

Hydrologic and Nutrient Transport Processes and GIS-based Decision Support System for Poultry Litter Management

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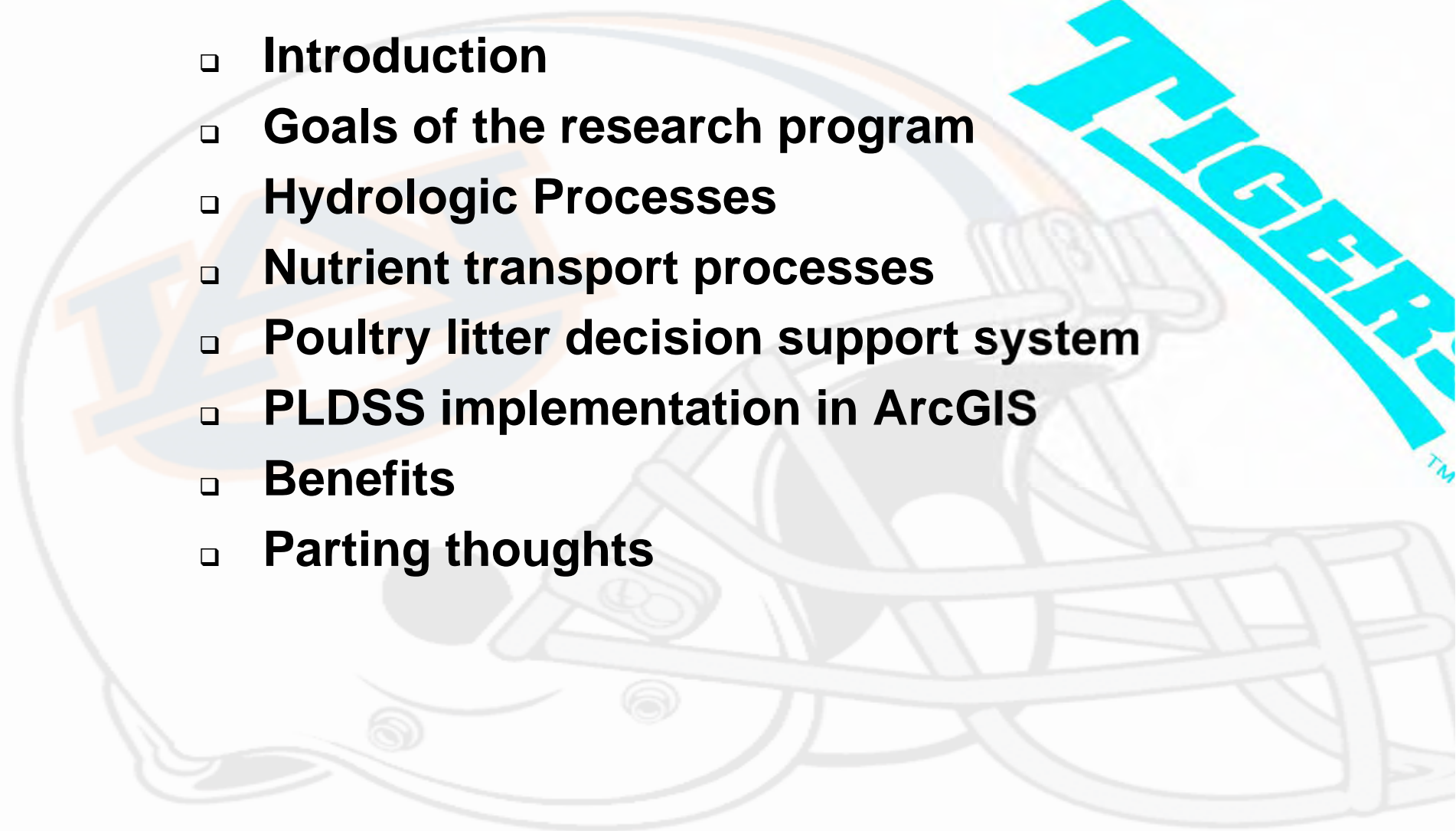
Collaborators: Moon Seong Kang, Tom Way, Kyung Yoo, Ted Tyson, John Fulton, Joey Shaw, Wes Wood, and Frank Owsley



Outline



- ❑ **Introduction**
- ❑ **Goals of the research program**
- ❑ **Hydrologic Processes**
- ❑ **Nutrient transport processes**
- ❑ **Poultry litter decision support system**
- ❑ **PLDSS implementation in ArcGIS**
- ❑ **Benefits**
- ❑ **Parting thoughts**

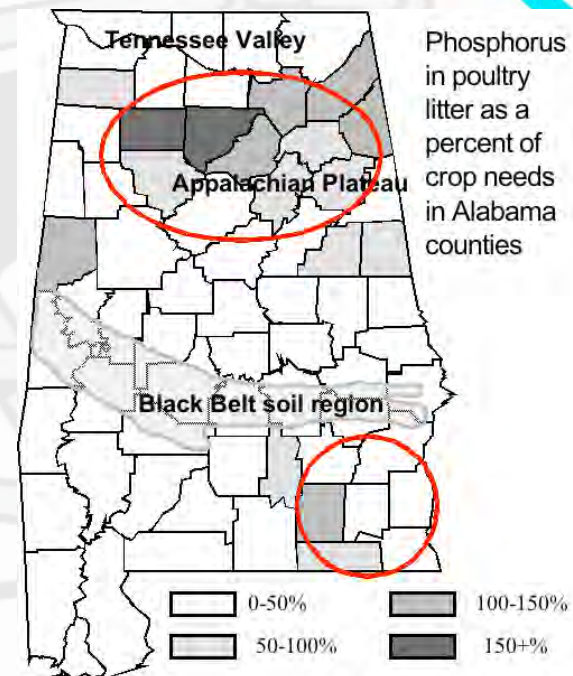




Introduction



- ❖ Alabama ranks in top three in broiler production
- ❖ More than 1 billion birds with receipts of \$2.41 billion
- ❖ About 500 CAFOs and 4000 AFOs; about 12,000 chicken houses
- ❖ Broiler litter production – 1.8 million tons/year
- ❖ Most of the poultry production occurs in 5 counties in Appalachian Plateau

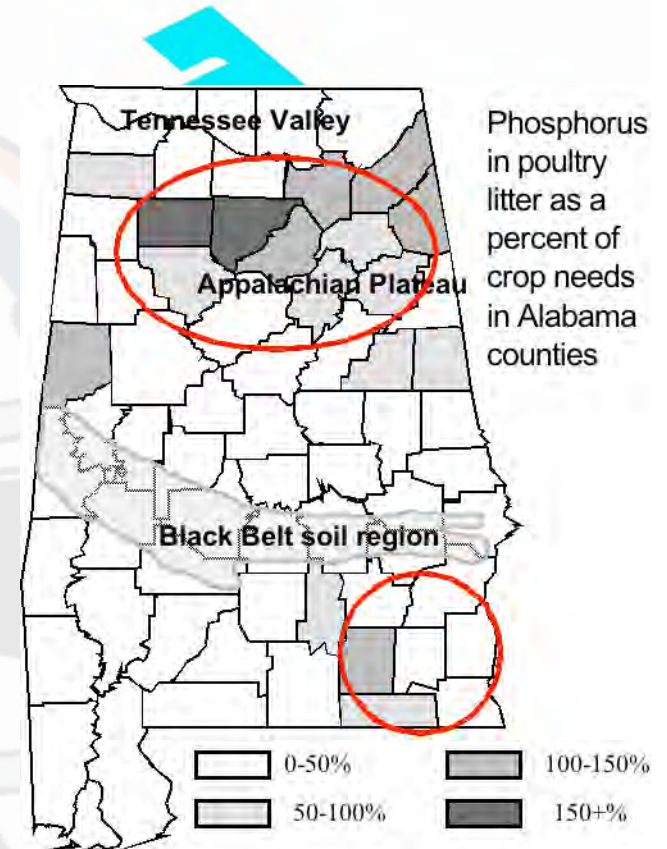




Introduction



- ❖ Litter application at nitrogen rate has led to build up of phosphorus (P) in many pastures/hay fields - other hay and cropland fields can still utilize poultry litter
- ❖ Black Belt region suffers from poor soil fertility in pasture
- ❖ P-Index and Comprehensive Nutrient Management Plan (CNMP) are BMPs to reduce P loads to water bodies





Introduction



- ❖ Treat an entire field as P contributing – what about consideration to hydrologic and nutrient transport process?
- ❖ Based on plot scale (rainfall simulator) experiments
- ❖ Over or underestimate P transport potential – can lead to
 - ❖ Reduction in land base for litter application
 - ❖ Threat of P transport
- ❖ Understanding hillslope hydrologic and nutrient transport processes important for improving P-index
- ❖ CNMP – required for CAFOs; developed by County Conservation Districts



Introduction



- ❖ AFO operators receive little help with their nutrient management planning

MAIN ISSUES

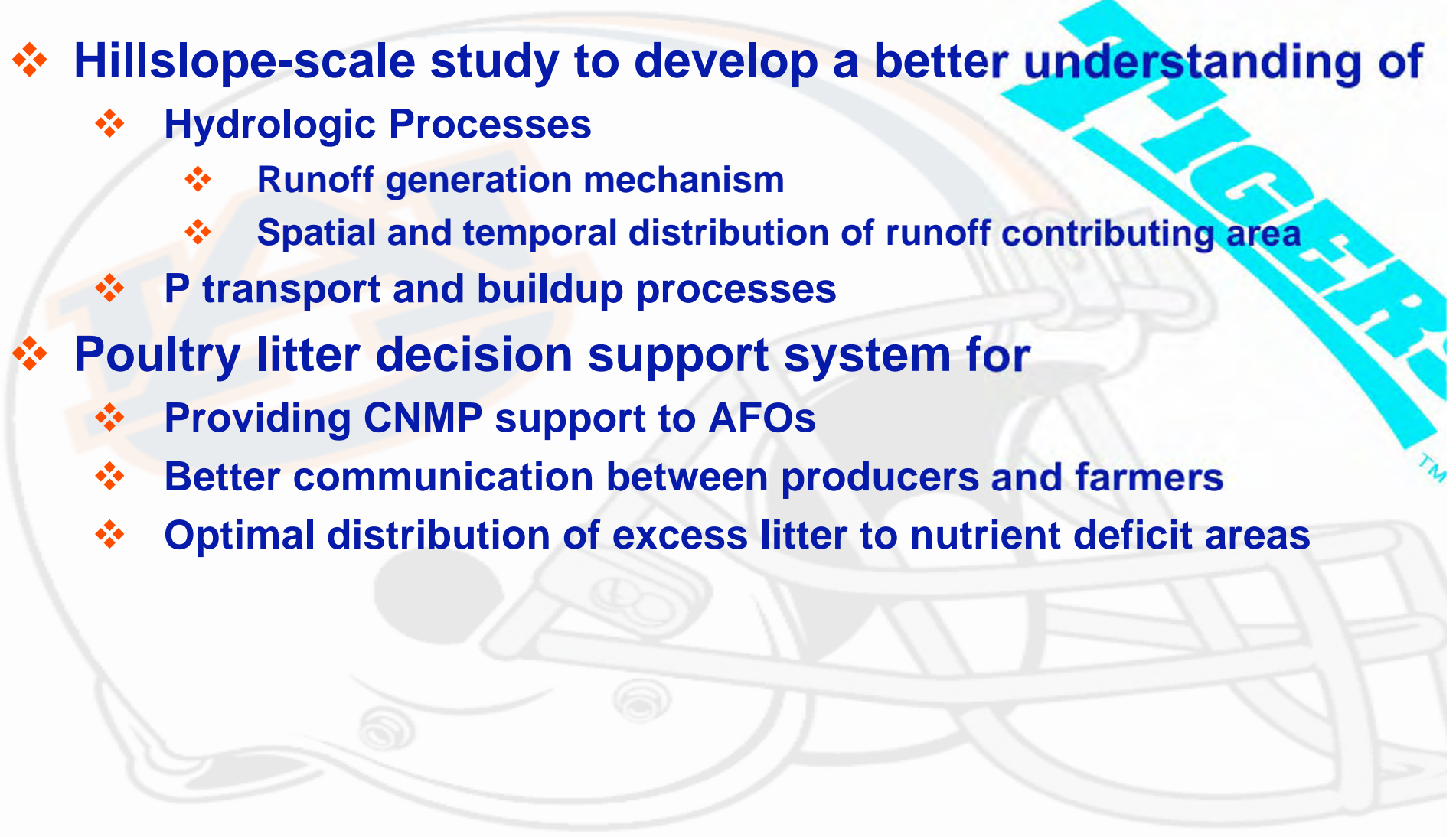
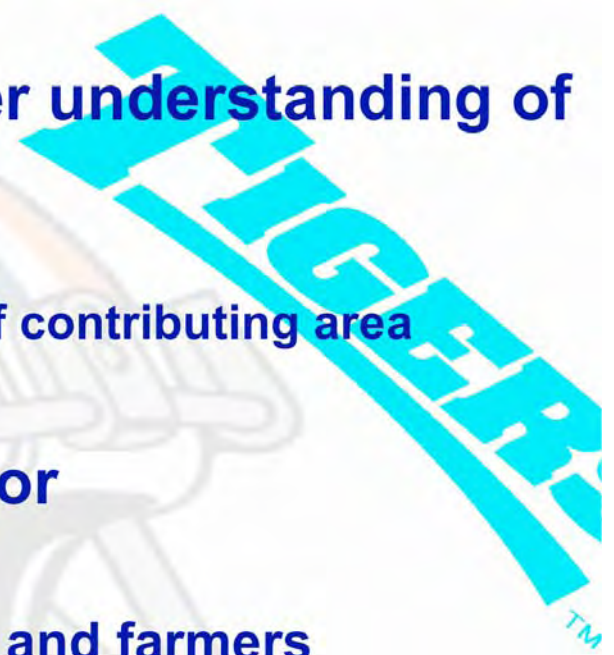
- ❖ Lack of sound understanding of hydrologic and nutrient transport processes at a field/hillslope scale
- ❖ Lack of support for AFOs – leads to over-application of litter
- ❖ Improper distribution of excess litter in Appalachian Plateau Region and to Black Belt Region



Research Program



- ❖ **Hillslope-scale study to develop a better understanding of**
 - ❖ **Hydrologic Processes**
 - ❖ **Runoff generation mechanism**
 - ❖ **Spatial and temporal distribution of runoff contributing area**
 - ❖ **P transport and buildup processes**
- ❖ **Poultry litter decision support system for**
 - ❖ **Providing CNMP support to AFOs**
 - ❖ **Better communication between producers and farmers**
 - ❖ **Optimal distribution of excess litter to nutrient deficit areas**





Hydrologic Processes



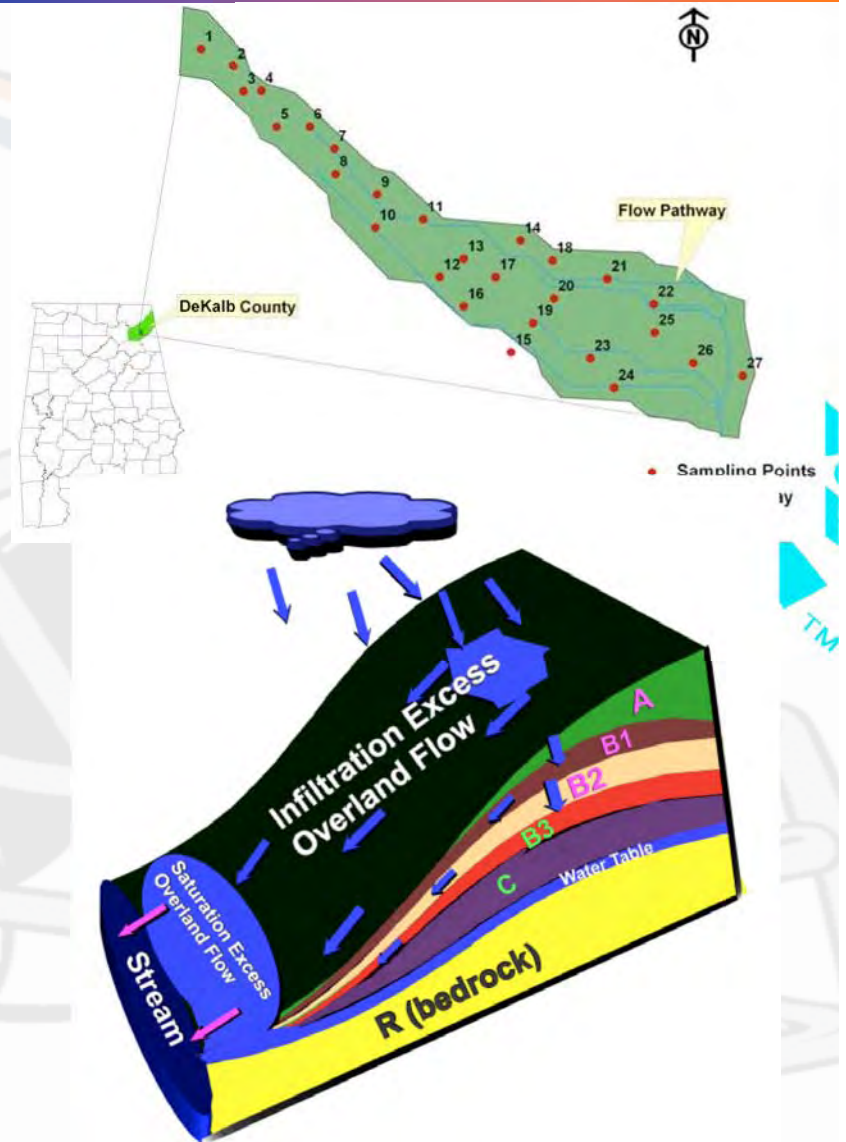
- ❖ Extensively instrumented hillslope at the Sand Mountain Research and Extension Center

- ❖ Hydrologic Processes

- ❖ Runoff generation mechanism

- ❖ Infiltration excess
 - ❖ Saturation excess

- ❖ Spatial and temporal distribution of runoff contributing area



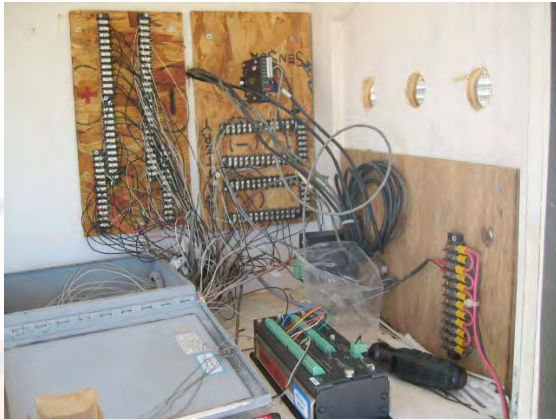


Hydrologic Processes



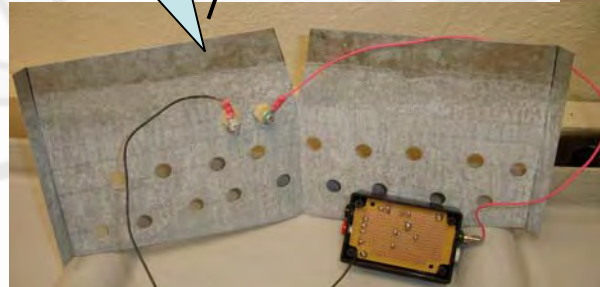


Hydrologic Processes



Surface sensor

Subsurface Sensor





Hydrologic Processes



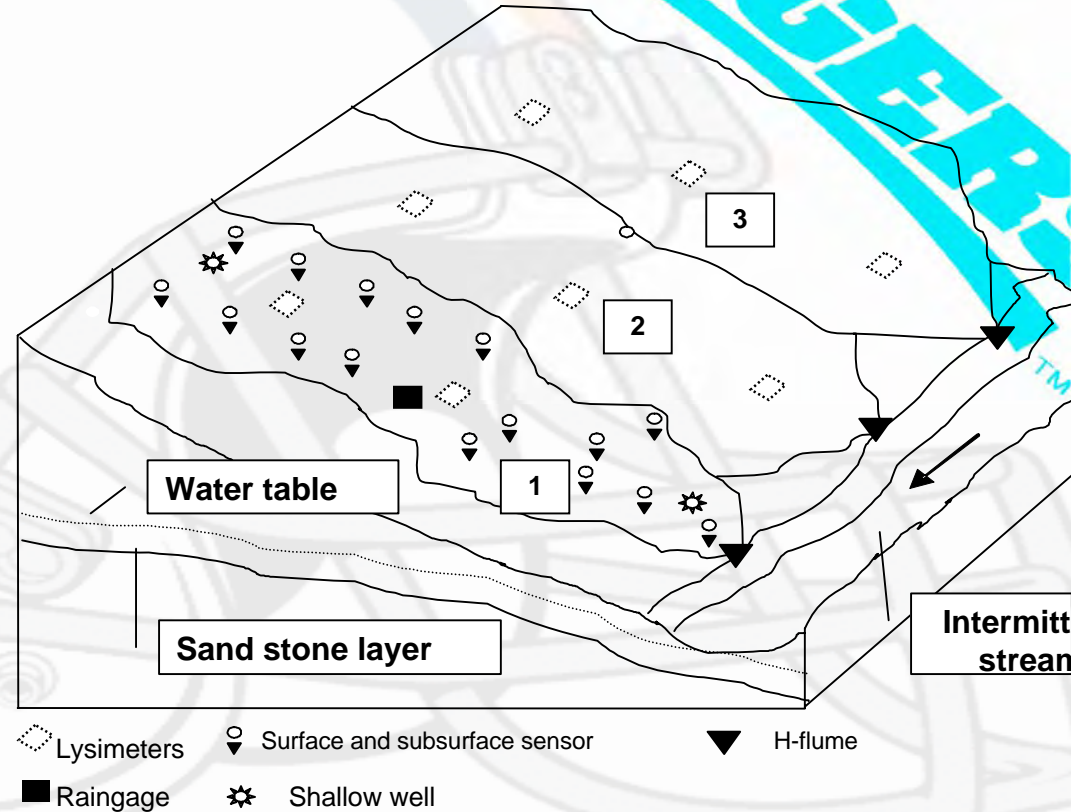
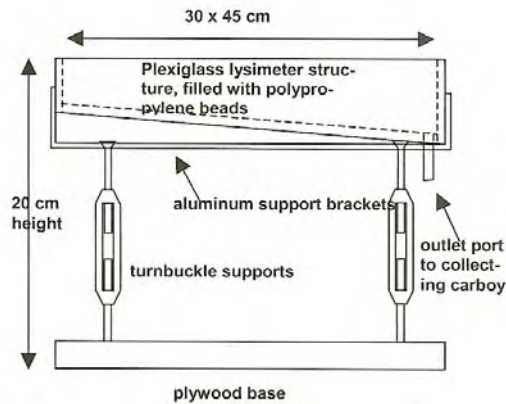
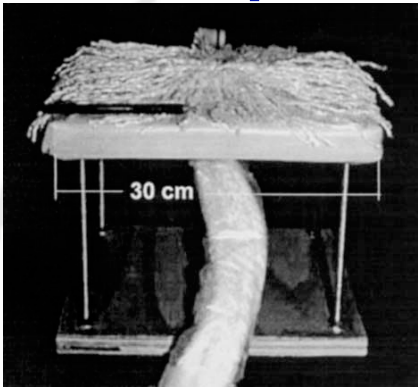
- ❖ Preliminary data suggest that runoff generation mechanism is mostly infiltration excess
- ❖ Runoff is generated
 - ❖ During parts of an intense storm – doesn't occur that often
 - ❖ From areas with low hydraulic conductivity
- ❖ Finding will be generalize through modeling for application in other areas
- ❖ Significant subsurface flow potential because of
 - ❖ Sandy loam soil with high infiltration rate
 - ❖ Underlain by low conductivity Sandstone layer



Nutrient Transport Processes



- ❖ Build up of P at a hillslope scale
- ❖ Transport of P in surface and subsurface flows





Poultry Litter Decision Support System (PLDSS)



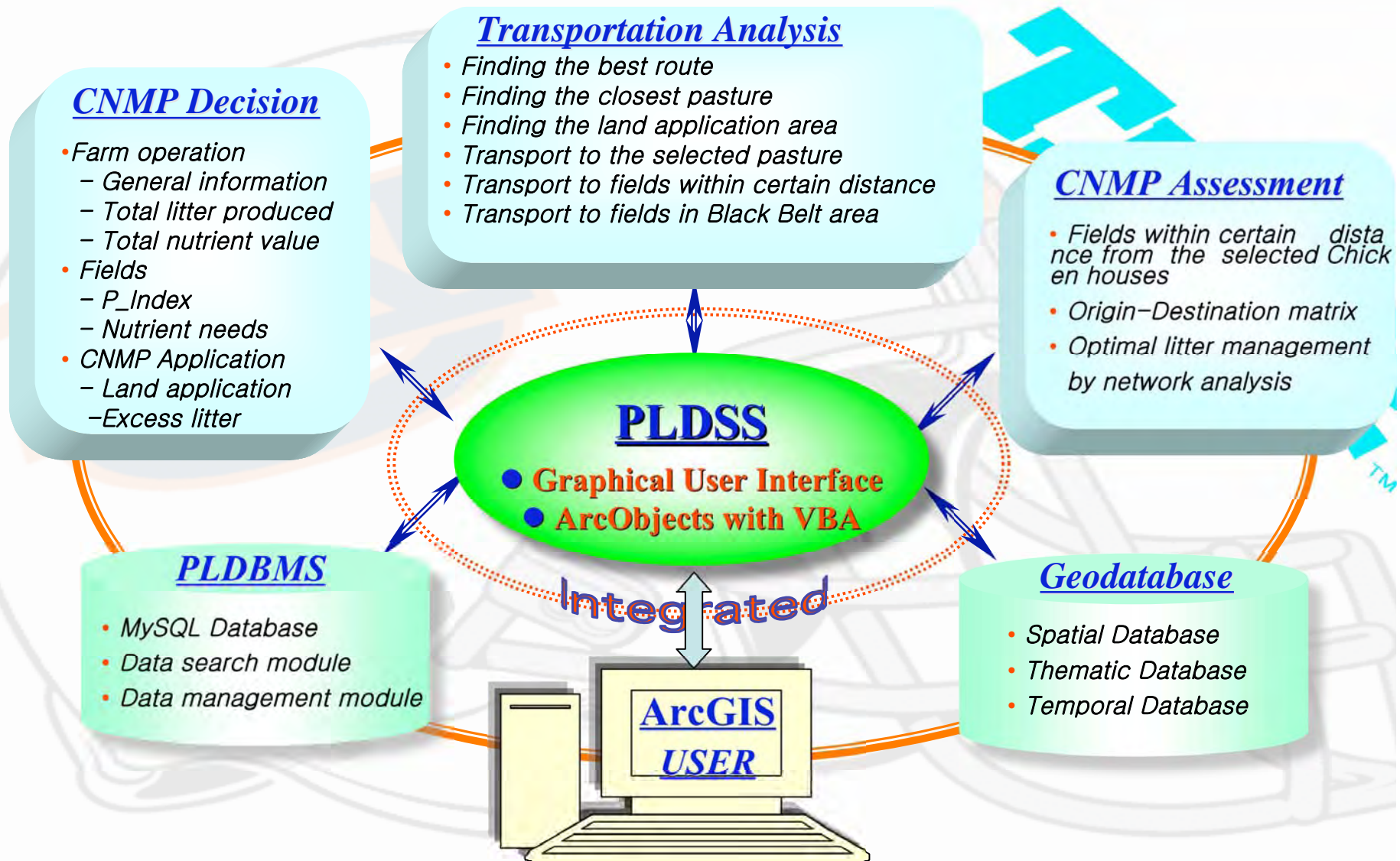
- ❖ Provides nutrient management planning for AFOs (and CAFOs)
- ❖ Conducts transportation analysis for cost-effective transportation of litter
- ❖ Developed using ArcGIS, Network Analyst, and VB Scripts
- ❖ A proof of concept for the web-based system for CAWVs and farmers – currently under development
- ❖ A spatial bulletin board to post availability and needs

Alleviate water quality problems in the Appalachian Plateau Region and poor soil fertility problems in the Black Belt Region



PLDSS

Framework and Modules





CNMP



□ CNMP Decision

- ❖ **USDA and EPA strategy to alleviate water quality and public health concerns arising from CAFOs/AFOs**
- ❖ **Alabama's CNMP**
 - Estimate poultry litter and compost production
 - Determine nutrient value of litter and compost
 - Map and calculate land area for spreading
 - Determine target crops and nutrient needs

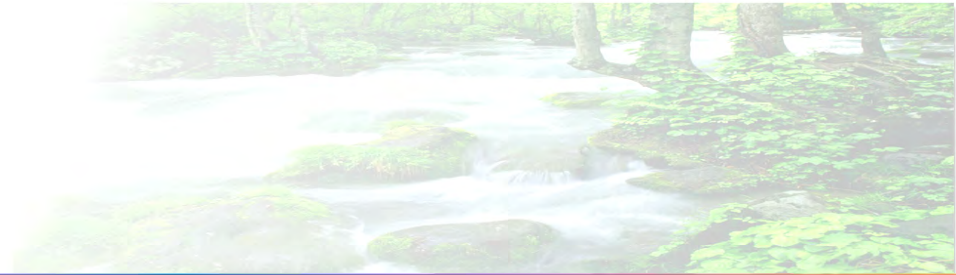


P-Index

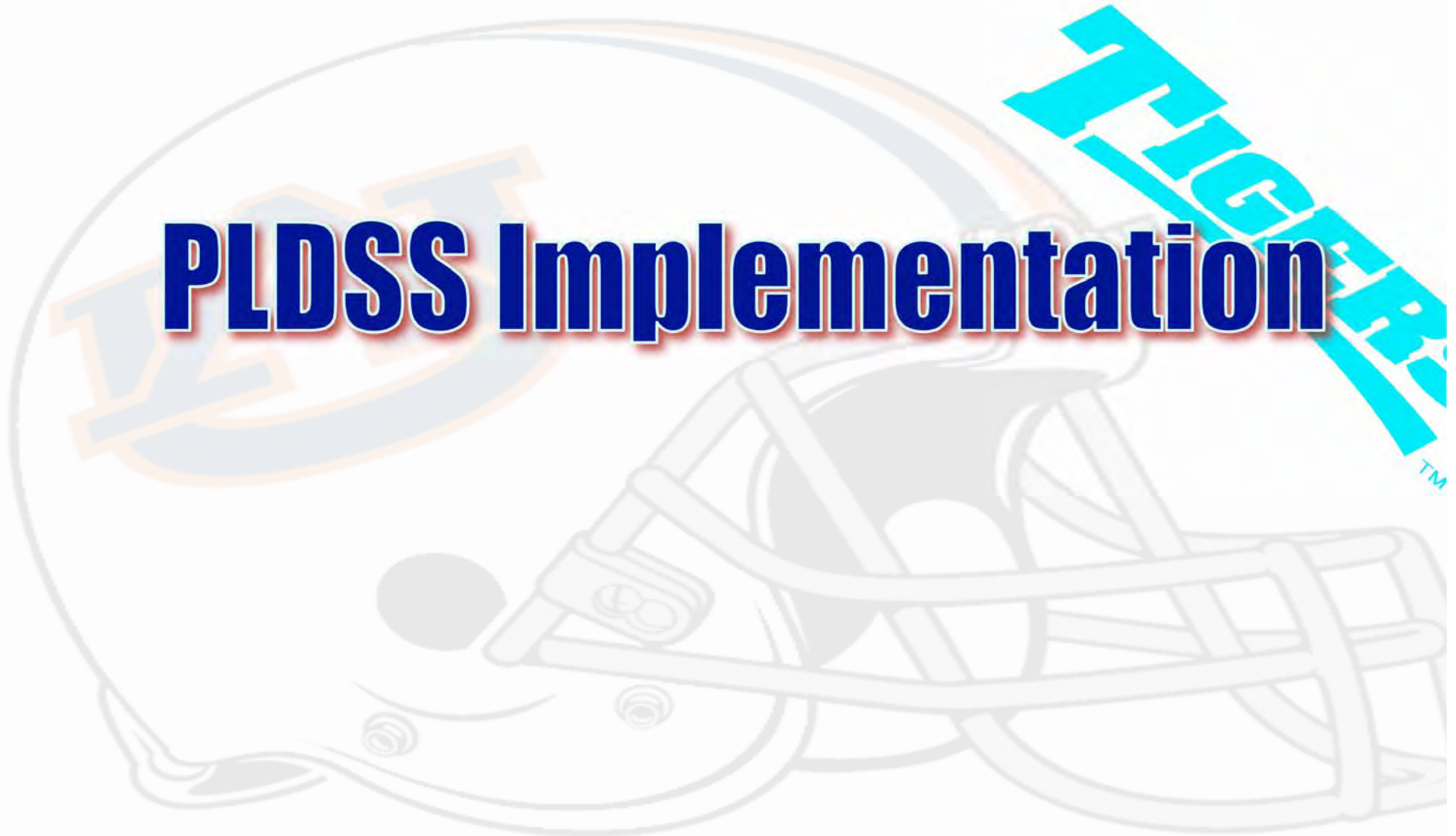


□ P-Index

- ❖ Tool used to assess the selected application site and management practices with regard to the potential risks posed by phosphorus movement to nearby surface waters
- ❖ Indicates poultry litter application rates based on site vulnerability for P transport
 - Nitrogen rate
 - 3 x P
 - 2 x P
 - 1 x P
 - No application allowed



PLDSS Implementation



CNMP Decision Module General Information Dialog Box

File Edit View Insert Selection Tools Window Help CNMP Decision Transportation Analysis PLDBM

New Route Select Features Create Network Location Select/Move Locations Find Best Route Show Map Network Analyst Window Create New Selectio

Select a farm

Did you select a chicken house on the map?

Yes No

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Select a farm

Please select a chicken house using tool menu 'Select Features'

OK

TP_select_chicken_house_BB

Executing Export Feature Attribute to Ascii...

Cancel

<< Details

Close this dialog when completed successfully

```

\TP_select_chicken.shp ObjectID Space
C:\Puneet_Project\VBA\Program\Temp
\TP_select_chicken_ID.txt
Start Time: Tue Jan 23 11:22:07 2007
Running script ExportXYv...
  
```

General Information

PLDSS_General Information

Operation

CNMP report No. BS_2007_01_23

Farm ID 161

Name Puneet Srivastava

Address CORD 1442

State AL Zip code

Office phone 123-456-789 Home phone 123-456-7777

Email address kangmoo@auburn.edu

Starting year 2007 Starting month Mar

Note Comprehensive Nutrient Management Plan

Edit Save Close

Owner

Name Puneet_1

Phone 334-844-1234

Email abc@auburn.edu

Operator

Name Puneet_2

Phone 334-844-1235

Email cde@auburn.edu

CAWW

Name Puneet_3

Phone 334-844-1236

Email fgh@auburn.edu

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Attributes of the selected farm extracted

CNMP Decision Module

Total Litter Produced and Nutrient Value Dialog Box

File Edit View Insert Selection Tools Window Help

New Route Select Features Create Network Location Select/Move Locations Find Best Route Show Map Network Analyst Window Create New Selection



Total Litter Produced

Input for estimating broiler litter

No. of houses :

Flock size (birds/hse) :

No. of batches (/yr) :

Market wt. (lb/bird) :

Mortality rate (%) :

wt. / dead bird (lb/bird) :

Dead bird disposal

Compost Incinerated Rendered

Calculate **Result** **Close**

Litter available for on-farm land application

Actual litter produced : ton

Incinerated or rendering : ton

Litter required to compost : ton

Compost produced : ton

Litter available : ton

Total Nutrient Value

Input for nutrient value of broiler litter and compost

Litter : Average available N-P2O5-K2O per ton

N : lb. / ton

P2O5 : lb. / ton

K2O : lb. / ton

Compost : Average available N-P2O5-K2O per ton

N : lb. / ton

P2O5 : lb. / ton

K2O : lb. / ton

Surface-applied litter ? Yes No

Output for nutrient value of broiler litter

Nutrient value of broiler litter and compost

N : lb. /

P2O5 : lb. /

K2O : lb. /

Compost

N : lb. /

P2O5 : lb. /

K2O : lb. /

Calculate **Result**

CNMP Decision Module P-Index Dialog Box

P-Index calculation

Did you select a field?

Yes No

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Buffer zones

How far is the distance used to create buffer zones?

Buffer zones

Distance: ft

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P_Index_Select_Pasture

Executing Export Feature Attribute to Ascii (2)...

Close this dialog when completed successfully

```
Completed script ExportXYv...
Executed (Export Feature Attribute to
Ascii (2)) successfully.
End Time: Tue Jan 23 23:09:59 2007
(Elapsed Time: 1.00 seconds)
```

Display

P-Index calculation

Input for Alabama Phosphorous Index

P rating
 Very Low / Low Medium High Very High Extremely High

P Application Rate
 None applied < 60 lb 60 - 120 lb 120 - 180 lb > 180 lb

Nutrient Application Method
 None applied Injected Sprinkler Incorporated < 30 Not incorporated

Grazing Animal (access to water)
 None No access Restricted Unlimited < 100 animals Unlimited > 100 animals

Underground Outler Systems
 None Grass filter Grass waterway Waterbodies < 30% of field Waterbodies > 30% of field

Erosion Rate (tons/ac/yr)
 < 2tons 3 - 5 tons 5 - 10tons 10 - 15tons > 15tons

P Application Distance to Water (ft)
 > 400 200-400 100-200 50-100 < 50

Filter Strip Width (ft)
 > 50 30-49 20-29 10-19 < 10

impaired, Outstanding, or Critical Habist Waters
 Field not in watershed > 400ft 200-400ft 100-200ft <100ft

Field Vulnerability for Phosphorus Loss

Field ID :

Field area (ha) :

Total points from P index :

P index :

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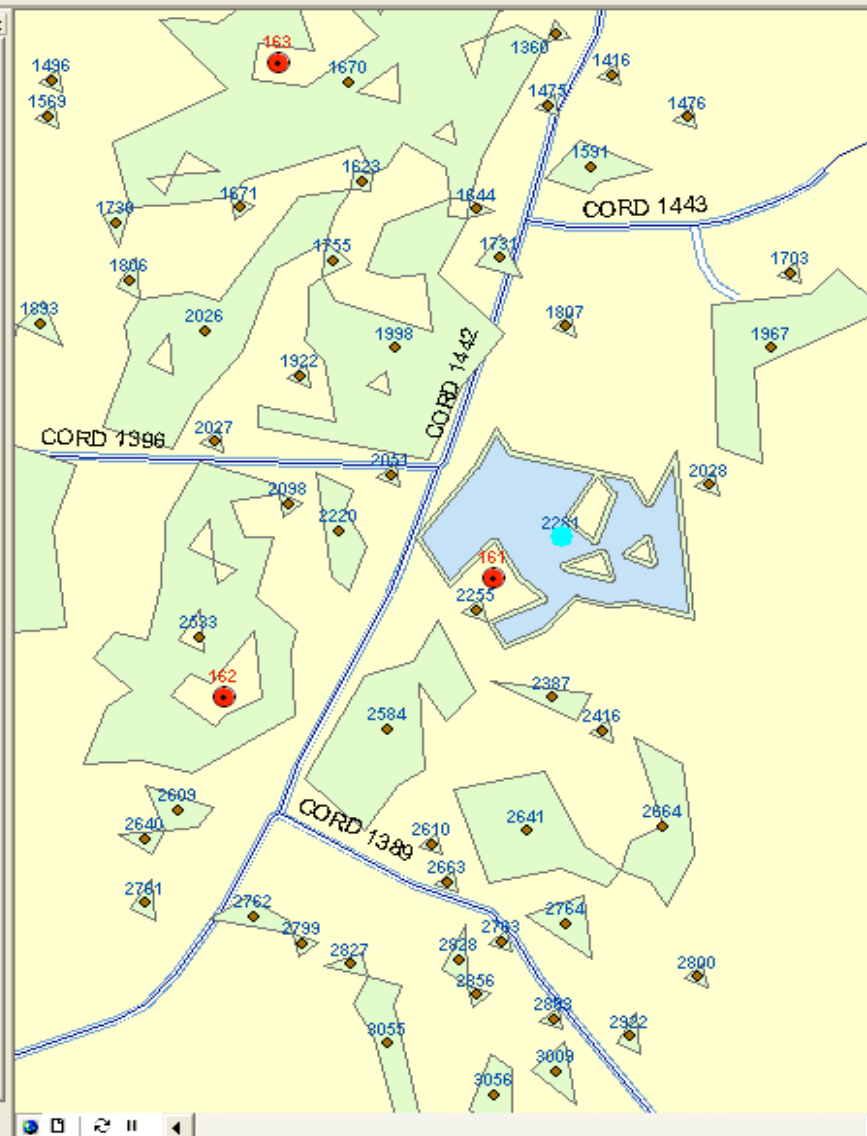
Attributes of the selected field extracted

CNMP Decision Module

Nutrient Needs Dialog Box

- Layers
 - Export_Output_5
 - al_cm_patures_slp_FeatureToC
 - rastert_majorit1_FeatureToPc
 - Black_Belt_Pasturet
 - al_cm_patures_slp_Select1_B
 - al_cm_patures_slp_Select1
 - al_cm_patures_slp
 - Alabama
 - ALHigh
 - urban_dtl_Select
 - BTS_Hydrography_In
 - BTS_Hydrography_ply
 - NetworkLayers_ND_Junctions
 - t_streets
 - NetworkLayers_ND
 - Edges
 - StreetMap USA
 - National
 - State
 - Regional

Display Source Selection



Calculate nutrient needs

Input for crop and nutrient needs

Field ID :

Field area (ha) :

Spreadable area (ha) :

P rating

VL L M H VH EH

Crop :

Crop yield : ton/acre

No. of Beef : 300 lb. beef

Nutrient needs

N : lb/yr

P205 : lb/yr

K20 : lb/yr

Compost need : ton/yr

Litter need : ton/yr

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CNMP Decision Module

CNMP Application Dialog Boxes

File Edit View Insert Selection Tools Window Help CNMP Decision Transportation Analysis PLDBMS

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New Route Select Features Create Network Location Select/Move Locations Find Best Route Show Map Network Analyst Window Create New Selection

Land Application

Farm information

Chicken house ID :

Compost produced : ton

Litter produced : ton

Field information

Field ID :

Nutrient need by compost : ton

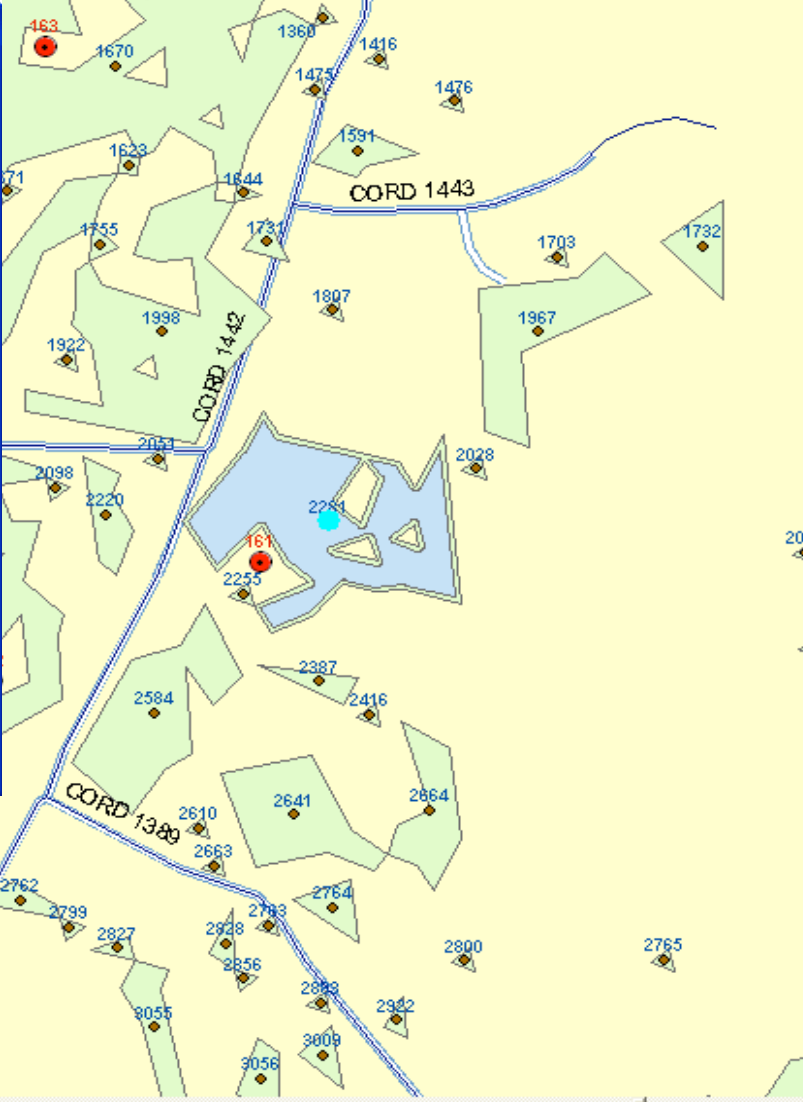
Nutrient need by litter : ton

Land Application

Compost : ton

Litter : ton

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Excess to CAWV

Excess to Certified Animal Waste Vendor

Date :

CAWV name :

CAWV no. :

Land App. by litter :

Land App. by compost :

Excess litter :

Excess compost :

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t_streets

NetworkLayers_ND

— Edges

StreetMap USA

National

State

Regional

Display Source Selection

Drawing

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516602.42 3793730.44 Meters

Transportation Analysis Module

Finding the Available Area Polygons

File Edit View Insert Selection Tools Window Help CNMP Decision Transportation An

New Route Select Features Create Network Location Select/Move Locations Find Best Route Show Map Network Analyst Window Create New Selection

Layers

- Service Area 2
 - Facilities
 - Error
 - Located
 - Unlocated
 - Barriers
 - Error
 - Located
 - Unlocated
 - Lines
 - Lines
 - Polygons
 - 0.3
 - 0.5
 - 1
- Export_Output_5
- al_cm_patures_slp_FeatureToPc
- rastert_majorit1_FeatureToPc
- Black_Belt_Pasturet

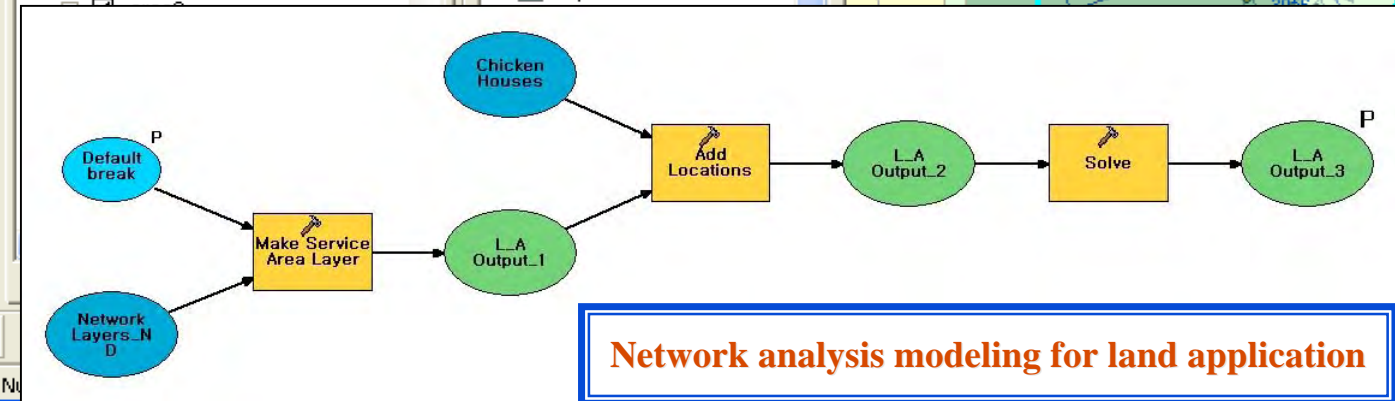
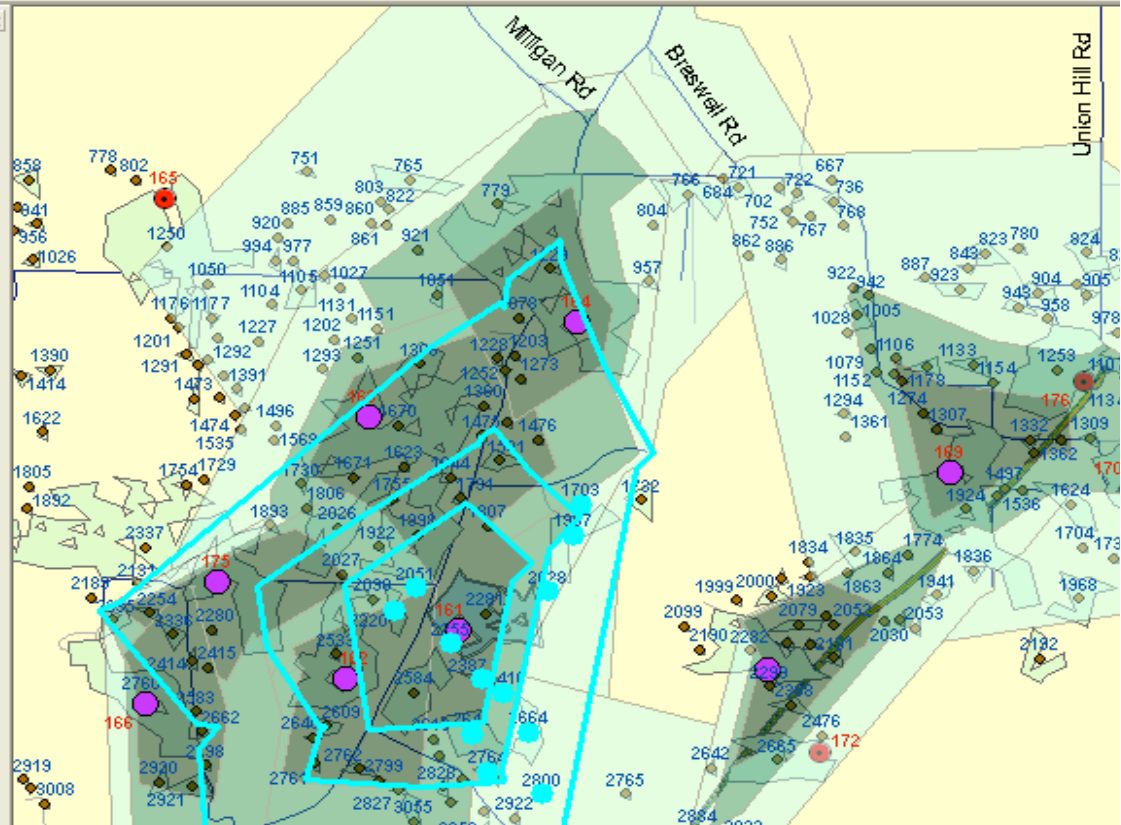
Service Area 2

- Graphic Pick 52
- Graphic Pick 54
- Graphic Pick 56
- Graphic Pick 58

Barriers (0)

Polygons (27)

- Graphic Pick 47 : 0.5 - 1
- Graphic Pick 52 : 0.5 - 1
- Graphic Pick 45 : 0.5 - 1
- Graphic Pick 44 : 0.5 - 1
- Graphic Pick 46 : 0.5 - 1
- Graphic Pick 56 : 0.5 - 1
- Graphic Pick 49 : 0.5 - 1
- Graphic Pick 58 : 0.5 - 1
- Graphic Pick 54 : 0.5 - 1
- Graphic Pick 44 : 0.3 - 0.5
- Graphic Pick 47 : 0.3 - 0.5
- Graphic Pick 46 : 0.3 - 0.5
- Graphic Pick 45 : 0.3 - 0.5
- Graphic Pick 46 : 0 - 0.3
- Graphic Pick 56 : 0.3 - 0.5
- Graphic Pick 52 : 0.3 - 0.5
- Graphic Pick 44 : 0 - 0.3
- Graphic Pick 58 : 0.3 - 0.5
- Graphic Pick 45 : 0 - 0.3
- Graphic Pick 49 : 0.3 - 0.5

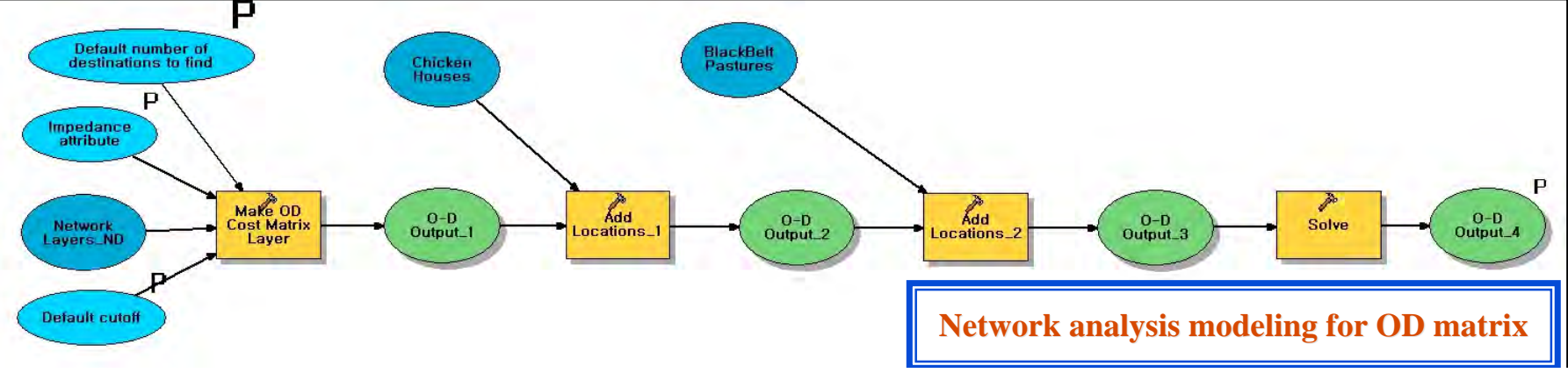
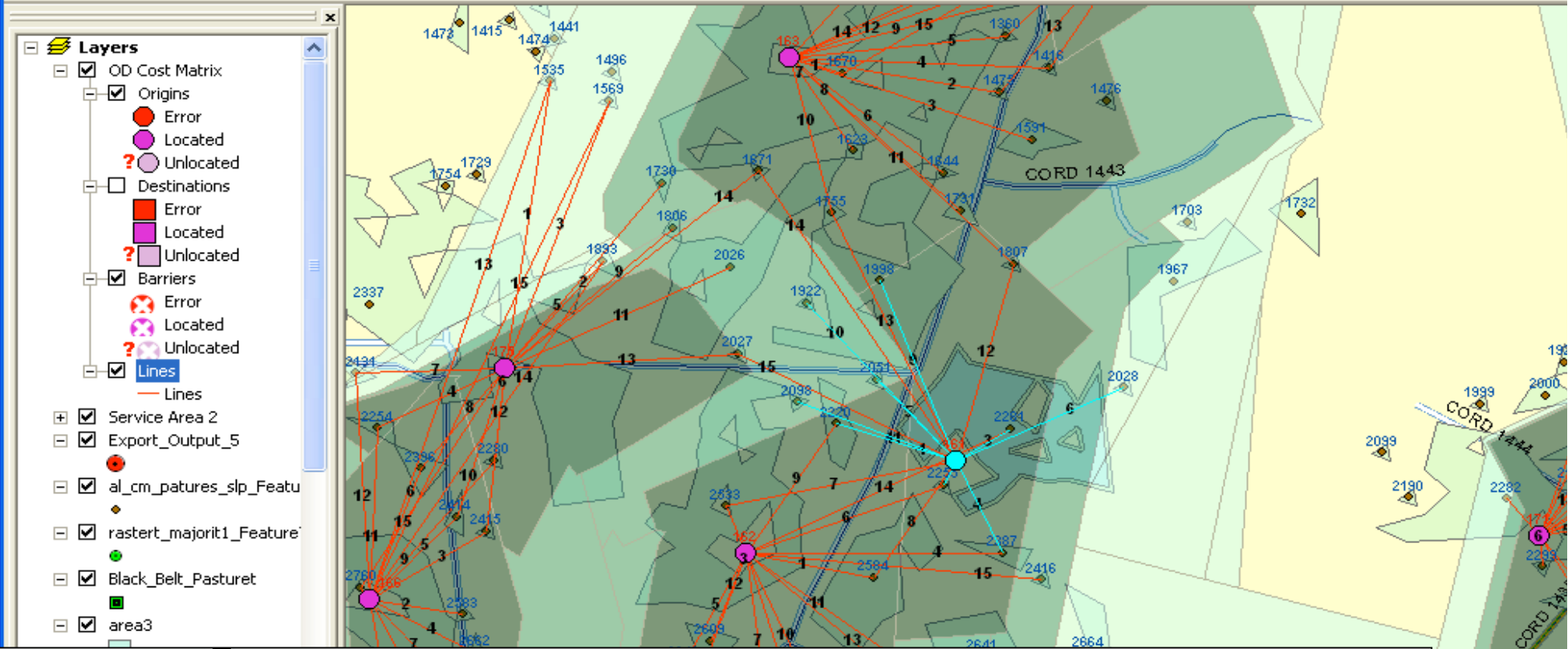


Network analysis modeling for land application

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Transportation Analysis Module

The Origin-Destination Matrix



Network analysis modeling for OD matrix

CNMP Assessment Module On-Farm Application

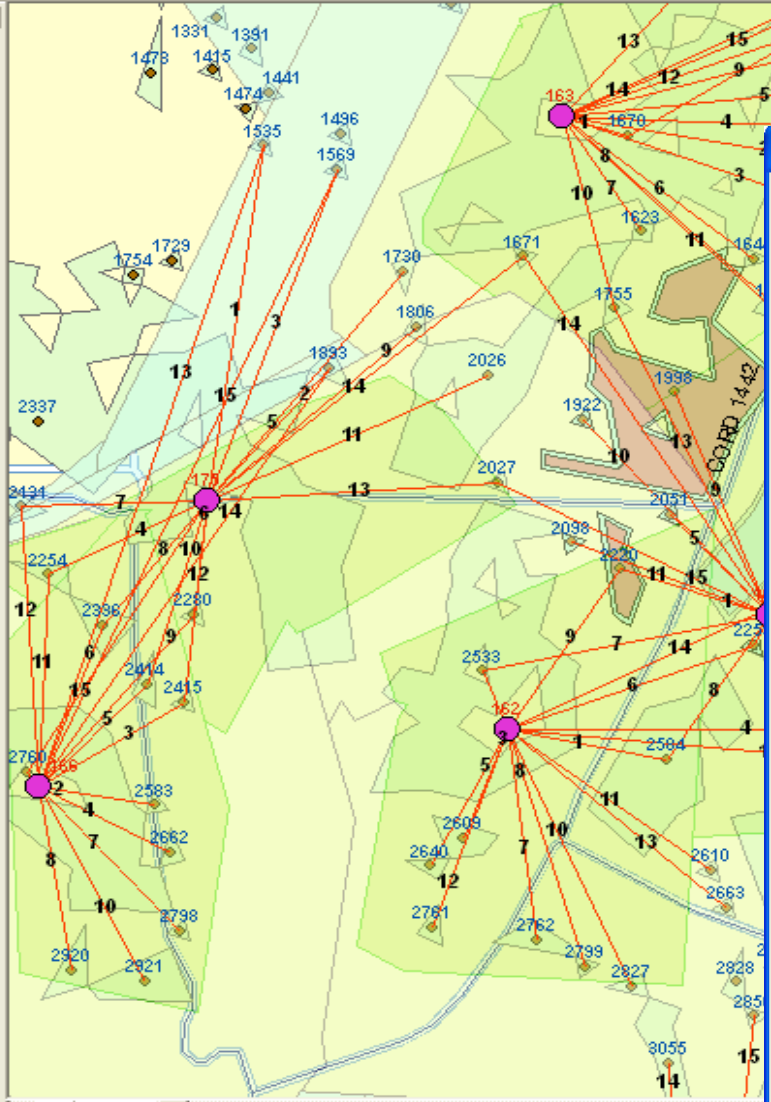
File Edit View Insert Selection Tools Window Help CNMP Decision Transportation Analysis PLDBMS CNMP Ass

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New Route Select Features Create Network Location Select/Move Locations Find Best Route Show Map Network Analyst Window Create New Selection

Layers

- OD Cost Matrix
- Service Area 2
 - Facilities
 - Error
 - Located
 - ? Unlocated
 - Barriers
 - ✕ Error
 - ✕ Located
 - ? Unlocated
- Lines
 - Lines
- Polygons
 - 0.3
 - 0.5
 - 1
- Export_Output_5
- al_cm_patures_slp_Featu
- rastert_majorit1_Feature
- Black_Belt_Pasturet
- al_cm_patures_slp_Select
- al_cm_patures_slp_Select
- area3
- al_cm_patures_slp_Select



CNMP Assessment - On farm application

CAWW

Farm ID: Date:

Name:

Phone: Email:

Excess litter to CAWW

Litter: ton Compost: ton

Available Land Application from O-D matrix analysis

	Rank	Field ID	Distance (miles)	Field Area (ha)	Spreadable Area (ha)	Compost Need (ton)	Litter Need (ton)	Applicable Compost (ton)	Applicable Litter
01	1	1922	< 1	0,0616	0,0056	0,0198	0,0180	0,0198	
02	2	1998	< 1	6,8743	5,4300	19,1676	17,4251	19,1676	
03	3	2028	< 1	0,0616	0,0056	0,0198	0,0180	0,0198	
04	4	2051	< 1	0,0616	0,0056	0,0198	0,0180	0,0198	
05	5	2098	< 1	0,0616	0,0056	0,0198	0,0180	0,0198	

Results of optimal Land Application

	Field ID	Applied Compost (ton)	Applied Litter (ton)	Excess Compost (ton)	Excess Litter (ton)	Applied Cost (\$)	Litter Cost (\$)
01	1922	0,0198	0	67,66	712,50	0,2	
02	1998	19,1676	0	48,49	712,50	191,7	
03	2028	0,0198	0	48,47	712,50	0,2	
04	2051	0,0198	0	48,45	712,50	0,2	
05	2098	0,0198	0	48,43	712,50	0,2	

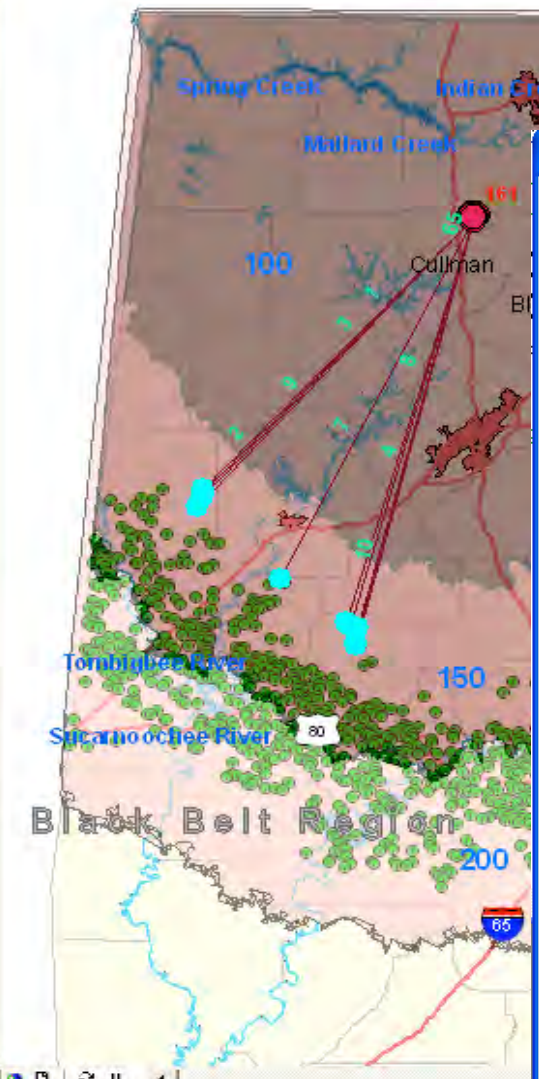
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CNMP Assessment Module

Offsite Application-Black Belt Region

- Layers**
- OD Cost Matrix
 - Service Area 2
 - Cal_Buffer_Area_FeatureToPoi
 - Export_Output_5_Select
 - Export_Output_5
 - al_cm_patures_slp_FeatureToP1
 - rastert_majorit1_FeatureToPoi
 - Black_Belt_Pasturet
 - Cal_Buffer_Area
 - Cal_area_1500_Select_Buffer1
 - Cal_area_1500_Select
 - al_cm_patures_slp_Select3_Bu
 - al_cm_patures_slp_Select3
 - area3
 - al_cm_patures_slp_Select1_Bu1
 - al_cm_patures_slp_Select1
 - al_cm_patures_slp
 - Alabama
 - ALHigh



CNMP Assessment - Black_Belt_Region

CAWV

Farm ID Date

Name

Phone Email

Excess litter to CAWV

Litter ton Compost ton

Available Land Application from O-D matrix analysis

	Rank	Field ID	Distance (miles)	Field Area (ha)	Spreadable Area (ha)	Compost Need (ton)	Litter Need (ton)	Applicable Compost (ton)	Applicable Litter
01	1	2469	114,6	144,09	139,83	493,60	440,72	0,00	44
02	2	2482	115,5	225,00	220,45	778,18	694,81	0,00	27
03	3	2490	116,3	144,09	139,83	493,60	440,72	0,00	0
04	4	2527	117,3	154,05	149,77	528,67	472,02	0,00	0
05	5	2715	119,0	154,05	149,77	528,67	472,02	0,00	0

Results of optimal Land Application

	Field ID	Applied Compost (ton)	Applied Litter (ton)	Excess Compost (ton)	Excess Litter (ton)	Applied Cost (\$)	Litter Valu (\$)
01	2469	0,00	440,7	46,2	271,8	7576,2	163
02	2482	0,00	271,8	46,2	0,0	4709,0	100
03	2490	0,00	0,00	46,2	0,0	0,0	
04	2527	0,00	0,00	46,2	0,0	0,0	
05	2715	0,00	0,00	46,2	0,0	0,0	

Poultry Litter Database Management System (PLDBMS)

PLDSS - Biosystems Engineering, Auburn University

- ❑ (A): Data Management sub-module for the CNMP data record form
- ❑ (B): CNMP data record form exported to MS-Excel file format
- ❑ (C): Data Search sub-module in the PLDBMS



Benefits



- **Appropriate application of PLDSS will**
 - ❖ **Protect water quality in the Appalachian Plateau region**
 - ❖ **Minimize transportation costs**
 - ❖ **Improve soil fertility in the Black Belt region**
 - ❖ **Help AFO operators and farmers to develop CNMP and distribute excess litter**
 - ❖ **Result in increased utilization of CNMP/P-Index**

=> Hence, this study will help alleviate water quality problems in the Appalachian Plateau region and poor soil fertility problems in the Black Belt region



Benefits



□ Facilitating other interesting analyses

- ❖ Bioenergy plant that utilizes poultry litter can be optimally located in the concentrated poultry production area
- ❖ Provide a database (spatial and temporal) of litter application to pastures, hay fields, and cropland fields
- ❖ Will help evaluate the watershed level water quality protection provided by P-index
- ❖ Will help truly quantify watershed-level water quality impact (nutrient, pathogens, etc.) of long-term animal waste application



Parting Thoughts



- ❑ P-Index needs to be improved using hydrologic and nutrient transport process operating in a particular area
- ❑ Poultry (broiler) litter needs to be transported from concentrated production areas for
 - ❑ Water quality protection
 - ❑ Nutrient management
 - ❑ Bioenergy production
- ❑ A better communication through web-based system is needed
- ❑ We need to allow CAWVs and AFO operators to handle their own NMP
- ❑ Litter transportation costs needs to be optimized for litter transportation to work