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# Integrating Build-Out Analysis and Water Quality Modeling to Predict the Environmental Impacts of Alternative Development Scenarios

A report prepared for the Chesapeake Bay Program

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Chesapeake Bay Program

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The U.S. Environmental Protection Agency; Maryland Office of Planning; Buzzards Bay Project; Thomas Jefferson Planning District Commission; National Oceanic and Atmospheric Administration; Massachusetts Bays Program; Orange Water and Sewer Authority; State Highway Administration, Maryland Department of Transportation; Johnson County Planning Office; and the College of William and Mary.

# EXECUTIVE SUMMARY

This report provides background information on the use of build-out analysis and water quality/environmental modeling as land planning and water quality predictive management tools. It also provides information helpful in assessing the utility of certain versions of these tools for use by the Chesapeake Bay Program in meeting the goals set forth in the *Chesapeake Bay Agreement* and elsewhere.

This report originated from the land management and protection goals set forth in the 1987 *Chesapeake Bay Agreement* and its 1992 amendments, from the priorities set forth in the Chesapeake Bay Program's 1996 report *Priorities for Action for Land, Growth and Stewardship in the Chesapeake Bay Region*; and from the Chesapeake Executive Council's *Adoption Statement on Land, Growth and Stewardship.*

This report provides background information helpful in determining if some form of build-out analysis/water quality modeling methodology exists that could help meet the goals of the Chesapeake Bay Program. It contains summaries of fourteen build-out analyses that have been conducted in various regions of the United States, including the Chesapeake Bay watershed, to predict the character of future landscapes of specific land areas such as watersheds and counties. A number of these analyses also modeled impacts on water quality or other environmental attributes that might result from the predicted changes in landscapes. In addition, the report provides general background information on both build-out analysis and water quality and environmental modeling, including a discussion of the purposes for these types of tools and models, brief descriptions of common versions of each, and alternative ways they can be applied to meet typical objectives.

Five of the build-out analysis methodologies are summarized in-depth in the main body of the document, while nine others are presented as two-page fact sheets. The five selected for in-depth summary receive greater attention because they include both build-out analysis and water quality or environmental modeling components in the same study and seem to have particular relevance to the Chesapeake Bay. The nine fact sheets summarize studies that focused primarily on build-out analysis methodologies, and not necessarily the application of water quality or environmental models.

The final chapter, "Evaluating Build-out Analysis and Water Quality Modeling Methodologies for Potential Use by the Chesapeake Bay Program," presents suggested criteria that can be used to evaluate the kinds of methodologies presented in this report. The criteria were developed by the Chesapeake Bay Program, and are: 1) Accuracy in predicting environmental impact; 2) Cost; and 3) Computer and staff resources required. These three general categories allow for evaluation based on some of the most important criteria that should be considered when evaluating alternative methodologies for further study or promotion.

Finally, Appendix A includes a detailed discussion of the potential role of the Chesapeake Bay Program's Hydrologic Simulation Program-Fortran (HSPF) Watershed Model in conducting build-out analyses, concluding that certain aspects of the model and its output could be useful, but full-scale model runs likely would not.

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# I. INTRODUCTION

This report provides background information on the use of build-out analysis and water quality/environmental modeling as land planning and water quality predictive management tools. It also makes a number of recommendations on the potential utility of certain versions of these tools for use by the Chesapeake Bay Program in meeting the goals set forth in the 1987 *Chesapeake Bay Agreement* and elsewhere.

> **What is a Build-Out Analysis?**
>
> A build-out analysis is a method used to predict the development potential of future landscapes of specific land areas, such as watersheds or counties. It is commonly used to answer questions such as "What is the maximum amount of development that could occur here?", or "Will public services be adequate to meet the needs of all future residents?"

The report contains summaries of fourteen build-out analyses that have been conducted to predict the character of future landscapes of specific land areas, such as watersheds and counties. A number of these analyses also modeled impacts on water quality that might result from the predicted changes in landscapes. Such analyses can be used to help predict whether future land use patterns may result in high pollution loads delivered to impacted water bodies, and this information can be used to catalyze changes in zoning and land management where necessary to maintain pollution at or below acceptable levels. In addition to summaries of projects that have been undertaken, this report provides general background information on both build-out analysis and water quality modeling, including a discussion of the purposes for these types of tools and models, brief descriptions of common versions of each, and alternative ways they can be applied to meet typical objectives.

## ORIGIN OF STUDY

In 1983 Maryland, Virginia, Pennsylvania, the District of Columbia, the U.S. Environmental Protection Agency, and the Chesapeake Bay Commission signed the *Chesapeake Bay Agreement*, which was strengthened in 1987 and amended in 1992. The *Agreement* commits the signatories to, among other things, implement strategies in each of the tributaries to the Chesapeake Bay that will result in a reduction of nutrients necessary to support living resources in both the Bay and its tributaries.

One of the formal Goals of the *Chesapeake Bay Agreement* is to "Plan for and manage the adverse environmental effects of human population growth and land development in the Chesapeake Bay watershed." One of the primary ways this Goal is being addressed is through the actions of the

Chesapeake Bay Program's Land, Growth and Stewardship Subcommittee (LGSS). As set forth in its mission statement, the Subcommittee is responsible for:

> *Identifying growth and land use issues of a Bay-wide nature, addressing development topics, and forging alliances with other organizations and interests to: 1) Promote sound land management decisions; 2) provide growth projections and assess the impacts of existing growth on the Bay and its tributaries; and 3) encourage public and private actions to reduce the impacts of growth.*

The CBP further refined these broad goals in its report *Priorities for Action for Land, Growth and Stewardship in the Chesapeake Bay Region*, released on October 10, 1996. Drawing from the report's recommendations, the Chesapeake Executive Council's *Adoption Statement on Land, Growth, and Stewardship* (October 10, 1996), directed the Chesapeake Bay Program to:

> *Identify models, technologies and practices, that can be used to assess and minimize the impacts of different development patterns and land use designs on nutrient loadings to the Bay. This information will be useful to state and local jurisdictions as they work to achieve the nutrient reduction and habitat restoration goals of the Program. The Chesapeake Bay Program will communicate and distribute collected materials on these models, technologies and practices to local governments, land use decision-makers, practitioners, realtors, homebuilders, and other stakeholders.*

The Chesapeake Bay Program has undertaken a number of projects pursuant to the objectives set forth in the Chesapeake Bay Agreement, the *Priorities for Action* report, and the Executive Council *Directive*. In July, 1996, CBP hosted a workshop at the Chesapeake Bay Program Office that brought together land use and demographic experts from State and local government agencies and academic institutions located throughout the Chesapeake Bay watershed. The workshop focused on alternative methodologies for conducting projections of future land use/land cover, and for conducting population projections. Also discussed in general terms was the use of build-out analysis as a tool to forecast future land development in a given land area, such as a watershed or county.

Participants at the July workshop made a number of recommendations to the Chesapeake Bay Program, among which was to promote further study of the potential of build-out analysis as a tool to promote land management that resulted in less environmental degradation, particularly less nutrient pollution to tributaries of the Chesapeake Bay. This report was prepared, in part, as a response to that request.

## PURPOSE OF STUDY

Thè purpose of this study is to provide background information necessary for determining if some form of build-out analysis/water quality modeling methodology exists that would be useful in helping to meet the goals of the Chesapeake Bay Program in promoting land development patterns that protect water quality. In particular, this study was undertaken to accomplish the following:

- To examine the utility of build-out analysis and water quality modeling as tools for local and regional land use and environmental planning

- To document as case studies relevant build-out analysis/water quality modeling projects that have been conducted in the Chesapeake Bay region and elsewhere

- To determine the feasibility of the Chesapeake Bay Program's Watershed Model and other watershed and water quality modeling tools that could be used in conjunction with build-out analysis

- To recommend one or more methodologies that the Chesapeake Bay Program may be able to promote or use for conducting build-out analysis/water quality modeling.

The remainder of this document is organized in three chapters and two appendices. Chapter II discusses build-out analysis as a planning tool. Chapter III contains several in-depth build-out analysis/water quality modeling case studies. Chapter IV consists of an evaluation of different kinds of build-out analysis and water quality modeling techniques and practices, and presents a ranking scheme to help determine which technique may be most appropriate for different needs. Appendix A contains an evaluation of the potential role of the Chesapeake Bay Program's Watershed Model in conjunction with build-out analyses. Appendix B contains nine summary fact sheets of build-out analysis/water quality modeling projects that have been completed throughout the United States and Canada.

# II. BUILD-OUT ANALYSIS AND WATER QUALITY MODELING AS A PLANNING TOOL

Build-out analysis, traditionally a land planning tool, can be combined with water quality modeling to predict the water quality impacts of alternative development scenarios. This chapter describes build-out analysis techniques and their integration with water quality modeling and other modeling approaches.

## BUILD-OUT ANALYSIS

As noted in the Introduction, a build-out analysis is a tool typically used by land use planners to predict future development patterns for a specific land area, such as a town, county, or watershed. A land area is considered "built-out" if all development allowed by zoning regulations and local by-laws and ordinances has occurred, and no further development is possible under existing regulations. Typically, a build-out analysis is conducted by first inventorying current land development patterns and characteristics, and then estimating the number and type of developments (e.g., single family homes), that could be accommodated in all land areas zoned for, but currently absent of, development (e.g., forested areas). Also common are "partial" build-out analyses, which analyze the number and type of developments at a certain point in time, or at a certain population. For example, a partial build-out analysis may be targeted to the year 2010, or to the addition of 100,000 residents.

Build-out analyses can be conducted to serve a number of purposes. Most commonly, they are undertaken by local or regional land use planning departments to determine whether the capacity of public services such as public schools, fire departments, roads, road intersections, sewer networks, and sewage treatment plants will be sufficient to serve the community if partial or full development potential is reached. Such analyses are sometimes combined with population projections for the same area, in order to predict development patterns at specific points in the future, such as 10 years from the present. Exhibit 1 provides an example of an analysis of a partial build-out scenario.

**Exhibit 1. A Simple Example of a Build-Out Analysis**

A county planner may wish to determine where and how much development will occur by the year 2020, based on U.S. Bureau of the Census projections that 100,000 additional people will live in the county by that time (a population projection is used here, but is not necessary to conduct a build-out analysis). In a simplified method, this 100,000 figure could be divided by the county's average number of residents per household, producing an estimated number of additional residential housing units. In this example, assume that the average household size is 4. Dividing 100,000 by 4 yields an estimated 25,000 new residential housing units by the year 2020. This number is then multiplied by the average number of acres that a typical housing unit currently occupies in that county, and the result is subtracted from the total acres of undeveloped land in the county zoned for development. If the average lot size for residential housing units in this county were one acre, the 25,000 new units would consume 25,000 acres of currently undeveloped land. If there were currently 45,000 acres of undeveloped land zoned for residential development in the county, this build-out analysis would indicate that over 55 percent of developable land would be developed by the year 2020, and that only 45 percent of undeveloped land would remain.

If full-build out will not be reached by the specified point in time (as was the case in the example in Exhibit 1), the analysis is called a "partial" build-out analysis. An actual example of such an analysis is the Maryland Office of Planning's study *Developing Growth Management Options for Maryland's Tributary Strategies*, reviewed in this report, which based its analysis on potential development patterns in the year 2010.

In general, it is possible to classify build-out analysis methodologies into three basic categories for purposes of comparison. There are a large number of variations to methodologies that do not fit neatly into any of these three categories, but the following descriptions provide basic working definitions that should aid the reader in using this report.

## Parcel-Level, Manual

This method involves forecasting potential development in a geographic area through a process of manually drawing potential roads, structures, and other types of development onto paper maps until all developable land areas are consumed. Individual development parcels are drawn onto undeveloped areas on maps based on zoning requirements for minimum lot size, frontage, and other constraints. Due to the time required to draw developments by hand, this method is only feasible for relatively small areas, such as a town or small county. However, it is an inexpensive method that requires little or no resources aside from paper maps and traditional drafting tools (such a manual method is described in high detail in the handbook *Manual of Build-out Analysis*, cited at the end of this report in "Relevant Literature.")

## Summed Area, Manual

This method can be used as an alternative to the parcel-level analysis. Using this method, development can be measured in a less precise, but much faster manner. Using a planimeter or other device to measure areas zoned for development on paper maps, the researcher sums the total acreage available for development in the study area and then divides this number by an average that represents typical housing unit lot size, plus a percentage representing required land that must be reserved for frontage and infrastructure. The result is an estimate of the total number of new residential lots that would be developed under build-out conditions. This method is less precise than the parcel-level method because it does not account for different development patterns that result from the size and shape of developable areas. For example, a long, narrow land area may comprise adequate acreage for 20 residential housing unit parcels, but not reach that level of development because parcels might not fit on either side of the road that currently runs down the middle due to frontage and road right-of-way requirements. This method is particularly appropriate for land areas too large to feasibly examine using the parcel-level method, or when a rough average is appropriate to answer the questions posed by the study.

### Geographic Information System

This method is the fastest of the three ways to conduct a build-out analysis. The method is essentially the same as the summed area method described above, but the calculation of total area is conducted using a geographic information system (GIS), rather than a human being. This is particularly useful when the land area is large and would require many hours of calculation by hand. In addition, the GIS could be configured such that development is projected into undeveloped areas in such a way as to maximize the number of units that could be accommodated. In other words, the GIS could determine the most efficient spatial patterns required to fit the largest number of development parcels in the developable areas, taking into account the size and shape of each area.

## WATER QUALITY MODELING

In this report, the term "water quality modeling" is used to refer to a range of models that predict the quality of runoff from land. Based on the number of processes they incorporate and level of detail they provide, existing water quality models can be grouped into three categories:

1) Simple models
2) Mid-range models
3) Detailed models

### Simple Models

Simple water quality models can provide a rapid estimate of pollutant loads with minimal effort and required data input. However, they provide only a rough estimate of sediment and pollutant loads, because they are not sophisticated enough to account for seasonal variations in meteorological conditions such as temperature and rainfall. Typically, simple models consist of a list of land use coefficients that translate an acre of land into a quantity of water pollution, based on the type of land and quantity of water or time involved. For example, a simple water quality model may consist of a computer spreadsheet containing estimates of the quantity of nitrogen produced per year per acre of agricultural land, forest land, and urban land in various columns. Within the spreadsheet, in another column, the actual acreage of each of these land use types in the overall land area under study can be entered. Multiplying all coefficients by all total acreages yields estimates of nitrogen produced per land use type per year, and the sum of these sub-totals represents all modeled nitrogen produced in the study land area per year. This procedure can be represented by the following equation:

(acres per land type)*(runoff coefficient per land type) = (load per land type)

Simple models can help determine the order of magnitude of pollution runoff from different land areas. They are effective at producing rough estimates quickly, which can help target further research priorities. Once that has been accomplished, it may be appropriate to engage a more sophisticated model in order to improve the precision of the analysis.

## Mid-Range Models

With slight modifications to a simple model, such as the addition of attenuation factors that account for changes in topography and distance, the transport of nitrogen through different land areas on route to water bodies can be more effectively modeled. These types of models can be classified as "mid-range." Improved precision, especially in terms of accounting for differences based on the location of the land areas being studied, is important because certain land types can serve as nitrogen sources, and others sinks. In general, the more a model simulates actual processes that occur as rain or other water travels on or through land, the more accurate are the resultant estimates of pollution in reaching water bodies.

## Detailed Models

The highest accuracy is found in detailed models, because they are designed to account for all physical and biological processes that occur in a watershed, as well as the influence of management practices such as application of best management practices (BMPs). Detailed models, often referred to as watershed models, are tools that evaluate or estimate point and nonpoint source loads from watersheds containing multiple pollutant sources and land uses. Typical model inputs include: time history of rainfall, temperature and solar radiation, land surface characteristics such as land use/land cover, and management practices such as nutrient management, and agricultural best management practices BMPs. Watershed models are usually technically complex and require a team of computer programmers and other technicians to calibrate and operate. If they are properly applied and calibrated, detailed models can provide an accurate prediction of pollution runoff water quality at any place in the study watershed. This additional precision, however, comes at the cost of much more time and resources to operate.

A number of build-out analyses evaluated in this report incorporated models to predict water quality resulting from different land uses. One, the Maryland Office of Planning's model, described in this report under the title *Growth Management for Watershed Protection*, incorporated a detailed model (a watershed model). Others, such as the Buzzard's Bay Project's build-out analysis of Buttermilk Bay, utilized a mid-range model. The choice of whether to use a detailed model or a more simplified model is often determined by the size of the study area and resources of the organization conducting the analysis. The larger the study area, the greater the need to account for processes affecting the transportation of pollutants from points of origin to receiving water bodies, which favors use of a detailed (watershed) model. For this reason, small organizations with limited financial and computer resources are more likely to analyze smaller areas, using simple or mid-range, rather than detailed, models.

This report contains a description of one highly sophisticated detailed (watershed) model currently being used by the Chesapeake Bay Program. The Chesapeake Bay Program's HSPF Watershed Model, discussed in Appendix A, is evaluated in this report for its potential use in conjunction with build-out analyses to predict the water quality impacts of alternative development scenarios. The Chesapeake Bay Program's Hydrologic Simulation Program-Fortran (HSPF) Watershed Model is used to simulate and help quantify the amount of nitrogen and phosphorous entering the Chesapeake Bay from its many tributaries. The Model is also used to help track progress in reducing the concentrations of these nutrients in the Bay 40 percent from 1985 levels by the year 2000, as set forth in the 1987 *Chesapeake Bay Agreement* and its 1992 amendments.

## USE OF WATER QUALITY AND OTHER MODELS IN CONJUNCTION WITH BUILD-OUT ANALYSES

As noted above, water quality models can be used to simulate pollutant loads delivered to water bodies from an inventory of current land use/land cover types. They can also simulate pollutant loads from past or future inventories of land use. The key input for these models is the appropriate land use input data; it makes no difference whether that data originated from a survey of current land use, or from a build-out analysis of project land use twenty years hence. For this reason, build-out analyses and water quality models can be applied in unison to predict the water quality impacts of alternative land development scenarios, whether under full build-out or any number of partial build-out conditions.

Four of the five in-depth build-out analysis summaries presented in the following section, "Growth Management for Watershed Protection"; "Buzzards Bay Project"; "Geographic Analysis of Bacterial Contamination"; and "Cane Creek Watershed Study," included some form of water quality modeling in the evaluation of their study land areas under partial or full build-out conditions.

The fifth study, "Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California," presents possible impacts on biological diversity from alternative development scenarios in the region of Camp Pendleton, CA. This study, although not focused on water quality, was included in this report to highlight the fact that there are other forms of environmental modeling in addition to watershed or water quality modeling that are appropriate for use with build-out analyses. In addition to models of biological diversity, there are also models that predict the air and water quality impacts of transportation-related forms of development, such as roads, highways, and vehicle-emitted pollution.

# III. BUILD-OUT ANALYSIS/WATER QUALITY MODELING CASE STUDIES

One of the primary purposes of this report is to provide information on build-out analysis and water quality modeling projects that have been undertaken in the Chesapeake Bay watershed and elsewhere. The intent is to provide members of the Chesapeake Bay Program (CBP) and particularly the Land, Growth and Stewardship Subcommittee (LGSS) with sufficient background information on these techniques to make informed decisions about whether to pursue application of build-out analyses and water quality modeling as tools to meet CBP objectives, and if so, which of the tools to investigate further.

In the following pages, five build-out analyses are summarized in-depth. A further nine build-out analyses are summarized in Appendix B as two-page fact sheets. The first five summaries were selected for in-depth review because they involved both build-out analysis and water quality or other environmental impact modeling (e.g., impacts on biodiversity). The nine fact sheets in Appendix B also provide useful background information about various build-out analysis methodologies, but they do not have sufficient emphasis on water quality or environmental modeling to warrant inclusion as in-depth summaries.

## RESEARCH METHODS

The fourteen build-out analysis case studies presented in this report were compiled through a combination of literature review, and telephone and personal interviews. Published reports and supporting documents were reviewed as primary information sources, with follow-up interviews to fill-in missing information and verify researchers' findings. In many cases, language contained in published documents was copied directly for use in the summaries and fact sheets. In addition, interviews often resulted in suggested wording from interviewees which was also incorporated directly. All summaries and fact sheets contain citations indicating where the information and text in the summary or fact sheet originated from.

Research for all summaries and fact sheets proceeded in an iterative fashion. Beginning with initial contact information and documentation on-hand at the Chesapeake Bay Program Office, a first set of projects was selected for research. During this initial research phase, additional projects and contacts were identified through communications with individuals involved with the projects selected for initial research. This process of identifying new projects and contacts ended when the Chesapeake Bay Program determined that a sufficient range of projects and models had been identified to meet the needs of this summary document.

It should be noted that the level of detail presented in each of the case studies varies, particularly in the "Methodology" sections. Many summaries present detail sufficient for the reader to follow and understand each step of the project from start to finish, while others provide less detail. Attempts were made to directly contact and/or exchange draft materials with the project principal investigators or other contacts. Unfortunately, contact and exchange of materials was not possible in all cases. For example, some principle investigators actually wrote materials that were included in the summaries and/or fact sheets, while other researchers were unable or unwilling to participate. Nonetheless, the case studies presented in this report provide a large amount of information, and indicate where further information can be obtained by an interested individual through contact information, World Wide Web and E-mail addresses, and relevant literature.

## OVERVIEW OF PROJECT SUMMARIES PRESENTED IN THIS REPORT

Table 1 summarizes the project summaries and fact sheets included in this report, in the order that they appear. The first five listed are in-depth summaries, while the remaining nine appear as two-page fact sheets in Appendix B.

### Table 1. Build-Out Analyses Reviewed in This Report

| Title of Report, Analysis, or Model | Sponsoring Organization | Geographical Location of Study Area | Page Location in this Report |
|---|---|---|---|
| Developing Growth Management Options for Maryland's Tributary Strategies | Maryland Office of Planning, Baltimore MD | Three MD watersheds: the Patuxent, Lower Potomac, and Lower Western Shore | 14 |
| Use of a Geographic Information System to Estimate Nitrogen Loading to Coastal Watersheds | Buzzards Bay Project, Marion MA | Buttermilk Bay, embayment of Buzzards Bay, south-eastern coast of Massachusetts | 28 |
| Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California | Harvard Graduate School of Design, Utah State University, National Biological Service, and USDA Forest Service, Nature Conservancy, and the Biodiversity Research Consortium | Region of Camp Pendleton, CA (located between Los Angeles and San Diego) | 39 |
| Geographic Analysis of Bacterial Contamination, Ipswich, Beverly, and Provincetown | Massachusetts Bays Program, Executive Office of Environmental Affairs, Boston MA | Case study communities of Ipswich, Beverly, and Provincetown, MA | 52 |
| Cane Creek Reservoir Watershed Study - Draft Report August 1996 | Orange Water and Sewer Authority | Carrboro, NC | 61 |

| Title of Report, Analysis, or Model | Sponsoring Organization | Geographical Location of Study Area | Page Location in this Report |
|---|---|---|---|
| Ground Water Supply Protection and Management Plan for the Eastern Shore of Virginia | Horsley Witten Hegemann, Inc., for Eastern Shore of VA Ground Water Study Committee | Eastern Shore, VA | B-1 |
| Living With the River: A Development Management Plan for the Severn River Watershed to the Year 2020 | The Severn River Commission (prepared by Land Ethics and Dodson Associates) | The Severn River watershed, Anne Arundel County, MD | B-3 |
| U.S. 301 Transportation Study Technical Report: Land Use and Growth Management | Maryland State Highway Administration | Route 301 corridor from the Potomac River to Rt. 50 | B-5 |
| Build-out Analysis of the Thomas Jefferson Planning District - Second Draft | Thomas Jefferson Planning District Commission | Charlottesville, VA | B-7 |
| Lancaster County Comprehensive Plan: Growth Management Plan | Lancaster County Planning Commission | Lancaster County, PA | B-9 |
| U.S. EPA Clean Lakes Report for the Occoquan Watershed | Northern Virginia Planning District Commission | Parts of Loudon, Fairfax, Prince William, and Fauquier Counties | B-11 |
| Alternative Futures for Monroe County, Pennsylvania | Harvard Graduate School of Design, funded by EPA RIII | Monroe County, PA | B-13 |
| Hillsdale Lake Watershed Population and Land Use Projections, 1990 - 2010, for the Hillsdale Lake Nutrient Study | Johnson County Planning Office | Johnson, Douglas, Franklin, and Miami Counties, KS | B-15 |
| Buildout Analysis on a GIS | Edward Lyman (MA Thesis, University of Vermont) | Four case study build-outs: two in Woodstock, Ontario, Canada; one in the Thomas Jefferson Planning District VA (reviewed here); and one in San Diego | B-17 |

## IN-DEPTH CASE STUDIES

The following section contains in-depth summaries of five build-out analysis projects that incorporate water quality and/or environmental modeling. As noted earlier, these projects are summarized in-depth due to their particular relevance to the Chesapeake Bay Program (described in each summary), and their focus on both build-out analysis and water quality/environmental modeling, rather than on build-out analysis alone. Each case study begins with a summary box containing basic information about the project, including contact information for key individuals. Subsequent sections of each summary describe the following:

- Introduction and Purpose of Study
- Relevance to the Chesapeake Bay Program
- Size and Geographic Boundaries of Study
- Description of Landscape
- Applicability of Method to Other Geographic Areas and Scales
- Alternative Development Scenarios Considered
- Methodology
- Study Results and Findings
- Types of Data Required for Model
- Data Acquisition and Level of Effort
- Required Computer and Other Resources
- Format of Final Product
- Lessons Learned and Alternative Approaches
- Additional Information, and
- Sources of Information and Text in this Fact Sheet.

## GROWTH MANAGEMENT FOR WATERSHED PROTECTION IN MARYLAND

| | |
|---|---|
| **TITLE OF PROJECT/REPORT:** | Developing Growth Management Options for Maryland's Tributary Strategies. Managing Maryland's Growth, Growth and Watershed Planning Series. Draft, March 1997. |
| **RESEARCH CONDUCTED BY:** | Maryland Office of Planning; Anne Arundel, Calvert, Charles, Harford, Howard, Montgomery, Prince George's, and Saint Mary's counties; Patuxent River Commission. |
| **SPONSORING ORGANIZATION(S):** | Maryland Office of Planning. |
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| **E-MAIL:** | Joe@mail.mop.md.gov |
| **PHONE NUMBER:** | (410) 767-4500. |
| **STUDY COMPLETION DATE:** | Publication expected January - February 1998. |
| **PROJECT LOCATION:** | The Patuxent River, Lower Potomac, and Lower Western Shore watersheds, located in central & southern Maryland. |

### INTRODUCTION AND PURPOSE OF STUDY

The State of Maryland, in cooperation with the Chesapeake Bay Program, has established 10 Tributary Strategies to reduce nutrient pollution in each of the State's major tributaries to the Chesapeake Bay. The goal for each tributary of a 40 percent reduction from 1985 levels was set in the 1987 *Chesapeake Bay Agreement* and its 1992 amendments, to which Maryland is a signatory.

In many areas in Maryland projected for large population increase and rapid development, tributary-specific nutrient loading "caps," necessary to keep the total contribution of nutrients to the Chesapeake Bay at or below 60 percent of 1985 levels, are projected to be exceeded by the year 2010 unless better planning and coordinated growth management and nonpoint source pollution controls are implemented. In order to meet that goal, the Maryland Office of Planning is working with State and local agencies responsible for managing growth and new development to examine the potential effects of their management actions on land resources, nutrient pollution loads, and local water resources.

This is being accomplished in large part through a Watershed Planning System that incorporates both build-out analysis and water quality modeling. It is designed to coordinate planning and management for growth and new development by watershed, and to predict future water quality-related characteristics of the watershed under alternative development scenarios. The System is intended to help local governments, State agencies, and Maryland's Tributary Strategy Teams more effectively pursue management of land development to enhance watershed protection. The draft report highlighted here provides guidelines for assessing the potential impacts of growth on local land resources and streams, and on Maryland's Tributary Strategies and the Bay. It identifies growth management activities that will contribute to the success of the Strategies while protecting local watersheds; and it quantifies the effects of "watershed planning" and "resource protection" management options defined in Maryland's Tributary Strategies.

The Patuxent River Demonstration Project is one of several pilot projects that have been undertaken by the Maryland Office of Planning to help meet the goals of the Tributary Strategies, and to maintain the nutrient "caps" after the year 2000. Several other pilot projects contributed to development of the featured report, in addition to the Patuxent River Demonstration Project. These include projects in the Winter's Run watershed (Harford County); Piney-Alloway Creeks watershed (Carroll County); Lower Potomac watershed (Charles, Prince George's, and Saint Mary's counties); and the Lower Western Shore watershed (Anne Arundel and Calvert counties).

## RELEVANCE TO THE CHESAPEAKE BAY PROGRAM

The Maryland Office of Planning is an active participant in the Chesapeake Bay Program, and, as noted above, has developed its Watershed Planning System in large part to help meet the nutrient reduction goals set forth in the Chesapeake Bay Agreement for Maryland's tributaries. The Office's work with the Watershed Planning System in the Patuxent River Demonstration and other pilot projects is relevant for the following reasons:

- Several of the pilot projects were conducted in large watersheds which are major Bay tributaries: the Patuxent, 560,000 acres; the Lower Potomac, 470,000 acres; and the Lower Western Shore, 171,000 acres. Analyses for each project took place at a "subcatchment" level, i.e., subwatersheds ranging in size from 1,100 to 20,000 acres. The Chesapeake Bay Program will likely consider a wide range of scales for potential application of build-out analyses, including analyses that may be conducted on large land areas within the Chesapeake Bay watershed.

- The Watershed Planning System has a high degree of flexibility in terms of data required for input. The System can function with both highly detailed data (e.g., at the individual land parcel level) and more generalized data (e.g., satellite images). This flexibility could prove useful for analysis within the Chesapeake Bay watershed, because data managed by different States and local jurisdictions on the land areas they manage is of widely differing levels of detail. For example, a methodology identical to the one employed by the Maryland Office of Planning in its analyses for the three tributary watersheds could not be used on the entire Chesapeake Bay watershed, due to the lack of comparable land use data in all locations (Virginia, Pennsylvania, and New York do not maintain land use data in as much detail as does Maryland). However, it could be adapted to represent generalized scenarios commensurate with available data.

## SIZE AND GEOGRAPHIC BOUNDARIES OF STUDY

The Patuxent River watershed is located in central Maryland. It is approximately 930 square miles (577,000 acres) in size. The watershed includes parts of seven Maryland counties: Howard, Montgomery, Anne Arundel, Prince George's, Calvert, Charles, and St. Mary's, with no county located entirely within the watershed. The Lower Potomac watershed (470,000 acres) is comprised of parts of Prince George's, Charles, and Saint Mary's counties; the Lower Western Shore (171,000 acres) is comprised of parts of Anne Arundel and Calvert counties.

## DESCRIPTION OF LANDSCAPE

The Lower Western Shore is a small, relatively highly developed (33%) watershed with relatively little agriculture (14%). Although it has the lowest projected rate of growth of the three tributaries (a 31% increase in households by 2010), the total amount of growth expected relative to watershed size (.15 households per watershed acre) suggests that growth will be an important factor affecting future pollution levels. Current programs in the watershed have the highest potential among the three tributaries to accommodate growth in sewered areas at relatively high densities.

The Lower Potomac is a large rural watershed. It is expected to grow at the fastest rate (a 72% increase in households), but the total amount of growth expected is smaller relative to tributary size

(.08 households per watershed acre) than in the other two tributaries. The potential to accommodate growth in sewered areas is the lowest of the three tributaries, as is the potential to concentrate growth at higher densities.

The Patuxent is a large heterogeneous watershed (24% developed, 45% forest, and 27% agriculture). Compared to the other two tributaries, a moderate rate of growth is projected (54% increase in households), but growth is likely to be a very important factor because the amount of growth expected is large relative to tributary watershed size (.16 households per watershed acre). Capacity for growth in sewered areas at higher densities is higher than in the Lower Potomac and slightly lower than in the Lower Western Shore.

## APPLICABILITY OF METHOD TO OTHER GEOGRAPHIC AREAS AND SCALES

The Maryland Office of Planning's Watershed Planning System can be applied to a variety of geographic areas and scales. For smaller areas, a greater level of detail can be incorporated, depending on data availability from the county(ies) included. For larger areas, a "coarser" analysis based on more limited data is preferable due to likely constraints on resources and the type of data analysis possible. Because of its flexibility, no land area is, *a priori*, too small or too large to be analyzed with the Watershed Planning System. The dominant constraints are data availability and the financial and staff resources of the entity conducting the analysis.

## ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED

The Maryland Office of Planning modeled land and water resource impacts in the three tributaries based on three primary alternative development scenarios. Each scenario was modeled out to the year 2010 using population, housing, and employment projections:

1) **2010 Base Zoning.** *Base Zoning* scenarios portray new development according to current zoning, but without the influence of other existing county subdivision and environmental ordinances, and without BMPs for nutrient pollution control. The effect of wetlands and forested riparian areas on pollution loads is estimated for those areas that remain in 2010, in the absence of resource protection programs to preserve them. *Base Zoning* provides a 2010 "worst case" scenario, against which the performance of growth management and pollution control measures in the other scenarios can be evaluated.

2) **2010 Current Programs.** This scenario estimates the effects of existing programs for growth management and pollution control. New development occurs according to current zoning, subdivision, and associated environmental regulations and requirements. Implementation of

agricultural nonpoint source pollution control measures is projected to occur at approximately current rates to the year 2010. Implementation of Stormwater Management practices represents counties' current stormwater management programs, according to the guidelines provided by each county. The effect of wetlands and riparian areas on pollution loads is estimated for those that remain in 2010 under current protection programs and growth management options.

3) **2010 Directed Growth.** "Directed Growth" scenarios include enhanced levels of growth management, land conservation, and pollution control practices. They essentially represent the Tributary Strategies, modified to account for growth to the year 2010, associated changes in land use, and the effects of alternative growth management options. Growth management options simulated under *Directed Growth* included a number of innovative planning, zoning, subdivision, and resource protection techniques (see below). Agricultural pollution control measures modeled were those specified in the Tributary Strategies. Stormwater management program requirements are essentially the same as those represented under *Current Programs*. The effect of wetlands and riparian areas on pollution loads is estimated for those areas that remain in 2010 as a result of the growth management and resource protection techniques simulated.

Within the 2010 Directed Growth scenario, eight specific options for growth management and resource protection were simulated:

- Forest Conservation;
- Stream Buffer Protection;
- Rural Clustering;
- Increased Development Potential in Growth Areas;
- Transfer of Development Rights (TDR) to Growth Areas;
- Extending Sewer Service in Designated Growth Areas;
- Protective Agricultural Zoning; and
- Purchase of Development Rights.

Specific details of each option are presented in the Office of Planning's report.

## QUESTIONS AND VARIABLES INCLUDED IN STUDY

The following questions and variables were addressed in the build-out analyses:

### Questions

- If current growth management and pollution control programs were practiced, and growth occurred as projected to the year 2010, what would be the effects on local streams, land resources, stream buffers, and nutrient loads? What if other management options for *Directed Growth* and pollution control were practiced instead?

- What effect will growth management have on overall pollution levels, compared to Best Management Practices (BMPs) for pollution control?
- What changes can be expected in each tributary and subwatershed under each of the development scenarios considered, in each of the following issue areas:
  a. Loss or gain of forest cover, both riparian and upland;
  b. Loss of agricultural land;
  c. Percentage of the watershed covered by impervious surfaces;
  d. Associated development impacts on local streams; and
  e. Nutrient loads delivered to surface waterways and the estuary.

### Variables

- Location and extent of soil types, wetlands, streams, stream buffer zones, and other environmentally sensitive areas.
- Location of zoning, growth and land preservation boundaries, and sewer service boundaries.
- Location of watershed, subwatershed and county boundaries.
- Location and/or extent of land areas affected by each type of zoning, subdivision, environmental, stormwater management, public health (septic system), and agricultural assistance programs and regulations.
- Current and future population, household, and employment statistics, and number and location of households on sewer and on-site sewage disposal systems, by county and subwatershed.

## METHODOLOGY

MDOP collaborated with county and city planning and zoning offices, State and local resource and environmental protection agencies, public works departments, and soil conservation districts to obtain information about existing growth management plans and regulations and about stormwater and agricultural management programs. It also compiled geographic information system (GIS) data for land use, soil types, slope, location of streams and wetlands, location of septic systems, zoning, sewer service, and current and projected population, households, and employment.

These data sources were used in the Office of Planning's Watershed Planning System (WPS) to evaluate current and future conditions in the Patuxent, Lower Western Shore, and Lower Potomac tributary watersheds. The WPS consists of three linked computer models that use data from these GIS and a variety of other sources to model future development and associated impacts on land resources, environmentally sensitive lands, nutrient pollution loads, and local water resources. The three models are: 1) The Baseline Inventory model; 2) The Growth Management Simulation model; and 3) The Nonpoint Source Management Scenario model. All of the models use data derived from composite GIS overlays, as well as other data described below in this section and under the section titled Types of Data Required for Model.

The specific steps taken to conduct the build-out analysis and project impacts on land and water resources for the three tributary watersheds are described below. To accomplish similar things for the Chesapeake Bay Watershed, each step in the analysis would be modified (in many cases greatly simplified), commensurate with the data bases available and the specific objectives of the analysis.

**Create GIS Data Layers**

A Workstation ArcInfo geographic information system (GIS) was used to organize 1990 data from each county in the watershed on land use/land cover, soils, streams, wetlands, and stream buffers (physical features); zoning, sewer service, and subdivision, development, and environmental regulations (land management data); current (1990) population, households, and employment (demographics); animal production facilities, households on septic systems, and households on sewer service (special source categories); and stormwater and agricultural management practices (NPS management).

**Develop Baseline Inventory of Land Features**

These data were organized by subwatershed within each county. Within each subwatershed, 1990 conditions were inventoried for each of the following: land use/land cover, stream buffers, households on sewer or on septic systems, nonpoint nutrient pollution sources, pollution management practices for stormwater and agriculture (BMPs), wetlands, and the occurrence of riparian areas within buffers of streams and other waterways.

**Develop Baseline Inventory of 1990 Pollution Loads**

Within each subwatershed, current (baseline) nutrient loads from forest, agricultural sources, developed land cover, septic systems, and other miscellaneous sources were estimated using the *Baseline Inventory* model of the Watershed Planning System. Data compiled from nonpoint source research, monitoring, and modeling was applied to the Baseline Inventory of land features to estimate nutrient loads delivered to streams by the following pathways: surface runoff, shallow subsurface flow, and groundwater.

Loads delivered to streams were estimated first, assuming the absence of BMPs, wetlands, and riparian buffers. To do this, distributions of in-stream loading rates for each source were compiled from research, primarily from monitoring studies screened for a variety of conditions, but also from the *Chesapeake Bay Watershed (HSPF) Model.* Values by source from appropriate Bay Model segments (in-stream loading rates) were sorted by physiographic province and incorporated into distributions of values compiled from other sources of information. The resulting range of values in a distribution was used to characterize high, moderate, and low loading rates for each pollution source type. These rates were then applied to sources within subwatersheds, using soil characteristics (erodibility, slope, hydrologic group, permeability, percolation, depth to groundwater, and presence of impermeable subsurface layers) as indicators of high, moderate, or low nutrient pollution export potential.

Delivered loads were partitioned by flow pathway using partitioning factors also derived from the *Bay Watershed Model.* Those factors were used in conjunction with data from other sources needed to partition loads from all of the source types represented in the Watershed Planning System, which covers a finer breakdown of source categories than is represented in the Watershed Model.

Subsequently, the effects of BMPs, wetlands, and riparian buffers on loads from each source are estimated by flow pathway. Removal efficiencies are based primarily on observations compiled from monitoring research results, but findings from both HSPF and CREAMS modeling (*Chemicals Runoff and Erosion from Agricultural Management Systems*) by the University of Maryland Department of Agronomy were also employed. The resulting in-stream loads are then delivered to the estuary using delivery ratios from the *Chesapeake Bay* and the *Patuxent Watershed HSPF* models.[1] Point source data (nutrient loads from waste water treatment plants) from the Patuxent, Lower Western Shore, and Lower Potomac Tributary Strategies was also incorporated.

## Estimate Demand and Capacities for New Development

Projected growth in population, households, and employment for the year 2010 represented the demand for new development in each subwatershed. Round 5 Small Area Forecasts for Transportation Analysis Zones were used. These are growth projections developed periodically by regional planning agencies and local governments in Maryland, for a variety of planning purposes. The forecasts were used to estimate growth in population, number of households, and employment in each subwatershed comprising the three tributaries and seven counties.

[1] The Patuxent Watershed HSPF model is distinct from the Chesapeake Bay Program's Watershed Model. The former was developed by the Maryland Department of the Environment, and consists of 40 Model Segments for the Patuxent River watershed; while the latter is less detailed, consisting of just 3 Model Segments.

Undeveloped land zoned for subdivision or other development represented the "supply" of developable land. Zoning, subdivision, incentives, and other regulations and programs affecting development were used to estimate the capacities of different types of developable land for new development, i.e., how much development (e.g., number of new households) could be accommodated on each type of land under existing or hypothetical programs. Capacities were determined for land use types within zoning districts and sewer service boundaries.

## Allocate Demand Under Different Growth Management Scenarios

The demand for new development was distributed to types of developable land based on capacity and county-specific considerations. This was done first by assuming current zoning and programs/regulations (the *Current Programs* scenario), and then for the two alternative scenarios (*Base Zoning* and *Directed Growth*, see the section *Alternative Development Scenarios Considered*, above). Each scenario assumed different zoning, regulations, and/or programs and procedures governing new development, particularly the density and distribution of new subdivisions and requirements/restrictions for site design and conservation of forested cover, stream buffers, and open space.

## Simulate Land Use Change and Project Implementation Levels of BMPs

Land use change to accommodate projected growth was estimated within each subwatershed for each scenario. Based on the demand for new development relative to the supply available on each type of developable land, the land was either:

- converted to a specific type of development to accommodate projected growth, based on zoning, relevant regulations, and the number of new households or amount of new employment allocated (in the preceding step);
- converted to forested cover to meet requirements of forest conservation programs;
- maintained in forested cover to satisfy requirements of stream buffer protection ordinances; or
- allowed to remain in its existing condition. This occurred when site design guidelines (e.g., rural clustering) protected existing open space, or when there was not enough demand for new development to warrant conversion to development.

Resulting conversions of land and "future" landscapes differed for each scenario. For each, implementation levels for agricultural and storm water management practices were also estimated, based on the implementation levels projected in the corresponding tributary strategies and counties' future expectations of their programs. Implementation levels of pollution control practices were adjusted to reflect estimated land use changes for the 2010 scenarios.

## Inventory Conditions and Estimate Pollution Loads in Each Scenario

2010 conditions were inventoried by subwatershed. Content of the inventories (land features and pollution loads) was the same as described for 1990 conditions: land use/land cover, stream buffers, households on sewer or on septic systems, estimated nutrient pollution loads from nonpoint sources, effects of management practices on loads, and effects of wetlands and riparian buffers on loads. Point source data (nutrient loads from waste water treatment plants), derived from the three Tributary Strategies, was also incorporated.

## Compare Scenario Results

Conditions in each of the 2010 scenarios and for 1990 were compared. Differences in land resources, pollution levels, and effects of management practices and riparian areas serve to quantify the impacts of growth and the effects of management alternatives. The results of each scenario can be compared to the nutrient pollution levels called for in the corresponding Tributary Strategy in order to determine which growth management and resource protection options will maintain those levels and which will not. The importance of these options can be compared to that of agricultural and stormwater management practices, in terms of cumulative effects on pollution loads. Results are also used to provide information and guidelines to local resource protection and planning agencies, to assist them in protecting local land resources and watersheds.

## STUDY RESULTS AND FINDINGS

- Implementation of both growth management and pollution control options are essential if Maryland is to maintain the nutrient loading caps called for in the Patuxent Tributary Strategy beyond the year 2000.
- In the year 2010, pollution levels will be much lower if growth and new development is well directed. In conjunction with other management tools like Best Management Practices (BMPs), growth management will be one of the most important factors determining future pollution levels. For example, the MDOP estimates that in the year 2010, nitrogen pollution loads in the Patuxent River watershed could be about 1,141,000 pounds lower if certain "Directed Growth" and "Resource Protection" options (defined in the report highlighted in this study) were used to manage growth as part of the Patuxent Tributary Strategy, in addition to BMPs. Similar findings for the Lower Western Shore and Lower Potomac tributaries and for phosphorus are also reported.
- By the year 2010, stream quality would degrade in nearly half the Patuxent watershed under *Current Programs*. Growth management, per the Directed Growth scenario, would limit degradation to about one quarter of the watershed. For an example at the county scale, significant degradation could occur in about 62% of one county's streams under *Current Programs*, but

would be limited to about 22% under *Directed Growth.* As expected, results vary by county, but follow a similar pattern.

- Results, findings, and guidelines are specific to individual county programs and subwatersheds, as appropriate for the objectives of these pilot projects. Findings and guidelines can be generalized for areas with similar conditions, projected amounts of growth, and existing management measures in place. Alternatively, the analysis itself can be generalized to compare more general scenarios for multiple jurisdictions over larger areas.

## TYPES OF DATA REQUIRED FOR MODEL

The following types of data were used in Maryland Office of Planning's analysis of the Patuxent River watershed:

| | |
|---|---|
| Maps: | Land use; soils; watershed and county boundaries; wetlands; streams; buffer zones; other environmentally sensitive areas; zoning, growth and land preservation boundaries; and sewer service boundaries. MDOP used a data base included in its proprietary computer program *Maryland Property View*. This data base includes parcel data that was obtained through 1:40,000 scale aerial photographs. Other data originated from satellite images. |
| Management Programs: | Zoning, subdivision, and environmental and stormwater management regulations; public health (septic systems), and agricultural assistance programs. |
| The U.S. Census: | Population; households; households on sewer and on-site sewage disposal; all for 1990 and (projected) 2010. |
| County Forecasts: | Population and household projections by County. |
| Small Area Forecasts: | Population, household, and Round 5 Small Area Forecasts by Transportation Analysis Zone. |
| Literature, Research, and Modeling: | Nonpoint source monitoring studies; research on the effects of land use, land use patterns, and sensitive areas; BMPs; and BMP systems on nonpoint source pollution; results from the Chesapeake Bay Watershed and Patuxent Watershed HSPF models; CREAMS applications; and Maryland's tributary strategies for the Chesapeake Bay. |

## DATA ACQUISITION AND LEVEL OF EFFORT

The costs of obtaining and preparing data for these projects, interacting with local jurisdictions, and modeling and analyzing results at the level of detail used in the pilot projects is estimated at about $80,000 to $100,000 for each of the seven counties included. A typical single county project requires about 6 months. More generalized analyses, comparing generic alternatives across all jurisdictions, could be done for a small fraction of this cost and time.

## REQUIRED COMPUTER AND OTHER RESOURCES

- Workstation ArcInfo GIS, which can be run on a Unix, Windows NT, or VMS platform.
- The Office of Planning used Paradox Applications Language for the analysis. However, for larger areas and faster completion of projects, a more robust relational database management system (RDBMS), such as Oracle, would be preferable. Such a system can be run on a variety of operating platforms, such as Unix, Windows NT, or VMS.

## FORMAT OF FINAL PRODUCT

A paper report is nearing completion. The report is intended for local and State agencies responsible for growth management and related watershed protection activities; local officials; Maryland's ten tributary teams; Maryland citizens and businesses involved in the implementation of Maryland's *Economic Growth, Resource Protection, and Planning Act of 1992* and of the Tributary Strategies; and interested Chesapeake Bay Program participants. Other products generated in this project include numerous GIS data layers and data sets containing zoning and other county-specific land use information.

## LESSONS LEARNED AND ALTERNATIVE APPROACHES

- Reconciling boundaries or other aspects of geographic information system data from different sources can be time consuming and difficult. Allow sufficient time for this important aspect of the project.

- Communicate early and often with the local jurisdictions involved in the study to ensure that they are aware, and supportive, of the assistance and collaboration that will be asked of their agencies.

- Clearly determine up-front the intended uses and users of the project: what questions must be answered and at what level of detail, to support what kinds of management decisions.

## ADDITIONAL INFORMATION

The Maryland Office of Planning will work indefinitely with the seven counties comprising the Patuxent River watershed, as well as other counties participating in the Watershed Planning process, to implement watershed protection strategies designed to reduce projected inputs of nutrients to Maryland's Chesapeake Bay tributaries. Based on the individual and cumulative effects of management options, alternatives have been identified that are feasible and that will conserve land and protect water resources. The estimated performance of these management actions is being used as a tool to help support their adoption through programs, procedures, or law, and to estimate their value in contributing to cumulative impacts or benefits at the watershed scale.

Additional information can be obtained from the Maryland Office of Planning using the contact information presented on the first page of this summary. Additional information sources are listed below under Relevant Literature. A particularly useful set of publications is the Office of Planning's "Models and Guidelines" series, which provides detailed information on growth management techniques used to concentrate growth. Specific Models and Guidelines reports that discuss such techniques include:

- *Regulatory Streamlining;*
- *Transferable Development Rights;*
- *Overlay Zones;*
- *Achieving Environmentally Sensitive Design in Growth Areas through Flexible and Innovative Regulations; and*
- *Urban Growth Boundaries.*

## SOURCES OF INFORMATION AND TEXT IN THIS FACT SHEET

Information and text for this fact sheet were compiled from the following sources:

Maryland Office of Planning. 1997. *Developing Growth Management Options for Maryland's Tributary Strategies.* Growth and Watershed Planning Series. (March 28 draft). Baltimore.

Maryland Office of Planning. 1995. *Growth, Resource Lands and Watersheds: The Need for Integrated Planning and Management.* Baltimore. Fact sheet.

Maryland Office of Planning. 1995. *An Integrated Watershed Planning Tool for Land Use Management and Nonpoint Source Pollution Control.* Baltimore. Fact sheet.

Tassone, J.F., R. E. Hall, N.S. Edwards, and D.M.G. Weller. 1996. *Integrated Watershed Planning and Management: Growth, Land Resources and Nonpoint Source Pollution.* Published in the Proceedings of the Watershed '96 Conference, Baltimore, MD.

## BUZZARDS BAY PROJECT

| | |
|---|---|
| **TITLE OF PROJECT/REPORT:** | Use of a Geographic Information System to Estimate Nitrogen Loading to Coastal Watersheds. 1994. |
| **RESEARCH CONDUCTED BY:** | Buzzards Bay Project. |
| **SPONSORING ORGANIZATION(S):** | Buzzards Bay Project and U.S. Environmental Protection Agency (through the National Estuary Program). |
| **CONTACT INFORMATION:** | Dr. Joseph E. Costa, Executive Director, Buzzards Bay Project. |
| **MAILING ADDRESS:** | Two Spring Street; Marion, MA 02738. |
| **WEB SITE:** | http://www.epa.gov/nep/nepbroc.html |
| **E-MAIL:** | Joe.Costa@state.ma.us |
| **PHONE NUMBER:** | (508) 748-3600. |
| **STUDY COMPLETION DATE:** | 1991. |
| **PROJECT LOCATION:** | Buttermilk Bay, an embayment of Buzzards Bay, a large estuary located on the south-east coast of Massachusetts. |

### INTRODUCTION AND PURPOSE OF STUDY

The Buzzards Bay Project, a participant in the U.S. Environmental Protection Agency's National Estuary Program, has developed a management strategy to protect and restore water quality and living resources in embayments of Buzzards Bay, Massachusetts, from excessive inputs of nitrogen from human activities. The implementation of this strategy requires an evaluation of existing and potential future inputs of anthropogenic nitrogen from sources within each embayment's drainage basin to determine if existing or future inputs will exceed recommended nitrogen loading limits. Such an approach requires an evaluation of each parcel of land within each drainage basin to determine the number of existing housing units and future development potential based on local zoning regulations (build-out analysis). In this way, existing and potential future non-point sources of nitrogen can be determined, and land development curtailed where necessary to limit nitrogen loading to the estuary. The first build-out analysis conducted by the Buzzards Bay Project was carried out in the Buttermilk Bay embayment of Buzzards Bay, and this analysis serves as the focus of this report.

## RELEVANCE TO THE CHESAPEAKE BAY PROGRAM

There are two primary reasons why the Buzzards Bay Project's build-out analysis of Buttermilk Bay is highlighted in this report:

1) The build-out analysis was conducted on a watershed in order to predict future land use in a quantitative manner (i.e., total number of residences and other land uses) at full development.
2) This build-out analysis was combined with nitrogen loading rates for every type of land use in the watershed studied in order to predict the total nitrogen loading rate for the entire watershed at full development potential.

As such, the method employed by the Buzzards Bay Project could be adapted to perform several types of analyses that could be useful to the Chesapeake Bay Program. Although this type of parcel level analysis would be infeasible for a large watershed such as that of the entire Chesapeake Bay, it could be effectively used in small watersheds, counties, or municipalities within the Chesapeake Bay Watershed. In addition, the Buzzards Bay Project has developed loading methodologies based on GIS coverages (described below) to estimate existing and future nitrogen loads that could also be applied for larger watersheds.

## SIZE AND GEOGRAPHIC BOUNDARIES OF STUDY

Buzzards Bay is a large estuary with a 430 square mile drainage basin and over 30 major coastal embayments. It is located on the south-eastern coast of Massachusetts, surrounded by 17 municipalities. The build-out analysis discussed in this report was conducted on Buttermilk Bay, one of the embayments of Buzzards Bay.

## DESCRIPTION OF LANDSCAPE

Buzzards Bay encompasses more than 280 miles of jagged Massachusetts coastline, salt marshes, tidal streams and flats, barrier beaches, rocky shores, and eelgrass beds. It provides a livelihood for many shell fishers, and offers recreational opportunities for both residents and tourists. Buttermilk Bay, the embayment highlighted in this report, has been characterized as typical of most embayments in the Buzzards Bay estuary. Like most other Buzzards Bay embayments, the soils of the Buttermilk Bay watershed are sandy and highly-permeable, dominated by ground water inflow rather than surface runoff.

## APPLICABILITY OF METHOD TO OTHER GEOGRAPHIC AREAS AND SCALES

The build-out and nitrogen loading estimation methods used by the Buzzards Bay Project are applicable at scales as small as one residential housing parcel. There is no upper size limit to these methods, although time and cost will become constraints at a scale that depends on the resources of the organization conducting the analysis. For larger watersheds and for establishing regional priorities, the Buzzards Bay Program's GIS methodology would be more appropriate.

## ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED

The Buzzards Bay program estimated nitrogen loading from the Buttermilk Bay watershed at full development potential, or completely "built-out." It was assumed in this model that all developable land was developed to the fullest capacity allowable under current zoning regulations. The future date at which full build-out potential would be reached was not estimated.

## VARIABLES AND QUESTIONS INCLUDED IN STUDY

Two primary questions were posed in this study:

1) How many acres of land in the Buttermilk Bay watershed would be developed at full development potential, and how many acres of each type of development would exist?
2) What are the nitrogen loading rates for each land use type in the watershed? At full development potential, how many pounds of nitrogen would enter Buttermilk Bay from the entire watershed?

There were two types of variables included in the build-out analysis of Buttermilk Bay: Demographic/land use-related variables, and nitrogen loading-related variables. The variables included were as follows:

### Demographic and Land Use-Related Variables

- Number of families and residents per dwelling unit.
- Local zoning requirements for minimum lot size.
- Ownership characteristics and location of each dwelling unit parcel.

- Percentage of forest land consisting of wetlands.
- Percentage of forest land available for development.
- Percentage of undeveloped land that would be required for roads and other infrastructure (and therefore not available for location of dwelling units).

## Nitrogen Loading-Related Variables

- Pounds of nitrogen produced per septic system, per person.
- Pounds of nitrogen produced per farm livestock per year.
- Point source discharges of nitrogen.
- Pounds of nitrogen produced per unit area of lawn, roof, parking lot, road and other impervious surface area.
- Pounds of nitrogen produced per unit area of agricultural land (primarily cranberry bogs).

# METHODOLOGY

This section is divided into two parts. The first part consists of a description of the methodology used to estimate the *current* extent and character of land use in the Buttermilk Bay watershed, and resulting nitrogen loading to the Buzzards Bay estuary. The second part consists of a description of the methodology used to conduct the build-out analysis, which predicted nitrogen loading from the watershed in the *future* at full development potential. The first part describes two separate methods that were used to estimate current land use patterns in the watershed, one involving a Geographic Information System (GIS) and one involving parcel-level data from town assessors offices. Both methods result in the same type of land use data, but the parcel-level analysis produces a much more accurate assessment than the coarser, GIS-based analysis.

## Methodology Used to Determine Current Land Use and Nitrogen Loading

### Method One: A GIS-Based Analysis

The following methodology was employed at the outset of the Buzzards Bay Project's effort to determine land use patterns in the Buzzards Bay watershed, which includes the Buttermilk Bay subwatershed. This method, which relied upon data layers from a Geographic Information System, was used to target subwatersheds with extensive development. A second, more detailed approach, was used to determine land use patterns in the Buttermilk Bay watershed. The second approach is described later in this section.

1) Land use types within the 30 Buzzards Bay sub-drainage basins were derived from the Commonwealth of Massachusetts MassGIS project, which employs ArcInfo software. The land use data was compiled by interpreting 1:25,000 scale infra-red aerial photographs taken in 1984. Features as small as 1 acre were interpreted and classified as one of 21 possible land use categories. Among these land use classifications were three agricultural land use categories and four residential categories.

2) For most of these categories, applicable nitrogen loading rates were compiled from published data and other assumptions described in the technical report cited at the beginning of this summary. Most of the effort involved estimating dwelling unit and population density within the four residential land use categories. It was assumed that residential land use accounts for the majority of nitrogen inputs to most Buzzards Bay embayments. Once housing unit densities were calculated, assumed loading rates were applied for septic systems, lawns, and impervious surfaces that were adopted by the Buzzards Bay Project.

3) To estimate housing unit density for the four residential land use categories, residential structures were counted within randomly selected polygons for each of the four residential land use categories on the GIS system. Residential structures were counted on either USGS 1:25,000 scale quad sheets, color photographs, or black and white orthophotographs. Different media were used due to a lack of an adequate range of years for any single medium. Counts from photographs from different years were sometimes interpolated, and each house counted was assumed to be a single family unit.

4) After estimating the number of units in the subbasin using the MassGIS land use data, this number was multiplied by the occupancy rate for that subbasin as estimated from US Census data to obtain the existing subbasin population. Both US Census population "block" and housing unit "block group" aggregate polygons have been digitized and registered with the land use data. For those blocks that crossed subbasin boundaries, an algorithm to divide populations within the block proportionally to the area of the polygon within the subbasin was developed.

5) The relatively large size of the "block group" polygons meant that they often crossed subbasin boundaries. To avoid potential error associated with assuming that housing densities were uniform over the block group aggregates, the ratio of population of the block group in the subbasin versus the total for the entire block group was estimated. This ratio was then multiplied by the total number of units in the block group to obtain the units of that block group in the subbasin.

6) The number of housing units in the subbasin was next multiplied by a per-unit nitrogen loading factor. This factor included assumptions about the contributions of nitrogen from septic systems, lawns, and impervious surfaces. Application of these assumptions required estimation of the average

lot size and associated impervious surface area for a "typical" housing unit, as well as the amount of nitrogen created by an average septic system. Although actual lot size varied widely in the four residential GIS land use categories, in practice lots were typically found to conform to lot sizes defined in zoning regulations. The density of housing units (units/acre) were determined through analysis of aerial photographs and other sources. Nitrogen loads from housing units were then added to the total of all estimated loads from all other land use types and point source loads.

7) The above steps were used to estimate existing loads. Nitrogen loading at build-out was estimated by taking undeveloped land in the watershed (primarily forest category) and projecting new housing units based on existing zoning and after subtracting land out for unbuildable wetlands, infrastructure, and open space.

**Method Two: A Parcel-Level Analysis**

While appropriate for large land areas and to obtain a quick, "rough" sense of current development in a land area, the methodology described above involves numerous assumptions and estimates that are necessary when data is obtained from data layers derived from aerial photographs or other remotely-sensed data. In the case of Buttermilk Bay, the Buzzards Bay Program chose to obtain a higher level of detail in its assessment of current land use patterns, because the analysis was to be the basis of local regulation and land use decision making. The methodology employed was as follows:

- Data on all land parcels in the Buttermilk Bay watershed, as well as the characteristics of each land parcel (e.g., ownership, size, location), were obtained from the town assessor's office in each of the three towns that comprise the watershed (Wareham, Plymouth, and Bourne).

- As in the methodology described above, nitrogen loading rates for each type of land parcel or use were compiled from published literature and other assumptions made by the Buzzards Bay Project.

- The total number and type of dwelling units were multiplied by the nitrogen loading rates per dwelling unit. The resulting totals were added to the nitrogen contributions from point and non-point sources in the watershed.

The resulting land use and nitrogen loading data was similar to that generated by the GIS-based methodology described above, but at a more accurate, finer level of detail. This methodology was made possible due to the availability of computerized parcel-level land use data sets from each of the three municipalities that comprise the watershed. This same methodology would have been far more difficult, if not impossible, to implement at the much larger scale of the entire Buzzards Bay watershed, of which the Buttermilk Bay watershed is but one of 30 subwatersheds. In other words, both methodologies are useful depending on the type of analysis required.

**Determining Potential Future Development**

Once current housing unit density and nitrogen loading rates had been established, the Buzzards Bay Project used the following methodology to estimate the extent and character of land use in the Buttermilk Bay watershed at full development potential, as well as the resulting nitrogen loadings:

1) Data on all land parcels in the Buttermilk Bay watershed, as well as the characteristics of each land parcel (e.g., ownership, size, location) were obtained from the town assessor's office in each of the three towns that comprise the watershed (Wareham, Plymouth, and Bourne).

2) It was assumed that 50 percent of the area defined as "forested land" was unbuildable because of wetlands or need for infrastructure, open space, protection of drinking water supplies, etc. The remainder of the forest land was presumed to be available for development in the residential and commercial/industrial land use classes.

3) The existing ratio between the area used for residential purposes and the commercial/industrial categories was assumed to remain constant into the future.

4) For the residential categories, it was assumed that new residential development would be proportional to existing land-use categories. The smallest land class (lots less than 1/4 acre) were excluded from the study because very few of such small lot sizes were expected to be approved for future development, because of current zoning regulations.

5) Agricultural land conversion to residential or commercial industrial land uses were considered in these build-out projections using the same assumptions as forested land. Cranberry bogs were excluded, because this agricultural land use has been expanding.

6) The total number of acres of remaining land was calculated. This land was classified as developable.

7) Massachusetts subdivision regulations and each town's zoning ordinances were examined to determine the allowable development density in each town.

8) The data from steps 6 and 7 were combined, yielding an estimate of the total potential future number and type of dwelling units per town and for the entire watershed.

9) The total number and type of dwelling units were multiplied by the nitrogen loading rates per dwelling unit, plus the nitrogen contributions from point and non-point sources in the watershed.

## STUDY RESULTS AND FINDINGS

For embayments like Buttermilk Bay, the Buzzards Bay project established nitrogen loading limits of 200 milligrams per cubic meter per flushing time. This translates to an acceptable yearly load of 115,617 pounds of nitrogen.

The parcel-level methodology described above was applied to the Buttermilk Bay embayment. The results of the modeling showed that impacts from the "build-out" population (that which is allowable under current zoning) would exceed critical loading rates for the embayment. To address this problem, amendments to the zoning of the three towns surrounding the embayment were drafted and ultimately adopted and implemented by each town.

The largest expected changes in land use will be the result of an increase in rural residential uses. This occurs because of the large lot size of those types of units, which range from one unit per one acre in one of the towns, to one unit per 17 acres in parts of another.

It was also recommended that, as a land use policy, the rural outlying areas not be developed at densities requiring waste water treatment facilities. Instead, each unit will be required to use a septic system.

## TYPES OF DATA REQUIRED FOR MODEL

### Land Use Data

- USGS 1:25,000 scale quad sheets, color photographs, or black and white orthophotographs.
- Parcel-level housing data in delimited format from the town assessor's office in each town included in the study. (Note: this level of detail not necessary for a simplified analysis, which requires only GIS land use coverages.)

## Demographic Data

- U.S. Census data stored in a Geographic Information System. Can be provided in delimited format for use in a spreadsheet (use of a GIS is optional).

## DATA ACQUISITION AND LEVEL OF EFFORT

Acquiring the data necessary for the type of methodologies described above does not have to be expensive or particularly time-consuming. Depending on availability, GIS data layers containing land use or Census data can be obtained at little or no charge, depending on the type of organization conducting the analyses. However, it is necessary to have staff members skilled in GIS manipulate the data layers to produce meaningful results. If such staff are not on-site, it may be necessary to hire an outside contractor, which has the potential to be expensive.

Parcel-level land ownership data can usually be obtained from town assessor's offices at little or no cost, if available. If these data are available computerized on disk, entering them into a spreadsheet can be done quickly and cheaply. If they are not computerized, the process of entering them into a spreadsheet (which is necessary for determining nitrogen loadings) can be time-consuming, particularly if the watershed to be analyzed is large and contains many separate land parcels. If the land area is very large, and parcel-level data are not available in a computerized format, it may be more time and cost effective to utilize a Geographic Information System such as that described above under "Method One: A GIS-Based Analysis."

## REQUIRED COMPUTER AND OTHER RESOURCES

### Analytical Tools

- None required. The Buzzards Bay Program created a methodology that did not require previously created analytical tools, and utilized instead standard spreadsheet software. However, use of a Geographic Information System such as ArcInfo is optional and can be used to conduct an analysis similar to the one conducted on the Buttermilk Bay watershed. The result would be similar, but at a coarser scale.

### Computer Resources

- IBM-compatible computer, 386 or greater.
- Town assessor's data on computer disk, in ASCII or other delimited format readable by a spreadsheet program.

- Land use maps containing parcel ownership data on a computer disk in ASCII or other delimited format readable by a spreadsheet program. Optionally, ArcInfo software can be used if town assessors data is available for all land areas to be included in the analysis.
- A commercial spreadsheet program.

## FORMAT OF FINAL PRODUCT

The Buzzards Bay Project has released several reports outlining both the methods used in, and the results of, its build-out analysis. These reports are listed at the end of this summary.

## LESSONS LEARNED AND ALTERNATIVE APPROACHES

- Build-out analyses can be conducted at low cost if in-house staff are skilled in this type of analysis. Otherwise, outside contractors may need to be hired, at potentially high cost.
- For time-consuming tasks that do not require a high level of skill (e.g., entering hundreds or thousands of lines of land parcel data into a spreadsheet, or measuring road frontage of parcels), utilizing volunteers or interns can result in significant cost savings.
- If the build-out analysis will include recommended changes in zoning regulations, be sure to work closely with local planners and citizens' groups to ensure a sense of buy-in and to avoid errors in the interpretation information about specific land parcels.

## ADDITIONAL INFORMATION

To protect Buzzards Bay, the Commonwealth of Massachusetts and the US Environmental Protection Agency (EPA) formed a partnership in 1985 to create the Buzzards Bay Project. Three years later, the Project joined the EPA's National Estuary Program to develop a comprehensive plan to restore and preserve the Bay's water quality and natural resources. Today that plan, the Buzzards Bay Comprehensive Conservation and Management Plan (CCMP), is considered by some as a blueprint for estuary protection, and the Buzzards Bay Project is working to implement this plan in all 30 embayments of the Buzzards Bay estuary. With this in mind, build-out analyses are currently underway for the Westport River, Allens Pond (in Dartmouth), Little Bay (in Fair Haven), Onset Bay (in Wareham), and West Falmouth Harbor (in West Falmouth). Ultimately, the Buzzards Bay Project hopes to conduct build-out analyses on all 30 embayments in the Buzzards Bay basin.

## SOURCES OF INFORMATION AND TEXT IN THIS FACT SHEET

Information and text for this fact sheet were compiled from the following sources:

Costa, J.E., D. Janik, N. MacGaffey, and D. Martin. 1994 (draft). *Use of a Geographic Information System to Estimate Nitrogen Loading to Coastal Watersheds.* Technical Report. Buzzards Bay Project. Marion, MA.

Costa, J.E., B.L. Howes, A.E. Giblin, and I. Valiela. 1992. *Monitoring Nitrogen and Indicators of Nitrogen to Support Management Action in Buzzards Bay.* In Ecological Indicators. D.H. KcKenzie, D.E. Hylact, and V. Janet McDonald (eds.), Vol. 1. Elsevier Press, London. Pp 499-531.

Buzzards Bay Project. 1991 *Buttermilk Bay Nitrogen Management Strategy.* Fact Sheet. Marion, MA.

Buzzards Bay Project. 1992. *Managing Nitrogen to Sensitive Embayments.* Fact Sheet. Marion, MA.

## BIODIVERSITY AND LANDSCAPE PLANNING: ALTERNATIVE FUTURES FOR THE REGION OF CAMP PENDLETON, CALIFORNIA

| | |
|---|---|
| **TITLE OF PROJECT/REPORT:** | Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California. 1996. |
| **RESEARCH CONDUCTED BY:** | A team of investigators from the Harvard University Graduate School of Design, Utah State University, the National Biological Service, the USDA Forest Service, The Nature Conservancy and the Biodiversity Research Consortium. |
| **SPONSORING ORGANIZATION(S):** | The Strategic Environmental Research and Development Program (SERDP), a joint program of: U.S. Department of Defense, U.S. Department of Energy, and the U.S. Environmental Protection Agency. |
| **CONTACT INFORMATION:** | David Mouat, SERDP Principal Investigator, U.S. Environmental Protection Agency, Environmental Research Laboratory. Bob Snieckus, U.S. Department of Agriculture, Natural Resources Conservation Service. |
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| **WEB SITE:** | Harvard Web Site for the Project: http://www.gsd.harvard.edu/brc/brc.html |
| **E-MAIL:** | Bob Snieckus at USDA: rsnieckus@ca.nrcs.usda.gov |
| **PHONE NUMBER:** | David Mouat: (541) 754-4330.<br>Bob Snieckus: (916) 757-8221. |
| **STUDY COMPLETION DATE:** | 1996. |
| **PROJECT LOCATION:** | Greater region of Camp Pendleton, California, located in southern California between Los Angeles and San Diego. |

## INTRODUCTION AND PURPOSE OF STUDY

*Biodiversity and Landscape Planning: Alternative Future for the Region of Camp Pendleton, California* was a two year research program aimed at exploring how urban growth and change in the rapidly developing area located between San Diego and Los Angeles might influence native habitats and the biodiversity of the region. The research strategy, which examined the impact of various development scenarios on the region, was based on the hypothesis that the major stressors causing biodiversity change are related to urbanization. As population in an area increases, habitat is typically lost due to grading, paving, ornamental landscaping, and other human activities related to development. There are also indirect, secondary, and cumulative effects on vegetation through hydrologic and fire influences resulting from development.

The purpose of the study was to provide information regarding issues, strategic planning options, and possible consequences related to biodiversity to the many stakeholders and jurisdictions whose actions will influence the region's future biodiversity. The team of researchers developed a computer-based geographic information system (GIS) to describe the region and for use in analyzing the possible future changes in land use patterns. The team studied future land use change at different scales (i.e., several restoration projects, a subdivision, a third order watershed, and the region as a whole) and simulated five regional-based alternative development scenarios. Each development scenario was evaluated using a set of process models that define the natural conditions of the region (e.g., soils, hydrology, fire, biodiversity and visual preference characteristics). The research team did not make specific recommendations on which alternatives to pursue; their purpose was to educate stakeholders of the risks and benefits of a range of alternatives for the Camp Pendleton region and to provide tools and techniques which may be helpful in guiding the future of urbanization and landscape changes in the region.

## RELEVANCE TO THE CHESAPEAKE BAY PROGRAM

The Camp Pendleton region biodiversity and landscape planning study is highlighted in this report for three primary reasons:

1) The build-out analysis was conducted at a scale large enough to include five major river drainage basins of a coastal region. The purpose of the build-out and development of alternative future scenarios for the region was to evaluate the impacts associated with increased urbanization on the natural resources of the region, in particular the impacts of urbanization on native habitats and biodiversity. While this study was not conducted at a scale large enough to encompass the entire Chesapeake Bay watershed, it does provide a context in which several different subwatersheds may be evaluated. In addition, some of the impacts associated with urbanization in the region of

Camp Pendleton may have similar characteristics and consequences that can be evaluated within the context of the Chesapeake Bay.

2) The Camp Pendleton study provides several alternative development scenarios and options that may be considered for managing urbanization in the Chesapeake Bay. Although the study focused on biodiversity management, it does provide a general context for developing alternative futures that minimize impacts to the natural environment. In addition, the Camp Pendleton study examines alternatives at four different geographic scales. Depending on the geographic scale of a build-out analysis in the Chesapeake Bay, this report may be a useful reference for such efforts.

3) The study draws upon a complex array of data sources to fully describe the natural environment of the Camp Pendleton region (e.g., soils, hydrology, biological species). It applies those types of data within the context of the region's demographic qualities and potential (e.g., population projections) to produce a thorough and well-defined description of the existing environment as well as a vision of the region at full build-out. Because performing build-out analyses in the Chesapeake Bay would require similar types of data, it would be useful to understand how the research team in the Camp Pendleton region acquired and applied the data using a geographic information system (GIS).

## SIZE AND GEOGRAPHIC BOUNDARIES OF STUDY

The Camp Pendleton region is located in southern California between Los Angeles and San Diego. The study region is a 50 by 84 mile rectangle that encompasses the five major river drainage basins directly influencing Camp Pendleton: San Juan, San Mateo, San Onofre, Santa Margarita, and San Luis Rey. The study area reaches east through portions of Orange, Riverside and San Diego Counties.

## DESCRIPTION OF LANDSCAPE

The landscape of the study area is unique in that it includes several different physiographic provinces: coastal plains, foothills, the Temecula Valley, mountains and at the eastern edge, desert. The study area is one of the most biologically diverse environments in the continental United States. It supports a variety of habitat types including coastal lagoons and estuaries, coastal scrub areas, maritime-influence chaparral and scrub communities, oak woodlands, coniferous mountain areas, and dry , hot, sparsely vegetated deserts. Each of these supports a unique range of animal species, including more than 200 plant and animal species listed by Federal or State agencies as endangered, threatened or rare.

The Marine Corps Base (MCB) Camp Pendleton is the largest unbuilt portion of land on the southern California coastline (49,857 ha) and thus central to maintaining the long term biodiversity of the region. In the surrounding Counties, population continues to increase and is expected to reach 1.6 million by 2010 (1990 population: 1.1 million).

## APPLICABILITY OF METHOD TO OTHER GEOGRAPHIC AREAS AND SCALES

The methodology used in the study encompassed four different geographic scales: the region of Camp Pendleton was examined through several alternative planning scenarios (the focus of this section); a sub-watershed of the Santa Margarita River was examined by comparing several different planning and development guidelines; a residential subdivision on the biologically sensitive Santa Rosa Plateau was examined for the creation of wildlife corridors within a rural residential area; and site-specific habitat improvements were proposed. These habitats consisted of a wildlife crossing on an interstate highway, and three zones of rare and endangered species habitat within Camp Pendleton.

Although many of the specifics of the study cannot be applied directly to the Chesapeake Bay due to differences in ecosystems and other characteristics, the methodology may provide useful insight into how the research team in the Camp Pendleton region approached biodiversity and landscape planning at four different geographic scales. Constraints on data availability and the financial and staff resources of the organization conducting such a study in a particular portion of the Chesapeake Bay will determine the applicability of the methods used in the Camp Pendleton region study.

## ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED

Six alternative development scenarios were considered for the region of Camp Pendleton. All of the scenarios are based upon a base map showing "constrained land" -- land that is either already developed or that is assumed to be protected from urban development, including Camp Pendleton's Military Impact Areas. The following discussion focuses on the six regional scenarios that include:

1) **Plans Build-Out.** This scenario assumes the continued demands of population growth, continued water supply, adherence to existing plans and the absence of compelling and intervening alternatives. This alternative scenario represents the single most likely long-term future for the study area and it is the scenario against which all other alternatives are compared. The scenario is based on the premise that if land is "unprotected" and developable, it will be altered (eventually) to its planned land use.

2) **Alternative #1. Spread.** This scenario assumes the continuation of the predominant regional trend of the spread of low density rural residential and clustered single family residential

development. It also assumes the weakening of some development constraints and the absence of any new conservation-oriented land acquisitions.

3) **Alternative #2. Spread with Conservation 2010.** This scenario follows the spread pattern, but implements a conservation strategy beginning in 2010. The conservation strategy assumes that all remaining areas of high conservation priority and all areas of riparian vegetation, coastal sage scrub and chaparral, will be conserved beginning in 2010 by purchase or other means. All land outside protected zones and not developed as of 2010 is assumed to be developed as zoned, to build-out.

4) **Alternative #3. Private Conservation.** This scenario follows a low-density pattern but proposes private conservation through large-lot ownership and management of land adjacent to and within important habitat areas as a means of conserving biodiversity.

5) **Alternative #4. Multi-Centers.** This scenario focuses on cluster development and new communities within the region as a means to focus urban growth and have the least possible impact on the ecological regimes. The scenario identifies a number (11) of development "centers" that will have a density of people and commerce sufficient to create a critical mass of activity including pedestrian and public spaces. The centers were located to avoid impacts to biodiversity, near intersections of major roads and on developable land that was neither steep nor wet.

6) **Alternative #5. New City.** This scenario focuses on accommodating most growth in the region in one new city. To encourage development within areas appropriate for urban development and away from areas critical for biodiversity, a new single center was located that would incorporate existing urban areas as satellite communities. To identify the appropriate location, consideration was given to the presence of transportation, sewer and water infrastructure and avoidance of steep and flood prone areas.

## QUESTIONS AND VARIABLES INCLUDED IN STUDY

The following questions were included in *Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California* to define the context of the landscape planning study. These questions were asked three times during the course of the study: the first time to define the context and scope of the research, the second time to specify the methods of study, and the third time to carry the project forward to a set of conclusions.

- How should the state of the landscape be described in content, space and time?
- How does the landscape operate? What are the functional and structural relationships among its elements?
- Is the current landscape working well?
- How might the landscape be altered -- by what actions, where and when?
- What predictable differences might the changes cause?
- How should the landscape be changed?

Additional questions developed by specific Federal and State agencies, regional planning agencies and local constituents were asked of the research team, but are not included here.

The variables that influence the impact of the various alternative scenarios on the landscape, including biodiversity, are as follows:

- Developable terrain (e.g., slope percentage and influence in constraining development)
- Soil composition, management requirements and productivity (e.g., agriculture, biodiversity management, development)
- Hydrological regime (i.e., the quantity, timing, location and quality of available surface water, soil water and groundwater)
- Fire regime (e.g., fire needs of biological species, fire needs in developed areas)
- Vegetation (e.g., climate, soil type, soil moisture, elevation and solar requirements of regional vegetation; relationship between vegetation types and species habitats; changes in vegetation resulting from development)
- Landscape ecological pattern (i.e., spatial relationships between structural and functional elements of the land needed to protect biodiversity)
- Single species potential habitat (i.e., emphasis on the quantitative relationships between environmental variables and habitat suitability for threatened and/or endangered species)
- Species Richness
- Visual Preference (i.e., what humans want to see in their surrounding environment)

Other variables that will influence the outcome of each alternative scenario include:

- Percentage of land that is currently protected or managed for biodiversity.
- Percentage of land that is currently protected or managed for biodiversity and will not likely be converted to another use in the future.
- Percentage of land that is currently protected or managed for biodiversity, but that may be converted to another use in the future.
- Percentage of land that cannot be developed due to physical constraints (e.g., slope, wetness).

## METHODOLOGY

The methodology used in the Camp Pendleton region study was conducted in four separate, yet integrated parts: development of a map describing the existing land cover and land use; development of a map showing the region at full build-out; development of five alternative development scenarios based on the build-out analyses; and development of specific models to evaluate the impacts of each alternative on the natural environment, in particular the impacts to biodiversity and species habitat. A GIS was designed to manage, integrate and analyze all of the data used in the study.

### Existing Land Cover and Land Use

To develop the base map of existing land cover and land uses in the Camp Pendleton region, researchers acquired data from several sources, with variations in spatial resolution and accuracy. Sources ranged from detailed observations made by wildlife biologists in the field to descriptions of roads and stream networks from national data bases of the U.S. Geological Survey and the Census Bureau. Additional data were provided by regional agencies and organizations, universities and others. While most source data were acquired in digital form, some data, such as the county level soils surveys, were digitized from printed originals. All data were assembled, standardized to a common set of descriptive terms and combined to produce the study's representation of the landscape.

The following categories of data were input to the GIS: water, riparian vegetation, oak-woodland, mixed forest, orchards, sage, chaparral, grassland, "altered land " (extensive agriculture), rural residential (1 house per 2 ha), single family residential (1 house per 1/10 ha), multi-family residential (1 house per 1/20 ha), military maneuver, military impact, commercial/industrial, and transportation. An additional eleven categories showing lands that are or could be protected or managed for biodiversity were included: Biological reserves (the most protected), National Forests; Bureau of Land Management Lands; State, County and local parks; steep or wet land; military impact areas, military maneuver areas, Indian reservations; agricultural land; private holdings; and urban areas (the least protected).

In the GIS used for the study, separate digital "layers" or maps, were used to represent the important aspects of the study area: topography, soils, vegetation, hydrology, roads, existing and planned land use, county and municipal boundaries, etc. Each separate layer is stored in "raster" form, which is a two dimensional array of "grid-cells" or "pixels." In addition, a number of linear features, such as roads, streams, county, municipal and other legal boundaries are maintained as a linear or "vector" data base.

## Build-Out Analysis

To perform the build-out analysis, researchers used the GIS to integrate information about the future plans for land use in the region, including the anticipated needs for housing, recreation, transportation commerce and industry. The build-out was completed using information derived from generalized community land use plans, which are coordinated at the county and regional level by San Diego Association of Governments (SANDAG) and Southern California Association of Governments (SCAG), from Marine Corps Base Camp Pendleton, and from information on other Federally managed lands. This data was collated and re-classified into land cover categories using the IMAGINE software developed by ERDAS.

The build-out analysis assumed that all existing urban land uses such as residential, commercial, industrial and transportation would remain as they are and that existing protection and management policies would be continued. All lands in higher levels of protection, including bioreserves, National Forests, BLM lands, special districts, and state and county owned lands were considered undevelopable. Military impact areas were also considered undevelopable. In the special case of Indian Reservations, which are not included in local and regional plans, it was assumed that they were developable at an overall rural residential density, while remaining subject to the full range of development and conservation alternatives.

## Alternative Development Scenarios

Six alternative development scenarios (including the build-out scenario) are compared in this study. They are listed and discussed in a preceding section of this chapter, "Alternative Development Scenarios Considered." All of the alternatives are based upon the same assumptions reflected in the build-out analysis (e.g., continuance of existing land uses, developable land, constraints to development because of protected or managed lands, etc). Each alternative is represented in two stages: its projected state by the year 2010 which accommodates the forecasted population increase of about 500,000 additional persons, and its projected state at build-out.

The final research report provides detailed information about how each of the alternatives were developed: what assumptions were made, what factors guide implementation of the alternative, and how the alternative scenario changes the existing landscape.

## Evaluation of Scenarios Using Specific Models

Models for soils, hydrology, fire, landscape ecological pattern, single species potential habitat, species richness, and visual preference were developed to evaluate the environmental impact of each alternative development scenario. Each model combines selected layers of the base data stored in the GIS to analyze or predict some aspect of the structure or function of the regional landscape. Some models require as an input the results of other models. Researchers presented the results of the evaluation in a graphic and detailed discussion. The graphic exhibits each of the alternative development scenarios along the *x* axis and the models along the *y* axis. Using color codes, each alternative is ranked from worst to best, depending on its impact on the particular aspect (e.g., soils, hydrology) represented in the model.

The results of most models are represented by one or more thematic maps. A thematic map might represent a conditional state, such as land cover in 1990+, an evaluation of species richness, or an impact such as loss of productive agricultural soil. Colors are used to identify different categories of that theme, or relative degrees of a characteristic such as density of development or soil moisture. In almost all cases, maps are rendered on shaded relief to clarify the relationships between the map theme, the physiographic terrain, and the hydrologic pattern of the study region.

## STUDY RESULTS AND FINDINGS

A comparison of the alternative futures was assessed by a series of specific models for the impacts of changes between 1990+ and 2010 and between 1990+ and Build-Out. The models used to evaluate the impacts of each alternative scenario include: Soils, hydrology, fire, landscape ecological pattern, single species potential habitat, species richness, and visual preference.

- In general, the Build-Out and Spread alternative scenarios would have the most severe impact on each of the elements modeled. For example, the Build-Out and spread scenarios would have the most severe impact on the hydrological regime of the region due to increased amounts of imperviousness that accompany development.
- In general, the Private Conservation alternative scenario would have the least severe impact on the effective management of the natural environment. For example, while fire management would be most difficult after implementation of the Build-Out, Spread and New City alternatives, Private Conservation would permit an adequate spatial distribution of development suitable for fire management within developed areas.
- From the perspective of landscape planning for biodiversity, the Build-Out and the Spread alternatives which do not have the management of biodiversity as a primary objective, perform poorly as alternative futures. The Multi-Centers and New City strategies seek to conserve biodiversity by attracting more concentrated development into appropriate areas while minimizing public cost for conservation and infrastructure. The alternative which seeks to protect the most significant habitat areas through Private Conservation succeeds, but at the risk of impacts associated with very low density and clustered development in some of the region's most

sensitive environments. The Multi-Centers and New City alternatives may present the best, most feasible options for future development even though they are less effective in protecting biodiversity.

## TYPES OF DATA REQUIRED FOR MODEL

The types of data required to develop a complete description of the study area landscape included:

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| Maps: | Topography, soils, vegetation, hydrology (e.g., presence of wetlands, streams, etc.), roads, existing and planned land use, county and municipal boundaries, habitat of endangered, threatened or rare biological species, agricultural land, existing management areas (e.g., Federally managed lands (especially MCB Camp Pendleton), Indian reservations, State and local parks), and private land holdings. |
| U.S. Census Data: | Population for 1990+ and projections for 2010. |
| Summary of Developable Lands: | Generalized community land use plans generated at the county and regional level by the SANDAG, the SCAG and MCB Camp Pendleton, and from information on other federally owned lands and several large special projects. |

For each of the models used in the analyses (i.e., soils, hydrology, fire, landscape ecological pattern, single species potential habitat, species richness, and visual preference), arrays of the above mentioned data types were combined with additional data relating to each specific model. This combination of data was used to complete a thorough representation of the landscape characteristics and potential impacts from changes in land use for each model. For example, additional data on the annual precipitation rates and runoff calculations were used in the development of the hydrology model. The report provides detailed information on specific data requirements for each of the models.

## DATA ACQUISITION AND LEVEL OF EFFORT

The data acquired for this study and for the development of research models are based on existing and publicly available data. No other information regarding the actual effort to gather this information was discussed in the report. However, more than 100 people representing numerous

Federal and State agencies, a non-profit organization, regional planning agencies, universities and technical consulting firms, contributed to the study.

A complex GIS was designed to contain digital data about the region, perform the analyses and produce maps, charts and other graphic and tabular results. The cost and level of effort required for this task is not known. However, given the quantity and different types of data entered into the system, is it assumed that substantial resources went into the development of the GIS and data collection effort.

## REQUIRED COMPUTER AND OTHER RESOURCES

### Computer Resources

- A computer system capable of performing the functions associated with the use of a GIS.
- The analytical models that use the base data were implemented as computer program modules using the Arc/Info GRID analysis package developed by Environmental Systems Research Institute, Redlands, California.
- Additional data re-classification and satellite data interpretation was performed in IMAGINE software developed by ERDAS, Atlanta, Georgia.
- Alternative development scenarios were developed with MapFactory GIS software produced by Think Space, Ontario, Canada.

### Other Resources

- Field observations made by wildlife biologists
- National data bases of the U.S. Geological Survey and the Census Bureau
- Various land use maps provided by SANDAG, SCAG and MCB Camp Pendleton
- Soil surveys of the Natural Resources Conservation Service.

## FORMAT OF FINAL PRODUCT

*Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California* is presented as a full color written report, including a series of maps that represent all examined aspects of the study area. A map of the study region, the existing land cover, managed areas, and maps for each alternative development scenario as well as many others are included in the report, in full color. The report also provides an extensive bibliography and a list of the associated members of the research team and other participants in the study, including their representation of the respective agency or organization.

## LESSONS LEARNED AND ALTERNATIVE APPROACHES

- The cooperation of all regional stakeholders including private, State, non-profit, and Federal interests, is essential to the long-term protection of biodiversity in the region of Camp Pendleton, CA.
- A collaborative and well-funded process for gathering and analyzing data will yield more thorough results in a regional biodiversity and landscape planning study and will contribute to the positive buy-in of Federal, State, regional, and local decision makers.
- Use of a GIS was a critical component of the Camp Pendleton region study.

## ADDITIONAL INFORMATION

There are several reasons that the research team selected the region of Camp Pendleton for study. First, it has one of the highest levels of biodiversity in the United States. Second, it is experiencing dramatic growth and will have to manage increasing development pressures. Third, a considerable amount of information about the area has been compiled, but had not yet been synthesized across county boundaries for the regional management of biodiversity in this part of California. Fourth, the research team, among many others, believe that there is still time to make a difference.

Effective management of biodiversity through landscape planning can only be addressed through the cooperation of interested parties, since species and their habitats cannot be confined to imposed boundaries such as political jurisdictions. To address this need for cooperation in the region of Camp Pendleton, the Biodiversity Research Consortium (BRC) was formed to develop analytical methods for assessing and managing risks to biodiversity. Current membership in the consortium includes the U.S. Environmental Protection Agency, U.S. Department of Interior through the National Biological Service, the U.S. Geological Survey, the U.S. Bureau of Land Management, U.S. Department of Agriculture Forest Service, U.S. Department of Defense, the Smithsonian Institution, and The Nature Conservancy. In addition, a number of academic institutions participate as research collaborators, including Harvard and Utah State Universities. In addition to the study of the Camp Pendleton region, other BRC studies include state-scale analyses of Oregon and Pennsylvania and a national-scale analysis of bird species diversity.

## SOURCES OF INFORMATION AND TEXT IN THIS FACT SHEET

Information and text for this fact sheet were compiled from the following sources:

The Strategic Environmental Research and Development Program. 1996. *Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California.* SERDP, a joint program of: U.S. Department of Defense, U.S. Department of Energy, and the U.S. Environmental Protection Agency.

Schiffman, Irving. *Alternative Techniques for Managing Growth.* Berkeley, California: Institute of Government Studies, University of California at Berkeley, 1990, c1989.

Southern California Association of Governments. *Open Space and Conservation.* In DRAFT Regional Comprehensive Plan. Los Angeles: California, December 1993.

Steinitz, Carl. *A Framework for Theory and Practice in Landscape Planning.* GIS Europe (July 1993).

## GEOGRAPHICAL ANALYSIS OF BACTERIAL CONTAMINATION

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|---|---|
| **TITLE OF PROJECT/REPORT:** | Geographic Analysis of Bacterial Contamination, Ipswich, Beverly, and Provincetown. 1996. |
| **RESEARCH CONDUCTED BY:** | Horsley & Witten, Inc., Environmental Services; Applied Geographics, Inc.; and the Massachusetts Bays Program. |
| **SPONSORING ORGANIZATION(S):** | The Massachusetts Bays Program, Executive Office of Environmental Affairs (Boston); Massachusetts Coastal Zone Management Office; and U.S. Environmental Protection Agency. |
| **CONTACT INFORMATION:** | Ms. Ruth Kuykendall, Massachusetts Bays Program; Office of Coastal Zone Management; Executive Office of Environmental Affairs. |
| **MAILING ADDRESS:** | 100 Cambridge Street, Room 2006; Boston, MA 02202. |
| **WEB SITE:** | http://www.epa.gov/nep/nepbroc.html |
| **PHONE NUMBER:** | (617) 727-9530, extension 402. |
| **STUDY COMPLETION DATE:** | October, 1996. |
| **PROJECT LOCATION:** | The towns of Ipswich and Beverly (north of Boston), and Provincetown (outermost extreme of Cape Cod). |

### INTRODUCTION AND PURPOSE OF STUDY

Many coastal communities in the Commonwealth of Massachusetts have experienced frequent shellfish area closures due to fecal coliform counts in excess of Commonwealth environmental limits. This problem was most severe in the late 1980s and early 1990s, but closures continue to be issued. In an attempt to resolve this problem, a Clean Water Act enforcement suit was brought by the Environmental Protection Agency against the Commonwealth of Massachusetts in 1988 to force the Commonwealth to take measures to better manage sewage discharged into Boston Harbor and elsewhere off of the Massachusetts coast. As part of the settlement, the Massachusetts Environmental

Trust was established, which is an environmental philanthropic organization dedicated to improving the Commonwealth's coastal and marine resources. The Trust, in turn, established the Massachusetts Bays Program (MBP), which is a collaborative effort of public officials, civic organizations, business leaders, and environmental groups to work towards improved coastal water quality. In 1990, the MBP became part of the EPA's National Estuary Program. This resulted in significantly increased funding available for research.

One of the primary research goals of the MBP is to study the sources, fate, transport, and effects of contaminants in the Massachusetts and Cape Cod Bays ecosystems. This research is intended to support the development of a comprehensive conservation and management plan for the coastal and marine resources of Massachusetts and Cape Cod Bays. This report presents a summary of one of the research projects that was carried out on behalf of the MBP.

The project created a water quality modeling tool, called FecaLOAD, which is used to estimate fecal coliform loading to selected embayments from stormwater runoff. The model was developed as a management tool for application in areas of shellfish beds and swimming beaches. The intended use of FecaLOAD is to calculate fecal coliform loading from the various land uses within a watershed under stormwater runoff conditions of various magnitudes. Environmental managers, land use planners and local officials can use FecaLOAD to evaluate water quality impacts from existing conditions as well as to provide predictions of impacts under differing future development scenarios.

## RELEVANCE TO THE CHESAPEAKE BAY PROGRAM

This study is relevant to the Chesapeake Bay Program for the following reasons:

- The study focuses on modeling of estuarine water quality contaminants that can result in shellfish bed closures, which has the potential to be a problem in the Chesapeake Bay depending on the density of residential developments in the Bay's watershed and their dependence on septic systems.
- The study resulted in the compilation of fecal coliform loading rates for a variety of land uses, and these loading rates could be applied to the evaluation of loadings from land areas in the Chesapeake Bay watershed.
- The geographic information system (GIS)-based build-out analysis methodology used is appropriate for any land area, including subwatersheds within the Chesapeake Bay watershed. It utilizes land use/cover data sets comparable to data sets available for large portions of the Chesapeake Bay watershed, including the entire State of Maryland.

## SIZE AND GEOGRAPHIC BOUNDARIES OF STUDY

Three Massachusetts towns were included in the study, Ipswich, Beverly, and Provincetown. Ipswich and Beverly are located North of Boston, and Provincetown is located on the outer extreme of Cape Cod. Specifically, the watersheds of the Lower Ipswich River, the Bass River (in Beverly), and Provincetown Harbor, and their 21 subwatersheds, were evaluated with the FecaLOAD model. The size of the watersheds evaluated are as follows: Lower Ipswich River watershed: 2,846 acres; Bass River watershed: 2,347 acres; and Provincetown Harbor: 288 acres.

## DESCRIPTION OF LANDSCAPE

The three study areas included in the Massachusetts Bays analysis represent a variety of hydrogeologic, climatic, and land use conditions including low, medium and high density development, impervious surfaces, storm sewers and drainage swales, septic systems and sewered areas, and wetlands (fresh and salt water). Surface geology in Beverly and Ipswich is predominantly till-covered bedrock having a generally low permeability. Provincetown is situated on high-permeability sand which has been strengthened with added fill to support development.

## APPLICABILITY OF METHOD TO OTHER GEOGRAPHIC AREAS AND SCALES

The FecaLOAD model can be used to quantify fecal coliform bacteria loading from land uses in coastal watersheds. Provided necessary input data are available, FecaLOAD could conceivably be used to evaluate any coastal watershed of any size. However, one necessary model input is detailed soils information for all areas within the study watershed. In the watersheds evaluated in the study summarized in this report, soils information was digitized into a GIS from Natural Resources Conservation Service County Soil Surveys. This can be a time-consuming process if the land area is large. The largest watershed included in the Massachusetts Bays study was only 8,486 acres. This represents, for example, only .0002 (two hundredths of a percent) of the Chesapeake Bay watershed. It is possible to substitute estimated soils data based on averages rather than using more accurate sources such as Soil Surveys, but the resulting reduction in the accuracy of modeled fecal coliform loadings may be unacceptably high.

The FecaLOAD model has also been successfully applied in Casco Bay, Maine, in an evaluation of three subwatersheds of Maquoit Bay. In general, there is no reason to assume that FecaLOAD model could not be applied in any other coastal watershed of sufficiently small size provided the necessary data for input into GIS data layers were available.

## ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED

The FecaLOAD model evaluated the three study watersheds under two conditions:

1) **Current Development.** This scenario was based on GIS data layers from aerial photography and land parcel maps from town assessors, and

2) **Full-Development (Build-Out).** In this scenario, no attempt was made to estimate the future date at which build-out conditions would be reached.

## QUESTIONS AND VARIABLES INCLUDED IN STUDY

The questions and variables included in each study watershed were as follows:

### Questions

- What average fecal coliform loadings would result in runoff from 0.5 and 3.0 inch rainfall events in each of the three study watersheds under both current and build-out conditions?
- How many residential units are there in the three study watersheds both on and off septic systems? How many will be in each of these categories under build-out conditions?
- What kind of buffering efficiency do different soil types exhibit?

### Variables

- Soil permeability and fecal coliform buffer capacity per soil type
- Number of households on and off septic systems under current and build-out conditions
- Number of fecal coliform bacteria released per day from humans, domesticated and undomesticated animals, and type of land use
- Amount of flow from each study watershed to each watershed's discharge point from 0.5 inch and 3.0 inch rainfall events
- Location of point sources of fecal coliform bacteria, and magnitude and frequency of discharge
- Extent and location of land areas under different zoning ordinances in each subwatershed
- Rainfall (inches)
- Time since last rain (days)
- Amount of precipitation in previous five days (inches)
- Season (summer, fall, winter, or spring)
- Days since manure was applied (to croplands, or agricultural land)

## METHODOLOGY

1) Subwatershed boundaries were delineated on USGS topographic quad maps and then digitized into an ArcInfo GIS, as were local soil characteristics, which were digitized directly from Natural Resource Conservation Service County Soil Survey maps.

2) These digitized data were combined with digital GIS maps of all land use/cover types in 1985 (for Ipswich and Beverly) and 1990 (for Provincetown), which were obtained from MassGIS (MacConnell Land Use data), and, in the case of sewerage, from the Metropolitan Area Planning Council. The 21 land use classifications in these data layers were converted into 8 categories used by the FecaLOAD model. Each land use type is associated with a unique set of fecal coliform generation or buffer coefficients. These data layers were used to determine aerial extent of different land uses and soil types as well as the proximity of those land uses to downgradient surface waters.

3) These data layers were entered into FecaLOAD, a spreadsheet model designed by Horsley and Witten. FecaLOAD automatically calculated the number of residential dwellings in the residential land use categories based on corresponding MacConnell Land Use Housing Density factors, which ranged from 1 dwelling per acre for low density land use areas to 5 dwellings per acre for multi-family land use areas. The model estimated fecal coliform loadings from different land uses within the study subwatersheds associated with runoff from two hypothetical events, one of 0.5 inches and one of 3.0 inches. Also calculated were the amount of watershed runoff and concentration of fecal coliform within that runoff. Fecal coliform concentrations were calculated for the discharge point of each subwatershed.

4) Step 3 was repeated with projected land uses at full development (build-out) in each of the subwatersheds in order to calculate fecal coliform loadings from each subwatershed under fully developed conditions. The build-out methodology used was as follows:

a) The GIS land use/cover data layers for 1985 and 1990 were analyzed to determine the location and extent of land areas where development was permitted by zoning regulations in the study watersheds, but had not yet occurred. This was achieved by first eliminating all land areas where development had already occurred, and all land areas where future development was prevented, either by zoning regulations or due to physical constraints (e.g., steep slopes, high water tables, etc.). The remaining land areas were classified as available for development.
b) A GIS data layer containing development constraints based on zoning regulations and local by-laws and ordinances (e.g., number and type of structures and minimum frontage area permitted per land use type) was topographically overlaid onto the data layer containing the location and extent of land available for development. Some of these data were available in

digitized GIS data layers from MassGIS. Where data were missing, the following simplifying assumptions were made:

i. Preservation of upland restricted open spaces was not included in the study
ii. Wetlands were considered "unbuildable"
iii. All agricultural and pasture land was considered developable as residential land
iv. Roads that passed through one type of land use and that would pass through a different type of land use under build-out conditions were converted to the latter land use type.

The number of residential units were calculated by multiplying the acreage of the residential category (low, medium, or high density or multi-family) by the MacConnell Land Use Housing Density values for Massachusetts (as noted above, this was the same method used to calculate the existing number of residential housing units). The resulting GIS data layer contained projected land use types, locations, extents, and corresponding numbers, types, and locations of structures.

c) The resulting GIS data layers were entered into the FecaLOAD model, which estimated resulting projected fecal coliform loads in the same way as it did for current land use/cover (using average loading rates for each type of land use and structure, and calculating the attenuation of fecal coliform based on the distance water from a storm event would pass through soil, and the buffering capacity of the soil).

## STUDY RESULTS AND FINDINGS

- Modeled concentrations of fecal coliform for a 0.5 inch rainfall event were uniformly higher than concentrations from a 3.0 inch event for both existing as well as build-out scenarios. This was true for every subwatershed, and is due to the diluting effect of large rain events.
- Modeled concentrations of fecal coliform during rainfall events were not uniformly higher or lower under build-out conditions in every subwatershed. The magnitude and direction of change in modeled concentrations from existing to build-out conditions depended on what each land area was projected to become under full development. For example, one subwatershed characterized by moderate density residential development dependent on septic systems but projected to become heavily industrial/commercial with a corresponding decrease in the number of residences on septic systems was modeled to generate less fecal coliform under build-out conditions than current development conditions. Conversely, a different subwatershed was projected to have 11 additional septic systems under build-out conditions compared to current development conditions, with correspondingly higher projected concentrations of fecal coliform. Whether concentrations increased or decreased in a specific subwatershed depended on current land characteristics and projected build-out characteristics.
- The most significant source of fecal coliforms common to the three case study communities is residential land use (i.e., septic systems and domestic animals).

## TYPES OF DATA REQUIRED FOR MODEL

- GIS data layers containing watershed boundaries of the areas to be studied, or, if unavailable, USGS topographic quad maps (watershed boundaries can be manually digitized into a GIS data layer).
- GIS data layers containing the geographic location and extent of all soil types in the study area, or, if unavailable, USDA Soil Conservation Service County Soil Survey maps (soil types can be digitized manually into a GIS data layer).
- Soil Suitability Ratings (SSR) for each soil type in the areas to be studied (SSR refers to the ability of a soil type to remove fecal coliform bacteria from contaminated water).
- Digital data on the current extent of sewered areas, land use/land cover types, and zoning.
- Zoning regulations and land use by-laws for all communities that are part of the land areas to be evaluated.
- Road length (in feet) for all road types.
- Fecal coliform bacteria loading rates from different types of land use/cover and from domesticated and non-domesticated animals from scientific literature.
- Average number of residential housing units per type of residential land.

## DATA ACQUISITION AND LEVEL OF EFFORT

The Massachusetts Bays Program hired an outside consulting firm (Horsley and Witten, Inc.) with expertise in geographic information systems and water quality modeling to conduct research for this project. This firm, in turn, hired a sub-contractor to conduct much of the ArcInfo GIS analyses. Thus, it is clear that this project required a high level of expertise, and could not have been undertaken without the assistance of skilled consultants.

In addition to technical skills, a large amount of data from disparate sources was required. Dozens of different types of data were collected from several State and Federal agencies, local planning departments, and from scientific research organizations, in addition to published scientific studies (see "Types of Data Required for Model" above). This data was supplemented with field testing of fecal coliform counts under rainfall events of different magnitudes in order to calibrate the FecaLOAD model and test the validity of its model predictions. This level of effort is time consuming and expensive, even though the three study areas combined comprised only a total of 5,481 acres (which, again, is only .0002 (two hundredths of a percent) of the Chesapeake Bay watershed).

## REQUIRED COMPUTER AND OTHER RESOURCES

- A GIS is not required to generate the kinds of data used in the FecaLOAD model; it is possible to generate these data manually. However, the process will be greatly accelerated with use of a GIS, particularly if the study areas are large. A personal computer or workstation with enough memory to run ArcInfò GIS (typically at least 16 Megabytes (MB) of Random Access Memory (RAM) and a 1 Giga-Byte (GB) hard drive is recommended).
- PC or Workstation ArcInfo, a proprietary geographic information system from Environmental Systems Research Institute, Inc. (ESRI).
- Staff trained in geographic information systems, particularly ArcInfo.
- Microsoft Excel or a similar spreadsheet software program.

## FORMAT OF FINAL PRODUCT

The final products are two published (paper) reports, one describing the project, and one providing additional detail on the methods used, as well as a series of spreadsheet tables containing projections of fecal coliform levels resulting from current and build-out development conditions in each of the three watersheds studied and their subwatersheds.

## LESSONS LEARNED AND ALTERNATIVE APPROACHES

- Zoning and other land use restrictions or guidelines digitized into geographic information systems to correspond with affected land areas are not always available for all land areas included in the study. It may be necessary to manually digitize such data from town assessor's books and/or make simplifying assumptions that can be applied equally to all land areas of the same type.

## ADDITIONAL INFORMATION

Modeling a biological pollutant such as fecal coliform bacteria is inherently difficult due to the complexities associated with how the pollutant responds to a wide variety of environmental conditions such as temperature, moisture, sunlight, and soils. Results of the historical modeling (ground truthing) demonstrated that, in most cases, FecaLOAD is capable of estimating fecal coliform inputs from land uses within one order of magnitude, its calibration target. In its present form, FecaLOAD is not designed to estimate concentrations of fecal coliform beyond the limit of the modeled subwatershed, such as concentrations for the embayment.

## SOURCES OF INFORMATION AND TEXT IN THIS FACT SHEET

Information and text for this fact sheet were compiled from the following sources:

Costa, J.E., Janik, D., MacGaffey, N., and Martin, D. 1994. *Use of a Geographic Information System to Estimate Nitrogen Loadings to Coastal Watersheds.* Buzzards Bay Program Draft Technical Report.

Horsley and Witten, Inc. 1996. *Geographic Analysis of Bacterial Contamination, Ipswich, Beverly, and Provincetown.* Report to the Massachusetts Bays Program. Barnstable, MA.

Horsley and Witten, Inc. 1996. *Companion Guidelines for FecaLOAD.* Report to the Massachusetts Bays Program. Barnstable, MA.

## CANE CREEK RESERVOIR WATERSHED STUDY

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| **TITLE OF PROJECT/REPORT:** | Cane Creek Reservoir Watershed Study. 1996. |
| **RESEARCH CONDUCTED BY:** | The Cadmus Group, Inc. |
| **SPONSORING ORGANIZATION(S):** | Orange Water and Sewer Authority. |
| **CONTACT INFORMATION:** | Edward A. Holland, Director of Planning and Development. |
| **MAILING ADDRESS:** | Orange Water and Sewer Authority; P.O. Box 366; Carrboro, North Carolina 27510. |
| **PHONE NUMBER:** | (919) 968-4421. |
| **STUDY COMPLETION DATE:** | August 1996. |
| **PROJECT LOCATION:** | Cane Creek Reservoir and Watershed, Orange County, NC. |

### INTRODUCTION AND PURPOSE OF STUDY

The purpose of the Cane Creek Watershed study is to aid in developing management plans to protect the quality of the water supply into the next century. Given the current predominance of agricultural and forested land in the watershed, proper management of those land use activities is now the primary concern for protection of the water supply. However, it is expected that over time the character of land use will shift to residential use and as a result present new challenges to protecting the water supply.

The Orange Water and Sewer Authority (OWASA) owns and operates the Cane Creek Reservoir as a water supply for residents of the towns of Chapel Hill and Carrboro and portions of Orange County, North Carolina. It is with this authority that OWASA commissioned this study and hired The Cadmus Group, Inc., to prepare the report. The study focuses on evaluating alternative options for achieving OWASA's overall water quality goal and objectives and to recommend the best option or set of options. Another important purpose of the study is to evaluate the effectiveness of existing watershed supply protection measures, particularly how they will perform over the long term.

## RELEVANCE TO THE CHESAPEAKE BAY PROGRAM

There are two primary reasons why the Cane Creek Watershed study is highlighted in this report:

1) The landscape of the Cane Creek Watershed bears some similarity to portions of the Chesapeake Bay watershed, in that it is largely comprised of agricultural and forested lands. As such, the build-out methodology used to determine future changes in the Cane Creek Watershed may be relevant to a build-out analysis of similar proportions conducted in the Chesapeake Bay.

2) The build-out analyses (at 25 percent and against 100 percent of build-out) were combined with water quality models to identify the greatest threats to future water quality in the watershed resulting from increased population and residential development. The methods used to calculate the water quality impacts associated with various management alternatives may provide useful insight and background information for build-out analyses in the Chesapeake Bay.

## SIZE AND GEOGRAPHIC BOUNDARIES OF STUDY

Cane Creek Watershed is approximately 31.6 square miles (20,227 acres), including the reservoir surface. The study area is located in the upper Cape Fear Basin in the central Piedmont region of North Carolina. Approximately 90 percent of the Cane Creek watershed is situated in Bingham township of southwestern Orange County. The remaining 10 percent, including parts of Toms Creek and Caterpillar Creek drainage areas is located in Alamance County.

## DESCRIPTION OF LANDSCAPE

The watershed is primarily rural and 62 percent of its land remains wooded. Agricultural use, including four active dairy farms, is significant (currently 24 percent), but decreasing. Pressures for additional residential development (currently covering about 12 percent of the watershed area), however, are increasing. Effective in Orange County January 1, 1994, residential lots must be a minimum of 2 acres and have a maximum impervious surface limit of 6 percent. Up to 1 percent of the watershed may be used for nonresidential uses such as churches, fire stations, and solid waste stations.

## APPLICABILITY OF METHOD TO OTHER GEOGRAPHIC AREAS AND SCALES

The approach developed by Cadmus certainly can be applied to other geographic areas and scales. Cadmus designed the approach, including a suite of analytical models, as a useful tool for long-term watershed management and protection. While the scope of the study focuses solely on the Cane

Creek Watershed, the methods used in the study may be adapted to fit different scenarios in other areas and at other scales in the Chesapeake Bay.

## ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED

A total of six different management scenarios were analyzed by Cadmus and evaluated by an Advisory Committee. To address future watershed conditions, each management scenario was evaluated at 25 percent and 100 percent of watershed development. The specific scenarios for protecting future watershed conditions include:

1) **Maintaining the Baseline (Current Protection Measures).**
2) **Construction of Tributary Detention Facilities.**
3) **OWASA Land Acquisition with 2-acre Zoning.**
4) **Preservation of Open Space Combined with BMPs.** One Option with 10 Percent Preservation and Another Option with 33 Percent Preservation.
5) **Preservation of Open Space Combined with Large-lot Zoning and BMPs.**
6) **Mandatory Cluster Development.**

The report provides a detailed description of each of the management scenarios.

## QUESTIONS AND VARIABLES INCLUDED IN STUDY

The study identifies six management objectives and a set of indicators to measure how well various management scenarios meet objectives. The objectives include: Minimize risks to public health; minimize loss of reservoir storage capacity due to sedimentation; minimize aesthetically objectionable taste, odor and color problems in tap water; maintain desirable quality for recreational and aesthetic enjoyment; minimize impacts on county residents who are not OWASA customers; and minimize rate increases to OWASA customers. The variables included:

- Total Organic Carbon (TOC) concentration
- Summer median chlorophyll-a (algal concentration)
- Percent of time with chlorophyll-a greater than 40ug/l
- Sedimentation rate
- Water clarity (Secchi depth)
- Dissolved oxygen profile
- Sediment delivery from agricultural land use
- Sediment delivery from residential land use
- Surface flow and sediment delivery from animal operations

- Fish habitat
- Utility costs
- Opportunity cost of changes in property value

## METHODOLOGY

The response of indicators to management scenarios and future land use was estimated using modeling tools. Cadmus developed a steady-state (i.e., average conditions) spreadsheet model of watershed land use, associated loading of pollutants, lake response, and anticipated impacts on indicators. Calibration of the spreadsheet model was based on background analyses using more detailed, time-dependent models including: Agricultural Management and Load Generation; Generalized Watershed-Scale Nonpoint Loading; In-lake processes (U.S. Army Corps of Engineers BATHTUB model, etc.).

The spreadsheet planning model is designed to calculate future land use resulting from a particular management scenario at two points in time: 25 percent of build-out and full build-out (100 percent). The planning model is geographic-based and is organized around six subwatersheds in the Cane Creek Watershed. It models land use, management, pollution load generation, and pollutant delivery for each subwatershed.

The spreadsheet planning model included four major components:

- Specify management options and development scenarios
- Estimate future land cover and land use
- Calculate runoff and load resulting from future land cover and land use in each subwatershed
- Estimate the impacts of reservoir water quality and other quantitative indicators.

Each management scenario was evaluated in two stages. First, Cadmus provided a quantitative assessment of predicted indicator values for each scenario and presented the results to the advisory committee. The committee then ranked the scenarios based on the indicator results, assessments reflecting uncertainty of meeting predicted results and potential for unintended results and other qualitative factors.

## STUDY RESULTS AND FINDINGS

- Existing water quality in the reservoir is generally acceptable and in compliance with all applicable water quality standards, but is not pristine.

- Modeling analyses indicate that development regulations and practices currently in place are not sufficient to protect water quality from anticipated new residential development.
- The greatest threats to future water quality are posed by increases in algal blooms, manganese concentrations, and total organic carbon levels, low dissolved oxygen concentration, reduced water clarity and microbial pathogens.
- No single management scenario can meet all of the objectives identified in the study. The committee must consider a combination of the four preferred options identified during the study process.

## TYPES OF DATA REQUIRED FOR MODEL

Types of data required for the models used in this study include current data on the quantitative environmental variables discussed earlier in this summary.

## DATA ACQUISITION AND LEVEL OF EFFORT

The level of effort performed by Cadmus to acquire the data for this study included:

- Coordinate projects and meetings
- Collect data
- Review and interpret existing waters quality data
- Estimate nonpoint pollutant loadings under existing conditions
- Evaluate water quality impacts of existing nonpoint pollution loads
- Evaluate water quality impacts of future nonpoint pollution loadings
- Formulate alternative management strategies for watershed protection
- Identify and evaluate in-lake methods for enhancing water quality
- Evaluate water quality impacts of alternative management strategies
- Evaluate regulatory, financial, and institutional requirements of the recommended watershed protection plan
- Prepare final report summarizing watershed protection plan

## REQUIRED COMPUTER AND OTHER RESOURCES

- PC or Workstation ArcInfo, a proprietary geographic information system developed by ESRI
- Staff trained in the use of GIS
- Microsoft Excel or a similar spreadsheet software program.

## FORMAT OF FINAL PRODUCT

The format of the final product includes a report, *Cane Creek Reservoir Watershed Study--Draft Report*, August 1996, The Cadmus Group, Inc.: Durham, NC.

As referenced in the report, Cadmus also developed a spreadsheet planning model to estimate impacts on watershed objectives from different management scenarios. This model may be a useful tool in advancing efforts to perform a build-out analysis for portions of the Chesapeake Bay watershed.

## LESSONS LEARNED AND ALTERNATIVE APPROACHES

One of the major lessons learned through the study process and identified during the advisory committee's evaluation of the various management scenarios was that no single management option would effectively meet all of the objectives defined. As a result, the final watershed management plan will be developed with additional public outreach and input and will most likely reflect a revised version of at least one of the preferred management scenarios.

## ADDITIONAL INFORMATION

In addition to the build-out analysis and the identification of preferred management scenarios, several steps were identified by the advisory committee that are needed to complete the development of an effective watershed management plan for Cane Creek Watershed. These steps include:

- Public review of the results of the study.
- Impact analysis of preferred management scenarios conducted by OWASA and local county planners in Orange County.
- Decision and implementation support from OWASA Board of Directors.
- Documentation of the plan of action to provide long-term reference and communication of implementation details.

## SOURCES OF INFORMATION AND TEXT IN THIS FACT SHEET

Information and text for this fact sheet were compiled from the following source:

Orange Water and Sewer Authority. 1996 (draft). *Cane Creek Reservoir Watershed Study*. Carrboro, NC.

# IV. EVALUATING BUILD-OUT ANALYSIS AND WATER QUALITY MODELING METHODOLOGIES FOR POTENTIAL USE BY THE CHESAPEAKE BAY PROGRAM

A total of fourteen build-out analysis/water quality modeling case studies are presented in this report. Five are presented as in-depth summaries in the main body of the document, and the remaining nine are presented as two-page Fact Sheets in Appendix B. All contain useful information about alternative methods that have been used to conduct build-out analyses. In addition, the five in-depth summaries also include information on water quality and environmental modeling methodologies that have been applied to land use output data sets from build-out analyses. There are numerous similarities and differences between the fourteen studies summarized in this report. Each has its own strengths and weaknesses. For those interested in understanding the commonalities and differences, strengths and weaknesses between the methods used in these studies, there is no substitute for actually reviewing the summaries and Fact Sheets, in addition to other relevant sections of this report. However, a rough comparison between some common build-out analysis and water quality/environmental modeling methodologies is provided below as well as some suggestions on how to meaningfully evaluate these and other build-out analysis and water quality/environmental modeling methodologies. The comparisons and suggestions are provided to help the reader determine the degree to which each methodology or model would meet the needs of a particular situation or organization.

## EVALUATION CRITERIA

A number of considerations should be thoroughly evaluated when determining the most appropriate build-out analysis and/or water quality modeling techniques to use for any particular situation. These considerations can be presented as key criteria to guide the decision-making process. Potential approaches should be evaluated against these criteria to ensure that the selection of final techniques is based on the most relevant information available.

There are various criteria that could be used to evaluate different build-out analysis and water quality/environmental modeling methodologies. Three criteria, designed to aid the reader in conducting a simple analysis of any methodology or model, are suggested in this section. These criteria were developed by the Chesapeake Bay Program. The criteria are: 1) Accuracy in predicting environmental impact; 2) Cost; and 3) Computer and staff resources required. After a general discussion of these criteria and the techniques that may be used in applying the methodologies, a matrix is presented that compares some common build-out analysis and water quality/environmental modeling methodologies using the criteria.

The following criteria are discussed in terms of both build-out analysis and water quality/environmental modeling methodologies. A summary of some common types of methodologies is presented following this discussion. Table 2 defines the types of build-out analysis and water quality modeling methodologies used in the studies summarized in this report. In addition, these methodologies are evaluated in Tables 3 and 4.

## Accuracy in Predicting Environmental Impact

Different types of models are better at simulating actual changes in land use or pollution loads than others. In general, complex models that take into account more variables are more successful at simulating true conditions than simplified models that rely on many averages and simplifying assumptions. For example, a build-out analysis methodology that incorporates land use data at the parcel level (i.e., specific information about the type of land use and number of structures at the individual land parcel ownership level), will produce a forecast of future land use patterns that is more precise than a methodology that relies on satellite-derived images that lump many land use types into broad categories and that typically can not distinguish land features at a resolution higher than 30 square meters.

Similarly, a full-scale detailed water quality model, such as the Chesapeake Bay Program's HSPF Watershed Model (described in Appendix A) will more accurately simulate the transport and fate of pollutants from land to receiving water than will a simple spreadsheet-driven model that cannot simulate the many physical and biological processes that occur in watersheds. It is important to note, however, that exceedingly high levels of precision may not be necessary to adequately serve the purposes of every build-out analysis. There are times when simplified models are perfectly adequate for generating information that will be used for "ball park" estimates of future water quality impacts resulting from development. This concept is explored more thoroughly in the section, "Considerations When Selecting a Methodology."

Discussed below are some key elements in determining the accuracy of build-out analysis and water quality/environmental modeling methodologies:

### Scale

The scale that a model operates on refers to the minimum area of land that the model recognizes in its functions. Some models can simulate land use or physical and biological processes down to the square foot, while others may refer to an acre as the smallest unit of measure. Large scales (e.g., square meter) are useful when the study area is small and generalizations or averages would render differences between land areas within the overall study with less clarity. Small scales (e.g., acres) are useful when the study area is large, averages provide adequate information, and collection of highly detailed large scale data would create a volume of information so large as to impede thorough and accurate analysis.

**Recognition of Distinct Land Use Types**

For reasons related to, yet distinct from, the scale used in the model, some build-out analysis methodologies are more suitable for recognizing differences between land use types than are others. Take, for example, a methodology that employs a geographic information system (GIS) to compile and analyze land use data. Current land use data derived from aerial photographs has been found to more accurately delineate between high-density and low-density residential developments than data derived from low resolution satellite images that lump all types of development into one category.

**Input Data**

In general, the more distinct types of relevant data included in a model, the better the model is at simulating actual processes. For example, a build-out analysis model that incorporates only Census Bureau Block Group population projections is likely to be less successful at predicting future land development patterns than one that also incorporates projected household size (residents per household), the average amount of land consumed by an average housing unit (average "lot size"), and other variables that influence land development patterns. Other types of relevant input data can include the amount of land in the study area under management programs such as agricultural best management practices (BMPs); physical variables such as temperature, rainfall, and slope of land areas; and other variables such as biological diversity, species richness and minimum habitat size requirements.

**Output Data**

Before selecting any model, it is essential to clearly identify the questions that need to be answered in the study. If the question is, "How much additional nitrogen will enter a water body given projected development patterns in the year 2010?", the model chosen should provide the information necessary to answer that question. But not all studies are carried out with few, easily answered questions in mind. Sometimes the questions are more vague, such as "What kind of environmental impact would result from the addition of 150,000 residents to our region?" In such cases, every attempt should be made to break larger questions into smaller, more quantifiable ones. In addition, a model should be selected that will generate enough data to answer all of the important questions. If the mandate of a study is necessarily general, it may make sense to format the model used to generate as many types of output data as possible, so that the necessary information will be there when more refined questions are asked.

## Cost/Resource Considerations

Cost can be measured in both dollars and time. If the staff involved in a project are paid (i.e., not volunteers), then time also generates cost in dollars. Certain build-out analysis/water quality modeling methodologies are costlier than others to implement, in terms of finances, staff time, or both. For example, the Chesapeake Bay Program's HSPF Watershed Model (discussed in Appendix A) requires a team of over six individuals to operate, and depends on data analysis by an off-site super computer. In contrast, the water quality model developed by the Buzzards Bay Program (reviewed earlier in this report) can be operated by one individual using a standard commercially available computer spreadsheet program.

In general, the more sophisticated a build-out analysis or water quality model is, the more expensive it is to obtain, tailor to local conditions, and operate. In any proposed project, the cost of the models used must be weighed against the level of precision necessary to meet the project's objectives.

## Ease of Meeting Computer and Staff Requirements

Directly related to cost are the characteristics of the computer and staff resources required to perform the build-out analysis or apply the water quality model selected. This is a measure of the level of required computer power and staff and expertise. Before deciding upon a methodology, the organization or person(s) making the decision should carefully investigate whether it will have the required computer hardware and software and skilled staff necessary to implement the methodology. The case studies presented in this report will give the reader a sense of the resources required to apply the methodologies that have been implemented by other organizations.

In general, if an organization does not have the sophisticated computers or software applications necessary for the type of analysis it wishes to use, and/or staff qualified to operate such systems, it may contract with an outside consulting firm that does have those resources. If the organization is a government agency, it may also seek assistance from another agency with adequate resources. If the type of analysis desired will be needed by the organization on a regular basis, it may be more cost effective and efficient to purchase the hardware, software, and hire skilled operators as permanent, in-house technical staff.

## EVALUATION OF MODELS PRESENTED IN THIS REPORT

Presented below in Table 2 are definitions of the types of build-out analysis and water quality modeling methodologies used by the studies summarized in this report. In addition, Tables 3 and 4 contain a preliminary evaluation of the different types of build-out analysis and water quality/environmental modeling methodologies presented in this report. The following evaluation refers to common types of methodologies used, rather than to any of the specific methodologies described in the case studies presented in this report. The methodologies presented in the case studies are all modified versions of the basic methodologies described below, as indicated in Table 2.

### Basic Build-Out Analysis Methodologies

The following general definitions apply to build-out analysis methodologies for purposes of interpreting Tables 3 and 4. Full descriptions of each methodology appear in chapter two.

#### Parcel-Level, Manual

This method involves a process of manually drawing potential roads, structures, and other types of development onto paper maps until all developable land areas are consumed. Due to the time required to draw developments by hand, this method is only feasible for relatively small areas, such as a town or small county. However, it is an inexpensive method that requires little or no resources aside from paper maps and traditional drafting tools.

#### Summed Area, Manual

Using a planimeter or other device to measure areas zoned for development on paper maps, the researcher sums the total acreage available for development in the study area and then divides this number by an average that represents typical housing unit lot size plus a percentage representing required land that must be reserved for frontage and infrastructure. The result is an estimate of the total number of new residential lots that would be developed under build-out conditions. This method is particularly appropriate for land areas too large to feasibly examine using the parcel-level method, or when a rough average is appropriate to answer the questions posed by the study.

#### Geographic Information System

This method is the fastest of the three ways to conduct a build-out analysis. The method is essentially the same as the summed area method described above, but the calculation of total area is conducted using a geographic information system (GIS), rather than a human being. This is particularly useful when the land area is large and would require many hours of calculation by hand.

## Basic Water Quality/Environmental Modeling Methodologies

The following general definitions apply to water quality/environmental modeling methodologies for purposes of interpreting Tables 2, 3, and 4. Full descriptions of each methodology appear in chapter two.

### Simple Models

Simple models tend to be less sophisticated and require less expertise and resources to create and operate than watershed models. In fact, a simple water quality model can often be one of several components of a watershed model. Typically, water quality models consist of a list of coefficients that translate an acre of land into a quantity of water pollution, based on the type of land and quantity of water or time involved. They may also incorporate highly simplified coefficients to simulate pollutant transport and fate, such as the degree to which a land use type serves as a pollutant source or sink, the proximity of each land area to the nearest downslope water body, and the buffering potential of the intervening land areas.

### Mid-Range Models

Mid-range models fall somewhere in between simple and detailed models. Typically, they are more sophisticated versions of simple (also called "spreadsheet") models. The added sophistication is often comprised of a geographic information system interface that modifies land use pollutant loadings based on the location of the land area in question in relation to other land areas and water bodies. For more detail on all three types of models, refer to chapter 2.

### Detailed Models

Detailed computerized models, called watershed models, simulate watershed hydrology and water quality for various pollutants. Watershed models simulate processes that occur in a watershed, and produce output data such as surface water flow rate, quantity of sediment per unit of time, and nutrient and pesticide concentrations. Watershed models are usually complex and require a team of computer programmers and other technicians to calibrate and operate, as well as powerful computers and computer programing languages.

## Table 2. Types of Build-Out Analyses and Water Quality Models Presented in This Report

| Title of Report, Analysis, or Model | Type of Build-Out Analysis | Type of Water Quality Model | Page Location in this Report |
|---|---|---|---|
| Growth Management for Watershed Protection in Maryland | Geographic Information System | Detailed | 14 |
| Use of a Geographic Information System to Estimate Nitrogen Loading to Coastal Watersheds | Parcel-Level, Manual *and* Geographic Information System | Simple | 28 |
| Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California | Geographic Information System | (Not applicable — analysis was of habitat loss, not water quality) | 39 |
| Geographic Analysis of Bacterial Contamination, Ipswich, Beverly, and Provincetown | Geographic Information System | Simple | 52 |
| Cane Creek Reservoir Watershed Study | Summed Area, Manual *and* Geographic Information System | Simple *and* Detailed | 61 |
| Ground Water Supply Protection and Management Plan for the Eastern Shore of Virginia | Summed Area, Manual | Simple | B-1 |
| Living With the River: A Development Management Plan for the Severn River Watershed to the Year 2020 | Parcel-Level, Manual | (None used) | B-3 |
| U.S. 301 Transportation Study Technical Report: Land Use and Growth Management | Summed Area, Manual | (None used) | B-5 |
| Build-out Analysis of the Thomas Jefferson Planning District | Geographic Information System | (None used) | B-7 |
| Lancaster County Comprehensive Plan: Growth Management Plan | Summed Area, Manual *and* Parcel-Level, Manual | (None used) | B-9 |
| U.S. EPA Clean Lakes Report for the Occoquan Watershed | Summed Area, Manual | Detailed | B-11 |
| Alternative Futures for Monroe County, Pennsylvania | Geographic Information System | (None used) | B-13 |
| Hillsdale Lake Watershed Population and Land Use Projections, 1990 - 2010, for the Hillsdale Lake Nutrient Study | Parcel-Level, Manual *and* Summed Area, Manual | (None used) | B-15 |
| Buildout Analysis on a GIS | Geographic Information System | (None used) | B-17 |

## COMPARISON OF BUILD-OUT ANALYSIS AND WATER QUALITY/ENVIRONMENTAL MODELING METHODOLOGIES FOR LARGE AND SMALL LAND AREAS

The following tables present a matrix that allows for a rough comparison of the some common, generic build-out analysis and water quality/environmental modeling methodologies. A number of things should be kept in mind when reviewing these tables: 1) The scale of comparison (1 = lowest, 5 = highest) is in terms of how each methodology compares to the other methodologies in the tables, not to an absolute scale. Thus, a methodology scoring 5 in accuracy is not necessarily perfectly accurate; it is simply at least as accurate as any of the other methods in the table; and 2) The difference between the "Cost/Resources Considerations" column and the "Ease of Meeting Computer/Staff Requirements" column is that the former refers to the cost of undertaking such an analysis in both dollars and hours typically required, and the latter refers to the level of power of the computers required to run the model, and the level of technical training required of the staff operating the model.

**Note**: These tables provide a quick summary of the methodologies included in this report. The information is intended to allow for a rapid, general evaluation of different kinds of models in common use. As noted earlier, the criteria used were developed by the Chesapeake Bay Program. The scores applied to each methodology, which reflected the degrees to which it met the criteria, were also developed by the CBP. For these reasons, the reader is strongly encouraged to read all of the in-depth summaries and Fact Sheets included in this report in order to gain a thorough understanding of available methodologies and their uses.

## Table 3. Evaluation of Methodologies for SMALL[2] Land Areas

| Methodology | | Accuracy | Cost/ Resource Considerations | Ease of Meeting Computer/Staff Requirements |
|---|---|---|---|---|
| Build-Out Analysis | Parcel-Level, Manual | 5 | 4 | 5 |
| | Summed Area, Manual | 3 | 4 | 5 |
| | Geographic Information System | 3 or 5* | 4 | 3 |
| Water Quality | Detailed Models | 5 | 1 | 1 |
| | Simple Models | 2 | 4 | 4 |
| | Mid-range Models | 3 | 3 | 3 |

Scale: 5 = highest, 1 = lowest.
* Accuracy is high when GIS is configured to assign development to land areas to maximize the number of parcels that could be accommodated.

## Table 4. Evaluation of Methodologies for LARGE[3] Land Areas

| Methodology | | Accuracy | Cost/ Resource Considerations | Ease of Meeting Computer/Staff Requirements |
|---|---|---|---|---|
| Build-Out Analysis | Parcel-Level, Manual | 5 | 1* | 5 |
| | Summed Area, Manual | 4 | 1* | 4 |
| | Geographic Information System | 4-5 | 4 | 3 |
| Water Quality | Detailed Models | 5 | 2 | 1 |
| | Simple Models | 1 | 4 | 4 |
| | Mid-range Models | 2 | 3 | 3 |

Scale: 5 = highest, 1 = lowest.
* The cost of undertaking a build-out analysis on a very large area without the assistance of a GIS is so high as to be essentially infeasible.

[2]For purposes of this table, a "small" land area is one for which it would be feasible to obtain land parcel-level data, such as from town assessor's offices.

[3]For purposes of this table, a "large" land area is one for which it would be infeasible to obtain land parcel-level data, requiring a more general analysis based on numerous averages and assumptions.

## Additional Considerations When Selecting a Methodology

The following are additional considerations when evaluating a build-out analysis or water quality modeling methodology for its potential use in a project:

### Determining Type and Number of Development Scenarios

The answers to the following questions will help determine the types of data necessary for model input, as well as the most appropriate build-out methodology.

- Will the study include a full build-out scenario (i.e., all land fully developed), or some number of partial build-out scenarios (e.g., 50 percent developed, 75 percent developed, etc., or build-out under varying population levels)?
- Is the goal of the study to determine how much land will be developed when the land area is fully developed, regardless of when that will occur, or would it be more useful to project development at some specific future date, such as ten years in the future?

### Data Requirements

A careful inventory of the kinds of data that will be required for the project prior to the start of the project will help determine whether the available models can be used effectively. If key input data can not be obtained at present, it may make sense to delay the start of the study until further background research can generate the necessary data. Some of the key data types that should be considered in this context are:

- Demographic
- Cartographic
- Natural Resources (including species habitat)
- Management Practices (including agricultural best management practices)
- Infrastructure (e.g., sewage lines, roads, wastewater treatment plants, etc.)
- Pollutant loading rates per land use type
- Existing Land Use

These are just some of the potential model inputs that may be required by the models an organization may be considering for use. A careful evaluation of model data needs should be conducted prior to the start of a study in order to determine whether all necessary data is available.

## Manual Versus Computer-Aided Spatial Analysis

As noted above, it is possible to conduct a simple build-out analysis using hard-copy (paper) maps and common planning tools such as pencils and planimeters to measure areas on maps in terms of actual physical space. However, this type of analysis is infeasible for large land areas due to the amount of time that would be required to conduct the analysis by hand. In such cases it is more appropriate to use a geographic information system to conduct most analyses. If computer-aided analysis will be required, the cost of such analysis should be recognized up front.

## Scale

If the land area to be analyzed is small (e.g., a town or small county), it is necessary to select a methodology capable of recognizing and modeling small units of area, such as square meters. This is not true for analyses of large areas, such as a large watershed encompassing several towns and counties. In such cases, a methodology that incorporates simplifying assumptions and averages in order to facilitate rapid analysis may be perfectly appropriate.

## Required Resources

The amount of resources necessary to undertake the analysis should be commensurate with the objective of the final product. In situations where a rapid and general analysis of a land area would be appropriate for initial planning purposes, it would not make sense to expend a great deal of money or staff time on a model that produces highly refined, sophisticated results. Conversely, if the analysis will be used to make large-scale and long-term decisions that will impact the environment and the quality of life of residents in the study area for decades to come, it may make sense to make a significant investment in a more sophisticated model. At a minimum, the following resource requirements should be carefully evaluated before a model is selected:

- Required computer hardware and software
- Level of staff technical expertise
- Length of time required to complete study
- Financial cost of completing the study

## User Applicability

Who will ultimately conduct the analysis? Who will use the results of the analysis? These are two critical questions to ask when considering build-out analysis/water quality modeling methodologies. The answers will help determine how sophisticated the model needs to be, how expensive it could be, and what types of information it should generate. It may make sense to consider the resources and needs of the following types of organizations:

- State governments
- County governments
- Local governments
- Multi-jurisdictional efforts like the Chesapeake Bay Program
- Non-profits
- Academic institutions

# APPENDIX A

## Evaluation of the Potential Application of the Chesapeake Bay Program HSPF Watershed Model to Build-Out Analyses

# EVALUATION OF THE POTENTIAL APPLICATION OF THE CHESAPEAKE BAY PROGRAM HSPF WATERSHED MODEL TO BUILD-OUT ANALYSES

One of the questions posed at the outset of this project (at the July workshop) was, to what extent could the Chesapeake Bay Program's Hydrologic Simulation Program-Fortran (HSPF) Watershed Model assist in conducting build-out analyses on land areas within the Chesapeake Bay watershed? The Watershed Model is the primary tool used by the Chesapeake Bay Program to help signatories to the *1987 Chesapeake Bay Agreement* and its 1992 amendments meet tributary-specific nutrient reduction goals. Following is a description and an evaluation of the Watershed Model in terms of its potential utility, if it were to be used in conjunction with a build-out analysis.

## Background Information on the Watershed Model

The Chesapeake Bay Program Watershed Model is a computer model written in Hydrologic Simulation Program-Fortran (HSPF) code that simulates the transport of point and nonpoint nutrient loads, flow and sediment from throughout the watershed to the Chesapeake Bay. Point source nutrients and flow are released directly into rivers and streams from sources such as municipal wastewater treatment plants and industrial plants. Nonpoint source nutrients, flow and sediment are washed off of various land use types (e.g., agricultural, urban) throughout the watershed into rivers and streams. The Watershed Model then simulates the transport of these point and nonpoint nutrient and sediment loads to the Chesapeake Bay via rivers and streams.

The model was first developed in 1987 and is currently in its fourth phase of development. Refinements have been made during each phase, from the development of more detailed input data to the incorporation of simulations that more accurately capture the actual environmental processes taking place on different land use types and within river and stream channels.

One of the key strengths of the Watershed Model is its ability to predict water quality impacts from different scenarios. Scenarios are used by managers as a "what if?" tool; they are designed to simulate management alternatives and the potential results such alternatives might have. Of the types of scenarios commonly run in the Watershed Model, there are several related to land use. For example, the forest scenario estimates nutrient loads delivered to the line separating the tidal and non-tidal portions of the Chesapeake Bay, or fall line, from an entirely forested watershed. This scenario can be used to assess the difference between an entirely forested watershed and other scenarios, such as nutrient loads delivered from existing land use in 1990.

The WSM represents the entire drainage area of the Chesapeake Bay as a series of land segments connected via a network of rivers and streams, called reaches or tributaries. Within each model segment, eight different land use categories are simulated providing surface and subsurface nonpoint nutrient loadings to the reach draining that segment. These land use categories are:

- conventional tillage cropland,
- conservation tillage cropland,
- hay land,
- forested land,
- pasture,
- manure acres (a subset of pasture),
- pervious urban land, and
- impervious urban land.

## Criteria the Watershed Model Must Meet to Perform Build-Out Analyses:

The following discussion highlights key criteria that determine the appropriateness of the Watershed Model for use in conjunction with build-out analyses.

### Size of Land Area

Build-out analyses may be conducted on relatively small land areas (county to town size areas) as well as medium or large land areas. In order to be useful, the Watershed Model must be applicable for use on a range of land area sizes.

### Delineation

Build-out analyses will most likely be applied both to areas that follow political as well as hydrological boundaries. The Watershed Model must be able to accommodate both types of boundaries.

### Input Data

Once a build-out analysis tool is in place, analyses will be conducted by changing data inputs and observing the resultant changes in nutrient loads and their sources. To facilitate the design and execution of such scenarios, the input data and their modification to simulate different conditions (e.g. changes in land use, number of septic systems, etc.) should be relatively straightforward.

### Accessibility

In order to be most accessible to the broadest range of users, a build-out analysis tool should be available in a PC-compatible format.

### Geographic Display

A straightforward or hard-coded link between the output from the build-out analysis tool and a geographic information system (GIS) or other geographic display tool will greatly enhance the ability to communicate large amounts of information efficiently and to discern geographic patterns or trends in development or nutrient load sources.

### Environmental Impact

Build-out analyses, when combined with models that measure the environmental impact of different land use types, can be conducted in order to estimate the potential environmental impacts of varying development scenarios. An effective build-out analysis/water quality modeling tool will quantify the effects of increased development (increased runoff from impervious surfaces, increased point and/or nonpoint nutrient loads, fragmented habitat) on environmental parameters such as in-stream water quality and species distribution and/or abundance.

## Evaluation of the Watershed Model as a Build-Out Analysis Tool

### Challenges in Applying the Watershed Model to Build-Out Analysis

The following discussion provides an overview of three key challenges to applying the Watershed Model to build-out analysis scenarios.

*Simulation Format*

The Watershed Model simulates one acre of each land use type and then multiplies through by acres in that land use type in a given segment to obtain total loads by segment. In other words, land use types within a given segment are in effect aggregated so that one cannot simulate different land use distributions within a simulation unit (e.g., forest buffers within a segment). These kinds of calculations can be done using attenuation factors -- the amount by which you would expect a given load to be reduced were it routed through a buffer -- once agreement is reached on what attenuation rates are.

*Toxics*

In many build-out analyses, researchers may wish to estimate potential impacts to the toxic load delivered to water bodies from alternative development scenarios. This is currently not possible with HSPF. The current application of the Watershed Model simulates nutrients and flow. HSPF has modules for the simulation of toxics, but these are not currently used in the Watershed Model. The toxics simulation modules were applied in a Bay Program study, but toxics data availability was a limitation.

*Simulation of Urban Land*

The majority of land in the Chesapeake Bay Watershed is forest and cropland. More resources have therefore been allocated to improve the Watershed Model code for the simulation of edge of stream loads for these land uses (AGCHEM NITR implementation in 1995, AGCHEM FOREST implementation in 1996) than for the simulation of urban land. Urban edge of stream loads were calibrated based on a regression relating percent impervious cover to nutrient loads.

## Watershed Model Performance with Respect to Build-Out Analysis Criteria

The following discussion evaluates the potential performance of the HSPF Watershed Model in conjunction with conducting a build-out analysis. Model performance is discussed in the context of the criteria developed above.

### Size of Land Area

The Watershed Model is most effectively applied on large land areas. However, it can be used on land areas as small as one acre.

### Delineation

The edge of stream portion of the Watershed Model can be applied to any land configuration, following political or hydrological boundaries. The reach simulation, however, should include all load sources to the given reach in order to give the best representation of the processes taking place within that reach. This means that hydrologic boundaries should be used for effective reach simulation.

## Input Data

Land use data are specified in the input deck and are easily modified from one scenario to another. External nutrient loads, such as point sources, atmospheric deposition and septic loads, are input to the model as time series data in a very specific format. They are easily multiplied by factors, and more intricate changes can be made to the time series themselves.

## Accessibility

HSPF is currently available and being used in a PC format. However, the size of the input and output data files and the nature of the simulation require a powerful, dedicated machine to execute model runs.

## Geographic Display

The geographic display of model output is done on a regular basis by the modeling team. This process could conceivably be streamlined and automated. The resolution of the geographic display is, however, limited by the size of the simulation units or segments.

## Environmental Impact

The Watershed Model can quantify changes in water quantity and quality as a result of changing development patterns, but cannot speak to resulting changes in species distributions or aspects of habitat quality other than water quality.

## Potential Role of the Watershed Model in Build-Out Analyses

The calibrated Watershed Model edge of stream nutrient loads per unit area could be used to test the impact of changing land use patterns without requiring a model run. The new land use distributions would be determined and multiplied by the appropriate unit load (lb/acre) to obtain a total load from a given land use type within the study area. Attenuation factors simulating the impact of buffers could also be applied in this manner, i.e. they could be developed on a segment basis and applied to the edge of stream loads without requiring a model run. For areas above the fall line, the proportion of the load that reaches the fall line can be determined using fall line transport factors. Fall line transport factors summarize the processes (sedimentation losses, scour, chemical and biological transformations) that take place within reaches as nutrients are transported from their point of origin to the fall line. Lb/acre loads are available for each land use type and for each model segment. Fall line transport factors are available for each model segment. Areas smaller than a

Watershed Model segment would use the loading rates and transport factors of the segment within which they are located. Areas spanning two or more model segments would use the loading rates and transport factors of each of the segments in the appropriate proportion (based on land use distribution). Use of the full HSPF-based Watershed Model in build-out analyses is possible but may not be cost-effective depending on the requirements of the specific study. Results of Watershed Model runs, such as edge of stream loads and transport factors, could be very useful in performing build-out analyses, but model runs for the entire Chesapeake Bay watershed may not be particularly useful. However, the Watershed Model could be combined with detailed land use data for a sub-watershed to perform build-out analyses at that level of detail. The key input would be detailed data on projected land use for the area selected.

# APPENDIX B

**Build-Out Analysis/Water Quality Modeling Fact Sheets**

# FACT SHEET # 1
## VIRGINIA EASTERN SHORE GROUND WATER SUPPLY MANAGEMENT

| | |
|---|---|
| **TITLE OF PROJECT/ REPORT:** | Ground Water Supply Protection and Management Plan for the Eastern Shore of Virginia. 1992. |
| **RESEARCH CONDUCTED BY:** | Horsley Witten Hegemann, Inc., formerly of Rockville, MD. |
| **SPONSORING ORGANIZATION(S):** | U.S. Environmental Protection Agency for the Virginia State Water Control Board and the National Oceanic and Atmospheric Administration for the Virginia Council on the Environment's Coastal Resources Management Program. Prepared for Eastern Shore of Virginia Ground Water Study Committee, Accomack, VA. |
| **CONTACT INFORMATION:** | Horsley and Witten, Inc. (formerly Horsley Witten Hegemann, Inc.) Consultants in Waters Resources and Land Planning. |
| **MAILING ADDRESS:** | 3179 Main Street, Barnstable, MA 02630. |
| **PHONE NUMBER:** | (508) 362-5570. |
| **STUDY COMPLETION DATE:** | May 5, 1992 |
| **LANDSCAPE CHARACTERISTICS OF STUDY AREA:** | Virginia's Eastern Shore, located within the Chesapeake Bay watershed, has a total area of approximately 537,000 acres, of which about 38 percent (206,000 acres) are wetlands and coastal islands that are unsuitable for development. Approximately 53 percent of the total area is used for forestry and agricultural purposes and the remaining 9 percent consists of residential use (3.2 percent), commercial/industrial use (0.6 percent), public lands (2.4 percent) and other uses (2.3 percent). |
| **PURPOSE OF STUDY:** | The purpose of the study was to investigate the impacts of existing and potential land uses on ground water quality on the Eastern Shore. The investigation focuses on a specific recharge area defined in the study. |
| **ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED:** | The development scenarios considered in this study include potential residential build-out analyses for each of the two counties within the study area (Northampton and Accomack Counties). |
| **DATA REQUIREMENTS:** | • Zoning requirements for each of the two counties located within the study area.<br>• Soils data from the Natural Resources Conservation Service, formerly the Soil Conservation Service, to determine development potential of land.<br>• Existing land use types and percentages. |

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| **BRIEF DESCRIPTION OF BUILD-OUT METHOD AND/OR WATER QUALITY MODEL USED:** | Researchers used U.S. Geological Survey (1:25,000 scale) topographic quadrangles and county land use district maps (1:25,000 scale) to delineate the recharge area and the area targeted for future development. Existing land uses were documented as well as the potential for future land development. A computerized spreadsheet program (Microsoft Excel) was used to perform the necessary calculations for build-out scenarios in each of the two counties being studied. The total number of possible future units was calculated by taking the total land area within each land use category minus 15 percent for roads and poorly drained soils and dividing that number by the permitted number of lots per acre allowed under current and recommended zoning regulations.<br><br>The scope of the study did not require the development of or use of a water quality assessment model. However, the results of the study were used in a nitrogen loading model to determine maximum nitrogen loading under the planned densities and land use types for both counties and loading that would result from future development scenarios and land use patterns. |
| **GENERAL CONCLUSIONS AND PRODUCTS:** | The potential for development of low-density residential units within the study area exceeded the current number of units in both counties. However, the realization of this potential is unlikely at this time since development of the Eastern Shore study area is not expected to increase dramatically in the near future. Opportunities exist to implement management tools now that will control future development and protect ground water.<br><br>The study methodology and results are included in the Ground Water Supply Protection and Management Plan for the Eastern Shore of Virginia. Contact the consultant that conducted this study for further details and information about the computer programs, software packages and mapping devices used in the study. |
| **SOURCE(S) OF INFORMATION/TEXT FOR THIS FACT SHEET:** | The source of information and text for this fact sheet is cited above under "Title of Project/Report" and "Research Conducted By." |

# FACT SHEET # 2
## SEVERN RIVER WATERSHED DEVELOPMENT MANAGEMENT PLAN

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| **TITLE OF PROJECT/REPORT:** | Living With the River: A Development Management Plan for the Severn River Watershed to the Year 2020. 1993. |
| **RESEARCH CONDUCTED BY:** | Dodson Associates and Land Ethics |
| **SPONSORING ORGANIZATION(S):** | The Severn River Commission |
| **CONTACT INFORMATION:** | The Severn River Commission, Dodson Associates and Land Ethics |
| **MAILING ADDRESS:** | The Severn River Commission, c/o Anne Arundel County Office of Planning and Zoning, Heritage Office Center 2664 Riva Road, Annapolis, MD 21404.<br>Dodson Associates, P.O. Box 160, Ashfield, MA 01330.<br>Land Ethics, 1400 16th Street, Suite 300 N.W., Washington, D.C. 20036. |
| **PHONE NUMBER:** | Land Ethics, (202) 939-3410. |
| **STUDY COMPLETION DATE:** | December 1993. |
| **GEOGRAPHIC CHARACTERISTICS OF STUDY AREA (LOCATION, SIZE, BOUNDARIES, LANDSCAPE FEATURES):** | The Severn River Watershed, as part of the larger Chesapeake Bay Watershed, encompasses approximately 78 square miles and includes 50 sub-watersheds. It is located entirely within Anne Arundel County, Maryland and includes the majority of the City of Annapolis, Maryland. The Severn River is a tidal tributary of the Chesapeake Bay with a relatively small contribution of fresh water from upstream drainage. The River and its watershed have supported a long history of fishing, farming and human settlement. Land use in the Watershed is comprised of 20 percent residential, 10-15 percent commercial/industrial, and 15 percent open space or under cultivation. Approximately 50 percent of the watershed is forested. |
| **PURPOSE OF STUDY:** | The purpose of the study was to determine the extent and impact of present and future development in the Severn River watershed through the years 2000 and 2020 and provide recommendations for ensuring balanced use and sustainable development. |
| **ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED:** | Two buildout scenarios were developed using population projections for the entire watershed to the years 2000 and 2020. |

**DATA REQUIREMENTS:**

- Existing regulatory and physical constraints to current development in the watershed (e.g., zoning laws, presence of wetlands and steep slopes, protected areas). Sources of data include the Anne Arundel County General Development Plan, the Generalized Comprehensive Zoning Map, the Critical Area Program, the Forest Conservation Plan, Habitat Assessment Manual, Subdivision Regulations and Erosion and Sediment Control regulations).
- Census data and demographic projections. Sources of information include the 1992 population and housing projections for the years 2000 and 2020, provided by the Anne Arundel County Office of Planning and Code Enforcement and the State of MD Office of Planning.
- Projected market conditions

**BRIEF DESCRIPTION OF BUILD-OUT METHOD AND/OR WATER QUALITY MODEL USED:**

The method used to develop the build-out scenarios for 2000 and 2020 initially involved mapping two sets of information: development constraints and development probabilities within the Watershed. To map the development constraints, researchers considered a set of factors ranging from areas where development is permanently prohibited in the Watershed (e.g., areas zoned for open space, highways, areas with slopes greater that 30 percent) to areas with minimal constraints (i.e., areas where no physical or regulatory barriers exist). To map development probability, researchers identified and ranked areas in the Watershed according to physical and regulatory limitations, market demand and demographic projections. These maps, in addition to an analysis of census projections provided the cornerstone of the build-out analyses. A total of four maps (at a scale of 1:2,000) were produced by Dodson Associates and Land Ethics that reflect development constraints and probabilities for both years. Using these maps and census data as a foundation, researchers developed build-out projections for 2000 and 2020. Produced at the same scale, two build-out maps, one for each year, reflect the projected pattern of development under existing regulations and likely future development trends. Maps illustrating recommended development for each of the years were also produced.

**GENERAL CONCLUSIONS AND PRODUCTS:**

The build-out analyses for 2000 and 2020 reveal that the majority of the development projected for the Severn River Watershed will occur in upland areas. This makes sense considering that 90 percent of the tidal area has experienced some level of development. The study provides recommendations about how and where future development should take place, issues that need to be addressed and various tools that may be used to accomplish manageable growth. The study also provides recommendations on how to alleviate some of the environmental concerns resulting from existing development. This study was published as a written report for the Severn River Commission. Contact the Commission or consultants for copies of the report and inquiries about the preparation of the build-out and other maps.

**SOURCE(S) OF INFORMATION/TEXT FOR THIS FACT SHEET:**

The source of information and text for this fact sheet is cited above under "Title of Project/Report." and "Research Conducted By."

# FACT SHEET # 3
## US 301 TRANSPORTATION STUDY

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| **TITLE OF PROJECT/REPORT:** | • US 301 Transportation Study Task Force Final Report. 1996;<br>• US 301 Task Force Final Recommendations. 1996.; and<br>• US 301 Transportation Study Technical Report: Land Use and Growth Management. 1997. |
| **RESEARCH CONDUCTED BY:** | • US 301 Transportation Study Task Force Final Report was prepared by the Task Force in cooperation with the Maryland Department of Transportation;<br>• US 301 Task Force Final Recommendations was prepared by the Task Force; and<br>• US 301 Transportation Study Technical Report: Land Use and Growth Management was prepared by Douglas R. Porter, Planning and Development Consultant in cooperation with Edwin Thomas, Robert G. Kramer & Associates and Parsons, Brinckerhoff, McQuade and Douglas. |
| **SPONSORING ORGANIZATION(S):** | The Governor's Office of the State of Maryland and the Maryland Department of Transportation. |
| **CONTACT INFORMATION:** | Heidi Van Luven, US 301 Transportation Study Project Manager<br>State Highway Administration, Maryland Department of Transportation. |
| **MAILING ADDRESS:** | P.O. Box 717, Mailstop C301, Baltimore, MD 21203-0717. |
| **PHONE NUMBER:** | (800) 548-5026. |
| **STUDY START DATE:** | US 301 Transportation Study, initiated in 1992. |
| **COMPLETION DATE:** | • US 301 Transportation Study Task Force Final Report, November 1996<br>• US 301 Task Force Final Recommendations, adopted July 17, 1996<br>• US 301 Transportation Study Technical Report: Land Use and Growth Management, January 1997. |
| **GEOGRAPHIC CHARACTERISTICS OF STUDY AREA (LOCATION, SIZE, BOUNDARIES, LANDSCAPE FEATURES):** | The study area of the US 301 Transportation Study includes five counties in Maryland and a portion of the District of Columbia. The area stretches east into Maryland from the District of Columbia to the Chesapeake Bay and from US 50 to the Potomac River on the state border. The area is part of the Washington/Baltimore Consolidated Metropolitan Area, which encompasses 13 counties, Washington, D.C., the City of Baltimore, four additional cities, and several smaller municipalities. The landscape of the study area varies widely in character, ranging from high density urban development including industrial and commercial enterprises to mostly rural and wooded areas, with waterfront development, located further away from the major urban areas. |

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| **PURPOSE OF STUDY:** | The purpose of the US 301 Transportation Study was to initiate a collaborative planning process to determine and relate future transportation needs, associated land use patterns and environmental concerns. The Maryland Department of Transportation had abandoned an earlier study for an eastern bypass of Washington, D.C. following strong opposition from environmental and other groups concerned with the effect of the proposed interstate-type highway improvement on spreading suburban development and its impact on sensitive environmental resources, including the Chesapeake Bay. |
| **ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED:** | In order to determine the optimal combination of potential transportation improvements, related land use patterns and environmental protection measures, the task force evaluated a range of alternative transportation improvements and programs in the context of several alternative future land use patterns. The land use alternatives considered included: A "current plans" alternative based on the regional land use projections for 1990 to 2020 made by the Metropolitan Council of Governments (MWCOG); "market-driven" and "policy-driven" alternatives. |
| **DATA REQUIREMENTS:** | The primary data requirements for the study included population, employment and housing projections for each county within the study area. The data were compiled by MWCOG. Other requirements included an understanding of county and municipal planning policies and regulations, county comprehensive plans and zoning ordinances. |
| **BRIEF DESCRIPTION OF BUILD-OUT METHOD AND/OR WATER QUALITY MODEL USED:** | Consultants to the task force used a set of evaluation measures to identify the significant effects of the patterns of land use "inputs" to a travel forecasting model for each land use alternative. The land use "inputs" included allocations of households and jobs among the counties, development and rural areas and transportation analysis zones (TAZs). The evaluation measures included: percent of new households and jobs in development areas; total additional acres developed; acres of farmland, forest and sensitive areas preserved; and jobs/housing ratio by county. |
| **GENERAL CONCLUSIONS AND PRODUCTS:** | A wide range of conclusions were drawn for future land use alternatives and transportation improvements within the study area. In general, the task force recommended that local land use plans and policies, among other things, minimize the amount of land consumed and environmental resources impacts. To accomplish this, the task force recommended that longer-term options such as the protection of rights-of-way, and establishment and expansion of hiker/biker facilities, ridesharing programs and telecommuting incentives. The Final Report and Technical Report listed above provide useful references to background documents and further details about the study. |
| **SOURCE(S) OF INFORMATION/TEXT FOR THIS FACT SHEET:** | The sources of information and text for this fact sheet are cited above under "Title of Project/Report" and "Research Conducted By." |

# FACT SHEET # 4
## THOMAS JEFFERSON PLANNING DISTRICT COMMISSION

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| **TITLE OF PROJECT/ REPORT:** | Build-out Analysis of the Thomas Jefferson Planning District. 1996. |
| **RESEARCH CONDUCTED BY:** | Thomas Jefferson Planning District Commission; locality planning staffs; and the Piedmont Environmental Council. |
| **SPONSORING ORGANIZATION(S):** | Thomas Jefferson Planning District Commission; Virginia Environmental Endowment; Federal Highway Administration Intermodel Surface Transportation Efficiency Act funding administered through the Virginia Department of Transportation. |
| **CONTACT INFORMATION:** | Mr. John Potter, GIS Planner. |
| **MAILING ADDRESS:** | Thomas Jefferson Planning District Commission; P.O. Box 1505; Charlottesville, VA 22902-1505. |
| **WEB SITE:** | http://monticello.avenue.gen.va.us/Gov/TJPDC |
| **E-MAIL:** | Tjpdc@monticello.avenue.gen.va.us |
| **PHONE NUMBER:** | (804) 979-7310. |
| **STUDY COMPLETION DATE:** | 1996. |
| **LANDSCAPE CHARACTERISTICS OF STUDY AREA:** | The Thomas Jefferson Planning District encompasses approximately 2,180 square miles, located in central Virginia. It includes the counties of Albemarle, Greene, Louisa, Fluvanna, and Nelson, as well as the city of Charlottesville. Common landscape features include rivers, flood plains, farms, forests, wetlands, mountains, valleys, and urban and suburban development. Two of the counties contain parts of Shenandoah National Park, and one contains part of George Washington National Forest. |
| **PURPOSE OF STUDY:** | To assess the development potential of the Thomas Jefferson Planning District. |
| **ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED:** | The study estimated the maximum amount of land that could be developed in the Planning District given current zoning regulations. It did not predict the date at which maximum development would be reached. |
| **DATA REQUIREMENTS:** | Data required included: Pertinent land records from the State Computerized Information System (CIS); the percentage of the total block acreage under environmental constraints from steep slopes, poor soils, and flood plains; total |

development rights for each census block; location and extent of soil types that preclude septic systems; location and extent of slopes in excess of 25 percent.; and USGS 1"=24,000" quadrangles.

**BRIEF DESCRIPTION OF BUILD-OUT METHOD AND/OR WATER QUALITY MODEL USED:**

1) All counties provided the Planning District with copies of pertinent land records from the "Computerized Information System" (CIS).
2) For each county, the percentage of the total block acreage under environmental constraints from steep slopes, poor soils, and flood plains was determined.
3) This percentage was removed from each Census block in the rural areas.
4) Applicable zoning ordinances were applied.
5) Development rights already used were subtracted from the total.
6) Total development rights were aggregated for each census block.

The Commission used the VIRGIS system developed at the Virginia Polytechnic Institute's Department of Agricultural Engineering. VIRGIS is raster based, which allows for multiple overlays in less time than that required for a vector based system.

**GENERAL CONCLUSIONS AND PRODUCTS:**

The product was the paper report cited at the beginning of this fact sheet, in addition to various GIS data layers used in their preparation.

**SOURCE(S) OF INFORMATION/TEXT FOR THIS FACT SHEET:**

The source of information and text for this fact sheet is cited above under "Title of Project/Report," "Research Conducted By," and "Contact Information."

# FACT SHEET # 5

## LANCASTER COUNTY COMPREHENSIVE PLAN: GROWTH MANAGEMENT PLAN

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| **TITLE OF PROJECT/ REPORT:** | Lancaster County Comprehensive Plan: Growth Management Plan. 1993. |
| **RESEARCH CONDUCTED BY:** | Lancaster County Planning Commission. |
| **SPONSORING ORGANIZATION(S):** | Lancaster County Planning Commission. Plan was approved by the Lancaster County Board of Commissioners. |
| **CONTACT INFORMATION:** | Ronald Bailey, Planning Director<br>Lancaster County Planning Commission. |
| **MAILING ADDRESS:** | Lancaster County Planning Commission, 50 N. Duke Street, P.O. Box 83480 Lancaster, PA 17608-3480. |
| **WEB SITE:** | http://www.co.lancaster.pa.us |
| **PHONE NUMBER:** | (717) 299-8333 Fax: (717) 295-3659. |
| **STUDY COMPLETION DATE:** | April 1993. |
| **LANDSCAPE CHARACTERISTICS OF STUDY AREA:** | Lancaster County, located due west of Philadelphia, is among one of the fastest growing counties in Pennsylvania. This growth is primarily the result of three main industries: agriculture, business-industry, and tourism. The County is the most productive non-irrigated county in the U.S., exceeding the agricultural production of 10 States. Agricultural zoning has been applied to over 280,000 acres in 36 of the County's 41 townships -- 72 percent of the 390,000 acres in farm use. Over 15,000 acres constituting 170 farms are preserved, most in perpetuity. The County is rich in natural resources, including the Susquehanna River and its tributaries, scenic vistas, woodlands, wetlands and a diversity of wildlife species. Suburban sprawl continues to threaten the landscape, with approximately 3,000 acres of lost agricultural land per year. The City of Lancaster is the largest municipality in the County. |
| **PURPOSE OF STUDY:** | The purpose of the Growth Management Plan is to provide a process for municipal officials to follow in guiding and influencing the pattern, location, and timing of growth within the municipalities of Lancaster County. The primary goal of the Plan is to promote the direction of future growth in Lancaster County to existing urban areas and away from the County's agricultural and natural resource lands through the establishment of Urban Growth Boundaries (UGBs). |

**ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED:** To achieve the goal of the Growth Management Plan, the Lancaster County Planning Commission developed three "visions" for the future of Lancaster County based on established UGBs: a County-wide Vision, and Urban Vision, and a Rural Vision. The County-wide vision calls for growth to be directed to urban areas where there is a full range of public services available to support residential and economic development. The Urban Vision calls for future growth in suburban areas, adjacent to the City of Lancaster and boroughs, to occur primarily on an infill basis and using innovative new development patterns. The Rural Vision calls for supporting agriculture as the backbone of the local economy, by encouraging villages to continue to function as community and service centers, and by protecting resource lands for uses which are compatible with their carrying capacities.

**DATA REQUIREMENTS:** The primary data requirements for developing the Visions for Lancaster County included projections of population growth and housing needs, Comprehensive Plans, knowledge of existing zoning ordinances, existing municipal boundaries and a breakdown of various land uses within the County.

**BRIEF DESCRIPTION OF BUILD-OUT METHOD AND/OR WATER QUALITY MODEL USED:** The County Planning Commission developed a four-step process for defining the UGBs. First, proposed urban growth areas were selected, each centered on one or more boroughs or the City of Lancaster. Second, 20-year population projections were made for each impacted municipality. Based on those projections, average household size, and other factors, the land use needs for each municipality were calculated. Finally, selection of the appropriate areas for inclusion were made and the recommendations taken to the municipalities for approval. Rural land use designations, according to the Plan, should be based upon the identification of areas suitable for agriculture, resource conservation and preservation uses outside of UGBs, as illustrated on the County-wide Future Land Use Map. Municipal Comprehensive Plan maps are to be generally consistent with the County-wide map.

**GENERAL CONCLUSIONS AND PRODUCTS:** Aside from promoting the use of UGBs to direct future growth in Lancaster County toward existing urban areas and away from rural areas, the Commission emphasized the importance of intergovernmental coordination and offered strategic guidance on making that a reality in Lancaster County. The Growth Management Plan offered some useful tools and techniques for managing growth at the local level, especially for municipalities located in Pennsylvania. In addition to the Growth Management Plan there are three additional components of the Lancaster County Comprehensive Plan: the Policy Plan, the Action Plan and the Regional Plans.

**SOURCE(S) OF INFORMATION/TEXT FOR THIS FACT SHEET:** The sources of information and text for this fact sheet are cited above under "Title of Project/Report" and "Research Conducted By."

# FACT SHEET # 6
## OCCOQUAN WATERSHED WATER QUALITY STUDY

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| **TITLE OF PROJECT/ REPORT:** | U.S. EPA Clean Lakes Report for the Occoquan Watershed. 1994. |
| **RESEARCH CONDUCTED BY:** | Northern Virginia Planning District Commission (NVPDC) Environmental and Land Use Services Division in association with the Occoquan Watershed Monitoring Laboratory (OWML). |
| **SPONSORING ORGANIZATION(S):** | U.S. Environmental Protection Agency. Report prepared for the Occoquan Watershed Policy Board. |
| **CONTACT INFORMATION:** | Kimberly Davis, NVPDC, Environmental Services. |
| **MAILING ADDRESS:** | NVPDC, 7535 Little River Turnpike, Suite 100, Annandale, VA 22003-2937. |
| **WEB SITE:** | http://www.nvpdc.state.va.us |
| **E-MAIL:** | nvpdc@dgsys.com |
| **PHONE NUMBER:** | (703) 642-0700 Fax: (703) 642-5077. |
| **STUDY COMPLETION DATE:** | June 1994. |
| **LANDSCAPE CHARACTERISTICS OF STUDY AREA:** | The Occoquan Watershed is located in the Northern Virginia suburban region lying to the south and west of Washington, D.C. It is bounded by the Potomac Estuary to the east and Bull Run Mountain to the west. At the location of the Occoquan High Dam, the basin drains 570 square miles. The landscape of the Watershed is characterized by low, rolling hills interspaced by steep-sloped gorges within which lie Civil War battlefields, regional parks, rural farms, numerous road systems and urban concentrations. The landscape that once supported a large agricultural economy continues to evolve into residential, commercial and light industrial development as suburban sprawl reaches out from the greater Washington, D.C. area. |
| **PURPOSE OF STUDY:** | The primary purpose of the Clean Lakes Report is to support the continuance of watershed management activities in the Occoquan Watershed. The specific objective of the report was to review the impacts of past, present and future land use on water resources (i.e., water supply, surface and ground water quality) of the Watershed. The study discussed the impacts that population growth and changing land uses have had on the Watershed's hydrology, levels of nonpoint source pollution entering the water supply and on biological resources. |

**Alternative Development Scenarios Considered:** The study did not focus on examining alternative development scenarios for the Watershed. However, it did review changes in land use from the late 1970s to the present and considered projections of land use for the year 2005.

**Data Requirements:** Land use projections for 2005 were based upon individual jurisdictional comprehensive plans and estimates of population growth for the jurisdictions.

The NVPDC and OWML conducted extensive research and monitoring of nonpoint source pollution to surface waters, excluding the reservoir (temperature, dissolved oxygen, hydrogen ion activity and alkalinity, conductance and total dissolved solids, suspended solids, nitrogen, phosphorus, degradable organic matter, and synthetic organic chemicals). For the reservoir, separate data were collected (temperature, dissolved oxygen, secchi depth, alkalinity, nitrogen, phosphorus, N.P. ratio, chlorophyll-a, phytoplankton, synthetic organic chemicals, trace metals in fish tissue, and synthetic organic compounds in fish tissue).

**Brief Description of Build-out Method And/Or Water Quality Model Used:** The Occoquan Basin Computer Model was used to analyze the effects of land use changes on pollutant loads delivered to receiving waters, including the Occoquan Reservoir and pollutant transformation with those waters. The model was developed from the Hydrocomp Simulation Program (Hydrocomp 1977) and the EPA Nonpoint Source Program (Donigan and Crawford, 1976). The model uses a nonpoint submodel to determine the nonpoint loadings and a module called LANDS to simulate surface runoff, subsurface interflow and groundwater flow to the stream segment. A module called CHANNEL accepts the inflows from LANDS and point source discharges and routes the flow through the stream segment. A module call QUALITY calculates advective transport, diffusion, chemical transformation, algal growth, nutrient uptake and mass balance for the simulation of BOD, DO, suspended sediment, nitrogen species, phosphorus species and chlorophyll-a.

**General Conclusions and Products:** The Clean Lakes Report discussed the use of land use controls and best management practice (BMP) requirements for existing and future management of the Occoquan Watershed. With land use (zoning controls) in place, future efforts at improved conditions will focus on improved BMP coverage, operation, efficiency and maintenance. The report did not offer specific recommendations for alternative land uses. However, it did discuss the use of BMPs to mitigate future impacts to water quality in the Watershed.

The full citations for the Hydrocomp Simulation Program and the EPA Nonpoint Source Program models were not included in the report. However, the contact name given at the beginning of this fact sheet may be able to provide additional assistance. Also, visit the NVPDC's Web site for additional information and updates on the Occoquan Basin Computer Model.

**Source(s) of Information/Text for This Fact Sheet:** The source of information and text for this fact sheet is cited above under "Title of Project/Report" and "Research Conducted By."

# FACT SHEET # 7
## ALTERNATIVE FUTURES FOR MONROE COUNTY, PENNSYLVANIA

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**TITLE OF PROJECT/REPORT:** Alternative Futures for Monroe County, Pennsylvania. 1994.

**RESEARCH CONDUCTED BY:** Harvard University Graduate School of Design.

**SPONSORING ORGANIZATION(S):** U.S. Environmental Protection Agency Region III, the Monroe County Commissioners, the Monroe County Conservation District, the Monroe County Planning Commission, and the USDA Forest Service, Pacific Northwest Research Station.

**CONTACT INFORMATION:** Carl Steinitz, Professor of Landscape Architecture and Planning, Harvard University Graduate School of Design.

**MAILING ADDRESS:** Harvard University, Graduate School of Design, Department of Landscape Architecture; Gund Hall; 48 Quincy Street; Cambridge, MA 02138.

**STUDY COMPLETION DATE:** December 1993 (report date).

**LANDSCAPE CHARACTERISTICS OF STUDY AREA:** Monroe County, PA is located within a 100 mile radius northwest and west of Philadelphia and New York City, respectively. The county is approximately 30 miles long from north to south and 35 miles across from east to west. The county, which rests on the Pocono Plateau, possesses unique landscape features as a result of the glaciation that occurred approximately 10,000 years ago. Characterized by the scenic Poconos mountains and valleys, the county consists of wetlands, unique bogs, open water, and a mix of maple, oak, hemlock and pine forests supporting a diversity of biological resources.

**PURPOSE OF STUDY:** The purpose of the study was to investigate future land use alternatives for Monroe County, Pennsylvania. The study provided a synthesis of the County's most pressing landscape and planning issues and examined a range of six alternatives for the County. It was prepared as an educational guide for Monroe County planning officials and citizens and students and professionals of landscape planning.

**ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED:** Six possible alternative land use scenarios were developed for Monroe County for the year 2020:

- *Plan-Trend Alternative*: Illustrated the continuation of existing development practices permitted by the Monroe County Comprehensive Plan.
- *Build-Out Alternative*: Assumed that the forces of free market development will lead to the suburbanization of Monroe County in the

same way that so many other metropolitan suburbs have developed, with low density housing spread over the landscape.

- *Township Alternative*: This scenario incorporated high density development in existing subdivisions and new development near town centers and plans for conservation of natural areas outside township boundaries.
- *Southern Alternative*: Focused development patterns in the County to reflect conservation of fragile and threatened natural resources in the northern portion and environmentally responsible growth in the southern, more suburban and agricultural, portion of the County.
- *Spine Alternative*: Concentrated development along a central corridor between the two major growth areas and preserved the rural character of the remainder of the County.
- *Park Alternative*: Envisioned conserving all of the currently undeveloped land in Monroe County.

**DATA REQUIREMENTS:** Six central processes formed the basis for the evaluation of the current condition of Monroe County and the assessment of the alternative land use scenarios. Described as separate landscapes, researchers collected data to describe Monroe County in terms of the geologic, biologic and visual landscape; and incorporated demographics; economics; and politics.

A geographic information system (GIS) was developed to display each of the landscapes described above. Data were collected from a variety of sources including the Environmental Protection Agency, the U.S. Census Bureau, the U.S. Geological Survey, The Nature Conservancy and Cornell University. Several new digital data sets were also compiled at Harvard University.

**BRIEF DESCRIPTION OF BUILD-OUT METHOD AND/OR WATER QUALITY MODEL USED:** Each of the six alternative land use scenarios were analyzed and synthesized using a combinations of several software packages including: ARC/INFO and ArcView (ESRI, Inc., Redlands, CA); Imagine (ERDAS, Atlanta, GA); and Map Factory (Thinkspace, Inc., London Ontario). After each alternative scenario was configured, the POLYTRIMS (Center for Landscape Research, University of Toronto, Ontario) program was used to produce view maps for each alternative.

**GENERAL CONCLUSIONS AND PRODUCTS:** The study provided an overview of how each alternative land use scenario would impact each of the six "landscapes" described above. For example, the Plan-Trend and Build-Out scenarios would have the most devastating impact on the natural resources of Monroe County, while the Park alternative would ensure enhanced protection of such resources (e.g., surface and groundwater quality). This study is published as a written report and includes references to many of the maps used.

**SOURCE(S) OF INFORMATION/TEXT FOR THIS FACT SHEET:** The source of information and text for this fact sheet is cited above under "Title of Project/Report" and "Research Conducted By."

# FACT SHEET # 8
## HILLSDALE LAKE WATERSHED POPULATION AND LAND USE PROJECTIONS, 1990-2010

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| **TITLE OF PROJECT/REPORT:** | Hillsdale Lake Watershed Population and Land Use Projections, 1990-2010, for the Hillsdale Lake Nutrient Study. |
| **RESEARCH CONDUCTED BY:** | Johnson County Planning Office, Johnson County Unified Wastewater District and James M. Montgomery, Consulting Engineers, Inc. |
| **SPONSORING ORGANIZATION(S):** | Johnson County Planning Office. |
| **CONTACT INFORMATION:** | Dean Palos. |
| **MAILING ADDRESS:** | 110 South Cherry, Olathe, KS 66061. |
| **E-MAIL ADDRESS:** | dean.palos@jocoks.com |
| **PHONE NUMBER:** | (913) 764-8484 ext. 6260. |
| **STUDY COMPLETION DATE:** | October 1990 (report date). |
| **GEOGRAPHIC CHARACTERISTICS OF STUDY AREA (LOCATION, SIZE, BOUNDARIES, LANDSCAPE FEATURES):** | The project's geographic (watershed) boundaries include portions of the cities of Gardner, Spring Hill, Wellsville, and all of Edgerton. Portions of Miami, Johnson, Douglas and Franklin counties and the southern part of Johnson County Industrial Airport. The study area totals 95,334 acres (149 square miles) and includes portions of several cities and counties. The study was undertaken in an inland watershed encompassing multiple jurisdictions. The watershed is almost entirely rural and is made up of predominantly farmland, streams and forest cover, in addition to Hillsdale Lake. U.S. Interstate 35 runs through the entire watershed from Northeast to Southwest, just north of Hillsdale Lake. |
| **PURPOSE OF STUDY:** | The goal of this build-out analysis was to predict the effects of future growth on the water quality of Hillsdale Lake using population projections and land use projections in conjunction with nutrient loading data. The analysis was prompted by a concern for the water quality of the lake and the amount of discharge from local sewage treatment facilities and runoff in the watershed. |
| **ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED:** | For the area of Hillsdale Lake Watershed that encompasses Miami County, three development scenarios were developed at rural residential densities. For each scenario, the ultimate development in terms of residential units and persons are included in the report. |

Three projections were made based on: 1) A regional model, 2) Local Comprehensive Plans, and 3) Building permit histories.

**DATA REQUIREMENTS:** The goal of this study was to project population growth and land use change over a twenty year period of time. Thus, the types of information required included population statistics from the U.S. Bureau of Census, and types of existing land use (e.g., residential, commercial, and industrial). The data obtained for the study were obtained from existing information, surveys and interviews with local officials knowledgeable of the watershed's development trends and potential. Population data were obtained from U.S. Census of Bureau Housing Count Statistics. Existing land use data were compiled from 1988 Johnson County aerial photos, special field surveys and from planning consultants in Miami County. A review was also made of the comprehensive plans for two of the towns and of available, recent and historical building permit records.

**BRIEF DESCRIPTION OF BUILD-OUT METHOD AND/OR WATER QUALITY MODEL USED:** Three population projections were made (A, B, and C), each based on these different methods. Population Projection A was based on the Mid-America Regional Council (MARC). Projection B was derived from the Edgerton and Gardner comprehensive plans. Projection C was based upon building permits issued within the watershed and assumptions about growth.

**GENERAL CONCLUSIONS AND PRODUCTS:** A published report, *Hillsdale Lake Watershed Population and Land Use Projections 1990-2010*, for the Hillsdale Lake Nutrient Study. 1990. Consultants, at the time the report was issued, were in the process of developing a computer model to project the degree of pollution in Hillsdale Lake that would result from increased residential development.

Population Projection "C" was recommended for use for the study of Hillsdale Lake, because of the quality of the information in comparison to that used in Projections A and B. Projection C offered the most current and geographic data, based on building permit issuance. The population in the watershed is expected to grow over the twenty year period by approximately 20% every ten years. The largest changes in land use will be the result of an increase in rural residential uses. This occurs because of the large lot size of those types of units ranging from one unit per one acre in Spring Hill to one unit per 17 acres in parts of Miami County.

**SOURCE(S) OF INFORMATION/TEXT FOR THIS FACT SHEET:** The sources of information and text for this fact sheet are cited above under "Title of Project/Report," "Research Conducted By," and "Contact Information."

# FACT SHEET # 9
## BUILD-OUT ANALYSIS ON A GEOGRAPHIC INFORMATION SYSTEM (GIS)

| | |
|---|---|
| **TITLE OF PROJECT/REPORT:** | Buildout Analysis on a GIS. |
| **RESEARCH CONDUCTED BY:** | Edward (Ted) Lyman. |
| **SPONSORING ORGANIZATION(S):** | Ted Lyman in fulfillment of the requirements for his Master of Science Degree at the University of Vermont. |
| **CONTACT INFORMATION:** | Ted Lyman. |
| **MAILING ADDRESS:** | P.O. Box 1318, Williamsburg, VA 23187. |
| **E-MAIL:** | Ted@infotech.ts.wm.edu |
| **PHONE NUMBER:** | (757) 221-1420. |
| **STUDY COMPLETION DATE:** | June 1996. |

**LANDSCAPE CHARACTERISTICS OF STUDY AREA:**

A total of three geographic areas were evaluated as part of this study. They included:

- The City of Woodstock in Oxford County, Ontario, Canada
- The City of Charlottesville, Virginia and five surrounding counties (all located in the Thomas Jefferson Planning District)
- San Diego County, California, including the county and the 18 cities within its boundaries.

**PURPOSE OF STUDY:**

The purpose of the study was to evaluate, through a review of four case studies, how a geographic information system (GIS) can be used as a tool to determine the build-out potential of an area and how the information may be used to influence policy decisions about future development.

**ALTERNATIVE DEVELOPMENT SCENARIOS CONSIDERED:**

Only the full build-out potential for each specific area was examined. No other alternative development scenarios were included.

**DATA REQUIREMENTS:**

As a first step in developing the GIS, each case began with an inventory of existing land resources and knowledge of existing land use regulations. Even though the specific objectives of each case study varied and the quality and quantity of available information was inconsistent from case to case, the data requirements for developing a GIS and performing a build-out analysis for all four studies was more or less similar. The other major data components included:

- Land use information, zoning maps
- Physical and regulatory constraints
- Current census data and rates of growth in housing
- Building records for residential construction activity.

**BRIEF DESCRIPTION OF BUILD-OUT METHOD AND/OR WATER QUALITY MODEL USED:**

The build-out methods used in each of the case studies differed from one another in the application of variables and the selection of basic geographic units. However, each produced a reasonable forecast of what a full build-out would look like under existing regulations and constraints. The GIS used in the case studies ranged from a singularly focused search for developable land to one that managed multiple models of growth forecasting. There was some variability among the case studies in the hardware selected, but the GIS application in each case was ARC/INFO (ESRI, Redland, CA).

Woodstock used data from an existing, parcel-based county land information system (form of GIS) and development constraints data as the basis for buildout analysis. Woodstock was able to identify vacant land, by parcel, that could be used to meet anticipated growth. The build-out method used in the Charlottesville case relied on the aggregation of data from tax parcel records into larger census blocks. This method was problematic in that the census block, zoning and parcel boundaries did not always coincide. The San Diego case study used a nested hierarchy of coverages in which boundaries did not overlap. They used the Traffic Analysis Zone (a subset of the census block and the smallest geographical unit of analysis for the regional system) and general land-use plan for each municipality to identify vacant lands and development potential.

**GENERAL CONCLUSIONS AND PRODUCTS:**

The study revealed potential applications of GIS as a build-out analysis and planning tool. GIS can be used to identify and illustrate the potential of future development in a geographic region by allowing planners to develop a spatial framework in which numerous variables (e.g., land use, physical constraints, existing development, mapping of ecological resources) can be graphically represented together. While none of the case studies reviewed by Mr. Lyman used a GIS to produce alternative development scenarios, the tool can be a powerful method of identifying options available to planners and communities and is highly functional in evaluating possible development alternatives.

The report prepared by Mr. Lyman is not a sufficient reference for replicating the methods used to perform a build-out in the four case studies. However, the report provides an excellent comparison of the studies and offers literature references for obtaining details on the other case studies.

**SOURCE(S) OF INFORMATION/TEXT FOR THIS FACT SHEET:**

The sources of information and text for this fact sheet are cited above under "Title of Project/Report," "Research Conducted By," and "Contact Information."

# APPENDIX C

## Relevant Literature

# RELEVANT LITERATURE


Buzzards Bay Project. 1992. *Managing Nitrogen to Sensitive Embayments.* Fact Sheet. Marion, MA.

Buzzards Bay Project. 1991. *Buttermilk Bay Nitrogen Management Strategy.* Fact Sheet. Marion, MA.

Chesapeake Bay Program. 1994. *Mission Statement.* Land, Growth and Stewardship Subcommittee. Annapolis, MD.

Chesapeake Bay Program. 1996. *Priorities for Action for Land, Growth and Stewardship in the Chesapeake Bay Region.* Land, Growth and Stewardship Subcommittee. Annapolis, MD.

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Costa, J.E., D. Janik, N. MacGaffey, and D. Martin. 1994 (draft). *Use of a Geographic Information System to Estimate Nitrogen Loading to Coastal Watersheds.* Technical Report. Buzzards Bay Project. Marion, MA.

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Johnson County Planning Office. 1990. *Hillsdale Lake Watershed Population and Land Use Projections, 1990-2010, for the Hillsdale Lake Nutrient Study.* Olathe, KS.

Lacy, J. 1992. *Manual of Build-Out Analysis.* Center for Rural Massachusetts, Department of Landscape Architecture and Regional Planning, University of Massachusetts, Amherst, MA.

Lancaster County Planning Commission. 1993. *Lancaster County Comprehensive Plan: Growth Management Plan.* Lancaster, PA.

Lyman, E. 1996. *Buildout Analysis on a GIS.* (Masters of Science thesis). University of Vermont: Burlington, VT.

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Maryland Office of Planning. 1995. *Growth, Resource Lands and Watersheds: The Need for Integrated Planning and Management.* Baltimore, MD. Fact sheet.

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Porter, D.R. and Edwin Thomas, Robert G. Kramer & Associates and Parsons, Brinckerhoff, McQuade and Douglas. 1997. *US 301 Transportation Study Technical Report: Land Use and Growth Management.* Baltimore, MD.

Schiffman, I. *Alternative Techniques for Managing Growth.* Berkeley, California: Institute of Government Studies, University of California at Berkeley, 1990, c1989.

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Steinitz, C. 1994. *Alternative Futures for Monroe County, Pennsylvania.* Harvard University: Cambridge, MA.

Steinitz, C. *A Framework for Theory and Practice in Landscape Planning.* GIS Europe (July 1993).

Tassone, J.F., R. E. Hall, N.S. Edwards, and D.M.G. Weller. 1996. *Integrated Watershed Planning and Management: Growth, Land Resources and Nonpoint Source Pollution.* Published in the Proceedings of the Watershed '96 Conference, Baltimore, MD.

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US 301 Transportation Study Task Force. 1996. *US 301 Task Force Final Recommendations.* Baltimore, MD.

U.S. Environmental Protection Agency. 1991. *Modeling of Nonpoint Source Water Quality in Urban and Non-urban Areas.* Office of Research and Development, Washington D.C.

## FOR ADDITIONAL INFORMATION

Additional information about build-out analyses and water quality and environmental modeling can be obtained in the following ways:

- Consult the literature presented in the previous section.
- Contact the Chesapeake Bay Program's Land, Growth and Stewardship Subcommittee Liaison (Menchu Martinez) by dialing 1-800-968-7229 (1-800-YOUR-BAY), Extension 704.
- Investigate the following World Wide Web sites:

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| http://www.chesapeakebay.net/bayprogram/ | (Chesapeake Bay Program Home Page) |
| http://www.op.state.md.us/ | (Maryland Office of Planning) |
| http://www.nvpdc.state.va.us | (Occoquan Reservoir Study) |
| http://www.epa.gov/nep/nepbroc.html | (National Estuary Program Home Page) |
| http://www.gsd.harvard.edu/brc/brc.html | (Camp Pendleton Study) |
| http://monticello.avenue.gen.va.us/Gov/TJPDC | (Thomas Jefferson Planning District Commission) |
| http://www.co.lancaster.pa.us | (Lancaster County Planning Commission) |
| http://www.nvpdc.state.va.us | (Northern Virginia Planning District Commission) |