Assessing
Land Use and Regulations
in
Rural
King County, WA*

*Prepared April 29,2014 for website

Context:

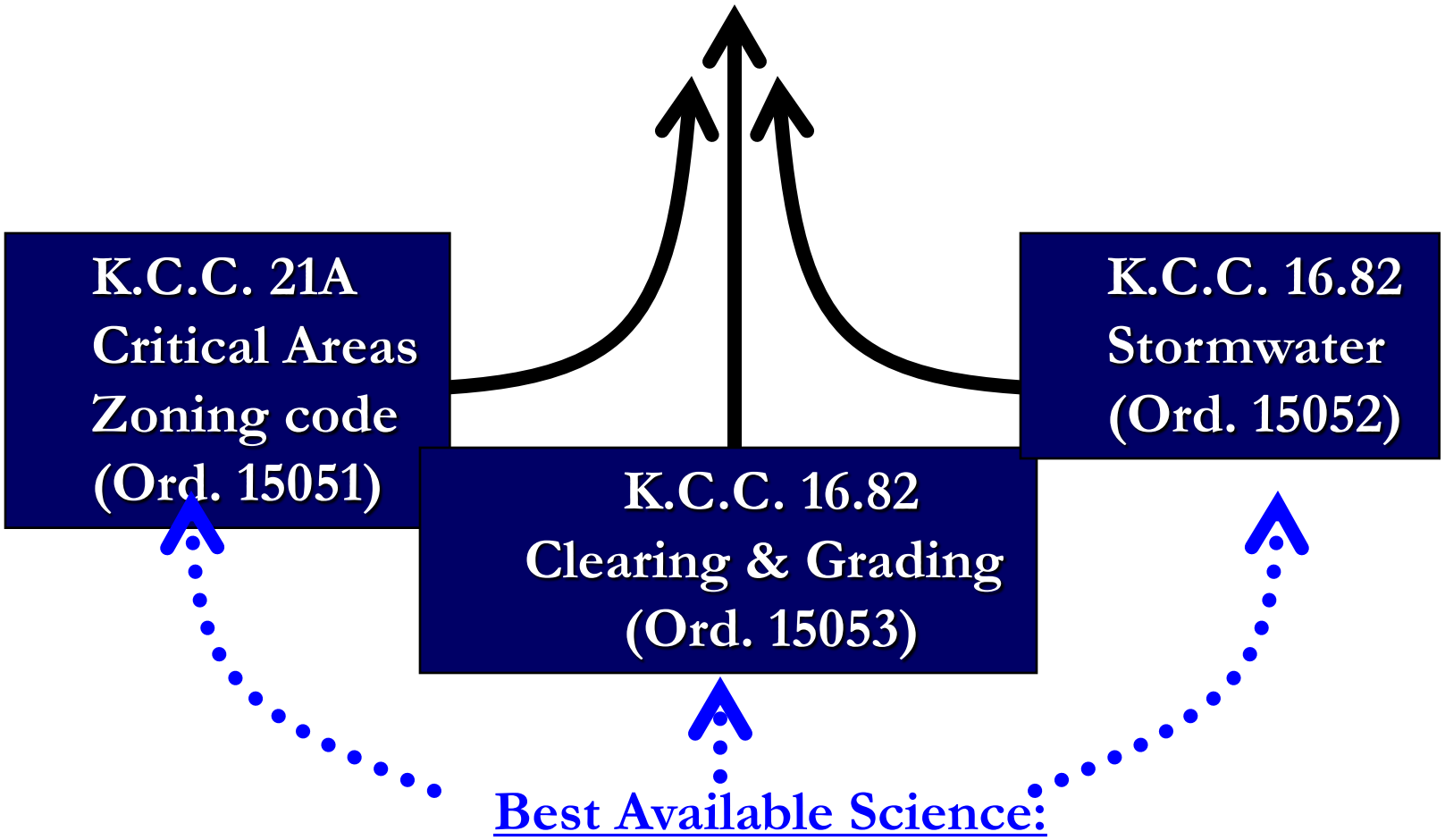
In 2005, Washington State Growth Management Act required Critical Areas Ordinance.

Critical Areas Ordinance required use of Best Available Science.

We used it. It survived appeals.

But, was it sufficient?

Critical Areas Ordinances (CAO)*



*Also have non-regulatory measures, e.g., stewardship and tax incentive programs, acquisitions, transfer of development rights, and habitat restoration projects

YOU IMAGINE
EW" BILLABLE
S THE C.A.O.
CREATE FOR
S. EMPLOYEES
PLUS AN HOUR?
HARRY REINERT,
THE AUTHOR OF
THE C.A.O., IS AN
ATTORNEY
NOT A SCIENTIST.
SIM'S & D.D.E.S. CLAIM
1,000 PEOPLE
WENT TO 23 MEETINGS.
NAME ONE PERSON
WHO SAID O.K. TO
THE THEFT OF 65%
CHOOSE CAREFULLY!
SIMS & D.D.E.S.
—OR—
ROPERTY OWNERS
& COMMON SENSE

Issue:

New regulations needed assessment.

Little information… no certainty

Wanted to know:

Will new regulations be sufficient?

If not, why?

And, what would change?

To find out, we:

- built an experimental framework, and
- conducted an experiment.

Hypothesis

If regulations are effective, either:

- No change, or
- If change, similar direction and magnitude among treatment and reference

Key Questions:

- Did the environment change (respond)? If so, was it related to CAO implementation?
- If response, how might the CAO be modified?
- How well were regulations followed?
- Did non-compliance have an effect?

Experimental Framework

Watersheds – Nine: 6 treatment, 3 reference

Puget Lowland Ecoregion

Headwater, small (200 to 3500 acre) – “tractable”

Till-dominated

No lakes, minimal wetlands

high sensitivity

Response Unit - Perennial, salmonid-bearing channels at outlet

Response Variables - Hydrology, biology, water quality and channel complexity (4 pathways - 12 variables)

Space – rural zoned, distributed (east-west/island-mainland)

Time - Five years (2007, 2009, 2010, 2012 high resolution orthos)

Detailed LC mapping (1:1200, hand-digitized)

Parcels and Permits

Select watersheds with highest amount of undeveloped parcels

Track change by type, location and parcel.

and…

a priori design:

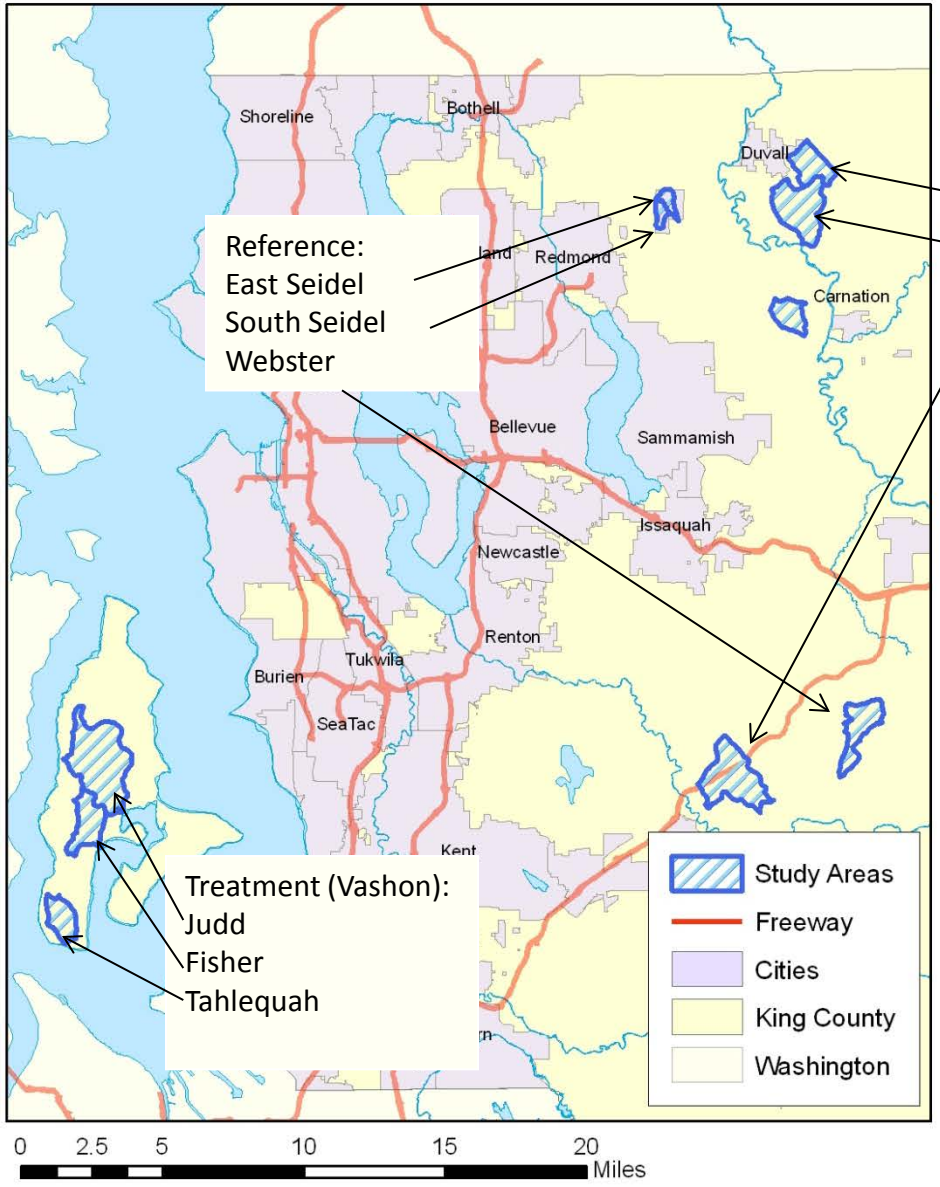
- BACI w/ multiple sites & response indicators
- Time *and* Space (no space-for-time substitution)
- Statistically strong to minimize Type II Error (likelihood of concluding no effect when, in fact, there was one)

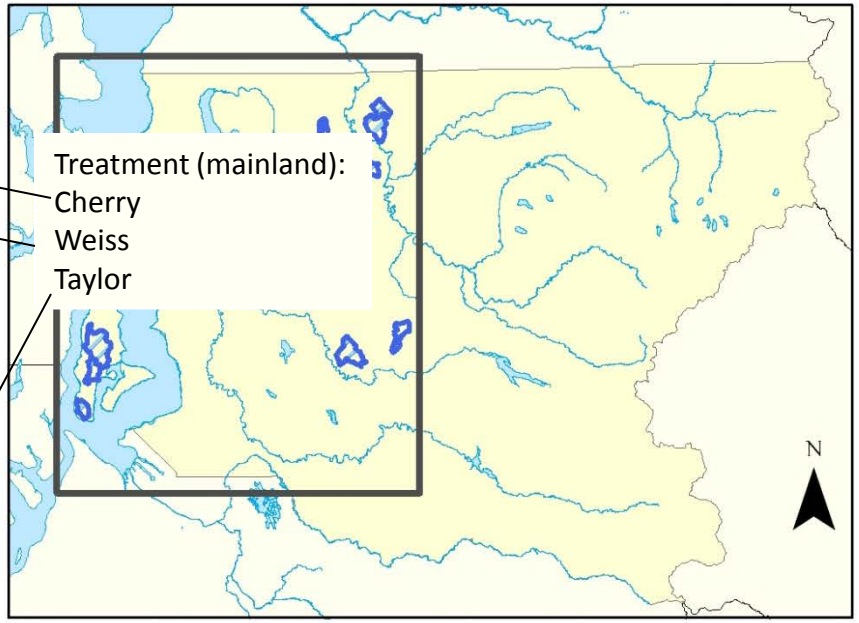
Assessed history (legacies)

Reference scenarios: historic, full build-out (worst-case) and urban

Reference

Study Watersheds





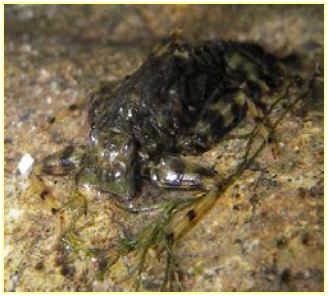
Selection Criteria:

- **Puget Lowland Ecoregion - common geology (mostly till), morphology and climate.**
- **Small headwater watersheds (60 to 1260 ha) w/ fish-bearing channels, no lakes, minimal wetlands**
- **Single jurisdiction and set of regulations**
- **Treatment basins: ongoing development with high potential for more**
- **Reference – forested, no development**

Measuring Environmental Response

Hydrology – High Pulse Counts

Biology



- Macro-invertebrates
- BIBI

Water Quality

- Conductivity, Temperature

Channel Complexity

- Reach-Averaged Velocity (salt tracers)
- EMAP – substrate, thalweg, pools, LWD

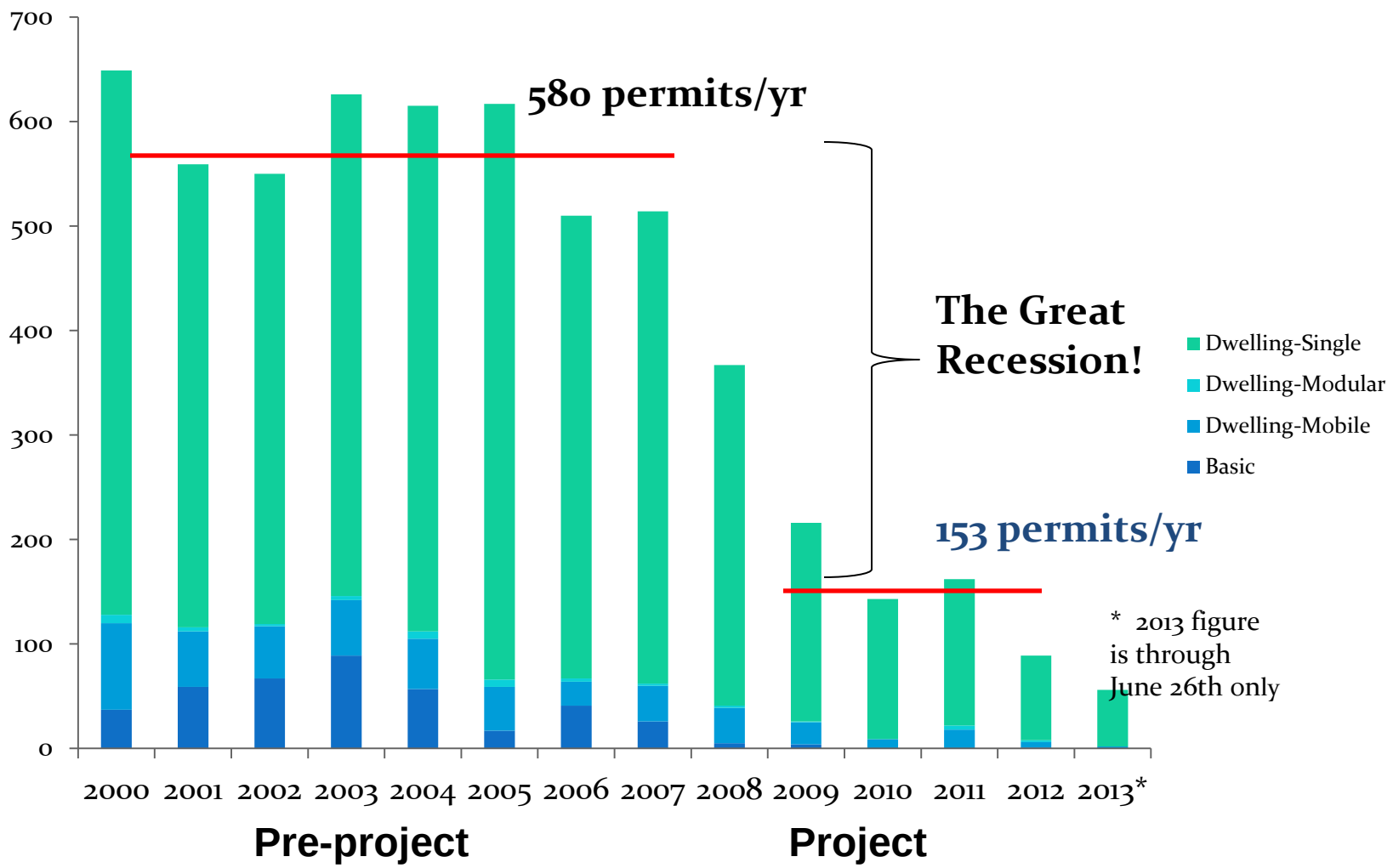
Salt Tracers - Measuring Channel Complexity*

- Repeatable
- Precise
- Simple (but must be exact in use!)
- Use with other measures (pool, substrate, thalweg) to understand change mechanism(s)
- Future: better understand influence of flow, gradient and confinement to discern effect of complexity.
- See "**Monitoring physical changes in stream channels with salt tracers**" (Appendix F)

* Originally suggested by Andy Gendaszek, USGS

Measuring Land Cover change as “treatment”

Just a slight problem along the way…
…building permits declined 75%



Land Cover Scenarios
(putting the present in perspective)

•**Project (2007 – 2012) –** hand-digitized land covers, high resolution (0.3 m) orthophotos (2007, 2009, 2010, 2012)

•**Historic (~1900 to 2007)** – are there "Ghosts of land use past" (Harding et al 1998)? Used reports and maps, aerial photos, satellite (see **Michalak et al 2013 Appendix D**)

• **Full Build-out –** possible "worst case"? Apply development footprint on undeveloped parcels to assess potential change.

•**Urban** – 2007 Juanita Creek

The Past - Data Timeline*

1907-08 1911 1936 1948 1965 1986 1991 1995 1999 2002 2007

Eastern and Control

Vashon

Timber

Soil Survey

Vashon and Control

All Basins

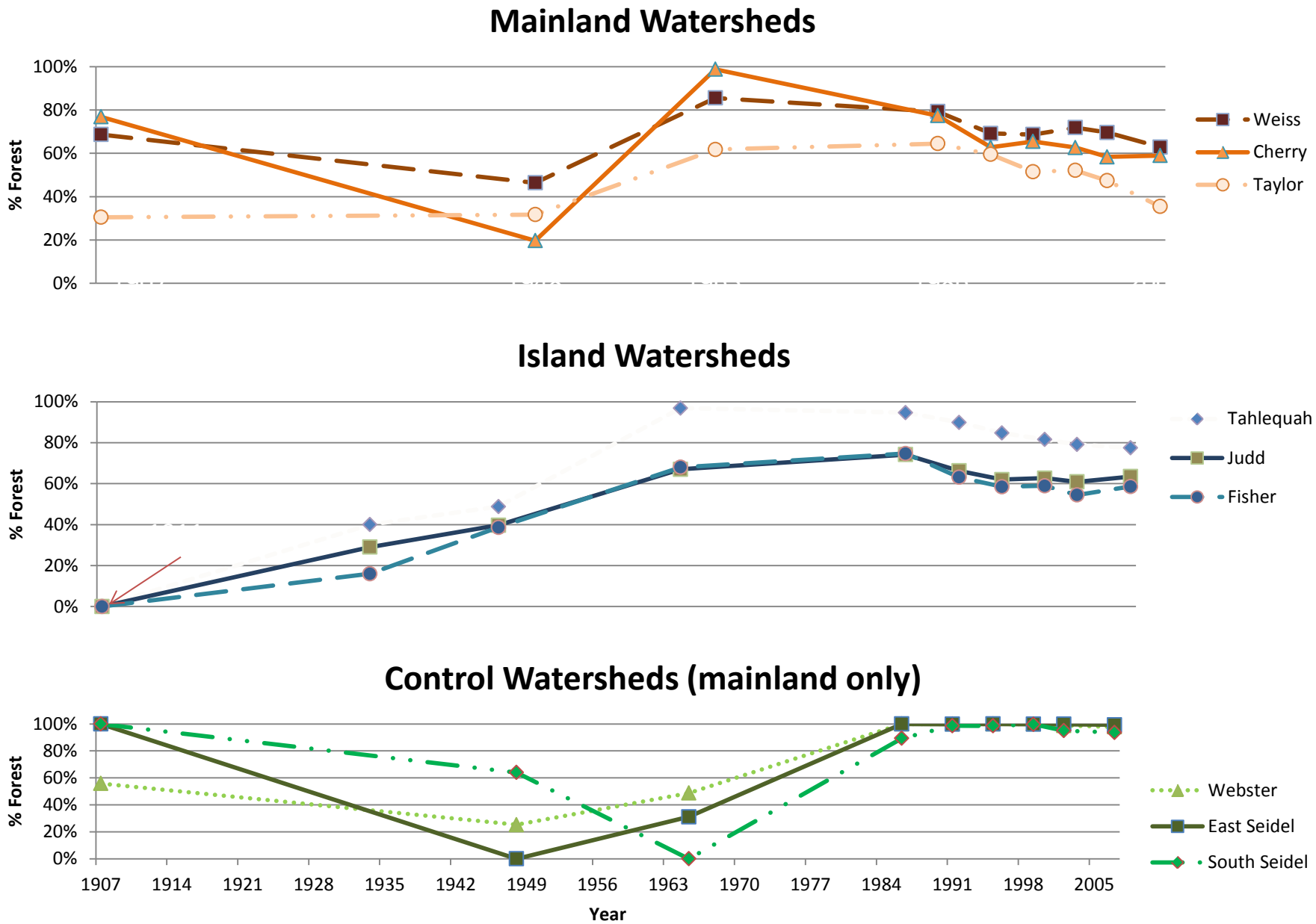
Aerials

All Basins

Land Cover
30 m pixels

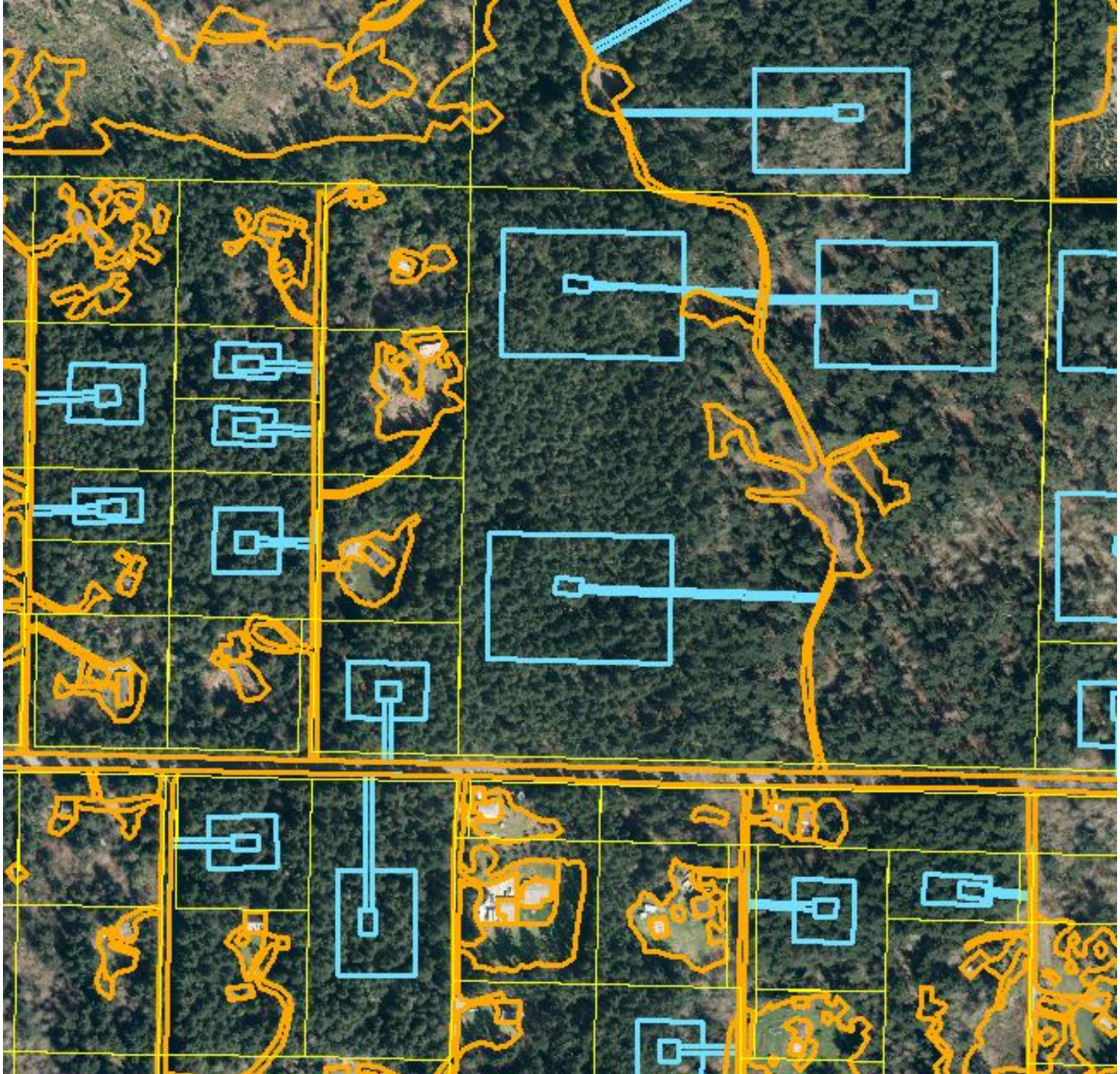
*Michalak e t al. 2013.

Change in % Forest Cover - 1907-11 to 2007*

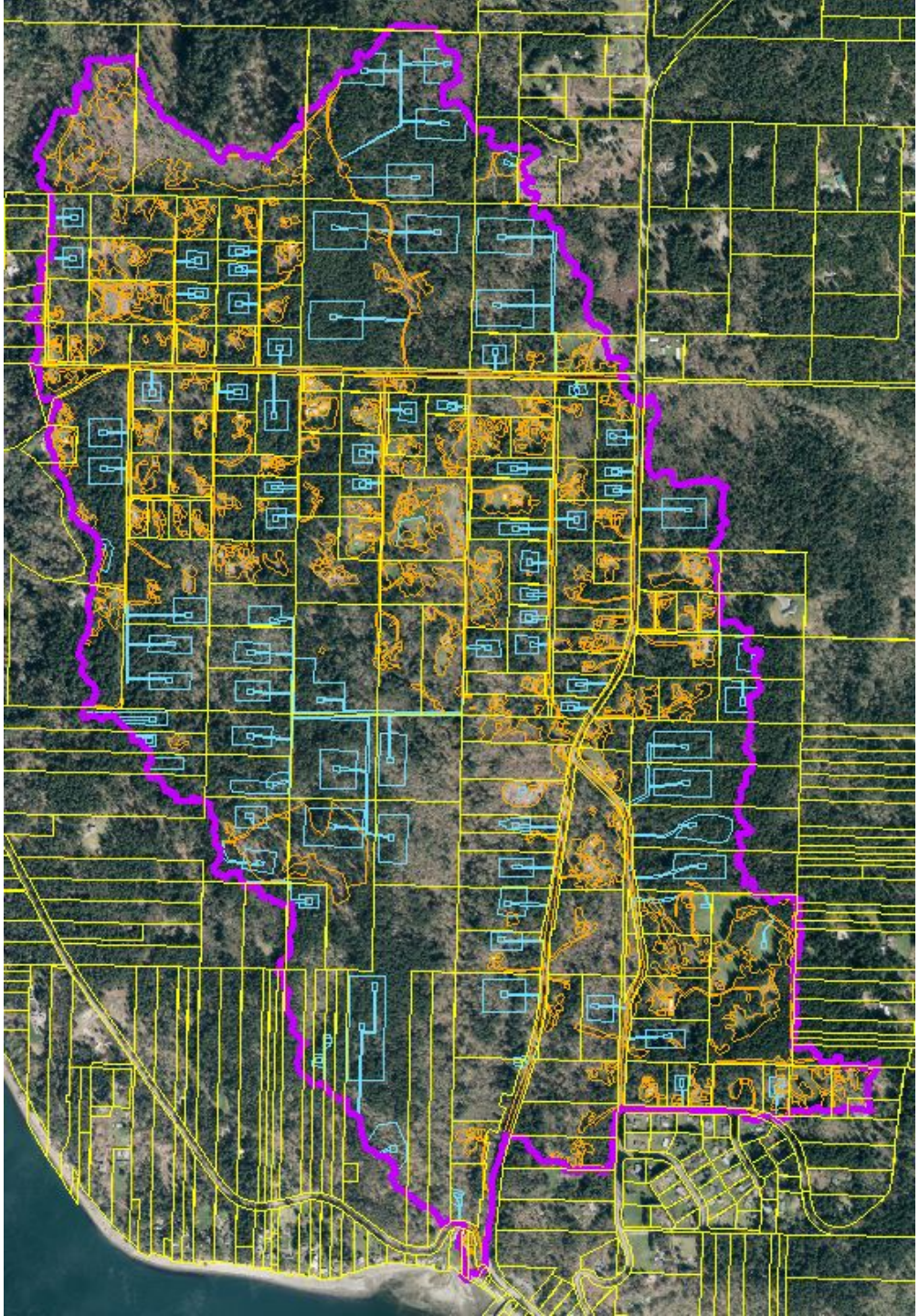


*Michalak et al. 2013

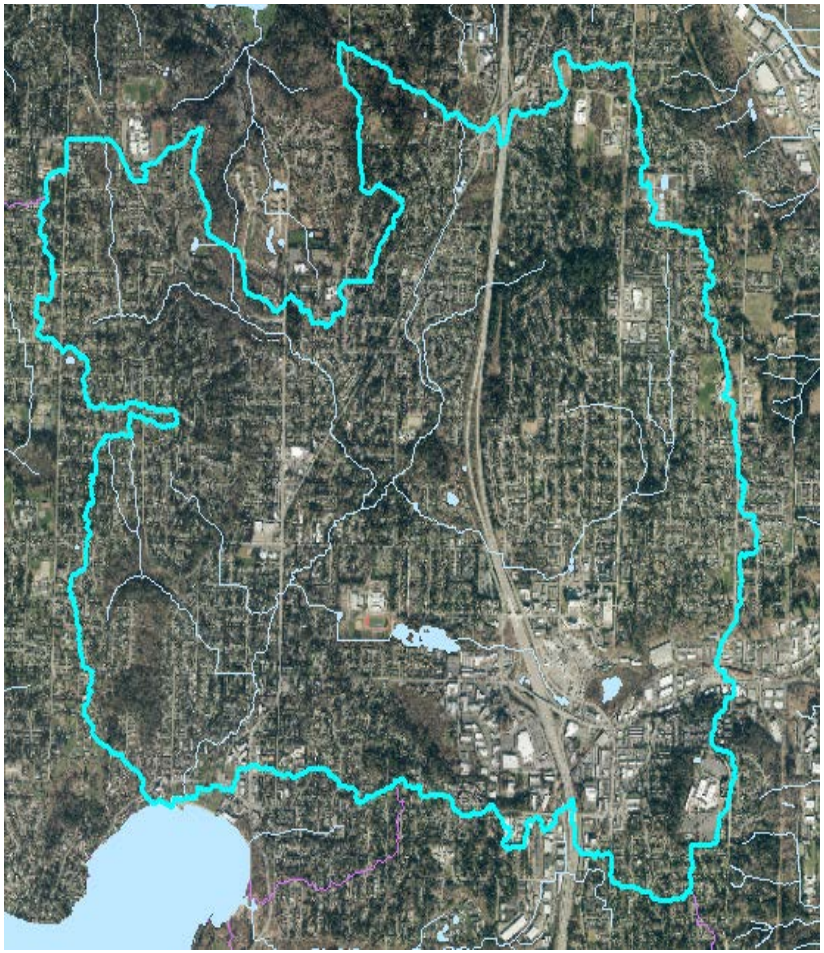
Estimating the Future Condition



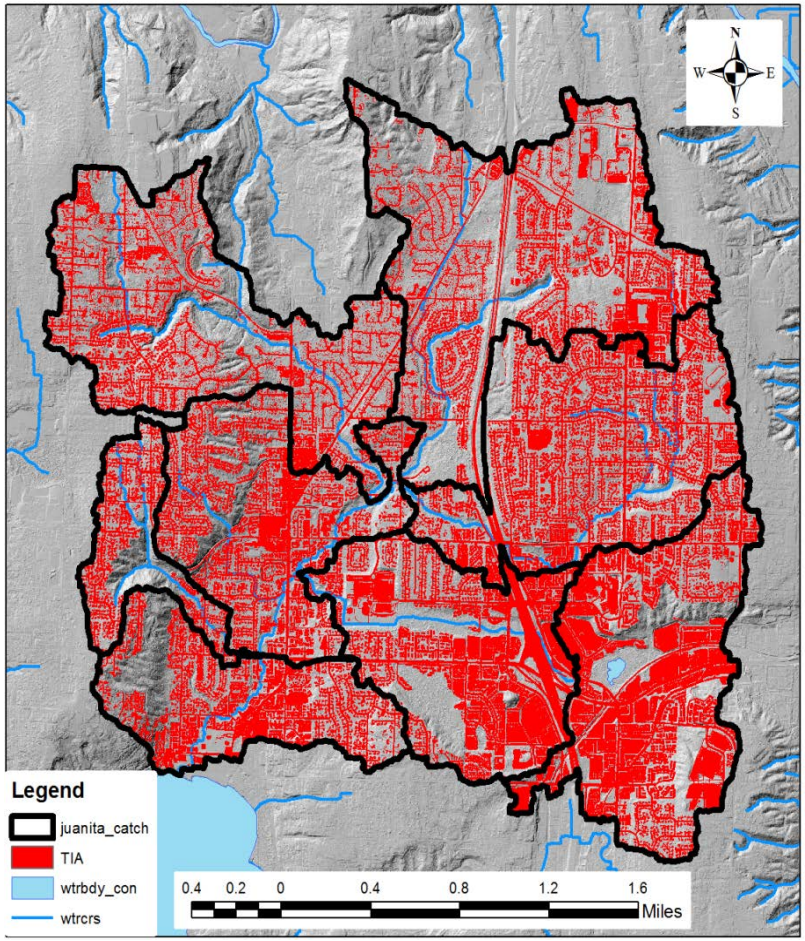
Tahlequah – Full Build-Out



An Urban Comparison - Juanita Creek



Orthophoto



Impervious cover

To compare scenarios, quantify <u>the effect</u> of land cover change (not just the change)

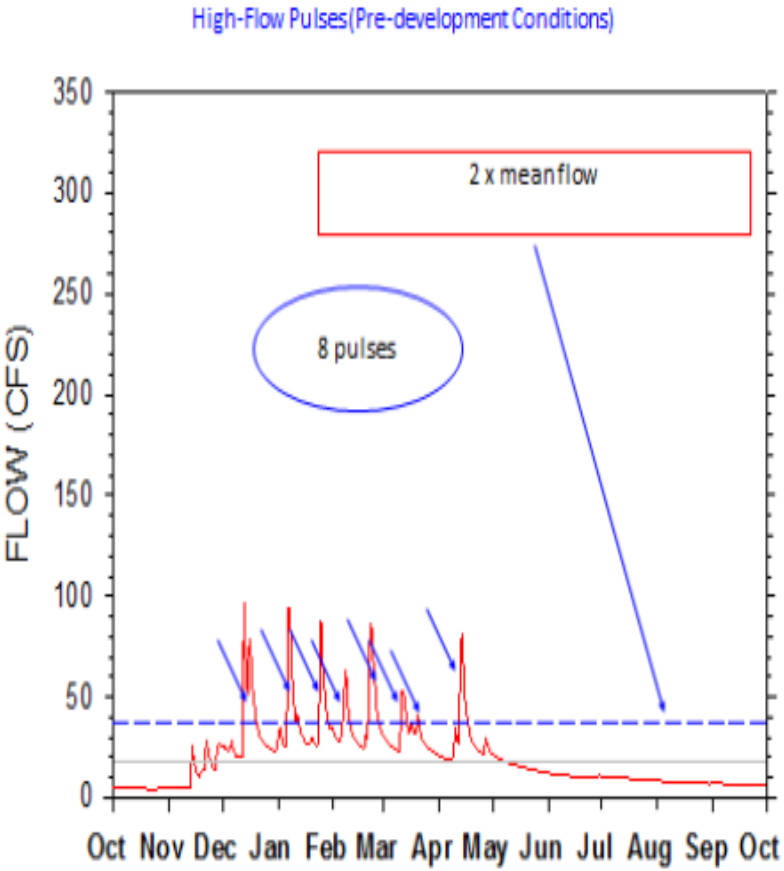
Hydrology the primary driver for response

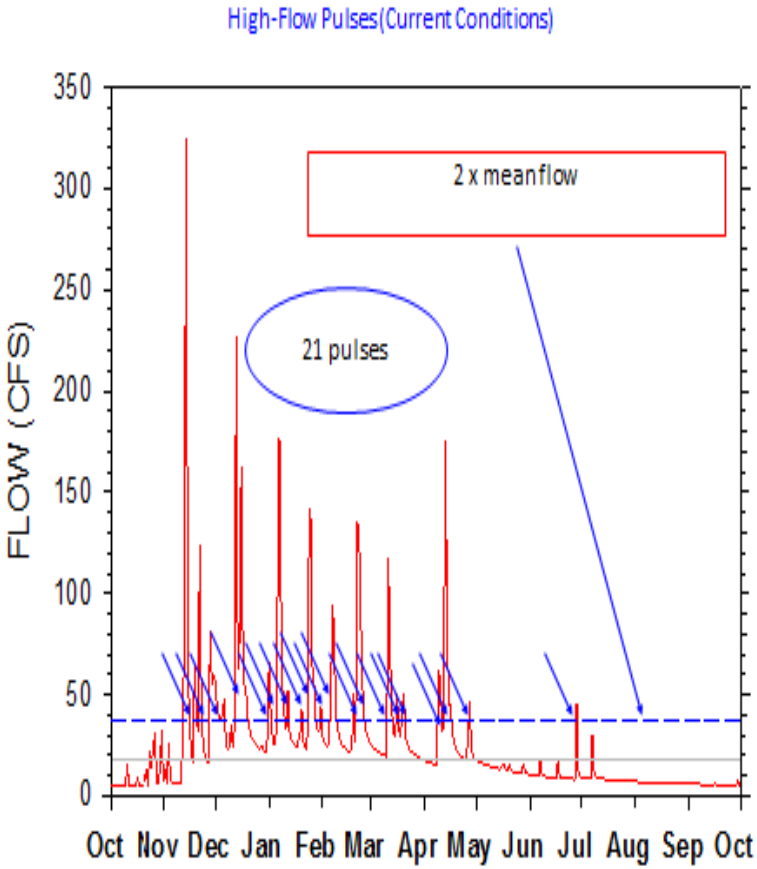
Hydrology used to:

- index watershed condition
- quantify effect of change over time

“Flashiness” most strongly correlated with Biology (DeGasperi et al 2009), so…..

High Pulse Counts*



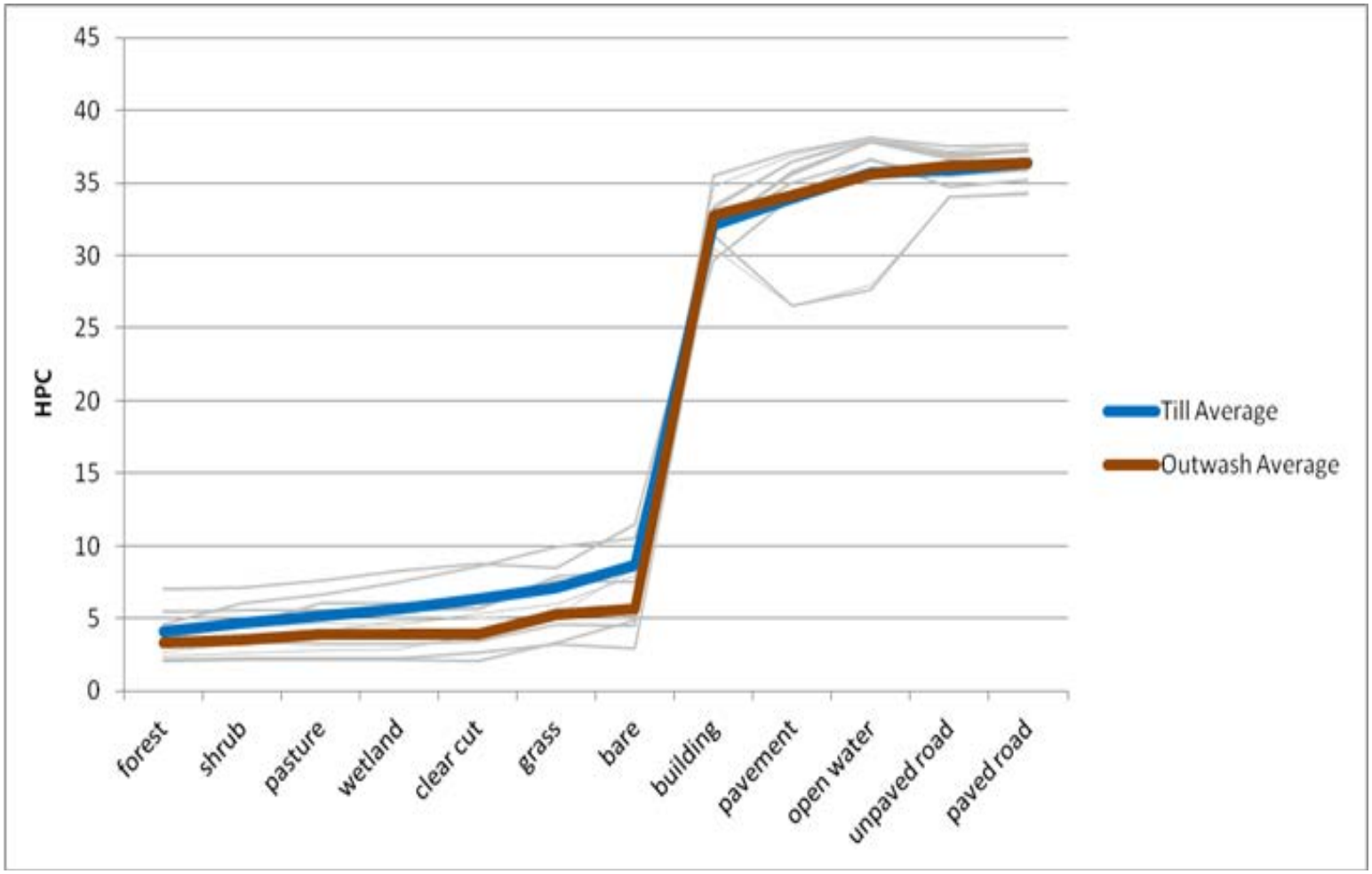


Pre-development

Post-development

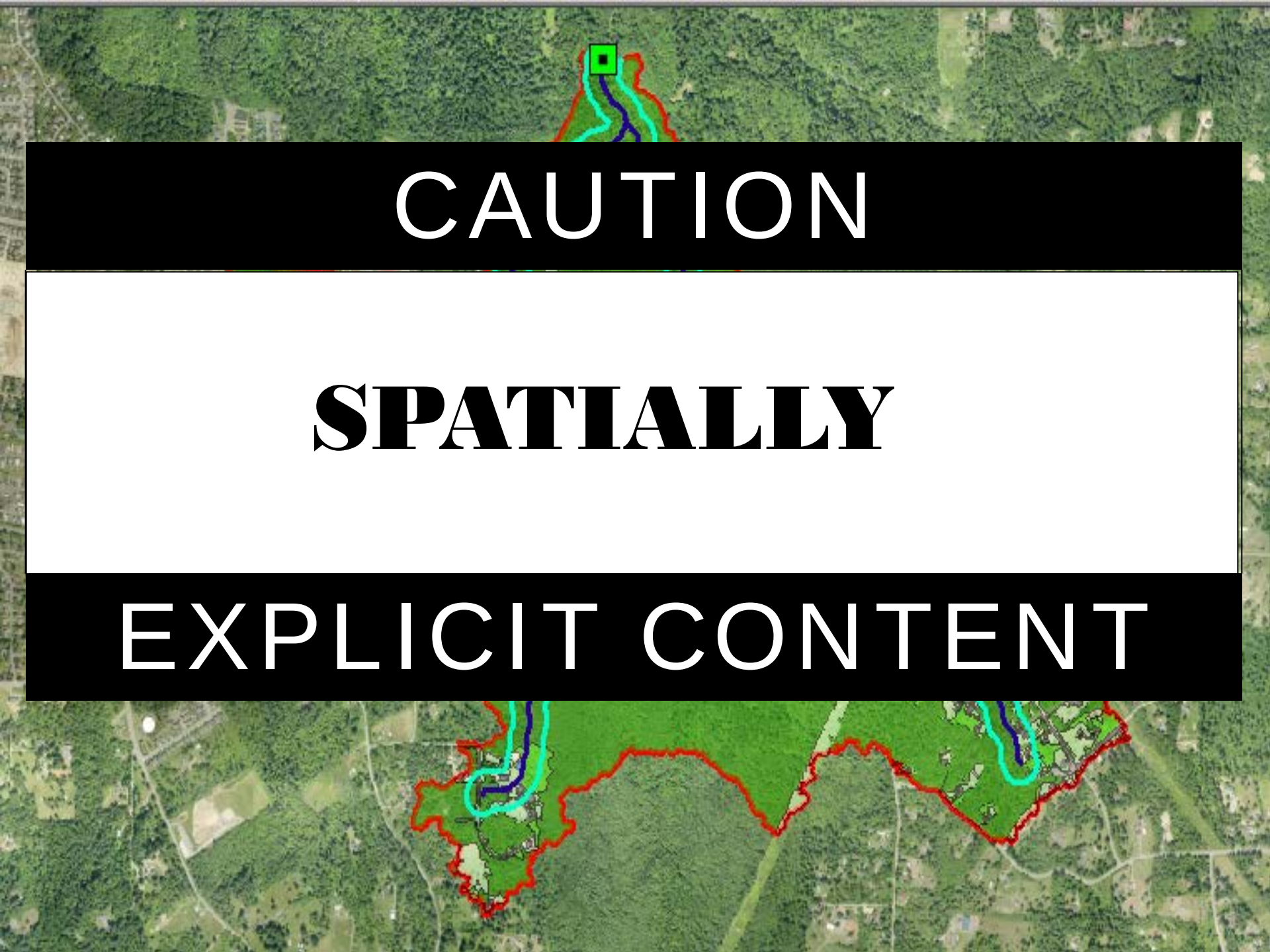
*** From Horner 2013**

High Pulse Counts*
Effect of geology and land cover

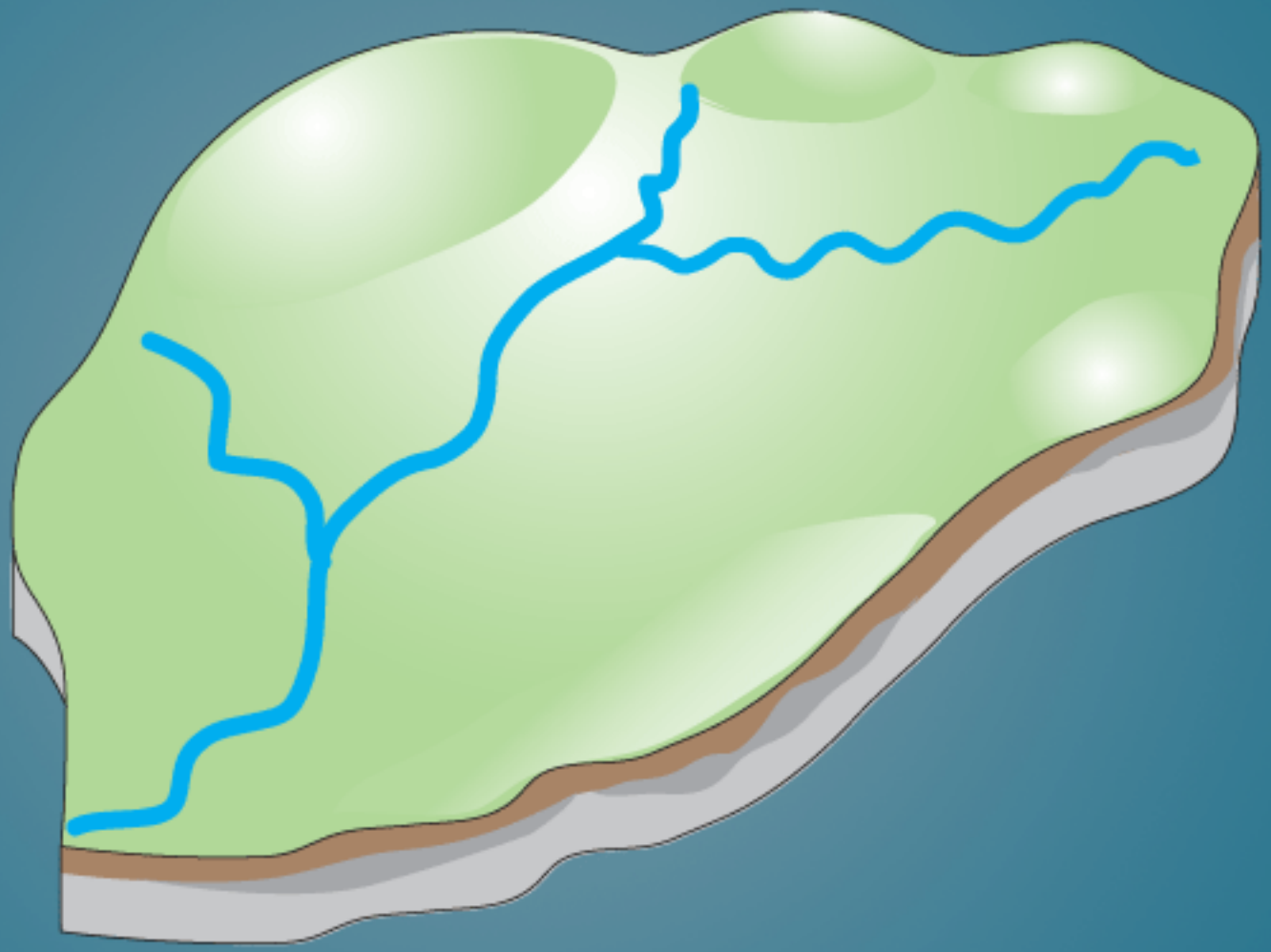


*** Modeled 61-year averages for pre-existing watershed models used to model the HCI**

accounting for
land cover, geology and distance

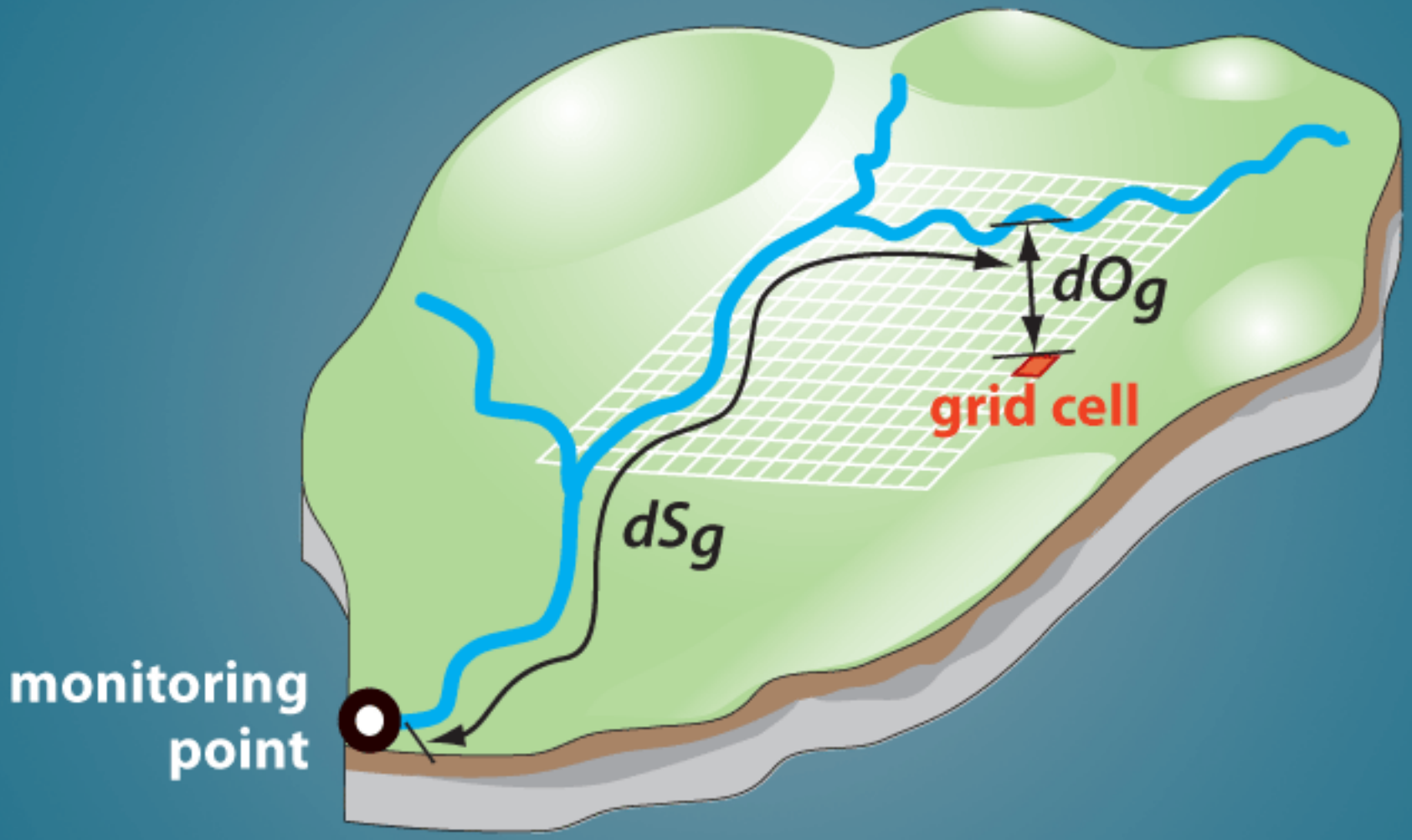

CAUTION
SPATIALLY
EXPLICIT CONTENT

Study Basin

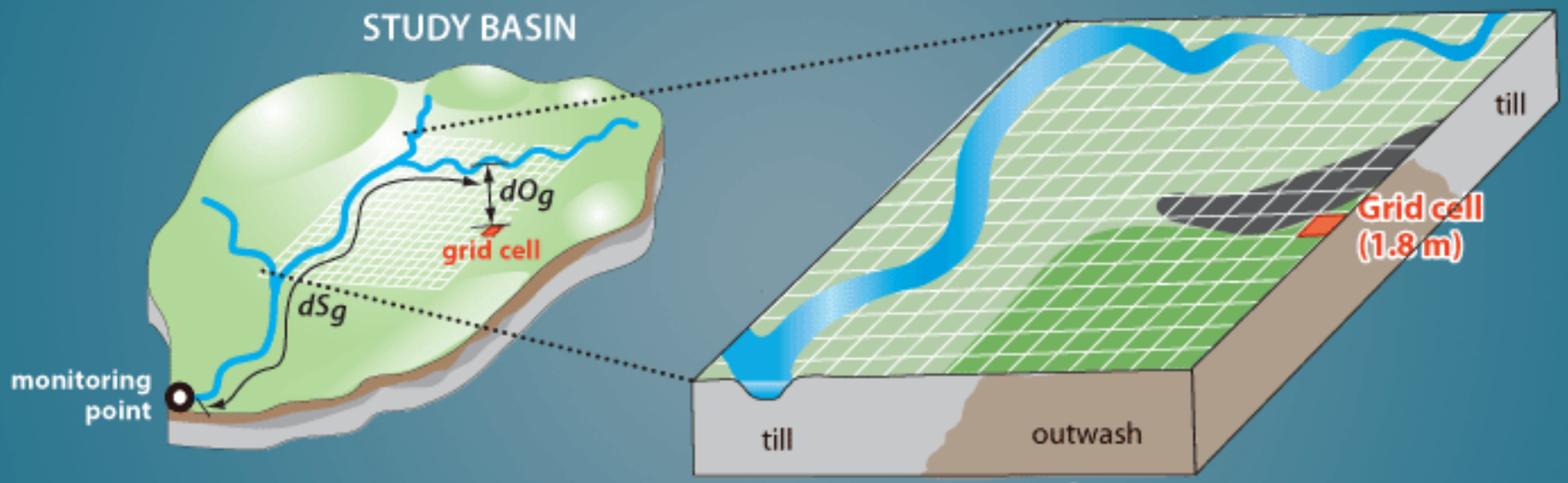


Setting Up the Study Area

Calculation of Grid Cell Distances



Surficial Geology

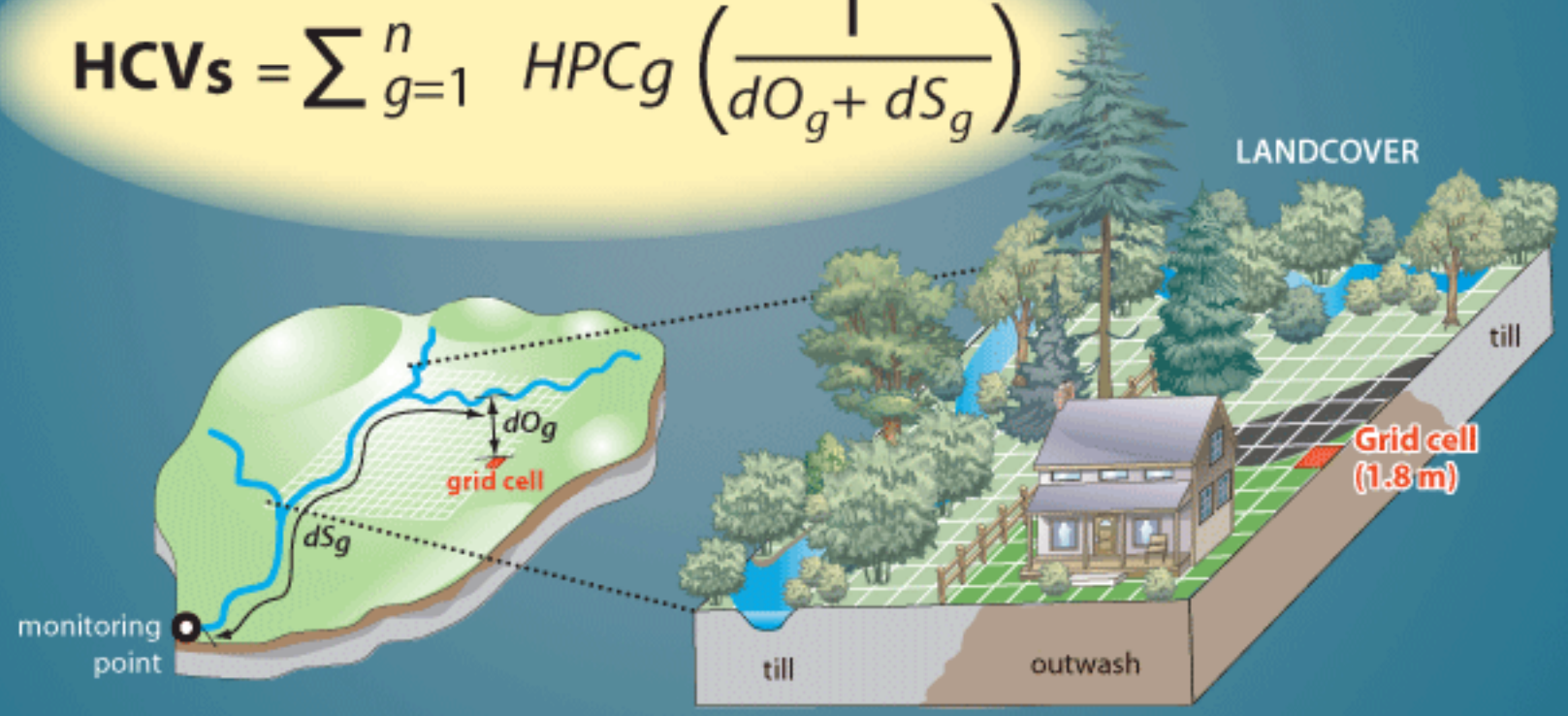


Low vs. High Permeability

Factoring in Landcover

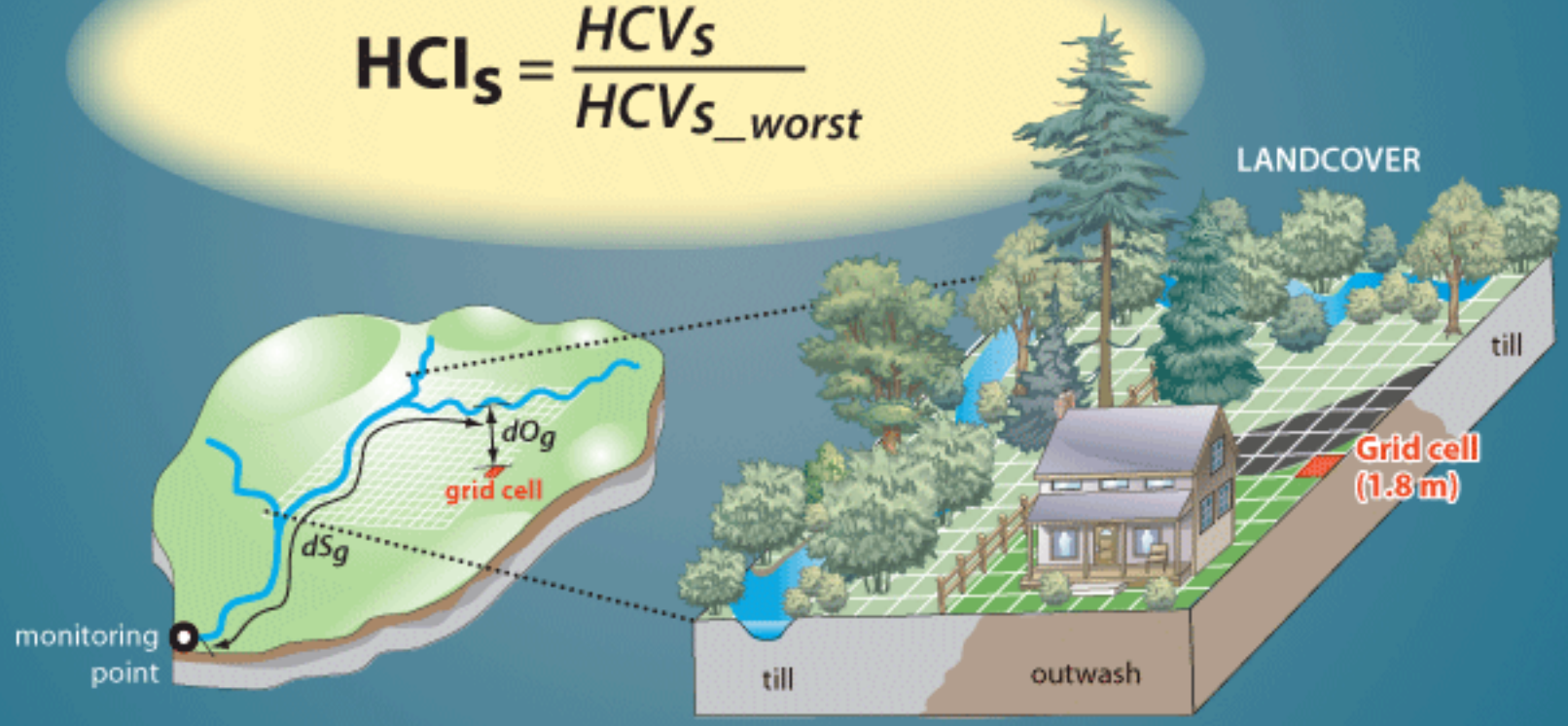
Calculating the Hydrologic Condition Index...Step 1

$$\mathbf{HCVs} = \sum_{g=1}^{n} HPCg \left(\frac{1}{dO_g + dS_g} \right)$$

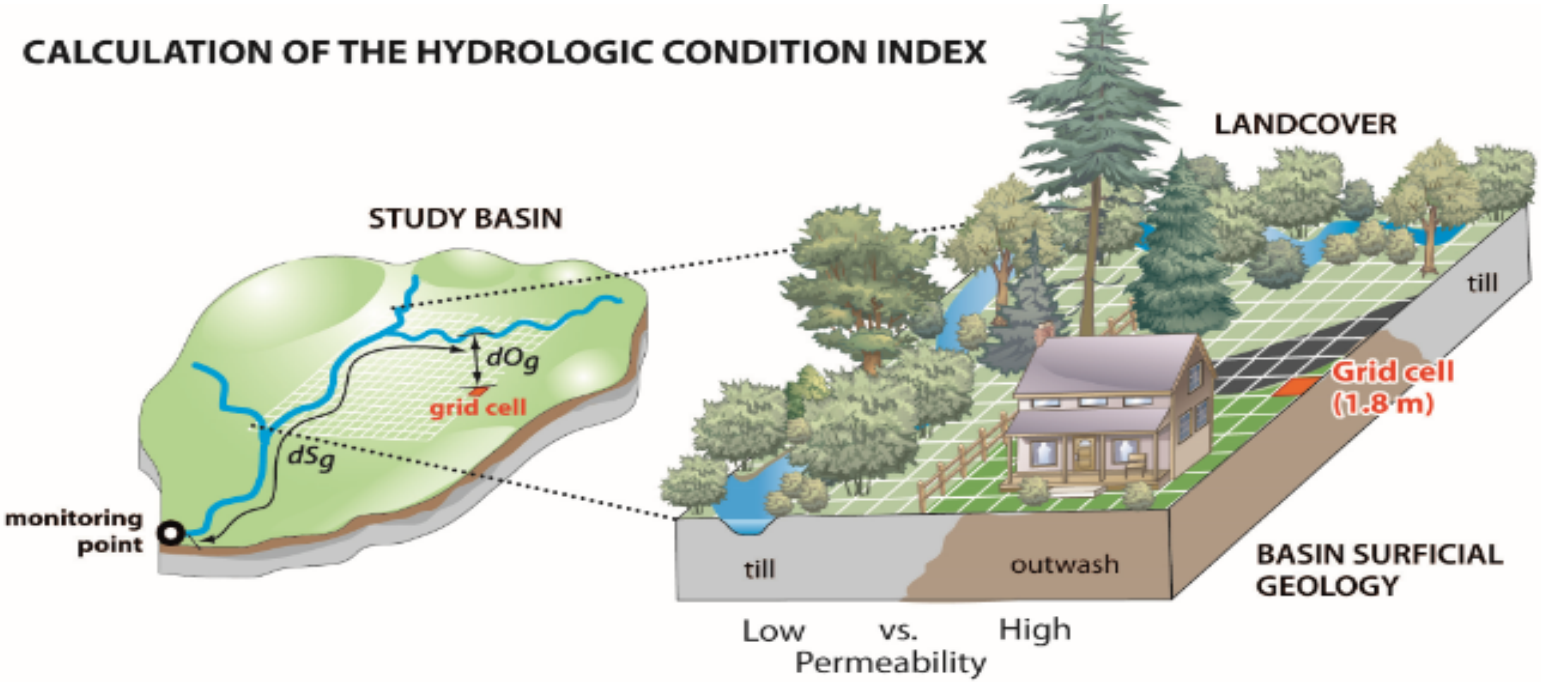


Calculating the Hydrologic Condition Index...Step 2

$$HCI_S = \frac{HCV_S}{HCV_{S_worst}}$$



CALCULATION OF THE HYDROLOGIC CONDITION INDEX



$$HCI_s = \frac{HCV_s}{HCV_{s_worst}}$$

$$HCV_s = \sum_{g=1}^{n} HPCg \left(\frac{1}{dO_g + dS_g}\right)$$

HCIs=the hydrological condition index for a stream site in a watershed, ***s***, given the LULC pattern for a particular year or simulated level of development

HCV*s* = the hydrological condition value for a stream site in a watershed, ***s***, given the LULC pattern for a particular year or simulated level of development

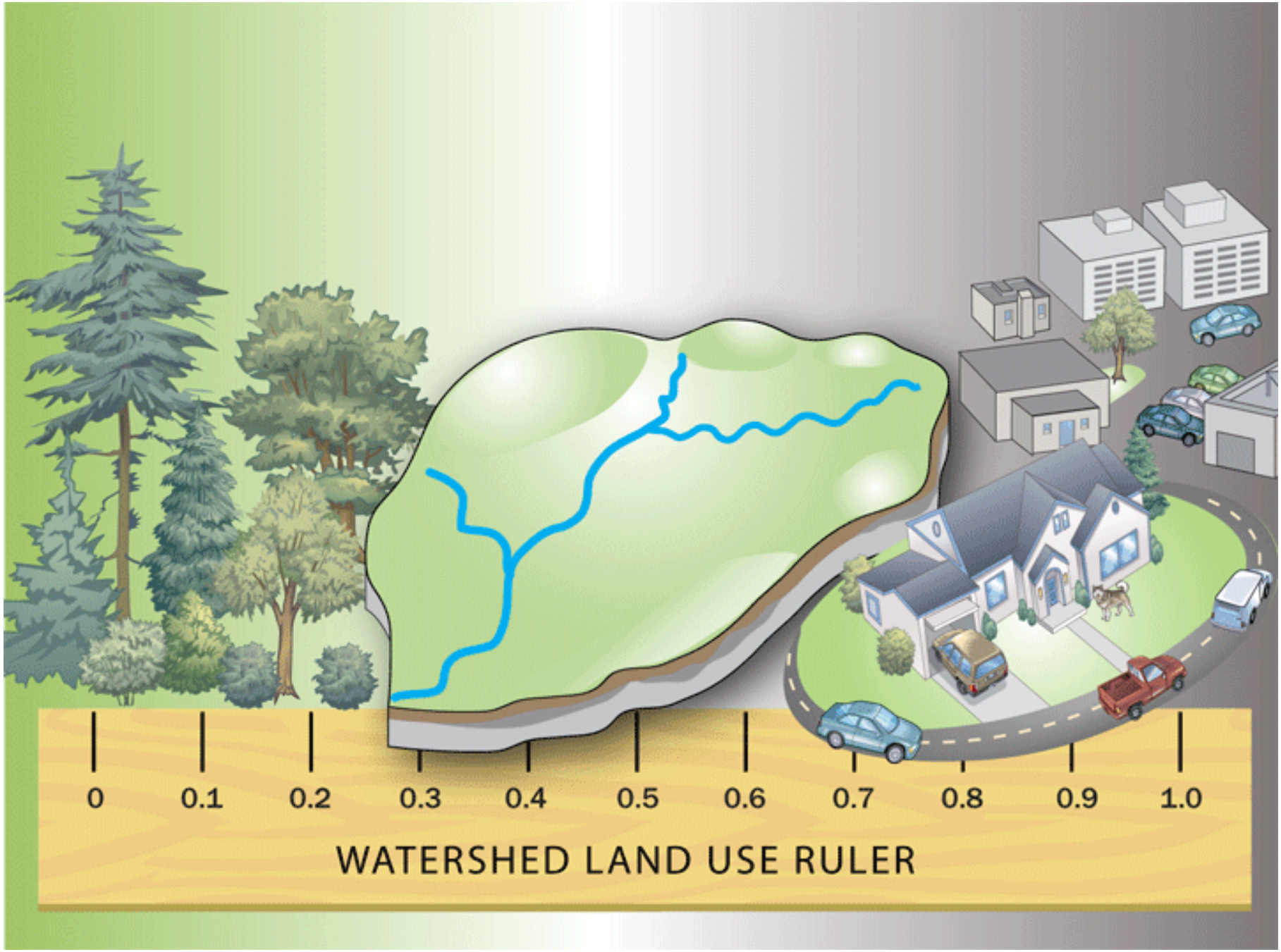
g = an index from 1 to n for all the grid cells within a watershed

HPCg = an average high pulse count value for each grid cell type, g. There are 24 values for HPC based on the combination of 12 LULC types and 2 underlying geology types

dOg = overland distance (Euclidean) from the grid cell, g, to the stream channel

dSg = stream channel distance measured from the intersection of the overland distance to the grid cell, g, to the sampling point downstream.

File: 0308_3363L_RegMonitorMODEL.ai Ipre


0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
WATERSHED LAND USE RULER

HCI = watershed hydrologic condition measuring stick

Accounts for spatial configuration of land covers and geology

X-axis - improved precision

Model accuracy and utility

Models used to estimate HPCs :

- Accuracy fair ($r^2 \geq 0.6$) to excellent ($r^2 \geq 0.9$) for in simulating hourly flow rates and HPCs,

- are being used for other major assessments (e.g., WRIA 9 Stormwater Retrofit Planning)

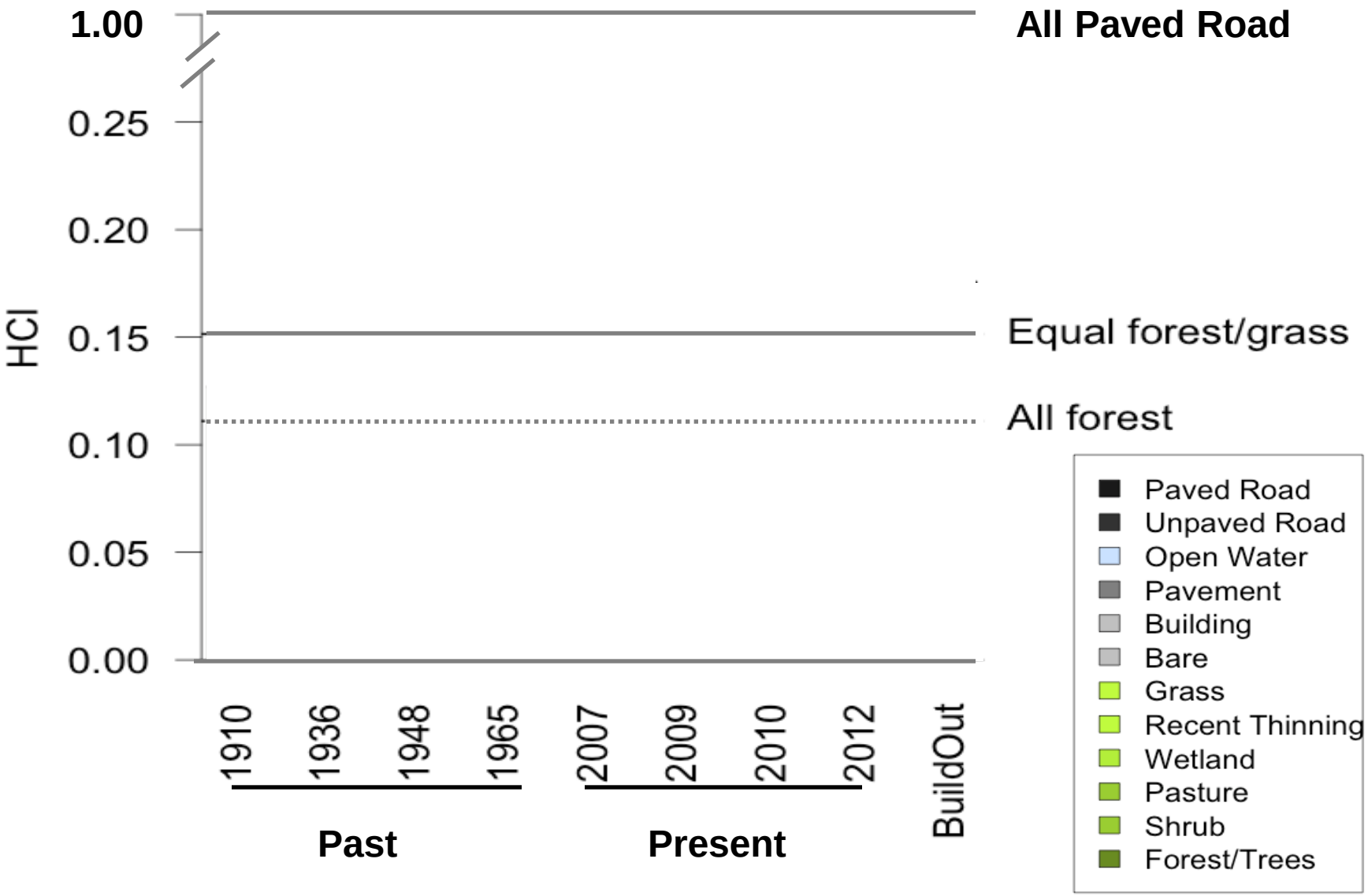
- are BAS

Project timeframe averages for six treatment watersheds	Average Watershed HCI		Average Regulatory Stream Buffer HCI	
	r	p-value	r	p-value
Watershed Percent Impervious	**0.94**	**<0.01**	0.68	0.07
Watershed Percent Forest	**-0.91**	**<0.01**	-0.58	0.12
Average Watershed HCI	-	-	0.71	0.06
Average Regulatory Stream Buffer HCI	0.71	0.06	-	-
Ratio of watershed and buffer HCIs	0.05	0.46	-0.66	0.08
High Pulse Count	**0.88**	**0.01**	**0.96**	**<0.01**
Average Annual Temp at Baseflow	0.20	0.36	0.6	0.10
Conductivity at Baseflow	0.08	0.44	-0.24	0.33
Percent Pool Length of Thalweg	0.44	0.19	-0.03	0.96
CV of Thalweg Depth	-0.44	0.19	-0.55	0.13
Average Velocity at MAD	0.36	0.24	0.85	0.02
Average Residual Pool Depth	0.08	0.44	0.68	0.07
Large Wood per 100m	0.64	0.09	0.55	0.13
Percent Silt and Sand	-0.36	0.24	-0.78	0.03
BIBI	0.42	0.21	0.56	0.12
X7DADMax	0.94	<0.01	0.68	0.07

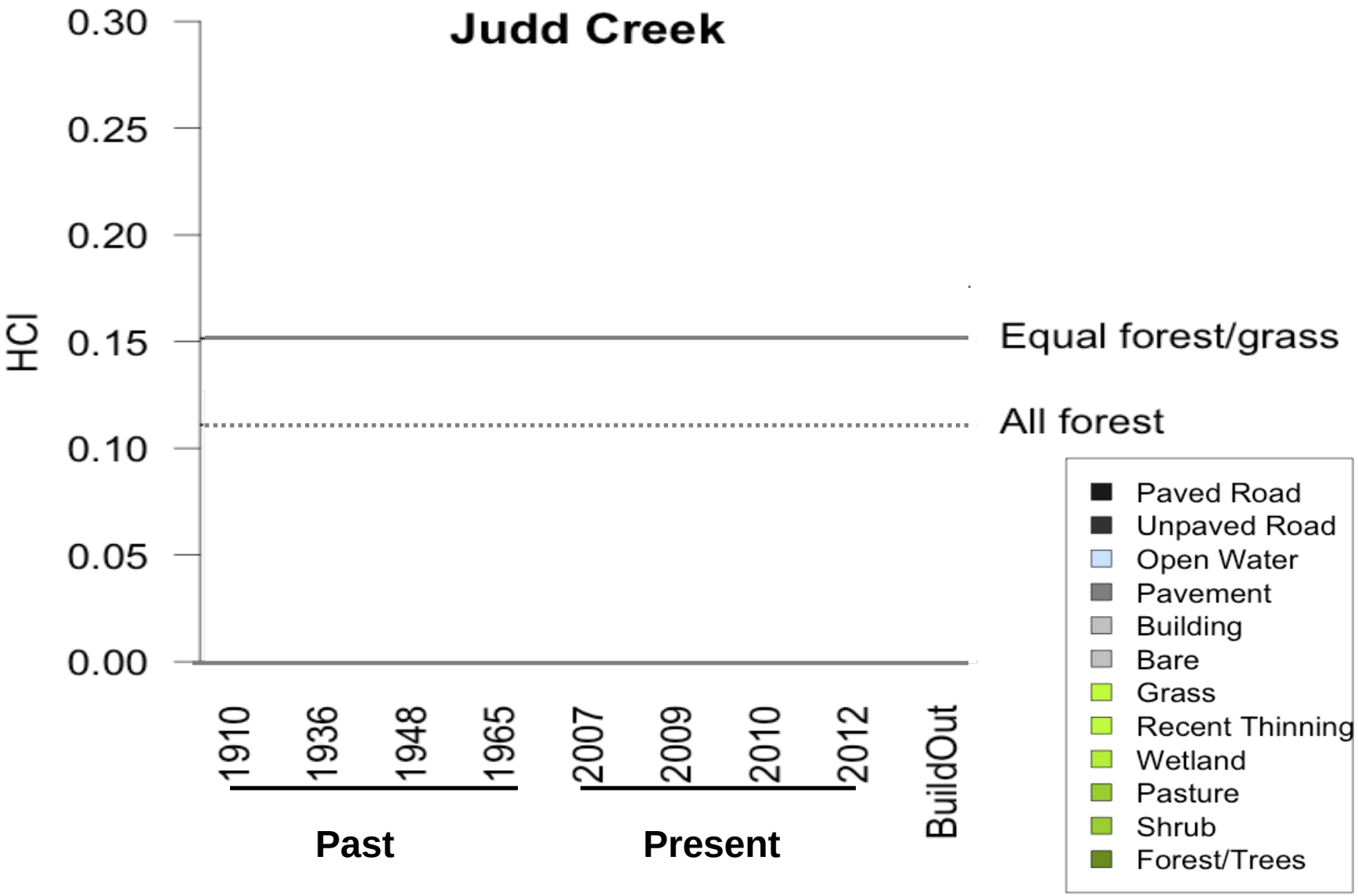
Putting it all together

Hydrologic condition over time

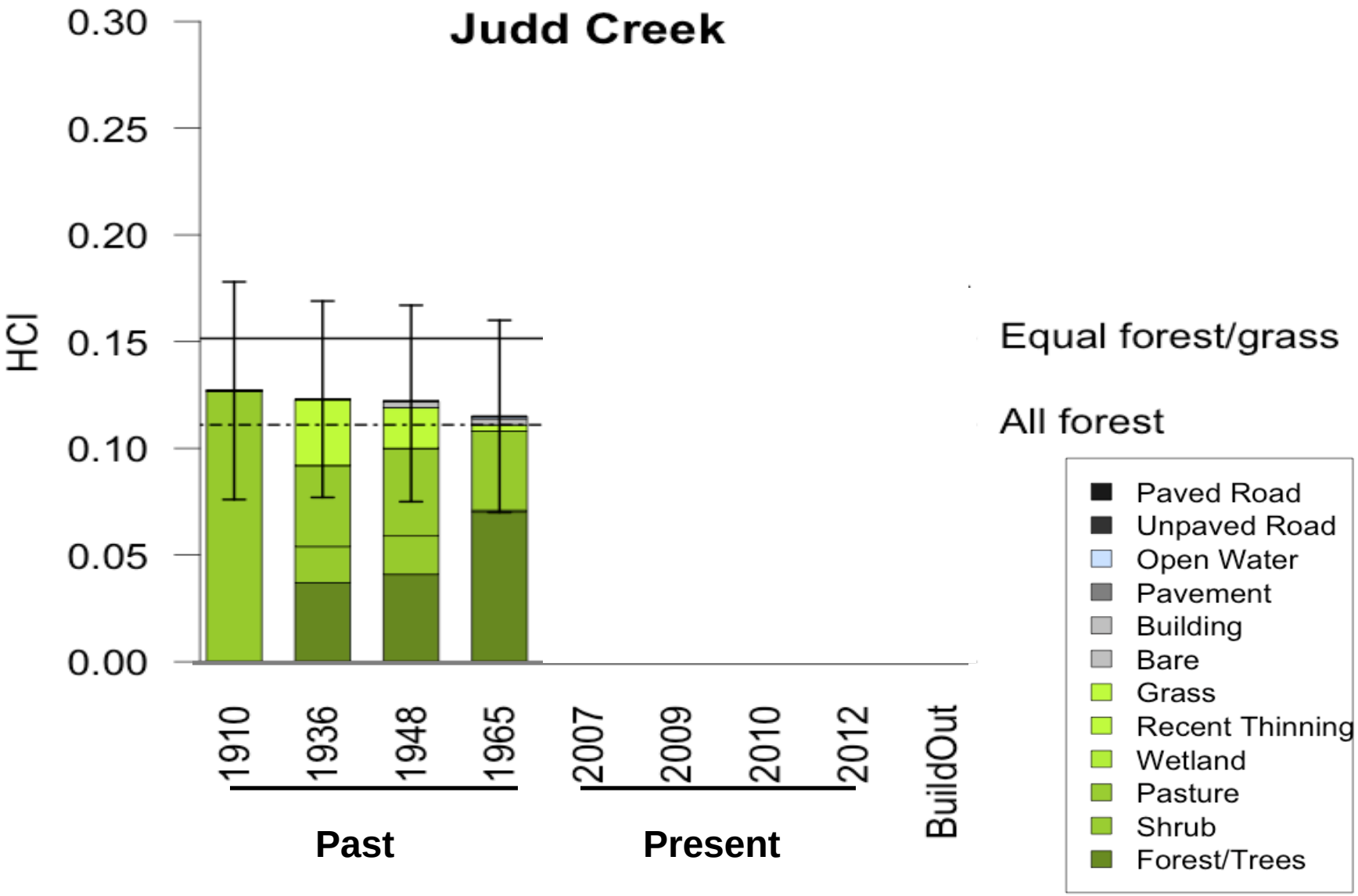
Hydrologic condition over time



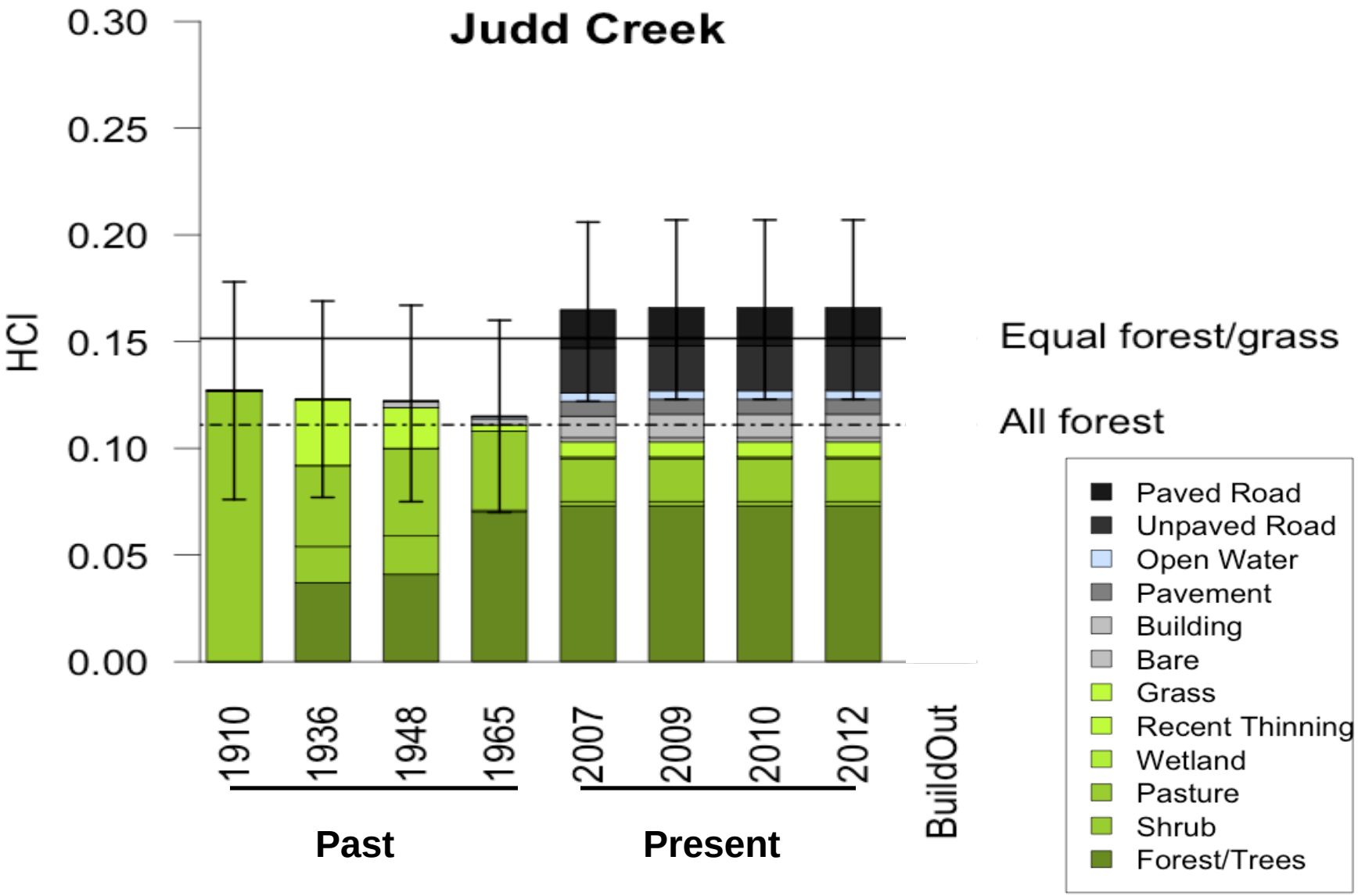
Hydrologic condition over time



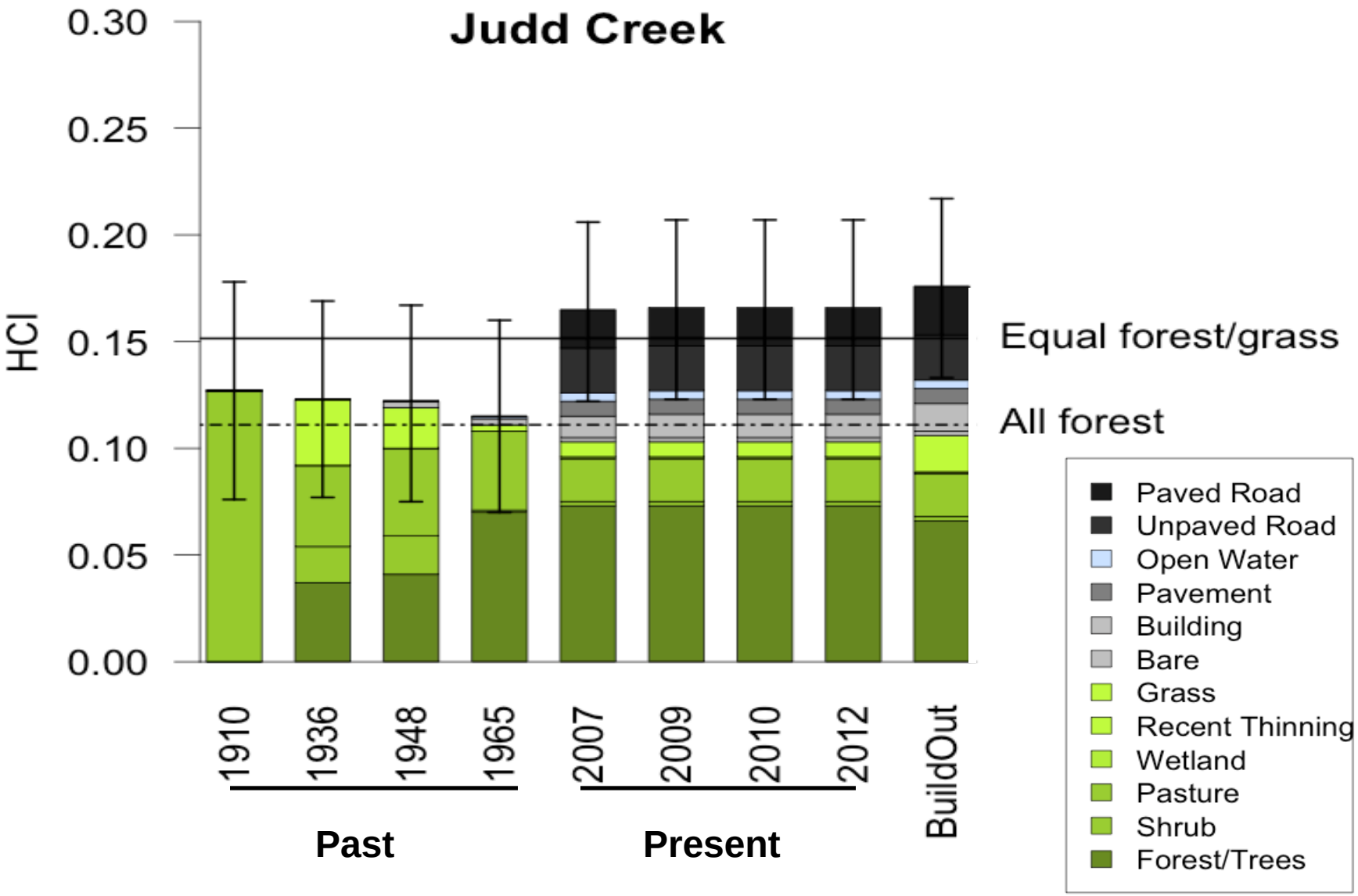
Hydrologic condition over time



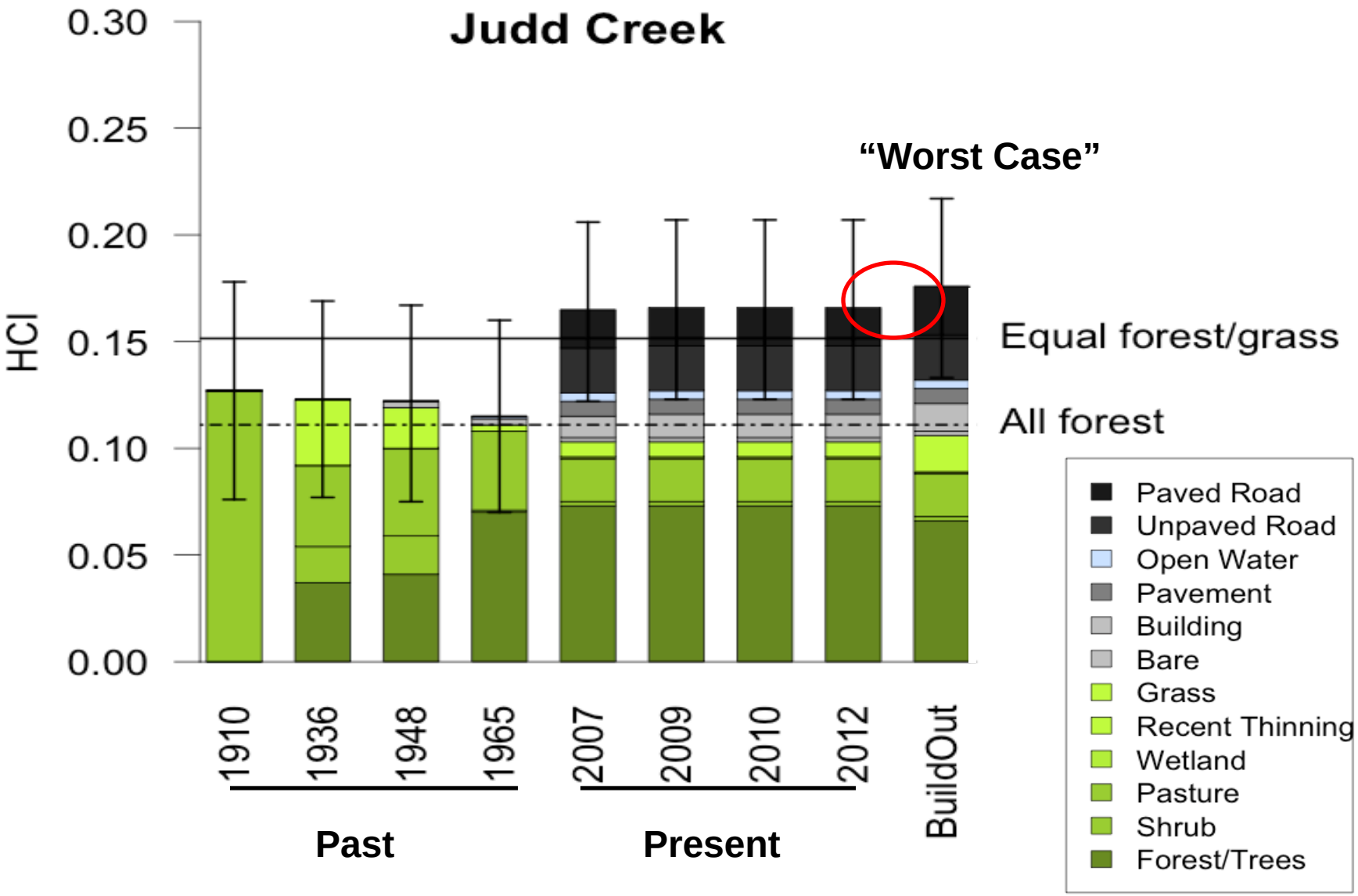
Hydrologic condition over time



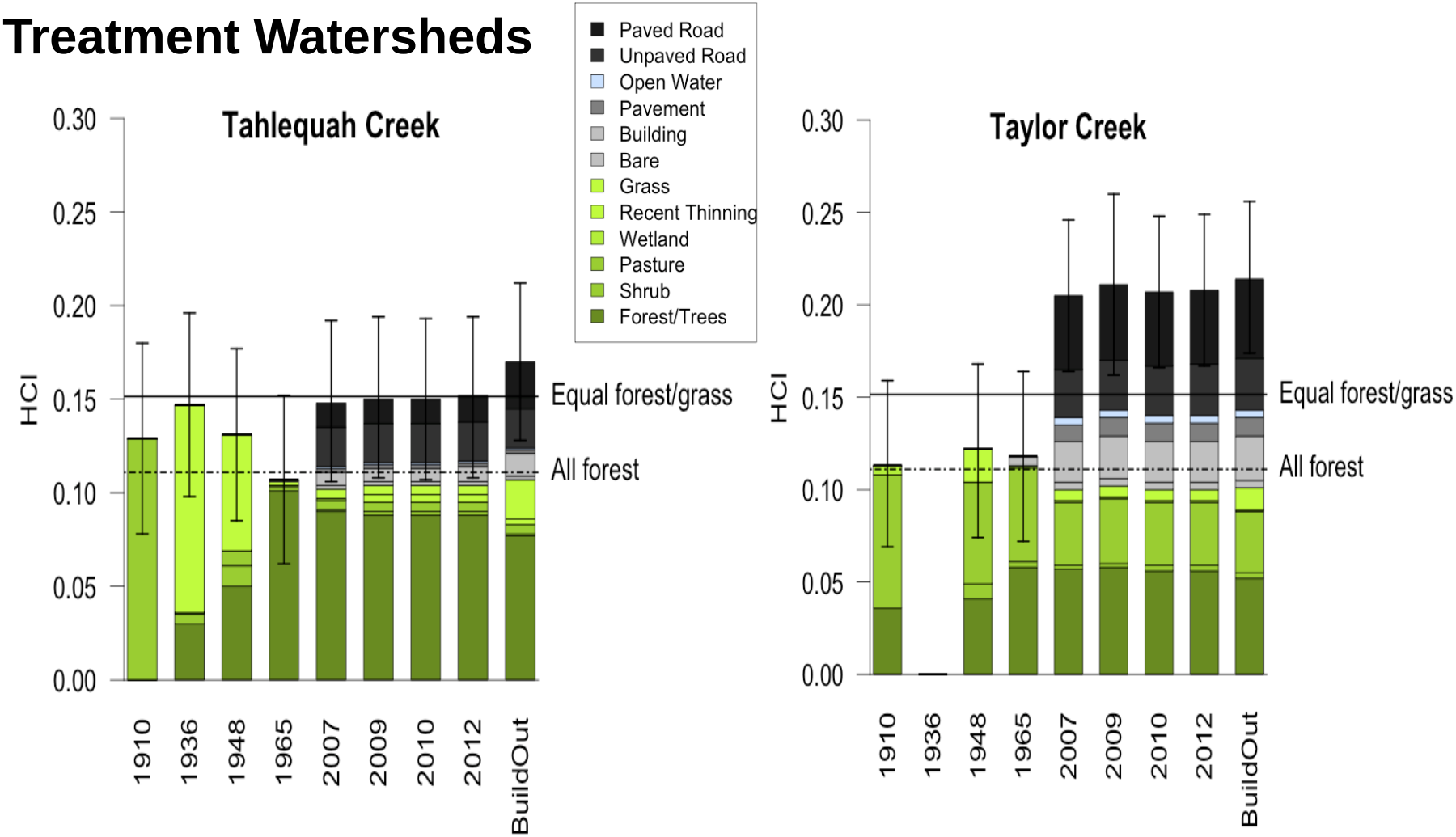
Hydrologic condition over time



Hydrologic condition over time



Treatment Watersheds

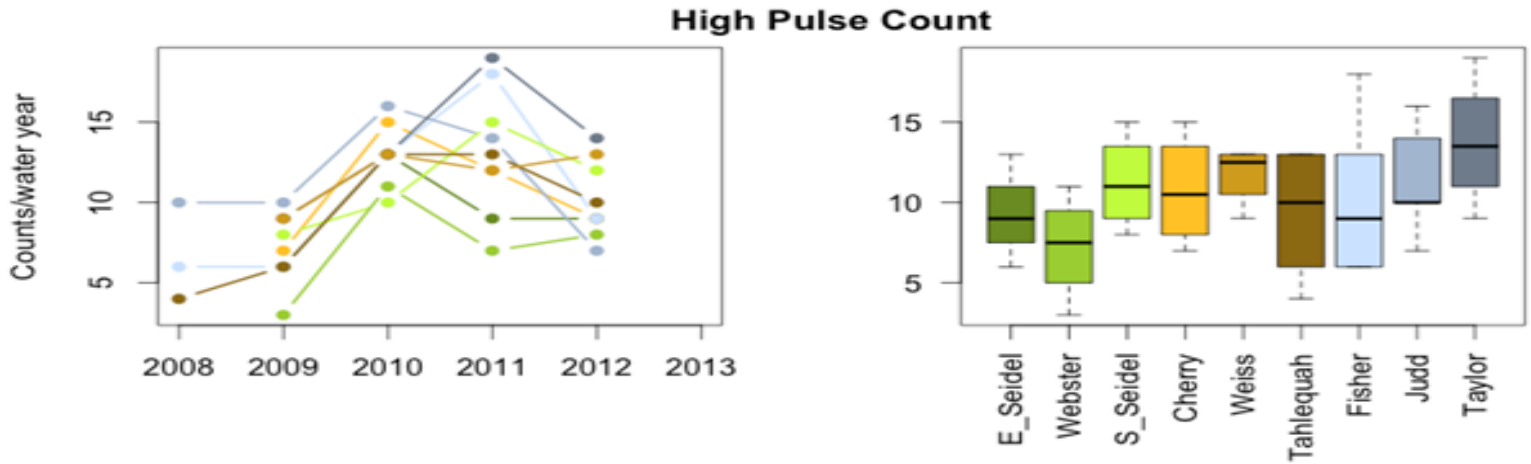


Least ⟷ **Most**

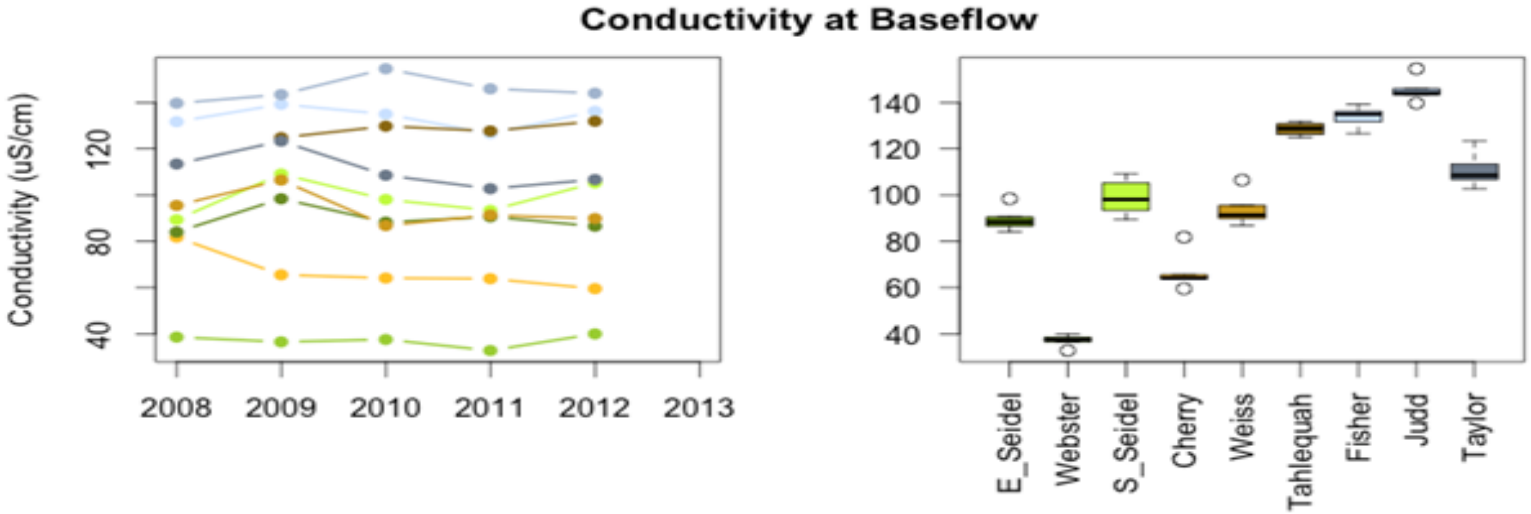
Level of current development

Environmental Variability

high temporal – low spatial



low temporal – high spatial



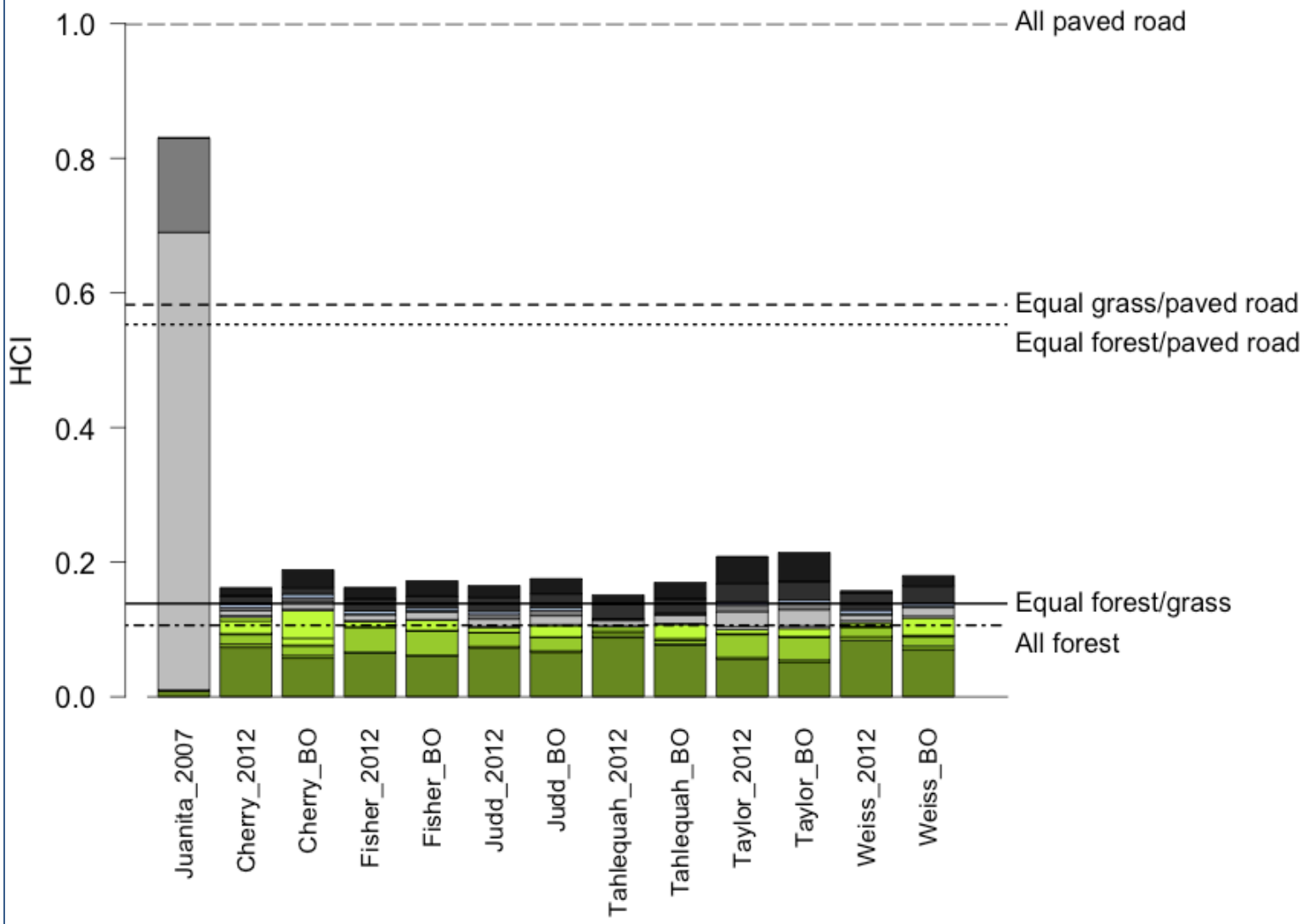
Environmental Response?

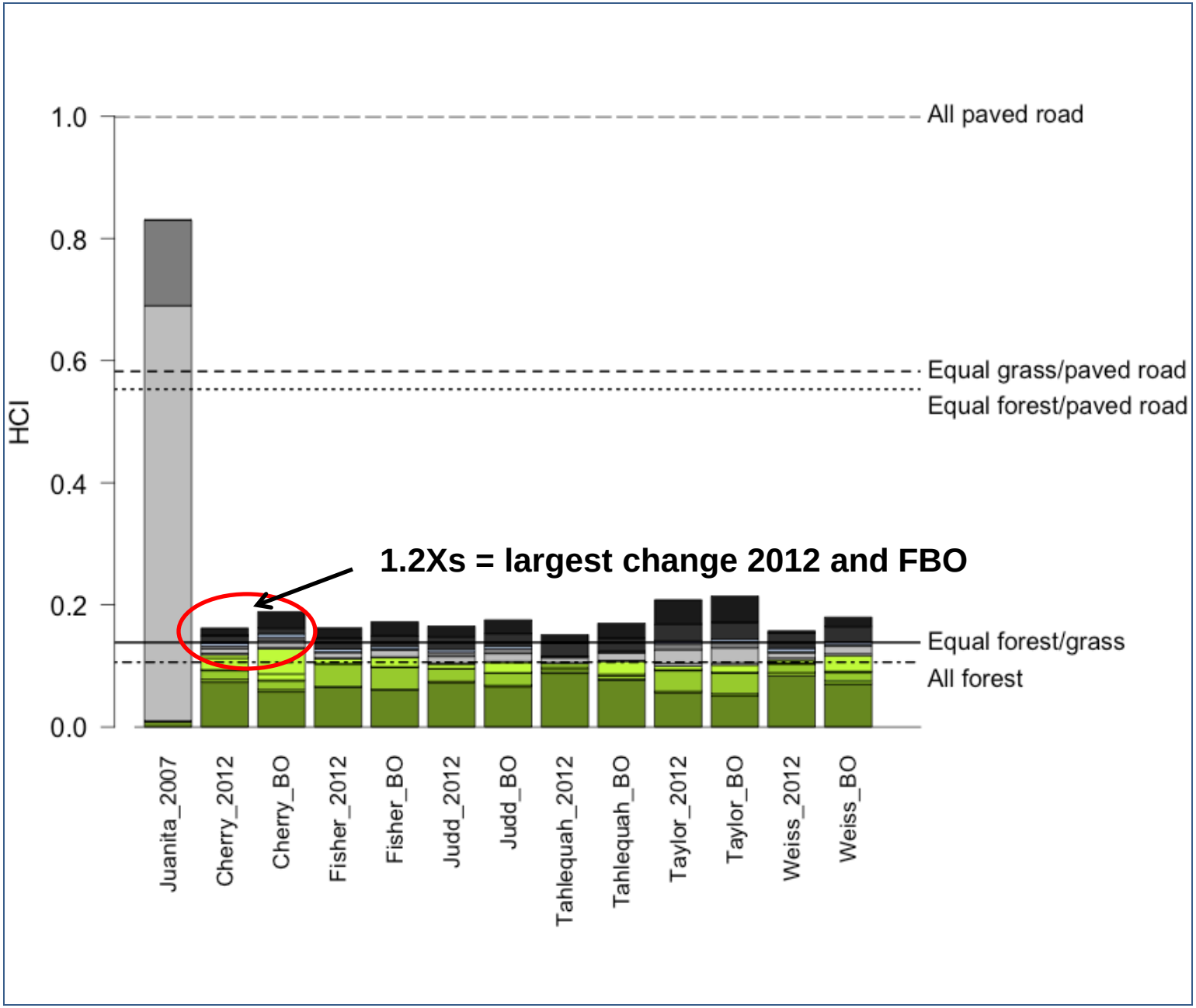
No change except,

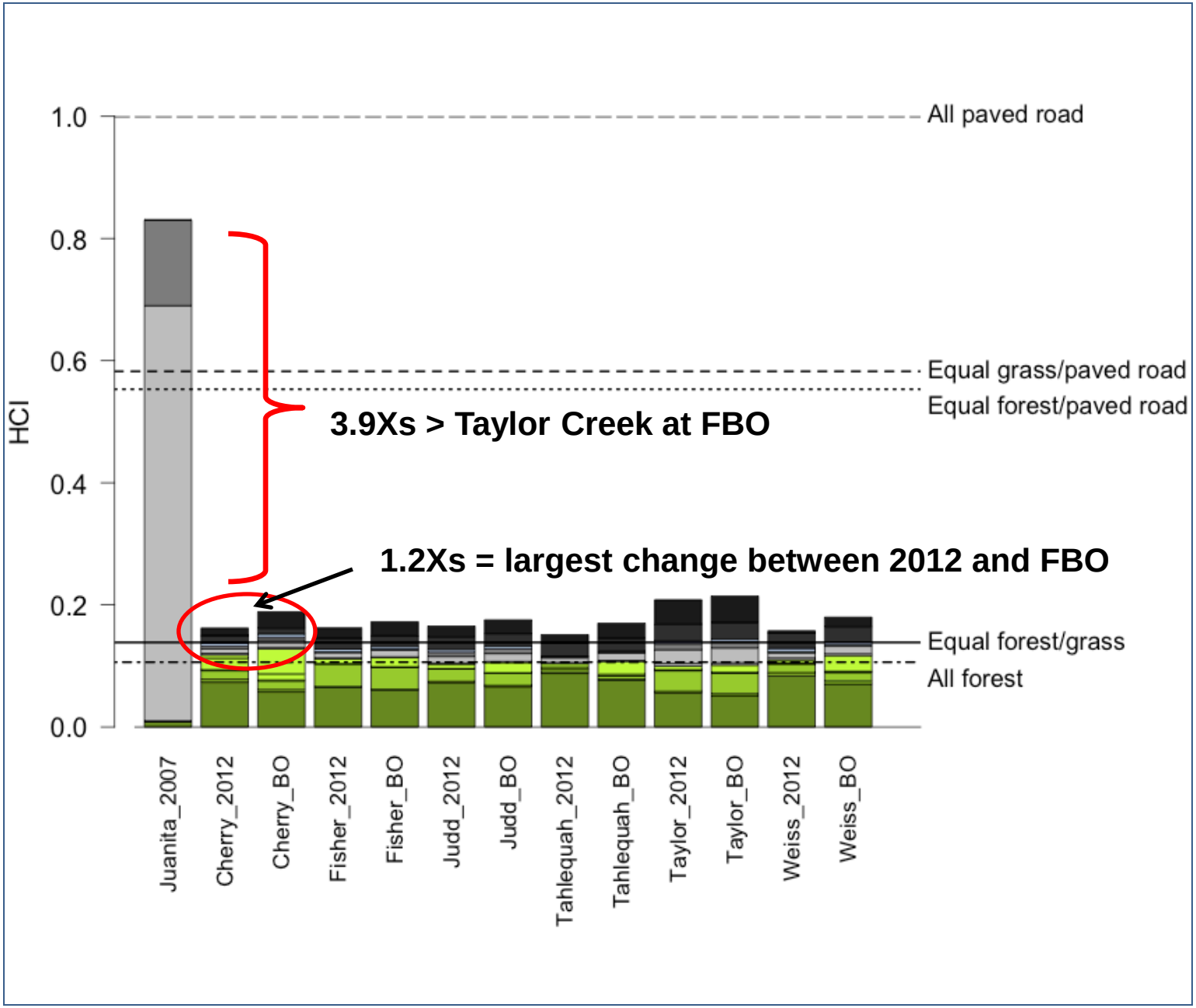
Two (secondary) habitat variables –

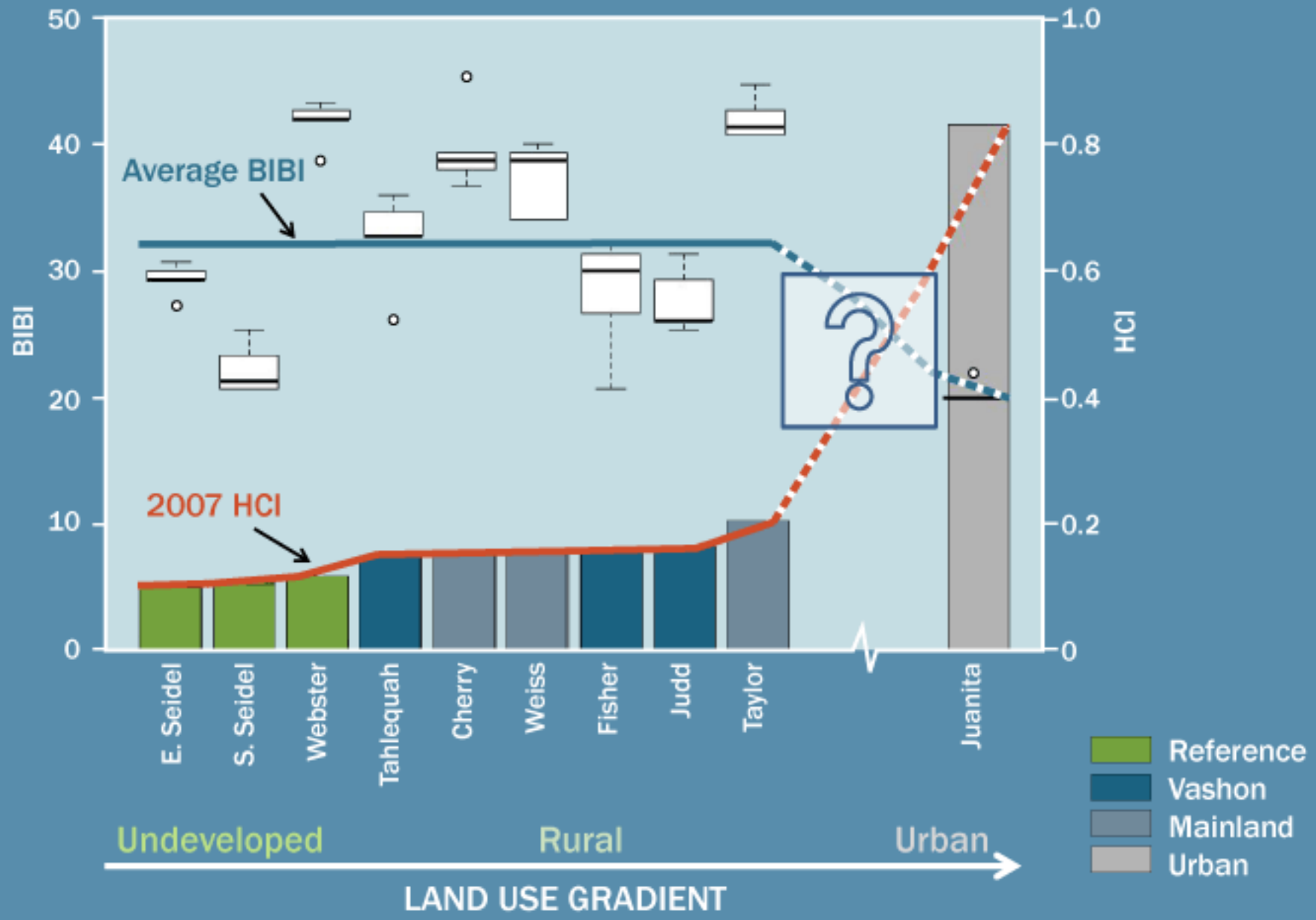
- thalweg length & % Pool
- But, in opposite direction predicted if CAO not effective, and
- both subject to high measurement error.

Juanita Creek (urban) comparison




1.0
0.8
0.6
0.4
0.2
0.0
HCI
All paved road
Equal grass/paved road
Equal forest/paved road
1.2Xs = largest change 2012 and FBO
Equal forest/grass
All forest
Juanita_2007
Cherry_2012
Cherry_BO
Fisher_2012
Fisher_BO
Judd_2012
Judd_BO
Tahlequah_2012
Tahlequah_BO
Taylor_2012
Taylor_BO
Weiss_2012
Weiss_BO


1.0
0.8
0.6
0.4
0.2
0.0
HCI
All paved road
Equal grass/paved road
Equal forest/paved road
Equal forest/grass
All forest
3.9Xs > Taylor Creek at FBO
1.2Xs = largest change between 2012 and FBO
Juanita_2007
Cherry_2012
Cherry_BO
Fisher_2012
Fisher_BO
Judd_2012
Judd_BO
Tahlequah_2012
Tahlequah_BO
Taylor_2012
Taylor_BO
Weiss_2012
Weiss_BO



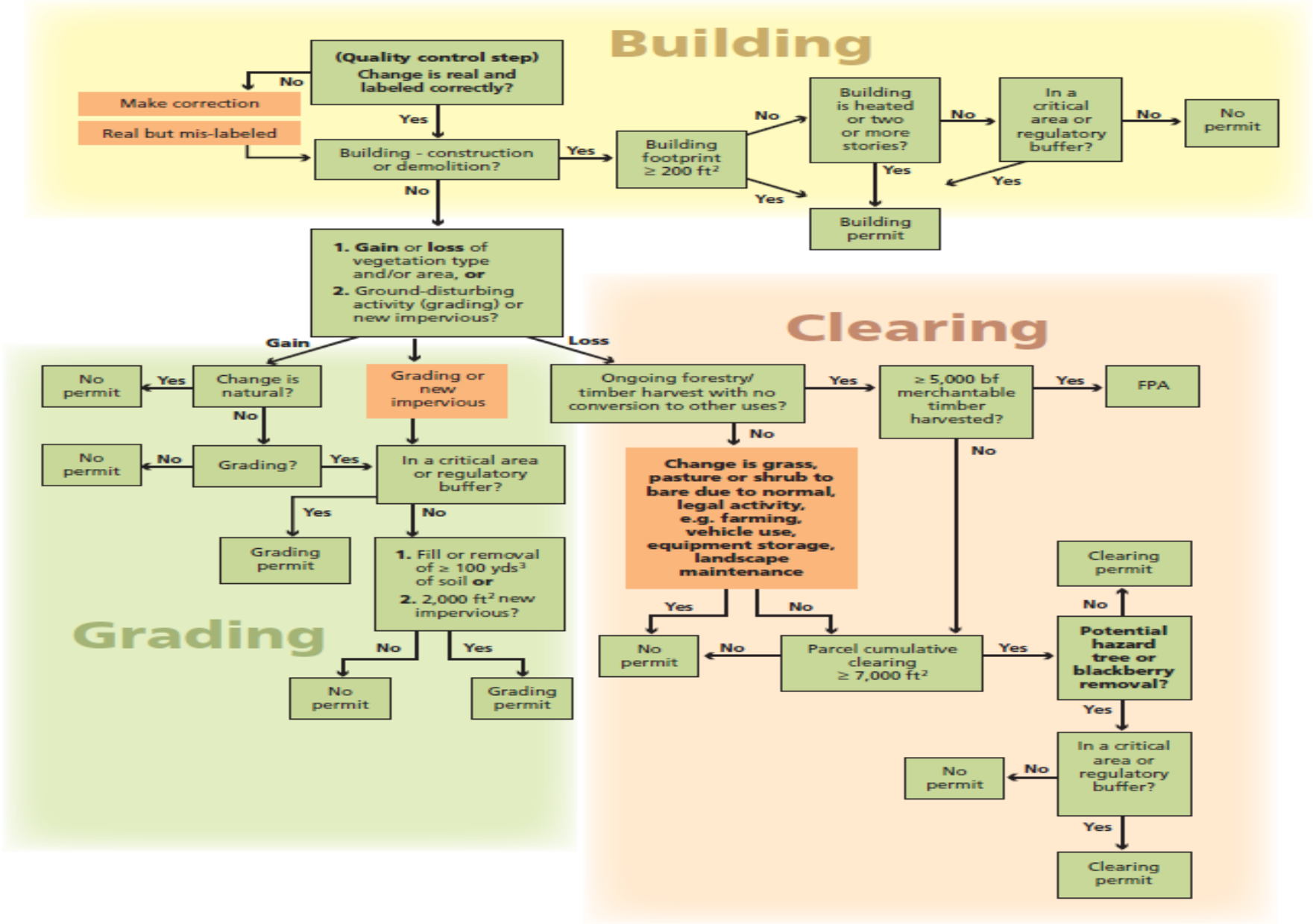
File: 1403_3852L_CAOmon_Hci_BIBIgraph.ai lpre

Compliance

- Compliance – Any LC change that required a permit and for which a permit was obtained

- Three Permit Types:
  - Building = > 200 ft^2 , heated, > 1-story, or in a CA
  - Grading = > 100 yd^3 or >2,000 ft^2 new impervious
  - Clearing = any vegetation removal on parcels w/ > 7,000 ft^2 cleared area

Permit Compliance Decision Tree



Permit Required?	Area with Permit / Total Area (ha)	% Compliant by Area	# changes with permit / total # changes	% Compliant by # changes
2007 to 2012 (5 years) Cumulative Summary				
Yes	60.7 / 92.1	66%	400 / 954	42%
Probably Yes	0.2 / 5	4%	9 / 223	4%
Sub Totals	60.9 / 97.1	**63%**	409 / 1177	**35%**
Indeterminate	0 / 0.1		0 / 3	
Probably No	0.04 / 4.8	NA	3 / 179	NA
No	1.9 / 38.2	NA	3 / 701	NA
2007 - 2012 Totals	**62.8 / 140.1**		**415 / 2,064**	

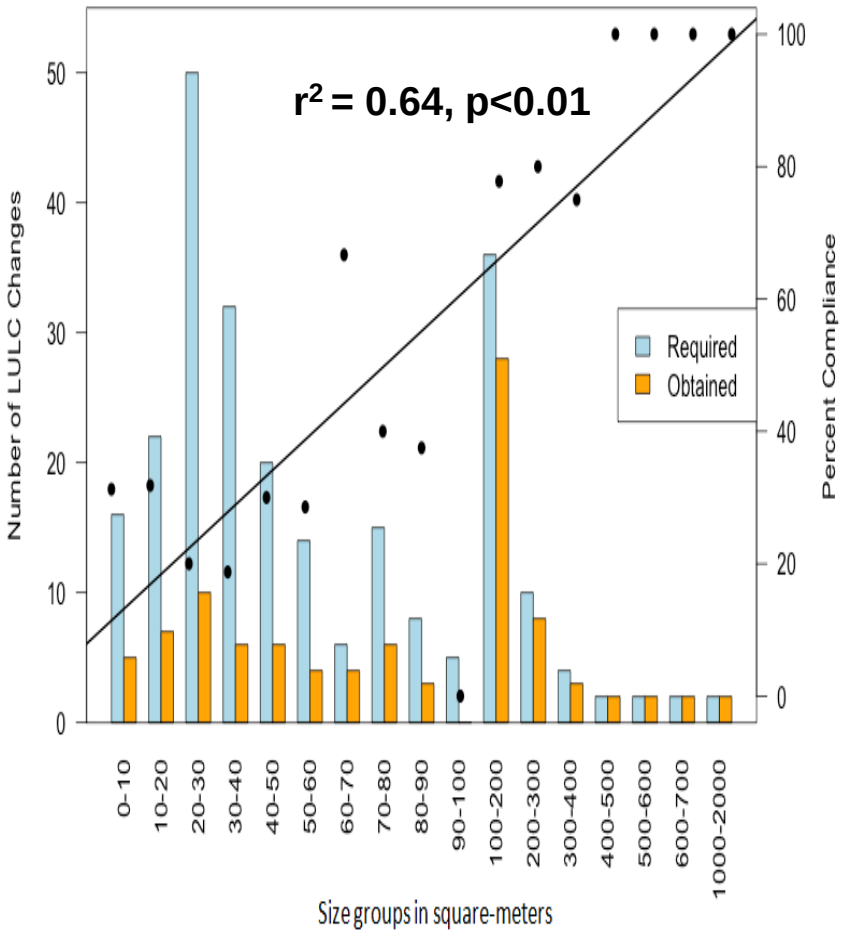
Land cover change over 5-years

Extent	Area (ha)	% area with no LC change	% area with LC change*	% area with Compliant LC change	% area with Non- compliant LC Change
Watershed	4105	96.6%	3.4%	2.4%	1.0%
Regulatory Stream Buffer	417	99.3%	0.7%	0.5%	0.2%

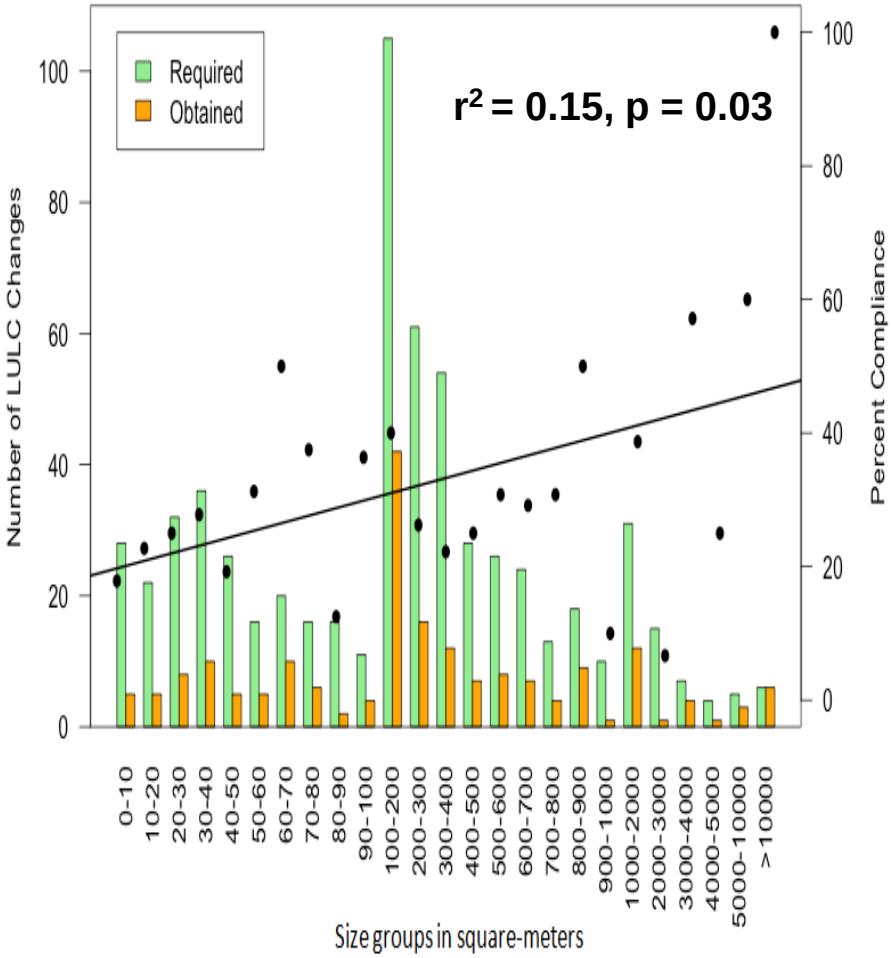
Compliance *rate* not great but *area* was small.

Compliance by Area and Permit Type

Buildings



Clearing and Grading



Effect of Hazard Tree Removal?

No permit needed:

- if outside a regulatory buffer
- only to extent necessary to remove the hazard

Turns out…

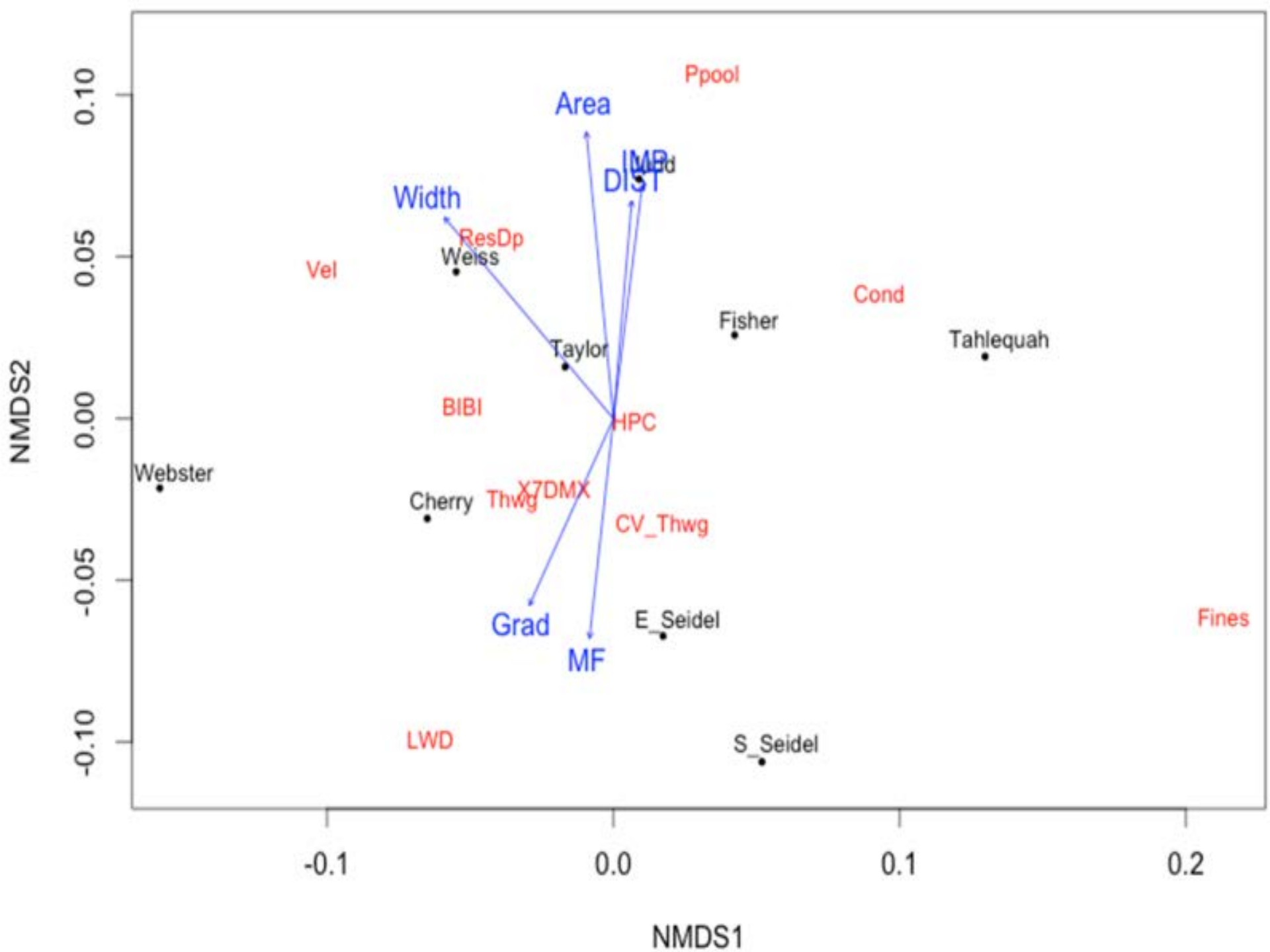
- ~ 25% of forest cover removal within 150’ (~ one site-potential-tree-height) of a building

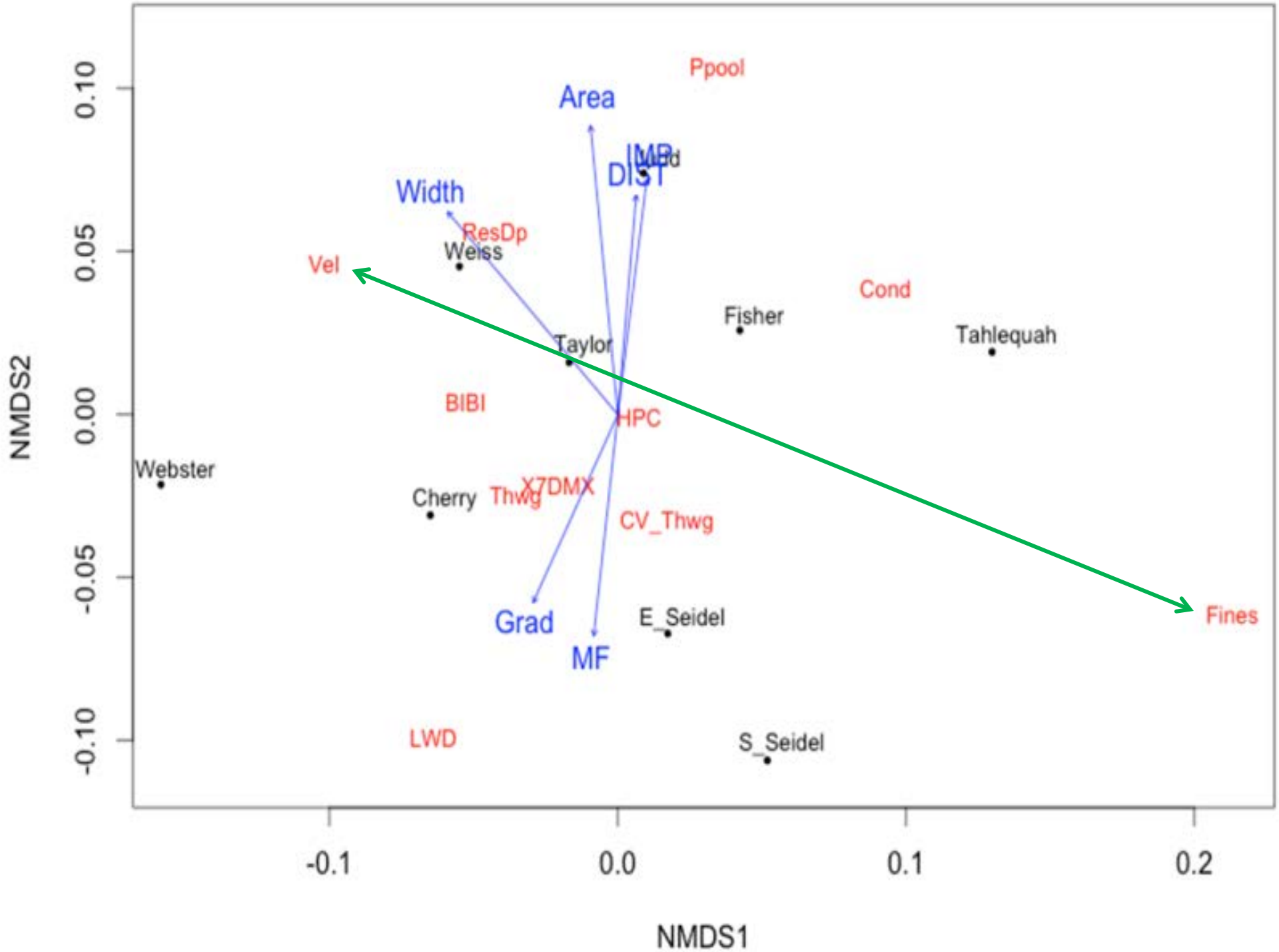
-In three watersheds (Judd, Taylor and Fisher), 75% of forest cover loss w/in 1 SPTH of a building

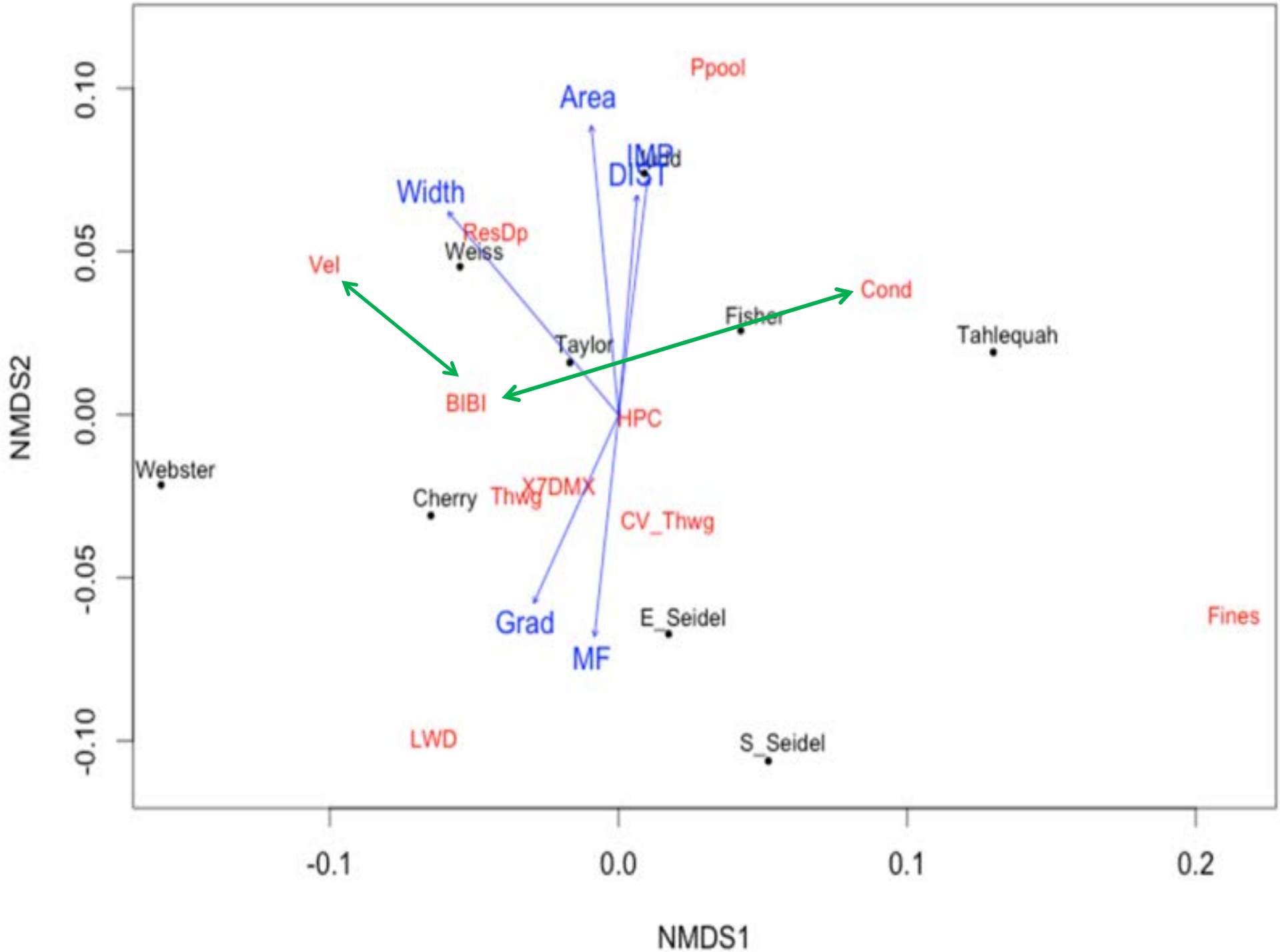
Ordination

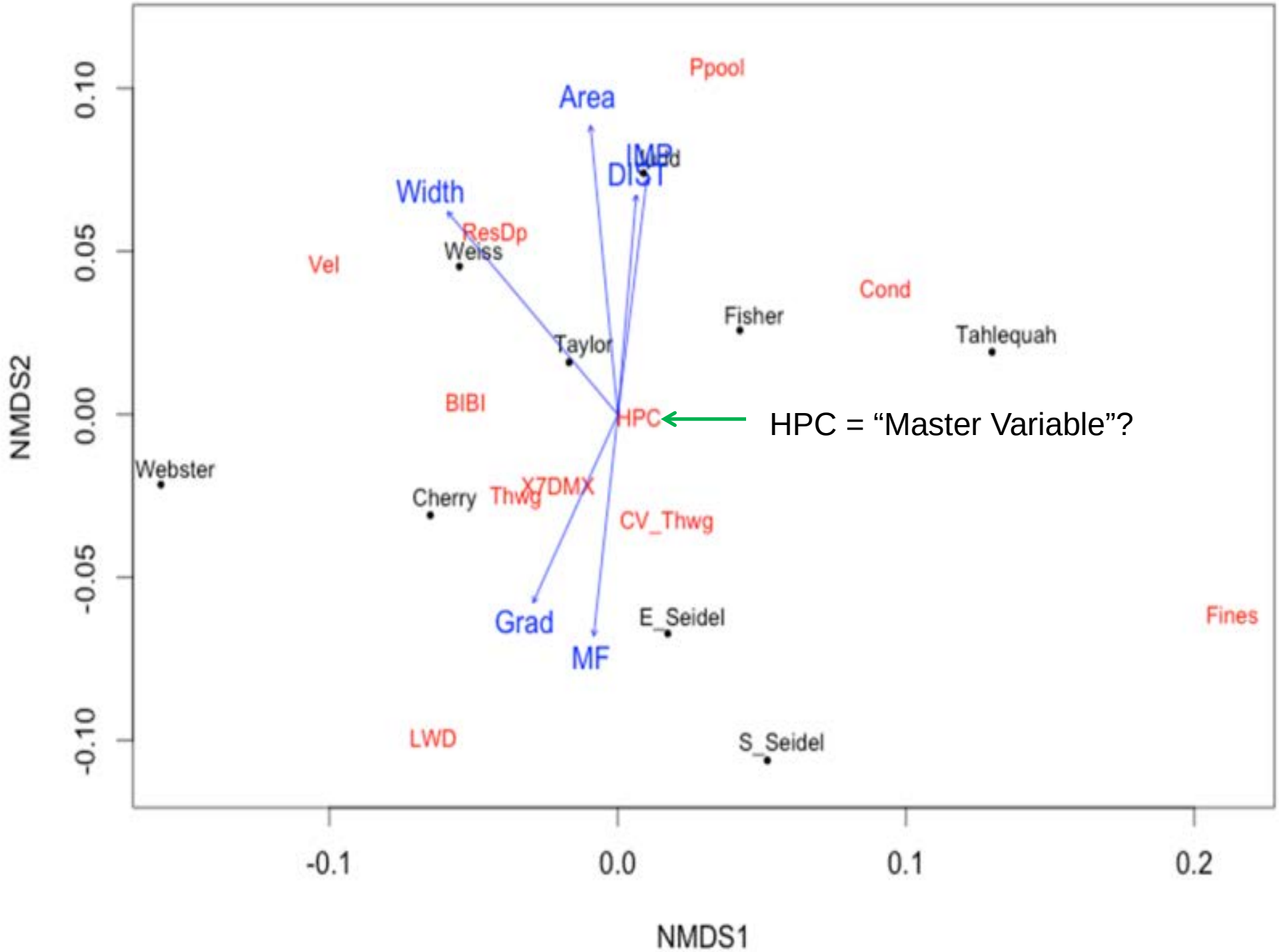
- Exploratory – “Putting things in order”

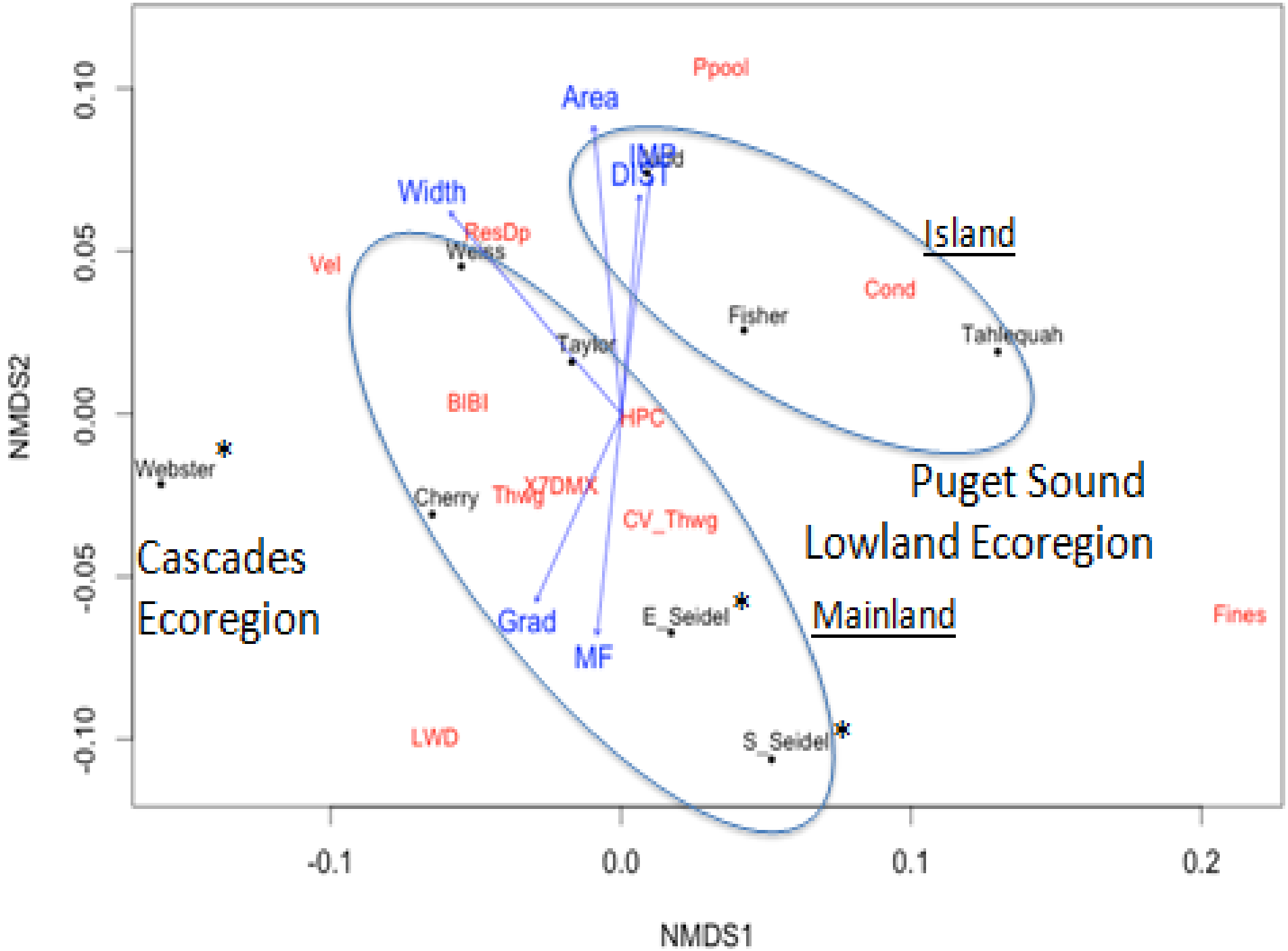
- Squeezing three dimensions into two

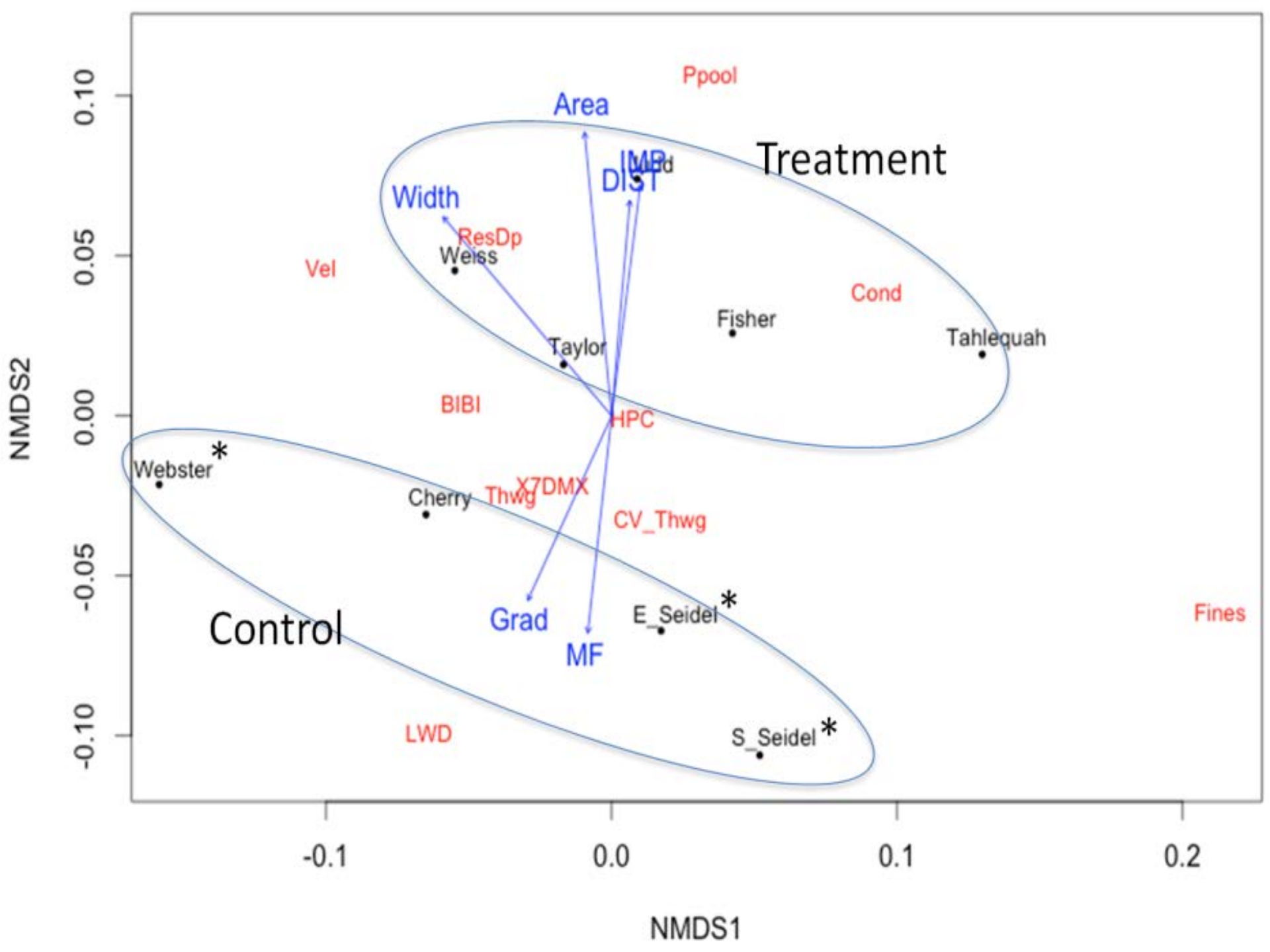

Ppool
Area
IMP
Mud
DIST
Width
ResDp
Weiss
Vel
Cond
Fisher
Tahlequah
Taylor
BIBI
HPC
Webster
Cherry
Thwg
X7DMX
CV_Thwg
Grad
E_Seidel
Fines
MF
LWD
S_Seidel
0.10
0.05
0.00
-0.05
-0.10
NMDS2
-0.1
0.0
0.1
0.2
NMDS1

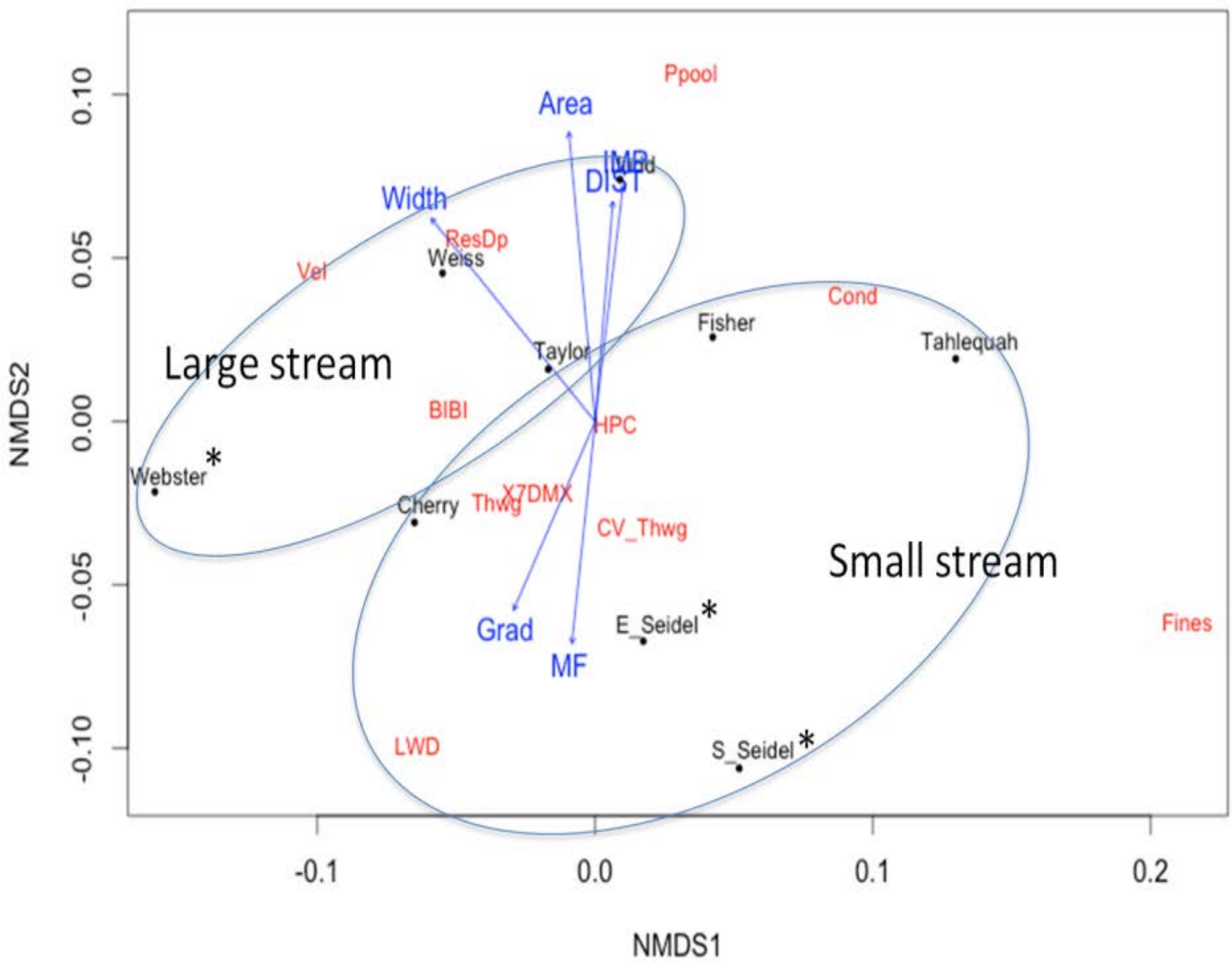

Ppool
Area
IMP
Mud
DIST
Width
ResDp
Weiss
Vel
Cond
Fisher
Tahlequah
Taylor
BIBI
HPC
Webster
Cherry
Thwg
X7DMX
CV_Thwg
Grad
E_Seidel
MF
Fines
LWD
S_Seidel
NMDS2
NMDS1
0.10
0.05
0.00
-0.05
-0.10
-0.1
0.0
0.1
0.2


Ppool
Area
IMP
Mud
DIST
Width
ResDp
Weiss
Vel
Cond
Fisher
Tahlequah
Taylor
BIBI
HPC
Webster
Cherry
Thwg
X7DMX
CV_Thwg
Grad
E_Seidel
Fines
MF
LWD
S_Seidel
0.10
0.05
0.00
-0.05
-0.10
NMDS2
-0.1
0.0
0.1
0.2
NMDS1


Ppool
Area
IMP
Mud
DIST
Width
ResDp
Weiss
Vel
Cond
Fisher
Tahlequah
Taylor
BIBI
HPC
HPC = "Master Variable"?
Webster
Cherry
Thwg
X7DMX
CV_Thwg
Grad
E_Seidel
Fines
MF
LWD
S_Seidel
NMDS2
NMDS1
0.10
0.05
0.00
-0.05
-0.10
-0.1
0.0
0.1
0.2


Ppool
Area
IMP
DIST
Width
ResDp
Vel
Weiss
Island
Cond
Fisher
Tahlequah
Taylor
BIBI
HPC
Webster
Cherry
Thwg
X7DMX
CV_Thwg
Puget Sound
Lowland Ecoregion
Cascades
Ecoregion
Grad
E_Seidel
Mainland
Fines
MF
LWD
S_Seidel
NMDS2
NMDS1
0.10
0.05
0.00
-0.05
-0.10
-0.1
0.0
0.1
0.2


Ppool
Area
Treatment
IMP
DIST
Width
ResDp
Weiss
Vel
Cond
Fisher
Tahlequah
Taylor
BIBI
HPC
Webster
Cherry
Thwg
X7DMX
CV_Thwg
Control
Grad
E_Seidel
MF
Fines
LWD
S_Seidel
NMDS2
NMDS1
0.10
0.05
0.00
-0.05
-0.10
-0.1
0.0
0.1
0.2


Ppool
Area
IMB
DIST
Width
ResDp
Weiss
Vel
Cond
Fisher
Tahlequah
Taylor
Large stream
BIBI
HPC
Webster
Cherry
Thwg
X7DMX
CV_Thwg
Small stream
Grad
E_Seidel
Fines
MF
LWD
S_Seidel
NMDS2
NMDS1
0.10
0.05
0.00
-0.05
-0.10
-0.1
0.0
0.1
0.2

Conclusions,

Recommendations,

Additional value

Are regulations effective?

To say definitively – <u>more treatment and/or time needed</u>

HCIs *suggest*:

- Small change over time among rural scenarios, and
- Urban much worse than rural worst case.

Study provides:

- Valuable baseline and new information
- Indication that regulations may be protective of watershed hydrology, and
- May facilitate restoration – not likely to be undone by degrading watershed.

Compliance? Was it a problem?

Could be better.

Still,

- no detectable effect of non-compliance (rates high, but actual area affected was small)
- no observed rampant or egregiously bad actions, and
- regulatory stream buffers much less affected/better condition

Should the CAO be modified?

No change recommended - no obvious problem so no basis

Follow-up/future work?

Assess more treatment and/or time in the study watersheds.

Apply framework elsewhere in PS Lowland Ecoregion

Prevention of Toxics? Protection of Wildlife?

Potential Additional Uses

- “Watershed Laboratory” - nine “wired” watersheds

- HCI – no need to build expensive hydrology models everywhere

Potential Additional Uses (cont.)

- Ordination –
  - Structuring study designs and databases
  - Hypothesis testing
- Time and Space Analyses
  - historic, current, future conditions analyses
  - parcel-based assessment could be nested in reach and watershed scale
- Tracers –
  - precise assessment of channel change
  - Improved understanding of eco-hydraulics

Summary – What we did

LC Change – Present, Past and Future

Environmental Response – Four Pathways, standard metrics plus tracers

Permitting and Compliance – How much?

Website and Final Report:http://www.kingcounty.gov/environment/data-and-trends/monitoring-data/critical-areas.aspx

Acknowledgements : 11 groups – over 60 people!

Funders: USEPA & King County

Tech Collaborators: EPA (Jayshika Ramrakha, Tony Fournier, Gretchen Hayslip, Krista Mendelman, Mike Rylko, John Gabrielson), UW UERL (Marina Alberti, Julia Michalak), USGS (Christian Torgersen, Rich Sheibley, Andrew Gendaszek, Bob Black),

Assistance: WDOE (Stephen Stanley) VCC, GRCC GIS Lab, KC Interns

KC Project Team:

DNRP – Gino Lucchetti (Project Manager), Josh Latterell, Ray Timm, Leska Fore, Jennifer Vanderhoof, Jeff Burkey, Dan Smith (gaging), Dan Smith (database), Charlie Zhen, David Funke, Stephanie Hess, Jo Wilhelm, Chris Gregersen, Chris Knutson, Ken Rauscher, Bob Fuerstenberg (ret.), Klaus Richter (ret.)

DDES - Harry Reinert, Paul McCombs, Jon Petersen, Steve Bottheim, Betsy MacWhinney, Pesha Klein