# Remote Sensing and Geospatial Application for Wetlands Mapping, Assessment, and Mitigation

**NCRST-E**

Hydrology

Soils

Vegetation
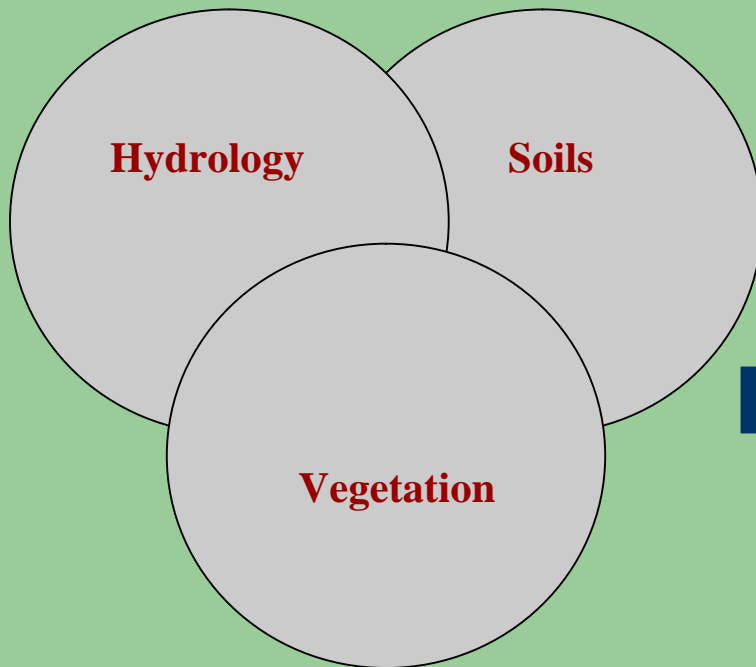
**MSU Seminar Series**

**Remote Sensing and Geospatial Applications September 4, 2002**

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# NEPA Streamlining
# Randolph County, North Carolina

For EarthData's "NEPA Streamlining TAP" in Randolph County, NC, MSU, EarthData, ITRES, and NC DOT developed a research partnership wherein MSU was asked to develop research to accomplish the following tasks:

- Evaluate new hyperspectral image, elevation, and hydrologic data;

- Develop enhancements for wetland identification methods; and

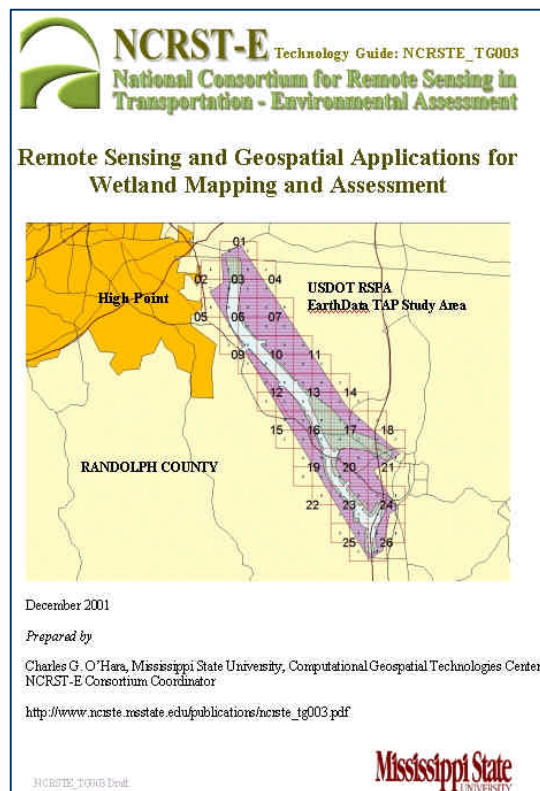- Evaluate the differences between traditional wetland mapping techniques for assessment.

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# Technology Guide: NCRSTE_TG003

The collaboration has resulted in the development of paper to be presented at the Pecora 15/ LandSatellite Information IV conference. Also, a draft document is in preparation that details the methods and techniques to be presented in this seminar.



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**Remote Sensing and Geospatial Applications for Wetland Mapping and Assessment**

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http://www.ncrste.msstate.edu/publications/ncrste_tg003.pdf

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# Research Steps

- Review Literature
- Review Wetland Definitions
- Review Assessment Methods
- Review Wetlands Determination Guidelines
- Study Use of Available Data and New Data Issues
- Develop Algorithms and Conduct Analyses
- Benchmark Results Other Methods

# Wetlands Definition

In the Corps of Engineers ***Wetlands Delineation Manual*** (Wetlands Research Program Technical Report Y-87-1, 1987) wetlands are defined as: "Those areas that are inundated or saturated by surface or ground *water* at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of *vegetation* typically adapted for life in saturated *soil* conditions. Wetlands generally include swamps, marshes, bogs, and similar areas."

# Wetland Assessment Methods

In most current approaches to the mapping and assessment of wetlands, field crews determine at sample locations which [if any] of three variables typical of wetland are present. These variables are wetland vegetation, hydric soils, and wetland hydrology.

(USDA, Forest Service, 1989, FIA Field Procedures for Wetland Identification)

# Wetland Determination Guidelines

*"When the routine approach is used, it may often be possible to make a wetland determination based on available vegetation, soils, and hydrology data for the area."*

*(CE Wetland Delineation Manual, 1987)*

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# Use of Available Data

Of the available data which may be helpful in making a preliminary wetland determination, remote sensing is listed as a source that may be one of the most useful in making a determination:

*"Remote sensing is one of the most useful information sources available for wetland identification and delineation."*

# Surrogate Processes

*The assessment of vegetation, soils, and hydrology forms the basis of standard wetlands field assessment work.*

*Determining how those assessments are made facilitates the development of surrogate processes using RS and geospatial technologies to produce similar results.*

Hydrology

Soils

Vegetation
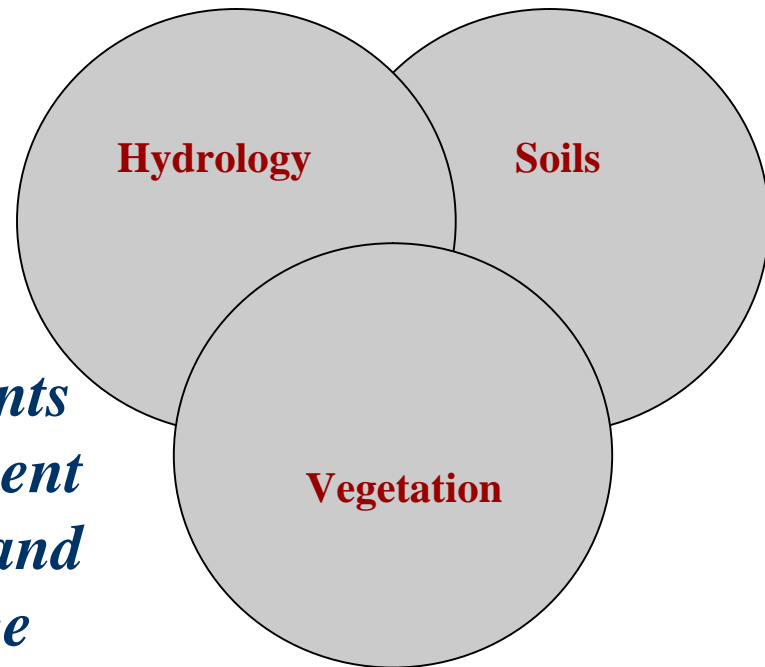
# EarthData's RS Data Collection Activities
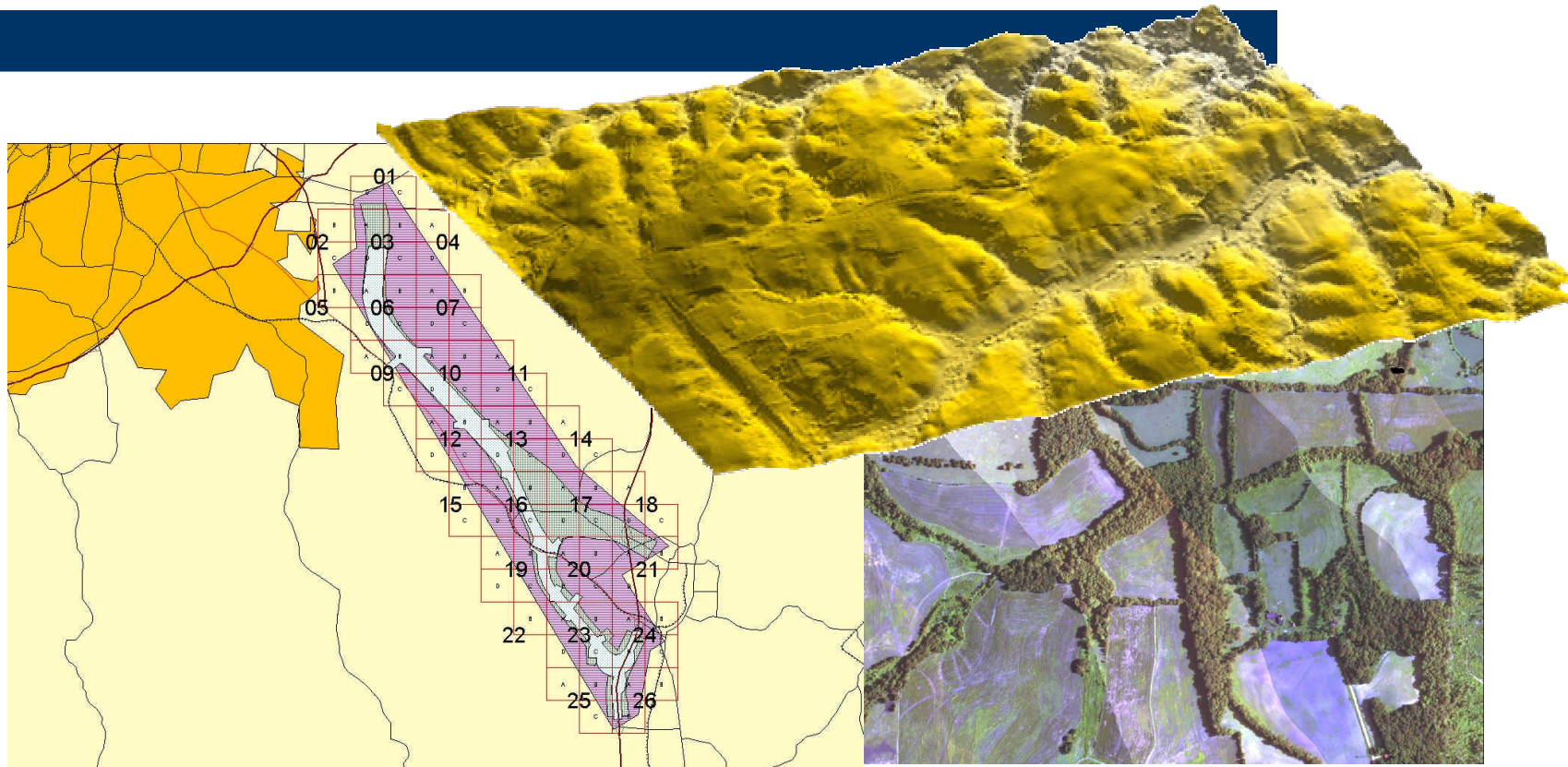
# Hyperspectral Image and Wetland Data Collection Randolph County, North Carolina

Hyperspectral image data were collected and classified to obtain classes that closely resemble those used in NWI surveys.
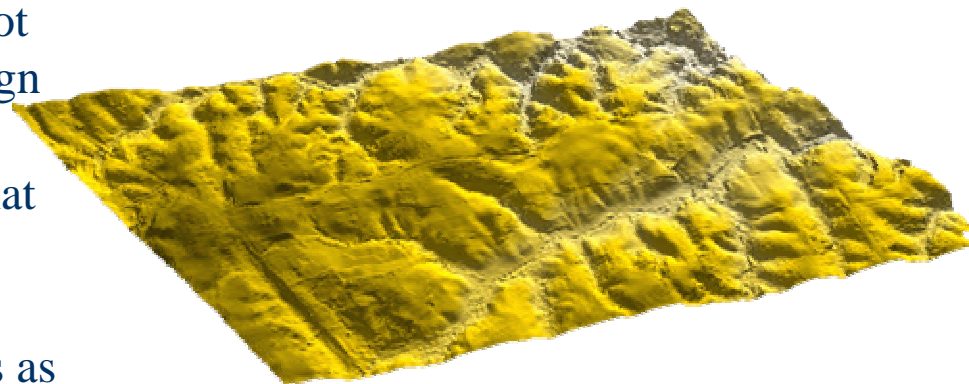


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# LIDAR Data and Derived DEM and Hydrologic Information Products

A high-resolution digital elevation model (DEM) was produced for the analysis development area using data collected by EarthData's airborne LIDAR system. The LIDAR data were evaluated for preliminary design as well as cut and fill analyses for roadway construction.

Typical DEM products such as USGS 1:24,000 scale DEMs are generally not of sufficient quality for roadway design and construction analysis. However, the quality of information products that can be developed with LIDAR show much promise for topographic, morphologic, and hydrologic analysis as well as for preliminary roadway design.



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# Best Available Data

For the study area, digital soils data, digital orthophotography, stream vectors, USGS quadrangle maps, and land cover and use maps were available. These data are useful for general characterization of the study area, but, by themselves, usually do not provide sufficient quantity or quality of information for making a preliminary wetland determination.

# High-Resolution Data Issues

Image data alone are not sufficient for a clear picture of land cover or wetlands on the landscape! The resultant land cover information is not clear. Also, the land cover must be assessed in the context of soils and hydrology.

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# Data Complexity Problems

The initial classified results of processing the high-resolution image data do not provide a conclusive information product. Due to the complex nature of the data, the high-resolution classification product does not provide a clear depiction of the distribution of features on the landscape.

# Classified Hyperspectral Image for Randolph County, North Carolina

| Description | Wetland Class and Color | |
|---|---|---|
| Unclassified | n/a | |
| Sedges, higher elevations | OBL | |
| Grasses, less dense | FAC, FACU | |
| Tree and scrub/shrub | FAC, FACU, U | |
| Dense grasses | FAC, FACU | |
| Sedges and rushes, lower elevations | OBL | |
| Willow | OBL, FACW | |
| Unvegetated soil | n/a | |
| Clear water | n/a | |
| Water with vegetation | n/a | |
| Water with vegetation and sediment | n/a | |
| Water with sediment | n/a | |
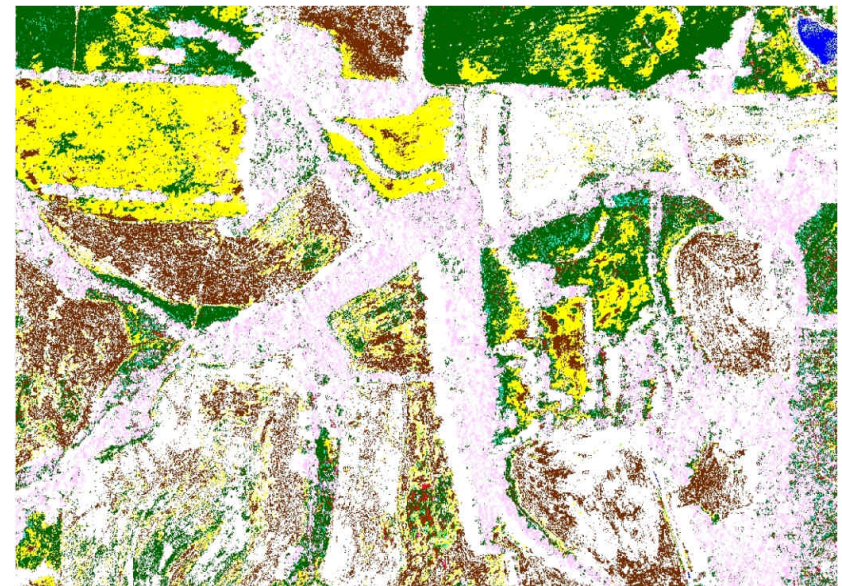


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# Highly Detailed Image and **Classified** Data Product
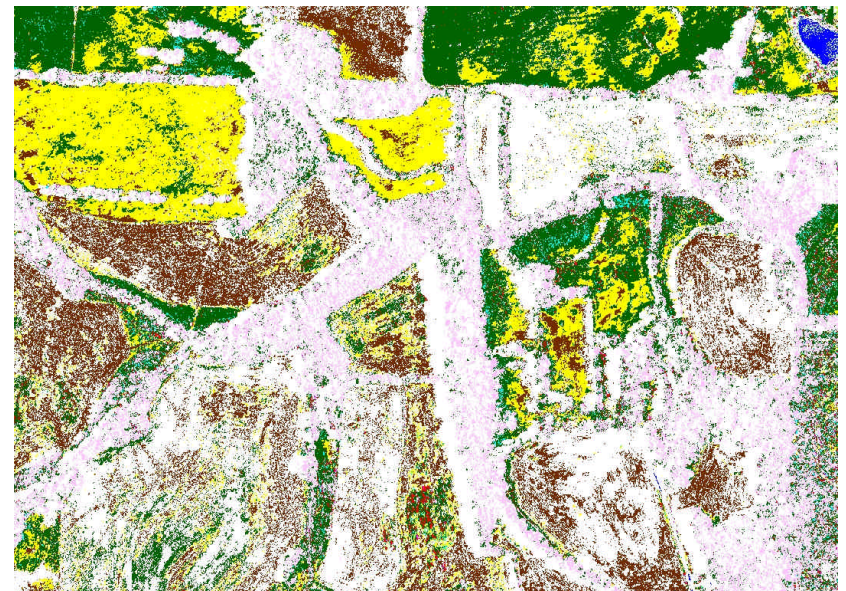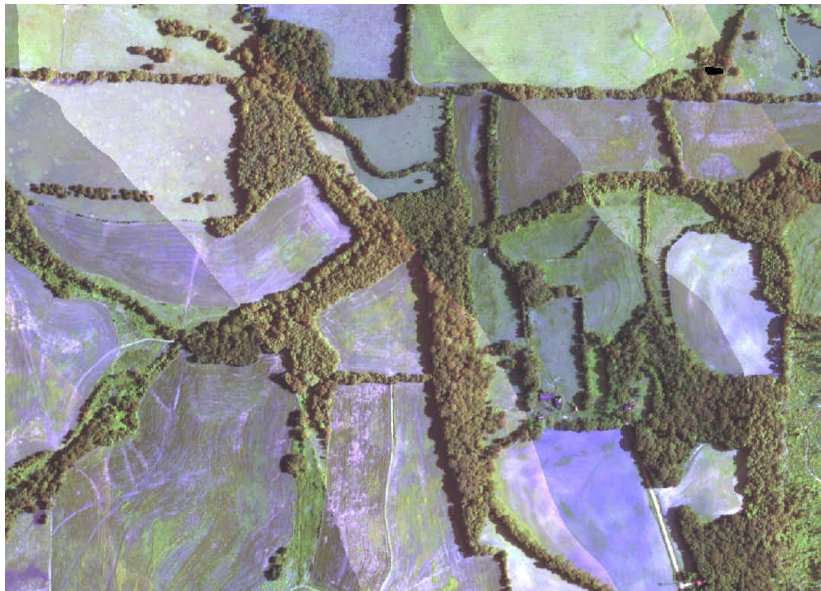
# Image and Classification Overlay

When fused with classification results, the image data shows discernable patterns, but the classified image data do not provide a conclusive information product for wetland mapping.
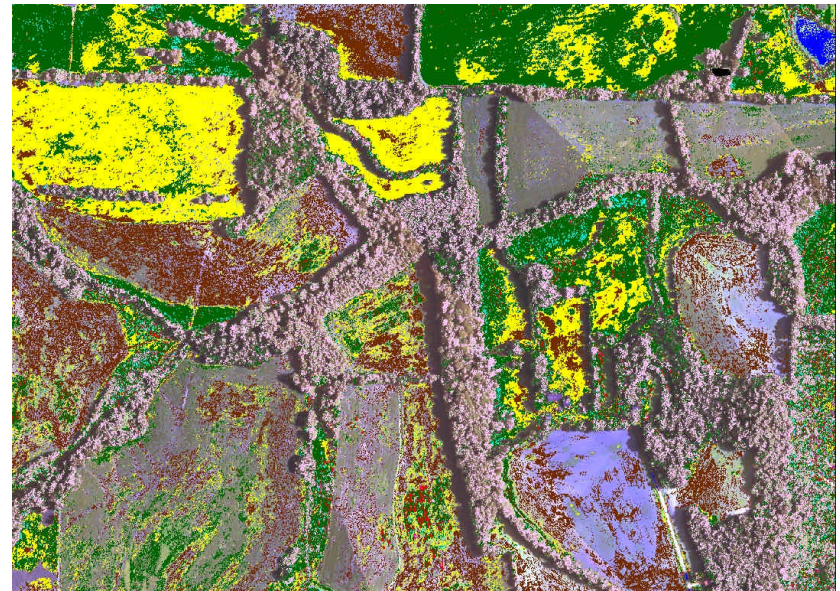
# Canopy Problems

Where mature forest is present, the spectral signatures (seen by an aerial or satellite passive sensor) of understory, wetland vegetation, or water may be obscured by the forest canopy. Thus, in these areas, the spectral signature of high spatial and spectral resolution remotely-sensed data alone cannot accomplish evaluation of water, wetland, and associated vegetation.

# Analysis Development Unit

An "Analysis Development Unit" shown in light red within the study area was selected to develop and test geospatial and remote sensing analysis techniques. The analysis development unit is about 1.9 square miles or 1220 acres in size.
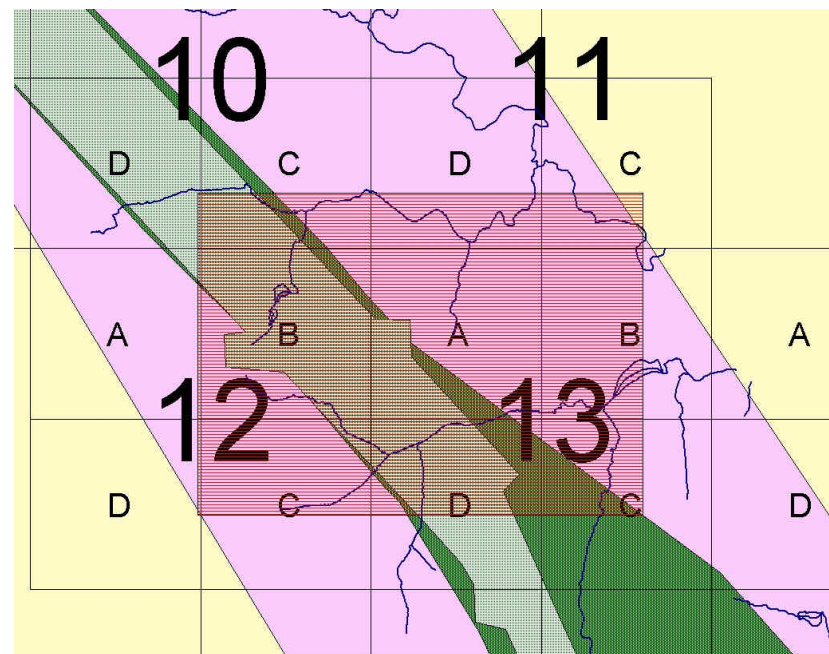


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# Surrogate Techniques

The determination of wetlands is made for an area, typically defined by a minimum mapping unit. Samples are typically collected within the study area, vegetation is classified, soils are assessed for hydric determination, and the hydrology of the area is assessed to see if wetland indicators are present.

A series of techniques have been developed to assess the vegetation in area areas adjacent to potential wetland pixels on a classified high-resolution remotely sensed image. The techniques were developed to provide a close surrogate for on-the-ground techniques wherein vegetative species are counted and an assessment is made.

# Algorithm Development

Quantitatively assessing the likelihood of wetlands occurrence requires that vegetation classes be stratified and clarified then ranked and combined and assessed in the context of hydrology and soils for the area.
To accomplish the contextual analysis, data analysis steps and products are grouped into vegetation and non-vegetation information groups. Soils and hydrology information products combined to contribute 30 possible points and the vegetation information products combined to contribute 30 possible points.
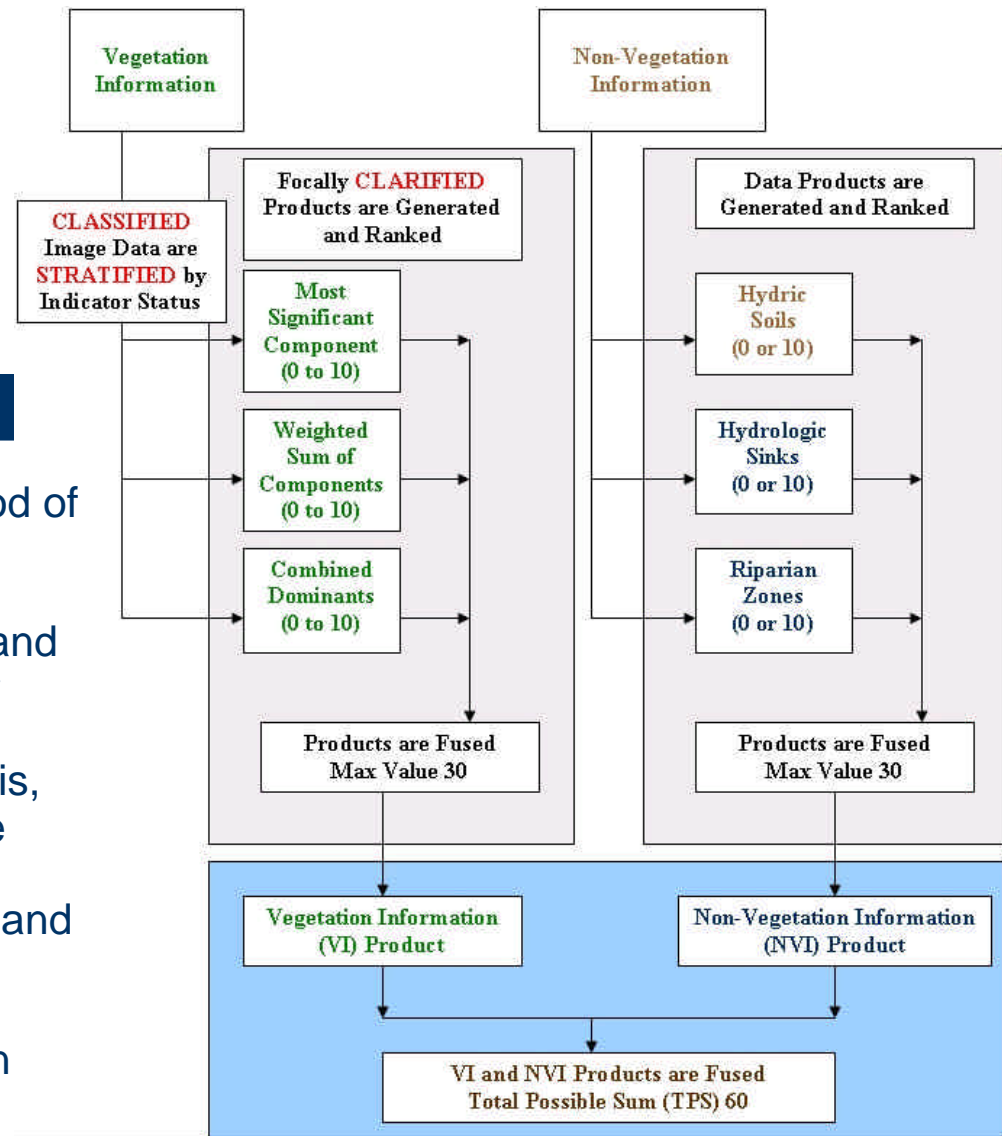


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# **Stratifying the Classified Image**

For the purpose of conducting geospatial analysis of wetland distribution, it is necessary that the complex image data, classified by vegetation type, be stratified into groups by wetland and non-wetland likelihood. For the purpose of this study, the wetland indicator status was used to group vegetative species.

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# Stratifying Classes: Groups, Codes, and Descriptions

| | |
|---|---|
| **OBLIGATE (OBL)** <br> **Value Code 10** | OBL species, under natural conditions, almost always (probability > 99%) occur in wetlands. Examples of obligate species are bald cypress and water tupelo. |
| **Facultative Wet (FACW)** <br> **Value Code 6** | FACW species usually occur in wetlands (probability of 67% - 99%), but can be found occasionally in non-wetlands. Examples of FACW species are pond pine, slash pine, laurel oak, and gallberry. |
| **Facultative (FAC)** <br> **Value Code 3** | FAC species have about an equal likelihood of occurring in wetlands as in non-wetlands (probability of occurring in wetlands is 34% to 66%). Examples of FAC species are loblolly pine, red maple, sweetgum, blue beech, sumac, and yaupon. Species that are classed FAC normally can be found over a very broad range of habitats. |
| **Facultative Upland (FACU)** <br> **Value Code 1** | FACU species usually occur in non-wetlands but occasionally can be found in wetlands. Estimated probability of occurrence in wetlands is 1% to 33%. Probability of occurrence in uplands is >34%. Examples of FACU species are white pine, basswood, redbud, and mountain laurel. |
| **Upland (UPL)** <br> **Value Code 0** | UPL species almost always occur in non-wetlands (probability 99% + of occurrence in uplands - probability of only 1% of occurrence in wetland) under natural conditions. Examples of UPL species are Virginia pine, shortleaf pine, scarlet oak, and flame azalea. |

# Focal Geospatial Processing for Clarifying Vegetation Patterns and Assemblages

The methods developed for vegetation analysis were designed to consider the pixels within the ¼ acre neighboring area. This was accomplished by specifying a circular focal neighborhood with a radius of 18 one-meter pixels around each pixel. The resultant area is approximately 1017 square meters or about ¼ of an acre.
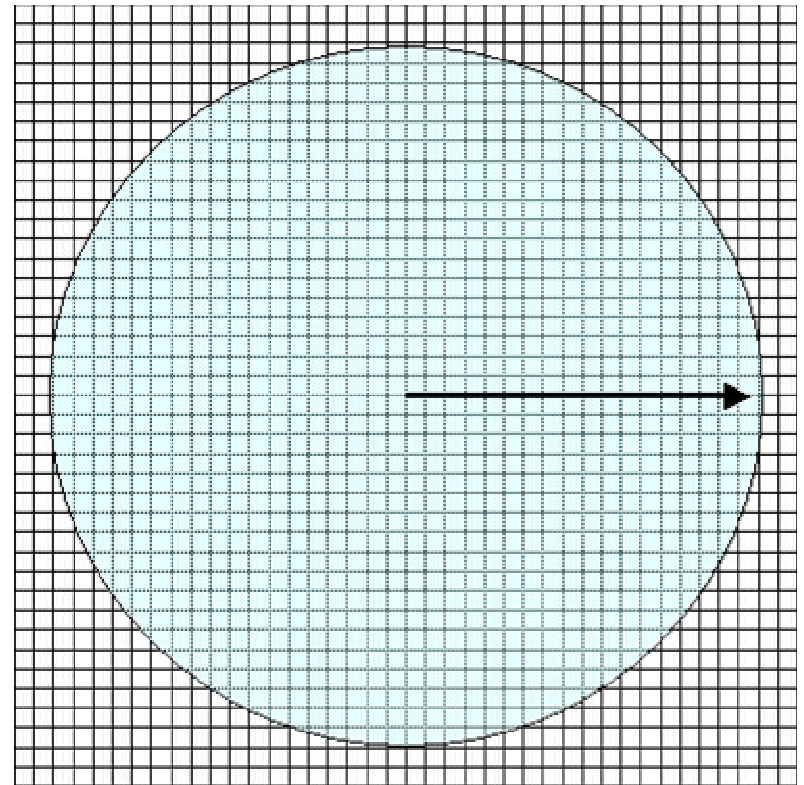
# Focal Clarification Analysis Techniques

The neighborhood vegetation analysis techniques were developed to assess the most significant vegetative component for the neighboring area around each classified image pixel, the weighted sum of components, and the combined dominants present in the neighboring area.

- **Most Significant Component (MSC): Focal Majority**
- **Weighted Sum of Components (WSC): Focal Sum**
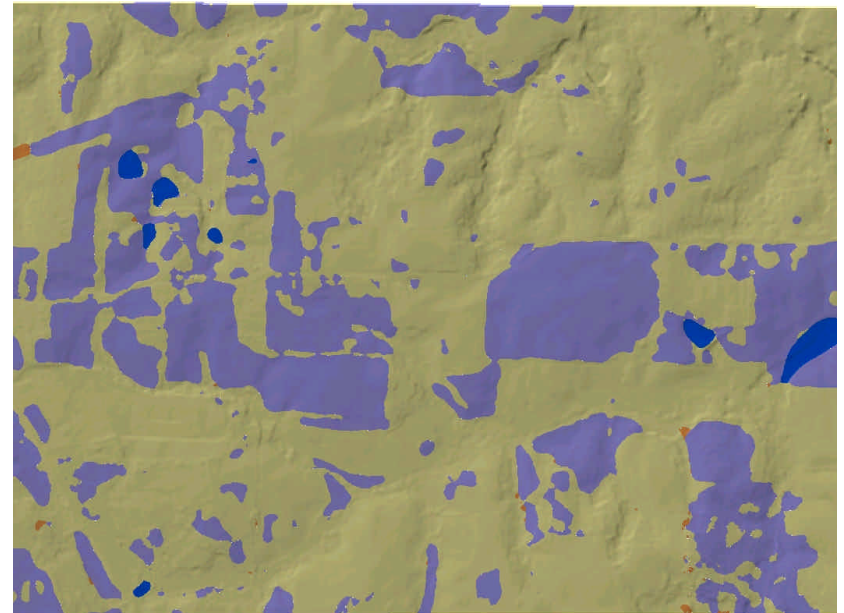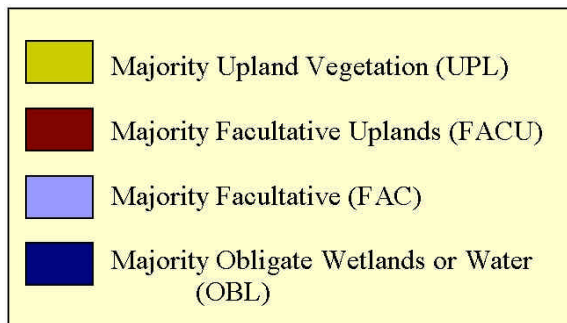- **Combined Dominants (CD): Combination of Focal Counts**

# Most Significant Component (MSC): Focal Majority

The MSC provides a clear picture of the vegetative types (grouped by indicator statues value code) that occupy a majority of the landscape for a given area.

The MSC function returns the most frequently occurring value in the neighborhood.



Majority Upland Vegetation (UPL)

Majority Facultative Uplands (FACU)

Majority Facultative (FAC)

Majority Obligate Wetlands or Water (OBL)

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# Weighted Sum of Components (WSC): Focal Sum

The WSC determines for each pixel the sum of all vegetative species and contextual classified components weighted by the likelihood that the species or contextual component occurs in a wetland or near water.
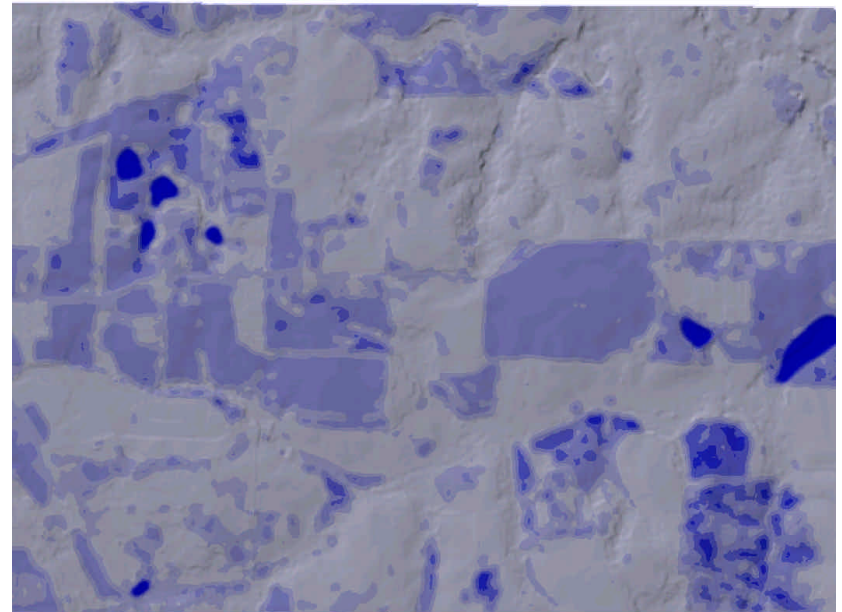
# Combined Dominants (CD): Combination of Focal Counts

In general, wetland vegetation criterion is met if more than 50 percent of the dominant species from each identified strata are obligate wetland (OBL), facultative wetland (FACW), or facultative (FAC) species.

The CD assessment determines, for each pixel, the count of pixels in the neighborhood that are (OBL)10, or (FACW) 6, or (FAC) 3. The count of cells that are 10, 6, or 3 is divided by the count of the total number of cells in the focal neighborhood resulting in the percent combined dominants for the focal neighborhood.
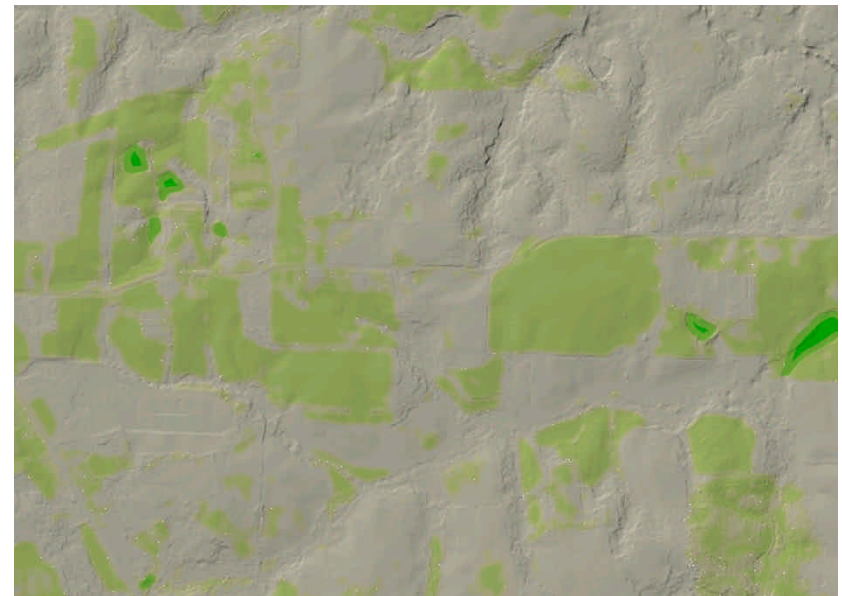
# Vegetation Information

The VI product is generated from the high-spatial resolution hyperspectral classified image data analysis products. The MSC, WSC, and CD analysis products are ranked from 0 to 10 and combined to produce the VI information product.
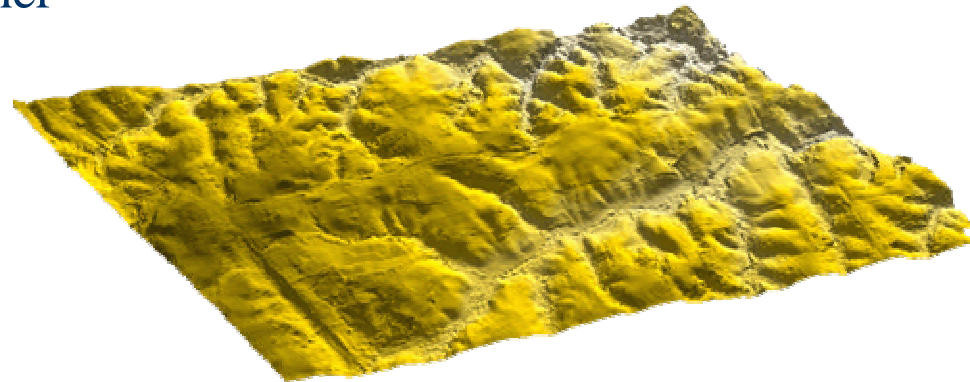


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# Hydrologic Information Products

The DEM created for the analysis development unit was used for hydrologic analysis. To conduct hydrologic analysis from a DEM, data derivatives must be generated. These include a filled surface so that water can properly flow on all areas of the surface.

From the filled surface several other data sets are generated including flow direction and flow accumulation.

# Hydrologic Depressions (Sinks)

Hydrologic depressions occur in areas where water can flow in, but becomes "trapped" because there are no lower elevation "cells" in the local area to which the water may flow.

The raw DEM is subtracted from a "filled" DEM to create a "sinks" surface. Sinks approximate the location and size of hydrologic depressions where surface water is likely to pond and stand on the land surface.
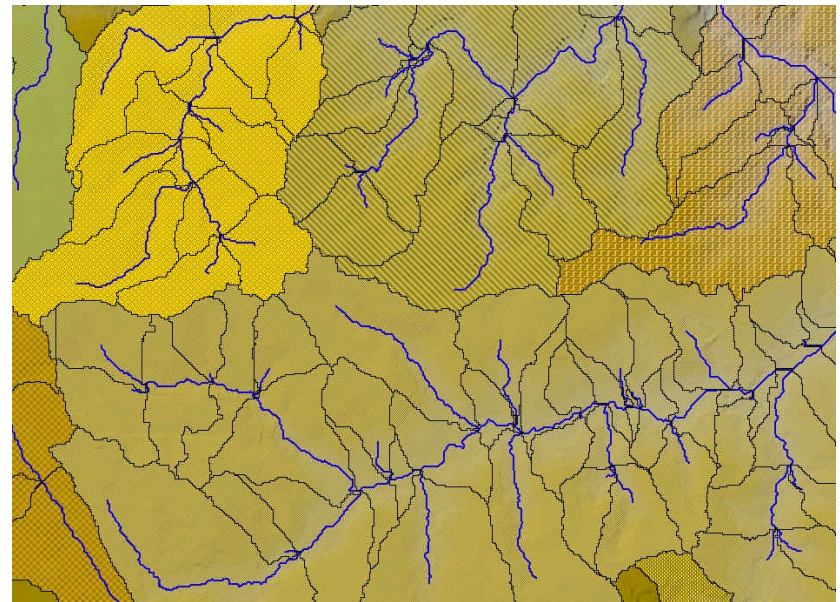
# Hydrologic Network Data

From the flow accumulation and flow direction data, watershed boundaries and synthetic stream networks were generated.

# Synthetic Stream Network

Flow direction and accumulation were used to create digital streams on the landscape. Streams occur when there is a sufficient amount of upland area drained such that flow begins. Areas around streams typically are zones that are transitional from water to land environments and habitats.
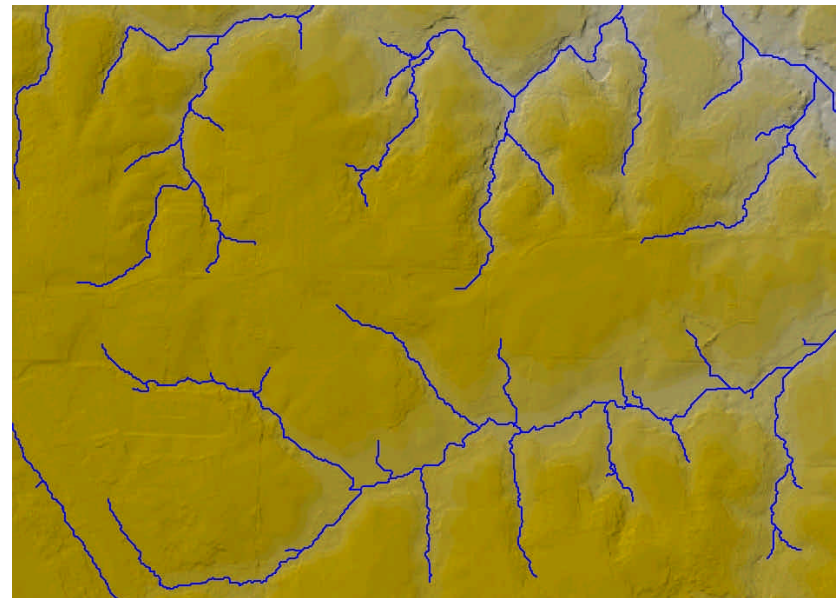
# Riparian Buffer Zone

The synthetic stream network was buffered to include an 18-meter distance (radius for a 1/4 acre focal area) from the theoretical drainage centerline that represents the transitional or riparian zone. Within the study area, wetlands along streams are typically completely hidden by the canopy of trees that thrive in this transitional environment.
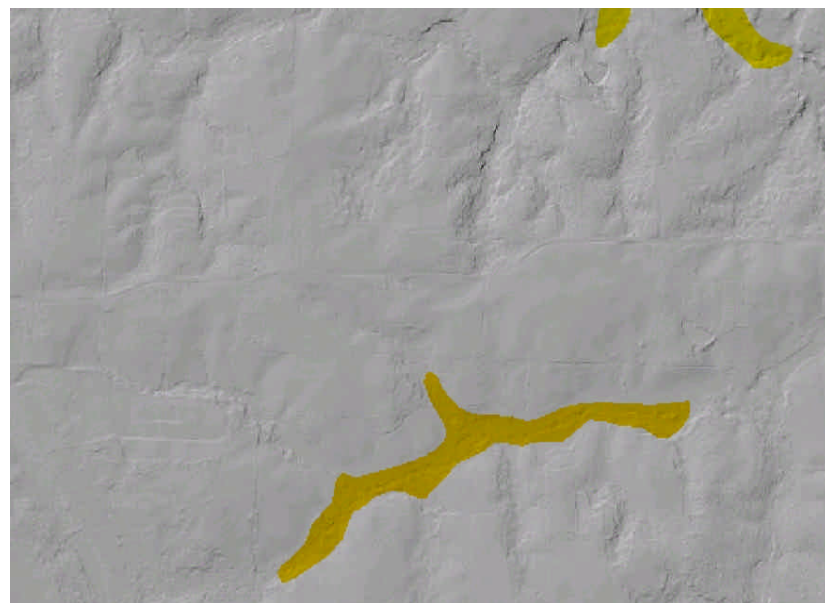


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# NRCS County Soils Data

The U.S. Department of Agriculture, Natural Resource Conservation Service (NRCS) maps county soils information and the data may be available as a digital product (SSURGO). In this analysis, digital county soils data were used to form a hydric soils layer.
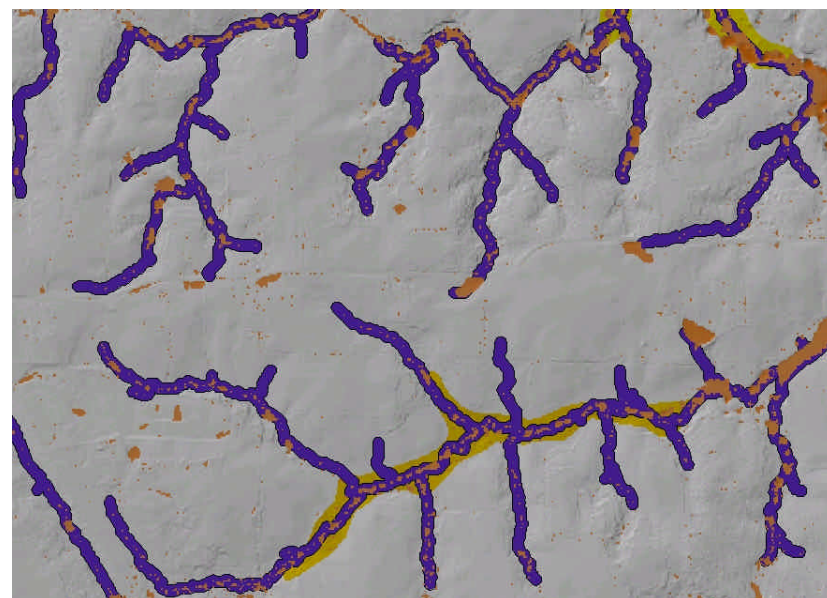
# Non-Vegetation Information Layers

The combination of non-vegetation information products illustrates the spatial overlay of stream and riparian zones, areas likely to pond overland flow, and soils typical of the wetland environment.
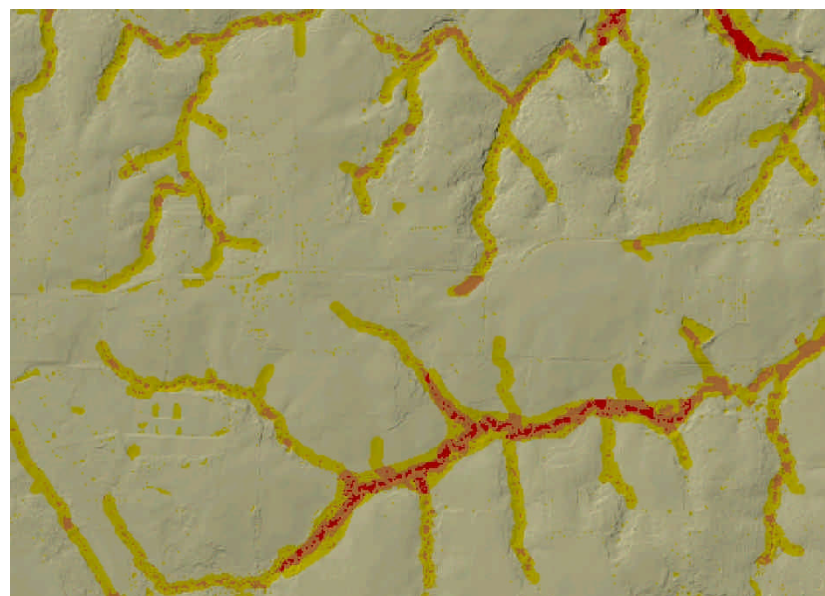
# Non-Vegetation Items (NVI)

The NVI product is generated from the topographic sinks, transitional zones, and hydric soils data layers. Each layers is ranked either as 10 for presence of topographic sinks, transitional zones, and hydric soils or as 0 for absence.

# Combination of VI and NVI

The total possible sum (TPS) of ranked information was determined by summing the ranked information for all six layers. Therefore, the maximum total possible sum is 60. A percent of possible sum (PPS) layer was determined by dividing the actual sum of all layers by the maximum possible value of 60.

| Group | Item | Ranking Description |
|---|---|---|
| Vegetation Information (VI) | | |
| | Most Significant Component (MSC) | Wetland Indicator Status Value Code provides ranks from 0 to 10. |
| | Weighted Sum of Components (WSC) | Values are normalized and ranked from 0 to 10. |
| | Combined Dominants (CD) | Values are normalized and ranked from 0 to 10. |
| Non-Vegetation Items (NVI) | | |
| | Hydrologic Depressions (Sinks) | Sinks receive a 10 and all non-sink areas are 0. |
| | Streams and Transitional Ripariam Zones | Areas within the buffer zone receive a 10 and all other areas a 0. |
| | Hydric Soils | Hydric soil areas receive a 10 and other areas a 0. |
| Total Possible Sum (TPS) of Ranked Information | | **60** |

# Vegetation and Non-Vegetation Information Products
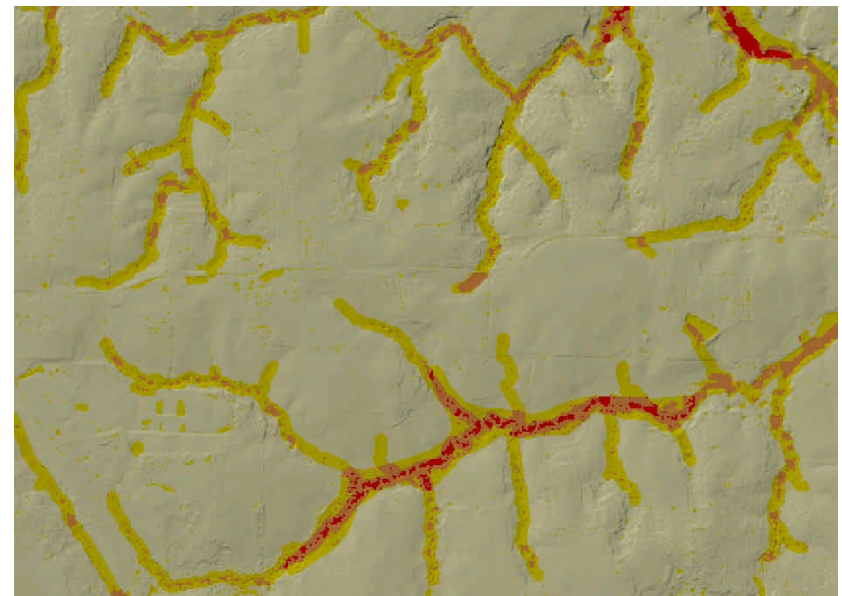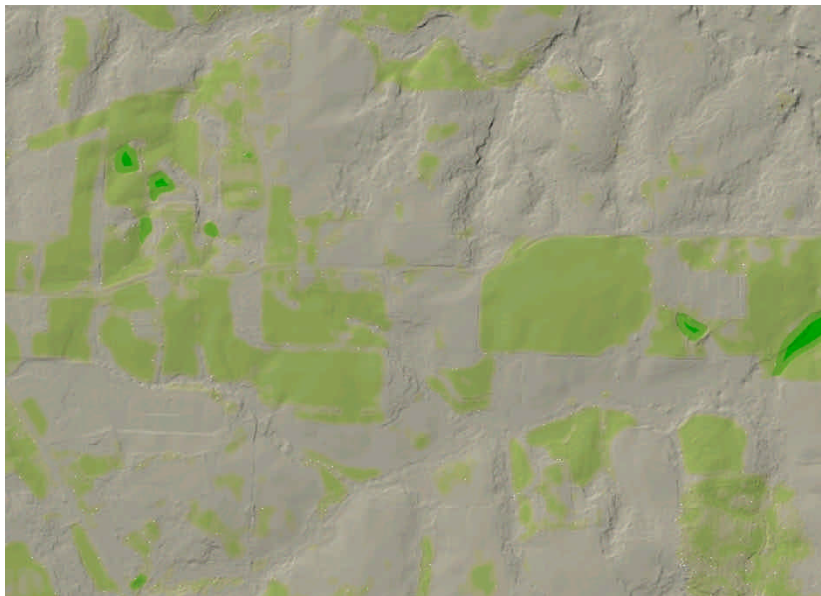
# TPS and PPS

The TPS and the PPS created by summing the VI and NVI are useful for comparison with existing data, for early screening of potential wetland areas, for planning field work, and for generating an alignment that travels the "least cost path" across either the TPS or PPS when used as resistance surfaces.
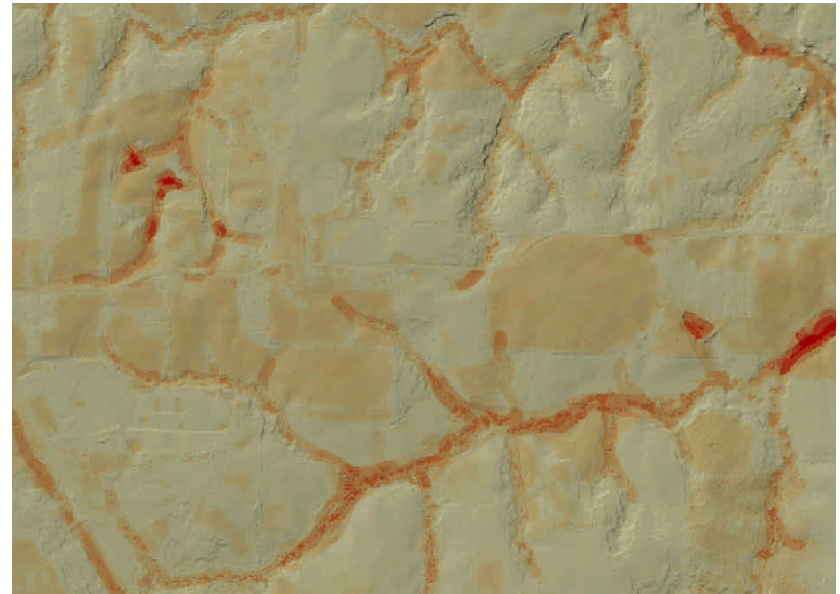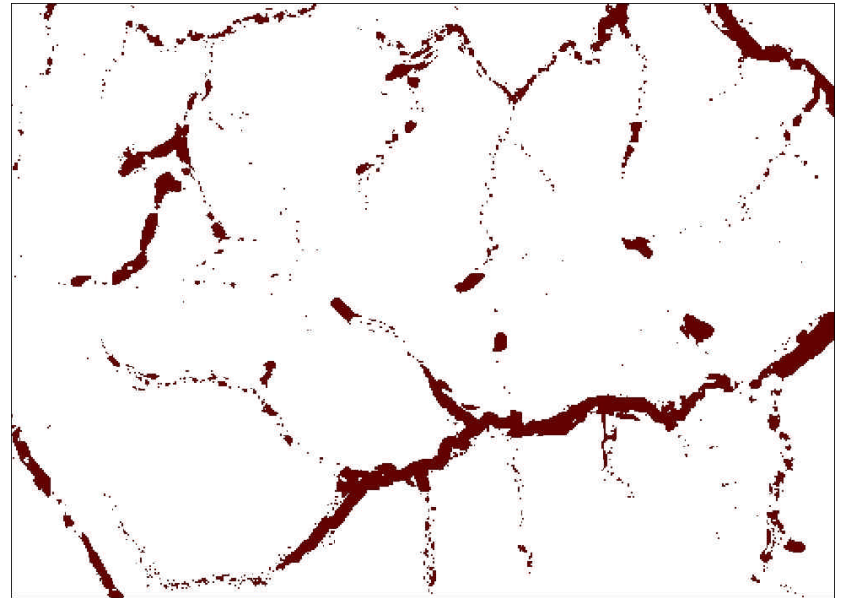
# TPS20

To estimate the areas that have a high likelihood of being wetlands it is necessary to define a threshold above which will be considered "high likelihood."
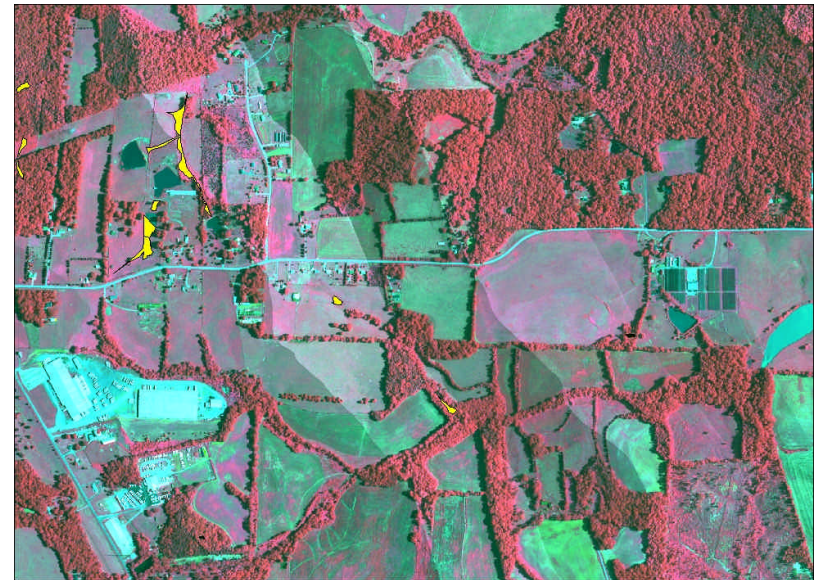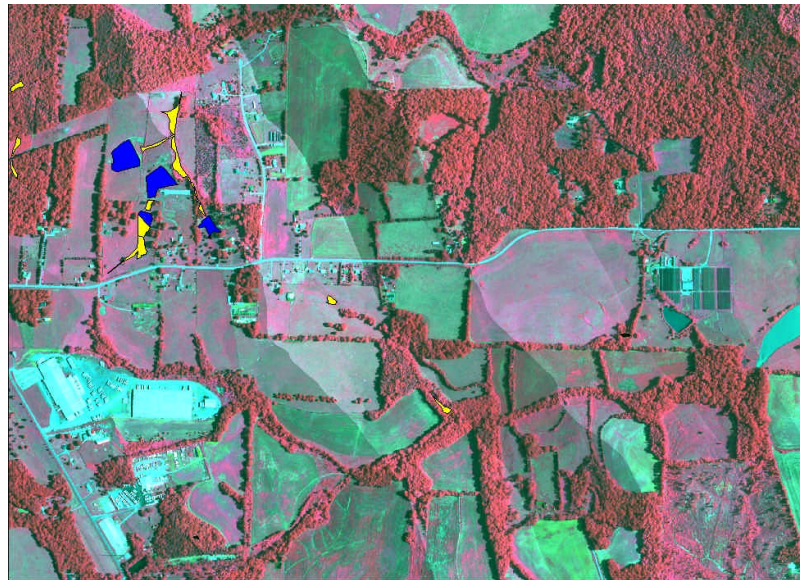
The value "20" represents one-third of the total possible sum, and it is reasonable to assert that areas that exceed a TPS of 20 have a high likelihood of meeting one out of three wetland criteria.

# Comparison Data: NWI Survey Results

# Comparison Data: NC DOT Field Wetland Assessments

# NC DOT Field Wetland Assessments and NWI Survey Results
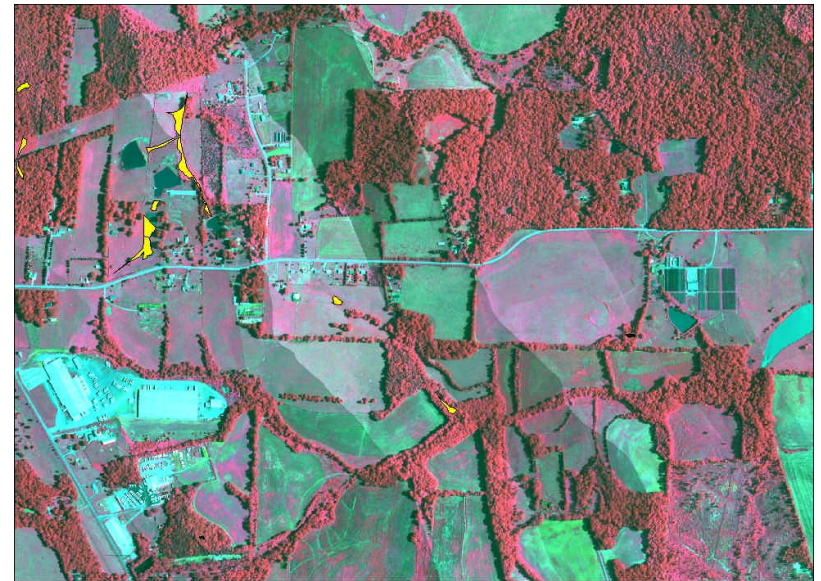
# TPS20 Distance Surface

To better estimate the degree of agreement between the NWI and NC DOT wetlands results and the TPS20 area, a distance surface was generated that shows the distance away from the TPS20 areas. The more area of the NWI and NC DOT wetlands results that directly corresponds to the TPS20 or short distances away from TPS20 the better the agreement.
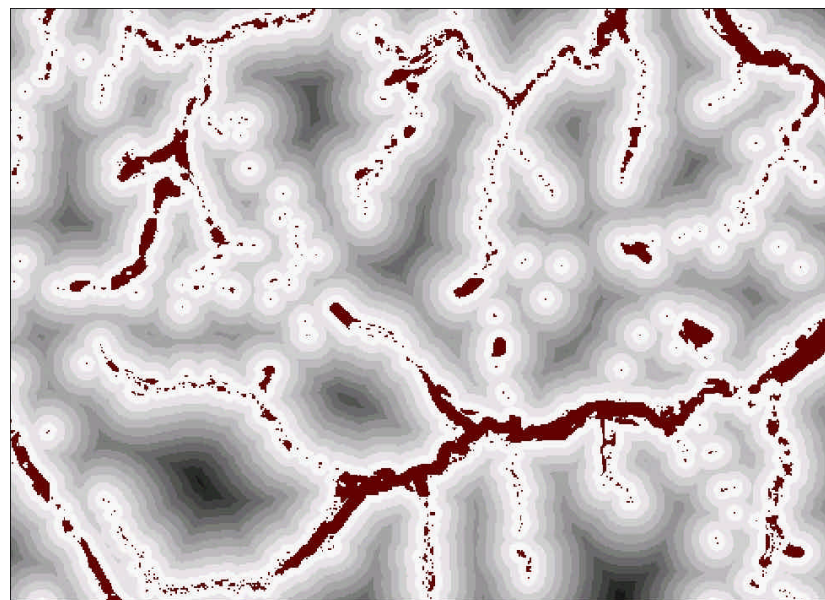
# NWI and NC DOT Results Overlaying the TPS20 Distance Surface
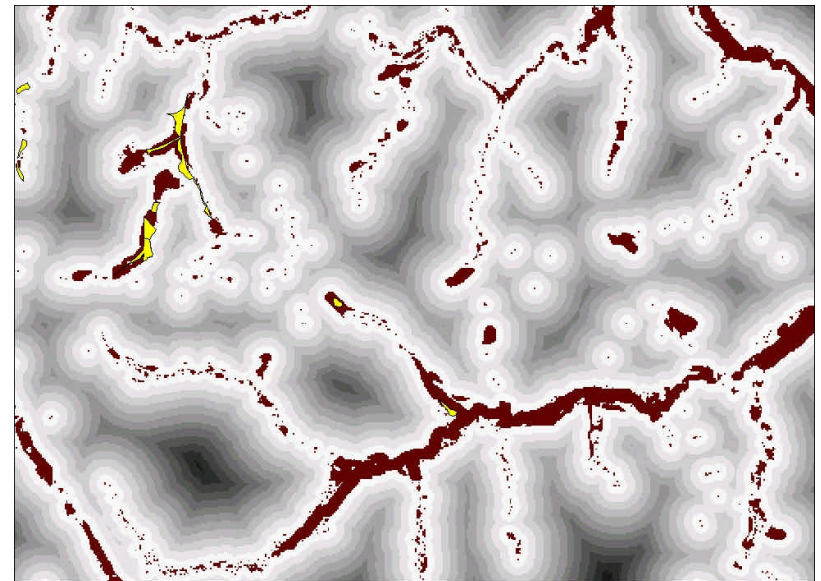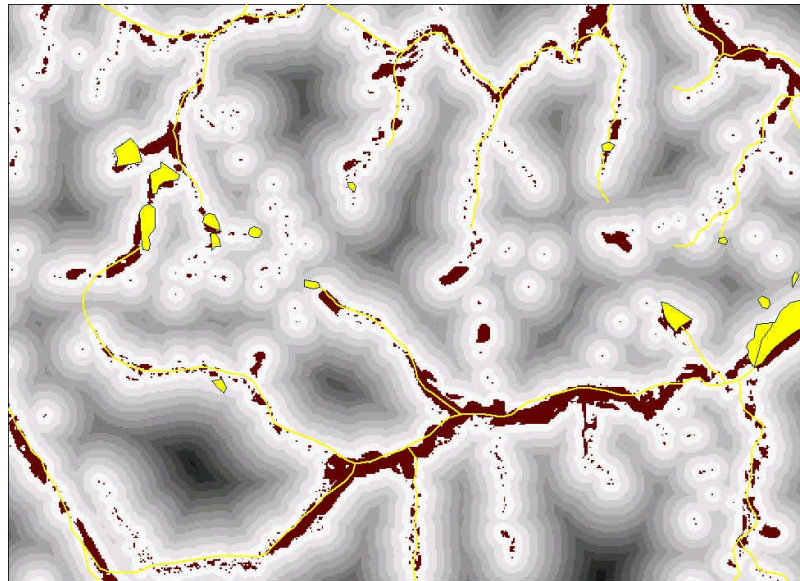
# Comparison and Tabulation of Geospatial Agreement

When compared to the results of the conventional NWI and NC DOT wetland mapping methods, over 95% of the areas mapped as NWI wetlands or NC DOT's Field Wetland Assessment areas were within 4 analysis cells of the areas predicted as having a high likelihood of wetlands (TPS20).

| NWI Area (sq-m) | Percent of NWI Area | Distance Away from TPS20 in cells (5 meter cells) |
|---|---|---|
| 140,175 | 70.09% | Zero or Adjacent (1) |
| 162,250 | 81.13% | Less than 2 cells |
| 174,175 | 87.09% | Less than 3 cells |
| 191,300 | 96.65% | Less than 4 cells |

| NC DOT FWA Area (sq-m) | Percent of FWA Area | Distance Away from TPS20 in cells (5 meter cells) |
|---|---|---|
| 11,175 | 81.87% | Zero or Adjacent (1) |
| 12,225 | 89.56% | Less than 2 cell |
| 12,750 | 93.40% | Less than 3 cells |
| 13,050 | 95.60% | Less than 4 cells |

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# Conclusions

- Remotely sensed data can be used to perform analysis of the likelihood of wetlands.

  – High-spatial resolution, hyperspectral digital data can be used to generate detailed land cover and vegetation information.

  – LIDAR-based digital elevation data can be used to create data layers related to hydrologic conditions including filled hydrologic surface, hydrologic sinks surface, and other hydrologic data derivatives such as flow direction and flow accumulation.

  – By using neighborhood analysis, hydrologic analysis, and data fusion techniques, information products can be generated that closely estimate the likelihood that wetlands criteria are met.

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# Additional Studies

- The process is being duplicated in Eddyville, Iowa -- RS data have been acquired and are being processes.

- The CSX railroad relocation EIS will likely use the wetlands analysis algorithm developed at MSU to identify areas with a high wetlands likelihood.