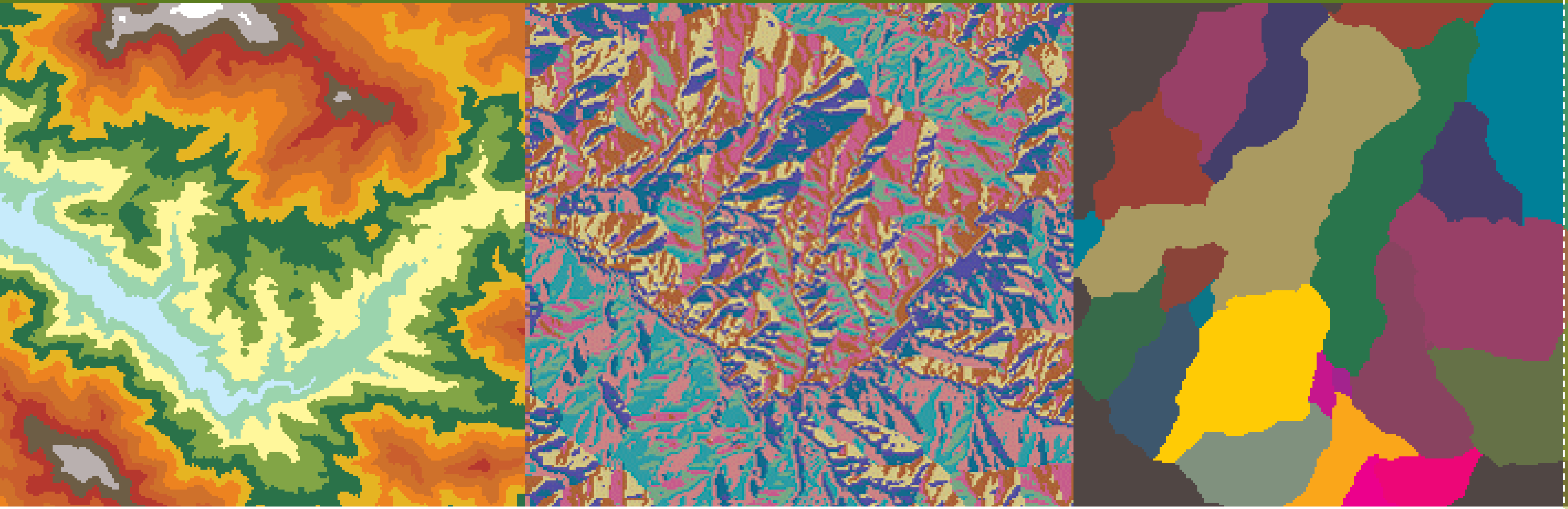
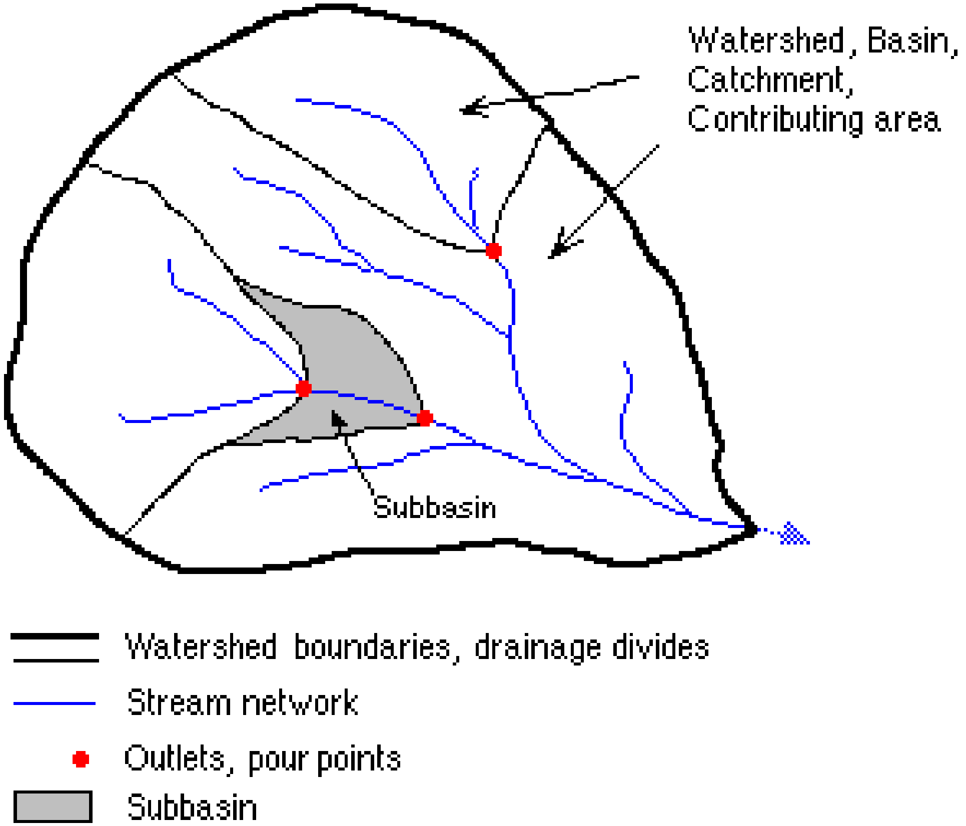
Watershed Delineation – Hydro-reconditioning



Portland State UNIVERSITY

Hydrological Analysis of Terrain Data

Stream links



Flow Direction

Single vs multi-flow directions (SFD vs MFD)

- e.g., D8 and FD8

Deterministic vs stochastic

- e.g., D8 and Rho8

(a)

6	7	8
5	0	1
4	3	2

(b)

64	128	1
32	0	2
16	8	4

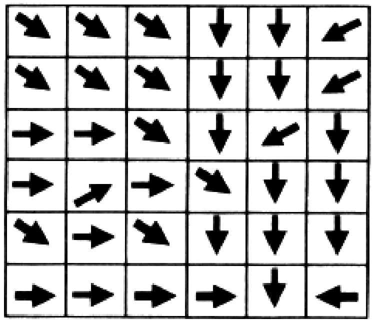
(c)

32	64	128
16	0	1
8	4	2

(a)

78	72	68	73	60	48
75	68	56	50	46	50
70	55	45	40	39	47
65	57	53	26	30	26
67	60	48	23	18	20
75	55	45	12	10	12

(b)



(c)

2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
1	128	1	2	4	4
2	1	2	4	4	4
1	1	1	1	4	16

Sinks (depressions, pits, …)

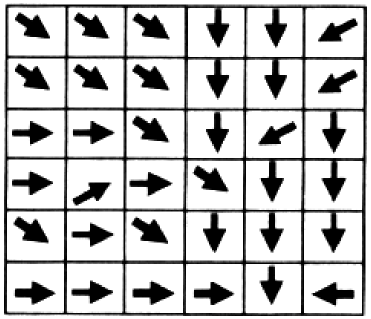
- All neighboring cells are higher than the sink cell
- Two cells flow into each other
- Sinks have undefined flow directions and are assigned a value that is the sum of their possible directions.
- For example, if the steepest drop and, therefore, flow direction, are the same to both the right (1) and left (16), the value 17 would be assigned as the flow direction for that cell.
- A digital elevation model (DEM) that has been processed to remove all sinks is called a depressionless DEM.

Flow Accumulation

(a)

78	72	68	73	60	48
75	68	56	50	46	50
70	55	45	40	39	47
65	57	53	26	30	26
67	60	48	23	18	20
75	55	45	12	10	12

(b)



(c)

2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
1	128	1	2	4	4
2	1	2	4	4	4
1	1	1	1	4	16

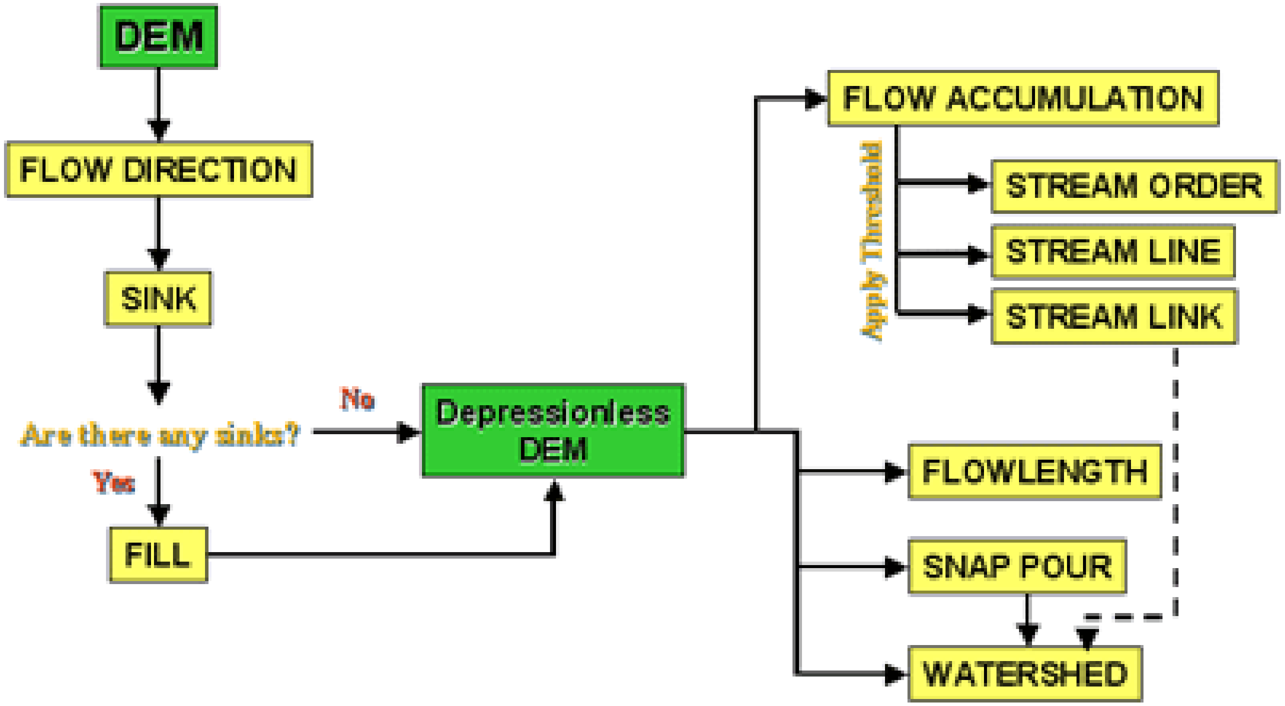
(a)

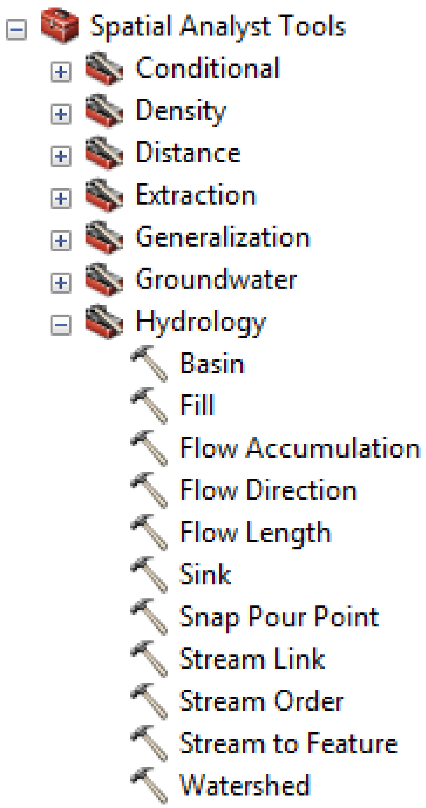
0	0	0	0	0	0
0	1	1	2	2	0
0	2	7	5	4	0
0	1	0	20	0	1
0	0	1	0	22	2
0	2	3	7	35	3

(b)

0	0	0	0	0	0
0	1	1	2	2	0
0	2	7	5	4	0
0	1	0	20	0	1
0	0	1	0	[illegible]	2
0	2	3	7	35	3

Watershed Delineation Steps





Stream link & stream order

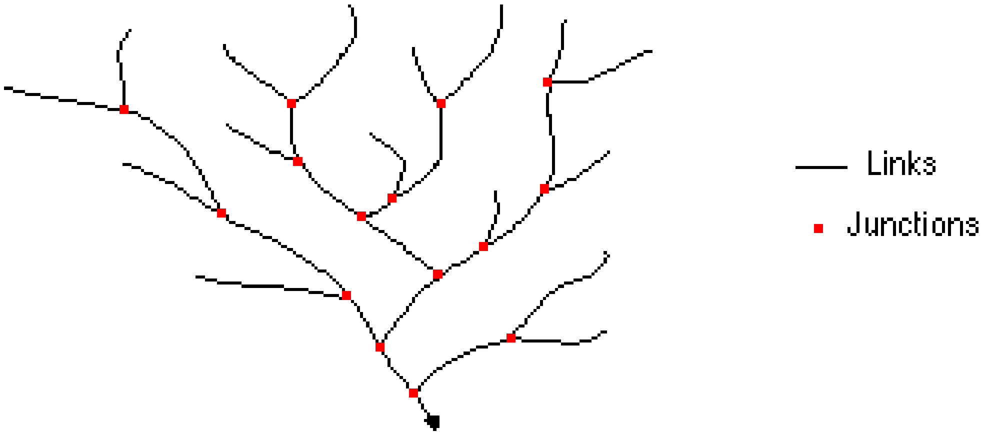
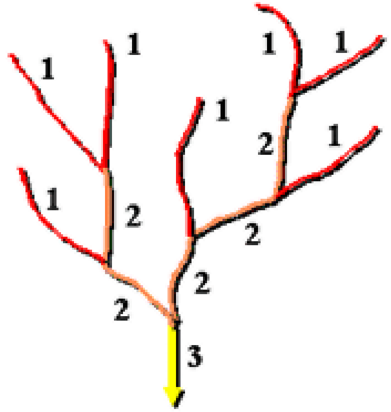
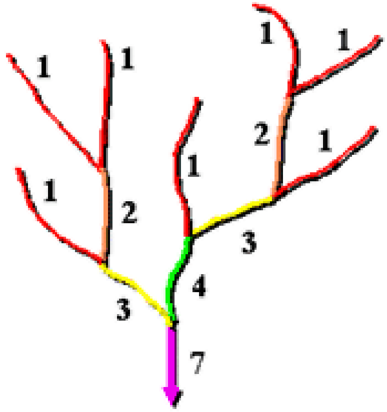


Illustration of the links in a stream channel



Strahler stream ordering method



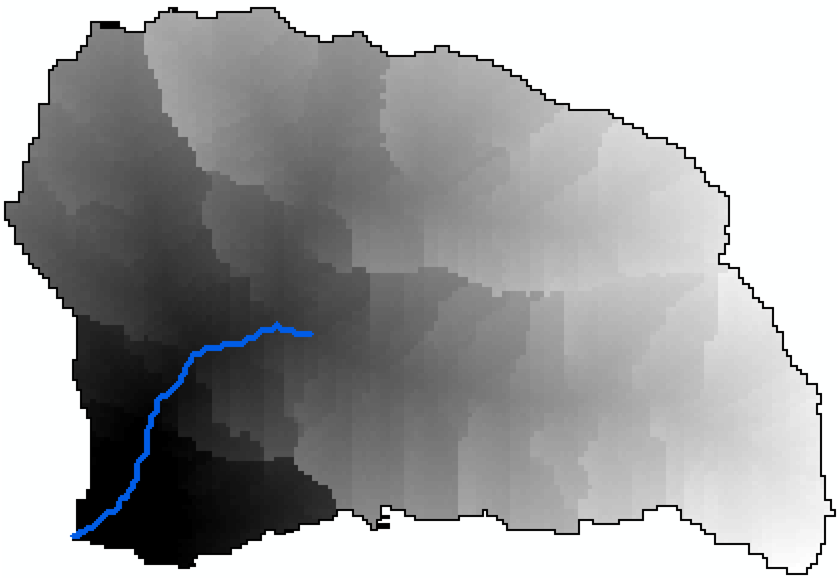
Shreve stream ordering method

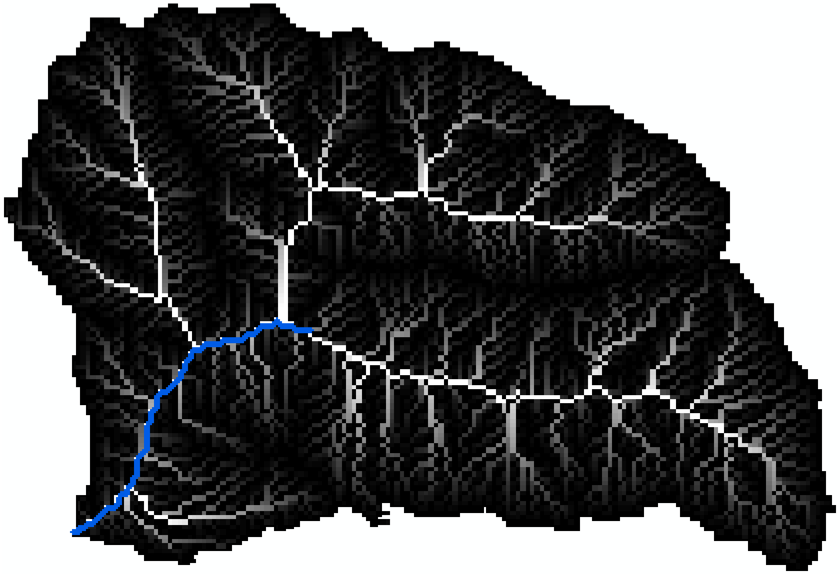
Portland State UNIVERSITY

Flow length - The direction of measurement along the flow path.

DOWNSTREAM — Calculates the downslope distance along the flow path, from each cell to a sink or outlet on the edge of the raster.

UPSTREAM — Calculates the longest upslope distance along the flow path, from each cell to the top of the drainage divide.





Lighter color indicates longer flow length.

Baker, M. E., Weller, D. E., and Jordan, T. E. 2006. Comparison of Automated Watershed Delineations: Effects on Land Cover Areas, Percentages, and Relationships to Nutrient Discharge. PE&RS 72(2): 159-168.

- Compared manual delineations and ten automated delineations of 420 watersheds in four physiographic provinces of the Chesapeake Basin
  - Appalachian Plateau
  - Appalachian Mountain
  - Piedmont
  - Coastal Plain
- Comparison indexes:
  - Watershed size
  - Land-cover composition (row crop ag)
- Correlated ag% with N concentration

Automated Methods:

- Un-enhanced
- Stream burning
- Normalized excavation
- Surface reconditioning (AGREE)
- Normalized reconditioning.

Stream Burning

Lower the Z of stream pixels by a uniform depth.

Raster calculator

“streamg” – stream raster: 1 stream, 0 non-stream

“dem” – original DEM

Con(“streamg” == 1, dem – 10, dem)

Normalized Excavation

Stream burning with adaptive depths informed by local minimum Z.

For example, depth = $(Z - Z_{min}) + 2$

Z_{min} is the min of Z within a 150 m searching window

In ArcGIS:

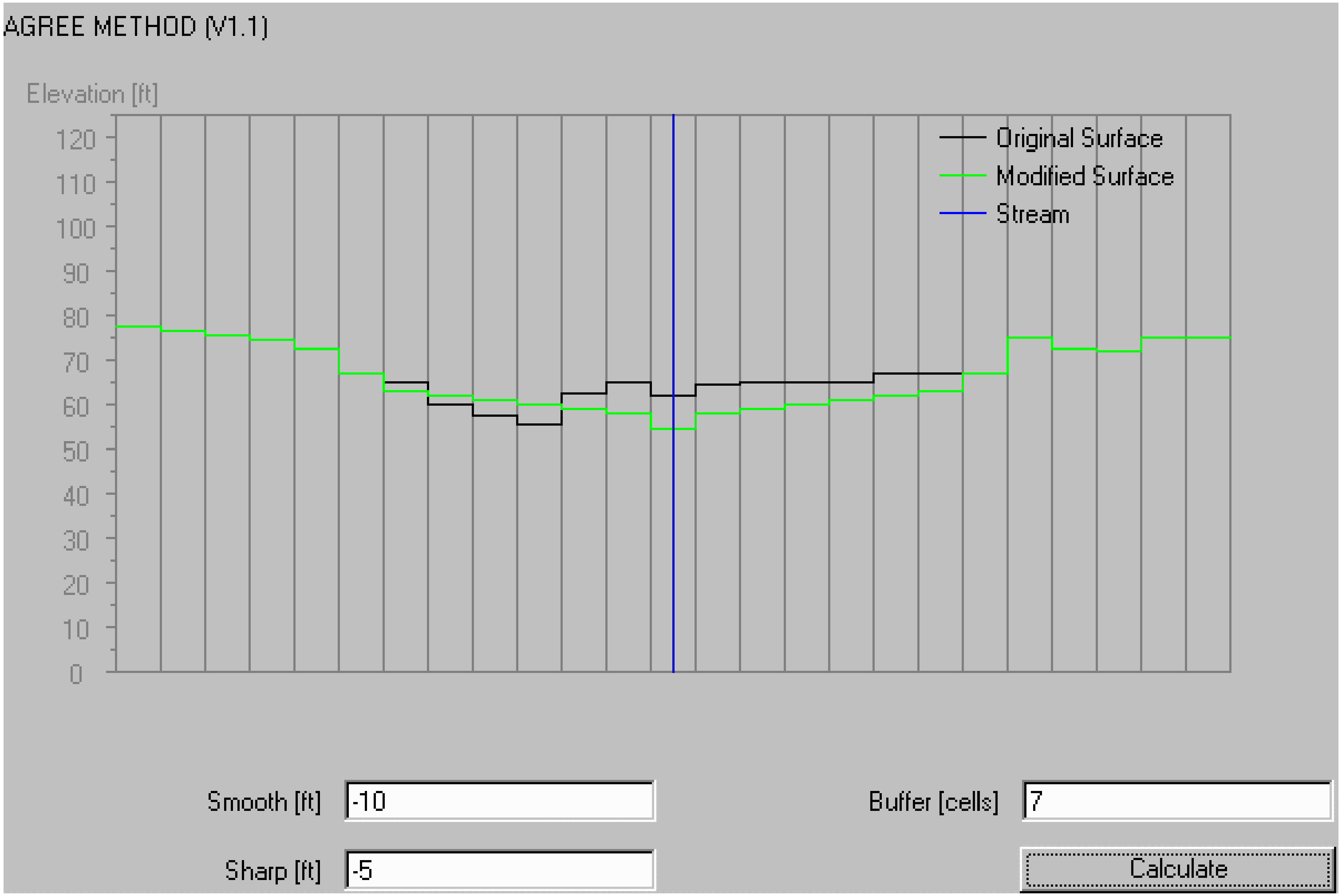
Focal Statistics and Con tools

AGREE Algorithm

1. Drop/raise the elevation of the cells corresponding to the vector lines a certain amount (Smooth)
2. Buffer the vector lines (Buffer)
3. Assign elevation to the cells inside the buffer so that there is a straight line path from the vector line to the original elevation just outside the buffer
4. Drop/raise the elevation of the cells corresponding to the vector lines a certain amount (Sharp)

http://www.ce.utexas.edu/prof/maidment/gishydro/ferdi/research/agree/agree.html#

AGREE



AGREE METHOD (V1.1)
Elevation [ft]
120
110
100
90
80
70
60
50
40
30
20
10
0
Original Surface
Modified Surface
Stream
Smooth [ft]
-10
Buffer [cells]
7
Sharp [ft]
-5
Calculate

Data Used

- USGS 7.5 minute (~30 m) DEM
- USGS DLG Hydrography map
- NLCD land-cover
- Nitrate concentration data

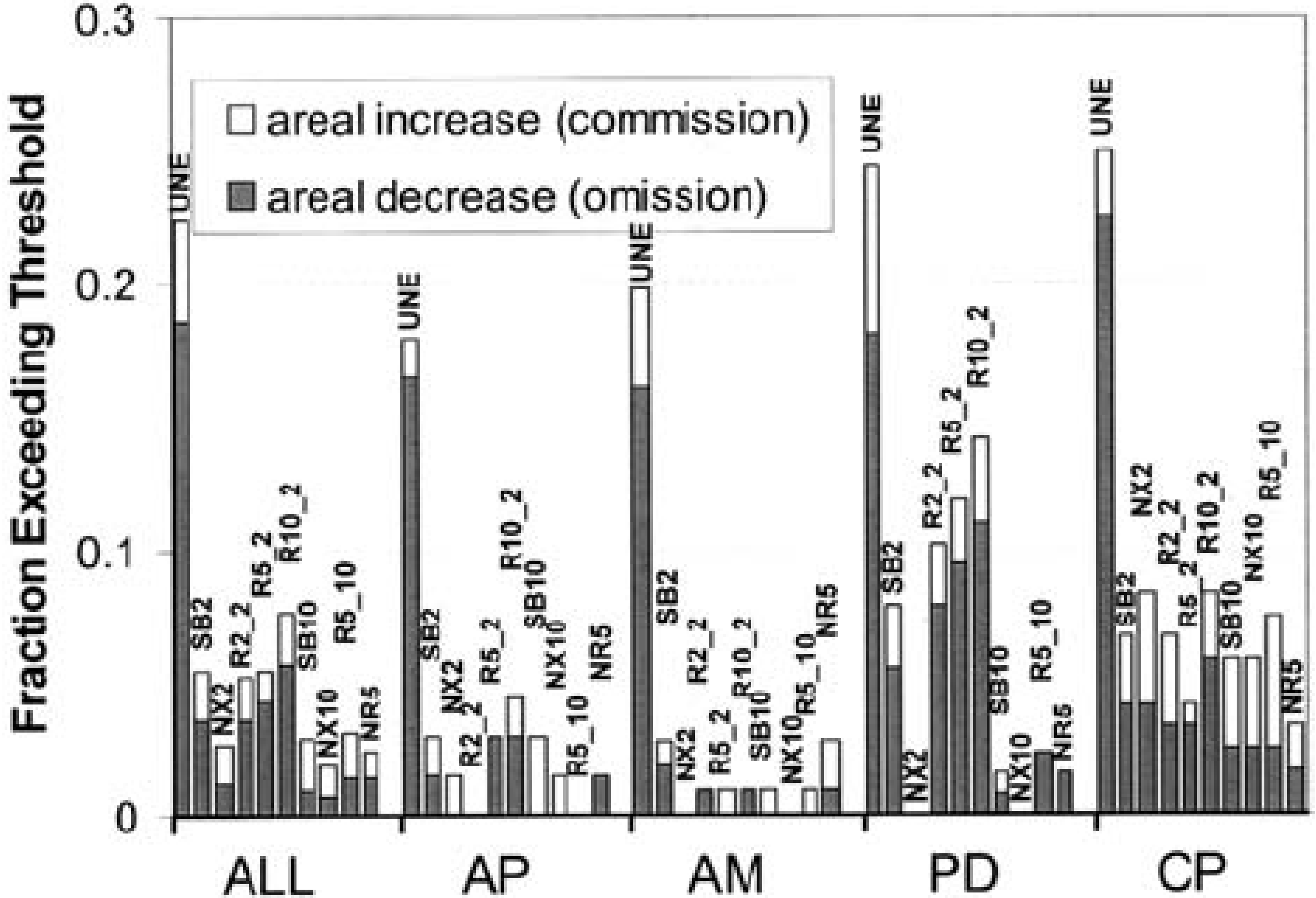
TABLE 1. AUTOMATED WATERSHED DELINEATION METHODS AND PARAMETERS

Method	Reconditioning Width (# 30-m cells)	Normalization Distance (m)	Excavation (Smooth Drop) Depth (m)	Code
Un-enhanced	•	•	•	UNE
Stream Burning	•	•	2	SB2
Normalized Excavation	•	150	(original elev-local min) + 2	NX2
Reconditioning (AGREE)	2	•	2	R2_2
Reconditioning (AGREE)	5	•	2	R5_2
Reconditioning (AGREE)	10	•	2	R10_2
Stream Burning	•	•	10	SB10
Normalized Excavation	•	150	(original elev-local min) + 10	NX10
Reconditioning	5	•	10	R5_10
Normalized Reconditioning	5	150	(original elev-local min)	NR5

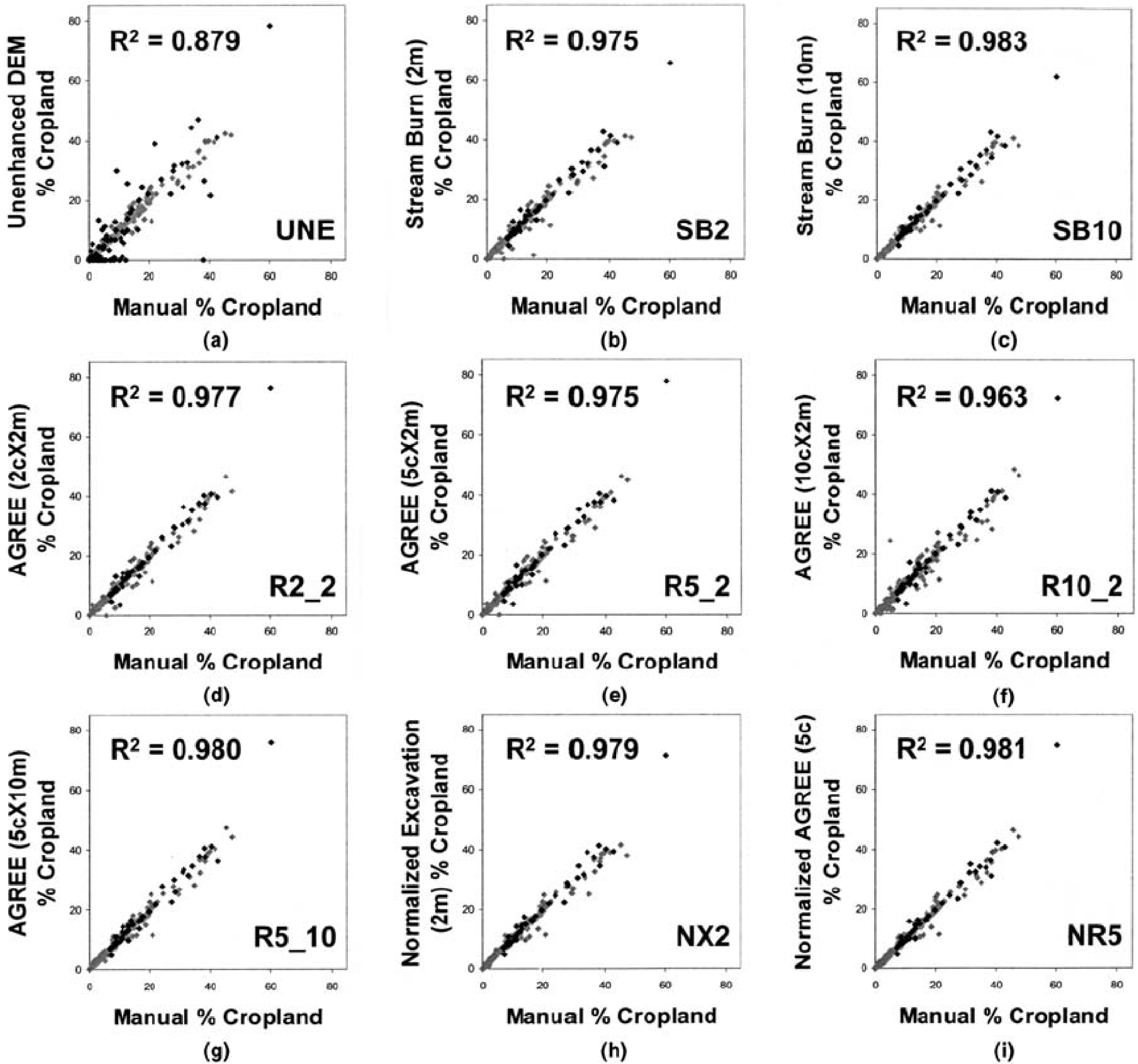
General observations:

- Enhanced methods are effective
- 10 m excavation depth is more effective than 2 m
- Increasing reconditioning width in AGREE leads to more error
- Simpler methods outperformed most of the more complex AGREE methods

Results



Fraction Exceeding Threshold
0.3
0.2
0.1
0
areal increase (commission)
areal decrease (omission)
UNE
SB2
NX2
R2_2
R5_2
R10_2
SB10
NX10
R5_10
NR5
ALL
AP
AM
PD
CP


R² = 0.879
UNE
Unenhanced DEM % Cropland
Manual % Cropland
(a)
R² = 0.975
SB2
Stream Burn (2m) % Cropland
Manual % Cropland
(b)
R² = 0.983
SB10
Stream Burn (10m) % Cropland
Manual % Cropland
(c)
R² = 0.977
R2_2
AGREE (2cX2m) % Cropland
Manual % Cropland
(d)
R² = 0.975
R5_2
AGREE (5cX2m) % Cropland
Manual % Cropland
(e)
R² = 0.963
R10_2
AGREE (10cX2m) % Cropland
Manual % Cropland
(f)
R² = 0.980
R5_10
AGREE (5cX10m) % Cropland
Manual % Cropland
(g)
R² = 0.979
NX2
Normalized Excavation (2m) % Cropland
Manual % Cropland
(h)
R² = 0.981
NR5
Normalized AGREE (5c) % Cropland
Manual % Cropland
(i)