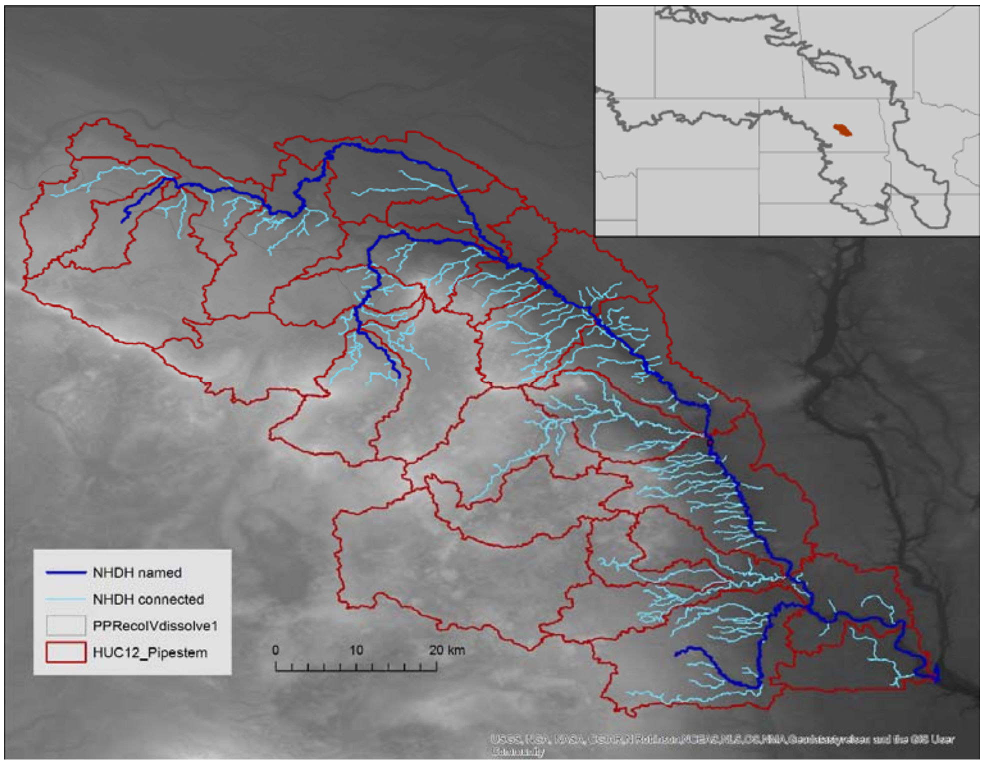
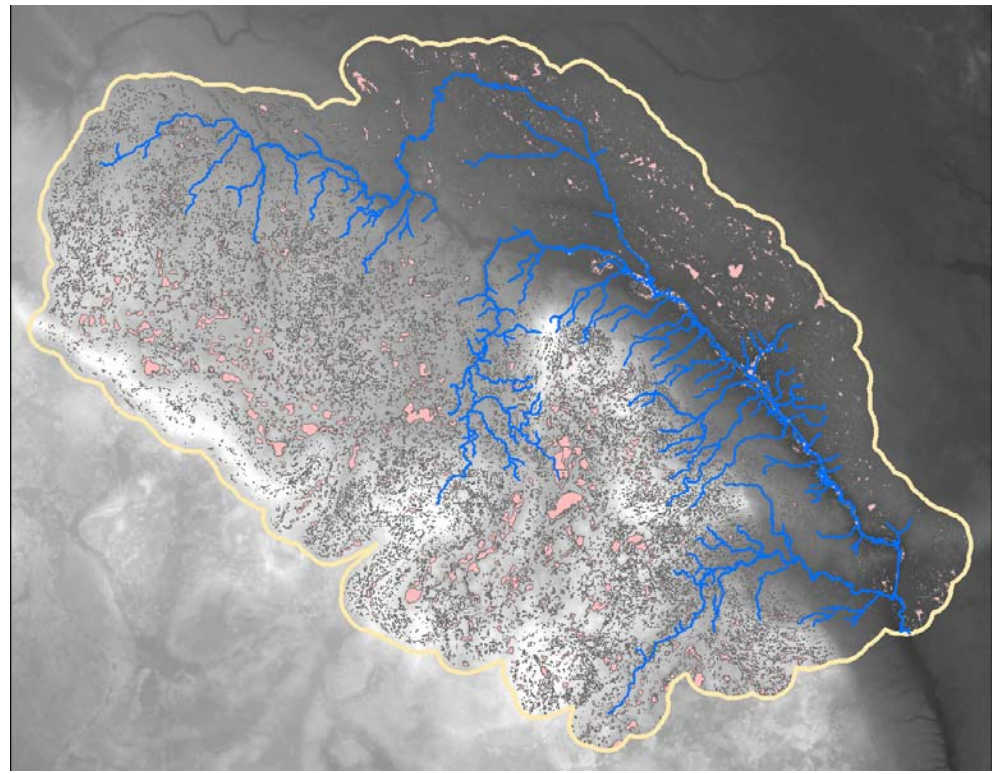
Geospatial connectivity metrics: Update on simple metrics for the Upper Pipestem

Jay Christensen, Scott Leibowitz, Laurie Alexander





Proposed Spatial Indicators for Comparative Connectivity Analyses

Scott G. Leibowitz, Laurie Alexander, Irena Creed, Amina Pollard

- Begin the development of simple metrics within the Prairie Pothole Region (Upper Pipestem) - compare and coordinate with PPR modeling work
- Apply and compare in other regions of North America
- Integrate selected metrics into national classification approach and assessment

Office of Research and Development
Western Ecology Division, Freshwater Ecology Branch, Corvallis OR

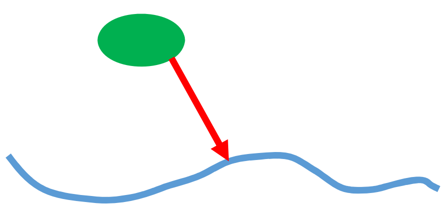
Overview

Three cases

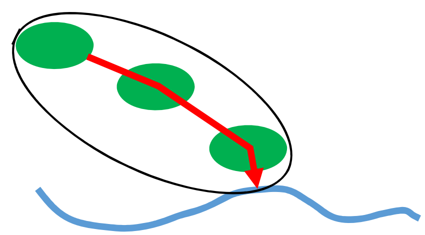
Case 1: Connectivity of individual wetlands to streams – static models

Case 2: Stepwise connectivity of wetland complexes to streams – simple dynamic models

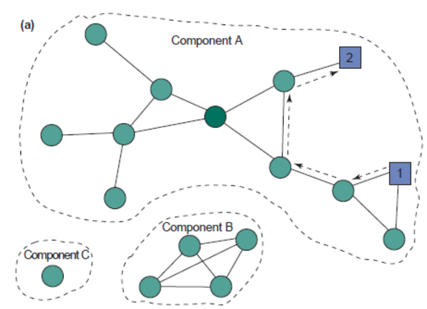
Case 3: Network analysis of landscape connectivity



Case 1

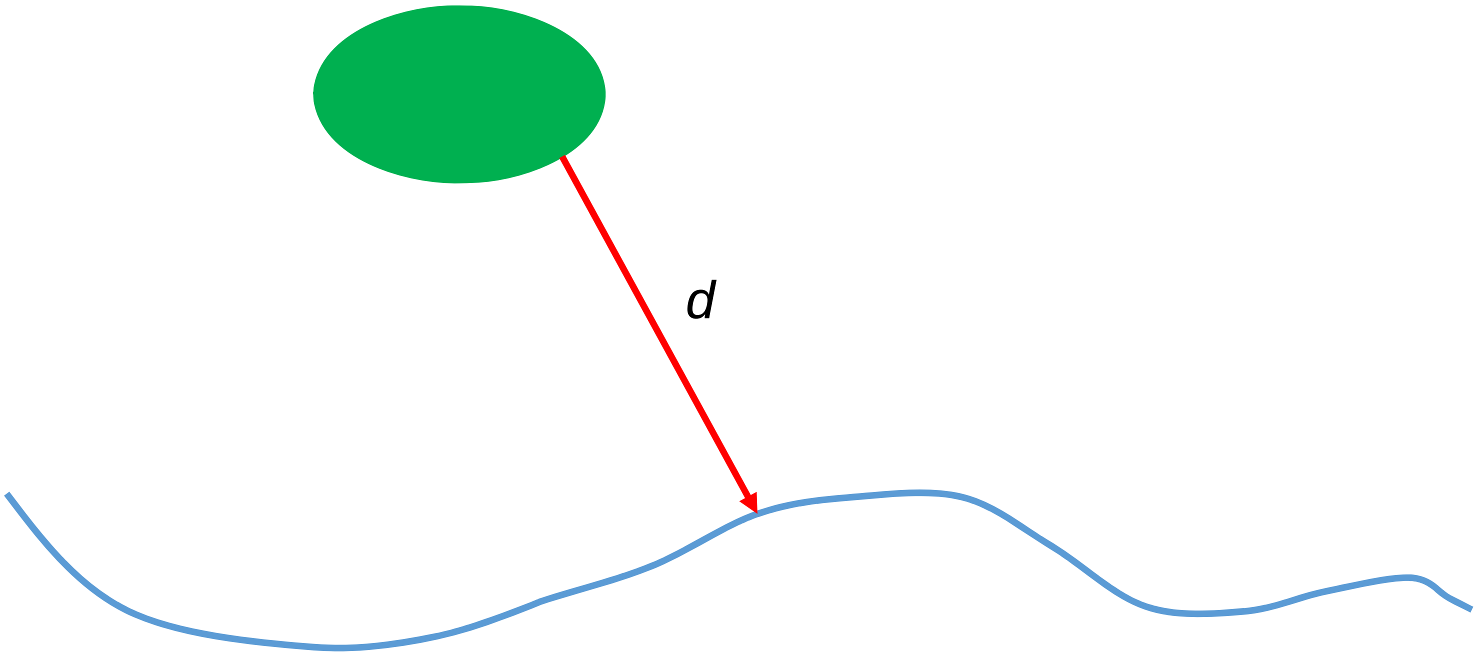


Case 2



Case 3

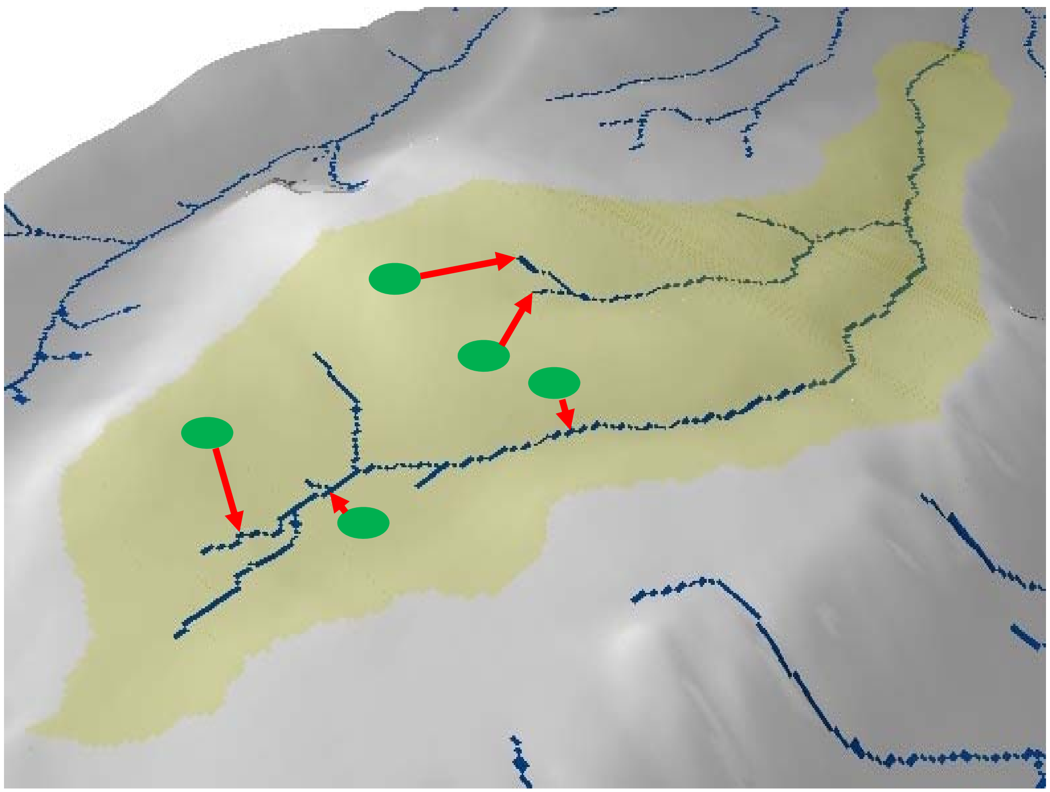
Case 1: Connectivity of individual wetlands to streams



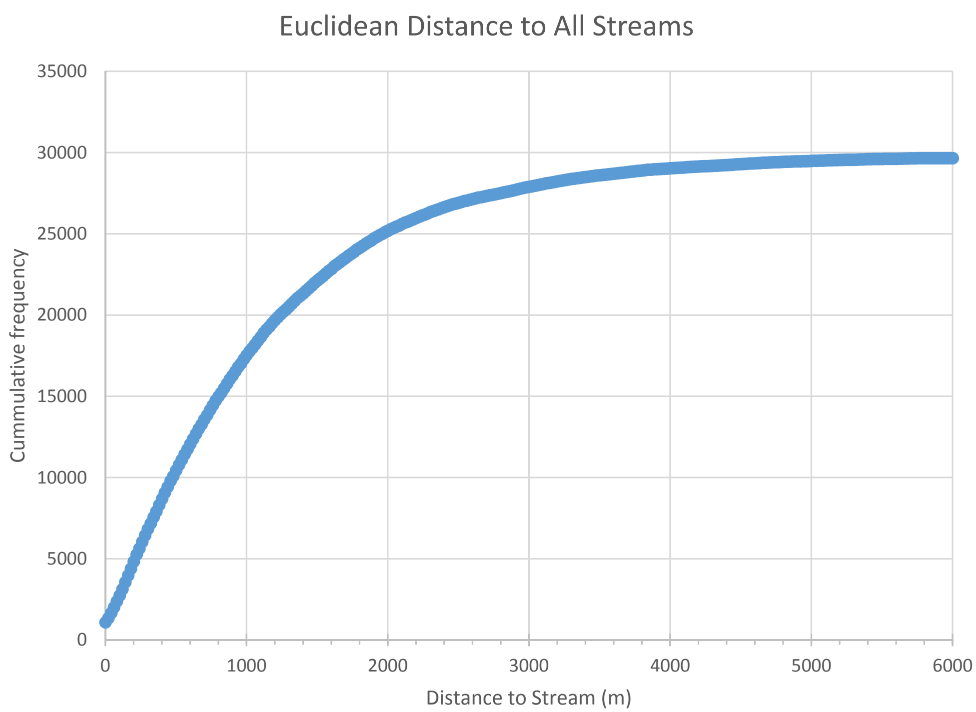
Distance between individual wetland and nearest stream point; distance determined biologically (structurally or functionally) or hydrologically

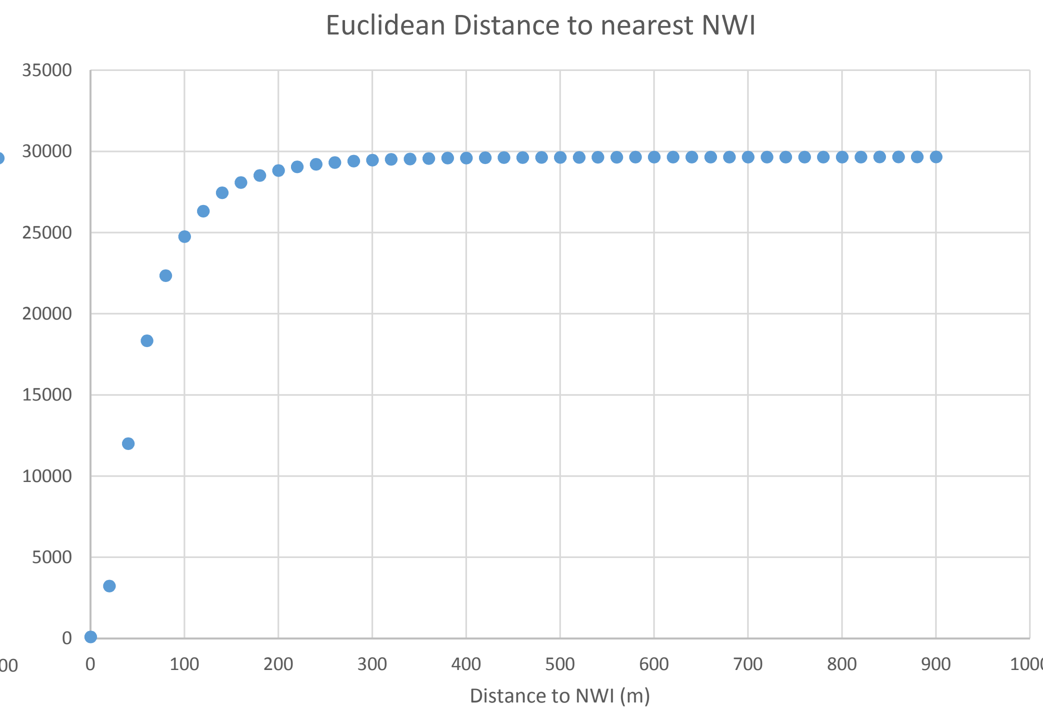
Case 1a

Minimum Euclidean distance between wetland and stream



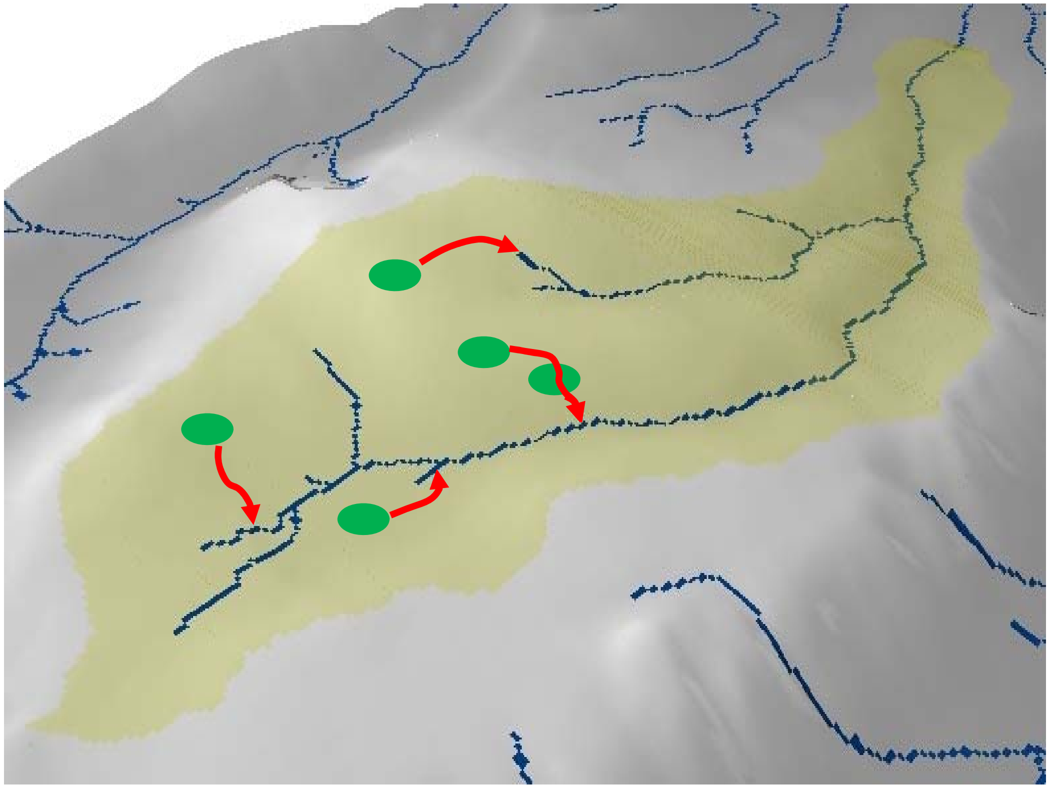
- Use “Near” function from ArcGIS
  - From NWI to Stream
  - From NWI to NWI
- USGS 1/3arc (10m) DEM
- Streams:
  - 1) all NHD-high segments
  - 2) only connected segments


Euclidean Distance to All Streams
Cummulative frequency
0
5000
10000
15000
20000
25000
30000
35000
0
1000
2000
3000
4000
5000
6000
Distance to Stream (m)


Euclidean Distance to nearest NWI
0
5000
10000
15000
20000
25000
30000
35000
0
100
200
300
400
500
600
700
800
900
1000
Distance to NWI (m)

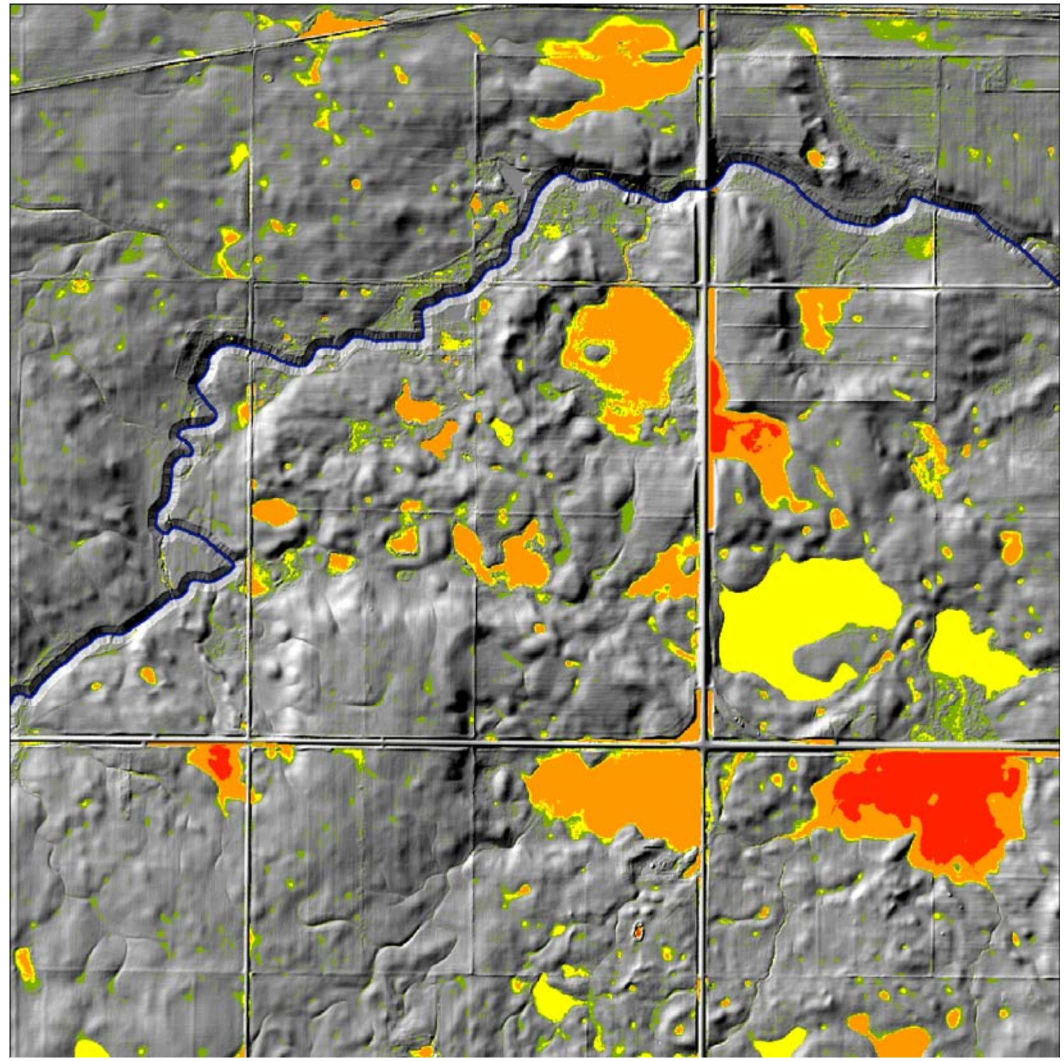
Case 1d

Flow path distance between wetland and stream



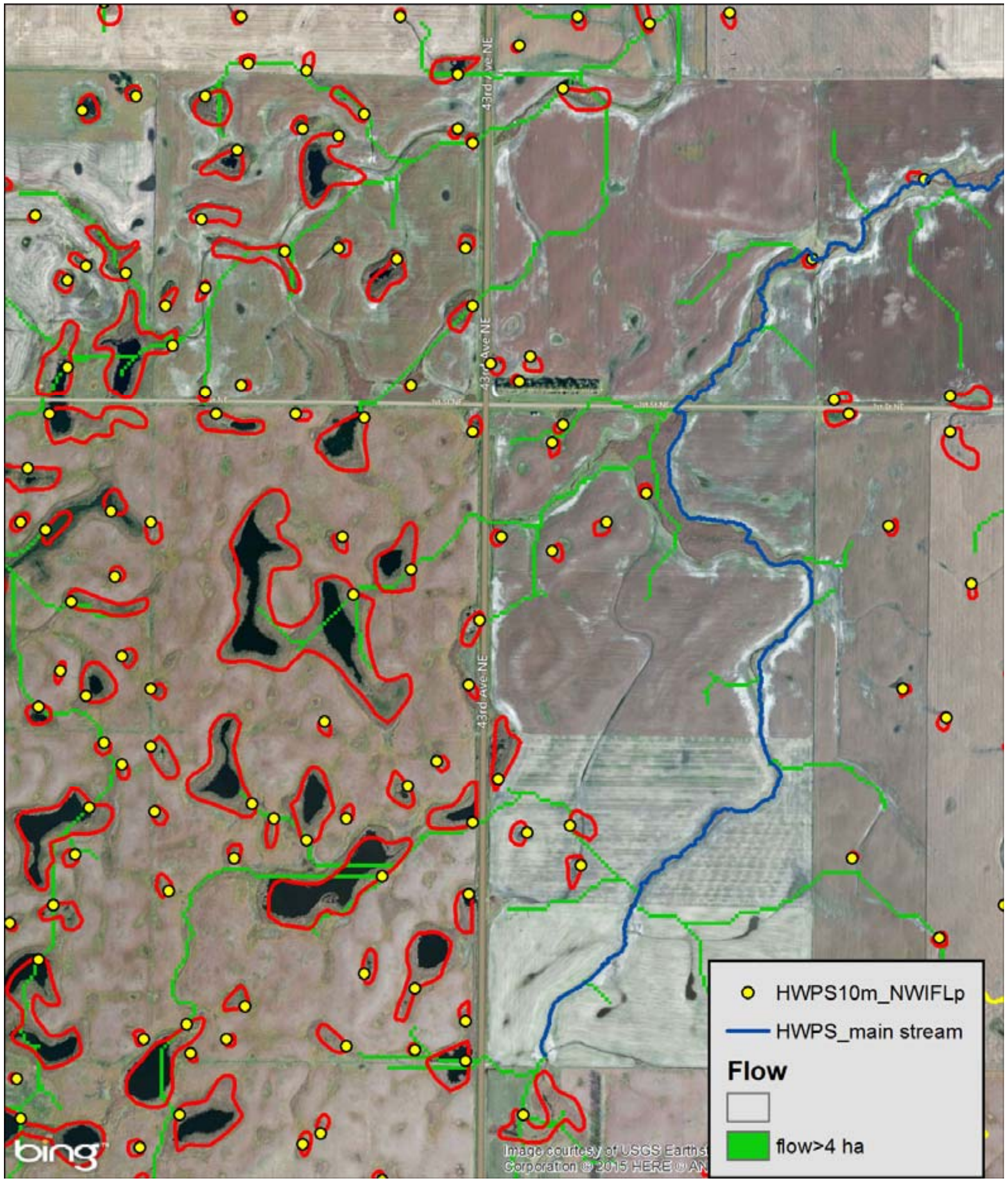
Defining Flow Paths

- Hydro-Enforcement
  - Match the NHD
  - Removes road obstacles that intersect NHD
  - Assumes NHD is truth
- DEM resolution test – slight differences in flow path length (ND and MD)
- Flow path algorithm tests - some differences but computationally intense



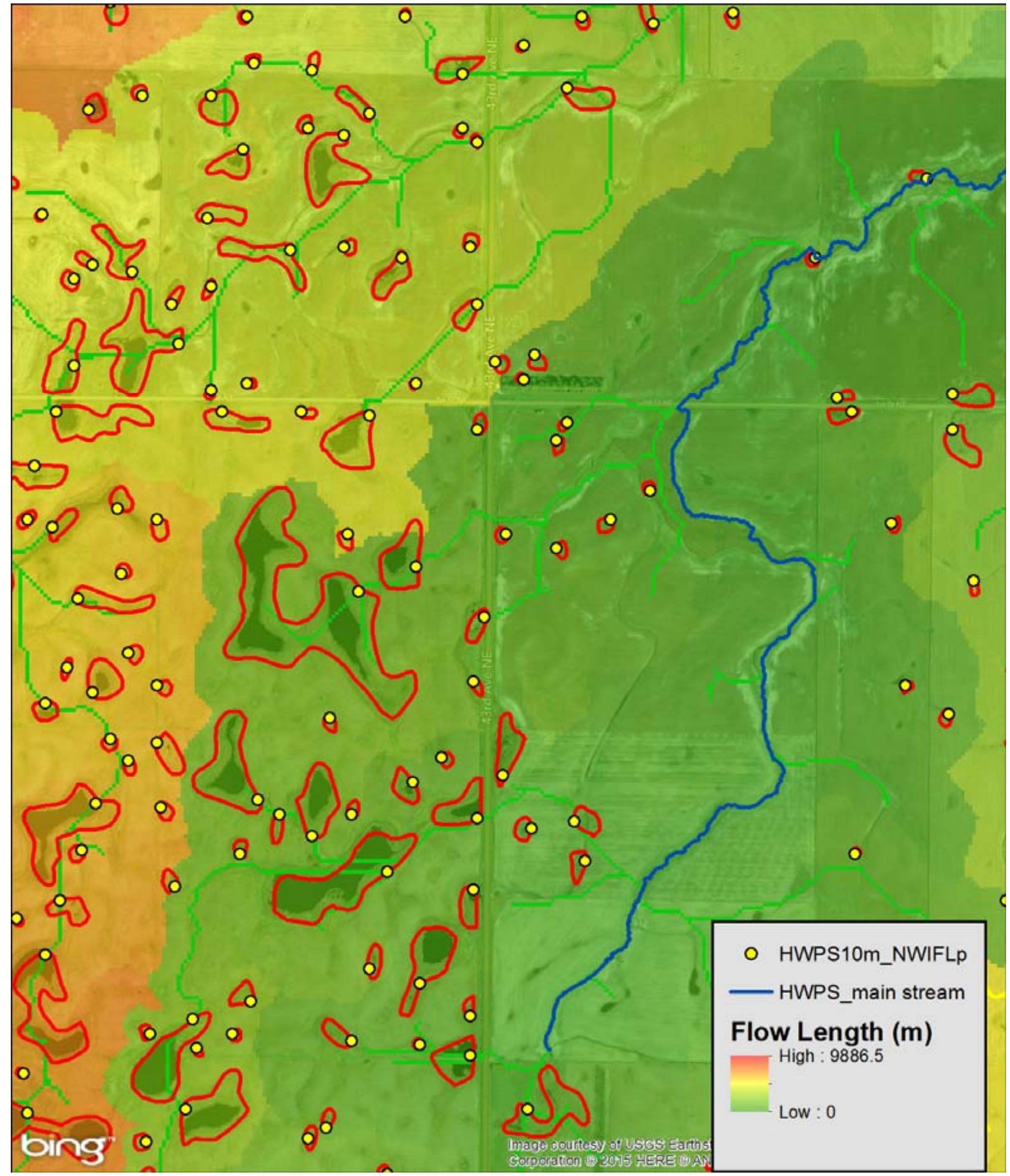
Defining Flow Paths

- 10m DEM with Hydro-enforcement and fill techniques
- Assume 1 spill point for NWI
- Spill point – highest Flow Accumulation within the wetland

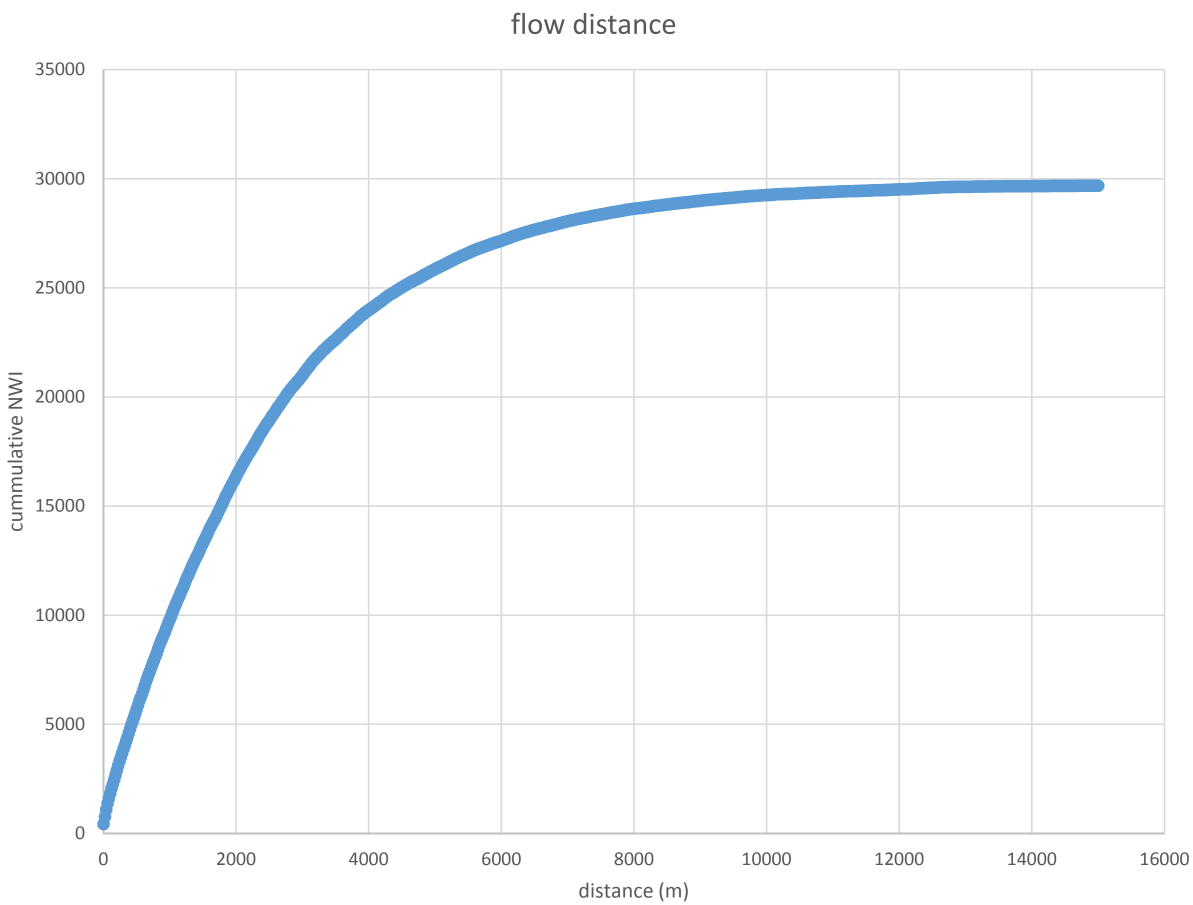


Defining Flow Paths

- 10m DEM with Hydro-enforcement and fill techniques
- Assume 1 spill point for NWI
- Spill point – highest Flow Accumulation within the wetland
- Run "Flow Length" to streams and identify the flow length at spill points

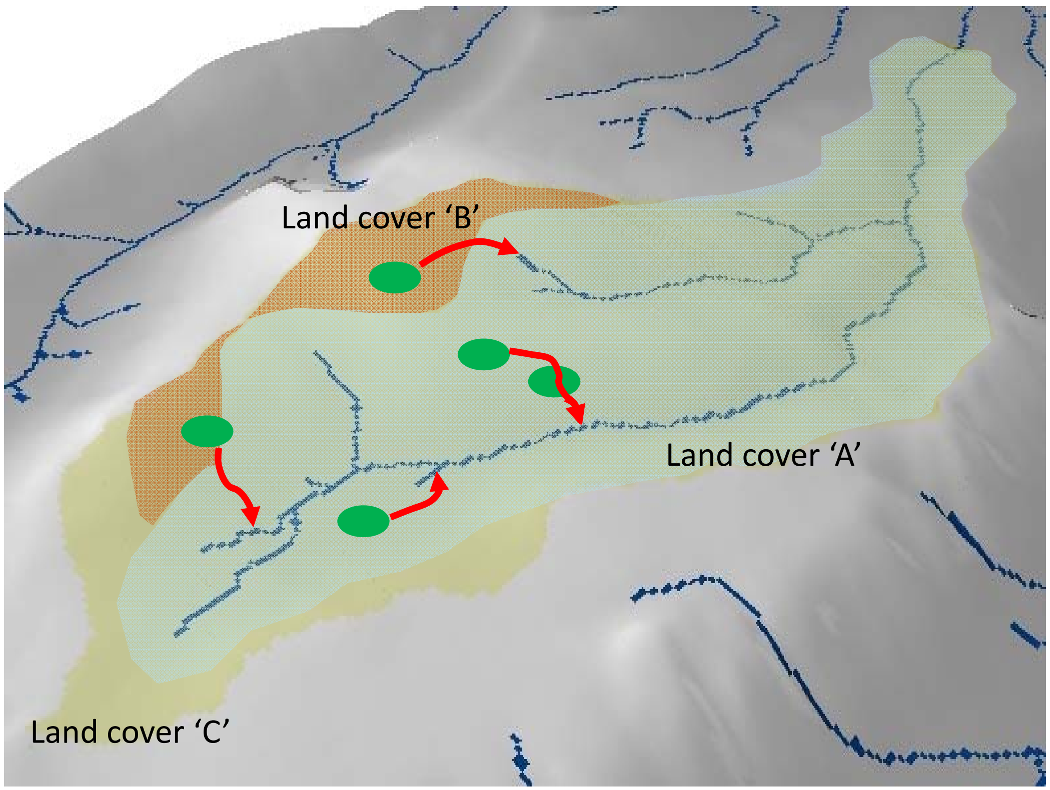


Flow path distance to all streams

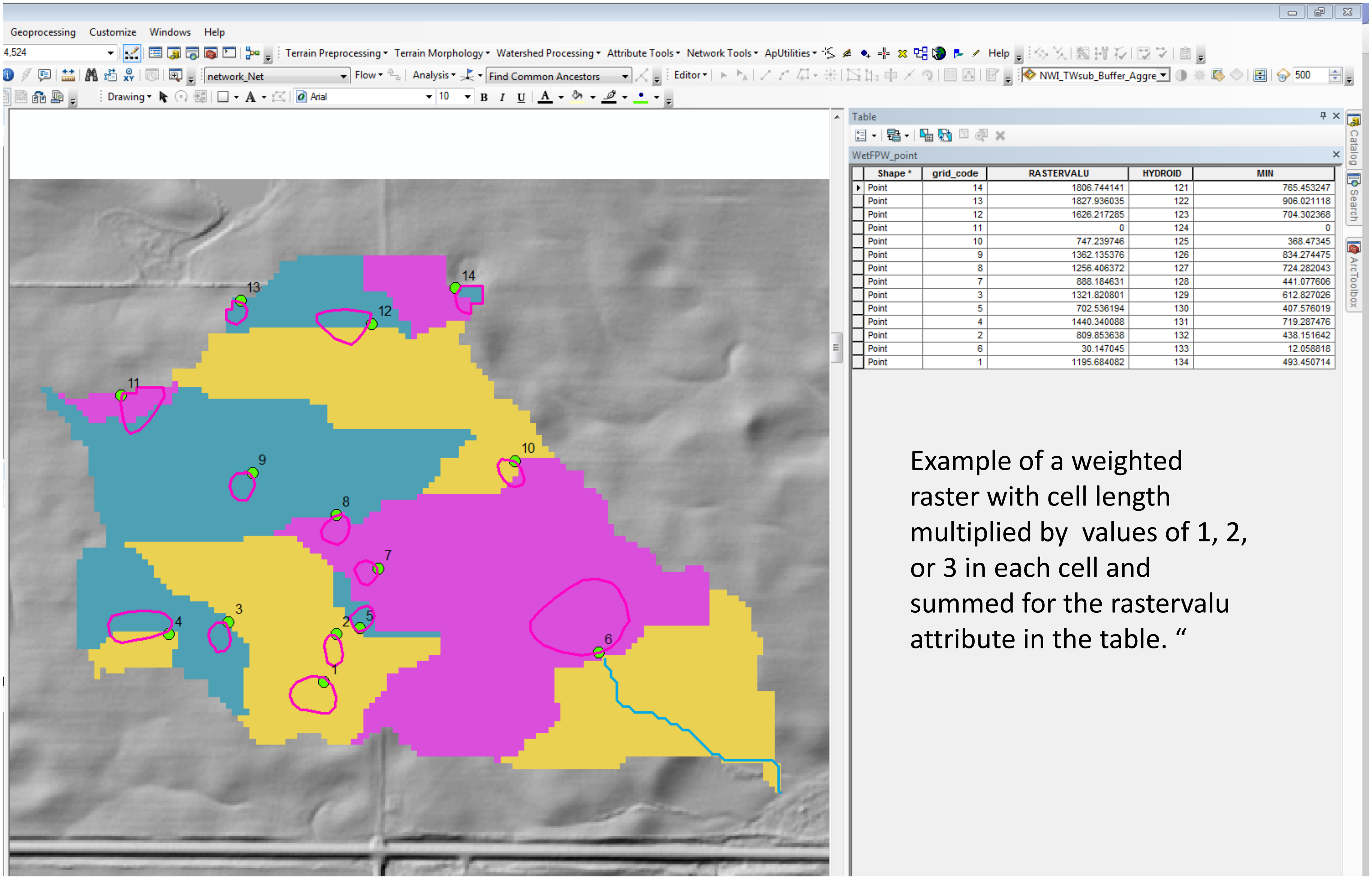


Case 1f

Weighted flow path distance between wetland and stream



- Add weight to flow lengths
  - manning's n coefficient values
  - Value for each wetland is a combination of it's distance to the stream and the land cover it passes through



Shape *	grid_code	RASTERVALU	HYDROID	MIN
Point	14	1806.744141	121	765.453247
Point	13	1827.936035	122	906.021118
Point	12	1626.217285	123	704.302368
Point	11	0	124	0
Point	10	747.239746	125	368.47345
Point	9	1362.135376	126	834.274475
Point	8	1256.406372	127	724.282043
Point	7	888.184631	128	441.077606
Point	3	1321.820801	129	612.827026
Point	5	702.536194	130	407.576019
Point	4	1440.340088	131	719.287476
Point	2	809.853638	132	438.151642
Point	6	30.147045	133	12.058818
Point	1	1195.684082	134	493.450714

Example of a weighted raster with cell length multiplied by values of 1, 2, or 3 in each cell and summed for the rastervalu attribute in the table. "

Simple Travel Time Estimate

$$t_{trav} = \frac{d}{v} = \frac{d}{\frac{k}{n} R^{2/3} S^{1/2}}$$

t_{trav} = Travel time

d = Distance – overland flow distance

v = Flow velocity

k = Conversion factor

n = Manning coefficient – average across the flow distance

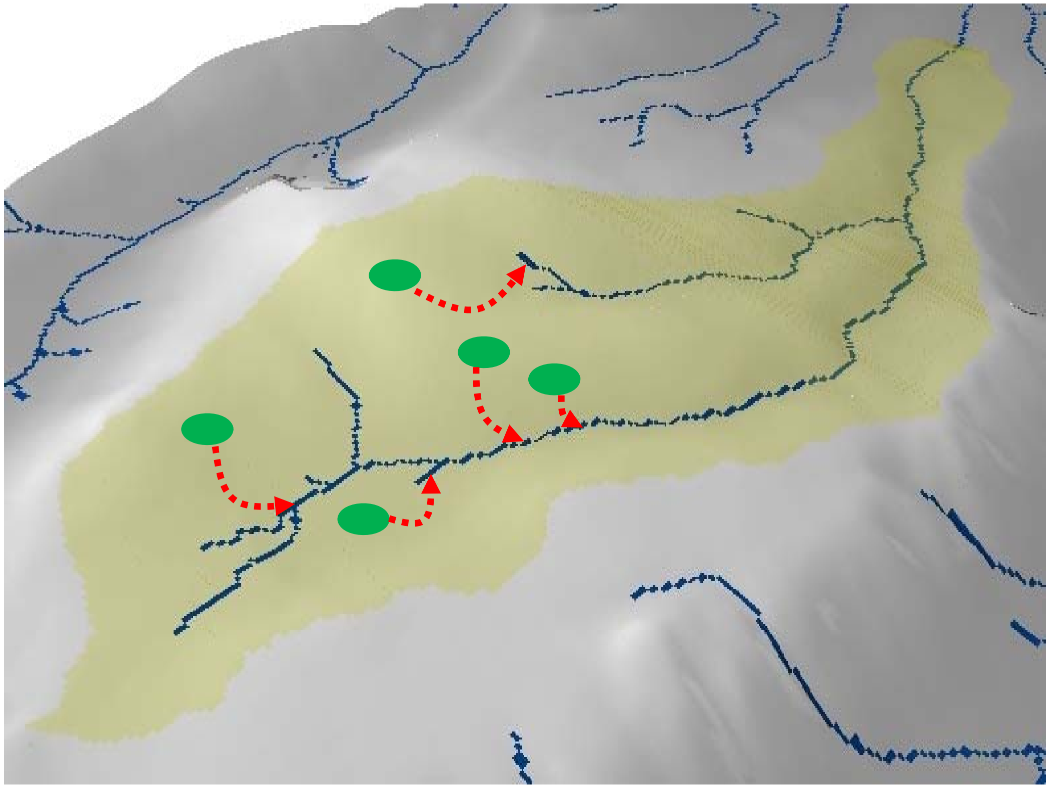
R = Hydraulic radius (flow area/wetted perimeter)

S = Downward slope – average across the flow distance

Note that this does not account for storage capacity along the flowpath or climate dynamics

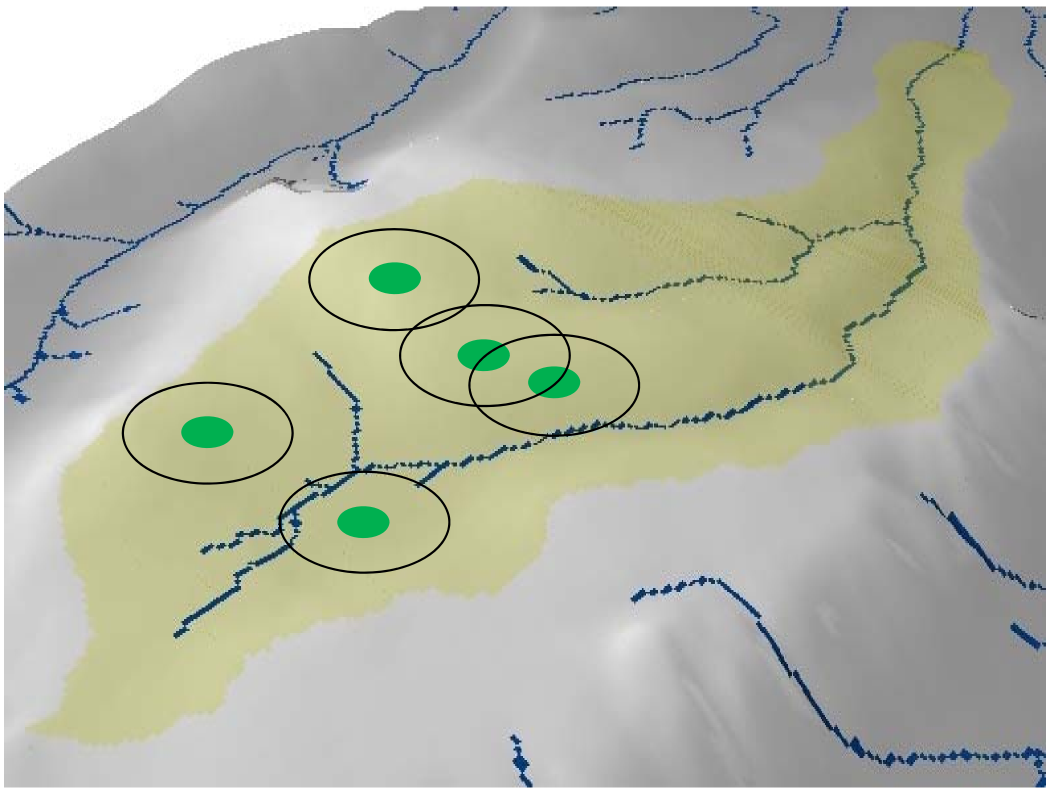
Case 1g

Subsurface travel distance between wetland and stream through Darcian flow – hasn't been addressed yet



Simple Dynamic Models - Case 2a

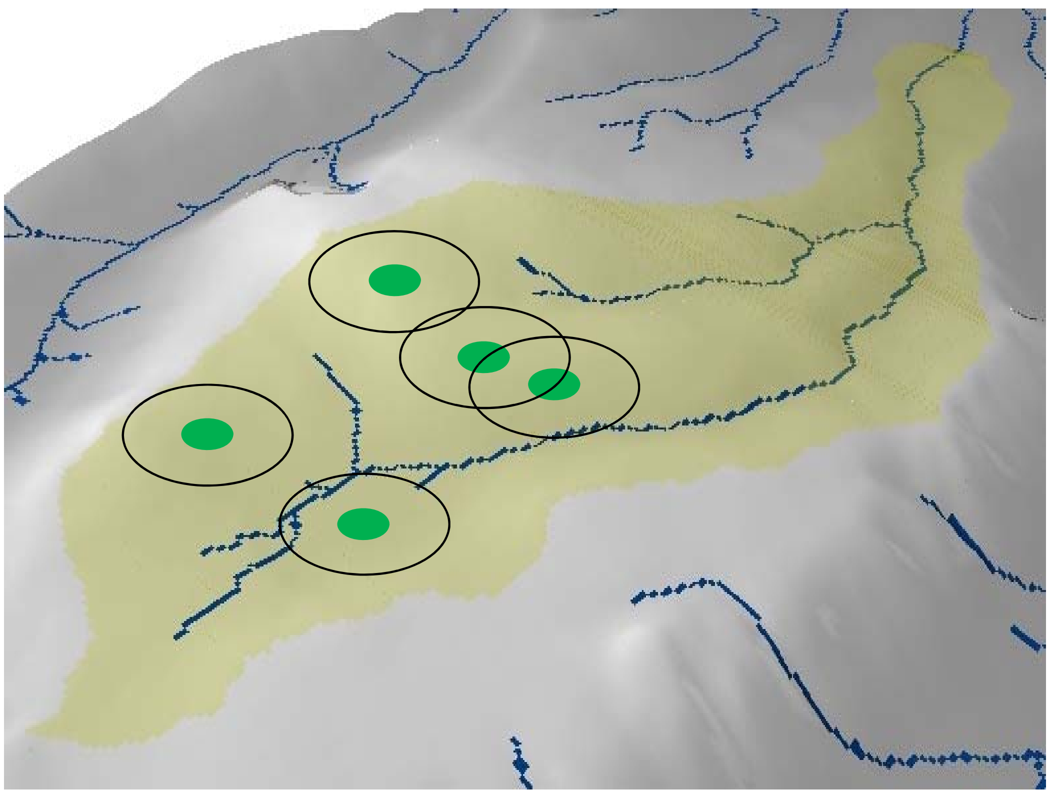
Stepwise Euclidean distances between clusters of connected wetlands and stream given Euclidean stepping stone distance



- Hydrology – expansion during wet periods
- Biology – dispersal distances

Simple Dynamic Models - Case 2a

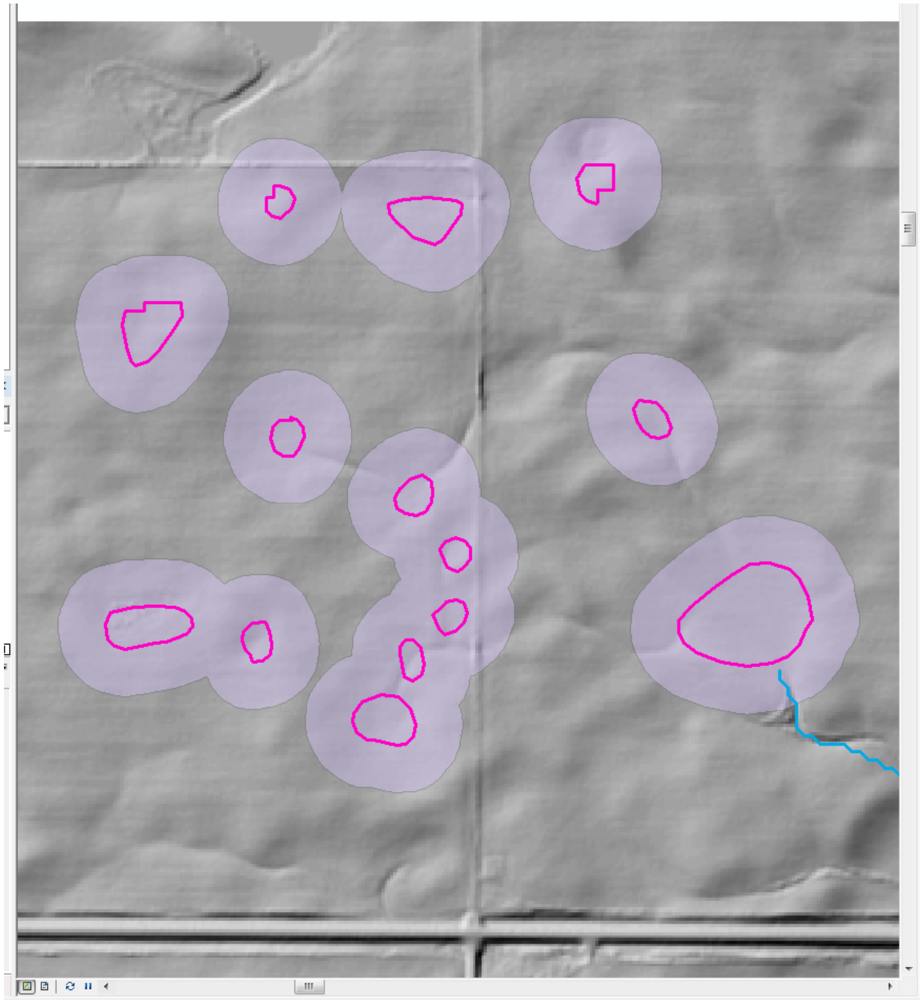
Stepwise Euclidean distances between clusters of connected wetlands and stream given Euclidean stepping stone distance



- Model Builder
  - Inputs: wetlands, stream, buffer distances
  - Output: table for aggregate buffers with # of clustered wetlands, min, max and mean Euclidean distance of clustered wetlands

Aggregated buffer distance of 50m shown

14 NWI wetlands
8 clusters
0 NWI touching stream
1 buffer touching stream

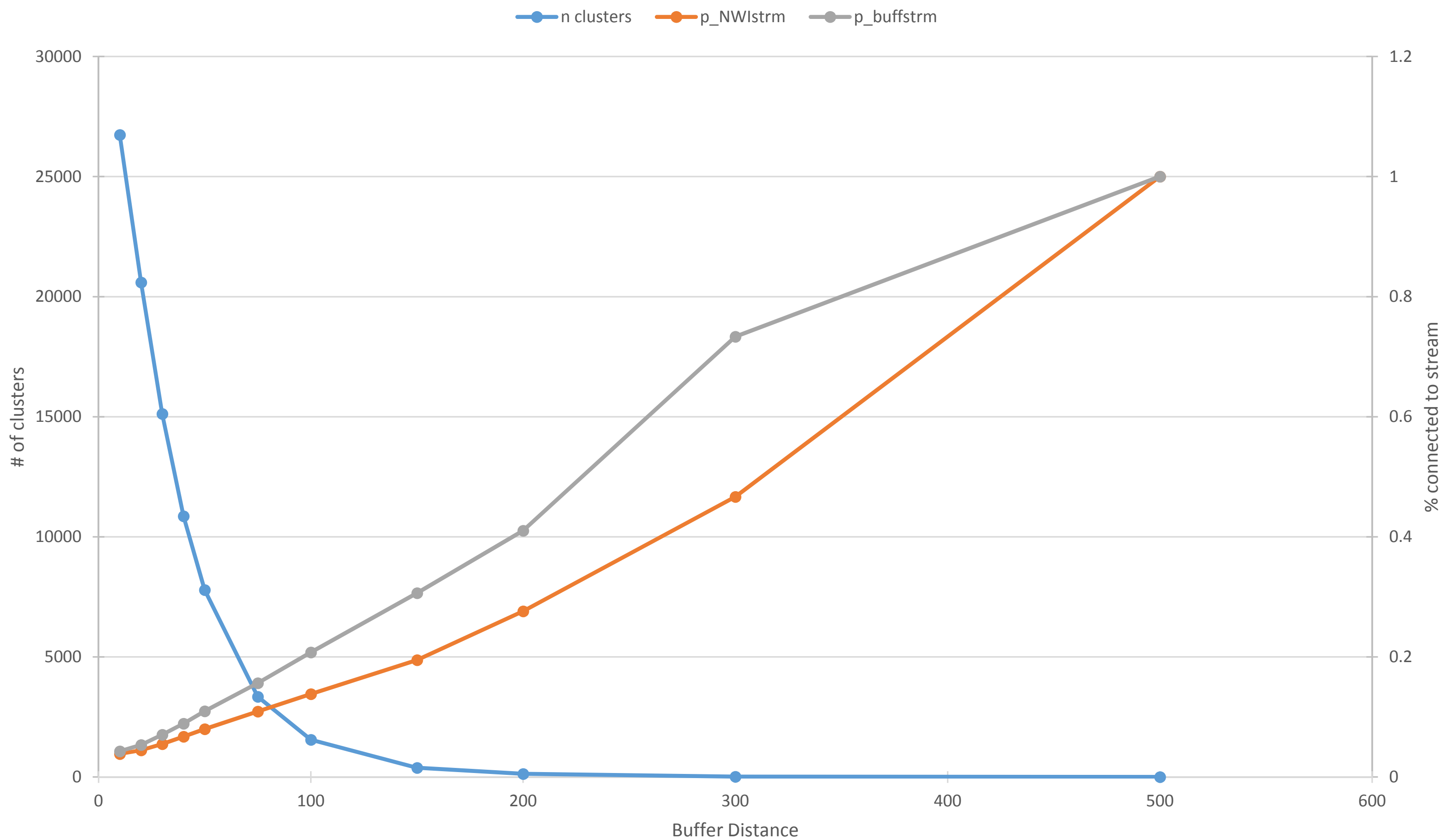


OBJECTI	TARGET_	FREQUE	MIN_NEAR_	MAX_NEAR_	MEAN_NEAR	BUFF_DI
1	1	1	535.682735	535.682735	535.682735	20
2	2	5	334.624548	407.909831	370.027246	20
3	3	1	10.64485	10.64485	10.64485	20
4	4	1	557.881729	557.881729	557.881729	20
5	5	1	620.478309	620.478309	620.478309	20
6	6	1	274.940661	274.940661	274.940661	20
7	7	1	529.39668	529.39668	529.39668	20
8	8	1	708.243892	708.243892	708.243892	20
9	9	1	732.61693	732.61693	732.61693	20
10	10	1	577.032699	577.032699	577.032699	20
11	1	5	334.624548	407.909831	370.027246	50
12	2	1	10.64485	10.64485	10.64485	50
13	3	2	535.682735	620.478309	578.080522	50
14	4	1	557.881729	557.881729	557.881729	50
15	5	1	732.61693	732.61693	732.61693	50
16	6	1	274.940661	274.940661	274.940661	50
17	7	1	529.39668	529.39668	529.39668	50
18	8	2	577.032699	708.243892	642.638295	50
19	1	12	334.624548	732.61693	509.289101	100
20	2	2	10.64485	274.940661	142.792756	100
21	1	14	10.64485	732.61693	456.93248	250
22	1	14	10.64485	732.61693	456.93248	500
23	1	14	10.64485	732.61693	456.93248	1000

1 (0 out of 23 Selected)

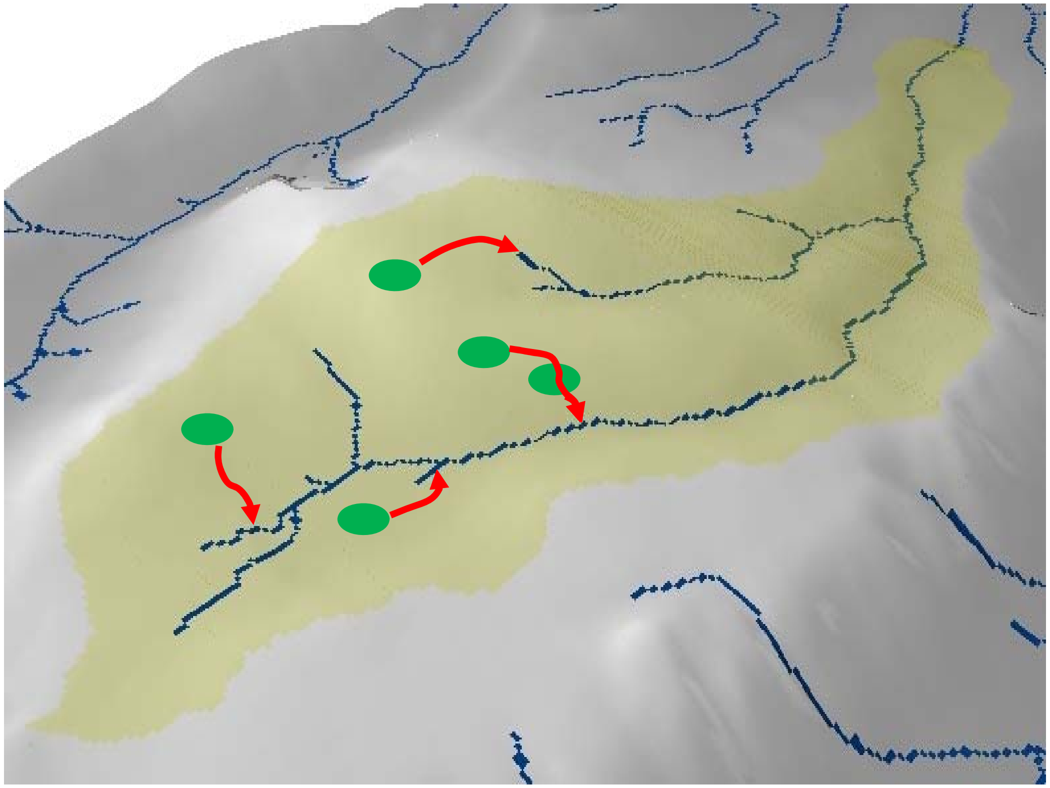
NWI_TWsub_Buffer_AggregatePo | NWI_TWsub_Buffer | buffertest.csv | NWI_buffer_stats0_Merge

Upper Pipestem Euclidean Nested Analysis



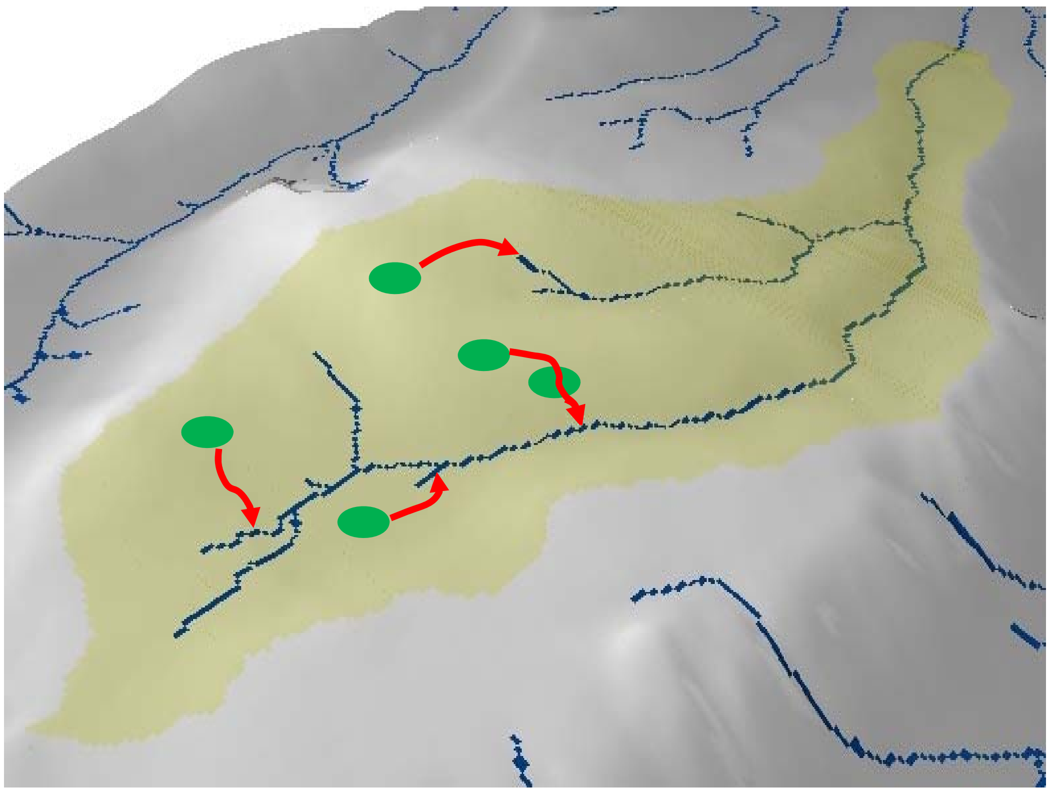
Case 2b

Maximum flowpath distance between clusters of wetlands connected by surface water from rising water tables in high permeability soil – In process



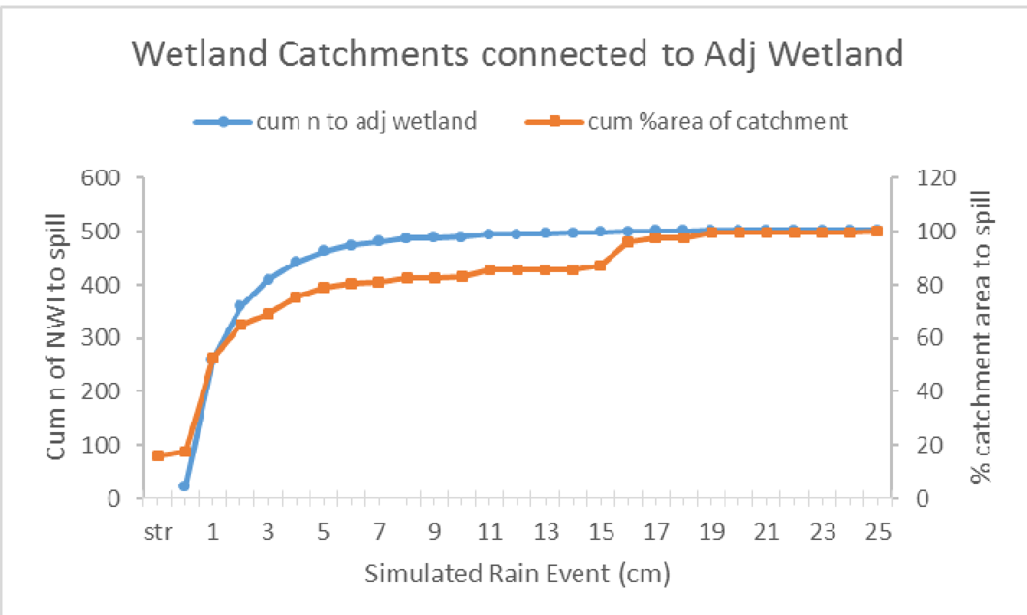
Case 2c

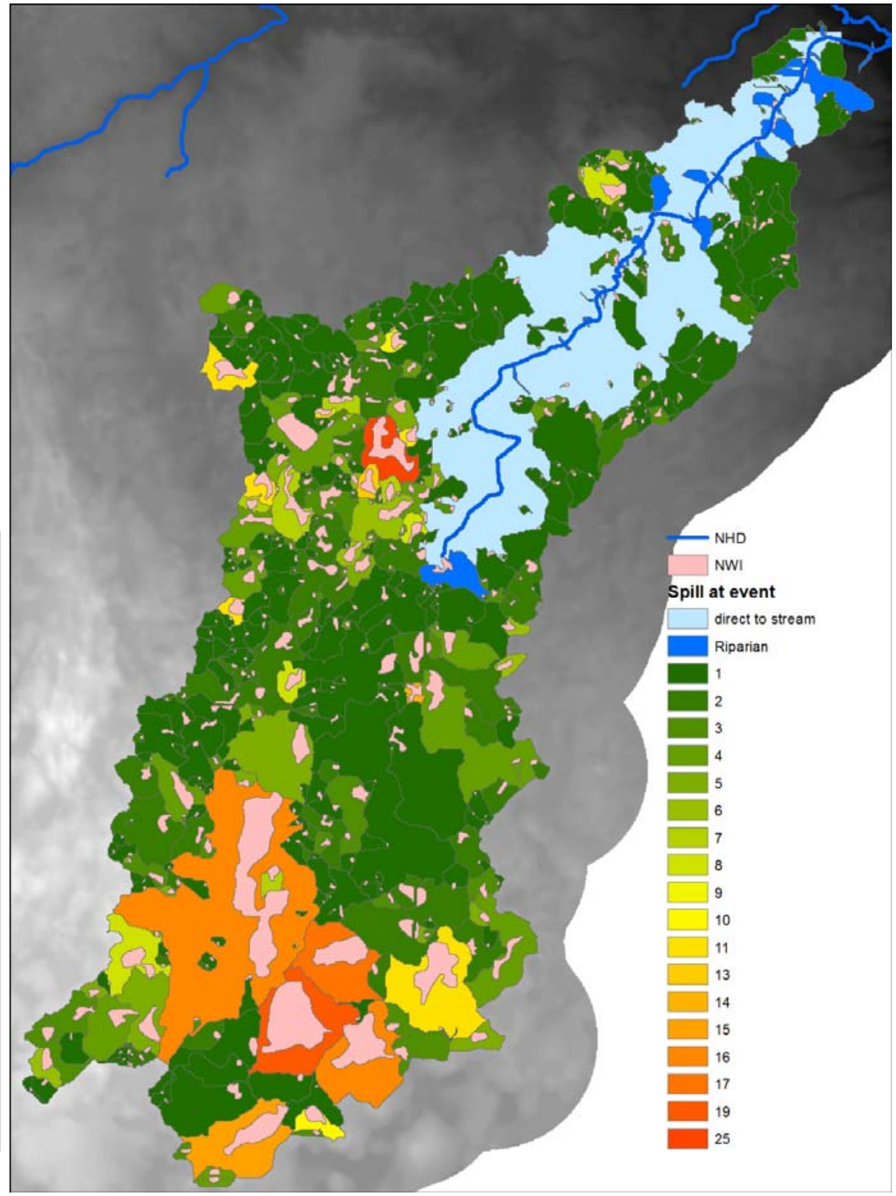
Maximum flowpath distance between clusters of wetlands connected by surface water from fill and spill in low permeability soil



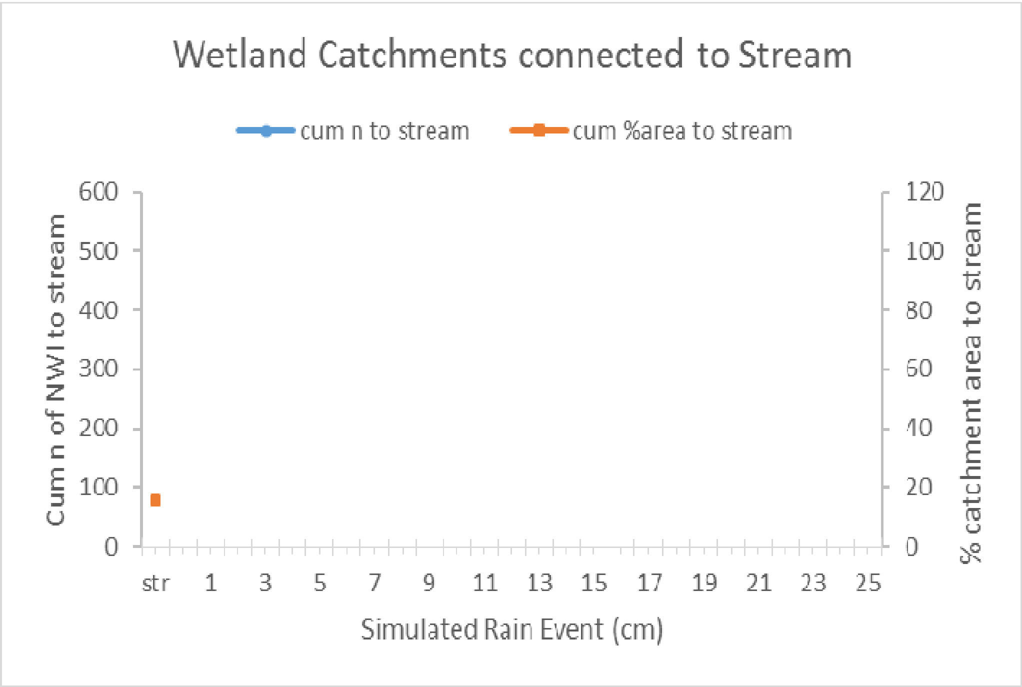
- Model Builder
  - Inputs: wetlands, stream polyline, DEM, Flow Direction Grid
  - Output: wetland area, local catchment area, the next downstream wetland
- R script
  - Estimates wetland volume from wetland area based on Gleason et al. 2007
  - Calculated volume for local catchment area for rain event and assumes land impermeable
  - Identifies when rain event volume exceeds wetland volume and delivers excess water to next downstream wetland
  - Identifies when wetland directly or indirectly (through fill-spill) connect to each other and to the stream

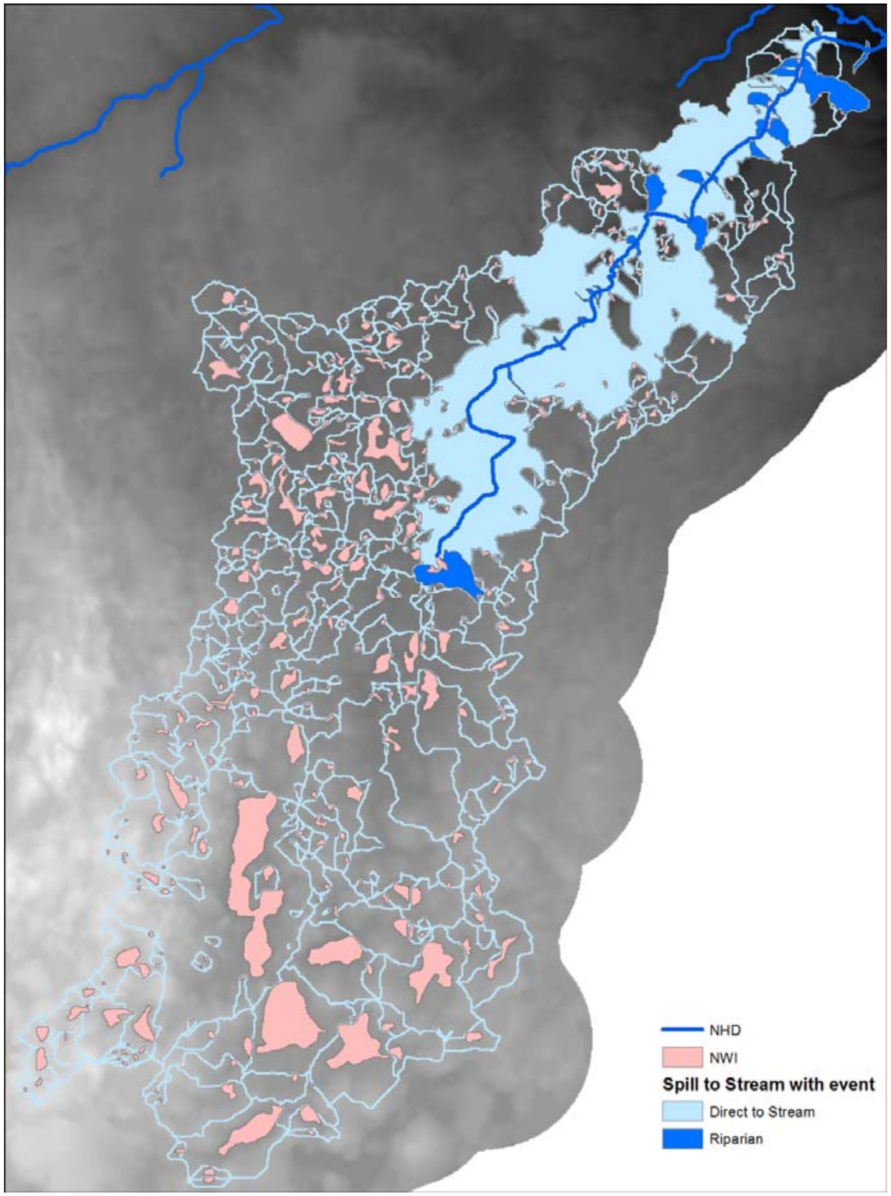
Spillage to adjacent wetland with given rain event (cm)



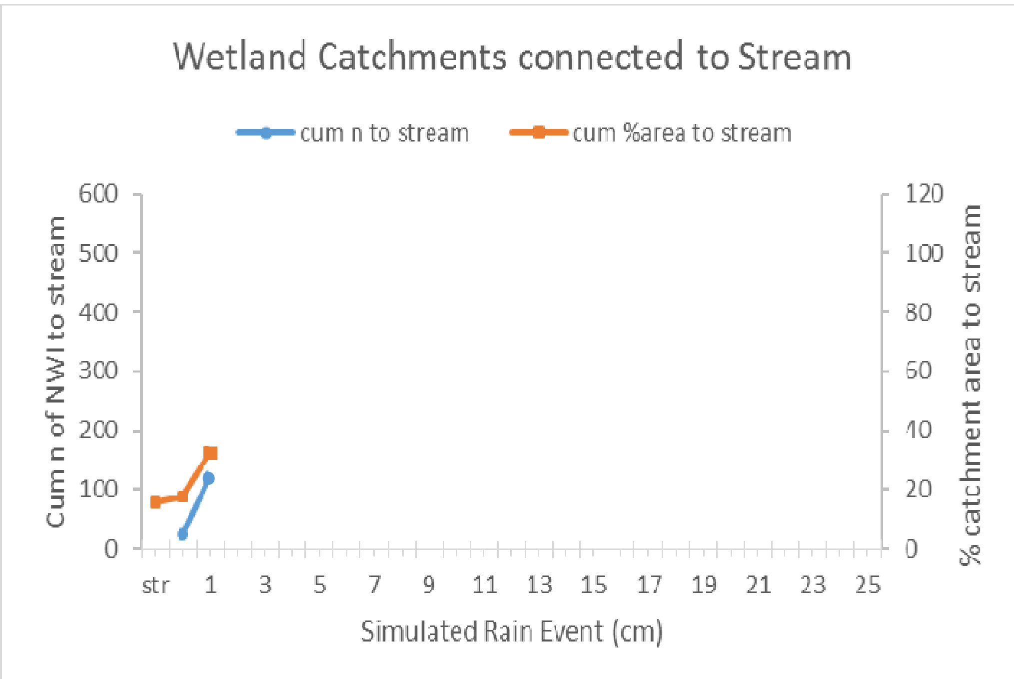


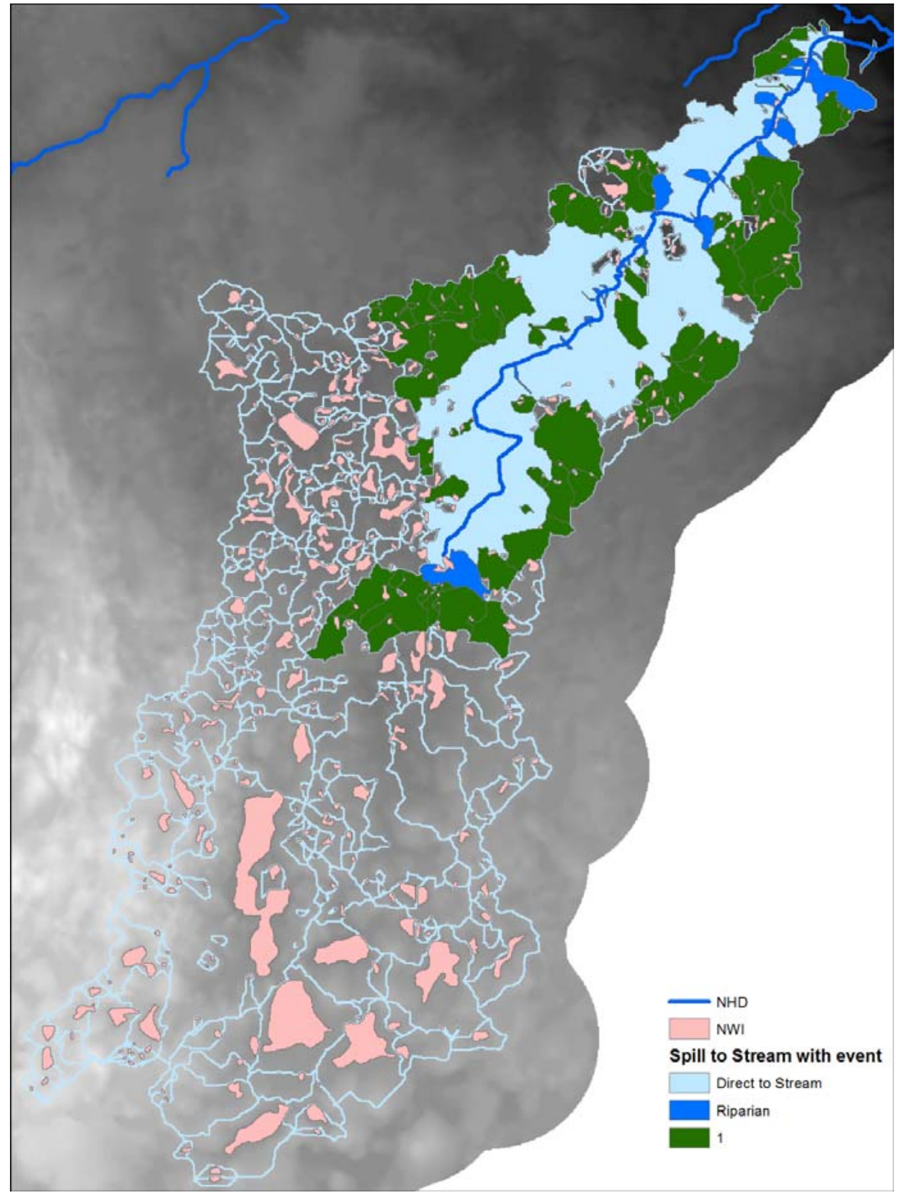
Spillage to stream with 0 cm rain event



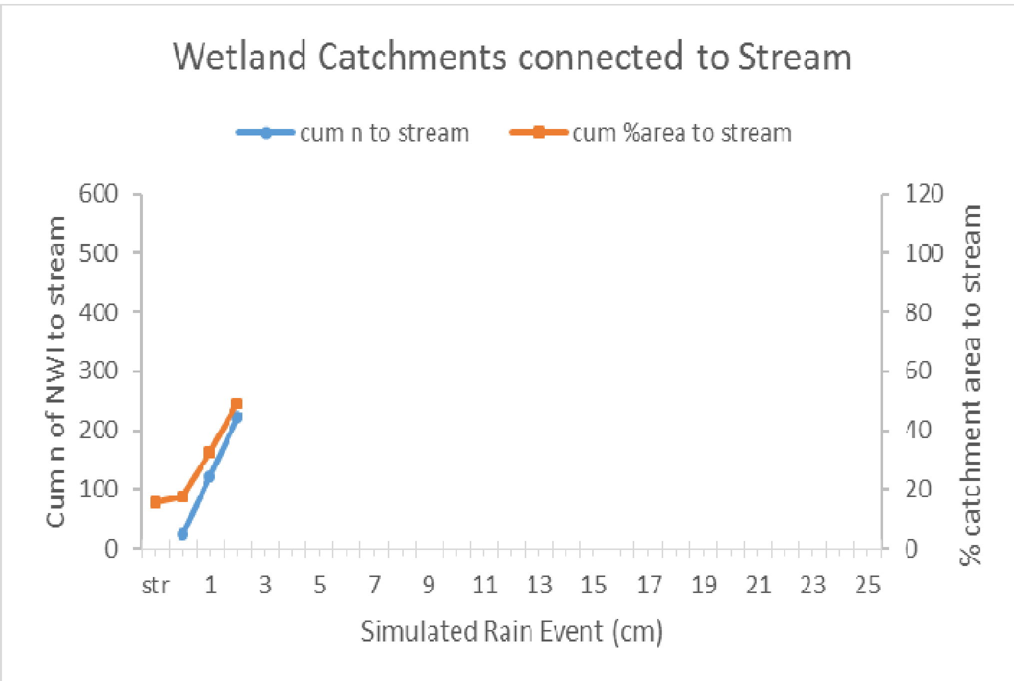


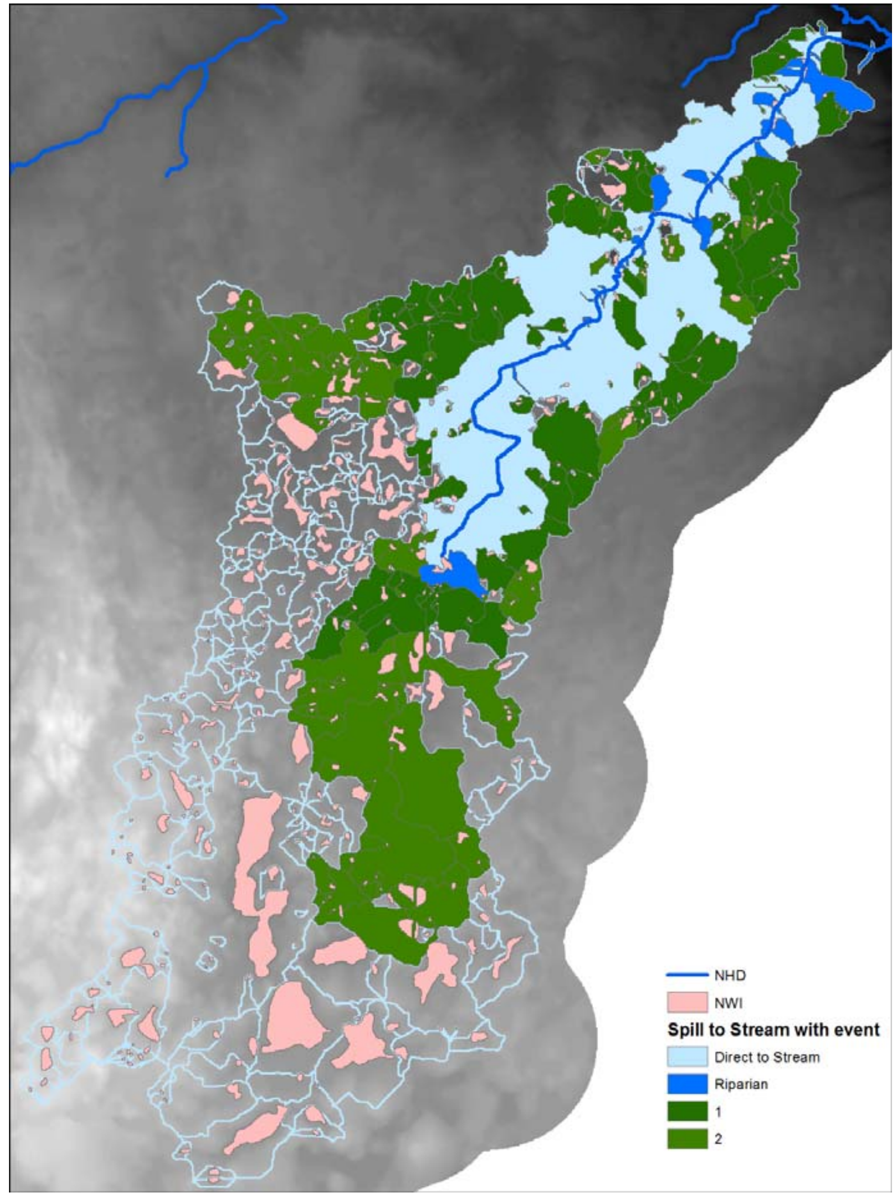
Spillage to stream with 1cm rain event



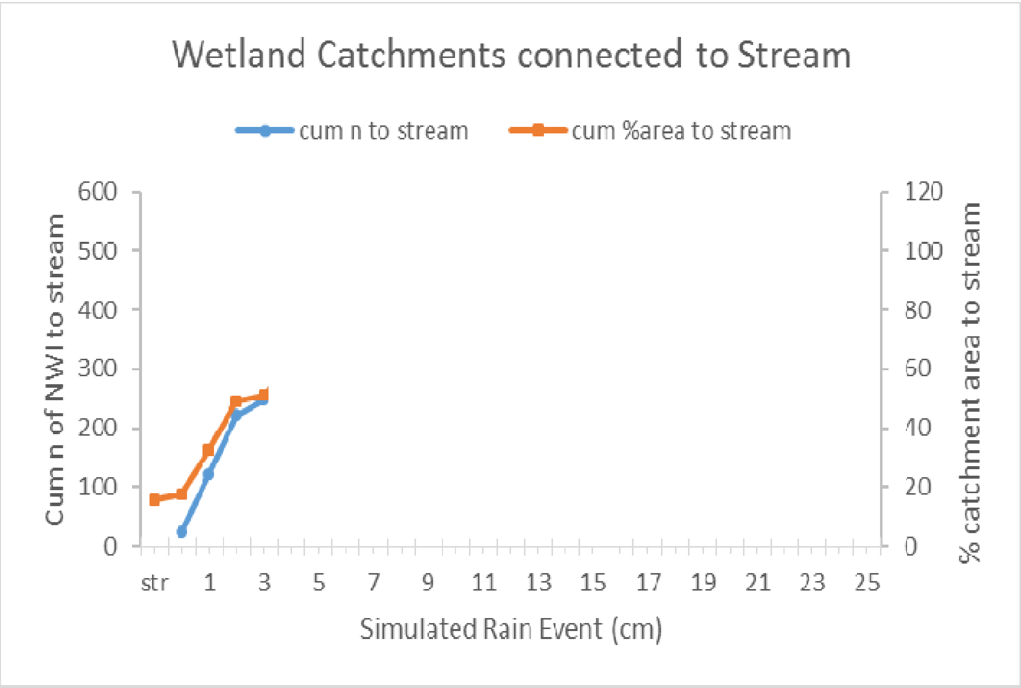


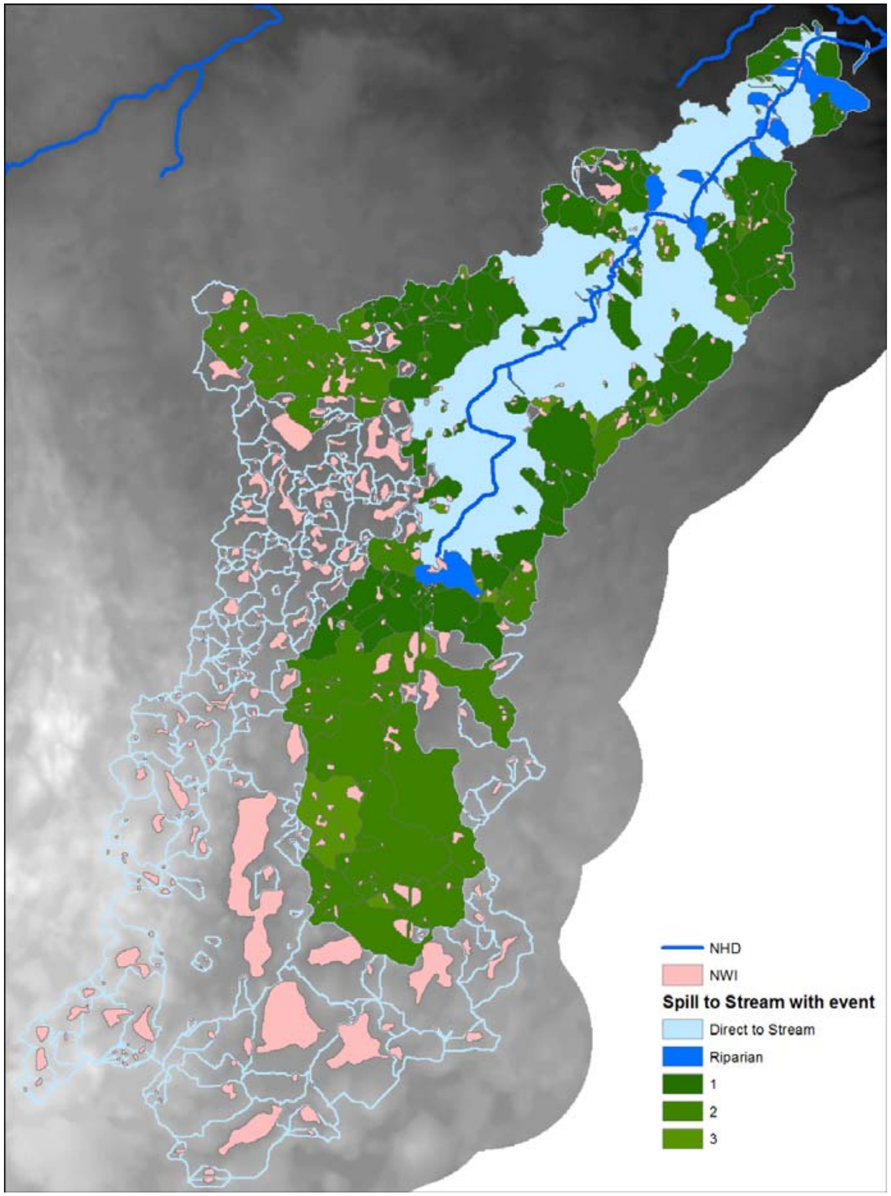
Spillage to stream with 2 cm rain event



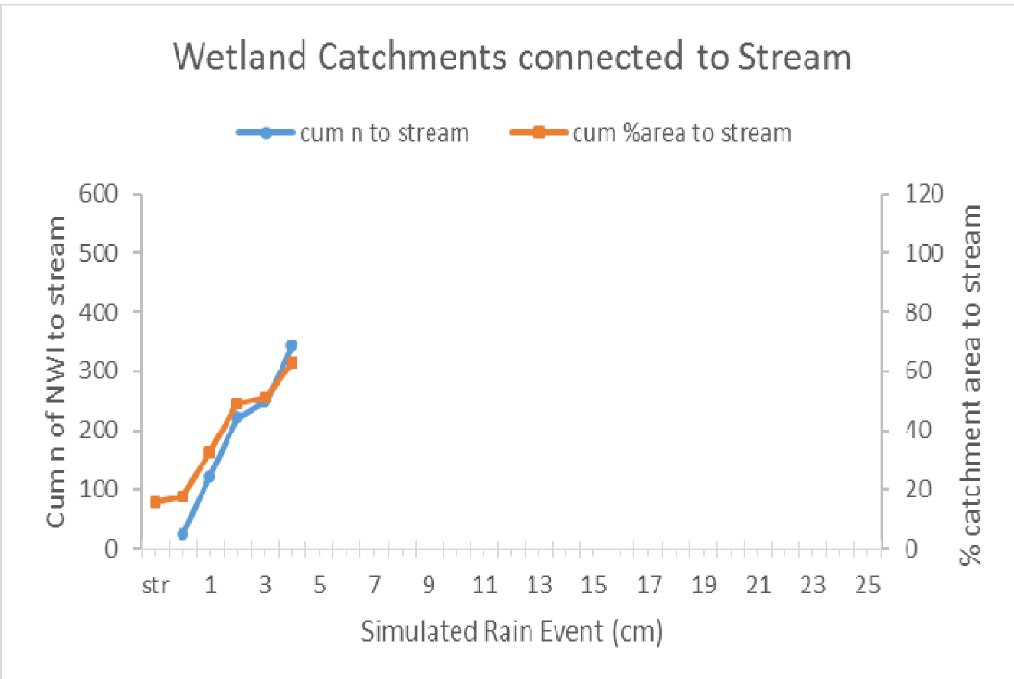


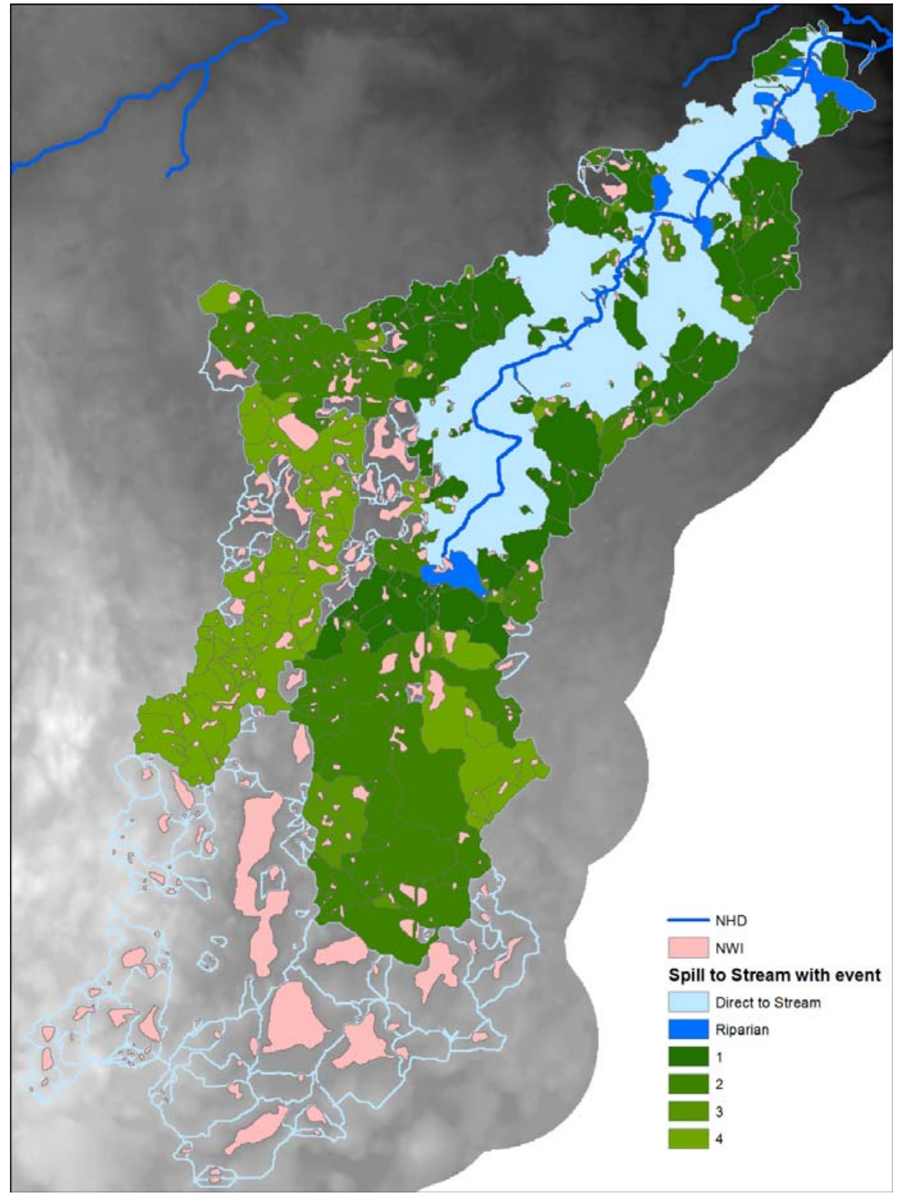
Spillage to stream with 3 cm rain event



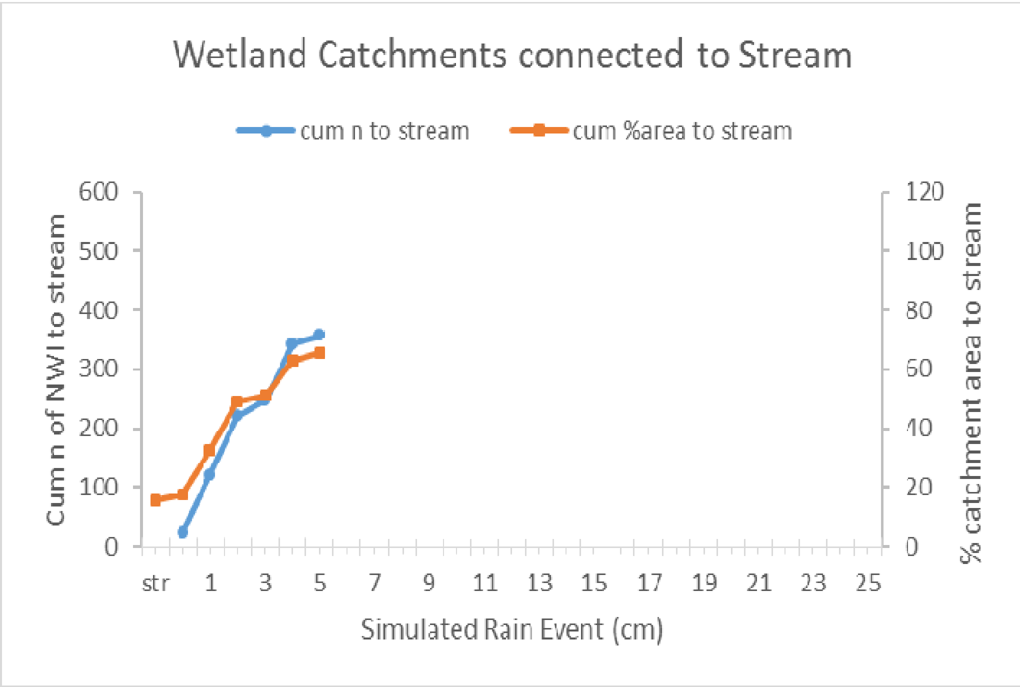


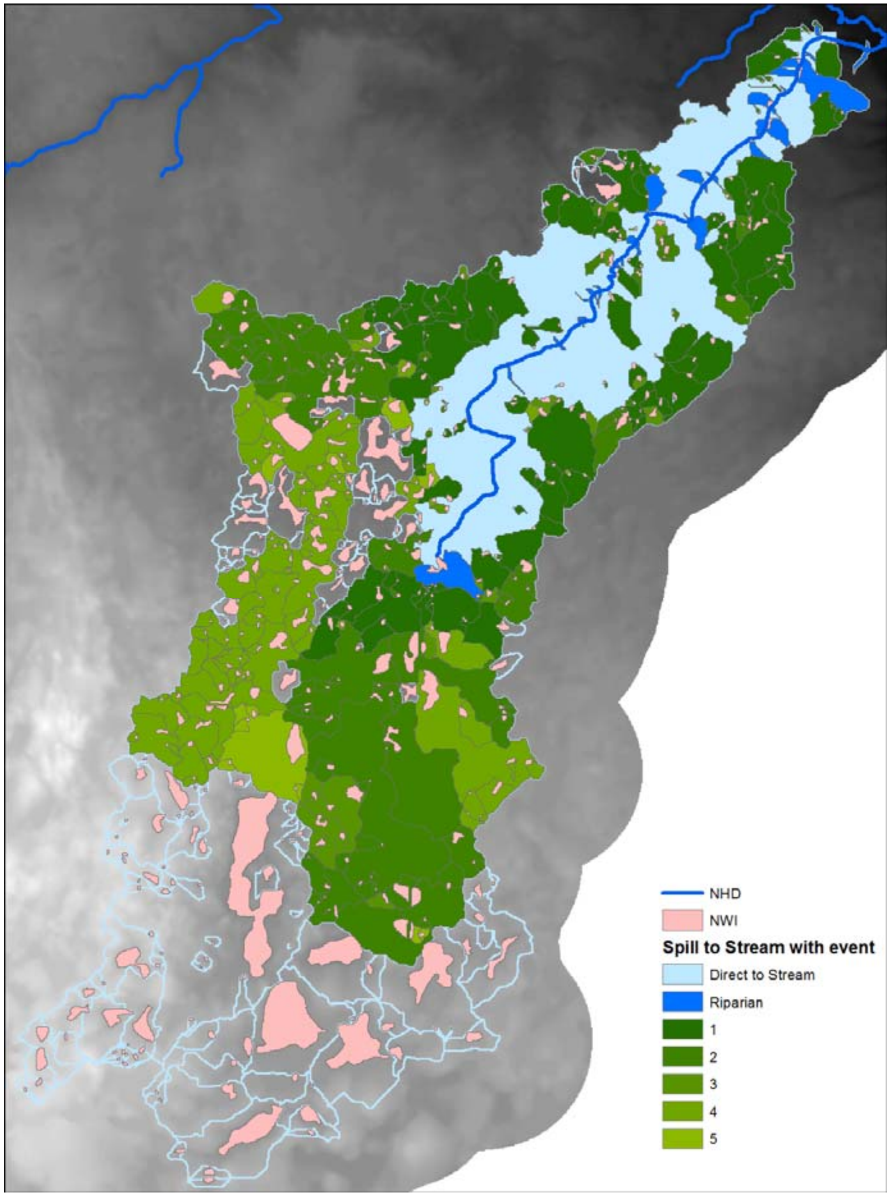
Spillage to stream with 4 cm rain event



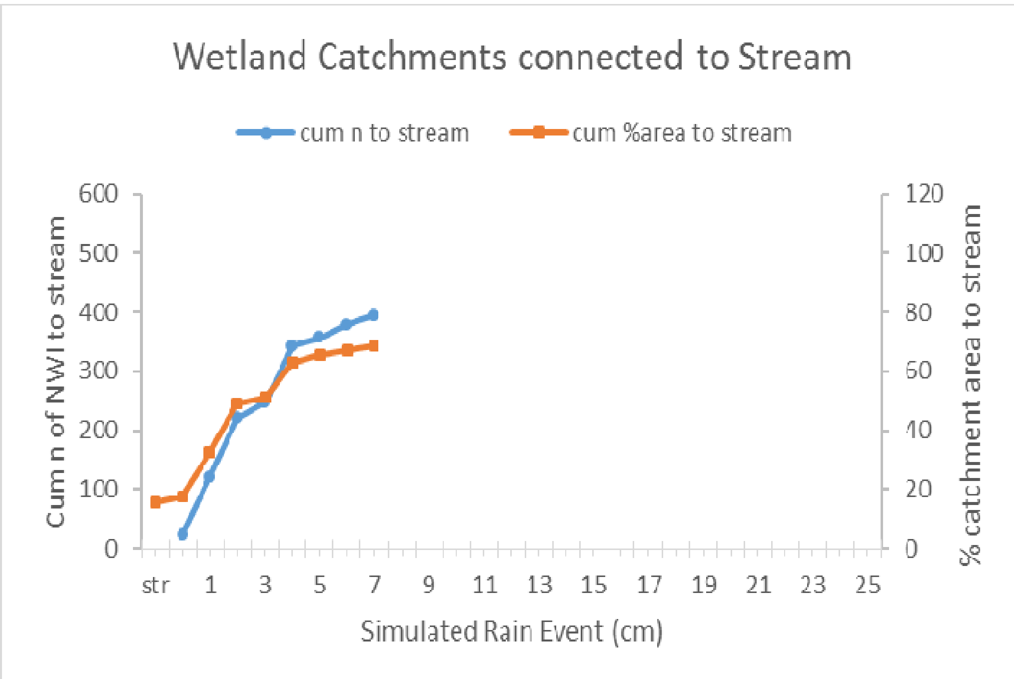


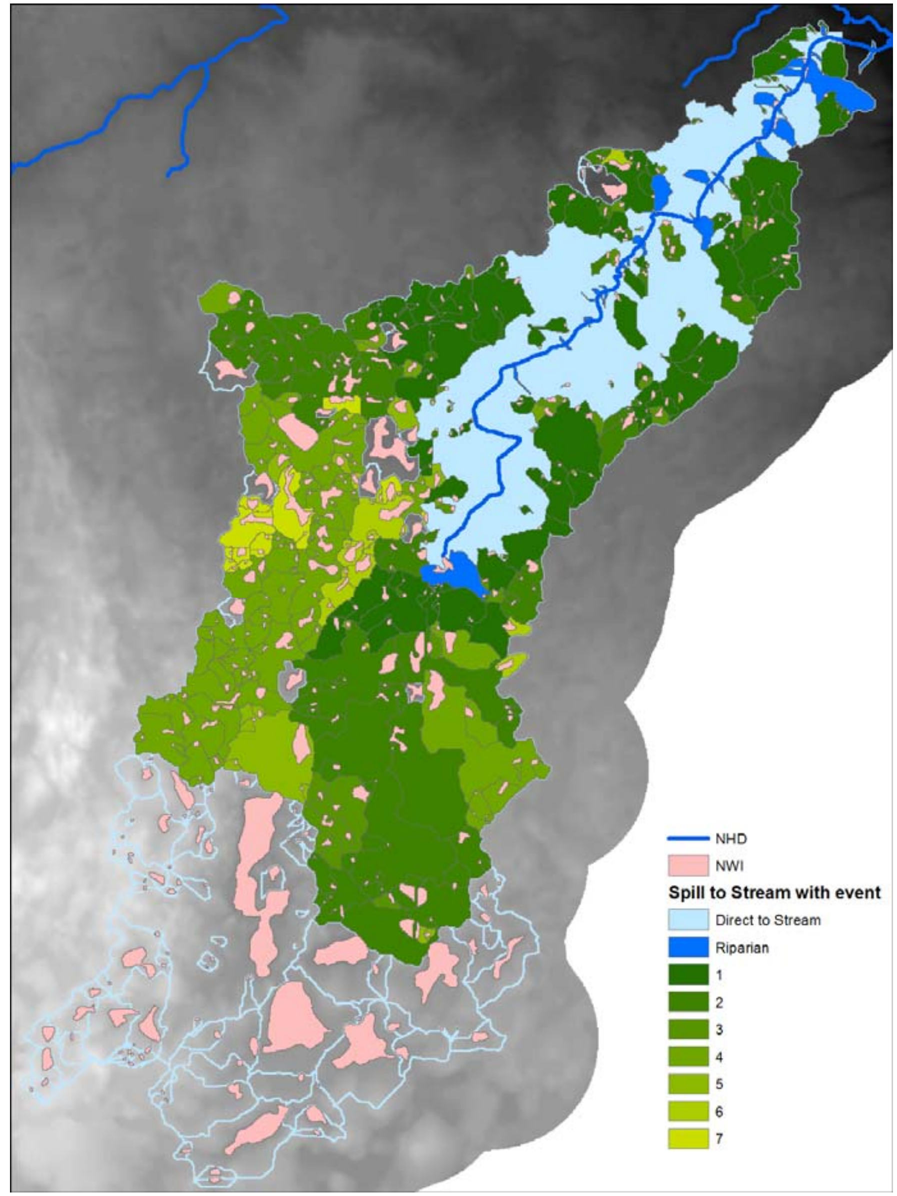
Spillage to stream with 5 cm rain event



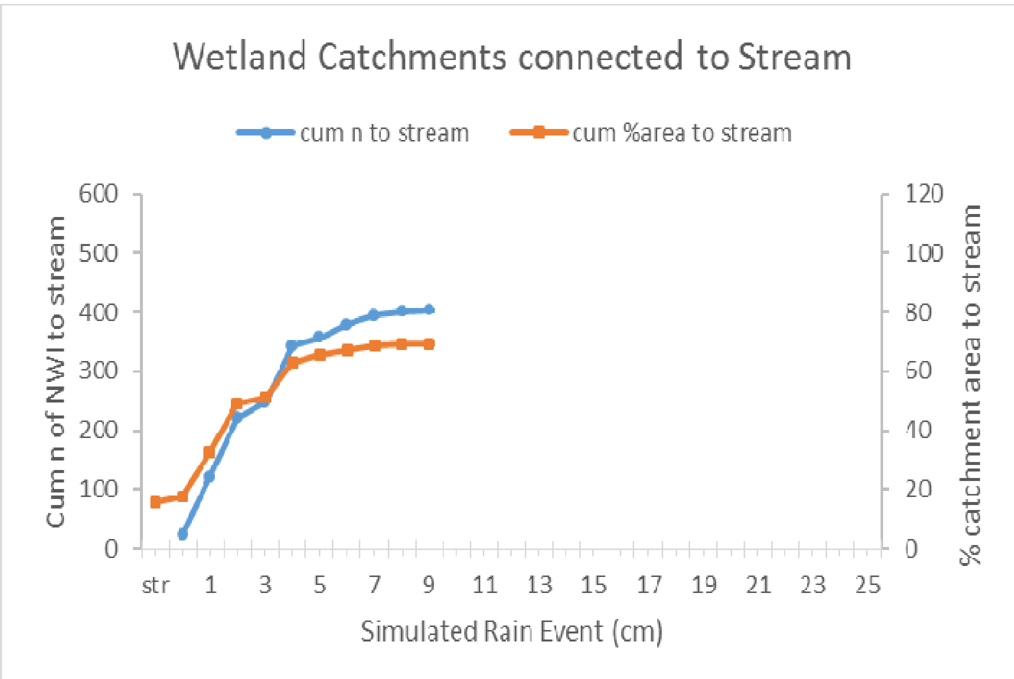


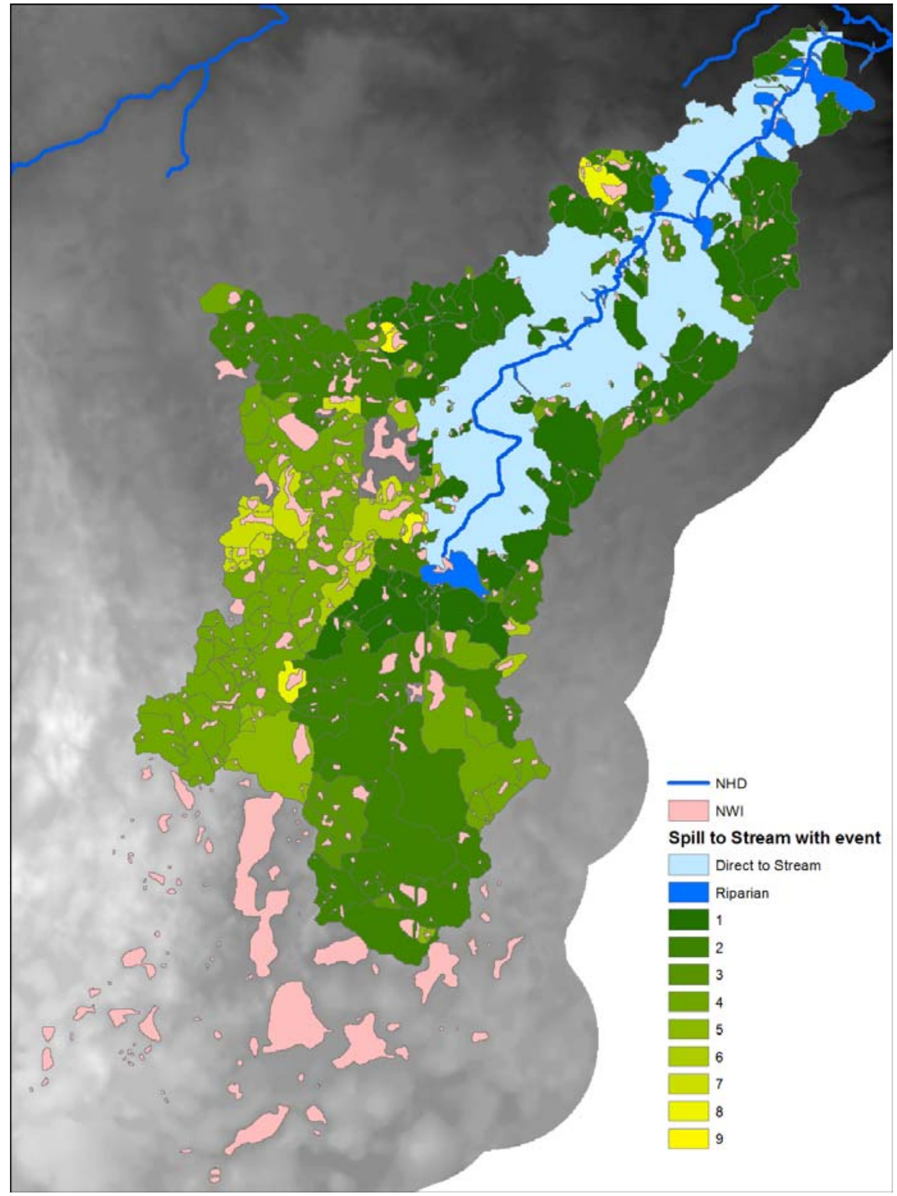
Spillage to stream with 7 cm rain event



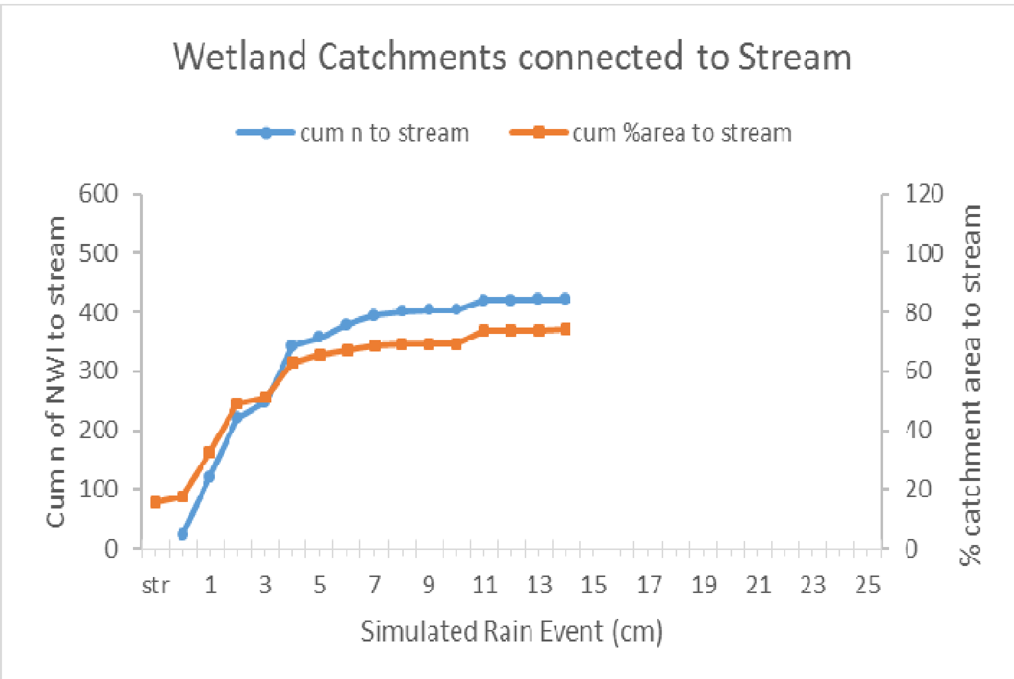


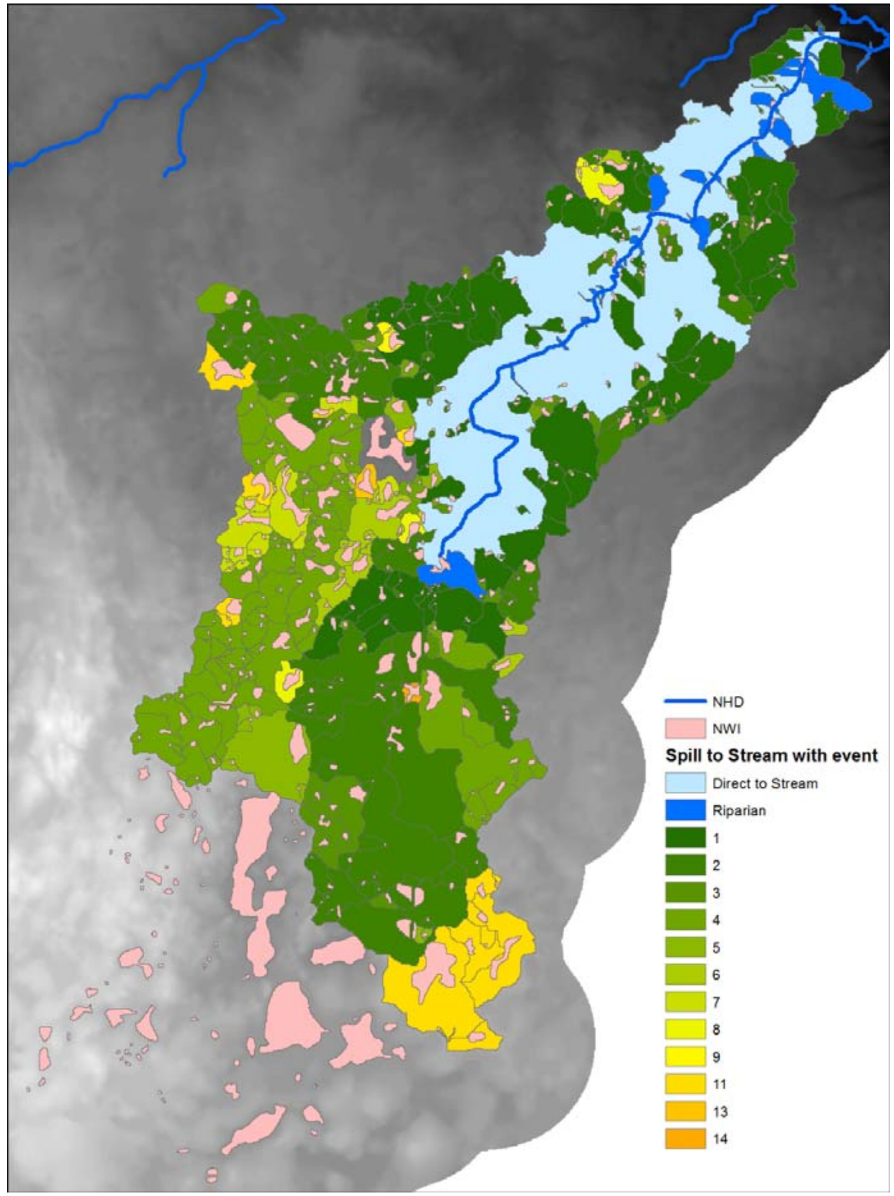
Spillage to stream with 9 cm rain event



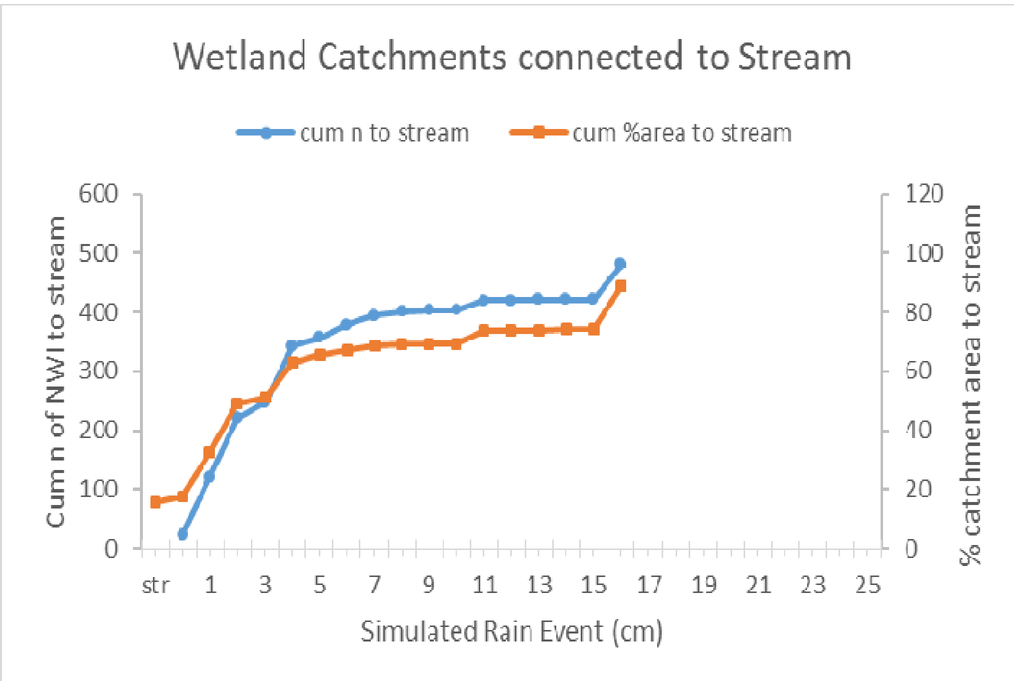


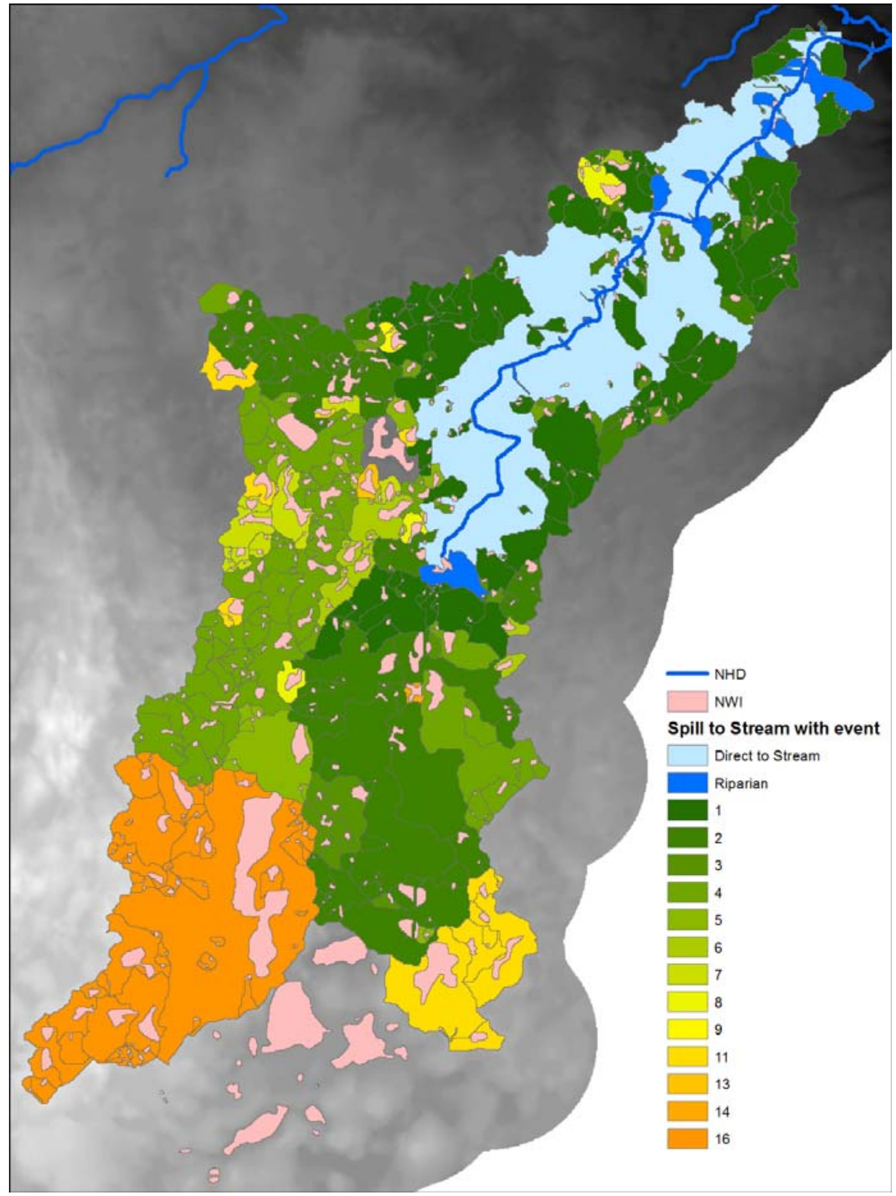
Spillage to stream with 14 cm rain event



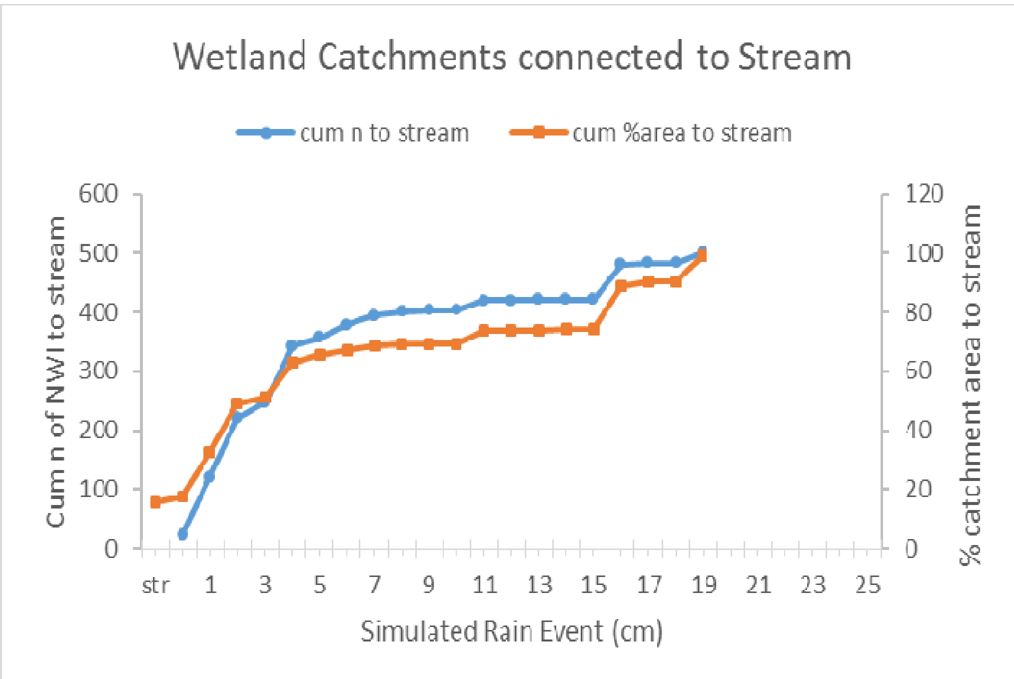


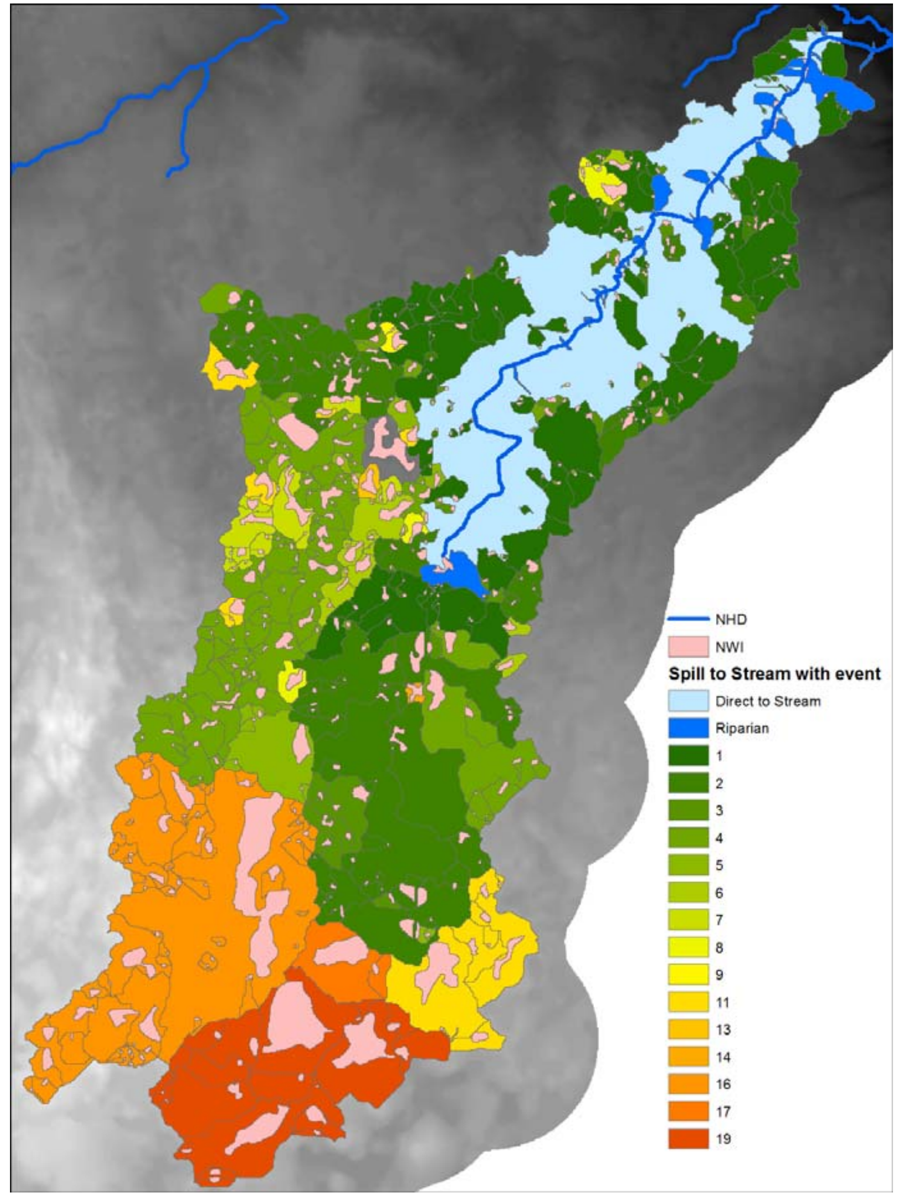
Spillage to stream with 16 cm rain event



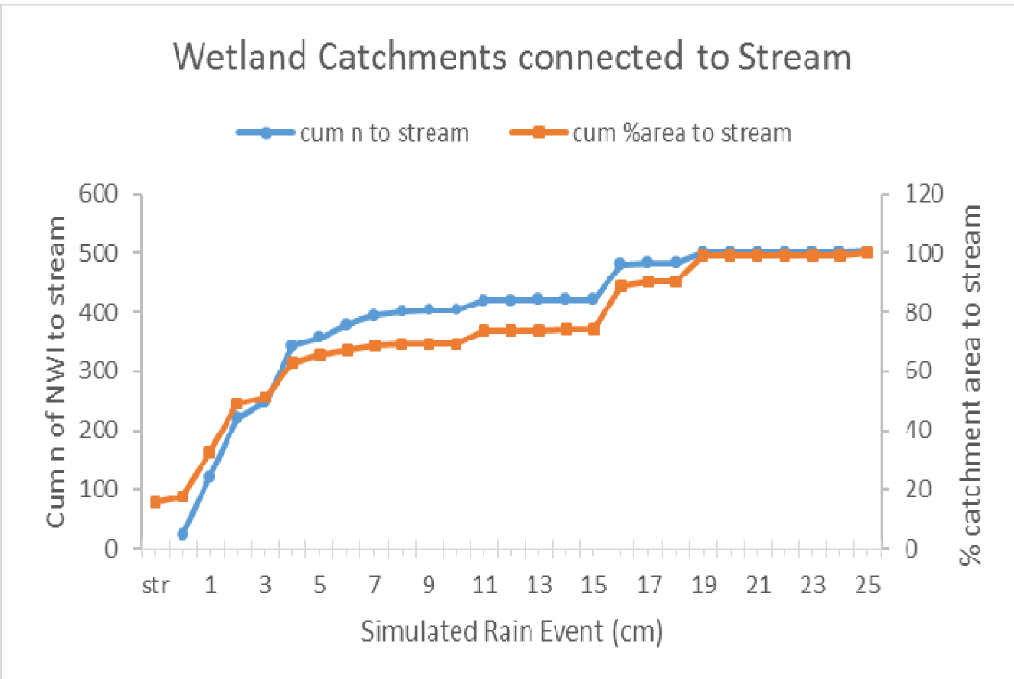


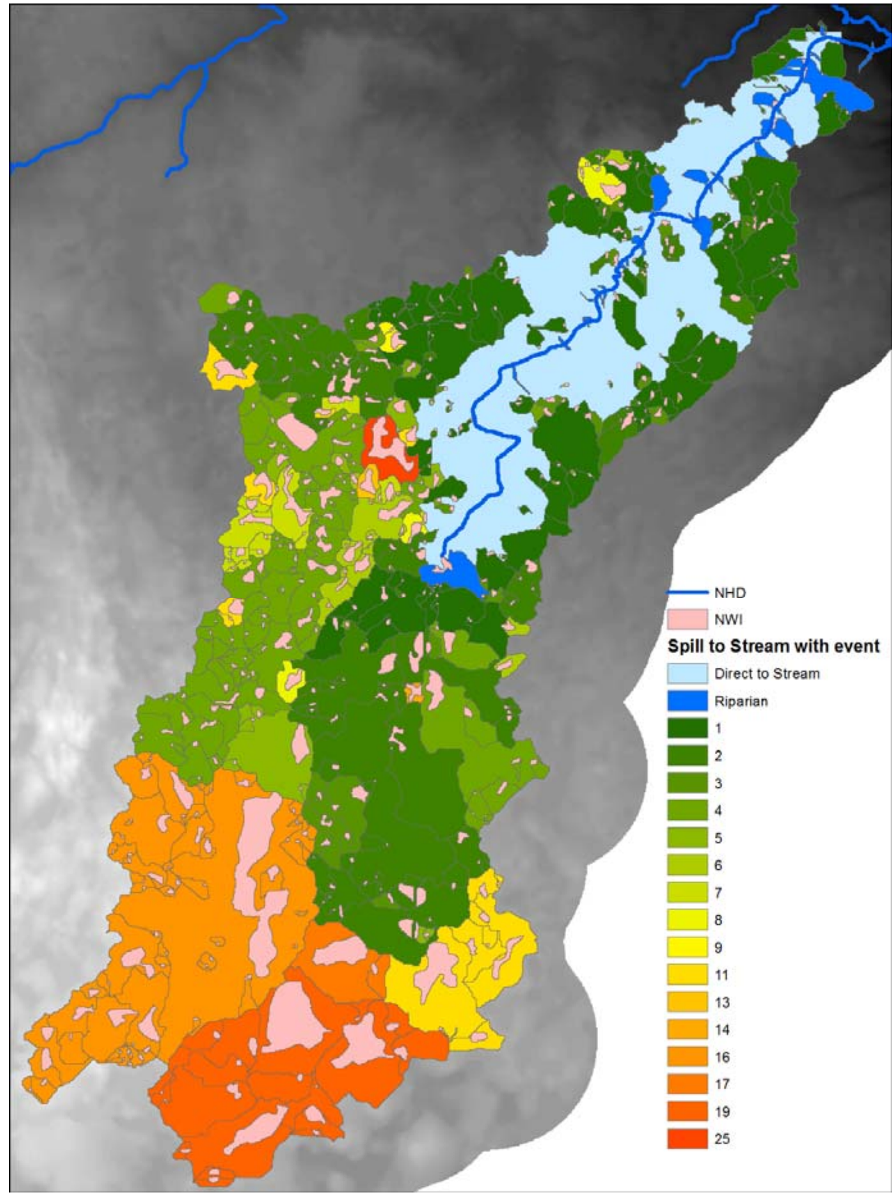
Spillage to stream with 19 cm rain event



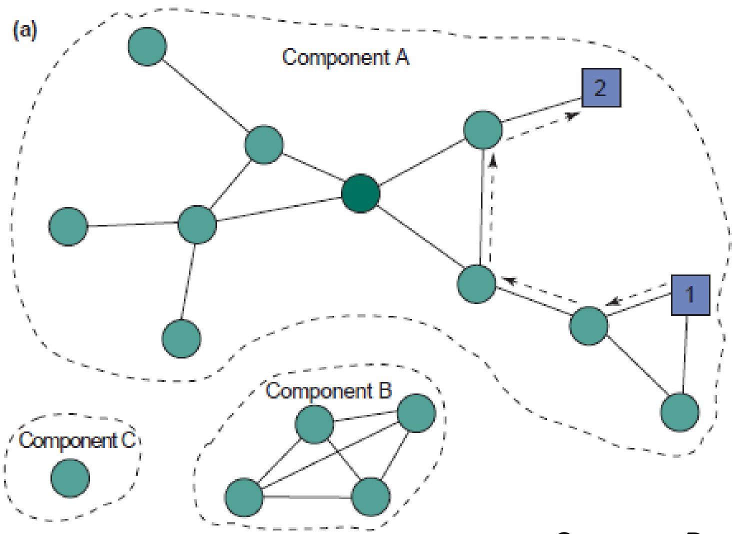


Spillage to stream with 25 cm rain event





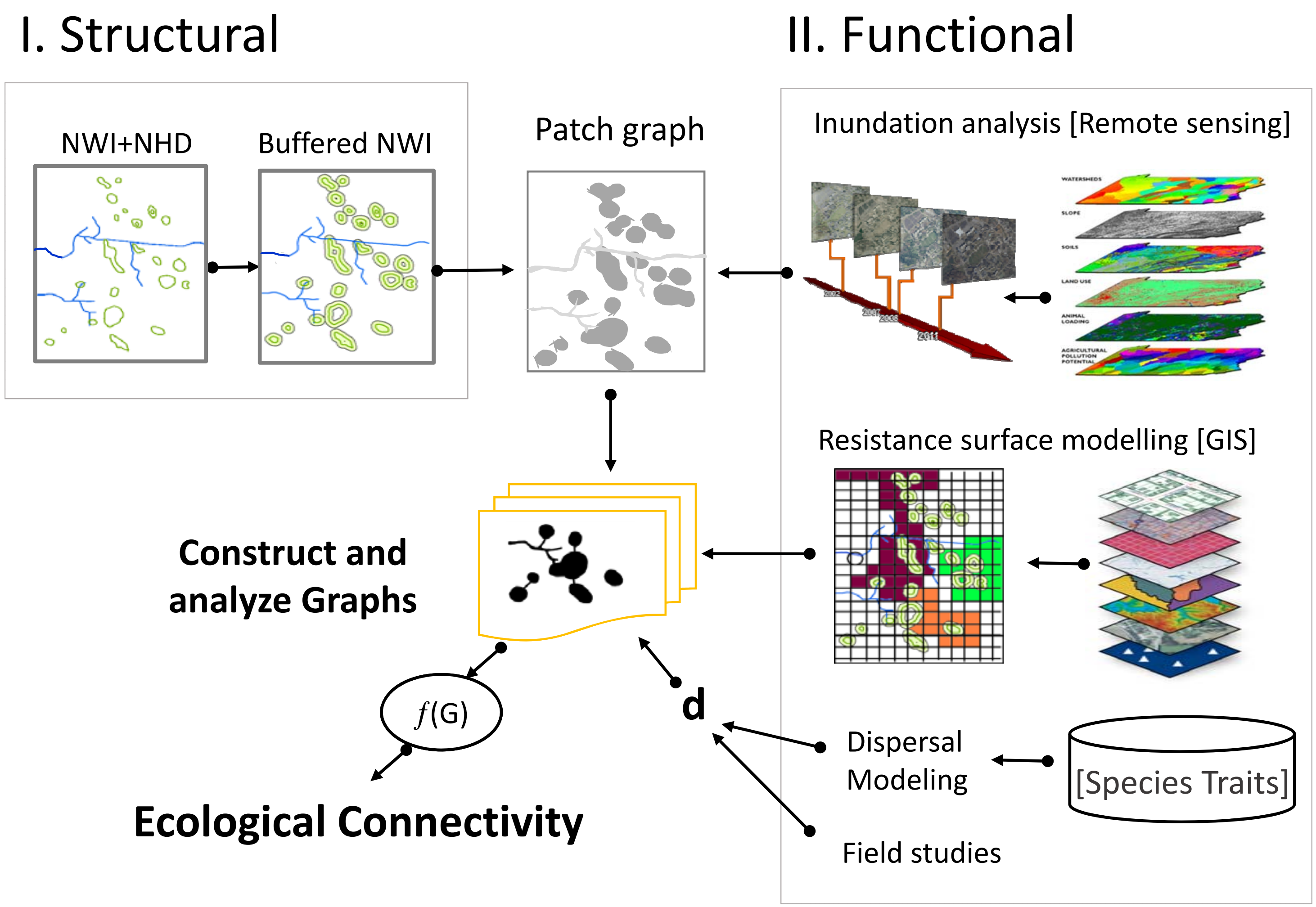
Case 3: Network analysis of landscape connectivity



Source: Proulx et al. 2005

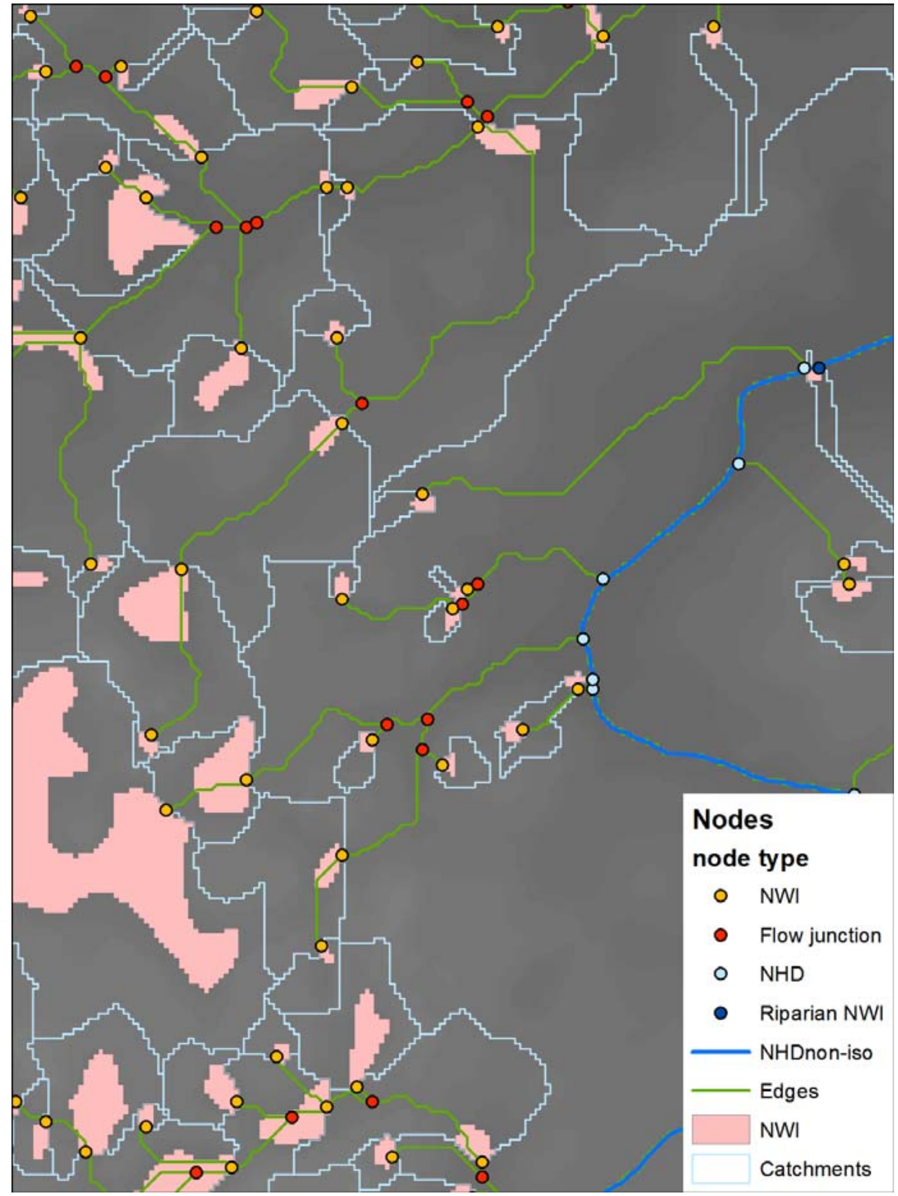
Ecological graph theory; habitat availability and population connectivity at the landscape scale

Approach


I. Structural
II. Functional
NWI+NHD
Buffered NWI
Patch graph
Inundation analysis [Remote sensing]
Resistance surface modelling [GIS]
Construct and analyze Graphs
f(G)
d
Dispersal Modeling
[Species Traits]
Field studies
Ecological Connectivity

Structural Network Creation

- Model Builder
  - Inputs: wetlands, stream, DEM, Flow Direction Grid
  - Outputs:
    - Nodes – wetland area, catchment area, NWI, flow junction, NHD, Riparian NWI
    - Edges – flow length, (average manning's n?)
- R script
  - Toggle on-off (from R fill-spill or SWAT)
  - Determine number of flows to nodes
  - Calculate numerous graph-based connectivity metrics for each wetland or for groups of wetlands



Cross Collaboration with PPR Hydrology

- Static Metrics
- Comparison of static metrics (Euclidean, FL, WFL) to SWAT derived connectivity maps – Is there a distance threshold where wetlands are less likely to be connected?
- Comparison of the simple travel time estimate with more dynamic estimates of travel time – Can simple travel time inform more complex dynamic estimates of travel time?

Cross Collaboration with PPR Hydrology

- Dynamic Metrics
- Comparison of simple dynamic metrics (Euclidean buffer, Fill-spill) to SWAT derived connectivity maps – Can simple dynamic models with large assumptions inform more complex models?
- Comparison of SWAT with Landsat derived measures – Can % inundation predict the % of contributing area to streams and/or the % connected between wetlands?