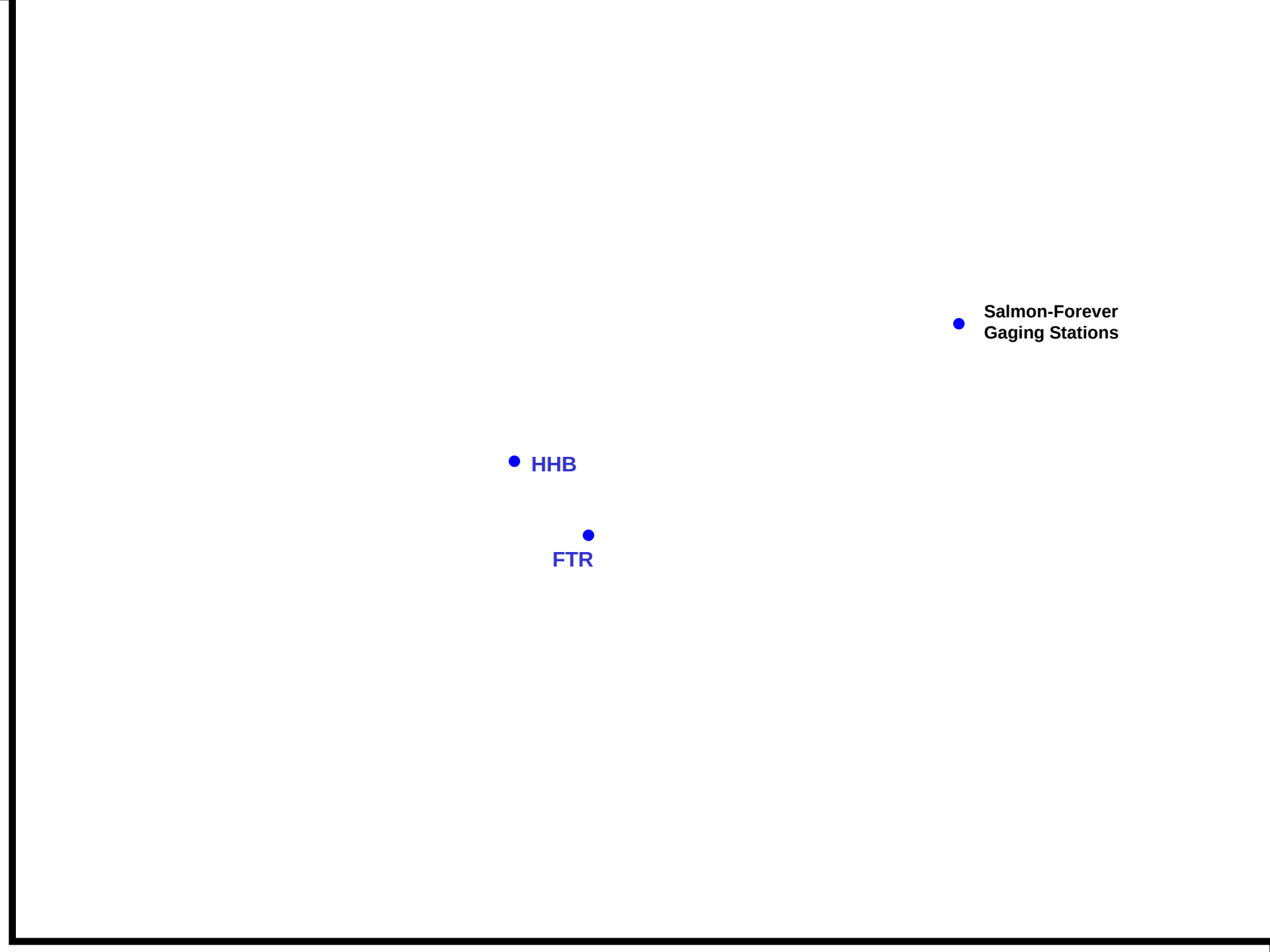
Salmon-Forever Gaging Stations

- Elk River
  - SFM – South Fork (50 km^2 =19 mi^2)
  - KRW – North Fork (57 km^2 =22 mi^2)
- Freshwater Creek
  - FTR – Upper mainstem (34 km^2 =13 mi^2)
  - HHB – Lower mainstem (72 km^2 =28 mi^2)

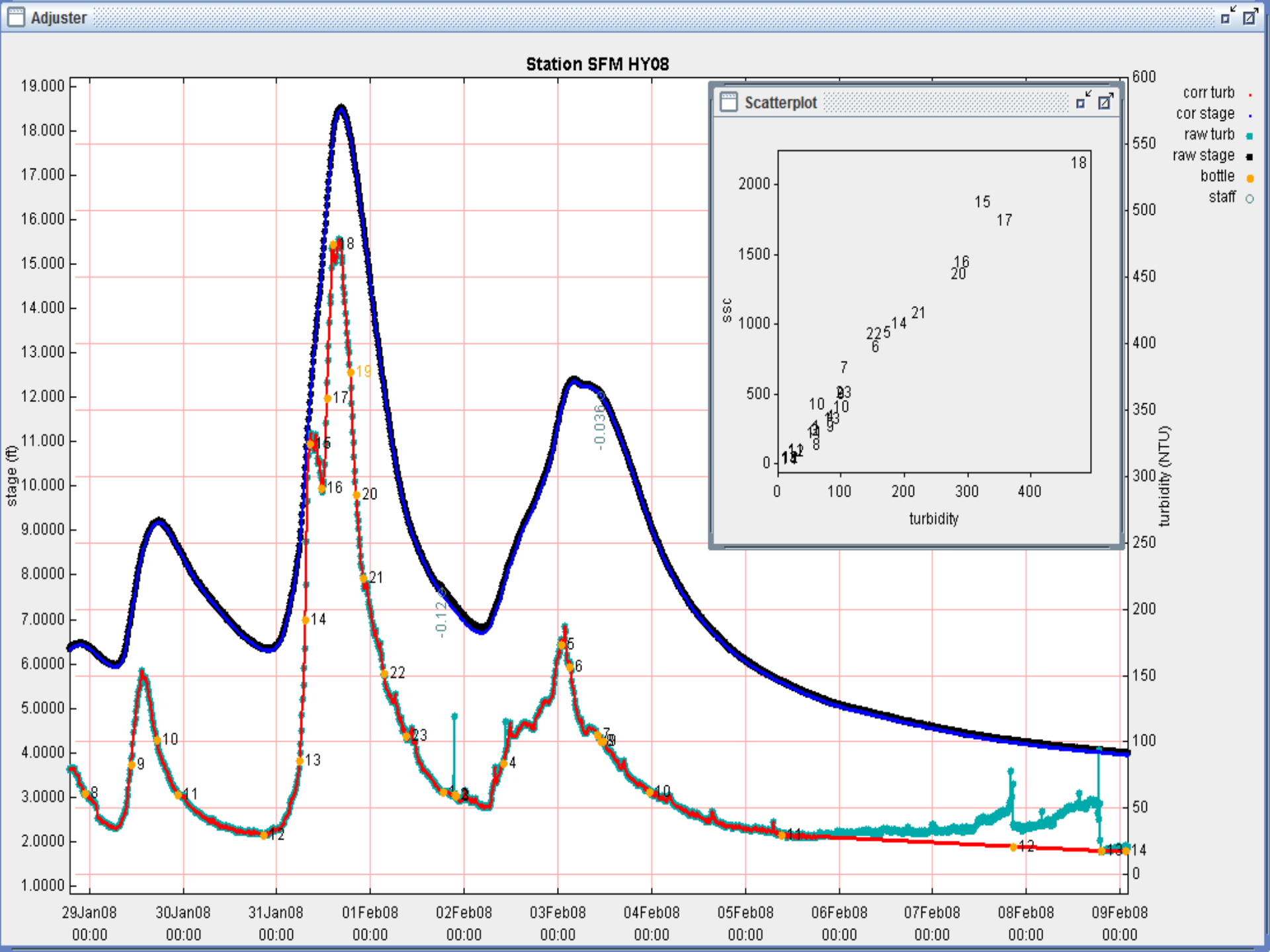

Legend
HRC
Green Diamond
Salmon Forever
Miles
0 0.5 1 2 3 4 5
Merlin Slough
Swanks Slough
Elk River
Shaw Gulch
Clapp Gulch
Railroad Gulch
Tom Gulch
SFM
KRW
Dunlap Gulch
Bridge Creek
North Fork Elk River
Lake Creek
Doe Creek
South Fork Elk River
McCloud Creek
Little South Fork Elk River
Corrigan Creek

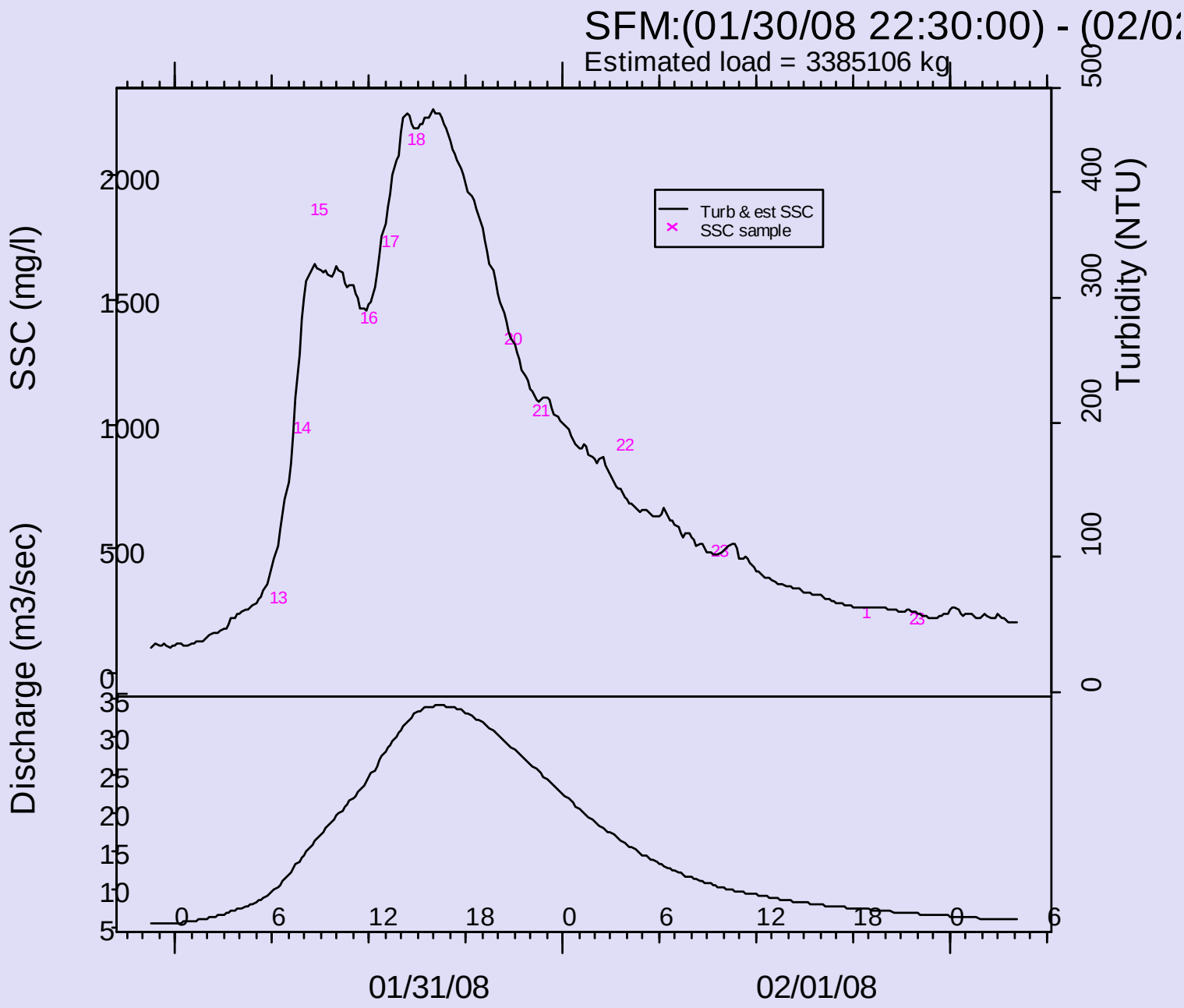

Legend
Public Lands
humgplu2_Clip
ZONING
AE; AE-40/W,R; AE-60/F,T; AE/A,F,T; AE/W,F
AG; AG-B-5(10); AG-B-5(5); AG-B-5(5)-Q; AG-B-6
C-1; C-3-Q; CG; CG/C,W; CG/C,W,F; CR; CR/C,F,W; CR/F; CR/F,W
CITY OF EUREKA
HWY 101
MC; MC/C,F,W
NR/B; NR/W; NR/W,F
PF1
R-1*; R-1*(P); R-1*-P; R-1*-P/GO; R-1*/GO; RS-20; RS-5; RS-5/A; RS-5/C,W,F; RS-5/F
R-2*; R-3*; R-3*/GO; R-4*; R-4*-Q; RM-15; RM-20/W,F,T
RA-5/A
TPZ; TPZ/W
Miles
0 0.5 1 2 3 4 5

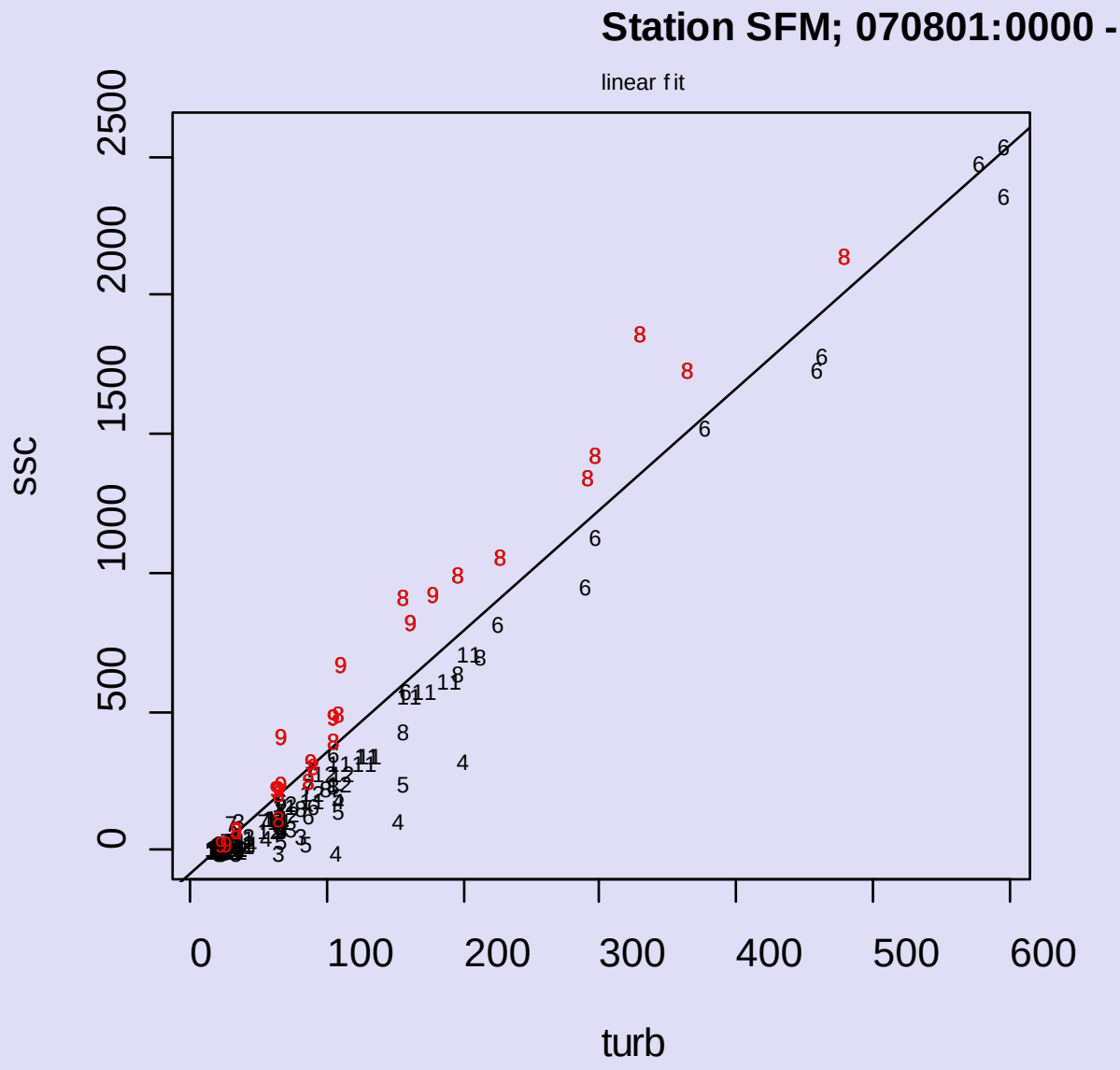

Geologic Terrains
Streams
Subwatersheds
Geologic Terrains
Nodata
Alluvial(Q-Qds-Qal)
Quaternary marine and nonmarine (Qh-Qmts-Qrt-Qt)
Wildcat (Qtwu)
Yager (Ty-y)
Franciscan (Kjfs)
0 1 2 3 4 Km
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

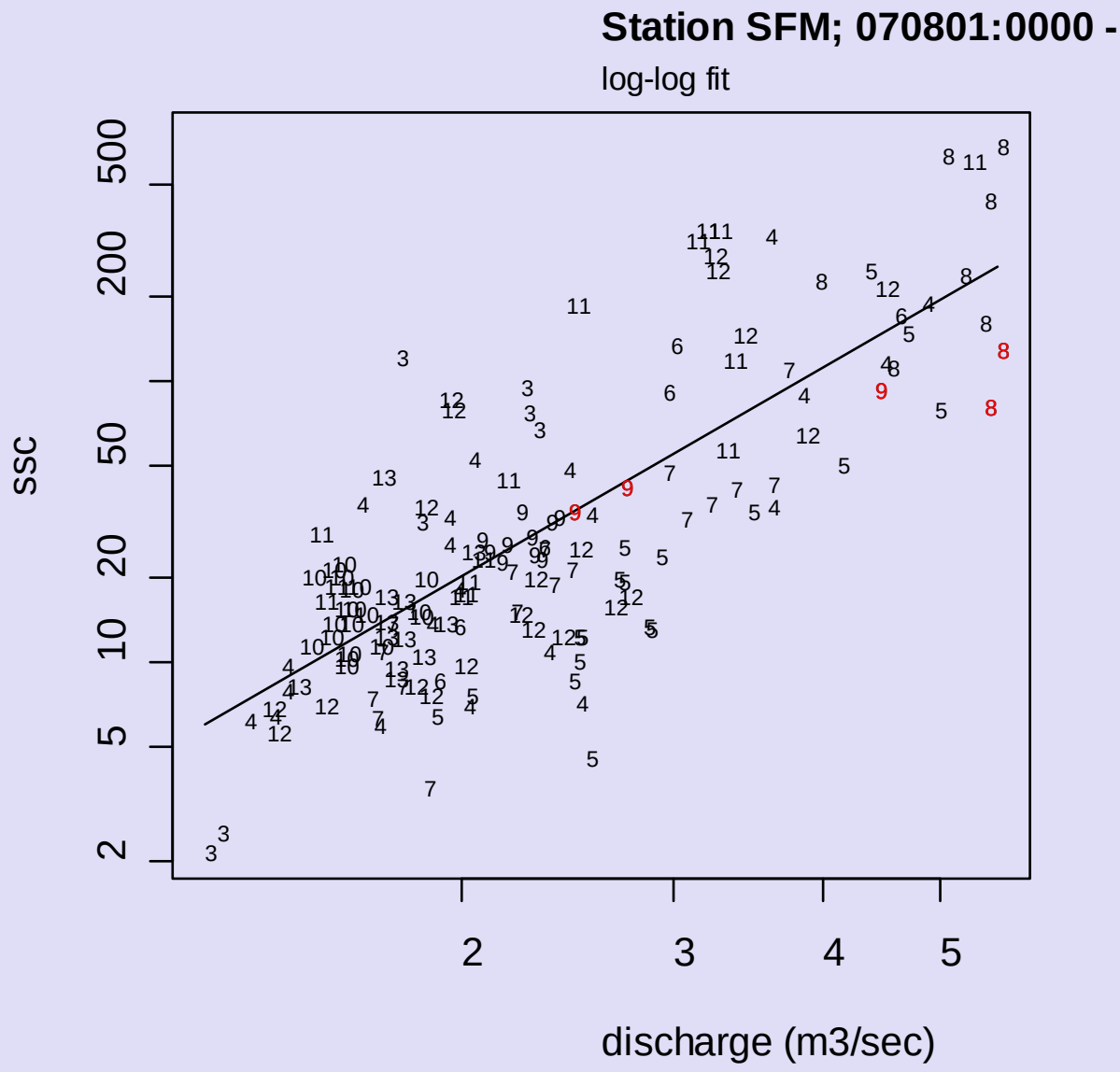

Salmon-Forever
Gaging Stations
HHB
FTR

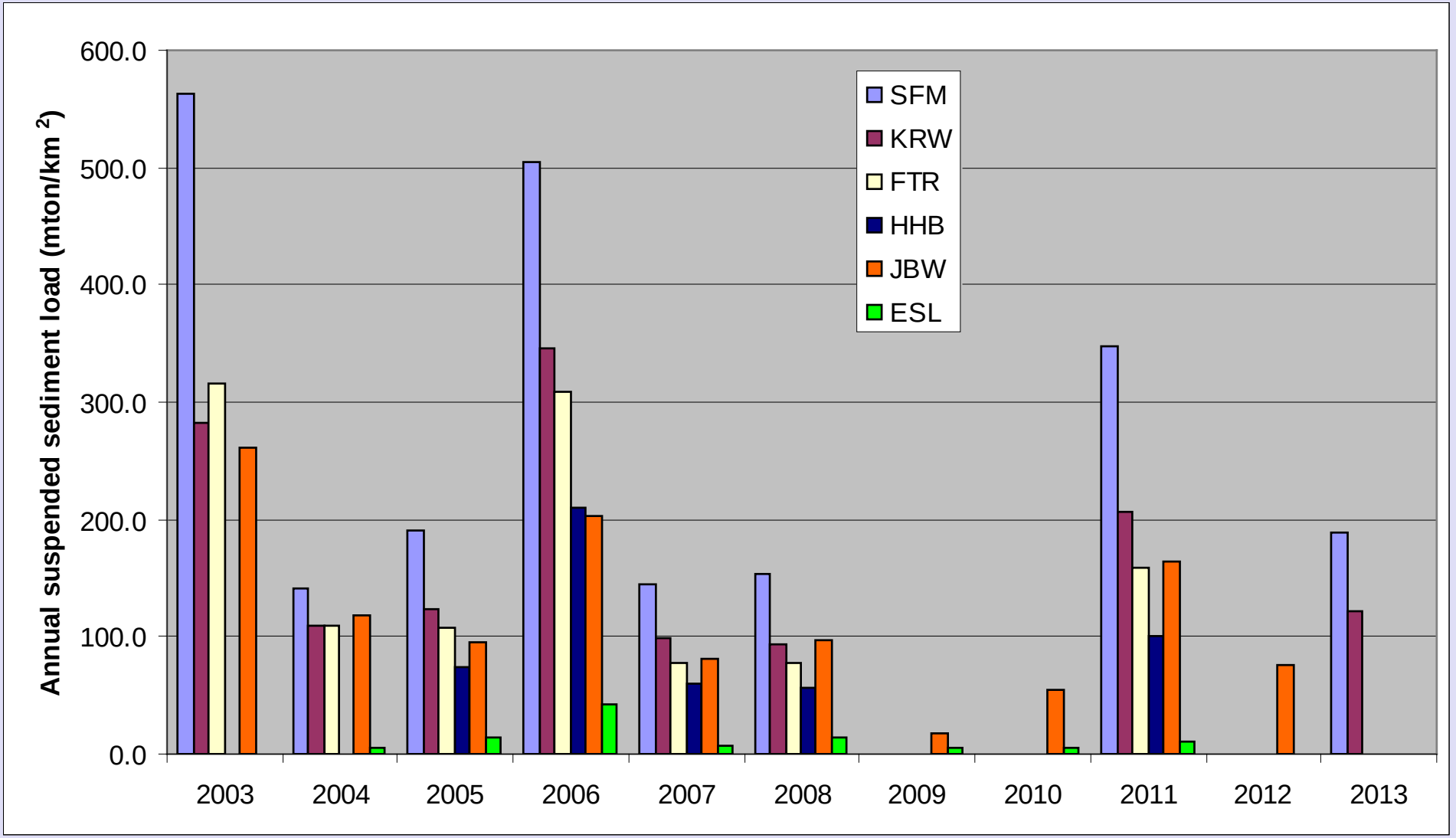

T-probe deployment at station FTR


Adjuster
Station SFM HY08
stage (ft)
turbidity (NTU)
corr turb
cor stage
raw turb
raw stage
bottle
staff
Scatterplot
ssc
turbidity
-0.036
-0.12
29Jan08 00:00
30Jan08 00:00
31Jan08 00:00
01Feb08 00:00
02Feb08 00:00
03Feb08 00:00
04Feb08 00:00
05Feb08 00:00
06Feb08 00:00
07Feb08 00:00
08Feb08 00:00
09Feb08 00:00


SFM:(01/30/08 22:30:00) - (02/0
Estimated load = 3385106 kg
SSC (mg/l)
Turbidity (NTU)
Discharge (m3/sec)
Turb & est SSC
SSC sample
2000
1500
1000
500
0
500
400
300
200
100
0
35
30
25
20
15
10
5
0
6
12
18
0
6
12
18
0
6
01/31/08
02/01/08
13
14
15
16
17
18
20
21
22
23
1


Station SFM; 070801:0000 -
linear fit
ssc
turb
0
500
1000
1500
2000
2500
0
100
200
300
400
500
600


Station SFM; 070801:0000 -
log-log fit
SSC
2
5
10
20
50
200
500
2
3
4
5
discharge (m3/sec)


Annual suspended sediment load (mton/km 2)
600.0
500.0
400.0
300.0
200.0
100.0
0.0
SFM
KRW
FTR
HHB
JBW
ESL
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

Trend Detection

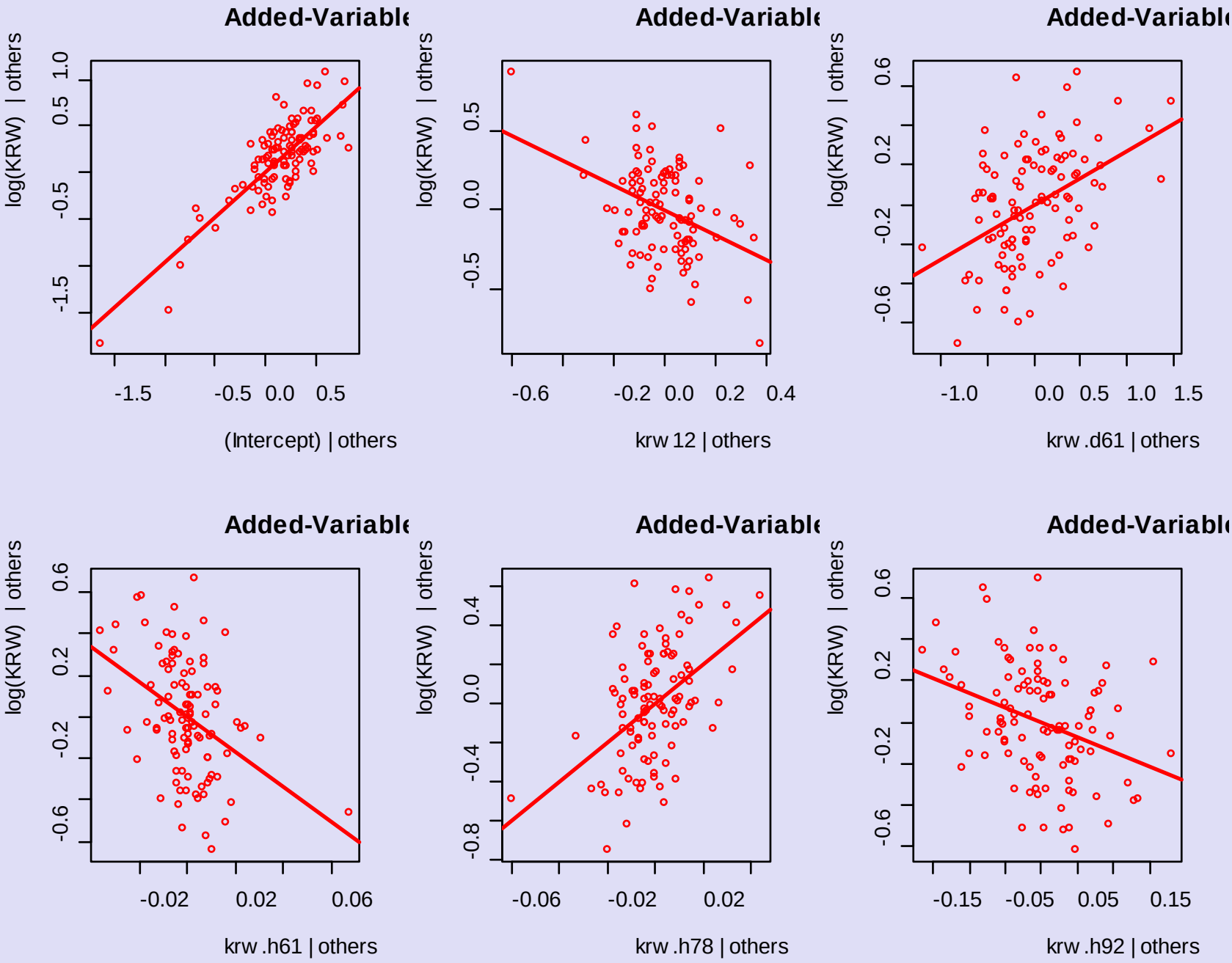
- Multiple regression and scatterplots
  - Explain as much variation as possible, then evaluate trend
- Responses
  - Storm event peaks
  - Storm event loads
  - Storm event mean SSC = load/flow
  - Instantaneous SSC
- Predictors
  - Same response at another watershed (preferably unmanaged)
  - Another related response at same watershed
  - Rainfall totals and decaying indexes (API)
  - Time: use scatterplots to assess linearity

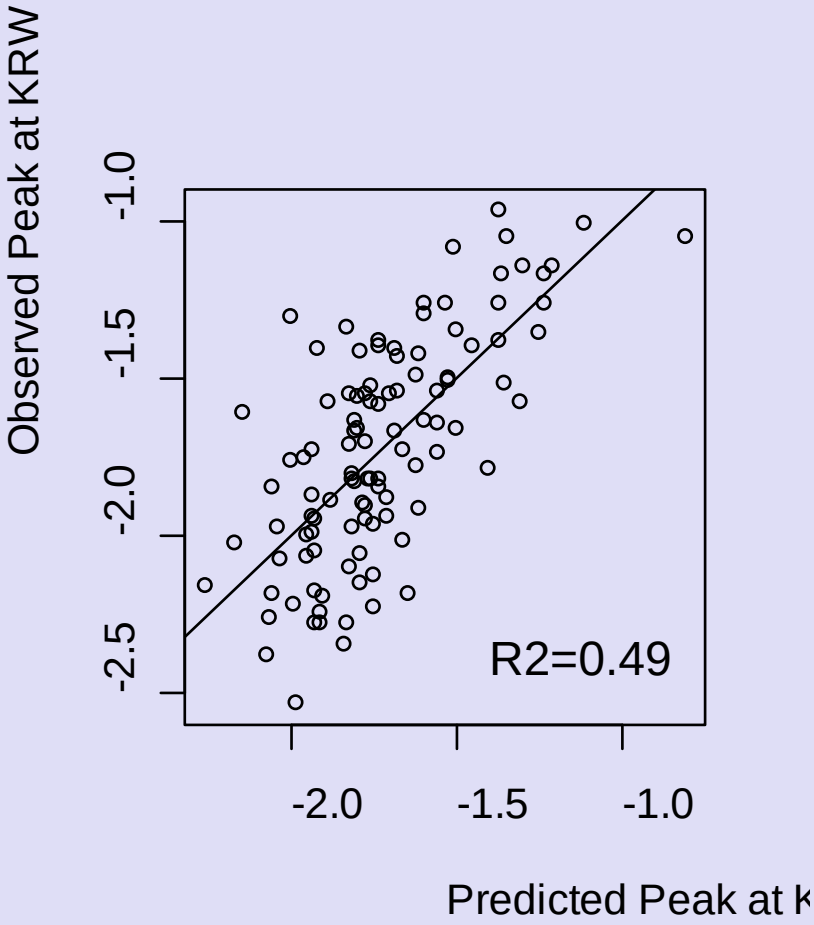
Models for Storm Peak Flow

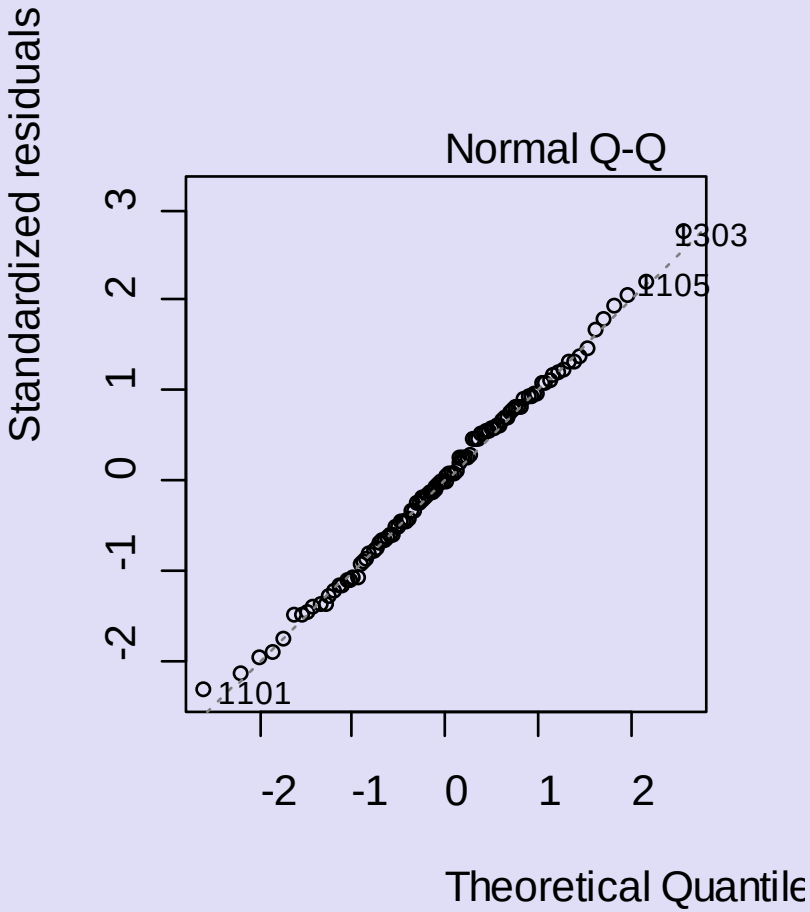
- Response
  - Logarithm of 6-hr maximum flow
- Predictors
  - Rainfall in the 6, 12, 18, or 24 hrs before peak
  - $API_{k,i} = k\, API_{k,i-1} + P_i$: hourly, daily
    - Half-lives from 1.4 hours to 32 days
  - Up to 5 predictors from all possible subsets
- Variation explained: SFM 51%, KRW 49%

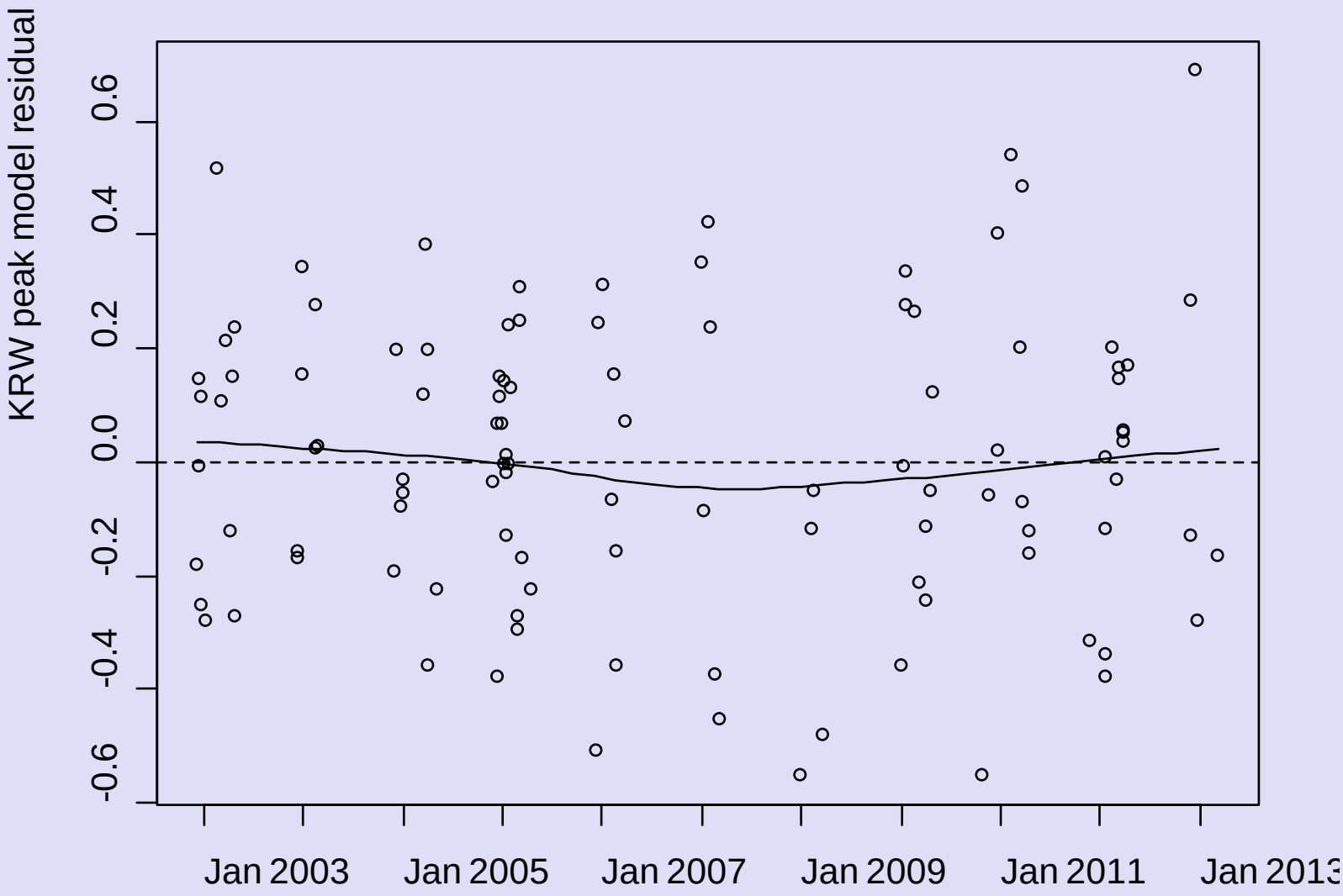
Daily API variables

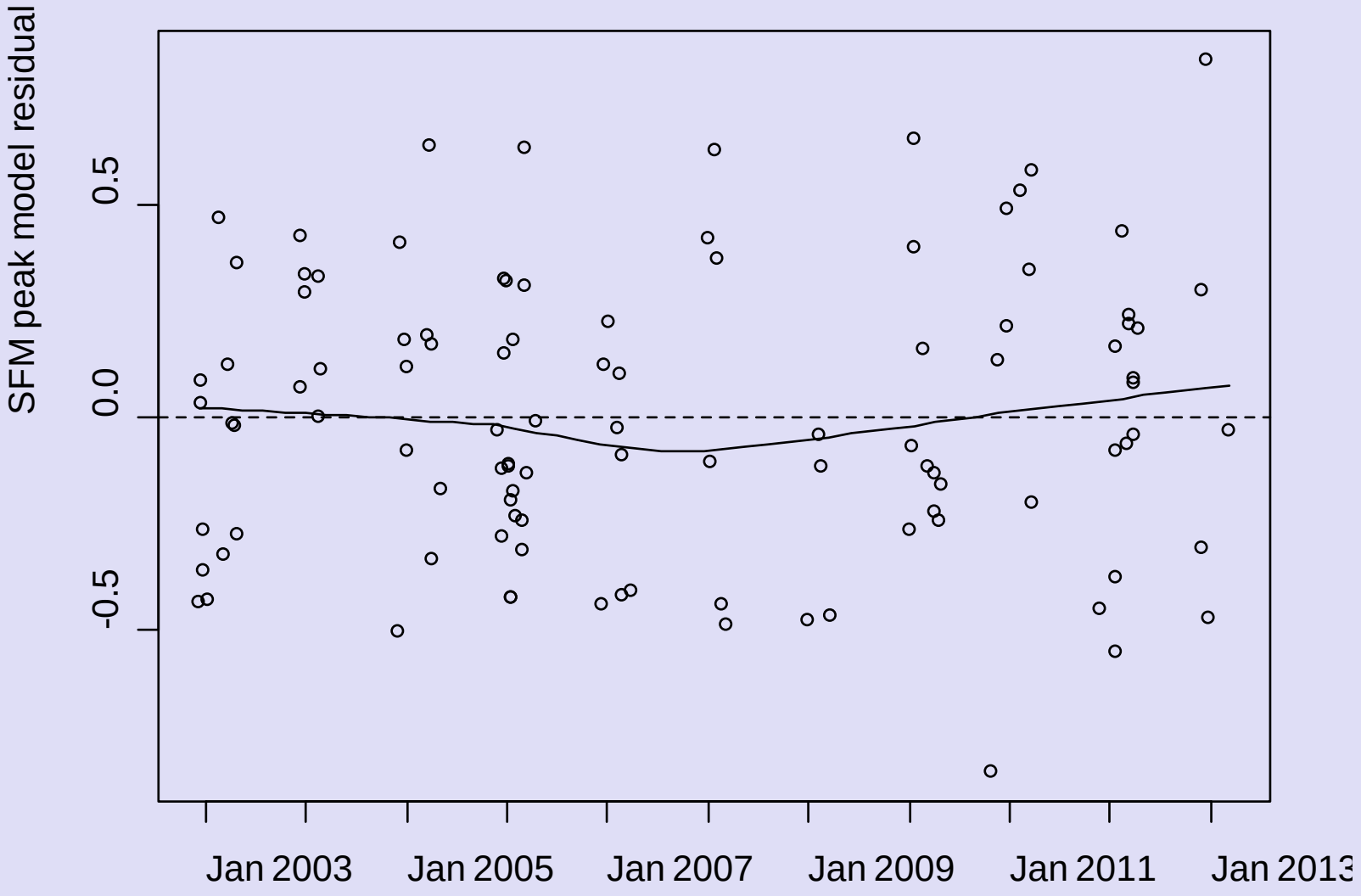
Variable	Decay rate	Half-life (days)
D61	0.6125	1.41
D71	0.7071	2.00
D78	0.7827	2.83
D84	0.8409	4.00
D88	0.8847	5.66
D92	0.9170	8.00
D94	0.9406	11.3
D96	0.9576	16.0
D97	0.9698	22.6
D98	0.9786	32.0

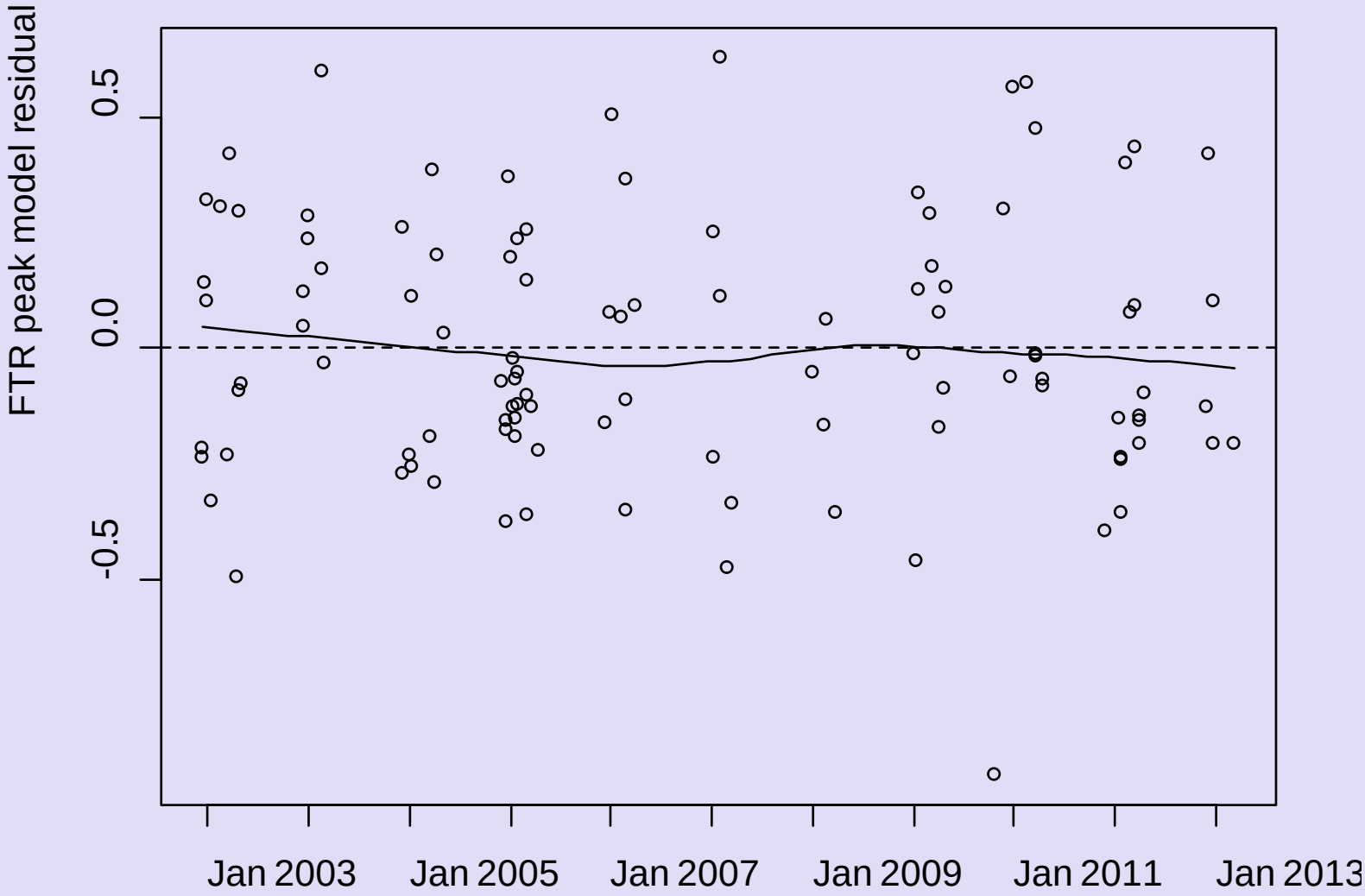

Added-Variable
log(KRW) | others
(Intercept) | others
Added-Variable
log(KRW) | others
krw 12 | others
Added-Variable
log(KRW) | others
krw .d61 | others
Added-Variable
log(KRW) | others
krw .h61 | others
Added-Variable
log(KRW) | others
krw .h78 | others
Added-Variable
log(KRW) | others
krw .h92 | others

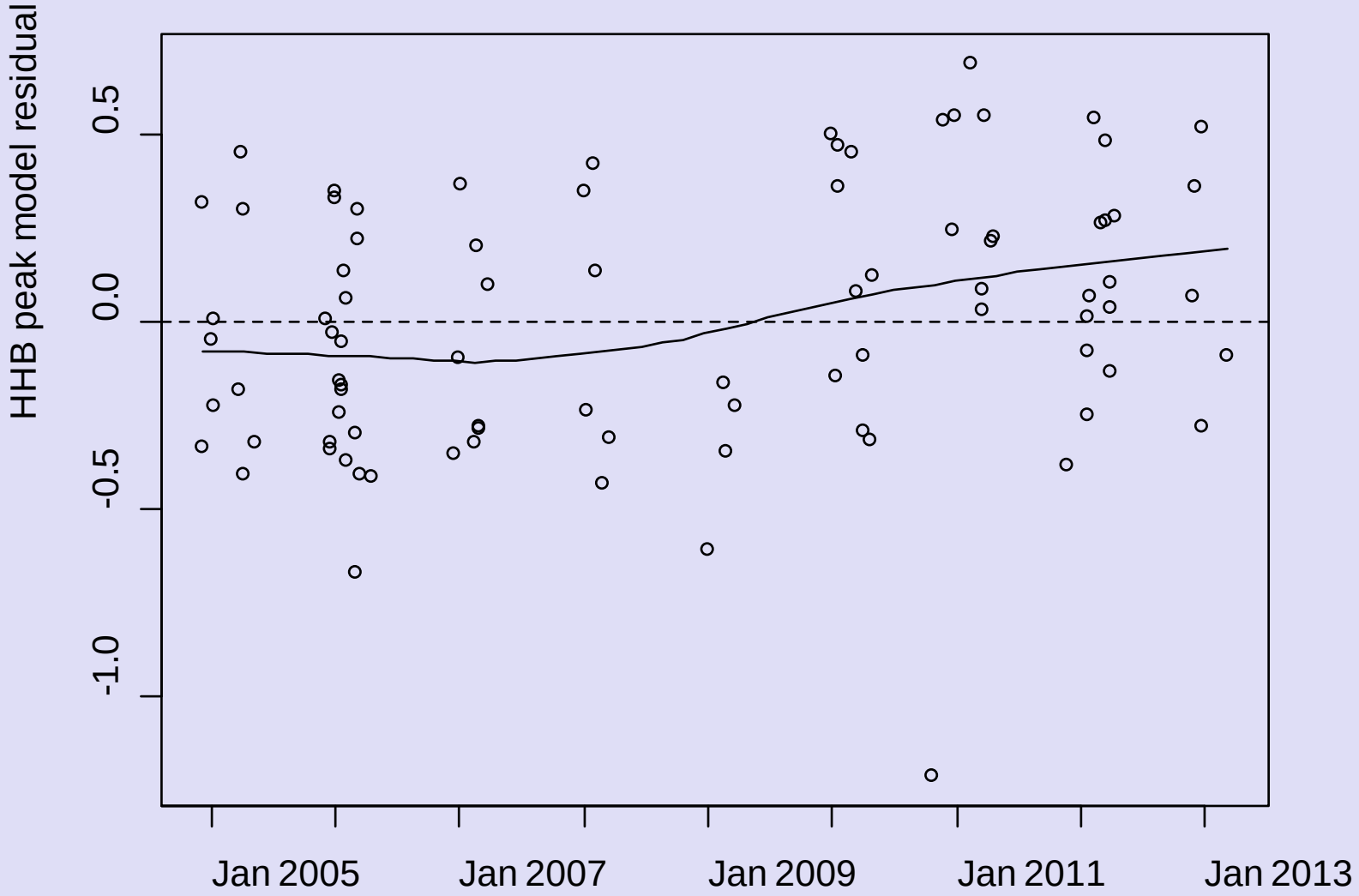

Observed Peak at KRW
-1.0
-1.5
-2.0
-2.5
R2=0.49
-2.0
-1.5
-1.0
Predicted Peak at K


Standardized residuals
Normal Q-Q
3
2
1
0
-1
-2
1303
1105
1101
-2
-1
0
1
2
Theoretical Quantile


KRW peak model residual
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Jan 2003
Jan 2005
Jan 2007
Jan 2009
Jan 2011
Jan 2013

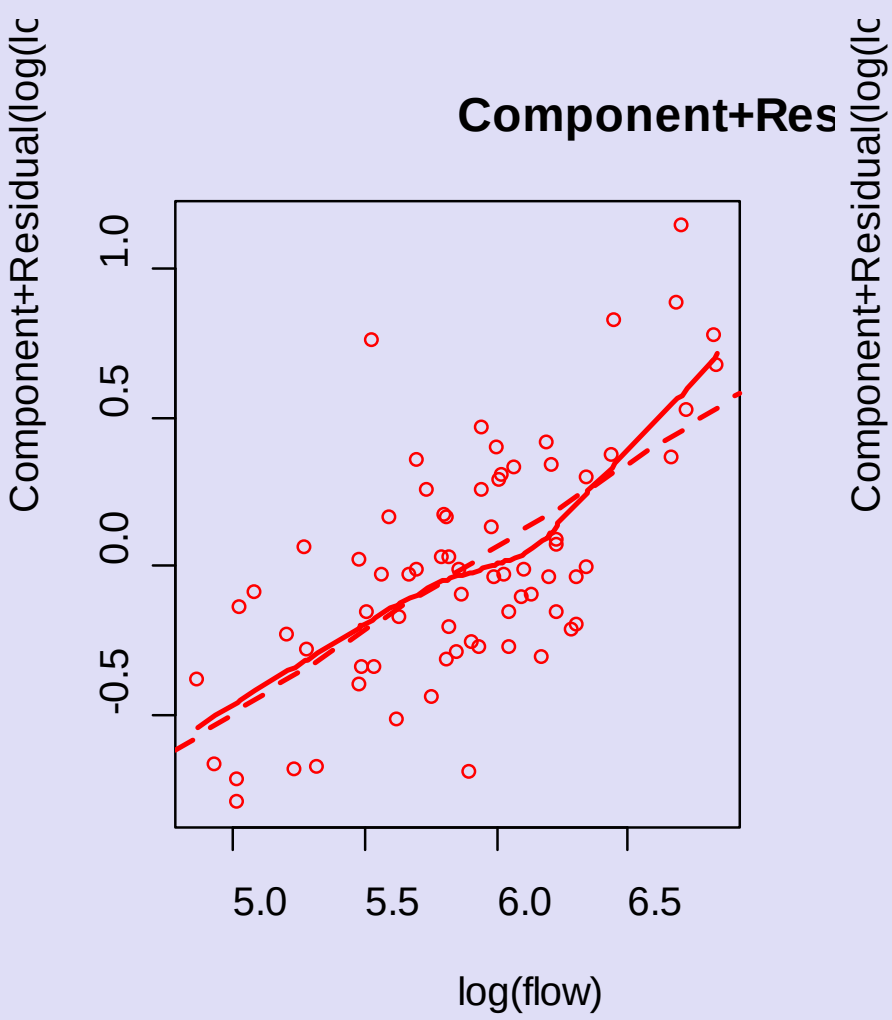

SFM peak model residual
0.5
0.0
-0.5
Jan 2003
Jan 2005
Jan 2007
Jan 2009
Jan 2011
Jan 2013

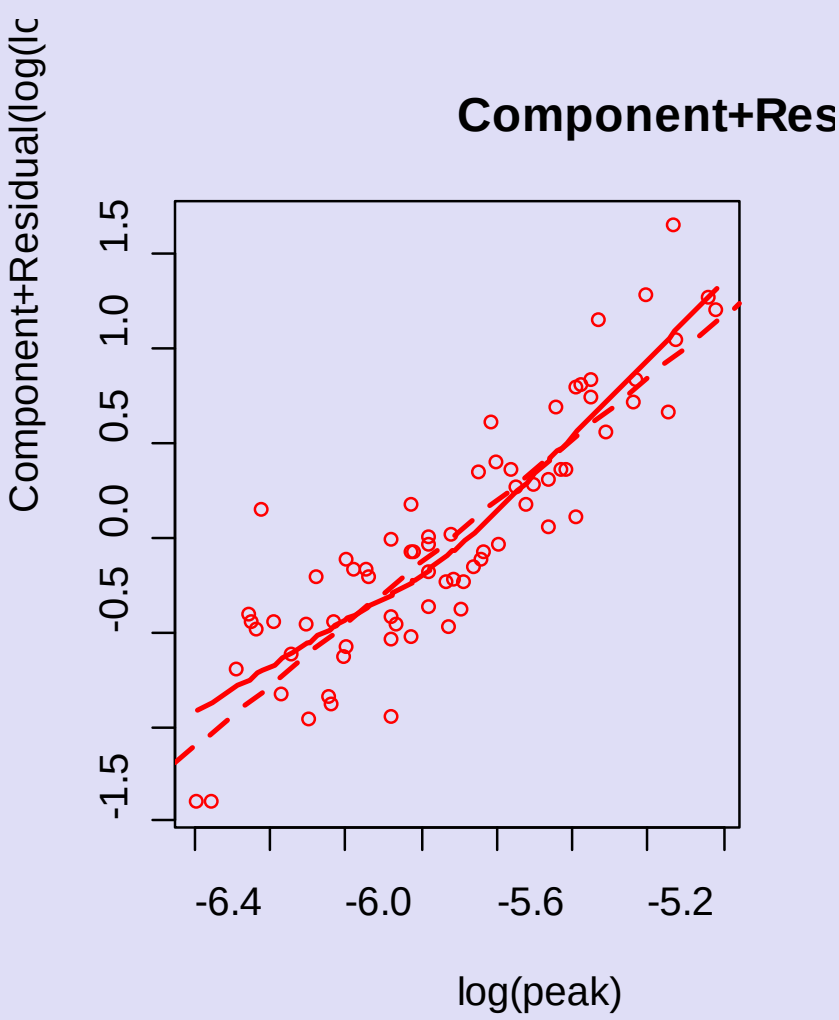

FTR peak model residual
0.5
0.0
-0.5
Jan 2003
Jan 2005
Jan 2007
Jan 2009
Jan 2011
Jan 2013

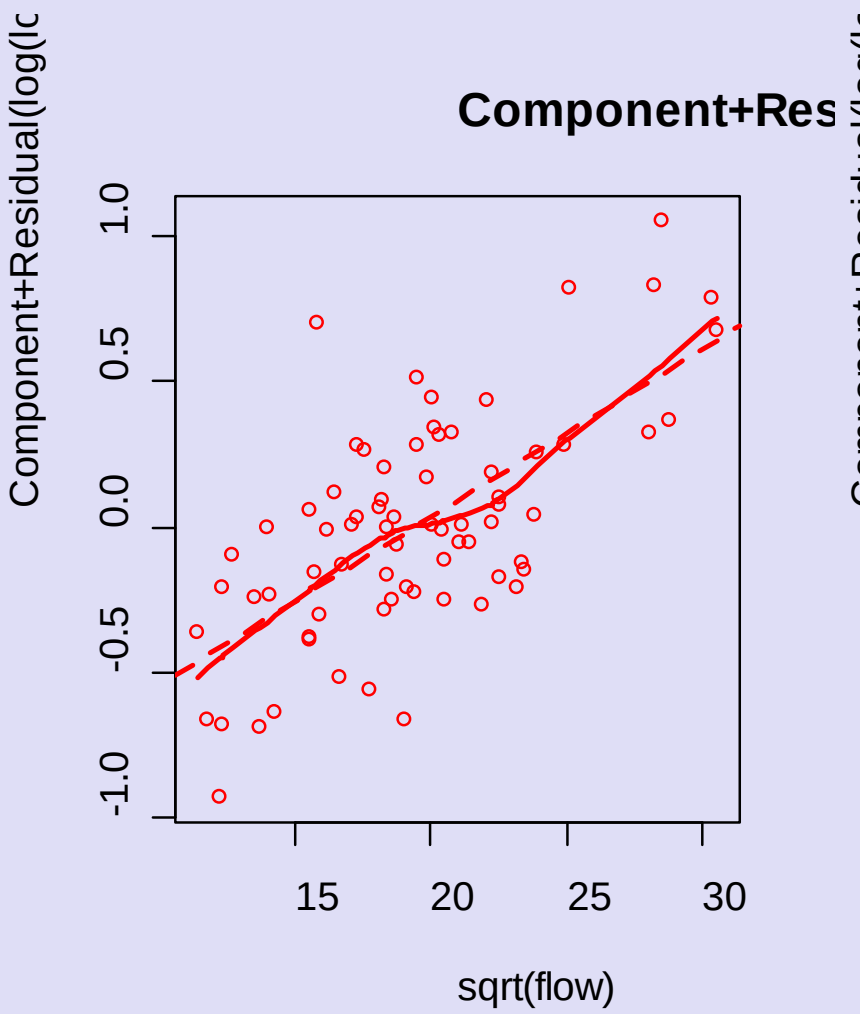

HHB peak model residual
0.5
0.0
-0.5
-1.0
Jan 2005
Jan 2007
Jan 2009
Jan 2011
Jan 2013

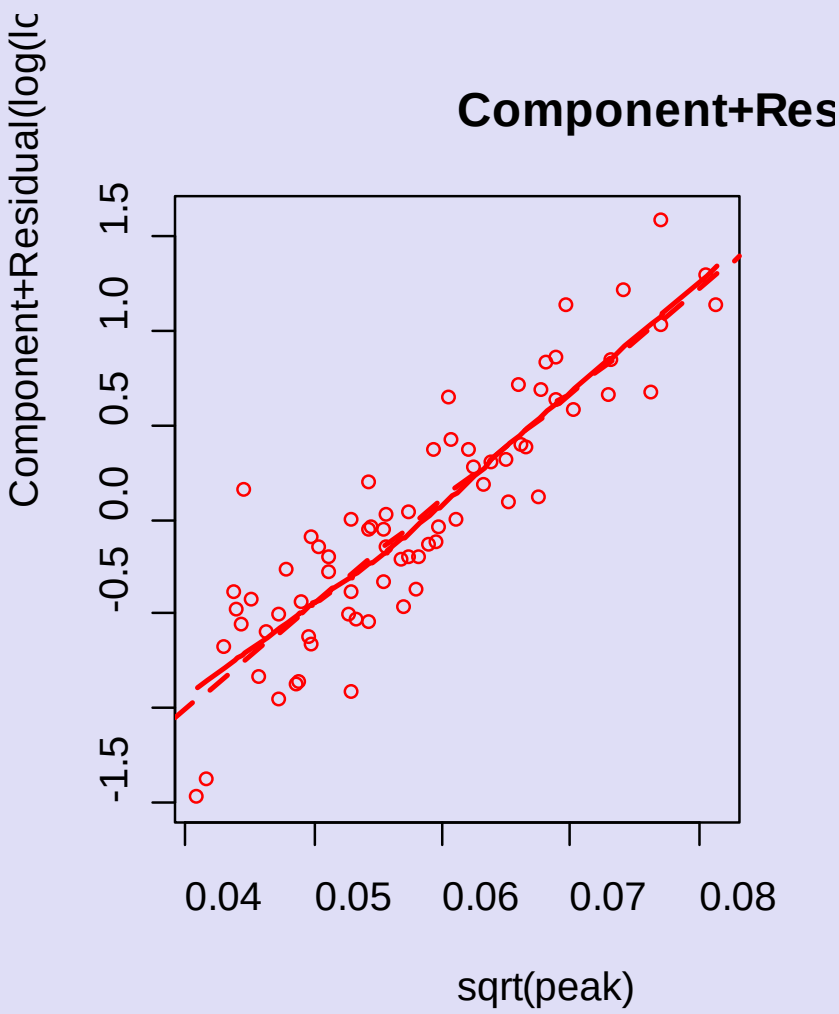
Regression Models for Storm Event Load

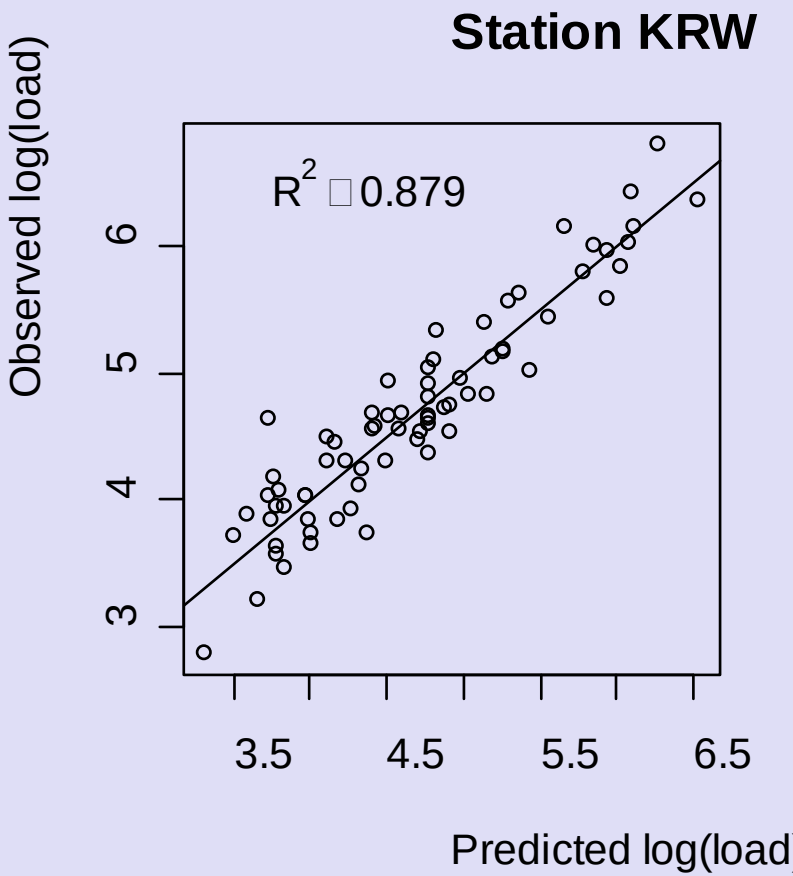
- Response
  - Logarithm of storm event load
- Predictors
  - Storm event flow volume (log or sqrt)
  - Storm event peak flow (log or sqrt)
- Residuals are not quite independent
  - Serial autocorrelation must be modeled

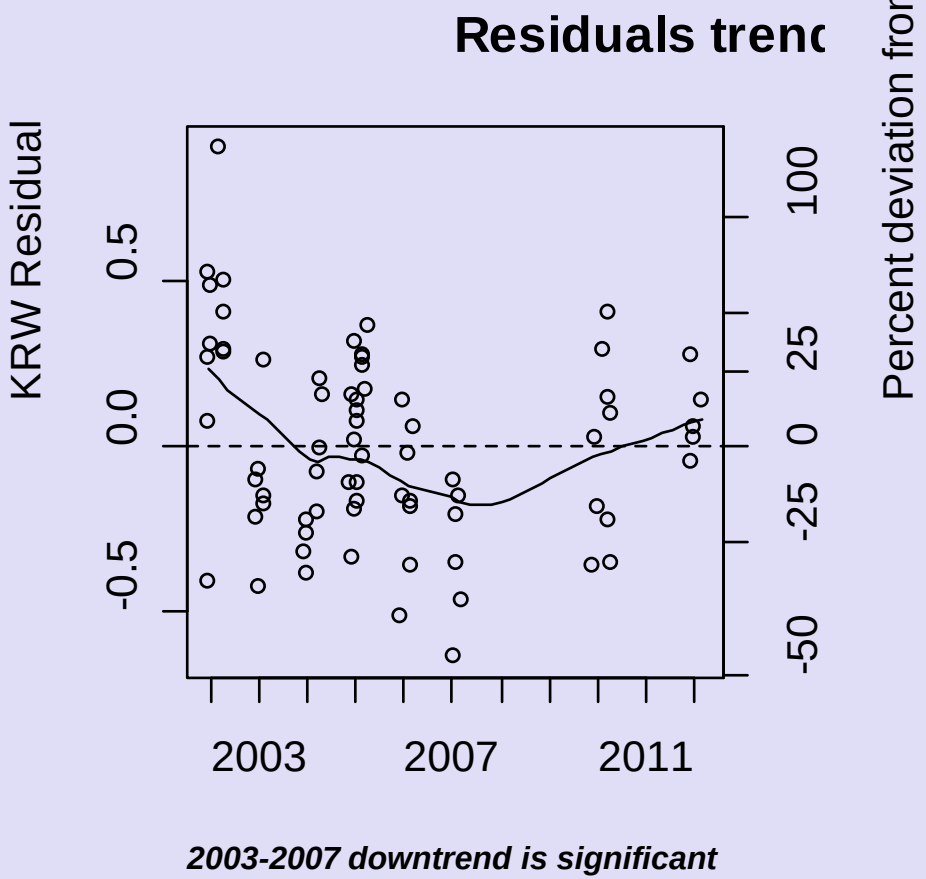

Component+Residual(log(Ic
Component+Res
1.0
0.5
0.0
-0.5
5.0
5.5
6.0
6.5
log(flow)


Component+Residual(log(Ic
Component+Res
1.5
1.0
0.5
0.0
-0.5
-1.5
-6.4
-6.0
-5.6
-5.2
log(peak)

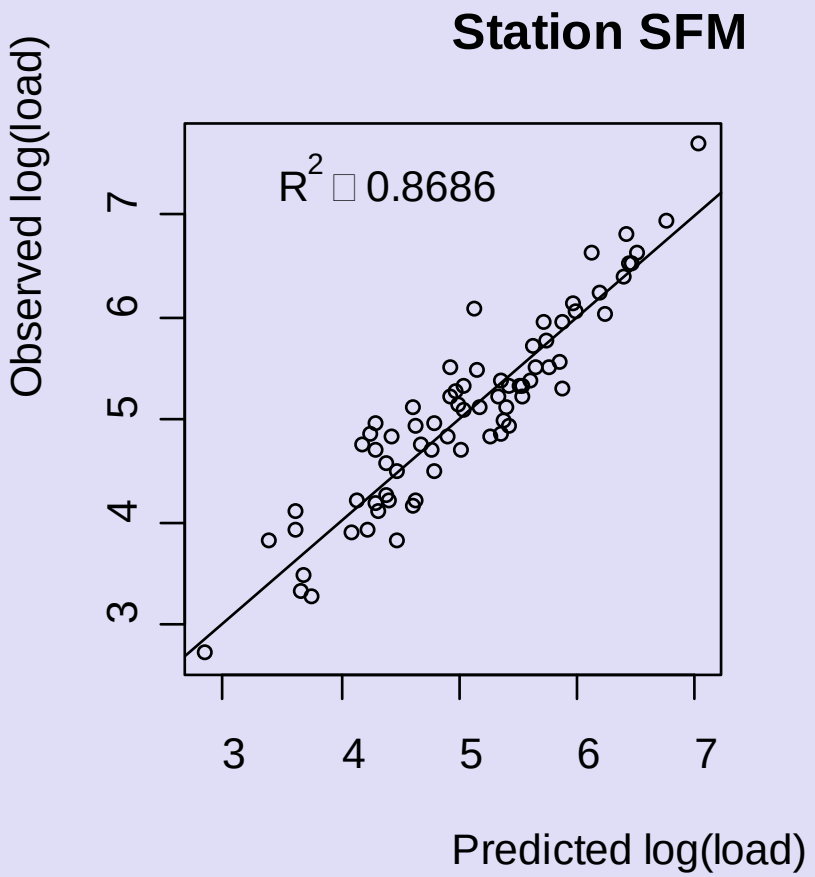

Component+Res
Component+Residual(log(lc
1.0
0.5
0.0
-0.5
-1.0
15
20
25
30
sqrt(flow)

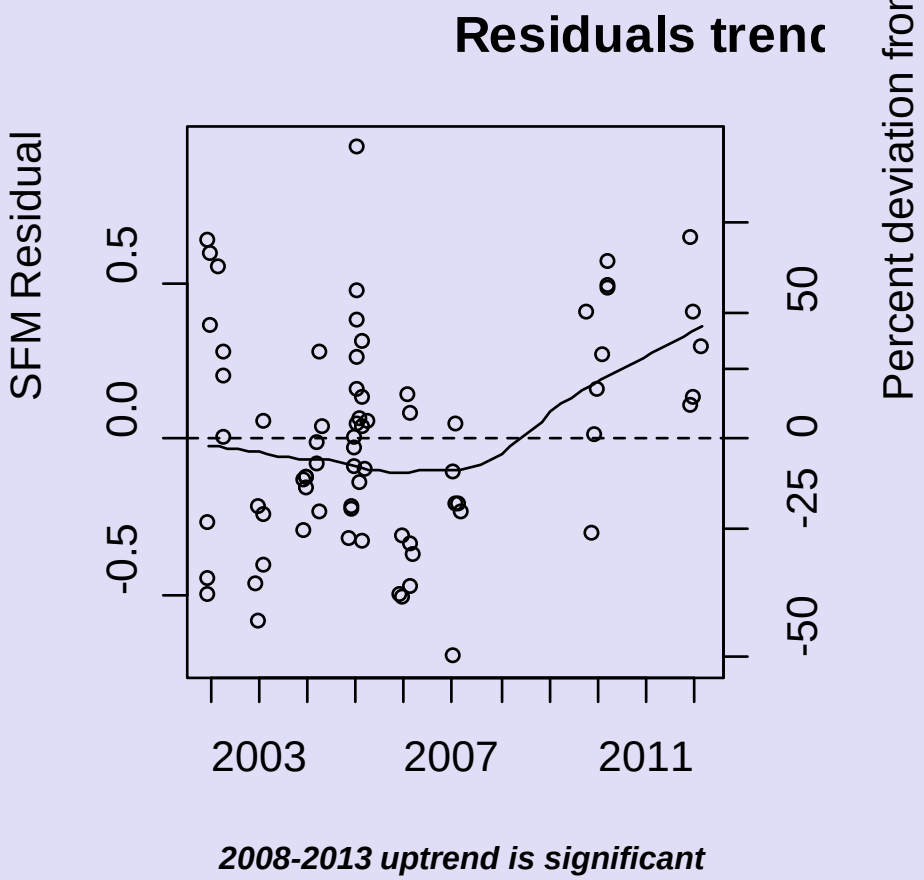

Component+Res
Component+Residual(log(lc
1.5
1.0
0.5
0.0
-0.5
-1.5
0.04
0.05
0.06
0.07
0.08
sqrt(peak)



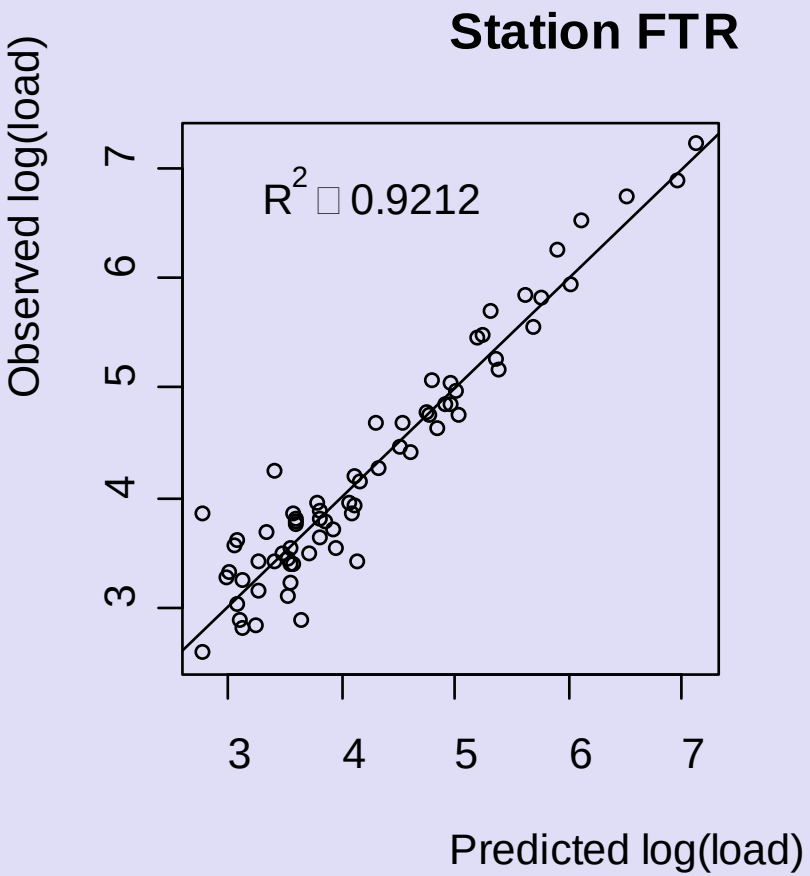


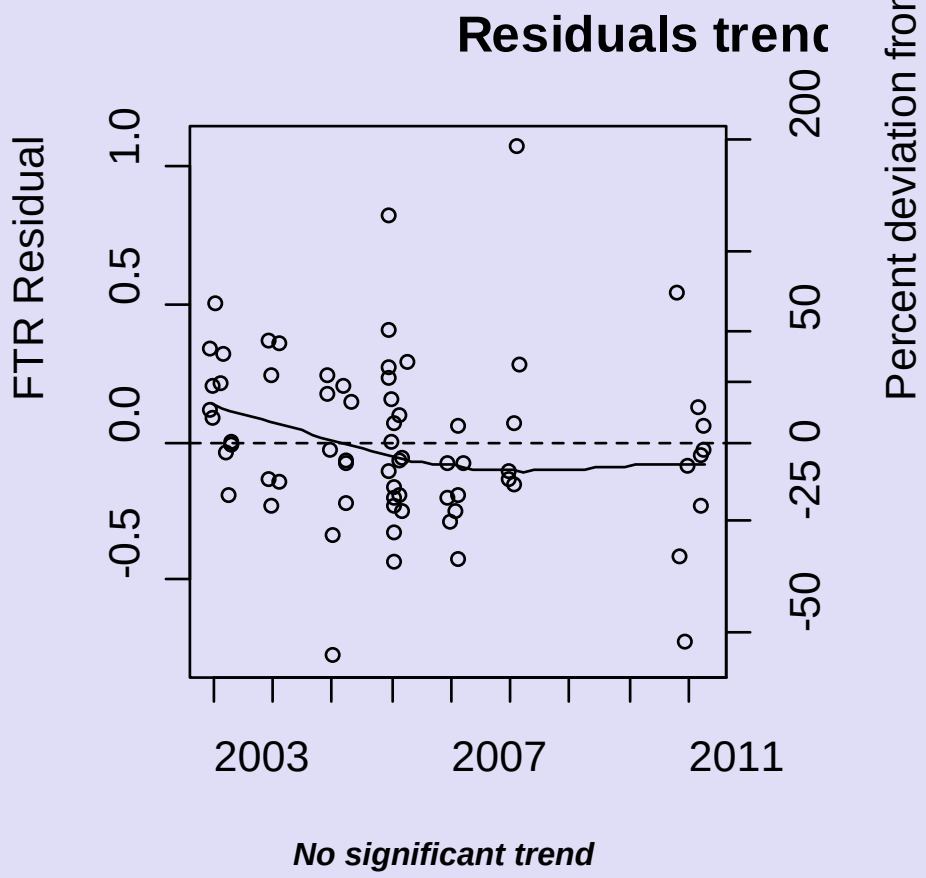
2003-2007 downtrend is significant



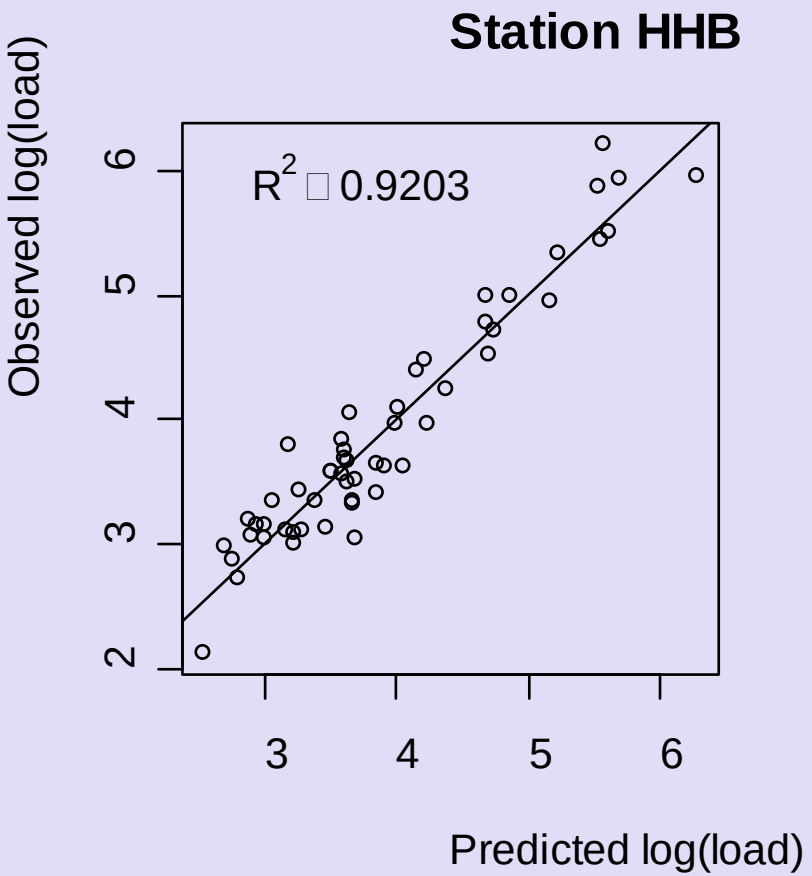


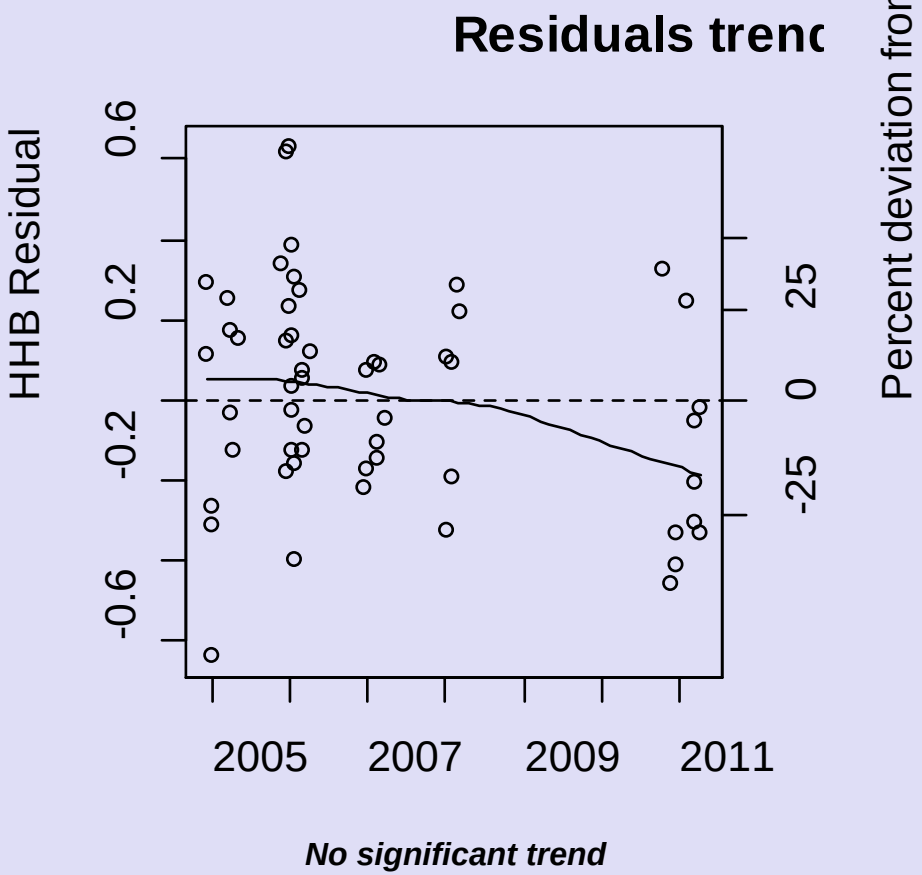
2008-2013 uptrend is significant





No significant trend





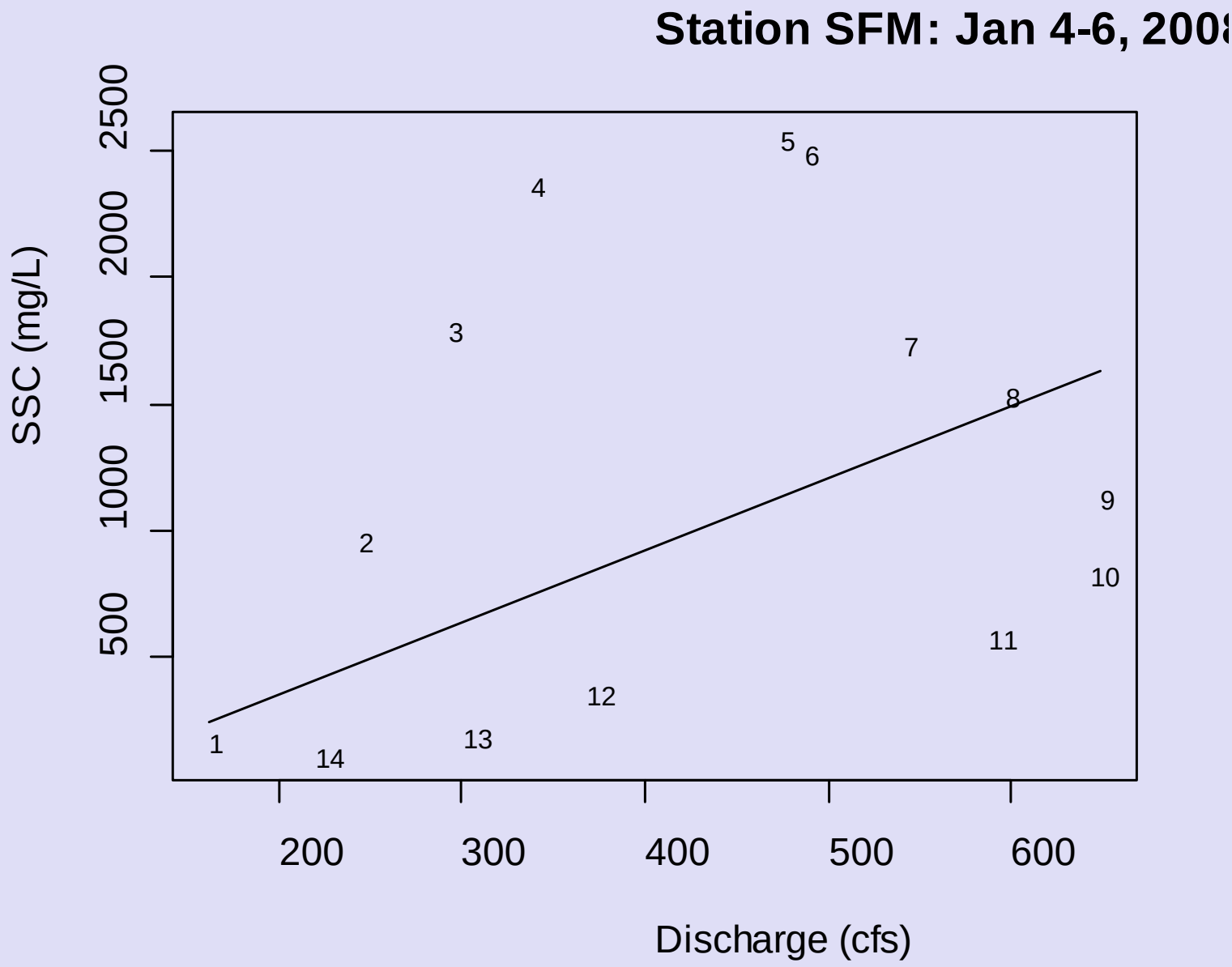
No significant trend

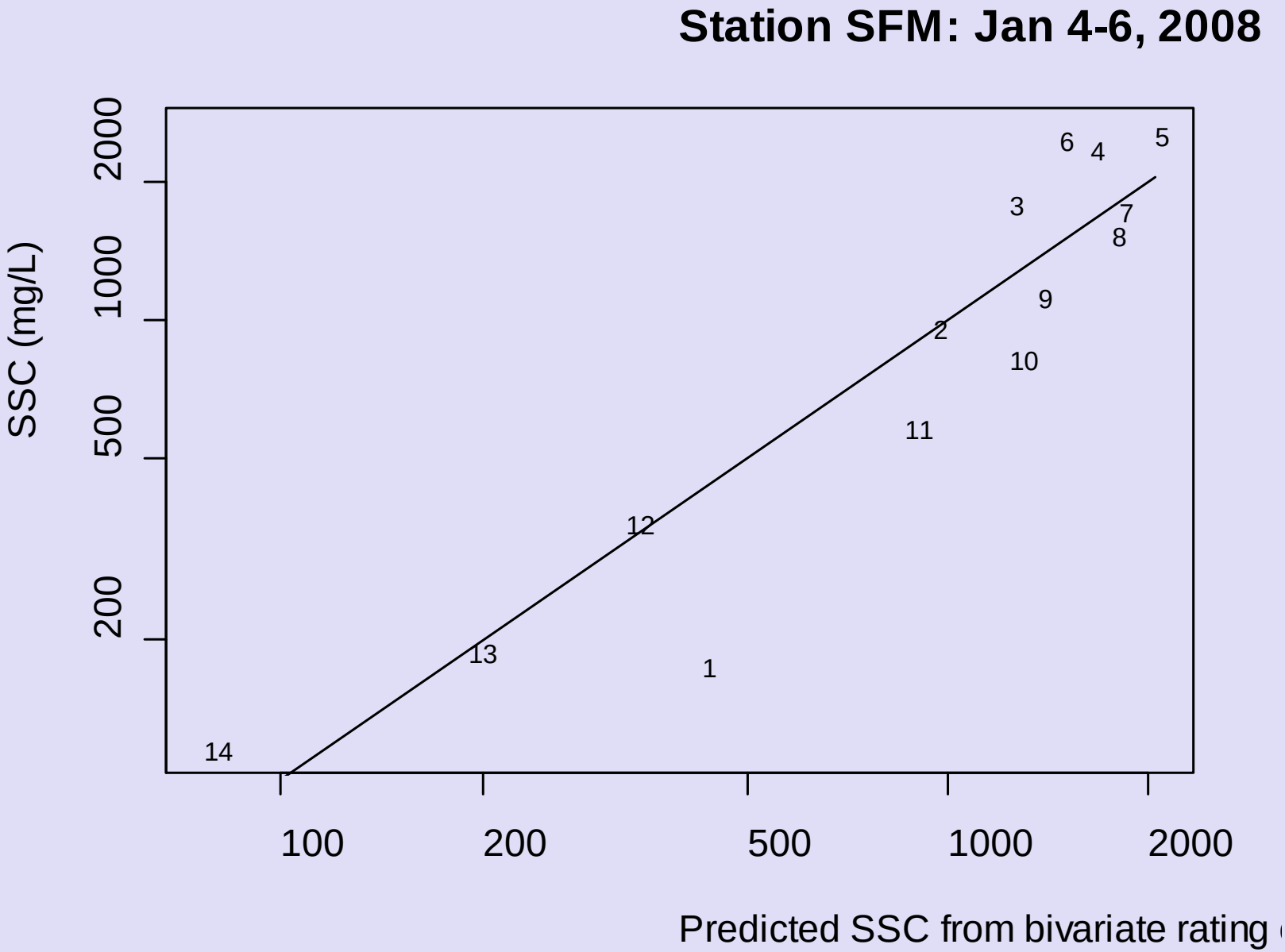
Significance tests for trend in storm event load

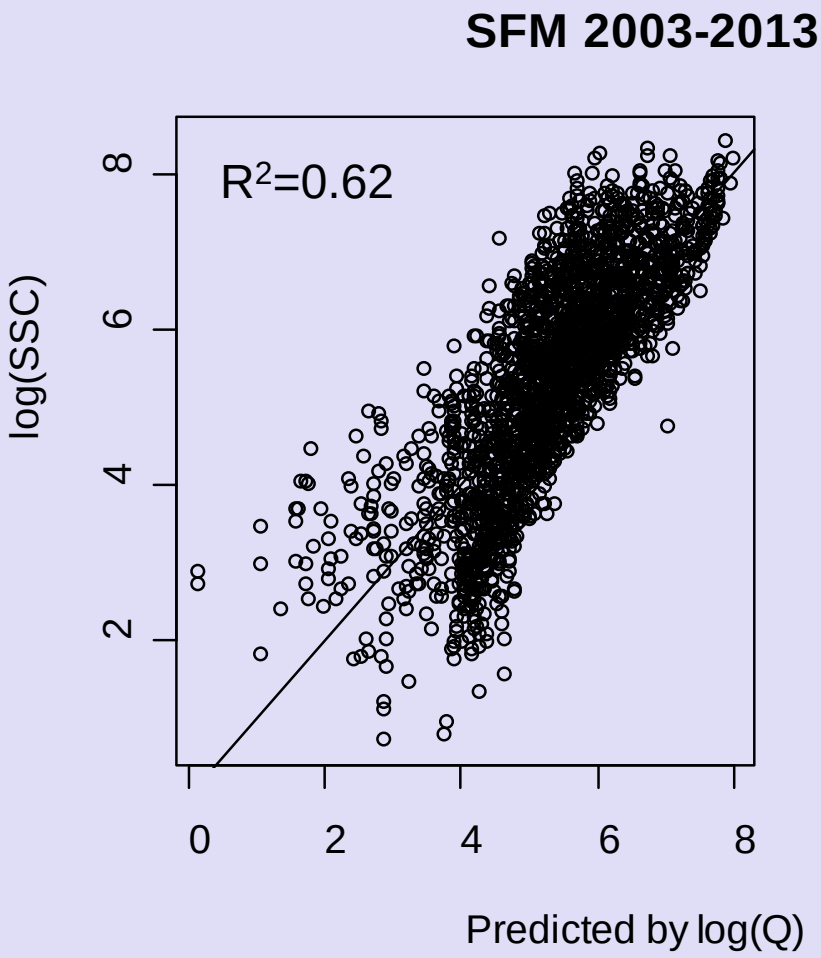
Station	Years	Flow variable	Peak variable	Adjusted R^2	Error model	Trend p-value
SFM	2003-2013	Log(flow)	Log(peak)	0.869	AR(2)	0.2045
	2006-2008	Log(flow)	Log(peak)	0.884	CAR(1)	0.3569
	2008-2013	Log(flow)	Log(peak)	0.881	IID	0.0027++
KRW	2003-2013	$flow^{0.5}$	$peak^{0.5}$	0.877	AR(3)	0.6798
	2006-2008	$flow^{0.5}$	$peak^{0.5}$	0.958	IID	0.0004--
	2008-2013	$flow^{0.5}$	$peak^{0.5}$	0.920	IID	0.0071+
FTR	2003-2011	Log(flow)	Log(peak)	0.923	AR(1)	0.3154
	2003-2007	Log(flow)	Log(peak)	0.942	IID	0.0390-
HHB	2005-2011	$flow^{0.5}$	$peak^{0.5}$	0.921	IID	0.0602
	2006-2011	$flow^{0.5}$	$peak^{0.5}$	0.935	IID	0.0086-

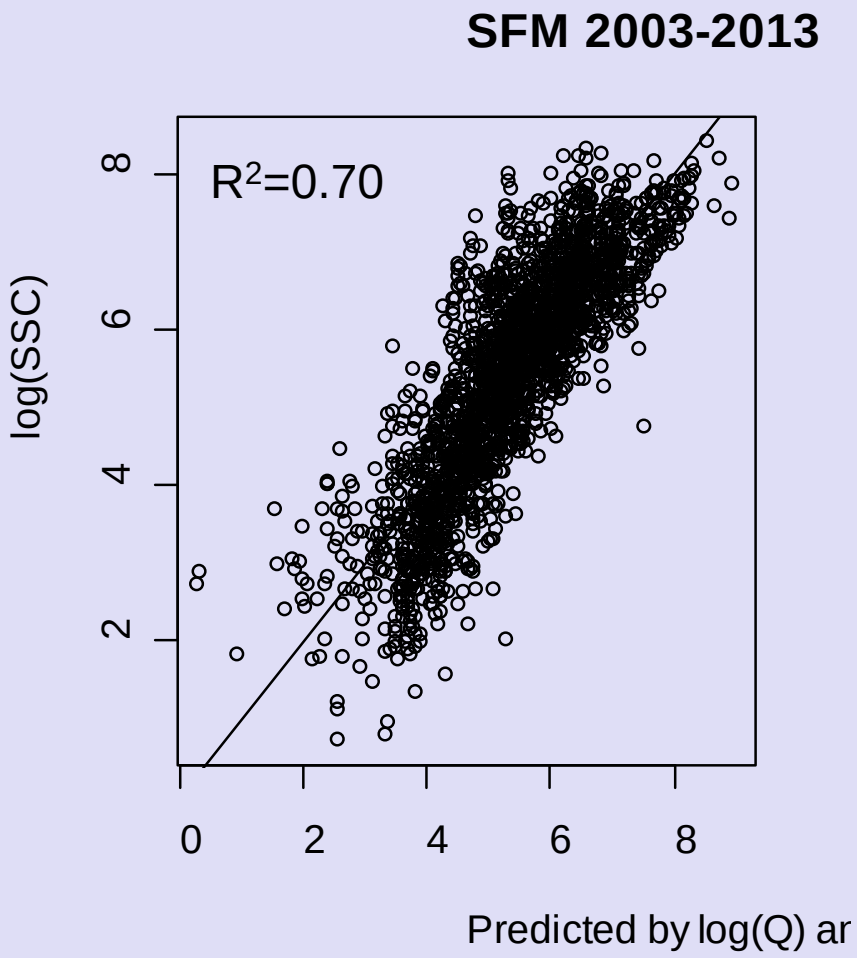
Models for Instantaneous SSC

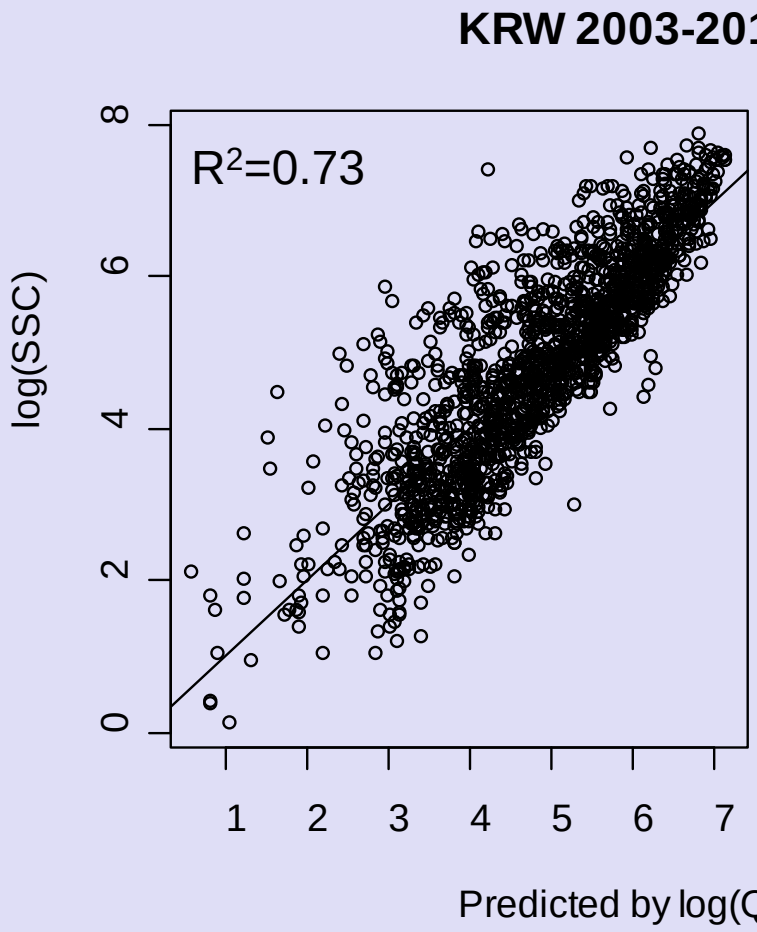
- Response
  - Logarithm of SSC
- Predictors
  - Logarithm of simultaneous discharge
  - Hourly API, half-life 3-4 hrs
  - Two predictors only
- Serial autocorrelation important

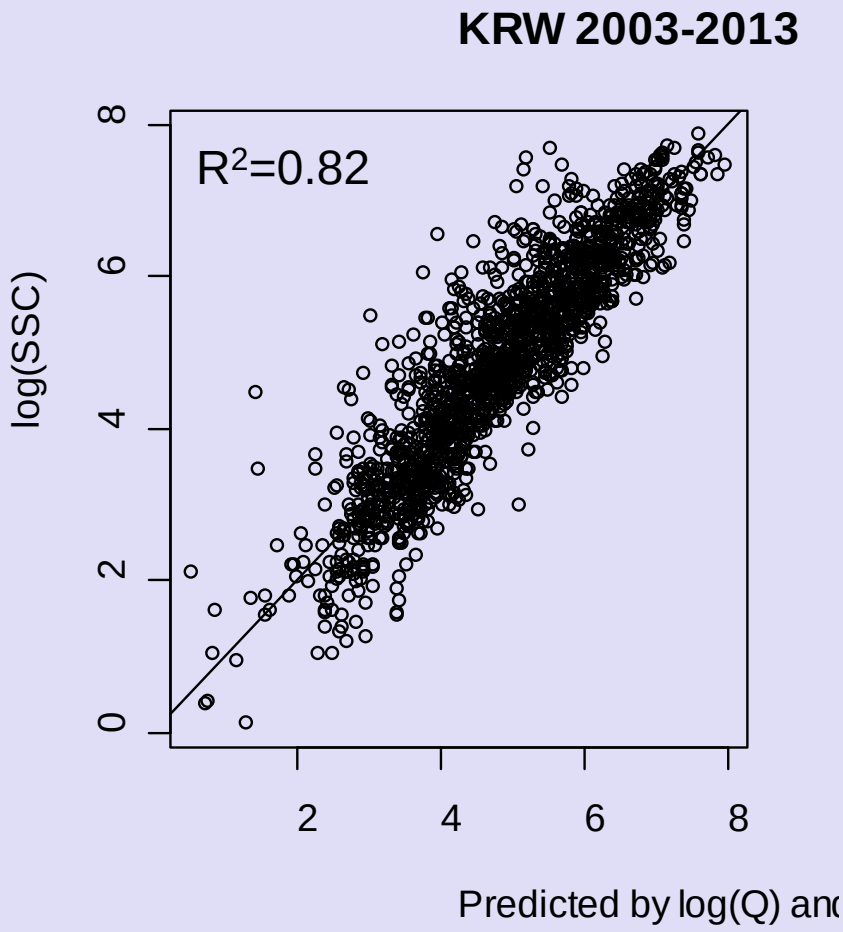

Station SFM: Jan 4-6, 2008
SSC (mg/L)
500
1000
1500
2000
2500
200
300
400
500
600
Discharge (cfs)
1
2
3
4
5
6
7
8
9
10
11
12
13
14

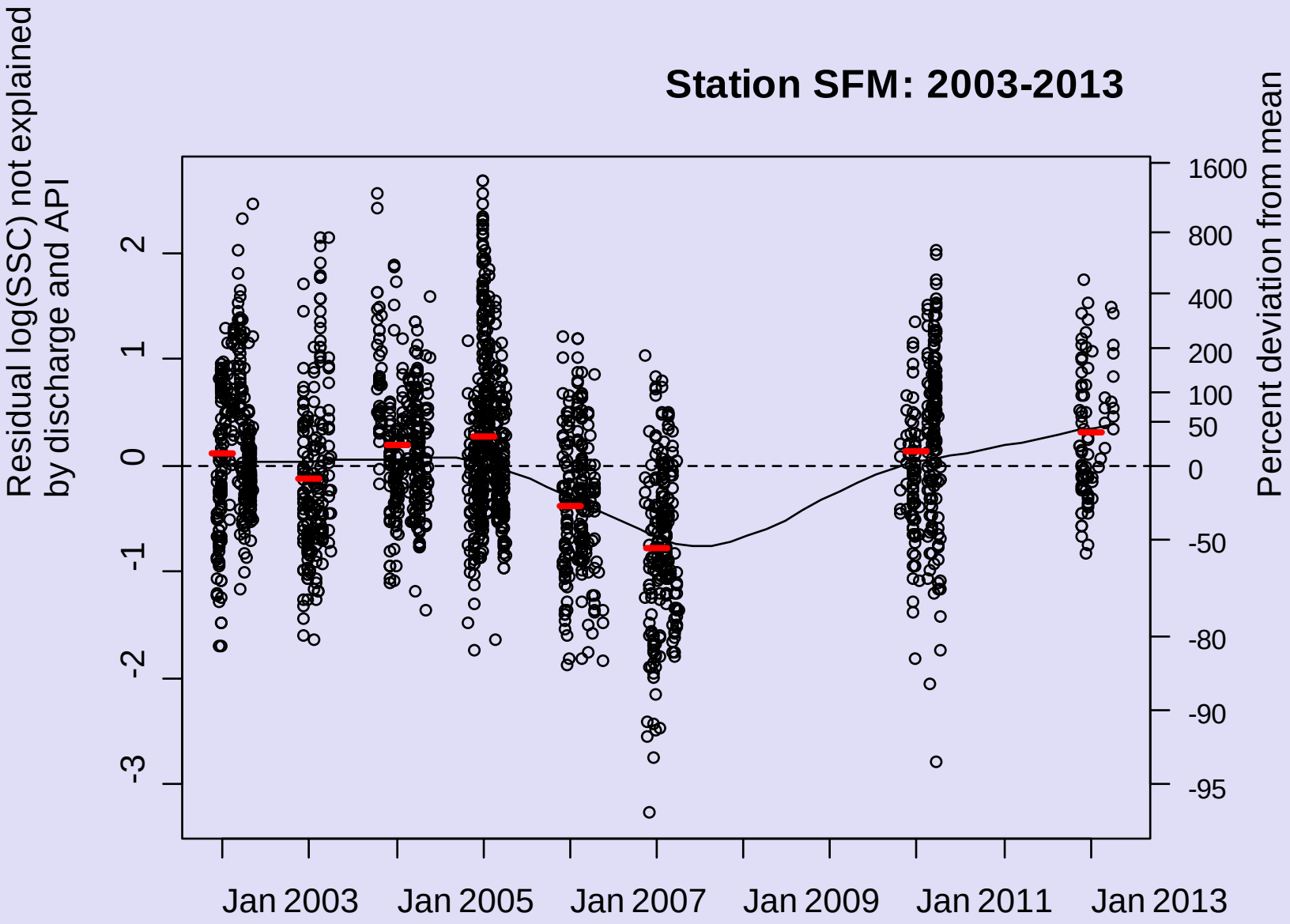

Station SFM: Jan 4-6, 2008
SSC (mg/L)
2000
1000
500
200
100
200
500
1000
2000
Predicted SSC from bivariate rating
6
4
5
3
7
8
9
2
10
11
12
13
1
14

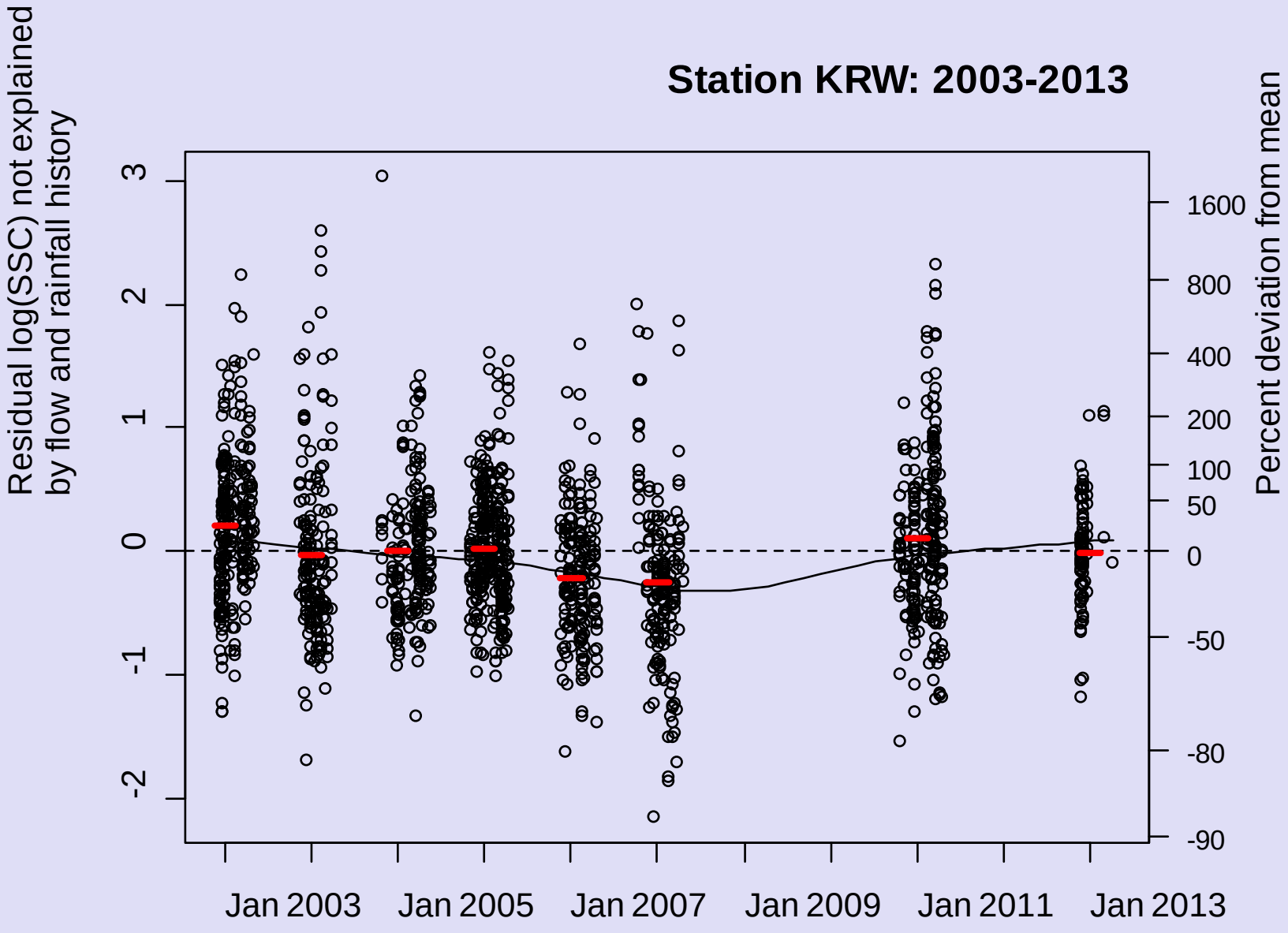

SFM 2003-2013
R2=0.62
log(SSC)
Predicted by log(Q)
0
2
4
6
8

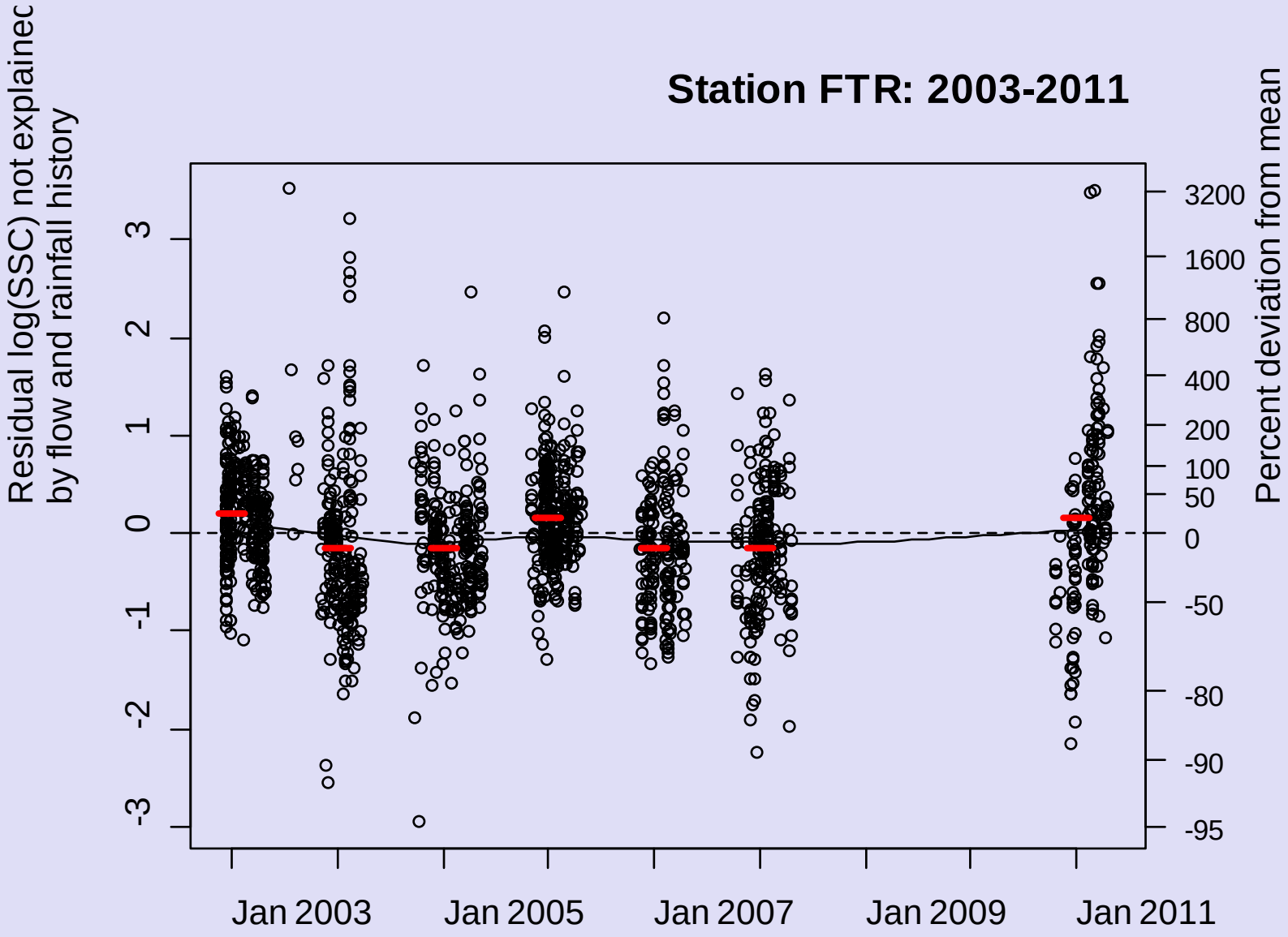

SFM 2003-2013
R2=0.70
log(SSC)
Predicted by log(Q) ar
0
2
4
6
8

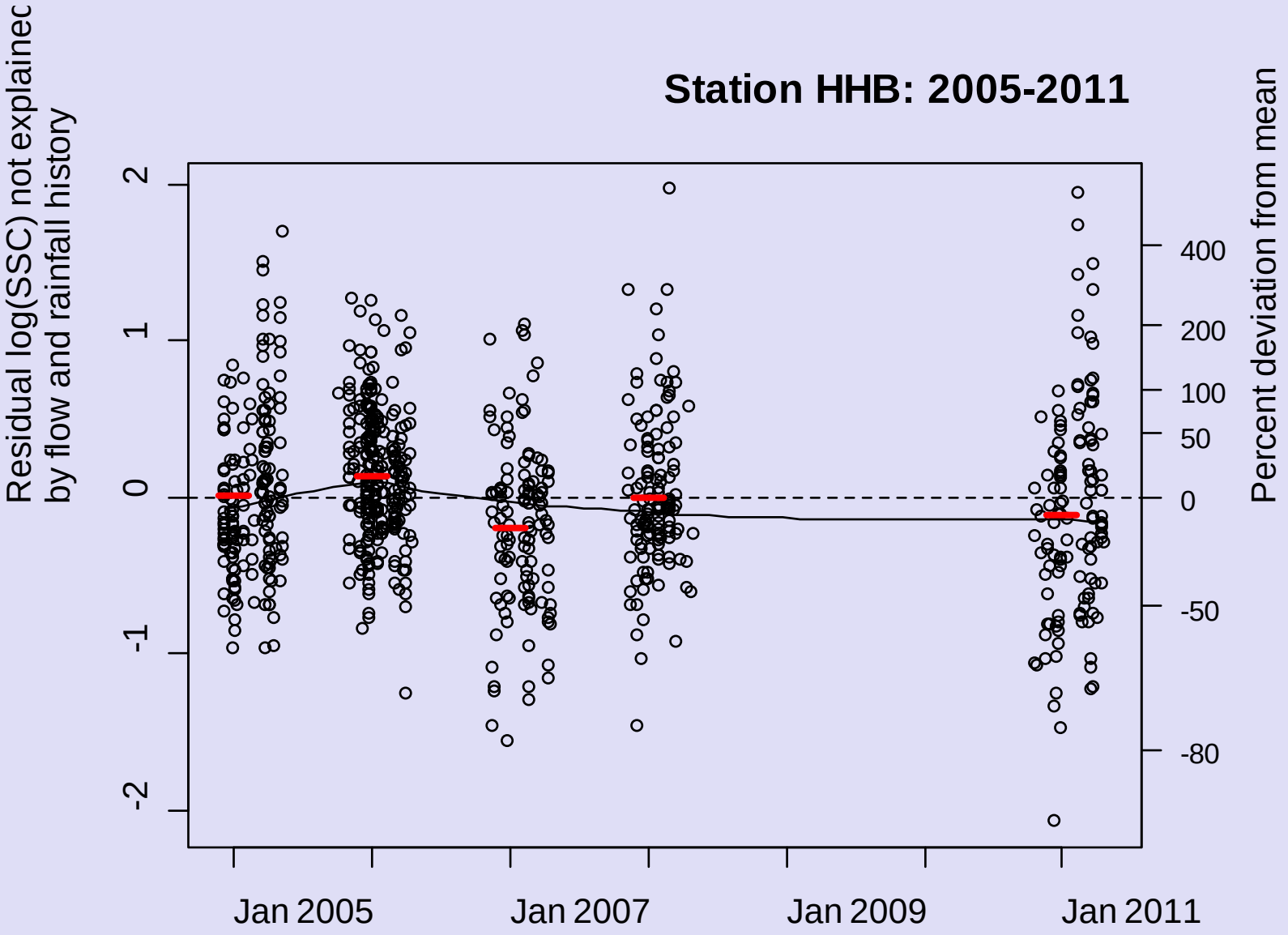

KRW 2003-2013
R2=0.73
log(SSC)
0
2
4
6
8
1
2
3
4
5
6
7
Predicted by log(Q)


KRW 2003-2013
R2=0.82
log(SSC)
0
2
4
6
8
2
4
6
8
Predicted by log(Q) and


Station SFM: 2003-2013
Residual log(SSC) not explained by discharge and API
Percent deviation from mean
-3
-2
-1
0
1
2
1600
800
400
200
100
50
0
-50
-80
-90
-95
Jan 2003
Jan 2005
Jan 2007
Jan 2009
Jan 2011
Jan 2013


Station KRW: 2003-2013
Residual log(SSC) not explained by flow and rainfall history
Percent deviation from mean
3
2
1
0
-1
-2
1600
800
400
200
100
50
0
-50
-80
-90
Jan 2003
Jan 2005
Jan 2007
Jan 2009
Jan 2011
Jan 2013

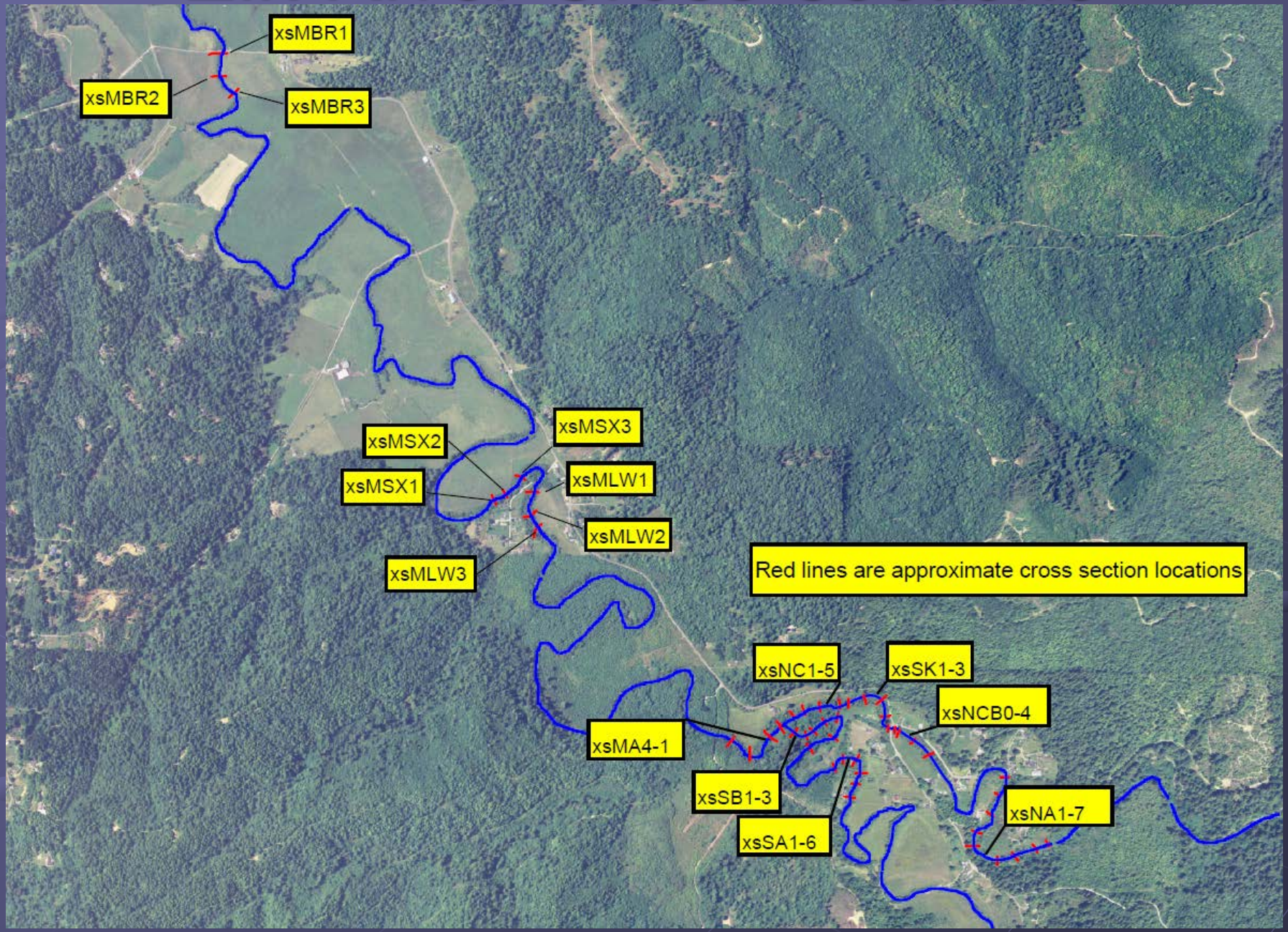

Station FTR: 2003-2011
Residual log(SSC) not explainec
by flow and rainfall history
Percent deviation from mean
3
2
1
0
-1
-2
-3
3200
1600
800
400
200
100
50
0
-50
-80
-90
-95
Jan 2003
Jan 2005
Jan 2007
Jan 2009
Jan 2011


Station HHB: 2005-2011
Residual log(SSC) not explainec
by flow and rainfall history
Percent deviation from mean
2
1
0
-1
-2
400
200
100
50
0
-50
-80
Jan 2005
Jan 2007
Jan 2009
Jan 2011

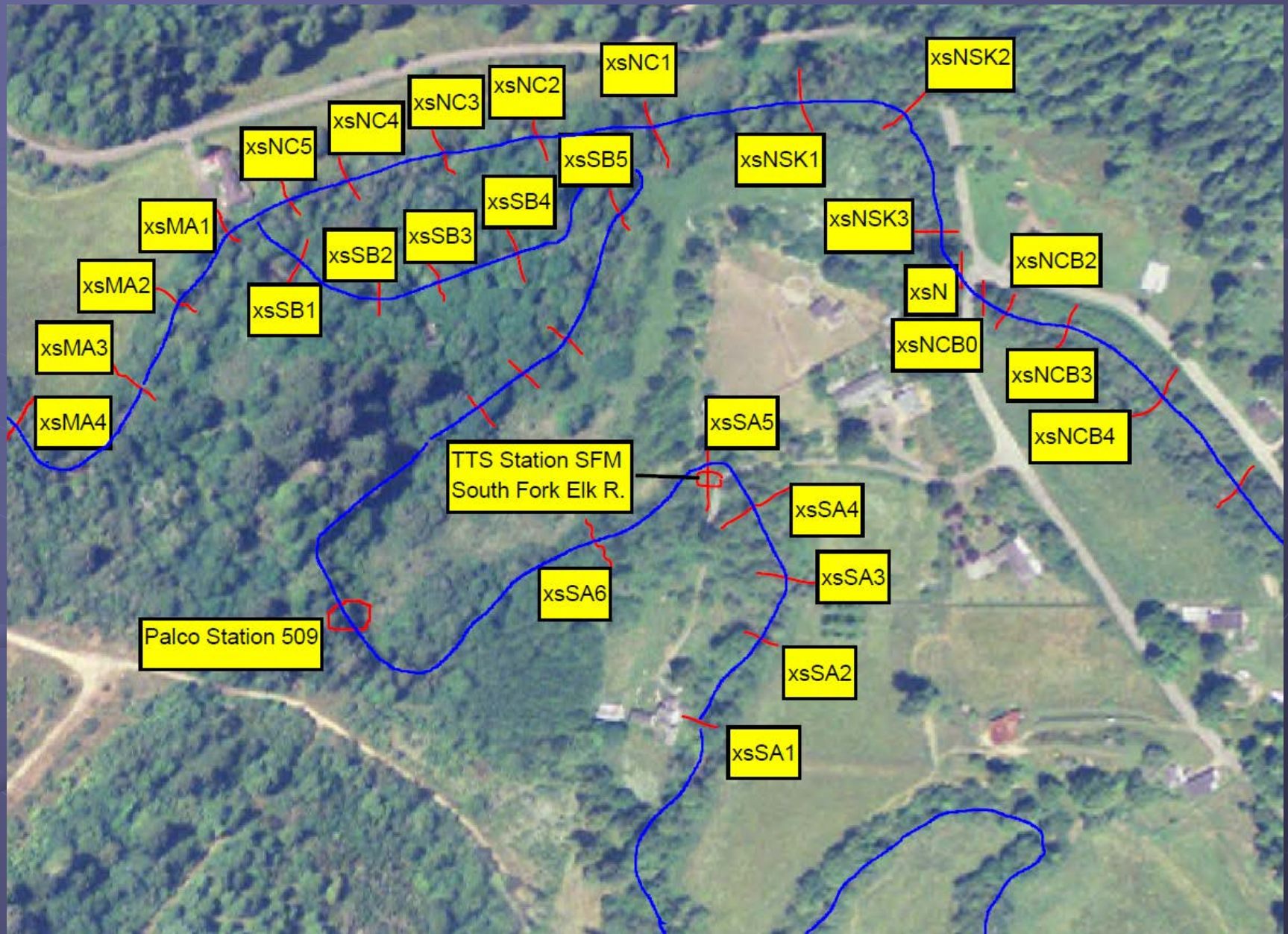
Significance tests for trend in instantaneous SSC

Station	Years	Flow variable	API variable	Adjusted R^2	Error model	Trend p-value
SFM	2003-2013	Log(Q)	$H82^{0.5}$	0.696	AR(4)	0.8960
	2006-2008	Log(Q)	$H84^{0.23}$	0.764	AR(2)	0.0003--
	2008-2013	Log(Q)	H80	0.834	AR(2)	0.0000++
KRW	2003-2013	Log(Q)	$H84^{0.5}$	0.817	AR(2)	0.5703
	2006-2008	Log(Q)	$H90^{0.5}$	0.856	AR(2)	0.0050--
	2008-2013	Log(Q)	$H88^{0.66}$	0.781	AR(2)	0.2676
FTR	2003-2011	$Q^{0.35}$	$H88^{0.7}$	0.808	AR(3)	0.8013
HHB	2005-2011	$Q^{0.2}$	$H85^{0.67}$	0.830	AR(1)	0.0813

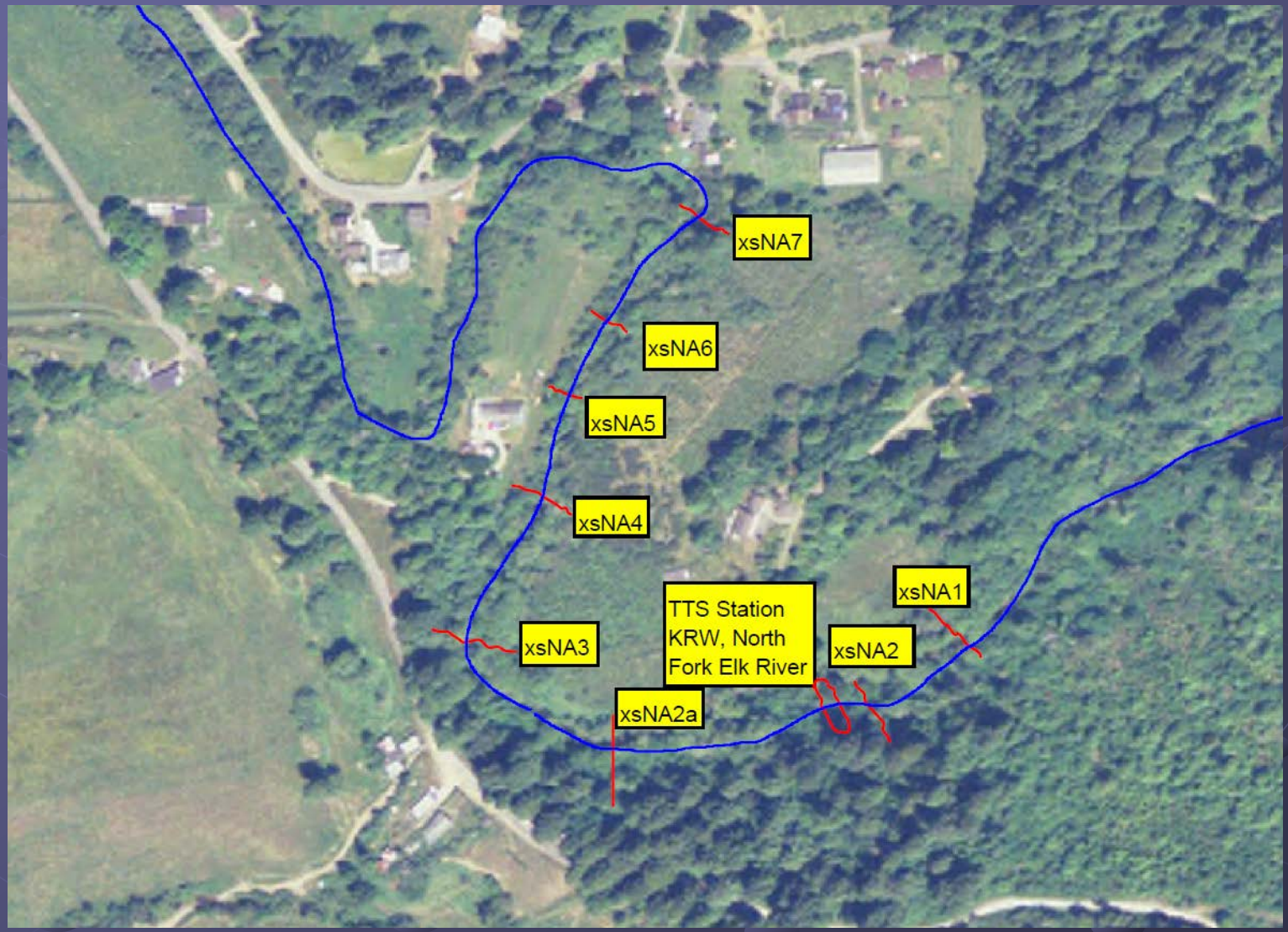
Elk River Cross-sections



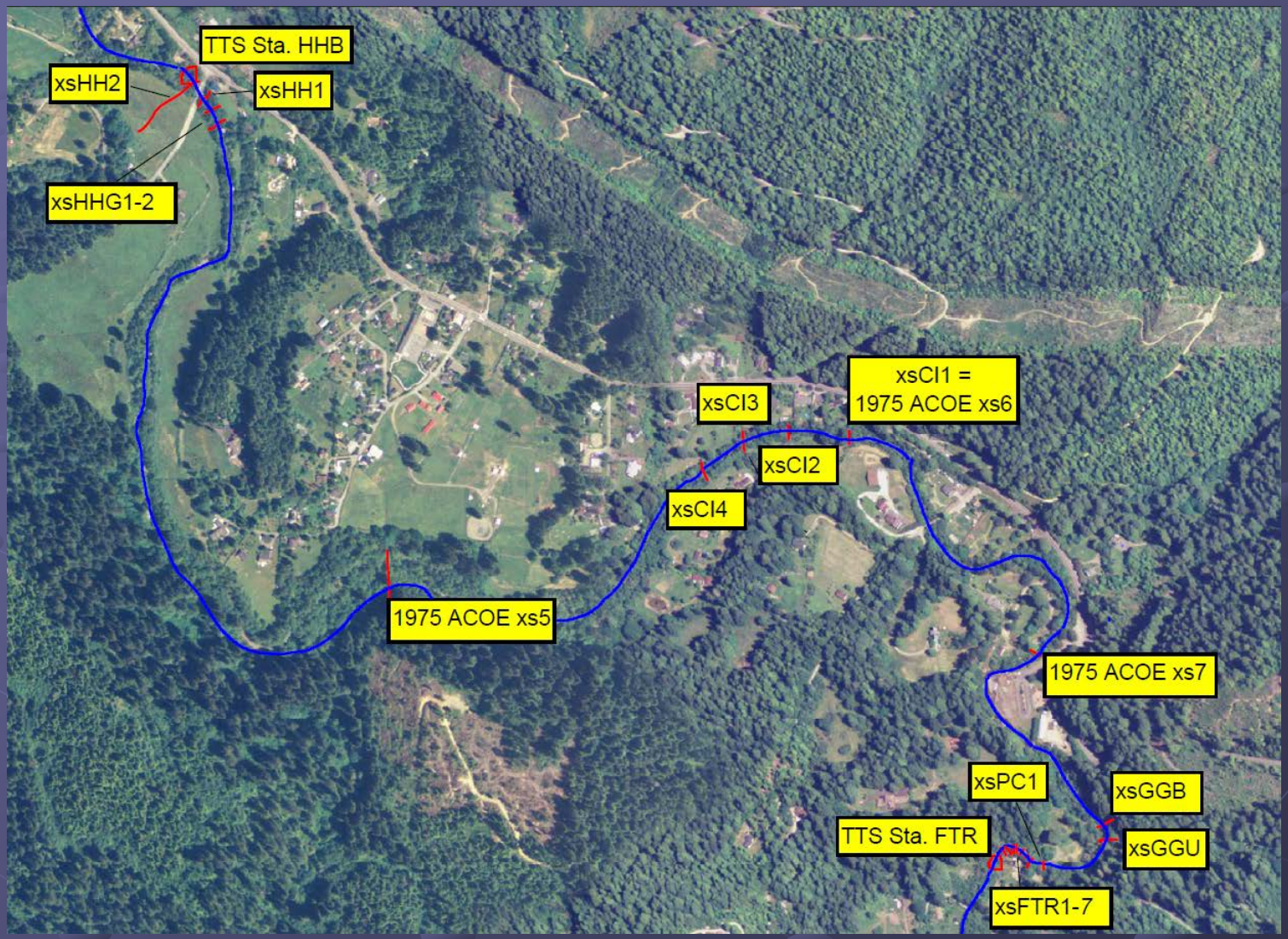
Cross-sections: Elk R. confluence



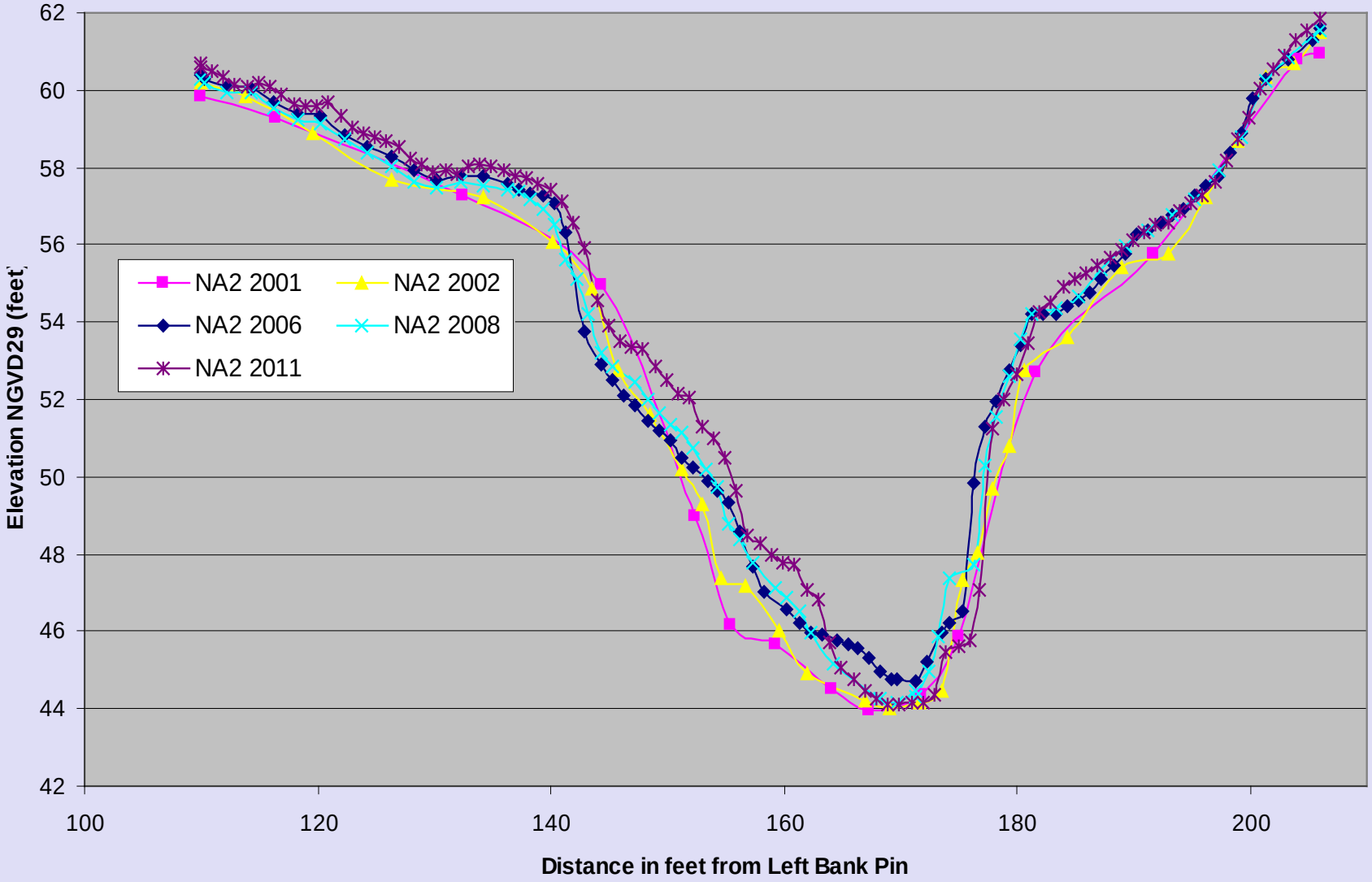
Cross-sections near KRW station



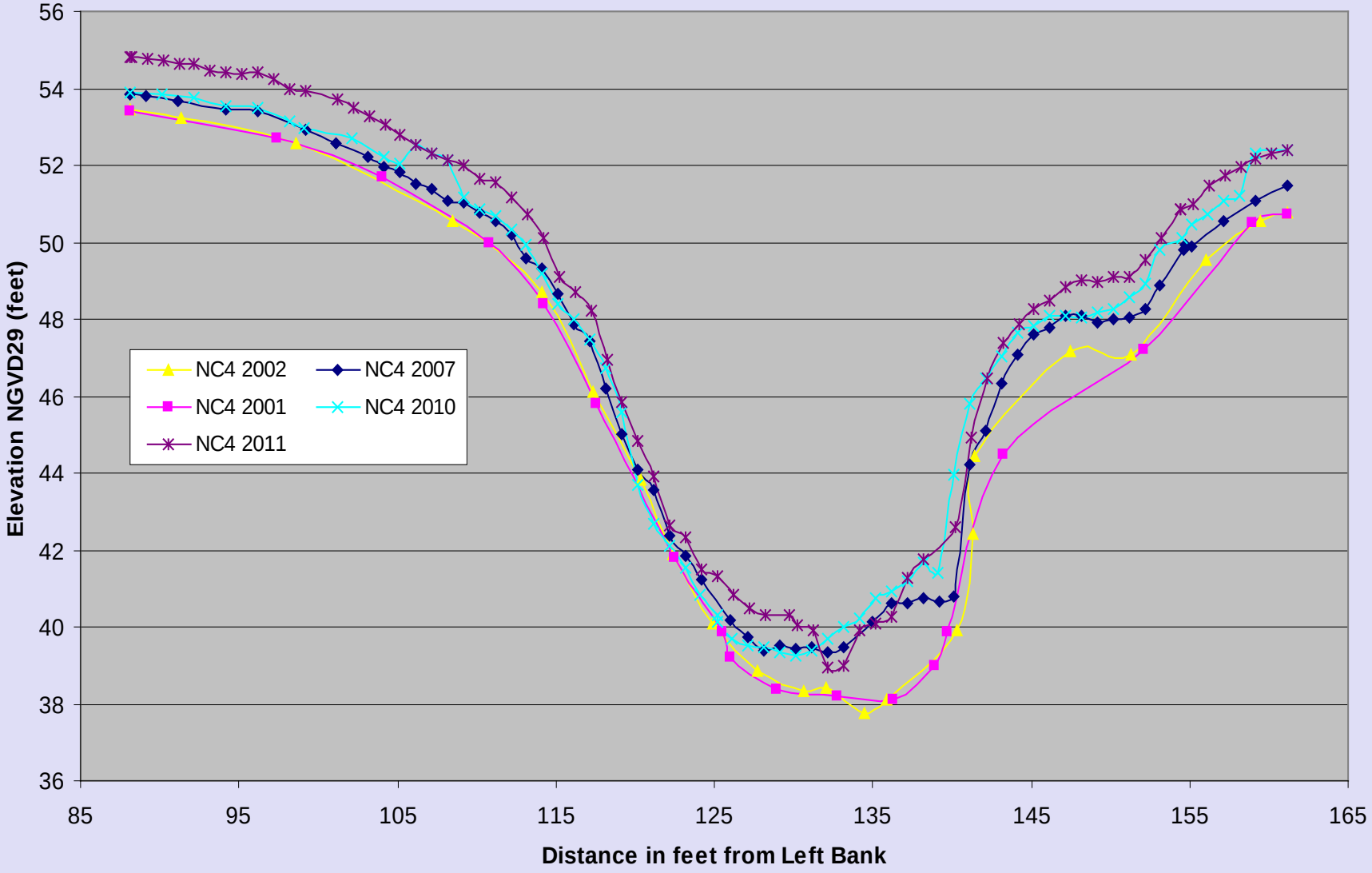
Freshwater cross-sections



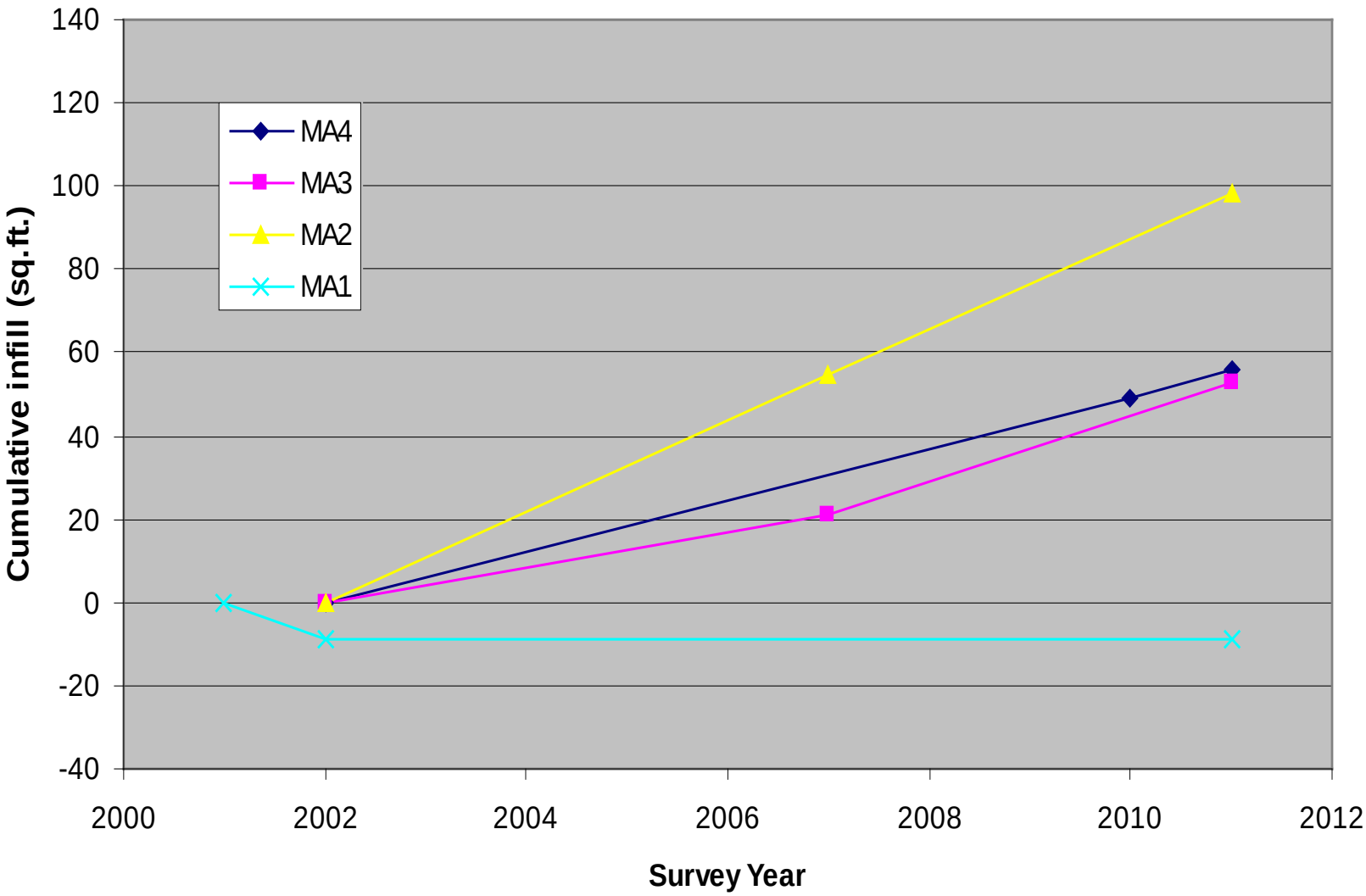
NA2: North Fork Elk River
Comparison Common Channel



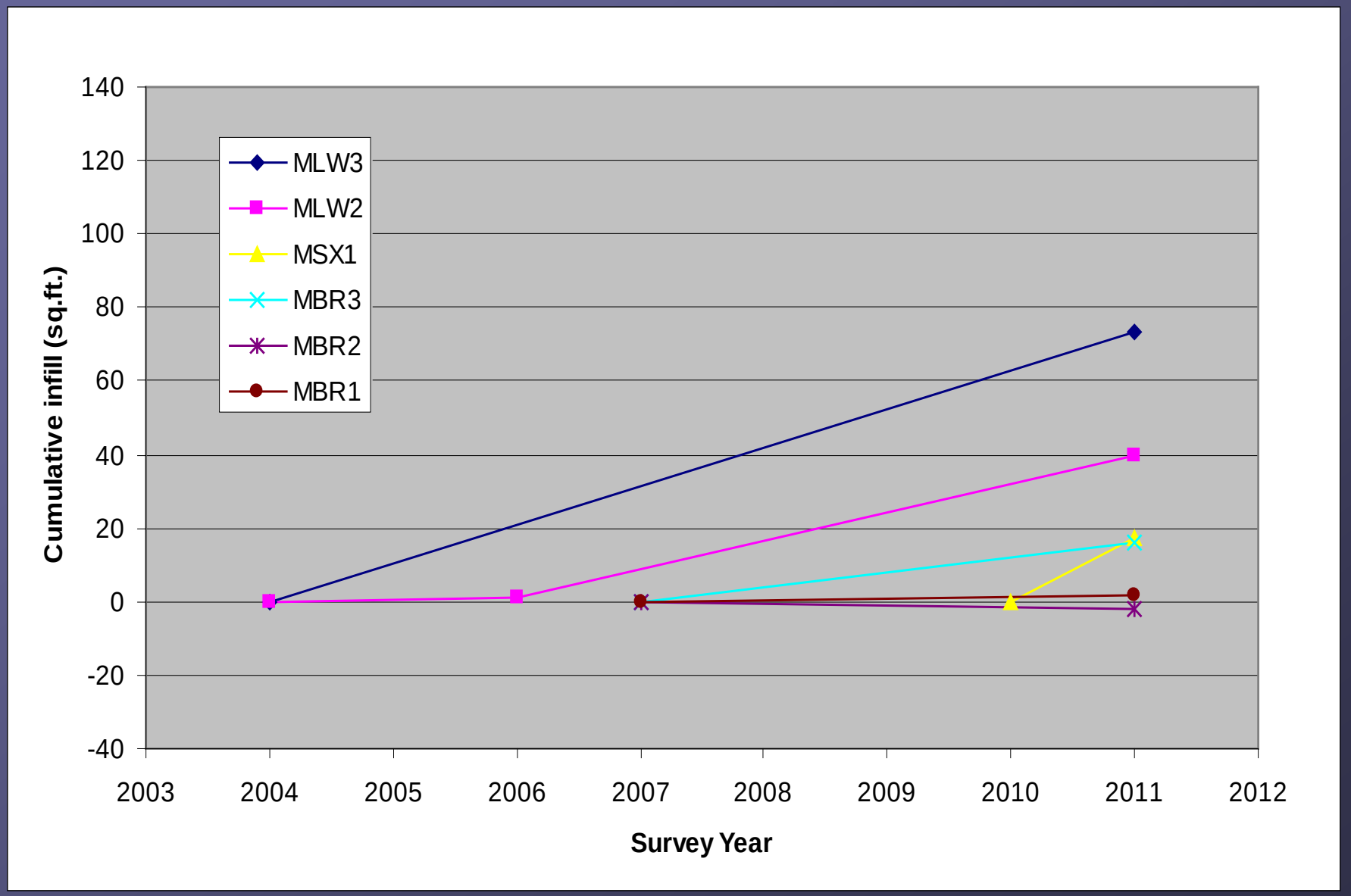
NC4: North Fork Elk River
Comparison Common Channel



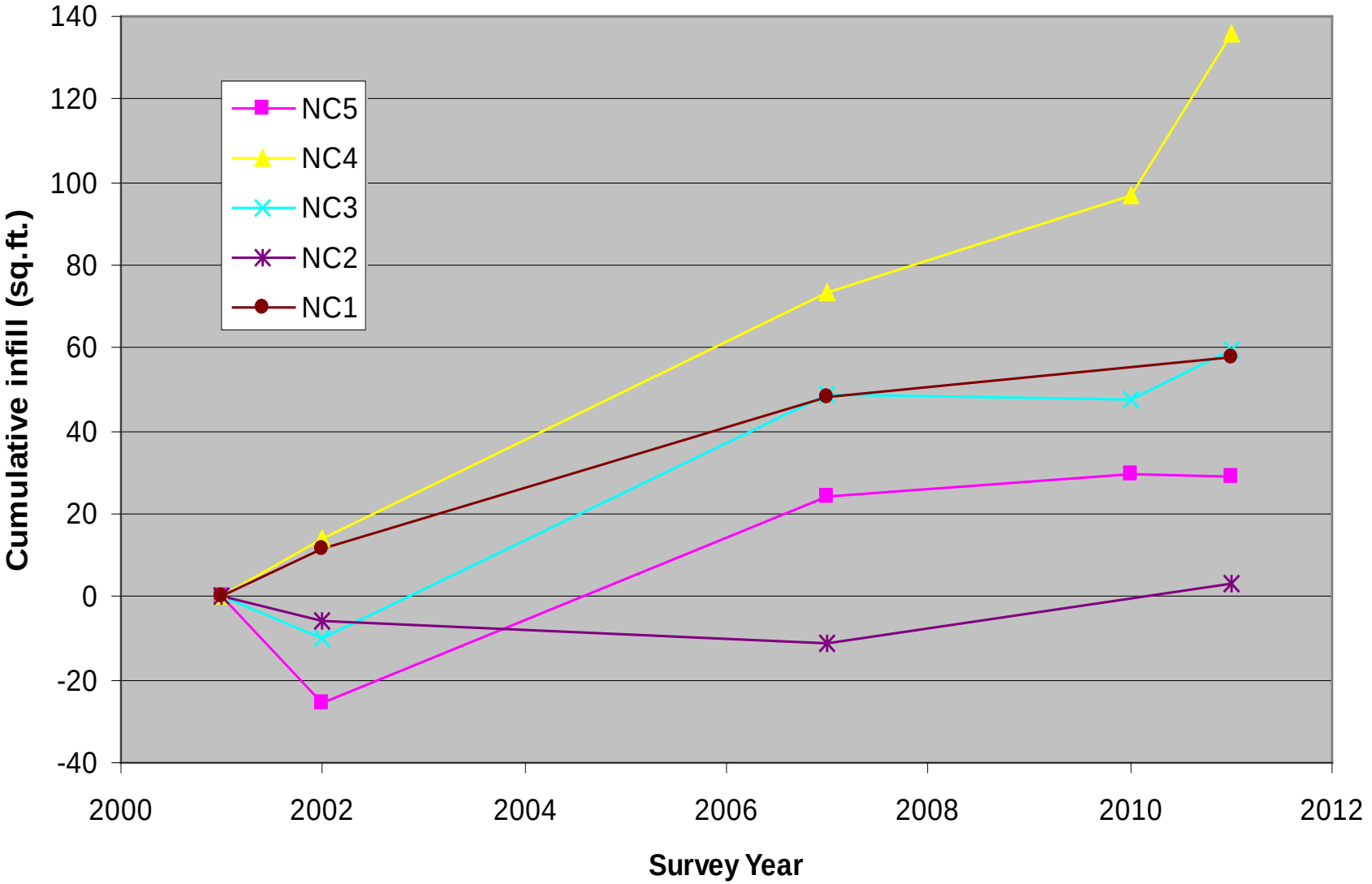
Mainstem below confluence



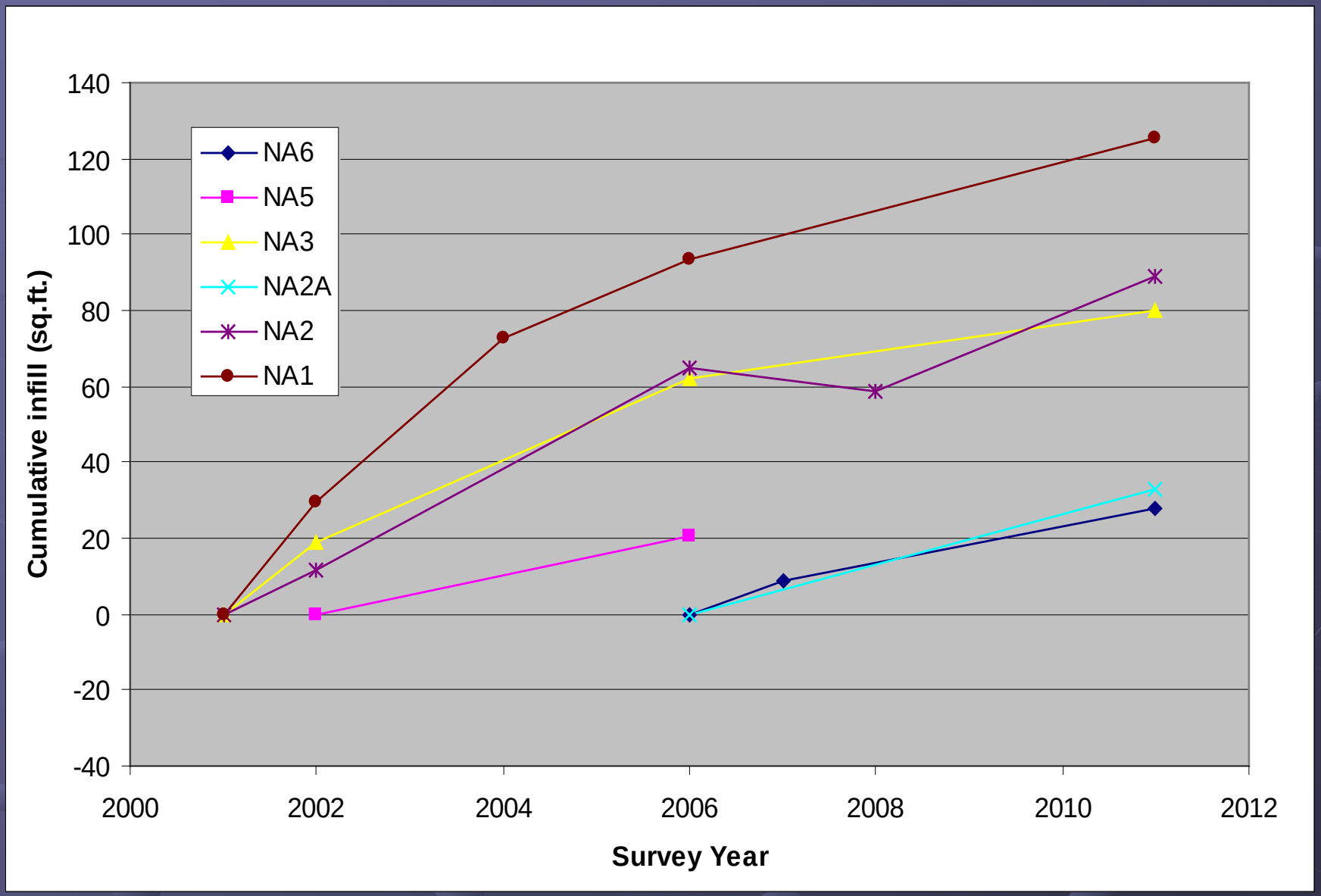
Larry Ward to Berta Road



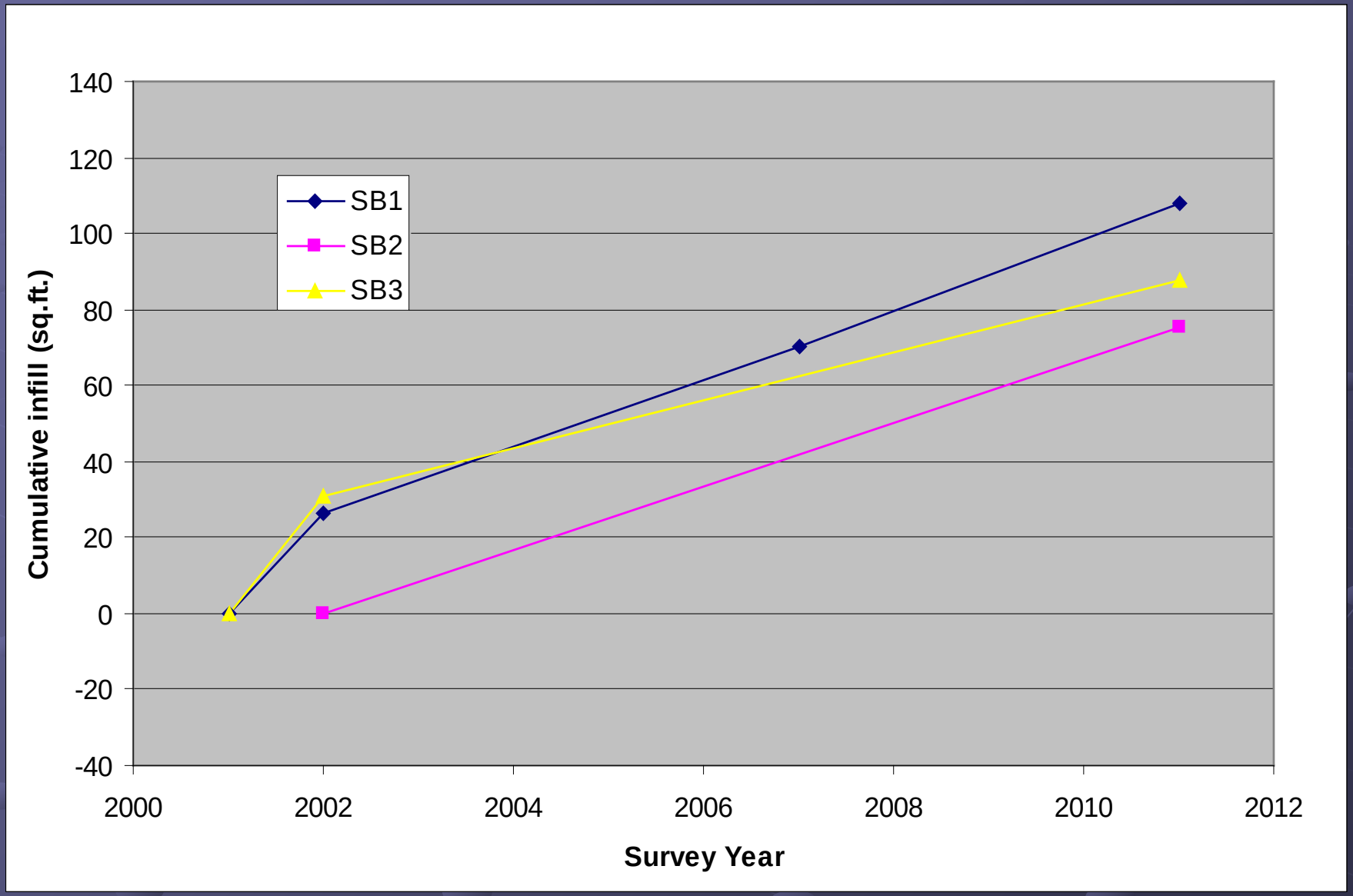
North Fork above confluence



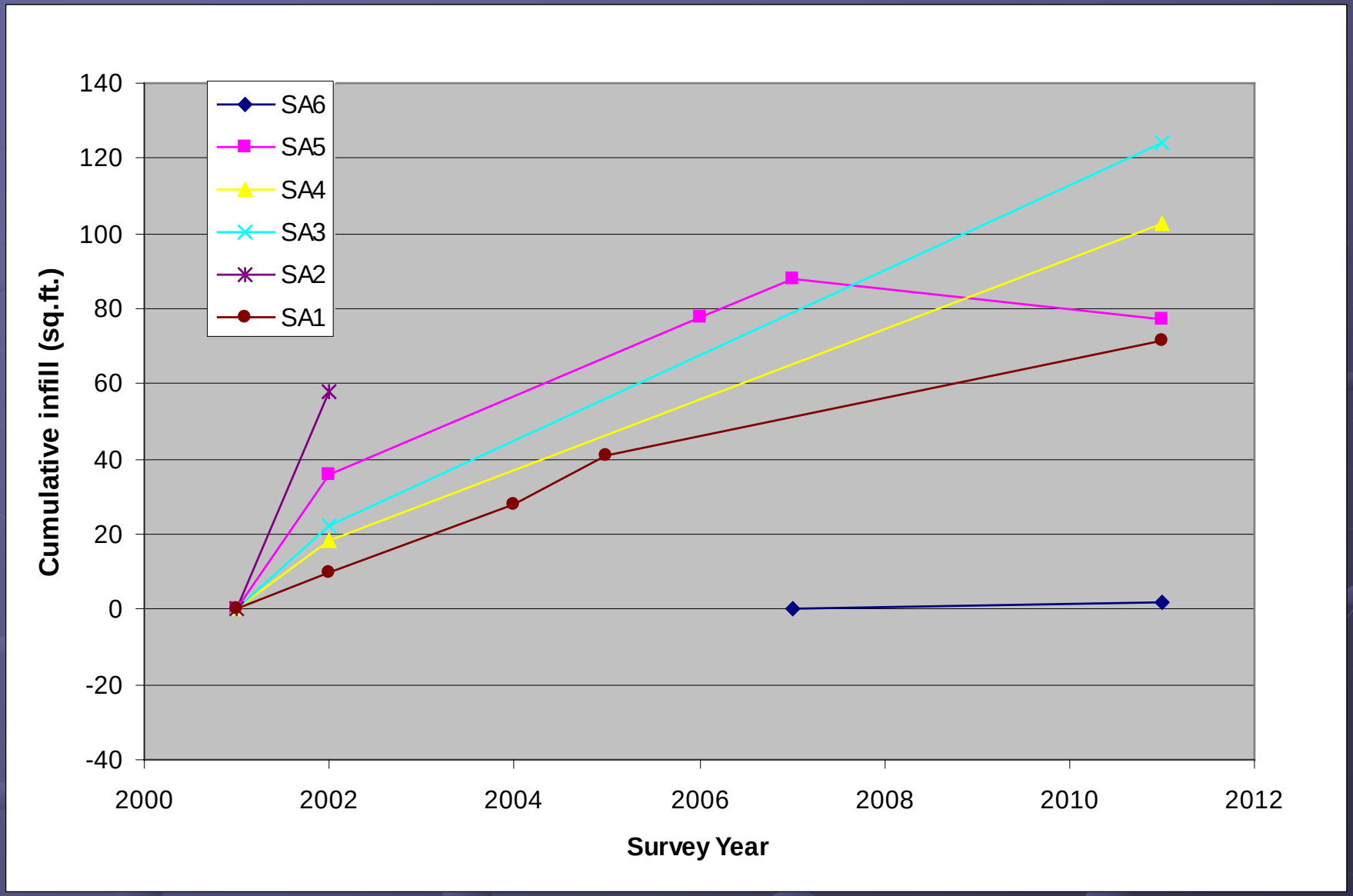
North Fork near KRW station



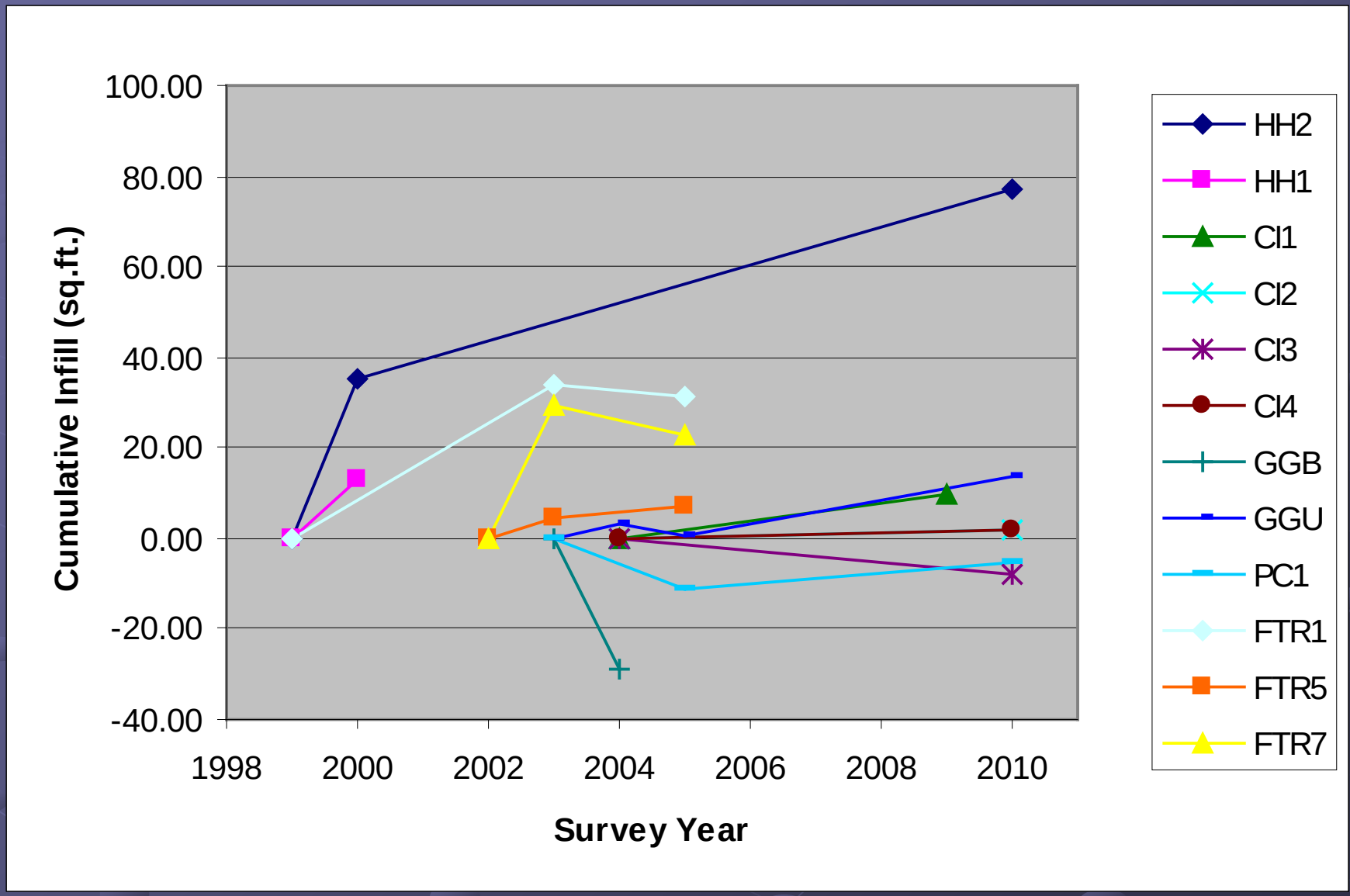
South Fork near confluence

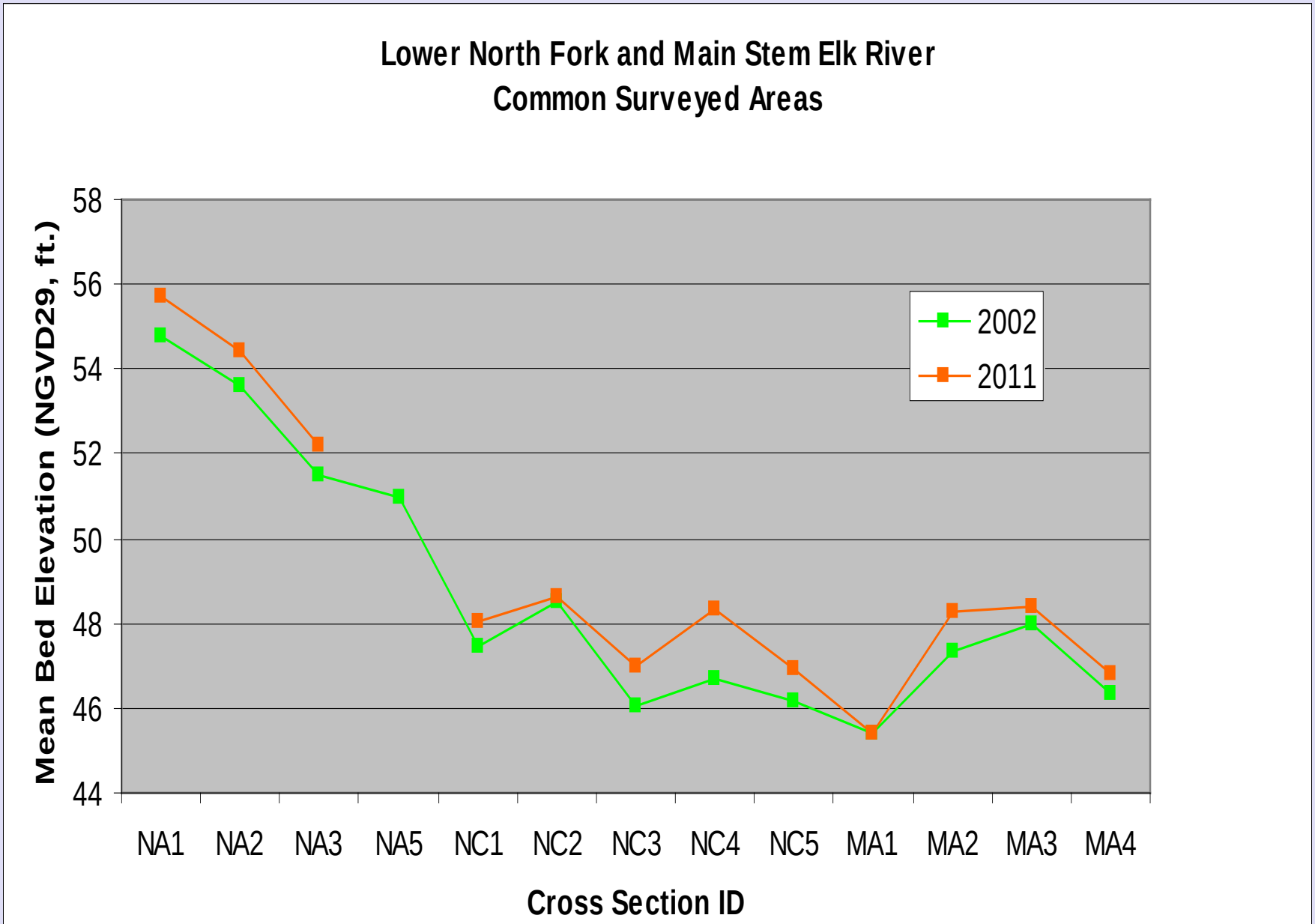


South Fork above SFM station

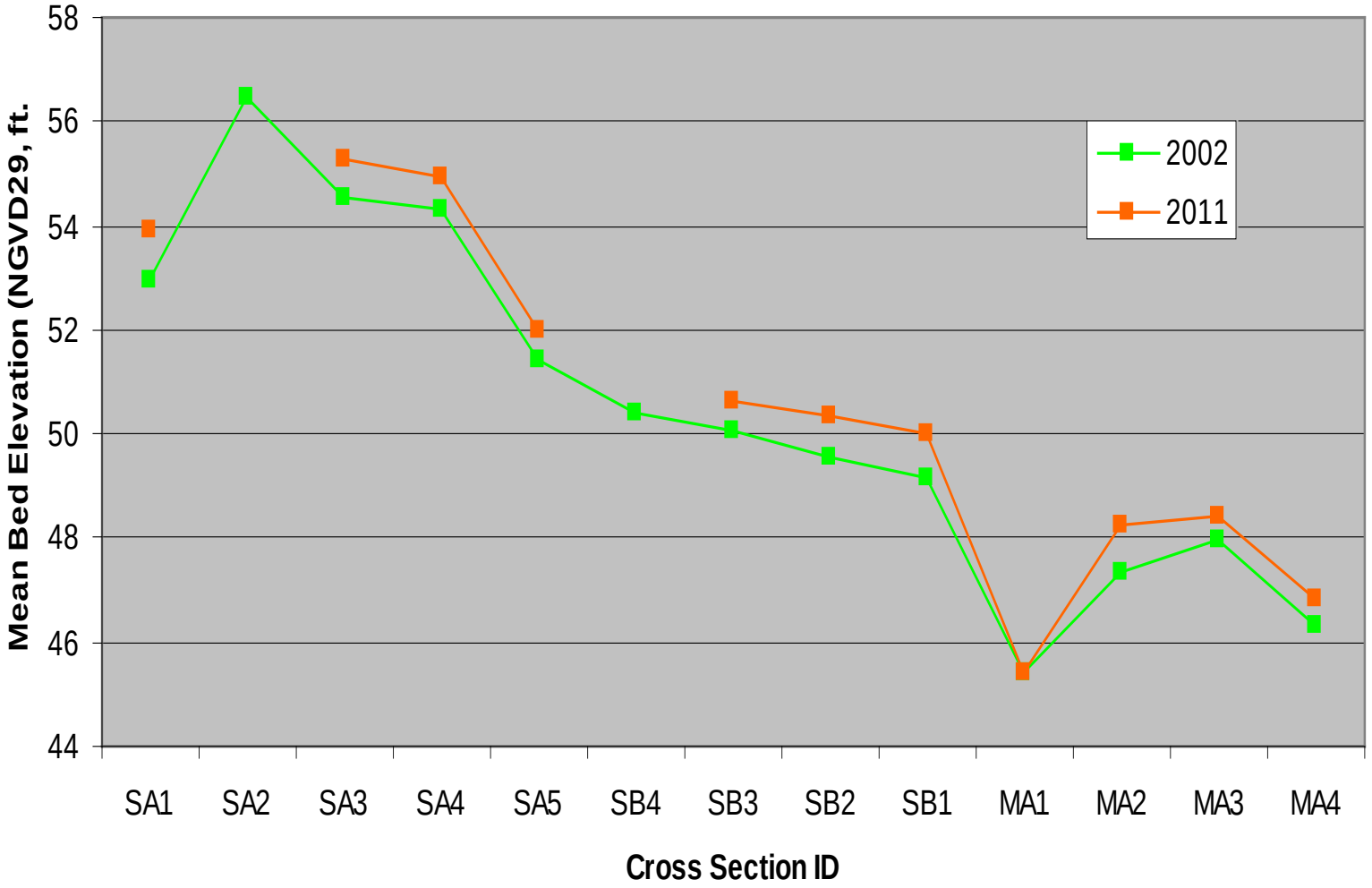


Freshwater Creek, all




Lower North Fork and Main Stem Elk River
Common Surveyed Areas
Mean Bed Elevation (NGVD29, ft.)
58
56
54
52
50
48
46
44
2002
2011
NA1
NA2
NA3
NA5
NC1
NC2
NC3
NC4
NC5
MA1
MA2
MA3
MA4
Cross Section ID

Lower South Fork and Main Stem Elk River
Common Surveyed Areas



Elk River Findings

- SFM has consistently the highest loads of streams monitored in the Humboldt Bay region. In most years, KRW is a distant second.
- Aggradation continues at most cross-sections in lower Elk River, often exceeding 1 ft or 100 ft^2 for the decade: SF > NF > main
- No trends in peak flows detected at either gaging station
  - Class 3 streams are certainly a different story; no data here
- Both Elk stations saw a decline in storm event loads and SSC prior to 2008, followed by a bounce in 2011. In 2013 SFM increased to 35-37% above the mean.

Freshwater Creek Findings

- Freshwater Creek loads are less than those in Elk River; At FTR the unit area loads are 30-60% higher than downstream at HHB.
- There is less information but apparently less aggradation than in Elk River. We know decadal change only at Howard Heights Bridge where infill has been 80 ft^2 or 9 inches in 11 years.
- No trends in peak flows detected at either Freshwater Creek gaging station
- No significant trends in SSC or loads for the whole period, but HHB loads may have declined after 2005.

Humboldt Redwood
COMPANY, LLC

P.O. Box 712
Scotia, CA 95565
Phone (707) 764-4392
www.HRCLLC.com

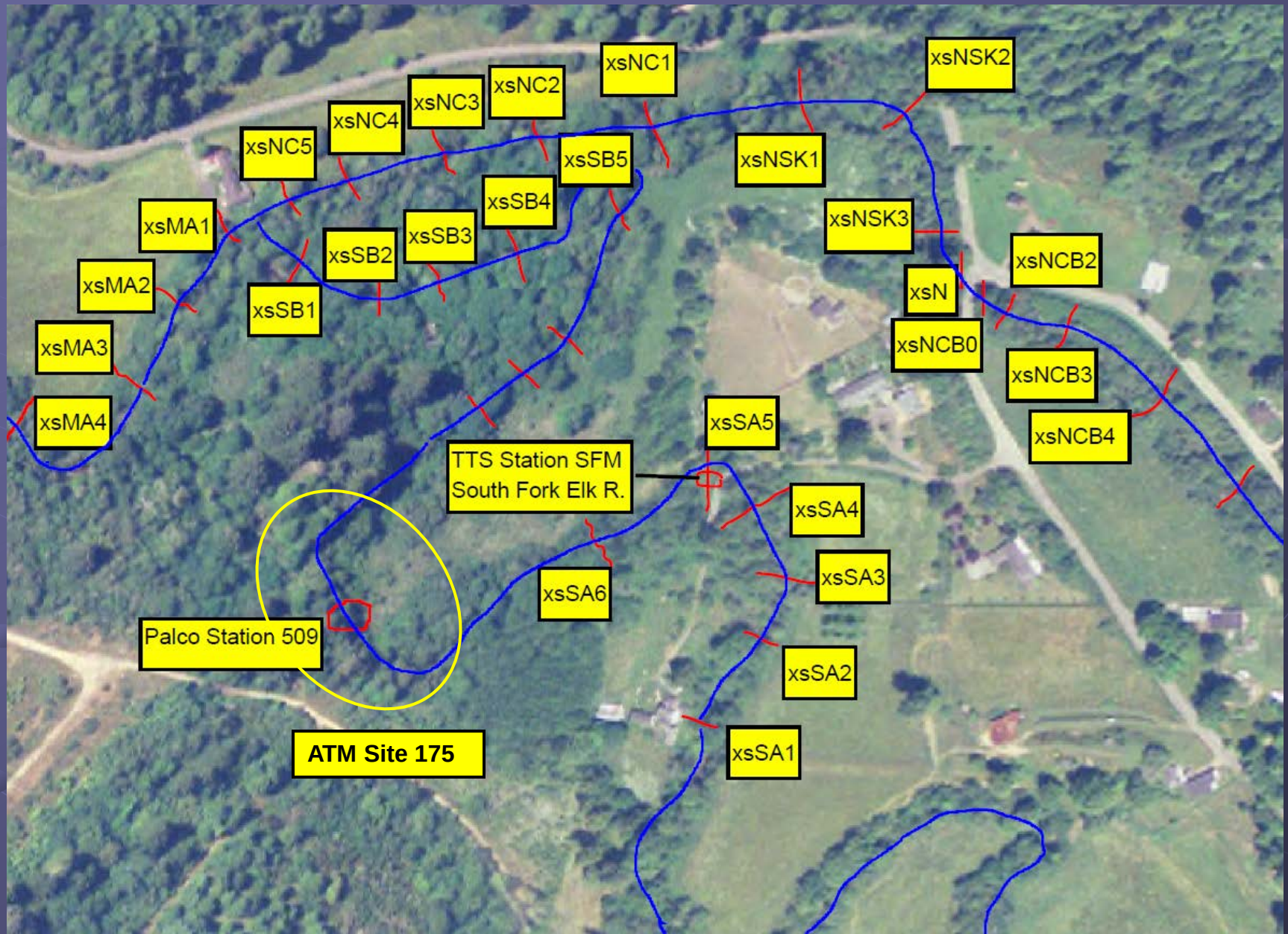
Trends in Sediment-Related Water Quality After a Decade of Forest Management Implementing an Aquatic Habitat Conservation Plan

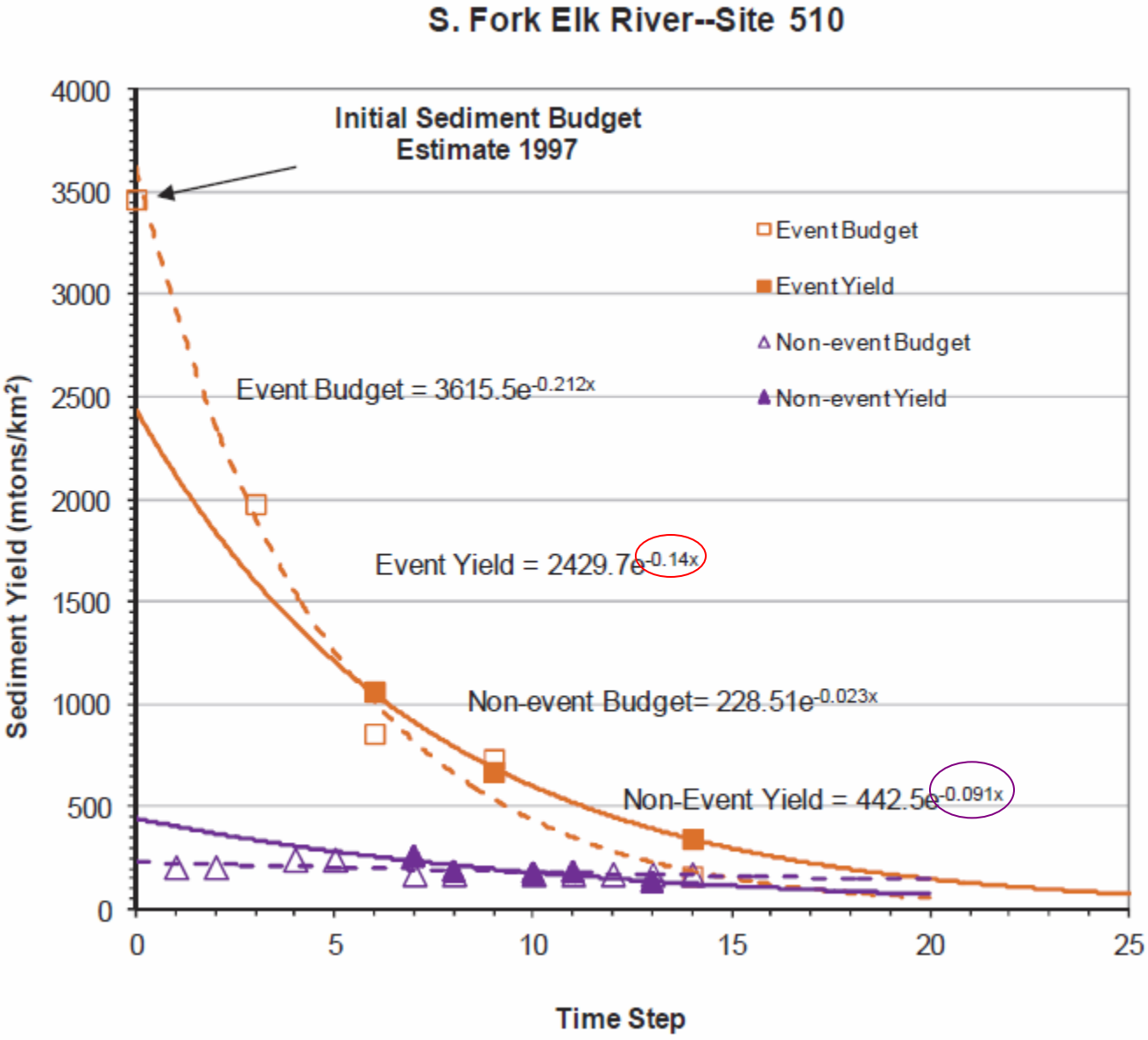
Sullivan et al, 2012

From the HRC report

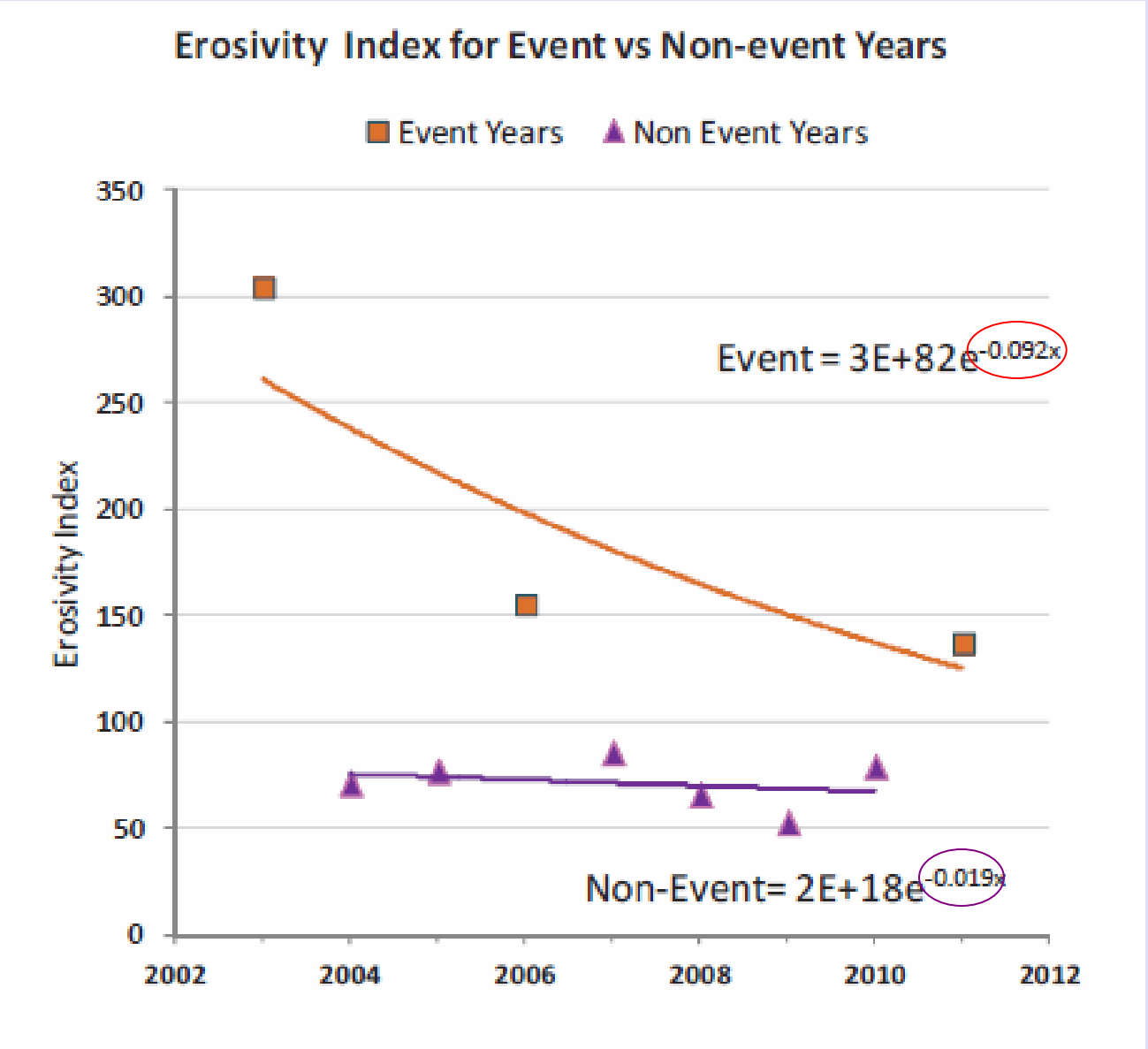
- “There has been no deposition within the lower reach of the South Fork Elk River since 2000.”
- “The majority of sites in both watersheds have declined [sediment yields] in time more than can be accounted for by the weather”
- “Within the weather-driven pattern, there was a small but statistically significant decreasing trend in sediment parameters during the measurement period from 2003 to 2011 at nearly all of the hydrology monitoring stations.”
- “Correlation analysis also showed that the relationship between sediment yield and time was strongly negative at most of the individual stations, while strongly positive at three.”

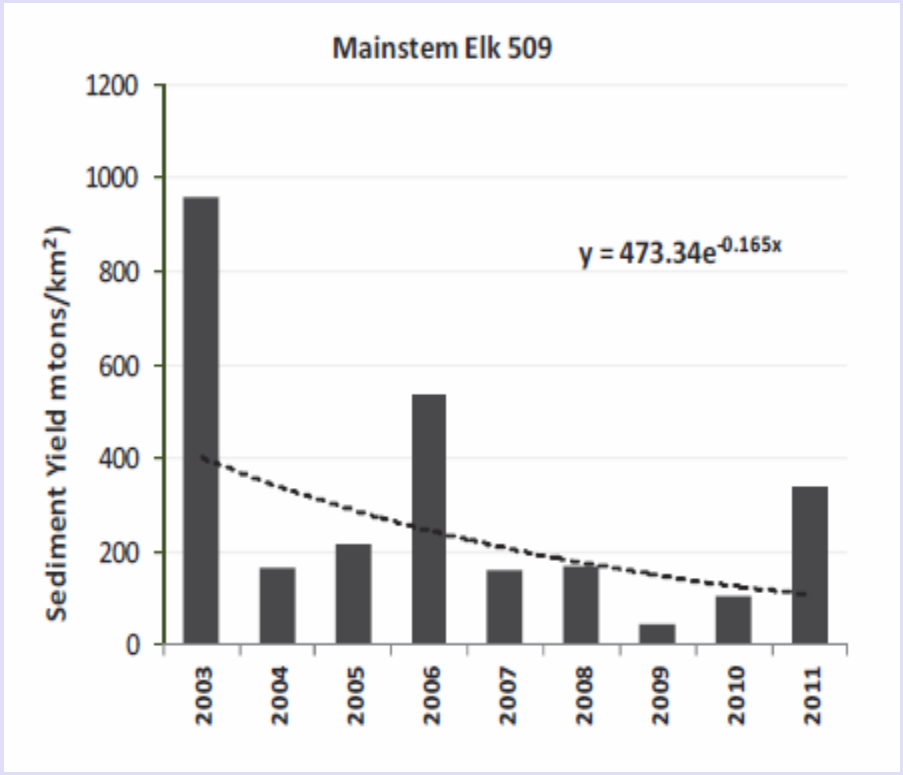
Cross-sections: Elk R. confluence

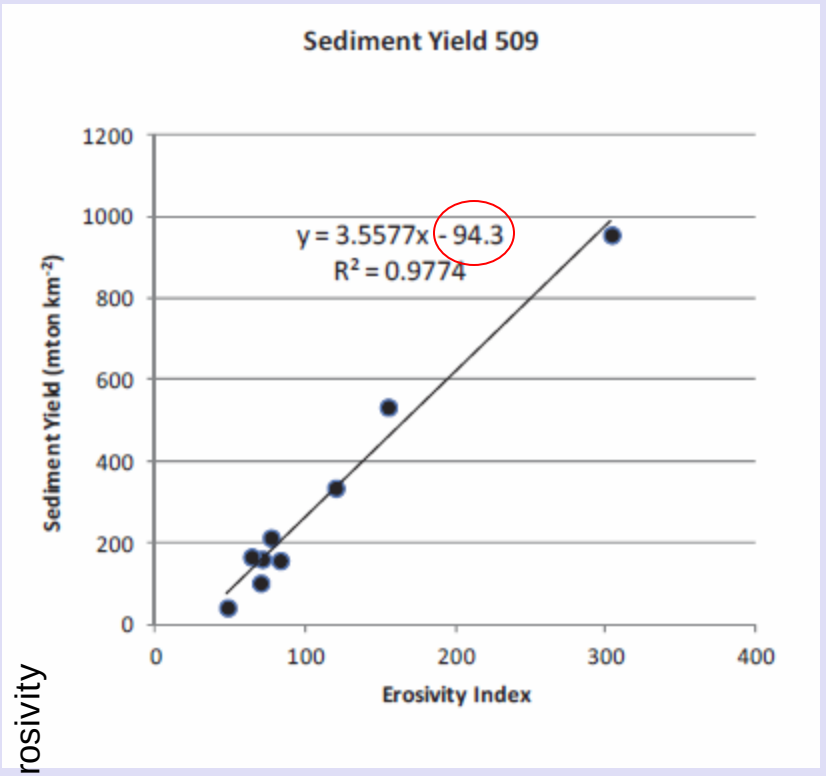



S. Fork Elk River--Site 510
Initial Sediment Budget Estimate 1997
Event Budget
Event Yield
Non-event Budget
Non-event Yield
Event Budget = 3615.5e-0.212x
Event Yield = 2429.7e-0.14x
Non-event Budget= 228.51e-0.023x
Non-Event Yield = 442.5e-0.091x
Sediment Yield (mtons/km2)
Time Step
0
500
1000
1500
2000
2500
3000
3500
4000
0
5
10
15
20
25

Erosivity Index = Annual Rainfall (in.) x Maximum Daily Rainfall (in.)







SY = 473 exp(-0.165t) [asymptote=0]

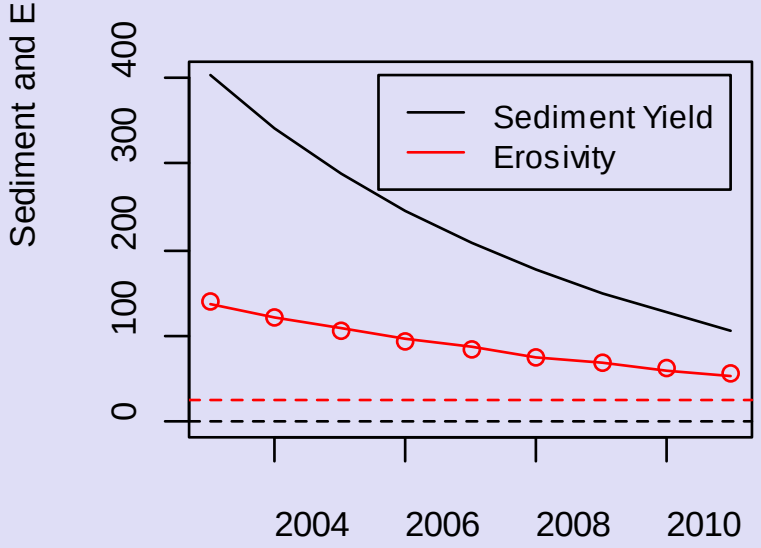
SY = 3.56 EI – 94.3

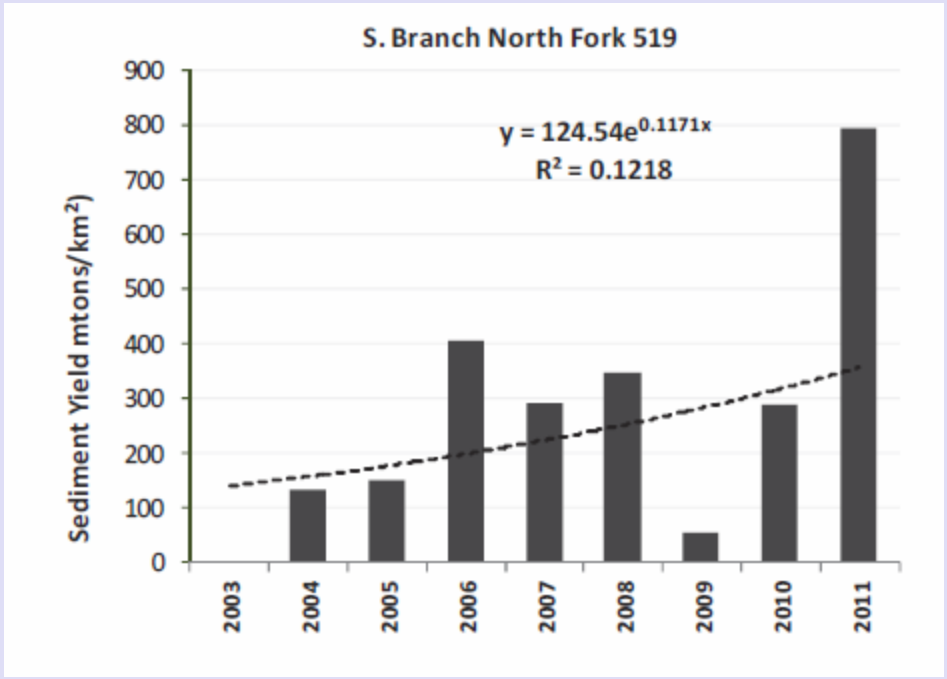
3.56 EI – 94.3 = 473 exp(-0.165t)

EI = (473 exp(-0.165t) + 94.3)/3.56

= 178 exp(-0.165t) + 25.2 [wrong form]

EI =~ 154 exp(-0.116t) [best fit]




S. Branch North Fork 519
y = 124.54e^0.1171x
R² = 0.1218
Sediment Yield mtons/km²)
900
800
700
600
500
400
300
200
100
0
2003
2004
2005
2006
2007
2008
2009
2010
2011

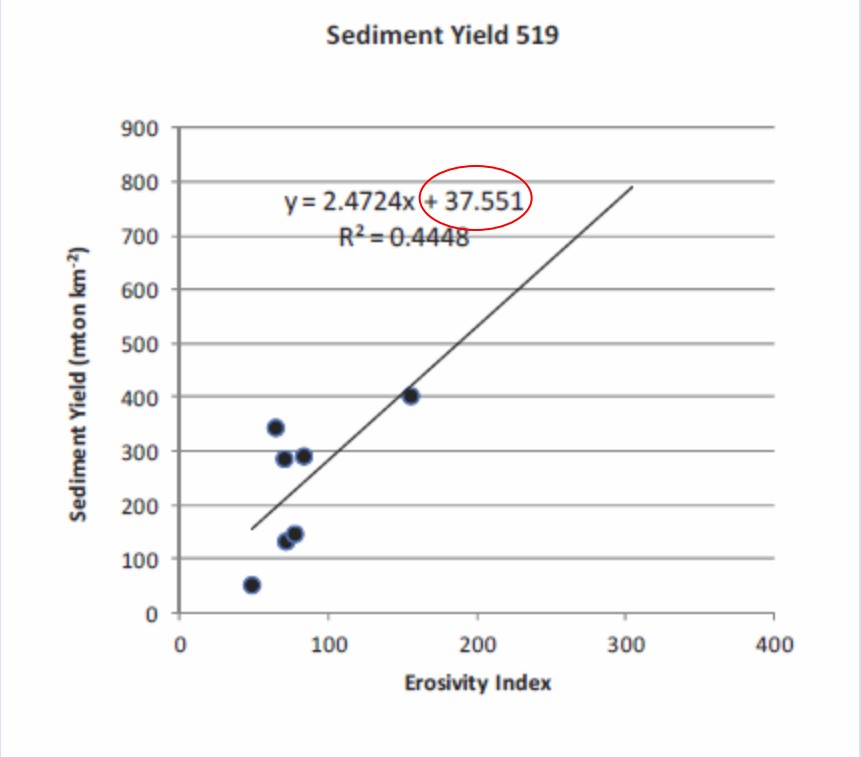

Sediment Yield 519
y = 2.4724x + 37.551
R² = 0.4448
Sediment Yield (mton km⁻²)
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
Erosivity Index

Table 10. Multivariate regression fixed effects model statistics for model evaluating sediment yield and turbidity 10% exceedance considering weather and time.

Parameter		Data Points	Regression Statistics
Sediment Yield	Event Years	55	

Effect	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept	5.459	0.3713	20	14.70	<.0001
Year	**-0.125**	**0.0143**	**32**	**-8.74**	**<.0001**
Unit_Peak_Q	0.679	0.1643	32	4.13	.0002

	Non-Event Years	120	

Effect	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept	3.564	0.2952	20	12.07	<.0001
Year	**-0.107**	**0.0201**	**97**	**-5.32**	**<.0001**
Unit_Peak_Q	**1.580**	**0.1426**	**97**	**11.09**	**<.0001**

Turbidity 10% Exceedance	Event Years	54	

Effect	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept	4.841	0.2989	20	16.20	<.0001
Year	**-0.059**	**0.0113**	**31**	**-5.21**	**<.0001**
Unit Peak Q	-0.137	0.1291	31	-1.06	0.2953

	Non-event Years	120	

Effect	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept	3.737	0.1513	20	24.70	<.0001
Year	**-0.058**	**0.0079**	**97**	**-7.32**	**<.0001**
Unit_Peak_Q	**0.324**	**0.0559**	**97**	**5.79**	**<.0001**

Interaction effects

- A significant interaction between site or watershed and time would mean the trends vary by location
- That none was detected may be related to:
  - sample size was reduced by splitting the data set
  - rejection level was lowered to p=0.0125 since 4 tests were done
- Failure to detect an effect ≠ no effect

Table 11. Regression statistics evaluating the interaction effects by watershed and site for predictors of sediment characteristics in event and non-event years. (SAS vs 9.2)

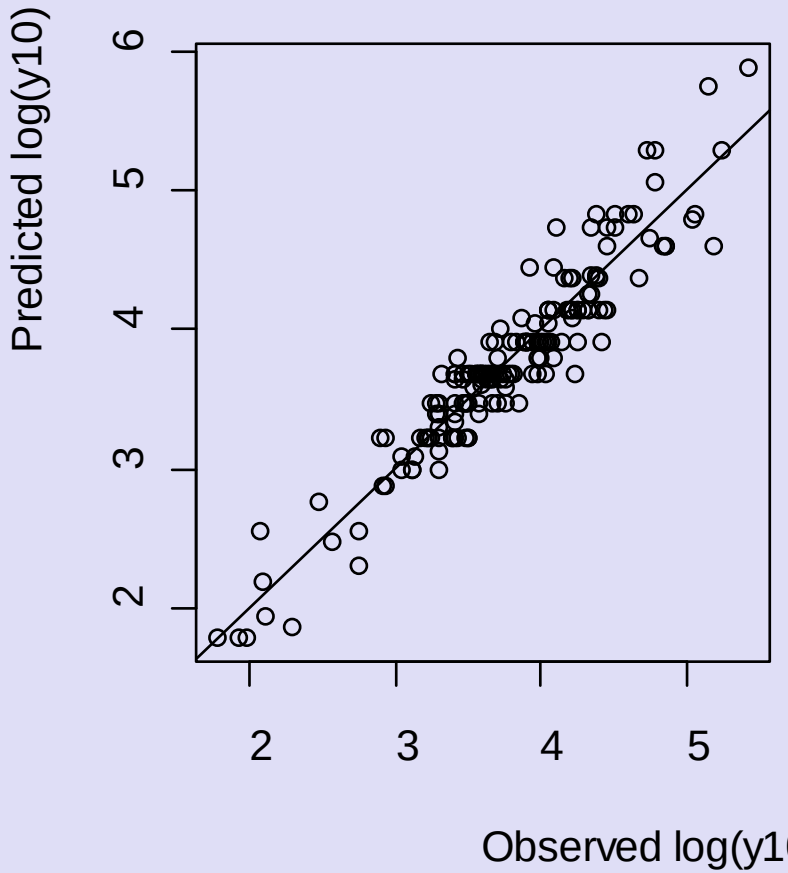
		P Values pr > F (significant Bonferronni Adj P =0.0125)	
Fixed Effects Tests	**Parameter**	**Event**	**Non-Event**
Watershed Effects watershed x year interaction	Sediment Yield	.277	.318
	Turbidity 10% Exceedance	.041	.279
Site Effects site x year interaction	Sediment Yield	.031	.518
	Turbidity 10% Exceedance	.521	.058

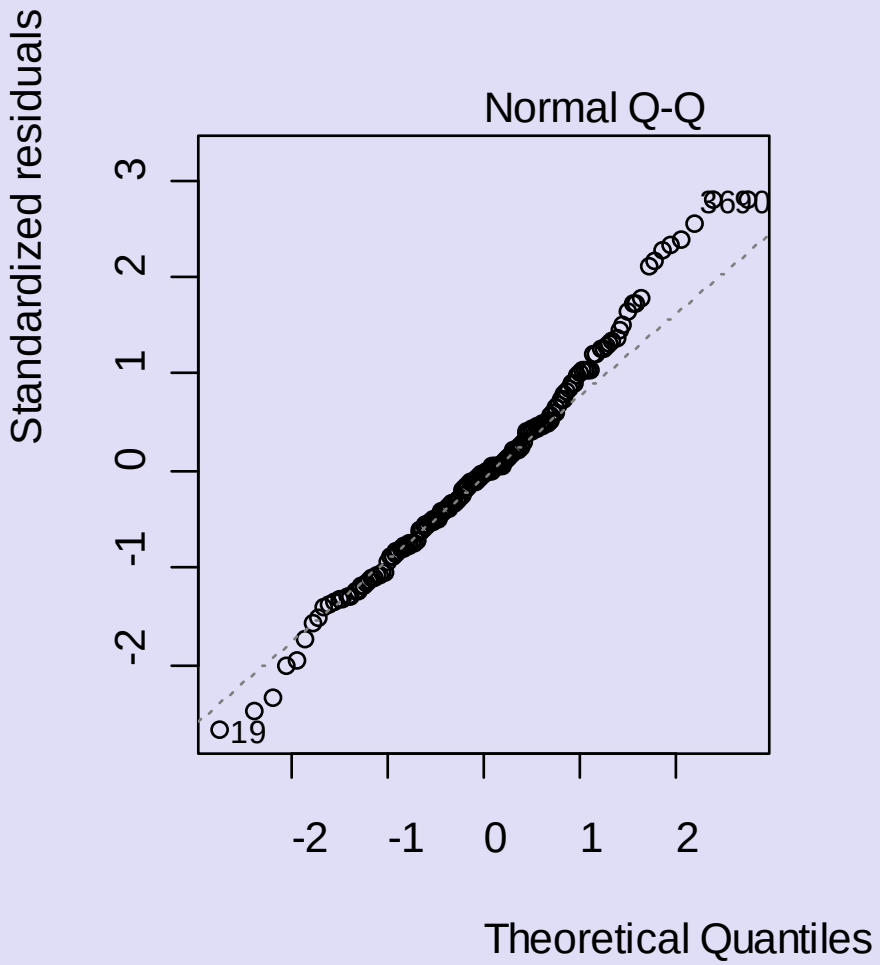
Conclusions from HRC Trend Analysis

- Regression analysis with all sites combined showed significant negative trends for both sediment yield and 10% turbidity
- The interaction of time and location was not statistically significant
  - Does that mean all sites and watersheds have the same trend?
- No further regressions were done, but partial correlation analysis detected NO significant time relationships for Elk or Freshwater as a whole or any individual sites except 528 (Little FW)
- What would you conclude?
- What did the HRC report conclude?
  - “Within the weather-driven pattern, there was a small but statistically significant decreasing trend in sediment parameters during the measurement period from 2003 to 2011 at nearly all of the hydrology monitoring stations.”
  - “Correlation analysis also showed that the relationship between sediment yield and time was strongly negative at most of the individual stations, while strongly positive at three.”

A better analysis?

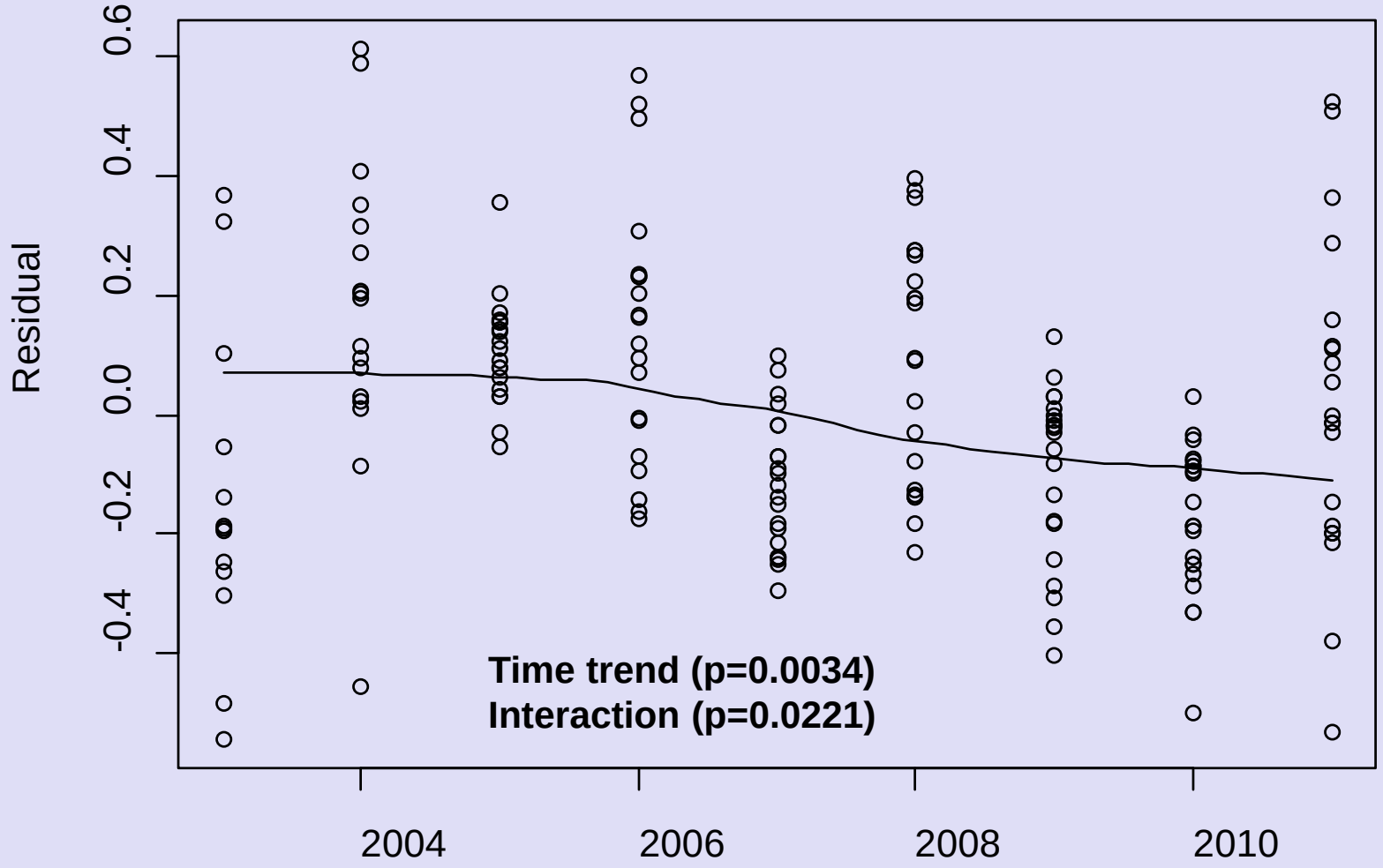
- Do not divide data set between “Event” and “Non-event” years
- Use Erosivity Index as a covariate when it explains more variability than Annual Flow Peak
- Plot the data to see what is going on
- Analyze Freshwater Creek and Elk River separately rather than relying on a borderline significant interaction to decide whether they are the same.





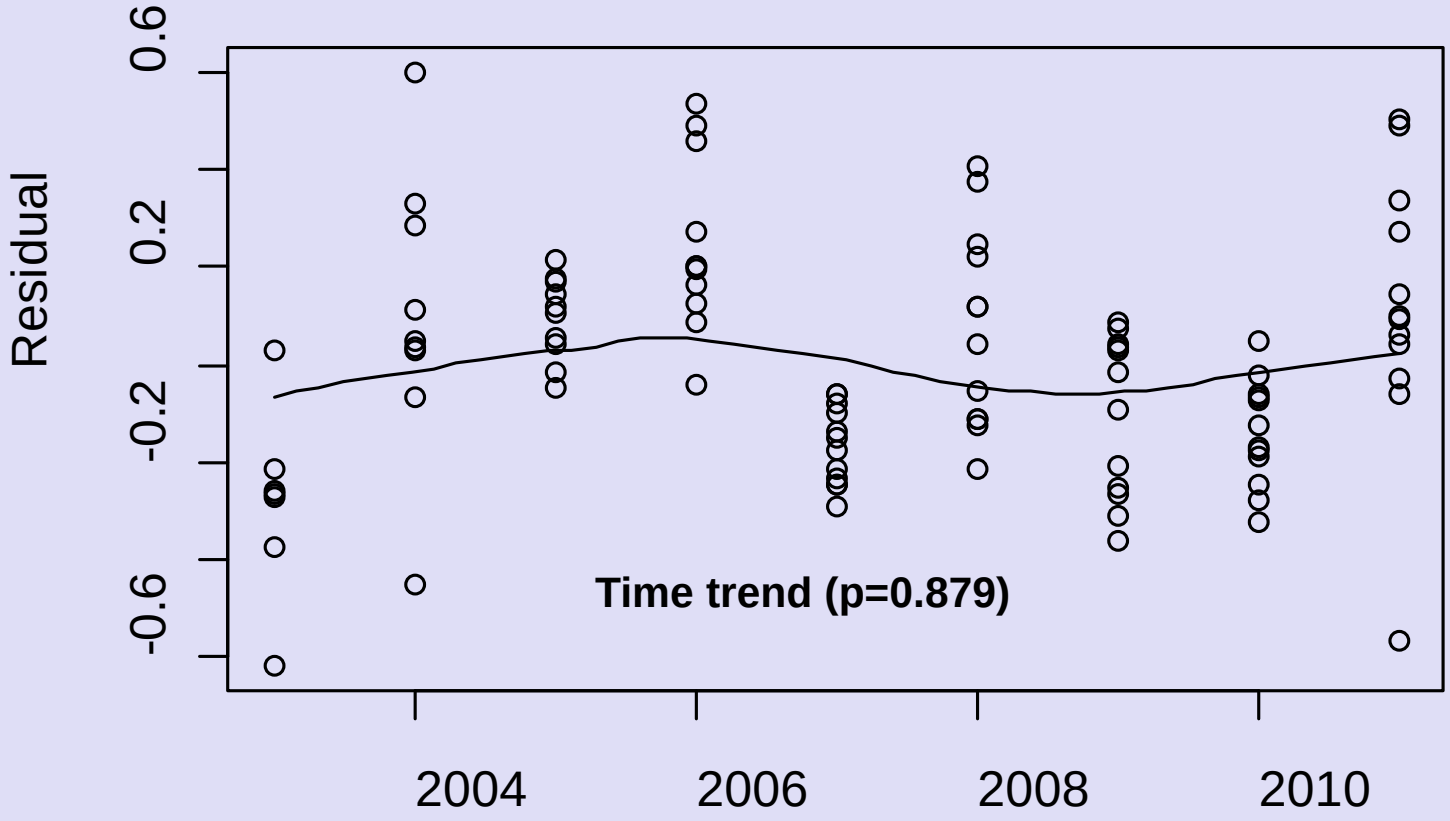
$$\log(T10) = \beta_0 + \beta_1 \log(EI) + \beta_2 t + b_i \quad \text{(site } i\text{)}$$

Overall Trend in 10% Exceeden



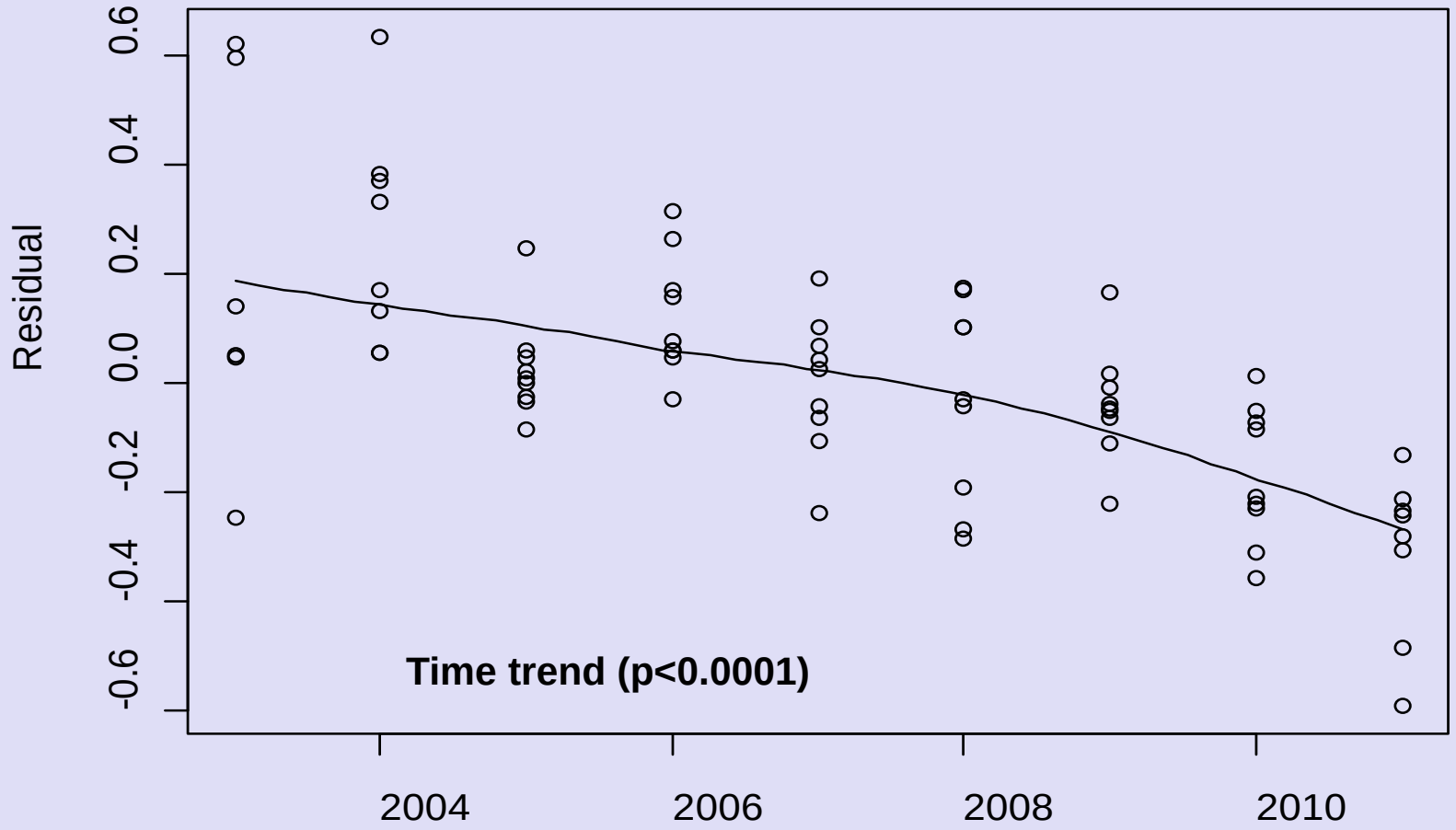
$\log(T10) = \beta_0 + \beta_1 \log(EI) + b_i$ (site i)

Elk River Trend in 10% Ex



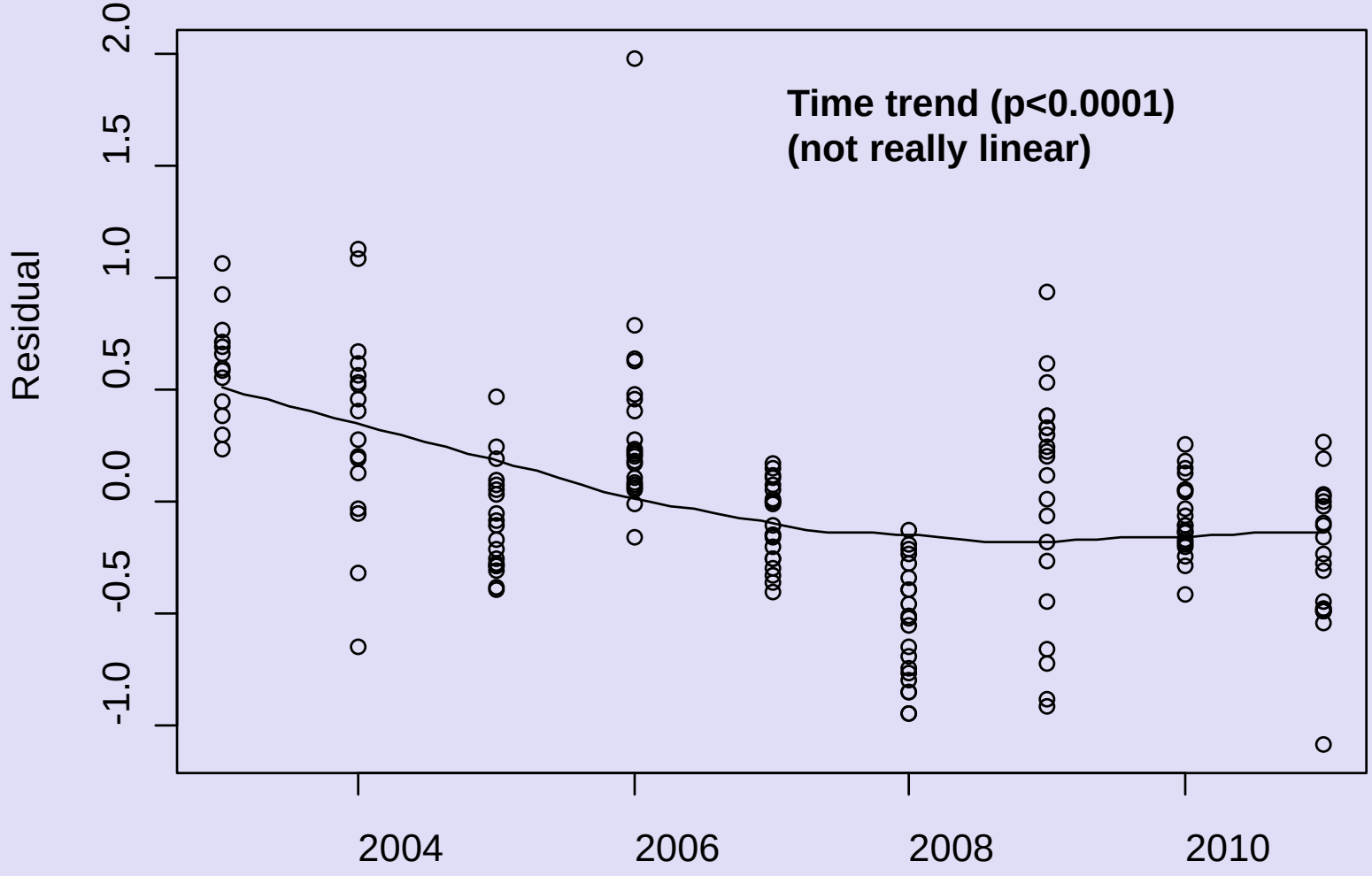
$\log(T10) = \beta_0 + \beta_1 \log(EI) + b_i$ (site i)

Freshwater Trend in 10% Excee



$$\log(T10) = \beta_0 + \beta_1 \log(Q) + b_i \quad \text{(site } i\text{)}$$

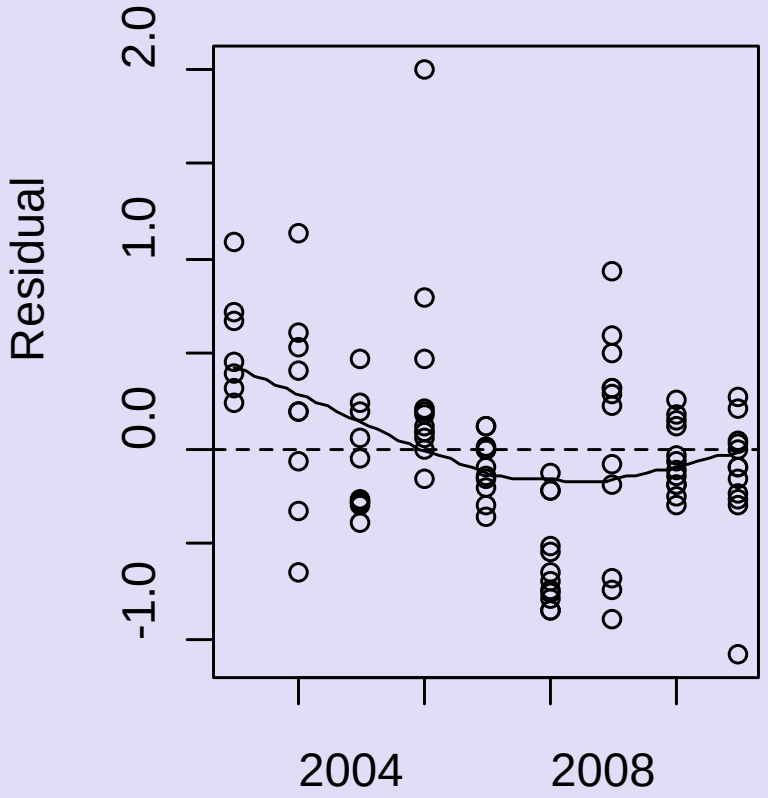
Overall Trend in Sediment Yield



$$\log(SY) = \beta_0 + \beta_1 \log(Q) + b_i \quad \text{(site } i\text{)}$$

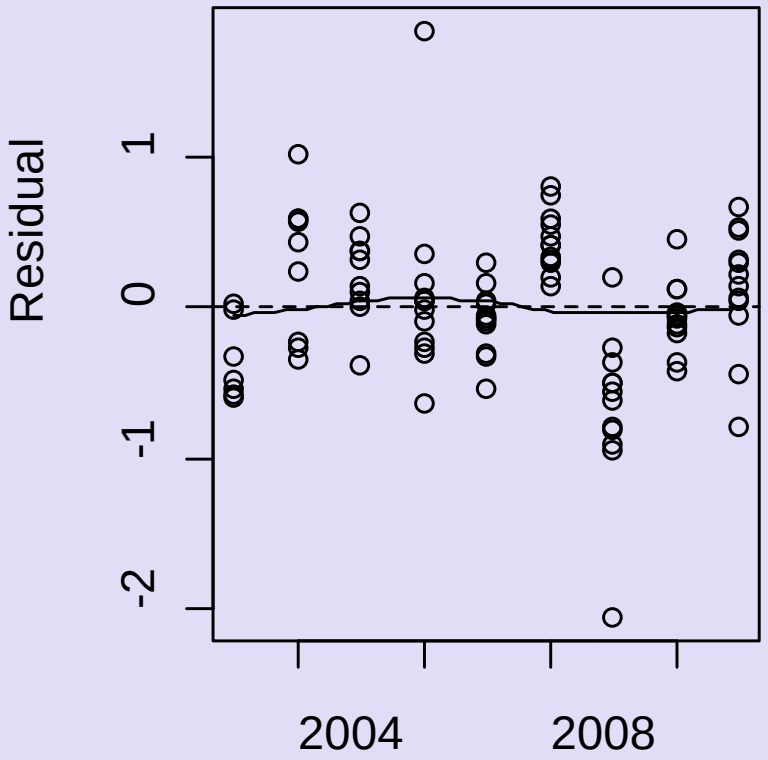
Elk River Trend in Sediment Yield

log(Q) model



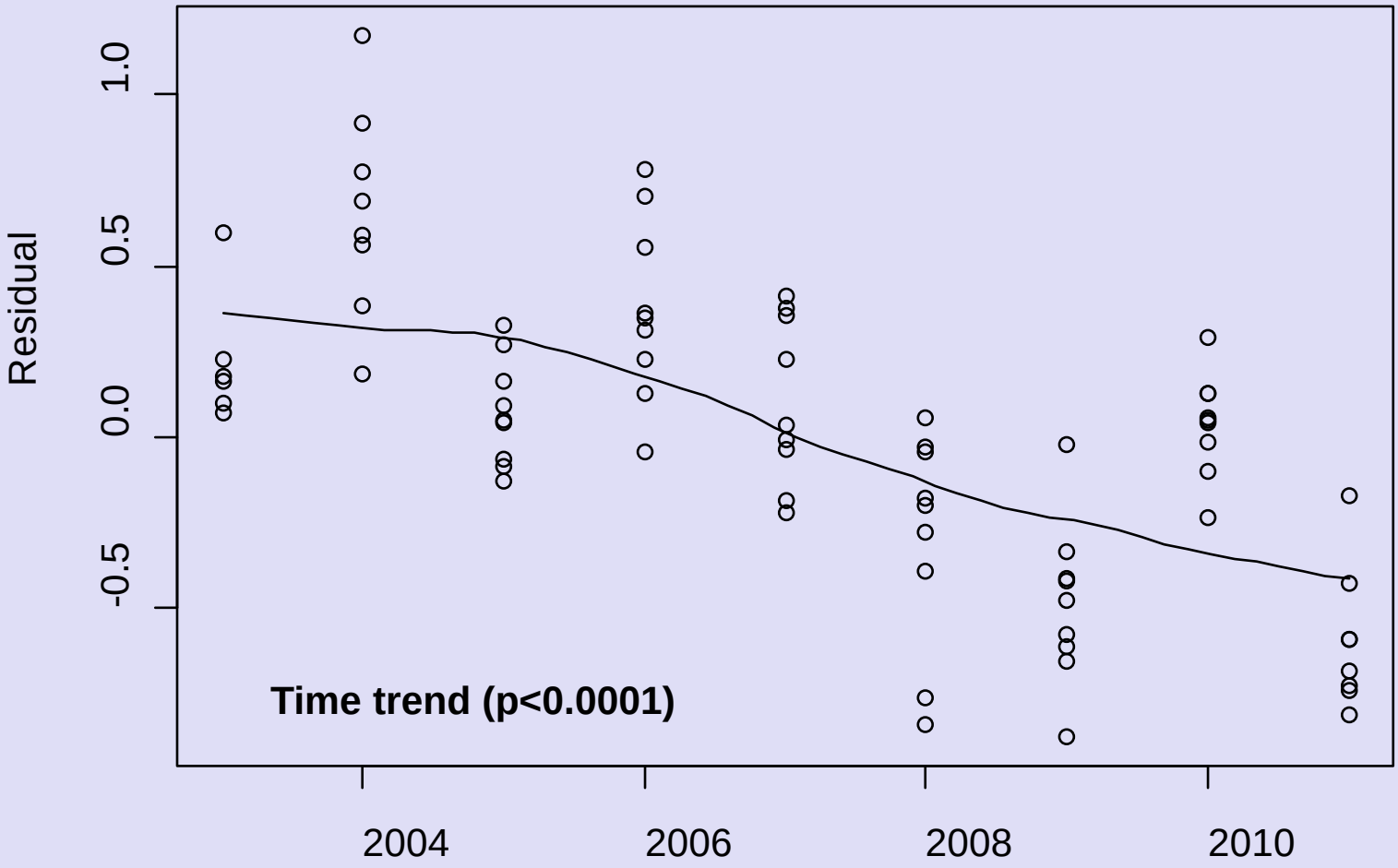
Time trend (p<0.0001)
significance depends on 2003

log(El) model



Time trend (p=0.365)
accounts for 6.7” on 12/27/12

Freshwater Trend in Sediment Y



$$\log(SY) = \beta_0 + \beta_1 \log(Q) + b_i \quad \text{(site } i\text{)}$$

Monitoring Recommendations

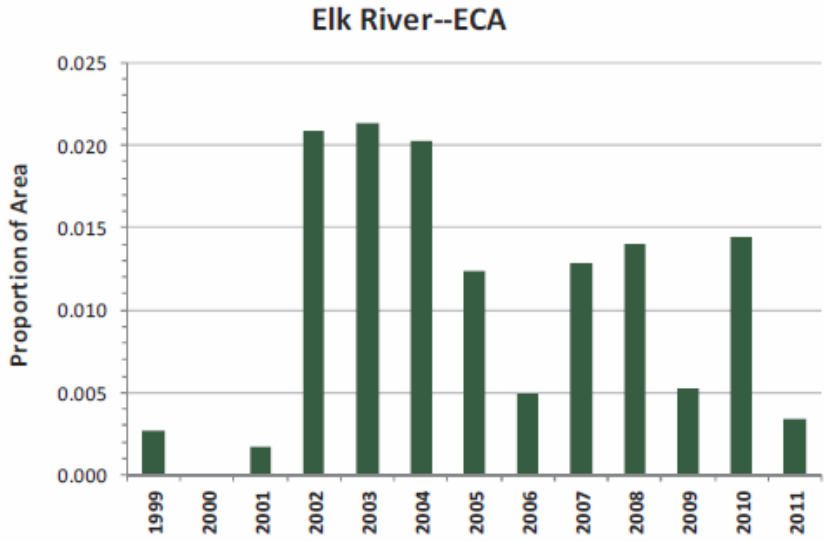
- We have a long enough record to begin to identify trends in watershed responses but it will take longer before trends may be attributed to recent mgmt changes
- Fund Salmon-Forever to bring their analyses up-to-date; continue x-sections and stream gaging
- Share and pool data with HRC and GDRC
- Improve access and continue monitoring Little South Fork Elk (Headwaters), or
- Establish a more accessible control watershed where logging will not occur. It need not be pristine or large, as long as its responses are well-correlated with other watersheds in the basin.

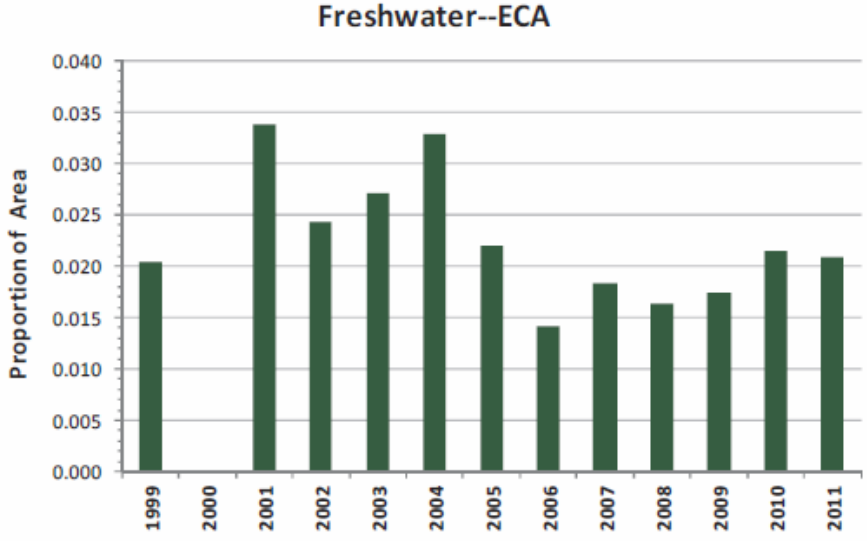
What Does This Tell Us About Management?

- By itself not a great deal; Salmon-Forever is monitoring outcomes only
- Hypotheses
  - Management is now benign and the monitoring reflects it; maybe in Freshwater, not in Elk River
  - Management is now benign but it will take more time for the monitoring to reflect it; plausible
  - Management has not improved enough or is still being applied over too much area; may depend on how harvest rates are calculated and reported

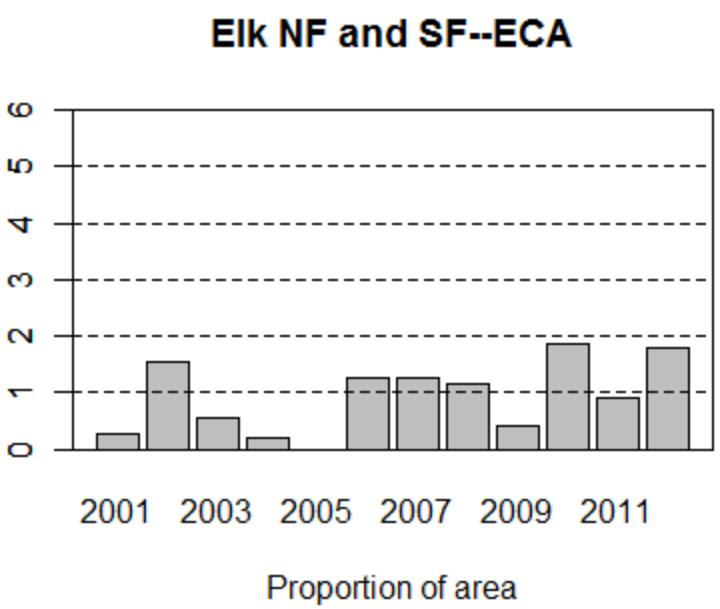
Harvest History from HRC Report

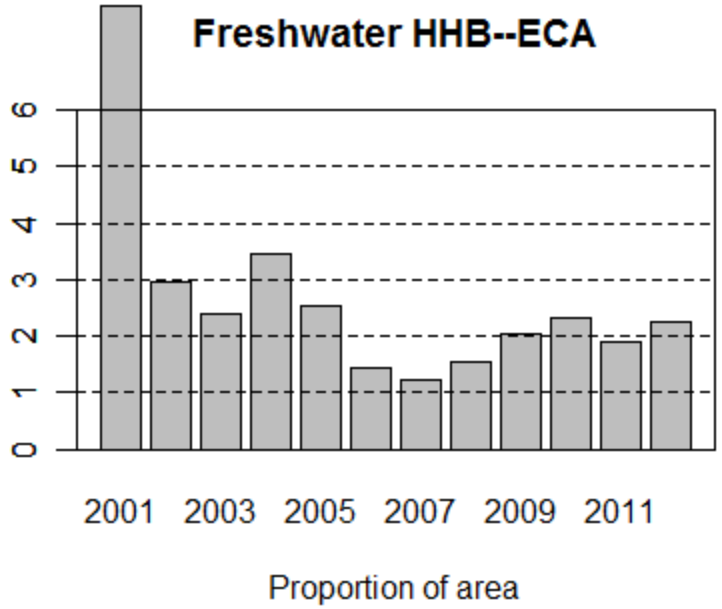
Figure 19. Harvest history expressed as proportion of watershed in equivalent clearcut area (ECA) for the HCP management period from 1999 to 2011.





Alternative Harvest History





- **HHB 2001-2005 data are from Randy Klein**
- **2012 data are projected from Adona White**
- **Remaining data from Adona White**

Management Recommendations

- Be cautious until improvements are measurable in Elk River
  - Keep out when roads and soils are wet
  - Limit canopy removal and keep openings small
  - Avoid the most unstable areas
  - Minimize ground disturbance, esp near stream channels, and maintain soil cover
  - Reduce the frequency of reentry
  - Be selective/smart when fixing legacy issues