Hydroecological tool: enhancements and results

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Sponsored by:

Great Lakes Protection Fund

Project partners:

Cornell University

Natural Heritage Institute

Toronto and Region Conservation for The Living City

The Nature Conservancy
Saving the last great places on earth

Motivation

Great Lakes Charter Annex

- establish uniform, regional protections for Great Lakes waters
- ensure that authority over the Lake waters remains in the Great Lakes basin
- establish a process to ensure that ecosystems are improved through water use

ecosystem improvement actions will accompany future water withdrawals

Great Lakes watersheds have many concerns

Purpose

Purpose of this project is to build a GIS model to predict where impairments are most likely to occur and identify the most cost-effective and beneficial improvement opportunities within Lake Ontario watersheds

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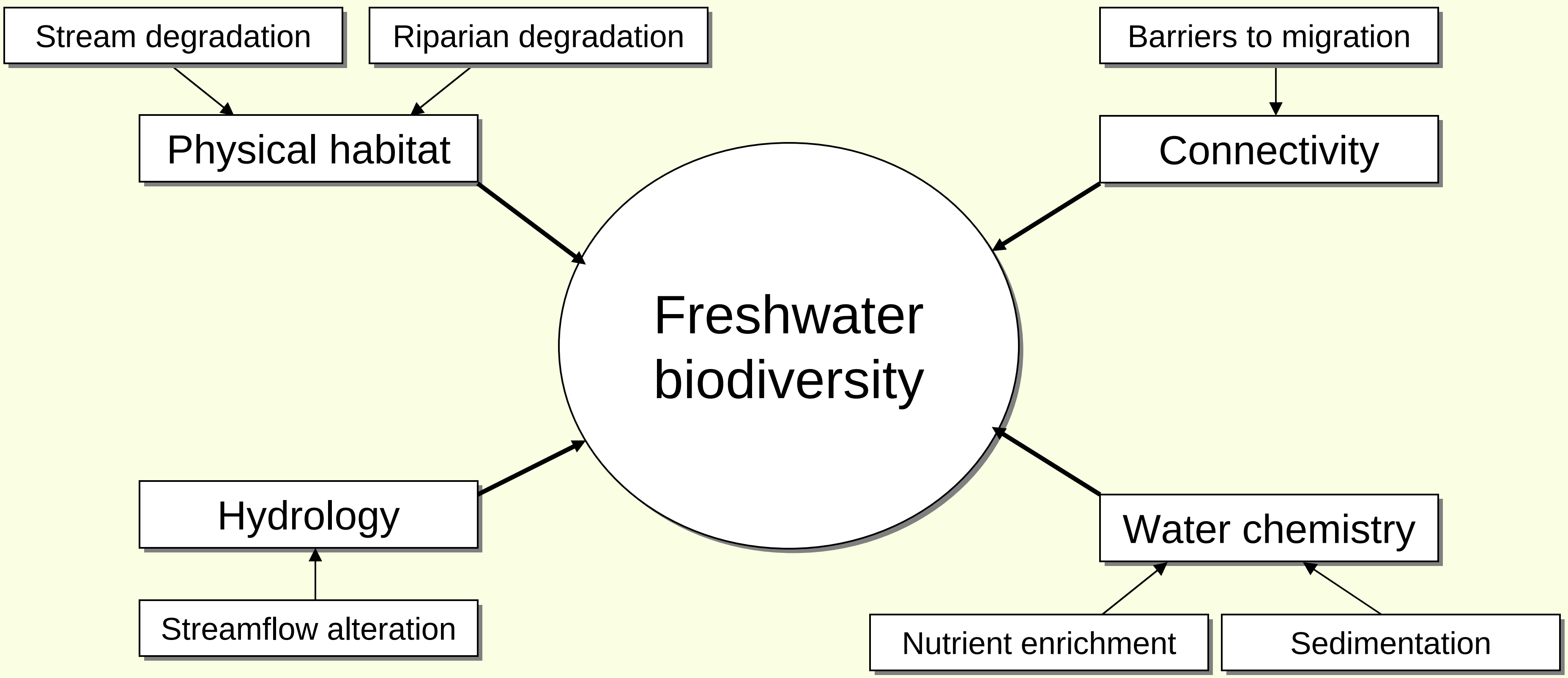
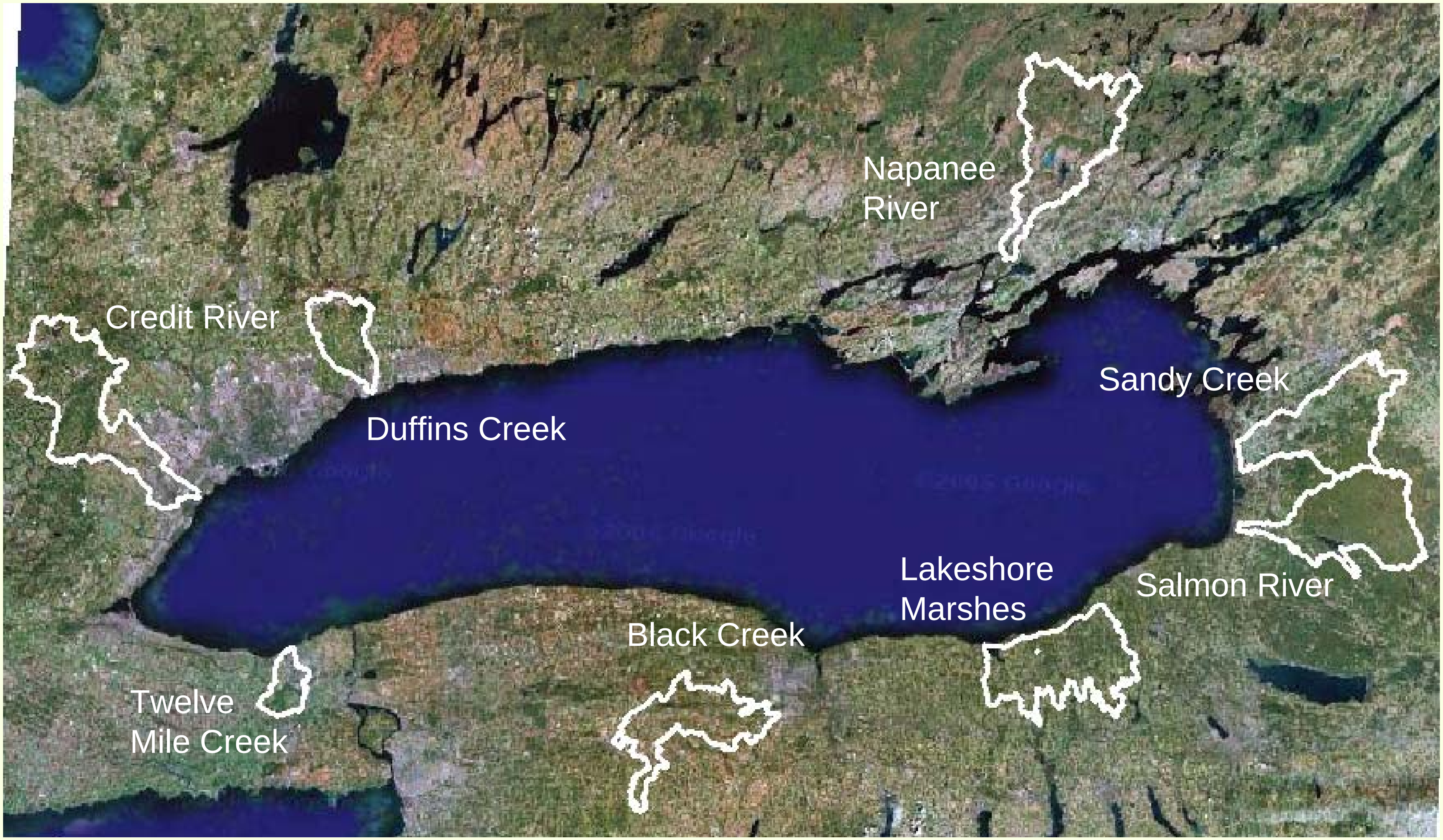
Modeled impairments



Study areas


Napanee River
Credit River
Sandy Creek
Duffins Creek
Lakeshore Marshes
Salmon River
Black Creek
Twelve Mile Creek

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Talk outline

- Methods and enhancements / Testing
- Study area characteristics
- Results
- Conclusions
- Future tasks

Testing

- Ordinal
- Methodological
- Quantitative

Ordinal: NYDEC

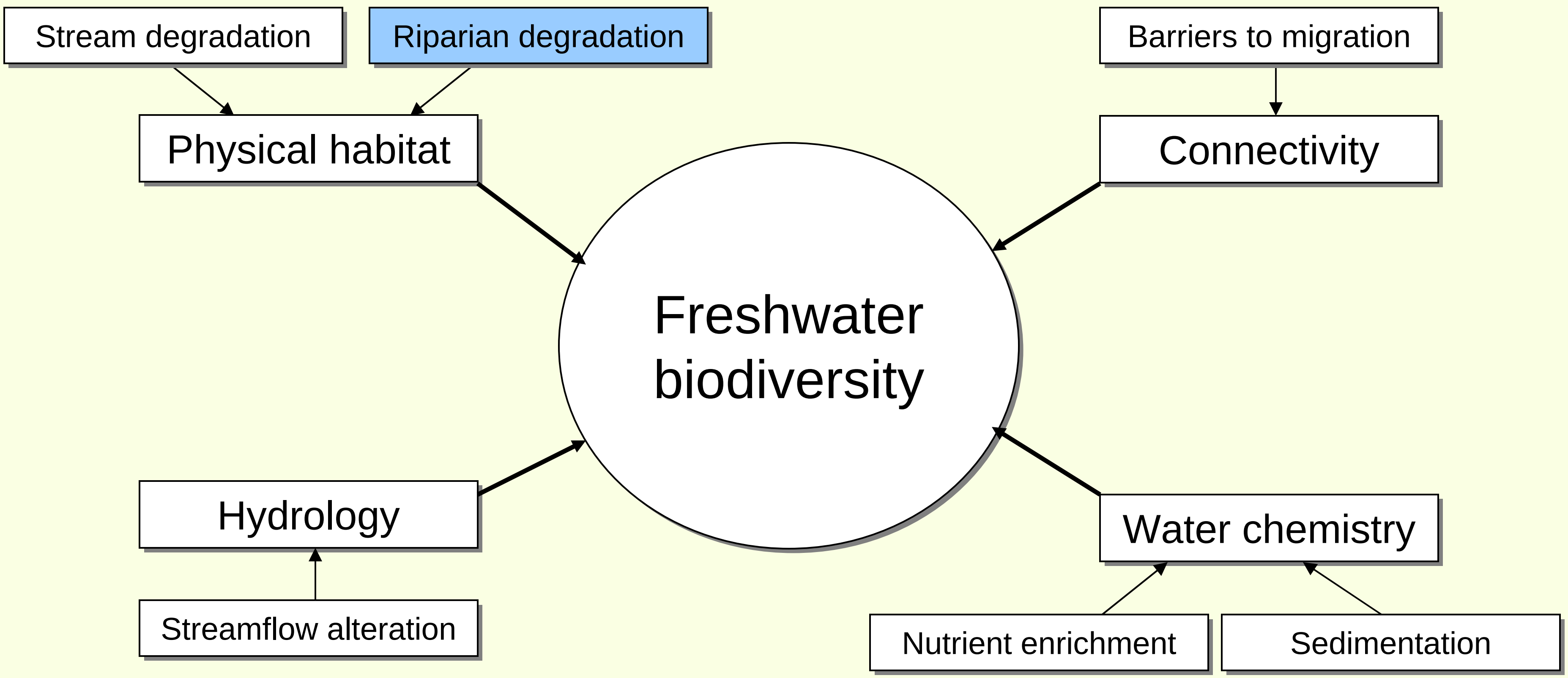
Doug Carlson – DEC fisheries expert

- All NY watersheds
- Sept 2006

Feedback:

- Riparian degradation too sensitive – revamped whole module including many new factors and metrics

Modeled impairments



Riparian degradation

Objective: identify the condition of the riparian zone surrounding each stream segment

Improvement opportunities: decrease bank erosion, lower water temperature, and increase organic inputs and cover necessary for healthy aquatic communities

Ordinal: IAGT

- Institute for the Application of Geospatial Technology, June 2006

Feedback: use variable width riparian buffer

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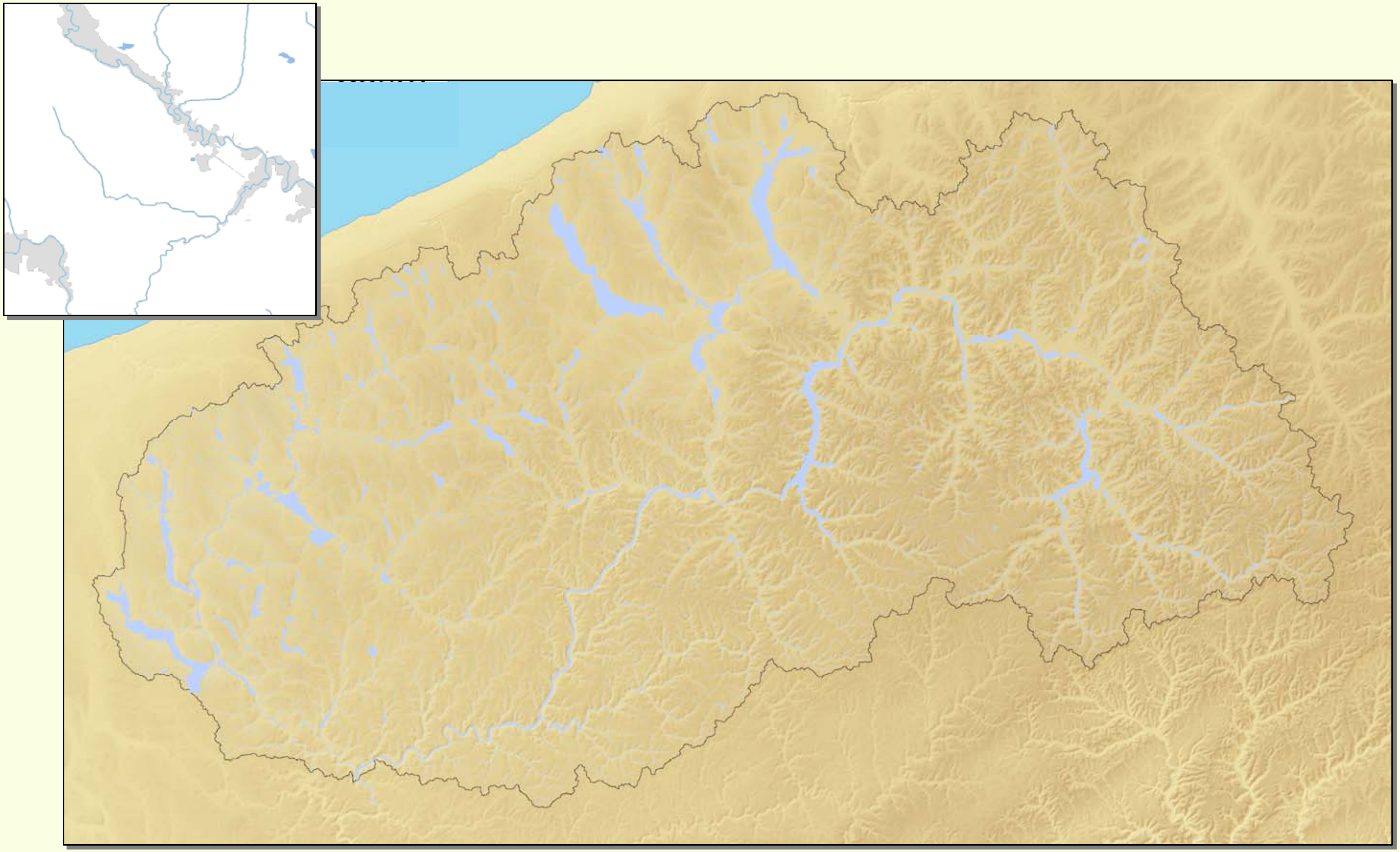
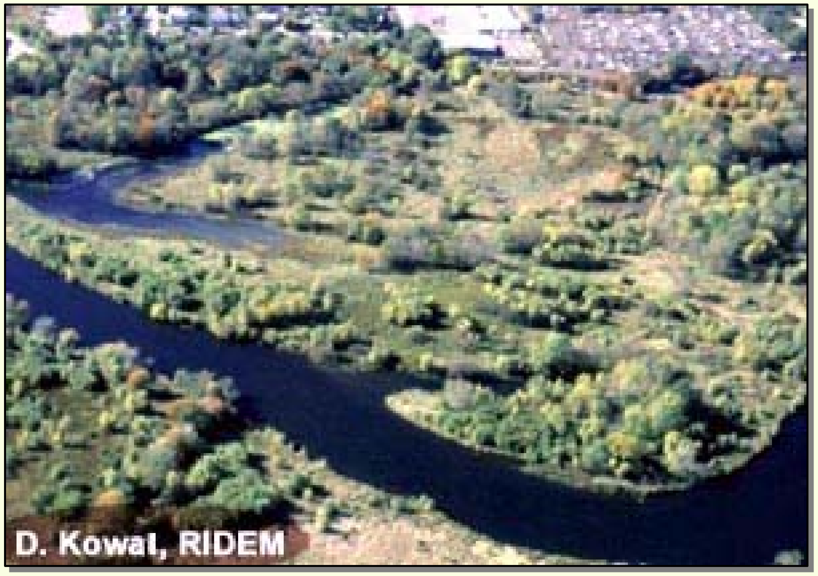
Riparian buffers

Riparian degradation



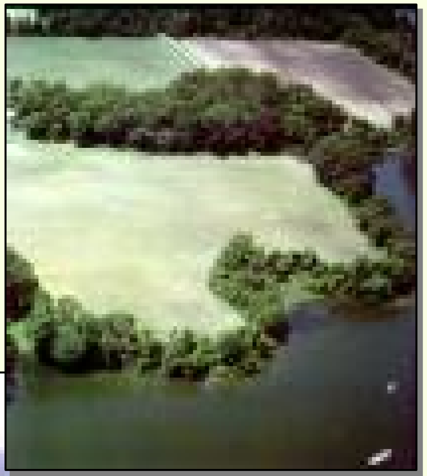
Fragmentation

- Percent urban/ag
- Percent forest
- Number of forested patches
- Mean patch density per hectare



Edge characteristics

Total forest edge



Spatial heterogeneity

Number of land use classes

Riparian degradation index

Landscape parameter	Threshold	Classification	Metric	Optimally
Fragmentation				
Percent forest cover	<47%	Poor	0.33	↑
	47-80%	Fair	0.66	
	>80%	Good	1	
Percent urban and agricultural development	>30%	Poor	0.33	↓
	10-30%	Fair	0.66	
	<10%	Good	1	
Mean patch density (#/ha)	>0.45	Poor	0.33	↓
	0.15-0.45	Fair	0.66	
	<0.15	Good	1	
Number of forest patches	>4	Poor	0.33	↓
	2-4	Fair	0.66	
	1	Good	1	
Spatial heterogeneity				
Number of land use classes	>2	Poor	0.33	↓
	1-2	Fair	0.66	
	1	Good	1	
Edge characteristics				
Total forest edge (km)	>21	Poor	0.33	↓
	15-21	Fair	0.66	
	<15	Good	1	

Riparian degradation categories	Riparian degradation index
Poor	0.33
Fair	> 0.33 and $\leq$ 0.66
Good	> 0.66

Ordinal: Tug Hill

- Tug Hill Commission – management experience
- Jefferson Soil and Water Conservation District - with field experience (2)
- DEC - stewardship biologist & fish biologist
- Chemung County Upper Susquehanna Coalition

- Sandy Creek watershed
- December 2006

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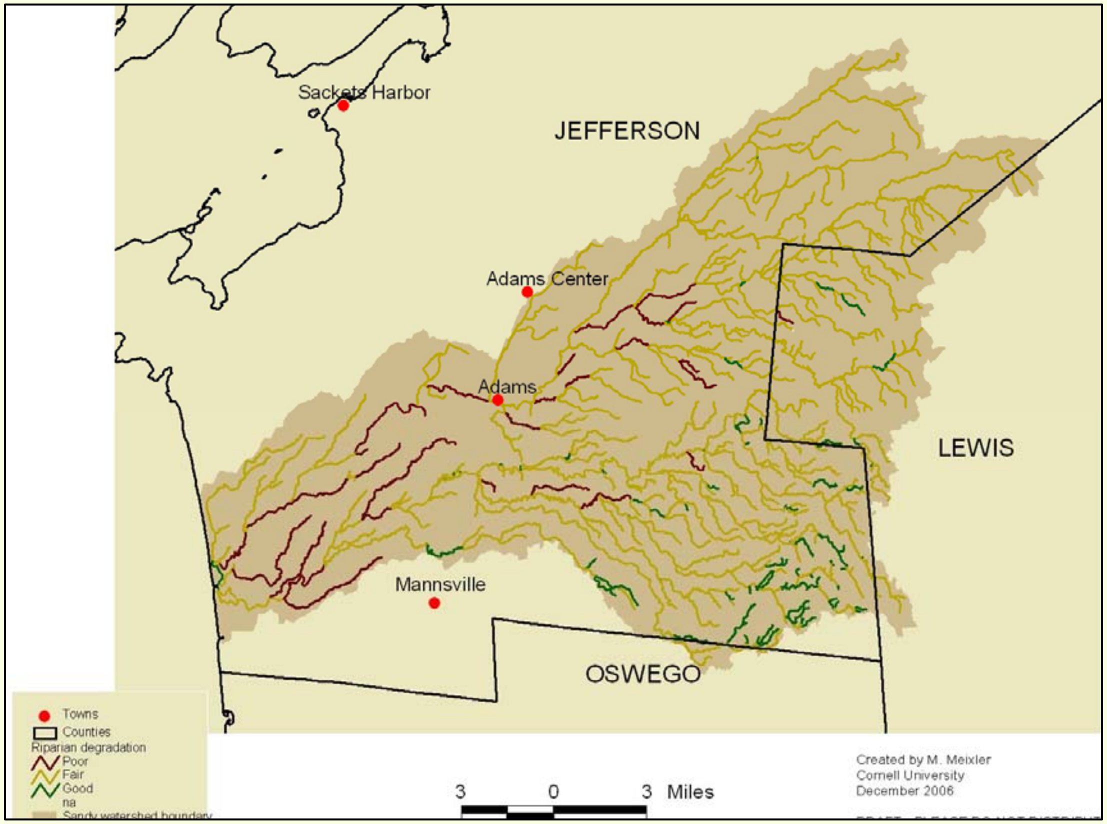
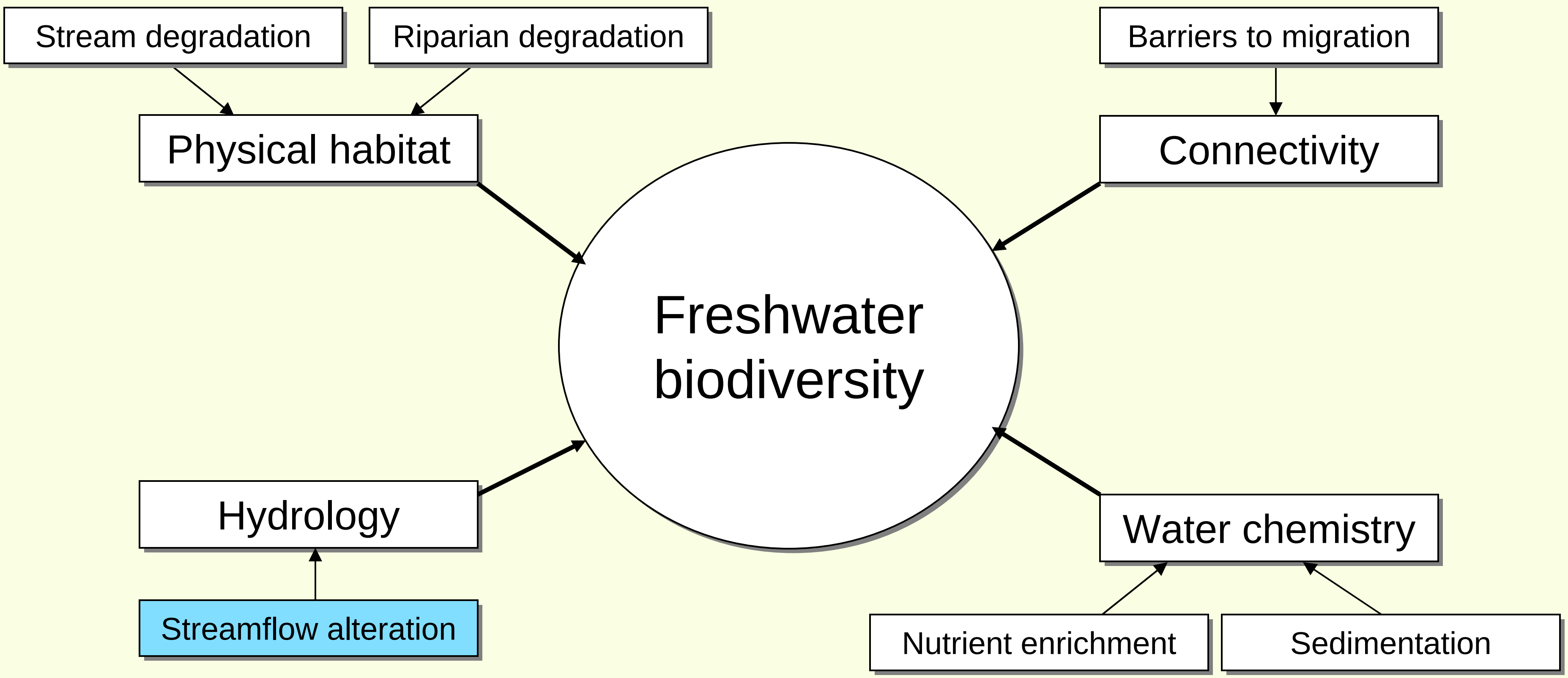
Ordinal: Tug Hill



"East is different kind of agriculture than to the west. East is transitional ag – large blocks of forest. East of Adams should be fairly good quality wildlife habitat and good trout habitat."

Modeled impairments



Ordinal: NYDEC

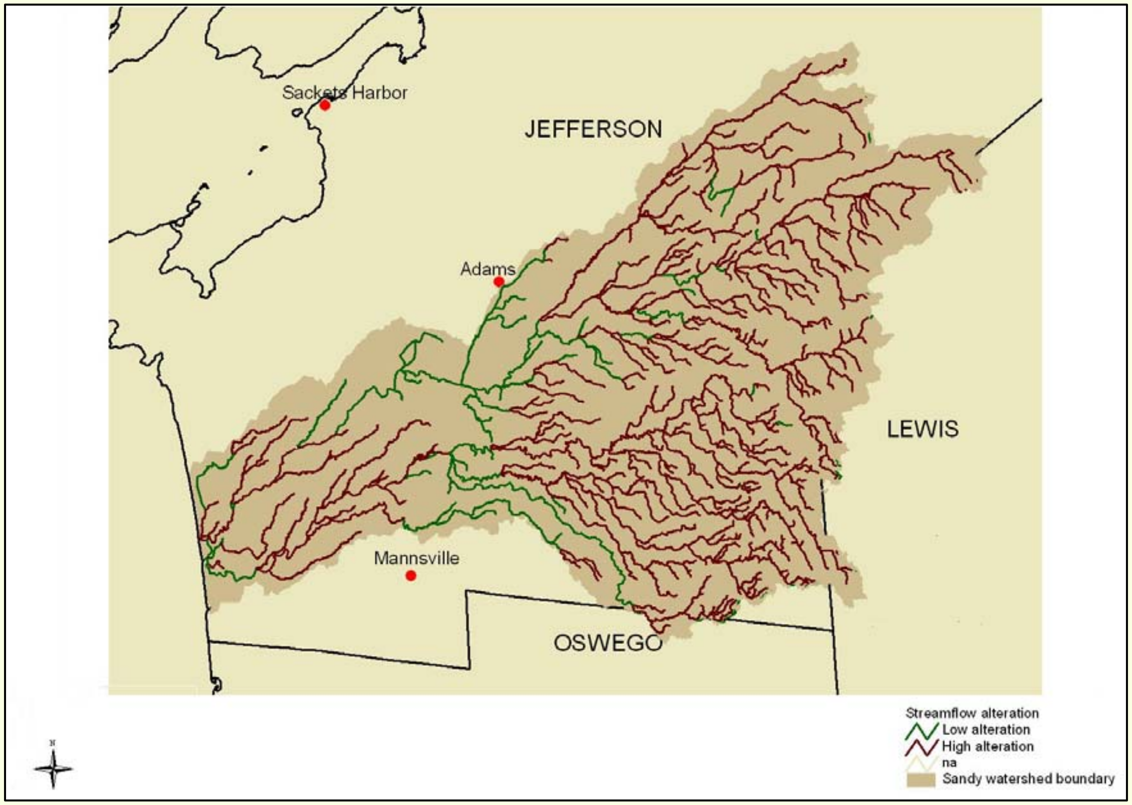
Doug Carlson – DEC fisheries expert

- All NY watersheds
- Sept 2006

Feedback:

- Streamflow alteration too sensitive

Ordinal: Tug Hill



"Variable stream flow is accurate for east. Between dams is green. It is lower gradient in that area. In the east rain comes out of Tug Hill fast. Lake effect – flashy episodes.

Best one of them all."

Changed thiessen polygons to Inverse Distance Weighting for climate data and made cutoff more robust

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Flow alteration

Stream flow alteration

Objective: mapping the degree of alteration from natural flow for each stream segment

Improvement opportunities : increase ecological integrity & biological diversity, improve water quality, and experience less frequent and less intense flooding

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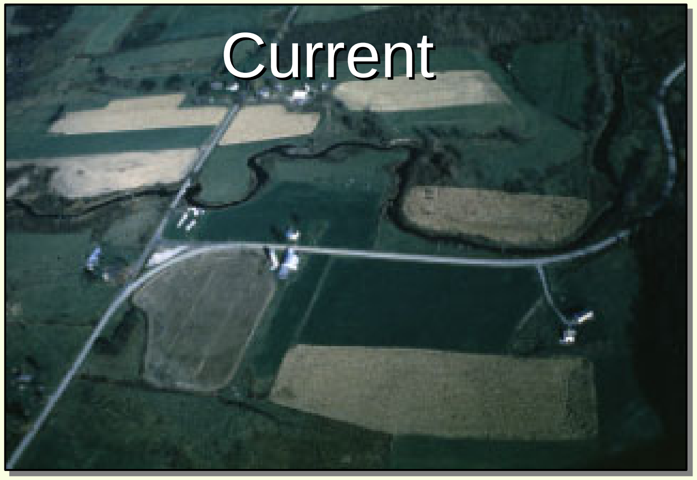
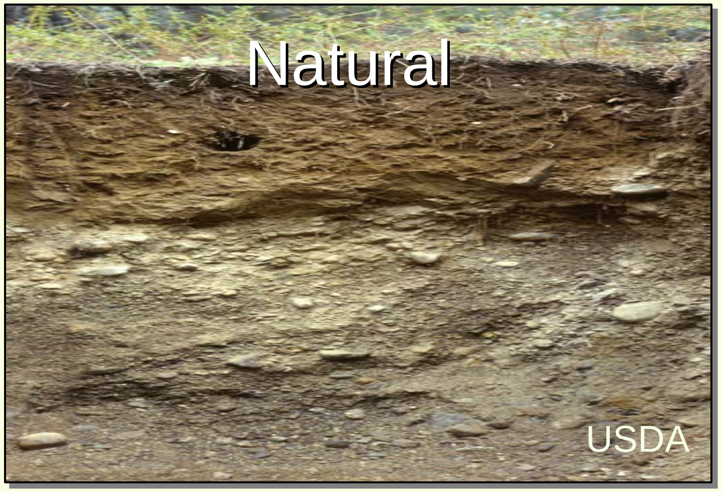
Current and natural conditions

Flow alteration

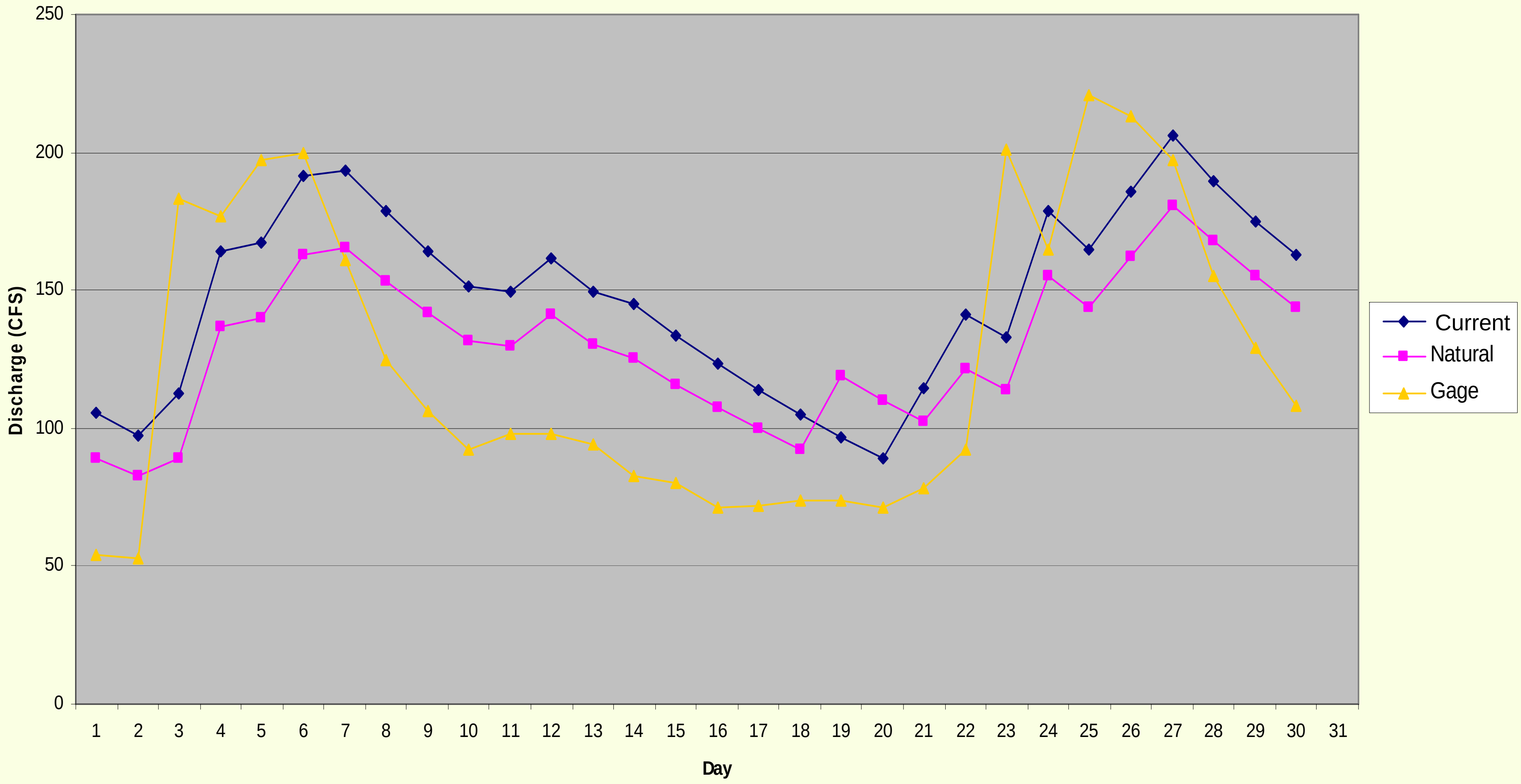
Land use



Soils

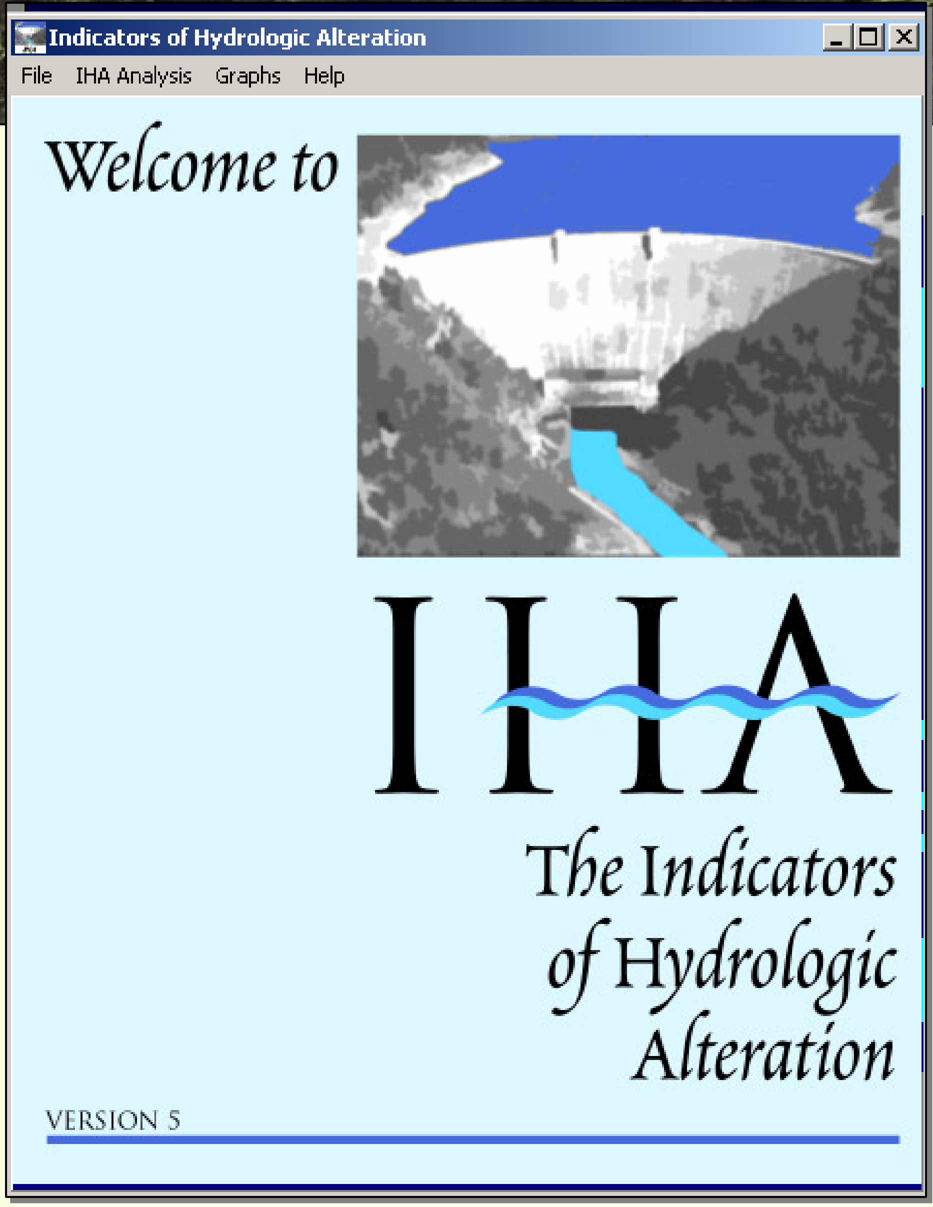


Flow model



250
200
150
100
50
0
Discharge (CFS)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Day
Current
Natural
Gage

Compares daily current and natural flows over a period of time to determine which factors indicate greatest hydrologic alteration



33 IHA factors

- Monthly averages
- Magnitude of annual extremes (1- to 90-day highs and lows)
- Timing of annual extremes
- Frequency & duration of high & low pulses
- Rates of flow changes
- Frequency of flow reversals
- Base flow index

Chosen IHA parameters

One day maximum
Fall rate

Regression equation variables
(R-sq: 91%, 95%)

Runoff coefficients

Cover coefficients

Temperature

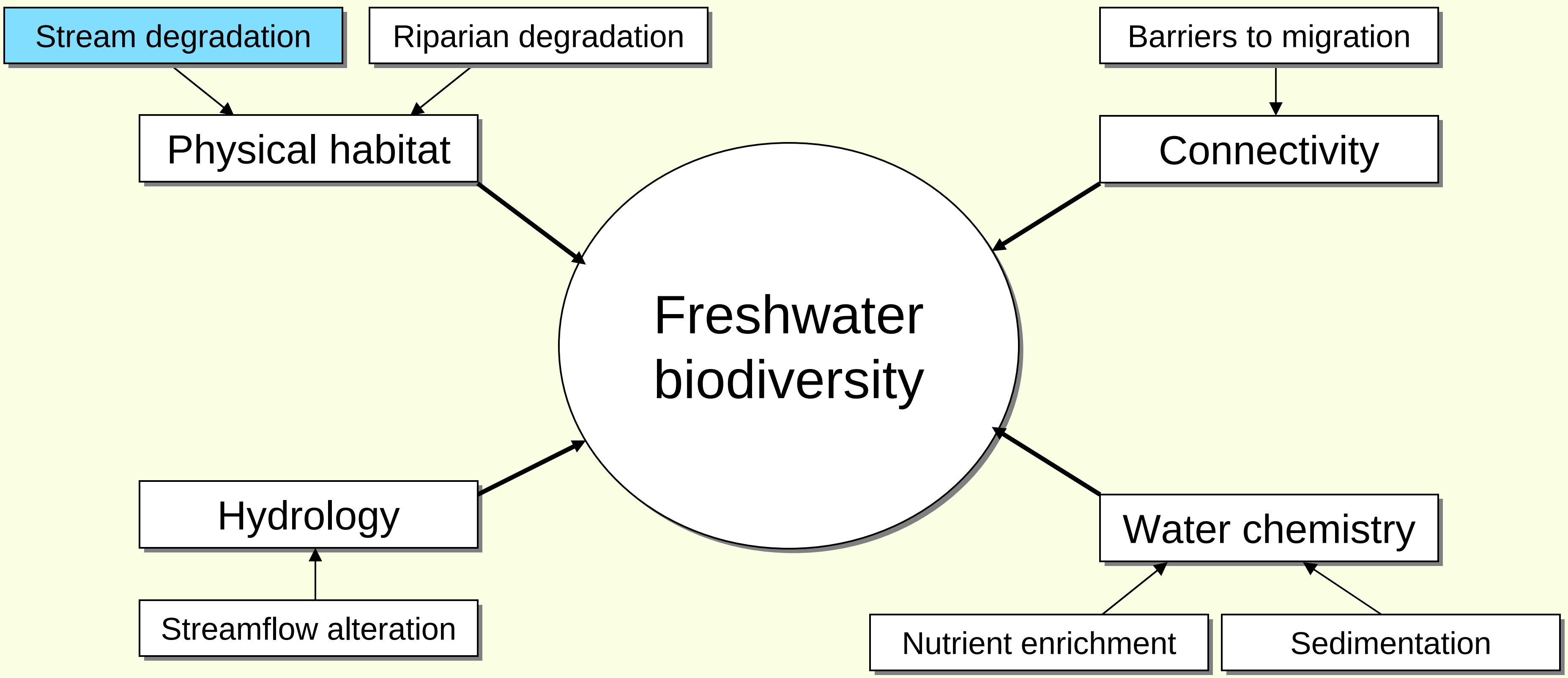
Precipitation

Stream flow alteration

Used logistic regression to classify streams into low or high alteration categories with a better than chance accuracy

Streamflow alteration rating		**Stream is classified into category with highest value given by the equations below**
Low alteration		-1.16+(12.33*onedmax)+(-30.54*fallrate)
High alteration		-172.91+(194.06*onedmax)+(13.13*fallrate)

Modeled impairments



Ordinal: NYDEC

Doug Carlson – DEC fisheries expert

- All NY watersheds
- Sept 2006

Feedback:

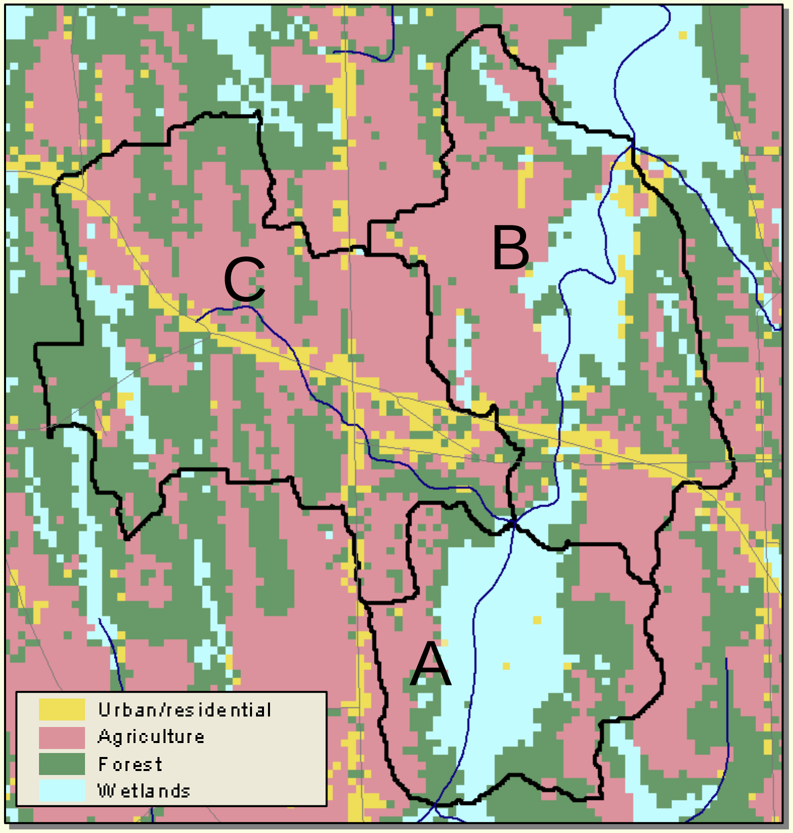
- Habitat degradation looks accurate

Stream degradation

Objective: To identify degradation in the valley and floodplain of each stream segment

Improvement opportunities: improve habitat for fish and invertebrates

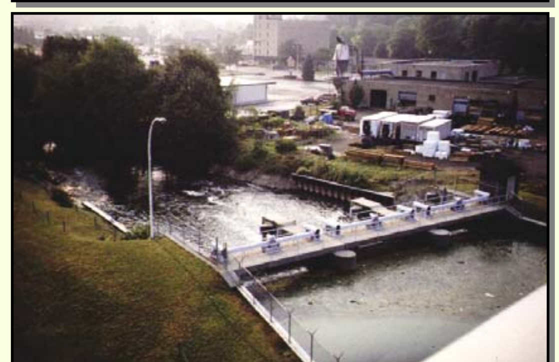
Anthropogenic disturbance



A
Intact

B Moderate

C
Highly
impacted



Anthropogenic disturbance index

Anthropogenic disturbances	Criteria	Score
Urban	> 30%	1
	10-30%	0.5
	< 10%	0
Agricultural	> 50%	0.75
	40-50%	0.37
	< 40%	0
Forest	0-100%	0
Water	0-100%	0
Wetland	0-100%	0
Barren	0-100%	0
Road/railroad density	≥ 5%	1
	< 5%	0

Anthropogenic disturbance index =

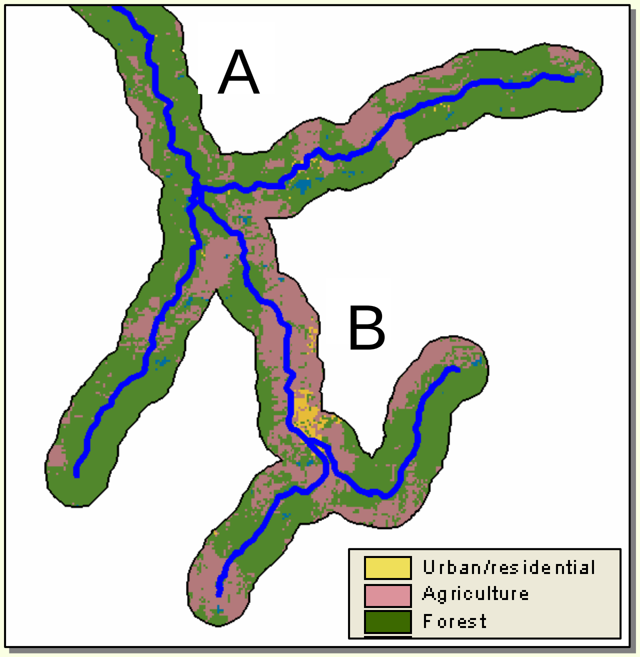
(0.8 * (urban score + ag score)) + (0.2 * (road score + railroad score))

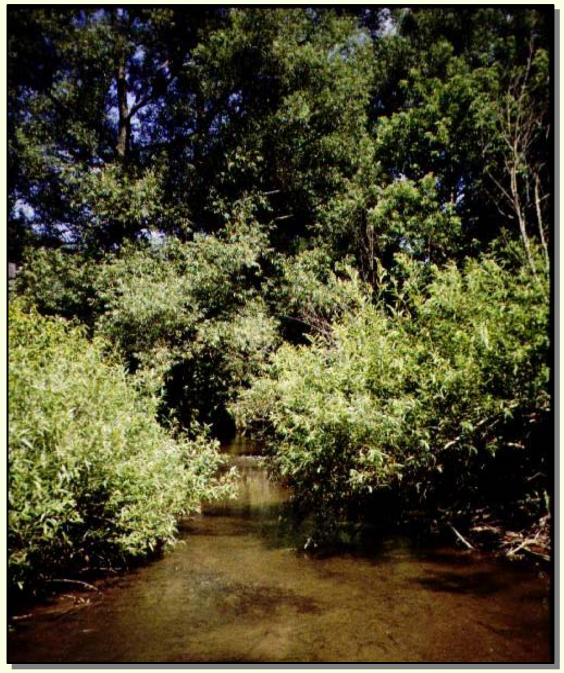
Anthropogenic disturbance categories	Anthropogenic disturbance index
Minimal	< 0.33
Moderately disturbed	0.33 - 0.66
Highly disturbed	> 0.66

Canopy density

A: Closed canopy

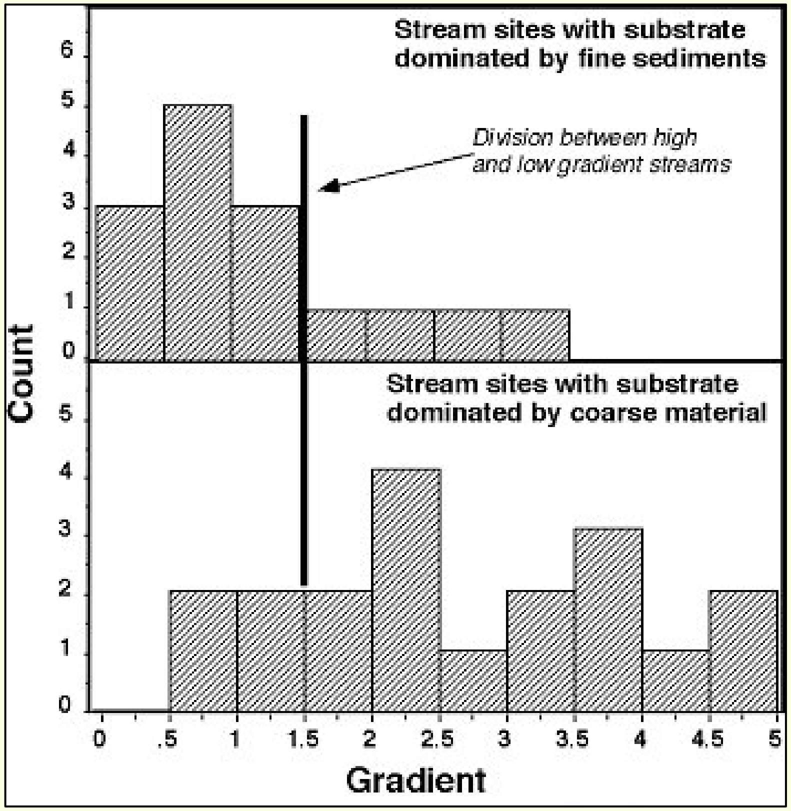
B: Open canopy





Riparian density rating	Criteria
Closed	> 28% forested riparian area
Open	≤ 28% forested riparian area

Substrate composition



Substrate composition	Criteria
Fine sediment	<1.5
Coarse sediment	$\geq$1.5

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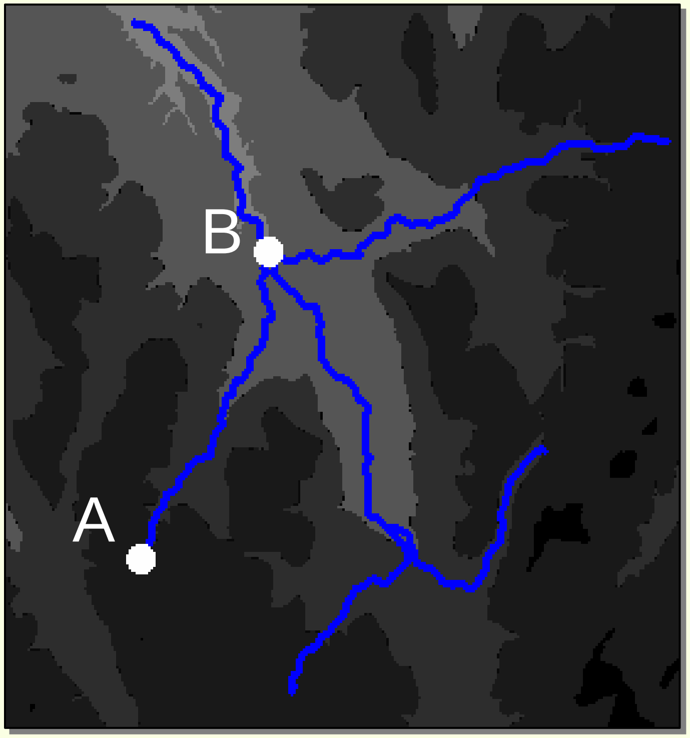
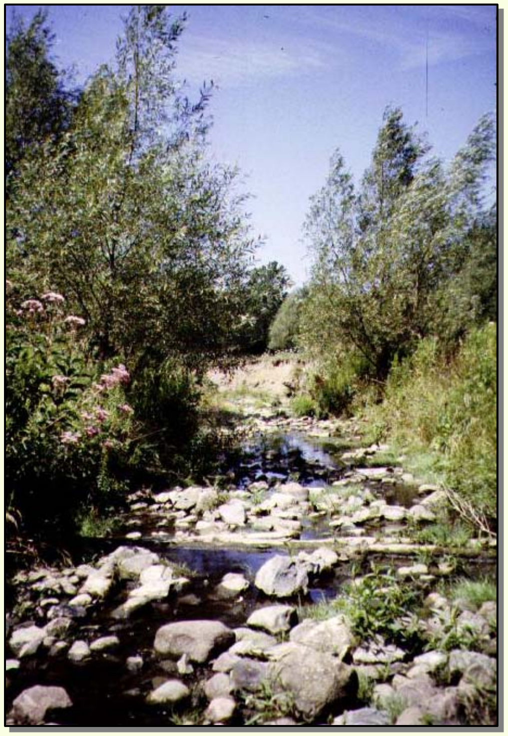
Substrate composition

Stream degradation



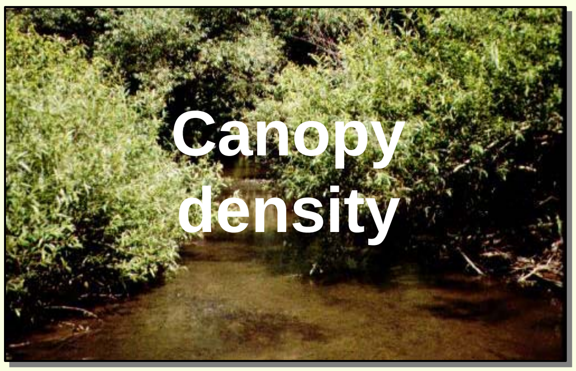
Low gradient Fine substrate	High gradient Coarse substrate



Stream degradation

Optimal scenario

Minimal



Closed

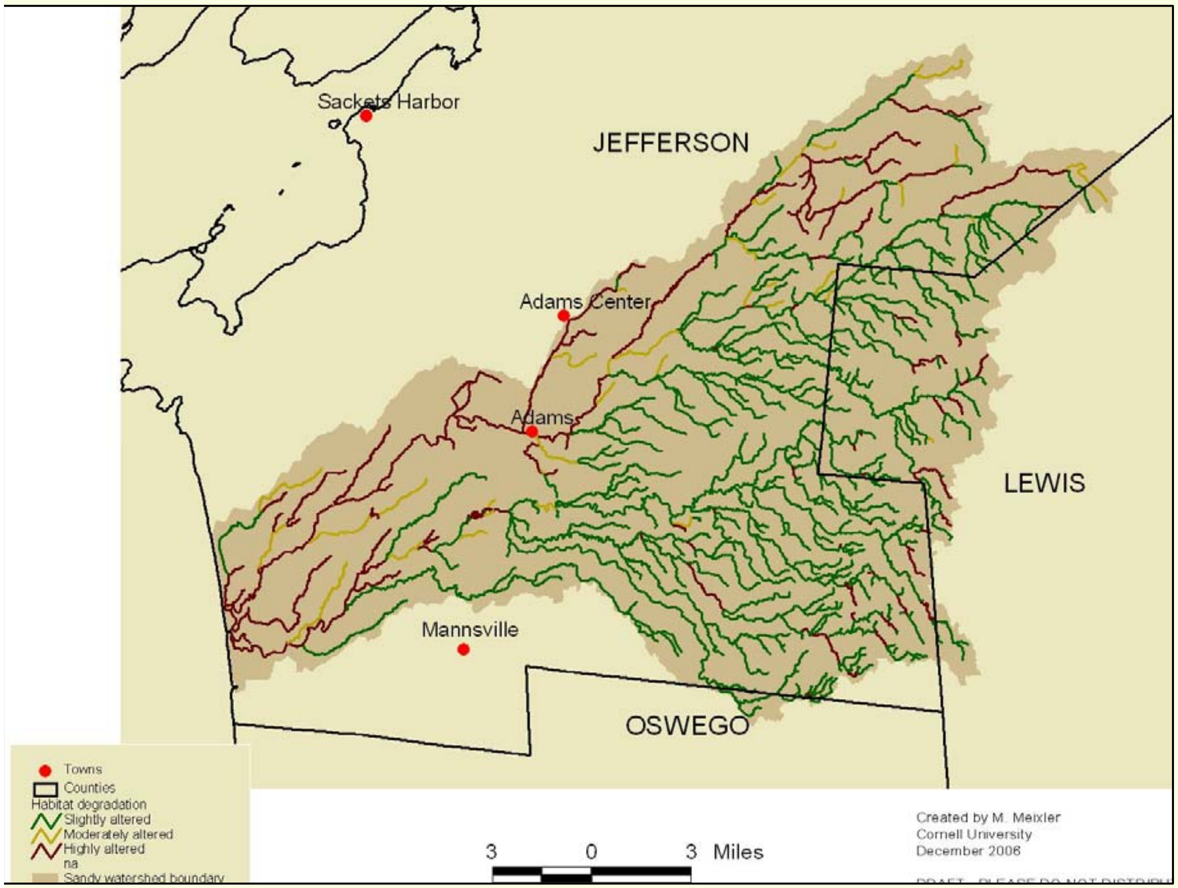
Coarse

Poor

Fair

Good

Ordinal: Tug Hill

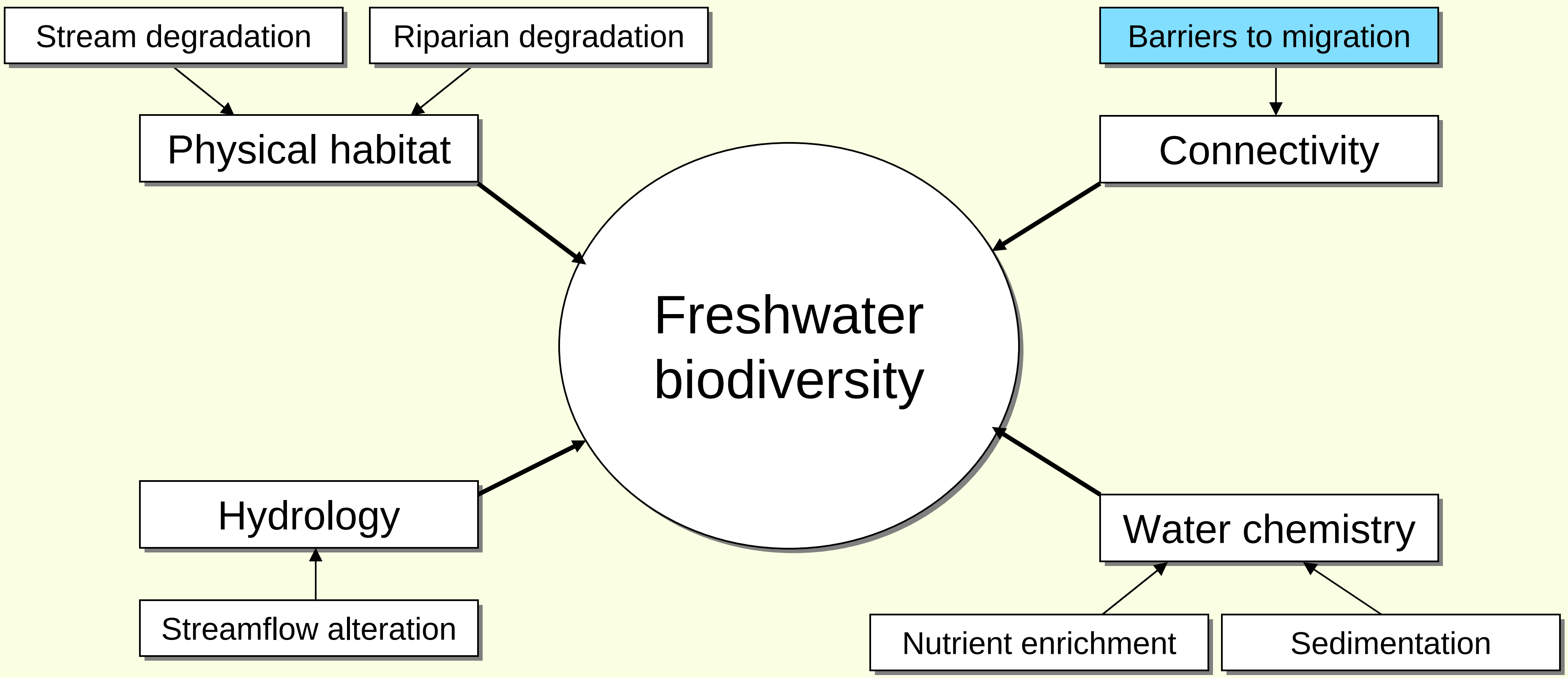


Tug Hill: East of Mannsville has no ground disturbance or change in area in years other than mowing hay. No significant development in that area.

Downstream reaches & to the west and south of Adams is heavy agriculture. Those areas have lots of land clearing particularly hedgerows and streambank clearing and more straightening and ditching.

Moderately altered from Mannsville to Adams.

Modeled impairments



Ordinal: NYDEC

Doug Carlson – DEC fisheries expert

- All NY watersheds
- Sept 2006

Feedback:

- Barriers to migration: Steelhead (rainbow trout) get to Adams in Sandy Creek (yes, they go up to exactly Adams, no further)
- No migratory salmonids in upper Genesee (right, they are blocked in lower Black Creek)

Barriers to migration

Objective: Identify extent of streams block to fish movement
Improvement opportunities: increased connectivity to fish spawning habitat

Migrating fish

White sucker

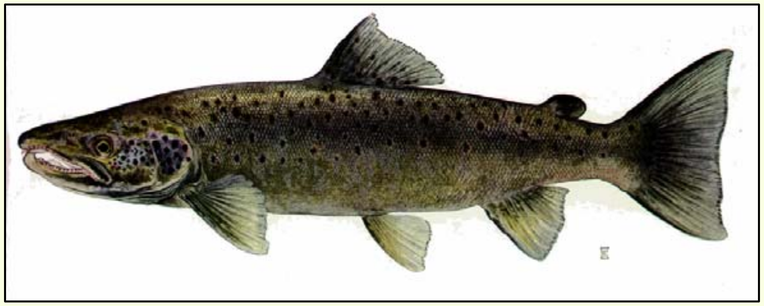
Spring migrator

Jumping height	0.6 m
Darting speed	3.43 m/s
Body length	0.38 m

Atlantic salmon

Fall migrator

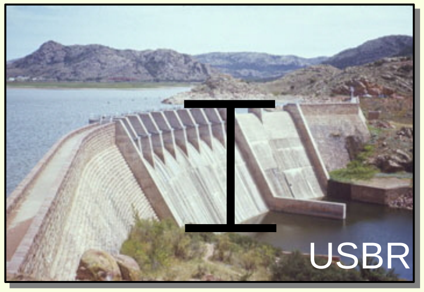
Jumping height	3.3 m
Darting speed	4.95 m/s
Body length	0.55 m



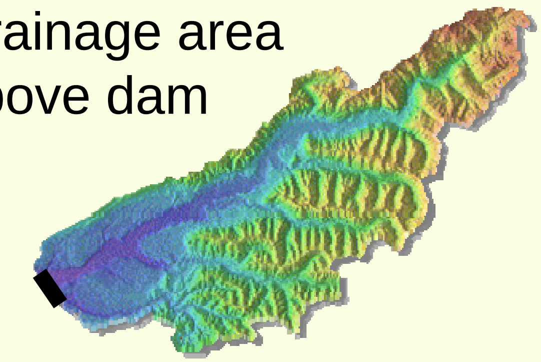
Barriers data

Known information

Dam height



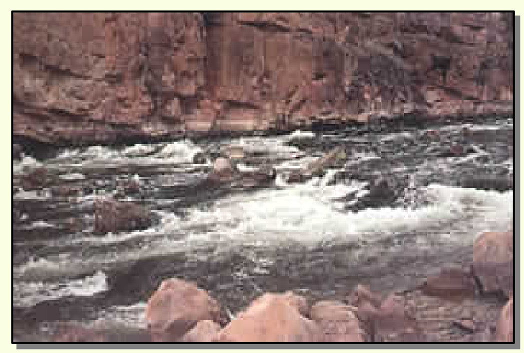
Drainage area above dam



Modeled information

Plunge pool depth
in spring and fall

Velocity
in spring and fall



Which dams are barriers?

1) Is the maximum jumping height of the fish higher than the structure?

2) Is the darting speed of the fish faster than the water velocity?

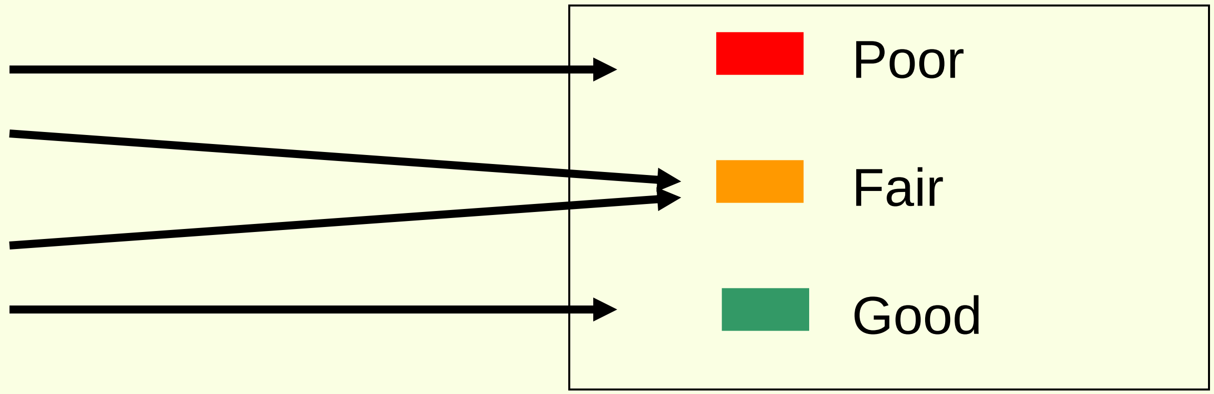
3) Is the plunge pool depth greater than the length of the fish?

If all three are "Yes", then the structure is not a barrier

Barriers to migration

Categories

- Always blocked
- Blocked in fall
- Blocked in spring
- Never blocked



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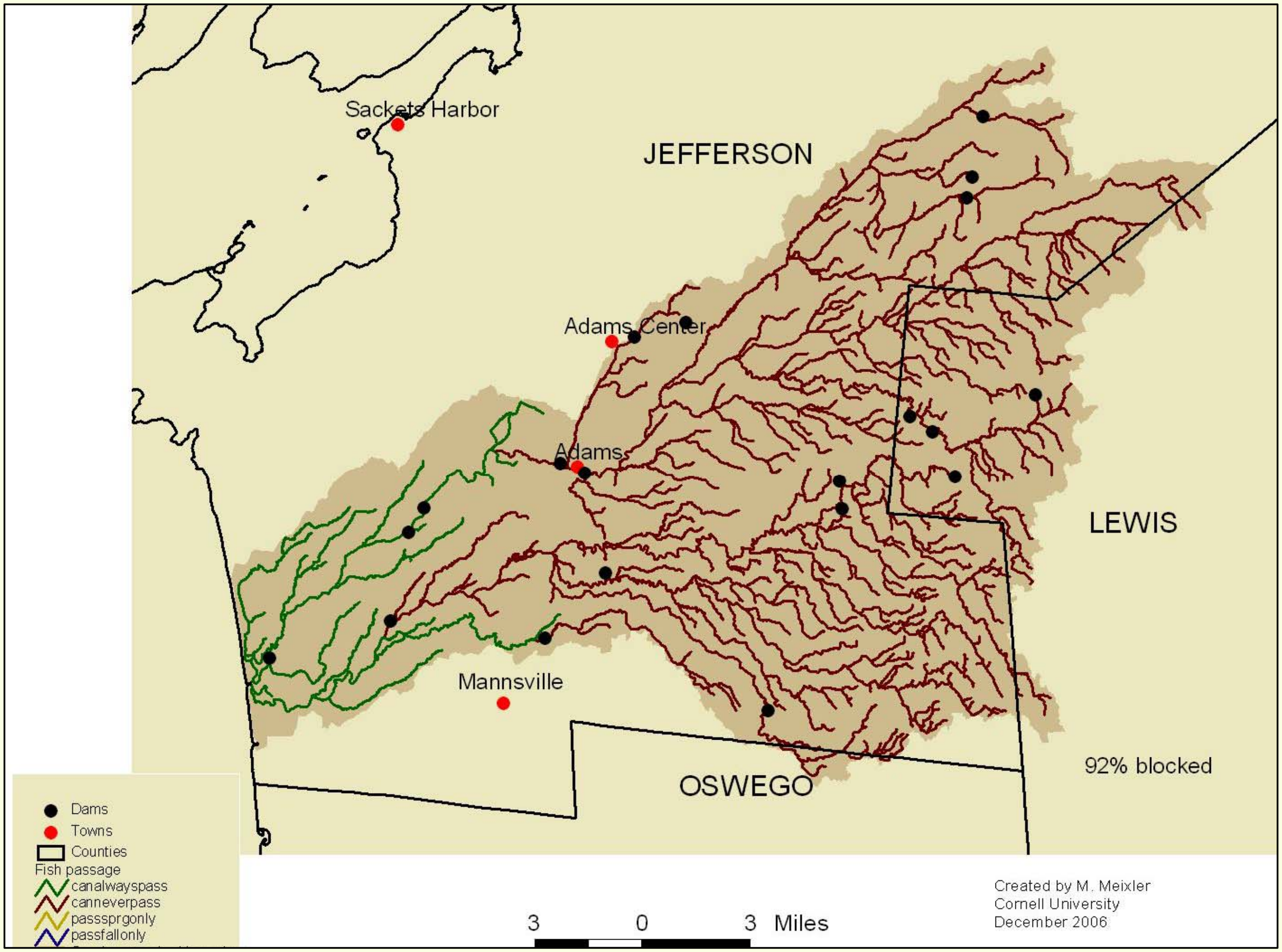
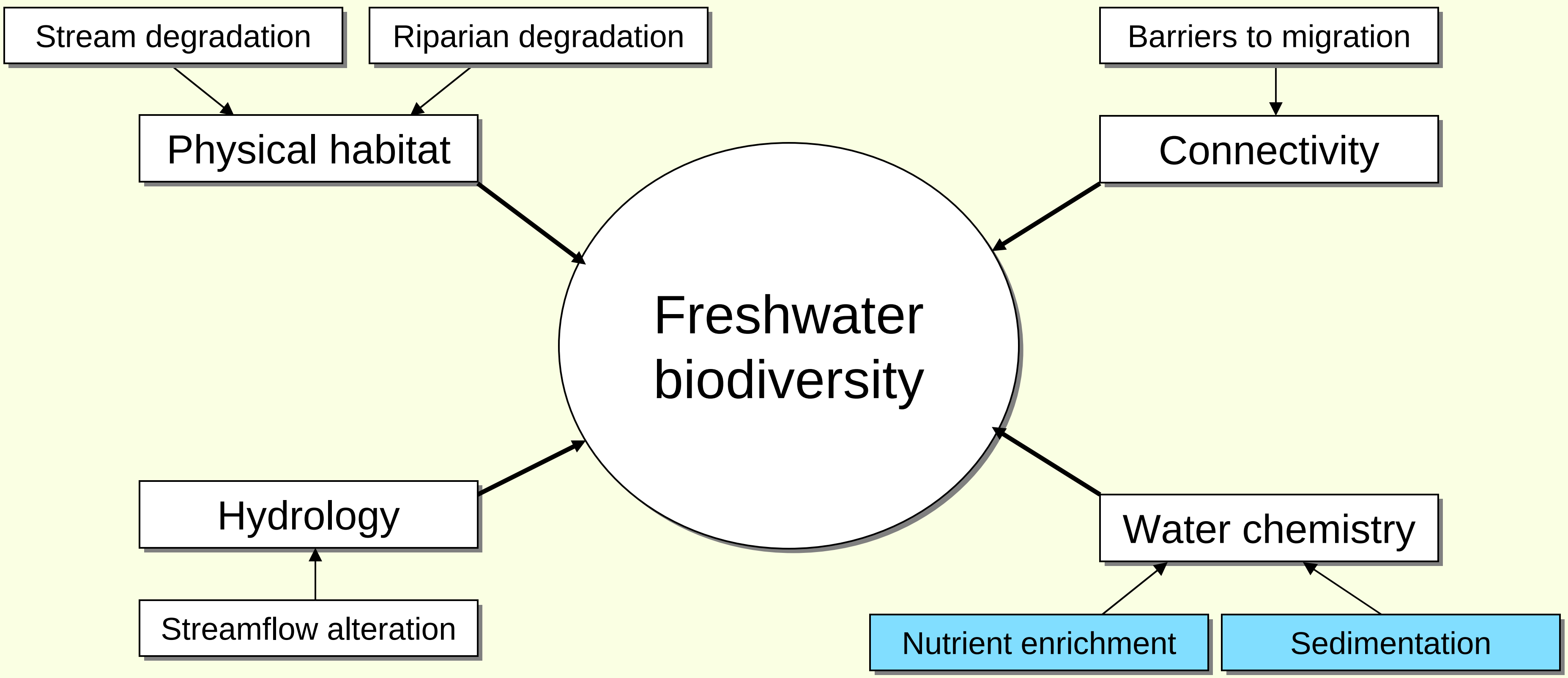
Ordinal: Tug Hill



"Looks accurate."

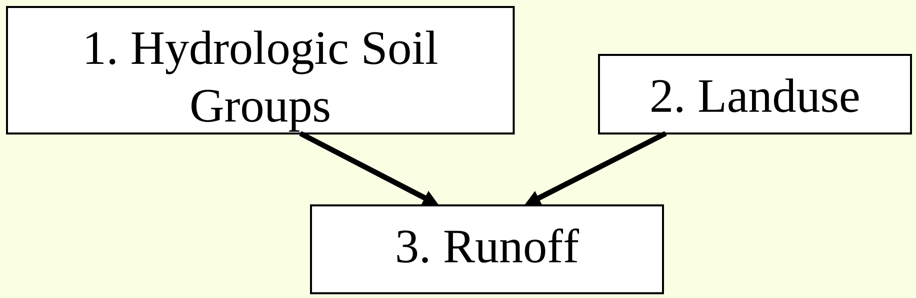
Modeled impairments



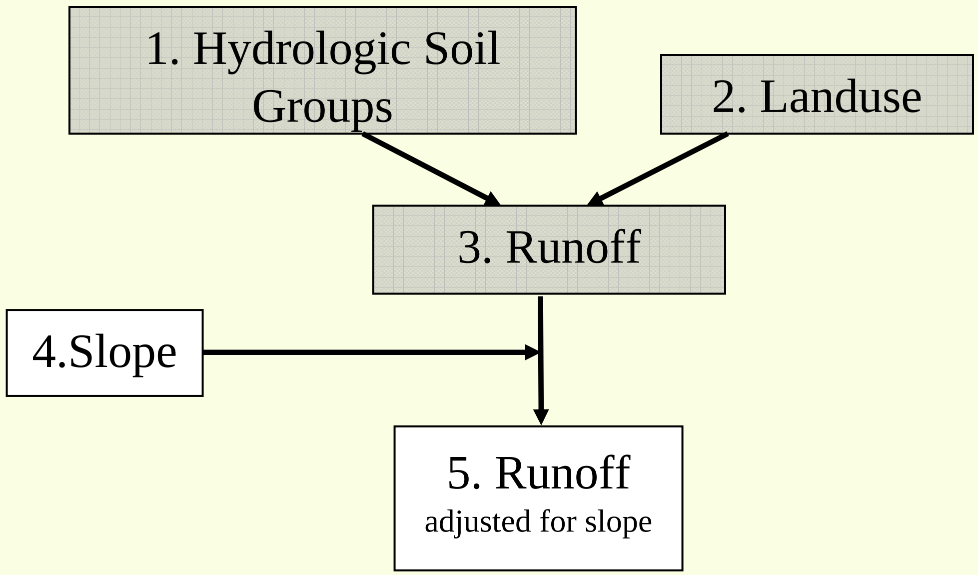
Nutrient enrichment & sedimentation

Objective: estimating the nutrient and sediment load that will end up in stream reaches given physical characteristics, climatic conditions, and land use practices in the study watersheds

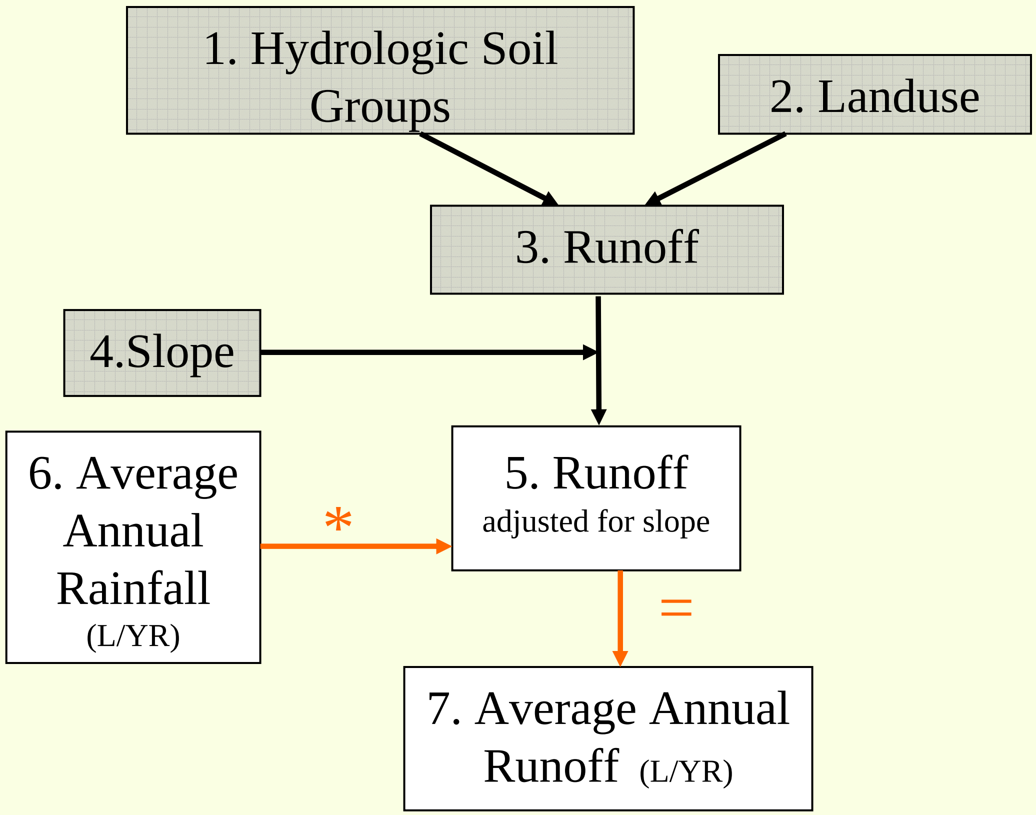
Improvement opportunities: improve water quality and increase biotic diversity

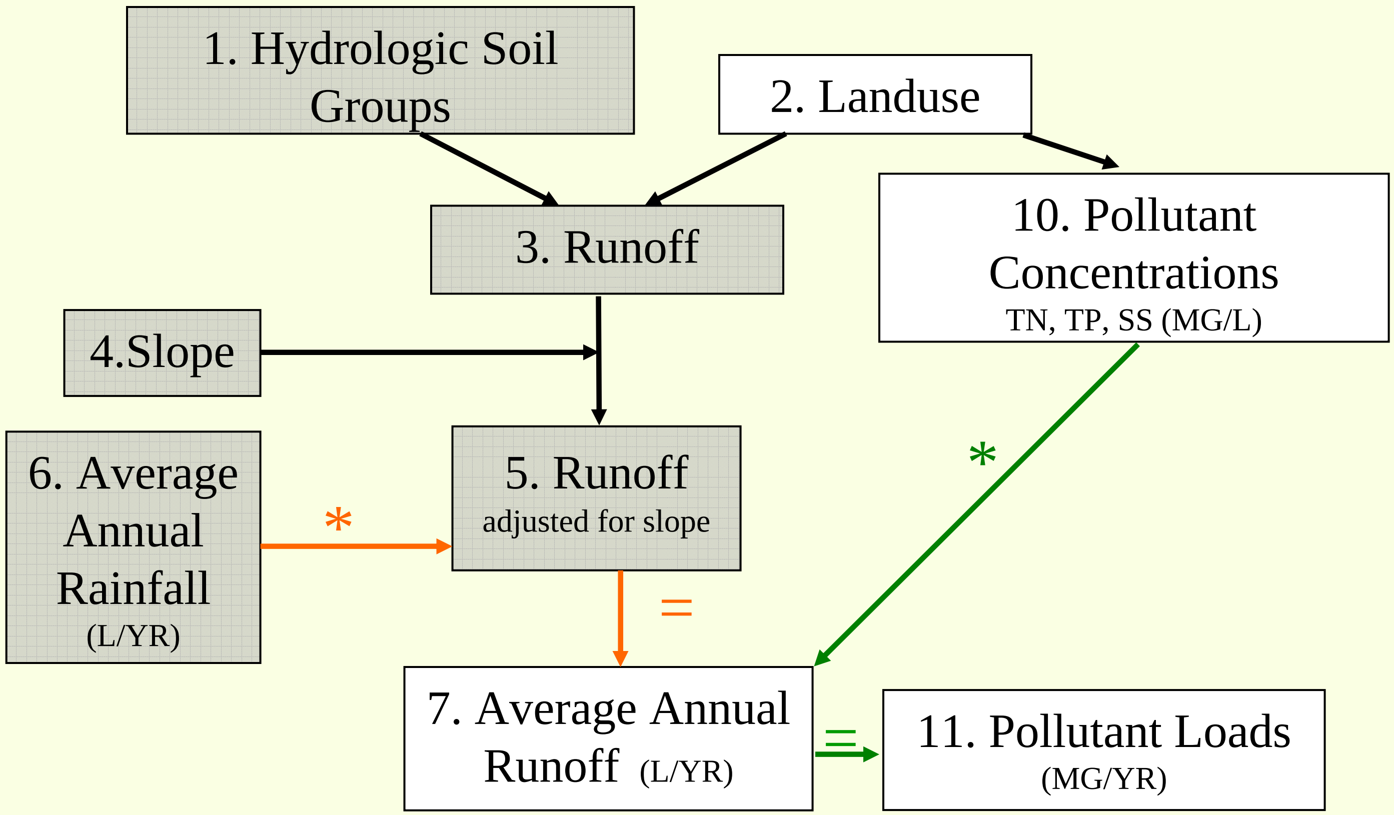


RCN VALUES				
	Hydrologic soil groups			
Land use type	**A**	**B**	**C**	**D**
Urban/residential	0.4	0.48	0.55	0.63
Agriculture	0.15	0.23	0.32	0.4
Forest	0.045	0.1	0.127	0.14
Water	0	0	0	0
Wetland	0.5	0.5	0.5	0.5
Barren	0.2	0.3	0.4	0.5



Percent rise	**Slope effect coefficients**
< 2	0.6
2-8	0.7
8-15	0.8
> 15	1

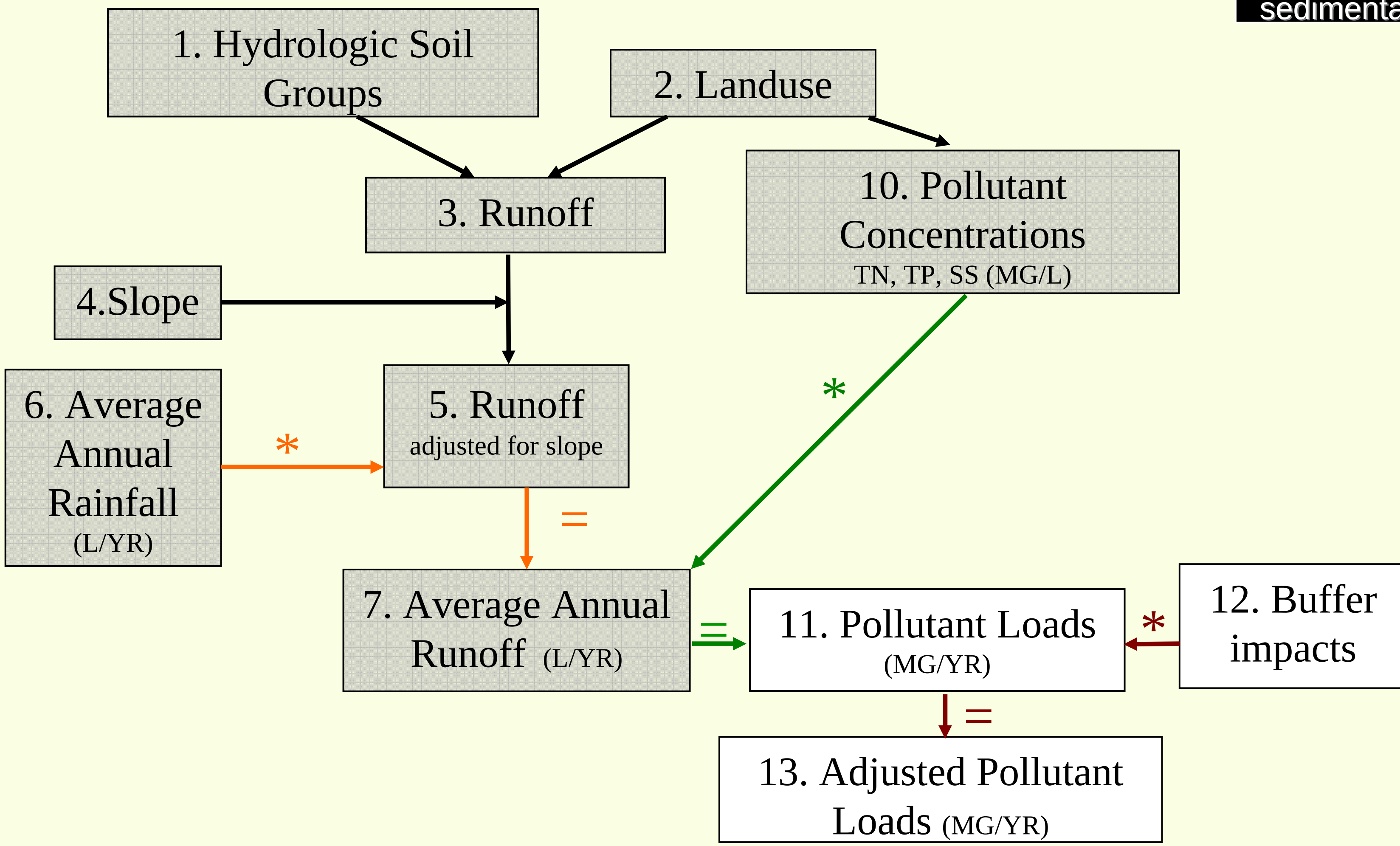

1. Hydrologic Soil Groups
2. Landuse
3. Runoff
4.Slope
5. Runoff
adjusted for slope
6. Average Annual Rainfall
(L/YR)
*
=
7. Average Annual Runoff (L/YR)



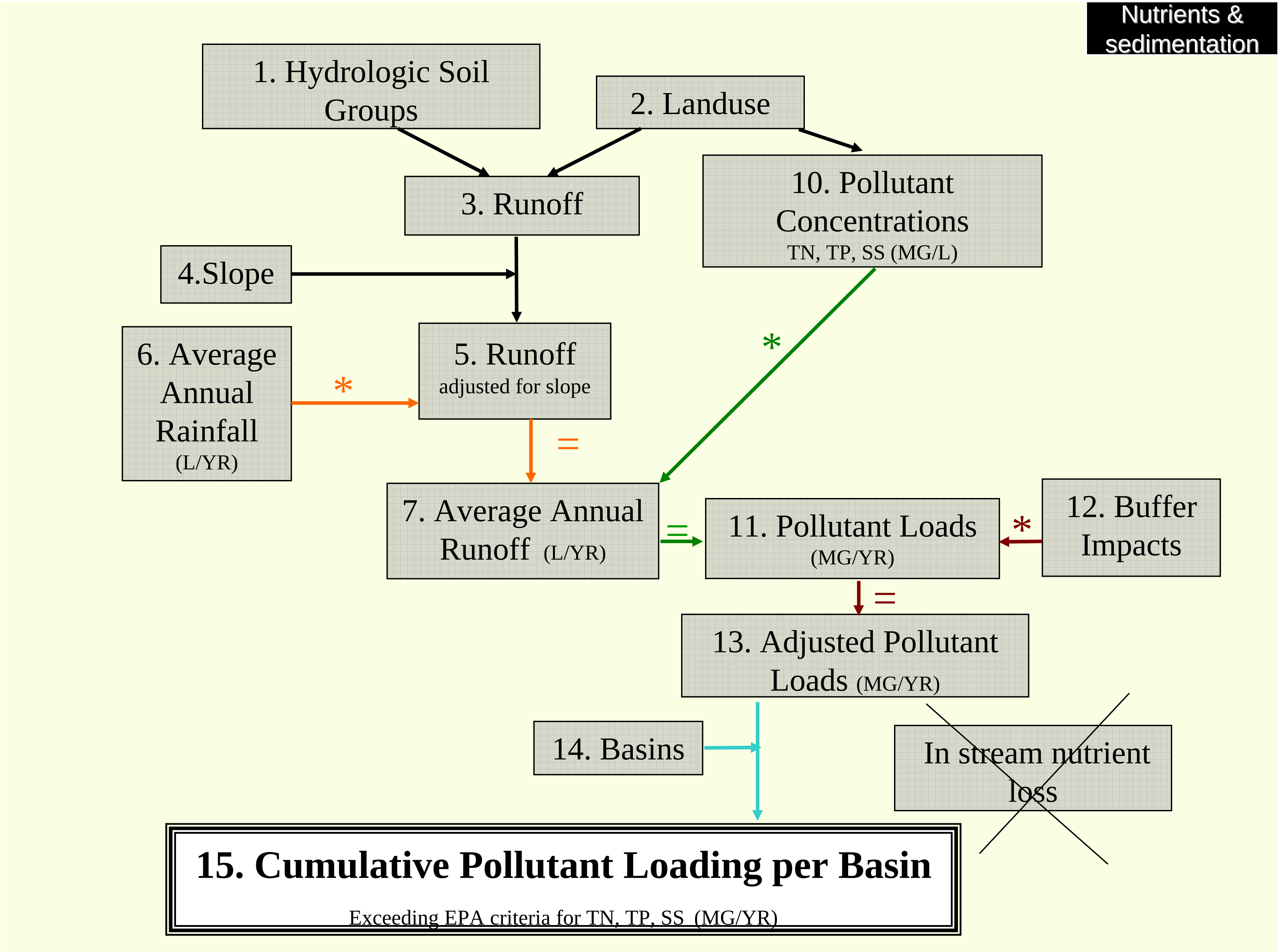
POLLUTANT CONCENTRATIONS (MG/L)

Land use type	TP	TN	SS
Urban/residential	0.15	1.18	81
Agriculture	0.34	2.32	55.3
Forest	0.04	0.5	11.1
Water	0.11	1.25	3.1
Wetland	0.19	1.6	10.2
Barren	0.15	1.18	93.9

Nutrients & sedimentation



Based on average width of forest in riparian zone


Nutrients & sedimentation
1. Hydrologic Soil Groups
2. Landuse
3. Runoff
10. Pollutant Concentrations
TN, TP, SS (MG/L)
4.Slope
*
6. Average Annual Rainfall
(L/YR)
*
5. Runoff
adjusted for slope
=
7. Average Annual Runoff (L/YR)
=
11. Pollutant Loads
(MG/YR)
*
12. Buffer Impacts
=
13. Adjusted Pollutant Loads (MG/YR)
14. Basins
~~In stream nutrient loss~~
15. Cumulative Pollutant Loading per Basin
Exceeding EPA criteria for TN, TP, SS (MG/YR)

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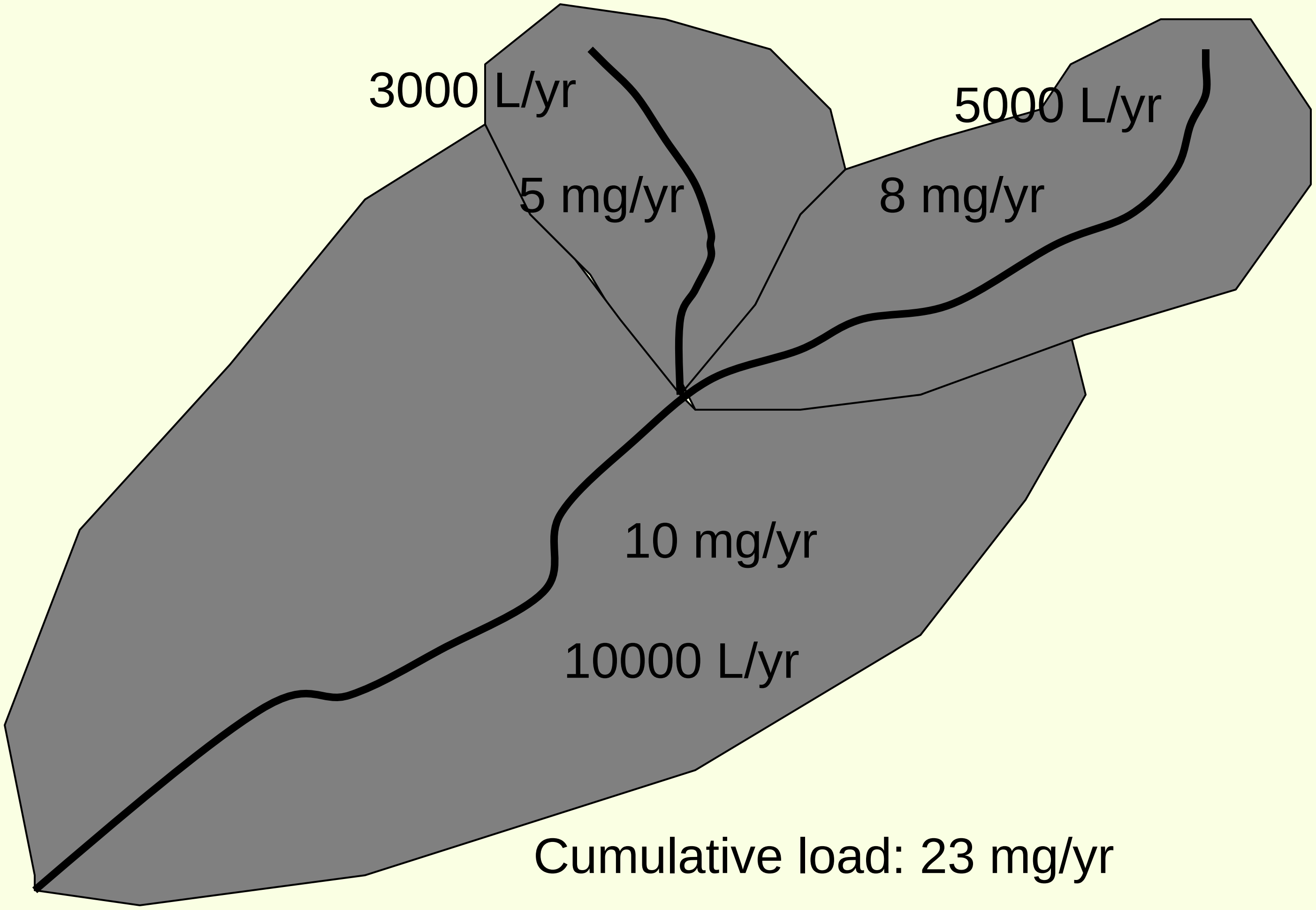
Cumulative loadings



Cumulative load: 23 mg/yr

Cumulative runoff: 18000 L/yr

Cumulative concentration: 0.001 mg/L

Nutrient enrichment & sedimentation

EPA CRITERIA VALUES

Pollutant	Value (mg/L)
TN	0.54
TP	0.033
SS	30

Concentration of TP, TN or SS

- Above EPA criteria level → Poor
- Within EPA criteria level → Good

Ordinal: Other exposure

- Threats to the Upper Allegheny Basin - TNC (Dec 2006)
- Using GIS to identify impairments in the Lake Ontario watershed, AFS meeting (Sep 2006)
- Lake Ontario improvement opportunity assessment modeling – Tug Hill, NYS Dept of State, IAGT (June 2006)

Methodological

- Close consultation with Professors Bain and Loucks at Cornell (throughout project)

  Advice: Add community capacity information; use statistical methods for classifying results (i.e. genetic algorithm)

- Seminar on methods to the Environmental and Water Resources Systems Analysis Group at Cornell (March 2007)

  Advice: put results on a 0-1 continuous scale

- Institute for the Application of Geospatial Technology

  Advice: variable width riparian buffer

Quantitative: Bode data

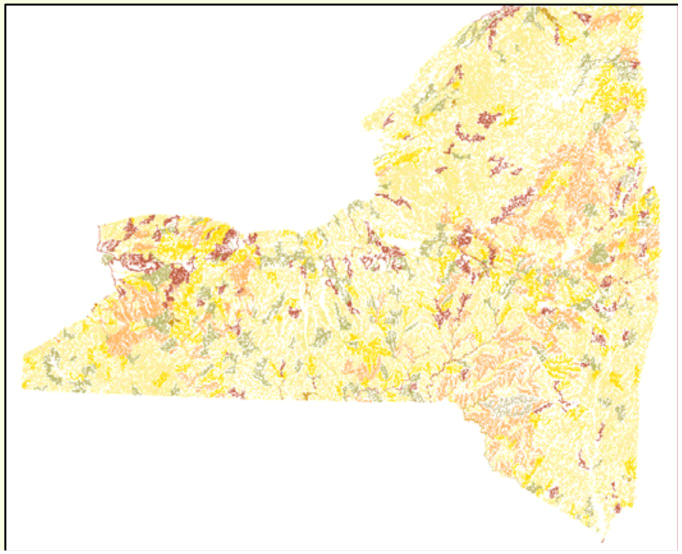
Black Creek:	9 sites	1%
Lakeshore Marshes:	4 sites	<1%
Salmon River:	8 sites	1%
Sandy Creek:	9 sites	<1%

Quantitative: Priority Waterbody List (NYDEC)

- The Waterbody Inventory/Priority Waterbodies List is...

  A statewide inventory (database) of New York State surface waters which characterizes water quality, the degree to which a waterbody supports its designated uses, and progress toward the identification and resolution of water quality problems, pollutants, and sources.

- Same resolution streams



Quantitative: Priority Waterbody List

- No Known Impacts: Segments where monitoring data and information indicate that there are ***no use restrictions or other water quality impacts/issues***.

- Threatened: Waterbodies for which uses are not restricted and ***no water quality problems currently exist, but where specific land use or other changes in the surrounding watershed are known or strongly suspected of threatening water quality***.

- Minor Impacts: Waterbodies where ***less severe water quality impacts are apparent*** but uses are still considered fully supported.

- Impaired Segments: Waterbodies with ***well documented water quality problems*** that result in precluded or impaired uses.

Quantitative: Priority Waterbody List

Checked PWL against combined nutrient enrichment and sediment data:

Sediment/TP/TN

Good	Good	Good	=	Good
Good	Good	Bad	=	Good
Good	Bad	Bad	=	Bad
Bad	Bad	Bad	=	Bad

PWL

No known impacts	=	Good
Threatened	=	N/A
minor impacts	=	Bad
Impaired	=	Bad

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Quantitative: Priority Waterbody List

	% matched
Sandy Creek	80.06%
Salmon River	99.15%
Black Creek	99.3%
Lakeshore marshes	99.5%

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Quantitative: Priority Waterbody List

	Lakeshore marshes	Sandy	Salmon	Black
No known impacts	N/A	9%	N/A	<1%
Threatened	N/A	N/A	N/A	N/A
Minor impacts	24%	36%	N/A	23%
Impaired	N/A	N/A	13%	55%
Unassessed /Needs verif	76%	55%	87%	21%

Hydroecological tool: enhancements and results

Quantitative: RIBS

New York State Department of
Environmental Conservation

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Routine Statewide Monitoring Program

More information from this division:

Division of Water
Bureau of Water Assessment and Management

Related information:

Statewide Monitoring and Assessment Schedule

The bureau is responsible for the routine monitoring of the waters of the state to allow for the determination of the overall quality of waters, trends in water quality, and identification of water quality problems and issues. This monitoring effort is coordinated through the Rotating Integrated Basin Studies (RIBS) Program. Specific component monitoring programs include Stream Biomonitoring, Lake Classification and Inventory, Citizens Statewide Lake Assessment Program (CSLAP)

A number of published reports and monitoring information are available.

Stream Biomonitoring Staff collects a kick sample

Rotating Integrated Basin Studies

Contact: Margaret Novak, Chief, Statewide Waters Monitoring Section
The RIBS Program represents the coordination of a number of monitoring efforts that focus on two or three of 14 drainage areas of the state each year. Components of the RIBS program include stream biomonitoring, physical/chemical monitoring, lake monitoring and evaluation, sediment sampling and toxicity testing.