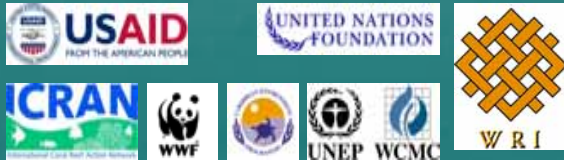


Watershed Analysis of the Mesoamerican Reef Region:

Application of the Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT)

Zachary Sugg

World Resources Institute



Outline

- Description
- Functions & Capabilities
- Applying to MAR
- Data Requirements
- Watershed Delineation
- NSPECT Analysis Concepts:
 - Runoff
 - Pollution
 - Erosion

Description (What is N-SPECT?)

- GIS-based tool for estimating and comparing nonpoint-source pollution and erosion.
- Extension compatible with ArcGIS 8.x and 9.x
- Public domain; developed by NOAA Coastal Change Analysis Program (CCAP), 2004.
- Initially developed for Wai'anae region, Oahu, Hawaii.
- Transferable – can be utilized in any location where input datasets are available.
- Flexible: adaptable to local areas, different time scales.
- Answers questions about effects of land cover change on water quality in watersheds.
- Relatively short processing times.

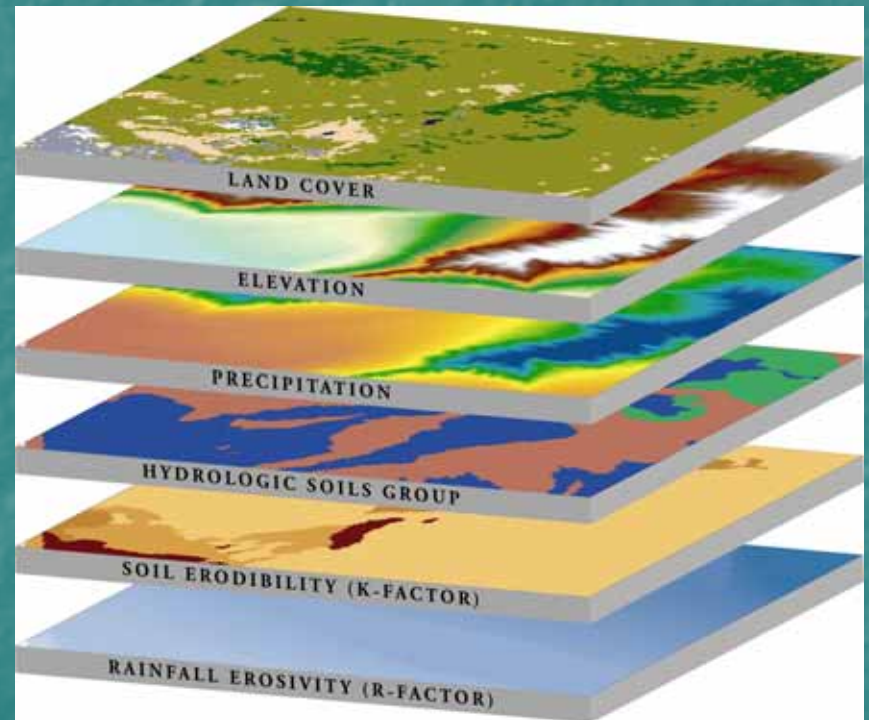
Functions & Capabilities

- Rainfall-runoff model
 - U.S. Soil Conservation Service (SCS) curve number technique
- Pollutant model
 - Concentration coefficients
- Sediment yield model
 - Universal Soil Loss Equation (USLE)
 - Modified (MUSLE)
 - Revised (RUSLE)



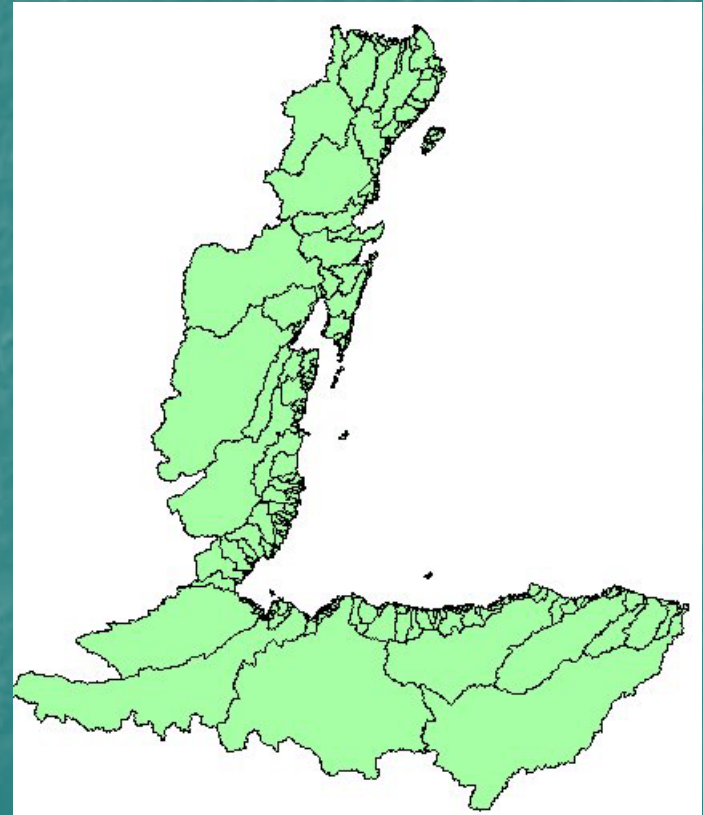
Data Requirements

- Land Cover grid
- Elevation (DEM)
- Precipitation grid
- Soils shapefile
 - Hydrologic soil group grid
 - Soil erodibility (K) grid.
- Rainfall Erosivity (R) Factor grid
- Pollutant/Nutrient Coefficients
- Water Quality Standards



Applying N-SPECT to the MAR region

- Adapt model to the region (data needs)
- Run several analyses to predict water quality changes.
 - Annual Erosion/Sediment loads
 - Pollutant loads
- Extract outputs to pour points



Performing Analyses with N-SPECT: Key Concepts

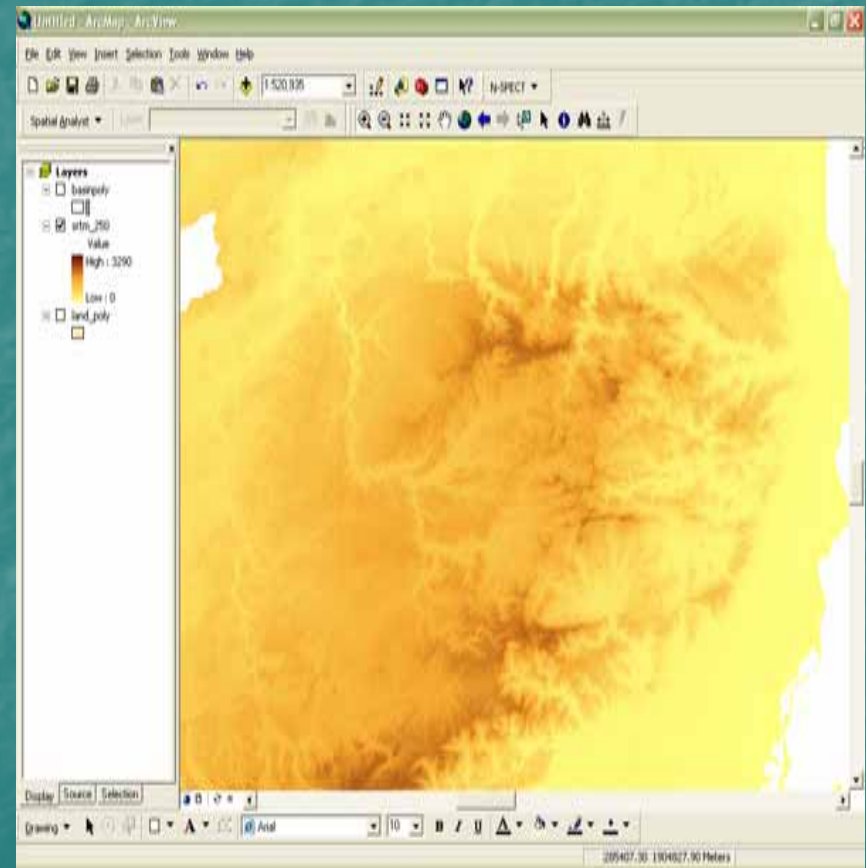
- Watershed Delineation
- Runoff volume
- Pollutants (accumulation & concentration.)
- Sediment Delivery (accumulation & concentration)



Photo: WWF, Sylvia Marin

Concept 1: Watershed Delineation in N-SPECT

- Why important?
Topography (DEM)
- Other grids derived
from DEM
- Analysis extent &
overlay
- Watershed boundary
shapefile the basic
unit for all analyses



Watershed Delineation Process (in N-SPECT)

- N-SPECT requires its own delineation based on a user's Digital Elevation Model (DEM)
- Creation of basins polygon shapefile
- FILL command
- Determines flow direction to locate streams.
- BASIN command to delineate drainage basins based on ridgelines of DEM and pour points.
- Very small watersheds, problematic areas of very low relief aggregated into larger watersheds.

Watershed Delineation: DEM preparation

- First step: creating input DEM (*burn_20pos*)
- DEM developed from 90m resolution NASA SRTM data resampled to 250m; water bodies “burned” at -20m relative to surface of DEM
- NSPECT considers negative values sinks, so the DEM was raised 21m to eliminate all negatives and preserve the burn.
- NSPECT then fills in actual sinks.

DEM Setup: New Watershed Delineation menu

- 1st step = input DEM
- Hydrologically corrected?
- Units
- Subwatershed size: small, medium, or large.
 - Subwatershed size is relative to DEM based on flow accumulation.

Based on the following conditions:

Small = 0.1% of max flow acc value

Medium = 1%

Large = 10%

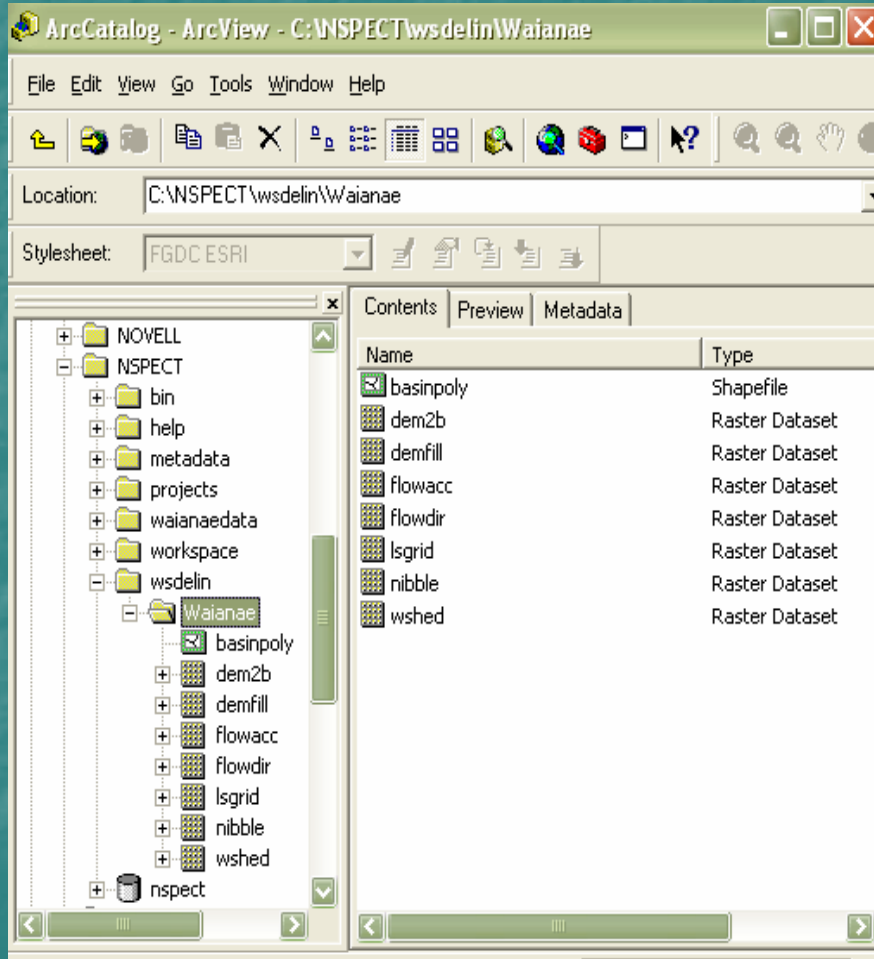
The 'New Watershed Delineation' dialog box contains the following fields and options:

- Create a new watershed delineation** (header)
- Delineation Name:** [Empty text box]
- DEM Grid:** [Empty text box with folder icon]
- DEM is hydrologically correct (filled)**
- DEM Units:** [Empty dropdown menu]
- Subwatershed Size:** [Empty dropdown menu]
- OK** and **Cancel** buttons

The 'Watershed Delineations' dialog box contains the following fields and options:

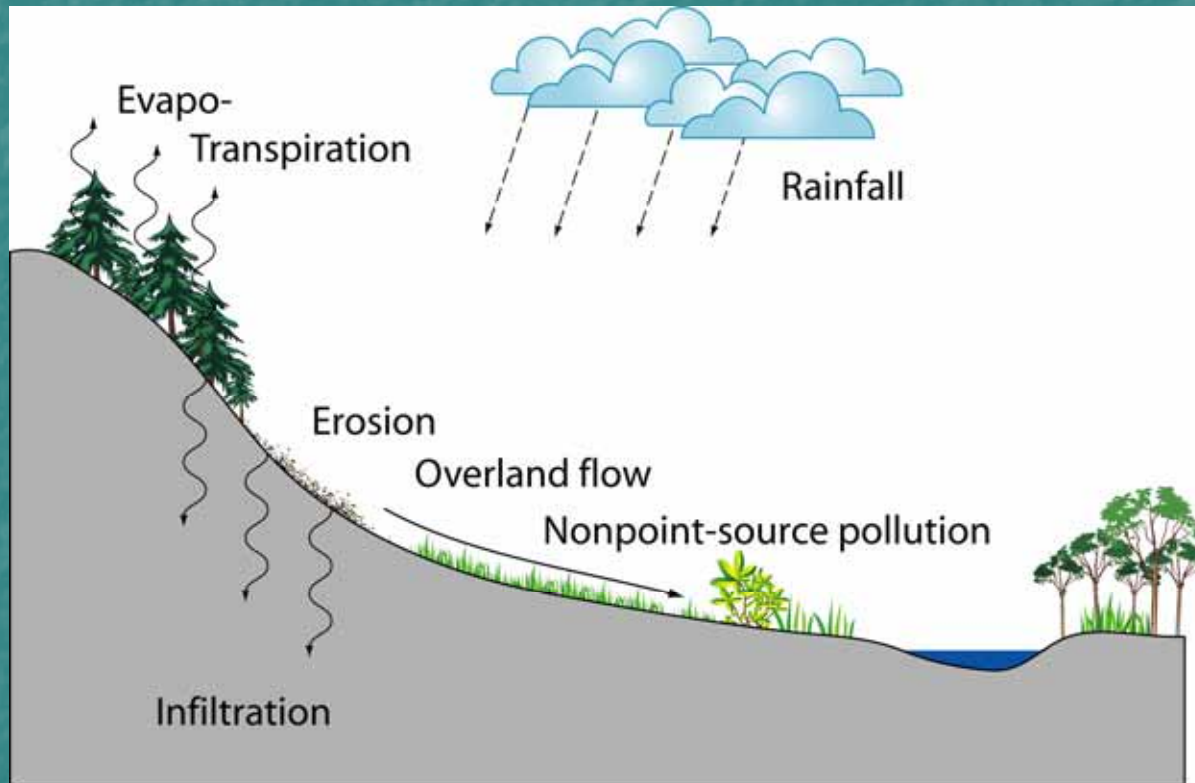
- Options** and **Help** (menu items)
- Browse Watershed Delineations** (header)
- Watershed Delineation Name:** [Dropdown menu with 'Waianae' selected]
- DEM Grid:** [Text box with 'C:\NSPECT\WaianaeData\dem']
- Units:** [Dropdown menu with 'meters' selected]
- Hydrologically Corrected DEM**
- Subwatershed Size:** [Dropdown menu with 'medium' selected]
- Watershed:** [Text box with 'C:\NSPECT\wsdelin\Waianae\basinpoly']
- Flow Accumulation Grid:** [Text box with 'C:\NSPECT\wsdelin\Waianae\flowacc']
- LS Grid:** [Text box with 'C:\NSPECT\wsdelin\Waianae\LSGrid']
- Cancel** button

Watershed Delineation: Location & Key Output data



- Basin polygon shapefile
- Basin grid
- Flow direction grid
- Flow accumulation grid
- LS Factor grid

N-SPECT Concept: Runoff Estimation



NOAA CCAP

*Soil characteristics, land cover, topography and precipitation determine **runoff***

Runoff: Inputs required

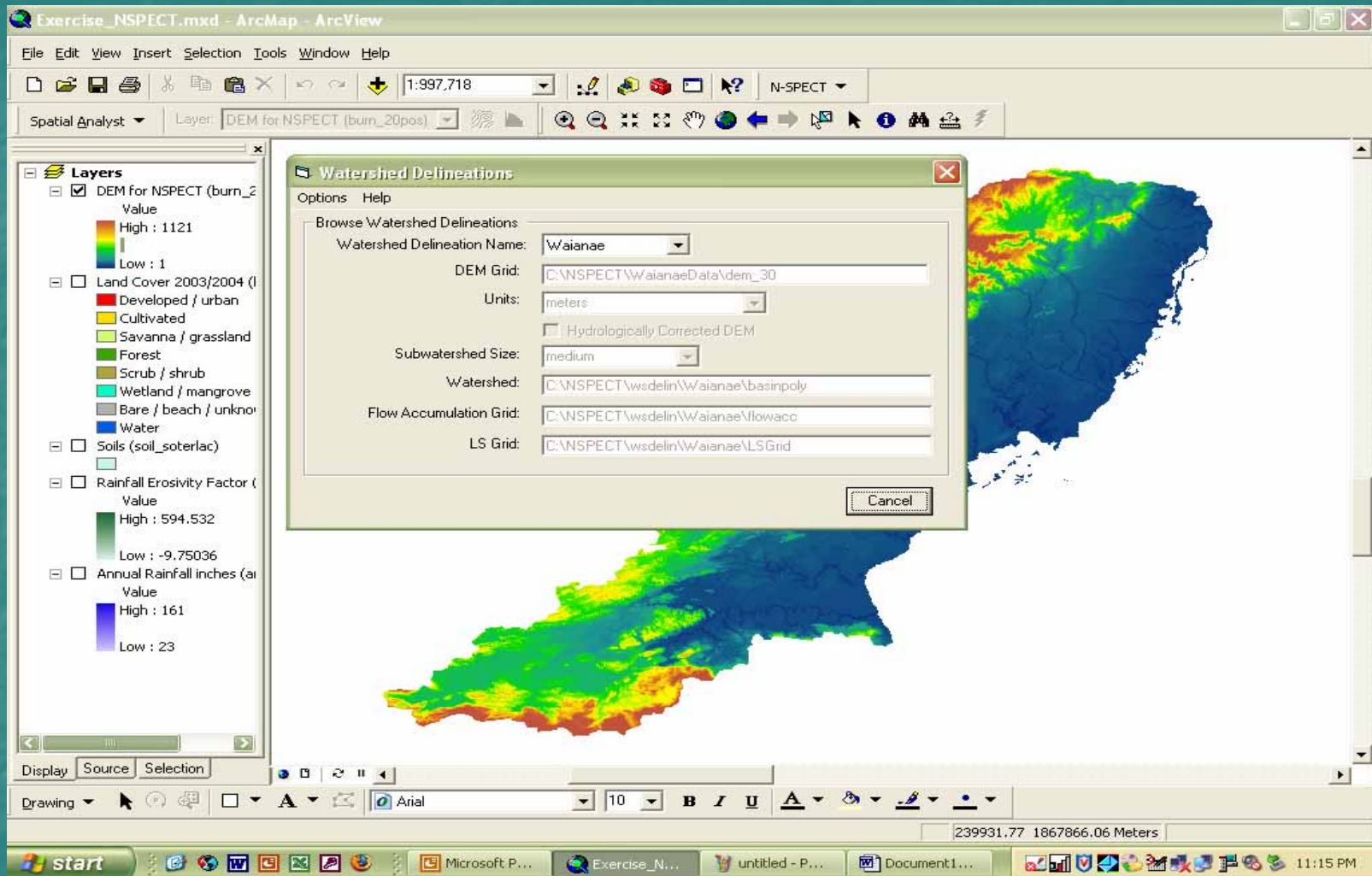
- Rainfall grid (annual or event)
- Elevation (DEM)
- Runoff Curve numbers
- Soil (hydrological group)

Precipitation

The screenshot displays the ArcMap interface with the following components:

- Title Bar:** Exercise_NSPECT.mxd - ArcMap - ArcView
- Menu Bar:** File, Edit, View, Insert, Selection, Tools, Window, Help
- Toolbars:** Standard toolbar with a scale of 1:7,345,624 and the Spatial Analyst toolbar.
- Layers Panel:**
 - DEM for NSPECT (burn_20pos) Value: High: 1121, Low: 1
 - Land Cover 2003/2004 (l): Developed / urban, Cultivated, Savanna / grassland, Forest, Scrub / shrub, Wetland / mangrove, Bare / beach / unkno, Water
 - Soils (soil_soterlac)
 - Rainfall Erosivity Factor (Value): High: 594.532, Low: -9.75036
 - Annual Rainfall inches (a):** Value: High: 161, Low: 23
- Map View:** A map of the Waianae area with a blue precipitation overlay.
- Precipitation Scenarios Dialog Box:**
 - Options: Help
 - Choose a precipitation scenario to view or edit
 - Scenario Name: Annual Precipitation
 - Description: Annual Precipitation for Waianae
 - Precipitation Grid: C:\NSPECT\WaianaeData\annual_prec
 - Grid Units: meters
 - Precipitation Units: inches
 - Time Period: Annual
 - Raining Days: 7
 - Type: Type I
 - Buttons: OK, Cancel
- Status Bar:** 368246.81 2448500.00 Meters
- Taskbar:** Windows taskbar with Start button, taskbar icons, and system tray showing 11:09 PM.

Elevation



Flow Direction & Accumulation
Resolution & processing time

Land Cover (Runoff Curve Numbers)

Exercise_NSPECT.mxd - ArcMap - ArcView

File Edit View Insert Selection Tools Window Help

Spatial Analyst Layer: DEM for NSPECT (burn_20pos)

1:1,123,921

N-SPECT

Layers

- DEM for NSPECT (burn_2 Value)
 - High : 1121
 - Low : 1
- Land Cover 2003/2004 (
 - Developed / urban
 - Cultivated
 - Savanna / grassland
 - Forest
 - Scrub / shrub
 - Wetland / mangrove
 - Bare / beach / unkno
 - Water
- Soils (soil_soterlac)
- Rainfall Erosivity Factor (Value)
 - High : 594.532
 - Low : -9.75036
- Annual Rainfall inches (a Value)
 - High : 161
 - Low : 23

Land Cover Types

Options Help

Land Cover Type: CCAP

Description: CCAP Landcover

Classification		SCS Curve Numbers				RUSLE	
Value	Name	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"/>
7	Evergreen Forest	0.3	0.55	0.7	0.77	0.004	<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"/>
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"/>

Restore Defaults Save Cancel

Land Cover Types 267701.68 2055906.19 Meters

start Microsoft P... Exercise_N... untitled - P... Document1... 11:18 PM

Runoff: SCS Curve Number method

- Developed by USDA-NRCS
- Curve numbers based on soil traits & represent permeability.
- Range: 0 (100% infiltration) to 100 (0% infiltration).
- Gridded by NSPECT, derived from land cover and hydrologic soil group.
- Runoff depth
- User-adjustable
- For more on actual processing equations, see tech guide.

Land Cover Types

Options Help

Land Cover Type: CCAP

Description: CCAP Landcover

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"/>
7	Evergreen Forest	0.3	0.55	0.7	0.77	0.004	<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"/>
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"/>

Restore Defaults Save Cancel

Hydrologic Soil Group

Land Cover Types

Options Help

Land Cover Type:

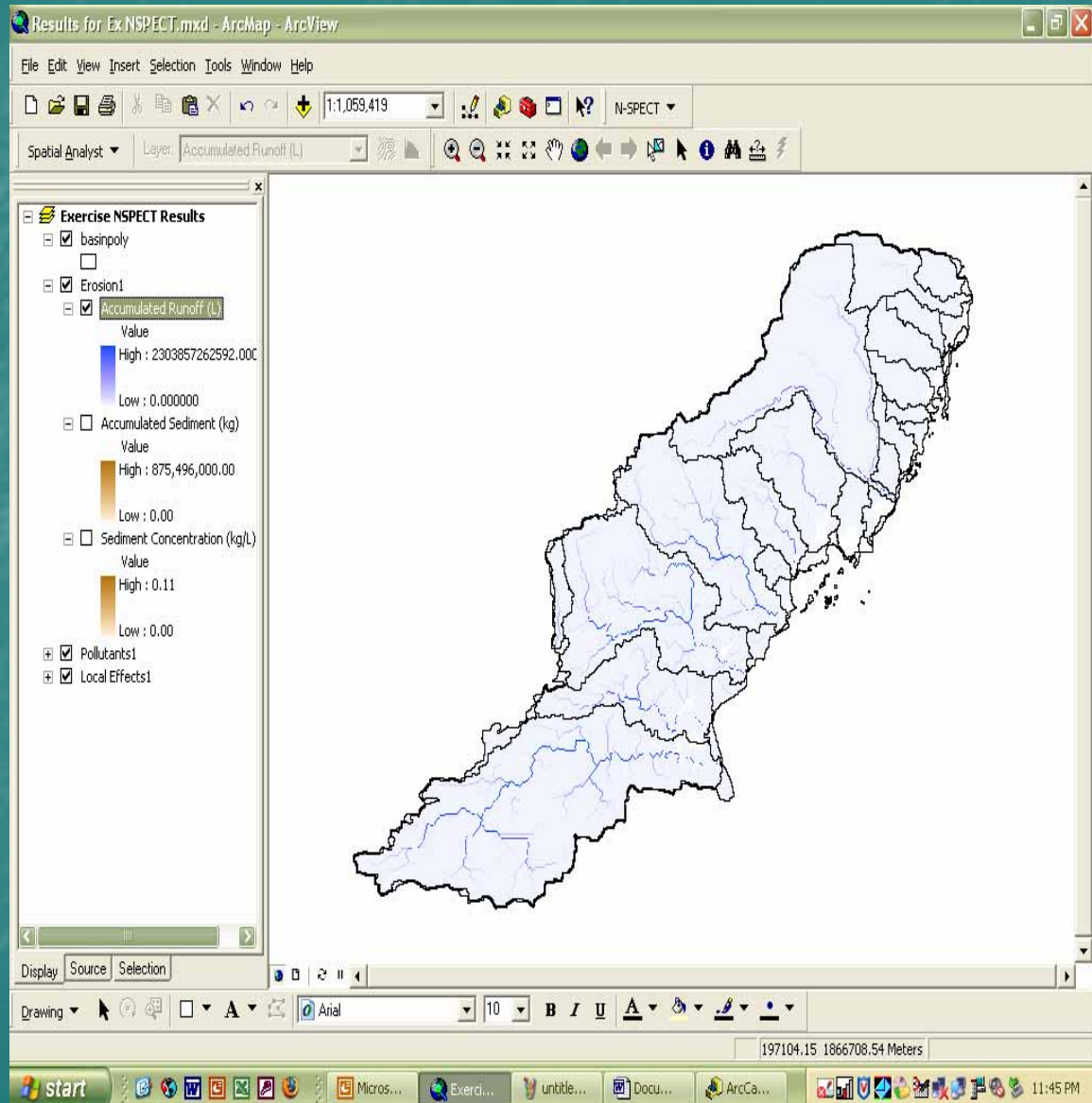
Description:

Classification		SCS Curve Numbers				RUSLE	
Value	Name	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"/>
7	Evergreen Forest	0.3	0.55	0.7	0.77	0.004	<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"/>
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"/>

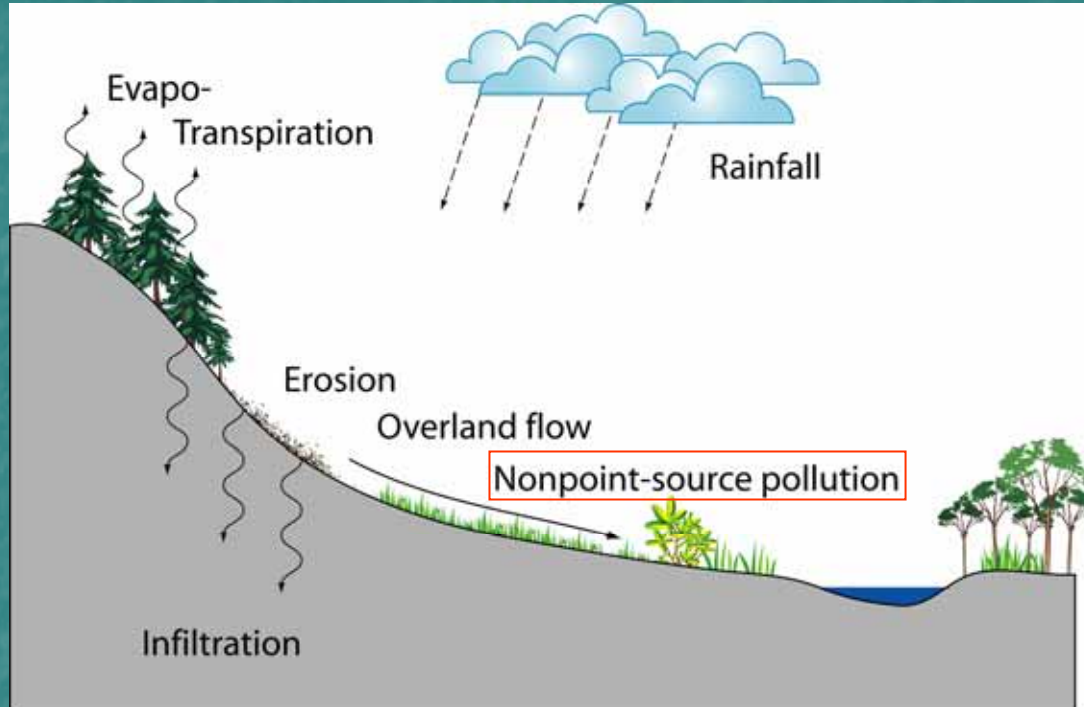
Hydrologic Soil Group	Soil Group Characteristics
A	Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well- to excessively-drained sands or gravels. These soils have a high rate of water transmission.
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, and moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
D	Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Runoff: Outputs

- **Runoff volume (L)**
(annual or event)
- *Runoff depth*
- *Runoff curve number grid*



N-SPECT Concept: Pollutants



NOAA CCAP

Eutrophication, algal blooms, closed beaches and shellfish beds, human health impacts through accumulation in food chain. (Arnold & Gibbons, 1996)

Runoff, land cover, topography and pollutant coefficients determine pollutant loads

Pollutants: Inputs

- Rainfall grid (annual or event)
- Elevation (DEM) derivatives
- Soil (hydrological group)
- Pollutant Coefficients
 - Expected pollutant mean concentration from each land cover type
 - Ideally, locally derived from WQ and land cover data.

Pollutants: Coefficient Method

Pollutants [Close]

Pollutants Coefficients Help

Pollutant Name: Nitrogen

Coefficients | Water Quality Standards

Coefficient Set: NitSet Land Cover Type: CCAP

Description: Nitrogen Coeff Set

Class		Coefficients			
Value	Name	Type1	Type2	Type3	Type4
2	High Intensity Developed	2.22	0	0	0
3	Low Intensity Developed	1.77	0	0	0
4	Cultivated Land	2.68	0	0	0
5	Grassland	2.48	0	0	0
7	Evergreen Forest	1.25	0	0	0
9	Scrub/Shrub	1.25	0	0	0
10	Palustrine Forested Wetland	1.1	0	0	0
16	Unconsolidated Shore	0.97	0	0	0
17	Bare Land	0.97	0	0	0
18	Water	0	0	0	0

OK Cancel

Pollutants: Output

Water Quality Standards

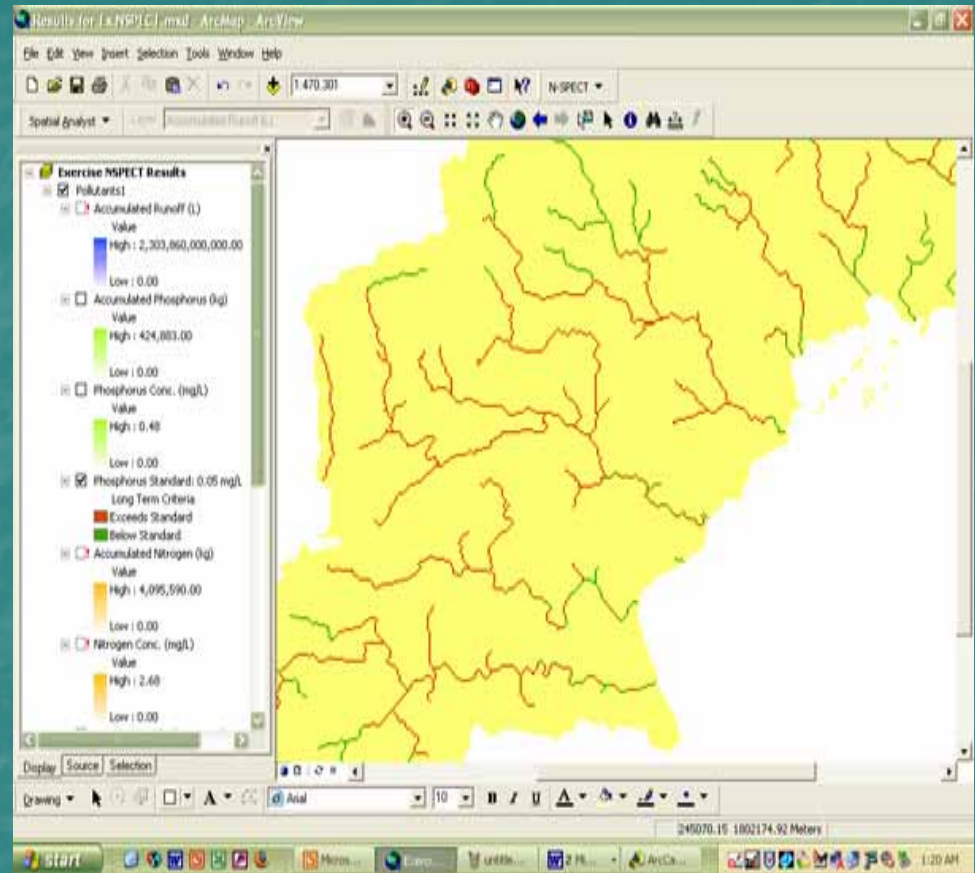
Options Help

Standard Name:

Description:

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

OK Cancel



- Accumulated Pollutant (kg)
- Pollutant Concentration (mg/L)
- Comparison to water quality standard (exceeds or below standard)
 - Short, moderate, and long-term

Water quality standards

- Concentration output compared to local standards – meet or exceed criteria?
- Short, moderate, or long term.

Water Quality Standards

Options Help

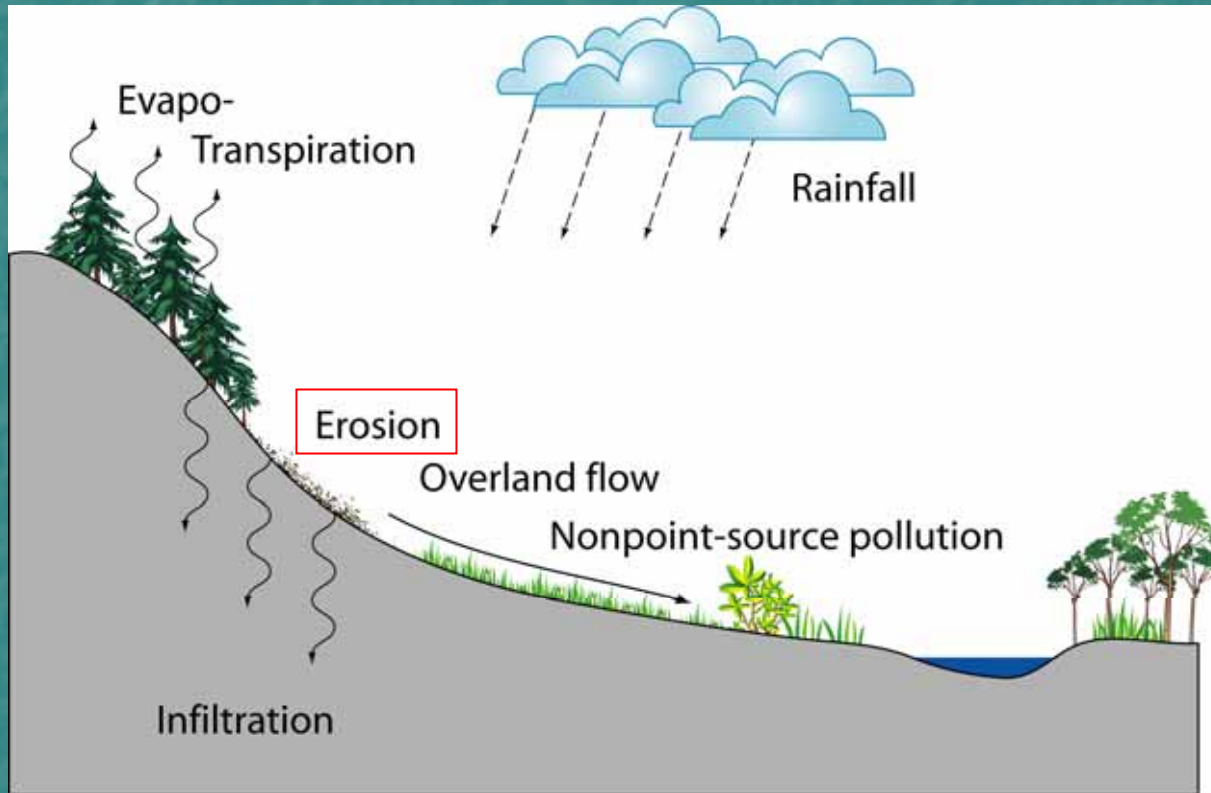
Standard Name: Long Term Criteria

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

N-SPECT concept: Erosion



NOAA CCAP

Runoff, topography, soil characteristics, and land cover determine sediment loads.

Erosion: USLE method

- Sediment yield & concentration
- Universal Soil Loss Equation
- Annual & Event (RUSLE & MUSLE)
- RUSLE: $A = R * K * L * S * C * P$
- Where:
 - A = avg. annual soil loss
 - R = rainfall/runoff erosivity factor
 - K = soil erodibility factor
 - L = slope length factor
 - S = slope steepness factor
 - C = cover management factor
 - P = supporting management practices factor

MUSLE method: Event based

- For single event precip scenarios
- Can locally calibrate equations for sediment yield.
- Q = storm runoff volume (acre-ft)
- q_p = peak runoff rate (ft³/second)
 - "Maximum volume of flow attained at a given point in a stream during a runoff event."

Soils Setup

Name:

DEM GRID:

Soils

Soils Data Set:

Hydrologic Soil Group Attribute:

K Factor Attribute:

Advanced MUSLE Specific Parameters

MUSLE Equation for sediment yield:
 $95 * (Q * q_p)^{0.56} * K * C * P * LS$

Locally calibrated MUSLE equation for sediment yield being used by N-SPECT:
 $18.943 * (Q * q_p)^{0.877} * K * C * P * LS$

OK Cancel

Erosion Inputs

- DEM (LS Factor)
- Land cover grid (C Factor)
- Soils (K-factor) grid
- Rainfall grid
- Rainfall erosivity (R-factor) grid.

Key RUSLE inputs: R-Factor

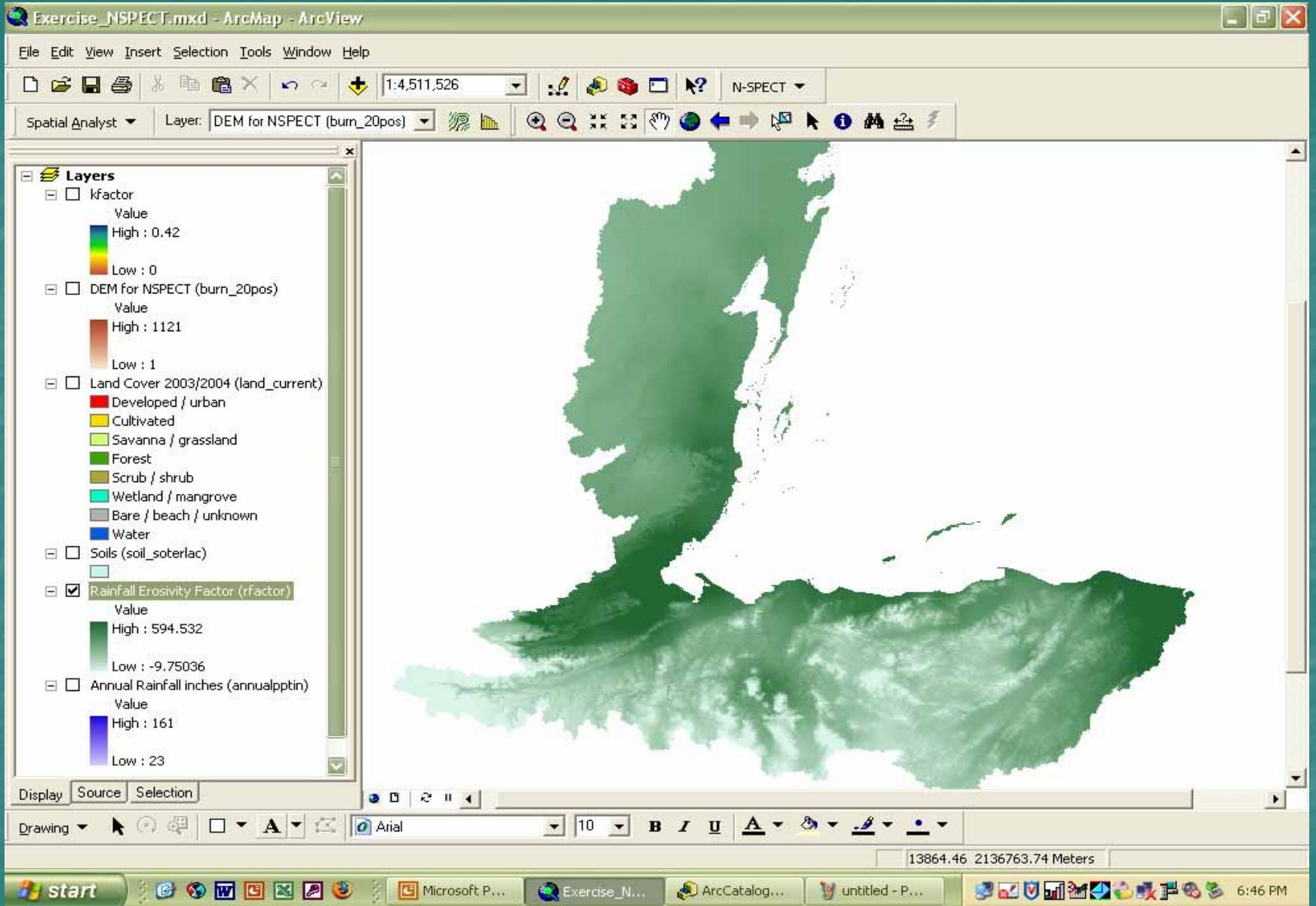
“Quantifies the effects of raindrop impact and amount and rate of runoff associated with the rain.” - USDA

- Preferable to derive R-factor empirically from actual rainfall data. OK for U.S. but not always available in other places.
- Many studies in literature have derived region-specific equations incorporating precipitation or precipitation & elevation.
- Sediment load output from several R-factor regression equations compared statistically to each other and to a physical model at Texas A&M. (see documentation on cd for more info on R-Factor and MAR implementation).
- Equation determined to be most appropriate for MAR region:
 - $R = 3786.6 + 1.5679(\text{Precip in mm}) - 1.9809(\text{Elevation in m})$
- Erosivity grid for MAR generated from annual precip grid and DEM

R-factor conversion for N-SPECT

- $R = 3786.6 + 1.5679 * (\text{Precip in mm}) - 1.9809 * (\text{Elevation in m})$
- Output in metric units $MJ * mm * ha^{-1} * h^{-1} * y^{-1}$
(megajoule * mm / hectare * hour * year)
- However, N-SPECT requires US units:
*hundreds of feet * tonf * inch * acre⁻¹ * hour⁻¹ * year⁻¹*
- Convert by Dividing by the conversion factor, 17.02.

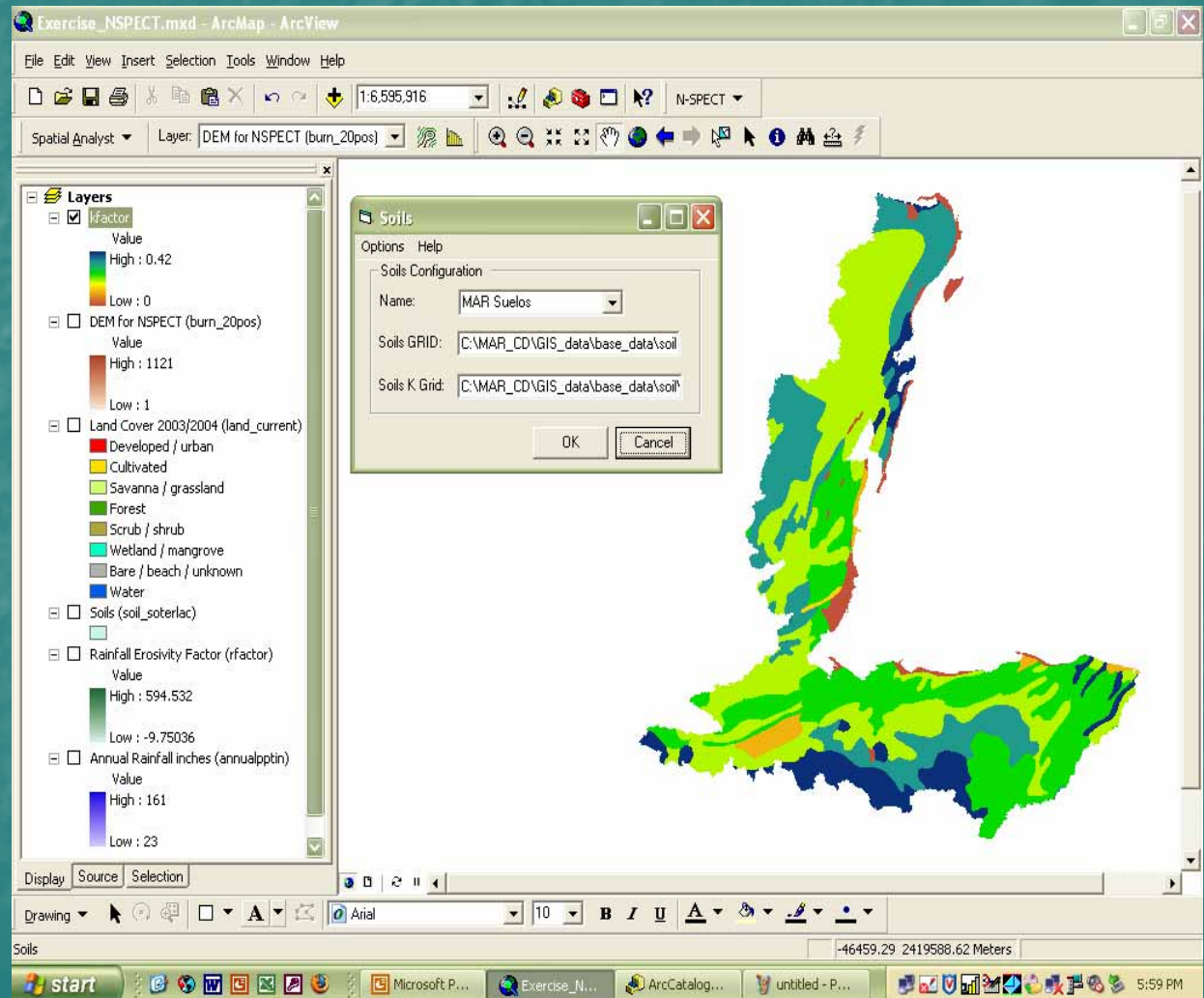
Reference: USDA-ARS Agriculture Handbook No. 703



$$R = 3786.6 + 1.5679(P) - 1.9809(E)$$

Key Input 2: K-factor

- Soil erodibility
- Average long-term soil response to stormwater erosion
- “Lumped” parameter. based on several different hydrologic soil processes.
- Contained in soil attribute table.



Ton * acre * hour / acres * tonf * feet * inch

Land Cover (C) Factor

Land Cover Types

Options Help

Land Cover Type: CCAP

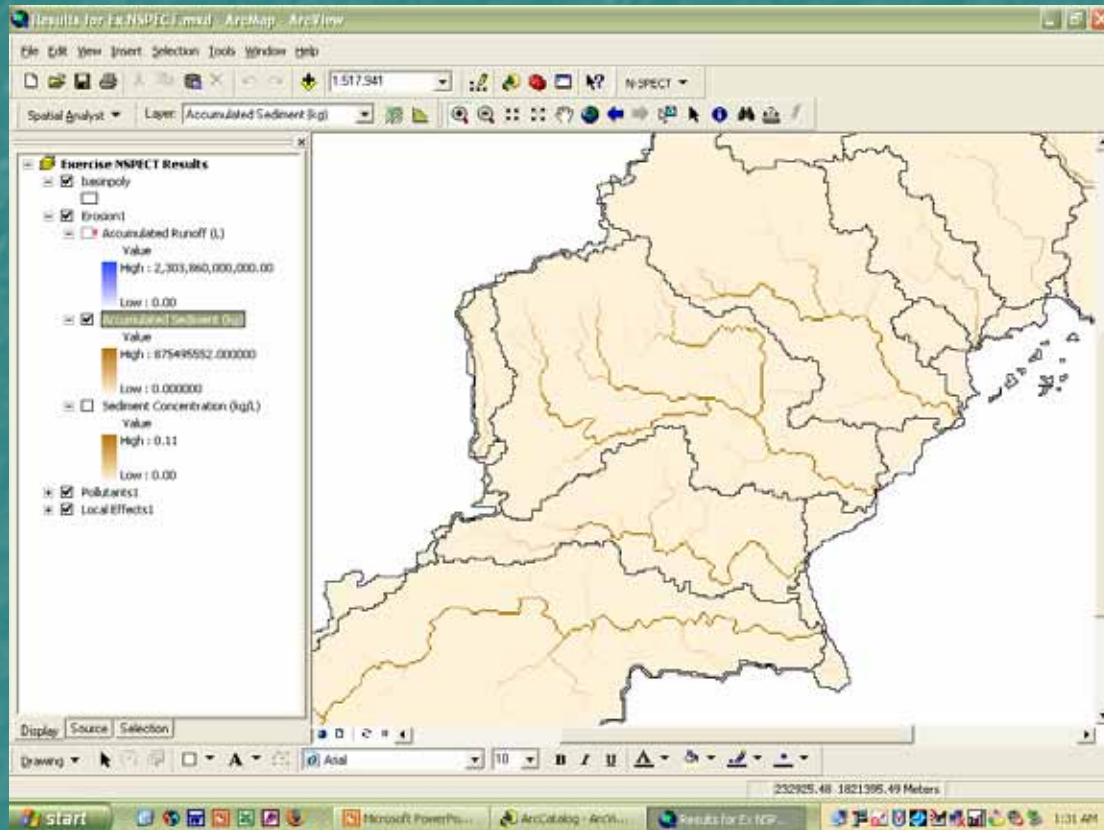
Description: CCAP Landcover

Classification		SCS Curve Numbers				RUSLE	
Value	Name	CN-A	CN-B	CN-C	CN-D	Cover-Factor	Wet
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10	Palustrine Forested 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"/>

Restore Defaults Save Cancel

- Complex coefficient representing impact of land management/cover on soil loss.
- Higher value = higher level of soil loss

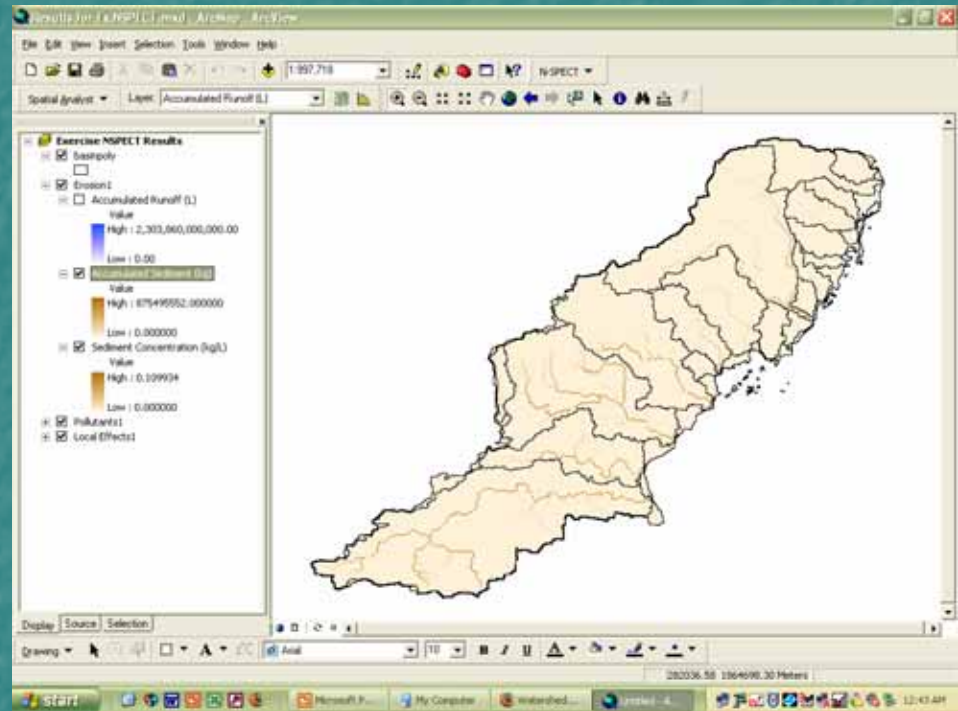
Erosion: Output GRIDs



- Accumulated Sediment (kg)
 - Total amount of sediment accumulated over a year's time
- Sediment concentration (kg/L)

Local Effects

- Contributions of single cells independent of upstream contributions through time.
- Pollution and erosion generated by single cells, groups of cells, with no input from upstream sources.



Land use & Management scenarios

- Not utilized for MAR region
- Allows you to overlay vector layers representing different land cover types and management scenarios.
- Compare effects of change on pollution and erosion.
- Additional training resources (Hawaii) available with N-SPECT.

Future improvement/adjustment

- Adapt to other regions
- Calibrate to real discharge and sediment
- Develop local pollutant coefficients
- Additional pollutants
- More detailed land cover/new curve #'s and cover factors
- Finer scale
- Locally accurate number of rainy days
- Higher res. Precip, DEM, & R-factor

N-SPECT Resources on CD

- Additional basic and advanced training exercises
- User's manual
- Technical guide

- Updates on web at

<http://www.csc.noaa.gov/crs/cwq/nspect.html>