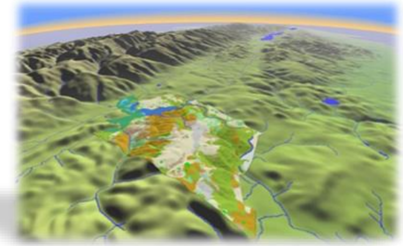
NICHOLAS SCHOOL OF THE ENVIRONMENT AND EARTH SCIENCES
DUKE UNIVERSITY



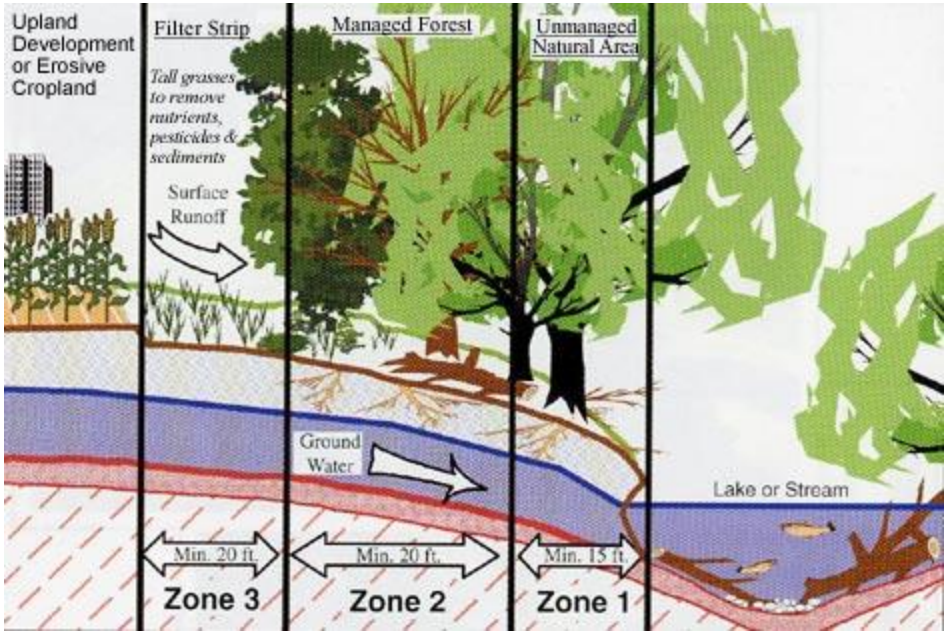
ENVIRON 761:
Elevation, Terrain & Ecology
Part 3: Modeling riparian buffers

Instructor: John Fay

Riparian buffering

Riparian buffers are understood to have beneficial qualities in maintaining stream water quality.

Buffers intercept many non-point source pollutants (nutrients and sediments) before they reach lakes or streams.



Riparian buffering

Central question:

How can we accurately quantify the buffering effects of forested areas on nutrient discharges?

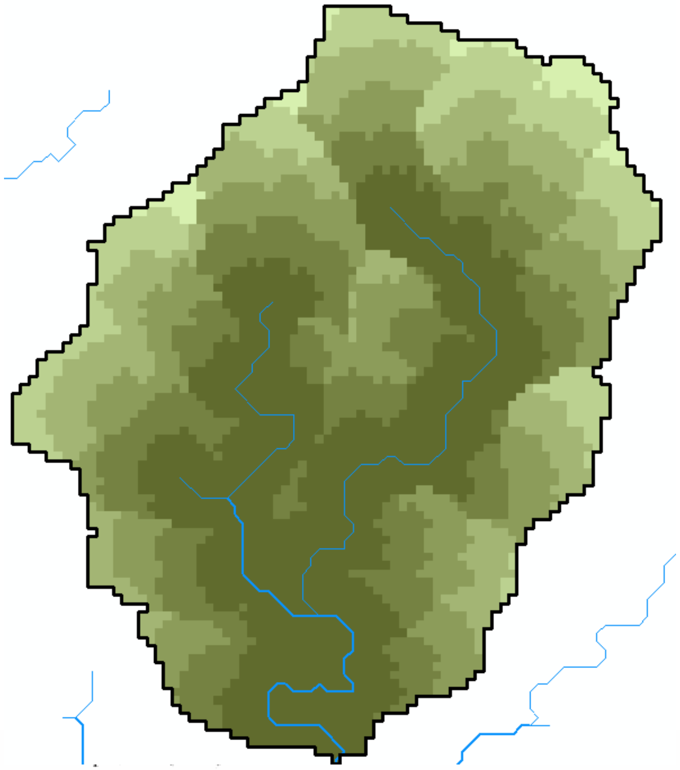
Modeling riparian buffering potential

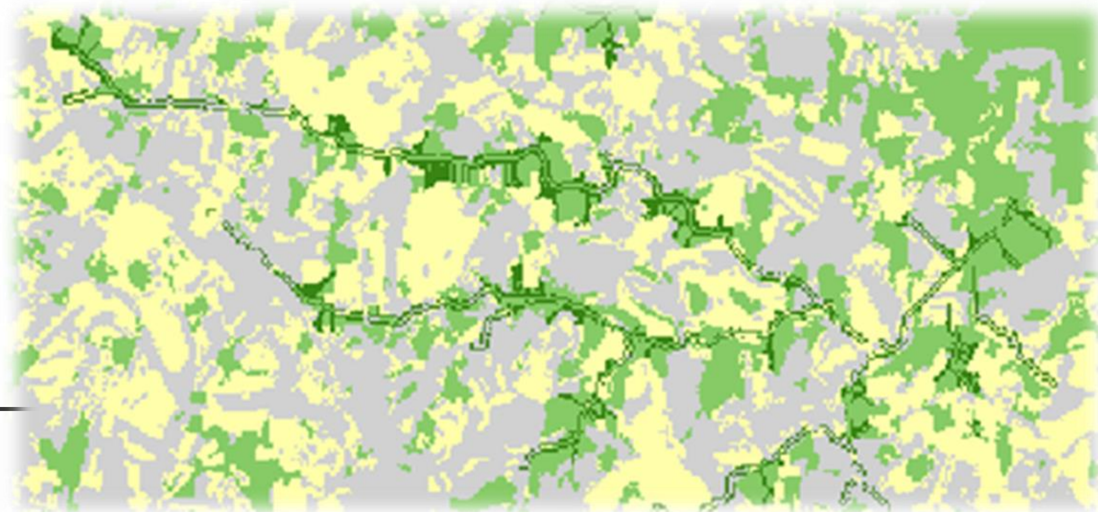
Quantifying the benefits of riparian buffers has long been limited to crude measurements:

- Calculating the ratio of non point source (NPS) cover types to buffering cover types across a catchment area…

- Or slightly better: calculating the percentage of buffering cover types with a *fixed distance of a stream*.

Modeling riparian buffering potential





DOI 10.1007/s10980-006-0020-0

RESEARCH ARTICLE

Improved methods for quantifying potential nutrient interception by riparian buffers

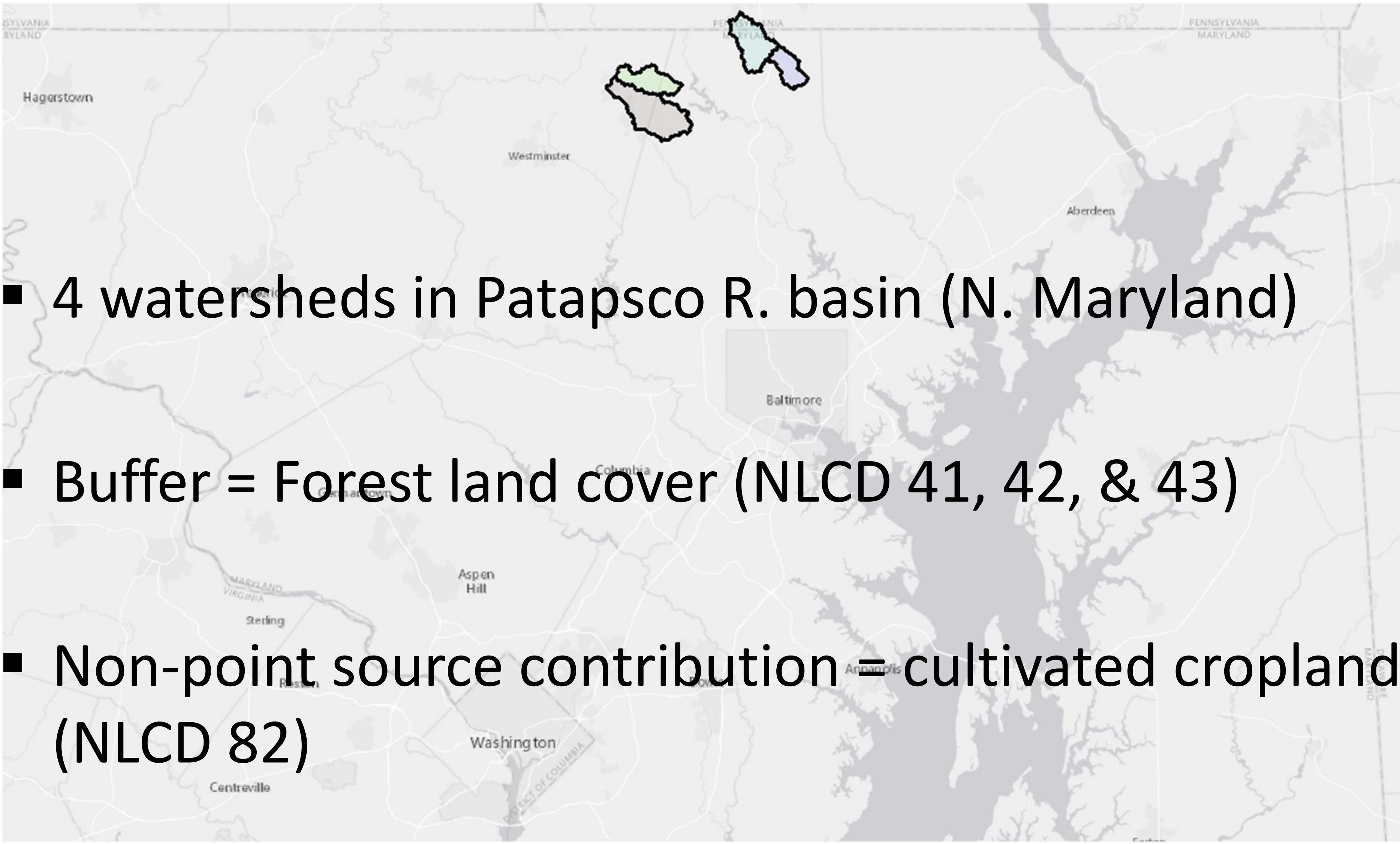
Matthew E. Baker · Donald E. Weller ·
Thomas E. Jordan

Approaches to modeling

- Catchment wide approaches…
- Fixed distance to stream approaches…
- “Unconstrained” method…
- “Flow path” method…

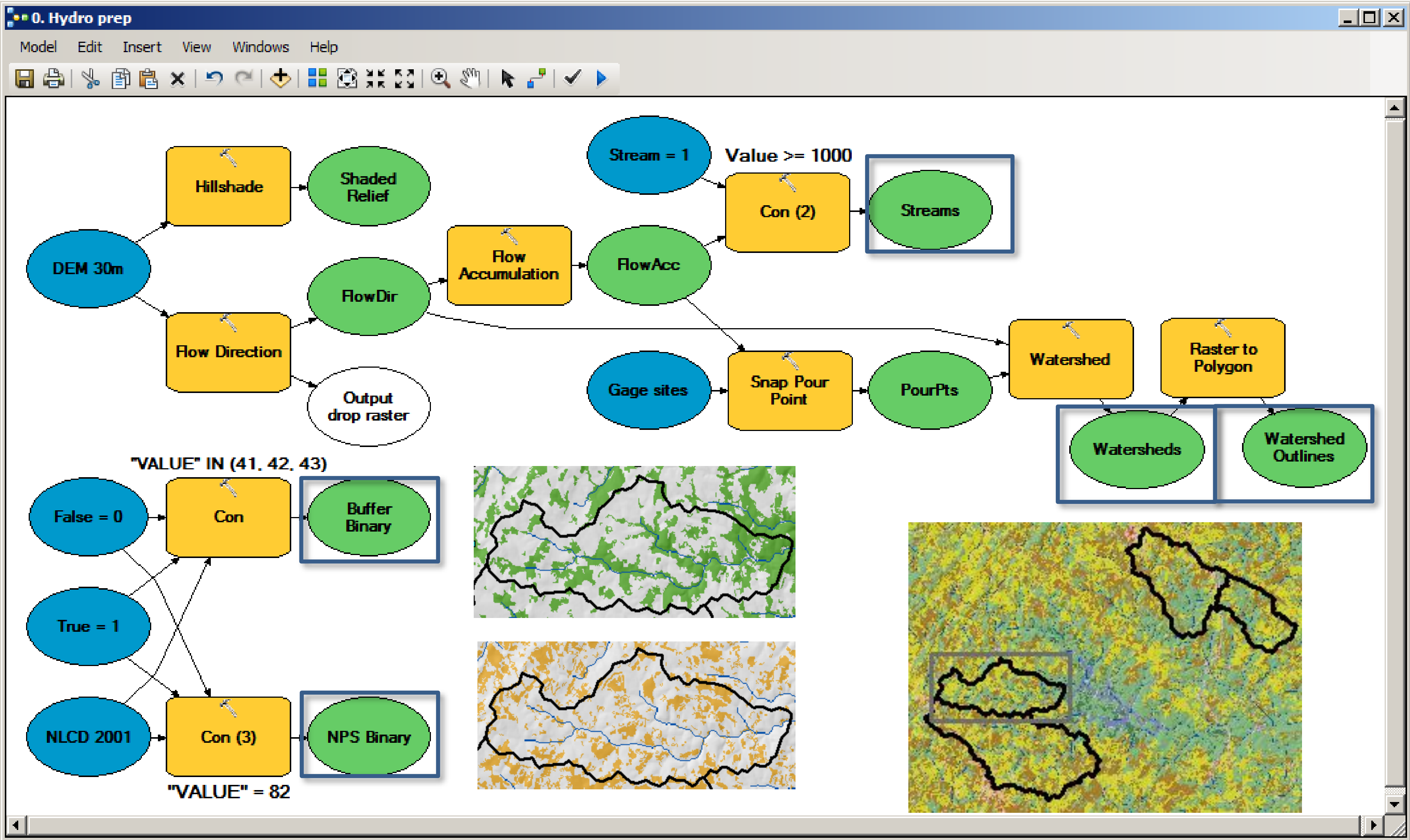
- Mapping floodplains in ArcGIS

Scenario:

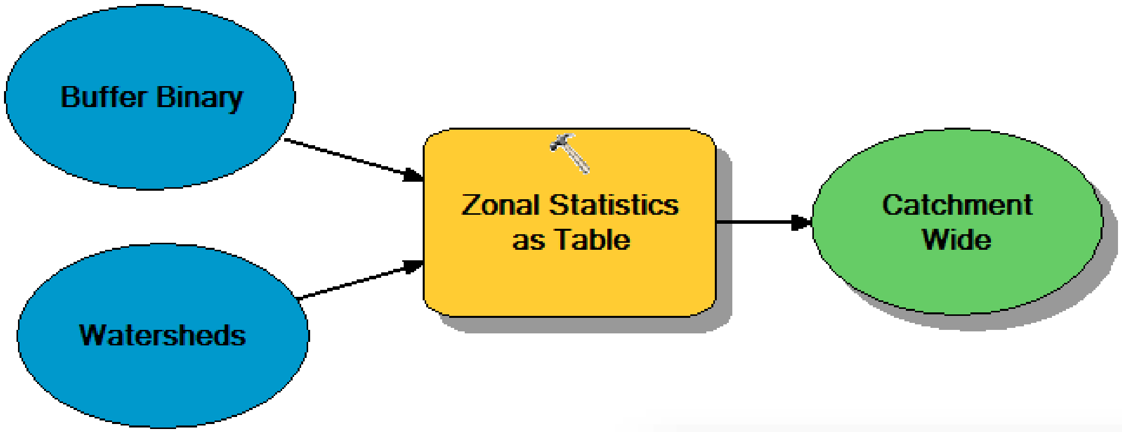


- 4 watersheds in Patapsco R. basin (N. Maryland)
- Buffer = Forest land cover (NLCD 41, 42, & 43)
- Non-point source contribution = cultivated cropland (NLCD 82)

Preparing the data

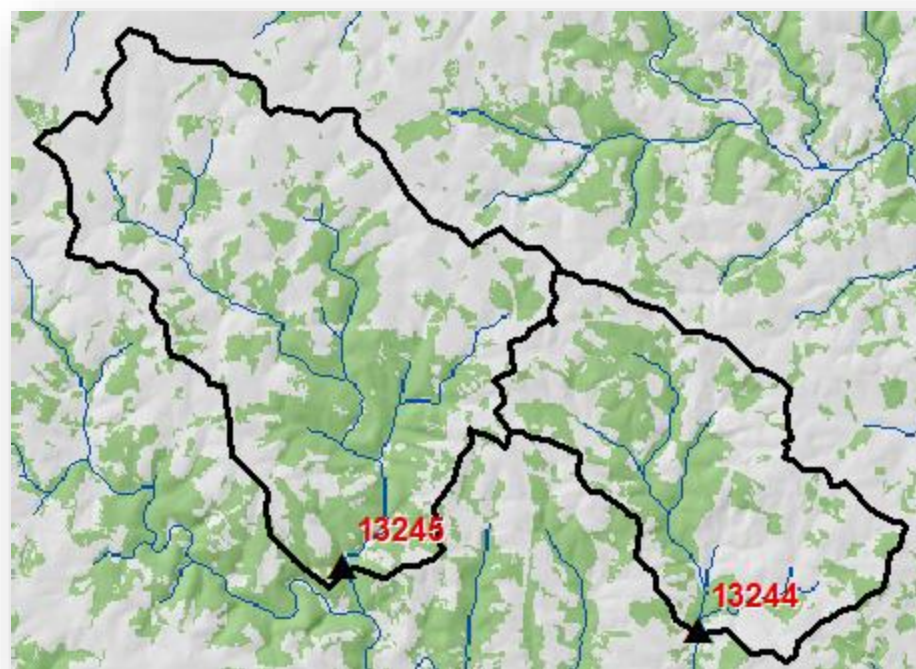


Catchment-wide buffer stats

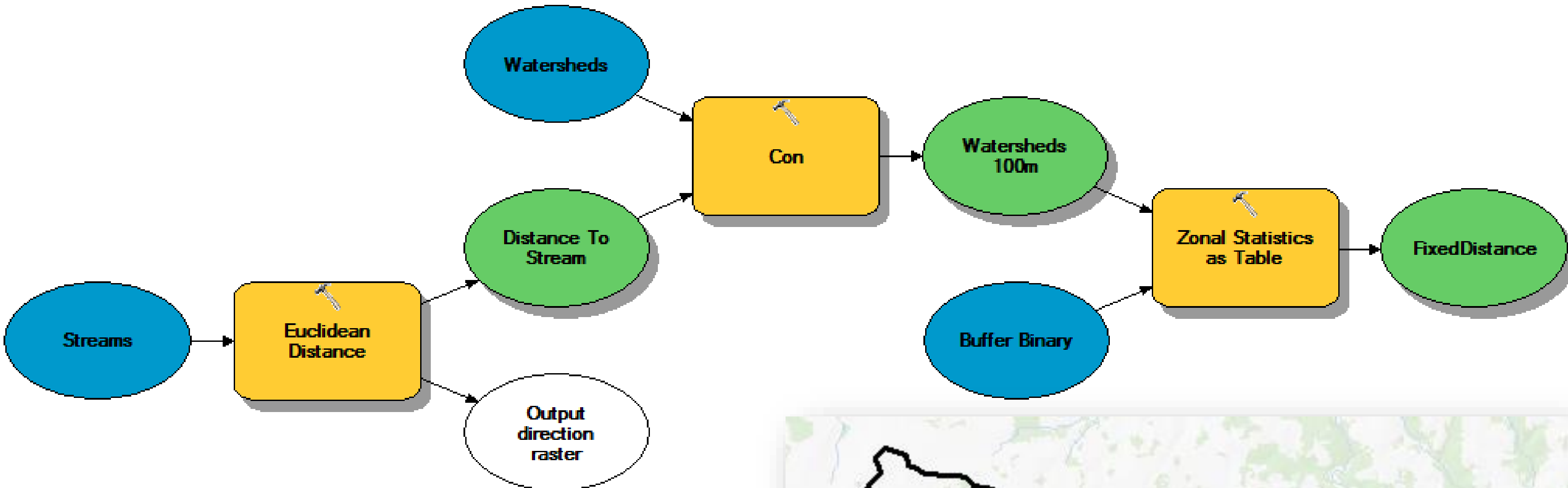


Catchment Wide

OBJ	Value	COUNT	AREA	MEAN
1	13184	45256	40730400	0.210027
2	13188	21807	19626300	0.366396
3	13244	15250	13725000	0.384393
4	13245	28390	25551000	0.383093

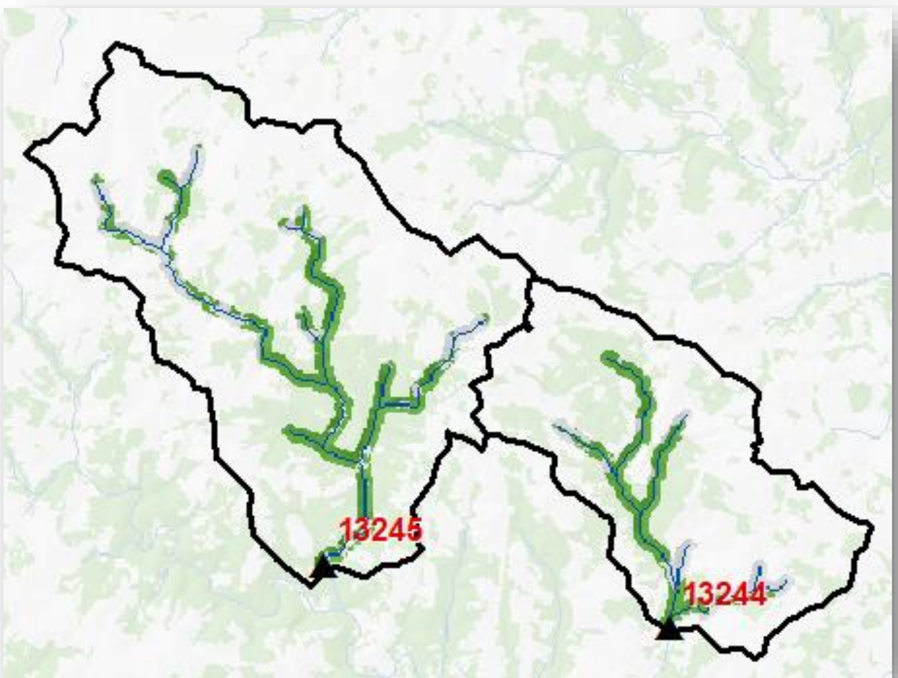


Fixed distance



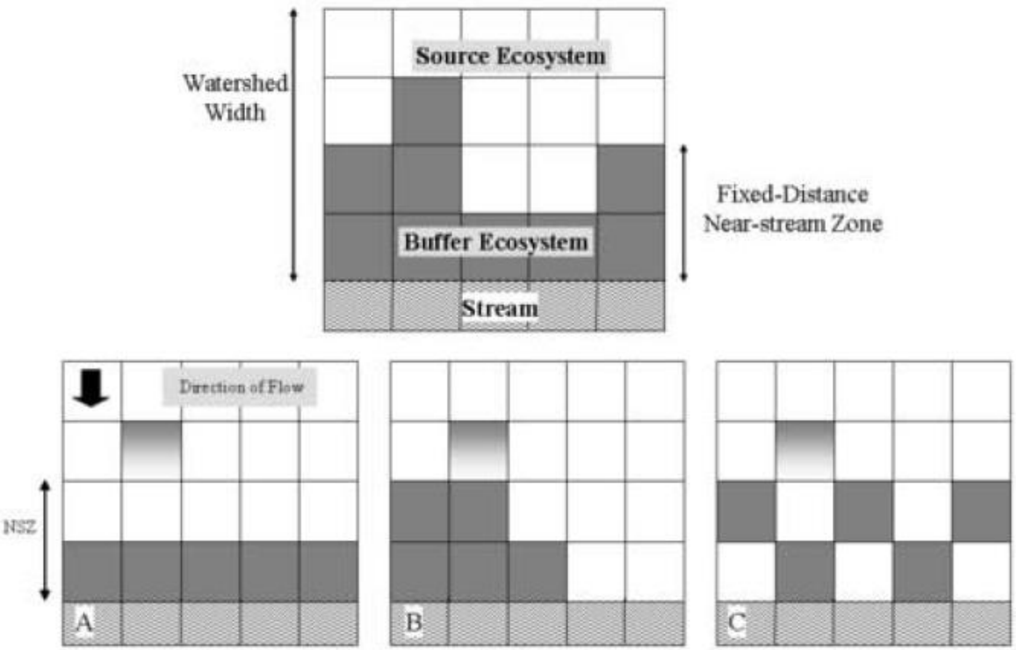
FixedDistance

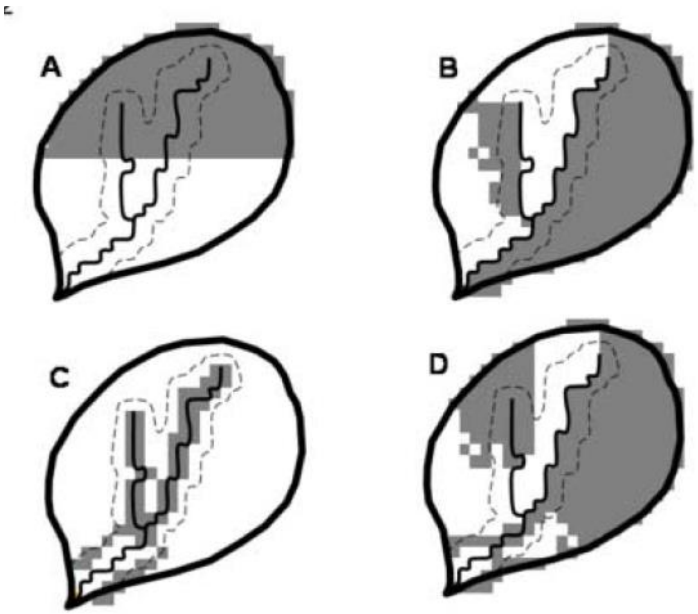
OBJ	Value	COUNT	AREA	MEAN
1	13184	7026	6323400	0.417876
2	13188	3215	2893500	0.685226
3	13244	2217	1995300	0.649075
4	13245	4081	3672900	0.670914



Catchment-wide & fixed distance: Problems

Catchment wide percentages don't account for where in the flow path the buffering land occurs.





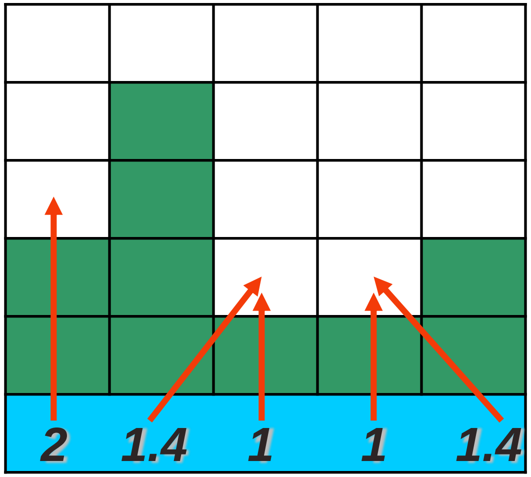
Fixed distance approaches often include areas irrelevant to buffering and misses areas that may increase the interception potential of buffering land cover.

Baker, et al. 2006

“Unconstrained” method

This method improves on the fixed distance metric as the buffer distance is <u>unconstrained</u>.

- Effective buffer depth is not limited to 100m.
- Focus is on forest/wetland <u>between</u> source and stream.



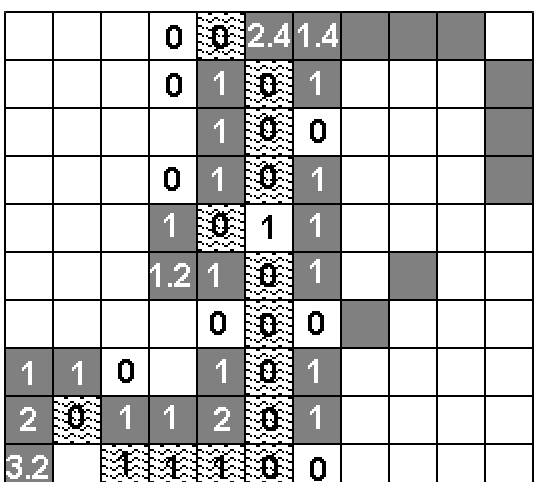
If you were a stream cell, what’s your shortest distance to get to a non buffering cell?

“Unconstrained” method

Method:

- Isolate forest/wetland clusters that are connected to streams.

- Find the least cost distance from upland cells to stream across a forest/wetland cells.



Wavy cells = stream

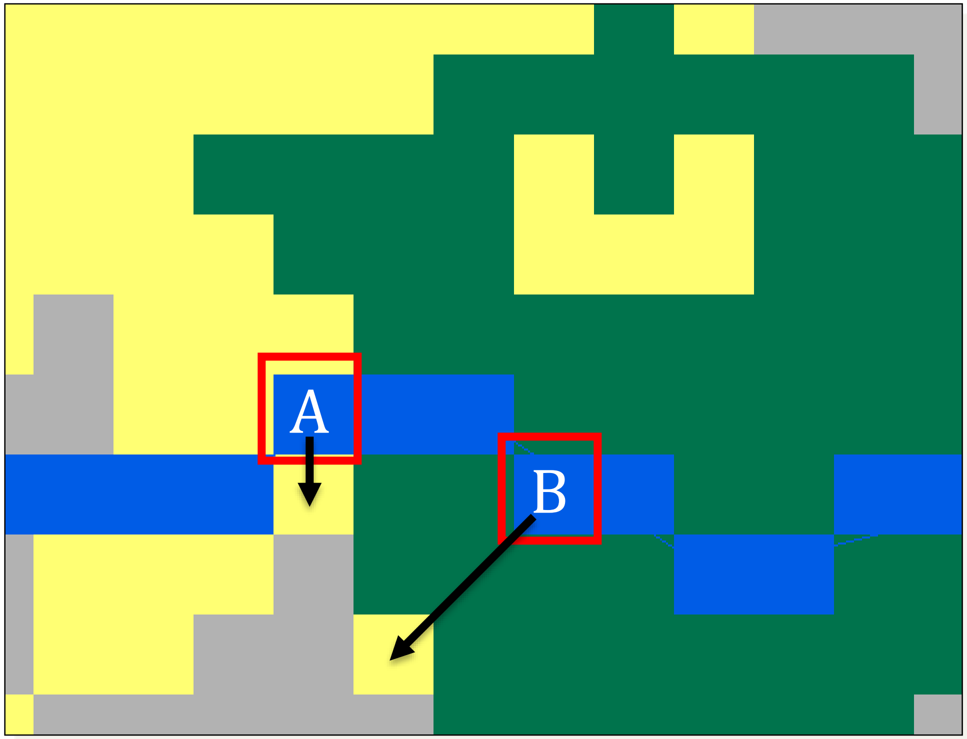
Shaded cells = forest/wetland buffer

White numbers = buffer width for cells adjacent to streams

Black numbers = min. buffer width for stream cells

Unconstrained – In ArcGIS

Objective: *Assign each stream cell a value corresponding to the shortest distance to a non-buffered (i.e. neither forest or wetland) cell.*

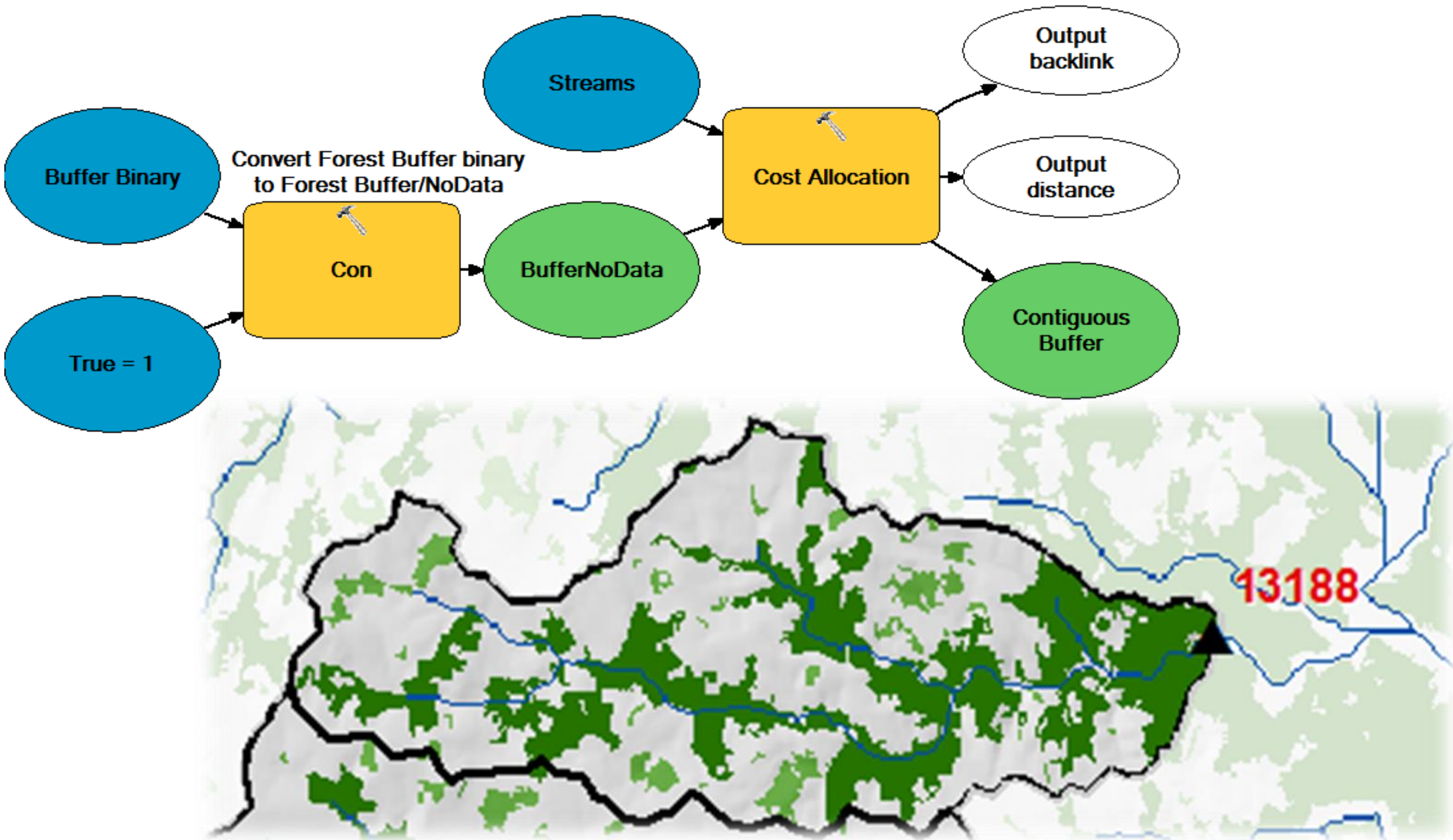


Mean value for all stream cells within a catchment? Variation?

Proportion of stream cells with no buffer?

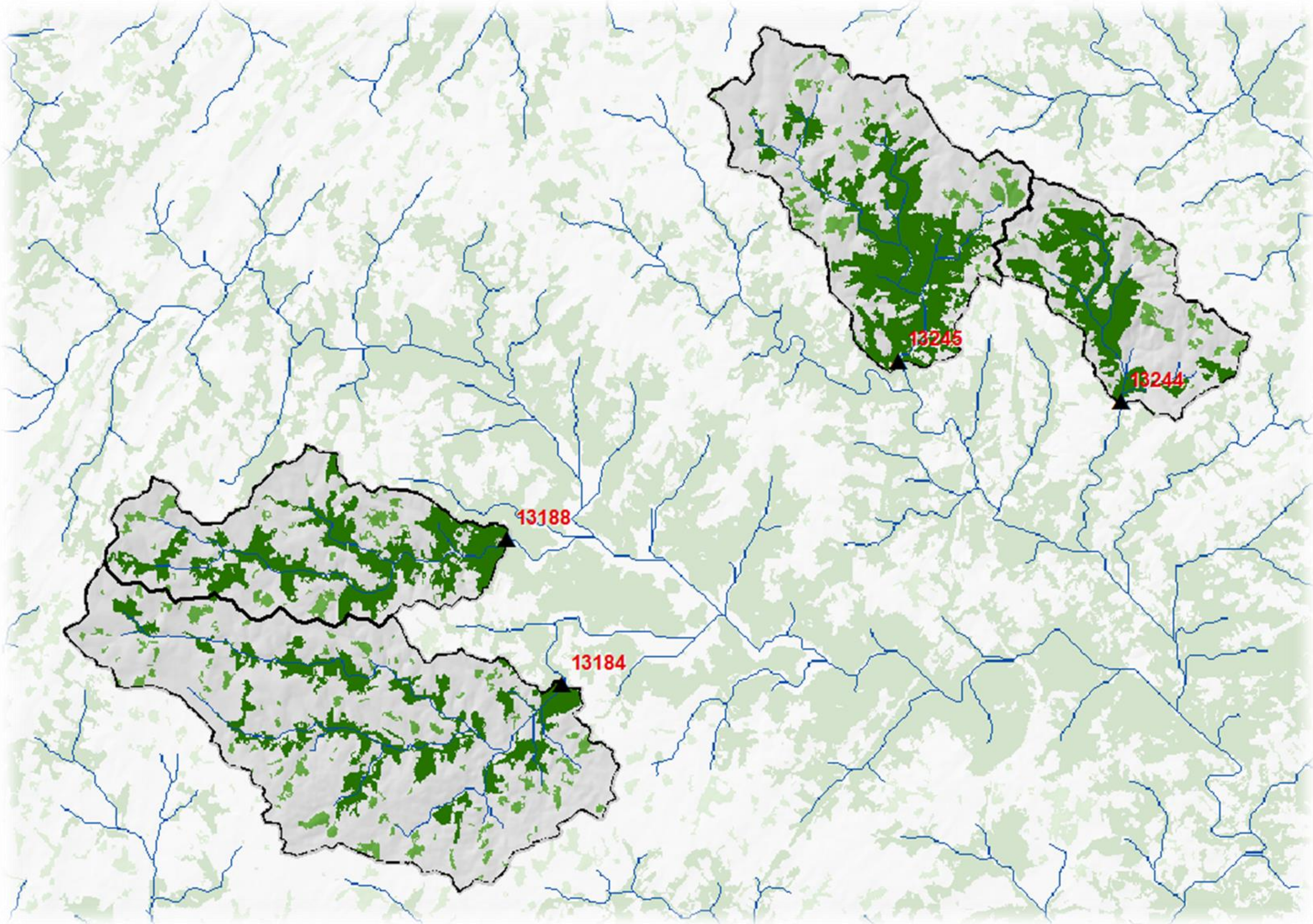
Unconstrained: Step 1

Step 1: Isolate contiguous forest clusters that are adjacent to streams…



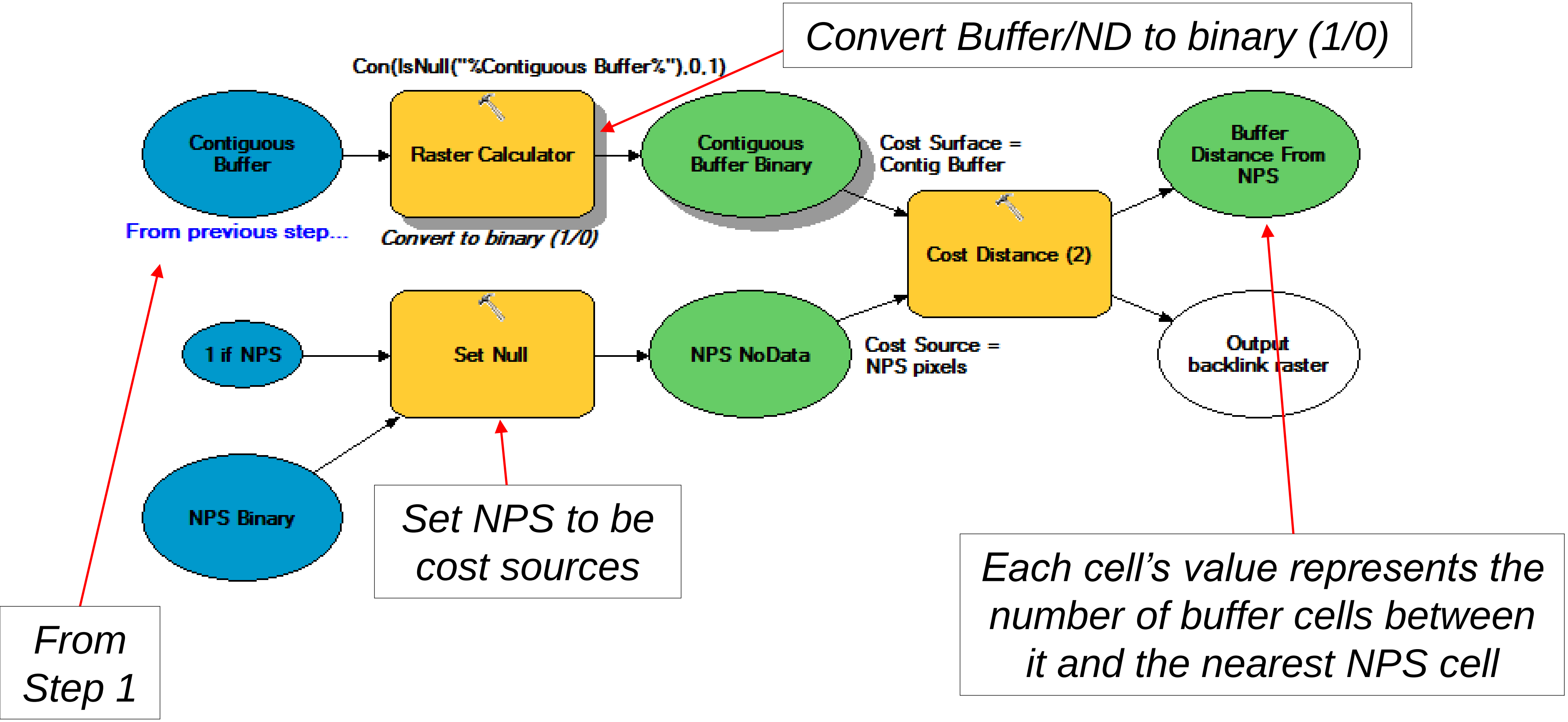
Speed tip: Set model mask to the Watersheds raster…

Unconstrained: Step 1

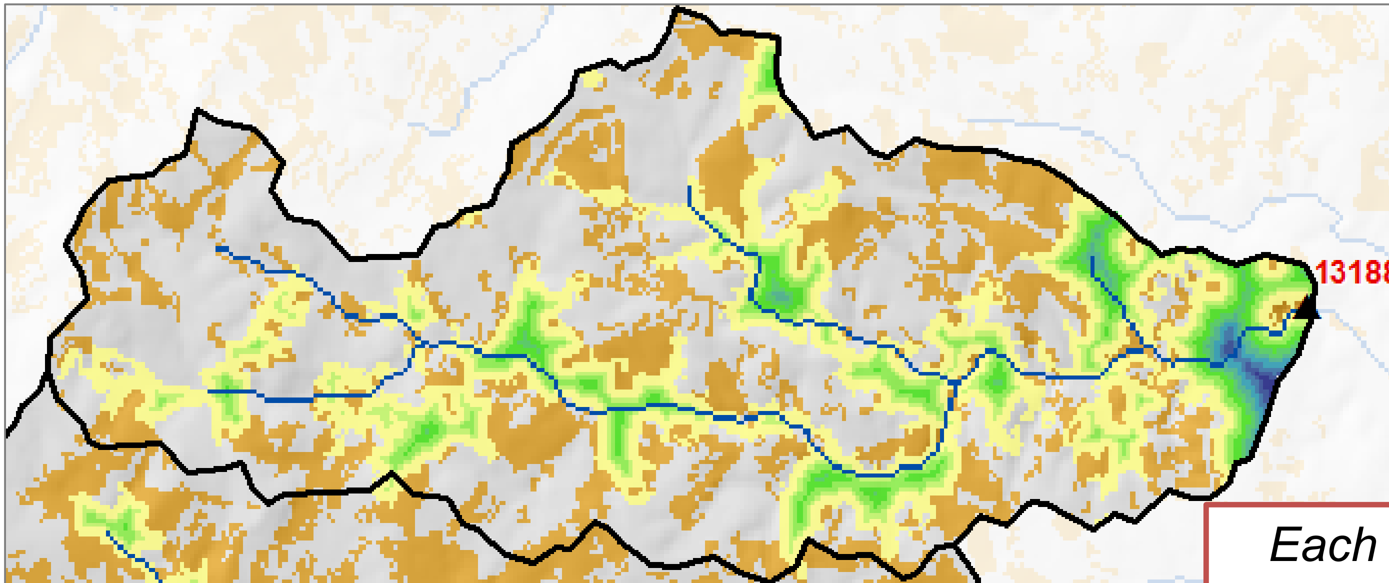


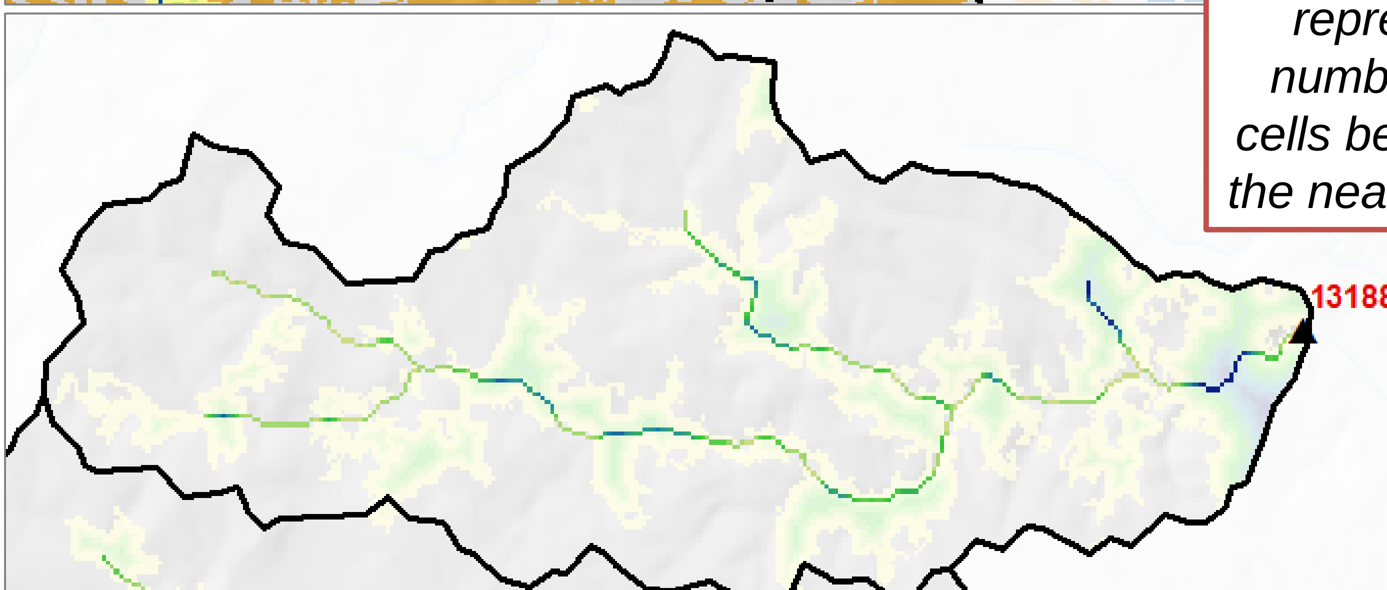
Unconstrained: Step 2

Step 2: Calculate the cumulative distance from crop cells to stream via only for/wet buffer cells.



Unconstrained: Step 2

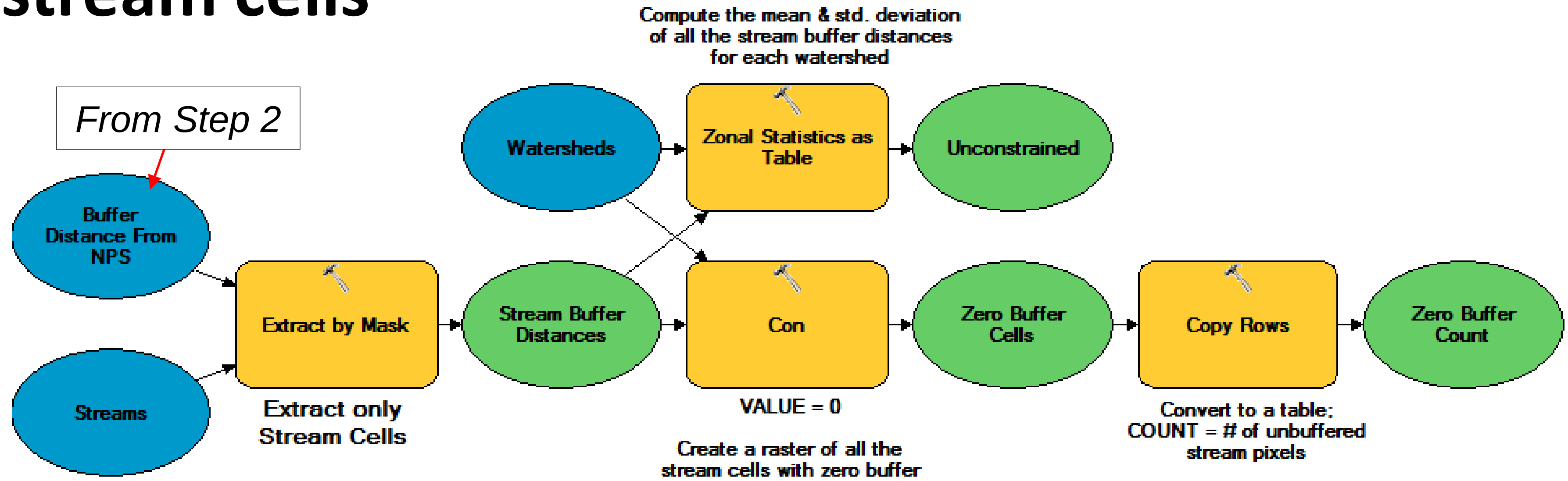




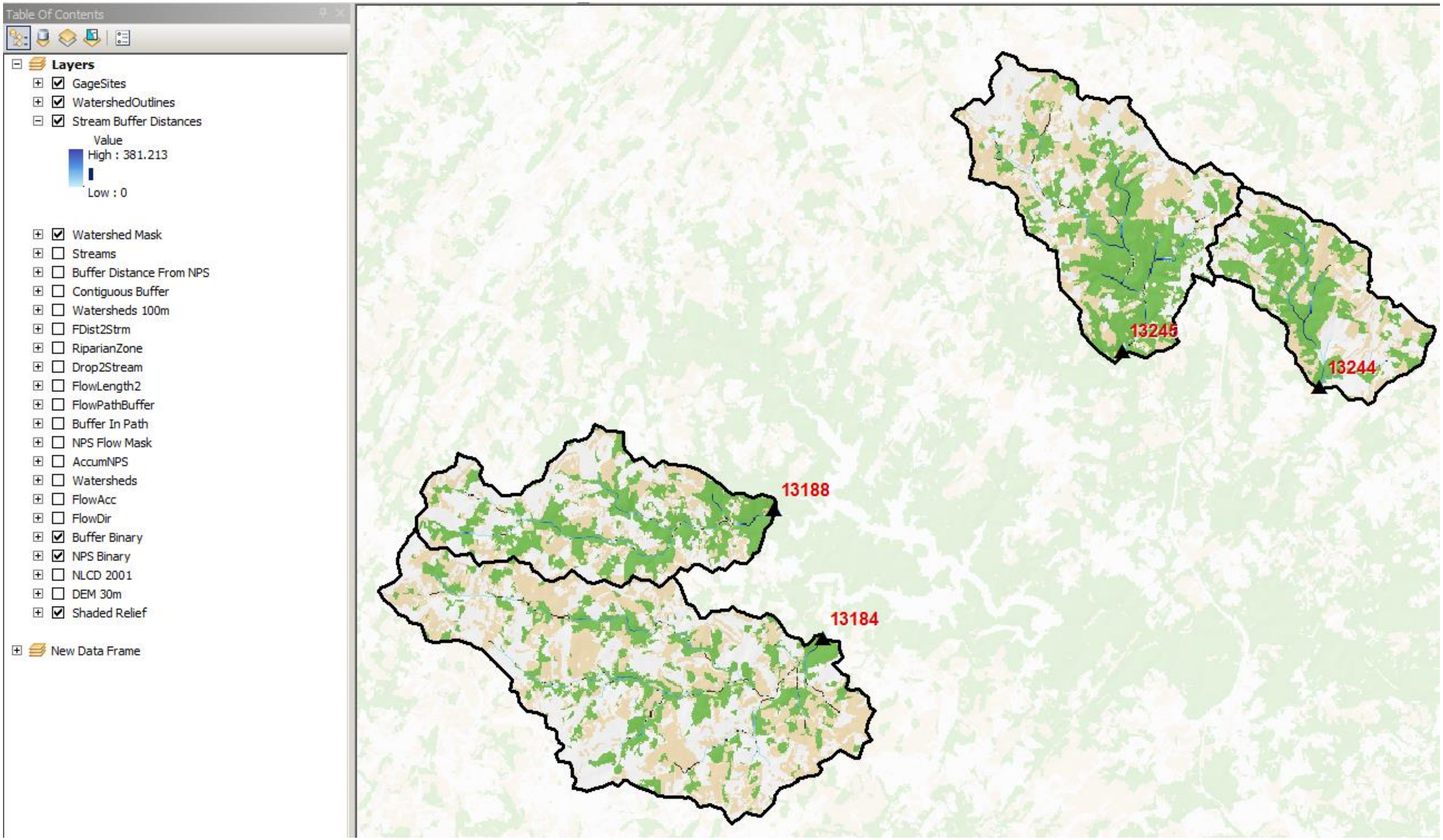
Each cell's value represents the number of buffer cells between it and the nearest NPS cell

Unconstrained: Step 3

<u>Step 3</u>: Assign values from the distance grid to the stream cells



Unconstrained: Step 3



Unconstrained

Results: Summarize stream buffer width by watershed.

1. Mean & Std Dev. of buffer width:

Unconstrained

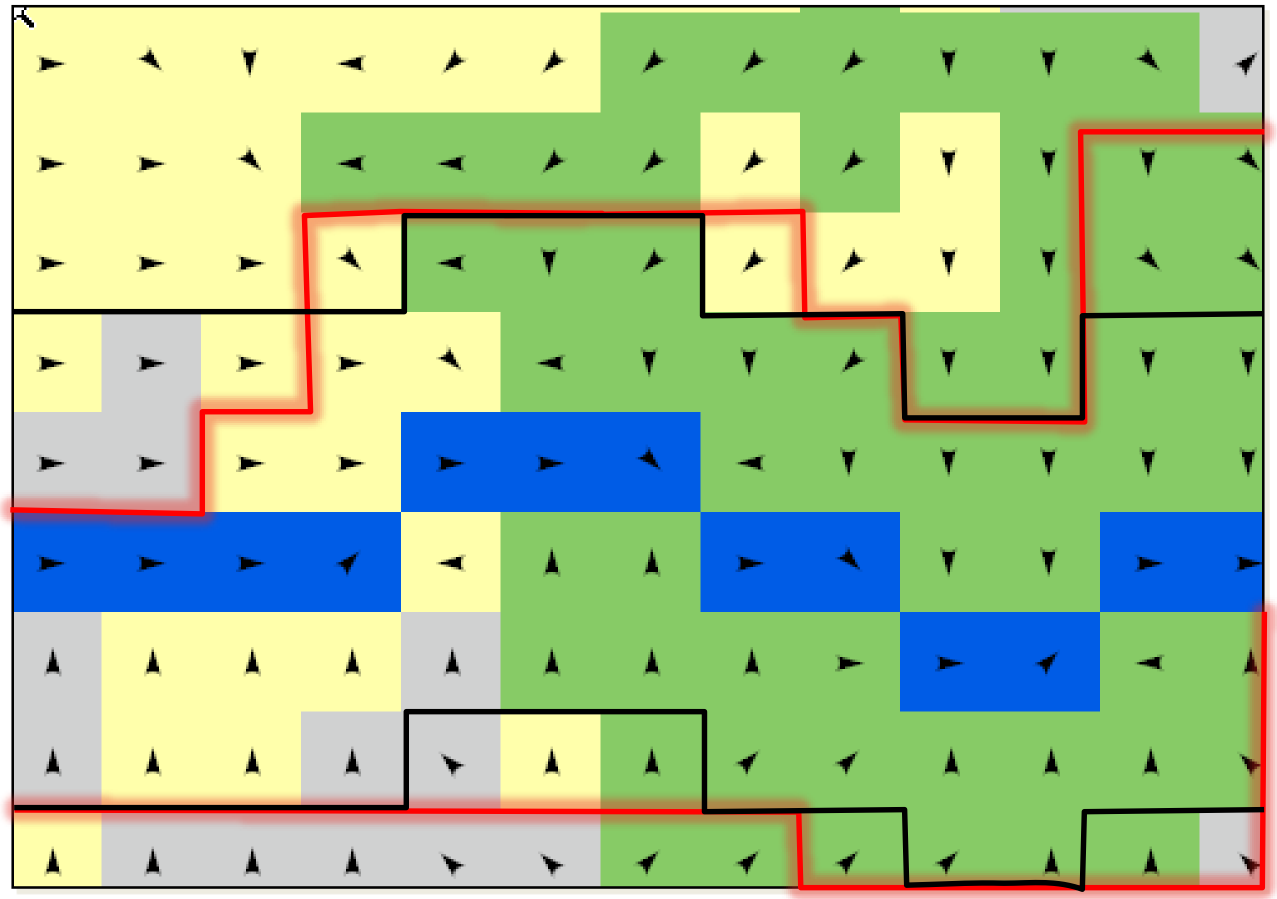
OBJ	Value	COUNT	AREA	MEAN	STD
1	13184	930	837000	26.317588	33.285932

2. Proportion of stream cells that are un-buffered (i.e. width = zero).

Zero Buffer Count

OBJ	Value	Count
1	13184	229

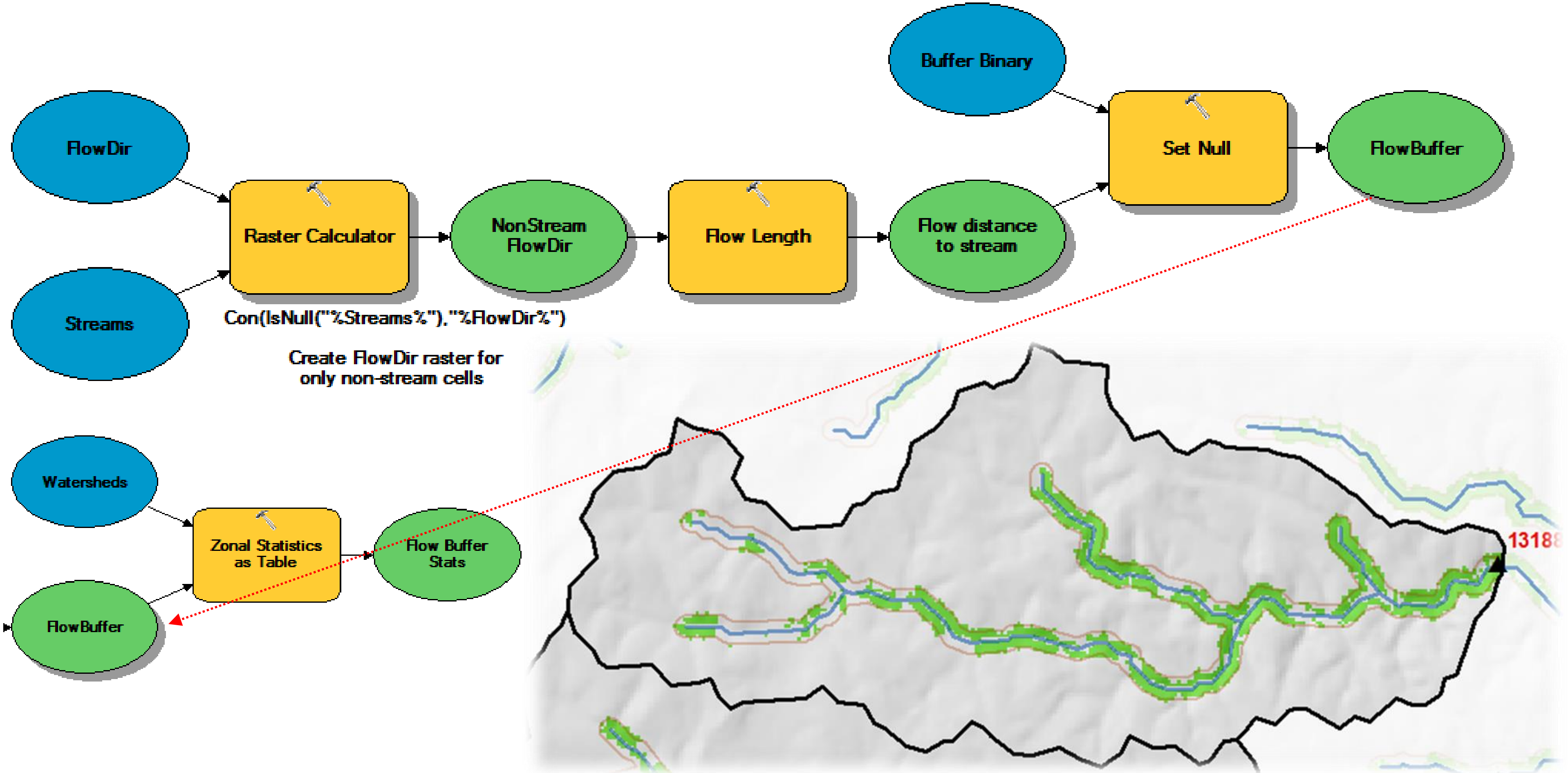
Euclidean vs flow path distances…



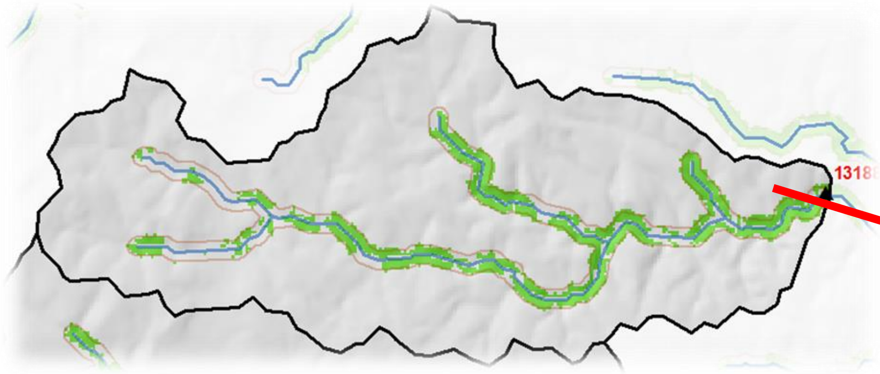
Flow path I: Easy

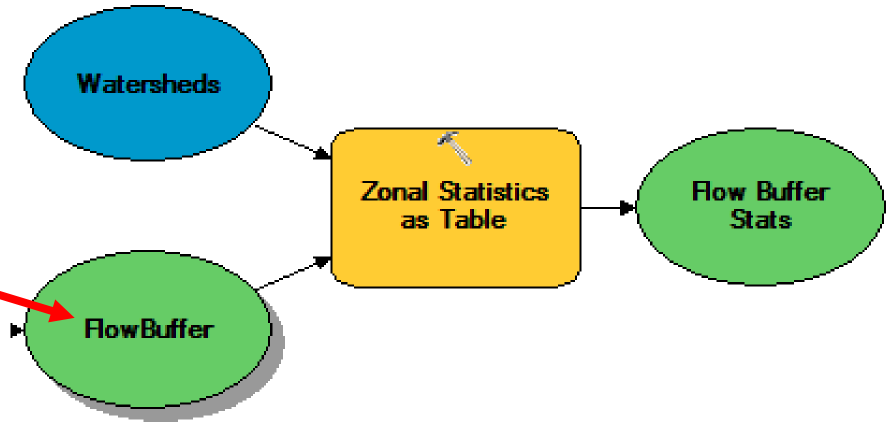
Objective:

Compute the area of forest within 100 m *along the flow path.*



Flow path I: Easy





Flow Buffer Stats

	OBJEC	Value	COUNT	AREA	MEAN
▶	1	13184	5837	5253300	0.406202

Fixed distance

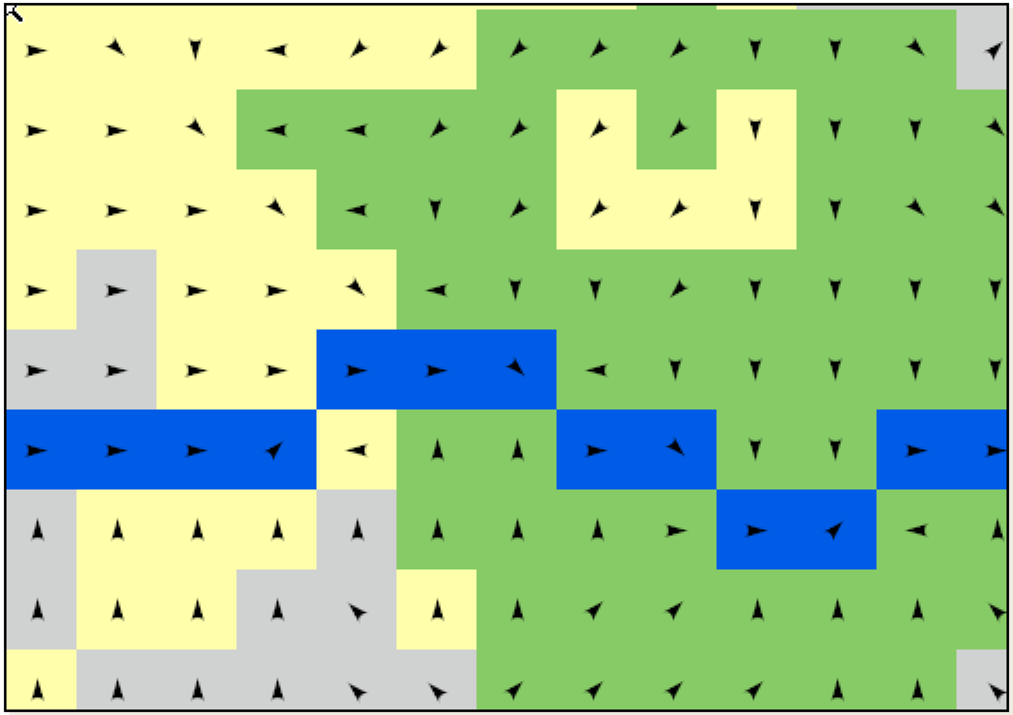
MEAN
0.417876

Proportion of cells within 100 m along the flow path that are buffer

Flow Path II: *Baker et al method…*

Objective 1:

Assign each stream cell a value corresponding to the shortest distance VIA FLOW PATH to a non-buffered (i.e. neither forest or wetland) cell.



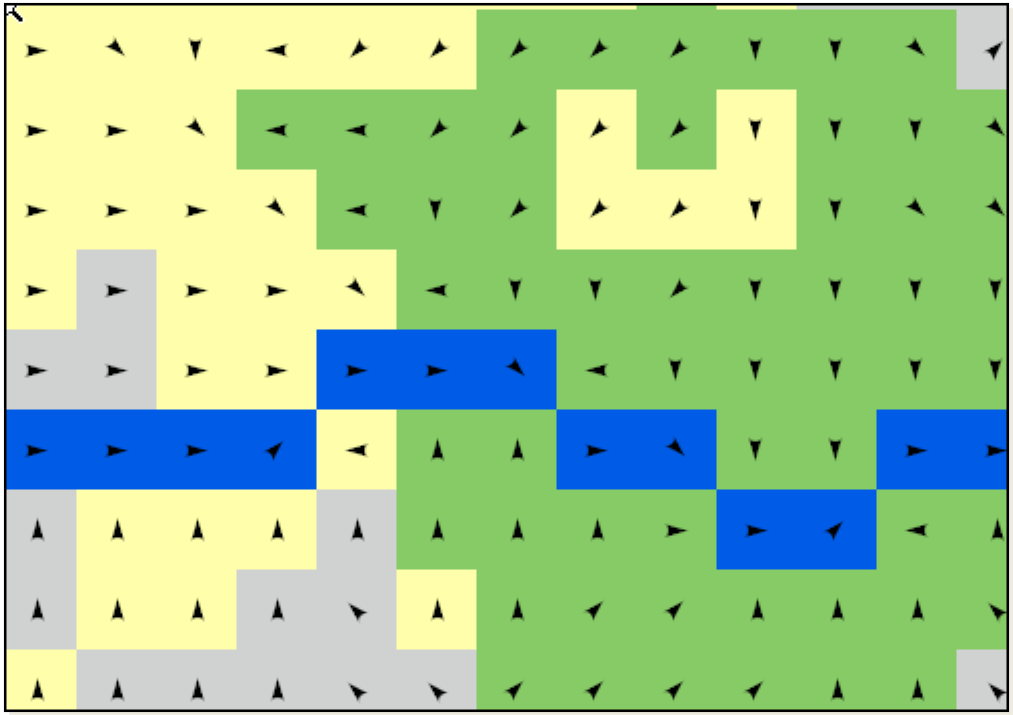
Mean value for all stream cells within a catchment? Variation?

Proportion of un-buffered stream cells?

Flow Path

Objective 2:

Determine the distance through forest that each non-point source contributing cell travels in its flow path to the stream.



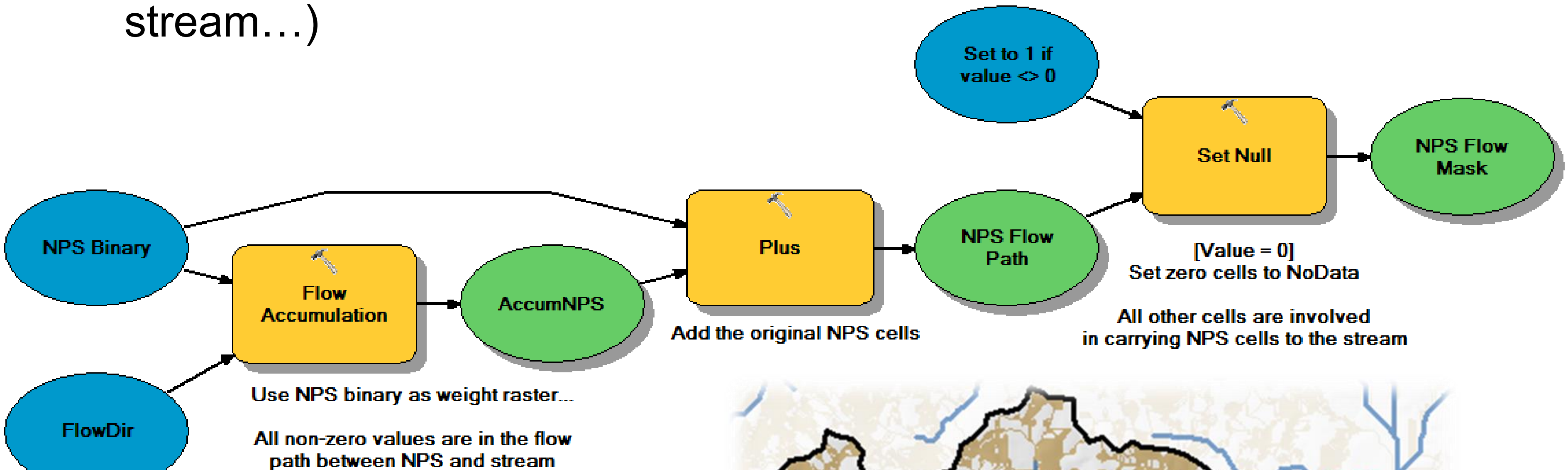
Total the buffer distances of all cropland cell within a catchment.

Divide by the number of cells to determine 'buffer adjusted crop NPS contribution'.

Flow Path II: Step 1

Step 1:

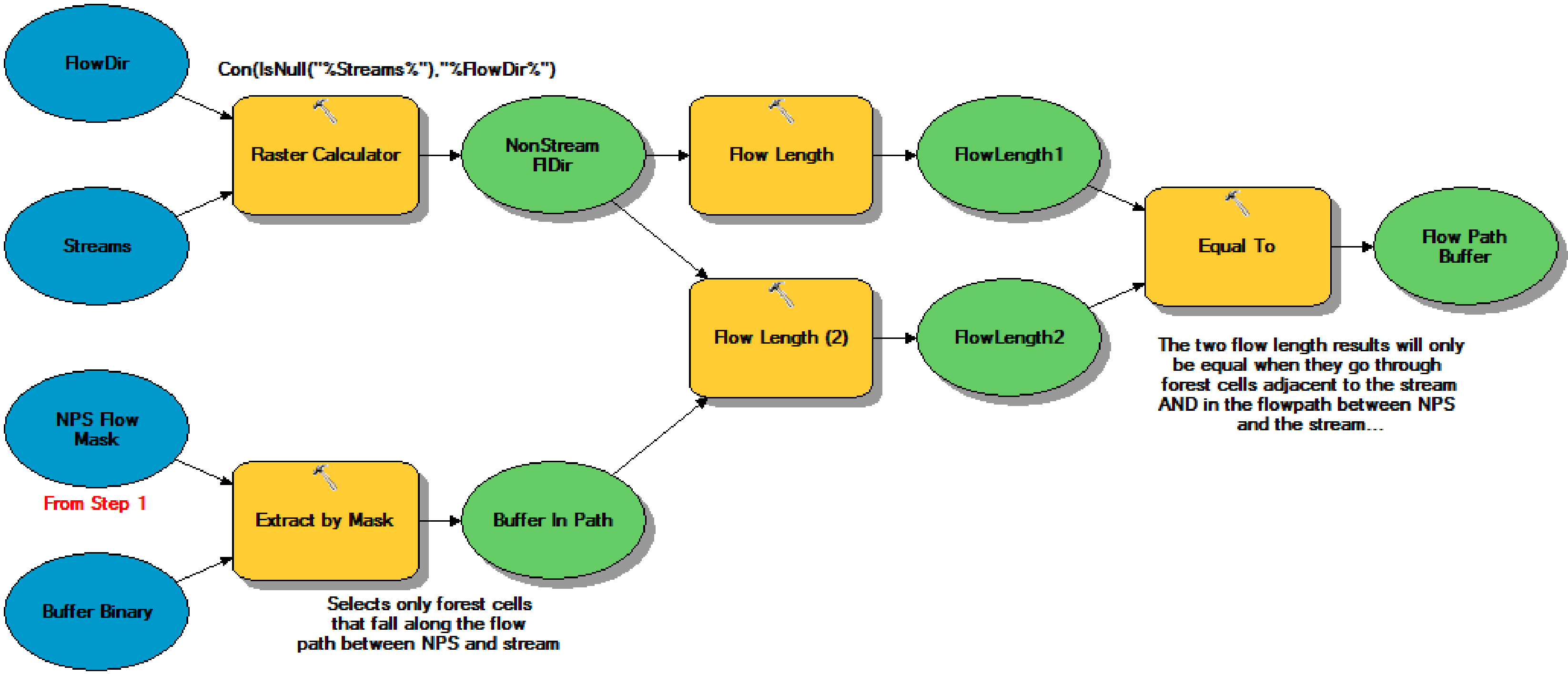
Create a mask of only cells involved in the contribution or delivery of NPS pollution to streams. This would be all cells classified as cultivated cropland or cells along the downward flow path between them and streams. (Either a NPS source or along the flow path from source to stream…)



Flow Path II: Step 2

Step 2:

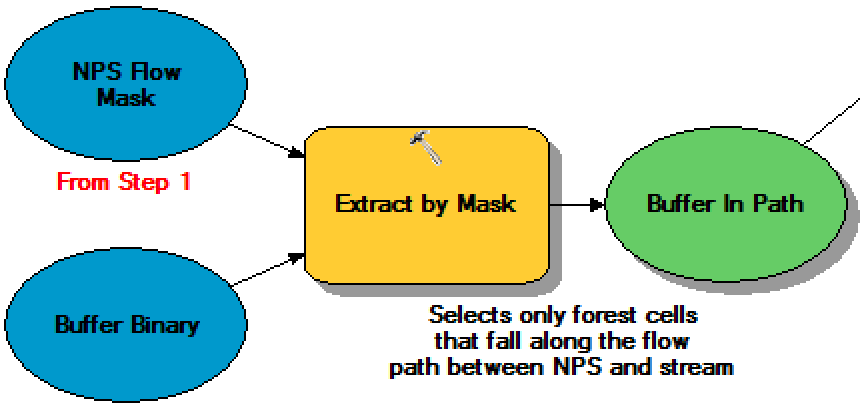
Isolate adjacent forest cells falling along the flow path between NPS & stream.

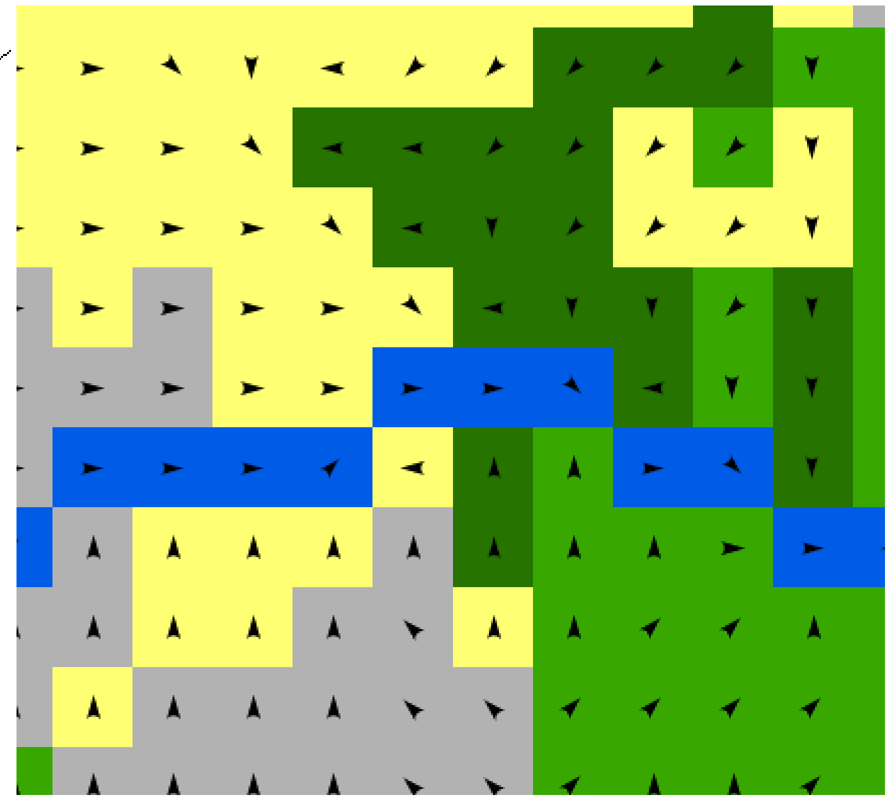


"We created two flow length maps from the stream upslope along the flow direction surface. The first flow length calculation was weighted so that only for-wet pixels (or adjusted buffer) were measured; the second flow length calculation used the entire watershed. If the two flow-length maps contained equivalent values, they indicated contiguous for-wet cover along a flow path (Fig. A.1f); this comparison was accomplished using the con function." (Baker 2006)

Flow Path II: Step 2

A. Isolate just the forest cells involved in the flow path from cropland to stream

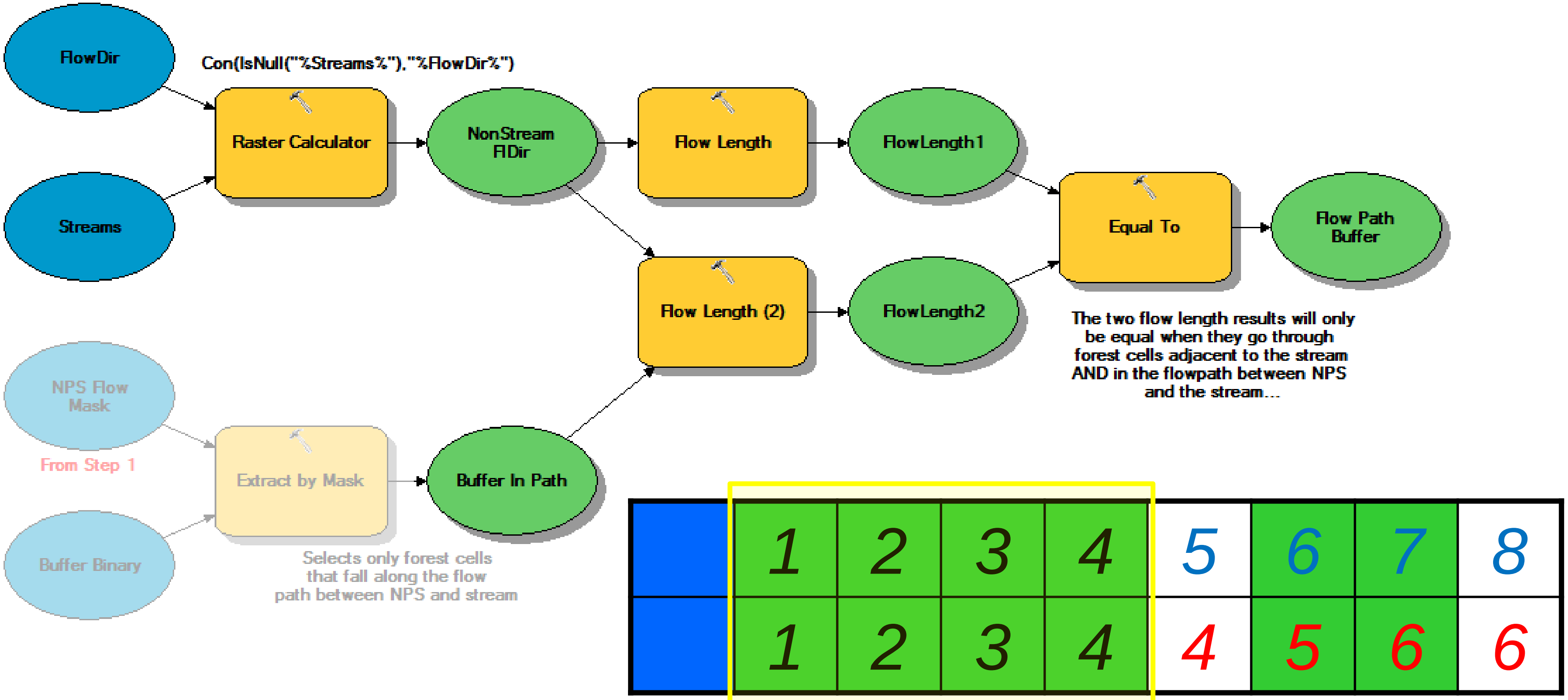




Excludes forest cells not in the flow path between cropland and stream…

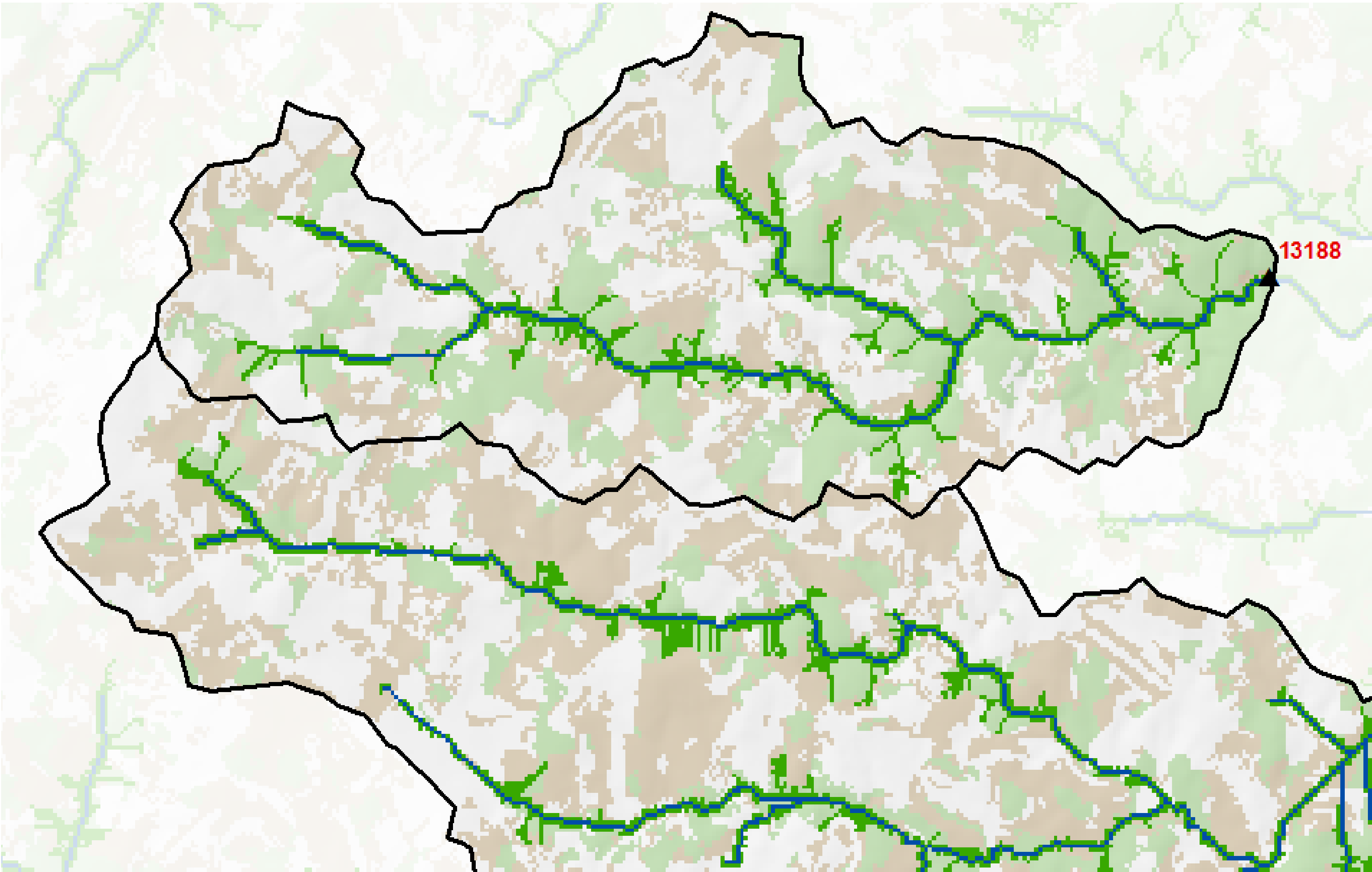
Flow Path II: Step 2

B. Compare the to-stream distances along flow paths to ones using only forest cells to tally distances. Those that are equal reflect the forest cells that actually buffer cropland.



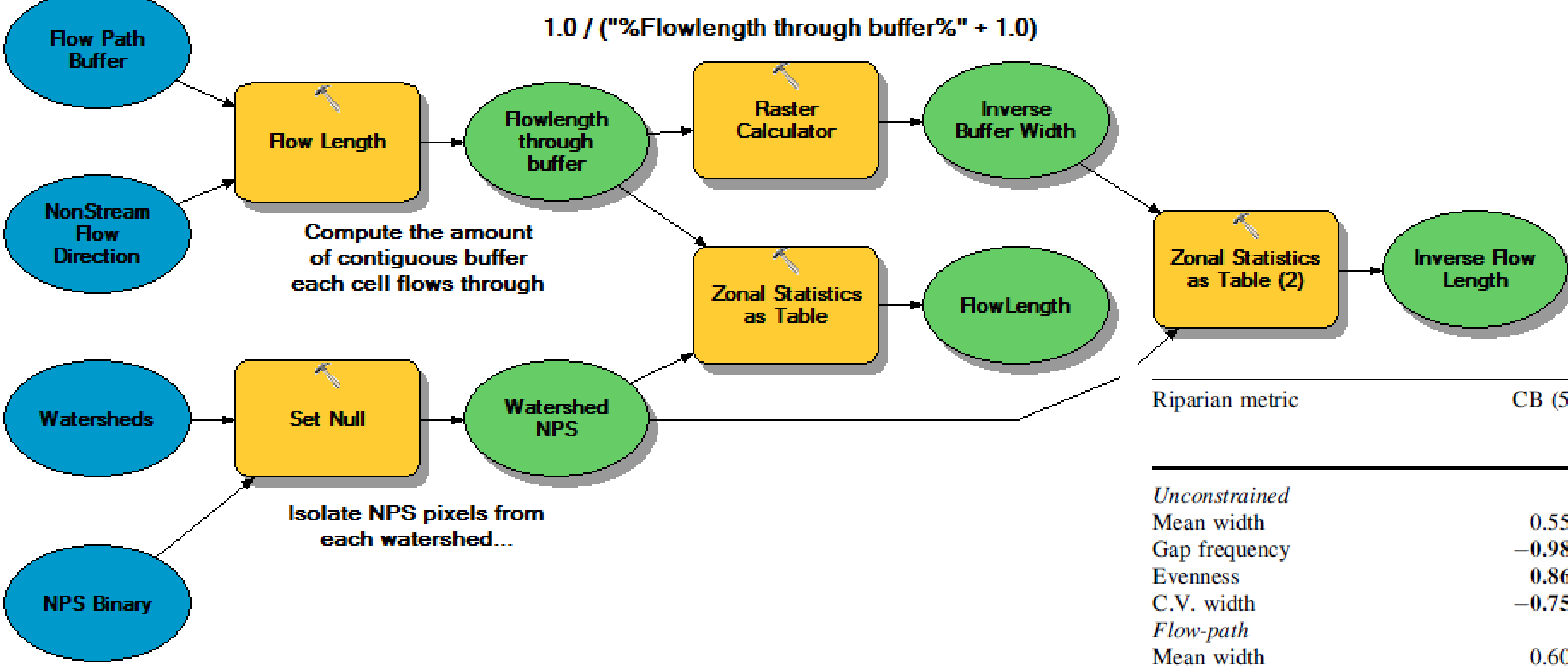
Finds flow path forest clusters adjacent to streams

Flow Path II: Step 2



Flow Path II: Step 3

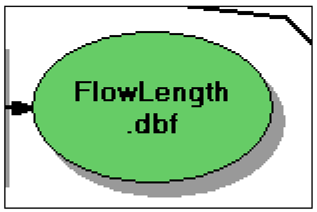
Step 3:
Tabulate to-stream flow lengths along adjacent buffers for entire catchment and determine the mean buffer width and inverse buffer width.



Riparian metric	CB (503)
Unconstrained	
Mean width	0.55
Gap frequency	**−0.98**
Evenness	**0.86**
C.V. width	**−0.75**
Flow-path	
Mean width	0.60
Gap frequency	**−0.75**
Evenness	0.50
C.V. width	−0.57
Mean inverse buffer width	**−0.73**
Adjusted % cropland	−0.66

Flow Path II: Step 3

Mean buffer width:

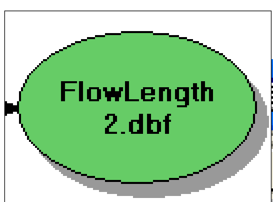


FlowLength

	OBJE	Value	COUNT	AREA	MEAN
▶	1	13184	15667	14100300	55.586676

Mean buffer = 55.6 cell widths
(Unconstrained = 10 cell widths…)

Inverse buffer width:

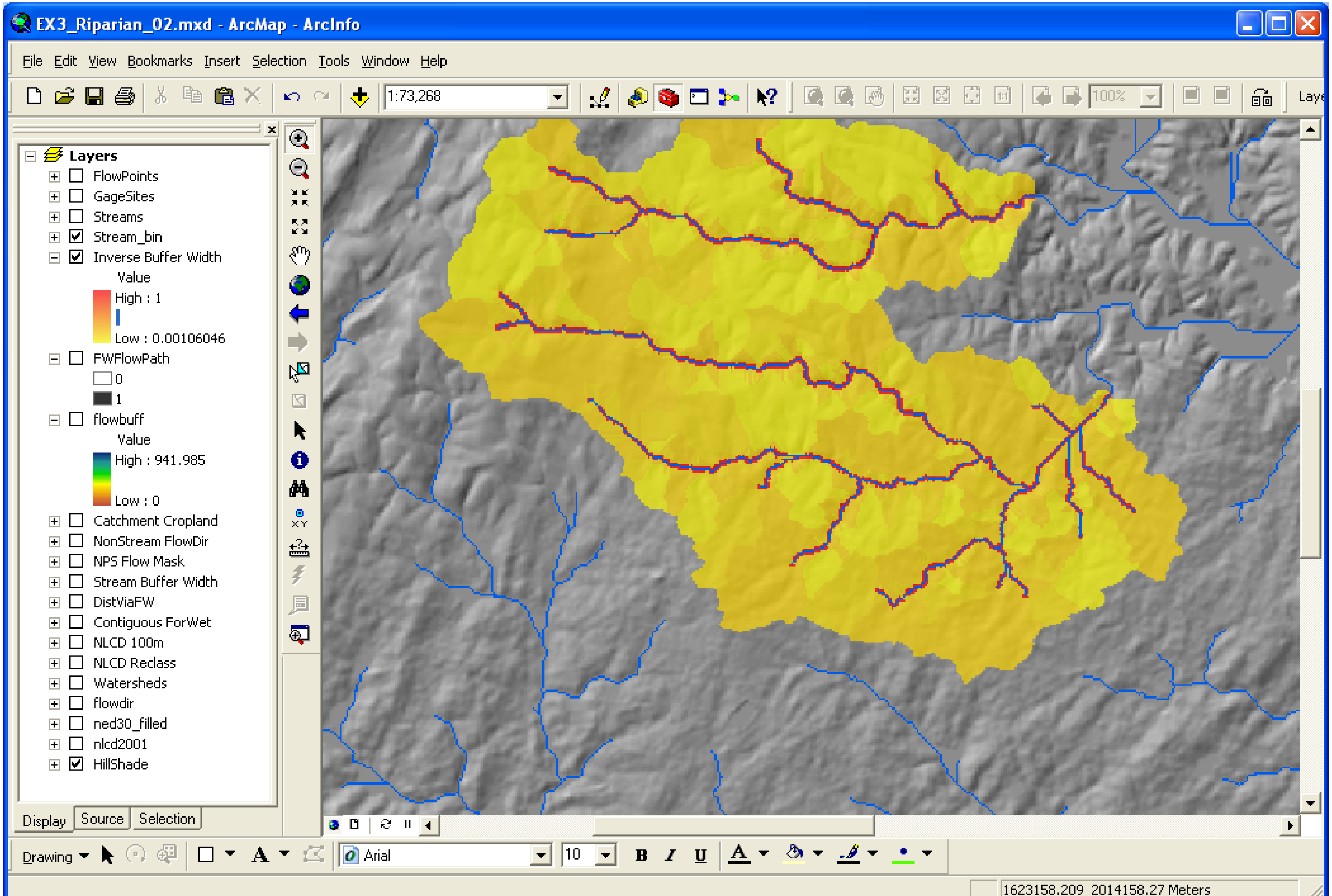


Attributes of FlowLength2

	OID	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
▶	0	13184	15667	14100300	0.00156	1	0.99844	0.0647	0.144155	1013.65

Divide sum by catchment area to get adjusted cropland proportion
(i.e. a proportion of cropland NPS contribution reduced by buffers)

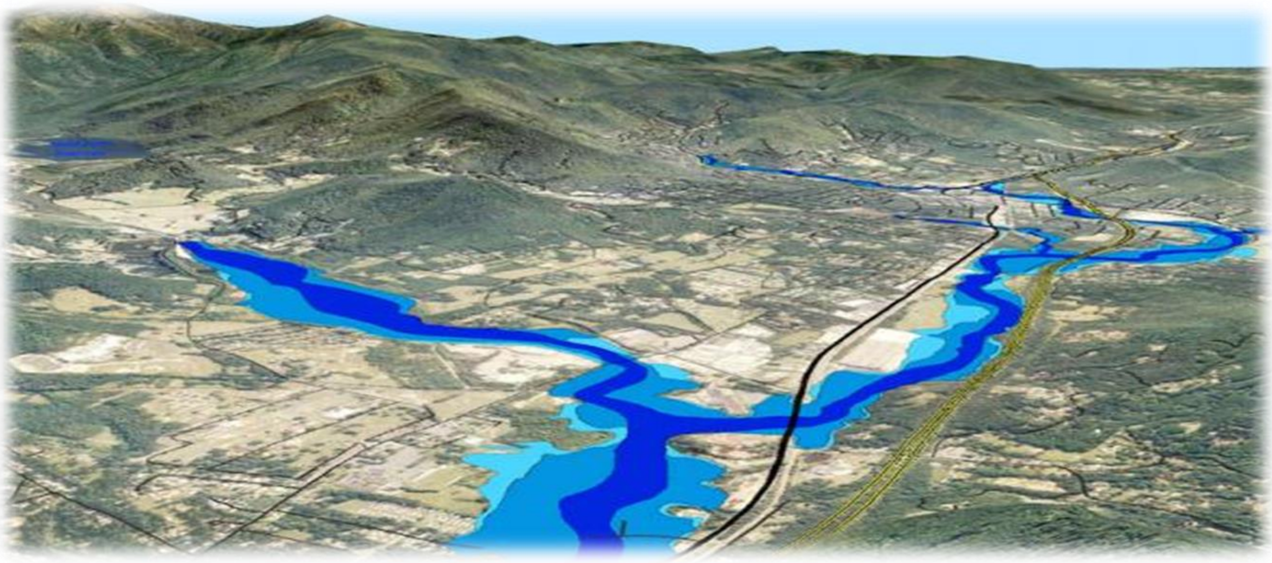
Flow Path II: Step 3



Computing flood plains

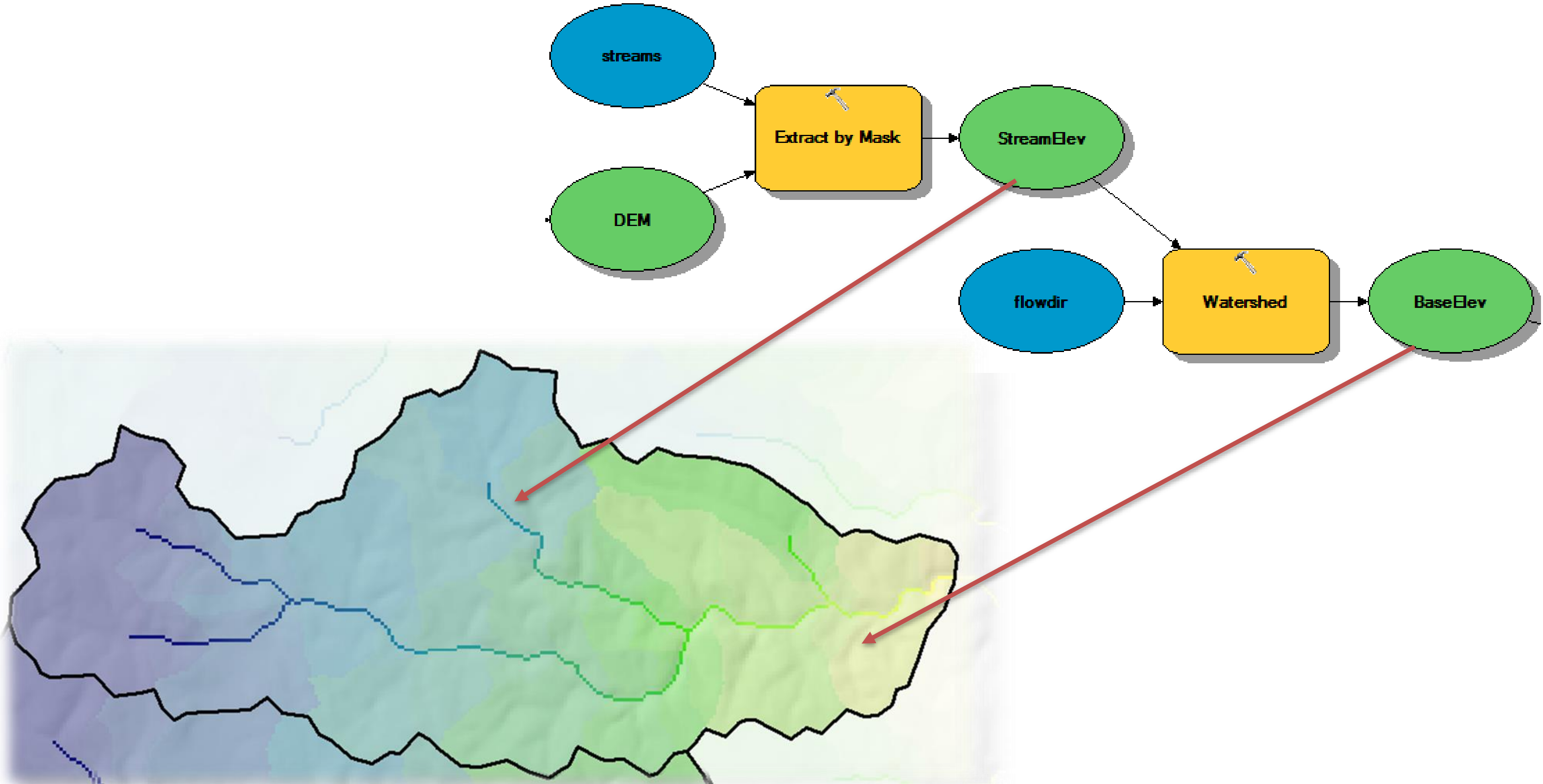
Objective:

Identify pixels that are within X m of elevation of the stream cell into which they drain…



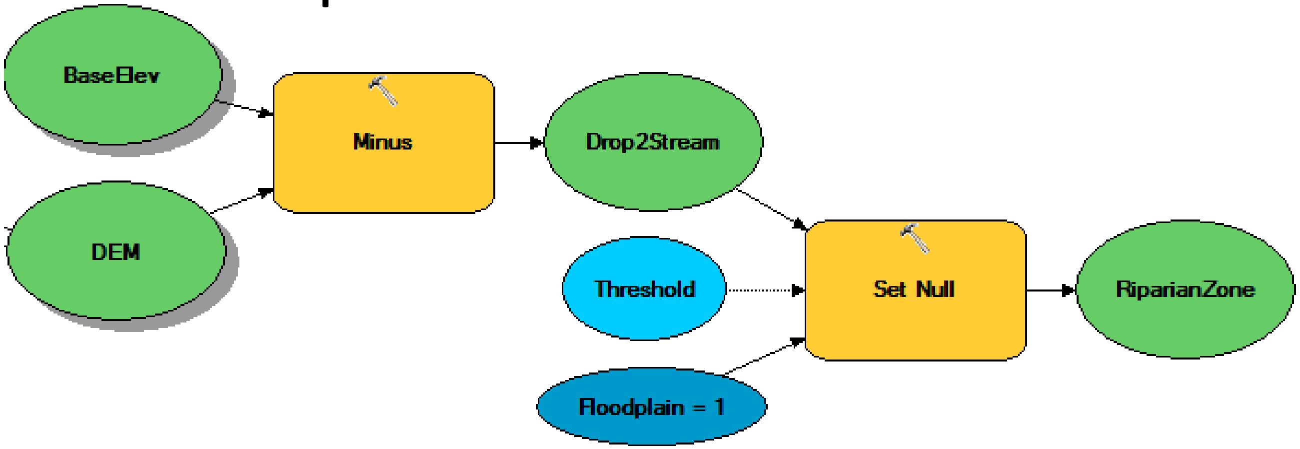
Computing flood plains

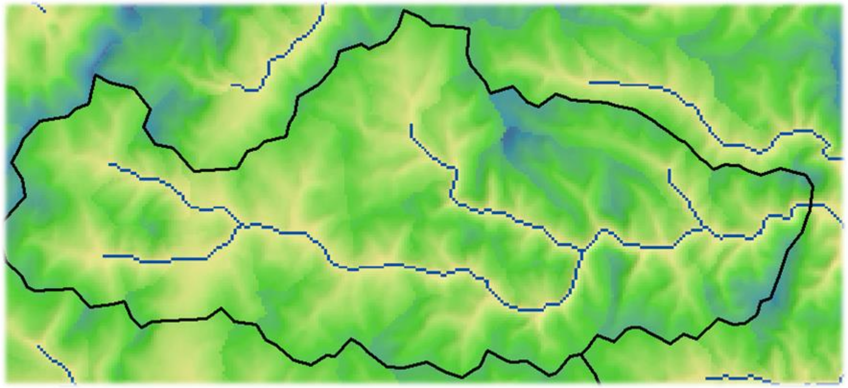
Step 1: Create a raster where pixel values are the elevation of the stream cell into which it drains…

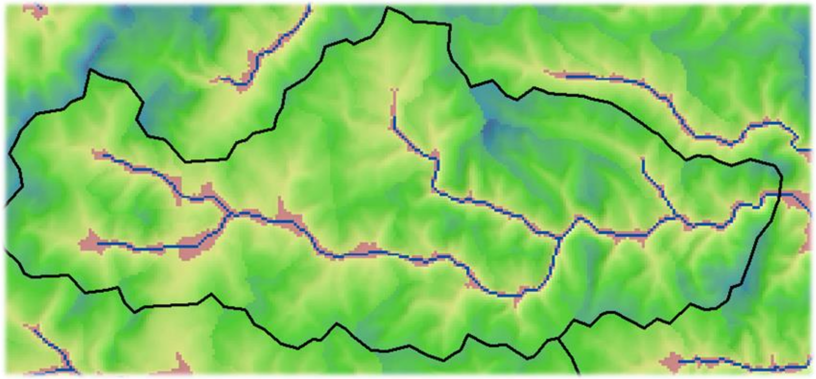


Computing flood plains

<u>Step 2:</u> Compute the vertical drop to stream by subtracting the "base" elevation from the actual elevation. Then identify cells within the "drop threshold".



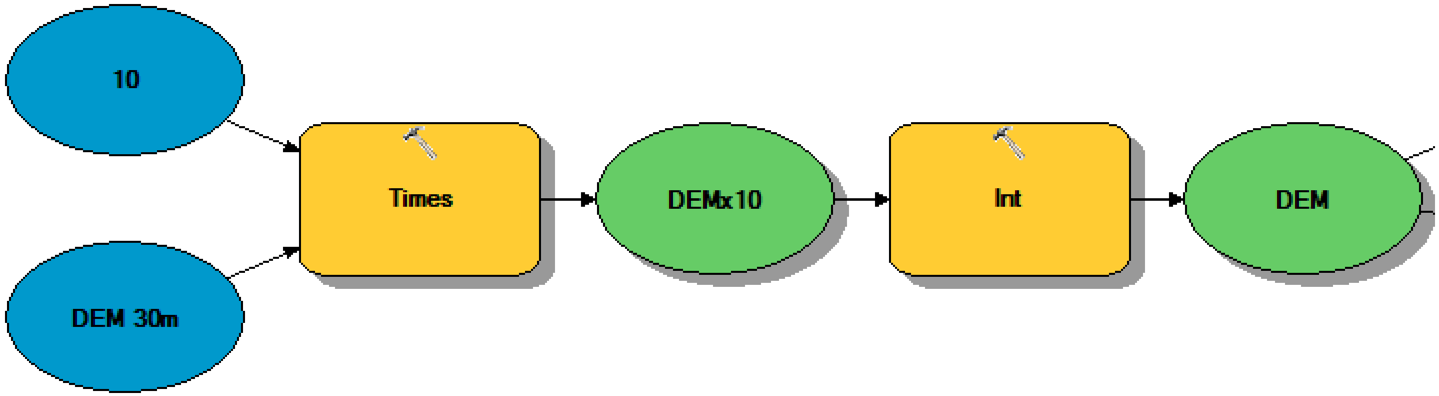




Computing flood plains

** Prepping the DEMs for computing floodplains:*

- DEM must be an integer to serve as pour points
- Multiply floating point values by 10 to conserve precision



Floodplain Stats

- Floodplain area within catchments…
- Proportion of floodplain that is forest…
- Houses within floodplain…

Terrain-based Predictive Modeling of Riparian Vegetation in a Northern Rocky Mountain Watershed

Levia Shoutis · Duncan T. Patten · Brian McGlynn

Table 2 Terrain predictors, the driver type, predictor abbreviations, and mean and range of each predictor for all plots, and for riparian plots only (WIS ≤2.7)

Terrain predictor	Driver type	Abbreviation	All plots mean (range)	Riparian plots mean (range)
Elevation above channel (m)	Fluvial	EAC	2.56 (0–10)	1.22 (0–5.96)
Distance from channel (m)	Fluvial	DFC	35 (0–190)	30 (0–152)
Plot gradient (%)	Lateral	GRAD	19 (0–79)	0.08 (0–0.31)
Valley width (m)	Fluvial/lateral	VALW	125 (39–240)	132 (39–240)
5 m upslope contributing area (# cells)	Lateral	UP5	1,852 (25–39,000)	3,063 (25–39,000)
5 m topographic wetness index	Lateral	TWI5	7.29 (2.71–20)	8.69 (3.32–20)
10 m topographic wetness index	Lateral	TWI10	8.46 (2.67–17)	8.93 (3.96–16.9)

Summary

What's the riparian buffering potential of a landscape?

- *Many ways to quantify the answer*
- *Varying ways to consider the landscape configuration*
- *Can involve very creative ways of using different GIS tools…*