

# Tools for Assessing Land Use Impacts on Water Quality:

*ISAT and N-SPECT*



**Jamie Carter**  
**NOAA Coastal Services Center**  
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# Outline

- Introduction
- Tool Descriptions
  - Impervious Surface Analysis Tool (ISAT)
  - Nonpoint-Source Pollution and Erosion Comparison Tool (N-SPECT)
- Example application
- Future Directions
- Resources/Contacts



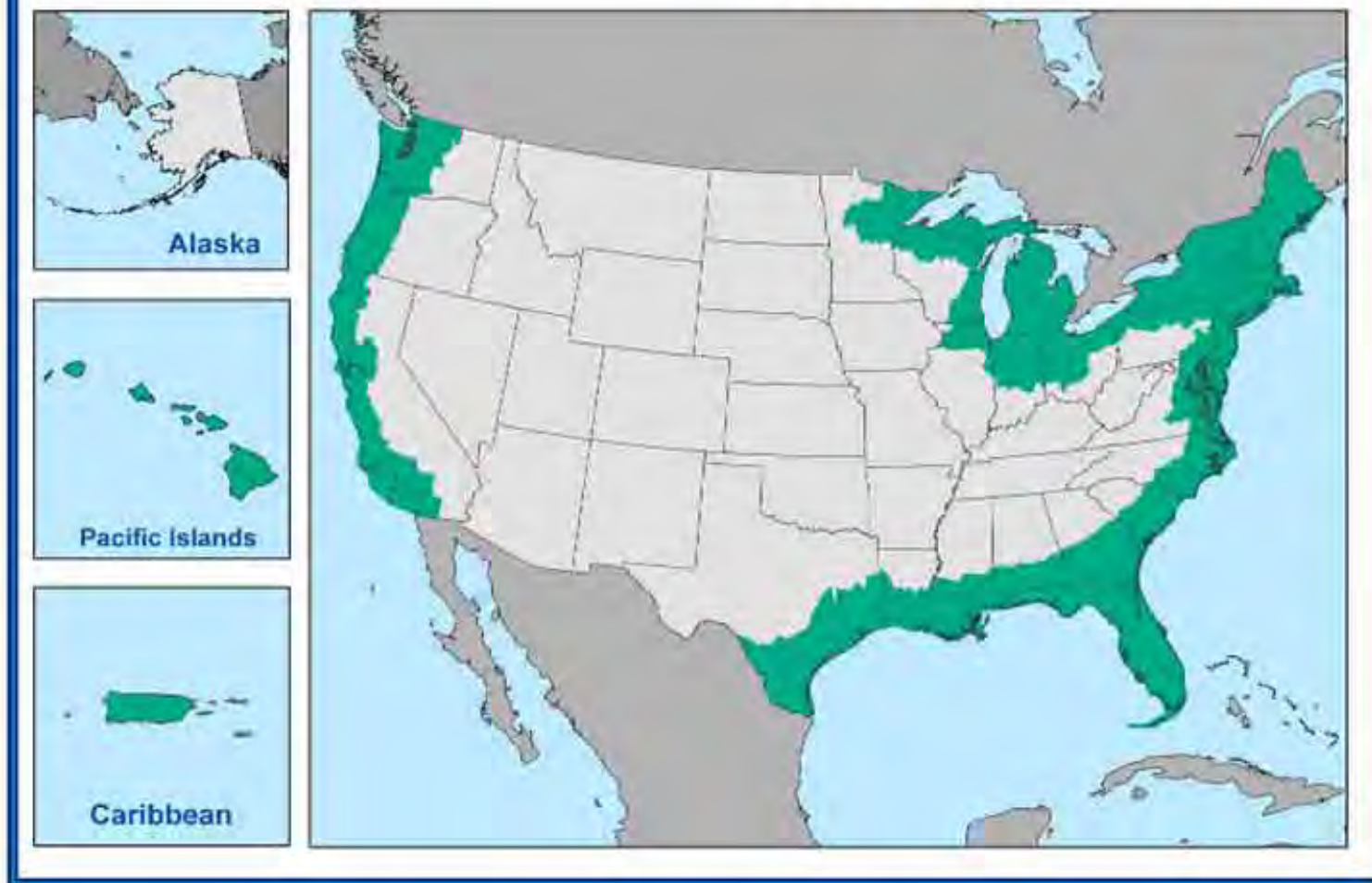
# NOAA Coastal Services Center

- Serving coastal resource managers
  - Data, tools, and information
  - Geographic information systems (GIS)
  - Remote sensing
  - Training
  - Social science / human dimensions
- “Watershed” focus areas
  - Conservation and restoration planning
  - Recreation and tourism planning
  - Alternative land use planning



# NOAA Coastal Services Center

## Where We Work



# CSC Tool Development

- Decision support tools
  - GOAL: to provide managers with more information
- Partnerships
  - Local, state, federal agencies
  - Networks, watershed and land trust groups, industry





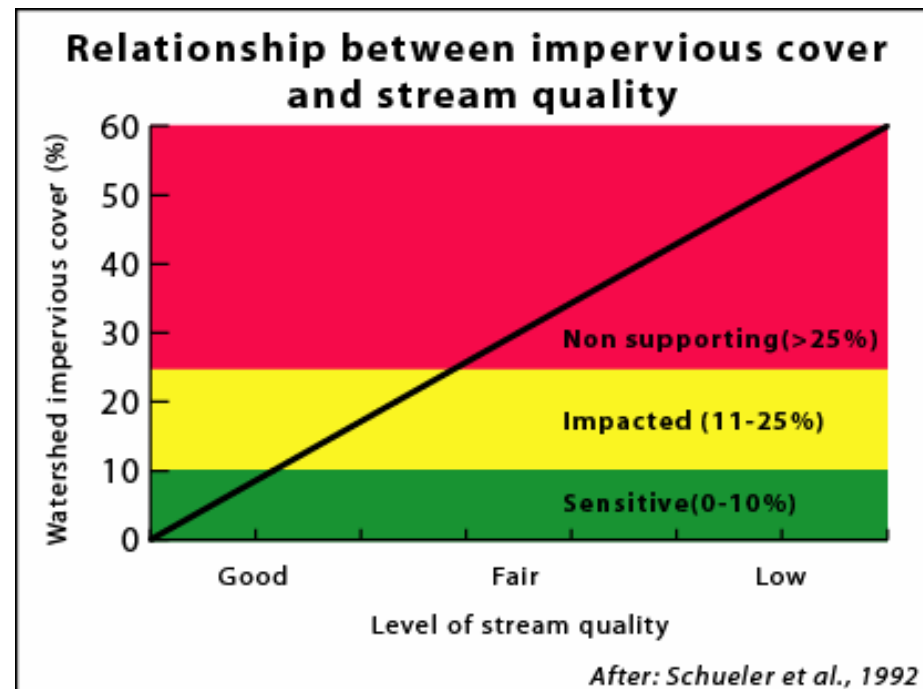
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# Introduction to ISAT

# ISAT

## *Impervious Surface Analysis Tool*

- Impervious surfaces prevent infiltration, increase runoff quantity and intensity, and increase sediment and pollutant loads to water bodies.



# Background

- Goal: To improve managers' ability to use remotely sensed land cover data to evaluate water quality.
- Three main activities:
  - Develop impervious surface tool
  - Test the tool
  - Test impervious surface vs. water quality relationship
- Partners:
  - University of Connecticut
  - NOAA Coastal Services Center (CSC)
  - Connecticut NEMO
  - New Jersey DEP





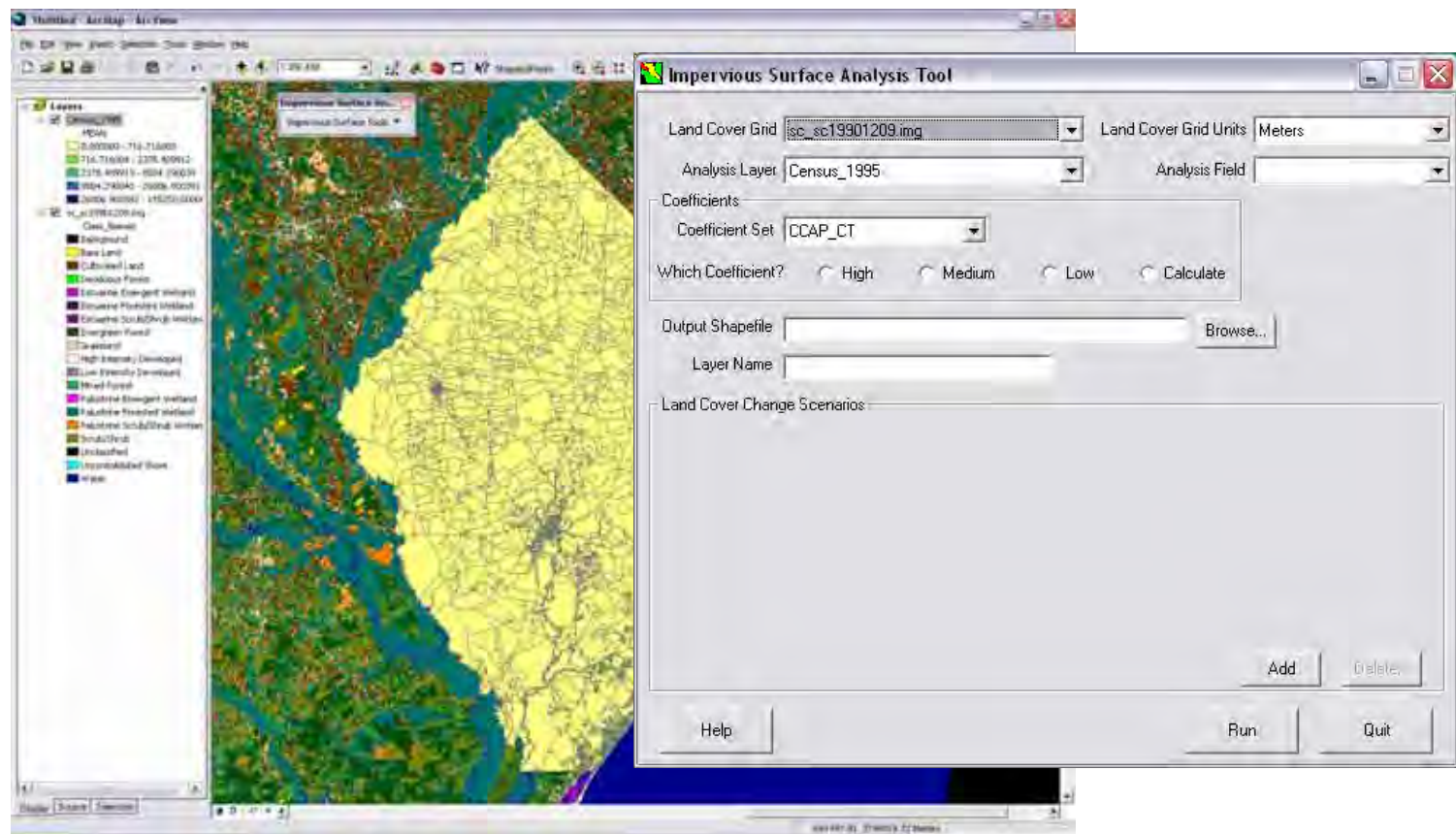
# Description

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- ISAT *estimates* the percentage of a given area covered by impervious surfaces
- Amount of impervious area varies by land cover type
- Population density influences amount of impervious area within each land cover type
- Impervious surface areas can be recalculated for different land cover and land use *scenarios*

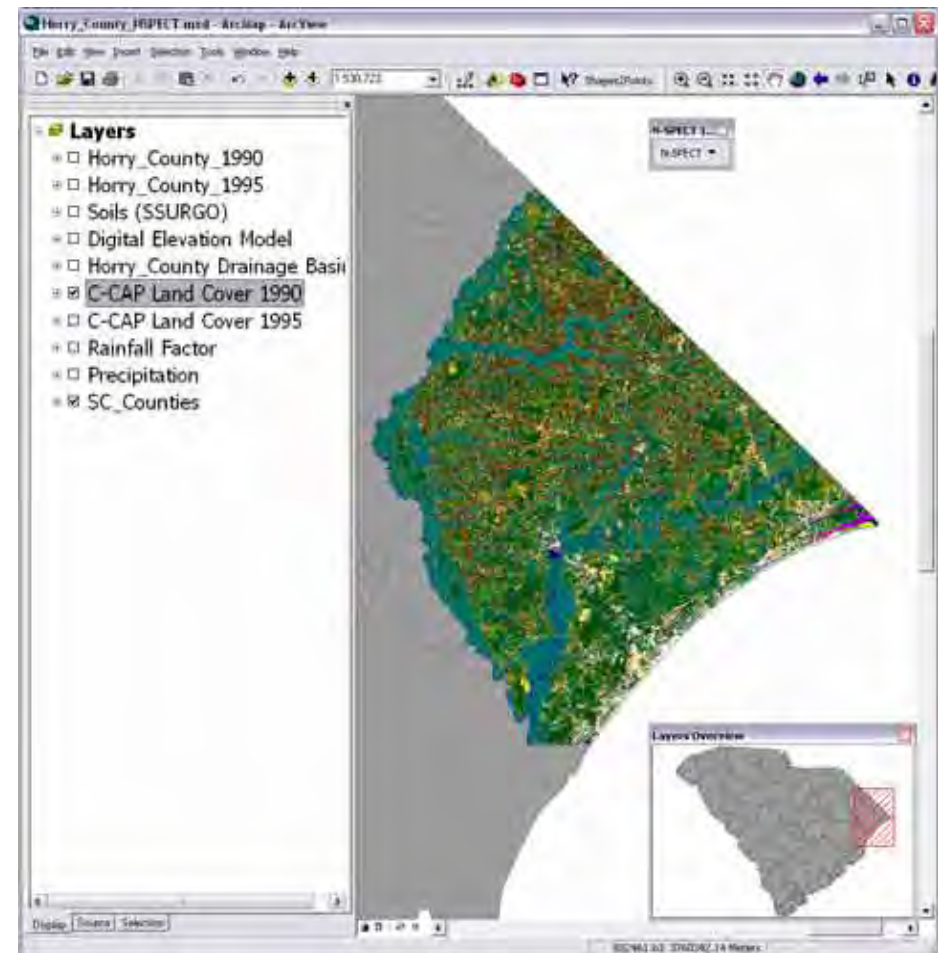
# Description

- Simple *graphical user interface* within ArcView 3.x and ArcGIS 8.x/9.x (Spatial Analyst required)



# Data Needs

- Available nationally:
  - Land cover
  - Population density
  - Analysis units
- Obtained locally:
  - Impervious surface coefficients
    - New Jersey
    - Connecticut
    - Sacramento, CA
    - Berkeley-Charleston-Dorchester Council of Governments (BCD COG)





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# Introduction to N-SPECT

# N-SPECT

## *Nonpoint-Source Pollution and Erosion Comparison Tool*

- The amount and type of nonpoint-source pollution can be related to the land cover from which the runoff occurred.
- N-SPECT calculates storm runoff, eroded sediment, and pollutant loads, and tracks these loads as they accumulate downstream.



# Background

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- Audience:
  - Coastal resource managers
  - Land-use planners
  - Educators
- Partners:
  - Hawaii's resource management community
  - Hawaii Coastal Zone Management Program (CZM)
  - NOAA Coastal Services Center (CSC)
  - NOAA Pacific Services Center (PSC)



# Background

- Hawaii's managers needed a simple, fast screening tool
- Initially applied in Wai'anae region on Oahu
  - Current pressure from residential development
  - Sensitive coastal habitats
  - Watershed management
- Component of the Center's landscape characterization in Hawaii (Wai'anae Ecological Characterization)



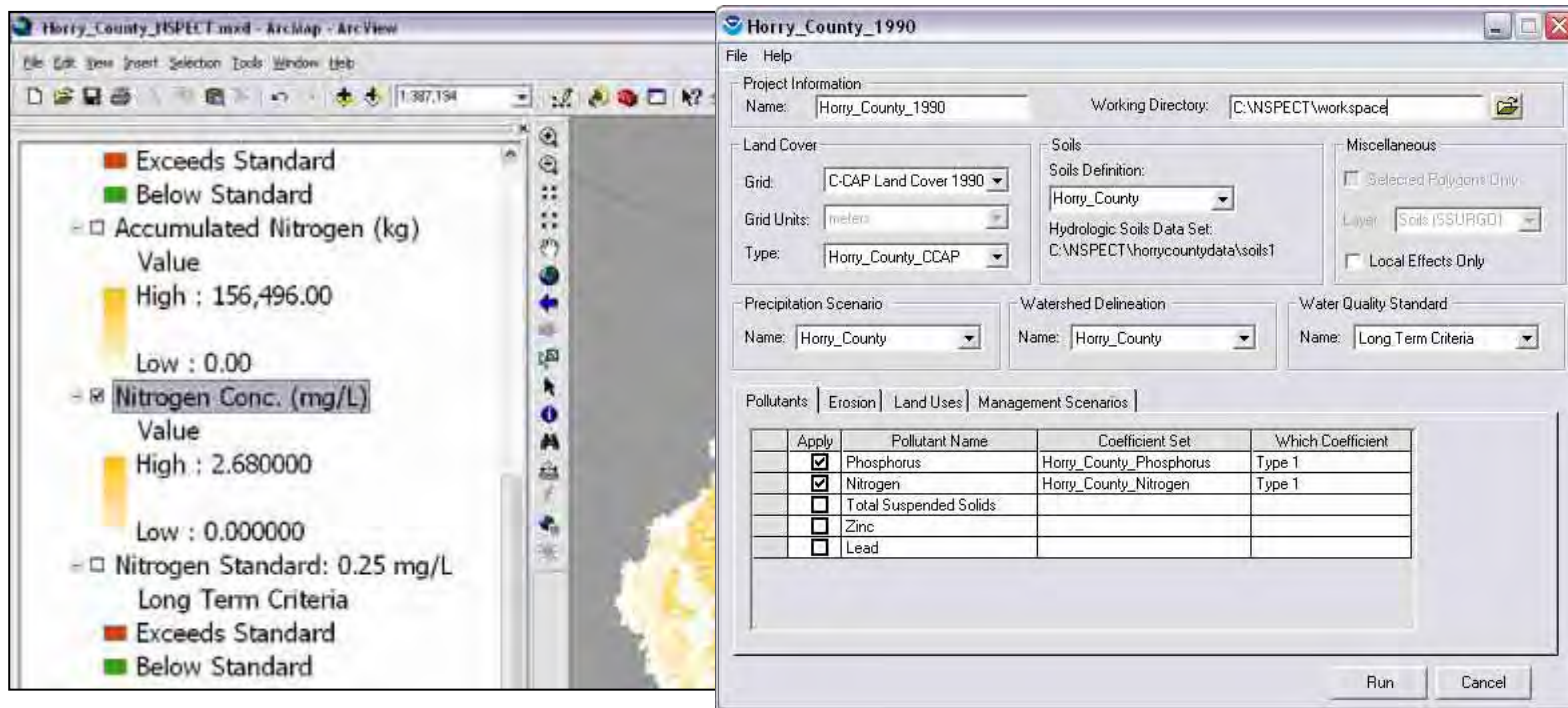
# Description

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- Water quality *screening* tool
- Provides conservative (worst case) estimates of storm runoff, nutrient loads, and sediment loads
- Allows comparisons of different land cover and land use *scenarios*
- Can answer: “How will a certain land use change affect runoff, sediment, and pollutant loads?”

# Description

- *Spatially distributed* (raster-based) pollutant and sediment yield model
- Simple *graphical user interface* within ArcGIS 8.x/9.x (Spatial Analyst required)



# Algorithms

- Rainfall-runoff model
  - SCS curve number (CN) technique
- Pollutant model
  - Event mean concentration values (EMCs)
- Sediment yield model
  - Universal Soil Loss Equation (USLE)
    - Modified (MUSLE)
    - Revised (RUSLE)
  - Sediment delivery ratio



	EVENT	ANNUAL
RUNOFF MODEL	SCS RUNOFF CURVE NUMBER	MODIFIED SCS CURVE NUMBER
EROSION MODEL	MUSLE	RUSLE
NONPOINT-SOURCE MODEL	EVENT MEAN CONCENTRATION	EVENT MEAN CONCENTRATION

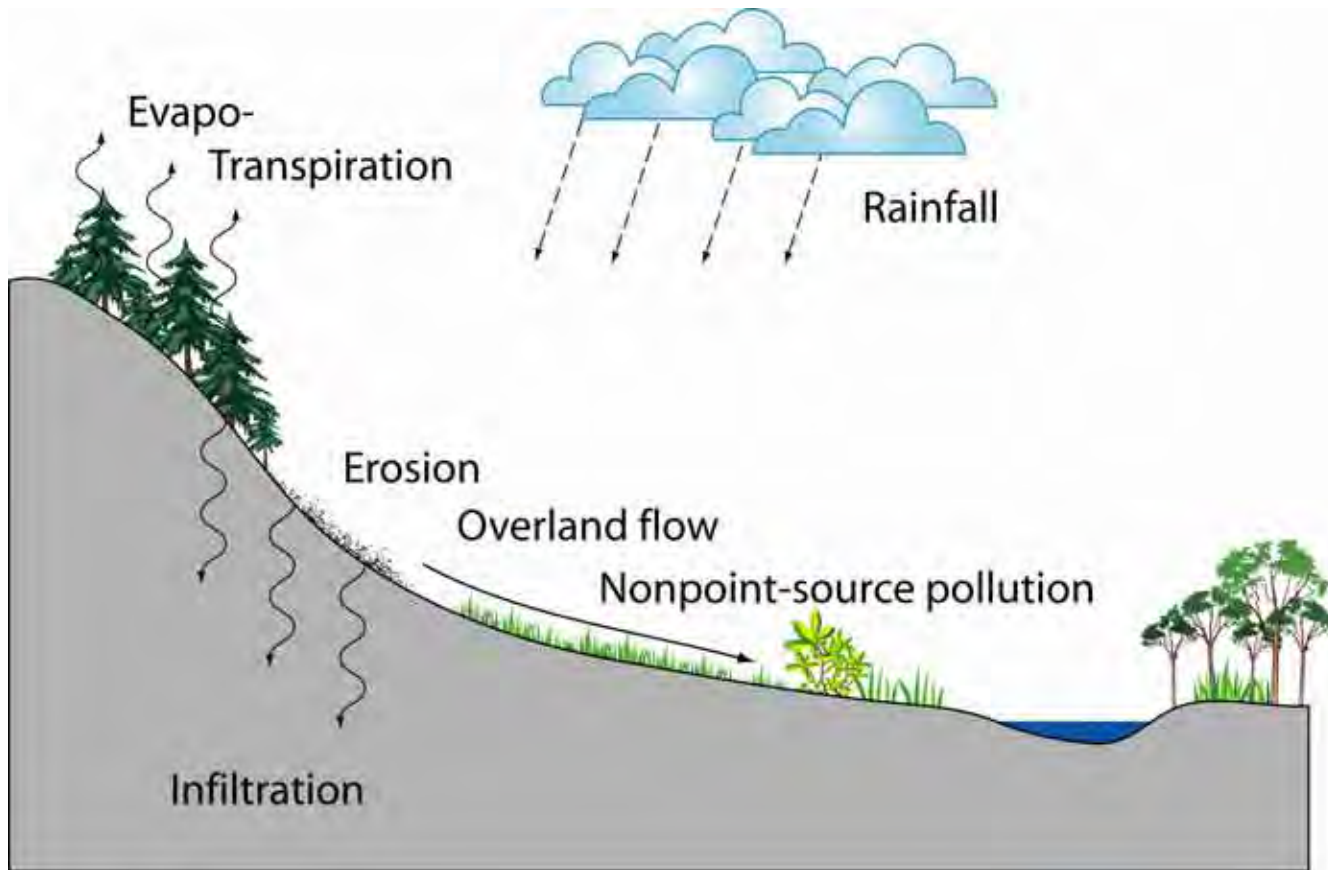
# Assumptions / Limitations

- Omitted processes:
  - Atmospheric deposition
  - Groundwater processes
  - Snow melt
  - Landslides
- No time-step support for:
  - Runoff dynamics
  - Sediment redeposition
  - Pollutant biogeochemistry

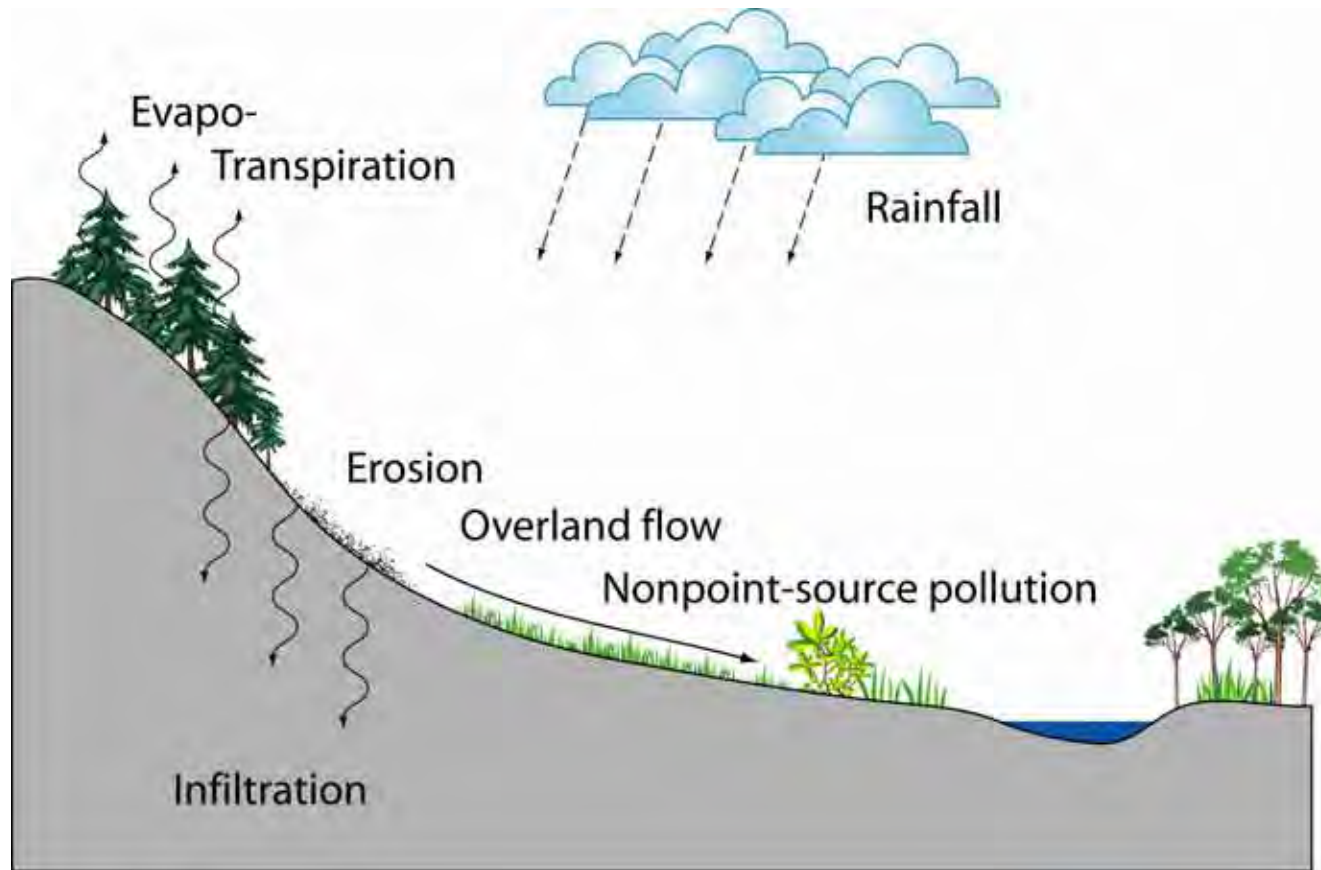


Source: NASA Earth Science Enterprise

# Physical Processes

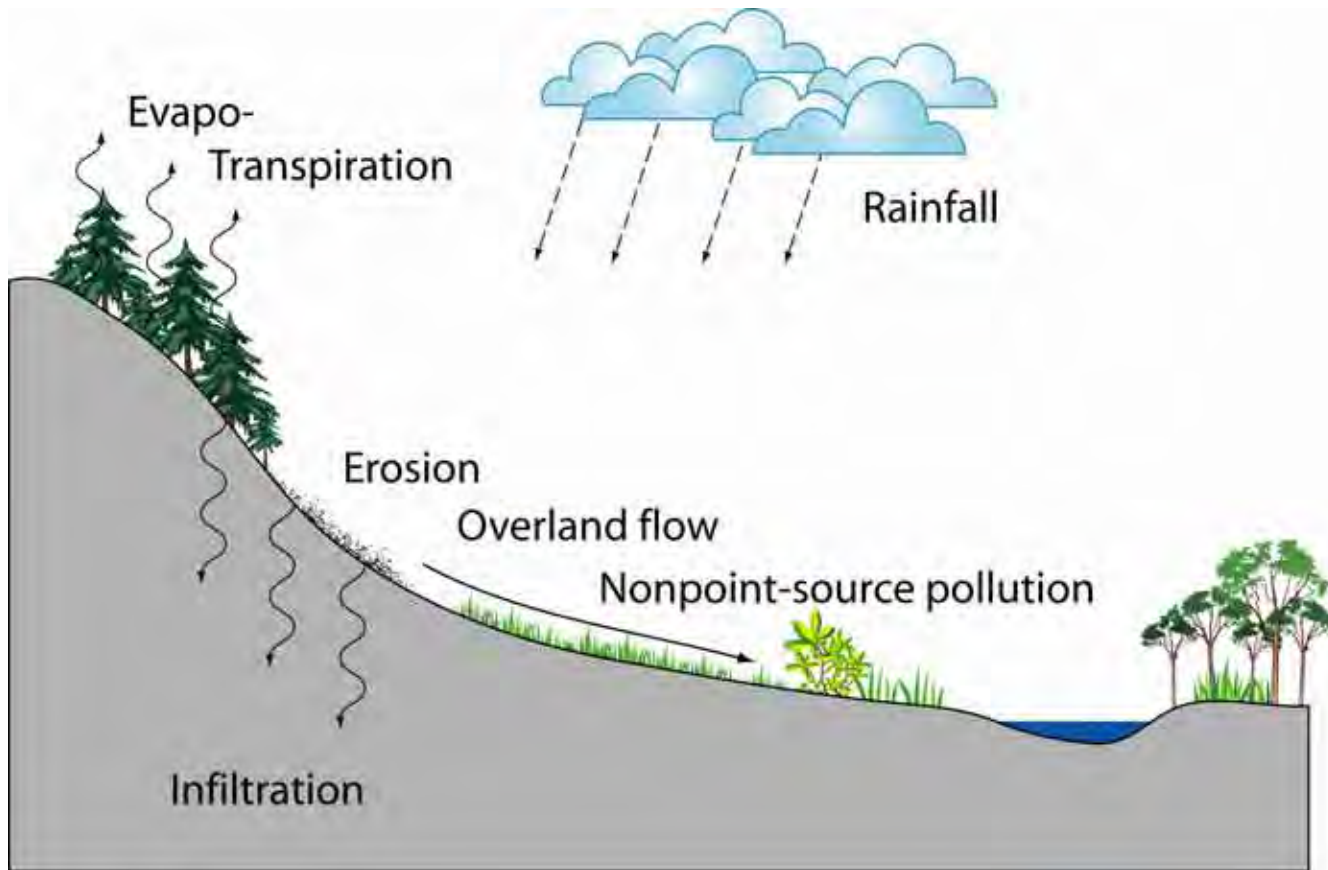


# Physical Processes



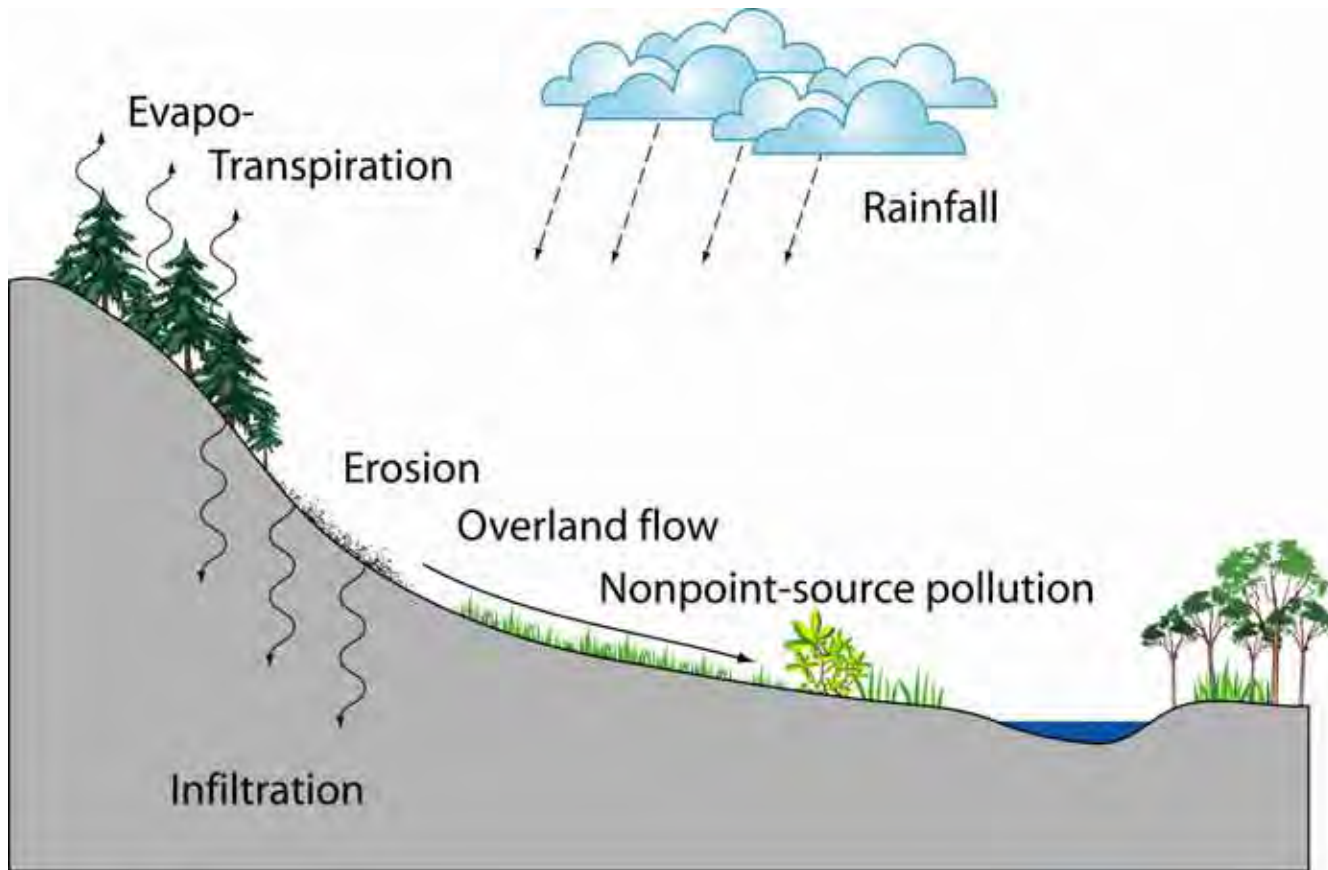
Topography determines flow direction and slope

# Physical Processes



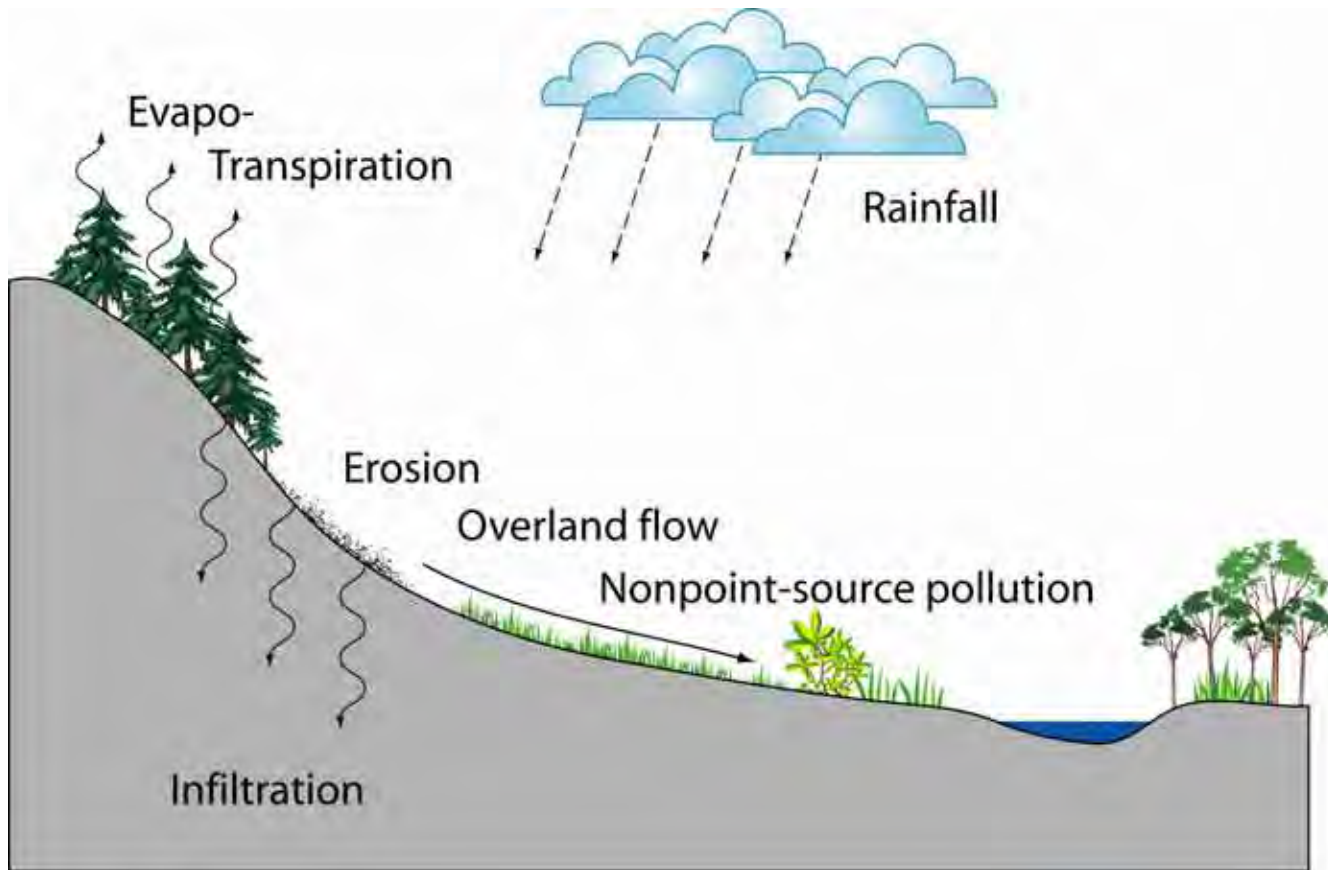
Soil characteristics, land cover, and precipitation determine runoff

# Physical Processes



Runoff, land cover, and pollutant coefficients determine pollutant loads

# Physical Processes



Climate, topography, soil characteristics, and land cover determine sediment loads

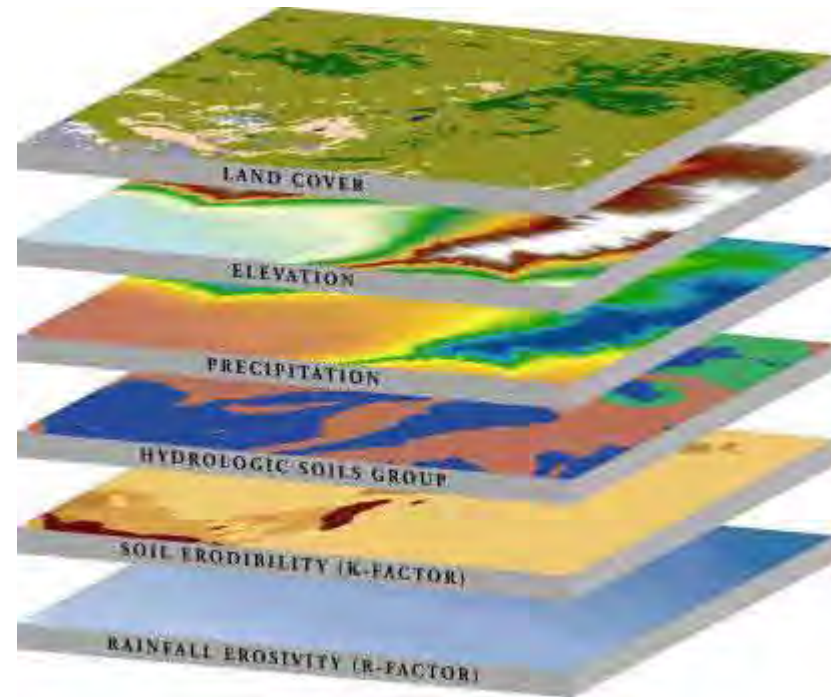


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# N-SPECT Inputs

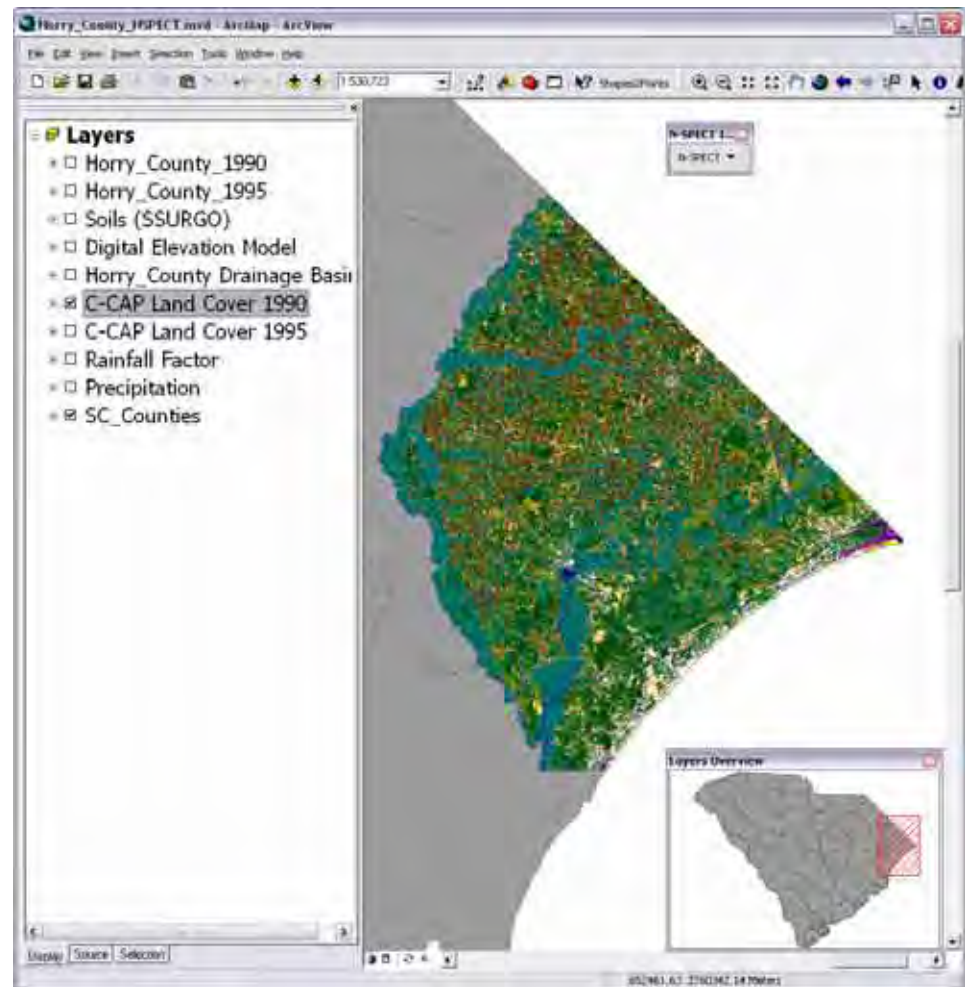
# Data Needs

- Available nationally:
  - Land cover
  - Topography
  - Soils
  - Precipitation
- Obtained locally:
  - Rainfall erosivity (R-factor)
  - Pollutant coefficients
  - Water quality standards



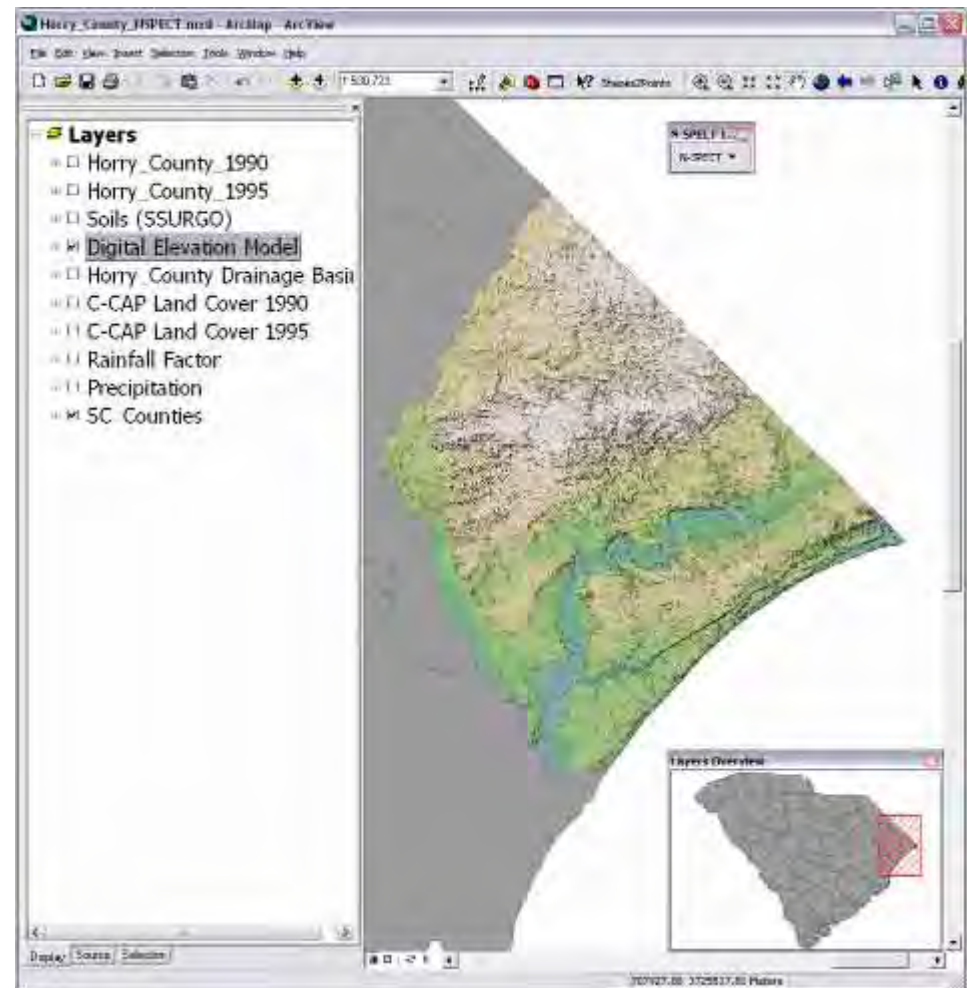
# Land Cover

- Foundation for runoff quantity, sediment yield, pollutant yield
- Default:
  - Coastal Change Analysis Program (C-CAP)
  - 30 m resolution
- Flexible
  - Can easily substitute any land cover grid



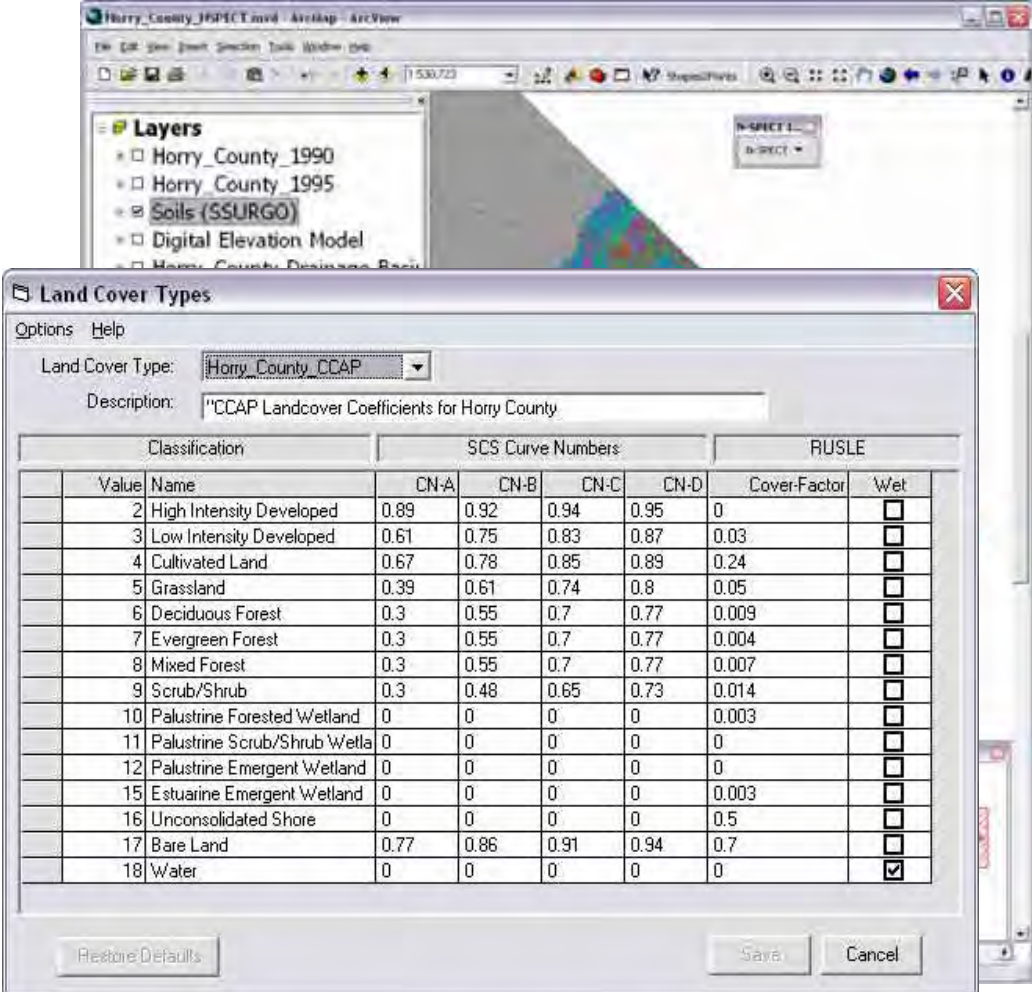
# Topography

- Defines flow direction, slope, stream networks, watersheds
- Default:
  - U.S. Geological Survey (USGS) 30 m resolution digital elevation model
- Resolution impacts processing speed and file size



# Soils

- Used in runoff and erosion calculations
- Default:
  - SSURGO soils<sup>†</sup>
  - County level resolution
- Hydrologic group
  - Infiltration rate
- K-factor
  - Soil erodibility



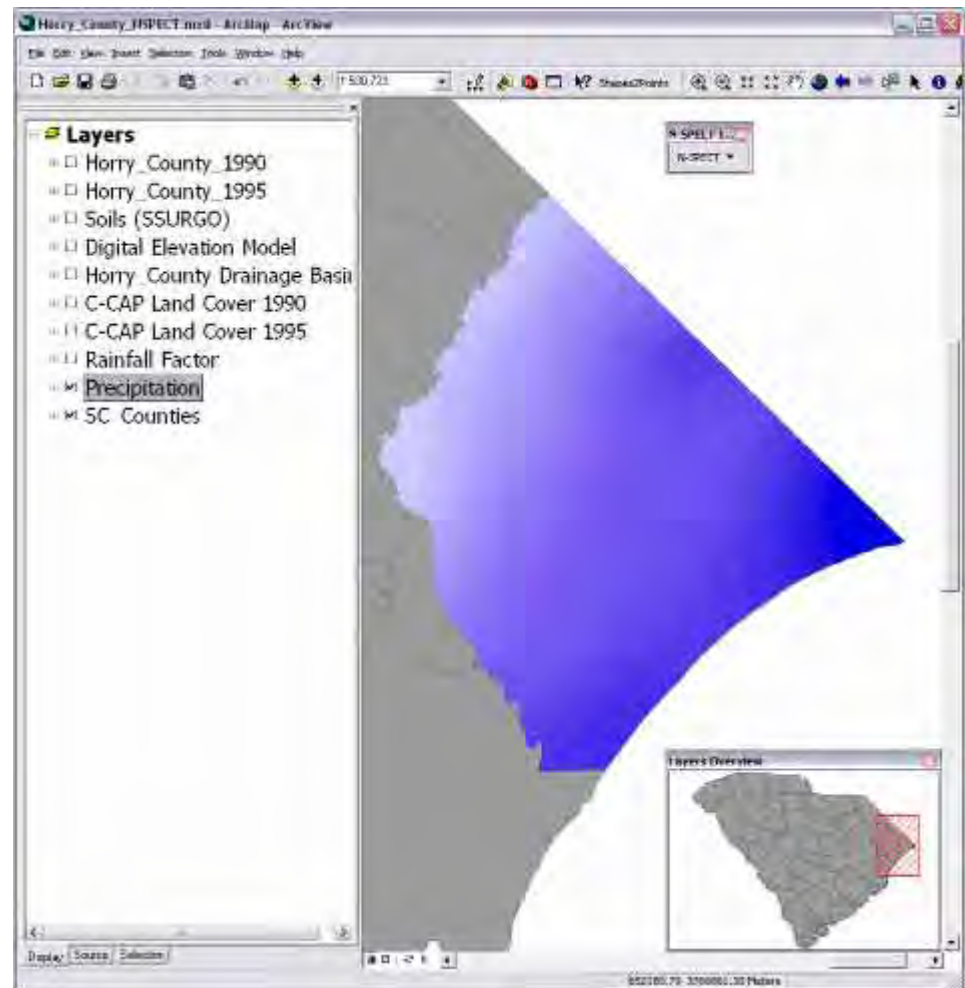
The screenshot shows the ArcView interface with a map of Horry County. The 'Layers' panel on the left lists 'Horry County 1990', 'Horry County 1995', 'Soils (SSURGO)', and 'Digital Elevation Model'. The 'Land Cover Types' dialog box is open, showing the 'Horry County CCAP' land cover type selected. The dialog box contains a table with the following data:

Value	Name	SCS Curve Numbers				RUSLE	
		CN-A	CN-B	CN-C	CN-D	Cover-Factor	Wet
2	High Intensity Developed	0.89	0.92	0.94	0.95	0	<input type="checkbox"/>
3	Low Intensity Developed	0.61	0.75	0.83	0.87	0.03	<input type="checkbox"/>
4	Cultivated Land	0.67	0.78	0.85	0.89	0.24	<input type="checkbox"/>
5	Grassland	0.39	0.61	0.74	0.8	0.05	<input type="checkbox"/>
6	Deciduous Forest	0.3	0.55	0.7	0.77	0.009	<input type="checkbox"/>
7	Evergreen Forest	0.3	0.55	0.7	0.77	0.004	<input type="checkbox"/>
8	Mixed Forest	0.3	0.55	0.7	0.77	0.007	<input type="checkbox"/>
9	Scrub/Shrub	0.3	0.48	0.65	0.73	0.014	<input type="checkbox"/>
10	Palustrine Forested Wetland	0	0	0	0	0.003	<input type="checkbox"/>
11	Palustrine Scrub/Shrub Wetla	0	0	0	0	0	<input type="checkbox"/>
12	Palustrine Emergent Wetland	0	0	0	0	0	<input type="checkbox"/>
15	Estuarine Emergent Wetland	0	0	0	0	0.003	<input type="checkbox"/>
16	Unconsolidated Shore	0	0	0	0	0.5	<input type="checkbox"/>
17	Bare Land	0.77	0.86	0.91	0.94	0.7	<input type="checkbox"/>
18	Water	0	0	0	0	0	<input checked="" type="checkbox"/>

<sup>†</sup> Soil Survey Geographic Database provided by the Natural Resources Conservation Service

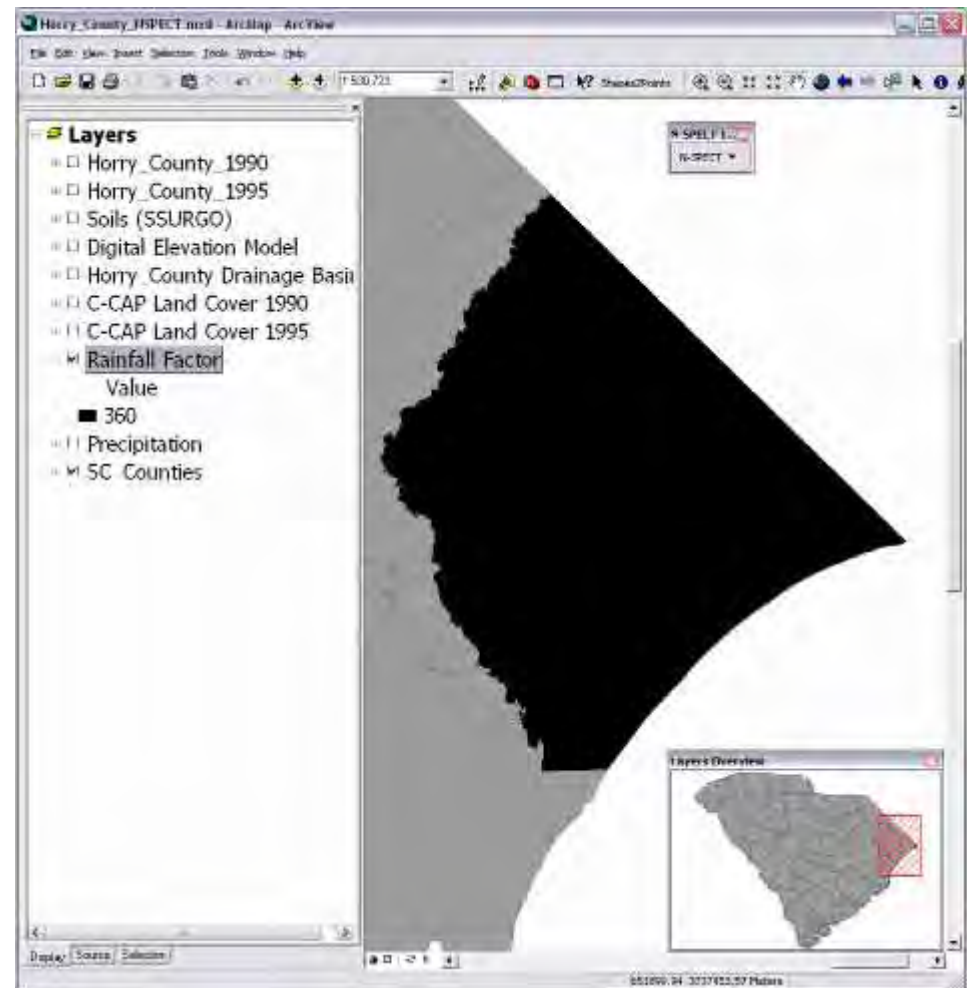
# Precipitation

- Used to calculate runoff
- Annual grids
  - Average annual rainfall
  - “Raining days”
    - Number of days having precipitation greater than a certain threshold
- Event grids
  - Event rainfall



# Rainfall Factor

- Parameter in RUSLE
- Rainfall erosivity index
  - Total storm kinetic energy times the maximum thirty minute intensity
- Can be a constant value or spatially explicit



# Pollutant Coefficients

- Event mean concentrations
- Land cover specific
- User-definable
  - Pollutants
  - Coefficients

The screenshot shows a software window titled 'Pollutants' with a menu bar (Pollutants, Coefficients, Help). The 'Pollutant Name' is set to 'Nitrogen'. The 'Coefficients' section is set to 'Water Quality Standards'. The 'Coefficient Set' is 'Horry County Nitrogen' and the 'Land Cover Type' is empty. The 'Description' field is also empty. Below this is a table with columns for 'Class' and 'Coefficients' (Type1, Type2, Type3, Type4). The 'Type1' column is highlighted with a red box, and an arrow points to it with the text 'EMCs (mg/l)'.

	Class	Coefficients			
	Value Name	Type1	Type2	Type3	Type4
2	High Intensity Developed	1.7	0	0	0
3	Low Intensity Developed	2.68	0	0	0
4	Cultivated Land	2.48	0	0	0
5	Grassland	1.25	0	0	0
6	Deciduous Forest	1.25	0	0	0
7	Evergreen Forest	1.25	0	0	0
8	Mixed Forest	1.25	0	0	0
9	Scrub/Shrub	1.1	0	0	0
10	Palustrine Forested Wetland	1.1	0	0	0
11	Palustrine Scrub/Shrub Wetland	1.1	0	0	0
12	Palustrine Emergent Wetland	1.1	0	0	0
15	Estuarine Emergent Wetland	0.97	0	0	0
16	Unconsolidated Shore	0.97	0	0	0

EMCs (mg/l)

# Water Quality Standards

- User-defined standards
  - Annual or event-specific
  - Regulatory or target
- Pollutant concentrations are compared to standards to assess potential impairment

Water Quality Standards

Options Help

Standard Name: Long Term Criteria

Description: Acute levels (toxics) & levels not to exceed > 10% of the tim

Pollutant	Threshold (ug/l)
Phosphorus	50
Nitrogen	250
Total Suspended Solids	20
Zinc	22
Lead	29

OK Cancel

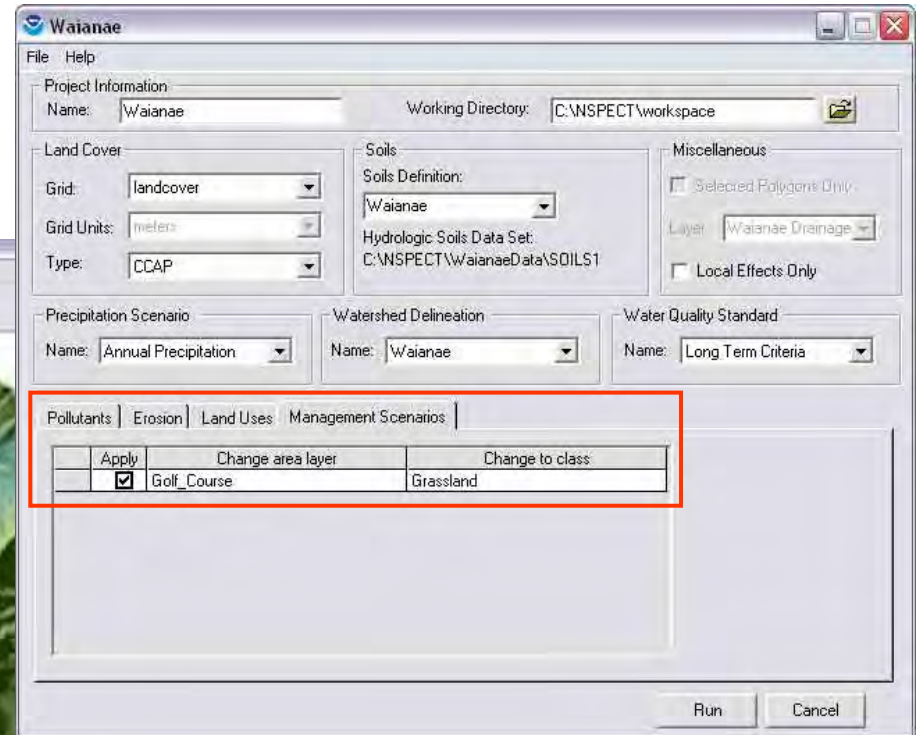
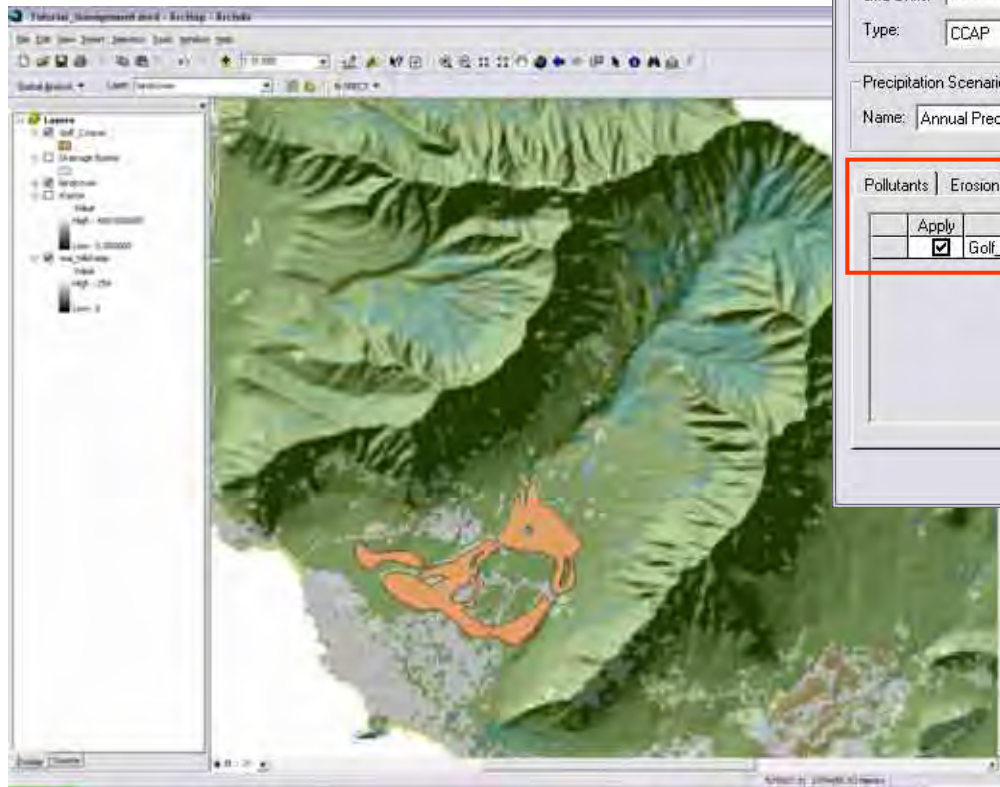


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# Advanced Functionality

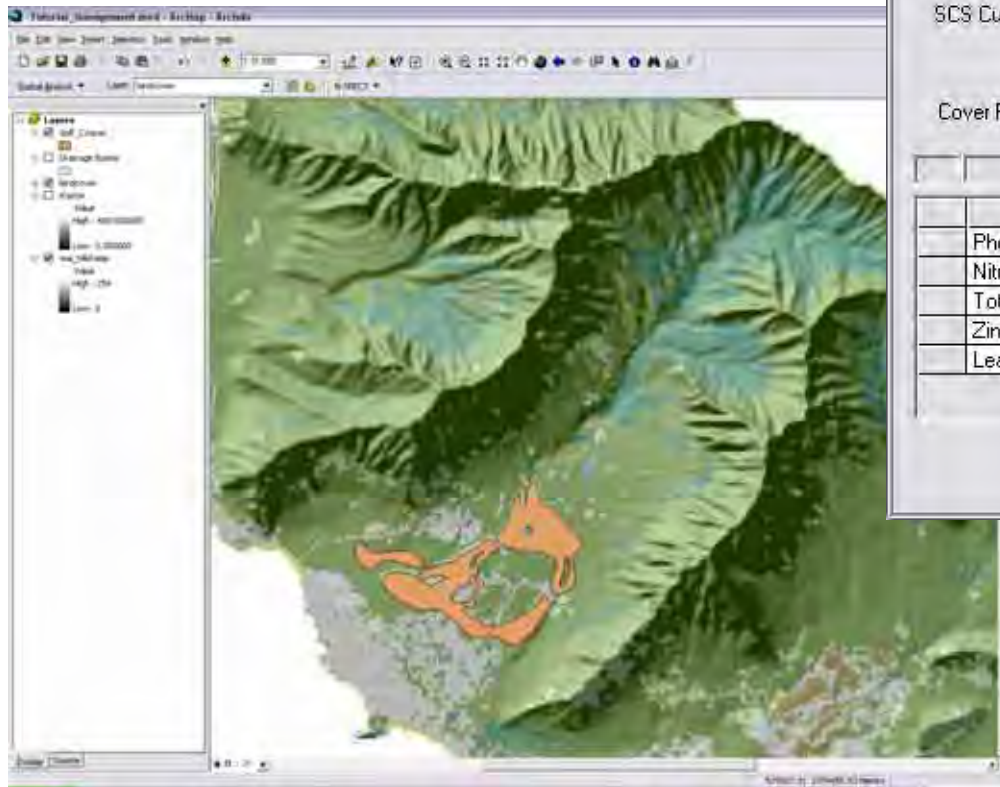
# Scenario Analysis

- Land cover change
  - Polygon delineates area
  - Change to predefined class



# Scenario Analysis

- Land use change
  - Polygon delineates area
  - User-defined parameters



**Add Land Use Scenario**

Scenario Name:

Layer:

Use Selected Polygons Only

SCS Curve Numbers:

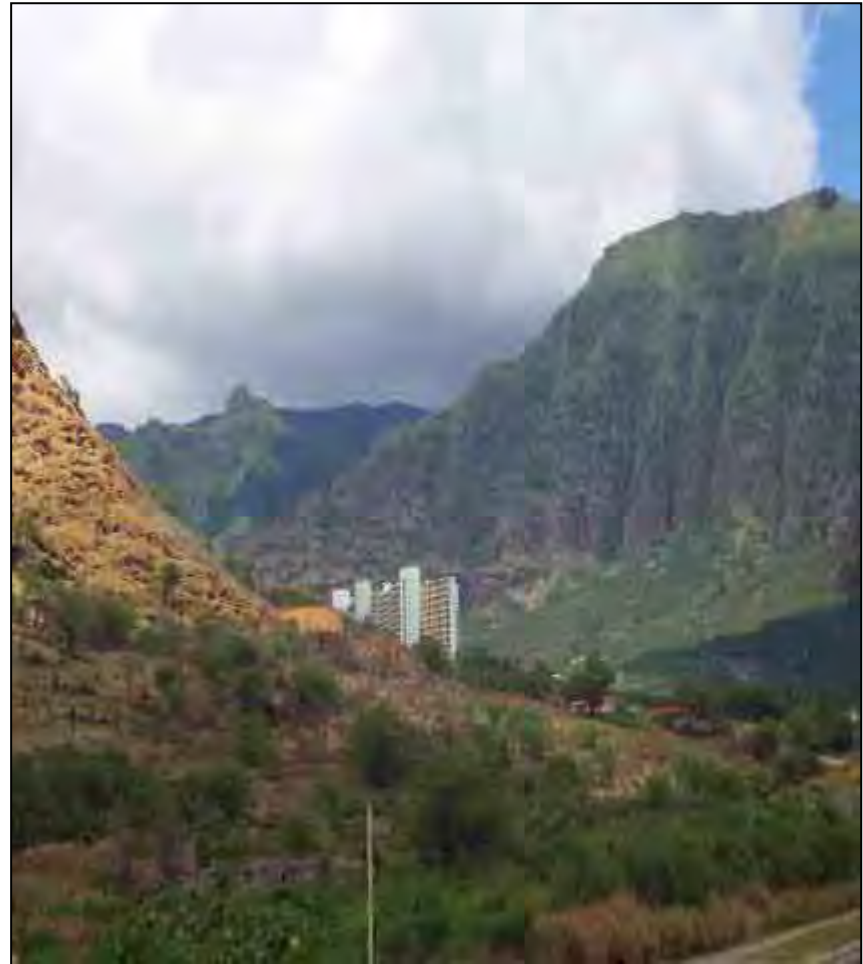
A	B	C	D
0.39	0.61	0.74	0.80

Cover Factor:   Water/Wetlands

Pollutant	Coefficients			
	Type 1	Type 2	Type 3	Type 4
Phosphorus	0.82	0	0	0
Nitrogen	1.01	0	0	0
Total Suspended Solids	150	0	0	0
Zinc	0	0	0	0
Lead	0	0	0	0

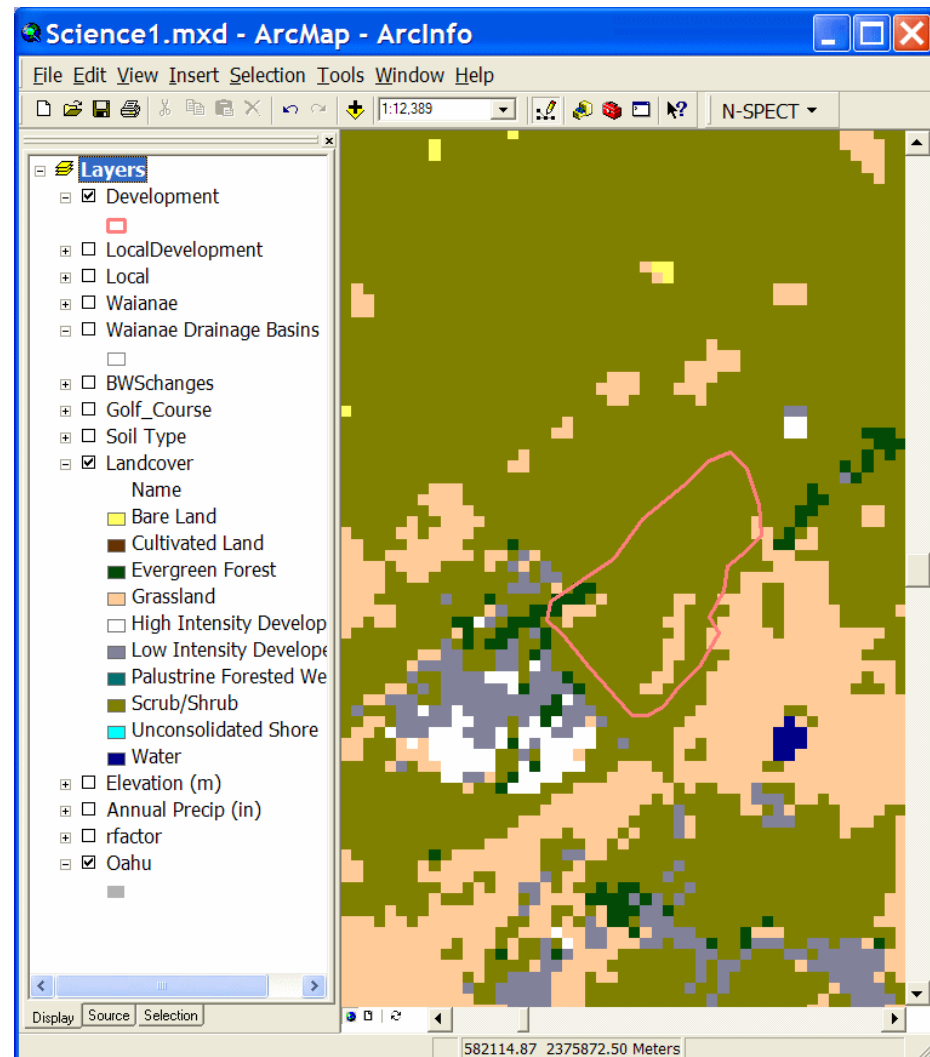
# Scenario Analysis

- Example application
  - Makaha valley, Hawaii
  - Annual time scale
  - “What-if” scenario
    1. Baseline
    2. Land cover change
      - New residential development
    3. Comparison



# Land Cover Change Scenario

- Area outlined in red...
- Currently undeveloped, but zoned residential
- N-SPECT scenario
  - Develop a subdivision
  - Change scrub/shrub vegetation to low intensity development



# Nitrogen (pre-change)

- Baseline
  - Scrub/shrub

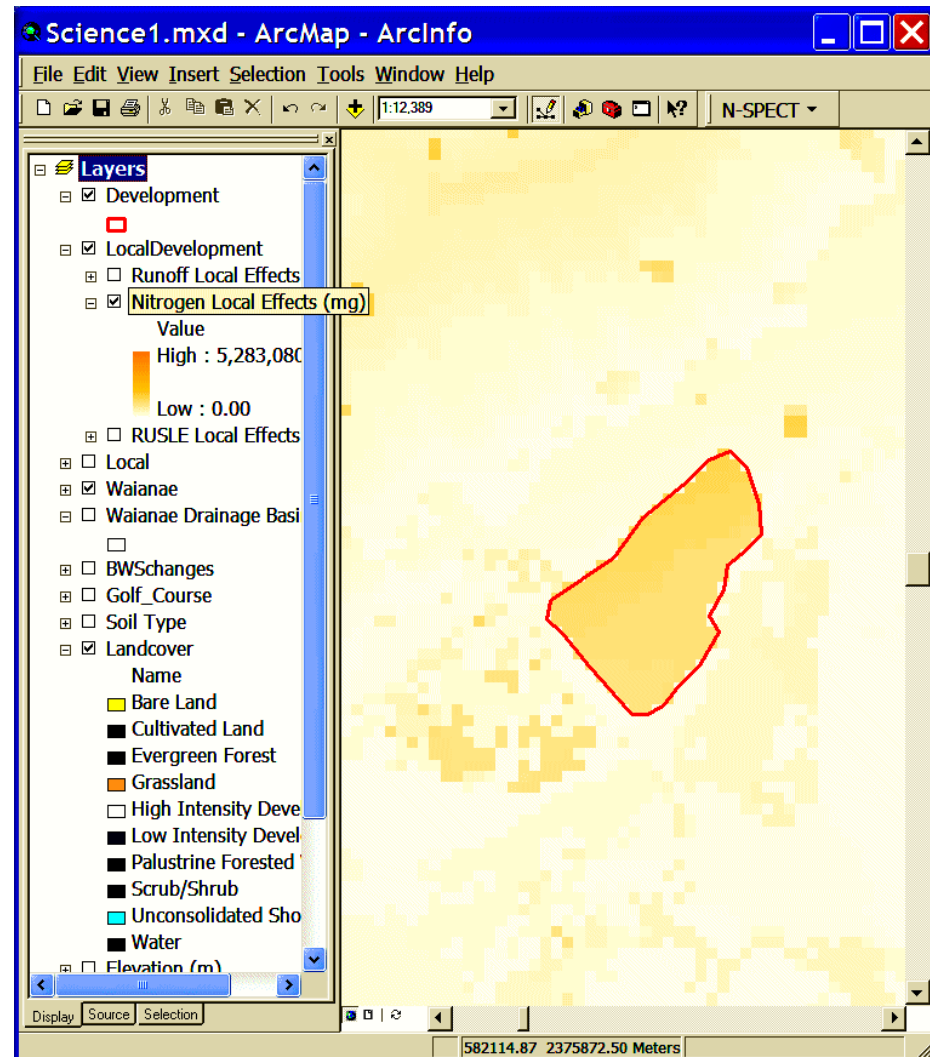
The image shows a screenshot of the ArcMap software interface. The main window displays a map titled 'Science1.mxd' with a legend for 'Nitrogen Local Effects (mg)'. The legend indicates a value range from 0.00 to 5,283,080. The map shows a yellowish area with a red outline. The 'Layers' panel on the left lists several layers, including 'Development', 'LocalDevelopment', 'Local', 'Runoff Local Effects', 'Nitrogen Local Effects (mg)', 'RUSLE Local Effects', 'Waianae', 'Waianae Drainage Basin', 'BWSChanges', 'Golf\_Course', 'Soil Type', 'Landcover', and 'Elevation (m)'. The 'Development' dialog box is open in the foreground, showing project information and various settings. The 'Development' dialog box has the following sections:

- Project Information:** Name: Development, Working Directory: C:\NSPECT\workspace
- Land Cover:** Grid: Landcover, Grid Units: meters, Type: CCAP
- Soils:** Soils Definition: Waianae, Hydrologic Soils Data Set: C:\NSPECT\WaianaeData\SOILS1
- Miscellaneous:** Selected Polygons Only: , Layer: Development, Local Effects Only:
- Precipitation Scenario:** Name: Annual Precipitation
- Watershed Delineation:** Name: Waianae
- Water Quality Standard:** Name: Long Term Criteria
- Pollutants:** Erosion, Land Uses, Management Scenarios
- Table:**

Apply	Change area layer	Change to class
<input checked="" type="checkbox"/>	Development	Low Intensity Developed
- Buttons:** Run, Cancel

# Nitrogen (post-change)

- Land cover change
  - Low intensity residential
- Compare baseline estimate to the estimated load after a change in land cover
- Estimated 138 percent increase in nitrogen load from this area



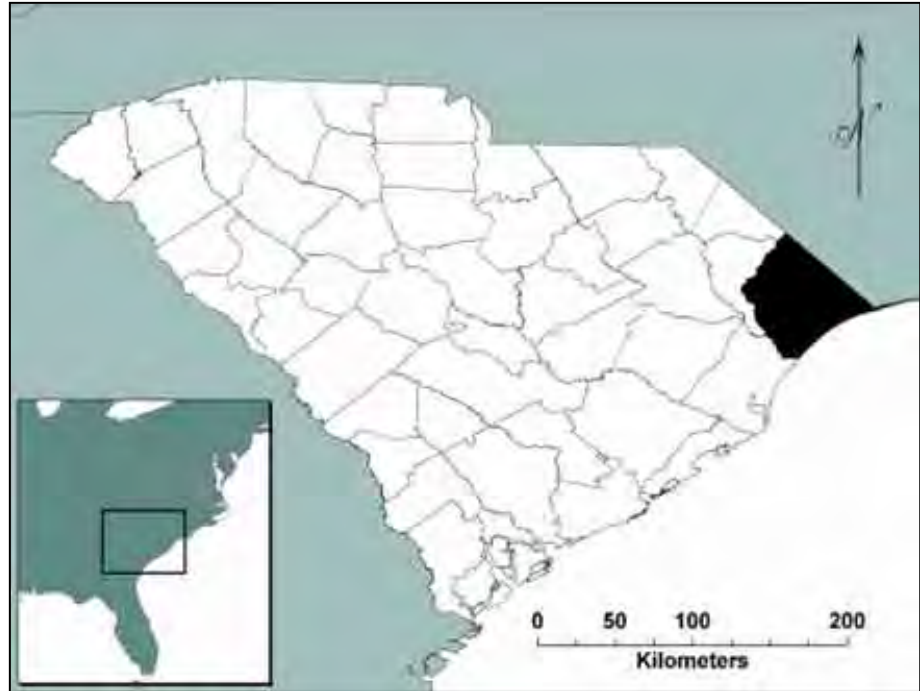


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# Applications of ISAT and N-SPECT

# Horry County Example


- Multi-temporal study with 1990 and 1995 C-CAP land cover data
- Horry County, SC
- ISAT and N-SPECT were both applied



# Land Cover Classification

## *C-CAP*

### *Coastal Change Analysis Program Land Cover Classification*

 Bare Land	 Low Intensity Developed
 Cultivated Land	 Mixed Forest
 Deciduous Forest	 Palustrine Emergent Wetland
 Estuarine Emergent Wetland	 Palustrine Forested Wetland
 Estuarine Forested Wetland	 Palustrine Scrub/Shrub Wetland
 Estuarine Scrub/Shrub Wetland	 Scrub/Shrub
 Evergreen Forest	 Unclassified
 Grassland	 Unconsolidated Shore
 High Intensity Developed	 Water

- Coastal Change Analysis Program (C-CAP) land cover data enables consistent, nationwide, and multi-temporal analyses to be performed

# Data Inputs and Outputs

## *ISAT*

### *Inputs:*

- ☞ Classified landcover (C-CAP)  
1990 and 1995
- ☞ Analysis units (census blocks)
- ☞ Population density (census blocks)  
1990 and ~1995
- ☞ Impervious surface coefficients

### *Output:*

- ☞ % Impervious surface cover

## *N-SPECT*

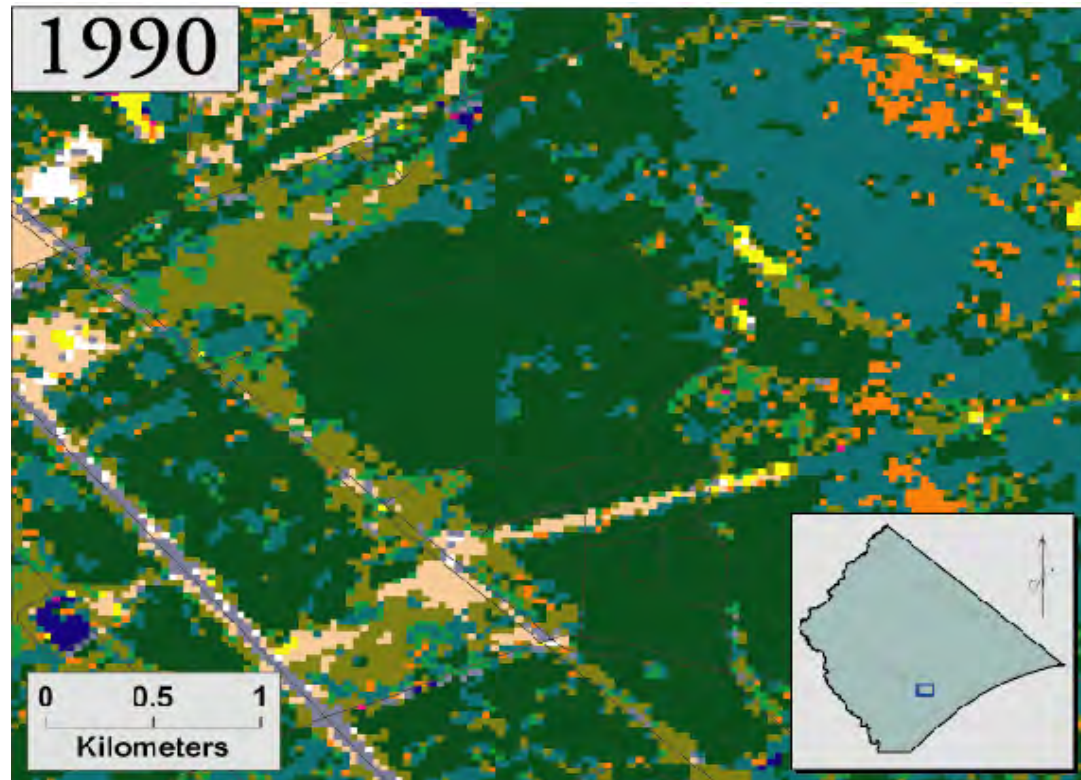
### *Inputs:*

- ☞ Classified land cover (C-CAP)  
1990 and 1995
- ☞ Elevation (U.S. Geological Survey)
- ☞ Soils (Soil Survey Geographic Database)
- ☞ Precipitation (National Weather Service)
- ☞ R-factor (U.S. Department of Agriculture)
- ☞ Pollutant coefficients

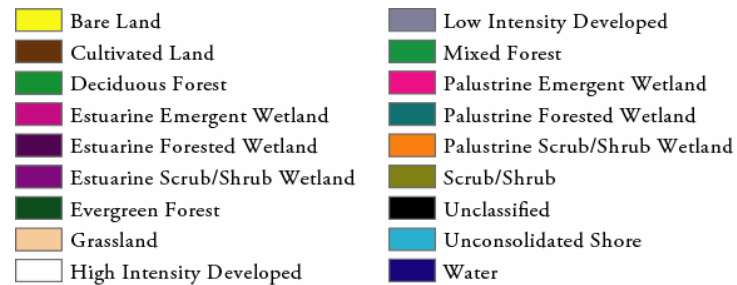
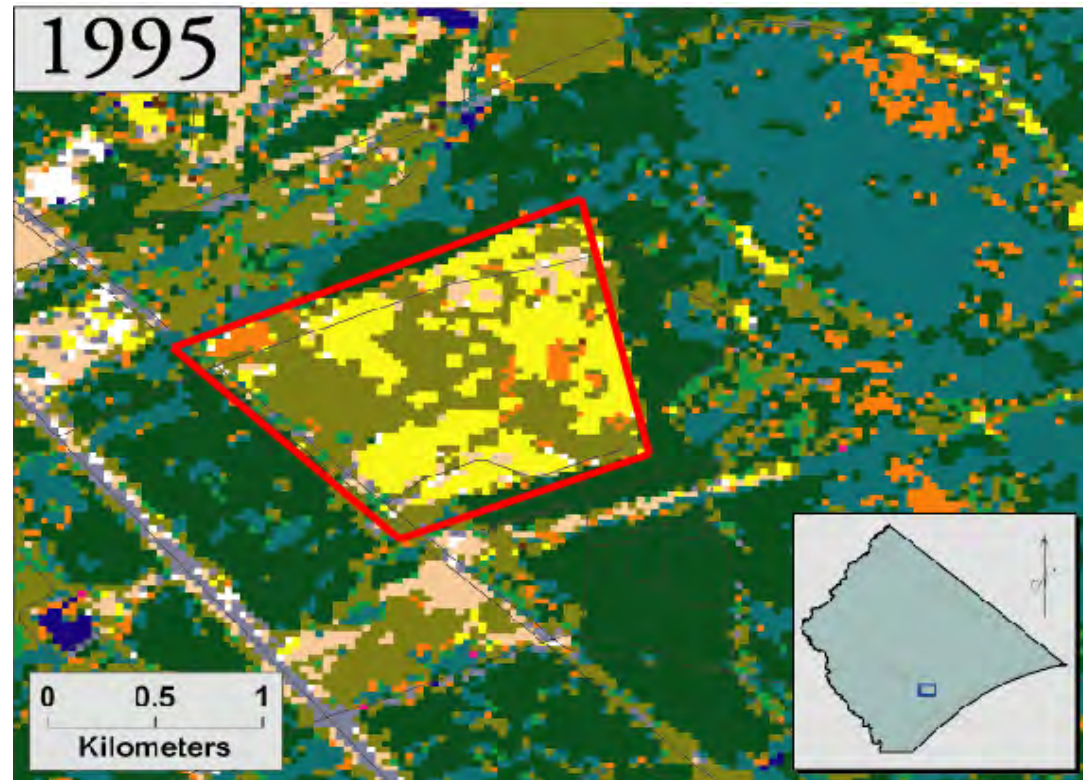
### *Outputs:*

- ☞ Runoff volume
- ☞ Accumulated pollutants
- ☞ Pollutant concentrations
- ☞ Accumulated sediment
- ☞ Sediment concentration
- ☞ Pollutant comparisons to  
water quality standards

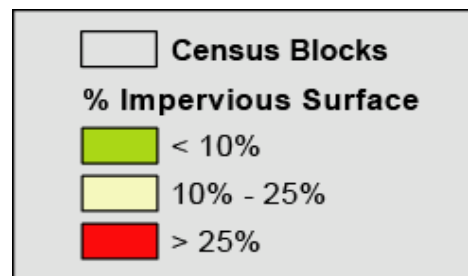
# C-CAP – 1990



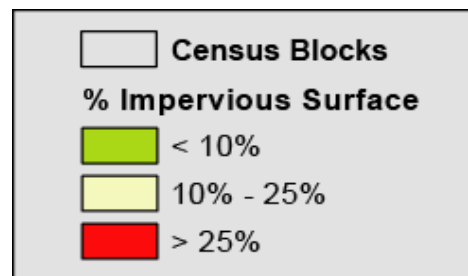
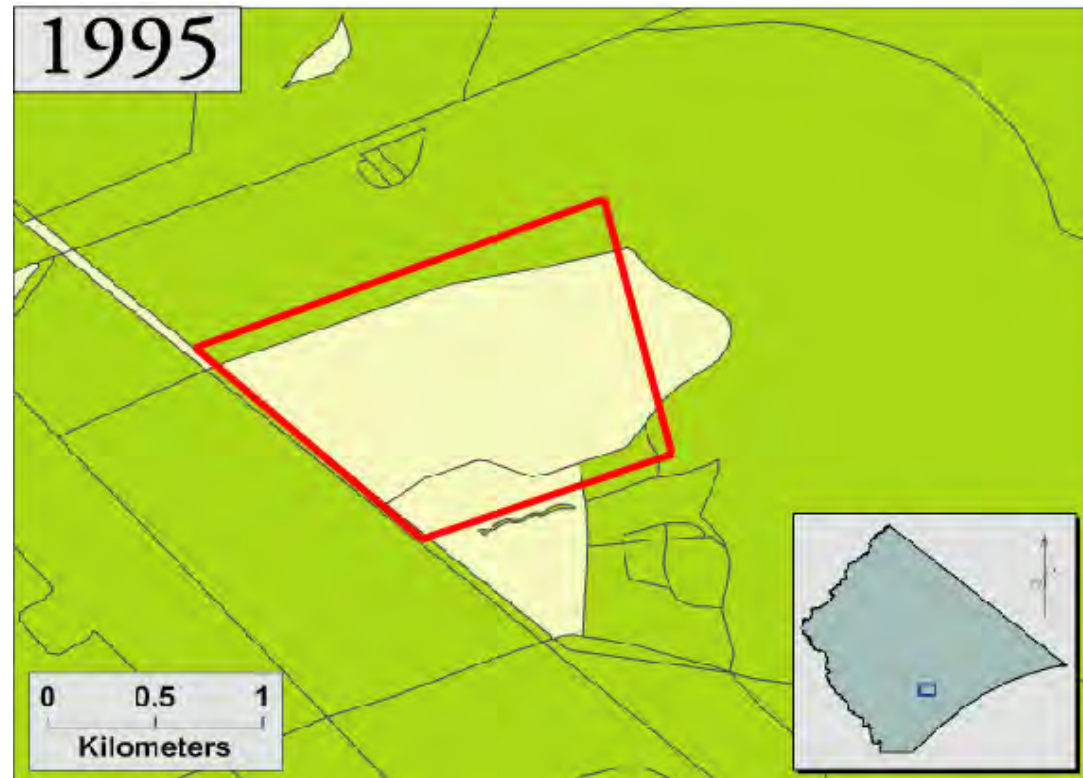
# C-CAP – 1995



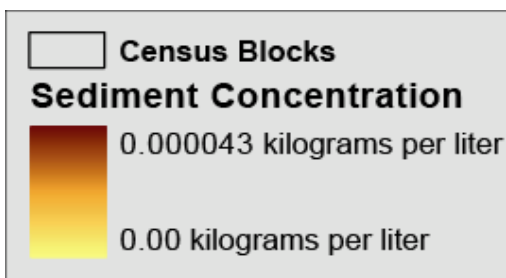
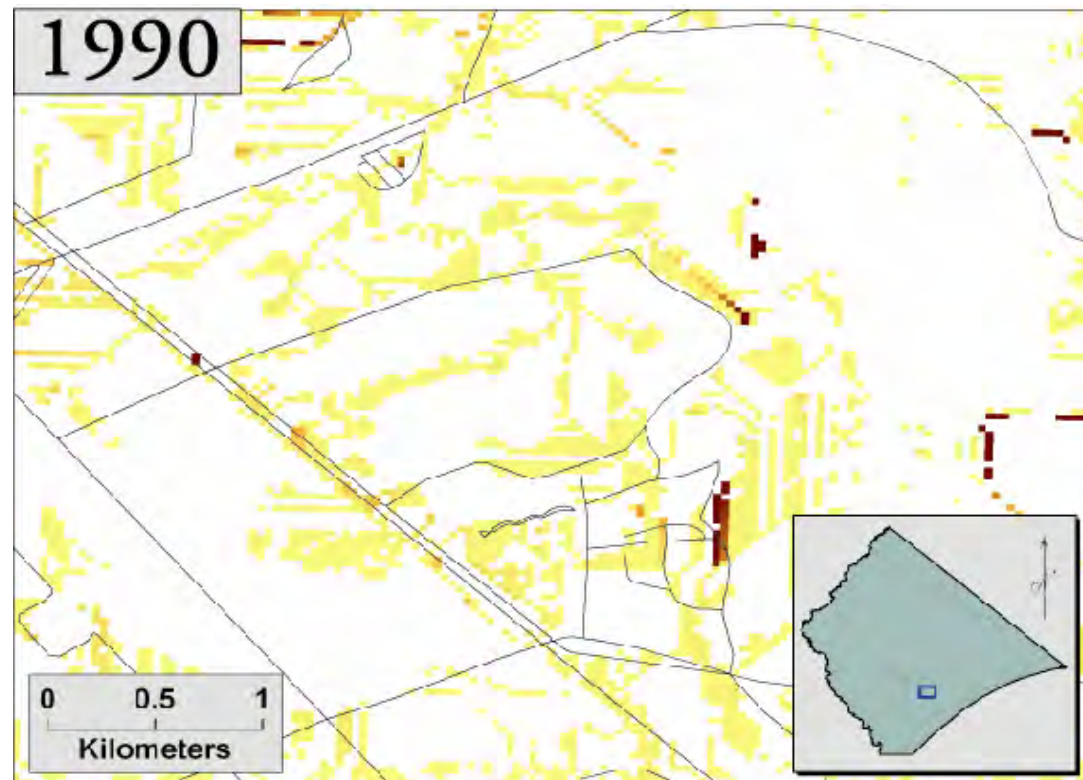
# ISAT – 1990



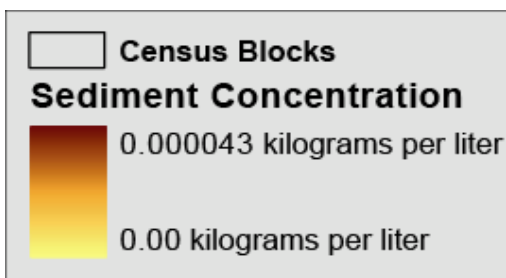
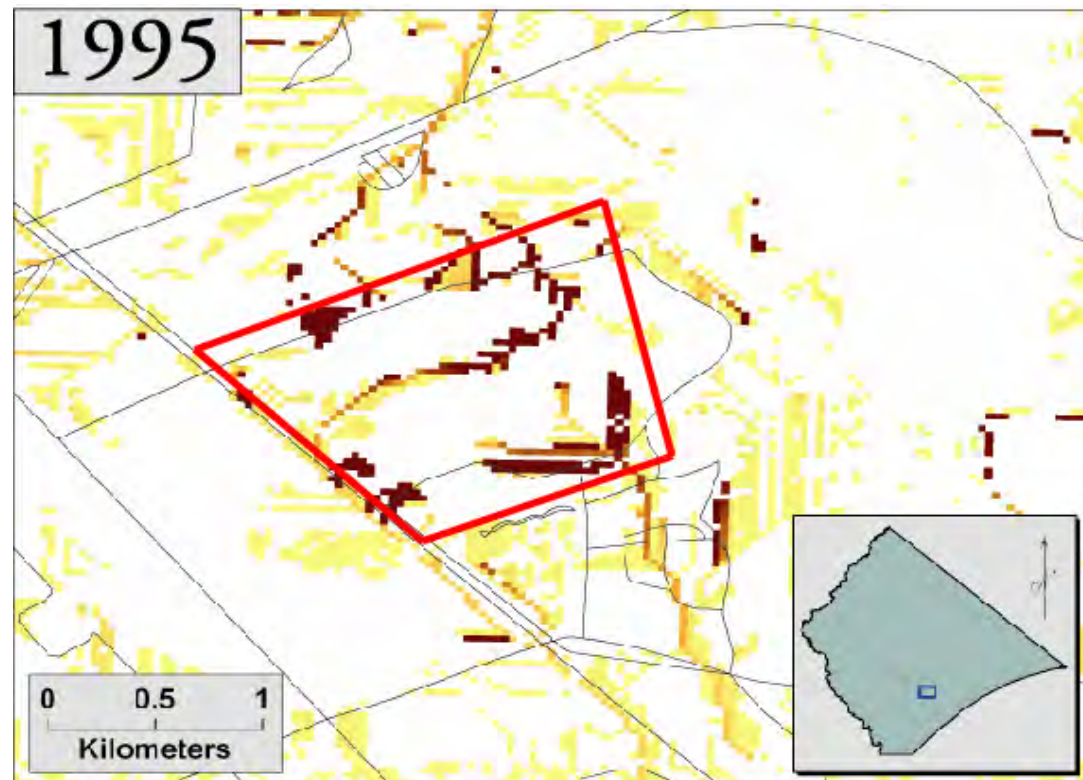
# ISAT – 1995



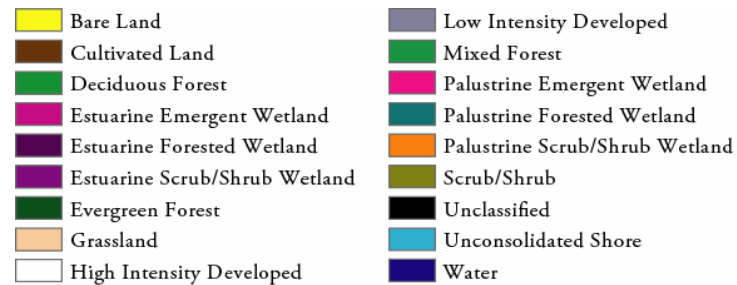
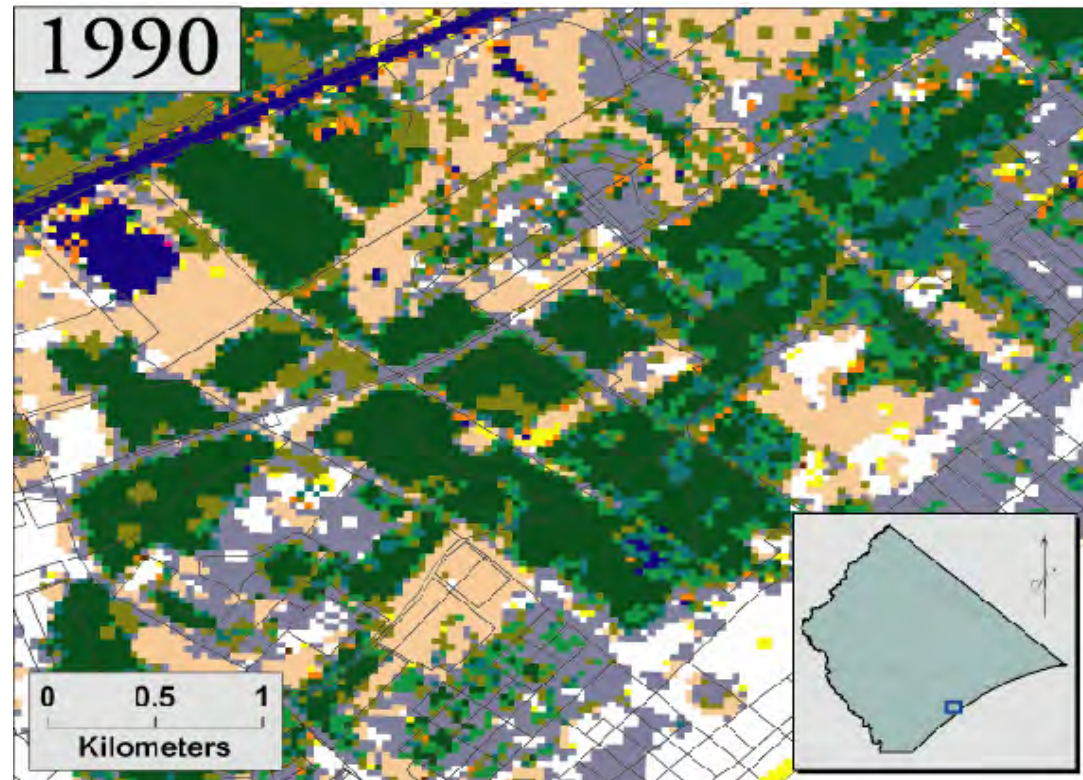
# N-SPECT – 1990



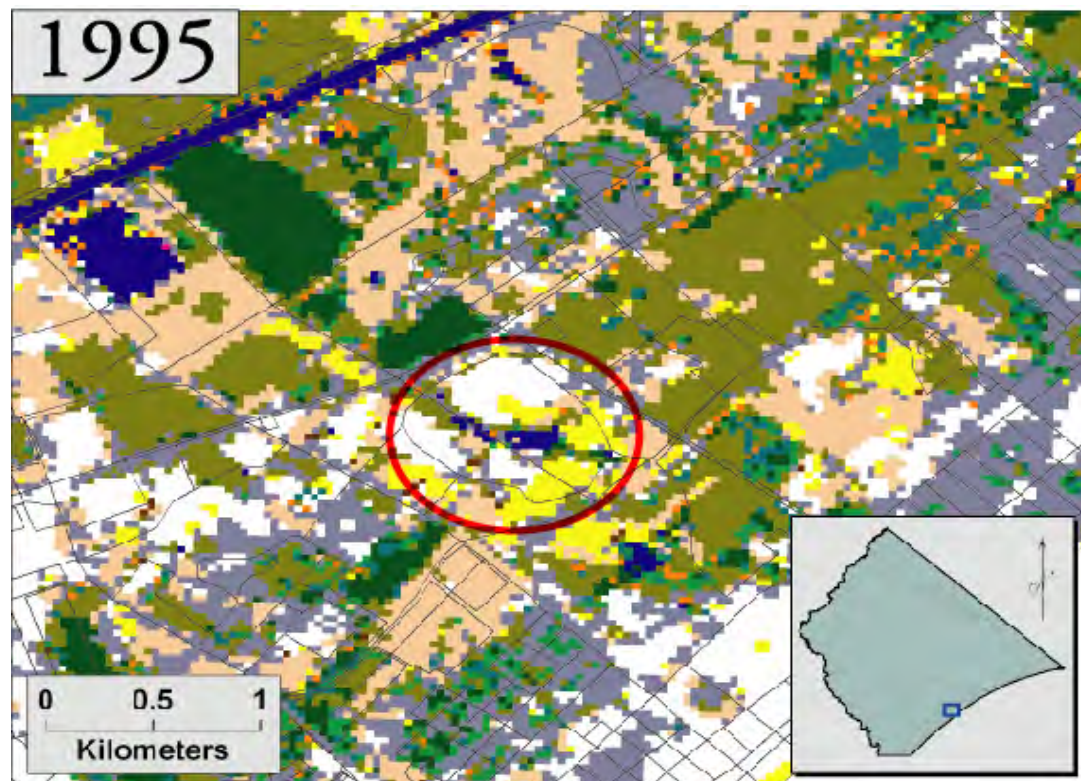
# N-SPECT – 1995



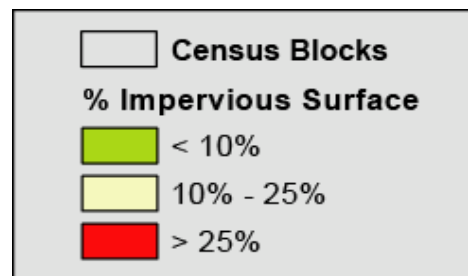
# C-CAP – 1990



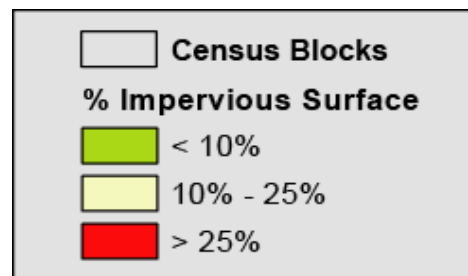
# C-CAP – 1995



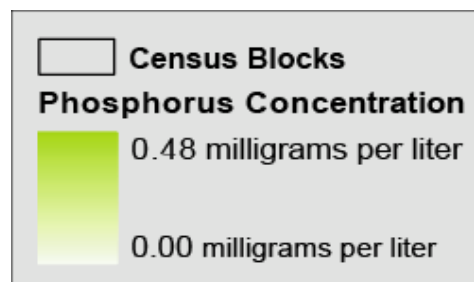
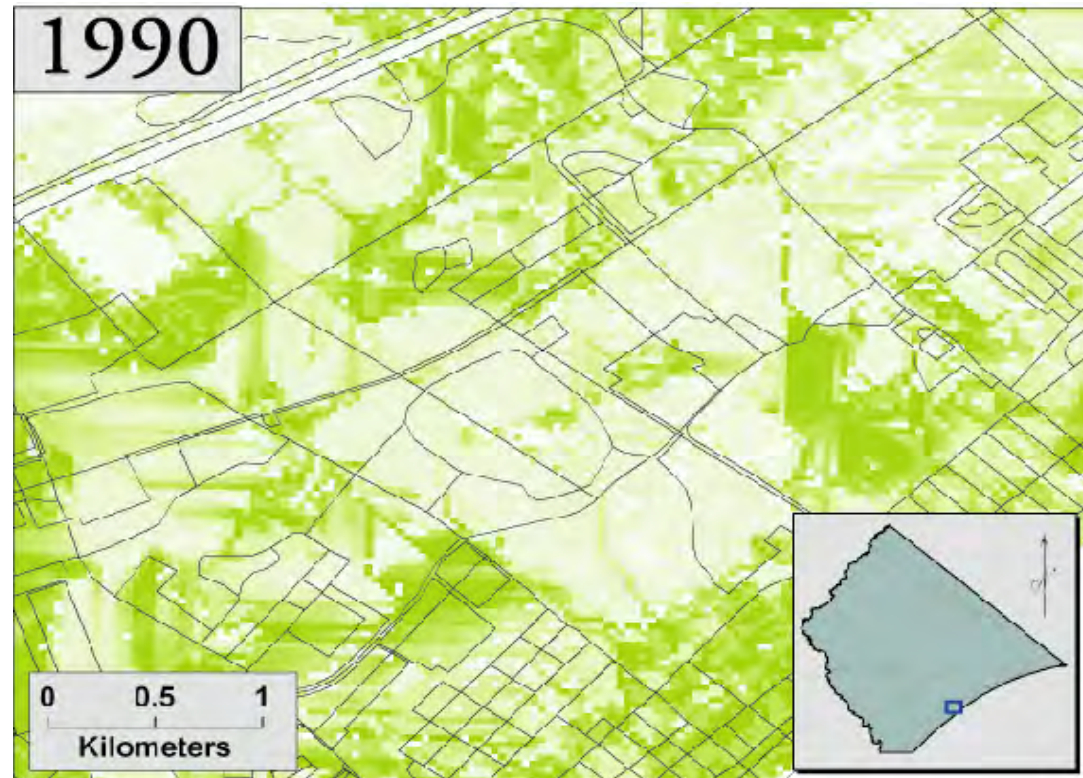
# ISAT – 1990



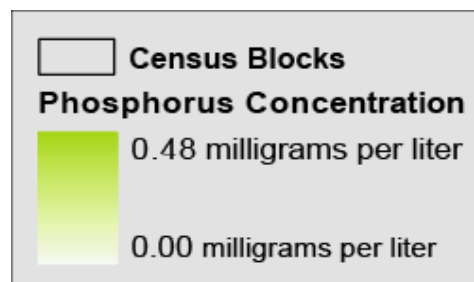
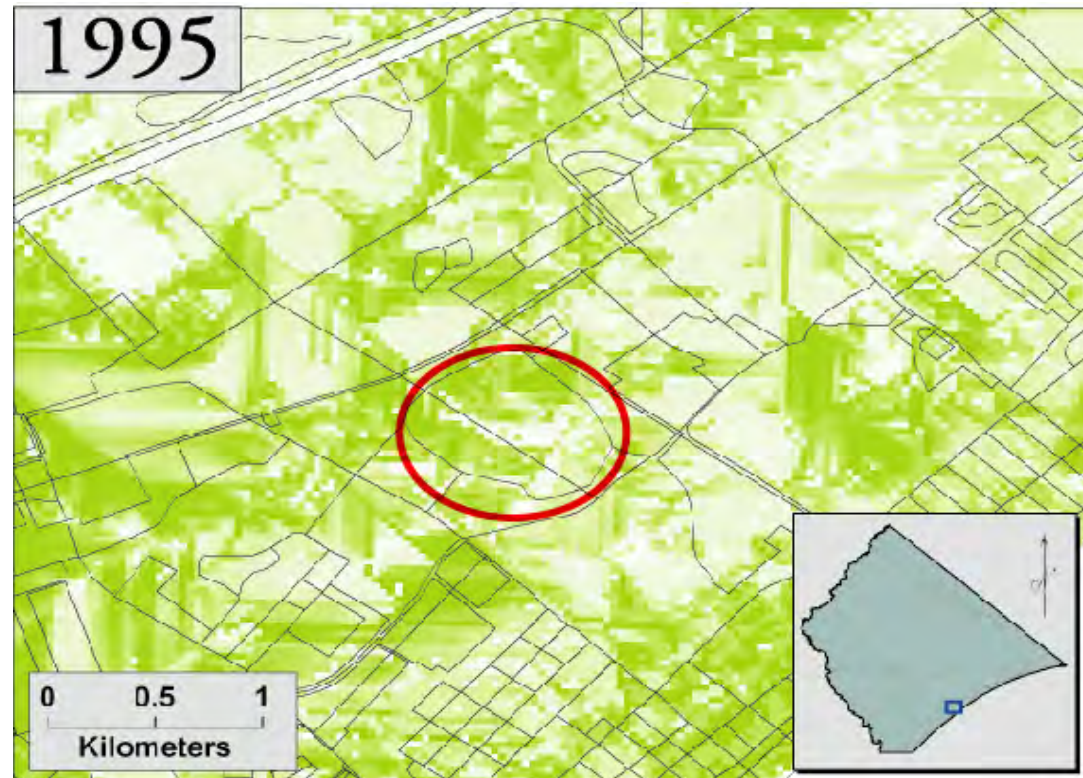
# ISAT – 1995



# N-SPECT – 1990



# N-SPECT – 1995



# Conclusions

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- By using multi-temporal data and two GIS-based tools, we were able to examine the impacts of land cover change on water quality through time.
- ISAT provides a general understanding of the impacts of change on water quality.
- N-SPECT provides a more detailed examination of the impacts of change on specific pollutant and sediment loads.
- Combined, these two tools reveal landscape attributes that are related to water quality in both space and time.

# Existing Applications

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- Mapping regional threats to coastal resources (WA)
- “Hot spot” targeting for Section 319 nonpoint source pollution management planning (ME)
- Visualization materials for community education (ME)
- Community based watershed planning for Section 319 nonpoint source management program (HI)
- Land cover change and water quality trends (SC, AL)
- More...

# Future Directions

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- Version 2 – to be released July 2007
- Application in Hawaii
  - Hanalei Watershed
- Application in Alabama
  - Weeks Bay National Estuarine Research Reserve (NERR)
- Training – local, regional, national
- Enhance interoperability with other planning tools

# Resources / Contacts

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- Online help files
- User manual
- Technical guide
- Tutorial
- List server
  - [n-spect@csc.noaa.gov](mailto:n-spect@csc.noaa.gov)
- Web sites
  - [www.csc.noaa.gov/crs/cwq/nspect](http://www.csc.noaa.gov/crs/cwq/nspect)
  - [www.csc.noaa.gov/crs/cwq/isat](http://www.csc.noaa.gov/crs/cwq/isat)
- Technical Support
  - Jamie Carter  
(843) 740-1190  
[Jamie.Carter@noaa.gov](mailto:Jamie.Carter@noaa.gov)
  - Dr. Dave Eslinger  
(843) 740-1270  
[Dave.Eslinger@noaa.gov](mailto:Dave.Eslinger@noaa.gov)