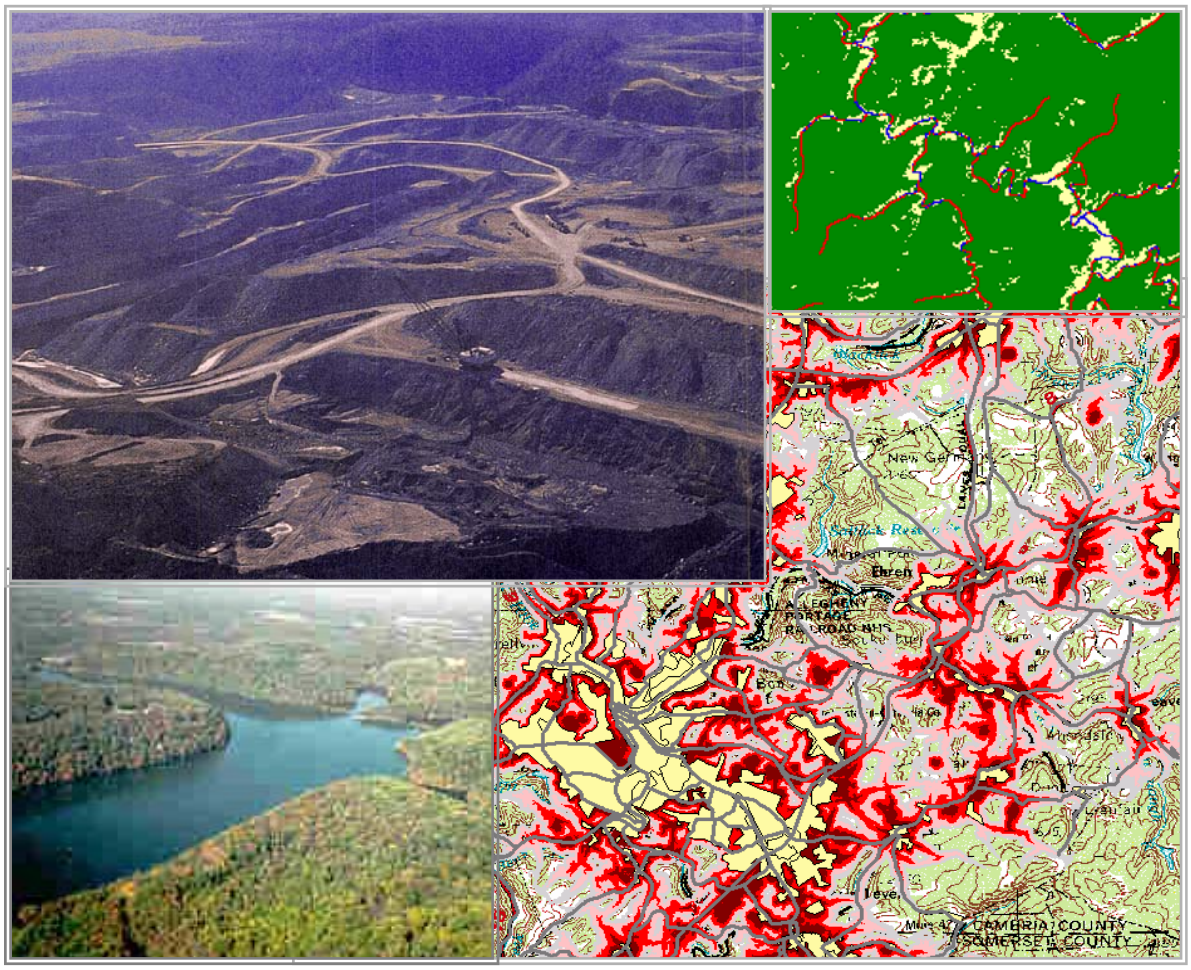
Landscape Assessment Tools:
Integrating Science and Data for Decision Support

Final Report

Natural Resource Analysis Center
West Virginia University



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Integrating Science and Data for Decision Support

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CANAAN VALLEY INSTITUTE MASTER AFFILIATION AGREEMENT
with
The West Virginia University Research Corporation
on Behalf of West Virginia University

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Section 1. Overview

This document is the project summary and final report for work performed by the Natural Resource Analysis Center at West Virginia University with the title "Landscape Assessment Tools: Integrating Science and Data for Decision Support". The Landscape Analyst project was a cooperative effort formulated through a series of discussions between the Natural Resource Analysis Center (NRAC) and the Canaan Valley Institute (CVI) beginning in fall 2000.

The original description of the project goal follows. The final product of this project is an ArcView 3.x extension and associated documentation. The outcome of the project follows the stated goals fairly well.

> "NRAC and CVI propose to develop a series of GIS based landscape assessment tools for use in environmental decision support throughout the CVI service area. These tools will be in the form of an ArcView GIS extension and associated GIS data layers. The ArcView extension (name to be determined) will enhance the capabilities of the ArcView GIS software by enabling users to perform detailed analyses of current landscape condition, as well as analyses of predicted or foreseeable land use change. Landscape and ecological condition will be analyzed in relation to key subject areas, including wildlife habitat, water quality, and development and related land use change.
>
> This project will be a highly cooperative effort between CVI and NRAC, drawing on the wide range of expertise in both organizations. This multi-disciplinary research and development effort will integrate established scientific principles and will also enhance existing capabilities of both CVI and NRAC. The ultimate outcome of the project will lead to a widely applicable analytical framework for landscape assessment and decision support within CVI's service area and beyond."
> *- from NRAC task order 2000-09, dated 11-12-00*

Section 2. Description of NRAC Work

This section first describes in general the tasks performed by NRAC for the Landscape Assessment Tools project period from November 2000 to December 31, 2001. Subsequent sections outline specific portions of the work. This project was a highly collaborative effort between NRAC and the Geospatial Team at CVI. The ultimate result of the efforts of NRAC and CVI is the Landscape Analyst Extension for Environmental Systems Research Institute's ArcView 3.x GIS software.

NRAC work on the Landscape Analyst extension involved four main areas. These included: (1) discussions and meetings with CVI and other interested parties, (2) extensive modification of portions of previously existing software products (Watershed Modeling and Characterization System), (3) research and development of additional modeling components, and (4) ArcView customization development.

(1) Project meetings and demonstrations were held somewhat regularly throughout the project period. Meetings with CVI technical staff (programmer, GIS team) offered the opportunity to critique and improve existing extension functionality. NRAC personnel attended several technical meetings related to landscape level analysis organized by CVI. NRAC and CVI also jointly presented preliminary work on the Landscape Analyst extension at the 21st Annual ESRI International Users Conference in July 2001.

(2) The majority of the water quality related functionality and analysis tools of the Landscape Analyst extension was based on previous work conducted by NRAC for the Watershed Characterization and Modeling System (WCMS) version 2.8 developed for the West Virginia Department of Environmental Protection (WVDEP), delivered in December 1998 (Strager et al. 1998). While many of the concepts first developed for the WCMS were used in the Landscape Analyst extension, major enhancements and improvements were incorporated into the Landscape Analyst work, and almost all computer code was significantly updated.

(3) NRAC work on the Landscape Analyst included research and development of new tools and functionality unique to this project, including the Development Suitability modeling method and the Runoff Curve Number calculations. This work involved background literature research, algorithm development, and ultimately programming and testing within ArcView.

(4) A large portion of the NRAC work on the Landscape Analyst extension involved ArcView customization development and programming. The Landscape Analyst extension is essentially composed of dozens of inter-related ArcView Avenue scripts (macros) and dialogs (user interface windows). All scripts and dialogs are contained in a master version of the Landscape Analyst extension ArcView Project file, maintained by CVI. NRAC contributed scripts for a variety of components directly related to modeling functions as well as dialogs related to user interaction. Functionality of all scripts and dialogs developed by NRAC was

modified to fit within the overall extension framework and user interface designed by CVI.

The following sections outline in more detail the work performed by NRAC for the Landscape Analyst. These sections focus on the water quality modeling components, the land use change and development model, and the landscape and wildlife indicator models.

2.1 Water Quality Modeling Components

The water quality modeling components in the Landscape Analyst extension are grouped into Models, Tools, and Indicators (see below). Water quality models and tools in the Landscape Analyst extension incorporate many fundamental concepts and procedures originally developed by NRAC as part of work on the WCMS for the WVDEP. Since completion, the WCMS has been in regular use by WVDEP personnel and has also been externally reviewed (Parham, 2001). WCMS components that were brought into the Landscape Analyst included the following models and tools:

Models
- Expected Mean Concentrations
- Fate transport
- Identifying potentially affected streams

Tools
- Tracking overland flow
- Delineate watershed from a point or designated sizes
- Estimate drainage area
- Stream flow estimation
- Calculate the percentage of land cover in a watershed
- Define study area by graphic display or listing of attribute features
- Report the coordinates of a point in different projection coordinates

Indicators
- Forested land cover adjacent to streams
- Agricultural land cover adjacent to streams
- Road/stream intersections

As part of the work on the Landscape Analyst extension, NRAC completed specific enhancements to WCMS-based capabilities and functionality. These included additional Expected Mean Concentration (EMC) modeling coefficients for 10 water quality parameters and 11 different land cover classes. In addition, a new method to calculate runoff using the Natural Resource Conservation Service (NRCS) Runoff Curve Number (RCN) method (Hornberger, et. al. 1998) was integrated into the Landscape Analyst. This method calculates runoff depth based on the soil type, landcover class, and precipitation for a watershed or any area of interest.

Water quality indicators were also developed and added to the water quality portion of the Landscape Analyst extension (see listing above).

Other fundamental enhancements to the water quality modeling components included eliminating cell size dependencies, enabling changes in spatial analysis extent, and

performing functions in an ArcView extension framework (rather than a project) as was the case in WCMS.

2.2 Land Use/Land Cover Change, including Development Model Background

In the original planning stages of this project, the ability to model land use/land cover changes was seen as a key feature of the Landscape Assessment Tools. In the final Landscape Analyst software product, land use change has been incorporated in two different methods: direct editing of land cover grid datasets, and a Development Suitability model developed by NRAC. Since the Development Suitability model was one of the major components of NRAC work on this project, the model is described in detail in this section.

The direct editing of land cover grids in the Landscape Analyst is accomplished through scripts and dialogs assembled by CVI. However, in the earlier stages of the project, NRAC contributed working scripts and dialogs that performed these same functions, although these were not used in the final project.

The Development Suitability Model for land use change analysis was developed through background research and development efforts by NRAC with guidance and input from CVI. In general, models of development predict or analyze suitability for future development (conversion of land uses to commercial, urban, or high density residential areas) based on current land use/land cover and constraints or limitations to such development. Previous models for development investigated by NRAC involved the use of travel cost calculations (based on resistance to "moving" between cells in a raster data framework) but were not used in the final Landscape Analyst extension. This initial development growth model was not used after CVI's related work in Hampshire County, WV suggested that growth was more related to locations of previously undeveloped areas (as opposed to expansion of existing development). For this reason, we instead focused on creating a development *suitability* model.

NRAC adapted literature-based use of fuzzy set or fuzzy logic concepts for use in the Development Suitability Model for the Landscape Analyst. The fuzzy logic framework allows for incorporation of an "error boundary" between data layers while traditional map overlay operations do not (Eastman and Weigen, 1995). A suitability model by definition will use a global approach to modeling, meaning all areas are considered and evaluated. The suitability model developed for the Landscape Analyst takes into account all areas in the predefined study area and allows the user to weight three basic criteria based on user preference to the assigned cutoff values.

The Development Suitability Model contained within the Landscape Analyst extension is based on a combination of relative "scores" for three landscape criteria to determine areas that are more suitable or likely for development to occur. Criteria include: distance to existing development, distance to existing roads, and slope. These criteria reflect landscape factors that make an area more or less suitable than another for potential development into commercial, urban, or high density residential use. These land uses

share some characteristics that make them unique. For example, areas suitable for these uses will have road access nearby, have a favorable slope for construction purposes, and are within a reasonable proximity of other development resources.

NRAC also developed the portion of the Landscape Analyst user interface (the Development Suitability and Development Suitability Results dialogs) that allows the user to change and test different model settings and parameters. The ultimate result of the Development Suitability Model is (if the user wishes) a newly created land use/land cover grid dataset, based on original land use/land cover data and the modeling results.

Because of the many complex issues involved in modeling and predicting development, we feel this approach (which considers existing landscape structure and patterns) holds up well in the absence of information regarding zoning, population trends, local policies, etc. The use of the Development Suitability Model gives the user an idea where the best possible development opportunities exist under current landscape conditions. Results of this model should not be considered an end, but rather a starting point for further analysis of more site-specific local data. While based on commonly used development criteria, the Development Suitability Model and associated user interface is one of the more unique aspects of the Landscape Analyst extension.

2.3 Landscape Indicators

The Landscape Analyst extension includes the ability to calculate a series of Landscape Indicator values for the user's study area. CVI's Valley Forge staff provided valuable assistance in formulating landscape indicator computation algorithms. NRAC modified the algorithms as necessary, integrated them into Avenue scripts, and developed related user interface components where needed. In addition to the actual calculations of the landscape indicator values (for example, percent forested within study area), NRAC also provided related portions of the user interface (including scripts and dialogs) to allow for variation in input datasets.

<u>Indicators</u>

- Percent forested
- Forest edge (approximately 7ha scale)
- Largest forest patch
- Forest interior (multiple scale)
- Road density (vector)
- Road density (raster)
- Human use index
- Agriculture on steep slopes
- Cropland on steep slopes

Additional indicators were considered from the 1997 EPA publication "An Ecological Assessment of the United States Mid-Atlantic Region" (Jones et al. 1997) but were not adopted. The main reason that the additional indicators (such as population change, pesticide loadings, soil loss potential etc.) were not used was that these indicators

required the use of less commonly available datasets. Since the final product is an ArcView extension (requiring users to assemble their own datasets) we did not feel that it was appropriate to require users to obtain these datasets, therefore the indicators were not incorporated.

2.4 Wildlife Indicators

The Landscape Analyst extension (as of December 2001) includes two wildlife-based indicators or models. CVI Valley Forge personnel provided the background information and basic research into these models. Additional models (including whitetail deer, black bear, and other simple Habitat Suitability Index models) may be incorporated at a future date following additional background research and development. NRAC provided the expertise to translate model information into ArcView code.

Indicators:

- Louisiana Waterthrush
- Bird Community Index

Section 3. Documentation

An important aspect of the Landscape Analyst effort was documentation of methods, scripts, and results. NRAC contributed to project documentation in several areas, including written papers, assistance with presentation materials, script and working project documentation, and user manual text.

The Landscape Analyst extension was presented in a moderated paper session at the 21st Annual ESRI International Users Conference in July 2001. NRAC wrote the text of the paper for the Conference Proceedings, with editorial review by CVI's GIS Coordinator and CVI's Valley Forge staff. NRAC also developed the presentation materials (Power Point slides) used for the ESRI presentation. The ESRI presentation was made by Michael Strager, with assistance from Don Kemlage. CVI personnel have since made several presentations and demonstrations of the Landscape Analyst extension to internal and external groups.

During the project time period, NRAC provided extensive documentation of working versions of the Landscape Analyst extension ArcView project file. Documentation was in the form of detailed descriptions of changes to the project file (i.e. new scripts, changed scripts, new dialogs, new graphics files). Documentation is also provided informally in individual scripts in the form of comments and header file information.

CVI has taken on the task of assembling the Landscape Analyst extension user manual in HTML format. NRAC contributed text and graphics for portions of the user manual that were directly related to NRAC work, including the Water Quality, Wildlife, and Landscape models, tools, and indicators, as well as background information on many of the extension's modeling components and specialized user interface dialogs.

Section 4. Internal Project Review

At various times throughout the project period, NRAC contributed informally to an ongoing project review process. The process of documenting bugs or suggested changes to the project became more formalized through CVI's creation of the Landscape Analyst Software Development System web page, whereby users and others enter bugs or software issues into a common database. NRAC has provided feedback and suggestions to CVI regarding the look and feel of the software, as well as regarding certain aspects of the software's functioning. NRAC comments and concerns have been provided in writing to CVI and/or have been entered into the Software Development System web page database.

NRAC has also addressed all user comments to date regarding NRAC's portion of the work contained within the Landscape Analyst extension. As of December 2001, comments have been received from CVI's Valley Forge office as well as an internal NRAC reviewer (Geraldine Jones). We appreciate the efforts of these reviewers, and anticipate quick resolution of any issues or bugs uncovered by future users as well.

Section 5. Future Work

There are several future directions for work related to the current version of the Landscape Analyst extension. NRAC welcomes the opportunity to continue refinement of existing capabilities within the extension, as well as the opportunity to incorporate new functionality based on the ideas of all involved in the project. Refinements of existing capabilities could include more information to allow users to interpret the results generated (for example, if a user runs Expected Mean Concentration modeling to obtain nitrogen loadings, provide the user with pertinent information on nitrogen loading rates considered to be in violation of various state water quality standards).

Ideas for new functionality of the Landscape Analyst were generated at several meetings held throughout the course of the project. Unfortunately not all of these valuable ideas could be incorporated during the first phase of this project, completed in December 2001. Ideas put forth included:

- Incorporation of optimization routines
- Percent impervious index
- Incorporation of Gap Analysis data & results
- Population change analysis
- Incorporation of census data

Due to the nature of the specialized datasets required, some of the ideas for new functionality might best be served in ArcView or ArcGIS customizations or programs that are ultimately independent of the Landscape Analyst extension product.

Section 6. Summary

Since late fall of 2000, the Natural Resource Analysis Center at West Virginia University has cooperated with the Canaan Valley Institute to produce the Landscape Analyst Extension for ArcView 3.x. The Landscape Analyst extension allows the user to run models and calculate indicator values for a variety of water quality, landscape, and wildlife related functions. NRAC involvement in this project included cooperative meetings, research and development of both new and existing functionality, ArcView customization and code development, and documentation. NRAC benefited from CVI's work on this project, which included background research, ArcView extension user interface and code development, extension documentation, and meeting coordination.

We feel that the resulting Landscape Analyst extension is a useful contribution to the field of landscape-based assessment within a Geographical Information Systems framework. Overall, the extension has a good deal of unique content and offers advantages for users when compared to related efforts in this field.

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