Assessing the Effectiveness of Land Use Regulations in Developing, Rural King County, WA

Gino Lucchetti, Dr. Joshua Latterell, Ray Timm, Julia Michalak, Dr. Christian Torgersen, Dr. Marina Alberti, and Christopher B. Knutson

King County

Overview and Background

Critical Areas Ordinances (CAO)

January 1, 2005

K.C.C. 21A Zoning code (Ord. 15051)

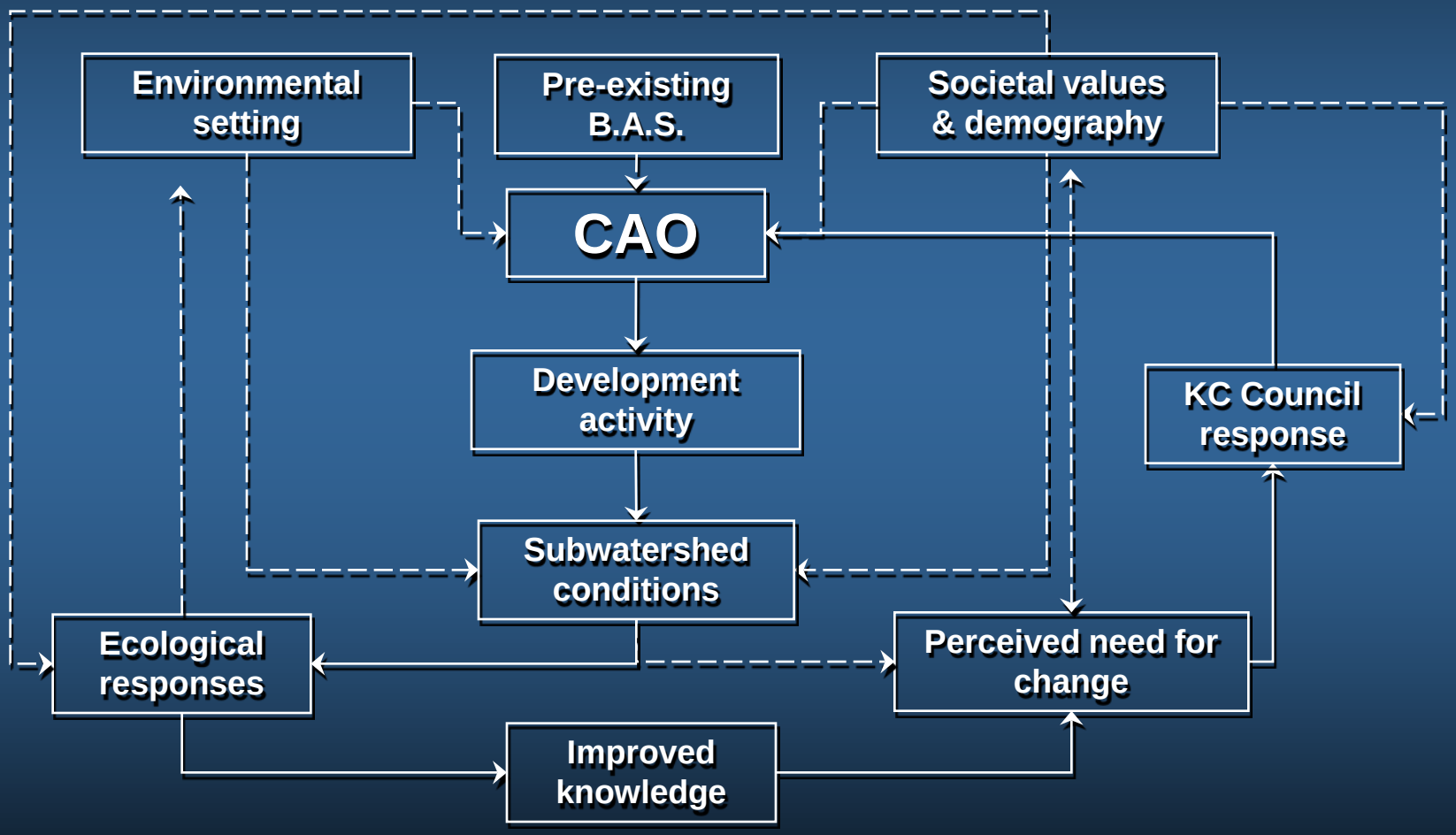
K.C.C. 16.82 Clearing & Grading (Ord. 15053)

K.C.C. 16.82 Stormwater (Ord. 15052)

Best Available Science:

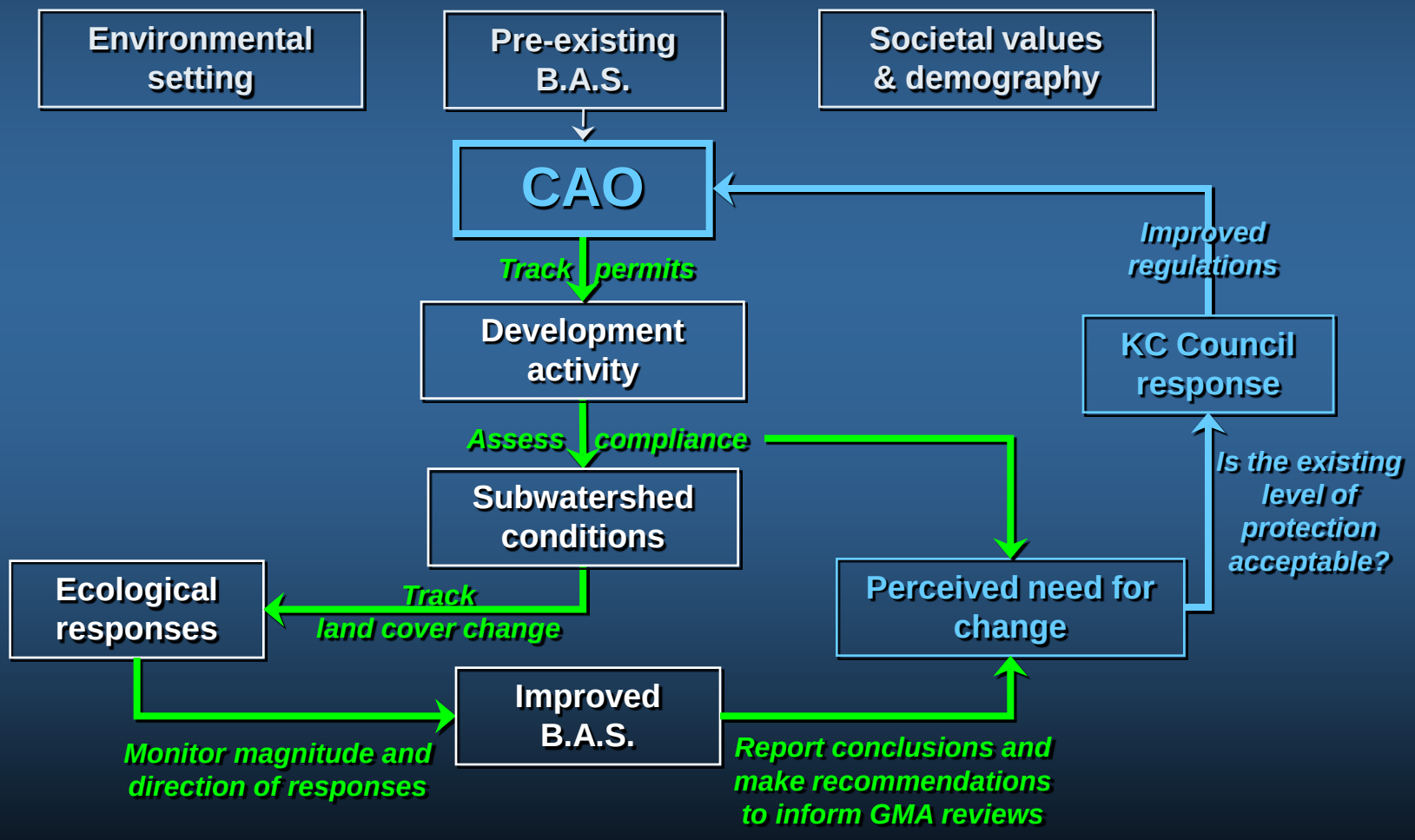
- **Riparian and landscape measures are needed**
- **Effectiveness of previous regulations poorly known**

Informing Decisions



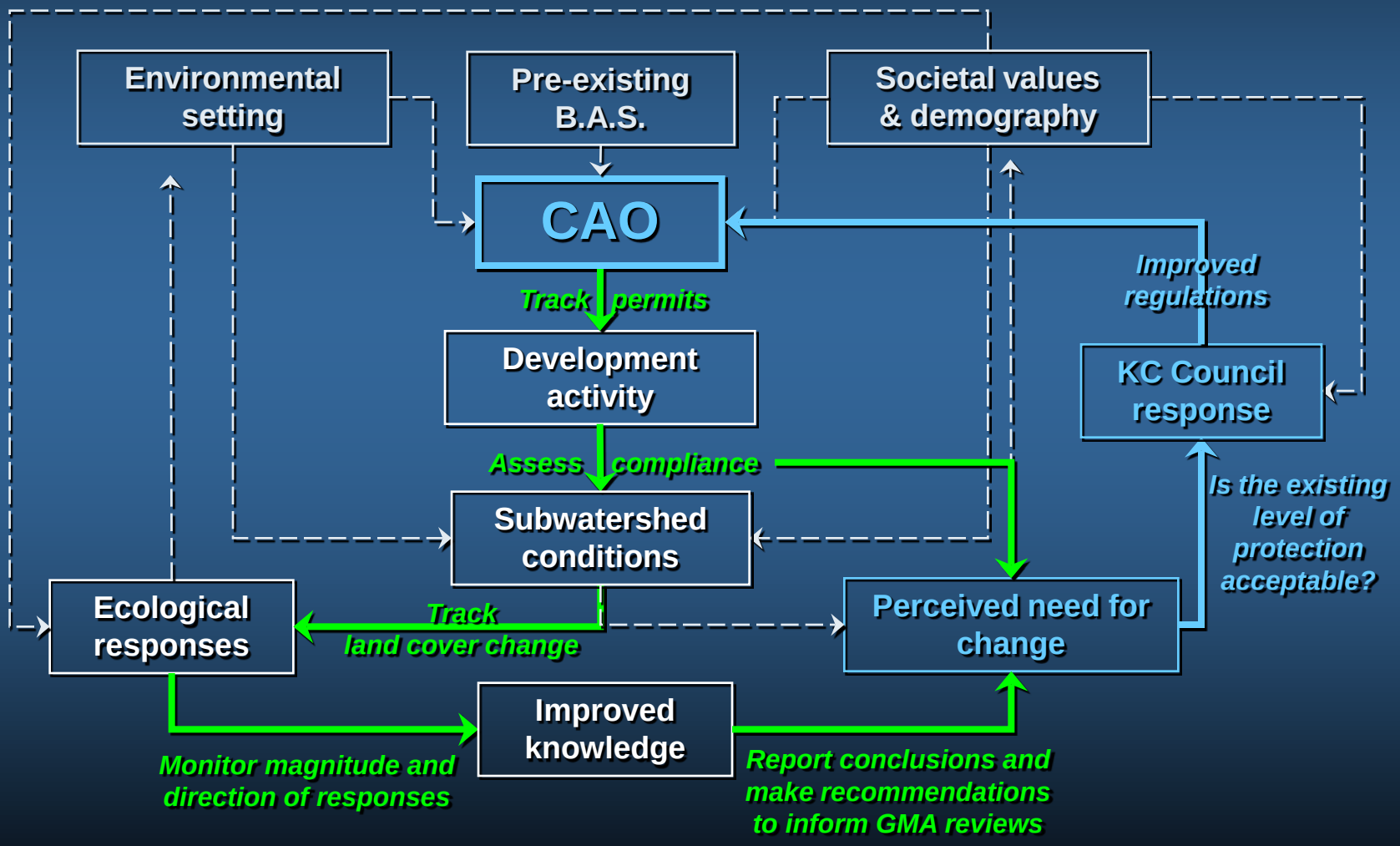
Modified from Grimm et al. 2000

Informing Decisions



Modified from Grimm et al. 2000

Informing Decisions



Modified from Grimm et al. 2000

Basic Approach

- Multiple watersheds & response variables
- Six Treatment – Three Control Watersheds
- Spatial scale -- not too big or too small – 200 to 3,000 acre (~ 2nd order)
- Measure Treatment (drivers) –development-driven changes in land cover, type and location of activity
- Measure Response Variables – select variables known to be affected by development at the catchment scale

Hypothesis

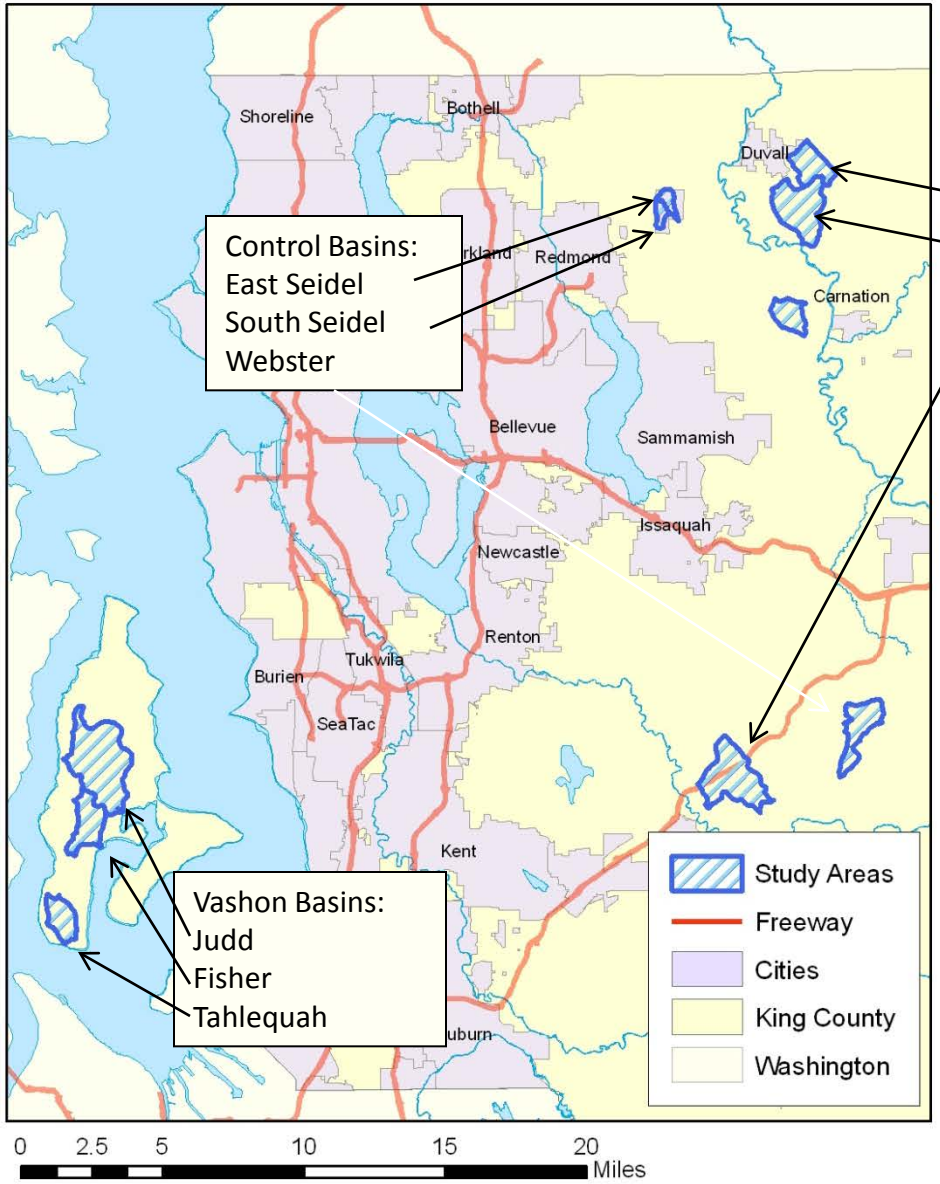
If CAO is “working” then the *direction* and *magnitude* of change in response variables should:

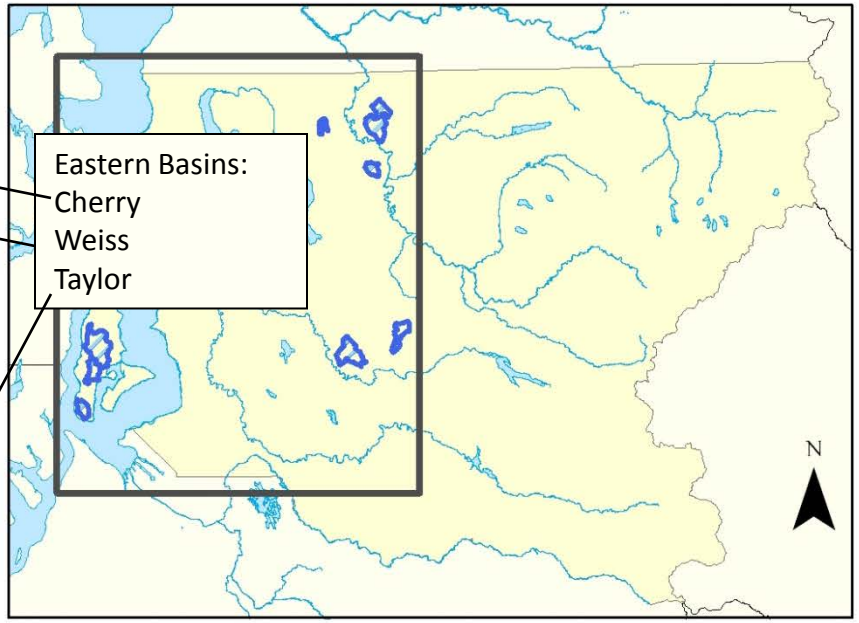
- a) be similar as for areas with no additional future development,
- b) not be commensurate with the potential cumulative impact (PCI) of actions

Measuring

Where
&
What?

Study Areas





Selection Criteria:

- Small watersheds - 2nd or 3rd order streams (60 to 1260 hectares)
- Common post-glacial geology (Elevation range 44 to 7933 ft)
- Single jurisdictions
- Treatment basins: high development potential

Response Indicators

Benthic macroinvertebrates

- BIBI, taxa abundance

Flow

- High/low pulse ct, TQmean, R-B index, Peak flow, low flow

Water quality

- Conductivity (semi-monthly, monthly, seasonal average)
- Temperature (7 Dadmax)

Hydraulic complexity

- Velocity (cm/sec)
- Flushing ratio (time to peak/time to 95% of background)
- substrate*, thalweg length, pool/channel width & depth, LWD*

Drivers

- Land development
  - Land cover (Impervious, vegetation), type of land use (urban, rural, PCI index), permit activity and compliance
- Climate
  - Precipitation, air temp
- Catchment Morphology/Geology
  - geology, elevation, aspect, stream network structure, forest type

Potential Cumulative Impact (PCI)

- Landcover Classes
  - Photo interpretation
- Hydrologic Correction
  - Study Watersheds
  - Sample sheds
  - Buffer sheds
  - Parcel sheds
- PCI index

$$PCI = \sum_{g=1}^{n} D_{x,w,p} + \sum_{g=1}^{n} E_{x,w,p}$$

Analysis and Interpretation

Relate PCI to…

Hydrology – Flow Dynamics

High pulse count

Low pulse ct

TQmean

R-B index

Peak flow

Low flow

Water Quality

- Conductivity (semi-monthly, monthly and seasonal averages)
- Temperature (7 Dadmax)

Benthic Index of Biotic Integrity

Taxa Richness & Composition
- Mayflies
- Stoneflies
- Caddisflies
- Total taxa
- Long-lived taxa

Population
- % Dominance

Tolerance
- Intolerant richness
- % tolerant

Feeding and habits
- Percent predator
- Clinger richness

Physical Habitat

- Pebble count
- Water velocity and depth
- Riparian characteristics
- Large wood
- Pools (frequency, length, depth)
- Bank stability

Channel Complexity (Salt Tracers)

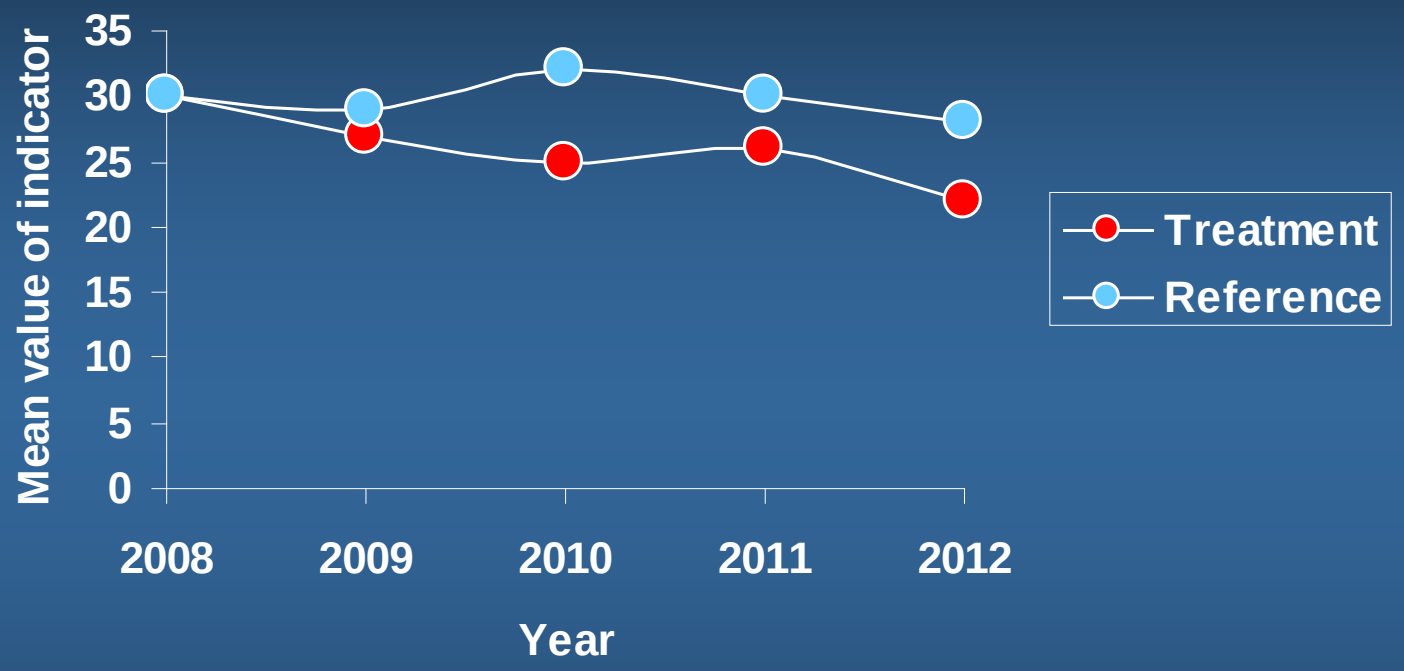
Velocity

(cm/sec)

Flushing ratio

(time to peak/time to 1% of peak)

Analysis

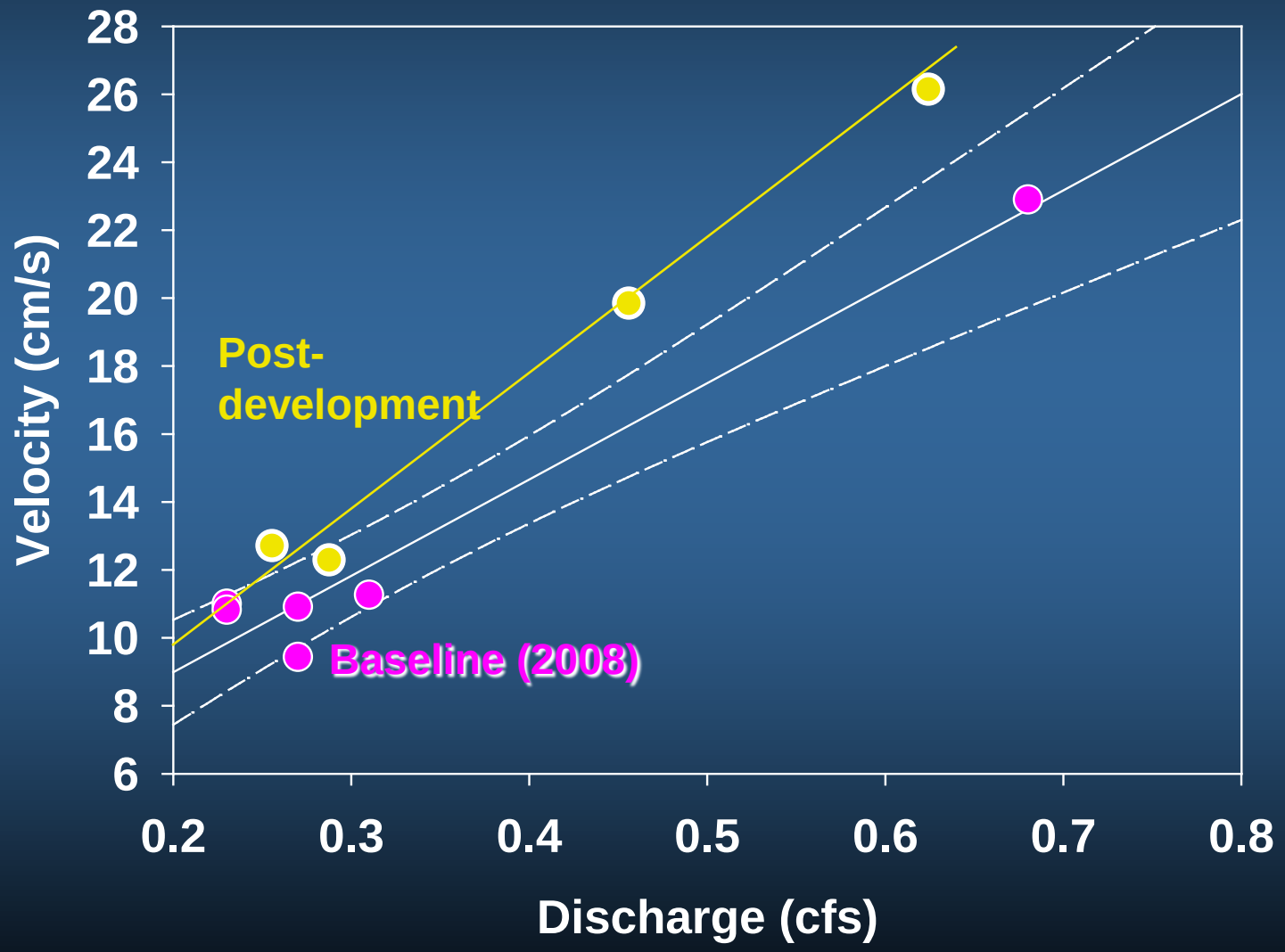


Do treatment sites have different mean indicator values than reference sites?

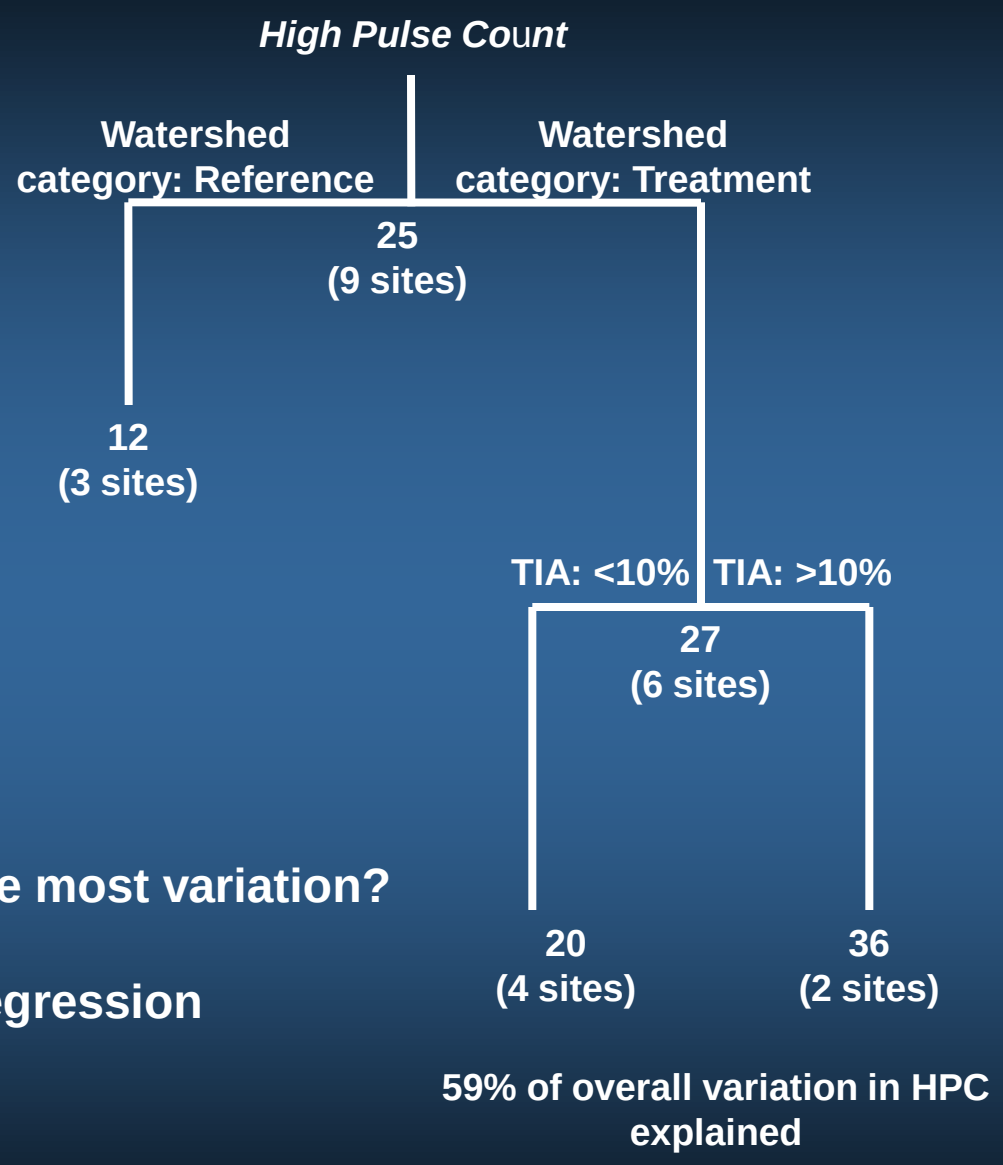
Are there differences in mean indicator values among years (or months?

Does the influence of watershed type on a given indicator depend on the year?

S Seidel Creek

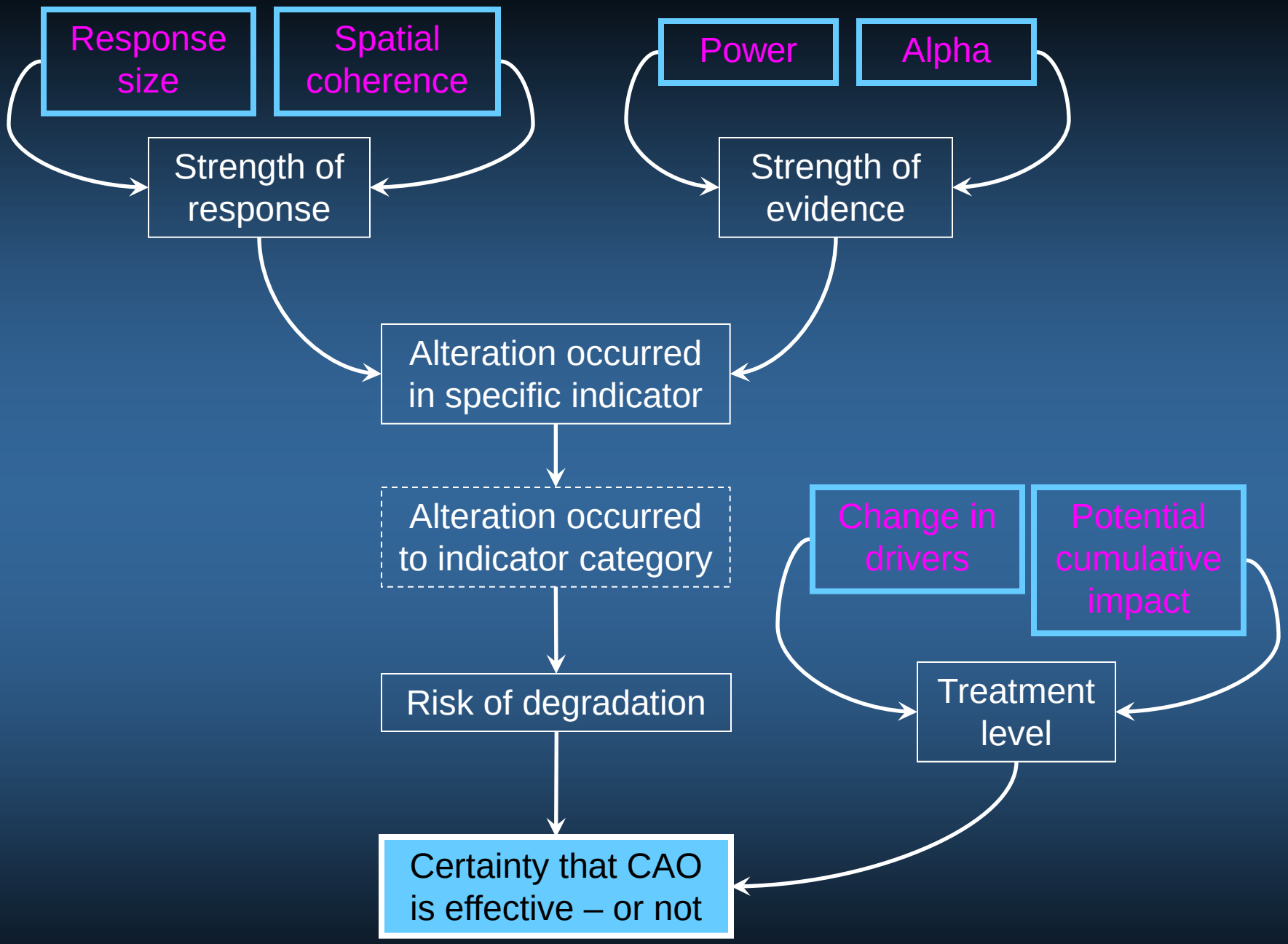


Classification/Regression Trees



59% of overall variation in HPC explained

- Which factors explain the most variation?
- Alternative to multiple regression


Response size
Spatial coherence
Power
Alpha
Strength of response
Strength of evidence
Alteration occurred in specific indicator
Alteration occurred to indicator category
Change in drivers
Potential cumulative impact
Risk of degradation
Treatment level
Certainty that CAO is effective – or not

Acknowledgements

- Funders: EPA & King County
- Tech Collaborators: EPA, UW UERL, USGS (Torgersen)
- Assistance: VCC, GRCC GIS Lab, KC Interns
- Project Team; DNRP, DDES
  - Josh Latterell, Ray Timm, Bob Fuerstenberg, Klaus Richter, Paul McCombs, Harry Reinert, The Gager and Data Dan Smiths, David Funke, Stephanie Hess, Jo Wilhelm

End of Show

- "What we see is not nature itself, but nature exposed to our method of seeing“ - Heisenberg

Objectives

To…

1) Select a set of critical areas

2) Assess direction and magnitude of land cover and land use change

3) Assess concurrent changes response variables

4) Assess compliance

5) Provide conclusions and management recommendations based on findings.

Key Questions:

What people may want to know in 2012 and beyond

- Q1: Did critical areas change? If so, was change related to CAO implementation?
- Q2: How did the environment respond and what was the significance of those changes?
- Q3: If responses were significant, how might the CAO be modified to reduce future impact?
- Q4: To what extent was change due to poor implementation, i.e., how well did people follow the regulations?

Purpose and Goals

Purpose

To provide information on implementation and effectiveness for 2012 review… and beyond

Goals

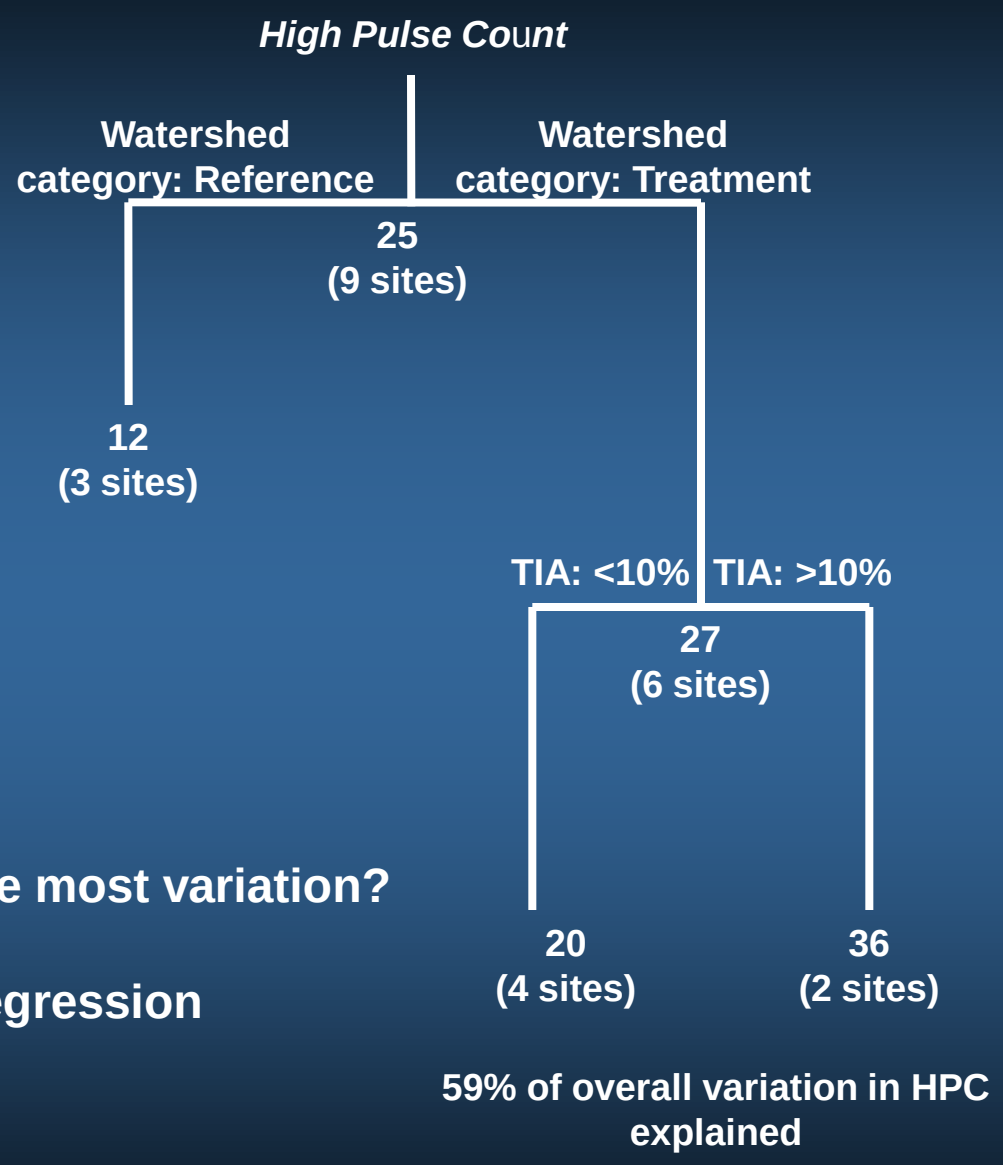
1) To track changes in critical areas

2) To determine if changes are related to CAO permit-driven actions

Field Work

- Hydrology
- Biology
- Water Quality
- Channel Complexity
- Site characterization (photo, video, physical surveys)
- Landowner approvals/interactions

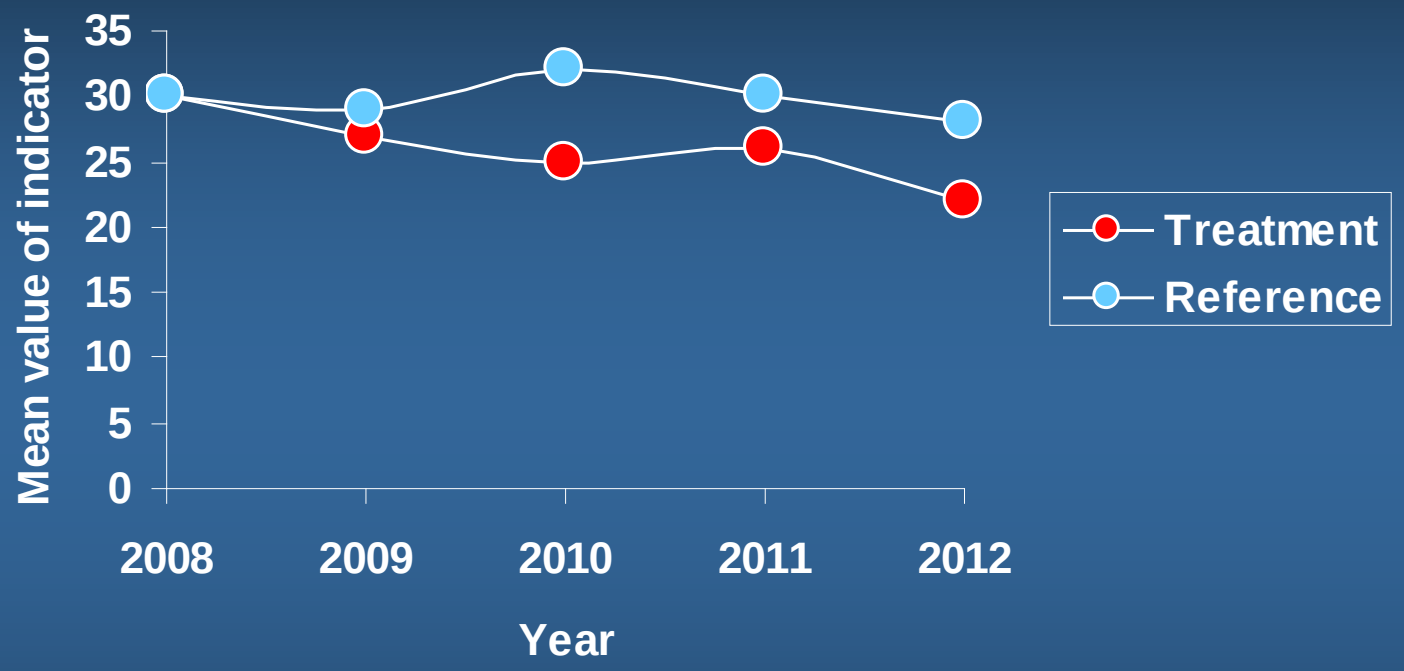
Classification/Regression Trees



59% of overall variation in HPC explained

- Which factors explain the most variation?
- Alternative to multiple regression

Analysis

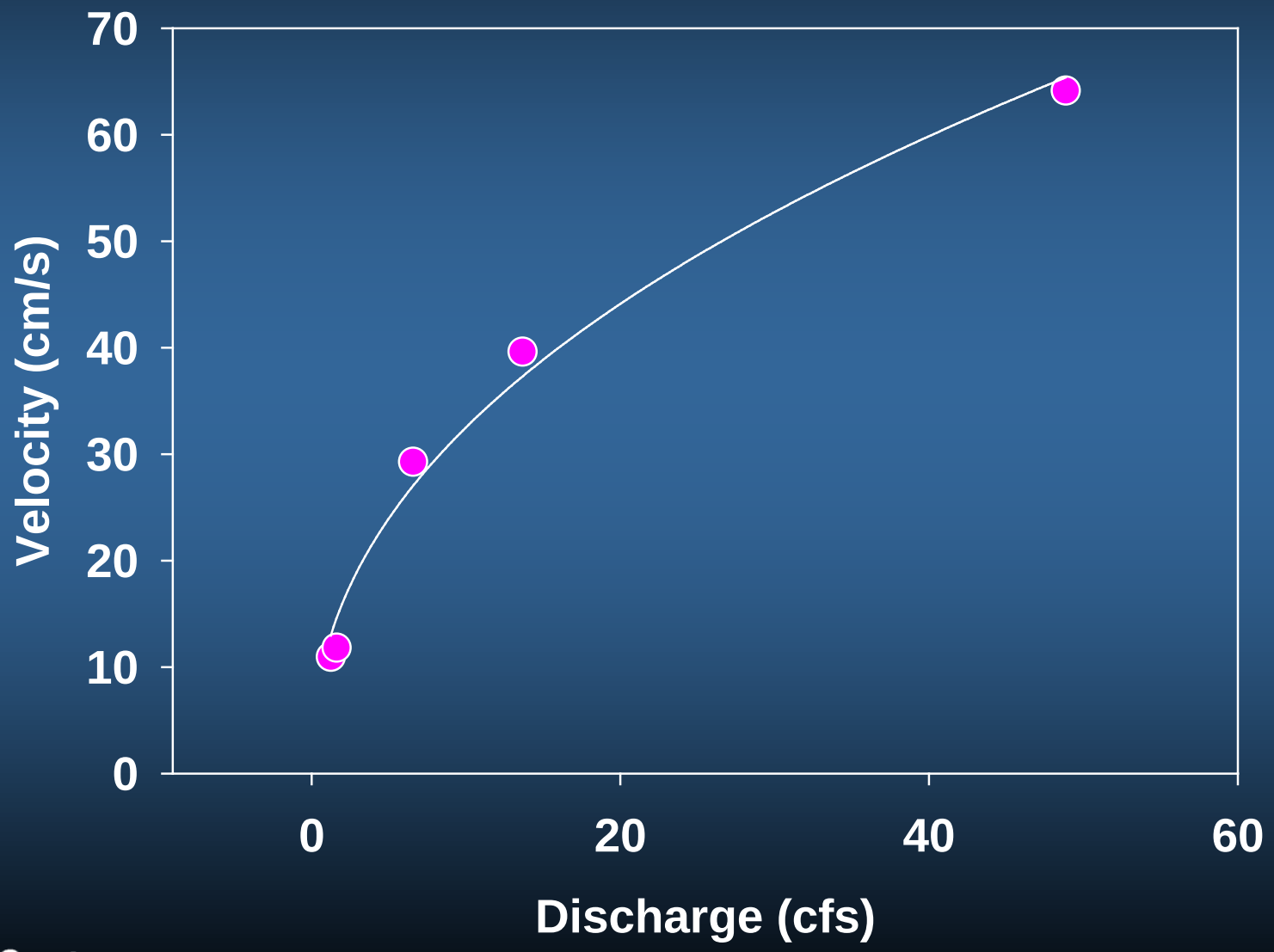


Do treatment sites have different mean indicator values than reference sites?

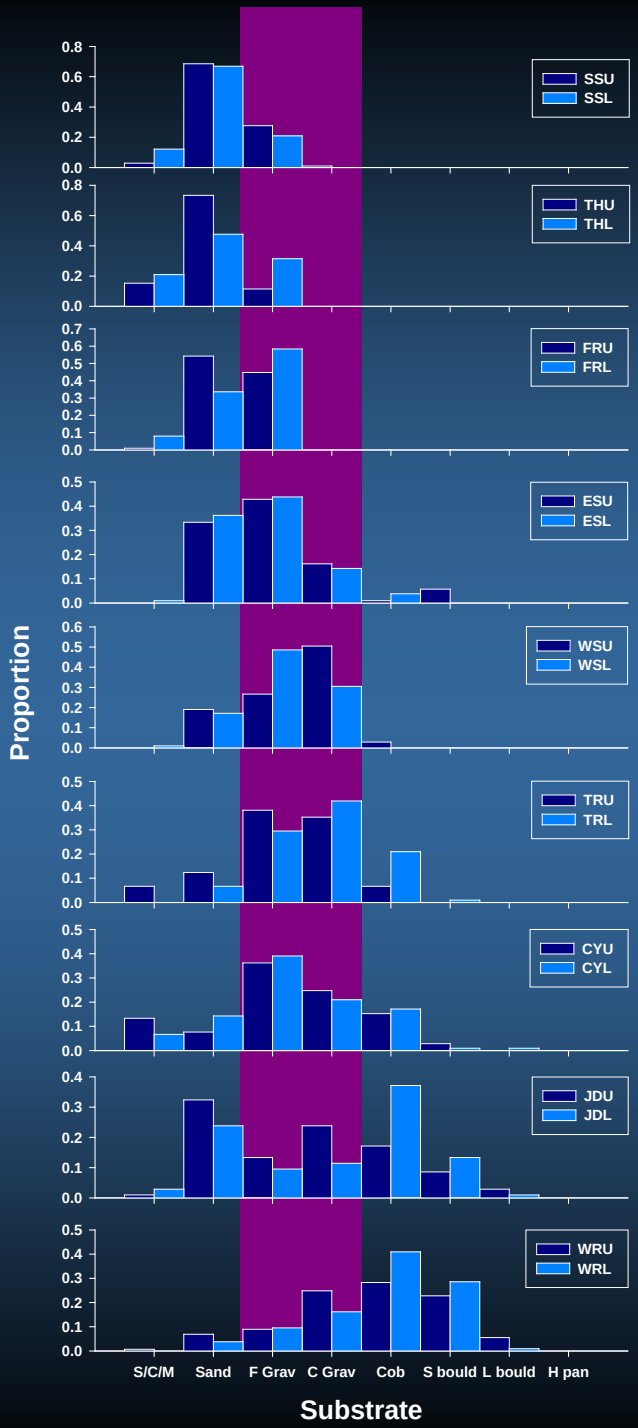
Are there differences in mean indicator values among years (or months?

Does the influence of watershed type on a given indicator depend on the year?

Taylor Creek



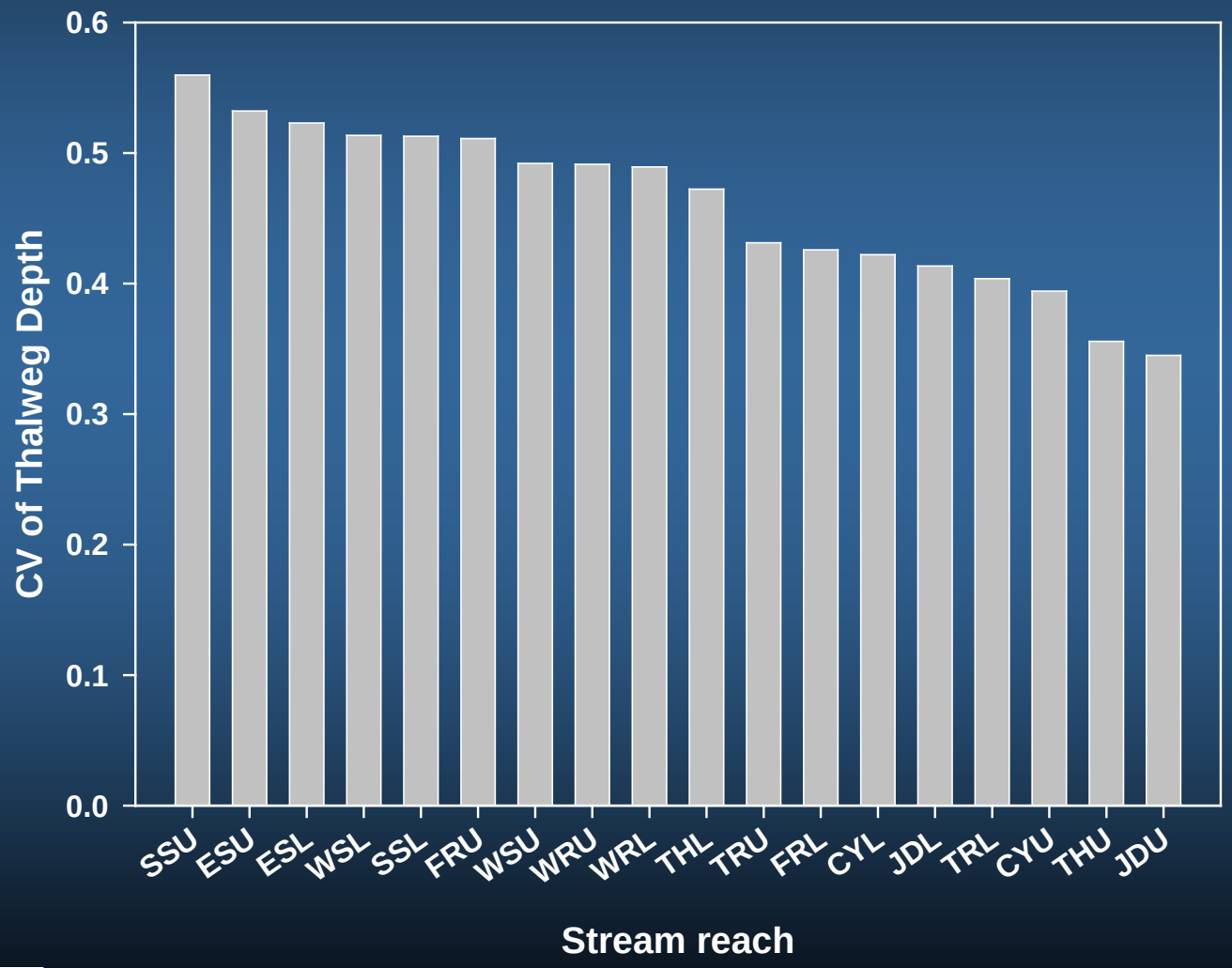
King County



	≤ Sand	Gravel	≥ Cobble
South Seidel*	X		
Tahlequah	X		
Fisher	X	X	
East Seidel*		X	
Weiss		X	
Taylor		X	
Cherry		X	
Judd			X
Webster*			X

King County

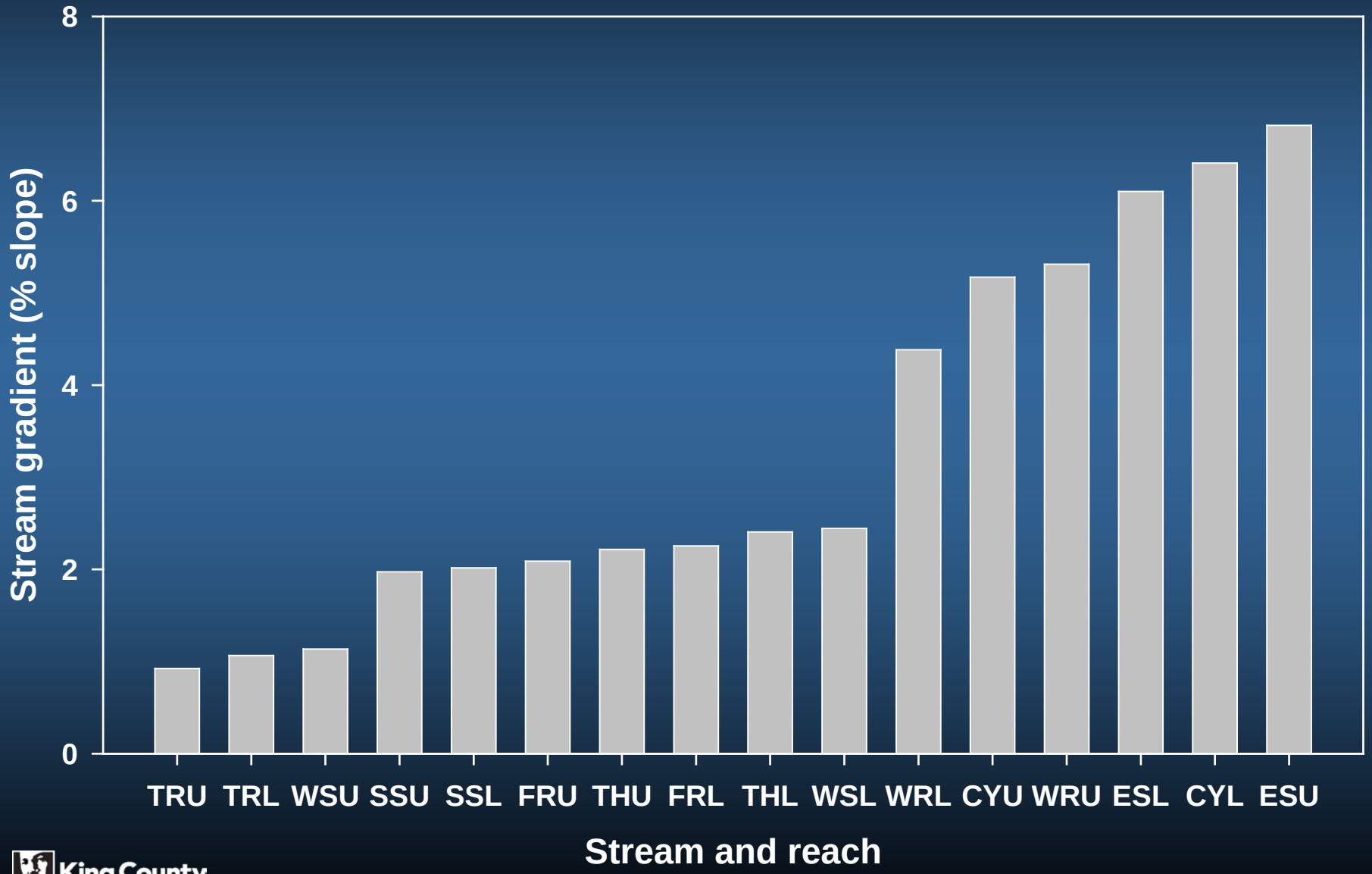
Coefficient of variation in thalweg depth



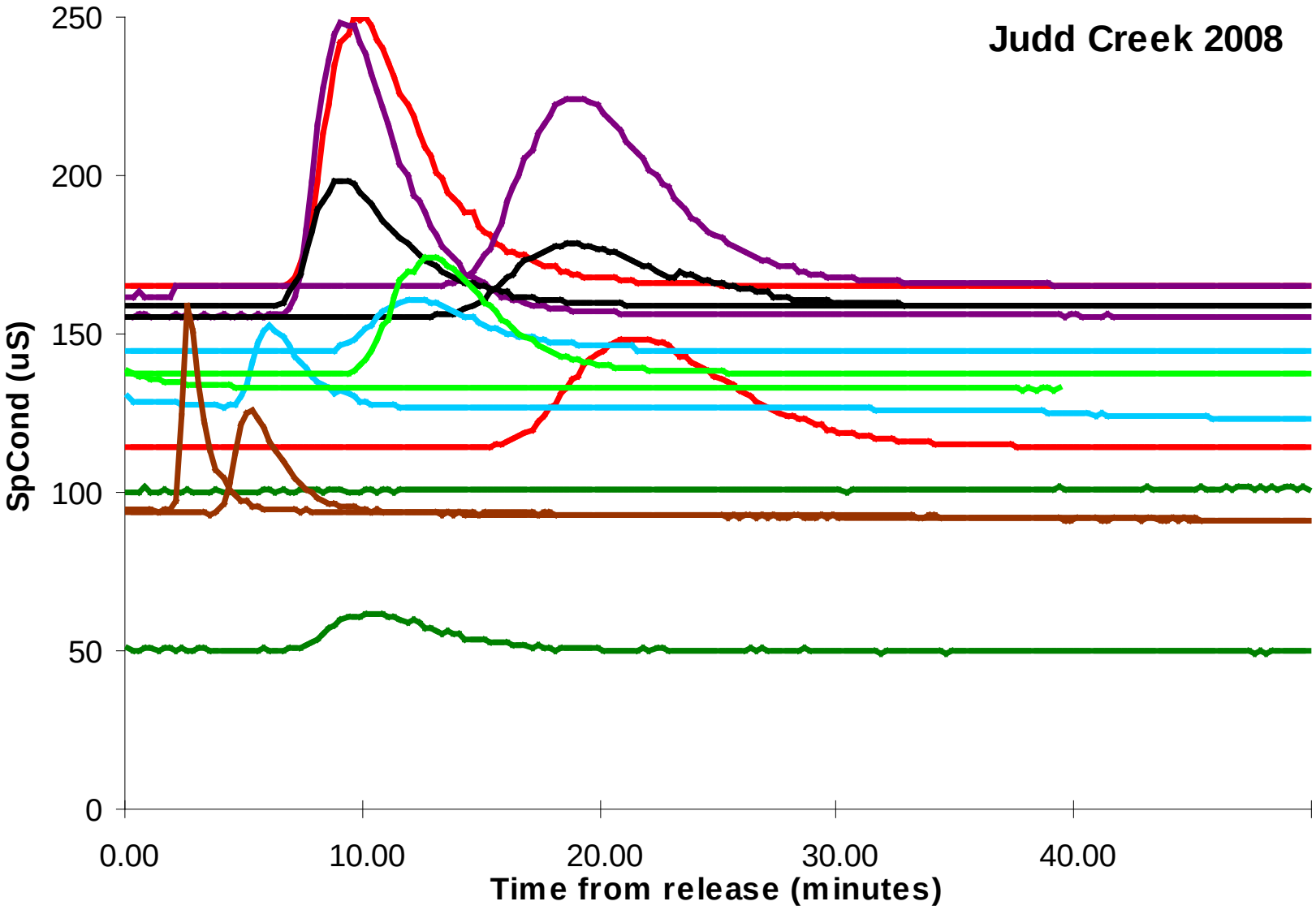
1. S Seidel Upper
2. E Seidel Upper
3. E Seidel Lower
4. Weiss Lower
5. S Seidel Lower
6. Fisher Upper
7. Weiss Upper
8. Webster Upper
9. Webster Lower
10. Tahlequah Lower
11. Taylor Upper
12. Fisher Lower
13. Cherry Lower
14. Judd Lower
15. Taylor Lower
16. Cherry Upper
17. Tahlequah Upper
18. Judd Upper

King County

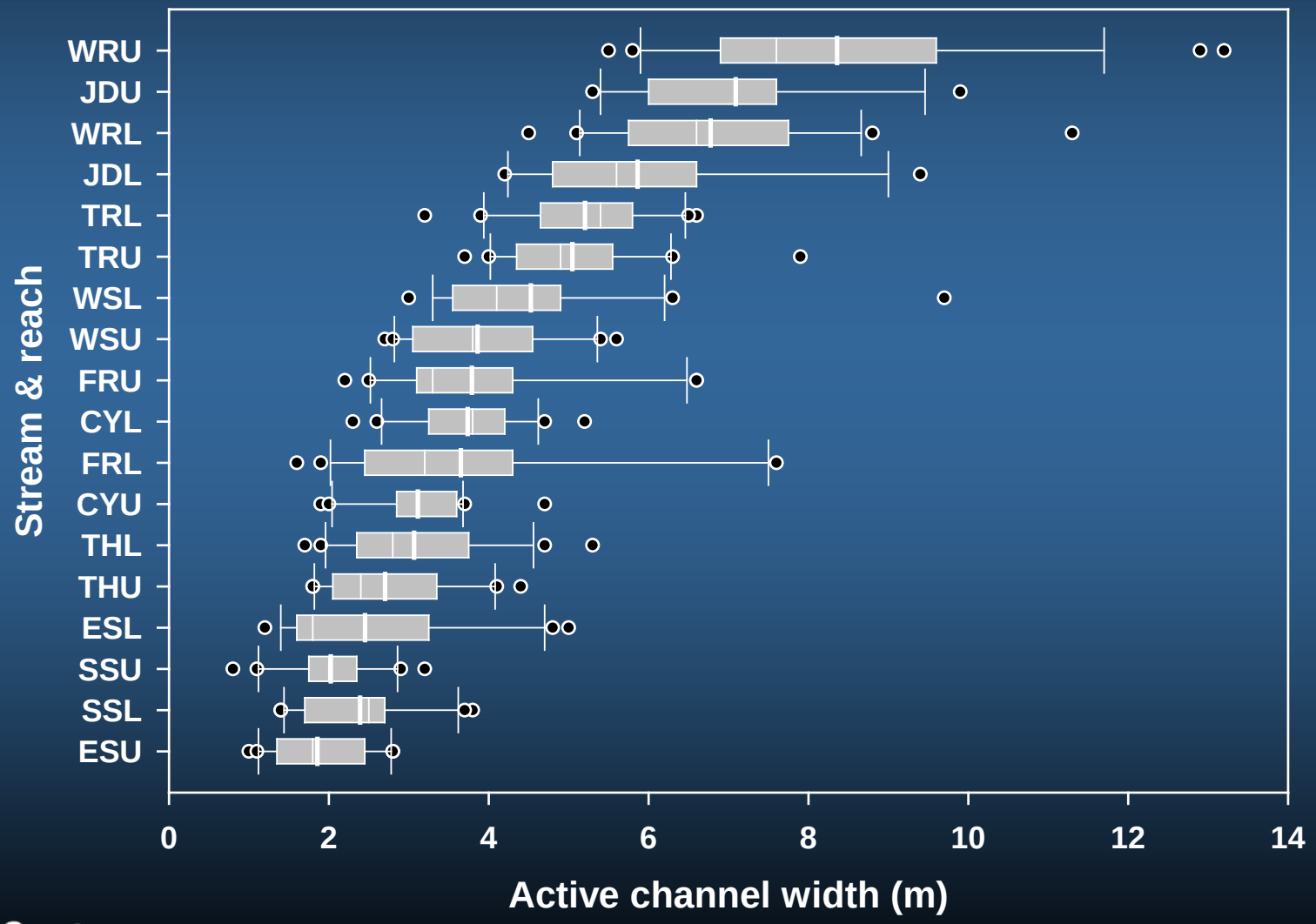
Stream gradient



King County

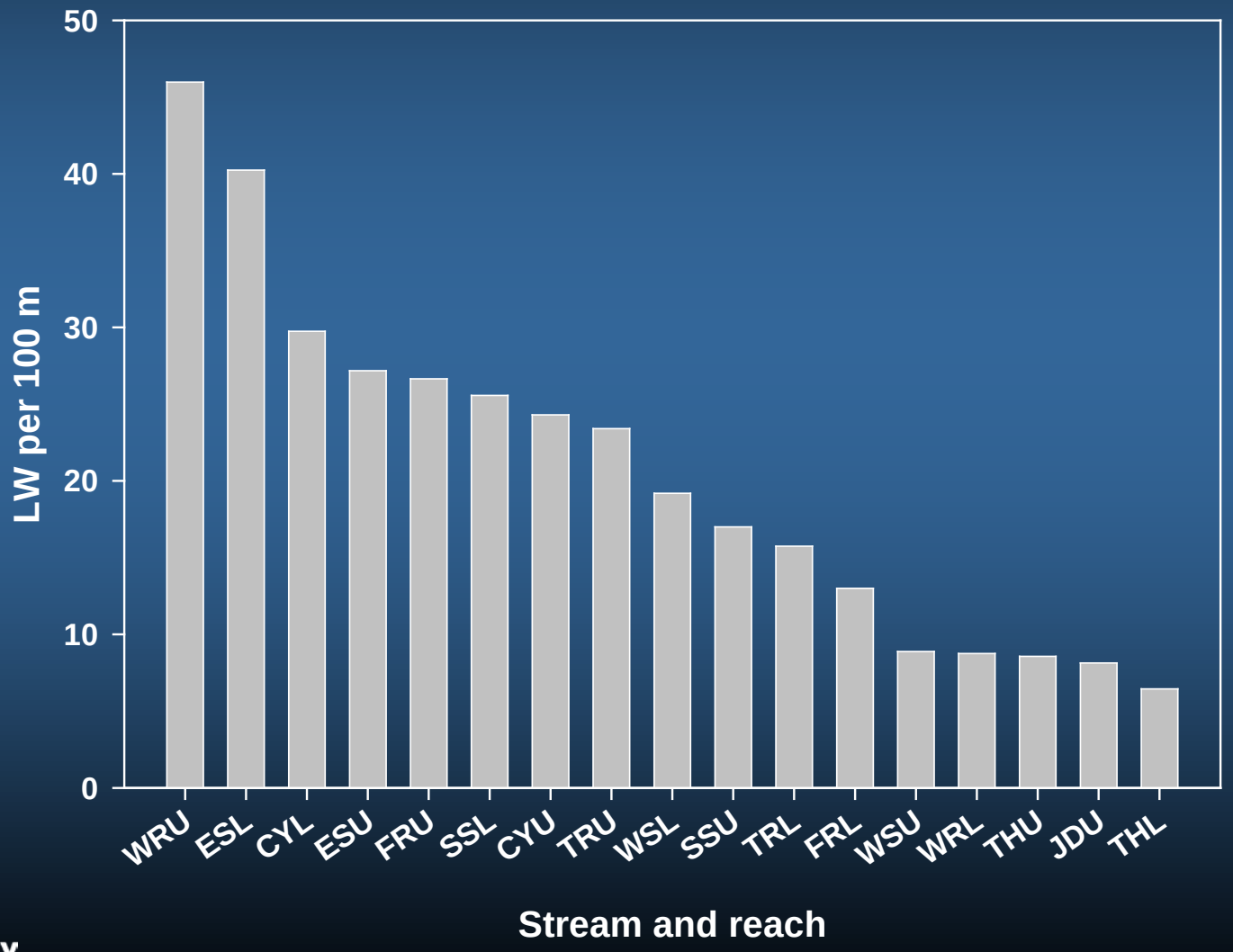

Judd Creek 2008
250
200
150
100
50
0
SpCond (uS)
0.00
10.00
20.00
30.00
40.00
Time from release (minutes)

Channel width



King County

Large wood frequency

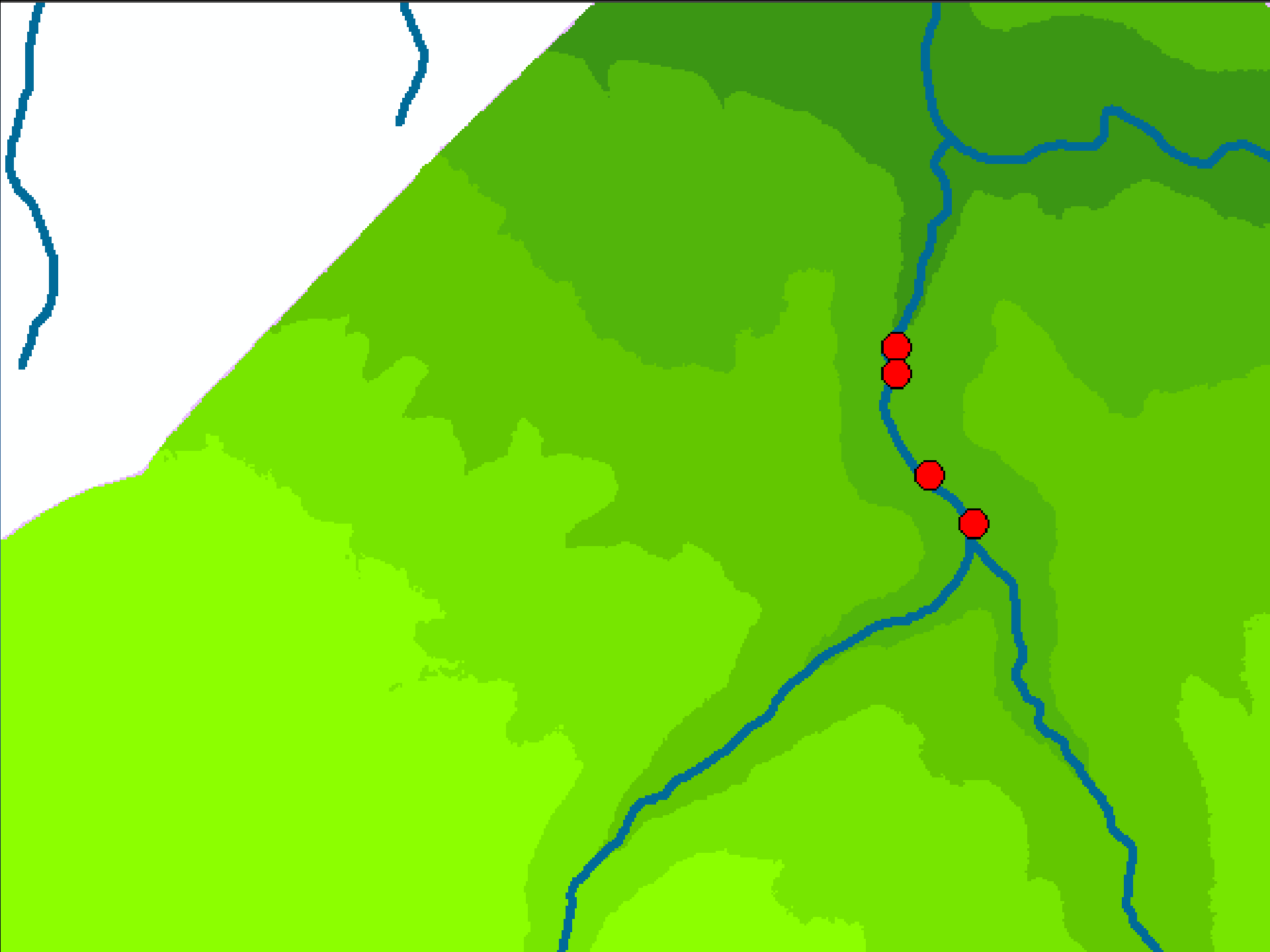


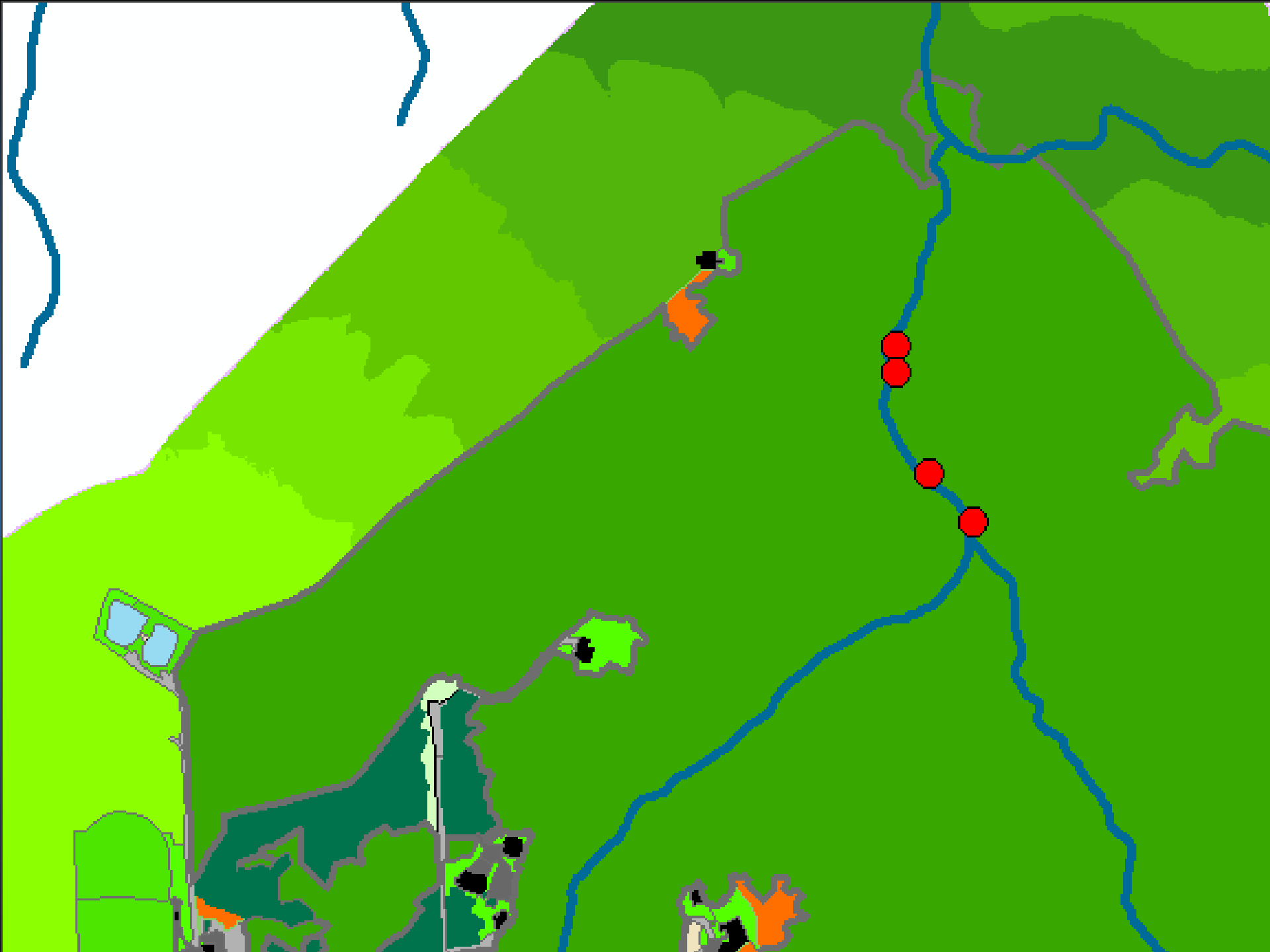
King County

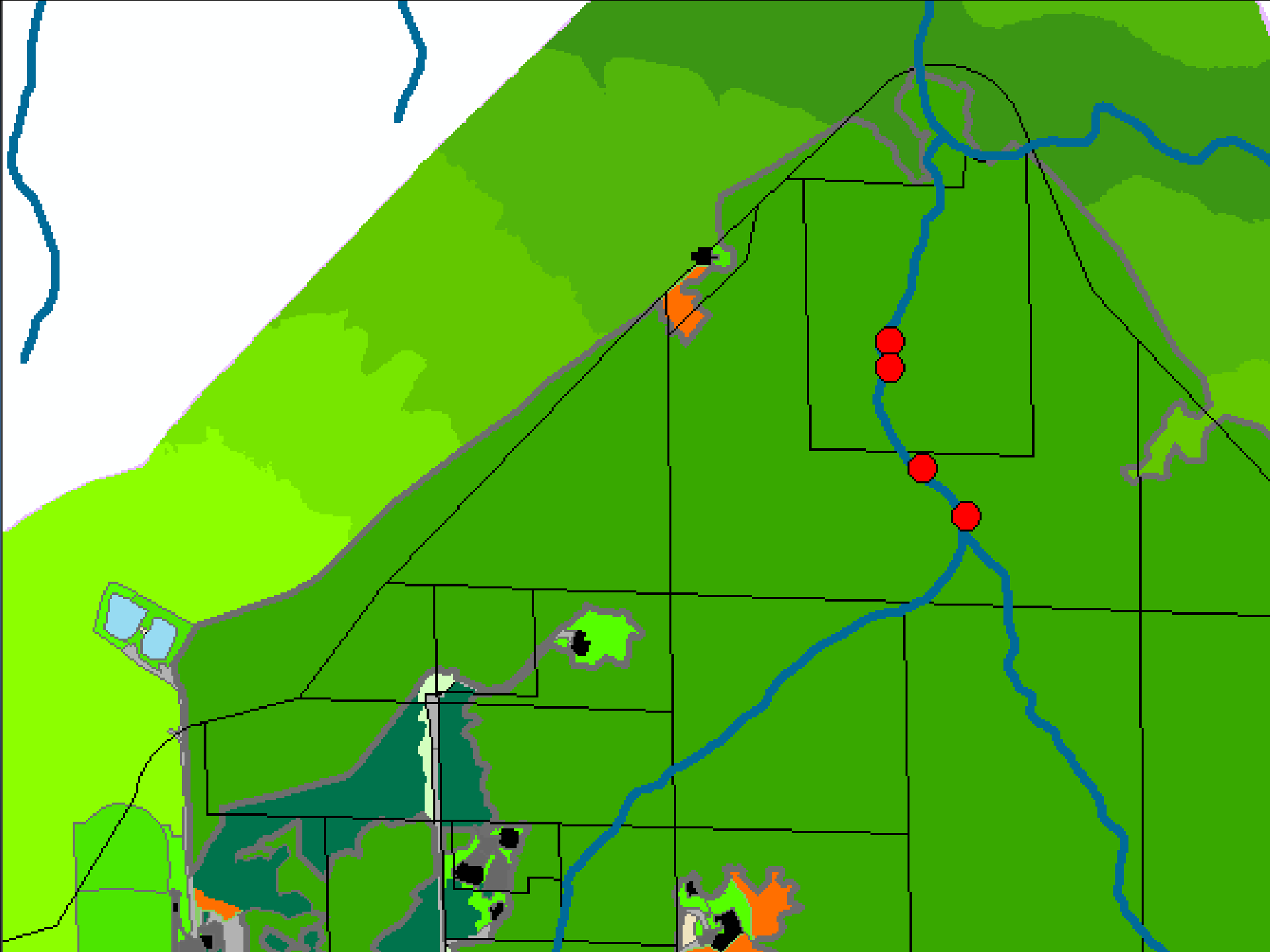
Results – Land Development

- Landcover Classes
  - Photo interpretation
- Hydrologic Correction
  - Study Watersheds
  - Sample sheds
  - Buffer sheds
  - Parcel sheds
- PCI index

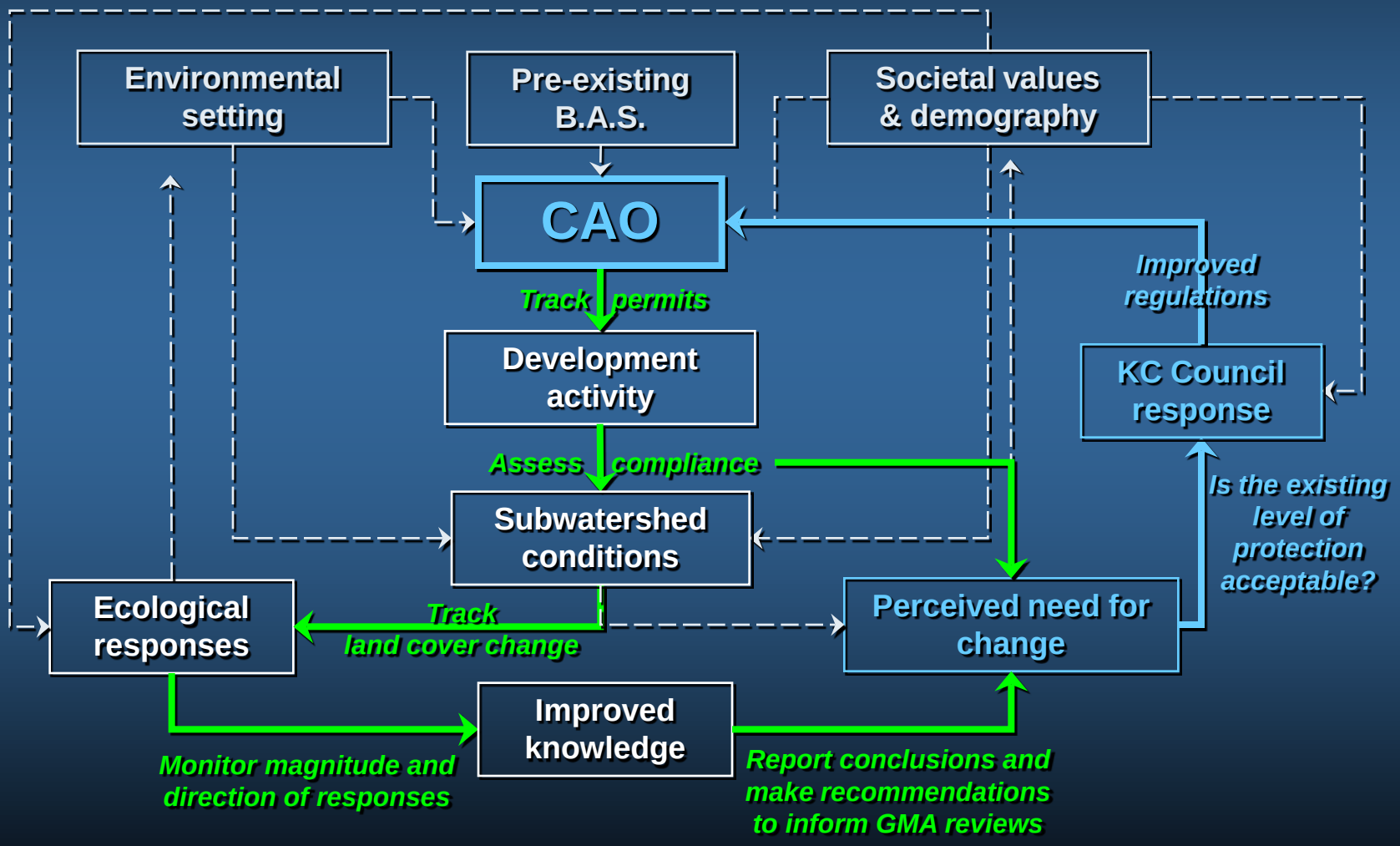
$$PCI = \sum_{g=1}^{n} D_{x,w,p} + \sum_{g=1}^{n} E_{x,w,p}$$







Summary



Modified from Grimm et al. 2000

Drivers – Basin hydrology

geology

elevation

aspect

network structure

forest type

Results - Climate

Precipitation

air temp

Results – Land Development

Impervious

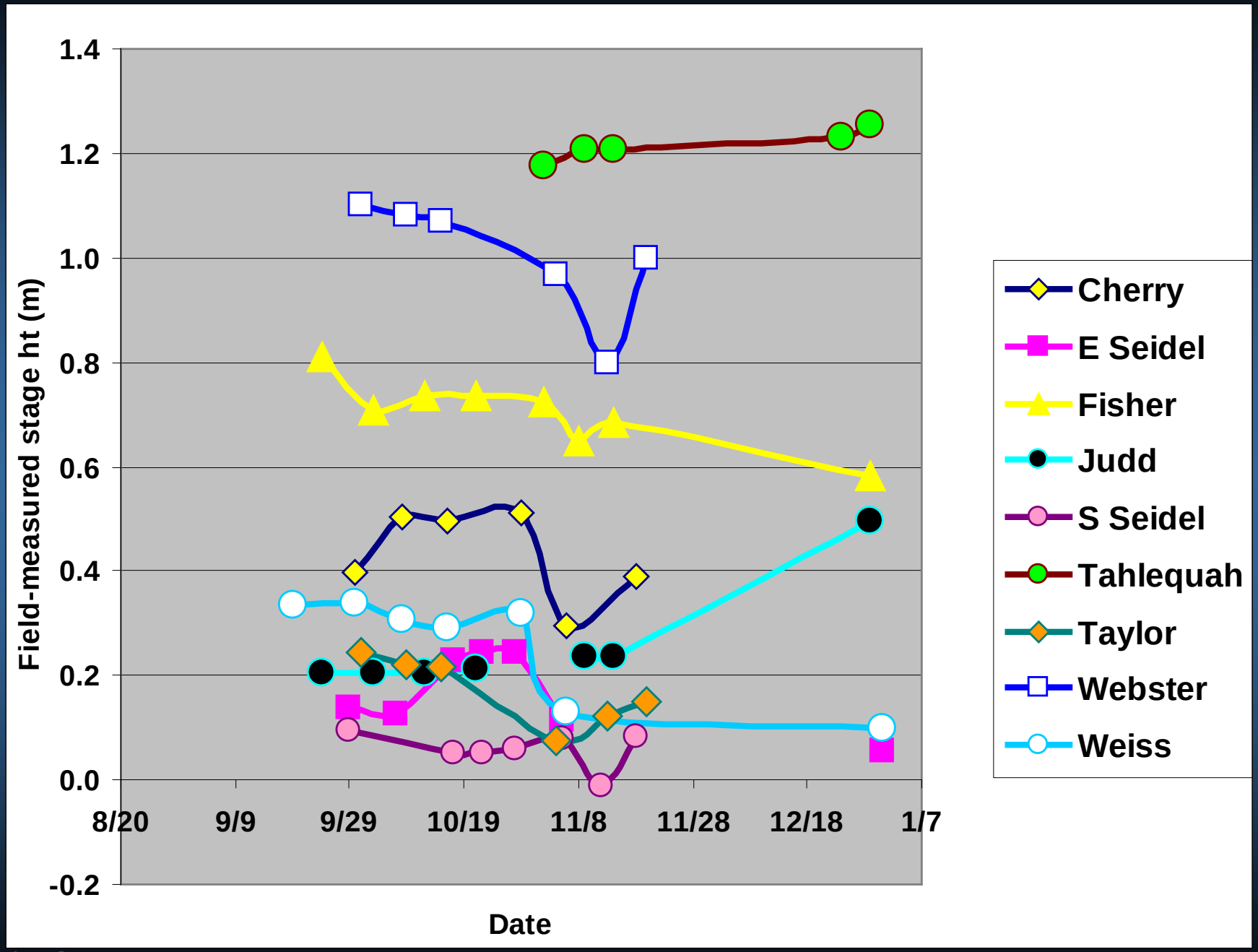
forest cover

Urban

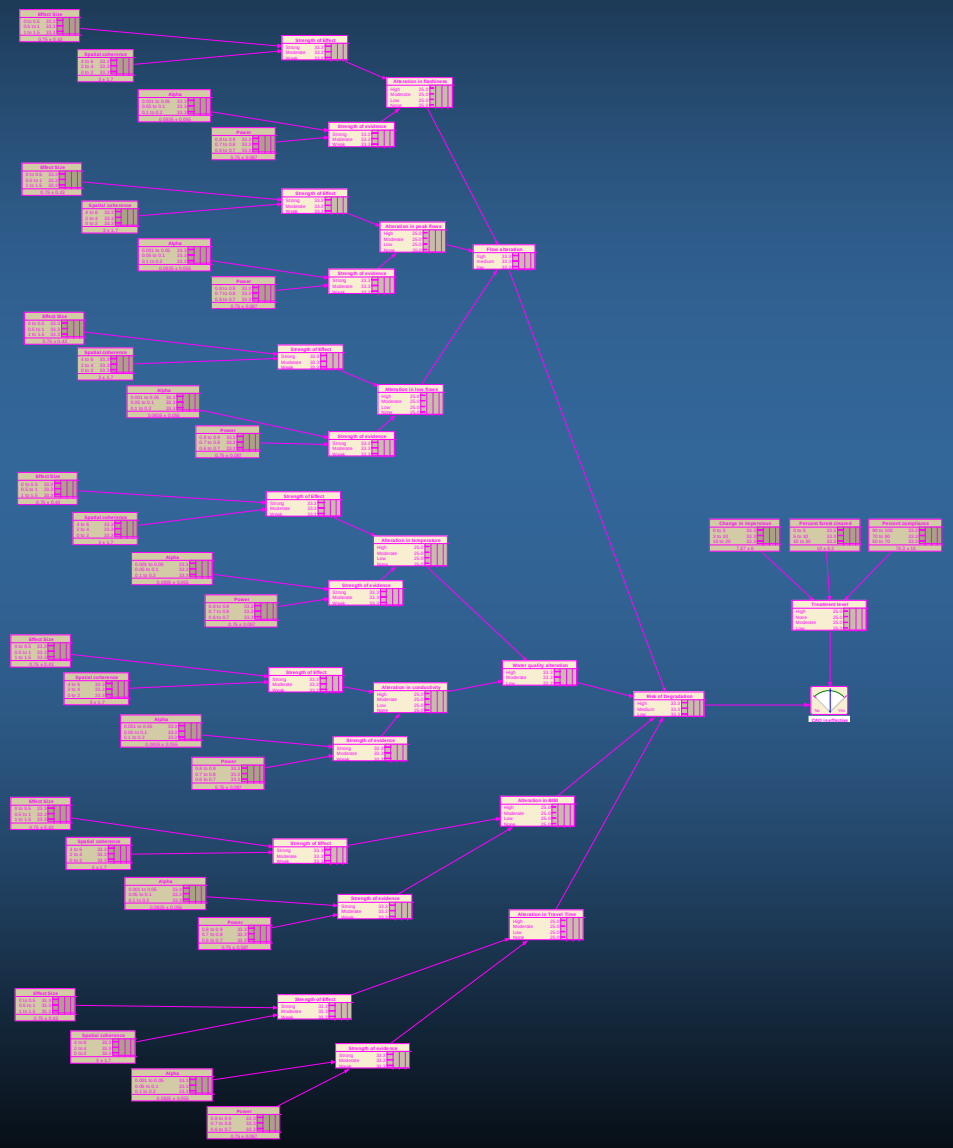
Rural

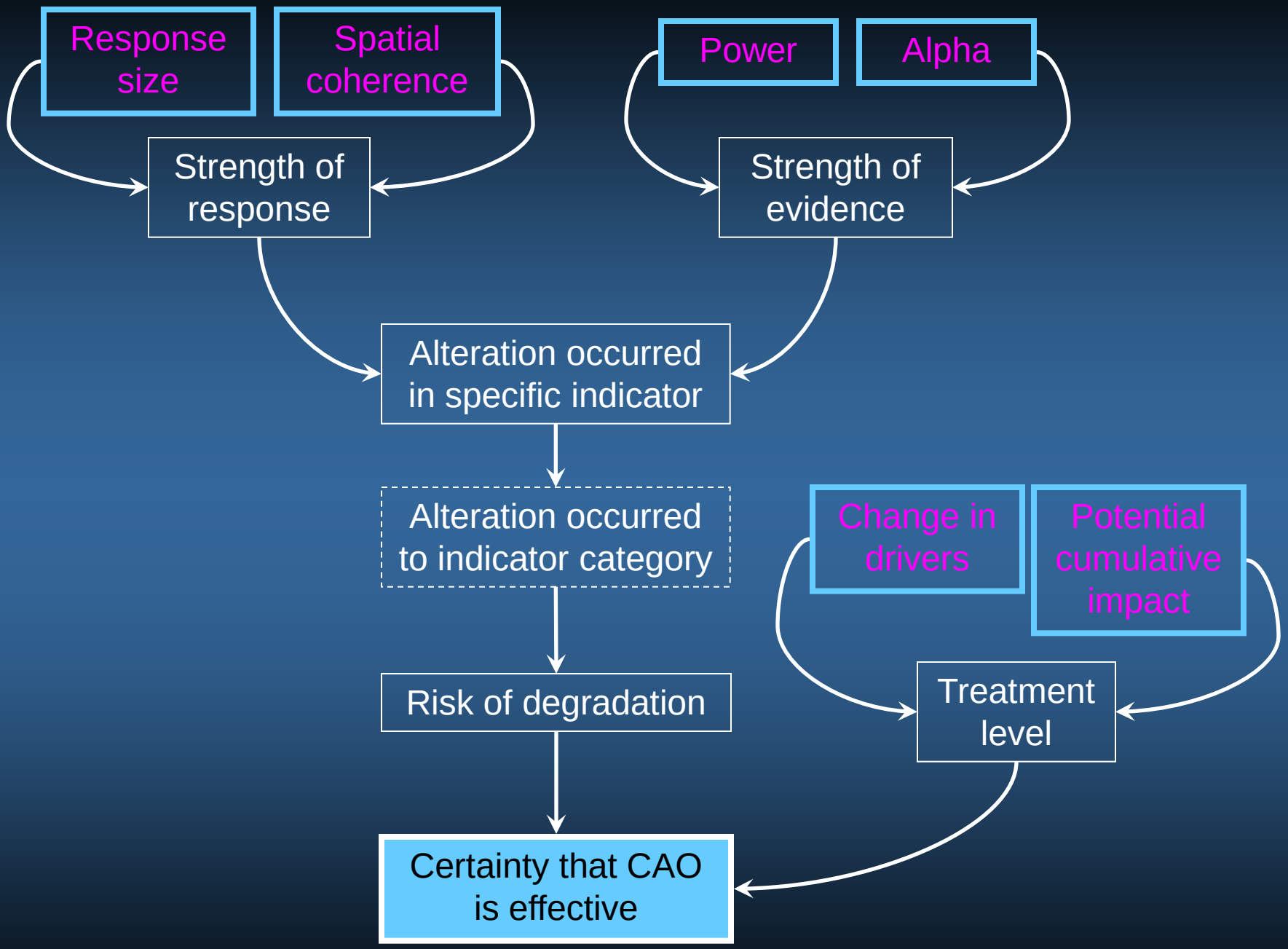
PCI index

permit compliance


1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
Field-measured stage ht (m)
8/20
9/9
9/29
10/19
11/8
11/28
12/18
1/7
Date
Cherry
E Seidel
Fisher
Judd
S Seidel
Tahlequah
Taylor
Webster
Weiss

Synthesis


Change in Impervious
Percent break-crushed
Percent compacted
Treatment train
Risk of Degradation
Water quality alteration
Alteration in Bed
Alteration in Travel Time
Flow alteration
Alteration in peak flows
Alteration in low flows
Alteration in temperature
Alteration in conductivity
Strength of Effect
Strength of evidence
Effect Size
Spatial coherence
Alpha
Power


Response size
Spatial coherence
Power
Alpha
Strength of response
Strength of evidence
Alteration occurred in specific indicator
Alteration occurred to indicator category
Change in drivers
Potential cumulative impact
Risk of degradation
Treatment level
Certainty that CAO is effective

Objective 1

Track regulatory implementation and degree of compliance in parcels developed under new regulations

- What percentage of parcels is developed in full compliance with permits?
- What percentage of parcels is developed without permits?
- What is the typical extent and type of unpermitted development and where does it occur relative to critical areas?

Objective 2

Quantify environmental change in catchments as development proceeds

- What is the extent, type, and intensity of development that has occurred during the study period?

Objective 3

Determine empirical response relationships

- Do treatment watersheds have different mean indicator values than reference watersheds?
- Are there differences in mean indicator values among years or months?
- Does the influence of watershed type on a given indicator depend on the year?
- What factors best explain observed variation in individual indicators?

Objective 4

Provide findings to King County Council

- Do land use regulations protect beneficial uses, including aquatic critical areas and associated biological resources?

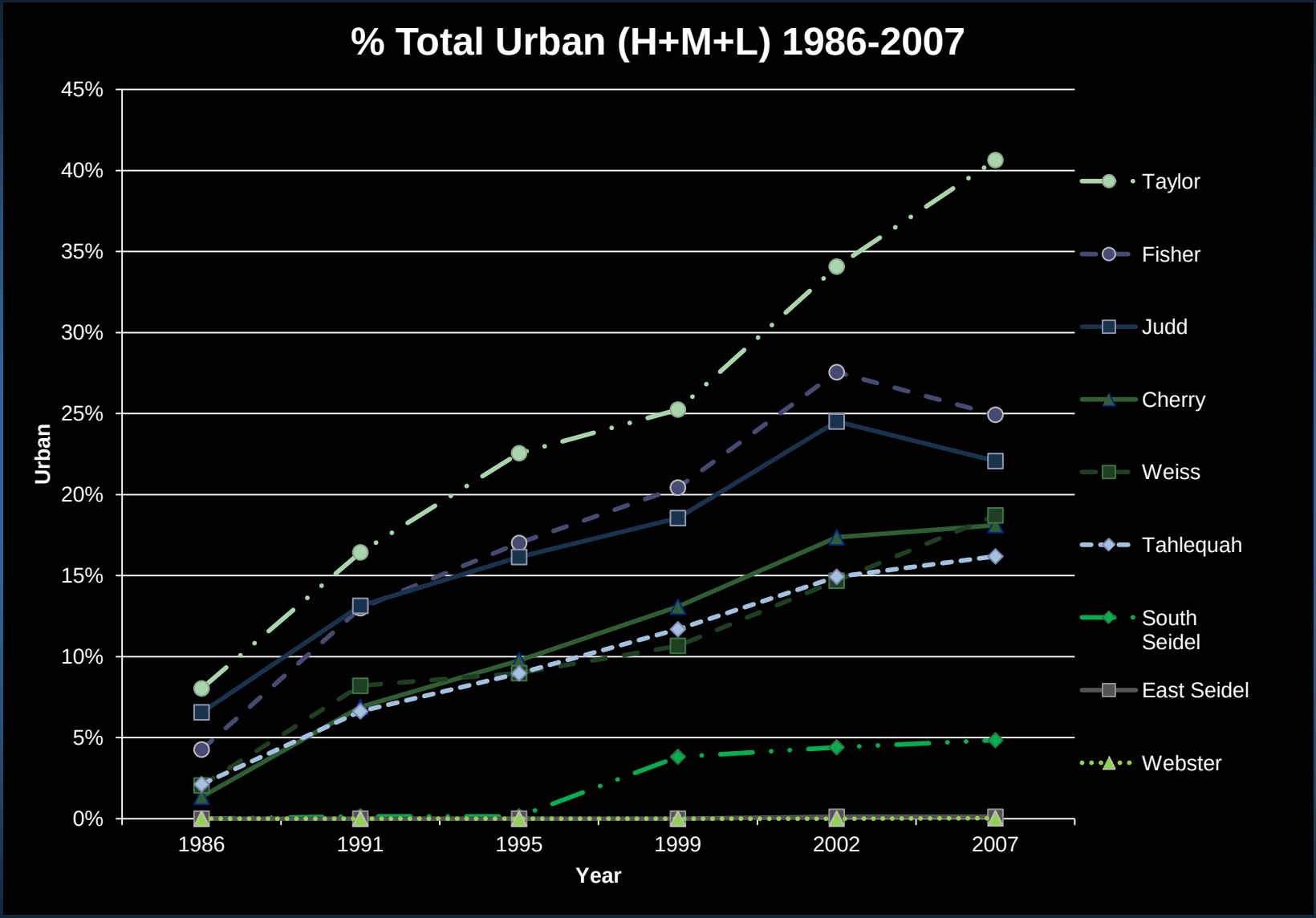
Objective 5

Disseminate framework and results to other appropriate audiences, including other Puget Sound Counties

- What are the strengths and weaknesses of this monitoring framework?
- What important lessons were learned and were there any major surprises?

Permits

Overview and Background


% Total Urban (H+M+L) 1986-2007
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Urban
1986
1991
1995
1999
2002
2007
Year
Taylor
Fisher
Judd
Cherry
Weiss
Tahlequah
South Seidel
East Seidel
Webster

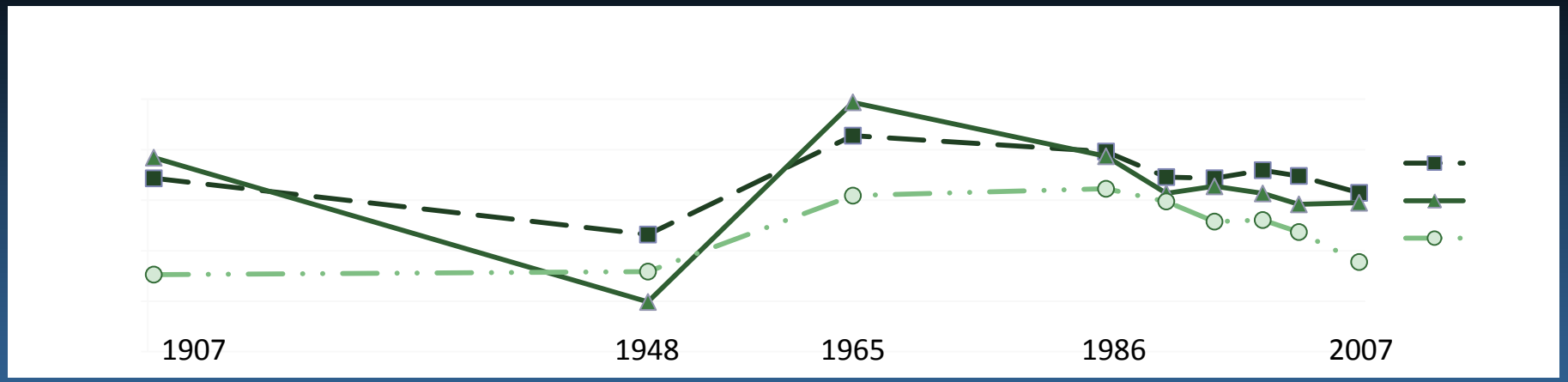
CONTEXT

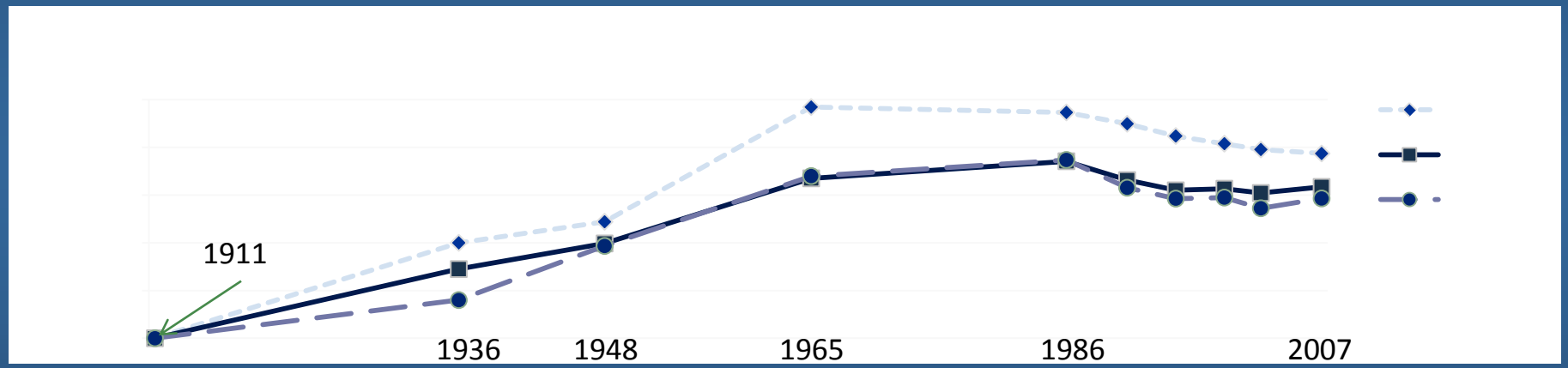
HISTORIC
&
FUTURE SCENARIOS

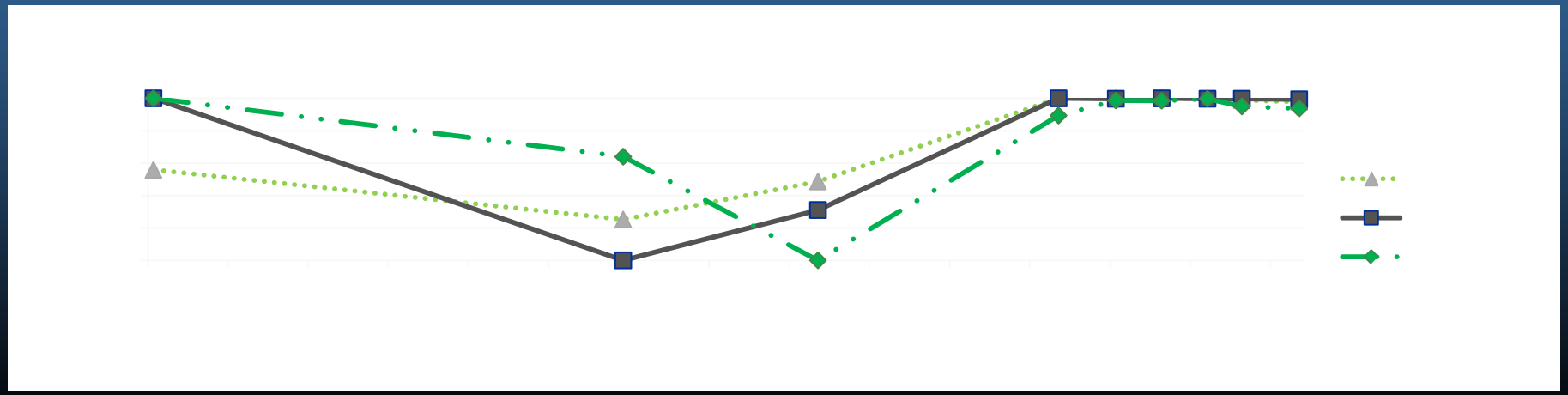
UW UERL

- Dr. Marina Alberti,
- Dr. Lucy Hutyra,
- Matt Marsik, Post-Doc
- Julia Michalak, PhD Candidate

Change in % Forest Cover - 1907-11 to 2007

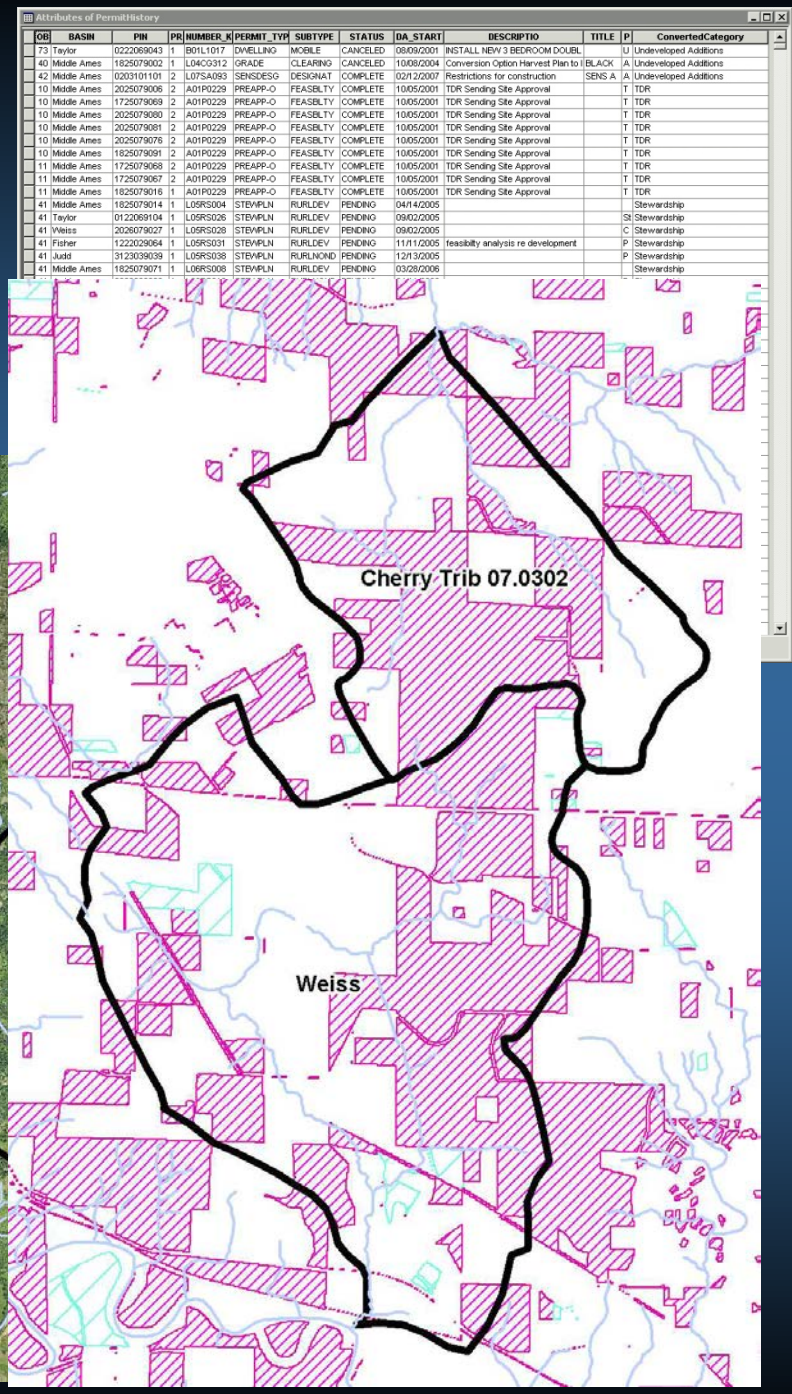






Permit Development History

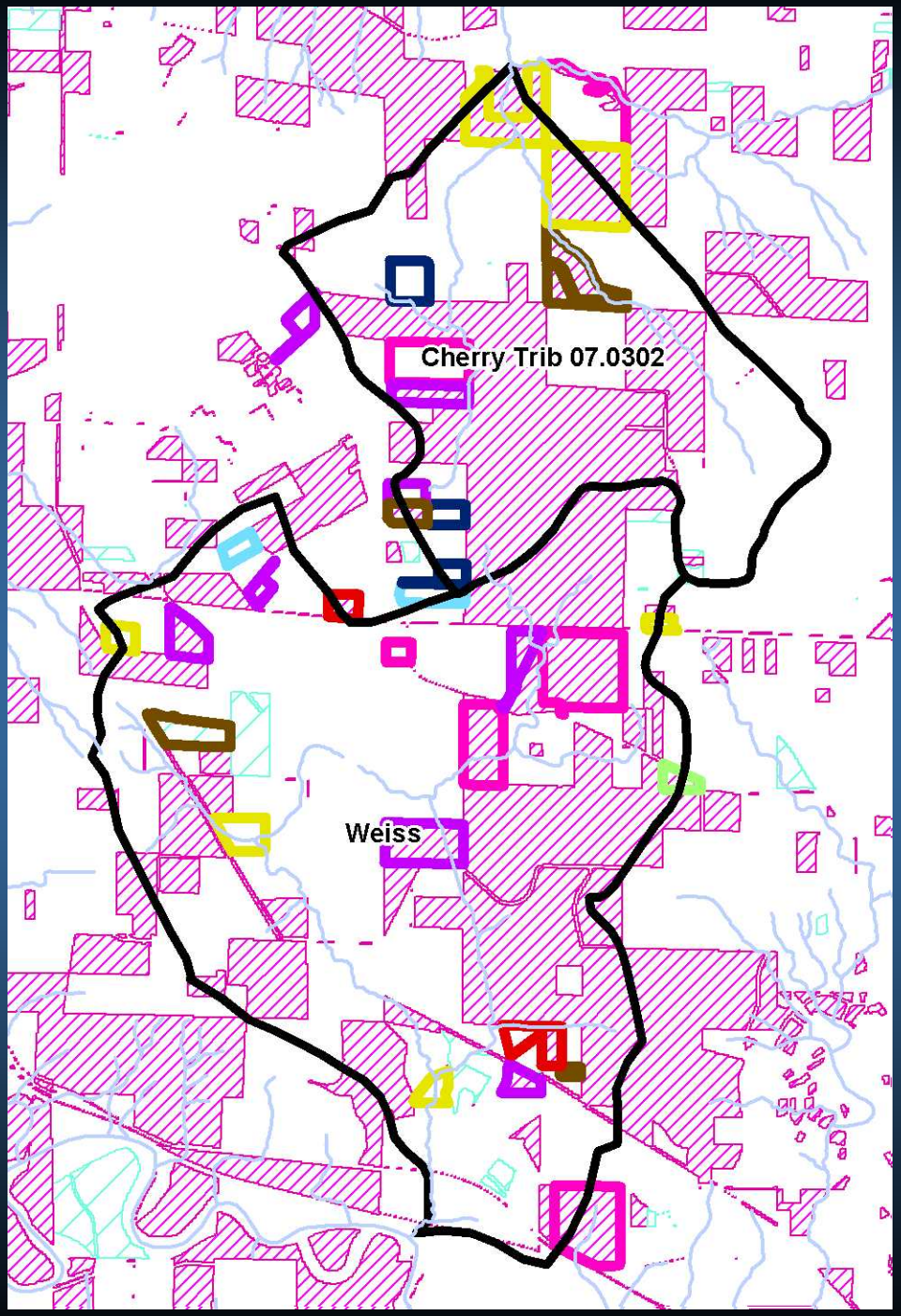
- **Historic Permit Data from DDES Data Warehouse**
- **Digital Aerial Photography from KCGIS Spatial Data Warehouse**
- **Previous GIS Analysis of Pre-CAO Development & Development Potential to Identify Basins to Monitor**

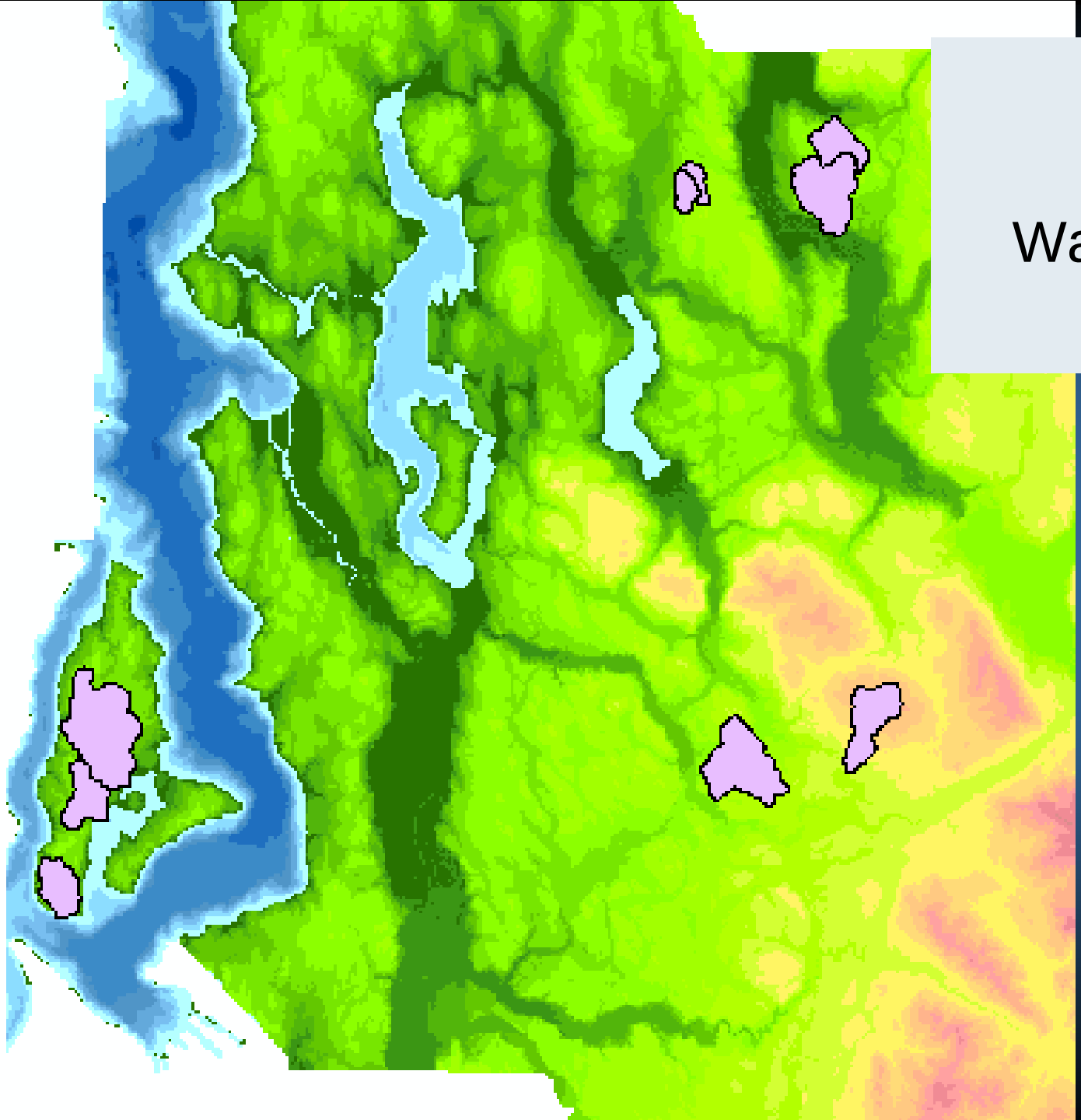
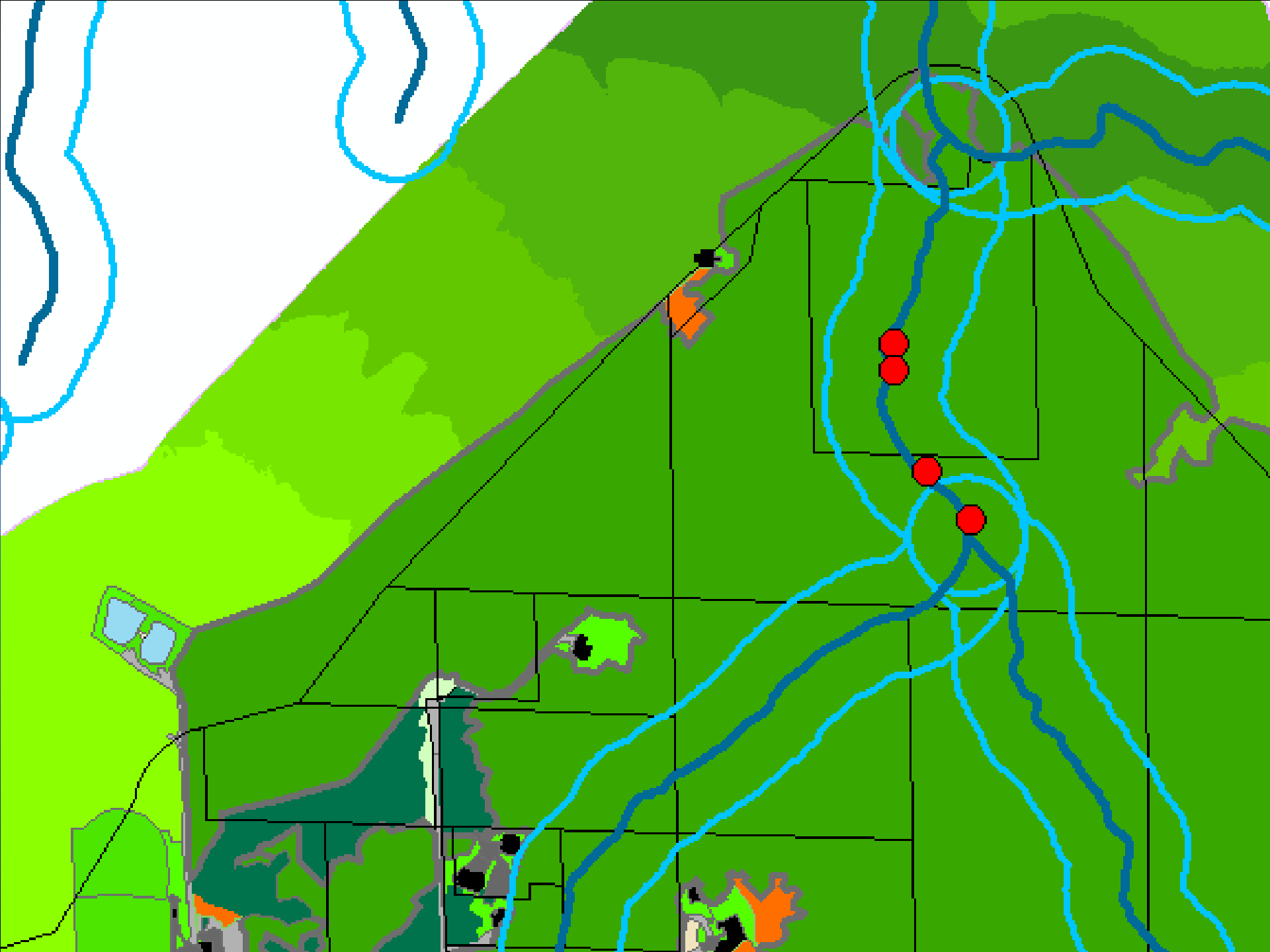
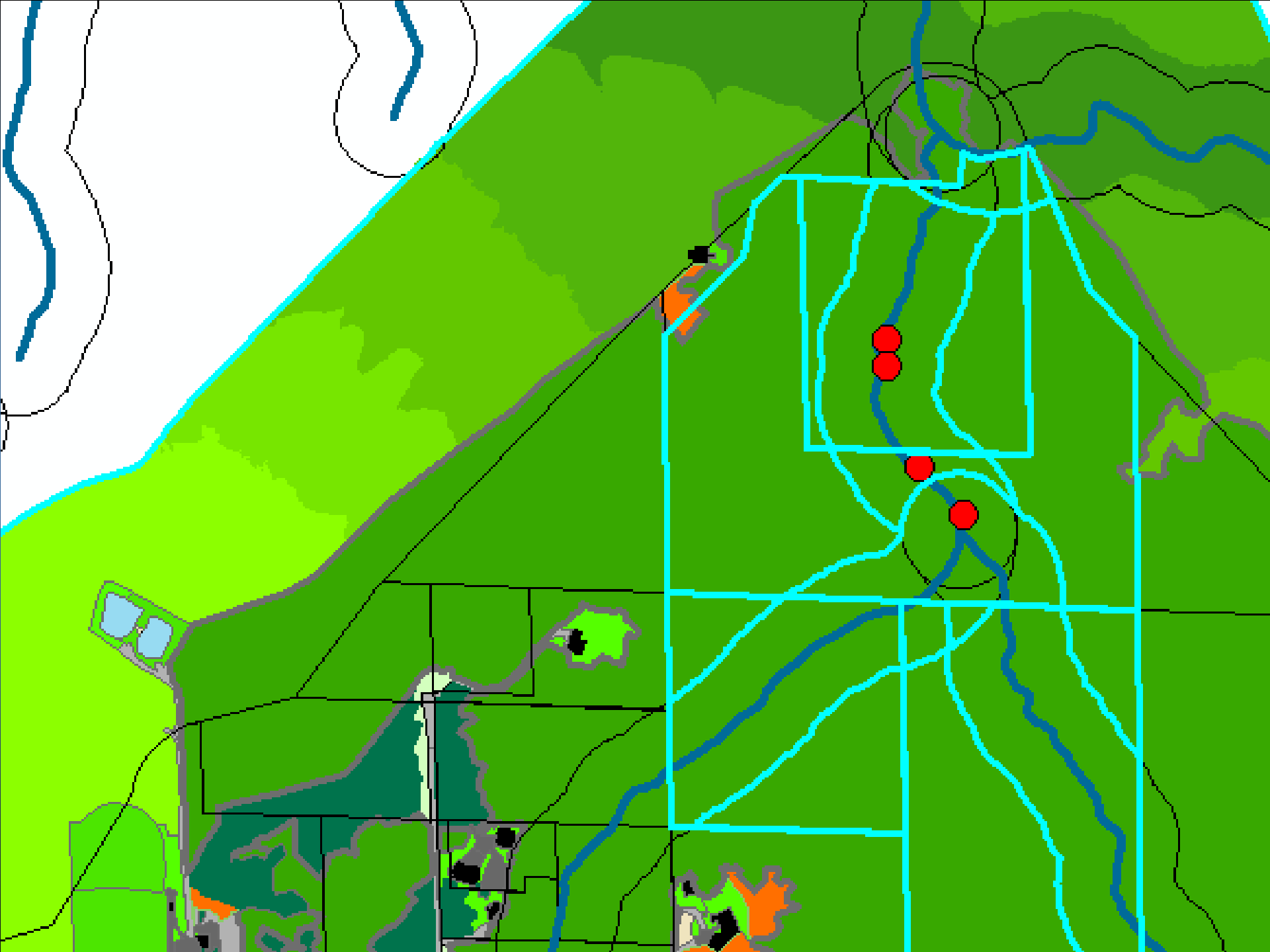


OB	BASIN	PIN	PR	NUMBER_K	PERMIT_TYP	SUBTYPE	STATUS	DA_START	DESCRIPTIO	TITLE	P	ConvertedCategory
73	Taylor	0222069043	1	B01L1017	DWELLING	MOBILE	CANCELED	08/09/2001	INSTALL NEW 3 BEDROOM DOUBL		U	Undeveloped Additions
40	Middle Ames	1825079002	1	L04CG312	GRADE	CLEARING	CANCELED	10/08/2004	Conversion Option Harvest Plan to I	BLACK	A	Undeveloped Additions
42	Middle Ames	0203101101	2	L07SA093	SENSDESG	DESIGNAT	COMPLETE	02/12/2007	Restrictions for construction	SENS A	A	Undeveloped Additions
10	Middle Ames	2025079006	2	A01P0229	PREAPP-O	FEASBLTY	COMPLETE	10/05/2001	TDR Sending Site Approval		T	TDR
10	Middle Ames	1725079069	2	A01P0229	PREAPP-O	FEASBLTY	COMPLETE	10/05/2001	TDR Sending Site Approval		T	TDR
10	Middle Ames	2025079080	2	A01P0229	PREAPP-O	FEASBLTY	COMPLETE	10/05/2001	TDR Sending Site Approval		T	TDR
10	Middle Ames	2025079081	2	A01P0229	PREAPP-O	FEASBLTY	COMPLETE	10/05/2001	TDR Sending Site Approval		T	TDR
10	Middle Ames	2025079076	2	A01P0229	PREAPP-O	FEASBLTY	COMPLETE	10/05/2001	TDR Sending Site Approval		T	TDR
10	Middle Ames	1825079091	2	A01P0229	PREAPP-O	FEASBLTY	COMPLETE	10/05/2001	TDR Sending Site Approval		T	TDR
11	Middle Ames	1725079068	2	A01P0229	PREAPP-O	FEASBLTY	COMPLETE	10/05/2001	TDR Sending Site Approval		T	TDR
11	Middle Ames	1725079067	2	A01P0229	PREAPP-O	FEASBLTY	COMPLETE	10/05/2001	TDR Sending Site Approval		T	TDR
11	Middle Ames	1825079016	1	A01P0229	PREAPP-O	FEASBLTY	COMPLETE	10/05/2001	TDR Sending Site Approval		T	TDR
41	Middle Ames	1825079014	1	L05RS004	STBVPLN	RURLDEV	PENDING	04/14/2005				Stewardship
41	Taylor	0122069104	1	L05RS026	STBVPLN	RURLDEV	PENDING	09/02/2005			St	Stewardship
41	Weiss	2026079027	1	L05RS028	STBVPLN	RURLDEV	PENDING	09/02/2005			C	Stewardship
41	Fisher	1222029064	1	L05RS031	STBVPLN	RURLDEV	PENDING	11/11/2005	feasibility analysis re development		P	Stewardship
41	Judd	3123039039	1	L05RS038	STBVPLN	RURLNOND	PENDING	12/13/2005			P	Stewardship
41	Middle Ames	1825079071	1	L06RS008	STBVPLN	RURLDEV	PENDING	03/28/2006				Stewardship

Permits with Actual Impact

- **Locate Permits 2000 to 2004**
- **Locate Permits 2005 to 2008**
- **Locate Invasive Plant Clearing Permits, Stewardship Plans, and Enforcement Activities**





Study Watersheds